AERI Instrument Status and Analysis Results

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Introduction

The U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Program objectives include the observation of spectrally resolved radiances in space and time and the testing of calculation models for the accurate prediction of the radiative properties of the atmosphere with the objective of incorporating parameterizations into general circulation models. This paper describes the progress toward these objectives contributed through the ARM science team project High Spectral Resolution Fourier transform infrared radiometer (FTIR) Observations for the ARM Program: Continued Technique Development, Data Evaluation and Analysis (H. Revercomb, PI). The focus for this work are infrared observations and analyses using the atmospheric emitted radiance interferometer (AERI) system developed at the University of Wisconsin Space Science and Engineering Center (UW-SSEC) (Revercomb et al. 1993). The first operational AERI system for ARM came on-line in July 1995 at the Southern Great Plains (SGP) site central facility (CF). In the period March 1997 to March 1998, the UW-SSEC has completed the fabrication and deployment of several new AERI systems to meet the needs of the new Arctic and Tropical Western Pacific (TWP) ARM sites in addition to the SGP site. This abstract will review the current (March 1998) status of the AERI systems for the ARM Program and draw attention to the scientific issues of interest related to the use of AERI data. These scientific issues include 1) confirmation of AERI calibration accuracy resulting from comparisons to a National Institute of Standards and Technology (NIST) reference source, 2) updated AERI/line-by-line radiative transfer model (LBLRTM) quality measurement experiment (QME) results, 3) new water vapor spectroscopic results (continuum and lines), 4) new “scanning” AERI data for use in aerosol research and land surface and emissivity measurements, and 5) first results from the Arctic with the longwave extended range AERI (AERI-ER).

AERI Status

In July 1997, an AERI destined for the ARM TWP Nauru site was delivered to Sandia for ARCS integration. Two more AERI systems were delivered to ARM with spectral coverage extending into the longwave rotational water vapor band (out to 25 μm from the 18 μm of the standard AERI system). One of these systems was deployed to the Surface HEat Budget of the Arctic (SHEBA) ice camp 300 miles north of Alaska in September 1997, where it has operated continuously except for a brief period when a lead opened up nearby. The second spectral AERI-ER was deployed to the ARM North Slope of Alaska (NSA) site in February 1998 and is operating successfully. Both systems incorporate some unique characteristics in their design which allow the AERI-ER to cover the spectral range 3.3 μm to 25 μm.

Initial development support of the AERI system was from the ARM Instrument Development Program (IDP). One of the important developments coming out of the IDP program at Wisconsin was the successful integration of a mechanical (Stirling cycle) cooler into the AERI system to provide cooling of the MCT/InSb sandwich detector thereby eliminating the need for cryogen. The past year saw two important milestones achieved by the AERI mechanical coolers. First, the cooler operating in the SGP AERI system achieved 21 months of continuous operation before requiring refurbishment, 75% greater than the expected duration. Second, the mechanical coolers for the Arctic AERIs (SHEBA and NSA) were able to achieve a sustained detector temperature of 68 K (i.e., nearly 10 degrees cooler than liquid nitrogen) helping to extend the longwave performance of these systems.

AERI Instrument Calibration

A milestone in the characterization of the absolute accuracy of AERI observations was accomplished during the Miami IR Workshop (2-4 March 1998) organized by Peter Minnett of the University of Miami. A Marine-AERI system, using identical blackbody reference sources as those used on the ARM AERI systems, was used to view a blackbody reference cavity maintained by NIST. The AERI system uses two internal blackbodies designed and built at the University of Wisconsin with calibration traceable to NIST temperature standards. One of the two AERI blackbodies used in routine internal calibration for each system is controlled to 60 °C while the second is allowed to drift with ambient temperature. The NIST blackbody uses a temperature controlled water bath to reduce gradients in the cavity. The comparison with the NIST blackbody was performed in a room with ambient temperature of about 30 °C at three reference blackbody temperature points: 20 °C, 30 °C, and 60 °C. The lowest temperature point (20 °C) was chosen to be above the dewpoint temperature in the uncontrolled laboratory environment. The agreement between the AERI system and the NIST blackbody reference was excellent at all temperatures and within the combined uncertainty of the AERI and NIST blackbodies. In the spectral range of AERI between 3.3 μm and 15 μm (excluding regions effected by the air path in the room) the AERI agreement with NIST was less than 0.02 °C at 20 °C, less than 0.03 °C at 30 °C, and less than 0.05 °C at 60 °C. The 60 °C comparison was performed in order to test the accuracy of the AERI hot blackbody in both knowledge of temperature and emissivity. The excellent agreement of the AERI with the NIST reference is an independent confirmation that the AERI systems for ARM are meeting or exceeding the stated absolute accuracy of 1% of ambient radiance. These tests also indicate that the absolute accuracy of Marine-AERI derived sea surface skin temperatures is better than 0.1 °C, an issue important for Earth Observing System (EOS) validation.

