GOES-R Progress Report for January-March 2005
University of Wisconsin-Madison
Cooperative Institute for Meteorological Satellite Studies

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Project Title:	CIMSS Participation in GOES-R Risk Reduction
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Co-Investigators:	Allen Huang, Chris Velden, Bob Knuteson
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FY2005 Funding:	$750,000 (budget period through February 2005)
Remaining Funds:	$0

Task 1. Soundings Algorithm Development

Significant Inputs in the last three months
- ❑ *Algorithms:*
  - o **Clear Sounding Retrieval Algorithm Development**

Retrieval algorithm testing using AIRS data at ARM CART site
The physical retrieval algorithm has been tested AIRS data over the ARM cart site where collocated in situ measurements are available for validation. Time and space co-located AIRS, MODIS, RAOB and other in-situ measurements are collected from July 2003 – April 2004. Retrievals are also compared with AIRS science team standard products. Figure 1 shows the root mean square error (RMSE) of temperature (left panel) and water vapor relative humidity (RH) (right panel) against radiosondes for both AIRS standard products and CIMSS physical retrievals. Retrievals from 25 clear AIRS footprints are compared with RAOB for RMSE statistics. Our algorithm is good for moisture and temperature at most layers. The boundary layer retrievals (might be contaminated by clouds or surface emissivity uncertainties) still need to be improved.
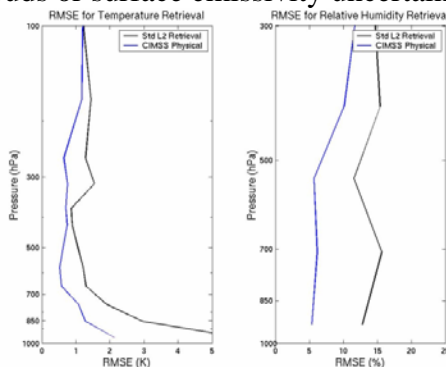
Fig.1: Collocated in-house AIRS vs. AIRS science team standard retrieval RMSE profiles of temperature (left) and water vapor (right). (**For internal use only**)

  - o **Synergistic Cloud-clearing Algorithm Development**

An optimal cloud-clearing for hyperspectral IR sounder radiances under single layer cloud cover using multi-spectral band imager data has been developed (Li et al. 2005). MODIS and AIRS data are used to proxy ABI/HES. Methodology of cloud-clearing two-layer cloudy HES footprint is under investigation. The two-layer cloud-clearing algorithm is expected to complement the single-layer cloud-clearing approach. Preliminary cloud clearing analysis has demonstrated that the AIRS/MODIS multi-channel cloud-clearing brightness temperature fit the collocated clear MODIS

