P5.28 AQUA RADIANCE COMPUTATIONS FOR THE OBSERVING SYSTEM SIMULATION EXPERIMENTS FOR NPOESS

Thomas J. Kleespies
NOAA/NESDIS, Camp Springs, MD
H. Sun, W. Wolf, QSS Group Inc, Lanham MD
M. Goldberg, NOAA/NESDIS, Camp Springs MD

1. Introduction

Global atmospheric observing systems provide the basic data for Numerical Weather Prediction (NWP) forecasts and the means to monitor and assess climate change. The National Polar-orbiting Operational Environmental Satellite System (NPOESS) is scheduled to fly in the 2008-2018 time frame. However, the impact of the suite of NPOESS instruments on NWP is still not clear.

An evaluation of a particular instrument's effect on NWP must be taken in the context of other measurements that provide similar or complementary information. The forecast impact of an observing system can be assessed by an experiment, in which observations or simulated observations are denied or added to observations from a standard data base. These experiments are known as Observing System Simulation Experiments (OSE) and Observing System Simulation Experiments (OSSE), have been performed for space-based sensors in the past (e.g., Atlas et al. 1985a, b). At the present time, a new series of OSSEs are needed to take into account the major recent advances in data assimilation methodology.

Accordingly, an OSSE for NPOESS is underway. This project is a collaboration between the National Environmental Satellite, Data and Information Service (NESDIS), the National Centers for Environmental Prediction Environmental Modeling Center (NCEP/EMC), the NASA/Goddard Data Assimilation office (DAO), and Simpson Weather Associates. In this experiment, a "nature run" was obtained from an ECMWF T213 spectral model 30-day forecast beginning on Feb 5th 1993. The first instruments to be tested in this OSSE are the Atmospheric InfraRed Sounder (AIRS), the Doppler Wind Lidar (DWL), the Cross track Infrared Sounder (CrIS), the Conically scanning Microwave Imager/Sounder (CMIS) and the Advanced Technology Microwave Sounder (ATMS). This paper gives a brief introduction of the AIRS radiance simulation for this OSSE.

2. The Atmospheric InfraRed Sounder

The AIRS is a high spectral resolution grating spectrometer with 2378 bands in the thermal infrared (3.7 - 15.4 µm) and 4 bands in the visible and near-IR (0.4 - 1.0 µm). The channels have been specifically selected to allow determination of atmospheric temperature with an accuracy of 1°C in layers 1 km thick, and humidity with an accuracy of 20% in layers 2 km thick in the troposphere. A ±49.5 degree swath centered on nadir is scanned in the cross-track direction every 2 seconds, followed by a rapid scan 2/3 second long calibration sequence. The calibration data consists of four independent cold space views, one view of an onboard blackbody, one view of an onboard spectral reference source, and one view of a photometric calibrator for the VIS/NIR photometer. Each scan line contains 90 IR fields of view (FOV), with a resolution of 13.5 km at nadir and 41km x 21.4 km at the scan extremes. The Visible/Near-Infrared spatial resolution is approximately 2.3 km at nadir. The AIRS, the Advanced Microwave Sounder (AMSU) and the Humidity Sounder Brazil (HSB) are onboard the Earth-Observing System Aqua spacecraft that was launched on May 4, 2002. It circles the globe 14.6 times per day in a 705 kilometer high polar orbit. AIRS will make measurements of the Earth's atmosphere and surface that should yield improved weather prediction and assist in observing changes in Earth's climate.

3. The Nature Run Data

For the OSSE, a long integration of an atmospheric forecast model is required to provide a "true atmosphere" for the experiment. This is called the "nature run". The observational data for existing instruments is simulated from the nature run. The nature run model needs to be sufficiently representative of the actual atmosphere but different from the model used for the data assimilation. For this project, the nature run was provided by the European Centre for Medium-Range Weather Forecasts (ECMWF). The description and evaluation of the nature run is given in Becker et al. (1996). For this OSSE a one month model run was made at resolution T213 and 31 levels starting from 5 February 1993.

