P2.27

Improvement in Groundbased Infrared Hyperspectral Retrieval of Thermodynamic Profiles

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1. Introduction

The United States Department of Energy's Atmospheric Radiation Measurement (ARM) program has funded the successful development of the Atmospheric Emitted Radiance Interferometer (AERI) instrument during the past decade. This has led to a hardened, autonomous system that measures downwelling infrared (IR) radiance at high-spectral resolution. Seven AERI systems have been deployed around the world as part of the ARM program. The initial goal of these instruments was to characterize the clear-sky IR emission from the atmosphere for thermodynamic profiling (Feltz et al. 2003), thus a temporal sampling was chosen (8-10 min per spectrum) to minimize random noise in the AERI observations. Recent research emphasis has been placed on the improvement of vertical resolution and temporal sampling on AERI derived atmospheric boundary layer thermodynamic profiles and cloud property retrievals.

Results indicate that the AERI derived temperature profiles more accurately represent strong surface based temperature inversions common through nocturnal radiative cooling with a higher vertical resolution line-by-line fast model. AERI retrieval results from the International H_20 Program (IHOP) demonstrate that improved vertical resolution of temperature within the lowest one kilometer of atmosphere has been achieved implementation of a new more accurate and higher vertical resolution fast model. The University of Wisconsin-Madison deployed an AERI instrument in its mobile AERIBago in 40-second rapid-scan mode during the CRYSTAL-FACE experiment in southern Florida. Temperature and moisture retrievals from the rapid-scan data also demonstrate fluctuations in the boundary layer thermo-dynamic profile that are lost due to averaging with the nominal sampling strategy.

2. AERIPLUS Retrieval Vertical Resolution Improvement

The AERIplus temperature and moisture retrieval algorithm has now implemented a new fast model based upon LBLRTM using Hitran 2000. The previous 50-level fast model was developed using FASCODE and a Hitran 1992 database. The new fast model provides a doubling of vertical resolution within the first 100 hPa of atmosphere (surface to 900 hPa) from 10-hPa spacing to 5 hPa (now 60 levels). The Hitran 2000 line parameter update has dramatically reduced the water vapor line residuals between AERI and calculation. Figure 1 shows an AERI observation compared to two fast model calculations from a radiosonde launched for the ARM SGP central facility on 06 October 1999 at 0530 UTC. The improved vertical resolution and use of updated line parameters has significantly improved agreement between calculation and AERI observation when strong gradients of temperature and water vapor are present just above the AERI instrument. The increased layering improves the agreement in regions of strong absorption by CO2 used for low-level temperature inversions (Figure 1). The new Hitran 2000 line parameters improve water vapor channel agreement, especially at the longer wavelength channels used for water vapor retrieval. As a result of the fast model improvement, the AERI retrieval algorithm will have a reduced dependence on using a spectral bias to account for fast model errors. Since the water vapor lines have become better understood spectroscopically, the vertical range and accuracy of retrieved profiles will improve by selecting well-known weakly absorbing lines with in the 8 - 12 um region.

An example of the temperature retrieval improvement is shown in figure 2 from the IHOP field program on 02 June 2002 from Lamont, Oklahoma. An AERI derived temperature profile from the 50-level algorithm and 60-level algorithm is compared to a radiosonde (black) at 1130 UTC indicating that the 60-level algorithm can better resolve multiple temperature inversions, thereby producing a better match to the radiosonde profile. The IHOP AERI data sets (six instruments) have been reprocessed for the IHOP experiment duration.

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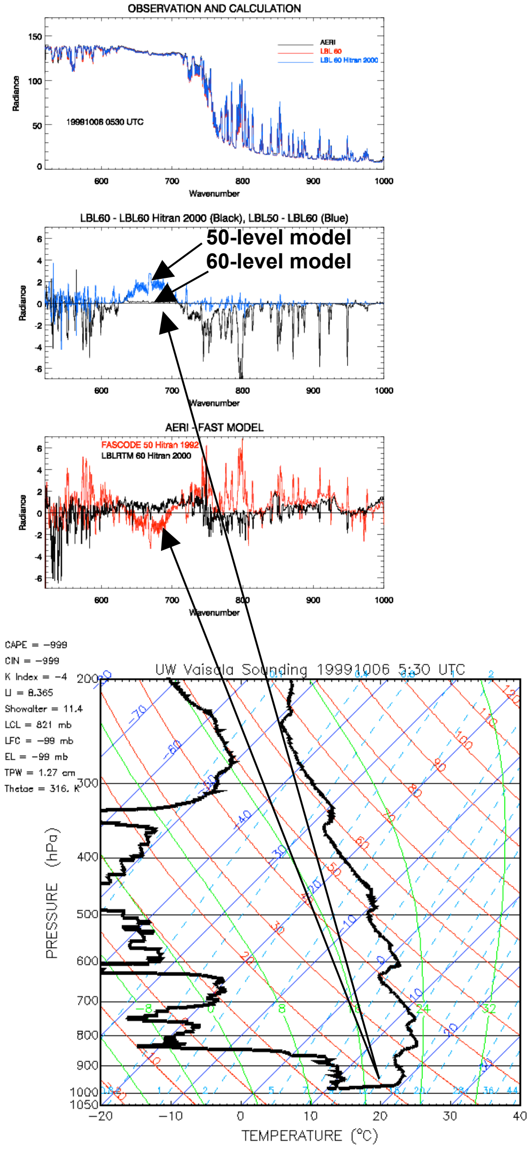

