

**The Cooperative Institute for Meteorological Satellite Studies
(CIMSS)**

**Semi-Annual Report to NOAA/NESDIS/ORA
for
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1 April 2004 to 30 September 2004

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The Cooperative Institute for Meteorological Satellite Studies (CIMSS) Semi-Annual Report to NOAA/NESDIS/ORA

1 April 2004 to 30 September 2004

1. GOES Improved Measurements and Product Assurance Program (GIMPAP)

1.1 Temperature and Moisture Retrieval

Begin to Use the Time Continuity of GOES Sounder Radiance Measurements

The GOES sounder provides hourly radiance measurements containing atmospheric sounding and cloud-top property information; the previous sounding retrieval algorithm is based on the single time step (Ma et al. 1999). Since atmospheric temperature and moisture evolution follows the dynamic rule, and the temperature and moisture profiles will not change dramatically within one hour, it is possible to take the time continuity of GOES observations into account in the sounding retrieval algorithm. We have started this work by taking the retrieval of the previous time as the first guess, using the radiance measurements of the current time to adjust the first guess. Figure 1 shows the correlation between the GOES-12 sounder radiances from 01 Z to 11 Z and the moisture retrieval at 11 Z based on a linear regression retrieval scheme taking into account the time continuity. Each panel ($i=01, 02, \dots, 11$) indicates the correlation between the radiances at time i Z contributed to the moisture retrieval at time 11 Z. Each panel (time i Z) shows the correlation between a given channel (see channel index in abscissa) and the moisture retrieval at 11 Z at a give pressure level (see the vertical ordinate). The three layers of moisture information from channels 10, 11 and 12 can be seen. It can be seen that the retrievals at time 11 are not only correlated with 11 Z radiances, but also are correlated to the radiances of previous times (e.g., from 07 Z to 10 Z). However, the correlation becomes weaker when the radiances are less current.

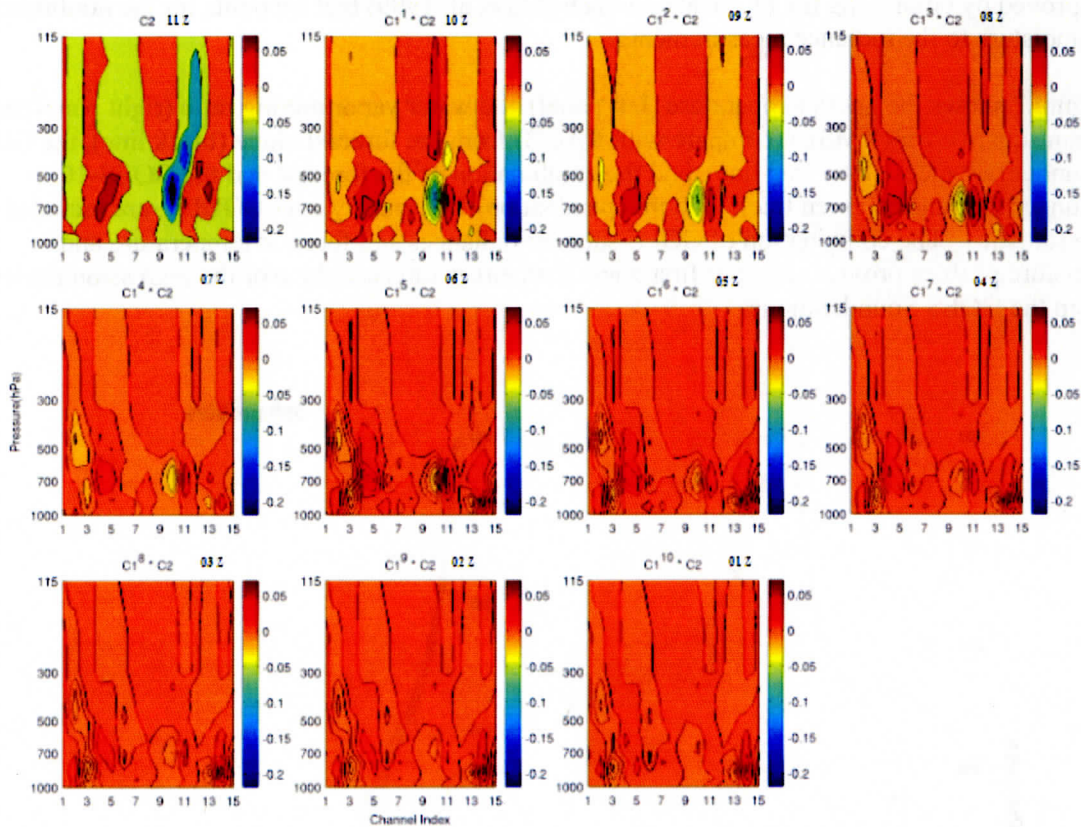


Figure 1: The correlation between the GOES-12 sounder radiances from 01 Z to 11 Z and the moisture retrieval at 11 Z based on a linear regression retrieval scheme taking into account the time continuity.

Better Sounding Retrievals Utilizing the Time Continuity of GOES Sounder Radiance Measurements

As a first step in the retrieval process, guess profiles of temperature and moisture are generated, usually from short-term numerical model forecasts. Thereupon, the first guess profiles are adjusted in a physical approach (Ma et al. 1999) so that forward calculations match the Sounder measured radiances; this iterative process results in the final retrievals. To date, GOES moisture retrievals have provided a noticeable improvement over the first guess, while temperature retrievals have remained very similar to the first guess, at least over CONUS. The lack of temperature profile improvement in the physical retrieval process might be caused by insufficient use of the GOES Sounder radiance information. In our recent progress, the forecast profile is used together with GOES Sounder radiances to produce the first guess. In practice, the forecast temperature and moisture profiles are used as additional predictors in the regression retrieval model. Initial results demonstrate that both guess temperature and moisture profiles can be improved (by up to ~ 0.5 K for temperature and ~5% for Total Precipitable Water) over the forecast when the GOES Sounder radiance measurements are used together with forecast temperature and moisture profiles in a simple statistical retrieval approach. This illustrates that the forecast profiles are used as reference or background in the regression retrieval, and the GOES Sounder radiances adjusts the forecast profiles for an improvement, thus the GOES Sounder radiance information is properly used to improve the first guess for the physical retrieval, or generate a simple statistical retrieval. The moisture first guess can be further

improved by employing the physical approach (Ma et al. 1999) that accounts for the nonlinearity of moisture to the radiance measurements.

Figure 2 shows the guess temperature (left panel) and water vapor mixing ratio (right panel) root mean square error (RMSE) (compare with RAOB) from the forecast alone (black line), the GOES Sounder radiances alone (red line), and the combination of the forecast and the GOES-10 Sounder Radiances (green line). 368 independent profiles, mostly over CONUS, are included in the statistics. The combination of GOES sounder radiances and forecast temperature and moisture profiles provides a better first guess than either forecast alone or the regression retrieval from the GOES Sounder alone.

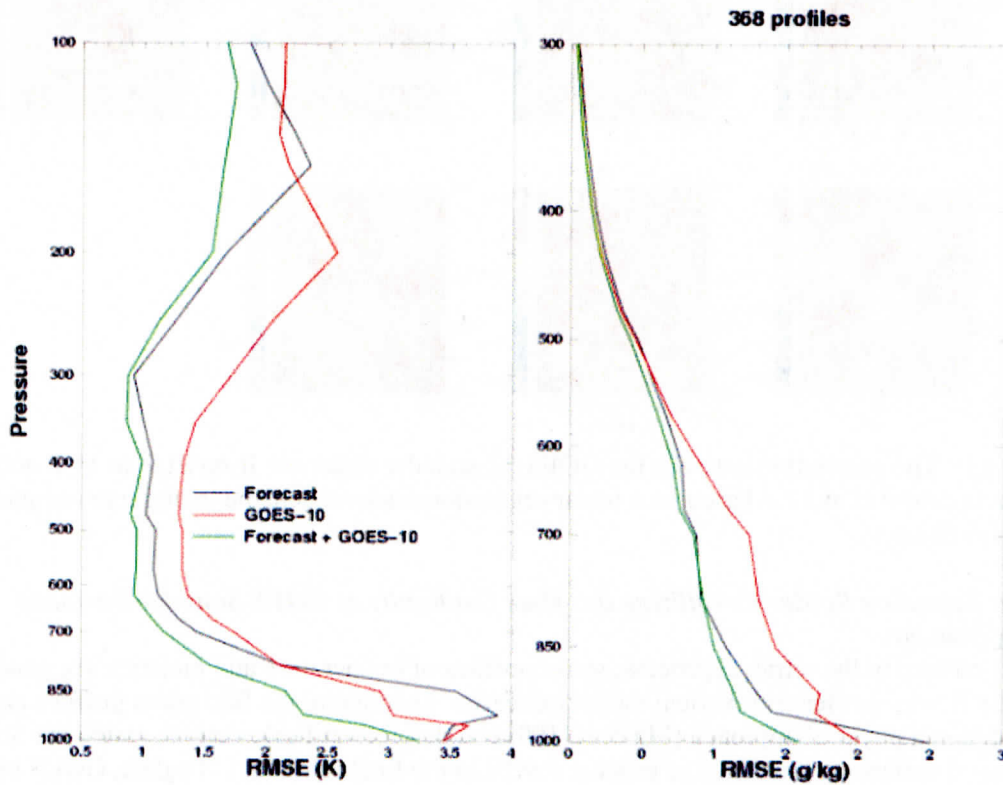


Figure 2: The guess temperature (left panel) and water vapor mixing ratio (right panel) root mean square error (RMSE) (compare with RAOB) from the forecast alone (black line), the GOES Sounder radiances alone (red line), and the combination of the forecast and the GOES-10 Sounder Radiances (green line).

Spatial Filtering of the Noise for Sounding Improvement

Spatial filtering of the noise from IR radiances measurements has been tested using GOES-8 data (Plokhenko et al. 2003). The signal-to-noise ratio (SNR) of GOES Sounder radiances can be improved by filtering the spatial structure of the GOES Sounder measurement errors. For example, taking advantage of large spatial gradients in the upper atmosphere, a simple 5 by 5 field-of-view (FOV) radiance averaging would reduce the noise of band 1 which is a stratospheric channel, while still retaining the atmospheric structure in the retrievals. Consequently, a 4 by 4 FOV radiance averaging can be applied to band 2 which is sensitive to tropopause temperature, 3 by 3 radiance averaging to band 3 which is sensitive to upper level temperature, and so on. The

size of the box for radiance averaging will be based on the weighting function peak of each channel. The lower level channels (6, 7 and 8) will not apply spatial smoothing in order to keep the single FOV (10 km spatial resolution) information. Figure 3 shows the GOES-12 Sounder band 1 (14.7 μm) and band 9 (9.7 μm) images before spatial filtering (left panels), images after spatial filtering (middle panels), and the difference images (right panel). The difference images reveal the noise filtered by the spatial smoothing. Noise filtering will improve the sounding products such as temperature and moisture profiles, total ozone, as well as cloud property product.

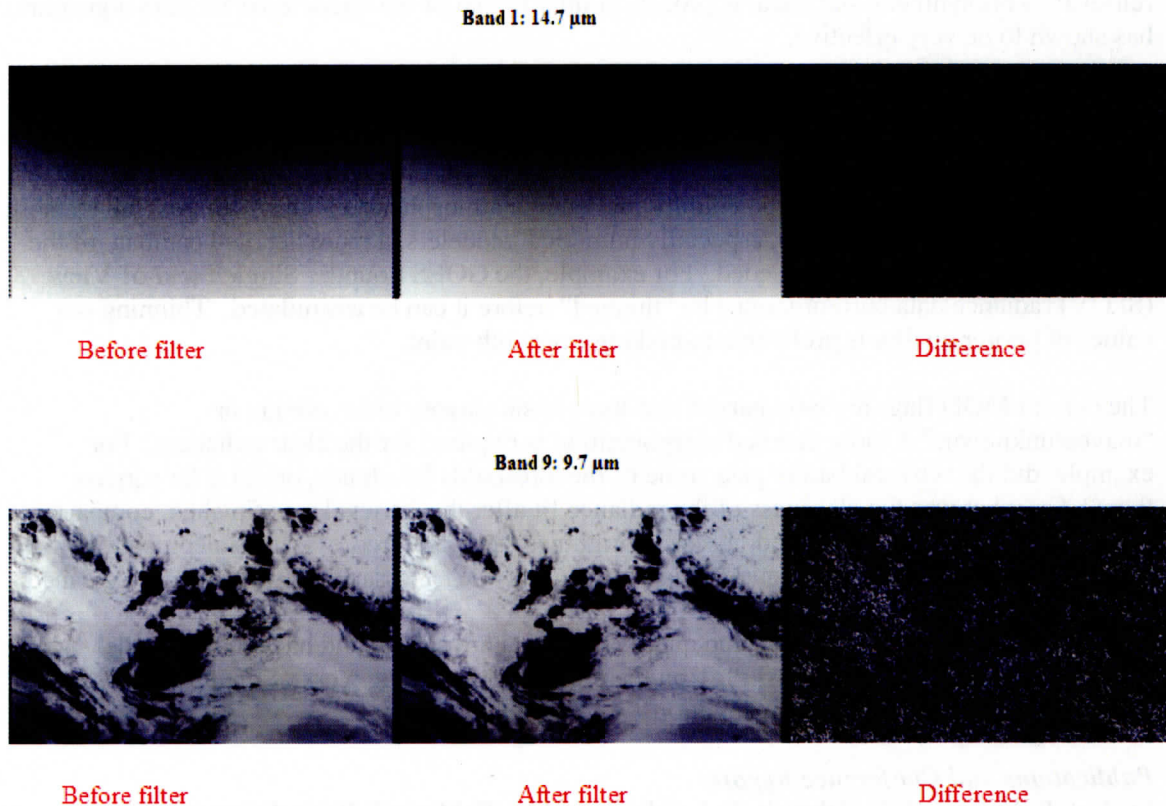


Figure 3: GOES-12 Sounder band 1 (14.7 μm) and band 9 (9.7 μm) images before spatial filtering (left panels), images after spatial filtering (middle panels), and the difference images (right panel).

Model Independent Guess, Surface Emissivity and Ozone Retrieval

Single Field of View (SFOV) development has continued on multiple fronts. SFOV code is continuously under development. The code is running in real-time and producing data for validation and to provide guidance for further improvements. The traditional approach of using numerical weather prediction model data for the first guess used in the physical retrieval is being compared to new model independent techniques. Ozone has been successfully integrated into the algorithm and is now part of the standard program. Prototyping work for a new Sounder retrieval code base has begun. The legacy Sounder processing code was written under the mainframe paradigm and as a result is not well suited for running on modern machines. The new code will be easier to maintain and run more efficiently.

Synthetic regression retrievals of model independent soundings and total ozone from the GOES Sounder require a hemispheric dataset of temperature, moisture, and ozone profiles in addition to estimates of skin temperature and emissivity to train the regression. A new data set consisting of more than 12,000 global profiles of temperature, moisture, and ozone has been created, drawing from NOAA-88, ECMWF, TIGR-3, ozonesondes, desert radiosondes. Work has been done to better characterize the skin temperature/surface air temperature difference and the global emissivity in order to assign these values to the training profiles using a more physical basis (Seemann and Borbas 2004, personal communication). We will use this new training data to generate a statistical retrieval model for model independent guess, surface emissivity and ozone retrieval. This synthetic statistical approach, similar to that of the operational MODIS algorithm, has shown to be very effective.

Quality Indicator Flags for Retrievals

The GOES Sounder retrieval algorithm from CIMSS contains basic quality indicator (MOD) flags. The flags indicate whether a given retrieval converges or if it may mistakenly include cloudy radiances (and hence is too cold throughout the atmospheric column). In general, as more data are made available to users, especially numerical modelers, a more detailed estimate of the quality of each observation is needed. For example, the GOES Sounder Single Field-of-View (SFOV) radiance data currently must be “thinned” before it can be assimilated. Thinning out values of poorer quality is preferable to picking every nth point.

The current MOD flags are only parsed into three basic classes: clear, cloudy or “maybe/unknown.” A more detailed categorization is required for the clear radiances. For example, did the retrieval barely pass some of the thresholds for clouds, or did it far surpass them? Or, what was the closeness of the radiance fit after the retrieval was finished, comparing differences between retrieved and observed brightness temperatures? Perhaps a comparison with a neighboring Sounder FOV (cloudy, clear?) will allow the necessary information to be gleaned.

CIMSS personnel continue to develop quality flags that are simple and have more details. We coordinated with NESDIS/ORAF/FPDT on the retrieval quality flag work. Some problems on SFOV cloud check are under investigation.

Publications and Conference Reports

Li, J., J. P. Nelson, C. C. Schmidt, T. J. Schmit, and W. P. Menzel, 2004: An approach to improve temperature and moisture retrievals from GOES sounder measurements. *Proceeding of 13th Conference on Satellite Meteorology*, 20 – 23 September 2004, Norfolk, VA. American Meteorological Society, Boston, MA.

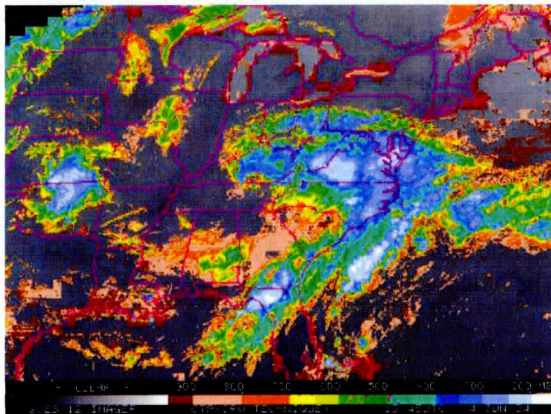
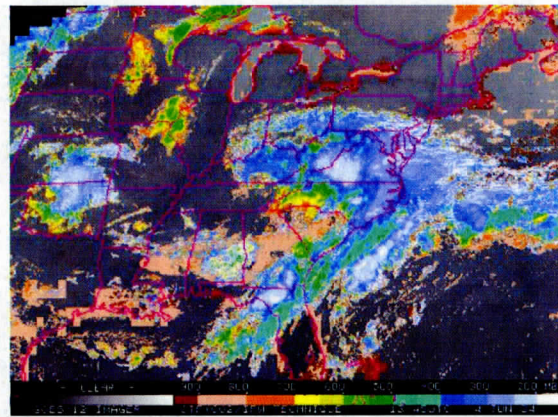
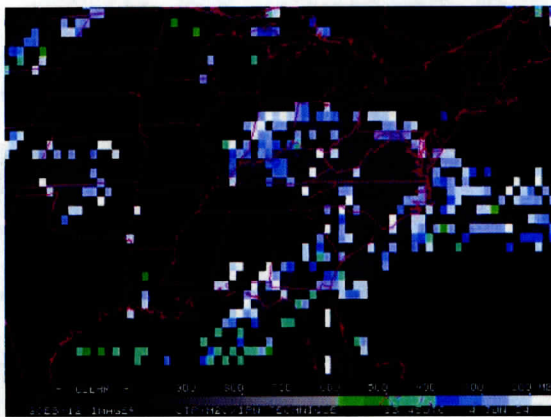
Schmidt C. C., and J. Li, 2004: High resolution GOES sounder ozone estimates. *Proceeding of 13th Conference on Satellite Meteorology*, 20 – 23 September 2004, Norfolk, VA. American Meteorological Society, Boston, MA.

1.2 Cloud Products and Volcanic Ash Detection

Comparison of Water Vapor/Infrared Window, CO₂/Infrared Window Ratio, and Infrared Window Cloud Product Techniques using radiance information from the GOES-12 Imager

The conclusions of this study, based on results from 30 days during the month of May 2004, showed that the CO₂/IRW ratio technique produces cloud heights in good agreement with lidar determinations although the occasional thin cloud eludes the CO₂/IRW slicing technique. H₂O/IRW intercept and the CO₂/IRW slicing techniques for inferring the heights of semi-

transparent ice cloud elements produce similar results on average, but individual cloud height comparisons differ considerably. The CO₂/IRW slicing technique is more robust (has fewer failures in producing cloud top pressure for a set of cloud tracers). The IRW technique consistently places the semi-transparent cloud elements too low in the atmosphere by roughly 200 hPa; only in more opaque clouds does it perform adequately. The CO₂/IRW slicing technique seems to produce the best cloud heights of the three approaches for high thin ice clouds. The results of this work were presented at the Seventh International Winds Workshop in Finland during June 2004. Figure 4 shows a comparison of the three cloud height techniques. Note the relatively poor coverage for the H₂O/IRW Intercept technique (Figure 4A) and the low clouds along the northern extent of the weather system in Ohio and Pennsylvania in the IRW technique (Figure 4C) compared to the CO₂/IRW technique (Figure 4B).



**Cloud Top Pressure
4 Jun 2004 13:45UTC**

- A. H₂O/IRW Intercept Technique
- B. CO₂/IRW Ratio Technique
- C. IRW Technique

Figure 4: Comparison of three cloud height techniques.

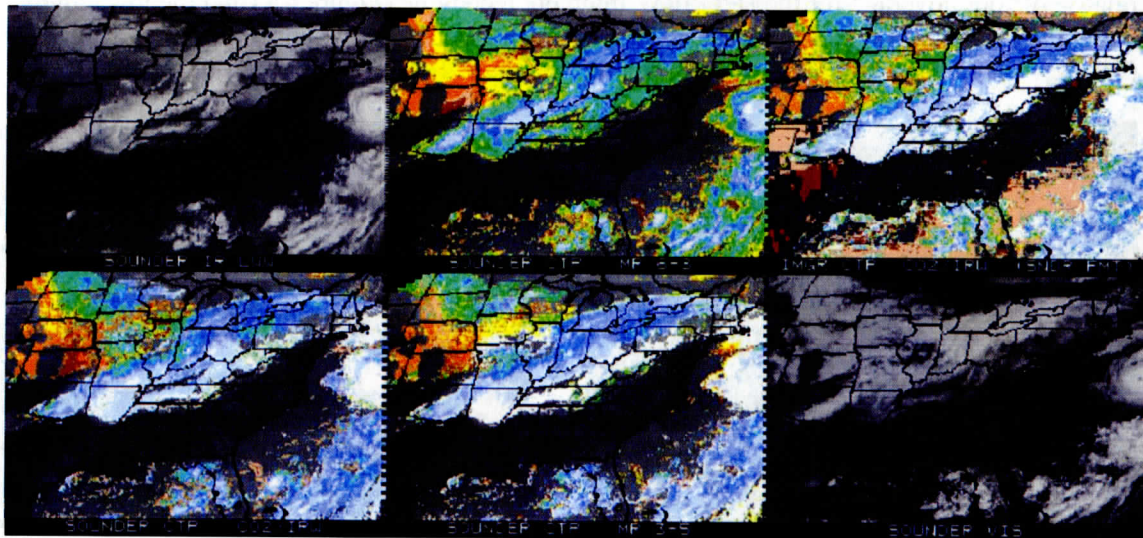
Application of the Minimum Residual Method for Generating Cloud Height and Effective Cloud Amount

The Minimum Residual (MR) method uses a technique similar to the CO₂ Absorption Method for deriving cloud height and amount based on GOES Sounder radiance information. The primary difference is that the MR method is based on a mathematical relationship rather than a physical relationship like the CO₂ technique. The advantages are that the MR technique is (1) computationally simpler and thus faster and (2) not limited to CO₂ bands. One primary disadvantage is that it presumes that the emissivity of the bands used is the same.

Preliminary results show that the greatest impact for this technique will be in the application of deriving height information for low level (950 – 650 hPa) clouds.

Figure 5 shows a comparison of the CO₂ Absorption Technique from the GOES-12 Sounder (Figure 5D) and the GOES-12 Imager CO₂/IRW ratio technique (Figure 5C) to the MR method (Figures 5B and 5D).

**GOES-12 Sounder
4 August 2004 1446UTC**



- | | |
|---|-------------------------------------|
| A. Sounder IR LWW | D. Sounder CTP CO ₂ /IRW |
| B. Sounder CTP MR 6-8 | E. Sounder CTP MR |
| C. GOES-12 Imager CTP
CO ₂ /IRW | F. Sounder Visible |

Figure 5: Comparison of the CO₂ Absorption Technique from the GOES-12 Sounder (D) and the GOES-12 Imager CO₂/IRW ratio technique (C) to the MR method (B and D).

Publications and Conference Reports

Schreiner, A. J., W. P. Menzel, A. K. Heidinger, J. Davies, and W. Feltz, 2004: Comparison of cloud motion vector height assignment techniques using the GOES-12 imager. International Winds Workshop VII, Helsinki, Finland, June 2004.

Volcanic Ash Detection

By using a differencing scheme of two infrared bands for the GOES Sounder, it is possible to detect and temporally resolve SO₂ plumes resulting from volcanic eruptions. This differencing technique was applied to the series of volcanic eruptions which took place at the Soufriere Hills volcano on the island of Montserrat in the eastern Caribbean over a three day period, 12-14 July 2003. A technique for displaying a potential SO₂ plume is made by generating a “band difference” image based on the 7.46 μ m (sensitive to sulfur dioxide) and a CO₂ absorption band (Band 5, 13.3 μ m and not sensitive to SO₂). In this case Band 5 is chosen because the weighting function for both bands peaks around the same region of the atmosphere, thus subtracting the effects of the background temperature. Of course the effects due to water vapor are not removed. An example of a 66 hour “loop” is shown in Figure 6 below. The SO₂ plume is denoted by the

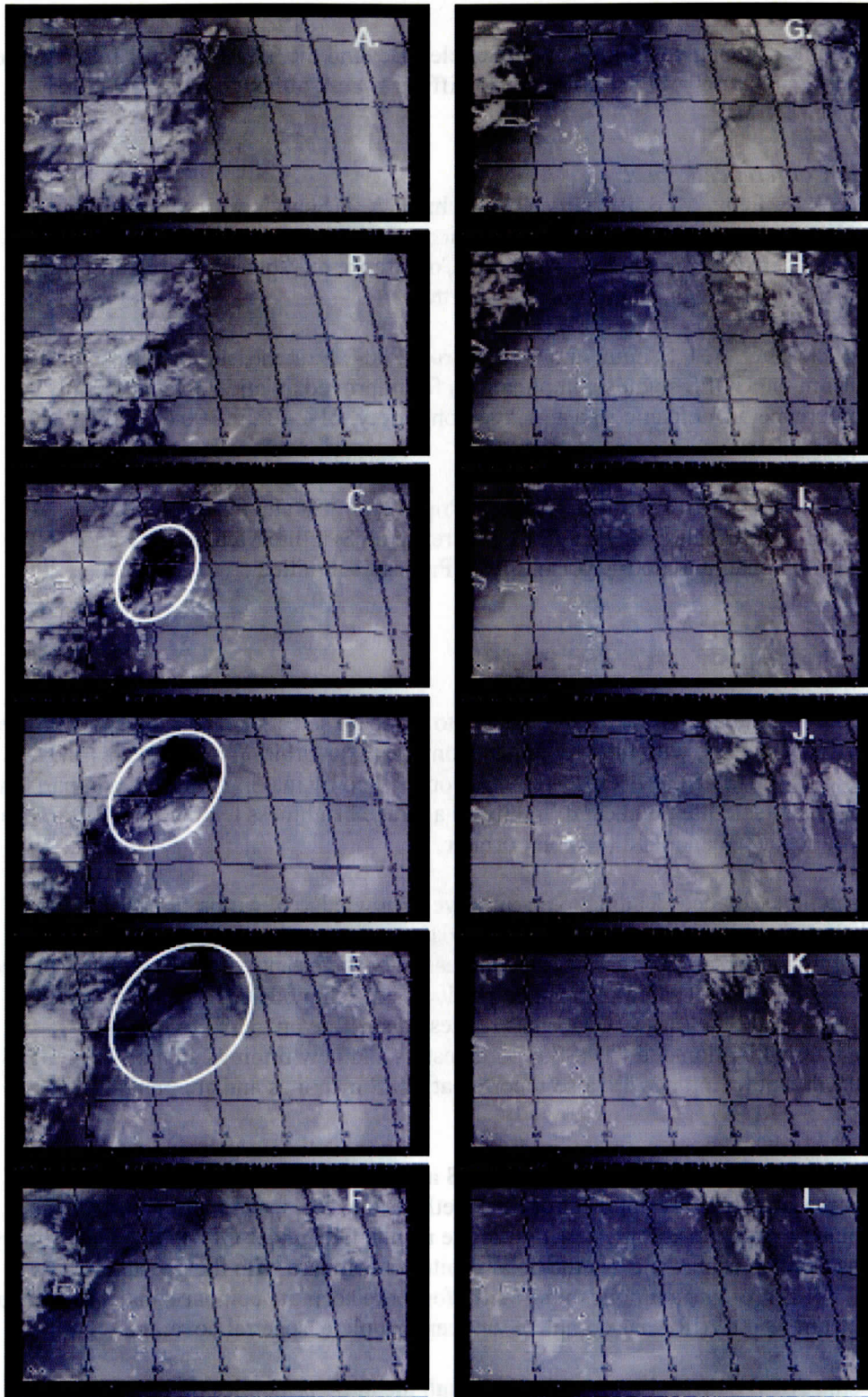


Figure 6: A 66 hour “loop” of GOES Sounder Band 10 ($7.46\mu\text{m}$.) minus Band 5 ($13.3\mu\text{m}$.). The initial time is 01:20 UTC 13 July 2003 and end time is 19:20 UTC 15 July 2003, and the temporal resolution is six hours. It demonstrates the evolution of the SO_2 plume (black) following the Soufriere Hills volcanic eruption on 13 July 2003 at 02:30 UTC.

dark or “black” plume (note area within the white circle). Beyond the 01:20 UTC 14 July (Figure 6E) time period the “signature” of the SO₂ plume is diffuse at best, although there are still remnants of the “vapor trail.”

Publications and Conference Reports

Ackerman, S. A., W. F. Feltz, M. S. Richards, T. J. Schmit, A. J. Schreiner, J. Murray, and D. Johnson, 2004: UW-Madison advanced satellite aviation weather products MODIS/AVHRR/GLI satellite volcanic ash detection. Second International Conference on Volcanic Ash and Aviation Safety, 21-24 June 2004, Raleigh, NC. Preprint submitted.

Prata A. J., A. J. Schreiner, T. J. Schmit, and G. P. Ellrod, 2004: First measurements of volcanic sulphur dioxide from the GOES sounder: implications for improved aviation safety. Second International Conference on Volcanic Ash and Aviation Safety, 21-24 June 2004, Raleigh, NC. Preprint submitted.

Schreiner, A. J., T. J. Schmit, G. P. Ellrod, and A. J. Prata, 2004: Can upper-level SO₂ be monitored using the GOES sounder? AMS 13th Conference on Satellite Meteorology and Oceanography, 20-24 September 2004, Norfolk, VA. Preprint submitted.

1.3 Intercalibration of GOES and POES

The primary purpose of the intercalibration project is to compare select channels on geostationary instruments (GOES, Meteosat) with those obtained from the polar-orbiting instruments (NOAA AVHRR and HIRS, EOS AIRS). This research is accomplished by making multiple comparisons at the geostationary sub-satellite points and finding an average brightness temperature difference between the geostationary imager and the polar orbiter.

Comparison of satellite radiances leading to an improved knowledge of calibration is important for various global applications of satellite data where data from more than one instrument are combined for a single purpose. This has become increasingly important with the emphasis placed on global models and the use of satellite data and products in such models. The Coordination Group for Meteorological Satellites (CGMS) has requested satellite operators to regularly perform satellite intercalibration and CIMSS reports results and new findings annually at CGMS meetings. Results and new findings are also reported at AMS meetings and are published for peer review.

Routine intercalibration is an ongoing effort at CIMSS and was covered in fiscal year 2004 by PSDI. However, research and development of new methods and tools, adding new instruments and new bands, and publication and presentation of the results falls under GIMPAP. The primary focus in 2004 has been on using AIRS as the polar orbiter to compare with the geostationary (GEO) imagers. AIRS presents a unique opportunity for more accurate comparisons in regions of the infrared spectrum where AIRS has complete, or near-complete, spectral coverage.

The approach using AIRS data is slightly altered, though the basic principles remain the same. Collocation in space and time (within thirty minutes) is required. Data are selected within 10 degrees from nadir for each instrument in order to minimize viewing angle differences. AIRS high spectral resolution data are convolved with the geostationary instrument’s spectral response function (SRF). Then the GEO data and convolved AIRS radiances are averaged to an effective 100 km resolution to mitigate the effects of different field of view (fov) sizes and sampling

densities; AIRS has a nadir 13 km fov, the GOES imager over-samples 4 km in the east west by 1.7, and METEOSAT-5 and -7 have a nadir 5 km fov. Mean radiances are computed within the collocation area. Mean radiances are converted, via the inverse Planck function, into brightness temperatures and the temperature difference between the GEO and AIRS is calculated.

The AIRS instrument does not spectrally cover the entire range of wavelengths covered by the geostationary instruments. Large spectral gaps, as seen in the water vapor channel, can greatly degrade the effectiveness of this method. Methods of either correcting this error or accounting for it are being researched.

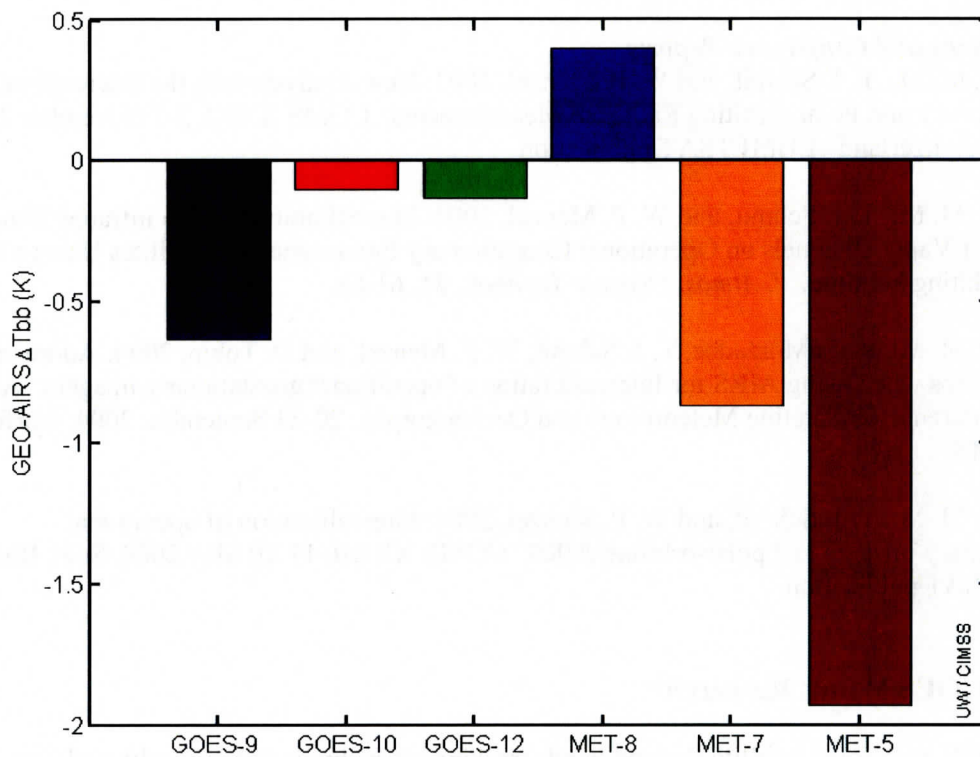


Figure 7: Mean Infrared Window brightness temperature differences between geostationary imagers and AIRS for between 8 and 16 cases in 2004. A negative difference means AIRS is measuring warmer than the Geo (differences are reported as Geo minus AIRS).

Comparisons of GOES and Meteosat to the Atmospheric InfraRed Sounder (AIRS) on the polar orbiting Aqua have been done and these methods, results, and findings were presented in the second half of 2004 at the 32nd CGMS meeting held 17-20 May 2004. An approach to correcting for spectral gaps in AIRS data was tested and the results presented at the AMS 13th Conference on Satellite Meteorology and Oceanography, held 20-23 September 2004, Norfolk, VA. These spectral gaps cause large discrepancies in the differences between AIRS and other instruments, which are not a reflection of calibration accuracy.

GOES-11 was brought out of storage for most of the month of June and data was ingested and archived by the SSEC Data Center. Imager to imager and sounder to sounder comparisons were

done with GOES-12. This activity was not planned for and therefore did not appear in the original proposal for FY04. A summary of GOES-11 activities at CIMSS was put on the Web: http://cimss.ssec.wisc.edu/goes/goes11_blog

At the end of the brief GOES-11 test period, GOES-11 was used to parallel-broadcast GOES-12 data using a new Sensor Processing System, informally named the Modern Sensor Processing System (MSPS). The MSPS data stream (actually SPS version 6.1.3) was compared to the operational SPS data stream (SPS version 5.1.2) and feedback given to NOAA. Very small differences were found between the two of approximately one GVAR count in the imager. Problems with the sounder arose in navigation, where it appeared the MSPS was off by approximately 20km, or two fields of view.

