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SURFACE AND ATMOSPHERIC RETRIEVALS FROM THE FUTURE GOES SOUNDER – ADVANCED BASELINE SOUNDER (ABS)

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1. INTRODUCTION

The Advanced Baseline Sounder (ABS), now being referred to as the HES (Hyperspectral Environmental Sensor), is being designed for future Geostationary Operational Environmental Satellites (starting with GOES-R in 2012) (Gurka and Dittberner, 2001). ABS/HES will have thousands of channels with widths on the order of single wavenumbers (approximately 0.5 cm^{-1}), while the current GOES Sounder has only 18 bands with widths on the order of tens of wavenumbers. In the absence of clouds, the ABS/HES has the capability to produce a three-dimensional depiction of temperature and moisture with better vertical resolution (approximately 1 km) and temporal resolution (hourly full disk soundings) while maintaining the horizontal resolution (better than 10 km). The ABS/HES products will include atmospheric vertical temperature and moisture profiles, structure of clouds, location and transport of key atmospheric constituents, and deriving surface properties (surface pressure, surface skin temperature and infrared spectral surface emissivity). These observations will be important in addressing the science questions related to the structure and dynamics of atmospheric systems, atmospheric chemistry, and transportation of constituents, and diurnal variations and short-term changes in the atmosphere and at the surface. The observations from the ABS/HES will also provide the operational data required for improved fine-scale modeling and with the Fifth-Generation NCAR / Penn State Mesoscale Model (MM5) cube data have forecasting of significant weather related to convective systems and cyclonic storms. Simulations been carried out to demonstrate the capability of ABS for high temporal, high spatial and high vertical resolution atmospheric, cloud and surface products with high accuracy. In addition, cloud top pressure (CTP) retrievals from simulated ABS/HES cloudy radiances in thin high clouds are improved over those achieved with the current GOES sounder. Recent hyperspectral Aqua Atmospheric Infrared Sounder (AIRS) measurements have been used for ABS/HES algorithm validation. The impact of band-to-band co-registration errors with ABS/HES 2-waveband configuration is also investigated.

2. GENERAL REQUIREMENT FOR ABS/HES

The ABS/HES shall produce data (while meeting all on-orbit calibration and navigation requirements) with the coverage specified below:

a) Scan within 62 degrees local zenith angle within one hour.
b) Scan selectable areas ranging from meso-scale areas (1000 by 1000 km) through the size of the full disk.

ABS/HES will be a 2-band interferometer (GIFTS like) or a 3-band dispersive sounder (AIRS like). Table 1 lists the ABS/HES interferometric and dispersive sounder wavebands.

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Table 1a. Interferometric Sounder Waveband Descriptions

Wavenumber (cm^{-1})	Wavelength (μm)	Unapodized spectral bin size (cm^{-1})	Number of bins (1840)
650 – 1200	15.38 – 8.33	0.625	880
1650 – 2250	6.06 – 4.44	0.625	960

Table 1b. Dispersive Sounder Waveband Descriptions

Wavenumber (cm^{-1})	Wavelength (μm)	Bin size (cm^{-1})	Number of bins (~1800)
650 - 950	15.38 – 10.54	0.625 cm^{-1}	~600
950 -1600	10.54 – 6.25	1.25 cm^{-1}	~600
2100 - 2350	4.8 – 4.25	1.25 cm^{-1}	~300
2400 - 2600	4.17 – 3.85	1.25 cm^{-1}	~300

ABS/HES radiance measurements, at varying spectral resolutions, can be converted into atmospheric temperature, moisture and ozone profiles. ABS/HES spectral resolution will resolve individual carbon dioxide absorption lines and should provide the high vertical resolution soundings with the required accuracy.

3. FAST FORWARD MODEL DEVELOPMENT AND RETRIEVAL ALGORITHM DEVELOPMENT

A new computationally efficient clear sky transmittance and radiance model has been developed for the ABS/HES 2-band spectral configuration. This includes algorithms for computing clear sky transmission profiles and top-of-atmosphere radiance spectra, as well as fast tangent linear (Jacobian) model. The new fast model is based on new LBLRTM version and updated HITRAN 2000 spectroscopy data with local zenith angle extended to 70^{o} (it was 65^{0} in the old model). The algorithm for retrieving atmospheric temperature and moisture profiles from ABS/HES two waveband radiances has been updated with the new fast forward model. This algorithm was a regression procedure with all spectral channels followed by a nonlinear iterative physical approach with optimally selected subset of channels (Li and Huang 1999; Li et al. 2000; Ma et al. 1999; Zhou et al. 2002).

