

GOES-R Progress Report for January - March 2006
University of Wisconsin-Madison
Cooperative Institute for Meteorological Satellite Studies

Project Title: CIMSS Participation in GOES-R Risk Reduction
Principle Investigator: Steve Ackerman
Co-Investigators: Allen Huang (Algorithms), Chris Velden (Winds),
 Ralph Petersen (Nowcasting), Bob Knuteson (Data Systems),
Additional Contributors: Jun Li, Xiolie Zhou (FSU), Ray Garcia
Program Manager: Tom Achtor
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Remaining Funds: \$0

Topics Summary

Task 1. Algorithm Development

Program Management and Coordination

A dedicated internal web site has been developed and implemented for GOES-R Risk Reduction Algorithm Development team. Monthly work reports, group quarterly reports, meeting minutes, and announcements are uploaded to the site for use at monthly team meetings. The web site has improved the coordination among groups and efficiency in communication to meet project objective and deadlines. The web site address is
http://cimss.ssec.wisc.edu/goes_r/internal/alg_dev/

Soundings Algorithm Development

In Q2 of FFY2006, four areas of sounding activities are conducted:

(1) Vertical distribution expression in physical retrieval

Retrieval of the vertical structure from HES is very important for the application of soundings. Usually the temperature and moisture are expressed as a linear combination of basis functions. There are several ways to choose the basis functions. For example, the AIRS science team use trapezoid functions (Susskind et al. 2003). CIMSS scientists use eigenvectors (EV) derived from a historical profile data set as basis functions. Preliminary analysis has shown that profile can be expressed by 7 and 15 EVs, respectively for the temperature and water vapor profile to retain most of the vertical resolution while also maintaining the good balance of achieving the stable profile retrieval. Details of this work are reported in the web site “AD Quarterly Reports” [Q1 2006 Report – Sounding](#).

(2) Synergy of MODIS/AIRS for direct cloudy sounding retrieval is further studied

The imager/sounder direct cloudy sounding retrieval has the following advantages compared with the imager/sounder cloud-clearing procedure.

- (a) It does not require ABI and HES on the same satellite or to have the same view angle;
- (b) It does not require spectral overlap between ABI and HES for retrieval;
- (c) There is no noise amplification;
- (d) ABI provides lower tropospheric temperature and moisture information in clear skies, HES cloudy radiances provide better sounding information above clouds, a combination of ABI clear and HES cloudy radiances will give a better sounding

The procedure has been tested with MODIS/AIRS. In the last report we showed an initial result, and this time we made refinement. Again details are reported in the web site “AD Quarterly Reports” Q1 2006 Report – Sounding.

(3) Ocean wind case retrievals generated for wind study

Cube data from the WRF model are used to generate the clear and cloudy radiances with GIFTS noise included. Retrievals are generated in both clear and cloudy soundings for moisture wind tracking. Examples of moisture retrievals, truth, and the differences between retrieval and truth can be found in <ftp://ftp.ssec.wisc.edu/ABI/OceanWind/>

(4) AIRS retrievals generated for Ralph Petersen for convective development study

Four AIRS granules on 20 July 2005 were processed to generate MODIS/AIRS cloud-cleared radiances and soundings. Ralph Petersen will use those retrievals to study the convective development in US Mid-West region.

Surface Emissivity Study & Modeling

Work this quarter focused on; 1) developing the high spectral resolution emissivity database using principal component analysis (“versions B & C”), 2) writing a paper on the derivation of the moderate spectral resolution emissivity database (“version A”, baseline spectral fit to MOD11 points) and its application to AIRS and MODIS temperature and moisture retrievals, 3) presenting a poster on the database and its application to MODIS MOD07 at the AMS annual meeting (Seemann et al., A Global Infrared Surface Emissivity Database), and 4) creating two websites, one for the global clear sky training dataset (http://cimss.ssec.wisc.edu/training_data/) and one for the IR surface emissivity (<http://cimss.ssec.wisc.edu/irem/s/>). Both pages are linked to the ITWG Radiative Transfer Working Group's page. Details of this work are reported in the web site “AD Quarterly Reports” Q1 2006 Report – Surface Property.

