University of Wisconsin-Madison MODIS Team

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and thanks to the Atmosphere PEATE

MODIS Science Team Meeting
April 15-16, 2013

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University of Wisconsin - Madison

Algorithms and Activities

- Cloud Mask
- Cloud Top Phase
- Cloud Top Pressure (temperature)
- Atmospheric Profiles
- Calibration
- Direct Broadcast

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For each algorithm

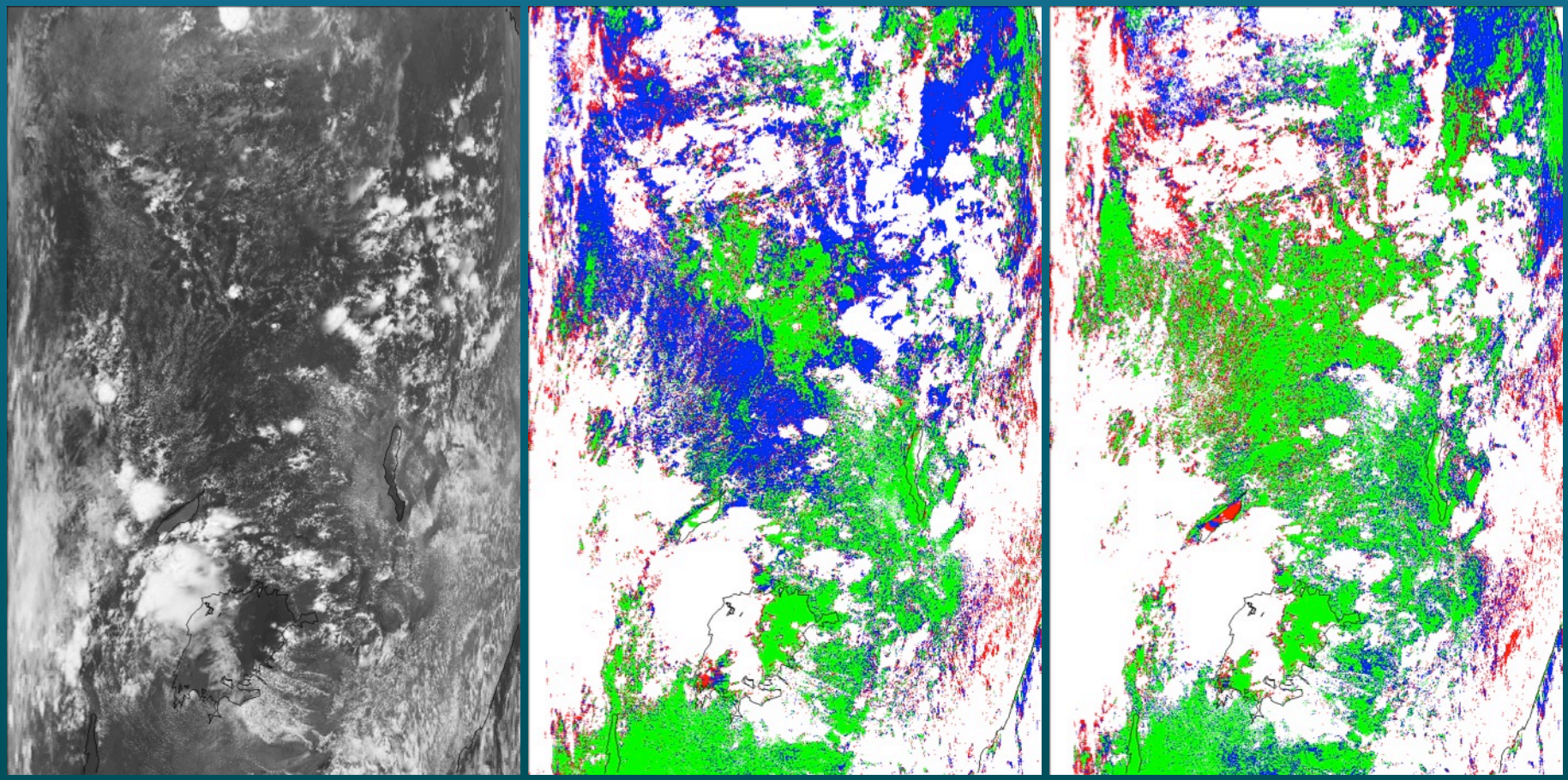
- Major difference between C5 and C6
- Example impacts
- Validation

Cloud Mask (MOD35/MYD35)

Primarily changes:

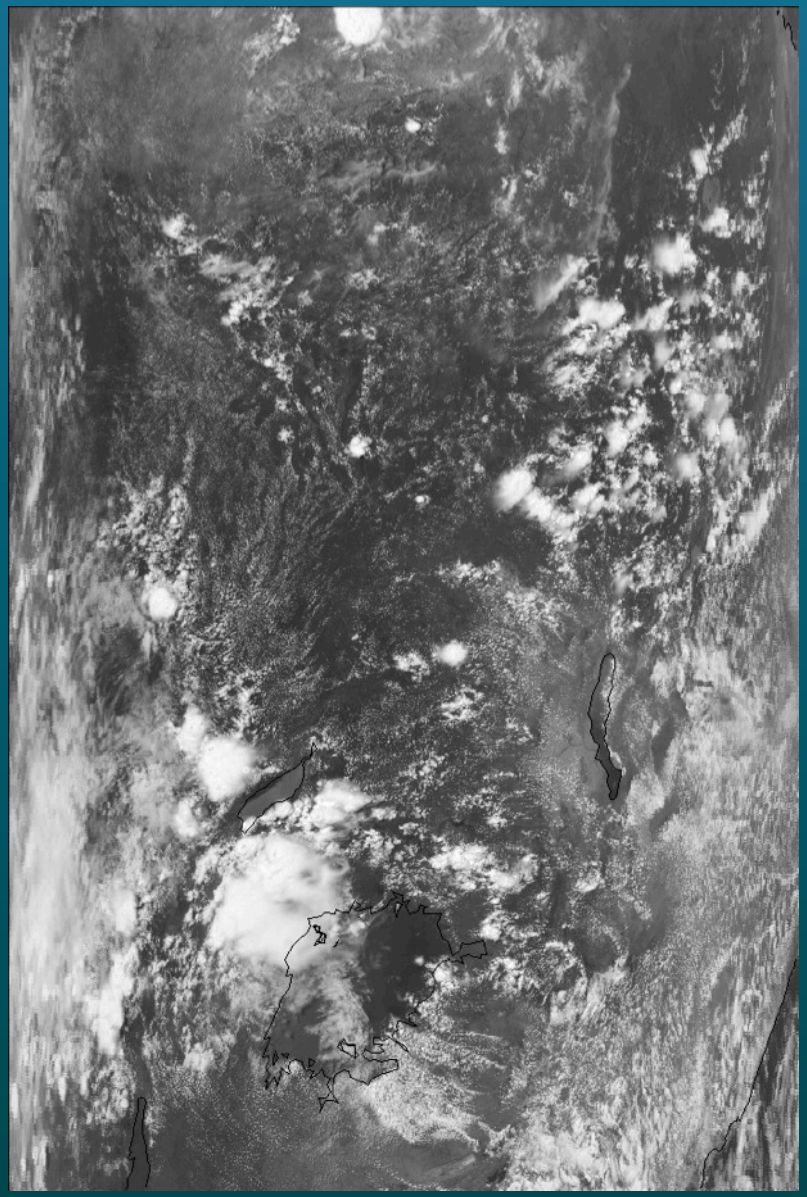
- Inclusion of thresholds based on NDVI background maps
- BT11-BT3.9 threshold a function of TPW

Use of NDVI Background Maps

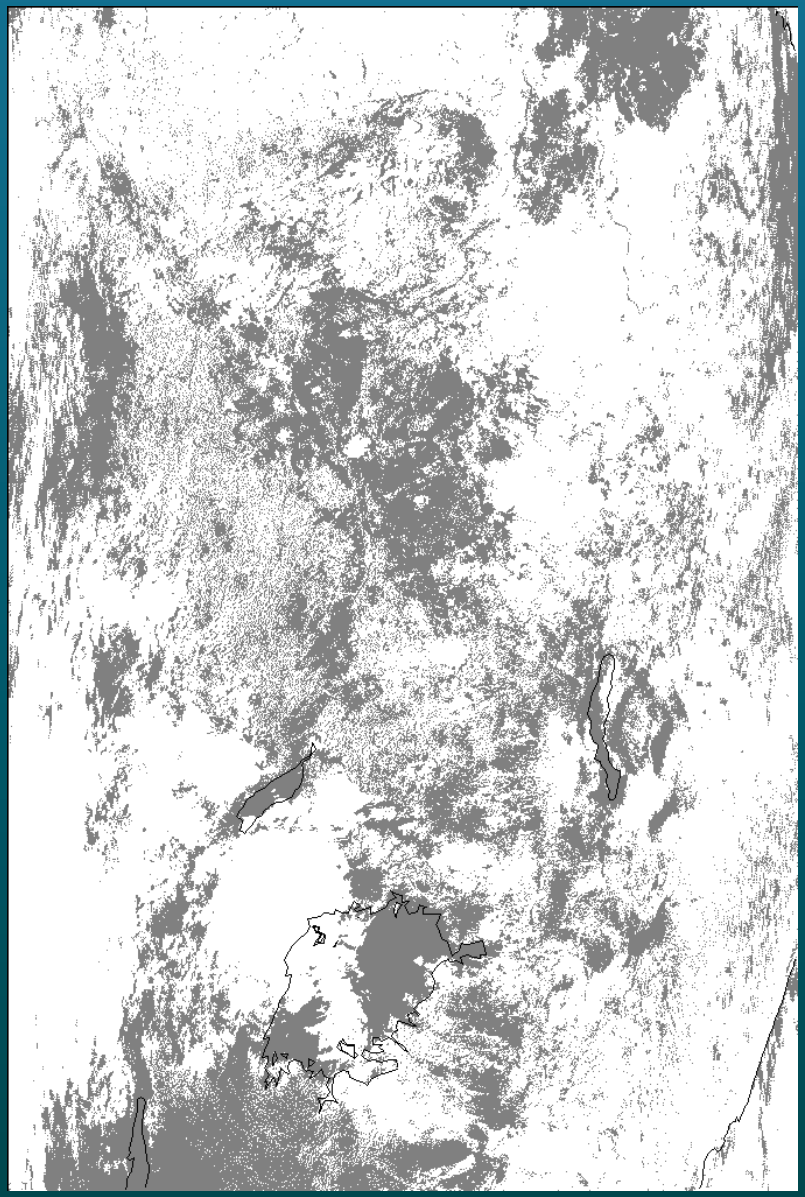


Greatly reduces the fraction of pixels processed as “desert” (NDVI < 0.3).
Reduces the frequency of clear-sky restorals.
Decreases numbers of “probably clear” results in vegetated regions under conditions of clear skies through better 0.67 µm test thresholds.
Biggest improvement is discrimination between surface and low-level cumulus

