USE OF HIGH-RESOLUTION MM5 SIMULATIONS FOR GIFTS FORWARD MODEL AND RETRIEVAL ALGORITHM DEVELOPMENT

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1. INTRODUCTION

The Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS) is scheduled for launch in 2006–2007, and represents a significant advance in the ability to image and sound the atmosphere from a geosynchronous orbit. GIFTS is targeted at a horizontal resolution of 4 km, vertical resolution of 1-2 km, and maximum temporal resolution of 10 seconds. As such, it will allow much more rapid and high-resolution retrievals of temperature, moisture, and wind than are available with any current geostationary instrument.

SSEC/CIMSS is currently tasked with testing and developing a GIFTS forward radiative transfer model and retrieval algorithms. In support of this work, high spatial and temporal-resolution numerical model simulations are used to produce a “truth” atmosphere, which is then passed through the GIFTS fast forward radiative transfer model to generate simulated top of the atmosphere radiances. Retrievals of temperature, water vapor and winds generated from these radiances are subsequently compared with the original simulated atmosphere to assess retrieval accuracy.

In this paper we present results from current work, which involves high-resolution MM5 simulations of two very different events. The first is a case of convective initiation that occurred on 12 June 2002 during the International H_2O Project (IHOP) intensive observing period. This simulation is designed to realistically depict very high-resolution water vapor features and late-day convection over the Oklahoma/Kansas border, and will be used to assess GIFTS ability to observe fine-scale water-vapor features, and thus to demonstrate GIFTS utility in increasing lead-time for forecasts of convective initiation. The second is a simulation of a strong mid-Pacific Ocean jet streak that occurred on 12 March 2003. This feature was extensively observed as part of the first Pacific THORPEX Observing System Test (TOST), the 2003 GOES rapid-scan WINDs EXperiment (GWINDEX), and the NOAA NCEP Winter Storms Research Program (WSRP). Winds derived from simulated GIFTS retrievals will be compared with winds tracked during GWINDEX to assess GIFTS potential to improve vertical and horizontal resolution of water-vapor tracked winds.

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2. ADJUSTMENTS TO MM5 PRE-PROCESSING PROGRAMS

In early tests, it was discovered that the MM5 pre-processing programs produced unrealistically high values of water vapor mixing ratio in the lower-stratosphere. Sensitivity tests with and without correction to initial and boundary condition lower-stratospheric mixing ratio revealed negligible impact on the evolution of the state of the troposphere. However, large values of mixing ratio in the lower stratosphere had a large impact on the output of the radiative transfer model, contributing to excessive noise in wavelength ranges sensitive to absorption by atmospheric water vapor. Figure 1a depicts an upper-tropospheric water vapor profile typical of uncorrected mixing ratios, while GIFTS long-wave spectra derived from uncorrected and corrected water vapor profiles is shown in figures 1b and 1c respectively.

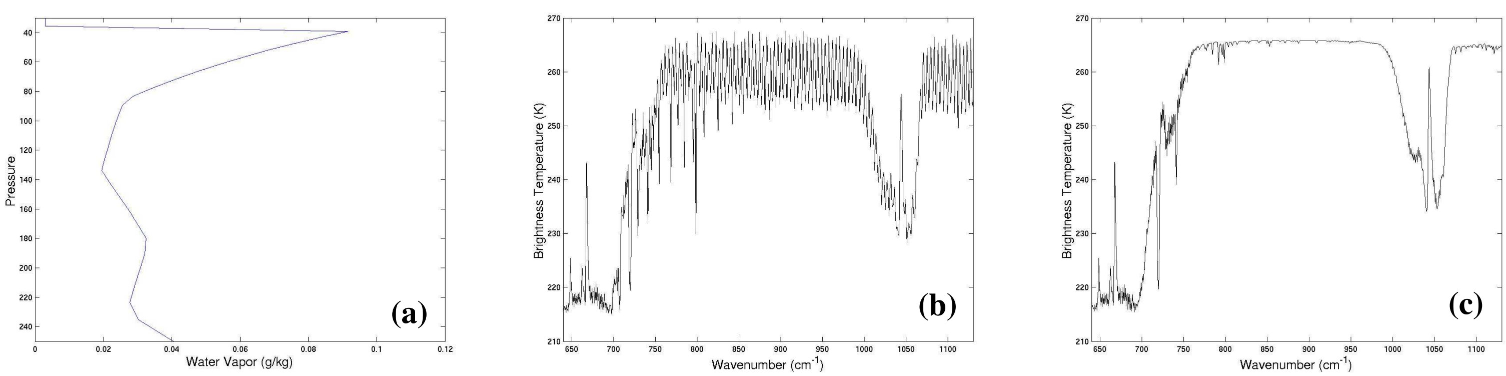

Figure 1: Effects of overestimated lower-stratospheric mixing ratios on GIFTS simulated radiances. (a) Sample uncorrected mixing ratio profile (b) GIFTS longwave brightness temperatures computed from uncorrected profile (c) GIFTS brightness temperatures computed from corrected mixing ratios