Publications and Conference Reports

Gunshor, M. M., T. J. Schmit, and W. P. Menzel, 2003: New Analysis with the Intercalibration of Geostationary and Polar-Orbiting Radiance Measurements. CGMS XXXI, 3-7 November 2003, Ascona, Switzerland. EUMETSAT publication.

Gunshor, M. M., T. J. Schmit, and W. P. Menzel, 2004: Intercalibration of the Infrared Window and Water Vapor Channels on Operational Geostationary Environmental Satellites Using a Single Polar Orbiting Satellite. *J. Atmos. Oceanic Technol.*, **21**, 61-68.

Gunshor, M. M., K. LeMorzadec, T. J. Schmit, W. P. Menzel, and D. Tobin, 2004: Addressing spectral gaps when using AIRS for Intercalibration of operational geostationary imagers. AMS 13th Conference on Satellite Meteorology and Oceanography, 20-23 September 2004, Norfolk, VA. AMS.

Gunshor, M. M., T. J. Schmit, and W. P. Menzel, 2004: Intercalibration of operational geostationary imagers and polar-orbiting AIRS. CGMS XXXII, 17-20 May 2004, Soci, Russia. EUMETSAT publication.

1.4 GOES Winds Research

The CIMSS automated satellite-derived winds tracking algorithm is continuously evolving. In order to advance the algorithm, new science and research ideas need to be developed and tested at CIMSS.

Accomplishments over the past 6-months include (but are not limited to):

1) The CIMSS winds-tracking software was modified to allow for easy adaptation to new instruments. Satellite-specific parts of the software were identified and isolated, thereby minimizing the effort required for adding new satellites and sensors. A specific example is the adaptation of the code to process new MSG data. CIMSS winds lead scientist, Chris Velden, visited EUMETSAT to discuss and learn more about MSG with the winds specialists there. This visit initiated the adaptation of the CIMSS winds code for processing of winds from MSG. Velden was also a co-chair of the 7th WMO-sponsored International Winds Workshop held in Helsinki, Finland, which resulted in an excellent exchange of ideas on current winds research areas.

2) CIMSS supported the Atlantic THORPEX Regional Campaign (ATReC) in late 2003, the first in a series of planned THORPEX field phases to be focused on high-impact weather over oceanic

regions. In support of this experiment, CIMSS collected and processed experimental winds datasets from GOES. A special scanning strategy for GOES was employed that includes a series of rapid scans (RS), allowing for the generation of higher density and quality satellite wind sets at CIMSS. The increased temporal resolution of these satellite wind products offers significant potential for a positive impact in rapidly developing 4D assimilation systems that provide the initial conditions for NWP. CIMSS researchers are now working with THORPEX scientists and the data assimilation community towards validating the quality and usefulness of the RS satellite wind parameters. Several NWP centers are running model forecast impact experiments with these datasets. PI Velden will present results of this effort at the upcoming THORPEX Science Symposium in December in Montreal.

3) GIMPAP provided partial support of a CIMSS Researcher Apprenticeship at the UKMet Office over the past year. CIMSS researcher Howard Berger's primary task was to work with UKMet scientists on satellite winds assimilation methods. Experiments were designed to reduce the correlated error within the winds by averaging the observations and co-located backgrounds within a box into a superobservation. The new superobbing algorithm and related issues of observation error and quality control were tested via model forecast impact studies (see Figure 8). The initial results were not strikingly positive, so this will be an area of ongoing research supported under another funding instrument.

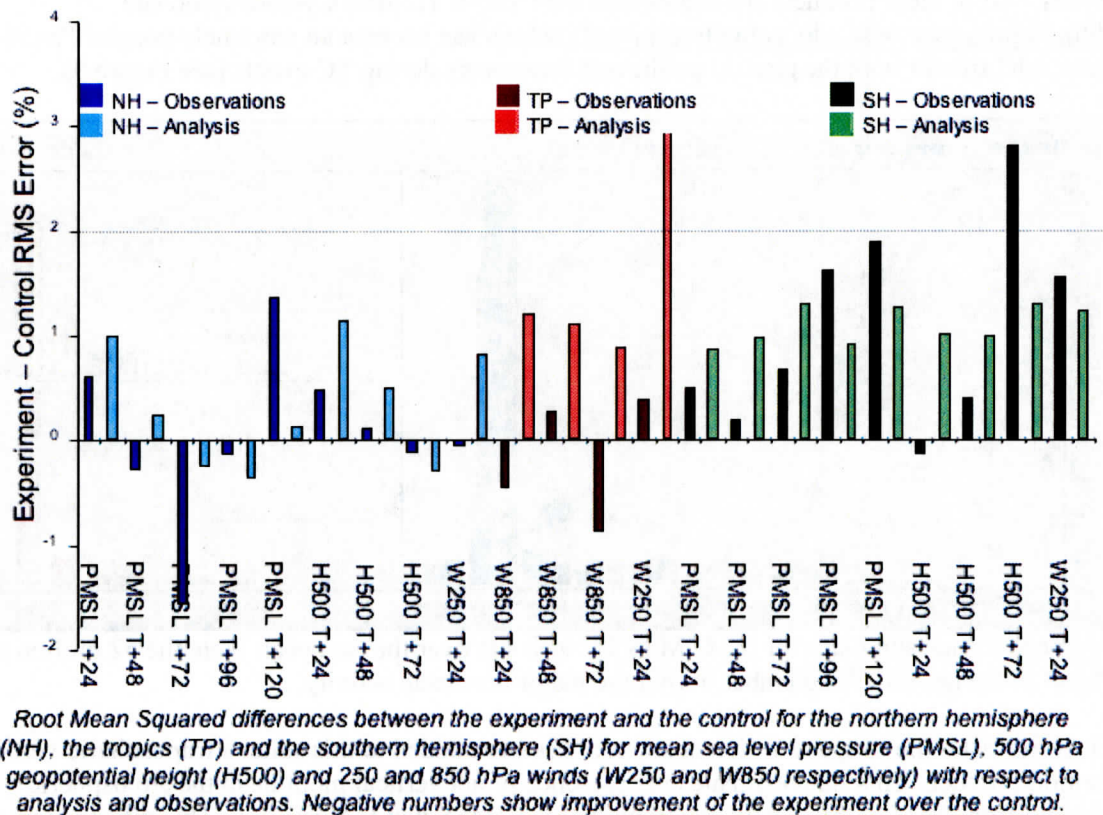


Figure 8: Results from model forecast impact studies using new superobbing algorithm.

4) Satellite image morphing techniques were explored as a potential novel idea for improving nowcasting and short term forecasting. Some of the features of the CIMSS wind-tracking algorithm are related to the techniques used in the field of image morphing (interpreting the

navigation of the image, feature tracking, and automated quality control). Morphing requires the identification of control points between successive images; the wind vector algorithms already have this issue resolved. Preliminary work indicates that GOES wind vectors could be an important guide for the “projection” or “extrapolation” of a near-real-time image sequence into the future for nowcasting purposes.

Publications and Conference Reports

Velden et al. 2005: Recent innovations in deriving tropospheric winds from meteorological satellites. To appear in the February 2005 issue of Bull. Amer. Meteor. Soc.

7th International Wind Workshop, Helsinki, Finland, June, 2004 - 2 papers presented.

13th AMS Conf. on Satellite Meteorology, Norfolk, VA, Sept. 2004 - 2 papers presented.

1.5 Tropical Cyclone Research

1) CIMSS has continued to develop new diagnostic fields derived from GOES winds analyses for applications to Tropical Cyclones (TCs). These products include analyses of vertical wind shear, vorticity, upper-level divergence, vertical wind shear tendency, and surface adjusted cloud-drift winds. All of these products are featured on the CIMSS Tropical Cyclones web site (<http://cimss.ssec.wisc.edu/tropic/tropic.html>), which has become an extremely popular “public outreach” site for both the general public and forecasters during TC events (see Figure 9).

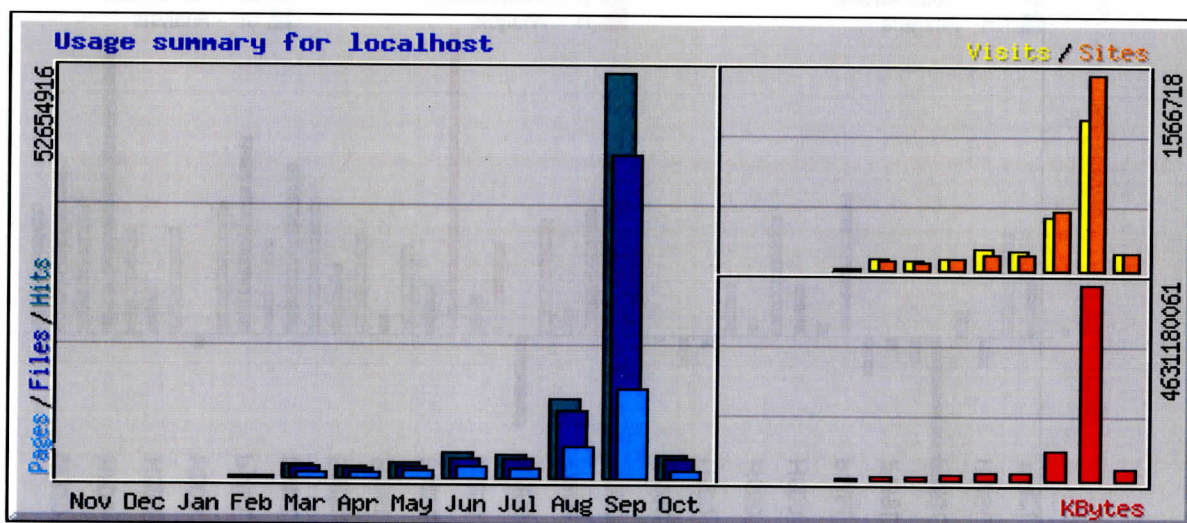


Figure 9: Usage summary for the CIMSS TC web site over the past year. Note the 52 million plus “hits” in the month of September during the major hurricane activity.

Over the last 6 months, a new diagnostic tool has been added to this suite: a tropospheric vertical motion product. This field estimates the presence of net vertical motions in the atmospheric column from 200-925 hPa analyses output by the CIMSS winds algorithm. This information will have applications to assessing potential regions of TC genesis and intensification and after more extensive testing and validation, will be made available in near real-time in multiple ocean basins (North Atlantic, Indian, North Pacific, and South Pacific Oceans).

2) The research on identifying the Saharan Air Layer (SAL) from GOES data and its influence on TC intensity has led to a major paper on the topic (see Figure 10). Dunion and Velden (2004)

have shown that the SAL suppresses TC activity in the North Atlantic and Caribbean Sea. The SAL's low humidity air can act to suppress convection by enhancing evaporatively-driven downdrafts in the TC, and the SAL's embedded mid-level easterly jet significantly increases the local vertical wind shear. The SAL is not readily detectable with the individual visible and infrared (IR) channels on the GOES imager. Although the individual spectral channels on the GOES satellites were not designed to track the SAL, recent tests have shown that the position of the SAL's dust and lower tropospheric dry air can be tracked most reliably with the split-window IR channels (10.7 and 12 μm) on the GOES-8/10 imager and the 3.9 and 10.7 μm channels on the GOES-12 imager to track the SAL in near real-time. The SAL products have been used by researchers and forecasters to monitor the position of the SAL and its affect on TCs during the 2004 hurricane season.

3) We have continued to upgrade the Advanced Objective Dvorak Technique (AODT) algorithm, which is now used by several of NOAA's tropical cyclone analysis centers. The algorithm upgrades have focused on the following primary areas: 1) refinement of the automated TC center finding routine, 2) improvement to the curve-banding scene type analysis for weak systems, and 3) statistical evaluation of the performance in specific cases to better understand the behavior and areas of weakness.

Publications and Conference Reports

Dunion, J., and C. Velden, 2004: The impact of the SAL on Atlantic tropical cyclone activity. *Bull. Amer. Meteor. Soc.*, **85**, 353-365.

26th AMS Conf. on Hurricanes, Miami, FL - 3 papers presented.

2004 Tropical Cyclone Conf., Honolulu, HI, - 1 paper presented.

2004 Interdepartmental Hurricane Conf., Charleston, SC, - 2 papers presented.

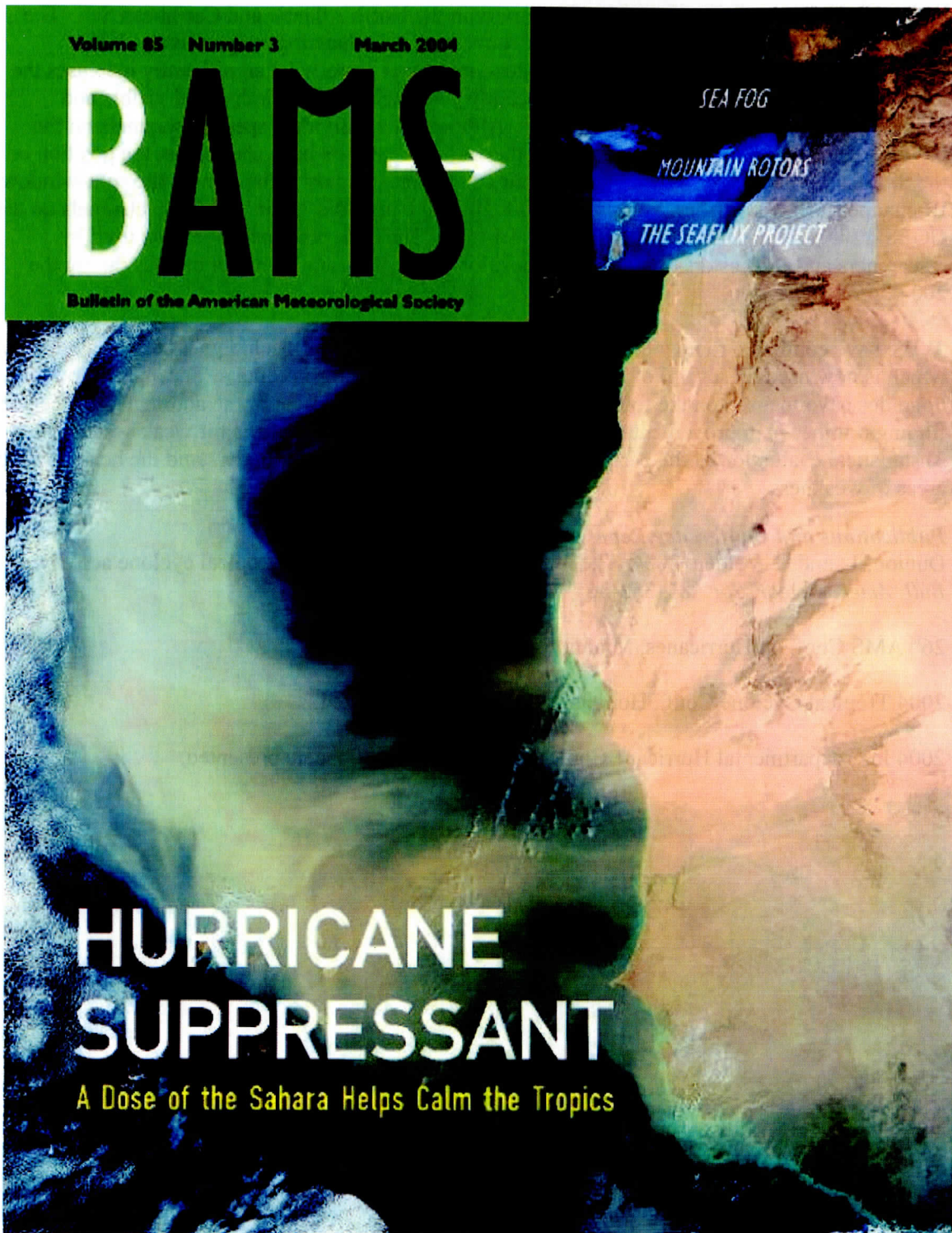


Figure 10: Research on identifying the Saharan Air Layer (SAL) from GOES data and its influence on TC intensity leads to a major paper in *BAMS*.

1.6 Biomass Burning

Activities during this period included:

- Continuing the GOES Wildfire Automated Biomass Burning Algorithm (WF_ABBA) trend analysis throughout the western hemisphere for applications in global change, real-time assimilation into aerosol transport models, air quality assessment, land-cover and land-use change studies and fire dynamics modeling.
- Participating in international multi-sensor fire product validation and comparison studies, including data fusion assessments.
- Continuing collaborations with the atmospheric modeling community to assimilate the GOES Wildfire ABBA fire product into aerosol/trace gas transport models on a case study basis and in real time.
- Continuing development and implementation of a global geostationary fire detection system in association with IGOS GOFD/GOLD.

Since September of 2000, CIMSS has used the GOES WF_ABBA half-hourly fire product to conduct trend analyses of fire activity throughout the Western Hemisphere. During the past year (September 2003 - August 2004) the spatial distribution of fire activity was similar to previous years, but there was an overall decrease of 22%. Figure 11 provides an overview of the number of fire pixels detected by the GOES-12 WF_ABBA over the past year in 10-degree latitude bins. In North America (30-70 (N)) the number of detected fire pixels decreased by 17% when compared with the previous year. This value does not include the fires that burned in Northwestern Canada and Alaska during the summer of 2004, since this is outside the processing area of the GOES-12 WF_ABBA. In Central America (10-30 (N)), there was a decrease of nearly 46%. The spring of 2003 was unusually dry in Central America and Mexico resulting in a very active fire season as opposed to the spring of 2004. Nearly 88% of all of the fire pixels observed during the past year were detected in South America (10 (N) - 30 (S)). The number of fire pixels detected in South America was approximately 20% less than observed in the previous year. There was a 21% reduction along the arc of deforestation in Brazil.

Multi-sensor comparisons and validation studies continue with an emphasis on comparisons of GOES with MODerate-resolution Imaging Spectroradiometer (MODIS) derived fire products. Comparisons of daily fire composites from MODIS and GOES in the Western Hemisphere show good qualitative agreement but at times there are significant differences in the location of fires. Initial analyses indicate that most of the differences are not due to false alarms, but rather are associated with instrument viewing capabilities, algorithmic differences, and diurnal variability that allow each sensor/algorithm to detect different fires. The user community has stressed the importance of characterizing these differences for proper data fusion and model assimilation. At the 8th International Global Atmospheric Chemistry (IGAC) Conference held in Christchurch, New Zealand, in September 2004, a paper was presented showing the advantages of using multi-sensor (GOES Imager, AVHRR, and MODIS) fused fire products to determine realistic biomass burning emission rates for pollutant transport in South America. The study focused on the time period of August - November 2002 and demonstrated that the higher spatial resolution of the MODIS fire products combined with the diurnal GOES fire information resulted in improved emissions products. The data fusion technique used in this study is currently being implemented in real-time at the Brazilian Instituto Nacional de Pesquisas Espaciais (INPE) Center for Weather Prediction and Climate Studies (CPTEC).

GOES WF_ABBA Annual Fire Summaries for the Western Hemisphere
Time Period: September 2001 - August 2004

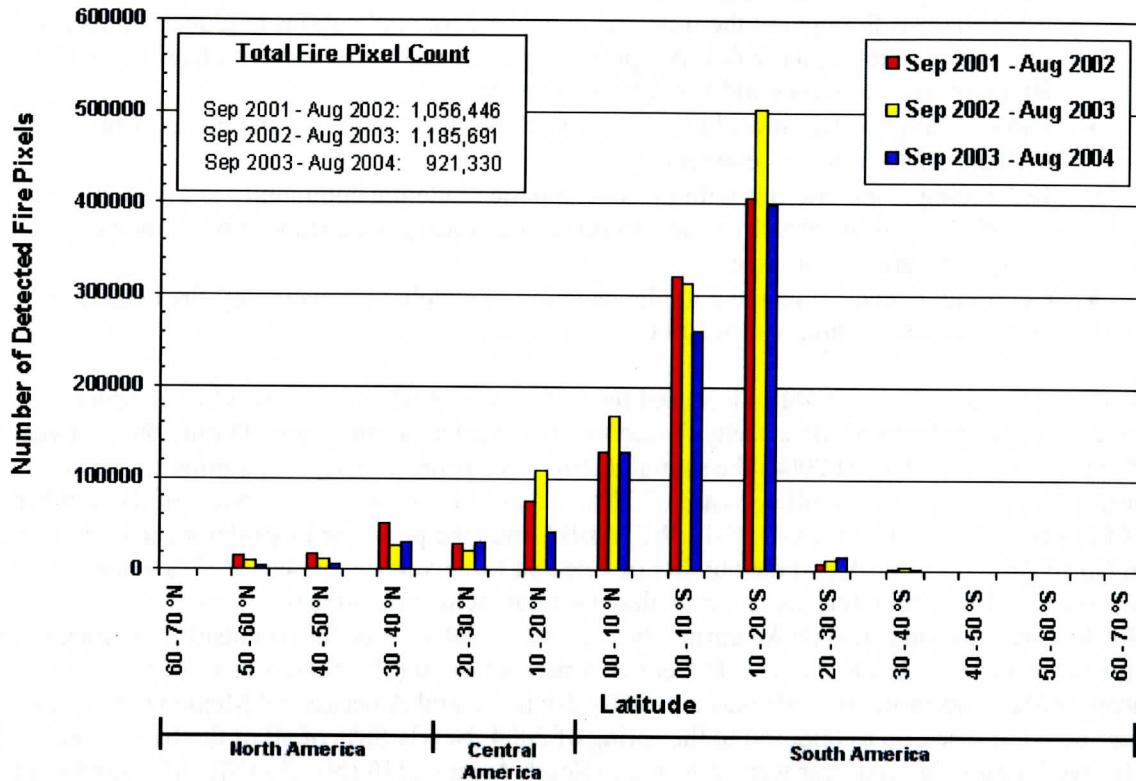


Figure 11: The number of fire pixels detected by the GOES-12 WF_ABBA over the past year in 10-degree latitude bins.

The CIMSS biomass burning team continues to participate in both national and international aerosol and air quality monitoring and model data assimilation efforts. Three peer reviewed papers have been submitted/published in association with model data assimilation collaborations with the Naval Research Laboratory (NRL-Monterey), the Brazilian INPE/CPTEC, and the University of Alabama - Huntsville. NRL - Monterey is assimilating half-hourly GOES-10/-12 ABBA fire products in the NAAPS (Navy Aerosol Analysis and Prediction System) model in real time to analyze and predict aerosol loading and transport. INPE/CPTEC is assimilating GOES-12 South American WF_ABBA fire products into the Regional Atmospheric Modeling System (RAMS) to analyze biomass burning emissions such as ozone and CO. At the University of Alabama - Huntsville, the Regional Atmospheric Modeling System - Assimilation and Radiation Online Modeling of Aerosols (RAMS-AROMA) was developed to assimilate satellite fire and aerosol products to provide better forecasts of smoke transport and increased understanding of the physical processes associated with this phenomenon. Nearly every year smoke aerosols from biomass burning in Central America are transported to the United States across the Gulf of Mexico. Figure 12 shows a case study from April 2003 when biomass burning in Central America had a significant impact on air quality in Texas and the Southeastern U.S. RAMS model results utilizing GOES WF_ABBA satellite-derived fire products provided an excellent overview of the situation and agreed well with ground-based observations. In this case they helped fill the gaps in MODIS derived aerosol products for the region.

Applications of WF_ABBA Fire Product Model Assimilation for Aerosol Air Quality Monitoring and Forecasting in the U.S.

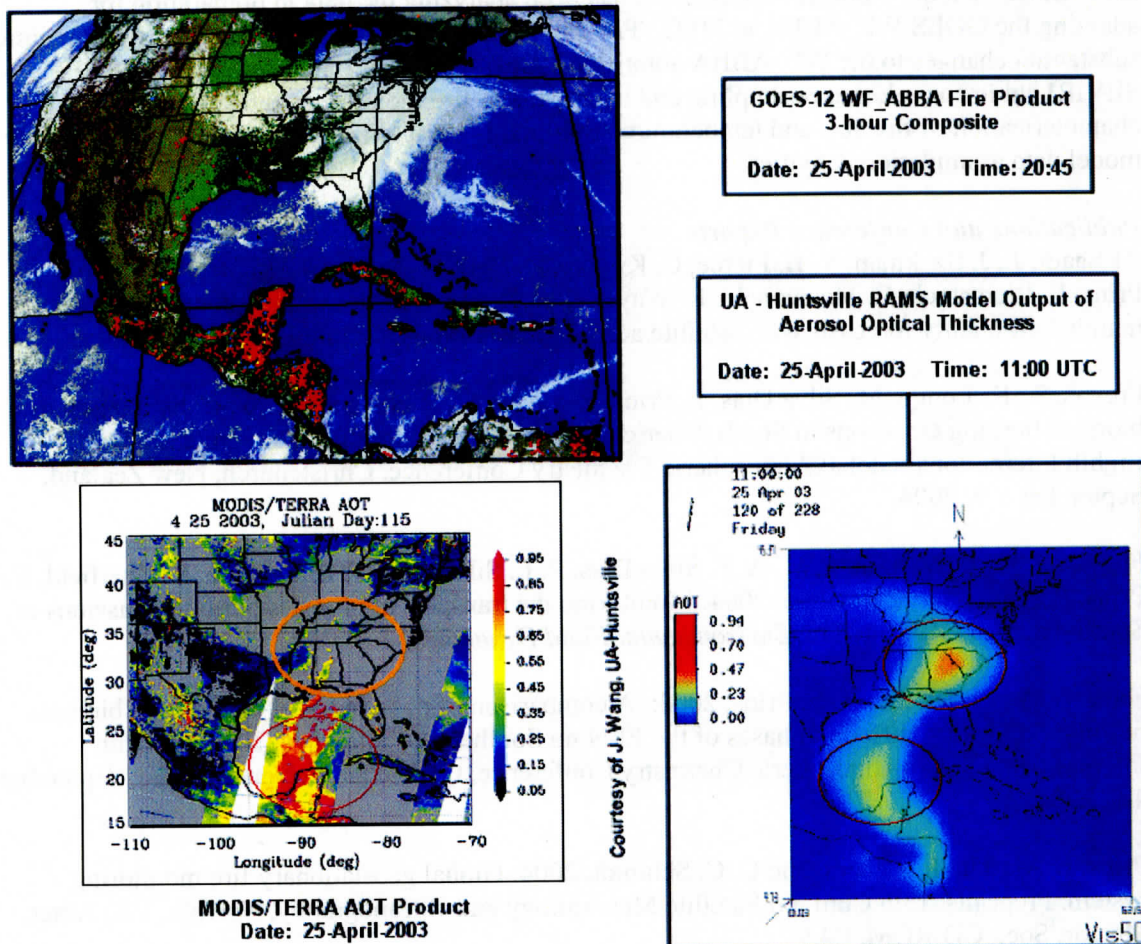


Figure 12: Case study from April 2003 when biomass burning in Central America significantly impacts air quality in Texas and the Southeastern U.S.

During the past quarter there has been a dramatic increase in discussions/collaborations with the air quality community in the United States, specifically with regard to the impact of biomass burning emissions on ozone and PM_{2.5}. One of the largest unknowns in air quality monitoring/modeling is non-standard emissions associated with biomass burning sources in the U.S. and long-range inter-continental transport. The air quality community in the United States is looking toward diurnal multi-sensor satellite monitoring to assist in identifying point sources, emissions, and transport. CIMSS is working with the Western Regional Air Partnership (WRAP) to produce fire emissions data for 2002 to assist them in fulfilling monitoring requirements for U.S. EPA regional haze regulations. The biomass burning team is also involved in a collaborative effort with S. Fine of NOAA's Office of Weather and Air Quality and S. Kondragunta of the NOAA/NESDIS Office of Research and Applications to investigate the use of satellite derived fire products for emissions estimates and air quality model data assimilation.

Development and implementation of a global geostationary active fire monitoring system is progressing in collaboration with the Integrated Global Observing Strategy (IGOS) Global Observation of Forest and Land Cover Dynamics (GOF/C/GOLD) fire working group. CIMSS is

currently adapting the WF_ABBA to the GOES-9 platform for fire monitoring in the Western Pacific. In March 2004, the SSEC Data Center began receiving MSG (Meteosat-8) multispectral data. Since then the biomass burning team has been analyzing the data in preparation for adapting the GOES WF_ABBA to MSG. Preliminary studies indicate that this effort will require substantial changes to the WF_ABBA algorithm. A primary issue of concern is the MSG SEVIRI cubic convolution resampling and its impact on fire monitoring and sub-pixel characterization of fire size and temperature. Sub-pixel characterization is needed for air quality model data assimilation activities.

Publications and Conference Reports

Al-Saadi, J., J. Szykman, R. B. Pierce, C. Kittaka, D. Neil, D. A. Chu, L. Remer, L. Gumley, E. Prins, L. Weinstock, C. MacDonald, R. Wayland, F. Dimmick, J. Fishman, 2004: Improving national air quality forecasts with satellite aerosol observations. Submitted to *BAMS*.

Freitas, S., K. Longo, M. Silva Dias, E. Prins, R. Chatfield, P. Silva Dias, 2004: Estimation of biomass burning emissions in South America using field observations and remote sensing. Eighth International Global Atmospheric Chemistry Conference, Christchurch, New Zealand, September 4-9, 2004.

Freitas, S. R., K. M. Longo, M. A. F. Silva Dias, P. L. Silva Dias, F. S. Recuero, R. Chatfield, E. Prins, P. Artaxo, F. S. Recuero, 2004: Monitoring the transport of biomass burning emissions in South America. Accepted by *Environmental Fluid Dynamics*.

Harkey, M., M. Hitchman, E. Prins, 2004: A comparison of passive tracer analyses of biomass burning plumes for different phases of the El-Nino Southern Oscillation (ENSO). Eighth International Global Atmospheric Chemistry Conference, Christchurch, New Zealand, September 4-9, 2004.

Prins, E. M., D. McNamara, and C. C. Schmidt, 2004: Global geostationary fire monitoring system. Preprints, 13th Conf. on Satellite Meteorology and Oceanography, Norfolk, VA, Amer. Meteor. Soc., CD-ROM, P4.6.

Reid, Jeffrey R., E. M. Prins, D. L. Westphal, C. C. Schmidt, K. Richardson, S. Christopher, T. F. Eck, E. A. Reid, C. Curtis, and J. Hoffman, 2004: Real-time monitoring of South American smoke particle emissions and transport using a coupled remote sensing/box-model approach. *Geophysical Research Letters*, Vol. 31, L06107, 5 pp.

Wang, J., S. A. Christopher, U. S. Nair, J. S. Reid, E. M. Prins, J. Szykman, 2004: Assimilation of satellite-derived smoke emission into a mesoscale model: applications for forecasting particulate matter air quality. Submitted to *Geophysical Research Letters*.

Wang, J., U.S. Nair, S. A. Christopher, R. T. McNider, J. Reid, E. M. Prins, and J. Szykman, 2004: An integrated system for studying the effect of Central American smoke aerosols on air quality and climate over the Southeastern United States. Preprints, 13th Conf. on Satellite Meteorology and Oceanography, Norfolk, VA, Amer. Meteor. Soc., CD-ROM, P3.9.

Weaver, J. F., D. Lindsey, D. Bikos, C. Schmidt, E. Prins, 2004: Fire detection using GOES rapid scan imagery. *Weather and Forecasting*, Vol. 19, No. 3, 496-510.

1.7 Outreach and Education

UW-Parkside 17th Annual Women in Math & Science Day

On April 2nd, the CIMSS on-line course “Satellite Meteorology for Grades 7-12” (<http://cimss.ssec.wisc.edu/satmet/>) was presented to middle school students attending the Women in Math & Science Day at University of Wisconsin-Parkside with CD versions distributed to all students. The conference committee requested an additional 25 CDs for distribution to other educators at the conference.

Updates to the Satellite Meteorology Course

A new module on Weather Forecasting was added to the on-line course in May 2004. (<http://cimss.ssec.wisc.edu/satmet/modules/4casting/>)

Grandparents University at UW-Madison

CIMSS and SSEC (the Space Science and Engineering Center) hosted a meteorology major for 20 UW alumni and their grandchildren on July 15th and 16th. This bustling group of 40 was split into two groups to cycle through programs on satellite meteorology, weather forecasting, satellite research, and Antarctica. The grandchildren enjoyed numerous hands-on activities while the adults were clearly impressed to learn about the wide range of research activities at CIMSS and SSEC. Everyone enjoyed the view from the 16-story building.

A Teacher Workshop in Satellite Meteorology

15 teachers from around the nation attended a two-day workshop in Satellite Meteorology at CIMSS on July 20th and 21st (Figure 13). 5 more teachers from South Africa joined the workshop at the last minute. The teachers worked their way through the Satellite Meteorology course and offered suggestions for improvement. CD-ROM versions of this course were distributed to all the teachers. Interspersed with these hands-on sessions were presentations on the operational and research applications of satellite meteorology. The teachers also watched the 22 minute “Sentinels Against the Storm” DVD produced by NOAA and The Weather Channel and requested copies which were promptly provided.



Figure 13: Teachers and organizers at Satellite Meteorology Teacher Workshop.

A Workshop on Atmospheric, Earth and Space Science for High School Students

CIMSS hosted the 12th annual Summer Workshop for High School Students from July 26th to July 29th (Figure 14). Ten students signed on for the adventure. The small class size prompted changes in the original agenda but the end result was another high quality program with ample exposure to multiple facets of the Earth Science professions. For meteorology, students had a McIDAS weather session, visited the Milwaukee/Sullivan National Weather Service Office, visited the WISC-TV weather station, worked on sections of the Satellite Meteorology course, and made a forecast for their geology field trip. They also viewed the “Sentinels Against the Storm” DVD. For remote sensing, they spent an afternoon investigating the use of satellite images in natural resource management utilizing GIS and the Internet. For astronomy they visited the UW-Space Place and the Washburn Observatory. For geology they took a guided tour of the Geology Museum before spending a full day hiking the Baraboo bluffs to wrap up their busy week of Earth Science Education.

Wisconsin Space Grant Consortium

Approximately 25 professionals attended two back-to-back presentations on the CIMSS summer workshops at the Wisconsin Space Grant Consortium 14th Annual Wisconsin Space Conference on August 19th.



Figure 14: Students who attended CIMSS Summer Workshop.

The Governor's Wisconsin Educational Technology Conference (GWETC)

On October 13th, the CIMSS on-line course "Satellite Meteorology for Grades 7-12" (<http://cimss.ssec.wisc.edu/satmet/>) was presented in an hour-long workshop to 24 educators attending the Governor's Wisconsin Educational Technology Conference (GWETC). The teachers were also informed of the summer workshop in satellite meteorology and most signed up to receive e-mail updates about the course and the workshop. CDs were distributed to all the teachers in attendance.

2. CIMSS Support for Polar and Geostationary Satellite Science Topics

2.1 Intercalibration of GOES and POES

Calibration and instrument intercomparison is the main method by which individual instruments can be validated with each other between the geostationary and polar orbiting platforms. Routine automated intercalibration provides the only picture of how operational geostationary environmental satellites around the globe compare radiometrically. CIMSS has been intercalibrating satellite instruments routinely since late 1999.

The primary purpose of the Intercalibration project is to compare the infrared window and water vapor channels on geostationary instruments (GOES, Meteosat, etc) by using the same polar-orbiting instrument (NOAA AVHRR and HIRS). This is accomplished by making multiple comparisons at the geostationary sub-satellite points and finding an average brightness temperature difference between the geostationary imager and the polar orbiter.

Comparison of satellite radiances leading to an improved knowledge of calibration is important for various global applications of satellite data where data from more than one instrument are combined for a single purpose. CGMS (Coordination Group for Meteorological Satellites) has requested satellite operators to regularly perform satellite intercalibration. This proposal project sets forth the means by which this request can be met at CIMSS. In 2002 the GOES Technical Advisory Committee (TAC) advised that CIMSS continue to meet CGMS requirements on this project.

In the second half of FY04 approximately 2,600 intercomparisons were made between polar-orbiting AVHRR and HIRS (on NOAA-15 and -16) and the imagers on GOES-9, -10, -12, Meteosat-5, and -7 in the infrared window and water vapor channels. Additionally, Meteosat-8 data is now being collected and processing software is in the process of being updated so that Met-8 becomes part of the fully automated processing software package. This will include comparisons for the infrared window, water vapor, and 13.3 micrometer bands. As part of periodically required maintenance of this project, roughly 8 gigabytes of archived data collected for intercalibration were stored on CD to clear space for new data. The software that makes regular updates to the Web needed maintenance, as some of the time series plots were not updating correctly.

Publications and Conference Reports

Gunshor, M. M., T. J. Schmit, and W. P. Menzel, 2003: New Analysis with the Intercalibration of Geostationary and Polar-Orbiting Radiance Measurements. CGMS XXXI held 3-7 November 2003, Ascona, Switzerland. EUMETSAT publication.

