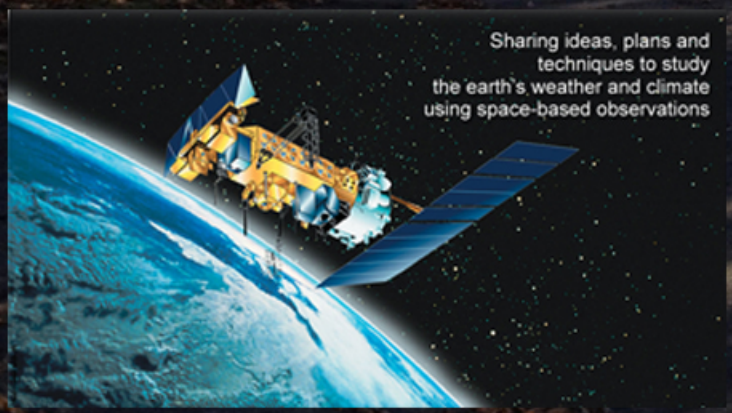
INTERNATIONAL ATOVS WORKING GROUP

A Report on the Twentieth International TOVS Study Conference

Lake Geneva, Wisconsin, USA

28 October - 3 November 2015



A Report on
The Twentieth International
TOVS Study Conference

Grand Geneva Resort
Lake Geneva, Wisconsin, USA
28 October – 3 November 2015

Conference sponsored by: University of Wisconsin-Madison / SSEC
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FOREWORD

The International TOVS Working Group (ITWG) brings together operational and research users and providers of infrared and microwave satellite sounding data. It is convened as a sub-group of the International Radiation Commission (IRC) of the International Association of Meteorology and Atmospheric Physics (IAMAP) and the Coordination Group for Meteorological Satellites (CGMS). The ITWG organises International TOVS Study Conferences (ITSCs) which have met approximately every 18 to 24 months since 1983. Through this forum, relevant experts exchange information on all aspects of the data processing and use, with a focus on inferring information on atmospheric temperature, moisture, and cloud fields. This includes evaluation of new data, processing algorithms, derived products, impacts in numerical weather prediction (NWP) and climate studies. The group considers data from all sounding instruments that build on the heritage of the TIROS Operational Vertical Sounder (TOVS), including hyperspectral infrared instruments.

This Working Group Report summarises the outcomes of the Twentieth International TOVS Study Conference (ITSC-XX) hosted by the Space Science and Engineering Center (SSEC) of the University of Wisconsin, Madison, USA, in Lake Geneva, Wisconsin, between 28 October and 3 November 2015. The ITWG Web site contains electronic versions of the conference presentations, posters and publications which can be downloaded (http://cimss.ssec.wisc.edu/itwg/). Together, these documents and web pages reflect a highly successful meeting at Lake Geneva.

We wish to thank SSEC for their efficient hosting of the conference, and in particular the local organizing committee, especially Maria Vasys, Leanne Avila, Dr Jonathan Gero, and Dr Allen Huang for leading the excellent local organization. It was very fitting to hold this mile-stone 20th meeting of this group in Wisconsin, for many the spiritual home of satellite sounding, in the same year as SSEC itself celebrated its 50th anniversary.

ITSC-XX was sponsored by industry and government agencies, including ABB, EUMETSAT, Exelis, JCSDA, Met Office, Météo France, NOAA/JPSS Program Office, Orbital Systems, SCISYS, STC, and the World Meteorological Organization (WMO).

The following report encompasses an executive summary highlighting the main developments and conclusions, followed by the detailed working group reports, the conference program, and abstracts of all presentations and posters.

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Co-Chair ITWG
ECMWF

Mitch Goldberg
Co-Chair ITWG
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TOVS STUDY CONFERENCE (ITSC-XX)
Lake Geneva, Wisconsin, USA: 28 October – 3 November 2015

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ITSC-XX Group Photo at The Grand Geneva Resort
Lake Geneva, Wisconsin, USA

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1. EXECUTIVE SUMMARY

1.1 INTRODUCTION

The twentieth International TOVS Study Conference, ITSC-20, was hosted by the Space Science and Engineering Center (SSEC) of the University of Wisconsin, Madison, USA, in Lake Geneva, Wisonsin, between 28 October and 3 November 2015. 160 participants attended the Conference from 35 organizations, providing a wide range of scientific contributions. Seventeen countries and three international organizations were represented: Australia, Brazil, Canada, China, Czech Republic, France, Germany, India, Japan, Norway, Poland, Russia, South Korea, Spain, Switzerland, United Kingdom, United States, ECMWF, EUMETSAT, and the WMO. The Working Groups had very productive discussions and it was again encouraging to see a large number of new, younger scientists participating.

Apart from excellent support by the local hosts, SSEC, ITSC-20 was sponsored by industry and government agencies. The industry and government agencies included: ABB, EUMETSAT, Exelis, JCSDA, Met Office, Météo France, NOAA/JPSS Program Office, Orbital Systems, SCISYS, STC, and the World Meteorological Organization (WMO). The great success of ITSC-20 was largely thanks to the excellent work of the local organizing committee from SSEC, including Allen Huang, Maria Vasys, Leanne Avila, and Jonathan Gero who also covered the essential and invaluable administrative and logistical support as usual.

The meeting benefitted from presentations about new operational satellite data from new global operational data providers, in particular China and Russia. Evaluations of data from instruments on FY-3C as well as Meteor-M N2 show promising results, with operational data usage of the FY-3C data being considered at several NWP centres. Efforts for international data provision and collaborative evaluation that builds on the international expertise were warmly welcomed and supported by the group. Within the context of a diversification of providers of polar-orbiting satellite sounding data, there is an on-going requirement for international coordination and optimisation of these activities. The group again expressed a strong requirement for both infrared and microwave sounders in at least three complementing orbital planes. Today we are experiencing the golden age of temporal coverage from polar orbiting satellites, which includes drifting satellites such as NOAA-15, NOAA-18, and NOAA-19, which of course enhances temporal coverage. A major discussion at the conference was the potential reduction of temporal coverage over the next decade and the importance of CGMS and WMO to study this in more detail to see how to better optimize the observing system of polar-orbiting sounder satellites. Another significant concern was the lack of a sounder on the DMSP weather satellite follow-on program. Current DMSP sounders have unique mesospheric sounding channels, which are not included in other satellite programs.

Critically contributing to the successful data usage are the continued developments of processing packages such as the ATOVS and AVHRR Pre-processing Package (AAPP) and the Community Satellite Processing Package (CSPP). The developments of direct broadcast packages also underpin a continued strengthening of fast retransmission services which uses existing local ground stations to process locally received data and to re-distribute it via the GTS to achieve a timeliness of 30 min or better. Previously known as Regional ATOVS Retransmission Service (RARS), this activity is now coordinated under the DBNet initiative of WMO, providing the renewed effort of coordination called for at previous meetings. New

guidelines for this service were dicussed at this meeting. Also the inclusion of software to process Russian satellite data was discussed in light of the encouraging data quality from the Meteor-M N2 satellite.

Observing system experiments presented at the conference underline the critical importance of satellite sounding data for Numerical Weather Prediction. A number of avenues are pursued to further improve and extend this use. Topics are the treatment of cloud-affected sounding radiances in data assimilation systems, the extended use of data over sea-ice or land, or improved treatment of biases.

A strong over-arching science theme was renewed efforts to rigorously characterise observational uncertainties, such as arising from data processing, radiative transfer modelling, or cloud screening. This is being considered from a number of angles, through several projects in a climate context for trend detection, as part of calibration/validation activities for new satellite data, or in data assimilation for appropriate weighting of observations. The latter activities are sparked by reports from several NWP centres of significant benefits in terms of forecast impact from a more refined treatment of observational uncertainties in NWP systems.

The efficient use of hyperspectral data continues to be a topic, and efforts to increase the use of the spectral information, for instance through principal component analysis, continue to be pursued. These developments are highly relevant for the future evolution of the global observing system, especially for hyperspectral instruments from geostationary orbit planned in Europe and China. They are also very relevant for instruments with even higher spectral resolution from polar orbit, such as IASI-NG. Also important in the very near term is the preparation by users for the full spectral resolution of CrIS on both Suomi NPP and the near future JPSS-1, scheduled for launch no later than March 2017. The full resolution will provide enhanced water vapour information and the monitoring and future assimilation of carbon monoxide.

Radiative transfer developments, including enhanced treatment of surface emissivity over land and sea, continue to be essential aspects, as they underpin all quantitative uses of sounding data.

Most of the meeting was organized in fourteen sessions of oral presentations and their associated poster papers. This comprised of 62 longer format oral presentations and 112 poster papers. Each poster was introduced through a short verbal summary to highlight the scientific content. The range of issues covered in oral presentations and posters included the following:

- Current, new and future observing systems;
- Operational reports from space agencies and NWP centres;
- Data assimilation applications;
- Climate applications;
- Processing software systems;
- Advanced Sounder science;
- Radiative transfer developments;
- Cloud and precipitation applications; and
- Retrieval science.

Working Groups were formed to consider six key areas of interest to the ITWG, including:

- Radiative Transfer,
- Climate,
- Data Assimilation and Numerical Weather Prediction,
- Advanced Sounders,
- International Issues and Future Systems, and
- Products and Software.

The Working Groups reviewed recent progress in the above areas, made recommendations on key areas of concern and identified items for action. These were further reviewed in a plenary session at the end of the conference. Working Group reviews and recommendations comprise an important part of the ITSC-20 Working Group Report. A summary of the key recommendations and actions arising from the conference is presented below.

Activities that had taken place since ITSC-19 in Jeju Island were presented in a dedicated session of Working Group status reports. This session also reviewed progress on the Action Items and Recommendations identified by the ITSC-19 Working Groups, and highlighted community topics of particular interest, such as the formulation of guidelines for DBNet or microwave frequency protection. Technical sub-groups also met during ITSC-20 to discuss developments and plans concerning specific software packages, shared and in common use.

A special evening session commemorated the evolution of ITWG since its inception in 1983 over the last 20 meetings, with contributions from former co-chairs and key members of the group, sharing anecdotes, but also highlighting key science mile-stones that lined the path of success of ITWG.

The conference agenda and all of the talks and many of the posters can be viewed at the ITWG Web site, located at http://cimss.ssec.wisc.edu/itwg/itsc/itsc20/program/index.html

1.2 SUMMARY OF MAJOR CONCLUSIONS

The ITSC-20 presentations, posters, Working Group meetings and discussions documented significant issues in many areas and identified areas for future activity. The full list of action items and recommendations can be found in the detailed reports from each working group. The main conclusions and recommendations are summarised below.

1. **To CGMS and other satellite agencies:** The constellation of at least three polar orbits (early morning, morning, and afternoon), each with full sounding capabilities (IR and MW), should be maintained. The overpass times of operational satellites with sounding capability (IR and MW) should be coordinated between agencies to maximize their value. Noting the excellent news regarding the move of FY-3E to the early morning orbit, the group recommends to consider how the early morning orbit will be covered post FY-3E or the DMSP satellites.
   When an agency has two or more satellites in the same nominal orbit (e.g. 2pm) they should be staggered by phase (as Metop). With multiple satellites from different agencies, it is recommended to stagger them in ECT.
2. **To US DoD:** Noting that the launch of F20 is currently uncertain, ITWG strongly recommends that SSMI/S on F20 should be flown, preferably in an early morning orbit, in support of maintaining a robust global satellite observing system.

3. **To space agencies:** The SSMIS 60 GHz upper stratospheric and mesospheric sounding capability should be continued, noting the trend for NWP models to extend higher in the stratosphere and lower mesosphere and the development of thermosphere modelling for Space Weather applications.
4. **To WMO/CGMS/other space agencies:** future programs should include the provision of high temporal frequency MW humidity sounding radiances (alongside cloud and precipitation sensitive observations).
5. **To space agencies:** ITWG recommends to develop, test, and implement an SI Traceable radiometric standard in space as soon as feasible.
6. **To space agencies and NWP centres:** Noting the urgent need for realistic trade-off studies regarding the field-of-view size, instrument noise and spectral resolution of future infrared sounders, and the continued lack of a coherent analysis of these aspects, ITWG recommends dedicated studies to investigate these trade-offs in an NWP context. Such studies should also consider the effects of clouds and other geophysical uncertainties. Space agencies should consider commissioning such studies to optimize the usefulness of future infrared sounders.
7. **To WMO/CGMS:** ITWG recommends to secure full government control for observations classed as essential under WMO Res 40.
8. **To space agencies and all agencies involved in GRUAN/ARM:** ITWG recommends the provision of more GRUAN and tropical ARM sites, noting the continued need for and scarcity of ground-based reference measurements.
9. **To WMO/CGMS:** ITWG recommends to further maintain OSCAR and SATURN, noting the strong positive feedback from ITWG Members.
10. **To CGMS and other space agencies:** ITWG recommends to assign Digital Object Identifiers (DOIs) to their data sets of heritage instruments and provide these DOIs to a central portal like WMO-OSCAR.
11. **To WMO/CGMS/GSICS:** To develop best practices in pre-flight characterisation of MW sensors, and to make instrument channel characterization data for future instruments publically available.
12. **To IRC and agencies involved in radiative transfer developments:** Noting the progress made in characterising observation uncertainty for hyperspectral sounders encourage further characterisation of LBL model error and errors arising from cloud screening, with a view to considering hyperspectral sounders as an absolute reference.
13. **To NWP centres:** Consider studies into the use of physical methods as well as diagnostic methods to characterise observational uncertainties, including their correlations, to improve the assimilation of satellite radiances.
14. **To IRC and agencies involved in radiative transfer developments:** ITWG recommends the continued support of LBL model development, both the forward model software and the measurements/calculations to improve the spectroscopy.
15. **To WMO/CGMS/space agencies:** ITWG continues to support low-cost fast delivery initiatives and welcomes the DBNet initiative for renewed coordination of such activities.
16. **To Roshydromet:** Roshydromet are encouraged to release a direct broadcast processing package for the Meteor-M N2 series, including level 1 processing for the MTVZA-GY microwave imager.
17. **To satellite agencies:** ITWG recommends open access to new satellite data during the calibration/validation phase (particularly for all NWP centres) to help with calibration and validation.
18. **To WMO/CGMS/space agencies:** ITWG supports initiatives to make data from R&D and pre-operational missions available, with a timeliness suitable for operational near-realtime applications (related to CGMS HLPP 2.3).

19. **To satellite agencies:** If PC compression is used to disseminate hyperspectral IR observations, a conservative approach should be taken in order to mitigate information loss (e.g., by retaining as many principal components as possible).
20. **To satellite agencies in dialogue with users:** Devise and document a mutually acceptable update strategy for the principal component basis when a principal component scores product is disseminated to users. Users are encouraged to monitor reconstructed radiances in parallel to operations so that the PC update strategy can be properly tested.
21. **To funding bodies of NWP centres and satellite agencies:** Consider, as part of the cost of satellite programs, providing computational and personnel resources targeted at operational NWP centres to optimise the public's return on investment from these expensive measurement systems.
22. **To the NWP community:** In support of continued efforts for frequency protection, national meteorological services should attempt to provide an assessment of the economic value of bands based on an impact assessment, as was done by the Met Office in 2005.

1.3 FUTURE PLANS

The ITWG will continue to meet and continue to inform the infrared and microwave sounding community of the latest news and developments through its Web site (currently maintained by the University of Wisconsin-Madison/CIMSS) and via the email list (also maintained by CIMSS).

The next meeting of the ITWG will be held in Darmstadt, Germany, 29 November – 5 December 2017. More information about ITWG and other ITSCs may be found at: http://cimss.ssec.wisc.edu/itwg/

1.4 ACKNOWLEDGEMENTS

This report relied on the active participation of all ITSC attendees and those working group chairs. We acknowledge that writing of this report is possible only through the collective work of ITWG members.

SUMMARY OF ACTIONS AND RECOMMENDATIONS

RADIATIVE TRANSFER AND SURFACE PROPERTY MODELLING

Action RTSP-1

Paul van Delst (IMSG@NCEP/EMC), Marco Matricardi (ECMWF), Jerome Vidot (MeteoFrance), and Pascal Brunel (MeteoFrance) to coordinate this task with the RTSP-WG to determine data requirements and define any standard approaches or data formats.

Action RTSP-2

Sergio Machado (UMBC) to provide a dataset of ~7000 AIRS spectra matched to ECMWF profiles that contain information on cloud liquid water and ice amount.

Action RTSP-3

RTSP WG co-chairs to contact Dave Turner (NOAA/NSSL) regarding aerosol refractive index data.

Action RTSP-4

Marco Matricardi to provide links to aerosol refractive index and optical property datasets, as well as electromagnetic theory code to compute aerosol optical properties.

Recommendation RTSP-1

The RTSP working group recommends that aerosol optical property data be made publicly available, including documentation of the particle size distributions.

Recommendation RTSP-2

The RTSP working group recommends encouraging research into laboratory measurements of aerosol refractive indices.

Recommendation RTSP-3

The RTSP working group recommends the continued support of LBL model development and validation, both the forward model science/software and the measurements/calculations to improve the spectroscopy in all spectral regions covered by fast RTMs.

Recommendation RTSP-4

Include the potential reformulation of the absorption line shape profile into other LBL model development plans (CLBL mentioned specifically, but applies to any LBL model).

Action RTSP-5

Marco Matricardi (ECMWF) to provide information on how to obtain the GRUAN datasets available on the RTSP-WG website.

Recommendation RTSP-5

The RTSP working group recommends that radiative transfer modelers continue investigating the biases observed in the 183GHz channels using state of the art spectroscopic data. The RTSP working group also encourages accurate laboratory

measurements of the spectroscopic line parameters and the use of alternative models for the water vapour continuum.

Action RTSP-6

Marco Matricardi to make the workshop final report available on the RTSP-WG website.

Action RTSP-7

Paul van Delst to make the measured spectral response functions for ATMS and GMI available via the RTSP-WG website.

Recommendation RTSP-6

The RTSP working group recommends having HDO be specified as a separate molecule in both the LBL models and the spectroscopic data to provide the flexibility to treat it separately in LBL calculations.

Recommendation RTSP-7

The RTSP working group recommends that funding be made available to research groups making measurements of land surface emissivity in the infrared.

Recommendation RTSP-8

The RTSP working group encourages the measurement of land surface emissivity and reflectivity in the microwave spectral regions of interest to the ITWG members.

Recommendation RTSP-9

The RTSP working group recommends development of BRDF models for use in fast RT models.

Recommendation RTSP-10

The RTSP working group recommends that users of any of the UW IREMIS datasets provide feedback to Eva Borbas to allow for reporting at the next ITSC.

Action RTSP-8

Ben Ruston to notify the RTSP-WG co-chairs when the improved snow emissivity dataset becomes available.

Recommendation RTSP-11

The RTSP working group recommends the addition of broadband emissivities to the available databases where appropriate or possible.

Recommendation RTSP-12

The RTSP working group recommends the results of the RTM intercomparison, including Jacobian comparisons, be reported to the ITWG, via the RTSP-WG, when they are available.

Recommendation RTSP-13

The RTSP working group recommends that the CRTM/RTTOV intercomparison continues, including Jacobians. Particular emphasis should be put on understanding the origin of the differences.

Recommendation RTSP-14

The RTSP working group recommends that agencies and/or manufacturers provide future microwave instrument channel characterization data. The GMI Spectral Requirements Verification Report can be used as a model.

Recommendation RTSP-15

The RTSP working group recommends that agencies provide responsivities for Fourier Transform Spectrometers (FTS) that can be used in modeling those instruments in current RT models.

Action RTSP-9

RTSP WG co-chairs to contact AER Inc. and find out what portions of the OSS software package are public.

Recommendation RTSP-16

The RTSP-WG encourages RT model developers to generalize the form of the RT equation introducing a vector formalism.

Action RTSP-10

Paul van Delst to followup on ITSC-19 RTSP-WG action items 1, 4, 12-14, 16-19, and 21.

Action RTSP-11

Stu Newman (MetOffice) to follow up on ITSC-19 RTSP-WG action items 3 and 7.

CLIMATE

Action Climate 1 on WG Co-Chairs

The webpage of the Climate WG needs to be updated. This will be done once the new CMS is available and the ITWG pages as well as the subgroup pages have been migrated to the new systems. The WG chairs will coordinate the update of the webpage. Focal points for each section of the webpage will be named to help with the implementation.

Action Climate 2 on Climate WG Co-Chairs

A specific mailing list for the Climate WG will be set up with the help from Leanne Avila.

Recommendation Climate 1 to community

Encourage people to work on VTPR, predecessor of HIRS, to develop CDR or for use in data assimilation in climate reanalyses. The data are available through the NOAA/NCEI website address: http://www.ncdc.noaa.gov/oa/rsad/vtpr.html. Interested users should contact Lei Shi for information and access to the data.

Recommendation Climate 2 to reanalysis providers

The Climate WG points out that traceability of input data used in the generation of the reanalysis data is important information for the users. Reanalysis providers should provide this information together with their data sets.

Action Climate 3 on Niels Bormann

Niels Bormann will check which of the data (satellite data and synoptic data) used as input for the ECMWF re-analysis can be made available to the public (e.g. via link to data provider or via ECMWF directly).

Recommendation Climate 3 to data providers

To encourages CGMS satellite operators to assign Digital Object Identifiers (DOIs) to their data sets of heritage instruments and provide these DOIs to a central portal like WMO-OSCAR or reanalysis.org.

Recommendation Climate 4 to satellite providers

Long-term measurements of comprehensive surface and atmospheric variables from measurement campaigns such as the ARM sites and validation sites such as from GRUAN are important for satellite validation. The Climate WG supports such campaigns and operational validation sites for validation activities and encourages satellite providers to provide sufficient funding for these activities for current and upcoming sensors.

Action Climate 4 on Cheng-Zhi Zou

Provide a brief description of and a URL link to the ARM project on the Climate WG webpage.

Recommendation Climate 5 to CDR developers

The Climate WG encourage the CDR community to develop HIRS based CDRs. The Climate WG members also expressed interest in connecting observations from the advanced hyperspectral sounders such as AIRS/IASI/CrIS to HIRS at the swath radiance level. It was suggested that this was done by integrating the hyperspectral channels to derive equivalent HIRS channels. The WG encourage the community to examine these convolution algorithms and use them to merge the hyperspectral sounders with HIRS. This will allow the continuity of the HIRS observation and extend it from 1979 to present and beyond.

Recommendation Climate 6 to NESDIS

The Climate WG recommends NESDIS to make the reanalysis community aware of the new SSU level-1c radiance dataset.

Action Climate 5 (on Cheng-Zhi Zou)

NESDIS to look for possibility to merge AIRS, IASI and CrIS with its recently developed SSU stratospheric temperature climate data record.

Action Climate 6 (on Rob Roebeling)

Provide information to the Climate WG webpage on different inter-calibration activities for Level-1 FCDR data, e.g. HIRS, AMSU, AVHRR, etc. This information will be made available via the Climate WG webpage.

Recommendation Climate 7 to data providers and reanalysis providers

The WG encourages other satellites agencies to also establish websites for monitoring instrument calibration anomalies and their long-term trends.

Action Climate 7 on WG members

The Climate WG needs to discuss on focus and aim of the Climate WG within ITWG. Until the next meeting the WG members are asked to provide their thoughts on the scope of the Climate WG. The discussion will be moderated by the Climate WG co-chairs and will most probably be started with a survey. Some time will be reserved at the next meeting to consolidate the scope of the Climate WG.

DATA ASSIMILATION AND NUMERICAL WEATHER PREDICTION

Action DA/NWP-1 on ITSC Co-chairs

To bring relevant recommendations to the attention of CGMS.

Recommendation DA/NWP-1 to all relevant space agencies

The constellation of at least three orbits (early morning, morning, and afternoon), each with full sounding capabilities (IR and MW), should be maintained. The overpass times of operational satellites with sounding capability (IR and MW) should be coordinated between agencies to maximize coverage and include a satellite in early morning orbit.

Recommendation DA/NWP-2 to the Defense Meteorological Satellite Program

In support of maintaining a robust global satellite observing system, SSMI/S on F20 should be flown, preferably in an early morning orbit.

Recommendation DA/NWP-3 to Space Agencies

New operational data dissemination infrastructure should be tested at an early stage (well before launch) with simulated data.

Recommendation DA/NWP-4 to Space Agencies

There should be open access to new satellite data for all NWP centres to help with calibration and validation.

Recommendation DA/NWP-5 to funding bodies of NWP centres and space agencies

Consider, as part of the cost of satellite programs, providing computational and personnel resources targeted at operational NWP centres to optimise the public's return on investment from these expensive measurement systems.

Action DA/NWP-2 on NWP WG members

Send any evidence of RFI to working group chairs for inclusion on the NWP WG RFI web page and forwarding to Jean Pla (jean.pla@cnes.fr) or Richard Kelley (richard.kelley@noaa.gov).

Action DA/NWP-3 on NWP WG members

If you have estimates of revised channel characteristics resulting from post-launch diagnostics, please email these to RTSP WG co-chairs.

Action DA/NWP-4 on WG co-chairs

Enhance NWP instrument usage survey to include template where centres can add information on channel blacklisting.

Action DA/NWP-5 on NWP centres

Continue to provide information on instrument channels assimilated and their observation errors for inclusion on the NWP Working Group pages in advance of each conference.

Action DA/NWP-6 on WG co-chairs

Set up new mailing list for communicating potential instrument anomalies.

Recommendation DA/NWP-6 to NWP WG members

Use the new instrument anomaly mailing list to alert other centres to potential data problems or changes in channel usage as soon as they arise.

Action DA/NWP-7 on WG co-chairs

Add link to NWP-SAF website on NWP instrument monitoring to the WG webpages.

Action DA/NWP-8 on WG members

Ensure their centre's monitoring sites are on the NWP-SAF website. Email NWP-SAF helpdesk if not to ask for it to be added.

Action DA/NWP-9 on WG co-chairs

Coordinate a group to define a set of monitoring plots that each centre should endeavour to provide with public access. Circulate the proposal to the NWP working group.

Recommendation DA/NWP-7 to NWP WG members

Update monitoring websites as soon as possible to include the plots requested in the monitoring proposal.

Recommendation DA/NWP-8 to Data Providers

Agree standardized procedure for inclusion of NEdT estimates within BUFR for microwave data.

Action DA/NWP-10 on Jörg Ackermann

Collate information regarding different algorithms used by data providers for calculating NEDT.

Action DA/NWP-11 on WG members who belong to member states of EUMETSAT

Request provision of NEDT in BUFR products for microwave sounders via EUMETSAT science working group.

Recommendation DA/NWP-9 to Data providers

Include azimuthal viewing and solar angles as appropriate in BUFR for present and future instruments.

Recommendation DA/NWP-10 to Space Agencies and data providers

When designing new or modified BUFR formats, please circulate drafts to the NWP community via the NWP Working Group for feedback, prior to submission to WMO.

Action DA/NWP-12 on NWP Centres

Contact Tom King (thomas.s.king@noaa.gov) to acquire CrIS FSR data, and confirm with him that it is acceptable.

Recommendation DA/NWP-11 on NWP Centres

Evaluate the de-striped ATMS radiances made available by Fuzhong Weng and report back to NOAA and the NWP Working Group, both on initial investigations with the sample dataset and on OSEs when a parallel data stream becomes available.

Recommendation DA/NWP-12 to data providers

If PC compression is used to disseminate hyperspectral IR observations, a conservative approach should be taken in order to mitigate information loss (e.g., by retaining as many principal components as possible).

Recommendation DA/NWP-13 to data providers and NWP users

A mutually acceptable update strategy should be devised and documented for the dissemination of PC products.

Action DA/NWP-13 on EUMETSAT

Circulate a proposal on update strategy for IASI PC basis vectors, including consideration of the length of the notice period, to the working group.

Action DA/NWP-14 on NWP WG Members

Provide feedback on the above proposal.

Recommendation DA/NWP-14 to NWP Centres

Monitor Reconstructed Radiances in parallel to operations so that the PC update strategy can be properly tested.

Recommendation DA/NWP-15 on Data Providers

When using PC compression, noise normalisation should be performed using the full noise covariance matrix.

Recommendation DA/NWP-16 on NWP Centres

Consider carrying out studies to evaluate the use of unapodised CrIS radiances, and/or to use the full spectral resolution apodised data combined with a full noise error covariance matrix.

Action DA/NWP-15 on Reima Eresmaa

Organise through the NWP working group a six-monthly telecon to update on progress and any new findings regarding assimilation of CrIS.

Recommendation DA/NWP-17 to Data providers

Use the AVHRR cluster algorithm available in AAPP for all hyperspectral sounders.

Action DA/NWP-16 on Andrew Collard

Request that the AVHRR/IASI clustering algorithm is implemented at NOAA/NESDIS/STAR for CrIS and AIRS data.

Recommendation DA/NWP-18 to data providers

Consider including a map of the sub-pixel information derived from imager pixels within hyperspectral sounder FOVs, should bandwidth allow.

Recommendation DA/NWP-19 to funding bodies

Provide finances for specific projects to look at the impact of data assimilation/forecast systems on the trade-off between field-of-view size, spectral resolution and instrument noise.

Action DA/NWP-17 on Bill Bell (Met Office)

To collate the available studies that have been performed on the increased yield and coordinate investigations into the impact of reduced field-of-view size combined with increased noise on model performance with an aim to inform decisions for the JPSS-3 CrIS.

Action DA/NWP-18 on Working Group Members

Please e-mail Bill Bell (william.bell@metoffice.gov.uk) if you have something to contribute to the FOV studies.

Action DA/NWP-19 on Likun Wang (U. Maryland)

To circulate information on the study he performed on the VIIRS cloud mask.

Recommendation DA/NWP-20 on Working Group members

To submit abstracts to the next ITSC on the topic of bias correction in regional models and bias correction of all-sky radiances.

Action DA/NWP-20 on Wei Han

Detail what information is required on radiometric and forward model uncertainty to constrain bias corrections, and circulate to the working group along with a proposal for how they would be used.

Recommendation DA/NWP-21 to NWP Centres

Consider studies into the use of physical methods as well as diagnostic methods to characterise observational uncertainties, including their correlations, to improve the assimilation of satellite radiances.

Action DA/NWP-21 on WG co-chairs

Define a superset of channels for hyperspectral IR instruments that are required for monitoring and assimilation at NWP centres to define minimum channel distribution through DBNet and send to ITSC chairs.

ADVANCED SOUNDERS

Recommendation AS-1 to Space Agencies

Consider the following priorities for the development/improvement of the next generation of advanced infrared sounders.

The prioritized recommendation lists from the highest are:

1. High spatial resolution to improve the probability of a uniform scene with the instrument FOV (i.e., all clear or all cloudy).
2. Spectral coverage from shortwave to longwave without gaps – to facilitate improved inter-satellite instrument cross-calibration.

3. Adopt/adapt calibration approaches traceable to international standards – to improve absolute radiometric calibration in order to achieve measurements closer to climate quality.

Action AS-1 to ITWG Co-Chairs
Bring this recommendation to the attention of Space Agencies at CGMS.

Recommendation AS-2 to Space Agencies
Coordinate with NWP Centres the generation of high resolution (1-3 km) nature runs.

Action AS-2 to ITWG Co-Chairs
Convey this recommendation to Space Agencies.

Action AS-3 to Stephen English
To investigate higher resolution nature runs at ECMWF and report back to ASWG.

Recommendation AS-3 to Space Agencies (NOAA)
Support further developments towards performing cluster analysis on imager pixels within advanced IR sounder field-of-views and providing statistical information of the collocated imager radiances as part of the sounder radiance observations. (The ASWG recommends that satellite agencies adopt the IASI/AVHRR approach to co-locate CrIS/VIIRS observations and provide radiance cluster and other analysis information in the CrIS SDR file.)

Action AS-4 to ITWG Co-Chairs
Convey this recommendation to Space Agencies (and NOAA in particular).

Recommendation AS-4 to NOAA
Future JPSS instrument enhancements should consider adding 118 GHz O2 band to the baseline design to advance the microwave sounding capability for the retrieval of precipitation over land and sea, including light precipitation and snowfall.

Action AS-5 to Mitch Goldberg
Convey this recommendation to NOAA.

Recommendation AS-5 to Space Agencies and Users
Establish a dialogue between providers and users of microwave soundings on the potential and capabilities of bolometer technology at 90 GHz and beyond.

Action AS-6
Steve English to act as the interface and provide related documentation.

Recommendation AS-6 to Space Agencies
Maintain and evolve the current microwave sounding capabilities for future systems.

Recommendation AS-7 to Space Agencies
Maintain and evolve the capability of microwave mesospheric sounding capabilities beyond SSMIS.

Action AS-7
ITWG Co-chairs to relay these recommendations to Space Agencies via CGMS.

Recommendation AS-8 to Space Agencies
Conduct studies to pursue high temporal resolution hyper spectral microwave sounding capabilities for future systems.

Action AS-8
ITWG Co-chairs to relay this recommendation to Space Agencies via CGMS.

Recommendation AS-9 to NASA
To implement the PATH mission.

Action AS-9
ITWG Co-chairs to bring this recommendation to the attention of NASA.

Recommendation AS-10 to Space Agencies
To pursue further development and implementation of microwave sounding missions in order to achieve global coverage of geostationary microwave sounding.

Action AS-10
ITWG Co-chairs to relay this recommendation to Space Agencies via CGMS.

Recommendation AS-11 to space agencies
Develop, test, and implement an SI Traceable radiometric standard in space as soon as feasible.

Action AS-11
ITWG Co-chairs to re-iterate this recommendation to Space Agencies via CGMS.

Recommendation AS-12 to Space Agencies
Re-establish regular dedicated radiosondes at one of the ARM TWP sites, or at a comparable tropical site (e.g., PMRF).

Action AS-12
ITWG Co-chairs to relay this recommendation to Space Agencies/Providers.

INTERNATIONAL ISSUES AND FUTURE SYSTEMS

Recommedation IIFS-1
Emphasize latency requirement in the HLPP Action 2.3 to increase the use of research and pre-operational satellites. (Action: Mitch Goldberg to propose to CGMS).

Recommendation IIFS-2
When an agency has two or more satellites in the same nominal orbit (e.g. 2pm) that they be staggered by phase (as Metop). With multiple satellites from different agencies it is recommended to stagger them in ECT. (Action: Mitch Goldberg to present to CGMS).

Recommendation IIFS-3

IIFS members to investigate optimal staggering to test working assumption that dual Metop configuration separated by about 180° is best option for future missions. (Action: IIFS members to provide evidence to IIFS co-chairs of advantages of orbit staggering).

Recommendation IIFS-4

Provision of high temporal frequency MW humidity sounding radiances (alongside cloud and precipitation sensitive observations). (Action: Jerome Lafeuille to present to WMO Vision 2040 workshop).

Recommendation IIFS-5

Provision of low-inclination MW humidity sounding to monitor diurnal cycle. (Action: Jerome Lafeuille to present to WMO Vision 2040 workshop).

Recommendation IIFS-6

Achieve SI traceability of operational hyperspectral IR sounders, and ultimately MW sounders, recognising growing need for assessment of calibration uncertainties. (Action: Mitch Goldberg and Peng Zhang to present to GSICS).

Recommendation IIFS-7

Provide more GRUAN and tropical ARM sites, given the need for ground-based reference measurements. (Action: Mitch Goldberg and Peng Zhang to present to GSICS).

Recommendation IIFS-8

Develop best practices in pre-flight characterisation of MW sensors (Action: Mitch Goldberg and Peng Zhang to present to GSICS).

Recommendation IIFS-9

Noting the progress made in characterising observation uncertainty for hyperspectral sounders encourage further characterisation of LBL model error and errors arising from cloud screening, with a view to considering hyperspectral sounders as an absolute reference. (Action: Mitch Goldberg to ensure this is delivered to IRC and RTWG.)

Recommendation IIFS-10

Clarify reporting procedure for notifying ITU of detected RFI. (Action: Rich Kelley to circulate proposed procedure and ITWG members to follow).

Recommendation IIFS-11

WRC outcomes to be provided to ITWG. (Action: Rich Kelley to email summary to ITWG mailing list).

Recommendation IIFS-12

IIFS and other ITWG members to provide information on current usage of protected bands to Rich Kelley. (Action: Stephen English to provide copy of recent ECMWF submission to OFCOM, and to request Met Office to provide copy of their submission as well as encourage other NMSs to provide similar information where it exists).

Recommendation IIFS-13

To make MW SRFs available to facilitate RFI investigations when needed. (Action: Stephen English to ask co-chairs to combine with Recs from other WGs and communicate to CGMS).

Recommendation IIFS-14

Update Steve English's study from 2005 on the value of individual MW protected bands. (Action: Sid Boukabara to ask Thomas Auligné to consider making this part of the FSOI intercomparison study and presenting to the WMO impacts workshop in Shanghai in 2016).

Recommendation IIFS-15

NMSs to attempt to provide an assessment of the economic value of bands based on the impact assessment, as was done by the Met Office in 2005. (Action: IIFS members to investigate in their countries).

Recommendation IIFS-16

WMO and CGMS satellite operators to further maintain OSCAR and SATURN, noting the strong positive feedback from ITWG Members. (Action: IIFS members to review SATURN and provide comments to Stephan Bojinski sbojinski@wmo.int)

Recommendation IIFS-17

Provide information on best practice for the design phase of new programmes. (Action: Dieter Klaes to circulate his paper from the ECMWF satellite seminar, and IIFS members to provide similar information to IIFS co-chairs for their agencies if possible.)

Recommendation IIFS-18

The NWP community to continue to produce and make available Nature Runs to support preparations for, and fair evaluation of, potential future observations. (Action: IIFS co-chairs to bring recommendation to attention of WMO, ECMWF and GMAO.)

Recommendation IIFS-19

Welcoming the decision of CMA to operate FY-3E on the e-am orbit but noting the current lack of any long-term plan for this orbit, to consider follow-up and back-up missions ensuring continuity of e-am post FY-3E and DMSP. (Action: Nancy Baker and Peng Zhang to pass Rec to DoD and CMA.)

Recommendation IIFS-20

Continue the SSMIS 60 GHz UAS capability, noting the trend for NWP models to extend higher in the stratosphere and lower mesosphere and the development of thermosphere modelling for Space Weather applications. (Action: Nancy Baker to report to DoD and Jerome Lafeuille to raise at WMO Vision 2040 workshop.)

Recommendation IIFS-21

WMO to promote standards to foster interoperability and usability of possible missions from commercial providers. (Action: Jerome Lafeuille or his successor to provide information when the need arises.)

Recommendation IIFS-22

Secure full government control for observations classed as essential under WMO Res 40. (Action: Mitch Goldberg to Report to CGMS.)

Recommendation IIFS-23

Noting the strong overlap of interest among the CGMS international science groups for some subjects (e.g. ITWG, IWWG and ICWG about MTG-IRS) co-chairs to ensure coordination where appropriate of communications to CGMS. (Action: Mitch Goldberg to Report to CGMS.)

PRODUCTS AND SOFTWARE

Recommendation PSWG-1 to NASA

NASA is encouraged to share products of the CIRAS demonstration project with appropriate science teams (e.g. CrIS, IASI, NWP centres) for evaluation.

Recommendation PSWG-2 to satellite agencies

Agencies to release details of instrument characteristics (e.g. channel definitions and data formats) well in advance of launch.

Action PSWG-1

PSWG members to review the "Guide To The Direct Broadcast Network (DBNet)" by 30 November 2015.

Recommendation PSWG-3 to Roshydromet

Roshydromet are encouraged to release a direct broadcast processing package for the Meteor-M N2 series, including level 1 processing for the MTVZA-GY microwave imager.

Action PSWG-2

PSWG members to review the list of software packages in the document linked from the PSWG web site and send corrections or additions to the co-chairs.

Recommendation PSWG-4 to satellite agencies

Agencies are encouraged to make future missions compatible with existing ground stations for direct broadcast, e.g. with regard to data rate, frequencies, polarisation, encoding etc., so that station operators do not have to buy new hardware (where possible) to support new satellite missions.

Recommendation PSWG-5 to satellite agencies

Agencies to consider "cloud" data delivery methods, where appropriate, as an alternative to direct readout for providing real-time data.

Recommendation PSWG-6 to NOAA and DBNet project

Consider ways for DBRTN and hyperspectral sounder data to be made available via rebroadcast services in the Asia-Pacific region.

Recommendation PSWG-7 to satellite agencies

Retransmission services are encouraged to consider broadening the scope to include imager products, level 2 products and full hyperspectral content.

Recommendation PSWG-8 to JAXA

JAXA to consider providing more geographical coverage for GCOM-W1 DB, and the release of level 1 software for AMSR2 to those receiving the DB.

Recommendation PSWG-9 to EUMETSAT

The PSWG supports the NWP SAF proposal to create a processing package for MTG-IRS (called IRSPP) that handles the PC compression aspects (e.g., creating reconstructed radiances).

Recommendation PSWG-10 to satellite agencies

Agencies are encouraged to develop instrumented ground sites for validation.

Recommendation PSWG-11 to participants in level 2 comparison studies

Results of level 2 comparison studies should be published in the open literature and also presented at ITSC-21.

Action PSWG-3

Martin Burgdorf to circulate the sections of the FIDUCEO framework doc that address errors associated with validation data as soon as they have been completed.

Action PSWG-4

Nigel Atkinson to circulate his Technical Memorandum on NedT to the PSWG group, and to the co-chairs of NWP group.

Action PSWG-5

Action: Nigel Atkinson to inform PSWG when samples of AMSU/MHS/HIRS BUFR files with NedT encoding are available, in order to check whether they can be decoded okay.

Recommendation PSWG-12 to ITWG co-chairs

Consider whether there is an unmet requirement for training on the applications of hyperspectral sounder products, and, if so, whether ITWG should provide a short course.

Recommendation PSWG-13 to ITWG members

ITWG members work with VLab to promote training activities related to satellite data.

Action PSWG-6

Graeme Martin to implement in CSPP GEO the algorithms to be made available by KMA.

Action PSWG-7

SSEC to modify IAPP so that it does not rely on Metop-A AMSU channel 8, and also to look at implementing improved bias correction (see poster by Szuchia Moeller).

Recommendation PSWG-14 to JPSS

Support development of VIIRS flood product as part of CSPP.

Recommendation PSWG-15 to JPSS

Support implementation of a polar winds product as part of CSPP.

Recommendation PSWG-16 to NOAA

Investigate the feasibility of providing a VIIRS cluster analysis in the CrIS footprint, including timeliness implications.

Recommendation PSWG-17 to NOAA

Clarify plans for distributing GOES-R data to users via mechanisms other than GRB.

Recommendation PSWG-18 to satellite agencies and DB system designers

Include geolocation information before or alongside the associated instrument observations in the data stream, in order to allow timely image generation for regional subsets.

2. WORKING GROUP REPORTS

2.1 RADIATIVE TRANSFER AND SURFACE PROPERTY MODELLING

Web site: https://groups.ssec.wisc.edu/groups/itwg/rtsp

Working Group Members: Marco Matricardi (Co-Chair, ECMWF), Paul van Delst (Co-Chair, IMSG@NCEP/EMC), Thomas August (EUMETSAT), Eva Borbas (UW-Madison/SSEC/CIMSS), Niama Boukachaba (MeteoFrance), Pascal Brunel (MeteoFrance), Virginie Capelle (LMD), Yong Chen (ESSIC/UMD, STAR/NOAA), Takumu Egawa (JMA), Robin Faulwetter (DWD), Louis Garand (Environment Canada), Rory Gray (Met Office), James Hocking (Met Office), Nicole Jacquinet (LMD), Masahiro Kazumori (JMA), Robert Knuteson (UW-Madison/SSEC), Heather Lawrence (ECMWF), Byung-il Lee (KMA), Qifeng Lu (CMA), Cristina Lupu (ECMWF), Yingtao Ma (AER@NOAA/STAR/JCSDA), Sergio Machado (UMBC), Aronne Merrelli (UW-Madison/SSEC), Stu Newman (Met Office), Kozo Okamoto (JMA), Benjamin Ruston (NRL), Bruna Silveira (CPTEC/INPE), Olaf Stiller (DWD), Jerome Vidot (MeteoFrance), Qiguang Yang (NASA Langley)

2.1.1 Scattering RT Intercomparison

With the increasing use of cloudy radiances in NWP and other applications, an intercomparison and validation of scattering RT fast models was proposed. There was discussion over what form this comparison would take (e.g., validating satellite imagery, using flight campaigns, using case studies, Jacobian comparisons, etc.) and what datasets would actually be needed and useful (e.g., profile datasets, optical properties, ground-based measurements, etc.).

It was decided a list of needs would be drawn up and disseminated to the group to allow for a more comprehensive survey of requirements.

Action RTSP-1

Paul van Delst (IMSG@NCEP/EMC), Marco Matricardi (ECMWF), Jerome Vidot (MeteoFrance), and Pascal Brunel (MeteoFrance) to coordinate this task with the RTSP-WG to determine data requirements and define any standard approaches or data formats.

Some specific announcements and requests for data came up in the meeting as part of this effort:

Colocated Datasets

Action RTSP-2

Sergio Machado (UMBC) to provide a dataset of ~7000 AIRS spectra matched to ECMWF profiles that contain information on cloud liquid water and ice amount.

Aerosol Optical Properties

Requests were made regarding the public availability of aerosol optical property data, as well as a recognition that current laboratory data for aerosol refractive indices should be reviewed for use in any intercomparisons.

Action RTSP-3

RTSP WG co-chairs to contact Dave Turner (NOAA/NSSL) regarding aerosol refractive index data.

Action RTSP-4

Marco Matricardi to provide links to aerosol refractive index and optical property datasets, as well as electromagnetic theory code to compute aerosol optical properties.

Recommendation RTSP-1

The RTSP working group recommends that aerosol optical property data be made publicly available, including documentation of the particle size distributions.

Recommendation RTSP-2

The RTSP working group recommends encouraging research into laboratory measurements of aerosol refractive indices.

2.1.2 Line-by-line Modeling

Recommendation RTSP-3

The RTSP working group recommends the continued support of LBL model development and validation, both the forward model science/software and the measurements/calculations to improve the spectroscopy in all spectral regions covered by fast RTMs.

Characterising RTM Error Covariance

The group discussed the possible use of ensemble techniques for characterizing RTM error covariances, in particular for line-by-line (LBL) models. The group expressed the view that it is not an intractable problem but is still a very difficult one. It was felt the group should pursue the more classical approach of using colocated datasets for validation at this point.

Absorption Line Profile Characterisation

It was noted that there is recent research about a reformulation of the absorption line shape profile – other than a Voigt line shape – used in LBL models. The rationale being that the simplified assumptions on which the Voigt profile is based (e.g., the collisional parameters are independent from the velocity of the absorber) can negatively affect the accuracy of the simulated spectra. The use of a new line shape would have an impact on not just the current LBL model implementations but also on the spectroscopic databases. There are many suggested models for the new line profile. Recently, the IUPAC task group recommended the adoption of the Hartmann-Tran profile.

Implementation of a new line shape formulation is already being tested in 4A/STRANSAC at LMD. There are currently no plans to include this reformulation in the Community Line-by-Line (CLBL) model at NOAA/JCSDA.

Recommendation RTSP-4

Include the potential reformulation of the absorption line shape profile into other LBL model development plans (CLBL mentioned specifically, but applies to any LBL model).

2.1.3 Datasets for Validation

Use of GRUAN datasets for validating LBL RT models was discussed. Several datasets of colocated ground-based and IASI measurements are available.

This topic was raised with respect to LBL model validation, but these data would also be useful for cloudy RT model comparisons, but would require specification of the cloud state variables.

Action RTSP-5

Marco Matricardi (ECMWF) to provide information on how to obtain the GRUAN datasets available on the RTSP-WG website.

2.1.4 183GHz Workshop

The 183Ghz Workshop was held 29-30 June 2015 in Paris to discuss biases observed between measurements at 183 GHz and calculations carried out using different radiative transfer models. The RTSP working group acknowledged that fact that there is still uncertainty regarding the full origin of the biases although it recognized that deficiencies in water vapour spectroscopy (line parameters and continuum) are probably making a significant contribution to the biases. Pascal Brunel mentioned tests he is performing to look at the impact of using Planck weighted transmittances to improve RT model results. It was also noted that the measured spectral response of microwave instruments are not generally available.

Recommendation RTSP-5

The RTSP working group recommends that radiative transfer modelers continue investigating the biases observed in the 183GHz channels using state of the art spectroscopic data. The RTSP working group also encourages accurate laboratory measurements of the spectroscopic line parameters and the use of alternative models for the water vapour continuum.

Action RTSP-6

Marco Matricardi to make the workshop final report available on the RTSP-WG website.

Action RTSP-7

Paul van Delst to make the measured spectral response functions for ATMS and GMI available via the RTSP-WG website.

2.1.5 Impact of HDO Absorption

The treatment of HDO, an isotopologue of water, in line-by-line modeling generally assumes a constant mixture with H2O in the vertical. However, it is well known that the vertical distribution of HDO compared with H2O can vary significantly both spatially and temporally. Assuming a constant mixture in LBL calculations introduces an error in the radiance spectra that could be as high as 1.5K. When the HDO/H2O vertical profile mixture differences are accounted for, those errors can decrease to 0.3K.

To mitigate this effect in hyperspectral infrared radiances at the affected frequencies, HDO should be specified as a separate molecule in LBL calculations, to allow for a separate concentration profile to be specified. This is already implemented in 4A/STRANSAC.

Recommendation RTSP-6

The RTSP working group recommends having HDO be specified as a separate molecule in both the LBL models and the spectroscopic data to provide the flexibility to treat it separately in LBL calculations.

2.1.6 Surface Properties

The first item discussed by the group regarded reference data sets for validation. Thomas August (EUMETSAT) brought to the working group's attention a research team – Dr. Folke Olesen's group at Karlsruhe Institute of Technology (KIT) – preparing to take FTIR measurements of surface emissivity. Given the benefit of these measurements for RT validation, a recommendation from the RTSP-WG was requested.

Recommendation RTSP-7

The RTSP working group recommends that funding be made available to research groups making measurements of land surface emissivity in the infrared.

A call for similar surface emissivity and reflectivity measurements in the microwave was also made. In addition, to maximize the utility of these measurements, it was recommended that sufficient in situ data for physical model validation (surface and soil temperature, surface and soil moisture, etc) be taken alongside any spectral measurements.

Recommendation RTSP-8

The RTSP working group encourages the measurement of land surface emissivity and reflectivity in the microwave spectral regions of interest to the ITWG members.

Physical Models

A recommendation was requested to encourage modeling of bidirectional reflectances for use in fast models. While the discussion focused on the microwave, similar efforts were encouraged for infrared and visible sensors.

Recommendation RTSP-9

The RTSP working group recommends development of BRDF models for use in fast RT models.

Surface Emissivity Datasets

Eva Borbas (CIMSS/SSEC/University of Wisconsin-Madison) put out a call for beta-testers of the new emissivity dataset (reported here at ITSC-20). Contact information: eva.borbas@ssec.wisc.edu.

Additionally, Eva Borbas asked the RTSP group, and the ITWG in general, for feedback on the emissivity covariance dataset. In particular, she is seeking information on the utility of these data and their actual use.

Recommendation RTSP-10

The RTSP working group recommends that users of any of the UW IREMIS datasets provide feedback to Eva Borbas to allow for reporting at the next ITSC.

Ben Ruston (NRL Monterey) brought to the RTSP group's attention that he, Eva Borbas, and Glynn Hulley (NASA/JPL) are working on a better definition of snow emissivity spectra in the infrared.

Action RTSP-8

Ben Ruston to notify the RTSP-WG co-chairs when the improved snow emissivity dataset becomes available.

Louis Garand (Environment Canada) inquired about the availability of broadband emissivities for use with radiation models in the current databases.

Recommendation RTSP-11

The RTSP working group recommends the addition of broadband emissivities to the available databases where appropriate or possible.

2.1.7 Ongoing RT Intercomparisons

EUMETSAT Retrieval Algorithm Comparison

It was noted that EUMETSAT is embarking on an intercomparison of retrieval algorithms and that the first step will involve an intercomparison of the RTMs used in the retrievals.

Recommendation RTSP-12

The RTSP working group recommends the results of the RTM intercomparison, including Jacobian comparisons, be reported to the ITWG, via the RTSP-WG, when they are available.

CRTM/RTTOV Intercomparison

Emily Liu (SRG@NCEP/EMC) has been running both CRTM and RTTOV in the NCEP data assimilation system in preparation for the assimilation of all-sky microwave radiances. The RTSP-WG has found the initial comparison of CRTM and RTTOV Jacobians for cloudy atmospheres has highlighted some interesting differences between the two models.

Recommendation RTSP-13

The RTSP working group recommends that the CRTM/RTTOV intercomparison continues, including Jacobians. Particular emphasis should be put on understanding the origin of the differences.

2.1.8 Spectral Response Function (SRF) Database Repository

There was insufficient time to discuss this topic with the group but the co-chairs would like to get the need for the following actions in the record:

- Providing SRF definition software and I/O (netCDF4) modules,
- Including FTS responsivities in the SRF databases, and
- Establishing a central repository for SRF data. This should be coordinated with similar efforts being undertaken by both GSICS and GEWEX.

Recommendation RTSP-14

The RTSP working group recommends that agencies and/or manufacturers provide future microwave instrument channel characterization data. The GMI Spectral Requirements Verification Report[1] can be used as a model.

[1] GMI Spectral Requirements Verification, Systems Engineering Report, Doc. No.2346140 Rev.A, Ball Aerospace & Technologies Corp., Oct. 30, 2010.

Recommendation RTSP-15

The RTSP working group recommends that agencies provide responsivities for Fourier Transform Spectrometers (FTS) that can be used in modeling those instruments in current RT models.

2.1.9 Other Issues

Action RTSP-9

RTSP WG co-chairs to contact AER Inc. and find out what portions of the OSS software package are public.

A continuation from the ITSC-19 RTSP-WG report, the group recognized that the use of the scalar form of the radiative transfer equation is not adequate for specific microwave simulations (reported on at ITSC-20). Depending on the application, the full or a reduced number of Stokes vectors is required.

Recommendation RTSP-16

The RTSP-WG encourages RT model developers to generalize the form of the RT equation introducing a vector formalism.

2.1.10 Carryover from ITSC-19

Action RTSP-10

Paul van Delst to followup on ITSC-19 RTSP-WG action items 1, 4, 12-14, 16-19, and 21.

Action RTSP-11

Stu Newman (MetOffice) to follow up on ITSC-19 RTSP-WG action items 3 and 7.

2.2 CLIMATE

Web site: http://cimss.ssec.wisc.edu/itwg/cwsg/

Nathalie Selbach (Co-Chair, DWD), Cheng-Zhi Zou (Co-Chair, NOAA/NESDIS/STAR), Bill Bell (Met Office), Niels Bormann (ECMWF), Martin Burgdorf (Universität Hamburg), Fabien Carminati (Met Office), Mitch Goldberg (NOAA), Timo Hanschmann (DWD), Robert Knuteson (UW-Madison/SSEC), Rob Roebeling (EUMETSAT), Lei Shi (NOAA NCEI), Nadia Smith (UW-Madison/SSEC), Bomin Sun (NOAA/NESDIS/STAR & IMSG), Peng Zhang (National Satellite Meteorological Center, CMA)

2.2.1 Actions from ITSC-19 – Update of Status During Meeting at ITSC-20

The WG members updated the last remaining open actions from ITSC-19. All actions could be closed:

Action Climate-1 from ITSC-19
NESDIS (Lihang Zhou) to provide a focus day of AIRS and IASI data that are spectrally convolved to CrIS data.
Status: closed
Data can be made available. Please contact Lihang Zhou or Likun Wang for access to the data.

Action Climate-2 to Climate-5 from ITSC-19 on inter-comparison study
Status: closed
Nadia Smith presented results on developments since ITSC-19. SSEC performed an instrument inter-comparison of retrieval products from AIRS, IASI and CrIS. One algorithm was used to retrieve profiles of temperature from all three instruments, namely the CSPP Dual-Regression software (used version 1.3, available at http://cimss.ssec.wisc.edu/cspp/uwhsrtv_edr_v1.3.shtml). The objective was to investigate how instrument and orbital differences affect the stability in retrieval products over large space and time scales. The results that were published (Smith et al. 2015, JAMC, doi:10.1175/JAMC-D-14-0299.1) are a step towards characterizing the sources of systematic uncertainty in retrieved (thematic) data products. It is recognized that an inter-comparison study of different retrieval algorithms (and the radiative transfer models they employ) will add value to the full characterization of systematic uncertainty.

Also, EUMETSAT has launched an inter-comparative study (by Stefan Tjemkes and Thomas August). Nadia Smith will visit EUMETSAT as "visiting scientist" in the new year (Jan/Feb 2016) with the main purpose to contribute to the Retrieval Algorithm Inter-comparison Study.

An inter-comparison of different algorithms (especially Level-2) could be followed up on in the Products and Software Working Group (PSWG), with recommendations to the climate community being fed back via the Climate WG. The Climate WG discussed that it should define the scale of inter-comparison (spatial and temporal) and provide recommendations to PSWG. The action was quite broad and needs to be defined more specific, depending on variables and societal need for climate information on interested regions.

