Atmospheric Radiation Measurement Science Applications of Atmospheric Emitted Radiance Interferometer Measurements

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Atmospheric Emitted Radiance Interferometer (AERI) data are being used to study meteorological processes in the Planetary Boundary Layer (PBL), the quasi-continuous sound of the atmosphere through the synergistic use of Geostationary Operational Environmental Satellite (GOES) data, diagnose cloud radiative properties, validate theoretical calculations of atmospheric and cloud radiation, and parameterize cloud radiative properties in terms of predictable atmospheric parameters.

This paper provides a synopsis of AERI-related research over the past year. AERI instruments were used for continuous atmospheric measurements at the Atmospheric Radiation Measurement (ARM) Cloud and Radiation Testbed (CART) site. A mobile AERI was used to obtain measurements of cloud and atmospheric properties during several field campaigns. Sea surface and atmospheric measurements were obtained in the Tropical Western Pacific using the Marine AERI (MAERI). The field campaigns which included the mobile AERI system included the Water Vapor Intensive Operational Period (WV-IOP) in September 1996, the Cumulo-STRATus (CSTRAT) experiment near Penn State University in October 1996, and the WINter Cloud Experiment (WINCE) centered at Madison, Wisconsin, in January 1997.

One of the primary ongoing activities involving AERI is the thermodynamic profiling of the PBL. The PBL contributes the greatest amount of thermal radiation from molecules to the surface radiation budget. Although AERI cannot achieve the vertical resolutions inherent in active systems (e.g., lidar and radio acoustic sounding system [RASS]), it can provide useful depictions of PBL processes at locations where such active systems may not be available (e.g., the boundary sites of the Southern Great Plains [SGP] CART). This technique associates temperature and water vapor structure in an atmospheric column with AERI-measured high spectral resolution carbon dioxide and water vapor radiance spectra as shown in Figure 1.

The AERI-based PBL sounding system now operational for the SGP CART site is synergistic in that it makes use of Micropulse lidar or ceilometer data to specify cloud base and microwave total precipitable water measurements and surface data to provide boundary conditions for the profile retrieval using AERI radiance data.

Figure 2 illustrates temperature and water vapor cross-sections compared to 3-hourly radiosonde measurements and raman lidar during the WV-IOP for a day with a cold front passage over the CART site. Of particular interest is the ability of AERI to resolve an elevated moist layer, verified by the higher resolution lidar data, but not well defined by the 3-hourly radiosondes. It is worthy to note the AERI profiling resolution degrades rapidly with altitude, which is obvious from the figure. The future goals are to emphasize AERI's ultra-high vertical resolving power in the lowest few hundred meters of the PBL. The current processing approach limits the vertical resolution of the retrieved profiles to about 100 meters. Errors in the AERI-derived temperatures and water vapor mixing ratio are believed to be less than 1 K and 10%, respectively, on the basis of comparisons with radiosondes at the CART site (Feltz et al. 1997).

As noted earlier, the vertical resolution of AERI soundings decreases exponentially with altitude and is extremely limited

