Microwave Limb Sounder (MLS)
Temperature Data Description

1. Intent of This Document

1a) This document is intended for users who wish to compare satellite derived observations with climate model output in the context of the CMIP5/IPCC 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 output. References to additional information for the expert user are provided at the end of this document.

This NASA dataset is provided as part of an experimental activity to increase the usability of NASA satellite observational data for the model and model analysis communities. This is not a standard NASA satellite instrument product. It may have been reprocessed, reformatted, or created solely for comparisons with the CMIP5 model. Community feedback to improve and validate the dataset for modeling usage is appreciated. Email comments to HQ-CLIMATE-OBS@mail.nasa.gov.

Dataset File Names (as they appear on the ESG):

Primary dataset:

ta_MLS_L3_v03-3_200408-201012.nc

Supporting datasets:

taNobs_MLS_L3_v03-3_200408-201012.nc

taStderr_MLS_L3_v03-3_200408-201012.nc

1b) Technical point of contact for this dataset:

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2. Data Field

There are 3 datasets provided for MLS air temperature in three separate files as noted in section 1a. The variable ta is the binned observed MLS air temperature. The variable taNobs details the number of satellite observations in each bin. The variable taStderr is the standard error within each bin.

CF variable name, units:	ta, kelvin.
Spatial resolution	The vertical resolution is determined by the CMIP5 mandatory levels. Additionally, we provide 6 optional levels (7 hPa, 5 hPa, 3 hPa, 2 hPa, 1 hPa, and 0.4 hPa). The horizontal resolution is 2 degrees of latitude by 5 degrees of longitude.
Temporal resolution and extent:	The product is formed with monthly averages covering the

	period from 2004 to 2011.
Coverage:	Global.

Note: While we provide data in the entire pressure range specified by CMIP5, the data at pressures larger than or equal to 300 hPa are not provided for scientific use as they represent purely *a priori* information. It is recommended to use AIRS temperature data for those pressures (greater than or equal to 300 hPa).

3. Data Origin

These date are derived from the standard MLS retrieved data (version v3.3) that can be obtained from the Goddard Earth Science (GES) Data and Information Services Center (DISC) data access [1].

The MLS air temperature is remotely sensed from observations of millimeter and sub-millimeter-wavelength thermal emission from the Earth's limb using two passive microwave receivers. The temperature is retrieved from MLS bands near O2 spectral lines at 118 GHz and 239 GHz that are measured with MLS radiometers R1A/B and R3, respectively. The 239-GHz line is the primary source of temperature information in the troposphere, while the 118-GHz line is the primary source of temperature in the stratosphere and above [2]. The retrieved temperature values are taken from the standard MLS data product (Level 2 Temperature Version 2.2), are filtered according to the documented quality screening rules, are binned in a regular grid with a 2 degree by 5 degree box, and are monthly averaged, leading to this data product. For each grid point, the temperature profile is linearly interpolated to the CMIP5 specified pressure levels using the logarithmic pressure as the interpolation axis.

It should be noted that the MLS temperature retrieval uses GEOS-5.2 data assimilation system temperature as its *a priori*. The precision of this *a priori* is deliberately overestimated so that it provides only a loose constraint on MLS temperature, nominally providing less than 1 percent of the information at all retrieved levels. However, due to the way in which the *a priori* is used in constraining the smoothness of MLS retrieved profiles, in some cases the influence of the *a priori* may approach 10 percent. Thus MLS temperature cannot be considered to be completely independent of GEOS-5.2 temperature.

4. Validation

The retrieved temperature values are validated with internal, systematic error estimations and comparisons with other available data products. Table 1 summarizes measurement precision and systematic biases of the retrieved temperature value at each pressure level [3]. The precision in Table 1 estimates the uncertainty in the retrieved profiles due to noise on the MLS radiance observations (reduced by the averaging implicit in these monthly means) [3,4]. The bias in Table 1 reflects systematic errors arising from instrumental effects such as imperfect radiometric calibration or field of view characterization, as well as from errors in laboratory spectroscopic data and retrieval formulation and implementation [3]. MLS temperature has persistent, vertically oscillating biases, in the troposphere and stratosphere, which is believed to be due to gain compression in intermediate-frequency amplifiers [2].

Table 1: Spatial resolution, retrieval precision, and systematic bias of MLS temperature measurements

Pressure [hPa]	Resolution Vertical x Horizontal [km]	Temperature Precision [K]	Temperature Bias [K]
0.4	8.3 x 170	0.25	+2.8 ± 2
1	7.9 x 165	0.25	+1.0 ± 2
2	7.1 x 165	0.23	+1.5 ± 2
3	6.3 x 165	0.20	+1.9 ± 2
5	5.7 x 165	0.19	+0.5 ± 2
7	5.1 x 165	0.17	+0.9 ± 2
10	4.3 x 165	0.15	0.0 ± 2
20	3.8 x 165	0.15	–2.4 ± 2
30	3.5 x 165	0.15	+0.5 ± 2
50	3.7 x 165	0.19	–0.5 ± 2
70	4.2 x 165	0.20	0.0 ± 2
100	5.2 x 165	0.20	+2.0 ± 2
150	5.1 x 165	0.22	+0.5 ± 3
200	5.0 x 169	0.24	–1.0 ± 4
250	5.1 x 170	0.25	+1.0 ± 4
300	5.3 x 170	0.25	+0.2 ± 2
>300	Not reliable	Not reliable	Not reliable

5. Consideration for Model-Observation Comparisons

If judicious model-observation comparisons are to be made, users should be aware of several aspects that distinguish these data products from model outputs.

