CIMSS Participation in the GOES-R Risk Reduction Program

Quarterly Progress Report for January – March 2007

from the
University of Wisconsin-Madison
Cooperative Institute for Meteorological Satellite Studies (CIMSS)

Project Title: CIMSS Participation in GOES-R Risk Reduction

Principle Investigator: Steve Ackerman

Topics/Lead Investigators:

1. Algorithms
   - 1.1 Sounding Algorithm Development - Jun Li, Allen Huang
   - 1.2 Winds – Chris Velden
   - 1.3 Ozone - Jun Li
   - 1.4 Radiative Transfer Modeling - Steve Ackerman
   - 1.5 Surface Properties - Bob Knuteson
   - 1.6 Biomass Burning-Elaine Prins, Chris Schmidt
   - 1.7 SATCAST / CI - Wayne Feltz
   - 1.8 Tropical Cyclones - Jim Kossin, Chris Velden
   - 1.9 Visualization (HYDRA integration) - Tom Rink
2. Nowcasting - Ralph Petersen
3. Data Assimilation / Simulations - Jason Otkin, Allen Huang
4. Validation - Dave Tobin
5. Ground System – Maciej, Smuga-Otto, Bob Knuteson

Program Manager: Tom Achtor

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1. Algorithms

1.1 Sounding Algorithm Development
Task Leads: Jun Li, Allen Huang

Summary on sounding algorithm development

In order to study the synergy of LEO (low earth orbit) hyperspectral infrared (IR) and GEO (geostationary orbit) imagers for sounding evolution, the LEO hyperspectral IR alone approach is studied as a first step. The physical algorithm for simultaneous retrieval of the emissivity spectrum and sounding is effective for both simulated and measured hyperspectral IR radiances. Atmospheric Infrared Sounder (AIRS) radiances are used for the emissivity algorithm development. A manuscript on emissivity and sounding is under preparation for Geophysical Research Letters (GRL). See section 1.1.1 for details.

A single field of view (SFOV) cloudy sounding approach using hyperspectral IR radiances was successfully tested with AIRS radiance measurements from EOS Aqua. A manuscript on cloudy sounding has been conditionally accepted by Geophysical Research Letters for publication. See section 1.1.2 for details.

Recently Jun Li was invited by Tom Pagano, AIRS science team manager, to present the emissivity and cloudy sounding work at the AIRS science team meeting held from 27 to 30 March 2007 in Pasadena, CA. The AIRS science team is very interested in the research progress made on the emissivity and cloudy sounding, and would like to collaborate on AIRS sounding studies. The emissivity and cloudy sounding algorithms will be adjusted to for ABI (Advanced Baseline Imager) processing. In addition, combination of LEO hyperspectral IR sounder and GEO Imager for profile evolution is also under investigation.

1.1.1. Progress on handling surface IR emissivity in sounding retrieval

Retrieval of the emissivity spectrum and sounding simultaneously with radiance measurements of hyperspectral IR sounders such as AIRS, IASI (Infrared Atmospheric Sounding Interferometer), CrIS (Cross-track Infrared Sounder) onboard the national and international polar orbiting satellites are very important because

(a) the retrieved hyperspectral IR surface emissivity global map can be used in a ABI retrieval processing scheme,
(b) improvement on handling IR surface emissivity will increase the assimilation of IR radiances over land in numerical forecast models,
(c) retrieval methods can be adjusted to process ABI radiances.

In our last quarterly report we presented the positive impact of a simultaneous physical retrieval of the IR surface emissivity spectrum and sounding on boundary layer temperature and moisture retrieval by using AIRS simulation. We also applied the algorithm to AIRS clear radiance measurements from a granule containing various land types (cropland, desert, grassland). The retrieved profiles have good accuracy in comparison to the ECMWF analysis and radiosonde observations. The retrieved emissivity spectrum is very reasonable when compared with the reference emissivity spectra, especially over the desert region. Figure 1 shows the AIRS surface emissivity images from first guess (regression) (upper left) and the physical simultaneous approach (upper right) at AIRS channel of 1227 cm^{-1} or 8.15 µm. The difference between physical and first guess (regression) can be seen, especially over the desert region. The lower panel shows the example of emissivity spectrum retrieval over the desert region, physical approach changes the regression in longwave and shortwave IR window regions, a reference of emissivity spectrum from data base is also shown. Accurate surface properties captured by hyperspectral measurements featured over the land, especially in the vicinity of the Sahara Desert, are clearly evident. The improvement of sounding in boundary layer from physical over the regression is also seen when compared with ECMWF analysis (not shown). A manuscript on this study has been written and will be submitted to Geophysical Research Letters in April for publication.

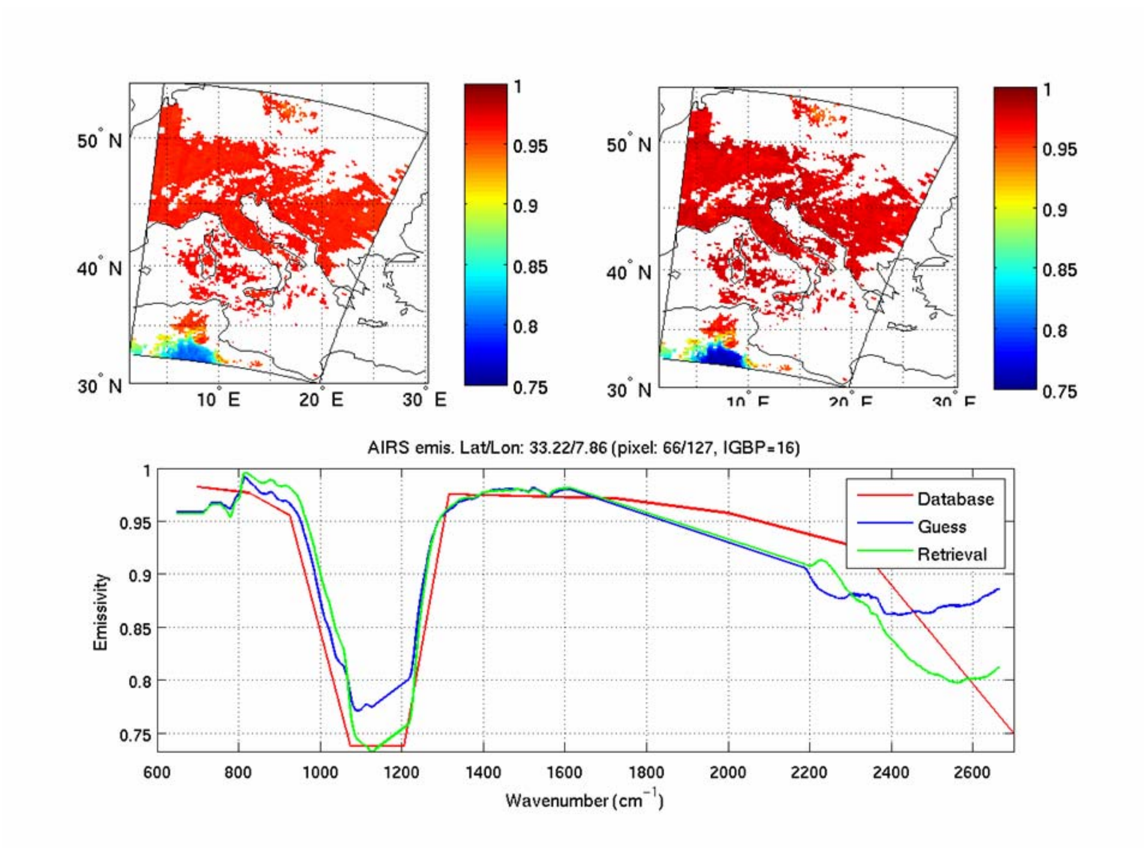

Figure 1. The emissivity retrieval from first guess (regression) (upper left) and the physical simultaneous approach (upper right) at AIRS channel of 1227 cm^{-1} or 8.15 µm. The lower panel shows the example of emissivity spectrum retrieval over the desert region, along with a reference of emissivity spectrum.

1.1 2. Single field of view cloudy sounding study

The SFOV cloudy sounding approach is very important because

(1) most IR sounder FOVs are contaminated with clouds while a single FOV profile product is very important for nowcasting severe weather events and forecasting mesoscale features,

(2) correctly handling clouds in the profile retrieval will help the assimilation of radiances in numerical forecast models in cloudy regions,

(3) the cloudy sounding approach can be adjusted to process ABI radiances under partial cloudy conditions.