Use of NDVI Background Maps



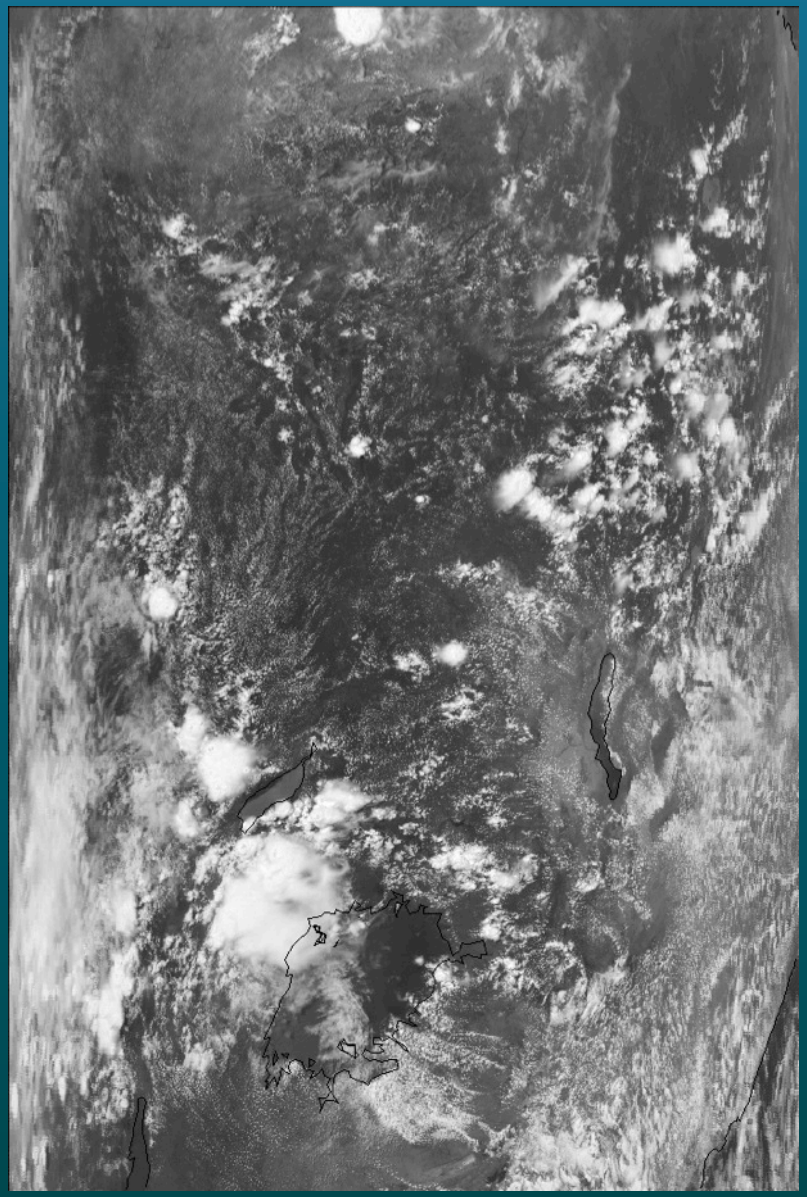
MODIS Band 1



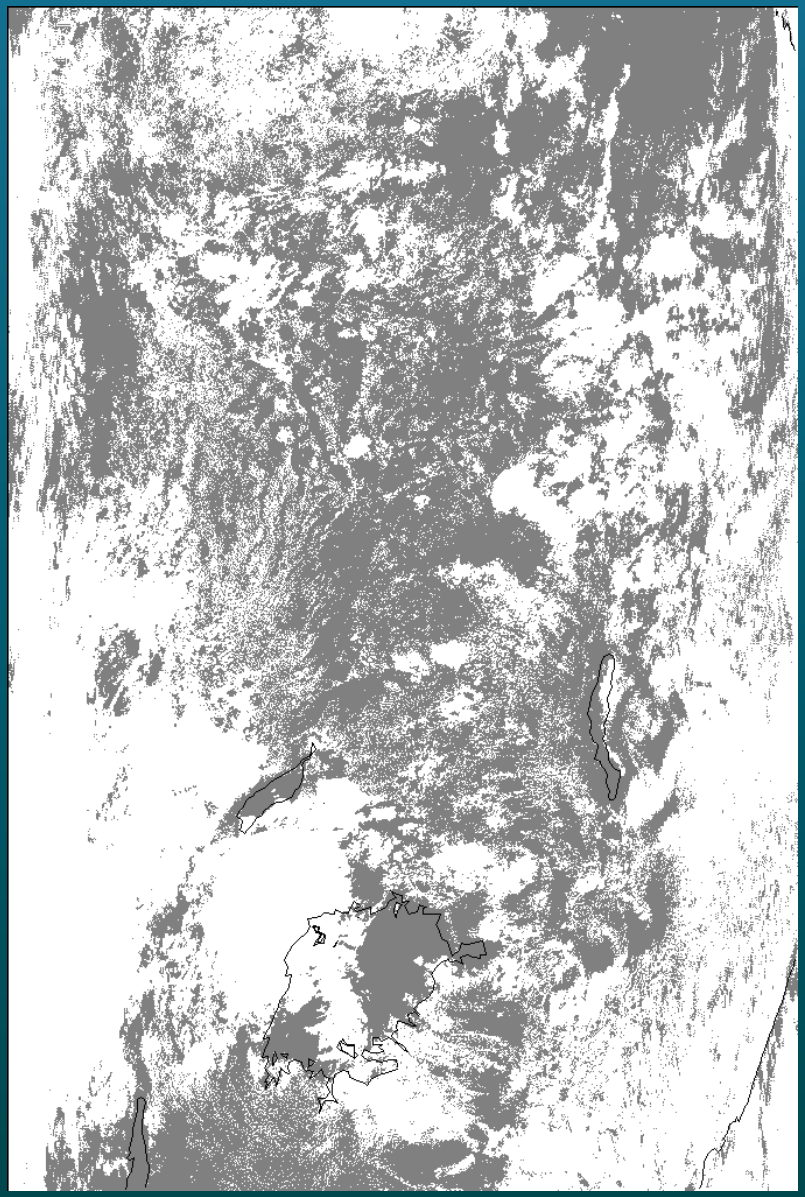
Collection 5 Visible Cloud Test

Aqua MODIS 2006240 at 11:20 UTC

Use of NDVI Background Maps

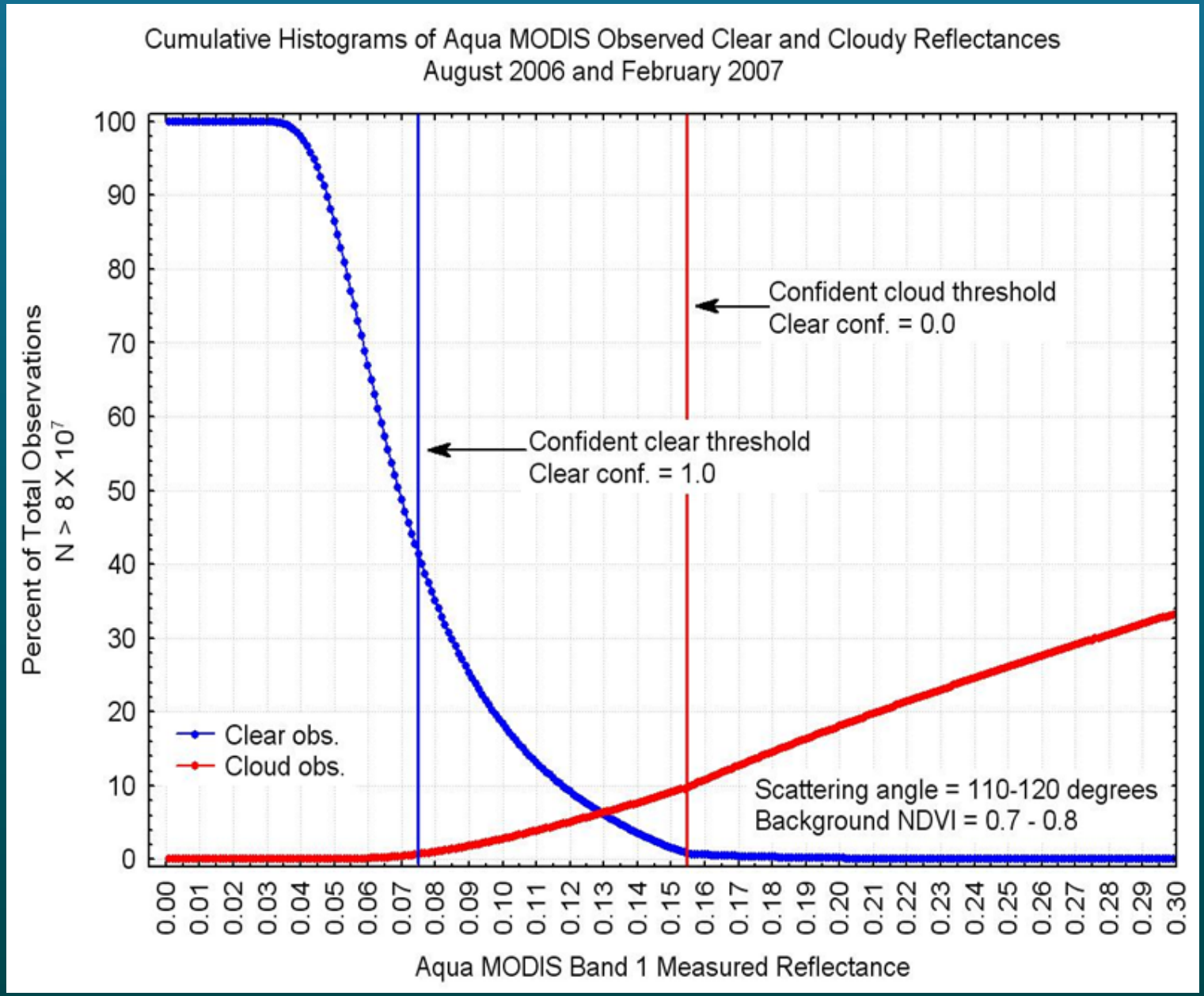


MODIS Band 1



Collection 6 Visible Cloud Test

Aqua MODIS 2006240 at 11:20 UTC



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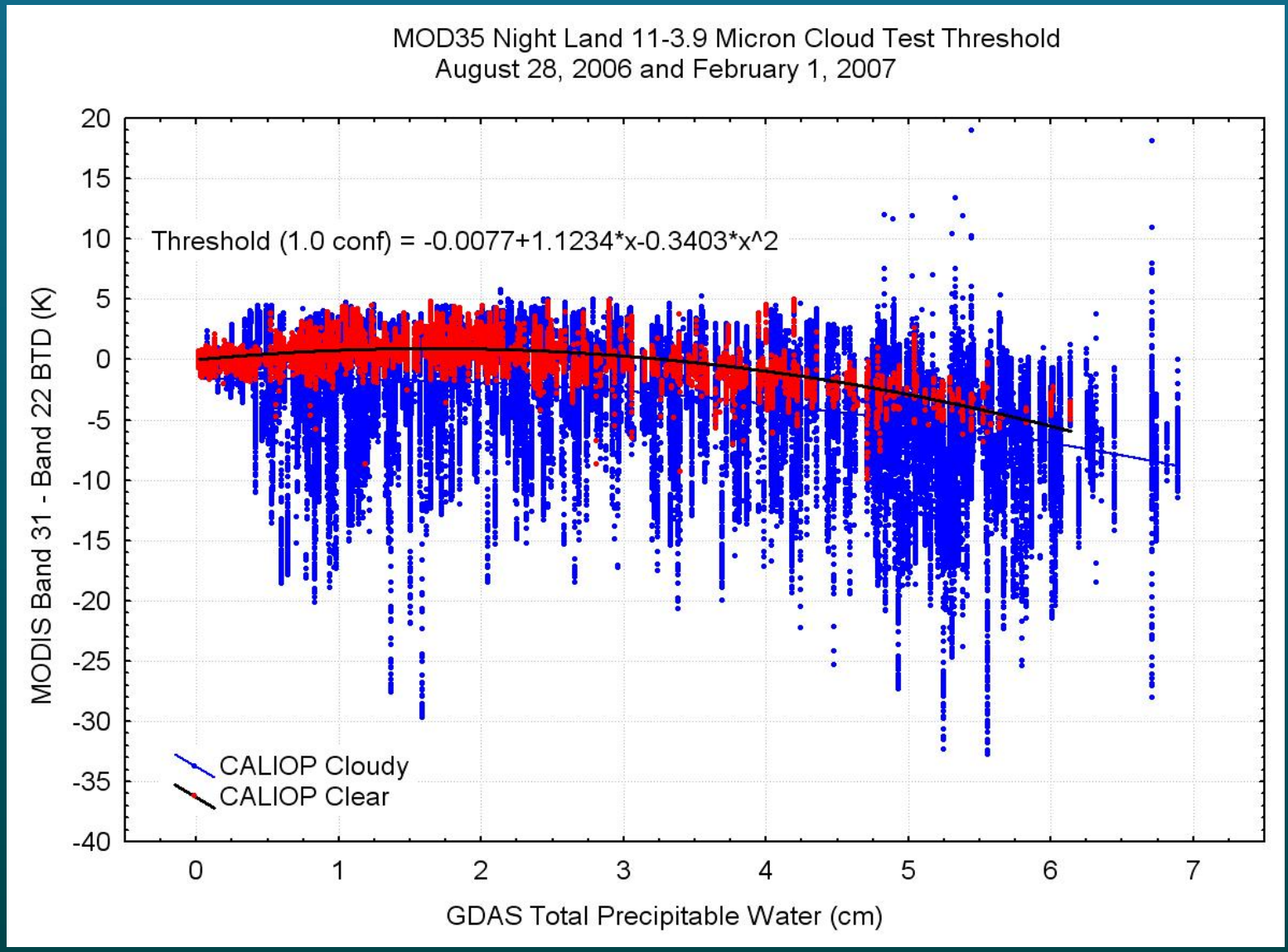
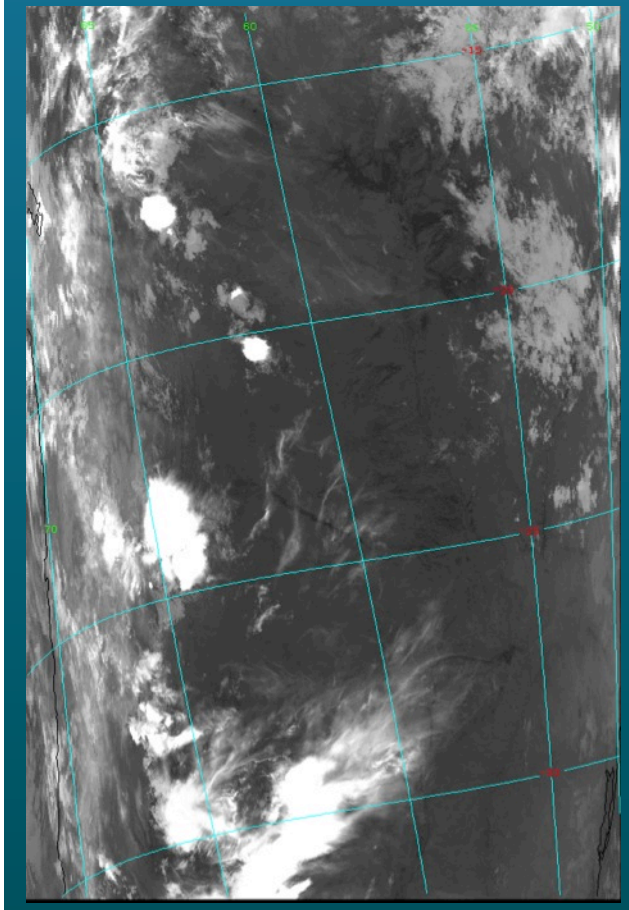
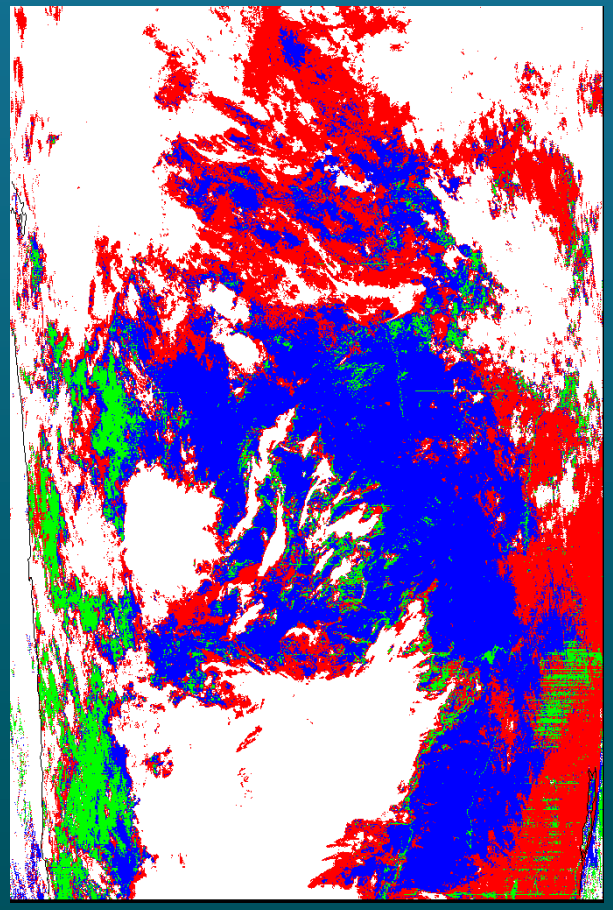
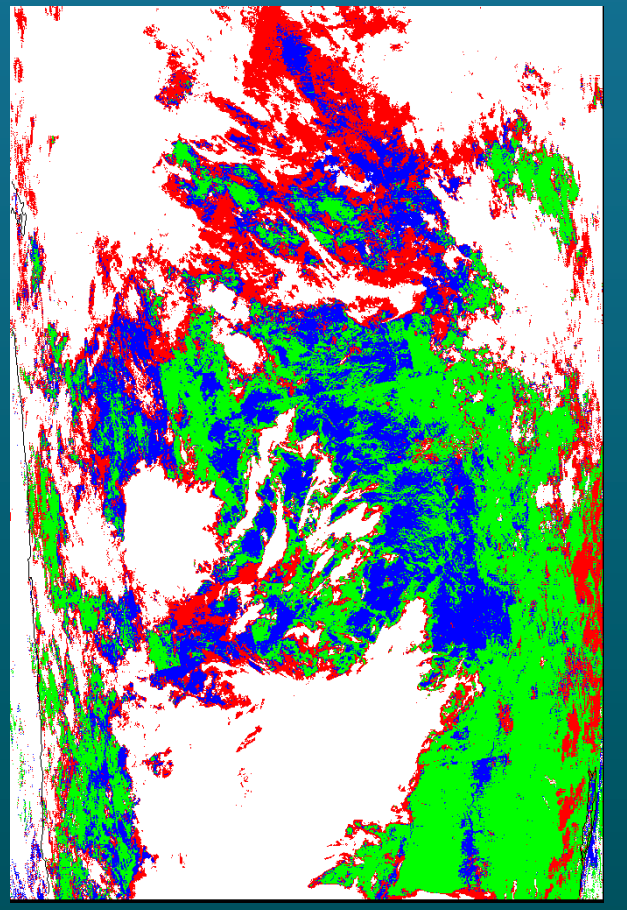
Use of TPW-Dependent 11-3.9 µm BTD Thresholds









Reduces number of “probably cloudy” and “probably clear” results in nighttime clear sky conditions especially in humid tropical locations such as the Amazon Basin (above). Better discrimination between clear and cloudy skies.

