CIMSS Cooperative Agreement Semi-Annual Report

Period Covered:
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Submitted by:
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Task A. Administrative Base Support

1. Board Meeting:

The annual Cooperative Institute of Meteorological Satellite Studies (CIMSS) Board of Directors meeting was held on Thursday, 14 December 2000, at the Space Science and Engineering Center (SSEC) in Madison, Wisconsin. Representatives from NOAA, NASA, the University of Wisconsin and CIMSS met to review past activities and the future direction of CIMSS. CIMSS Director Steve Ackerman presented an overview of CIMSS activities during the past year and Henry Revercomb, Acting Director of SSEC, discussed the current leadership and future plans for SSEC. Several SSEC and CIMSS scientists presented program overviews on remote sensing applications and visualization tools. The Board was very encouraged by CIMSS activities.

2. Graduate Students:

CIMSS is supporting several UW-Madison graduate students on projects related to GOES and POES measurements:

Paolo Antonelli completed his Ph.D. degree investigating methods of data compression. The results of this work are applicable to preparing for the high data rates of ABS/ABI.

Kurt Brueske is working on his Ph.D. degree on improving the estimation of tropical cyclone intensity using multiple satellite measurements, especially warm core information that can be derived from the NOAA –15 AMSU instrument.

Amy Doherty is a Ph.D. candidate from the University of Greenwich, England visiting CIMSS for a year to work with scientists on determining rainfall rate retrieval from NOAA AMSU radiance measurements.

3. Visitors:

Each year CIMSS provides financial and facilities support to a few longer term visitors (one month to one year) who work on collaborative projects of mutual interest. During the past 6 months, the following longer term visitors have worked at CIMSS:

Dr. Eva Borbas is a visiting scientist from the Hungarian Meteorological Service studying satellite based retrieval methods from GPS occultation. Dr. Borbas is also participating in the validation of temperature and moisture retrieval from the NOAA polar ATOVS instruments.

Task B. Remote Sensing Research and Development

1. GOES Sounder Retrieval:

Contributions from the Wisconsin component of the GOES-11 check-out were collected and edited. The report summarizes the improved data (less noise and striping) from the GOES-11 Sounder and also the improved retrievals (total precipitable water vapor RMSE was improved by 1 mm). GOES-11 retrievals were also validated at the DOE/ARM CART site.

Experimentation was performed with Jun Li's regression guess code and 3 sets of coefficients for sounder retrievals. The significance of this work is that it may lead to a guess-independent GOES retrieval solution. This type of solution is preferred by both numerical weather prediction users as well as forecasters. Preliminary results are encouraging.

A manuscript entitled "Introducing the GOES-M Imager" was submitted to the journal National Weather Association Digest. The manuscript summarizes the hardware changes on the GOES-M imager and also discusses which imager-based products will be improved or degraded. Improved products include the imager-based cloud information and satellite-derived motion vectors. The loss of the 12 micron channel will negatively impact the detection of volcanic ash plumes.

The changes to the imager also resulted in updates being made to the radiative forward model used for the sounder. The reason changes in the imager hardware affected the sounder software is that one package is used to support both instruments.

The routine generation of hourly GOES sounder products continued. By running the algorithms, the code is continually being tested. In order to successfully produce the GOES Sounder temperature/moisture products (including the Derived Product Images), maintenance of software and monitoring of ancillary data are required on a routine basis. Running these algorithms constantly tests the code and any changes made to it. We also maintain a daily tape archive of the retrievals and ancillary data (approximately 2.75 gigabytes per day).

Work continues on refining the GOES sounder retrievals by using an explicit surface emissivity term. A case from September 6, 2000 has been used to compare the updated retrievals with both the real-time retrievals and radiosondes.

CIMSS supplied a host of users of GOES sounder data with both real-time and historical data sets.

We are continuing to collaborate with the Europeans at EUMETSAT on the generation of stability parameters from their next generation imager data. GOES sounder radiance biases were calculated and shared. An abstract that is in part on this topic was submitted to the AMS Conference on Satellite Meteorology and Oceanography to be held October 2001 in Madison, WI. It is titled, "An evaluation of several years of CIMSS and NESDIS GOES Sounder data," and was submitted along with two other abstracts:

"Is the resolution of GOES sounder data sufficient to support single field of view retrievals and derived products?"