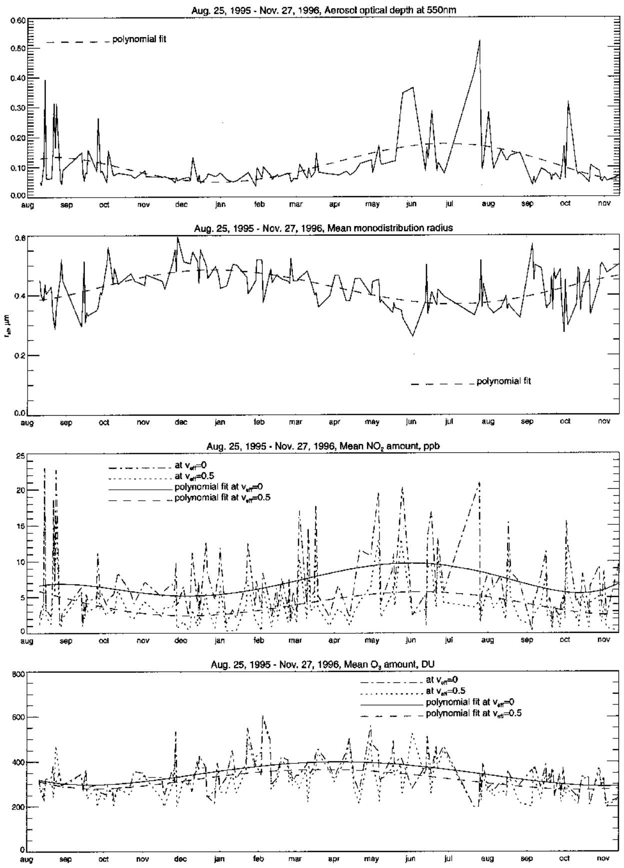

Figure 1. AERI-measured atmospheric downwelling radiance. Spectral regions used in temperature and water vapor retrievals are shown. Note the low atmospheric emission between absorption lines. These regions are used to study cloud radiative properties.

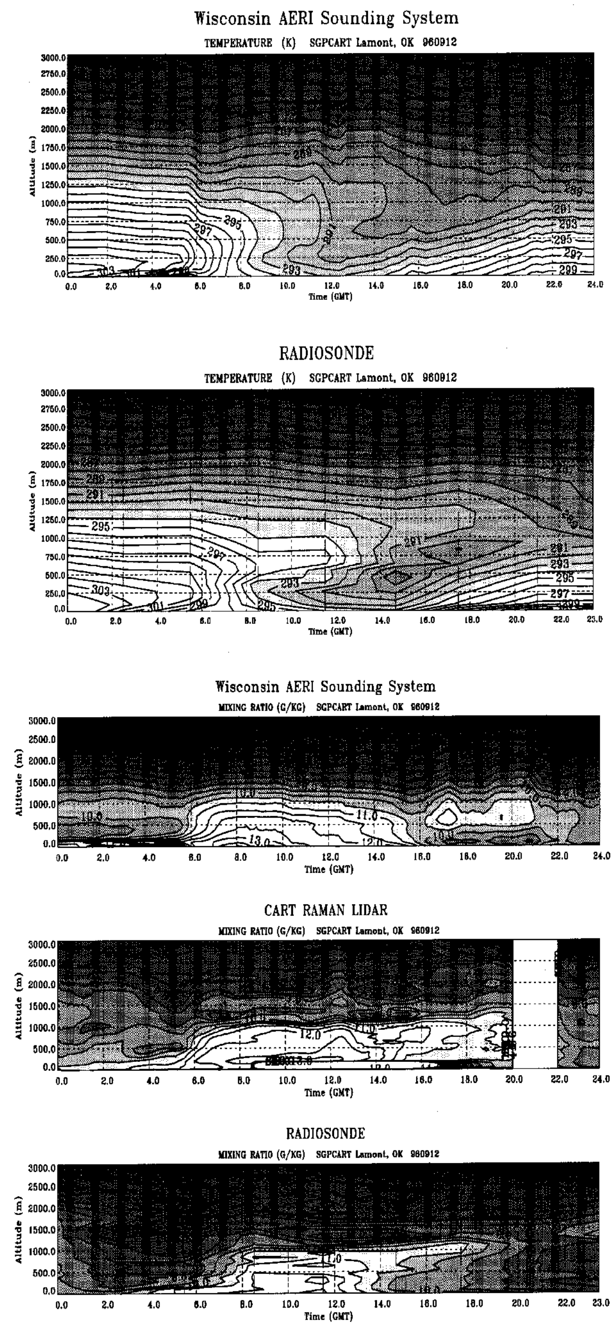

Figure 2. AERI retrieval time cross sections of temperature (above) and water vapor (below) compared to radiosonde and raman lidar data. Notice that the cold frontal passage, which occurred at 6 UTC, is easily resolved in the AERI temperature retrieval cross section. An elevated moist layer shown in the raman lidar water vapor cross section is also resolved by the AERI.

above 1 to 2 km. Combining geostationary satellite radiance information soundings synergistically to AERI sounding radiances will improve the retrieval in the free troposphere above the PBL. Figure 3, from the work of Ho,[a] shows theoretical performance expectations of the combined AERI and GOES systems compared with the individual accuracies of each instrument.