Action Climate-9 from ITSC 19 on the update of Climate WG webpage
Status: closed

It is proposed to formally close the action from ITSC-19 and re-word it as a new action from ITSC-20 to better reflect the current status of the developments at SSEC. SSEC plans to update the ITWG page (at the same time as the update of their SSEC page). This will include the change to a new Content Management System (CMS, WordPress Multisite), which will allow the group to update content on the webpage on their own.

Action Climate 1 on WG Co-Chairs

The webpage of the Climate WG needs to be updated. This will be done once the new CMS is available and the ITWG pages as well as the subgroup pages have been migrated to the new systems. The WG chairs will coordinate the update of the webpage. Focal points for each section of the webpage will be named to help with the implementation.

Action Climate 2 on Climate WG Co-Chairs

A specific mailing list for the Climate WG will be set up with the help from Leanne Avila.

2.2.2 Comments on the HLPP from the Climate WG

The Climate WG discussed different sections of the HLPP being thought as important for the Climate WG. The following sections are sorted according to the section headings of the HLPP.

Section 1 Coordination of Observing Systems and Protection of Assets

a) Usage of VTPR

The Vertical Temperature Profile Radiometer (VTPR) was an operational 8-channel infrared sounding system flying on NOAA-2 to NOAA-5 and was a predecessor of the High-Resolution Infrared Radiation Sounder (HIRS). VTPR data is available from late 1972 to early 1979. A re-processed data set of VTPR is available via the NOAA NCEI webpage.
One example of usage of the VTPR for climate applications is the assimilation in ECMWF's reanalysis.

Recommendation Climate 1 to community

Encourage people to work on VTPR, predecessor of HIRS, to develop CDR or for use in data assimilation in climate reanalyses. The data are available through the NOAA/NCEI website address: http://www.ncdc.noaa.gov/oa/rsad/vtpr.html. Interested users should contact Lei Shi for information and access to the data.

b) Traceability of input data for reanalysis

The Climate WG discussed the importance of traceability of input data used in the reanalysis data records. It has been pointed out that ECMWF generates statistics on data used in the reanalysis. These feedback statistics will be made available via the ECMWF webpage.

Recommendation Climate 2 to reanalysis providers

The Climate WG points out that traceability of input data used in the generation of the reanalysis data is important information for the users. Reanalysis providers should provide this information together with their data sets.

Action Climate 3 on Niels Bormann

Niels Bormann will check which of the data (satellite data and synoptic data) used as input for the ECMWF re-analysis can be made available to the public (e.g. via link to data provider or via ECMWF directly).

This action could already be closed during ITSC-20. Niels Bormann has confirmed that all observations that will go into the ERA5 reanalysis will be made publically available through ECMWF's data portal (in ODB format or ASCII) and will contain source information where available.

c) Digital Object Identifiers

It was discussed how the accessibility of data used as input to re-analysis can be improved. The group agreed that it would be useful to have a central web-site summarizing the input data and the location where they can be found. A web-site that is already providing this type of information is WMO-OSCAR. Rob Roebeling suggested that it may be possible to provide, via WMO-OSCAR, information or links pointing the user to the archive where these data can be obtained. Another option would be the inclusion on reanalysis.org, a page that is intended to be a place to provide researchers with help to obtain, read and analyze reanalysis datasets created by different climate and weather organizations.

In order to ascertain that these links are stable and follow common conventions, it was suggested to encourage data providers to publish the existing data records with a Digital Object Identifier (DOI). A DOI is a persistent identifier that can be used for a published data record or document. Information on this data record/document is presented via a DOI landing page. Registering data or documents with a DOI requires from the registering entity that the data or documents should follow a strict protocol, e.g. data/documents should be presented with the required DOI metadata and additional information, it should be available for at least 10 years, etc. Note that data or documents can only be registered with a DOI when they are published, which is the case for data records of heritage satellites, but not for the data records of current satellites (which are still changing with time).

Recommendation Climate 3 to data providers

To encourages CGMS satellite operators to assign Digital Object Identifiers (DOIs) to their data sets of heritage instruments and provide these DOIs to a central portal like WMO-OSCAR or reanalysis.org.

d) Validation data

The Climate WG pointed out the importance of availability of long-term measurements of campaigns such as the ARM sites as well as operational validation data such as from GRUAN for validation of satellite data and derived products. The availability of high-quality validation data (including uncertainty characterization) over a sufficient time period is essential for validation of long-term data records. Existing sites should be further supported and establishing new sites to broaden the representativeness of the data should be considered (e.g., validation sites in different climate zone).

Recommendation Climate 4 to satellite providers

Long-term measurements of comprehensive surface and atmospheric variables from measurement campaigns such as the ARM sites and validation sites such as from GRUAN are important for satellite validation. The Climate WG supports such campaigns and operational validation sites for validation activities and encourages

satellite providers to provide sufficient funding for these activities for current and upcoming sensors.

Action Climate 4 on Cheng-Zhi Zou

Provide a brief description of and a URL link to the ARM project on the Climate WG webpage.

Section 2 Enhance the Quality of Satellite-derived Data and Products

a) Satellite climate data records from different sources

Satellite climate data records developed by multiple groups from either the same instrument on multiple satellites or from different instruments for a same variable can help improving the CDR accuracy through mutual validation activities.

b) Heritage HIRS channels

Historical observations from the HIRS have been assimilated into climate reanalyses to provide useful information on climate changes. Independent temperature CDRs from HIRS may also be helpful for detecting climate changes and comparing/validating CDRs derived from other instruments such as MSU and SSU.

Recommendation Climate 5 to CDR developers

The Climate WG encourage the CDR community to develop HIRS based CDRs. The Climate WG members also expressed interest in connecting observations from the advanced hyperspectral sounders such as AIRS/IASI/CrIS to HIRS at the swath radiance level. It was suggested that this was done by integrating the hyperspectral channels to derive equivalent HIRS channels. The WG encourage the community to examine these convolution algorithms and use them to merge the hyperspectral sounders with HIRS. This will allow the continuity of the HIRS observation and extend it from 1979 to present and beyond.

c) Spectral gaps in CrIS

It was noted that CrIS on the current Suomi NPP has spectral gaps, causing issues when comparing and merging with IASI instrument. Filling spectral gaps has been proposed to the Program Office for the future CrIS on JPSS. Climate WG endorses this proposal.

d) Extended SSU temperature CDR and radiance FDCR

SSU has been merged with AMSU-A by NESDIS to provide temperature CDR for climate change monitoring and investigation in the stratosphere. The infrared hyperspectral sounder AIRS had quite a few years of overlaps with SSU. Merging of AIRS and SSU will generate an extended SSU time series which allows mutual validations with the merged SSU/AMSU-A products for improvement of the stratospheric temperature CDRs.

In addition to SSU/AMSU-A temperature CDR, a new recalibrated SSU level-1c radiance FCDR has been made available by NESDIS with improved accuracy by accounting for space view anomalies in the calibration. The recalibration procedure was documented and the data set is available from the NESDIS/STAR website ftp://ftp.star.nesdis.noaa.gov/pub/smcd/emb/mscat/data/SSU/Level-1C_radiances/. Interested users may contact Cheng-Zhi Zou for information and access to the data.

Recommendation Climate 6 to NESDIS

The Climate WG recommends NESDIS to make the reanalysis community aware of the new SSU level-1c radiance dataset.

Action Climate 5 (on Cheng-Zhi Zou)

NESDIS to look for possibility to merge AIRS, IASI and CrIS with its recently developed SSU stratospheric temperature climate data record.

e) Inter-calibration activities

Inter-calibration activities are performed at different organizations with several projects. Therefore, it is sought important to coordinate the provision of information on different inter-calibration activities for Level-1 FCDR data, e.g., HIRS, AMSU, AVHRR, etc. This information will be made available via the Climate WG webpage.

A long-term aim could be to assess the differences between existing FCDRs of the same instrument. Note that the EU H2020 FIDUCEO project (www.fiduceo.eu) aims to generate FCDRs for four relevant heritage instruments: AVHRR-GAC, HIRS, microwave humidity sounders, and Meteosat First Generation.

To inquire if the EU H2020 FIDUCEO project sees themselves in the role as coordinator of, or contributor to an assessment of the FCDRs covered by FIDUCEO (AVHRR-GAC, HIRS, microwave humidity sounders).

Action Climate 6 (on Rob Roebeling)

Provide information to the Climate WG webpage on different inter-calibration activities for Level-1 FCDR data, e.g. HIRS, AMSU, AVHRR, etc. This information will be made available via the Climate WG webpage.

Rob Roebeling indicates that the topic of logging satellite calibration events has been taken up by CGMS and GSICS since 2011, through a series of actions and recommendations. In 2011, the 39th meeting of Coordination Group for Meteorological Satellites (CGMS) recommended: "*CGMS Satellite Operators to provide regular information on satellite/ instruments events affecting calibration and establish corresponding websites*" [Recommendation 39.12, CGMS MR 39]. Similarly, the Global Space-based Inter-Calibration System (GSICS) working group recommended *"Satellite operators to provide "a log of satellite / instrument events" to support the identification of "spurious" events/trends in calibrated data set*s". In 2013, the 41st meeting of CGMS tasked GSICS: "*GSICS to take on calibration event monitoring activities following the recent work on calibration event monitoring. Such information should be included in the next update of the WMO OSCAR database*" [CGMS-41: WGII/3 Action 41.21]. In 2014, the CGMS Task Team on Calibration Events Logging was established and tasked to coordinate among the CGMS Space Agencies the presentation of instrument specifications, as well as instrument events, in particular calibration events, and instrument monitoring [CGMS-42: WGII/3 Action 42.0]. In 2015, the 43rd CGMS meeting tasks the Calibration events logging task team "*Calibration events logging task team to prepare a white paper outlining the set of parameters, the nomenclature, and the standards to be used for reporting on instrument calibration across space agencies*." [CGMS-43: WGII/3 Action 43.01].

The list below gives the nominated CGMS representatives of the Task Team on Calibration Events Logging.

Name	Organization	Country
Dr. Li, Yuan	CMA	China
Mr. Miu, Peter	EUMETSAT	Germany
Dr. Bojkov, Bojan	ESA	Italy
Dr. Takahashi, Masaya	Meteorological Satellite Center (MSC) Japan Meteorological Agency (JMA)	Japan
Dr. Lee, Byung-Il	National Meteorological Satellite Center (KMA)	Korea
Mrs Yuhas, Cheryl	NASA	USA
Mr. Bali, Manik	NOAA	USA
Dr. Lafeuille, Jerome	WMO	Switzerland

Table 1: *Nominated CGMS representatives of the Task Team on Calibration Events Logging.*

Mitch Goldberg suggested that monitoring of instrument anomaly events and its long-term trend will help the reanalysis developers to understand anomalies in satellite input data for reanalyses. The already available webpage from the NOAA ICVS (Integrated Calibration and Validation System) provides a good example on this aspect.

Recommendation Climate 7 to data providers and reanalysis providers

The WG encourages other satellites agencies to also establish websites for monitoring instrument calibration anomalies and their long-term trends.

Section 3 Cross Cutting Issues and New Challenges

NESDIS (C. Zou) found that the long-term time series and trends in global mean stratospheric temperatures simulated by the advanced chemistry-climate models agreed very well with the stratospheric temperature climate data record derived from the merged infrared and microwave sounders. This excellent agreement is non-trivial. It suggests that the chemistry-climate models may have most likely reached a maturity level that they are able to simulate climate changes in the past with good accuracy, building confidence on using these models for projection of the future climate changes. Such a capability in climate modeling will help the society to get informed climate change information. This is one case that a CDR may help the decision makers to make informed policy decisions on mitigation and adaptation to climate changes.

2.2.3 Way forward of Climate WG of ITWG

The Climate WG members discussed the current scope of the Climate WG at ITWG and the possible developments in the future.

Action Climate 7 on WG members

The Climate WG needs to discuss on focus and aim of the Climate WG within ITWG. Until the next meeting the WG members are asked to provide their thoughts on the scope of the Climate WG. The discussion will be moderated by the Climate WG co-chairs and will most probably be started with a survey. Some time will be reserved at the next meeting to consolidate the scope of the Climate WG.

Possible areas mentioned during the WG discussion include CDR development linked to NOAA CDR Program, the EUMETSAT FCDR and CDRs and the EU's HORIZON 2020 project FIDUCEO, CDR analysis linked to the EU's Horizon 2020 GAIA-CLIM Project and comparison/validation of existing CDRs.

2.3 DATA ASSIMILATION AND NUMERICAL WEATHER PREDICTION

Web site: https://groups.ssec.wisc.edu/groups/itwg/nwp

Working group members: Fiona Smith (Co-Chair, Met Office), Andrew Collard (Co-Chair, NOAA/NCEP/EMC), Jörg Ackermann (EUMETSAT), Javier Andrey Andres (Météo-France), Thomas August (EUMETSAT), Bill Bell (Met Office), Patrik Benacek (CHMI), Niels Bormann (ECMWF), Pascal Brunel (Météo-France), James Cameron (Met Office), Bill Campbell (NRL), Fabien Carminati (Met Office), Keyi Chen (ZAP/CAS), Yong Chen (NOAA/NESDIS/STAR), Chu-Yong Chung (KMA), Mohamed Dahoui (ECMWF), Takumu Egawa (JMA), Reima Eresmaa (ECMWF), Robin Faulwetter (DWD), Louis Garand (Environment Canada/MSC), Rory Gray (Met Office), Vincent Guidard (Météo-France), Wei Han (CMA), Yong Han (NOAA/NESDIS/STAR), Xin Jin (NOAA/NESDIS/STAR), James Jung (CIMSS), Masahiro Kazumori (JMA), Heather Lawrence (ECMWF), Eunhee Lee (KMA), Jinlong Li (CIMSS), Jun Li (CIMSS), Agnes Lim (CIMSS), Haixia Liu (NOAA/NCEP/EMC), Qifeng Lu (CMA/NSMC), Cristina Lupu (ECMWF), Stephen Macpherson (Environment Canada), Marco Matricardi (ECMWF), Tanya Maurer (NRL), Kozo Okamoto (JMA), Simon Pellerin (Environment Canada/MSC), Joe Predina (Logistikos), Roger Randriamampianina (Met Norway), Indira Rani (NCMRWF, India), Awdhesh Sharma (NOAA/NESDIS/OSPO), Sanjeev Kumar Singh (NCMRWF, India), Yi Song (NOAA/NESDIS/STAR), Olaf Stiller (DWD), Jérôme Vidot (Météo-France/CMS), Likun Wang (Univ. of Maryland), Pei Wang (CIMSS), Tiger Yang (NOAA/NESDIS/STAR), Xiaoyan Zhang (NOAA/NCEP/EMC), Yanqiu Zhu (NOAA/NCEP/EMC)

2.3.1 Standing Actions and Recommendations

Action DA/NWP-1 on ITSC Co-chairs

To bring relevant recommendations to the attention of CGMS.

Polar Orbiting Constellation

Over the years, many observation impact experiments have demonstrated benefits from using MW and IR sounding data from three or more polar orbiting systems in NWP, compared to using data from just two orbits. An even spacing of orbits (early morning, morning, afternoon orbit) ensures the most homogeneous coverage, with benefits for forecast impact. The WG strongly supports international cooperation to ensure harmonization of orbits. The group would like to recognise that good work has been done in support of this recommendation already over the last few years. Recently it has been agreed that the Chinese satellite FY3E will be placed in early morning orbit, but for future FY satellites the orbit has not yet been decided. The working group therefore noted the continuing uncertainty around the presence of sounding instrumentation in the early morning orbit.

Recommendation DA/NWP-1 to all relevant space agencies

The constellation of at least three orbits (early morning, morning, and afternoon), each with full sounding capabilities (IR and MW), should be maintained. The overpass times of operational satellites with sounding capability (IR and MW) should be coordinated between agencies to maximize coverage and include a satellite in early morning orbit.

Also, whilst SSMI/S is recognised as an instrument that provides alternative sounding capability, the launch of F20 is still uncertain. F20 would help with gap mitigation, and the WG recommends that F20 should be flown.

Recommendation DA/NWP-2 to the Defense Meteorological Satellite Program

In support of maintaining a robust global satellite observing system, SSMI/S on F20 should be flown, preferably in an early morning orbit.

Cal/val of Future Instruments

The working group feels that the distribution of test data prior to launch is of such importance that the following recommendations should be repeated to ensure that users have adequate test data to fully prepare for future systems.

Recommendation DA/NWP-3 to Space Agencies

New operational data dissemination infrastructure should be tested at an early stage (well before launch) with simulated data.

Furthermore, NWP data has proven to be a critical resource in the Cal/Val process for new instruments.

Recommendation DA/NWP-4 to Space Agencies

There should be open access to new satellite data for all NWP centres to help with calibration and validation.

Investment to Fully Realise Potential of New Satellites in Operational Use

New satellite programs can cost hundreds of millions of Euros and yet it can take many years to learn to properly exploit the data in numerical weather prediction. Additional investment in operational NWP (which while still expensive is only a few percent of the satellites themselves) therefore represents an efficient path for improving the cost/benefit ratio for satellite observations. This investment should focus on improved computational resources (allowing more sophisticated models to be run and more resources for research); development of new assimilation techniques (many centres are still not running 4D assimilation systems thereby reducing the impact of observations with high temporal frequency) and improvement to the forecast models, as well as methods focused on the particular observations themselves. Investment in operational NWP is preferred as research conducted in this paradigm from the start is more easily transferred to operational status. It is also noted that the larger the number of operational centres able to conduct cutting-edge research, the more likely that breakthroughs will be made in the use of satellite data.

Recommendation DA/NWP-5 to funding bodies of NWP centres and space agencies

Consider, as part of the cost of satellite programs, providing computational and personnel resources targeted at operational NWP centres to optimise the public's return on investment from these expensive measurement systems.

Radio Frequency Interference

At ITSC-17, an activity was started to collect evidence from existing Radio Frequency Interference (RFI) or research into potential impacts of RFI in NWP systems. A website has been set up for this task (https://groups.ssec.wisc.edu/groups/itwg/nwp/rfi_and_nwp), including examples for Windsat, SMOS, and AMSR-E. We need to be able to document instances of RFI so that evidence can be presented to the relevant national authorities who may be able to remove offending illegal transmissions.

Action DA/NWP-2 on NWP WG members

Send any evidence of RFI to working group chairs for inclusion on the NWP WG RFI web page and forwarding to Jean Pla (jean.pla@cnes.fr) or Richard Kelley (richard.kelley@noaa.gov).

Updated Channel Characteristics

NWP systems or Simultaneous Nadir Overpass (SNO)-methods have been used to revise channel characteristics such as central pass-band frequencies for microwave instruments or spectral response functions for IR sounders. The group noted that it would be useful to collect this information at a central location, as such updates have been shown to reduce some airmass-dependent biases and therefore aid the assimilation of the affected data. The channel characteristics web-page of the RT WG seems a logical place for this, and Paul van Delst agreed to include such information.

Action DA/NWP-3 on NWP WG members

If you have estimates of revised channel characteristics resulting from post-launch diagnostics, please email these to RTSP WG co-chairs.

2.3.2 WG support to NWP community

The ITSC NWP WG is recognized as an ideal forum to exchange information and inform/update NWP users about new developments, aided by Wiki-pages and a dedicated email list. For several meetings, the survey on the use of satellite data has been capturing the broad developments in the assimilation of sounder data in NWP, with the results posted on the NWP WG web pages. Ahead of ITSC-20, the survey has been further enhanced to include more instruments and details on channel selection etc.

During the meeting the WG discussed enhancing the content of the survey further to include channel blacklisting information.

Action DA/NWP-4 on WG co-chairs

Enhance NWP instrument usage survey to include template where centres can add information on channel blacklisting.

Action DA/NWP-5 on NWP centres

Continue to provide information on instrument channels assimilated and their observation errors for inclusion on the NWP Working Group pages in advance of each conference.

Increased use of the NWP WG email list was discussed during the meeting. There have been several recent examples of channels dropping out or instruments exhibiting unusual performance in NWP models, where information has been shared only between individual centres. In the past, the NWP WG email list was used to discuss data usage or to alert the community of data problems. However, the group agreed that there should be a new mailing list specifically for these issues, as in many centres there may be other people who do not attend ITSC that are involved in instrument monitoring who it would be useful to include.

There was a feeling among the group that people were reluctant to immediately spread news of anomalies because the first thought is always that it is likely to be a specific problem in their own system which may not be of interest to others. The consistent availability of monitoring reports from other centres would help to identify such problems (see discussion

below). However, it was agreed that it would be better to raise the alarm sooner rather than later, even if it turned out to be a model issue. Guidance will be provided on what the address should be used for. If people are unsure about emailing personally, questions can be addressed to the co-chairs who can then forward the message on to others. A list of names subscribed to the mailing list will be made available on the DA/NWP working group website so that everyone knows who the recipients are.

Action DA/NWP-6 on WG co-chairs

Set up new mailing list for communicating potential instrument anomalies.

Recommendation DA/NWP-6 to NWP WG members

Use the new instrument anomaly mailing list to alert other centres to potential data problems or changes in channel usage as soon as they arise.

Several working group members expressed frustration that monitoring plots from different centres were often insufficient to help with diagnosing instrument/model issues that affect radiance assimilation. It was noted that most centres' monitoring pages are linked from the NWP-SAF website, but that the plots available varied considerably, and some websites require password access.

The group discussed putting together a proposal for a consistent set of monitoring plots (c.f. paper by Tom Auligne and Fiona Hilton in 2006 which proposed plots for IASI monitoring) to aid diagnosis of issues. The document should propose channel subsets for monitoring and a list of the type of plots that should be produced. The list should be prioritised so that centres that do not have the scope to produce the full range of plots do produce the highest priority ones.

Action DA/NWP-7 on WG co-chairs

Add link to NWP-SAF website on NWP instrument monitoring to the WG webpages.

Action DA/NWP-8 on WG members

Ensure their centre's monitoring sites are on the NWP-SAF website. Email NWP-SAF helpdesk if not to ask for it to be added.

Action DA/NWP-9 on WG co-chairs

Coordinate a group to define a set of monitoring plots that each centre should endeavour to provide with public access. Circulate the proposal to the NWP working group.

Recommendation DA/NWP-7 to NWP WG members

Update monitoring websites as soon as possible to include the plots requested in the monitoring proposal.

2.3.3 Provision of BUFR data

At the last meeting, the group made the following recommendation:

Recommendation DA/NWP-8 to Data Providers

Agree standardized procedure for inclusion of NEdT estimates within BUFR for microwave data.

This time we noted that this recommendation is part of the CGMS HLPP. It did not seem that much progress had been made in this area. The primary purpose of such data is for use in physical error models (e.g., talk by Hyoung-Wook Chun this conference), such that temporal variation of noise characteristics can be taken account of during assimilation. This information is available currently for ATMS.

It was noted that the provision of this information for other sensors would require modification of the BUFR tables.

A further issue regards the method of calculation of the NEDT. Jörg Ackermann reported significant differences between NEDT reported by NOAA and by EUMETSAT. This is not just a simple offset but channel-dependent. The NOAA algorithm includes orbital variability but EUMETSAT takes account only of variability of warm target calibration counts. There have also been recent changes at NOAA to use the Allan variance. It is unclear which measure is more useful to users. The Allan variance does not include gain variability in the calculation as this can theoretically be accounted for separately.

Action DA/NWP-10 on Jörg Ackermann

Collate information regarding different algorithms used by data providers for calculating NEDT.

Action DA/NWP-11 on WG members who belong to member states of EUMETSAT

Request provision of NEDT in BUFR products for microwave sounders via EUMETSAT science working group.

The group retained the following two recommendations from the previous conference:

Recommendation DA/NWP-9 to Data providers

Include azimuthal viewing and solar angles as appropriate in BUFR for present and future instruments.

Recommendation DA/NWP-10 to Space Agencies and data providers

When designing new or modified BUFR formats, please circulate drafts to the NWP community via the NWP Working Group for feedback, prior to submission to WMO.

CrIS Full Spectral Resolution BUFR data is available for users to test. Centres are encouraged to download test datasets as soon as possible so that the format can be confirmed.

Action DA/NWP-12 on NWP Centres

Contact Tom King (thomas.s.king@noaa.gov) to acquire CrIS FSR data, and confirm with him that it is acceptable.

2.3.4 Microwave Sounding Data

Striping on ATMS

NESDIS would like ATMS radiance products with striping effects mitigated to be tested by NWP centres. JMA tested the destriped ATMS data provided by Fuzhong Weng and found that observation first-guess departure histograms are good and noise is improved spatially.

JMA would now like to have near-real-time data to do a forecast impact experiment. (Met Office, NCEP, ECMWF, NRL, DWD also expressed interest.)

Recommendation DA/NWP-11 on NWP Centres

Evaluate the de-striped ATMS radiances made available by Fuzhong Weng and report back to NOAA and the NWP Working Group, both on initial investigations with the sample dataset and on OSEs when a parallel data stream becomes available.

2.3.5 Hyperspectral Infrared Sounders

Efficient Dissemination of Hyperspectral Radiances

For future hyperspectral sounders (particularly geostationary imagers such as MTG-IRS) it will be challenging to losslessly disseminate all data. Several items in the CGMS HLPP relate to prescribing appropriate PC compression methods for hyperspectral data dissemination.

At the previous conference, the working group discussed the possibility for a two-stream dissemination approach, where a low data volume stream suitable for operational assimilation would be provided with high reliability, and timeliness, combined with a lossless full resolution dataset (which can be used for research purposes) with reduced reliability and timeliness constraints. There was a recommendation for this to be discussed further, but there has been no progress since last meeting.

The following recommendations, which relate to CGMS HLPP items on PC compression are retained by the working group.

Recommendation DA/NWP-12 to data providers

If PC compression is used to disseminate hyperspectral IR observations, a conservative approach should be taken in order to mitigate information loss (e.g., by retaining as many principal components as possible).

Recommendation DA/NWP-13 to data providers and NWP users

A mutually acceptable update strategy should be devised and documented for the dissemination of PC products.

At the last conference, the following actions were placed that were not completed before this conference. They are retained (and renumbered):

Action DA/NWP-13 on EUMETSAT

Circulate a proposal on update strategy for IASI PC basis vectors, including consideration of the length of the notice period, to the working group.

Action DA/NWP-14 on NWP WG Members

Provide feedback on the above proposal.

No plan was circulated before the meeting. However, at this meeting, Thomas August confirmed that a change in basis vectors would constitute a "business as usual" type change, which would involve a minimum 4 week notice period (in practice 6-8 weeks + test data). A change in the number of vectors (or other more radical change) would be considered a larger change that would require more notice, and a period of parallel dissemination with specific

users asked to act as beta testers, then a trial phase for all users. Registered users will be notified directly in either case.

The working group discussed whether this strategy is acceptable. It was agreed that it was very difficult to determine whether 4 weeks would be sufficient when centres currently do not use PC-compressed IASI operationally. For example, for centres assimilating PC scores, changes to RT coefficients or modified QC might be required. It is also not clear how such updates would be initiated - by users or by EUMETSAT (likely to be a combination of the two). For example, would an update be initiated immediately after a few outlier spectra are identified? Given the lack of clarity the working group retains the above two actions.

However, acknowledging that we need to make more use of the data in order to be able to test the proposed update strategy, the following recommendation is made:

Recommendation DA/NWP-14 to NWP Centres

Monitor Reconstructed Radiances in parallel to operations so that the PC update strategy can be properly tested.

We also add the following recommendation:

Recommendation DA/NWP-15 on Data Providers

When using PC compression, noise normalisation should be performed using the full noise covariance matrix.

CrIS

The community is encouraged to investigate the use of high-spectral resolution CrIS data, including unapodised radiances.

Recommendation DA/NWP-16 on NWP Centres

Consider carrying out studies to evaluate the use of unapodised CrIS radiances, and/or to use the full spectral resolution apodised data combined with a full noise error covariance matrix.

However, software changes by the data provider are required with unapodised data to reduce the effects of spectral ringing. Users should wait until that change has been made to the data processing chain before trying to use unapodised CrIS data.

The following open action from the previous meeting is retained (but with a change of actionee), as there is still interest, particularly given the imminent arrival of CrIS FSR.

Action DA/NWP-15 on Reima Eresmaa

Organise through the NWP working group a six-monthly telecon to update on progress and any new findings regarding assimilation of CrIS.

Provision of Collocated Imager Data from within the Footprint of Hyperspectral Sounders

The sub-pixel information from imagers that is reported with hyperspectral radiance BUFR data varies from instrument to instrument. It is suggested that a common form of colocated imager data be provided for AIRS, IASI, CrIS and other operational hyperspectral IR sounders and that the AVHRR clustering algorithm currently used for IASI is preferred.

The clustering algorithm provides the mean and standard deviation of radiances within the IASI field-of-view for each AVHRR channel (up to 7 clusters). In addition a percentage cloud fraction derived from AVHRR cloud flags is provided. Note that the ISSWG is also currently addressing this issue for IASI-NG (from 2020).

The product provided should be able to be supported by direct readout packages.

Points to note: The IASI clustering algorithm operates simultaneously on the AVHRR footprints that fall into all 4 FOVs in a FOR. For CrIS, this would mean operating over 9 FOVs, for IASI-NG over 16.
The current processing of VIIRS cloud data within the CrIS field of view requires the data to be present within ten minutes of the CrIS acquisition, otherwise the cloud flag is missing. Is this a suitable strategy for the cluster analysis?
The latest version of AAPP can perform geolocation matches between VIIRS and CrIS and also contains the required clustering algorithm.

Recommendation DA/NWP-17 to Data providers

Use the AVHRR cluster algorithm available in AAPP for all hyperspectral sounders.

Action DA/NWP-16 on Andrew Collard

Request that the AVHRR/IASI clustering algorithm is implemented at NOAA/NESDIS/STAR for CrIS and AIRS data.

There has been discussion in the IASI user community on including more detailed information on the distribution of imager radiances within the IASI-NG sounder field of view.

Recommendation DA/NWP-18 to data providers

Consider including a map of the sub-pixel information derived from imager pixels within hyperspectral sounder FOVs, should bandwidth allow.

Reduced Field of View Size for Hyperspectral Sounders

It has been suggested that it is possible to reduce the field-of-view size from 14km to 7km for CrIS on JPSS-3, while keeping the sampling frequency the same (i.e., resulting in sampling that is not spatially continuous). This will result in approximately a doubling of NEdT for the CrIS radiances. The advantage would be potentially a greater number of clear and/or homogeneous fields of view.

It has long been recognized that there is a tradeoff in instrument performance between field-of-view size, spectral resolution and instrument noise, but that opinion remains divided on the optimal solution.

It was noted that there have been a number of studies on clear-sky yield as a function of instrument field of view size and that a review of these studies would be desirable (known papers include the present study by Likun Wang using CrIS/VIIRS; a 2010 study by Lydie Lavanant using IASI/AVHRR; a 2007 study by Krijger et al. using MODIS). However, the effect of these changes and the associated noise increase on forecast model performance has not been extensively studied. It is very hard to reach consensus on this issue without this

additional information (and it was also noted that even full assimilation studies are limited because of the difficulty in anticipating the data assimilation systems in the coming decades).

Finally, it was noted that these issues are moot if sampling is frequent enough to allow observation averaging or super-obbing.

Recommendation DA/NWP-19 to funding bodies

Provide finances for specific projects to look at the impact of data assimilation/forecast systems on the trade-off between field-of-view size, spectral resolution and instrument noise.

Action DA/NWP-17 on Bill Bell (Met Office)

To collate the available studies that have been performed on the increased yield and coordinate investigations into the impact of reduced field-of-view size combined with increased noise on model performance with an aim to inform decisions for the JPSS-3 CrIS.

Action DA/NWP-18 on Working Group Members

Please e-mail Bill Bell (william.bell@metoffice.gov.uk) if you have something to contribute to the FOV studies.

Action DA/NWP-19 on Likun Wang (U. Maryland)

To circulate information on the study he performed on the VIIRS cloud mask.

2.3.6 Bias Correction

On Friday evening, a sub-group met to discuss bias correction in regional models.

Present: Tom Auligné (JCSDA), Nancy Baker (NRL), Patrik Benacek (CHMI), James Cameron (UKMO), Bill Campbell (NRL), Chu-Yong Chung (KMA), Andrew Collard (NOAA/NCEP/EMC), Robin Faulwetter (DWD), Vincent Guidard (Météo-France), Wei Han (CMA), James Jung (CIMSS), Masahiro Kazumori (JMA), Eunhee Lee (KMA), Agnes Lim (CIMSS), Stephen Macpherson (Environment Canada), Kozo Okamoto (JMA), Roger Randriamampianina (Met Norway), Indira Rani (NCMRWF), A.K. Sharma (NOAA/NESDIS), Inchul Shin (KMA), Sanjeev Kumar Singh (NCMRWF), Fiona Smith (Met Office), Pei Wang (CIMSS), Xiaoyan Zhang (NCEP),

The group effectively conducted the survey on bias correction strategies recommended at the previous ITSC during the meeting. The results are included in the table below.

Centre	**Global model available?**	**Strategy**
Met Norway	Yes	AROME uses VarBC, assimilating ATOVS and IASI. 24-hr cycling of coefficients.

DWD	Yes	Global bias correction scheme is a dynamically-updated off-line Harris and Kelly (HK) -like scheme. No radiances yet in the assimilation model, but plans to assimilate cloud-affected radiances in regional ETKF.
Environment Canada	Yes (same model top)	Global model runs dynamically-updated off-line HK scheme. All radiances in global model are used also in regional, using global BC coeffs.
JMA	Yes	Global uses VarBC. Mesoscale model imports global coeffs.
KMA	Yes	Global uses static HK. Regional model imports the global coefficients. LAM does not assimilate satellite data.
CMA	Yes	No satellite data yet assimilated, GEO CSR will be added using bias corrections derived in the mesoscale model itself.
NCEP	Yes (global model stratosphere blended on)	Regional model runs VarBC separate from global model. Wide domain.
NCMRWF	Yes	Global model uses VarBC Regional model does not yet assimilate satellite data, but it is planned to use VarBC in IMDAA reanalysis, which will begin soon.
Météo-France	Yes	Global uses VarBC. Regional model uses imported coefficients from the global. Due to the particularly low model top, the predictors needed to be adapted in the global model. The exception is High-Res SEVIRI, for which VarBC is used in AROME.
NRL	Yes	Global uses VarBC Current 3D-Var regional model uses a HK-like scheme. New 4D-Var to use global coefficients. Hard to spin up regional coeffs as may need to be done at short notice over a very small domain.
CHMI	No	3D-Var with 6-hour assimilation windows and VarBC. Starting to assimilate MSG. 24-hour cycling of coefficients

Met Office	Yes	Global currently static HK, but moving to VarBC. Regional model currently uses global coeffs. Future strategy is not yet set. AMSU-B is sometimes spun up from the UKV.
CIMSS	No	WRF, uses input from GSI coeffs (VarBC global)

Main Issues

1. Where centres use coefficients from a global model for bias correction in a regional model, mismatches in
    a. Model top and
    b. Vertical layering

    can mean that coefficients do not perform well in the regional model.
2. If you do not have a global model, you do not have the possibility to use global coeffs anyway. It can be particularly hard to spin up bias corrections because of extremely variable observation coverage.
3. Small domain size and short assimilation window length are the main issues for very limited area models. In the case of VarBC, 24-hour cycling with separate coefficients for each assimilation cycle is often required. There is a trade-off between requirements for fast adaptation rate and stable VarBC performance.
4. Bias correction of all-sky radiances is of particular interest to some members of the group.

The group did not feel that an intercomparison exercise would be easy to achieve. The group recommends that studies in this area are carried out and experiences shared. It would be particularly useful to have studies that compared the bias corrections derived from global models with those derived from LAMs to understand their differing properties.

Recommendation DA/NWP-20 on Working Group members

To submit abstracts to the next ITSC on the topic of bias correction in regional models and bias correction of all-sky radiances.

At the last conference there was an action (DA/NWP-17) on Wei Han to evaluate whether the information on the RT group website is sufficient to provide radiometric uncertainty information needed for a study to constrain biases to realistic levels. Wei Han said that it was not sufficient, but that he would still like to attempt such a study.

Action DA/NWP-20 on Wei Han

Detail what information is required on radiometric and forward model uncertainty to constrain bias corrections, and circulate to the working group along with a proposal for how they would be used.

2.3.7. Use of Correlated Errors for Data Assimilation

There has been significant progress in the use of correlated observation error covariance matrices for NWP in recent years. Most progress has been made in the use of matrices diagnosed using the Desroziers technique or Hollingsworth-Lönnberg. One of the main drawbacks of these methods is that they have many assumptions built into them that are

frequently violated, and the output matrices often require inflation before they can be used without causing significant degradation.

The working group noted a new line of work presented at this conference (5.04 Hyoung-Wook Chun) using a physical approach to estimate correlated errors. The group would like to encourage further work in this area. Parts of the physical model are easier to estimate than others; in particular understanding the random component of line-by-line RT errors and representivity errors require further study.

Recommendation DA/NWP-21 to NWP Centres

Consider studies into the use of physical methods as well as diagnostic methods to characterise observational uncertainties, including their correlations, to improve the assimilation of satellite radiances.

2.3.8 Direct Broadcast

Action DA/NWP-21 on WG co-chairs

Define a superset of channels for hyperspectral IR instruments that are required for monitoring and assimilation at NWP centres to define minimum channel distribution through DBNet and send to ITSC chairs.

2.3.9 Other Items from the CGMS HLPP

CGMS Recommendation 1.1.2: Support satellite impact studies including regional verification

We note that many satellite impact studies are performed at NWP centres, and there were many papers at this conference on this topic. Several centres reported on the assimilation in regional models, though verification schemes for regional models are often designed to verify local weather rather than upper air performance, and satellite data impacts may be hard to demonstrate.

CGMS Recommendation 1.1.3: Facilitate the evolution of research short-term missions to an operational status

NWP Centres are keen to use all sources of data in their models, but note that there is significant work required to prepare assimilation systems for new data, and that if the research mission is short-lived there is a risk that this work is wasted. In summary, NWP centres perform work in this area as appropriate.

CGMS Recommendation 3.7.3: Perform validation and intercomparison of LBL models/spectroscopy

The working group strongly supports work in this area, as good RT is fundamental for assimilation of sounding data. The group is particularly interested in studies that provide information on uncertainty estimates, particularly in correlated error structures and the separation of bias and random error, that can be used for physical error estimation for data assimilation.

2.4 ADVANCED SOUNDERS

Web site: http://cimss.ssec.wisc.edu/itwg/aswg/

Working Group members: Dieter Klaes (Co-Chair, EUMETSAT), William L. Smith (*Co-Chair, SSEC/UW-Madison and Hampton Univ.*), *Jörg Ackermann (EUMETSAT), Nigel Atkinson (Met Office, UK), Thomas August (EUMETSAT), Fabrizio Baordo (BOM), Chris Barnet (Science and Technology Corp.), Patrik Benácek (CHMI), Sid Boukabara (NOAA/NESDIS&JCSDA), James Cameron (Met Office, UK), Keyi Chen (LAP.CAS), Chu-Yong Chung (NMSC/KMA), Dorothée Coppens (EUMETSAT), Mohamed Dahoui (ECMWF), Stephen English (ECMWF), Reima Eresmaa (ECMWF), Louis Garand (Environment Canada), Mitch Goldberg (NOAA), Vincent Guidard (Météo France), Yong Han (NOAA-STAR), Wei Han, (NWPC/CMA), Allen Huang (CIMSS/SSEC), James Jung (CIMSS), Björn Lambrigtsen (JPL), Jinlong Li (CIMSS/UW Madison), Jun Li (UW Madison), Agnes Lim (CIMSS), Nick Nalli (NOAA/NESDIS/STAR), Eric Pequinot (CNES), Myriam Peyre (Météo France), Alexander Polyakov (St.Petersburg University), Joe Predina (Logistikos Engineering), Roger Randriamampiannina (MET Norway), Indira Rani (NCMRWF, India), Awdhesh Sharma (NOAA/NESDIS/OSPO), Sanseev Kumar Singh (NCMRWF India), Yi Song (NESDIS/STAR), Steve Swadley (NRL), Denis Tremblay (NOAA-STAR), Alexander Uspensky (SRC Planeta), Likun Wang (UMD), Xiaozhen Xiong (NOAA/NESDIS/STAR), Tiger Yang (NOAA-STAR)*

2.4.1 Introduction

The Advanced Sounder Working Group (ASWG) focuses on scientific issues affecting the optimal performance of advanced satellite sounder systems. The working group reviews the status of the development of advanced sounder systems and recommends changes pertaining to instrument specification, performance, data processing, and utilisation. For the purpose of this group, "Advanced Sounders" are defined as instruments that present significant new scientific and technological challenges and which require new methods for data processing and utilization. Thus, Advanced Sounders currently include high spectral/spatial resolution passive infrared and microwave sounders and active sensors.

2.4.2 Advanced Sounding from Polar Orbit

Improved sounding from polar orbit has been one of the highly recommended action items from ITWG. The consideration for advancing polar orbiting sounding improvements includes high spatial resolution and denser spatial sampling to increase the density of high quality clear air radiance measurements commensurate with finer grid size of current and future NWP models as well as improvements in absolute accuracy, traceable to radiometric standards, and spectral coverage for the purpose of cross-calibration of instruments of lesser accuracy in geostationary and polar orbits. With recent advancement in sensor technology and impact assessment study from the assimilation of cloud contaminated sounding radiance data, the ASWG reached a general consensus to recommend improvements in horizontal resolution as the highest priority for future infrared sounding instruments.

The ASWG expressed the following concerns and general recommendations:

1) ***Improved Utilization By Forecasting Centers:*** Forecast centers only assimilate a small fraction of the spectral channels and spatial samples of sounding radiance data available. Data denial studies with results presented at the ITSC-20 show that forecast skill improves with the addition of IR hyperspectral sounding radiance data. As a result, **NWP centers should make it a priority to develop the means to assimilate**

the majority of IR hyperspectral sounding radiance data available in order to obtain further improvements in forecast skill.

2) ***Absolute accuracy amongst all detectors within the instrument Field of Regard (FOR):*** Priority should be given to maintain better than 50 mK equivalent brightness temperature calibration match of all sounder FOV radiances over the full brightness temperature measurement range. If this is achieved at the 1b product level, then NWP centers will have a stronger incentive to use all FOV data within the instrument's FOR in NWP models.

3) Intersatellite Instrument Cross-calibration: On-orbit hyperspectral IR sounders offer the best means available today for establishing intersatellite radiance calibration for a fleet of diverse on-orbit IR instruments with various spectral responses. An SI traceable radiance scale having one sigma uncertainty of 35 mK across the IR spectral band (climate class instrument) can be incorporated into systems, such as IASI, CrIS and IRFS, with current technology. The evolution of current sounding systems toward climate class measurement uncertainties should be a priority in the development of future hyperspectral IR sounders. This can be achieved with modest incremental cost of existing systems.

4) Spectral Gaps: Augmenting spectral coverage in the gaps between existing bands of future CrIS instruments can be achieved at a very modest cost. This augmentation can be accomplished without detriment to the existing JPSS mission. Consequently, evolving CrIS into a full spectral coverage instrument should be pursued in order to support a worldwide intersatellite calibration capability in the wavenumber range 650 – 2760 cm^{-1}. This recommendation should be simultaneously coupled with technology insertion to support SI traceable climate class radiance measurements.

5) Instrument Horizontal Resolution: CrIS currently has high signal to noise ratio margin relative to what is needed for EDR production. Forward model noise/uncertainty dominates over instrument observation noise. A SNR degradation up to a factor of 4 will have no significant impact on CrIS EDR retrievals, based upon current NEdN performance and trade studies done at the beginning of the CrIS program. The signal to noise margin is even higher when considering the ability to horizontally average high horizontal resolution clear FOV radiance data. This consideration opens up an opportunity to reduce the FOV size on CrIS to as small as 5km without significant EDR retrieval penalty. Reduction of CrIS FOV size should be pursued on future systems given the current system SNR margin. This will yield significantly more high quality cloud free retrievals. The reduction of FOV size is also expected to improve cloud cleared radiances as a result of increasing the contrast between cloudy and clear FOVs.

6) Hyperspectral IR Sounding at GEO Orbit: Hyperspectral sounding instruments in geostationary orbit enable the derivation of 3D wind vectors for improving NWP. Successful generation of 3D wind vectors having high spatial and temporal resolution has been acknowledged as the highest need from NWP centers for improving weather forecasts. Similar benefits associated with improved severe storm warning are also possible based upon limited experiments/observations from low earth orbit systems. The ASWG recommends that a pathfinder hyperspectral IR sounder mission targeting

moisture cell tracking and 3D wind vector generation at geo orbit should become an applied research priority and demonstrated on-orbit by 2020.

7) ***Complimentarity of GEO and LEO Hyperspectral IR Sounders for 3D Winds:*** Wind observations made from both GEO and constellations of LEO satellite have complimentary capability. Localized severe weather prediction is best served by a GEO platform. Full global coverage for global extended range NWP modeling is better served by constellations of LEO platforms. Thus, the ASWG recommends that both types of systems should be pursued and developed for improved weather forecasting.

8) Increasing FOV Number Within Existing IR Sounder FORs: Although useful to increase the number of detectors and therefore density of FOVs (i.e., 6 x 6 vs. 3 x 3 or 2 x 2 detector arrays), since the probability of obtaining a clear field of view within the instruments FOR, the ASWG feels that this achievement is less important than any of the concerns, 1 through 7, listed above for NWP applications of the data. This is because FOV data is ultimately thinned in NWP models and small FOV size with good SNR provides sufficient sampling with good quality EDRs even if small gaps exist between FOVs. In addition, rotation of the CrIS field of regard with scan angle will always produce gaps in FOV coverage no matter how dense the FOR is packed with FOVs. Growth of FOV density beyond 6 x 6 will require alternate detector focal plane technology and represents a significant upgrade expense. Consequently, increasing the CrIS FOV number beyond 6 x 6 should be pursued as a lower priority since the cost penalty also extends to data rate and ground processing resources. In any case, recommendations 1 and 2 above must be resolved first before any benefit can be obtained by increasing FOV density further.

Recommendation AS-1 to Space Agencies

Consider the following priorities for the development/improvement of the next generation of advanced infrared sounders.

The prioritized recommendation lists from the highest are:

1. High spatial resolution to improve the probability of a uniform scene with the instrument FOV (i.e., all clear or all cloudy)*.

2. Spectral coverage from shortwave to longwave without gaps – to facilitate improved inter-satellite instrument cross-calibration.

3. Adopt/adapt calibration approaches traceable to international standards – to improve absolute radiometric calibration in order to achieve measurements closer to climate quality.

*Although maintaining FOV contiguity is also desired in order to increase the spatial density of the data and associated probability of obtaining clear FOVs within the instruments Field of Regard (FOR), increasing the spatial resolution alone would provide significant improvements in both radiance data assimilation and sounding retrieval.

Action AS-1 to ITWG Co-Chairs

Bring this recommendation to the attention of Space Agencies at CGMS.

In order to support these recommendations, it also necessary to:

- Coordinate NWP centers to generate high resolution (1-3 km) nature runs to support OSSE to demonstrate the NWP benefits of these measurement improvements, and

- Request satellite agencies to continue to support and accelerate advanced sounder IFOV size OSSE studies.

Recommendation AS-2 to Space Agencies

Coordinate with NWP Centres the generation of high resolution (1-3 km) nature runs.

Action AS-2 to ITWG Co-Chairs

Convey this recommendation to Space Agencies.

The ASWG noted with interest that a 1 km nature run is being performed by NASA GMAO. The 7 km nature run being basically completed a 1,5 km nature run has started. Plans exist to double the number of levels.

In this context the following action was accepted by Stephen English:

Action AS-3 to Stephen English

To investigate higher resolution nature runs at ECMWF and report back to ASWG.

Studies have shown that the co-located high spatial resolution imaging data provide valuable sub-grid cloud information that greatly improves the assimilation of cloud contaminated sounder data. Such background-independent information is crucial for the cloud detection over land surfaces where background knowledge of surface emission is relatively poor. AVHRR statistics in clusters within IASI field-of-view have proved useful to assisting the cloud detection. There is easy access to collocated imager data currently only in the case of IASI. An aggregate VIIRS radiance product is becoming available soon for the use with CrIS, but should only be considered as an intermediate step as it still relies on the accuracy of the VIIRS cloud mask.

Recommendation AS-3 to Space Agencies (NOAA)

Support further developments towards performing cluster analysis on imager pixels within advanced IR sounder field-of-views and providing statistical information of the collocated imager radiances as part of the sounder radiance observations. (The ASWG recommends that satellite agencies adopt the IASI/AVHRR approach to co-locate CrIS/VIIRS observations and provide radiance cluster and other analysis information in the CrIS SDR file.)

Action AS-4 to ITWG Co-Chairs

Convey this recommendation to Space Agencies (and NOAA in particular).

The development of future MW sounders as an advance of current MW imaging/sounding radiometers with conical and cross-track scanning should include an increased number of channels, especially upper level sounding channels, as well as spatial resolution improvement. As a result the resolution should be close to the one of advanced IR sounders. Besides, the efforts should be focused on refining the technologies for on-board and post launch radiometric calibration in order to provide consistent accuracy of the radiance measurements. Also it will be useful to maintain a constellation of early morning, morning and afternoon polar satellites with advanced MW sounders onboard.

SNPP and JPSS-1/2 ATMS have a temperature sounding capability near the 50-60 GHz O2 absorption line. In strong precipitation and severe storm conditions, these channels can be severely impacted by scattering from large ice and liquid phase hydrometeors, which can significantly degrade the quality of the temperature profiles. Also, the double O2 sounding also allows for deriving the cloud hydrometeor profiles as demonstrated in a recent study published in GRL by Han et al. (2015).

Recommendation AS-4 to NOAA

Future JPSS instrument enhancements should consider adding 118 GHz O2 band to the baseline design to advance the microwave sounding capability for the retrieval of precipitation over land and sea, including light precipitation and snowfall.

Action AS-5 to Mitch Goldberg

Convey this recommendation to NOAA.

The new ATMS sounding capability with double O2 bands will allow JPSS to generate microwave observations that are compatible with those from EUMETSAT and CMA polar missions which all considered adding this 118 GHz band in their current and future baseline microwave sounding systems.

The ASWG discussed the availability of new microwave technologies and noted that bolometer technology at 90 GHz and beyond has reached a level of maturity to achieve a successful implementation. It is necessary and beneficial to establish a dialogue between providers and the user community to achieve progress in the implementation.

Recommendation AS-5 to Space Agencies and Users

Establish a dialogue between providers and users of microwave soundings on the potential and capabilities of bolometer technology at 90 GHz and beyond.

Action AS-6

Steve English to act as the interface and provide related documentation.

The group discussed and noted with satisfaction the beneficial role and impact of microwave soundings in NWP and the need to maintain this capability.

Recommendation AS-6 to Space Agencies

Maintain and evolve the current microwave sounding capabilities for future systems.

Recommendation AS-7 to Space Agencies

Maintain and evolve the capability of microwave mesospheric sounding capabilities beyond SSMIS.

Action AS-7

ITWG Co-chairs to relay these recommendations to Space Agencies via CGMS.

The group identified the need to pursue the advancement of microwave sounding capabilities via a microwave hyper spectral sounding capability. This could be from either GEO or from a constellation of micro-cube sats in polar orbit.

Recommendation AS-8 to Space Agencies

Conduct studies to pursue high temporal resolution hyper spectral microwave sounding capabilities for future systems.

Action AS-8

ITWG Co-chairs to relay this recommendation to Space Agencies via CGMS.

2.4.3 Advanced Sounding from Geostationary Orbit

The group discussed the potential to perform microwave sounding from geostationary orbit and noted that technology seems to have reached a level of maturity now to allow a successful implementation in orbit.

Recommendation AS-9 to NASA

To implement the PATH mission.

Action AS-9

ITWG Co-chairs to bring this recommendation to the attention of NASA.

Recommendation AS-10 to Space Agencies

To pursue further development and implementation of microwave sounding missions in order to achieve global coverage of geostationary microwave sounding.

Action AS-10

ITWG Co-chairs to relay this recommendation to Space Agencies via CGMS.

2.4.4 SI Traceable Reference Instruments for Improved Climate Observatories

The AS working group continues to believe that advanced climate observatories to benchmark the Earth's climate could provide opportunities to cross-calibrate operational sounding instruments to SI-traceable standards. Techniques like CLARREO could lead to climate quality measurements. This would increase the value of soundings for documenting and quantifying the climate state and decadal trends.

Recommendation AS-11 to space agencies

Develop, test, and implement an SI Traceable radiometric standard in space as soon as feasible.

Action AS-11

ITWG Co-chairs to re-iterate this recommendation to Space Agencies via CGMS.

2.4.5 New Technologies and Opportunities

The ASWG discussed the increasing use of small platforms and cubesats and their potential for implementing advanced sounding capabilities. It was noted that studies are currently ongoing to investigate the potential of such platforms. It was also noted that with the advancement of technology to establish high quality instruments on small satellites, the possibility to test associated micro-instruments on large operational polar platforms becomes a feasible option.

2.4.6 Ground Truth Sites

The ASWG has expressed concern over the recent closing of the tropical DOE ARM-sites (in operation since 1996), namely the Tropical Western Pacific (TWP) sites located either at

Manus Island, Papua New Guinea, Nauru Island, Republic of Nauru, or Darwin, Australia. The ARM TWP stations were located in the tropical western Pacific warm-pool, a region of key importance in terms of interannual climate anomalies (e.g., ENSO) as well as a heat engine driver the earth's atmosphere-ocean system. With the exception of the NOAA Aerosols and Ocean Science Expedition (AEROSE) campaigns (two being conducted in 2013, and one scheduled for Nov-Dec 2015), along with the TWP launches in 2013-2014 and PMRF launches in 2012-2014, the SNPP CrIS/ATMS cal/val program is now without a regular tropical ground truth site.

As time progresses and RAOB truth data are collected at other dedicated (e.g., ARM SGP, NSA, ENA) and reference (e.g., GRUAN) sites, we will find ourselves increasingly with a sample skewed toward extra tropical locations, and JPSS Long-Term Monitoring (LTM) will be compromised for EDRs/SDRs in the tropics. GRUAN sites-of-opportunity have also been utilized as part of the dedicated/reference validation strategy however as these sites launch radiosondes at synoptic times, good collocations with SNPP overpasses tend to be limited to sites located over northern Europe (i.e., near the Prime Meridian). As of this writing, there are no tropical GRUAN sites that collocate well with SNPP overpasses.

Recommendation AS-12 to Space Agencies

Re-establish regular dedicated radiosondes at one of the ARM TWP sites, or at a comparable tropical site (e.g., PMRF).

Action AS-12

ITWG Co-chairs to relay this recommendation to Space Agencies/Providers.

2.5 INTERNATIONAL ISSUES AND FUTURE SYSTEMS

Working Group members: Steve English (Co-Chair, ECMWF), Jérôme Lafeuille (Co-Chair, WMO), Nancy Baker (NRL), Sid Boukabara (NOAA), Louis Garand (EC), Mitch Goldberg (NOAA), Wei Han (CMA), Allen Huang (UW/SSEC), Rich Kelley (NOAA), Dieter Klaes (EUMETSAT), Rob Roebeling (EUMETSAT), Alexander Uspensky (Roshydromet), Peng Zhang (CMA)

2.5.1 Introduction

The ITSC-20 Working Group on International Issues and Future Systems (IIFS) convened on Saturday 31 October 2016 and discussed the following topics:

- The CGMS High Level Priority Plan
- Global Design of the GOS, Implementation and Continuity Issues
  - Best practices in the design phase of new instruments
  - Provision of Nature Runs for OSSEs
  - Pre-flight characterisation and traceability of calibration to SI standards
  - User interaction before launch (Satellite User Readiness Navigator- SATURN) and during operations
- Radiative transfer standards
- RFI and frequency management
- Commercial satellite observation providers
- Links between ITWG and other CGMS International Science Groups

The attendance at the IIFS was slightly higher than at previous ITSCs, which was considered at least in part to be due to the decision of the ITWG co-chairs to have only three of the six WGs in parallel on Saturday, enabling more people to participate. The decision of the ITWG co-chairs was therefore welcomed by the IIFS.

2.5.2 Summary of ITSC-19 Actions and Suggested Topics for Discussion

Progress has been made on some but not all actions and recommendations from ITSC-19. Action IIFS19-1 remains open, and all other actions are closed. All recommendations remain valid.

The status of the actions and recommendations was agreed to be as follows:

- **Recommendation IIFS19-1: Still valid**. Expectation that results are likely to be presented at the WMO OSE workshop in Shanghai.
- **Recommendation IIFS19-2: Still valid**. EUMETSAT and CMA plan to provide hyperspectral geo sounders. Recommendation remains valid for other agencies to follow suit.
- **Action IIFS19-1: Open**, the action is continuing for feedback on the CGMS contingency plan.
- *Action IIFS19-2: Closed.*
- *Action IIFS19-3: Closed.*
- **Recommendation IIFS19-3: Still valid**. More feedback on SATURN is strongly encouraged.
- *Action IIFS19-4: Closed.*
- **Recommendation IIFS19-4: Still valid**. Implementation of notification procedure still recommended.

