High Spectral Resolution Fourier Transform Infrared (FTIR) Instruments for the Atmospheric Radiation Measurement Program: Focus on the Atmospheric Emitted Radiance Interferometer

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Ground-based Fourier Transform infrared (FTIR) instruments are being produced at the University of Wisconsin (UW) and the University of Denver (UD) for the Atmospheric Radiation Measurement (ARM) Program's Cloud and Radiation Testbed (CART) sites as part of a joint Instrument Development Program (IDP). The three instrument types under development are summarized in Table 1. For each ARM site, the 1 cm^{-1} resolution Atmospheric Emitted Radiance Interferometer (AERI) is expected to be operated both at the central site and at four extended boundary locations to allow its use for radiometric studies and for remote sensing of horizontal inhomogeneities. The AERI is being built by the UW and is the primary subject of this report. The extra high resolution AERI-X and the ultra high resolution Solar Radiance Transmission Interferometer (SORTI) are planned for the central sites and are described in more detail in a separate abstract by the UD.

AERI Configuration and Status

The AERI will measure an accurately calibrated spectrum of the downwelling sky radiance every 10 minutes. It makes use of a commercially available interferometer (Michelson Series MB100 from BOMEM, Inc., of Quebec, Canada) linked to a data system of networked IBM PC computers. The major role of this IDP effort is to incorporate a subsystem for accurate radiometric calibration and to integrate the required hardware, operational control software, and analysis software into a complete system which can be linked to the CART data system and operated remotely without the attendance of expert operators.

The primary model of the AERI uses two detector channels to give the broad spectral coverage desired. The basic radiometric sensitivity of the two-channel MB100 system

Table 1. System Configurations Summary

	AERI	AERI-X	SORTI
Function	Zenith viewing atmospheric emission	Extra high resolution zenith viewing atmospheric emission	Ultrahigh resolution by solar tracking for atmospheric transmission
Spectral Coverage	3.5 - 20 µm	4 - 20 µm	3 - 20 µm
Spectral Resolution	1 cm^{-1}	0.1 cm^{-1}	0.002 cm^{-1}
Calibration Sources	2-3 high emissivity blackbodies	2 high emissivity blackbodies	Uses airmass variation to derive transmission

is illustrated in Figures 1 and 2, which show the measured responsivity in the spectral domain and the noise equivalent radiance. In both channels, the ratio of a typical peak radiance to the noise will be larger than 1000:1.

The AERI radiometric calibration subsystem consists of up to three reference blackbodies, one hotter than ambient by 30-40°C, one at ambient temperature, and one at liquid nitrogen temperature. The current plan is to use the hot and the ambient reference sources for routine calibration to avoid the problems associated with operating cold references in humid environments. The LN_2 source will be used for early development and for occasional checks on the long-term stability of the hot/ambient calibration. Periodic cycling through approximately two-minute views of the reference blackbodies and four-minute nadir sky views will yield a calibrated sky spectrum approximately every 10 minutes. All of the reference sources are high emissivity cavities (copper or aluminum with diffuse black overcoat) built at the UW. The hot and ambient sources are of identical design, although the temperature of the ambient source will probably be allowed to float. They use high precision thermistors for temperature monitoring and for input to the heater control servo. Heat is applied by a wire-wound heating element on the cylindrical portion of the cavity. The LN_2 blackbody consists of a cavity submerged in a widemouthed LN_2 dewar. The blackbodies will be viewed in a fashion that will avoid (or allow accurate correction for) errors associated with polarization. Several options for the specific implementation are being evaluated.