NWP Modeling for Geostationary hyperspectral resolution measurement simulation

During this period of time:

1. The WRF model (ARW core) was used to generate a simulated atmospheric profile dataset for a case study referred to as the “OCEAN-WINDS” simulation. This simulation contains a single 1070 x 1070 grid point domain with 2-km horizontal resolution that covers the eastern U.S. and a portion of the western Atlantic. A simulated dataset with 30-minute temporal resolution and 4-km horizontal resolution (a coarsened version of the original model data) was generated for a 24-hour period during this simulation. A web page containing a brief description of the WRF model simulation and gif images of various atmospheric fields has been constructed for this case study. The webpage address is: <http://www.ssec.wisc.edu/~jasono/goes-r-awg/oceanwinds/index.html> .
2. A journal article entitled “Mesoscale numerical weather prediction models used in support of infrared hyperspectral measurements simulation and product algorithm development” was submitted to the Journal of Atmospheric and Oceanic Technology.
3. In an effort to better parameterize cloud microphysical processes in the WRF model, a recently developed double-moment microphysics scheme has been evaluated for use in future model simulations.
4. The WRF model (ARW core) was used to generate a simulated atmospheric profile dataset for a case study referred to as the “NP-CONVECTION” simulation. A webpage containing a brief description of the WRF model simulation and gif images of various atmospheric fields has been constructed for this case study. The web page address is:

http://www.ssec.wisc.edu/~jasono/goes-r-awg/np_convection/index.html .

5. Two different data assimilation utilities that have been developed for the WRF model were explored. Both utilities are still early in their development and as such are not currently able to assimilate satellite radiances.

Details of the above work is documented in the web site “AD Quarterly Reports” [Q1 2006 Report – NWP](#).

Cloudy Fast Forward Model Development

Work conducted during this period are summarized below:

- Ping Yang completed new reflection/transmission lookup databases for FIRTM2 that are based on Bryan Baum’s bulk scattering models
- Tom Greenwald wrote tangent linear model for FIRTM2 and performed initial testing.
- Leslie Moy completed forward, tangent linear and adjoint models for FPLOD (written in F95) and submitted them to our code repository.
- Tom Greenwald made further significant improvements to FIRTM2 code
- Version 1 of the complete GIFTS cloudy sky forward model (written in F95) was officially released
- Forward model code was provided to the sounding group for testing purposes
- Drafts of sections 9.1, 9.2 and 10.2 of the ATBD were created
- Tom Greenwald wrote a driver for the GIFTS cloudy sky forward model that directly reads a WRF output netCDF file, computes a TOA radiance spectrum at each grid point in the model domain and then writes out the radiances to a netCDF file. This code was used by Ray Garcia to determine computing resources needed for processing TOA radiances and will eventually replace the F77 version of the code that is currently used.

Significant Achievements in the last three months

- Optimization of HES vertical resolution for sounding retrieval.
- Refinement of synergistic processing approach for using imager and sounder data.
- Simulated and AIRS retrieval to support wind and convective development study.
- Generation of a global emissivity database and training dataset.
- Version 1 of the complete GIFTS cloudy sky forward model was officially released
- A double-moment microphysics scheme now can be used in WRF model to generate explicate cloud property.
- Working progress toward completing first version of sounding ATBD.
- A new three-dimensional winds dataset was produced for the Ocean Winds case using an updated retrieval algorithm that simulates HES soundings with cloud-masking.

Recent presentations & publications:

Wu, X., J. Li, W. P. Menzel, H. L. Huang, K. Baggett, H. Revercomb, 2005: Evaluation of AIRS cloud properties using MPACE data, *Geophysical Research Letters* (in press).

Li, J., H.-L. Huang, C.-Y. Liu, P. Yang, T. J. Schmit et al., 2005: Retrieval of cloud microphysical properties from MODIS and AIRS. *J. Appl. Meteorol.*, 44, 1526 – 1543.

