STATUS REPORT – EOS Aqua Validation

VALIDATION OF THE ATMOSPHERIC INFRARED SOUNDER OVER THE ANTARCTIC PLATEAU

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Overview:

Dome Concordia is an ideal site for calibration and validation of infrared satellite instruments. The large continental ice sheet is one of the most homogeneous land surfaces on earth in terms of surface temperature and emissivity. Surface-based measurements of upwelling infrared radiation from the surface between 8-12 micrometers are very nearly equal to those measured by satellite instruments because of minimal atmospheric absorption and emission. Therefore, accurate measurements made at the surface of spectral infrared radiance can provide valuable validation data for satellite instruments.

In January 2003, our group performed field work at Dome Concordia to validate NASA's Atmospheric Infrared Sounder (AIRS). We measured upwelling and downwelling spectral infrared radiances with the Polar Atmospheric Emitted Radiance Interferometer (PAERI) atop a 6-meter tower. A narrow-band infrared radiometer, called the AIRS Mobile Observing System (AMOS), was dragged behind a snowmobile to map changes in surface radiation at spatial scales similar to the field of view of AIRS. Radiosondes were launched to obtain atmospheric temperature and humidity profiles. A ground-based GPS unit was operated in an attempt to measure the extremely low values of total precipitable water (about 1 mm in summer). In addition, surface meteorological measurements and total-column ozone measurements were made by other groups at Dome C during January 2003.

Validation Goals:

The goals of this study are to provide validation data for both level 1 and level 2 products derived from the AIRS instrument. Our contributions to the level 1 validation will include top-of-the-atmosphere (TOA) radiances derived from radiative transfer calculations that use as input the model atmospheres and retrievals of the spectral emissivity and skin temperature of the snow surface. We will supply model atmospheres for the summertime Antarctic, derived from radiosondes and ancillary data (surface met obs and ozone measurements), and also provide retrievals of the surface spectral emissivity and cloud microphysical properties for Level 2 validation. We will make detailed comparisons to coincident AIRS data and provide our assessments of AIRS radiances and products.

Initial Field Experiment:

Our initial field experiment at Dome Concordia occurred from 28 December 2002 until 2 February 2003. Radiosondes were launched during this time period in collaboration with astrophysics groups from the University of Nice and the University of New South Wales. The Polar Atmospheric Emitted Radiance Interferometer (PAERI) was operated from 13 January until 29 January; the AIRS Mobile Observing System (AMOS) operated from 17 January until 29 January. During the 2.5 weeks of PAERI operation, there were 106 Aqua overpasses over Dome C. Thirty-five of these overpasses had viewing angles within 22.5° of nadir. Eighteen of the overpasses were under clear-sky conditions; six of these were near nadir. Clear skies were observed on 15, 16, 28, and 29 January. There were 8 radiosondes launched on these days that were timed with Aqua overpasses. We also launched one sonde during clear-sky conditions to coincide with the overpass of the Terra satellite at the request of the MODIS Science Team (C. Moeller, pers. comm., 2002).

Ground-based Instrument Calibration:

The PAERI was calibrated in the field using a standard infrared source after it was shipped to Dome C. Calibration tests were performed by viewing an infrared source at 318 K and 253 K and then comparing the PAERI measurements to theoretical values derived from knowledge of the source's temperature and spectral emissivity; the calibration of all the infrared sources used with the PAERI are traceable to NIST standards. Figure 1 shows that the PAERI is calibrated to within 0.03 K at 318 K and to within about 0.04 – 0.05 K at 253 K. The low-temperature calibration is especially significant because the radiance conditions of this test were very similar to the actual radiances being measured for AIRS validation (that is, a cold snow surface with high emissivity at temperatures between about 230 and 245 K). Therefore, the absolute calibration of the PAERI measurements in the field is excellent, and comparable to the calibration of the Marine-AERI measurements made at sea by the University of Miami (P. Minnett, pers. comm., 2003). Because of this, the AMOS instrument was frequently inter-calibrated to the PAERI by viewing the identical field-of-view within a couple of minutes of the PAERI. In addition, the AMOS was calibrated prior to deployment inside an environmental chamber at NOAA/CMDL using three different infrared sources, including one used to calibrate the PAERI. These tests were conducted over a range of temperatures (-45 to -10 C) and were used to obtain regression standard deviations of < 0.1 C. Calibrations were also conducted in the field using a target with an emissivity of 0.98 for comparison with laboratory results (in progress).

