Retrieval and Visualization of AERIPLUS Temperature and Moisture Profiles for Assimilation into ARM Single-Column Models

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Introduction

Using remotely sensed temperature, moisture, and wind data to initialize and drive Single-Column Models (SCM) is an important goal of the Atmospheric Radiation Measurement (ARM) Program. Since December 1998, five atmospheric emitted radiance interferometer (AERI) (Revercomb et al. 1993) systems have been running nearly continuously at the central and boundary facilities at the Southern Great Plains Cloud and Radiation Testbed (SGP CART). Retrievals of temperature and water vapor from the surface to the top of the troposphere are produced from AERI radiance and Geostationary Operational Environmental Satellite (GOES) observations. An excellent sample of statistical comparisons of temperature and water vapor profiles compared respectively to radiosondes and Raman lidar are shown within this paper. Visualization of the data in time and space from all five sites is possible with VisAD, an interactive visualization tool, which is freely available for the scientific community. This animation ability is essential to understand coherent meteorological structure passing over the AERI systems. Results of an investigation into the utility of the retrievals within SCMs will also be shown.

Retrieval Accuracy

Since December 1998, five AERI systems have been operating continuously at Purcell, Lamont, Morris, and Vici, Oklahoma, as well as Hillsboro, Kansas. Each of the AERI systems are collocated next to National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) wind profiler systems. The AERI system's ability to physically retrieve 10-minute resolution temperature and water vapor retrievals within the planetary boundary layer (PBL) in clear sky and to cloud base is well documented (Feltz et al. 1998; Smith et al. 1999; Turner et al. 2000). To improve the accuracy and range of the physical retrieval using the AERI radiances, a new hybrid first guess methodology has been employed. The temperature profile from a numerical weather prediction model (currently ETA) is linearly blended into the AERI statistical retrieval between 2-3 kilometers. Hourly water vapor profiles provided by physically retrieved water vapor from the GOES satellite is used to provide a better first guess of water vapor within the upper PBL. The improvement this hybrid first guess offers to the physical retrieval is documented within the following ARM Science Team Meeting proceedings: http://www.arm.gov/docs/documents/technical/conf_9803/smith-98.pdf

Statistical comparisons to concurrent radiosonde launches for temperature and Raman lidar water vapor profiles (Figures 1 and 2) indicate temperature root mean square (RMS) differences of approximately 1° kelvin and absolute water vapor differences of 6% to 8%.

Visualization

Retrievals are now produced operationally at all five AERI sites. With the expansion of the AERI network, new visualization schemes have been explored to help interpret coherent meteorological mesoscale structures. Using VisAD, a relatively new Java three-dimensional-based visualization tool developed at the Space Science and Engineering Center (SSEC) within the University of Wisconsin (Hibbard 1998), AERI-retrieved temperature and moisture structure can be advected by retrieved winds from collocated wind profiler systems. Figure 3 is a snapshot example of a remotely sensed cold frontal passage on January 12, 2000. The VisAD-generated flags are defined by the magnitude and direction of