Gunshor, M. M., T. J. Schmit, and W. P. Menzel, 2004: Intercalibration of the Infrared Window and Water Vapor Channels on Operational Geostationary Environmental Satellites Using a Single Polar Orbiting Satellite. *J. Atmos. Oceanic Technol.*, **21**, 61-68.

2.2 GOES Wildfire Algorithm

The biomass burning monitoring team proposed the following research activities at CIMSS.

- CIMSS will continue to produce half-hourly WF_ABBA fire products in real time and make them available via the web and anonymous ftp.
- CIMSS will work with the user community to develop and implement a Rapid Scan WF_ABBA to take advantage of high temporal resolution data for early wildfire detection applications in the U.S.
- CIMSS will continue to participate in international satellite fire product validation and inter-calibration activities. Results will be used to reduce false alarms and minimize actual fires eliminated by temporal filtering techniques.

Over the past year UW-Madison CIMSS continued to produce half-hourly GOES-10/-12 Wildfire Automated Biomass Burning Algorithm (WF_ABBA) fire products for the Western Hemisphere in near real-time, with products available via anonymous ftp within 20-30 minutes after receiving the imagery. The product includes ASCII text files and alpha-blended composite fire imagery. Animations are made available to the user community via the web at <http://cimss.ssec.wisc.edu/goes/burn/wfabba.html>. The GOES WF_ABBA ASCII text files are provided via an anonymous FTP site at CIMSS. In order to accommodate an increase in user requests for archived fire products, the on-line archive of the GOES WF_ABBA at the Fire Locating And Monitoring of Burning Emissions (FLAMBE) web site (<http://www.nrlmry.navy.mil/flambe/index.html>) (extending back to September 2000) was updated to allow downloads of up to 500 files at a time. The user community includes climate change scientists, the aerosol and trace gas transport modeling community, the land-use and land-cover change detection research community, government agencies, resource managers, fire managers, international policy and decision makers, educational institutions, and the general public. The WF_ABBA fire product for North America is now part of the National Geophysical Data Center Comprehensive Large-Array data Stewardship (CLASS) archive. The CLASS Archive and Distribution System (ADS) is responsible for long-term preservation of data and products by NOAA observing systems. During the past quarter two additional parameters were added to the CLASS data set. These parameters are the instantaneous estimates of sub-pixel fire size and temperature.

The GOES WF_ABBA processing system is being modified for rapid scan fire detection, monitoring, and reporting. In order to process rapid scan imagery in real-time, CIMSS purchased a Dell 1750 rack mounted system with two 3.06ghz CPUs. The WF_ABBA software and processing system is currently being ported to the new Dell system. Implementation is expected to be completed by the end of the year and will be available to the fire management community during the next fire season. The fire management community has expressed interest in obtaining rapid scan WF_ABBA fire products for the western U.S. during high fire danger periods and in support of active wildfire monitoring and fire weather forecasting. A paper highlighting the advantages of using rapid scan GOES imagery for fire detection and monitoring was recently published in *Weather and Forecasting* by Weaver et al.

In South America, validation and multi-sensor comparison studies continue in the state of Acre, Brazil and along the arc of deforestation. Collaborations with the Woods Hole Research Center and the Universidade Federal do Acre in Rio Branco, Brazil have provided valuable insight into the capabilities of the GOES Imager, the Advanced Very High Resolution Radiometer (AVHRR), and the MODerate-resolution Imaging Spectroradiometer (MODIS) for identifying and monitoring fires in South America. From 16 August to 9 September 2003, wildfires raged out of control in colonization projects in the Municipality of Capixaba, in the state of Acre, Brazil. Ground truth was used to validate GOES, AVHRR, and MODIS fire products. Each product provided different views of the fire activity. Initial results presented by L. Johnson (Universidade Federal do Acre) at the 3rd Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) Scientific Conference held in July 2004 in Brasilia, Brazil, showed that the AVHRR and MODIS fire products provided more accurate spatial summaries of the wildfires, but that the GOES WF_ABBA presented a better temporal summary of the evolution of the wildfires. A multi-sensor overview along with ground truth information provided the most complete assessment of the wildfire activity.

Publications and Conference Reports

Al-Saadi, J., J. Szykman, R. B. Pierce, C. Kittaka, D. Neil, D. A. Chu, L. Remer, L. Gumley, E. Prins, L. Weinstock, C. MacDonald, R. Wayland, F. Dimmick, J. Fishman, 2004: Improving national air quality forecasts with satellite aerosol observations. Submitted to *BAMS*.

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Freitas, S. R., K. M. Longo, M. A. F. Silva Dias, P. L. Silva Dias, F. S. Recuero, R. Chatfield, E. Prins, P. Artaxo, F. S. Recuero, 2004: Monitoring the transport of biomass burning emissions in South America. Accepted by *Environmental Fluid Dynamics*.

Harkey, M., M. Hitchman, E. Prins, 2004: A comparison of passive tracer analyses of biomass burning plumes for different phases of the El-Nino Southern Oscillation (ENSO). Eighth International Global Atmospheric Chemistry Conference, Christchurch, New Zealand, September 4-9, 2004.

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Reid, Jeffrey R., E. M. Prins, D. L. Westphal, C. C. Schmidt, K. Richardson, S. Christopher, T. F. Eck, E. A. Reid, C. Curtis, and J. Hoffman, 2004: Real-time monitoring of South American smoke particle emissions and transport using a coupled remote sensing/box-model approach. *Geophysical Research Letters*, Vol. 31, L06107, 5 pp.

Wang, J., S. A. Christopher, U. S. Nair, J. S. Reid, E. M. Prins, J. Szykman, 2004: Assimilation of satellite-derived smoke emission into a mesoscale model: applications for forecasting particulate matter air quality. Submitted to *Geophysical Research Letters*.

Wang, J., U.S. Nair, S. A. Christopher, R. T. McNider, J. Reid, E. M. Prins, and J. Sykzman, 2004: An integrated system for studying the effect of Central American smoke aerosols on air quality and climate over the Southeastern United States. Preprints, 13th Conf. on Satellite Meteorology and Oceanography, Norfolk, VA, Amer. Meteor. Soc., CD-ROM, P3.9.

Weaver, J. F., D. Lindsey, D. Bikos, C. Schmidt, E. Prins, 2004: Fire detection using GOES rapid scan imagery. *Weather and Forecasting*, Vol. 19, No. 3, 496-510.

2.3 Geostationary Winds Support

CIMSS has supported the research and development of the automated satellite winds tracking software for the last 25 years. Under this funding, the CIMSS winds research team is committed to help maintain and advance the winds algorithm science modules and capabilities. This includes any new science advances, validation, and developments for the science community. The algorithm upgrades are then made available to colleagues at NOAA/NESDIS for operational consideration/implementation.

The primary accomplishments during this reporting period were:

- Code modifications to accommodate GOES-12 winds production. A new CO₂ heights approach was tested, evaluated and implemented. The approach utilizes an IR-window temperature threshold to determine whether CO₂ heights should be attempted or not. Several temperature thresholds were tried and statistically validated. This logic takes the place of using a discreet pressure level as the threshold.
- Code advances/upgrades provided to USAF/AFWA (NESDIS operational national backup). CIMSS is providing software assistance and upgrades to AFWA as their winds production is now operational. The goal is to keep the algorithm version reasonably close to the NOAA/NESDIS operational version for output consistency.
- Code upgrades to accommodate new satellites/instruments. Any new code modifications or implementations done by CIMSS to accommodate new satellites or instruments are made available to NOAA/NESDIS. In this reporting period, several modifications were made to the winds algorithm for handling new MSG imagery. Also, a few modifications were put into place to accommodate the MODIS winds. One important addition was the code that accounts for parallax.
- The implementation and testing of new QC software obtained from John LeMarshall (JCSDA) has begun. This code will append a new vector "expected error," that will be useful for data assimilation purposes. As a first step, the code is being rewritten from its current format into code compatible with GOES winds algorithm versions currently in place at CIMSS and NOAA/NESDIS.

In addition to the above accomplishments, CIMSS is a responder to Winds POP action items, as well as an active member of the WMO-sponsored International Winds Workshops. Through these venues, ideas are continuously exchanged between the CIMSS PIs, the NOAA/NESDIS winds specialists, and the international winds community.

2.4 GOES Spectral Response Studies

CIMSS scientists prepare for quantitative use of both GOES Sounder and Imager radiances through the generation of transmittance files calculated from Spectral Response Functions (SRF) used in conjunction with a line by line radiative transfer model (LBLRTM). This project addresses activities necessary to prepare for the eventual use of those satellite data and eventual generation of research products.

The goal of this research is to maintain a high level of accuracy in the calculations obtained from the GOES series of sounders and imagers. Specifically, this task addresses future needs with GOES-N. The Planck function coefficients (PFCs) needed to convert radiances into temperature for the GOES-N imager and sounder were to be calculated. GOES-N sounder PLOD transmittance files were to be generated and tested.

The primary activity for this study is to average (by detector) the spectral response functions (SRF) for GOES-N. Regression transmittance files are then generated using these SRF files. GOES-N is expected to launch in December 2004. For GOES-N, SRF from both the GOES imager and sounder need to be processed into transmittance coefficients. Currently the GOES Sounding retrievals use PLOD (Pressure Layered Optical Depth), also called Pressure layer Fast Algorithm for Atmospheric Transmittances (PFAAST), as the fast forward model. Completing this work in a timely fashion will help determine if there are problems with the SRF database. This task has been performed for every GOES in the series.

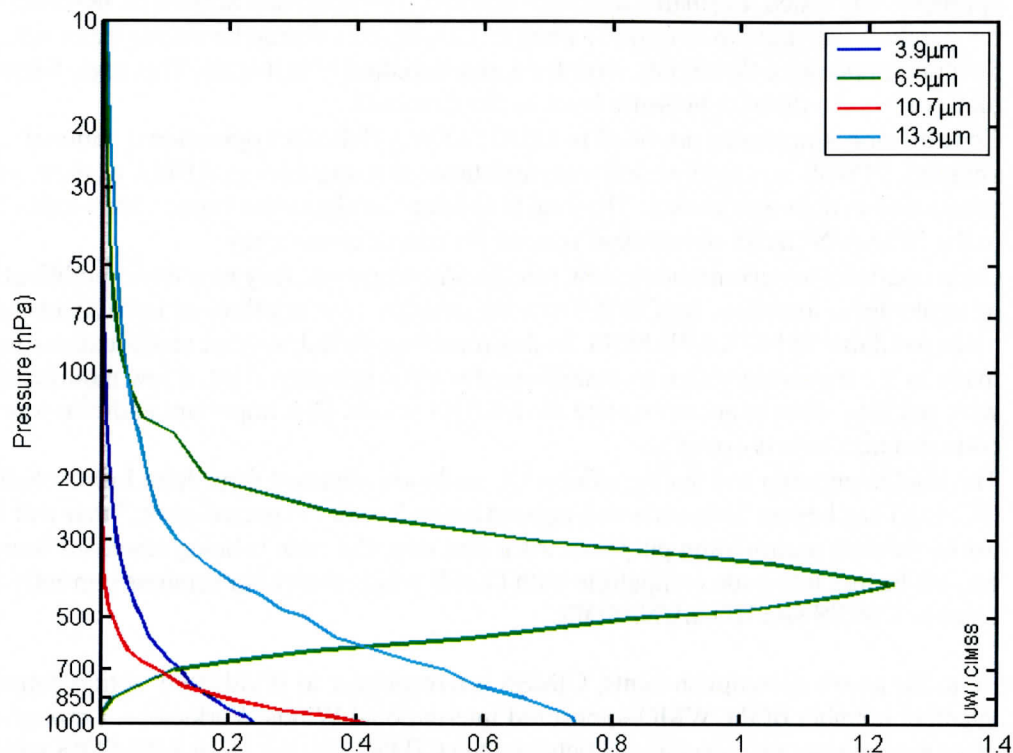


Figure 15: GOES-N Imager weighting functions calculated for the US Standard Atmosphere at nadir view.

The primary activities of this project were completed in the first half of FY04. GOES-N Planck function coefficients were provided to McIDAS programmers so that future versions of McIDAS software will be able to handle GOES-N data (converting radiance to brightness temperature).

Investigations into the latest LBLRTM versions continue. AER (Atmospheric Environmental Research), Inc. continually updates the line by line radiative transfer model and these updates are investigated for their effects on GOES forward model calculations, retrievals, and other related software. In addition, new water vapor continuum regression techniques are being investigated. GOES transmittance coefficient files for a 101 level atmospheric model, which includes GOES-N, have been generated and are available for the wider satellite community.

2.5 GOES Quality Assurance & Algorithm Maintenance

This PSDI program supports GOES Imager and Sounder data quality assurance and science algorithm maintenance. It is a broad-based program, involving aspects of both computer software and hardware. For example, we might need to repair a problem(s) that arise concerning the GOES Sounder and (or) Imager retrieval products, such as modifying software to handle special atmospheric or computing environment conditions. Work supported under this proposal is essential to maintaining the integrity of all the GOES Imager and Sounder research products that

CIMSS makes available to the meteorological community through its Web site at <http://cimss.ssec.wisc.edu/goes/realtime/realtime.html>

The FY 2004 proposal mentions a number of proposed tasks to be undertaken during the year. Namely, software development will continue to display statistics showing temperature and moisture retrieval quality in near-realtime on the Web. Collocated radiosonde information will be used as "truth." Monitoring of GOES Imager and Sounder product systems hardware will continue, as will interfacing with technical computing personnel within SSEC as needed. Software related to both Sounder and Imager applications will be made more robust, in terms of multi-platform use (AIX, IRIX, Linux, etc.), organization (e.g., being able to quickly and easily gather all software needed to compile and run a given application), enhanced code documentation and appearance, etc. McIDAS software updates will be installed to upgrade the computing environment within which the GOES research products are produced.

During the period 01 April 2004 through 30 September 2004, various quality assurance and algorithm maintenance tasks were accomplished, including the following:

- New versions of McIDAS-X were installed on computer systems used for our GOES work.
- Occasional, simple checks were performed on the daily tape archive of CIMSS temperature/moisture and cloud retrieval data. The data for this archive is saved and transferred daily to the SSEC Data Center via software that was developed in the past under this program.
- Numerous files were added to the SSEC CVS repository containing various software and ancillary files. This ongoing task continues to enhance the stability (i.e., less susceptibility to losing the software or ancillary files due to a disk crash) and accountability of our software and files. Work was done on a UNIX script that will, when complete, allow for a total rebuild of our system from the CVS repository in the event of a catastrophic disk failure on one of our computers. Other software written over the years by Fred Nagle and Hal Woolf was also added to the CVS repository, preserving it for future use.
- Late in May, the legacy CIMSS 3x3 Field-of-View (FOV) retrievals were resurrected on a different system, after being interrupted in early March due to the failure of one of our main retrieval processing computers. Even though Single FOV (SFOV) retrievals are now the state of the art, it is important to continue to produce the legacy 3x3 FOV retrievals as a baseline check.

Late in the period, some time was spent organizing additional hardware purchases that will greatly increase the computational and (in particular) disk storage capacity for our GOES work. Finally, easy but long-overdue repairs were made early in the period to the retrieval/RAOB collocation file software to fix the twice-daily production of a couple files.

2.6 Clear Sky Brightness Temperature (CSBT)

Transfer of Processing Code to CVS and Ultimately to a Linux Machine

The Clear Sky Brightness Temperature (CSBT) software was incorporated into a Concurrent Versions System (CVS) repository. This includes all scripts, macros, programs, subroutines, and data files used to generate the CSBT retrievals. The next step was to transfer the code from the CVS repository on an IBM AIX processing machine to a Linux computer. By the end of the reporting period all code was transferred, modified and successfully compiled on the Linux

machine. To be completed is the final check out making sure the new processing system on the Linux platform is concurrent with the routine processing now taking place on the IBM AIX machine. These data are being used operationally by the European Centre for Medium Range Forecasting (ECMWF) forecast office in England and being collected by the National Center for Environmental Prediction (NCEP) in Washington, D.C.

Routine Processing of “Gaussian” Version of Imager Cloud Product

An additional scheme, a “Gaussian Fit” parameter scheme, was introduced in order to better identify clear and cloudy pixels within the observation box (11x17) for the Imager, which corresponds to approximately a 50 km resolution. Error flag parameters were also introduced into the output Binary Universal FoRm (BUFR) file to be used by the modelers as quality control parameters when introducing these data into numerical model forecasts. Numerical modeling scientists at both NCEP and ECMWF are currently testing the quality of the new data sets. An example of the “Gaussian Fit” scheme is shown in Figure 16.

Rough Draft Version of the Operator’s and Programmer’s Manuals

In order to satisfy operational requirements for transfer of the CSBT processing software to OSDPD facilities in Washington D.C., rough draft versions of both the Operations and the Programmers Manuals have been completed. Once transfer of all software to the Linux is completed and processing routinely, the final version of the manuals will be completed and accompany the CSBT software package.

GOES–10 Imager Comparison at 0900 UTC (Local Midnight)

The latest version of the Clear Sky Brightness Temperature (CSBT) algorithm incorporates Gaussian and other techniques to help determine clear and cloudy field-of-views.

The new version appears to perform much better at “local midnight”.

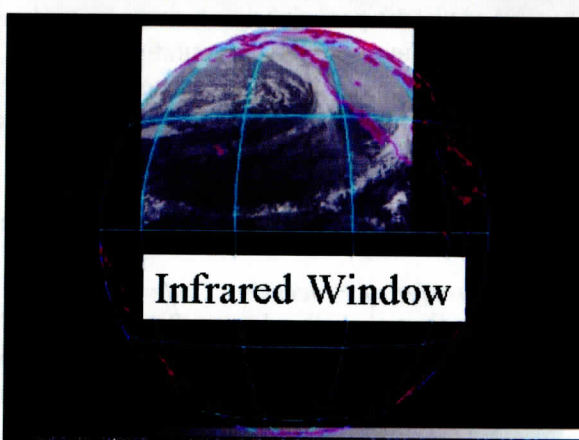
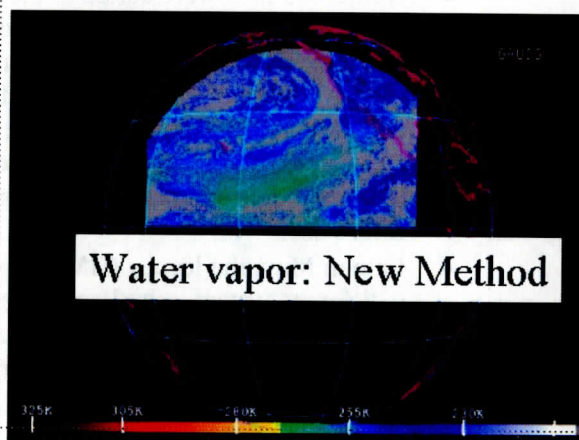
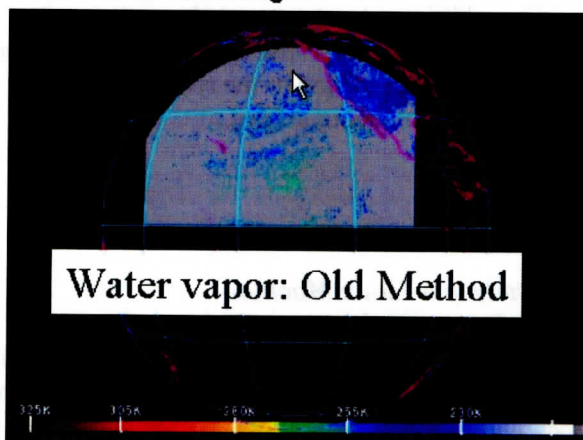


Figure 16: Example of the “Gaussian Fit” scheme for the Imager cloud product.

2.7 Cloud-Drift and Water Vapor Winds in the Polar Regions from MODIS

Geostationary satellite radiance measurements have been used to generate cloud-drift winds in the low- and mid-latitudes of the western hemisphere for more than two decades. Fully automated cloud-drift wind production from the Geostationary Operational Environmental Satellites (GOES) became operational in 1996, and wind vectors are routinely used in operational numerical models of the National Centers for Environmental Prediction (NCEP). Unfortunately, GOES is of little use at high latitudes due to the poor viewing geometry. The objective of this project is to generate wind vectors over the polar regions from polar-orbiting satellites. Of primary interest is the MODIS instrument on NASA's Terra and Aqua satellites. Our goal is to create an experimental wind product that can be used in numerical weather prediction systems.

The project Principal Investigator at CIMSS is Christopher Velden. David Santek is performing the analyses and oversees the implementation and modification of McIDAS (Man computer Interactive Data Access System) and heritage wind generation software for use with MODIS. Jeff Key, NOAA/NESDIS, works on the project in collaboration with CIMSS scientists, and is the NESDIS point of contact for the project.

Over the past six months we have continued the real-time generation of the MODIS polar winds product from both Terra and Aqua. The data are made available to users via anonymous ftp. MODIS data are acquired directly from a NOAA computer at NASA Goddard Space Flight Center (thanks to Gene Legg, NESDIS/OSDPD, and Mitch Goldberg, NESDIS/ORR). The MODIS winds product is experimental, routinely generated by CIMSS for scientific research; it is not an operational product at this time.

We have been providing the MODIS winds to several numerical weather prediction (NWP) sites. The NASA Global Modeling and Assimilation Office (GMAO) and the European Centre for Medium-Range Weather Forecasts (ECMWF) have been using the winds operationally for more than a year. Two additional sites have recently added the winds into their operational model: the Japan Meteorological Agency (JMA) in May 2004 and the Canadian Meteorological Centre (CMC) in September 2004. The UK Met Office, the Deutscher Wetterdienst (DWD, Germany's weather service), and the U.S. Navy Fleet Numerical Meteorology and Oceanography Center continue using the real-time winds in their experimental systems. The National Centers for Environmental Prediction's Environmental Modeling Center (NCEP/EMC) is evaluating the MODIS winds.

A Polar Winds session was held as part of the Seventh International Workshop in Helsinki, Finland (14-17 June 2004). Reports from CIMSS and NOAA scientists provided a status of the project, while seven NWP centers reported mostly positive impact in using the winds in experimental and operational forecast models. This positive impact is not only in the polar regions, but extends into mid-latitudes (see Figure 17).

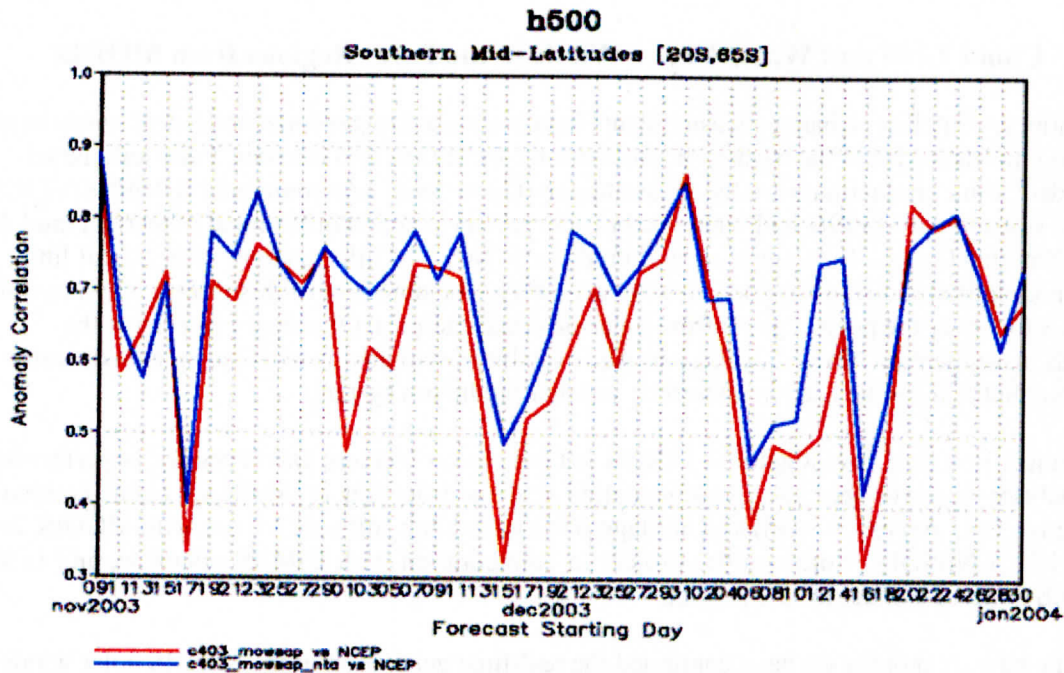


Figure 17: 500 hPa anomaly correlation for the southern hemisphere mid-latitudes from Nov. 2003 through Jan. 2004. The red represents the control; the blue includes MODIS polar winds. Note the increase correlation using the MODIS winds, especially in cases of forecast ‘busts.’ (from Lars Peter Riishojgaard at the GMAO)

The lag between the times of the MODIS overpass to the availability of wind vectors is typically 3-5 hours. In our discussions with the NWP centers, we were told that delays in the MODIS-derived wind fields must be less than 4 hours to meet the cut off time for assimilation into their system. We cannot consistently meet that time delay, so alternative data sources are being investigated. One option would be receiving data from Direct Broadcast (DB) stations. We have conducted experiments with DB sites at Kiruna, Sweden (European Space Agency) and Fairbanks, Alaska (Geographic Information Network of Alaska, University of Alaska). We have begun discussions with a DB site in Tromso, Norway (Kongsberg Satellite Services) and a proposed site in McMurdo, Antarctica. Indications are that we may be able to decrease the total processing time by about 1 hour.

Software testing is complete on modifications to the winds processing algorithm to improve the quality of the product. The most significant changes are: a parallax correction and the use of the MODIS calibration. The parallax correction will not only improve the accuracy of the current single-satellite product, but it will allow us to derive winds from alternating passes of Aqua and Terra. This should result in a more timely product and higher quality winds due to the shorter time interval between images. The addition of the MODIS calibration will improve the cloud height determination and allow the use of a higher bit-depth in the feature tracking correlation between images. Previously, the data were reduced to 8-bit. We are evaluating the impact of these changes on the winds product.

Publications and Conference Reports

Bormann, N., J-N. Thépaut, J. Key, D. Santek, and C. Velden, 2002: Impact of polar cloud track

winds from MODIS on ECMWF analyses and forecasts. Proceedings of the 15th Conf. on Numerical Weather Prediction, American Meteorological Society, San Antonio, TX, 12-16 August, 2002.

Key, J., D. Santek, C.S. Velden, N. Bormann, J.-N. Thepaut, L.P. Riishojgaard, Y. Zhu, and W.P. Menzel, 2002: Cloud-drift and Water Vapor Winds in the Polar Regions from MODIS. *IEEE Trans. Geosci. Remote Sensing*, 41(2), 482-492.

Key, J., D. Santek, C.S. Velden, and W.P. Menzel, 2001: Cloud-drift and water vapor winds in the polar regions from MODIS. Proceedings of the 11th Conference on Satellite Meteorology and Oceanography, American Meteorological Society, Madison, Wisconsin, 15-18 October 2001, 320-323.

Key, J., C. Velden, and D. Santek, 2001: High-latitude cloud-drift and water vapor winds from MODIS. Proceedings of the Sixth Conference on Polar Meteorology and Oceanography, American Meteorological Society, San Diego, 14-18 May 2001, 351-354.

Santek, D., J. Key, and C. Velden, 2003: Real-time Derivation of Cloud Drift and Water Vapor Winds in the Polar Regions from MODIS Data. Proceedings of the 12th Conf. on Satellite Meteorology and Oceanography, American Meteorological Society, Long Beach, CA, 9-13 February 2003.

2.8 CLAVR-x

Validation of CLAVR-x Algorithms

Over the past six months, we have undertaken several validation activities of the CLAVR-x operational cloud products. We have used data from the MODIS cloud top pressure generated here at CIMSS to validate and help improve the pixel-level AVHRR cloud temperature product. In addition, we have continued to validate the CLAVR-x cloud type product using ground based instrumentation from the ARM sites. This validation was included in a manuscript submitted during this period.

Improvements to CLAVR-x Algorithms

Over the past six months, we have focused our algorithm development efforts on improving the cloud temperature for AVHRR data used in CLAVR-x. The algorithm uses a split-window approach to estimate temperature and emissivity simultaneously and is similar to CO₂ slicing approach in this regard. One benefit to this approach is the fact that is a purely infrared technique that works for all orbits. Cloud temperature is a critical product since it is used to determine cloud layers.

Implementation of Near Real-Time Processing at CIMSS

We have set up a near real-time processing of all AVHRR GAC data at CIMSS to serve as test-bed for the operational system at NOAA. We have developed a simple Web site to deliver these products and provide some images of the global fields (<http://cimss.ssec.wisc.edu/clavr>). In addition, we have worked with NCEP to help them use this data. This activity has involved writing tools and readers for NCEP uses. Members of the NOAA Joint Center for Satellite Data Assimilation (JCSDA) are also using this data for testing. An example image from the CIMSS near real-time processing is shown in Figure 18.

Support NOAA's Effort to Make CLAVR-x Operational

Over the past six months, we have helped NOAA transition CLAVR-x to operations by providing documentation and assisting in testing of the operational code.

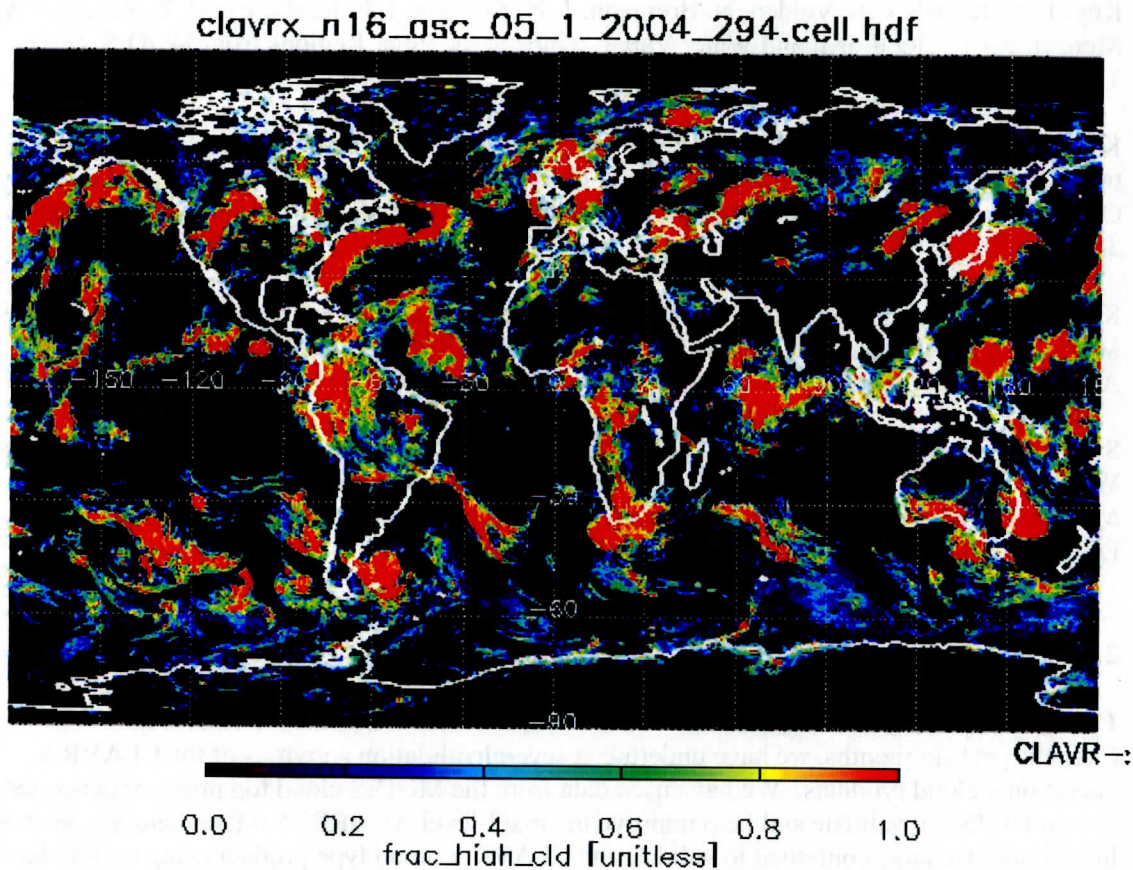


Figure 18: Example image of near real-time processing of AVHRR GAC data.

Publications and Conference Reports

Evan, Amato, A. K. Heidinger and M. J. Pavolonis, 2004: A new algorithm for dust detection over water utilizing the AVHRR imager, *AMS 13th Conference on Satellite Meteorology and Oceanography*, Norfolk, Virginia.

Heidinger, Andrew K., M. Goldberg, D. Tarpley, A. Jelenak, and M. J. Pavolonis, 2004: Initial Trends in Cloud Amount from the AVHRR Pathfinder Atmospheres Extended Data-set, *AMS 13th Conference on Satellite Meteorology and Oceanography*, Norfolk, Virginia.

Pavolonis, M. J. and A. K. Heidinger, 2004: Daytime Cloud Overlap Detection from AVHRR and VIIRS. *Journal Applied Meteorology*, **43**, Number 5, 762-778.

3. Ground Systems Research

3.1 GOES-12 and MSG winds

As new satellites are launched, the CIMSS/NESDIS automated winds processing code needs to be updated and modified to handle the inputs. During this reporting period, efforts were focused on adapting the algorithm to the new Meteosat Second Generation (MSG) data. Updated calibration modules have been written and incorporated into the code. The algorithm was also adapted to handle the 2-byte MSG data.

The primary accomplishments during this reporting period were:

- Integration and testing of MSG-specific code. McIDAS MSG navigation and calibration routines have been incorporated into the automated winds processing code. These include the following calibration conversion routines: total transmittance from temperature, moisture and ozone profiles; brightness temperature from Planck radiance; Planck radiance from temperature. Note: in the process, satellite-specific routines to do the above were combined to eliminate redundant code and simplify the process of adding new satellites.
- CO₂ slicing height assignment code testing and integration. CIMSS completed and tested new CO₂ height routine logic that uses a threshold Tbb to discriminate scenes that are eligible for the CO₂ algorithm. This new logic has been merged in with the targeting code. In our testing, we noted apparent height discrepancies due to surface elevation. This is being investigated. The new logic will apply to the IR winds processing from both GOES-12 and MSG.

Both CIMSS and the Air Force Weather Agency (AFWA) are now producing winds from MSG in real time for demonstration/validation purposes. AFWA plans to go operational shortly.

3.2 GOES-12 Cloud Top Pressure and Effective Cloud Amount

Comparison of GOES-12 Imager Cloud Top Pressure During ATREC

Using GOES-12 Imager Cloud Top Pressure determinations and cloud pulse lidar data from the Atlantic THORPEX (The Observing system Research and Prediction Experiment) Regional Campaign (ATReC) experiment comparisons of the compatibility between the observations were made. ATReC took place during December 2003 in the Atlantic off the coast of North Carolina. The results are shown in the Figure 19.

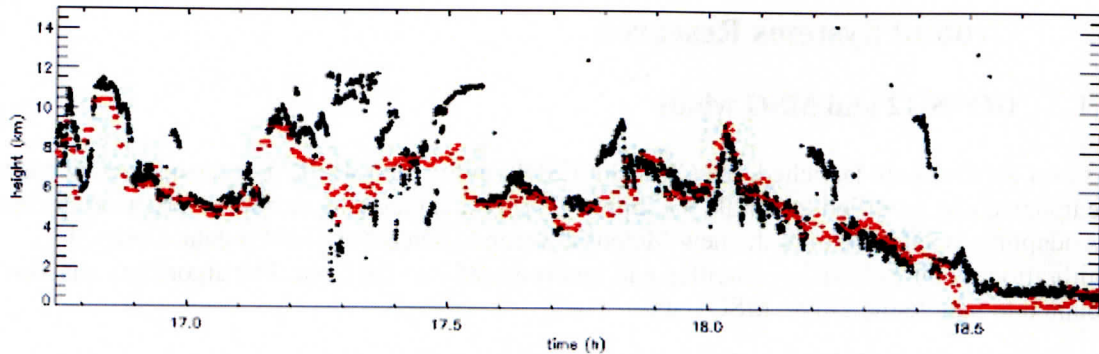


Figure 19: ATReC cloud phase lidar cloud top height (black) comparison with GOES-12 Imager Cloud Product (red) along the ER2 flight. The date of the flight is 5 December 2003.

3.3 GOES-9 Sounder Evaluation

The GOES-9 satellite continues to operate over the western Pacific ocean, centered over the equator at 155 degrees east longitude. Each hour, radiances from the Sounder instrument are received at CIMSS and used to generate several experimental meteorological products, such as retrieved atmospheric temperature and moisture profiles, retrieved cloud parameters, as well as various associated Derived Product Images (DPI). GOES-9 Sounder product generation is very important because sounding the atmosphere from geostationary orbit has never before been done over this portion of the globe.

