

# Collection 6.1 Change Document

## TERRA MOD07 Atmospheric Profile Products

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### Background

Observations in the Terra MODIS Photovoltaic (PVLWIR) bands 27 – 30 are known to be influenced by electronic crosstalk. The magnitude of this crosstalk affecting L1B radiances has been steadily increasing throughout the mission lifetime, causing, for example, earth surface features to become prominent in atmospheric band 27, increased detector striping, and trends in radiometric biases.

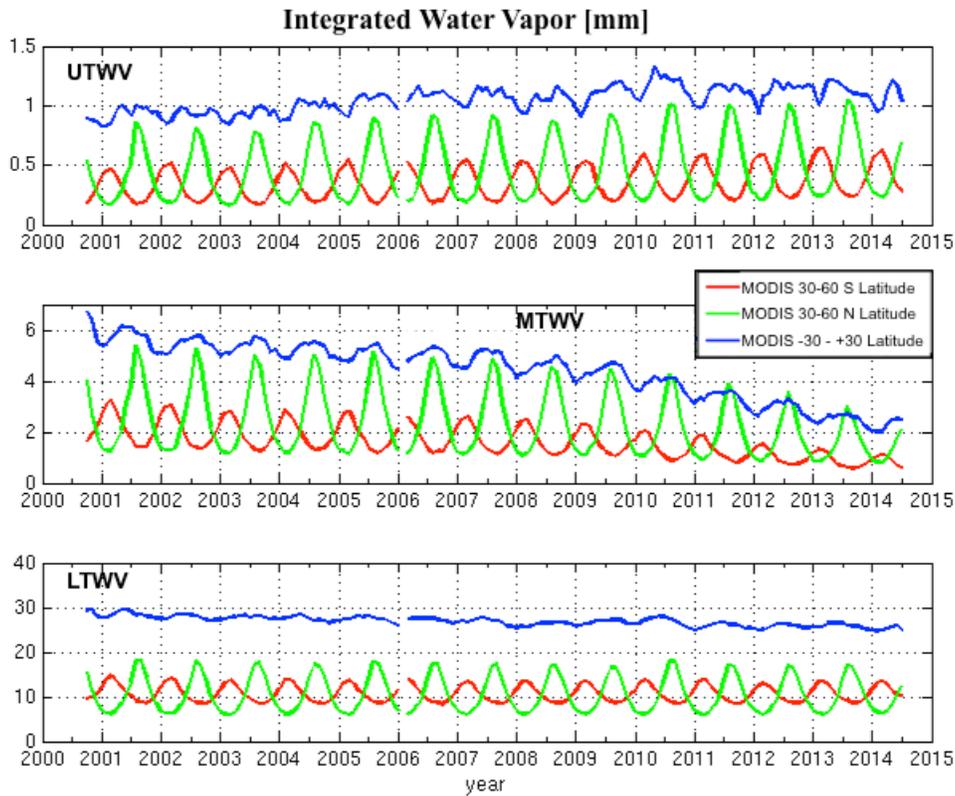
In addition, on February 18, 2016 the Terra MODIS instrument entered a safe mode status when the Terra spacecraft exceeded specified limits on pointing during an inclination adjustment maneuver. MODIS was in safe mode from 18 to 24 February and its focal plane temperatures were uncontrolled. After the safe mode, the electronic crosstalk behavior showed a significant increase for all PVLWIR bands in amplitude (Wilson et al., 2017).

In recent years, the crosstalk contamination has been recognized as compromising the climate quality status of several MODIS L2 and L3 science products that depend on the PVLWIR bands. In response, the MODIS Characterization Support Team (MCST) has generated a crosstalk correction algorithm in the operational L1B radiance algorithm. The crosstalk corrected L1B radiances have been tested (Moeller et al., 2014, 2017) in several Terra MODIS L2 science product algorithms, including MOD35 (Cloud Mask), MOD06 (Cloud Fraction, Cloud Particle Phase, Cloud Top Properties), and MOD07 (Atmosphere Profiles). This document describes these so-called Collection 6.1 (061) changes to MODIS MOD07 Moisture and Total Ozone Atmospheric Profile Products.

