Rapid Scan AERI Observations: Benefits and Analysis

W. F. Feltz, D. D. Turner, R. O. Knuteson, and R. G. Dedecker
Space Science and Engineering Center
Cooperative Institute of Mesoscale Meteorological Studies
University of Wisconsin-Madison
Madison, Wisconsin

D. D. Turner
Pacific Northwest National Laboratory
Richland, Washington

Introduction

The U.S. Department of Energy's (DOE's) Atmospheric Radiation Measurement (ARM) Program has funded the development of the atmospheric emitted radiance interferometer (AERI). This has led to a hardened, autonomous system that measures downwelling infrared (IR) radiance at high-spectral resolution. Seven AERI systems have been deployed around the world as part of the ARM Program. The initial goal of these instruments was to characterize the clear-sky IR emission from the atmosphere, and thus a temporal sampling was chosen (8-10 min per spectrum) to minimize random noise in the AERI observations. This sampling strategy is inadequate for sampling cloud radiative properties (Turner et al. 2003), or to capture fast (i.e., 1 min) fluctuations in water vapor in the boundary layer. The development of a set of noise filtering tools, which utilize a principal component analysis of the spectra (Huang and Antonelli 2001), allow the AERI to be run at much higher (less than 1 min) temporal resolution and maintain the same noise level and calibration accuracy as the nominal 10-min AERI data. The University of Wisconsin-Madison deployed the AERI in its mobile AERIBago in this rapid-scan mode during both the Cirrus Regional Study of Tropical Anvils and Cirrus Layers – Florida Anvil Cirrus Experiment (CRYSTAL-FACE) in Southern Florida and at the ARM Southern Great Plains site as part of the Texas 2002 experiment. Examples of cloud property retrievals from the rapid-scan data demonstrate the clear superiority of the faster temporal resolution over the nominal resolution. Temperature and moisture retrievals (Feltz et al. 2003) from the rapid-scan data also demonstrate fluctuations in the boundary layer thermodynamical profile that are lost due to averaging with the nominal sampling strategy.

AERI Cloud Property Detection Benefits

Cloud fields, and thus cloud optical properties, have a range of spatial and temporal scales. When the cloud field is broken, and especially when there is more than one cloud layer, rapid sampling of the radiative field is required in order to successfully retrieve cloud properties from the measured radiance. If the averaging period is too long, then the received signal could be a convolution of the radiance from both the upper and lower level clouds, making the retrieval of cloud properties extremely difficult.

Therefore, given the nominal sampling strategy of the AERI, retrievals of cloud properties are restricted to periods where the cloud field is uniform over the AERI's averaging interval (currently 8-10 minutes).

An example that highlights the necessity for rapid sampling in multi-layer cloud conditions is given in Figure 1. In this figure, the black lines denote the downwelling radiance (converted to brightness temperature) at 900 cm^{-1} for the rapid scan mode (a 12-s sky dwell approximately every 40 s). The data were then post-processed back up to the nominal AERI resolution of a 3-min sky dwell every 8 minutes; these data are indicated by the red dots. The data cover a 42-h window from the CRYSTAL-FACE experiment.

