Continuation of Data Analysis Software Development for the Atmospheric Emitted Radiance Interferometer (AERI) Progress Report 1999

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R. O. Knuteson, W. F. Feltz, D. H. DeSlover, and D. Tobin
University of Wisconsin, Cooperative Institute for Meteorological Satellite Studies (CIMSS), Madison -- Wisconsin (608) 265-6283

P.D. Brown, S.A. Clough, E.J. Mlawer
Atmospheric & Environmental Research, Inc.
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I. Introduction

Important progress has been made for the goals funded under DOE Award DE-FG-02-98ER61365. Two papers have appeared in print describing the retrieval of atmospheric boundary layer temperature and water vapor from the groundbased AERI radiance observations [Feltz, 1998, Smith 1999] One paper on initial results from the AERI observations during SHEBA has also been published [Tobin, 1999]. Additional AERIs have been deployed at the ARM SGP, NSA, and TWP sites and data from these instruments are being used in both remote sensing of the atmospheric state and making improvements to radiative transfer models. Progress has also been reported at the ARM science team meetings [Feltz, 1999].

II. AERI/GOES Retrieval Validation

In addition to the AERI system that has been operating in Lamont, Oklahoma at the ARM SGP central facility since 1995, four new AERI systems have been deployed at the DOE ARM SGP boundary facilities near Morris, OK, Purcell, OK, Vici, OK, and Hillsboro, KS. The synergistic retrieval of AERI groundbased measurements coincident with satellite observations from the geostationary GOES sounder has been extended to include all five AERI sites in the Southern Great Plains[Feltz, 1999]. The five site AERI/GOES temperature and water vapor retrieval algorithm has been tested since January 1999 and has validated with excellent results against radiosondes during the Winter and Spring SCM IOPs. A Single Column Model remote sensing data assimilation group has been formed to test the utility of driving the SCM's completely with remotely sensed temperature, water vapor, and winds. Work is in progress to produce temperature and water vapor profiles from the North Slope of Alaska and SHEBA AERI radiances.

With the addition of four new AERI systems it is now possible to produce vertical temperature and water vapor profiles at the SGP CART column boundaries at ten minute resolution. In combination with the central facility AERI system, atmospheric water vapor flux, convergence and divergence calculations are now possible. Validation of profiles at all five sites has been done by calculating statistics compared to radiosondes for the two SCM IOP periods during January and March 1999. Figure 1 provides temperature retrieval rms statistics vs radiosondes for AERI/GOES (red), AERI only (blue), and GOES only (black). Rms differences for the combined AERI/GOES temperature retrieval are between 1 and 1.5 K and are the most accurate using the combined AERI and GOES physical retrieval technique. Due to known issues with the Vaisala radiosonde water vapor profiles, validation for AERI water vapor was conducted through comparison to the Raman Lidar water vapor profiles. Dave Turner has concluded differences of 5-10 % absolute water vapor amounts between the passive (AERI) and active (Raman Lidar) remotely sensed water vapor for over one thousand profile time matches. GOES and AERI/GOES total precipitable water vapor has been compared to the microwave radiometer at the central facility for a two month period in March/April 1998 indicated within figure 2. Hourly GOES 30 km by 30 km retrievals of water vapor show good correlation to the column microwave radiometer total precipitable water vapor. The AERI boundary layer radiance information provides the necessary mesoscale information to the GOES retrieval to agree to the microwave radiometer within 1 mm with little bias.

Several new meteorological products have been developed from the grid of AERI systems. A real time AERI/GOES retrieval web site (http://zonda.ssec.wisc.edu/~waynef) has been developed for the ARM community as well as exposure to the NOAA National Weather Service and National Severe Storms Laboratory. Ten minute resolution atmospheric stability indices can be derived from the AERI/GOES profiles providing valuable nowcasting information about the onset of severe convection. Several cases of pretornadic thunderstorm conditions were detected one – two hours ahead of the thunderstorm development. Interest in the DOE ARM program from NASA and NOAA has been expressed in this regard.

III. SCM Retrieval Assimilation Progress

With the maturity of the retrieval algorithm, there is high confidence that the retrievals will successfully substitute for radiosondes during non IOP (no radiosondes launched) periods. Sensitivity tests have been planned to test the concept by first using radiosondes to drive the SCM and then using

AERI/GOES retrieval profiles along with collocated wind profilers. Among the members we are interacting with are Ric Cederwall and Minghua Zhang. We plan to test the AERI/GOES retrievals through the winter, spring, and summer SCM IOP periods.

IV. Clear Sky Radiative Transfer

The use of extended AERI data from the SHEBA campaign has been instrumental in developing an improved version of the water vapor continuum, CKD_2.4. This version includes changes from 400-600 cm^{-1} to the foreign-broadened continuum made necessary by the AERI data from SHEBA. The modifications made to the model were as a result of years of comparisons between AERI data and LBLRTM calculations [Tobin, et al., 1999]. The results of AERI-LBLRTM QME continue to provide an important constraint on the behavior of the continuum, which includes restricting the use of certain candidate functions under consideration in the effort to derive a revised formulation for the continuum [Mlawer, ARM poster 1999].