Figure 1 shows water vapor mixing ratio weighting functions for ABS/HES 2-band short midwave (SMW) band (1650 - 2250 cm**-1) and the current GOES sounder (Menzel and Purdom 1994), along with the ABS/HES SMW brightness temperature spectra. ABS/HES has much more vertical water vapor information in troposphere than current GOES sounder.

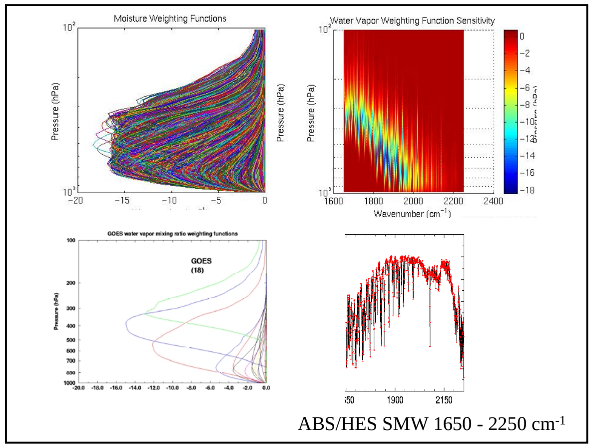

Figure 1, water vapor mixing ratio weighting functions (upper left and upper right panels) for ABS/HES SMW band (1650 - 2250 cm**-1). The lower left panel is the current GOES sounder water vapor weighting functions, the lower right panel shows the ABS/HES SMW brightness temperature spectra. U.S. standard atmosphere is used in the calculation.

Trade studies are being performed to support ABS/HES instrument design. For example, when one spectral band fails or is too noisy for a given pixel, a one band retrieval is tested against the two-band retrieval. The impact of reduced or increased instrument noise on retrieval is also being tested. The impact of LW cutoff 685 cm^{-1} versus 650 cm^{-1} on retrievals was being investigated. Figure 2 shows the 1km vertical temperature retrieval RMSE (left panel) and 2km vertical water vapor (RH) retrieval RMSE (right panel) from HES LW only, SMW only, LW+ SMW, compared with the current GOES sounder. It can be seen that temperature information is mostly provided by LW. For moisture information, LW provides very useful boundary layer information while SMW provides most water vapor information above 700 hPa; LW + SMW gives the best moisture vertical information. HES two band TRD noise is added in the ABS/HES simulation. For more details on those trade-off studies, see Li et al. (2002).

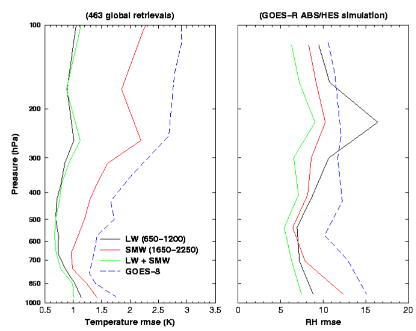

Figure 2, the 1km vertical temperature retrieval RMSE (left panel) and 2km vertical water vapor (RH) retrieval RMSE (right panel) from HES LW only, SMW only, LW + SMW, and current GOES sounder. 463 global independent profiles are included in the retrieval statistics; TRD noise is used in the simulation.

4. IMPACT OF BAND-TO-BAND CO-REGISTRATION ERROR ON SOUNDING RETRIEVAL FROM ABS/HES

The impact of band-to-band co-registration error on various sounding retrievals from ABS/HES 10km spatial resolution radiances are quantified using MODIS 1km IR bands with band-to-band co-registration errors of 10% (1km), 20% (2km) and 50% (5km). The errors of MODIS IR bands are spectrally interpolated to ABS two-band spectra. Then this band-to-band co-registration error is added in the ABS/HES simulation. The upper panel of Figure 3 shows ABS/HES two waveband LW TRD noise and the errors with 10%, 20% and 50% band-band mis-alignment (or mis-registration), all the noises are scaled to NeDT@250K, while the lower panel show the brightness temperature spectra calculated from a standard atmosphere.