Since the cloud properties (cloud-top pressure, optical thickness, particle radius) are simultaneously retrieved with sounding, we reported the AIRS retrieved SFOV CTP (cloud-top pressure) and the operational MODIS (Moderate Resolution Imaging Spectroradiometer) CTP product are close each other. More cases were studied and results show that MODIS and AIRS have similar CTP retrievals for most cloudy cases except for very low cloud cases. We also compared the cloudy sounding with radiosonde observations. Figure 2 shows the AIRS BT image at a window channel (upper left), the AIRS BT spectrum at ARM (Atmospheric Radiation Measurement) Cart Site (lower left), AIRS SFOV cloudy temperature and dew point sounding retrievals (red line), two RAOBs at ARM Cart Sites with different times of AIRS overpass. The AIRS BT image shows cirrus clouds over Southern Great Plains, the slope in the longwave IR window spectral region (low left) shows the cirrus cloud signature, on the other hand, the clouds are not thick so the AIRS sees the low level temperature (the water vapor absorption lines are up in the longwave IR window region). Therefore, both cirrus cloud signature and low level temperature inversion are reflected in AIRS BT spectrum. The AIRS SFOV cloudy sounding approach does retrieve the inversion structure! The RAOBs also reveals the low level temperature inversion. The cloud properties from AIRS are also reasonable, for example, the CTP is 308 hPa for this cirrus case. Note that this AIRS footprint at the ARM Cart Site is overcast according to MODIS cloud mask, but since it is not optically thick clouds, the AIRS sounding 'sees' down to the surface. The temperature sounding differences between AIRS and RAOBs might be due to the 3-hour time difference.

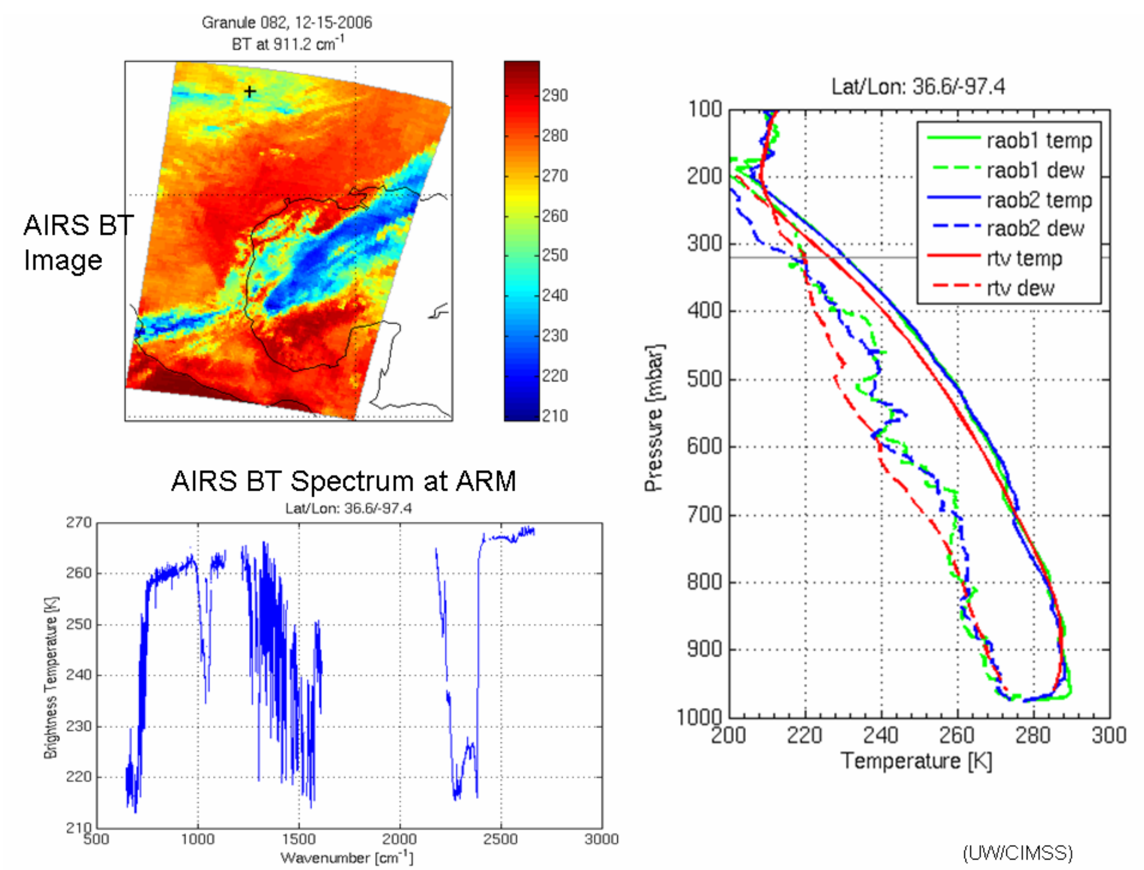

Figure 2. The AIRS BT image at a window channel (upper left), the AIRS BT spectrum at ARM Cart Site (lower left), AIRS SFOV cloudy temperature and dew point sounding retrievals (red line), two RAOBs at ARM Cart Sites with different times of AIRS overpass.

1.1.3. LEO/GEO combination of profile evolution is under investigation

With a reliable hyperspectral IR alone sounding approach, the next step is to combine LEO hyperspectral IR sounder (e.g., IASI, CrIS) and GEO imager (e.g., SEVIRI, ABI) data for profile evolution. Currently we are also developing the algorithm for profile retrieval using combined ABI and forecast. SEVIRI data has been used for testing the algorithm, some very preliminary results have been presented by Mitch Goldberg at HISE (Hyperspectral Imaging and Sounding of the Environment) topical meeting held in Santa Fe, New Mexico from 11 to 15 February 2007. We have started on the simulation for CrIS/ABI combination, for example, using two times of CrIS and 48 times of ABI per day for profile evolution. Some results are expected in next quarter.

Publications during January 01 – March 31, 2007

Li et al. (2007), Physical retrieval of emissivity spectrum from hyperspectral IR radiances. Manuscript to be submitted to *Geophysical Research Letter*.

Weisz, E., Jun Li, Jinlong Li, D K. Zhou, H.-L.Huang, M. Goldberg, and P. Yang, (2007), Cloudy sounding and cloud-top height retrieval from AIRS alone single field-of-view radiance measurements. Geophysical Research Letters (submitted).

Conference presentations during January 01 – March 31, 2007

Jun Li attended the Hyperspectral Imaging and Sounding of the Environment (HISE) topical meeting from February 11 to 15, 2007 in Santa Fe, New Mexico sponsored by Optical Society of American, and gave an invited talk entitled “Development and demonstration of hyperspectral infrared only sounding retrieval”.

Invited by Tom Pagano of AIRS science team manager, Jun Li attended AIRS science team meeting held from 27 to 30 March 2007 in Pasadena, California, and gave a talk entitled “Single field-of-view cloudy sounding retrieval from IR hyperspectral radiances”.

1.2 Winds
Task Lead: Chris Velden

Previous GOES-R winds work concentrated on demonstrating the ability to target and track features from WRF model moisture fields and simulated moisture retrievals. The ATReC and Ocean Winds datasets were used to successfully demonstrate the concept.

The next dataset being investigated (FULLDISK) dwarfs the previous two cases 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 has now received retrieved moisture fields from the FULLDISK case, and the processing of winds can be tested. We plan to refine the cloud mask and derive multi-level winds from simulated hyperspectral sounder retrieved moisture fields on the FULLDISK case. This will mark the completion of the demonstration of winds from hyperspectral sounder retrieved fields. Future efforts will be focused on ABI winds risk reduction.

Accomplishments in the last three months

1. Staging of FULLDISK case study in preparation for winds demonstration.
2. Conversion of retrieved moisture fields into input files for the winds algorithm.
3. Initial development of a cloud mask, which will need additional work before winds can be attempted.

Publications

Velden, C. and others, 2007: Clear sky AMV derived from the GOES sounder and simulated hyperspectral GOES-R sounder retrievals. GOESR/NPOESS Symposium, AMS Annual Meeting, San Antonio, TX., P1.28.

1.3 Ozone
Task Lead: Jun Li

In our last quarterly report, we reported that ABI and SEVIRI can achieve the similar total column ozone retrieval accuracy of the current GOES Sounder (~4-5 %) if forecast temperature information is used together with IR spectral band radiances. The temperature information is not required in the current GOES Sounder SFOV TCO retrieval since the CO_2 spectral bands already provide the temperature information. A manuscript entitled "Retrieval of Total Column Ozone from Imagers Onboard Geostationary Satellites" by Xin Jin, Jun Li, Christopher C. Schmidt, Timothy J. Schmit, and Jinlong Li, has been submitted to IEEE Transactions on Geoscience and Remote Sensing for publication. We have received the three reviewers' comments, and made revisions. The paper is conditionally accepted for publication. We are processing one month of SEVIRI data; the ozone product will be carefully evaluated with OMI ozone measurements. Spatial and temporal sampling resolutions for the TCO product are being evaluated using the one month of OMI/SEVIRI ozone analysis. Improvement will be made on the optimal use of the spatial and temporal continuities. Results are expected in the next quarter.

In addition, using the AIRS SFOV cloudy sounding approach (see the current Quarterly report on sounding algorithm development), the ozone profile above the clouds can be reliably achieved with hyperspectral IR radiances. The cloudy approach will be tested with SEVIRI, and the impact of partial cloudiness on TCO retrieval will be investigated.

Publications during January 01 – March 31, 2007

Jin, Xin, Jun Li, Christopher C. Schmidt, Timothy J. Schmit, and Jinlong Li, 2007: Retrieval of Total Column Ozone from Imagers Onboard Geostationary Satellites, *IEEE Transactions on Geosciences and Remote Sensing* (revised manuscript submitted).