Validation Data Examples:

After completing our field experiment in early February, we are now performing quality control on all of our datasets. These include the temperature and humidity profiles. Figure 2 show raw radiosonde profiles taken on days with the minimum (-40 C) and maximum (-19 C) surface air temperatures between 13 and 29 January 2003. Note that the profiles contain data from both the ascent and descent of the balloon. The similarity of the temperatures measured during ascent and descent suggest that the atmosphere is quite stable in the vicinity of Dome C. Wind data from radiosondes launched at Dome C frequently show that the wind speeds are quite low (often less than 10 m s^{-1}) throughout the entire troposphere, so these sondes probably did not drift as far downwind as sondes typically do in windier environments.

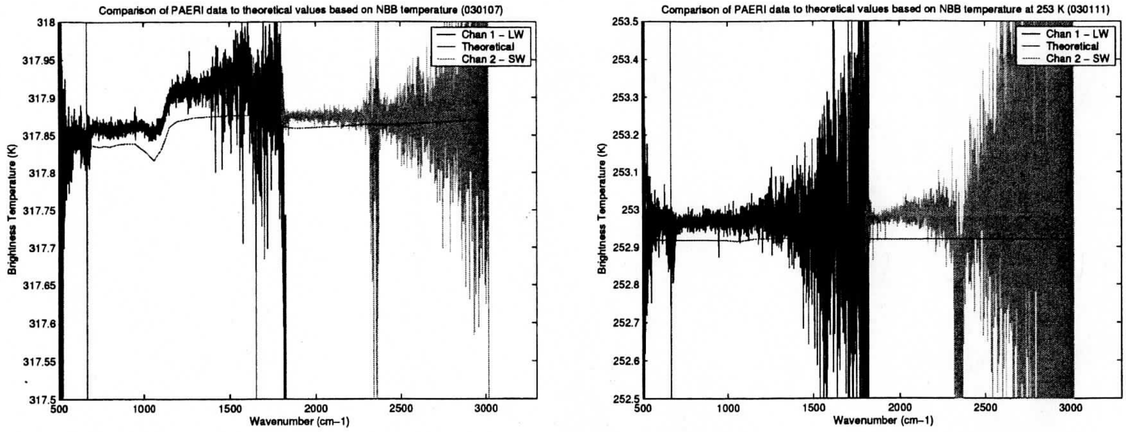

Figure 1. Comparison of calibrated, brightness-temperature spectra measured by the PAERI with theoretical curves derived from knowledge of the calibration source's temperature and spectral emissivity. The spectral regions that are best calibrated are the window regions from 700 to 1200 cm^{-1} and 1800 to 2300 cm^{-1}. The other regions are still well calibrated, but are affected by gaseous absorption and emission by water vapor and carbon dioxide between the calibration source and the PAERI.

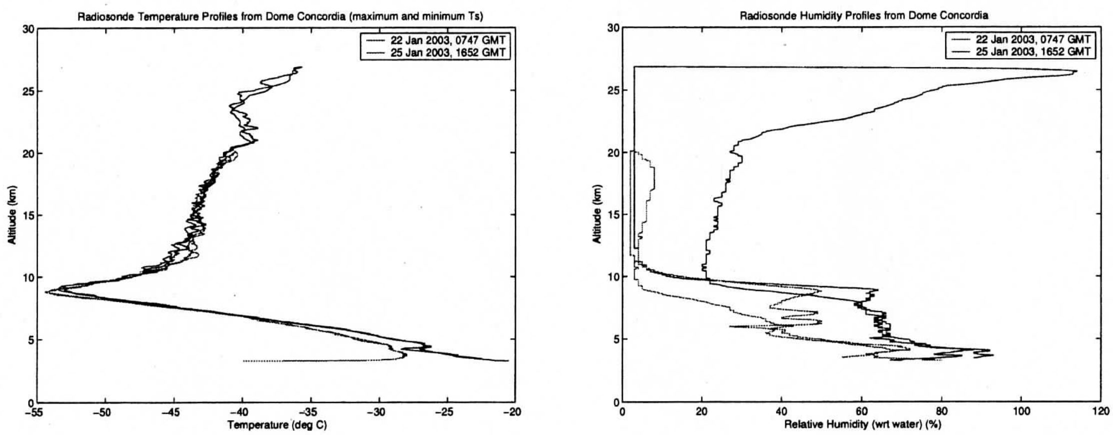

Figure 2. Raw radiosonde profiles obtained from Dome Concordia, Antarctica. Data from both the balloon ascent and descent are shown for both days. The temperature profiles (left) indicate that the atmosphere is quite stable, since the ascent and descent data agree well. The humidity profiles have not yet been corrected for the lag of the humidity sensor; the data above 10 km are probably not usable.

