CIMSS Participation in the
GOES-R Risk Reduction Program

Quarterly Progress Report for
1 July – 30 September 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, Jinlong Li
   - 1.4 Radiative Transfer Modeling - Steve Ackerman, Tom Greenwald
   - 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
   - 1.9 Visualization (HYDRA integration) - Tom Rink, Tom Achtor
2. Nowcasting - Ralph Petersen
3. Data Assimilation / Simulations - Jason Otkin, Allen Huang
4. Ground System – Maciej Smuga-Otto, Bob Knuteson

Program Manager: Tom Achtor

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FY2007 Funding: $800,000

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Table of Contents

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1. Algorithms

1.1 GOES-R3 Sounding Algorithm Development and Risk Reduction

Task Leads: Jun Li, Allen Huang
Other contributors: Elisabeth Weisz, Jinlong Li, Xin Jin, Chian-Yi Liu, Hal Woolf

Handling surface IR emissivity in ABI legacy soundings
Currently the ABI legacy sounding physical retrieval algorithm uses emissivities from a regression based on global training data set developed at CIMSS (http://cimss.ssec.wisc.edu/training_data/). Better handling of surface emissivities are under investigation, there are three other potential approaches: (a) using a pre-determined emissivity database, (b) using independent retrieval emissivities with radiances from multiple time steps, and (3) using emissivity retrievals from LEO (low earth orbit) hyperspectral IR radiances. Approach (3) is currently ongoing, the retrieval method (Li et al. 2007 - GRL) developed for retrieving the hyperspectral IR emissivity spectrum is used to process one month of global AIRS data. The global hyperspectral IR emissivity map will be derived for the SEVIRI/ABI legacy sounding study. The impact of emissivity uncertainty on legacy sounding retrieval will be quantified.

Combining ABI and LEO hyperspectral IR data for sounding evolution
In order to combine high temporal resolution ABI from GEO and hyperspectral IR data from LEO, algorithms for ABI alone in clear skies and hyperspectral IR radiances alone in both clear and cloudy skies are being developed. The ABI legacy sounding physical algorithm has being tested with SEVIRI data while the hyperspectral IR sounding algorithm has being tested with IASI data. See below for details.

ABI legacy sounding physical retrieval algorithm tested with SEVIRI
The **A**BI legacy sounding algorithm has been tested with SEVIRI data through collaboration with EUMETSAT, The EMETSAT Nowcasting SAF (Satellite Application Facility) provided collocated SEVIRI radiance data, SEVIRI cloud single field of view (FOV) cloud mask, ECMWF 12-hour forecast and ECMWF 6-hour analysis. The legacy sounding physical retrieval algorithm were tested with SEVIRI data, results show that physical retrieval does improve the forecast for moisture due to information from the 6.2 and 7.35 µm bands, when added to the forecast. A rmse (root mean square error based on absolute difference) of 2 – 4% for Relative Humidity (RH) is found above the 700 hPa atmospheric layers when compare with ECMWF analysis at RAOB sites. The SEVIRI barely changes the temperature forecast as expected since there is only one CO_2 absorption band. ABI should perform better for legacy sounding products than SEVIRI due to more spectral bands and expected better signal-to-noise ratio.

Hyperspectral IR alone sounding algorithm tested with IASI
A hyperspectral IR radiances alone single FOV sounding algorithm (Weisz et al. 2007 - GRL) has been applied to IASI data. Due to the advantage of high spectral resolution and full spectral coverage, IASI is ideal for a hyperspectral IR radiances alone sounding study, as well as using the data for simulating ABI radiances. The IASI and AIRS from the Joint Airborne IASI Validation Experiment (JAIVEx) have been used to test the algorithm. Very preliminary results show that

IASI and AIRS have the similar sounding capability, there are some differences (vertical structure) between AIRS and IASI in moisture retrieval, which needs to be investigated. The differences might be due to the time difference between AIRS and IASI observations, or instrumental difference between AIRS and IASI. The IASI preliminary results were presented by Jun Li at the EUMETSAT/AMS joint satellite conference in September 2007. Graeme Kelly from ECMWF, John Eyre and colleagues from UK Met Office discussed the hyperspectral IR study with Jun Li during the conference. They thought the SFOV sounding results are very encouraging. The hyperspectral IR alone SFOV sounding algorithm will be further improved in cloudy regions with an advanced physical approach. The ultimate goal is to combine ABI and LEO hyperspectral IR radiances for better legacy sounding evolution. Figure 1 shows an IASI SFOV temperature and moisture retrieval cross-section along with the ECMWF analysis for 2 May 2007 (IASI starting time is 1614 UTC). IASI and analysis agree very well both vertically and horizontally.

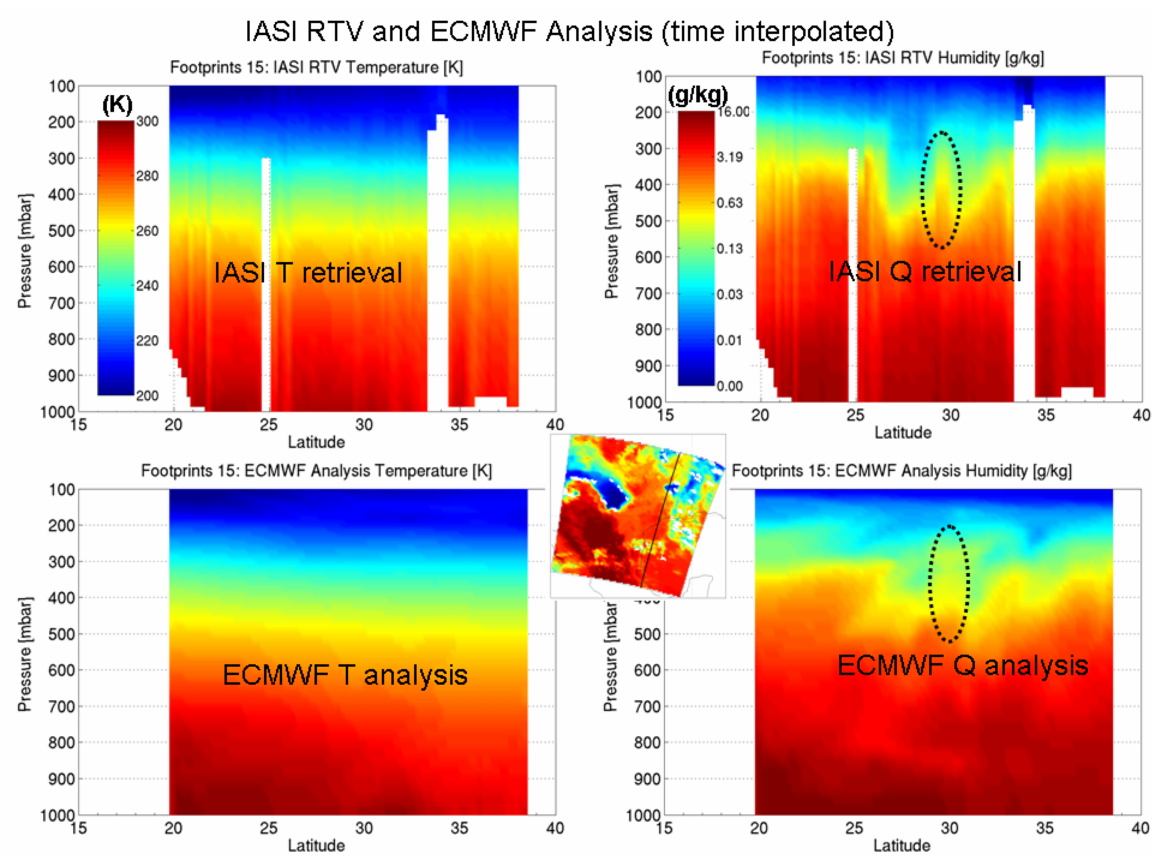


Figure 1. IASI SFOV temperature and moisture retrieval cross-section along with ECMWF analysis for May 02, 2007 (IASI starting time is 1614 UTC).

Peer-reviewed journal publications from 01 July to 30 September 2007.

With partial support of this project, three peer-reviewed journal papers have been published during last three months and one manuscript was submitted for publication.

Li, Jun, Jinlong Li, Elisabeth Weisz, and Daniel K. Zhou, 2007: Physical retrieval of emissivity spectrum from hyperspectral IR radiances. *Geophysical Research Letters*. 34, L16812, doi:10.1029/2007GL030543.

Schmit, T. J., J. Li, J. J. Gurka, M. D. Goldberg, K. Schrab, Jinlong Li, and W. Feltz,

2007: The GOES-R ABI (Advanced Baseline Imager) and the continuation of GOES-N class sounder products, *J. of Appl. Meteorol. Cli.* (submitted)
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,* 34, L12802, doi:10.1029/2007GL030219.
Weisz, Elisabeth, Jun Li, W. Paul Menzel, Andrew Heidinger, and Brian Kahn, 2007: Comparison of AIRS, MODIS, CloudSat and CALIPSO cloud top height retrievals, *Geophysical Research Letters*, 34, L17811, doi:10.1029/2007GL030676, 2007.