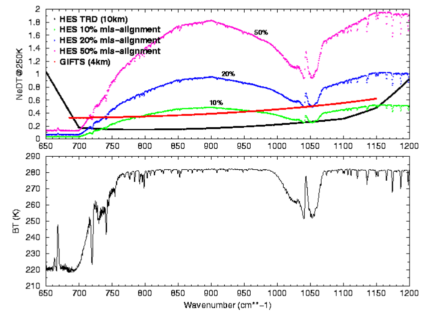

Figure 3, ABS/HES TRD noise and RMS error with 10%, 20% and 50% LW band-to-band co-registration error.

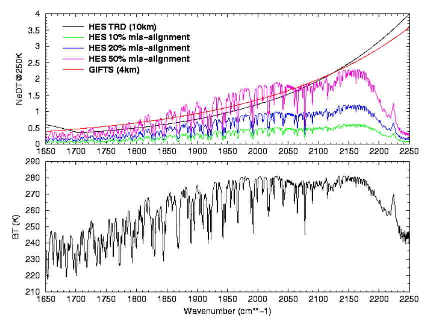

Figure 4, ABS/HES TRD noise and RMS error with 10%, 20% and 50% SMW band-to-band co-registration errors.

Figure 4 is the same as Figure 3 but for SMW band.

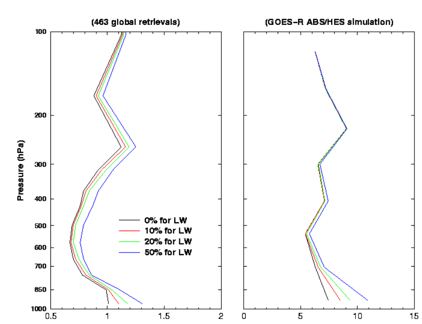

Figure 5, the 1km vertical temperature and 2km RH retrieval RMSE from ABS/HES two waveband simulation with 0% (no mis-alignment error), 10%, 20% and 50% band-band mis-alignment errors from LW band only.

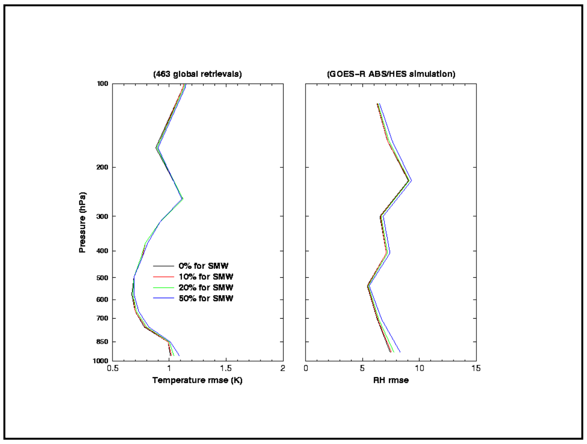

Figure 6, the 1km vertical temperature and 2km RH retrieval RMSE from ABS/HES two waveband simulation with 0% (no mis-alignment error), 10%, 20% and 50% band-band mis-alignment errors from SMW band only.

Figure 5 shows the 1km vertical temperature and 2km RH retrieval RMSE from ABS/HES two waveband simulation with 0% (no mis-alignment error), 10%, 20% and 50% band-band mis-alignment errors from LW band only. It can be seen that LW mis-alignment error will affect temperature and boundary layer moisture retrievals.

Figure 6 shows 1km vertical temperature and 2km RH retrieval RMSE from ABS/HES two waveband simulation with 0% (no mis-alignment error), 10%, 20% and 50% band-band mis-alignment errors from SMW band only. It can be seen that SMW mis-alignment error will only slightly affect temperature and boundary layer moisture retrievals.

5. ABS/HES SIMULATION STUDY USING CUBE DATA FROM MM5

In order to demonstrate the capability of high temporal resolution ABS/HES on monitoring the evolution of a weather system, atmospheric cube data from MM5 has been created for a simulation study. The time step is half hour; temperature and moisture regression retrievals (currently no physical retrieval are used in this study) are created from simulated ABS/HES clear radiances with TRD noise added. Retrieval fields are compared with true atmospheric fields from the cubes to demonstrate the spatial and temporal characteristics of ABS/HES radiances and sounding retrievals.

