Atmospheric Infrared Sounder/Advance Microwave Sounding Unit (AIRS/AMSU) Obs4MIPs V2

Relative Humidity Description

1. Intent of This Document

1a) This document is intended for users who wish to compare satellite derived observations with climate model outputs in the context of the CMIP especialy CMIP6, historical experiments. Users are not expected to be experts in satellite derived Earth system observational data. This document summarizes essential information needed for comparing this dataset to climate model outputs. References are provided at the end of this document to additional information for the expert user.

This NASA AIRS Obs4MIPs hur dataset is a new data set that was not provided in the AIRS Obs4MIPs V1 dataset as part of the experimental activity to increase the usability of NASA satellite observational data for the model and model analysis communities [1-3].

Dataset File Name (as it appears on the ESG):

hur_mon_AIRS-HUR-v2.0_BE_gn_200209-201609.nc

hurStderr_mon_AIRS-HUR-v2.0_BE_gn_200209-201609.nc

hurNobs_mon_AIRS-HUR-v2.0_BE_gn_200209-201609.nc

1b) Technical point of contact for this dataset:

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2. Data Field Description

CF variable name, units	hur, 1
Spatial resolution	The vertical resolution is determined by the CMIP6 mandatory levels. The longitude and latitude resolution is 1 degree by 1 degree.
Temporal resolution and extent	This data product is a regularly gridded, monthly averaged relative humidity measured by AIRS/AMSU between September 2002 and September 2016.
Coverage	Global

Note: The vertical pressure levels (plev) include all the CMIP6 mandatory levels from 1000 hPa to 10 hPa. However, we only provide the valid data up to 300 hPa and assign a missing value (1.e20) for levels above 300 hPa because AIRS measurements are not as reliable for levels above 300 hPa as other instruments such as Microwave Limb Sounder (MLS), which is specially designed for the accurate measurements of the atmospheric humidity profiles in the upper troposphere and lower stratosphere. The MLS measurements for levels above 300 hPa are provided as a separate dataset. It is therefore highly recommended for a user to combine the AIRS and MLS datasets to create a complete relative humidity profile from 1000 hPa to 10 hPa.

3. Data Origin

The data used to make this product was the AIRS Version 6 (V6) Level 3 (L3) standard monthly products in the "TqJoint" grids from the AIRS/AMSU combined retrievals obtained from the Goddard Earth Science (GES) DISC data access (https://disc.sci.gsfc.nasa.gov). On September 24, 2016, the AMSU instrument lost its power and stopped working. As a result, the AIRS/AMSU combined retrievals are available from September 2002 to September 2016 which is the time period of this data set.

The AIRS/AMSU instrument suite is carried on the NASA Aqua spacecraft, in a sun-synchronous orbit at 1:30 local time. The northward/southward moving observations are obtained during daytime/nighttime. (See Section 6 below for an Overview of the AIRS/AMSU instrument suite.) The AIRS/AMSU relative humidity is derived from infrared and microwave radiances measured from space, so is not an *in-situ* measurement. The infrared emission radiations emitted by different Earth scenes are remotely sensed by a spectrometer, and the microwave observations are obtained by a radiometer [4]. First, measurements are transformed into calibrated radiances for all footprints and all channels. Then, physical quantities such as the relative humidity are derived ('retrieved') from these geolocated radiance products [5, 6]. The retrieved physical quantities are then averaged over a month [7]. The data we obtained from the NASA GES DISC was at this last processing level. We then applied an additional processing step to adapt the data according to the CMIP6 model output format.

This data product is the monthly average of the AIRS/AMSU retrieved relative humidity profiles in the regularly gridded 1 degree by 1 degree latitude and longitude boxes. The AIRS/AMSU relative humidity profile is originally reported in 12 levels that are the subset of the CMIP6 mandatory levels and are all included in this data set.