The MODIS MOD07 L2 operational algorithm for retrieving temperature and moisture profiles, total column ozone, total and layer integrated water vapor from infrared (IR) radiances observed by the NASA Terra MODIS instrument is a clear sky synthetic regression retrieval algorithm called MOD07. MOD07 inputs are the clear-sky radiances over land and ocean for both day and night from eleven MODIS infrared channels (25, 27-36) that include the crosstalk affected PVLWIR bands. The operational algorithm consists of several procedures that include cloud filtering (MOD35), averaging clear radiances over 5 by 5 field-of-view (FOV) areas, forward model calculations, and a regression based retrieval. The radiative transfer calculation of the MODIS spectral band radiances is performed using the JCSDA Community Radiative Transfer Model (CRTM) transmittance model (Han et al., 2005) including spectral shifts to some bands (27-28, 30, 34-36) to bring their radiances in line with those of the AIRS (Tobin et al., 2006) and IASI sensors (Quinn et al., 2010).

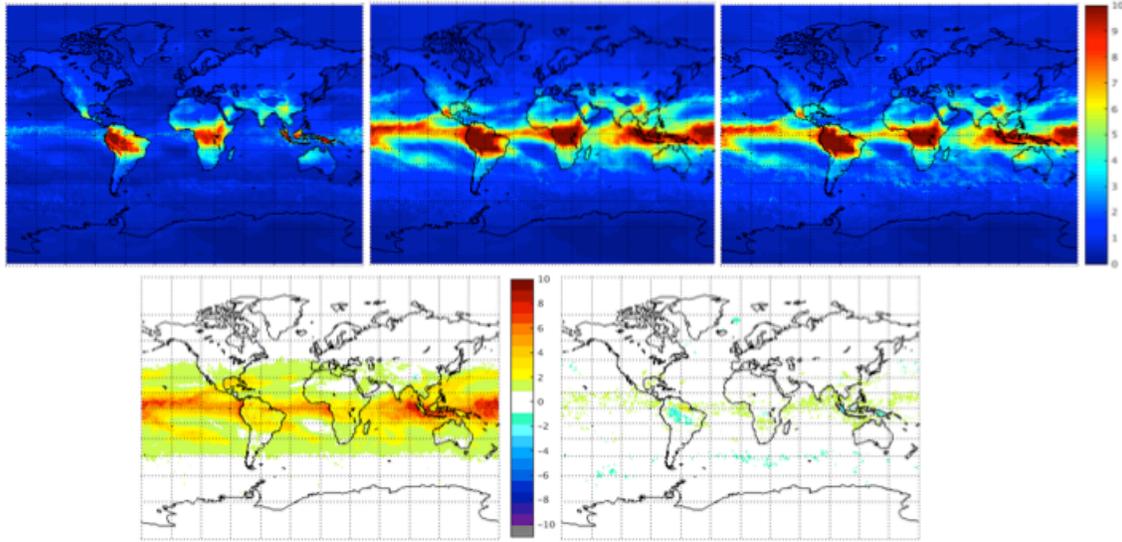
## TERRA/MOD07 Water Vapor Products

Trends in the C6 MOD07 upper (UTWV, above 440 hPa), middle (MTWV, between 440 and 640 hPa) and lower (LTWV, below 640 hPa) troposphere water vapor show a noticeable negative trend in the MTWV and a modest positive trend in the UTWV, especially over the tropics (Figure 1). These trends are not found in corresponding Aqua MODIS C6 products and point towards a biasing of the Terra MODIS trends due to crosstalk increasing in the PVLWIR bands.



