The MODIS MOD07 Collection 6 products:
The impact of the H2O/CO2/O3 channel spectral shifts

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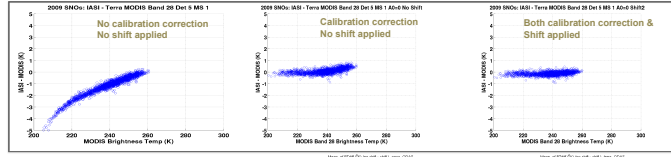
Abstract: The operational algorithm for retrieving temperature and moisture profiles and total column ozone and water vapor from infrared (IR) radiances observed by the NASA / MODIS instrument is a clear sky synthetic regression retrieval algorithm called MOD07. MOD07 clear-sky radiances over land and ocean for both day and night from eleven MODIS infrared channels (25, 27-36). A new version of this algorithm (Collection 6) will be promulgated soon. This poster introduces the new updates - focusing on the impact of the H2O/CO2/O3 channel spectral shifts - and offers local and global comparisons between the collection 5 and 6 products, using Southern Great Plains cart site measurements and the Atmospheric Infrared Sounder (AIRS) retrievals and Total Ozone Mapping Spectrometer (TOMS) products.
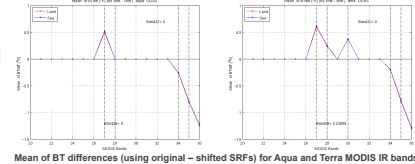
The H2O/CO2/O3 channel spectral shifts

First, Tobin et al. (JGR, 2006) comparison between AIRS and MODIS radiances suggested the Aqua/MODIS H2O channels (27, 28) need to be more opaque and the CO2 channels (34-36) less opaque.

Second, IASI-MODIS comparison study (Quinn et al, http://www.ssec.wisc.edu/~gregg/iasi-modis-2011-06/plots-shifted/plots.html) for 2009 showed that BT biases can be reduced by shifting the Spectral Response Functions and Terra/MODIS bands (20-30) need to be calibration corrected.

The MOD07 algorithm updates for Collection 6

- Update the radiative transfer model to CRTM V2 (from prototype CRTM V1.2)
- Apply zero bias adjustment in the radiative transfer calculation
- Apply H2O/CO2/O3 channel spectral shifts (Tobin et al., 2006, JGR, Tobin, Moeller and Quinn, 2011)
- Update NedT for both Terra and Aqua
- Update surface emissivity spectra in the training database to the current version
- Make the Aqua and Terra DAAC code uniform
- Modify the TPW low and high products to be able to calculate 3 layer water vapor means. The new layers are: (low) sfc-680 and (high) 440-10 hPa
- Improve QA/QC flags, QA usefulness and Confidence flag bug is fixed
- Output file updates: adding offset/scale factor usage, list of pressure levels, K-index valid range fixed, surface temperature changed to skin temperature, mixing ration profile added .

The following Spectral Response Function (SRF) shifts were suggested by the two studies: :

Band	Terra Shift (cm-1)	Aqua Shift (cm-1)
27	4	4
28	2	0
30	1	0
34	0.8	0.8
35	0.8	0.8
36	1.0	1.0

Mean of BT differences (using original – shifted SRFs) for Aqua and Terra MODIS IR bands of 15704 clear sky training profiles (SeeBor V 5.1) calculated by CRTM 2.0.2 (ODAS)

The effect of theH2O/CO2/O3 channel spectral shifts on TPW over the SGP ARM Cart Site

A database of clear sky cases at the ARM SGP-ACRF (36° 36'N;97° 29'W) site has been developed for evaluation of the MOD07 total precipitable water (TPW) product. This database includes all overpasses determined to be clear during the period from launch through August 2005: 345 Terra and 317 Aqua cases. MODIS sensor zenith angle was less than 50° to the Lamont, OK SGP site for all cases. These cases are readily reprocessed in-house to test any changes to the algorithm or training data. MOD07 TPW is compared with the ARM microwave water radiometer (MWR), radiosonde, and TPW from the GOES for all cases.