During FY 2004, CIMSS proposed the following activities:

- the experimental products mentioned above will continue to be produced from GOES-9 Sounder data.
- Work will also proceed on adding more DPI imagery to the Web.
- Derived total column ozone retrievals and associated DPI imagery will be added to the DPI suite.
- BUFR-format temperature and moisture profiles will be made available via anonymous ftp.
- GOES-9 retrieved cloud parameters will also be made available via ADDE to McIDAS and other users.
- Finally, the GOES-9 production software will be ported from the current IBM-AIX environment to a Dell-Linux environment.

During the period 01 April 2004 through 30 September 2004, GOES-9 production resumed on a different computer (actually accomplished in early July). The processing had been suspended since early March when the system that was responsible for production broke down. The DPI imagery currently available via the Web remains the same as before the system failure, and consists of total precipitable water (TPW) and cloud top pressure (CTP), each available as part of montages involving GOES-9, -10 and -12 data (Figures 20 and 21).

This and other GOES-9 imagery can be seen at:

<http://cimss.ssec.wisc.edu/goes/realtime/grtmain.html#g3pw>
<http://cimss.ssec.wisc.edu/goes/realtime/grtmain.html#gsall>

Unfortunately, no further progress has been made toward making BUFR-format retrieved temperature and moisture profiles available via anonymous ftp. Furthermore, we have not added any additional DPI imagery to the Web, or worked toward deriving GOES-9 total column ozone, or finished porting GOES-9 production from the current IBM-AIX environment to a Dell-Linux environment. However, the plan still remains to fulfill these tasks. On a brighter note, the GOES-9 retrieved cloud parameters have been available to McIDAS users for some time via ADDE. Finally, since early April 2004 the GOES-9 retrieved cloud parameters have been available to all users in ASCII format via anonymous ftp (ftp.ssec.wisc.edu, pub/ssec/rtascii/sndrcloudproduct, *.g9.cldp).

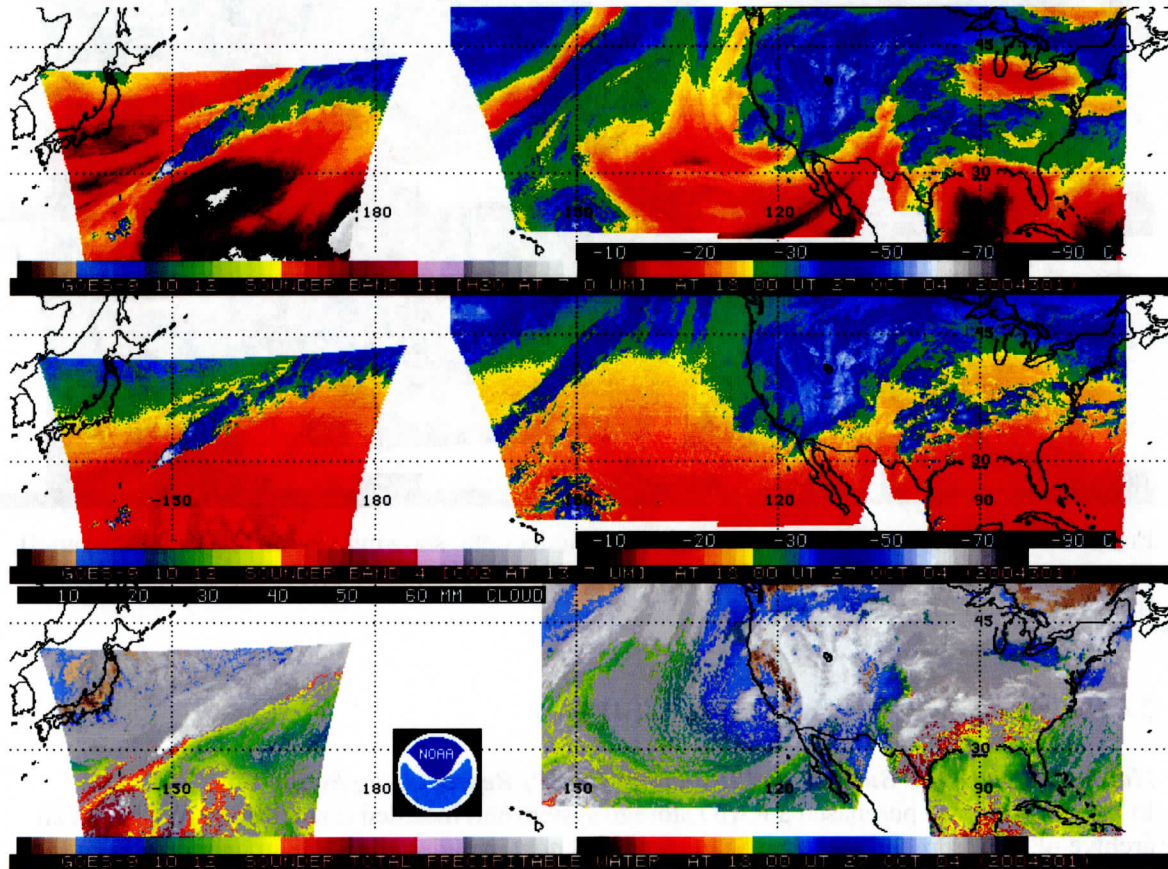


Figure 20: Montage of GOES-9, -10 and -12 Sounder data, showing $7.0\mu\text{m}$ imagery (top panel), $13.7\mu\text{m}$ imagery (middle), and Total Precipitable Water (TPW) imagery (bottom), from 18UTC on 27 Oct 2004.

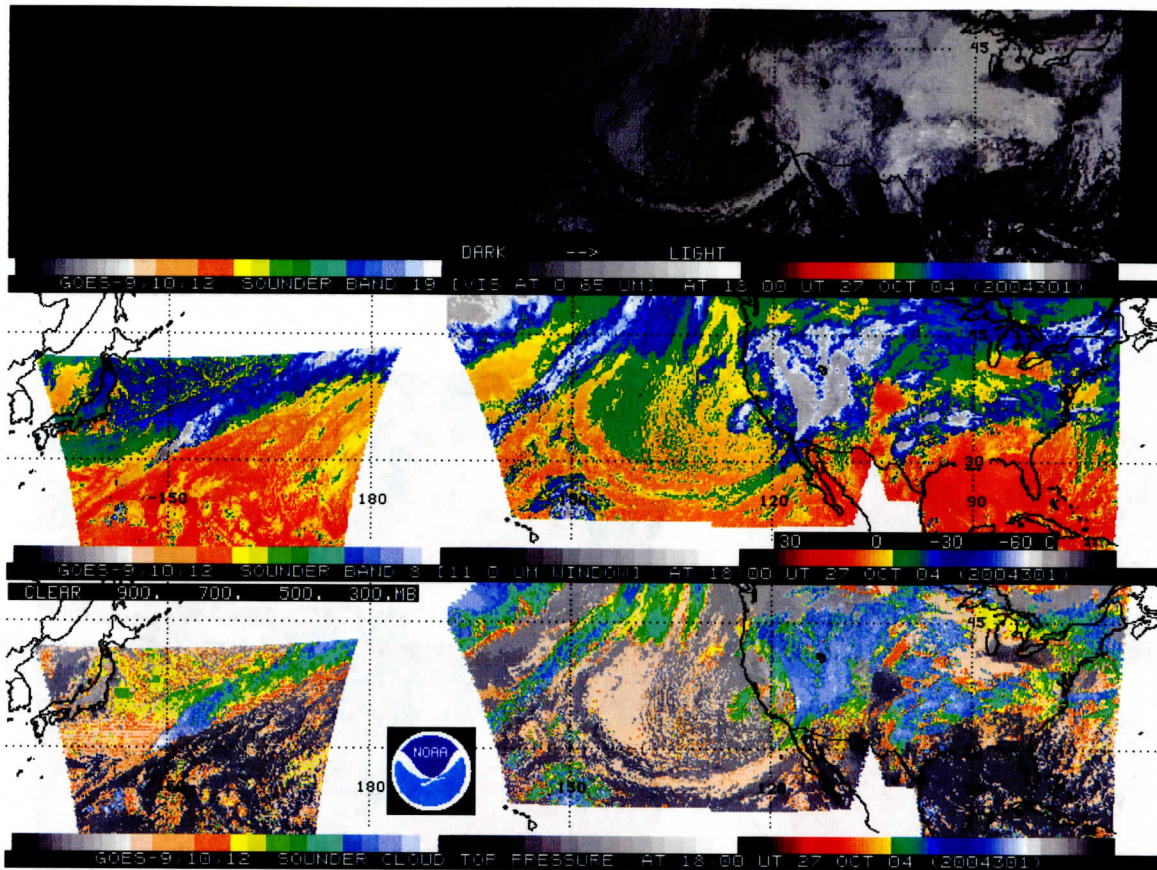


Figure 21: Montage of GOES-9, -10 and -12 Sounder data, showing visible imagery (top panel), $11.0\mu\text{m}$ window channel imagery (middle), and Cloud Top Pressure (CTP) imagery (bottom), from 18UTC on 27 Oct 2004.

3.4 Reprocessing GOES insolation (GSIP)

Hardware for GOES Surface and Insolation (GSIP) Reprocessing Setup

In the first year, we purchased a RAID storage system and installed it at CIMSS. We began an archive of data from the real-time SSEC feed that now includes all GOES imager data from March 2004 to the present for GOES 10 and GOES 12. In addition, we have included GOES 9 from June 2004 onwards. Our goal for this initial archive is three years of data, which we feel will allow for robust testing of the GSIP-fd system for climate applications. When complete, our archive will include 2002-2004. This period was chosen to allow us to study the continuity of products from GOES-8 and GOES-12. We will begin making climatologies in the next six months.

Improvements to the GSIP-fd System

In addition to these activities, we also installed the GSIP-fd system on a linux workstation at CIMSS. Working in sync with the ORA/DC GSIP-fd team, we added some needed capabilities to the GSIP-fd code as it nears its completion and transition to OSDPD. In addition, we have more modifications necessary for reprocessing. Our accomplishments are listed below.

- Incorporation of OPTRAN for computation clear sky radiances with a NESDIS standard procedure.
- Updating all cloud algorithms to be consistent with the latest improvements in the Clouds from AVHRR Extended (CLAVR-x) system.
- Development of scripts that allow for reprocessing.
- Transition to a netCDF data format to facilitate the use of our climate products by a wide community.

Examples of two standard products (cloud temperature and insolation) from the GSIP-fd reprocessing system at CIMSS are shown below.

cld_temp, GOES-10, NHEM, 2004, Day 296, 19:00 UTC

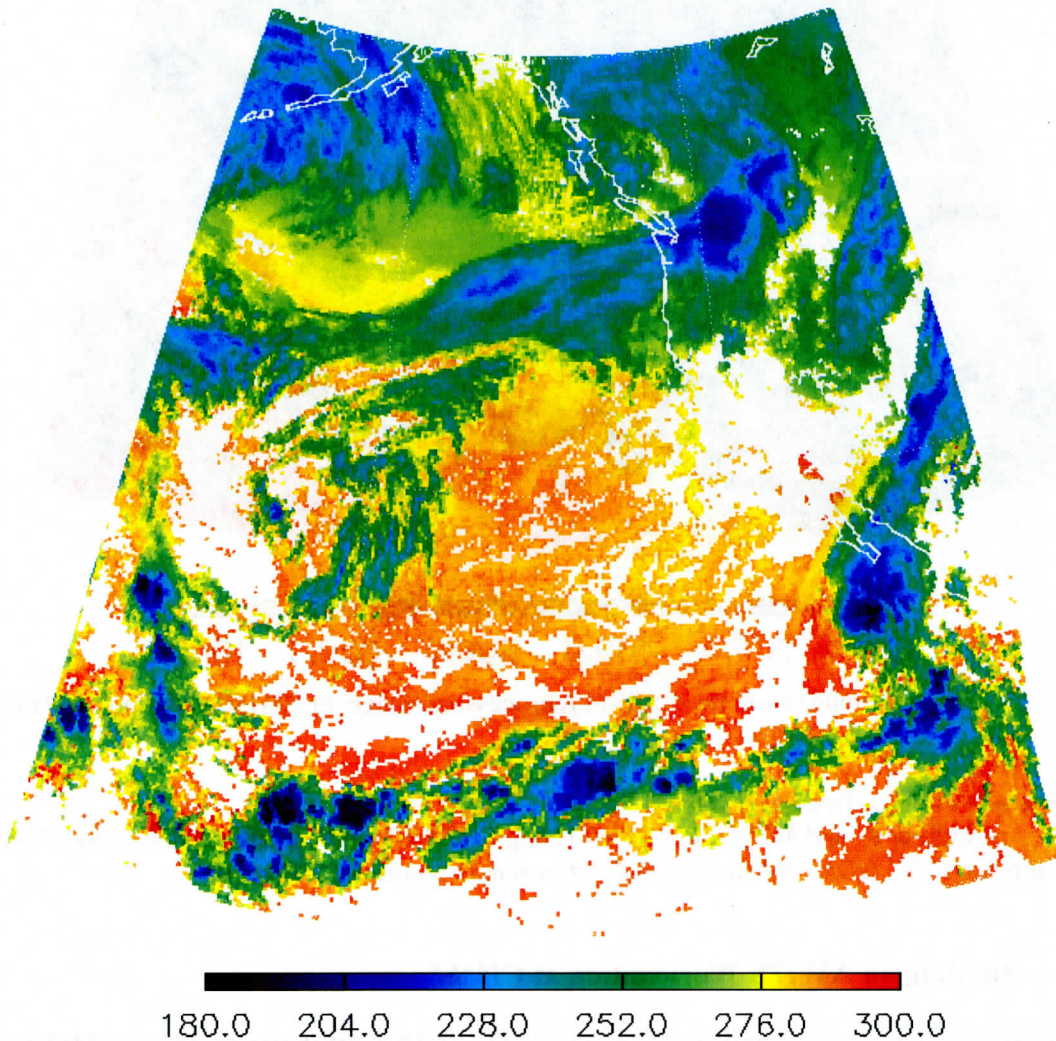


Figure 22: Example of cloud temperature from the GSIP-fd reprocessing system at CIMSS.

swd_sfc, GOES-10, NHEM, 2004, Day 296, 19:00 UTC

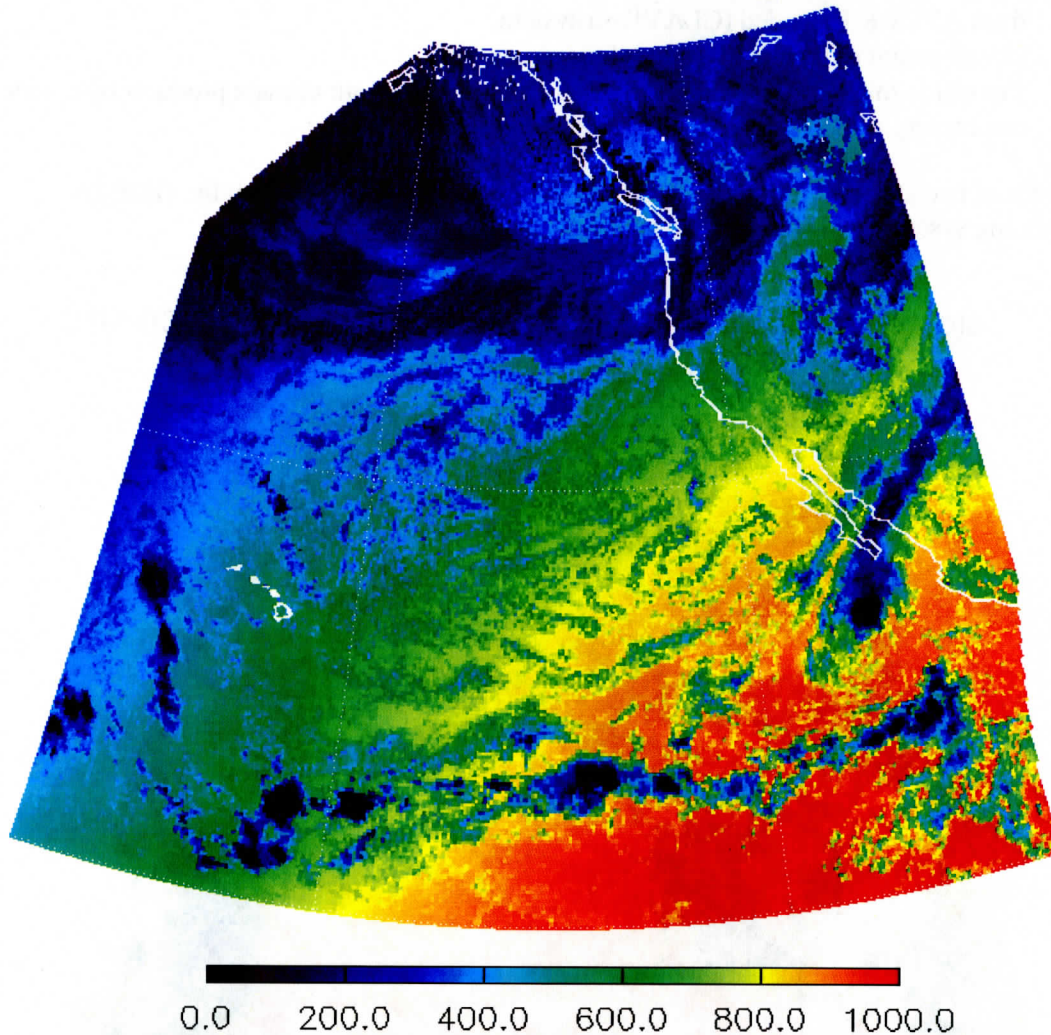


Figure 23: Example image from the GSIP-fd reprocessing system at CIMSS showing insolation.

Publications and Conference Reports

Heidinger, Andrew K. and M. Walters, 2004: Using GOES Cloud Properties to Diagnose NWP cloud forecasts. *3rd GOES-R Data Users Conference*, Broomfield, Colorado.

3.5 Building an AWIPS Workstation at CIMSS

Following the objective to establish a fully functional AWIPS workstation at ASPT/CIMSS to aid in training development, validation, and implementation of satellite products, we have continued to pursue the unique capability to receive all the standard data streams in real-time (in a non-National Weather Service (NWS) setting). The important distinction for this effort is that, at ASPT/CIMSS, there is no ready mechanism to access real-time data in a format straightforwardly compatible with AWIPS. At National Weather Service (NWS) offices, and facilities co-located with them, the ingestion of real-time NOAAPORT data streams effectively takes place within

“black box” equipment, provided for all NWS sites and often situated in the “back room” equipment area. The AWIPS workstations out in the NWS forecast areas receive their data from these “black box” ingestors, not directly from a NOAAPORT signal.

To acquire this necessary capability, CIMSS has interacted with other facilities which also desire to run real-time AWIPS operations. Specifically, CIMSS personnel have discussed viable options with the NOAA/NESDIS/ORA Regional and Mesoscale Meteorology Team (RAMMT) in Fort Collins, CO; the NOAA/OAR Forecast Systems Laboratory (FSL) in Boulder, CO; and components of the University Center for Atmospheric Research (UCAR), also in Boulder, specifically within the Unidata and COMET (Cooperative Program for Operational Meteorology, Education, and Training) programs. However, no packaged set of hardware and software is yet established for straightforward ingestion of the NOAAPORT signal into a non-NWS sited AWIPS system.

Due to the complete NOAAPORT conversion to Direct Video Broadcast (DVB) mode of transmission scheduled for the first quarter of 2005, the transition to reception of the NOAAPORT signal in DVB is well underway at the University of Wisconsin Space Science and Engineering Center (SSEC). This transition is a second necessary component [the first being the re-formatting ingestion capability to make the NOAAPORT files compatible in AWIPS] to provide real-time data to an AWIPS workstation, and is proceeding well at SSEC.

Some of the limited NOAAPORT test data that is currently being routinely sent in DVB has been successfully ingested at SSEC. Code installed from T. Yoksas (Unidata) was used to take the DVB-fed data and place these data into a machine running LDM (Unidata’s Local Data Manager), which were then accessed by another computer (running McIDAS (SSEC’s Main computer Interactive Data Access System) and displayed successfully. The test LDM data have not yet been put into a computer running AWIPS here. The latest AWIPS build (or version), running Linux, has been received from T. Alberta (COMET) but has not been modified and installed to run here. S. Wanzong (SSEC Technical Computing) has done the work here for the AWIPS applications, but unfortunately, has only been able to work on this part time (due to his current workload).

Thus, two major issues remain. First, although the DVB ingest portion appears to work successfully, the subsequent use of the LDM to transfer data into AWIPS is not readily known, having not been readily documented by the individuals from FSL who have (supposedly) done this. Although code from efforts at COMET to use LDM to provide data to AWIPS has been made available, modification is still required as that code does not use a DVB feed. So, progress continues to hinge on simultaneous but collaborative efforts out-of-house. Secondly, due to SSEC Technical Computing workloads, resources have not been sufficiently available. A trip to Boulder (to work with FSL staff) has been suggested for the Technical Computing staff member who will likely need to be committed heavily to this task for some time (~month or two).

The need for working with AWIPS in real-time remains. Current AWIPS use at ASPT/CIMSS is limited to access through the Weather Event Simulator (WES), which, in essence, is an AWIPS workstation restricted to data sets from specific historical case studies. Figure 24 shows the default color enhancement on AWIPS for the Geostationary Operational Environmental Satellite (GOES) Sounder Derived Product Image (DPI) of Lifted Index (LI) stability from a severe weather case on 22 July 2003. The figure illustrates a serious deficiency in how the GOES Sounder DPI continue to be poorly presented in AWIPS. [The default AWIPS enhancement on the right is not nearly as effective as the default CIMSS enhancement for emphasizing the area over the mid Mississippi Valley as favorable for severe weather.] Current real-time examples in

AWIPS projections, with which NWS forecasters are most comfortable and familiar, are thought to be the more effective and relevant way to promote new satellite products on AWIPS, as well as to encourage better feedback for, and interaction with, satellite researchers, who need to be AWIPS savvy.

Appearing in NWS offices: GOES Sounder DPI

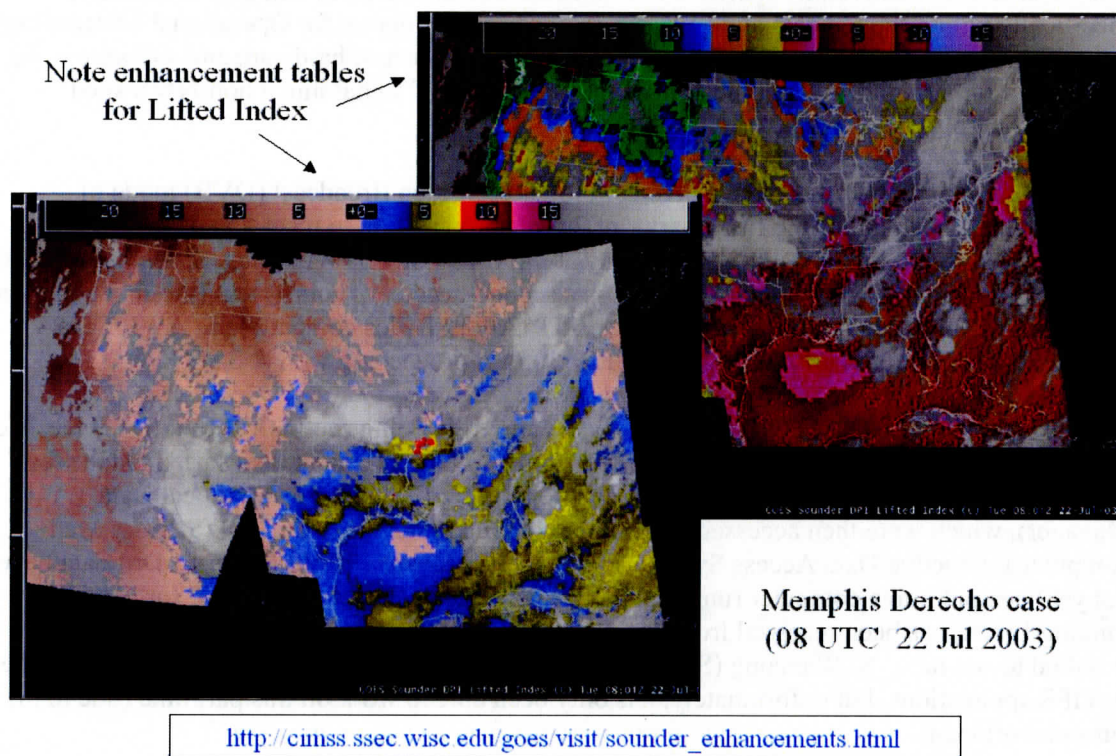


Figure 24: Default color enhancement on AWIPS for the Geostationary Operational Environmental Satellite (GOES) Sounder Derived Product Image (DPI) of Lifted Index (LI) stability from a severe weather case on 22 July 2003.

4. Joint Center for Satellite Data Assimilation (JCSDA)

4.1 Data Assimilation Experiments using Data Denial

CIMSS has been granted computer resources by the National Centers for Environmental Prediction (NCEP) to undertake data denial studies in NCEP's Global Forecast System (GFS). The methodology used in these studies is nearly identical to the studies performed in the Eta Data Assimilation System (EDAS). However, the global studies have several advantages over the previously completed regional EDAS studies. First, the global experiments remove contamination from the lateral boundary conditions of the model. Second, the global studies allow investigation of data types not available within the regional EDAS domain.

Even though these global studies are in their early stages, they have already identified results of interest about existing data types. These studies also have the ability to provide impact studies of new data types coming online in the future before they are accepted into the operational data stream. Finally, perhaps the biggest advantage of these global studies is that appropriate computer time was allocated for them to be performed at the operational resolution used by NCEP. Prior to this study, both computer and human resources limited the ability of NCEP personnel to complete such studies.

The GFS simulations investigated thus far have spanned the periods 1 January to 15 February 2003 and 1 August to 20 September 2003. Each denial has been integrated to 17 days using resolutions of T254 with 64 levels to 84 hours, T170 with 42 levels to 180 hours and T126 with 28 levels to 384 hours.

The forecast model and Spectral Statistical-Interpolation analysis system (SSI) used for these experiments was identical to the operational versions as of late 2003. Initial conditions and all assimilated data were taken from NCEP's operational archives. The transformation from spectral to grid space, post processing and the anomaly correlation calculations were all done using NCEP's verification software.

Simulations completed thus far include a variety of data sets during the two seasons. Specifically, the various data types denied include: AMSU, HIRS, Quikscat, Geostationary motion vectors, all conventional data except surface pressure, rawinsondes, and all satellite data.

During these time periods a GFS control run was completed which included all data types used in the GFS. For the experiments, one data type was removed at a time. Forecast impacts were evaluated over both the entire domain and within subsections traditionally verified for the GFS (20-80N and S). Since these simulations are integrated to 17 days, a temporal evaluation of the forecast impact is also completed.

A time series of 500 hPa geopotential height Anomaly Correlations (AC) for 20-80N and S for the control experiment, removal of all satellite data, and removal of all conventional data are shown in Figs. 25 and 26, respectively. Clearly both the conventional and satellite data play a key role in GFS forecast quality, especially satellite data in the southern hemisphere.

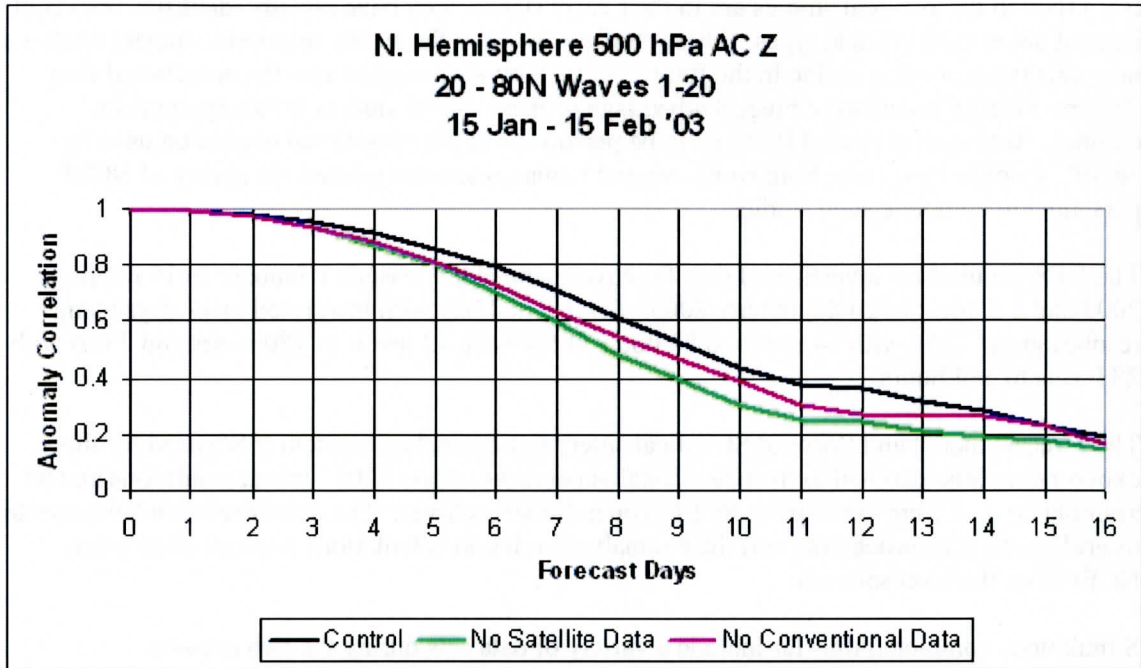


Figure 25: Day 0-16 500 hPa geopotential height anomaly correlation coefficient for 20-80N during the period 15 January-15 February 2003. (BLUE) Control run with all operational data types assimilated, (MAGENTA) No Satellite data assimilated, (GREEN) No Conventional data assimilated except for surface pressure.

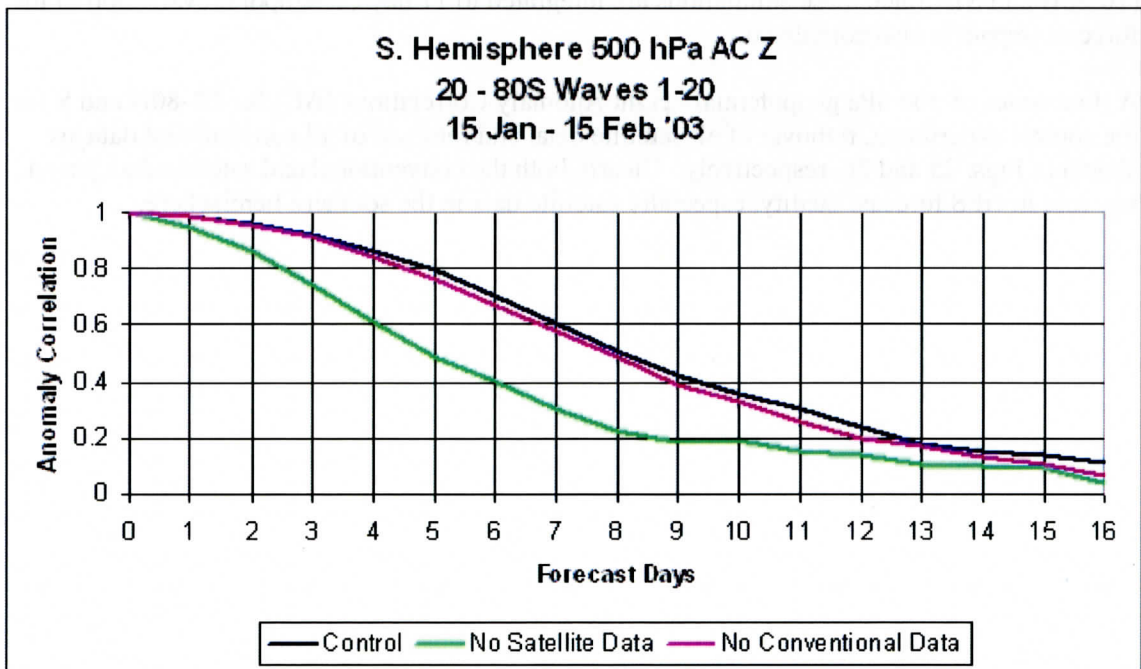


Figure 26: Day 0-16 500 hPa geopotential height anomaly correlation coefficient for 20-80S during the period 15 January-15 February 2003. (BLUE) Control run with all operational data types assimilated, (MAGENTA) No Satellite data assimilated, (GREEN) No Conventional data assimilated except for surface pressure.

A geographic distribution of the 500 hPa day 5 forecast impact of height is shown in Figure 27. Consistent with Figures 25 and 26, the southern hemisphere impacts are very positive, while the northern hemisphere impacts are in general smaller but still positive. Figure 28 shows the temporal decay of forecast impact every 6 hours to 96 hours for temperature averaged over the globe. As expected, largest satellite impacts are in the lower stratosphere and decrease rapidly with time.

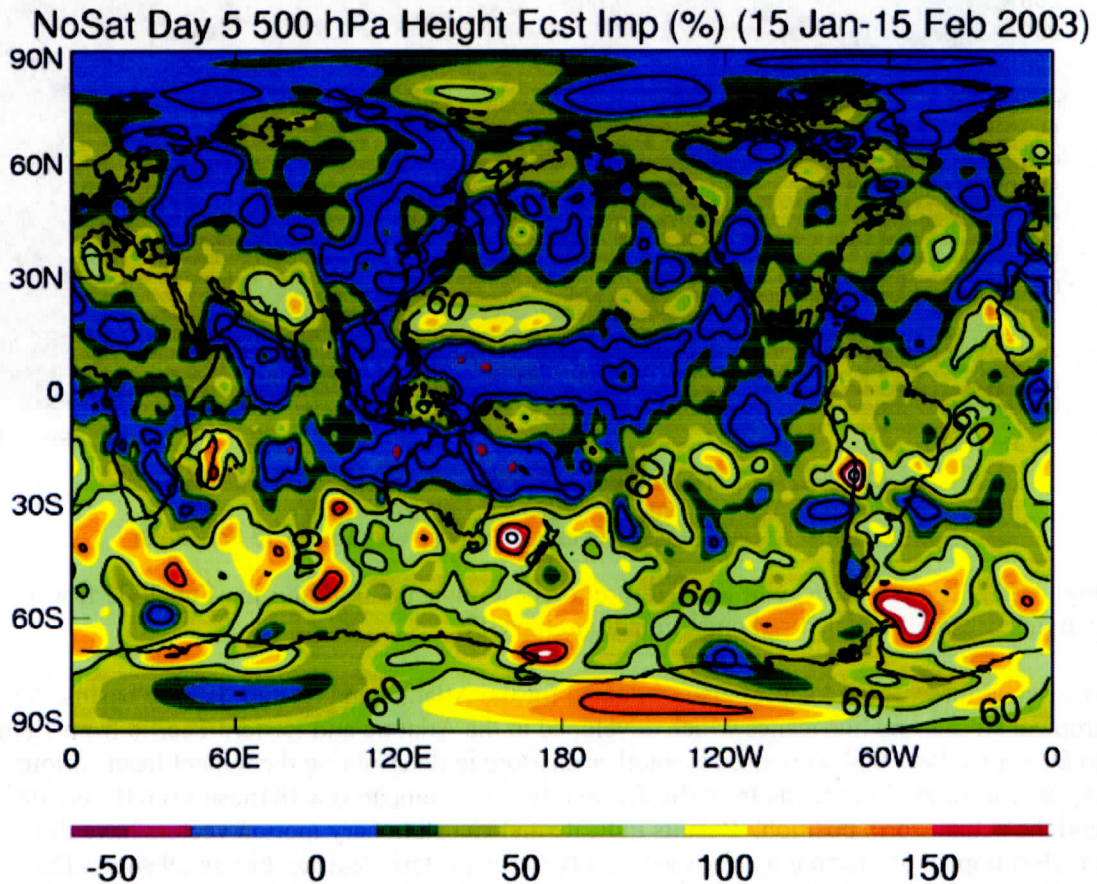


Figure 27: Geographic distribution of day 5 geopotential height forecast impact (%) during Jan-Feb 2003 from denying all satellite data used operationally in the GFS.