Conference presentations during January 01 – March 31, 2007

Xin Jin attended the Hyperspectral Imaging and Sounding of the Environment (HISE) topical meeting from February 11 to 15, 2007 in Santa Fe, New Mexico sponsored by Optical Society of American, and gave a poster presentation entitled "Study of high temporal ozone product from imagers onboard geostationary satellites".

1.4 Radiative Transfer Modeling
Task Lead: Steve Ackerman

During this quarter a single-layer cloudy sky fast radiative transfer model for application to the GOES R ABI channels was developed by Texas A&M University and has delivered to CIMSS to support other GOES-R Risk Reduction and Algorithm Working group research. While the initial delivery only focuses on the solar and near-infrared channels, the model for the short and long – wave infrared channels is under development. One main routine along with 16 subroutines are coded in FORTRAN77 which were tested and later on converted to FORTRAN 90 standard. Initial tests have indicated some problems in the calculation of reflectances for water cloud cases. Efforts are also underway to improve this deficiency.

A publication in the improvement of cloud scattering for the fast calculation of high spectral infrared radiances was published in Journal of Quantitative Spectroscopy and Radiative Transfer (JQSRT) 105, (2007) 243-263, entitled "A Fast Infrared Radiative Transfer Model Based on the Adding-Doubling Method for Hyperspectral Remote Sensing Applications".

1.5 Surface Properties
Task Lead: Bob Knuteson

Proposed Work
The CIMSS GOES-R Risk Reduction activity in 2006 related to land surface properties was focused on the development of a global gridded high spatial resolution multi-year infrared emissivity database for use by 1) the AWG proxy data team for simulation of realistic Earth emitted radiation, 2) the sounder team for temperature and water vapor retrieval algorithm development, and 3) for data assimilation in Numerical Weather Prediction models. A paper was submitted in late 2006 to the Journal of Applied Meteorology and Climate (JAMC) by lead author Suzanne Wetzel Seemann that describes the methodology used to create this database from a combination of MODIS observations and laboratory measurements. This development was conducted in collaboration with the MODIS land products team and has been used for the comparison of AIRS products produced by NOAA STAR.

We proposed to continue this work in 2007 with an emphasis on deriving land surface temperature and surface emissivity for the ABI sensor. Our approach is to collaborate with the EUMETSAT Land Satellite Applications Facility (LAND SAF) in Portugal, especially Dr. Isabel Trigo, in an algorithm for using the temporal change of the SEVIRI instrument measurements to determine infrared emissivity for the SEVIRI infrared channels. We will create a prototype algorithm for ABI that takes advantage of the time change of surface temperature to separate surface temperature and surface emissivity. We will apply this algorithm to the SEVIRI observations over Africa and Europe for a case study. The independent emissivity product created from the SEVIRI infrared channels will be used to validate the University of Wisconsin emissivity database. This database is being used by the EUMETSAT Climate SAF in the profile retrieval of temperature and water vapor over land. We will collaborate with Ralf. Bennartz (UW-AOS) on the impact of improvements in the land surface emissivity on profile retrievals using SEVIRI as a proxy for ABI.

Accomplishments January – March 2007
1. During this period, a paper submitted last fall to JAMC was revised. Final figures were prepared and submitted. Significant changes were made to improve the paper, including an

expanded discussion of the selection of the hinge points which is now placed more explicitly in the context of a conceptual model. More information about the selection of the laboratory data is included, as well as more detail about the BF fitting procedure itself. The evaluation of the BF method has been expanded to include more discussion of its limitations, including a focus on two cases with reststrahlen features at higher wavelengths than predicted by the BF conceptual model. An additional evaluation of BF fitting procedure using a larger set of laboratory data was also included. The paper references is given below.

2. A poster was presented at the 2007AMS annual meeting regarding the validation of the UW global emissivity database using AIRS (Lihang Zhou) and SEVIRI (Isabel Trigo) data.

3. A task was initiated to compare the results of the MODIS BF method database with products from the NOAA HIRS generated by Ben Ruston as part of the evaluation of the GOES-R proxy datasets. Dr. Ruston visited CIMSS in February to coordinate this activity.

4. A dataset for the investigation of the proposed emissivity product from SEVIRI data was identified. The data to be used in this study was provide in HDF format by Mike Pavolonis using the GEOCAT algorithm and is from August 2006.

Publications:

Seemann, S.W., E. E. Borbas, R. O. Knuteson, G. R. Stephenson, H.-L. Huang, 2007: Development of a Global Infrared Land Surface Emissivity Database for Application to Clear Sky Sounding Retrievals from Multi-spectral Satellite Radiance Measurements, J. Appl. Meteor.

Eva Borbas, L. Moy, S. W. Seemann, R. Knuteson, P. Antonelli, J. Li, H. L. Huang, I. Trigo, and L. Zhou, A global infrared land surface emissivity database and its validation, 11th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS), AMS Annual Meeting, San Antonio, TX, January 2007.

1.6 Biomass Burning- Task Leads: Elaine Prins, Chris Schmidt

GOES-R ABI biomass burning research and development activities for 2007 will focus on active fire detection and sub-pixel characterization utilizing simulated and current global geostationary multi-spectral data. CIMSS is investigating application of the dynamic Baseline Emissivity dataset which contains monthly estimates of spectral band emissivities derived from MODIS data to improve sub-pixel fire characterization. CIMSS will utilize 15-minute MSG SEVIRI data and the MSG WF_ABBA product over Africa to investigate how to exploit high temporal data to identify and monitor small fast-burning agricultural and grass fires. CIMSS will continue to investigate fire characterization using both Dozier estimates of instantaneous sub-pixel fire size and temperature and fire radiative power (FRP) as derived from both MODIS simulated ABI data and other sensors as appropriate. Collaborations will continue with NRL-Monterey and NOAA/NESDIS on emission studies and data assimilation into the NAAPS model. Although initial efforts by NOAA/NESDIS to obtain 2 km MTSAT-1R JAMI data have not been successful, CIMSS is eager to utilize this data if it is made available. These risk reduction activities will ensure enhanced future fire detection, monitoring and characterization.

Accomplishments:

Work to create simulated ABI data from MODIS data continued from 2006. CIMSS now has a technique that properly accounts for the viewing geometries of the two satellites and the spatial response function of the ABI when generating the simulated imagery. This technique replaces the straightforward averaging and the simplified remapping techniques that have been used in the past.

CIMSS compared FRP calculated from Dozier instantaneous sub-pixel fire characteristics with FRP calculated from the 3.9 micron radiances. For relatively large fires with Dozier fire temperatures between 650K and 1200K there is a nearly 1:1 correlation between the two techniques, which had been expected because the Dozier technique is known to work best for those fires. These results validate that FRP and Dozier are tightly coupled together. Unfortunately these results do no address the accuracy of FRP estimates for small and cool, large and cool, or small and hot fires (size and temperature as determined by the Dozier technique).

