MODIS-Terra cross-calibration for ocean color bands

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MODIS calibration changes since launch
band 8 412nm

SD – Solar Diffuser

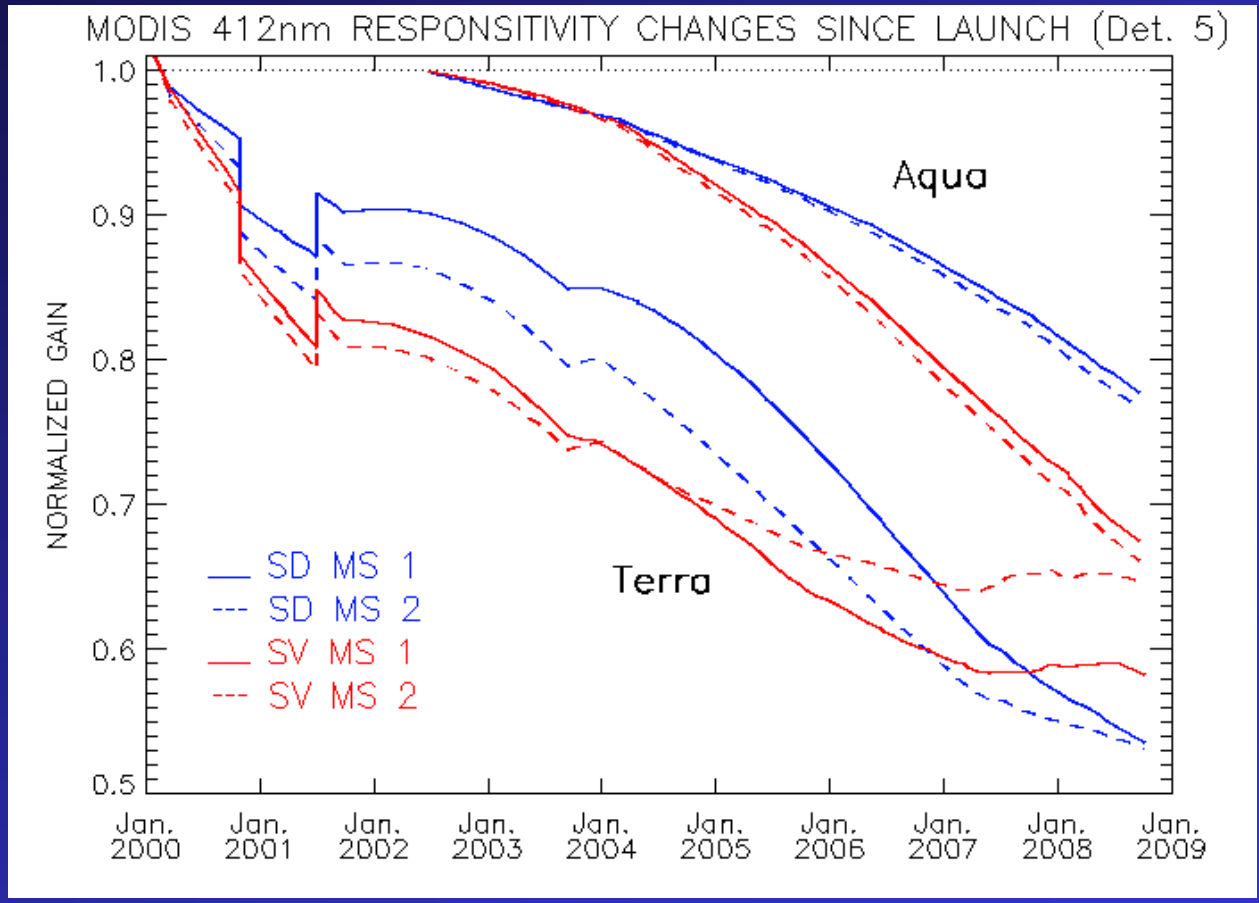
frame 979, mirror AOI 50.3^0

SV – Space View

frame 23, mirror AOI 11.4^0

MS1 – Mirror Side 1

MS2 – Mirror Side 2



Terra

pre-launch damage to mirror coating, MS2

B side electronics

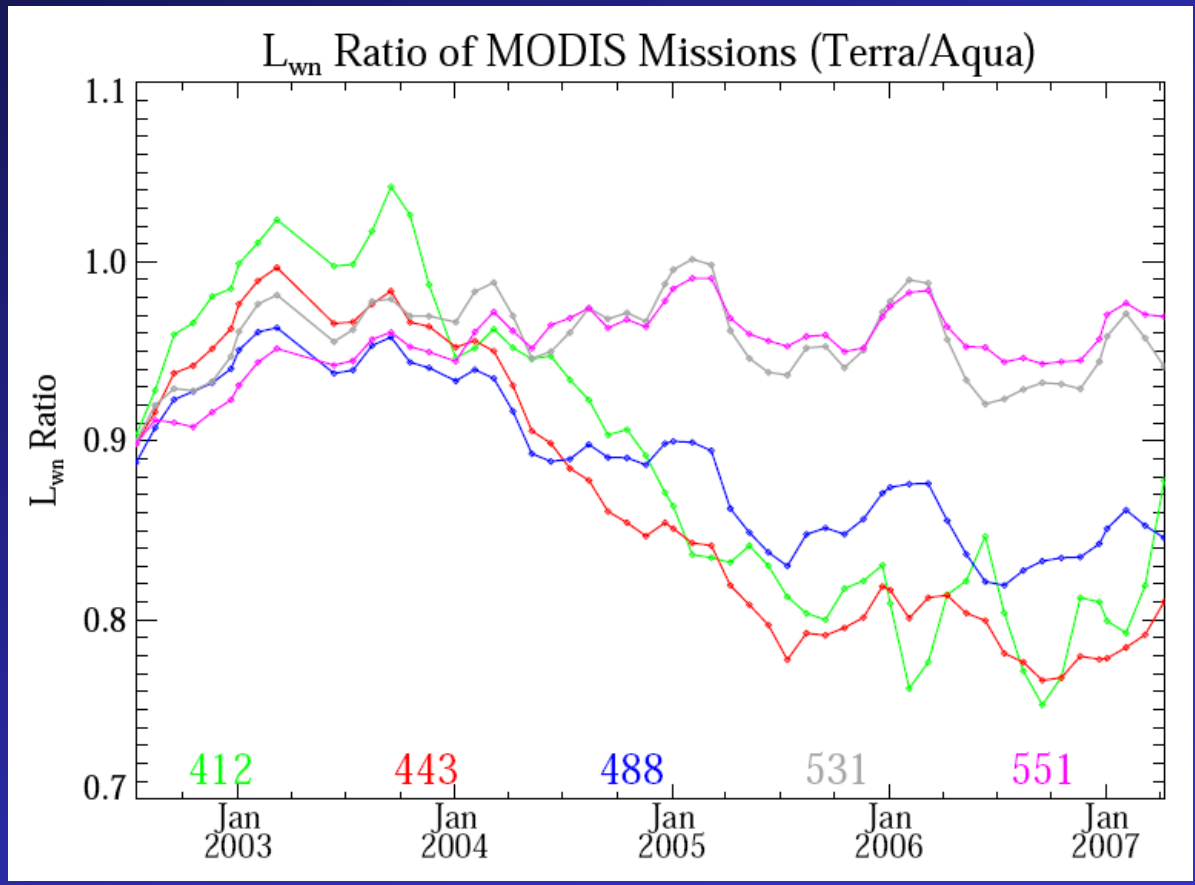
A side electronics

SD door permanently opened

MODIS trends in ocean color products

Terra/Aqua ratios normalized water-leaving radiances L_{wn}

L_{wn}(412nm) band 8
L_{wn}(443nm) band 9
L_{wn}(488nm) band 10
L_{wn}(531nm) band 11
L_{wn}(551nm) band 12