measurements much better than the AIRS/AMSU (AIRS science team approach). Fig.2 is the cloud-cleared fitting error of MODIS/AIRS (in filled blue bar) and cloud-cleared RMS error of AIRS/AMSU (in open red bar) estimated one global AIRS data of 6 September 2002.
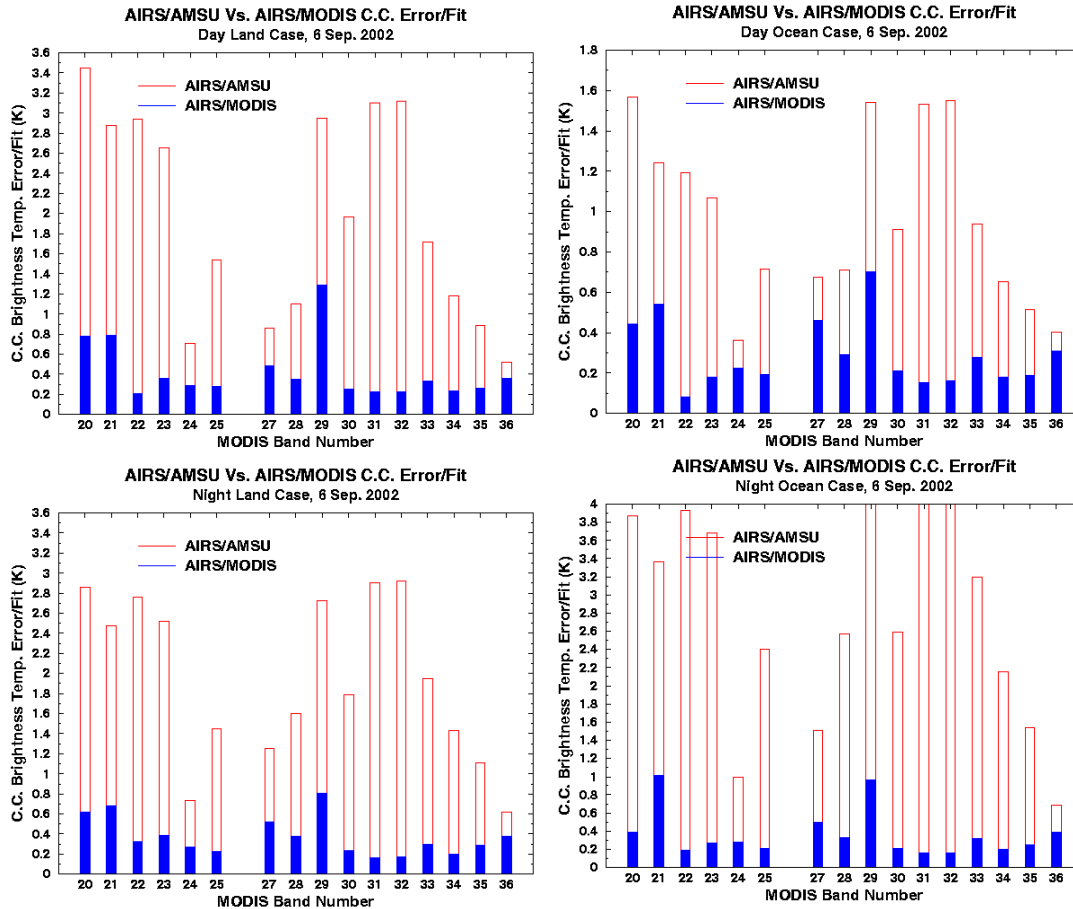

Fig. 2: AIRS/MODIS cloud-cleared brightness temperature fitting error (in filled blue bars) and AIRS/AMSU cloud-cleared brightness temperature RMS error (in open red bars) over day/land (upper left), day/ocean (upper right), night/land (lower left), and night/ocean (lower right) conditions for 6 September of 2002.). **(For internal use only)**

- o **Cloudy Sounding Retrieval Algorithm Development**

Another approach for dealing with clouds in IR sounding retrieval is to simulate radiances under various cloudy situations. A cloudy training date set and a realistic cloudy radiative transfer model is required for generating the cloudy regression coefficients. The cloud-top height (CTH) and soundings above the CTH will be simultaneously obtained using this approach. Preliminary results have been obtained through collaboration with Dan K Zhou (NASA/LaRC) using NASTI data, retrievals above the clouds agree well with dropsonde observations, which demonstrates the potential application of this approach in HES cloudy sounding retrieval when ABI is not available.

- o **NWP Modeling for Geostationary hyperspectral resolution measurement simulation**

The Weather Research and Forecasting (WRF) model is adopted and used to generate a high-resolution simulation of an intense extratropical cyclone that developed off the eastern coast of North America during the Atlantic Thorpex Regional Experiment (ATREC). The model simulation was initialized at 00 UTC 05 December 2003 with 1° GFS data and then run for 24 hours on a single 1070 x 1070 grid point domain with 2-km horizontal resolution and 50 vertical sigma levels. The simulation employed the following parameterizations:

- WRF single-moment 6-class (WSM6) microphysics
- Yonsei University (YSU) planetary boundary layer
- RRTM/Dudhia radiation
- NOAH land-surface model
- Explicit convection (i.e. no cumulus parameterization)

