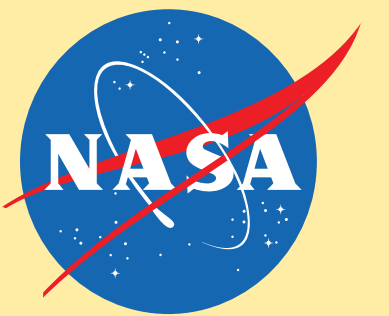


# MLS Level 2 Version 4: Improved Products for TTL Studies

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## Version 4: A new release of data from MLS on Aura

The Microwave Limb Sounder (MLS) on the Aura satellite has been operating nearly continuously since August 2004, measuring 3500 globally-distributed profiles per day of ~15 trace gases, temperature, cloud ice and geopotential height on product-dependent pressure surfaces ranging from the upper troposphere through the mesosphere. MLS radiometers measure thermal, millimeter-wave radiation from limb (tangential) views of the atmosphere, scanning vertically forward along the orbital path of the satellite, and products are retrieved from spectral signatures in these radiances.

The recently developed v04.2x retrieval algorithms have been used to reprocess the entire, 11-year, (>13 million profile) data record. Production of v02.x and v03.x data products has been discontinued as of July 1, 2015.

Artifacts resulting from the presence of thick clouds (convective cores) along limb-viewed tangent paths were present in v03x upper tropospheric data products, in some cases requiring complex data screening. **The reduction of these cloud-induced artifacts is a major success of the v04.2x development.**

Carbon monoxide (CO), water vapor (H<sub>2</sub>O), ozone (O<sub>3</sub>) and nitric acid (HNO<sub>3</sub>) products are of particular interest for Tropical Tropopause Layer (TTL)/ Upper Troposphere-Lower Stratosphere (UTLS) studies and improvements in these products with the release of v04.2x is the focus of this presentation.

## Carbon Monoxide

MLS CO is retrieved on 6-surfaces-per-decade of pressure from 215 into the mesosphere using spectral signatures from the MLS 240-GHz radiometer. The retrieval resolution (taken to be the full width at half maximum of the averaging kernel) of v04.2x is essentially unchanged from v03.x: at 215 hPa, vertical resolution (v) is 5.4 km and along-track horizontal resolution (h) is 690 km and resolution improves to 4.9 km x 450 km at 100 hPa. Single measurement precision is ~15 ppbv in the UTLS.