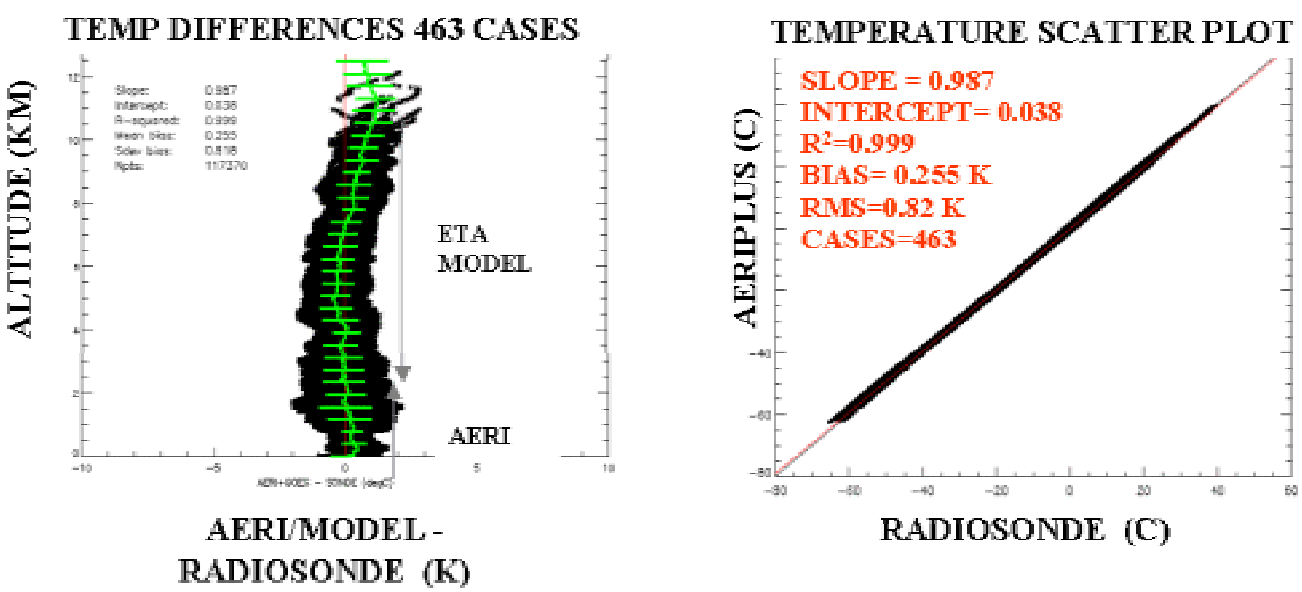

Figure 1. Temperature differences between 463 concurrently launched radiosondes and AERIPLUS physical retrievals. Since the AERI radiance information is only valid to three kilometers, differences above this point between the ETA model and radiosondes. The green line represents the standard deviation and mean of the difference profiles with altitude. The figure on the right is a scatterplot of temperature for concurrent altitudes.

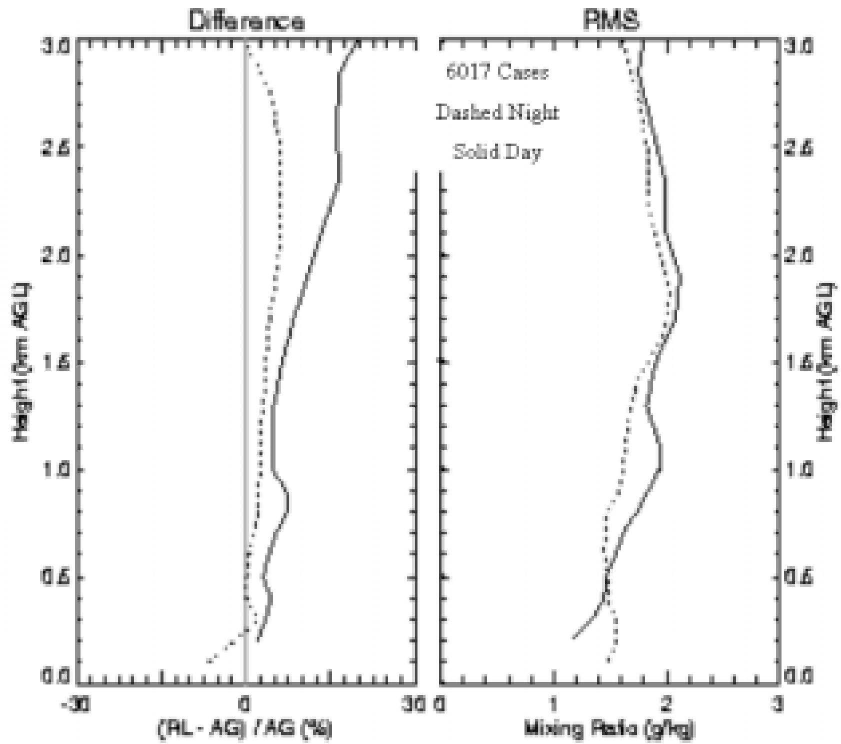

Figure 2. Mean difference (left) and RMS statistics (right) as a function of height for AERIPLUS water vapor mixing ratio versus Raman lidar, broken into nighttime (dashed line) and daytime (solid line) clear-sky cases. There are 6017 and 2749 cases in each ensemble, respectively.

