AERI + GOES Retrievals at the SGP ARM Site: SCM Data Assimilation and Convective Forecasting Utility

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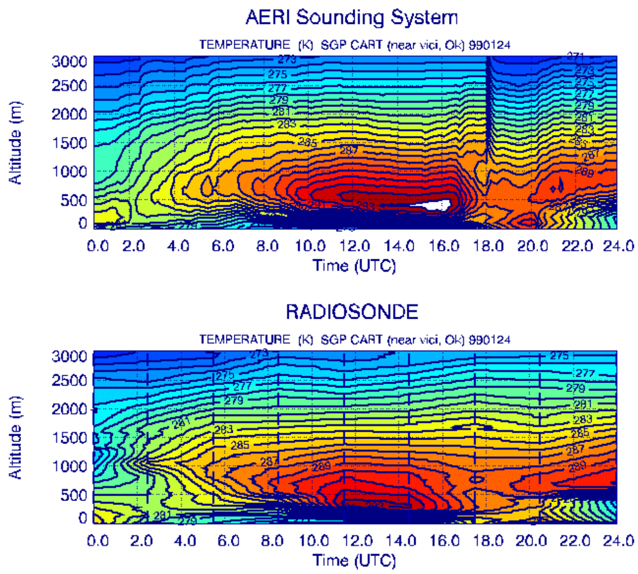
Introduction

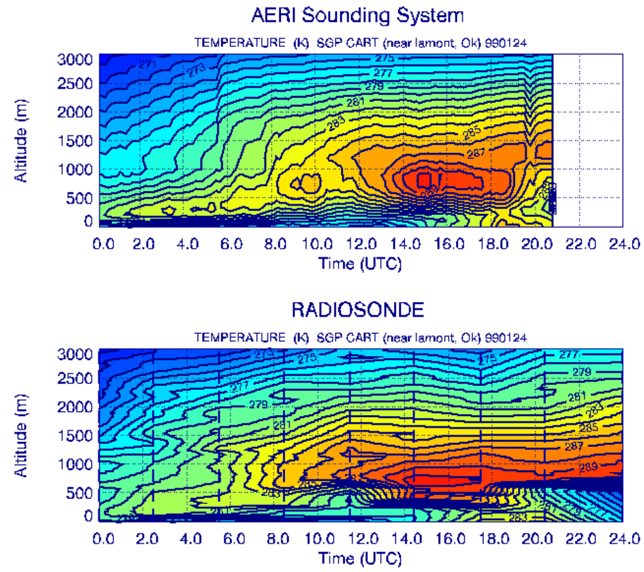
Four additional Atmospheric Emitted Radiance Interferometer (AERI) systems have been deployed at the U.S. Department of Energy's (DOE's) Atmospheric Radiation Measurement (ARM) Southern Great Plains Cloud And Radiation Testbed (SGP CART) site boundary facilities. The AERI + GOES (Geostationary Operational Environmental Satellite) temperature and water vapor retrieval product is now operational at Pacific Northwest National Laboratory (PNNL) allowing continuous monitoring of atmospheric thermodynamics at each of the CART site facilities (Lamont, Vici, Purcell, Morris, and Hillsboro) at a ten-minute temporal resolution. These unique temperature and water vapor profile measurements along with collocated profiler winds can be incorporated into single-column models (SCMs) and will be tested this year to supplement radiosonde launches. Time contiguous retrievals will be shown and discussed indicating data applications such as data assimilation and feasibility for nowcasting severe thunderstorm development.

A grid of five AERI systems are now in continuous operation located at each of the SGP CART site boundary facilities and at the central facility. The tropospheric temperature and water vapor profiles can now be obtained at ten-minute temporal resolution (Feltz et al. 1998). Figure 1 demonstrates the temperature profiling capability of the systems compared to radiosonde time cross sections during the SCM Winter Intensive Observation Period (IOP) on January 21, 1999. Both the ten-minute AERI/GOES retrievals and three hourly radiosonde launches indicate an elevated mixed layer advecting of the ARM CART site. This feature is noticed as an elevated warm layer of atmosphere between 14 Universal Time Coordinates (UTC) and 16 UTC at Vici, Oklahoma, 16 UTC and 18 UTC at Purcell, Oklahoma, and 18 UTC and 20 UTC at Morris, Oklahoma. The correlation of the features shown in the AERI/GOES and radiosonde cross sections is excellent. This retrieval product is now operational at PNNL and will provide a useful thermodynamic state product to the single-column modeling community. The utility of the retrievals will be tested this year by testing them in place of radiosondes during the SCM IOPs of January and March 1999.