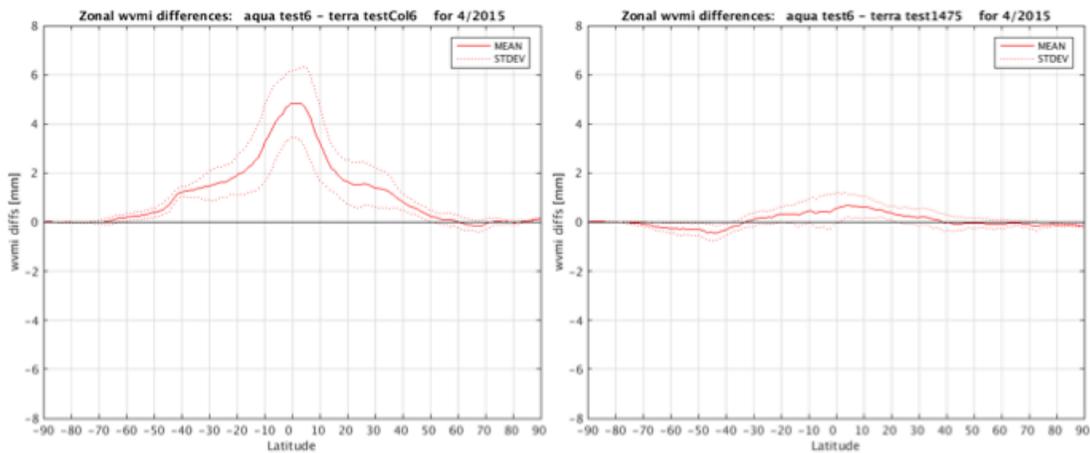
**Figure 1.** Time series of C6 monthly mean Terra MODIS upper, middle and lower troposphere integrated water vapor (UTWV, MTWV, LTWV, respectively) for the mid-latitude North (30N - 60N, red), mid-latitude South (30S - 60S, green) and tropical latitude (30N - 30S, blue) zones at nighttime.

To investigate this, the NASA DAAC provided Terra MODIS crosstalk corrected L1B plus MOD07 and MOD08 (L3) products for the month of April in every year from 2000 through 2016, plus July 2016. Figure 2 shows three (Terra C6, Aqua C6, and Terra crosstalk corrected) fields of MTWV for April 2015. The bottom panels show the MTWV differences between C6 Terra and C6 Aqua (left) products and between the crosstalk corrected Terra and C6 Aqua (right). The C6 Terra MTWV (top left panel) is artificially reduced by crosstalk errors in band 27 and band 28, especially in the tropics over ocean. However, the crosstalk corrected MTWV (top right panel) much more closely matches that of Aqua MYD07 (top middle panel) with differences falling to less than 2 mm over the entire globe (bottom right panel).



**Figure 2:** The MOD08 integrated water vapor of the middle troposphere (MTWV) for April 2015 from Terra MODIS C6 (top left), Aqua MODIS C6 (top middle) and crosstalk corrected Terra MODIS (top right). Differences between Terra C6 and Aqua C6 (bottom left) and Terra crosstalk corrected and Aqua C6 (bottom right) are also shown.

The distribution of the latitudinal mean differences of MTWV for April 2015 is plotted in Figure 3. The left panel represents the mean and standard deviation of the differences between C6 Terra and Aqua and the right panel shows the same using the Terra crosstalk corrected data. The Terra C6 differences shows a strong latitudinal dependence in the distribution with the maximum monthly mean occurring in the Equatorial zone (5mm; ~ 50% of the absolute value); after the crosstalk correction, the mean differences are reduced at all latitudes and the latitudinal dependence is largely removed with equatorial zone differences less than 0.8mm (< 10% of absolute mean value). Standard deviations are also significantly lowered, suggesting that the uncertainty of the MOD08 product is reduced.



**Figure 3:** The latitudinal profile of the April 2015 MOD08 MTWV differences between Aqua MODIS C6 and Terra MODIS C6 (left), and between Aqua MODIS C6 and Terra MODIS crosstalk corrected (right).

Figures 4 and 5 are similar to Figures 2 and 3, except showing UTWV results. The effect of the crosstalk error on the UTWV is to on average increase the water vapor amount (opposite of MTWV). Again, after crosstalk correction, the Terra MODIS UTWV product much more closely matches that of Aqua MODIS. Figure 5 illustrates that the maximum differences occurring in the equatorial zone are also largely eliminated and standard deviations are reduced by the crosstalk correction (right panel of Fig 5).