the wind profiler winds with altitude, while the colors (blue – red) are defined by the water vapor mixing ratio magnitude. The flags are animated with time (10-minute resolution) allowing high-time resolution monitoring of temperature and water vapor advection. Notice the moisture flags turn from south-westerly to northerly with time and the drying (blue color) that occurs behind the front. The VisAD software allows rapid comprehension of remotely sensed data and how each of the individual profiling sites relate to each other. This tool is a valuable asset and should be used for SCM data evaluation as well as other ARM-related data visualization.

SCM Data Assimilation

An evaluation of replacing radiosonde data with AERIPLUS temperature and moisture retrievals for driving SCM calculations has been conducted by Xie and Cederwall (2000). Figure 4 indicates around 0.5°C differences between radiosondes and AERI temperature retrievals. Above 800 mb, the ETA model temperature shows large differences compared to radiosondes. This problem is being rectified by using rapid update cycle (RUC)2 profiles instead of ETA for building the first guess for the AERI retrieval. A moist bias within the boundary layer is apparent for both the AERI retrievals and the RUC2 model. A known dry bias exists within the radiosondes used for the study. This water vapor

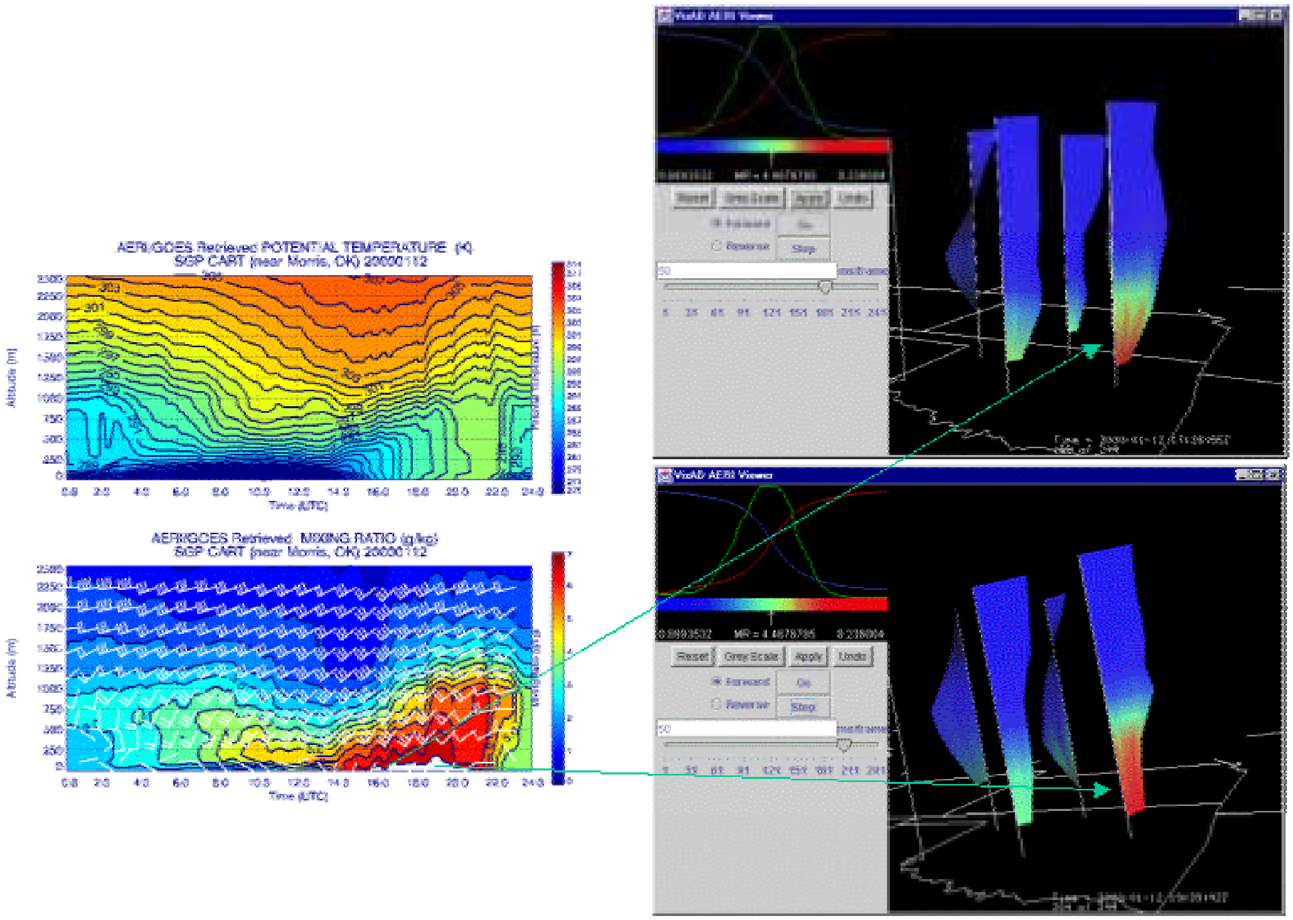

Figure 3. An example of an AERIPLUS time-height cross section for Morris, Oklahoma, indicating the potential temperature and moisture field over Morris for January 12, 2000. Wind profiler winds are overlayed on top of the cross section. The two images on the left show the new VisAD visualization for the same day over all the AERI systems. The "flag" direction and magnitude in a function of the wind vector from the wind profiler while the flag color is defining the magnitude of the retrieved water vapor mixing ratio from the AERI systems. Notice the cold frontal passage from northwest to southeast and the deepening of moisture with time in Morris, Oklahoma.

comparison will be reevaluated with a moisture correction applied to radiosondes using microwave radiometer total precipitable water. The general conclusions for this study are as follows:

- AERIPLUS retrievals can provide accurate temperature profiles within the boundary layer. However, the temperatures above the PBL (mainly from the ETA model results) show large biases. RUC2 gives a better temperature profile above 500 mb.

- The differences in the moisture field between retrievals and radiosondes should be reduced when the dry bias in regular radiosondes is corrected.

- The SCM gives similar results when forcings derived from the different data sources are used, indicating that the principal behavior of the SCM can be evaluated using these data.