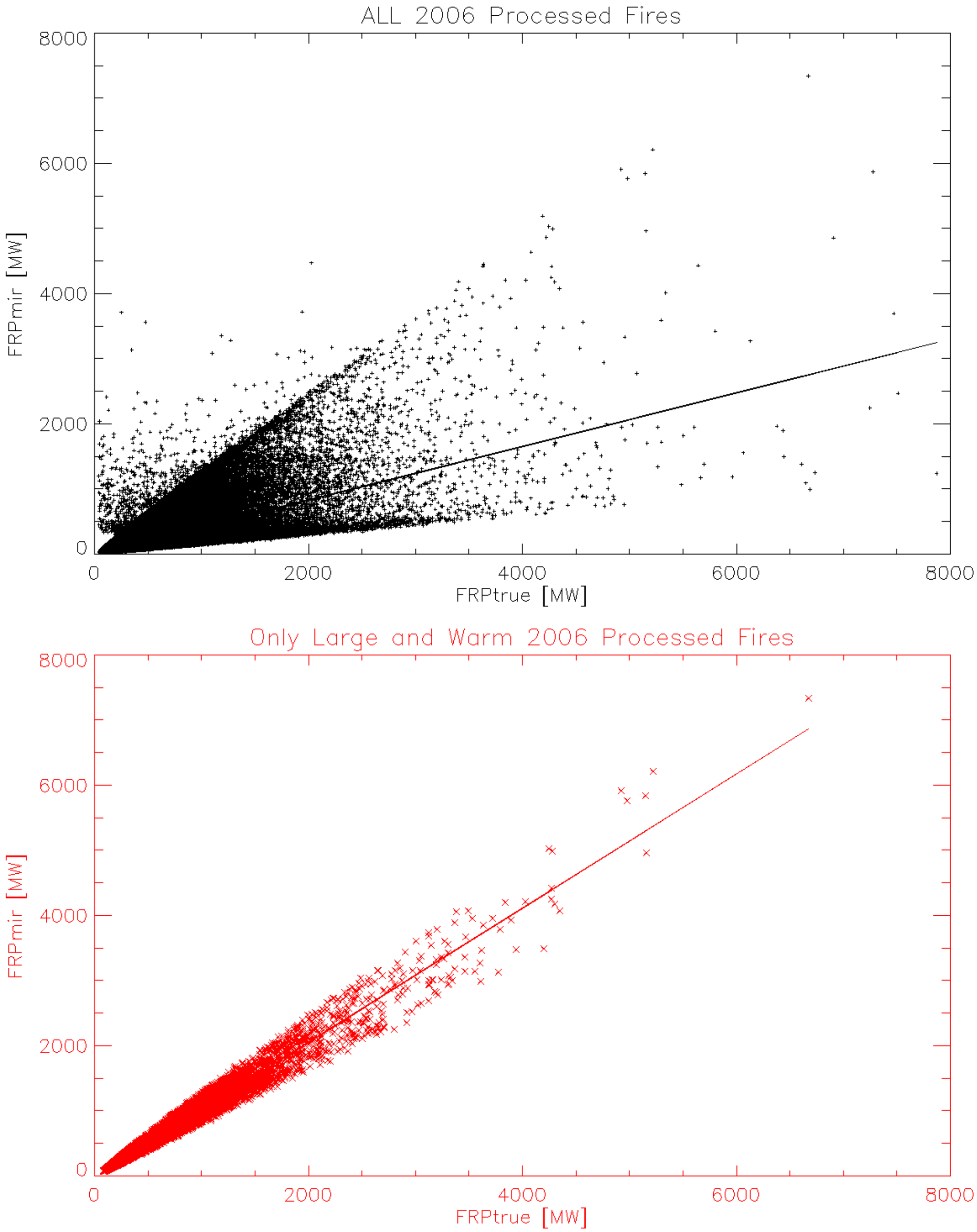

Figure 3. Comparison of FRP derived from Dozier fire characteristics (FRP_{TRUE}) and the 3.9 micron radiance (FRP_{MIR}) for all GOES-12 WF_ABBA processed fires in 2006. For large and warm fires the correlation is nearly 1:1, but when all sizes and temperatures are examined the correlation breaks down though primarily falls within a cone-shaped region.

Work to utilize the Baseline Emissivity (formerly referred to as the SeeBor) dataset and the collaborations with NRL-Monterey and NESDIS on emission studies and data assimilation into the NAAPS model have continued.

1.7 SATCAST / CI
Task Lead: Wayne Feltz

Work Description

This research task seeks to adapt SATCAST for use with MSG SEVIRI imager radiance data in anticipation of application on the GOES-R ABI imager. The CIMSS Satellite Nowcasting and Aviation APplications (SNAAP) team will conduct this research.

We propose to take advantage of the upcoming Convective and Orographically-induced Precipitation Study to be held in Southern Germany and Eastern France in the Summer of 2007. Collaboration is currently underway between CIMSS, Dr. Volker Gaertner (EUMETSAT), Dr. Marianne Koenig (EUMETSAT), and Dr. Volker Wulfmeyer (U of Stuttgardt) to transition the SNAAP/ASAP convection initiation and mesoscale atmospheric motion vector applications to using SEVIRI radiance inputs. This experiment will provide an opportunity to use a current imager containing more ABI channels than currently possessed by GOES imager. New radiance channels can be used to optimize the convective initiation algorithm.

Milestones/Accomplishments

- Adapt the GOES imager SatCAST algorithm to work with MSG SEVIRI radiance data.
    - Progress: The SatCAST algorithm has been adapted to work with SEVIRI data (figure below). Several case studies have been produced showing excellent CI forecast results.
- Optimize convective initiation, mesoscale AMV, cloud type classification algorithm using additional SEVIRI radiance information which will allow risk reduction for ABI through using consistent channels
    - This work will be ongoing during the Summer 2007
- Collaborate and install SatCAST algorithm within EUMETSAT (Darmstadt, Germany) for evaluation.
    - SatCAST algorithm has been implemented at EUMETSAT for validation and testing during the upcoming COPS field experiment to be conducted over Germany.
- Provide preliminary validation of SEVIRI-based CI product using Convectively-induced Orographic Precipitation Study (COPS) experiment to be held June – August 2007 near the German-France Rhine Valley area as a validation resource for the SatCAST convective initiation forecast locations.
    - To be completed Fall 2007
- Research optimal ABI convective initiation methodology for Aviation AWG
    - To be completed Fall 2007

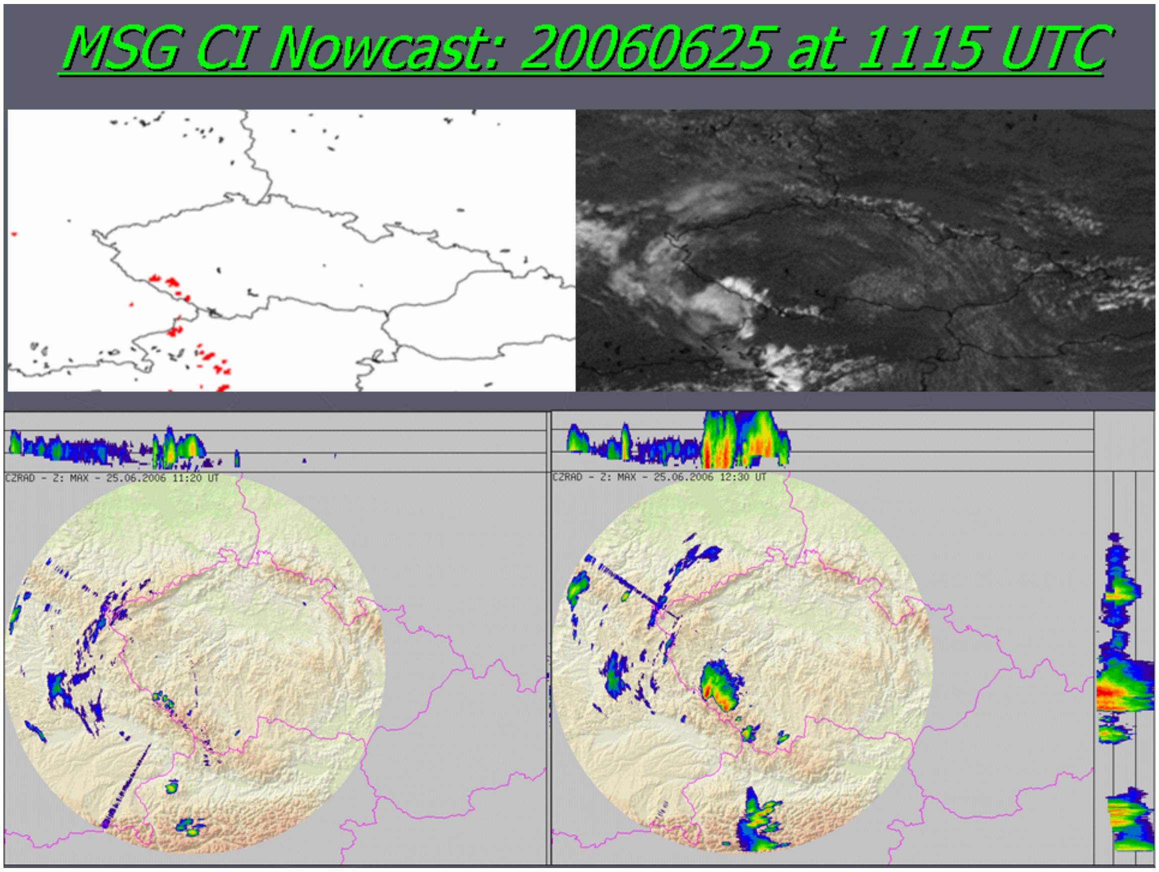

Figure 4. Upper Left: SATCAST MSG-SEVIRI convective initiation nowcast at 1115 UTC on 06/25/2006 over the Czech Republic. Upper Right: SEVIRI 1 km visible imagery at the time of the CI nowcast. Lower Left: Radar reflectivity at 1120 UTC. Lower Right: Radar reflectivity ~1 hour later at 1230 UTC. The SATCAST CI nowcast captured newly developing cumulus in the western Czech Republic far in advance of their evolution into cumulonimbus. Also, SATCAST nowcasted continued development of small precipitation echoes in Austria, which verified well in subsequent radar imagery.

1.8 Tropical Cyclones
Task Leads: Jim Kossin, Chris Velden

Project Description I (Kossin)
The goal of this project is to explore the relationships between GOES IR imagery and structure and size of the low-level wind fields of hurricanes. Information about storm structure/size is presently very limited but is a priority item for the NOAA National Hurricane Center forecast office.

Accomplishments in the last three months
Using a new dataset constructed by Task Leader Kossin and colleagues at the NOAA National Climatic Data Center (NCDC), we have significantly extended the record of critical wind radii in hurricanes. These radii [radius of maximum wind (RMW), and radius of 34, 50, and 64 knot wind (R34, R50, R64)] are now available for all storms during the period 1983–2005. The new data comprises a systematic compilation of GOES imagery during this period, and will be updated annually through the present period and into all future GOES projects. An example of a general wind radii climatology is shown in Figure 5. We are in the process of more thoroughly

documenting the error characteristics of our algorithm under various stratifications of interest to forecasters, and our climatologies will have associated error bars in the near future.