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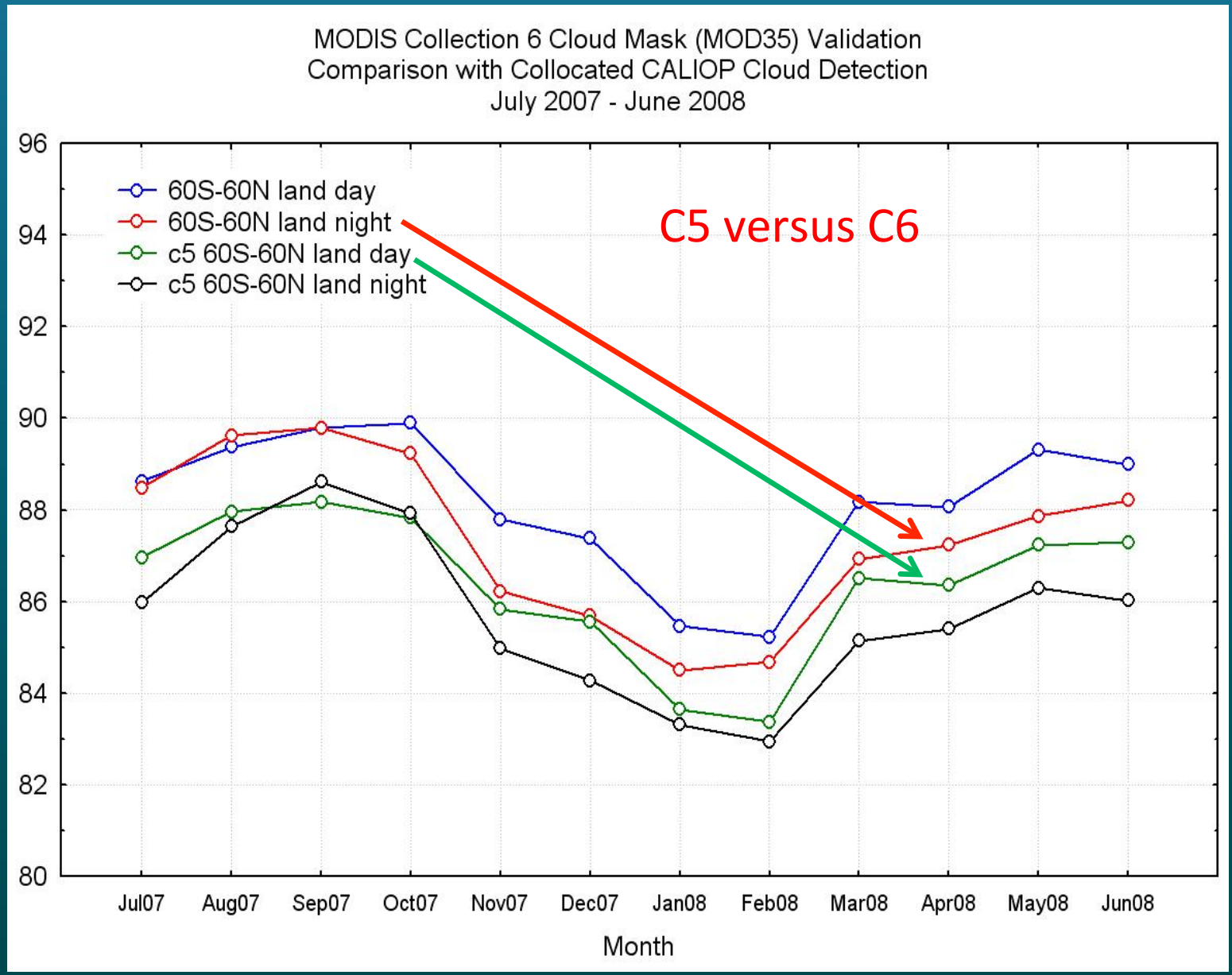

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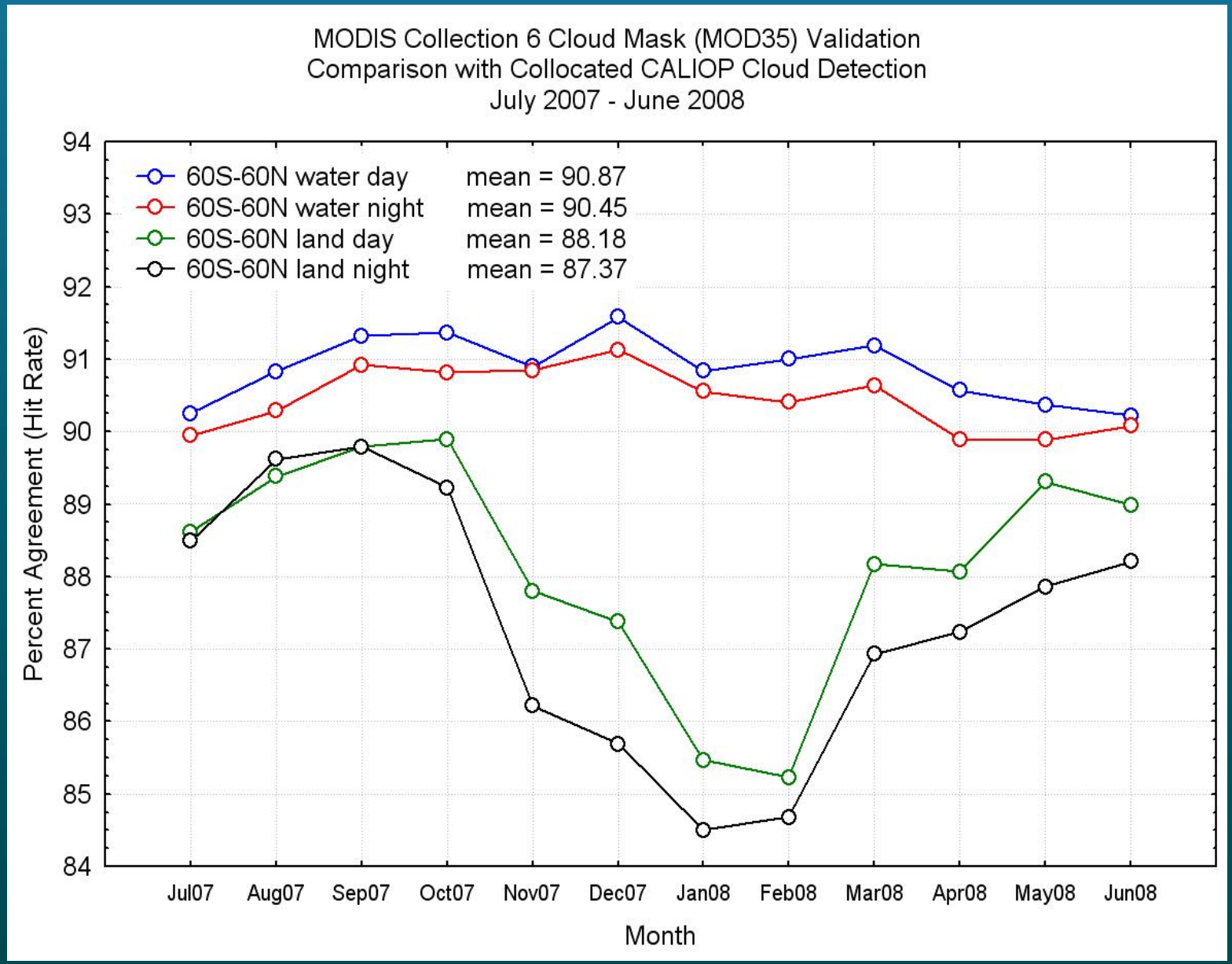

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Cloud Mask Summary

- C6 night time over land has a better hit rate (in comparison to CALIOP) than C5 daytime land.
- Day and Night global cloud amount are similar
- From a user: *“My initial exploration of the C6 MOD35 is that the land cover 'bias' is significantly reduced in my test region of Venezuela. In fact, the proportion of "cloudy" days has decreased by >20% in some parts of the region in some months. “*

IR Phase Modifications for Collection 6

Collection 5:

-- Based on 8.5/11-micron brightness temperatures and their differences
-- Provided only at 5-km resolution

Collection 6:

--Supplement BT/BTD tests with emissivity ratios (β ratio)
-- β ratios are based on 7.3, 8.5, 11, 12-micron bands
-- Use of β ratio mitigates influence of the surface
-- Approach imposes new requirements:
- clear-sky radiances, which implies knowledge of…
- atmospheric profiles, surface emissivity, and a fast RT model

This RT capability is provided in a local software package (LEOCAT) but not in the older software used for 5-km products. As a result, this approach can be implemented for only the 1-km products

The Beta ratio is based on cloud emissivity profiles

A cloud emissivity profile for a single band:

$$e(p) = \frac{(I - I_{clr})}{[I_{ac}(p) + T_{ac}(p) I_{bb}(p) - I_{clr})]}$$

where
I_{clr} = clear-sky radiance
$I_{ac}(p)$ = above cloud emission at pressure p
$I_{bb}(p)$ = TOA radiance for opaque cloud at pressure p
$T_{ac}(p)$= above cloud transmission

$$b_{x,y}(p) = \frac{\ln[1-e_{c,y}(p)]}{\ln[1-e_{c,x}(p)]}$$

where x and y are two channels used to compute the ratio

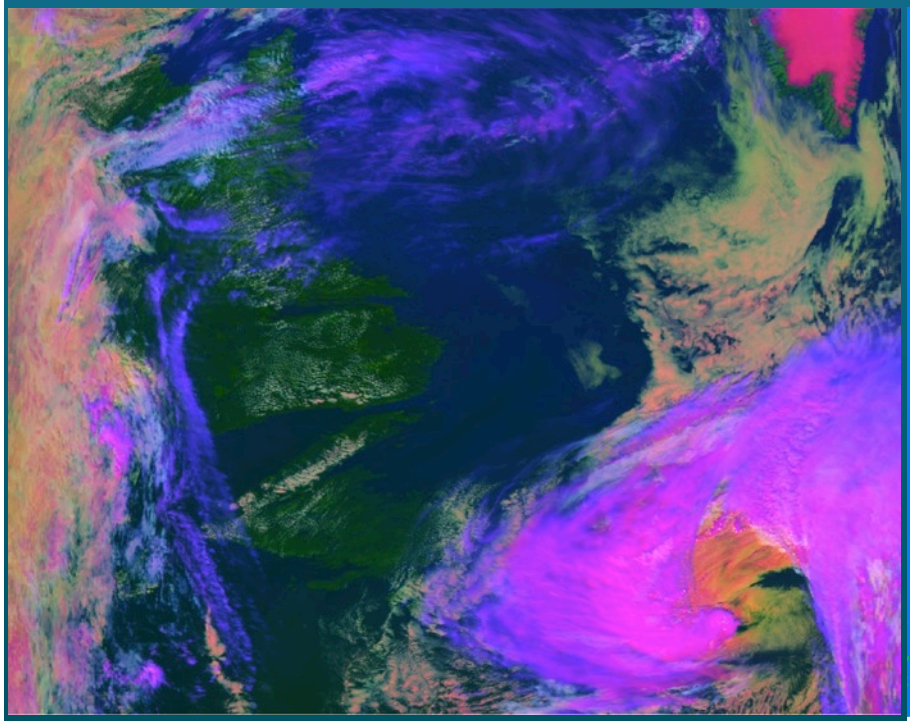
Beta ratios used for C6 IR phase tests

8.5/11: has the most sensitivity to cloud phase

11/12: sensitive to cloud opacity; implementation of this pair helps with optically thin clouds (improves phase discrimination for thin cirrus)

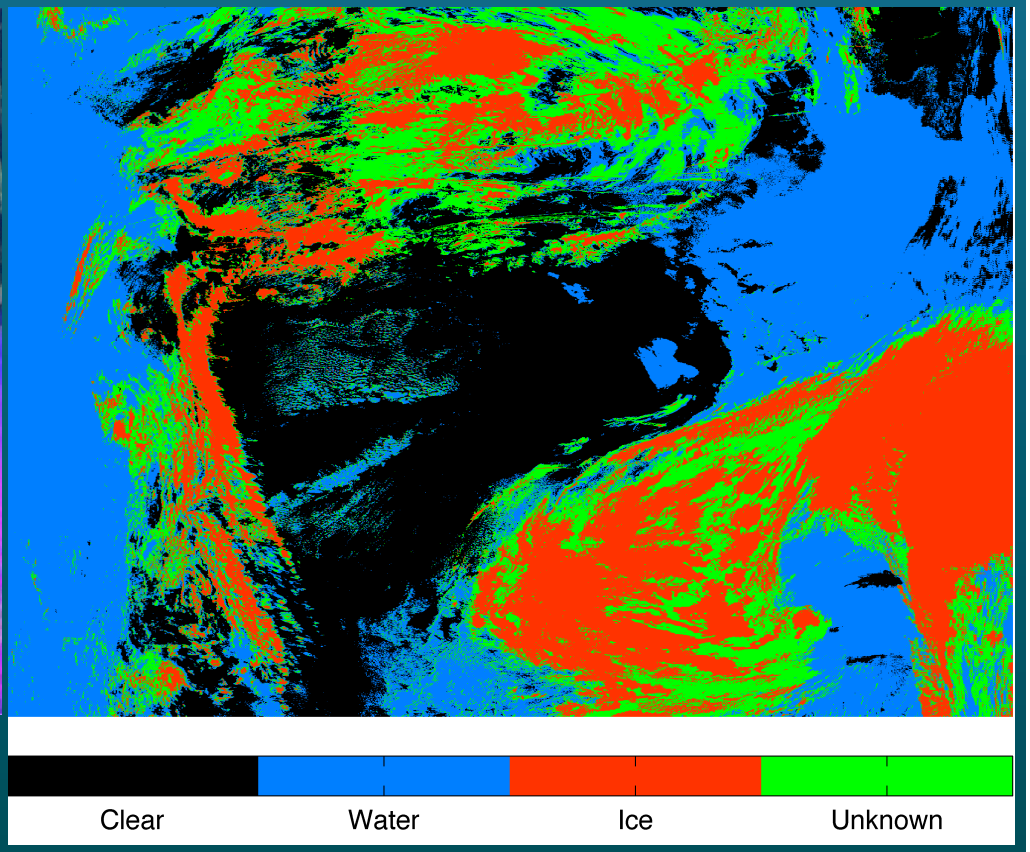
7.3/11: sensitive to high versus low clouds; helps with low clouds (one of the issues was a tendency for low-level water clouds to be ringed with ice clouds as the cloud thinned out near the edges)

