

GOES-R Risk Reduction Program

**Progress Report for January – December 2006
including the period October – December 2006**

from the

University of Wisconsin-Madison

Cooperative Institute for Meteorological Satellite Studies

Project Title: CIMSS Participation in GOES-R Risk Reduction
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Remaining Funds: \$0 (through December 2006)

1 GOES R Risk Reduction

1.1 Algorithm Development – Allen Huang and Chris Velden, Team Leaders

1.1.1 GOES-R Risk Reduction Algorithm Development (ABI fire detection) – Elaine Prins and Christopher Schmidt

Proposed Work

The UW-Madison CIMSS biomass burning team proposed the following tasks for 2006. Research and development activities in 2006 will center primarily on active fire product development and validation. Development will focus on active fire detection and sub-pixel characteristics for emission estimates, including the investigation of fire radiative power. This effort will involve the use of multiple data sources (geo and leo) that take advantage of the strengths of each system to create improved fused fire products. This risk reduction activity will ensure enhanced future fire detection, monitoring and characterization. Initially CIMSS will investigate GOES ABI fire monitoring capabilities by simulating ABI with MODIS, MSG (METEOSAT Second Generation), and MTSAT-1R (Multi-functional Transport SATellite) multispectral data.

Summary of Accomplishments and Findings

UW-Madison GOES-R Risk Reduction biomass burning algorithm development efforts began in April 2006 and focused on simulation of GOES-12 Imager and GOES-R ABI data from higher spatial resolution MODIS data to better understand the differences between current and future geostationary fire detection and characterization capabilities. MODIS observations of the large destructive fires in Southern California in October 2003 were used to simulate GOES-12 Imager and GOES-R ABI 3.9 and 11 μm data and fire characterization capabilities. In order to more accurately simulate Imager and ABI data, appropriate point spread functions were applied in the simulation process. Figure 1.1.1 shows the spatial response and sampling differences between GOES-R ABI and GOES-I/M Imagers. The figure shows the spatial response of each instrument with each grid point representing 1km² at the sub-satellite point. The scanning pattern represents an approximation of the size and sampling for both sensors overlaid on the MODIS 3.9 μm image

of the Verdale fire. GOES-R is expected to have minimal oversampling compared to the current GOES, which oversamples by a factor of 1.75 in the East/West direction. The red boxes on the point spread function plots represent the nominal 4 km and 2 km fields of view for GOES-12 and GOES-R respectively.

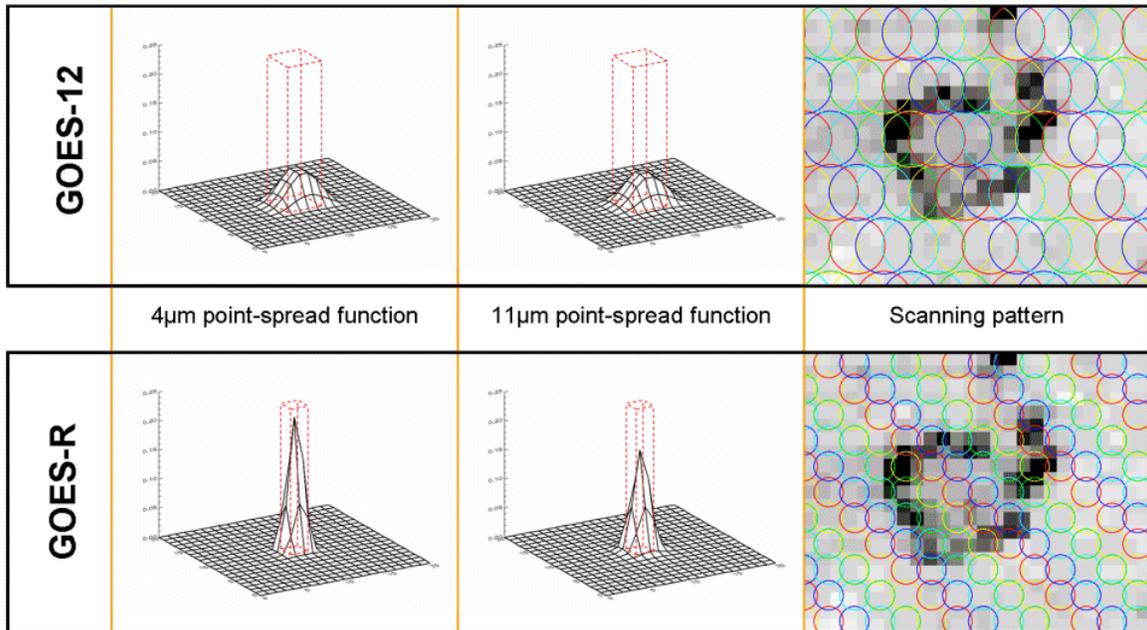


Figure 1.1.1: GOES-R ABI and GOES-I/M spatial response and sampling differences.

A modified version of the GOES Wildfire Automated Biomass Burning Algorithm (WF_ABBA) was applied to the simulated GOES-12 Imager and GOES-R ABI data to determine Dozier estimates of instantaneous sub-pixel fire size and temperature. GOES-12 and GOES-R were assumed to be located directly over the fires to limit issues introduced by remapping data. Fire Radiative Power (FRP) was derived from the Dozier output. Saturation in the 3.9 μm band on GOES-12 inhibited determination of FRP for 20% of the fire pixels. Only 4% of the ABI fire pixels were saturated. ABI was also able to characterize more of the variability in fire intensity due to the increased spatial resolution. The mean fire pixel FRP was 46 Wm⁻² for GOES-R ABI and 24 Wm⁻² for GOES-12. This is primarily due to the fact that several of the hotter fires were included in the average for GOES-R ABI, but were not included in the GOES-12 Imager calculation due to saturation. This difference shows the substantial improvement in fire characterization with GOES-R ABI allowing for more realistic estimates of emissions.

Initial efforts to simulate GOES-R ABI data from higher spatial resolution MODIS consisted of applying simple averaging or point spread functions to higher resolution MODIS data in the native MODIS projection. In order to create more realistic GOES-R ABI data sets that can be used to develop improved fire detection and sub-pixel characterization, it is necessary to take into consideration point spread function and oversampling issues, variations in pixel size with view angle, diffraction, band-to-band co-registration, and other factors. These are issues which strongly impact fire detection and sub-pixel characterization. UW-Madison is investigating ways to simulate more realistic ABI data utilizing MODIS, Met-8 SEVIRI and GOES data. For a given region of interest the MODIS and coincident GOES/Met-8 data can serve as bookends over a period of time with GOES and Met-8 providing the diurnal signature. At the bookends, the MODIS data can be made to look more like the SEVIRI/GOES data at a higher ABI resolution

and then nudged over time (between the bookends) with guidance from the GOES/MET-8 data. Since fires can often appear as an on/off type feature, the diurnal GOES/Met-8 data can be used to introduce variation in fire location and intensity over time. It would also be possible to use an educated random fire generator for certain biomes.

CIMSS is modifying existing McIDAS code to create enhanced more realistic simulated data sets for all ABI IR channels that have similar MODIS channels. Although the band widths for ABI and MODIS can be quite different, this type of simulation would provide “real world” proxy data that can be used in conjunction with model simulated data, with applications in various product development activities. The McIDAS remapping software is being modified to take into consideration factors such as point spread function and oversampling, view angle dependencies, diffraction, etc. CIMSS is focusing on simulating GOES ABI from MODIS data collected on 24 April 2004 in Central America and on 27 October 2003 in Southern California. These case studies include excellent examples of diurnal variability in fire activity in both clear and cloudy situations. Figure 1.1.2 shows an initial example of generating simulated GOES-R ABI 3.9 micron data in a geostationary projection from MODIS data collected at 2055 UTC on 27 October 2003 in Southern California.

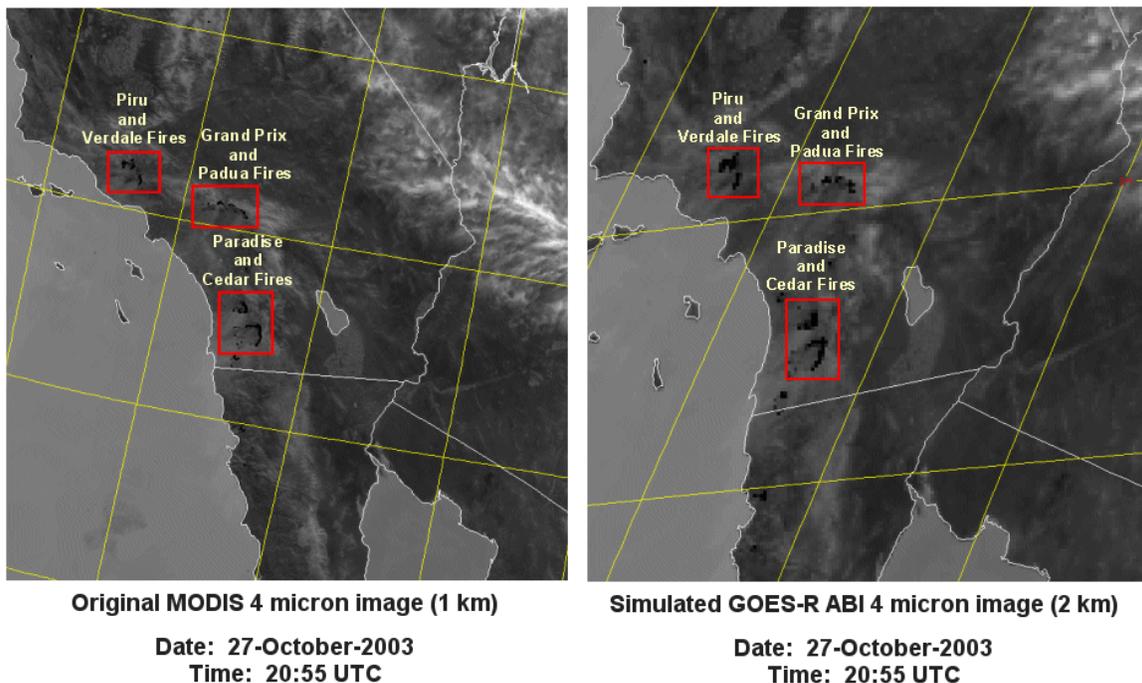


Figure 1.1.2: Original MODIS and GOES-R ABI simulated 4 micron image for 2055 UTC on 27 October 2003.

In order to characterize sub-pixel fires, accurate estimates of surface emissivity are needed for the short (4 micron) and long-wave (11 micron) infrared window bands. Currently the WF_ABBA emissivities are assigned based on the AVHRR GLCC version 2 dataset available from the USGS using a table that relates emissivities to land cover types in the GLCC dataset. CIMSS is investigating application of the dynamic SeeBor dataset which contains monthly estimates of spectral band emissivities derived from MODIS data. Figure 1.1.3 shows a comparison of the current WF_ABBA 4 micron static emissivity map and the SeeBor 4 micron emissivity map for July 2005. The red highlighted regions in the current emissivity map represent fire detection

block out zones primarily associated with urban areas. There are noticeable differences between these two emissivity data sets especially along biome transition zones. Additional analyses will be done to determine the impact on fire characterization utilizing the SeeBor dynamic emissivity maps.