Zhou, D. K, W. L. Smith, X. Liu, A. M. Larar, H. –L. Huang, J. Li, M. J. McGill, and S. A. Mango, 2005; Thermodynamic and cloud parameter retrieval using infrared spectral data, *J. Geophysical Letter*, 32, doi: 0.1029/2005GL023211.

Wu, X., J. Li, W. Zhang, and F. Wang, 2005: Atmospheric profile retrieval with AIRS data and validation at the ARM CART Site, *Advances in Atmospheric Sciences*, 22, 647 – 654.

Pradeep Thapliyal gave a seminar on 6 Mar 2006: Some Aspects of AIRS Sounding Retrieval and their Impact on IMAPP Products

Xuebao Wu gave a seminar on 6 Mar 2006: AIRS Sounding and Cloud Property Study

Plans for Next Three Months

- Continue to adopt and adapt the newly developed cloud property lookup table to improve cloudy forward model performance and speed.
- Continue to improve and refine cloudy sounding algorithm and update sounding retrieval strategy.
- Continue to refine ATBD and use latest ATBD to guide algorithm development and implementation.
- Continue to refine approaches to improve high spectral resolution global gridded emissivity database.
- The ATReC and Ocean Winds datasets will be validated against collocated rawinsondes.
- A new case is being prepared by the modeling and retrievals group that will simulate full-disk GOES-R HES coverage over a 24-hour period. The winds group will attempt to derive vector fields from this case once we are provided with the retrieval moisture fields.

Task 1: Winds Work Summary

A new dataset was recently provided by the GOES-R retrieval algorithm group for the “Ocean Winds” case that includes AIRS cloud-cleared or flagged retrievals (Figure 1). This new set of cloud-cleared AIRS retrieval moisture fields was used by the winds group to re-derive the height-resolved winds over the oceanic marine boundary layer and assess the quality. In the example shown (Figure 2), targets and wind vectors derived by tracking the constant-altitude moisture surface (729 hPa) over three consecutive 30-minute analyses (yellow vectors) are achieved in the clear sky regions. Similar wind vector coverage is achieved at other levels of the marine boundary layer and is shown in the plot in Figure 3.

The simulated GOES-R winds for this case will be validated against available rawinsonde observations, and this assessment will be covered in the next report.

Significant Accomplishments in the last three months

A new three-dimensional winds dataset was produced for the Ocean Winds case using an updated retrieval algorithm that simulates HES soundings with cloud-masking.

Plans for Next Three Months

The ATReC and Ocean Winds datasets will be validated against collocated rawinsondes.

A new case is being prepared by the modeling and retrievals group that will simulate full-disk GOES-R HES coverage over a 24-hour period. The winds group will attempt to derive vector fields from this case once we are provided with the retrieval moisture fields.