MODIS IR Phase for a granule on 28 August, 2006 at 1630 UTC Over N. Atlantic Ocean between Newfoundland and Greenland



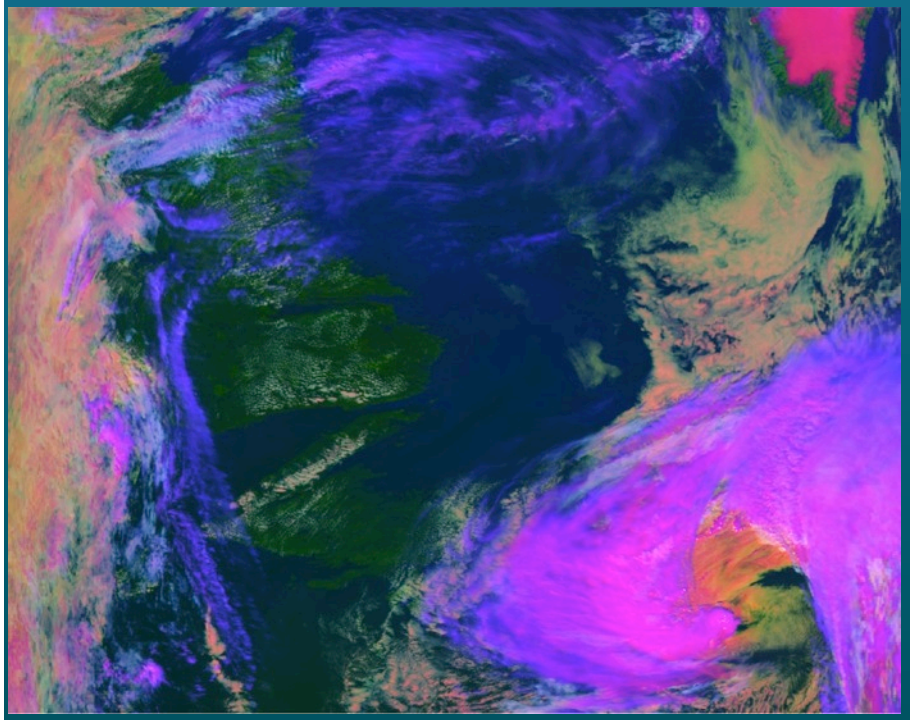
False color image
Red: 0.65 μ m; Green: 2.1 μm; Blue: 11 μ m

Thin cirrus: blue
Opaque ice clouds: pink
Water clouds: white/yellow
Snow/ice: magenta (Southern tip of Greenland)
Ocean: dark blue
Land: green

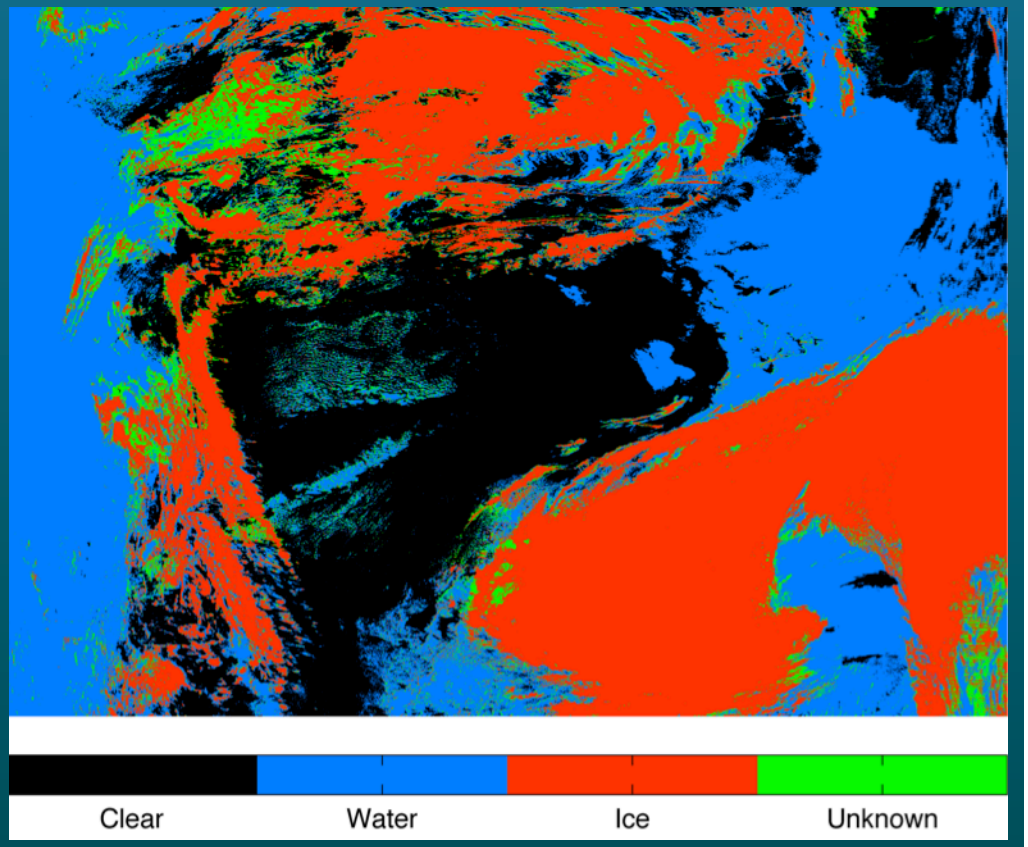


Collection 5 algorithm but with uncertain and mixed phase pixels combined into "uncertain" category

MODIS IR Phase for a granule on 28 August, 2006 at 1630 UTC Over N. Atlantic Ocean between Newfoundland and Greenland



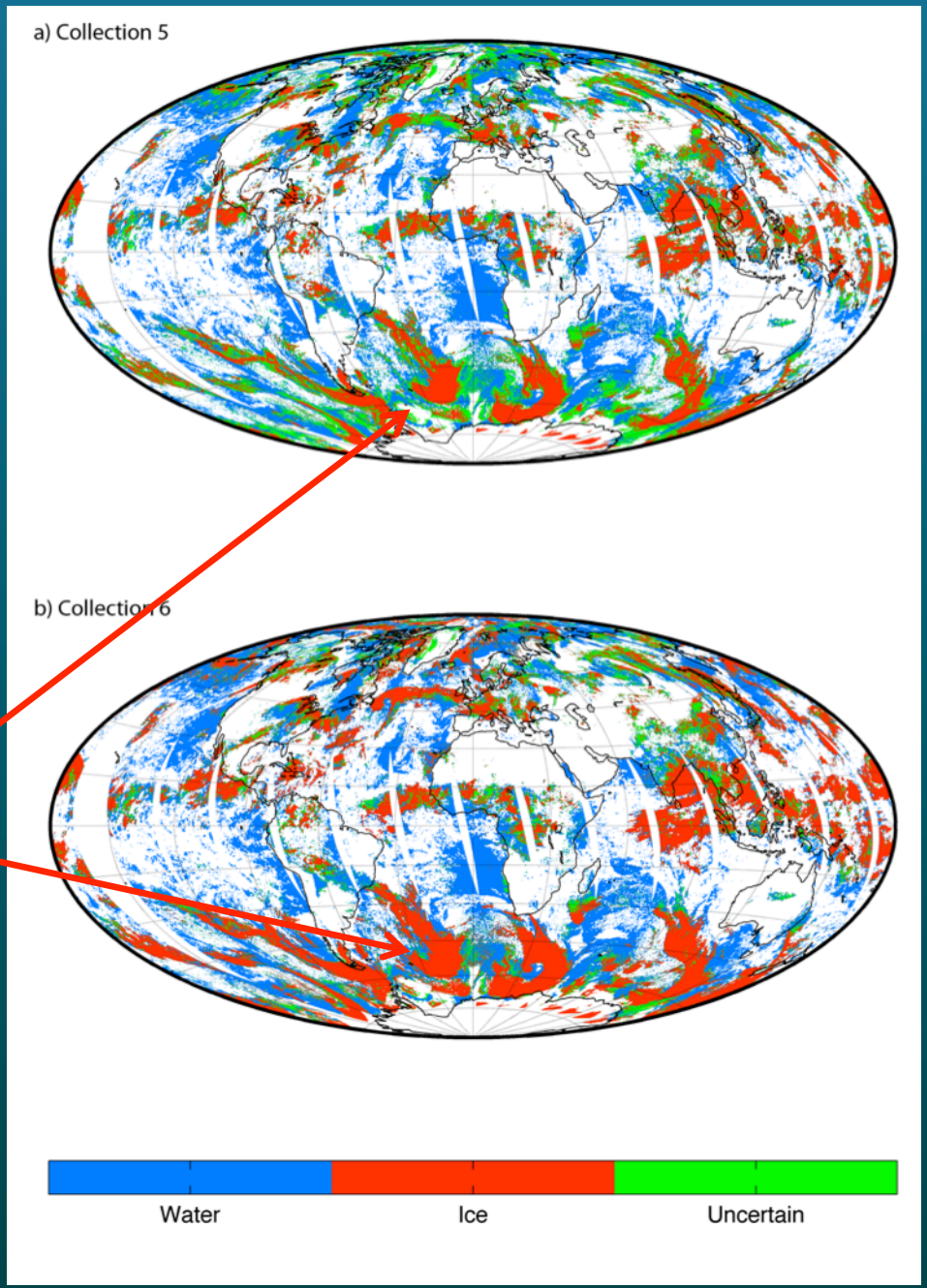
False color image
Red: 0.65 μm; Green: 2.1 μm; Blue: 11 μm



Collection 6 algorithm:
Propose 3 categories, deleting mixed phase since there is no justification for this category

C5 (top) versus C6 (bottom) cloud phase comparison

(less uncertain)



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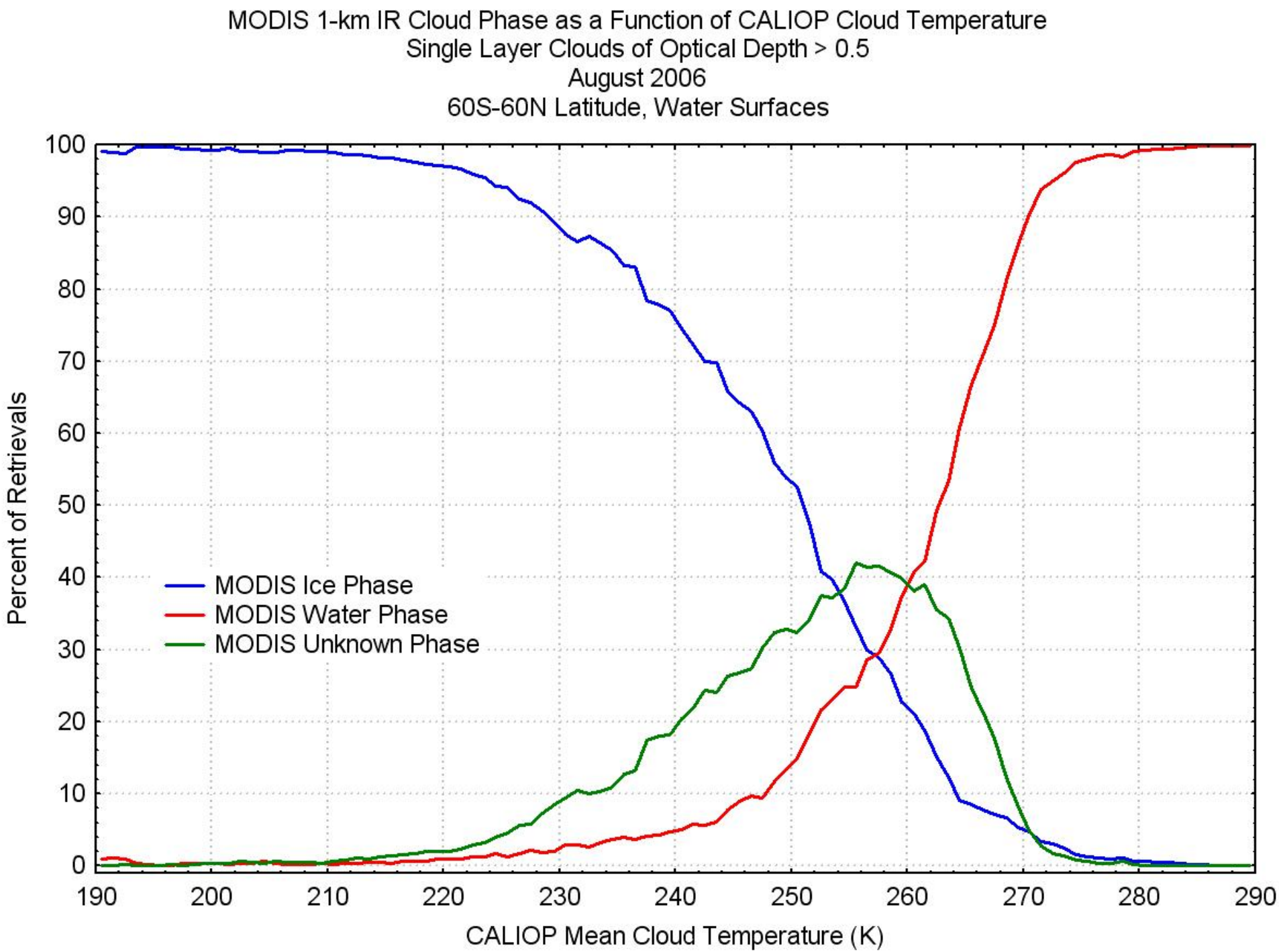
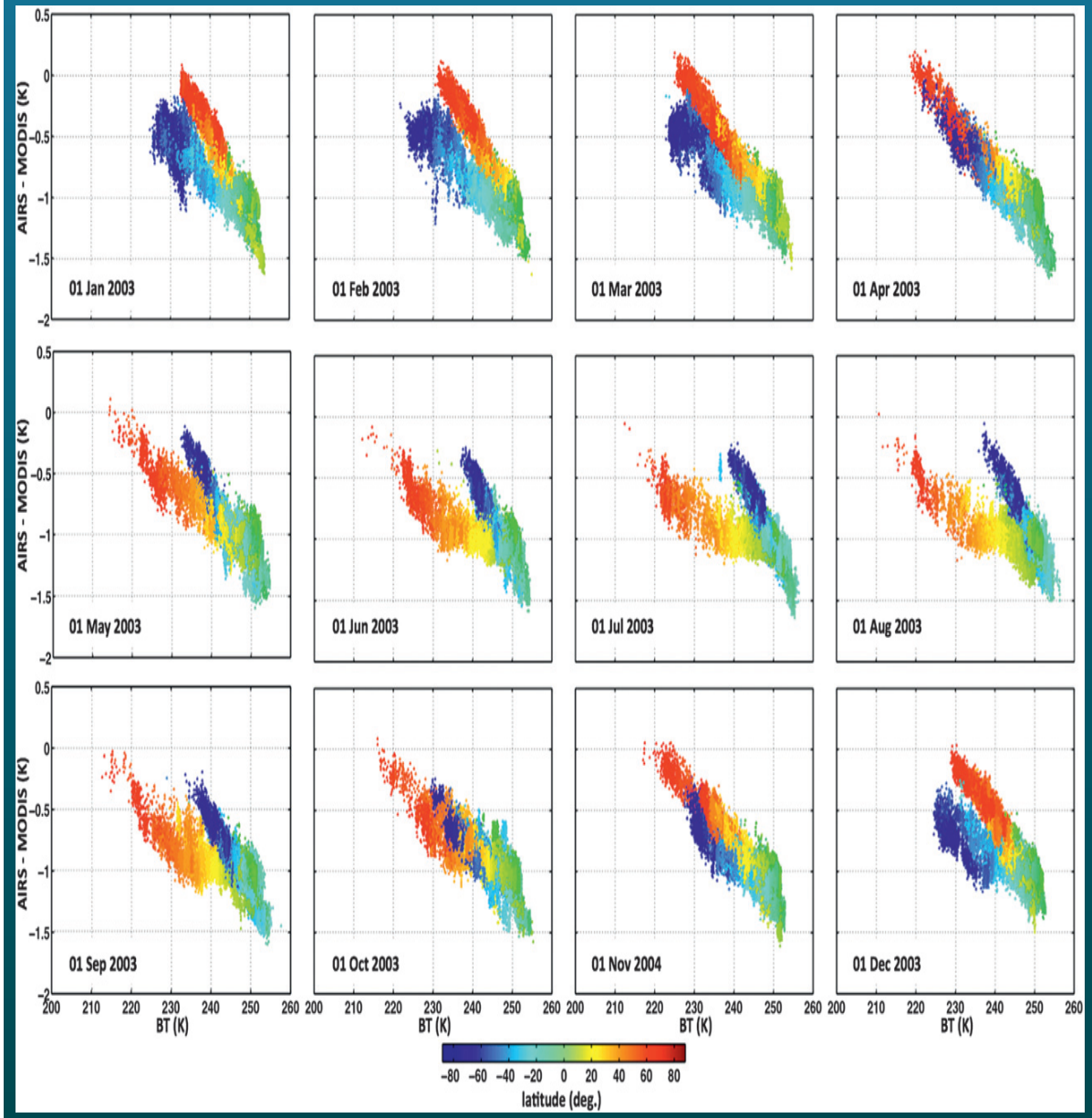