Conference presentations from 01 July 01 to 30 September 2007.

Partially under support of this project, Jun Li, Jinlong Li and Xin Jin attended the SPIE annual meeting held in San Diego, CA from 26 – 30 August 2007 and gave three oral presentations on sounding studies.

Jin, Xin, J. Li, J. P. Nelson III, C. C. Schmidt, Z, Li, T. J. Schmit, and M. D. Goldberg, 2007: An improved atmospheric profile retrieval system for GOES Sounder and SEVIRI data, *Proceedings of SPIE 6684*.

Jinlong Li, Jun Li, E. Weisz, T. J. Schmit, M. D. Goldberg, and D. K. Zhou, 2007: Simultaneous retrieval of hyperspectral IR emissivity spectrum along with temperature and moisture profiles from AIRS, *Proceedings of SPIE 6684*.

Li, Jun, Elisabeth Weisz, Jinlong Li, X. Jin, C. Liu, T. J. Schmit, A. Huang, and M. D. Goldberg, 2007: All sky sounding retrievals from hyperspectral infrared radiances alone, *Proceedings of SPIE 6684*.

Jun Li attended EUMETSAT/AMS joint satellite conference held from 24 to 28 September 2007 in Amsterdam, The Netherlands, he gave an oral presentation and two poster presentations.

Li, Jun, et al. 2007: Single Field-of-View Soundings from Geostationary Infrared Sounder Radiances, oral presentation at EUMETSAT/AMS satellite conference.

Li, Jinlong, et al. 2007: Hyperspectral IR emissivity retrieval, poster presentation at *EUMETSAT/AMS satellite conference* (presented by Jun Li)

Weisz, Elisabeth, et al. 2007: Hyperspectral IR SFOV cloudy sounding retrieval, poster presentation at *EUMETSAT/AMS satellite conference* (presented by Jun Li)

1.2 GOES-R Winds Work Summary
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 Matlab and McIDAS stitches the cubes together into a McIDAS AREA file as preparation for the winds retrievals.

Accomplishments in the last three months

Retrieved moisture fields (8 km spatial resolution, 40 minute. temporal resolution) from the FULLDISK case were made available, and these were used to derive winds on 34 constant pressure surface levels (300hPa down to 986hPa). Shown in Figure 2 is a plot of the targets from a single moisture field (729hPa) to show the typical spatial coverage. Figure 3 shows an example of moisture-tracked wind vectors over a selected segment of the FULLDISK.

Given the decommissioning of the HES from GOES-R, this will mark the end of our efforts to demonstrate the three-dimensional winds possible/achievable from a HES-like instrument.

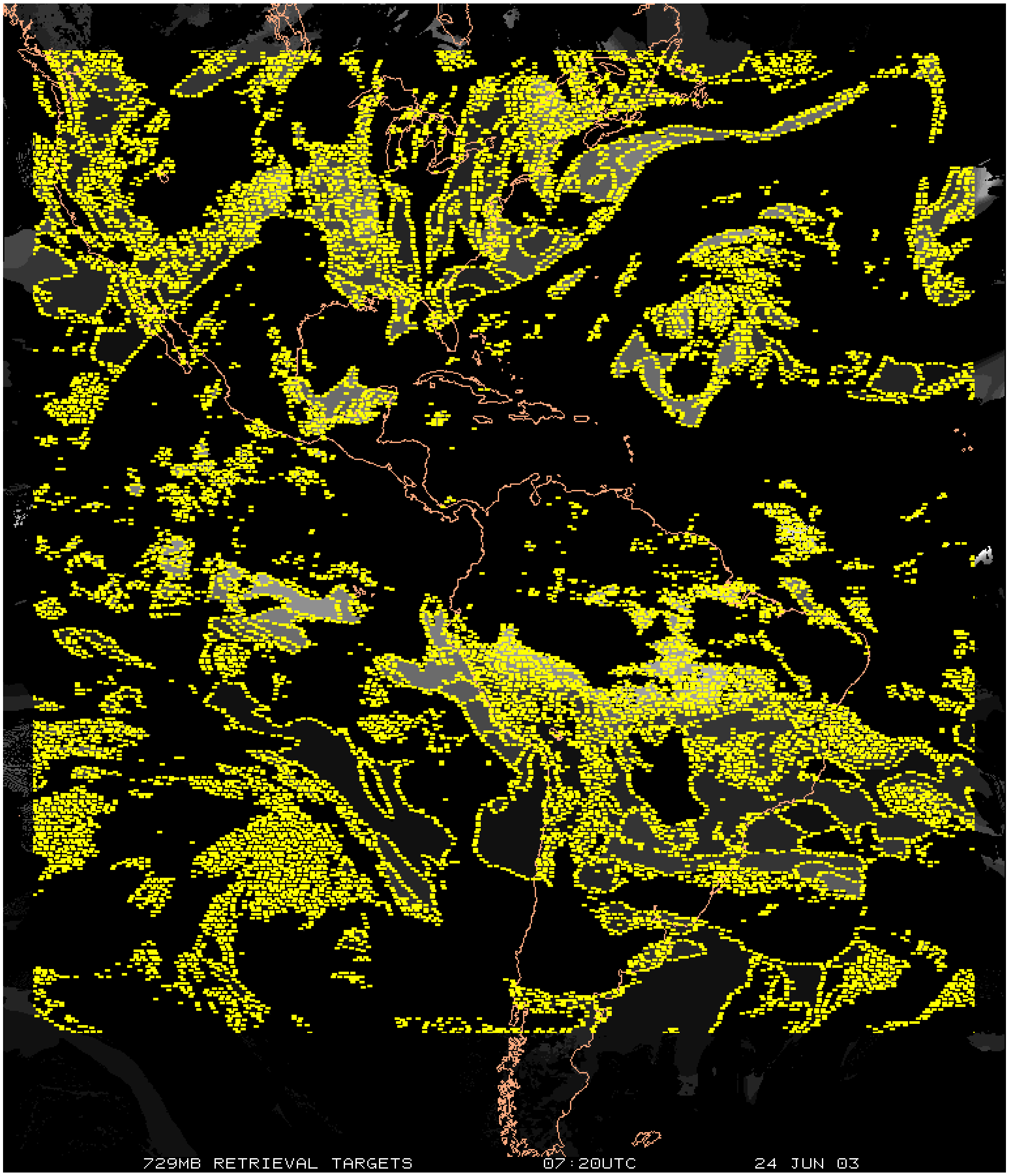


Figure 2. Initial moisture gradient "targets" for a selected constant pressure level analysis (729 hPa) based on simulated HES moisture retrievals.

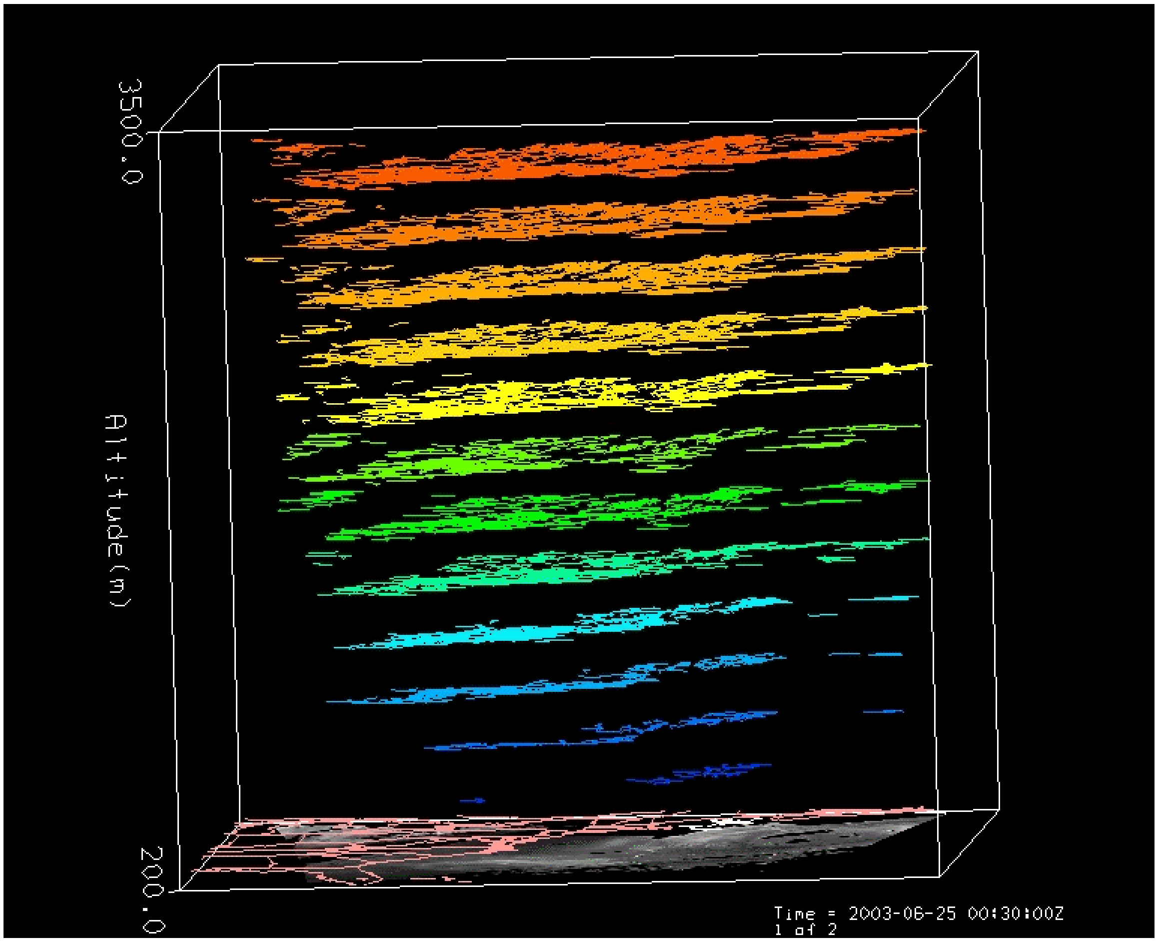


Figure 3. An example of moisture-tracked wind vectors derived from constant pressure level simulated HES retrieved fields for a selected sector of the FULLDISK case, off of the eastern Atlantic seaboard. The plot emphasizes the marine levels, and shows the vertical resolution achievable.