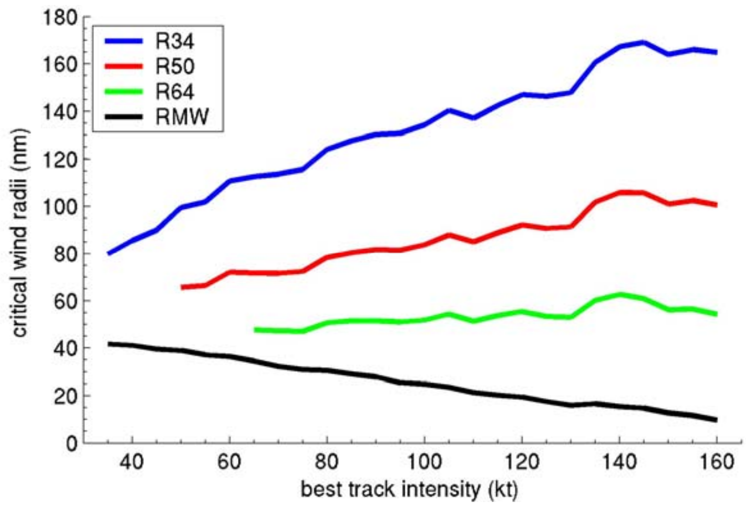

Figure 5: Mean radii as a function of hurricane intensity.

Project Description II (Velden)

One of the objectives of our GOES-R risk reduction work is to demonstrate what will be achievable with the availability of the ABI. One way to do this is 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. An example of the GOES-11 r/s AMVs for a time period during Emily was shown in a previous Quarterly Report. 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.

Accomplishments in the last three months

We are in the process of creating time series of upper-level quantities derived from the GOES R/S AMVs over Emily and other TCs. From these we hope to identify trends and potentially associations with the hurricane's structure and intensity fluctuations. In order to investigate kinematic quantities such as vorticity and divergence, the AMVs had to be analyzed on a uniform grid. This was done using an iterative Barnes scheme. The Barnes scheme allows an analysis to fit the observations coarsely where observations are sparse and a tightly where the observations are dense.

AMVs are analyzed during Hurricane Emily (July 11th – 21st, 2005) onto a 0.2-degree grid. Included in the analyses are AMVs assigned a height between 150 hPa and 200 hPa and located approximately 700 kilometers from the NHC best-track storm center are included. In regions without AMVs, a 1-degree numerical weather prediction background was used. The Figure 6 shows an example of a storm-centered vorticity field calculated from the analysis of Emily valid 18z on the 18th of July, 2005. The observation wind barbs (ms^{-1}) that made up the analysis are plotted on top of the vorticity field as well. Although Emily was a weak category-one hurricane at this time, she intensified 10 kts in the subsequent 6-hours. The analysis captures the cyclonic circulation over the storm's center, and the asymmetric, anti-cyclonic outflow region to the north and northeast of the storm.

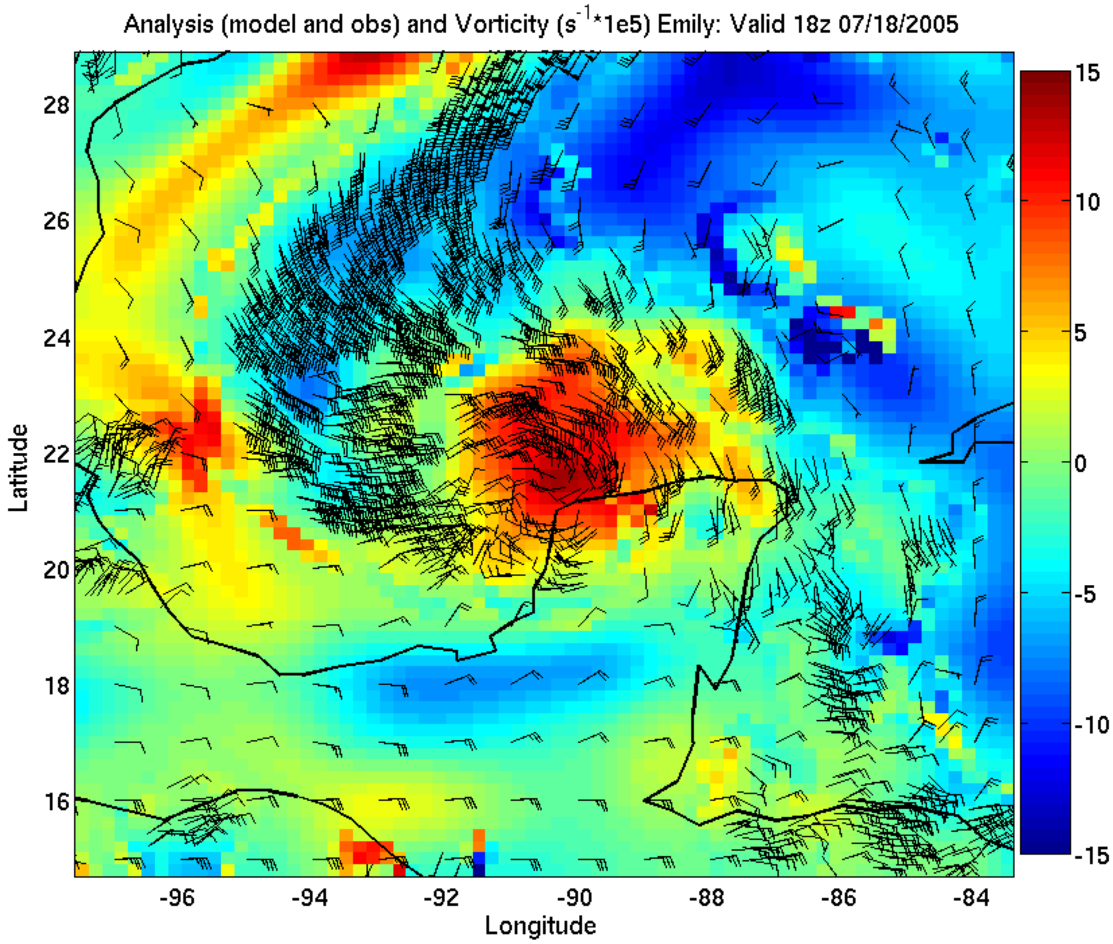

Figure 6: Storm-Centered vorticity analysis and observed AMVs at 18Z on July 18th, 2005 for Hurricane Emily. The color-contours show vorticity ($10^5 s^{-1}$) and the wind barbs show the observations in ms^{-1}. The analysis captures the cyclonic structure in the storm's center and the anti-cyclonic outflow to Emily's north. These asymmetric outflow channels are often associated with storm strengthening. Emily is a weak hurricane at this time, but subsequently intensifies 10-kts in 6 hours, and 55-kts in 30-hours.

To examine the trends in vorticity over the lifecycle of the storm, average vorticity values were calculated and compared with Emily's intensity. For each analysis, a circular region in the inner 200 kilometers, and the outer 200 kilometers are averaged in order to examine the inner cyclonic flow in the storm's eye-wall and its anti-cyclonic outflow. A time series of the average values of these two quantities is compared to the Emily's maximum wind-speed is shown in Figure 7, and shows how the two vorticity averages change as Emily's intensity changes. In general, as Emily intensifies, it's inner vorticity increases. The one period where this relationship is not as strong is during Emily's peak intensity. This may be related to the difficulty in generating AMVs over a

TC's center when it is very intense due to the uniformity (or lack of cloud) in the eye-region. The vorticity-intensity relationship is much clearer during the final intensification period around July 20th (day 201). The inner-vorticity increases significantly while the outer-region is getting more negative, corresponding to increased anticyclonic outflow. The inner-vorticity average correlates to Emily's intensity at around 60%.

The geographic constraints of our AMV datasets prevented us from capturing the very early stages of Emily. One can see, however, how the two-vorticity quantities do not differ appreciably prior to intensification or after it dissipates. It is possible that these quantities can be used to investigate genesis, and will be examined more thoroughly for additional storms and disturbances. Although this analysis only represents one case study, it shows the potential of analyzing the upper-level flow and relating it to TC intensity and intensity change. Further investigation into these and other parameters should lead to a better understanding as to how the upper-levels impact and are modified by TC intensity change.

