Atmospheric Emitted Radiance Interferometer Status and Quality Measurement Experiment Results

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Instrument Status

The atmospheric emitted radiance interferometer (AERI) central facility instrument at the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) site has been operational since July 1995. This instrument, identified by the serial number AERI-01, is the first of a series of operational instruments designed and built at the University of Wisconsin Space Science and Engineering Center for the Department of Energy (DOE) ARM program under contract to Pacific Northwest National Laboratory. The AERI-01 system replaced an AERI prototype instrument that had operated at the ARM SGP site since deployment in March 1993. The AERI prototype instrument was returned to Wisconsin where it was integrated into a research vehicle to serve as a mobile observing laboratory.

The most important operational step between the AERI prototype and the AERI-01 was the integration of a Stirling cycle mechanical cooler into the operational system to replace the 8-hour liquid nitrogen detector dewar used by the AERI prototype instrument. Not only does this lift an operational constraint from the site operators, it greatly increases the amount of useful data collected during periods when the instrument could not be serviced. By the time of the ARM science team meeting in March 1997, the AERI-01 had demonstrated over 10,000 hours of continuous operation on the same Stirling cycle cooler without failure. It is anticipated that these coolers will need to be refurbished annually or bi-annually at a fairly nominal cost.

In 1996, an important enhancement of the AERI system design was made to help maintain the integrity of the radiance observations under adverse environmental conditions. The AERI-01 system encountered a calibration problem associated with Oklahoma dust settling on the system scene- viewing mirror. It was determined that this mirror contamination was leading to a "scattering" component of radiation from around the ceiling hatch opening, and this component was not being subtracted in the calibration process. A three- pronged approach was applied to the solution to this problem. First, a warning light was added to the site operator's display to indicate when the system scene mirror requires cleaning. A clean mirror avoids any possible scattering contribution. The second approach was to match the "scattering" field of view to the blackbodies to that of the sky. This was accomplished by installing a "sky view aperture" at the same distance (and of the same diameter) as that of the calibration reference blackbodies. Matching the "scattering" fields of view means that any scattering component of radiation will be subtracted in the calibration process. Last, the previously exposed scene-viewing mirror was almost completely enclosed by modifying the blackbody support structure to eliminate all openings except the one required for vertical sky viewing and to include a filtered fan to provide "positive pressure" in the front end optics enclosure. This last modification will help prevent dust, sea spray, or ice crystals from settling on the scene-viewing mirror. These approaches have been demonstrated at the Oklahoma central facility and will be a part of all of the future AERI systems for ARM. This immunity to environmental conditions is important because many ARM sites are even more remote than the one at Lamont, Oklahoma.

The remaining AERI instruments in a series under construction for the DOE ARM program include two instruments for Atmospheric Radiation and Cloud Station (ARCS) sites at Nauru and Christmas Island in the Tropical Western Pacific, an instrument for the North Slope of Alaska in Barrow, an instrument for participation in the interagency Surface HEat Budget of the Arctic Ocean (SHEBA) experiment on the ice pack north of Alaska, and one instrument for each of the four boundary facilities of the ARM SGP site. The two "tropical AERIs" will address issues related to validation of the infrared water vapor continuum under conditions of high absolute water amount and questions related to the role of clouds in the tropical surface radiation budget. The two "arctic AERIs" are unique in that they integrate "extended range" detectors, which extend the AERI spectral coverage from the standard 3.3 - 18 microns out to about 24 microns.

This expanded spectral coverage will provide the first absolute measurement of the important water vapor rotational band at high enough spectral resolution to test the water vapor continuum in this spectral region. Validation of radiative transfer models at both high and low water amounts is an important goal of the ARM program. The four AERIs for the SGP boundary facilities will exploit the excellent ability of the AERI instrument to characterize the temperature and water vapor profiles in the atmospheric boundary layer on a continuous basis. These profiles will help in the definition of the atmospheric state for use in ARM single-column model experiments. The boundary layer retrieval is being performed by Wayne Feltz under the ARM science team project of William L. Smith, Sr., also of the University of Wisconsin - Madison.

Combined Sensor Program Cruise

As mentioned previously, the AERI prototype was removed from the ARM SGP site in July 1995 and returned to Wisconsin where it continues to play several important roles. One of the tasks given the AERI prototype was participation in the ARM-sponsored Combined Sensor Program (CSP) cruise to the Tropical Western Pacific in March-April 1996.

The AERI prototype was reconfigured to allow both vertical observation of the atmosphere (and clouds), as well as angle scanning of the atmosphere and the ocean surface. This measurement technique was used to obtain a highly accurate measurement of the ocean surface radiative "skin" temperature on an "around-the-clock" basis for the duration of the 30-day cruise.