MODIS 1-km IR Cloud Phase as a Function of CALIOP Cloud Temperature
Single Layer Clouds of Optical Depth > 0.5
August 2006
60S-60N Latitude, Water Surfaces
Percent of Retrievals
CALIOP Mean Cloud Temperature (K)
MODIS Ice Phase
MODIS Water Phase
MODIS Unknown Phase
0
10
20
30
40
50
60
70
80
90
100
190
200
210
220
230
240
250
260
270
280
290

C6 Cloud Top Properties

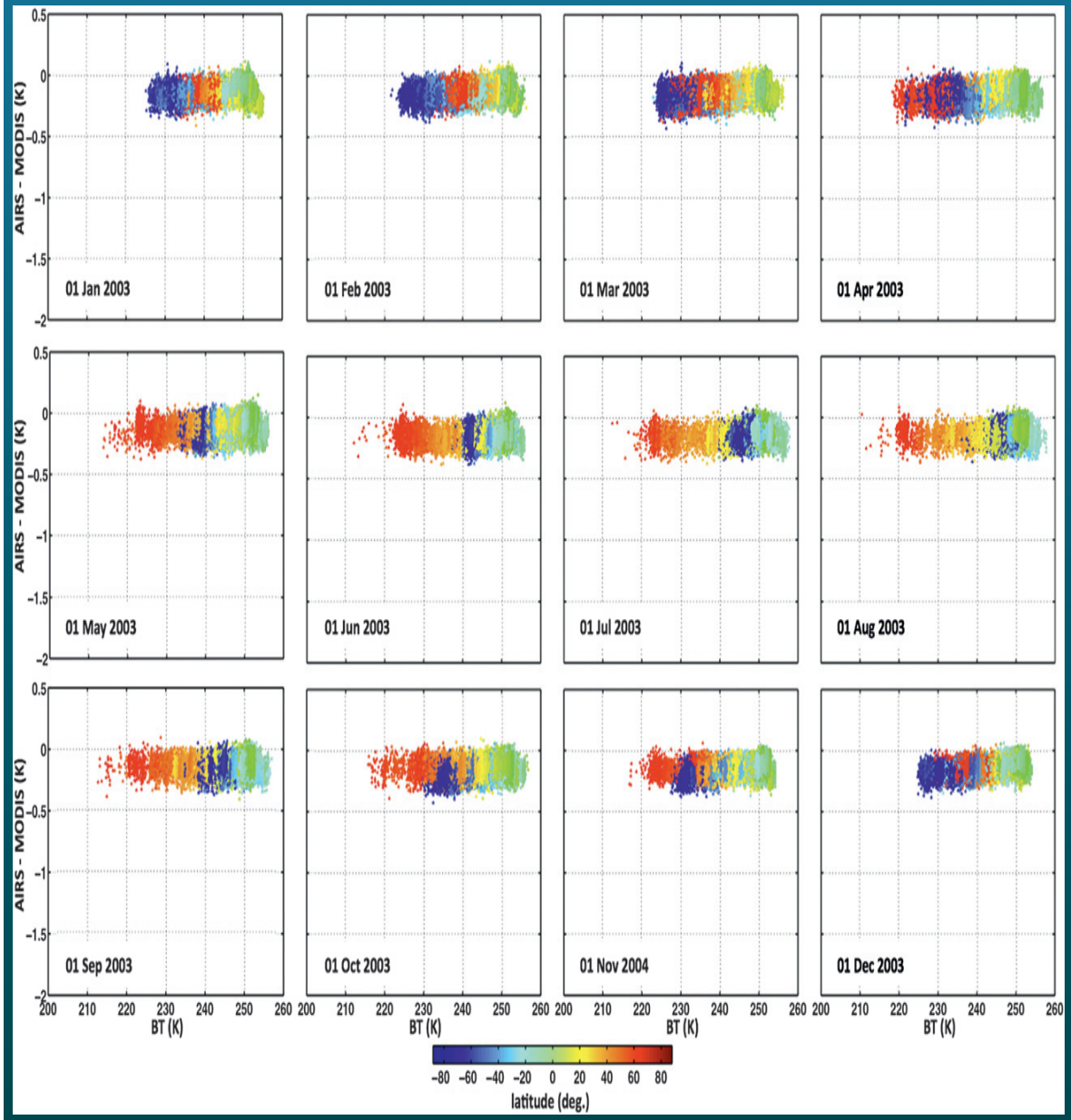
Summary of Changes for Collect 6 (MOD06CT & MYD06CT)

- Lower "noise" thresholds (clear minus cloudy radiances required to indicate cloud presence in CO_2 bands) enabling more CO_2 slicing solutions for high thin clouds.
- Adjust ozone profile between 10 and 100 hPa to GDAS values instead of using climatology (so that CO_2 radiances influenced by O_3 profiles are calculated correctly).
- Prohibit CO_2 slicing solutions for water clouds; use only IRW solution. Avoid IRW solutions for ice clouds; use CO_2 slicing whenever possible.
- Restrict CO_2 channel pair solutions to the appropriate portion of troposphere (determined by CO_2 band weighting functions so 36/35 < 450 hPa, 35/34 < 550 hPa, and 34/33 < 650 hPa).
- Implement CO_2 spectral band shifts suggested by Tobin et al. (JGR 2006) for Terra and Aqua MODIS
- Implement marine stratus improvement where a constant lapse rate is assumed in low level inversions according to latitude region



(AIRS–MODIS) BTDs, calculated with AIRS convolved using unshifted Aqua MODIS SRFs, shown as a function of 11-µm BT. BTDs are color coded with red (blue) points coming from high NH (SH) latitudes

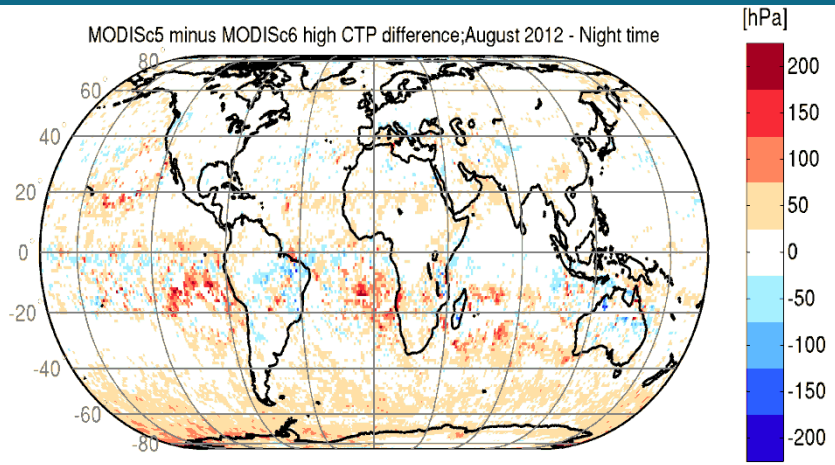
MODIS band 35 (13.9 micron)

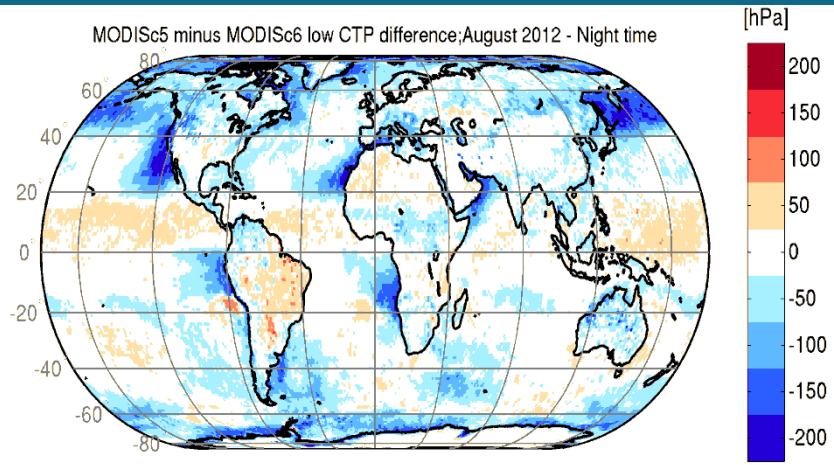


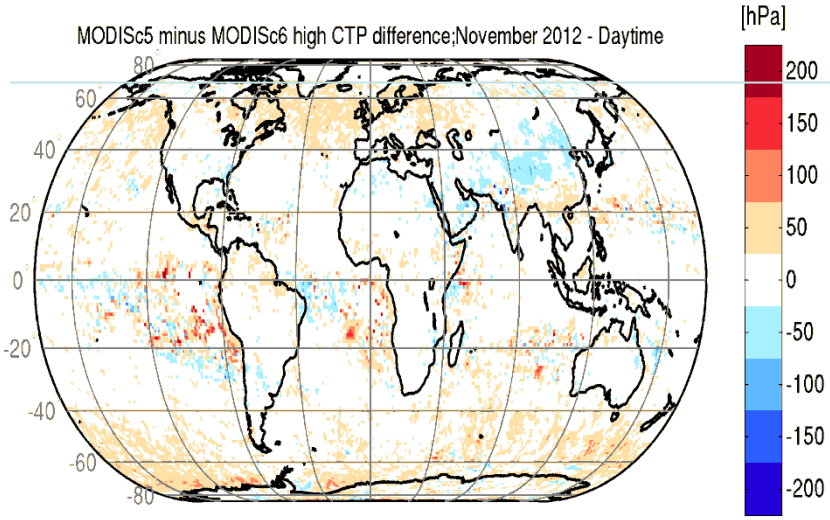
(AIRS–MODIS) BTDs, calculated with AIRS convolved using shifted Aqua MODIS SRFs, shown as a function of 11-µm BT. BTDs are color coded with red (blue) points coming from high NH (SH) latitudes (Baum et al. JAMC 2012).

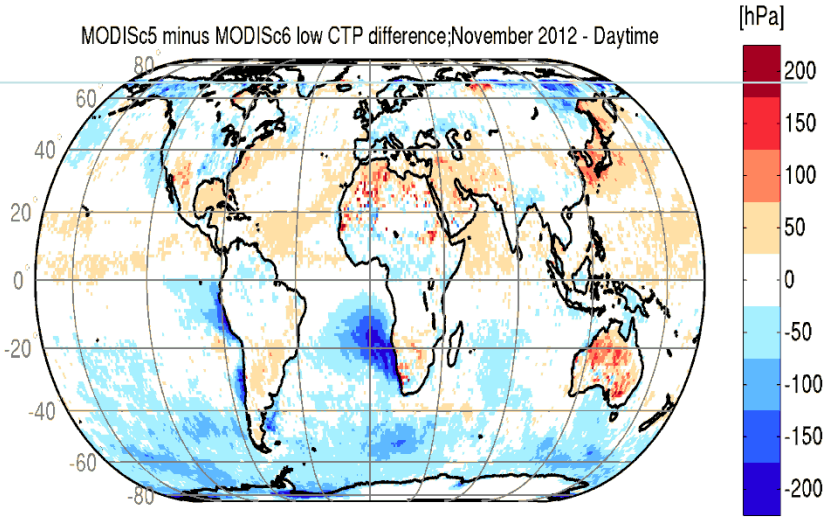
MODIS band 35 (13.9 micron)