5.1 Time Sampling Bias

Because MLS is on board the Aura satellite in a sun-synchronous polar orbit, it samples at the two fixed local solar times at each location (e.g. 1:45 AM and 1:45 PM at the equator) and does not resolve the diurnal cycle [5]. MLS observations at a given latitude on either the ascending (north-going) or descending (south-going) portions of the orbit have approximately (to within several minutes) the same local solar time throughout the mission, as indicated in Fig. 1 [6]. In contrast, typical model monthly averaged outputs contain the

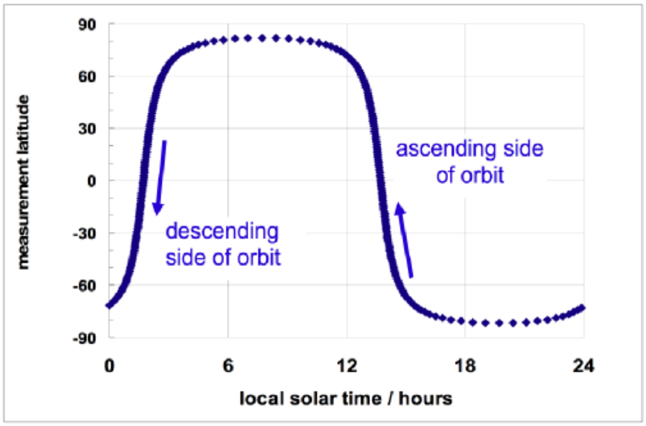

Figure 1: Local solar time when MLS observes a given latitude on the Aura sun-synchronous polar orbit.

averaged values over every point in a time series of data with a fixed time interval (e.g. every 6 hours). For many constituents in the upper troposphere, this difference is not likely to be an issue. However, for regions influenced by deep convection and its modulation of the diurnal cycle (e.g. tropical land masses), this time sampling bias should be considered.

5.2 Inhomogeneous Sampling

Because the monthly averaged value in this MLS data product is an average over observational data available in a given lat-lon box, the number of samples used for averaging varies with the location of the box. Due to the geometry of the Aura sun-synchronous polar orbit, there are no observations above latitude 82° and there are more observations near the boundary (70°-82°) than the rest of the area. Figure 2 shows the distribution of the typical number of samples used for the monthly averaged product.

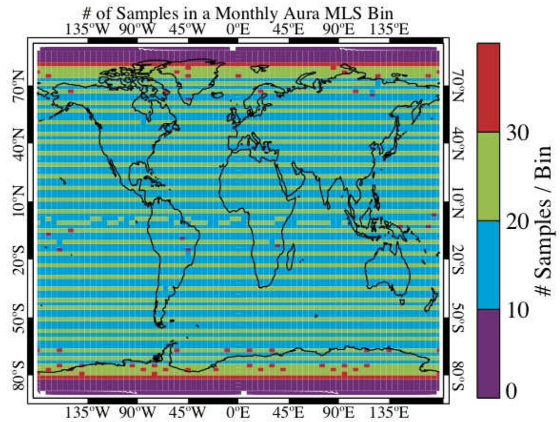

Figure 2: Distribution of the typical number of samples used for the monthly averaged MLS data.

5.3 Anisotropic and Inhomogeneous Resolution

While a typical model output has a fixed horizontal resolution, MLS observations have anisotropic and inhomogeneous resolutions in a horizontal direction due to its viewing geometry and radiometric response. MLS horizontal resolutions for temperature measurements are ~7 km across the orbit track and ~200 km along the orbit track (see Table 1 for details). Therefore, MLS observations have elongated shape ‘footprints’. The sample data used in the monthly averaging are the collection of observations whose footprint centers are located in a given grid box. This means that the averaged value for a given grid box can be influenced by the state of the atmosphere in neighboring grid boxes, due to the mismatch between the gridded box resolution and the MLS native observation resolution.

6. Instrument Overview

The Earth Observing System (EOS) Microwave Limb Sounder (MLS) is a satellite instrument that provides observations of atmospheric composition, temperature, moisture, and cloud ice profiles in the upper troposphere and lower stratosphere. The MLS measurements are designed to (1) track stability of the stratospheric temperature layer, (2) help improve predictions of climate change and variability, and (3) help improve understanding of global air quality.

MLS is one of four instruments on the NASA's EOS Aura satellite, launched on July 15th 2004. Aura is in a near-polar 705 km altitude sun-synchronous orbit. As Earth rotates underneath it, the Aura orbit stays fixed relative to the sun and gives daily global coverage at a fixed local times for each latitude on the ascending and descending side of the orbit, with observations in the tropics and mid-latitudes made around 1:45am (descending) and 1:45pm (ascending), and ~13 orbits per day. Aura is part of NASA's A-train group of Earth observing satellites. These satellites fly in formation with the different satellites making measurements within a short time of each other as shown in Fig. 3.