4. Instrument forward models

Instrument forward models are required in order to generate simulated observations that would have the same characteristics as real observations. These instrument models (and statistics) are also used in the assimilation procedure in the same manner as they would be if real observations were being assimilated. The AIRS simulation package was originally developed at the Jet Propulsion Laboratory (Fishbein, et al., 2001). The code used in the simulation is developed with kCARTA (Strow, et al., 1998) for temperature sensitive channels, and OPTRAN (McMillin et al, 1995) for channel sensitive to water vapor. The fast forward model was developed based on the pre-launch spectral response functions.

5. Simulation of the AIRS data

5.1 *Geolocation Simulation*

The simulated observation must represent what the operation instrument would sample on orbit. A Geolocation Simulator is part of the simulation package. Simulated computations are performed by routines in the EOS Science Data Processing (ESDP) Toolkit Geolocation Package (Noerdlinger, 1995). Footprint position is evaluated from the AIRS viewing angle relative to the platform coordinate system and the time of the measurement. Time is nominally reported in seconds of secTAI93 (seconds Temps Atomique International, 1993 epoch). The positions of the instrument and sun relative to the footprint are also provided by the toolkit. Land fraction, surface elevation and their errors are integrated quantities evaluated by sampling a digital elevation model (DEM) over the AIRS FOV. Figure 1 is the diagrammatic sketch of the AIRS scan geometry.

5.2 *Surface Properties Simulation*

Surface Properties include skin temperature, surface pressure, land fraction, topography and infrared emissivities and reflectivity. Skin temperature and surface pressure are obtained from the nature run. Topographical data is provided with the ECMWF data. The emissivities and reflectivity are obtained by linear interpolation

in frequency with the emissivities and reflectivity at the frequency hinge points, which are the frequencies at which the properties are specified. The infrared surface emissivities and reflectivity at

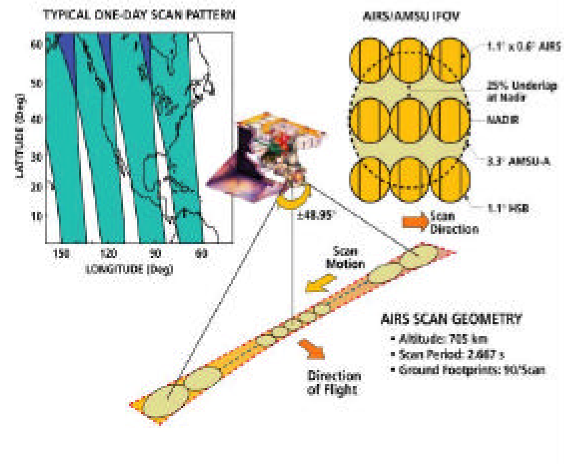

Figure 1 Observation Geolocation Simulation (from Morse, et al, 1999)

the hinge points are calculated based on surface material properties within each footprint. Currently 7 surface materials are used. These materials include sea water, 1 type of ice, 2 types of soils and 3 types of vegetation. All materials are assumed to be Lambertian reflectors in the infrared. The contribution of each material is determined by land fraction, the amount of vegetation and the types of vegetation defined by the International Geosphere Biosphere Program (IGBP) land use surface classification, and 3 or fewer random uniform normalized varieties. The IGBP land use class of each footprint is determined from a digital IGBP land use map. Vegetation and water amounts are determined from AVHRR NDVI imagery and the sampled DEM.

The emissivity for the ices and vegetation are interpolated from emissivities produced by the CERES group (Wilber,et al. 1999). Emissivities of the two soil types were obtained from the Infrared Handbook (Wolfe and Zissis, 1978) and a simplified model. Ocean emissivity is determined by a functional fit to the tabulated values of Masuda *et. al.*, 1988.

5.3 *Atmosphere Simulation*

The ECMWF nature run data, the UARS climatology and the Harvard tropospheric ozone climatology are adopted to define the atmosphere profile and cloud amount. Temperature, humidity and liquid water are provided at the 31 sigma levels of the nature run. UARS climatology data consists of monthly and zonally averaged means and variances of temperature and 18 other species including water vapor, ozone, methane and carbon monoxide. The UARS profiles are provided at 31 pressure levels. Harvard tropospheric ozone climatology contains monthly tropospheric ozone values in 13 pressure levels.

