A preliminary comparison of Aura MLS upper tropospheric humidity measurements with AIRS

W. G. Read[1], H. C. Pumphrey[2], D. L. Wu[1], J. H. Jiang[1], N. J. Livesey[1], J. W. Waters[1], E. J. Fetzer[1], and E. T. Olsen[1]
1. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Ca. bill@mls.jpl.nasa.gov
2. Institute of Atmospheric and Environmental Science, University of Edinburgh, UK.

ABSTRACT

MLS on the Aura spacecraft was launched 15 July 2004 and began science operations on 12 August 2004. The Aura satellite flies 15 minutes behind the Aqua satellite which contains the AIRS instrument. The close proximity of these measurements provides a continuous stream of near coincident upper tropospheric humidity profile measurements for validation and comparison. We will show some preliminary results from these comparisons for the first three months of Aura MLS humidity data.

DATASETS AND METHODS

MLS is a microwave limb scanning instrument on-board the EOS Aura satellite. It measures water vapor by observing the intensity and lineshape change of the 183 GHz water line as the instrument's field-of-view (FOV) is scanned across the Earth's limb. MLS makes vertically resolved water vapor measurements from 316 to 0.02 hPa. The profile in the stratosphere and troposphere is sampled every 2.7 km and in the mesosphere every 5.4 km. The vertical resolution based on the full width at half maximum of the averaging kernel is only slightly worse than the profile grid point resolution. The estimated precision is usually better than 5% in the upper troposphere and lower stratosphere, degrading to 10% at 316 hPa. MLS takes its measurements along the satellite orbit track with profiles separated every 1.5° degrees giving a daily total of 3496 profiles. The horizontal resolution is 160×8 km^2 (along $\times$ cross track). The latitude coverage is from 82°S–82°N. The MLS retrieval uses a novel two dimensional inversion technique [1]. In this poster we concern ourselves with the three MLS tropospheric levels: 316, 215 and 147 hPa.

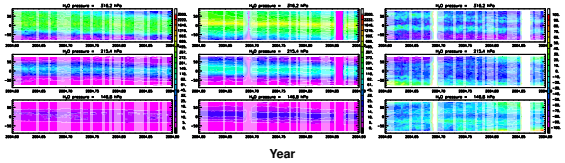
AIRS is a nadir-looking side-to-side scanning radiometer that spectrally resolves the 6.3 μm H_2O band. It has a horizontal resolution of 13.5×13.5 km^2 at nadir and provides 324000 profiles per day. AIRS produces vertically resolved humidity profiles on the 28 standard assimilation levels. In this study we are only interested in the upper tropospheric levels: 400, 300, 250, 200, and 150 hPa. The AIRS humidity product is 20% accurate in the upper troposphere.

Unless otherwise specified, the AIRS data used here is from the Goddard Earth Sciences DAAC version 3.1 level 2 humidity product on standard pressure levels. The MLS data is version 01.46. AIRS on-board the Aqua and MLS on-board the Aura satellites are part of the EOS A-train where both instruments observe the same air mass separated by approximately 8 minutes. For the comparisons done here the AIRS data is either gridded onto a $1° \times 1°$ longitude-latitude grid or the nearest coincident profile measured within 2-12 minutes later by MLS. The AIRS data was quality screened by only using profiles having `retrieval_type` = 0 (best quality). The MLS profiles are screened by the sign of its uncertainty which is negative if there is insufficient information available. Some MLS profiles can be contaminated by scattering emissions from thick clouds. In this comparison we have not screened the data for this.

The AIRS data have been converted to the MLS profile height breakpoints by fitting the stepwise AIRS profile representation with the MLS linear breakpoint representation with a least squares fit.

ZONAL TIME SERIES COMPARISON

Figure 1 shows the MLS, AIRS and their % difference time series from 3 August 2004 (first day of MLS science operations) to 23 November 2004. Data across unprocessed days have been linearly interpolated from days with data but are shown in faded colors. Currently the MLS SIPS does not have adequate processing capability to process all level 1 data to level 2. The days shown for AIRS are those where there is a corresponding MLS level 2 retrieval. AIRS has level 2 data for all of the days covered above.



Year

Figure 1, Zonal time series for MLS (left), AIRS(center), and the % difference (100(MLS-AIRS/AIRS) from 3 August–23 November 2004 at 316, 215 and 147 hPa. Faded colors are interpolated data for unprocessed days. Units are ppmv or %.

The time series shows overall qualitative agreement with both data sets showing a tropical moist humidity band tracking the sun southward as the northern hemisphere enters winter. Quantitatively, it is clear that MLS is 20–50% drier than AIRS. Perhaps of interest is that MLS shows stratospheric-like humidities ($<$10 ppmv) at 215 hPa at high northern latitudes at all times shown whereas AIRS sees tropospheric-like concentrations at high northern latitudes until October.

SCATTER PLOT COMPARISON

The left hand side of Figure 2 shows a scatter plot comparison among all the coincident MLS and AIRS profiles taken on 29 November 2004. Other days are similar. Color of the scatter point is the measurement latitude with blue being high southern latitudes, yellow and green are low latitudes and reds are high northern latitudes. Correlation with smallest bias occurs when the atmosphere is moist over the tropics. The correlation tends to be very poor when MLS measures concentrations less than 10 ppmv or when MLS sees dry stratospheric air. It is also apparent especially at 315 hPa that MLS occasionally has very dry values. This is sometimes a symptom of cloud contamination but screening for clouds does not catch all the occurrences.