The ATREC domain and a representative image of the simulated composite reflectivity are shown in Fig. 3. The very fine horizontal structure of the composite reflectivity field clearly demonstrates the ability of the WRF model to simulate fine-scale atmospheric features. This infrastructure will be used in the generation of a 24 hours fine temporal and hemispheric, CONUS, and regional simulation datasets to support the algorithms development, and data processing system design and testing.
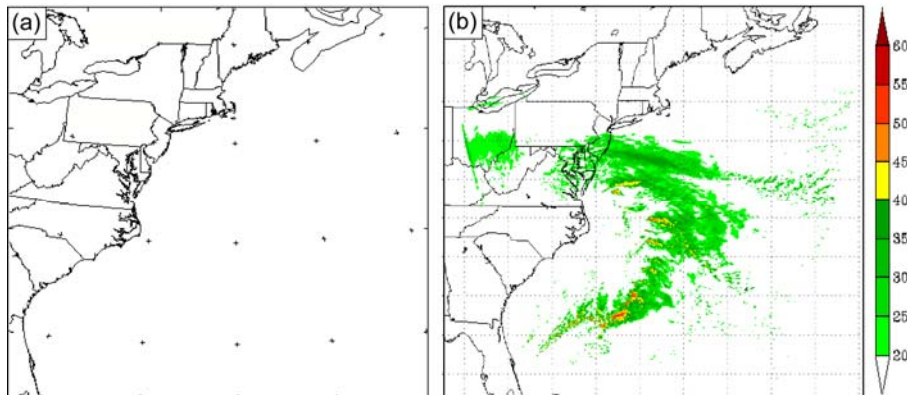

Fig. 3. (a) Geographical region covered by the 1070x1070 grid point domain used for the WRF simulation. (b) Simulated composite reflectivity (dbz) for 18 UTC on 05 December 2003.

- o **Cloudy Forward Model Development**

To account for the scattering and absorption effects in ice clouds and water clouds, a fast radiative transfer cloudy model for a hyperspectral IR sounder is being developed through joint efforts at the CIMSS and Texas A&M University. During this quarter the progress is summarized below:

1) We have continued to refine the implementation of the two-layer cloud model in the framework of the GIFTS fast model (ly2g). By leveraging with navy MURI project we are able to develop a database, with co-I Prof. Ping Ynag of Texas A&M university, of the scattering properties of ice crystals for a spectral region spanning from 3 µm to 100 µm. Several ice crystal habits (plates, solid and

      hollow columns, bullet rosettes, aggregates, spheroids, and droxtals) with particle sizes ranging from 1 to 10000 µm have been accounted for in the database.

2) We have submitted a manuscript for publication in Applied Optics, which entitles: "Scattering and absorption database for nonspherical ice particles in the near- through far-infrared spectral region".

3) We also are preparing a publication with the tentative title of :" A Rapid and Accurate Hyperspectral Infrared Clear and Cloudy Radiative Transfer Model".

❑ *Publications (since 1 Oct. 2004):*

Li, J., C.-Y. Liu, H.-L. Huang, T. J. Schmit, W. P. Menzel and J. J. Gurka, 2005: Optimal cloud-clearing for AIRS radiances using MODIS, IEEE Trans. On Geoscience and Remote Sensing. (in press)

Zhou, D. K, W. L. Smith, X. Liu, A. M. Larar, H. –L. Huang, J. Li, M. J. McGill, and S. A. Mango, 2005; Thermodynamic and cloud parameter retrieval using infrared spectral data, J. Geophysical Letter (submitted).

Yang Ping, H. Wei, H-L Huang, B.A. Baum, Y. X. Hu, G.W. Kattawar, M.I. Mishchenko and Q. Fu, 2005: Scattering and absorption property database for nonspherical ice particles in the near- through far-infrared spectral region. Appl. Optics.

Plans for Next Three Months
- ❑ Conduct routine algorithm working group meetings to coordinate work loads and optimize resources.
- ❑ To improve quarter report coordination and document progress.
- ❑ Revised all submitted publication papers.
- ❑ Prepare new publication papers.
- ❑ Start testing of the new two-layer cloudy forward model
- ❑ To derive cloud-clearing algorithm and design approaches to perform more than one-layer of cloud-clearing.
- ❑ Start to study potential approaches to consider the time continuity aspect of the geo sounding and imaging measurements
- ❑ To refine ATBD and use latest ATBD to guild algorithm development and implementation.
- ❑ To provide realistic dataset and algorithms for ground system data processing team to test their system performance and run through the system for prototyping demonstration.