1.3 Ozone
Task Lead: Jun Li, Jinlong Li
Other contributors: Xin Jin, Christopher C. Schmidt

Total column ozone bias study

We have applied an ABI total column ozone (TCO) algorithm to process SEVIRI data. We found that SEVIRI underestimates TCO over the ocean. After investigation, we think that some of the bias may be due to low cloud contamination over the ocean, which leads to apparently colder skin temperatures, which effectively lowers to TCO value. Given the same atmosphere and same observed brightness temperatures a cooler skin temperature will appear to have less ozone above it than a warmer skin temperature, leading to an underestimate of the ozone column. This is due to the fact that the 9.6 um band is an absorption band and the radiance difference between it and other window channels is the largest single source of ozone information in the algorithm. Decreasing that difference decreases the apparent TCO. Another possible reason is that the training database contains fewer samples over ocean, and the regression is likely biased toward cooler skin temperatures for given surface air temperatures. Therefore, handling low clouds and expanding training over ocean is important to reduce the bias over ocean.

SEVIRI TCO compared with the AIRS ozone product

We compared the co-located TCO products between SEVIRI, AIRS and OMI (Ozone Monitoring Instrument on EOS Aura) using data between 14 and 15 February 2006. To minimize the errors caused by the different spatial resolutions we only compared the pixels within 5 km. Using OMI as the standard, comparisons show that SEVIRI and AIRS have similar TCO accuracy over land, while AIRS has a larger RMSD (root mean square difference) over ocean. The larger RMSD over ocean might be due to the cloud contamination in AIRS FOR (field of regard, 45 km). Table 1 shows the SEVIRI and AIRS TCO RMSD over land and ocean, respectively.

Table 1. RMSD between OMI and SEVIRI/AIRS TCO

Instruments	SEVIRI	AIRS
Over Land	12.6	13.1
Over Ocean	13.3	22.5

Publications during 1 July – 30 September 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* (in press).

1.4 Radiative Transfer Modeling
Task Leads: Steve Ackerman, Tom Greenwald

Proposed work

The main goals of this task are to expand on our previous GOES-R Risk Reduction RTM activities by extending cloudy sky RT calculations into the solar spectrum and by developing a "unified" RTM that is applicable from the solar through the microwave. Developing fast methods for computing solar radiance that are needed for simulating ABI channels 1-7. A unified RTM will provide a simpler and more consistent framework from which to compute radiances in support of the proxy data and other multi-spectral applications.

During this period we have begin to build a full solar capability into the Successive Order of Interaction (SOI) RTM initially developed by Heidinger et al. 2006. Currently, the SOI model has the ability to compute solar radiances (in addition to thermal radiances) but assumes an azimuthally averaged radiance field. The model is undergone modification to include a Fourier expansion of the radiance field. Cloud optical property databases developed by Baum et al. 2005 will also be utilized from the solar through infrared. Optical property databases in the microwave have already been developed. We anticipate exploiting well-known OPTRAN-like approaches for computing gas absorption.

We also are utilizing another fast model developed at Texas A&M University, called FIRTM-AD (Zhang et al. 2007), which is more accurate than our current 2-layer-cloud IR RTM (FIRTM2) and which allows multiple cloud layers. Comparative tests will be undertaken between the SOI RTM, FIRTM-AD and FIRTM2 in the thermal infrared.

Accomplishments:

The code for the full solar version of SOI RTM as been developed; we are currently in the process of fully testing the model. Significant modifications to the forward model system were needed to accommodate new solar SOI RTM.

To satisfy the cloud simulations, we have completed Mie calculations from 0.42 microns to 2.3 microns for 16 different sized water spheres and decomposed the scattering phase function data into Legendre polynomial expansion terms. This is part of a lookup tables and we have completed the code to read tables.

The decomposed scattering phase function data for ice particles for ABI bands 1-7 have also been generated and converted to lookup tables with code to read tables.

Peer-reviewed journal publications:
Zhang, Z., P. Yang, G. Kattawar, H.-L. Huang, T. Greenwald, J. Li, B. Baum, D. Zhou, and Y. Hu, 2007: A Fast Infrared Radiative Transfer Model Based on the Adding-Doubling Method for Hyperspectral Remote Sensing Applications, J. of Quantitative Spectroscopy & Radiative Transfer, in press.

1.5 Surface Properties
Task Lead: Bob Knuteson
Other contributors Leslie Moy, Eva Borbas, Allen Huang, Suzanne Seemann

Comparison of Land Surface Emissivity from MODIS, AIRS, and SEVIRI
An accurate infrared land surface emissivity product is critical for deriving accurate land surface temperatures, needed in many studies including surface energy and water balance research. An emissivity product is also useful for mapping geologic and land-cover features. Three emissivity products have been developed from MODIS, AIRS, and SEVIRI satellites, each with their own methodologies and associated strengths and weaknesses. Calculations of brightness temperatures using the different emissivity products will be compared to observed SEVIRI channels.

The observed top of atmosphere (TOA) radiation is the sum of atmospheric, surface, and reflected contributions. Using a Radiative Transfer Model (RTM) to make calculations for each part we can easily evaluate the TOA radiation assuming any given surface emissivity. Then we can compare these calculated radiances to observed SEVIRI radiances for an objective evaluation of the different emissivity products.

The calculated brightness temperature using the three different emissivity products is in good agreement with SEVIRI observations at 12.0 µm - about +0.1 K, +0.1 K and -0.4 K respectively for UW MODIS Baseline Fit (BF), Land Surface Analysis Satellite Applications Facility (LSA SAF), and AIRS Level 2. At 10.8 µm the agreement is good also; approximately +0.4, +0.6, and -0.02 K respectively. However all the emissivity models lead to a disagreement with SEVIRI observations of about +3 K at 8.7 µm, and between +2.3 to +2.9 K at 3.9 µm. The use of 12.0 and 10.8 µm for the determination of land surface temperature appears to be valid. UW MODIS BF and AIRS L2 emissivities are in generally good agreement with each other while the LSA SAF emissivity is limited by its lack of spatial detail.

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

GOES-R ABI biomass burning research and development activities for 2007 focuses 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. These risk reduction activities will ensure enhanced future fire detection, monitoring and characterization.

Accomplishments:
Simulated ABI data has been created from MODIS data. The CIMSS technique accounts for the viewing geometries of the two satellites and the spatial response function of the ABI when generating the simulated imagery. This remapped data is being used as proxy data for the GOES-R ABI WF_ABBA development effort. Figure 4 compares the output from the new CIMSS remapping technique and the standard nearest-neighbor technique. The WF_ABBA has been applied to the PSF-remapped data and the results are encouraging.

CIMSS continued to work with the proxy data team at CIRA to develop model-derived ABI proxy data for use with the WF_ABBA. CIRA delivered three cases: *(i)* fires of constant size and temperature over the course of several hours with no clouds, *(ii)* fires of constant size and varying temperature over the course of several hours with no clouds, and *(iii)* fires of constant size and temperature with a field of convectively induced clouds. CIMSS has applied the WF_ABBA to the three cases and the WF_ABBA has performed well, with the most difficulty being introduced by the clouds in the third test dataset, as expected. In the clear sky cases WF_ABBA derived fire size are within 50% of "truth", which is within specification. Fire Radiated Power (FRP) was also calculated, and FRP values derived from radiances agreed with FRP values derived from instantaneous fire size and temperature as calculated by the WF_ABBA for reasonably large fires with temperatures between 650 K and 1200 K. Outside of that range of size and temperatures derived the two FRPs were poorly correlated. The same result was obtained when 2004-2006 GOES data was analyzed. Calculating FRP "truth" in the case of the model-based proxy data is a difficult task given the large number of saturated pixel present in the model-derived case. Those calculations are underway.

The UW Baseline Emissivity dataset has been integrated into the GOES-R ABI WF_ABBA as a replacement for the look-up table that had been utilized in the past.

