



Corrections to the calibration of MODIS ocean color bands derived from SeaWiFS data

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NASA Code 614.2

Ocean Ecology Branch

OBPG (Ocean Biology Processing Group)

1/6/11

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Ocean Biology Processing Group:

- Responsible for producing Ocean Color (OC) products at NASA (CZCS, SeaWiFS, MODIS Aqua and Terra, MERIS, etc.)
- Website: oceancolor.gsfc.nasa.gov

The screenshot shows a Firefox browser window displaying the OceanColor WEB website. The browser's address bar shows the URL <http://oceancolor.gsfc.nasa.gov/>. The website features a large satellite image of the Earth's oceans with a color-coded overlay representing ocean color data. The text "OceanColor WEB" is prominently displayed in white and blue. Below the main image is a navigation menu with links for Missions, Data, Documents, Analyses, People, Forum, Services, and Links. A Google Custom Search box is also visible. The page is divided into three main sections: Data Access, Ocean Color Feature, and Support Services. The Data Access section includes a Data Distribution Status indicator (all systems nominal) and a note about FTP connections. The Ocean Color Feature section highlights recent topics and imagery, with a sub-section titled "A Boost for SeaWiFS" and a small image showing orbit altitude. The Support Services section features the SeaDAS package, described as a comprehensive image analysis package for processing, display, analysis, and quality control of ocean color data.

Firefox File Edit View History Bookmarks Tools Window Help

OceanColor Home Page

<http://oceancolor.gsfc.nasa.gov/> Google

Most Visited Getting Started Latest Headlines Apple Yahoo! Google Maps YouTube Wikipedia News Popular The New York Times

OceanColor Home Page

OceanColor WEB

Missions Data Documents Analyses People Forum Services Links

Google Custom Search Search

Data Access

Data Distribution Status

All systems nominal

NOTE: FTP connections must be made in PASSIVE mode

Ocean Color Feature

Recent topics and imagery of interest to the OceanColor community.

A Boost for SeaWiFS

Orbit altitude

Support Services

SeaDAS

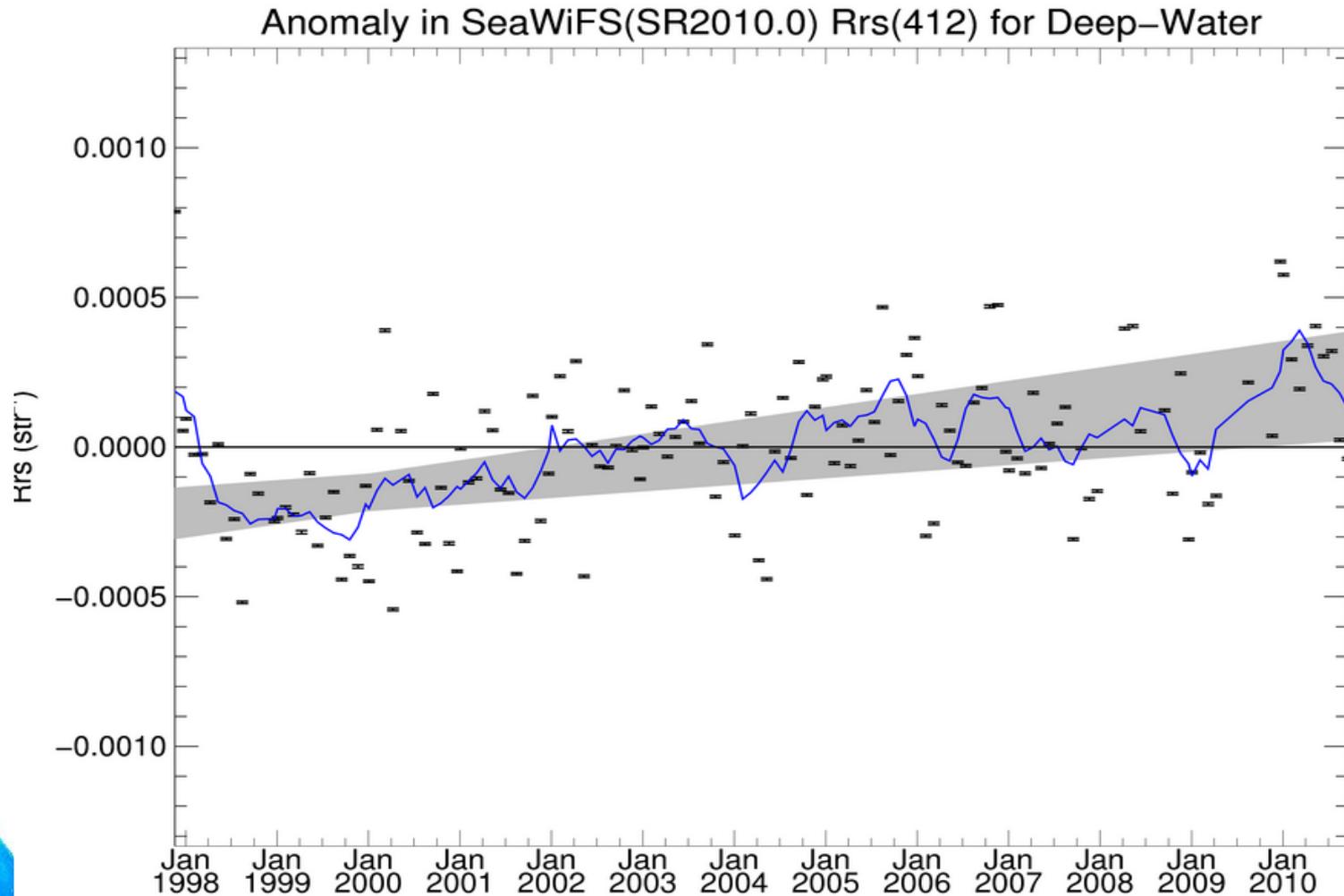
A comprehensive image analysis package for the processing, display, analysis, and quality control of ocean color data.

MODIS issues:

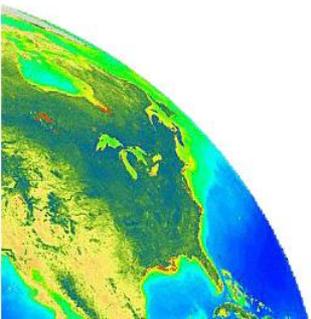
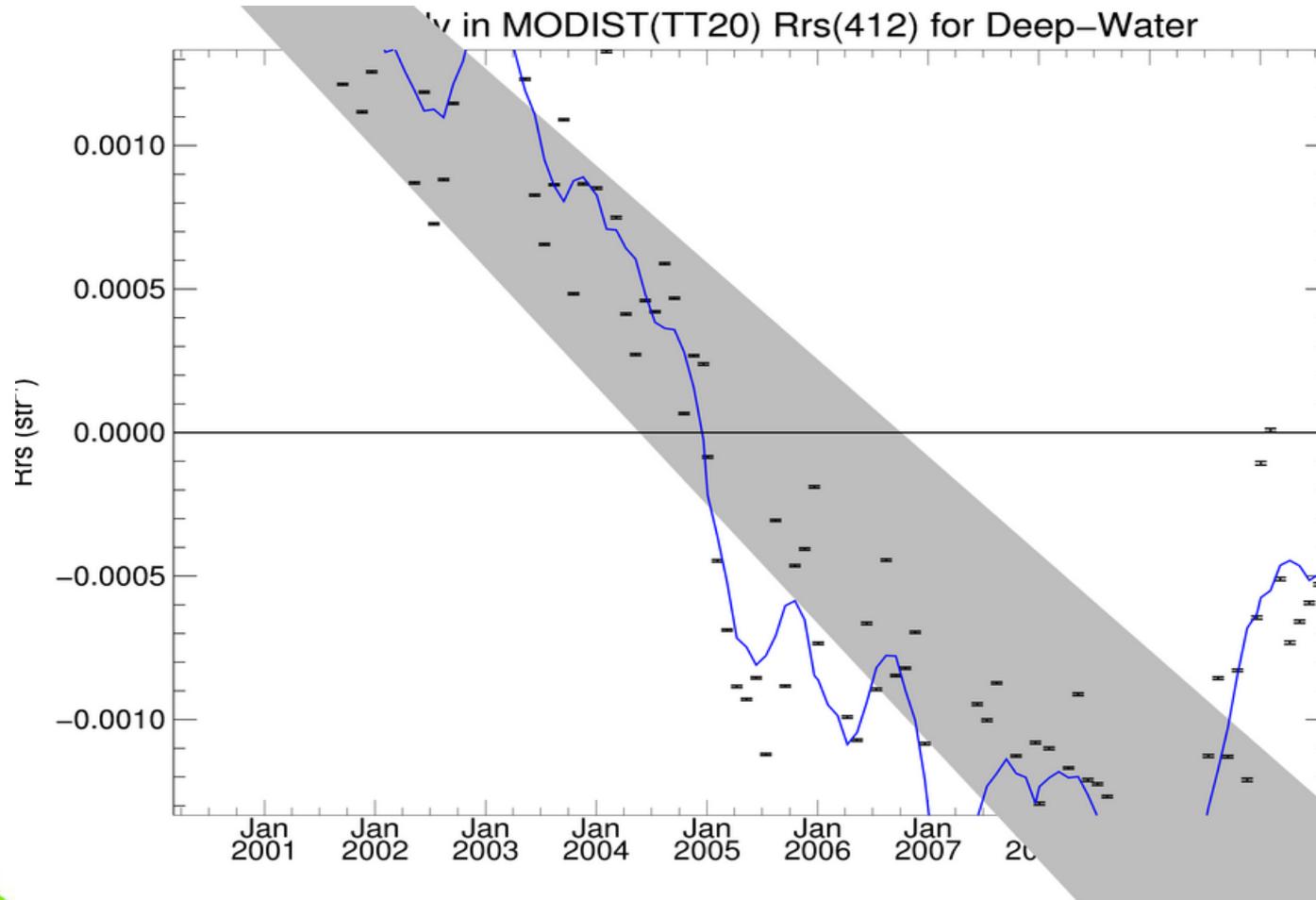
- Small calibration errors lead to striping/erroneous trending in OC products
- On-orbit calibration can only be trended for lunar view angle (beginning of scan) and solar diffuser view angle (2nd half of scan)
- No on-board capability to trend polarization sensitivity changes on-orbit (not an issue yet for MODIS Aqua, but for MODIS Terra)



Temporal issues: 412nm SeaWiFS anomaly (seasonal cycle removed)

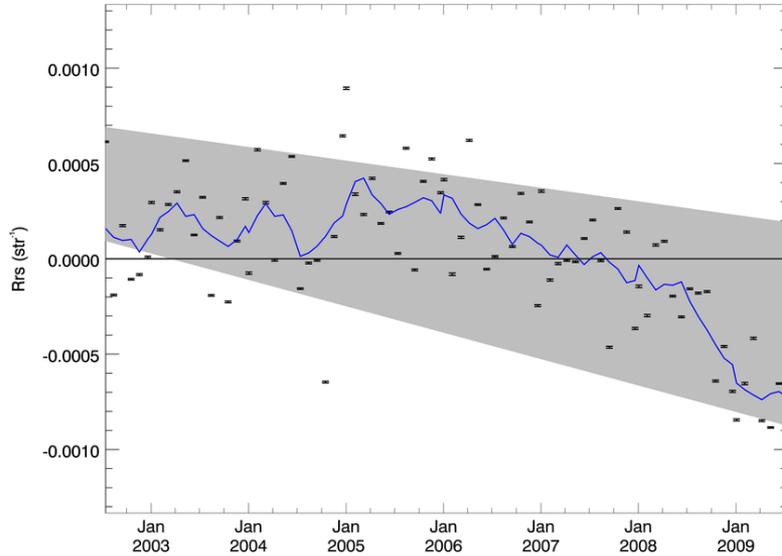


Temporal issues: 412nm MODIS Terra (combine with previous slide)

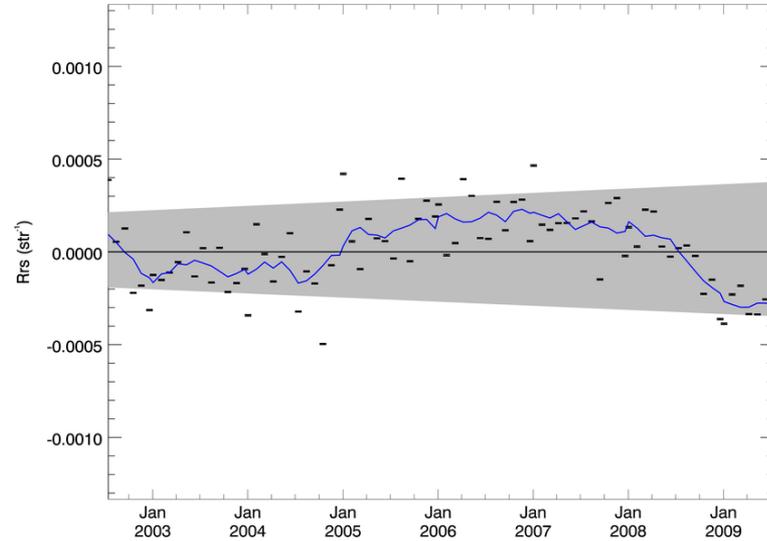


Temporal issues MODIS Aqua: 412nm

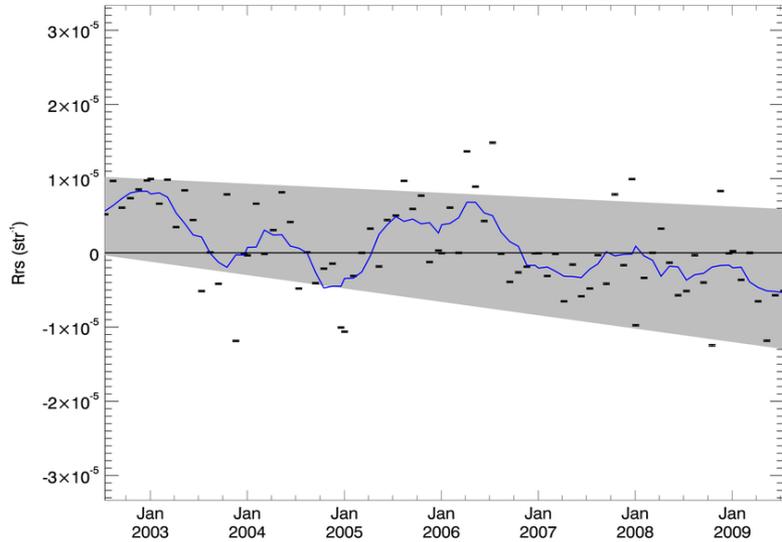
Anomaly in MODISA(AT42) Rrs(412) for Oligotrophic



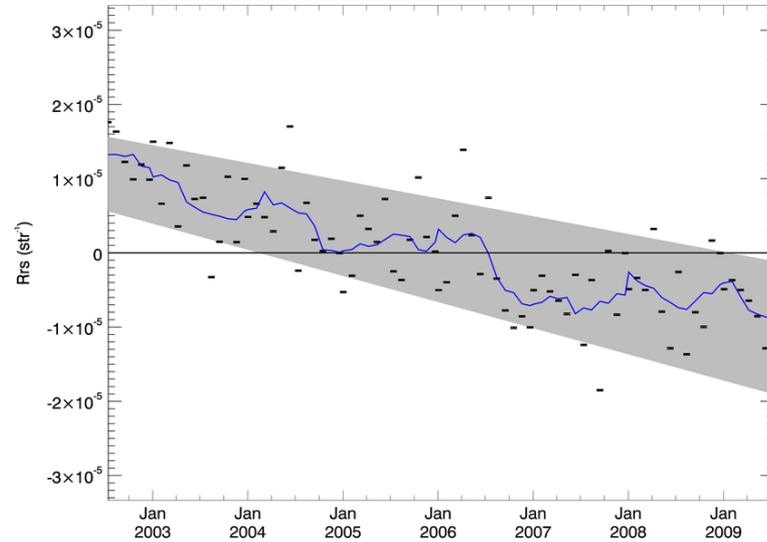
Anomaly in MODISA(AT42) Rrs(443) for Oligotrophic



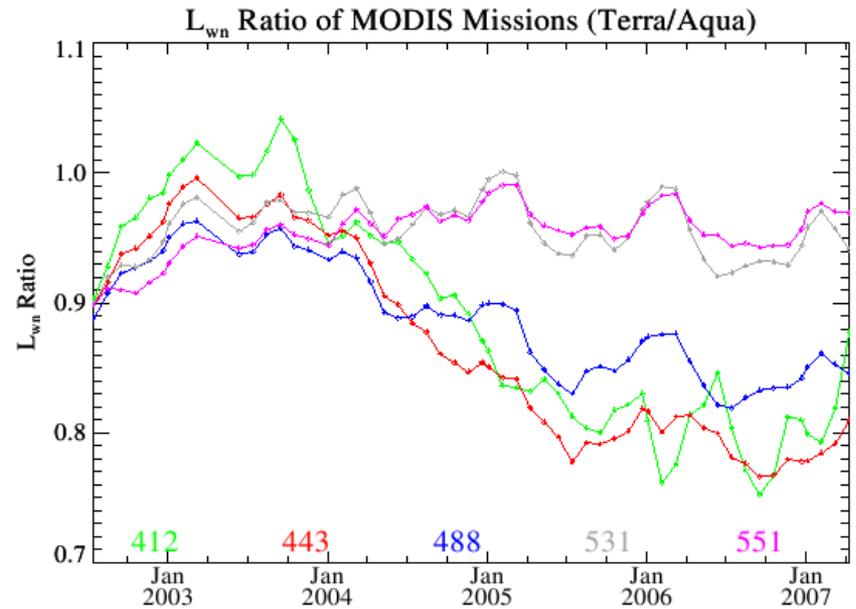
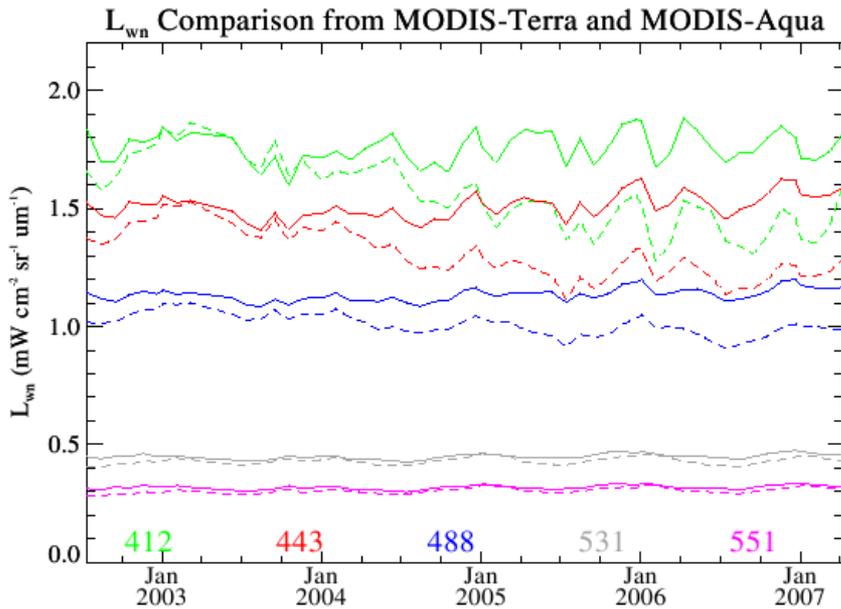
Anomaly in MODISA(AT42) Rrs(667) for Oligotrophic