"Calibration of GOES Visible Channels."

Publications:

Dostalek, J. F, and T. J. Schmit, 2001: Total precipitable water measurements from GOES Sounder derived product imagery. Submitted to *Wea. Forecasting*.

Ellrod, G. P., J. P. Nelson III, M. R. Witiw, L. Bottos, and W. P. Roeder, 2000: Experimental GOES Sounder products for the assessment of downburst potential. *Wea. Forecasting,* 15, 527-542.

Schmit, T. J., W. F. Feltz, W. P. Menzel, J. Jung, A. P. Noel, J. N. Heil, J. P. Nelson III, and G. S. Wade, 2001: Validation and use of GOES sounder moisture information. – Revisions sent to *Wea. Forecasting.*

Schmit, T. J, E. M. Prins, A. J. Schreiner, and J. J. Gurka, 2001: Introducing the GOES-M Imager. Submitted to the *National Weather Association Digest.*

Plokhenko, Y. and W. P. Menzel, 2000: Mathematical aspects for meteorological processing of infrared spectral measurements from the GOES sounder: Constructing the measurement estimate using spatial smoothing. Accepted pending minor revision by J. Appl. Meteor., Vol 40, p 556 - 567

2. Cloud Products from the GOES Sounder

After comments from forecasters, and in order to more correctly identify the heights of clouds over the eastern Pacific using the GOES Sounder radiances, a technique was developed taking into account the low level boundary layer and resultant strong temperature inversion. A technique to accommodate for these incorrectly assigned cloud heights was developed based on work performed by Frederick R. Mosher and Larry Hinson at the Aviation Weather Center in Kansas City, Missouri. The technique was implemented in the CIMSS' routine processing of GOES Sounder cloud product in December 2000. An article describing the technique and the impact to numerical forecasts using the improved cloud product will be submitted to the National Weather Association *Digest* in May 2001.

A technique using the long wave, short wave, and dirty windows, plus the visible and 13.4 μm bands on the GOES Sounder was developed to detect snow in May 2000. In January 2001, it was implemented to run in parallel mode to the CIMSS' routine processing of the GOES Sounder cloud product. It will replace the current snow detection technique in June 2001. A plan to incorporate this daytime snow product for nighttime applications is to be accomplished before winter 2001/2002.

In collaboration with James Hawkinson, Wayne F. Feltz, and Timothy J. Schmit, comparisons of the GOES Sounder cloud product to Micropulse Lidar/Millimeter Cloud Radar (MPL/MMCR) ground-based data from the Department of Energy's (DOE) Atmospheric Radiation Measurement (ARM) program Cloud and Radiation Testbed (CART) site near Lamont, Oklahoma were made. The comparison shows high correlation coefficients (>0.9) between the two independent measurements. The measurements also agree upon the existence or lack there of a cloud three-fourths of the sampled time for data compiled during March 2000. An abstract on this topic was submitted for the AMS Conference on Satellite Meteorology and Oceanography to be held October 2001 in Madison, WI.

Several outside users and researchers have requested output from the GOES Sounder cloud product processing system either in a real-time mode or for special cases. The outside users and their requests are as follows:

Dr. Randall J. Alliss, Northrup-Grumman-Litton-TASC. Requested continuous hourly GOES Sounder derived cloud product in area format for all four Sounder sectors.

Dr. James F. Garten, Space Physics Research Laboratory, University of Michigan. Requested GOES Sounder derived cloud in ASCII format to compare with remotely retrieved cloud tops from the High-Resolution Doppler Imager (HRDI).

Cloud Product from the GOES-M Imager

In preparation for the next in the series of GOES Imagers (which is to be launched in July 2001) software is being modified to accommodate the addition of the 13.3 μm band and the loss of the 12.0 μm band. The addition of the new channel will permit cloud products via the CO_2 absorption technique and the elimination of the 12.0 μm band will require modifications to the cloud mask algorithm. A figure (in the form of .GIF) compares the bands and band widths for GOES-8 and (the soon to be designated) –12 Imager. An abstract on this topic was submitted for the AMS Conference on Satellite Meteorology and Oceanography to be held October 2001 in Madison, WI.