- **Recommendation IIFS19-5: Still valid.** Roshydromet still recommended to make DB software available to the community. This was discussed at ITSC-20 and there was encouraging progress.

The status of the valid recommendations and open action will be reviewed again at ITSC-21.

2.5.3 The CGMS High Level Priority Plan (HLPP)

The coordination activities of CGMS are reflected in a High Level Priority Plan (HLPP) initially endorsed by the CGMS-40 plenary session in 2012. Items relevant to the IIFS from the HLPP were reviewed. In general the HLPP was welcomed. The IIFS would like to see a greater emphasis on the latency requirement for research and pre-operational observations, which would greatly facilitate their uptake by operational centres. The IIFS members will continue to review progress against the HLPP at future ITSCs and provide feedback where appropriate.

Recommedation IIFS-1

Emphasize latency requirement in the HLPP Action 2.3 to increase the use of research and pre-operational satellites. (Action: Mitch Goldberg to propose to CGMS).

2.5.4 Global Design and Calibration of the GOS

The group noted that WMO was convening two weeks later a workshop on the vision of the space-based observing system in 2040, which was an opportunity to convey a message regarding future design of the GOS from an ITWG viewpoint.

The success of the dual Metop satellite configuration was noted. At ITSC-19 the group had remained inconclusive whether it was best to stagger the orbits or adopt an "A-train" type configuration. At ITSC-20 the group agreed there was a significant advantage to staggering satellites of the same nominal orbit (i.e., am, pm, e-am) in order to improve the sampling and coverage. Bearing in mind the spacecraft operations constraint, it was considered that similar spacecraft of a same agency could be staggered in phase within the same orbital plane, while different spacecraft could be staggered by small differences in Equatorial Crossing Time (ECT).

Recommendation IIFS-2

When an agency has two or more satellites in the same nominal orbit (e.g. 2pm) that they be staggered by phase (as Metop). With multiple satellites from different agencies it is recommended to stagger them in ECT. (Action: Mitch Goldberg to present to CGMS).

The group went on to discuss the Metop configuration in more detail, noting that it is considered to be sub-optimal for some instruments (e.g., scatterometer, where a closer separation is better) but optimal for others (e.g., the sounders). In order to provide clear guidance for future configurations the group considered that more evidence was needed to determine the best overall orbital separation.

Recommendation IIFS-3

IIFS members to investigate optimal staggering to test working assumption that dual Metop configuration separated by about 180° is best option for future missions.

(Action: IIFS members to provide evidence to IIFS co-chairs of advantages of orbit staggering).

The group noted the significant progress in the use of and impact of MW humidity sounding radiances, in particular the success of the SAPHIR instrument on Meghatropiques and GMI on GPM building on the AMSU-B, MHS, ATMS, MWHS and SSMIS heritage. In particular there is now evidence for the need for high temporal frequency MW humidity sounding observations, alongside microwave imagery data. The group noted that there is more than one proposal being considered for how high temporal resolution MW observations could be provided (polar LEO constellation, Geo MW, HEO MW, low inclination LEO missions).

Recommendation IIFS-4

Provision of high temporal frequency MW humidity sounding radiances (alongside cloud and precipitation sensitive observations). (Action: Jerome Lafeuille to present to WMO Vision 2040 workshop).

Results presented at ITSC-20 showed the specific value of low-inclination LEO missions such as SAPHIR to sample the diurnal cycle, which is helping to separate biases arising from the observations and those arising from temporal sampling during the diurnal cycle.

Recommendation IIFS-5

Provision of low-inclination MW humidity sounding to monitor diurnal cycle. (Action: Jerome Lafeuille to present to WMO Vision 2040 workshop).

The group went on to consider the absolute calibration of satellite observations, noting efforts such as the Horizon2020 projects GAIA-CLIM and Fiduceo in Europe to establish SI traceability of MW and broadband IR observations to reference observations, as well as CLARREO for hyperspectral observations in the United States. The group welcomed these efforts and encouraged their continuation. The group noted GSICS leadership in this area and encourage GSICS to pay specific attention to SI traceability of hyperspectral sounders.

Recommendation IIFS-6

Achieve SI traceability of operational hyperspectral IR sounders, and ultimately MW sounders, recognising growing need for assessment of calibration uncertainties. (Action: Mitch Goldberg and Peng Zhang to present to GSICS).

The group noted that an issue for the GAIA-CLIM and Fiduceo projects is the small number of reference observation sites (e.g., only 16 GRUAN stations), and were concerned that some tropical ARM sites may not continue to be funded.

Recommendation IIFS-7

Provide more GRUAN and tropical ARM sites, given the need for ground-based reference measurements. (Action: Mitch Goldberg and Peng Zhang to present to GSICS).

The group noted that the provision of pre-flight characterisation data is very important to the efforts to achieve SI traceability and to diagnose and understand observed biases. However the quantity and quality of this pre-flight characterisation information from MW sensors is not consistent between different agencies. Agencies are encouraged to develop and adopt best practices.

Recommendation IIFS-8

Develop best practices in pre-flight characterisation of MW sensors (Action: Mitch Goldberg and Peng Zhang to present to GSICS).

Finally, in this section, the group noted that whilst efforts to improve the absolute SI traceable calibration of the observations was making progress, this must be complemented by similar efforts in characterising biases in the Line by Line (LBL) model and from quality control procedures such as cloud screening for hyperspectral sounders. Only when the biases in all these areas are well understood and characterised can hyperspectral and MW sounders be considered as an absolute reference within the GOS. The group noted with appreciation the efforts to improve understanding of LBL errors at 183 GHz recently organised by LATMOS, ECMWF and Météo-France.

Recommendation IIFS-9

Noting the progress made in characterising observation uncertainty for hyperspectral sounders encourage further characterisation of LBL model error and errors arising from cloud screening, with a view to considering hyperspectral sounders as an absolute reference. (Action: Mitch Goldberg to ensure this is delivered to IRC and RTWG.)

2.5.5 Radio Frequency Interference Issues

The group welcomed recent successes in work carried out by many agencies including NOAA, EUMETNET, EUMETSAT and ESA, including substantial preparations for the WRC15 due to take place shortly after ITSC-20. However there remains a clear and growing risk to the activities of ITWG from other users of the spectrum. The group therefore discussed in some detail ITWG's role in this area.

Richard Kelley noted that very few incidents of RFI were being noted and reported by the ITWG community. He felt that this was probably down to the ITWG members not knowing what to report or how to report it. Therefore procedures will be circulated to ITWG members and ITWG members are encouraged to be more pro-active.

Recommendation IIFS-10

Clarify reporting procedure for notifying ITU of detected RFI. (Action: Rich Kelley to circulate proposed procedure and ITWG members to follow).

Richard Kelley noted that the WRC-15 will take place shortly after ITSC-20 and offered to provide a summary of issues relevant to ITWG.

Recommendation IIFS-11

WRC outcomes to be provided to ITWG. (Action: Rich Kelley to email summary to ITWG mailing list).

The group noted that it is important that those working on behalf of ITWG have detailed and up to date information on current usage of bands that may be the object of attention from other interested parties (e.g., mobile telecommunications). It was noted that in the United Kingdom the regulatory authority, Ofcom, has been pro-active in engaging with all interested parties, including ECMWF and the Met Office, and recently conducted a user consultation service where ESA and EUMETSAT were also invited. The group encouraged organisations

that provide information to user consultation exercises such as this in their own country to share the information with other agencies. Richard Kelley offered to be a point of contact to receive this information.

Recommendation IIFS-12

IIFS and other ITWG members to provide information on current usage of protected bands to Rich Kelley. (Action: Stephen English to provide copy of recent ECMWF submission to OFCOM, and to request Met Office to provide copy of their submission as well as encourage other NMSs to provide similar information where it exists).

The group noted that in addition to the very strong case for provision of MW Spectral Response Functions (SRFs) for radiative transfer calculations that was made during ITSC-20 there is an equally strong, and arguably stronger, case for their provision of SRFs in support of enforcement of RFI regulation. If RFI is detected by a user or data provider in a particular channel of an instrument (e.g., MHS), the regulatory authorities cannot act unless the detailed SRF is known, because the emission may be from outside the protected band.

Recommendation IIFS-13

To make MW SRFs available to facilitate RFI investigations when needed. (Action: Stephen English to ask co-chairs to combine with Recs from other WGs and communicate to CGMS).

The group noted that the case for allocations of frequency bands for exclusive or shared passive remote sensing is most convincing when based on societal and economic benefit. Therefore the group made two recommendations, the first to update the actual forecast impact of specific bands, and the second to attempt to quantify this in economic terms, as the Met Office did in 2005. Detailed information in such studies is often commercial in confidence, but the total economic impact is useful information. Regulatory authorities may request the detailed financial case, treating all information as commercial in confidence.

Recommendation IIFS-14

Update Steve English's study from 2005 on the value of individual MW protected bands. (Action: Sid Boukabara to ask Thomas Auligné to consider making this part of the FSOI intercomparison study and presenting to the WMO impacts workshop in Shanghai in 2016).

Recommendation IIFS-15

NMSs to attempt to provide an assessment of the economic value of bands based on the impact assessment, as was done by the Met Office in 2005. (Action: IIFS members to investigate in their countries).

2.5.6 Implementation of New Instruments and Continuity Issues in the GOS

The group continues to strongly support WMO's OSCAR and SATURN facilities and thanked WMO for their continuing strong support to the community through their provision. IIFS members reported that OSCAR is now very well established source of information in standard working practices and that the SATURN initiative is also very warmly welcomed. The group encourages WMO to continue to support these efforts and to help establish SATURN through constructive feedback.

Recommendation IIFS-16

WMO and CGMS satellite operators to further maintain OSCAR and SATURN, noting the strong positive feedback from ITWG Members. (Action: IIFS members to review SATURN and provide comments to Stephan Bojinski sbojinski@wmo.int)

It was noted that in addition to the information on SATURN, which is about the preparations for a new satellite, there is also a need to establish best practice in the design phase of new programmes. The group noted the success of the process followed by EUMETSAT for MTG and EPS-SG and Dieter Klaes offered to provide information on EUMETSAT's practices, that could led to the adoption of best practice.

Recommendation IIFS-17

Provide information on best practice for the design phase of new programmes. (Action: Dieter Klaes to circulate his paper from the ECMWF satellite seminar, and IIFS members to provide similar information to IIFS co-chairs for their agencies if possible.)

As part of the design phase for new programmes some agencies are required to run Observation System Simulation Experiments (OSSEs). The group noted that these are complex to design and get right, and poorly designed OSSEs in the past have given these techniques a bad reputation in some agencies. However the view was expressed that if well designed they can provide useful information. A key part of the establishment of good OSSEs is the Nature Run, and the provision of new and improved Nature Runs with high resolution, more accurate dynamical core and improved physics is recommended. In the past ECMWF and GMAO have been active in provision of Nature Runs.

Recommendation IIFS-18

The NWP community to continue to produce and make available Nature Runs to support preparations for, and fair evaluation of, potential future observations. (Action: IIFS co-chairs to bring recommendation to attention of WMO, ECMWF and GMAO.)

The group welcomed the excellent news that CMA is committed to deploying FY-3E in the so called Early Morning Orbit. This will ensure good coverage of this orbital plane until the end of that mission. At present continuation of e-am coverage after FY-3E (and the plans for a post DMSP e-am mission) remain in the planning stage. The group encourages CMA and DoD to keep in mind during these considerations the need to provide continued coverage in the E-AM orbital plane.

Recommendation IIFS-19

Welcoming the decision of CMA to operate FY-3E on the e-am orbit but noting the current lack of any long-term plan for this orbit, to consider follow-up and back-up missions ensuring continuity of e-am post FY-3E and DMSP. (Action: Nancy Baker and Peng Zhang to pass Rec to DoD and CMA.)

The group recognised the pioneering work achieved for upper stratospheric and mesospheric sounding by the SSMIS instrument. Until recently most NWP models did not extend to these high altitudes. However the group noted that now many centres are becoming more interested in these altitudes both for improving medium range forecasts and seasonal prediction, as well as links to space weather. However given the low level of use of these channels to date

making the case for their continuity is not as straightforward as it is for observations that are already widely used. Nonetheless the group anticipated that their importance will grow significantly in the coming decade. It remains unclear if DMSP spacecraft will fly beyond F-19, and in any case no agency has plans to maintain this capability post-DMSP. The group also noted that RO observations are not sensitive to these very high altitudes so cannot be considered as a substitute. Therefore there is a risk of losing a capability to sound this region of the atmosphere that may be important to the future requirements of operational agencies. The group noted that the development of the WMO Vision for 2040 is an opportunity to emphasise the expected value of these observations on that timescale, and also to feedback to the US DoD the importance of maintaining this capability in the future.

Recommendation IIFS-20

Continue the SSMIS 60 GHz UAS capability, noting the trend for NWP models to extend higher in the stratosphere and lower mesosphere and the development of thermosphere modelling for Space Weather applications. (Action: Nancy Baker to report to DoD and Jerome Lafeuille to raise at WMO Vision 2040 workshop.)

The group noted that whilst in the past most observations have been provided by publicly funded Space Agencies there may be a trend in the future for more commercial companies to acquire observations. The group noted that users have worked closely with Space Agencies over many years to establish high standards of interoperability and usability of missions, coordinating with WMO, and it is important that these same standards are met by all providers of observations, regardless of their commercial interest.

Recommendation IIFS-21

WMO to promote standards to foster interoperability and usability of possible missions from commercial providers. (Action: Jerome Lafeuille or his successor to provide information when the need arises)

It was also agreed that whilst commercial providers may be able to enhance the GOS with provision of non-essential but valuable data it remains important that observations classed as essential are provided freely, with full government control to ensure that this happens.

Recommendation IIFS-22

Secure full government control for observations classed as essential under WMO Res 40. (Action: Mitch Goldberg to Report to CGMS)

Finally the group noted that in future there will be more overlap in the interest of ITWG and all the other CGMS International Science Groups than we have seen in the past (e.g., ITWG and IPWG for rain affected radiances; ITWG, ICWG and IWWG for MTG-IRS; ICWG and ITWG for clouds; IROWG and ITWG for UTLS sounding). The group encourages the co-chairs to continue to engage with the co-chairs of the other Science Groups, and to coordinate where appropriate.

Recommendation IIFS-23

Noting the strong overlap of interest among the CGMS international science groups for some subjects (e.g. ITWG, IWWG and ICWG about MTG-IRS) co-chairs to ensure coordination where appropriate of communications to CGMS. (Action: Mitch Goldberg to Report to CGMS)

The IIFS thanked Jérôme Lafeuille for his outstanding service as co-chair, and wished him well on his forthcoming retirement.

The actions and recommendations from IIFS at ITSC-20 will be reviewed every 3-6 months between ITSC-20 and ITSC-21.

2.6 PRODUCTS AND SOFTWARE

Web site: http://cimss.ssec.wisc.edu/itwg/pswg

Working group members: Nigel Atkinson (Co-chair, Met Office), Liam Gumley (Co-chair, SSEC, UW), Jörg Ackermann (EUMETSAT), Chris Barnett (NOAA), Nick Bearson (SSEC, UW), Anna Booton (Met Office), Jessica Braun (SSEC, UW), Pascal Brunel (Météo-France), Martin Burgdorf (Univ. Hamburg), Dorothée Coppens (EUMETSAT), Geoff Cureton (SSEC, UW), Ray Garcia(SSEC, UW), Katja Hungershoefer (DWD), Bozena Lapeta (IMGW-PIB), Byung-il Lee (KMA), Graeme Martin (SSEC, UW), Katerina Melnik (Scanex), Scott Mindock (SSEC, UW), Alexander Polyakov (St. Petersburg State Univ.), Pascale Roquet (Météo-France), Nathalie Selbach (DWD), A.K.Sharma (NOAA), Lei Shi (NOAA), Inchul Shin (KMA), Kathy Strabala (SSEC, UW), Denis Tremblay (NOAA), Sergey Uspensky (SRC Planeta), Xiaozhan Xiong (NOAA)

2.6.1 Introduction

The following topics were discussed in the meeting held 1st November 2015:

1. CGMS High Level Priority Plan (HLPP) – achievements since ITSC-19 and future work. Specific topics were suggested by the ITSC co-chairs;
2. Review of PSWG Action items from previous ITSCs; and
3. Other items.

2.6.2 High Level Priority Plan items suggested by ITWG co-chairs

References to specific paragraphs from the HLPP are given below in bold and italics.

CGMS 1.1.3 Facilitate the evolution of research short-term missions to an operational status

It was noted that Tom Pagano (JPL) has been funded by NASA for a technology demonstration of hyperspectral sounding on small satellites (CubeSat Infrared Atmospheric Sounder or CIRAS).

Recommendation PSWG-1 to NASA

NASA is encouraged to share products of the CIRAS demonstration project with appropriate science teams (e.g., CrIS, IASI, NWP centres) for evaluation.

It was noted that Canada and Russia have plans for imaging missions in high elliptical orbits. To be considered when details are known.

The following recommendation is generally relevant to section 1.1 of the HLPP on Coordination of observing systems, facilitating rapid progress in implementing new data:

Recommendation PSWG-2 to satellite agencies

Agencies to release details of instrument characteristics (e.g. channel definitions and data formats) well in advance of launch.

CGMS 1.4.1 Evaluate standards for dissemination mechanisms

Dissemination methods are discussed in the DBNet Guide:

Action PSWG-1

PSWG members to review the "Guide To The Direct Broadcast Network (DBNet)" by 30 November 2015

CGMS 1.4.2 Facilitate the transition to new direct readout systems (GOES-R, JPSS, FY-3, Meteor-M)

Achievement: The group welcomed the release by CMA of Level 0 and Level 1 processing software for FY-3C, and the collaborative FY-3C evaluation project. The group also welcomed the initiative to evaluate MTVZA-GY microwave imager data and proposals for routine distribution of the global data.

There was a desire for Level 2 products from FY-3 (including imager products such as fire detection). UW has software for MERSI True Colour, available on request but not yet publicly released. This could be considered for future public release.

Recommendation PSWG-3 to Roshydromet

Roshydromet are encouraged to release a direct broadcast processing package for the Meteor-M N2 series, including level 1 processing for the MTVZA-GY microwave imager.

A document giving a list of level 0, level 1 and level 2 software packages has recently been made available on the PSWG Web site; it is currently at http://cimss.ssec.wisc.edu/itwg/pswg/software_packages.html

Action PSWG-2

PSWG members to review the list of software packages in the document linked from the PSWG web site and send corrections or additions to the co-chairs.

CGMS 1.4.3 Work together to define a set of recommendations seeking affordable future receiving stations or alternatives to direct read-out solutions

Recommendation PSWG-4 to satellite agencies

Agencies are encouraged to make future missions compatible with existing ground stations for direct broadcast, e.g. with regard to data rate, frequencies, polarisation, encoding etc., so that station operators do not have to buy new hardware (where possible) to support new satellite missions.

The group also noted initiatives such as use of GEANT by EUMETSAT, and the Himawari Cloud data distribution (accessible to national weather centres).

Recommendation PSWG-5 to satellite agencies

Agencies to consider "cloud" data delivery methods, where appropriate, as an alternative to direct readout for providing real-time data.

CGMS 1.4.4 Provide level-1 processing software packages, consistent with global processing software, for processing of Direct Broadcast data from the new generation of LEO satellites

The group considers that this is being addressed satisfactorily. It was noted that a Level 1 package for Metop Scatterometer winds is being considered by EUMETSAT for release in 2016. Landsat and Sentinel-2 were mentioned, but considered out of scope for this group.

Plans are progressing for DB software for EPS-SG instruments, based on global processing software.

CGMS 1.4.5 Further enhance the Regional ATOVS Retransmission Services (RARS) initiatives through inclusion of the NOAA Direct Broadcast Real Time Network (DBRTN) and an extension to advanced sounders for at least half of the globe.

This is being addressed through the DBNet Coordination Group. The DBRTN data are not yet being widely distributed, but this should happen once a connection to EUMETSAT has been set up.

Recommendation PSWG-6 to NOAA and DBNet project

Consider ways for DBRTN and hyperspectral sounder data to be made available via rebroadcast services in the Asia-Pacific region.

The following recommendation is not related to a specific HLPP item, but is generally relevant to section 1.4 on Regional Retransmission Services, noting that the user base for such services may be wider than just NWP:

Recommendation PSWG-7 to satellite agencies

Retransmission services are encouraged to consider broadening the scope to include imager products, level 2 products and full hyperspectral content.

CGMS 2.1 Support the user-provider dialogue on regional/continental scales through regional coordination groups

This is addressed through groups such as GODEX-NWP (formerly NAEDEX/APSDEU). No specific recommendation.

CGMS 2.3 Increase access to, and use of, data from R&D and pre-operational missions

The group strongly appreciates the efforts of NASA, JAXA, etc. in making data from non-operational missions available in near real time. For example: Rapidscat, Aqua, Terra, GPM. It was noted that GCOM-W1 provides DB over some parts of the globe (e.g., it has been received at SSEC). Wider coverage may be possible; potential users would need to liaise with JAXA to obtain the necessary agreements.

Recommendation PSWG-8 to JAXA

JAXA to consider providing more geographical coverage for GCOM-W1 DB, and the release of level 1 software for AMSR2 to those receiving the DB.

CGMS 2.6 Develop efficient standardized data handling for high-resolution imaging and hyper-spectral instruments

Achievement: The group appreciates the efforts of EUMETSAT in devising the CVIIRS format for VIIRS SDR data, and enabling the inclusion of this data in the EARS system.
Principal Component scores are included in EARS-IASI, but are not routinely used for CrIS. NOAA would look into it if there was a user requirement, but so far no requests have been received.

The group noted that PC scores are the baseline dissemination format for MTG-IRS and that a standardised method of handling this data is desirable.

Recommendation PSWG-9 to EUMETSAT

The PSWG supports the NWP SAF proposal to create a processing package for MTG-IRS (called IRSPP) that handles the PC compression aspects (e.g. creating reconstructed radiances).

CGMS 3.2.5 To establish together with the user community a commonly agreed approach for retrieval of Principal Component scores and associated parameters from hyperspectral infrared data

The issue of whether to use global or regional eigenvectors was noted. No firm conclusions were reached.

CGMS 3. Enhance the quality of satellite-derived data and products

Additional topic: There is a need for more instrumented validation sites for satellite sounder data, in particular at lakes such as Lake Titicaca (Peru) and Lake Quinghai (China), which are already used for satellite monitoring, but are not instrumented.

Recommendation PSWG-10 to satellite agencies

Agencies are encouraged to develop instrumented ground sites for validation.

It was noted that Direct Broadcast can provide a vital role in supporting field campaigns, because of the excellent timeliness of the data.

CGMS 3.3.3 Conduct an intercomparison study between the different methods to derive level 2 data from infrared hyperspectral sounders

Achievement: A comparison of HSRTV and NUCAPS has been presented at ITSC-20 by Elisabeth Weisz, which included a description of the differences and similarities of the two systems. Follow-on studies are planned in the context of a visiting scientist mission by Nadia Smith, at EUMETSAT.

NASA is also planning a comparison, for AIRS and CrIS. It would be desirable to add IASI, and also to look at IAPP and MIRS for the microwave.

Recommendation PSWG-11 to participants in level 2 comparison studies

Results of level 2 comparison studies should be published in the open literature and also presented at ITSC-21.

CGMS 3.5.1 Establish a common vocabulary and methodology with appropriate error propagation to include the errors associated with validation data (e.g. radiosonde temperature, water vapour, precipitation and winds)

Some work has been done on this in the context of FIDUCEO:

Action PSWG-3

Martin Burgdorf to circulate the sections of the FIDUCEO framework doc that address errors associated with validation data as soon as they have been completed.

CGMS 3.5.3 Agree on standardized procedures to derive NedT estimates for microwave sounders, and include such estimates in the disseminated BUFR data

An action has been taken by the NWP group to look into this.

In addition, Nigel Atkinson has produced a document on NedT calculation. The document compares several existing methods. It would be useful also to include the Allan Variance method described in Fuzhong Weng's talk.

Action PSWG-4

Nigel Atkinson to circulate his Technical Memorandum on NedT to the PSWG group, and to the co-chairs of NWP group.

Regarding encoding into BUFR, Nigel reported that two methods are currently in use: in the first an NedT descriptor is included in the BUFR sequence (implemented for ATMS); in the second (applicable to existing BUFR sequences), back references are given to the standard deviation of the brightness temperatures. It is planned to include this as an option in the next update release of AAPP, for AMSU, MHS and HIRS.

Action PSWG-5

Action: Nigel Atkinson to inform PSWG when samples of AMSU/MHS/HIRS BUFR files with NedT encoding are available, in order to check whether they can be decoded okay.

CGMS 3.6.1 Establish a sustained interaction with the operational Nowcasting communities with a view to fully utilise the commonality of the future geostationary imagers and sounders

The group recognised that this is an important topic, but there were no specific recommendations.

CGMS 3.6.2 Report on the progress within the Nowcasting community toward the use of hyperspectral sounders and work toward common products to serve the requirements of the global community

DWD reported that their forecasters make use of IASI L2 products. Their main complaint is the poor timeliness of global data: in the future it is planned to use EARS data.

Products are also provided via AWIPS to Alaska. There are initiatives for other weather services to evaluate the products. Ralf Peterson (UW) is active in this area.

Temperature and humidity are the most important products. Chris Barnet reported that the NCEP forecasters like to derive their own stability indices, because they often modify boundary layer profiles. On the other hand, other centres (e.g., Poland) make use of the supplied stability index products.

It was noted that there is no standard method of computing CAPE (convective available potential energy).

Training is very important in the use of hyperspectral sounders in nowcasting. It was noted that the International Precipitation Working Group (IPWG) does training in the precipitation products.

Recommendation PSWG-12 to ITWG co-chairs

Consider whether there is an unmet requirement for training on the applications of hyperspectral sounder products, and, if so, whether ITWG should provide a short course.

CGMS 3.8.1 Conduct studies to trade off benefits of spectral, radiometric, and spatial resolutions of infrared sounders
CGMS 3.8.2 Conduct studies to investigate the technical feasibility to reduce the field of view sizes for future microwave sounders
These are being looked at by the Advanced Sounders Working Group. No specific recommendation.

CGMS 4.2.1 Continue to foster optimum use of satellite data for weather forecasting, climate applications, and environmental assessments including hazardous events
Achievements: CSPP workshops and CM SAF yearly workshops. The next CM SAF workshop will take place at ECMWF in Reading, UK, in mid-November 2016. The focus of the workshop will be the applications of satellite-based data sets (mainly from the CM SAF) in numerical modeling.

There is a JPSS-funded initiative for training in flooding, fire, smoke and sounding products: the Proving Ground initiative.

EUMETSAT are planning training activities in preparation for MTG.

The group commended the WMO/CGMS Virtual Laboratory for Training and Education in Satellite Meteorology (VLab) and noted that there is an event week coming up on "Preparing for the Next Generation of Satellites" (16-20 November). See **http://www.wmo-sat.info/vlab/next-generation-of-satelliles/**

Recommendation PSWG-13 to ITWG members
ITWG members work with VLab to promote training activities related to satellite data.

It was suggested that GPU programming is likely to become more widely used in the next 10 years, and training may be needed for this. However, there is no specific recommendation at present.

2.6.2 Review of PSWG Actions, and Recommendations from previous ITSCs

- ITSC19-PSWG-3: on Validation Datasets: Thomas August confirmed that this is being taken forward by the RT Working Group. **PSWG Action closed.**
- ITSC19-PSWG-4: Graeme Martin to contact KMA and explore the mechanism for transferring algorithms to CSPP GEO. Contact has been made and a way forward has been identified. **Action closed.**

Action PSWG-6
Graeme Martin to implement in CSPP GEO the algorithms to be made available by KMA.

- ITSC19-PSWG-5: on IAPP: The group expressed their appreciation of SSEC in providing a home for IAPP, ensuring that the capability to process older instruments is maintained. The CM SAF relies heavily on IAPP.
  It was noted that IAPP is currently not working for Metop-A because of the failed AMSU channel 8.

Action PSWG-7

SSEC to modify IAPP so that it does not rely on Metop-A AMSU channel 8, and also to look at implementing improved bias correction (see poster by Szuchia Moeller).

- ITSC18-PSWG-14: on Metadata: Although this action is several years old, Geoff Cureton noted that there had been developments in the last 12 months. **Action remains open** and Geoff will distribute a document soon.
- ITSC18-PSWG-19: on ADL lessons learnt: Graeme pointed out that although the audience for lessons on ADL is limited, there may be useful general statements about porting global software to DB applications. **Action remains open** and Graeme will write and distribute a document in the next 6 months.
- ITSC18-PSWG-20: Guide to compiling portable binary code: A document is available and Ray will circulate to the group for comment. **Action remains open but expect to close soon.**
- Recommendation ITSC19-PSWG-3: *Provide information on algorithm, software, LUT, and format changes, and comparisons between IDPS SDR and NASA L1B radiance products.* Liam Gumley reported that NASA has defined their version of the VIIRS L1B format and it is available at SSEC. The CrIS L1B format has also been defined; there are some differences with the IDPS SDR product; comparisons will be done in the next 6 months. For ATMS, Bjorn Lambrigsten is the lead. The emphasis for these NASA products is to provide climate quality. NOAA is not planning to change to the NASA L1 products, therefore NWP users are not affected. Also, CLASS will continue to archive the NOAA SDR products. In some cases, SDR re-processing will be done by NOAA.

2.6.3 Other items

Katerina Melnik asked whether it would be possible to provide a VIIRS/MODIS flooding product in CSPP. An internal product exists, but is not yet released.

Recommendation PSWG-14 to JPSS

Support development of VIIRS flood product as part of CSPP.

It was noted that a polar winds processor had been proposed in the DB Technical subgroup, and subsequent discussions confirmed that the processor developed by Jeff Key would be a suitable candidate for implementation in CSPP.

Recommendation PSWG-15 to JPSS

Support implementation of a polar winds product as part of CSPP.

Pascal Brunel conveyed a request from the NWP Group for VIIRS cluster analysis to be included in the CrIS SDR, in the same way as an AVHRR cluster analysis is included in IASI 1c. So, for a number of clusters (up to 7 for IASI) we would have the mean and standard deviation of the VIIRS radiance for selected channels. This is not a cloud analysis: it allows NWP centres to derive information on the uniformity of the CrIS footprint.

It was pointed out that VIIRS and CrIS are processed independently in the IDPS, and granules are not in time order. Consequently, if such a scheme were implemented in the global data there would be some degradation in timeliness, as the CrIS processing would have to wait for VIIRS. This is less of an issue for DB.

Recommendation PSWG-16 to NOAA

Investigate the feasibility of providing a VIIRS cluster analysis in the CrIS footprint, including timeliness implications.

GOES-R data distribution was discussed. While plans for distributing data via GRB are well documented, information on other data distribution channels such as NOAAPort, GEONETCast, and terrestrial networks would help users to plan for GOES-R.

Recommendation PSWG-17 to NOAA

Clarify plans for distributing GOES-R data to users via mechanisms other than GRB.

A recommendation was brought by Nick Bearson after the meeting. It is based on recent requests from international GOES-R users and is intended to facilitate use of those observations as soon as they are received, and to allow users to capture and process a localized subset of the larger observation set. With the current GOES-R system design, users have to wait for the full image to be received (up to 15 minutes for a full disk) before any geolocation data are available.

Recommendation PSWG-18 to satellite agencies and DB system designers

Include geolocation information before or alongside the associated instrument observations in the data stream, in order to allow timely image generation for regional subsets.

LIST OF ACRONYMS

AAPP: Advanced ATOVS Processing Package
ABI: Advanced Baseline Imager
AEROSE: Aerosols and Ocean Science Expedition
AHI: Advanced Himawari Imager
AIRS: Atmospheric InfraRed Sounder
AMSR: Advanced Microwave Scanning Radiometer
AMSU: Advance Microwave Sounding Unit
ARM: Atmospheric Radiation Measurement
AROME: Applications of Research to Operations at Mesoscale
ATMS: Advanced Technology Microwave Sounder
ATOVS: Advanced TIROS Operational Vertical Sounders
BRDF: Bi-directional Reflection Distribution Function
BUFR: Binary Universal Form for the Representation of meteorological data
CAPE: Convective Available Potential Energy
CDR: Climate Data Record
CGMS: Coordination Group for Meteorological Satellites
CIMSS: Cooperative Institute for Meteorological Satellite Studies
CIRAS: CubeSat Infrared Atmospheric Sounder
CLARREO: Climate Absolute Radiance and Refractivity Observatory
CLASS: Comprehensive Large Array-data Stewardship System
CLBL: Community Line By Line
CMA: China Meteorological Administration
CNES: Centre National d'Etudes Spatiales
CrIS: Cross-track Infrared Sounder
CRTM: Community Radiative Transfer Model
CSPP: Community Satellite Processing Package
DB: Direct Broadcast
DBRTN: Direct Broadcast Real Time Network
DISORT: Discrete Ordinate Radiative Transfer
DMSP: Defense Meteorological Satellites Program
DoD: Department of Defense (US)
DOI: Digital Object Identifiers
DWD: Deutscher Wetterdienst (German Weather Service)
EARS: EUMETSAT Advanced Retransmission Service
ECMWF: European Center for Medium Range Weather
ECT: Equatorial Crossing Time
ECV: Essential Climate Variables
ENSO: El Niño–Southern Oscillation
EOS: Earth Observing System
EPS: EUMETSAT Polar Satellite
ESA: European Space Agency
ESTO: Earth Science Technology Office (NASA)
ETKF: Ensemble Transform Kalman Filter
EUMETSAT: European Organization for the exploitation of meteorological satellites
FCDR: Fundamental Climate Data Record
FIDUCEO: Fidelity and uncertainty in climate data records from Earth Observations

FOV: Field of View
FTS: Fourier Transform Spectrometer
FY-3: LEO satellite from China
GAIA-CLIM: Gap Analysis for Integrated Atmospheric ECV CLImate Monitoring
GCOM-W/GCOM-W2: Global Change Observation Missions
GCOS: Global Climate Observing System
GEWEX: Global Energy and Water Cycle Experiment
GMI: Global Precipitation Measurement (GPM) Microwave Imager
GOES: Geostationary Operational Environmental Satellite
GOS: Global Observing System
GPM: Global Precipitation Measurement
GPS: Global Positioning System
GRUAN: GCOS Reference Upper Air Network
GSICS: Global Space-Based Inter-Calibration System
GTS: Global Telecommunications System
GUI: Graphical User Interface
HIRS: High-Resolution Infrared Radiation Sounder
HLPP: High Level Priority Plan
HSRTV: Hyperspectral Sounder Retrieval
IAMAP: International Association of Meteorology and Atmospheric Physics
IASI: Infrared Atmospheric Sounding Interferometer
IASI-NG: IASI- Next Generation
ICVS: Integrated Calibration and Validation System
ICWG: International Cloud Working Group
IDPS: Integrated Data Processing Segment
IPCC: Intergovernmental Panel on Climate Change
IPWG:International Precipitation Working Group
IR: Infrared
IRC: International Radiation Commission
IRFS: instrument onboard Meteor-M N2 satellite
ISS: International Space Station
ITSC: International TOVS Study Conference
ITWG: International TOVS Working Group
IWWG: International Winds Working Group
JAXA: Japan Aerospace Exploration Agency
JPSS: Joint Polar Satellite System
LATMOS: Laboratoire Atmosphères, Milieux, Observations Spatiales
LBL: Line By Line
LBLRTM: Line By Line Radiative Transfer Model
LEO: Low Earth Orbit
LTE: Local Thermodynamic Equilibrium
LTM: Long-Term Monitoring
LUT: Lookup Table
MACC: Monitoring Atmospheric Composition and Climate
MetOp: Meteorological Operational
MHS: Microwave Humidity Sounder
MODIS: Moderate-resolution Imaging Spectroradiometer
MTG-IRS: Meteosat Third Generation - Infrared Radiometric Sounder
MTVZA: Russian Imaging/Sounding Microwave Radiometer
MVIRI: Meteosat Visible and InfraRed Imager

MW: Microwave
MWHS: Microwave Humidity Sounder
NASA: National Aeronautics and Space Administration
NEdT: Noise Equivalent Delta Temperature
NESDIS: National Environmental Satellites, Data, and Information Service
NOAA: National Oceanic and Atmospheric Administration
NPROVS: NOAA PROducts Validation System
NRL: Naval Research Laboratory
NWP: Numerical Weather Prediction
OMPS: Ozone Mapping and Profiler Suite
OPS: Operations
OSCAR: Observing Systems Capability Analysis and Review
OSS: Optimal Spectral Sampling
PATH: Precipitation and All-weather Temperature and Humidity mission
PC: Principal Component
PCRTM: Principal Component-based Radiative Transfer Model
PMRF: Pacific Missile Range Facility
POES: Polar Operational Environmental Satellite
PSWG: Products and Software Working Group
QC: Quality Control
RARS: Regional ATOVS Retransmission Services
RDR: Raw Data Record
RFI: Radio Frequency Interference
RO: Radio Occultation
RT: Radiative Transfer
RTM: Radiative Transfer Model
RTTOV: Radiative Transfer for TOVS
SAF: Satellite Application Facility
SAPHIR: Sondeur Atmosphérique du Profil d'Humidité Intertropicale par Radiométrie
SATURN: Satellite User Readiness Navigator
SDR: Sensor Data Record
SMHI: Sweden's Meteorological and Hydrological Institute
SMOS: Soil Moisture and Ocean Salinity
SNO: Simultaneous Nadir Overpass
SRF: Spectral Response Function
SSEC: Space Science and Engineering Center
SSMI: Special Sensor Microwave Imager
SSMIS: Special Sensor Microwave Imager/Sounder
SSU: Stratospheric Sounding Unit
STAR: Center for Satellite Applications and Research
Suomi NPP: Suomi National Polar-orbiting Partnership
TOVS: TIROS Operational Vertical Sounder
TWP: Tropical Western Pacific
VarBC: Variational Bias Correction
VIIRS: Visible/Infrared Imager Radiometer Suite
VTPR: Vertical Temperature Profile Radiometer
WG: Working Group
WMO: World Meteorological Organization
WRC15: World Radiocommunication Conference 2015

ITSC-XX AGENDA

Wednesday, 28 October 2015

8:00	Registration (continues to 15:00) Poster setup	
8:30 – 9:00	**Welcome**	**Mitch Goldberg and Niels Bormann (ITWG Co-chairs)**
	Welcome by SSEC	**Hank Revercomb**
	Overview of SSEC	
	Local arrangements	**Jonathan Gero**
	Review of agenda	**Mitch Goldberg and Niels Bormann (ITWG Co-chairs)**

9:00 – 10:00 Session 1a: Cal/val of new and current observations (oral presentations - 12 minutes) **Chairs: Paul Menzel and Peng Zhang**		
1.01	Qifeng Lu	FY-3C evaluation overview: CMA, ECMWF and UKMO
1.02	Nigel Atkinson	The FY-3C evaluation project: microwave sounder calibration and direct broadcast experiences
1.03	Heather Lawrence	Evaluating and assimilating microwave humidity sounding data from China's FY-3C MWHS-2 instrument in all-sky conditions at ECMWF
1.04	Fabien Carminati	Assimilation of observations from the Microwave Humidity Sounders on board China's FY-3B and FY-3C Meteorological Satellites

10:00 – 10:15 Session 1b: Cal/val of new and current observations (poster introductions - 1 minute: no visual aids) **Chairs: Paul Menzel and Peng Zhang**		
1p.01	Qifeng Lu	Characterizing FY-3C Microwave Temperature Sounder MWTS2
1p.02	Keyi Chen	Assessment of FY-3A and FY-3B/MWHS observations
1p.03	Erin Jones	Assimilating Megha-Tropiques SAPHIR Data in the NOAA GDAS
1p.04	Masahiro Kazumori	Recent activities on microwave radiance data assimilation at JMA
1p.05	Stu Newman	Assimilation of AMSR2 radiances at the Met Office
1p.06	Kevin Garrett (for Zaizhong Ma)	HIMAWARI-8 AHI radiance assimilation with GSI at JCSDA
1p.07	Dorothee Coppens (for Bertrand Theodore)	Characterisation of AHI IR channels with IASI measurements
1p.08	Sanjeev Kumar Singh	The Impact of INSAT-3D Sounder Radiance Assimilation in the NCMRWF Global Forecast System (T574L64)

10:15 – 10:45 Break and poster viewing 1b

10:45 – 12:15 Session 1c: Cal/val of new and current observations (oral presentations - 12 minutes) **Chairs: Dieter Klaes and William Bell**		
1.05	Sergey Uspensky	An initial assessment of microwave imager/sounder MTVZA-GY data from Meteor-M N2 satellite
1.06	Alexander Polyakov	IRFS-2 instrument onboard Meteor-M N2 satellite: measurements analysis
1.07	Yong Han	CrIS Full Spectral Resolution SDR and S-NPP/JPSS-1 CrIS Performance Status
1.08	Fuzhong Weng	Updates on Operational Processing of ATMS TDR and SDR Products
1.09	Erin Jones	Assimilating New Passive Microwave Data in the NOAA GDAS
1.10	Indira Rani	Impact of Megha-Tropique's SAPHIR humidity profiles in the Unified Model Analysis and Forecast System

12:15 – 12:30 Session 1d: Cal/val of S-NPP observations (poster introductions - 1 minute: no visual aids) **Chairs: Dieter Klaes and William Bell**		
1p.09	Hu Yang	Antenna Emissivity Correction for ATMS Calibration Bias Characterization
1p.10	Xiaolei Zou	Striping Noise Analysis and Mitigation for ATMS, GMI and MWTS Data
1p.11	Yong Chen	Evaluation of Different Calibration Approaches for JPSS CrIS
1p.12	Yong Chen	SI Traceable Algorithm for Characterizing Hyperspectral Infrared Sounder CrIS Noise
1p.13	Aronne Merrelli	True Ringing Artifacts in Unapodized FTS Measurements
1p.14	Xiaozhen (Shawn) Xiong	Update on S-NPP CrIS Full Spectral Resolution SDR Processing at NOAA/STAR
1p.15	Yi Song (for Walter Wolf)	Preparation for the Full Resolution CrIS Hyperspectral Radiance Data in BUFR Format
1p.16	Likun Wang	Accurate Collocation of VIIRS measurements with CrIS
1p.17	withdrawn	

12:30 – 13:30 Lunch

13:30 – 14:00 Poster viewing 1d

14:00 – 14:15 Session 1e: Cal/val of new and current observations (oral presentations - 12 minutes) **Chairs: Eva Borbas and Louis Garand**		
1.11	Stephen English	A report on the outcomes of a workshop aimed at improved understanding of biases observed in analysis of 183 GHz observations

14:15 – 15:00 Session 2a: Radiative transfer (oral presentations - 12 minutes) **Chairs: Eva Borbas and Louis Garand**		
2.01	Jerome Vidot	High resolution IR cloudy radiances simulations : comparison between RTTOV and VLIDORT
2.02	Virginie Capelle (for Raymond Armante)	Interactive use of the new generation of TIR and SWIR space-borne instruments to increase the performance of radiative transfer models, spectroscopic and atmospheric databases (4A, GEISA, TIGR, ARSA)
2.03	Cristina Lupu	An evaluation of radiative transfer modelling errors in AMSU-A data

15:00 – 15:15 Session 2b: Radiative transfer (poster introductions - 1 minute: no visual aids) **Chairs: Eva Borbas and Louis Garand**		
2p.01	James Hocking	Update on RTTOV developments
2p.02	Pascale Roquet	Addition of 1D-VAR retrieval to RTTOV-GUI
2p.03	Paul van Delst	An update on CRTM developments
2p.04	Yingtao Ma	Development of the Community Line-By-Line radiative transfer Model (CLBLM)
2p.05	Nicole Jacquinet	The GEISA spectroscopic database in 2014: context and contents
2p.06	withdrawn	
2p.07	Qiguang Yang	Ultrafast High Accuracy PCRTM_SOLAR Model for Cloudy Atmosphere
2p.08	Olaf Stiller (for Leonhard Scheck)	A fast forward operator for the assimilation of visible SEVIRI observations in KENDA-COSMO
2p.09	Cristina Lupu	Monitoring infrared satellite radiance biases using the ECMWF model

15:15 – 15:45 Break and poster viewing 2b

15:45 – 16:30 Session 3a: Processing packages and direct broadcast applications (oral presentations - 12 minutes) **Chairs: Nigel Atkinson and Sergey Uspensky**		
3.01	Kathleen Strabala	NASA International MODIS/AIRS Processing Package (IMAPP): Supporting the Aqua and Terra Direct Broadcast Community for 15+ Years
3.02	Liam Gumley	Support for NOAA, NASA, EUMETSAT, and CMA satellites and sensors in CSPP

3.03	Elisabeth Weisz	Assessing Hyperspectral Retrieval Algorithms and their Products for Use in Direct Broadcast Applications

16:30 – 17:00 Session 3b: Processing packages (poster introductions - 1 minute: no visual aids) **Chairs: Nigel Atkinson and Sergey Uspensky**		
3p.01	Allen Huang	Community Satellite Processing Package (CSPP) - Facilitating Timely and Optimal Use of Weather Satellite Data
3p.02	Ray K. Garcia	Automated Verification of CSPP SNPP SDR products
3p.03	Geoff Cureton	Near Real Time Level-2 Products Via Direct Broadcast Using the CSPP-International ATOVS Processing Package (CSPP-IAPP)
3p.04	Geoff Cureton	Level-2 Products in the CSPP-GEO Direct Broadcast Package
3p.05	Scott Mindock	CSPP GEO Level 1 Packages
3p.06	Nick Bearson	CSPP CLAVR-x
3p.07	Nick Bearson	Reconstructing GOES Rebroadcast with CSPP Geo GRB
3p.08	Graeme Martin	CSPP Geo support for processing GOES-R, Himawari-8 and current GOES data
3p.09	Yi Song	A BUFR and GRIB Tailoring System for Satellite Operational Products
3p.10	David Hoese	Polar2Grid 2.0: An easy way to create high resolution satellite images
3p.11	Szuchia Moeller	Bias Correction in CIMSS IAPP Retrieval Software
3p.12	Jessica Braun	Aqua and Terra Direct Broadcast Processing at CIMSS/SSEC Using a New Merged Pass System
3p.13	Katerina Melnik	Using available DB satellite processing packages for case studies in Russia

Thursday, 29 October 2015

8:30 – 9:45 Session 4a: Retrievals (oral presentations - 12 minutes) **Chairs: Elisabeth Weisz and Nicholas Nalli**		
4.01	Antonia Gambacorta	Status of the NOAA hyper spectral retrieval system: algorithm development and lessons learned from recent field campaigns
4.02	Nicholas Nalli (for Quanhua (Mark) Liu)	NUCAPS products validations
4.03	Thomas August	The operational IASI L2 products version 6: status, applications and developments
4.04	William Smith	The Retrieval of Atmospheric Profiles from Satellite Radiances for NWP Data Assimilation
4.05	Virginie Capelle	Dust infrared aerosol properties observed from infrared hyperspectral sounders: Analysis of the diurnal variation

9:45 – 10:15 Session 4b: Retrievals (poster introductions - 1 minute: no visual aids) **Chairs: Elisabeth Weisz and Nicholas Nalli**		
4p.01	Awdhesh Sharma	Updates on operational sounding processing systems at NOAA/NESDIS and the exploitation of hyperspectral Sounder and microwave sounder data from CrIS/ATMS, IASI/AMSU, and ATOVS
4p.02	Bomin Sun	Ongoing monitoring and analysis of NOAA-Unique CrIS/ATMS Processing System (NUCAPS) sounding products using NPROVS and its expansion
4p.03	Nadia Smith	Characterizing NUCAPS retrieval quality for CO and CH4 - A step towards improving air chemistry applications
4p.04	Nadia Smith	Novel Applications of Temperature Soundings in High Latitude Regions - Aviation in Alaska
4p.05	Jessica Gartzke	Ten Years of CAPE Observations in the U. S. SGP from the AIRS Hyperspectral IR Sounder: Climatology, Validation, and Near-real Time Applications
4p.06	Brian Kahn (for Joao Teixeira)	AIRS science: Weather, climate and applications
4p.07	Thomas August (for Tim Hultberg)	Evolutions and self-organisation of the piece-wise linear regression for IASI
4p.08	Eva Borbas (for Laura Dobor)	Evaluation of the S-NPP VIIRS TPW algorithm with ground based-derived measurements
4p.09	Xin Jin	A Comprehensive Review of SNPP CrIS Instrument Performance and Data Quality

10:15 – 10:45 Break and poster viewing 3b, 4b

10:45 – 12:00 Session 5a: Assimilation of hyperspectral IR (oral presentations - 12 minutes) **Chairs: Fiona Smith and Luis Gustavo de Goncalves**		
5.01	Andrew Collard	Improved use of CrIS Radiances at NCEP
5.02	William F Campbell	Accounting for Correlated Satellite Observation Error in NAVGEM
5.03	Niels Bormann	Enhancing the impact of IASI observations through an updated observation error covariance matrix
5.04	Hyoung-Wook Chun	A physically based observation error covariance matrix for IASI
5.05	Benjamin Ruston	Improvements in the Use of Humidity from Hyperspectral IR

12:00 – 12:15 Session 5b: Assimilation studies (poster introductions - 1 minute: no visual aids) **Chairs: Fiona Smith and Luis Gustavo de Goncalves**		
5p.01	Fiona Smith	Met Office use of CrIS, IASI and AIRS
5p.02	Reima Eresmaa	Assimilation of spectrally-adjacent pairs of IASI channels

5p.03	Vincent Guidard	Using realistic ozone fields for the assimilation of IASI data
5p.04	Agnes Lim (for Yan'an Liu)	Assimilation of AIRS radiances in regional model and its impact of typhoon forecast
5p.05	Louis Garand	Impact of inter-channel radiance observation error correlations in Environment Canada's EnVar data assimilation system
5p.06	Heather Lawrence	Scene-Dependent Observation Errors for AMSU-A in the ECMWF system

12:30 – 13:30 Lunch

13:30 – 14:00 Poster viewing 5b

14:00 – 14:45 Session 6: NWP centre reports (poster introductions - 3 minutes, 1 slide) **Chairs: Nancy Baker and Kozo Okamoto**		
6p.01	Andrew Collard (NCEP) (for John Derber)	Progress and plans for the use of radiance data in the NCEP global and regional data assimilation systems
6p.02	Takumu Egawa (JMA)	Recent developments in satellite data assimilation at JMA
6p.03	Eunhee Lee (KMA)	Status and plans for satellite data assimilation at the Korea Meteorological Administration
6p.04	Mohamed Dahoui (ECMWF)	Update on changes to the ECMWF NWP system since ITSC-19
6p.05	Robin Faulwetter (DWD) (for Christina Köpken)	Developments in satellite data assimilation at DWD
6p.06	Sid Boukabara (JCSDA)	Overview of NOAA/NESDIS Satellite Data Assimilation Activities in Support of the U.S. Joint Center for Satellite Data Assimilation (JCSDA)
6p.07	Vincent GUIDARD (Meteo France) (for Jean-Francois Mahfouf)	Overview of the radiance assimilation in the Meteo-France NWP models
6p.08	Bill Bell (Met Office)	NWP Status Report: Upgrades in the Met Office use of satellite radiance data
6p.09	Ben Ruston (NRL)	An Update on NRL Atmospheric Data Assimilation Activities
6p.10	Simon Pellerin (CMC)	Status of radiance assimilation at CMC
6p.11	Fabrizio Baordo (BoM) (for Chris Tingwell)	Recent upgrades to the Bureau of Meteorology ACCESS NWP system

Action Items from ITSC-19

Moderators: Mitch Goldberg and Niels Bormann

14.45-14.55 CGMS report (Mitch Goldberg)

14.55-15.40 Working group action items from ITSC-19 (10 minutes)

- **NWP (Fiona Smith and Andrew Collard)**
- **Radiative transfer and surface properties (Marco Matricardi and Paul van Delst)**
- **Climate (Nathalie Selbach and Cheng-Zhi Zou)**

15.40-16.00 BREAK

16.00-16.40 Working group action items from ITSC-19 (10 minutes)

- **Advanced Sounders (Dieter Klaes and Bill Smith)**
- **Products and Software (Nigel Atkinson and Liam Gumley)**
- **International and Future Systems (Jerome Lafeuille and Stephen English)**

16:40-17:05 Special topics (10 minutes)

- **Guide to the Direct Broadcast Network for Near Real-Time Relay of LEO Satellite Data (DBNet) (Jerome Lafeuille)**
- **Spectrum over the next four years (Richard Kelley)**

17.05-17.25 Technical sub-group reports (5 minutes each)

- **Direct broadcast packages (Liam Gumley)**
- **RTTOV (James Hocking)**
- **CRTM (Paul van Delst)**
- **Remote Sensing and Modeling of Surface Properties**

17.30-18.30 Technical Sub-Group meetings

- **RTTOV (James Hocking)**
- **CRTM (Paul van Delst)**
- **RARS/DBNet and direct broadcast packages (Jerome Lafeuille, Liam Gumley)**

Friday, 30 October 2015

8:30 – 10:00 Session 7a: Climate (oral presentations - 12 minutes) **Chairs: Antonia Gambacorta and Hank Revercomb**		
7.01	Cheng-Zhi Zou	SSU Climate Data Record Verifying Anthropogenic Global Warming Theory
7.02	Martin Burgdorf	Reprocessing of Fundamental Climate Data Records From Microwave Sounders
7.03	Paul Menzel	The UW SSEC/CIMSS Global Clear Sky Infrared Moisture Products derived from HIRS data
7.04	Nadia Smith	The consistency between measured radiance and retrieved profiles at climate scales - a study in uncertainty propagation
7.05	Jacola Roman	Measurement Requirements and Current Capabilities for Satellite Remote Sensing of Precipitable Water Vapor
7.06	Timo Hanschmann	Three decades of cloud properties from HIRS: a new climate dataset by CMSAF

10:00 – 10:15 Session 7b: Climate (poster introductions - 1 minute: no visual aids) **Chairs: Antonia Gambacorta and Hank Revercomb**		
7p.01	Lei Shi	Deriving long-term global dataset of temperature and humidity profiles from HIRS
7p.02	W. Paul Menzel	Extending the HIRS cloud record with CrIS abd IASI measurements
7p.03	Nathalie Selbach (for Marc Schröder)	The GEWEX water vapor assessment (G-VAP) - results from inter-comparisons and stability analysis
7p.04	Nathalie Selbach (for Marc Schröder)	Climatology of free tropospheric humidity: Extension into the SEVIRI era, evaluation and exemplary analysis
7p.05	Nathalie Selbach	Application of CHARMe in satellite based climate monitoring
7p.06	Nathalie Selbach	Provision of Climate Data Records of the EUMETSAT Satellite Application Facility on Climate Monitoring and User Services
7p.07	Dorothee Coppens	Exploitation of SI-1 data from Meteor-28 and 29 spacecraft for climate purposes
7p.08	Niels Bormann (for Carole Peubey)	Enhanced use of satellite data in the next ECMWF reanalysis ERA5
7p.09	Sergio DeSouza-Machado	Geophysical Trends Derived from 12 years of AIRS Infrared Radiances: comparisons to AIRS L3 and ERA Reanalysis

10:15 – 10:45 Break and poster viewing 7b

10:45 – 12:00 Session 8a: Clouds (oral presentations - 12 minutes) **Chairs: Stephen English and Ben Ruston**		
8.01	Yanqiu Zhu	Configuration of All-sky Microwave Radiance Assimilation in the NCEP's GFS Data Assimilation System
8.02	Haixia Liu	Variational cloud-clearing with CrIS data at NCEP
8.03	Jun Li	Progress on the assimilation of advanced infrared sounder radiances in cloudy skies
8.04	Reima Eresmaa	Developments in clouds and aerosols detection for infrared radiance data
8.05	Kevin Garrett	1DVAR Preprocessor Applications for Satellite Data Assimilation: Quality Control, Background Adjustment, and Cloud Radiance Assimilation

12:00 – 12:30 Session 8b: Clouds (poster introductions - 1 minute: no visual aids) **Chairs: Stephen English and Ben Ruston**		
8p.01	Emily Huichun Liu	The Validation of Observation Operator and Single Observation Experiments for Microwave Radiances under All-sky Condition in NCEP Assimilation System

8p.02	Jason Otkin (for Sharon Nebuda)	Assessing the Accuracy of Cloudy Sky Infrared and Microwave Brightness Temperatures in the GFS
8p.03	Xiaoyan Zhang	Assimilation of All-sky SEVIRI Radiance Data in NCEP Hourly-update NAM System
8p.04	Reima Eresmaa (for Julie Letertre-Danczak)	The detection of dust in infrared radiance spectra
8p.05	Olaf Stiller	Application of observation cross-validation method to IASI cloud screening
8p.06	Thomas S. Pagano	Assessing and improving IR sounder radiances in cloudy scenes using imager radiances
8p.07	Andrew Heidinger	Merger of Imager and Sounder Data for Improved Cloud Height Estimation
8p.08	Andi Walther	Consistency of reflected moonlight based nighttime precipitation product with its daytime equivalent
8p.09	Bozena Lapeta	The quality of H-SAF ATOVS based precipitation products over Poland
8p.10	Dirceu L. Herdies	Combination of Satellite Precipitation Estimates and Rain Gauge for high Spatial and Temporal Resolutions
8p.11	withdrawn	

12:30 – 13:30 **Lunch**

13:30 – 14:00 **Poster viewing 8b**

14:00 – 15:15 Session 9a: Assimilation of hyperspectral IR and impact studies (oral presentations - 12 minutes) **Chairs: Vincent Guidard and Andrew Collard**		
9.01	Fiona Smith	Observing System Experiments with IASI Reconstructed Radiances
9.02	Marco Matricardi	Toward the NWP assimilation of the full IASI spectrum: recent experience using principal component data
9.03	Javier Andrey-Andrés	Assimilation of IASI radiances as from Principal Components IASI product in AROME
9.04	Mohamed Dahoui (for Tony McNally)	Observation impact studies
9.05	Sid Boukabara	Impact Assessment of Potential Gaps in the Satellite Constellation on NOAA's Global NWP

15:15 – 15:25 Session 9b: Assimilation of hyperspectral IR and impact studies (poster introductions - 1 minute: no visual aids) **Chairs: Vincent Guidard and Andrew Collard**		
9p.01	James Jung	Infrared and Microwave Data Addition Observing System Experiment Impacts using the NCEP Global Forecast System
9p.02	Helena Barbieri de Azevedo	Data impact assessment using G3DVAR

9p.03	Camila Cossetin Ferreira	Assessing the AMSU-A impacts in the CPTEC/INPE regional ensemble prediction system
9p.04	Luis Gustavo Goncalves De Goncalves	A rapid update data assimilation cycle over South America using 3DVar and EnKF

15:25 – 16:15 Break and poster session for 1b, 1d, 2b, 3b, 4b, 5b, 6, 7b, 8b, 9b, 10b

16:15 – 17:00 Session 10a: Surface studies (oral presentations - 12 minutes) **Chairs: Fuzhong Weng and Marco Matricardi**		
10.01	Glynn Hulley	MEaSUREs High Spectral Resolution MODIS/ASTER Emissivity Database
10.02	Louis Garand	Assimilation of surface sensitive infrared channels over land at Environment Canada
10.03	Niama Boukachaba	Improved assimilation of IASI data over continent in the convective scale AROME model

17:00 – 17:30 Session 10b: Surface studies (poster introductions - 1 minute: no visual aids) **Chairs: Fuzhong Weng and Marco Matricardi**		
10p.01	Eva Borbas	A Unified and Coherent Land Surface Emissivity Earth System Data Record
10p.02	Rory Gray	Development of a Dynamic Infrared Land Surface Emissivity Atlas based on IASI Retrievals
10p.03	Bruna Barbosa Silveira	Assessment of the land surface microwave emissivity in the CPTEC/INPE GSI Global 3DVar Data Assimilation System
10p.04	Stu Newman	Enhanced use of AMSU-A radiances over land
10p.05	Fabrizio Baordo	Assimilation of microwave humidity sounding channels over sea-ice at ECMWF
10p.06	Brunna Romero Penna	The role of skin temperature in the three-dimensional variational assimilation global system of CPTEC/INPE
10p.07	Suping Nie	An assimilation study based on FY-3B MWRI soil moisture data using the EnKF
10p.08	Byung-il Lee	Improvements to Accuracy for COMS SST and SSI products, and their Impact in KMA's NWP system
10p.09	Robert Knuteson	Combined Imager and IR Sounder Observations of LST over the Greenland Ice Sheet

Saturday, 31 October 2015

9:00 – 12:30 Working group meetings

- Advanced Sounders (Dieter Klaes and Bill Smith)
- Climate (Nathalie Selbach and Cheng-Zhi Zou)
- Radiative transfer and surface properties (Marco Matricardi and Paul van Delst)

Sunday, 1 November 2015

9:00 – 12:30 Working group meetings

- NWP (Fiona Smith and Andrew Collard)
- Products and software (Nigel Atkinson and Liam Gumley)
- International (Jerome Lafeuille and Stephen English)

Monday, 2 November 2015

8:30 – 10:00 Session 11a: Assimilation studies (oral presentations - 12 minutes)
Chairs: Indira Rani and Steve Swadley

11.01	James Cameron	The testing and planned implementation of VarBC at the Met Office
11.02	Anna Booton	An improved bias correction for SSMIS: Assimilation Assessment
11.03	Tanya Maurer	Assimilation Impacts of SSMIS Upper Atmosphere Soundings with Improved Orbital Bias Predictors in NAVGEM
11.04	Takumu Egawa	Assimilation of ATMS radiances into the JMA's global NWP system
11.05	Hyojin Han	Improving tropical cyclone forecasts by assimilating microwave sounder cloud-screened radiances and the GPM precipitation measurements
11.06	Olaf Stiller	Cross-validation methods for quality control, cloud screening, etc.