The values described here are means of the daytime and nighttime values, provided there are enough observations in each category to make the values statistically significant. The minimum is 20 observations each, except for latitudes beyond +/- 80 degrees, where we relax the limits to compensate for a much lower number of observations. Since clouds have a significant effect on observed infrared radiances (see section 5.1 below), the retrieval process includes steps to retrieve the relative humidity from radiance in the presence of clouds. The horizontal resolution of each AIRS/AMSU scene is 45 km, and the instrument samples in a swath are 30 scenes wide (see Figure 3 below), yielding 324,000 scenes per day. However, the atmospheric relative humidity can be inferred in about 70% of these scenes, with the remainder affected by thick clouds or precipitation.

4. Validation

AIRS retrievals have been validated against a variety of in situ data (radiosondes, airborne sun photometer, ship-based measurements), other satellite measurements and model-generated data (fully coupled global ocean- atmosphere General Circulation Models, collocated model forecasts compared with radiosondes). The table below summarizes these findings and can be found in reference [8]. The uncertainty estimates are calculated based on the difference between AIRS retrievals and radiosonde observations and are valid in the troposphere below 300 hPa.

Geophysical Conditions Studied	RMS Requirement	Uncertainty Estimate
Subtropical ocean, 1000-300 hPa	N/A	15%
Polar land, 1000-300 hPa	N/A	15-25%

Table 1: Uncertainty estimate for different conditions.

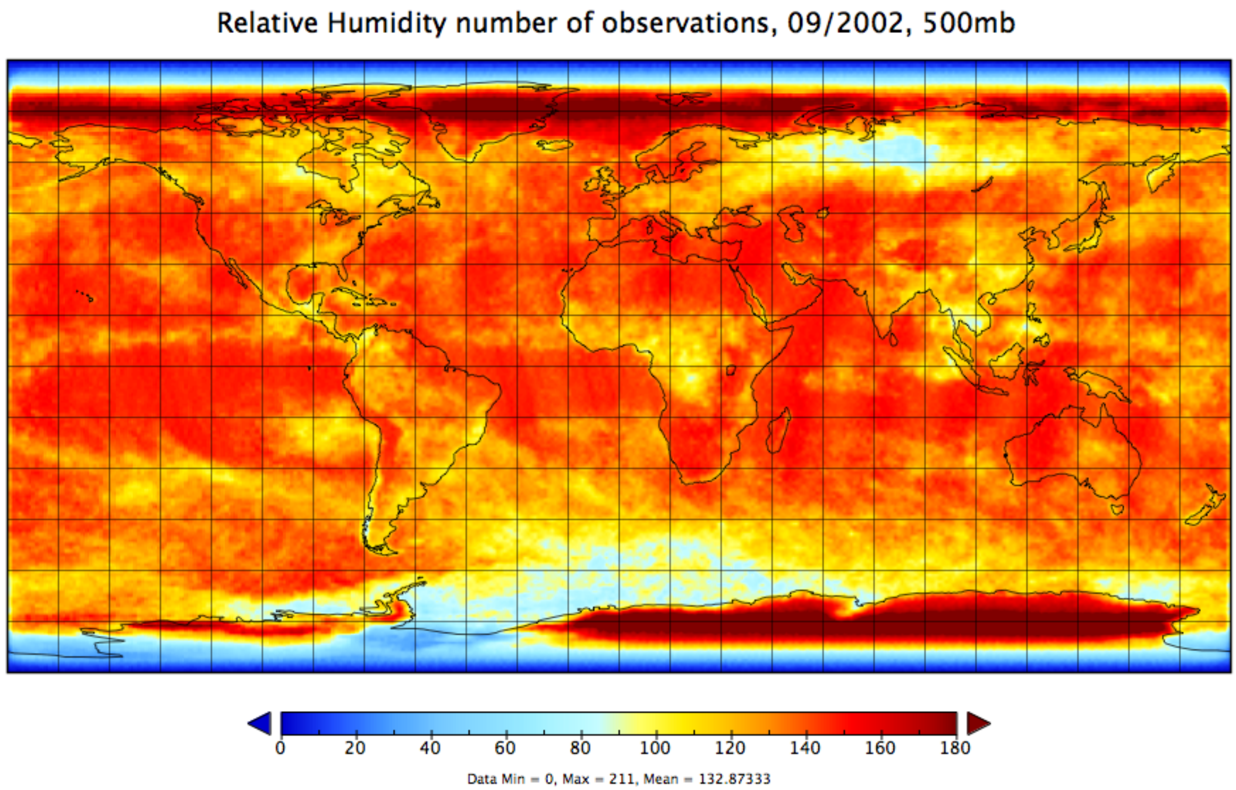

Figure 1: Relative Humidity sampling at 500 hPa for the month of September 2002.