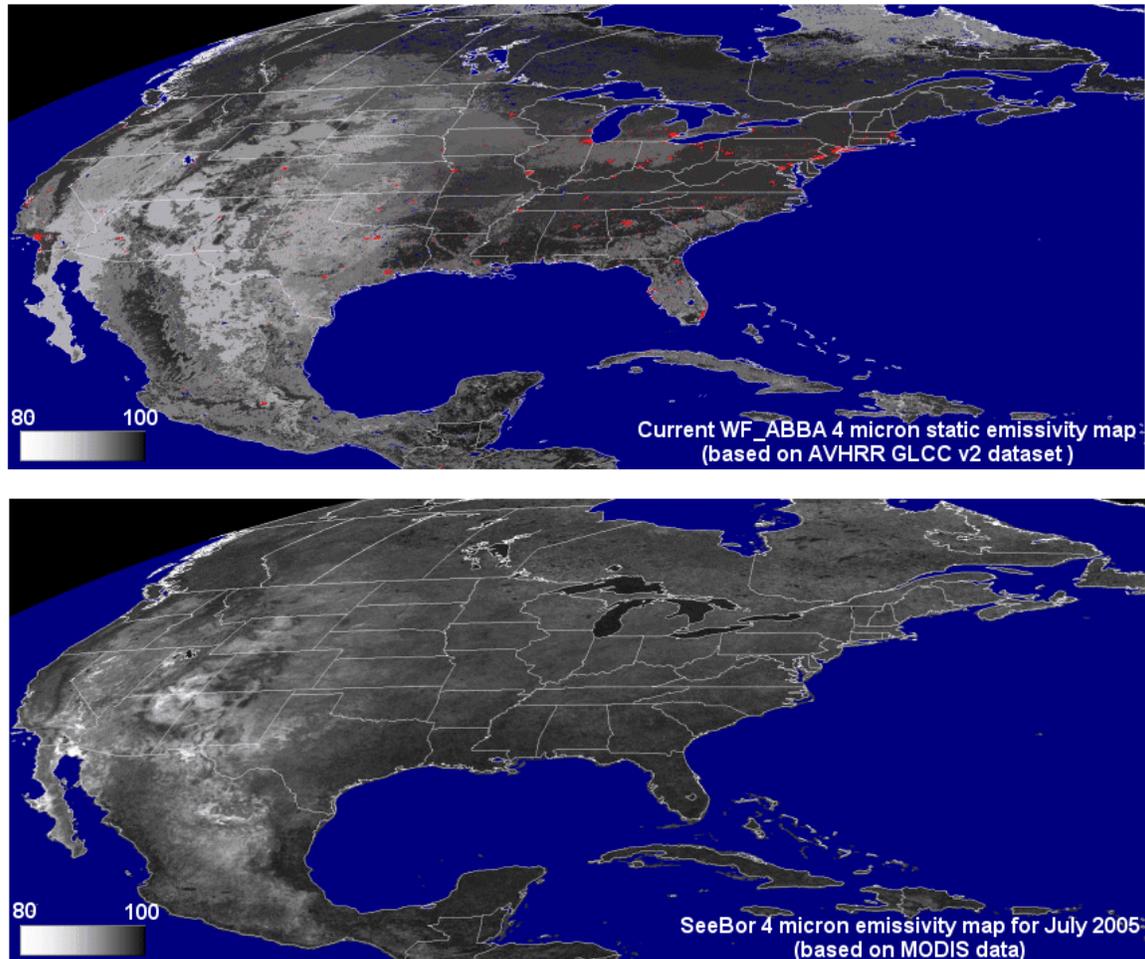


Figure 1.1.3: Comparison of the current static WF_ABBA 4 micron emissivity data set and the SeeBor 4 micron data set for July 2005.

NOAA/NESDIS has indicated that 2 km MTSAT-1R JAMI data will be made available for specific case studies. Obtaining access to this data set provides a wonderful opportunity to investigate the lower thresholds for GOES-R fire detection and monitoring capabilities from a large detector array with a spatial resolution similar to ABI. UW-Madison CIMSS provided input to NOAA/NESDIS regarding priorities for MTSAT-1R 2 km data coverage of fire activity.

Publications and Conference Reports

Peer-Reviewed Publications

Prins, E., C. Velden, J. Hawkins, F. J. Turk, J. Daniels, G. Dittberner, K. Holmlund, R. Hood, A. Laing, S. Nasiri, J. Puschell, J. M. Shepherd, J. Zapotocny, 2006: 13th AMS Conference on Satellite Meteorology and Oceanography, Meeting Summary on Next Generation Environmental

Sensors and Emerging Applications in Satellite Meteorology and Oceanography, *BAMS*, 87, 5, 633 – 637.

Conference Papers/Posters

Schmidt, C. C. and E. M. Prins, 2006: Comparison of Current and Future GOES Fire Characterization, Fourth GOES-R Users Conference, May 1-3, 2006, Broomfield, CO.

1.1.2 GOES-R Risk Reduction Algorithm Development Tropical Cyclone Project – J. P. Kossin and C. S. Velden

Proposed Work

We proposed to perform an important subset of the testing and validation portions of retrieval development by examining retrieval algorithm performance and impacts in the unique and challenging environments around tropical cyclones (TCs). Another goal of the proposed work was to demonstrate the potential of high-temporal-resolution ABI imagery to delineate structure changes in the TC upper-levels and form upper-level fields of parameters related to intensity change (e.g., divergence, potential vorticity, and inertial stability).

Summary of Accomplishments and Findings

Comparison of in situ data with retrieved products in clear regions of the tropical cyclone (TC) environment

Two hurricane cases (Fran and Ivan 2004) were selected for the in situ measurement and retrieval data comparison. The selection was based on the large number of available high altitude aircraft dropsondes that were available for these storms, and their good spatial and temporal overlap with available data from the AQUA Atmospheric Infrared Sounder (AIRS) instrument. The dropsondes were released from Gulfstream-IV aircraft tasked specifically for hurricane reconnaissance, and many were released into relatively clear regions that typically surround the cirrus canopy above the storms. The dropsonde data were gathered from archives at the NOAA Hurricane Research Division, with assistance from Dr. Michael Black (NOAA/AOML).

AIRS L1B radiances were used to retrieve the vertical temperature profiles through IMAPP (International MODIS/AIRS Processing Package) AIRS level 2 retrieval software (version 1.2). Since the AIRS retrieval algorithm is presently only applicable to clear sky conditions, AIRS pixels with clear sky condition were selected for this phase of the study. MODIS has its own cloud mask algorithm and MODIS products have 1 km × 1 km cloud mask information on MYD06 datasets. AIRS has 90 × 135 pixels on one granule and each pixel has a diameter around 13 km at nadir. AIRS do not produce cloud mask information. One AIRS pixel has several hundred MODIS 1 km × 1 km pixels. Since the MODIS and AIRS instruments are both available on a common platform (EOS-AQUA), and they observe the earth simultaneously, MODIS cloud mask information can be used to determine the AIRS pixel cloud mask.

The MODIS cloud mask includes four categories – “confidently clear”, “probably clear”, “probably cloudy”, and “confidently cloudy” – and each MODIS pixel has its own cloud mask as mentioned above. To identify clear regions, we summed the numbers of “confidently clear” and “probably clear” collocated MODIS pixels. If this sum was over 65% of the total number of collocated MODIS pixels, the AIRS pixel was assumed to be clear. A total of eighteen clear pixels were selected with these criteria.

ECMWF reanalysis data were also collected to compare the vertical temperature profiles with the in situ measurements using dropsonde during hurricane period and the contemporaneous AIRS

retrieved soundings. The ECMWF data ($0.5^\circ \times 0.5^\circ$) were interpolated to the resolution of the AIRS pixels (13 km at nadir) around the TC environment.

The differences between the in situ temperature and moisture measurements and ECMWF analysis or AIRS retrievals were calculated as a simple arithmetic difference (ECMWF or AIRS minus dropsonde). These differences are shown in Figure 1.1.4, along with the RMS error of the AIRS and ECMWF soundings, and give an indication of the performance characteristics of the AIRS retrievals in the hurricane environment.

This work was performed by members of the CIMSS retrieval team (Yong-Keun Lee and Elisabeth Weisz). The data we collected will be combined with data being constructed at CIRA/CSU, who are applying the data to a different problem.

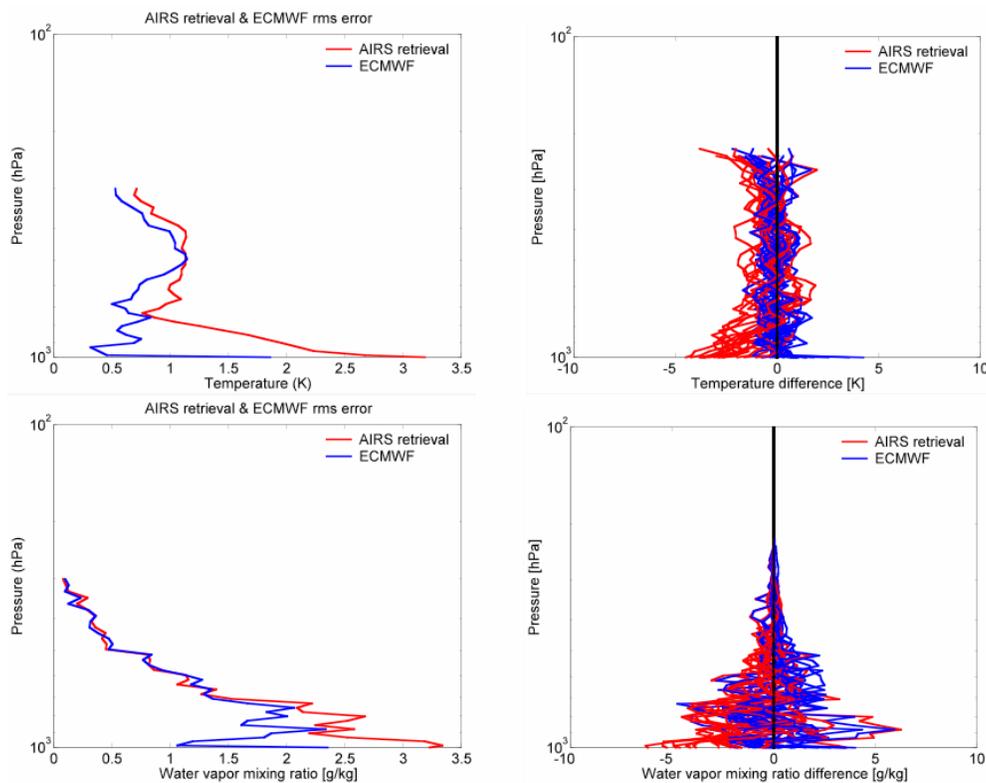


Figure 1.1.4: Sounding error. Left panels: RMS error of temperature (top) and moisture (bottom). Red (blue) shows error in AIRS retrievals (ECMWF profiles). Right panels: Differences (error) of the soundings defined as ECMWF or AIRS minus dropsonde.

Atmospheric Motion Vectors with GOES-R spatial and temporal resolution

A second objective of our GOES-R risk reduction work has been to demonstrate what will be achievable with the availability of the ABI. One way to do this was to employ currently existing GOES observing strategies that mimic what will be possible with ABI. Specifically, in regards to tropical cyclones, the upper-level outflow is thought to be important toward understanding intensity change. Atmospheric motion vectors (AMVs), derived from special GOES five-minute rapid-scan (r/s) imaging operations, can be effective at simulating what will be available on a routine basis once GOES-R is launched.

As a demonstration of this capability, GOES-11 AMVs were derived from 5-min. r/s imagery during a special observing period as NASA's Tropical Cloud Systems and Processes (TCSP) experiment was taking place in July of 2005. Hurricane Emily traversed the sampling domain and provides a good case study, as the intensity fluctuated during the period of observation. Upper-level divergence is one parameter often associated with intensity change. Divergence from a particular analysis, calculated on spherical coordinates, is shown in Figure 1.1.5. The wind observations (in ms^{-1}) are also plotted. The divergence was only calculated for points that have at least two observations within 0.25 degrees of the analysis point in order to avoid spurious divergence features created by the analysis scheme. The analysis in Figure 1.1.5 captures some of the upper-level divergence over the hurricane (100 kts max wind at the analysis time). This divergence precedes Emily strengthening to 130 kts over the subsequent twenty-four hours.

We are in the process of creating time series of upper-level quantities derived from the GOES r/s AMVs over Emily. From these we hope to denote trends and potentially associations with the hurricane's structure and intensity fluctuations. High-resolution data such as this will be routinely possible from the GOES-R ABI, and our intent is to see what we can observe and learn from current GOES capabilities (special observing modes) in advance of this deployment.

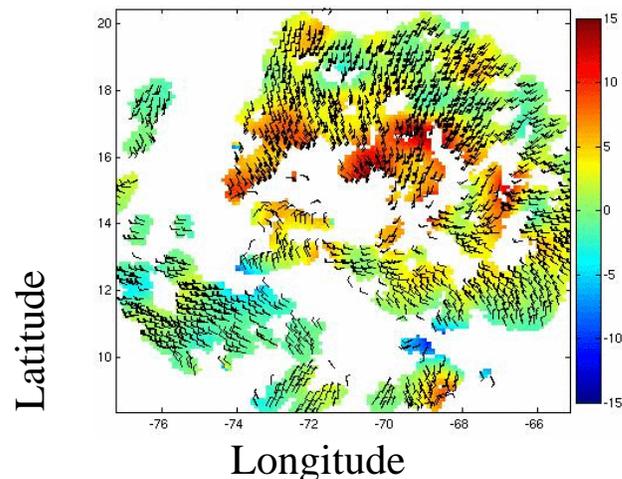


Figure 1.1.5: Divergence (10^5 s^{-1}) analysis centered on hurricane Emily valid 16z on 15 July, 2005.