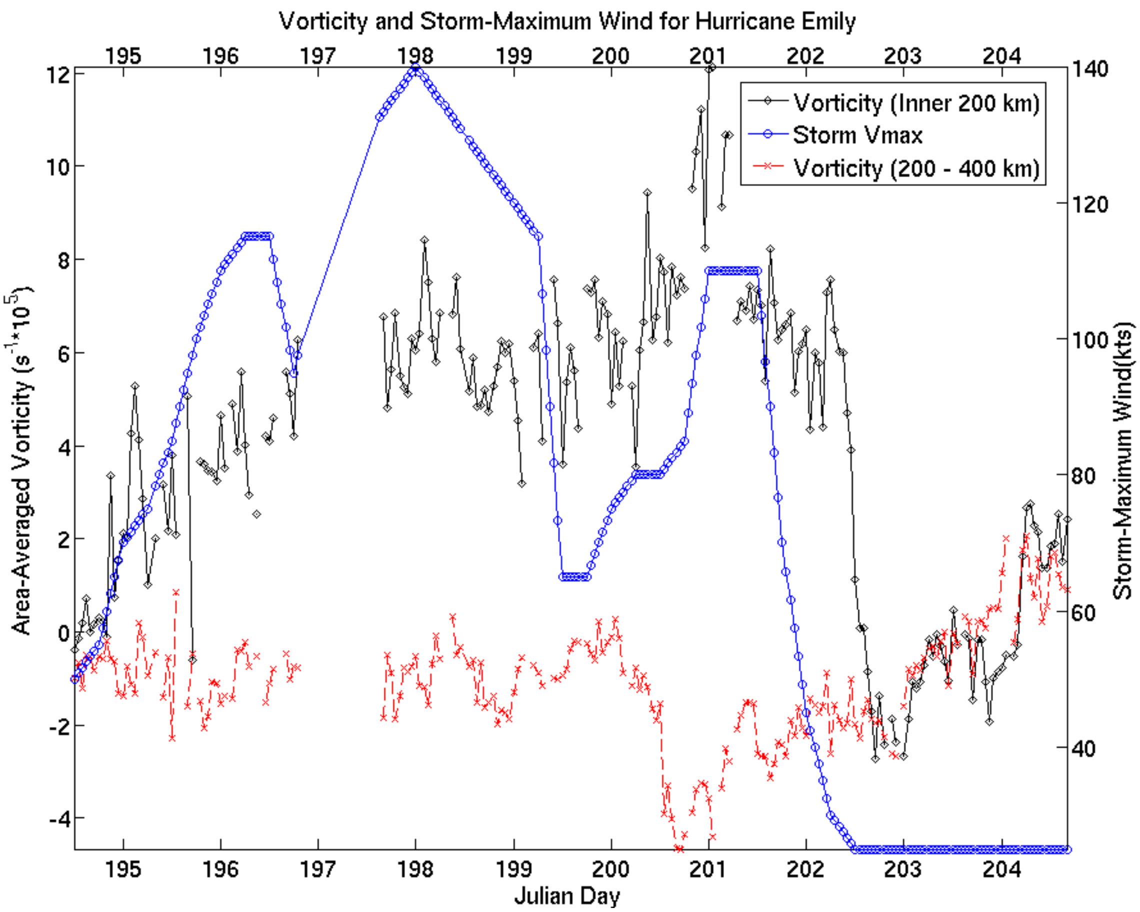

Figure 7: Hurricane Emily (2005) time series of inner 200km averaged vorticity (black-diamond curve, left-axis), outer 200-400 km averaged vorticity (red-x curve, left axis) and best-track storm maximum wind-speed (blue-circles, right axis). As Emily intensifies, the inner vorticity increases. During the re-intensification around day 201 (July 20th), the inner-region increases even more and the outer vorticity average becomes more negative. The inner-vorticity and storm maximum wind speed are correlated at about 60%. The missing points in the time series are due to times of missing or poor quality data.

1.9 Visualization (HYDRA integration)
Task Lead: Tom Rink

The integration of HYDRA into the GOES-R visualization and data analysis environment has been broken down into two phases of development effort:

Phase 1: Prototyping HYDRA capabilities within the Integrated Data Viewer (IDV).
The goal of this work is to explore and make an assessment of the process required to integrate the strengths of these two systems, mainly the rich set of libraries for visualizing geo-science data available in the IDV, and the multi- and hyper-spectral data specific capabilities in HYDRA. Both already share a common data model, i.e. VisAD. Many HYDRA users have requested functionality already present in the IDV and conversely IDV users would like HYDRA's functionality available to them. It's important to point out that this development, IDV/HYDRA/VisAD, will be tailored to the precise requirements of the visualization and data analysis needs of the GOES-R program. To this end, it was deemed important to create some demonstrations of how this can be accomplished, and some examples of what the initial system might look like. Some of this work will be directly applicable to Phase 2 below. Figure 8 shows AIRS data being interrogated in the IDV. Figure 9 shows MODIS Aerosol Optical Thickness, and MODIS Cloud Optical Properties combined with the Calipso Lidar in a 3D display. Much of this was accomplished by extending IDV classes, and adapting them to HYDRA classes for multi-spectral data and display.

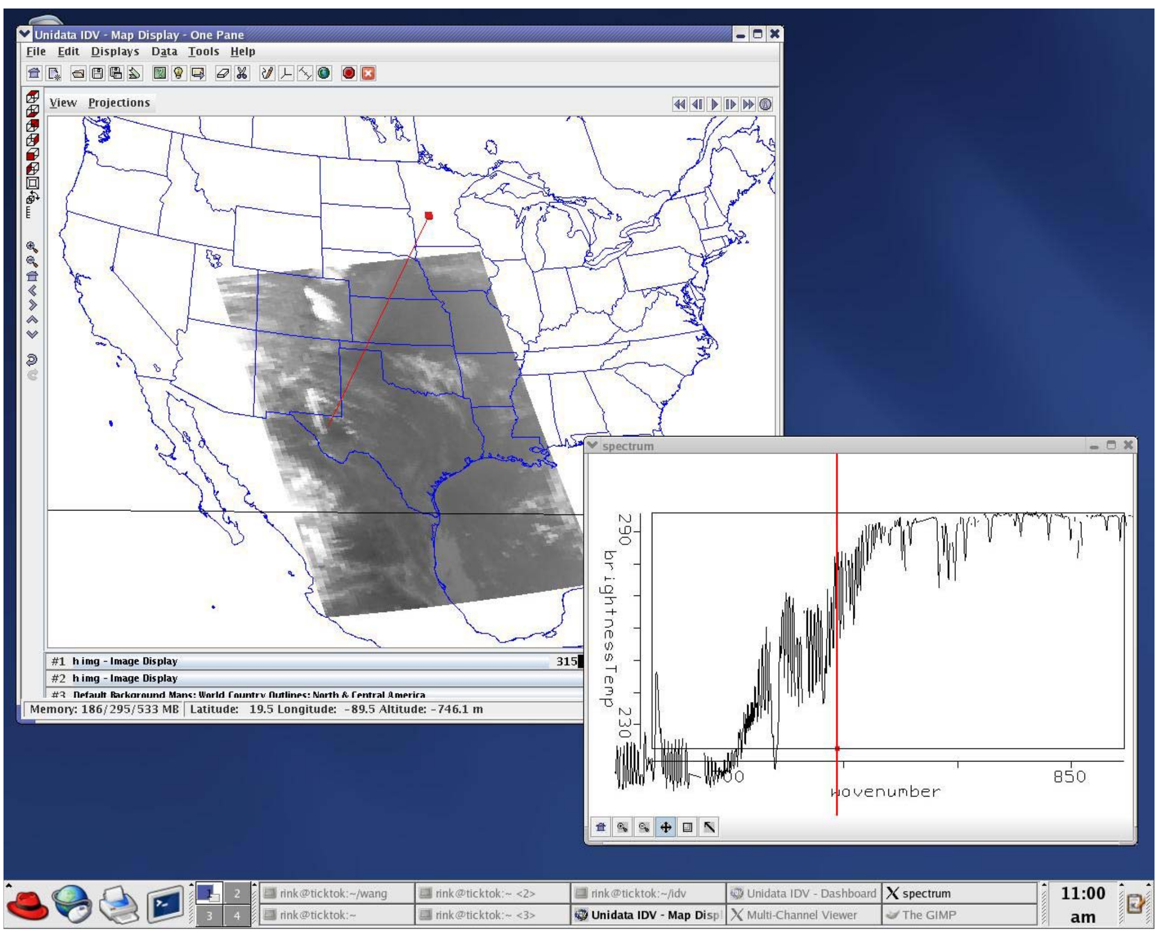

Figure 8. Example AIRS spectra and image display of one spectral band.