SD door permanently opened

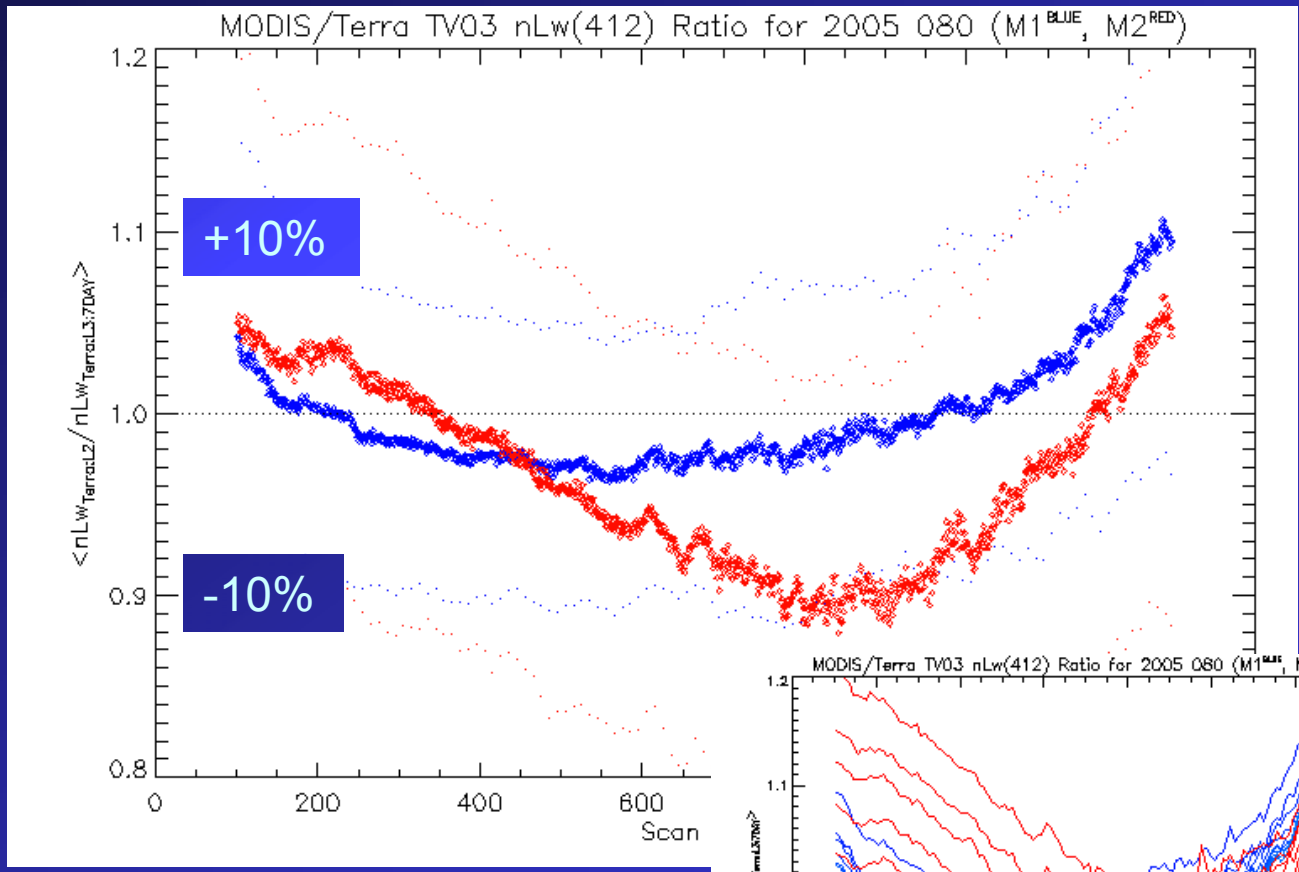
MODIS-Terra ocean color RVS band 8 412nm

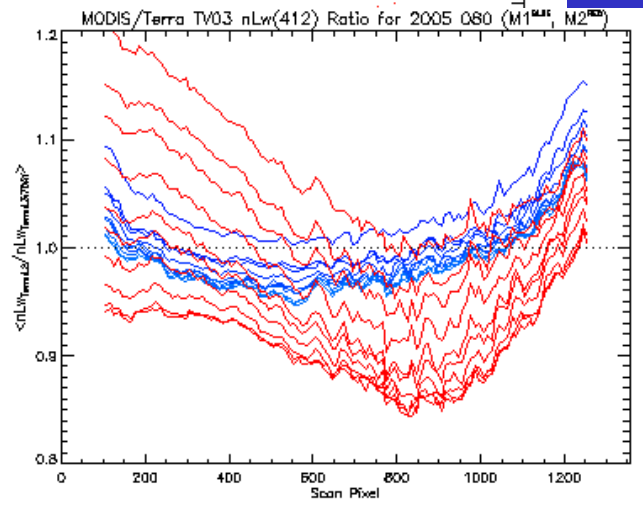
Terra response versus scan angle (RVS) in terms of normalized water-leaving radiances L_{wn}

L_{wn}(412nm) band 8

Mirror side 1 MS1

Mirror side 2 MS2





per detector

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 Terra characterization
  - RVS
  - polarization sensitivity

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
9-day mean

$L_{wn}(\lambda')$

Vicarious TOA MODIS total signal

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

$$\begin{bmatrix} L_m \\ Q_m \\ U_m \\ 0 \end{bmatrix} = \begin{bmatrix} M_{11} & M_{12} & M_{13} & M_{14} \\ M_{21} & \cdots & & M_{24} \\ M_{31} & \cdots & & M_{34} \\ M_{41} & M_{42} & M_{43} & M_{44} \end{bmatrix} \cdot \begin{bmatrix} L_t \\ Q_t \\ U_t \\ 0 \end{bmatrix}$$

TOA sensor cross-calibration

MODIS measured TOA radiance, polarized

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

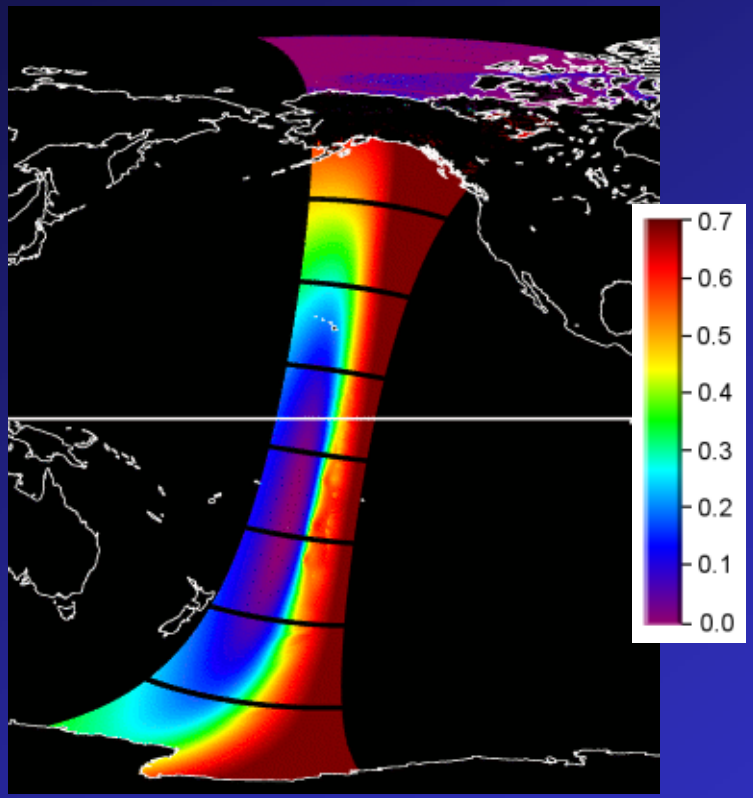
- minimize over global distribution of path geometries
- find best M_{11}, M_{12}, M_{13} per band, detector, and mirror-side
- M_{11}, M_{12}, M_{13} = f (mirror AOI)
- do this for one day per month over the mission lifespan