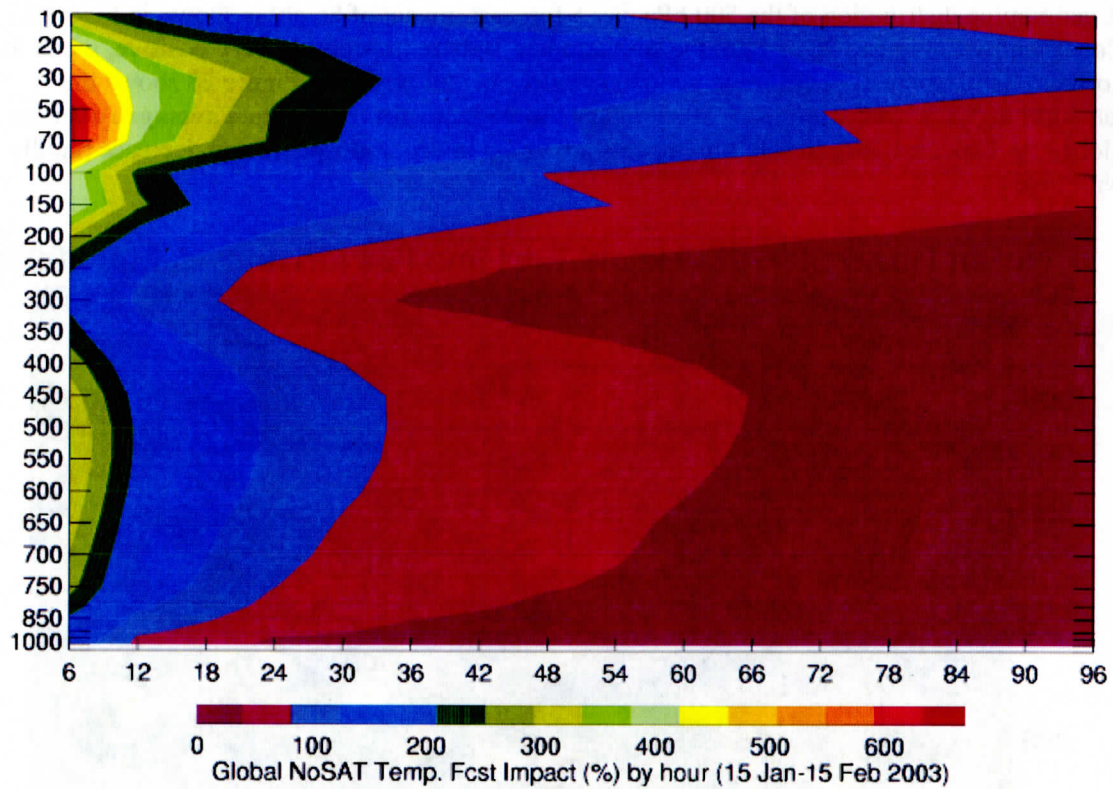


Figure 28: Temporal decay of temperature forecast impact (%) during Jan-Feb 2003 from denying all satellite data used operationally in the GFS.

Hurricane forecast tracks were also evaluated for the Atlantic and Eastern Pacific basins. The tropical storms and hurricanes which developed in the Atlantic and Eastern Pacific from 1 August to 20 September 2004 were used as another measure in determining the impact from various data types. Storm track forecasts from the denial runs were compared with those from the control run and the actual storm position. Results indicate that Geostationary motion vectors have the greatest impact on storm track forecast quality in the Eastern Pacific. Figure 29 shows the percentage of forecast tracks degraded by using AMSU, HIRS, GEO-AMV and Quikscat data. On average 79% of the storm tracks were worse without the GEO-AMV data. Results for the Atlantic basin were not as dramatic.

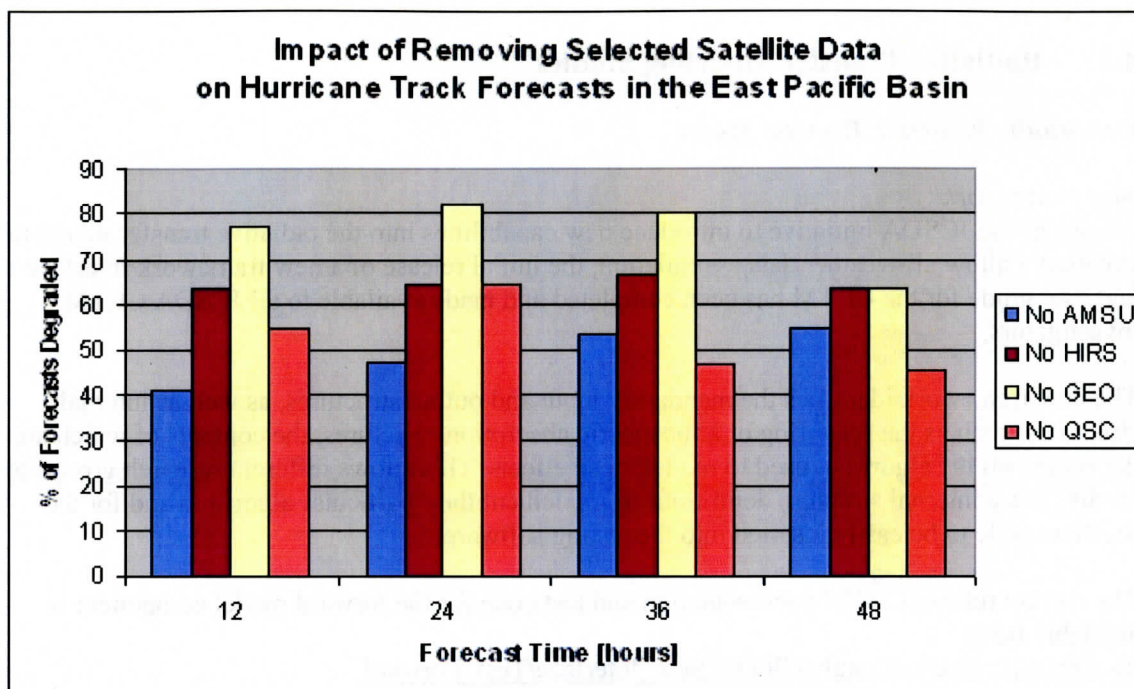


Figure 29: Percentage of forecast tracks degraded by removing the various data types. NOTE: a 50% forecast degradation is a neutral score.

Publications and Conference Reports

Jung, J.A., A. J. Schreiner, W. F. Feltz, S. M. Thomas, T. J. Schmit, and J. M. Daniels, 2004: Improvements to the GOES-12 Imager Cloud Product. Presented at the 13th conference on satellite meteorology and oceanography, 20-24 September 2004, Norfolk, VA.

Jung J. A., T. H. Zapotocny, W. P. Menzel, and J. P. Nelson III, 2004: Diagnosing Data Assimilation Impacts in the NCEP GDAS and EDAS. Presented at the 13th conference on satellite meteorology and oceanography, 20-24 September 2004, Norfolk, VA.

Zapotocny T. H., J. A. Jung, W. P. Menzel, and J. P. Nelson III, 2004: Diagnosing Data Assimilation Impacts in the NCEP GDAS and EDAS. Presented at the GOES-R users conference, 10-13 May 2004, Boulder, CO.

Zapotocny, T. H., W. P. Menzel, J. A. Jung, and J. P. Nelson III, 2004: A four season impact study of rawinsonde, GOES and POES data in the Eta Data Assimilation System. Part I: The total contribution. Accepted for publication in *Wea. Forecasting*, October 2004.

Zapotocny, T. H., W. P. Menzel, J. A. Jung, and J. P. Nelson III, 2004: A four season impact study of rawinsonde, GOES and POES data in the Eta Data Assimilation System. Part II: Contribution of the components. Accepted for publication in *Wea. Forecasting*, October 2004.

4.2 Radiative Transfer Modeling Studies

Community Radiative Transfer Model

New Framework

As part of the JCSDA initiative to introduce new capabilities into the radiative transfer model to eventually allow all-weather data assimilation, the initial release of a new framework/interface and user guide for the CRTM has been completed and made available to all JCSDA CRTM investigators.

The new framework identifies the mandatory input and output structures, as well as internal structures, such as the scattering or atmospheric absorption structures, the contents of which are dependent on the algorithm used to model those effects. This allows different research groups to modify these internal structure definitions to implement their particular algorithm and for the resultant code to be easily inserted into the testing software.

The current release CRTM documentation and test code for the forward model component is available from:

ftp://ftp.ssec.wisc.edu/paulv/CRTM/New_Interface/Test_Forward.

New Example and Test Codes

As part of the new CRTM framework, new testing and display software has been created to allow rapid inspection of the result of changes to the CRTM, as well as simple example programs that can be distributed to users, along with the documentation, to illustrate how the CRTM should be used.

Like the CRTM itself, the testing code input/output (I/O) has been implemented via structures to allow for adaptation to new CRTM modules as they become available and minimizing the changes required to the test code itself. The I/O routines have been implemented in both Fortran-95 (for the CRTM tests) and IDL (for the display of the results). All CRTM component comparisons – Forward/Tangent-linear, Tangent-linear/Adjoint, and Adjoint/K-matrix – have also been implemented. A screen shot of the Forward/Tangent-linear model test Graphical User Interface (GUI) is shown in Figure 30. Similar GUIs exist for the other display codes.

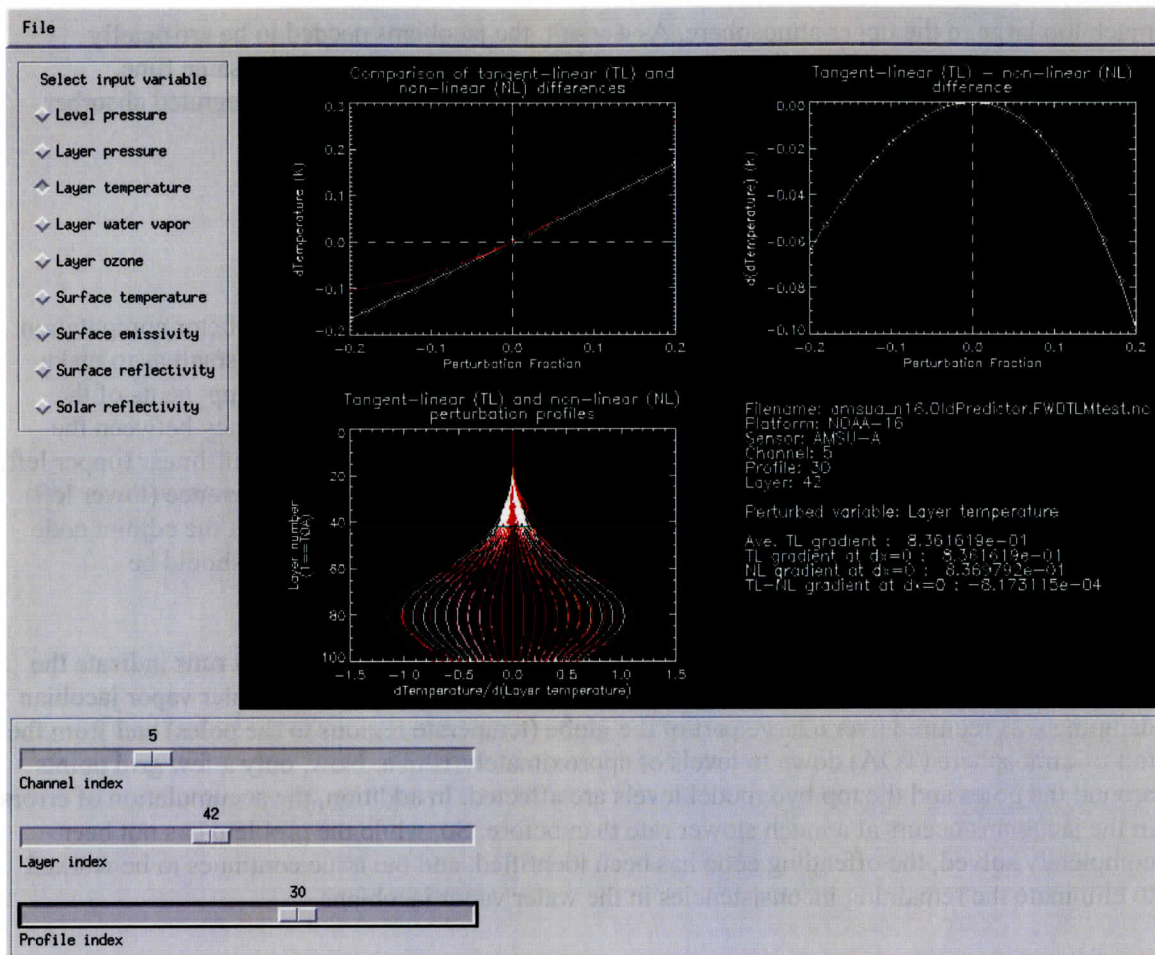


Figure 30: Screen shot of the Forward/Tangent-linear model test Graphical User Interface (GUI).

Updates and Fixes to Current Operational RTM

While the focus for future developments with respect to atmospheric radiative transfer is on the CRTM, the current radiative transfer model (RTM) is still being used as the operational model and CRTM test bed. There have been two main developments over the past six months.

Firstly, as mentioned in the previous semi-annual report, optional arguments were added to allow the user to specify the solar reflectivity and the downwelling flux diffusivity angle, and the “order index” in the gas absorption algorithm (compact OPTRAN) has been fully implemented. These changes have been fully implemented and tested in all four RTM components (forward, tangent-linear, adjoint, and K-matrix.). The addition of the “order index” in compact OPTRAN reduces the polynomial order of many of the absorption model coefficient reconstructions, and has led to an increase in the amount of satellite observations that are passing quality control. This change is partly credited with a slight, but noticeable, improvement in the positive impact of the satellite data in the assimilation system.

Secondly, in the course of testing these updates, a numerical problem related to the predictor calculation in the gas absorption component (OPTRAN) of the RTM was discovered and fixed.

Since the last operational RTM update in the NCEP GDAS, it was noticed that, for some atmospheric profiles, the water vapor jacobians for sensitive channels (e.g. HIRS ch12) were

much too large in the upper atmosphere. As a result, the jacobians needed to be artificially damped to prevent non-physical results for the affected channels/data. At the same time, problems were identified with the computation of the inverse of powers of integrated absorber amounts, $A(k)$, in the OPTRAN predictor module. These values,

$$\frac{1}{A(k)}, \frac{1}{A^2(k)}, \frac{1}{A^3(k)}, \text{ and } \frac{1}{A^4(k)}$$

where k represents a pressure layer, are used as normalizing factors in the predictor computation and were checked individually to determine if the powers of $A(k)$ were not so small as to make the result infinite. This approach was found to be incorrect, since different components of the RTM did not use all of the above inverse values. The result was an inconsistency between the various RTM components. To illustrate the problem, Figure 31 shows a tangent-linear (upper left) and adjoint (upper right) water vapor jacobian calculation, along with the difference (lower left). The tangent-linear code included a fix for the incorrect inverse calculation, but the adjoint code did not. The result is a large difference between the two, when the difference should be identically zero.

The fix has since been applied to all the RTM components and parallel GDAS runs indicate the water vapor jacobian problem has greatly diminished. Previously, artificial water vapor jacobian damping was required over a large part of the globe (temperate regions to the poles) and from the top-of-atmosphere (TOA) down to levels of approximately 10hPa. Now, only a few grid points around the poles and the top two model levels are affected. In addition, the accumulation of errors in the jacobians occurs at a much slower rate than before. So, while the problem has not been completely solved, the offending code has been identified, and the issue continues to be worked to eliminate the remaining inconsistencies in the water vapor jacobians.

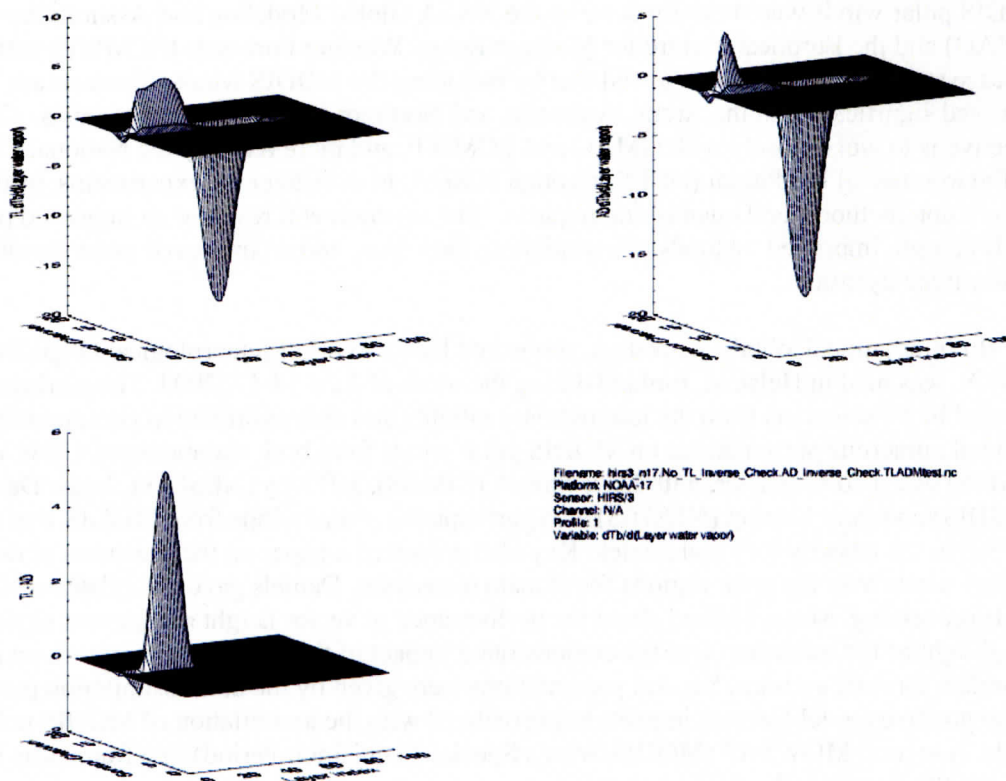


Figure 31: A tangent-linear (upper left) and adjoint (upper right) water vapor jacobian calculation, along with the difference (lower left).

WindSat Transmittance and Coefficient File

Transmittances and CRTM coefficient files have been produced for the WindSat instrument on Coriolis. The spectral coefficient (SpCcoeff) and compact OPTRAN coefficient (TauCcoeff) data files for WindSat, as well as all the other valid instrument coefficient data files, can be downloaded from :

ftp://ftp.ssec.wisc.edu/paulv/CRTM/Coefficient_Data

These data, and accompanying software, can also be obtained from my web site,

<http://cimss.ssec.wisc.edu/~paulv>

via the “[SpCcoeff utility](#)” and “[TauCcoeff utility](#)” links.

Publications and Conference Reports

Kleespies, T. J., P. van Delst, L. M. McMillin, and J. Derber, 2004: Atmospheric transmittance of an absorbing gas. 6. OPTRAN status report and introduction to the NESDIS/NCEP community radiative transfer model. *Applied Optics*, **43**, 3103-3109.

4.3 Polar Winds Data Assimilation Experiments

Approximately two years ago we developed a methodology for generating wind vectors in the polar regions using the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA’s Terra and Aqua satellites. The goal of this project, which is supported by the Joint Center for Satellite Data Assimilation (JCSDA), is to improve the use of satellite-derived, high-latitude wind

information in numerical weather prediction (NWP) systems. Model impact studies with the MODIS polar winds were initially done by the NASA Global Modeling and Assimilation Office (GMAO) and the European Centre for Medium-Range Weather Forecasts (ECMWF) with a 30-day case study. Those studies showed that by including the MODIS winds, forecasts are improved significantly in the Arctic, Antarctic, and Northern Hemisphere extratropics. Our objective is to work closely with GMAO and ECMWF, and more recently the National Centers for Environmental Prediction (NCEP) through JCSDA, in devising new experiments, testing new assimilation methods, and quantifying impacts. The research will result in an improved polar winds dataset, improved methods of assimilating the winds, and an improved understanding of high-latitude dynamics.

The 7th International Winds Workshop, sponsored by the World Meteorological Organization (WMO), was held in Helsinki, Finland during the week of June 14-17, 2004. The workshop was attended by 50 scientists from the international satellite and data assimilation communities and included numerous presentations on MODIS polar winds from both communities. Chris Velden (CIMSS) was a co-organizer, with Dave Santek (CIMSS), Jeff Key (NESDIS), Jaime Daniels (NESDIS) and Paul Menzel (NESDIS) also participating. Polar winds from MODIS was the topic covered in the talks by Key and Santek. Key also presented a paper on the prospects of deriving thermal winds over the polar regions for climate reanalyses. Daniels gave an update on NESDIS winds processing. Menzel talked about the performance of vector height assignment algorithms. A highlight of the workshop was the demonstrated impact of the MODIS polar winds on global numerical forecast systems. Several presentations were given by the data assimilation participants on the positive model forecast impacts being realized with the assimilation of MODIS polar winds. A second MOWSAP (MODIS Winds Special Acquisition Period) timeframe was selected to cover the Northern Hemisphere summer.

Model impact studies continue to be performed at seven NWP centers: the European Centre for Medium-Range Weather Forecasts (ECMWF), the NASA Global Modeling and Assimilation Office (GMAO), the (UK) Met Office, the Canadian Meteorological Centre (CMC), the Japan Meteorological Agency (JMA), the US Navy, Fleet Numerical Meteorology and Oceanography Center (FNMOC), and Deutscher Wetterdienst (DWD). Additionally, NCEP through JCSDA began impact studies earlier this year. The status of the MODIS winds at the various NWP centers is as follows:

- ECMWF - Using winds in operational system.
- NASA GMAO - Using winds in operational system.
- JMA - Using winds in operational system (Arctic only)
- CMC - Using winds in operational system
- US Navy, FNMOC - Using winds in operational system
- NCEP/EMC - Engaged in impact studies
- UK Met Office - Using winds in experimental system
- DWD - Using winds in experimental system

Overall, the impact of the MODIS polar winds on numerical weather forecasts is positive. Most centers have demonstrated a positive impact in the Arctic and Antarctic. Results for the Northern and Southern Hemisphere (poleward of 20 degrees latitude) vary, in some cases positive and in other cases negative or neutral. Impact studies will continue.

Figure 32 shows the anomaly correlation from the NCEP/JCSDA (J. Jung) experiment for January-February 2004 over the Arctic. The figure shows a positive impact in the Arctic for the

500 hPa geopotential height forecasts. The MODIS winds have a positive impact overall even when the snow emissivity correction for AMSU is used (J. Jung, personal communication, 2004).

We are currently developing a system to generate the MODIS winds from the direct broadcast site in McMurdo, Antarctica. A computer was shipped to McMurdo and is being configured at the time of this writing. The X-band antenna will be installed at McMurdo in December 2004. The production of MODIS winds should begin in January 2005. The wind data will be transferred back to CIMSS and NESDIS over the Internet and will be immediately available to NWP centers.

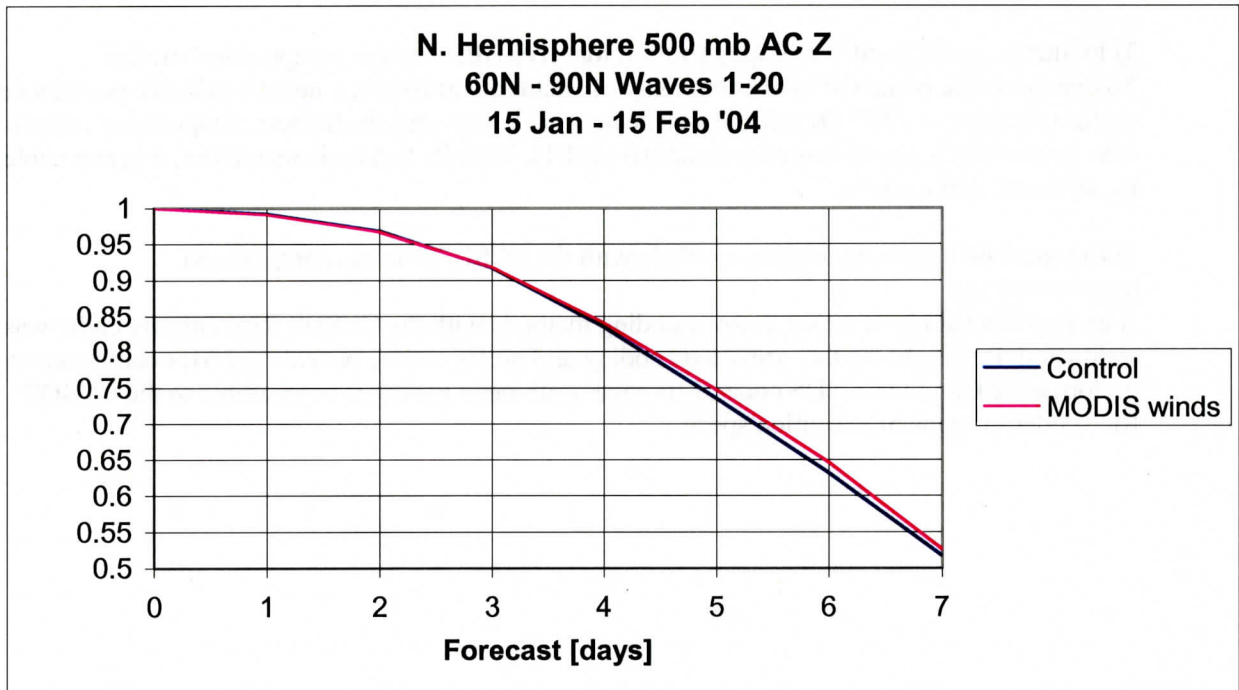


Figure 32: Anomaly correlation from the NCEP/JCSDA experiments for the Northern Hemisphere at 500 hPa for the end of the first MOWSAP timeframe.

5. GOES-R Instrument Studies

5.1 HES Data Compression Studies

The proposed activities included benchmark of the HES data compression performance based on different combinations of data preprocessing algorithms, transform-based, predictor-based, clustering-based compression methods, and various entropy coding schemes.

Our accomplishments include:

1) Mean-removed Nearest-Neighbor Reordering for ABS/HES lossless compression studies
In order to improve the compression gains of the 2D predictor-based compression algorithms (CALIC, JPEG-LS) and 2D wavelet-based algorithm (JPEG 2000) on the hyperspectral sounder data, a mean-removed nearest-neighbor reordering (MRNNR) scheme has been developed to convert the 3D data into 2D with the more spectrally correlated channels rearranged together. The

scheme can also explore the spatial correlations of disjoint geographical regions affected by the same type of absorbing gases or clouds. The results show that the combination of MRNNR with CALIC, JPEG-LS and JPEG 2000 significantly improve their original compression ratios on AIRS radiance data.

2) Inter-channel prediction with least-squares optimization for ABS/HES lossless compression studies

A least-squares optimized inter-channel prediction scheme was developed that gives significantly higher compression ratios than state-of-the-art compression algorithms such as CALIC, JPEG-LS, JPEG 2000 for the AIRS radiance data.

3) Predictive partitioned vector quantization for ABS/HES lossless compression studies

To overcome the computational complexity of vector quantization, a novel predictive partitioned vector quantization (PPVQ) scheme was developed. It provides the highest compression ratios to date for the AIRS digital counts granules (over 3:1). With its fast implementation, it is amenable for on-board applications.

4) Comparison of entropy coding methods with the CCSDS lossless compression recommendation

A comparative study of newer entropy coding methods with the CCSDS Rice entropy coder was conducted. It was shown that arithmetic coding and prefix coding provide superior compression performance than the CCSDS coder. Moreover arithmetic coding is comparable to the CCSDS Rice coder in terms of execution speed.

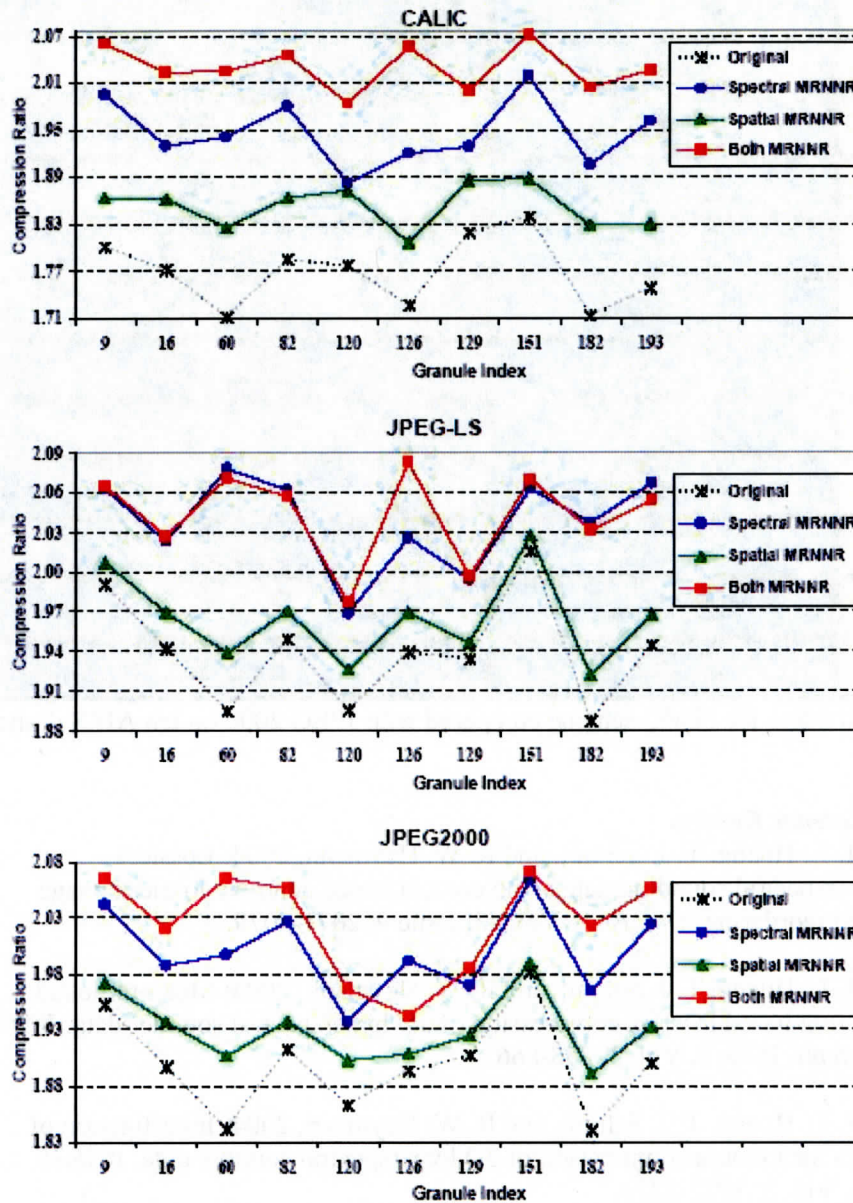


Figure 33. Compression ratios for CALIC, JPEG-LS and JPEG 2000 with and without different MRNRR schemes on ten AIRS radiance granules.

Granule	JPEG2000	PPVQ
9	2.378	3.352
16	2.440	3.360
60	2.294	3.303
82	2.525	3.385
120	2.401	3.308
126	2.291	3.293
129	2.518	3.376
151	2.335	3.259
182	2.251	3.224
193	2.302	3.272
Average	2.374	3.313

Figure 34. Compression ratios for PPVQ scheme compared with JPEG 2000 on ten AIRS digital count granules.

Publications and Conference Reports

Huang, B., A. Ahuja, H.-L. Huang, T. J. Schmit, and R. W. Heymann, 2004: Lossless compression of 3D hyperspectral sounding data using context-based adaptive lossless image codec with bias-adjusted reordering. *Opt. Eng.*, Vol. 43, Issue 9, 2071-2079.

Huang, B., A. Ahuja, H.-L. Huang, T. J. Schmit, and R. W. Heymann, 2004: Mean-removed nearest neighbor reordering based lossless compression of 3D hyperspectral sounder data. *WSEAS Trans. Circuits and Systems*, Issue 4, Vol. 3, 858-866.

Huang, B., A. Ahuja, H.-L. Huang, T. J. Schmit, and R. W. Heymann, 2004: Investigation of predictor-based schemes for lossless compression of 3D hyperspectral sounder data. *WSEAS Trans. Systems*, Issue 5, Vol. 3, 2222-2228.

Huang, B., A. Ahuja, H.-L. Huang, T. J. Schmit, and R. W. Heymann, 2004: Comparison of arithmetic coding and prefix coding with the CCSDS lossless compression recommendation for satellite data. *AMS 13th Conf. Satellite Meteor. Oceanography*, 20-24 Sept. 2004, Norfolk, Virginia.

Huang, B., A. Ahuja, H.-L. Huang, T. J. Schmit, and R. W. Heymann, 2004: Predictive partitioned vector quantization for hyperspectral sounder data compression. *Atmospheric and Environmental Remote Sensing Data Processing and Utilization: an End-to-End System Perspective*, Proc. of SPIE Vol. 5548, Oct. 2004, pp. 70-77.

Huang, B., H.-L. Huang, A. Ahuja, H. Chen, T.J. Schmit, R.W. Heymann, 2004: Lossless data compression for infrared hyperspectral sounders – an update. *Atmospheric and Environmental*

5.2 ABI/HES Instrument Studies

ABI Band Simulation from Current Satellite Data

ABI band studies include the band selection, the spectral coverage and the merit of each spectral band in weather and environmental applications. 16 bands covering visible (0.47 and 0.64 μm), near IR (0.86, 1.38, 1.61, 2.26 μm) and IR (3.9, 6.19, 6.95, 7.34, 8.5, 9.61, 10.35, 11.2, 12.3 and 13.3 μm) spectral regions have been selected for ABI (<http://cimss.ssec.wisc.edu/goes/abi>). ABI bands have been simulated using existing high spectral resolution AVIRIS, AIRS, NAST-I, high spatial resolution MODIS, and high temporal resolution MSG data to demonstrate the spectral and spatial characteristics and also provide a simultaneous data set of all ABI spectral bands for algorithm testing and development. Figure 35 shows a simulated "16 band" ABI multiple panel image from 11 April 2004 at approximately 13 UTC. This image over France is built from measurements from three separate satellite instruments (MODIS, MET-8 and AIRS).

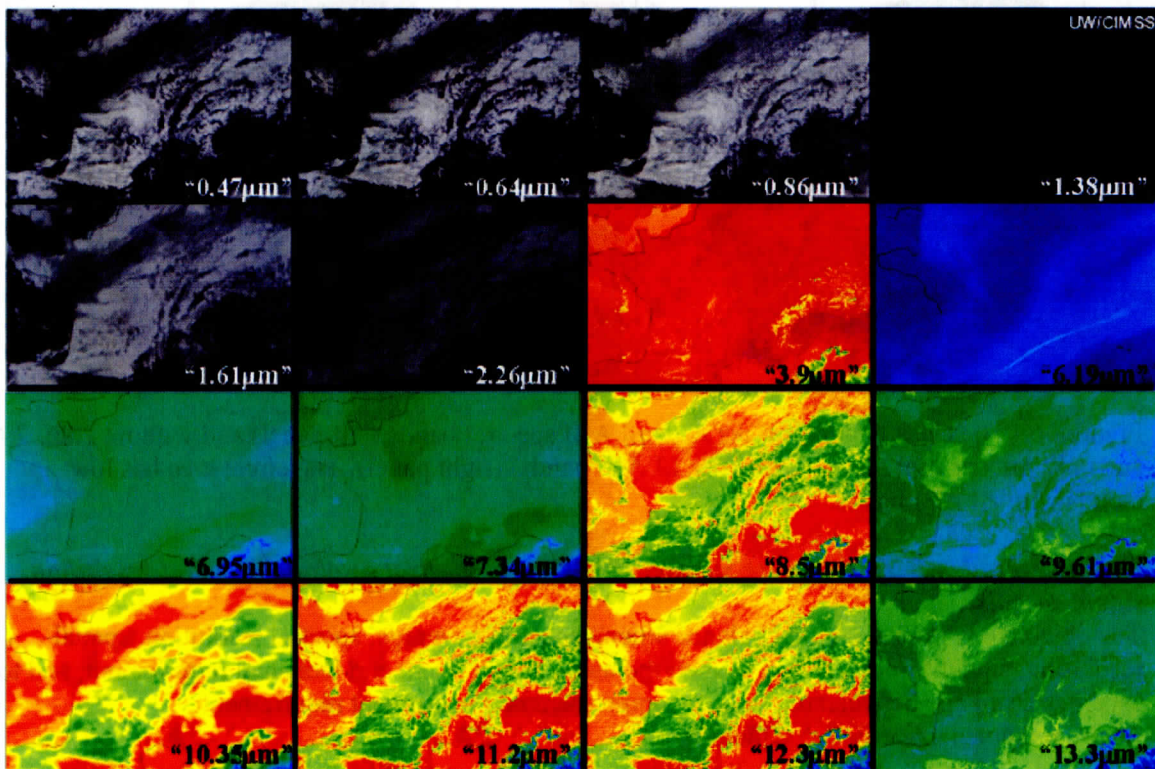


Figure 35: A simulated "16 band" ABI multiple panel image from 11 April 2004 at approximately 13 UTC.

ABI Band Elimination Study for Cloud Masking

The objective is to study the impact on user requirements if some of the ABI spectral bands are eliminated, including

- (1) The 2.26 μm channel,
- (2) The 2.26 and 9.61 μm channels,
- (3) The 2.26, 9.61, and 7.4 μm channels,
- (4) The 2.26, 9.61, 7.4, and 0.47 μm channels.

The impacts on various products are studied. In particular, the impact of the ABI band elimination on the cloud detection and masking is studied. Due to the unique information provided by each of the four ABI spectral bands that are being studied for elimination, along with the effects on a host of products, none of these bands should be removed from the ABI.