TPW comparison at the ARM SGP site between MWR and MYD07 derived TPW. Dry and wet cases are separated. SRF shift (yes or no) is indicated in the second column. Note that for the Aqua/Col6/CRTMV1.2 case, the SRF of band28 was also shifted by 2 wavenumbers.

Aqua/MYD07 Versions / FM/TM	SRF shift	DRY (TPW<15mm)(228) Bias	RMS	WET (TPW >=15mm)(89) Bias	RMS	ALL (317 cases) Bias	RMS
Col 5.2/pCRTM	No	-0.4	2.2	3.6	5.1	0.8	3.3
Col6/CRTM1.2/ODAS	No	-0.2	2.3	4.6	5.7	1.1	3.6
Col6/CRTM1.2/ODAS	Yes	-0.8	2.5	2.3	3.8	0.1	3.0
Col6/CRTM2/ODPS	No	-0.9	2.6	2.5	4.3	0.04	3.1
Col6/CRTM2/ODPS	Yes	-0.6	2.5	2.5	4.3	0.2	3.1
Col6/CRTM2/ODAS	No	-1.1	2.8	1.3	3.7	-0.4	3.1
Col6/CRTM2/ODAS	Yes	-1.0	2.7	1.5	3.9	-0.3	3.1

TERRA/MOD07 versions/FM/TM	SRF shift	DRY (TPW<15mm)(217) Bias	RMS	WET (TPW >=15mm)(128) Bias	RMW	ALL (345 cases) Bias	RMS
Col 5.2/pCRTM	No	-0.7	2.0	1.1	3.2	-0.04	2.5
Col 6/CRTM1.2/ODAS	No	-0.7	2.0	1.9	4.0	0.3	2.9
Col6/CRTM2/ODPS	No	-0.8	2.1	2.0	4.2	0.2	3.0
Col6/CRTM2/ODPS	Yes	-0.3	2.0	2.8	4.5	0.9	3.2
Col6/CRTM2/ODAS	No	-0.7	2.1	1.6	4.1	0.2	3.0
Col6/CRTM2/ODAS	Yes	-0.2	2.0	3.0	4.6	1.0	3.2

TERRA/MOD07 Col6/CRTM2/ODAS	SRF shift	DRY (TPW<15mm) (173) Bias	RMS	WET (TPW >=15mm)(93) Bias	RMW	ALL (266 cases) Bias	RMS
No Cal. corrected	no	-0.6	2.1	2.0	4.2	0.3	3.0
Yes Cal. corrected	no	-0.3	2.0	2.2	4.3	0.6	3.0
Yes Cal. corrected	yes	0.2	2.0	3.5	4.8	1.3	3.3

The effect of the H2O/CO2/O3 channel spectral shifts on Total Ozone over Budapest, Hungary

The MOD07 total ozone data were compared to the daily 1°×1° horizontal grid resolution OMI data for Europe and the surface Brewer measurements, representing the most accurate measurements of the vertically integrated ozone values. The Brewer spectrophotometer is located in Budapest, Hungary (as the 152nd member of the Brewer Network). The MODIS data were received by the polar orbiting satellite receiving station of the Eötvös Loránd University, in Budapest, Hungary (47.475°N, 19.062°E) and processed using the IMAPP software. The comparisons were performed using MODIS data of selected overpasses for 2007 comprising 102 and 41 mostly cloud free overpasses of Terra and Aqua, respectively, in the vicinity of Budapest and the Carpathian-Basin.