Conference Publications:
Schmidt, Christopher C., Elaine M. Prins, Jay P. Hoffman, Scott Lindstrom, Jason C. Brunner, and Joleen Feltz, 2007: GOES-R ABI fire detection and monitoring with the WildFire ABBA, The joint 2007 EUMETSAT Meteorological Satellite Conference and the 15th America Meteorological Society (AMS) Satellite Meteorology & Oceanography Conference, RAI Center, Amsterdam, Netherlands, 24-28 September 2007.

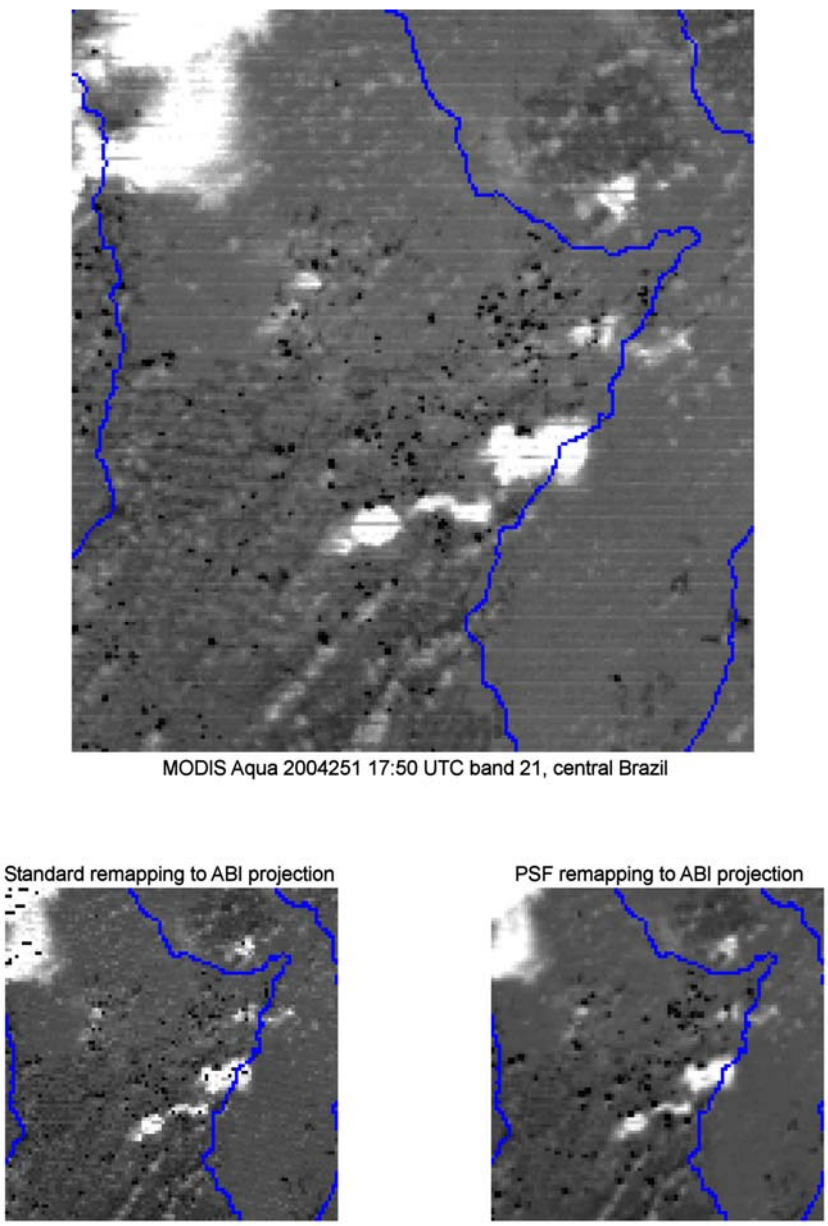


Figure 4. Original MODIS data from 28 August 2004 17:50 UTC AQUA overpass over central Brazil is on top. Remapping utilizing standard nearest-neighbor technique is on the left and utilizing the new CIMSS technique incorporating point spread functions is on the right. ABI simulated data was remapped from source 1 km data to 2 km ABI with ABI navigation. Fire shapes and locations are highly distorted on the left but look much closer to the original MODIS image when the PSFs are used. This image was located near the center of the MODIS overpass, and the remapping has blended the striping noise into the data in the PSF remapped image while creating patterns in the left-hand image.

1.7 SATCAST / Convective Initiation
Task Lead: Wayne Feltz

Work Proposed
This research task seeks to adapt a GOES imager infrared cooling rate and convective initiation algorithm 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 proposed to take advantage of the current Convective and Orographically-induced Precipitation Study (COPS) being conducted 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). Transitioning the SNAAP/ASAP convection initiation and mesoscale atmospheric motion vector applications to using SEVIRI radiance inputs has been accomplished. This experiment has ended but it has provided 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.

Accomplishments
The GOES imager SatCAST algorithm has been successfully adapted to use SEVIRI radiances as input datastream. Additional channels including 8.5 and 12.0 μm have been used to optimize algorithm performance. SATCAST has been implemented at EUMETSAT in collaboration with Marianne Koenig and Volker Gaertner and was used for operational support during the COPS experiment which ended on August 31, 2007. The convective initiation datasets are being archived for further study and Dr. Marianne Koenig has requested that members of our SNAAP team return to Darmstadt after COPS has ended to review possible cases of interest for study. An online archive is located at this address: http://cimss.ssec.wisc.edu/snaap/cops/quicklooks.php

The SATCAST algorithm is currently using 15-minute resolution SEVERI data however a special 5-minute temporal resolution mode has been invoked over the COPS domain during intensive operational periods. This 5-minute SEVIRI data has been archived at EUMETSAT and is accessible for case study use. Currently, a new methodology for calculating cooling rate by taking advantage of higher temporal resolution SEVIRI and GOES imager data is being investigated since the current SATCAST algorithm requires calculation of mesoscale winds which will most likely not be needed for 30-sec or 5-minute resolution ABI modes of operation. The removal of the requirement to calculate mesoscale wind reduces computational expense and improves temporal latency of satellite derived convective fields. Preliminary validation of the SATCAST SEVIRI CI products is being conducted in collaboration with EUMETSAT and new box-average CI cooling rate will be investigated, taking advantage of higher temporal resolution expected from ABI. A case study was also conducted for a convective case occurring over South Africa in support of Marianne Koenig (EUMETSAT) and Estelle de Coning (South African Weather Service) to demonstrate cooling rate/CI algorithm flexibility over various geographical domains. Figure 5 shows results when applying the cooling rate/convective initiation methodology over South Africa. Results were presented at the EUMETSAT/AMS Satellite Conference in Amsterdam 24-28 September 2008.

In the 4th quarter, Marianne Koenig will visit SSEC/CIMSS to focus on validation of convective initiation product and Kris Bedka will be working with her to optimize the algorithm using 5-minute SEVIRI data. The CTCR and CI algorithm will be executed over South Africa during the convective season from November 2007 – January 2008 which should provide another rich validation data set to help transition algorithm to ABI. An abstract titled “Improving Nowcasting of convective storm development using MSG SEVIRI, MODIS, and GOES-12 imagery as risk reduction for GOES-R ABI" was submitted for the 2008 AMS GOES User's Conference which describes our GOES-R risk reduction effort.