Figure 36 shows the classification masks with all ABI spectral bands (left panel) and without the 2.26, 7.4 and 0.47 μm spectral bands (with only 13 ABI bands) (right panel). The circle area has low clouds with all ABI bands. However it is classified as clear with scattered low clouds when the 2.26, 7.4 and 0.47 μm bands are excluded. MODIS data (MOD021KM.A2002179.1640.004.2003208221115.hdf) are used in the study.

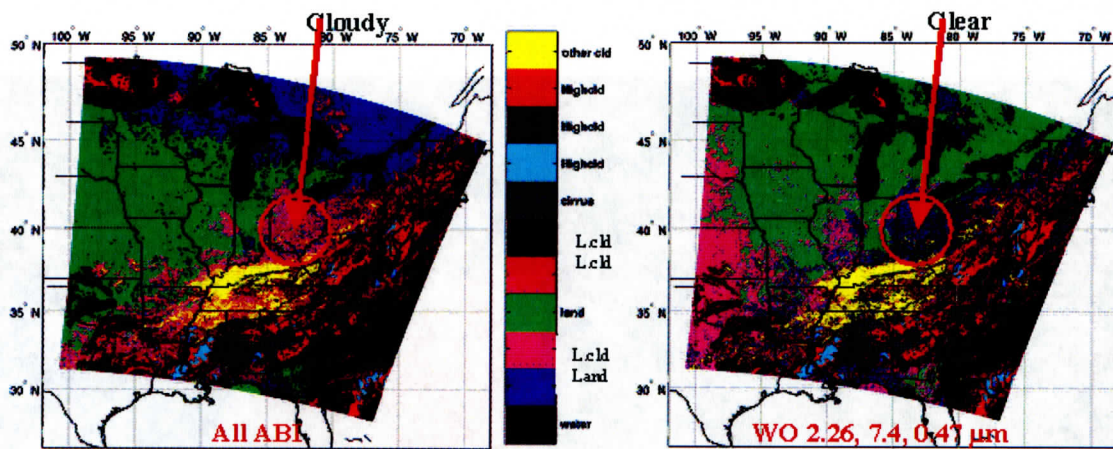


Figure 36: The classification masks with all ABI spectral bands (left panel) and without 2.26, 7.4 and 0.47 μm spectral bands (with only 13 ABI bands) (right panel). The circle area has low clouds with all ABI bands.

Continue Trade-off Study for HES (spectral coverage, spectral resolution, spatial resolution, signal-to-noise, etc.)

The objective is to find optimal balance among spectral coverage, spectral resolution, spatial resolution, signal-to-noise, etc. based on the users' requirement and technical requirement, and to establish a linkage between the science requirement and instrument requirement.

Accomplishments and findings include:

- NAST-I retrievals at 2km spatial resolution are used to demonstrate the requirement of HES spatial resolution.
- A vertical resolution analysis was created for HES trade-off studies. Trade-off studies have been done on spectral coverage, spectral resolution and spatial resolution; trade-off studies have continued with focus on the vertical resolution of atmospheric temperature, moisture and ozone profile retrieval from HES. An algorithm has been developed to analyze the vertical resolution from various spectral resolutions, options of spectral coverage, and different signal-to-noise ratios for HES. Trade-off studies on HES signal-to-noise were conducted with vertical resolution

analysis in this year. The signal-to-noise is crucial to achieve the high vertical resolution according to the study.

- Longer midwave (LMW) versus shorter midwave (SMW) on temperature and moisture retrieval is re-evaluated using the updated NeDT from Product Operation Requirement Document (PORD). Either LW+LMW or LW+SMW is fine for HES temperature and moisture retrievals; LW+LMW is slightly better than LW+SMW in terms of temperature and moisture retrievals based on the PORD NeDT. Ideally, LW+LMW+SMW is the best option in terms of temperature, moisture, ozone and other trace gas (e.g., CH₄, SO₂, and CO) information.

Spectral resolution and signal-to-noise ratio also determine the vertical resolution of temperature and moisture soundings. Higher spectral resolution and better signal-to-noise ratio correspond to higher vertical resolution. Figure 37 shows the temperature vertical resolutions from the HES two-band option (LW+SMW) with reduced noise, nominal noise and double noise, respectively. Reduced noise significantly improves the vertical resolution of temperature retrieval. The vertical resolution study will continue on spectral resolution, spectral coverage, etc.

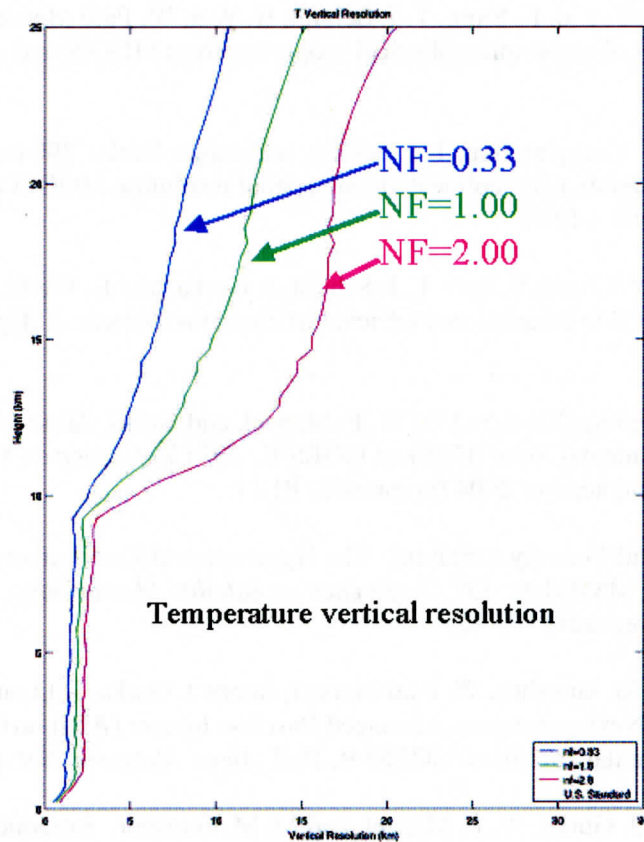


Figure 37: Temperature vertical resolutions from HES two-band option (LW+SMW) with reduced noise, nominal noise and double noise, respectively.

ABI/HES Synergism Studies

The objective is to investigate the better use of data from the ABI/HES system; algorithms for products by synergistically using the ABI and HES are developed. MODIS/AIRS on EOS Aqua are used in the study. Accomplishments and findings include:

- 1) HES sub-pixel cloud characterization using ABI mask products has been studied; MODIS/AIRS data were used. Collocated MODIS mask products (cloud mask, cloud phase mask, and cloud classification mask) with 1km are very useful for AIRS (Li et al. 2004b)
- 2) MODIS/AIRS are synergistically used for cloud property retrieval.
 - a) The MODIS cloud mask is used to generate the AIRS cloud mask.
 - b) The MODIS cloud mask is used to generate the AIRS phase mask.
 - c) As an option, MODIS cloud products can serve as the background and first guess information in variational retrieval of cloud properties from AIRS cloudy radiances (Li et al. 2004c; 2004a).

The advantage of ABI/HES synergism is also studied using MODIS and AIRS data; for example, ABI can help HES in (1) cloud detection, (2) sub-pixel cloud characterization by identifying the cloud phase mask and cloud classification mask, (3) cloud-clearing for partly HES cloudy footprints, (4) improving the retrieval by providing the background and first guess information in the variational approach. Results show that cloud property retrievals from the combination of imager/sounder (ABI/HES) are better than those from either imager (ABI) alone or sounder (HES) alone (Li et al. 2004c).

Publications and Conference Reports

Li, J., H.-L. Huang, C.-Y. Liu, P. Yang, T. J. Schmit, H. Wei, W. Paul Menzel, E. Weisz, and L. Guan, 2004a: Retrieval of cloud microphysical properties from MODIS and AIRS. *J. Appl. Meteorol.* (submitted)

Li, J., W. Paul Menzel, Fengying Sun, T. J. Schmit, and James Gurka, 2004b: AIRS sub-pixel cloud characterization using collocated high spatial resolution MODIS data. *Journal of Appl. Meteorol.* **43**, 1083 – 1094.

Li, J., W. P. Menzel, W. Zhang, F. Sun, T. J. Schmit, J. Gurka, and E. Weisz, 2004c: Synergistic use of MODIS and AIRS in a variational retrieval of cloud parameters. *J. Appl. Meteorol.* (in press).

Li, Jun, Timothy J. Schmit, Chian-Yi Liu, W. P. Menzel, and Gurka, James. Studies on the Hyperspectral Environmental Suite (HES) on GOES-R. *13th Conference on Satellite Meteorology*, Norfolk, VA, 20 – 23 September 2004 (preprints). P1.11.

Liu, Chian-Yi, J. Li, and Timothy J. Schmit. The Hyperspectral Environmental Suite (HES) simulation study using MM5 data. *13th Conference on Satellite Meteorology*, Norfolk, VA, 20 – 23 September 2004 (preprints). P1.12.

Schmit, T. J., Mathew M. Gunshor, W. Paul Menzel, James J. Gurka, J. Li, and Scott Bachmeier, 2004: Introducing the Next-generation Advanced Baseline Imager (ABI) on Geostationary Operational Environmental Satellites (GOES)-R, *Bull. Amer. Meteorol. Soc.* (submitted)

Schmit, J. Timothy, J. J. Gurka, W. P. Menzel, and M. M. Gunshor. Introducing the next generation geostationary imager – GOES-R's Advanced Baseline Imager (ABI). *13th Conference on Satellite Meteorology*, Norfolk, VA, 20 – 23 September 2004 (preprints). P1.6.

Wei, H., P. Yang, J. Li, B. A. Baum, H. L. Huang, S. Platnick, and Y. X. Hu, 2004: Retrieval of Semitransparent Ice Cloud Optical Thickness from Atmospheric Infrared Sounder (AIRS) measurements, *IEEE Trans. on Geosci. and Remote Sensing* (in press).

Zhou, D. K., W. L. Smith, J. Li, and S. A. Mango, 2004: Tropospheric CO observed with NAST-I: retrieval algorithm and first results. *Applied Optics* (submitted).

6. GOES-R Risk Reduction

6.1 Temperature and Moisture Retrieval Algorithm

Physical Retrieval Algorithm Testing Using AIRS Data

The physical retrieval algorithm has been successfully used in HES simulation study. The algorithm is an iterative approach to find the solution by minimizing the differences between the observations and calculations with a fast radiative transfer model developed at CIMSS. A first guess from either eigenvector regression or optimal channel regression provides constrain on the solution. Figure 38 shows the HES simulation retrieval RMS profile. This algorithm has also been applied to process AIRS level 1B data. Initial results from AIRS single FOV clear measurements show that: (1) the radiance residual between AIRS observations and calculations is significantly reduced from first guess to the physical retrieval, especially over the water vapor absorption spectral region (1200 – 1600 cm^{-1}), and (2) moisture retrieval with a physical scheme is improved over the first guess when comparing with ECMWF and radiosonde observation. More experiments will be conducted on some important issues such as optimal channel selection, observation and first guess error characterization the iterative procedure, combination of high spatial resolution MODIS data (e.g., surface temperature) and AIRS radiances for better sounding retrieval.

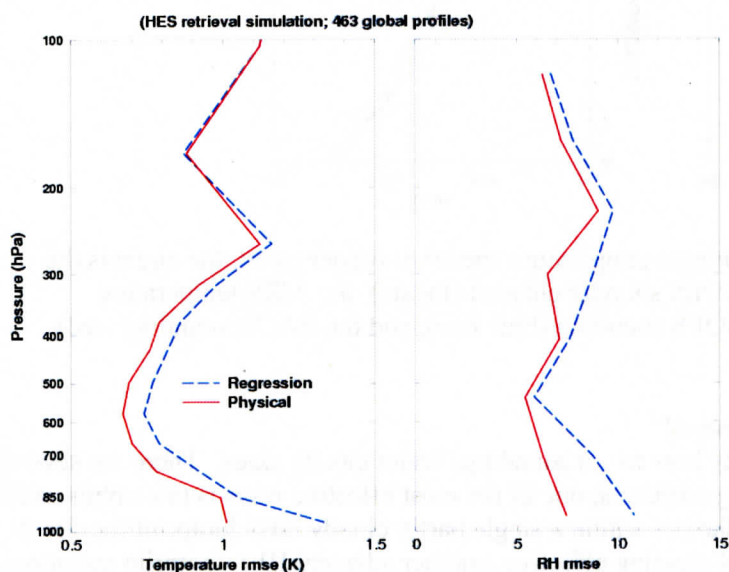


Figure 38: Temperature and RH retrieval RMS from simulated HES radiances with PORD NeDT included. Two bands (650 – 1200, 1650 – 2250 cm^{-1}) are assumed in HES.

Sounding Capability – HES Versus Current GOES Sounder

The objective of this work is to study how much improvement HES will provide over the current GOES sounder. Conducting simulations using MM5 data, we found that (1) HES captures spatial and temporal features better than the current GOES sounder, and (2) HES is able to provide soundings in the thin cloudy footprint while the current GOES sounder with 18 channels can only

provide soundings under clear skies. Real data experiment over the ARM cart site with time/space collocated AIRS retrieval (CIMSS algorithm) and the current GOES sounding also demonstrates the advantage of the hyperspectral IR sounder over the current GOES sounder. Figure 39 shows the AIRS observed brightness temperature spectrum (upper panel, the circle is the spectral centers where the current GOES sounder channels locate), the AIRS temperature sounding (green line), the current GOES sounding (blue line), and the RAOB sounding (red). The AIRS sounding fits RAOB better than the current GOES sounding for both temperature and water vapor.

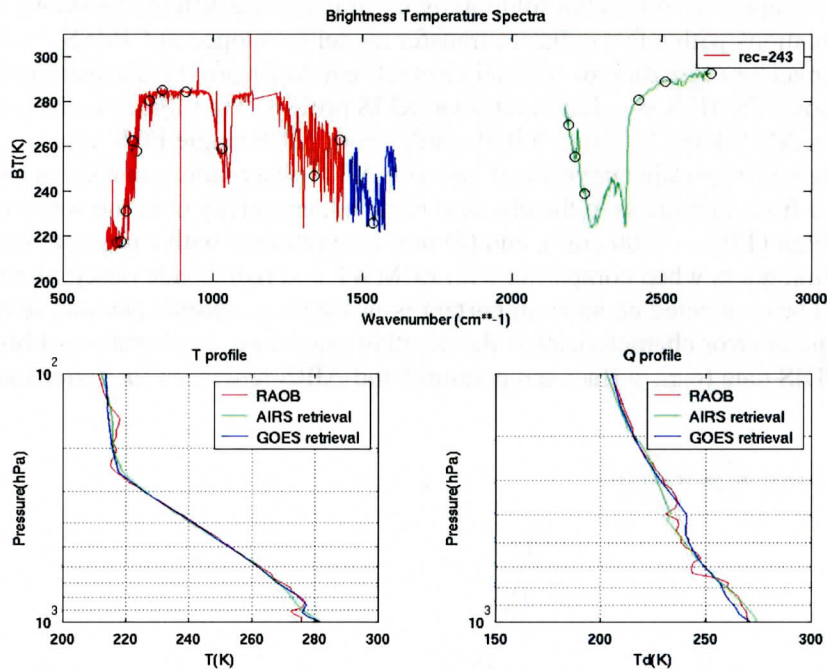


Figure 39: The AIRS observed brightness temperature spectrum (upper panel, the circle is the spectral centers where the current GOES sounder channels locate), the AIRS temperature sounding (green line), the current GOES sounding (blue line), and the RAOB sounding (red).

Handling Clouds in Sounding Retrieval

The objective of this work is to study how to get soundings under cloudy skies. There are several ways to handling clouds in sounding retrievals; one of the most effective ways is to combine ABI clear radiances and HES cloudy radiances within a single partly cloudy HES footprint for cloud-clearing. In order to make the cloud-clearing effective, another adjacent HES footprint radiances contains clouds will also be used. The algorithm has been developed. MODIS and AIRS single pair N* cloud clearing approach originally developed by Bill Smith is briefly summarized below.

The Single Pair AIRS/MODIS Cloud-clearing Algorithm

The simple yet efficient use of co-located MODIS clear radiances for AIRS two adjacent FOV “pair” cloud-clearing is to use the actual MODIS 11 μm channel (W) clear radiance with the simulated MODIS 11 micron radiances derived from the observed AIRS data to compute for each of the two adjacent FOV pair’s N*

$$N^*(i) = \frac{R_i(W) - R_{clear}(W)}{R_0(W) - R_{clear}(W)}; i = 1,8 \quad (1)$$

where $R_i(W)$ and $R_0(W)$ are observed AIRS simulated MODIS radiance measurements for the central FOV, 0, and the eight neighboring FOVs i , for the 11 micron window region, W , and $R_{clear}(W)$ is two FOV weighted average measurement of the MODIS clear column window radiance made by the MODIS cloud mask defined as confident clear pixels. If $0 \leq N^*(i) \leq 1$, then consider this combination a valid pair; otherwise, discard this pair. After this check, accumulate the total number of valid pair as j (j will be ranging from 1 to 8). Using all the valid pairs' N^* , we compute the AIRS clear radiance spectrum as follows:

$$R_{clear,k}(v) = \frac{R_0(v) - N^*(k)R_k(v)}{1 - N^*(k)}; \quad k=1,j \quad (2)$$

where $R_0(v)$ and $R_k(v)$ are the AIRS spectra for the central and the valid neighboring FOVs used to provide $N^*(k)$. The resulting cloud cleared radiance spectrum at the central FOV 0 is defined as:

$$R_{clear,0}(v) = \frac{\sum_{k=1}^{k=j} (R_{clear,k}(v)(1 - N^*(k)))}{\sum_{k=1}^{k=j} (1 - N^*(k))} \quad (3)$$

After obtaining cloud-cleared radiances at the central FOV 0, rigorous quality control is done using another MODIS cloud sensitive band (i.e. band 32, and/or band 20 and 21 if at night) to ensure the AIRS cloud clearing radiances at other spectral regions also match their respective MODIS observed clear measurements. The quality control criteria are defined as the difference between AIRS/MODIS cloud-cleared simulated MODIS band radiance and the respective observed MODIS band clear radiances are within 4 times of band NEdR divided by the $(1 - \bar{N}^*)$, where \bar{N}^* is mean of all valid j N^* . The AIRS/MODIS single pair cloud-cleared retrieval will be rejected if it fails this quality control in any of the bands checked.

Preliminary results show the MODIS/AIRS cloud-clearing provides a single pair cloud-cleared radiance spectrum with a reasonable accuracy over land (0.5 ~ 1.0 K). Figure 40 shows the current AIRS/AMSU golf ball (3 by 3 AIRS FOVs) version 3.5.0.0 and AIRS/MODIS pair (1 by 2 AIRS FOVs) cloud-cleared radiance performance in terms of convolved MODIS band 20 brightness temperature images. It can be seen that AIRS/MODIS pair cloud-cleared radiances maintain high spatial resolution and compare favorably with the "true" MODIS clear measurements. The AIRS/AMSU golf ball cloud-cleared image appears to be less stable and have lower resolution. We are currently evaluating their respective performance and will report any results when they become available.

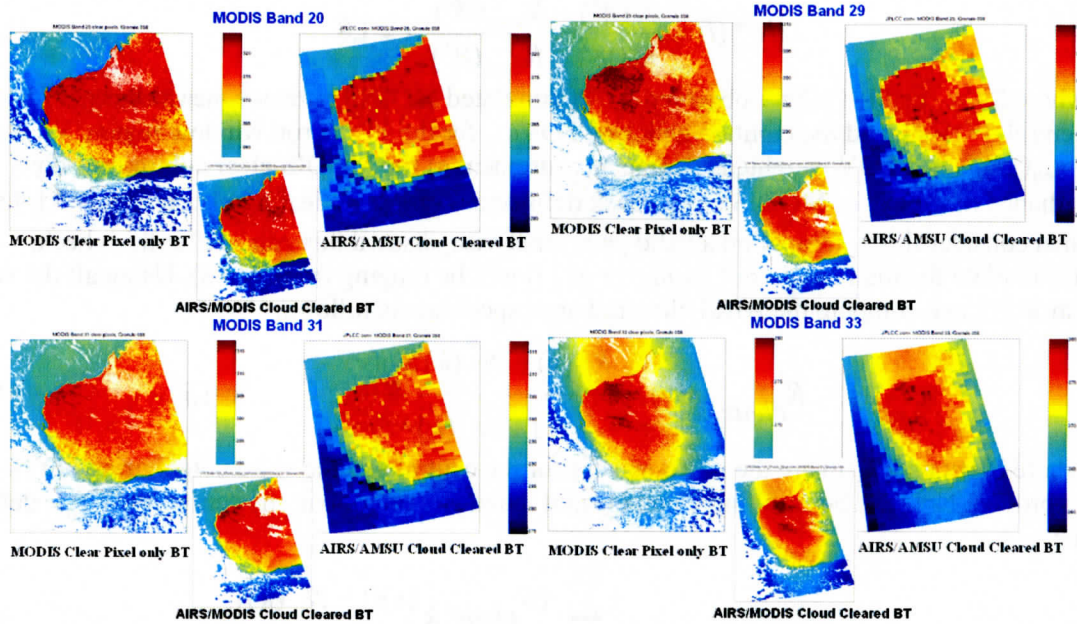


Figure 40: Plots of brightness temperature of MODIS and AIRS/MODIS and AIRS/AMSU cloud cleared MODIS simulated images used to validate cloud-clearing performance. Images of band 20 (upper left), band 29 (upper right), band 31 (lower left), and band 33 (lower right) are shown respectively. For each panel MODIS clear pixel (left), AIRS/MODIS cloud-cleared simulated MODIS (middle), and AIRS/AMSU cloud-cleared simulated MODIS (right) brightness temperature images for the different MODIS bands are displayed.

Similar cloud-clearing algorithm with imager/sounder data, such as ABI and HES, are also under development.

AIRS Detector Array Mis-Registration Error Analysis

AIRS is a grating instrument that requires the use of many thousands of detectors to make high spectral resolution in each field of view (FOV). Many detectors are mounted on separated detector modules; for example, Figure 41 shows that the longwave spectral region is measured by three separated modules, module 7, 8 and 9 as labeled. Because precise mounting of these detector modules relative to optical center is difficult, it can sometimes produce so called “mis-registration error” caused by not all the detector modules being able to view the exact area of the FOV desired. The spectral discontinuities shown in Figure 41 are a classic example of what happens due to the mis-alignment of detector module used by AIRS. It is important for the GOES-R risk reduction effort to study this instrument problem especially under cloudy and non-uniformity scenes. Preliminary analysis of some limited hurricanes and focus day data have shown that this mis-registration issue can be of great concern since there are likely to be more than 15 to 20 % of AIRS measurements over land, and cloudy areas have mis-registration errors of more than 1 degree K, twice to three times as large as the noise level of the spectral region center around 850 1/cm where two modules separated. There even is evidence indicating this problem is not limited to modules 8 and 9. Modules 7 and 8 may result in an even larger mis-registration error than the error between modules 8 and 9. To avoid any red herring we will continue to conduct an independent and careful analysis of this issue and will discuss the findings in the next report.

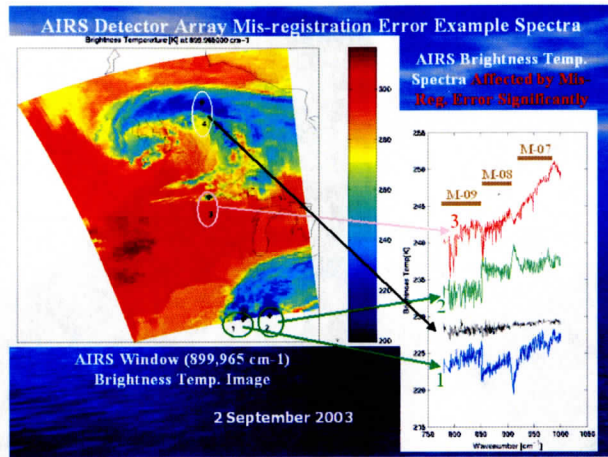


Figure 41: Example AIRS spectra significantly affected by the mis-registration of detector modules located in the infrared longwave region.

6.2 GOES R Winds Algorithm

The concept of deriving tropospheric winds from retrieved moisture analyses provided by hyperspectral sensors was proven in the last reporting period through simulated GIFTS datasets and one case of NAST-I aircraft measurements. The PI (Velden) gave several presentations on this effort as part of workshops/conferences that included the AMS annual meeting, the SPIE summer meeting, and during a visit to EUMETSAT.

During this reporting period, there was relatively little new R&D activity. However, one area of investigation centered around the exploration of deriving winds from AIRS data. The first test was to attempt to track AIRS radiance features from 2 channels for one day, 7 April 2004. The channels chosen were close to the MODIS bands used for the real-time polar winds processing (Table 1).

Table 1: Channels used for MODIS and AIRS tracking.

Instrument	IR band (wavelength)	WV band (wavelength)
MODIS	31 (11 μm)	27 (6.7 μm)
AIRS	770 (10.976 μm)	1685 (6.764 μm)

Figure 42 is representative of the difference in coverage and the number of vectors between MODIS and AIRS derived winds.

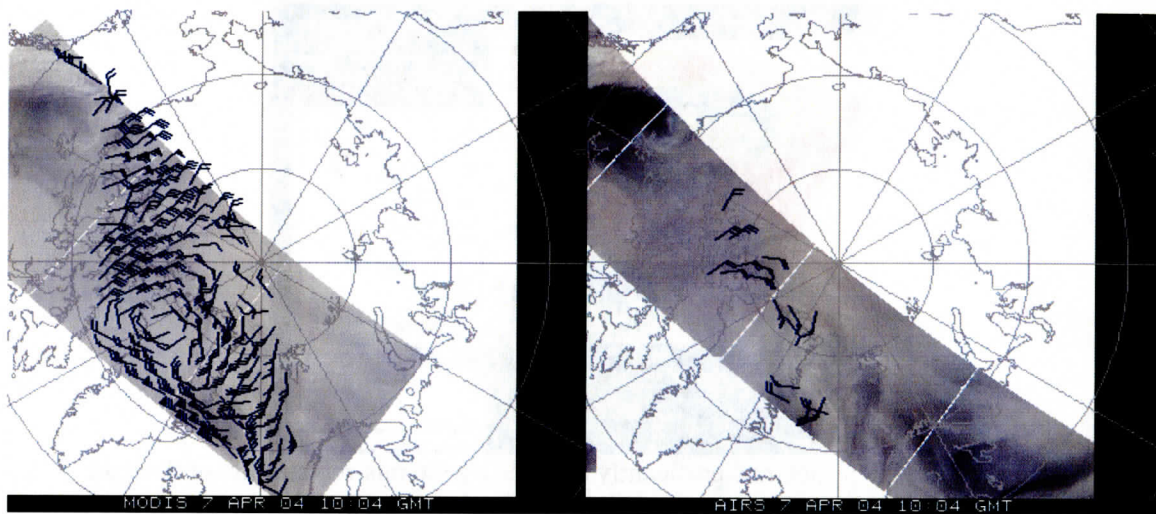


Figure 42: MODIS-derived vectors on the left, AIRS on the right. These vector plots are decluttered and do not represent all the vectors.

Table 2: The number of vectors derived for one time period, centered at 10:04 GMT. These numbers are representative for other time periods.

Instrument	IR winds	WV winds
MODIS	790	1953
AIRS	7	26

From Table 2, there are several reasons for the reduced number of vectors from the AIRS images:

- The MODIS features are tracked at 2 km resolution. Since AIRS has a subpoint resolution of 13.5 km, we chose 16 km resolution for tracking. This is a 64 time increase in target resolution area.
- There is a narrower swath width for AIRS, resulting in a smaller overlap region for tracking.
- Cloud height determination is problematic due to the narrow spectral response of the AIRS channels. The brightness temperature can differ by more than 5 K in the water vapor channel between MODIS and AIRS. The window IR differences are on the order of 1 K.
- The QI step reduces the number of vectors. This may be related to data resolution since a one-pixel error, 16 km, is nearly 3 m/s.

Tracking AIRS Retrievals

The second test (work in progress) will attempt to track moisture features from height-resolved analyses derived from AIRS retrievals. Operational AIRS retrievals are done with 3x3 FOV AIRS footprints. To track these retrievals, the resolution of the data would be about 50 km per pixel. With a 100-minute orbit, a one-pixel error would correspond to about 8 m/s. This means we would not be able to detect motions slower than about 8-16 m/s (1-2 pixels). Therefore, we will attempt to derive fields of moisture from single FOV AIRS retrievals. The retrieval algorithm will employ an experimental cloud-clearing routine. These moisture fields at constant altitudes will be used to target and track features in sequential images to derive vectors. The CIMSS AIRS retrieval algorithm team will provide us with AIRS cloud-cleared SOV sounding fields of water vapor (mixing ratio) from 3 simultaneous passes over the polar regions. We will convert these

isobaric analyses to images in an attempt to track WV features and obtain height-resolved wind vectors. The results will appear in the next report.

6.3 Preparing for High Spectral Resolution Data Assimilation

Working with CIMSS colleague, Jim Jung at the JCSDA, we are developing a clear and cloudy channel detection scheme to improve the yield of the using cloud contaminated AIRS data. The goal is to use any AIRS channels that are not affected by clouds. For example strong CO₂ or H₂O absorption channels that usually are not affected by low clouds have not been used because the cloud contamination check is at the field of view level. Any contamination by low or high clouds if detected and the FOV is declared to be cloudy and all spectrum information (~2300 channels) discarded by data assimilation.

Objective and independent of the NCEP model background, a clear channel detection scheme has been designed and is under development. The concept is to perform clear retrievals as if all AIRS FOVs are cloud free. For those FOVs where retrievals possess a large residual between observed and calculated (performing radiative forward model calculation from the input retrieval profile), spectra can be potentially identified as spectral channels affected by clouds. Since channels that do not “see the clouds” will have a much smaller residual due to the forward calculation of the real clear retrieval they will usually match the observed spectrum within the accuracy of linear statistically retrieval and measurement noise. CIMSS will share this algorithm with Jim Jung for his implementation into GFS for an AIRS impact study. We will report this progress when results become available.

6.4 Ground System Design and Studies

CIMSS has proposed research studies into the requirements and methodologies for developing a ground based architecture needed to support measurement validation and operational utility of the GOES-R instrument and studies into schemes for archiving and locating retrieving data sets from data libraries. Through studies using data sets derived from other FTIR instruments, CIMSS also will help define requirements for processing algorithms.

In order to prepare a prototype near-real-time data processing engine for public distribution, continuing NOAA-supported work during the April - September 2004 period focused on establishing specific design methodology and interface convention for data processing components. To support this research, there were continuing teleconferences and exchanges of ideas with staff at NOAA and at AC Technologies.

Research into the object-oriented software design in the telecommunications domain introduced a set of metaphors extending the Unified Modeling Language for real-time systems design (UML-RT). This UML-RT encourages that data processing systems be conceived as networks of collaborating software “capsules,” adapting the metaphor of physical silicon chips and buses which has a proven track record of delivering high-performance and reliable real-time systems. Capsules are recursively specified; they operate within timing constraints derived from overall system requirements, and exchange messages amongst themselves and the controlling state machine of the enclosing capsule. These exchanges follow specifically prescribed protocols. This approach simplifies the modeling of pre-existing software systems, and encourages interface boundaries with formalized but implementation-agnostic behavior.

Sequence Diagram for the Pixel Data Processing Use Case

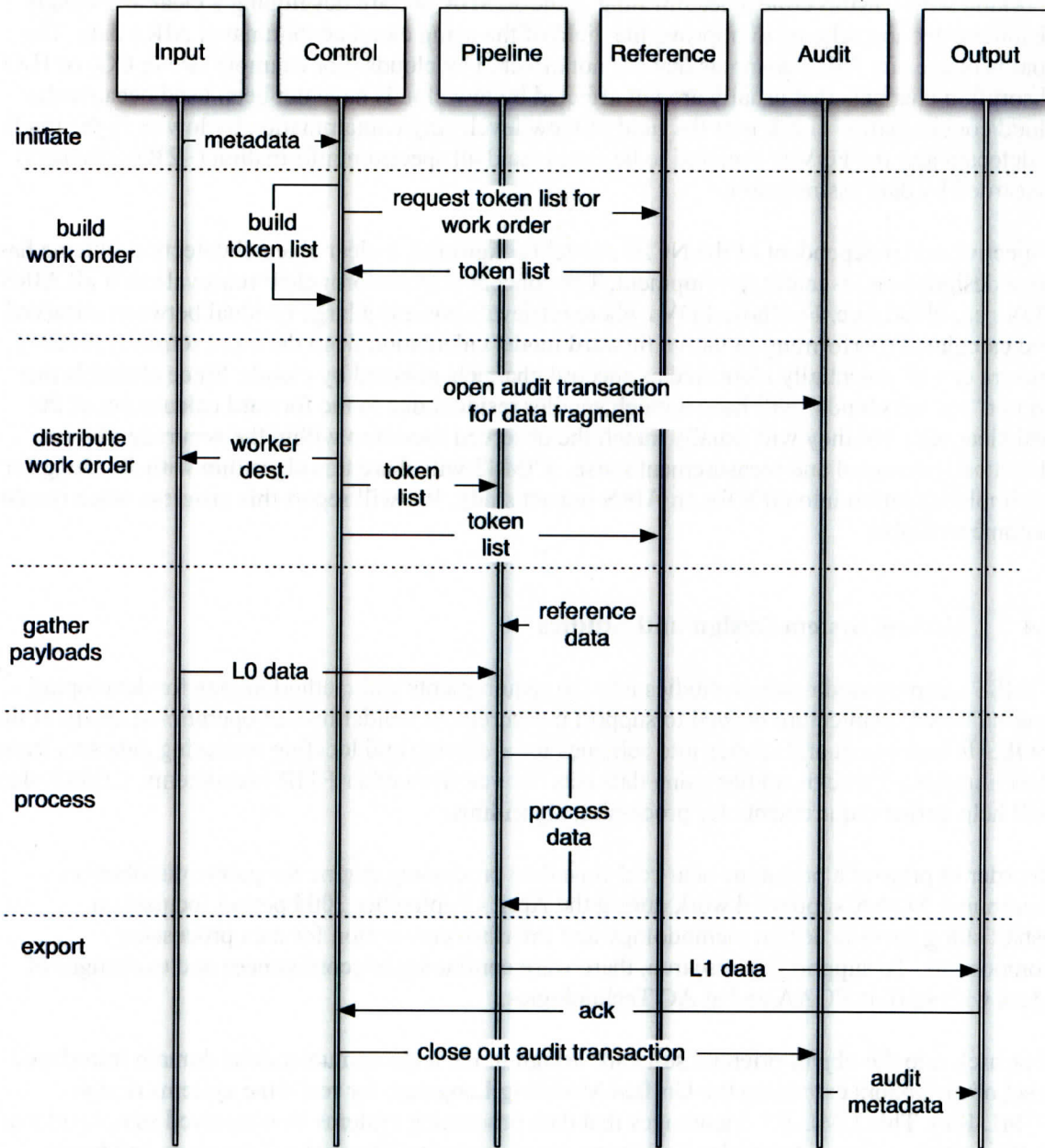


Figure 43: Illustration of data processing pipeline as part of an overall data processing system.

The UML-RT also permits the representation of multiprocessing systems such that data processing components can be deployed on uniprocessor, symmetric or distributed multiprocessor systems solely by elaborating on external state machines and inter-capsule connectors in the data processing system framework. This results in development efficiency as it encourages the verification and validation of algorithm components by way of test fittings.

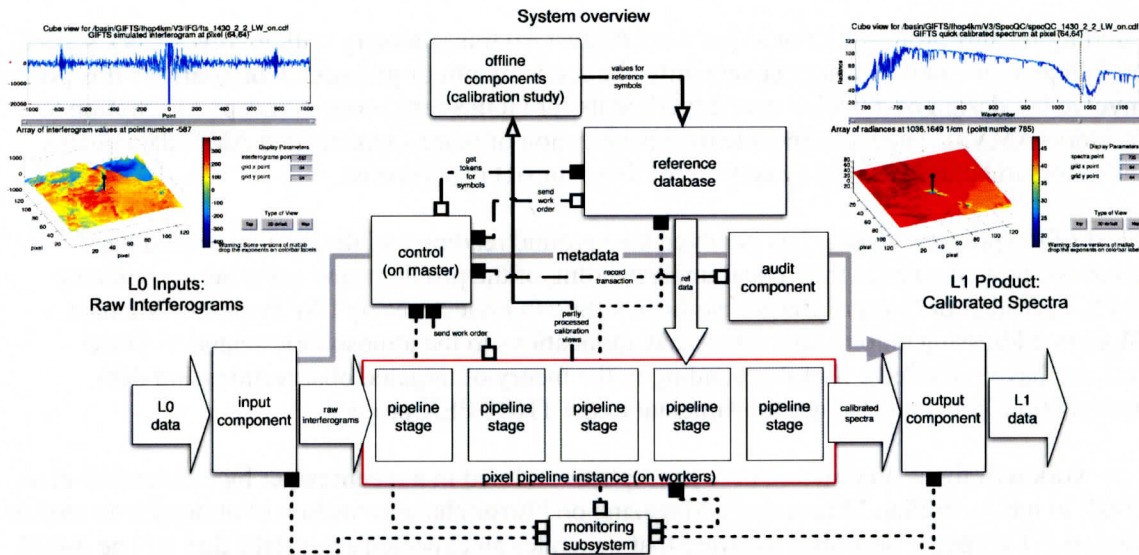


Figure 44: Sample UML sequencing diagram of processing pipeline interacting with an enclosing data processing system.