10:00 – 10:15 Session 11b: Assimilation studies (poster introductions - 1 minute: no visual aids)
Chairs: Indira Rani and Steve Swadley

11p.01	Nancy Baker	An Assessment of the Impact of DMSP SSMIS Microwave Sounder and Imager Assimilation for Global Numerical Weather and Wave Forecasting
11p.02	Stephen Macpherson	Assimilation of ATMS data at Environment Canada
11p.03	Jinlong Li	A near real time regional satellite data assimilation system for high impact weather studies
11p.04	Pei Wang	The impact of the high temporal resolution GOES/GOES-R moisture information on severe weather systems in a regional NWP model
11p.05	Wei Han	Constrained bias correction for satellite radiance assimilation in limited area model considering model diurnal bias
11p.06	Roger Randriamampianina	Towards operational use of satellite radiances in an Arctic mesoscale model
11p.07	Patrik Benacek	Radiance bias correction in LAM

11p.08	Robin Faulwetter	Feedback processes between radiances and the ICON model
11p.09	Mohamed Dahoui	Automatic data checking system at ECMWF

10:15 – 10:45 Break and poster viewing 11b

10:45 – 12:15 Session 12a: Validation and applications of sounding data (oral presentations - 12 minutes) **Chairs: Sid Boukabara and Thomas August**		
12.01	Xavier Calbet	Consistency for water vapour between GRUAN RS92 Sondes, LBLRTM and IASI
12.02	Bomin Sun	Characteristics of radiosonde observations and their impact in satellite sounding product validation
12.03	Xavier Calbet (for Tony Reale)	Integrating Uncertainty in Atmospheric Profile Validation
12.04	Michelle Feltz	Comparisons of IR Sounder and COSMIC RO Temperatures: Guidance for CrIS NUCAPS Validation
12.05	Chris Barnet	The use of temperature and water vapor profiles for weather applications: recent activities in the NOAA/JPSS Proving Ground
12.06	Joe K. Taylor	Calibration Validation Of The Cross-track Infrared Sounder (CrIS) With The Aircraft Based Scanning High-resolution Interferometer Sounder (S-HIS)

12:15 – 12:25 Session 12b: Validation and applications of sounding data (poster introductions - 1 minute: no visual aids) **Chairs: Sid Boukabara and Thomas August**		
12p.01	Bomin Sun (for Tony Reale)	GCOS Reference Upper Air Network
12p.02	Bill Bell	The EU's GAIA-CLIM project
12p.03	Jonathan Gero	Sea-based Infrared Radiance Measurements of Ocean and Atmosphere from the ACAPEX/CalWater2 Campaign
12p.04	Vincent Guidard	Atmospheric profile retrievals from IASI in the framework of the Concordiasi campaign

12:30 – 13:30 Lunch

13:30 – 14:00 Poster viewing 12b

14:00 – 14:30 Session 13: Space agency reports (Space agency poster introductions - 5 minutes: 2 slides) **Chairs: Allen Huang and Jerome Lafeuille**		
13p.01	Peng Zhang	Fengyun meteorological satellites and their contribution to NWP
13p.02	Dieter Klaes	EUMETSAT Systems and Plans

13p.03	Alexander Uspenskiy	Russian meteorological polar satellite Meteor-M N2: instrument performance assessment and data applications
13p.04	Mitch Goldberg	NOAA Report on Current and Planned Activities
13p.05	Kozo Okamoto	Status report of space agency: JMA and JAXA

14:30 – 15:30 Session 14a: Future observations (oral presentations - 12 minutes) **Chairs: Allen Huang and Jerome Lafeuille**		
14.01	Hank Revercomb	The Absolute Radiance Interferometer (ARI): Capable of climate Benchmark quality IR measurements from a CLARREO Pathfinder on ISS
14.02	Eric Pequignot	IASI-NG processing overview
14.03	Agnes Lim	Impact Analysis of LEO Hyperspectral Sensor IFOV size on the next generation high-resolution NWP model forecast performance
14.04	Brian H. Kahn	Why observe temperature, water vapor, and cloud structures with high-spectral-resolution infrared observations at 1-km horizontal scales?

15:30 – 15:45 Session 14b: Future observations (poster introductions - 1 minute: no visual aids) **Chairs: Allen Huang and Jerome Lafeuille**		
14p.01	Bjorn Lambrigtsen	The development of a U.S. geostationary microwave sounder
14p.02	Francois Bermudo	IASI-NG Program: General Status Overview
14p.03	Adrien Deschamps	Strategy for the validation of IASI-NG Level 1 processing
14p.04	Myriam Peyre (for Javier Andrey-Andrés)	Evaluation of IASI-NG impact on NWP and atmospheric chemistry compared to IASI
14p.05	Denis Tremblay	Correlated and Uncorrelated noise of the JPSS-1 Crosstrack Infrared Sensor (CrIS)
14p.06	Byung-il Lee (for Su Jeong Lee)	Evaluation of sounding capability of the next generation Imager of Korea using the Advanced Himawari Imager data
14p.07	Zhenglong Li	Exploring Value-added Impact from Geostationary Hyperspectral Infrared Sounder on Hurricane Forecasts

15:45 – 16:45 Break and poster session 10b, 11b, 12b, 13, 14b

17:00 – 17:30 Working groups finalise reports

19:00 Banquet, including

- **Presentation of prizes for best oral and poster presentations**
- **ITWG: past, present and future – with our former co-chairs**

Tuesday, 3 November 2015

9:00-10:15 **Session 15: Working Group Reports (15 minutes)**
Co-chairs: Mitch Goldberg and Niels Bormann

- **RT (Marco Matricardi, Paul van Delst)**
- **Climate (Nathalie Selbach, Cheng-Zhi Zou)**
- **NWP (Andrew Collard, Fiona Smith)**

10:15-10:45 BREAK

10:45-12:00 **Session 15: Working Group Reports (15 minutes)**
Co-chairs: Mitch Goldberg and Niels Bormann

- **Advanced Sounders (Dieter Klaes, Bill Smith)**
- **International and Future Systems (Stephen English, Jerome Lafeuille)**
- **Products and Software (Liam Gumley, Nigel Atkinson)**

12:00-12:30 **Session 16: Technical Sub-Group Reports (5 minutes)**
Co-chairs: Mitch Goldberg and Niels Bormann

- **RARS/DBNet and Direct broadcast packages (Jerome Lafeuille and Liam Gumley)**
- **RTTOV (James Hocking)**
- **CRTM (Paul van Delst)**

12:30-12:45 **Closing Session**
Co-chairs: Mitch Goldberg and Niels Bormann

ITSC-XX ABSTRACTS

Session 1a: New Observations

1.01 FY-3C evaluation overview: CMA, ECMWF and UKMO

Presenter: Qifeng Lu, NSMC/CMA
Authors: Qifeng Lu, Heather Lawrence, Niels Bormann, Stephen English, Katie Lean, Nigel Atkinson, William Bell, Chunqiang Wu, Yang Guo, da wei an, Shenli Wu, Chengli Qi and Mi Liao

After the third polar-orbit meteorological satellite of China FY-3, FY-3C, was launched in September 2013, the CMA, ECMWF and UKMO cooperate closely to evaluate and improve the data quality, and assess the potential contributions to the NWP operational forecast. To actively support the operational assimilation into NWP, CMA/NSMC especially develops the FY-3 satellite data early warning, monitoring and biases correction system. This talk, as a summary talk, would like to generally review the initial achievements of evaluating FY-3C data from CMA, ECMWF and UKMO, and there will be several separate talks to specify the details from each part of the joint cooperative evaluation work.

1.02 The FY-3C evaluation project: microwave sounder calibration and direct broadcast experiences

Presenter: Nigel Atkinson, Met Office
Authors: Nigel Atkinson, Qifeng Lu, Bill Bell, Katie Lean, Niels Bormann and Heather Lawrence

Since the launch of FY-3C in September 2013, there has been an international partnership between CMA/NMSC, the Met Office and ECMWF to evaluate the data for use in NWP. The main focus initially was on comparisons of observed brightness temperatures with NWP model simulations: these are reported in other presentations. More recently, a particular effort has been made to understand the details of the calibration process for the sounder instruments (mainly MWTS-2 and MWHS-2); the Met Office and CMA have been working closely together, through visiting scientist missions, to enable this. The talk will describe the findings from these investigations, and will discuss the relationship between pre-launch measurements of instrument characteristics (e.g. nonlinearity parameters and antenna pattern) and the operational calibration process. It is hoped that by understanding the FY-3C process clearly, and verifying the implementation, the way will be smoothed for a rapid implementation of data from FY-3D when that is launched.

In addition, direct broadcast users around the world have been receiving FY-3C data and processing it using the direct broadcast package provided by CMA. (The first release of the DB package was during ITSC-19). This covers level 1 processing for the MWTS-2, MWHS-2, IRAS, VIRR and MERSI instruments. In response to an ITSC-19 action from the Products and Software Working Group, the talk will describe the characteristics of the data and the experiences at the Met Office (and elsewhere) with using the processing package. The importance of global-local consistency will be stressed, noting that the long-term plan of the WMO DBNet programme (the successor to RARS) is to include sounder data from FY-3 satellites as part of its remit.

1.03 Evaluating and assimilating microwave humidity sounding data from China's FY-3C MWHS-2 instrument in all-sky conditions at ECMWF

Presenter: Heather Lawrence, ECMWF
Authors: Heather Lawrence, Qifeng Lu, Niels Bormann, Stephen English, Alan Geer

Microwave sounding instruments flown on the Chinese FY-3 series of satellites provide information on atmospheric temperature and humidity profiles, which are important for numerical weather prediction models. In September 2013, the latest satellite in the polar Feng-Yun-3 (FY-3) series, FY-3C, was launched with the aim of becoming the first operational satellite in this series. It carries a number of instruments which are expected to be important for NWP, including the microwave humidity sounding instrument, MWHS-2, which is the subject of this paper. MWHS-2 has sounding channels in the 183 GHz water vapour band with the same frequencies as MHS and ATMS, but also has, for the first time, channels positioned around the 118.75 GHz oxygen line. These channels are expected to provide new insights, for instance on cloud parameters.

In this paper we present firstly a short summary of the work done at the European Centre for Medium-range Weather Forecasting (ECMWF) to evaluate the quality of the data from this instrument, including comparing observation minus short-range forecast statistics to similar instruments such as ATMS, MHS and AMSU-A. Secondly we present results of assimilation trials

using both the well-established 183 GHz channels and the new 118 GHz channels in the all-sky system at ECMWF.

1.04 Assimilation of observations from the Microwave Humidity Sounders on board China's FY-3B and FY-3C Meteorological Satellites
Presenter: Fabien Carminati, Met Office
Authors: Fabien Carminati, Katie Lean, and William Bell

China's Feng-Yun 3 (FY-3) platforms are a series of polar orbiting satellites which will become a major source of data for numerical weather prediction (NWP) and climate monitoring over the next two decades. The Microwave Humidity Sounder (MWHS) -1 on board FY-3B and the MWHS-2 on board FY-3C both have humidity sounding channels in the 183GHz band that have been shown to have comparable first guess departures to equivalent channels on well established operational instruments such as AMSU-B, MHS, or ATMS. Therefore, assimilation experiments in the Met Office NWP model have been conducted for MWHS-1 and -2 independently. All preliminary results show a neutral impact on both short and long range forecasts. Nonetheless, improvements are observed in the fit of observations to the model for independent humidity sensors. While MWHS-1 appears to mostly impact the window sensitive channels of infrared instruments such as AIRS and IASI (up to 6% reduction of the standard deviation in first guess departure after two weeks of assimilation), MWHS-2 improves the standard deviation in first guess departure of most infrared and microwave sounders humidity channels (up to 1.2% reduction after two weeks of assimilation). Our preliminary results are hitherto consistent with the results of similar experiments performed at ECMWF.

Session 1b: Cal/val of new and current observations

1p.01 Characterizing FY-3C Microwave Temperature Sounder MWTS2
Presenter: Qifeng Lu, NSMC/CMA
Authors: Qifeng Lu, Niels Bormann, Dawei An, Nigel Atkinson, Heather Lawrence, Stephen English, Katie Lean, William Bell, Chunqiang Wu, Yang Guo, Shenli Wu

Microwave Temperature Sounder, MWTS2, from FY-3C (the third polar-orbit meteorological satellite of China FY-3) was much improved compared to MWTS from FY3A and FY3B, for MWTS2 with 13 channels (ATMS-like instrument) while for MWTS with 4 channels (MSU-like instrument), for MWTS2 all channels locked by phase loop looked oscillator while for MWTS using Gunn diode oscillator. So for MWTS2, no significant channel frequency biases was occurred, but large negative biases and land/sea contrast were observed by the joint cooperative evaluation of CMA, ECMWF and UKMO. To correct these biases, based on the prelaunch measurement and NWP-based radiative transfer modeling, several possible contributors, such as, antenna pattern effect, antenna efficiency loss, radiometer non-linear effect, Doppler effect and possible channel interference, were evaluated to characterize the MWTS2. The characterization helps the data quality improved before it is going to NWP VarBC. This topic is about to details of the MWTS2 instrument characterization from the joint cooperative work of CMA/NSMC, ECMWF and UKMO.

1p.02 Assessment of FY-3A and FY-3B/MWHS observations
Presenter: Keyi Chen, IAP CAS
Authors: Keyi Chen, Stephen English, Niels Bormann, Jiang Zhu

The FY-3 series began in May 2008 with the launch of the FY-3A satellite. The Microwave Humidity Sounders (MWHS) provide vertical information about water vapour, which is important for numerical weather prediction (NWP). The Noise Equivalent Delta Temperature (NEDT) of the MWHS is higher than that of the Microwave Humidity Sounder (MHS) instrument (e.g. on MetOp-B) but lower than that of the older AMSU-B instruments (on NOAA-15, 16 and 17). Assimilation of MWHS observations into the ECMWF Integrated Forecasting System (IFS) improved the fit of short-range forecasts to other observations, notably MHS, and also slightly improved the longer-range forecast scores verified against analyses. Also, assimilating both the MWHS/FY-3A and the MWHS/FY-3B gave a larger impact than either instrument alone. Furthermore when MWHS and MHS were added separately to a baseline using neither, the MWHS impact was found to be comparable to MHS. Consequently, ECMWF have been assimilating the FY-3B MWHS data in the operational forecasting system since September 24th, 2014. This is the first operational use of Chinese polar orbiter satellite data by an NWP centre outside China.

1p.03 Assimilating Megha-Tropiques SAPHIR Data in the NOAA GDAS

Presenter: Erin Jones, NOAA/NESDIS/JCSDA
Authors: Erin Jones, Kevin Garrett, Eric Maddy, Krishna Kumar, Sid Boukabara

At present, data from the Megha-Tropiques satellite Sondeur Atmosphérique du Profil d'Humidité Intertropicale par Radiométrie (SAPHIR) instrument are not operationally assimilated in the National Oceanic and Atmospheric Administration's (NOAA) Global Data Assimilation System (GDAS). The Center for Satellite Applications and Research (STAR), in support of the Joint Center for Satellite Data Assimilation (JCSDA), is working to develop the capability to assimilate SAPHIR L1A2 data into the NOAA GDAS. The ability of SAPHIR to provide information of water vapor profiles in the tropics has the potential to improve numerical weather model analyses and forecasts, if these data are properly assimilated. To be discussed here are an overview of the assimilation of SAPHIR data into the NOAA GDAS, and a summary of the efforts to optimize this assimilation using Gridpoint Statistical Interpolation (GSI). The impact of the assimilation of these data on Global Forecast System (GFS) forecast results will also be explored.

1p.04 Recent activities on microwave radiance data assimilation at JMA

Presenter: Masahiro Kazumori, JMA
Authors: Masahiro Kazumori

Space-based microwave radiance data provide essential information for today's numerical weather prediction (NWP). In the JMA global NWP system, microwave sounder data, i.e., AMSU-A and MHS radiance, have been used to extract temperature and humidity information for estimating accurate initial conditions. Furthermore, microwave imager (e.g., AMSR-E, TMI, and SSMIS) radiance data have been important to obtain atmospheric water vapor information. The stable use of their data must be ensured to maintain accuracy of weather forecasting. Moreover, enhanced use of those data in a NWP system is necessary to improve forecasting skill. In this paper, two recent activities to enhance the microwave radiance data assimilation at JMA are presented.

The first topic is an assessment of SAPHIR/Megha-Tropiques radiance data and the impacts of their assimilation into the JMA global data assimilation (DA) system. SAPHIR uses six channels near 183 GHz water vapor absorption line to observe atmospheric water vapor profiles in the tropics. SAPHIR radiance data were evaluated in terms of first guess (FG) departure. The assimilation experiments of the SAPHIR radiance data in the clear sky region were conducted using the JMA global DA system. The assimilation brought significant improvements in its analyzed water vapor field and FG departure fit to the other humidity and temperature observations. Furthermore, the assimilation of SAPHIR radiance data improved tropical cyclone track prediction significantly in the JMA system. Based on these findings, SAPHIR radiance data are now in use at JMA.

The second topic is a progress toward all-sky microwave radiance assimilation in the JMA global DA system. In the all-sky assimilation, several microwave imagers' radiance data (e.g. AMSR2/GCOM-W, GMI/GPM, and SSMIS/DMSP) were evaluated and their FG departures were examined. The all-sky FG departure statistics revealed biases originated from cloud physics scheme of JMA global model. The results indicate that there are excessive light rain areas forecasted in the tropics and cloud liquid water amounts are underestimated in stratocumulus areas. These biases in the FG departure are issues in the all-sky radiance assimilation at JMA. However, in spite of these issues, preliminary experiment of the all-sky microwave radiance assimilation showed positive impact on tropical cyclone track prediction and made better FG fit to wind and humidity observations. The assimilation of the microwave imager radiance data outweighed the bias issues. Results of the preliminary all-sky radiance assimilation experiments in the JMA system are discussed in the conference.

1p.05 Assimilation of AMSR2 radiances at the Met Office

Presenter: Stu Newman, Met Office
Authors: Stu Newman, Amy Doherty, Bill Bell

Satellite microwave imager observations provide information on global humidity fields which may be exploited for numerical weather prediction. The use of Advanced Microwave Scanning Radiometer-2 (AMSR2) radiances has been trialled within the Met Office global data assimilation system. We report on a Day-1 configuration, with a discussion of quality control methods and choice of observation errors. Trial results versus a full observing system are presented, and we demonstrate the complementarity of imager observations with those from conventional microwave humidity sounders.

1p.06 Himawari-8 AHI radiance assimilation with GSI at JCSDA

Presenter: Kevin Garrett (for Zaizhong Ma, NOAA/NESDIS/JCSDA)
Authors: Zaizhong Ma, Sid Ahmed Boukabara, Eric Maddy and Tong Zhu

A new era in environmental satellites began in October 2014 when Japan's Himawari-8 attained geostationary orbit. Main instrument of the satellites is the Advanced Himawari Imager (AHI) which is comparable to the Advanced Baseline Imager (ABI) on board the U.S. GOES-R class satellites. The AHI is a multi-purpose imager for weather watch, NWP utilization and environment monitoring; and wind derivation by tracking clouds and water vapor features. It features 16 channels operating in the VIS, NIR and IR spectral bands. The coverage cycle is 10 minutes for full disk.

Efforts are currently ongoing at the NOAA/NESDIS Center for Satellite Applications and Research (STAR) to assimilate Himawari-8 AHI radiance measurements in the NOAA Global Data Assimilation System. All plumbing in the Gridpoint Statistical Interpolation (GSI) system to allow assimilation of Himawari-8 AHI radiance has been completed, and the impact of the real AHI observations is determined in the global framework at JCSDA. All sky (clear, cloudy, and precipitation) IR radiance of Himawari-8 will be expand beyond the assimilation of only clear sky IR channels. It is toward the ultimate goal to routinely assimilate these data to improve global weather forecasts as well as to improve global cloud and precipitation analyses. The cycling experiments with/without real H8 AHI have been performed to assess its Analysis/Forecast impacts. The preliminary scientific results about the ingestion of Himawari-8 AHI data and the impact on the NOAA GFS model forecast will be presented in this Conference.

1p.07 Characterization of AHI IR Channels with IASI Measurements

Presenter: Dorothee Coppens (for Bertrand Theodore), EUMETSAT
Authors: Bertrand Theodore, Dorothee Coppens and Dieter Klaes

Japan's next generation geostationary meteorological satellite "Himawari" has been successfully launched in October 2014 and placed over the West-Pacific. It carries the Advanced Himawari Imager (AHI) that provides an image of the Earth in 16 bands in the visible and the infrared domains, every 10 minutes.

As part of the operational monitoring of the products measured from the Infrared Atmospheric Sounding Interferometer (IASI) instruments currently flying on two Metop satellite, EUMETSAT has initiated a comparison of the infrared channels of AHI with collocated IASI measurements. Since the launch of the first IASI in 2007, the instrument has proven an excellent reference for inter-calibration studies thanks to a well characterized calibration, a very good stability in time and a continuous spectral coverage from 3.6 to 15.5 microns.

This paper will give an overview of the algorithm used to find observations coincident in space and time and to make direct comparison using a spatial and a spectral averaging. Preliminary results based on AHI images acquired during the commissioning seem to indicate that AHI IR measurements are slightly biased with respect to IASI. The comparison has been performed over different periods of time in order to detect a possible evolution of the differences. These results will be presented and discussed.

1p.08 The Impact of INSAT-3D Sounder Radiance Assimilation in the NCMRWF Global Forecast System (T574L64)

Presenter: Sanjeev Kumar Singh, NCMRWF
Authors: V.S. Prasad, Sanjeev Kumar Singh, and C.J. Johny

INSAT-3D is a meteorological, data relay and satellite aided search and rescue satellite developed by the Indian Space Research Organisation and was launched successfully on 26 July 2013 from French Guiana. It is positioned at 82 Degree East longitude. INSAT-3D has a 6 channel imager and 19 channel sounder payload. This adds a new dimension to weather monitoring through its atmospheric sounding system, which provides vertical profiles of temperature (40 levels from surface to ~70 km), humidity (21 levels from surface to ~15 km) and integrated ozone from surface to top of the atmosphere. NCMRWF (National Centre for Medium Range Weather Forecasting) receives all Indian conventional and satellite data on near real time basis along with that of all other global data sets. The Clear Sky Radiance (CSR) product of INSAT-3D sounder is now made available to the center. NCMRWF is also consistently updating its data processing and assimilation systems to make use of all these new observations from time to time. To enable the INSAT-3D radiance observations being used as additional observation type, the assimilation scheme of NCMRWF Global Forecast System (NGFS) has been modified. In order to find the

impact of these radiances, Observing System Experiments (OSE) is conducted for the period 16-31 December, 2014. It is observed that impact of INSAT-3D sounder data is neutral to marginal positive. Before assimilation of these radiances into the model, quality of the data is also validated with the model first guess.

Session 1c: Cal/val of new and current observations

1.05 An initial assessment of microwave imager/sounder MTVZA-GY data from Meteor-M N2 satellite

Presenter: Sergey Uspenskiy, SRC Planeta
Authors: S.Uspensky, E.Kramchaninova, A.Uspensky, P.Poli and S.English

An initial assessment of observations from the MTVZA-GY instrument on Meteor-M N2 (Cherny et al 2010.) has been undertaken at SRC Planeta/Roshydromet and ECMWF for evaluation of calibration accuracy. The MTVZA-GY is a microwave imager/sounder instrument similar to the SSMIS instrument on the DMSP F16 to F19 satellites.A two-point calibration technique is used for converting the signals from MTVZA-GY to antenna brightness temperatures. Both MTVZA-GY and SSMIS are conically scanning instruments combining dual polarized imaging channels, mostly below 50 GHz with temperature sounding channels at 50-60 GHz and humidity sounding channels at 183 GHz. However there are also some notable differences. MTVZA-GY has dual polarized channels at 10 GHz, which SSMIS does not, and MTVZA-GY has a nadir viewing angle of 53.3°, giving a normal earth incidence angle of 65°. MTVZA-GY also has no fewer than four window channels between 31 and 48 GHz whereas SSMIS only has 37 GHz. MTVZA-GY does not have the upper stratospheric and lower mesospheric channels found on SSMIS. However in terms of impact on NWP and scientific assessment these differences are not critical, we can consider it to be of the same genre of instrument as SSMIS.The SSMIS instrument calibration has been extensively studied (e.g. Bell et al. 2008) and an initial focus of the evaluation of MTVZA-GY was to compare how similar its characteristics are to the SSMIS.In this initial assessment it appears likely that the MTVZA-GY has broadly comparable performance to SSMIS. Latest results will be presented.

1.06 IRFS-2 instrument onboard Meteor-M N2 satellite: measurements analysis

Presenter: Alexander Polyakov, Saint-Petersburg State University
Authors: A.V. Polyakov, Yu. M. Timofeyev, Ya. A. Virolainen, A.B Uspensky, A.N.Rublev, Yu.M. Golovin, F.S. Zavelevich, D.A .Kozlov

Fourier-transform spectrometer IRFS-2 is currently being flown onboard new Russian Meteor-M N 2 satellite. The measured range is defined as 5-15 u-m with the spectral resolution of 0.7 - 1.4 cm-1 (after apodization). In order to assess the reliability of measured IR spectra a number of comparisons were performed with the simulated data for cloud-free conditions. A LBL Radiative transfer code was used for the modeling of the measured spectra. Comparisons were performed for the 8-12 um range and various absorption bands of atmospheric gases (CO2, O3, etc.). The observed discrepancies between real and simulated spectra are analyzed. Comparison spectral data vs other hyperspectral instruments showed that statistical parameters (mean, SD) IRFS-2 and IASI-A, -B are mutually close. Estimate of information content IRFS-2 and other hyperspectral instrument showed high enough quality of IRFS-2 spectral measurements. Retrieval algorithms for various parameters including temperature and humidity profiles, total amount of some of the atmospheric gases (O3, CH4 etc.) are described. The validation of those products was performed by comparison with radiosonde and NWP data, as well as various sub-satellite measurements.

1.07 CrIS Full Spectral Resolution SDR and S-NPP/JPSS-1 CrIS Performance Status

Presenter: Yong Han, NOAA/STAR
Authors: Yong Han

The Cross-track Infrared Sounder (CrIS) is a Fourier Transform spectrometer, measuring Earth view interferograms at 30 cross-track positions, each with a 3x3 array of Field-of-Views in the three infrared spectral bands from 650 to 1095 cm-1(LWIR band), 1210 to 1750 cm-1(MWIR band) and 2155 to 2550 cm-1 (SWIR band). Before December 2014, the CrIS on the Suomi National Polar-orbiting Partnership Satellite (S-NPP) was operated in the normal spectral resolution (NSR) mode, in which the interferograms are recorded with a maximum path difference (MPD) of 0.8, 0.4 and 0.2 cm for the LWIR, MWIR and SWIR bands, respectively. Since December 2014, the S-NPP CrIS has been operated in the full spectral resolution (FSR) mode, in which the interferograms of all the three bands are recorded with an MPD of 0.8 cm. The next CrIS instrument on the first Joint-Polar Satellite System (JPSS-1) will be operated in the FSR mode. JPSS-1 is scheduled to be launched in

early 2017. Currently, the JPSS-1 CrIS pre-launch ground testing work, including the TVAC data collection and analysis, has been completed. The performances of both instruments are excellent.

The measured interferograms are processed into calibrated and geolocated spectra at ground by the CrIS Sensor Data Record (SDR) algorithm. For the NSR measurements, the spectral resolutions are 0.625 cm-1, 0.125 cm-1 and 2.5 cm-1 in the LWIR, MWIR and SWIR bands, respectively, and for the FSR mode measurements, they can be processed into the FSR spectra with a resolution 0.625 cm-1 for all the three bands or the NSR spectra. At the time of this writing, an offline FSR SDR processing system has been providing the FSR SDR to the user community, while the NOAA official processing system continues to generate the NSR SDRs by truncating the FSR interferograms.

Since the last ITSC conference, the CrIS SDR Science team has made good progress in reducing spectral ringing artifacts of the SDR radiance spectra, which are unapodized. This effort followed the requests from the user community during the ITSC-19 conference to test the impacts of using CrIS un-apodized radiance spectra on NWP and atmospheric profile retrievals. Major sources of the ringing artifacts include non-circular onboard digital filter, suboptimal calibration equation and missing the instrument responsivity functions in radiative transfer models for simulating CrIS spectra. The solutions to address these issues have been developed and implemented. In the first part of this presentation, we will overview the FSR SDR algorithm and results, and in the second part, overview the performances of the S-NPP and JPSS-1 CrIS instruments.

1.08 Updates on Operational Processing of ATMS TDR and SDR Products

Presenter: Fuzhong Weng, NOAA/NESDIS/STAR
Authors: Fuzhong Weng

The Suomi National Polar-orbiting Partnership (NPP) satellite was launched on October 28, 2011 and carries the Advanced Technology Microwave Sounder (ATMS) on board. ATMS is a cross-track scanning instrument observing in 22 channels at frequencies ranging from 23 to 183 GHz, permitting the measurements of the atmospheric temperature and moisture under most weather conditions. The recent major updates on operational processing of ATMS TDR and SDR products include full radiance calibration, radiance destriping, correction of the flat reflector emission and noise characterization from Allan variance. These updates have been made into JPSS Interface Data Processing Segment (IDPS, ADL 4.2 with MX8.8) as well as NOAA/STAR offline processing system. It is found that the ATMS SDR brightness temperatures have smaller biases in upper air sounding channels after the calibration process is switched to the full radiance calibration with the corrected non-linearity sign. For the characterization of the ATMS instrument sensitivity or noise equivalent differential temperatures (NEDT), both standard deviation and Allan variance of warm counts are computed and compared. It is shown that NEDT can be significantly overestimated from the traditional standard deviation method since the warm calibration count has an unstable mean value within an orbit. With the neighborhood two-sample Allan variance, the NEDT can be accurately quantified. It is found that the NEDT of AMSU and MHS in other NOAA and METOP satellites could have been also overestimated from the standard deviation approach. These overestimated NEDTs for AMSU/MHS and ATMS could have some significant impacts on users who are applying the values in their remote sensing systems and radiance data assimilation.

It is also found that the ATMS antenna brightness temperature displays a distinct scan angle dependent bias in the NWP O-B field, especially at the window channels. The scan-angle dependence in brightness temperature is directly observed when the ATMS was pitched over to scan the deep space where the radiation is uniform across the scan. The scan angle dependent radiance in cold space may be mostly related to the ATMS flat reflector emission. Thus, a physical model is developed to characterize the flat reflector emission and then retrieve the emissivity from ATMS pitch-over maneuver data. It is shown that ATMS reflector emissivity from K, V, W and G bands is within a range of 0.002 to 0.007. This model allows for reducing the ATMS scan angle dependent bias when it observes the earth scene.

1.09 Assimilating New Passive Microwave Data in the NOAA GDAS

Presenter: Erin Jones, NOAA/NESDIS/JCSDA
Authors: Erin Jones, Kevin Garrett, Eric Maddy, Krishna Kumar, Sid Boukabara

The National Oceanic and Atmospheric Administration's (NOAA) Center for Satellite Applications and Research (STAR), in support of the Joint Center for Satellite Data Assimilation (JCSDA), has been working to extend the Gridpoint Statistical Interpolation (GSI) scheme to assimilate

L1 data from select passive microwave sensors that, up until this point, have not been operationally assimilated in the Global Data Assimilation System (GDAS). These sensors, including the Global Precipitation Measurement (GPM) Microwave Imager (GMI), have wide frequency ranges and provide information about the state of the atmosphere over much of the atmospheric column in a timely manner across a large portion of the globe, and thereby possess the potential to improve numerical weather model analyses and forecasts when appropriately assimilated. To be presented are an overview of the assimilation of data from these sensors into the NOAA GDAS, and the impacts that the assimilation of these data have on Global Forecast System (GFS) forecasts.

1.10 Impact of Megha-Tropique's SAPHIR humidity profiles in the Unified Model Analysis and Forecast System

Presenter: Indira Rani, NCMRWF
Authors: S. Indira Rani, Amy Doherty, Nigel Atkinson, William Bell, Stuart Newman, Richard Renshaw, John P. George, E.N. Rajagopal

This paper discusses the impact of Microwave (MW) humidity sounder radiances from SAPHIR onboard Megha-Tropique (MT) satellite in the UK Met Office's Unified Model (UM) Data Analysis and Forecast system, which is being used at NCMRWF. MT provides high frequency observations over a given area in the Tropics three to six times per day because of its orbital inclination (20º with the Earth's equatorial plane). SAPHIR, the six channel MW sounder, provides humidity information from the surface to around 10km, using frequencies around the 183 GHz water vapour line. Assimilation of SAPHIR radiances increases the number of assimilated humidity sensitive MW and IR radiances from instruments onboard other satellites, especially over the Tropics. The standard deviations of the innovations of the overlapping channels of other instruments such as ATMS and AMSU-B/MHS are reduced by ~2% and the average number of observations assimilated from these instruments increased by ~1.5% with respect to the control experiment. Similar behavior has been noticed in the in the IR channel radiances from other instruments such as AMSU-A as well as in the hyperspectral radiances like IASI, AIRS, and CrIS. SAPHIR radiance assimilation in the UM system clearly shows improvement in the analysis and forecast system both globally and over the Tropics.

Session 1d: Cal/val of S-NPP observations

1p.09 Antenna Emissivity Correction for ATMS Calibration Bias Characterization

Presenter: Hu Yang, University of Maryland
Authors: Hu Yang, Fuzhong Weng

The Advanced Technology Microwave Sounder (ATMS) onboard the Suomi National Polar-orbiting Partnership (NPP) satellite is a total power radiometer and scans across the track within a range of ±52.77° from nadir. It has 22 channels and measures the microwave radiation at either quasi-vertical or quasi-horizontal polarization from the Earths' atmosphere. ATMS scanning reflector is made of the beryllium coated with gold and can have an emission due to the surface roughness. An estimate of the reflector emissivity in the prelaunch phase was not explored. In this study, a new methodology is developed to assess the antenna emission from the ATMS pitch-over observations. It is found that the antenna emission is significant and dominates the scan angle dependent features in the ATMS antenna temperatures. Retrieved emissivity from K to G bands ranges from 0.002 to 0.006. Error model was also developed to assess the impact of antenna emissivity to calibration accuracy of antenna temperature products.

1p.10 Striping Noise Analysis and Mitigation for ATMS, GMI and MWTS Data

Presenter: Xiaolei Zou, University of Maryland
Authors: Xiaolei Zou and Fuzhong Weng

Observations from satellite microwave radiometers contain random noise and sometimes also coherent noise. For the Advanced Microwave Sounding Technology (ATMS) on board Suomi NPP satellite, coherent striping noise at 50-60 GHz (V-band) are noticeable in the global differences of brightness temperatures between observations (O) and simulations (B) and is also shown as 1/f noise spectrum of calibration counts. This striping noise in ATMS data is of a serious concern for many applications and can degrade the data impacts on NWP forecast skill if not identified and eliminated. In this study, we present a new technique for reducing the striping noise contained in ATMS, Microwave Humidity Sounder (MHS), the Advanced Microwave Sounding Unit–B (AMSU-B) and the Global Precipitation Measurement Microwave Imager (GMI) data. Note that the striping noise is visually discernible in global O-B fields in ATMS V-band channels, but hidden in WG and K/Ka band channels due to

much larger and smaller scale dynamic variability of the O-B difference than that those at V-band channels. Since the striping noise is present in both the earth scene count and the calibration counts, the de-striping to calibration counts alone is in general not sufficient for removing the striping noise in brightness temperatures. A combined method of principal component analysis (PCA) and Ensemble Empirical Mode Decomposition (EEMD) allows the cross-track striping noise be separated from the atmospheric signals, which can then be used for developing the "optimal" filters to smooth out striping noise in brightness temperatures without altering small-scale weather features. A detailed analysis of the striping noise features and the de-striping results will be shown for both ATMS, GMI and MWTS data.

1p.11 Evaluation of Different Calibration Approaches for JPSS CrIS

Presenter: Yong Chen, ESSIC/UMD, NOAA/STAR
Authors: Yong Chen, Yong Han

The Cross-track Infrared Sounder (CrIS) on Suomi National Polar-orbiting Partnership Satellite (S-NPP) is a Fourier transform spectrometer. It provides a total of 1305 channels in the normal mode for sounding the atmosphere. CrIS can also be operated in the full spectral resolution (FSR) mode, in which the mid-wave (MWIR) and short-wave (SWIR) band interferograms are recorded with the same maximum path difference as the long-wave (LWIR) band and with spectral resolution of 0.625 cm-1 for all three bands (total 2211 channels). NOAA operated CrIS in FSR mode from normal mode on December 4, 2014 for S-NPP, and will operate CrIS in FSR mode for the Joint Polar Satellite System (JPSS). Based on CrIS Algorithm Development Library (ADL), CrIS full resolution Processing System (CRPS) has been developed to generate the FSR Sensor Data Record (SDR). This code can also be run for normal mode and truncation mode SDRs.

In this study, four different calibration approaches are implemented in the FSR ADL code to study and understand the ringing artifacts and to support to select the best calibration algorithm for CrIS on JPSS-1. These calibration approaches can be divided into two categories based on the calibration order: radiometric calibration first, then CMO to spectral calibration; CMO to spectral first, then radiometric calibration.

We developed the CrIS FSR SDR Validation System to quantify the CrIS radiometric and spectral accuracies, since they are crucial for improving its data assimilation in the numerical weather prediction, and for retrieving atmospheric trace gases. In this study, CrIS full resolution SDRs are generated using these four calibration algorithms in CRPS with the data collected from FSR mode of S-NPP. The results are assessed by LBLRTM v12.2 with European Centre for Medium-Range Weather Forecasts (ECMWF) forecast fields as inputs. The biases between SDR radiances using different calibration approaches and simulations are assessed under clear sky over ocean. Evaluation results from different calibration approaches are presented and the ringing features observed in CrIS unapodized spectra are discussed.

1p.12 SI Traceable Algorithm for Characterizing Hyperspectral Infrared Sounder CrIS Noise

Presenter: Yong Chen, ESSIC/UMD, NOAA/STAR
Authors: Yong Chen, Fuzhong, and Yong Han

The Cross-track Infrared Sounder (CrIS) on Suomi National Polar-orbiting Partnership Satellite (S-NPP) is a Fourier transform spectrometer and provides the sensor data record (SDR) that can be used for retrievals of the atmospheric temperature and water vapor profiles and can be also directly assimilated in numerical weather prediction models. The Noise Equivalent Differential Radiance (NEdN) is part of CrIS SDR products and represents the amount of random noise in the interferometer data. It is a crucial parameter affecting the accuracy in retrieval and satellite radiance assimilation. In this study, International System of Units (SI) traceable method Allan deviation is used to estimate the CrIS NEdN due to the internal calibration target (ICT) radiance slowly varying with time. Compared to the current standard deviation method, it is shown that the NEdN calculated from Allan deviation is converged to a stable value when a number of samples or average window size is set to 510. Thus, Allan deviation can result in CrIS NEdN SI traceable noise. Also, an optimal averaging of window size is 30 if the NEdN is calculated from the standard deviation.

1p.13 "True Ringing" Artifacts in Unapodized FTS Measurements

Presenter: Aronne Merrelli, UW-Madison/SSEC
Authors: Aronne Merrelli, David Tobin, Robert Knuteson, Thomas Greenwald, Hank Revercomb

In order to simulate high accuracy FTS spectra, one needs to derive an instrument resolution spectrum from a monochromatic spectrum calculated by a line by line radiative transfer model. This can be done either by direct convolution and sampling with the ILS, or by the equivalent Fourier transform based method given by the Convolution

Theorem. From a theoretical point of view, to simulate an idealized FTS, one should start with a monochromatic spectrum containing all spectral frequencies - the "infinite bandwidth" spectrum. The typical approach is to limit the simulated monochromatic spectrum to a larger range than the measurement band and taper the edges with an envelope derived from an analytic function. The tradeoff is to include enough out of band spectral range to minimize ringing artifacts while keeping the spectral range small enough to reduce the computational complexity.

In practice, all real sensors have a band-limited spectral response due to the optical components and detector responsivity. The shape of this responsivity curve will produce a different ringing artifact than the idealized infinite bandwidth FTS. We call this ringing artifact "true ringing", since it is directly related to the actual instrument spectral response, and represents the actual measurement better than the idealized infinite bandwidth FTS. We show example calculations of the true ringing in CrIS spectral measurements (both at normal and full resolutions), coupled with observation - calculation residuals to show where the true ringing is important in real data.

1p.14 Update on S-NPP CrIS Full Spectral Resolution SDR Processing at NOAA/STAR

Presenter: Xiaozhen Xiong, NOAA/NESDIS/STAR
Authors: Xiaozhen Xiong, Yong Han, Yong Chen, Likun Wang , Denis Tremblay, Xin Jin, Lihang Zhou

The Cross-track Infrared Sounder (CrIS) on Suomi National Polar-orbiting Partnership Satellite (S-NPP) and Joint Polar Satellite System (JPSS)-1 is a Fourier transform spectrometer for atmospheric sounding. CrIS on S-NPP started to provide measurements in 1305 channels in its normal mode since its launch on November 2011 to December 4, 2014, and switched to the full spectral resolution (FSR) mode on December 4, 2014, in which the spectral resolutions in both the MWIR (1210-1750 cm-1) and SWIR bands (2155-2550 cm-1) are increased to 0.625 cm-1 as in the LWIR band (650-1095 cm-1), thus providing measurements in 2211 channels. One major benefit to use the FSR data is to improve the retrieval of atmospheric trace gases, such as CH4, CO and CO2 which are listed in the level-1 requirements in J-1. While the NOAA operational Sensor Data Record (SDR) processing (IDPS) continues to produce the normal resolution SDRs by truncating full spectrum RDR data, NOAA STAR started to process the FSR SDRs data since December 4, 2014 to present, and the data is being delivered through NOAA STAR website (ftp://ftp2.star.nesdis.noaa.gov/smcd/xxiong/) with a latency of about 6-12 hours. The current FSR algorithm was developed on basis of the CrIS Algorithm Development Library (ADL), and is the baseline of J-1 CrIS SDR algorithm. The FSR data from S-NPP will be used to evaluate and improve the J-1 SDR algorithm. In this presentation we will introduce this processing system and update the S-NPP CrIS FSR SDR data status.

1p.15 Preparation for the Full Resolution CrIS Hyperspectral Radiance Data in BUFR Format

Presenter: Yi Song (for Walter Wolf, NOAA/NESDIS/STAR)
Authors: Walter Wolf, Yi Song, Tom King, Letitia Soulliard, and Mike Wilson

NOAA/NESDIS is currently creating and distributing Cross-track Infrared Sounder (CrIS) radiances from the Suomi National Polar-orbiting Partnership (S-NPP) satellite in Binary Universal Form for the Representation of meteorological data (BUFR) format to the global Numerical Weather Prediction (NWP) centers. Two BUFR files are currently being made available, the truncated resolution set of 1305 channels and a representative subset containing 399 channels. For the next CrIS instrument on the J1 satellite, the full resolution channel set containing 2223 channels will be downlinked. To prepare for this larger data set, NOAA/NESDIS/STAR will be making upgrades to the CrIS processing system running in NESDIS operations and to the distributed BUFR files. STAR will also be implementing a new representative channel subset to replace the 399 channel BUFR file. If the S-NPP downlink is changed to bring down the full resolution CrIS channel set, then these updates to the BUFR files will be implemented for S-NPP. The updates to the CrIS processing system, the channel subset and the BUFR files shall be presented.

1p.16 Accurate Collocation of VIIRS measurements with CrIS

Presenter: Likun Wang, University of Maryland
Authors: Likun Wang, Bing Zhang, Denis Tremblay, and Yong Han

A state-of-the-art high-spatial-resolution imager and a high-spectral-resolution sounder, the Visible Infrared Imaging Radiometer Suite (VIIRS) and the Cross-track Infrared Sounder, respectively, are both residing on the on the Suomi National Polar-orbiting Partnership (SNPP) and future Joint Polar Satellite System (JPSS) satellites. Specifically, VIIRS is a whiskbroom scanning imaging radiometer, collecting visible and infrared imagery of the Earth through 22 spectral bands between 0.412 and

12.01 um. These bands include 16 moderate resolution bands (M-bands) with a spatial resolution of 750m at nadir, 5 imaging resolution bands (I-bands) with a 375m at spatial resolution nadir, and 1 panchromatic day-night band (DNB) with a 750m spatial resolution. In contrast to VIIRS, CrIS has much higher spectral resolution including 1305 spectral channels over three infrared bands, but the spatial resolution (~14.0 km at nadir) is coarser than that of VIIRS and does not have the solar spectral bands. The combination of VIIRS and CrIS on SNPP and JPSS provides an opportunity to quantify the trade-offs between spectral and spatial coverage and, furthermore, to quantify the added value of atmospheric (and surface) retrievals from a combined multisensor, multiwavelength retrieval approach. In addition, inter-calibration of CrIS and VIIRS at similar spectral coverage bands serves an important role for quantifying radiometric calibration accuracy of both sensors. To achieve these applications needs accurate and fast collocation of VIIRS and CrIS measurements. In this study, we address: 1) How to accurately collocate VIIRS measurements within CrIS instantaneous field of view (IFOV) directly in celestial space? 2) How to account for geolocation offset between CrIS and VIIRS to improve the collocation accuracy? 3) How sensitively does the CrIS spatial response functions effect on collocation accuracy? And 4) How to collocate VIIRS Environmental Data Products with terrain-corrected geolocation fields with CrIS FOVs in form of geodetic latitude and longitude on the Earth ellipsoid? Finally, several case studies (for example, using VIIRS cloud products to examine CrIS clear-sky measurements) will be presented.

1p.17 withdrawn

Session 1e: Cal/val of new and current observations

1.11 A report on the outcomes of a workshop aimed at improved understanding of biases observed in analysis of 183 GHz observations
Presenter: Stephen English, ECMWF
Authors: Stephen English, Helene Brogniez and Jean-Francois Mahfouf

The Advanced Technology Microwave Sounder (ATMS, onboard Suomi-NPP) and the Sondeur Atmospheric du Profil d'Humidite Intertropical par Radiometrie (SAPHIR, onboard Megha-Tropiques) give an improved sampling of the 183GHz water vapor absorption line. ATMS provides channels similar to MHS supplemented by additional channels 1.8GHz and 4.5GHz out from the line centre. SAPHIR has nearly identical channels plus a 0.2GHz channel very close to the centre of the line and a 11.0GHz channel that observes the wings of the line. Cross-comparisons of these and the Microwave Humidity Sounder (MHS onboard MetOp-A and B) show good consistency among them, within the radiometric noise of the instruments. However, when the measurements are assimilated in a numerical weather prediction model, or compared to radiative transfer model calculations that use radiosonde profiles of temperature and humidity, a channel-dependent bias that increases from the centre to the wings of the 183 GHz line is observed. As there are many potential causes of such biases a 2-day workshop was held on 29-30 June 2015 under the auspices of both the ITWG and WCRP-GEWEX activities and sponsored by the Megha-Tropiques mission in order to make an assessment of the current state-of-the-art in radiative transfer modeling, spectroscopy, measurements of water vapor, and analysis techniques. The conclusions and recommendations of this workshop will be presented and discussed.

Session 2a: Radiative transfer

2.01 High resolution IR cloudy radiances simulations : comparison between RTTOV and VLIDORT
Presenter: Jerome Vidot, CMS/METEO-FRANCE
Authors: Jerome Vidot and Laurent C.-Labonnote

Infrared cloudy radiances assimilation is considered as one of the major goal in improving Numerical Weather Prediction. For such goal, a preliminary step is to include cloud scattering in fast Radiative Transfer Model. The RTTOV model uses the Chou scaling approximation to modelize the scattering pattern in order to get accurate computation in cloudy conditions. This approximation is supposed to simulate IR scattering with few tenth of error on the brightness temperature. We compared RTTOV TOA infrared simuled spectra (IASI-like) in both clear-sky and cloudy-sky with simulations made with the full scattering model VLIDORT. In order to evaluate the scattering scheme only, the atmospheric transmittance as well as the optical properties of clouds as calculated by RTTOV are used in VLIDORT. A database of many realisitc cloud profiles including ice clouds and water clouds have been used. The effect of different

geometries as well as different surface emissivities have been also tested.

2.02 Interactive use of the new generation of TIR and SWIR space borne instruments to increase the performance of radiative transfer models, spectroscopic and atmospheric databases (4A, GEISA, TIGR, ARSA)

Presenter: Virginie Capelle (for Raymond Armante, LMD/CNRS/IPSL)
Authors: R. Armante, A. Chedin, N.A. Scott, A. Feofilov, V. Capelle, N. Jacquinet, L. Crepeau, M. Ben Sassi, J. Pernin, C. Burlaud, C. Crevoisier

Improving the quality of climate variables retrieved from Thermal Infrared (TIR) and Short Wave Infrared (SWIR) hyperspectral sounders observations must go hand in hand with that of atmospheric spectroscopy and radiative transfer modeling, leading to accurate calibration/validation of level1 and level2 products. This allows eliminating inconsistencies that may limit the usefulness of the radiances for inversion or assimilation applications.

At LMD, the 4A line by line radiative transfer model, GEISA spectroscopic data base, TIGR and ARSA, climatological and radiosonde databases, have been, for many years, at the leading edge of their specific research fields, mainly based on their continuous validation and updates (http://ara.abct.lmd.polytechnique.fr). Upon request, they are widely distributed in our international community.

4A (in its operational version 4A/OP, http://4aop.noveltis.com) and GEISA are recognized as reference model and spectroscopic database by CNES for IASI level1 CAL/VAL and level1 operational processing. 4A/OP is now deeply involved with CNES and associated research groups in the definition of the MicroCarb, IASI-NG, and MERLIN future missions.

In the shortwave Infrared spectral region, we have used all the potential of the highest resolved instruments of the TCCON network of ground-based Fourier Transform Spectrometers (~ 2x10-3 cm-1 spectral resolution).

In the Thermal Infrared spectral region, in addition to laboratory measurements, as was done in the past, we have used observations provided by AIRS (from 2003 onwards) and IASI (MetOpA from 2007 onwards, MetOpB from 2013 onwards), TANSO-FTS (2009), CrIs (2011).

For every single month of observations, we have performed hundreds of comparisons between simulated and observed radiances (so called residuals) for global, land, sea, night, day, scan angle dependent, clear sky conditions of observations. In particular, we have taken advantage of the high radiometric stability of IASI as well as of its continuous spectral scanning from 645 to 2760 cm-1 to cross-check the values of the residuals in spectral regions of various sensitivity to such or such variable. This made it possible to detect the spectral signature of errors - e.g. those related to the spectral line calculation (spectroscopic parameters, line mixing, NLTE, continua, etc) and to identify the required corrections. Work is in progress with the LISA/IPSL research group (J. Lamouroux, Ha Tran, J.M. Hartman) in order to keep tractable the modeling of the line mixing as implemented in the current version of 4A/OP with any new updating of GEISA.

We will present our most recent validation results and the impact on the 4A radiative transfer model and on the 2014 version of GEISA, according to IASI and TCCON.

2.03 An evaluation of radiative transfer modelling errors in AMSU-A data

Presenter: Cristina Lupu, ECMWF
Authors: Cristina Lupu, Alan Geer, Niels Bormann and Stephen English

Systematic biases relative to numerical weather prediction models are often observed in AMSU-A channels sensing in the 50-60 GHz range. These biases could arise from inaccuracies in the radiative transfer model calculations that are used to simulate radiance observations from the model state or from the instrument itself. The effect of correcting airmass dependent biases by two different approaches is investigated. The first approach is to use an empirical gamma correction whereas the second uses modified AMSU-A coefficient files for RTTOV based on band pass centre frequency shifts for each channel that minimise the bias. We will show results of these experiments and discuss their impact on the ECMWF data assimilation system through an analysis of first-guess departure statistics and an evaluation of residual biases in AMSU-A data. Although the new shifted AMSU-A coefficient files lead to improved fits between model and observations for most of the lower tropospheric AMSU-A temperature sounding channels, some degraded fits between model and observations are noticed for upper-tropospheric and lower-stratospheric AMSU-A channels, as well as for other observations (e.g., ATMS, AMVs). This also results in a measurable negative impact on the forecast scores that will be further discussed.

