AERI Plus Retrieval Developments at the DOE ARM Sites

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Abstract

Atmospheric Emitted Radiance Interferometer (AERI) plus retrieval results are presented from all three U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) sites. The AERI plus retrievals from the Southern Great Plains (SGP) site will show improvement in the hybrid first guess by including rapid update cycle-2 (RUC-2) numerical weather prediction (NWP) model temperature and moisture profile information above the boundary layer. In addition, progress has been made to automate calculation of moisture flux divergence and convergence between the five AERI sites using wind profiler information. New retrieval datasets are available in near real-time from the North Slope of Alaska (NSA) and Surface Heat Budget of the Arctic Ocean (SHEBA) providing high temporal resolution profiles for large-eddy simulation (LES) and single-column model (SCM) validation. The Nauru 99 AERI datasets from Nauru and the Japanese vessel Mirai will also be presented for determination of the influence of Nauru Island on the Tropical Western Pacific (TWP) ARM datasets.

Southern Great Plains Site Developments

A grid of five AERI instruments (Revercomb et al. 1993) at the SGP ARM site is routinely producing temperature and moisture retrievals within the atmospheric boundary layer. The AERI physical retrieval algorithm (Smith et al. 1999; Feltz et al. 1998) is now linearly blending RUC-2 model (Benjamin et al. 1998) temperature and moisture profiles into the AERI retrieval statistical first guess between 1.5 to 2.0 kilometers. This has improved the physical retrieval of the boundary-layer thermodynamic state in the upper boundary layer (2 to 3 km) as well as providing a better hourly mid/upper tropospheric atmospheric state profile. The hourly RUC-2 temperature profile is substantially better than Eta model (Black 1994) temperature profiles (temperature structure used in Geostationary Operational Environmental Satellite [GOES] physical retrievals) because RUC-2 incorporates hourly a priori information (Aerodynamic [Research Incorporated] Communication and Recoding System [ACARS], GOES, wind profiler, Global Positioning System [GPS], etc.) through data assimilation techniques. The

Eta model is reinitialized on a 6-hr cycle at most, and therefore an hourly forecast is used until the next Eta initialization time. This inherently increases the root mean square (rms) differences between the Eta temperature and moisture profiles and radiosondes.

Figure 1 indicates the improvement in temperature and water vapor rms differences obtained within mid-/upper-level troposphere using RUC-2 numerical model initial state (purple line) as compared to the Eta model (black line) forecast during March to December 2000 at the central SGP facility near Lamont, Oklahoma. A total of 522 radiosonde launches were used in the comparison. The red line indicates AERI rms differences showing an improvement of nearly 1.5°C in the lowest 50 mb of atmosphere over either numerical weather prediction model. Most of the NWP model temperature error within the boundary layer is due to the inability of the model to resolve nighttime nocturnal inversions. Similar improvement in the AERI water vapor mixing ratio over the Eta and RUC-2 from the surface to 750 mb as compared to radiosondes is noted.

Figure 2 provides an individual example of how the AERI boundary-layer retrievals contain useful model validation information. Three time-height cross sections of relative humidity (RH) are shown from October 11, 2000 at the SGP Central Facility. The top panel contains 10 min AERI-derived RH, the center panel displays linearly interpolated radiosonde data when provided (white dashed lines), and the bottom panel is derived from the RUC-2 hourly analysis (extracted profiles over the Lamont, Oklahoma location). The RUC-2 is under analyzing the magnitude of the RH within the layer of moisture at 2 km between 0000 Universal Time Coordinates (UTC) to 0800 UTC and then 1 km between 0800 UTC to 2400 UTC relative to the AERI or radiosonde cross section. This may have

