Temperature and Water Vapor Profile Retrievals from AERI-X High Spectral Resolution Emission Spectra

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Introduction

The University of Denver Atmospheric Emission Radiance Interferometer-Extended (AERI-X) produces calibrated 0.1 cm^{-1} resolution spectra of the downwelling infrared emission of the atmosphere. These spectra are used to retrieve temperature and water vapor profiles for the lower part of the atmosphere with the optimal estimation spectral fitting routine known as SEASCRAPE (Sequential Evaluation Algorithm for Simultaneous and Concurrent Retrieval of Atmospheric Parameter Estimates).

SEASCRAPE Details

SEASCRAPE was originally developed at the National Aeronautics and Space Administration's (NASA's) Jet Propulsion Laboratory (JPL). As of August 1996 SEASCRAPE has been supported and marketed by Remote Sensing Analysis Systems (RSA) of Altadena, California. It provides the ability to do both the forward modeling and to solve the inverse problem. The SEASCRAPE forward model has been compared to the University of Oxford GENLN2 code and FASCODE (Fast Atmospheric Signature Code), with an indicated agreement of better than 1%. Our own comparisons with the Line-by-Line Radiative Transfer Model (LBLRTM) verify this. In solving the inverse problem, it allows the simultaneous retrieval of multiple profiles from one or more spectral regions, and/or one or more spectra.

The AERI-X Instrument

The AERI-X instrument is a Michelson interferometer employing corner cubes for the moving (50 mm travel) and fixed mirrors. It has an effective spectral resolution 0.1 cm^{-1} and a spectral bandpass: 650 cm^{-1} to 1350 cm^{-1}. It is a single channel instrument with a HgCdTe detector that records single-sided interferograms with a small section before the zero path difference point (Zpd). The basic instrument was constructed by Idealab of Franklin, Massachusetts, and packaging was done at Denver University (DU).

The radiometric calibration is carried out using the method of Revercomb et al. (1988) and a more complete description of the instrument is available in Olson et al. (1996).

The AERI-X collects data via an automatic collection program twice per hour, conditions permitting. The data set presented here was collected during the week of June 22, 1997. The data from June 26 and 27 were selected for this analysis, based on quality and atmospheric conditions.

Retrieval Details

Atmospheric Radiation Measurement (ARM) radiosonde data were used in creating the a priori data set and for comparison to the retrievals. Spectra from mid-afternoon on June 26 were selected as representative of a situation with considerable diurnal heating. Spectra from the morning of June 27 demonstrate a low-level inversion and its dissipation.

The first step in the retrieval process was the construction of a priori data sets. Initially, three sets were constructed, so that the sensitivity to the a priori profile might be studied. The sets corresponded to averages over 3 days, 1 week, and roughly the summer season (May to September). The atmosphere over the ARM Southern Great Plains (SGP) site is apparently quite stable during the summer as the three a priori profiles are quite similar. Spectral regions were then selected to use in the inversion. Two regions were used: 740 cm^{-1} to 765 cm^{-1}, which contains the edge of the 15 micron CO_2 band; and 930 cm^{-1} to 970 cm^{-1}, which includes much of the CO_2 hot band. Both bands contain water vapor lines as well as contribution from the water vapor continuum. It is particularly strong in the first region.

The temperature at the surface is fairly tightly constrained to be similar to radiosonde ground level temperatures. The initial retrievals indicated the presence of some unmodeled influence, and comparison of the experimental spectra to that produced by the forward model showed the presence of a base line "ripple" of a few percent. By degrading the AERI-X spectra to 1 cm^{-1} and dividing by University of Wisconsin AERI data, we were able to create a representation of the ripple signature. The ripple signature was then filtered to approximately 5 cm^{-1} resolution, to smooth out small variations likely to be atmospheric in nature. This was then subtracted from the AERI-X spectra, effectively removing the ripple. A comparison of the original and corrected spectra is shown in Figure 1.