Satellite-based TOZ vs. Surface Brewer Measurements	Bias [DU]	Stdev [DU]	RMSE [DU]
OMI at Terra overpass times	6.8	6.9	9.7
Terra Col5.2/pCRTM	-16.8	20.0	26.1
Terra Col6 /CRTM1.2/ODAS no shifts	-26.5	17.3	31.6
Terra Col6/CRTM2/ODAS no shifts	-28.0	24.9	37.5
Terra Col6/CRTM2/ODAS with shifts	-6.2	22.1	23.0
Terra Col6/CRTM2/ODPS no shifts	-35.5	26.7	44.4
Terra Col6/CRTM2/ODPS with shifts	-9.6	21.6	23.6
OMI at Aqua overpass times	0.6	7.5	7.6
Aqua Col5.2/pCRTM	6.0	20.8	21.6
Aqua Col6/CRTM1.2/ODAS no shifts	-1.2	17.6	17.7
Aqua Col6/CRTM1.2/ODAS with shifts	4.0	16.0	16.5

Total Ozone on April 14 2007 at 09:50 UTC

Scatter plot of Terra/MODIS and OMI Total Ozone vs. ground-based Brewer Measurements for 2007 at Budapest, Hungary.

Time series of Total Ozone observations for the year 2007 over Budapest, Hungary.
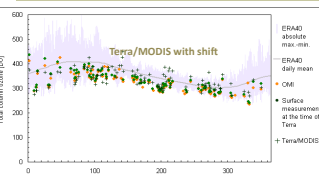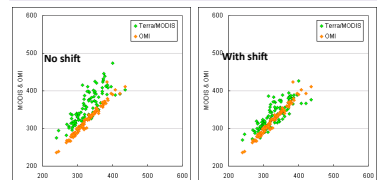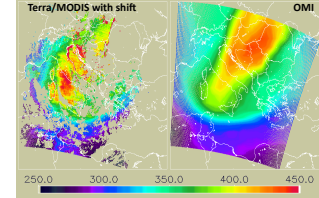
The effect of the H2O/CO2/O3 channel spectral shifts on Global TPW and Total Ozone

MODIS Total Precipitable Water (TPW) and Total Ozone (TOZ) retrievals from the Collection 5 and the new Collection 6 MOD07 algorithms are compared globally against AIRS and TOMS products for three days for both Aqua and Terra. The TOMS measurements are from the Earth Probe platform (Version 8 products) or the OMI platform (Version 3 products) depending on the study date. Version 5 Level 2 standard retrieval AIRS products (AIRSX2RET) are used in our comparisons. The UW space-time gridding algorithm (Smith et al., 2011) was used for projecting data from their unique instrument domain to a uniform space-time domain. The instrument observations (or retrievals) are first snapped into nearest neighbor clusters then the clusters are averaged into single grid cell values. The result is a uniform equal-angle latitude-longitude grid. The space-time algorithm was used here to create daily averages on 1° × 1° grids of TPW and TOZ retrievals from both Terra and Aqua MODIS, AIRS on Aqua, and OMI on Aura.
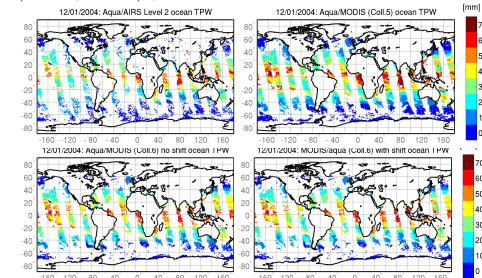
Global clear-sky TPW [mm] retrievals on 1 December 2004. Results represent daytime retrievals over ocean resampled and averaged to a 1° x 1° latitude-longitude grid.