5.4 *Vertical Interpolation and Averaging*

All the atmosphere profiles used in the radiative transfer calculation are interpolated to 100 pressure levels. Input profiles from the nature run are first transfered from sigma coordinates to 31 pressure levels using tangent linear in log pressure (Program provided by Michiko Masutani, NCEP/EMC). All 31 pressure levels profile are interpolated to the 100 pressure levels profile using linear interpolation in the logarithm of pressure for input to the instrument forward model. Figure 2 shows an example of interpolation of the temperature profile from sigma levels to pressure levels.

5.5 *Air Temperature*

The air temperature profile is obtained from the nature run and the UARS temperature climatology. Two profiles are combined with a tie point at the top of nature run forecast pressure levels. Figure 3 shows two sample results, one at a high latitude and one at a low latitude.

5.6 *Water Vapor*

The nature run contains profiles of relative humidity on 31 sigma levels. The profiles are extrapolated upward using a power law.

$$X_{H2O}(p) = X_{H2O}(p^T)(p/p^T)^3 \qquad 1.0$$

where p^T is the pressure at the top of the nature run sigma levels. Figure 4 shows two sample profile compared to the U.S standard atmosphere. The U.S standard water vapor mixing ratio has a much lower lapse rate in the stratosphere than the other profiles. There are still some problem that need to be resolved in stratosphere water vapor profile specification.

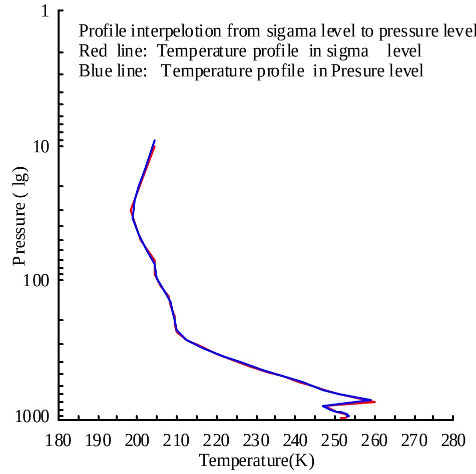

Figure 2: Interpolation between sigma levels and pressure levels.

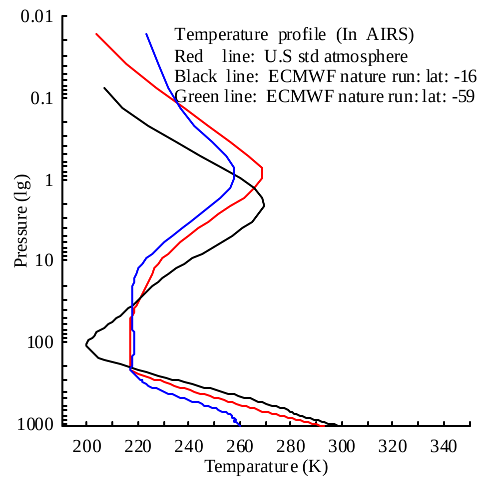

Figure 3. Example temperature profile

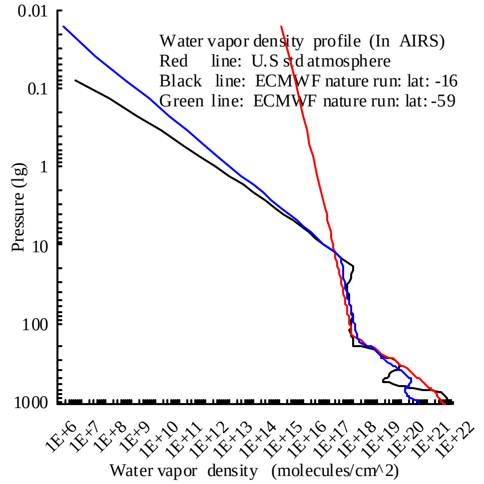

Figure 4: Example water vapor profile

5.7 ***Ozone***

There is no ozone data available in the nature run. Ozone data is provided by the UARS climatology for the upper stratosphere and mesosphere. The Harvard climatology provides a better estimate for the troposphere. The two data sources are combined at 100 hPa to obtain the ozone profile used in radiance simulation. Figure 5 illustrates an ozone profile.