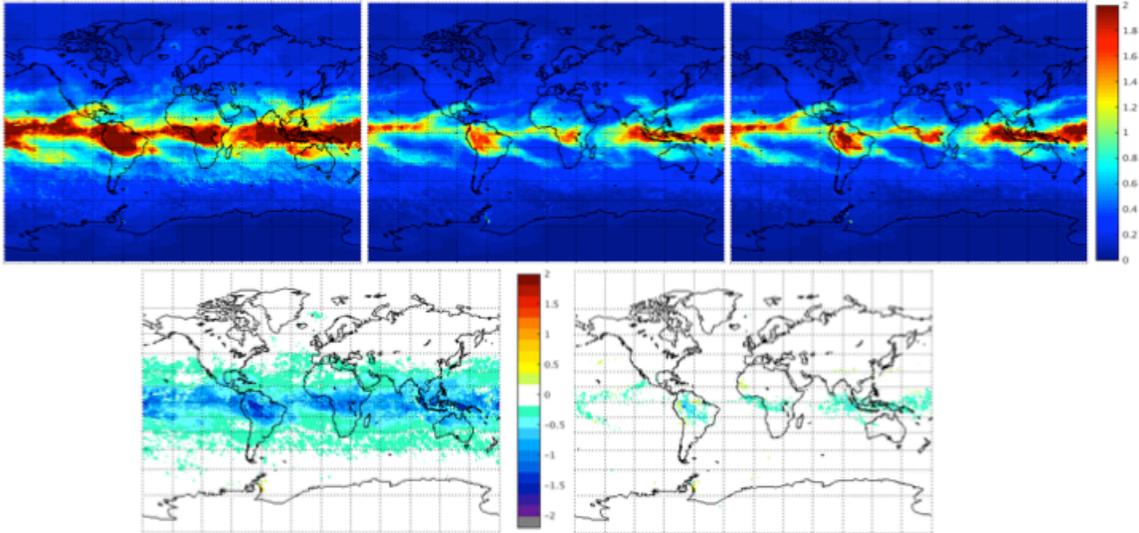


Figure 4. Same as Figure 2, except for upper troposphere (UTWV).