Anomaly in MODISA(AT42) Rrs(678) for Oligotrophic

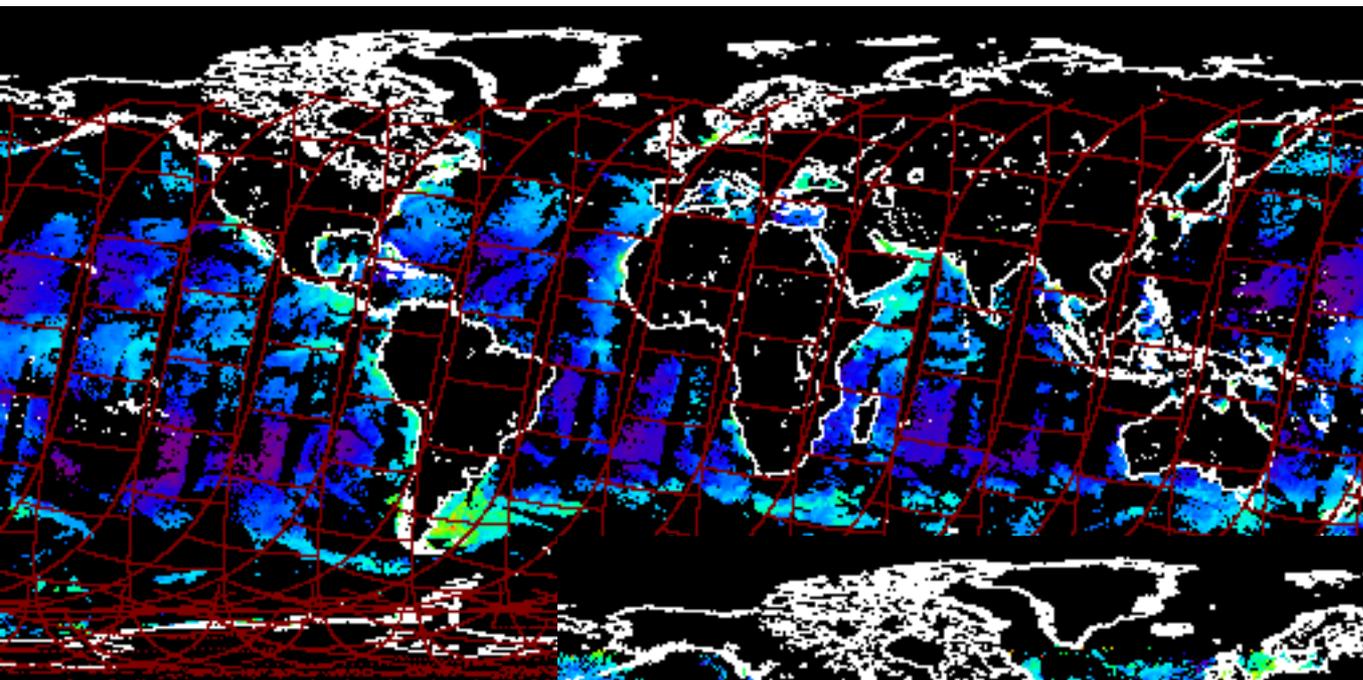


Ratio MODIS Terra/Aqua as a function time:

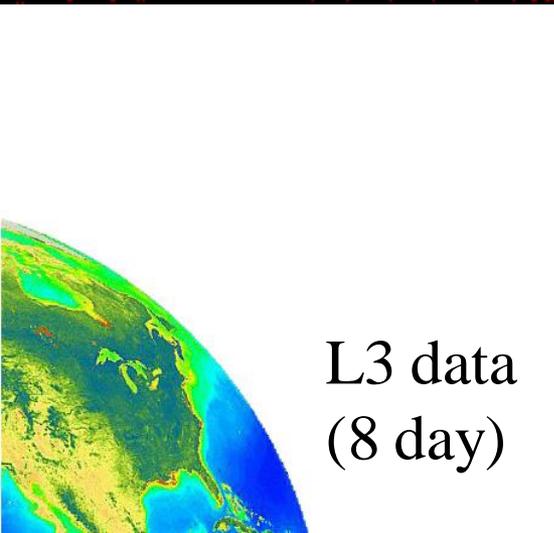


(from Franz et al., 2008)

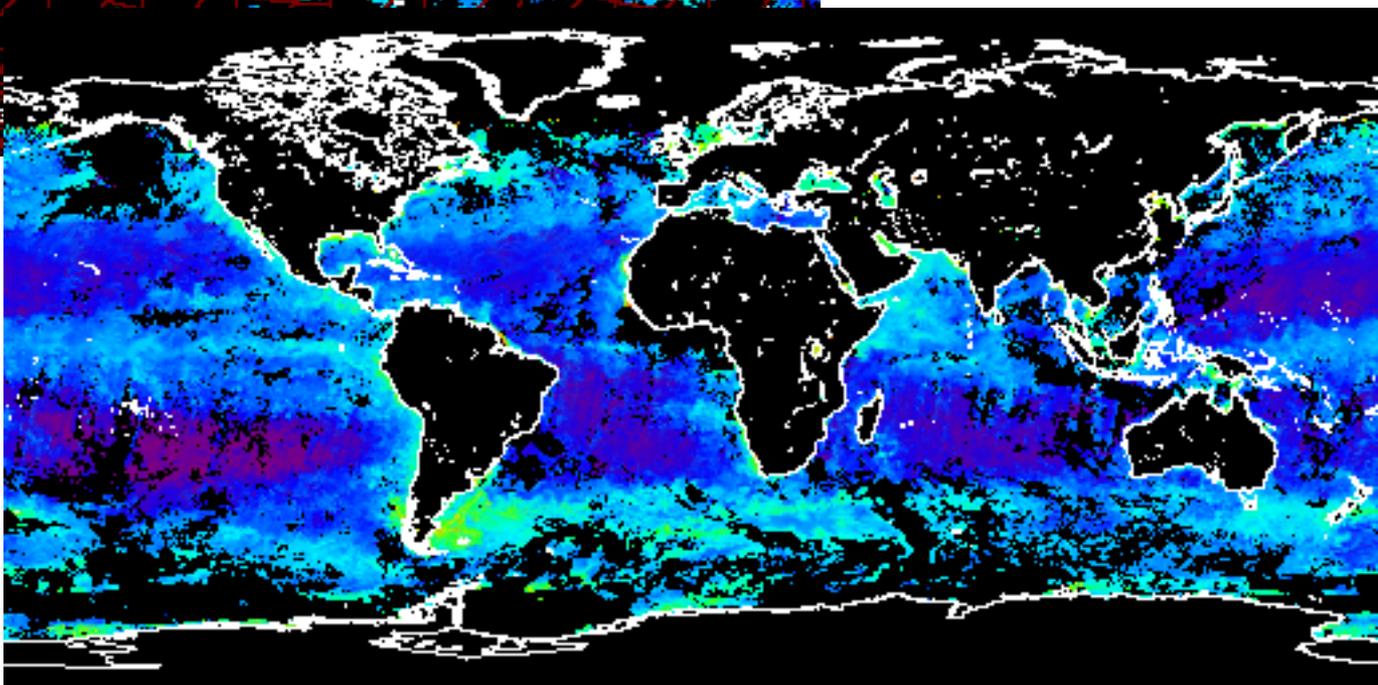
Scan angle dependence of ocean color products:



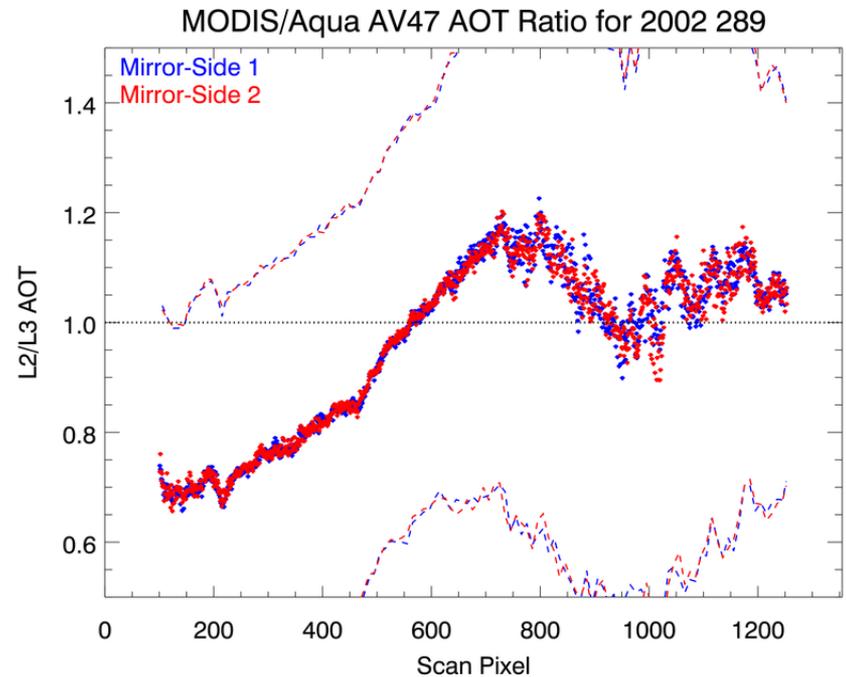
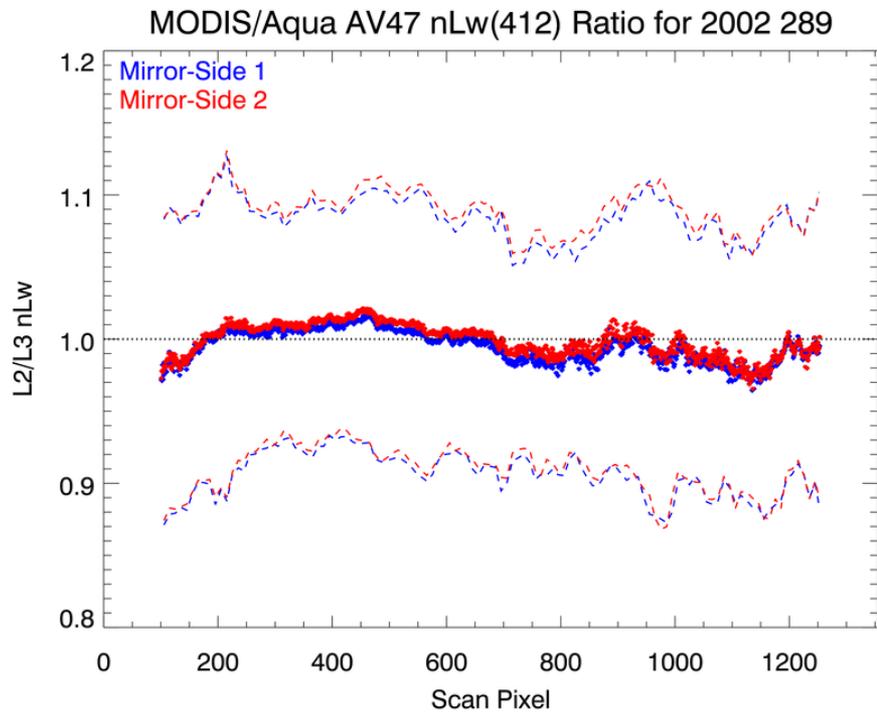
L2 data (chl.)



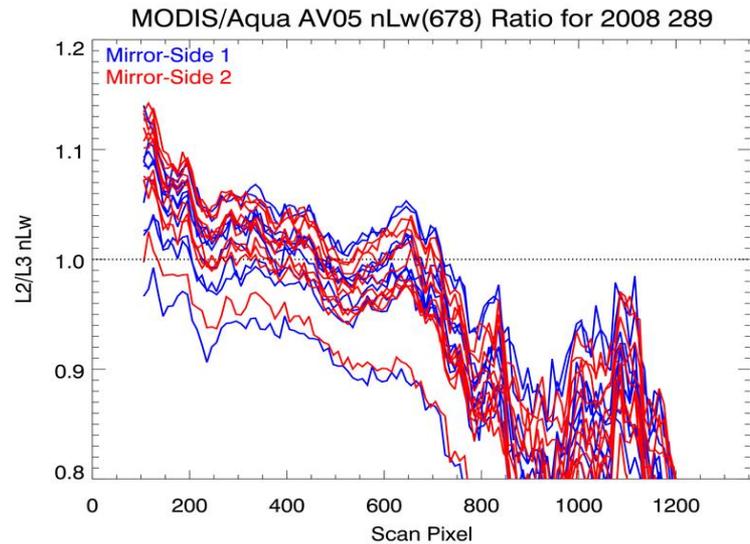
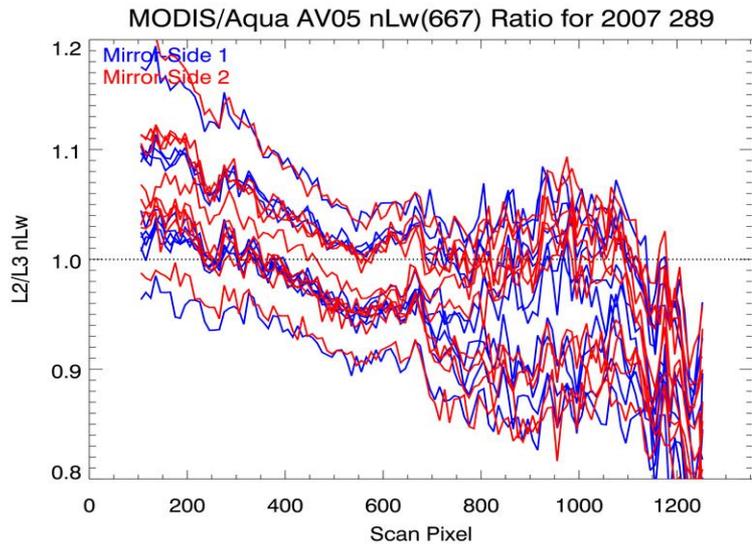
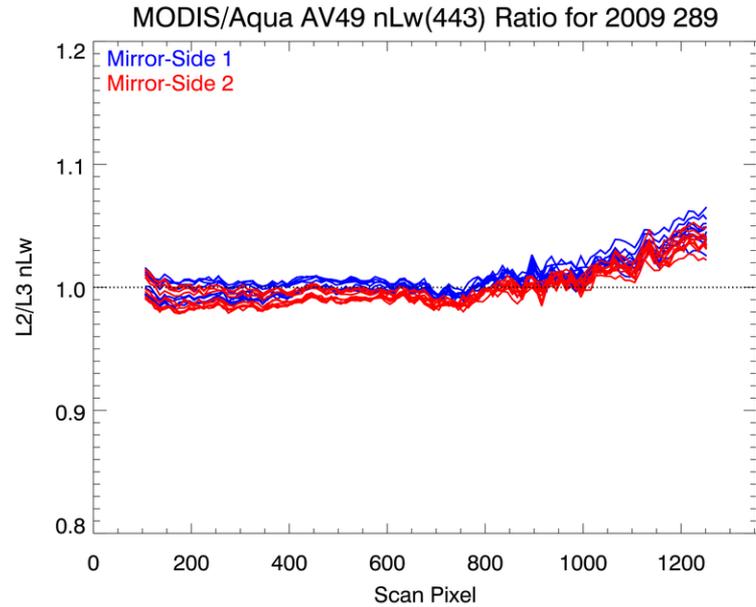
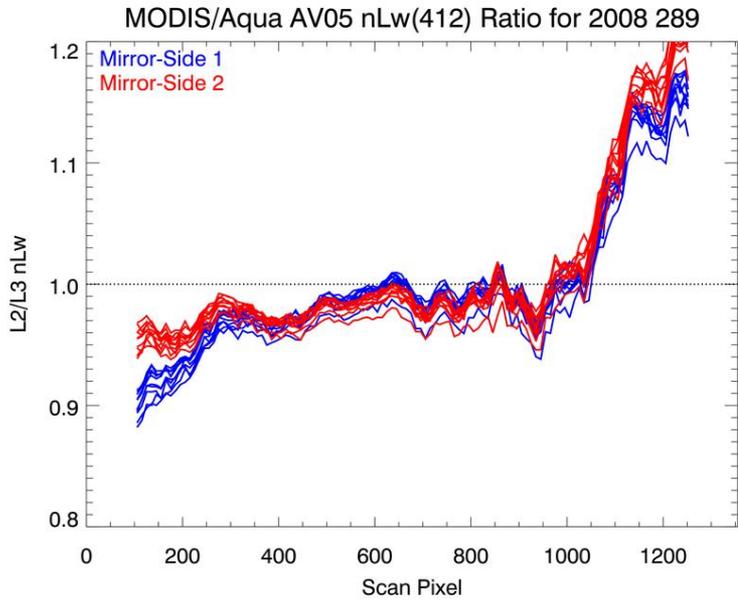
L3 data
(8 day)