Session 2b: Radiative transfer

2p.01 Update on RTTOV developments
Presenter: James Hocking, Met Office
Authors: James Hocking, Roger Saunders, Peter Rayer, David Rundle, John Eyre, Pascal Brunel, Jerome Vidot, Pascale Roquet, Marco Matricardi, Alan Geer, Cristina Lupu

RTTOV (Radiative Transfer for TOVS) is a fast radiative transfer model developed within the context of the EUMETSAT NWP SAF (Satellite Applications Facility for Numerical Weather Prediction) and designed for use in operational NWP environments. The model allows rapid simulations of radiances for satellite visible, infrared or microwave nadir-scanning radiometers given an atmospheric profile of temperature, variable gas concentrations, cloud and surface properties. Versions 11.2 and 11.3 of RTTOV were released in June 2014 and September 2015 respectively. These incremental updates introduced a number of new features including the RTTOV graphical user interface (GUI), the ability to call RTTOV from Python or C++ and improvements to the treatment of surface emissivity. Looking ahead RTTOV v12 is due to be released at the end of 2016 with planned features including multiple scattering for visible/near-infrared channels, sulphur dioxide as a variable gas and further improvements to surface emissivities. An overview of the new capabilities and future developments will be presented.

2p.02 Addition of 1D-VAR retrieval to RTTOV-GUI
Presenter: Pascale Roquet, METEO-FRANCE
Authors: Pascale Roquet/ Jerome Vidot

RTTOV-GUI is a graphical user interface for the radiative transfer model RTTOV developed in the context of the EUMETSAT NWP-SAF project and is included in the RTTOV package. The RTTOV-GUI was designed for educational purposes and was used in the NWP-SAF's satellite data assimilation training course. The last of version of RTTOV-GUI includes a 1D-VAR retrieval functionality. The algorithm is based on the NWP-SAF 1D-VAR retrieval package scheme. It allows visualizing retrieved T and Q profiles from a user-defined profile and background and observation error covariances. The last version of RTTOV-GUI also offers new enhancements corresponding to new RTTOV-V11.3 features.

2p.03 An update on Community Radiative Transfer Model (CRTM) developments
Presenter: Paul van Delst, IMSG @ NCEP/EMC
Authors: Paul van Delst

The CRTM is used in the operational forecasting systems in NCEP. This poster will detail the current status of the CRTM, and future development plans.

2p.04 Development of the Community Line-By-Line radiative transfer Model (CLBLM)
Presenter: Yingtao Ma, AER@NOAA/STAR/JCSDA
Authors: Yingtao Ma, Jean-Luc Moncet, Eli J. Mlawer, Sid-Ahmed Boukabara, Gennady Uymin, Matthew J Alvarado, Quanhua Liu, Paul van Delst

The Line-By-Line Radiative Transfer Model (LBLRTM) and its monochromatic version, the Monochromatic Radiative Transfer Code (MonoRTM) are accurate and efficient line-by-line models for calculating spectral transmittance and radiance. It is being extensively used in atmospheric radiative transfer community. The LBLRTM traces its heritage to FASCODE, developed by Clough and collaborators 40 years ago. It was structured to make the best of the limited capabilities of 70's computer technology. A joint effort towards the modernization of the source code and capabilities of LBLRTM and MonoRTM so they can effectively support future key community needs has been initiated by NOAA/NESDIS/JCSDA and AER. The ultimate goal is the development of a community-based modern line-by-line radiatve transfer model, the Community Line-by-Line Model (CLBLM) model. The existing algorithm structure will be redesigned and enhanced, user-interface and documentation will be upgraded, and the code will be rewritten in modern Fortran. In this presentation, we will present the new design of the CLBLM, its feature set, development road map and the current status of the project.

2p.05 The GEISA Spectroscopic Database in 2014: Context and contents
Presenter: Nicole Jacquinet, Laboratoire de Meteorologie Dynamique (LMD) Ecole Polytechnique
Authors: N. Jacquinet, R. Armante, L. Crepeau, N.A. Scott, A. Chedin

The already important role of molecular spectroscopy in atmospheric research has entered a new promising perspectives phase for remote sensing applications (meteorology, climatology, chemistry) with the advent of highly sophisticated and resolved instrumentations like AIRS (2002), IASI (2006, 2012 and 2017), TANSO-FTS (2009) and CrIs (2011). A precise knowledge of spectroscopic data appears to be at the root of the investigation

of climate change providing an improved understanding of the different phenomena driving the atmospheric system.

In this context, the ARA/ABC(t) group at LMD[1] develops and maintains since 1974 - celebrating its 40th birthday during the workshop GEISA [2] (June 2014, Paris, France), the GEISA spectroscopic database (Gestion et Etude des Informations Spectroscopiques Atmosphériques: Management and Study of Atmospheric Spectroscopic Information[3]). It comprises not only a line-by-line parameters database in the spectral range from 10^{-6} to 35,877.031 cm^{-1}, but also two additional sub-databases: on infrared and ultraviolet absorption cross-sections and on microphysical and optical properties of atmospheric aerosols.

GEISA has been at the heart of state-of-the-art developments in spectroscopy and radiative transfer modelling to meet the needs of the international space agencies by constantly collecting, and archiving all the best available spectroscopic data and necessary inputs for atmospheric radiative transfer models and public dissemination. Following the findings of the GEISA workshop, a feasibility study on new appropriate methods to bring an added value to GEISA has been undertaken, i.e.: based on a strong experience in CAL/VAL activities at LMD (see presentation by R. Armante), a chain of validation, aiming to compare the differences between results of model simulations and satellite observations remote data has been developed and applied to assess and monitor suitably the archived spectroscopic parameter values, traceability and precision, of the GEISA archive.

This poster will display:

- The current contents (2014 last release) and planned evolution of each of the GEISA system three sub-databases, and of the work in progress in the CNES-MENINGE scientific group for the future of the IASI instruments (IASI-NG);
- Emphasis will be placed on results of validations of the 2014 version of GEISA, according to IASI and TCCON network of ground-based Fourier Transform Spectrometers (~ $2x10^{-3}$ cm^{-1} spectral resolution);
- Comparisons with other databases like HITRAN-2012 will be presented, underlining the complementary benefit of using both HITRAN and GEISA archives.

A demonstration of the GEISA access facilities through the CNES/CNRS/IPSL Pôle Ether distribution services WEB site[4] will be made available. It is used on-line by more than 300 laboratories working in various domains like atmospheric physics, planetology, astronomy, astrophysics.

[1] http://ara.abct.lmd.polytechnique.fr

[2] GEISA workshop, June 2014, Paris

[3] Jacquinet-Husson et al., JQSRT 112, 2395-2445 (2011)

[4] http://ether.ipsl.jussieu.fr/etherTypo/ Ether GEISA website distribution

2p.06 withdrawn

2p.07 Ultrafast High Accuracy PCRTM_SOLAR Model for Cloudy Atmosphere

Presenter: Qiguang Yang, NASA Langley Research Center
Authors: Qiguang Yang, Xu Liu, Wan Wu, Ping Yang, Chenxi Wang

An ultrafast high accuracy PCRTM_SOLAR model is developed based on PCA compression and principal component-based radiative transfer model (PCRTM). A fast algorithm for simulation of multi-scattering properties of cloud and/or aerosols is integrated into the fast infrared PCRTM. We completed radiance simulation and training for instruments, such as IASI, AIRS, CrIS, NASTI and SHIS, under diverse conditions. The new model is 5 orders faster than 52-stream DISORT with very high accuracy for cloudy sky radiative transfer simulation. It is suitable for hyperspectral remote data assimilation and cloudy sky retrievals.

2p.08 A fast forward operator for the assimilation of visible SEVIRI observations in KENDA-COSMO

Presenter: Olaf Stiller (for Leonhard Scheck), Deutscher Wetterdienst (DWD)
Authors: Leonhard Scheck, Tobias Necker, Pascal Frerebeau, Bernhard Mayer, Martin Weissmann

Due to their high spatial and temporal resolution satellite observations are well-suited as input parameters for convective scale data assimilation (DA). However, current operational DA systems in general utilize only clear sky thermal infrared and microwave radiance observations, which mainly provide temperature and humidity information. The scattering processes dominating at visible and near-infrared wavelengths make radiative transfer computations very complex. Consequently, fast forward operators for these bands are not yet available. Visible and near-infrared observations, which contain information about cloud

distribution and cloud properties, can therefore not be considered in DA.

To address this shortcoming, a fast forward operator for visible and near-infrared reflectance observations from MSG-SEVIRI is currently in development. A preliminary version of the operator has been completed and implemented in the pre-operational km-scale Ensemble Data Assimilation (KENDA) system of DWD. The operator simulates synthetic satellite images from COSMO-DE model output and relies on a loop-up table based method that is sufficiently accurate and orders of magnitude faster than conventional radiative transfer solvers for the visible spectrum. We present this novel operator and first results from assimilation experiments.

2p.09 Monitoring infrared satellite radiance biases using the ECMWF model

Presenter: Cristina Lupu, ECMWF
Authors: Cristina Lupu, Marco Matricardi and Anthony P. McNally

The use of radiance observations from satellites for data assimilation depends directly on the accuracy of the radiative transfer model (RTTOV-11). This is used in conjunction with a set of radiative transfer coefficient files and is maintained at the forefront of the science by regular updates in the framework of the NWP-SAF project of EUMETSAT. This study summarises the evaluation of the most recent release of infrared coefficient files based on enhancements on the number of layers the atmosphere is divided into (54 rather than the 44 or 51 levels in previous files) and on the recent line-by-line radiative transfer model, LBLRTM v12.2.

Monitoring and assimilation experiments have been carried out at ECMWF to compare infrared observed radiances (from IASI, AIRS, CRIS, HIRS and geostationary satellites) to radiances simulated by the RTTOV-11 fast radiative transfer model using regression coefficients based on different line-by-line models and molecular databases and different atmospheric layering. Changes in mean biases and their standard deviations were used to evaluate differences between the line-by-line models and the quality of the spectroscopic databases on which the RTTOV coefficients are based. The impact of using the newly released set of RTTOV-11 infrared coefficient files on the ECMWF analyses and forecast is also evaluated and discussed.

Session 3a: Processing packages and direct broadcast applications

3.01 NASA International MODIS/AIRS Processing Package (IMAPP): Supporting the Aqua and Terra Direct Broadcast Community for 15+ Years

Presenter: Kathleen Strabala, CIMSS/SSEC/UW-Madison
Authors: Kathleen Strabala, Liam Gumley, Hung-Lung Huang, Rebecca Cintineo, James Davies, David Hoese, Elisabeth Weisz, Nadia Smith, William Smith, Sr., Bradley Pierce

NASA's commitment to support global operational environmental satellite users has resulted in the sponsorship of the International MODIS/AIRS Processing Package (IMAPP) for more that 15 years. Since its inception, IMAPP has promoted the operational use of Aqua and Terra direct broadcast data through the release of software packages that support the AIRS and MODIS calibration, geolocation and creation of science products and their applications.

The IMAPP user base now consists of more than 2000 registrants representing more than 70 countries. The suite of supported products now includes MODIS Level 2 Collect 6 Atmosphere science software, AIRs Collect 6 Level 1 and 2 software from JPL, two different Air Quality Forecast applications including aerosol pollution trajectories based upon the MODIS AOD MOD04 product, and Stratospheric Ozone Intrusions based upon a University of Wisconsin-Madison AIRS single Field-of-View AIRS retrieval. Other packages include a complete Aqua and Terra direct broadcast processing system that allows uses to take advantage of the entire suite of software freely available to the user community. This package is released in the form of a Virtual Appliance that allows installation on Windows, Macintosh and Linux operating systems.

IMAPP also fosters the education of satellite users through local direct broadcast application workshops. Teaming up with organizations including the WMO, IGARSS and GEOSS, IMAPP has co-sponsored 12 local workshops on 6 continents. This presentation will present a review of the current status of the IMAPP software suite, along with scheduled near-term releases, with a focus on global users and their local applications.

3.02 Support for NOAA, NASA, EUMETSAT, and CMA satellites and sensors in CSPP

Presenter: Liam Gumley, SSEC, UW-Madison

Authors: Liam Gumley, Allen Huang, Kathy Strabala, Scott Mindock, Graeme Martin, Ray Garcia, James Davies, Geoff Cureton, Nick Bearson, Jessica Braun, Mitch Goldberg

The Community Satellite Processing Package (CSPP) was initially developed to support real-time processing of VIIRS, CrIS, and ATMS data from the NOAA/NASA Joint Polar Satellite System (JPSS) Suomi NPP satellite. Since the initial release of CSPP SDR (Level 1) processing software for Suomi NPP in 2012, the CSPP software suite has expanded to include support for real-time processing of data from 7 different meteorological satellites including Suomi NPP, Terra, Aqua, Metop-A, Metop-B, NOAA-18, and NOAA-19. CSPP now includes 10 separate software packages for processing imager and sounder data from 25 separate sensors on this collection of meteorological satellites, with products and applications for atmosphere and clouds, land surface properties, and ocean properties. Of particular note is the inclusion in CSPP (in cooperation with NOAA/NESDIS/STAR) of retrieval algorithms developed by NOAA supporting multiple satellites and sensors, including:

- CLAVR-x for multispectral imager retrievals of cloud, aerosol, and surface properties from VIIRS, MODIS, and AVHRR;
- NUCAPS for combined infrared/microwave retrieval of atmospheric temperature, moisture, and trace gas profiles from CrIS/ATMS; IASI/AMSU, and AIRS/AMSU;
- MIRS for microwave sounder retrievals of temperature and moisture profiles, surface properties, snow and ice cover, and rain rate from ATMS, AMSU, and MHS;
- ACSPO for multispectral imager retrievals of sea surface temperature from VIIRS, MODIS, and AVHRR.

We have recently added support for processing of MERSI image data from CMA FY-3B and FY-3C. This presentation will cover the broad range of software packages and products now supported by CSPP, and describe the future plans for supporting new missions including JPSS-1 and new capabilities including CrIS full spectral resolution.

3p.03 Assessing Hyperspectral Retrieval Algorithms and their Products for Use in Direct Broadcast Applications

Presenter: Elisabeth Weisz, UW SSEC/CIMSS

Authors: Elisabeth Weisz, Nadia Smith, William L. Smith Sr.

Software released under the Community Satellite Processing Package (CSPP) runs stand-alone on direct-broadcast (DB) user systems to enhance the latency and reliability of data distribution for real-time applications. Here we are specifically interested in characterizing two hyperspectral retrieval algorithms that are currently available in CSPP, the University of Wisconsin-Madison Dual-Regression (DR) algorithm and the NOAA Unique CrIS/ATMS Processing System (NUCAPS). With this we address concerns raised by users on how best use these algorithms to meet specific needs. Providing relevant information on these algorithms and their products together with close user collaboration will help identify new and innovative applications. Real-time applications, which have been recently defined and prioritized through discussions with the DB user community, are presented, and current plans to further enhance the use of hyperspectral satellite retrieval data in meteorological and environmental real-time operations are discussed.

Session 3b: Processing packages

3p.01 Community Satellite Processing Package (CSPP) - Facilitating Timely and Optimal Use of Weather Satellite Data

Presenter: Allen Huang, SSEC/CIMSS UW-Madison

Authors: Allen Huang, Liam Gumley, Kathy Strabala and Mitch Goldberg

In cooperation with the NOAA Suomi NPP/JPSS program, CIMSS/SSEC continues to leverage and expand the NASA funded International MODIS/AIRS Processing Package (IMAPP) effort, and to facilitate the timely and optimal use of international polar orbiter satellite data through the development of a unified Community Satellite Processing Package (CSPP) to support the Suomi NPP and JPSS. Furthermore, CSPP is expanding to support operational geostationary meteorological and environmental satellites GOES-R, METOP, and FY series, for the global weather and environmental data user community.

We will start with some highlights from IMAPP, now with more than 1,900 registered users in 70 countries. This will be followed by an overview of recent CSPP development, itself now with more than 1,000 registered users. CSPP is employed to transform VIIRS, CrIS, and ATMS Raw Data Records (RDRs) (i.e. Level 0) to Sensor Data Records (SDRs) (i.e. Level 1), and from those SDRs to generate

Environmental Data Records (EDRs) (i.e. Level 2) in support of Suomi NPP, and subsequently the JPSS missions, for direct broadcast (DB) vendors and users.

The main emphasis of this presentation is to report several ongoing CSPP sister projects including 1) JPSS Analysis Facility for Instrument Impact on Requirement (JAFIIR) - OSSE for Next-Generation CrIS, 2) Innovative Satellite Enhancement Exploration (ISEE), 3) DB network low-latency S-NPP data forecast impact on the real-time Rapid Refresh system, and 4) Adaption of high-performance computing for NWP applications. These collective efforts seek to advance CSPP towards facilitating timely and optimal use of satellite assets deployed by the international weather/climate agencies to enhance weather forecasts and climate applications, and to innovate in satellite remote sensing informatics.

3p.02 Automated Verification of CSPP SNPP SDR products

Presenter: Ray Garcia, UW SSEC
Authors: R. K. Garcia, S. R. Mindock

The Community Satellite Processing Package set generates timely and easy-to-use science and environment product data from a variety of satellite instruments, including VIIRS, ATMS and CrIS aboard the Suomi NPP spacecraft. While SNPP science products are generated using software sourced from the spacecraft ground system - IDPS - the possibility exists that products could differ by amounts outside instrument precision specifications. Ancillary dataset selection, alternate operating modes, direct broadcast data availability, and differences in processor and compiler configuration can all contribute to product differences. To quickly assess and quantifiably verify the CSPP SNPP SDR science products versus their IDPS counterparts, software automation at UW-SSEC builds comparison reports which are reviewed as web pages. We present in this poster a summary of the methodology, as well as current comparisons for a relevant set of IDPS-CSPP verification products.

3p.03 Near Real Time Level-2 Products Via Direct Broadcast Using the CSPP-International ATOVS Processing Package (CSPP-IAPP)

Presenter: Geoff Cureton, CIMSS, University of Wisconsin-Madison
Authors: Geoff Cureton, Liam Gumley

The International ATOVS Processing Package (IAPP), developed within the Cooperative Institute for Meteorological Satellite Studies (CIMSS), has for over a decade provided users with a means of processing High Resolution Infrared Radiation Sounder (HIRS), Advanced Microwave Sounding Unit-A (AMSU-A), and Microwave Humidity Sounder (MHS) data (in level-1d format)through to level-2 products (temperature and water vapor profiles etc...), in NetCDF format. Currently supported satellites are NOAA-18, NOAA-19, Metop-A and Metop-B.

With integration into the Community Satellite Processing Package (CSPP) suite to create CSPP-IAPP, users now have access to a modern command-line interface, automated ancillary data ingest and transcoding, expanded logging and quicklookgeneration. CSPP-IAPP is directed at usage in the direct broadcast environment to generate near-real-time level-2 products.

3p.04 Level-2 Products in the CSPP-GEO Direct Broadcast Package

Presenter: Geoff Cureton, CIMSS, University of Wisconsin-Madison
Authors: Geoff Cureton, Scott Mindock, Graeme Martin, Liam Gumley

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) has a long history of supporting the Direct Broadcast (DB) community for various sensors, recently with the International MODIS/AIRS Processing Package (IMAPP) for the NASA EOS polar orbiters Terra and Aqua, and the Community Satellite Processing Package (CSPP) for the NOAA polar orbiter Suomi-NPP. CSPP has been significant in encouraging the early usage of Suomi-NPP data by US and international weather agencies, and it is hoped that a new package, CSPP-GEO, will similarly encourage usage of DB data from GOES-R, Himawari, and other geostationary satellites.

One of the capabilities of CSPP-GEO will be to generate Level-2 data products from Level-1 data, using operational algorithms present in the CIMSS geostationary processing framework, GEOCAT. GEOCAT is wrapped in a layer of scripting which serves to handle the various input preparation, ancillary data ingest and user interface handling tasks which lend themselves to a rapid-development scripting approach.

In this work we describe the architecture of the CSPP-GEO Level-2 package, list the supported algorithms, and show examples of various Level-2 outputs generated using the package.

3p.05 CSPP GEO Level 1 Packages

Presenter: Scott Mindock, UW-Madison/SSEC

Authors: Scott Mindock, Nick Bearson, Ray Garcia, Jessica Braun, Graeme Martin

The CSPP GEO project is being developed at the University of Wisconsin Space Science and Engineering Center. This project focuses on the development of a Level 1 and Level 2 processing packages to support the GOES-R project. However, Level 1 processing packages are being developed to provide Level 1 data from GVAR and Himawari in formats compatible for use with the CSPP GEO Level 2 Cloud packages. This poster details the data flow and requirements necessary to get GOES-R Cloud Algorithm products using proxy data sources.

3p.06 CSPP CLAVR-x

Presenter: Nick Bearson, UW-Madison/SSEC
Authors: Nick Bearson, Andrew Heidinger, Denis Botambekov, Andi Walther

The Clouds from AVHRR Extended System (CLAVR-x) is a processing system developed at NOAA/NESDIS and UW/CIMSS for generating quantitative cloud products in real-time from AVHRR, MODIS, VIIRS, and other sensors. It is NOAA's operational cloud processing system for the AVHRR, and its cloud algorithms are scheduled to migrate to the operational processing system for NOAA JPSS. CLAVR-x was packaged and released for the direct broadcast community as part of the CSPP suite in May 2014 and receives ongoing support. We report on the status of CSPP CLAVR-x, its ease of use, and improvements users can find in the new version.

3p.07 Reconstructing GOES Rebroadcast with CSPP Geo GRB

Presenter: Nick Bearson, UW-Madison/SSEC
Authors: Nick Bearson, Tommy Jasmin

GOES Rebroadcast (GRB) will provide the primary relay for full resolution, calibrated, near-real-time direct broadcast of imager, lightning mapper, space environment, and solar data captured aboard GOES-R. To support the direct broadcast community's use of GRB, the CSPP Geo team is developing and distributing CSPP Geo GRB: a free and open-source software package that can create easy-to-use NetCDF-4 and FITS files from the GRB stream. We report on the capabilities of CSPP Geo GRB, its progress, and the opportunities and challenges presented by this new data source.

3p.08 CSPP Geo support for processing GOES-R, Himawari-8 and current GOES data

Presenter: Graeme Martin, UW-Madison/SSEC
Authors: Graeme Martin, Liam Gumley, Nick Bearson, Jessica Braun, Geoff Cureton, Ray Garcia, Tommy Jasmin, Scott Mindock, Kathy Strabala

The next-generation GOES-R satellite is scheduled to be launched into geostationary orbit in late 2016 or early 2017. The instruments on-board will include the Advanced Baseline Imager (ABI), the Geostationary Lightning Mapper (GLM), and several space weather instrument suites. Direct broadcast users will have access to data from all of the instruments via the GOES Rebroadcast (GRB) stream.

The Community Satellite Processing Package for Geostationary Data (CSPP Geo) has been funded by the GOES-R Program Office to develop and distribute software that will allow direct broadcast users to process GRB data received on their antennas. Capabilities will include processing raw GRB data and constructing Level 1 products for all instruments, as well as Level 2 products for GLM. Level 1 ABI data can be further processed to Level 2 geophysical products.

In addition to supporting GOES-R, CSPP Geo offers an expanding suite of software to process data from the current GOES Imager and the Japanese Advanced Himawari Imager (AHI).

The significantly higher data rate from the new generation of imagers including ABI and AHI poses challenges from a data processing perspective, affecting both software design and hardware requirements.

This talk covers the currently available and planned software packages in support of GOES-R, GOES Imager, and AHI processing. Topics include Level 1 processing packages, the GEOCAT Level 2 processing package, the AIT Framework Level 2 processing package, hardware requirements, current project status, and future plans.

3p.09 A BUFR and GRIB Tailoring System for Satellite Operational Products

Presenter: Yi Song, IMSG at NOAA/NESDIS/STAR
Authors: Yi Song, Thomas King, and Walter Wolf

A tailoring software system that will convert the satellite operational products into Binary Universal Form for the Representation of meteorological data (BUFR) and GRIdded Binary Edition 2 (GRIB2) formatted files is under development at NOAA/NESDIS/STAR. This Reformatting Toolkit will convert the products of the NPOESS Preparatory Project (NPP)/Joint Polar Satellite System (JPSS), the Global Change Observation Mission 1st - Water (GCOM-W1) Advanced Microwave Scanning Radiometer 2 (AMSR2), the Japanese next

generation Himawari-8/9 Advanced Himawari Imager (AHI), and the Geostationary Operational Environmental Satellite - R Series (GOES-R) into BUFR and GRIB2 files. The current toolkit development schedule consists of five phases, each adding new tailoring capabilities. In phase 1, the NPP Cross-track Infrared Sounder (CrIS) Radiances, Advanced Technology Microwave Sounder (ATMS) Radiances and Visible/Infrared Imager Radiometer Suite (VIIRS) Radiances will be converted into BUFR files. In phase 2, this software system will reformat the NPP VIIRS Aerosol Optical Thickness (AOT), Ozone Mapping and Profiler Suite (OMPS) Nadir Profile (NP) and OMPS Total Column (TC) data into BUFR files. In phase 3, the NPP VIIRS Polar Winds and the Advanced Clear-Sky Processor for Oceans (ACSPO) Sea Surface Temperature (SST) will be converted into BUFR files, and the Global and Regional Green Vegetation Fraction (GVF) will be converted into GRIB2 files. In phase 4, this software will reformat the GCOM-W1 AMSR2 Microwave Brightness Temperature and Sea Surface Temperature (SST) into BUFR files, Sea Ice into GRIB2 files, and convert the AHI Radiances into BUFR file. In phase 5, the GOES-R radiances, Winds and other products will be converted into BUFR files. Currently, the toolkit is running in the NPP Data Exploitation (NDE) system tailoring phase 1, 2, 3 and part of phase 4 products. The NDE is distributing these tailored products to the NOAA Environmental Modeling Center (EMC) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) in near real-time. The phase 4 tailoring capabilities are currently in development with a scheduled delivery in 2015. The GOES-R Winds BUFR table has been designed and under review. The details of this toolkit design and its products will be discussed.

3p.10 Polar2Grid 2.0: An easy way to create high resolution satellite images

Presenter: David Hoese, UW-Madison/SSEC
Authors: David Hoese

Polar-orbiting multi-band meteorological sensors such as VIIRS and MODIS pose substantial challenges for taking imagery the last mile to forecast offices, scientific analysis environments, and the general public. To do this quickly and easily, the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin has created an open-source, modular application system, Polar2Grid. This bundled solution automates tools for converting various satellite products like those from VIIRS and MODIS into a variety of output formats, including GeoTIFF and AWIPS, as well as NinJo forecasting workstation formats. Polar2Grid includes perceptual enhancements for products such as the VIIRS Day-Night Band (DNB) and sharpened true color images. Polar2Grid performs conversions and projections in seconds on large swaths of data. Polar2Grid is currently providing VIIRS imagery over the Continental United States, as well as Alaska and Hawaii, from various Direct-Broadcast antennas to operational forecasters at the NOAA National Weather Service (NWS) offices in their AWIPS terminals, within minutes of an overpass of the Suomi NPP satellite.

3p.11 Bias Correction in CIMSS IAPP Retrieval Software

Presenter: Szuchia Moeller, UW-Madison/SSEC/CIMSS
Authors: Szuchia Moeller, Robert Knuteson, Jun Li, Richard Frey, Elisabeth Weisz, Henry Revercomb, Steve Ackerman, Wayne Feltz, Liam Gumely

The University of Wisconsin-Madison has a long history of supporting the ATOVS community with software to derive atmospheric state variables from AMSU/HIRS observations using forward radiative transfer models. The most updated version of the International ATOVS Processing Package (IAPP) has recently been made available through the Community Satellite Processing Package (CSPP). The uncertainties in HIRS/AMSU observations and the PFAAST (Pressure layered Fast Algorithm for AtmoSpheric Transmittance) forward model simulations are inevitable. In order to achieve optimal accuracy in its retrieval products, a bias correction is required in IAPP. Jun Li et al (2000) discussed and analyzed the HIRS/AMSU bias with collocated radiosonde profiles, specifically for NOAA15 HIRS, and demonstrated the impact of the bias correction on the retrievals. In this study, collocated ERA-Interim (ECMWF ReAnalysis-Interim) model 12UTC atmospheric profiles are used in forward model calculations and compared with 3x3 FOV brightness temperature averages from HIRS on selected satellite instruments, specifically Metop-A and Metop-B. Cloudy conditions are identified using ECMWF cloud information and collocated AVHRR GAC data and are discarded to minimize cloud influence on the biases. Preliminary results on the bias correction impact on the IAPP retrieval product will be presented and discussed.

3p.12 Aqua and Terra Direct Broadcast Processing at CIMSS/SSEC Using a New Merged Pass System

Presenter: Jessica Braun, UW-Madison/SSEC

Authors: Jessica Braun, Liam Gumley, Kathy Strabala, Bruce Flynn

The Direct Broadcast (DB) group at CIMSS/SSEC has been processing MODIS, AIRS, and AMSU data from Aqua and Terra direct broadcast data for over 10 years. A new merged ingest system has recently been implemented, which uses an overpass prediction method to merge collocated Level 0 PDS files ingested from multiple DB sites across the United States. The resulting PDS files have more extensive coverage and higher quality of data, as the majority of dropouts and bad packets are removed. The merged passes are processed into Level 1 and Level 2 products and distributed for use by many operational sites including the National Weather Service (NWS) and NOAA CoastWatch. The True Color Imagery produced is often seen across social media outlets including Facebook, Twitter, and weather-related blogs.

3p.13 Using available DB satellite processing packages for case studies in Russia

Presenter: Katerina Melnik, ScanEx, Hydrometeocenter of Russia
Authors: K. Melnik, I. Gorlach

Meteorological satellites are a valuable source of information for synoptical analysis, severe weather event analysis and nowcasting, as well as natural hazards and air quality monitoring. Due to an overwhelming amount of satellite data acquired daily, case studies have been carried out to determine the most appropriate suite of data for several recent anomalous events. Rarely occurring in Russia but nevertheless potentially dangerous, these events require special attention. The cases of very heavy rainfall (more than a half average amount of monthly rainfall in 24 hours), high ground-level ozone content (mean values exceeding 0.05 mg/m3) and wet snow (against a background of positive temperatures at ground levels) have been chosen. RT-STPS, AAPP, IAPP, MIRS, IMAPP, CLAVR-X, HSRTV, IDEAI-I Ozone, OMPSNADIR SPA packages were used to generate L1 and L2 products from NOAA-18,19, Terra, Aqua and Suomi NPP DB data. McIDAS-V and CSPP Sounder Quicklooks packages along with quicklooks generators included in the aforementioned software packages were used to analyze and visualize the data.

Session 4a: Retrievals

4.01 Status of the NOAA hyper spectral retrieval system: algorithm development and lessons learned from recent field campaigns

Presenter: Antonia Gambacorta, STC/NOAA
Authors: Antonia Gambacorta, Chris Barnet, Mitch Goldberg

The NOAA operational hyper spectral retrieval system was developed to produce cloud-cleared radiances and atmospheric temperature, water vapor and trace gas profiles from hyper spectral infrared sounders such as CrIS, IASI and AIRS, in conjunction with microwave sounders, such as ATMS, AMSU and MHS. These retrieval products are accessible in near real time (about 3 hour delay) through the NOAA Comprehensive Large Array-data Stewardship System. Since February 2015, the NOAA Unique CrIS/ATMS Processing System (NUCAPS) retrievals have been also available to the science community with unprecedented low latency (less than 0.5 hours) through Direct Broadcast.

Our current research aims towards the development of a robust retrieval algorithm suitable for both near real time regional forecast applications and long term climate analysis. This talk is organized into two main foci. We first present an overview on the status of the retrieval system, with a highlight on the latest enhancements to the algorithm. Secondly, we discuss some of the lessons learned during recent intensive field campaigns targeted at validating our products and engaging new user applications.

4.02 NUCAPS product validation

Presenter: Nicholas Nalli (for Quanhua (Mark) Liu), NOAA/NESDIS/STAR
Authors: Quanhua (Mark) Liu, Nicholas Nalli, Antonia Gambacorta, Flavio Iturbide-Sanchez, Changyi Tan, Kexin Zhang, Michael Wilson, and Andrew Mollner

The NOAA Unique CrIS/ATMS Processing System (NUCAPS) operationally generates vertical profiles of atmospheric temperature (AVTP), moisture (AVMP), and other trace gases as well as outgoing long-wave radiation (OLR). These products have been publicly released through NOAA CLASS from April 8, 2014 to present. This paper presents the validation of these products.

For AVTP and AVMP are validated by comparing against ECMWF analysis data and dedicated radiosondes. The dedicated radiosondes achieve higher quality and reach higher altitudes than conventional radiosondes. In addition, the launch

times of dedicated radiosondes specifically fit Suomi NPP overpass times within 1 hour generally. We also use ground based lidar data provided by collaborators (The Aerospace Corporation) to validate the retrieved temperature profiles above 100 hPa up to 1 hPa. The Suomi NPP FM5-Ed1A OLR from CERES prior to the end of May 2012 is available now for us to validate real-time CrIS OLR environmental data records (EDRs) for NOAA/CPC operational precipitation verification. However, the quality of CrIS sensor data records (SDRs) for this time frame on CLASS is suboptimal and many granules (more than three-quarters) are invalid. Using the current offline ADL reprocessed CrIS SDR data from NOAA/STAR AIT, which includes all CrIS SDR improvements to date, we have subsequently obtained a well-distributed OLR EDR.

This paper will also discuss the validation of the CrIS infrared ozone profile.

4.03 The operational IASI L2 products version 6: status, applications and developments

Presenter: Thomas August, EUMETSAT
Authors: T.August, T.Hultberg, M.Crapeau, D.Klaes, R.Munro, C.Clerbaux, P.Coheur, D.Hurtmans, D.Zhou

The IASI level 2 (L2) processor version 6 (v5), whose products are disseminated in near-real time via Eumetcast and the GTS, is operational since 30 September 2014. It includes a number of innovations which allow unprecedented sounding capabilities at the IASI single footprint resolution [August, Hultberg et al, ITSC-19]. The measurements of the microwave companion instruments AMSU and MHS are for instance used in synergy with the IASI spectra as inputs to a quasi all-sky statistical first-guess retrieval, referred to as PWLR for piece-wise linear regression. The subsequent step is an optimal estimation method (OEM) retrieval, so far still solely attempted in clear-sky and with IASI measurements only. It uses the PWLR as variable prior information; where a static global climatology was used until v5. Another decisive innovation deals with the use of reconstructed radiances in a new channel selection by application of principle component analyses which optimises the spectral information exploited by the OEM [Hultberg et August, ITSC-18]. As a result, useful temperature and water-vapour soundings are enabled in about 85% of the IASI pixels, with a typical precision of about 1K for temperature, below 1k in clear-sky and in the mid troposphere and of about 1-1.2g/kg for water-vapour depending on the actual moisture content.

We present here the status and monitoring of these new products one year after the operational release, with an overview of their assessment in new applications and first results of recent algorithms developments and refinements. The first improvement is with the first-guess land surface temperature retrieval, which forms part of the v6.1 update. It reduces daytime biases over bare surface inherited from the NWP-based training set. Another area of development deals with the land surface emissivity, with the objective to include it as a variable parameter of the OEM to enable successful convergence over deserts and improve the low tropospheric sounding in general. A pre-requisite for this is a more accurate first-guess land surface emissivity for which non-linear methods are studied to improve on the linear statistical method or static databases still currently employed in operations. We show that the IASI observations are better fitted with PWLR-retrieved land surface emissivities. The assessment of the improvements is also seen through the realisation of the subsequent OEM retrieval step.

The ultimate step in the IASI L2 processing sequence is the atmospheric composition module. It is fed with the atmospheric temperature and humidity profiles, the surface parameters and the cloud information retrieved before in the sequence. The version 6 includes the FORLI [Hurtmans et al, JQSRT 2012] and BRESCIA [Clarisse et al, AMT 2012] libraries developed at ULB/LATMOS. The CO was the first product of a series to be integrated in IASI L2 v6 with these libraries. It is now routinely generated and consists of profiles and averaging kernels, while v5 only provided the total column. We give here an update of the status of its qualification and the plans for the upcoming SO2, O3 and HNO3 atmospheric composition products.

4.04 The Retrieval of Atmospheric Profiles from Satellite Radiances for NWP Data Assimilation

Presenter: William Smith, UW-Madison/SSEC
Authors: W. L. Smith Sr., E. Weisz, and H.E. Revercomb

Atmospheric profiles retrieved from surface based and satellite borne spectrometer radiance measurements contain vertical resolution biases resulting the relatively poor vertical resolution of the radiance observations. These biases led to vertical resolution aliasing of model background states when these profiles were assimilated into Numerical Weather Prediction (NWP) systems, since the profiles were assimilated as high vertical resolution radiosonde soundings rather than the

low vertical resolution sounding information that they represented. In order to achieve a positive impact of the satellite data, NWP centers began to assimilate the radiance observations into the analysis/forecast system rather than the profile retrievals. This change led to consistent positive impact of the satellite data since the assimilation of radiance with its assumed low noise and low vertical resolution characteristics prevented vertical resolution aliasing of the model background fields. For prior generation satellite filter radiometers, this approach was also more efficient than assimilating atmospheric profiles, since there was a relatively small number of radiance observations to assimilate compared to the number of atmospheric profile levels contained in the forecast model.

However, the current advanced ultraspectral sounding spectrometers output several thousands of spectral channel radiances rather than a couple dozen channels, as was characteristic of prior generation filter radiometers. Thus, the NWP centers are limited to the assimilation of a very small percentage of radiance channel information available. However, profile retrievals utilize almost all the spectral radiance information, which leads to much higher vertical resolution profiles than is achievable from the relatively small subset of the spectral channels used for radiance assimilation.

In this paper, a simple method for correcting satellite profile retrievals for vertical resolution dependent biases is formulated. Here the satellite profile retrievals were obtained using the statistical Dual Regression (DR) method used in the University of Wisconsin Community Satellite Processing Project (CSPP) to process Direct Broadcast Aqua AIRS, Metop IASI, and S-NPP CrIS ultraspectal data received at numerous ground stations around the globe. However, the vertical alias correction method is applicable to any other profile retrieval algorithm. The utility of the method is demonstrated through several case studies conducted using data collected during two different Suomi-NPP satellite radiance data calibration validation field programs. It is shown that the vertical alias corrected retrievals compare more favorably with radiosonde observations than do the uncorrected profile retrievals, particularly for moisture, and improve the diagnoses of pre-convective weather environments better than do either the uncorrected retrievals or the model profiles that were used to achieve the alias-corrected profile result.

4.05 Dust infrared aerosol properties observed from infrared hyperspectral sounders: Analysis of the diurnal variation

Presenter: Virginie Capelle, LMD/CNRS
Authors: V. Capelle, A. Chédin, M. Pondrom, R. Armante, C. Crevoisier, L. Crepeau, N. A. Scott, C. Pierangelo

Aerosols represent the dominant uncertainty in radiative forcing, partly because they present a very high spatio-temporal variability and remaining uncertainties concerning their composition, size, etc. In this context, satellite observations may offer a global and continuous observation at high resolution. In particular, remote sensing in the thermal infrared has several advantages: observations are available both for daytime and nighttime, dust characterization is possible over desert and, even more important, vertical sounders allow retrieving dust layer mean altitude. In this study, observations from infrared hyperspectral sounders, (IASI and AIRS), are interpreted in terms of dust aerosol properties (AOD and mean altitude). The method is based on a “Look-Up-Table” (LUT) approach, where all radiative transfer computation is performed once for all and “off-line”, for a large selection of atmospheric situations, of observing conditions, of surface characteristics (in particular the surface emissivity and temperature), and different aerosol refractive index models. The inversion scheme follows two main steps: first, determination of the observed atmospheric thermodynamic situation, second, simultaneous retrieval of the 10µm coarse-mode AOD and of the mean altitude. The method is here applied to the latitude band 60S-60N, over sea and over land, at daily scale daytime and nighttime, and at the satellite pixel resolution (12 km at nadir). A special focus is given to the hourly variation of aerosol properties within a day. In this context, both IASI and AIRS overpasses are processed, providing two measurements at 9:30AM and PM (equator local time) for IASI and at 1:30 AM and PM for AIRS, each day, opening the way to the analysis of the aerosol diurnal cycle. Comparisons are made with AERONET AOD ground-based measurements, when available, in order to 1) evaluate the results, and 2) show the importance of a better knowledge of the aerosol diurnal cycle, especially close to the sources. Mean aerosol layer altitude obtained from IASI is compared at local scale with the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP/CALIPSO) aerosol altitude.

Session 4b: Retrievals

4p.01 Updates on operational sounding processing systems at NOAA/NESDIS and the exploitation of hyperspectral Sounder and microwaves sounder data from CrIS/ATMS, IASI/AMSU, and ATOVS

Presenter: Awdhesh Sharma, NOAA/NESDIS
Authors: Awdhesh Sharma

The current operational polar sounding systems running at the National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite Data and Information Service (NESDIS) for processing the sounders data from the Cross-track Infrared (CrIS) onboard the Suomi National Polar-orbiting Partnership (SNPP) under the Joint Polar Satellite System (JPSS) program, the Infrared Atmospheric Sounding Interferometer (IASI) onboard Metop-1 and Metop-2 satellites under the program managed by the European Organization for the Exploitation of Meteorological (EUMETSAT), and the Advanced TIROS (Television and Infrared Observation Satellite) Operational Vertical Sounding (ATOVS) onboard NOAA-18 and NOAA-19 in the NOAA series of Polar Orbiting Environmental Satellites (POES).

In an effort to ensure consistent levels of service and quality assurance for the CrIS/ATMS data the NOAA Unique CrIS/ATMS Product System (NUCAPS) data products, the Office of Satellite and Product Operations (OSPO) has implemented and executing new, innovative tools to better monitor performance and quality of the operational sounder and imager products that are being generated. The incorporation of these tools in the OSPO operation has facilitated the diagnosis and resolution of problems when detected in the operational environment.

This presentation will include several of these tools developed and deployed for the sounding products monitoring and data quality assurance which lead to improve the maintenance and sustainment of the Environmental Satellites Processing Center (ESPC) processing systems. The presentation will include the discussion on the ESPC system architecture involving sounding data processing and distribution for CrIS, IASI, and ATOVS sounding products. Discussion will also include the improvements made for data quality measurements, granule processing and distribution, and user timeliness requirements envisioned from the next generation of JPSS and GOES-R satellites. There have been significant changes in the operational system due to system upgrades, algorithm updates, and value added data products and services. User requirements for POES and GOES sounder data products will also be discussed.

4p.02 Ongoing monitoring and analysis of NOAA-Unique CrIS/ATMS Processing System (NUCAPS) sounding products using NPROVS and its expansion

Presenter: Bomin Sun, NOAA/NESDIS/STAR & IMSG
Authors: Bomin Sun, Tony Reale, Frank Tilley, Mike Pettey, Nick Nalli, and Quanhua (Mark) Liu

The NOAA-Unique CrIS-ATMS Product System (NUCAPS) was developed by the NOAA/NESDIS Center for Satellite Application and Research (STAR) and has been running operationally at the NOAA/NESDIS Office of Satellite and Product Operation (OSPO) since 2013. In this report, we present the ongoing activity of monitoring and validation of the NUCAPS IR+MW and MW-only temperature and water vapor retrievals using the NOAA Products Validation System (NPROVS) and its expansion (NPROVS+), supported by the NOAA Joint Polar Satellite System (JPSS) EDR cal/val program.

In this work, the NUCAPS retrieval characteristics are analyzed using multiple reference datasets, i.e., global conventional raobs and JPSS-funded dedicated and intensive field campaign raobs, and NCEP forecast and ECMWF analysis), and compared with legacy NOAA products (e.g., AIRS, IASI, and MiRS), all of which are collected at NPROVS via collocation in space and time with raobs. This analysis is conducted in terms of both global sampling and case studies, i.e., NUCAPS retrieval applications in monitoring and forecasting of special weather events, including polar vortex, middle and low latitude cyclones, and atmospheric river, and in terms of both time-averaging statistics and seasonal and year-to-year variability.

4p.03 Characterizing NUCAPS retrieval quality for CO and CH4 - A step towards improving air chemistry applications

Presenter: Nadia Smith, SSEC/CIMSS/UW-Madison
Authors: Nadia Smith, R. Bradley Pierce, Gregory J. Frost, Michael Trainer, Si-Wan Kim, Stuart McKeen, Ravan Ahmadov, James E. Davies, John S. Holloway, Jeff Peischl, Tom Ryerson and Chris Barnet

WP-3D aircraft measurements of pollutant gases over target sites were made during two dedicated field campaigns, SENEX (Southeast Nexus) in 2013 and SONGNEX (Shale Oil and Natural Gas Nexus) in 2015. Together they provide high quality profile

measurements with which to characterize trace gas retrievals from satellite radiance measurements. Of specific interest are the CrIS/ATMS NUCAPS products of Carbon Monoxide (CO) and Methane (CH4), neither of which have been well characterized before. In fact, CO retrieval products can reach operational quality only since the full-spectral-resolution capability was switched on for CrIS in December 2014. Given the scope and space-time extent of SENEX and SONGNEX, we aim to characterize NUCAPS CO/CH4 retrieval accuracy and precision for a number of different events over known source sites. With this we will learn how well NUCAPS products are able to depict horizontal and vertical transport of pollutant air masses. The results from this study will support two efforts specifically, that of trajectory-based forecasts of smoke dispersion as well as the improvement of chemical-transport models used in atmospheric research and air quality forecasting operations.

4p.04 Novel Applications of Temperature Soundings in High Latitude Regions - Aviation in Alaska

Presenter: Nadia Smith, SSEC/CIMSS/UW-Madison
Authors: Nadia Smith, Bradley T. Zavodsky, Eric Stevens, Kristine Nelson, John Dostalek, Tony Reale, David Hoese, Elisabeth Weisz, Emily Brendt, Chris Barnet

This poster will present the latest results in a collaborative effort among scientists, developers and forecasters aimed at developing application-specific visualization of temperature soundings from polar-orbiting platforms. The focus here will be on the depiction of cold air masses (< 65C) in the upper troposphere (500 to 100 hPa) that affect commercial aviation across the Alaskan region. Of interest are data products retrieved from the Cross-track Infrared Sounder (CrIS) onboard the Suomi NPP platform in a ~13h30 local time orbit. The Community Satellite Processing Package (CSPP) generates real-time products of both the Dual-Regression and NOAA Unique CrIS ATMS Processing System (NUCAPS) retrieval algorithms from direct-broadcast CrIS measurements and these will be compared for their relevance and accuracy in operational aviation forecast applications.

4p.05 Ten Years of CAPE Observations in the U. S. SGP from the AIRS Hyperspectral IR Sounder: Climatology, Validation, and Near-real Time Applications

Presenter: Jessica Gartzke, UW-Madison/CIMSS/SSEC
Authors: Jessica Gartzke, Robert Knuteson, Grace Przybyl, Steve Ackerman, and Wayne Feltz

This work is motivated by two very dangerous and very deadly EF5 tornados that struck Oklahoma in 2013. The first tornado struck Moore, Oklahoma on May 20th. At 2:56 pm local time the Moore tornado killed 24 people in 39 minutes, including 7 children. Winds measured up to 210 miles per hour. Only 11 days later on May 31st the second tornado struck El Reno. The widest tornado in history killed 8 people in 40 minutes. The tornado was unpredictable and changed direction with recorded winds up to 296 miles per hour. It is clear that high priority must be given in research for new remote sensing applications especially relating to severe weather. Severe weather climatologies should be incorporated into risk assessment through remote sensing applications. For example, a climatology of Convective Available Potential Energy (CAPE) is routinely used to characterize convection as having moderate or severe potential. Relating this climatology to near real time observations from meteorological sensors on weather satellites is going to be a valuable tool in assessing the risk of severe weather. This research makes use of research radiosondes launched at the Southern Great Plains site, NWP model reanalysis fields from ERA-Interim, and satellite data products from AQUA AIRS. CAPE was computed from vertical profiles of pressure, temperature, and dewpoint temperature from high vertical resolution radiosonde data, NWP model (60 levels) and AIRS soundings (101 levels) using a common algorithm. CAPE values were selected within a radius of 50, 150, and 300 km of the DOE SGP ARM site for each satellite overpass. Results show that the ERA-interim and AIRS data are very consistent with each other but underestimate CAPE values by 10 to 20 percent relative to high vertical resolution research radiosondes. We have identified four types of error that could contribute to this discrepancy. They are measurement, temporal, spatial and vertical error. We find that the decreased vertical resolution of the ERA-interim and AIRS profiles accounts for much of the total error. By taking the vertical resolution bias into account through a proposed correction formula, NWS forecasters could make use of CAPE estimates from operational satellite sounders such as CrIS and IASI on JPSS and METOP platforms two to four times a day. We outline a path towards obtaining near-real time hyperspectral satellite soundings of temperature and water vapor from direct broadcast and making these data available to the

NWS Storm Prediction Center (SPC) via the SHARPpy software.

4p.06 AIRS science: weather, climate and applications

Presenter: Brian Kahn (for Joao Teixeira, JPL/Caltech)
Authors: J. Teixeira, E. Fetzer, H. Aumann, T. Pagano and B. Lambrigtsen

The Atmospheric Infrared Sounder (AIRS) is an infrared hyper-spectral sounder onboard the Aqua spacecraft, which is part of the NASA A-Train constellation at a 705-km altitude orbit, that started collecting data in September 2002. The sounder footprint is about 13 km at nadir. Almost global coverage is achieved twice per day from ascending (cross-equator time at 1:30 pm) and descending (cross-equator time at 1:30 am) orbits. Assimilated AIRS radiances have played a critical role in numerical weather prediction. Data-denial experiments have shown that AIRS is arguably the single most important satellite instrument in terms of weather prediction improvement over the last decade. Recently, AIRS data has played key roles in a variety of climate and weather research topics, from cloud and boundary layer physics to extreme weather events. These key contributions by AIRS will be reviewed in this presentation, with a particular emphasis on the future role of IR sounders in climate and weather science and applications.

4p.07 Evolutions and self-organisation of the piece-wise linear regression for IASI

Presenter: Thomas August (for Tim Hultberg), EUMETSAT
Authors: Tim Hultberg, Thomas August

The first retrieval stage of the IASI L2 processor version 6 operated at EUMETSAT [August et al, ITSC-20] uses a statistical method trained with teaching pairs of real hyperspectral observations and collocated analyses from the ECMWF model. In its current operational version, the retrieved parameters are the temperature, humidity and ozone profiles; the surface air temperature and humidity; and the surface skin temperature. The non-linear relationship between the input measurements (nominally from IASI, MHS and AMSU) and the sought geophysical parameters is modeled by a function linear in parts, where linear regressions between the input and output vectors are characterised in different classes of measurements. The method is therefore referred to as the piece-wise linear regression (PWLR).

We present here the extension of the retrieval concept to other geophysical parameters, for instance to the land surface emissivity (LSE). Different training experiments are carried out where real observations are associated with land surface emissivities extracted from different climatological atlases. The added-value of the PWLR is illustrated by calculating clear-sky radiances (CALC) with RTTOV, a given set of atmospheric profiles and different LSE: the PWLR and two static atlases. The corresponding IASI observations (OBS) are best fitted with the PWLR LSE than with the static emissivities atlases. These are important results for the LSE product itself but are also relevant in view of the exploitation of IASI measurements for low tropospheric sounding, especially of humidity, when low peaking channels with some surface sensibility are used in L2 processing or in data assimilation in numerical models. In both instances, the LSE is often assumed constant or looked-up in static atlases and inaccurate surface characterisation is expected to alias in the water-vapor and temperature profiles. The further extension of the PWLR to atmospheric constituents is explored.

The second part of the study deals with the generation of the classes where a simple linear relationship is modeled between the satellite observations and the geophysical parameters. Different strategies to generate such classes for statistical retrieval systems aimed at practical operations can be found in the literature. For instance the clustering can be made statically based on geophysical parameters (e.g. land/sea/cloud/elevated surfaces...) or based on the geolocation and time in the year. In the latter case, the classification aims at distinguishing climatological regions. One disadvantage with these approaches is the potential spatial or temporal discontinuities they may occur at the edge between two classes. Another potential drawback is the negative impact on the retrieval of inaccurate a priori classification (e.g. Wrong cloud detection, unusual temperature for a given seasonal class...). To circumvent this, the classes of the PWLR implemented in the operational IASI processor are determined essentially with the input measurements, limiting the need for prior information in the classification. This however involves human intervention to analyse the dynamic of the leading input parameters, possibly interpret them in geophysical terms, and elaborate the classes. In addition the retrieval of a given geophysical parameter with the operational PWLR so far results from a single linear regression in a single class. However, the combination of

statistical retrievals performed with the same method but with different configuration coefficients, e.g. from slightly different training settings, or from different methods (e.g. mixing non-linear and linear retrievals) has shown slight benefits in accuracy and precision by different teams and for different applications. We show here positive results of combining PWLR retrievals in classes built manually in different ways and explore the potential of self-organising maps using Kohonen artificial neural networks to generate an automated clustering from the satellite measurements. Linear regressions are trained in each individual classes and retrievals are tested from a single class and as an ensemble retrieval from neighboring classes.

4p.08 Evaluation of the S-NPP VIIRS TPW algorithm with ground based-derived measurements

Presenter: Eva Borbas (for Laura Dobor), UW-Madison/CIMSS/SSEC
Authors: Laura Dobor, Eva Borbas, Zhenglong Li, Paul Menzel

The goal of the Soumi NPP VIIRS Moisture Project is to provide total column water vapor (TPW) properties from merged VIIRS infrared measurements and CrIS plus ATMS water vapor soundings to continue the depiction of global moisture at high spatial resolution started with MODIS. While MODIS has two water vapor channels within the 6.5 µm H2O absorption band and four channels within the 15 µm CO2 absorption band, VIIRS has no channels in either IR absorption band. The VIIRS/CrIS+ATMS TPW algorithm being developed at CIMSS is similar to the MOD07 synthetic regression algorithm. It uses the three VIIRS longwave IR window bands in the regression relation and adds the CrIS+ATMS water vapor product to compensate for the absence of VIIRS water vapor channels.

This poster presents an evaluation of the S-NPP TPW products with TPW data from the ground-based Global Positioning System (GPS) over the SOUMI network and with TPW data from the Microwave Radiometer (MWR), Universal RAwinsonde Observation (RAOB) and GPS over the Atmospheric Radiation Measurement (ARM) Cloud and Radiation Testbed (CART) sites at different climate regions (Tropical Western Pacific, North Slope of Alaska and Southern Great Plain).

4p.09 A Comprehensive Review of SNPP CrIS Instrument Performance and Data Quality

Presenter: Xin Jin, NOAA
Authors: Xin Jin, Ninghai Sun, Yong Han, Fuzhong Weng, Yong Chen, Likun Wang, Denis Tremblay

The instrument performance and official radiance product quality of the SNPP CrIS are comprehensively monitored since the day one of the mission through a dedicated long-term satellite data calibration/validation system (ICVS) developed at NOAA/STAR. The CrIS instrument performance is very stable in the past three and half years, offering an ideal environment for advancing the calibration algorithm and improving the ground processing system. In this report, the statistics based on the information collected through ICVS are addressed to show the steady improvement of the official radiance data product quality.

Session 5a: Assimilation of hyperspectral IR

5.01 Improved use of CrIS Radiances at NCEP

Presenter: Andrew Collard, IMSG@NOAA/NCEP/EMC
Authors: Andrew Collard, Kristin Bathmann, Li Bi, Haixia Liu

CrIS has been assimilated operationally at NCEP since August 2013 and has since been an integral part of the global data assimilation system.

This presentation details the steps taken to improve the use of CrIS data including revised quality control and observation error tuning. In addition there will be discussion of the use of direct cloudy radiance assimilation; cloud cleared radiances and the possibility of using correlated observation error.

5.02 Accounting for Correlated Satellite Observation Error in NAVGEM

Presenter: William Campbell, Naval Research Laboratory
Authors: William F Campbell and Elizabeth Satterfield

We will show results from the inclusion of vertical (interchannel) correlation terms in the observation error covariance matrix (denoted R) for both the Advanced Technology Microwave Satellite (ATMS) and the (IASI) instruments in the Navy's 4D-Var data assimilation system (NAVDAS-AR). Our dual formulation 4D-Var data assimilation scheme make NRL uniquely well suited to explore correlated observation error, and the closely related problem of error of representation.

Until recently, most operational NWP centers assumed that observation errors were

uncorrelated (a notable exception is the Met Office, which has been using vertically correlated observation error for IASI since January 2013 (Weston et al., 2014)). Typically, when observation errors are actually correlated, techniques such as thinning (discarding) or averaging data, and/or inflation of the assigned observation error variance, must be used to compensate. Such techniques are suboptimal and can be rendered unnecessary by correctly accounting for correlated error.

The vertical observation error covariance for the ATMS and IASI were estimated using the Desroziers method (Desroziers et al., 2005) and an archive of historical satellite and NAVGEM model data. The results suggest lowering the error variance (diagonal of R) and introducing strong correlations (off-diagonal terms), especially in the moisture-sensitive channels. Because of the dual formulation of our data assimilation scheme, the inverse of the R matrix is not required, which has benefits both in reduced computation time and in solver convergence.