AERI/LBLRTM QME

A focus of the Instantaneous Radiative Flux (IRF) working group of ARM over the last 5 years has been a QME between the downwelling infrared radiance observations from the AERI at the SGP Cloud and Radiation Testbed (CART) site central facility and line-by-line calculations using the LBLRTM radiative transfer model. This AERI/ LBLRTM QME was reprocessed in 1997 to adjust the water vapor profiles used in the calculations by scaling the radiosonde profiles to the total water content as measured by the ARM SGP CART Microwave Radiometer (Turner et al. 1998). Figure 1 shows the observed minus calculated results for the summer and fall of 1997 plotted as a percent error of the downwelling emitted radiance integrated over the AERI spectral range of 3.3 μm to 19 μm. This plot makes use of an atmospheric stability criterion based on the time change of AERI radiances in addition to the cloud clearing based on the Micropulse Lidar (MPL). The infrared observed minus calculated residual as a fraction of the total downwelling radiance is below 3%.

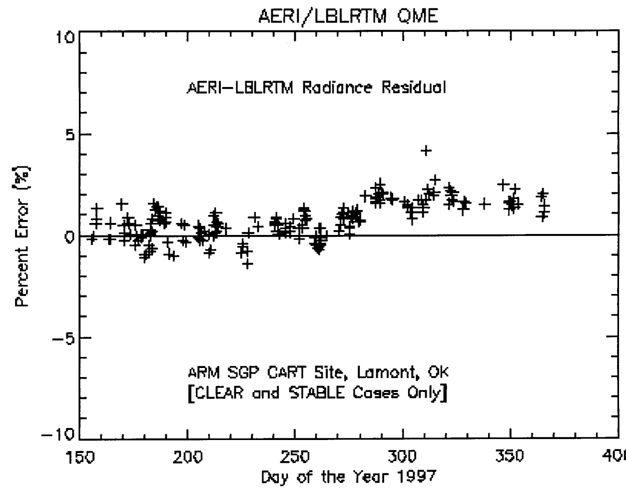

Figure 1. AERI/LBLRTM QME (1997).

Scanning AERI Data

Over the last 2 years a mobile AERI system has been developed at the University of Wisconsin that allows us to perform angle scanning of the atmosphere and land surface. The atmospheric scanning data will be used to study the infrared effects of atmospheric aerosols and to address the retrieval of absolute water vapor column from weak water lines. Similar angle scanning data of the land surface from the Oklahoma CART site have been used to derive soil and vegetative emissivity characteristics for a limited set of locations near the SGP CF site.

Water Vapor Spectroscopy

Several related efforts to characterize absorption by water vapor have continued in the last year. Continuum absorption, which accounts primarily for the cumulative effects of far-wing lineshape behavior, has been measured under the cold, dry conditions at the SHEBA Ice Station. For the extended longwave region, Tobin et al. (1998) report on these measurements and show comparisons to previous measurements and models. Similarly, air-broadened continuum coefficients have been derived from AERI-ER spectra in an analogous way for the important 1320 cm^{-1} to 1420 cm^{-1} region. These are shown in Figure 2 along with previous laboratory measurements of Burch at 353K, Tobin at 296K (Tobin et al. 1996), and two versions of the CKD model (Clough et al. 1989) used in LBLRTM. A possible