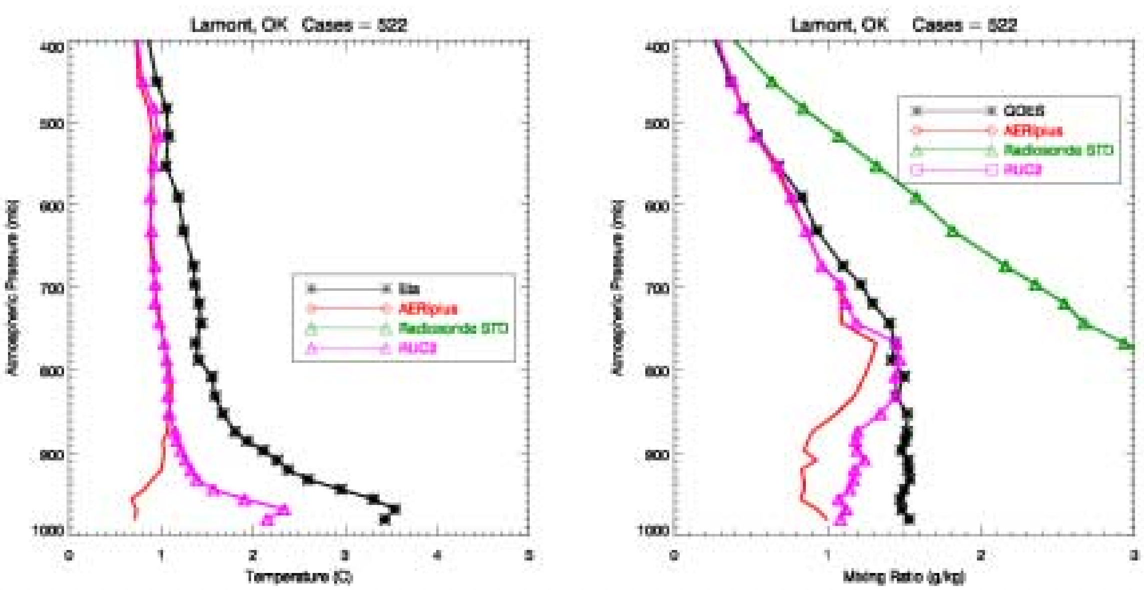

Figure 1. Temperature and mixing ratio rms differences compared to 522 Vaisala radiosonde launches compared to Eta (black line), RUC-2 (magenta line), and physically retrieved AERI profiles (red line) for March to December 2000 at the central SGP Cloud and Radiation Testbed (CART) site facility. A green line indicates the radiosonde standard deviation for temperature and mixing ratio during this period if within x-axis domain.