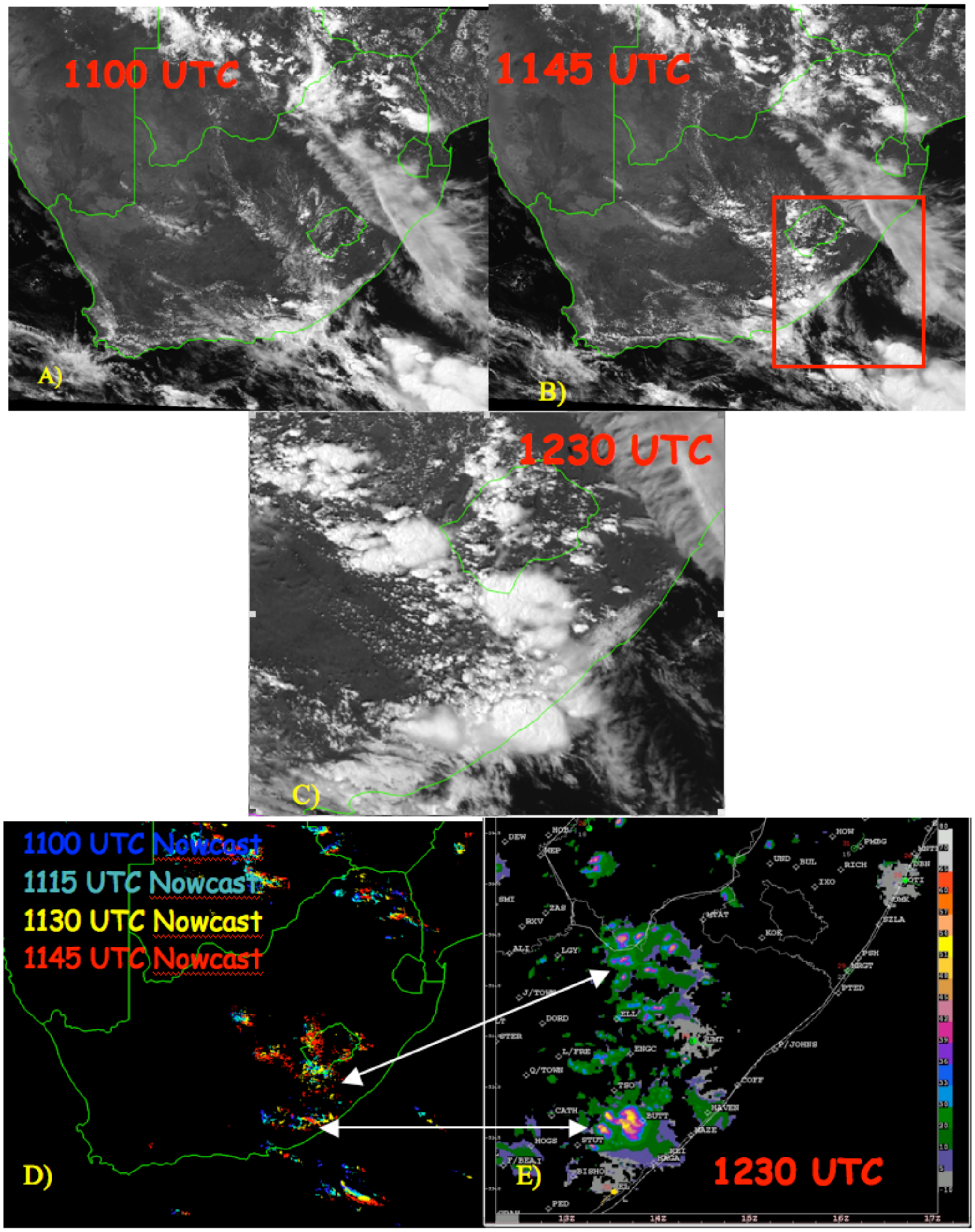


Figure 5: SEVIRI visible images in panels A-C indicate rapid development of convection over the S. Africa region between 1100 and 1230 UTC. Panel D shows the SEVIRI imager based box-average convective initiation nowcast for consecutive 15-minute data. Panel E indicated radar echo intensification in very near proximity of nowcast convective development.

1.8 Tropical Cyclones

Task Leads: Jim Kossin

Other contributor: Matthew Sitkowski

When hurricanes become intense (V > 100 kts), they sometimes form a second eyewall at some distance around their primary eyewall. This "secondary eyewall formation", which we abbreviate as SEF, is generally the precursor to an eyewall replacement cycle. These cycles often cause dramatic and rapid changes in intensity and are very important to recognize in a forecasting setting, particularly when a hurricane is approaching land. At present, forecasters have no objective methods to help recognize SEF, and they need to rely on aircraft reconnaissance data, coastal radar imagery, or satellite microwave imagery to make a subjective determination of whether SEF is occurring or not. These data are not always available in a timely manner.

A major goal of this project is the construction of an algorithm that will utilize environmental analyses and GOES IR imagery, all readily available in an operational setting, to objectively diagnose SEF in real-time. Our first milestone for this quarter is the completion of an exhaustive and unprecedented database of global SEF occurrence. Over 4,500 SSMI, SSMIS, TRMM, and AQUA microwave images were downloaded from the Naval Research Laboratory website. The images, in combination with aircraft, radar, and additional satellite data, were used to examine nearly 175 tropical cyclones to determine the approximate time of SEF. A catalogue of major tropical cyclones and the number of these that experience SEF are shown in the top two rows of Table 2. Some storms experience more than one occurrence of SEF in their lifetime, and this is reflected in the bottom row of the table.

Table 2: Inventory of major tropical cyclones (TC), and climatology of SEF occurrence.

	1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**Sum**
Major TCs	21	14	14	12	18	19	14	23	19	19	173
SEF TCs	11	5	6	7	9	13	10	14	10	13	98
SEF Cases	15	5	7	7	10	16	16	28	20	21	145

The inventory shown in Table 2 is global. For this project we are interested in the future application of GOES-R imagery in the North Atlantic and Eastern North Pacific, where about 35% of SEF occurrence takes place (Figure 6). We are presently constructing a broad objective SEF climatology for these basins.

For each fix where a storm had maximum winds greater than 100 kt, our new database allows us to answer the question: does this storm form a secondary eyewall in the following 12 hours or not? The climatology of SEF counts from our new inventory tells us that there is a 26% probability of SEF *on average*. Our second milestone for this quarter is the addition of skill to this climatological probability based on environmental conditions.

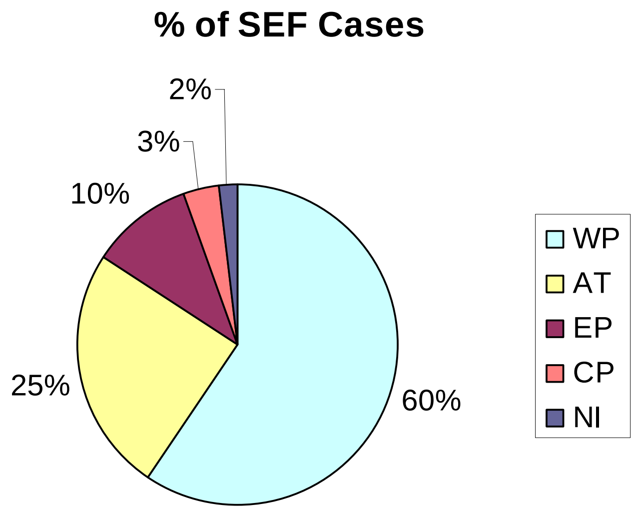


Figure 6: Distribution of SEF occurrence by ocean basin.

Thus far, we have identified a number of environmental features that relate significantly to SEF. These include the amplitude and meridional structure of the ambient SST anomalies, low-level and mid-level moisture, vertical wind shear, and lapse rates, among others. To identify these environmental features, we first centered the environmental reanalysis fields about the storm center at every 6-hourly storm position fix, and then we performed composite analyses, which were then subjected to statistical significance tests. Additionally, Principal Component Analysis (PCA) was applied to the storm-centric environmental fields and the expansion coefficients of the leading modes of environmental variability were stratified by cases of SEF and tested for statistical significance. As just one example, the composite analysis for sea surface temperature (SST) is shown in Fig.7. We find that SEF is associated with warmer SST in general, and the differences are particularly pronounced to the north of the storm center. This indicates a reduction of meridional SST gradient associated with SEF, which is physically reconcilable with the hypothesis that SEF is more likely in an environment that's more symmetric around the storm.

We then applied the features identified in the composite analyses and PCA in a Bayesian classification framework that combines climatological probabilities of SEF with "class conditioned" probability density functions for the environmental features. Here, we have two classes (binary classification). Class 1 comprises tropical cyclone fixes with intensity greater than 100 kt, but no SEF occurred in the following 12 hours. Class 2 comprises the sample of cases where SEF did occur within 12 hours. The Bayesian classifier provides probabilities that a particular group of features belongs to a particular class. Figure 8 shows how much additional skill beyond climatology is gained with the inclusion of the feature matrix. The climatological probability of 26% is what we would always predict if we had no other information. With the inclusion of the feature matrix, we correctly predict, on average, significantly higher probabilities in class 2 and lower probabilities in class 1, as desired.