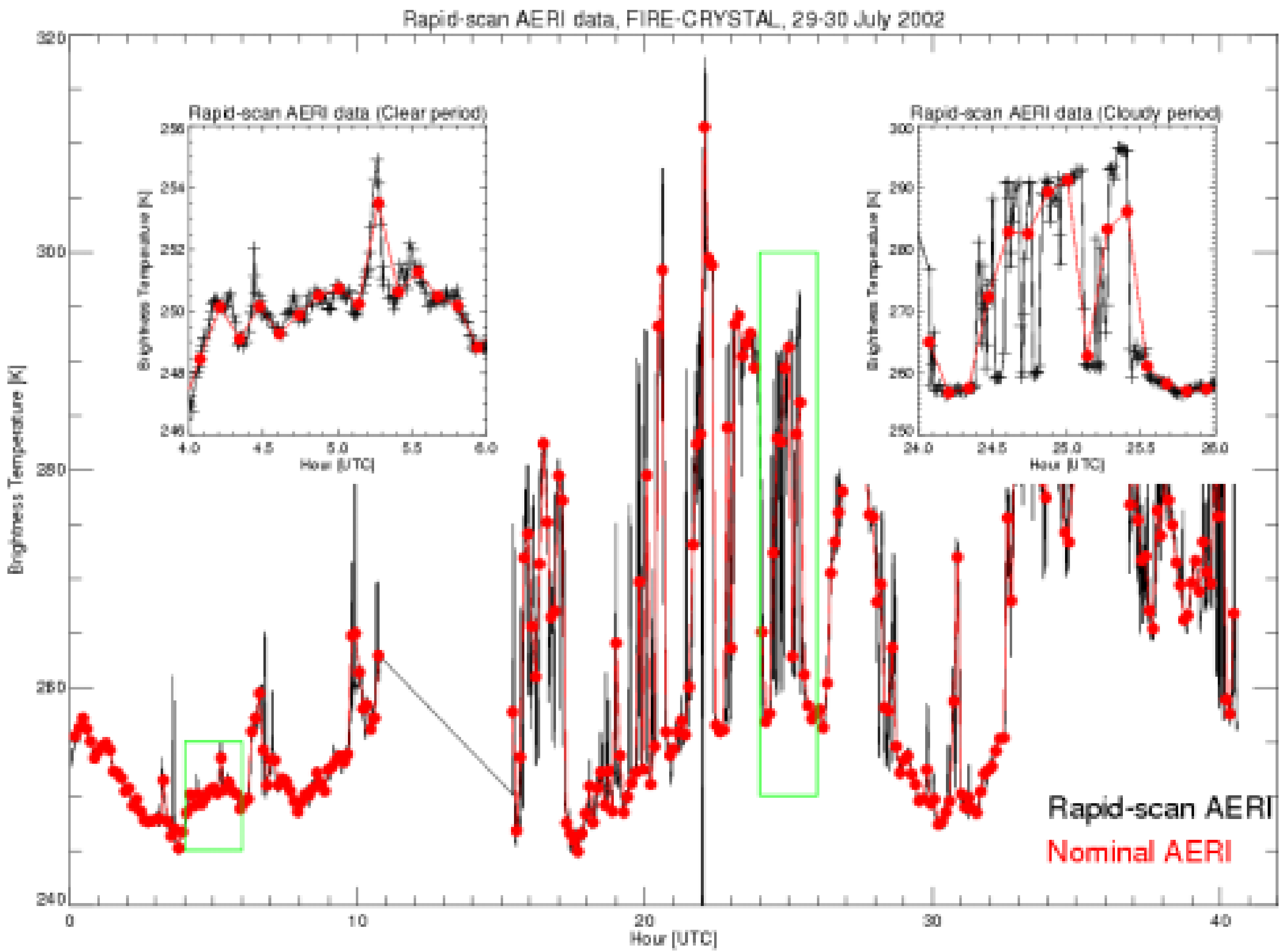

Figure 1. A time series of AERI microwindow brightness temperature measured at 900 cm^{-1} on July 29-30, 2002, during the CRYSTAL-FACE experiment in Southern Florida. The temporal sampling is less than 1 minute for the rapid scan AERI mode, while brightness temperatures are calculated for the normal 10-minute resolution mode.

The sky condition was clear during the first few hours of the scene, during which the noise-filtered rapid-scan data and nominally sampled AERI data agree very well (see left inset box). However, in the middle of the period, a two-layered cloud system advected over the site, with a cirrus cloud overlying a broken lower layer. If the nominal sampling strategy of the AERI is used, many of the samples are shown to have a brightness temperature between the temperature of the lower and upper levels (which are approximately 293 K and 258 K, respectively—see right-hand inset image). However, with the rapid scan data collected by the AERI, many more samples are found where only one cloud layer is in the scene during the instrument's sky dwell period, and thus the retrieved cloud properties will be much more accurate.

AERI Thermodynamic Retrieval Benefits

Temperature and moisture profiles were calculated with the rapid scan AERI CRYSTAL-FACE dataset (Figure 2). The retrieval technique and profile applications are described in Feltz et al. 2003. The variation of the water vapor structure within the planetary boundary layer (PBL) is very important for detection of boundary layer turbulence. The current 10-minute time resolution, which if the current