Polarization of the atmosphere

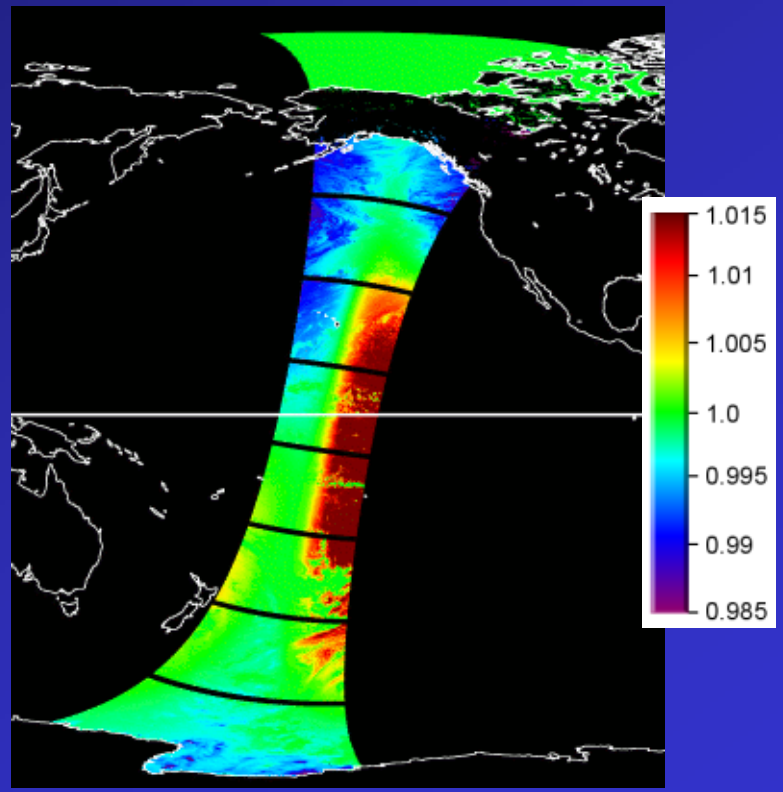
MODIS Terra swath

412nm band 8

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



polarization correction f_p
pre-launch MODIS characterization



$$d_p = \frac{\sqrt{Q_t^2 + U_t^2}}{L_t} \qquad f_p = \frac{L_m}{L_t}$$

Blue band temporal trends

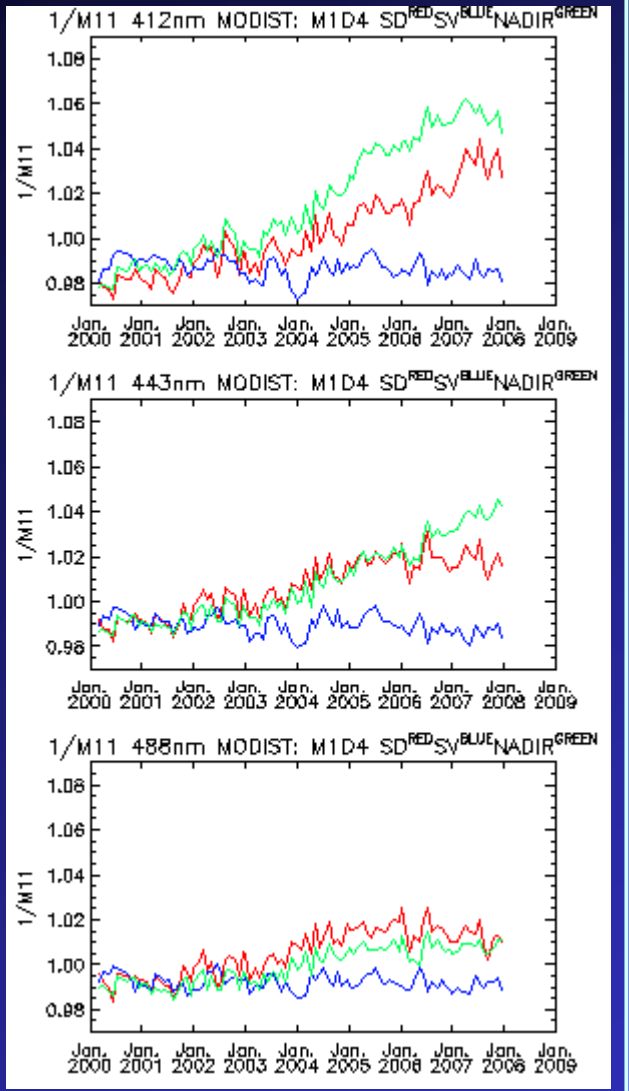
Mirror side 1

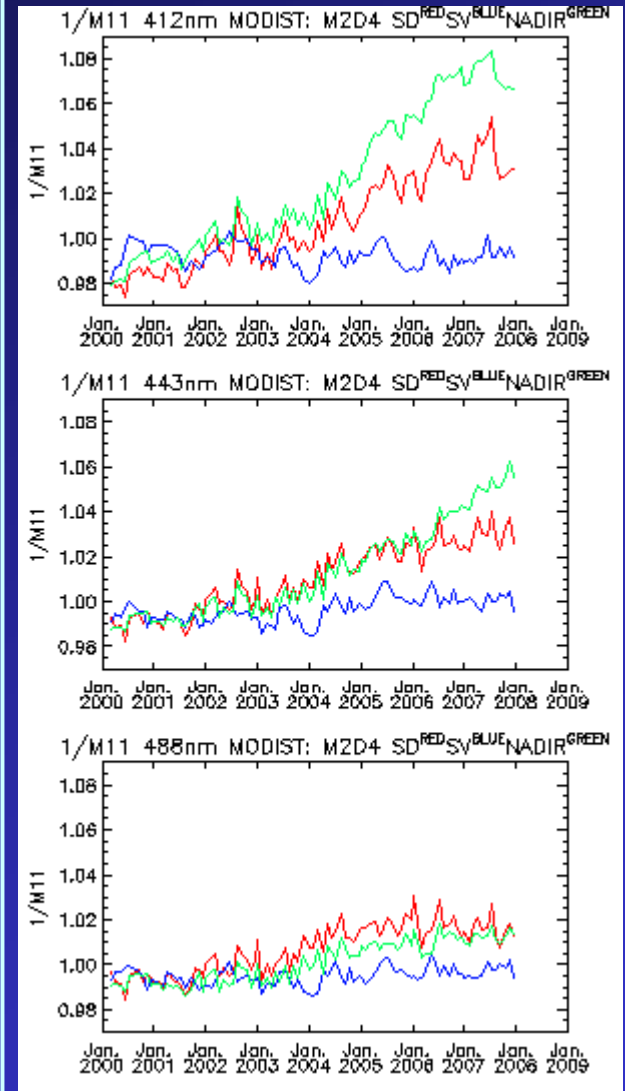
Mirror side 2

412

443

488





$RVS = 1/M_{11}$

Detector 4

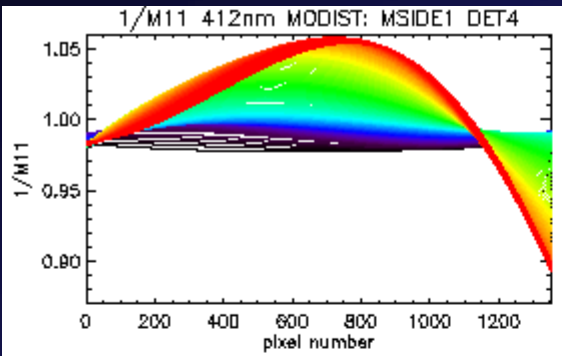
Space View (lunar) frame