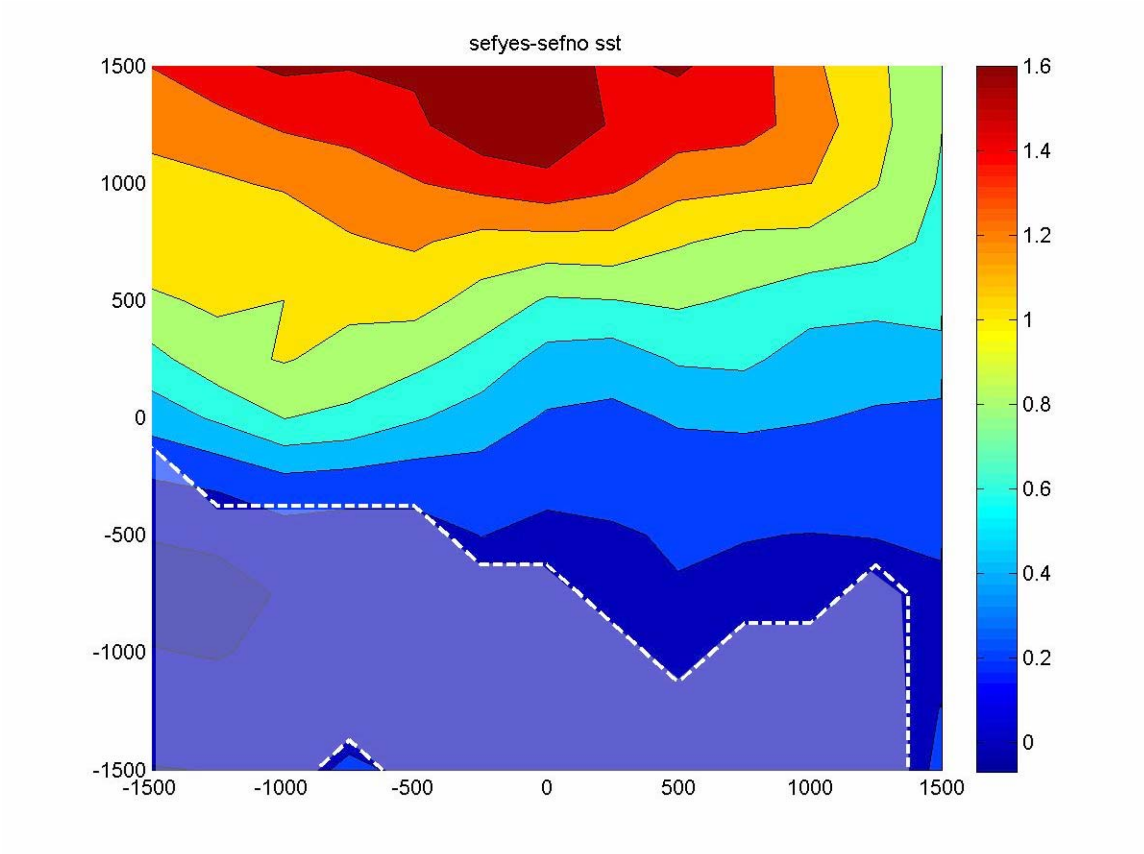
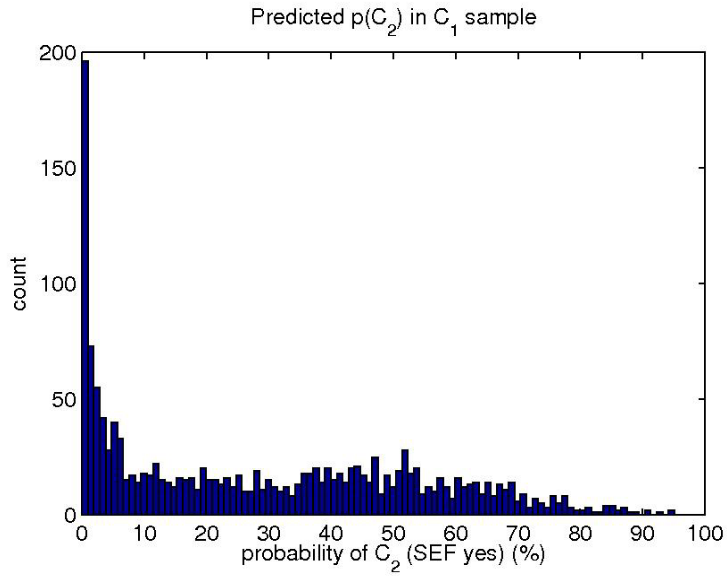


Figure 7: Composite differences in storm-centered sea surface temperature between cases where SEF occurred at some time in the following 12 h versus cases where no SEF occurred. All differences outside the shaded region are significant at 95% in a two-sided t-test.

As we continue to explore the environmental features related to SEF, a crucial step in our future work will be the inclusion of GOES infrared imagery in our analyses to extract new features in the brightness temperature fields that relate to SEF. Another important future step will be the inclusion of the existing features that are used in the SHIPS model. This will allow us to directly compare the environments associated with SEF to the environments associated with annular hurricane formation. This will then ultimately enable us to mesh our algorithm with the annular hurricane algorithm developed at CIRA by John Knaff and Mark DeMaria.



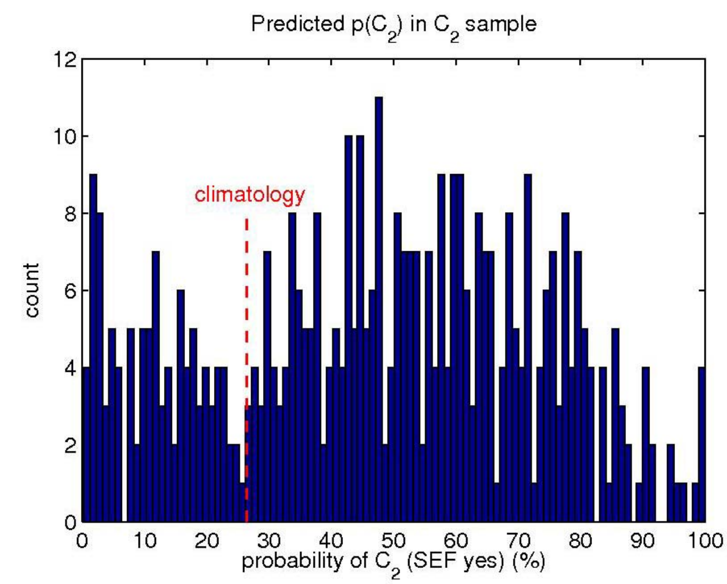


Figure 8: Distribution of predicted probabilities that SEF will occur within the next 12 hours. Top panel: cases when SEF did not occur. Bottom panel: cases when SEF did occur. All points to the right of climatology in the bottom panel represent cases where the feature matrix provided useful information (skill in the large sample).

1.9 Data Analysis and Visualization: HYDRA integration
Task Lead: Tom Rink, Tom Achtor

Support for hyper-spectral visualization and analysis is being added to the IDV (Integrated Data Viewer) by re-developing and enhancing HYDRA capabilities in terms of the IDV development framework. The initial plan is to make these enhancements available to both IDV and McIDAS-V (IDV based) users through the IDV plug-in architecture. Over time, a separate application may be needed but that's to be determined at this point in development; the former would be preferred. The goal of this project is the development of an interactive analysis and visualization system capable of fusing geo-science data including satellite (Hyper-Spectral, Multi-Spectral), as well as, in-situ observations and NWP.

Specific tasks completed for this reporting period include the incorporation of IASI and AIRS, Level1C and Level1B respectively, radiances into the IDV framework (see Figure 9). The important step here was to include HYDRA's abstract data adapting layer for multi-dimension data. This layer is designed to be extensible to new satellite instruments and particular storage formats. Currently, NetCDF, HDF4 and OpenDAP are supported, and soon HDF5 will be available via Java-NetCDF. In addition to data acquisition, much progress has been made in employing IDV data and display software components to add HYDRA-type functionality to IDV architecture. This includes extensions to the appropriate IDV Java classes to capture HYDRA's optimizations specific to high spatial and spectral resolution data.

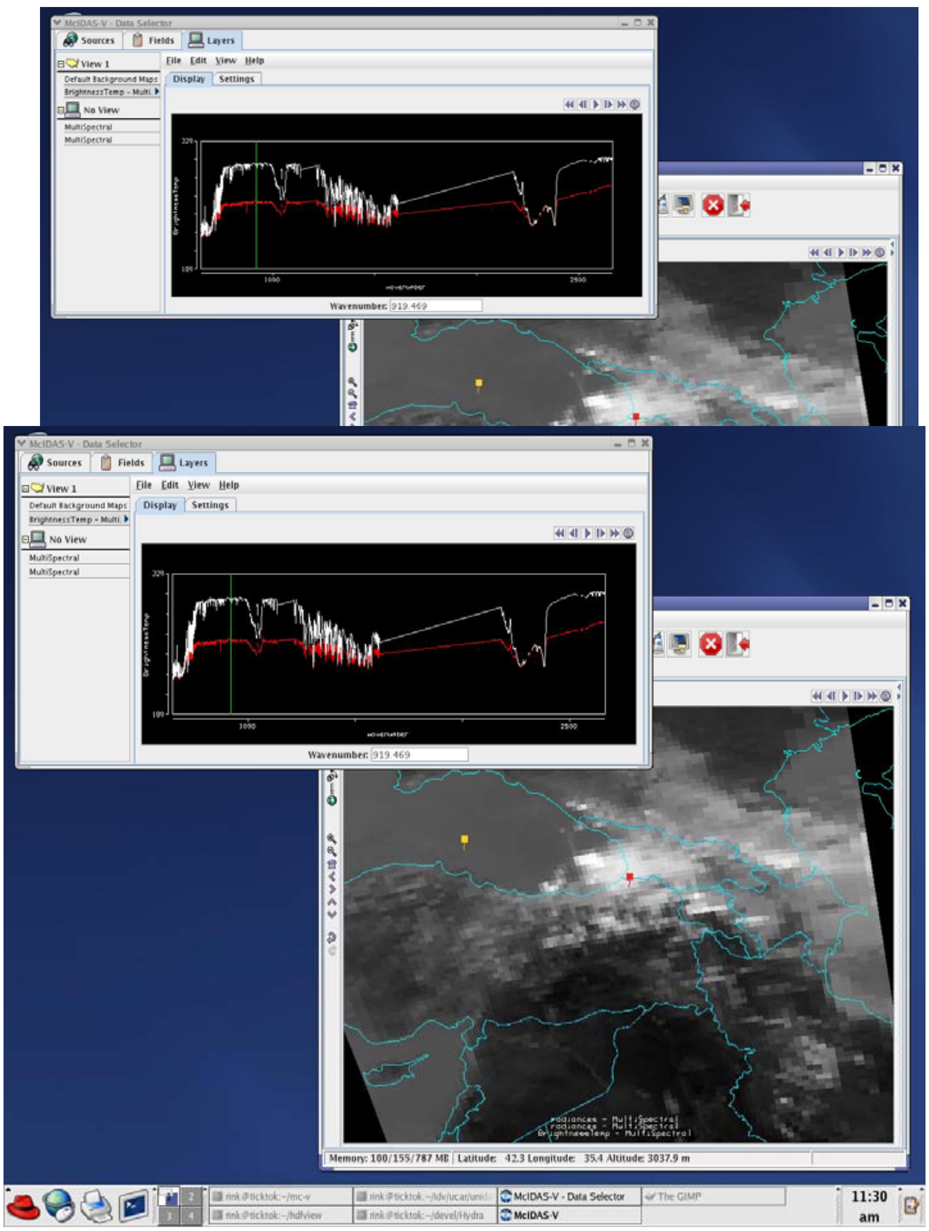


Figure 9. Depiction of AIRS and IASI data in McIDAS-V.

