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HES SIMULATION STUDY USING CUBE DATA FROM MM5

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1. INTRODUCTION

The Hyperspectral Environmental Suite (HES) is currently slated to be launched in 2013. A sounding retrieval algorithm has been developed for processing the HES clear sky radiances and/or brightness temperature (BT). The atmospheric temperature and moisture profiles are retrieved by eigenvector regression retrieval with all the spectral channels followed by a nonlinear iterative physical retrieval with optimally selected channels. Trade-off studies have been performed according to HES radiances from a set of global radiosonde profiles. These studies include the spectral coverage, spectral resolution, spatial resolution, temporal resolution, signal-to-noise ratio (Li et. al. 2003). HES could be a GIFTS-like 2 waveband infrared Michelson interferometer or an AIRS-like 3 waveband grating dispersive sounder with spectral resolution between 0.5 cm^{-1} and 2.5 cm^{-1}. Mesoscale model analyses can provide atmospheric profile data with high temporal and spatial resolutions. The atmospheric cube data from the output of PSU/NCAR MM5 version 3.5 (Grell etc, 1994) over the Southern Great Plains ARM-CART domain during the 2002 IHOP field experiment is used to simulate HES top of atmosphere clear sky radiances by a fast forward model (Hannon et al. 1996). These cube data are the "truth" atmosphere, which is used to generate simulated HES radiances with the forward calculation. Retrieved atmospheric temperature, moisture, ozone profiles and surface skin temperature are then compared with the model profiles ("truth") to calculate root mean square error (rmse). A similar study is also done with GOES-12 to demonstrate the advantage of HES over the current GOES sounder for the sounding retrievals.

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2. SIMULATION OF HES RADIANCE

The atmospheric cube data corresponds to the time period from 1200 UTC on 12 June to 0000 UTC on 13 June 2002. The time step for the successive cube data is half hour. Output has 6 (2 by 3) cubes in every half hour, each cube comprises a 128 x 128 array of pixels, each pixel contains atmospheric profiles, surface conditions and cloud parameters. Within the 128x 128 arrays, each pixel is 4km square. The cube data includes atmospheric profiles (air temperature, water vapor and ozone) at 101 vertical pressure levels from 0.05 to 1100 hPa. Surface properties (surface skin temperature, surface pressure and surface altitude) and cloud properties (cloud top with respect to liquid and ice, liquid water path and ice water path, and the concentration and effective diameters of five condensate types: rain, liquid, ice, snow and graupel) (Posselt, 2003) are also included.

The HES will have spatial resolution better than 10km and provide hourly full disk soundings. The cube data are averaged to 8 km spatial resolution and 1-hour intervals. The 8 km cube data (128 by 196 pixels) are considered as "true" atmospheric status. The clear sky detection is simply determined by testing for the existence of either liquid or ice cloud. Clear sky profiles are approximately 51% of all of the 8km cube data from 1200 UTC on 12 June to 0000 UTC on 13 June 2002 at hourly intervals. The HES radiances are simulated by the clear sky fast forward model (Hannon et al. 1996). The spectral regions of longwave band (650-1200cm^{-1}) and short middlewave band (1650-2250cm^{-1}) with a spectral resolution of 0.625 cm^{-1} are assumed for HES in the radiance simulation. Figure 1 shows the clear-sky BT images of 1900 UTC on 12 June 2002 for the four selected HES channels.