Also under development is a QME product to assess and articulate our capability to model the Longwave Flux at the Surface using the Longwave Radiometer Measurements and to assess the sensitivity of the modeling to uncertainties in the specification of the Atmospheric State. The strategy is to extend the approach for the AERI/LBLRTM QME to the Broadband, taking advantage of the AERI spectral observations. Initial implementation has been for Clear Sky and will be followed by implementation of an appropriate version of Wisconsin/AER/PNNL Cloud approach. AERI radiances are spectrally integrated over the 16 RRTM spectral bands from 500-3000 cm^{-1}. The 500-550 cm^{-1} region in the first RRTM band is supplemented by an LBLRTM calculation. These radiance results are compared with RRTM calculations. The AERI integrated radiances are converted to flux units and can be compared with broadband radiometric instrument observations.

V. Conclusions

The temperature and water vapor retrieval algorithm based on AERI data only has been operating for several years. The recent combination of groundbased AERI and satellite GOES observations has allowed the temperature and water vapor profiles to be obtained through the entire troposphere. The AERI/GOES algorithm has been applied to data since Jan 1998 (1 ½ years of data) at the SGP central facility and has been operating in real-time at all five SGP AERI sites since Jan 1999. A process is underway which will led to the use of these retrieval products as input to the ARM SCM models with the intention that these SCM models can be operated on a more continuous basis than the current IOP mode. The retrieval algorithm is also being extended for use with the AERIs at the arctic and tropical western pacific ARM sites.

The comparison of AERI radiances to line-by-line model calculations (AERI/LBLRTM QME) has led to important conclusions regarding the accuracy of the calculations as well as providing insight into the measurement requirements for atmospheric water vapor, the most important greenhouse gas. In particular, arctic observations made during the ARM/SHEBA experiment have been used to improve the water vapor continuum in the 400 – 600 cm^{-1} (longwave) region. The validation of calculations from this spectral region have very positive implications on the calculation of radiation emitted to space in the upper troposphere and thus on our knowledge of atmospheric cooling rates.

The funding left for the rest of the budgeted period (January 31, 2000) is approximately $47,000. It is anticipated that this funding (DOE Award DE-FG-02-98ER61365) will be spent before the end of this budgeting period.

VI. References

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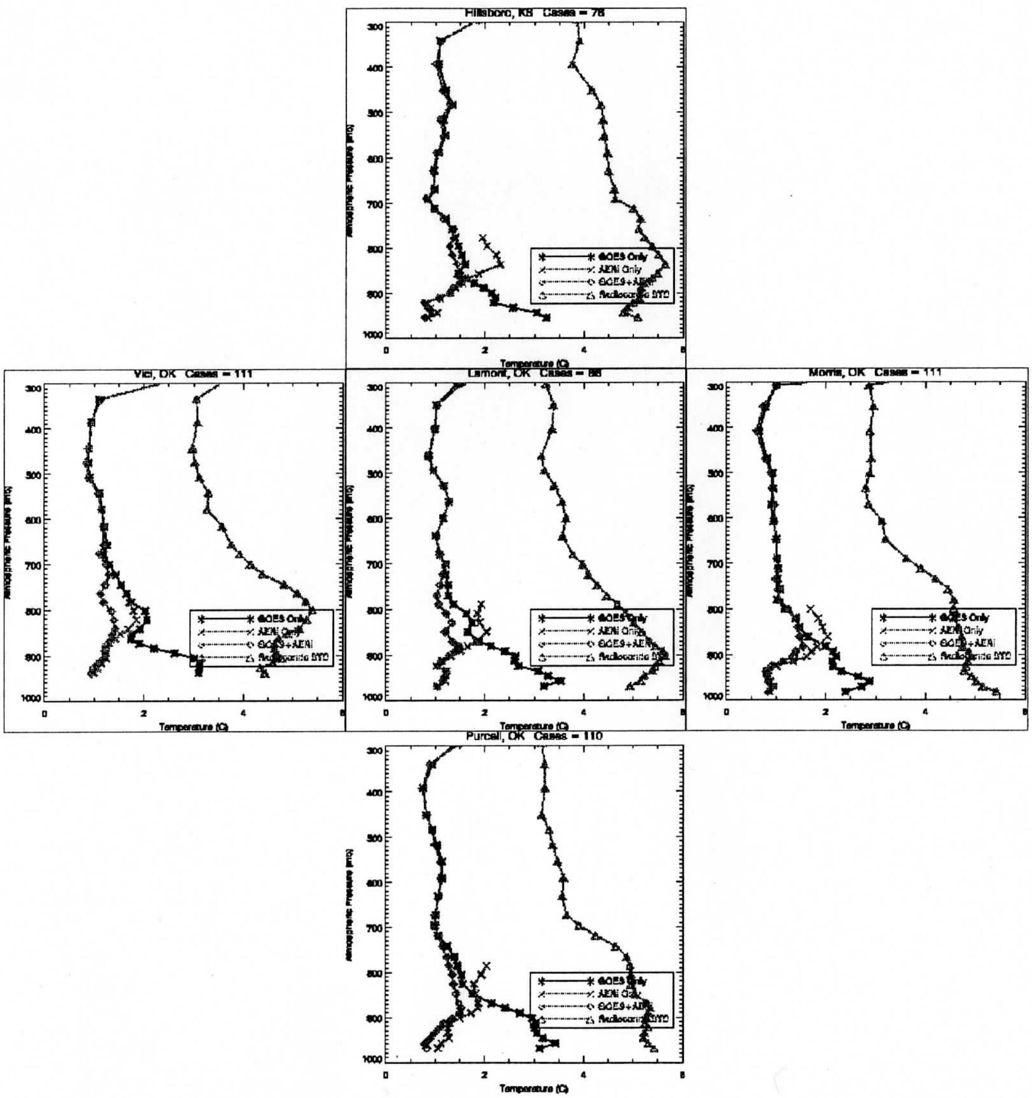