2. Nearcasting
Task Lead: Ralph Petersen

The overall goal of this project is to provide and test new tools to identify areas of convective destabilization 1-6 hours in advance of storm development using moisture data from current and future GOES satellites. Note that the name for this effort has changed. Because the term "Nowcasts" is traditionally used to describe 0-1 hr projections made by extrapolation of radar observations, these slightly longer range products based primarily on satellite data are being called "NearCasts".

Testing Lagrangian NearCasting System running in real time
Task: Transferring the NearCasting system from the developmental to fully automated Linux computers.
Progress: Porting the codes from the current research-based computer is nearly completed. Remaining problems with graphics programs are being resolved with additional programmer support. Run times on the new hardware systems appear to be about 10 times faster than on the older developmental hardware. CIMSS has committed to have the systems ported, tested and running 24/7 prior to transfer to CCNY-CREST later this fall.

Determining the optimal predictor for DPI NearCasts
Task: Testing the NearCasting system using both TPW and θ_e as conservative tracers.
Progress: Significant effort has been placed in removing undesirable, small-scale 'noise' from the initial wind fields obtained from the RUC-II. Tests showed that significant smoothing was necessary to eliminate small-scale imbalances from the initial wind fields, which contain excessive divergence and deformation which can amplify in the later hours of the NearCasts. Alternatives based on partial geostrophic and/or semi-geostrophic balance have shown little additional success. In addition, the use of RUC 3-hour forecast (versus analysis) wind fields both appear to be more dynamically consistent than the initial analyses and also are available from previous RUC runs immediately upon access to the GOES DPI data, thereby allowing the NearCasts to be run sooner. Additional verifications were also developed using surface-based GPS TPW as a standard (see Figure 10) which validate rapid successions of water vapor increase and decrease observed by GOES NearCast products, but not present as vividly in NWP guidance.

Determining the utility of NearCast products in WFOs
Task: This most important work is being initiated with local WFOs both in educating and training of forecasters on the concept of the GOES NearCasting systems and then in getting real-time NearCasting products into the WFOs for their evaluation and feedback. The objective of this evaluation is to improve forecasts of the timing and location of hard-to-predict isolated thunderstorms, and will test the utility of the DPI predictions of both 'event' and 'non-event' forecasts.
Progress: Results of NearCasting development efforts were presented at three meetings during the last quarter, included IUGG in Italy in July, AMS/Eumetsat Satellite in Amsterdam in September, and the NWS Great Lakes Operation Meteorology (GLOM) Workshop in Milwaukee in September. Interest was expressed by Eumetsat for possible future transfer to the system for their operations. Forecasters at GLOM responded extremely positively and several additional SOOs offered to participate in the assessment process. Planning for training and data display in WFOs is continuing, with a training session being planned for GRB in January 2008.

Additional Task: The joint CIMSS-NOAA/ESRL/GSD Nowcasting Proposal to JCSDA (for GOES-RRR Nowcasting funds and as recommended by TAC) which was submitted earlier in the year was denied with a statement that proposal was outside of scope of JCSDA priorities.

In September, a CCNY-CREST graduate student was trained on the use of the model at CIMSS, with the goal of integrating the moisture prediction capabilities of the NearCasting Model with the hydrological prediction efforts developing at CCNY.

Presentations/Publications: Oral presentation abstracts have been accepted for GOES-R User's Workshop, New Orleans, January 2008.

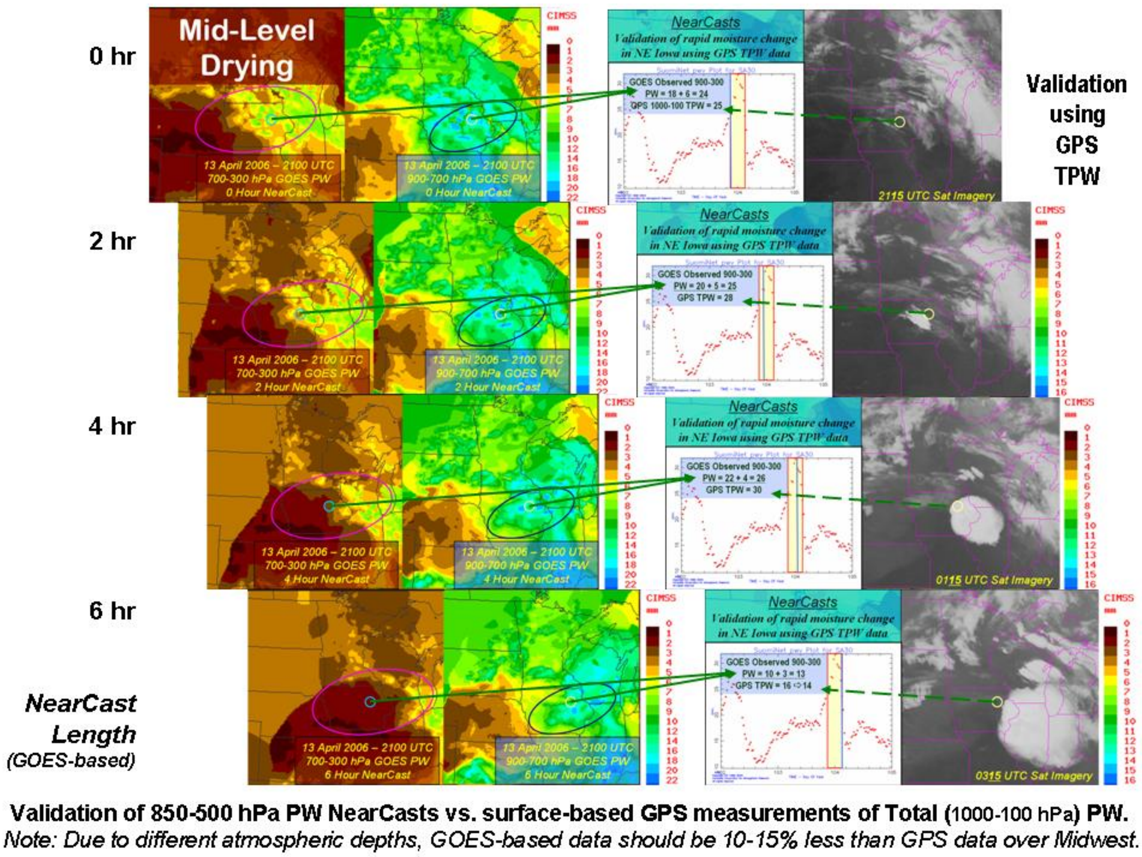


Figure 10. Example of verification observations and NearCasts of GOES 2-layer Precipitable Water (G-PW) with surface GPS Total Precipitable Water (TPW) data from northeastern IA for case of rapidly developing convection. Note that the speed of both the moistening prior to storm development and drying after in the G-PW products are corroborated by the independent GPS data, as well as the magnitude of the G-PW data.

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

In an effort to more thoroughly characterize the realism of proxy ABI radiance datasets derived from numerical model output, a very large, high-resolution Weather Research and Forecasting (WRF) model simulation is currently being performed at the National Center for Supercomputing Applications (NCSA). The simulation contains a single 5950 x 5420 grid point domain with 52 vertical levels covering the entire Meteosat viewing domain between 58º S and 58º N with 3-km horizontal resolution (Figure 11). Due to the large size of the simulation, 300 processors and nearly 1.5 TB of memory are currently being utilized on the NCSA supercomputer. The Meteosat domain was chosen for this case in order to leverage the availability of many ABI-like channels on SEVIRI, as well as to utilize its high spatial and temporal resolution. Upon completion of the simulation, high-resolution proxy ABI and SEVIRI brightness temperature datasets will be generated from the WRF model data and then compared to the corresponding SEVIRI observations in order to validate the forward radiative transfer models and the realism of the proxy datasets.