Figure 3 shows radiance and brightness temperature spectra of upwelling radiation from the snow surface and downwelling radiation from the atmosphere measured at Dome C. The surface brightness temperature is about 247 K, or -26 C. These measurements were taken at 1340 local time, so this was near the peak temperature for that day. Later in the evening, the surface brightness temperature was around 232 K, or -41 C. Because of the diurnal cycle at Dome C, it is important to make radiation measurements that are coincident with Aqua overpasses. The PAERI and AMOS instruments were typically operated over time periods that spanned Aqua overpasses.

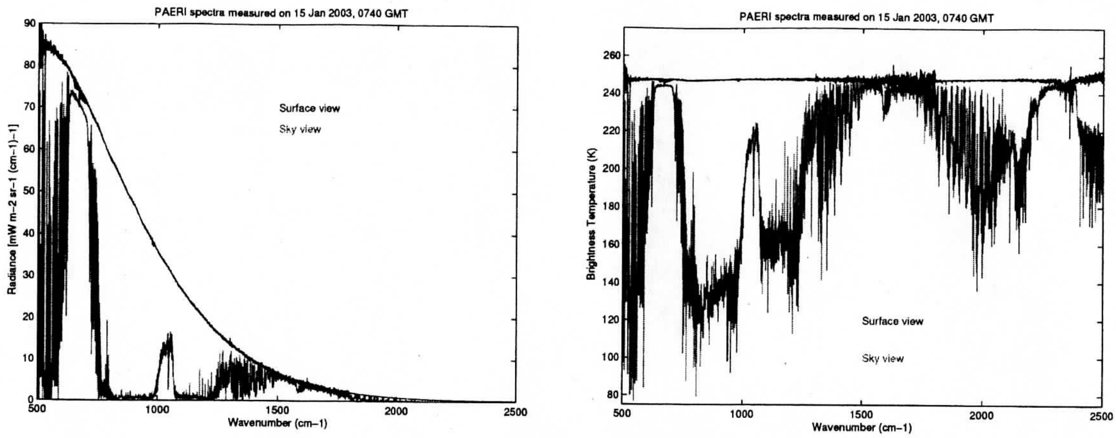

Figure 3. Measured radiance (left) and brightness temperature (right) spectra of upwelling radiation from the snow surface (blue) and downwelling radiation from the atmosphere (red) from the Polar Atmospheric Emitted Radiance Interferometer (PAERI) obtained on 15 January 2003 at 0740 GMT. The surface brightness temperature is approximately 247 K.

The AMOS data were obtained over various spatial scales, including triangular tracks with 1- and 5-km legs. The AMOS also performed tests over scales of tens of feet, which sampled a few characteristic sastrugi. In contrast to the "dynamic" sled-based measurement runs when the AMOS was in constant motion, the small-scale tests were done by moving the instrument a few feet and then remaining in a fixed position throughout the measurement. The AMOS data will be used to determine the distribution of upwelling solar irradiance (using a LICOR visible sensor) and surface temperature (infrared emission). The "static sastrugi" tests, as well as the inter-calibration of the AMOS to the PAERI, will be used to tie the PAERI measurements to these pixel-scale distributions, allowing us to "scale" the surface temperature derived from the PAERI to that viewed by AIRS.

In addition, a unique data set of multi-spectral photometric measurements was collected during the field project using a system developed by NOAA/CMDL in conjunction with the Institute of Atmospheric and Climate Sciences (ISAC) – National Research Council, Italy. Visible cloud optical depths, derived from the observations, will be used to investigate the opacity of ice crystal precipitation, and thin to moderately thick cirrus clouds. Eight wavelengths from 368 to 1050 nm are available for quantifying aerosol and cloud properties. These measurements will complement the cloud retrievals from the PAERI.

Figure 4 below shows some sample data that we have archived for detailed comparisons with our TOA radiance calculations.

Data Archival Strategy and Connections to AIRS Validation:

The radiosonde temperature profiles will be archived as netCDF files in two different ways. The raw profiles that have been through our quality control procedures will be archived as soon as possible. Another set of profiles will be submitted after the humidity profiles have been corrected for the lag of the humidity sensor by Dr. Larry Miloshevich at NCAR (L. Miloshevich, pers. comm., 2003). These profiles will be available for use in calculations of downwelling radiance using the AIRS forward-model. These radiances can then be compared with measurements of the downwelling radiance from the atmosphere made by the PAERI.