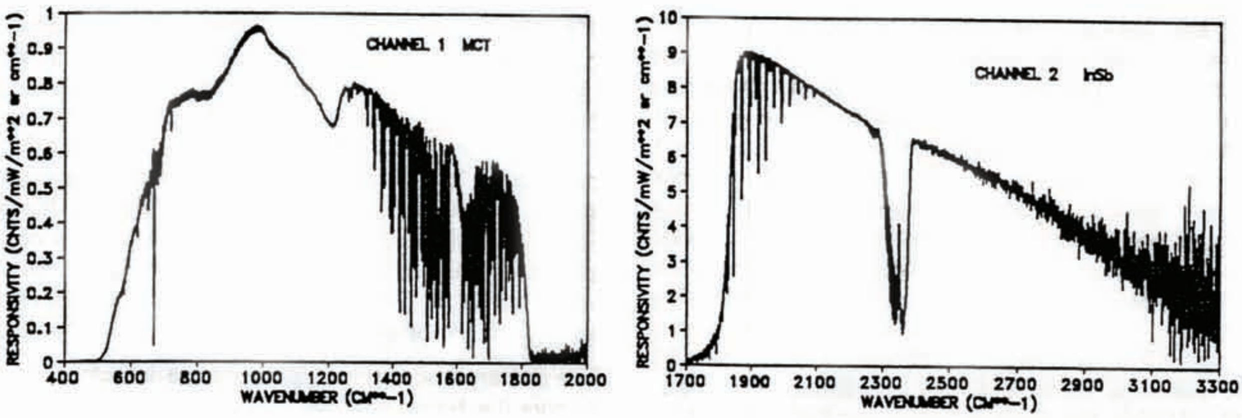

Figure 1. AERI Instrument Responsivity. Note the effect of atmospheric H_2O and CO_2.

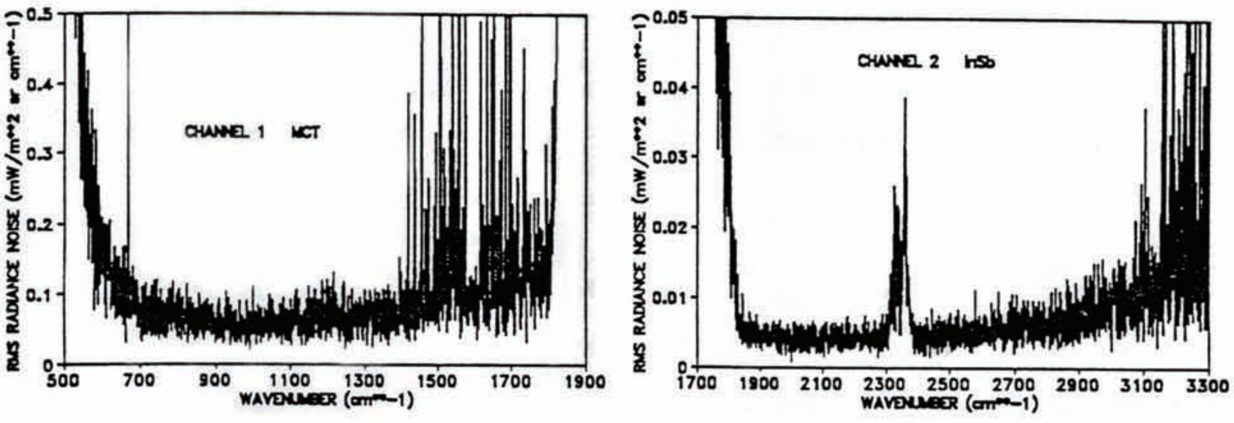

Figure 2. AERI Noise Equivalent Radiance for a Dwell Time of 2 Minutes.

A completely functional, but not optimized, AERI operated very successfully at the Spectral Radiance Experiment (SPECTRE) conducted at Coffeyville, Kansas, in November and December in conjunction with the NASA First ISCCP Regional Experiment (FIRE) II cirrus cloud experiment. It is expected that a system, modified based on this field experience, will be tested at the first CART site in 1992 and that several other systems will be fabricated in a timely fashion.

AERI Prototype Observations

The AERI currently being fabricated has had the benefit of a single-channel prototype instrument with many components of similar construction. The prototype was constructed following the success of uplooking observations made with the High-resolution Interferometer Sounder (HIS) aircraft instrument during the Ground-based Atmospheric Profiling Experiment in 1988. During 1991, the prototype was operated successfully in two field experiments, resulting in data sets containing a large number of spectra, simultaneous balloon sonde atmospheric profile measurements, and many other concurrent observations.

Examples of spectra are shown in Figures 3 and 4. The spectrum of Figure 3 is from the ARM component of the Winter Icing and Storm Program (WISP) conducted in Platteville, Colorado, during February and March of 1991. The relatively high elevation (surface pressures of 840 mb) and dry atmospheric conditions account for the strong definition of the water vapor lines in the long wavelength rotational water vapor band and very low radiances between lines in the atmospheric windows. The observation of Figure 4 is from aboard the National Science Foundation (NSF) ship *Point Sur* off the coast of Monterey, California, in May 1991. The presence of considerable water vapor is evident from both the nearly opaque rotational water band and from the strong continuum and water lines in the atmospheric windows.