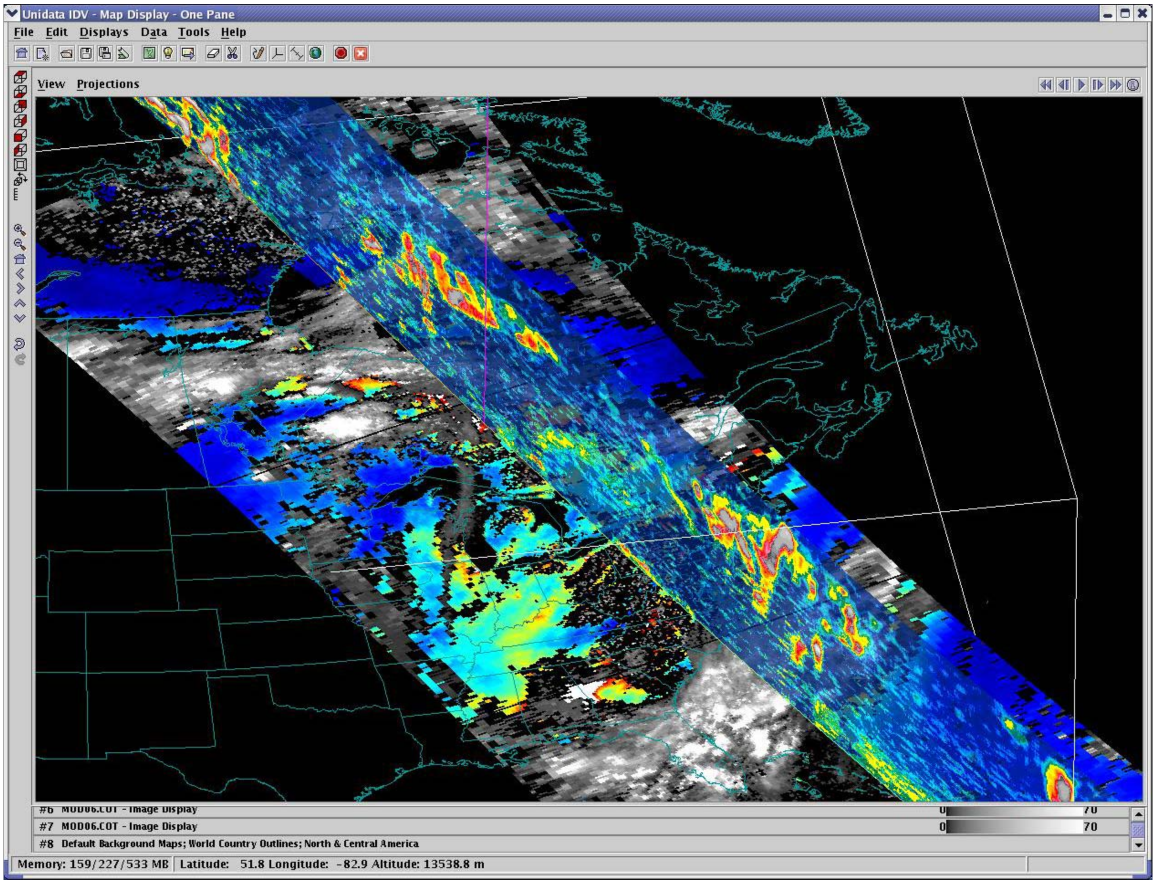

Figure 9. 3D display of MODIS Aerosol Optical Thickness, and MODIS Cloud Optical Properties combined with the Calipso Lidar

Phase 2: Implementation. Divided into two categories:

Data:

The goal is to generalize HYDRA's abstract data access layer for multi- and hyper- spectral Level1B and Level2 datasets. Work is in progress to open up HYDRA's local read access to HDF4 via Java, and to create adapters to HYDRA's data access classes which can used within the IDV. There a two concurrent development paths here: the first involves the Level 2 products, e.g. MODIS and AIRS, and the second involves primarily the Leve1B hyper-spectral data. The former is a more natural fit to the IDV because of the analogous relationship to the display and internal data representation of meteorology grids. The later is more involved, and will likely take the most effort of the two because of the specialized strategies employed in HYDRA to visualize, analyze and interrogate multi and hyper-spectral Level1B data.

Capabilities:

We plan to reuse, where possible, HYDRA classes for analyzing and interrogating high spatial and/or spectral resolution datasets. We will tailor the User Interface (UI) directly to the needs of the scientists.

2. Nowcasting
Task Lead: Ralph Petersen

The overall goal of this project is to provide new tools to identify areas of convective destabilization 3-6 hours in advance of storm development using moisture data from current and future GOES satellites. The nowcasting system development has reached sufficient maturity so that the overall objective for 2007 is directed at completing tasks necessary for performing initial product testing in selected NWS/WFOs.

Goal 1: Test Lagrangian Nowcasting System running in real time
Task: Transferring the nowcasting system from the developmental environment to fully automated Linux computers.

Progress: Porting the codes from the current research-based computer has begun. The porting methodology is similar to that used for other models being run regularly at CIMMS. The final steps of the porting should be completed during Q2/07. Once this is accomplished, the connections to the existing real-time web page will be completed and the products will be available to users in real time.

Goal 2: Determine the optimal predictor for DPI nowcasts
Task: Testing the nowcasting system using both multi-layer Total Precipitable Water (TPW) and Equivalent Potential Temperature (θ_e) as conservative tracers.

Progress: θ_e profilers have been obtained for the 13 April 2006 hail storm case. The data will be averaged across multiple levels of the single field-of-view GEOS soundings to create 3-level DPIs of θ_e. Comparative tests of θ_e, vs. layer mean PW will be conducted during the next quarter both to assess the value of using θ_e and to determine the impact of layer-mean T errors from layer-mean Q errors in the θ_e calculations.

Goal 3: Determine utility of Nowcasting products in WFOs
Task: This most important work will be initiated with local WFOs in educating and training of forecasters on the concept of the GOES nowcasting systems and then getting real-time nowcasting products into the WFOs for their evaluation and feedback. The objective of this evaluation would be to improve forecasts of the timing and location of hard-to-predict isolated thunderstorms, and would take into account the utility of the DPI predictions of both 'event' and 'non-event' forecasts.

Progress: Based upon feedback from forecasters and attendees at the AMS Annual Meeting, a final change is needed to the nowcast displays before training can begin at WFOs. This involves identifying areas on the nowcast images where no new data have been available for multiple hours. A new procedure is being incorporated into the display production which adds 'cloud obstructions' based upon whether any observations had been projected into the 10x10km display boxes during the past several during the past nowcast cycles. If no data have been present at that site, a shade of gray is displayed, rather than extrapolating data from surrounding points.

Additional Task: Following recommendations of GOES-RRR TAC, CIMSS has joined with NOAA/ESRL/GSD (formerly FSL) in preparing a collaborative proposal to the JCSDA on improving the use of GEOS data in very short range forecasts from the Rapid Refresh version of the WRF. The proposal both expands upon the success of this nowcasting effort and incorporates new activities to improve the use of cloud data in the WRF-RR.

Presentations/Publications:
Oral presentation at the AMS Symposium on Integrated Observing Systems: An Objective Nowcasting Tool that Optimizes the Impact of Satellite Derive Sounder Products in Very-Short-Range Forecasts, by Ralph Petersen and Robert Aune

Oral presentation abstracts have been accepted for:

AMS Satellite Conference in September, 2007

IUGG Annual Meeting in July 2007.

3. Data Assimilation / Simulations
Task Leads: Jason Otkin, Allen Huang

A proposal submitted by Otkin and Huang to the National Center for Supercomputing Applications (NCSA) at the University of Illinois was accepted in late December 2006. The proposal award for 192,000 processor hours on an SGI Altix supercomputer will be used to perform two high-resolution Weather Research and Forecasting (WRF) model simulations covering very large geographical domains. Proxy atmospheric profile and ABI radiance datasets will be generated for each simulation. Fig. 10 shows the domain configuration for the first simulation. The domains were chosen to correspond to the anticipated GOES-R scanning regions (i.e. full disk, CONUS, and mesoscale). Domain 1 covers the entire GOES-R viewing area with 6-km horizontal resolution, domain 2 covers the CONUS region with 2-km horizontal resolution, and domain 3 represents a special mesoscale viewing region with 667 m resolution. The simulation will be initialized at 00 UTC on 04 June 2004 and then run for 30 hours. It is anticipated that the entire simulation will be completed within 2-3 months. Effort in the adoption of a WRF-3DVar Beta version that has the radiance assimilation capability is also underway.

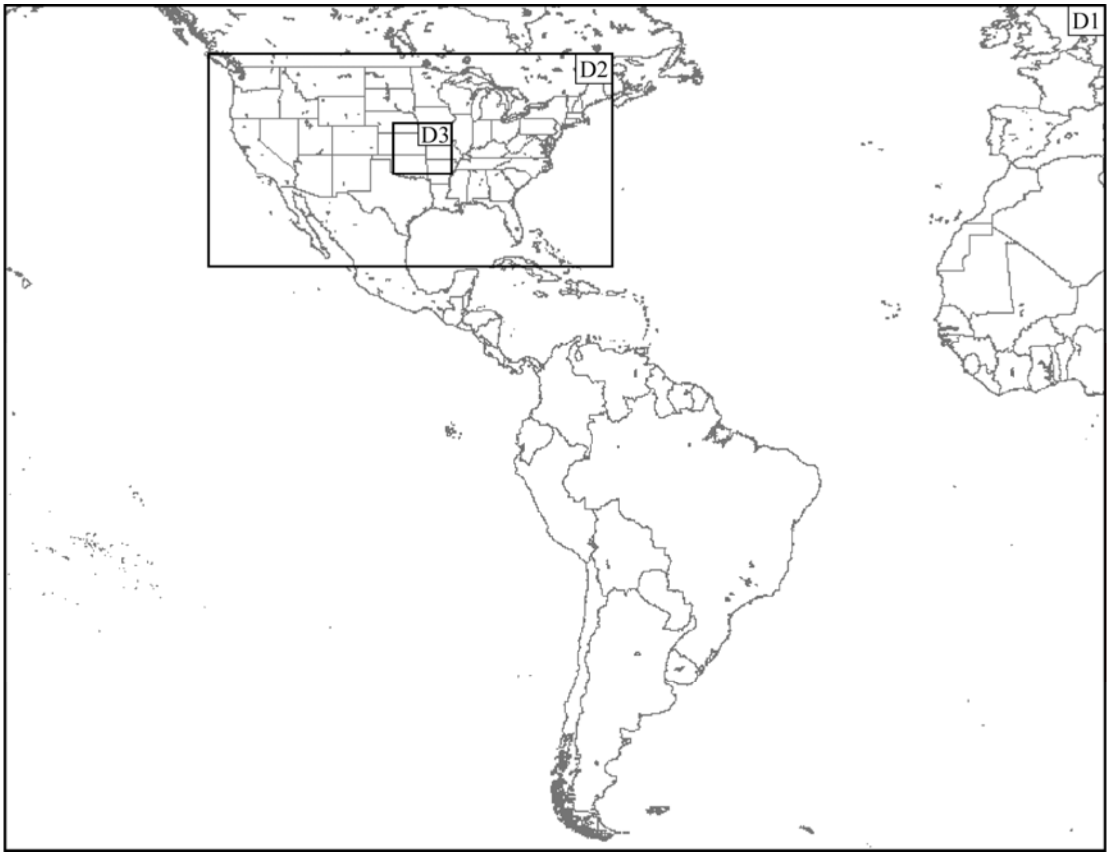

Fig. 10 WRF model domain configuration. D1 contains 6-km horizontal resolution, D2 contains 2-km horizontal resolution, and D3 contains 0.666-km horizontal resolution.