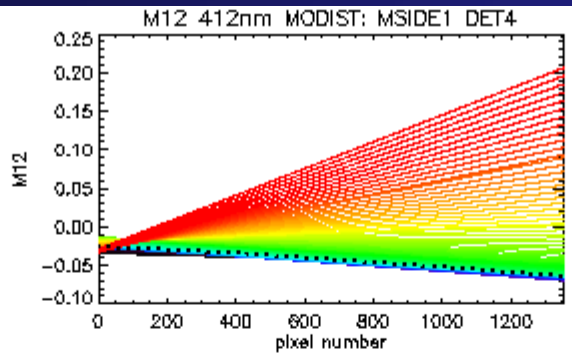
Nadir frame

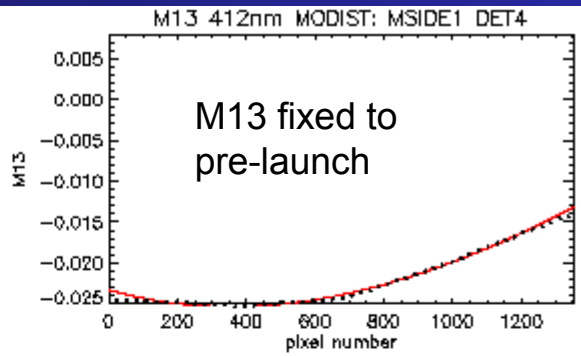
Solar Diffuser frame

Blue band RVS & polarization sensitivity MS1

412







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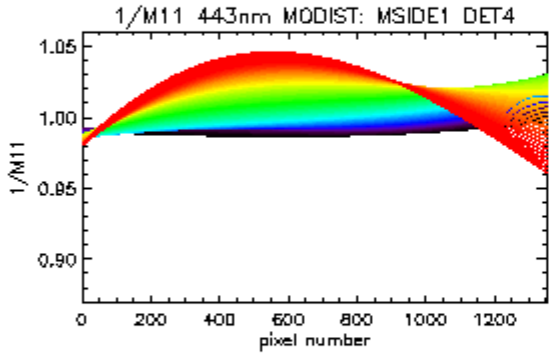

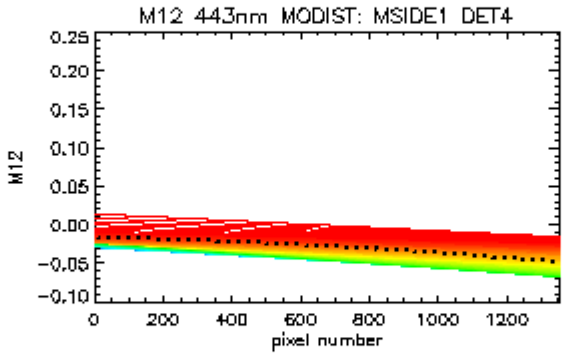

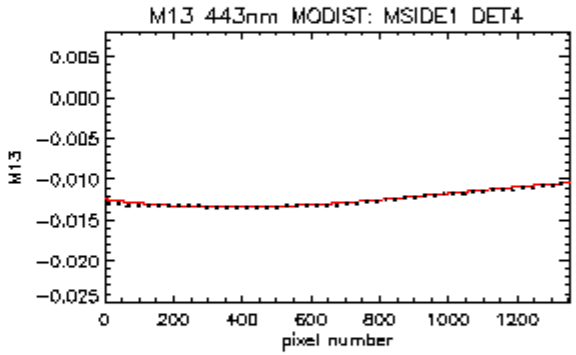

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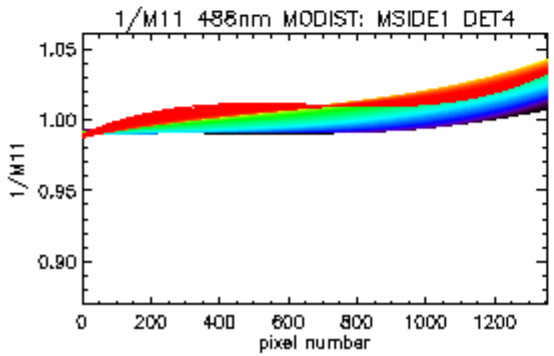
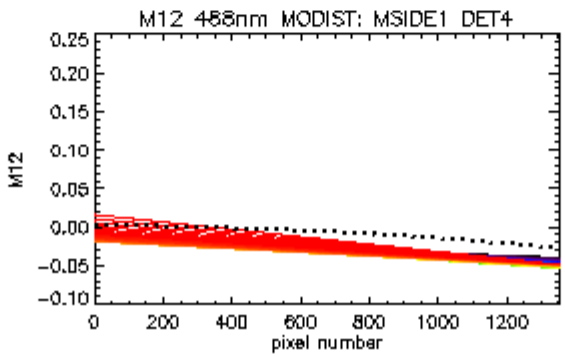
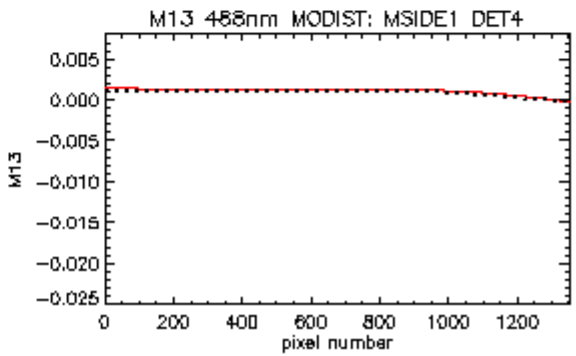
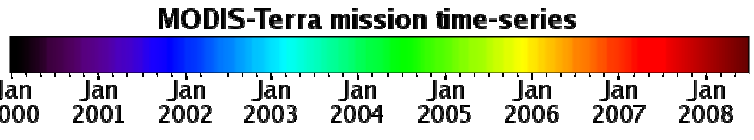