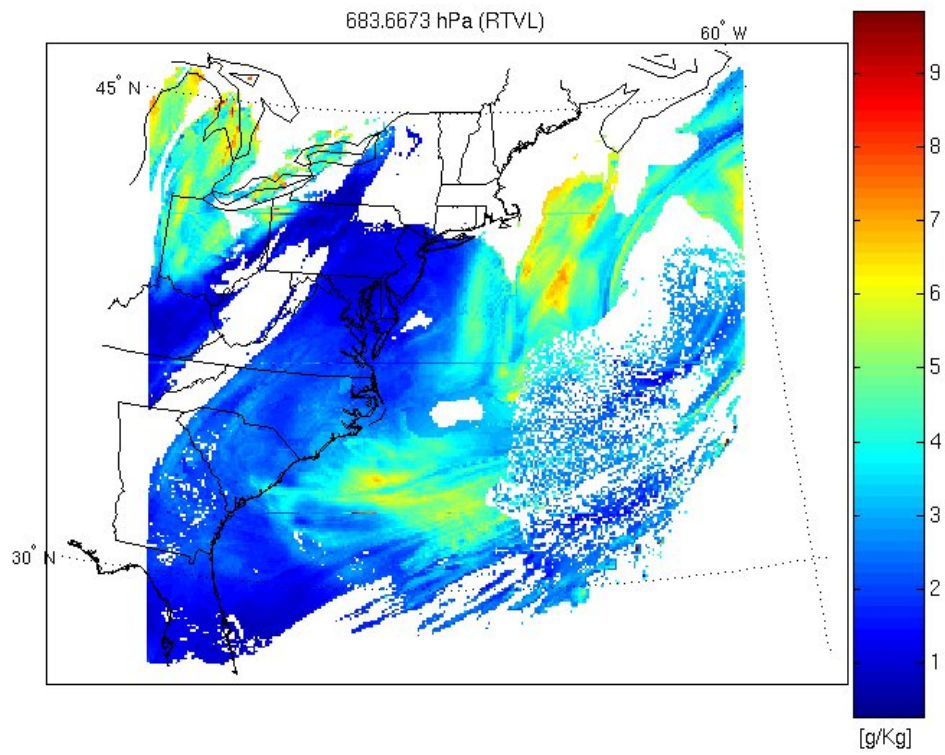


Fig 1. Case 2 – Ocean Winds Domain, concentration is on marine boundary layer

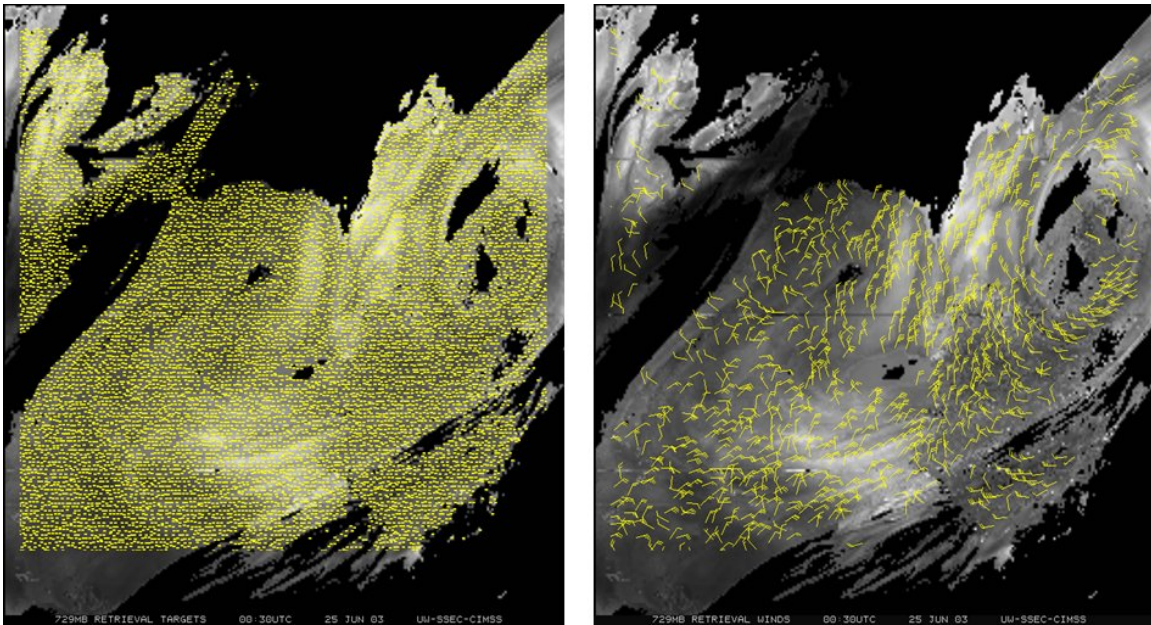


Fig 2. At 729 mb level: Left - Noise filter retrievals (14,414 targets): Right - QI Noise Filtered Retrievals (1,912 vectors)