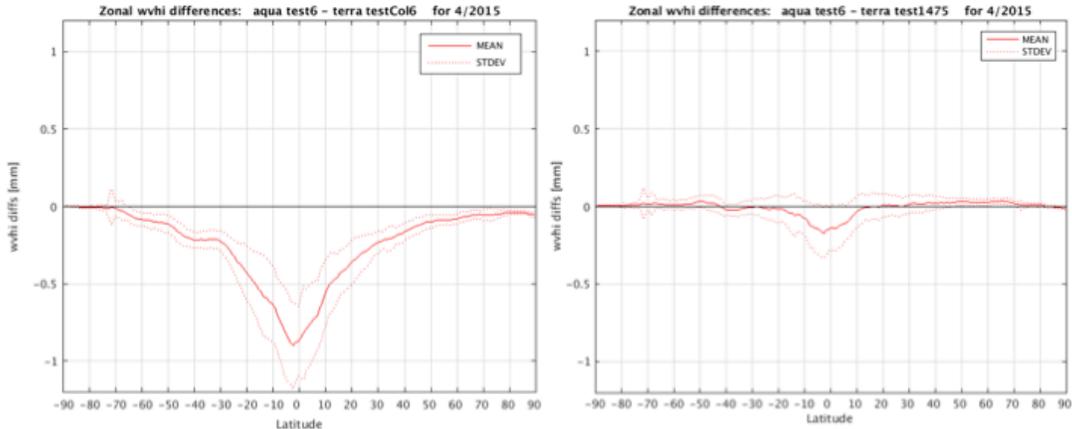
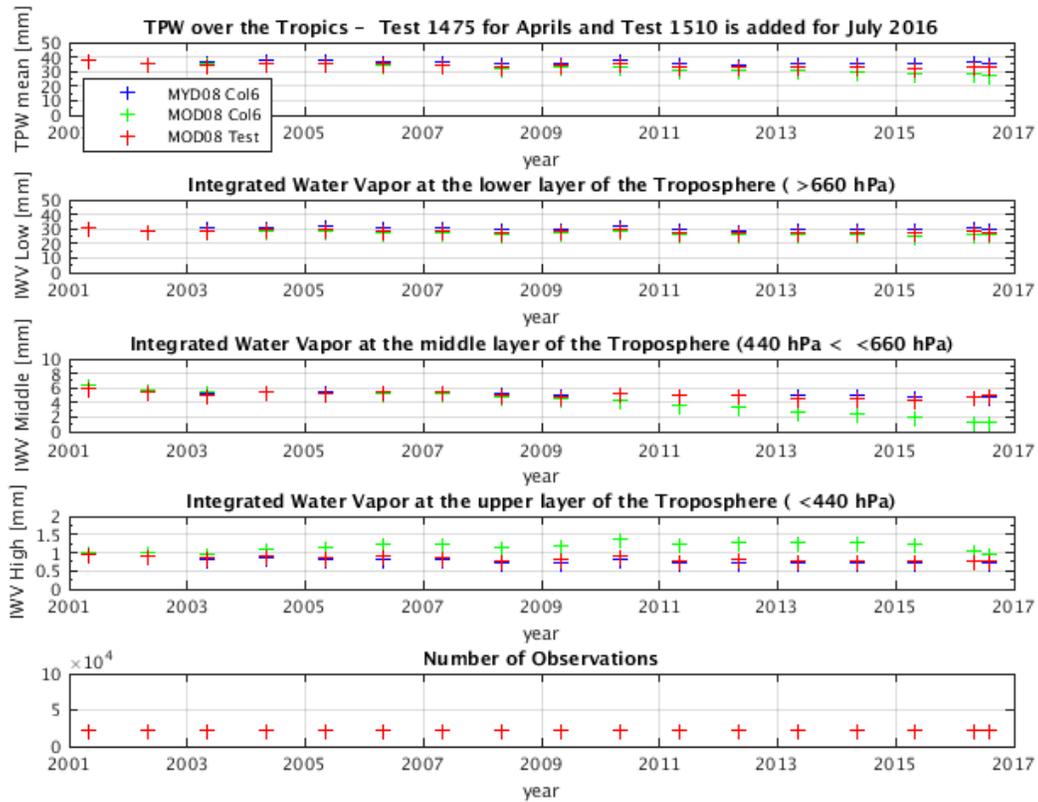