1.1.3 GOES-R Risk Reduction Algorithm Development Sounding Algorithm Development - Jun Li

Proposed Work

- Evaluate AIRS clear, cloud-cleared and cloudy retrieval sounding algorithms
- Develop IASI clear sounding retrieval algorithm
- Conduct synergistic IASI/VHRR sounding retrieval and evaluate its performance

Summary of Accomplishments and Findings

Handling surface emissivity in sounding retrieval

Emissivity knowledge is very important in ABI (Advanced Baseline Imager) sounding retrieval. Due to the limited spectral information, it is unlikely to derive the surface emissivities together with sounding from ABI infrared measurements. It is necessary to have emissivity prior information for ABI sounding products. Usually there are two ways for emissivity prior

information: using ecosystem classified global emissivity database, or using emissivity spectrum derived from hyperspectral infrared sounder from polar orbiting satellites. Since the hyperspectral IR derived emissivity spectrum is spectrally close to the ABI measurements, it can be used in ABI sounding retrieval.

Progress has been made on the retrieval of emissivity spectrum from hyperspectral IR radiance measurements. AIRS (Atmospheric Infrared Sounder) radiances are used for this study. The eigenvectors of hyperspectral IR emissivity are derived from a lab measured hyperspectral IR emissivity spectrum. In the retrieval process, the emissivity spectrum is expressed as a linear combination of the first 6 eigenvector, and the 6 eigenvector coefficients are retrieved simultaneously with temperature and moisture soundings. The retrieved hyperspectral emissivity spectra then can be spatially, temporally, and spectrally interpolated for ABI sounding retrieval. Simulated AIRS radiances show the simultaneous retrieval of emissivity spectrum and sounding in a physical way is promising, it is a new approach in sounding retrieval. Figure 1.1.6 shows the Root means square error (RMSE) of emissivity retrieval (upper panel), temperature profile retrieval (lower left) and water vapor Relative Humidity (RH) profile retrieval (RH in range of 0 ~ 100%). 32 simulated AIRS radiance spectra over desert region are used, realistic desert emissivity spectra are used in the simulation. The algorithm is being tested with AIRS real measurements. Results will be reported in next quarterly report.

Retrieval for Desert (32 profiles)

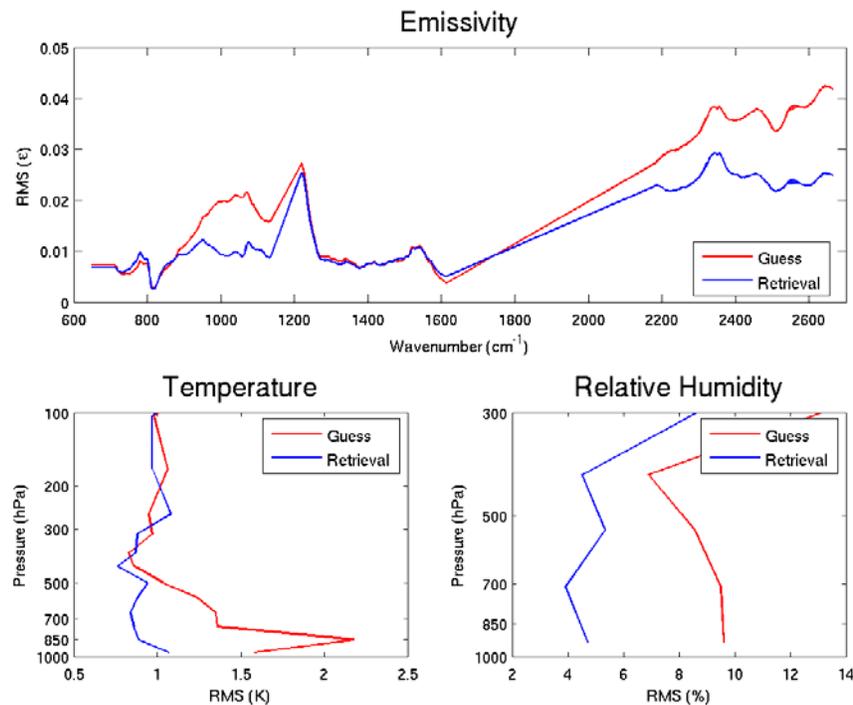


Figure 1.1.6: Root means square error (RMSE) of emissivity retrieval (upper panel), temperature profile retrieval (lower left) and water vapor Relative humidity (RH) profile retrieval (RH in range of 0 ~ 100%). 32 simulated AIRS radiance spectra over desert region are used, realistic desert emissivity spectra are used in the simulation.

Using time continuity in sounding retrieval

Time Continuity (TC) is the unique aspect of GOES observations. Use time continuity in sounding retrieval will assure the optimal process of GOES-R measurements. In order to test the impact time continuity on retrieval, a simple test is performed to the disk GIFTS simulated radiances: (1) using static training data set – time independent set (TIS), and (2) using the known dynamic training data set before the satellite observations – time dependent data (TDD). Figure 1.1.7 shows the water vapor mixing ratio retrieval RMSE from TIS and TDD. Retrievals are improved using TDD that contains the time continuous information. The next step is to use the measurement continuity in retrieval process.

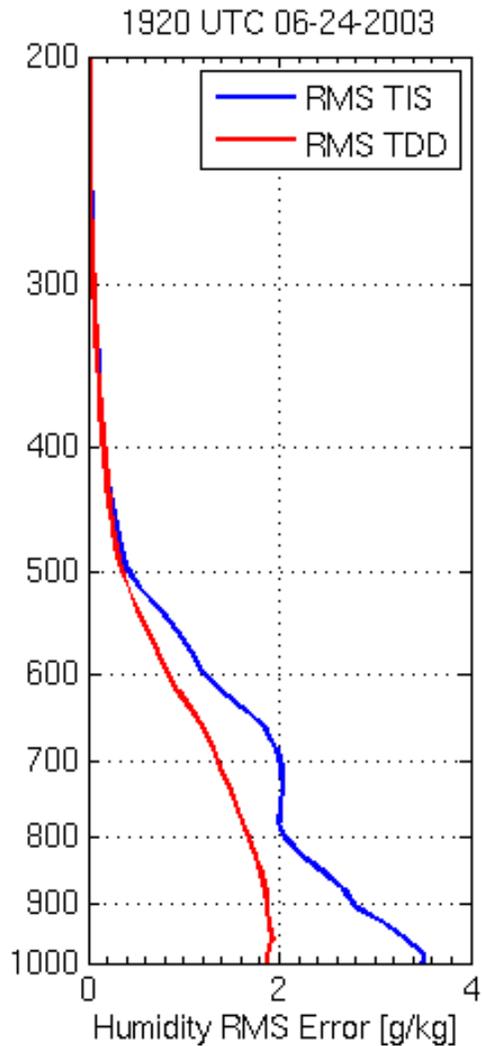


Figure 1.1.7: The water vapor mixing ratio retrieval RMSE (root mean square error) from TIS and TDD, GIFTS simulated disk clear sky radiances are used in the retrieval. Retrievals are improved using TDD that contains the time continuous information.

Cloudy sounding retrieval algorithm tested with AIRS

Simulation with GIFTS radiances shows that the above-cloud sounding approach is effective. We have tested the cloudy sounding algorithm using the AIRS (Atmospheric InfraRed Sounder) radiance measurements. Results are promising when compare the above-cloud sounding retrievals with ECMWF analysis. Specifically, the cloud-top pressure (CTP) retrievals from AIRS single footprint agree very well with the operational MODIS CTP product. Note that MODIS CTP product uses sounding profiles from global forecast, while AIRS above-cloud sounding approach retrieves CTP and above-cloud sounding simultaneously. Figure 1.1.8 shows the AIRS CTPs (13.5 km spatial resolution at nadir) from above-cloud sounding approach (left panel) and the operational MODIS CTP product (5 km spatial resolution at nadir) (right panel).

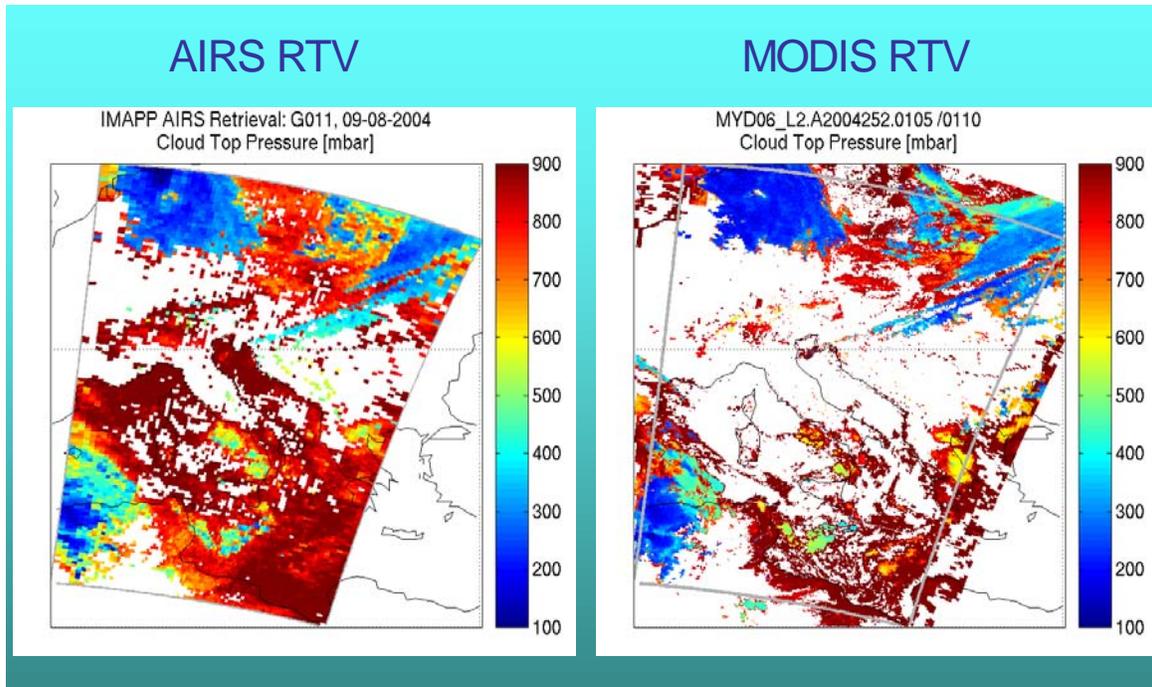


Figure 1.1.8: AIRS CTPs (13.5 km spatial resolution at nadir) from above-cloud sounding approach (left panel) and the operational MODIS CTP product (5 km spatial resolution at nadir) (right panel).

1.1.4 GOES-R Risk Reduction Composite Algorithm Development - Jun Li

Proposed Work

In addition to the simulated trace gases spectral data, IASI data will also be used to explore the composition retrieval for their total and layer concentration profile. The advantages of the temporal resolution of geostationary hyperspectral will also be addressed to demonstrate the optimal processing strategy to extract the desirable information on trace gases.

Summary of Accomplishments and Findings

Total column ozone retrieval algorithm development with ABI/SEVIRI

The algorithm has been developed for Advanced Baseline Imager (ABI), and the algorithm has been tested using the Spinning Enhanced Visible and Infra-Red Imager (SEVIRI) onboard Meteosat-8. Simulation shows that ozone from SEVIRI is worse than that from the current GOES Sounder due to lack of stratospheric CO₂ absorption spectral bands in SEVIRI. However, with help of temperature profile from forecast, the SEVIRI/ABI provides ozone with similar

accuracy of the current GOES Sounder (Jin et al. 2006, submitted to IEEE TGARS) but with much large spatial coverage (disk). Preliminary results show that the total column ozone retrievals from SEVIRI agree well with ozone measurements from Ozone Monitoring Instrument (OMI) onboard the Earth Observing System's Aura platform. Figure 1.1.9 shows the OMI (upper) and SEVIRI (lower) total column ozone measurements in clear skies from 15 to 16, February 2006 over Europe. OMI provides global ozone once every day while SEVIRI provides ozone in disk coverage every 15 minutes. In addition, SEVIRI with 15-minute temporal resolution depicts the ozone transportation and evolution very well.

We also collaborated with Dr. Johannes Schmetz, Head of Meteorological Division and Marianne Koenig at EUMETSAT on our ABI/SEVIRI ozone retrievals. Currently EUMETSAT SEVIRI ozone product has artificial gradients which follow coastlines, especially along desert areas. In CIMSS SEVIRI ozone research product, the surface artifacts are mitigated due to properly handling the surface emissivity in the retrieval. Phil Watts at EUMETSAT will revisit the SEVIRI ozone product produced at EUMETSAT and will send us their results according to Dr. Johannes Schmetz.

The ozone algorithm will be improved with better cloud detection and handling large local zenith angle.