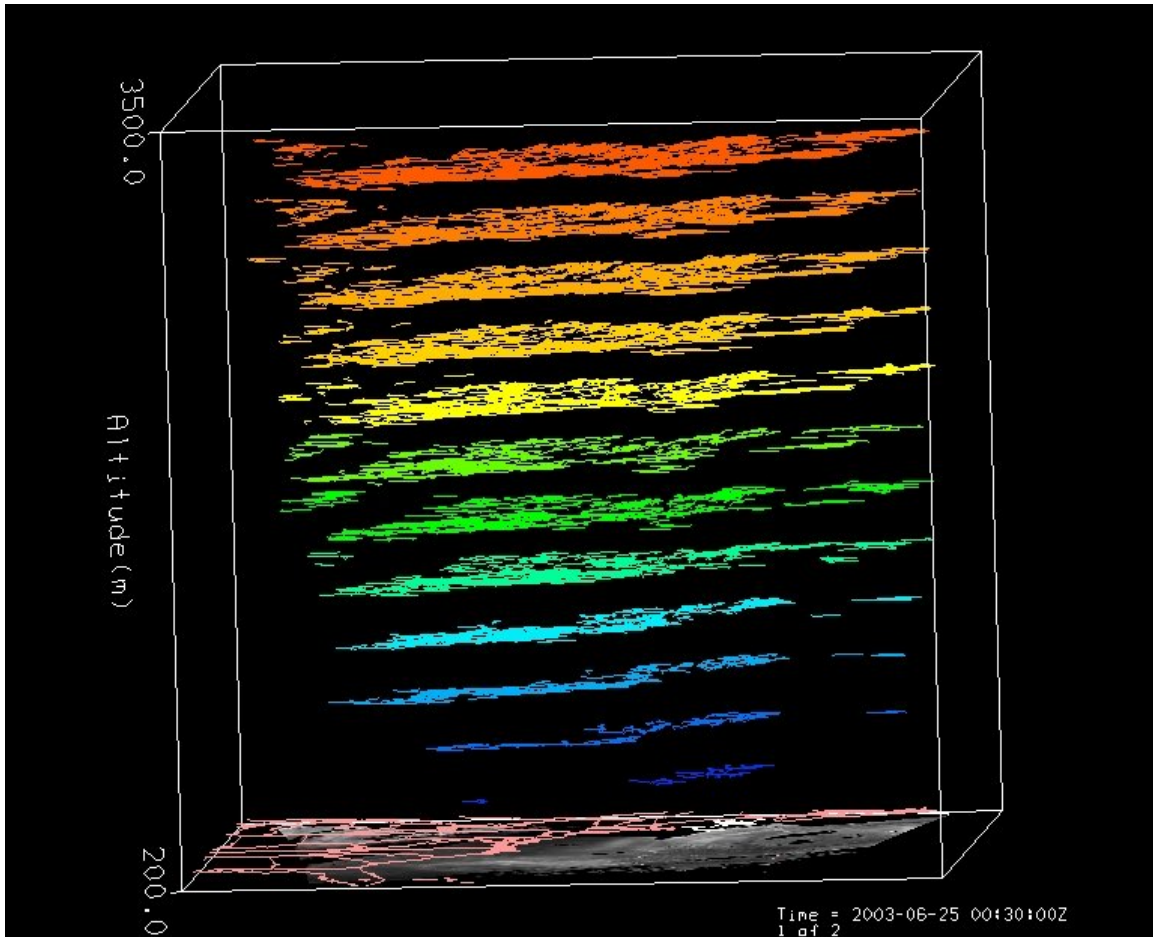


Figure 3:IDV display of retrieval winds shows the data density and vertical distribution.

Task 2: Nowcasting

Work is underway in four areas during CY06.

1) Development of visualization tools. - Much of this work during the last quarter has focused on development of improved visualization tools and web presentation capabilities. An hourly updated nowcast web page is scheduled to become available regularly at CIMSS in Q2-CY06. This will include animations of DPI-like colored images of mid- and high-level precipitable water parcel motion 3-6 hours into the future, as well as continuous analyses of the nowcasts. Additional fields of vertical moisture gradients, an essential signature of the development of convective instability, may also be included in the near future. Efforts have also been made to improve the representativeness of the RUC wind data used as initial values for the parcel motions, moving from single level, mid-layer values to layer average values. This has eliminated much of the imbalances noted in the previous experiments.

