Atmospheric Infrared Sounder (AIRS) Obs4MIPs V2.1 Specific 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 CMIP6 historical experiments. The 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 users.

This NASA Atmospheric Infrared Sounder (AIRS) Obs4MIPs V2.1 specific humidity (hus) dataset [1] is a sampling-bias-corrected version of the AIRS Obs4MIPs V2.0 specific humidity dataset [2] provided as part of the experimental activity to increase the usability of NASA satellite observational data for the model and model analysis communities. The major difference between the AIRS Obs4MIPs V2.0 and V2.1 datasets is that the sampling biases of the V2.0 data have been estimated based on the ERA5 reanalysis and removed in the V2.1 data.

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

hus_mon_AIRS-2-1_BE_gn_200209-201609.nc

husStderr_mon_AIRS_Obs4MIPs_V2.1_200209-201609.nc

husNobs_mon_AIRS_Obs4MIPs_V2.1_200209-201609.nc

1b) Technical point of contact for this dataset:

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1c) Users of this dataset should reference the following papers:

Tian, B., & Hearty, T. (2020), Estimating and removing the sampling biases of the AIRS Obs4MIPs V2 data, *Earth Space Sci.*, https://doi.org/10.1029/2020EA001438.

Tian, B., Fetzer, E. , & Manning, E. (2019), The Atmospheric Infrared Sounder Obs4MIPs version 2 data set, *Earth Space Sci.*, *6*(2), 324-333, https://doi.org/doi:10.1029/2018EA000508.

2. Data Field Description

CF variable name, units	hus, kg/kg
Spatial resolution	The vertical resolution is determined by the CMIP6 mandatory levels. The horizontal resolution is 1-degree longitude by 1-degree latitude.
Temporal resolution and extent	This data product is a regularly gridded, monthly averaged specific humidity measured by AIRS with its sampling bias removed 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 to be consistent with the AIRS Obs4MIPs V2.0 specific humidity dataset.

3. Data Origin and Processing Methodology

The main data used to make this product are the AIRS Obs4MIPs V2.0 data as described in the references [2, 3] and their sampling bias estimates based on the fifth generation of ECMWF atmospheric reanalyses (ERA5) as described in the reference [1].

The AIRS Obs4MIPs V2.0 data are produced based on the AIRS Version 6 (V6) Level 3 (L3) standard monthly products in the "TqJoint" grids from the AIRS/Advanced Microwave Sounding Unit (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 the AIRS Obs4MIPs V2.0 dataset. Please refer to the references [2, 3] for more details of the AIRS Obs4MIPs V2.0 dataset.

A sampling difference exists between the climate model outputs and the AIRS Ob4MIPs V2.0 data because the former is sampled on regular spatial and temporal grids while the latter is not [2]. The AIRS instrument on the Aqua spacecraft is in a Sun-synchronous low Earth orbit with a limited swath and a limited sampling of the diurnal cycle and synoptic events. Moreover, since the AIRS is an infrared instrument, the AIRS sampling is influenced by clouds, aerosols, coastlines, and other factors that affect its ability to perform successful physical retrievals. Also, for certain months AIRS can have amounts of missing data because of Aqua spacecraft maneuvers. For example, the AIRS instrument was placed in a safe mode for parts of October and November 2003 to avoid possible damages from a solar flare. It also suffered an anomaly in January 2010, that involuntarily placed it in a safe mode for most of that month. All of these sampling differences between the climate model outputs and AIRS data can affect the comparisons between the AIRS Obs4MIPs V2.0 data and climate model outputs [2, 4-7].

The specific humidity from the fifth generation of ECMWF atmospheric reanalyses (ERA5) gridded reanalysis product [8], the quality flags and geolocation from the AIRS V6 Level 2 (L2) standard products [9], and the methodology described in Hearty, Savtchenko [5] were used to estimate the sampling biases of the AIRS Obs4MIPs V2.0 specific humidity data. The downloaded HRES (High Resolution) sub-daily (0.25-degree, hourly) ERA5 specific humidity data were first used to simulate the AIRS V6 L2 observations using the AIRS V6 L2 time, geolocation and quality control information. Each AIRS L2 specific humidity profile was matched with the nearest hourly ERA5 reanalysis specific humidity profile in time and space. Only the data that passed the quality control criteria used for the AIRS Obs4MIPs V2.0 specific humidity were kept and gridded to match the AIRS Obs4MIPs V2.0 specific humidity product to conform to the CMIP6 model output format. The difference between this monthly mean ERA5 reanalysis data sampled like the AIRS Obs4MIPs V2.0 data product and the monthly mean ERA5 reanalysis data sampled over all their time steps and spatial grids is an estimate of the sampling biases of the AIRS Obs4MIPs V2.0 data. The sampling biases of the AIRS Obs4MIPs V2.0 data were also estimated based on the Modern-

Era Retrospective Analysis for Research and Application (MERRA), Version 2 (MERRA-2) reanalysis [10] as a validation.