Task 2. Preparation for Data Assimilation

Significant Inputs in the last three months
- ❑ *Algorithms:*

Work completed by FSU under the supervision of Prof. X. Zou, our GOES-R3 subcontractor, during the previous few quarters is summarized below:

Using the GIFTS clear-sky radiative transfer model, its adjoint model and a clear-sky sounding extracted from a 24-h model forecast made at 4-km resolution simulating a convective episode that took place during 12-13 June 2002, the relative sensitivity of simulated GIFTS radiances at all channels to atmospheric temperature and water vapor was calculated and shown in Figure 4. It was found that GIFTS radiance is one and half order more sensitive to temperature than to water vapor at all channels, including water vapor channels (Fig. 4a-b). The height where the maximum sensitivity to temperature only approximately (not exactly) coincides with the height at which the maximum sensitivity to water vapor is located (Fig. 4c-d).
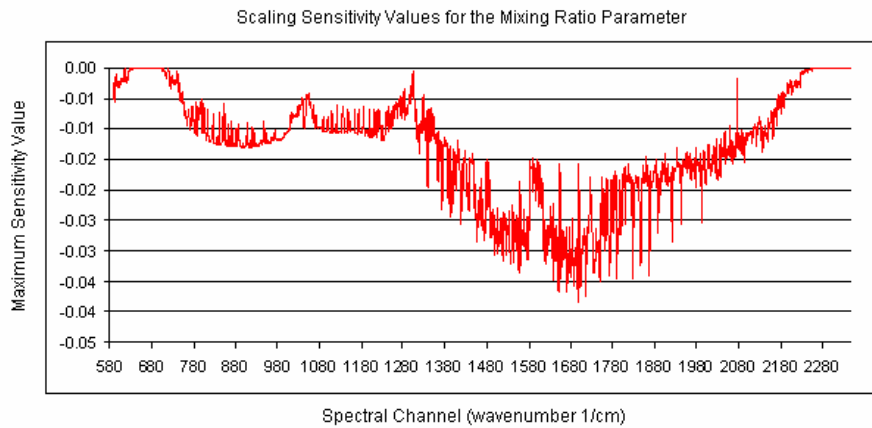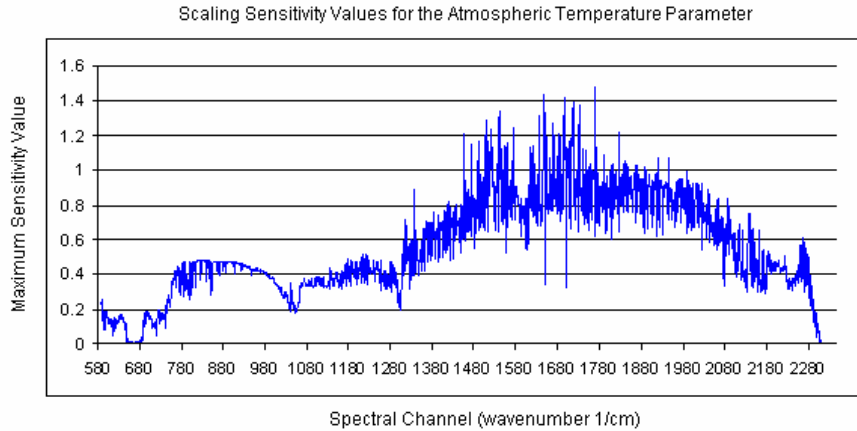
❑ *Publications:*
A master thesis was produced in year 2004 and 1st quarter of 2005, which was entitled "Assessing the potential impact of GIFTS data to severe convective precipitation prediction" by Yorsaner (2005).
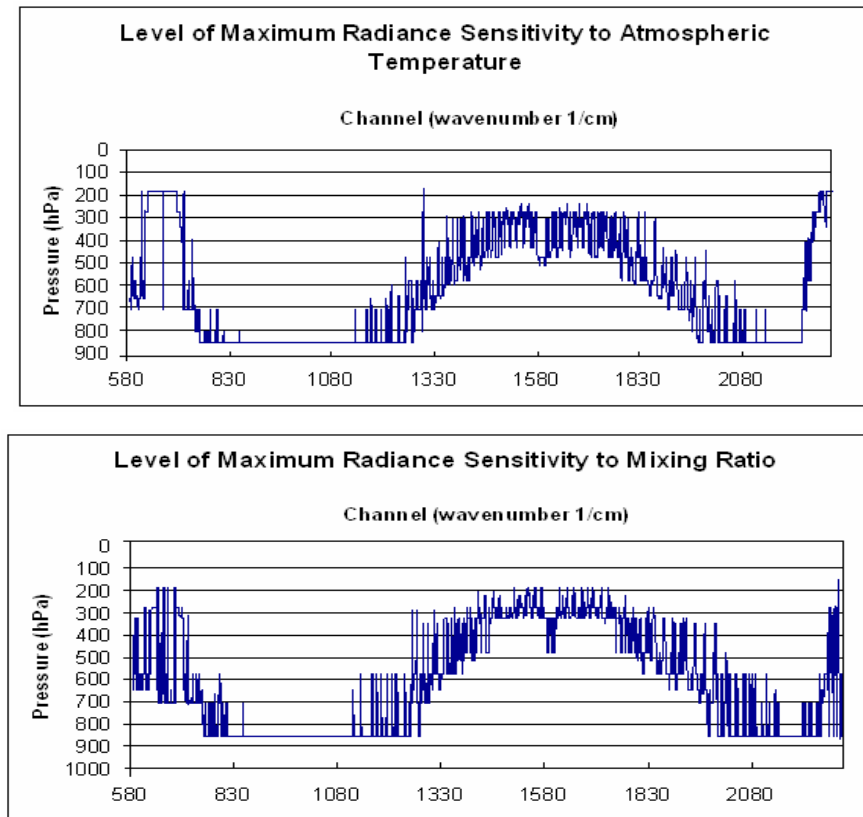
Figure 4. The relative sensitivity of simulated GIFTS radiances at all channels to the atmospheric temperature and water vapor profile.