Cloud Trends

An article was written and accepted (see below) based on twenty-six months of sampled cloud product information from the GOES Sounder. Additionally, this article detailed the cloud masking techniques used in generating retrieved products (cloud and temperature/moisture retrievals plus the derived product imagery) from the GOES Sounder. Sampled cloud data continues to be archived and monitored. The data set is continuous from November 1997 to present.

Publications:

Li, Jun, W. P. Menzel, and A.J. Schreiner, 2001: Variational retrieval of cloud parameters from GOES sounder longwave cloudy radiance measurements. *J. Appl. Meteor.*, 40, 312-330.

Schreiner, A.J., T.J. Schmit, W.P. Menzel, 2001: Observations and trends of clouds based on GOES sounder data. Accepted for publishing by *J. Geophys. Res.*

Conferences:

Schreiner, A.J., W.F. Feltz, J. Hawkinson, and T.J. Schmit, 2000: Maritime Inversions and the GOES sounder cloud product. N.W.A. 25th Annual Meeting, 14-20 October 2000, Gaithersburg, Maryland.

3. Winds

CIMSS participated in GWINDEX (GOES rapid-scan WINDs EXperiment) and PACJET (PACific landfalling JETs experiment) programs through the use of its research cloud-motion wind sets. The objective was to demonstrate improved quantity and quality of winds derived from special 7.5-minute rapid-scan visible and infrared imagery from GOES-10. Feedback from forecasters and PACJET mission planners was positive. A paper was submitted to the AMS Weather Analysis and Forecasting meeting in July. The datasets were also transmitted in real time to FSL for inclusion in a special PACJET RUC cycle. The impact of these winds on the RUC forecasts is being evaluated. A paper has been submitted to the AMS NWP conference in July.

An online archive of these wind sets was produced and is available on the CIMSS web site:

http://gale.ssec.wisc.edu/

Modifications were made to the automated GOES winds algorithm both in preparation for and as a consequence of these experiments. Historically, targeting has been performed on the initial image in a three-image sequence, and wind vectors produced by tracking those targets on subsequent images. To facilitate tracking of transient, small-scale features made apparent by rapid-scan imagery, scientists at NESDIS and CIMSS collaborated to develop and implement a new method in which the middle image of the triplet is used for targeting, and vectors are calculated backward and forward to the features' locations on the first and third images. All GOES-10 winds produced during the GWINDEX demonstration period used this new and improved method.

Two additional modifications were instituted as a result of observations of sparse and missing high-level winds early in the experiment period. Quality control and auto-editing were rejecting winds along the edge of jet streaks where very fast vectors failed checks against model forecast guess fields. A post-processing routine was developed to restore winds that had been rejected under these circumstances. Other high-level winds were being rejected because errors in height assignment were placing them too high in the troposphere. An upper limit, based on the height of the tropopause from the model forecast, was imposed to override assigned heights in these cases. All of these modifications have been tested and statistically analyzed.

We have started experimenting with the GOES shortwave IR (3.9 micron) channel for tracking low clouds at night. While this study is just underway, preliminary indications are positive. In cases of low-level stratocumulus clouds off the west coast, vectors numbers are considerably higher using the 3.9 channel vs. the conventional long-wave (11 micron). Further study, including a rigorous statistical analysis, is planned.

Polar winds

Efforts have been initiated to show that high-latitude winds can be estimated by tracking clouds from high-resolution polar orbiter images. Wind sets covering both the Arctic and Antarctic regions have been generated as proof of concept using MODIS images (11 micron infrared and 6.7 micron water vapor) from consecutive overpasses about 1.5 hours apart. Preliminary results suggest that the wind sets produced are coherent and may provide valuable wind estimates in these data sparse regions. Further work is underway to refine the CIMSS automated winds algorithm to employ MODIS images and create winds over the polar regions.

4. AERI and ARM Satellite Validation Report

This research project can be separated into three distinct areas. The first is development and validation of Atmospheric Emitted Radiance Interferometer (AERI) boundary layer temperature and moisture profiles in the Southern Great Plains. The second area of research is using ground-based Department of Energy Atmospheric Radiation Measurement (ARM) data to validate GOES and NOAA polar orbiting operational satellite products. The third area of focus was validation of Water Vapor Sensing Systems mounted on United Parcel Service (UPS) aircraft at Louisville, Kentucky.

