Calibration and characterization adjustments to the MODIS ocean color bands by the OBPG

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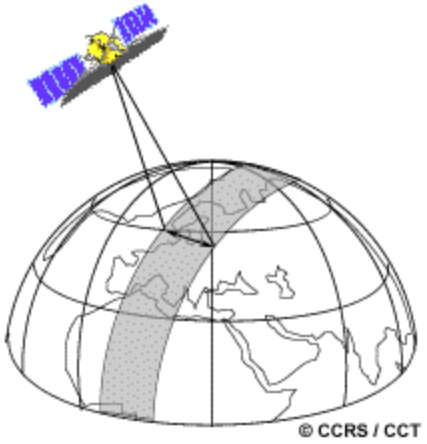
MODIS issues:

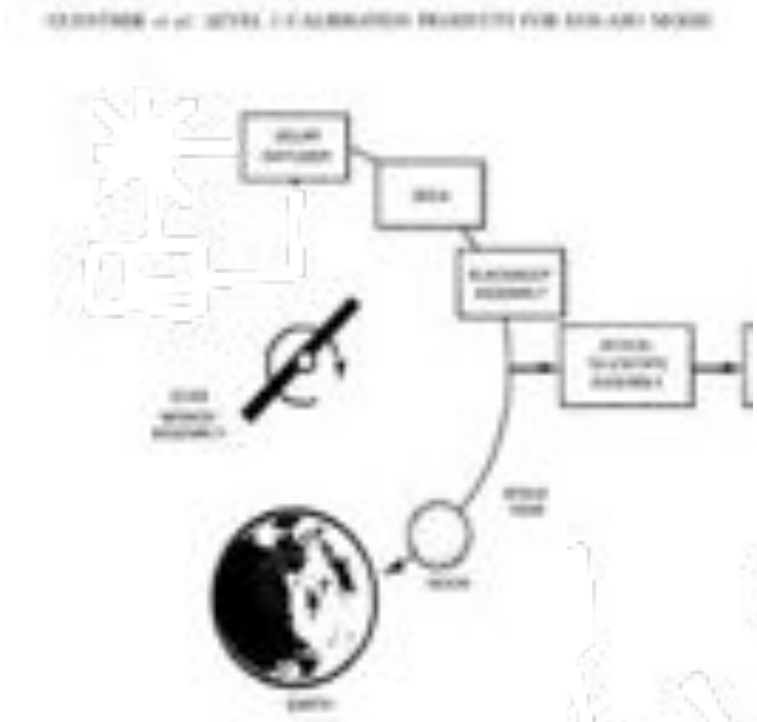
- Small calibration errors (~0.1%) lead to striping/ erroneous trending in OC products
- MODIS scan angle radiometric sensitivity changes with time (not for SeaWiFS)
- On-orbit calibration can only be trended for lunar view angle (beginning of scan) and solar diffuser view angle (2nd half of scan, see later slide)
- No on-board capability to trend polarization sensitivity changes on-orbit (not an issue yet for MODIS Aqua, but for MODIS Terra)

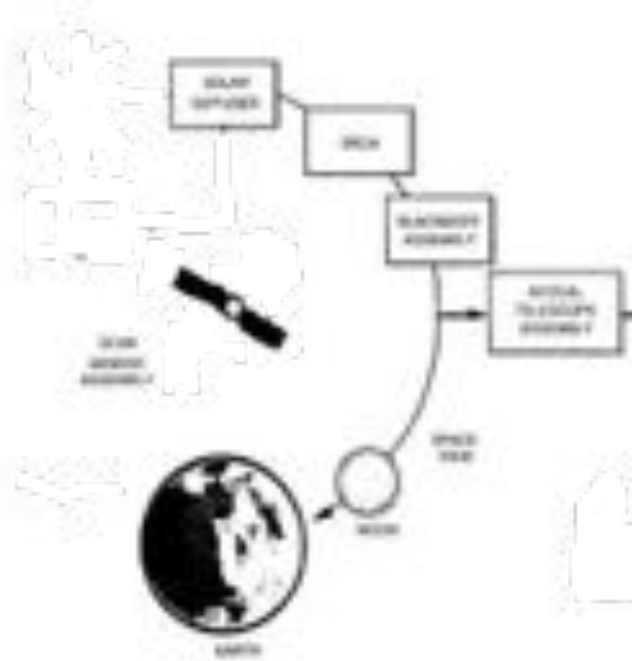


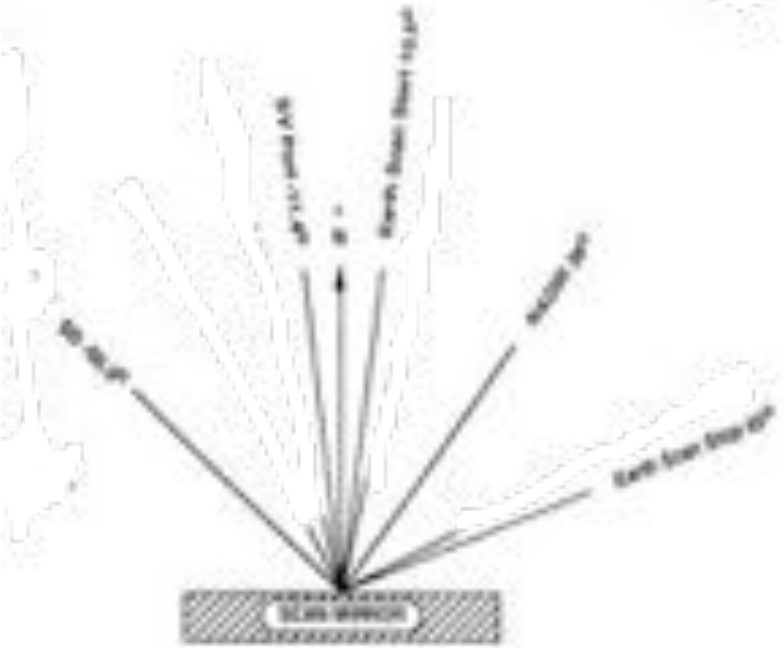
Overview:

- First part: MODIS Terra
  - significant degradation in the blue bands, for both radiometric gain and polarization sensitivity
  - temporal adjustments, based on SeaWiFS for bands 8-12, MODIS Aqua for bands 13-14
- Second part: MODIS Aqua
  - significant degradation in the blue bands for radiometric gains only
  - temporal radiometric gain adjustments for bands 8-9 only, based on SeaWiFS, constant RVS adjustment (small) for bands 10-14