5. Consideration for Model-Observation Comparisons

Because this data product is observational data, there are several aspects that distinguish this product from model outputs. In particular, there is a sampling issue caused by orbit, geophysical scene and retrieval algorithm for the AIRS data. See reference [3, 9-11] for more on the implication of the sampling issue in AIRS/AMSU retrievals. The user of this data product should be aware of and consider the sampling issue of the AIRS data in order to make judicious model-observation comparisons.

5.1 Cloud Induced Sampling

AIRS/AMSU coverage is limited by the presence of optically thick clouds because AIRS is an infrared instrument. The combination of infrared and microwave radiances allows retrieval of high-resolution relative humidity profiles for infrared cloud fraction (the product of emissivity and coverage) up to about 70% [5, 6]. This limitation of the infrared measurement makes the AIRS/AMSU observation scene, especially cloud, dependent and in turn, causes a spatially inhomogeneous sampling as illustrated on Figure 1. The AIRS sampling is low (~100) in cloudy sky regions, such as the Intertropical Convergence Zone (ITCZ) (e.g., the equatorial western

Pacific warm pool) and the midlatitude storm tracks (e.g., north Pacific, north Atlantic and 60°S latitude belt). The AIRS sampling is high (~160) in clear sky regions, such as subtropics and midlatitude land regions [11].

5.2 Asynoptic Time Sampling

Because Aqua satellite is in a sun-synchronous polar orbit, AIRS samples the atmosphere at two fixed local solar times at each location (e.g. 1:30 AM and 1:30 PM at the equator) and cannot fully resolve the diurnal cycle. In contrast, typical model monthly averaged outputs contain the averaged values over a time series of data within a fixed time interval (e.g. every 6 hours). For relative humidity over ocean and in the upper atmosphere with a small diurnal cycle, this difference is not likely a problem. However, for relative humidity in the boundary layer or over land regions strongly influenced by the diurnal cycle, this time sampling limitation should be considered.

5.3 Inhomogeneous Sampling

Because the monthly averaged value in this AIRS data product is an average over observational data available in a given grid cell (see Figure 1), the number of samples used for averaging varies with the geo-location of the cell. Because of the convergence of longitude lines near the poles, the time range of data collection broadens as one moves from the equator toward either pole, with the ranges in the polar regions including all times of day and night [11, 12]. So, there are more observations in the regions near the poles (~70° to ~85°) than the rest of the area.

5.5 Missing data

AIRS went into a safe mode at the end of October 2003 to avoid possible damage from a large solar flare. It did not resume data flow until mid-November 2003. Our preparation of this product for CMIP6 added a requirement of a minimum number of observations for each grid square from each of ascending and descending orbits. With only half of a month data, many grids cells do not meet these criteria for November 2003. The only significant outage since December 2003 was the safe mode event from January 9th to the 26th, 2010. Thus, the January 2010 product has about half the data of a full month. However, there should be no bias introduced in comparing the data from January 2010 to January of other years. In addition, September 2016 is also an incomplete month because of the power failure of AMSU on September 24, 2016.

6. Instrument Overview

Launched into Earth-orbit on May 4, 2002, Aqua is part of NASA's "A-train" satellite constellation (see Figure 2), a series of high-inclination, Sun-synchronous satellites in low Earth orbit designed to make long-term global observations of the land surface, biosphere, solid Earth, atmosphere, and oceans. The Aqua satellite is in a sun-synchronous orbit at an altitude of 705 km, with a track that takes it north across the equator at 1:30 P.M. (ascending node) and south across the equator at 1:30 A.M. (descending node). There are six instruments on Aqua: The Atmospheric Infrared Sounder (AIRS), the Advanced Microwave Sounding Unit (AMSU), the Humidity Sounding Unit (HSB), the Moderate Resolution Imaging Spectroradiometer (MODIS), the Clouds and the Earth's Radiant Energy System (CERES), and the Advanced Microwave Scanning Radiometer-EOS (AMSR-E) [12].