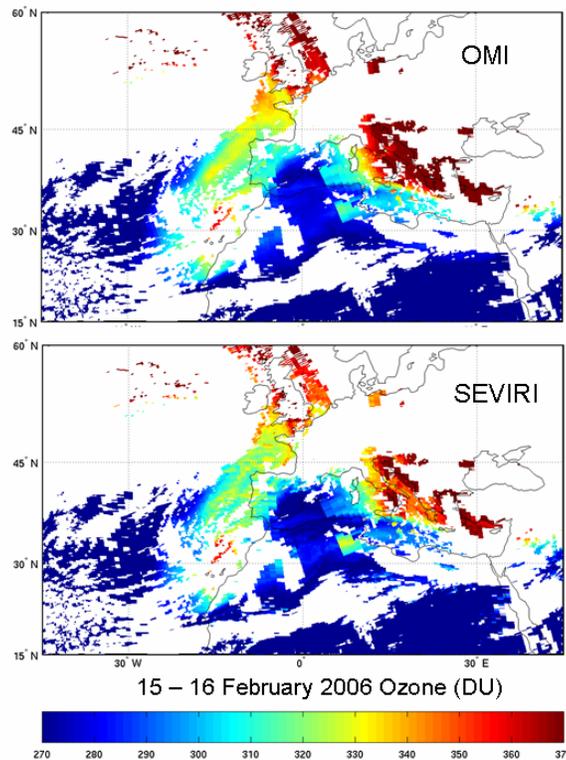


Figure 1.1.9: The scatter plot of OMI (upper) and SEVIRI (lower) total column ozone measurements in clear skies over Europe from 15 to 16 on 15 February 2006. SEVIRI agrees well with OMI.

Improvement on dust detection with ABI/SEVIRI

Dust detection has been improved over ocean. An IR-based dust detection and property retrieval algorithm has been developed for ABI, SEVIRI data are tested (Li et al. 2007, International Journal of Remote Sensing, in press). However, the algorithm has defect over ocean. The dust

diction technique has been improved over ocean by employing separate ocean and land surface emissivities. Results (not shown) agree better now with the composite color image over ocean.

1.1.5 GOES R Risk Reduction Winds – Chris Velden

Proposed Work

The primary goals of the GOES-R Risk Reduction work on wind algorithms are to focus on innovative methods to derive vector fields from the increased spectral capabilities that will be offered by GOES-R. We accomplish this by using both real and simulated satellite data.

Summary of Accomplishments/Findings over the past 12-months include (but are not limited to):

Our initial GOES-R winds focus concentrated on demonstrating the initial concept to target and track features from simulated GOES-R moisture retrievals. Several steps are involved in producing the clear sky profiles of winds. Mesoscale models are used to generate simulated atmospheric profiles with detailed horizontal and vertical resolution. Top of atmosphere (TOA) radiances are determined using these profiles along with the GIFTS forward radiative transfer model. Single field of view vertical temperature and water vapor retrievals are calculated from the TOA radiances. Moisture profiles from the retrievals are analyzed on constant pressure surfaces, and converted to images. Three successive analyses (images) are used to generate targets and clear sky AMV using existing tracking techniques.

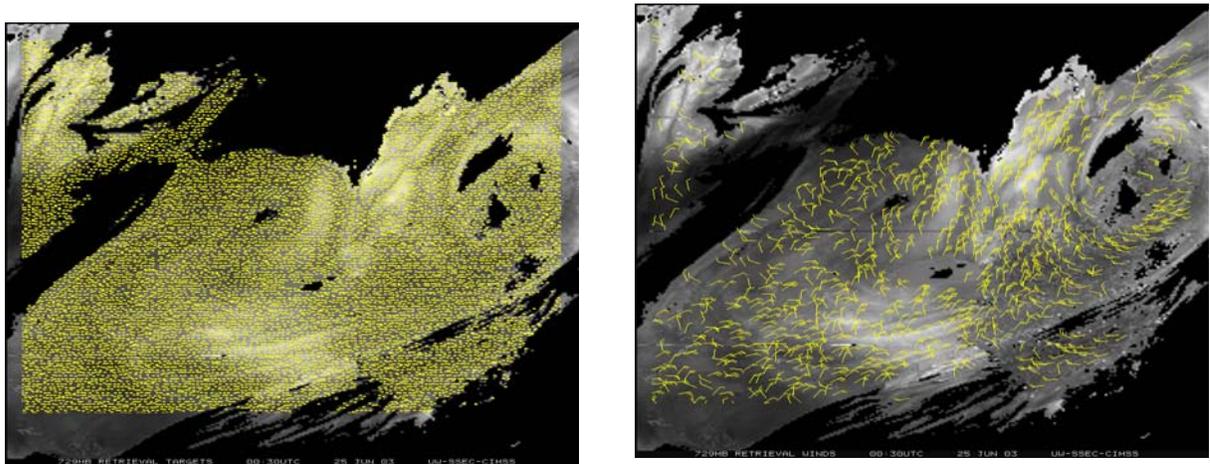


Figure 1.1.10: Plot of targets (left) and traceable wind vectors (right) at 729mb, derived from tracking simulated retrievals of water vapor from 3 successive 30-min. analyses.

As an example, a WRF model simulation was initialized at 0000 UTC, 24 June 2003, and run for 30 hours, with output every 30-minutes. 101 pressure levels were available for each time period (3 successive 30-min fields were employed for attempts at feature tracking) and retrieved moisture fields were derived and converted to images for input to the CIMSS automated tracking software. Winds were calculated at every available pressure level. A representative level is shown in Figure 1.1.10.

Figure 1.1.10 shows a prominently cloud-free environment, allowing good water vapor observations and winds coverage. Note the low level circulation defined by the winds in the

northeast section of the image. Figure 1.1.11 below shows the vertical density of the resultant lower-tropospheric wind field achieved in this simulation.

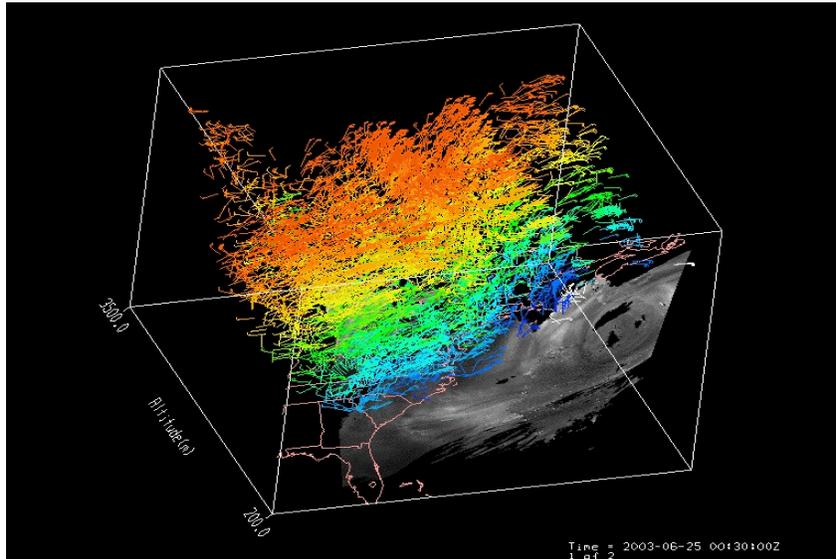


Figure 1.1.11: IDV display of winds from the simulated retrievals illustrating the vertical density. Orange wind barbs are at the top level of 683mb. Blue wind barbs are at the lowest level of 986mb.

In this case, the only quality control routine applied to the wind set was the automated objective Quality Indicator (QI). The final wind field is validated by comparing it to the actual WRF model wind field, and to the winds generated using the WRF model mixing ratios as input to the CIMSS automated tracking routines. A comparison of all collocated vectors is shown in the table below.

100km Vector Match Distance	Winds with QI > 50
Simulated Retrieval Wind Count	13812
WRF Wind Count	851968
Match Count	13812
Speed Bias (m/s)	1.3
Vector RMS (m/s)	6.7

100km Vector Match Distance	Winds with QI > 50
Simulated Retrieval Wind Count	13812
Model Q-tracked Winds Count	32737
Match Count	13741
Speed Bias (m/s)	0.3
Vector RMS (m/s)	8.4

100km Vector Match Distance	Winds with QI > 50
Model Q-tracked Winds Count	32737
WRF Wind Count	851968
Match Count	32737
Speed Bias (m/s)	0.7
Vector RMS (m/s)	4.9

The comparison results show that the retrieval winds are slightly faster than the WRF model winds, but with lower biases. The RMS error values are fairly consistent, and closely represent values from operational winds production. Although this product is in its infancy, and too early to draw conclusions from the statistics on one case study, the results are encouraging.

The next dataset being investigated (FULLDISK) dwarfs the previous case in the number and size of files. WRF simulations run on a full-disk domain simulating the expected GOES-R coverage are broken up into “cubes” to simulate HES sounding blocks. These cubes are written as Unidata network Common Data Form (NetCDF) files. Each NetCDF file contains the moisture field information. New data staging code using Jython stitches the cubes together into a McIDAS AREA file as preparation for the winds retrievals. Jython is an implementation of Python integrated with the Java platform.

The Winds Group is now working on data received from the Retrievals Team for retrieved moisture fields from the FULLDISK case. Staging of the FULLDISK case study in preparation for winds demonstration is now underway. The work on demonstrating multi-level winds from simulated hyperspectral sounder retrieved moisture fields will be wrapped up with the completion of the FULLDISK case. Future efforts will be focused on ABI winds risk reduction.

The trials in this study were limited to simulated hyperspectral data sets. The results indicate that method/algorithm improvements are needed to exploit this new capability. However, the proof of concept has been demonstrated, and the method is next applied to real data using the GOES sounder moisture retrievals as a next step.

Geostationary Operational Environmental Satellite (GOES) East and West sounders provide real-time retrievals of temperature and moisture in cloud-free regions on an hourly basis. The single field-of-view product has spatial resolution of about 10 km. The vertical profiles can be converted to images of temperature or moisture at all or selected pressure levels, which then serve as input image sequences for satellite wind retrieval algorithms. By their nature, the sounder generated moisture fields on constant pressure surfaces will overcome the existing problem of determining heights of the wind vectors. This work is an attempt to deduce winds from real GOES-derived dew point temperature (T_d) images using the CIMSS automated feature-tracking algorithm. In the same manner as the method employing simulated data above, the potential applicability of GOES sounder moisture fields for deriving winds is tested.

In late 2005, NOAA/NESDIS implemented a new integrated GOES Sounder product processing system that derives atmospheric products such as clear sky radiances, temperature and moisture profiles, cloud-top pressure, and surface skin temperature at the full GOES sounder resolution of about 10km². These products not only have better geographical coverage, but also provide improved depiction of gradient information, which allow for constant pressure level moisture analysis fields of significant contrast to be extracted and used as input to our wind retrieval algorithm.

The GOES full resolution sounder product processing system provides hourly Single-Field-Of-View (SFOV) retrievals of the atmospheric state in clear sky regions at nominal spatial resolution of 10 km. The atmospheric profiles of temperature and moisture are derived using a nonlinear physical retrieval algorithm. First, the GOES sounder radiances are navigated and calibrated, and it is determined if a pixel is cloudy or clear. For each cloud-free pixel, a first guess temperature profile is obtained from a space-time interpolation of fields provided by NWS (National Weather Service) forecast models; currently the GFS (Global Forecast System) model is used. Hourly surface observations and sea surface temperature from AVHRR help provide surface boundary

information. Sounder radiances are then used with a forward radiative transfer model to simultaneously retrieve temperature and moisture profiles as well as surface skin temperature. At this time, relative humidity (RH) and dew point temperature (Td) are provided at the same pressure levels as temperature, occupying 31 pressure levels between 1000 and 10mb.

GOES sounder vertical profiles are converted to a set of images representing moisture on constant pressure levels by extracting the variable of interest (i.e., Td) from each profile at the desired available constant pressure level. Hourly images (3) are then used to attempt winds retrieval. Winds are derived for 20 pressure levels between 1000mb and 100mb. An example of GOES sounder winds from 5 December 2003 are shown in Figure 1.1.12. The vertical distribution of the derived wind vectors is fairly even throughout the altitude range of 0-15 km.