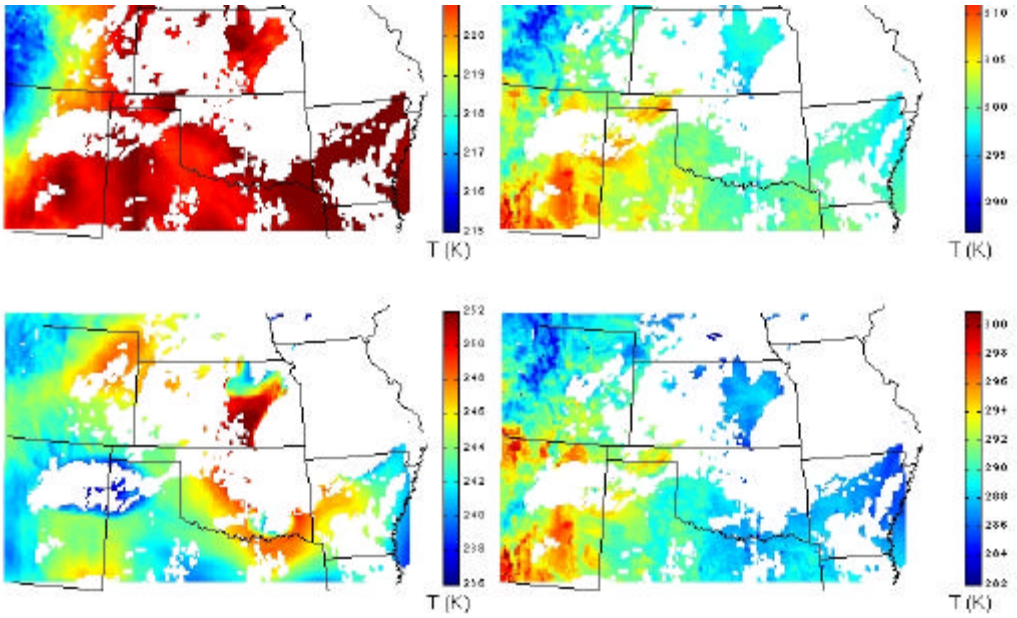

Figure 1. Simulated HES BT images of 1900 UTC on 12 June, 2002 at 685.5 cm^{-1} (upper left), 900.0 cm^{-1} (upper right), 1650.4 cm^{-1} (lower left) and 2100.1 cm^{-1} (lower right).

3. SIMULATION ON HES SOUNDING RETRIEVALS

The algorithm for retrieving the atmospheric temperature, moisture, ozone profiles and surface skin temperature from the simulated HES radiances is a two-step procedure, a Principle Component Regression (PCR; Huang and Antonelli, 2001) followed by a non-linear physical retrieval method (Li and Huang 1999; Li Jun, et. al, 2003). The regression retrieval is used as the first guess in the physical retrieval. 312 channels out of 2005 channels in total, optimally selected from both the CO_2 (685-810 cm^{-1}) and the water vapor (1665-2000 cm^{-1}) absorption regions, as well as the IR window region, are used in the physical retrieval procedure to improve the regression retrieval accuracy. In the regression procedure, the regression coefficient is calculated from 6532 training profiles and corresponding calculated HES BTs with HES noise added. The 14bit HES noise from Technical Requirement Document (TRD) is used in the simulation. The training set is also from the MM5 model output.

Figure 2 shows an example of the MM5 Model analyses ("truth"), HES retrievals and the difference between the "truth" and retrievals of 700 hPa water vapor mixing ratio (g/kg) at 1900 UTC on 12 June 2002. The mesoscale features and

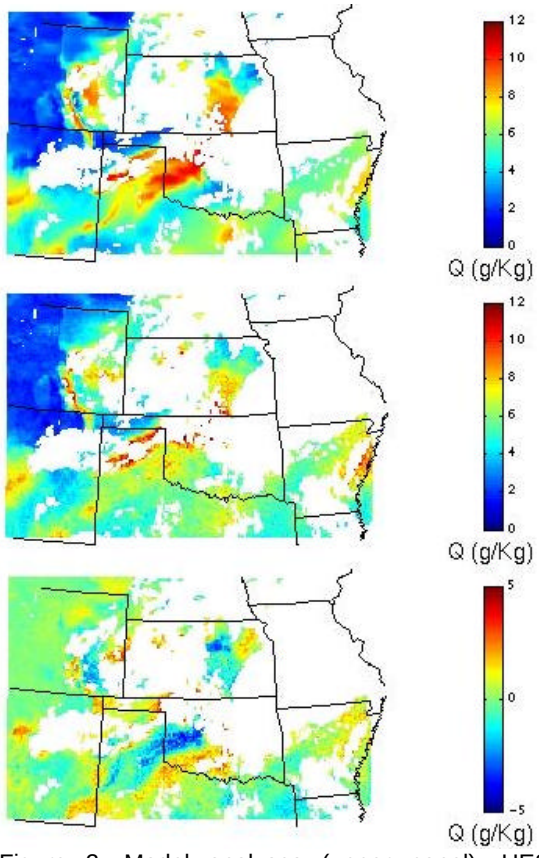

Figure 2, Model analyses (upper panel), HES retrievals (middle panel) and the difference between HES retrievals and model analyses (lower

panel) of 700hPa water vapor mixing ratio at 1900UTC on 12 June 12.

the gradients of water vapor are well identified by the HES retrievals. Figure 3 shows the temperature retrieval rmse at 1km vertical resolution from HES regression, HES physical, and GOES regression, respectively. Figure 4 is the same as Figure 3 but for water vapor relative humidity (RH) retrieval rmse at 2km vertical resolution. The retrieval accuracy of air temperature and water vapor with EOF regression physical is better than 1K at 1km vertical layer excepting boundary layer and 10% RH for water vapor at 2 km vertical layers. The physical retrieval procedure significantly improves the accuracy of moisture regression retrievals (blue line). A similar physical retrieval is done using model analyses one hour early as the first guess (see green line) instead of using regression retrieval. The study shows that the water vapor retrievals are better than that from the EOF-