4. Validation
Task Lead: Dave Tobin

Proposed Work

The proposed validation/demonstration activities include 1) efforts to validate the accuracy of combined Geo/Leo temperature and water vapor soundings and 2) Geo/Leo radiance inter-calibration efforts related to GSICS.

Accomplishments

Major accomplishments this quarter relate to the proposed Geo/Leo radiance inter-calibration work. The first major task of the recently formed GSICS (Global Space-Based Inter-Satellite Calibration System) is the development of a system to inter-compare Geo/Leo infrared radiance observations. That is, to intercompare all of the world's Geo sensors by making use of coincident Leo observations. In particular, the various Geo's will be assessed by intercomparing with the AIRS sensor on EOS Aqua. We have proposed to draw upon the CIMSS experience with Geo/Leo intercomparisons and with the high spectral resolution observations to make significant contributions to this project. In particular, we proposed to 1) provide input regarding the optimal use and interpretation of the high spectral resolution AIRS data, and 2) to contribute to the development of the intercalibration system by performing various trade studies to determine the optimal set of criteria (e.g. observation time collocation, spatial collocation, spatial smoothing, view angle constraints, etc.) for the Geo/Leo inter-comparisons. This includes collaboration with other GSICS contributors and involvement in GSICS working group meetings. The expected outcomes are input to the GSICS regarding AIRS data usage, optimal inter-calibration techniques, and analyses regarding the resulting Geo/Leo intercomparisons.

GRWG-I: As part of these efforts, CIMSS scientists Mat Gunshor and Dave Tobin attended the first meeting of the GSICS Research Working Group (GRWG-I) 22-23 January 2007 in the NOAA Science Building in Camp Springs, Maryland. Tobin and Gunshor presented summaries of intercalibration work done at CIMSS over the past decade covering a wide-range of satellite to satellite intercalibration, aircraft-based validation, and ground-based validation of satellite instrument calibration. Recommendations were made to the international GSICS council on how to proceed with coordinated efforts to intercalibrate the world's geostationary imagers using polar-orbiting high spectral resolution instruments such as the AIRS onboard Aqua and eventually the Infrared Atmospheric Sounding Interferometer (IASI) onboard MetOp-A.

GRWG-I prototype code: As a result of the GRWG-I meeting, Tobin and Gunshor provided pseudo-code and test input and output datasets to the group for defining procedures for intercomparing broadband Geo observations with the high spectral resolution AIRS data. These approaches are being incorporated by the various Geo processing centers in order to provide a common approach for performing the Geo/Leo intercalibrations.

Geo/Leo Inter-calibration: Expanding the CIMSS Geo/Leo intercomparison database, initial comparisons of MET-9 to AIRS from late September/early October 2006 have been performed. The results are encouraging, and MET-9 looks to be well-calibrated and in good agreement with MET-8.

AIRS Noise Characterization: A paper describing the analysis of AIRS Earth scene noise characteristics was submitted to the Journal of Atmospheric Remote Sensing: Tobin, D. C., P. Antonelli , H. Revercomb , S. Dutcher , D. Turner , J. Taylor , R. Knuteson , K. Vinson, Hyperspectral Data Noise Characterization using Principle Component Analysis: Application to the Atmospheric Infrared Sounder, Journal of Applied Remote Sensing, 2006, in review.

Preparation for IASI: IASI data from the recently launched METOP-A platform is expected to contribute significantly to the Geo/Leo intercalibration efforts. In contrast to AIRS, IASI has continuous spectral coverage in the thermal IR, and therefore is expected to provide a more accurate reference when simulating broadband sensor response functions. To prepare for IASI data usage, we have downloaded and begun working with preliminary IASI data provided by EUMETSAT via NOAA. Various software tools have been developed, such as file readers and various functions to de-apodize the IASI Level 1-C spectra, reduce the spectra to lower spectral resolution, and to collocate the IASI IR image data with the radiance spectra. We have also begun several studies to assess the accuracy and noise performance of IASI. Initial results suggest that IASI Earth scene spectra are meeting the noise and radiometric calibration specifications. We have also participated in the planning of the upcoming Joint Airborne IASI Validation Experiment (JAIVEx), an aircraft-based campaign in April/May 2007 aimed at providing detailed validation of IASI.

5. Ground Systems
Task Leads: Maciej, Smuga-Otto, Bob Knuteson

The SSEC recently demonstrated a lightweight web-oriented system for distributed processing, management and visualization of hyperspectral data, nicknamed Origami. The first stage of the demonstration took as an example task the calculation of relative humidity fields from other atmospheric state variables, for geo-temporal regions specified by a prior search, with results of the calculation being sent to IDV, a Java-based visualization environment developed by Unidata. The purpose of this demonstration was to highlight the novel use of existing technologies - namely a cluster processing environment, a centralized Storage Area Network and desktop visualization software - in tandem.

The work proposed for 2007 involves addition of new computational tasks to the Origami framework, the packaging of Origami for distribution across multiple projects, and development of the infrastructure itself to make the Origami framework more robust.

In this quarter, planning, requirements gathering and recoding key parts of Origami were all conducted to satisfy the overall goals of this project. Proxy data for GOES-R, composed of existing WRF simulations as well as data gathered from existing instruments, such as the SSEC's Scanning HIS aircraft based interferometer, were evaluated for ingest into the Origami metadata store. Also, requirements gathering and preliminary work was accomplished in the effort to decouple the individual parts of Origami to enable the distribution and independent use of these parts.

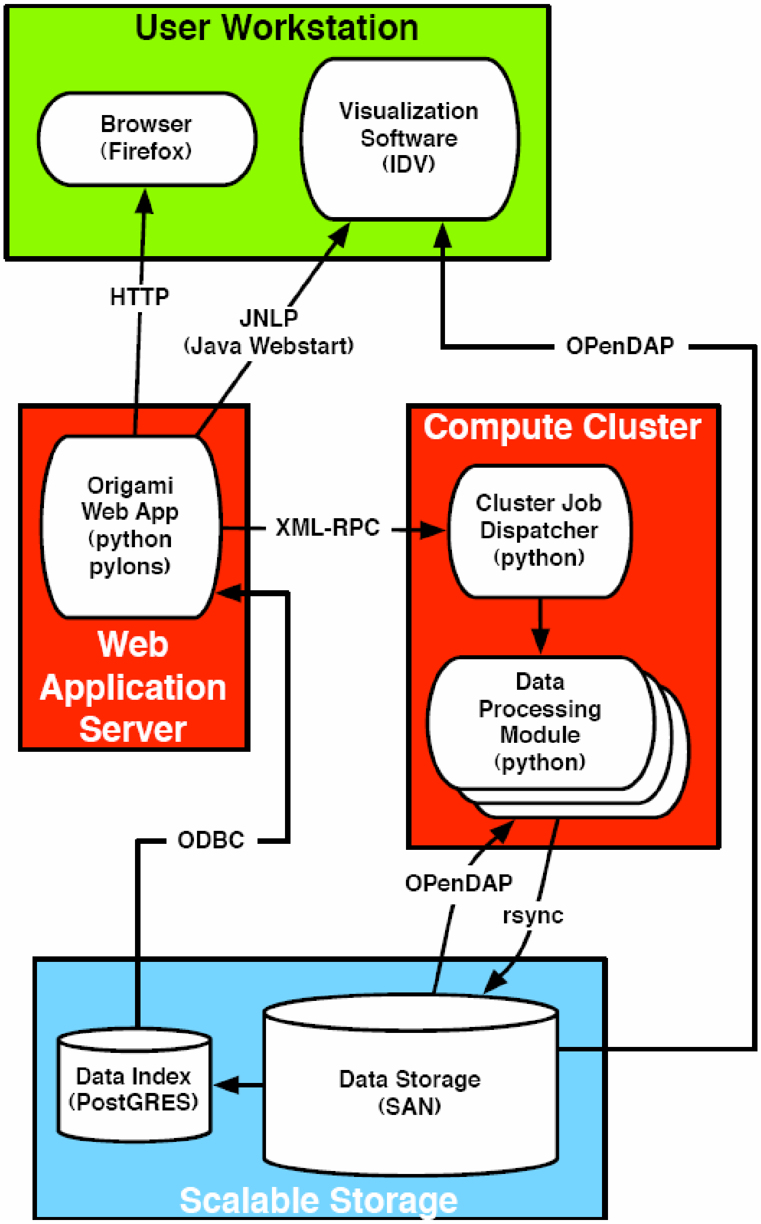

Figure 11: A block diagram of technologies used in the Origami demo, and the connections between them.

End of Report