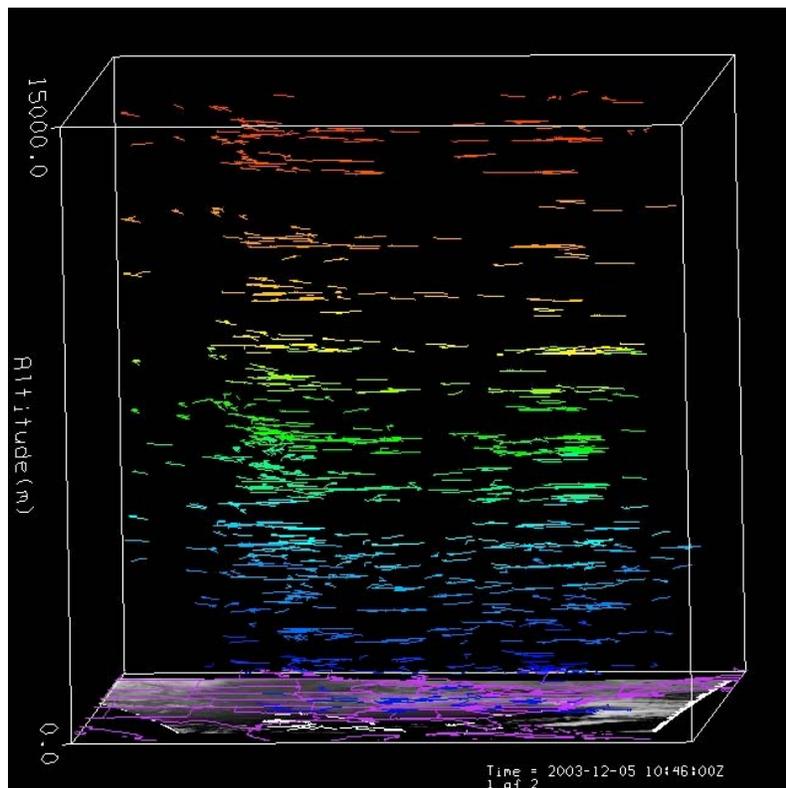


Figure 1.1.12: Vertical distribution of winds from the GOES sounder-derived moisture (Td) constant-pressure fields on 5 December 2003, 12 UTC.

Publications

Velden, C., S. Wanzong, I. Genkova, D. A. Santek, J. Li, E. R. Olson, and J. A. Otkin, 2007: Clear-sky atmospheric motion vectors derived from the GOES sounder and simulated hyperspectral moisture retrievals. AMS Annual meeting, GOES-R Symposium.

Wanzong, S., and C. Velden, 2006: Wind vector calculations using simulated hyperspectral satellite retrievals. 8th International Winds Workshop, Beijing, China.

Genkova, I., and C. Velden, 2006: Satellite wind vectors from GOES sounders moisture fields. 8th International Winds Workshop, Beijing, China.

1.1.6 GOES-R Risk Reduction Algorithm Development - Cloudy sky radiative transfer models – Tom Greenwald

Proposed work

The objective of this work is to develop state-of-the-art radiative transfer forward and adjoint models for rapidly calculating top-of-atmosphere radiances in cloudy conditions and to utilize the latest cloud optical property databases. The proposed work for this year included:

- Verify accuracy of the GIFTS fast model in cloudy conditions
- Compare GIFTS fast model to the SOI (Successive Order of Interaction) RT model in terms of accuracy and speed (referred to as our “bake-off”)
- Release version 1 of the fast forward model
- Build an adjoint for the fast model
- Improve and refine forward models

Summary of accomplishments and findings

- Using over 75,000 WRF simulated cloud profiles, a comparison was made between the GIFTS fast model and the SOI model in terms of their errors due solely to multiple scattering. Results indicated (see Figure 1.1.13) that the SOI model is significantly more accurate for cirrus clouds (optical depth < 3.6) but is about 60% slower than the GIFTS model.
- Version 1 of the GIFTS fast model (written in Fortran 95) was released in February.
- An adjoint version of the clear sky part of the fast model (PLOD) was built and tested.
- Developed a new fast model that allows for multiple cloud layers, called FIRTM-AD (Texas A&M group – see publication below)
- Improvements and enhancements were made to the GIFTS fast model, including incorporating the latest cloud optical property database developed by Dr. Bryan Baum, incorporating the land surface emissivity database, improving integration of the thermal source function, and numerous code modifications.

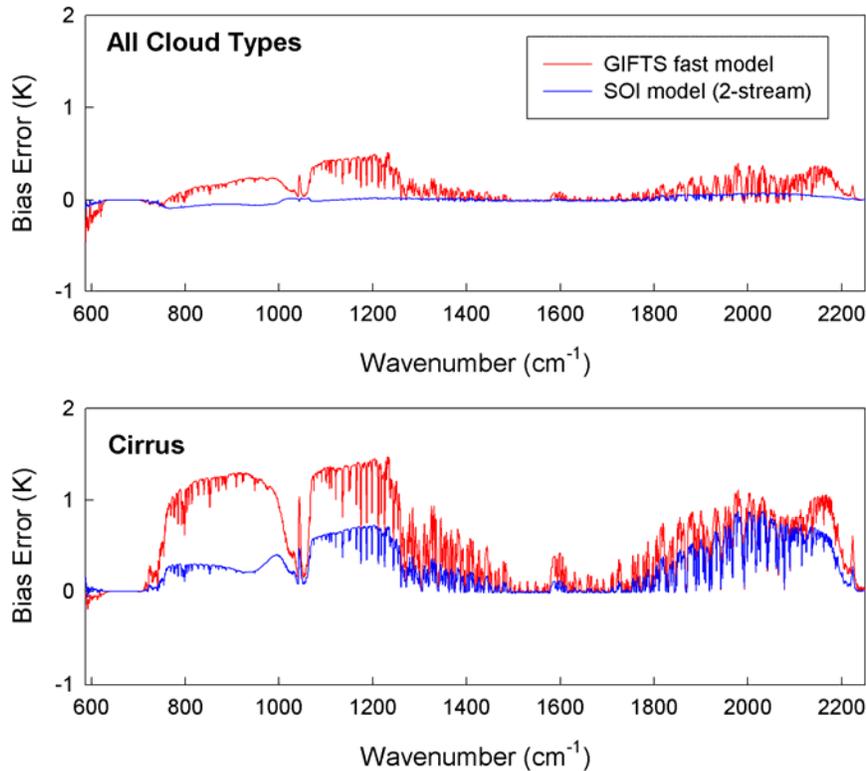


Figure 1.1.13: Accuracy of the GIFTS fast model and the two-stream SOI model for top-of-atmosphere brightness temperatures at an observation zenith angle of 55° based on (top panel) for all WRF simulated cloud profiles and (bottom panel) cirrus only profiles.

Publications and conference reports

Greenwald, T., H.-L. Huang, D. Tobin, P. Yang, L. Moy, E. Olson, J. Otkin, B. Baum, H. Woolf and X. Xu, 2006: CIMSS Forward Model Capability to Support GOES-R Measurement Simulations, Fourth GOES-R Users Conference, Broomfield, Colorado.

Zhang, Z., P. Yang, G. Kattawar, H-L. Huang, T. Greenwald, J. Li, B. Baum, 2006: A Fast Infrared Radiative Transfer Model Based on the Adding-Doubling Method for Hyperspectral Remote Sensing Applications, *J. of Quantitative Spectroscopy & Radiative Transfer*, provisionally accepted.

1.2 GOES-R Risk Reduction Validation / Demonstration – Dave Tobin

Proposed Work

The demonstration effort proposed for 2006 involves an independent assessment of the capabilities of the derived geophysical data and products. CIMSS participates in this demonstration program by: 1) comparing radiances and derived products with independent correlative measurements from ground-based networks, comprehensive test sites, and field campaigns; 2) comparing radiances and derived products with independent satellite retrieval products from instruments on different platforms; and 3) by performing selected forecast model impact case studies.

Once an algorithm is developed and then implemented with the Data Processing and Archive System, efforts will focus on assessing: 1) the computational efficiency of the algorithm with respect to production requirements, and 2) the accuracy of the products with respect to product requirements. As stated above, the accuracy assessment will make use of comparisons with independent data sources and other validation approaches. Where appropriate and necessary, the algorithm may be developed and implemented for an existing sensor (not GOES-R) such that the demonstration may take place in the pre-launch phase. The proposed demonstration activities for 2006 were:

- Write the first draft of the Product Verification Plan, which will document how we will demonstrate the production and assess the accuracy of the HES-like products.
- Demonstrate and assess the accuracy of the GIFTS L0-L1 algorithms and L1 products using both simulated and real GIFTS data hosted by the GIPS.
- Demonstrate and assess the initial accuracy of a baseline T/q retrieval algorithm hosted by the GIPS. This will be demonstrated by implementing the baseline algorithm for aircraft (S-HIS or NAST-I), AIRS, and/or IASI and assessing the accuracy of the products by comparisons to independent validation data.

Summary of Accomplishments and Findings

Major accomplishments in this area during 2006 were related to the GIFTS L0-L1 algorithm. With the completion of the fabrication of GIFTS in early 2006 and subsequent thermal vacuum and ground based measurement characterization testing, we have been able to demonstrate both the accuracy and processing feasibility of the GIFTS L0-L1 processing algorithms.

GIFTS has 3-sigma (not-to-exceed) overall radiometric calibration requirements of 1K for a range of typical scene brightness temperatures. This accuracy is required for remote sensing applications and is also relevant to satellite inter-calibration efforts. An accurate high spectral resolution sensor in Geo orbit offers the ability to inter-calibrate with numerous LEO sensors to accurately determine, understand, and remove inter-satellite biases.

The GIPS processing algorithms have been refined to work with the real GIFTS data. Major steps in this process during 2006 have involved the implementation of a spectral phase alignment process (which accounts for missed metrology laser fringe counts during interferometer scan turn-arounds), construction of a bad pixel mask, and implementation of a new spectral resampling algorithm. Previous quarterly reports have detailed the progress on some of these aspects of the GIPS.

A focus of the GIPS processing has been the Atmospheric Variability Experiment (AVE) conducted during the GIFTS Ground Based Measurement (GBM). During the GBM, GIFTS was configured to view the atmosphere using a ZnSe chamber window and a 45 degree fold mirror. During AVE, GIFTS data was collected on a regular interval and coincident radiosonde launches were performed to capture the evolution of the boundary layer over approximately 12 hours. Additionally, coincident AERI data was collected, allowing detailed comparisons of GIFTS and AERI radiance spectra. Figure 1.2.1 shows a sample comparison of GIFTS and AERI clear sky spectra. Refinement of the GIPS processing algorithms is on-going under separate funding. In particular, we are refining and implementing a radiometric non-linearity correction for the GIFTS data.

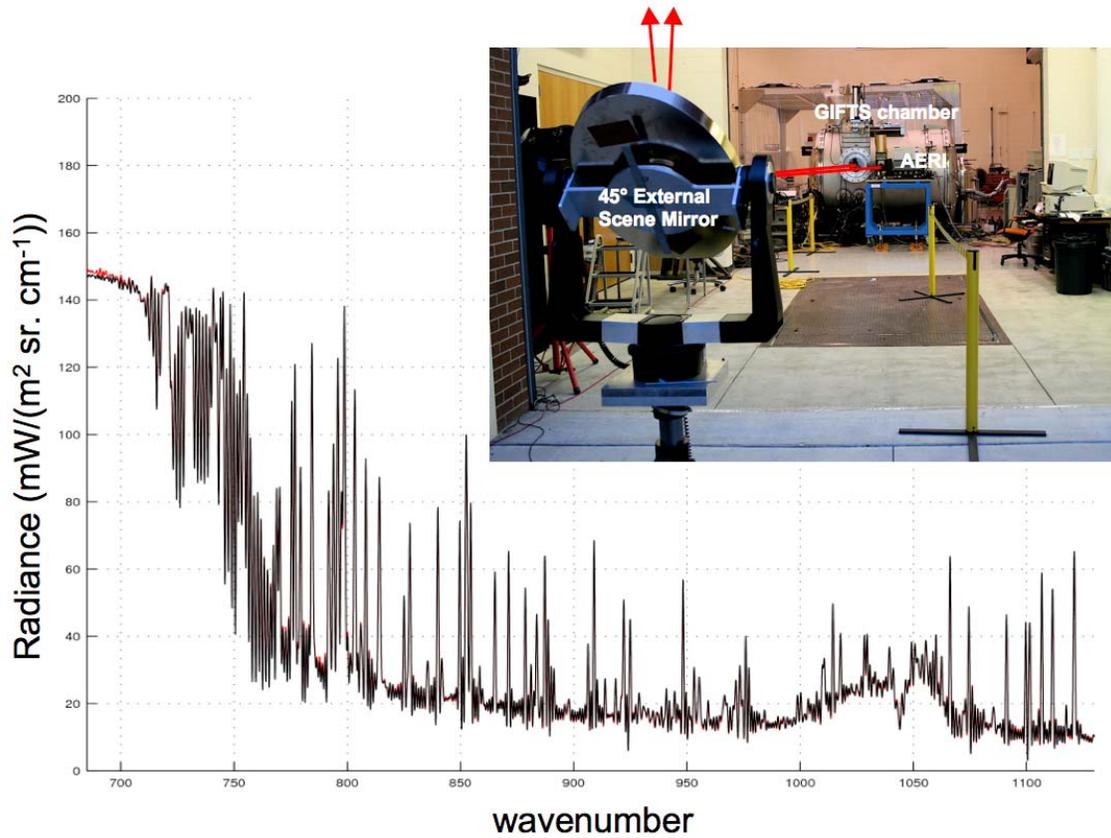


Figure 1.2.1: Comparisons of GIFTS (black) and AERI (red) clear sky zenith viewing radiance spectra collected during the GIFTS Ground Based Measurement Campaign in September 2006.