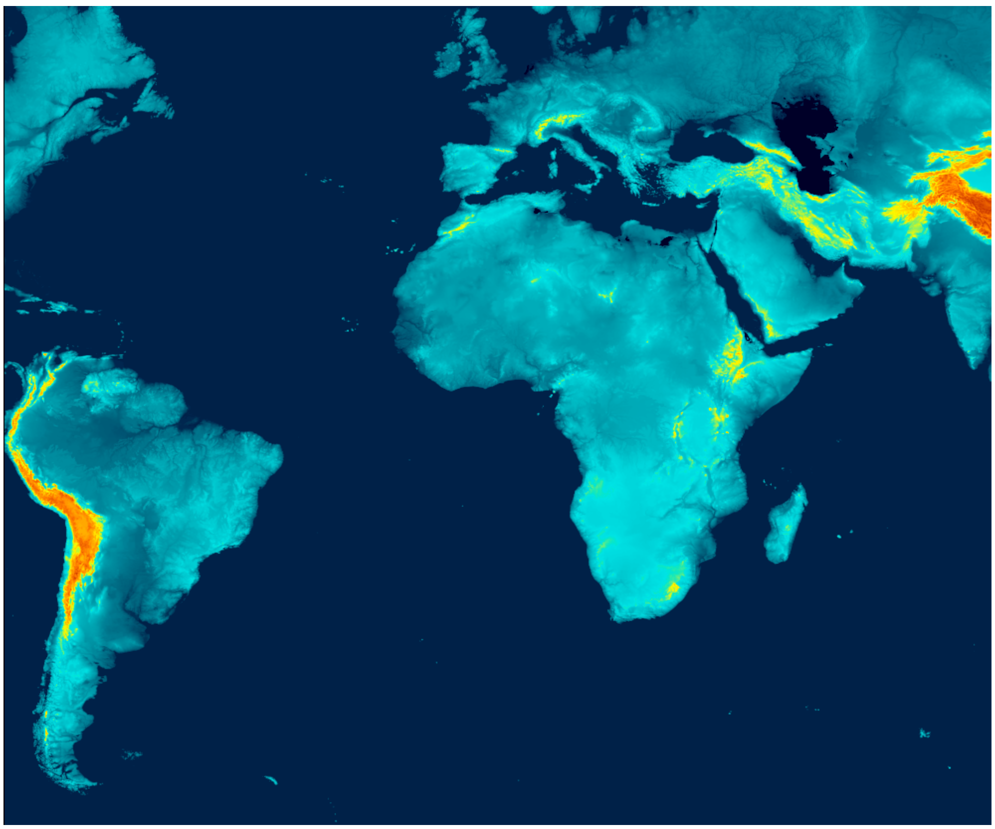


Figure 11. WRF model domain configuration. The domain contains 5950 x 5420 grid points with 3-km horizontal resolution.

Earlier this year, we completed a large WRF model simulation containing three nested domains designed to represent the anticipated GOES-R scanning regions (i.e. full disk, CONUS, and mesoscale) with the appropriate spatial and temporal resolutions. Proxy atmospheric profile and ABI radiance datasets with 30-minute temporal resolution were generated for each domain during a 24-hour period from 06 UTC on 05 June 2005 to 06 UTC on 06 June 2005. Additional datasets with very high temporal resolution (15-minute full disk, 5-minute CONUS, and 1-minute mesoscale) were also generated for a two-hour period from 22 UTC on 5 June to 00 UTC on 6 June.

In order to account for differences in both the map projection and horizontal resolution between the model-derived proxy ABI datasets and a geosynchronous observation grid, a flexible utility was written to remap the proxy datasets to a hypothetical GOES-R grid. This utility will be used to provide proxy ABI radiance datasets containing the correct number of observations and horizontal resolution throughout the entire domain to the GOES-R community.

Publications during 1 July – 30 September 2007

Otkin, J. A., and T. J. Greenwald, 2007: Comparison of WRF model-simulated and MODIS-derived cloud data. *Mon. Wea. Rev*, accepted for publication.

Conference presentations during 1 July – 30 September 2007

Otkin, J. A., and T. Greenwald, 2007: An intercomparison study of MODIS-derived and WRF-simulated cloud data. *15th Satellite Meteorology and Oceanography Conference*, Amsterdam, Netherlands.

Otkin, J. A., H.-L. Huang, T. Greenwald, E. R. Olson, and J. Sieglaff, 2007: Large-scale WRF-simulated proxy atmospheric profile datasets used to support GOES-R research activities. *15th Satellite Meteorology and Oceanography Conference*, Amsterdam, Netherlands.

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

Last year, the SSEC demonstrated a lightweight web-oriented system for distributed processing, management and visualization of hyperspectral data, nicknamed Origami. Extensions to Origami proposed for 2007 involved integration of new algorithms 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 Q3 of 2007, the XML-based interface description scheme for algorithms was refined, along with tools used to generate Origami-compatible source language files from the XML interface. The original motivation for this architectural decision was explained in the Ground Systems section of the Q2 GOES RRR report.

In addition, preparatory steps were taken to integrate the distributed science workflow parts of Origami into the McIDAS-V environment being developed at the SSEC. In the integrated workflow envisioned as a result of merging efforts from these two projects, the scientist will search for datasets and order distributed computations of intermediate products (such as reprocessing calibrated data) directly from the visualization software interface, without having to cut and paste between the visualization software and the original Origami web interface. This adaptation can be performed while keeping most of the core Origami codebase, and only changing its lightweight user interface component.

The re-scoping of Origami as a component for integration into other applications prompted a rethinking of high-level design for science applications dealing with large volume datasets. The new design restructures the application space so that it allows for a component-by-component examination of whether to build a new solution or to adopt an existing one. A diagram of the new design as it relates to Origami was presented at this year’s joint EUMETSAT/AMS meeting in Amsterdam, Holland (Figure 12).

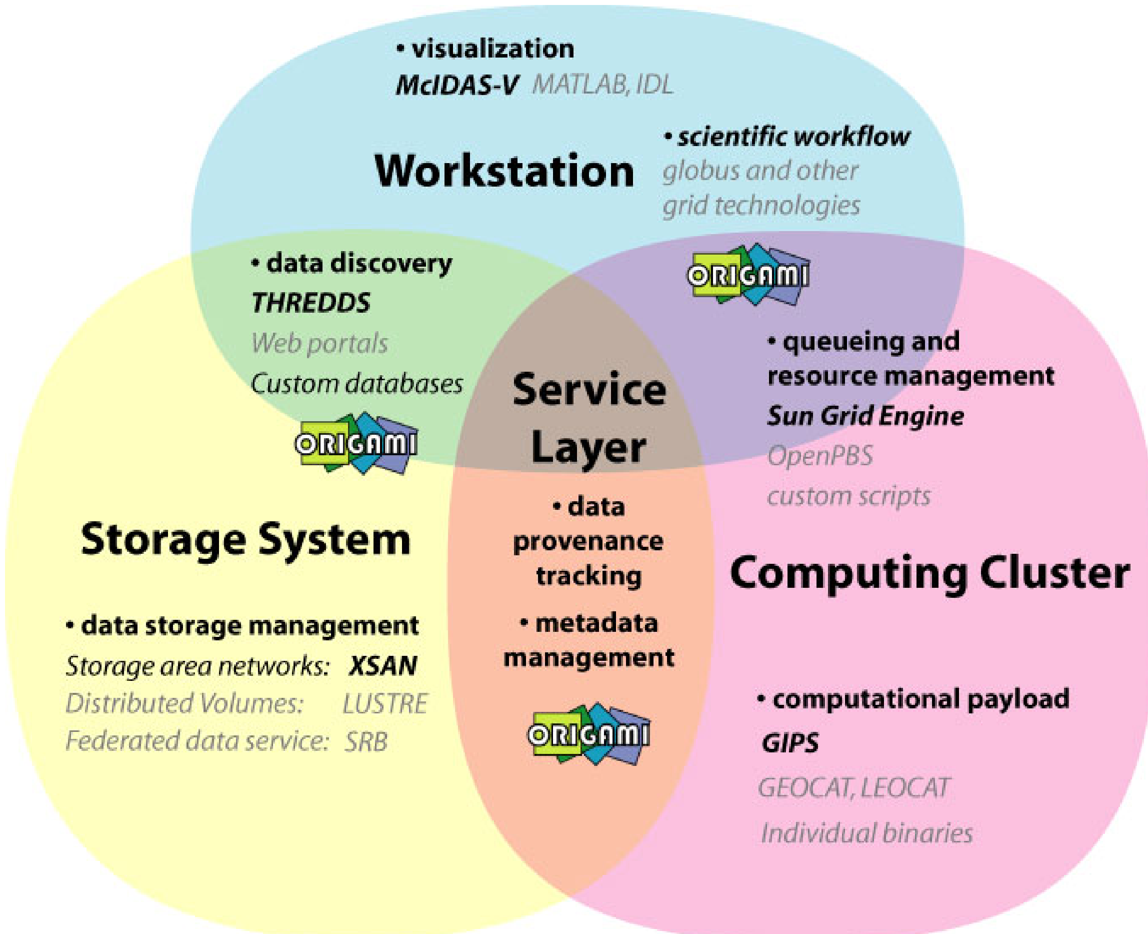


Figure 12: High level design of a distributed science workflow application for dealing with high volume datasets.