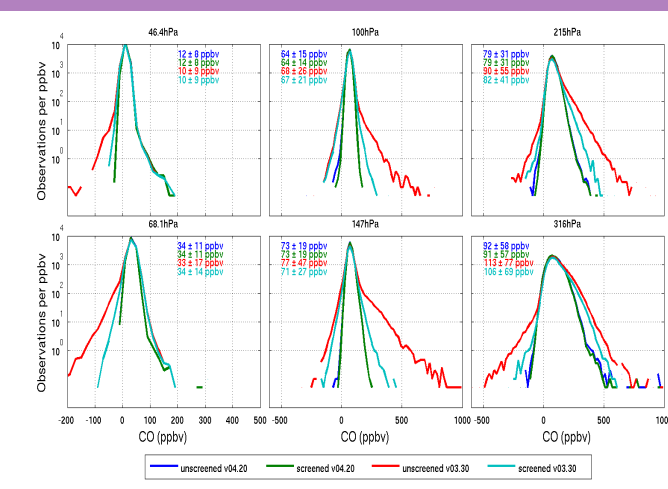


Figure 1

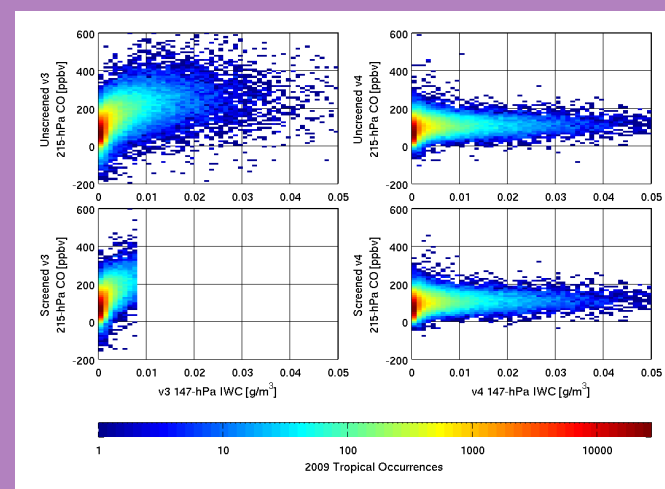


Figure 2

Version 3 CO has cloud-induced artifacts that result in the outlier tails (Figure 1, red lines) of unscreened v3 2009 tropical data. Spurious values, mostly positive at the lower levels and mostly negative at higher levels, were reduced but not totally eliminated by recommended screening (cyan lines), while rejecting 13% of tropical UT profiles. V04.2x greatly reduces the outlier tails and recommended v04.2x screening is simpler to implement and rejects only 2% of UT profiles. While the 316-hPa retrieval level is shown on Figure 1, it is not recommended for scientific use as its averaging kernel actually peaks at 215 hPa.

Figure 2 shows histograms of 215-hPa tropical retrieved values for the two versions, with and without screening, plotted against 147 hPa Ice Water Content (IWC). High 147-hPa IWC indicates the presence of a deep convective cloud. V03.x CO has a clear positive correlation with IWC that is truncated but not fully eliminated by recommended screening. Note, these joint histograms (PDFs) are plotted with a logarithmic color scale, so the density of points is four orders of magnitude larger for dark red bins than for dark blue bins.

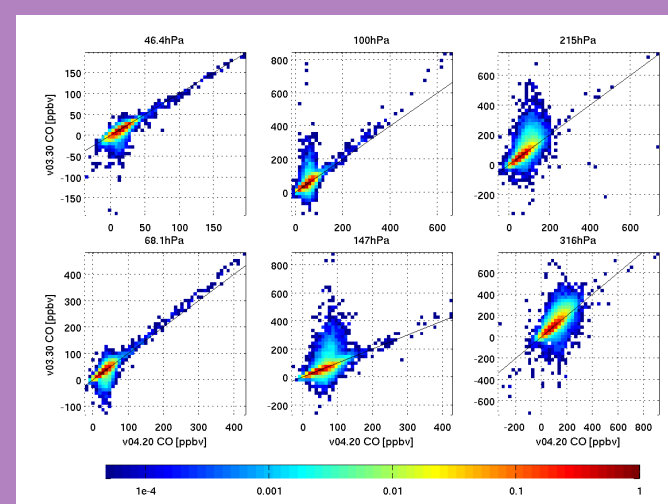


Figure 3

Figure 3 shows v03.x and v04.2x CO retrievals plotted against one another from February 2009, including extratropical profiles. The Australian “Black Saturday” fire, a singular event in the 11-year MLS record, injected high values of CO into the the southern stratosphere that remained in somewhat coherent blobs as they were advected and radiatively lofted throughout the month. The tails of high values along the black 1-to-1 lines show that the v04.2x retrieval, while eliminating the spurious high values of v03.x, is able to retrieve nonspurious high values seen in both versions.

## Water Vapor

The MLS v04.2x water vapor (H<sub>2</sub>O) product is retrieved down to 316 hPa, with UTLS profiles on the same 12-surfaces per decade as used by the v03.x product. Resolution of v04.2x (v x h) is 1.3 km x 168 km at 316 hPa, degrading to 3 km x 198 km at 100 hPa, comparable or slightly better than that of v03.x. Improved rejection in v04.2x of cloud-impacted radiances leads to significant reduction in poor radiance fits and of spurious retrieval values. V04.2x recommended screening rejects 7% of tropical UTLS profiles while v03.x screening rejects 18% of tropical UTLS profiles.