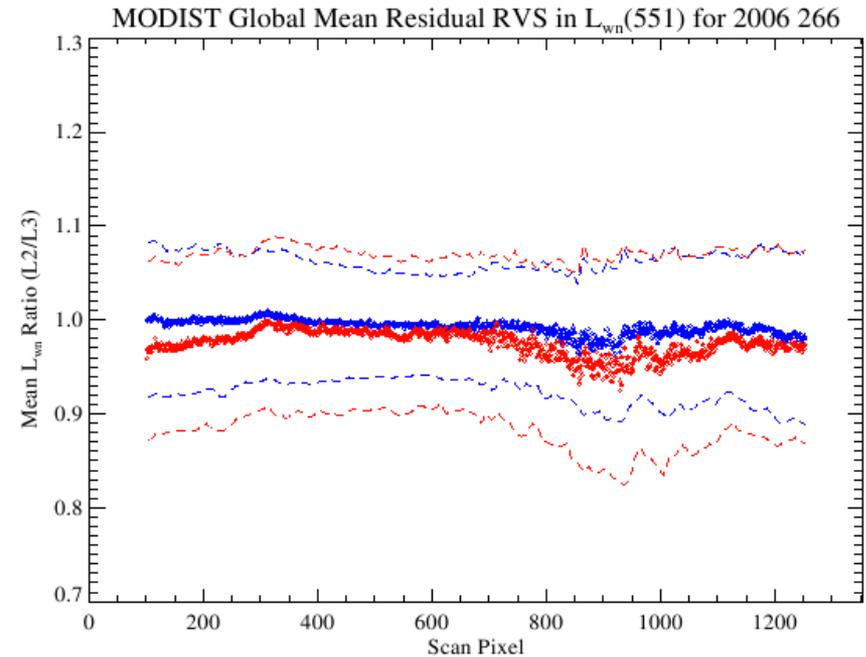
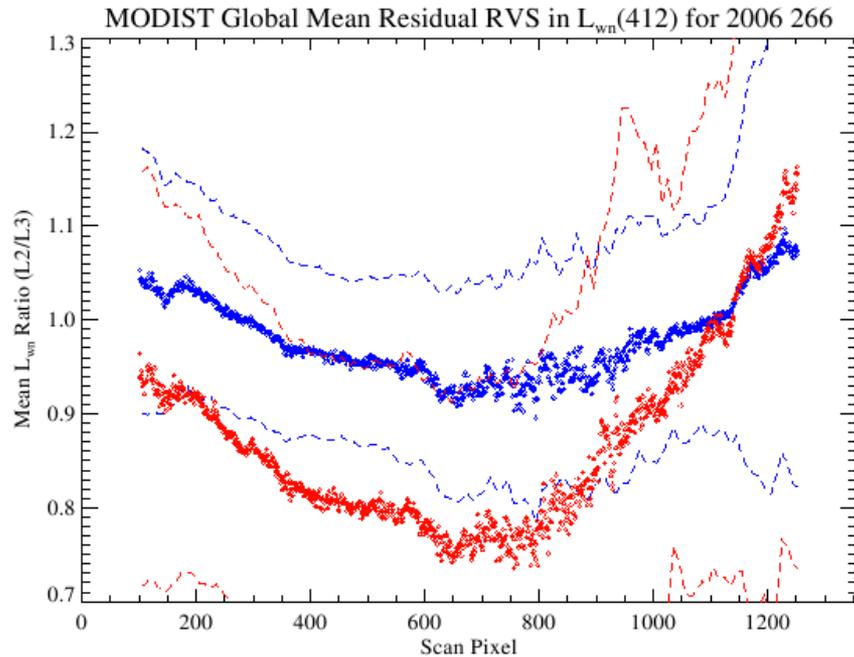
MODIS Aqua RVS early in the mission:



MODIS Aqua RVS issues: 412nm, red bands



MODIS Terra RVS issues: 412nm, green band OK



(from Franz et al., 2008)

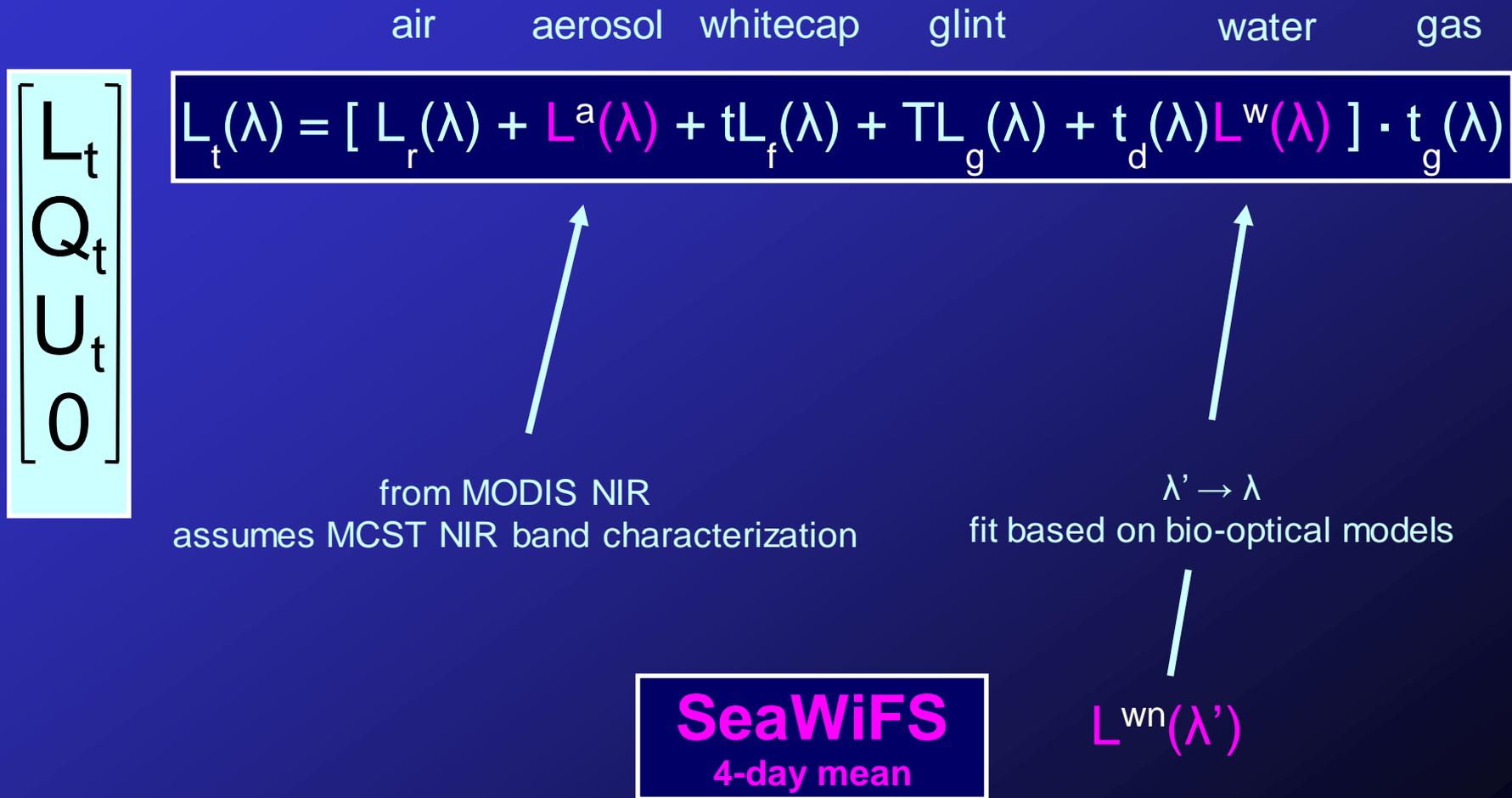


Approach summarized:

- Baseline: MCST lunar and SD trending (coll. 6)
- New MCST lunar analysis: time dependent NIR RVS
- MODIS Aqua crosscalibrated to SeaWiFS (as for Terra in Kwiatkowska et al., Applied Optics, 2008)
- Approach: Use SeaWiFS L3 nLw, bring to TOA, adjust MODIS calibration for every month of the mission (4-day L3)
- Verify with analysis using only MODIS Aqua data: temporal trends (seasonal cycle removed) and ratio of L2/L3 versus scan angle



Modeling of TOA Stokes vector over oceans



Crosscalibration approach:

$$L_m/M_{11} = L_t + m_{12}*Q + m_{13}*U$$

L_m : measured TOA radiance (MODIS)

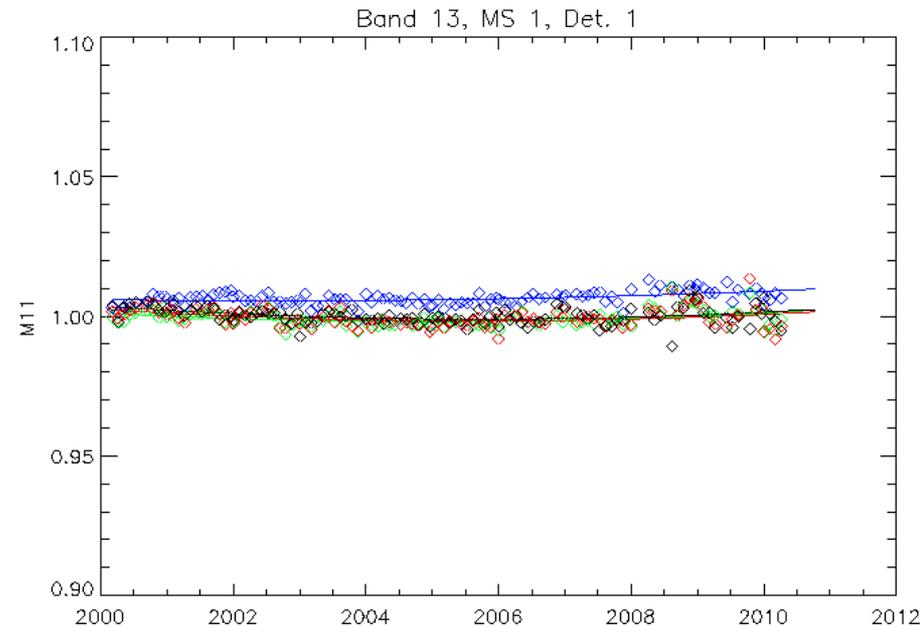
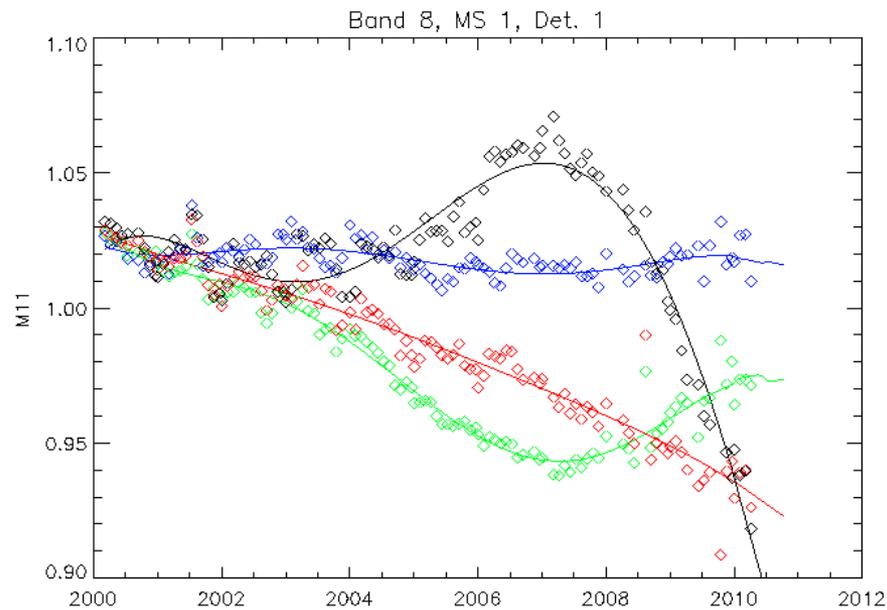
L_t : true TOA radiance (from SeaWiFS)

Q, U : linear Stokes vector components,
modeled from Rayleigh and glint

M_{11}, m_{12}, m_{13} : fitted instrument
characterization parameters (depend on
band, MS, detector, scan angle)



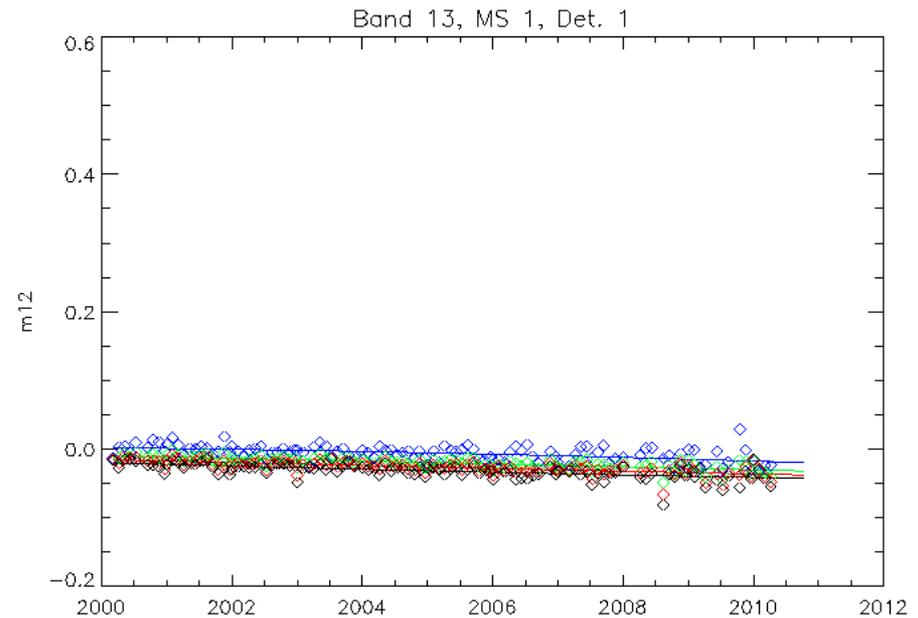
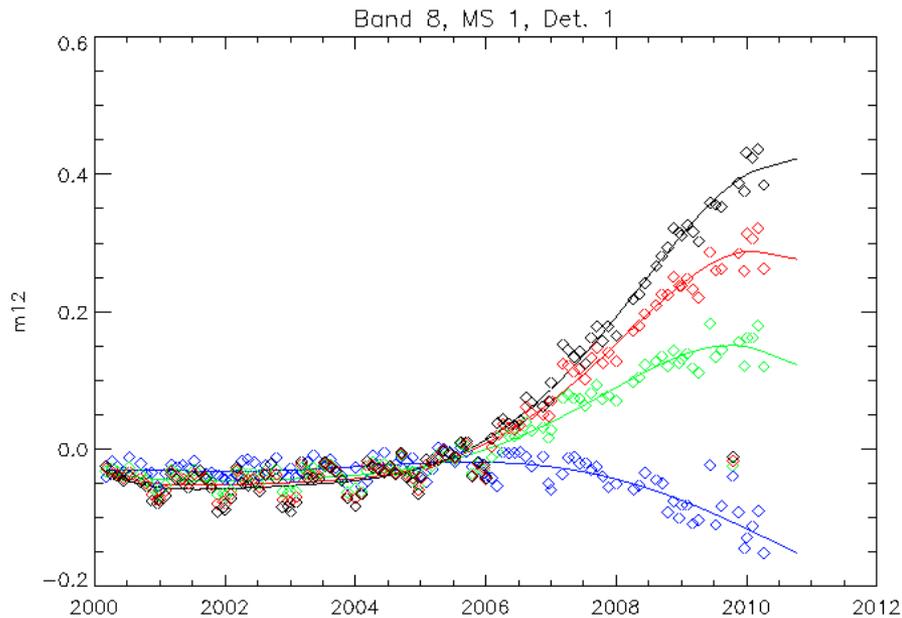
MODIS Terra radiometric corrections as a function of time at different view angles:



Color coding: Frames (pixels) **22** **675** **989**, 1250 (out of 1354)
Solid line is a fit to the measurements of each month (diamonds)

Significant corrections in the blue (up to 10% at 412nm (band 8)), very small corrections for the red (band 13 at 667nm)

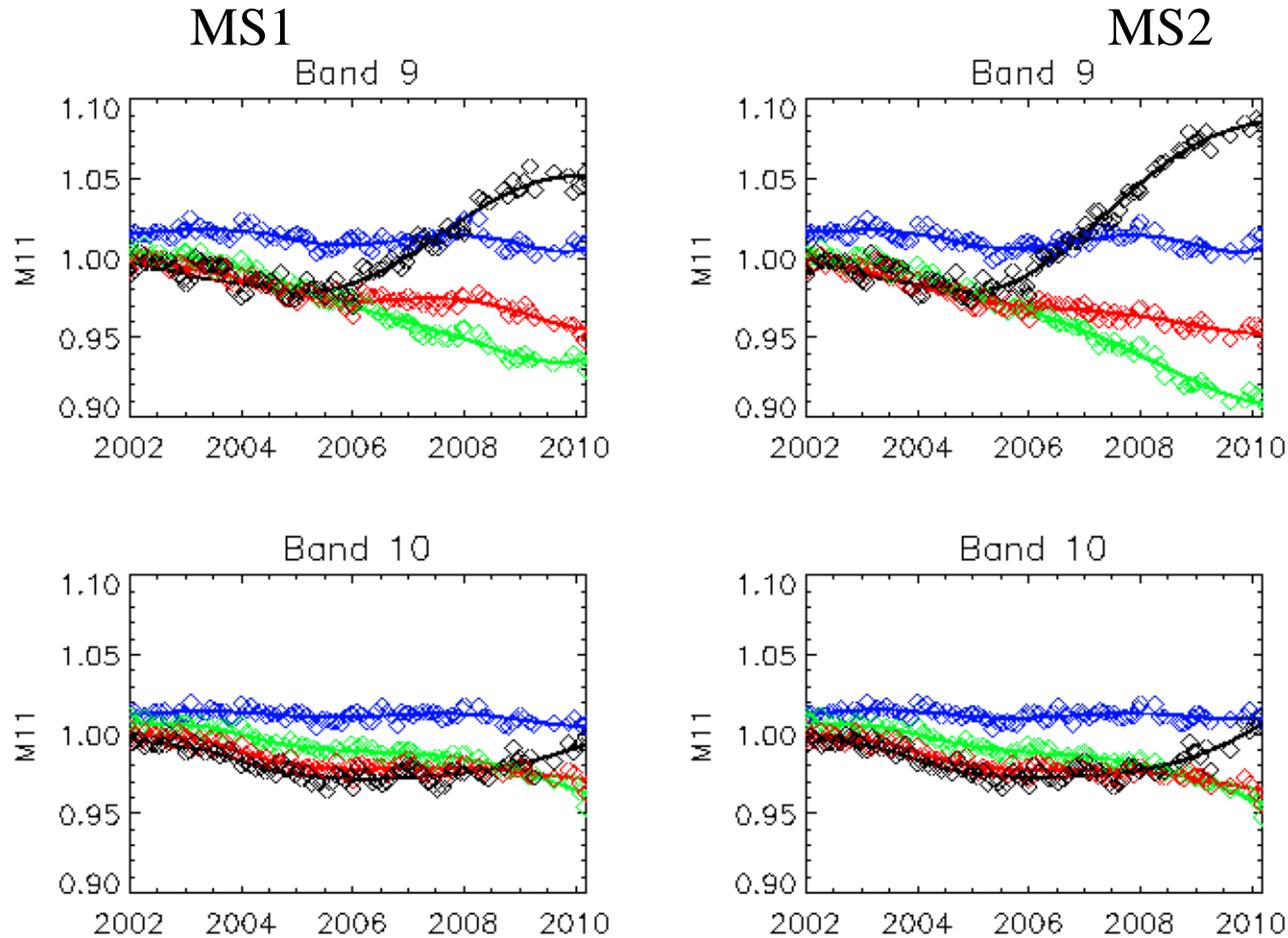
Comparison to MODIS Terra polarization sensitivity as a function of time at different view angles:



Color coding: Frames (pixels) **22** **675** **989** 1250 (out of 1354)
Solid line is a fit to the measurements of each month (diamonds)

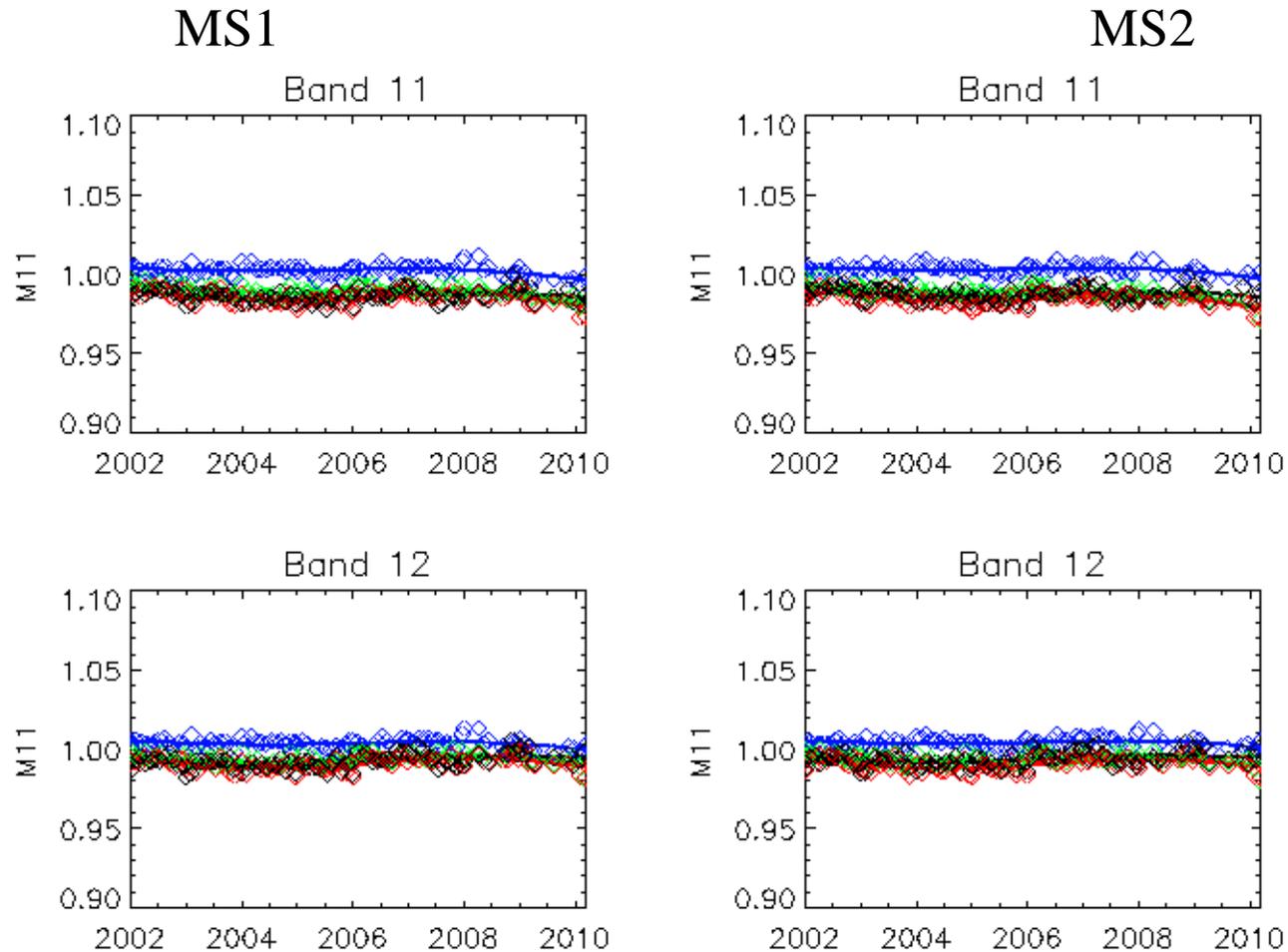
Significant variations in the blue (up to 40% at the end of scan at 412nm (band 8)), very small corrections for the red (band 13 at 667nm)

MODIS Terra radiometric corrections as a function of time at different view angles:



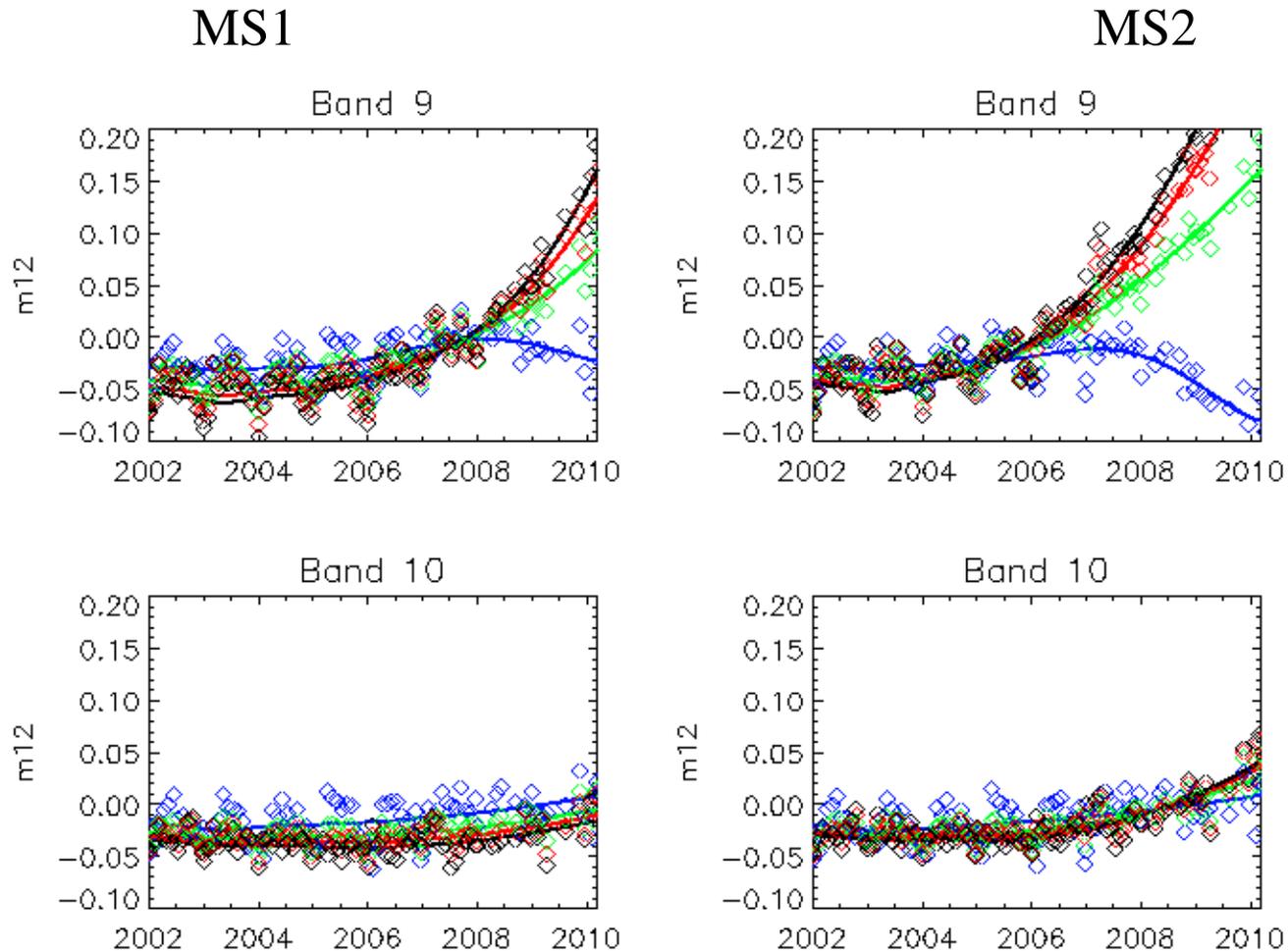
Color coding: Frames (pixels) 22 675 989, 1250 (out of 1354) 17
Solid line is a fit to the measurements of each month (diamonds)

MODIS Terra radiometric corrections as a function of time at different view angles:



Color coding: Frames (pixels) 22 675 989, 1250 (out of 1354) 18
Solid line is a fit to the measurements of each month (diamonds)

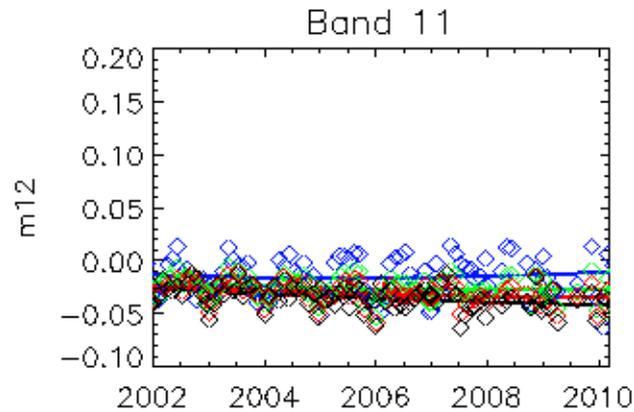
MODIS Terra polarization corrections as a function of time at different view angles:



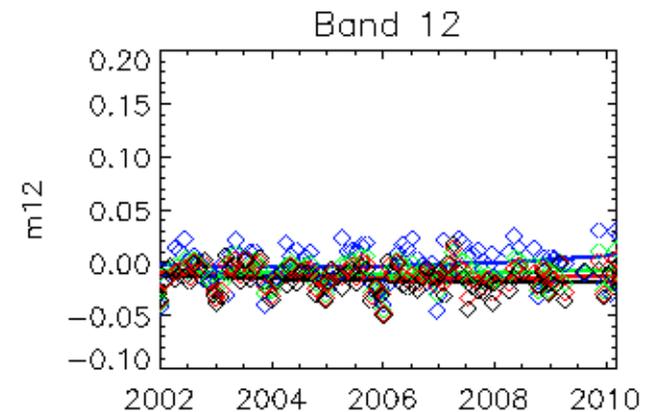
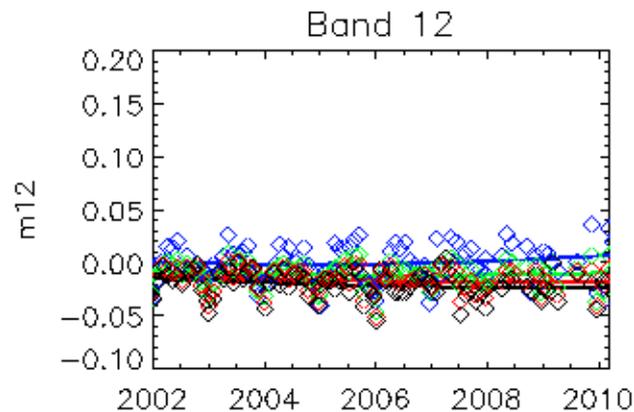
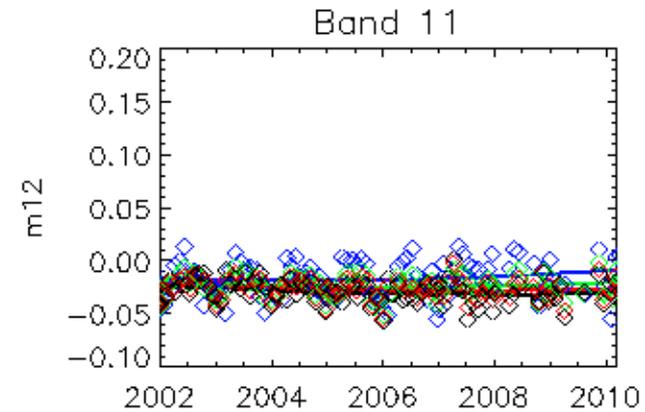
Color coding: Frames (pixels) 22 675 989, 1250 (out of 1354) 19
Solid line is a fit to the measurements of each month (diamonds)

MODIS Terra polarization corrections as a function of time at different view angles:

MS1

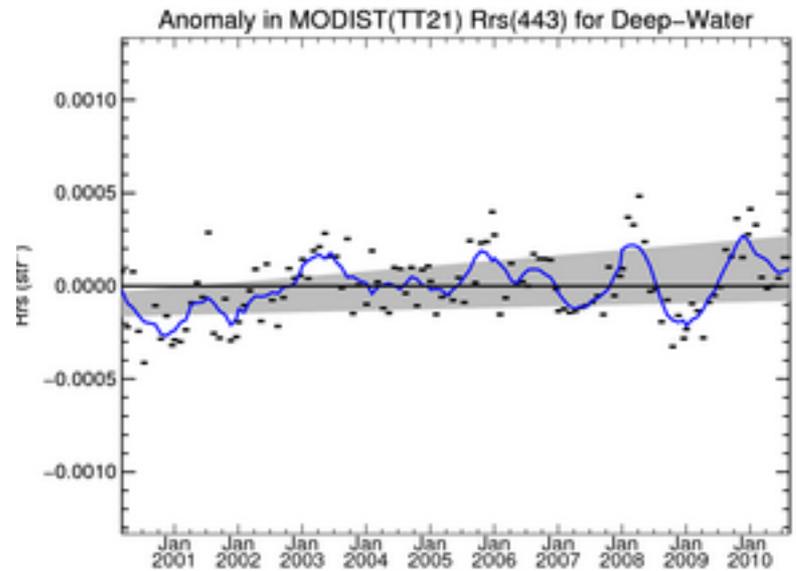
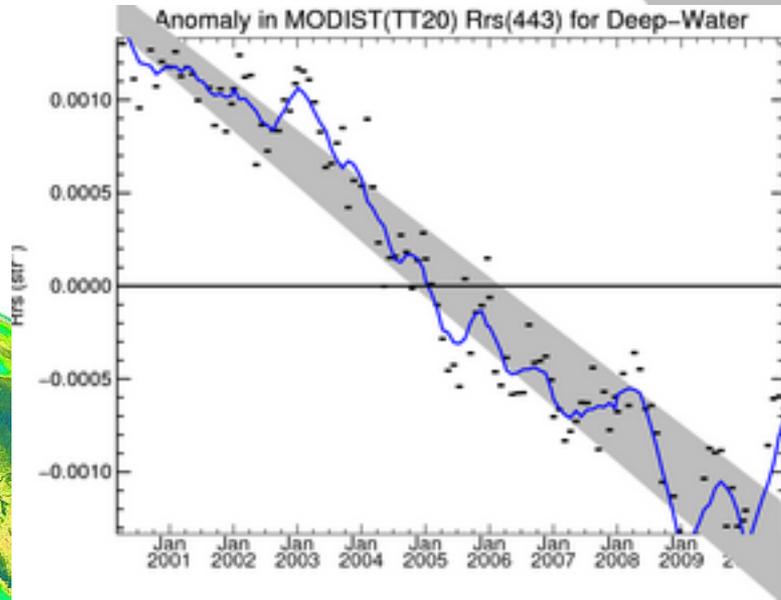
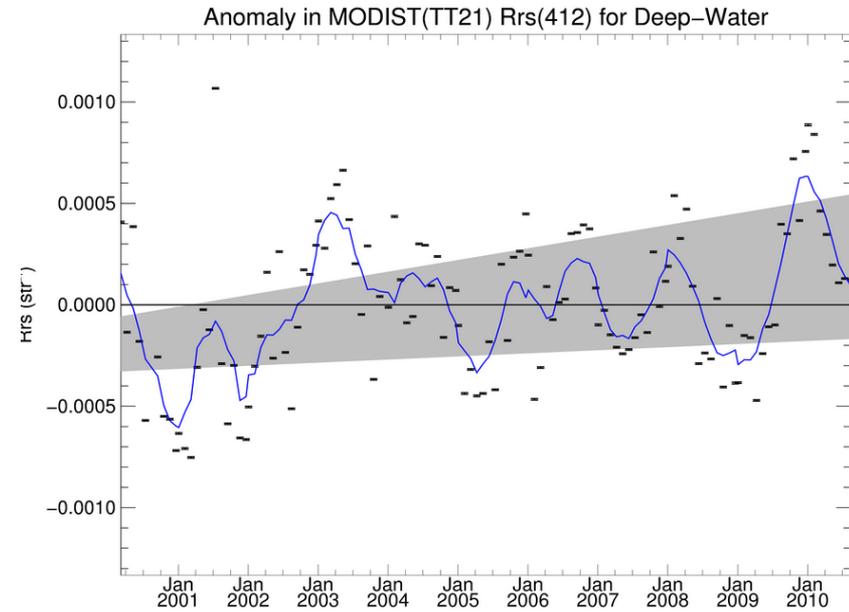
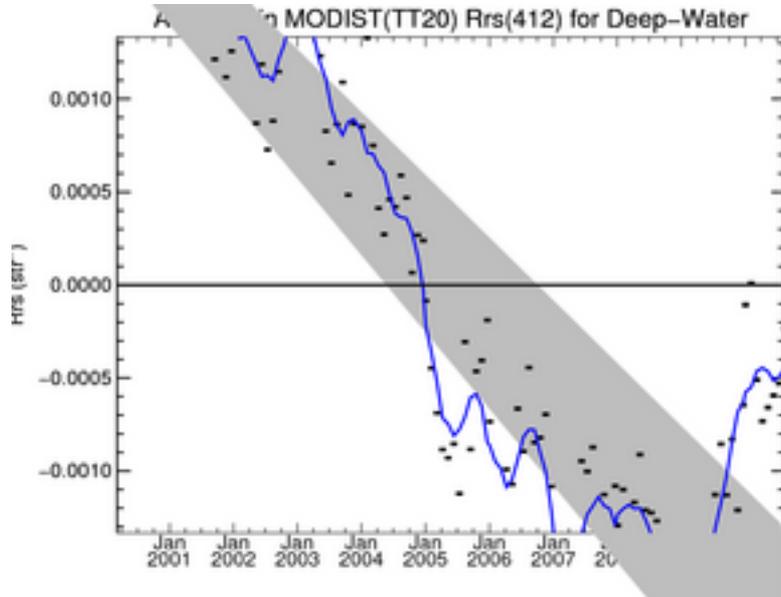