Last, the sampling-bias-corrected AIRS Obs4MIPs V2.1 data were produced by removing the sampling biases of the AIRS Obs4MIPs V2.0 data estimated based on ERA5 from the AIRS Obs4MIPs V2.0 data. Please refer to the reference [1] for more details.

4. Validation

AIRS retrievals have been validated against a variety of in situ data (radiosondes, ship-based measurements), other remote measurements, from other satellites, and model-generated data. The table below summarizes these findings and can be found in reference [11]. The uncertainty estimates are calculated based on the difference between AIRS retrievals and radiosonde observations and are valid in the troposphere, between the boundary layer and 300 hPa.

Geophysical Conditions Studied	**Uncertainty Estimate**
Non-polar ocean, 1000-300 hPa	15-25%
Non-polar land, 850-300 hPa	15-25%
Non-polar land, 1000-850 hPa	30-40%
Polar, 1000-300 hPa	30-40%

Table 1: Uncertainty estimate for different conditions.

5. Consideration for Model-Observation Comparisons

In this data product, we have removed the sampling biases of the AIRS data estimated based on the ERA5 reanalysis from the AIRS data product. Thus, the users of this data product do not need to worry about the sampling difference between climate model outputs and the AIRS data. However, the users of this data product still should consider the measurement errors of the AIRS data when they compare this data product to climate model outputs.

6. Instrument Overview

Launched into Earth-orbit on May 4, 2002, Aqua is part of NASA's "A-train" satellite constellation (see Figure 1), 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.

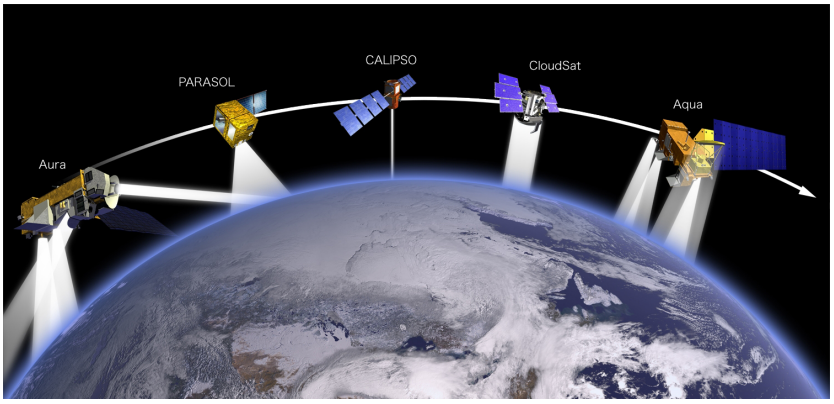

Figure 1: NASA's A-train group of Earth observing satellites.

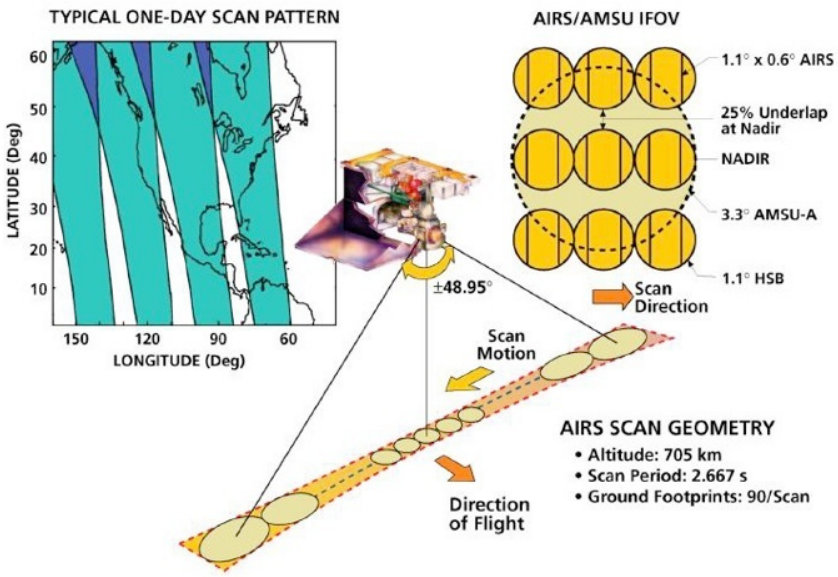

Figure 2: AIRS scanning and coverage geometry.

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 2, 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

1. Tian, B. and T.J. Hearty, *Estimating and removing the sampling biases of the AIRS Obs4MIPs V2 data.* Earth and Space Science, 2020: p. submitted.

2. Tian, B., E.J. Fetzer, and E.M. Manning, *The Atmospheric Infrared Sounder Obs4MIPs Version 2 Data Set.* Earth and Space Science, 2019. **6**(2): p. 324-333.
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4. Tian, B., et al., *Evaluating CMIP5 models using AIRS tropospheric air temperature and specific humidity climatology.* Journal of Geophysical Research-Atmospheres, 2013. **118**(1): p. 114-134.
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8. Revision History

Rev 0 – 20 Aug 2020 This is a new document.