A real-time ten minute resolution temperature and moisture retrieval algorithm has been developed to produce profiles from high spectral resolution infrared measurements from AERI instruments. The DOE ARM program has deployed a suite of five instruments located in Oklahoma and Kansas collocated next to NOAA 404 MHz wind profilers. Near real-time stability indices are calculated and displayed at the following internet site:

http://zonda.ssec.wisc.edu/~waynef

The data can also be used to validate operational numerical weather prediction models such as the Rapid Update Cycle (RUC-2) model. The AERI instruments are currently being evaluated as potential temperature and moisture profiling systems to monitor Gulf of Mexico water vapor return flow and rapid thermodynamic destabilization.

Another area of research has been focused upon validation of GOES temperature, moisture, integrated water vapor, and cloud top altitude products with DOE Atmospheric Radiation Measurement (DOE ARM). Specifically, an area of emphasis has been placed on validating GOES retrieved cloud top pressure using micropulse lidar and millimeter cloud radar data from the DOE ARM site near Lamont, Oklahoma. A correlation of greater than 90% exists between the ground-based and satellite cloud top altitudes. A project to compare GOES integrated water vapor in near real-time to DOE ARM measurements has continued. Results are available at:

http://zonda.ssec.wisc.edu/~waynef/aerigoes/lamont/goes_validation/tpw

Other GOES products will be validated in a similar manner as more DOE ARM real-time data becomes available. A unique validation data set will become available in Fall 2002 after the International H_2O Project (IHOP) project which will be conducted in the Oklahoma/Kansas area to effectively map the four dimensional water vapor field. A planning meeting for the campaign was attended and great interest in NOAA operational satellite products was expressed.

A final report and peer reviewed paper was written on the Water Vapor Sensing System experiment conducted at the Louisville International airport in Fall 1999. A suite of instruments was deployed from the University of Wisconsin - Madison SSEC to evaluate the quality of water vapor sensors installed in UPS aircraft. This sensor would supplement ACARS data (temperature and winds) already available from commercial aircraft. Although WVSS instrument calibration was an issue, the data looks promising as another potential profiling system near airport hubs.

Peer Reviewed Papers:

Feltz, W. F. and J. R. Mecikalski, 2001: Monitoring high temporal resolution convective stability indices using the ground-based Atmospheric Emitted Radiance Interferometer (AERI) during the 3 May 1999 Oklahoma/Kansas tornado outbreak. *Weather and Forecasting*, In review.

Fleming, R. J., D. R. Gallant, W. F. Feltz, J. G. Meitin, W. R. Moninger, S. F. Williams, and R. T. Baker, 2001: Water vapor profiles from Commercial Aircraft. Bull. Amer. Meteor. Soc., Submitted.

Lehmiller, G. S., H. B. Bluestein, P. J. Neiman, F. M. Ralph, W. F. Feltz, 2000: Wind structure in a supercell thunderstorm as measured by a UHF wind profiler. *Weather and Forecasting*, In Press.

Schmit, T. J., W. F. Feltz, W. P. Menzel, J. Jung, J. P. Nelson III, and G. S. Wade, 2001: Validation and Use of GOES Sounder Moisture Information. *Weather and Forecasting*., In review.

Whiteman, D.N., K.D. Evans, B. Demoz, D.O'C. Starr, D. Tobin, W. Feltz, G.J. Jedlovec, S.I. Gutman, G.K. Schwemmer, M. Cadirola, S.H. Melfi, F.J. Schmidlin: 2001, "Raman lidar measurements of water vapor and cirrus clouds during the passage of hurricane Bonnie", J. Geophys. Res., Vol 106, No D6, 5211-5225.

Conferences:

Feltz, W. F., 2000: Nowcasting Convective Initiation with the Atmospheric Emitted Radiance Interferometer (AERI). 20th Conference on Severe Local Storms, Orlando, FL, 11-15 September 2000 (preprints). Boston, MA, American Meteorological Society, pp575-578.

Feltz, W. F., R. O. Knuteson, H. B. Howell, and D. D. Turner, 2000: Near Continuous Profiling of Temperature, Moisture, and Atmospheric Stability Using the Atmospheric Emitted Radiance Interferometer (AERI). Fifth International Symposium on Atmospheric Stability, 4-8 December 2000 (preprints). Extended Abstracts, pp7-9.