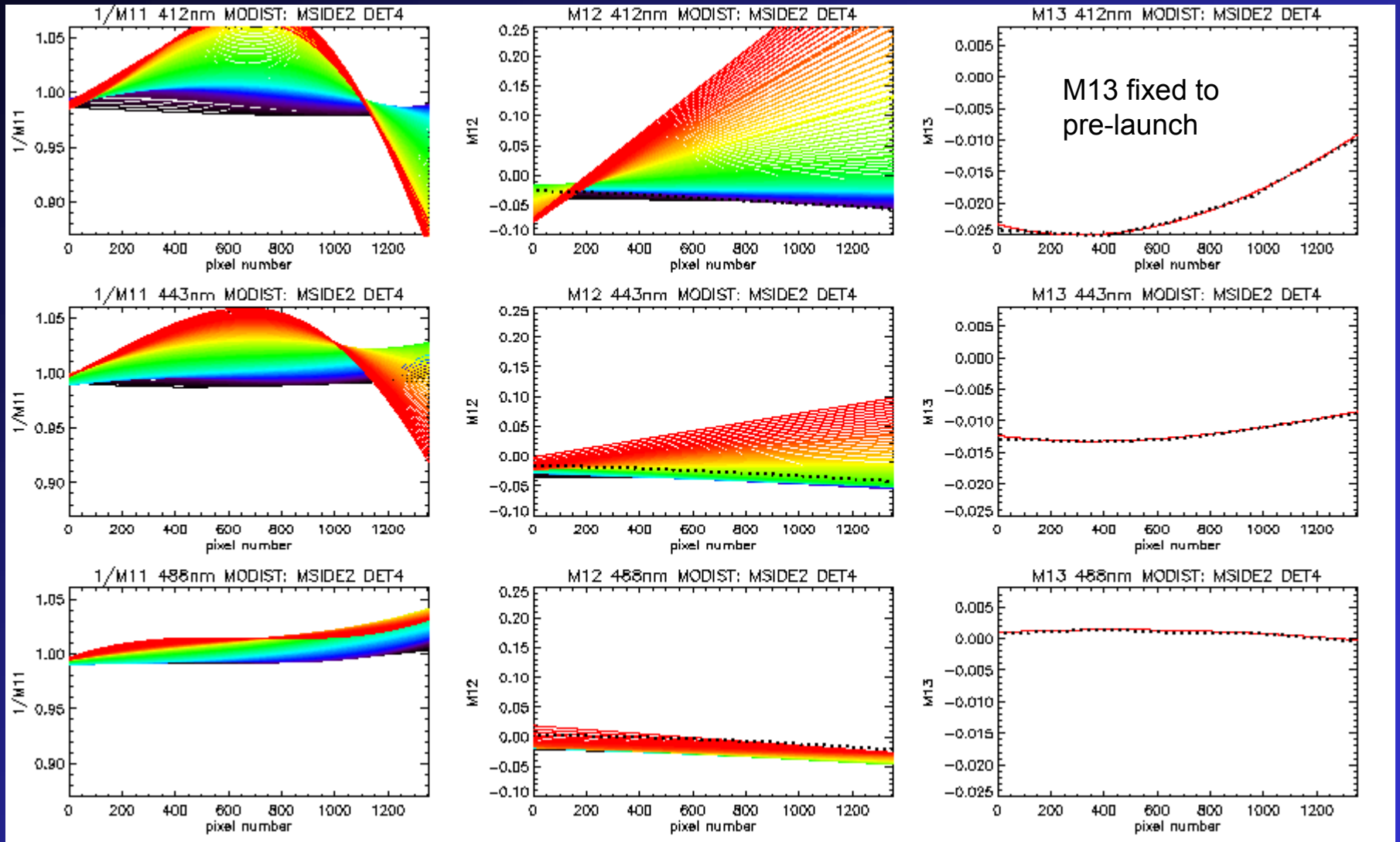
Detector 4

Blue band RVS & polarization sensitivity MS2

412

443

488



Detector 4

MODIS-Terra vicarious characterization

MS1, Detector 4

MS2, Detector 4

RVS M12 M13

412

443

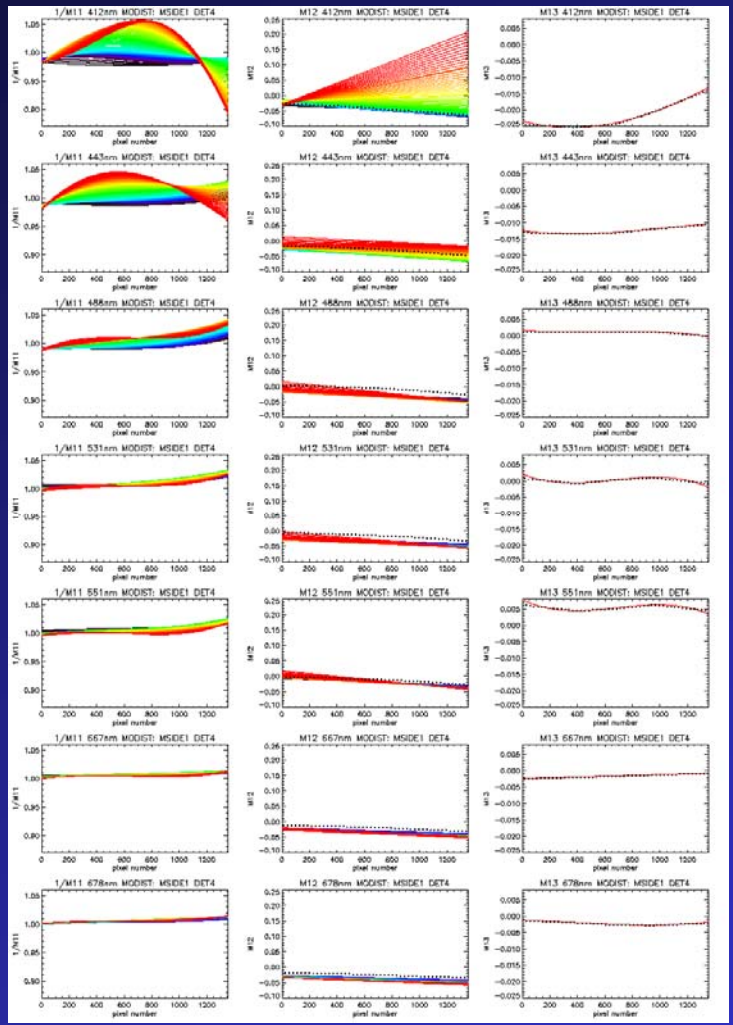
488

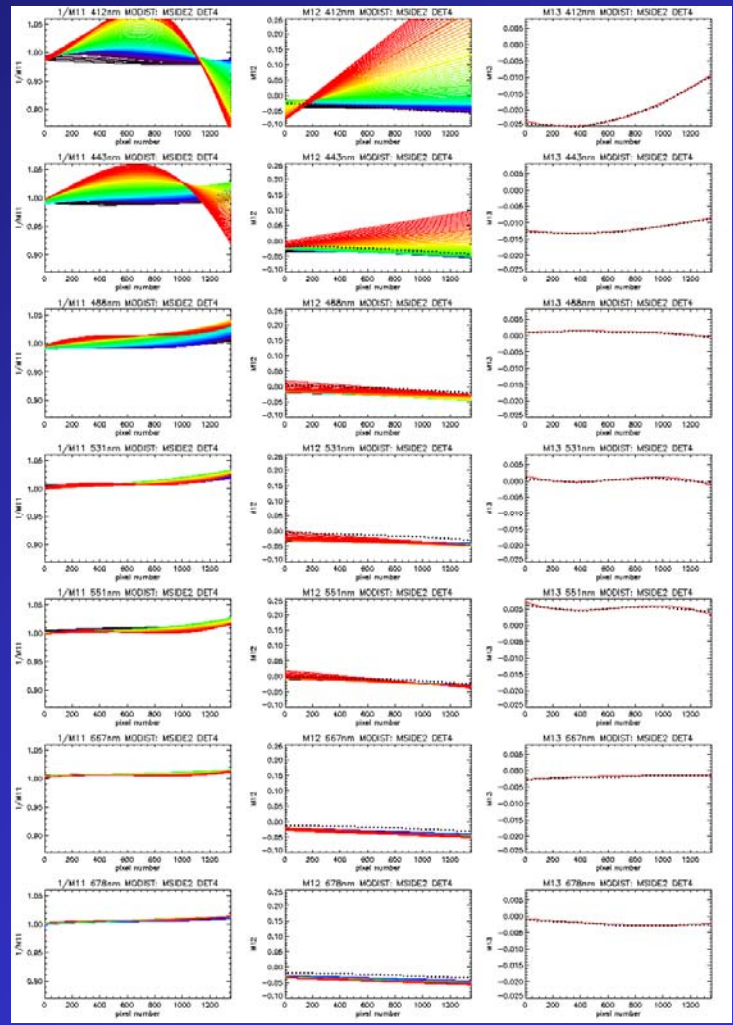