Figure 5. Same as Figure 3, except for upper troposphere (UTWV).

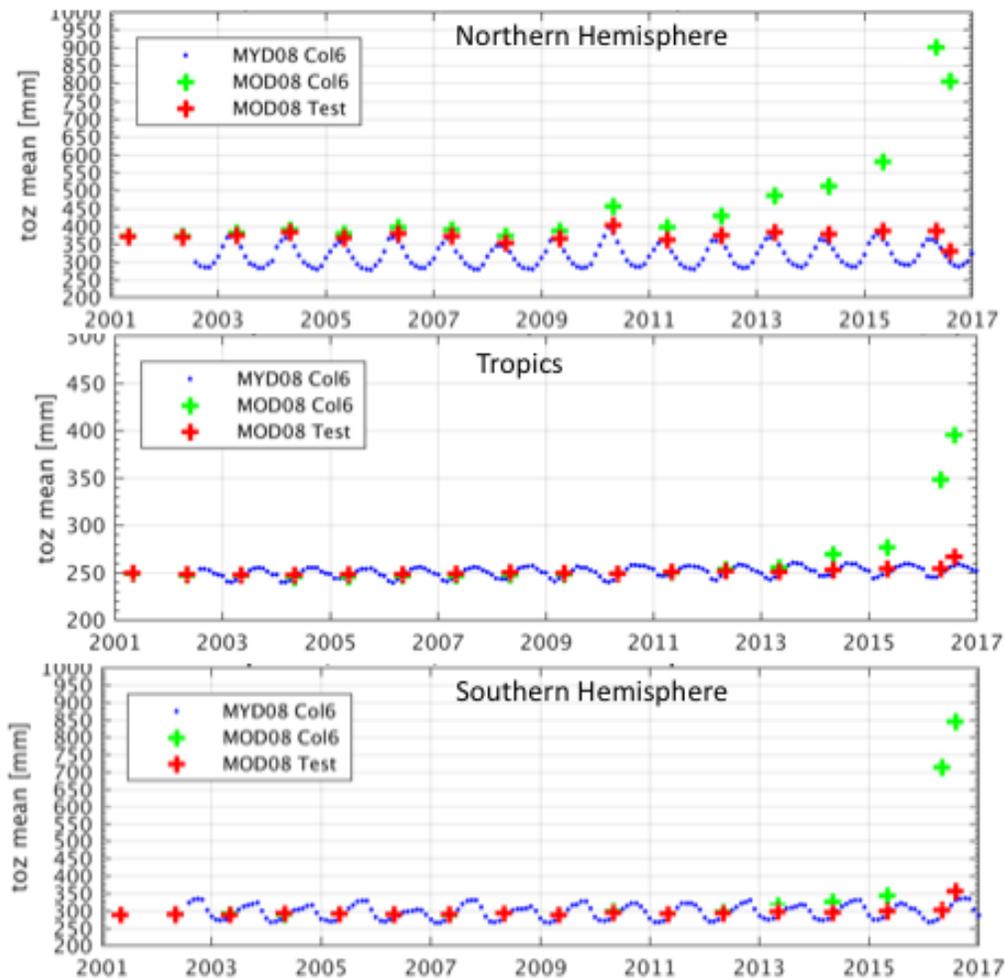
Figure 6, a time series of the L3 total, LTWV, MTWV and UTWV integrated water vapor in the tropics, indicates that the crosstalk error in C6 radiances caused a moisture deficit in the lower and middle layer of the troposphere and excessive moisture in the upper troposphere. The time series show this becoming more pronounced in about 2010 (see green crosses) for LTWV and MTWV and evident already in 2003 for UTWV (note that the scaling is different for each plot and may be masking behavior of LTWV and MTWV earlier in the mission). The trends from 2001 to the present for crosstalk corrected Terra TPW, UTWV, MTWV and LTWV (red crosses) show that the crosstalk correction is moving the Terra moisture products closer to the Aqua determinations (especially for UTWV and MTWV). The crosstalk corrected Terra trends may be further altered by adjustments to the spectral shifts of bands 27-28 and 30. These shifts will be re-evaluated using crosstalk corrected L1B radiances.



**Figure 6:** Terra (MOD) and Aqua (MYD) tropical integrated water vapor 16 year trends for total (TPW), lower, middle and upper layers for C6 and for Terra crosstalk corrected (“Test”). The crosstalk correction moves the Terra moisture trends into closer agreement with the Aqua trends in all layers.