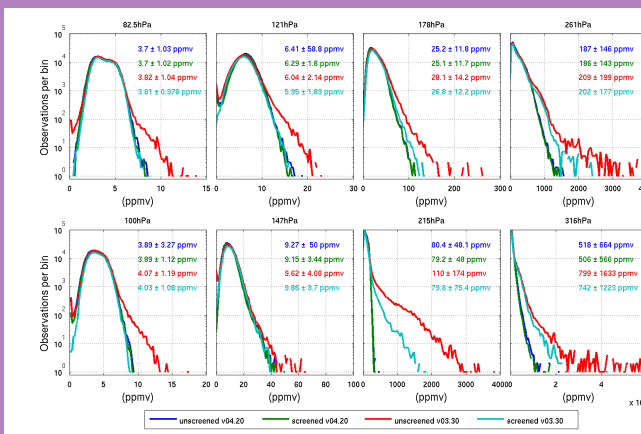


Figure 4

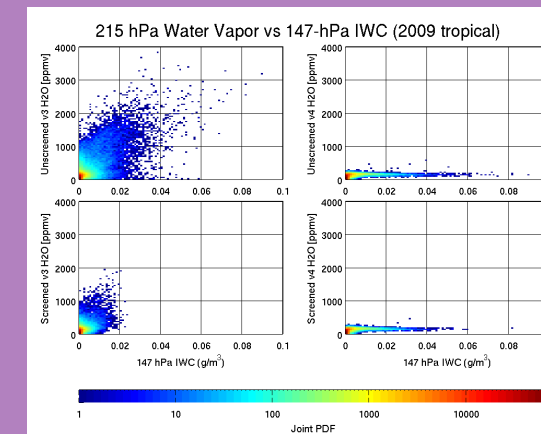


Figure 5

Figure 4 shows histograms of 2009 tropical v03.30 H<sub>2</sub>O (unscreened, red; screened, cyan) and v04.20 H<sub>2</sub>O (unscreened, blue; screened, green). Outlier tails in unscreened v03.30 are effectively removed by screening at the higher retrieval levels shown (albeit with more than twice as many profiles rejected as in v04.20) but are only partly eliminated at 316–215 hPa.

Figure 5 shows 215-hPa H<sub>2</sub>O vs 147-hPa IWC for unscreened H<sub>2</sub>O (top) and screened H<sub>2</sub>O (bottom), for v03.30 (left) and v04.20 (right). 215 hPa is the level at which the v03.x retrieval is most susceptible to cloud-induced artifacts, while spuriously high values in v04.20 are nearly nonexistent at this level, even in unfiltered data.

We note that at 121–83 hPa on Figure 4 there is a nonphysical tail of retrieved values near zero in the unscreened data of both versions that is rejected by v03.x screening but not by v04.20 screening. The recommended screening for v04.20 may need to be modified to address this tail.

## Nitric Acid

The MLS v04.2x nitric acid (HNO<sub>3</sub>) product is retrieved down to 215 hPa, with UTLS profiles on the same 6 surfaces per decade as were retrieved by the v03.x algorithm. Resolution (v x h) is 1.3 km x 168 km at 316 hPa, degrading to 3 km x 198 km at 100 hPa, comparable or slightly better than that of v03.x. Susceptibility to cloud-induced artifacts present in v03.x has been significantly reduced by v04.2x algorithms. The fraction of tropical profiles rejected by recommended screening is similar for the two versions, 15.7% for v03.30 and 13.2% for v04.20.

