Atmospheric Emitted Radiance Interferometer Data Analysis Methods

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Introduction

Data from the Atmospheric Emitted Radiance Interferometer (AERI) have been analyzed for the Atmospheric Radiation Measurement (ARM) Program's Fourier Transform Data Analysis Tools science team project under the direction of William L. Smith of the University of Wisconsin-Madison. The data consist of observations of the downwelling infrared emission at the surface from gaseous atmospheric constituents and from cloud and particulate aerosols. The observations are at 0.5 cm-1 spectral resolution over the spectral range from 500 to 3000 cm-1.

Observations from the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) have been made with an AERI prototype since March 1993. A small sample of the data collected by the AERI at the SGP CART site is given in Figure 1. These CART observations, combined with data collected during other field experiments, have been used to develop techniques for extracting valuable information from the infrared spectra.

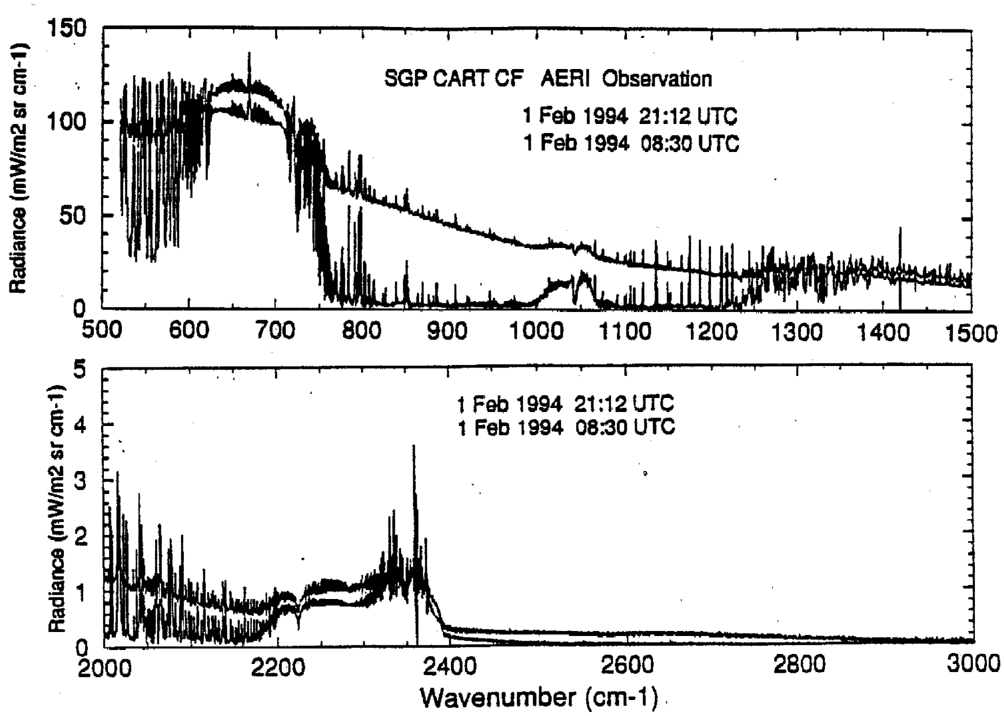

Figure 1. Clear and cloudy downwelling radiance spectra from the AERI prototype at the SGP CART central facility.

The science objectives of this data analysis include 1) addressing issues in radiative transfer modeling, 2) modeling cloud microphysical properties, 3) inferring cloud emissivity and reflectivity, 4) classifying spectral content, and 5) retrieving boundary layer vertical profiles of atmospheric temperature and water vapor.

Radiative Transfer

High-spectral resolution Fourier transform observations, such as those from the AERI, are necessary to validate radiative transfer model. Measurements of the downwelling radiance are particularly valuable in testing model parameterizations of the water vapor foreign and self-broadened continuum cross-sections. Using line-by-line radiative transfer models, FASCOD3P and LBLRTM with the HITRAN92 database, we have performed numerous detailed investigations of the spectroscopic residuals.

In addition, as a part of this project, S. A. Clough at Atmospheric Environmental Research, Inc. (AER) has initiated a quality measurement experiment. In the experiment, AER will make routine and automated comparisons between calculated downwelling radiance using best estimates of temperature and water vapor at the SGP CART site and coincident AERI observations.

Cloud Microphysical Properties

A preliminary version of a multiple scattering model to simulate high-spectral resolution observations in cloudy conditions has been completed. Results from this model were presented at the 1993 Society of Photo-optic Instrumentation Engineers (SPIE) meeting in Orlando, Florida (Ackerman and Knuteson 1993). The model combines a doubling model with FASCOD3 transmittance calculations, dividing the atmosphere into cloud and cloud-free layers above, within, and below the cloud layer. The results from this model will be compared with a more complete model being developed by AER. A recent improvement to the model has been the inclusion of solar reflection, a necessary addition for modeling the 3-5 μm window region during the daytime.