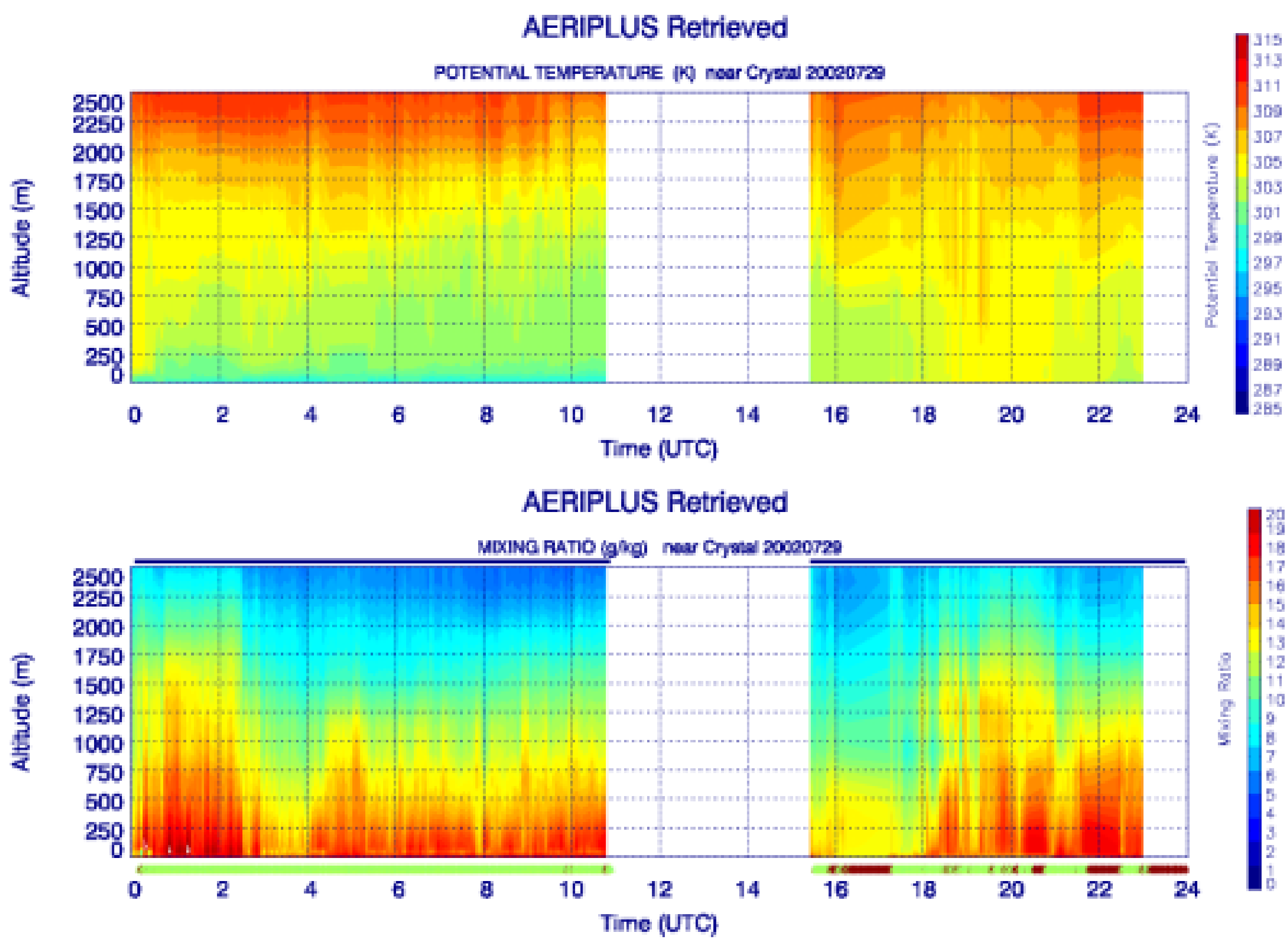

Figure 2. A time-height cross-section of rapid scan AERI retrieved potential temperature and water vapor mixing ratio for July 29, 2002, during the CRYSTAL-FACE campaign in Southern Florida.

configuration for the DOE ARM AERI systems, under samples the boundary layer turbulent plumes. Detection of the PBL thermodynamic boundary layer plumes is important for large-eddy simulation (LES) validation and initialization. LES studies provide a method to take observed PBL structure and parameterize the processes within numerical weather prediction models. Rapid scan AERI temperature and moisture retrievals should provide a new source of data for LES studies.

Corresponding Author

Wayne F. Feltz, wayne.feltz@ssec.wisc.edu, (608) 265-6283

References

Feltz, W. F., H. B. Howell, R. O. Knuteson, H. M. Woolf, and H E. Revercomb, 2003: Near continuous profiling of temperature, moisture, and atmospheric stability using the atmospheric emitted radiance interferometer (AERI). *J. Appl. Meteor.*, **42**, 584-597.

Huang, H. -L., and P. Antonelli, 2001: Application of principal component analysis to high-resolution infrared measurement compression and retrieval. *J. Appl. Meteor*., **40**, 365-388.

Turner D. D., S. A. Ackerman, B. A. Baum, H. E. Revercomb, and P. Yang, 2003: Cloud phase determination using ground-based AERI observations at SHEBA. *J. Appl. Meteor*., **42**, 701-715.