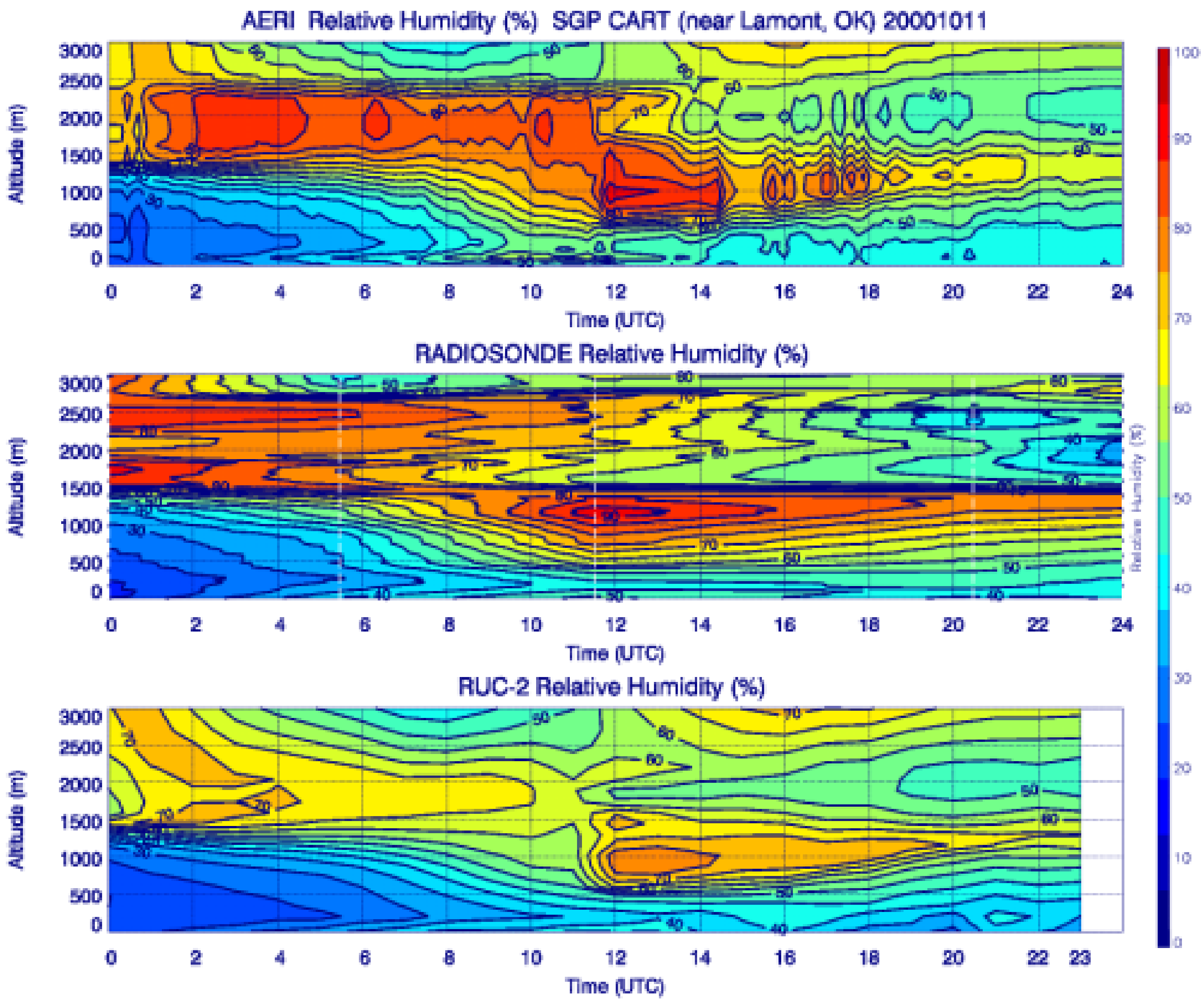

Figure 2. Time-height cross sections of RH from the AERI instrument, radiosondes, and RUC-2 numerical weather prediction model on October 11, 2000. The time resolution for the AERI profiles are 10 min, white lines indicate radiosonde launches, and the RUC-2 data is the hourly analysis.

important consequences for cloud formation within the numerical weather prediction model. The radiosonde time series must be carefully examined since radiosonde information only exists at 0000, 0530, 1130, 2030, and 2330. All data between these times are interpolated. The AERI physical retrieval algorithm is correcting boundary-layer discrepancies obtained within the RUC-2 initial analysis by adjusting the temperature and moisture structure to fit the observed downwelling AERI radiances. Since the RUC-2 is now being used as a background thermodynamic state in ARM cloud-resolving simulation models (CRMs) and SCM, the AERI boundary-layer retrievals should provide significant improvement within the first two kilometers for the troposphere.

All five AERI system retrieval datasets collocated with wind profiler systems may be used to calculate moisture flux convergence and advection between the sites. This has been evaluated during the May 3, 1999, Oklahoma/Kansas tornado outbreak (Feltz and Mecikalski 2001). Figure 3 indicates the three AERI systems used to calculate the moisture advection/convergence values prior to convective initiation later in the period. In Figure 4 are examples of AERI/wind profiler-derived moisture advection and convergence from 1500 UTC to 2100 UTC for the center of the triangle shown in Figure 3. The equivalent potential temperature field indicates rapid destabilization of the boundary layer between 2000 UTC and 2100 UTC. Prior to this period, moisture flux divergence was occurring with little moisture advection. A rapid transition from moisture divergence to convergence occurred around 1830 UTC providing significant rapid destabilization within the boundary layer. These measurements indicate that observing high-resolution moisture gradients is critical to understanding the convective initiation problem. Area-averaged moisture advection and convergence between SGP CART site locations would provide another validation product for comparison to SCM model output and the means to drive CRM/SCMs between intensive operational periods (IOPs).