Figure 1: Observed and calculated AERI spectra (top panel); calculation differences (middle panel), and AERI observation/calculation differences (bottom panel). The calculations were performed using the radiosonde shown in right figure. A SKEWT diagram of a radiosonde launched at 0530 UTC on 06 October 1999. This radiosonde was selected due to high confidence of atmospheric state based upon microwave radiometer observations. Calculations shown on figure 1 were performed with this radiosonde profile. Notice the strong surface temperature inversion is spectrally resolved within left figure using the 60-level LBLTRM fast model.

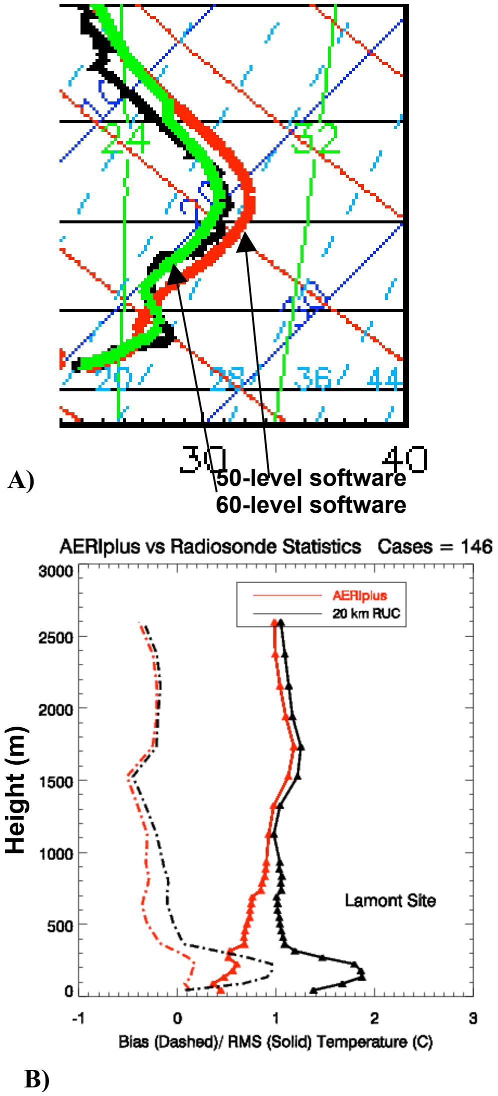

Figure 2: The top figure (A) shows an example of the updated AERIplus temperature retrieval improvement during the IHOP field experiment. One profile was calculated with the 50-level FASCODE fastmodel while the other profile uses the new 60-level LBLRTM based fast model with improved vertical resolution and spectroscopy as compared to radiosonde (thick black line). The bottom figure (B) indicates the improvement in root mean square (solid lines) and mean bias (dashed line) the AERI radiances make to collocated Rapid Update Cycle (RUC) analysis profiles as compared to 146 radiosondes during the IHOP program at Lamont, Oklahoma.

3. AERIPLUS Retrieval Temporal Resolution Improvement

The standard AERI temporal sampling strategy (~8 minutes) was chosen to optimize the signal-to-noise ratio in clear sky conditions. The radiance data has been used to provide accurately calibrated radiances to validate line-by-line radiative transfer models and profile atmospheric boundary layer temperature and moisture. This sampling strategy is inadequate for sampling cloud radiative properties (Turner et al. 2003), or to capture high frequency (i.e., 1 min) fluctuations within water vapor in the boundary layer. The development of a set of noise filtering tools, which utilize a principal component analysis of the spectra (Huang and Antonelli, 2001), allow the AERI to be run at much higher temporal resolution and obtain adequate noise levels and calibration accuracy as the nominal 10-min AERI data.