Combined with lidar data, AERI has also been used to investigate cloud radiative and microphysical properties. An

(a) S.-P. Ho, Atmospheric profiles from simultaneous observations of upwelling and downwelling spectral radiance, Ph.D. Thesis, University of Wisconsin-Madison, expected 1997.

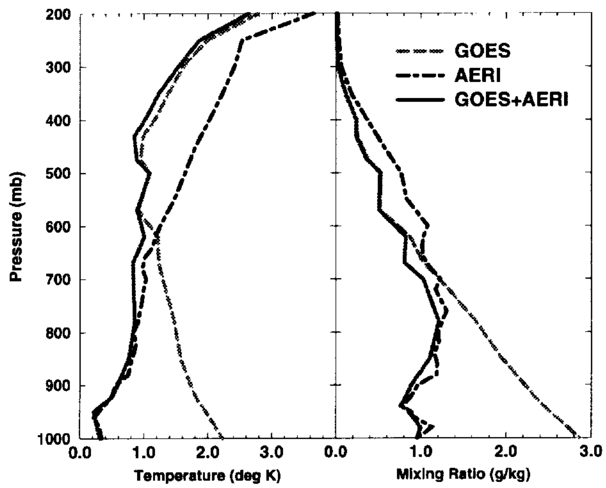

Figure 3. AERI, GOES, and AERI/GOES combined temperature and water vapor mixing ratio profile RMS differences compared with radiosondes for 153 simulated retrieval cases. Note the improvement from synergistically combining AERI and GOES radiances.

ongoing study at University of Wisconsin-Madison involves the High Spectral Resolution Lidar (HSRL), which provides vertical, absolutely calibrated, visible aerosol optical depth profiles. Figures 4a and 4b illustrate HSRL aerosol back-scatter cross section and AERI downwelling radiance, respectively.

The lidar data are used to effectively weight the cloud radiance, solving the radiative transfer equation in a forward solution to derive the visible to infrared cloud optical depth ratio (a key climate model parameter) for a number of atmospheric ‘microwindow’ regions (DeSlover 1996). These microwindows are the most transmissive portions of the atmosphere, spectrally located between water vapor lines. Figure 4c shows the spectral visible to infrared optical depth ratios using this approach, relative to Mie theory for ice spheres. Note the strong dependence on particle size for regions of weak absorption.

The MAERI has been developed to provide validation data for the Earth Observing System (EOS) satellite inferences over the world’s oceans. The MAERI participated in the Combined Sensor Program involving measurements from *RV Discovery* in the Tropical Western Pacific (TWP). The results, presented more extensively by Knuteson et al. (1997) and Minnett and Knuteson (1997), confirm a ‘cool skin’ of the ocean in the warm pool of the TWP of as much as 0.5° C, due to evaporation (Figure 5). The AERI data are also being used to estimate the ocean-atmosphere surface