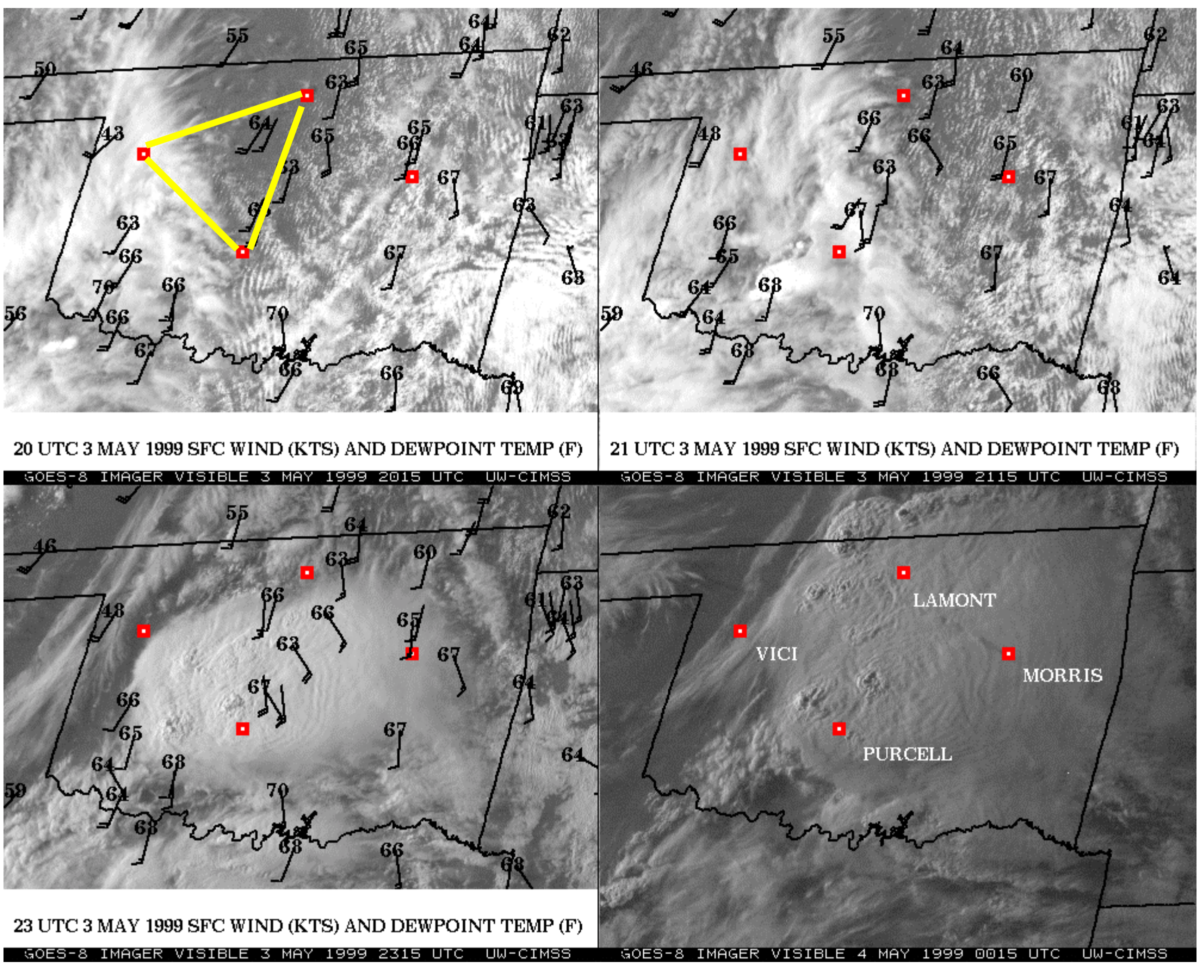

Figure 3. GOES-8 visible satellite images from 2000 UTC to 2359 UTC on May 3, 1999, over the ARM SGP CART site domain. The AERI locations are indicated by the red dots. Moisture flux advection and divergence calculations were conducted for the three AERI systems connected by the yellow triangle.