531

551

667

678



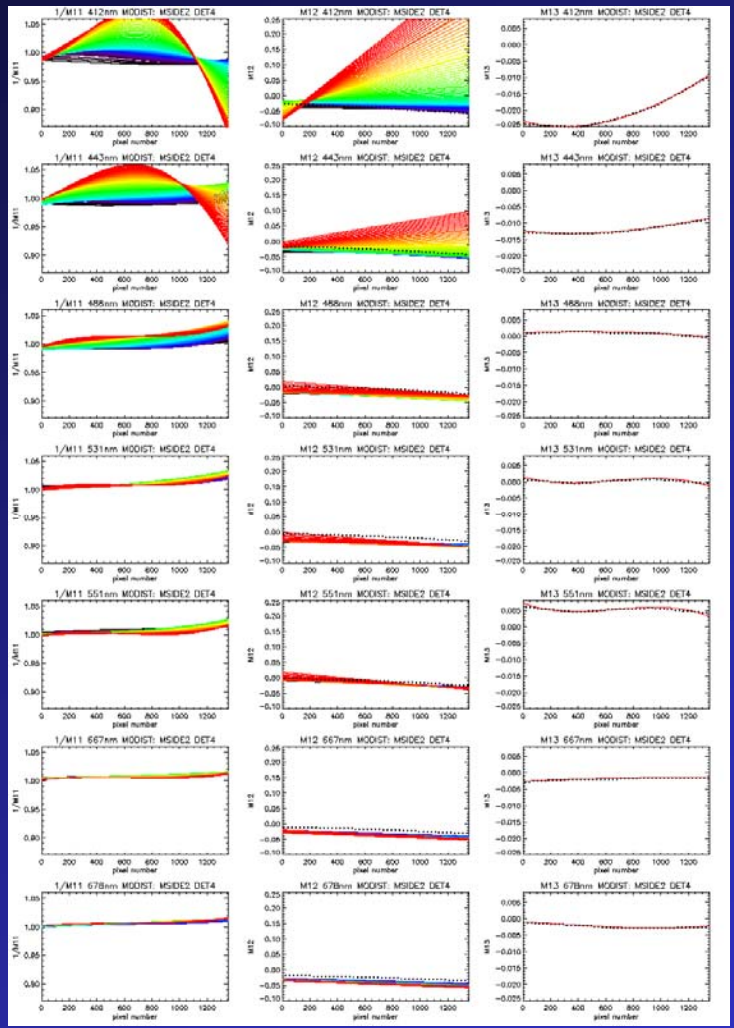


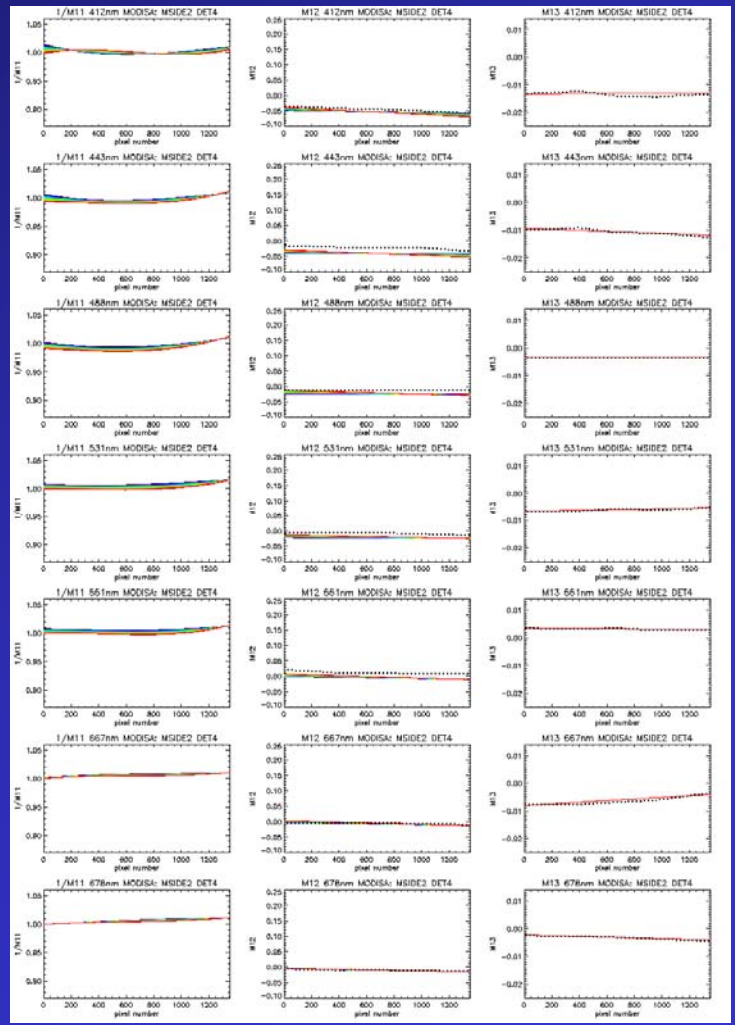
MODIS Terra and Aqua comparison

Terra MS2, Detector 4

Aqua MS2, Detector 4

	Terra RVS	Terra M12	Terra M13	Aqua RVS	Aqua M12	Aqua M13
412						
443						
488						
531						
551						
667						
678						

