Infrared Emission Measurements in the High Arctic using the Extended-range Atmospheric Emitted Radiance Interferometer

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What is the E-AERI?
- Extended-range Atmospheric Emitted Radiance Interferometer
- Manufactured by ABB Bomem (Quebec City)
- MI-300 series Infrared Fourier Transform Spectrometer (FTS) with 1cm⁻¹ resolution (max OPD = 1 cm)
- Extended wavelength range covers 400-1400 cm⁻¹ (3-25 µm)
- Measurement of accurately calibrated downwelling infrared thermal emission from the atmosphere (DCE, 1990, Knuteson et al. 2004a)
- Automated radiance calibration unit with temperature controller (two blackbodies - ambient temperature and 310 K)
- Spectra every 7 min, 24 hours a day, 365 days a year (precipitation permitting)

Clear-sky vs. Cloudy Measurements
The ability of AERI systems to detect the presence of clouds and analyze cloud properties has been well demonstrated (Collard et al. 1995; Deller et al. 1999; Turner 2005, and Shaw et al., 2006). As shown in the adjacent figures, the E-AERI radiance increases in the afternoon of April 16, 2009 in the 400-600 cm⁻¹ and 750-1400 cm⁻¹ regions due to cloud particle emission. This correlates with the Millimeter Wave Cloud Radar’s (MWR) detection of a low-altitude, relatively thick (~2 km) cloud that first appeared above Eureka at 04:00 LT and remained above Eureka for the remainder of the day. The MWR is installed at 0PAL and provides equivalent radar reflectivity, Doppler velocity, spectral width, and Doppler spectra over 2-second intervals. Such large increases in radiance in these spectral regions provide a proxy for cloud detection and analysis of cloud optical depth, phase, and particle size (Turner 2005). Cloud detection is crucial in the post-processing of E-AERI data since temperature and trace gas retrievals are significantly more difficult in cloudy scenes.

Measurement Site: Eureka
- Polar Environment Atmospheric Research Laboratory (PEARL) is operated by the Canadian Network for the Detection of Ozone Depletion
- Conducting, measuring and analyzing atmospheric surface and regional processes
- Instrument on 0 PAL, 10 m altitude
- Instrument on PAL, 610 m altitude
- Extensive-range Atmospheric Emitted Radiance Interferometer
- E-AERI undergoing repairs inside 0PAL
- Front-end of the E-AERI mounted through the PAL wall

Performance Evaluations
Comparisons of E-AERI radiance measurements with 2 other AEIs at the University of Wisconsin Space Science and Engineering Center (UW-SCEDC) were performed on Sept. 26, 2008. Agreement between the E-AERI and the other two AEIs is comparable to the agreement between the AEI-07 and AEI-Bags. Side-by-side comparisons of the E-AERI and a similar instrument, the Polar-AEIRI (P-AERI) (non-extension range), installed at 0PAL in 2008, were conducted on October 20, 2008. Agreement within ±1 mW/(m²⋅cm²⋅sr) for the MCT detector and ±0.12 mW/(m²⋅cm²⋅sr) for the HgCdTe detector is achieved for the InSb detector with the exception of 400-500 cm⁻¹ (DCE, 1990, Knuteson et al. 2004a; 2004b). The majority of the measurement overlap period (October 22, 2008 – April 4, 2009) are shown for clarity (differences past 1800 cm⁻¹). The largest differences typically occur around the 600-800 cm⁻¹ range, installed at 0PAL in 2006, were conducted on October 20, 2008. Agreement within ±1 mW/(m²⋅cm²⋅sr) for the MCT detector and ±0.12 mW/(m²⋅cm²⋅sr) for the HgCdTe detector is achieved for the InSb detector with the exception of 400-500 cm⁻¹. InSb detector with the exception of 400-500 cm⁻¹)

Retrievals of Trace Gases
Total columns of these gas species have been retrieved year-round using SFIT2. Currently the E-AERI and P-AERI can retrieve total columns of O₂, N₂O, CO₂, CO, NO₂, HCN, CH₃Cl, and CH₄. For instance, spectral fits and averaging kernels from April 4, 2009 retrievals of O₂ and CO are shown below for both the E- and P-AERI instruments. Differences between both instruments' retrieved total columns are less than 6% for most gases (bottom table), indicating good agreement. This allows the identification and quantification of chemical ozone loss at Eureka during each Arctic winter-spring period. From A, the vertical resolution of the retrieval can be quantified, called the Degrees of Freedom for Signal (DFS): DFS = (2πw)²

Summary and Future Work
E-AERI radiance measurements have been extensively validated and show good agreement with three other previously-validated AEI systems, as well as with Fulib. Simulations of the radiative impact of clouds has been measured by the E-AERI, showing a strong increase in radiance in particular in the 750-1400 cm⁻¹ region, which incurs >100% downwelling radiance increase on average. Comparisons between the E- and P-AERI's measurements of total columns of trace gases agree within 10% and demonstrate the ability to monitor ozone loss at Eureka and fill in a gap in the PEARL data series during Polar night.

Adjusting the SFIT2 retrieval code so it can be automated will permit the entire E- and P-AERI data series to be analyzed. Combined with P-AERI radiance data from 10 m, the ability to measure the effects of different types of meteorological features, such as clouds, ice crystals, and fog at two altitudes with different measurement sensitivities has been well demonstrated. Hence a climatology of downwelling radiance for different meteorological features can be created for the Arctic, as well as a climatology of trace gas measurements above Eureka that covers Polar night.

References