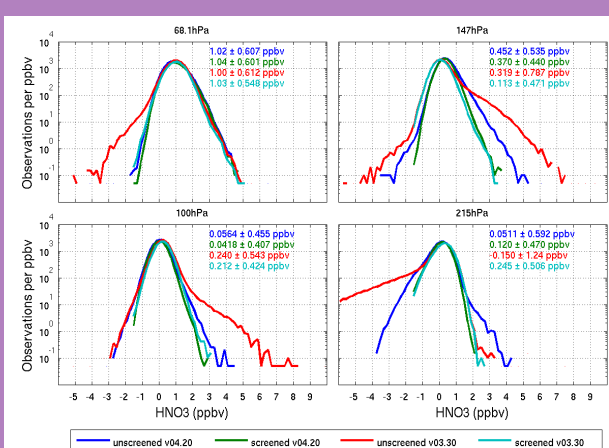


Figure 6

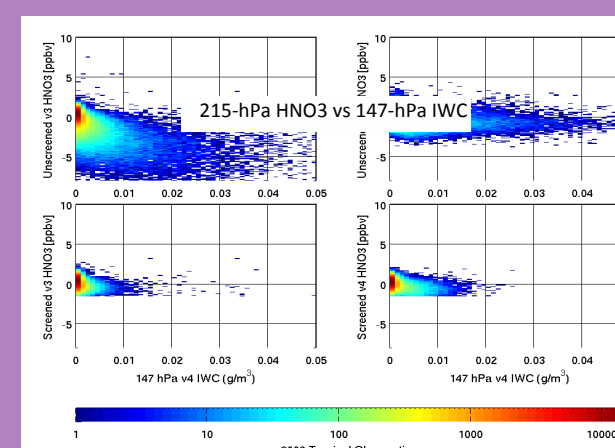


Figure 7

Figure 6 shows 2009 tropical histograms of the four HNO<sub>3</sub> retrieval levels from 215–82.5 hPa, screened and unscreened for v04.20 and v03.30 data. It is generally the case that unscreened v03.30 has larger outlier tails than does v04.20, with the exception being for high outliers at 215 hPa. As can be seen from Figure 7, these high v04.20 values are not correlated with high IWC. Low outliers in v03.30 HNO<sub>3</sub> are, indeed, correlated with high IWC in the upper-left panel of Figure 7. Histograms of screened data for the two versions, shown on Figure 6, are actually quite similar. Given the improved performance of v04.20 in the presence of clouds, there is hope that a less-aggressive v04.20 screening recommendation could pass a larger fraction of the v04.20 data without significantly compromising data quality.

## Ozone

MLS O<sub>3</sub> is retrieved in the UTLS on 12-surfaces-per-decade of pressure down to 261 hPa using spectral signatures from the MLS 240-GHz radiometer. V03.x O<sub>3</sub> was subject to vertical oscillations at low latitudes as well as cloud-induced artifacts; these issues have largely been resolved in v04.2x. Increased vertical smoothing results in slightly poorer resolution than that reported for v03.x: at 215 hPa it is 3.5 km x 350 km (v x h) for v04.2x and 3 km x 400 km for v03.x. At 100 hPa it is 3 km x 300 km for v04.2x and 2.5 km x 300 km for v03.x. Recommended screening rejects 5.5 % of tropical UTLS profiles for v04.2x and 13.7% of tropical UTLS profiles for v03.x.

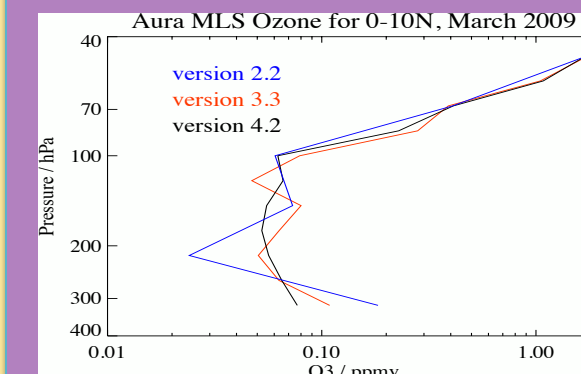


Figure 8

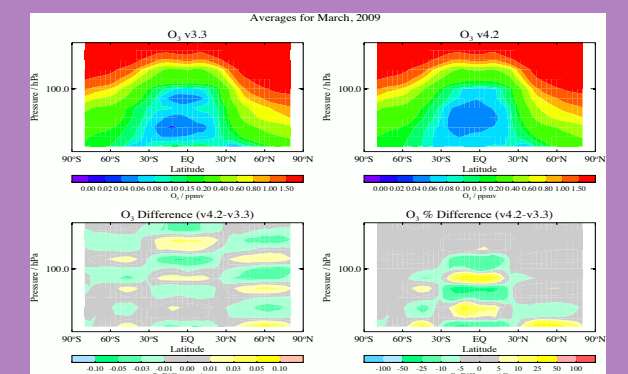


Figure 9

Figures 8 and 9 show the improvement in v04.2x O<sub>3</sub> with regard to vertical oscillations. The nonphysical “notch” that was often seen in tropical v03.x profiles at 147 hPa has largely been eliminated. Figure 9 shows the two versions for March, a month with particularly bad vertical oscillations in v03x. Oscillations are largely eliminated in v04.2x (Figure 9, top right).