Regarding Level 2 algorithm demonstration, an initial Level 2 AIRS temperature and water vapor profile retrieval algorithm has been delivered by the Algorithm Developers for implementation in the Data Processing system. Work is underway within the Data Processing group to implement this algorithm. Demonstration efforts will be conducted in the next quarter to evaluate the accuracy of the resulting products, primarily via comparison with ARM site matchup validation data. Additionally, an alternative algorithm has been used to produce temperature and water vapor profiles.

No notable progress was made towards the creation of a Product Verification Plan this year. Under NASA support, a GIFTS Measurement Concept Validation Plan was produced in 2001 (Tobin, D. C., C. Velden, N. Pougetchev, S. Ackerman, *GIFTS Measurement Concept Validation Plan, GIFTS Project Document GIFTS-MCVP-02-002, 12 February 2001*). We had previously planned to build upon this document and the existing GIFTS Product Evaluation Plan to create a draft Product Verification Plan for GOES-RRR algorithms and processing in the GOES-R pre-launch time frame.

Publications and Conference Reports

Reference software implementation for GIFTS ground data processing, R. K. Garcia, H. B. Howell, R. O. Knuteson, G. D. Martin, E. R. Olson, and M. J. Smuga-Otto, Proc. SPIE Int. Soc. Opt. Eng. 6301, 63010Y (2006)

Techniques used in improving the radiance validation of Atmospheric Infrared Sounder (AIRS) observations with the Scanning High-Resolution Interferometer Sounder (S-HIS), Kenneth H. Vinson, David C. Tobin, Henry E. Revercomb, Robert O. Knuteson, Fred A. Best, William L. Smith, Nick N. Ciganovich, Steven Dutcher, Scott D. Ellington, Raymond K. Garcia, H. Benjamin Howell, Daniel D. LaPorte, Joe K. Taylor, Paul van Delst, and Mark W. Werner, Proc. SPIE Int. Soc. Opt. Eng. 6405, 640505 (2006)

Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS) thermal vacuum testing: aspects of spectral characterization, David C. Tobin, Henry E. Revercomb, Joe K. Taylor, Fred A. Best, Robert O. Knuteson, William L. Smith, John Elwell, Greg Cantwell, Gail Bingham, Joe Tansock, Robert A. Reisse, and Daniel K. Zhou, Proc. SPIE Int. Soc. Opt. Eng. 6405, 64050G (2006)

The geosynchronous imaging Fourier transform spectrometer (GIFTS): noise performance, Joe K. Taylor, Henry E. Revercomb, David C. Tobin, Fred A. Best, Robert O. Knuteson, John D. Elwell, Gregory W. Cantwell, Deron K. Scott, Gail E. Bingham, William L. Smith, Daniel K. Zhou, and Robert A. Reisse, Proc. SPIE Int. Soc. Opt. Eng. 6405, 64050J (2006)

Performance verification of the Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS) on-board blackbody calibration system, Fred A. Best, Henry E. Revercomb, David C. Tobin, Robert O. Knuteson, Joseph K. Taylor, Donald J. Thielman, Douglas P. Adler, Mark W. Werner, Scott D. Ellington, John D. Elwell, Deron K. Scott, Gregory W. Cantwell, Gail E. Bingham, and William L. Smith, Proc. SPIE Int. Soc. Opt. Eng. 6405, 64050I (2006)

1.3 GOES-R Risk Reduction Preparation for Data Assimilation – Allen Huang and Xiaolei Zhou

Proposed work

- Expand on the sensitivity study of the GOES-R HES measurements to the actual demonstration of GOES-R high temporal and spectral resolution HES data in the assimilation and analysis system.
- Prepare for data assimilation by demonstrating how to quantify the measurement and product information content provided by simulated HES.
- Optimize the use of GOES-R simulated measurements and explore ideal assimilation and analysis approaches.
- Refine currently available forward and backward operators required by the assimilation system.
- Adapt preprocessing tools such as cloud detection, optimal channel selection, dynamic measurement noise estimation, measurement noise filtering and radiances and sounding products error characterization for the demonstration of AIRS, IASI and simulated HES.
- Document and share preprocessing tools and results from these experiments with other GOES-R Risk Reduction data assimilation teams to assist their HES data assimilation studies.

Summary of accomplishments and findings

Impact of “clear-channel” radiances on storm-scale prediction

We completed a paper entitled “identifying cloud-uncontaminated AIRS spectra from cloudy FOV based on cloud top pressure and weighting functions” (accepted for publication in Mon. Wea. Rev.). In 2007, we’ll apply and test a similar algorithm to GIFTS radiances at storm scales.

Consistency between horizontal resolution and vertical resolution

We are conducting an EOF analysis of observed and modeled vertical profiles of the atmospheric temperature and water vapor. Channel selection is not a new topic, but no existing literature focuses on developing a channel selection algorithm that captures the maximum vertical variability derivable from high-spectral resolution radiance data. Preliminary work was completed in 2006. In 2007 we hope to complete a journal paper on this subject.

Applying the sensitivity results of radiance for model's forecast verification and data assimilation

We are writing a journal paper entitled “verifying mesoscale forecasts using the advanced infrared sounder (AIRS) observations and adjoint sensitivity results of radiance.” The results of the adjoint sensitivity of radiance are compared and contrasted with the vertical structures of RTM weighting functions, while highlighting the advantages of the adjoint sensitivity study. An error analysis of mesoscale forecasts is then carried out for a mesoscale test case using the AIRS observations and the adjoint sensitivity results. It is shown that such an error analysis may provide useful insights in determining the forecast skill of a model and which AIRS channels may provide the most important information for improving the relevant forecasts. We’d like to conduct a similar study for a storm case next year.

1.4 GOES-R Risk Reduction Nowcasting – Ralph Petersen

Proposed Work

The proposed work focuses on identifying areas of convective instability 3-6 hours in advance of storm development based on the moisture data from current and future GOES satellites. Study areas include: 1) continued development and testing of the Lagrangian model, 2) development of visualization tools to view predicted DPIs in formats identical to the current observational products, 3) use AIRS soundings as a surrogate for GOES-R HES data in assessing the impact of higher vertical resolution on resolving the pre-convective environment, 4) improved utilization of satellite sounders by projecting GOES sounder products ahead in time and space to provide new nowcasting products, 5) assessment of the relative benefits of using moisture retrievals versus radiances in nowcasting and NWP assimilation systems over land, and 6) interaction with NWS/WFOs, NSL and NCEP/SPC to evaluate new objective nowcasting products. Tests using AIRS data to assess the impact of improved GOES sounder vertical resolution on NWP have been de-emphasized following the decision to eliminate HES from the GOES-R series. Experiments using AIRS data in nowcasting are still planned, however. The removal of HES and reduction in program funding also eliminated the proposed collaboration with ORA/ERSL.

Summary of Accomplishments and Findings

Development and testing of Lagrangian model; and improved utilization of satellite sounders to provide new nowcasting products

Efforts this year concentrated on improving the representativeness of the wind data being used to initialize the Lagrangian forecast parcels and to test the system using additional case studies. Much emphasis has been placed on the 13 April 2006 hail event over southern Wisconsin that was not captured in conventional operational NWP guidance, but was evident in detailed nowcasts made 6-hours in advance of the event. In an effort to make the stability calculations more exact

and to incorporate the effects of localized diurnal heating evident in GOES data, the nowcasting system is being expanded to include multi-layer predictions of Equivalent Potential Temperature (2e) and vertical differences (the rigorous definition of convective instability). In order to support real-time operational evaluation of the nowcasting products, the model codes are also being transferred from an older developmental platform to a much faster and more reliable Linux-based system.

Develop visualization tools to view predicted DPIs

Work continued to improve tools for anticipating development of severe thunderstorms, especially hard-to-forecast isolated severe events. Recent efforts focused on developing visualization tools and web presentation capabilities that allow operational forecaster to easily integrate consistent images of the DPI observations and nowcasts, and rapidly identify the most important features. A prototype nowcast web page showing the 13 April 2006 WI hail event nowcasts is available at http://cimss.ssec.wisc.edu/model/ncstR_13Apr06/nowcast.html. It includes hourly animations of DPI-like images of mid- and high-level precipitable water and derived vertical moisture gradients (key indicators for convective instability), along with verification satellite imagery. In addition, the production of nowcast product images has been modified to use a contemporaneous image from the previous hourly nowcast run as a 'first-guess'. This process increases resolution and retains past nowcast data in new products.

Tests focused on the 13 April 2006 Wisconsin hail storms, which tracked from south of Madison to west of Milwaukee and caused millions of dollars of property damage. Although the standard NWP guidance from the NAM model showed no evidence for this storm development, the nowcast system (see Figure 1.4.1) indicated that the low-level moisture observed over central Indiana in the initial DPI data would transport to an isolated band across south-central Wisconsin within six hours. Simultaneously, an overlaying narrow area of mid-level dryness was shown to move into the same area from south-western Minnesota. Derived vertical moisture differences show an initial development of isolated instability (dark blue to bright red area) over central Iowa at the time of a tornado sighting there, followed by rapid development of instability over extreme southern Wisconsin six hours into the nowcast, when and where the hail storms developed. The results clearly show both the value of the multi-layer moisture data from GOES and the ability of the nowcast system to retain and project isolated moisture extremes in anticipation of hard-to-forecast convective events.

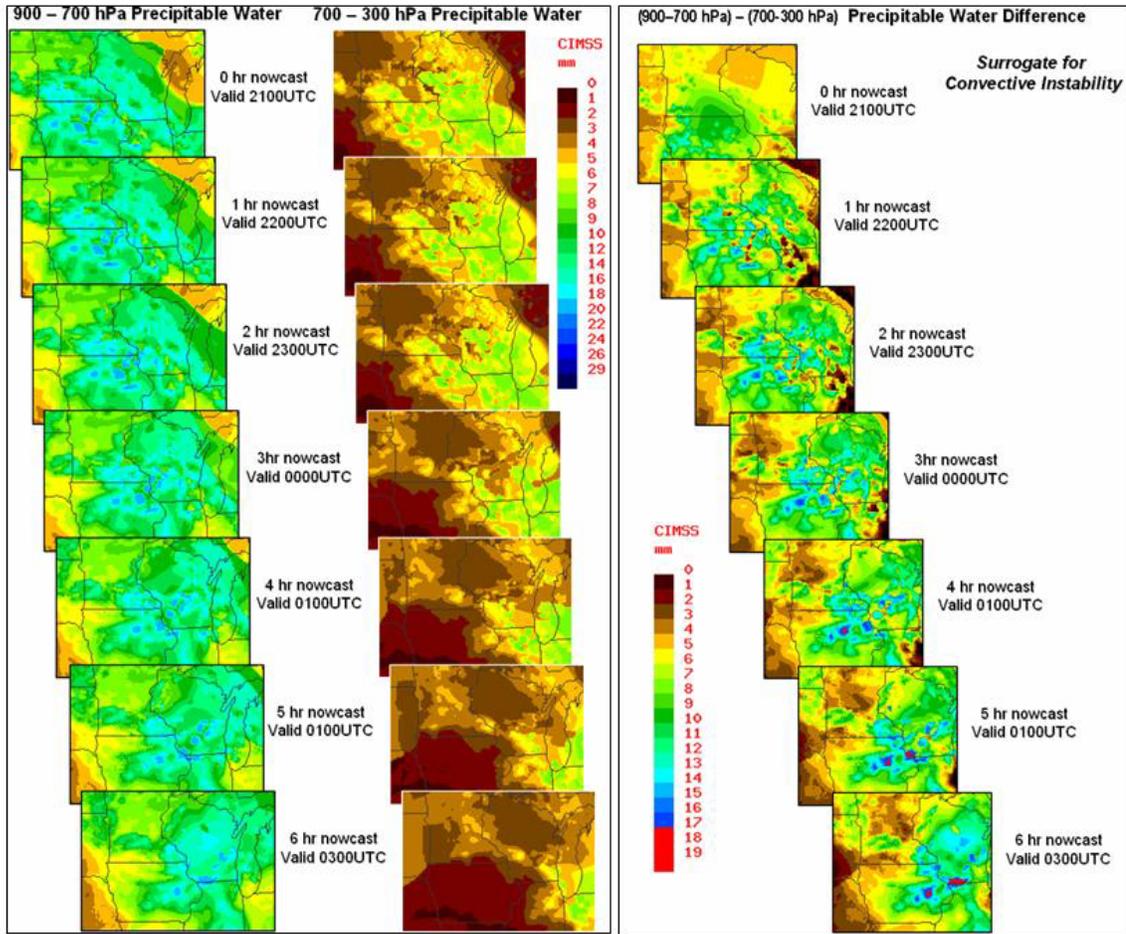


Figure 1.4.1: NAM model NWP guidance (left) and Nowcast product output (right) for severe hail case study over southern Wisconsin.