Measurements were made from American Samoa to Manus Island along the equator and back again to Hawaii. Measurements of this type are important for the validation of algorithms for the measurement of sea surface temperature from satellite data and provide an important connection to the instrumentation that will soon be available as part of the National Aeronautics and Space Administration's Earth Observing System.

At the same time, a preliminary assessment of the Line-By-Line Radiative Transfer Model (LBLRTM) of Clough was made under conditions of high (> 5 cm precipitable water) absolute water amount. Initial analyses indicate consistency with ARM measurements from the Tropical Ocean Global Atmosphere-Coupled Ocean Atmosphere Response Experiment (TOGA-COARE) in 1993 and imply the existence of an "enhanced" emission due to water vapor in the 8-12 micron region, a result that is not easily explained. AERI measurements from the ARM tropical sites will be used to further characterize this "anomalous" behavior.

AERI-01 / AERI Prototype Intercomparison

The September 1996 water vapor intensive operating period (WVIOP96) provided an opportunity to intercompare two AERI instruments collocated at the ARM SGP central facility. The two AERIs were the operational instrument at the central facility (AERI-01) and the AERI prototype installed in a mobile vehicle (the "AERIbago").

Each instrument obtains a calibrated radiance spectrum of the downwelling atmospheric infrared emission in a zenith view at approximately 10-minute intervals. The excellent agreement ($< 1\,mW/m^2\,sr\,cm^{-1}$) between these instruments provides confidence in the reproducibility of the measurements obtained by the AERI systems. In particular, the radiance difference between the two AERIs is an indication of the size of the measurement uncertainty of the AERI-01, which is relevant to the interpretation of the AERI/LBLRTM Quality Measurement Experiment (QME).

AERI/LBLRTM QME

The ARM program's primary tool for the validation of radiative transfer modeling in the infrared region has been the AERI/LBLRTM QME. This QME has been in place since April 1994, using first the AERI prototype instrument and then the operational AERI-01 unit to compare observed infrared radiance spectra with calculated spectra.

Until recently, the QME depended entirely on the central facility balloon soundings for characterization of the atmospheric state (atmospheric pressure, temperature, and water vapor versus height). The ARM Instantaneous Radiative Flux working group concluded at the beginning of 1996 that the ability of this QME to test the validity of the LBLRTM was limited by the absolute accuracy and statistical fluctuations of the Vaisala radiosonde system (balloon-borne sounding system [BBSS]) used at the SGP central facility to perform the balloon soundings.

Using the AERI as a reference standard and the LBLRTM model as a transfer standard, the AERI/LBLRTM QME has shown that sonde-to-sonde peak variations can be as much as 30% of absolute water amount and the sonde batch-to-batch calibration can change by as much as 10% of absolute water amount. The desired accuracy for validation of the LBLRTM model is more like 3-5% of absolute water amount (at the SGP site).

This sonde "problem" has brought to the forefront the need for a water vapor reference standard that can be applied to the sonde profiles (or the Raman water profiles) to correct for sonde calibration errors. The September 1996 Water Vapor IOP at the SGP site was focused (in part) on the evaluation of candidates for this reference standard. Candidates included the microwave radiometer (MWR), chilled mirror sensors on a tethered balloon, and calibrated sensors on the 60-meter tower.

There is a dramatic reduction in the QME residual (AERI minus LBLRTM) when the MWR is used as a water vapor reference standard. It appears that use of the MWR to scale the balloon sondes will meet the previously stated requirements. The AERI/LBLRTM QME will be reprocessed to reflect this change.

Sonde Reprocessing

One of the activities carried out at the WVIOP96 deserves special mention. A detailed study of the BBSS performed by Barbara Whitney of the University of Wisconsin, in coordination with the BBSS instrument mentor, indicated that the automated processing of the radiosonde data included some significant artifacts that made comparison of the sonde data with the 30-meter and 60-meter tower sensors problematic.

The sonde time of launch, as determined by the automated BBSS software using the pressure sensor, was frequently in error. This "time of launch" error often translates into a height error of 5-10 meters. This level of uncertainty would probably be acceptable if the automatic software did not also replace the measured sonde temperature and humidity values with "interpolated" values, often putting grossly incorrect data into the final data product.

The solution to this problem was to determine a time of launch from the "raw" sonde data and to simply substitute the "raw" data values in the sonde profile in the first 100 meters in place of the values produced by the automatic software. Dr. Whitney performed this "reprocessing" for all the sondes launched during the 1996 Water Vapor IOP. These reprocessed sonde files should be used by any investigations that need an accurate temperature and humidity profile in the first 100 meters, such as sonde/tower comparisons. These reprocessed sondes are available as part of the WVIOP96 dataset from the ARM archive.