GLOBAL DAILY ATMOSPHERIC STATE PROFILES FROM THE ATMOSPHERIC INFRARED SOUNDER

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ABSTRACT

The Atmospheric Infrared Sounder (AIRS) on the EOS Aqua spacecraft provides calibrated radiances and geophysical products for Earth science investigation and validation of processes affecting weather and climate. A description of the major products including temperature profiles, water vapor profiles, surface products, cloud products and composition products is presented. The wide variety of products available from AIRS make it uniquely able to address science questions involving interaction of geophysical variables in the climate system.

Index Terms- Hyperspectral Infrared, Remote Sensing, AIRS, Sounder, Temperature, Water Vapor, Carbon Dioxide

1. INTRODUCTION

The Atmospheric Infrared Sounder (AIRS) is a hyperspectral infrared instrument on the EOS Aqua Spacecraft, launched on May 4, 2002. AIRS has 2378 infrared channels ranging from 3.7 μm to 15.4 μm and a 13.5 km footprint. AIRS, in conjunction with the Advanced Microwave Sounding Unit (AMSU), produces temperature profiles with 1K/km accuracy on a global scale, as well as water vapor profiles, clouds, dust and trace gas amounts for CO_2, CO, SO_2, O_3 and CH_4.[1] AIRS data are used for weather forecasting and studies of global climate change. The AIRS is a "facility" instrument developed by NASA as an experimental demonstration of advanced technology for remote sensing and the benefits of high resolution infrared spectra to science investigations

2. CALIBRATED RADIANCE PRODUCT

The most fundamental product from AIRS are the calibrated radiances and geolocation in the Level 1B data product. The upwelling infrared spectrum contains a wealth of information about the state of the atmosphere including temperature profile, water vapor, and the trace gases mentioned above. The AIRS radiances are derived from the instrument signal (digital counts) by applying a 2 point calibration using the on-board blackbody and space views. A nonlinearity and polarization correction are also applied. The resulting calibration radiometric accuracy is better than 0.2K across the spectrum and stable to less than 10 mK/year [2].

The AIRS radiances are assimilated into Global Circulation Models (GCM's) at weather prediction centers worldwide. A significant positive impact has been achieved. Six hours on the 5 day forecast has been achieved by assimilating 1 in 18 footprints [3, 4] an additional 5 hours on the 5 day forecast has been shown to be possible. AIRS radiances are also being assimilated into regional weather forecast models with significant forecast improvements of regional scale processes and local precipitation estimates out to 48 hours [McCarty et al. 2008 – in preparation for JGR submission] The radiance spectra are also used to understand processes affecting climate [5] and validate climate models directly [6]

3. SCIENCE DATA PRODUCTS

The AIRS Science Team has developed retrieval and Radiative Transfer Algorithms that transform the AIRS radiances into geophysical state of the atmosphere. Products are generated by JPL, NOAA, UMBC, and GSFC, and are available to the public, free of charge through the NASA Goddard Earth Sciences/Data and Information Services Center (GES/DISC) Geophysical products and cloud-cleared radiances are found in the AIRS Level 2 standard product [1]. Most L2 products are produced on at 45 x 45 km resolution at nadir and are "cloud cleared", with valid retrievals up to 80% cloud cover. Level 2 temperature fields agree well with NWP center predictions (ECMWF, NCEP) [7], however comparison with water vapor and most trace gases has identified model prediction errors. This makes AIRS data very useful as a validation tool as the models develop. The AIRS L2 data products are available for near-real-time weather forecast prediction and are available 3 hours from data acquisition, and in real time from the direct broadcast receiving stations. Real-time products are also used for detection of clouds, aerosols and trace gases for flight science validation campaigns.