MS2

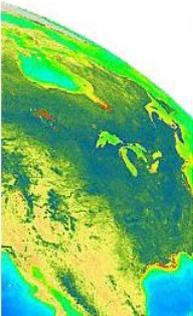
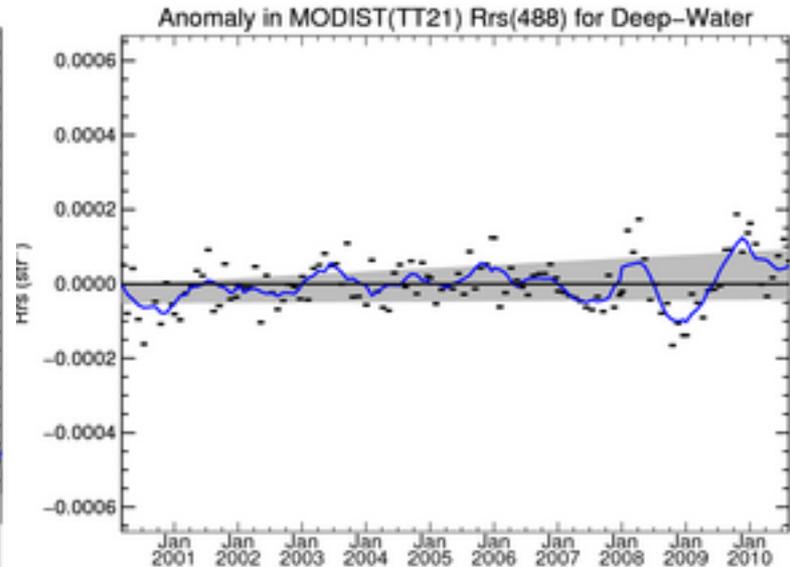
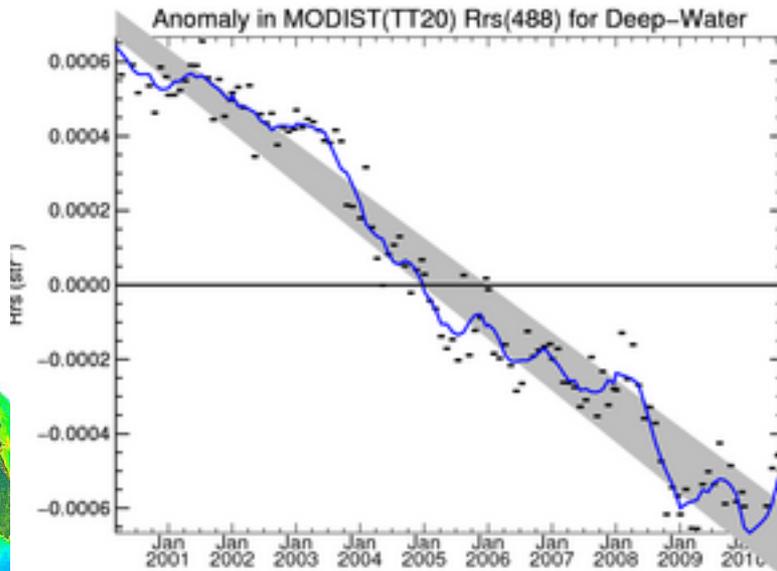
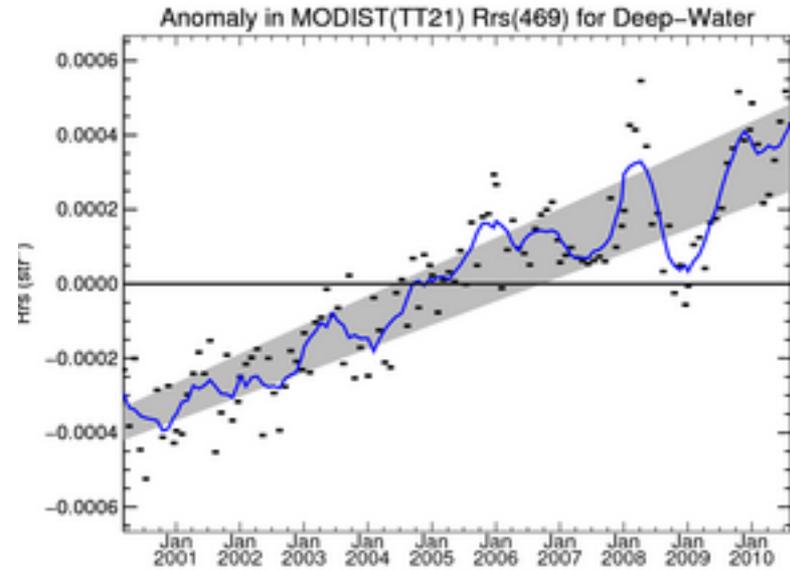
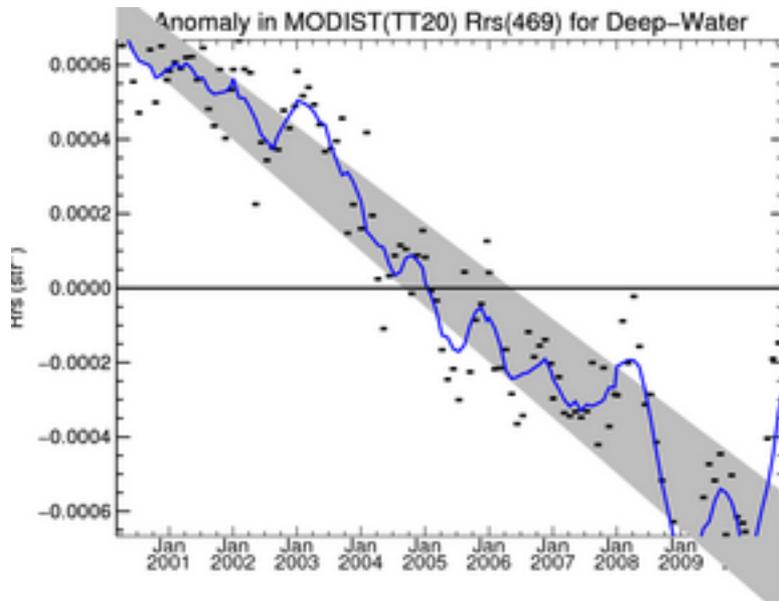


Color coding: Frames (pixels) 22 675 989, 1250 (out of 1354) 20
Solid line is a fit to the measurements of each month (diamonds)

Temporal anomaly before/after xcal:



Temporal anomaly before/after xcal:



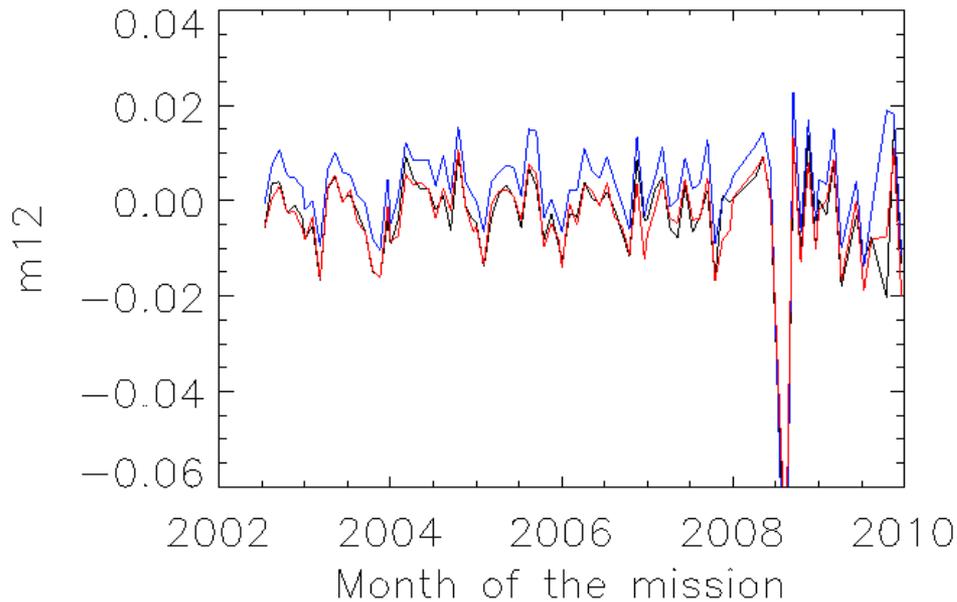
Crosscalibration results: Polarization (temporal)

- Cycle in m12 decreases with wavelength
- All bands stable over time

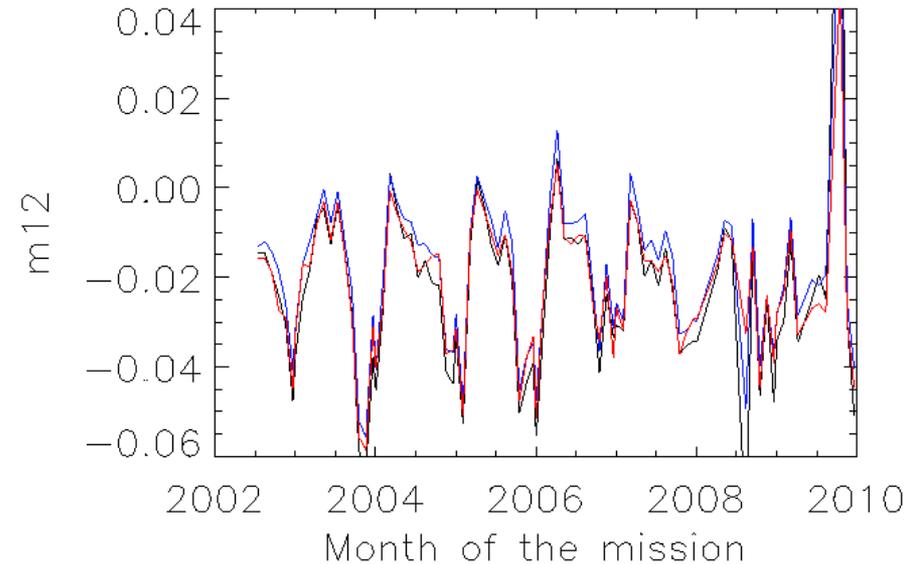
Band 10: 488nm

Band 13: 667nm

Aqua band 13



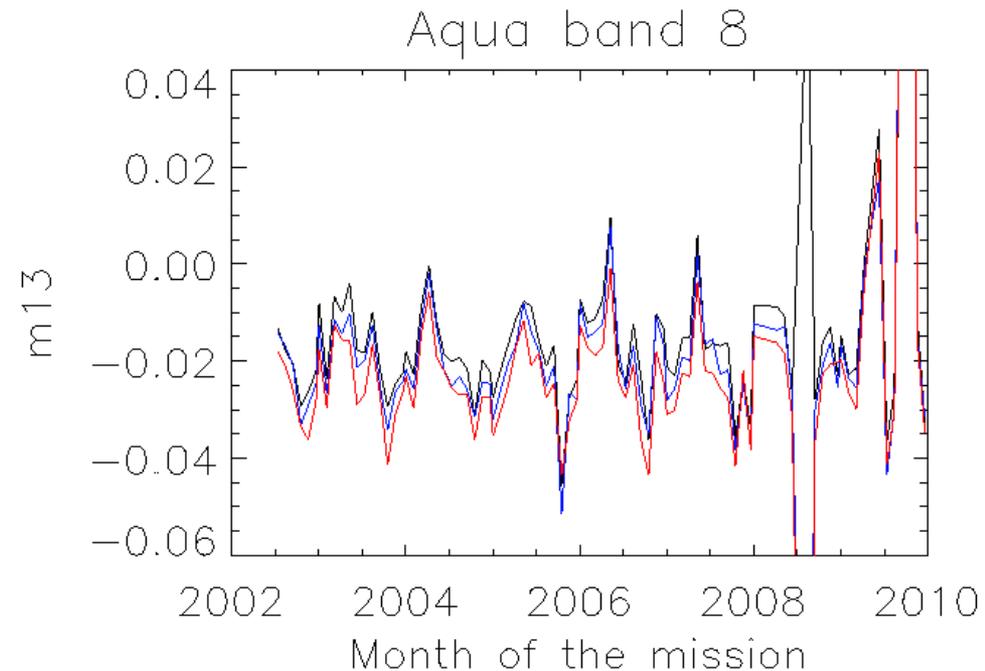
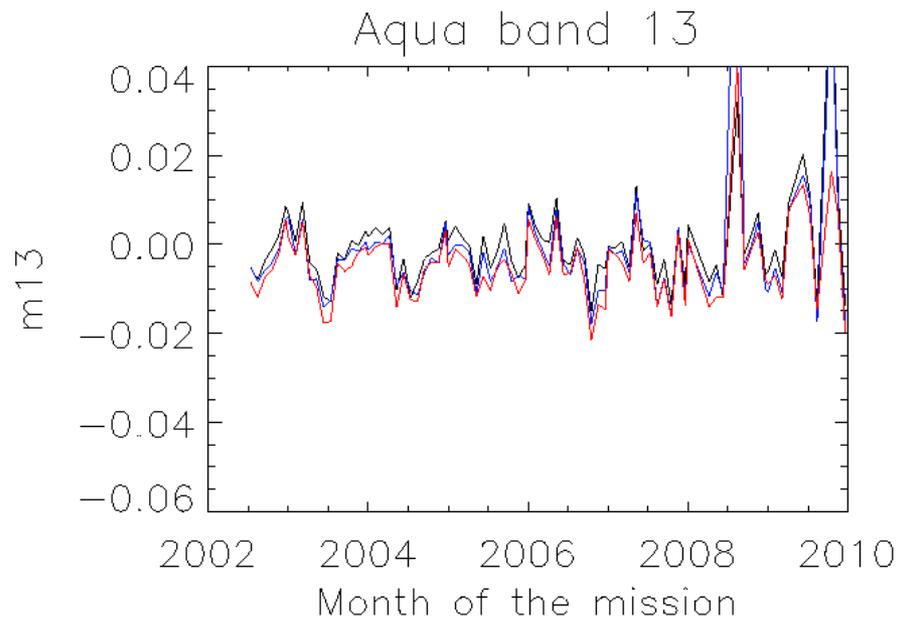
Aqua band 10



Crosscalibration results: Polarization (temporal)

- Variability in m13 similar as in Terra
- All bands stable over time, prelaunch values used

Band 8: 412nm
Band 13: 667nm



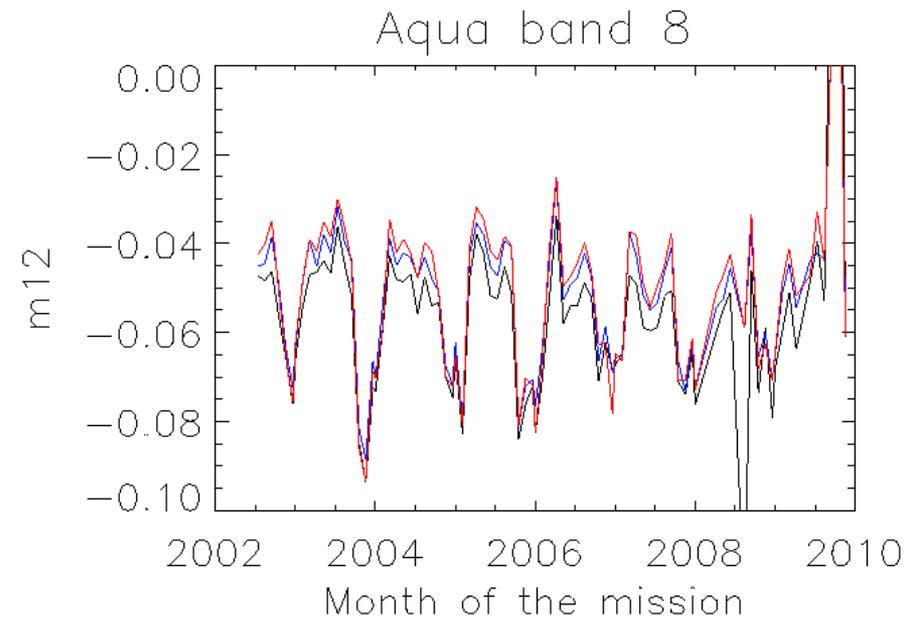
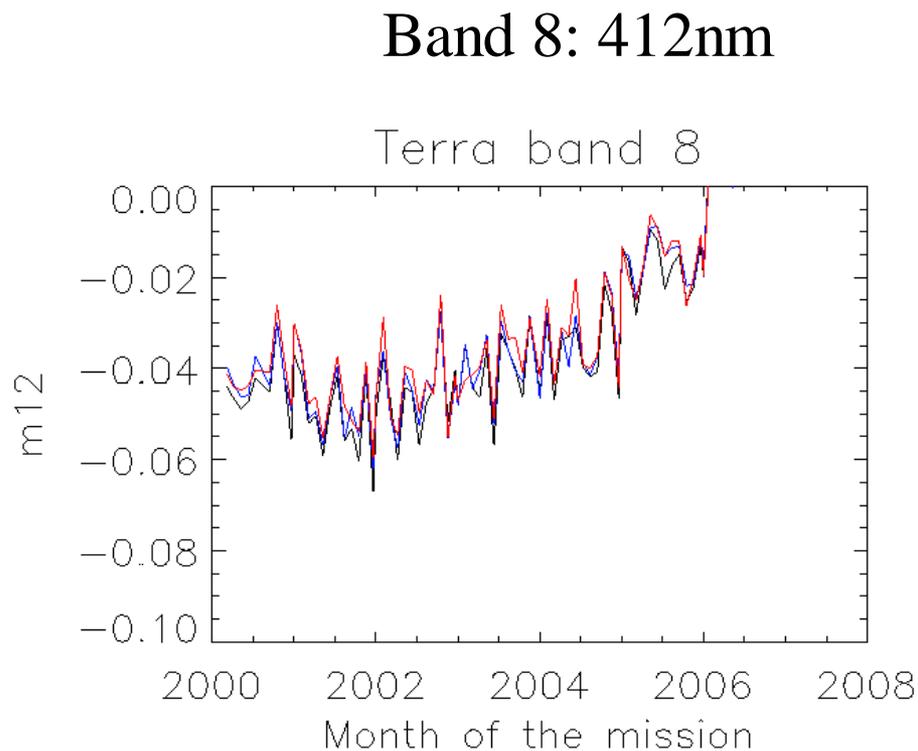
Summary

- **Main OBPB modifications for MODIS Terra calibration and characterization:**
 - RVS and polarization is adjusted for bands 8-12 using results from crosscalibration to SeaWiFS
 - Bands 13 and 14 are adjusted to MODIS Aqua with similar technique
 - Bands 15 and 16 are not modified
 - Band 3 is adjusted using spectral interpolation of crosscalibration results of bands 9 and 10
- **Resulting improvements to ocean color products:**
 - Strong improvement in temporal trends of nLw of bands 8-11
 - Improvement of scan angle dependence for bands 8-13 (not shown here, but expected due to earlier tests)
 - Band 3 was overcorrected



Crosscalibration results: Polarization (temporal)