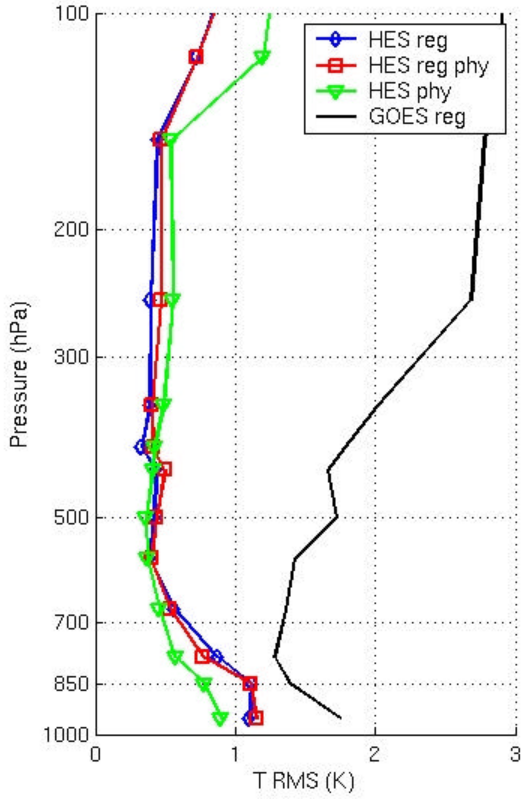

Figure 3. Temperature retrieval rmse at 1km vertical resolution. Blue line: HES EOF regression retrievals; red line: HES EOF regression physical retrievals; green line: HES physical retrieval with one-hour early model analyses as the first guess; black line: GOES-12 regression retrievals.

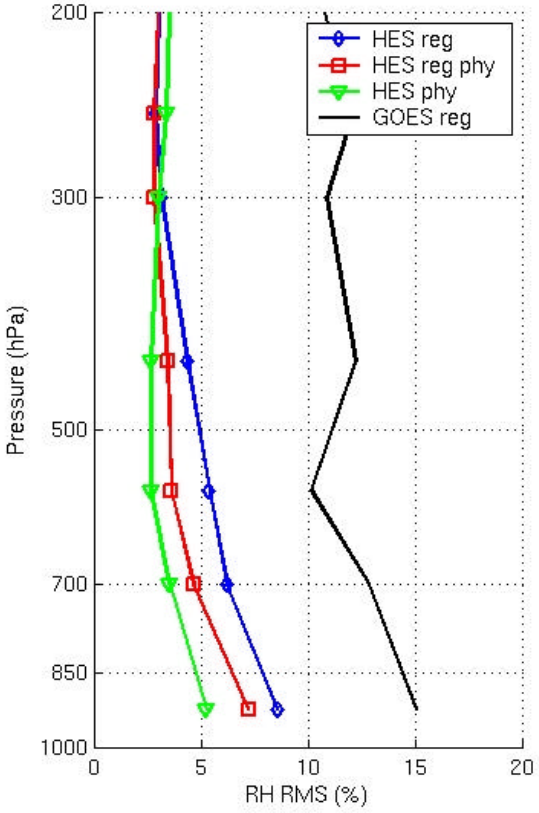

Figure 4. Water vapor RH retrieval rmse at 2km vertical resolution. Blue line: HES EOF regression retrievals; red line: HES EOF regression physical retrievals; green line: HES physical retrieval with one-hour early model analyses as the first guess; black line: GOES-12 regression retrievals.

regression-physical retrievals. For temperature, the retrievals are better below 400hPa while degraded about this pressure level.

GOES-12 top of atmosphere radiances are also simulated using the GOES sounder fast forward radiative transfer model. A statistical regression retrieval algorithm (Seemann et al. 2003) is applied to the simulated GOES radiances with the GOES-12 spectral band noise added in the radiances. Regression retrievals for GOES-12 sounder are also created (see the black line in Figures 3 and 4). GOES-12 has 18 spectral bands with spectral widths on the order of tens of wavenumbers. As seen from Figures 3 and 4, the GOES-12 radiances provide less information about the vertical structure of the atmospheric temperature and moisture.

4. SUMMARY

The retrieval results from simulations using MM5 numerical model data show that HES enables monitoring the evolution of detailed temperature and moisture structures. The retrieval accuracy of air temperature and water vapor is better than 1 K for temperature at 1 km vertical resolution and better than 10% for water vapor relative humidity at 2 km vertical resolution. This is a significant improvement over GOES-12 sounder. Future work includes further simulations using MM5 cube data in both clear and cloudy skies and more ABI (Schmit and Gurka 2002; Schmit et al. 2004) simulations using MM5 data.

ACKNOWLEDGEMENT

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