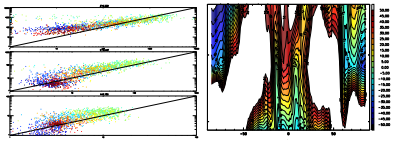


Figure 2, Scatter plot (left) between MLS (x-axis) and AIRS (y-axis) at 316 (top), 215 (middle) and 147 (bottom). Point color indicates latitude with blue being high southern, yellow-green being low, and red being high northern latitudes. A 1:1 line is plotted. Percent difference (right panel) in the zonal mean (100 (AIRS - MLS)/MLS) between MLS and AIRS. The y axis ranges from 316 to 147 hPa. Units are %.

The right-hand side of Figure 2 shows the % difference between MLS and AIRS (100 (AIRS - MLS)/MLS). Agreement is best over the tropics where the differences are -10%–+50% with AIRS usually wetter.

COMPARISON WITH METEOROLOGICAL DYNAMICS

An important consideration is the consistency of the upper tropospheric moisture field with dynamics. In Figure 3 are shown 3 global maps of MLS, AIRS sampled and mapped like MLS and AIRS gridded by $1° \times 1°$. Comparing the two AIRS maps shows the effect of horizontal smoothing and interpolation that must be applied to the MLS data to produce a daily map.

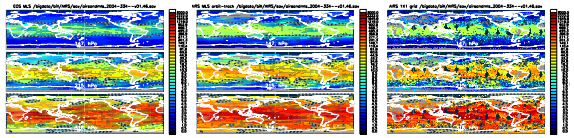


Figure 3, Daily humidity maps on 29 November 2004 at 147 hPa (top), 215 hPa (center), and 316 hPa (bottom) with the 3.5 PVU contour overlaid. The left column is MLS measurements, center column is AIRS sampled and mapped like MLS and right column is AIRS from a $1° \times 1°$ grid. Data not passing the quality criterion are omitted and show as "holes" in the maps. Units are ppmv.

The 3.5 Potential vorticity units (PVU) contour is overlaid and is a representation of the dynamical tropopause. Potential vorticity is provided by Goddard's Global Modeling and Assimilation Office (GMAO). Poleward of the 3.5 PVU contour is the stratosphere where H_2O concentrations are $<$10 ppmv. At 215 and 147 hPa, both MLS and AIRS show good consistency with the PVU contour; however, MLS appears to follow it more closely. Additionally, there are some interesting PV features such as the one over the southwestern US which indicates that the tropopause has dropped down to 316 hPa or higher pressure.

The MLS H_2O is consistent with the dynamical interpretation showing very dry stratospheric values down to 316 hPa. AIRS also captures this feature showing drier values relative to its surroundings but it only shows the dry stratospheric air at 215 hPa but not at 316 hPa.

A CASE STUDY

The November 3 2004 Aura Validation Experiment (AVE) flight from Ellington Texas encountered dry stratospheric air dropping to low altitudes [Robert Herman:2004, Personal communication]. Figure 4 shows corresponding MLS and AIRS maps with Potential Vorticity overlaid.

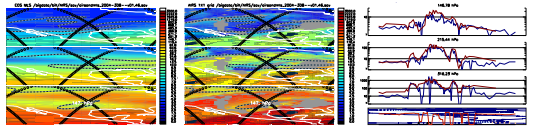


Figure 4, humidity maps in the vicinity of Texas on 3 November 2004 with the 3.5 PVU potential vorticity contour overlaid. The PVU contour is the location of the dynamical tropopause. MLS measurements (left) at 316(bottom), 215(middle), and 147(top) hPa. AIRS $1° \times 1°$ (center) for the same heights is shown at right. Bad or missing data are omitted and show as "holes" in the maps. The circles are the MLS measurement track. H_2O concentrations are in ppmv. The coincident humidity measurements made by MLS (blue) and AIRS (red) at the three heights is shown as an orbit series at right. The orbit as shown below (dots whose color indicates the local solar time along with MLS quality (red) and status (blue)) is for the orbit on the maps that proceeds from east to west traveling north near the center of the map. The quality represents the χ^2 of the fit is a number ranging from 0 (bad) to 1 (good). Quality is a bit field from 0 to 255 indicating many aspects of the retrievals such as the number of measurements used and clouds detected. 0 is best and non-zero indicate possible problems.

GMAO Potential vorticity shows the tropopause dropping down to at least 315 hPa over Texas. MLS shows humidities less than 10 ppmv at all three levels within the 3.5 PVU contour at 316 hPa. AIRS shows extreme dryness at 215 and 147 hPa but a moist 316 hPa. The orbit time series which shows just the coincident measurements show the same behavior. Low concentrations are seen in the MLS data at 316, 215, and 147 hPa over Texas but AIRS is similar at 215 and 147 but much wetter at 316 hPa. Overall, the time series show that AIRS and MLS track the broad features well but each instrument can have its own fine structure. Closer to the tropics on the orbit series, MLS shows a dry spike at 316 hPa not accompanied with dryness at 215 and 147 hPa. This is probably a cloud contaminated profile. The status shown below (blue line) is 34 indicating a cloud detection.

CONCLUSIONS

The Aura MLS version 1.46 humidity product qualitatively agrees with the AIRS v3.1 humidity at 316, 215 and 147 hPa. Quantitatively, the agreement is best at low latitudes where humidity is high. At 316 hPa over the tropics MLS and AIRS agree within 10% in the zonal mean. The 215 hPa zonal mean shows AIRS is -5–40% wetter over the tropics; and 147 hPa, AIRS is $>$30% wetter over the tropics. At higher latitudes MLS and AIRS do not agree particularly well especially when MLS measures less than 10 ppmv. The AIRS and MLS track the broad humidity features when the concentrations are greater than 10 ppmv but each instrument seems to measure fine structure that does not correlate.

ACKNOWLEDGMENTS

The research described here is done at the Jet Propulsion Laboratory, California Institute of Technology under contract with the National Aeronautics and Space Administration.

REFERENCES

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