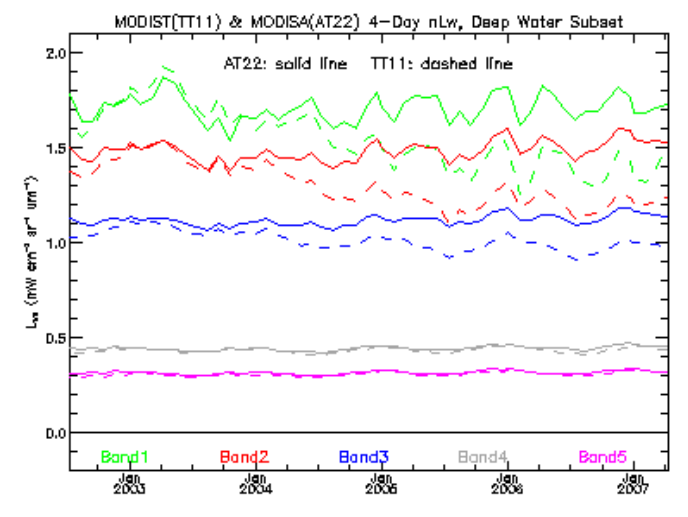


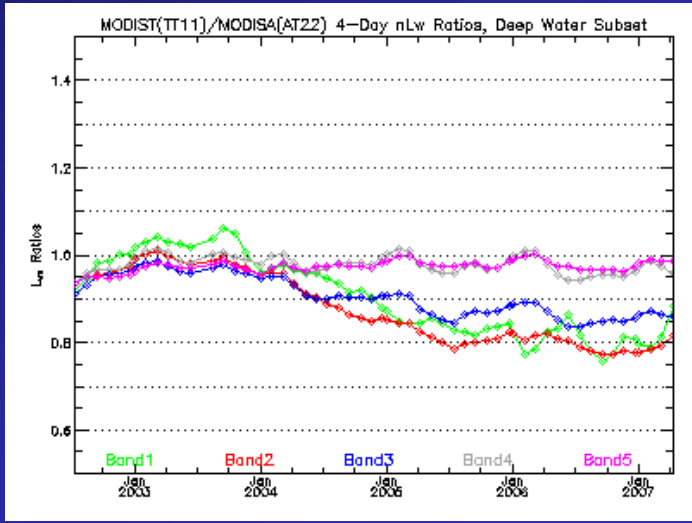


Comparison of MODIS-Terra and MODIS-Aqua L_{wn}

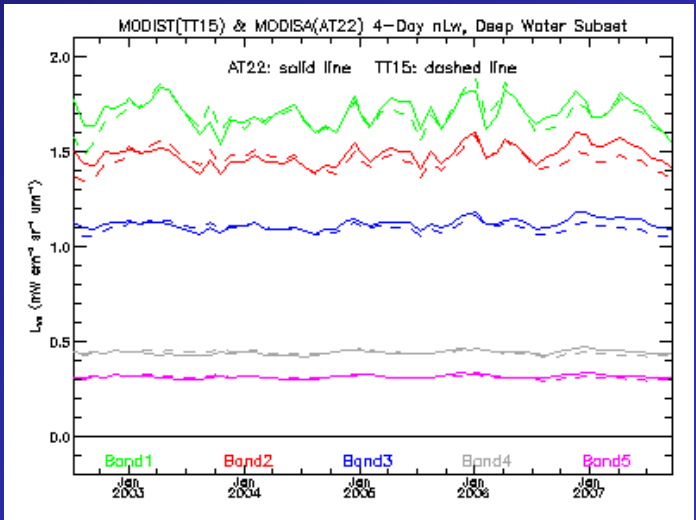
L_{wn}(412nm) band 8
L_{wn}(443nm) band 9
L_{wn}(488nm) band 10
L_{wn}(531nm) band 11
L_{wn}(551nm) band 12