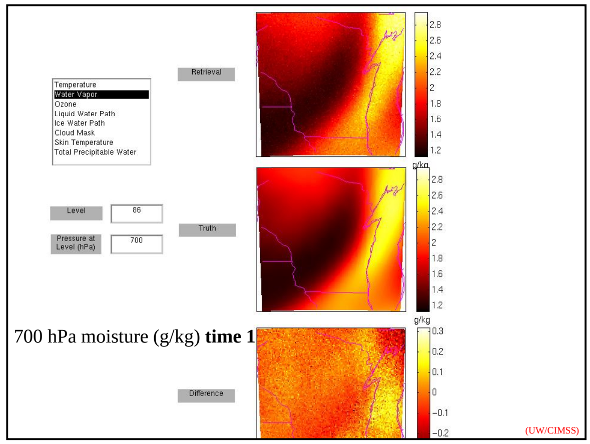

Figure 7, simulated ABS/HES clear 700 hPa water vapor mixing ratio retrieval image (upper panel), true image (middle panel) and the difference between retrieval and true (lower panel) at time 1.

Figure 7 shows simulated ABS/HES clear 700 hPa water vapor mixing ratio retrieval image (upper panel), true image (middle panel) and the difference between retrieval and true (lower panel) at time 1. Figure 8 is the same as Figure 7 but for time 2.

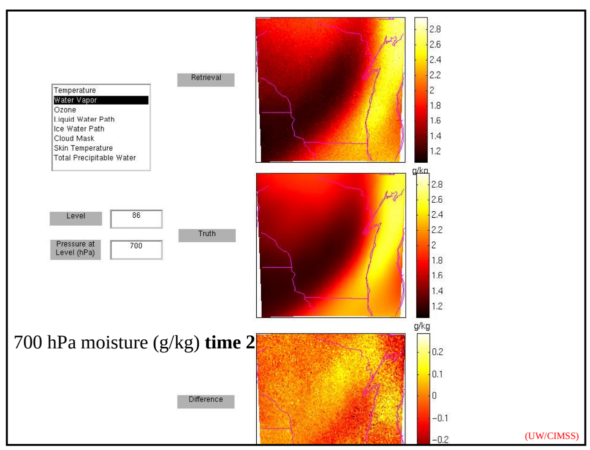

Figure 8, simulated ABS/HES clear 700 hPa water vapor mixing ratio retrieval image (upper panel), true image (middle panel) and the difference between retrieval and true (lower panel) at time 2.

6. CLOUD PROPERTY RETRIEVAL FROM ABS/HES CLOUDY RADIANCES

The high spectral resolution in the CO_2 region enables ABS/HES to provide much more cloud property information than the current GOES spectral broad CO_2 bands. Figure 9 shows ABS/HES 2-band LW cloud pressure sensitivity spectra with a cloud top pressure (CTP) of 200, 300, 500, 700 and 850hPa as a function of effective cloud amount (ECA) or effective cloud emissivity. Four panels show the calculations from 4 different atmospheric states.

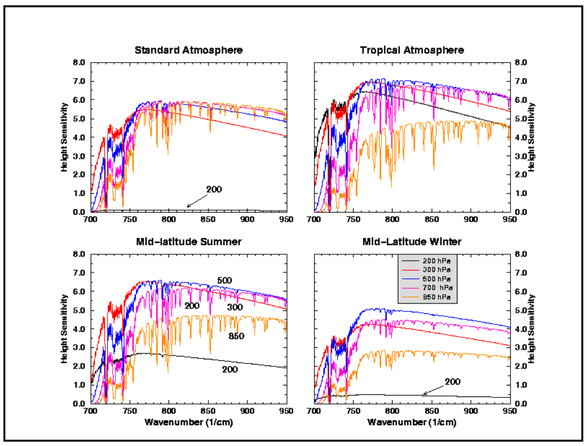

Figure 9, CTP sensitivity spectra with 200, 300, 500, 700 and 850 hPa CTPs, four atmospheric conditions are used in the calculations (see the 4 panels).