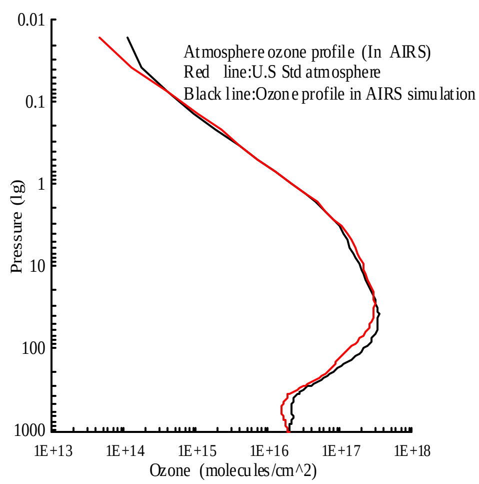

Figure 5: Ozone profile

5.8 ***Other constituents***

The atmosphere methane profile is provided by Gunson *et. al.*, (1990). Figure 6 illustrates the methane profile used in the AIRS radiance simulation. Atmospheric carbon monoxide profiles are taken from the U.S. standard atmosphere.

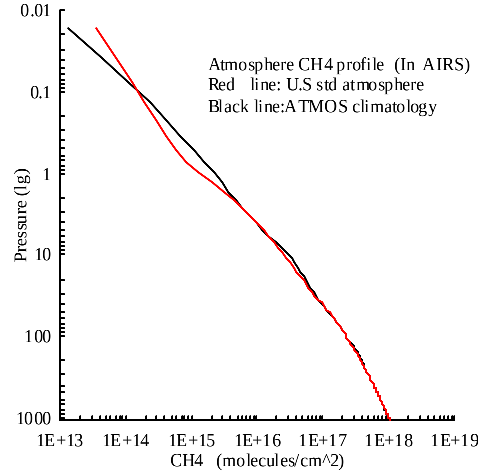

Figure 6: Methane profile

In atmosphere carbon dioxide profile specification, a model developed by S. Leroy is used (Fishbein et al, 2001). This model is based on measurements of CO_2 at ground stations and a realistic representation of meridianal and vertical transport. In the model, a positive secular trend, seasonal variability and a surface source whose rate is slow compared to transport are included.

5.9 ***Clouds***

In AIRS radiance simulation, the required cloud parameters are cloud top and bottom pressures, cloud liquid water, cloud fraction and cloud emissivities and reflectivity. The cloud liquid water and cloud fraction on each sigma level are provided by the nature run. The clouds are stratified into three groups, high, middle and low defined by cloud bottom pressures above 300 mb, 500 hPa to 300 hPa, and below 500 hPa respectively. All clouds are assumed to be opaque and Lambertian reflectors.

5.10 ***Simulation Results***

The simulated AIRS radiances are produced in BUFR (Binary Universal form for the Representation of meteorological data) format. Figure 7a-7f is the simulated brightness temperature for March 5^{th} 1993. Figure 7a is of AIRS channel 10, which is at 651.7 cm^{-1} in the center of 15um CO_2 absorption band. Figure 7b is of Channel 672 at 871.2 cm^{-1} which is an atmosphere windows channel. Channel 1092 at 1040 cm^{-1} is sensitive to ozone. Channel 1826 at 1586 cm^{-1} is in the water vapor absorption band. In the AIRS simulation, AMSU and HSB radiances are also produced at the same time. AMSU channel 1 and HSB channel 3 simulations are presented in Figures 7e and 7f .

6. Summary

The purpose of this work is to provide an OSSE with simulated AIRS radiance. The forecast impact of AIRS can be assessed by the OSSE, in which the simulation AIRS observation are denied or added to observing system. In this paper, the procedure of the simulation and the data set used were described, and some simulation results were presented.