Mecikalski, J. R. and W. F. Feltz, 2000: Nowcasting the 3 May 1999 Oklahoma tornado outbreak using the AERI ground-based interferometer. 20th Conference on Severe Local Storms, Orlando, FL, 11-15 September 2000 (preprints). Boston, MA, American Meteorological Society, pp25-28.

Petersen, R. A., W. F. Feltz, J. Schaefer, R. Schneider, 2000: An analysis of low-level moisture-flux convergence prior to 3 May 1999 Oklahoma city tornadoes. 20th Conference on Severe Local Storms, Orlando, FL, 11-15 September 2000 (preprints). Boston, MA, American Meteorological Society, pp619-621.

5. Intercalibration

Intercalibration of the polar orbiting and geostationary satellite systems is an ongoing effort at CIMSS. The goal is intercalibration of the five geostationary satellites with a single polar orbiting satellite using temporally and spatially co-located measurements. This is being done currently for the 6.7 μm water vapor channel and the 11 μm infrared window channel for comparisons of GOES-8, GOES-10, METEOSAT-5, METEOSAT-7, and GMS-5 with NOAA-14 HIRS and AVHRR. The technique for intercalibration has been developed over the past several years at CIMSS. The results are presented annually at the Coordination Group for Meteorological Satellites (CGMS) meeting. Daily updates are reported on the World Wide Web via computer automation:

http://cimss.ssec.wisc.edu/goes/intercal

Recent efforts have focused on making the software portable. The current software utilizes four separate software formats (FORTRAN77, MATLAB, FORTRAN77 for McIDAS, and C for McIDAS). Thus all software products used for intercalibration are being converted to Fortran77 to be run in McIDAS for ease of use, portability, and understanding. This process is nearly complete and we expect to provide the code to interested persons before the end of summer, 2001.

New instruments have been, and continue to be, added to the intercalibration software suite. The software is prepared to process MODIS data, although MODIS data is difficult to collect in real-time at geostationary nadir which blocks efforts to intercalibrate routinely with the other instruments. GOES-M is scheduled to launch July 12, 2001 and the software is being updated to meet the launch date. In anticipation of the future degradation or possible loss of NOAA-14, the software is being upgraded to include NOAA-15 and NOAA-16 HIRS and AVHRR, though we will continue to use NOAA-14 for as long as possible to maintain a continuous data set. We are prepared to use GOES-11, though that instrument is currently being kept in storage mode.

In addition to the ongoing daily comparisons, there have been experiments with varying the methodology. In collaboration with colleagues at EUMETSAT and NOAA, the intercalibration technique was applied to compare the METEOSAT-7 11 μm channel to the AVHRR 12 μm channel on NOAA-14. Our results appear to be more optimistic than those obtained at EUMETSAT. This led to investigating our computational methods.

The intercalibration program at CIMSS is currently undergoing two major changes in methodology, which we anticipate will significantly affect the results. The first change is to update the fast forward model to a current version of PLOD/PFAAST. This is believed to provide more accurate results. The second change is to stop converting radiances to brightness temperatures using the slope of the Planck function but to use the inverse Planck function instead. We believe both of these changes will enhance the intercalibration process scientifically, though the implementation of the second change may produce results that appear less optimistic in terms of how well the different instruments compare. We believe these results will be better understood, by our colleagues at EUMETSAT and elsewhere, than the results using prior methods.

Conferences:

Submitted "Intercalibration of geostationary (GOES, Meteosat, GMS) and polar orbiting (HIRS, AVHRR, MODIS) Infrared window and Water Vapor Radiances" by Gunshor, M. M., T. J. Schmit, and W. P. Menzel. CGMS (Coordination Group for Meteorological Satellites) XXVIII held 16 – 20 October 2000 in Woods Hole, MA. An EUMETSAT publication.

Submitted an abstract on intercalibration titled "Intercalibration of geostationary and polar orbiting infrared window and water vapor radiances" by Mathew M. Gunshor, T. J. Schmit, and W. P. Menzel to the AMS Conference on Satellite Meteorology and Oceanography scheduled to take place in Madison, WI on 15-18 October 2001. The poster will focus on recent updates in methodology made to the routine intercalibration of geostationary satellites (GOES-8, -10, Meteosat-5, -7, and GMS-5) using a single polar orbiter (NOAA-14 HIRS and AVHRR).