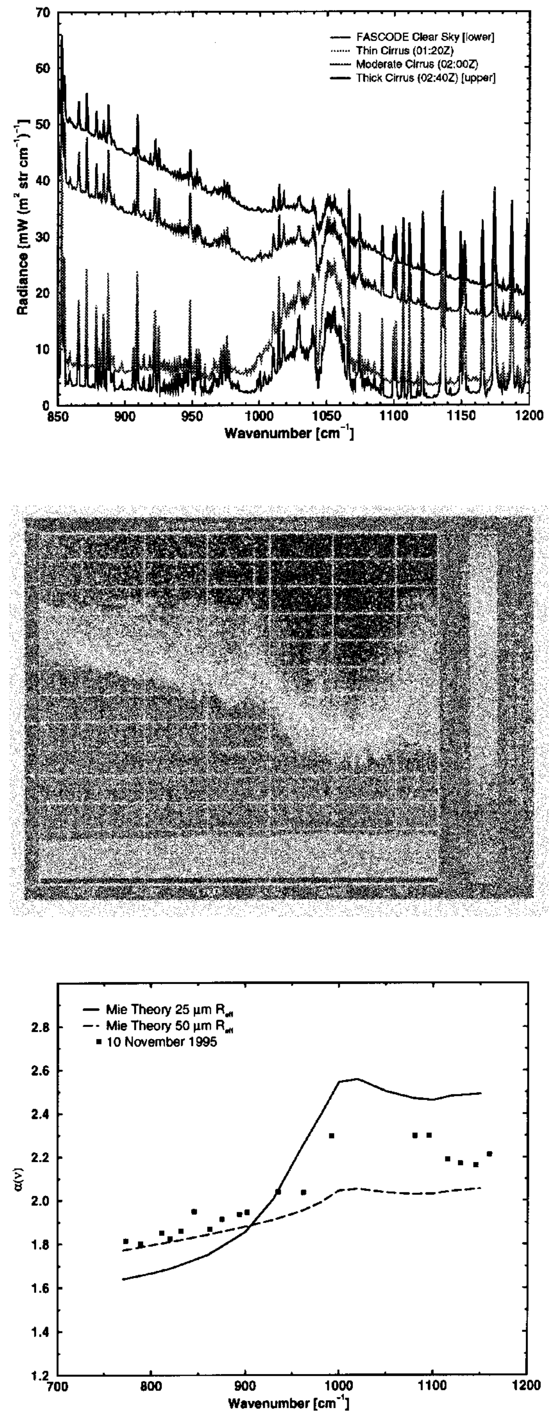

Figure 4. (a) HSRL aerosol backscatter cross section as a function of time. (b) AERI downwelling radiance for various cloud optical thickness. (c) Visible to infrared optical depth ratios (spheres), relative to Mie theory for 25 and 50 μm ice spheres (lines).

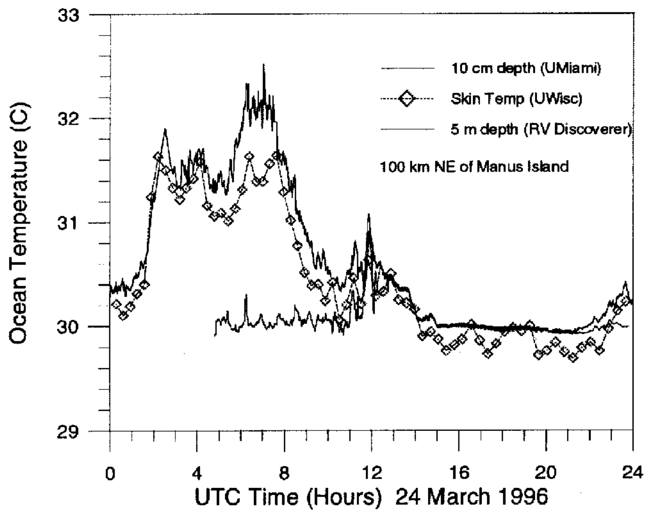

Figure 5. Preliminary comparison of MAERI skin temperatures with in situ observations at 10 cm and 5 m depth illustrating both the "cool skin" effect and evidence of a "warm layer."

heat flux which can be validated using the Suomi Ocean Heat Flux Buoy deployed in the TWP for this purpose (Sisko 1996)

Future studies will include a real-time implementation of GOES and AERI soundings. Absolute calibration of SGP CART raman lidar using AERI and microwave radiances, which will improve AERI temperature retrieval using the RASS virtual temperature and raman water vapor profile measurements when available. Cloud radiative properties will be derived using Micropulse lidar and AERI data at the SGP CART site. AERI and High-resolution Interferometer Sounder (HIS) cloud base and top radiative properties will be compared for various field campaigns to study the vertical inhomogeneity of cloud radiation. SGP CART measurements will provide information necessary to parameterize cloud radiative properties in terms of predictable atmospheric variables as needed to incorporate cloud radiative effects in climate models.

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