Use AIRS soundings as a surrogate for GOES-R HES data in assessing the impact of higher vertical resolution on resolving the pre-convective environment

This work, including the incorporation of AIRS sounder products into the NCEP-based WRF/GSI system to accelerate the use of HES in conventional NWP, was scheduled to become more active later in the year. Due to lack of funding at ERSI and the cancellation of HES, many of the resources intended for this work are being redirected to pre-ABI related activities. However, examination of AIRS data for a previously studied severe thunderstorm case showed that POES observations alone could not replace the enhanced spatial and temporal resolution provided by GOES. In this case, the important mesoscale moisture features that were critical to the location and timing of the convective development were entirely missing in the AIRS data – either ‘lost’ in the data gaps between orbits or ‘masked’ by cirrus outflow which formed after the initial convection developed prior to the 12-hourly AIRS overpasses (See Figure 1.4.2).

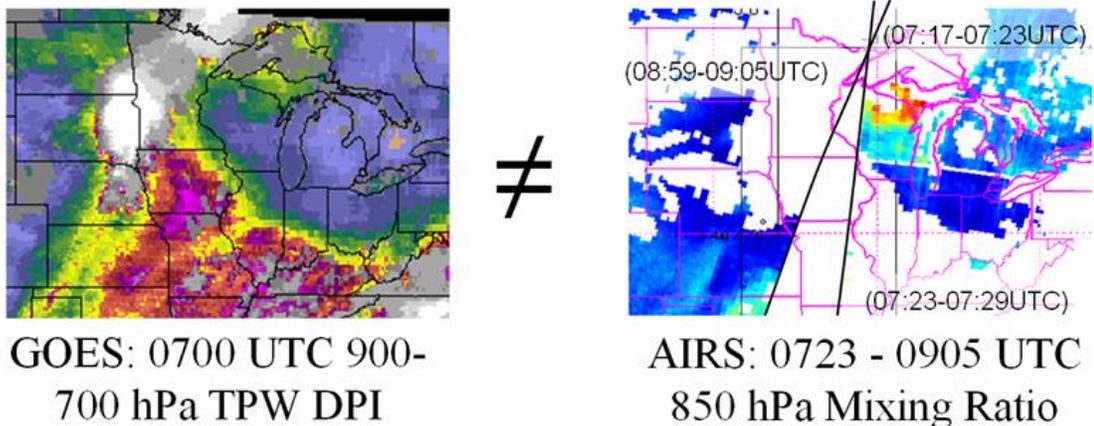


Figure 1.4.2: Severe thunderstorm case illustrating that POES observations alone (right) can not replace the enhanced spatial and temporal resolution provided by GOES (left).

AIRS data for the 13 April 2006 hail case have also been processed with both the standard AIRS processing and CIMSS processing. Preliminary results show major improvement in CIMSS data over land. Limited tests of the utility of these higher-vertical resolution data in nowcasts are planned for the coming year.

Interact with NWS/WFOs, NSL and NCEP/SPC to evaluate new objective nowcasting products

Initial discussions have begun with NWS/Green Bay (GRB) and NWS/Sullivan. GRB has offered to host an overview seminar this winter based on the fully functional web page and real-time model output. The seminar would include discussions of how to best quantify the usefulness of the products, and how to improve presentation methods for next year's severe storm season. Based on review of the case study results discussed above, GRB has further offered to expand the seminar participation to include NWS offices at Sullivan, LaCrosse, Minneapolis and Marquette for expanded testing and evaluation.

Publications and Conference Reports

Petersen, R. A., 2006: Travels with Charlie: An invited paper on the future direction of international aviation meteorology presented at the WMO Commission on Aeronautical Meteorology. Geneva, Switzerland

Petersen, R. A. and R. Aune, 2006: An objective nowcasting tool that optimizes the impact of GOES Derive Product Imagery in very-short-range forecasts. AMS Satellite Conference. Atlanta, GA

Petersen, R. A. and R. Aune, 2006: An objective nowcasting tool that optimizes the impact of GOES Derive Product Imagery in very-short-range forecasts. GOES Users' Conference. Boulder, GA

Petersen, R. A. and R. Aune, 2006: An objective nowcasting tool that optimizes the impact of GOES Derive Product Imagery in very-short-range forecasts. *Proceedings of SPIE Optics and Photonics 2006 -- Volume 6301: Atmospheric and Environmental Remote Sensing Data Processing and Utilization II*. San Diego, CA

1.5 GOES-R Risk Reduction Ground System Design and Studies – Bob Knuteson

Proposed Work

The CIMSS GOES-R Risk Reduction activities related to ground data processing design and system studies in 2006 had three major objectives; 1) the evaluation of on-orbit algorithms for the L0 to L1 calibration of the Geostationary Imaging Fourier Transform Spectrometer (GIFTS) as a risk reduction activity for the GOES-R Hyperspectral Environmental Suite (HES) sounder, 2) the preliminary design of ground processing architectures suitable for the large data volumes and high throughput requirements of the GOES-R sensors (ABI and HES), and 3) the demonstration of advanced computing technology in the areas of data storage and retrieval, cluster computing, high speed networks and distributed computing specifically applied to the data anticipated in the GOES-R time frame. Significant progress was made in each of these areas which can now be transitioned into the implementation needed for NOAA Algorithm Working Group integration and for the future ground data processing system for GIFTS or any other geostationary hyperspectral infrared sounder.

Summary of Accomplishments and Findings

Significant progress was made in each of the task areas in 2006. Highlights are provided below:

- A 24 hour simulation of “full-disk” Earth emitted radiances was developed under this risk reduction activity in order to support the large scale simulation studies required for the ABI and HES sounder. This dataset has since become one of the proxy datasets that will be used by the Algorithm Working Groups. A paper on the 24 hour full disk simulation was presented at the AMS annual meeting in January 2006. The full simulation was completed mid-year and is available upon request. In addition to the WRF model fields, the dataset includes top of atmosphere radiances for a broad continuous spectral region of the infrared at high enough spectral resolution to allow the simulation of numerous infrared sensors including the ABI and GIFTS. In addition, interferograms were created from this dataset simulating the GIFTS on-orbit observations. This “raw” sensor data has been used in a successful demonstration of the scalability of the GIFTS Information Processing System (GIPS) software under another NOAA grant for the Office of Systems Development (McKenzie). It is anticipated that future simulated datasets of this type will be supported by the AWG proxy data team using the approach developed under this risk reduction task.
- A draft GIFTS L0-L1 Algorithm Theoretical Basis Document (ATBD) was prepared in conformance to the NOAA STAR documentation guidelines and is available from the UW-Madison SSEC web site. A paper was presented at the 2006 AMS annual meeting on this topic. The draft GIFTS L0-L1 ATBD is intended to be an evolutionary document that describes both the theoretical equations for the target algorithms and the detailed performance tradeoffs that need to be considered in software implementation of the algorithms. In 2006, real data from the GIFTS thermal vacuum testing was used to evaluate existing algorithms and modify or extend them for application to the actual thermal vacuum test data. Data sets with both laboratory blackbody and sky-viewing scenes were identified from tests run by NASA at Space Dynamics Laboratory in Logan, Utah between May and September 2006. Simply acquiring these datasets for evaluation is a significant task due to the relatively large data volumes involved and the need to develop new tools for working with the data files as provided by NASA. The GIFTS ATBD has been used in the GIPS software development project mentioned previously. While there is a need for continuing refinement of these algorithms it is suggested that

further ATBD changes be funded by a GIFTS specific ground system development activity rather than under GOES-R risk reduction. This is consistent with the mature level of this algorithm development.

- Designs of the system level concept for processing of GOES-R data in an efficient and reliable manner have been captured in the form of data flow diagrams (see diagrams below). The primary technologies that are being leveraged for the future system designs are cluster computing and intelligent storage systems combined with high speed networks for efficient parallel processing of sensor fields of view. This approach of parallel mass computing reflects the needs of the GOES-R program where the future sensors are anticipated to collect multiple fields of view simultaneously with nearly two orders of magnitude increase in sensor data rates. The UW-Madison SSEC has also performed some computing and cost estimation studies which are summarized below for the GIFTS sensor as it is currently configured for flight. Further work to refine these system designs will be deferred until the status of the geostationary hyperspectral sounder is clarified.
- A preliminary design study for GOES-R Level 2 processing was conducted assuming the use of simulated Earth observations in a high performance computing environment. A diagram showing an example data flow is provided below. Numerous technical details have been identified in an assessment of the existing UW-Madison SSEC software code base which will be used in the development of a prototype implementation of the water vapor winds processing. The activities under this risk reduction task are being coordinated with the AWG Algorithm Integration Team (AIT) leader (W. Wolf). It is anticipated that further CIMSS work in this task area will be supported directly by the AWG AIT under separate funding.
- A forward looking demonstration, called Origami, was developed during the task period in order to link distributed computing methods, client-server data distribution, and database management to visualization tools with a user friendly web interface. The Origami demonstration was extremely successful in illustrating how existing modern infrastructure technologies, e.g. storage area network, database engines, cluster computing, and open data access protocols, can be coupled with the next generation UW-Madison SSEC visualization tools (the IDV which is built upon VISAD) to create a development environment suitable for the GOES-R era. While the Origami demonstration was intended to highlight the integration of modern technologies, it also shows how large scale computing resources can be coupled in a seamless manner to three dimensional visualization of model and observed state parameters in a manner that can be scaled up to any size problem. The scalability of a computing system suitable for GOES-R that has the features contained by the existing McIDAS system for the current GOES sensor plus the additional functionality required for the GOES-R series is the ultimate goal of this work. A diagram of the Origami concept is provided below and was presented at the Fall AGU meeting in December 2006. Future progress in this area will be limited by available funding but continuing the exploration of this work under GOES-R risk reduction is highly recommended.

Diagrams developed under GOES-R Risk Reduction funding for ground data processing system design and study are provided below:

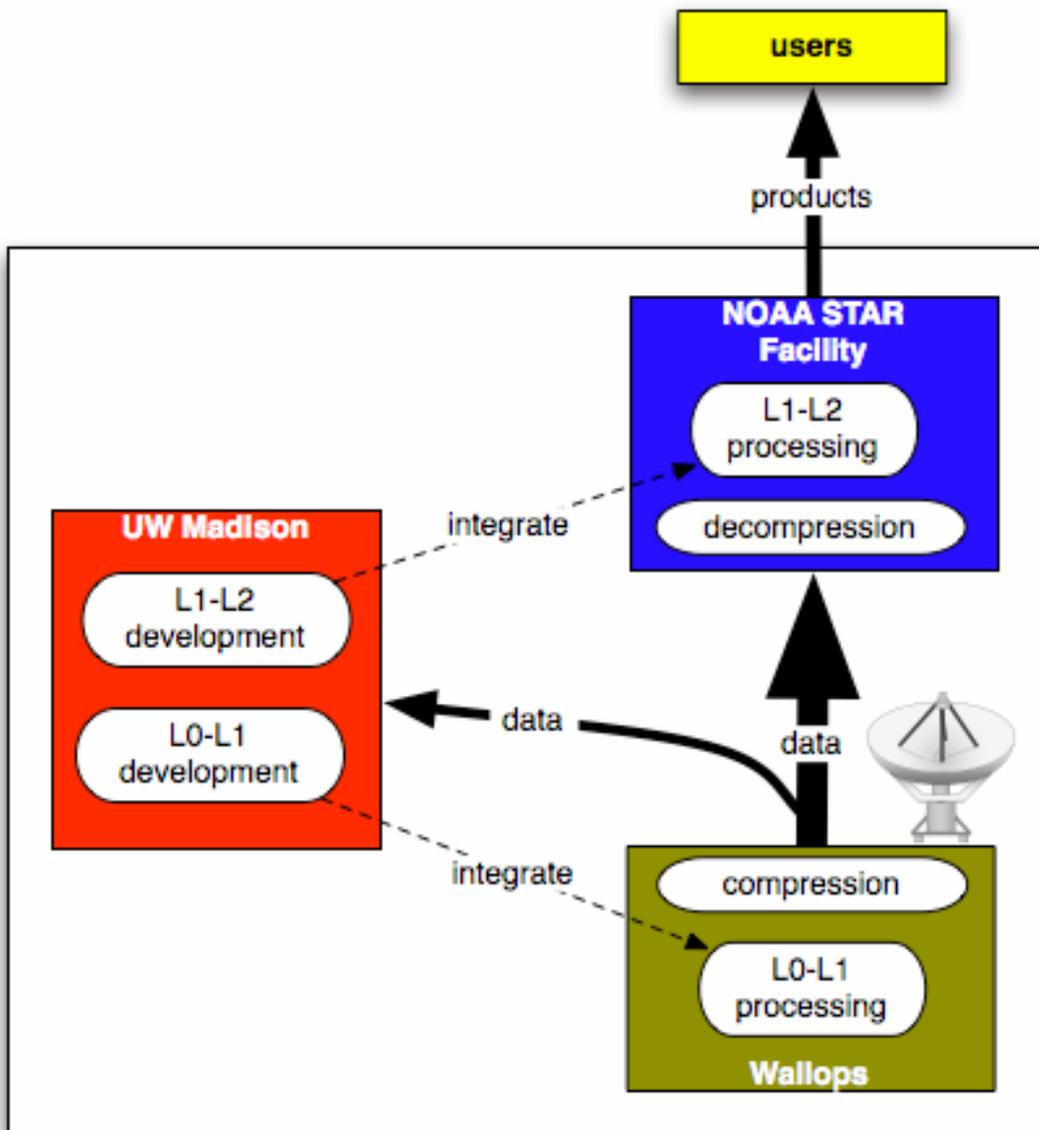


Figure 1.5.1: Ground Segment Concept Proposed by UW-Madison CIMSS.