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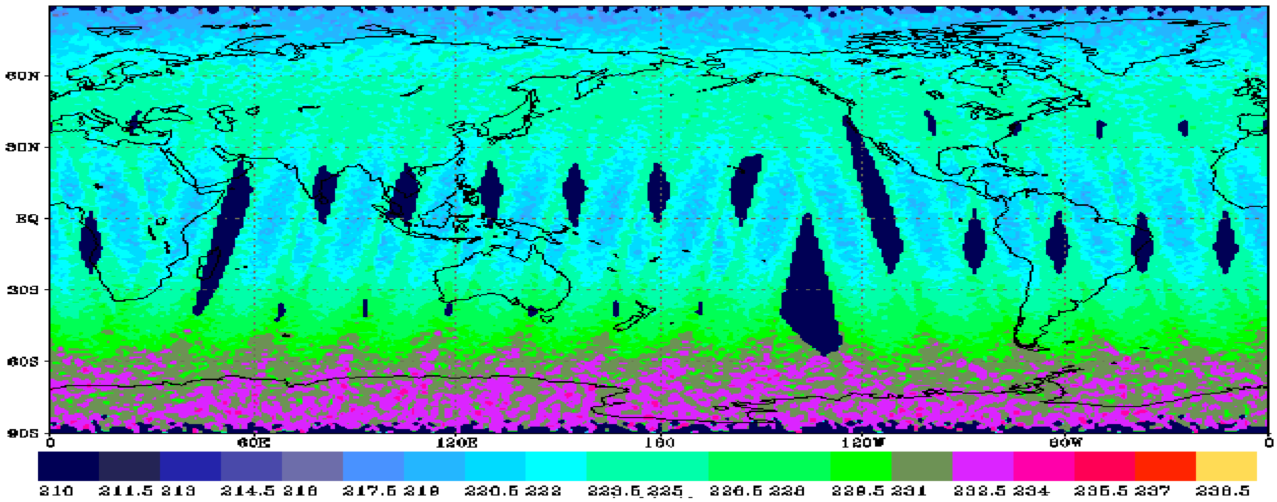

Figure 7a AIRS Brightness Temperature. Channel :10 (651.7 cm^{-1})

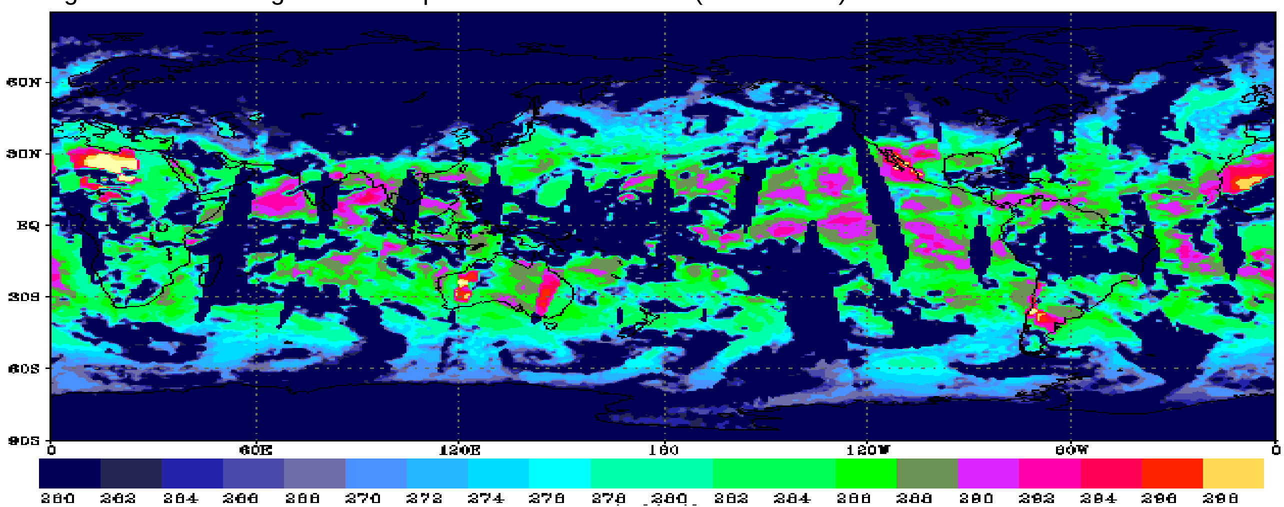

Figure 7b AIRS Brightness Temperature. Channel :672 (871.2010 cm^{-1}).