Plans for Next Three Months

- ❑ To conduct exercise to demonstrate MM5 adjoint capabilities to study the sensitivity of hyperspectral measurements. The MM5 adjoint model is delivered to CIMSS by Professor X. Zou of FSU.
- ❑ Prof. Zou of FSU, under subcontract agreement, will perform the following activities during the next few quarters:
  - Channel selection for improved convective QPF --- one way to optimize data assimilation approaches for HES;
  - Development of the tangent linear and adjoint operators of a cloudy radiative transfer model (RTM); and
  - Observing system simulation experiments (OSSEs) (e.g., data assimilation using simulated HES data), aiming at assessing full information content of HES for NWP data assimilation by taking advantage of time continuity of HES, and identifying risks and potential problems associated with assimilation of HES data.

Task 3: GOES R Winds

Very little work was done on GOES-R winds in this reporting period. A major milestone was achieved in the last reporting period with the successful derivation of winds over the polar region from a set of AIRS moisture analyses. The winds group is now waiting on the retrieval group to provide a new set of cloud-cleared or flagged retrievals so we can better depict clouds in the moisture fields when tracking features.

Significant Inputs in the last three months
Presentations: GOES-R Risk Reduction meeting in DC

Instrument guidance: Defined need for accurate cloud flags in the retrieved moisture fields for improved target selection and tracking

Plans for Next Three Months
If the retrieval algorithm group gets us a new set of cloud-cleared retrievals for the case study completed in the last reporting period, we will re-derive the winds and assess the differences.