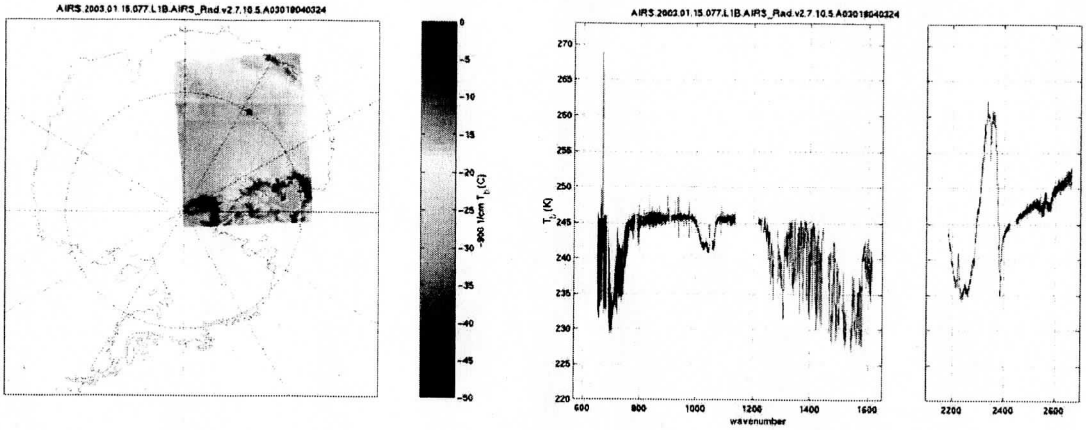

Figure 4. Examples of AIRS data acquired over Dome Concordia, Antarctica on 15 January 2003. The figure on the left shows a brightness temperature map derived from radiances at 900 cm^{-1}. The figure on the right are the nine, overlayed spectra that were nearest to Dome Concordia on this particular overpass.

TOA radiances, calculated using the AIRS kcarta model, will be submitted as validation data as soon as possible. These calculations will use as input the model atmospheres derived from the radiosonde and ancillary data, as well as the spectral emissivity and surface temperature derived from PAERI measurements of upwelling radiance. Our sensitivity studies using the AIRS kcarta model show that the TOA brightness temperatures for about 50% of the AIRS frequencies over the Antarctic Plateau vary by less than 0.05 K when simulating large uncertainties in both the radiosonde temperature and humidity profiles. This is due to the fact that the atmosphere is quite thin throughout a large portion of the infrared spectrum. This suggests that the PAERI retrievals of [ε B(T_s)], derived from measurements at the surface, should not be significantly affected by uncertainties in the radiosonde profiles.

The spectral emissivity of the surface will be retrieved from the PAERI upwelling measurements under clear-sky conditions. These should be available soon, because they are needed in the kcarta calculations, and, therefore, for Level 1 radiance validation. The emissivity retrievals will be used to validate the Level 2 emissivity product over Antarctica. In addition, cloud microphysical properties will be determined from the downwelling radiance spectra using the methods described by Mahesh et al (2002 a,b), and will be used for Level 2 validation. These retrievals will be performed in the summer of 2003.

Contact with AIRS Science Team members:

We have initiated contact with key members of the AIRS Science Team regarding our initial validation efforts. Dr. Larrabee Strow has requested our radiosonde profiles and measurements of the downwelling infrared radiance at the surface. The profiles can be used as input to the AIRS forward model. The outputed radiances from the forward model can be compared with the downwelling measurements from the PAERI. Dr. Chris Barnet has supplied us with preliminary temperature retrievals, which we will be comparing to radiosonde profiles. He has requested our retrievals of surface snow emissivity for Level 2 validation.

Future Work:

We will perform a longer field season at Dome Concordia in December 2003 and January 2004. Our primary goals will be to repeat the successful measurements of our initial campaign. In addition, we will attempt to better characterize the surface inhomogeneity caused by differential heating of sastrugi by solar radiation.

Professional Activities:

Presentation at the AIRS Science Team meeting, JPL, Pasadena, CA, November 2002, *Validation of AIRS over the Antarctic Plateau: Low radiance, low humidity, and thin clouds.*

Presentation at the AIRS Validation Team Net meeting, 16 December 2002, *Update: Validation of AIRS over the Antarctic Plateau: Low radiance, low humidity, and thin clouds.*

Presentation at the AIRS Science Team meeting, Camp Springs, MD, 25-27 February 2003, *An Update on AIRS Validation Activities at Dome Concordia, Antarctica.*

References:

Mahesh, A., V.P. Walden, and S.G. Warren, 2002a: Ground-based infrared remote sensing of cloud properties over the Antarctic Plateau. Part I: Cloud-base heights. J. Appl. Met., 40, 1269-1278.

Mahesh, A., V.P. Walden, and S.G. Warren, 2002b: Ground-based infrared remote sensing of cloud properties over the Antarctic Plateau. Part II: Cloud optical depths and particle sizes. J. Appl. Met., 40, 1279-1294.