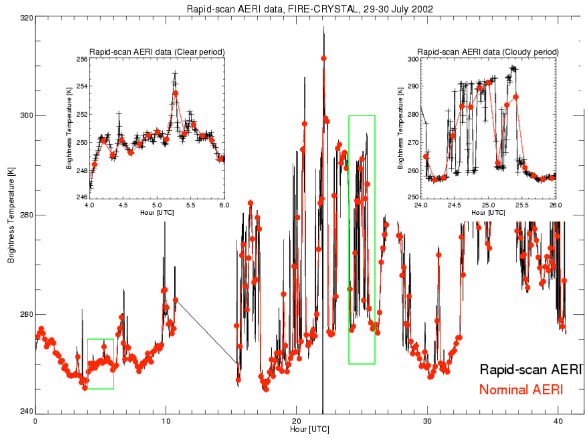

Figure 3: A time series of AERI microwindow brightness temperature measured at 900 cm^{-1} on July 29-30, 2002 during the CRYSTAL experiment in southern Florida. The temporal sampling is less than one minute for the rapid scan AERI mode while brightness temperatures are calculated for the normal ten-minute resolution mode.

The University of Wisconsin-Madison deployed the AERI in its mobile AERIBago in this rapid-scan mode during the CRYSTAL-FACE and Texas 2002 experiments. An example that highlights the necessity for rapid sampling in multi-layer cloud conditions is given in Fig 3. In this figure, the black lines (star symbols) denote the downwelling radiance (converted to brightness temperature) at 900 cm^{-1} for the rapid scan mode (a 12 s sky dwell approximately every 40 s). This data was then post-processed back up to the nominal AERI resolution of a 3 min sky dwell every 8 minutes; these data are indicated by the gray lines (dots). The data cover a 42 h window from the CRYSTAL-FACE experiment. Temperature and moisture retrievals from the rapid-scan data also demonstrate fluctuations in the boundary layer thermodynamic profile that are lost due to averaging with the nominal sampling strategy. This new sampling strategy has been implemented at the University of Wisconsin – Madison is being considered within the DOE ARM program to optimize AERI radiance retrievals. Figure 4 indicates how AERI retrieved high temporal resolution water vapor can be used to estimate and infer the presence boundary layer roll structures. Please see paper P2.25 (Bedka et al.) for more information regarding this research. Gaps in the data are due to low clouds.

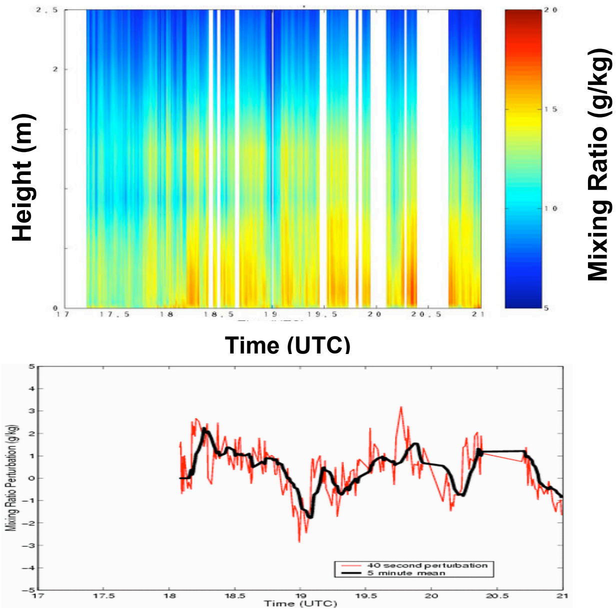

Figure 4: AERI water vapor mixing ratio profiles at 40-s time resolution obtained during the CRYSTAL-FACE experiment (upper panel). A time series of AERI retrieved water vapor perturbations calculated (red line) based on a 60 min running mean (black line) at 315 m above ground level for the period 17 – 21 UTC on July 29, 2002 (lower panel).

4. CONCLUSIONS

Improvements have been made in both the vertical and temporal resolution of AERI retrievals. New applications for this data include validation of large eddy simulation, investigation of boundary layer turbulence, and analysis of mesoscale phenomenon. The DOE ARM program will be converting all the AERI systems to a rapid sample mode of less than 30 sec primarily for improved cloud property retrieval (Turner et al. 2003), however new thermodynamic retrieval applications are also being realized.

5. ACKNOWLEDGEMENTS

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