Discussion of Retrieved Temperature and H_2O Profiles

SEASCRAPE allows us to retrieve temperature and H_2O simultaneously to good effect. The temperature profiles retrieved from the mid-afternoon data of June 26 are very consistent (Figure 2). They differ somewhat (2 K to 3.5 K) from the radiosonde temperature profile between 1.2 km and 2.2 km, but fit to approximately 1 K for the rest of the profile from ground-level to 5 km. The difference is likely due to the radiosonde sampling the atmosphere along a path different from the instrument line-of-sight. Temperature profiles retrieved from June 27 demonstrate the ability to retrieve a temperature inversion (Figure 3). The agreement on the early spectra is quite good throughout the profile. The difference at the peak is approximately 1 K. Largest error of approximately 2 K is again at 2.2 km. Figure 4 illustrates the last retrieval from June 27, showing the breakdown of the inversion. Again, the retrieved profile compares very well to the radiosonde profile. The major discrepancy is at ground level. In this case, the surface a priori point was not tightly constrained to the radiosonde value. All the retrieved profiles have moved away from the a priori profile to a reasonable extent.

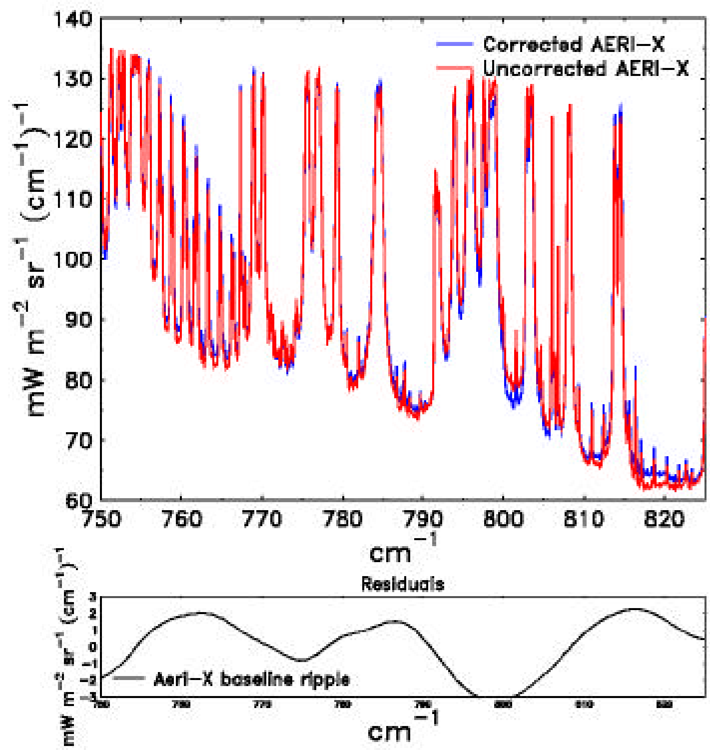

Figure 1. Comparison of corrected and uncorrected AERI-X spectra.

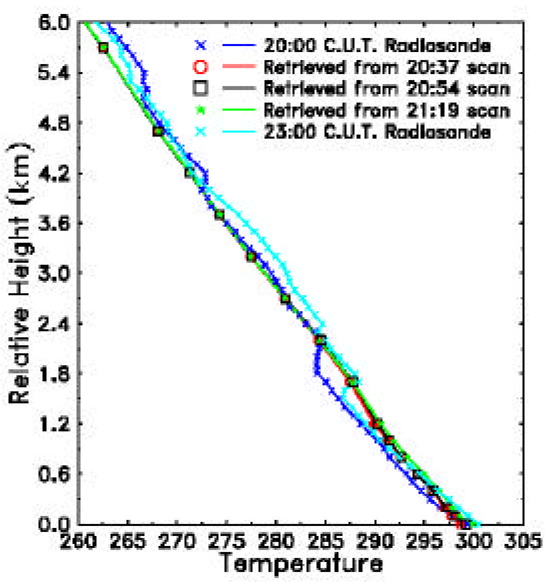

Figure 2. Three temperature profiles retrieved from spectra near 21:00 Coordinated Universal Time (CUT) on June 26, 1998.

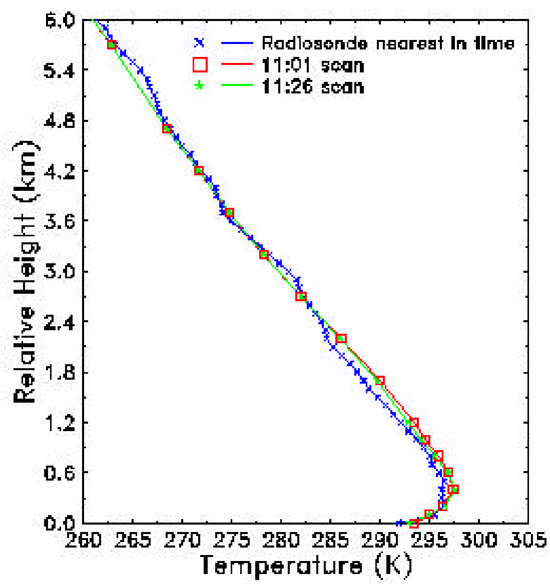

Figure 3. Temperature profiles retrieved from scans near 11:00 CUT. Also shown is the 11:00 CUT sonde.