AERI water vapor retrievals have now been validated using the DOE ARM Raman Lidar system. The lidar has the same temporal resolution as the AERI retrievals allowing unprecedented validation opportunities due to the variation of the water vapor field temporally. Figure 2 indicates a dryline passage on April 13, 1998. Both the passive (AERI) and active (Raman Lidar) systems compare very favorably to each other in both tendency and magnitude. The 915-MHz Wind Profiler wind field was



(a)



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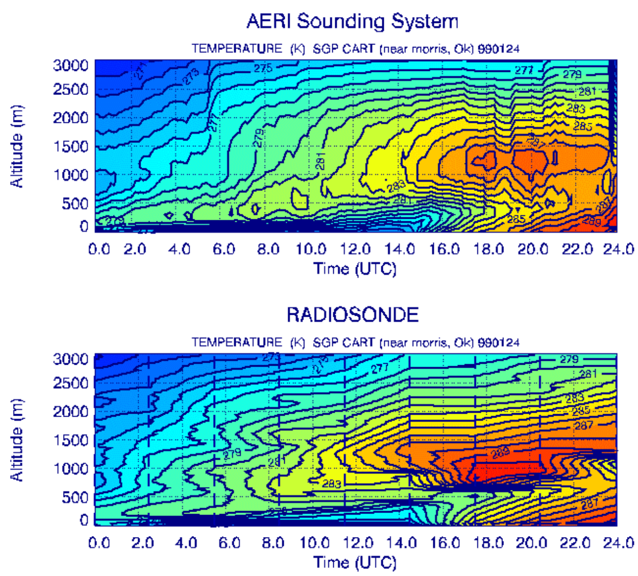

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Figure 1. Radiosonde validation of AERI temperature retrievals using time-height cross sections of temperature from west to east across the CART site (Vici, Lamont, and Morris) indicating an elevated mixed layer advecting over the SGP CART site. Time cross sections are from January 21, 1999, during the Winter SCM IOP.

placed on top of the time cross section to help interpret the meteorological features. The improvements made to the AERI retrieval algorithm through Raman Lidar validation at the central facility will improve the detection of atmospheric state at the other four AERI sites.