Given that this domain model was an appropriate superset of the component system design approach, design practices were researched that are consistent with the UML-RT which could be applied to the implementation of a prototype component library for data processing. Discussions of these conventions were included at a Technical Interchange Meeting in August 2004, which was attended by UW, NOAA, and AC Technologies staff.

After several iterations on use cases, requirements, and design practices, a core set of components in the C++ language has been implemented which are available on the SSEC web site. Work will continue in order to release a useful pipeline processing demonstration by end-of-year, and in order to demonstrate a real-time processing pipeline using these components aboard the airborne UW Scanning High-Resolution Interferometer Sounder during the first half of 2005. Continued expertise was also gained in the characterization of and optimization of specific interferometry processing algorithms needed for GIFTS. This involved exercising prototype implementations with real and test data in order to understand performance-accuracy trades which will require balancing in a deliverable processing engine.

Generalizing these components to be applied to other aircraft, ground-based, and satellite interferometers through 2005 in order to provide realistic real-time data processing demonstrations is also an implementation target. Verifying and validating the algorithm components using such data sets as well as simulated GIFTS data will then permit the component library to become the core of an instrument validation toolset used to support thermal vacuum testing of the GIFTS instrument.

Our continuing work was presented as a poster and extended abstract (5548-64), "Component-oriented design studies for efficient processing of infrared imager data" at the SPIE 49th annual meeting.

7. THORPEX Support and Science

Funding for this project did not arrive until August, so this summary only involves work started on 1 September, and therefore covers only about one month of progress. Our goals for this project involve the design of model impact experiments for GOES rapid-scan Atmospheric Motion Vectors (AMVs). They also include the investigation of more sophisticated AMV data quality indicators to be used as quality control for these impact experiments.

Most of the progress to date has involved background reading and discussions with other scientists to gain a better theoretical understanding of the problem, and some set-up software work. Investigator Howard Berger has been sitting in on lectures by UW Professor Michael Morgan addressing adjoint techniques and applications to the atmospheric sciences. These lectures have provided a useful grounding in the theory of targeted observations and data assimilation, concepts that are fundamental to the THORPEX project.

Our work will focus on utilizing new concepts as outlined in a recent paper by LeMarshall et al. 2004, in the Australian Meteorology Magazine on "Error characterization of atmospheric motion vectors." This paper describes software that generates an expected error (EE) that will be useful for AMV quality control. The EE will also hopefully provide a more detailed understanding of the AMV random and correlated errors. Implementing this EE software on a Linux workstation here at CIMSS and integrating it into our winds algorithm has been the main focus to date. The software provides several McIDAS executables that can be run to generate expected error values for each wind observation. It also performs various statistics for the winds that can be used for monitoring and evaluation. Once the EE software is fully implemented, the GOES rapid scan winds for the recent Atlantic Thorpex Regional Campaign (ATReC) are ready to be tested.

8. VISIT Participation

We had proposed to continue participating in National Weather Service teletraining, extend the capabilities of the VISITview software, and begin gathering more extensive case study datasets for use in future presentations.

We hosted the annual VISIT meeting, which this year was combined with a working meeting on SHyMet. This summit was attended by 17 people from NESDIS, CIMSS, CIRA, NWS/FDTB, COMET, and NWS/WDTB. In addition, four SOOs joined in the discussions.

We demonstrated a lesson on Mesoscale Convective Vorticies (MCV, see Figure 45) using VISITview more than 20 times, with an audience of about 410 forecasters. We also created an audio version of this lesson which can be reviewed asynchronously by anyone. This lesson demonstrates how to identify MCVs and discusses how various models handle the analysis. We also acquired some new data for MCV cases in 2004, which was incorporated into the lesson.

We participated in the WMO virtual lab teleconferences with colleagues in the Caribbean to use the VISITview tools to discuss realtime tropical weather and gain experience with presentations.

We also provided technical support to assist CIRA in setting up a suite of products to be used by the participants using VISITview.

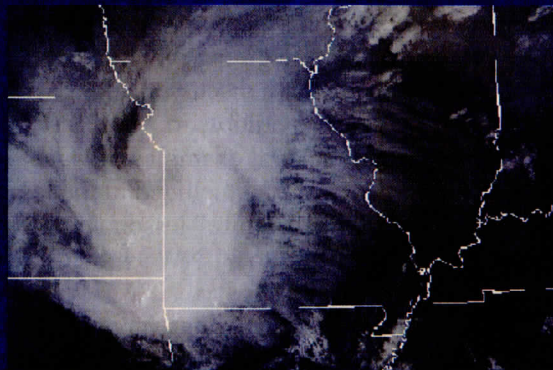
The VISITview lesson on “Water Vapor Channel Satellite Imagery” was updated with new examples and graphics, and was demonstrated 6 times to 27 National Weather Service forecast offices during the period. The recorded audio version of this lesson was also completed. This lesson provides a review of the remote sensing aspects of the 6-7 micrometer “water vapor channel,” including examples of water vapor weighting function profiles to aid in interpretation. Changes to the GOES-12 water vapor channel are discussed, along with new sources of water vapor channel imagery and products recently available in AWIPS (GOES sounder water vapor channels and water vapor winds products). Several examples of water vapor channel imagery from the polar-orbiting MODIS instrument are also included in the lesson.

The “Enhanced-V: A Satellite Severe Storm Signature” lesson was also updated with new material and graphics, and demonstrated 7 times to 31 NWS forecast offices.

Work continued on the development of a follow-up water vapor lesson which covers more advanced applications to weather analysis and forecasting. An extensive library of daily AWIPS case study data is being archived (October 2003 - June 2004) in order to obtain a diverse collection of cold season and warm season weather events where the use of water vapor imagery can be demonstrated in the forecast process. Content from this advanced water vapor lesson will also be applied to other satellite education activities such as COMET and SHyMet.

There were three updates to the VISITview teletraining and collaboration software issued. These updates included some extensions requested by users, and corrected a problem with importing PNG files. In addition, the hurricane season had a detrimental impact on the NWS Internet communications, resulting in the interruption of several teletraining sessions; we modified VISITview to automatically retry to establish connections when this happened. This has prove itself to be very helpful for NWS instructors and other participants and users.

MESOSCALE CONVECTIVE VORTICES



Scott Lindstrom

SSEC/UW-Madison

Scott Bachmeier

SSEC/UW-Madison

CIMSS

Figure 45. Title slide for the VISITview presentation on Mesoscale Convective Vortices.

9. GOES 11 Sounder Evaluation at IHOP

The International H₂O Project (IHOP) was conducted in the DOE ARM Southern Great Plains (SGP) region of the United States from 13 May – 25 Jun 2002. Two of the primary goals for the program were to measure water vapor variability at high temporal/spatial resolution and to study the mechanisms for convective initiation. GOES-11 was activated by the National Environmental Satellite, Data, and Information Service (NESDIS) for part of the IHOP campaign in order to improve the sounder time resolution to 30 minutes and to provide a more vertical scanning position over the IHOP domain. Activation of a spare GOES satellite was unique to a large-scale field program. The IHOP field experiment provided a unique opportunity to validate 1x1 (10x15 km) single field of view (SFOV) GOES sounder derived products.

Microwave radiometer and radiosonde data from the IHOP and Department of Energy Atmospheric Radiation Measurement (DOE ARM) programs were used to provide preliminary validation of GOES 11 total precipitable water (TPW) sounder derived products. A preliminary comparison of coarser spatial resolution 3x3 FOV TPW to the SFOV TPW products for GOES-11 has been conducted to quantitatively demonstrate the accuracy and utility of the relatively higher spatial resolution data. Figure 46 shows the adjustment the GOES physical retrieval makes to the ETA model first guess over Vici, Oklahoma on June 14-15, 2004. Most of the adjustment is made toward the microwave radiometer total precipitable water values from the ETA model TPW. The GOES-11 physically retrieved TPW does not include new radiance noise and cloud

clearing improvements. The outlier GOES physically retrieved TPW should be corrected once this is implemented.

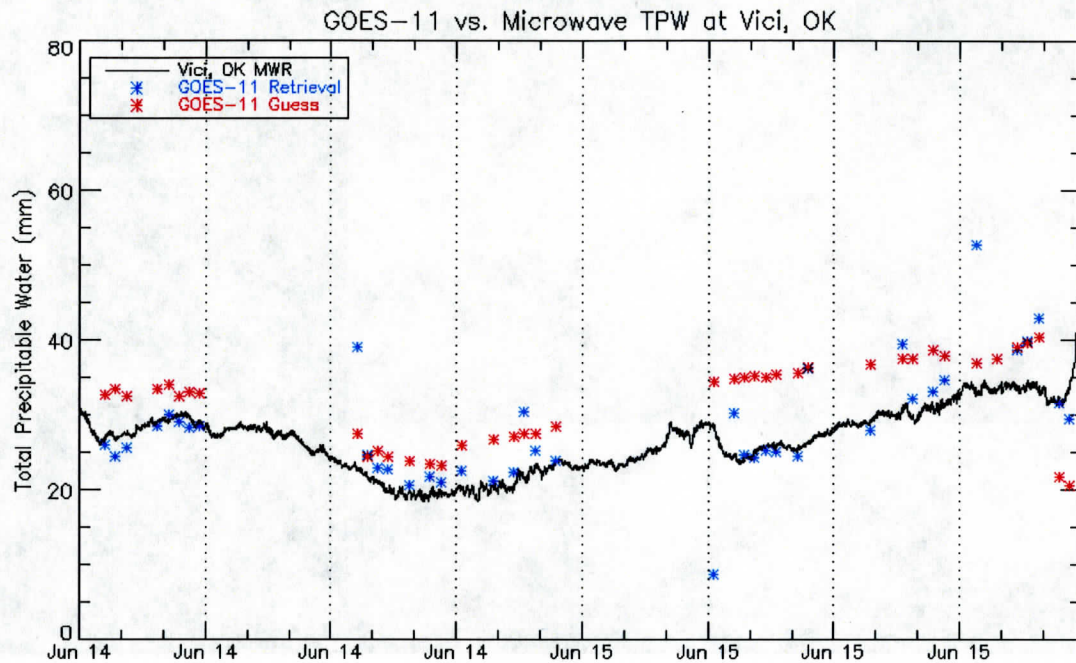


Figure 46: A time series of GOES-11 guess (ETA model, red), GOES-11 physical retrieved (blue), and microwave radiometer (black) total precipitable water vapor on 14-15 June 2002 over Vici, Oklahoma.

In preparation for improvement to SFOV GOES-11 retrievals, the SFOV physical retrieval algorithm has been compiled on a LINUX work station and is recalculating the GOES-11 SFOV retrieval with techniques to reduce radiance noise and cloud filtering. Figure 47 shows the dramatic improvement in radiance signal possible with a physical digital filtering technique that attempts to minimize the order (maximize the entropy) of the difference image. Initial parameters for the filter were derived from the work of Plokhenko and Menzel (2001, 2003). Further tuning of the filter parameters is necessary, as well as characterization of the error level of filtered data. The final goals are to do a complete reprocessing of the GOES-11 data set with improved radiance signal to noise ratio at single field of view resolution and evaluate water vapor magnitudes and gradients for specific convective case studies.

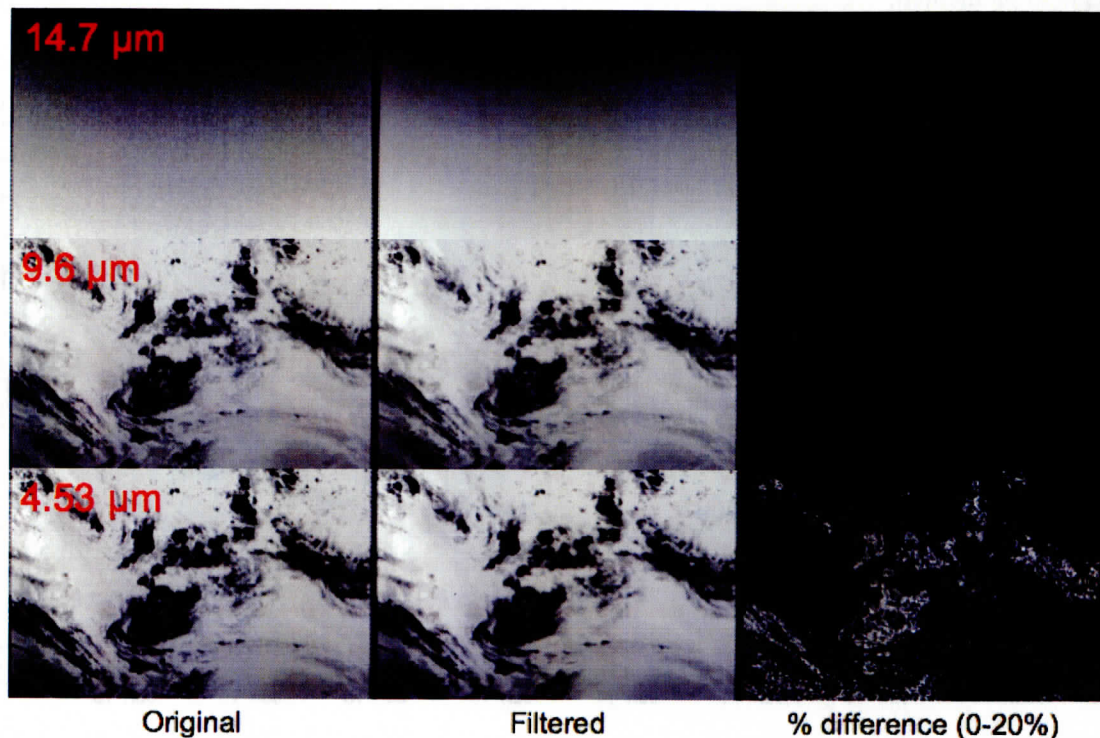


Figure 47: An example of digital filtering applied to GOES sounder channels indicating the dramatic improvement in radiance signal.

Our accomplishments include:

- 1) Validation of GOES-11 SFOV sounder derived stability, moisture, and cloud top pressure products (May 2004) (Feltz and Ackerman)

Preliminary validation of GOES-11 Sounder SFOV indicated problems with cloud clearing and daytime retrievals, which are being addressed. The NOAA FPDT GOES SFOV retrieval algorithm was implemented at SSEC/CIMSS to provide a consistent benchmark to begin improvement of SFOV GOES sounder retrievals. This is the same algorithm that is being used operationally. Therefore any improvements made for this study will be transitioned back to Washington, DC.

- 2) Reprocess GOES-11 sounder derived products to correct single field of view (SFOV) daytime cloud flagging problem and evaluate improvement of CIMSS SFOV retrieval technique

A new digital filtering technique is showing dramatic improvement in radiance field noise reduction (figure 47). The GOES sounder SFOV algorithm has been transitioned to a LINUX operating system with the goal to reprocess the GOES-11 data and then add digital filtering and cloud clearing. SFOV ozone retrieval logic is also being incorporated into the algorithm (Li et al. 2001). Complete reprocessing of 30-min resolution GOES-11 sounder SFOV processing has been accomplished for the IHOP period and reprocessing with reduced noise radiances is underway. Retrieval improvement is currently being evaluated through comparison to DOE ARM microwave radiometers and radiosondes.

Publications and Conference Reports

Plokhenko, Youri and W. Paul Menzel, 2001: Mathematical Aspects in Meteorological Processing of Infrared Spectral Measurements from the GOES Sounder. Part I: Constructing the Measurement Estimate Using Spatial Smoothing. *J. App. Met.*, **40**, 556-567.

Plokhenko, Youri and W. Paul Menzel, 2003: Mathematical Aspects in Meteorological Processing of Infrared Spectral Measurements from the GOES Sounder. Part II: Analysis of Spatial and Temporal Continuity of Spectral Measurements from the GOES-8 Sounder. *J. App. Met.*, **42**, 671-685.

10. SHyMet

CIMSS is collaborating closely with CIRA and NWS in the development of the SHyMet program. A workshop was hosted at CIMSS on September 27 and 28 to review current plans and NWS needs for such a course. Feedback from potential users in this workshop is being incorporated into the course design. The revised organizational structure draft is outlined below.

1. Orientation

Introductions, course logistics, etc.

2. Familiarization of AWIPS satellite products and displays

3. Satellite imagery in the Forecast Process

A. Understanding satellite imagery as observation

a. Remote Sensing fundamentals

b. GOES and POES Imaging and Sounding –

- GOES Imager routine scans and rapid scans: area coverage and time schedules

- GOES Sounder scans: area coverage and image frequency

- POES swaths: area coverage and image frequency

- channels and products

- simple identification: cloud types, cloud patterns, the earth's surface (land and water), atmospheric pollutants

d. Water Vapor Imagery – a great synoptic resource

e. Meteorological Sounders (IR and Microwave)

Synoptic scale cloud and moisture patterns

Fronts and waves

Depressions in mid-latitudes

Convective Cloud Patterns

Fog and Stratus

Orographic and polar phenomena

B. Satellite integrated with model guidance

a. Satellite data for model initialization – What gets in? How do the models handle it?

b. Model data vs. real-time satellite imagery. Oops, the model says it's cloudy, but the satellite image is clear...

C. The Interactive Forecast Preparation System (IFPS)(Use WES cases)

Tips on using satellite data to prepare the digital forecast and coordinate with neighboring offices.

Optional Topics:

+ Aviation

- + Marine and Coastal
 - + Precipitation Estimation and Forecasting (QPE and QPF)
 - + Tropical
 - + Winter Weather
 - + Satellite Data for Model Initialization
 - + Verification
 - + Satellite Cloud Climatologies
- D. Special considerations in using satellite imagery for the Warning Decision Making Process (Use Weather Event Simulator (WES) - cases)
- a. Situational awareness for Convection and Severe Weather -:
Satellite monitoring (detection) of pre-convection and near storm environment (boundaries, moisture advection, winds (jet streaks), sounder DPI/retrievals, etc.)
 - b. Nowcasting Convection and Severe Weather (old boundaries, new boundaries, moisture advection, winds (jet streaks), sounder DPI/retrievals, etc.)
(Should we break down the following topics for situational awareness and nowcasting also?)
 - c. Flooding
 - d. Tropical
 - e. Winter Weather
- E. Space Based Remote Sensing for Hydrology
- F. Future Plans and Advances
- GOES-R+
 - NPOESS
 - Advances in Satellite Data / Model Initialization
 - With contributions from:
JCSDA, SPORT, CIRA, CIMSS, DOD

11. NPOESS Support from the Integrated Program Office

11.1 GPS and Sounders

Investigation of combined AIRS/GPS regression based profile retrievals and comparison of results with RAOBs continued. After collecting a clear sky test dataset containing 373 collocated data, statistical and principal component statistical regression algorithms were tested further using various subsets of AIRS channels only on AIRS retrievals. The PC regression algorithm using 1688 selected channels gave the best quality temperature retrievals around the tropopause region (Figure 48) and thus was selected for further combined AIRS/GPS study.

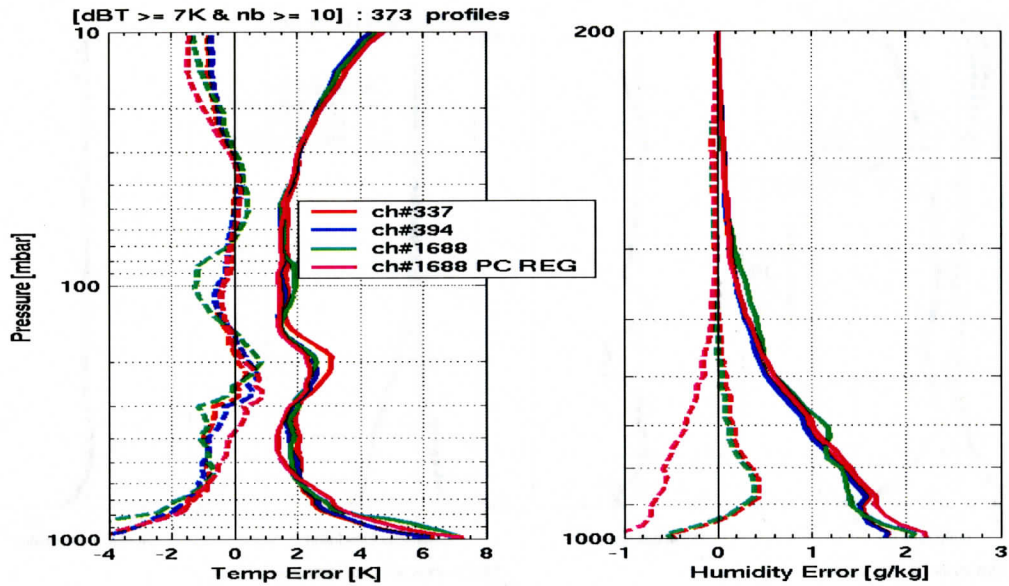


Figure 48: Comparison of using different number of optimal channels in the statistical regression retrievals. PC regression result using 1688 channels is also added.

The PC algorithm, developed by Elisabeth Weisz, was modified to accommodate addition of GPS data. The effect of three different vertical ranges of GPS data (between 8 and 26 km; between 5 and 26 km; and between 1 and 26 km) on retrievals were investigated (Figure 49). The vertical resolution was 200 meters in all three cases. Using more GPS information closer to the surface introduces negative impact under the tropopause, so GPS profiles between 8 and 26 km were selected for further combined AIRS/GPS study.

The three clear sky cases for 6 September 2002 were recalculated using PC regression methods instead of statistical regression method for AIRS/GPS retrievals. In Figure 50 one case over Germany is shown; operational AIRS and AIRS+AMSU retrievals are also shown.

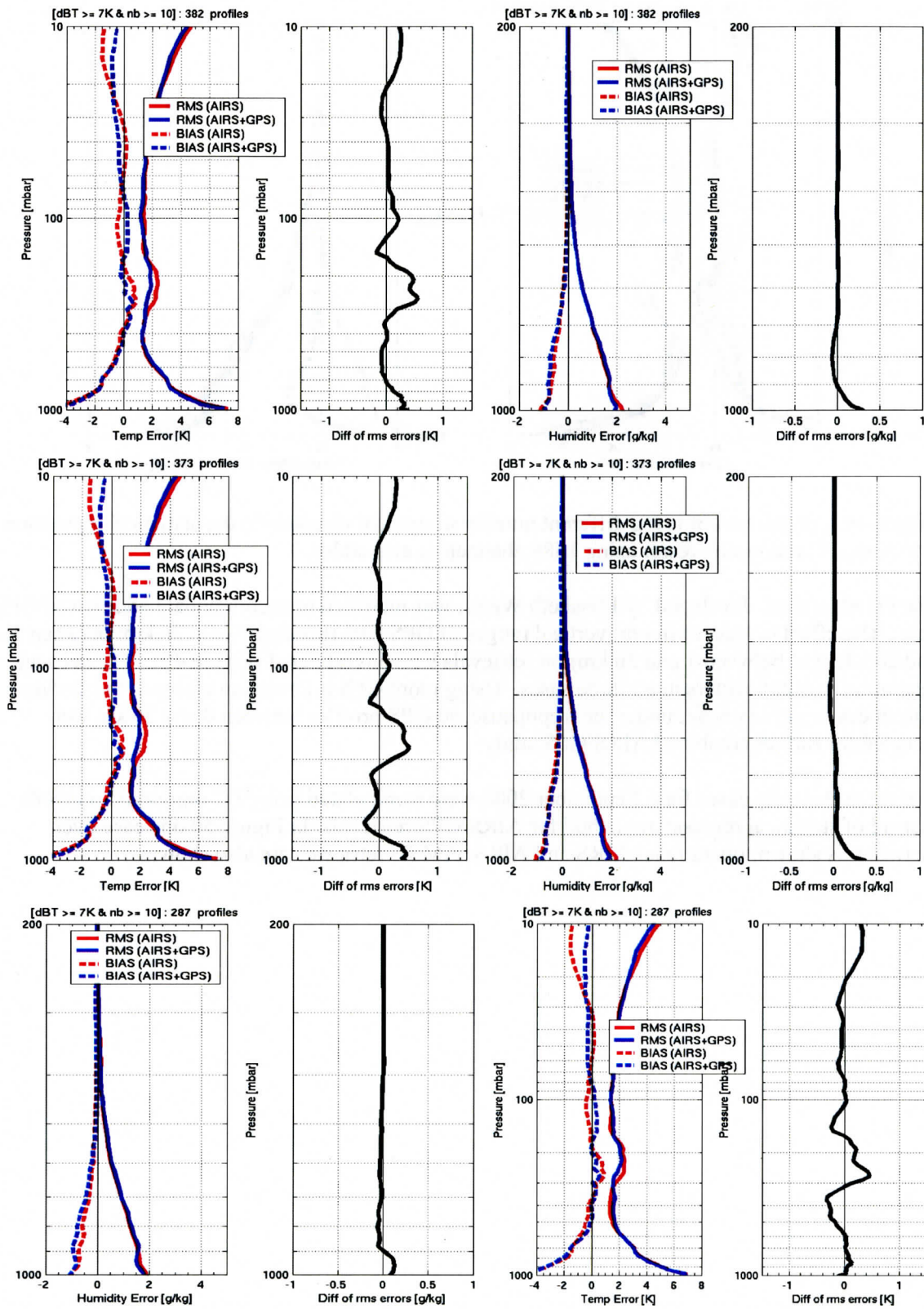


Figure 49: AIRS and AIRS + GPS temperature and humidity PC regression retrievals including GPS from 8 to 26 km (top panels), 5 to 26 km (middle panels) and 1 to 26 km (bottom panels).

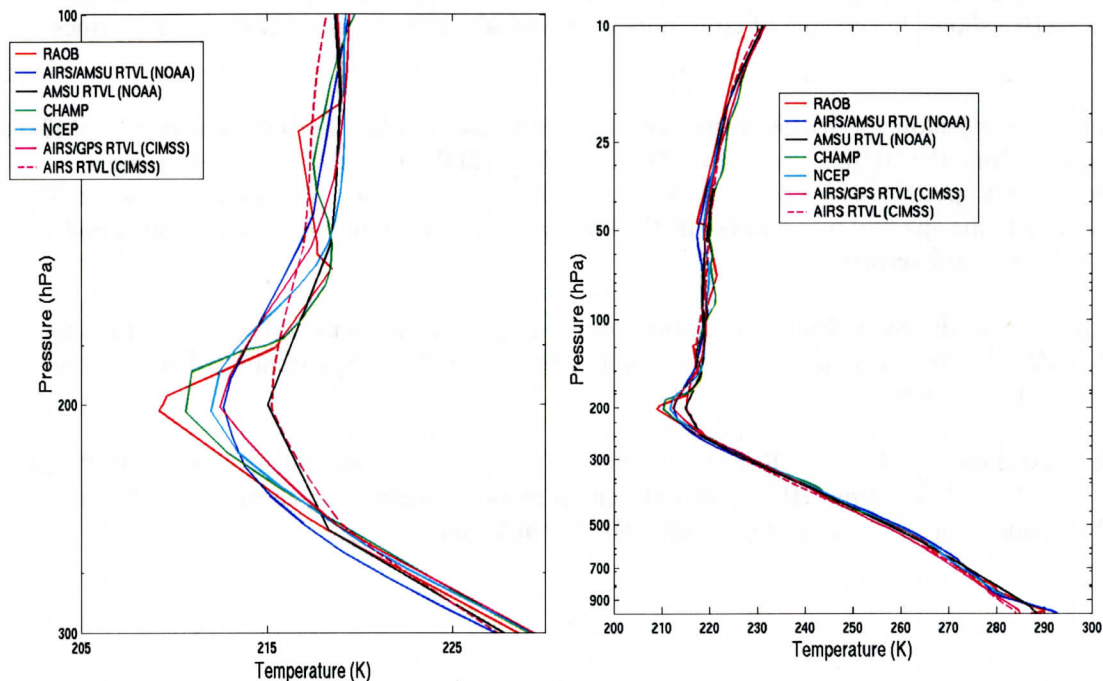


Figure 50: A temperature profile comparison on September 6, 2002 (Lat:52.1 N, Lon:6.4E). The operational AIRS and AIRS+AMSU retrievals are also added. The tropopause region is highlighted on the right panel.

In this quarter, the database was extended to August 2004 for GPS and January 2004 for AIRS-RAOBs matchup data. Addition of AMSU data to the regression profile retrievals is planned; AMSU data is being collected now from the DAAC.

In the next months we will (a) investigate the negative impact on AIRS+GPS temperature retrievals using GPS data closer to the surface, (b) collect AMSU-A data collocated with AIRS/GPS/RAOB for the test cases, (c) modify the PC regression to enable addition of AMSU, and (d) prepare a technical document summarizing the results.

11.2 Investigating High Spectral Resolution IR Data and Surface Emissivity

AIRS spectral measurements from Granule 001 on 16 November 2002 (over Egypt) were analyzed and surface emissivity in the 9.6 μ m band (sensitive to atmospheric ozone) was estimated. To do this a non-linear algorithm for atmospheric ozone estimation was developed and spectral channels in the 9.6 μ m band were included in the emissivity estimation. Solution of radiative transfer equation now includes spectral surface emissivity, surface temperature, and vertical profiles of atmospheric temperature, moisture and ozone.

Figures 51 (a-f) show spatial distributions of the spectral surface emissivity solutions for the Eastern Mediterranean – Sahara desert. The Mediterranean Sea can be seen. The Sahara Desert is characterized by lower emissivities (c-e). The delta of the Nile River and its valley, the Red Sea, c also be discerned (at the right-middle (c-e)). Figures 51 (b, c) show surface emissivity estimates in 9.6 μ m ozone band: they demonstrate the joint influence of surface emissivity and atmospheric ozone in the inverse problem solution. Figures 51 (d,e) show unusually low estimates in the 8-8.5 μ m spectral band. Specific spatial shape of emissivity minimums like “ “, indicates that

perhaps we are observing spectral effects of an atmospheric dust, transporting by the wind. Figure 51(e) shows the change of emissivity estimates along the transect of element 35, lines 1-70.

Figures 52 (a-f) show the spatial distributions of the moisture solutions $100 \cdot (W_s - W_i) / W_i$ [%] at levels (a) 71mb, (b) 103mb, (c) 125 mb, (d) 151 mb, (e) 200mb, (f) 247mb. These images demonstrate a spatial consistency and significant moisture variations. The solutions show a high sensitivity to the spectral measurements; the retrieved fields contain mesoscale features both in the horizontal and vertical.

Preliminary results show that the algorithm adjusted for ozone absorption is effective for analysis of hyperspectral measurements. The solution is stable and exhibits apparent sensitivity to the spectral measurements.

In the next three months we will resume testing calibration/validation concepts with IHOP and TX-2002 data, start testing VIIRS plus CrIS cloud property algorithms, continue AIRS data analysis, and wrap up AIRS and CHAMP / SAC-C analysis.

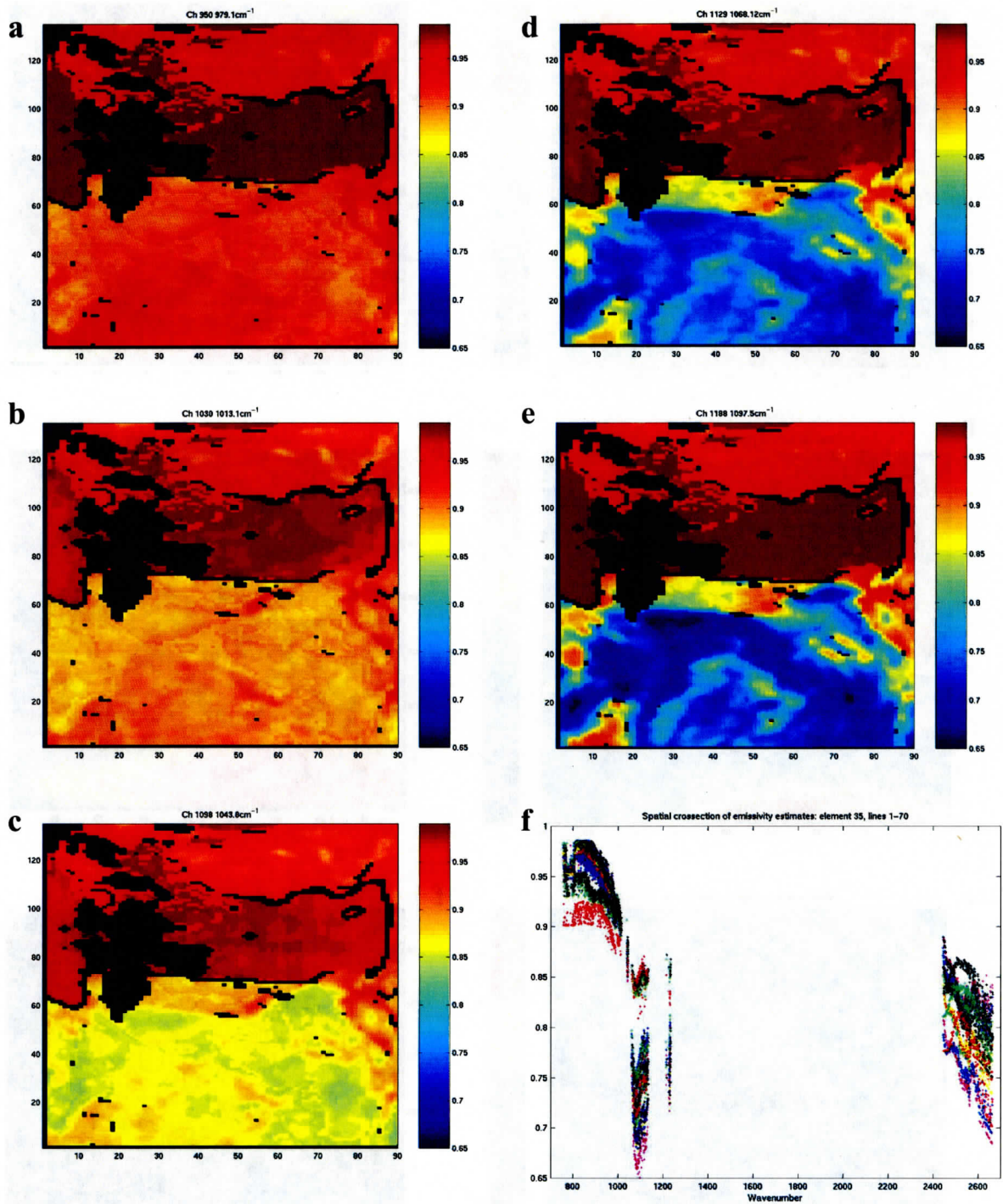


Figure 51: Spectral emissivity solutions for (a) 979 $1/\text{cm}$, (b) 1013 $1/\text{cm}$, (c) 1043 $1/\text{cm}$ (d) 1129 $1/\text{cm}$, and (e) 1180 $1/\text{cm}$ shown with (f) the transect of lines 1-70 (every 5th line), element 35 for the Egypt 1 site in AIRS Granule 001 on 16 November 2002.