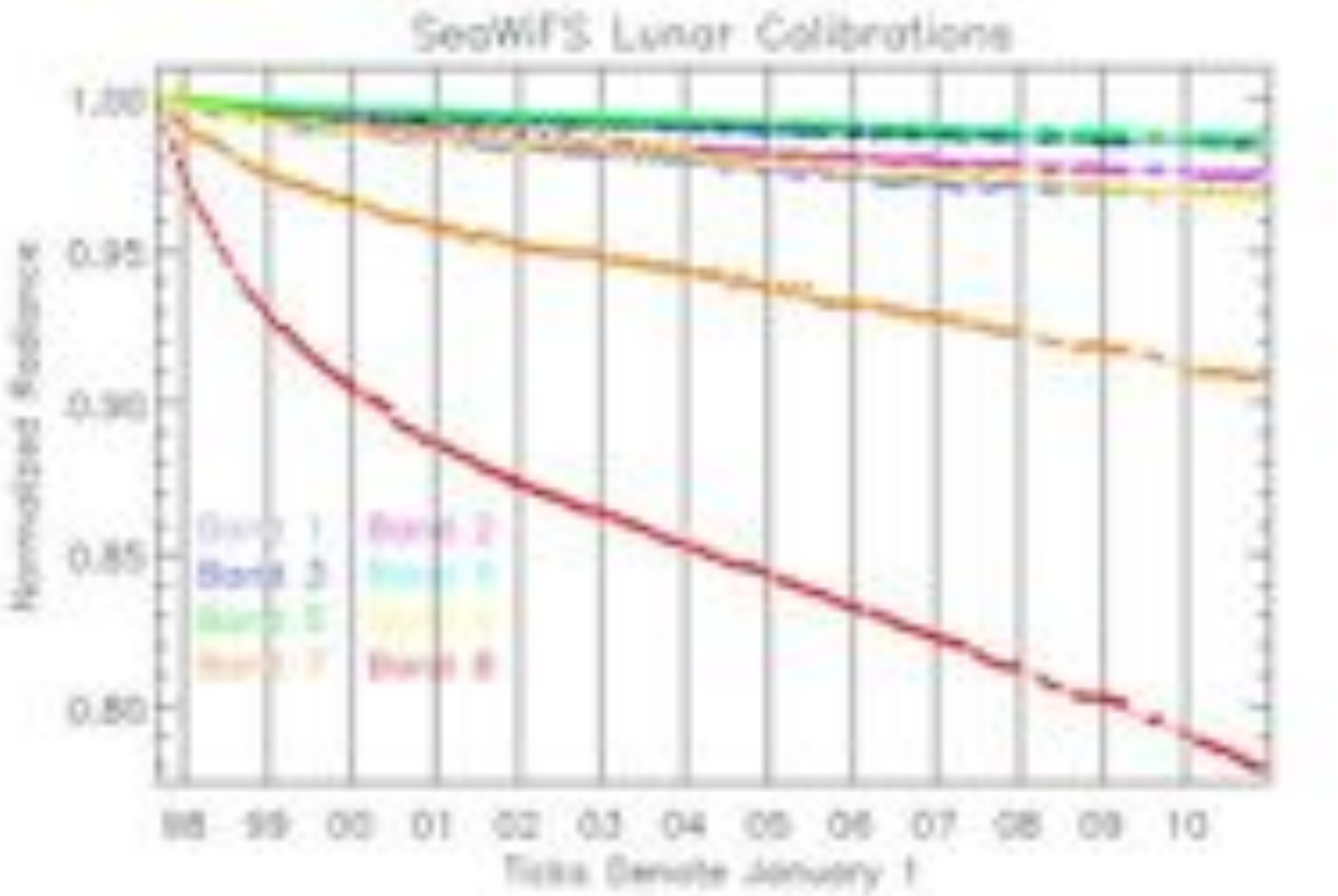
MODIS Optical System

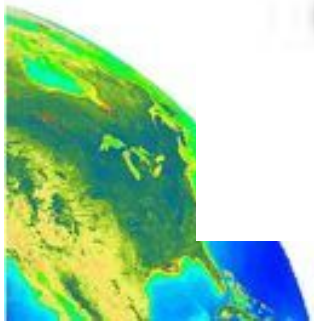




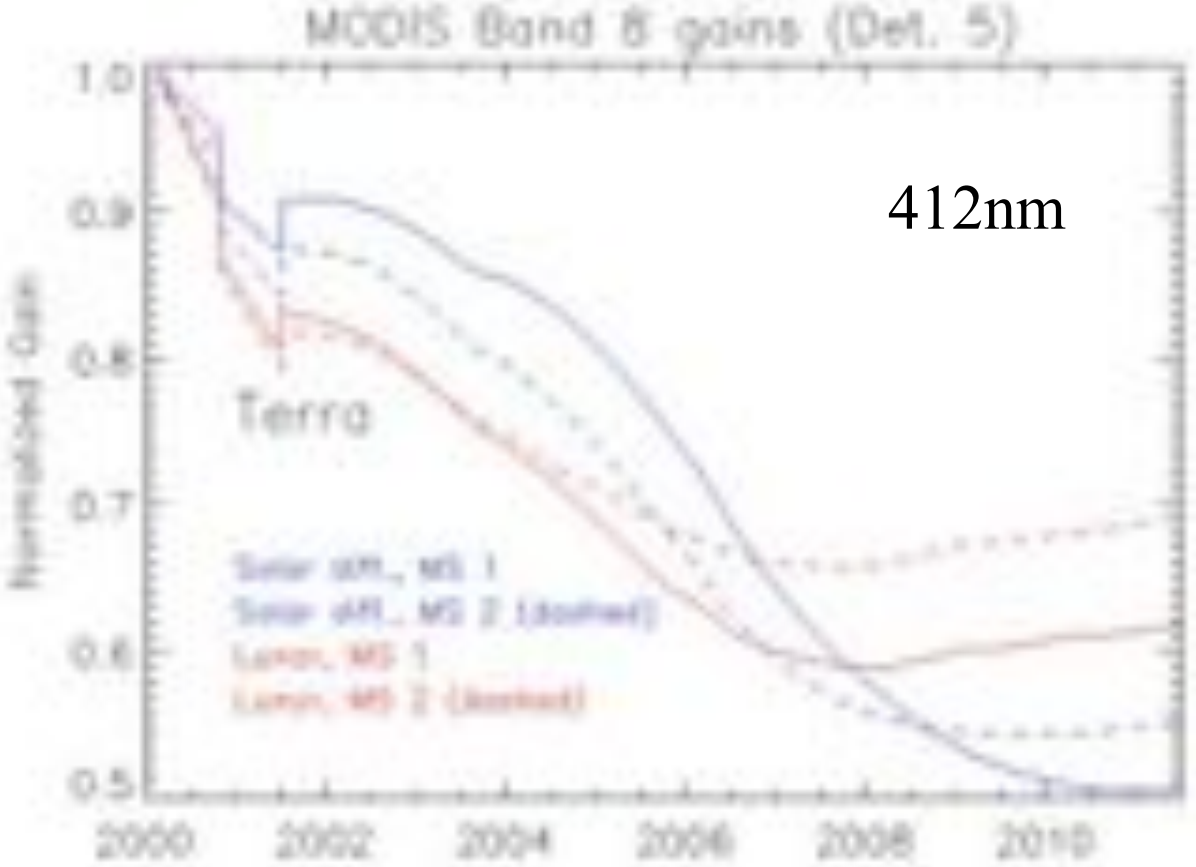


Sensor degradation: SeaWiFS

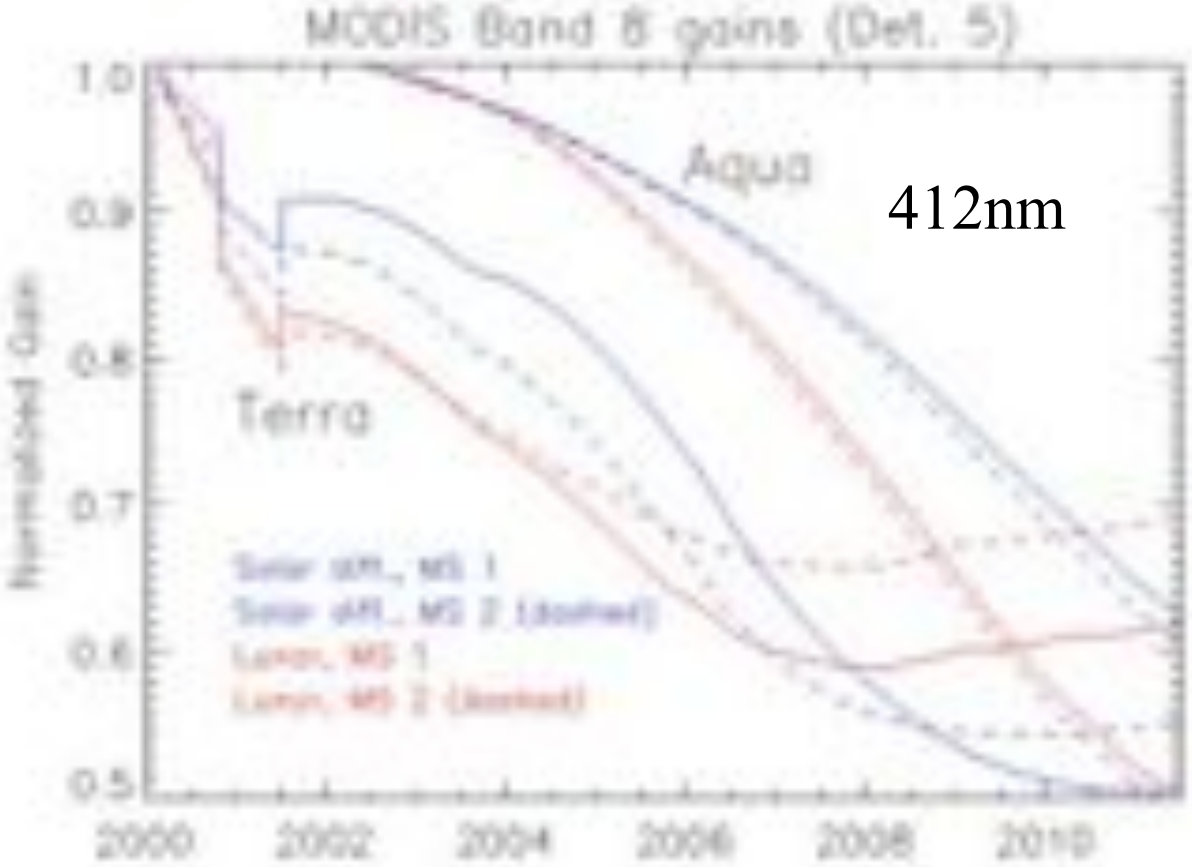




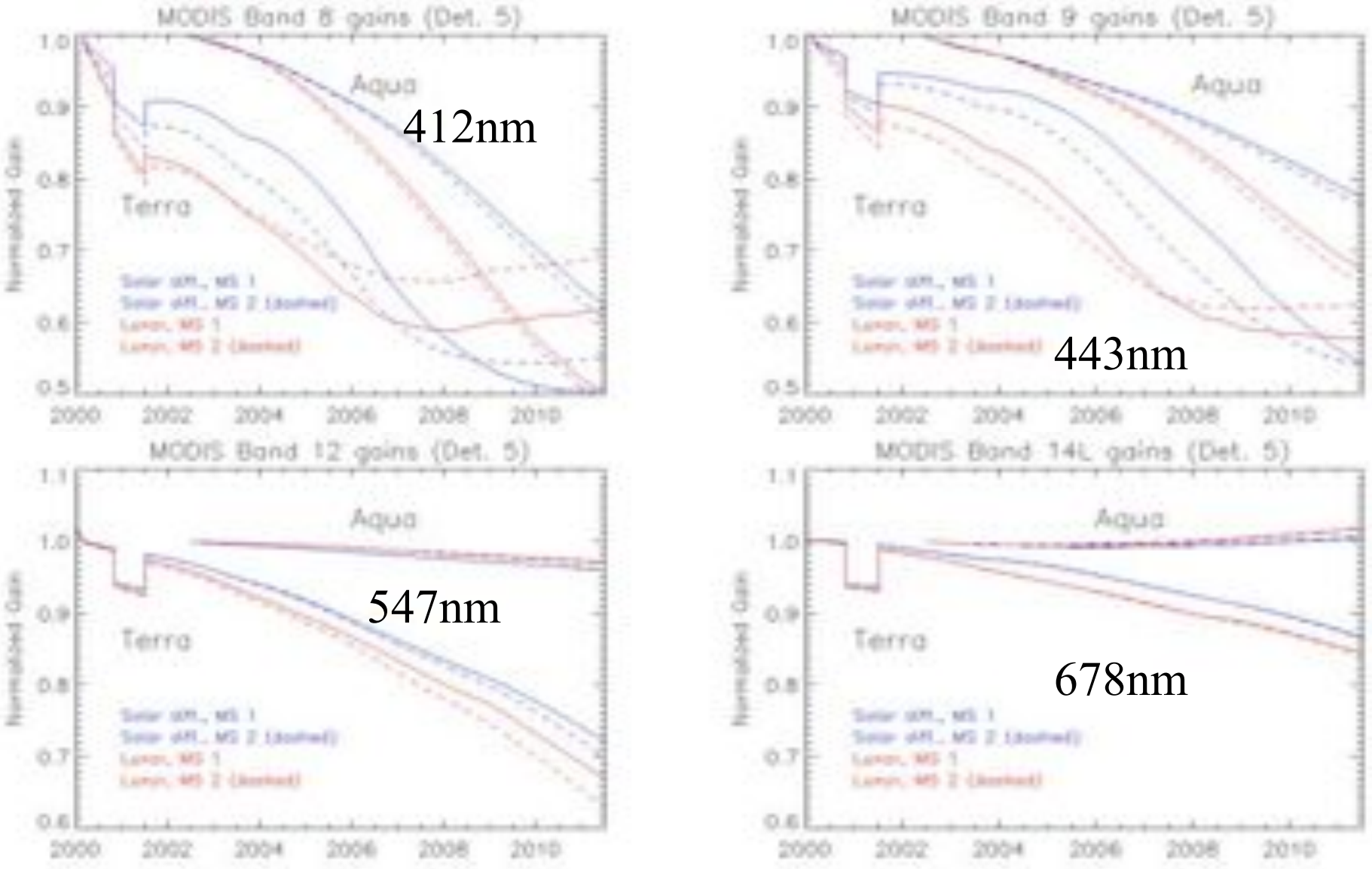
Sensor degradation: MODIS Terra



Sensor degradation: MODIS Terra and Aqua

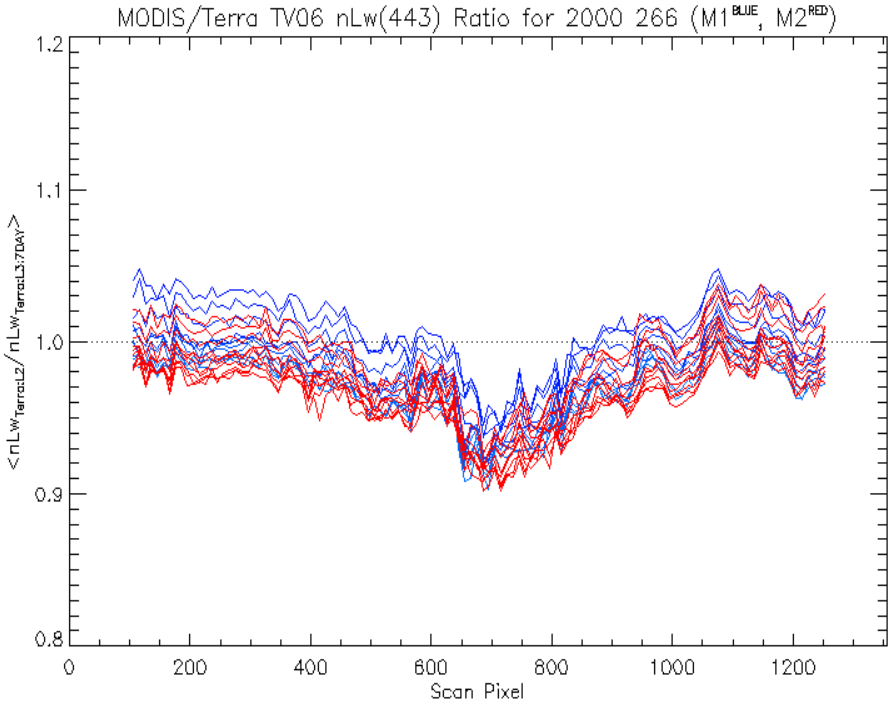


Sensor degradation: MODIS Terra and Aqua

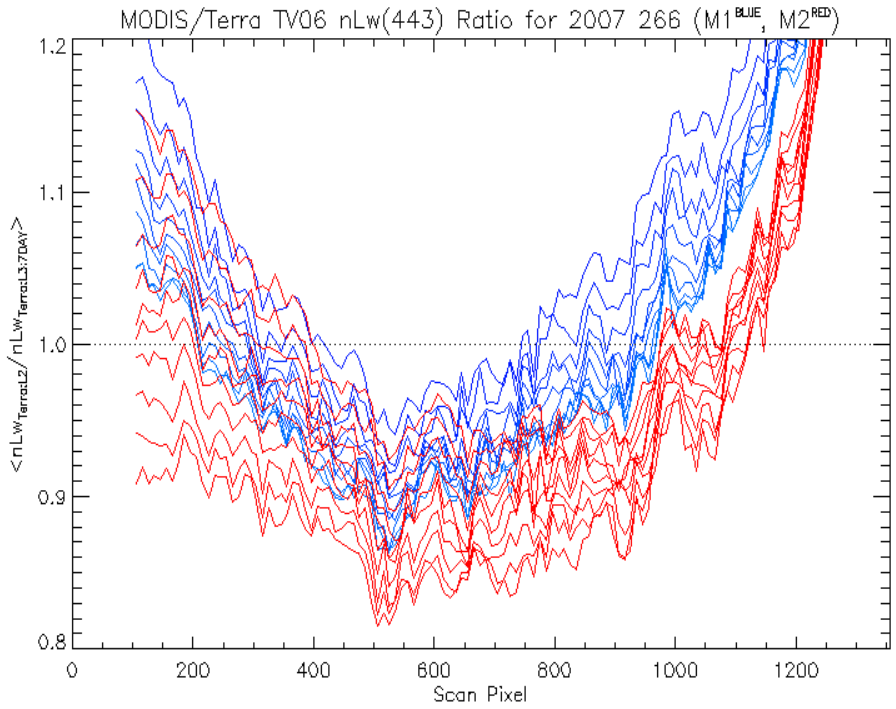


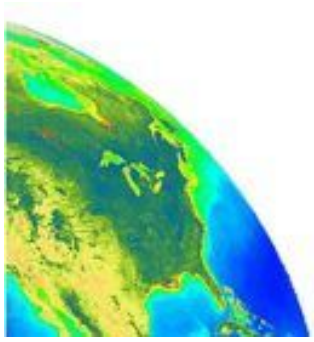
MODIS Terra response-versus-scan (RVS): 443nm

RVS 2000:



RVS 2007:





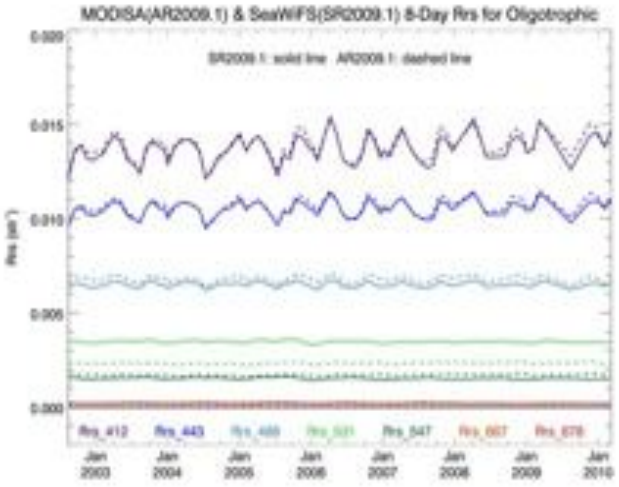
- Some striping and small RVS dependency in 2000
- Strong striping (mirror side and detector) and large RVS dependency in 2007

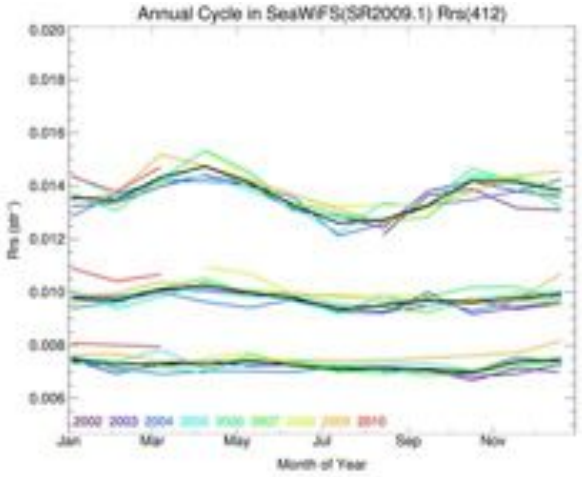
Temporal trend analysis:

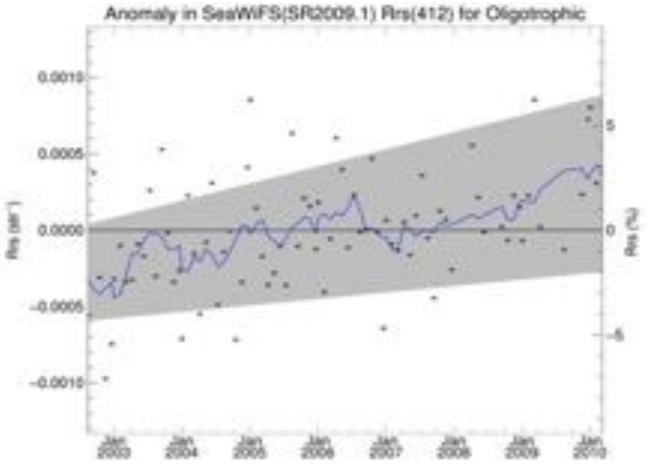
Example: SeaWiFS Rrs 412nm for oligotrophic regions

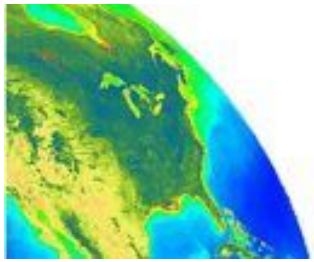
Global average minus **annual cycle** equals **anomaly**

(solid purple line) (mean of top lines) (dots:value with error bar, blue line:same data smoothed gray area:linear trend range)