3. CASE DESCRIPTIONS AND SIMULATION OUTPUT:

3a. IHOP 2002 CONVECTIVE INITIATION CASE

At approximately 2100 UTC on 12 June 2002 a line of strong convective cells formed in the presence of strong low-level moisture convergence along a weak low-level trough in western Oklahoma. This case occurred during a day specifically targeted for study of convective initiation during IHOP 2002, and was characterized by very complex lower-tropospheric water vapor structures and wind patterns. Special datasets collected during an intensive observing period between 1600 and 2300 UTC included cross-dryline flights by Proteus, King Air, and P3 aircraft, three-hourly radiosonde launches, and 5-minute imagery from GOES-11. In addition, the Forecast Systems Lab Rapid Update Cycle (RUC) model was run at 10 km grid spacing every three hours over the length of the IHOP 2002 experiment. Reports specific to the convective missions on 12 June 2002 can be viewed at the UCAR JOSS IHOP web page:
http://www.joss.ucar.edu/cgi-bin/catalog/ihop/report/index.html

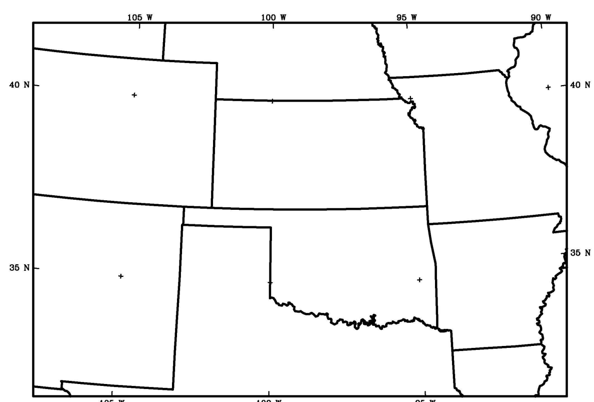

Figure 2: Aerial coverage of IHOP 2002 simulation domain.

Simulated atmospheric fields were generated using MM5 version 3.5.4 initialized from a combination of the zero-hour forecast from the 10 km RUC, 1-degree grid spacing GDAS analyses (for soil moisture and sea-surface temperatures), and an estimate of photosynthetically active vegetation fraction derived from the Advanced Very High Resolution Radiometer (AVHRR) Normalized Difference Vegetation Index (NDVI) product. Horizontal coverage of the model domain is depicted in figure 2.

Extensive sensitivity testing was performed to determine the optimal physical parameterizations, domain configuration, and initialization time for this particular case. In all of the test cases, the MM5 was able to effectively generate convection on 12 June, however the timing and horizontal extent of the convection varied considerably. The final configuration contained 60 vertical levels and employed the following physical parameterizations:

- Goddard microphysics
- MRF boundary layer
- RRTM/Dudhia radiation
- OSU land surface scheme
- Explicit cumulus (no cumulus parameterization)

10.7 micron brightness temperatures observed by GOES-11 and derived from two selected simulations at 2200 UTC 12 June 2002 is shown in figures 3a-c. Comparison between simulated and observed satellite imagery at this and several other times (not shown) revealed that the modeled convection was most accurately represented in a simulation that was constantly nudged toward the RUC analyses. Because the primary objective of this simulation work was to obtain a highly realistic and dynamically consistent depiction of the initiation and evolution of convection, output from the fully-nudged simulation was not used. Instead, a suitable compromise was reached by nudging the simulation toward the RUC analyses over a 6-hour spinup period, then ramping down the nudging coefficients well prior to the initiation of convection. Although the simulation of choice exhibited overactive convection in eastern Oklahoma, it retained the primary features of interest, including the wind-shift and moisture boundary in the Texas/Oklahoma panhandle and the convective outflow boundary in north-central Oklahoma.

3b. 2003 PACIFIC THORPEX OBSERVING SYSTEM TEST JET STREAK CASE

During 2100 UTC 12 March – 0400 UTC 13 March 2003 a zonally-oriented jet streak was located over the