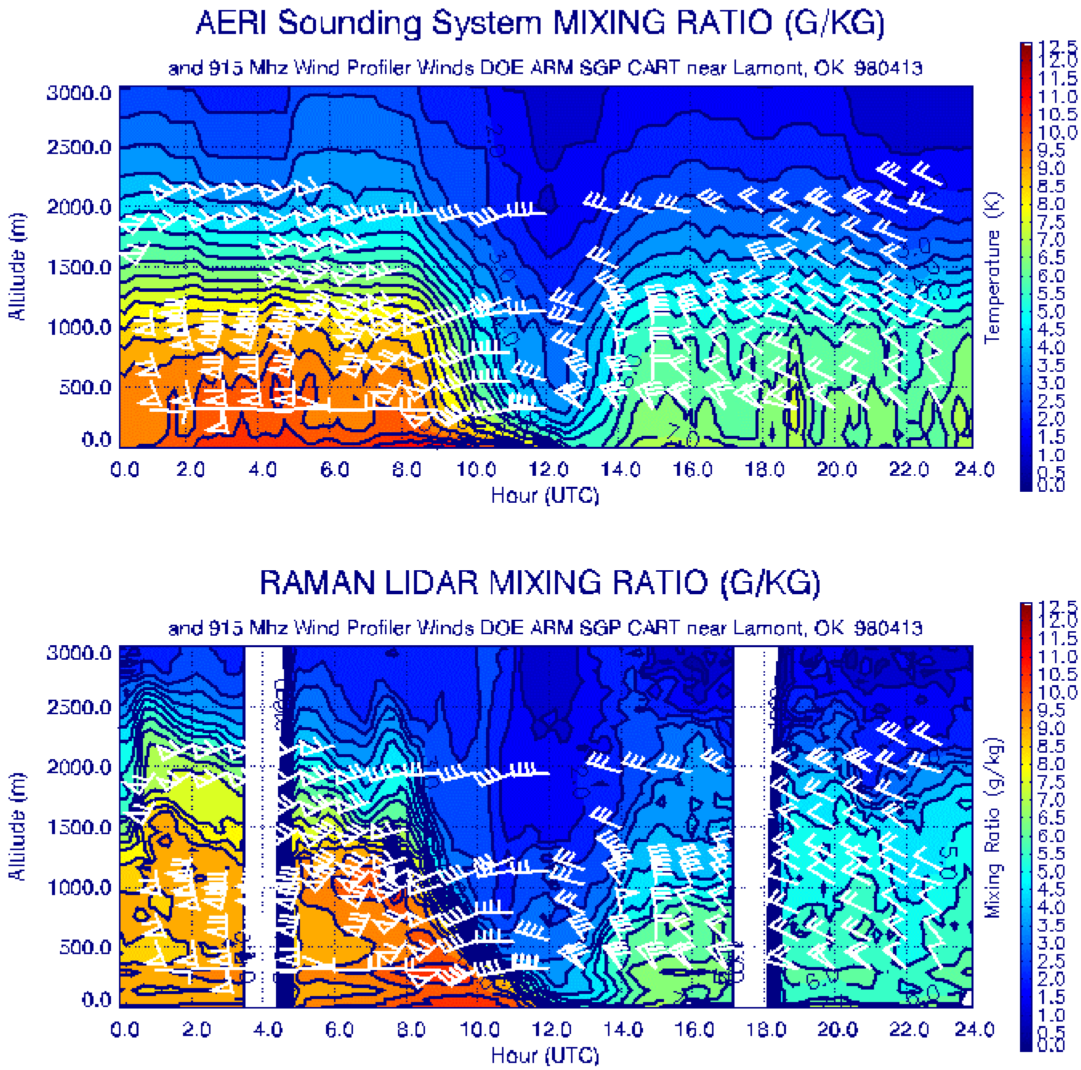

Figure 2. A time-height cross section comparison of water vapor from the passive AERI instrument retrieval and active Raman Lidar instrument retrieval. Both systems indicate a rapid drying of boundary layer moisture between 8 UTC and 10 UTC on April 13, 1998. The time cross sections are augmented by wind profiler wind date to help with the analysis.

These retrieval improvements not only help in providing data for assimilation within SCMs but also are providing invaluable meteorological information to operational weather forecasting. The higher temporal resolution, provided by the AERI+GOES retrieval product, reveals an exciting new source of meteorological data to the forecast meteorologist. Figure 3 shows AERI+GOES water vapor retrievals in the planetary boundary layer (PBL) along with ten-minute resolution lifted index, convective available potential energy (CAPE), and convective inhibition (CIN) on May 24, 1998. A cool front had moved through the northern Oklahoma area drying and stabilizing the atmosphere between 0 UTC and 12 UTC. As time progressed, the front moved back to the north as a warm front, indicated by the wind barbs, and brought with a rapid advection of moisture within the PBL between 16 UTC and 24 UTC.