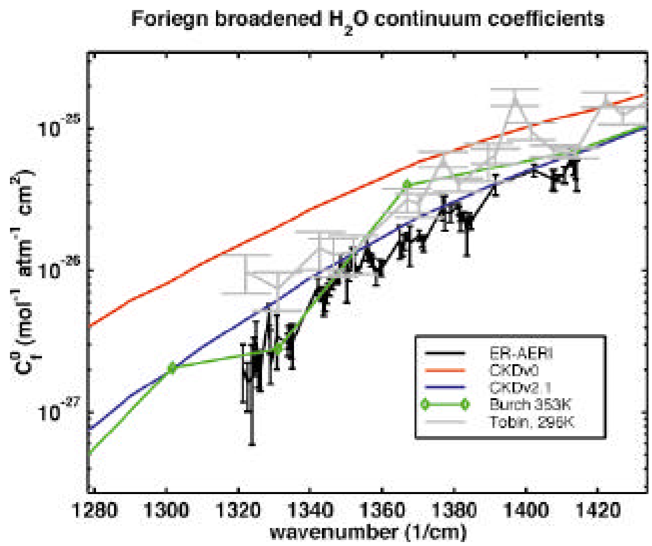

Figure 2. AERI-derived continuum values compared with laboratory measurements. (For a color version of this figure, please see *http://www.arm.gov/docs/documents/technical/conf_9803/knuteson-98.pdf*.)

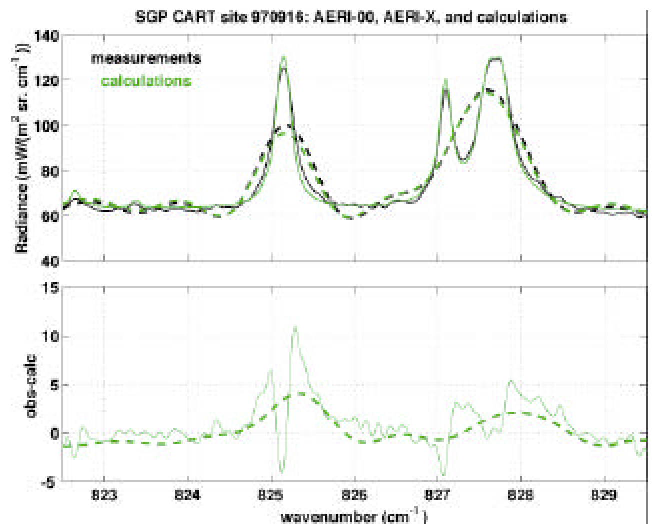

Figure 3. Using AERI (medium resolution) and AERI-X (high resolution) to evaluate infrared H_2O line strength and width accuracy. (For a color version of this figure, please see *http://www.arm.gov/docs/documents/technical/conf_9803/knuteson-98.pdf*.)

explanation for the differences between the measurements is a strong temperature dependence of the foreign broadened H_2O continuum, a result that is predicted for this spectral region by the theoretical calculations of Ma and Tipping (Ma and Tipping 1992). A comprehensive examination of additional AERI spectra for a range of water amounts and temperatures, along with new laboratory observations, is expected to resolve this issue.

In an effort to improve remote sensing of land surface temperature and emissivity, atmospheric water vapor and temperature, and cloud top heights from high resolution satellite based sensors and to utilize AERI as a source of absolute integrated precipitable water vapor measurements, we have begun research to determine the accuracy of existing H_2O spectral line parameters (HITRAN and JPL extended), and to measure these parameters (strength/width products and positions) in the 8-µm to 12.5-µm window through the use of AERI and AERI-X (high resolution) spectra. AERI-X spectra are particularly useful for this because many of the pressure-broadened water lines are fully resolved by AERI-X. Figure 3 shows an example of a case study from the 1997 Water Vapor Intensive Observation Period, which consists of AERI and AERI-X spectra, and calculations based on our best estimate of the atmospheric temperature and water vapor profiles. For situations in which we have confidence in the atmospheric state, the spectral line parameters can be refined to obtain better agreement with the observed spectra. Similarly, for spectral lines which are known more accurately, the atmospheric state (column water vapor) can be derived.

Arctic Cloud Radiative Forcing

Preliminary analysis of infrared spectral data from the extended spectral range AERI-ER at the SHEBA ice camp have been used to investigate the monthly mean effects of clouds on the surface energy budget in the Arctic.