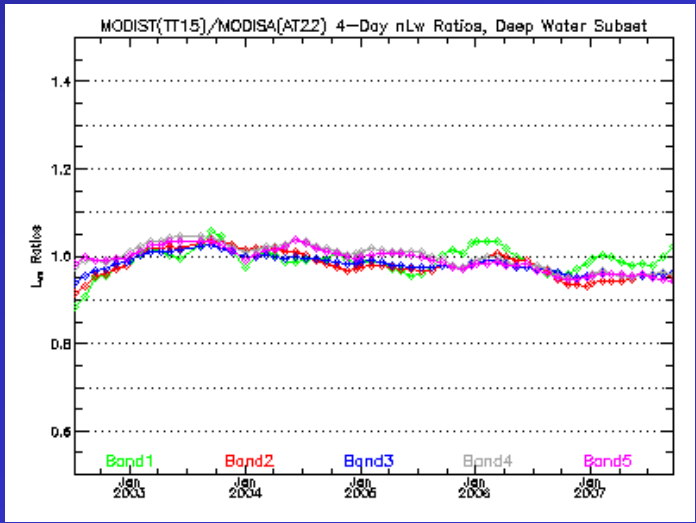
Before Vicarious Characterization





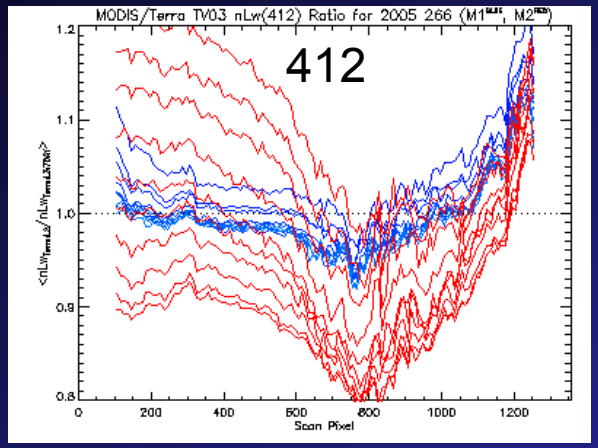
After Vicarious Characterization

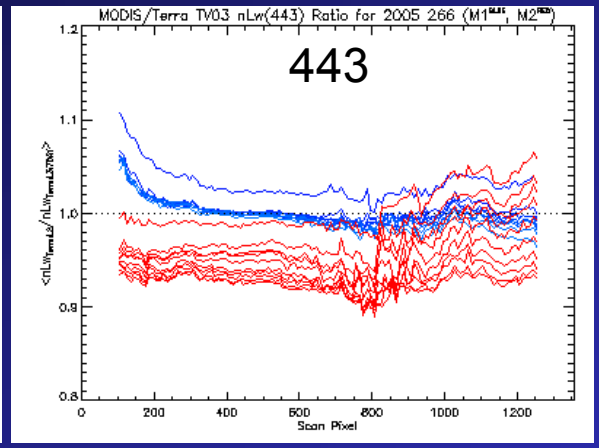


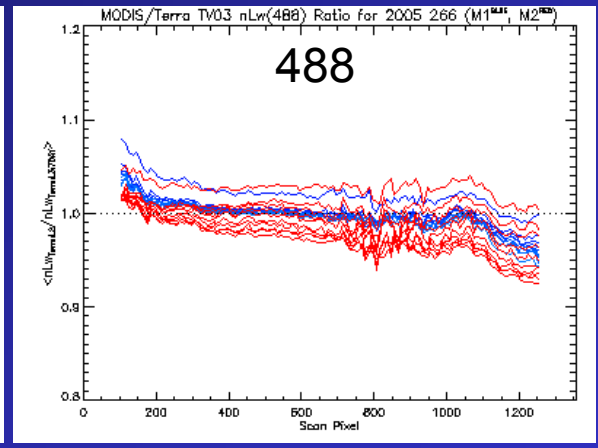


MODIS-Terra residual RVS in L_{wn}

Before Vicarious Characterization



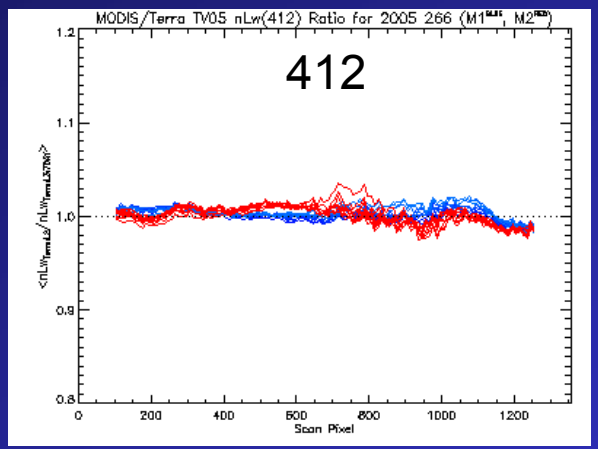


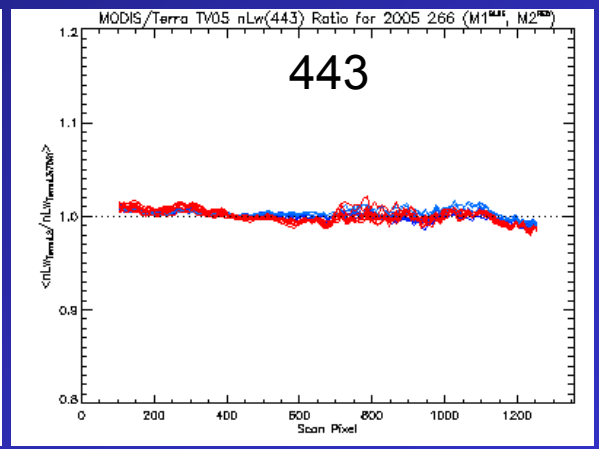


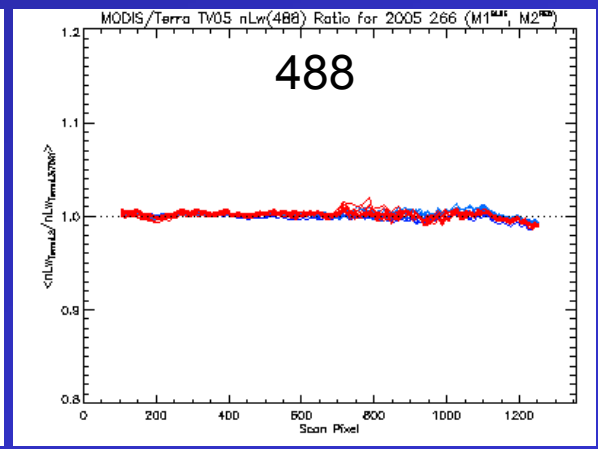
MS1

MS2

After Vicarious Characterization



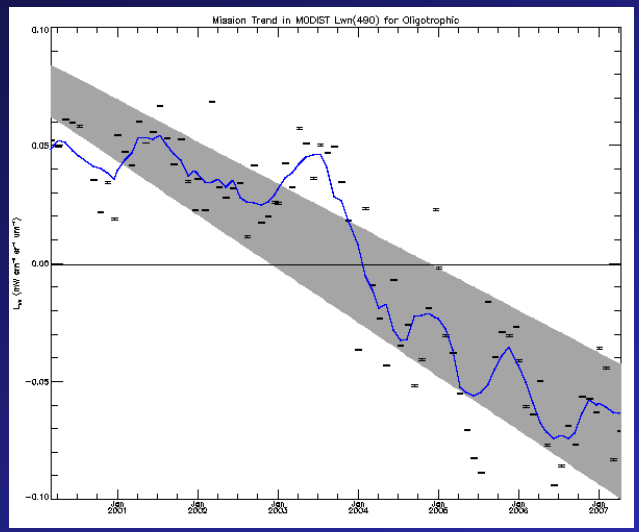




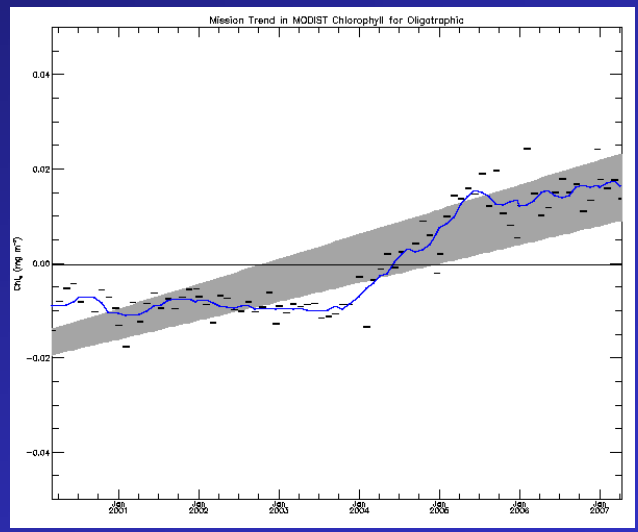
MODIS-Terra temporal anomalies

Before Vicarious Characterization

L_{wn}(488nm) band 10

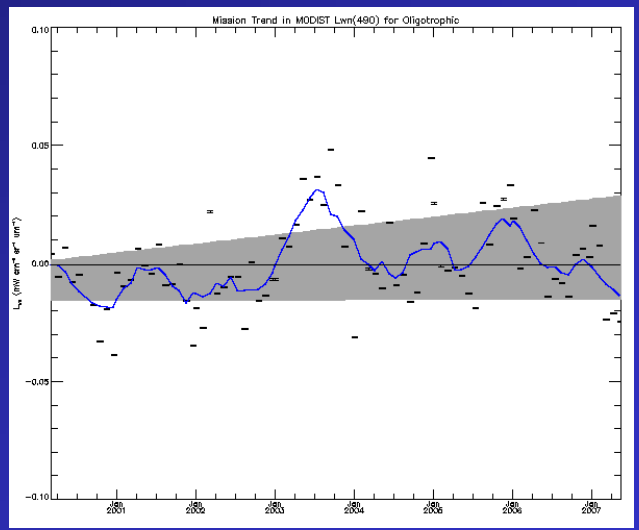


chlor_a

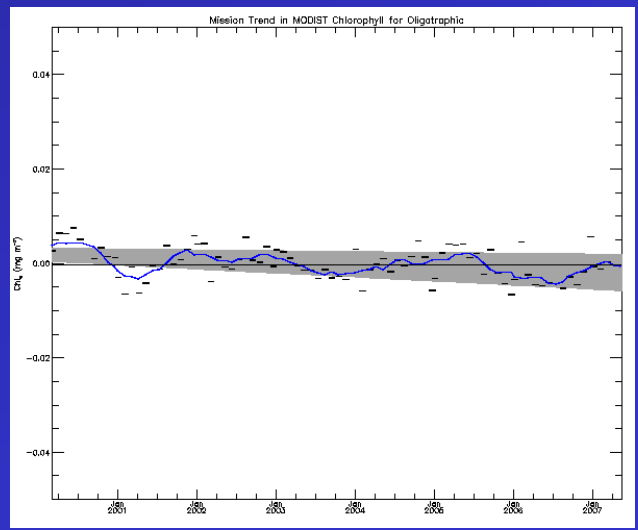


After Vicarious Characterization

L_{wn}(488nm) band 10



chlor_a



Summary

- MODIS-Terra shows evidence of residual error in instrument response versus scan-angle and/or changes in polarization sensitivity.
- The MODIS on-board calibration system can not assess changes in RVS “shape” or changes in polarization; these characteristics are restricted to our pre-launch knowledge, which itself may be in error.
- The OBPG developed a vicarious on-orbit characterization for visible band polarization and RVS changes over time, using SeaWiFS L_{wn}.
- Results show significant improvement in agreement between MODIS-Terra and MODIS-Aqua L_{wn} over the combined mission lifetime.
- Future work will focus on vicarious characterization of the NIR.

Franz, B.A., E.J. Kwiatkowska, G. Meister, and C.R. McClain (2008). Moderate Resolution Imaging Spectroradiometer on Terra: limitations for ocean color applications. *J. Appl. Rem. Sens.*, in press.