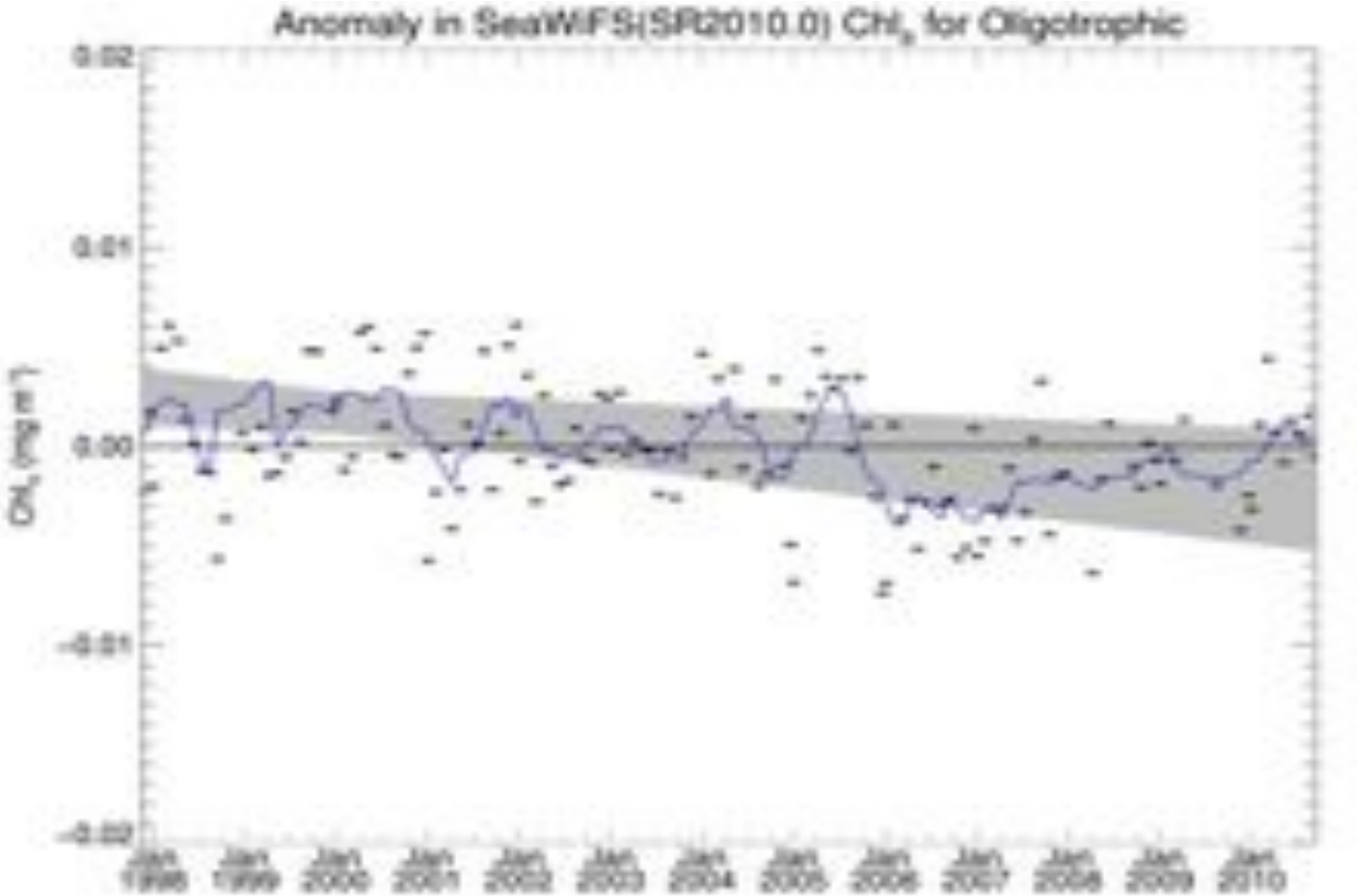




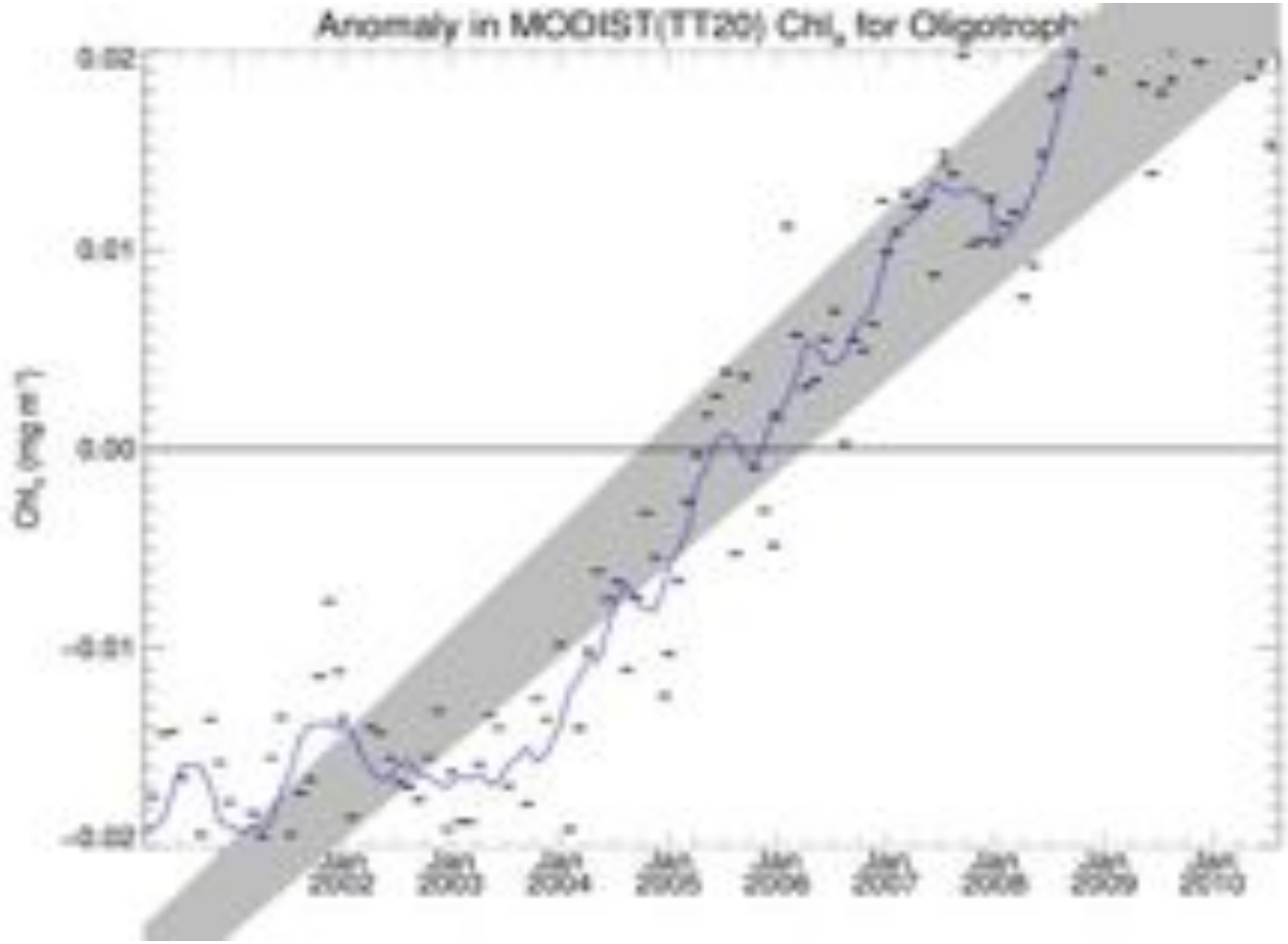




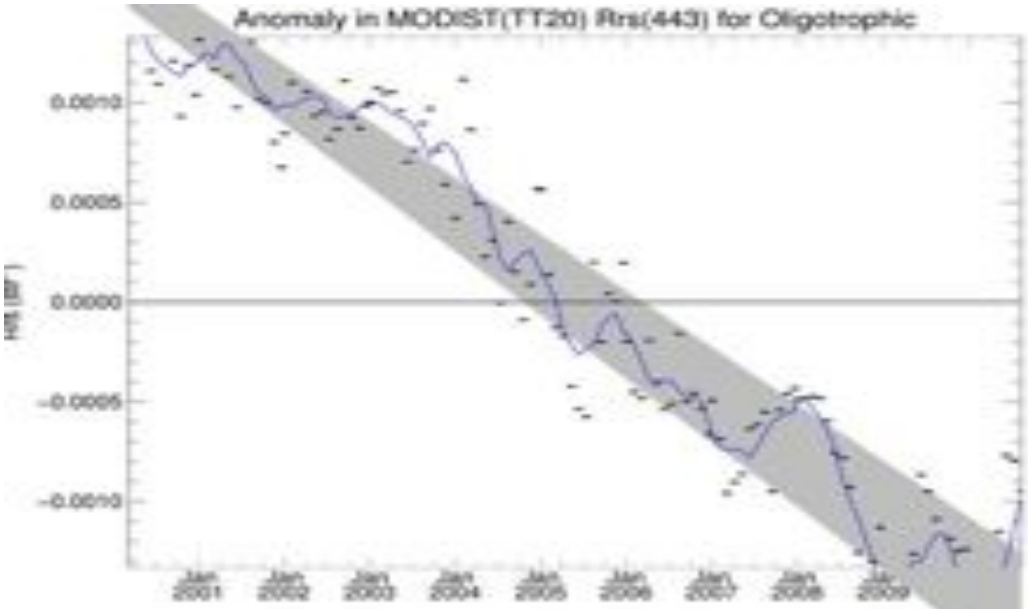
Temporal trend: chl-a SeaWiFS

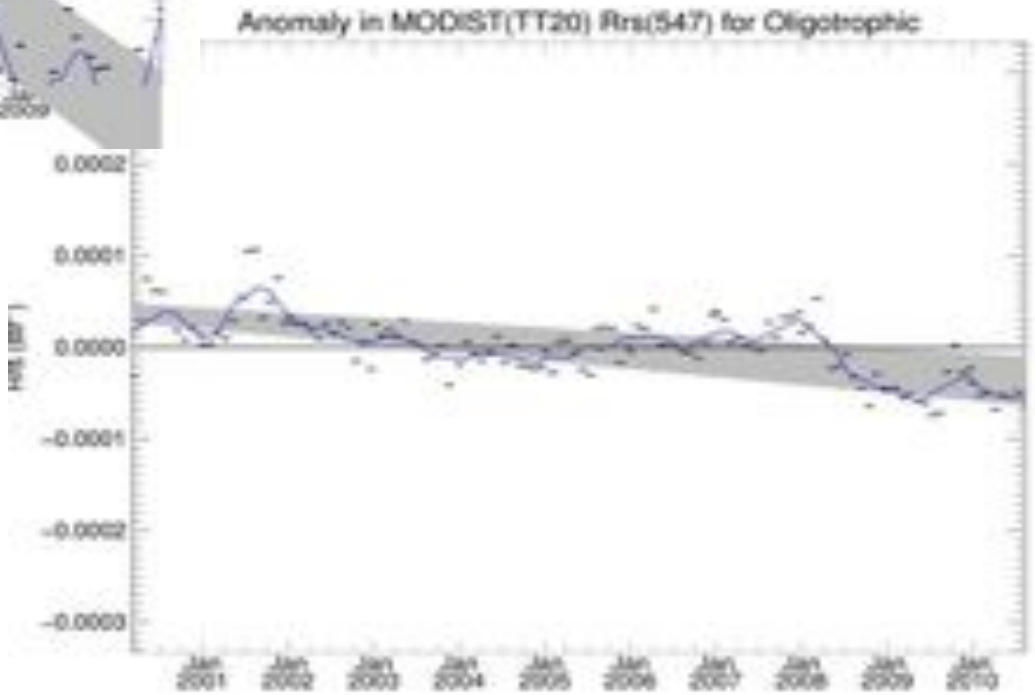


chl-a trend in MODIS Terra w/o calibration adjustment



443nm and 547nm trend in MODIS Terra w/o cal. adj.





Approach summarized:

- Baseline: MCST lunar and SD trending (not official Collection 6 LUT)
- MCST lunar analysis: time dependent NIR RVS
- MODIS Terra bands 8-12 (& 3-4) 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 (15-day L3)
- Verify with analysis using only MODIS Terra data: temporal trends (seasonal cycle removed) and ratio of L2/L3 versus scan angle

Modeling of TOA Stokes vector over oceans

air aerosol whitecap glint water gas

$$\begin{bmatrix} L_t \\ Q_t \\ U_t \\ 0 \end{bmatrix}$$

$$L_t(\lambda) = [\, L_r(\lambda) + L^a(\lambda) + tL_f(\lambda) + TL_g(\lambda) + t_d(\lambda)L^w(\lambda) \,] \cdot t_g(\lambda)$$

from MODIS NIR
assumes MCST NIR band characterization

$\lambda' \rightarrow \lambda$
fit based on bio-optical models

SeaWiFS
15-day mean

$L^{wn}(\lambda')$

Crosscalibration approach:

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

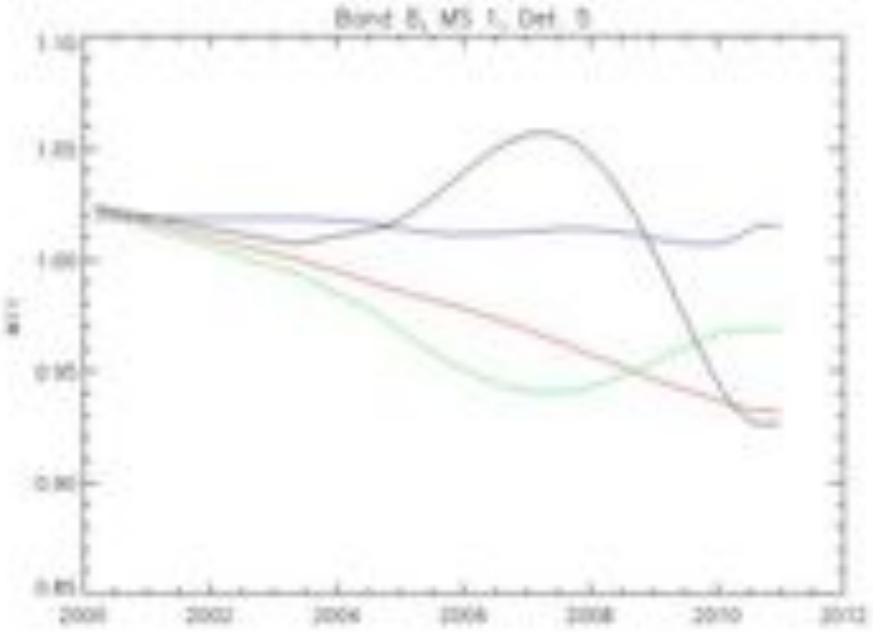
L_m: measured TOA radiance (MODIS)

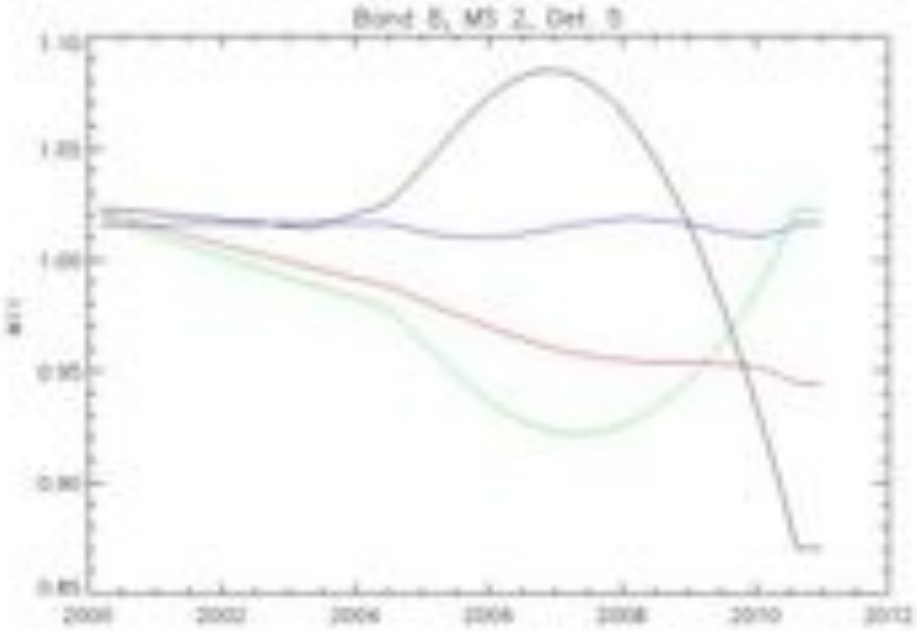
L_t: true TOA radiance (from SeaWiFS)

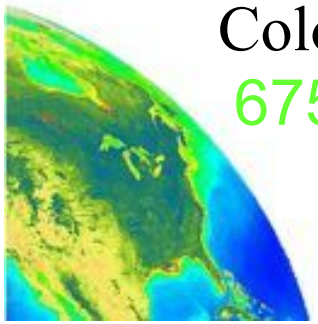
Q, U : linear Stokes vector components, modeled from Rayleigh and glint