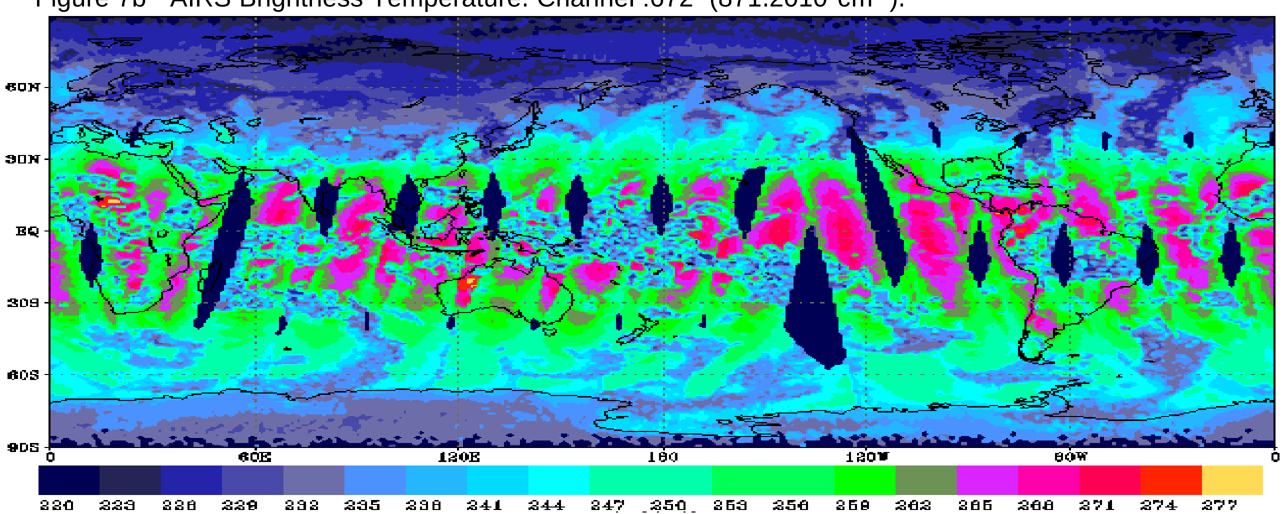

Figure 7.c AIRS Brightness Temperature. Channel :1092 (1040 cm^{-1}).

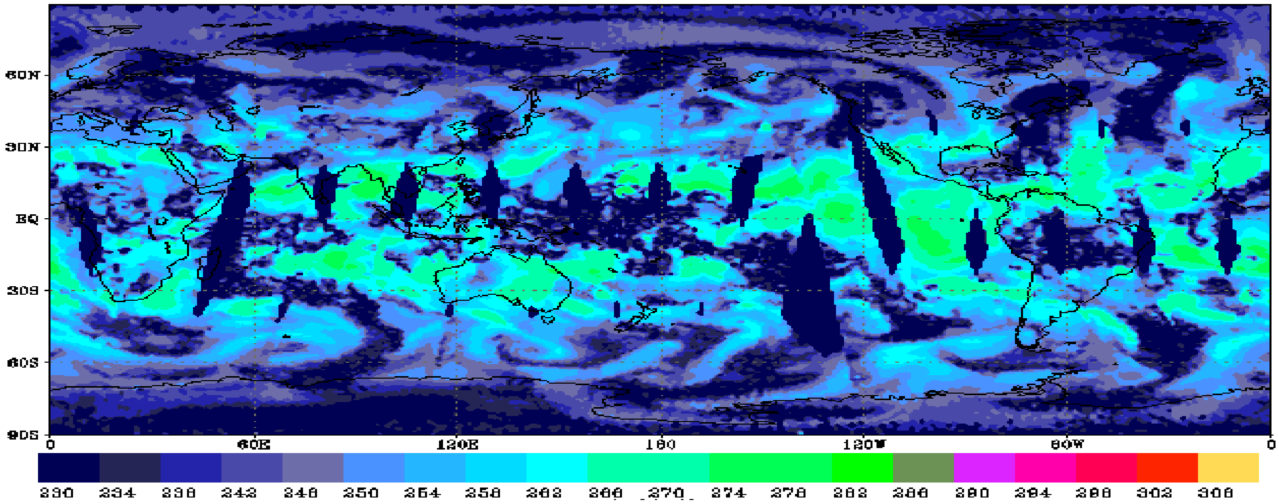

Figure 7d AIRS Brightness Temperature. Channel :1826 (1586.0649 cm^{-1}).