3.1 Temperature and Water Vapor Products

Temperature and Water Vapor Profiles are the primary standard products from AIRS. They are widely used for weather forecast improvement operations and research, climate model validation, and climate process studies. Like all the AIRS products, they are provided globally, daily, over land and ocean under clear and cloudy conditions [7]. The wide swath and high yield make the AIRS a desired product for global modelers. Figure 1 shows a single day of AIRS water vapor with day and night acquisitions combined and a small amount of interpolation of remaining gaps.

Traditionally, forecast centers have assimilated radiances, however, recent work has shown that assimilation of temperature profiles offers considerable improvement that was not realized before [8]. Modelers at NASA's SPoRT have found that assimilation of temperature and water vapor into the regional models can improve prediction of pressure anomalies and rainfall [9]. Additionally, AIRS temperature and moisture profiles are being used operationally by NWS weather forecast offices in their Advanced Weather Information Processing System (AWIPS) as a supplement to the coarsely spaced twice daily weather balloon observations. These asynoptic profiles provide mesoscale spatial resolution information of changing moisture and stability fields important for convective weather development over the continental United States. The AIRS temperature and water vapor profiles are well validated. That makes them useful for validating climate models. Results have shown that several major climate models have considerable errors in the vertical and horizontal distribution of water vapor on an annual climatology [10, 11, 12]. Scientists have improved the understanding of the process of supersaturation in the stratosphere using AIRS data; an important result for understanding the role of clouds on global warming [13]. Most recently, scientists have related reduced cloudiness and downwelling radiation to the associated ice loss in the arctic region [14].

3.2 Surface Temperatures and Emissivity

The AIRS Sea Surface Temperature (SST), and Land Surface Temperature (LST) and Surface Emissivity have been met with limited success until recently. Under clear ocean conditions, the products all look very good, however other sources of data (MODIS, AMSR-E) have achieved better than AIRS under these conditions with higher spatial resolution. The value in AIRS comes in the ability to produce a spectrum of the surface leaving radiance and from this a temperature and spectral emissivity. The spectral emissivity over land is highly desirable quantity for weather forecast data assimilation and should provide considerable forecast improvement. Until recently, the high degree of variability in the scene and the effects of clouds in the boundary layer have limited the retrieval accuracy in this region. Recent efforts use the shortwave channels for temperature retrieval and the longwave channels for cloud clearing resulting in a major improvement in the surface products [15].

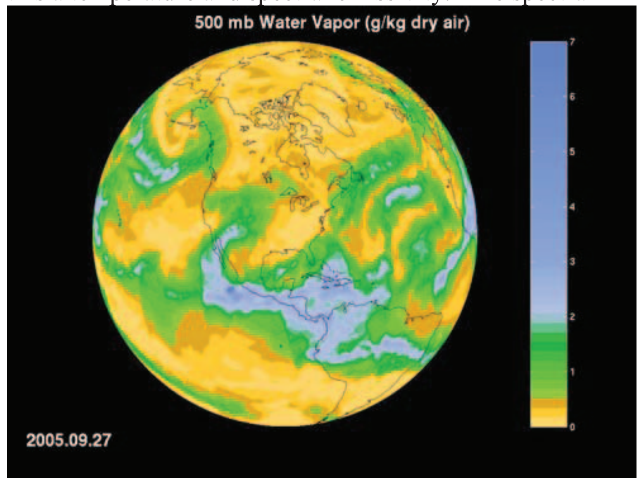

Figure 1. Daily Mid Tropospheric Water Vapor from AIRS (500 mb).

3.3 Cloud Products

The AIRS standard products include cloud height, cloud fraction and cloud top temperature. These products are just beginning to find their value as scientists attempt to understand the relationship between changing climate and cloud radiative forcing. To date, the products have proved valuable through intercomparison with MODIS and CloudSat [16,17], but there is considerable new information in the AIRS spectra about cloud microphysical properties [18] and thin cirrus [19,20]. This information has been used to detect Polar Stratospheric Clouds, ice clouds in the Antarctic polar stratosphere. [21]

3.4 Composition Products

The profile of ozone and the total burden are produced from the AIRS retrieval as a necessary part of the temperature and water vapor retrieval. Scientists have successfully retrieved other trace gases including, CO, CH_4 and CO_2 from AIRS because of the value to Earth Science and paucity of available data sets from other observational platforms.