Clouds affect earth's climate by both reflecting shortwave (solar) radiation back to space and by preventing loss of longwave (infrared) radiation to space. The reflection of shortwave radiation tends to cool the earth, while the trapping of longwave radiation tends to warm it. These effects can be quantified by defining the cloud radiative forcing (CRF), which can be expressed for the top-of-the-atmosphere, the surface, and the atmosphere itself (Charlock and Ramanathan 1985; Ramanathan 1987; Gupta et al. 1993). Here we consider only the CRF at the surface. In the polar regions, the longwave component dominates in wintertime, thus the CRF equals the mean longwave all-sky net flux minus the mean longwave clear-sky net flux. Figures 4 and 5 use observations from the AERI-ER located at the SHEBA ice camp to determine the cloud radiative forcing at the surface for the months of November and December of 1997 and January 1998. The 20 µm longwave window can be seen to have an important role in the CRF in the Arctic. Its role is most important in December and January, when the forcing in this spectral region is comparable to that in the 11-µm window from 750 cm^{-1} to 1000 cm^{-1}.

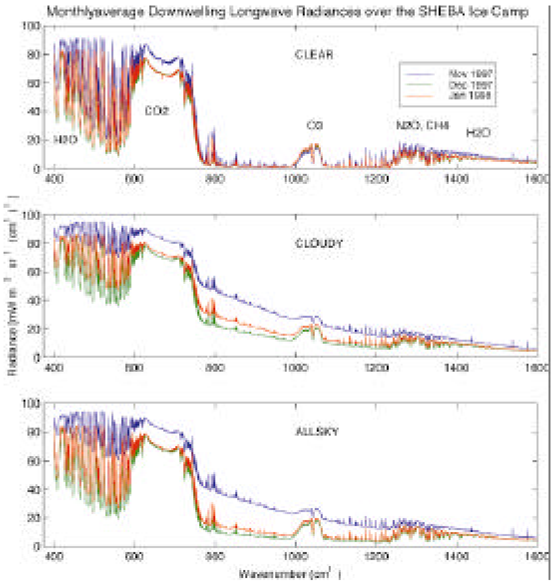

Figure 4. Monthly mean infrared radiance at SHEBA from AERI-ER observations. (For a color version of this figure, please see *http://www.arm.gov/docs/documents/technical/conf_9803/knuteson-98.pdf*.)

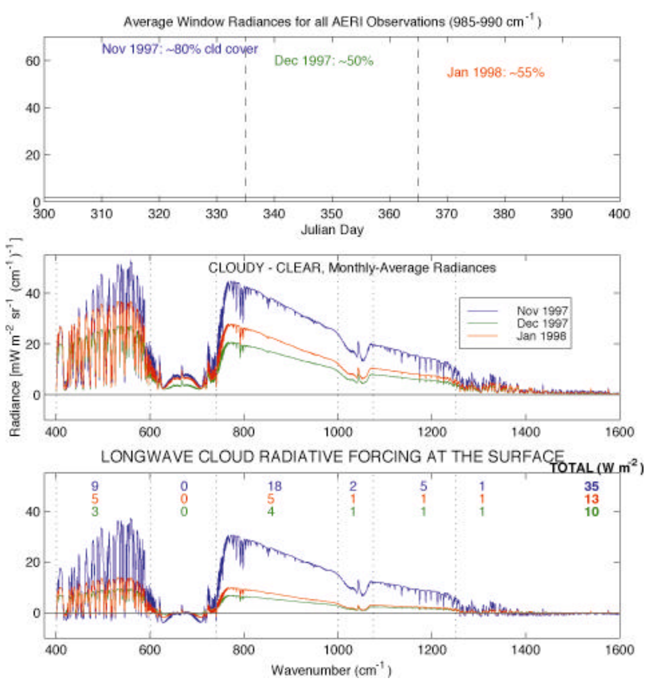

Figure 5. Preliminary estimates of cloud radiative forcing from AERI-ER observations. The rows of numbers in the lower panel (top to bottom) correspond to the cloud radiative forcing for November 1997, December 1997, and January 1998. (For a color version of this figure, please see *http://www.arm.gov/docs/documents/technical/conf_9803/knuteson-98.pdf*.)

Acknowledgments

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