Global Distribution of C5 minus C6 CTP Differences



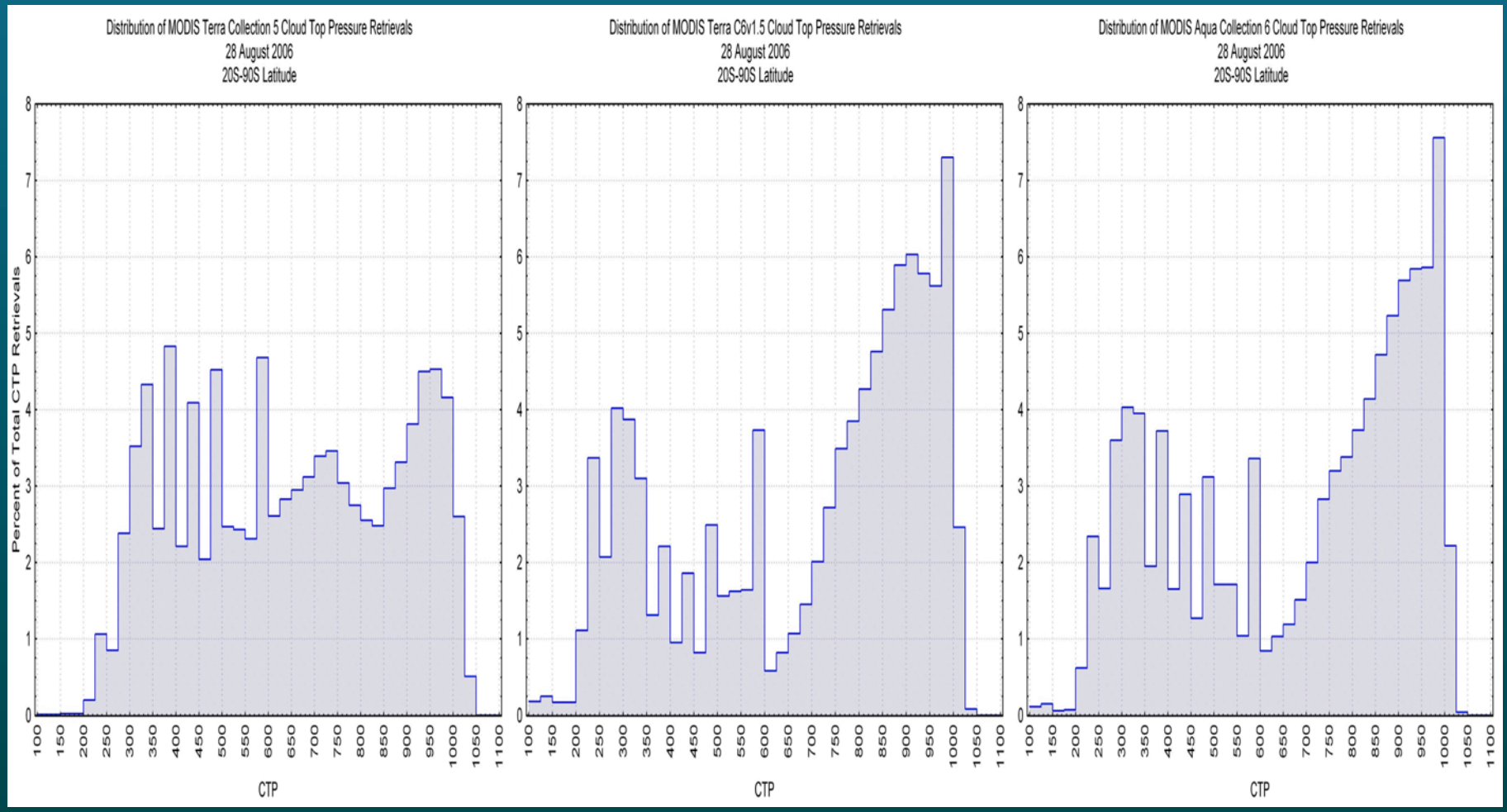






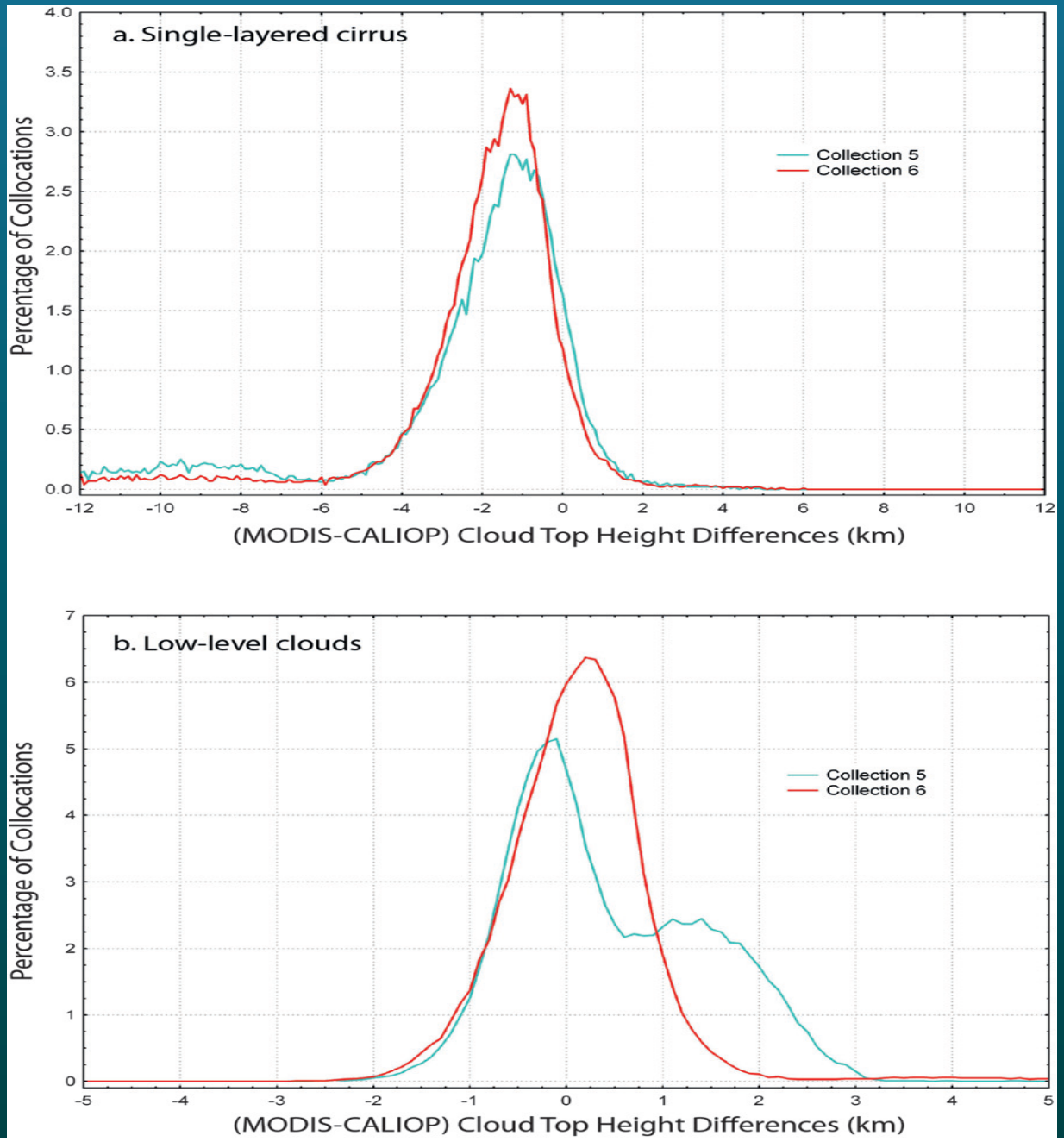
Vertical Distribution of Terra and Aqua Clouds Comes Into Agreement

Vertical distribution of clouds in latitude bands (90S-20S, 20˚S-20˚N, and 20˚N–90˚N) for 28 August 2006 show closer agreement for Terra and Aqua with C6 algorithm changes.



Terra C5 (left) & C6 (middle) along with Aqua C6 (right) results for 90˚S-20˚S

Comparisons with CALIOP Confirm C6 Improvements



Aqua
August 2006

Collect 6 CTP improvements

- Spectral shifts reduce the radiance bias for Terra
- CO_2 slicing is used more often so that CTP is decreased for high clouds
- Marine stratus cloud CTPs are increased
- Vertical distributions of Terra and Aqua CTPs show better agreement
- Consistency with IR phase

Collection 6 MOD07 AP Products

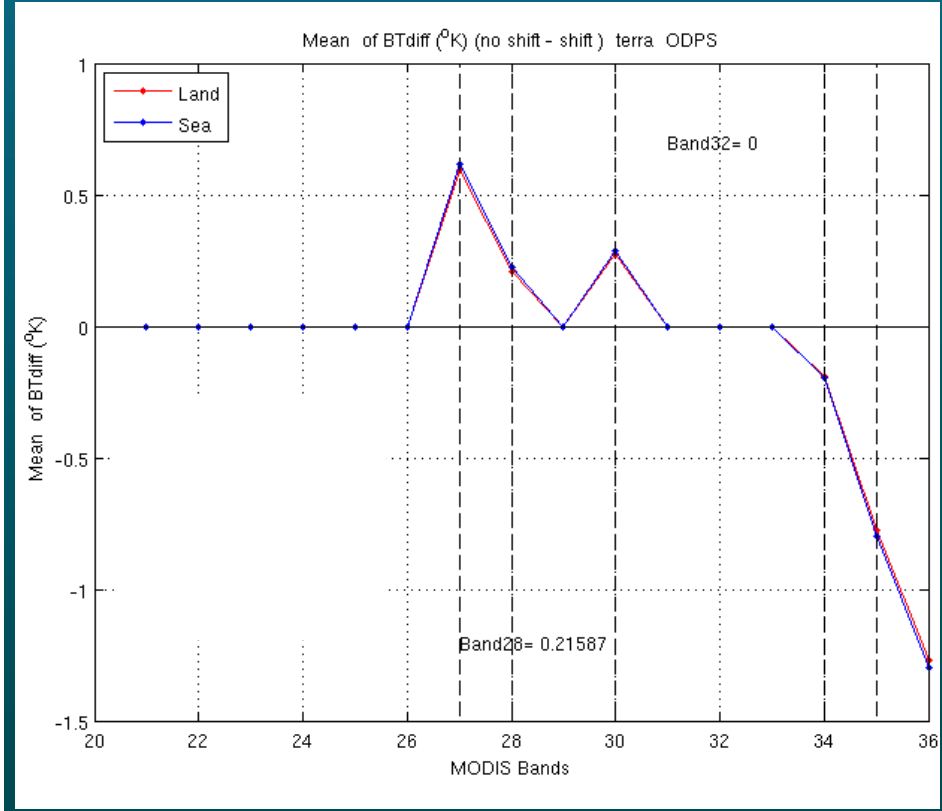
Main updates:

- Forward Model Update (CRTM V2.0.2 / ODPS for Terra / CRTM 1.2/ODAS for Aqua). Update surface
- H2O/CO2/O3 spectral band SRF by IASI-MODIS comparison study (Tobin, M were implemented in the FM calculation t **TOZ biases**
- Make the Aqua and Terra DAAC code unifo
- Modify definition of 3 layer water vapor me are: (Low) sfc-680 and (high) 440-Top (10h
- Improve QA/QC flags & QA usefulness and bug
- Update output file: adding offset/sca pressure levels, mixing ratio profile, fixing K changing surface temperature to skin temp

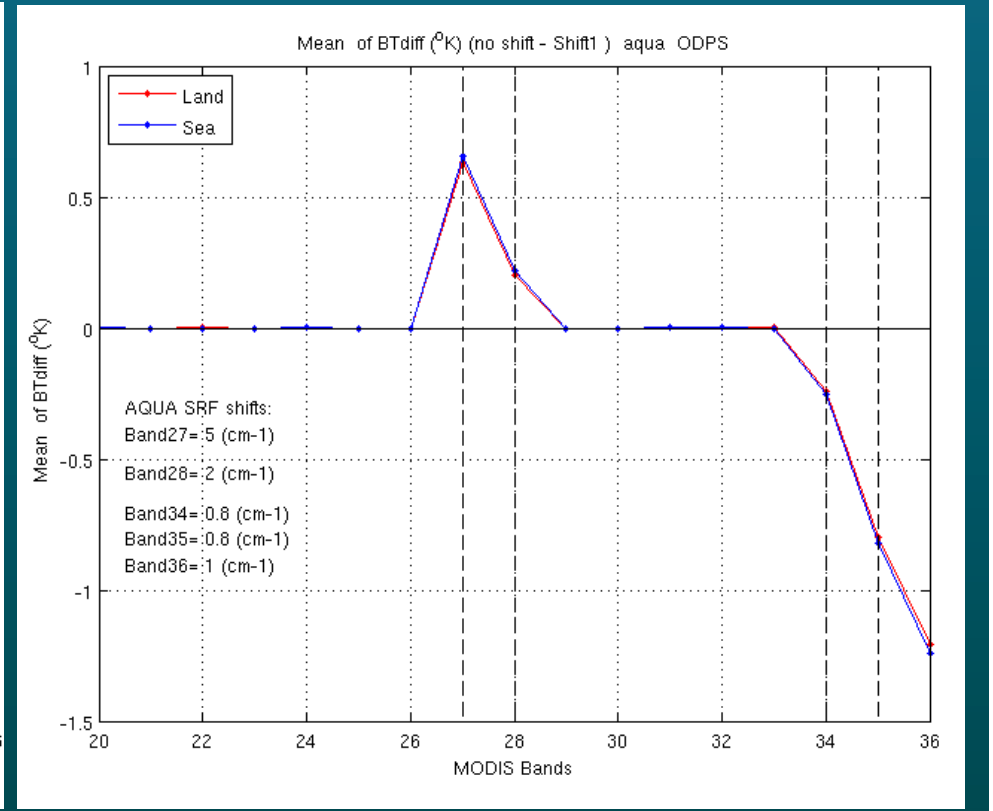
Band	Terra Shift (cm-1)	Aqua Shift (cm-1)
27 (H2O)	4	5
28 (H2O)	2	2
30 (O3)	1	0
34 (CO2)	0.8	0.8
35 (CO2)	0.8	0.8
36 (CO2)	1	1

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

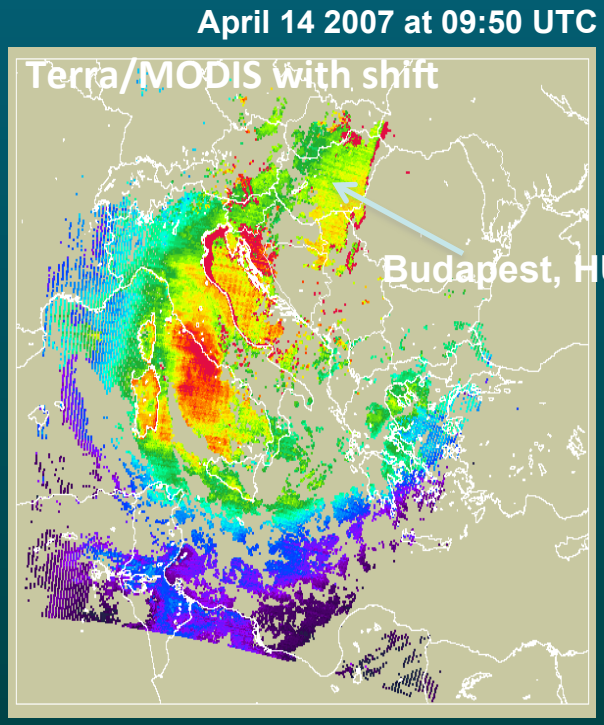
Terra

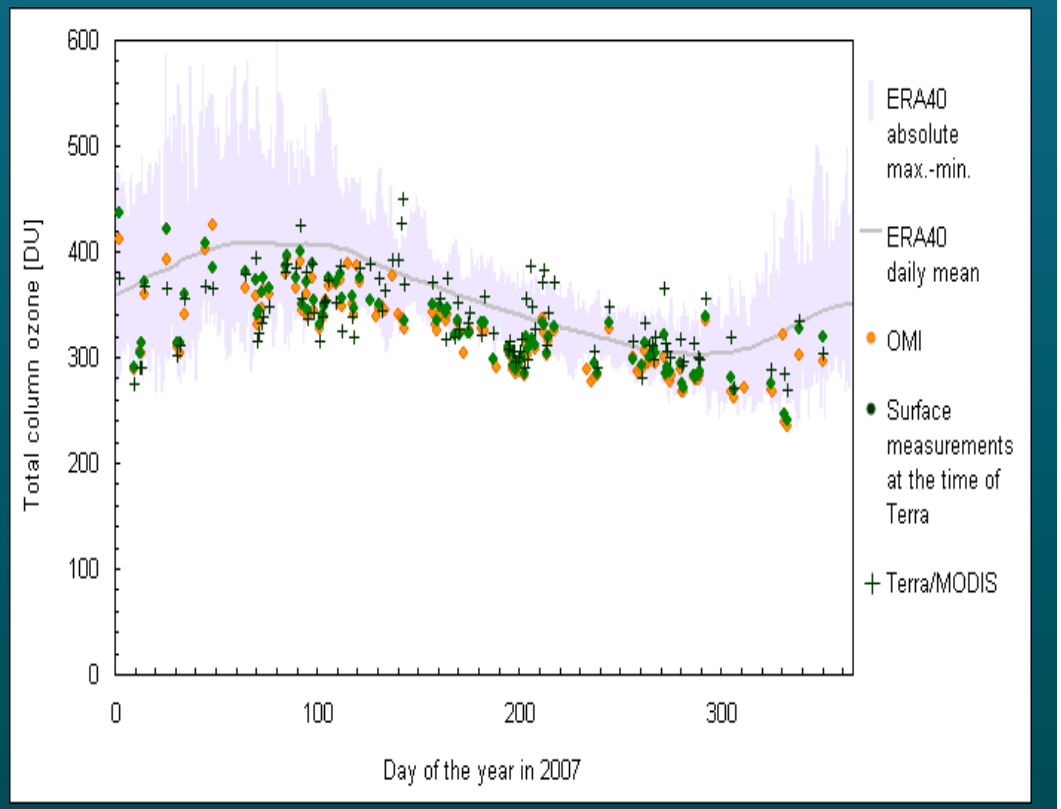


Aqua



The impact of the Terra H2O/CO2/O3 channel spectral shifts on MOD07 TOZ over Budapest, HU over 2007: Comparison with ground-based Brewer Spectrophotometer measurements