Terra Time TOZ [DU] DAYTIME	AIRS-MOD07 (Col. 5) bias±stdev Land	Ocean
2006070: no shifts	-61±79 (ns=225)	-20±54 (ns=3062)
: with shifts	-15±57 (ns=225)	-0.4±35 (ns=3062)
2006240: no shifts	-13±24 (ns=291)	-7±23 (ns=3413)
: with shifts	4±19 (ns=291)	11±20 (ns=3416)

Terra Time TOZ [DU] NIGHTTIME	AIRS-MOD07 (Col. 6) bias±stdev Land	Ocean
2006070: no shifts	-77±96 (ns=159)	-11±36 (ns=2566)
: with shifts	-32±70 (ns=159)	5±27 (ns=2566)
2006240: no shifts	-8±16 (ns=153)	-10±16 (ns=3316)
: with shifts	6±14 (ns=153)	6±16 (ns=3316)

Aqua TPW [mm] DAYTIME	AIRS-MOD07 (Col. 5) bias±stdev Land	Ocean	AIRS-MOD07 (Col. 6) bias±stdev Land	Ocean
2004336: no shift	0.1±4.4 (386)	-2.6±4.9 (6367)	-2.7±5.1 (481)	-4.2±5.2 (6350)
: with shifts	N/A	N/A	-2.4±5.0 (481)	-3.8±4.9 (6350)
2006240: no shift	-2.5±5.3 (508)	-2.2±4.1 (7279)	-4.3±5.4 (513)	-4.4±4.9 (7462)
: with shifts	N/A	N/A	-4.2±5.4 (513)	-4.1±5.0 (7462)
2007032: no shifts	-1.0±4.6 (474)	-1.9±4.8 (6940)	-2.6±4.5 (474)	-4.7±5.0 (6944)
: with shifts	N/A	N/A	-2.3±4.5 (474)	-4.0±4.8 (6944)

Aqua TPW [mm] NIGHTTIME	AIRS-MOD07 (Col. 5) bias±stdev Land	Ocean	AIRS-MOD07 (Col. 6) bias±stdev Land	Ocean
2004336: no shift	0.4±2.5 (301)	-1.4±4.7 (5353)	0.1±2.4 (590)	-2.1±4.5 (5346)
: with shifts	N/A	N/A	0.3±2.3 (590)	-1.9±4.3 (5346)
2006240: no shifts	-0.9±4.5 (233)	-0.8±3.6 (6383)	-0.9±3.8 (279)	-2.2±3.7 (6641)
: with shifts	N/A	N/A	-0.7±3.8 (279)	-2.3±3.8 (6641)
2007032: no shifts	0.4±2.7 (284)	-0.8±4.4 (5625)	0.0±3.1 (284)	-2.5±4.3 (5628)
: with shifts	N/A	N/A	0.2±3.2 (284)	-2.0±4.1 (5628)

Globally gridded TPW (above) and TOZ (right) comparison of MODIS with AIRS separated by sea / land and day / night time. (MODIS min(obs) = 10 angle (viewing angle < 42))

Conclusions and Future Plans

- Overall, application of Terra spectral shifts shows significant improvement (reduced bias and rms) for MOD07 TOZ products in both the local (Budapest, Hungary) and global validation cases.
- In our earlier study (using CRTM V1.2) a positive improvement was realized for the Aqua/MODIS TPW over the SGP Cart site by applying the spectral shifts, particularly for the wet cases (TPW > 15mm) where the rms error was reduced by 1.9 mm and the bias was reduced by 2.3 mm.
- In this study (using CRTM V2.0.2) even without applying the spectral shifts, the OPTRAN-based transmittance algorithm of the new CRTMV2.0.2 reduces the bias by 1 mm for the wet cases (TPW > 15mm) and applying the spectral shifts yields no further improvement for Aqua/MODIS and slight degradation for Terra/MODIS. This may suggest investigating the H2O shifts in the other direction. **In the future** we are planning to study further the effect of the H2O bands.
- **In the near future** we are planning to investigate the effect of the calibration corrected Terra/MODIS level 1b data on the MOD07 TPW, TOZ and Temperature products on a global scale.
- For globally projected browsers of MOD07 Atmosphere Products see http://modis-atmos.gsfc.nasa.gov/IMAGES/index.html