Task 4: GOES-R Ground System Design and Studies
Work continues on researching and preparing algorithms, technologies and practices for dealing with the extremely large data processing volumes expected for the GOES-R HES infrared sounder. Specifically, our immediate focus areas are: the generation of simulation data using the GIFTS instrument as a specific example and forging techniques for tracking, sorting and searching data products.

Calibration Algorithm Refinement
The NASA GIFTS instrument was undergoing system integration during this quarter at Utah State University. The GIFTS sensor is being used to demonstrate algorithms suitable for the ground data processing of this HES-like instrument. One of the accomplishments of this quarter was the presentation at the AMS meeting of the science and performance algorithm tradeoffs between two key data processing approaches. Both approaches provide similar accuracy but one has a significant advantage in flexibility and simplicity (Knuteson et al. 2005).

Metadata
A plan to inject metadata at data inception into processing systems was developed (based on the characterization of metadata as ephemeral data (1)) and a way of tracking and enhancing it as it moves through processing stages was proposed. The metadata format is a global attribute list followed by a per-variable attribute list, adhering to relevant NetCDF and UDUnit metadata standards (http://www.unidata.ucar.edu/). Investigations into lightweight generation and tracking of universally unique identifiers (UUIDs) also started.

Data generation and management
A plan is underway to generate up to 24 hours of simulated GIFTS data, using a WRF model at GIFTS resolution – 4 km sq per pixel - over North America, or using a reduced resolution over the entire disc. A modified version of a forward infrared radiative transfer model will then translate this 24 hour dataset into TOA radiances, which would be fed through the GIFTS FTS simulator to produce interferograms as seen from the instrument.

The purpose of this exercise is as much to test the Level0 – Level1 processing pipeline being implemented under separate funding (NOAA OSD) as it is to push the development of infrastructure - both hardware and software - for dealing with GIFTS/GOES-R anticipated data volumes, and to provide a demonstration of processing and visualization capability.

Testing software in anticipation of an automated processing pipeline assembler
A set of test scripts was written which will form the core of a full testing environment. These lightweight scripts interface to a component pipeline with an external set of datafiles, but are programmed so as to provide potentially greater flexibility – namely, to match data feeds with the announced capabilities of the pipeline modules, thus allowing an eventual automated assembly procedure.

Significant Inputs in the last three months

Publications:
Calibration Algorithm Accuracy Versus Efficiency Tradeoffs For a Geosynchronous Imaging Fourier Transform Spectrometer R. O. Knuteson et al, 21st Conference on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology - 2005 AMS Annual meeting

Plans for Next Three Months
Produce and process 6 hours of simulated GIFTS data in anticipation of the eventual 24 hours simulation goal. We expect this shorter term simulation run to uncover issues not yet identified, and to move on solving these issues. This simulation will be released to the GOES-R research community for use, review and commentary.

Produce and test variants of the radiometric calibration algorithm on the test data, planned for publication in SPIE Aug 2005 meeting. Continue work on testing system, with the above tests in mind, also focusing on developing underlying scripting/metadata/automation technologies. This testing software will be used in the evaluation of the significant amounts of data produced by the GIFTS in Thermal Vacuum testing in late 2005.

Investigate a prototype software module for metadata tracking, to merge in and demonstrate with our growing processing software code-base.

References
1. Jim Gray, Alexander S. Szalay, Ani R. Thakar, Christopher Stoughton, Jan vandenBerg, "Online Scientific Data Curation, Publication, and Archiving", *Microsoft Research Technical Report*, MSR-TR-2002-74, 2002.

FUNDING AND SPENDING PLAN:

GOES R Risk Reduction Funding

Through 2/2004	$1,270K
Through 2/2005	$ 750K
Total funding to date	$2,020K
Expected funding 2005	$ 910K

GOES R Risk Reduction Spending

Through 2/2004	$1,299K
3/2004 - 2/2005	$ 880K
Total spending to 3/1/05	$2,179K

The 2004 funds budget period ended 28 February 2005. The 2005 funding has not arrived. Assuming funding arrives soon, for the next three months, spending is estimated to be:

March 2005 = $70K	April 2005 = $90K	May 2005 = $90K