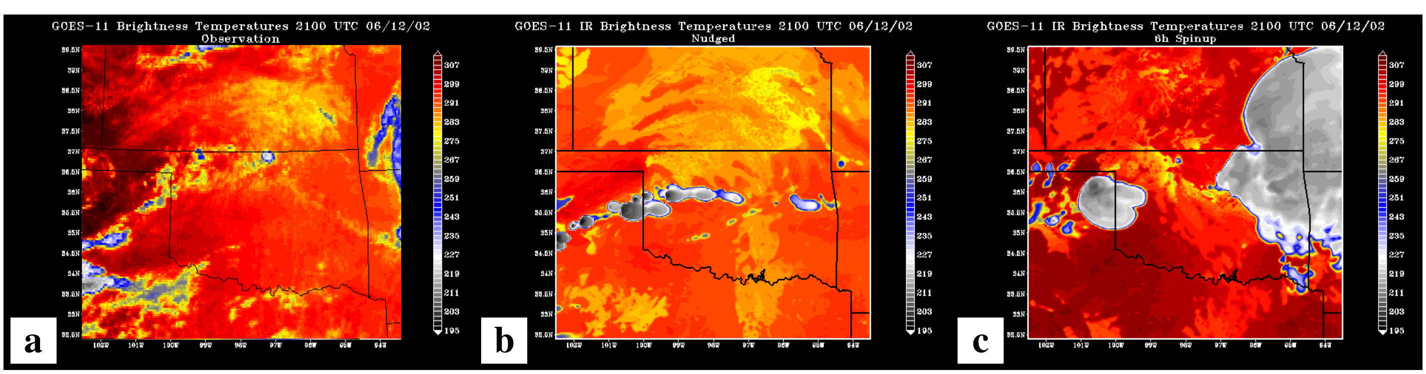

Figure 3: Comparison of observed (a) GOES-11 10.7 micron brightness temperatures with two different MM5 simulations. (b) Simulated IR image from an MM5 simulation nudged to RUC analyses and (c) simulated IR image from MM5 simulation with a 6-hour spin-up period.

north-central Pacific Ocean, with maximum analyzed wind speeds on the order of 190 knots. Figure shows the GOES-10 IR image valid at 2200 UTC 12 March with part of the NASA ER-2 flight track overlaid on it. This particular case was selected because it occurred during a day specifically targeted for study of jet streak dynamics during Pacific TOST 2003. Observational datasets collected during the ER-2 flight between 2100 UTC 12 March and 0400 UTC 13 March included remotely-sensed observations from the NPOESS Aircraft Sounder Testbed-Interferometer (NAST-I), Scanning High-resolution Interferometer Sounder (SHIS), MODIS Airborne Simulator (MAS), and Cloud Physics Lidar (CPL), as well as dropsondes across the jet streak core. Reports specific to the mission flown on 12 March 2003 can be viewed at the 2003 Pacific TOST web page:
http://www.angler.larc.nasa.gov/thorpex/missionsummary/mar12/

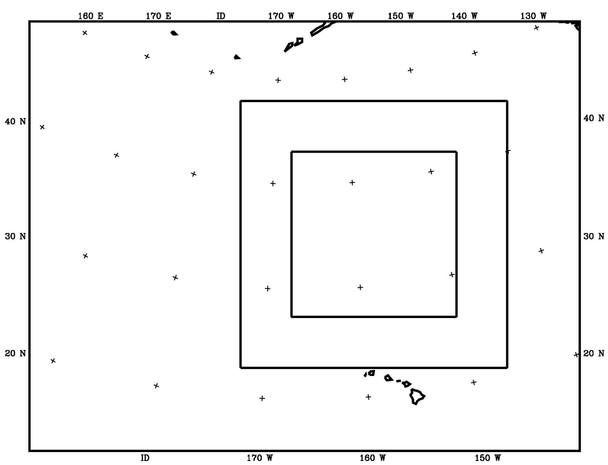

Figure 4: Aerial coverage of the Pacific Ocean domain.

Simulation of this case is still in preliminary stages, but early results indicate success representing the gross features that existed over the flight domain. In the latest test simulation, MM5 was initialized at 1200 UTC 11 March from the NCEP GDAS analysis and allowed to spin up for 33 hours before the start of the ER-2 flight at 2100 UTC 12 March. Such a long spin-up time was chosen to allow sufficient time for the MM5 simulation to properly generate realistic fine-scale cloud and moisture features from the original coarse-resolution GDAS analyses. Preliminary results are shown from a simulation that was run with 50 vertical levels and the following physical parameterizations:

- Goddard microphysics
- MRF boundary layer
- RRTM/Dudhia radiation
- Grell cumulus: 36 and 12 km domains, fully explicit convection: 4 km domain

The aerial coverage and nest configuration for this case is shown in figure 4.

A comparison between simulated and observed GOES-09 10.7 micron brightness temperatures is shown in figures 4a and 4b. In this plot, it is evident that the MM5 successfully captured the primary observable features including a broad low-level cumulus field, the cyclone to the north of the jet axis, and the baroclinic zone in the southeast corner of the domain.