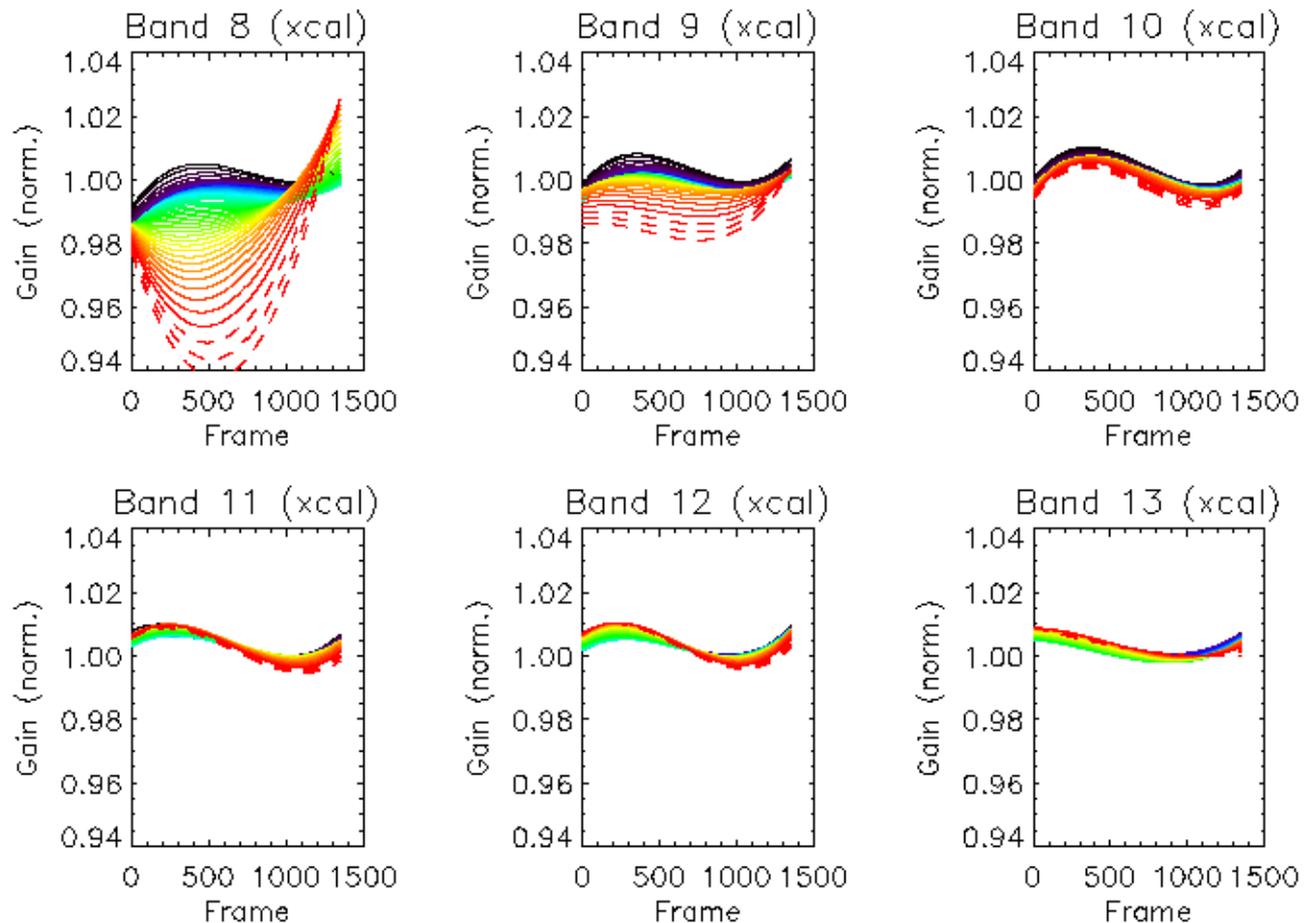
- Larger seasonal cycle than in MODIS Terra
- No trend in polarization coefficient m12 until 2008, not clear if trend afterwards



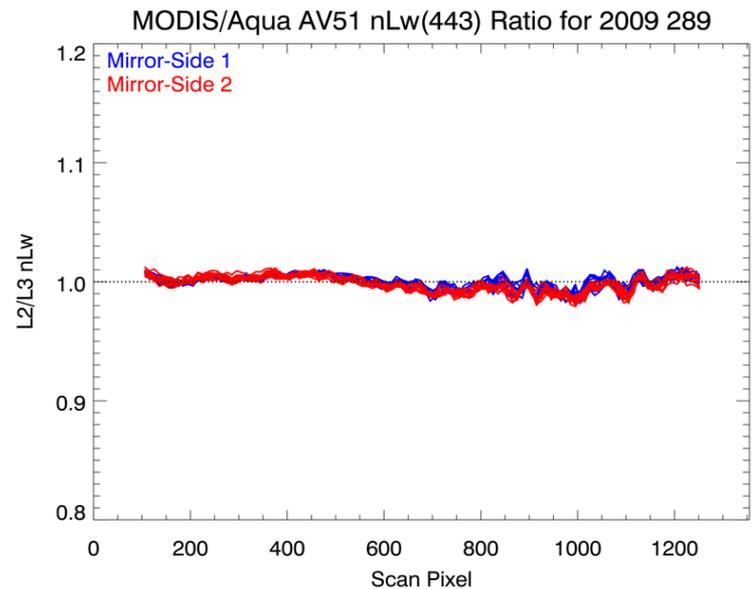
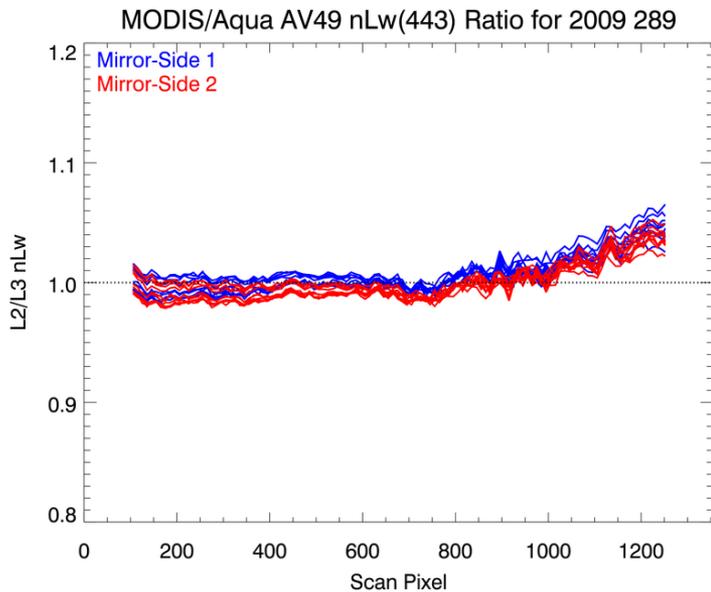
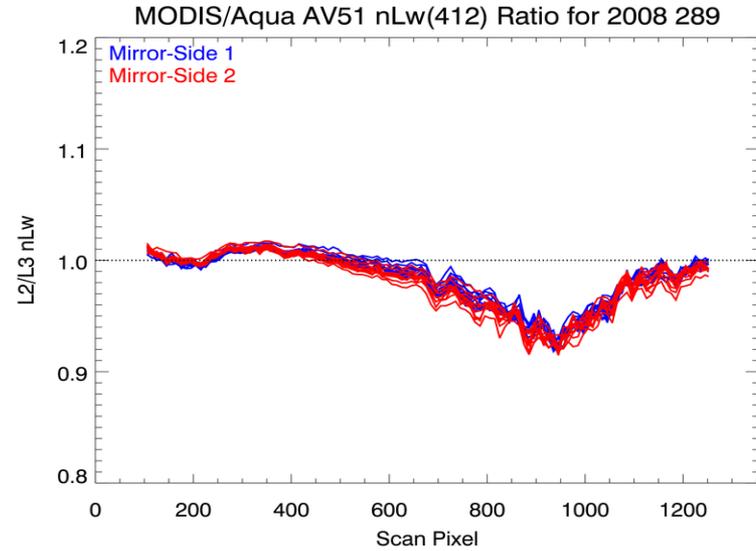
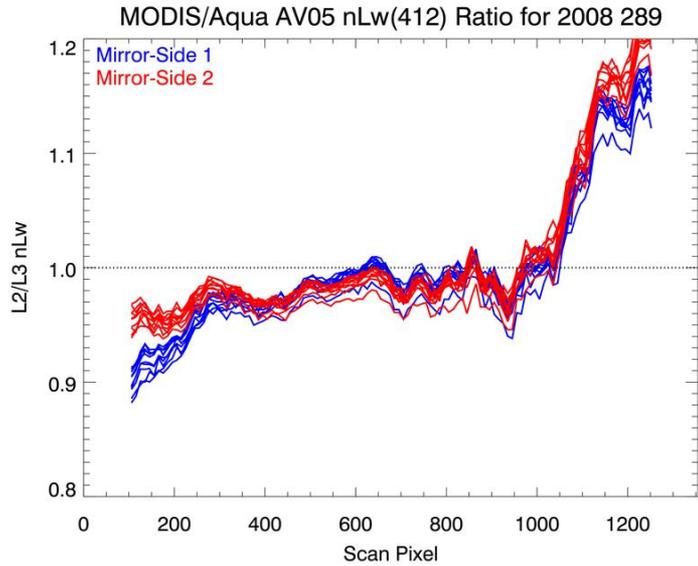
Black, blue, red:
detectors 1,5,10, MS 1
View angle: nadir

Crosscalibration results: Calibration (m1 and RVS)

- Implementation for 2010 MODIS Aqua reprocessing: Temporal correction for 412-443nm, constant correction for 488-678nm

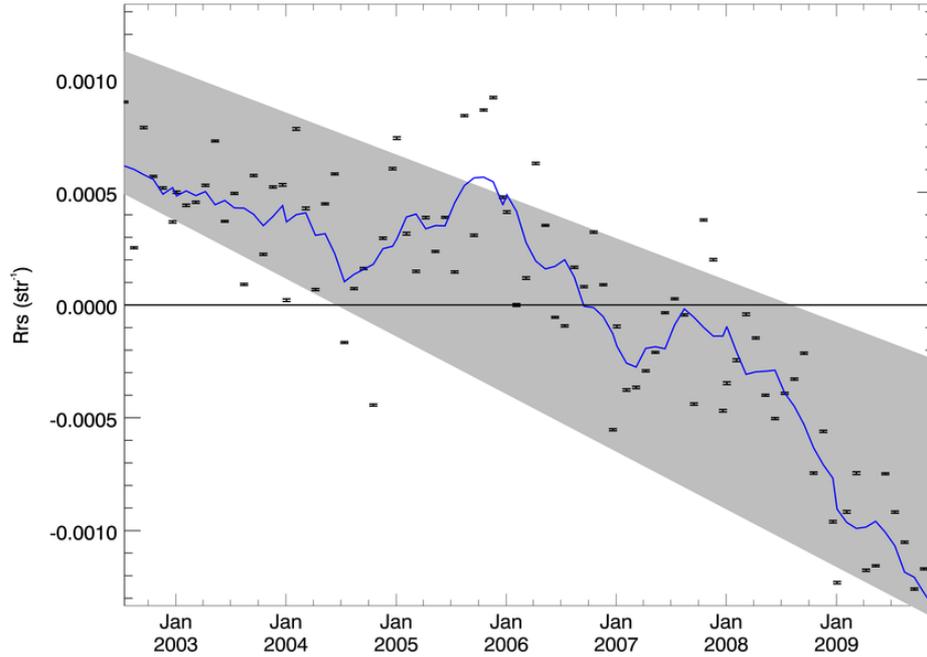


RVS issues resolved: 412nm, 443nm

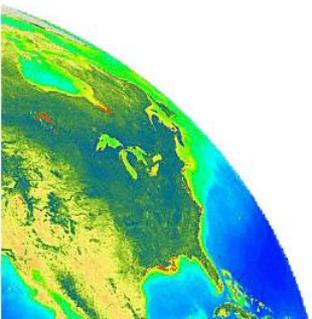
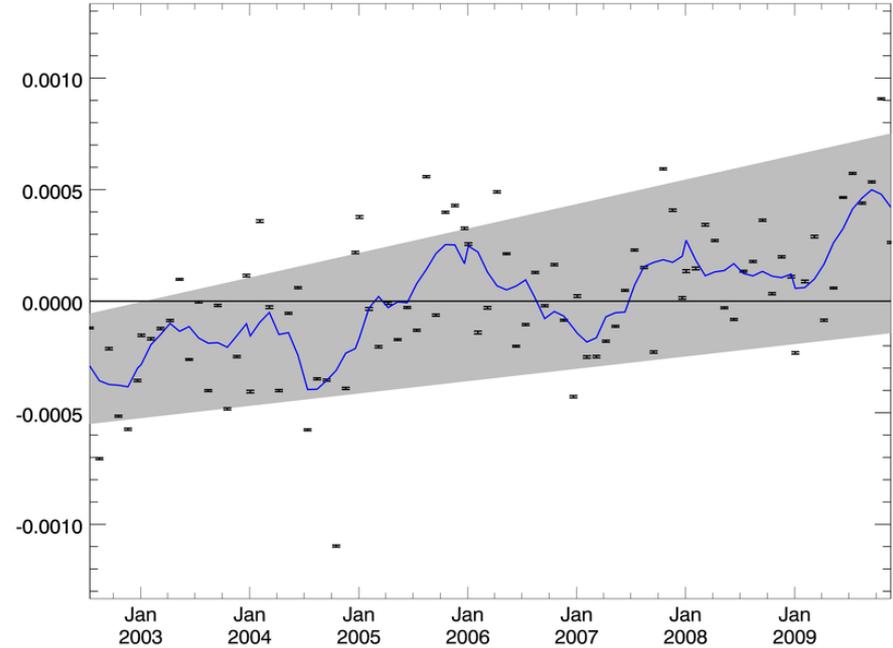


Temporal issue resolved: 412nm

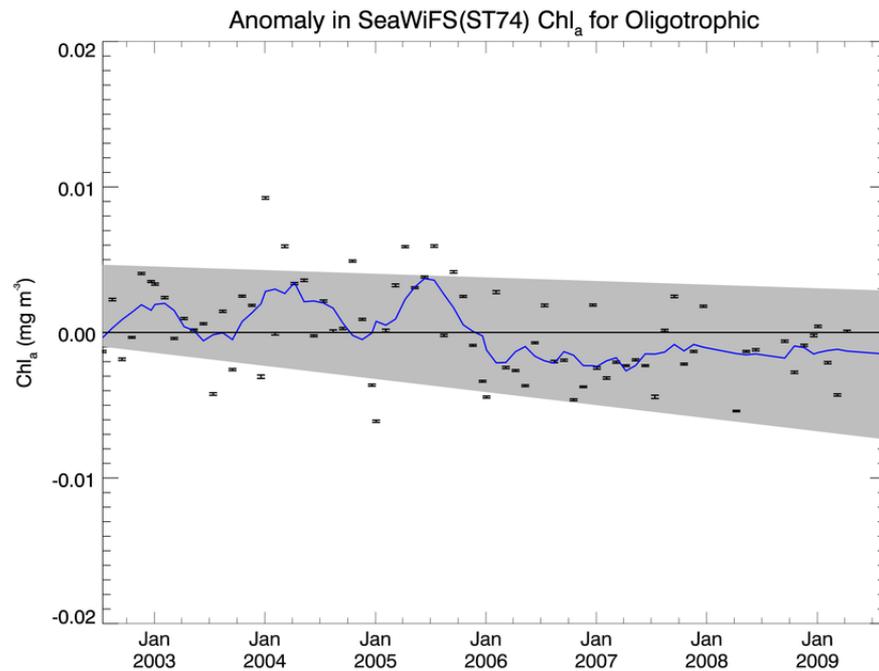
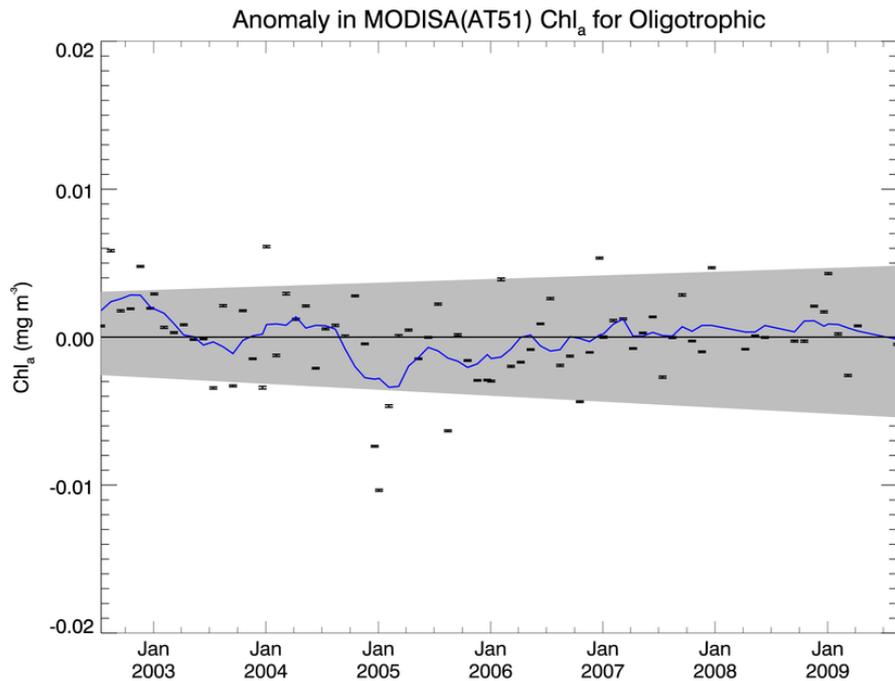
Anomaly in MODISA(AT47) Rrs(412) for Oligotrophic