The convergence rate of the solver, which varies inversely with the condition number of the representer matrix in the dual formulation, is an important issue. The condition number of the R matrix derived from the Desroziers method can be quite large. We used a procedure that optimizes the approximation to a poorly conditioned matrix in a given norm and allows the user to choose any condition number required. Full cycling data assimilation experiments using standard forecast metrics for two-month boreal winter and summer cases were run with approximate interchannel correlation matrices for ATMS, IASI, and both instruments simultaneously (not including cross-correlation between instruments). In addition, we ran the same experiments with reduced observation error variances, which are suggested by the Desroziers diagnostic and the fact that the error variances had been artificially inflated partly to compensate for correlated error. The inclusion of correlation terms typically showed positive or neutral results on the FNMOC scorecard (modified to replace self-analysis with an independent ECMWF analysis) Future work will include vertically correlated R for other instruments such as CrIS, AMSU-A, and high-resolution conventional obs.

5.03 Enhancing the impact of IASI observations through an updated observation error covariance matrix

Presenter: Niels Bormann, ECMWF

Authors: Niels Bormann, Massimo Bonavita, Rossana Dragani, Reima Eresmaa, Marco Matricardi, and Tony McNally

We investigate the use of an updated observation error covariance matrix for IASI in the ECMWF system. The new observation error covariance matrix is based on observation-space diagnostics and includes inter-channel error correlations, but also assigns significantly altered error standard deviations. The use of the new observation error is investigated in detail in assimilation experiments, including an assessment of the role of error inflation and taking inter-channel error correlations into account.

The updated observation error covariance leads to a significant improvement in the use of IASI data, especially in the tropics, the stratosphere, and for humidity. The benefits are particularly strong for the short-range forecasts, whereas the impact in the medium range is less pronounced. The update also has a particularly large positive impact on the ozone analysis, related to especially large modifications in the observation error for ozone-sensitive channels.

The study highlights the benefits of taking inter-channel error correlations into account, which allows the use of an observation error covariance for IASI that is overall more consistent with departure statistics. At the same time, the study also demonstrates that error inflation can be used to partially, though not fully, compensate for neglected error correlations. Adjustments such as scaling of the originally diagnosed observation error estimates are found beneficial also when inter-channel error correlations are taken into account.

5.04 A physically based observation error covariance matrix for IASI

Presenter: Hyoung-Wook Chun, KIAPS

Authors: Hyoung-Wook Chun, Reima Eresmaa, Anthony P. McNally, Niels Bormann, and Marco Matricardi

This presentation describes efforts to construct an observation error covariance matrix for IASI radiance assimilation from a knowledge of individual sources of error. This physically based approach differs from the practice of diagnosing estimates of the covariance from data assimilation innovation departure statistics. In the current study uncertainties due to instrument noise, imperfect cloud detection, inaccurate radiative transfer and representativeness are explicitly estimated for IASI radiance data. The combination of these produces a covariance with larger errors

(diagonal elements) than those diagnosed from innovations and stronger inter-channel correlations. The physically based error estimate performs well in assimilation tests, comparable to that of an empirically tuned covariance based on innovation diagnosis.

5.05 Improvements in the Use of Humidity from Hyperspectral IR

Presenter: Benjamin Ruston, Naval Research Lab
Authors: Benjamin Ruston, Nancy Baker, Rolf Langland, and William Campbell

Hyperspectral sounders such as AIRS, IASI and CrIS are critical components in most global NWP data assimilation systems. In the Navy assimilation system; however, the humidity observations are currently underutilized. One component is adding correlated error, but beyond this there still are remaining issues such as optimally adjusting the observation error variance, and re-examining the quality control. Statistical methods such as those due to Desroziers, which are based on the innovation and its residual, are being used to find channels with extremely high error correlations that adversely impact the condition number of the correlation matrix. The adjoints of the forecast models and assimilation system can be used to produce forecast sensitivity to observation and background error variances that are used in the assimilation. Channels with large error correlations and observation error variance adjustments can be assessed using these statistical tools. In addition, there is an apparent shortcoming in the ability of the radiative transfer to simulate humidity fields in certain atmospheric conditions. An examination of the Jacobians for different atmospheric conditions shows the occasional appearance of multiple strong peaks, which typically causes problems in the conjugate gradient descent. A simple method to identify these cases and remove them from the assimilation yields more consistent behavior in the minimization of the Navy 4-dimensional data assimilation scheme. Although it is difficult to see the impact in global statistics, we can show that these enhancements enhance the stability of the data assimilation system and remove occasional spurious increments contaminating the analysis.

Session 5b: Assimilation studies

5p.01 Met Office use of CrIS, IASI and AIRS

Presenter: Fiona Smith, Met Office
Authors: Fiona Smith, Peter Weston, Bill Bell, Ed Pavelin, Andrew Smith, James Cameron

Since the last ITSC, we have been working on implementation of correlated error covariance matrices for AIRS and CrIS. This work follows from the benefits seen on introduction of correlated errors for IASI. For CrIS, implementation has been harder because the covariance matrix has a less diagonal structure due to the lower instrument noise. The error covariance matrix is dominated by radiative transfer and representativeness errors.

The other main area of work on the hyperspectral sounders within the operational DA systems has been to introduce the instruments to the UKV convective scale model. IASI was successfully implemented in February 2015, and at ITSC AIRS and CrIS should be about to enter operational assimilation.

Results from observing system experiments trialling the correlated errors and the implementation of hyperspectral sounders in the UKV will be presented.

5p.02 Assimilation of spectrally-adjacent pairs of IASI channels

Presenter: Reima Eresmaa, ECMWF
Authors: Reima Eresmaa

Spectrally-adjacent channels of the Infrared Atmospheric Sounding Interferometer (IASI) are known to share strong observation error correlations because of the signal apodization carried out as part of preprocessing. As the common approach in the assimilation of satellite radiances is to ignore any observation error correlations, it has been considered undesirable to include pairs of spectrally-adjacent channels in active channel subsets used in the data assimilation. However, the current trend is towards routinely accounting for inter-channel-correlated observation error, implying the need to optimize the active channel subsets for the presence of correlated error. According to the linear estimation theory, there is potential for exploiting the presence of well-known error correlations, as long as those channels that share the correlated error are sufficiently different in terms of their atmospheric sensitivities.

Taking the currently-operational subset of 191 active IASI channels as a starting point, we have produced an alternative channel subset that contains several pairs of spectrally-adjacent channels. The alternative subset is based on statistical analysis of observed brightness temperature data in a global sample. As compared with a reference system that uses the operational channel subset and accounts for the well-known error correlations, using the alternative channel

subset produces no major improvement in overall forecast system performance. There are, however, consistent indications of improved background fit to stratospheric channels of microwave sounders and ozone-sensitive data, particularly in the tropics.

5p.03 Using realistic ozone fields for the assimilation of IASI data

Presenter: Vincent Guidard, Meteo-France and CNRS
Authors: Vincent Guidard, Olivier Coopmann, Leo Duconge, Matthieu Plu

Hyperspectral infrared sensors like IASI onboard Metop polar-orbiting European satellites cover a wide range of the infrared spectrum. Parts of this spectrum is sensitive to ozone. During the assimilation process, a priori profiles of temperature, humidity, etc. are mandatory, including ozone profiles.

In Meteo-France operational system, information on ozone within the numerical weather prediction (NWP) process is a climatological profile, constant in space and in time. In this study, we present the use of realistic ozone fields of the day from the French Chemistry model MOCAGE to replace the climatological ozone profile.

Impacts on observations minus model will be described.

Impact on the assimilation process and the temporal evolution of the bias correction will be highlighted.

5p.04 Assimilation of AIRS radiances in regional and its impact on typhoon forecast

Presenter: Agnes Lim (for Yan'an Liu, East China Normal University)
Authors: Yan'an Liu; Hung-Lung Allen Huang; Wei Gao; Agnes H. N. Lim; Jiong Shu

Under the background of global climate change, the increase of extreme severe weather, such as typhoon and rainstorm, has intensified the damage on natural and human environment. Assimilation of hyperspectral infrared radiance data, which provides high resolution of temperature and humidity profiles, has significantly improved the forecast accuracy in global model. With the growing attention to meso-small scale severe weather simulation and forecast, more studies on application of hyperspectral data in regional model can be seen. However, many difficulties prevented the application of hyperspectral infrared radiance data on regional model assimilation. These difficulties come from the fact that regional model used forecasting/analysis field from global model as initial and boundary conditions. Therefore, spatial coverage of satellite observations varies in different time span. What is more, available assimilation data is limited in regional model compared to global model. In this study, mesoscale model WRF-ARW (Advanced Research Weather Research and Forecasting) was chosen as forecast model, community model GSI (Gridpoint Statistical Interpolation) as analysis system, and infrared radiance from AIRS (Atmospheric Infrared Sounder) was chosen as input. It was an application of assimilation basing on AIRS infrared radiances that took terrain and climate of China and surrounding regions into account, and it also included the tuning of background error covariance matrix (B matrix) and bias correction. This study helped to deepen the understanding of the regional assimilation procedure and mechanic on hyperspectral infrared radiance data. Meanwhile, it explored the influence of tuning of B matrix and bias correction on typhoon track and intensity forecast.

Main topics and contributions of this study are as follows:

(1) Based on AIRS channels used in the assimilation of NCEP (National Centers for Environmental Prediction) GDAS (Global Data Assimilation System), a temperature sensitivity analysis was used to exclude channels that contributed most to weight function at atmosphere above 10hPa in regional model. Also, quality control on cloud detection in GSI, thinning, and threshold control in Asian regional data was diagnosed and analyzed. These steps enable the qualified AIRS radiance measurement data to be assimilated in the regional model.

(2) Based on NMC (National Meteorological Center) method with two-month forecast, and combined the regional weather conditions, the regional B matrix was estimated. The B matrix was then compared with the global B matrix predefined in GSI so as to know more about the structure of regional B matrix. On overcoming the drawbacks of current B matrix estimation using NMC method, this study creatively used sensitivity method to optimize horizontal length-scale and standard deviations, which are important parameters in B matrix. The optimized B matrix was then applied to WRF. The 24-hour forecasted

temperature field, humidity field, and wind field were validated using radiosonde observations. The result showed that length-scale of regional B matrix was underestimated; while the standard deviations were overestimated. The tuned B matrix was then applied to typhoon forecast, and it significantly improved the accuracy of typhoon 72-hour track forecast.

(3) Using a scheme combining scan bias correction and air-mass bias correction, characteristics of bias in a one-month time-series was summarized. It was found that AIRS channels located in 15 μm CO2 absorption band had large scan bias, and nadir bias has strong time dependence. By contrast, other channels had small scan bias and weak time dependence. In air-mass bias correction, predictors of zenith and temperature lapse rate had huge oscillatory due to regional model various data coverage. The effect of this scheme on correction in regional model was verified with the help of the histogram analysis on innovation (O-B, observed radiance subtracted by background simulated radiance). The verification showed that correction on most of the channels got satisfied results except several land surface channels. The corrected histogram satisfied the requirement of un-bias and a normal distribution. In typhoon forecast experiment, the influence of radiance bias correction on forecast result was tested. It showed that, compared to parameters from GDAS, regional radiance correction parameters from this study improved the prediction of typhoon 72-hour forecast.

(4) After the tuning of B matrix and bias correction, a case of landing typhoon was studied. It exemplified the convergence of cost function during the GSI 3DVAR (Three-dimensional Variation) assimilation of AIRS radiances. It also summarized the contrast of O-B/O-A (Observation-Background / Observation-Analysis) between pre-assimilation and post-assimilation in order to justify analysis increment. As a result, the assimilation of AIRS radiances improved both the typhoon track and intensity of the typhoon in a 72-hour forecast.

5p.05 Impact of inter-channel radiance observation error correlations in Environment Canada's EnVar data assimilation system

Presenter: Louis Garand, Environment Canada
Authors: Sylvain Heilliette and Louis Garand

Inter-channel observation error correlations (IOEC) were introduced for most instruments (microwave and infrared) in Environment Canada's EnVar global and regional data assimilation systems, i.e. 4 hyperspectral IR sounders (AIRS, two IASI, CrIS) and 7 AMSU-A, AMSU-B or MHS sounders (including ATMS). Inter-channel correlations were estimated using Desrozier's diagnostic method. Tests indicated that observation error variances (values on the diagonal) should not be modified significantly (i.e. remain inflated). The matrix inverse is computed at each location, depending on which channels are selected for assimilation. The convergence rate and associated time to produce analyses are not significantly affected (i.e. by about 3 %). A convincing positive impact on forecasts up to 5 days was demonstrated, this over most of the troposphere, both against ECMWF analyses and radiosonde observations . The impact is found to be larger in the Southern Hemisphere. Neighboring channels for CrIS, characterized by high IOEC (~0.6), were not considered up to now, but we plan to evaluate their added value.

5p.06 Scene-Dependent Observation Errors for AMSU-A in the ECMWF system

Presenter: Heather Lawrence, ECMWF
Authors: Heather Lawrence, Niels Bormann, Stephen English

The Advanced Microwave Sounding Unit-A (AMSU-A) is a key satellite instrument used in numerical weather prediction systems around the world. Currently the data from AMSU-A instruments flown on 6 different satellites is actively assimilated at ECMWF, in addition to the recent ATMS instrument, which includes channels with the same frequencies as AMSU-A. These instruments have been shown to have a highly positive impact on forecast scores, particularly the lower tropospheric channels which are important for weather forecasting.

In order to assimilate these instruments, observation errors must be defined and these should include uncertainties due to instrument noise as well as uncertainties in the forward model used to convert atmospheric fields to the observed radiances. For the lower tropospheric channels, sensitive to the surface, the latter includes surface emissivity errors as well as errors from undetected cloud and precipitation. Instrument noise varies

for different satellites and forward model errors depend on atmospheric and surface conditions. Currently this is ignored in the ECMWF system and AMSU-A is assigned a constant observation error per channel. In this paper we present a study where new observation errors were developed and tested for AMSU-A instruments. These errors include a constant term for channels 5 - 13 which varies for different satellites, and emissivity and cloud forward model errors for channels 5 - 8, which vary with surface type (land, sea, sea ice, snow cover), sensitivity to the surface (surface-to-space transmittance) and the liquid water path.

We discuss the influence of the new observation errors on observation-fit statistics and forecast impact, and investigate the resulting opportunities to extend coverage.

Session 6: NWP centre reports

6p.01 Progress and plans for the use of radiance data in the NCEP global and regional data assimilation systems

Presenter: Andrew Collard (for John Derber), IMSG@NOAA/NCEP/EMC
Authors: John Derber, Russ Treadon, Rahul Mahajan, David Groff, Daryl Kleist, Emily Liu, Haixia Liu, Edward Safford, Catherine Thomas, Paul van Delst, Yanqiu Zhu and Andrew Collard

Since the last International TOVS Study Conference in March 2014, there has been one major operational upgrade to the data assimilation system at NCEP (in January 2015) and testing has begun on the next implementation: expected in early 2016.

On January 14, 2015, an operational upgrade to the NOAA National Centers for Environmental Prediction (NCEP) Global Forecast and Analysis (GFS/GDAS) was implemented. The forecast model has been changed significantly, most notably by a change from Eulerian to Semi-Lagrangian dynamics and an increase in resolution from Eulerian T574 (~27 km) to Semi-Lagrangian T1534 (~13km).

Before this upgrade, the analysis was performed on a linear grid that corresponds to the model truncation T574 (1152x576 gridboxes) while the 80-member ensemble that prescribes 75 percent of the solution was at T254 (512x256). For the new system, both the GSI analysis and the members of the ensemble are computed at T574, so now the resolution of the main background error term (and therefore the typical resolution of the increments) is consistent with the analysis. The increment is then transformed into wavespace and added to the full-resolution background. This approach is more consistent with what is done at most other NWP centers, although the observation innovations are still calculated at the truncated resolution – which should be addressed in future upgrades.

On the satellite radiance side, the first-guess departure (O-B) statistics for low-peaking microwave channels have benefited from significant improvements to the FASTEM microwave sea surface emissivity module in the CRTM. Figure 1 demonstrates how both the position of the peak of the histogram and the dependence on wind speed of the O-Bs for AMSU-A channel 2 are much improved on going from FASTEM-1 (the previous default version in the GSI) through FASTEM-4 to FASTEM-5.

Further improvements to the bias characteristics of this and other satellite measurements are coming from improvements to the radiance bias correction scheme (Zhu et al., 2014). This scheme removes the requirement for the previous two-step bias correction scheme (where the scan-dependent component is calculated outside of the variational framework) by including extra predictors to describe this through a fourth-order polynomial of scan angle. In addition, the pre-conditioning for the bias-correction coefficients is now prescribed based on the Hessian rather than through pre-specified parameters (which greatly improves convergence); new bias correction predictors have been introduced to handle large land-sea differences and for SSMIS; automatic initialization of new data is performed; and improved handling of data that go missing and then recover is introduced.

The above two changes plus a fix to a bug in the way AMSU-A radiances are used around the ice edge have resulted in a much improved analysis in the Southern Hemisphere with significant improvement in forecast skill. This upgrade also included the assimilation of the sounding channels on SSMI which was previously not possible to assimilate because of large biases in the data, which were a function of the position of the satellite in its orbit but which also varied with season. This was addressed by adding two new SSMIS-specific bias correction predictors to the bias-correction scheme: node x cos(latitude) and sin(latitude). Here node is +1 for the ascending part of the orbit and -1 for the descending part. The inclusion of SSMIS results in a small but positive impact in the Southern Hemisphere.

Other upgrades to the system include replacing GOES 6-hourly winds with hourly winds plus

quality control changes; improvements to the quality control of GPSRO observations in the lower atmosphere where the refractivity has high vertical gradients; turning on the assimilation of IASI on Metop-B; and adjustments to the ATMS observation errors.

The next operational upgrade will include the following major components that will affect the assimilation of radiance data:

The 3DEnsVar data assimilation system will be extended to 4DEnsVar, thereby allowing the time evolution of the the background error statistics within the assimilation window.

Assimilation of cloudy radiances for AMSU-A will be introduced.

The microwave sea-surface emissivity model in CRTM will be upgraded to FASTEM-6 (which has the effect of effectively removing a 2K bias seen in AMSU-A channels 1, 2 and 15) and the algorithms that process the azimuthal dependence of the emissivity will be revised.

The monitoring of a large number of new instruments will also be introduced at this time.

6p.02 Recent developments in satellite data assimilation at JMA

Presenter: Takumu Egawa, Japan Meteorological Agency
Authors: Takumu Egawa, Akira Okagaki

This poster overviews the operational upgrades to the data assimilation system in Japan Meteorological Agency (JMA) numerical weather prediction (NWP) system since the last ITSC in April 2014, including the introduction of several new satellites' data.

Clear radiances from the Metop/IASI and the Aqua/AIRS have been operationally assimilated into JMA's global NWP system since 4 September 2014. Long-wave temperature sounding channels (around 15 μm) were selected as assimilation targets to improve the accuracy of the temperature field in analysis. There are 69 selected channels for IASI and 76 for AIRS. For AIRS, 9 channels around 4.4 μm are added only in the nighttime. The impact of IASI and AIRS assimilation was evaluated through a pre-operational experiment, in which the root mean square (RMS) of first-guess (FG) departure from AMSU-A and MHS was reduced and errors of short-range forecasting were also reduced significantly.

Megha-Tropiques/SAPHIR radiance data have been operationally assimilated into JMA's global NWP system since 25 June 2015.

6p.03 Status and plans for satellite data assimilation at the Korea Meteorological Administration

Presenter: Eunhee Lee, KMA
Authors: Eunhee Lee, Youngchan No, Yoonjae Kim, Jung-Rim Lee, Sangwon Joo, Hyun-Cheol Shin and B.J. Sohn

The Korea Meteorological Administration (KMA) has recently introduced several upgrades to the use of satellite data in its Global Data Assimilation and Prediction System (GDAPS). Since the last ITSC, KMA has introduced assimilation of Direct Readout IASI radiances and GNSS-RO data from MetOp-A. Direct Readout IASI radiances have a positive effect on GDAPS forecasts, especially when typhoons are located near the Korean peninsula because they provide valuable information over the ocean. GNSS-RO data also give a generally positive impact, and preliminary results from the use of KOMPSAT-5 RO data are also promising. To make more use of hyper-spectral IASI observations, a new selection of 200 channels has been applied to GDAPS (No et al. 2014). An initial trial shows a slightly positive impact on upper-tropospheric humidity and temperature fields. CrIS and ATMS are also being tested in GDAPS and will be made operational together with an upgrade of the GDAPS model, which increases its horizontal resolution from 25 to 17 km.

Recently, KMA has been attempting to assimilate satellite data into a 1.5 km high resolution regional model over the Korean peninsula with surrounding ocean. The assimilation of ground-based GNSS data over the Korea peninsula gives a positive impact on the lower tropospheric humidity field in early forecast times, and significant improvements for heavy rainfall cases in the summer. To make better use of the Ground-based GNSS data, the quality control and bias corrections have been tuned based on long-term monitoring results, and will be applied operationally at the end of 2015. Use of newly-developed COMS satellite products such as high resolution AMVs and pixel-based clear-sky radiances is now being tested in the high resolution model, with the aim of improving heavy rainfall prediction.

6p.04 Update on changes to the ECMWF NWP system since ITSC-19

Presenter: Mohamed Dahoui, ECMWF
Authors: M. Dahoui and S. English

Since ITSC-19, ECMWF implemented only one new model cycle (41r1). This cycle gave useful positive impact. However there have been many changes in observation use between cycles. There were also a number of operational data incidents that required actions. Notable observation changes have included the switch on of CrIS, the move of MHS to the all-sky framework, active use of SSMIS moisture sounding channels over land and sea-ice, addition of surface-sensitive ATMS channels over land, introduction of ASCAT in soil moisture analysis, introduction of Altika and Cryosat altimeter wave height data and assimilation of GPS-RO with two-dimensional observation operator. Apart from the data usage changes, 41r1 had many other model upgrades that included: revised semi-Lagrangian extrapolation reducing stratospheric noise; new surface climate fields (land-sea mask, sub-grid orography); new CO2/O3/CH4 climatologies from latest MACC-II reanalysis produced at ECMWF; Activation of lake model (FLAKE); changes to the cloud scheme for rain evaporation, auto-conversion/accretion, riming, precipitation fraction, representation of supercooled "freezing" rain and modified convective detrainment.

The data assimilation changes included an upgrade of the inner loop resolutions of 4D-Var to TL255 for each of the three iterations of the outer loops, a reduction of number of iterations in 1st inner loop and use of full linear physics package. There was a change in the calculation of background error covariances from using EDA samples of perturbations from last cycle (1/3) and climatology (2/3). Attention is now focussed on a major resolution change early in 2016, which will be introduced alongside a suite of improvements to the model and assimilation. This cycle is expected to give very substantial positive impact.

6p.05 Developments in satellite data assimilation at DWD

Presenter: Robin Faulwetter (for Christina Koepken-Watts), German Meteorological Service (DWD)
Authors: Ch. Koepken-Watts , R. Faulwetter, O. Stiller, A. Fernandez, A. Rhodin

This poster presents the status of operational satellite data assimilation at DWD as well as developments in the areas of data assimilation algorithms and the use of satellite data. Described past operational changes include the operational introduction of hyperspectral IASI sounding data as well as the introduction of the new numerical ICON model. Current development and future research areas are described, like the preparation for the introduction of an ensemble based global data assimilation system, extended data usage over land as well as assimilation tests with visible channel information for high-resolution short-range forecasting in an ensemble data assimilation context.

6p.06 Overview of NOAA/NESDIS Satellite Data Assimilation Activities in Support of the U.S. Joint Center for Satellite Data Assimilation (JCSDA)

Presenter: Sid Ahmed Boukabara, NOAA/NESDIS & JCSDA
Authors: S. Boukabara, K. Garrett, E. Maddy, E. Jones, K. Kumar, L. Liu, Y. Ma, J. Chen, M. Chattopadhyay, Z. Ma, Y. Li, Q. Liu

We suggest to present a general overview of the current NOAA/NESDIS activities in the area of satellite data assimilation, performed in support of the U.S. Joint Center for Satellite Data Assimilation (JSCDA) objectives. This overview will present the major projects and give the context for their development, and their main status and results. These activities encompass a wide variety of projects, ranging from fundamental scientific efforts, such as the development of the Community Line By Line Model (CLBLM), a rewrite of of the LBLRTM model, critical for the Community Radiative Transfer Model (CRTM), to the more mundane tools such as those dedicated to BUFR formatting and visualization. We propose to highlight (1) the development of an advanced universal quality control (QC) and preprocessing tool for data assimilation (MIIDAPS) for all satellite data (microwave and Infrared), (2) the demonstration of the assimilation of several new sensors (Himawari-8 AHI, GPM/GMI, ISS-RapidScat, etc) data into NOAA systems, (3) the development of a tool to optimize how we thin/sample the satellite data (and represent it within a grid), (4) the results from a recent effort to assimilate hydrometeor-impacted satellite data. It is worth noting that all these tools are designed to be stand-alone tools, applicable to a multitude of assimilation systems. In addition, we will go over two major activities that were initiated a couple years ago. We plan to provide a description of the S4 Operations-To-Research (O2R) environment developed in partnership with academia (University of Wisconsin). Thsi O2R environment has served the research community well, in providing the computing infrastructure to do their research and help them performing the R2O transition of their projects. We will also report on the progress and NESDIS contribution to the OSSE community tool being worked on in collaboration with multiple partners from NOAA,

NASA and academia, with an end goal of providing the community with a robust tool to assess the impact of observing systems (and data assimilation techniques improvements) on the NOAA global forecast systems.

6p.07 Overview of the radiance assimilation in the Meteo-France NWP models

Presenter: Vincent Guidard (for Jean-Francois Mahfouf), METEO-FRANCE and CNRS
Authors: Jean-Francois Mahfouf, Philippe Chambon, Nadia Fourrie, Vincent Guidard, Louis-Francois Meunier, Patrick Moll

The recent changes in Meteo-France NWP operational systems will be presented. Both usage of infrared and microwave sensors will be depicted. The poster will mainly focus on recent developments for microwave imagers and sounders.

6p.08 NWP Status Report: Upgrades in the Met Office use of satellite radiance data

Presenter: William Bell, Met Office
Authors: Bill Bell, James Cameron, Pete Weston, Anna Booton, Ed Pavelin, Katie Lean, Fabien Carminati, Stu Newman, Amy Doherty, Indira Rani, Nigel Atkinson, Fiona Smith, Stefano Migliorini, Andrew Smith

Since ITSC-19 in March 2014 the Met Office have implemented two operational upgrades involving changes in the use of satellite radiance data: Parallel Suite (PS) 34 in July 2014; and PS35 in February 2015. A third, and larger, set of changes are currently in the final stages of (PS37) testing and are scheduled to become operational in December 2015.

PS34, principally a global model resolution upgrade (to 17km) enabled by an improved dynamical core (ENDGAME), saw changes in the thinning of IASI data (to 80km) and ATOVS data (to 100km).

Improvements in the quality control of humidity sensitive radiances at PS35, through the use of a new background error covariance matrix in the Met Office 1D-Var pre-processor, together with more aggressive assimilation of CrIS data over land, and better handling of inter-channel error correlations for AIRS contributed to modest improvements in forecast skill (~1% reductions in short range RMSE for 500hPa heights [H500]). IASI radiances were assimilated in the UK convective scale model (UKV) as part of the PS35 upgrade.

PS37 incorporates several significant upgrades to the Met Office assimilation of radiance data. These include variational bias correction (VarBC) of radiance data in a scheme (see Cameron et al, this meeting) which includes: a set of (20) orbital bias predictors; a set of (6) Legendre polynomials for the correction of residual cross scan biases; and the ability to harmonise bias correction adaption rate across channels. Throughout extensive testing VarBC has produced consistently positive results (e.g. 3-7% reduction in RMSE for 500 hPa heights for days 1-3). In addition PS37 sees the introduction of data from: three SSMIS instruments (F-17, F-18, F-19) (see Booton et al, this meeting); Megha-Tropiques Saphir; AMSR-2 (Newman et al, this meeting); the FY-3B and FY-3C humidity sounders (Carminati et al, this meeting); as well as a treatment of correlated observation errors for CrIS (Smith et al, this meeting). These additions further improve analysis and forecast performance, for example by 1-2 % in RMSE for extra-tropical H500 - resulting in a combined benefit of 5-10% RMSE reductions in H500.

In the UKV model AIRS, CrIS and ATMS data will be introduced at PS37.

6p.09 An Update on NRL Atmospheric Data Assimilation Activities

Presenter: Ben Ruston, Naval Research Lab
Authors: Benjamin Ruston, Nancy Baker, Liang Xu, Steve Swadley, Tanya Mauer, Bill Campbell, Dave Kuhl and Liz Satterfield, with further contributions from NRL Marine Meteorology, Space Science and Remote Sensing Divisions

The Naval Research Laboratory in Monterey is partnered with the U.S. Navy's Fleet Numerical Meteorology and Oceanography Center to provide real time global and regional weather forecasts. For the global system, a 4D-Var has been developed which is called the NRL Atmospheric Variational Data Assimilation System - Accelerated Representer (NAVDAS-AR). This is embedded in the Navy Global Environmental Model (NAVGEM), which became operational in March of 2013. A variational bias correction algorithm was used with satellite radiance observations in NAVGEM v1.1. The ATMS sensor was added with NAVGEM v1.2 in November of 2013. While the update to NAVGEM v1.2.1 in July of 2014 saw the inclusion of IASI water vapor radiances, the ability to assimilate OMPS and SBUV/2 Ozone profiles, and the activation of the IASI from MetOp-B. The SSMIS assimilation in NAVGEM v1.2.1 was also prepared for DMSP-F19, which became operational in Dec2014. For the GNSS-RO assimilation NAVGEM v1.2.1 also saw the inclusion of a new tropospheric error model with a latitudinal dependence in both the error magnitude at the surface and its vertical

structure. The most recent update was to NAVGEM v1.3 in June of 2015 which saw an increase in both horizontal and vertical resolution of the model, but in addition improved usage of the new BUFR radiosonde data and the ability to assimilate the Upper Atmospheric Sounding (UAS) channels from SSMIS. A follow-on update NAVGEM v1.3.1 has been delivered and is in operational testing in October 2015. This will bring BUFR radiosonde utilization update to 75%, includes CrIS assimilation (both temperature and water vapor), inclusion of water vapor channels from AIRS, and an update to the ROPP v8. The next system increment to NAVGEM v1.4 will be the introduction of a hybrid data assimilation scheme using an 80-member ensemble to create a dynamic background error covariance. Further NAVGEM v1.4 is planned to include correlated observation error for both ATMS and the hyperspectral IR sounders. The SSMIS Unified Pre-processor for both LAS and UAS was updated in 2015 to include orbit angle , these are planned to be used as bias predictors for SSMIS. This new NAVGEM v1.4 system is scheduled for delivery in early 2016.

6p.10 Status of radiance assimilation at CMC
Presenter: Simon Pellerin, Environment Canada

The Canadian Meteorological Center (CMC) will likely have implemented at the time of the conference the assimilation of Cris (103 channels) and ATMS (17 channels, see MacPherson poster) radiances. The total number of assimilated radiances will then reach about 13 M/day. With that implementation, inter-channel error correlations are also considered for all radiances, showing significant impact (see poster). R&D is being pursued on the assimilation of surface sensitive infrared radiances over land from AIRS, IASI (MetopA/B), and Cris (oral presentation). A reduced radiance thinning (currently 150 km) is also under evaluation.

6p.11 Recent upgrades to the Bureau of Meteorology ACCESS NWP system
Presenter: Fabrizio Baordo (for Chris Tingwell), Bureau of Meteorology

The Australian Community Climate and Earth System Simulator (ACCESS) provides the Australian Bureau of Meteorology with a suite of Numerical Weather Prediction (NWP) systems that incorporate data assimilation and forecast model components developed by the UK Met Office and adapted for local use by the Bureau's Research & Development Branch (formerly CAWCR). The ACCESS Global, Regional and Tropical Cyclone systems feature 4D-VAR assimilation of conventional and satellite-based remotely sensed data which include infrared and microwave radiances from ATOVS, hyperspectral infrared radiances from AIRS and IASI, GPS Radio Occultation data, and Atmospheric Motion Vectors derived from geostationary and polar orbiter imagery. Crucially for the regional ACCESS system, which employs an early data cut-off assimilation cycle in order to generate timely operational forecasts, the Bureau processes ATOVS and hyperspectral radiances from Australian receivers and also receives radiance data via the Asia-Pacific Regional ATOVS Retransmission Service (RARS).

The assimilation of a wide variety of satellite data by means of a state-of-the-art 4D-VAR system is a significant contributor to the excellent forecast skill provided by the ACCESS systems; the contribution of satellite data is, of course, especially important in the southern hemisphere.

We are currently in the final stages of upgrading the operational ACCESS NWP systems: key features of this upgrade include significant increases in horizontal resolution in all ACCESS systems, the use of more recent versions of the Unified Model, OPS, VAR and SURF software, and assimilation of new observation types including infra-red radiances from the Suomi-NPP CrIS instrument and microwave radiances from ATMS. We are also now assimilating clear sky radiances from the geostationary MTSAT-2, which will be replaced with data from the recently launched Himawari-8 platform in the near future.

Work has also begun on the next ACCESS upgrade which will be implemented on the Bureau's newly acquired Cray XC40 system. This will include further resolution increases, extended use of satellite data and, very significantly, the introduction of data assimilation in the Bureau's high resolution city based ACCESS-C systems. This will be implemented as hourly rapid update cycles (RUC) in ACCESS-C: a key data source for these systems will be cloud property data derived from Himawari-8 IR imagery. The implementation of city-based RUC DA in ACCESS is seen as a key component of the Bureau's prioritisation of short-range significant weather forecasting.

We will also report on work that is underway to develop a land surface data assimilation system built around the JULES land surface model and driven by atmospheric fields from ACCESS.

Special Topics

Guide to the Direct Broadcast Network for Near Real-Time Relay of LEO Satellite Data (DBNet)
Presenter: Jerome Lafeuille, WMO
Authors: Jerome Lafeuille and Mikael Rattenborg

The Direct Broadcast Network for Near Real-Time Relay of Low Earth Orbit Satellite Data (DBNet) is a collaborative effort to provide timely access to advanced sounder data and other LEO satellite data received by a wide network of Direct Broadcast receiving stations. It involves the Regional ATOVS Retransmission Service (RARS) partners, NOAA, CGMS and WMO, and aims in particular to meet the requirements of NWP users. As requested by ITSC-19 (RARS Technical Sub-group)WMO will present a draft "Guide to DBNet" developed by the DBNet team. The Guide defines the high-level specifications and the standards and best practices to ensure the quality,interoperability and global consistency of DBNet data. The feedback from ITWG will be important for finalizing this Guide.

Spectrum over the next four years
Presenter: Richard Kelley, Alion Science for DOC/NOAA/NESDIS
Authors: Alfredo Mistichelli, Rich Kelley

The International Telecommunication Union-Radiocommunication (ITU-R) sector is wrapping up its current cycle of evaluating future use of the spectrum. As we are meeting in Geneva, Wisconsin; ITU-R is meeting in the eponymous location in Switzerland in the World Radiocommunication Conference (WRC-15). Decisions made this year will impact the next four years of spectrum study for the passive microwave remote sensing community. Among the topics of interest is the search for spectrum for use by the international mobile telecommunications community, above 6 GHz. The interest shown in use of the 5 GHz band for use by the RLAN community is of interest to those who rely on data from and develop uses from missions such as OSTM/Jason.

Session 7a: Climate

7.01 SSU Climate Data Record Verifying Anthropogenic Global Warming Theory
Presenter: Cheng-Zhi Zou, NOAA/NESDIS/STAR
Authors: Cheng-Zhi Zou

Anthropogenic global warming theory predicts that the stratosphere has a cooling response to human-induced changes in atmospheric trace gases: ozone depletion is expected to cause the stratosphere to cool, due to less absorption of the ultraviolet radiation from the sun; increases of carbon dioxide and other greenhouse gases are expected to cause stratospheric cooling as more greenhouse gases trap more outgoing infrared radiation close to the Earth's surface and emit more radiation into space from the stratosphere, causing a net energy loss in the stratosphere.

Such a cooling response has been well simulated by the climate models in the Coupled Model Intercomparison Project-5 (CMIP5), with input of trace gas variations to the best of human knowledge at the time, although individual models had resulted in slightly different stratospheric cooling rate. Unfortunately, accurate measurement of the stratospheric cooling rate was difficult to make because (1) radiosonde observations are difficult to reach to the middle and upper stratospheres, (2) lidar observations are too sparse for global trend determination, and (3) satellite observations are subject to inhomogeneity that has to be homogenized for accurate trend determination.

NOAA/STAR has recently released its second version of the stratospheric temperature climate data record (CDR) derived from the Stratospheric Sounding Unit (SSU) observations onboard NOAA TIROS-N polar orbiting satellite series (Zou et al. 2014). The SSU observations were well inter-calibrated and merged between satellite pairs to remove instrument specific drifts and inter-satellite biases which resulted in homogenized CDR for stratospheric temperature trend investigations. Agreement between the homogenized SSU observations and ensemble means of multiple CMIP5 model simulations were found to be within the uncertainty estimates at least for channels 2 and 3. This excellent agreement represents a significant milestone toward verifying anthropogenic global warming theory and climate model capabilities in simulating the past climate changes. This presentation will review and summarize the recalibration and merging methodologies in generating homogenized SSU CDR, discuss SSU trend uncertainties from the CDR construction point of view, and compare with the SSU CDR with CMIP5 model simulations.

7.02 Reprocessing of Fundamental Climate Data Records From Microwave Sounders
Presenter: Martin Burgdorf, Universität Hamburg
Authors: M. Burgdorf, S. A. Buehler, I. Hans, V. John

The aim of the FIDUCEO (Fidelity and Uncertainty in Climate data records from Earth Observations) project is to create new Fundamental Climate Data Records (FCDRs) with complete and traceable estimates of stability and uncertainty. New tools for metrologically rigorous analysis will be created, for example tools for stability analysis and ensemble creation. Based on the new HIRS and microwave humidity sounder FCDRs it will be one of the tasks to produce CDRs of upper tropospheric humidity (UTH). Infrared and microwave data cannot be merged but will be evaluated jointly. With this synergetic, novel microwave/infrared view on UTH we expect to shed new light on the long-term evolution of UTH. Other CDR datasets to be generated by FIDUCEO are sea and lake surface temperature, aerosol optical depth, and surface albedo.

7.03 The UW SSEC/CIMSS Global Clear Sky Infrared Moisture Products derived from HIRS data

Presenter: Paul Menzel, UW-Madison/SSEC
Authors: E. E. Borbas and W. P. Menzel

The High resolution Infrared Radiation Sounder (HIRS) has been flown on seventeen satellites from TIROS-N through NOAA-19 and METOP-B forming more than a 30-year record. Sensor to sensor radiance calibration differences have been mitigated using high spectral resolution infrared data from the Infrared Atmospheric Sounding Interferometer (IASI) as a reference to adjust spectral response functions in the recent HIRS data (NOAA-15 through NOAA-19). Satellite Nadir Overpasses (SNOs) have been used to intercalibrate the HIRS sensors before IASI (NOAA-9 through NOAA-14). A thirty five year record of moisture measurements now have been reprocessed.

The HIRS moisture algorithm (developed for processing MODIS data) retrieves total column precipitable water vapor and integrated high (UTH), mid, and low layer tropospheric humidity. It is a statistical regression (Seemann et al 2003 and 2008) developed from an atmospheric profile database (SeeBor, Borbas et al, 2005) that consists of geographically and seasonally distributed radiosonde, ozonesonde, and ECMWF ReAnalysis data. TPW and UTH are determined for clear sky radiances measured by HIRS (at 20km and later 10km resolution) over land and ocean both day and night.

The HIRS TPW and UTH products are binned into a global map of 0.5 degree lat-lon boxes, for 4 time periods daily, compiled into monthly amounts, and inspected for trends over a 35-year time period (1979-2015). The HIRS TPW data is also compared to the NASA NVAP-Climate and the ten year MODIS datasets.

7.04 The consistency between measured radiance and retrieved profiles at climate scales - a study in uncertainty propagation

Presenter: Nadia Smith, SSEC/CIMSS/UW-Madison
Authors: Nadia Smith, Dave Tobin, Robert Knuteson, William L. Smith, Sr. Elisabeth Weisz, Henry Revercomb

The need to measure and characterize large-scale climate change makes the overall record of infrared hyperspectral satellite measurements an important resource. With four instruments operational in polar-orbit today, hyperspectral sounders measure top-of-atmosphere (TOA) emitted radiance at different local times from which vertical atmospheric profiles and cloud properties can be retrieved. In order to use these measurements in climate research, their uncertainty needs to be well-characterized. At present, the consistency between measured radiance and retrieved profiles at large scales are mostly unknown. The goal of this paper is to characterize three potential sources of radiance uncertainty as they propagate through to retrieval records for the Atmospheric Infrared Sounder (AIRS), Infrared Atmospheric Sounding Interferometer (IASI) and Cross-track Infrared Sounder (CrIS) instruments. (A) Radiance product quality: there are two data products for AIRS radiances, namely Level 1B and Level 1C. The former is optimized for channel-specific applications, and the latter for applications employing the full spectrum. The Level 1C product was recently released with the intent to support climate applications and our goal is to characterize the difference in retrieval records derived from these two AIRS radiance records. (B) Calibration accuracy: for IASI and CrIS, the calibration errors are well characterized such that their radiances can serve as standard to test the sensitivity of retrievals to calibration errors associated with different Earth scenes. (C) Instrument differences: CrIS and AIRS are different instrument technologies, an interferometer spectrometer and grating spectrometer, respectively. It is critical to characterize both radiance and retrieval uncertainties that are dependent on these different technologies. We will use time and space coincident AIRS and CrIS Earth scene data to characterize instrument technology dependent radiance and retrieval differences.

The ability to explain observed trends in emitted radiance with coincident trends in atmospheric parameters given known uncertainties will make a critical contribution towards the utilization of satellite measurements in climate research.

7.05 Measurement Requirements and Current Capabilities for Satellite Remote Sensing of Precipitable Water Vapor

Presenter: Jacola Roman, University of WI-Madison AOS/CIMSS/SSEC
Authors: Jacola Roman, Robert Knuteson, Thomas August, Tim Hultberg, Steve Ackerman, and Hank Revercomb

The IPCC 4th Assessment found that changes in extreme events, such as droughts, heat waves, and flooding, have occurred and the frequency of such events is expected to increase. Precipitable Water Vapor (PWV) is a useful parameter for forecasters in determining atmospheric stability and the probability of convection; it is critical for determining the occurrence of extreme weather events. Furthermore, distinguishing between future model predictions through the use of observations will aid in understanding the future socio-economic impacts of climate change.

This study is two-fold. First, this paper investigates the time to detect (TTD) mean and extreme PWV trends in order to quantify the accuracy needed from global satellite observations. This study determined the theoretical Time To Detect (TTD) Global Climate Model (GCM) Precipitable Water Vapor (PWV) 100-year trends when realistic measurement errors are considered. Second, this paper assesses the ability of the current IR sounders, AIRS and IASI, to retrieve PWV in both mean conditions and extremes. Results are presented that highlight the differences and agreements between the sounders and validation data, consisting primarily of SuomiNet GPS data. The SuomiNet ground-based GPS measurements of water vapor are analyzed on three scales; 1) international station matchups, 2) continental scale using climatic regions, and 3) Zonal statistics. Additional validation is performed at the tropical, mid-continental, and arctic ARM sites with comparisons against the Microwave Radiometer (MWR) and Vaisala radiosondes.

7.06 Three decades of cloud properties from HIRS: a new climate dataset by CMSAF

Presenter: Timo Hanschmann, Deutscher Wetterdienst (DWD)
Authors: Timo Hanschmann, Martin Stengel, Claudia Stubenrauch, Artem Feofilov

The EUMETSAT Satellite Application Facility on Climate Monitoring (CMSAF) produces datasets of cloud properties on a relevant scale for climate studies. Traditionally, most of these long-term cloud property datasets are based on imager data, i.e. AVHRR. One limitation of retrieval techniques for imager data is the detection of semi-transparent high clouds and/or the correct height assignment for them. IR sounders, making use of channels with differing CO2 absorption, provide an alternative approach to overcome this limitation.

As an addition to the existing (and currently updated) CMSAF datasets CLARA and CLAAS, an alternative dataset for cloud amount, cloud emissivity and cloud top height is introduced. The dataset uses the HIRS measurements from all NOAA and MetOp satellites and will cover at least the years from 1984 to 2013. The Cloud Retrieval from Infrared Sounders (CRIS) algorithm, initially developed for the 3I (Improved Initialization Inversion) retrieval at LMD, is used to derive cloud properties. The weighted chi2 method of CRIS minimizes the difference between observed and calculated radiances along the spectral slope of the CO2 atmospheric absorption for a predefined set of vertical levels. This enables an improved detection of semi-transparent high clouds, also in the case of low-level clouds underneath. The CRIS retrieval is already used at LMD to build cloud climatologies from the Atmospheric Infrared Sounder (AIRS) and the Infrared Atmospheric Sounding Interferometer (IASI). The HIRS data allow building a cloud climatology covering three decades.

At the conference the scientific method and its application to HIRS will be presented, including validation results against A-Train observations. Furthermore, the full HIRS datasets will be introduced, which is based on new HIRS L1 dataset by EUMETSAT, and comparisons to existing cloud datasets (based on imager and sounder data) are indicated.

Session 7b: Climate

7p.01 Deriving long-term global dataset of temperature and humidity profiles from HIRS

Presenter: Lei Shi, NOAA's National Centers for Environmental Information
Authors: Lei Shi, Jessica L. Matthews

Temperature and humidity profiles are derived based on NOAA polar orbiting satellites' High-resolution Infrared Sounder (HIRS) measurements from 1979 to present. To achieve homogeneity of

the time series, HIRS longwave channel data are inter-calibrated to a base satellite. The retrieval of temperature and humidity are derived using a neural network technique. The algorithm derives profiles at standard pressure levels from the surface to lower stratosphere for temperature and from the surface to upper troposphere for humidity. A two-tiered approach is used to remove cloud-contaminated HIRS observations. Cloudy pixels are first identified and removed by using a neighboring variance method in both spatial and temporal dimensions. The remaining pixels are further screened by co-located Advanced Very High Resolution Radiometer cloud products. Flags are assigned to HIRS pixels to indicate their likelihood of cloud contamination. Radiosonde data and profiles derived from Global Positioning System Radio Occultation are incorporated to reduce retrieval biases. Preliminary results show that for the temperature retrieval scheme, the root mean square errors are 1.96-2.81 K for lower troposphere, 1.48-1.61 K for mid to upper troposphere, and 1.96-2.52 K for stratosphere when compared to global radiosondes. For humidity retrievals, the root mean square error is 2.20 g/kg at 850 hPa and gradually decreases with height. More detailed analyses are ongoing.

7p.02 Extending the HIRS cloud record with CRIS and IASI measurements

Presenter: Paul Menzel, UW-Madison/SSEC
Authors: W. Paul Menzel, Elisabeth Weisz, and Richard Frey

We report on a study for extending the 35+ year record of HIRS cloud determinations using IASI and CrIS measurements. This involves reducing the high spectral resolution IASI / CrIS data to resemble the HIRS broad band spectral coverage and estimating the cloud top pressures and effective emissivities. Co-located HIRS and IASI data from Metop are being used initially to provide comparison data sets. In addition the high spectral resolution data are being investigated for opportunities to characterize the uncertainties in the broad band cloud products. Cloud top processing using Dual Regression (DR) on IASI, DR on simulated HIRS, CO2 slicing on HIRS, CO2 slicing on simulated HIRS, and CO2 slicing on IASI are compared. These five CTPs will be sorted by cloud height and effective emissivity at individual CTPs to characterize the CTP accuracy as a function of cloud semitransparency. The final outcome of this work will be an IASI / CrIS CTP algorithm that continues the HIRS cloud record.

7p.03 The GEWEX water vapor assessment (G-VAP) - results from inter-comparisons and stability analysis

Presenter: Nathalie Selbach (for Marc Schroeder), Deutscher Wetterdienst
Authors: Marc Schroeder, Maarit Lockhoff, Lei Shi

A large variety of water vapour data records is available to date. Without proper background information and understanding of the limitations of available data records, these data may be incorrectly utilised or misinterpreted. The overall goal of assessments of CDRs is to conduct objective and independent evaluations and inter-comparisons in order to point out strengths, differences and limitations and, if possible, to provide reasons for them. The need for such assessments is part of the GCOS guidelines for the generation of data products. The GEWEX Data and Assessments Panel (GDAP) has initiated the GEWEX water vapor assessment (G-VAP) which has the major purpose to quantify the current state of the art in water vapour products (upper tropospheric humidity, specific humidity and temperature profiles as well as total column water vapour) being constructed for climate applications. In order to support GDAP and the general climate analysis community G-VAP intends to answer, among others, the following questions:

a) How large are the differences in observed temporal changes in long-term satellite data records of water vapour on global and regional scales?
b) Are the differences in observed temporal changes within uncertainty limits?
c) What is the degree of homogeneity (break points) of each long-term satellite data record?

A general overview of G-VAP will be given. The focus of the presentation will be on observed inconsistencies among the long-term satellite data records as observed by inter-comparisons and comparison to in-situ observations and the stability analysis. On basis of consistently applied tools major differences in state-of-art CDRs have been identified, documented and to a large extend explained. Also, the science questions given in the introduction have largely been answered. The results and the answers for TCWV are summarized as follows: On global ice free ocean scale the trend estimates among six long-term data records were generally found to be significantly different. Maxima in standard deviation among the data records are found over, e.g., tropical rain forests. These and other noticeable regions coincide with maxima in mean absolute differences among trend

estimates. These distinct features can be explained with break points which manifest on regional scale only and which do not appear in stability analysis relative to ground-based observations.

First results from profile inter-comparisons will also be shown. Besides stability issues relatively large differences occur due to different representations of sharp vertical gradients as observed, e.g., in stratocumulus regions. Future efforts within G-VAP will concentrate on enhancing the data base, among others, by considering a large variety of data records with shorter temporal coverage.

7p.04 Climatology of free tropospheric humidity: Extension into the SEVIRI era, evaluation and exemplary analysis

Presenter: Nathalie Selbach (for Marc Schoeder), Deutscher Wetterdienst
Authors: Marc Schroeder, Remy Roca, Laurence Picon, Anke Kniffka, Helene Brogniez, Nathalie Selbach

Water vapour has an amplifying role in a warming environment through a strong positive climate feedback loop as evident in climate predictions, and this water vapour feedback loop is dominated by water vapour in the tropical free troposphere (Held and Soden, 2000). The importance of humidity in the free troposphere originates from the non-linear interaction between humidity and long-wave radiation. The outgoing longwave radiation (OLR) is much more sensitive to perturbations at the dry end than at the moist part of the distribution (Spencer and Braswell, 1997; Roca et al., 2011). Sherwood et al. (2010a) recently reviewed the processes that determine the humidity distribution in the intertropical region. They emphasize the strong connection between the large scale dynamics and water vapour and the roles of eddies in establishing these links pointing out to a broad range of scale implied in the humidity distribution. Satellites that observe the humidity of the free troposphere, and particularly, geostationary platforms are very well suited to contribute to this constraint by providing observations at kilometres and hours scale resolution over a 30 years long period.

An enhanced free tropospheric humidity (FTH) data record is presented. It extends the previous record composed of observations of Meteosat-2 - 5 and Meteosat-7 Meteosat Visible and Infrared Imager (MVIRI) to Meteosat-8 and -9 Spinning Enhanced Visible and Infrared Imager (SEVIRI). With this extension the data record now covers the period 1983 - 2009 with a spatial and temporal resolution of 0.625 degree and 3 hours. The record is freely available from http://www.cmsaf.eu/wui.

The FTH product is compared against FTH computed on the basis of the Analysed RadioSoundings Archive (ARSA) observations. An average relative bias and root mean square difference (RMSD) of -3.2% and 16.8%, respectively, are observed. The RMSD confirms the expectation from an analysis of the total uncertainty of the FTH product. The decadal stability is 0.5+-0.45% per decade.

As exemplary applications the inter-annual standard deviation, differences on decadal scales and the linear trend in the FTH data record and the frequency of occurrence of FTH<10% (FTHp10) are analysed per season. These analyses have been also used to identify possible problems with the data record. Among others, we found positive trends in FTHp10 which coincide with gradient areas and regions of minimum FTH, maximum FTHp10 as well as with negative differences between decadal FTHp10 averages of the 1990s and 2000s. However, they are accompanied by maximum standard deviation and are therefore hardly significant. Finally, indications of shifts in spatial patterns of dry regions are also observed and will be analysed in more detail in the future.

7p.05 Application of CHARMe in satellite based climate monitoring

Presenter: Nathalie Selbach, Deutscher Wetterdienst
Authors: Nathalie Selbach, Petra Fuchs, Frank Kratzenstein

CHARMe (Characterization of Metadata to enable high-quality climate applications and services) as a GMES/COPERNICUS-project was supported by the EU-FP7 (SPACE) programme and is a contribution towards a European Climate Service. CHARMe aims to link climate datasets with complementary information like publications, user feedback and other relevant annotations (so-called “commentary metadata”). CHARMe helps users to learn from previous community experience and select datasets that best suit their needs. It also provides direct traceability between conclusions and the data that supported them.

The CHARMe project was realized applying the principles of Linked Data and adopting the Open Annotation standard to record and publish commentary information. A plug-in developed within the CHARMe project has been implemented at DWD to link the CHARMe annotation data base to satellite based climate data records. In addition, a web map tool has been installed to compare

commentary metadata of several climate data records and the data itself.

This presentation will demonstrate, how CHARMe was realized at DWD to link satellite based climate data records with complementary meta information. The potential of CHARMe to support European Climate Services and further plans to apply CHARMe to other climate data records will be shown.

7p.06 Provision of Climate Data Records of the EUMETSAT Satellite Application Facility on Climate Monitoring and User Services
Presenter: Nathalie Selbach, Deutscher Wetterdienst
Authors: Nathalie Selbach, Petra Fuchs, Karsten Fennig, Uwe Pfeifroth, Britta Thies, Diana Stein, Stefan Finkensieper, Jinghong Tan

The EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) generates, archives and distributes widely recognized high-quality satellite-derived products and services relevant for climate monitoring. Several data sets have been released by CM SAF during the last years and new editions of climate data records (CDR) have been published this year. Thus, users have access to many parameters of the water and energy cycle based on operational satellite instruments. The time series of the climate data records range from 8 to about 30 years with a global coverage for data based on polar orbiting satellites, while those based on geostationary satellite data cover the region of the METEOSAT disk.

CM SAF is offering CDRs generated from ATOVS, AVHRR, SSM/I and SSMIS on different polar orbiting satellites as well as from the MVIRI, SEVIRI and GERB instruments onboard the METEOSAT series. These CDRs are made available via a web user interface which also allows applying post-processing procedures, such as the extraction of sub-areas or re-projection.

Further climate data records are planned to be released during the next years, covering several cloud parameters, surface albedo, radiation fluxes at top of the atmosphere and at the surface, aerosols, precipitation as well as different water vapour parameters and fluxes. These will be derived from different sensors onboard operational polar orbiting and geostationary satellites including instruments such as AVHRR (in GAC resolution), SSM/I and SSMIS, GERB, MVIRI and SEVIRI. As for the already released data sets, different areas of the globe will be covered in varying temporal resolution depending on the satellite type.

This contribution will present the newly released CM SAF climate data records and will give a general overview of the current and planned re-processing activities at the CM SAF. It will describe the access to all CM SAF data records and user services.

7p.07 Exploitation of SI-1 data from Meteor-28 and 29 spacecraft for climate purposes
Presenter: Dorothee Coppens, EUMETSAT
Authors: Dorothee Coppens, Bertrand Theodore, Wolfgand Doehler, Antimo Damiano, Dieter Oertel, Dieter Klaes, Dietrich Spaenkuch

Three German Infrared Fourier Transform Spectrometers were flown on onboard the Soviet weather satellites Meteor 25, 28, and 29 in the years 1976-1979 as an activity of the "Intercosmos Cooperation". These Spectrometer Interferometer-1 (SI-1) instruments were designed to perform measurements of the atmospheric temperature profile over a wide spectral domain extending from 6.25 to 25 µm with a spectral resolution of 5 cm-1. Measurements were performed at nadir with a rectangular field of view of 2 x 2 degrees. The SI-1 instruments on the three Meteor satellites acquired more than 4000 spectra world-wide. The Meteorological Service of the German Democratic Republic (GDR) and the Hydrometeorological Service of Union of Soviet Socialist Republics (USSR) were both responsible for the higher level data processing and data evaluation.

Thirty five years later, EUMETSAT has been granted access to measurements performed by SI instruments on:

- Meteor-28 launched on 29th June 1977, which provided measurements during 19 days between July and September 1977;
- Meteor-29, launched on 25th January 1979, which provided measurements during 40 days between January and June 1979. Both satellites were placed on circular polar orbits slightly above 600 km.

After reading the original data and merging them with the meta-information available, parameters originally missing in the products and needed for the analysis have been added. It concerns, in the first place, orbital elements which were retrieved from the reconstructed two lines elements using measurement time and location. A second step focused on checking the radiance quality, removing inconsistencies with the provided meta-information like cloudiness information or surface temperatures. Then, comparison with a selection

of IASI data, assessment on the calibration and further consistency analysis could be made, completing the SI-1 products with dedicated quality flags.