Results of the nowcasting development to date were presented at the AMS Satellite conference in Atlanta.

2) Incorporate AIRS sounder products into the NCEP-based WRF/GSI system. - This work, in collaboration with ESSL, is planned to begin later in the year, even though funding has not come available for the ESSL portions of these assimilation activities.

3) Use of POES satellites in nowcasting. - A case has been identified and data are being developed to be used for comparing existing GOES moisture data with AIRS sounding products over land using data provided by Jun Li. Tests using these higher-vertical resolution data will be conducted beginning in Q2-CY06. Assessments of the temporal and spatial representativeness of 6-minute Wind Profiler are also being conducted to assure that parcels initiated using observed data at wind Profiler sites (in addition to analyzed RUC wind fields) can add value to the nowcasts.

Results of the Profiler evaluation (including new Q/C approaches) will be presented at the Atmospheric Profiling meeting in Boulder this June. Preliminary results of the GOES-AIR intercomparisons are being submitted to the August SPIE meeting.

4) Develop relationships with several National Weather Service Forecast Offices (WFOs), the National Severe Storms Laboratory and NCEP/SPC to evaluate new objective nowcasting products. - Initial data availability will be via web page, as noted above. Discussions have begun with the SOO and forecasters at NWS/GRB, both during a visit to GRB and at the AMS annual meeting in Atlanta. An overview seminar will be made once the web page is available, including discussions on means of quantifying the usefulness of the products and presentation methods. Additional interactions are planned with WFO in Sullivan and LaCrosse.

WVSS-II Assessment - A preliminary assessment of results for the June 2005 co-location tests between radiosondes and WVSS-II sensors mounted on UPS aircraft has been performed and presented to NOAA/NWS (copy available upon request). Results showed extremely good agreement between the aircraft data and high-quality radiosonde data taken within tight time and space limits. The results showed almost no bias and Standard Deviations that are well with WMO requirements, especially for values less than 10 g/kg. For higher values, work performed under this project identified a major flaw with the data communication encoding procedures. An alternative has been developed and will be used in future tests planned for fall 2006.

Because moisture flux is of such importance to short-range forecasting, comparisons were also made between wind reports from WVSS-II aircraft and TAMDAR aircraft. These show that the WVSS-II aircraft have wind errors that are as much as 50% less than those from the smaller TAMDAR aircraft – leading the TAMDAR program to reassess the types of aircraft used for their measurements.

Task 3. Preparation for Data Assimilation

Topics Summary

Reviewed previous work on observed and modeled vertical resolution.

Excessive horizontal resolution could resolve atmospheric phenomena whose vertical wavelengths might be too small to be resolved with the vertical resolution of the same or other available observing instruments. When models have fine horizontal resolution, motions at the small scales will inevitably develop. If these motions are not adequately resolved in the vertical

then these scales will contribute only to the "noise" field and degrade the overall accuracy of the solution. High vertical resolution models require high vertical resolution initial conditions.

HES will provide high horizontal resolution (about 4 km) radiance data at multiple channels. It is important to investigate the required vertical resolution for resolving the vertical variability of those atmospheric phenomena resolvable by the 4-km horizontal resolution. The atmosphere exhibits abrupt vertical variability. A review of existing literature reveals that most large-scale numerical weather prediction models and past satellite data had inadequate vertical resolution (Δz), especially near the equator. In other words, the vertical resolution $\Delta z > f_0 \Delta L / N$, where ΔL is the horizontal resolution, f_0 is the Coriolis parameter and N is the Brunt-Vaisala frequency. At mesoscale and storm scales, gravity waves play a major role in producing clouds and precipitation, are a major mechanism for transporting momentum and energy upward through the atmosphere, and account for a significant portion of the spectrum of atmospheric motions (e.g., Gossard and Hooke 1975; Lindzen 1990).