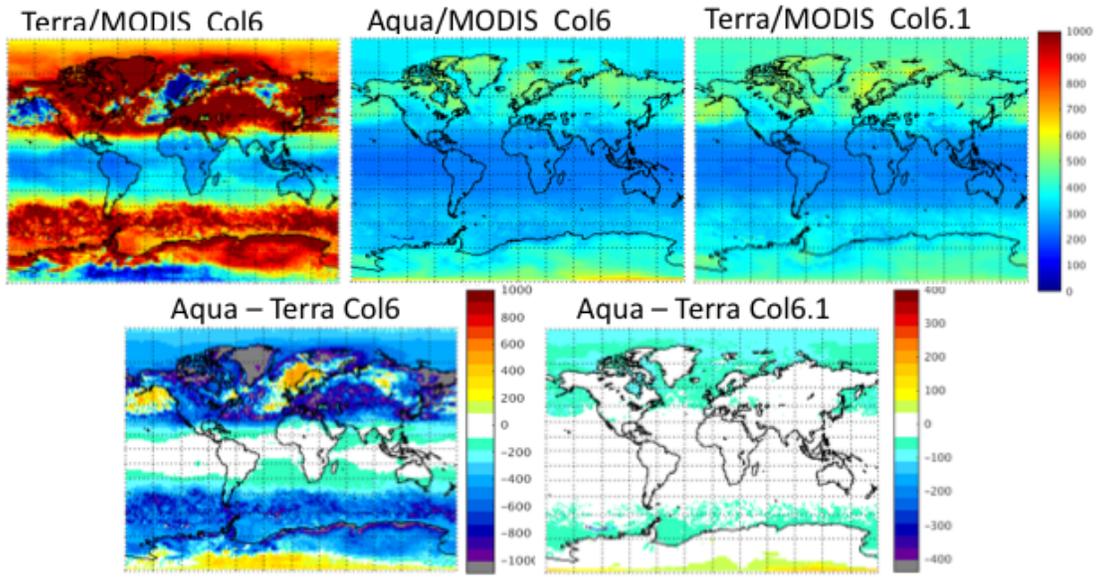
## TERRA/MOD07 Total Ozone Product

Determination of total ozone in the MOD07 Algorithm is performed by integrating ozone profiles through the atmospheric column. The time series (see Figure 6) of the L3 total ozone separately over the Northern and Southern Hemisphere (between 30 and 60-degree latitude) and Tropics indicates that the crosstalk error in C6 radiances caused excessive ozone for all three latitudinal bands. The time series show this becoming more pronounced in about 2010 (see green crosses), and after the safe hold (Feb 2016) the increase became much stronger (>100%). The trends from 2001 to the present for crosstalk corrected Terra TOZ show that the crosstalk correction is moving the Terra TOZ products closer to the Aqua determinations, although there are still some increase (~20-30 DU) after the safe hold mode (Feb 2016) perhaps due to some residual electronic crosstalk in band 30 after the crosstalk correction.



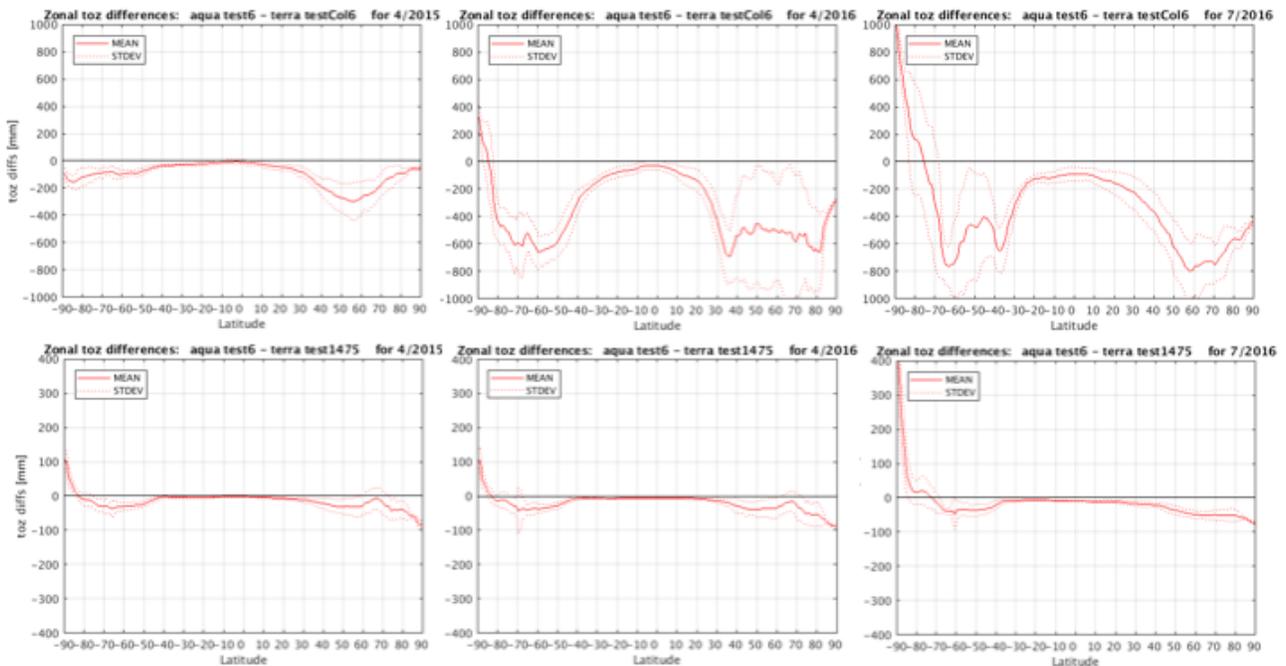
**Figure 7:** Terra (MOD) and Aqua (MYD Total Ozone 16 year trends over Northern Hemisphere (top), Tropic (middle) and Southern Hemisphere (bottom) for C6 and for Terra crosstalk corrected (“Test”). The crosstalk correction moves the Terra total ozone trends into closer agreement with the Aqua trends in latitudinal region.