These measurements are of potentially great interest for climate applications as they can help detecting changes in the spectrum of outgoing longwave radiations, like in comparing with IASI to assess increases in greenhouse forcing. Further assessments have been made using principal components analysis and from an attempt to retrieve vertical profiles of temperature and humidity.

7p.08 Enhanced use of satellite data in the next ECMWF reanalysis ERA5

Presenter: Niels Bormann, ECMWF
Authors: Carole Peubey, Paul Poli, Hans Hersbach, Dick Dee and Niels Bormann

Over the next few years, ECMWF will produce a new flagship reanalysis to succeed the previous ERA40 and ERA-Interim reanalyses. The new reanalysis will benefit from the latest model and data assimilation developments and provide fields at the significantly enhanced spatial resolution of 31 km, covering the period 1979 to the present day. Of particular interest will be the use of a number of reprocessed observations, especially for satellite data, some of which will be used in a reanalysis context for the first time. Analyses together with observation feedback information will be made available widely, allowing unprecedented studies on the performance of the analysed observations by the wider community.

The poster outlines the plans for the ERA5 setup and the expected production schedule, as well as the observational datasets that will be used or monitored.

7p.09 Geophysical Trends Derived from 12 years of AIRS Infrared Radiances: comparisons to AIRS L3 and ERA Reanalysis

Presenter: Sergio DeSouza-Machado, UMBC
Authors : Sergio DeSouza-Machado, L. Larrabee Strow, Steve Buczkowski

We determine zonal temperature and humidity trends from Optimal Estimation retrievals performed using 12 years of near-nadir AIRS L1b radiance trends. The radiances are obtained under both clear and cloud conditions. Variability is also examined using monthly averaged anomalies from the dataset. Comparisons are made against trends and anomalies from ERA model fields and AIRS L3 products

Session 8a: Clouds

8.01 Configuration of All-sky Microwave Radiance Assimilation in the NCEP's GFS Data Assimilation System

Presenter: Yanqiu Zhu, IMSG @ NOAA/NCEP/EMC
Authors: Yanqiu Zhu, Emily Liu, Rahul Mahajan, Catherine Thomas, David Groff, Paul Van Delst, Andrew Collard, Daryl Kleist, Russ Treadon, John Derber

In the current operational NCEP's hybrid 3D Ensemble-Variational Global Forecast System (GFS), the clear-sky approach for radiance data assimilation is employed, in which radiances for cloud-free Field of Views (FOVs) and FOVs that include thin clouds are assimilated. For the FOVs that include thin clouds, the cloud signal is removed by applying a cloud liquid water bias term in the radiance bias correction scheme. The Advanced Microwave Sounding Unit-A (AMSU-A) microwave radiometer includes 12 sounding channels in the 60 GHz oxygen band, and 3 window channels at 24, 31 and 89 GHz that are sensitive to variability in water vapor, cloud and precipitation. Presently, AMSU-A channels 1-13 and 15 are assimilated in the operational GFS.

Improvements to the Community Radiative Transfer Model (CRTM) and the forecast model have been concurrent with all-sky radiance data assimilation development in the Gridpoint Statistical Interpolation (GSI) data assimilation system at NCEP. To date, cloud-affected AMSU-A radiance assimilation development has been limited to FOVs with non-precipitating clouds. These efforts have expanded the use of AMSU-A observations over cloud-affected regions. Furthermore, after accounting for non-precipitating cloud information in the inputs to the CRTM in the satellite-radiance observation operator, simulations of satellite radiances are more realistic over a much larger footprint of meteorologically active weather conditions. This has allowed us to improve the satellite radiance innovation (OmF) statistics, enabling the production of better analyses of temperature and moisture.

In the GFS, a cloud control variable is explicitly employed. Cloud water, including cloud liquid water and cloud ice, has been used in the clear-sky approach of the operational GFS. One of the benefits of the all-sky approach is that, the radiance data information is mapped onto not only the temperature and moisture fields, but also cloud fields via the brightness temperature Jacobians with respect to hydrometeors. CRTM

does not produce a cloud Jacobian in cloud-free areas, but this is overcome by providing a very small cloud amount to the radiative transfer model in these cases. The background error covariance is composed of two parts, 75% from the flow-dependent ensemble and 25% from a static term. With the capability of choosing either individual hydrometeors or cloud water as cloud control variable(s) in the all-sky approach, a normalized cloud water control variable is used in this study to reduce spurious clouds generated from the static part of the background error covariance. While cloud analysis increments are produced through the background error cross-covariance in the clear-sky approach, additional analysis increments are generated from the projection of the radiance data information onto the cloud fields for clouds, temperature and moisture in the all-sky approach.

The symmetric observation error method (Geer and Bauer 2010; Bauer et al. 2010) is adopted in the all-sky approach for AMSU-A channels 1-5 and 15. On top of the symmetric observation error, additional quality control and situation-dependent observation error inflation are applied. Several factors are considered in the situation-dependent inflation: the cloud liquid water difference between the first guess and the observation, the large scattering index, the mismatched cloud information between the first guess and the observation, as well as the surface wind speed.

As for the radiance bias correction, the cloud liquid water bias term, which is defined as the cloud liquid water difference between the guess and the observed, has been constructed in the clear-sky approach to remove the cloud signal. As this cloud liquid water bias term is no longer necessary in the all-sky approach, a new radiance bias correction strategy is formulated for the all-sky approach (Zhu et al. 2014). While all quality-controlled radiance data are used to obtain the analysis, bias correction coefficients in the all-sky approach are derived using only a selected data sample with consistent cloudy information between the first guess and the observation, and the radiance data with mismatched cloud information are bias corrected using the latest bias coefficients available.

The all-sky microwave radiance configuration has been tested in a T670 low-resolution hybrid 3D Ensemble-Variational GFS system. The experiment results showed a neutral impact on the forecast skill in the Northern Hemisphere but a positive impact in the Southern Hemisphere. It is included in the pre-implementation package and is being tested in the NCEP parallel hybrid 4D Ensemble-Variational(4D EnVar) data assimilation system for the next implementation. Meanwhile, tests are underway on applying the averaged cloud liquid water bias term from the observation and the guess to further improve the performance of the bias correction. The balance between the analysed variables (particularly cloud, temperature and humidity) will be investigated further in the near future.

8.02 Variational cloud-clearing with CrIS data at NCEP

Presenter: Haixia Liu, NOAA/NCEP/EMC
Authors: Haixia Liu, Andrew Collard, John Derber

The variational assimilation of satellite radiance observations is a major contributor to the forecast skill of the Global Forecast System (GFS) at NCEP. However, satellite observations are underused at most meteorologically important areas due to the presence of cloud. For infrared (IR) channels, only channels unaffected by cloud have been assimilated in the Grid-point Statistical Interpolation system (GSI): the NCEP operational data assimilation system. This limits the ability to continue improving the model initial conditions through assimilating radiance data from partly cloudy and cloudy regions.

NCEP has developed an inline cloud-clearing algorithm to utilize the observed radiances from hyperspectral IR instruments in partly cloudy areas by removing cloud radiative effects. With the assumption that the surface, atmospheric state and cloud formation characteristics are the same within one field of regard and only cloud fraction varies among adjacent pixels, the clear-column radiances can be reconstructed by minimizing the difference between the radiances with cloud radiative effects removed and simulated clear-sky radiances from radiative transfer model using the GSI first guess fields. The above process differs from other existing cloud-clearing systems in that it is integrated to the GSI system itself. The reconstructed clear-column radiances are estimated in each GSI outer loop and then assimilated together with all other observations in the inner loop. Details of this algorithm will be discussed and the impact of the CrIS cloud-clearing radiances on the global analysis and forecast skills will be reported at the conference.

8.03 Progress on the assimilation of advanced infrared sounder radiances in cloudy skies

Presenter: Jun Li, UW-Madison/SSEC/CIMSS
Authors: Jun Li, Pei Wang, Mitch Goldberg, Jinlong Li, Zhenglong Li, and Timothy J. Schmit

Accurate cloud detection is very important for assimilating advanced infrared (IR) sounder radiances in numerical weather prediction (NWP) models. Most operational centers use IR sounder stand-alone cloud detection approach which could bring some cloudy contaminated radiances in assimilation. Collocated high spatial resolution imager (e.g., MODIS, VIIRS) cloud mask are used for IR sounder (e.g., AIRS, CrIS) sub-pixel cloud detection, impact study has been conducted for three typical hurricanes, Sandy (2012), Irene (2011) and Ike (2008), with WRF (Weather Research and Forecasting) as the forecast model and GSI (Gridpoint Statistical Interpolation) as the assimilation system. Results indicate that forecasts of both hurricane track and intensity are substantially improved when collocated high spatial resolution MODIS cloud mask is used for AIRS cloud detection, and VIIRS cloud mask is used for CrIS cloud detection. Furthermore, based on the IR sounder sub-pixel cloud detection with imager cloud mask, the assimilation of thermodynamic information under partially cloudy skies is also conducted by using the cloud-cleared IR radiances. Since the cloud-clearing method obtains clear equivalent radiances, the same clear radiance assimilation approach can be applied directly to the cloud-cleared IR radiances. By assimilating the cloud-cleared AIRS radiances in cloudy skies for the three hurricanes mentioned above, the 48 and 72 hours temperature forecast standard deviation (STD) are reduced by 0.1- 0.3 K between 300 and 850 hPa. The substantial improvement in reducing track forecasts error in the range of 10 to 50 km was achieved. The IR sounder sub-pixel cloud detection and cloud-clearing with collocated high spatial resolution imager data could reduce the usage of cloud contaminated IR radiances to be treated as clear in assimilation, and also enhance the assimilation of thermodynamic information in partially cloudy skies. The methodologies can be applied to operational assimilation of advanced IR sounder radiances from AIRS, CrIS and IASI.

8.04 Developments in clouds and aerosols detection for infrared radiance data

Presenter: Reima Eresmaa, ECMWF
Authors: Reima Eresmaa, Hyoung-Wook Chun, Julie Letertre-Danczak, Anthony McNally

Undetected cloud and aerosol contamination contributes substantially to the observation error budget and limits the capability to retrieve useful information from infrared radiance data. This is particularly critical with very low-noise radiances, such as those provided by the Cross-track Infrared Sounder (CrIS). However, attempts to minimize the effect of the undetected contamination with very strict cloud screening can result in false alarms and large amounts of data being rejected unnecessarily.

Recent advances in the detection of contaminated infrared data at the European Centre for Medium-range Weather Forecasts (ECMWF) include the use of collocated imager information and a dedicated (background independent) identification of aerosol contamination. A new test facility has been developed using synthetic observations where the detection algorithm can be exercised under a variety of differing conditions of cloud, measurement noise and background error. This will be applied to the detection of clouds in CrIS data and the detection of clouds over land.

8.05 1DVAR Preprocessor Applications for Satellite Data Assimilation: Quality Control, Background Adjustment, and Cloud Radiance Assimilation

Presenter: Kevin Garrett, NOAA/NESDIS/STAR/JCSDA
Authors: Kevin Garrett, Eric Maddy, and Sid Boukabara

We present recent efforts supported by the Joint Center for Satellite Data Assimilation (JCSDA) to advance and increase satellite observations assimilated within the GSI analysis system used to initialize both the Global Forecast System (GFS) model and regional Hurricane WRF (HWRF) model at the National Oceanic and Atmospheric Administration (NOAA) . Specifically, the use of a 1D-variational (1DVAR) preprocessor within the GSI will be discussed. The 1DVAR preprocessor, known as the Multi-Instrument Inversion and Data Assimilation Preprocessing System (MIIDAPS), is applicable to current and future microwave satellite sounders and imagers including those from POES and MetOp AMSU-A and MHS, NPP/JPSS ATMS, DMSP F16-F20 SSMI/S, GCOM-W AMSR2, TRMM/TMI and GPM GMI. Recently MIIDAPS has been extended to hyperspectral IR sensors included NPP/JPSS CrIS for IR only and IR/MW combined assimilation. The capability of MIIDAPS (which applies over all-surfaces and in all-sky conditions) includes increased quality control (QC) of the radiances to be assimilated, provides dynamic surface emissivity over all surfaces therefore extending assimilation capabilities to more surface sensitive observations, and cloudy and rainy data assimilation by providing hydrometeor (cloud, rain, ice) information to the assimilation system. The capability for advanced QC and all-surface/all-sky assimilation allows the

MIIDAPS to perform a "background adjustment" to the assimilation guess field prior to 3D or 4DVAR data assimilation, removing large displacements between background and observation fields. Here we present the impact on the global analysis and forecast using MIIDAPS within the GDAS/GFS. Specifically, metrics based on the number of observations passing quality control, analysis increments, and fits to observations will be used to assess analysis improvements, while traditional metrics such as anomaly correction and hurricane track error will be use to assess forecast impact.

Session 8b: Clouds

8p.01 The Validation of Observation Operator and Single Observation Experiments for Microwave Radiances under All-sky Condition in NCEP Assimilation System

Presenter: Huichun (Emily) Liu, EMC/NCEP/NOAA
Authors: Emily Huichun Liu, Yanqiu.Zhu, Andrew Collard and John Derber

The current operational 3DVAR/Ensemble Grid-point Statistical Interpolation (GSI) analysis system used in conjunction with the National Centers for Environmental Prediction (NCEP) global spectral model at the Environmental Modeling Center (EMC) and with the Hurricane Weather Research and Forecast System (HWRF) assimilates satellite radiances under clear-sky conditions only. The satellite radiance are under-utilized in cloudy and precipitating areas where numerical weather prediction is challenging. The inclusion of cloudy radiances in the analysis may be potentially beneficial to forecasts by providing greater coverage in meteorologically active areas and constraining cloud and precipitation directly. The capabilities for assimilating cloudy radiances in the GSI have been developed and diagnostics of these capabilities to assimilate Advanced Microwave Sounding Unit A (AMSU-A radiances under all-sky conditions are currently underway, which will provide guidance for further developments.

This paper will present the use of AMSU-A radiances under all-sky conditions in the NCEP global model for the following aspects:(1) validation of the observation operator for non-precipitating clouds; (2) characteristics of innovations; (3) estimation of observation error; (4) quality control; (5) single observation experiments for diagnosing the effectiveness of ensemble estimated background error covariances. In addition, the validation of the observation operator for precipitating clouds and the characteristics of innovations from the HWRF model will also be discussed.

8p.02 Assessing the Accuracy of Cloudy Sky Infrared and Microwave Brightness Temperatures in the GFS

Presenter: Jason Otkin (for Sharon Nebuda), UW-Madison/SSEC
Authors: Sharon Nebuda and Jason Otkin

To aid efforts to assimilate all-sky radiances in the GFS, we are assessing the accuracy of the CRTM in cloudy scenes. Cycled data assimilation experiments are underway with passive monitoring of cloud-affected infrared and microwave radiances using version 2.1.3 of the CRTM and GFS Hybrid EnKF assimilation system at T670 resolution. Our analysis has focused on exploring cloud-dependent relationships in the departures between observed and model equivalent brightness temperatures for several infrared and microwave sensors onboard polar orbiting satellites. Results from CrIS and ATMS will be presented.

8p.03 Assimilation of All-sky SEVIRI Radiance Data in NCEP Hourly-update NAM System

Presenter: Xiaoyan Zhang, NOAA/NCEP
Authors: Xiaoyan Zhang

A summary of recent research results of evaluating the assimilation of radiance products from Meteosat-9 SEVIRI (Spinning Enhanced Visible and Infrared Imager) observations into an hourly-updated version of NCEP's North American Mesoscale (NAM) forecast system will be presented. As a geostationary satellite, Meteosat-9 is positioned at 0 degrees and provides full disc imagery every 15 minutes over the Atlantic Ocean, Europe and Africa. In order to get the most complete use of SEVIRI observations the hourly-updated NAM, known as NAM Rapid Refresh (NAMRR), was placed over SEVIRI's coverage area (i.e. the Atlantic Ocean, Europe and Africa). Two water vapor channels (WV6.2μm & 7.4μm) of all-sky SEVIRI radiance are assimilated with NCEP regional 3D-Var data assimilation system (NDAS) for both the 12-km resolution parents domain, and 4-km resolution nested domain. The SEVIRI all-sky radiance data source is EUMETSAT 16x16 all- sky SEVIRI product.

Following the method used in ECMWF operationally to assimilate all-sky Infrared radiance, the 3D-Var analysis control variables in NCEP NDAS has been extended to include the cloud-top pressure as cloud parameters. In this approach clouds are assumed to be single-layer

blackbody. The background cloud-affected radiance is computed in NDAS using cloud-top height, cloud fraction and the clear-sky radiance computed from CRTM. The additional control variable cloud-top pressure is diagnosed from the observations, not taken from the NMMB model. At this stage, however, the cloud fraction is not included in the control variables, which used in ECMWF (Lupu, 2012). Six channels including two water vapor channels around 6.2 um and 7.3um, and four IR channels around 8.5, 11.2, 12.3 and 13.3um are used to define background estimates of cloud-top pressure and cloud fraction. The impact of assimilating all-sky SEVIRI will be evaluated for the Africa domain configuration and the severe storm forecast over Lake Victoria.

8p.04 The detection of dust in infrared radiance spectra

Presenter: Reima Eresmaa (for Julie Letertre-Danczak), ECMWF
Authors: Julie Letertre-Danczak

Brightness temperature observations from IASI, CrIS and AIRS are assimilated operationally at ECMWF and are known to improve the quality of numerical weather forecasts. In addition, atmospheric composition products derived from IASI are used to produce analyses of atmospheric species in the MACC project. High resolution spectra measured by these instruments can be significantly affected by the presence of aerosols which, if unaccounted for in the assimilation, will damage the NWP analyses of temperature and humidity. Currently aerosol affected situations are identified and rejected as part of the operational ECMWF cloud screening process. This poster shows the effectiveness of the current detection algorithm and demonstrates some recent improvements that have made for the particular case of desert dust.

8p.05 Application of observation cross-validation method to IASI cloud screening

Presenter: Olaf Stiller, Deutscher Wetterdienst (DWD)
Authors: Olaf Stiller

It is demonstrated how the cross-validation (CV) formalism (see presentation by O. Stiller at this work shop) can be applied to the cloud screening of IASI radiances. Regarding first only long wave temperature and window channels, a comparison with the cloudy field of Views (FoVs) identified by the (at DWD operational) scheme from Mc Nally and Watts (M-W) shows

- excellent agreement for high and medium high clouds
- significantly less lower clouds (here the M-W scheme is known to detect too many clouds)

Only in the limit of extremely small assumed background errors for the sea surface temperature (SST) sink variable and (even more importantly) for humidity, the new scheme flags largely the same low clouds as M-W. In other words, the clouds detected by the two schemes agree well if the possibility that part of the FG departures may be caused by background humidity or SST errors is discarded in the new scheme.

Similar to the M-W scheme, a gradient criterion for the identification of the cloud top (i.e., the lowest channels probably not affected by the cloud) is presented and motivated. Differences to the M-W scheme are discussed.

Different ways of including also the humidity channels are discussed. For these channels the CV formalism also provides a useful estimate for the observation error variances. Applying the CV formalism to different outer loops of a 1D Var minimisation, a strong dependence on the different linearisation states is observed for some FoVs.

8p.06 Assessing and improving IR sounder radiances in cloudy scenes using imager radiances

Presenter: Thomas Pagano, NASA/JPL
Authors: Thomas S. Pagano, H. Aumann, E. Manning, D. Elliott, S. Broberg

The Atmospheric Infrared Sounder (AIRS) on the EOS Aqua Spacecraft was launched on May 4, 2002. AIRS acquires hyperspectral infrared radiances in 2378 channels ranging in wavelength from 3.7-15.4 um with spectral resolution of better than 1200, and spatial resolution of 13.5 km with global daily coverage. The AIRS is designed to measure temperature and water vapor profiles for improvement in weather forecast and improved parameterization of climate processes. As with most instruments, the AIRS Point Spread Functions (PSFs) are not the same for all channels. When viewing a non-uniform scene, this causes a significant radiometric error in some channels that is scene dependent and cannot be removed without knowledge of the scene response. The magnitude of the error depends on the non-uniformity of the AIRS spatial response for a given channel and the non-uniformity of the scene, but typically only affects about 1% of the scenes and about 10% of the channels. The current solution is to avoid those channels when performing

geophysical retrievals. In this effort we use data from the MODIS instrument to provide information on the scene uniformity that is used to correct the AIRS data. The residual errors are on the order of the noise level determined using a Principal Component (PC) reconstruction. Results are compared to the new AIRS Level 1C product that uses PC reconstruction to correct impacted channels. The method can be used to recover impacted channels and avoid the need for reconstruction in L1C of up to 90% of the affected channels. We also take a first look at the properties of CrIS in cloudy scenes using similar techniques and VIIRS data.

8p.07 Merger of Imager and Sounder Data for Improved Cloud Height Estimation

Presenter: Andrew Heidinger, NOAA/NESDIS@CIMSS
Authors: Andrew Heidinger, Michael Foster, Mike Hiley, Yue Li, Andi Walther and Steve Wanzong

Cloud height is an important parameter remotely sensed from both satellite imager and sounders. Cloud height is used for the height assignment for cloud-drift winds, assessing aviation hazards and is an important climate data record on its own. With the exclusion of MODIS, polar orbiting imagers (AVHRR and VIIRS) lack the IR absorption channels in the H2O and CO2 absorption bands, which are critical for the accurate height retrieval of cirrus cloud. We present here a method for deriving these IR absorption channels from polar orbiting sounders (HIRS, IASI, CrIS) and using this information in the imager optimal estimation cloud height retrieval. This analysis will show that this technique can improve the imager results using the sounder observations while preserving the fine spatial resolution offered by the imager data. Examples using VIIRS/CrIS and AVHRR/HIRS will be shown.

8p.08 Consistency of reflected moonlight based nighttime precipitation product with its daytime equivalent

Presenter: Andi Walther, UW-Madison/CIMSS
Authors: Andi Walther, Andrew Heidinger

Several VIS/NIR based rain rate retrievals have been developed which relate cloud optical properties to precipitation at daytime. They usually assume that the probability of precipitation is a function of cloud liquid water path, which can in turn computed from cloud optical thickness (COD) and cloud effective radius (REF).

More physically based rain rate algorithms from satellites use passive microwave radiometer observations, which penetrate clouds. Their principle is based on the physical relationship between observed microwave brightness temperatures and column water vapor and liquid water path and works equally well at day and night. The main disadvantages are the low spatial resolution (up to 2000 times coarser) and the higher uncertainty over land surfaces.

The Suomi-NPP constellation with ATMS and VIIRS/Day-Night-Band (DNB) on the same satellite gives us ideal opportunity to make synergistic use of both precipitation retrieval techniques with merging the advantages of the high spatial resolution of VIS channels on S-NPP/VIIRS combined with quantitative adjustments of the more physically based rain rates from ATMS. The new and unique approach is the use of moon light reflectance measurements during night in DNB, which can be transformed to precipitation rate also when sunlight is not present.

We will demonstrate the consistency and performance of precipitation retrieval at day and night. Special focus lies on the performance for Alaska region, where daytime observations are rarely available during winter, and thus will be particularly valuable for weather forecast and climate research.

8p.09 The quality of H-SAF ATOVS based precipitation products over Poland

Presenter: Bozena Lapeta, Institute of Meteorology and Water Management, National Research Institute
Authors: Bozena Lapeta and Danuta Serafin-Rek

Heavy and prolong precipitation proved to be a main cause of local floods and landslides in Poland. Therefore its monitoring is a very important element of early warning systems working in Poland. Alongside radar information, satellite datasets are crucial source of information on precipitation temporal and spatial distribution, however, its application to operational hydrology requires subsequent uncertainty estimation.

The main goal of EUMETSAT Satellite Application Facility in Support to Operational Hydrology and Water Management (H-SAF) is to provide satellite products for operational hydrology. Products of H-SAF concerns precipitation, soil moisture and snow cover parameters. Among them, the H-SAF precipitation products based on both passive microwave sensors (AMSU and MSH) and IR sensors calibrated by MW have been operationally available for meteorological and hydrological users.

In the presentation, the quality of mentioned above H-SAF precipitation products in precipitation detection and estimation is analysed. The analysis was performed using data from both rain gauges and radar data from Polish ground measurement networks. The quality of the satellite products was studied using continuous and categorical statistical parameters within appropriate precipitation classes.

8p.10 Combination of Satellite Precipitation Estimates and Rain Gauge for high Spatial and Temporal Resolutions

Presenter: Dirceu Herdies, CPTEC/INPE
Authors: Rute C. Ferreira, Dirceu L. Herdies, Daniel A. Vila and Cesar A. A. Beneti

The satellite rainfall estimate is widely used due to its spatial coverage, obtaining estimates even to remote areas and difficult to access. In addition, there are many products that combine satellite precipitation estimates and rain gauges. However, most of these products are combined for a period of 24-hour, because the rain gauge data are obtained for a 24-hour accumulation period. However, with the use of telemetric stations it is possible to get the accumulated precipitation in periods from 15 minutes. This work describes a new product with high temporal-spatial resolution using gauge-satellite-based analysis of 3-hour precipitation over South America making use of telemetric station of Parana state. This technique can be used to validate the precipitation in the early hours of the models and for nowcasting. The new product, called CoSch-3 has the great advantage of identifying the precipitation related to mesoscale convective systems and other systems that generate large cumulative rainfall in short periods. This product is based on about 100 telemetric stations and the Tropical Rainfall Measuring Mission (TRMM). The results show the remarkable improvement in the quality of the final product used for tracking systems with large accumulated precipitation in a few hours.

8p.11 withdrawn

Session 9a: Assimilation of hyperspectral IR and impact studies

9.01 Observing System Experiments with IASI Reconstructed Radiances

Presenter: Fiona Smith, Met Office
Authors: Fiona Smith, James Cameron

The use of radiance spectra reconstructed from principal component scores is an area of active research at many operational NWP centres at the present time, both from the perspective of potentially receiving PC compressed data to reduce future bandwidth, and because the method potentially provides more efficient access to spectral information than sparse channel selections.

Previously presented work has shown that it is important to take proper account of the error covariance structure for reconstructed radiances, and to use a channel selection designed specifically for the transformed dataset and its errors.

This presentation will show results from observing system experiments with IASI reconstructed radiances, using a channel selection chosen while taking account of the full error covariance structure diagnosed for IASI using the Hollingsworth-Loennberg technique. The results support the theoretical findings in terms of the importance of using the correct errors and a tailored channel selection, but overall the forecast impact of the reconstructed radiances is disappointing. Some possible reasons for this will be explored.

9.02 Toward the NWP assimilation of the full IASI spectrum: recent experience using principal component data

Presenter: Marco Matricardi, ECMWF
Authors: Marco Matricardi

The ECMWF operational ECMWF 4D-Var has been adapted to allow the direct assimilation of principal component (PC) scores derived from high spectral resolution infrared sounders radiances. The primary aim of this development is towards an efficient use of the entire measured spectrum that could not be achieved by traditional radiance assimilation. We present a system were we assimilate truncated PC scores representing the information contained in the 5421 spectral radiances from IASI Band 1 and Band 2. The new scheme has been extensively tested in a full data assimilation system that uses all operational observations (satellite and conventional). In our presentation we discuss the quality of the analysis produced by the assimilation of the truncated PC scores and the verification of the forecasts launched from these test analyses. Finally, we discuss the work needed to take this system forward to a stage where it can be considered as an option for the safe and efficient operational exploitation of high spectral resolution infrared sounders radiances.

9.03 Assimilation of IASI radiances as from Principal Components IASI product in AROME
Presenter: Javier Andrey-Andrés, Meteo-France
Authors: Javier Andrey-Andrés, Vincent Guidard, Nadia Fourrie, Jean-François Mahfouf

With the new generation of hyperspectral infra-red sounders (IASI-NG and IRS), there has been a huge increase in satellite radiances available to the user community. Such observations are beneficial to NWP models at both global and regional scales but the large volume of data raises technical issues for both retransmission and archiving services. Moreover, for scientific and technical reasons, only a small sub-set of the measured radiances in the infra-red spectrum can be assimilated (for example, only about 100 IASI channels are used among the 8461 in the NWP Météo-France models). Given the redundancy of information contained in the thousands of channels from hyperspectral instruments, a Principal Component (PC) analysis seems to be a rather natural technique to compress data by keeping the most informative linear combinations.

As first step, a monitoring of EUMETSAT Reconstructed Radiances (RR) from PCs have been implemented at Météo-France. The assimilation results of RR in the place of the instrument radiances are shown as the second phase of the studies carried out by Météo France to prepare the arrival of MTG. The latter work has been using the mesoscale AROME model.

9.04 Observation impact studies
Presenter: Mohamed Dahoui (for Tony McNally), ECMWF
Authors: Tony McNally

Two established approaches for estimating the forecast impact of satellite observations are critically compared. Observing System Experiments (OSE) involve running assimilation systems with certain observations deliberately denied (or added) and comparing the performance to a control system where the observations have (or have not) been used. While this is a very direct and understandable measure of the observation impact, important criteria must be met for the results to be considered valid. More recently adjoint techniques have been used to assess the impact of observations on forecast accuracy. A huge computational advantage over OSE has led to this approach becoming very popular - but interpretation of these results requires great care. It will be shown that they are not a proxy for the more traditional impact studies (OSE) and in some cases can yield inconsistent results. Finally, a recent assessment of the impact of key satellite systems on NWP forecast impact will be presented.

9.05 Impact Assessment of Potential Gaps in the Satellite Constellation on NOAA's Global NWP
Presenter: Sid Boukabara, NOAA/NESDIS & JCSDA
Authors: S.-A. Boukabara, K. Garrett and K. Kumar

There is, based on the nominal lifetimes of the current space based sensors and given the current fiscal constraints that might delay these launches, the risk that potential gaps might occur in the global satellite constellation. The gaps referred to are: (1) the afternoon polar orbit might experience a gap between the currently flying Suomi NPP (S-NPP) mission and the first JPSS-1 mission as well as between JPSS-1 and JPSS-2, (2) the radio occultation COSMIC-2 low inclination coverage is considered secured for 2016, but the higher inclination coverage is currently scheduled for 2018 creating a potential risk for a polar coverage gap from this mission if COSMIC-1 fails. NOAA is taking many steps to reduce the risk of these gaps from happening, but given the importance of these two data types (polar afternoon sounders and the radio occultation measurements) on global numerical weather prediction (NWP), NOAA has initiated a thorough study to implement data gap mitigation strategies, to reduce the potential impact, in the event that these gaps actually happen. The present study aims at assessing, at global scales, the impacts of these potential gaps on the medium-range (1 to 7 days) weather forecasting performances. As part of the assessment, we assess the impact of the loss of secondary (backup) sensors in the current observing systems. A number of experiments were undertaken in this study to deny afternoon orbit microwave and infrared data from the NOAA NWP system, and to deny polar-based radio occultation data from COSMIC-1 to simulate a tropics-only coverage of the COSMIC2 mission. The performances were assessed in terms of standard metrics of anomaly correlation and root mean square errors (RMSE) for a multitude of parameters (temperature, geopotential height, moisture and winds, etc). In order to encapsulate the results from all assessments, we also introduce an overall forecast score that combines all metrics after normalizing them in order to give appropriate weights to all metric, all parameters, all lead times at all levels. The first result from this study suggests that the removal of redundant satellite-based sensors, which is expected to happen in the upcoming years, will result in a significant degradation of the global forecast skills

in NOAA. The potential of data gap in the afternoon orbit, as sometimes assumed between S-NPP and JPSS-1, on top of the removal of the redundant sensors, is found to degrade further the forecast performances, by a statistically significant margin. To a lesser degree, the loss of the polar coverage of COSMIC radio occultation data also reduces the global forecast performances. The magnitude of these degradations will be discussed in detail in this study and will include global statistics as well as the assessment on hurricane tracks forecast performances.

Session 9b: Assimilation of hyperspectral IR and impact studies

9p.01 Infrared and Microwave Data Addition Observing System Experiment Impacts using the NCEP Global Forecast System
Presenter: James Jung, UW-Madison/CIMSS
Authors: James Jung, Mitch Goldberg

Observing System Experiments (OSEs) are used to quantify the contributions to forecast skill by various types of sensors or observing systems. They help to highlight the impact of some of the numerous data sources available today. The purpose of this study is to investigate the overall impact of the major infrared and microwave sensors used by the National Centers for Environmental Prediction's (NCEP) Global Forecast System (GFS).

The design of these experiments will consist of a two week spin-up period followed by a month long assimilation-forecast cycle during two extreme seasons (January and August). The experiments will start from a baseline of conventional and the Global Positioning System - Radio Occultation (GPS-RO) data. From this baseline, the individual sensors (AIRS, IASI, CrIS, AMSU, ATMS, and SSMIS) will be added. The forecasts from these experiments will be verified against a control which uses nearly all of NCEP's operational data. The forecast skill will then be compared to the control, the baseline as well as the individual sensors.

9p.02 Data Impact Assessment using G3DVAR
Presenter: Helena de Azevedo, Brazilian National Institute for Space Research
Authors: Helena Barbieri de Azevedo; Luis Gustavo Goncalves de Goncalves

The Center for Weather Forecast and Climate Studies (CPTEC from its Portuguese acronym) from the Brazilian National Institute for Space Research (INPE, Instituto Nacional de Pesquisas Espaciais), implemented in 2013, in operational mode, a three-dimensional variational data assimilation scheme based on the GSI (Gridpoint Statistical Interpolation). The coupling between GSI and GCM-CPTEC/INPE (Global Circulation Model from CPTEC/INPE) is the so called G3DVAR (Global 3DVAR). This study aims to evaluate the impact of three observing systems that are assimilated using the G3DVAR in its forecasts cycle using a technique of Experiments Systems Observations (OSE). For this study, three experiments were performed in each was denied a data source: satellite, GPS and radiosonde. These experiments were carried out for January 2013 and assessed using standard statistical metrics as an anomaly correlation and root mean square error. The results show that radiance data are extremely important and need in Numerical Weather Prediction, mainly to areas lacking conventional data. There was a heavy dependence on data from the model in SH, while the NH this dependence was observed over three-day forecast.

9p.03 Assessing the AMSUA impacts in the CPTEC/INPE regional ensemble prediction system
Presenter: Camila Ferreira, National Institute for Space Research / Center for Weather Forecast and Climate Research
Authors: Camila Cossetin Ferreira, Luis Gustavo Gonçalves de Gonçalves, Luiz Fernando Sapucci, Eder Paulo Vendrasco, João Gerd Zell de Mattos, Eduardo Georges Khamis, Bruna Barbosa Silveira, Simone Sievert da Costa

Assessment of the results from a shortrange regional prediction system proposed for CPTEC/INPE based on the Ensemble Kalman Filter (EnKF) approach are presented in this study. Particular interest is in the impact of brightness temperatures in the microwave window channels over critical regions such as Amazonia and semi-arid areas in northeast Brazil. The DTC (Developmental Testbed Center) recently released a version of GSI (Gridpoint Statistical Interpolation) that includes the LETKF, which in turn is easy to implement, with parallel capabilities and able to ingest non local observations, all desired characteristics for operational NWP. CPTEC/INPE has first tested the EnKF DA cycle over South America using WRF/ARW to be used to initialize its regional ensemble forecast however, planning to extend this framework also to its other operational regional models. The current LETKF algorithm makes use of 20+1 ensemble members, in a resolution of 12km and 38 vertical levels, with a DA cycle intermittent every 6 hours. The

conventional dataset used in this study comprise temperature, surface pressure, moisture and zonal/meridional winds. The initial set of radiances being tested are the following: NOAA 15, NOAA 18 and Metopa. This observational dataset is first assimilated and 24h forecasts taken after a 2week DA cycle spin up are evaluated against surface observations and radiosondes during February 2015. Another set of runs is performed during the same period however, without the microwave AMSUA channels and the 24h model forecasts performance are evaluated again. Multiplicative and additive inflation are applied in order to compensate for the low spread among the ensemble members. Results show how critical AMSUA microwave channels are to NWP over the Amazon and the semiarid regions of South America.

9p.04 A rapid update data assimilation cycle over South America using 3DVar and EnKF

Presenter: Luis Gustavo de Goncalves, CPTEC/INPE
Authors: Luis Gustavo Goncalves de Goncalves, Luiz F. Sapucci, Eder Vendrasco, João G. Z. de Mattos, Camila C. Ferreira, Eduardo Khamis, Fabio Diniz, Nicolas M. C. Salvador, Olivio N. Bahia, Simone Costa, Nelson J. Ferreira

The Center for Weather Forecast and Climate Studies (Centro de Previsão de Tempo e Estudos Climáticos - CPTEC) from the Brazilian National Institute for Space Research (Instituto Nacional de Pesquisas Espaciais - INPE) has started on July, 2015 its rapid update cycle (RUC) in experimental mode over South America. CPTEC/INPE plans to extend this rapid data assimilation cycle using its convective scale regional models no later than end of 2015 with reduced latency using local data collection such as Regional ATOVS Retransmission Services (RARS). Both DTC versions of GSI in deterministic (3DVar) and Ensemble Kalman Filter (EnKF) regional forecasts using nested domains over South America, and selected locations over regional operational centers over Brazil were initially implemented. Information from observations including radar operated at these local centers will be used to be assimilated as well as validation data. This work aims to assess the preliminary results from this CPTEC/INPE Regional Modeling System (RMS) and the value of conventional and satellite information assimilated at convective scale over South America. Particular interest is in the impact of brightness temperatures in the microwave window channels over critical regions such as Amazonia and semi-arid areas in northeast Brazil. The 3DVar system runs at 9 km over South America and 3 km over the regional centers with also 38 vertical levels with a DA cycle intermittent every 3 hours. The current EnKF algorithm makes use of 20+1 ensemble members, in a resolution of 12km and 38 vertical levels. The conventional datasets used in this study comprise temperature, surface pressure, moisture and zonal/meridional winds and full set of satellite data for 3DVar whereas EnKF uses only radiances from NOAA 15, NOAA 18 and Metop-a.

A sensitivity analysis for the impact of AMSU-A and HIRS infrared channels on both 3DVar and EnKF are presented assessing its impact over the Amazon and the semi-arid regions of South America on both systems.

Session 10a: Surface studies

10.01 MEaSUREs High Spectral Resolution MODIS/ASTER Emissivity Database

Presenter: Glynn Hulley, Jet Propulsion Laboratory
Authors: Glynn Hulley, Eva Borbas, Robert Knuteson

Land Surface Temperature and Emissivity (LST&E) data are essential for a wide variety of studies from calculating the evapotranspiration of plant canopies to retrieving atmospheric water vapor. LST&E products are generated from data acquired by sensors in low Earth orbit (LEO) and although these products represent the same measure, they are produced at different spatial, spectral and temporal resolutions using different algorithms. NASA has identified a major need to develop long-term, consistent, and calibrated data and products that are valid across multiple missions and satellite sensors. As part of this endeavor we have developed a land surface emissivity product as part of a NASA MEASUREs project - termed A Unified and Coherent Land Surface Temperature and Emissivity (LST&E) Earth System Data Record (ESDR). Part of this project is to develop a unified high spectral resolution emissivity database by combining the MODIS baseline-fit emissivity database (MODBF) produced at the University of Wisconsin-Madison and the ASTER Global Emissivity Database (ASTER GED) produced at JPL. The unified 'MODAST' Emissivity ESDR will be produced globally at 5 km resolution in mean monthly time-steps and for 13 bands from 3.6-14.3 micron and extended to 417 bands using a PC regression approach. The MODAST Emissivity ESDR product will benefit numerous applications such as improving atmospheric retrievals and in radiative transfer simulations. The utility of the new Emissivity ESDR product will be evaluated in an

improved atmospheric retrieval scheme as part of this study.

10.02 Assimilation of surface sensitive infrared channels over land at Environment Canada
Presenter: Louis Garand, Environment Canada
Authors: Louis Garand and Surya Kanti Dutta

Work toward the assimilation of surface sensitive infrared channels over land surfaces has been progressing at Environment Canada (EC) since the last ITSC conference where preliminary results were presented. Assimilations cycles were conducted for two-month periods using EC's global EnVar analysis system. That system uses a flow-dependent background error covariance matrix which includes terms relating surface skin temperature and atmospheric variables. About 140 AIRS and IASI channels are assimilated. Among these, about 40 are sensitive to the lower troposphere and surface. The experiment consists in allowing the assimilation of surface sensitive AIRS and IASI channels over land under certain restrictive conditions, essentially clear sky, relatively flat topography, and high surface emissivity (above 0.90). Polar regions are currently excluded. Under current quality control conditions, the volume of assimilated surface-sensitive channels increases by about 15 %. Details of the approach will be presented along with most recent results.

10.03 Improved assimilation of IASI data over continent in the convective scale AROME model
Presenter: Niama Boukachaba, Meteo-France
Authors: Niama Boukachaba, Vincent Guidard, Nadia Fourrie

The technical progress made in remote sensing contribute to look further into our scientific knowledge in climate and environment domains. Land surface temperature (LST) is one of the key parameters that enters the understanding of the energy balance of the earth. LST is a widely used product by the scientific community because it's strongly related on land surface processes like hydrology and agrometeorology. LST product can also improve meteorological and climate models.

Hyperspectral instruments such as IASI on board the Metop satellite provide a large amount of information allowing to describe accurately surface parameters (such as LST and emissivity on a wide range of wavelengths). However, the forecast of continental surface temperature is not realistic enough to use the infrared information in the lower troposphere and close to the surface over continent.

We present the land surface temperatures which have been retrieved from IASI measurements over the AROME-France domain. These retrievals are compared to the retrievals from SEVIRI on board the geostationary Meteosat second generation satellite.

Then, a new channel selection for IASI has been set up, based on the better description of surface properties. This new channel selection is used in assimilation experiments. Impacts on analyses and forecasts are presented, including a focus on precipitation forecasts.

Session 10b: Surface studies

10p.01 A Unified and Coherent Land Surface Emissivity Earth System Data Record
Presenter: Eva Borbas, UW-Madison/SSEC
Authors: Borbas, E, G. Hulley, R. Knuteson, S. Hook, M Andreson, R. Pinker, C. Hain and P. Guillevic

Land Surface Temperature and Emissivity (LST&E) data are essential for a wide variety of studies from calculating the evapo-transpiration of plant canopies to retrieving atmospheric water vapor. LST&E products are generated from data acquired by sensors in low Earth orbit (LEO) and by sensors in geostationary Earth orbit (GEO). Although these products represent the same measure, they are produced at different spatial, spectral and temporal resolutions using different algorithms. The different approaches used to retrieve the temperatures and emissivities result in discrepancies and inconsistencies between the different products. There is a major need to develop long-term, consistent, and calibrated data and products that are valid across multiple missions and satellite sensors.

This poster will introduce the land surface emissivity product of the NASA MEASUREs project called A Unified and Coherent Land Surface Temperature and Emissivity (LST&E) Earth System Data Record (ESDR).

To develop a unified high spectral resolution emissivity database, the MODIS baseline-fit emissivity database (MODBF) produced at the University of Wisconsin-Madison and the ASTER Global Emissivity Database (ASTER GED) produced at JPL will be merged. The unified Emissivity ESDR will be produced globally at 5km in mean monthly time-steps and for 13 bands from 3.6-14.3 micron and extended to 417 bands using a PC regression approach. The poster will introduce this data product. LST&E is a critical ESDR for a wide variety of studies in particular ecosystem and climate modeling

10p.02 Development of a Dynamic Infrared Land Surface Emissivity Atlas based on IASI Retrievals
Presenter: Rory Gray, Met Office
Authors: Rory Gray

The radiative emission from the earth's surface is characterised by its skin temperature and spectral surface emissivity. Uncertainties in these properties limit the use of infrared sounders and imagers over land, for which a more accurate estimate of them is required. This is particularly important in limited area models, where the proportion of land surface is usually higher than in global models. A method to produce a high spectral resolution, near real-time global atlas of land surface emissivity using spectral emissivity retrievals from IASI is introduced.

Hyperspectral IR sounders such as IASI allow exploitation of the spectral structure of surface emissivity, which is retrieved in the form of a limited number of principal component weights in a 1D-Var pre-processor, simultaneously with skin temperature and atmospheric temperature and humidity profiles. The analysed surface spectral emissivity and skin temperature vary at each assimilation cycle, thereby permitting the capture of more temporal variability than possible with a climatological emissivity atlas. Verification will be performed against other data sources. The emissivity product will be updated on an observation-by-observation basis, and will be provided as a gridded dataset suitable for a range of applications.

Preliminary test results are displayed, and it is anticipated that the final resultant product will prove beneficial to observations from other current and future instruments, including SEVIRI, HIRS, MTG-FCI and MetOp-SG.

10p.03 Assessment of the land surface microwave emissivity in the CPTEC/INPE GSI Global 3DVar Data Assimilation System
Presenter: Bruna Barbosa Silveira, National Institute For Space Research
Authors: Bruna Barbosa Silveira, Luis Gustavo G. de Gonçalves, Simone Costa

The Center for Weather Forecast and Climate Studies (CPTEC) from the National Institute for Space Research (INPE) in Brazil, has been operationally using GSI 3DVar as its global data assimilation (DA) system since 2013. However, since its implementation at CPTEC, no assessment of the quality of the land surface simulated emissivity for the microwave channels was evaluated with independent sources of information. CPTEC/INPE assimilates operationally, in addition to other radiances, the following microwave platforms AMSU-A and MHS. The DA system uses the CRTM version 2.0 with the Weng et al., (2001) emissivity model as a multilayer scheme that considers different land surface covers, ranging from snow to densely vegetated tropical forests. In this work, preliminary results are presented where surface emissivity at AMSU-A (NOAA-19 and METOP-A) surface sensitivity channels (1 and 2) estimated from CPTEC's Atmospheric General Circulation Model backgrounds are evaluated against surface emissivity retrieved from satellite. These channels are not being assimilated into DA system. The period analyzed was March/2015. After masking out the oceans, the results are compared with previous studies and particular attention is given to desert region at North Africa and Amazon region over South America. The results show that in the Amazon region the simulated emissivity was overestimate when compared against emissivity retrieved, the same characteristic was found in the desert region. The semi-arid region, at Northeast of Brazil, also was analyzed, and the results showed that the emissivity simulated agree with the retrieved data. These characteristics were found for the both window channels that were studied (23.8GHz and 31.4GHz).

10p.04 Enhanced use of AMSU-A radiances over land
Presenter: Stu Newman, Met Office
Authors: Stu Newman, Bill Bell, TR Sreerekha

AMSU-A channels 4 and 5 have sensitivity both to atmospheric temperatures in the mid- and lower-troposphere and to surface emission. These channels have been assimilated over ocean in the Met Office global data assimilation system but not, to date, over land where uncertainties in surface emissivity and temperature are larger. A 1D-Var pre-processor has been extended to retrieve surface emissivity and temperature for AMSU-A window channels. A monthly atlas of global microwave emissivity is used as a first guess in the retrieval, with parameters subsequently passed to the full 4D-Var assimilation. Global NWP trial results against a full observing system baseline are presented.

10p.05 Assimilation of microwave humidity sounding channels over sea-ice at ECMWF
Presenter: Fabrizio Baordo, Bureau of Meteorology
Authors: Fabrizio Baordo and Alan J. Geer

We have recently explored the existing FASTEM parametric models for microwave emissivity over

sea-ice in order to evaluate the possibility of using them for satellite data assimilation in numerical weather prediction systems. To guide our study we used retrievals of emissivity derived from SSMIS observations. We found that the FASTEM model cannot be used for the humidity sounding channels at 183 GHz: the emissivity predicted by the model is lower than that derived from SSMIS observations and this was also confirmed by the magnitude of the first-guess departures at 183$\pm$7 and 183$\pm$3 GHz which have systematically large positive biases. The existing FASTEM models show emissivity decreasing as a function of frequency at 183 GHz when really it starts to increase again. To have a better estimate of emissivity for the humidity sounding channels, we studied the relationship between the SSMIS retrieved emissivities at 183$\pm$7 and 150 GHz and we found possible to approximate the emissivity at 183 GHz as a linear function of the emissivity at 150 GHz. The outcome is that the linear model generally helps to improve the fit to the observations although the magnitude of the improvements clearly has a seasonal and geographical dependency. This bias in the retrieved emissivity is thought to be the cause of a 0.2 K warming of the lower troposphere over sea-ice regions when MHS and SSMIS are assimilated in the ECMWF system. In order to address this issue, assimilation experiments are being proposed for SSMIS and MHS 183 GHz channels using the improved sea-ice emissivity model. Results will be available by the time the TOVS conference.

10p.06 The role of skin temperature in the three-dimensional variational assimilation global system of CPTEC/INPE

Presenter: Brunna Penna, INPE
Authors: Brunna Romero Penna, Luis Gustavo Gonçalves de Gonçalves, João Gerd Zell de Mattos

In the recent years, the operational numerical weather prediction centers have been increased the number of observations assimilated. This increase in the data volume was due, mainly to the observations from remote sensing. These, in turn, are of great importance over the Southern Hemisphere, where there is a limited number of conventional data, in particular over the oceanic domain. Nevertheless, there are still difficulties in incorporating data from the satellite sensors in the channels under strong influence from the land surface in the data assimilation systems. This is due the fact that the assimilation methods impose certain criteria for data acceptance. In the satellite observations case, i.e. radiances, that also can be represented as brightness temperature simulated by a radiative transfer model within the data assimilation system itself. To simulate the brightness temperature in the case of the channels sensible to the surface, the radiative transfer model needs input information such as temperature and land surface emissivity with certain accuracy. However, land surface temperature is provided by a atmospheric general circulation model coupled to a land surface mode, and given it is a numerical model it tries to represent the atmosphere and it interaction with the surface upon a number of simplifications therefore, the land surface temperature is not accurately prognostic. In that context, the land surface temperature from the land surface model (i.e. SSiB) coupled to the AGCM is investigated and cold biases were identified over the semi-arid regions and a method for bias correction for this variable proposed. As a result from this methodology, there was a decrease in the RMSE between the simulated (guess) initial land surface temperature and the observations resulting generally in an increase of the number of radiances from the channels sensible to the surface over the semi-arid regions and over the South America.

10p.07 An assimilation study based on FY-3B MWRI soil moisture data using the EnKF

Presenter: Suping Nie, National Climate Center, China Meteorological Administration
Authors: Suping Nie, Tongwen Wu, Xueli Shi, Zaizhi Wang

The Beijing Climate Center (BCC) Global Land Data Assimilation System (BLDAS) based on the Microwave Radiation Imager (MWRI) surface soil moisture products from the Chinese polar-orbiting Fengyun-3 series satellite (FY-3B) and the BCC new generation land surface model BCC_AVIM is developed for operational seasonal climate prediction in BCC. Firstly, a multi-steps quality control (QC) procedure is incorporated on MWRI soil moisture data to remove outlier records and mismatched values to the simulation of BCC_AVIM. Analysis of the test results from June to August of 2012 indicated that the spatial consistency of FY-3B data is well, and the positive bias of soil moisture observations verves BCC_AVIM simulations caused the most outlier records in this QC procedure. Then, the QC-based FY-3B soil moisture data was assimilated during a test period from June to August of 2012 using the Ensemble Kalman Filter (EnKF) method. Assimilation of MWRI observations into the BCC_AVIM model improved the biases,

correlations, and root mean square errors of model simulations of surface soil moisture. The PDFs of soil moisture difference between assimilation data and GLDAS validation data are more gaussian. These results suggest that the FY-3B series MWRI soil moisture data has the quality required for use in BLDAS and can be implemented at BCC next generation operational seasonal forecast system.

10p.08 Improvements to Accuracy for COMS SST and SSI products, and their Impact in KMA's NWP system

Presenter: Byung il Lee, NMSC/KMA
Authors: Byung-il Lee, Tae-Myung Kim, Eun-Bin Park, Sung-Rae Chung, Mi-Ja Kim, Hyun-Cheol Shin, Jae-Gwang Won

Sea Surface Temperature (SST) and Snow cover and Sea Ice (SSI) are very important parameters for better understanding of interaction between the sea and land surface and the atmosphere (Reynolds et al., 2007). But there has been no snow observation information incorporated into the NWP model (Samantha et al., 2010). Recently, Satellite-derived SST and SSI are frequently used in NWP model to improve surface conditions.

We not only improved the accuracy of COMS SST through robust quality control process of in-situ SST and cloud screening, but also developed a blending technique of multi-sensor SST from COMS and LEO SST over the East Asia region. The accuracy of new COMS SST and multi-sensor SST was -0.52ºC, -0.025ºC for bias and 1.25ºC, 0.807ºC for RMSE respectively.

Interactive Multisensor Snow and Ice Mapping System (IMS)'s snow cover has been used to modify background snow amount of the operational KMA NWP model. However, snow cover was frequently overestimated with IMS data in the East Asia. So, we try to adjust the model background snow amount by using COMS SSI.

In this paper we present results of the improvement of COMS SST and SSI which is used in KMA NWP model. Also, we will present the impact of these two products on KMA NWP model simulation.

10p.09 Combined Imager and IR Sounder Observations of LST over the Greenland Ice Sheet

Presenter: Robert Knuteson, UW-Madison/SSEC
Authors: Robert Knuteson, Eva Borbas, Dave Tobin, Joe Taylor, Hank Revercomb, Glynn Hulley

Some of the earliest signals of climate change due to CO2 doubling are expected to be in the found Arctic. Satellite remote sensing is the only practical way to monitor changes across this vast region. Traditionally, land surface temperature (LST) has been obtained from infrared imagery from low Earth orbit, however uncertainties due to sensor calibration, atmospheric state, and surface emissivity limit the accuracy of these data. This study takes advantage of the improved sensor calibration accuracy of hyperspectral infrared sounders and the spectral resolving capability of these instruments to reduce the uncertainty in LST over snow and ice surfaces. A recent aircraft field campaign over the Greenland ice sheet plateau provides an opportunity to cross-calibrate the four currently operating hyperspectral satellite sensors (AIRS, CrIS, IASI-A, -B) with the UW Scanning-HIS and LaRC NAST-I sensors. This cross-calibration is providing a valuable assessment of the uncertainty of these satellite sensors for the cold temperatures of the Arctic. Ice and snow have a narrow emissivity peak in the 8 to 12 micron window. The spectral resolving capability of the hyperspectral IR sounders can be used to improve the estimates of LST measured by imagers. The method used in this study takes advantage of colocated imager and sounder footprints to characterize the uniformity of each sounder scene, ECMWF profiles are used to characterize the atmospheric state, and laboratory measured snow and ice emissivity spectra are used for the surface emissivity. Uncertainties in remote sensing of LST over snow and ice conditions will be quantified for the Greenland ice sheet for cold scene temperatures.

Session 11a: Assimilation studies

11.01 The testing and planned implementation of VarBC at the Met Office

Presenter: James Cameron, Met Office
Authors: James Cameron

A variational bias correction (VarBC) system is being tested at the Met Office. It is anticipated that the system will be used operationally for the bias correction of satellite sounding instruments from late 2015. Only the bias of actively assimilated channels will be varied in the initial system. The bias correction applied to channels which are only used for quality control will continue to be generated using the current system, which is based on the method of Harris and Kelly.

The VarBC system will be configured so that the biases evolve according to a user-specified bias halving time. The majority of satellite sounding

instruments will continue to use two air-mass predictors, specifically the 850-300hPa thickness and 200-50hPa thickness. Four Legendre Polynomials will be used to analyse small corrections to static scan bias corrections.

SSMIS data suffers from complex biases driven by solar heating and solar intrusions. The bias of SSMIS will be modelled using a Fourier series where the phase angle is the position in the orbit measured from the intersection of the orbital plane and the ecliptic.

The system has been extensively tested and is performing well. The new analyses are typically colder and drier than current analyses with reduced spin-down through the forecast range. The new global average analysis temperature at 850hPa is more consistent with the value from ECMWF, NCEP and JMA analyses. Verification against analysis is significantly improved, consistent with reduced spin down. A six month long assimilation experiment has been run and the RMSE of Northern Hemisphere extra-tropical 500hPa geopotential heights, verified against analysis, is improved by 6.6% at T+24 and 1.4% at T+144. There is typically a 2% reduction in the standard deviation of the background fit to AMSU-A channel 6 and a reduction of between 1 and 2.5% for AMSU-B channels.

11.02 An improved bias correction for SSMIS: Assimilation Assessment

Presenter: Anna Booton, Met Office
Authors: Anna Booton, William Bell, Edward Pavelin

The Special Sensor Microwave Imager Sounder (SSMIS) instruments flying on the Defense Meteorological Satellite Program's (DMSP) platforms are known to suffer calibration anomalies that manifest as complex biases. Despite physically based corrections being employed, significant residual biases remain that hamper the successful exploitation of SSMIS radiance information within numerical weather prediction (NWP) models. However, an improved, complimentary bias correction technique has been developed and demonstrated in offline studies to have great potential for effectively mitigating these difficult orbital biases. The new technique uses a Fourier series in the orbital angle to parameterize the instrument biases, with the coefficients tuned within the Met Office's variational bias correction scheme.