Gravity waves are mainly generated in the troposphere. Shear instabilities in the planetary boundary layer generate small-scale gravity waves with wavelengths of a few kilometers and periods near 10 minutes. Medium-scale GWs, with typical horizontal wavelengths of order 1 to 10 km, and periods of order 10 min to 1 h, are excited in the unstable jet streams and within or around various meteorological disturbances such as fronts, thunderstorms and cumulonimbus convection (Steiner and Kirchengast; 2000). There is no way to find a 4-dimensional description of these small-scale atmospheric features with high horizontal, vertical and temporal resolutions from existing literatures. It is clear that GIFTS/HES observations will offer an unique opportunity for providing much needed knowledge on the consistency between horizontal and vertical resolution at small scales.

Collected GPS radio occultation profiles that were co-located with AIRS measurements.

The relatively new space-borne GPS radio occultation (RO) observations contain valuable information of the vertical variability of the atmospheric temperature and water vapor variables and will contribute to the retrieval of the atmospheric vertical variations from GIFTS/HES observations. As the first step toward combining GIFTS/HES radiance data with GPS RO, data from the Atmospheric Infrared Sounder (AIRS), which provides 2,378 spectral channels with a 3.7-15.4 μm spectral range twice daily, will be used. Efforts were made to find and download GPS ROs that were co-located with AIRS radiance data.

Simplified the MM5 4D-Var system into a 1D-Var system (vertical).

As the first step toward defining an optimal channel selection procedure aiming at capturing observed and modeled vertical variability of the atmospheric state in severe storms, efforts were made to carry out 1-dimensional (vertical direct) variational data assimilation experiments. The co-located RO will be used either as verification profile or as an auxiliary data for background error covariance construction and direct assimilation.

Plans for Next Three Months

Prof. Zou of FSU, under subcontract agreement, will continue to perform the following activities during the next few quarters:

1. Data assimilation of high temporal and high spectral resolution clear-sky radiances in combination with GPS radio occultation (RO) data.
2. Comparison of mesoscale model winds after assimilation of clear-sky high temporal and high spectral resolution radiances with AMVs.

3. Optimal channel selection aiming at capturing observed and modeled vertical variability of the atmospheric state in severe storms.

Results of this work were presented in several papers at the AMS annual meeting and have been accepted for the upcoming Atmospheric Profiling meeting in Boulder.

Task 4: GOES-R Ground System Design and Studies

Data Processing and Archive System Research

The following specific activities were proposed:

1. Evaluate and refine the ATBD for the algorithms used to produce calibrated radiances from raw FTS data using Thermal Vacuum test data from the NASA GIFTS sensor.
2. Continue research into the use of internal calibration reference sources in the optimization of absolute calibration accuracy for the GOES-R program.
3. Process GIFTS “option 2” thermal vacuum test data through the data processing system.
4. Process a 24 hour simulation of GIFTS on-orbit measurements using the GIFTS Information Processing System (GIPS) with special focus on characterizing the radiance calibration (and corresponding errors) over a range of instrument temperatures as it would experience them on orbit.
5. Create a searchable database of hyperspectral metadata products from the GIFTS simulated on-orbit data and the GIFTS thermal vacuum test data and demonstrate the data items unique to these large hyperspectral datasets.
6. Design a Level 2 data processing architecture using the algorithms developed elsewhere in this proposal as a baseline for GOES-R.

Task 1 & 2 Progress: Radiometric Calibration & the GIFTS ATBD

A paper was presented on the GIFTS calibration methodology to the 2006 American Meteorological Society (AMS) meeting in Atlanta. The title was “*Preliminary Evaluation Of The Gifts Calibration Algorithm Using The Gips*” with R. Knuteson, UW-CIMSS as lead author. The abstract of this paper is provided here:

“Ground calibration algorithms for a Geosynchronous Imaging FTS (GIFTS) are being developed at the University of Wisconsin-Madison Space Science and Engineering Center. This development is being conducted in support of NOAA's GOES-R Risk Reduction program with a focus on the hyperspectral sounder that is anticipated to be a part of the GOES-R Hyperspectral Environmental Suite (HES). The near term objective is to develop calibration algorithms that can be evaluated using thermal vacuum test data from NASA's Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS). The GIFTS is designed to produce 128x128 interferograms in two spectral bands every 11 seconds using a Michelson interferometer and two detector focal plane arrays. In preparation for the thermal vacuum test data, simulated data has been used in the GIFTS Information Processing System (GIPS) to illustrate expected accuracy of a unique on-orbit calibration approach using two high emissivity internal reference cavities plus a space view.”