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

MODIS Terra gain corrections as a function of time at different view angles at 412nm:

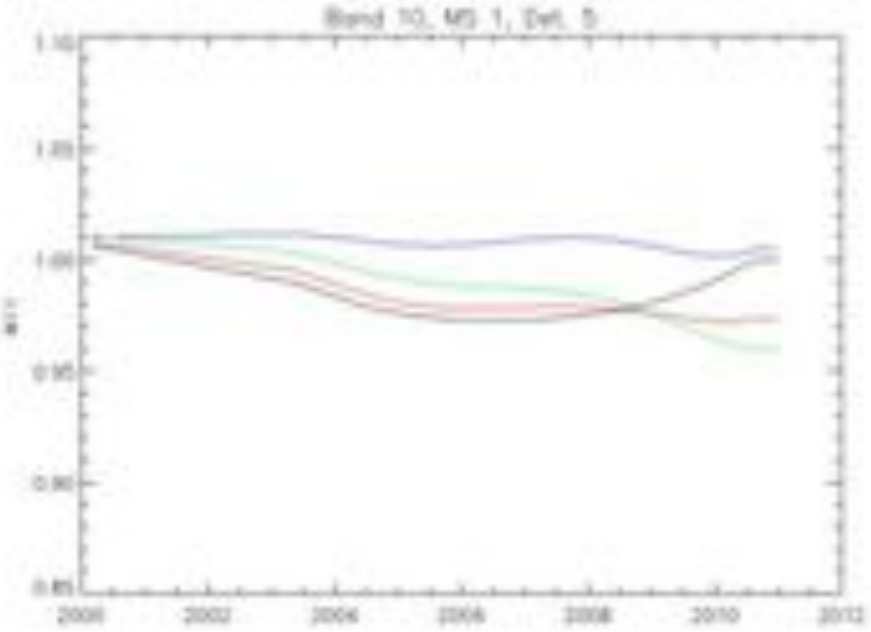


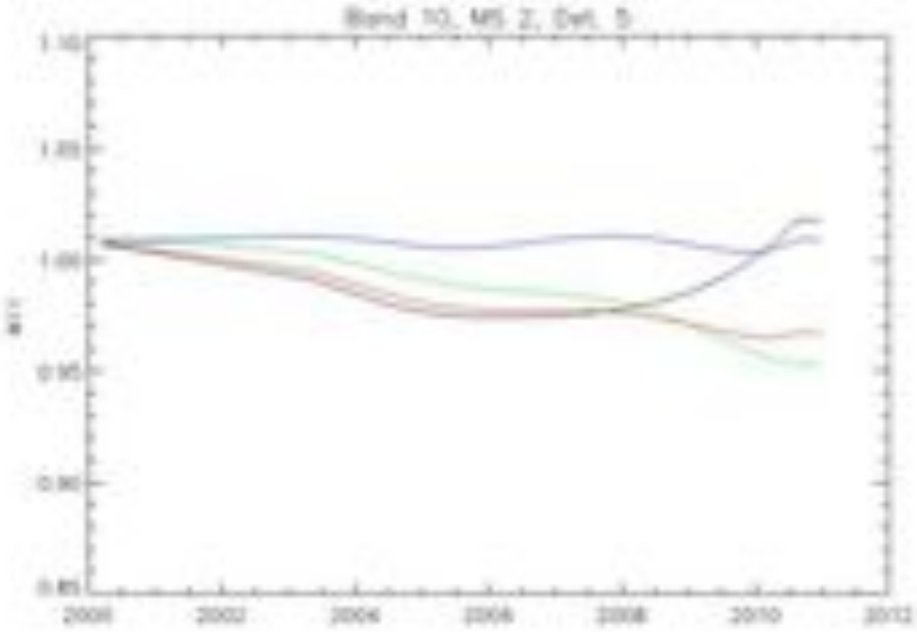


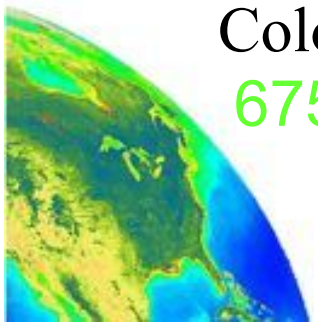


Color coding: Frame/pixel 22 (beginning of scan, lunar), 675 (nadir), 989 (solar diffuser), 1250 (end of scan)

MODIS Terra gain corrections as a function of time at different view angles at 488nm:

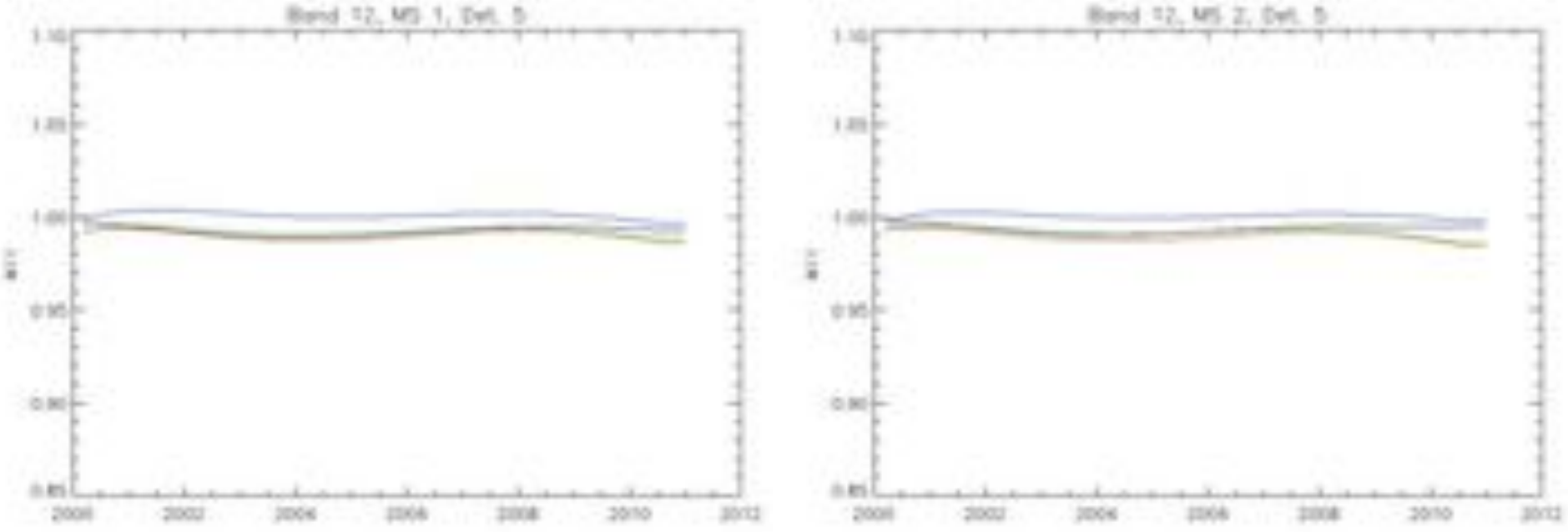






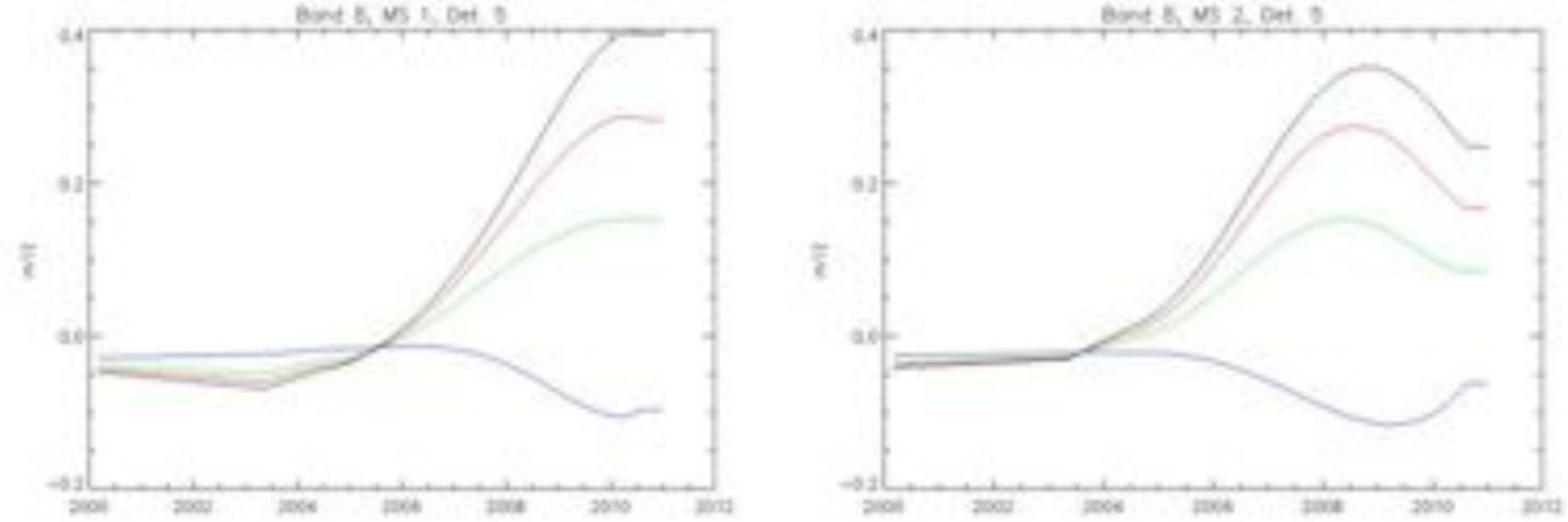
Color coding: Frame/pixel 22 (beginning of scan, lunar), 675 (nadir), 989 (solar diffuser), 1250 (end of scan)

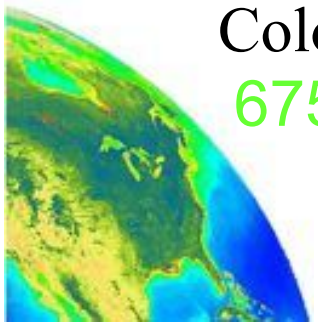
MODIS Terra gain corrections as a function of time at different view angles at 547nm:



Color coding: Frame/pixel 22 (beginning of scan, lunar), 675 (nadir), 989 (solar diffuser), 1250 (end of scan)

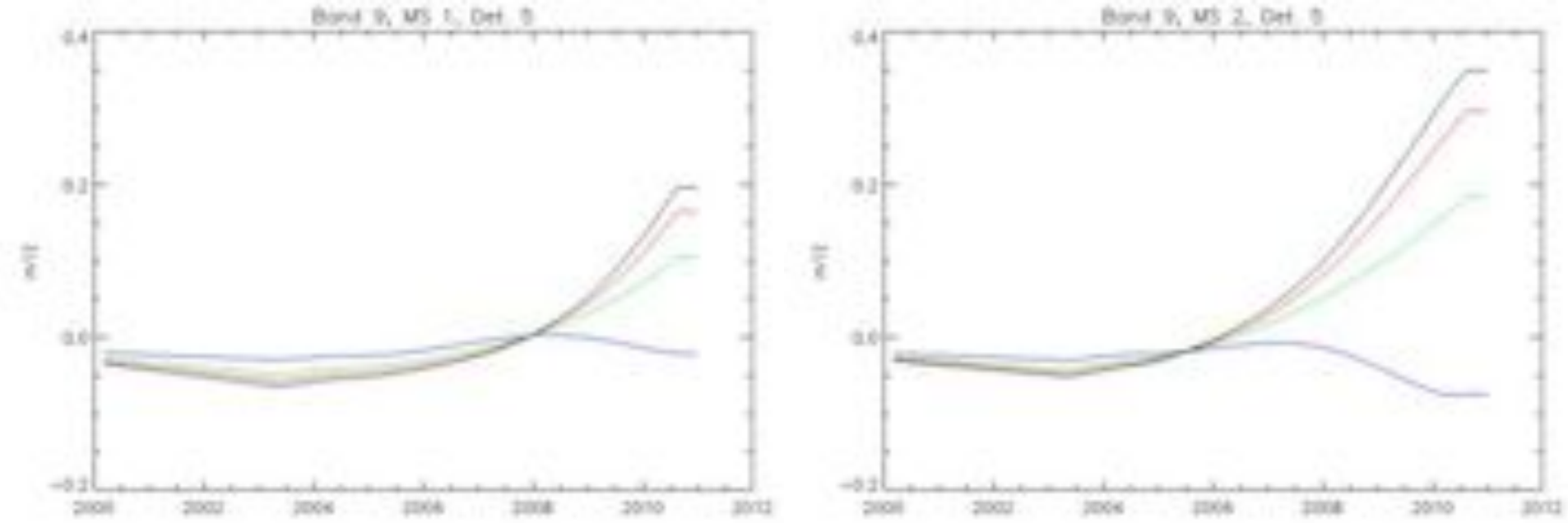
MODIS Terra polarization corrections as a function of time at different view angles at 412nm:

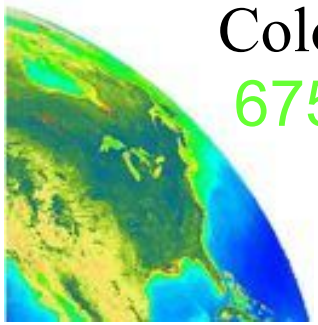




Color coding: Frame/pixel 22 (beginning of scan, lunar), 675 (nadir), 989 (solar diffuser), 1250 (end of scan)

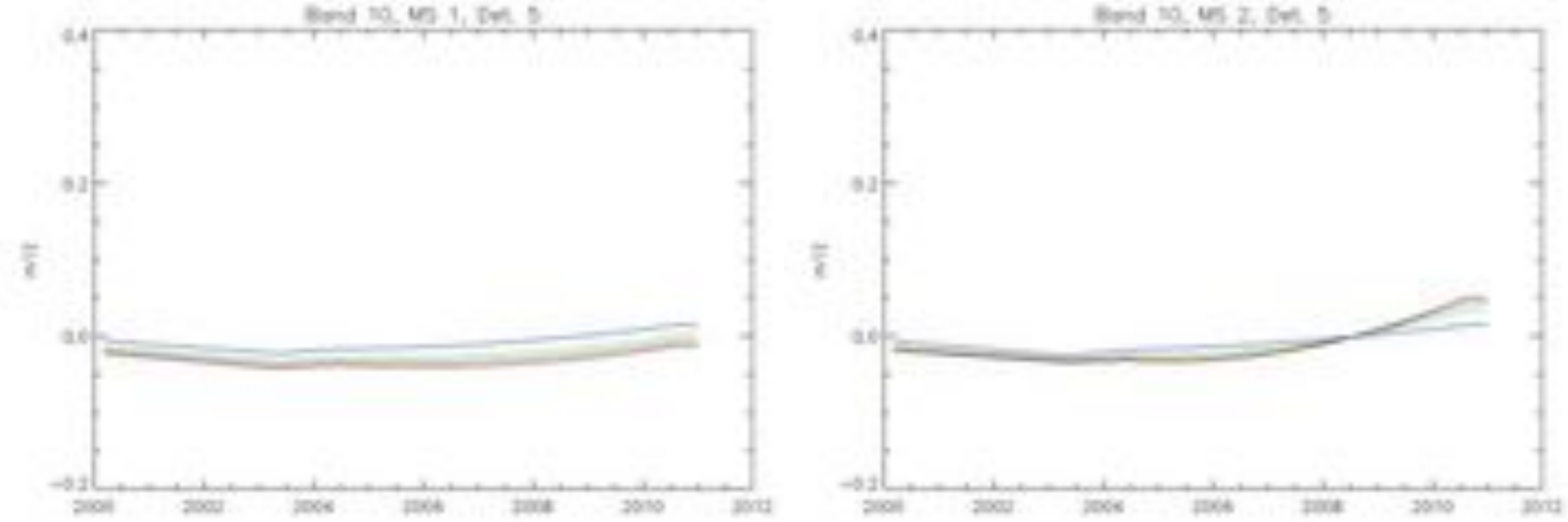
MODIS Terra polarization corrections as a function of time at different view angles at 443nm:

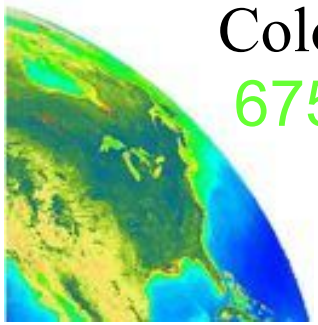




Color coding: Frame/pixel 22 (beginning of scan, lunar), 675 (nadir), 989 (solar diffuser), 1250 (end of scan)

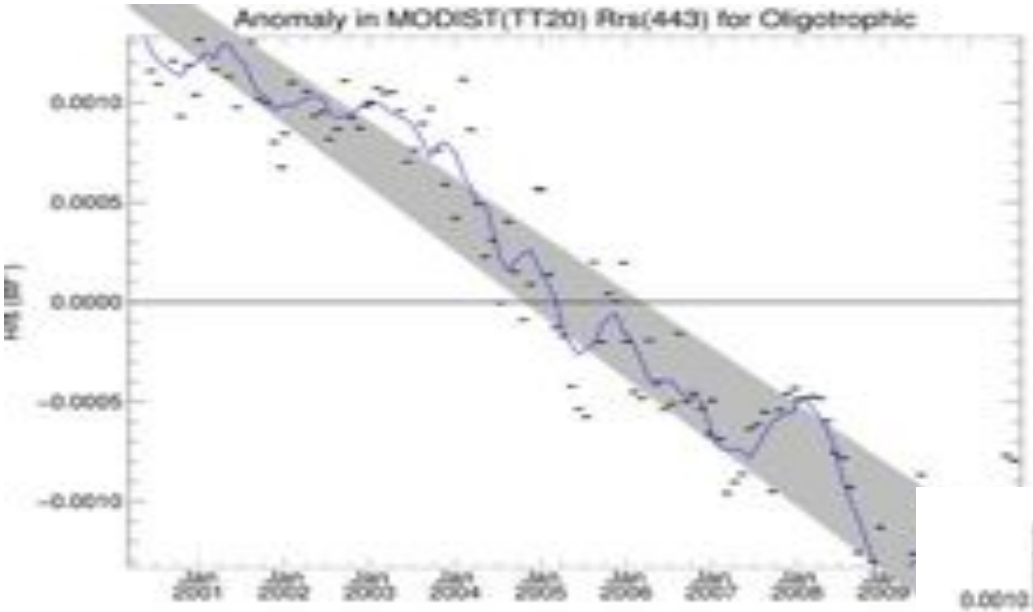
MODIS Terra polarization corrections as a function of time at different view angles at 488nm:

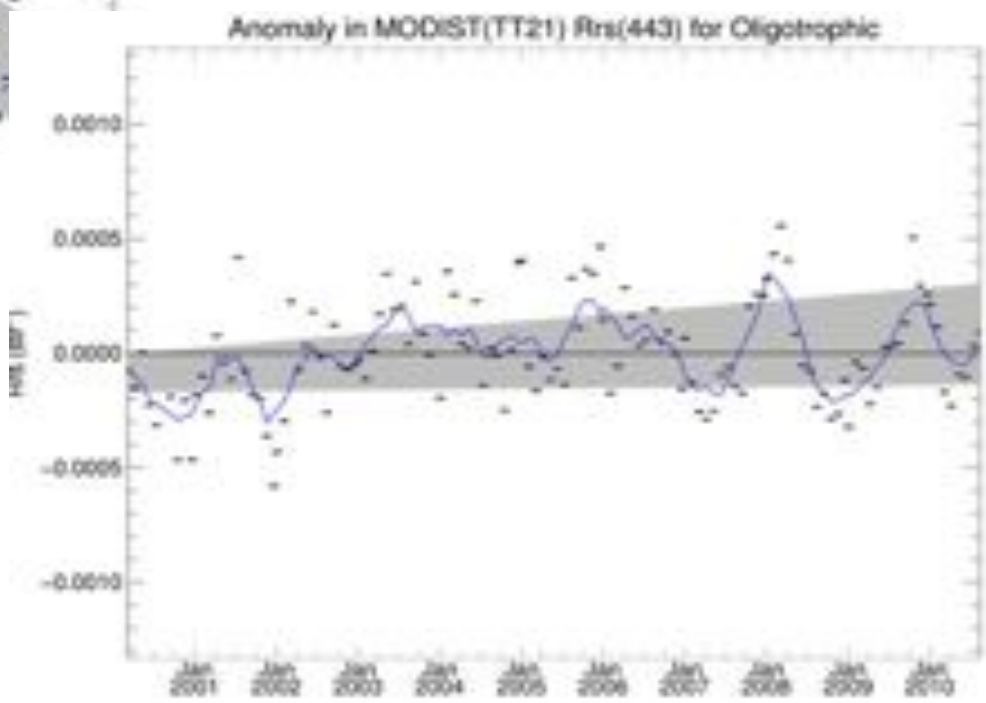




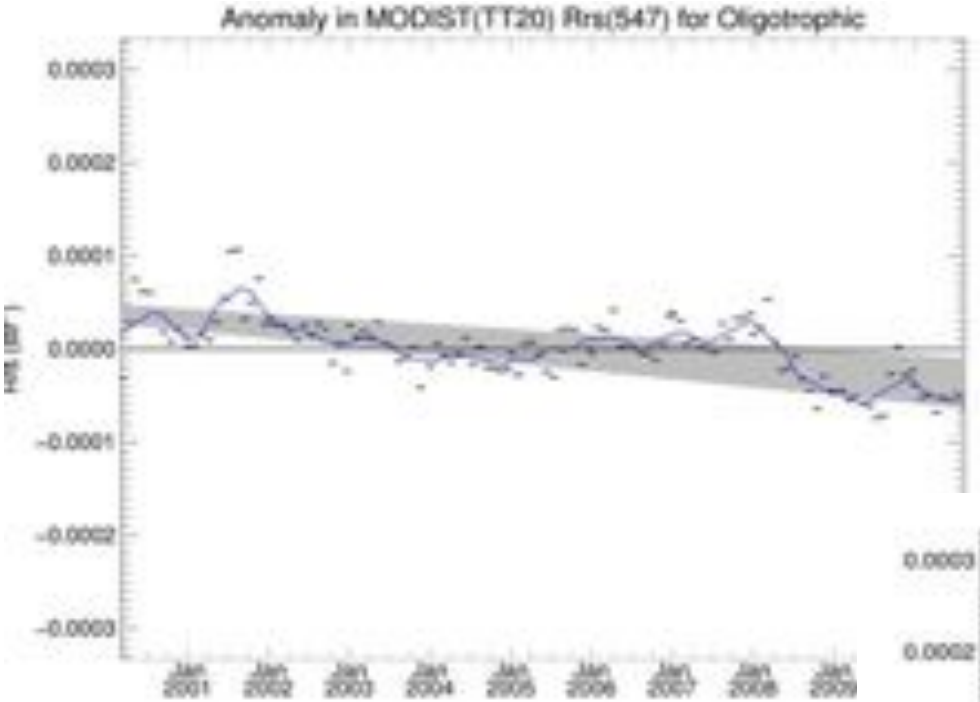
Color coding: Frame/pixel 22 (beginning of scan, lunar), 675 (nadir), 989 (solar diffuser), 1250 (end of scan)

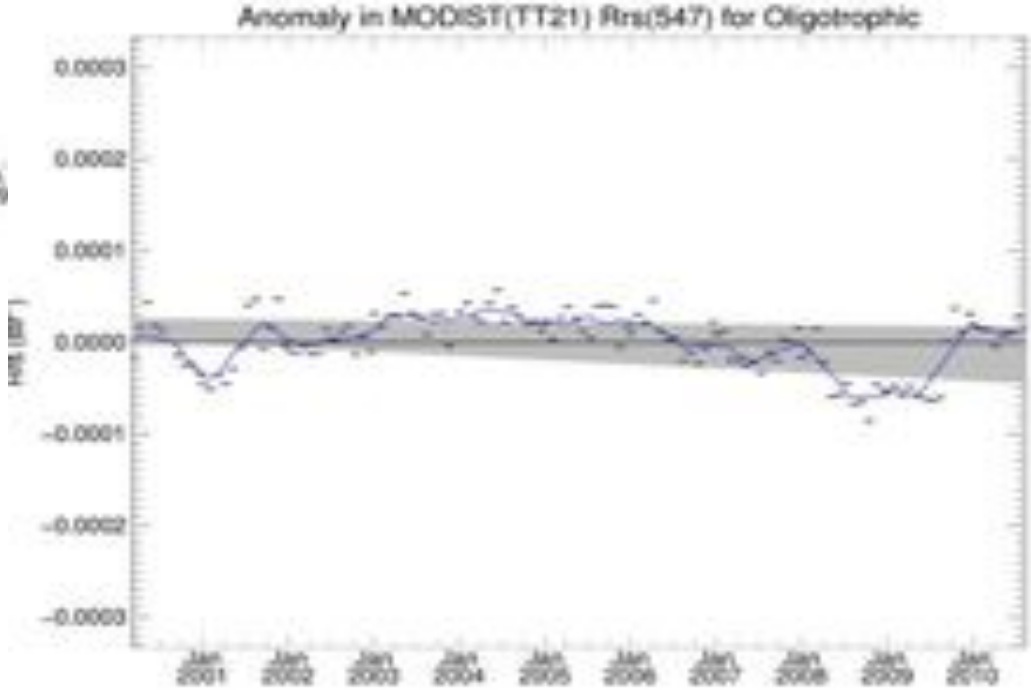
443nm trend in MODIS Terra with & w/o xcal



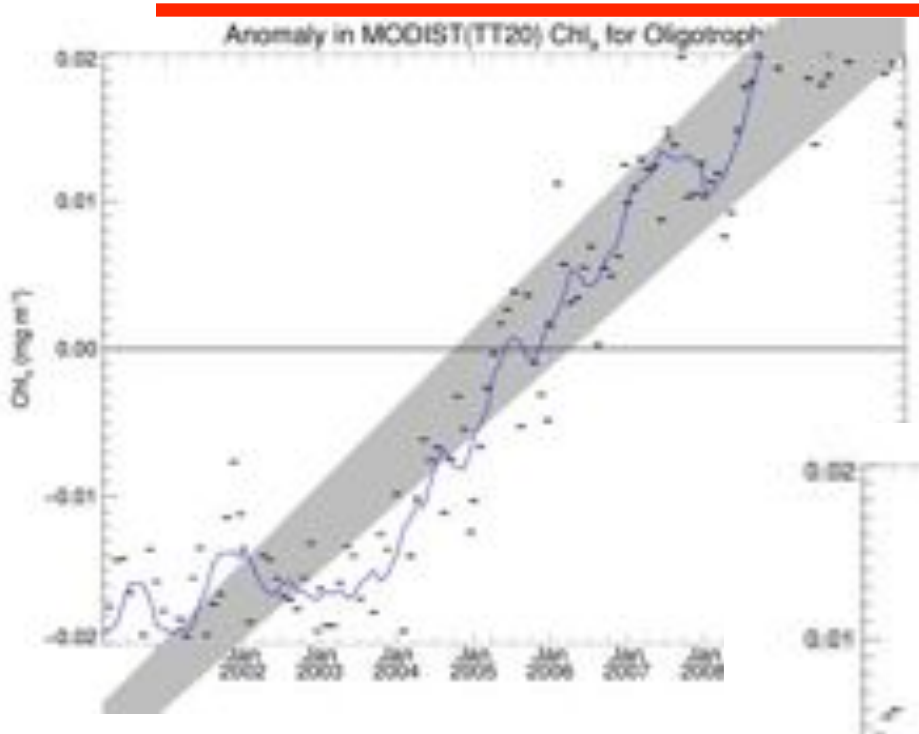


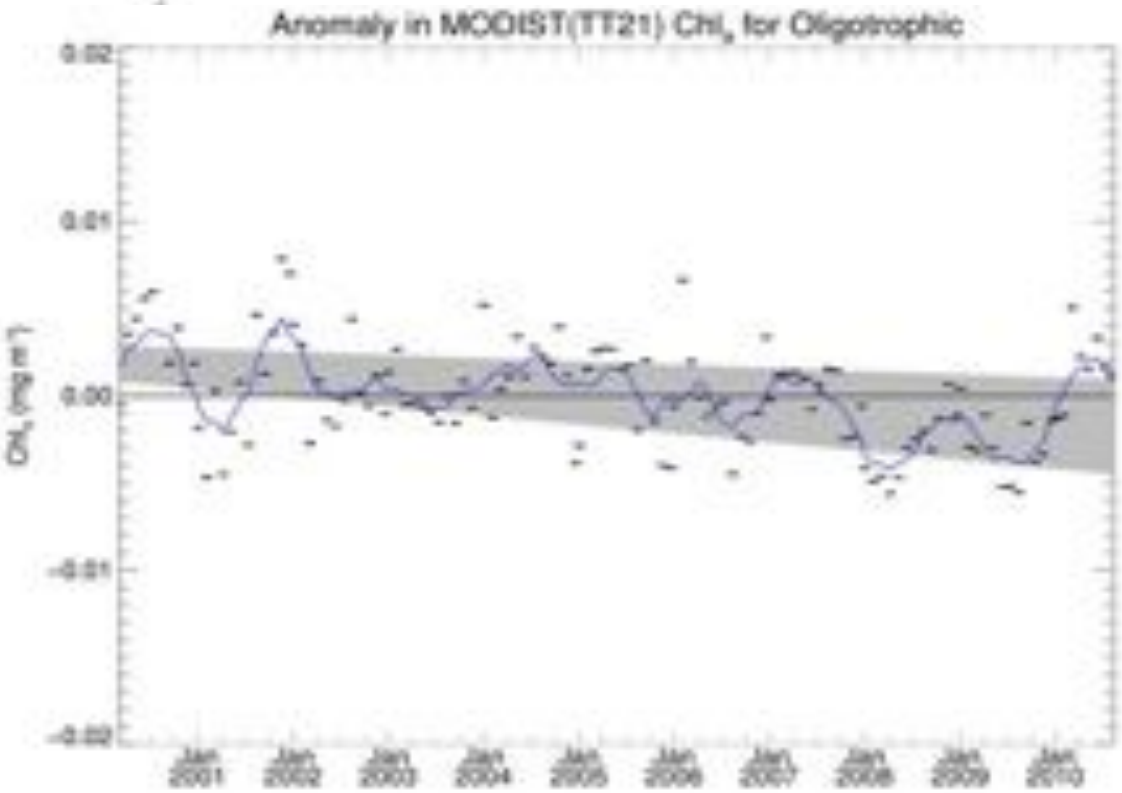
547nm trend in MODIS Terra with & w/o xcal