AIRS measures the total column and profile of ozone with approximately 2 pieces of information in the boundary between the tropopause and the stratosphere. A sample day of AIRS ozone is shown in Figure 2. This makes the AIRS ozone ideal for studies of stratospheric-tropospheric exchange during severe convection events and the global transport of ozone through the Brewer-Dobson circulation]. AIRS ozone data have undergone rigorous validation using aircraft data and ozonesondes [22]. AIRS' 1600 km cross-track swath and cloud-clearing retrieval capabilities provide daily global CO maps over approximately 70% of the Earth. Validation indicates AIRS CO retrievals are approaching the 15% accuracy target set by pre-launch simulations [23]. The most significant trace gas retrieved by AIRS for the study of anthropogenic effects on climate is carbon dioxide. AIRS CO_2 retrievals use an analytical method for the determination of carbon dioxide and other minor gases in the troposphere from AIRS spectra. The AIRS data have been shown to be accurate to ±1.20 ppmv of the aircraft observations [24]. Global monthly maps of CO2 have been generated and identify global transport patterns in the mid-troposphere. These results will aid climate modelers in parameterization of mid-tropospheric transport processes of CO2 and other gases. The accuracy of AIRS CH4 is about 1.2-1.5% depending on different altitudes, which should be able to map seasonal variation of CH4 and can provide valuable information of atmosphere in mid-upper troposphere [25]. AIRS Scientists have observed a significant summer enhancement of CH4 in high northern hemisphere which correlates well with soil temperature and is most likely due to northern wetland emission in summer. Finally, the hyperspectral infrared observations from AIRS show considerable sensitivity to the spectrum of dust and may allow retrieval of dust optical thickness in the near future [26].

4. CONCLUSIONS

The Atmospheric Infrared Sounder provides daily state profiles of atmospheric temperature, water vapor, cloud properties, surface temperature, trace gases and dust. The water vapor and temperature products are mature and well validated. Considerable progress has been made recently in the areas of cloud and surface products. AIRS Composition products are finding their way into the scientific community due to their global area coverage and rapid revisit facilitating transport studies. Use of the AIRS data for atmospheric correction of higher spatial resolution thermal sensors including Landsat, MODIS or ASTER have not been fully explored. The benefit will be in that the AIRS water vapor will be better than the forecast models. Difficulties arise when trying to account for the varying spatial resolution of the instruments particularly in non-uniform scenes and over land. New techniques for correcting the AIRS non-uniform response have been developed to facilitate the use of the radiances which may help [27].

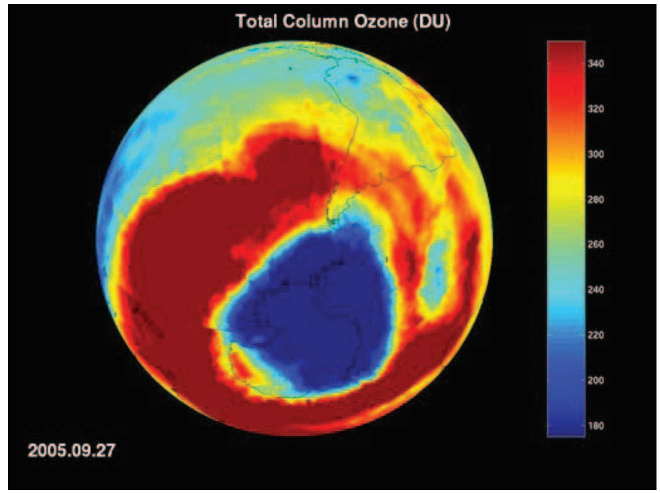

Figure 2. AIRS Total Ozone shows ozone hole in September 2005.

5. ACKNOWLEDGEMENTS

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