Task E. Data Assimilation Studies

1. EDAS Studies:

The 48km Eta Data Assimilation System (EDAS), which uses radiances, has been ported to an SGI platform. This new version of the EDAS uses satellite radiances instead of the retrieval soundings. This version also uses GOES Sounder moisture radiances over the ocean instead of the PW retrievals while still using GOES Sounder PW product over land.

A cloud assimilation routine has been incorporated into the 48km Eta model. The routine adjusts the cloud field in the model during each physics timestep (480 sec.) during the 12 hour data assimilation cycle. Cloud is removed down to the level of cloud top pressure. Then, if no cloud exists at the observed cloud top level, cloud water mass is added. Precipitation threat score analysis and RAOB match statistics for 3 weeks during the winter have been completed.

While coding and testing the cloud assimilation routine, an inconsistency was discovered in the specific humidity being advected into the Eta model from the boundaries. The boundary conditions contain unrealistic super saturation conditions which are causing excess cloud to be generated. Work continues to resolve this issue.

Publications in progress:

"Validation and Use of GOES Sounder Moisture Information" by Timothy J. Schmit, et, al.

"An Impact Study of Five Remotely Sensed and Five In-situ Data Types in the Eta Data Assimilation System" by Tom H. Zapotocny et. al.

Conferences:

A poster presentation titled "Assimilation of GOES Sounder Cloud Top Pressure in NCEP's 48 km Eta Mesoscale Model" was submitted for the AMS 11th Conference on Satellite Meteorology and Oceanography to be held October 2001 in Madison, WI.

2. A Three Season Impact Study of Five Satellite and Five In-Situ Data Types in the Eta Data Assimilation/Forecast System

The impact of five satellite and five in-situ data types in the Eta Data Assimilation/Forecast System (EDAS) is studied for 10-day time periods during three seasons. The satellite data types include GOES Sounder marine three layer clear air precipitable water (PW) (GOESPW), SSM/I marine vertically-integrated PW (SSM/I), TOVS marine temperature retrievals down to cloud top (TOVCD), GOES Imager marine infrared cloud drift winds (GOESCD), and GOES Imager marine water vapor cloud top winds (GOESWV). The in-situ data types include RAOB temperature, moisture and height (RAOBM), RAOB winds (RAOBW), ACARS temperature (ACARM), ACARS winds (ACARW), and surface land observations (SFCLM).
The case studies chosen include 10-day periods during December 1998, April 1999 and July 1999. During these periods, eleven EDAS runs are executed twice daily. The eleven runs include a control run utilizing all data types used in the EDAS, and ten experimental runs in which one of the data types described above is denied. Accumulated differences between the experimental runs and control run are then analyzed to demonstrate the 00-hr sensitivity and 24-hr and 48-hr forecast impact of these data types in the EDAS. Meteorological state variables evaluated include temperature, east-west component of the wind, and relative humidity on pressure levels spanning the troposphere from the ground to jet stream level.

Results show that a positive forecast impact is achieved in the EDAS from nearly all of the data types. The 300 hPa SSM/I east-west wind forecast impact is the only exception. The RAOBM, RAOBW and GOESCD data types provide the most positive forecast impact when considering all three fields as a whole. When considering relative humidity, SSM/I and GOESPW display similar forecast impacts throughout the troposphere as RAOBM, RAOBW and GOESCD.

Both RAOB components and GOESCD provide a nearly equal contribution during each of the three seasons. On the other hand, GOESPW and SSM/I are approximately four times larger in summer than winter, especially in the lower to middle troposphere. Contribution from the TOVCD data type is approximately three times larger during the winter season than the summer season. The remaining four data types (GOESWV, ACARM, ACARW and SFCLM) provide smaller positive forecast impacts, and remain relatively constant from season to season.

Publications:

Zapotocny, T. H., W. Paul Menzel, J. P. Nelson III, and J. A. Jung, 2000: An impact study of five remotely sensed and five in-situ data types in the Eta data assimilation system. Conditionally accepted for publication in *Wea .and Forecasting*.