AIRS/AMSU observe the global water and energy cycles, climate variation and trends, and the response of the climate system to increased greenhouse gases. The term "sounder" in the instrument's name refers to the fact that temperature and water vapor are measured as a function of height.

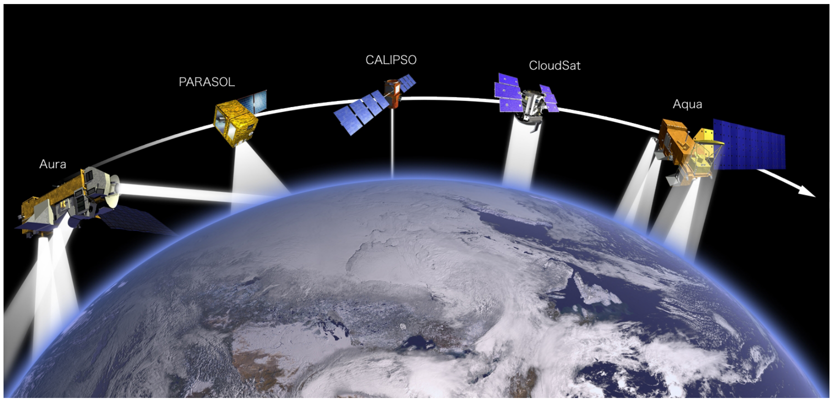

Figure 2: NASA's A-train group of Earth observing satellites.

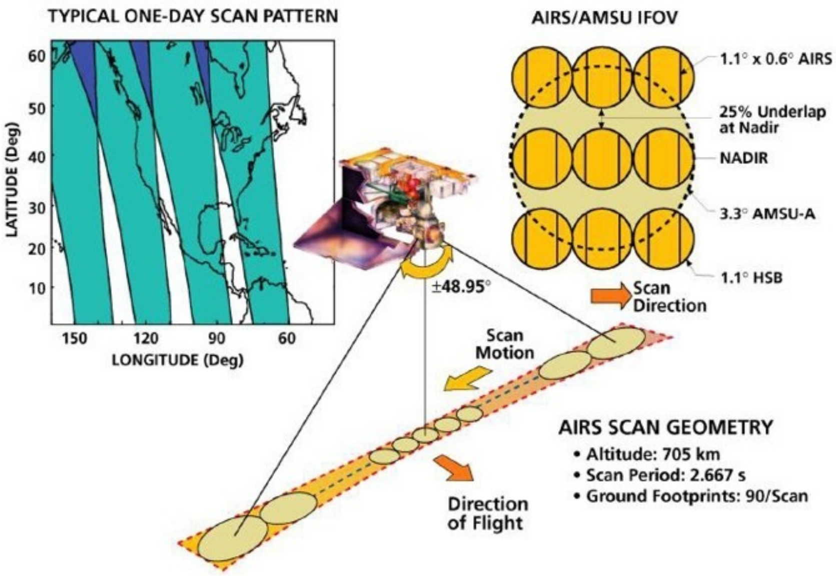

Figure 3: AIRS scanning and coverage geometry.

AIRS coverage is pole-to-pole and covers the globe two times a day. Because the swaths (scanning sweeps) do not overlap at low latitudes, some points near the equator are missed. However, these points are eventually scanned within 2-3 days. As depicted on Figure 3, AIRS scans laterally with respect to its direction of flight. With the scanning angle being 49.5 degree about nadir, the swath width is 1650 km. One orbit period is 98.8 minutes.

7. References

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11. Hearty, T.J., et al., *Estimating sampling biases and measurement uncertainties of AIRS/AMSU-A temperature and water vapor observations using MERRA reanalysis.* Journal of Geophysical Research-Atmospheres, 2014. **119**(6): p. 2725-2741.
12. Parkinson, C.L., *Aqua: An earth-observing satellite mission to examine water and other climate variables.* IEEE Transactions on Geoscience and Remote Sensing, 2003. **41**(2): p. 173-183.

8. Revision History

Rev 0 – 20 Mar 2018 This is a new document.