The accurate radiometric performance of the prototype has been demonstrated in laboratory testing and by comparisons with HIS observations. Because of the high radiometric accuracy of the HIS measurements, sample HIS observations are currently being used for the ITRA tests of line-by-line radiative transfer codes.

Summary

The first AERI instrument will soon be ready to provide accurate, high-resolution observations at the first ARM program CART site.

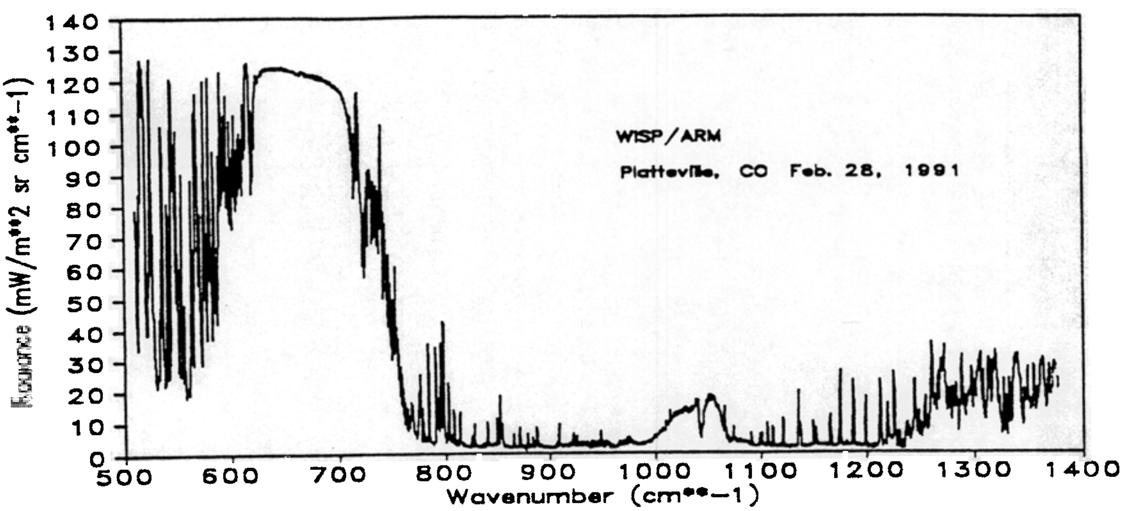

Figure 3. Sample Downwelling Radiance Spectrum from AERI Prototype at WISP/ARM.

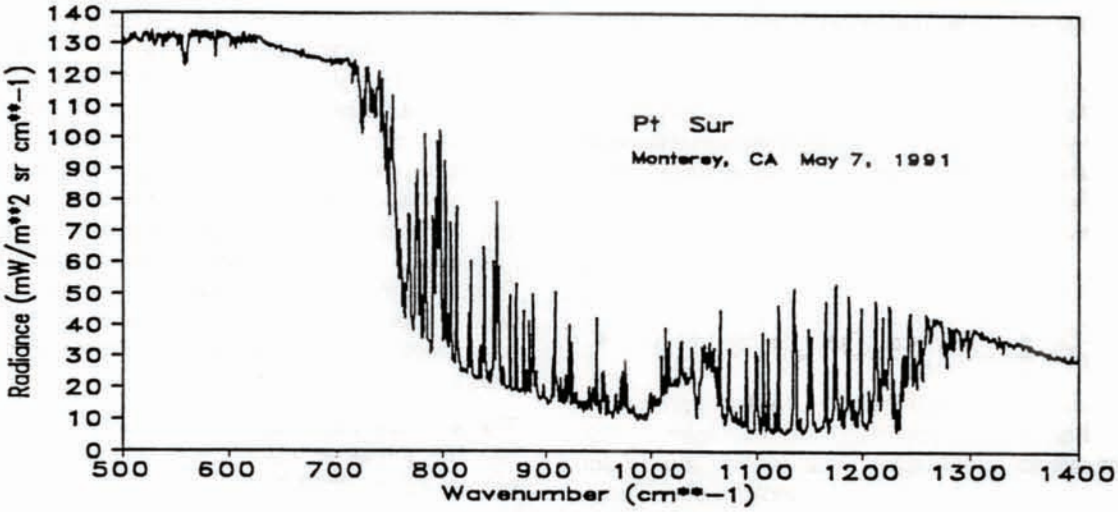

Figure 4. Sample Radiance Spectrum from Shipboard, 7 May 1991