Cloud Optical Properties

A method of estimating cloud radiative properties (i.e., spectral emissivity and reflectivity) in the infrared based on AERI observations has been developed and published (Smith et al. 1993). A simplified version of this technique has been implemented in prototype software for the near real-time retrieval of cloud emissivity and cloud fraction. In addition, the method developed by Ackerman et al. (1990) for aircraft observations has been extended to ground-based observations and applied to data collected by the AERI prototype (Smith et al. 1994).

Spectral Radiance Classification

A procedure has been developed for handling data received from the SGP CART site. The procedure includes quick-look displays for assessment of data quality and documentation. An example of a quick-look plot of AERI summary data is shown in Figure 2, where low window channel brightness temperatures indicate “clear” sky conditions and high window channel brightness temperatures contain cloud radiative contributions. These narrow spectral channels, combined with the variance of the sky view, have been used to make a preliminary separation of scenes under variable cloud conditions from those with uniform cloud or clear conditions. Continued work in this area is leading to techniques for classifying spectral content in near real-time for incorporation into a queryable database, an important consideration for research extending over many years.

Temperature and Water Vapor

The development of algorithms for retrieving vertical profiles of temperature and water vapor has continued, with the contribution of the shortwave infrared channel radiances for retrieval of temperature under moist oceanic conditions being successfully demonstrated. These results build upon the previous good results obtained with the longwave radiance channels under dry to moderate moisture conditions (Ding 1993).

In addition, the algorithm has become considerably more robust with the extension beyond clear sky conditions to the successful retrieval of atmospheric temperature and water vapor profiles below cloud base. Two intensive field experiments in 1993, the Convection and Moisture Experiment (CAMEX) (see Figure 3) and the Variation of Coastal Atmospheric Refractivity (VOCAR) experiment, offered an opportunity to test the real-time data processing software under conditions much like an ARM intensive

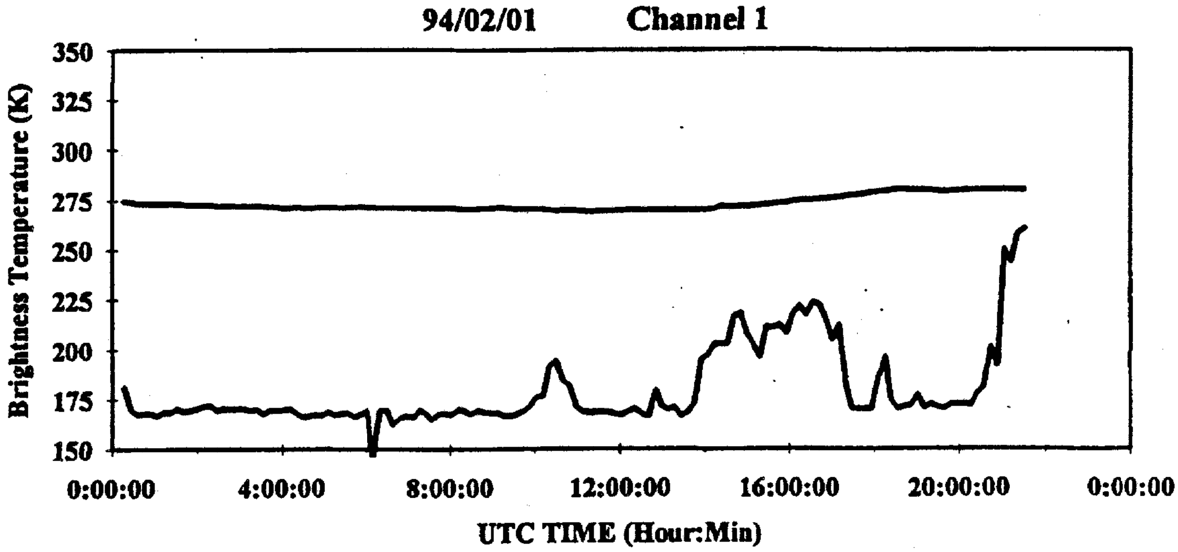

Figure 2. Time sequence of narrow radiometric channels used to assess clear and cloudy atmospheric conditions. The top curve is for a narrow channel of the 15 µm CO_2 band where the atmosphere is opaque. The brightness temperature in this region is a measure of the surface air temperature. The bottom curve is for a narrow region in the 10 µm window where low brightness temperatures indicate clear skies; high temperatures are clouds.

observing period (IOP), i.e., in conjunction with RAMAN lidars and frequent research balloon sonde launches.