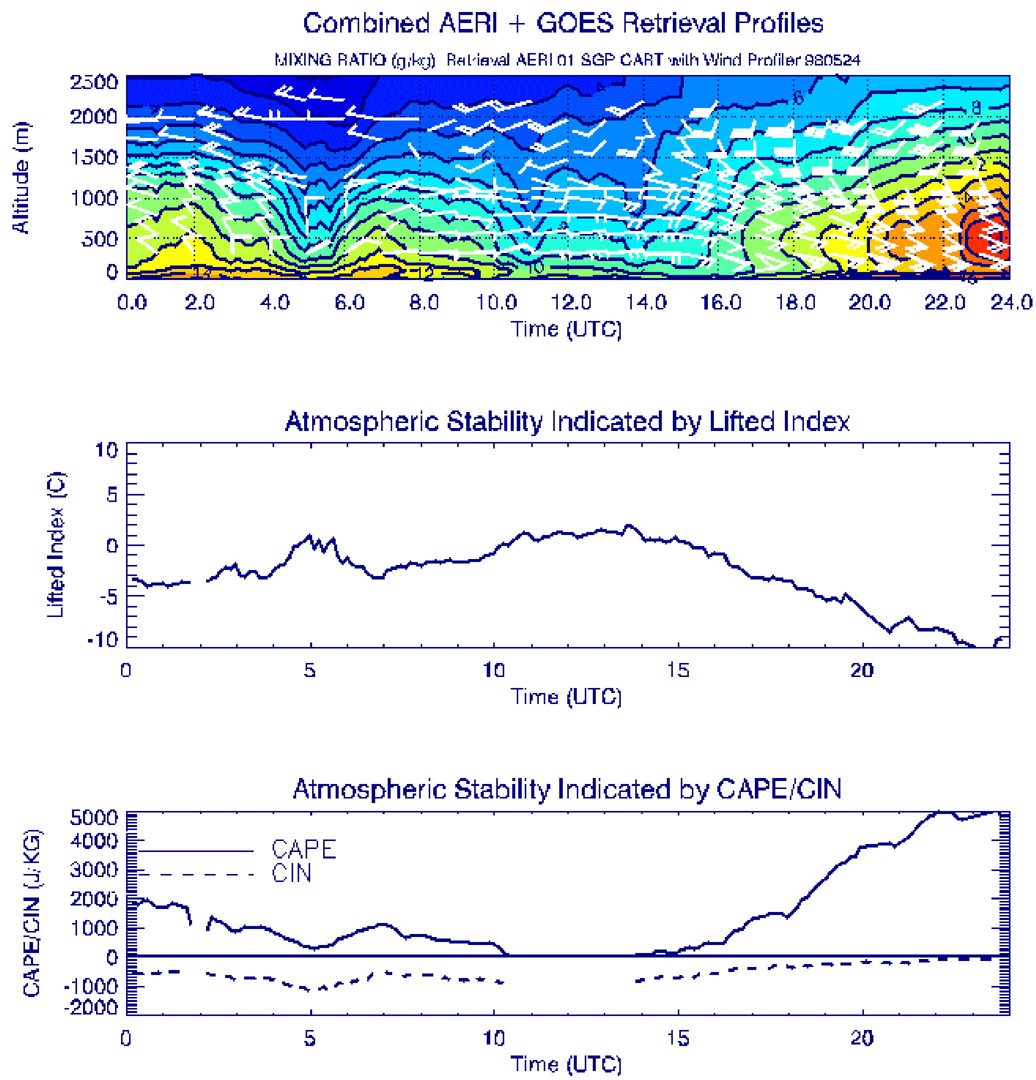

Figure 3. The upper panel shows a time-height cross section of AERI-derived water vapor mixing ratio retrieved on May 25, 1998. 915-MHz Wind Profiler winds are plotted over this cross section. Between 0 UTC and 12 UTC substantial drying is indicated in the PBL due to a frontal passage. Rapid moistening is indicated as the front retreats back to the north as a warm front. The mid and lower panel show the stability indices calculated from this time period from AERI+GOES retrievals.

Rapid destabilization of the atmosphere at ten-minute resolution is shown where the lifted index drops from 0 at 12 UTC to -10 at 24 UTC. A rapid rise in CAPE values from 0 J/KG at 16 UTC to 5000 J/KG at 24 UTC indicates the rapid increase in energy available for explosive convection. Most importantly, the AERI retrievals are very good at monitoring the inversion inhibiting the thunderstorm development. This is indicated by the CIN values near -900 J/KG at 16 UTC and rapidly approaching 00 J/KG at 24 UTC. All of these indices indicate rapid destabilization and important information to an operational forecaster. An important note is that no radiosondes were launched from the CART site this day because it was a Sunday. This data was derived through remote sensing of the infrared spectrum. A supercell developed northwest of the SGP site spawning an F4 tornado, which occurred within three miles of the site location.

The AERI systems are an important remote sensor of PBL structure. When combined with satellite-based broadband radiances, temperature and water vapor vertical structure can be determined at high temporal resolution through passive remote sensing. These retrievals will be used as input into the SCM models instead of radiosondes to bridge the gap between IOPs when radiosondes launches are minimized. Passive infrared monitoring of atmospheric state will provide invaluable meteorological information especially when several AERI systems are dispersed geographically. This data can provide time tendency of standard stability indices used by an operational forecaster at ten-minute resolution. Further research includes improving the physical retrieval algorithm to work in all climates, understanding the mesoscale processing captured with the AERI retrievals, and providing the retrievals simultaneously from the five operational AERIs in Kansas and Oklahoma to a mesoscale model to study forecast sensitivity to the retrievals.

References

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