Figure 1.5.1 shows the proposed concept for a ground system for GOES-R which combines the efforts of NOAA OSD, NOAA STAR, and the cooperative institutes. This diagram is suitable for ABI and other sensors. In particular, the UW-Madison CIMSS has estimated the system elements for the NASA GIFTS sensor assuming that it would be processed under this concept. A preliminary computing estimate for a L0-L1 (raw downlink to calibrated radiances) near real-time cluster processing system is about 150 dual cores or 75 quad core machines using current commodity hardware. Most of the CPU time needed is for easily parallelizable computations such as FFTs, which can be performed independently on every pixel in a cube of incoming data, making compute cluster computing the natural low-cost solution for deploying a ground system. Higher level data processing (beyond calibrated radiances) is believed to require a system of similar size.

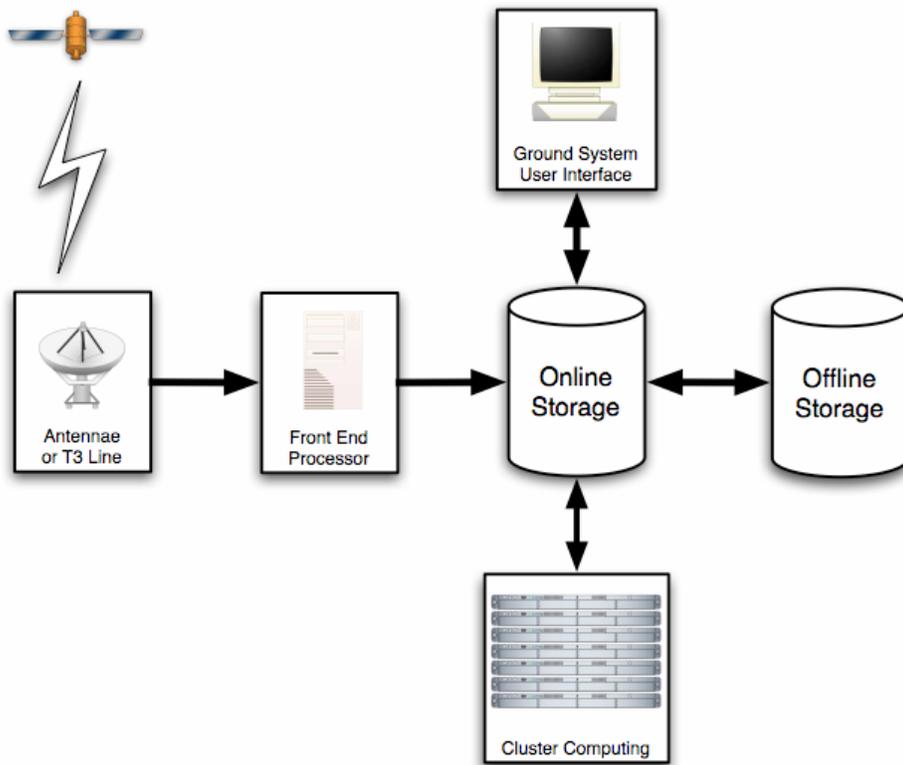
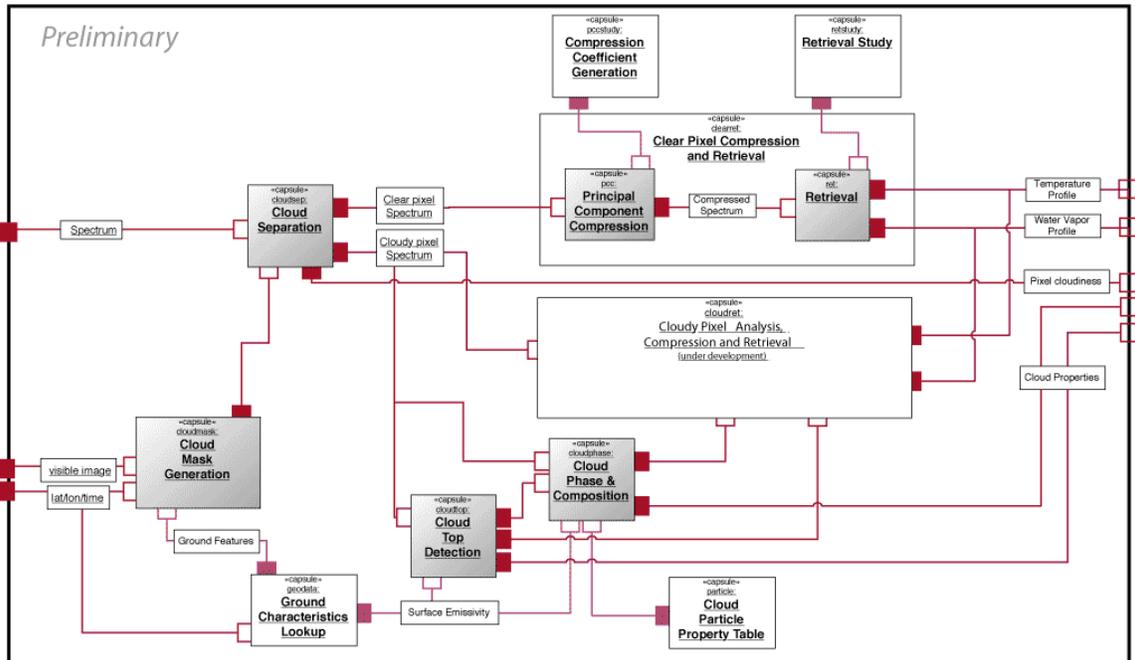


Figure 1.5.2: Ground Data Processing System Concept for UW-Madison CIMSS Development System.

Figure 1.5.2 illustrates the elements required in any ground data processing system independent of sensor or product. This diagram in particular is intended to identify the design concept of the development system which is suggested be located at UW-Madison CIMSS for support of the GOES-R algorithm development and subsequent data processing. Detailed cost estimates for a system designed to process GIFTS on orbit data in an on-demand mode are available by contacting the investigators.



Conceptual UML-RT Component Diagram of L1-L2 Processing Pipeline

Figure 1.5.3: Data Flow Diagram for Level 2 Products from GOES-R.

Figure 1.5.3 shows a possible module and dependency graph for processing calibrated spectra into retrieved T/WV profiles and cloud mask. Refining the individual algorithms identified in this diagram is an active area of research of the Algorithm Working Group. This style of diagram makes use of Unified Metadata Language (UML) which provides a consistent framework for the definition of interfaces between software modules. This example is of the temperature and water vapor profile product but serves as an illustration of the type of diagram that needs to be created by the Algorithm Integration Team for each GOES-R product.

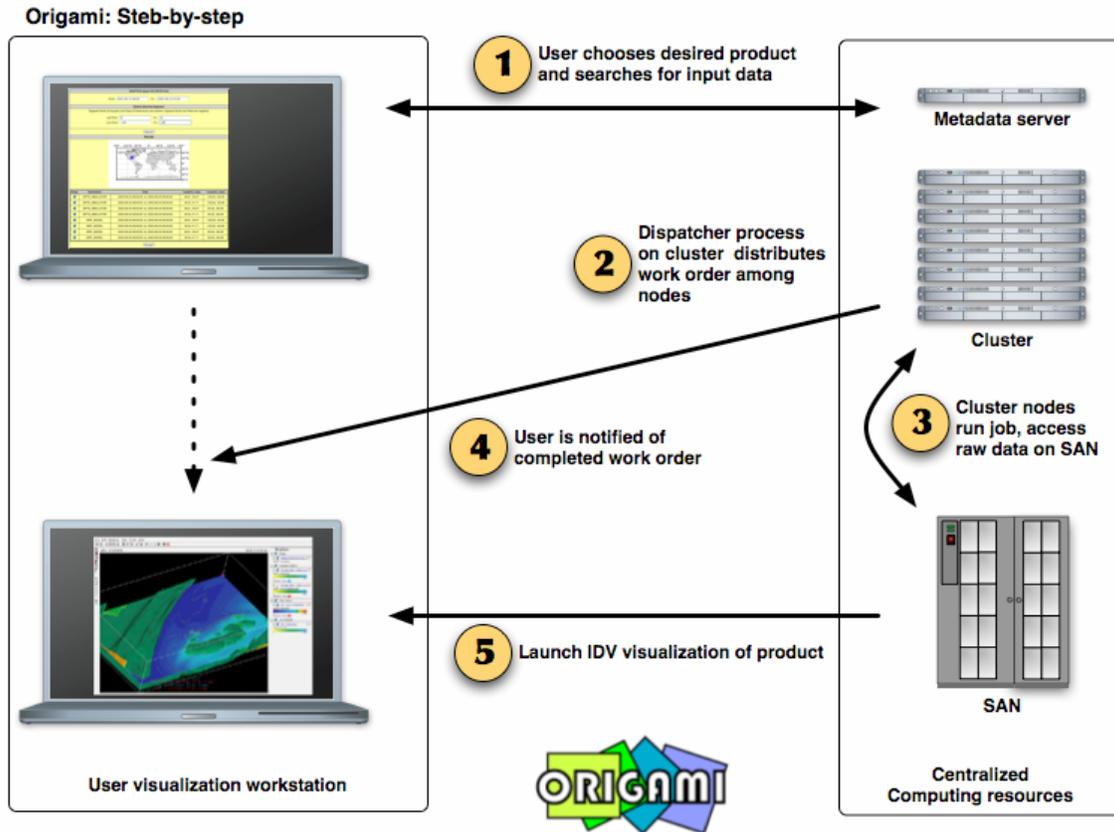


Figure 1.5.4: Origami Demonstration Conceptual Diagram.

The Origami demonstration is a lightweight on-demand processing model for computing subsets of online or archived GOES-R data for algorithm development and product validation. The demonstration shows how to couple scalable computing resources (cluster compute nodes and storage area networks) with fully three dimensional visualization tools using with a simple web browser based user interface. The technologies used within the Origami demo are key elements for any future GOES-R ground data processing system and moreover provide a bridge both to the past GOES (McIDAS) systems and to data from external systems like POES/NPOESS polar data and NMC model fields.

Publications and Conference Reports

Knuteson, R., R. Garcia, E. Olson, H. Revercomb, M. Smuga-Otto, D. Tobin, 2006: Preliminary Evaluation of the GIFTS Calibration Algorithm Using the GIPS, AMS Annual Meeting in Atlanta, Georgia, January 2006

Olson, E., J. Otkin, R. Knuteson, M. Smuga-Otto, R. Garcia, W. Feltz, H.L. Huang, C. Velden, L. Moy, 2006: Geostationary Interferometer 24-Hour Simulated Dataset for Test Processing and Calibration, AMS Annual Meeting in Atlanta, Georgia, January 2006

Smuga-Otto, M., R. Garcia, R. Knuteson, G. Martin, B. Flynn, D. Hackel, 2006: Integrating a High-Throughput Parallel Processing Framework and Storage Area Network Concepts into a Prototype Interactive Scientific Visualization Environment for Hyperspectral Data, poster paper American Geophysical Union (AGU) Fall Meeting, San Francisco, December 2006.