To investigate the spatial distribution of the effect of the crosstalk correction, the global map and latitudinal zonal mean is plotted. Figure 8 shows the three (Terra C6, Aqua C6, and Terra crosstalk corrected) fields of TOZ for April 2016. The bottom panels show the TOZ differences between C6 Terra and C6 Aqua (left) products and between the crosstalk corrected Terra and C6 Aqua (right). The C6 Terra TOZ (top left panel) is artificially increased (max diff is 650 DU) by crosstalk errors in band 30, especially in above the 30 degree Latitudes. However, the crosstalk corrected TOZ (top right panel) much more closely matches that of Aqua MYD07 (top middle panel) with differences falling to less than 100 DU over the entire globe (bottom right panel).



**Figure 8:** The MOD08 Total Ozone for April 2016 from Terra MODIS C6 (top left), Aqua MODIS C6 (top middle) and crosstalk corrected Terra MODIS (top right). Differences between Terra C6 and Aqua C6 (bottom left) and Terra crosstalk corrected and Aqua C6 (bottom right) are also shown. Note that the scaling is different for the bottom right panel.

The distribution of the latitudinal mean differences for April 2015 (left panels), April 2016 (middle panels) and July 2016 (right panels) is plotted in Figure 9. The top panels represent the mean and standard deviation of the differences between C6 Terra and Aqua and the bottom panels show the same using the Terra crosstalk corrected data. The Terra C6 differences shows a strong latitudinal dependence in the distribution with the maximum monthly mean occurring in both Southern and Northern 60-70 degree latitudes (600 DU; ~ 100% of the absolute value); after the crosstalk correction, the mean differences are reduced at all latitudes apart from the high polar latitudes (80-90 degrees), and the latitudinal dependence is largely removed with differences well below 100 DU (< 15 % of absolute mean value). Standard deviations are also significantly lowered, suggesting that the uncertainty of the MOD08 TOZ product is reduced.



**Figure 9:** The latitudinal profile of the April 2015 (left column), April 2016 (middle column) and July 2016 (right column) MOD08 Total Ozone differences between Aqua MODIS C6 and Terra MODIS C6 (upper panels), and between Aqua MODIS C6 and Terra MODIS crosstalk corrected (bottom panels).

## SUMMARY

A crosstalk correction developed by MCST for Terra MODIS PVLWIR bands 27-30 has been tested in the L3 MOD07 moisture and total ozone science products to address poor performance found in Terra MODIS Collection 6 products that use the PVLWIR bands. The effect of the crosstalk error on the MOD07 moisture products has a strong latitudinal dependence in the distribution peaking at the Tropics causing a huge moisture deficit (50%) in the lower and middle layer of the troposphere and a moisture increase (50%) in the upper troposphere. The correction has brought the Terra MODIS moisture into much closer agreement with that of Aqua MODIS, reducing the moisture increase in the low and middle layer and deficit in the upper layer to less than 10%. A latitudinal dependence caused by the crosstalk error is also largely eliminated.

The crosstalk error in C6 radiances caused excessive ozone for all over with a strong latitudinal dependence in the distribution with the maximum monthly mean occurring in both Southern and Northern 60-70 degree latitudes. This effect became more pronounced in about 2010, and after the safe hold (Feb 2016) the increase became much stronger (>100% ~ 600DU). We demonstrated that the crosstalk correction reduced the mean differences at all latitudes and the latitudinal dependence is largely removed although there are still some increase (max 100 DU at the 60-70 degree latitudes) after the safe hold mode (Feb 2016).

After the crosstalk correction, some departures for both the moisture and ozone products yet exist which may signal that the spectral shifts applied to bands 27, 28 and 30 for C6 MOD07 processing are not accurate after the crosstalk correction. These shifts will be reviewed and updated. This work suggests that these Terra MODIS products can be restored to climate quality status by the crosstalk correction.

## ACKNOWLEDGEMENTS

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