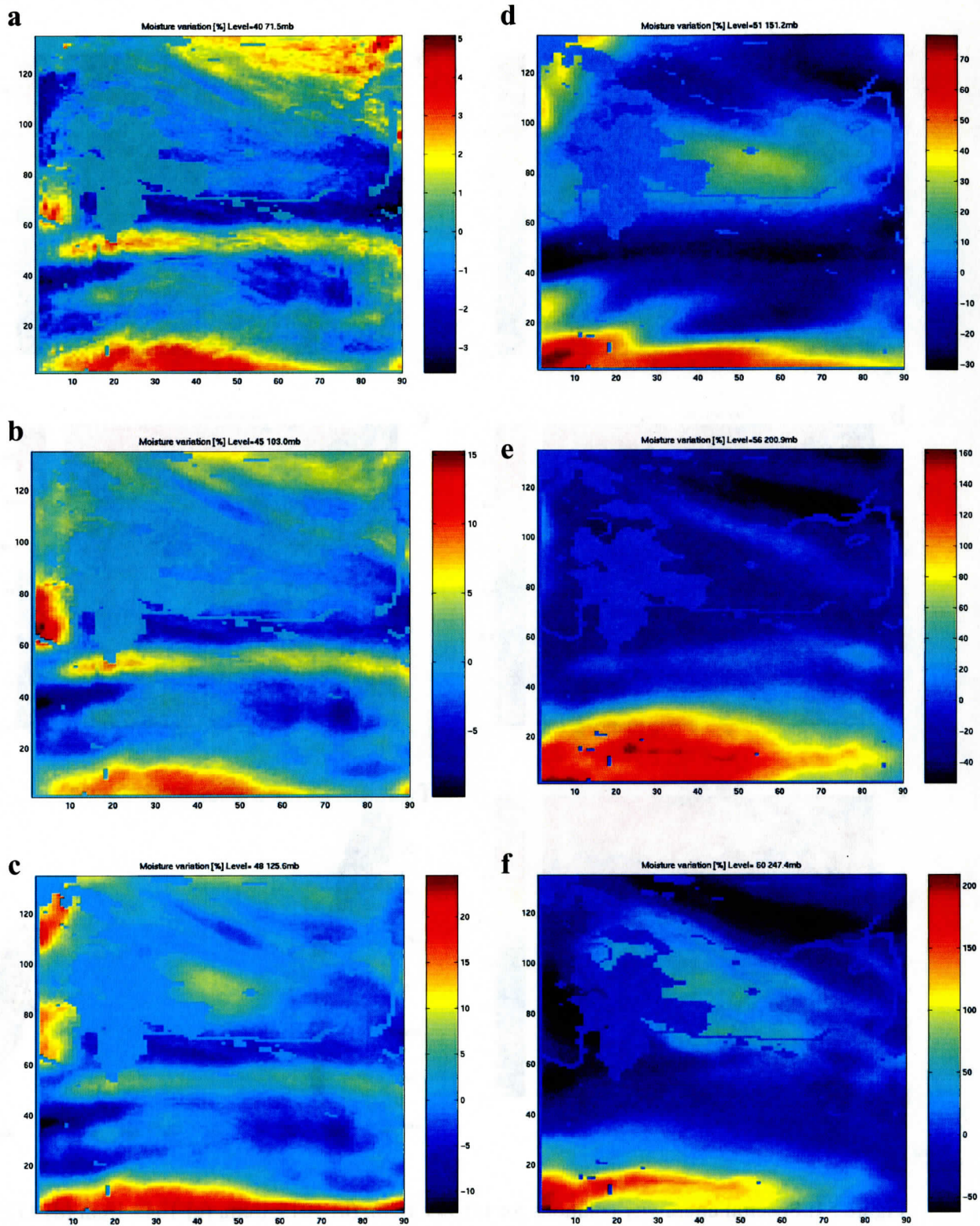


Figure 52: Moisture solutions of $100 \cdot (W_s - W_i) / W_i$ [%] for levels (a) 71 mb, (b) 103 mb, (c) 125 mb, (d) 151 mb, (e) 200 mb, and (f) 247mb for the Egypt 1 site Granule 001 on 16 November 2002.

11.3 VIIRS Snow and Ice Cover Risk Reduction for NPOESS

A number of VIIRS Environmental Data Records (EDRs) cover high-latitude surface and atmospheric parameters and the cryosphere overall: ice surface temperature, surface albedo and reflectance, fresh water ice, sea ice age and motion, snow and ice cover, and cloud properties. The purpose of this project is to evaluate algorithms that have been proposed for these EDRs in order to reduce the risk in their use after launch. Specifically, we are investigating retrievals of snow/ice surface temperature and albedo, snow/ice cover, and ice motion through the development of models, applications with existing sensors (MODIS, AVHRR, GOES, and SSM/I), and field data for validation. The work is intended to improve current algorithms, increase our understanding of their limitations, and identify potential uses in numerical weather prediction and climate studies.

Ice Surface Temperature

Ice surface temperature (IST) retrieval research has continued with MODIS. Our algorithm, which is currently used by the MODIS Snow and Ice Products group, is applicable to VIIRS, though additional research is needed on surface emissivity effects. Previous validation activities with surface data in the Arctic and Antarctic showed that the MODIS ISTs have a bias of -0.9K and a root-mean-square (RMS) difference ("error") of 1.6K . The negative bias means that the satellite retrieval is less than the air temperature. A paper on this work has been published (Hall et al. 2004).

Sea Ice Motion

We continue to evaluate our recently developed procedure for estimating ice motion from MODIS in order to evaluate the accuracy of the VIIRS ice edge motion EDR. The procedure runs in real-time and is based on the cloud-drift wind algorithm and code base. Problems with cloud contamination need to be addressed, and validation data need to be explored. We are setting up a comparison with a more traditional method of ice tracking developed at the University of Colorado.

Polar Cloud Detection

While not the focus of the proposed research, cloud detection and, to a lesser extent, cloud properties play important roles in the remote sensing of snow and ice cover. All snow and ice EDRs depend on the cloud mask, and understanding cloud properties aids in cloud detection. Polar clouds are unique in their height, temperature, and phase distributions in ways that profoundly affect remote sensing methodologies.

We have developed new and modified cloud and clear spectral tests, particularly those utilizing the 3.9, 13.3, and $7.2\ \mu\text{m}$ bands. These have proven to be critical to the accuracy of the MODIS cloud mask over the polar regions. A paper on the subject has been published (Liu et al. 2004).

Publications and Conference Reports

Liu, Y., J. Key, R. Frey, S. Ackerman, and W.P. Menzel, 2004, Nighttime polar cloud detection with MODIS, *J. Appl. Meteorol.*, **92**, 181-194.

Hall, D.K., J. Key, K.A. Casey, G.A. Riggs, and D.J. Cavalieri, 2004, Sea ice surface temperature product from the Moderate Resolution Imaging Spectroradiometer (MODIS), *IEEE Trans. Geosci. Remote Sensing*, **42**(5), 1076-1087.

12. AMSU Pointing Accuracy

An accurate geo-referencing of satellite observations is a necessary prerequisite for all subsequent processing steps. In particular, if the observed fields are inhomogeneous, the accuracy of the navigation of the single footprints also constrains e.g. the accuracy of validation efforts at level 2. Demands on beam pointing accuracy are typically better than 5 km and thus in sub-pixel resolution compared to the moderate resolution of passive microwave radiometers such as AMSU.

We will determine both the absolute geo-referencing of AMSU-A and AMSU-B as well as the relative pointing accuracy of both instruments. A similar study has been performed after launch of NOAA-17. More detailed information can be found in the final report for the NOAA-17 geo-referencing study (Bennartz (2002) final project report to NOAA/NESDIS on NOAA-17 geo-referencing).

Project status: Waiting for NOAA-N launch

13. Microwave Radiance Assimilation of Clouds and Precipitation

This project aims at preparing for the assimilation of observed radiances of current and future passive microwave satellite sensors in the framework of the GFS/GDAS under cloudy and precipitating conditions. Given the complexity of the problem we consider this project a necessary first step toward the assimilation of these data. The project is sub-divided into two parts: First, the development and test of appropriate fast forward, tangent linear and adjoint microwave radiative transfer models for clouds and precipitation. Secondly, the monitoring of biases between simulated and satellite observed microwave radiances and the associated adjoint sensitivities for GFS/GDAS for a significant time to identify shortcomings in the radiative transfer model, regional biases, to establish quality control, and possible feedback to cloud physics.

Over the last six months, our team has made great progress testing and refining the Successive Order of Interaction (SOI) radiative transfer model for scattering atmospheres. Several simple refinements have broadened the scope of the model for use in the thermal infrared and submillimeter, as well as for the microwave as initially designed. Other optimizations have considerably sped up the code, such that it should not noticeably slow down the assimilation code by including it for the radiative transfer. Our other main achievement regarding the SOI model was the successful coding and testing of both tangent-linear and adjoint versions of the code. One manuscript has already been accepted for publication in the Journal of Applied Meteorology. Two more manuscripts are currently in preparation and will be submitted before the end of the year. In addition, a technical report on the SOI model has been compiled and several conference proceedings have been published.

First Results for the Adjoint Radiative Transfer Model

We find the adjoint code agrees to machine-level accuracy with the tangent-linear code and is quite fast, only roughly 3-5 times slower than the forward model itself. To illustrate use of the adjoint, we have run both the forward and adjoint code on a 12-hour forecast GFS model output file, corresponding to 12Z on 21 September 2004. Because precipitation profile data are not available in the GFS output, we have made several simple assumptions about the precipitation

structure in the atmosphere, based on the 6-hour average surface precipitation rate as well as the cloud height and temperature profile. All frozen precipitation is taken for simplicity to be graupel. Mie calculations were performed and their output was combined with the absorption profiles due to gas and liquid water to obtain a complete set of optical properties (extinction, single scatter albedo, and asymmetry parameter) for each of the 26 model layers. Surface emissivity for each polarization was calculated using the FASTEM-2 emissivity model.

Figure 53 shows the modeled brightness temperature at 89 GHz across the northern Atlantic for nadir incidence. Hurricanes Jeanne and Karl are both apparent; on this day, Karl (centered at roughly -47° longitude, 22° latitude) was classified as a category 4 hurricane. Figure 54 shows the cross-section of the sensitivity of this brightness temperature to the scattering coefficient k_s at -47° longitude (dotted line in Figure 53). This sensitivity is large high in the atmosphere and over the storm activity, because increasing the scattering there will effectively increase the amount of cold space reflected by the atmosphere into the sensor, lowering the received brightness temperature. Near the surface, the opposite is happening, as the cold ocean is more obscured by the scattering precipitation directly above it, which has the effect of increasing the TOA brightness temperature.

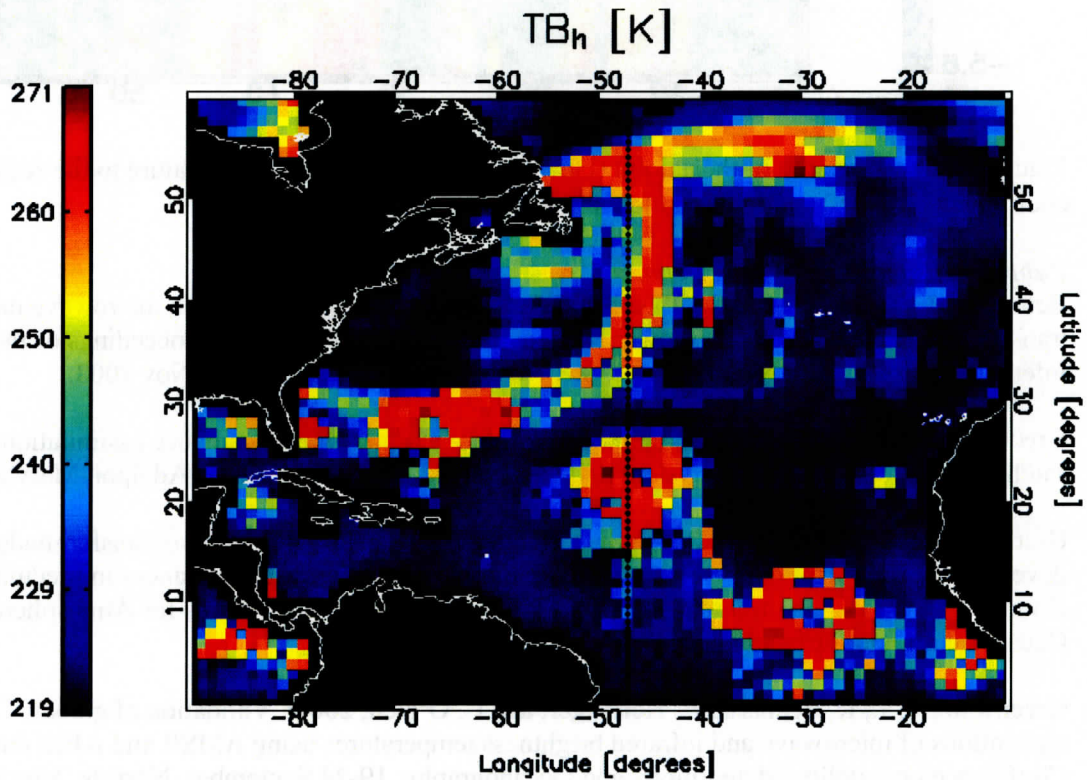


Figure 53: SOI simulation of horizontally polarized brightness temperatures at 89 GHz at nadir derived on GFS data for 12Z on 21 September 2004.

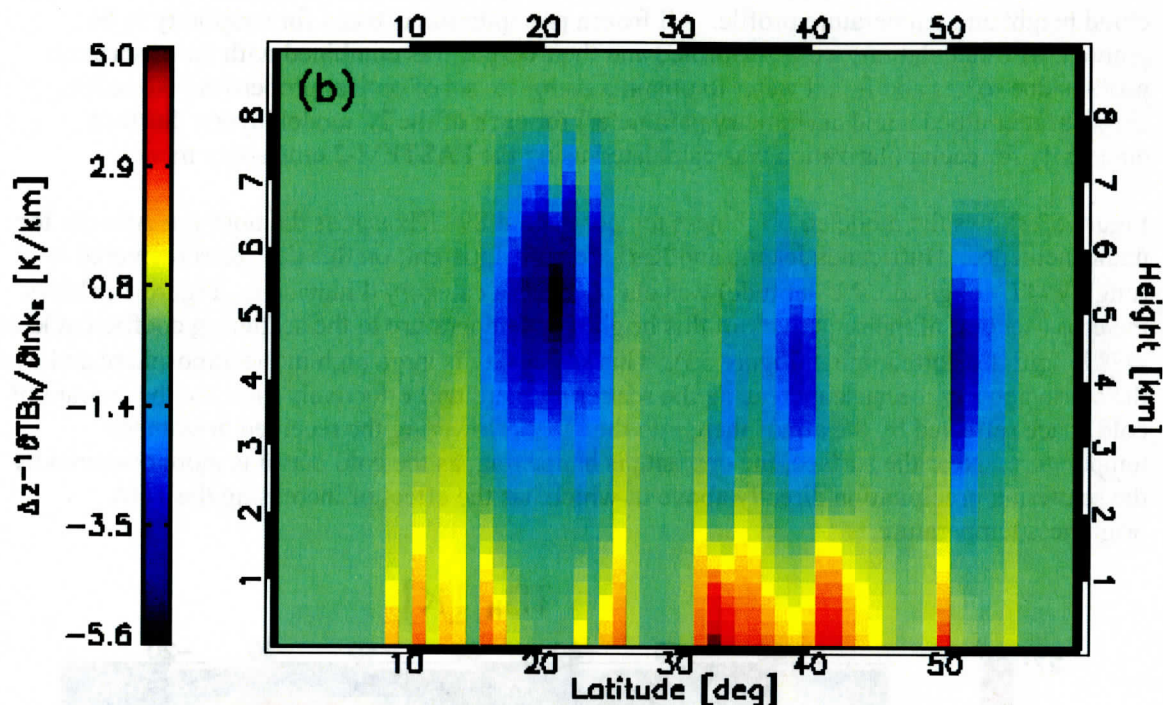


Figure 54: Cross-section of the adjoint sensitivity of this brightness temperature to the scattering coefficient k_s at -47° longitude (dotted line in Figure 53).

Publications and Conference Reports

Bennartz, R., T. Greenwald, C. O'Dell, and A. Heidinger, 2004: Fast passive microwave radiative transfer in precipitating clouds: Towards direct radiance assimilation. In Proceedings of the XIII-International TOVS Study Conference, Ste. Adele, Canada, 29th Oct – 4th Nov 2003.

Greenwald, T. J., 2004: Toward improving cloud forecasts by direct radiance assimilation of satellite data. 1st Symp. Earth System Scholars Netwk., 27-29 September, Adelphi, Maryland.

Greenwald, T. J., R. Bennartz, A. Heidinger, and C. O'Dell, 2004: Radiative transfer model development for operational global assimilation of passive microwave radiances in precipitating clouds. 8th Symposium on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface, 11-15 January, Seattle, Washington.

Greenwald, T. J., R. Bennartz, A. Heidinger, and C. O'Dell, 2004: Validation of global simulations of microwave and infrared brightness temperatures using AMSR and AIRS data. 13th Conference on Satellite Meteorology and Oceanography, 19-24 September, Norfolk, Virginia.

Greenwald, T., R. Bennartz, C. O'Dell, and A. Heidinger, 2004: Fast computation of microwave radiances for data assimilation using the successive order of scattering approximation. Accepted to *Journal of Applied Meteorology*.

Heidinger, A., C. O'Dell, T. Greenwald, & R. Bennartz, 2004: The Successive Order of Interaction Radiative Transfer Model, Part I: Theoretical Basis. To be submitted to the *Journal of the Atmospheric Sciences*.

O'Dell, C., R. Bennartz, T. Greenwald, and A. Heidinger, 2004: The Successive Order of Interaction (SOI) Radiative Transfer Model – Documentation. Technical report.

O'Dell, C., A. Heidinger, T. Greenwald, and R. Bennartz, 2004: The Successive Order of Interaction Radiative Transfer Model, Part II: Model Performance and Applications. To be submitted to the *Journal of the Atmospheric Sciences*.

14. NPP ATMS-VIIRS Co-registration

Mapping of VIIRS to ATMS to identify clouds on an ATMS sub-pixel level has been identified as a needed intermediate product for ATMS retrievals to identify cloudy and partly cloudy observations and to quantify the amount of cloud within an ATMS FOV. Within our ongoing NPP-ATMS Risk Reduction activities we are currently developing a prototype co-registration algorithm for VIIRS to ATMS using MODIS and AMSR. The status of this work is described below. Within the next year we plan to fully implement this method, to study its impact on ATMS retrievals, and to develop and test validation methods for the early postlaunch cal/val phases of NPP.

A generic mapping tool is being developed that allows to map VIIRS to ATMS. The main requirements for this mapping tool are that it has to be fast and should be available for both level 1 and level 2 data. We have developed such a tool and are currently testing a collocation tool for AMSR/MODIS on AQUA. The only information needed for this tool is the time coordinate of the microwave and vis/ir nadir track data. All information about the respective scan geometry is provided in lookup tables. This collocation tool is extremely fast and is not affected by navigation uncertainties in both sensors. The mapping accuracy is within 1 to 1.5 km both along-track and along-scan.

15. Marine Biophysical Feedback

In the last half year or so, we have worked mainly in implementing a scheme that incorporates the solar penetration depth into the coupled Fast Ocean Atmosphere Model (FOAM). After a close collaboration with Dr. R. Jacob from Argonne National Lab, we finally are able to separate the short wave component from the coupler and then implement the solar penetration depth for the short wave forcing on the ocean component. It took a while to realize that the model after implementation of the scheme differs only slightly from the original model, because of machine round-off error. Final testing shows that the climatology of the model remains the same. This result provided a base run for our simulations.

As a first test and for future understanding of the mechanism, we performed a 100-year simulation with a uniform solar penetration depth of 17-m over the world ocean. The result shows a substantial impact on global SST (Figure 55). The most dramatic result is a substantial improvement of the equatorial cold tongue/warm pool in both the Pacific and Atlantic. Coupled models so far all suffer from a common serious problem in its equatorial climate, the cold tongue penetrates westward too far, substantially suppressing the warm pool. As a result, the warm pool in our model is about 2°C colder than in the observation. The inclusion of solar penetration improves precisely the warm pool the most, offering a promise for the improvement of a coupled climate model. To our knowledge, this result has not been reported in a fully coupled model so far. In addition, the equatorial annual cycle is also improved substantially, as reported by

Schneider and Zhu. Finally, there is a substantial change of the SST in the extratropics, cooling in the subtropical gyre and warming in the subpolar gyre, a result that has not been reported so far.

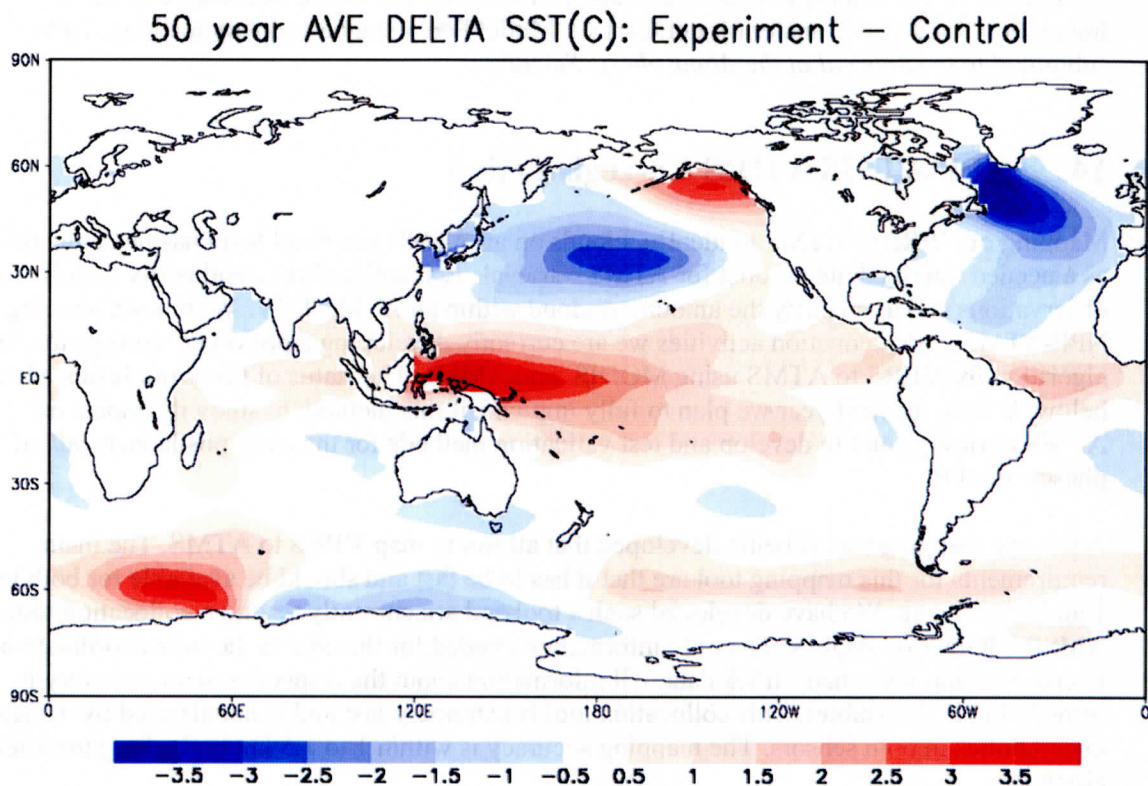


Figure 55: SST difference between the simulation with a uniform 17-m solar penetration depth and the simulation without solar penetration.

To understand the mechanism of the SST change, we further added two members to form a three member ensemble experiment. The study of the ensemble experiment suggests that the SST change is robust. Physically, the loss of solar penetration to the subsurface induces a cooling on the surface and a warming in the subsurface, initially. In several months, the SST, however, is overwhelmed by the upwelling of subsurface warming anomaly in the regions of the equator and subpolar gyre. In the subtropics, however, the downward subduction does not affect the SST change, leaving it as cold as in its initial development. According to this mechanism, we speculate that a further deepening of the solar penetration depth should induce a similar SST change. This speculation is confirmed by an additional simulation with a double solar penetration depth ($2 \times 17\text{m} = 34\text{-m}$), which produces a SST change from the 17-m penetration depth run almost the same as the difference between the 17-m run and the base run.

To further understand the effect of solar penetration depth on climate variability such as ENSO (El Nino – Southern Oscillation) and PDO (Pacific Decadal Oscillation), we are extending the each of the three members of the ensemble to 400-years. This should give us sufficient statistics to examine the change of ENSO and PDO.

For future studies, after consulting with Dr. Raghu Murtugudde at CICS, Univ of MD, College Park, we have obtained the observed global distribution of the solar penetration depth. We are in

the process of implementing these observed solar penetration depths into FOAM. We prepare to perform two long simulations, one with the annual mean depth and the other with the annual cycle of the penetration depth. We are also planning to test the sensitivity of the solar penetration depth to the vertical resolution of the ocean model. We plan to study the mechanism of the solar penetration induced changes in both the mean climatology and the variability. The fast FOAM model has proven to be advantageous because it enables us to perform multiple long simulations, which are critical for a better understanding of the mechanism.

16. Creating a 20 Year Polar Region Wind Data Set

An accurate depiction of the wind field in numerical climate prediction models is essential for studying surface-atmosphere interactions, feedback mechanisms, and climate change. For example, a recent study of Arctic climate trends over the last 20 years showed that changes in cloud and surface properties are a function of large-scale circulation rather than local processes. Unfortunately, it appears that two of the most useful tools for studying recent climate change, the NCEP/NCAR and European Center for Medium-range Weather Forecasts (ECMWF) Reanalysis products, have large errors in the wind field for areas with little or no wind observations like the polar regions. These errors are not surprising given that a major gap in the global observing system exists because no routine measurements of tropospheric winds are made over the Arctic Ocean and most of the Antarctic continent. While geostationary satellites provide useful wind information at lower latitudes, they are of little use in the polar regions due to poor spatial resolution. Considerable interest in a polar winds product has been expressed by the numerical weather prediction community (e.g., NCEP, ECMWF, NASA Global Modeling and Assimilation Office, UK Met Office, Canadian Meteorological Centre, Japan Meteorological Agency).

The objective of this project is to generate a 20-year tropospheric wind data set covering both polar regions, poleward of approximately 65 degrees latitude, using the historical Advanced Very High Resolution (AVHRR) Global Area Coverage (GAC) data from NOAA satellites. We anticipate that the dataset will be used by the National Centers for Environmental Prediction (NCEP) and the National Center for Atmospheric Research (NCAR) in future versions of their Reanalysis product. We currently generate winds in real-time using the AVHRR and MODIS sensors, so the winds data set proposed here will extend the record back 20 years, providing an invaluable product for the verification of, and assimilation in, climate prediction models. This project falls under the NOAA Mission Goal of understanding climate variability and change to enhance society's ability to plan and respond.

The project Principal Investigator at CIMSS is Christopher Velden. A new graduate student brought into the program in September, Richard Dworak, is performing the data acquisition and analysis; this project will be the focus of his Masters thesis work. Dave Santek will assist as necessary. Jeff Key, NOAA/NESDIS, works on the project in collaboration with CIMSS scientists, and is the NESDIS point of contact for the project.

Over the past six months we have continued to collect AVHRR GAC data in conjunction with the Office of Research and Applications (ORA) AVHRR reprocessing effort. Data are being acquired from NOAA's Satellite Active Archive (SAA). We have just completed the acquisition of European Centre for Medium-Range Weather Forecasts (ECMWF) ERA-40 Reanalysis data. The dataset contains temperature, humidity, and wind profiles that are needed for wind retrievals. A computer and raid disk system, purchased last year, will be dedicated to the project.

The MODIS polar winds procedure has been adapted for use with AVHRR data to generate an experimental, operational product at the CIMSS. Global Area Coverage (GAC) 4 km data is currently obtained via NOAAPORT and processed in a near real-time mode. Daily composites of all winds obtained over a 24-hour period for both polar regions are generated and made available to the public on the Web at <http://stratus.ssec.wisc.edu/products/rtpolarwinds>. A complementary near real-time product of surface and cloud properties from the AVHRR is also available. See <http://stratus.ssec.wisc.edu/products/rtcaspr> for details. The entire procedure is automated. Figure 56 gives an example of AVHRR GAC winds over the Arctic and Antarctic on a single day, where winds from all overlapping orbital triplets are plotted on the daily composite image. Of course, the actual time for all wind vectors is retained in the data set.

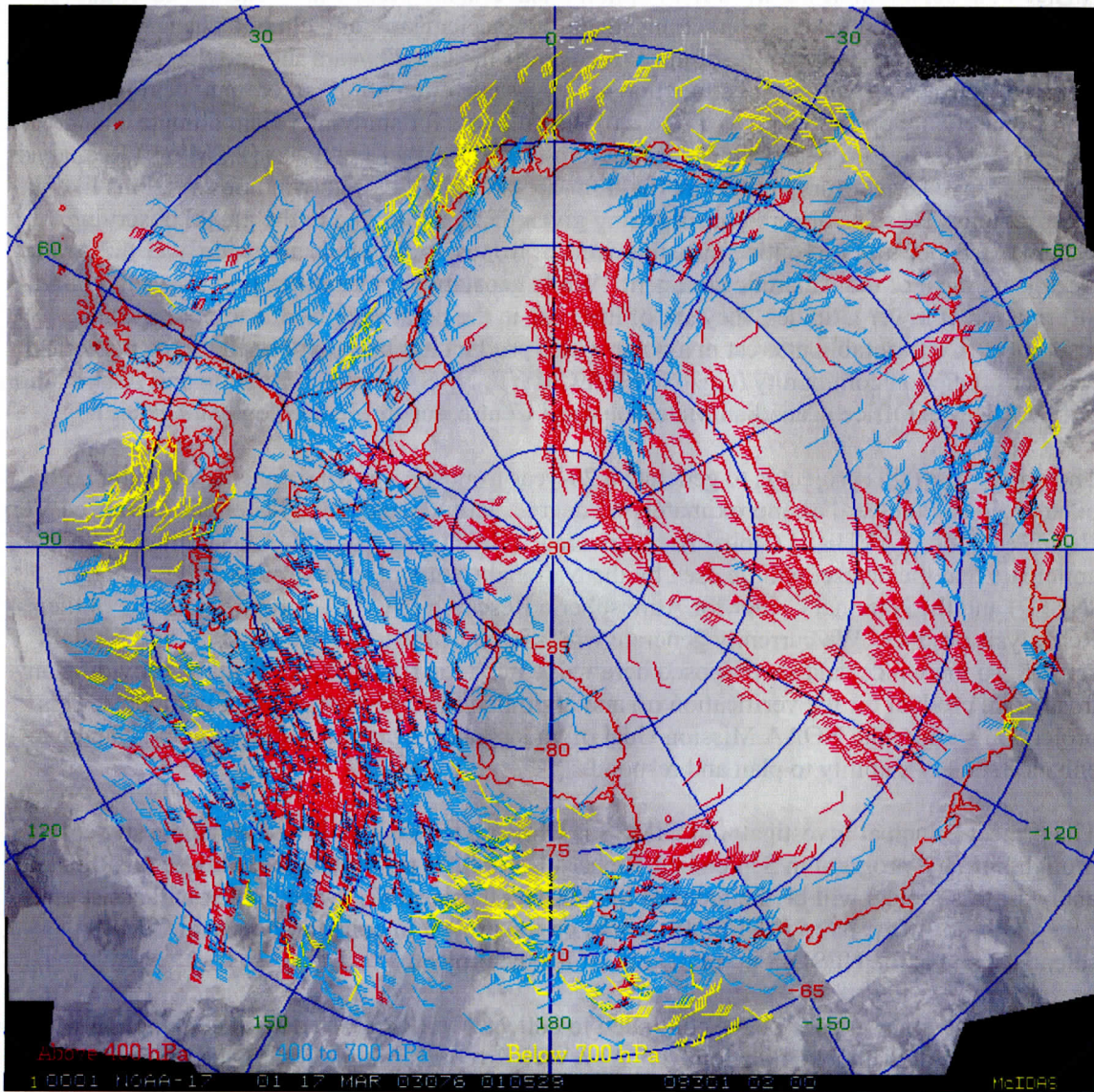


Figure 56: Daily composite of wind vectors derived from NOAA-17 AVHRR GAC data on 17 March 2003 over Antarctica. The South Pole is at the center of the image. The background is the AVHRR 11 micron brightness temperature image. Wind vectors are grouped into three height categories (for illustration only): below 700 hPa (yellow), from 400 to 700 hPa (cyan), and above 400 hPa (magenta). This plot shows vectors from multiple orbits on one day; the data product retains the time of each vector.

17. Retrospective Analysis of Arctic Clouds and Radiation

The objective of this project is to understand Arctic climate change using satellite data. The research not only examines overall changes in the Arctic during the past 20 years, but also explores feedback mechanisms, regional variability in climate change, and the relationship between Arctic change and the global climate system. Our focus is on clouds and radiation but attention is also given to surface properties, especially pertaining to recent trends in Arctic snow cover and sea ice that can induce a temperature-cloud-albedo feedback.

Satellite retrieval techniques for use with the AVHRR Polar Pathfinder (APP) dataset have been refined and validated with data from SHEBA and from Barrow, Alaska. Surface, cloud, and radiation characteristics for 19 years of APP data have been estimated, and a data product has been made available to the public. An analysis of trends shows that the Arctic has been cooling at the surface during the winter, but warming at other times of the year. The surface albedo has decreased, particularly during the autumn months. Cloud amount has been decreasing during the winter but increasing in spring and summer. During summer, fall, and winter cloud forcing has tended toward increased cooling. This implies that if seasonal cloud amounts were not changing, surface warming would be even greater than that observed. An example of trends is given in Figure 57.

Our plans for the future are to focus on data analysis, including spatial and temporal variability, trends, and relationships to the AO and North Atlantic Oscillation (NAO). Climate indices will be explored.

Publications and Conference Reports

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Wang, X. and J. Key, 2004: Arctic surface, cloud, and radiation properties based on the AVHRR Polar Pathfinder data set. Part II: Recent trends. Accepted by *J. Climate* (July 2004).

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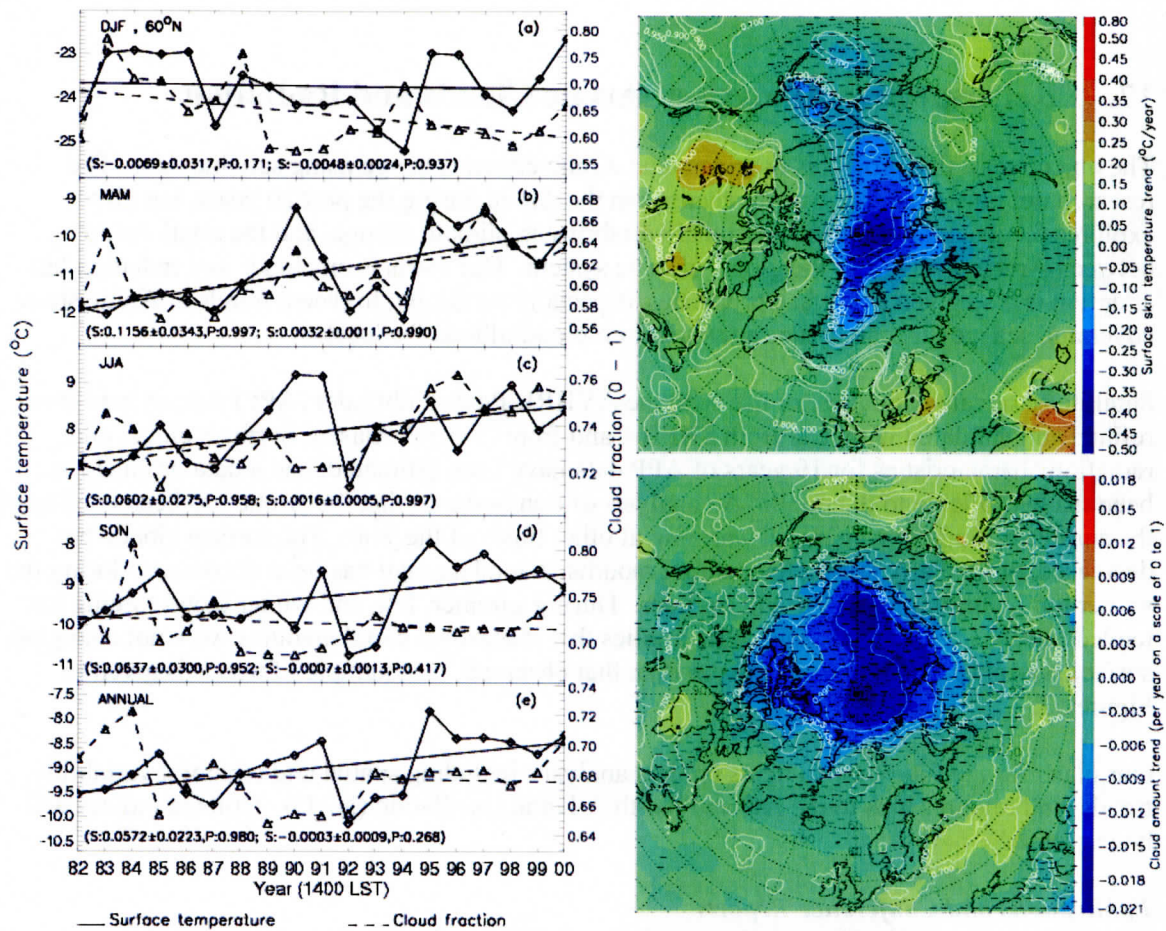


Figure 57: **Left:** Time series and trends in cloud fraction and surface skin temperature in winter (DJF), spring (MAM), summer (JJA) and autumn (SON) over the area north of 60°N. The numbers in parentheses are the slope of the trend with its uncertainty and F test confidence level, where S stands for slope per year and P for confidence level for that slope. The first group of S and P denotes the surface temperature trend (solid line); the second group denotes the cloud fraction (dashed line). **Right:** The spatial distribution of the trends in surface temperature (*upper*) and cloud fraction (*lower*) over the period of 1982 – 2000 in winter. The contours are the confidence levels; colors denote the trend magnitude, and areas with dash marks indicate decreasing trends.

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