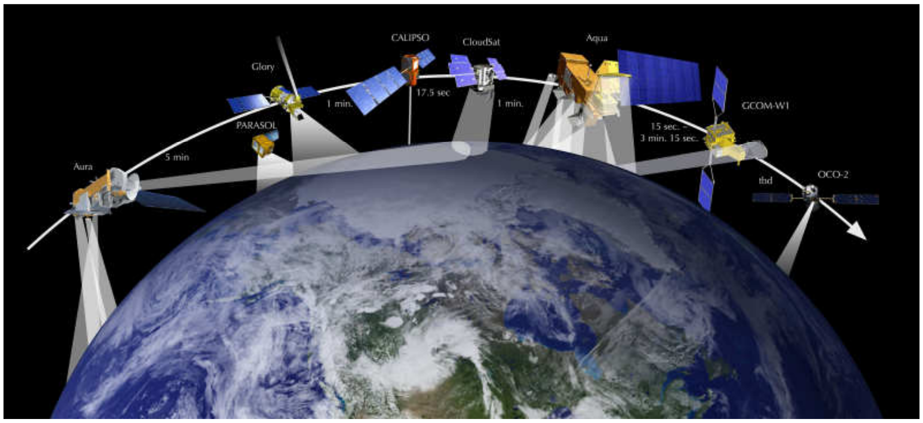

Figure 3: NASA's A-train group of Earth observing satellites.

MLS obtains remote measurements of atmospheric parameter profiles by measuring millimeter and sub-millimeter-wavelength thermal emission with seven microwave receivers using a limb viewing geometry, MLS views forward along the Aura satellite flight direction and scanning its view from the ground to ~90 km altitude. The limb viewing geometry of MLS is shown in Fig. 4. Thanks to the limb viewing geometry, MLS provides the relatively good vertical resolution for composition observations in the upper troposphere and lower stratosphere, compared to nadir sounders. At present, the MLS record is more than 7 years long, the instrument remains in good health and we expect several years of continued operation.

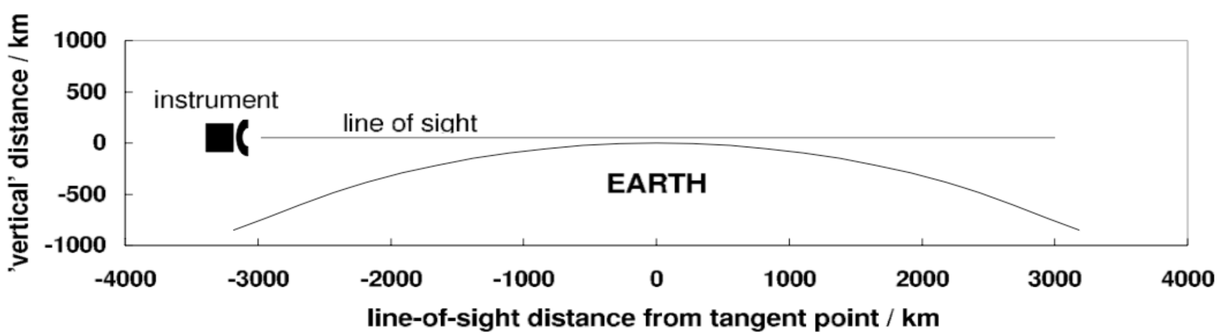

Figure 4: MLS viewing geometry. The geometry is drawn to scale with an instrument in 705 km altitude orbit of the Aura satellite and the line of sight having 50 km tangent height. The orbit plane for EOS MLS is the plane of the paper [7]

7. References

[1] http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/MLS/index.shtml

[2] EOS Aura Microwave Limb Sounder Version 2.2 Level 2 data quality and description document, v2-2_data_quality_document.pdf. See Table 3.12

[3] M. J. Schwartz *et al.*, "Validation of the Aura Microwave Limb Sounder temperature and geopotential height measurements", JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 113, D15S11, doi:10.1029/2007JD008783, 2008

[4] The monthly averaged data described in this document have the same accuracy as the MLS retrieval but the precision is improved by the factor of $1/\sqrt{N}$ due to the averaging over independent samples, where N is the number of the samples. As shown in Fig. 2, the number of samples N fluctuates around 16 (with a standard deviation of 5.4) between 72 degrees of latitude North and 72 degrees of latitude South. We used the data available in [2] to generate Table 1. We interpolated between two levels when a particular pressure level and its associated data were not available and we updated the precision using the number of samples involved in the monthly averaging.

[5] EOS MLS Level 3 Algorithm Theoretical Basis, eos_l3_atbd.pdf, p9, p30.

[6] An Overview of the EOS MLS Experiment, eos_overview_atbd.pdf, p38.

[7] An Overview of the EOS MLS Experiment, eos_overview_atbd.pdf, p6.

8. Revision History

Rev 0 - 1/13/12 -