A series of assimilation experiments independently utilizing the SSMIS observations from the temperature sounding, humidity sounding and imaging channels are assessed. The effectiveness of the bias correction technique is illustrated through the examination of observation-minus-background field differences, in which the measurement uncertainties of the F-17, F-18, F-19, SSMIS brightness temperatures are now found to be comparable with those of the AMSU instruments. Furthermore, assimilation of the improved data is shown to provide positive impact on forecast quality.

11.03 Assimilation Impacts of SSMIS Upper Atmosphere Soundings with Improved Orbital Bias Predictors in NAVGEM

Presenter: Tanya Maurer, Naval Research Laboratory
Authors: Tanya Maurer, Steve Swadley, Ben Ruston, Anna Booton

The Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager/Sounder (SSMIS) is an operational microwave radiometer that provides sounding capabilities into the mesosphere (~90 km). The high-peaking upper atmosphere sounding (UAS) channels present unique assimilation challenges as they are affected by Doppler shifts of channel passband centers as well as the Zeeman splitting of the of the oxygen absorption lines by the Earth's magnetic field. These channels are also subject to SSMIS orbital biases that result from unique calibration anomalies associated with interactions between solar radiative forcing on the SSMIS instrument. A new bias correction scheme based on a Fourier series expansion in the orbital angle, defined with respect to the sun and satellite position, has been developed by the Met Office to correct for the periodic SSMIS orbital biases. Four assimilation trials were performed in order to assess the performance of both the addition of SSMIS UAS channels into the Navy Global Environmental Model (NAVGEM) as well as the implementation of the new orbital bias predictors: (1) no UAS data; (2) UAS data; (3) UAS data with a reduced set of bias predictors; and (4) UAS data including new orbital bias predictors. UAS assimilation into NAVGEM required a special version of the Community Radiative Transfer Model (CRTM) and a UAS-specific version of the Unified Pre-Processor (UPP). Operational assimilation of SSMIS UAS channels within NAVGEM is currently limited to channel 21 due to the 70 km model top. However, because SSMIS is currently the only operational microwave sensor with mesospheric sounding capabilities, it will be crucial in providing necessary observational constraints as NWP models continue to extend their upper boundaries.

11.04 Assimilation of ATMS radiances into the JMA's global NWP system

Presenter: Takumu Egawa, Japan Meteorological Agency
Authors: Takumu Egawa

The objective of this study is to find the effective way to use ATMS radiance data for the operational global numerical weather prediction (NWP) system in Japan Meteorological Agency (JMA). Since AMSU-A and MHS clear-sky radiance data have been operationally assimilated in the JMA's system, the first step is to evaluate the similar method as AMSU-A and MHS.

The first results of the experiment with assimilating ATMS temperature sounding channels (6 to 15) over ocean showed a neutral to slightly negative impact on forecast scores. The root mean square (RMS) of first-guess (FG) departure for MHS was reduced by the introduction of water vapor sounding channels (18 to 22) though a neutral impact was seen on forecast scores.

Secondly, ATMS surface-sensitive channels (7 and 8) over land were additionally assessed. In the assimilation experiment, a fixed value of the land surface emissivity and inflation of observation errors were adopted. And the result showed large errors in polar and desert areas. Since these errors were caused by the emissivity differences over those regions, the climatological land surface emissivity values supplied with RTTOV-10 for AMSU-A and MHS were also employed to ATMS. The results will be shown in the conference.

11.05 Improving tropical cyclone forecasts by assimilating microwave sounder cloud-screened radiances and the GPM precipitation measurements

Presenter: Hyojin Han, UW-Madison/CIMSS
Authors: Hyojin Han, Jun Li, Mitch Goldberg, Pei Wang, Jinlong Li, and Zhenglong Li

Tropical cyclones (TCs) accompanied with heavy rainfall and strong wind are high impact weather systems, often causing extensive property damage and even fatalities when landed. Better prediction of TCs may lead to substantial reduction of social and economic damage; there are growing interests in the enhanced satellite data assimilation for improving TC forecasts. Due to the uncertainties of cloud properties and their impacts on satellite observed radiances, accurate cloud detection is one of the most important factors in radiance assimilation. To enhance the accuracy of cloud detection and improve the TC forecasts, AMSU-A and ATMS radiances are collocated with high spatial resolution cloud products from MODIS and VIIRS respectively, and then the cloudy microwave FOVs are screened by using the collocated imager cloud products, such as liquid water path, cloud fraction, cloud phase, etc. The cloud-screened microwave radiances are assimilated for Hurricane Sandy (2012) and Typhoon Haiyan (2013) forecasts using the Weather Research and Forecasting (WRF) model and the 3DVAR-based Gridpoint Statistical Interpolation (GSI) data assimilation system. For a more recent TC, Typhoon Neoguri (2014), precipitation estimation from GPM launched in February 2014 and CrIS radiances are assimilated in addition to ATMS radiances. Although cloud screen observations may lead to substantial improvement of track forecast, the intensity remains challenging, due to most information provided by sounder (CrIS and ATMS) data for TC forecasting comes from the surrounding environment. Therefore, incorporating more information in precipitating areas from GPM data, especially within the TC inner core, is needed for intensity forecasts. The value-added impact of assimilating GPM data in all-sky conditions on TC forecasts is also demonstrated in this presentation. Impact studies on CrIS, ATMS and GPM assimilation show improvement in TC forecasting by eliminating cloud contaminated CrIS and ATMS radiances with collocated high resolution VIIRS cloud mask product, and the importance of GPM precipitation products in data assimilations for TC forecasts, especially for intensity.

11.06 Cross-validation methods for quality control, cloud screening, etc.

Presenter: Olaf Stiller, Deutscher Wetterdienst (DWD)
Authors: Olaf Stiller

The exploitation of remote sensing data for NWP strongly relies on quality control (QC) methods including (often quite sophisticated) screening procedures aimed at identifying observations affected by influences (as, e.g., from clouds or land surfaces) for which the employed observation operator is not adequate. Improving such QC (or screening) methods may be essential for an increased and/or more efficient use of this observation type. Apart from the most simple QC checks (which only check the magnitude of the first guess departures of the individual observations) most screening methods consider collective properties of groups of observations for which they impose thresholds. In a more general sense, such QC schemes can be considered as cross validation methods as the validity of

observations is assessed from their consistency with other observations (plus the model background).

While these consistency assessments are generally quite heuristic, the work presented here gives a mathematically rigorous framework for computing the conditional probability of observations (or subsets of observations) given the background and other observations. While a straight forward computation of such probabilities would involve a large number of analysis (i.e., data denial) experiments, the method proposed here is extremely cost effective and aimed for operational use prior to the DA minimization step. Applications include the identification of (i) outliers and (ii) breaches in data sets (i.e., groups of observations affected by systematic influences like, e.g., clouds). The difference between observations and their expectation values (given other observations) as well as the corresponding standard deviations are derived. For the case of uncorrelated observation errors, the "expectation values" can be identified as the analysis values which would be obtained when assimilating only the "other observations".

As an example for an application of the method, a cloud screening scheme for IASI data is presented. A more detailed discussion of this scheme and its properties is given in a poster presentation.

Session 11b: Assimilation studies

11p.01 An Assessment of the Impact of DMSP SSMIS Microwave Sounder and Imager Assimilation for Global Numerical Weather and Wave Forecasting

Presenter: Nancy Baker, Naval Research Lab
Authors: Nancy L. Baker, Steve Swadley, Ben Ruston, Jon Moskaitis, Justin Tsu and Paul May

In this study, we evaluated the complementary nature and relative contributions of the DMSP SSMIS microwave imager and sounder to numerical weather prediction (NWP) and ocean wave forecasting. We focused on October and November, 2014 – a period which includes the two intense Western Pacific Super Typhoons, Vongfong and Nuri. Typhoon Vongfong was the most powerful tropical cyclone (TC) of 2014, while Typhoon Nuri was the third strongest typhoon. As the remnants of Nuri tracked into the Bering Sea, the system rapidly intensified and became one of the most intense extratropical cyclones ever recorded in the North Pacific Ocean, with an estimated central pressure of 924 hPa, wind gusts to 43 ms-1 (97 mph) at Shemya (Eareckson Air Station) and waves in excess of 15 meters (50 feet). The strong poleward surge of energy led to an amplification of the Northern Hemisphere flow, and contributed to the unusually cold November temperatures over the United States to the east of the Rocky Mountains.

We used the Navy's NAVGEM v1.3 global forecast model with the NAVDAS-AR 4DVar data assimilation system. The NAVGEM surface winds provided the atmospheric forcing for the WAVEWATCH III® v4.18 wave model, which was run in a cycling mode without data assimilation. We selectively withheld either SSMIS sounder radiances or SSMIS MW imager products (ocean surface wind speed and total precipitable water) from the 4DVar assimilation, and compared the results to a control run which assimilated the full suite of observations. For expediency, the operational sea-surface temperature, sea-ice and surface fields along with the operational TC warning messages from the Joint Typhoon Warning Center (JTWC) and National Hurricane Center (NHC) were used. The TC warning messages are used to generate synthetic observations that are assimilated by NAVDAS-AR as pseudo radiosonde profiles. Previous studies have suggested that these synthetic observations have the greatest impact during the TC genesis period, or for data denial experiments, but have little impact when millions of observations (including the important MW and IR sounder radiances) are assimilated. The role of the TC warning messages will be further examined as part of the evaluation.

11p.02 Assimilation of ATMS data at Environment Canada

Presenter: Stephen Macpherson, Environment Canada
Authors: S. Macpherson, L. Garand, S. Heilliette

Assimilation of radiance data from the Advanced Technology Microwave Sounder (ATMS) on the Suomi-NPP (S-NPP) satellite is included in new versions of the Environment Canada global and regional deterministic prediction systems and global ensemble prediction system to be implemented in the fall of 2015. The 22 channel ATMS instrument combines the capabilities of heritage AMSU-A and MHS instruments, including two additional humidity sounding channels. Channels 5-15 and 17-22 are selected for assimilation.

Results of data impact experiments in the global system will be presented, along with details on data pre-processing and quality control. Data biases with respect to short-term forecasts (backgrounds) will be discussed, including an assessment of bias correction performance with

respect to view-angle dependent biases. Inter-channel observation error correlations were also evaluated and included in the final tests. These correlations are higher for humidity channels (17-22) than for temperature channels.

11p.03 A near real time regional satellite data assimilation system for high impact weather studies

Presenter: Jinlong Li, UW-Madison/CIMSS
Authors: Jinlong Li, Jun Li, Pei Wang, Hyojin Han, Feng Zhu, Tim Schmit, Mitch Goldberg, Steven Goodman

Under the NOAA JPSS and GOES-R program support, researchers from Cooperative Institute of Meteorological Satellite Studies (CIMSS) at University of Wisconsin-Madison have developed a near realtime regional Satellite Data Assimilation system for Tropical storm forecasts (SDAT). The core system is built with the community Gridpoint Statistical Interpolation (GSI) assimilation and advanced Weather Research Forecast (WRF) model. With GSI, SDAT can assimilate all operational available satellite data including AMSUA/AMSUB, HIRS, MHS, ATMS, AIRS and IASI radiances and some satellite derived products. In addition, some research products are added into the system, such as hyperspectral IR retrieved temperature and moisture profiles, GOES imager atmospheric motion vector (AMV) and GOES sounder layer precipitable water (LPW). Currently we are also working to add Global Precipitation Measurement (GPM) retrieved rainfall rate data into the assimilation. Using SDAT as a research testbed, studies have been conducted on the improving the use of satellite data in numerical weather forecast, for example, how to better handle cloud information for hyperspectral IR sounder and microwave sounder radiance by using the collocated high spatial imager data. Since the fall of 2013, the SDAT system has been run in near realtime. A new GOES imager simulation from the WRF model output along with the realtime GOES imager observation have also been added into SDAT system recently. The results from past two seasons' realtime run and recent research progress from SDAT will be shown in the presentation.

11p.04 The impact of the high temporal resolution GOES/GOES-R moisture information on severe weather systems in a regional NWP model

Presenter: Pei Wang, UW-Madison/CIMSS
Authors: Pei Wang, Jun Li, Yong-Keun Lee, Zhenglong Li, Jinlong Li, Zhiquan Liu, Tim Schmit, Steve Ackerman

The quality of a humidity analysis directly impacts severe storm analysis and forecasts. With high temporal and spatial resolution, GOES-R's humidity information can improve regional/storm scale initialization through data assimilation. The Advanced Baseline Imager (ABI) (Schmit et al. 2005) from GOES-R will provide atmospheric water vapor with three water vapor absorption spectral bands during both day and night, which is very important for improving the initialization of regional/storm scale numerical weather prediction (NWP) models. However, utilization of high temporal resolution moisture information in NWP remains challenge. In order to enhance the use of GOES-R water vapor regional and storm scale NWP, the current GOES Sounder data are used as proxy for investigating the assimilation of high temporal resolution moisture information in a regional NWP model. Both radiances and layer precipitable water (LPW) products at three sigma layers (0.3-0.7, 0.7-0.9, and 0.9-1) are assimilated and compared. The Weather Research and Forecasting (WRF) with 4 km resolution is used in the forecast experiments while the DTC-GSI 3D-var is used as assimilation system. The LPW products from GOES-13/-15 Sounder are retrieved using the GOES-R legacy atmospheric profile (LAP) algorithm (Lee et al. 2014) and a forward operator is developed and integrated into GSI for assimilating LPW. Focuses are on how to better assimilate the high temporal moisture information, including cycling assimilation scheme, bias adjustment, observation error setting, use of information in cloudy region, radiance assimilation versus retrieval assimilation, etc. To verify the impacts of assimilating GOES Sounder radiances and LPW, the forecasted accumulated precipitation, radar reflectivity, and temperature and moisture profiles are compared with the real measurements. The 24 hour, 6 hour and 1 hour accumulated precipitation from forecasts are verified against the NCEP Stage IV analysis precipitation. The temperature and moisture profiles are verified with the radiosondes profiles. Both the frequency bias and the equitable threat score (ETS) are calculated to show the impacts of LPW and radiances on storm precipitation forecasts over CONUS.

11p.05 Constrained bias correction for satellite radiance assimilation in limited area model considering model diurnal bias

Presenter: Wei Han, NWPC/CMA
Authors: Wei Han, Peiming Dong

Radiance bias correction is crucial to the successful assimilation of satellite radiance observations which are typically affected by biases that arise from uncertainties in the absolute calibration, the radiative transfer modeling, or other aspects. These biases have to be removed for the successful assimilation of the data in NWP systems. There are several issues in the implementation of the bias correction method in limited area models (LAMs) which was originally developed for global models. One of these important issues is how to separate the observation bias from the innovations if there are obvious model diurnal biases in LAMs using adaptive bias correction in 3D-Var. In this work, the constrained bias correction scheme is proposed and tested considering the estimate of radiometric uncertainties in calibration and the relative model diurnal bias.

11p.06 Towards operational use of satellite radiances in an Arctic mesoscale model

Presenter: Roger Randriamampianina, Norwegian Meteorological Institute
Authors: Roger Randriamampianina, Yurii Batrak, Mariken Homleid, Harald Schyberg

The Norwegian Meteorological Institute (MET Norway) participated in the European Union founded ACCESS (Arctic Climate Change, Economy and Society) project. Among other tasks, MET Norway has evaluated the forecasting and monitoring capabilities, defined key areas to improve the forecasting capabilities, and based on observing system simulation experiments provided recommendations on how to improve the conventional observing network for accurate analyses and short-range forecasts over the Arctic. Knowledge of sea ice distribution is essential for a reliable radiances assimilation. Thus, a high resolution non-hydrostatic AROME model was built for this project, where a simple sea ice scheme, incorporating three snow layers was implemented.

The first part of our presentation will describe in details the impact of data, originating from ATOVS and IASI instruments on analyses and forecasts, with and without the improved sea ice scheme. In the second part we intend to answer the following question: what is essential in daily aggregation/cycling of the bias correction coefficients for limited area models compared to the “normal” aggregation/cycling, performed at each assimilation time?

11p.07 Radiance bias correction in LAM

Presenter: Patrik Benacek, The Czech Hydrometeorological Institute
Authors: Patrik Benacek

A variational bias correction scheme (VarBC) is commonly used in global data assimilation systems (Dee, 2005). Although this scheme is used in many weather centres in their global systems, its adaptation to mesoscale limited area model (LAM) raises further questions (Stengel, 2008). The main VarBC shortcomings in LAM system are related to observation sample size, a simplified 3D-Var assimilation technique as well as a coarser vertical resolution in the higher altitudes. The coverage of mainly polar-satellite data in LAM domain varies in every analysis depending on satellite orbits and/or a current weather situation when only cloud-free data are considered. It makes more difficult to estimate radiance biases in LAM (Kazumori, 2014) as well as the setting of background error covariance matrix for bias parameters (Sato, 2006). Furthermore, three-dimensional variational (3D-Var) data assimilation technique commonly used in LAM system, brings further drawbacks. Satellite measurements sampling within an excessively long assimilation window increases representativeness error of the assimilated data and influences quality control (e.g. cloud detections, first-guess checks, etc.). Moreover, it affects the estimation of radiance biases in LAM and may cause an over-fitting in the bias correction.

We aim to examine the most questionable aspects of VarBC in mesoscale LAM system ALADIN/CZ. Firstly, we investigate the data representativeness issues of 3D-Var assimilation window length. As a result, optimal window lengths for different polar satellite sensors (AMSU-A, MHS, IASI) will be proposed. In addition, an effect of the vertical resolution in LAM on VarBC predictors and satellite channel selection is studied. Secondly, the current global VarBC selection of predictors, regression model assumptions and the relevance of predictors based on diagnostic methods proposed by Auligne (2007) are examined in LAM system. Finally, we conduct a preliminary study of the background constraint on the bias parameters in LAM system and we propose more appropriate approach to adapt the bias parameters.

Auligne T., 2007: An objective approach to modelling biases in satellite radiances: application to AIRS and AMSU-A. Q. J. R. Meteor. Soc. 133: 1789-1801

Dee D.P., 2005: Bias and data assimilation. Q. J. R. Meteor. Soc., 131, 3323-3343

Kazumori M., 2014: Satellite Radiance Assimilation in the JMA Operational Mesoscale 4DVAR System. Monthly Weather Review., Vol. 142, 1361-1381.

Sato Y., 2006: Introduction of variational bias correction technique into the JMA global data assimilation system. CAS/JSC Research Activities in Atmospheric and Oceanic Modelling, 37, 1-19.

Stengel M., 2008: Assimilation of SEVIRIs Water Vapour Channel Observations in Clear-Sky Conditions.

11p.08 Feedback processes between radiances and the ICON model

Presenter: Robin Faulwetter, German Meteorological Service (DWD)
Authors: Robin Faulwetter, Christina Koepken-Watts, Olaf Stiller, Harald Anlauf

The new global, non-hydrostatic model ICON was introduced operationally at the DWD (German Meteorological Service) in January 2015. During the adaptation of the operational data assimilation system to the new numerical model anomalous increment structures occurred, that could be traced back to feedback processes between radiance assimilation and model physics and dynamics. The poster presents and discusses three such processes and the implemented solutions in order to illustrate the complex interaction of radiance assimilation and model characteristics and the necessary tuning to obtain an enhanced positive impact of satellite radiances on analyses and forecasts.

The first process is related to the occurrence of regional model biases in temperature and the specification of the humidity background error. A model temperature bias in the tropical lower troposphere was observed to translate into erroneously large positive humidity analysis increments caused by the, albeit small, humidity sensitivity of the so-called "temperature sensitive channels". The additional humidity systematically destabilizes the thermal stratification and triggers excessive convection in the early model integration. A retuning of the humidity model background errors alleviates this issue.

In the tropical middle and upper stratosphere a checkerboard pattern is prevalent in zonal mean temperature analysis increments. This pattern could be traced back to a feedback process that involves a model temperature bias, meridional heat transport and the negative vertical temperature correlations in the B matrix.

The third issue presented relates to the setup chosen for initialization of bias correction in the applied online-bias correction scheme. In case the bias correction from the previous model is used as a first estimate to initialize the bias correction for ICON, the model tropical stratosphere remains trapped in a model state, that is far away from the new model's climate. This is due to a feedback between the model and the radiance bias correction. Other observations are not able to successively correct the bias correction used. This implies that the full assimilation system has multiple equilibria.

11p.09 Automatic data checking system at ECMWF

Presenter: Mohamed Dahoui, ECMWF
Authors: M. Dahoui and N. Bormann

For several years ECMWF has been running an automatic data checking system to trigger warnings if there are changes in the quality or availability of observations actively assimilated by the ECMWF four-dimensional variational data assimilation system (4DVAR). Such automatic tools are becoming necessary given the significant and steady increase of data volumes. Initially the system was designed for satellite observations but later it has been extended to cover in-situ measurements. More recently, the system has been complemented with an automatic checking of persistent quality improvements of in-situ data that are blacklisted in the Integrated Forecasting System (IFS), for potential future use in the analysis. For each set of observations, selected statistical quantities (e.g. number of observations, bias correction, mean bias corrected innovations (i.e. observation minus background) are checked against an expected range. An appropriate alert message is generated if statistics are outside the specified limits. A severity level ('slightly', 'considerably', 'severely' or 'severely persistent') is then assigned to each message depending on how far statistics are from the expected values. The automatic checking uses two kinds of ranges: soft and hard limits. Soft limits are updated dynamically and are intended to detect sudden changes of statistics. Hard limits are fixed in order to detect long-term drifts. Results from the automatic checking system are published publically on the ECMWF website. Warnings are also communicated via email to ECMWF internal users and to a limited number of external partners. Over the years the system has detected successfully and promptly most of data anomalies. It also helped to detect situations where the forecast model or the data assimilation itself has weakness.

Session 12a: Validation and applications of sounding data

12.01 Consistency for water vapour between GRUAN RS92 Sondes, LBLRTM and IASI

Presenter: Xavier Calbet, AEMET
Authors: Xavier Calbet

Measurements for climate applications demand a typical accuracy of 5% for atmospheric water vapour. This places a high demand on actual measurements, since typical accuracies of regular atmospheric water vapour measurements also lie in this range. A way to estimate the systematic uncertainties involved in these measurements is to compare different and independent types of measurements made on common atmospheric air parcels. If, in addition, these measurements are considered references in their respective areas, the comparison will provide an estimate of the state of the art accuracies actually achievable in practice.

GRUAN RS92 sensors currently constitute the reference for radiosonde measurements. IASI is currently the reference for satellite infrared radiation measurements. Radiative transfer models bridge the gap between atmospheric geophysical parameters and satellite based radiation measurements, in this respect, LBLRTM constitutes one of the reference radiative transfer models available. Comparison of measurements made on common air parcels using all these systems should be consistent, within their uncertainties, in order to be confident on the overall accuracy of atmospheric water vapour measurements.

In this work, radiances measured from IASI and calculated using collocated GRUAN RS92 sondes and LBLRTM are compared. Their previously estimated uncertainties are also taken into account in this comparison. Final results on these comparisons and the remaining systematic uncertainty of these measurements are shown. Common pitfalls in these type of exercises are also highlighted.

12.02 Characteristics of radiosonde observations and their impact in satellite sounding product validation

Presenter: Bomin Sun, NOAA/NESDIS/STAR & IMSG
Authors: Bomin Sun, Tony Reale, Mike Pettey, and Frank Tilley

Conventional radiosonde observations (RAOBs) from global operational upper air network have historically been used as a commonly accepted ground-truth data set in satellite measurements and derived products monitoring and validation. Issues, however, may be present in this application, in terms of RAOB measurement quality and the consistency of RAOB profile resolution/atmospheric structure with expected satellite sensor sensitivity.

In this work, we provide a summary of the major characteristics of RAOB data based on the analysis of three years (2010-2012) of global RAOB collocations with NOAA IASI/AMSU retrieval profiles collected at the NOAA Products Validation System (NPROVS), a near-real-time satellite EDR monitoring/validation system, supported by the NOAA Joint Polar Satellite System (JPSS). These include the overall accuracy of RAOB temperature and humidity measurements and the capability of RAOB profiles to detect atmospheric structure features including surface temperature inversion, planetary boundary layer height and tropopause height of interest in satellite product applications in weather monitoring and forecasting. We show how these characteristics are reflected in satellite product evaluation and in their consistency with expected satellite sensor sensitivity and constraints. We also show the overall usefulness of conventional RAOBS in satellite product validation by assessing the thermodynamic relationship between cloud, temperature and humidity in the NOAA IASI/AMSU sounding retrieval system (also adopted for Suomi-NPP NOAA-Unique CrIS/ATMS Processing System, NUCAPS).

12.03 Integrating Uncertainty in Atmospheric Profile Validation

Presenter: Xavier Calbet (for Tony Reale, NOAA)
Authors: Tony Reale and Bomin Sun

The NOAA Products Validation System (NPROVS) operated at the NOAA Center for Satellite Applications and Research (STAR) routinely compiles collocated conventional RAOB (and Dropsonde) and environmental satellite data from over 8 satellites and 20 independents sounding product systems. In 2013 NPROVS was expanded to routinely access available refernce RAOB from the GCOS Reference Upper Air Network (GRUAN). This is referred to as NPROVS+, which was further expanded in 2014 to include routine access of JPSS funded dedicated RAOB from ARM sites and special research experiments such as AEROSE and CALWATER. A brief review of this program is provided including activities to process dedicated RAOB using GRUAN software to make them reference observations including traceable uncertainty estimates. The following talk present

results comparing NUCAPS and MiRS sounding products from S-NPP, COSMIC and ECMWF profiles using NPROVS+ and their utility to guide satellite product algorithm development. Results include the integration and use of GRUAN uncertainty measurement (GUM) strategy to estimate uncertainties for selected satellite and ECMWF profiles including the uncertainty introduced when comparing profiles with different spatial and temporal, referred to as the SIGMA uncertainty component.

12.04 Comparisons of IR Sounder and COSMIC RO Temperatures: Guidance for CrIS NUCAPS Validation

Presenter: Michelle Feltz, UW-Madison/SSEC
Authors: Michelle Feltz, Robert Knuteson, Lori Borg, Steve Ackerman, Dave Tobin

Radio occultation (RO) and hyperspectral infrared (IR) sounders are two technologies that serve as climate-quality measuring systems with SI traceability. IR sounder radiance measurements are highly accurate and calibrated onboard. RO phase delays are extremely stable and do not require inter-calibration. However, both IR sounder and RO measurements' derived temperature profile products contain much larger uncertainties and can suffer from characteristic retrieval errors.

Radiosondes and model simulations have traditionally been used as validation references for IR sounder profile products, however, the use of these as strict validation references holds disadvantages. Radiosondes lack homogenous global coverage, being biased towards having more samples over Northern Hemisphere land, often fail to reach above 50 hPa, and have been shown to contain various biases in their datasets. Model simulations are not truly independent references as they ingest RO and IR sounder data. Therefore, this work compares RO and IR sounder temperatures against each other. Neither the IR sounder nor RO data is assumed to be a validation truth reference, but their comparison is used to characterize their differences which can give insight into some of the instruments' common retrieval errors.

Comparisons of UCAR COSMIC RO (Rocken et al., 2000) dry temperature profile products with both the new operational CrIS NOAA NUCAPS temperature retrievals and the AIRS NASA v6 retrievals are made. A profile-to-profile matchup methodology is used that minimizes spatial and temporal mismatch errors (Feltz, M., et al. JGR, 2014; Feltz, M., et al. AMT, 2014). Six years of AIRS NASA v6 retrievals and COSMIC matchup temperatures over the time period 2007-2012 are analyzed. Averaging kernels for stratospheric channels are calculated and applied to AIRS-COSMIC temperature differences on a case-by-case basis to account for the different vertical resolutions of the instruments at these levels. Preliminary results from the COSMIC and CrIS NUCAPS retrieval comparisons are shown for four different months representing the four seasons. Statistical measures including bias and RMS are shown for monthly and zonal scales.

12.05 The use of temperature and water vapor profiles for weather applications: recent activities in the NOAA/JPSS Proving Ground

Presenter: Christopher Barnet, Science and Tech. Corp.
Authors: Chris Barnet, Antonia Gambacorta, Bill Sjoberg, William Line, Mitch Goldberg

The NOAA Unique CrIS/ATMS processing System (NUCAPS) is the operational retrieval system for sounding products from the Suomi National-Polar-orbiting Partnership (Suomi-NPP). NUCAPS produces cloud-cleared radiances from the Cross-track Infrared Sounder (CrIS) field-of-regard that is co-located with the Advanced Technology Microwave Sounder (ATMS) in order to provide information as close to the surface as possible. Numerous environmental data products (EDR) are derived from the cloud cleared radiances including, profiles of atmospheric temperature, moisture, ozone and other trace gases, cloud and surface products.

Recently, NUCAPS products have been made available in both the Advanced Weather Interactive Processing System (AWIPS) and the Community Satellite Processing Package (CCSP). This presentation will summarize the results from a number of initiatives sponsored by the NOAA Joint Polar Satellite Systems (JPSS) Office (NJO). The first was participation in CalWater-2015, a field campaign focusing on variability of the water supply and the incidence of extreme precipitation events along the west coast of the United States. CSPP direct broadcast data was used to support flight planning and analysis of these mesoscale events. The second initiative was the use of AWIPS-II NUCAPS soundings in the Hazardous Weather Testbed 2015 Spring Experiment. Here National Weather Service (NWS) forecasters evaluated NUCAPS in developing convective environments. Many other on-going initiatives will also be discussed.

12.06 Calibration Validation Of The Cross-track Infrared Sounder (CrIS) With The Aircraft Based Scanning High-resolution Interferometer Sounder (S-HIS)

Presenter: Joe Taylor, UW-Madison/SSEC
Authors: Joe K. Taylor, David C. Tobin, Henry E. Revercomb, Fred A. Best, Ray K. Garcia, Aronne Merrelli, Mitch Goldberg

The second Suomi NPP dedicated airborne calibration validation campaign was conducted in March 2015. The primary goals of the campaign are to assess the radiometric calibration and environmental product retrieval for polar conditions. The campaign was conducted out of Keflavik, Iceland with high altitude under-flights of the Suomi-NPP, METOP-A, METOP-B, and NASA Aqua satellites on the NASA ER-2 over the Greenland ice sheet. During this calibration validation campaign, the NASA ER-2 payload consisted of the Scanning-High resolution Interferometer Sounder (S-HIS), the NPOESS Atmospheric Sounder Testbed-Interferometer (NAST-I), the NPOESS Atmospheric Sounder Testbed-Microwave Spectrometer (NAST-M), and the NASA MODIS/ASTER airborne simulator (MASTER).

This presentation will include an overview of the radiance calibration approach, the calibration accuracy and traceability of the S-HIS validation data, a detailed assessment of a single SNPP under-flight, and a summary assessment of the CrIS, IASI-A, IASI-B, and AIRS spectral radiance observations for the under-flights.

Session 12b: Validation and applications of sounding data

12p.01 GCOS Reference Upper Air Network

Presenter: Bomin Sun (for Tony Reale, NOAA)
Authors: Tony Reale

Present status and plans for Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN) (www.gruan.org)

12p.02 The EU's GAIA-CLIM project

Presenter: William Bell, Met Office
Authors: Bill Bell, Stu Newman, Stefano Migliorini and Fabien Carminati

A key aim of the EU's GAIA-CLIM (Gap Analysis for Integrated ECV Climate Monitoring) project is to demonstrate the capability of NWP models and data assimilation systems to validate new satellite datasets. The three year project started in March 2015, and will include a detailed assessment of L1B radiance data from FY-3C temperature and humidity sounders; GCOM-W AMSR-2, and F-19 SSMIS. In addition the project aims to demonstrate how reference quality radiosonde data, from the GRUAN network, can be used to assess uncertainties in model background fields and radiances simulated from them.

These investigations will be carried out at both the Met Office and ECMWF, to assess the model dependence of the uncertainties derived.

12p.03 Sea-based Infrared Radiance Measurements of Ocean and Atmosphere from the ACAPEX/CalWater2 Campaign

Presenter: Jonathan Gero, UW-Madison/SSEC
Authors: Jonathan Gero, Robert Knuteson, Jacola Roman

The ARM Cloud Aerosol Precipitation Experiment (ACAPEX) / CalWater2 was a joint DOE/NOAA field campaign in early 2015 to study atmospheric rivers in the Pacific Ocean and their impacts on the western United States. The campaign goals were to improve understanding and modeling of large-scale dynamics and cloud and precipitation processes associated with atmospheric rivers and aerosol-cloud interactions that influence precipitation variability and extremes in the western United States. Coordinated measurements were made from ground-, aircraft- and sea-based platforms. The second ARM mobile facility (AMF-2) was deployed on board the NOAA Ship Ronald H. Brown for this campaign, which included a new Marine Atmospheric Emitted Radiance Interferometer (M-AERI) to measure the atmospheric downwelling and reflected infrared radiance spectrum at the Earth's surface with high absolute accuracy.

The M-AERI measures spectral infrared radiance between 520–3020 cm-1 (3.3–19 μm) at a resolution of 0.5 cm-1. The M-AERI can selectively view the atmospheric scene at zenith, and ocean/atmospheric scenes over a range of ±45° from the horizon. The AERI uses two high-emissivity blackbodies for radiometric calibration, which in conjunction with the instrument design and a suite of rigorous laboratory diagnostics, ensures the radiometric accuracy to be better than 1% (3σ) of the ambient radiance.

The M-AERI radiance spectra can be used to retrieve profiles of temperature and water vapor in the troposphere, as well as measurements of trace gases, cloud properties, surface emissivity and ocean skin temperature. We present preliminary results on measurements of ocean skin temperature, ocean emissivity properties as a

function of view angle and wind speed, as well as comparisons with radiosondes and satellite observations.

12p.04 Atmospheric profile retrievals from IASI in the framework of the Concordiasi campaign
Presenter: Vincent Guidard, Meteo-France and CNRS
Authors: Vincent Guidard, Olivier Coopmann, Nadia Fourrie

One of the main goals of the Concordiasi campaign was to validate the atmospheric profiles and surface parameters retrieval techniques from satellite sensors and mainly from IASI. During the main field campaign, between September and December 2010, 13 super-pressure balloons from CNES were launched from Mc Murdo. They were fitted with the NCAR dropsounding facility. More than 600 dropsondes were released with various purposes, including coincident Metop overpasses to validate IASI retrievals.

In this study, we present retrieval statistics using IASI operational settings. Then new developments (new channel selection, non-diagonoal R matrix, etc.) will also be evaluated in this framework.

Session 13: Space agency reports

13p.01 Fengyun meteorological satellites and their contribution to NWP
Presenter: Peng Zhang, National Satellite Meteorological Center, CMA
Authors: Peng Zhang

The history, current status and future program of the Chinese Meteorological Satellite, i.e. Fengyun satellite (FY) is introduced in this presentation. Currently, there are 2 FY polar satellites and 3 FY geostationary satellites are in operational. The type of the instruments amounted on FY satellites includes the optical imager, the atmospheric sounder, the microwave imager, the atmospheric composition detector, and the radiation budget mapper. The variety of measurements from FY satellites provides the NWP communities an independent data source. The data quality of FY satellites is illustrated through global space-based inter-calibration system (GSICS) in this presentation. The works of FY satellite data assimilation is reviewed. The applications of the FY-3 sounding data and the FY-2 cloud derived wind product are emphasized especially. The program of the FY-3 early morning orbit satellite is presented at last. The initial utilization has built the confidence that FY satellite data can contribute positively to NWP model forecasting. It is believed that the FY series not only benefit the nation of China, but they are also a valuable contribution to the international meteorological, hydrological, and environmental community.

13p.02 EUMETSAT Systems and Plans
Presenter: Dieter Klaes, EUMETSAT
Authors: K. Dieter Klaes

This poster will provide the usual update on the status of EUMETSAT's current and future programmes and plans.

13p.03 Russian meteorological polar satellite Meteor-M N2: instrument performance assessment and data applications
Presenter: Alexander Uspenskiy, SRC Planeta
Authors: V.Asmus, L.Makridenko, O.Milekhin, V.Solovjev, A.Rublev, A.Uspensky, A.Frolov, M.Khailov

Last year, a new Russian polar orbiting meteorological satellite Meteor-M N2 was successfully launched. According with the Russian Federal Space Program, it is planned to create a constellation of 4 of such satellites. Those are planned to be placed on both morning and afternoon orbits. The payload includes scanning radiometers of visible and IR range, IR and microwave sounders along with the SAR instrument. The results of the commissioning phase are presented together with the performance assessment for the main payload. A special focus is made on the calibration/validation issues for the sounding instruments. A brief overview is presented on the data applications.

13p.04 NOAA Report on Current and Planned Activities
Presenter: Mitch Goldberg, NOAA/NESDIS/JPSS

This poster will discuss the status of current and future NOAA programs.

13p.05 Status report of space agency: JMA and JAXA
Presenter: Kozo Okamoto, JMA/MRI
Authors: Kozo Okamoto, Misako Kachi, Kotaro Bessho

JMA launched the next generation geostationary satellite "Himawari-8" in October 2014 and plans to start the operation in July 2015. JAXA launched GPM Core Observatory in February 2014 and is developing cloud profiling radar on EarthCARE, GCOM-C and GOSAT-2. Their status and initial results will be presented.

Session 14a: Future observations

14.01 The Absolute Radiance Interferometer (ARI): Capable of climate Benchmark quality IR measurements from a CLARREO Pathfinder on ISS
Presenter: Henry Revercomb, UW-Madison/SSEC
Authors: H. E. Revercomb, F. A. Best, J. K. Taylor, P. J. Gero, D. C. Tobin, R. O. Knuteson, D. Adler, C. Pettersen, and M. Mulligan

The NASA Climate Absolute Radiance and Reflectivity Observatory (CLARREO, recommended as a Tier 1 Mission by the first Earth science Decadal Survey of the National Research Council in 2007) would use highly accurate, spectrally resolved infrared emission and reflected solar measurements to quantify global trends in the climate of the Earth. CLARREO implementation is being led by NASA LaRC and progress on the scientific justification and approach has been reported in BAMS (Wielicki, et al., 2013). This year, the resources for a CLARREO Pathfinder/Tech Demo flight of IR and reflected solar instruments on the International Space Station (ISS), were included in the 2016 President's recommended budget.

The technical readiness for this ISS mission has been proven by NASA supported instrument developments, including that of the Absolute Radiance Interferometer (ARI), a prototype for the infrared portion of CLARREO. ARI was developed by our group teamed with the Anderson Group at Harvard University and ABB of Quebec, Canada (supported by the NASA Earth Science Technology Office, ESTO).

The ARI instrument measures absolute spectrally resolved infrared radiance (3.7-50 μm) with ultra-high accuracy (< 0.1 K 3-sigma brightness temperature). Resolving spectral lines allows ARI to provide products for climate trending with much higher information content than those from current radiation budget measurements. While ARI accuracy requirements are demanding, the overall instrument is relatively simple and low-cost, because of the limited requirements on spatial sampling (25-100 km nadir-only footprints spaced at < 250 km) and on noise performance (decadal trending products are created by combining many samples).

The key new aspect of the ARI instrument is the On-orbit Verification and Test System (OVTS) for proving its accuracy on-orbit by reference to International Standards (SI). The OVTS includes an On-orbit Absolute Radiance Standard (OARS), a high emissivity cavity blackbody that can be operated over a wide range of temperatures to verify ARI calibration. The OARS uses 3 small phase change cells to establish its fundamental temperature scale to better than 10 mK and a broad-band heated-halo source for monitoring its cavity spectral emissivity. A Quantum Cascade Laser (QCL) is also used by the OVTS to monitor the ARI spectral lineshape and the emissivity of its calibration blackbody relative to that of the OARS. These new technologies are now at NASA Technical Readiness Level 6 (ready for a flight program).

The International Space Station (ISS) offers a good platform to demonstrate this new capability. The natural precession of the ISS orbit gives good time of day coverage for latitudes below 52 degrees and many opportunities for calibration transfer to high resolution sounding instruments (CrIS, IASI and AIRS) in sun-synchronous orbits. The value of these operational satellite systems for decadal climate trending can be greatly enhanced by implementing this on-orbit calibration transfer standard. Combining all of these observations would allow an ARI pathfinder mission on the ISS to demonstrate key CLARREO decadal trending capability with climate benchmark products covering all latitudes.

14.02 IASI-NG processing overview
Presenter: Eric Pequignot, CNES
Authors: E. Pequignot, B. Tournier, J. Donnadille, C. Standfuss, H. Makhmara, A. Deschamps, F. Bernard, E. Baldit, S. Guibert, S. Rousseau, F. Bermudo, P-L. Georgy, J-F. Pasquier

IASI-NG System is developed by CNES and currently in phase B. It includes the development and delivery of IASI-NG instruments and Level 0 Processor (ICPU) to be flown on the Metop-SG A Satellites, the development of the Level 1 Processor (L1 POP) as part of the EPS-SG ground segment, and the development of a Technical Expertise Centre (IASTEC) in charge of the in-flight calibration, validation and continuous performance monitoring.

The present paper reports on latest developments of the Level 0 and Level 1 Processor concerning the IASI-NG sounder science data. IASI-NG instrument generates sampled raw interferogram. The user product is level 1C. This corresponds to geo-located atmospheric spectra, spectrally and radiometrically calibrated, after equalization of the instrument spectral response function and numerical apodisation with a truncated Gaussian function with a full-width half maximum of 0.25 cm-1.

Opposite to the IASI system, IASI-NG level 0 data transmitted to the ground segment consist of uncalibrated, complex raw spectra. In addition to the removal of instrument dependent variations of the spectral response, and to apodisation, radiometric calibration will also be part of the Level 1 processor.

While the successful principles of IASI level 0 and level 1 processing are adopted for IASI-NG, some modifications, on the background of a modified instrument concept, are required in view of the main design drivers (SRF Estimation model accuracy, enhanced performance requirements, computation time constraints).

One key aspect is equalization of the instrument spectral response function and numerical apodisation in one operation. This implies a quasi-monochromatic, time efficient removal process applied to the response of each spectral channel. The second key aspect is the quality of the SRF estimation process, for IASI-NG supported by additional in-flight measurements (multi-laser metrology, Fabry-Perot device, wave front sensor mode).

The paper presents details on these key aspects.

14.03 Impact Analysis of LEO Hyperspectral Sensor IFOV size on the next generation high-resolution NWP model forecast performance
Presenter: Agnes Lim, UW-Madison/CIMSS/SSEC
Authors: Agnes Lim, Zhenglong Li, James Jung, Allen Huang, Jack Woollen, Greg Quinn, FW Nagle, Jason Otkin, Mitch Goldberg, Robert Atlas

Reduced error in the initial conditions through improvements in forecast model physics, increased computational resources to allow models to run at higher grid resolution and accompanied by rapid increase in number and better use of satellite observations through data assimilation have led to steady improvement of forecast skill in the past three decades. These improvements will help in defining with greater fidelity the critical extreme weather events.

Operational Numerical Weather Prediction (NWP) centers throughout the world are moving in the direction high spatial resolution forecasts. Spatial resolution of satellite observations needs to increase to maintain its positive influence on forecast improvements. Though some centers have begun to assimilate some cloudy observations, NWP systems are originally designed to only assimilate cloud free observations; there remain many challenges before the substantial impact from cloudy assimilation can be achieved. Cloud detection is an important quality control to reject observations from assimilation for a hypersepctral infrared sounder such as Cross-track Infrared Sounder (CrIS), whose observations are sensitive to clouds. A smaller CrIS field-of-view (FOV) will have a higher probability of being cloud free, increasing the CrIS observations to be assimilated and thus potentially making a larger contribution to the analysis.

Impact of FOV size for CrIS on NWP will be assessed through satellite data assimilation using the NCEP Global Forecast System (GFS) in the presence of existing observing network. As CrIS with a smaller FOV is not yet available on any of the present satellites, impact assessment will be performed in a simulated environment, also known as an Observing System Simulation Experiment (OSSE). CrIS observations at both the current and increased resolution are simulated from a known state of the atmosphere or the Nature Run. The control run assimilates CrIS observations at the current resolution, which is about 14km at nadir; and the experiment run assimilates CrIS observations that have a smaller FOV. Forecasts between the two runs will be evaluated. Prior to carrying out the CrIS experiments, the OSSE system will be calibrated against the real system to verify that the simulated data impact by comparing it to the real data impact.

14.04 Why observe temperature, water vapor, and cloud structures with high-spectral-resolution infrared observations at 1-km horizontal scales?
Presenter: Brian Kahn, NASA/JPL
Authors: Brian H. Kahn and Evan Fishbein

We will discuss a few ongoing scientific problems that will benefit from future generation, high-spectral-resolution infrared sounders that could make 1-km spatial scale observations. These are an order of magnitude higher than current operational sounders. The scale dependence of the probability distribution functions (pdfs) of temperature, water vapor, and cloud properties from general circulation models (GCMs), cloud-resolving models (CRMs), large-eddy simulation (LES), currently operational satellite-based imagers, sounders, and their derived geophysical products, and aircraft and surface-based in situ observations will be summarized in the context of resolving, observing, and sampling the atmosphere's scale-dependent variability. Quantifying the dependence of these pdfs by cloud regime, and their respective covariances, remains a broad challenge to the weather and

climate community. Advances are essential for providing the most relevant constraints for subgrid-scale parameterizations that are needed for further improvements in numerical weather prediction (NWP) and climate GCMs. A few notable discrepancies between observations and numerical simulations will be highlighted, and suggestions regarding observational priorities for high-spatial-resolution sounding observations will be put forth.

Session 14b: Future observations

14p.01 The development of a U.S. geostationary microwave sounder

Presenter: Bjorn Lambrigtsen, NASA/JPL
Authors: Bjorn Lambrigtsen

A geostationary microwave sounder, capable of providing temperature, water vapor, clouds, precipitation, and wind vectors in the presence of clouds and precipitation, will add tremendously to our ability to observe dynamic atmospheric phenomena, such as hurricanes and severe storms, monsoonal moisture flow, atmospheric rivers, etc. Such a sensor is now feasible, enabled by technology that has been developed under NASAâ's Instrument Incubator Program. The Jet Propulsion Laboratory has led that development in partnership with the University of Michigan. A prototype, the Geostationary Synthetic Thinned Aperture Radiometer (GeoSTAR), is essentially an "AMSU in GEO", i.e. it has similar capabilities as AMSU would have if it were operating on a geostationary satellite, including similar spatial resolution. GEO orbits are almost 50 times higher than the LEO orbits that current AMSUs operate from, and the corresponding scaling of aperture size required to maintain spatial resolution has stymied the development of such a sensor for many decades. The aperture synthesis approach implemented with GeoSTAR finally overcomes that obstacle, and the large number of microwave receivers and associated electronics required is made possible with the new technology that has now been developed. This development also enables the decadal-survey Precipitation and All-weather Temperature and Humidity (PATH) mission, and it is possible that NASA will elevate PATH from a low-priority "third-tier" mission to a higher priority first or second tier. In the meantime, a low-cost demonstration mission implementing a subset of the PATH objectives is feasible and has been proposed as a hosted payload on a commercial communications satellite, through the NASA EV-I Venture program. The objectives of such a mission is to advance our understanding and modeling of storm processes that control rapid or explosive intensification of hurricanes, mesoscale convective systems, and extratropical cyclones. Retrieval of temperature and water vapor profiles is possible even in the presence of moderate precipitation, and with the ability to derive horizontal wind vectors by tracking water vapor features, a rich set of parameters measuring the thermodynamics, dynamics and convection and sampled every 15 minutes, will enable significant progress in storm science.

14p.02 IASI-NG Program: General Status Overview

Presenter: Francois Bermudo, CNES
Authors: F. Bermudo, S. Rousseau, E. Péquignot, F. Bernard, S. Guibert

With notable improvements on spectral and radiometric performances compared with IASI first generation, CNES will develop the New Generation of the Infrared Atmospheric Sounding Interferometer (IASI-NG) key element of the EUMETSAT Polar System Second Generation (EPS-SG).

For the IASI-NG program, a cooperation agreement will be implemented between CNES and EUMETSAT. Under this agreement, CNES has technical oversight responsibility for the development and procurement of the instruments, the definition of instrument in flight operations, the Level 1 data processing software (L1C POP) and the IASI NG Technical Expertise Centre developments. (IASTEC) in charge of the in-flight calibration, validation and continuous performance monitoring. EUMETSAT will be in charge of operating IASI-NG, archiving and distributing data to the users.

IASI NG program has successfully reached an important milestone in spring 2015 with the successful completion of the Instrument Preliminary Definition Review. This review conducted with the instrument prime Airbus Defense and Space France selected by CNES in 2013 for the development of the IASI NG instrument, ended 1 and ½ year of phase B activities. The successful completion of this definition Review allowed moving to instrument Phase C/D activities with the objective to develop an build 3 flight models , one Proto Flight model (PFM) and 2 recurrent models (FM2 and FM3).

In the meantime CNES is consolidating the definition of the Level 0 and Level 1 Processing simultaneously with the specification of the L1 Operational processor and the Technical Expertise Centre. A system preliminary definition review planned in November 2015 will conclude these ongoing phase B activities.

The present paper reports on latest general status overview of IASI NG program, focusing on CNES involvements in this cooperation.

14p.03 Strategy for the validation of IASI-NG Level 1 processing

Presenter: Adrien Deschamps, CNES
Authors: A. Deschamps, B. Tournier, J. Donnadille, C. Standfuss, H. Makhmara, E. Pequignot , F. Bernard, E. Baldit, S. Rousseau, F. Bermudo

The definition and the development of the IASI-NG Level 1 processing are under responsibility of CNES. Whereas the information about the algorithms constituting the Level 1 Processor are given in the paper named "IASI-NG processing overview" (Pequignot et al.), this papers aims at presenting the strategy adopted for the validation of the processing chains.

In order to validate the different steps needed to obtained geo-located spectra, spectrally and radiometrically calibrated (Level 1 products) from uncalibrated raw spectra (Level 0 products), a simulator has been developed. In a first part, we present this simulator, developed for CNES by Noveltis. Thanks to this tool, raw interferograms can be simulated, then transformed into complex spectra in the on-board processing and finally calibrated during the on-ground processing. This simulator has already been used to establish performances budgets for the IASI-NG system.

Then, we describe the strategy adopted to validate, functionally and scientifically, the Level 1 processing chain using this simulator through different sensitivity studies. In particular, we present the scheme for the equalization of the instrument spectral response function then we assess the impact of several instrumental defaults (microvibrations, wave-front errors, refractive index variations) on this equalization.

Other steps of the level 1 processing chains have been studied, such as the radiometric calibration of the spectra.

14p.04 Evaluation of IASI-NG impact on NWP and atmospheric chemistry compared to IASI

Presenter: Myriam Peyre (for Javier Andrey-Andrés, Meteo-France)
Authors: Javier Andrey-Andrés, Vincent Guidard, Nadia Fourrie

The hyperspectral infrared sounder IASI has already demonstrated its high capabilities for Numerical Weather Prediction (NWP), atmospheric composition and climate studies. As the second generation of the European Polar System (ESP-SG) is being prepared, a new generation of IASI has been designed and will be on board EPS-SG: IASI-NG (Crevoisier et al., 2013). IASI-NG will benefits from an increased design compared to IASI: double spectral resolution and radiometric noise decreased by a factor 2.

In order to get ready to use this new instrument and to evaluate its impact on various applications, a series of simulated data has been built up. The database of simulations contains also spatial and temporal coordinates, IASI viewing geometry, surface emissivities and vertical profiles of some chemical compounds and cloud properties. 4 Metop full orbits have been simulated for IASI and IASI-NG. This work presents the simulations carried out, focusing on the database available information and how they were carried out.

Additionally, 1D-Var assimilation experiments have been carried out for different conditions and world regions to evaluate the impact of IASI-NG with respect to IASI. Results will be presented.

14p.05 Correlated and Uncorrelated noise of the JPSS-1 Crosstrack Infrared Sensor (CrIS)

Presenter: Denis Tremblay, SDPI/NOAA/ERT
Authors: Denis Tremblay, Yong Chen, Yong Han, Likun Wang, Xin Jin, Xiaozhen Xiong, Lihang Zhou

The CrIS FM2 is manifest onboard the JPSS-1 satellite scheduled for launch is 2017. CrIS is a Michelson-type Fourier Transform Spectrometer (FTS). It will measure the IR spectral radiance in three separate frequency bands covering from 650 to 2550 cm-1 at resolution of 0.625 cm-1 for all 3 bands (long wavelength or LWIR, medium wavelength or MWIR, and short wavelength or SWIR). Knowledge of the noise characterization is important for radiance assimilation into forecasting models.

The TVAC scan scenario data (5 hours of operational mode data) were processed giving the CrIS radiance. The calculated noise equivalent differential radiance (NEdN) shows that CrIS meets the requirements to the exception of the MWIR FOV 9 which has some outages. The requirements define the noise as being calculated without the effect of the inverse self-apodization (ISA) and the resampling matrices for unapodized data.

Compared with CrIS on S-NPP satellite (FM-1), FM-2 has higher noise in the MWIR and SWIR. The higher number of data points (2X for MWIR and 4X for SWIR) increases the noise by a square root factor (1.4X for MWIR, 2X for SWIR). The ISA matrix forms the basis of the instrument line shape (ILS) correction which is part of the SDR algorithm. It contains increasingly higher off-diagonal values with higher frequency. As result, the unapodized data shows an increase of noise due to the ISA matrix that has a dependency on the frequency and the FOV off-axis location that affect the SWIR band.

14p.06 Evaluation of sounding capability of the next generation Imager of Korea using the Advanced Himawari Imager data

Presenter: Byung-il Lee (for Su Jeong Lee), NMSC/KMA
Authors: Su Jeong Lee, Myoung-Hwan Ahn, Sung-Rae Chung

A physical retrieval algorithm has been developed in the preparation of the second generation geostationary imager of Korea, the Advanced Meteorological Imager (AMI). The prototype algorithm is based on the Global Instability Indices (GII) retrieval scheme from the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), which uses one dimensional variational approach to iteratively retrieve atmospheric temperature and moisture profiles. For the forward model, the latest version of Radiative Transfer for TOVS (version RTTOV 11.2) is adopted. For the background profiles, the Unified Model (UM) 6-hour forecast fields with the spatial resolution of 25 km are utilized. For the validation of the prototype algorithm and the investigation of feasibility of newly launched high performance imager data, i.e the 16-channel Advanced Himawari Imager (AHI) on board Himawari-8, to the real time monitoring of severe weather phenomena, we applied the prototype algorithm to the AHI. For the validation, we use both radiosonde and NWP analysis field, although the comparison period is limited (i.e the AHI data is available after July, 2015). For the feasibility test, we will investigate several case studies which produce the severe weather phenomena over the interested area and the detailed results are going to be presented during the conference.

14p.07 Exploring Value-added Impact from Geostationary Hyperspectral Infrared Sounder on Hurricane Forecasts

Presenter: Zhenglong Li, UW-Madison/SSEC
Authors: Zhenglong Li, Jun Li, Timothy Schmit, Feng Zhu, Pei Wang, Agnes Lim, Jinlong Li, Robert Atlas, and Ross Hoffman

Future geostationary (Geo) hyperspectral InfraRed (IR) sounders have finer spatial, spectral, and temporal resolutions compared with the existing Geostationary Operational Environmental Satellite (GOES) sounders, providing much improved resolving power of atmospheric thermodynamic information. When quantitatively assessing the value added impact from such instruments over the current sounding systems onboard the Low Earth Orbit (Leo) satellites, the real question is what is the optimal impact using the current assimilation/forecast system. More specifically, will assimilating more observations from future Geo IR sounders with the current assimilation/forecast system yield improved forecast as expected? And if so, how to assimilate the high temporal resolution Geo sounding information and what is the impact on forecasts? Taken tropical cyclone (TC) forecasting as an example, this study tries to answer these questions through a quick Observing System Simulation Experiments (OSSE) study. The synthetic observations are simulated from the sample European Center for Medium-Range Weather Forecast (ECMWF) T1279 nature run (NR) for Hurricane Sandy (2012), including Radiosonde Observations (RAOB, representing conventional observations), the Leo Atmospheric InfraRed Sounder (AIRS), and Geo AIRS. Various experiments were carried out using WRF 3.6.1 and GSI 3.3 to study the impact on Sandy track forecast. And the study shows that a) it is critical to assign a large observational error (R matrix, 4~5 times of normal values) in order to show improved positive impacts from Geo AIRS over Leo AIRS; b) cycling of 3/6-hourly shows improved positive impacts over none cycling, but hourly cycling shows worse forecast among all experiments, and c) with thinning (120 ~ 240 km), the impacts have the following order: hourly > 3-hourly > 6-hourly > none cycling. These experiments indicate that while more observations may improve forecast, much more observations actually degrade the performance with the current assimilation system. There exists a tradeoff between the number of observations and impact of single observation in order to maintain the value-added impact. The ultimate objective of this study is to find the optimal point where the advantage of observations is maximized with existing assimilation/forecast system. This will be done by adjusting the relative weight between the background and the observations. While keeping

the O and R matrices unchanged, a single regulation parameter will be added to the background term in the cost function, with a large value indicating more weight on the background. For each cycling experiment, an optimal value of the regulation parameter will be determined to yield the optimal forecasts. And these forecasts will be used to determine whether future high temporal resolution Geo IR sounders may improve the hurricane forecast.