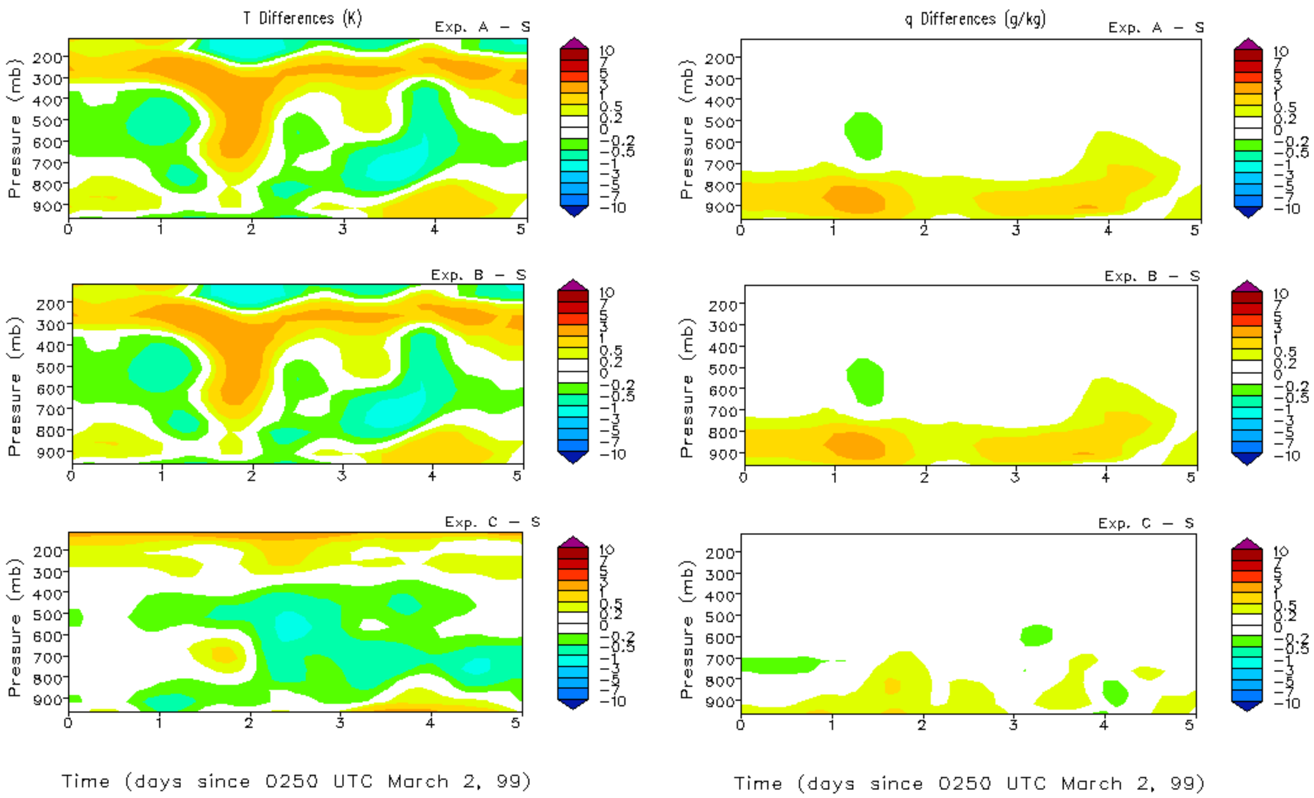

Figure 4. Time-height cross sections of temperature differences (left) and water vapor differences (right). Field “S” is a control run derived from three hourly radiosonde launches. Field “A” is temperature and moisture derived from AERIPLUS retrievals and winds from wind profilers. Field “B” is the same as A, only RUC2 winds are used. Field “C” is a field of T, q, and winds entirely made up of RUC2 model data. Notice the AERI temperatures (800 mb - surface) are in agreement to within 0.5°C of the radiosonde data, while there is both a moist bias in the AERI and the RUC2 data as compared to the radiosondes. It is well known that these radiosondes have a dry bias so further research is needed.

These are exciting conclusions, meaning the potential of driving SCMs solely with remotely sensed data through non-precipitating periods is possible. This shows potential to bridge SCM runs between intensive operational periods (where radiosondes are launched at three hourly intervals from all five sites) allowing annual SCM comparisons and statistics.

Future Work

The AERIPLUS retrieval product will be improved as follows:

- The RUC2 model analysis profiles at all five sites will be linearly interpolated into the AERIPLUS statistical first guess to improve the temperature a priori information above the boundary layer. The RUC2 model assimilates commercial aviation temperature and winds along with other conventional and remotely sensed data at hourly resolution which the ETA model does not.

- A 200-level fastmodel based upon line-by-line radiative transfer model (LBLRTM) is being implemented within the retrieval algorithm, which should improve the vertical resolution within the first kilometer of the atmosphere. Currently, a 50-level fastmodel based on Fastcode from 1993 is being used under sampling the true AERI vertical resolution.

- The retrieval algorithm will be employed operationally for the North Slope of Alaska and Tropical Western Pacific AERI systems.

- The Surface HEat Budget of the Arctic Ocean (SHEBA) AERI data set will be processed to produce boundary layer temperature and water vapor retrievals for use in large eddy simulation (LES) studies.

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