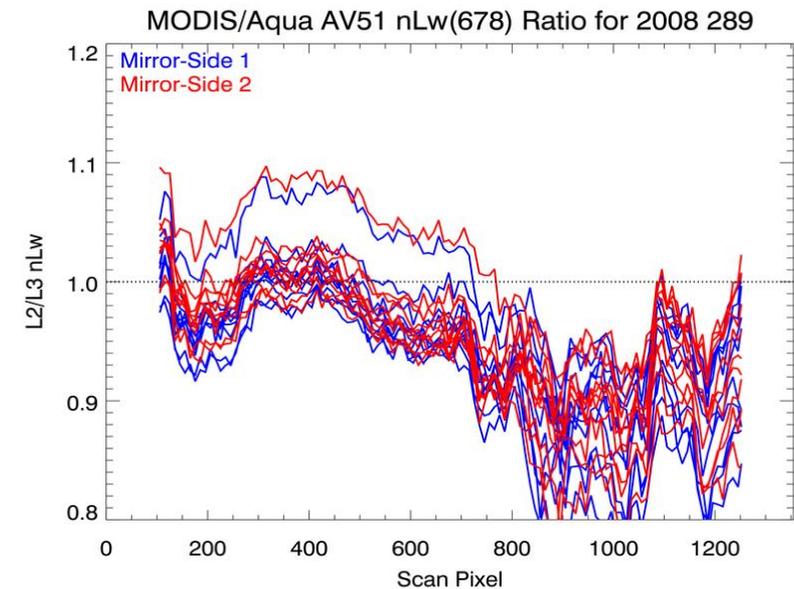
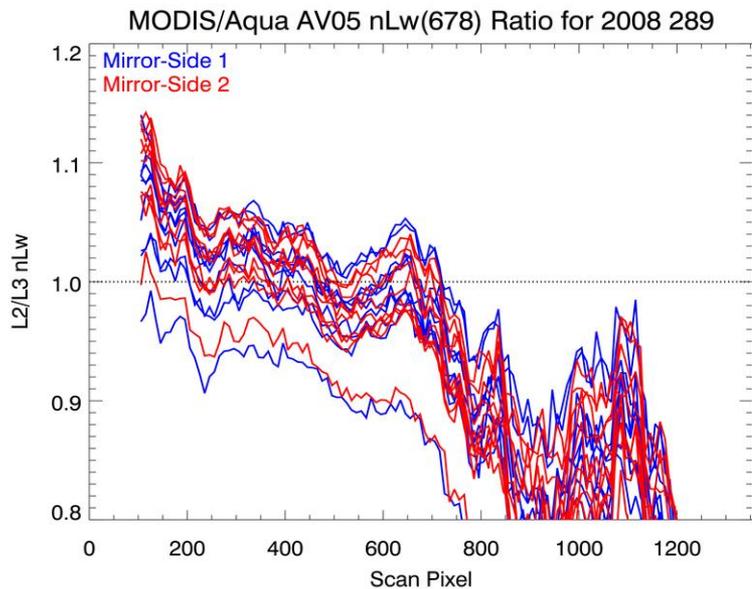
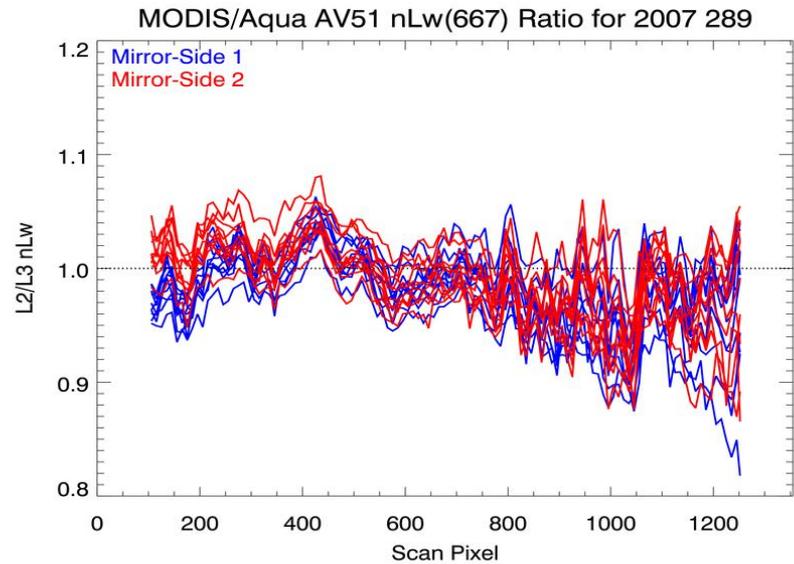
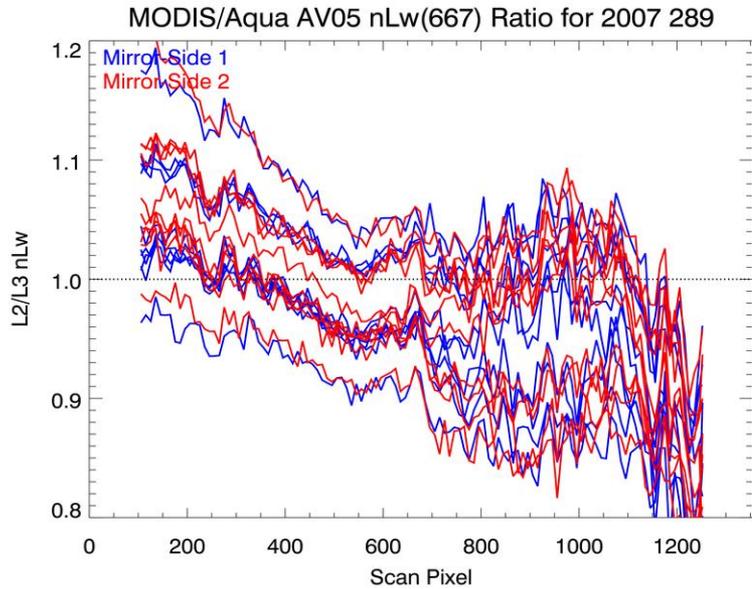
Anomaly in MODISA(AT51) Rrs(412) for Oligotrophic



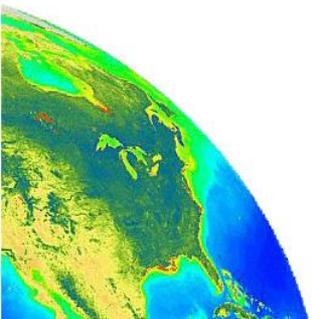
Chlorophyll trends: similar to SeaWiFS



RVS issues resolved: red bands (not EOM)

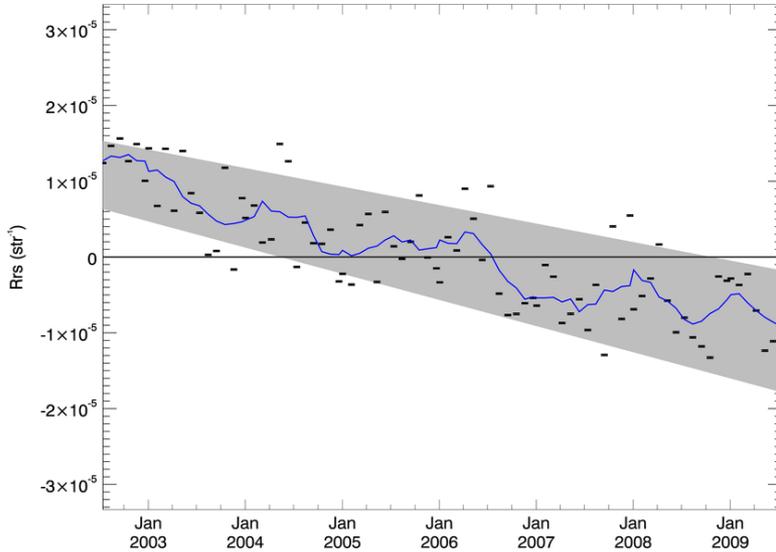


Backup

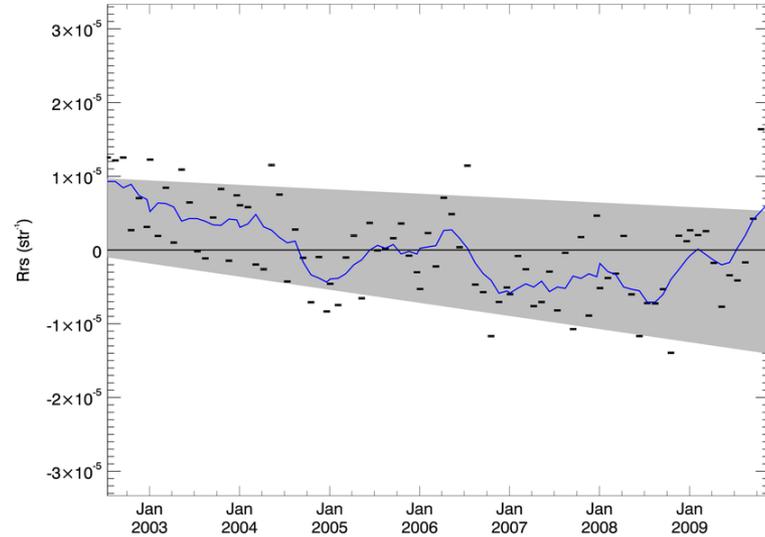


MCST coll. 6 resolves temporal issue for 678nm, FLH:

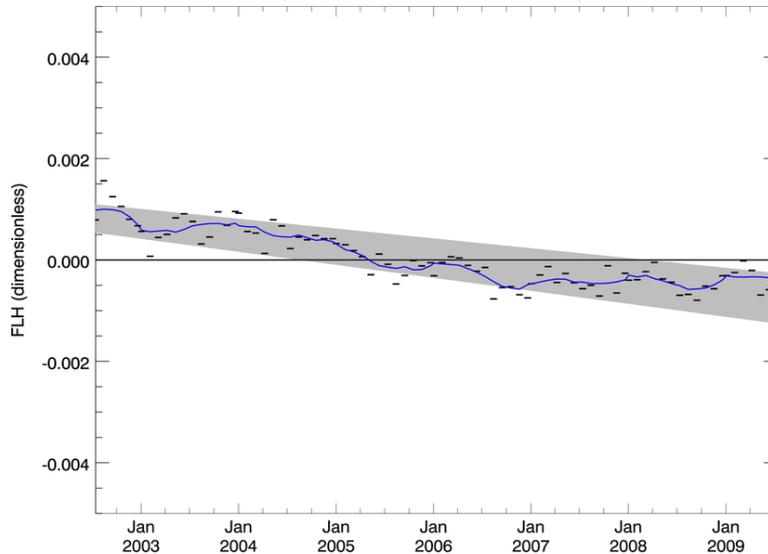
Anomaly in MODISA(AT42) Rrs(678) for Oligotrophic



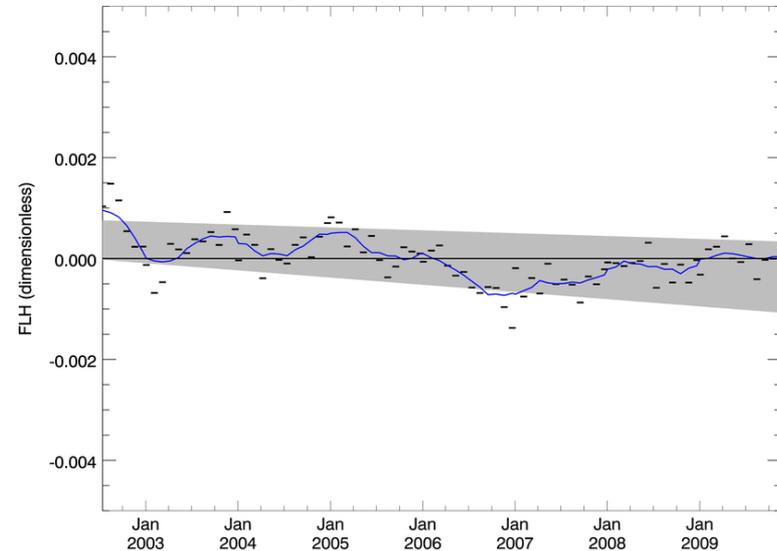
Anomaly in MODISA(AT51) Rrs(678) for Oligotrophic



Anomaly in MODISA(AT42) FLH for Oligotrophic

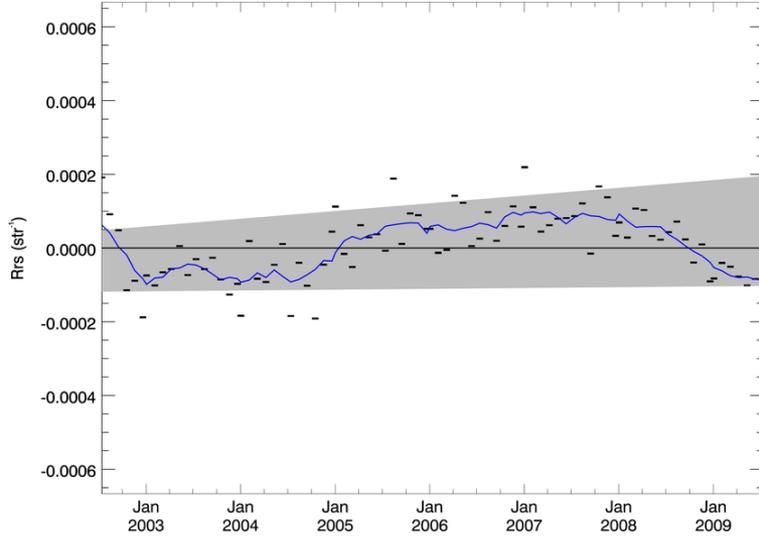


Anomaly in MODISA(AT51) FLH for Oligotrophic

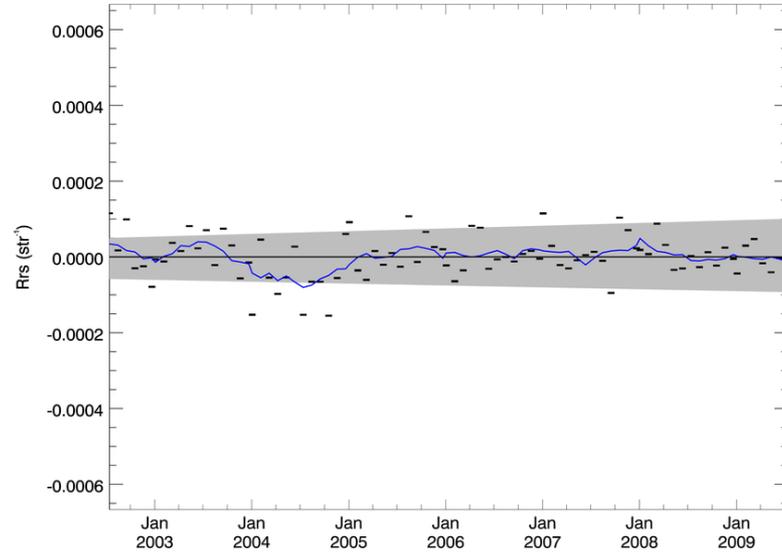


MCST coll. 6 reduces temporal variation for 488-547nm:

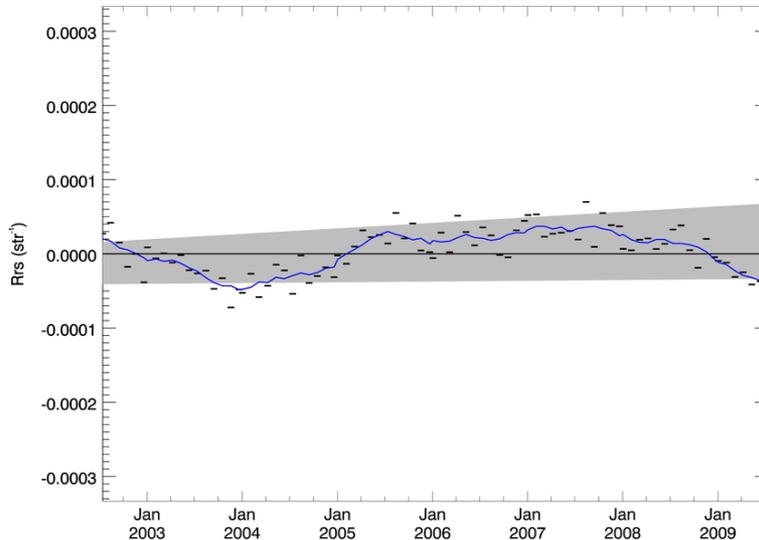
Anomaly in MODISA(AT42) Rrs(488) for Oligotrophic



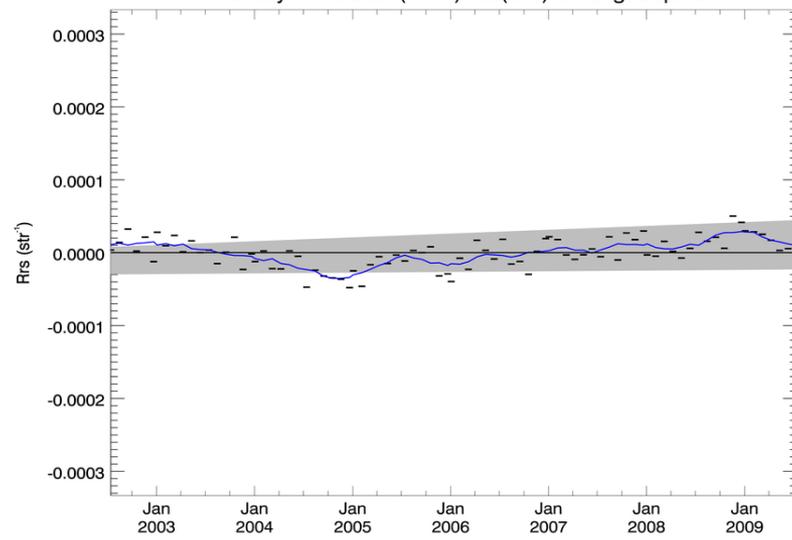
Anomaly in MODISA(AT47) Rrs(488) for Oligotrophic



Anomaly in MODISA(AT42) Rrs(547) for Oligotrophic

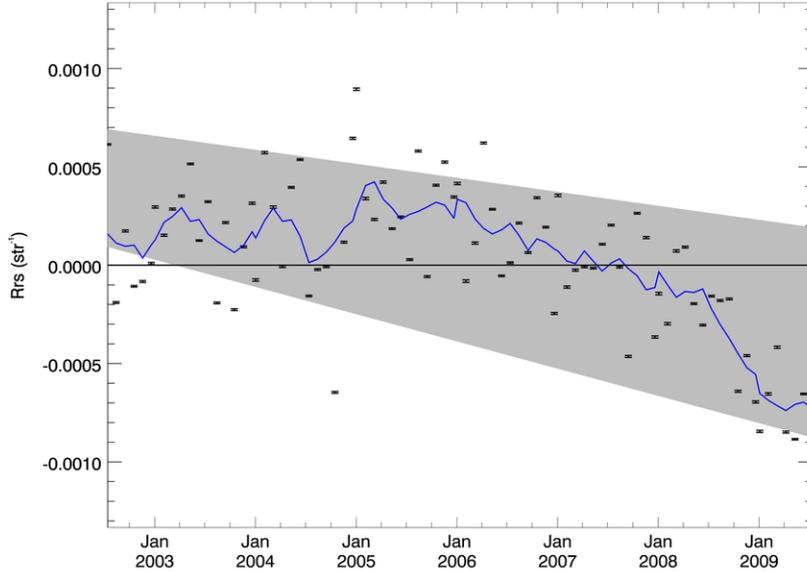


Anomaly in MODISA(AT47) Rrs(547) for Oligotrophic

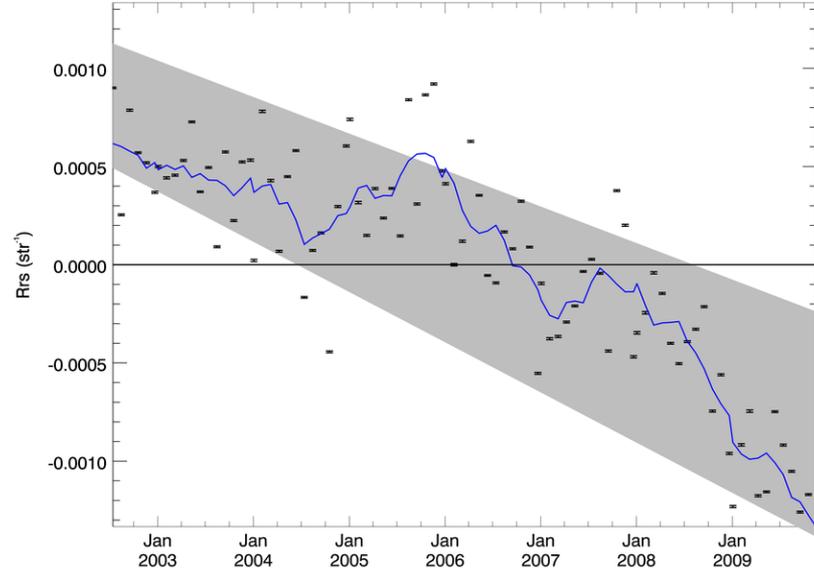


MCST coll. 6 increases trend in 412nm, improves angstrom:

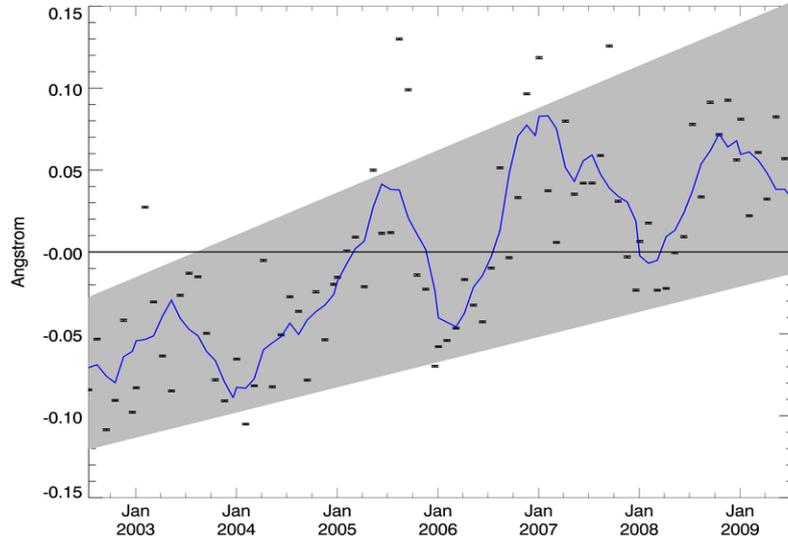
Anomaly in MODISA(AT42) Rrs(412) for Oligotrophic



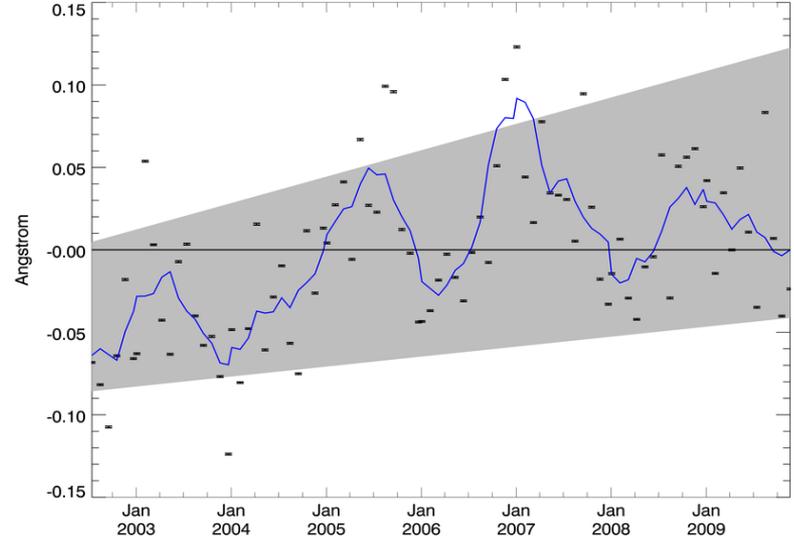
Anomaly in MODISA(AT47) Rrs(412) for Oligotrophic



Anomaly in MODISA(AT42) Angstrom for Oligotrophic



Anomaly in MODISA(AT47) Angstrom for Oligotrophic



Vicarious TOA MODIS total signal

$$L_m(\lambda) = M_{11}L_t(\lambda) + M_{12}Q_t(\lambda) + M_{13}U_t(\lambda)$$

$$\begin{bmatrix} L_m \\ Q_m \\ U_m \\ O_m \end{bmatrix} = \begin{bmatrix} M_{11} & M_{12} & M_{13} & M_{14} \\ M_{21} & \dots & & M_{24} \\ M_{31} & \dots & & M_{34} \\ M_{41} & M_{42} & M_{43} & M_{44} \end{bmatrix} \cdot \begin{bmatrix} L_t \\ Q_t \\ U_t \\ O_t \end{bmatrix}$$

TOA sensor cross-calibration

MODIS measured TOA radiance, polarized



$$L_m^m(\lambda) = M^{11} L_t(\lambda) + M^{12} Q_t(\lambda) + M^{13} U_t(\lambda)$$

- minimize over global distribution of path geometries
- find best M_{11} , M_{12} , M_{13} per band, detector, and mirror-side
- M_{11} , M_{12} , $M_{13} = f$ (mirror AOI)
- do this for one day per month over the mission lifespan

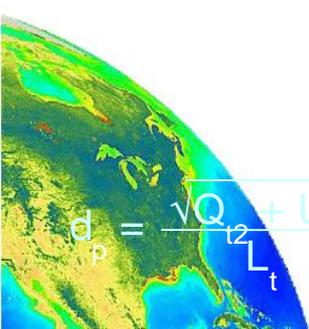
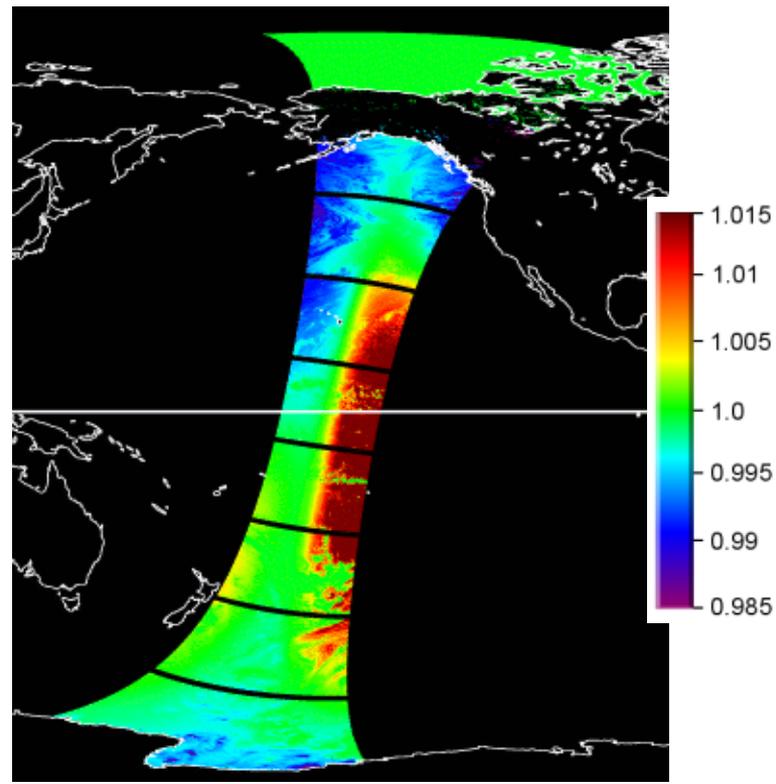
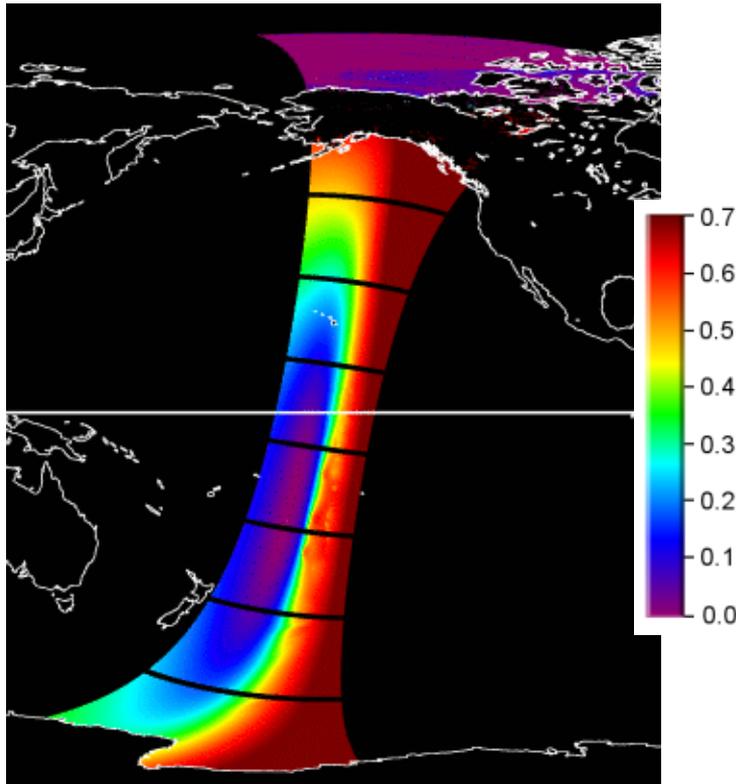


Polarization of the atmosphere

degree of atmospheric polarization d_p
 air molecule (Rayleigh) and glint scattering

polarization correction f_p
 pre-launch MODIS characterization

MODIS Terra
 swath
 412nm band 8



$$d_p = \frac{\sqrt{Q_{12}^2 + U_{12}^2}}{L_t}$$

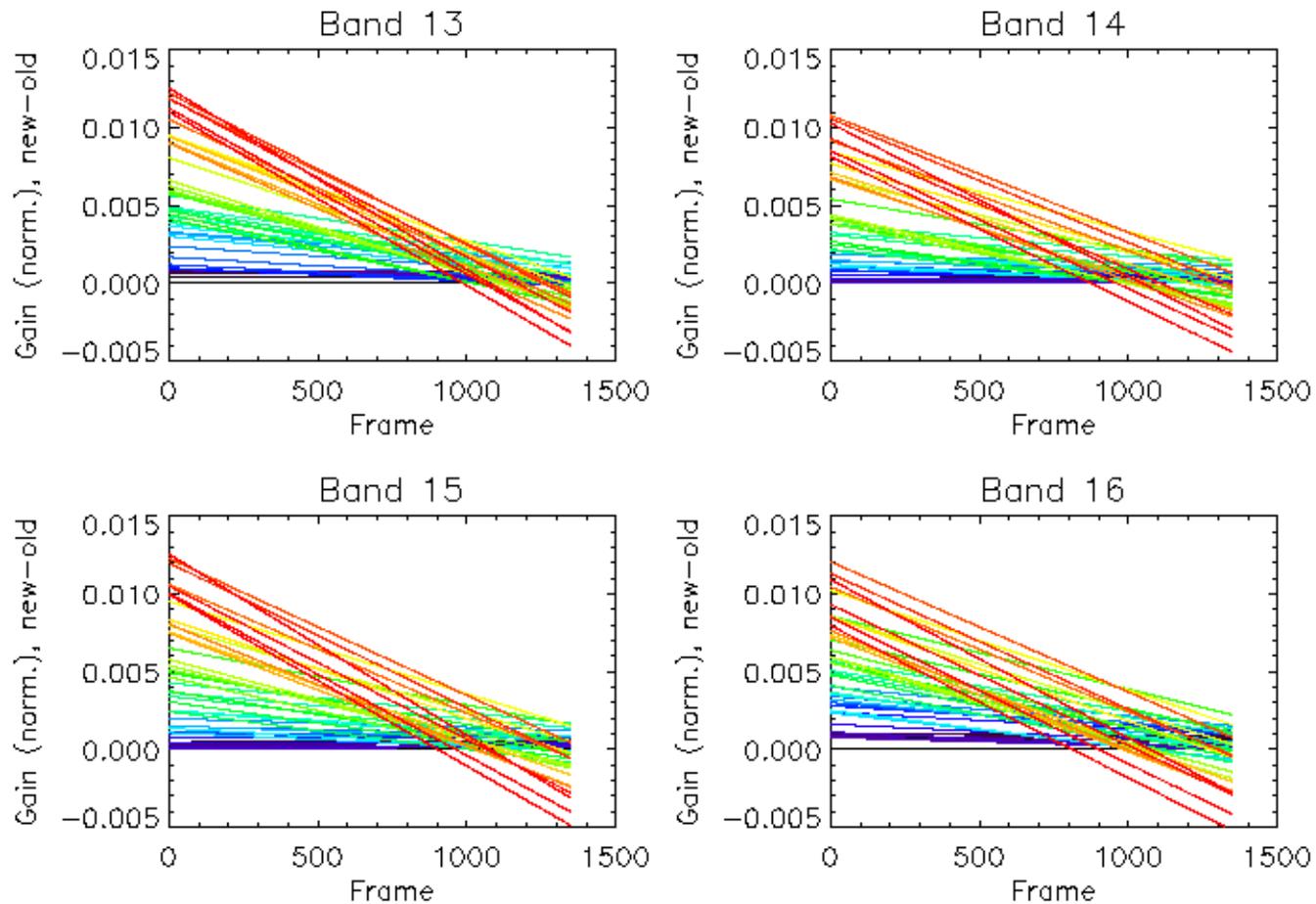
$$f_p = \frac{L_m}{L_t}$$

Issues and limitations with MODIS-Terra

- Temporal and scan-dependent trend in L_{wn} of MODIS-Terra suggests
 - instrument RVS may be in error
 - polarization sensitivity may be changing
 - on-board calibration capabilities may be degrading (SD, SDSM)
- On-board calibration (lunar or solar) CANNOT assess
 - changes in RVS “shape”
 - changes in polarization sensitivities
- OBPG developed a vicarious approach for on-orbit characterization of Terra
 - RVS, and
 - polarization sensitivity

New lunar trending of bands 13-16 (667-869nm)

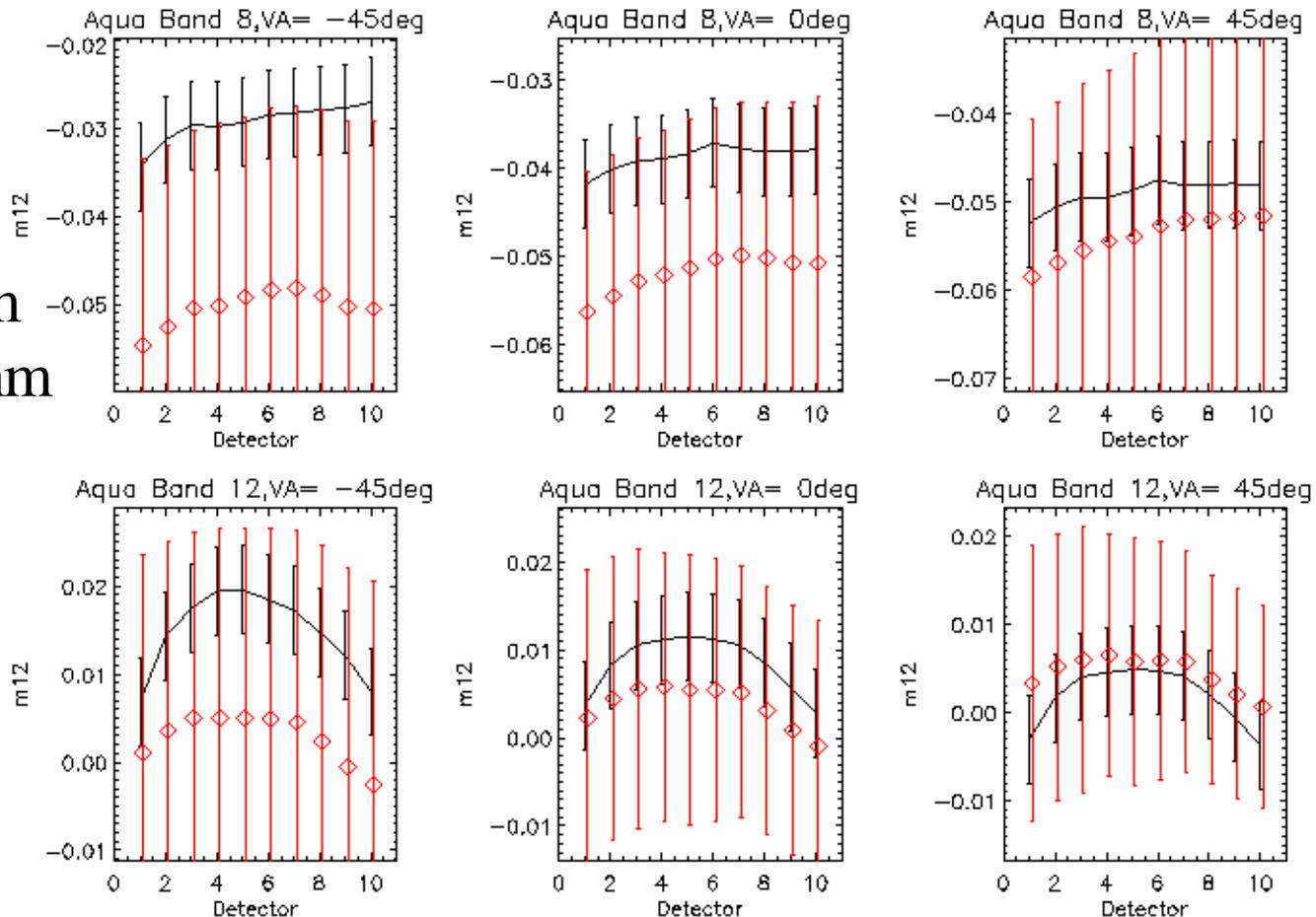
Comparison of collection 5 LUT to coll. 6:



Crosscalibration results: Polarization (detectors)

- Crosscalibration results confirm detector trend from prelaunch measurements (not used before)
- Absolute offset at BOS (low TOA deg. of pol.)

Band 8: 412nm
Band 12: 547nm



Surface Effects

Sun Glint



White Caps



Corrections based
on statistical models
(wind & geometry)