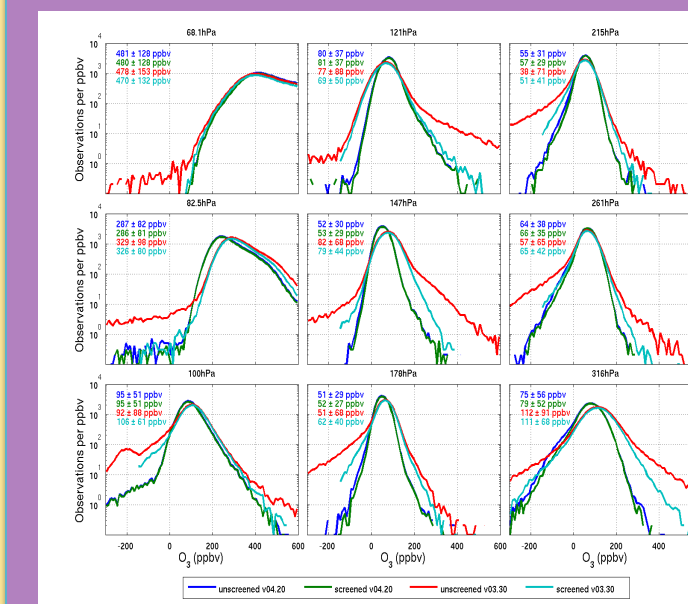


Figure 10

Figure 10 shows screened and unscreened tropical O<sub>3</sub> histograms for 2009 v04.20 and v03.30 data for retrieval levels from 316 hPa (not recommended for scientific work) in the lower right to 68 hPa in the upper left. Cloud-induced artifacts in unscreened v03.30 data (red) are reduced, but not eliminated by screening (cyan). Unscreened (green) and screened (blue) v04.20 data are similar on this plot.

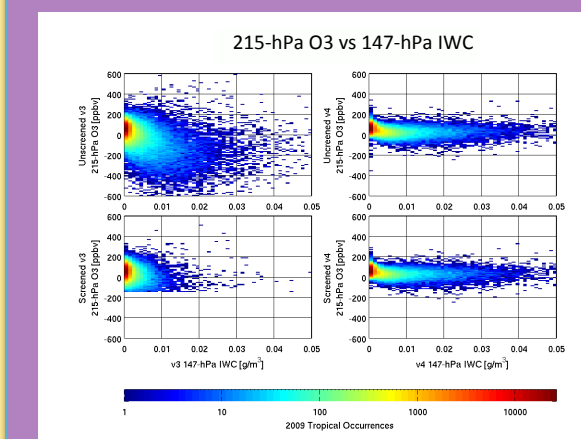


Figure 11

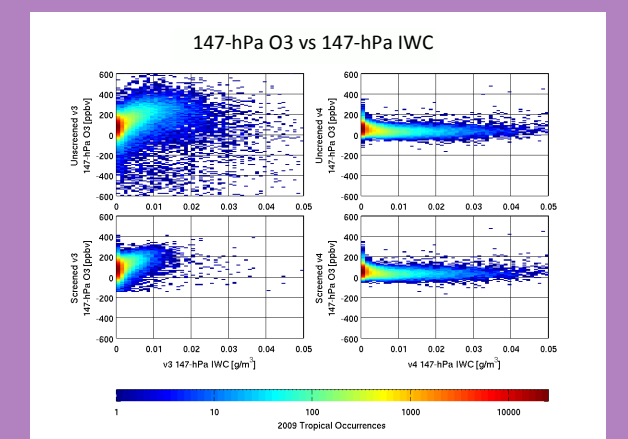


Figure 12

Figures 11 and 12 show that, indeed, the low (negative) outliers in v03.30 O<sub>3</sub> at 215 hPa and the positive outliers in v03.30 O<sub>3</sub> at 147 hPa are correlated with convective cores, as expected. There are little or no cloud-induced artifacts in v04.20 data.

## Data Availability

MLS v04.2x and v03.x data (through the June 30, 2015 termination of v03.x processing) are available through the GSFC Earth Sciences Data and Information Services Center (GES-DISC).  
<http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/MLS/index.shtml>

An updated version of the MLS Data Quality Document is also available through GES-DISC, discussing data interpretation, recommended screening, precision, accuracy and artifacts. Users are encouraged to contact MLS team members with questions concerning use of these data.