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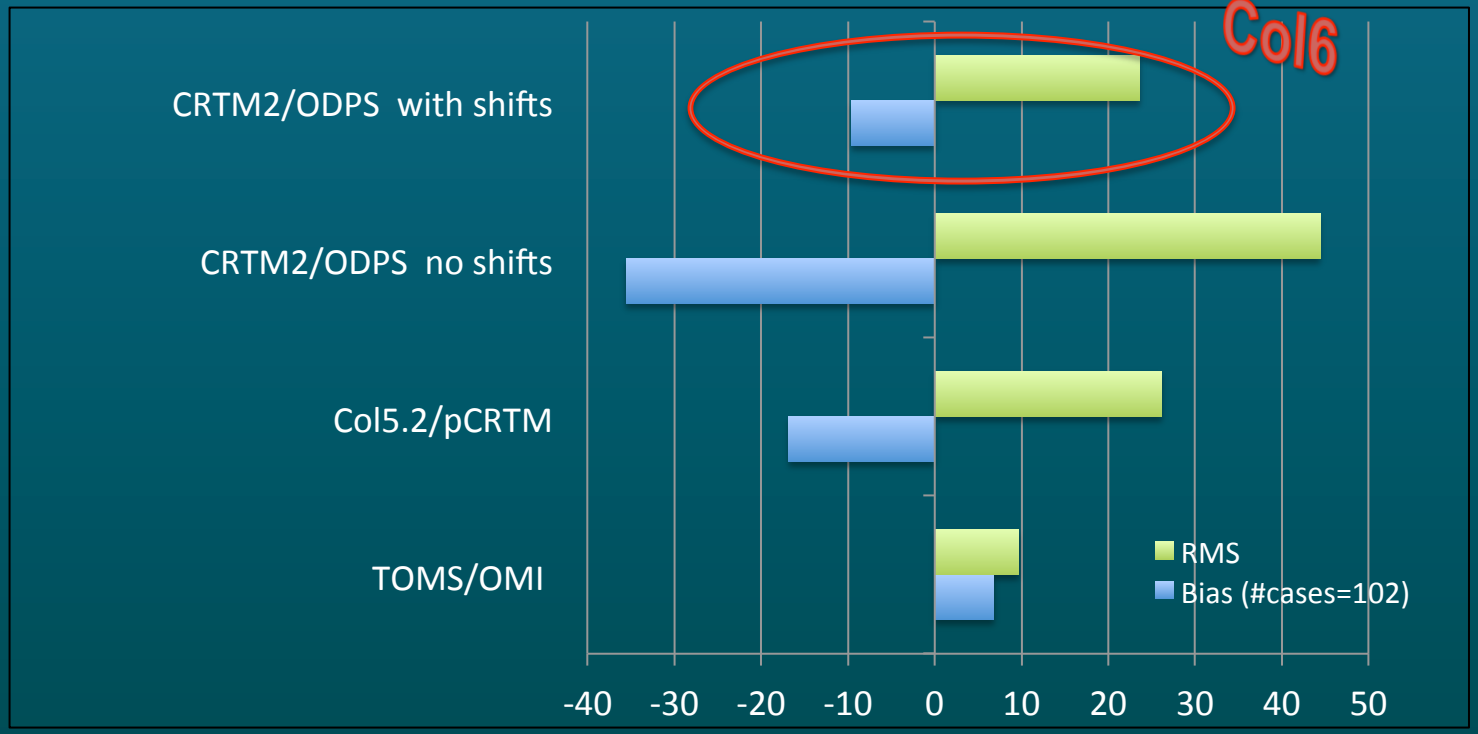


The impact of the Terra H2O/CO2/O3 band spectral shifts on MOD07 TOZ over Budapest, HU for 2007: Comparison with ground-based Brewer Spectrophotometer measurements

Aqua/MYD07 TPW comparison with ground-based observations at the SGP CART site

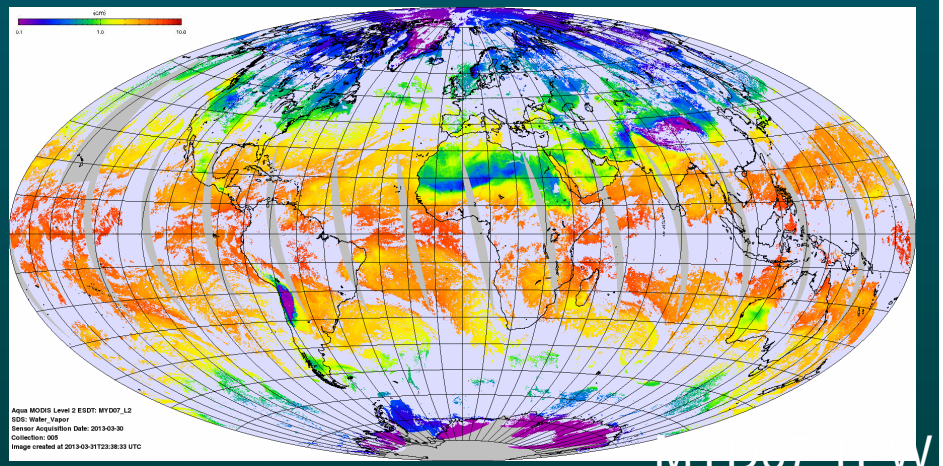
Comparison of total precipitable water (mm) at the ARM SGP site from MODIS, with the ground-based ARM SGP microwave radiometer for 317 clear sky Aqua cases from 4/2001 to 8/2005.

MOD07 Conclusions

TOZ: Overall, application of Terra spectral shifts *reduce bias and rms* for MOD07 TOZ products in both the local (Budapest, Hungary) and global validation studies. The Aqua TOZ is also positively effected on the global scale by the H20/CO2 spectral shifts.

TPW: Application of Aqua spectral shifts (using CRTM V1.2/ODAS) a ***significant positive improvement*** was realized for the Aqua/MODIS TPW over the SGP Cart site by applying the Band 27 & 28 spectral shifts. Comparing to the Col5 product, the bias for the dry and wet cases has been reduced by 1.1mm!

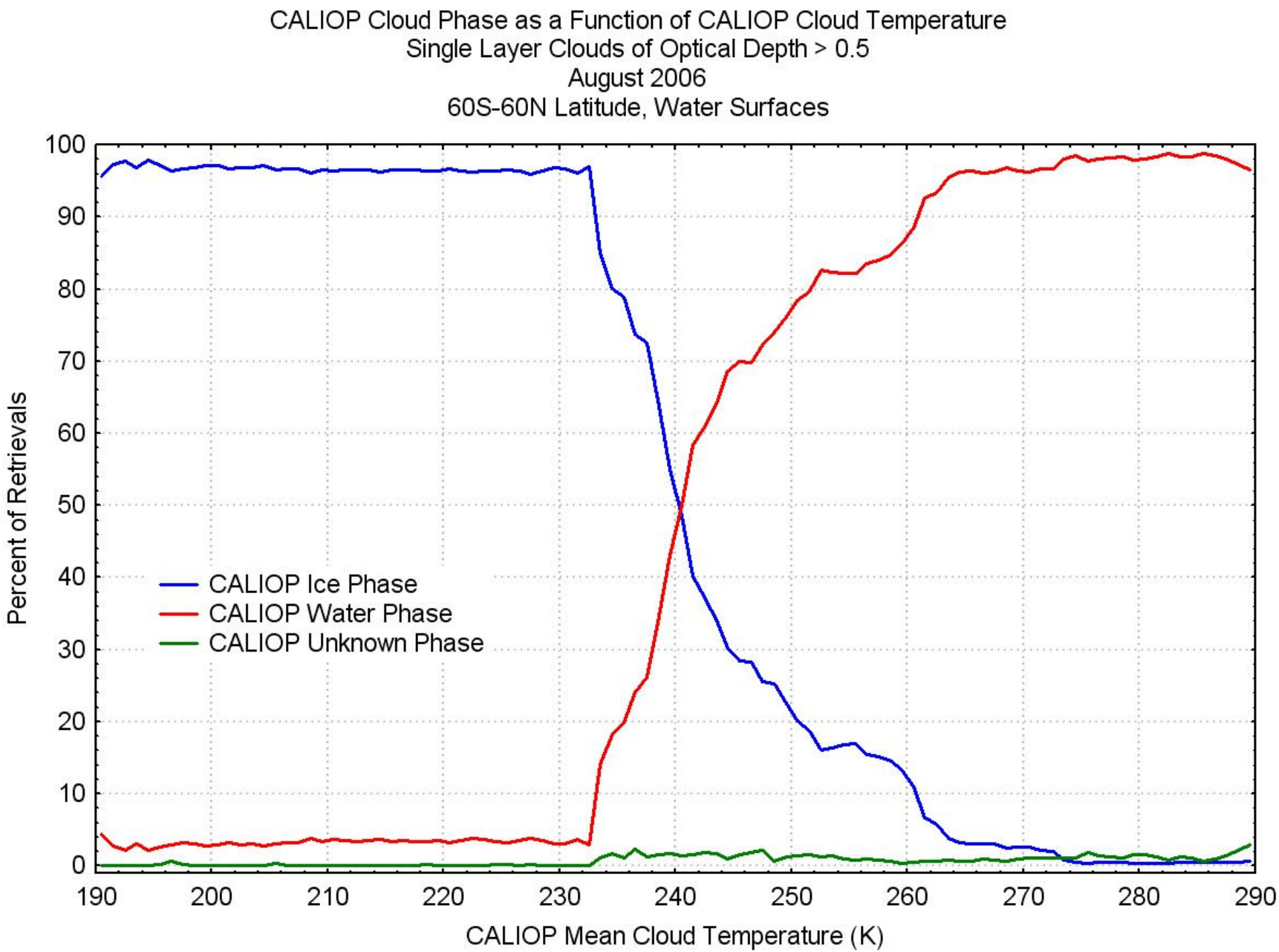
For application of Terra spectral shifts show a positive effect for the dry cases (bias reduced by 0.5 mm), but have a negative effect for the wet and overall cases (0.7 mm bias increase). The overall rms differences are not changed significantly.



Summary

C6 algorithms (cloud mask, IR cloud phase, cloud top and atmospheric profiles) have been updated, improvement has demonstrated and code delivered