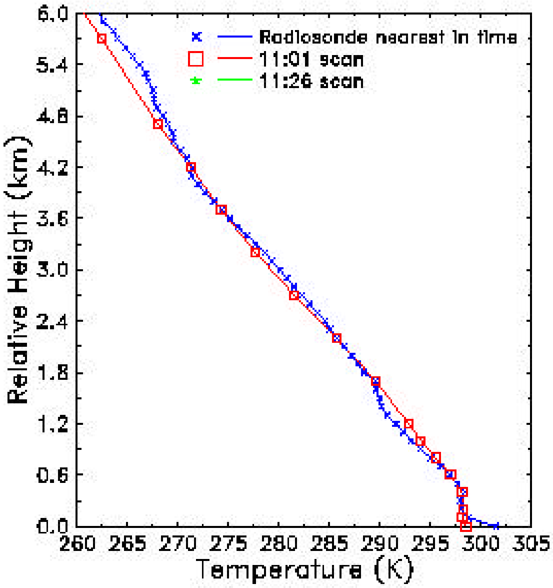

Figure 4. Profile retrieved from the 14:05 CUT scan showing the break-up of the inversion.

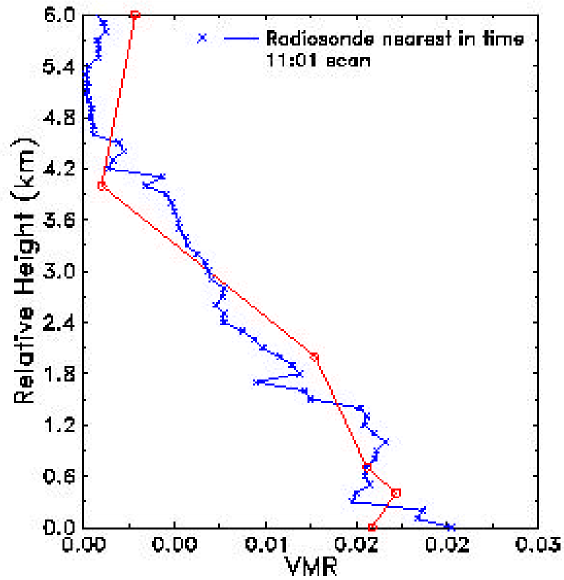

Figure 5. Water vapor profile retrieved from 11:01 spectrum on June 27.

In this study, the emphasis was on temperature retrieval, so the H_2O a priori are fairly close to the radiosonde profile of the 27th. In general, two shortcomings make H_2O retrievals difficult: 1) The SEASCRAPE continuum model is not the most current version of the CKD model. This has minimal impact in this region. 2) The line parameters are not correct. This results in a substantial H_2O signature remaining in the residuals. The line parameter issue was improved somewhat by using the Toth water lines (as available on the ARM Web Site), which have improved line strengths, although no change is made to the line widths. Improvement will come as continuum models continue to improve, and an updated version of the CKD model will be included in the next SEASCRAPE release (private communication, Jean Patterson, RSA). As seen in Figure 5, the resulting H_2O retrievals are quite good, although a priori covariance of approximately 10% may be artificially small.

Conclusions

The fact that the AERI-X spectra could be corrected with the AERI spectra demonstrates that AERI-X and AERI provide comparable radiances, and the very good agreement with both SEASCRAPE and LBLRTM indicate that the AERI-X is providing radiometrically accurate spectra, with the exception of the AERI-X baseline ripple.

When SEASCRAPE is applied to the AERI-X spectra, the inversion results in a very good retrieved temperature profile, with the demonstrated ability to detect an inversion feature close to ground level. SEASCRAPE can also provide a credible water vapor profile retrieval, which will be improved in next version. Future work will expand the use of SEASCRAPE to other constituents and other data sets, such as the analysis of spectra provided by the University of Denver SOlar Radiation Transmission Interferometer (SORTI) instrument also located at the ARM SGP site.

References

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