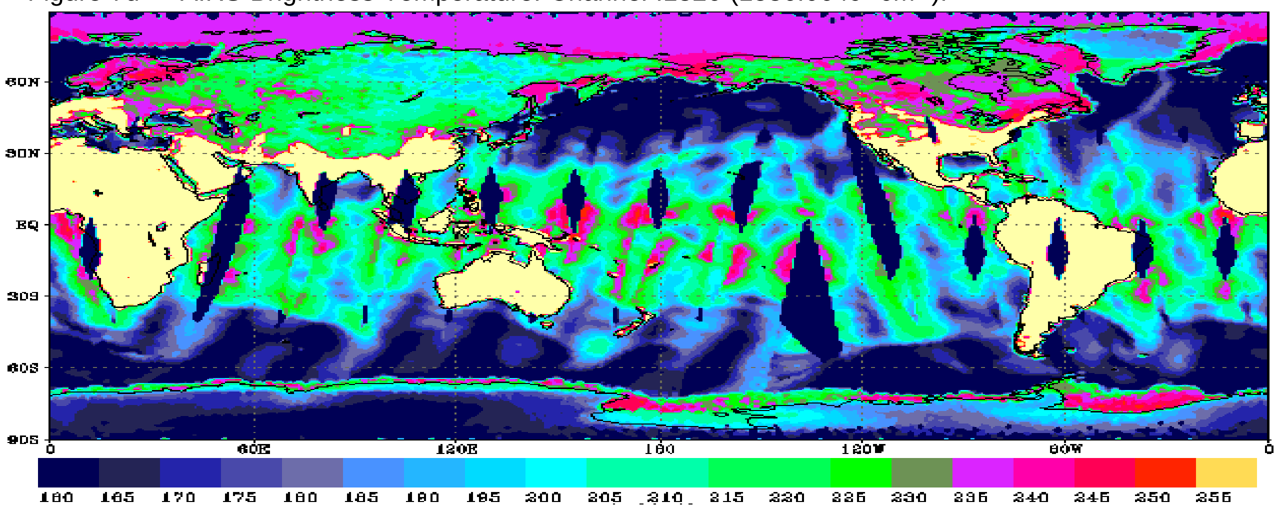

Figure 7e AMSU Brightness Temperature. Channel :1 (23.8 GHZ).

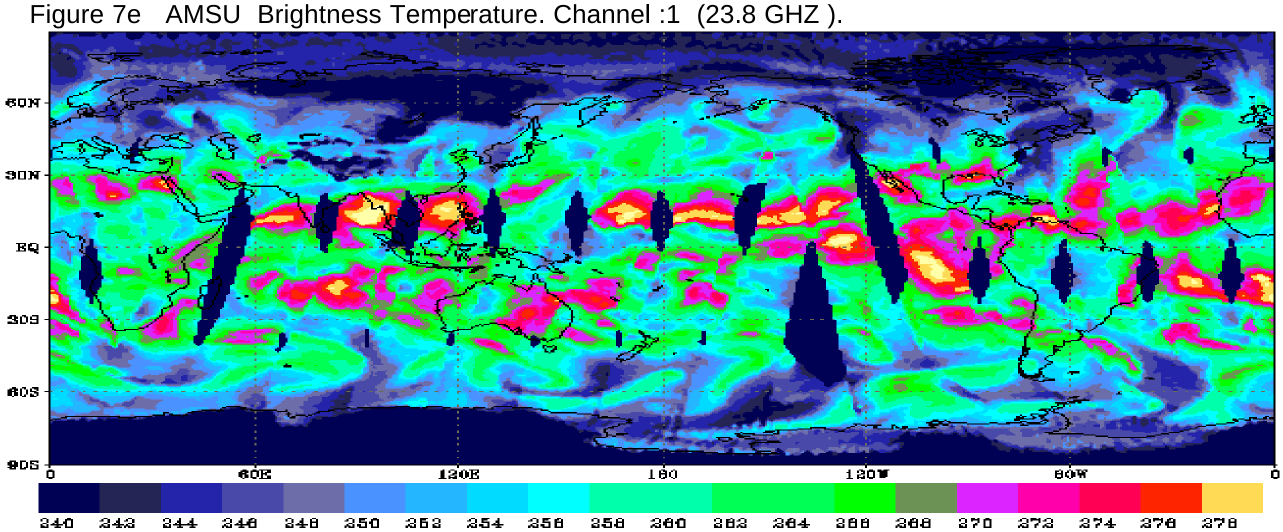

Figure 7f HSB Brightness Temperature. Channel :3 (184.31 GHZ).