Figure 1: Statistical comparisons of the five AERI system temperature retrievals compared to radiosondes. The plots have been placed in their relative geographical location. The boundary facility systems are approximately 125 km from the central facility. The lines are defined as red -

AERI/GOES retrieval, blue - AERI only, and black - GOES only. Notice that the combined retrieval RMS statistics are better than each instrument alone in all cases.

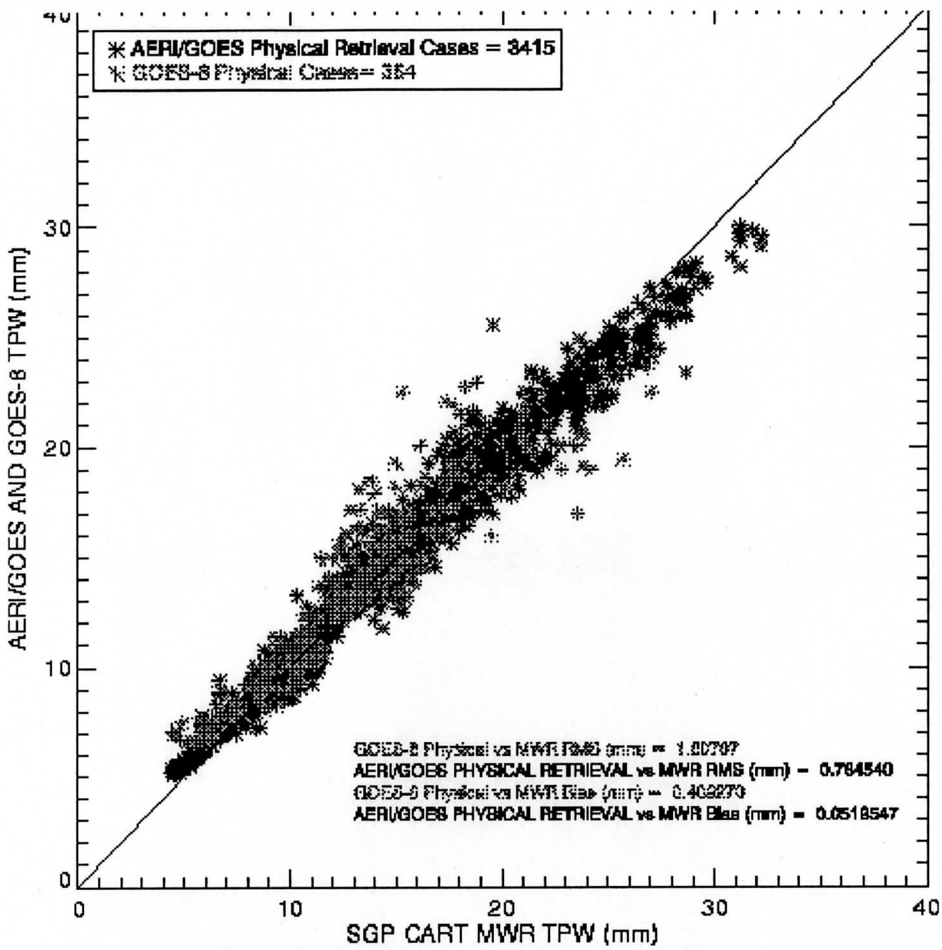

Figure 2: Comparison of AERI/GOES and GOES only physical retrievals to concurrent microwave radiometer total precipitable water vapor. The AERI boundary layer radiance information provides mesoscale detail to the hourly 30 km by 30 km GOES retrievals especially at high water vapor amounts. AERI/GOES retrieval rms statistics compare to within one millimeter for over 3000 cases with little or no bias.