4. RADIANCE SIMULATION AND RETRIEVALS

To generate simulated GIFTS top of the atmosphere radiances, UW-CIMSS has developed a GIFTS-specific forward radiative transfer model. This model ingests atmospheric profiles of temperature, water vapor mixing ratio, liquid and ice cloud, and ozone, and generates top of atmosphere radiances in the GIFTS spectral range. These radiances are then used to retrieve atmospheric temperature, water vapor, and winds, which are then compared with the original atmospheric fields to assess the robustness of the retrieval method. A comparison between simulated and retrieved mixing ratio is shown in figure 6.

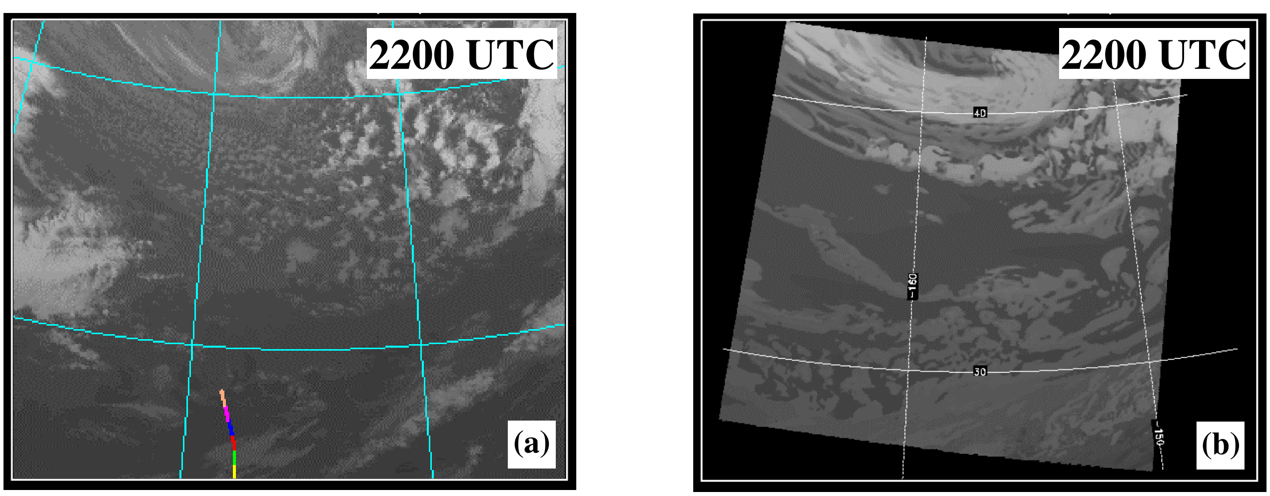

Figure 5: Comparison of observed (a) and simulated (b) GOES-11 10.7 micron brightness temperatures over the 4 km nest domain.

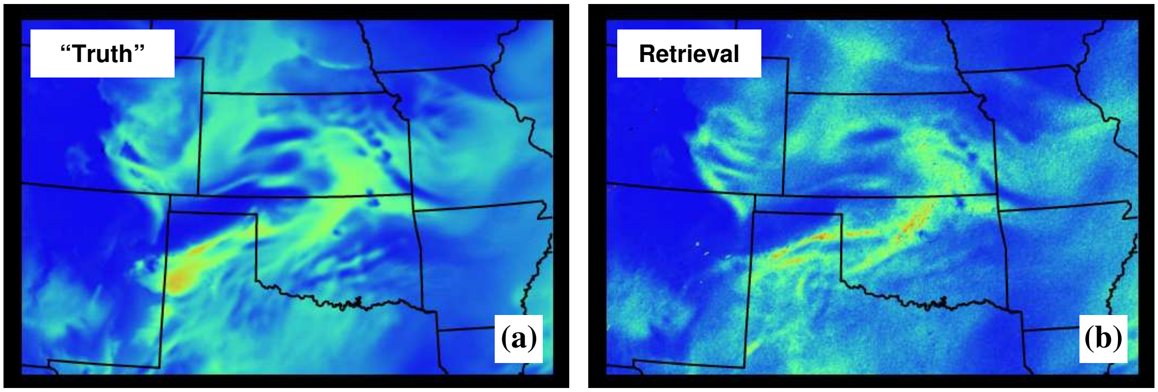

Figure 6: Comparison between simulated (a) and retrieved (b) 750 hPa water vapor mixing ratio at 1800 UTC 12 June 2002.

5. CONCLUSIONS

UW-CIMSS is currently occupied with development and testing of the GIFTS fast forward radiative transfer model and concurrent atmospheric retrieval methods in preparation for GIFTS launch in 2006–2007. As part of this initiative, UW-CIMSS is using output from high-resolution MM5 simulations of several different atmospheric cases to demonstrate GIFTS projected ability to remotely sense small-scale water vapor structure and gradients, and to improve the ability to produce wind observations from water vapor gradient tracking. Preliminary results indicate that the MM5 was effectively able to simulate cases of convective initiation and jet streak evolution with a high degree of realism.

ACKNOWLEDGEMENTS

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