Task 3 Progress: GIFTS Thermal Vacuum Data

The UW-CIMSS has started to evaluate the GIFTS data collected at Utah State University Space Dynamics Laboratory under NASA contract. The thermal vacuum tests of the GIFTS instrument were begun during the reporting period and the (very large) datasets needed for analysis were identified, categorized, and transported to UW-CIMSS. The data is being prepared for use with

the GIFTS Information Processing System (GIPS) software package developed separately under OSD support (K. McKenzie). A larger scale processing of the GIFTS data is planned for the next period.

Task 4 Progress: HES 24 hour dataset Simulation Processing

A paper on the GIFTS/HES 24 hour simulation dataset was presented at the 2006 annual AMS meeting by E. Olson, titled, “*Geostationary Interferometer 24-Hour Simulated Dataset for Test Processing and Calibration*”. That paper contains the details of how the simulated dataset was created. Progress on this task to date has included the processing of selected “data cubes” of simulated GIFTS interferograms to the level of calibrated and spectrally corrected radiances. A larger scale processing demonstration of the simulated GIFTS data for the Earth full disk is planned in collaboration with NOAA and the Algorithm Working Group.

Task 5 Progress: Searchable Metadata Database

A low level of effort is going on in development of a methodology for the creation, formatting, storage, and retrieval of metadata science information relevant to the GOES-R era. The dramatic increase in the raw and processed data rates will require that key variables are extracted as metadata items by the data processing system and stored in a format compatible with database search methods. In the reporting period the 24 GIFTS dataset was used (approx. 5 TB in size) as a test bed for the extraction of brightness temperatures at selected wavelengths. These brightness temperature values are being imported into a relational database so that SQL language queries can be performed to find the intersection among time, latitude, longitude, and scene brightness temperatures and provide a reference to the location of the desired pixels. Work on this task is expect to continue after an upgrade to the database engine server hardware to accommodate the large metadata datasets.

Task 6 Progress: Design a L2 Processing Architecture

The Level 2 product algorithms are being evaluated by the Algorithm Working Groups (AWG). This risk reduction task is to look ahead at how the candidate algorithms can best be implemented in a high performance computing environment. Activity in this reporting period was limited to discussion with algorithm providers on the characteristics of the candidate algorithms and consultation with NOAA on a common development approach.

Plans for Next Three Months

Progress is expected in all task areas however the primary emphasis will be the preliminary processing of GIFTS thermal vacuum test data using the GIPS software to assist in sensor characterization. Instrument responsivity, noise levels, absolute and relative radiometric calibration accuracy, and spectral calibration and correction are the primary initial objectives. Nonlinearity, polarization, and other secondary effects will be addressed as time permits. Ground based sky data collection using GIFTS is in the planning stages and UW-CIMSS will perform calculation comparisons using atmospheric radiative transfer models when that data becomes available.

CIMSS Finances Summary: GOES-R Funding and Spending Plan

GOES R Risk Reduction Funding

| | |
|-----------------------|----------------|
| Through 2/2004 | \$1,270K |
| Through 2/2005 | \$ 750K |
| Through 2/2006 | <u>\$ 910K</u> |
| Total funding to date | \$2,930K |

GOES R Risk Reduction Spending

| | |
|------------------------------|----------------|
| Through 2/2004 | \$1,299K |
| 3/2004 - 2/2005 | \$ 880K |
| 3/2005 – 12/2005 | <u>\$ 645K</u> |
| Total spending thru 12/31/05 | \$2,824K |

Updated funding and spending information will be provided when FY2006 funding arrives.

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