chl-a trend in MODIS Terra with & w/o xcal

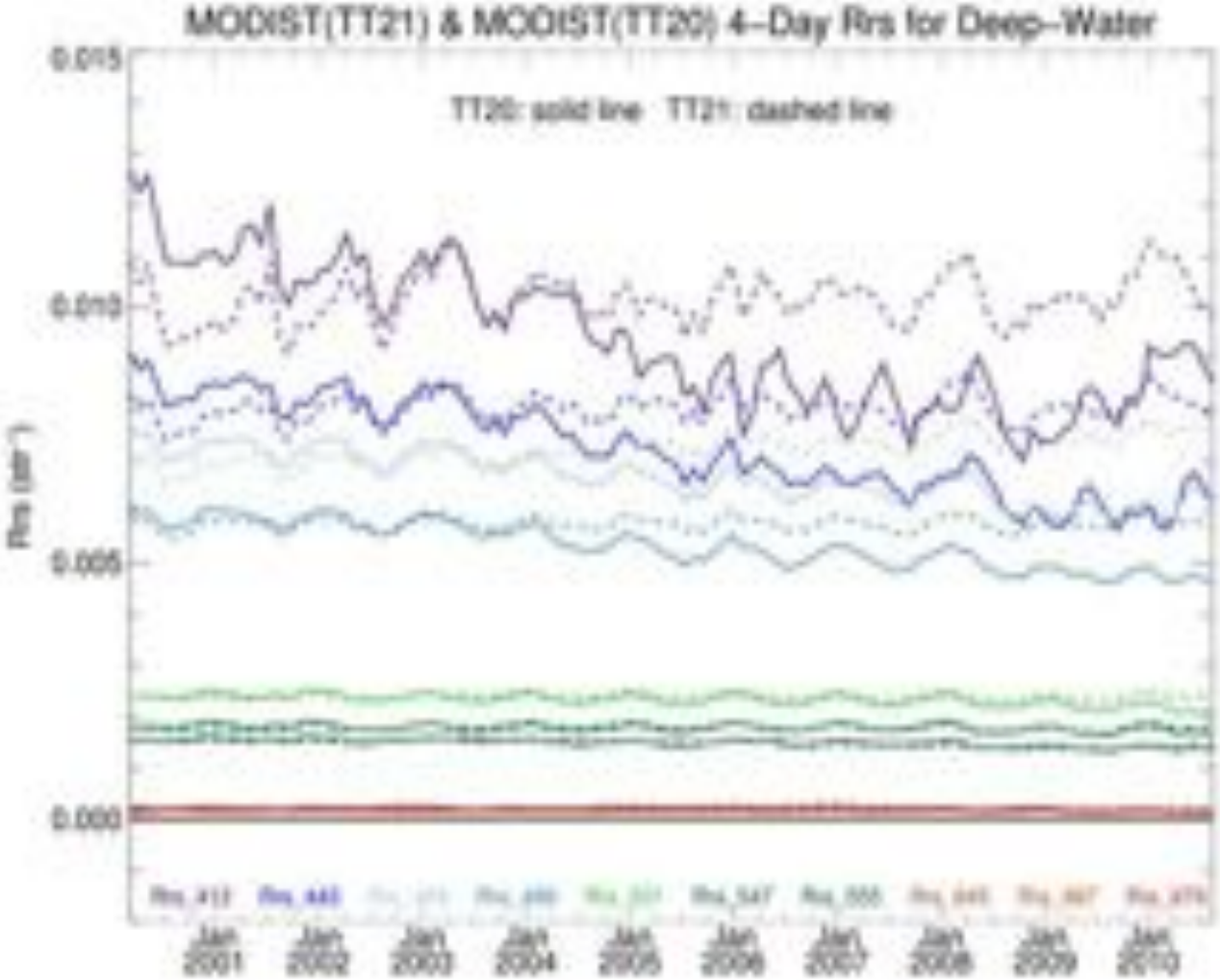




MODIS Terra with & w/o xcal

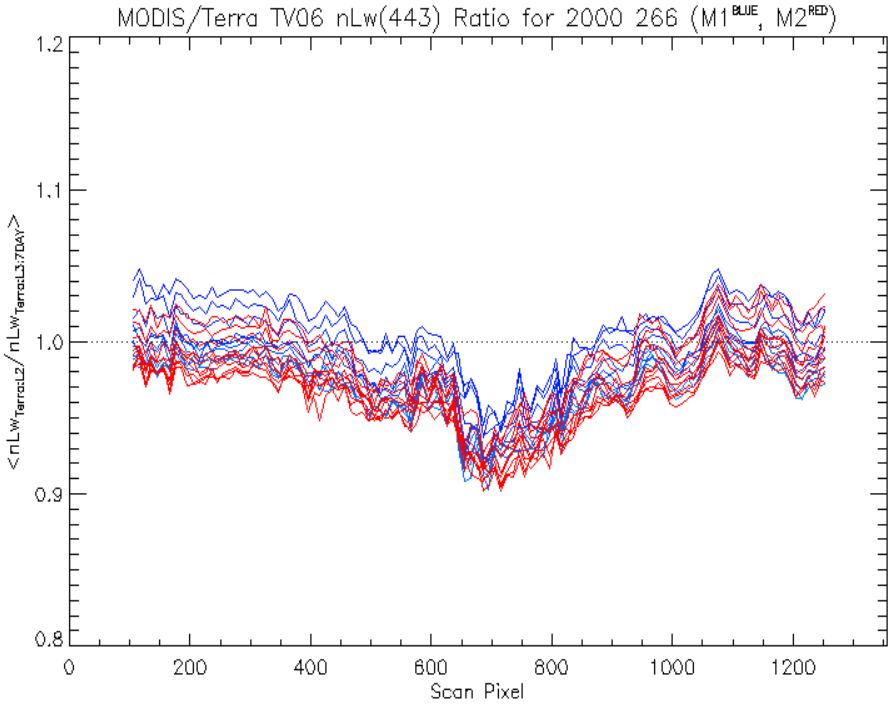
Terra R2010.0 includes land bands, (under evaluation)

Red bands (667nm and 678nm) have been adjusted using MODIS Aqua

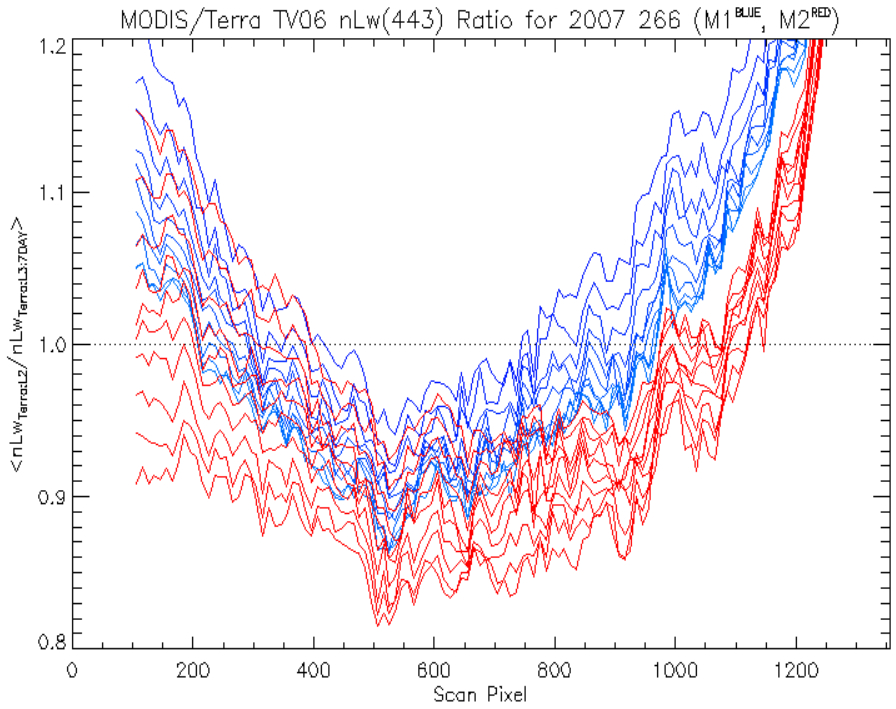


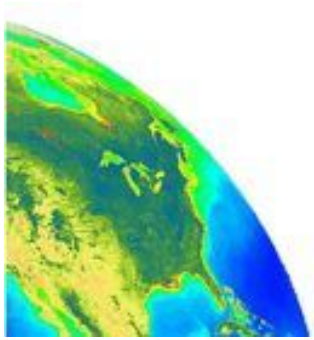
MODIS Terra RVS w/o xcal: 443nm

RVS 2000:



RVS 2007:

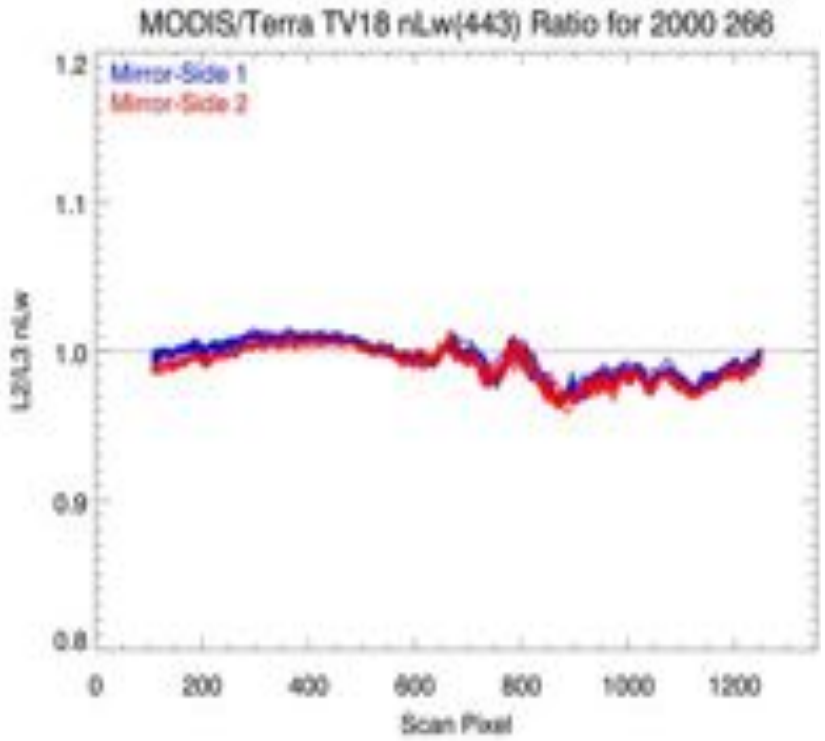




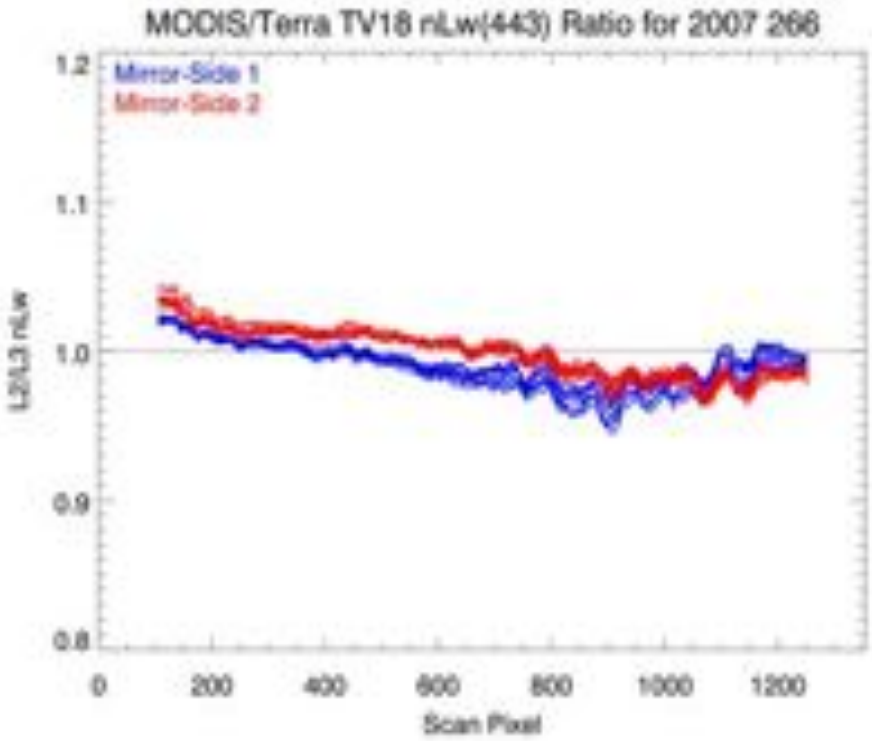
- Some striping and small RVS dependency in 2000
- Strong striping (mirror side and detector) and large RVS dependency in 2007

MODIS Terra RVS with xcal: 443nm

RVS 2000:

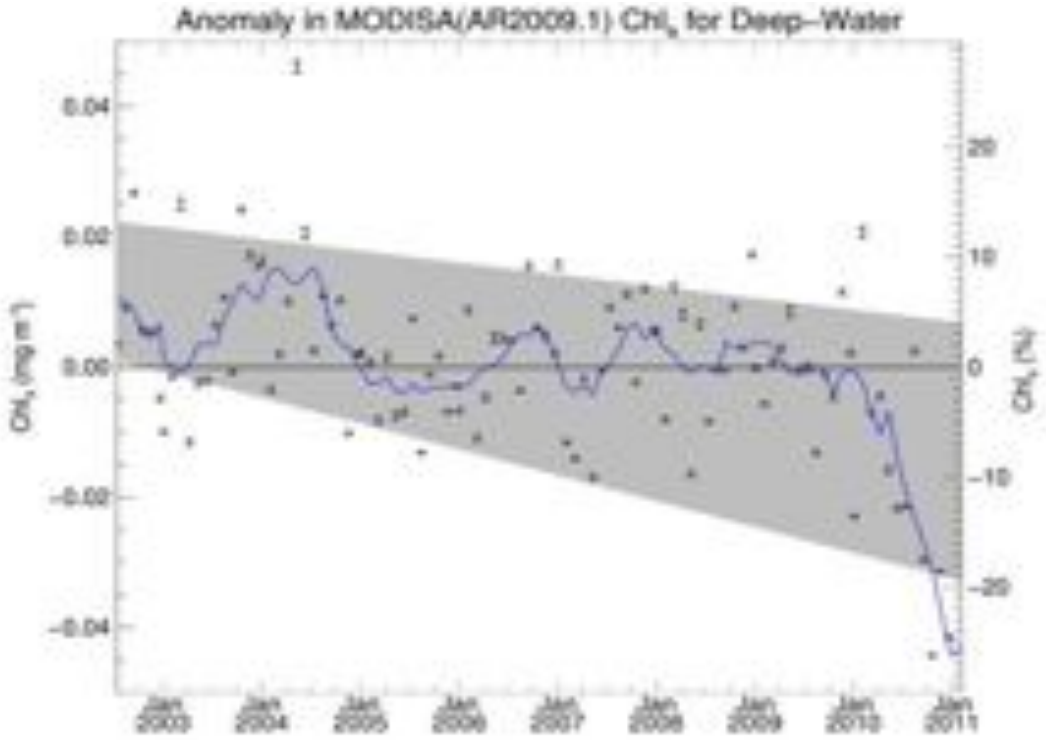


RVS 2007:



- Significant improvement for striping and RVS, residual mirror side striping in 2007
- Analysis shown not from final configuration

chl-a trend in MODIS Aqua R2009.1

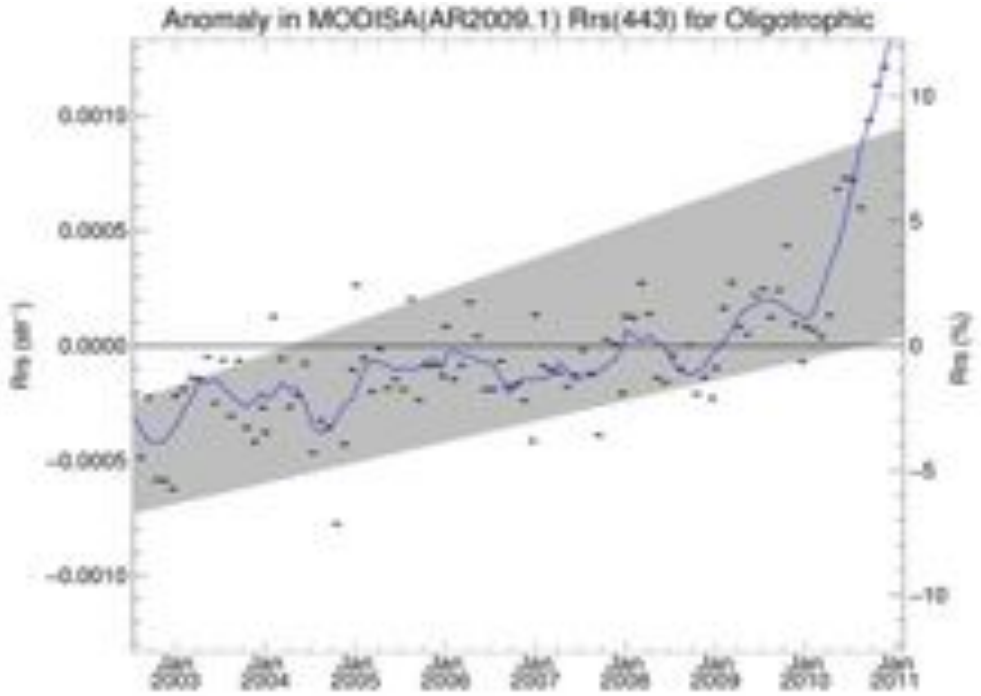


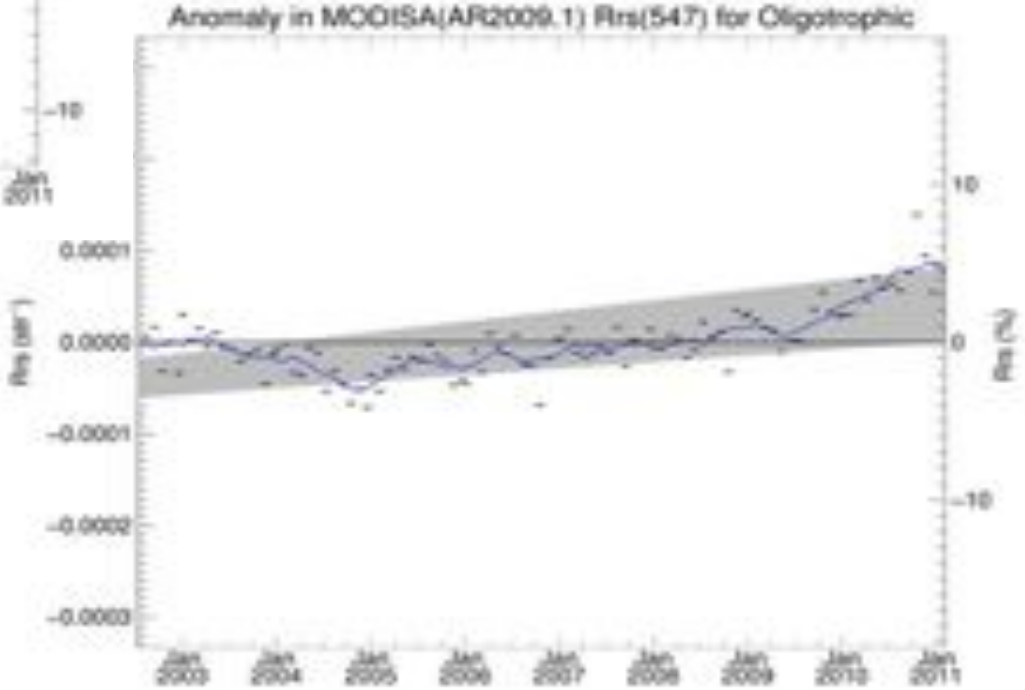
Includes xcal from Sep. 2009

Good until early 2010

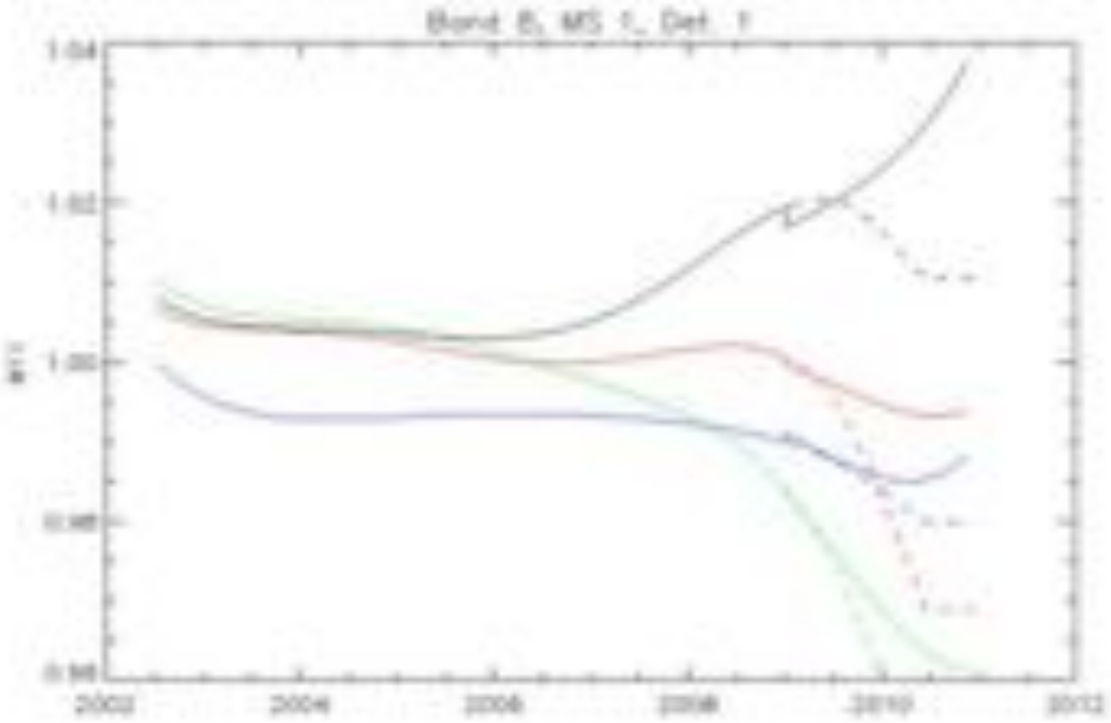
Problems in 2010 due to inadequate xcal (not updated) and difficulty of adjusting to new C6 trending

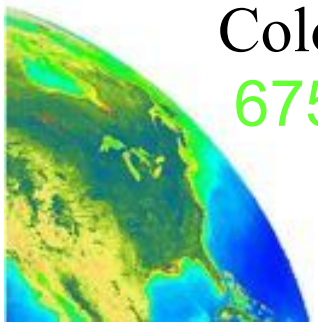
443nm and 547nm trend in MODIS Aqua R2009.1





MODIS Aqua gain corrections as a function of time at different view angles at 412nm:



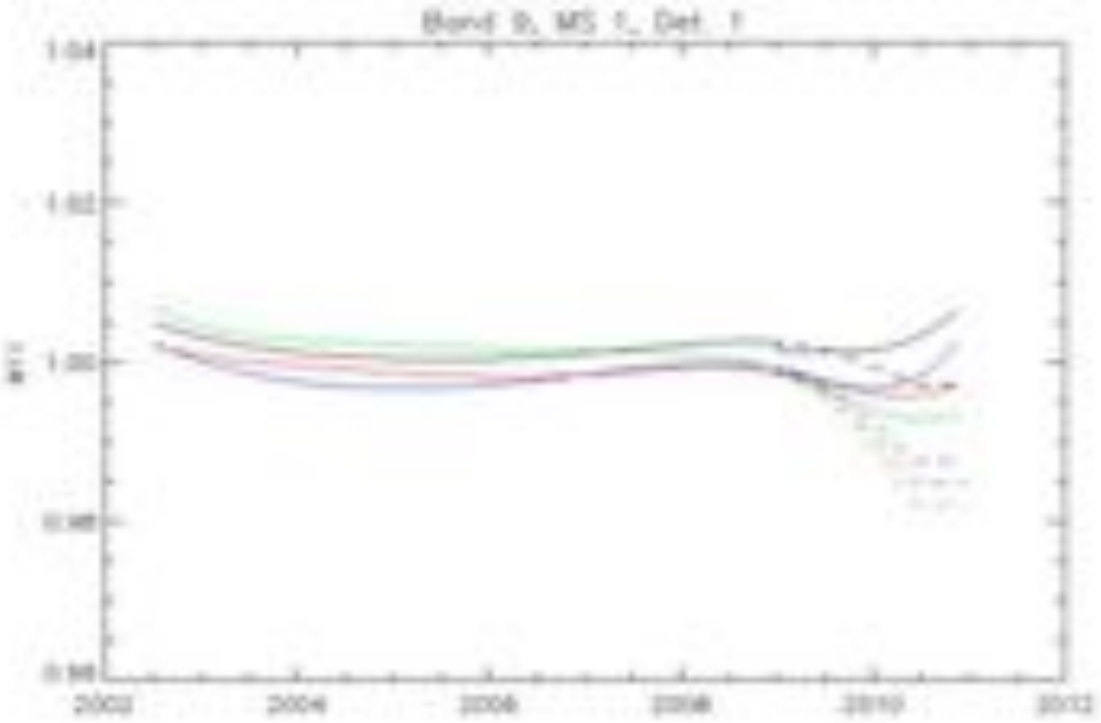


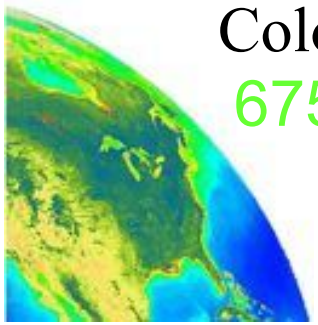
Color coding: Frame/pixel 22 (beginning of scan, lunar), 675 (nadir), 989 (solar diffuser), 1250 (end of scan)

Solid line: R2010.0 (data from 2009 and later)

Dashed line: R2009.1

MODIS Aqua gain corrections as a function of time at different view angles at 443nm:



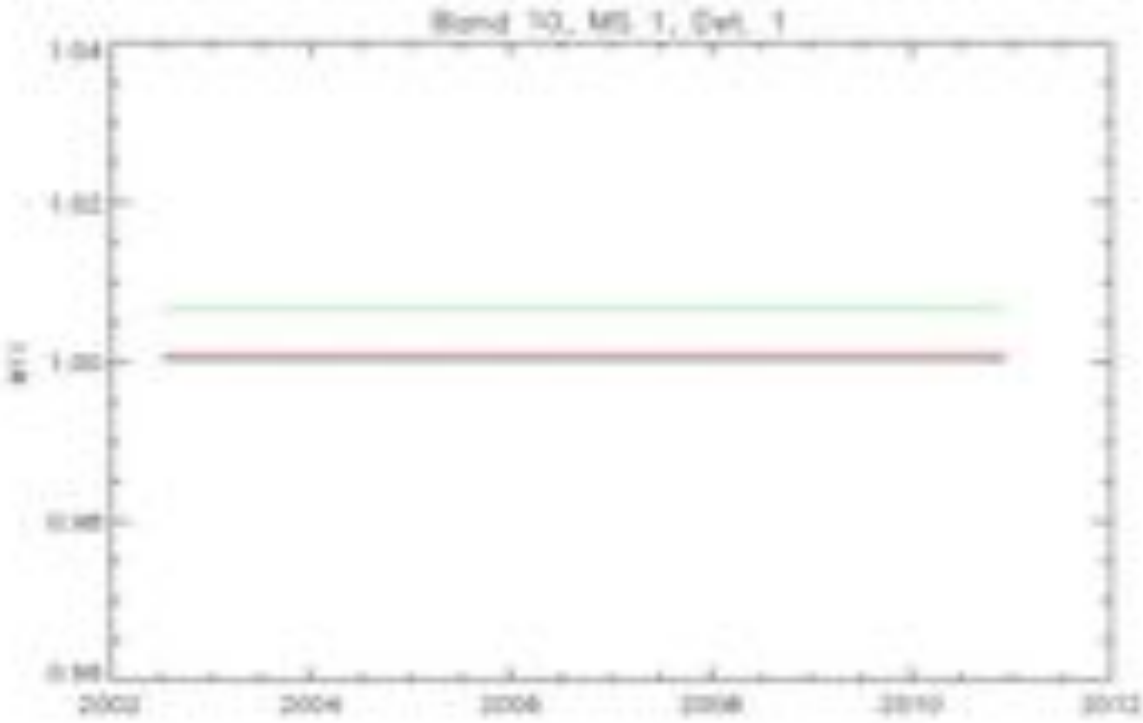


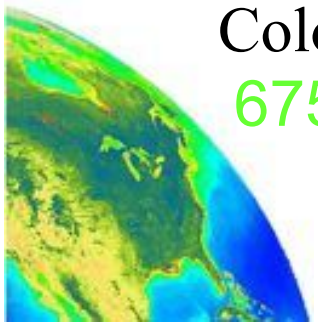
Color coding: Frame/pixel 22 (beginning of scan, lunar), 675 (nadir), 989 (solar diffuser), 1250 (end of scan)

Solid line: R2010.0

Dashed line: R2009.1

MODIS Aqua gain corrections as a function of time at different view angles at 488nm:

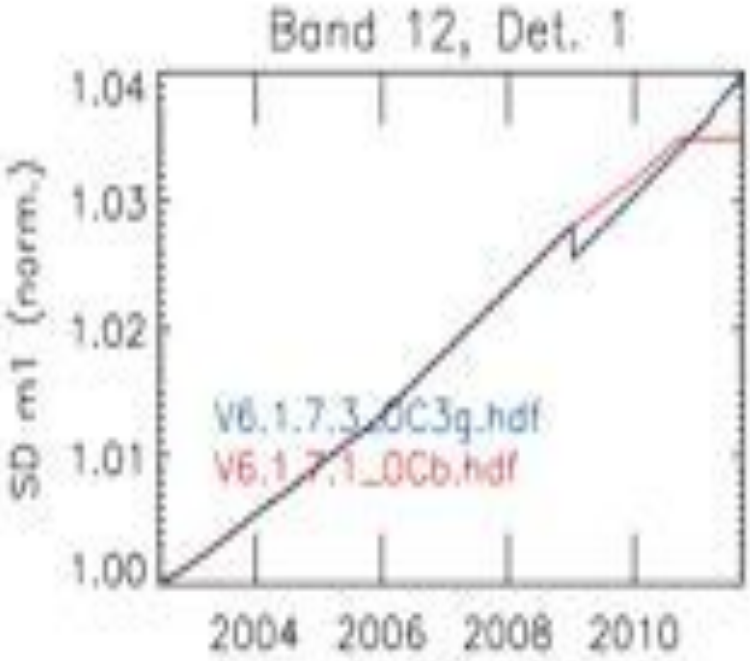


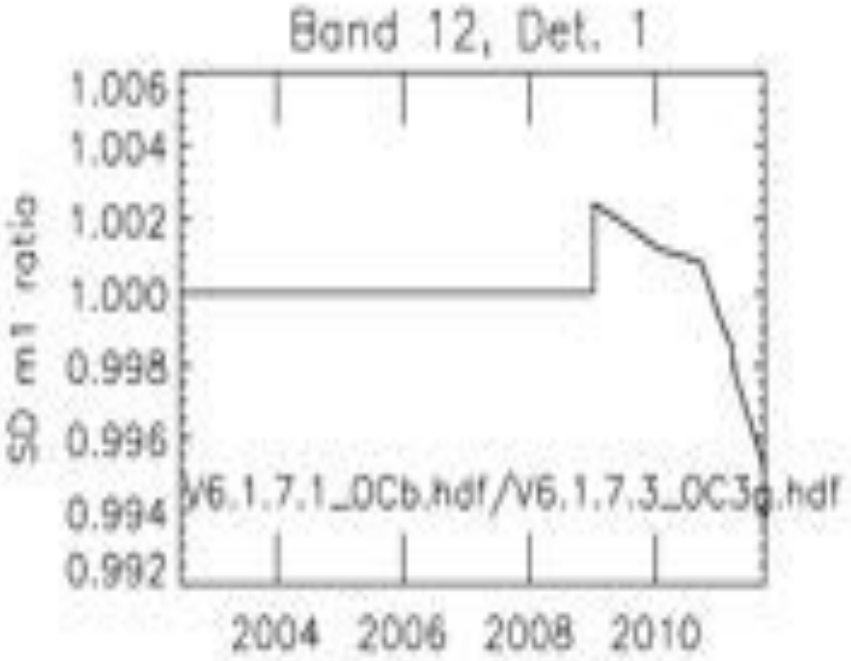


Color coding: Frame/pixel 22 (beginning of scan, lunar), 675 (nadir), 989 (solar diffuser), 1250 (end of scan)

MODIS Aqua m1 as a function of time at 547nm:

MCST provides m1 (gain at solar diffuser view angle), OBPG xcal is relative to MCST trending

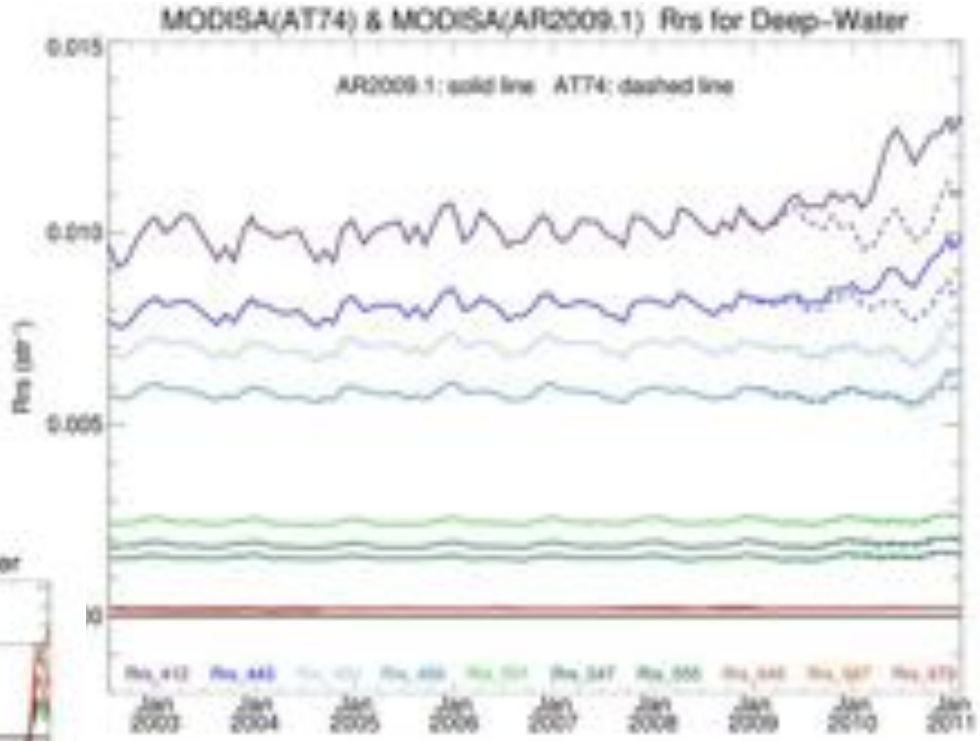


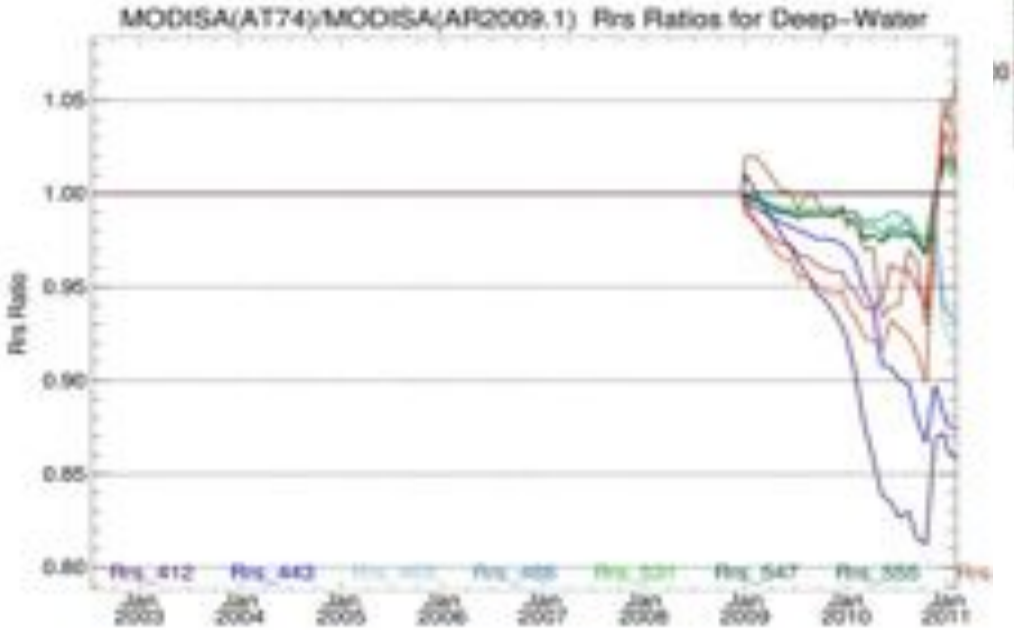


Color coding:
m1 from R2010.0, m1 from R2009.1

MODIS Aqua R2009.1 and R2010.0 global Rrs averages:

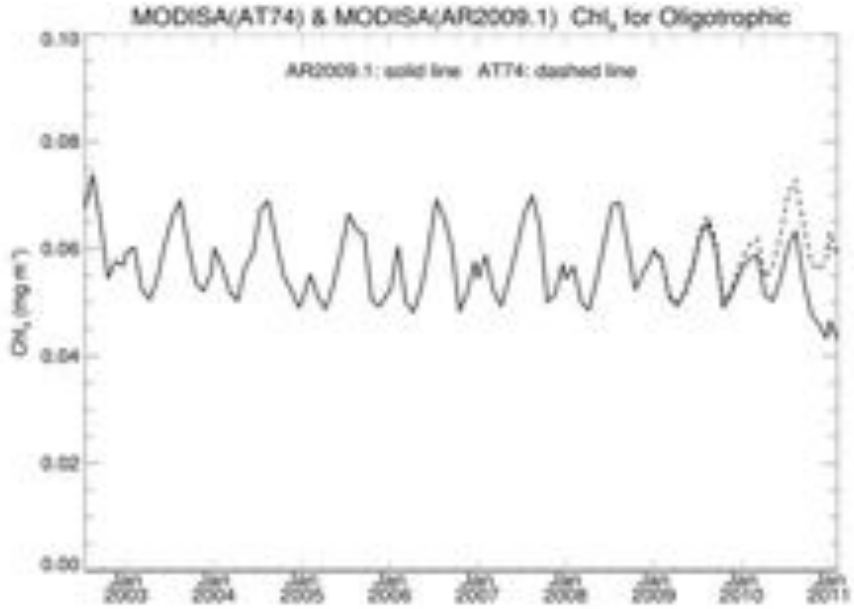
Identical up to end of 2008

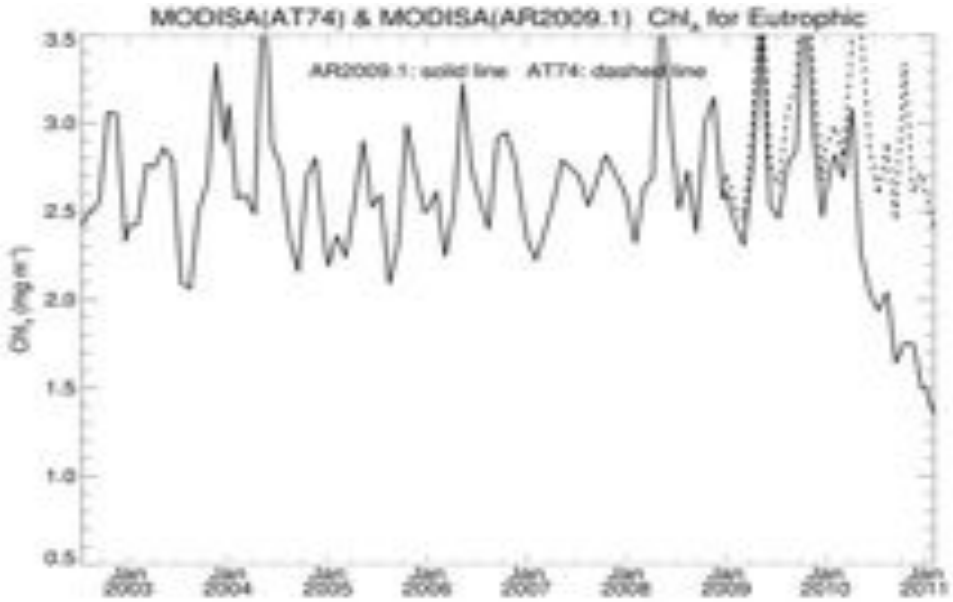




MODIS Aqua R2009.1 and R2010.0 global chl. averages:

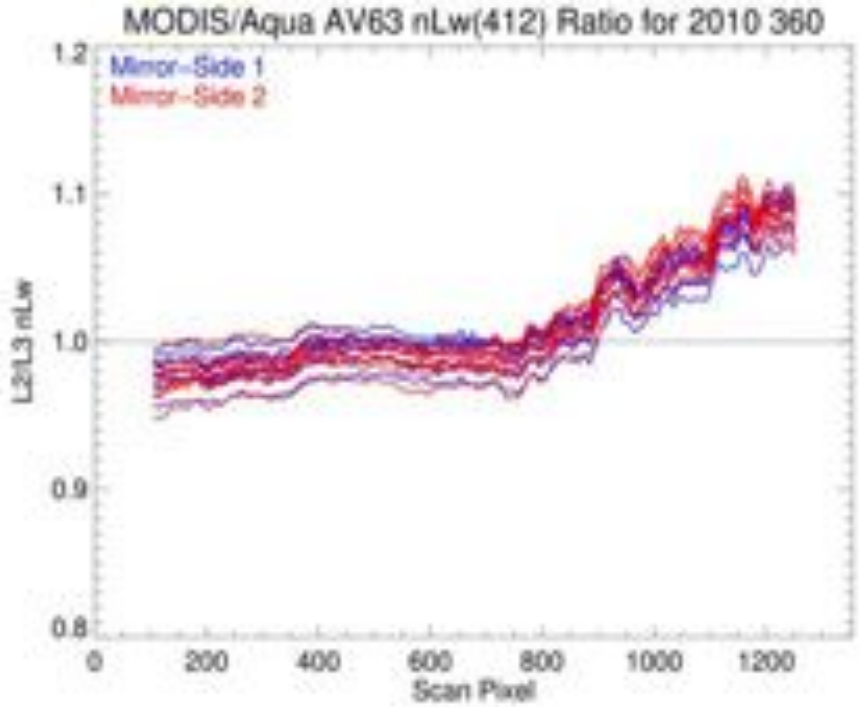
Small improvement for olig. (right),
large improvement for eutr. (below)

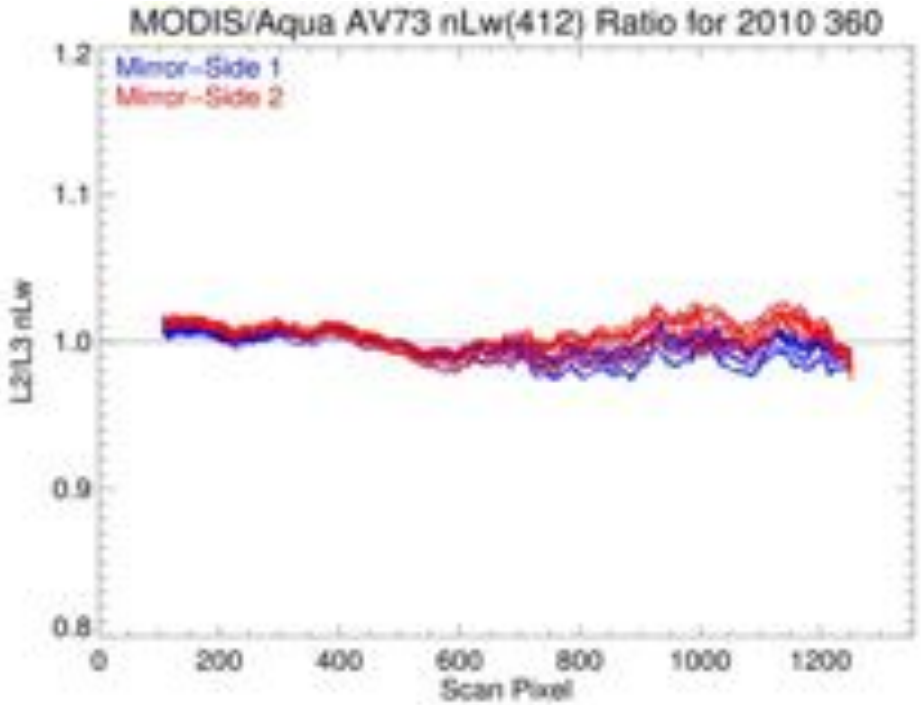




MODISA R2009.1 and R2010.0 scan angle dependence:

Operational (right) has strong increase in 2nd half of scan, removed in new version (below)





Summary:

- MODIS Terra reprocessing finished Jan. 2011
  - Good agreement with SeaWiFS and Aqua for long term global averages (temporal trending and scan angle dependence)
  - Sensor degradation in blue (gain and polarization) will impact quality, especially for L2
- MODIS Aqua partial reprocessing R2010.0 to start soon
  - Same approach as before (bands 8 and 9 temporal gain adjustments, no pol. Correction)
  - Only data from 2009 onward
  - Produces good agreement with SeaWiFS until end of 2010 (Rrs and chl., olig. to eutr.)
  - Correction approach without SeaWiFS under development