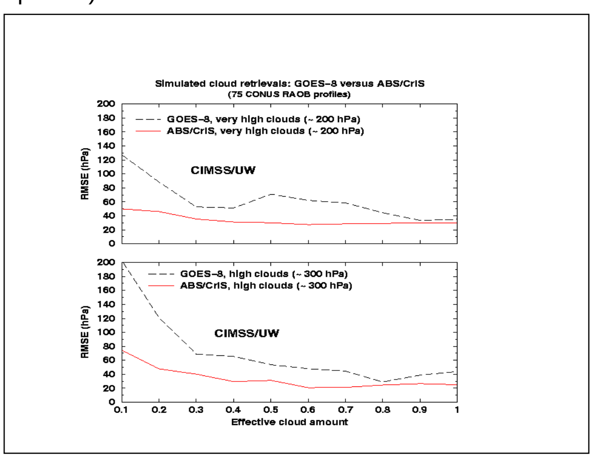

Figure 10, simulated ABS/HES and current GOES sounder CTP retrieval RMSE as a function of ECA.

To compare the ABS/HES and current GOES sounder cloud parameter retrievals, a simulation study was conducted using a set of 75 CONUS radiosonde profiles, that represent different atmospheric conditions. Twenty combinations were formed from each profile by assigning two CTPs plus 50 hPa random variation (200 hPa and 300 hPa corresponding to very high- and high-level clouds) and 10 ECAs (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.0). The ABS/HES and GOES-8 longwave spectral band cloudy radiances were simulated for all combinations of each profile. An infrared surface emissivity of 0.98 for each longwave spectral band was assumed in the simulation. The ABS/HES TRD noise and GOES-8 instrument noise were added into the cloudy radiance. Cloud retrievals from both ABS/HES with local minimum emissivity variance (LMEV, Huang et al. 2002) and GOES-8 sounder with 1DVAR (Li et al. 2001) are compared with true CTPs for RMSE calculations. In order to account for the surface uncertainties and the atmospheric profile error in the LMEV and 1DVAR cloud retrievals, nominal errors were considered in the simulation. For atmospheric temperature, a 1.5 K random error was assumed at each pressure level, which is close to the accuracy of the forecast analysis. For surface skin temperature a nominal random error of 2.5 K was assumed in the simulation. In addition, 1.0% error was included for infrared (IR) surface emissivity and 15% error was included for water vapor mixing ratio at each pressure level.

Figure 10 shows the simulated ABS/HES and current GOES sounder CTP retrieval RMSE as a function of effective cloud amount (ECA) or effective cloud emissivity. For thin clouds, high spectral is very important for more accurate CTP.

7. INITIAL ABS/HES ALGORITHM VALIDATION USING AIRS MEASUREMENTS

ABS/HES algorithms are being tested using Aqua's Atmospheric Infrared Sounder (AIRS) radiance measurements to ensure the operational robustness of the algorithm. The ABS/HES algorithm has been adjusted to the AIRS fast forward model for retrieval processing with AIRS measurements. Initial water vapor retrieval results from AIRS are compared with those from GOES and

MODIS; results will be presented at the conference.

8. CONCLUSIONS

Retrieval simulations have been carried out to demonstrate the sounding capability of ABS/HES on remote sensing. The following conclusions can be drawn.

(1) ABS/HES has much better spatial coverage, vertical resolution, and sounding accuracy than the current GOES sounder.
(2) The ABS/HES TRD noise meets the temperature and moisture retrieval accuracy (1K for temperature and 10% for moisture).
(3) LW band co-registration error has impact on both boundary layer temperature and moisture retrieval, 10% co-registration error will double the system noise in longwave window region. LW band co-registration error has less impact on the upper tropospheric temperature and moisture retrieval, however, surface skin temperature and emissivity retrieval is expected to be impacted significantly by the LW band co-registration error.
(4) SMW band co-registration error of less than 50% won't significantly add error to temperature and moisture retrievals in this particular case.
(5) The MM5 cube study shows that both spatial and temporal features of the atmosphere can be detected from the ABS/HES retrievals.
(6) ABS/HES provides much better CTP retrieval accuracy over the current GOES sounder, especially for thin high clouds.

Future work will focus on sounding and cloud retrieval using a combination of ABS/HES and Advanced Baseline Imager (ABI) (Schmit et al. 2002) data and validation of the HES/ABI algorithm with AIRS/MODIS measurements.

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