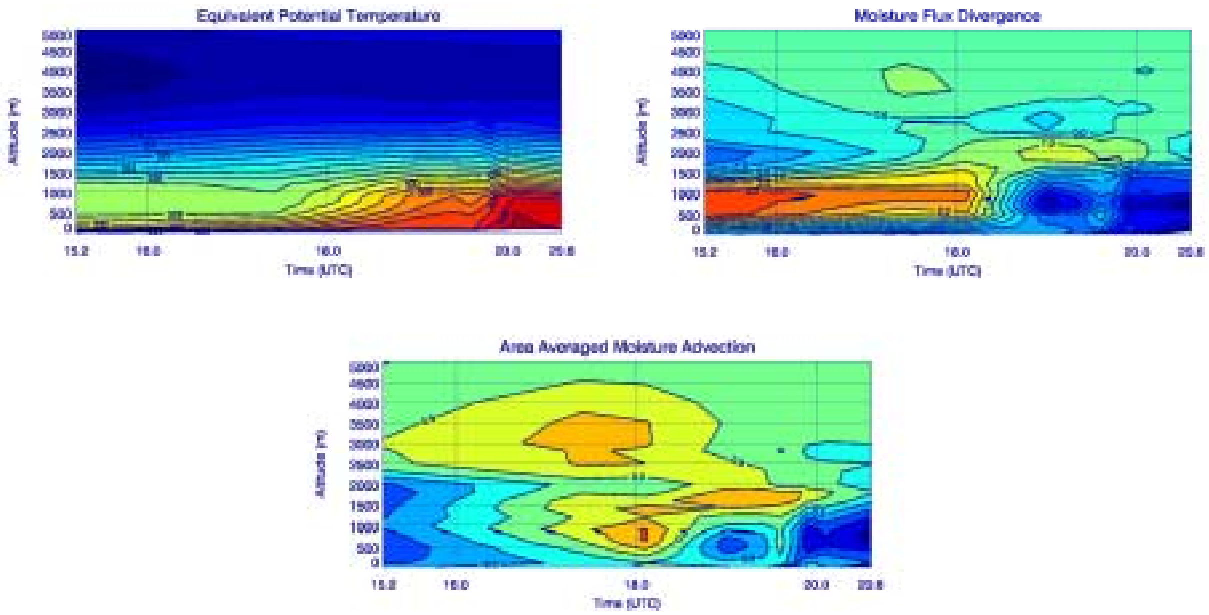

Figure 4. Average equivalent potential temperature, moisture flux divergence (red divergence/blue convergence), and moisture advection (red divergence/blue convergence) for the three AERI systems during the May 3, 1999, Oklahoma/Kansas tornado outbreak.

Tropical Western Pacific Developments

During the TWP Nauru 1999 deployment, a Marine-AERI (M-AERI) system was operating aboard the Japanese ship Mirai. The University of Miami M-AERI system was taking ocean skin sea-surface temperature (SST), ocean emissivity, and downwelling atmospheric radiances at a 20-minute cycle. Temperature and moisture retrievals were calculated from the downwelling radiances and compared to retrievals derived from the Nauru Island AERI system. During the three IOP days of July 1 to 3, 1999, a heat island effect is noticed during the day of about 1.5°C each day near the surface with influence to 500 meters (see Figure 5). The Mirai was located approximately 45 km southwest of Nauru island and

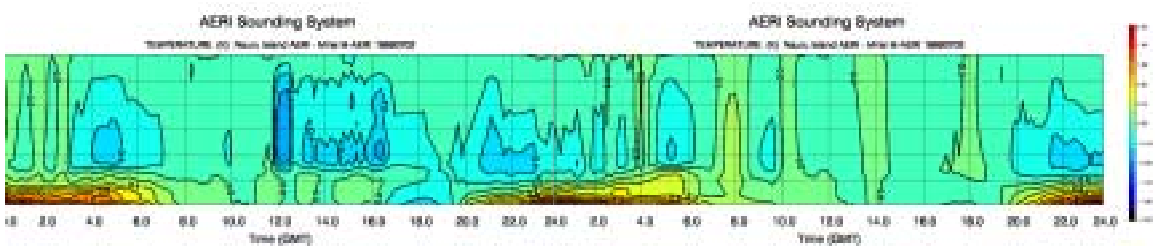

Figure 5. A 3-day time-height cross section (July 1 - 3, 1999) for Nauru AERI-derived temperature (K) profiles differences from the ship-based Mirai M-AERI-derived temperature field. Daily temperature differences of up to 1.5°C are indicated up to an altitude of 500 meters. The pulsing feature above the first kilometer is due to cloud contamination within the retrievals.

therefore was unaffected by any island influence. There was also an increase in water vapor mixing ratio during the day on Nauru Island. Validation using the two microwave radiometers and surface measurements is ongoing.

Conclusions and Future Work

New progress has been made in improving the AERI physical retrieval algorithm for all three permanent ARM sites. RUC-2 numerical weather prediction model temperature and moisture profiles above the boundary layer have improved the number of successful AERI physical retrievals and provided a better hourly mid/upper tropospheric atmospheric state. AERI-retrieved temperature and moisture fields in the lowest 2 km of the boundary layer can be used to validate how representative the thermodynamic state is within NWP models. AERIplus/wind profiler moisture flux convergence and advection has been evaluated during the May 3, 1999, Oklahoma/Kansas tornado outbreak indicating that observing high-resolution moisture gradients is critical to understanding the convective initiation problem. Area-averaged moisture advection and convergence between SGP CART site locations would provide another validation product for comparison to CRM model output. The Nauru 99 AERI datasets were processed to produce temperature/moisture retrievals aboard the Mirai and on Nauru Island. A heat island effect of approximately 1.5°C was observed on Nauru Island. Near real-time ER-AERI retrievals have been implemented from Barrow to monitor boundary-layer inversion and instrument operations. Future work includes the following:

- 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 NSA and TWP AERI systems.

- Routine moisture flux divergence and advection products will be produced between the AERI/wind profiler locations in the SGP for CRM/SCM input.

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