As shown in Figure 4, statistics from these experiments indicate that a one degree RMS accuracy in temperature (about 3°C in dewpoint temperature) is routinely obtained from the ground to an altitude of several kilometers using only the passive infrared radiance from the AERI. Since profiles are obtained every 10 minutes, assimilation of these data from the ARM central and boundary sites will provide an important part of the characterization of the atmospheric boundary layer in the CART grid cell.

References

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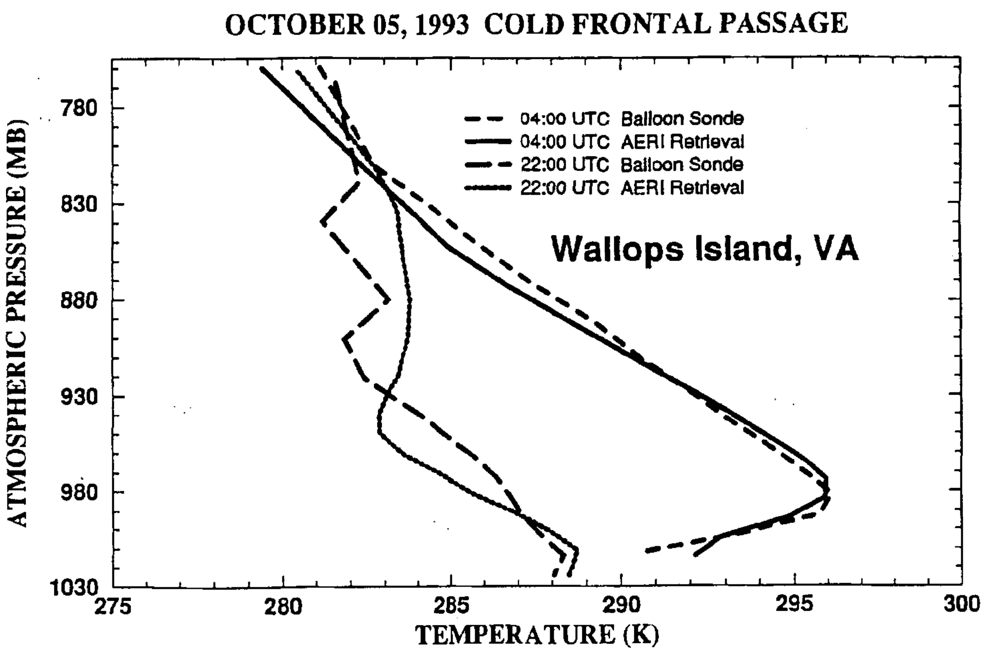

Figure 3. Temperature retrieval before and after a cold frontal passage. Derived from AERI infrared spectral data collected during the CAMEX experiment.

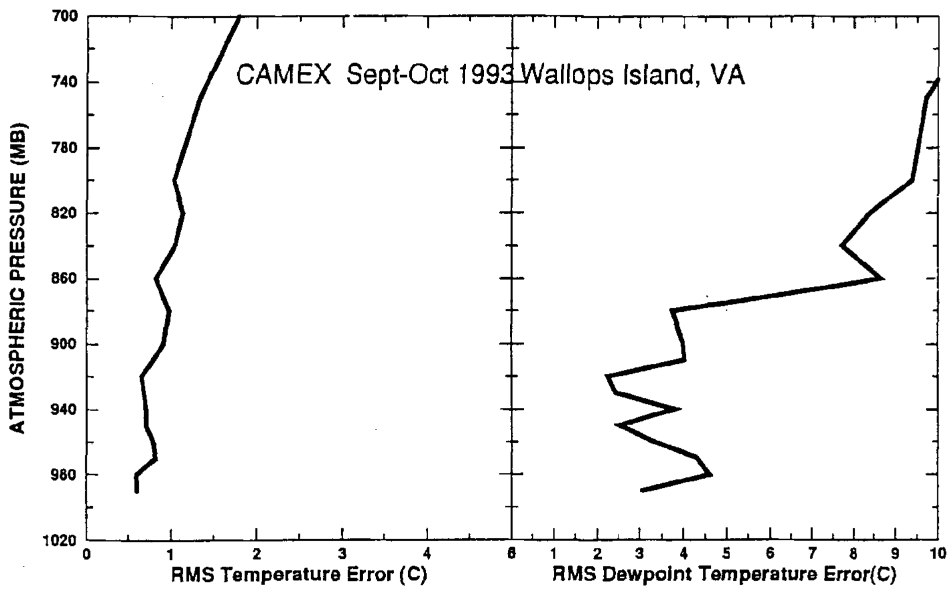

Figure 4. Temperature and water vapor RMS difference from radiosonde measurements for the recent CAMEX field experiment at Wallops Island.