BACKUPS


CALIOP Cloud Phase as a Function of CALIOP Cloud Temperature
Single Layer Clouds of Optical Depth > 0.5
August 2006
60S-60N Latitude, Water Surfaces
Percent of Retrievals
CALIOP Mean Cloud Temperature (K)
CALIOP Ice Phase
CALIOP Water Phase
CALIOP Unknown Phase
0
10
20
30
40
50
60
70
80
90
100
190
200
210
220
230
240
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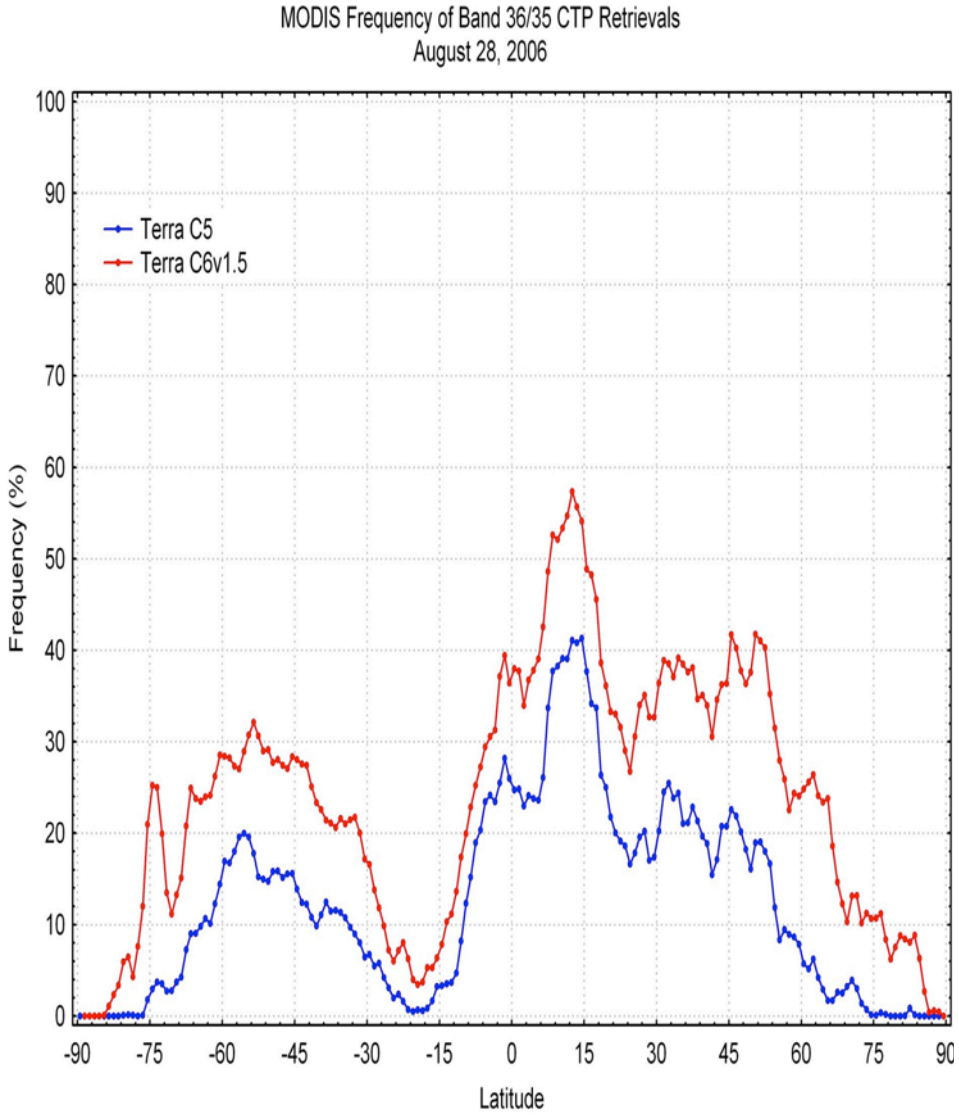
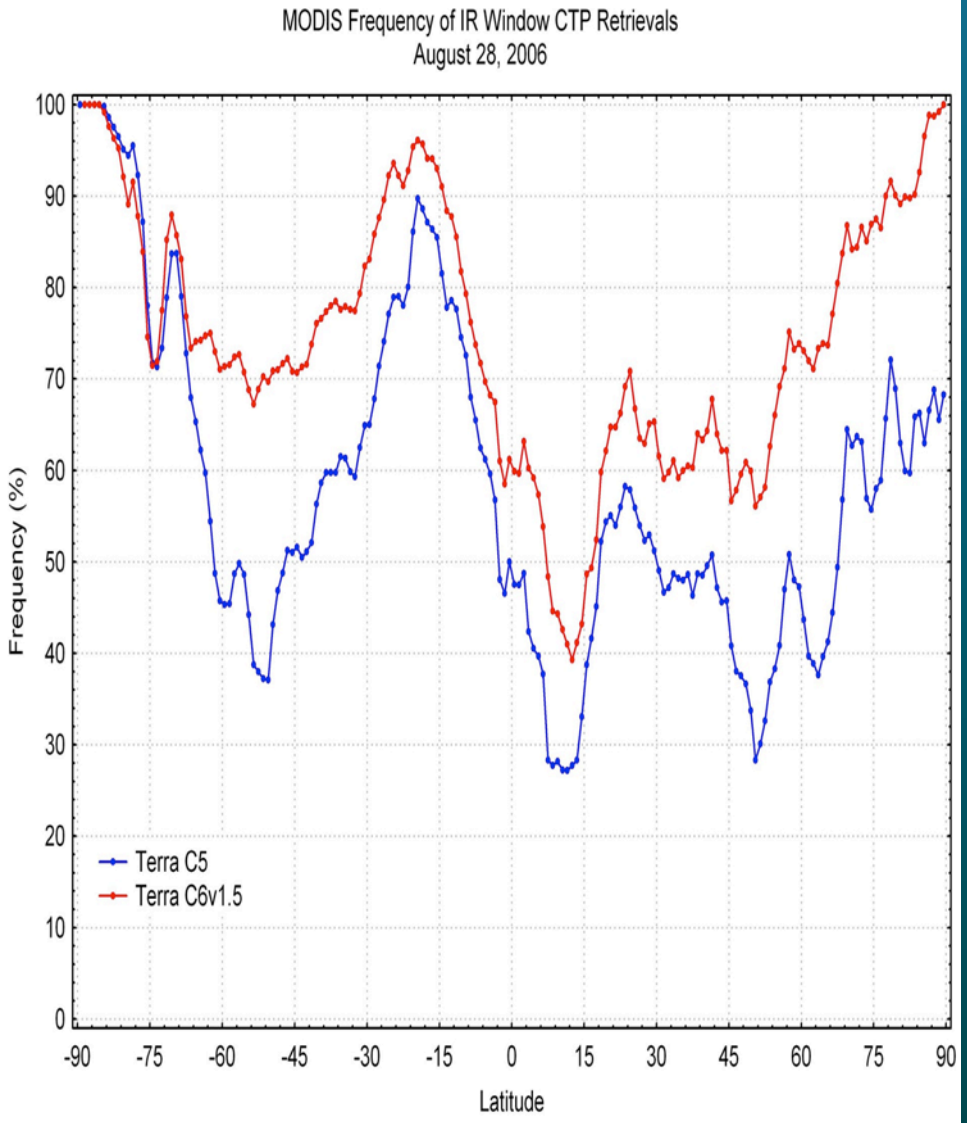
260
270
280
290

C6 Produces More High CO_2 Slicing and Low IRW Solutions

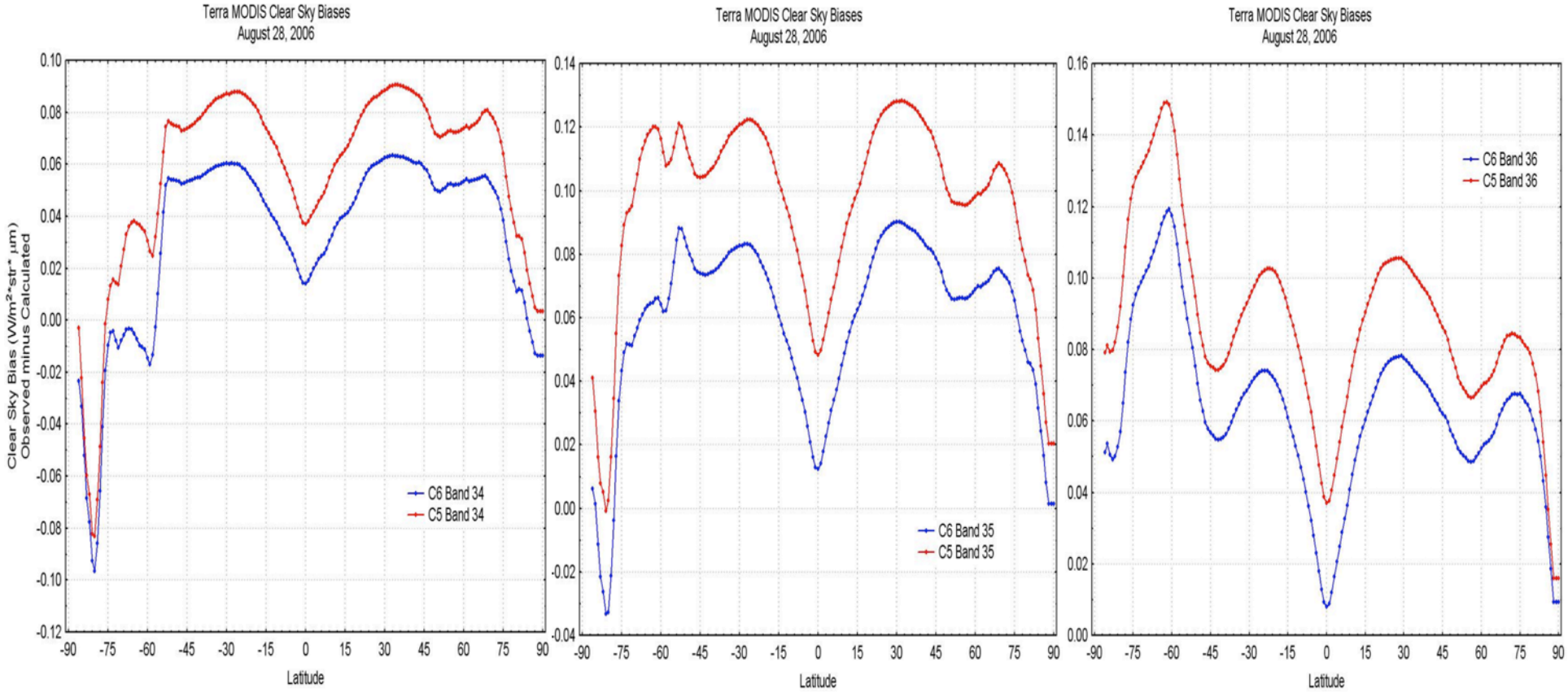
caused by spectral shift and cloud phase discriminator





Collect 5 versus 6 latitudinal distribution of high cloud CO_2 slicing solutions (from 36/35) and low water cloud IRW solutions for Terra MODIS on 28 August 2006 (in % of all cloudy observations)

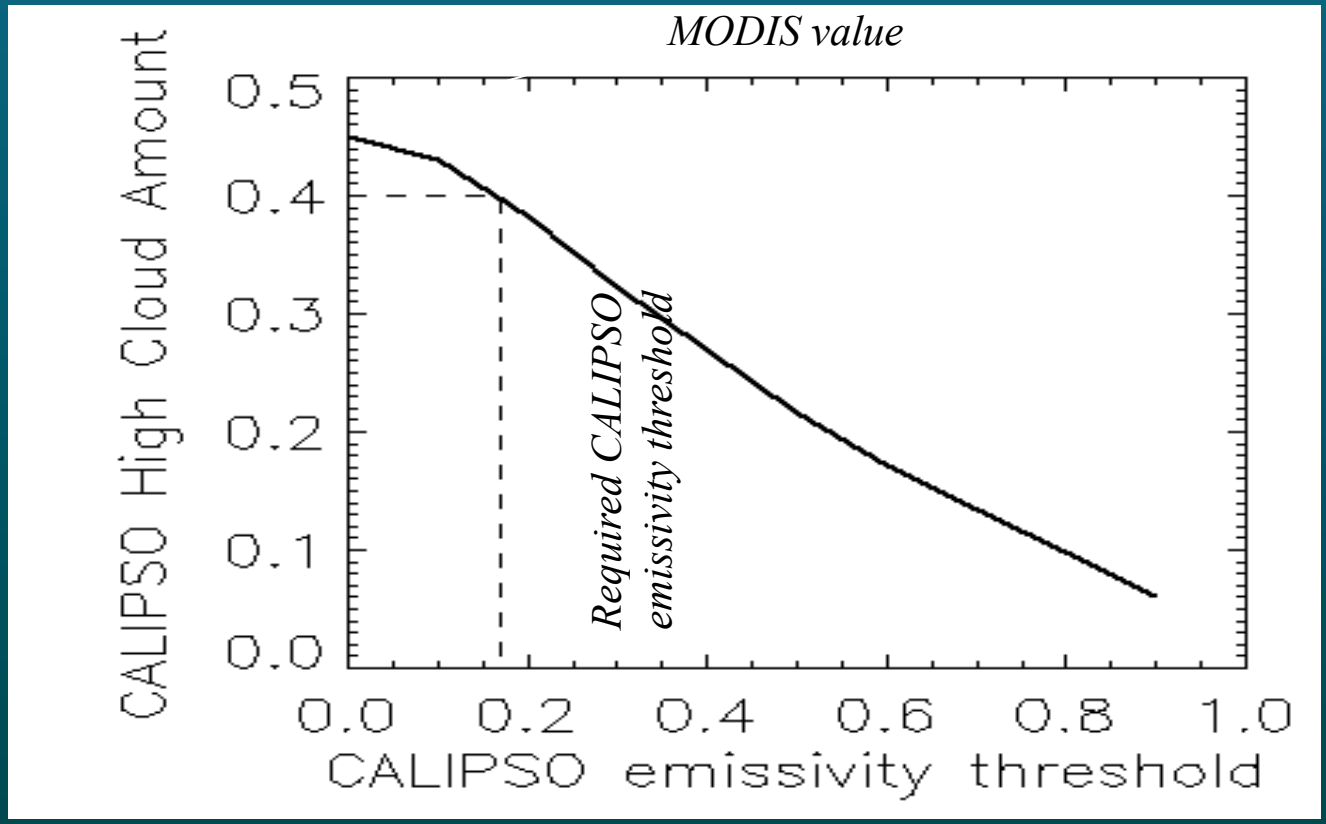
Spectral Shifts Reduce Calculated vs Observed Radiance Biases



8-day 1-degree latitude zone means of observed minus calculated clear-sky radiances for Terra MODIS bands 33-36 (in 5-zone moving averages) are created from 8-day 25-km biases for daytime land, nighttime land, and ocean data

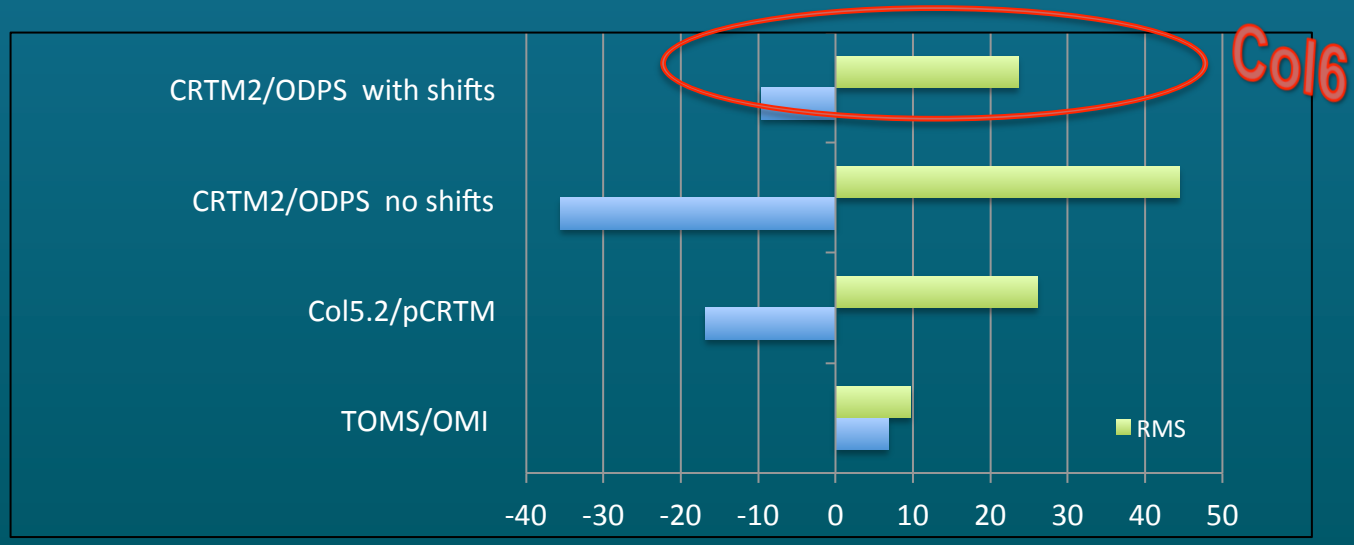
CALIOP Confirms MODIS Thin Cloud Sensitivity

By matching the Aqua MODIS high cloud amount values to CALIPSO's curve of high cloud amount versus cloud emissivity, we can determine the sensitivity of MODIS to cloud emissivity.



For the Tropics in August 2006, the MODIS high cloud amounts are about 0.4. This gives a cloud emissivity limit of about 0.18.

The impact of the Terra H2O/CO2/O3 channel spectral shifts on MOD07 TOZ over Budapest, HU over 2007: Comparison with ground-based Brewer Spectrophotometer measurements



The impact of the Terra H2O/CO2/O3 band spectral shifts on MOD07 TOZ over Budapest, HU for 2007: Comparison with ground-based Brewer Spectrophotometer measurements