MODIS-Terra cross-calibration for ocean color bands

Ewa Kwiatkowska
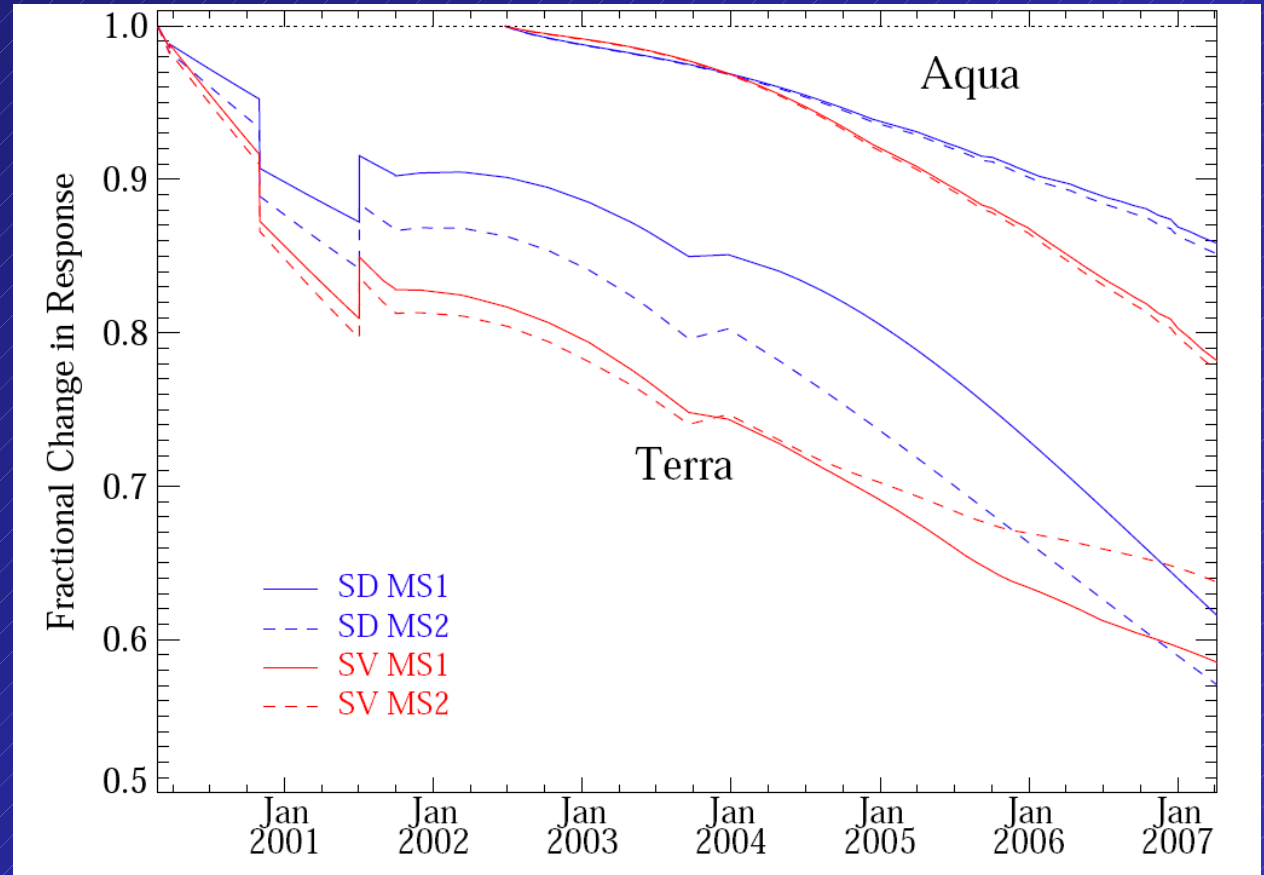
Bryan Franz, Gerhard Meister, Gene Eplee

OBPG

30 January 2008

MODIS calibration changes since launch band 8 412nm

SD – Solar Diffuser
   frame 979, mirror AOI 50.3⁰

SV – Space View
   frame 23, mirror AOI 11.4⁰

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

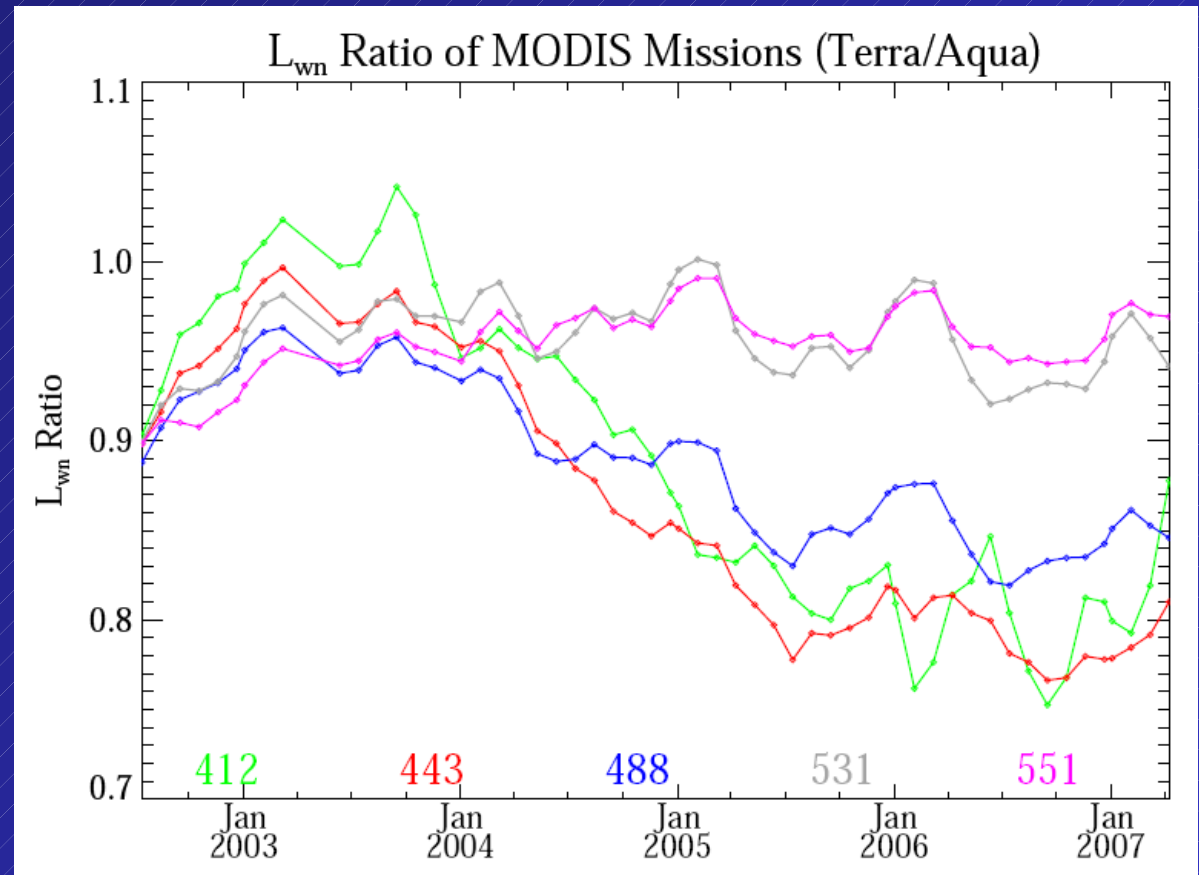Terra/Aqua ratios normalized water-leaving radiances L_{wn}

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

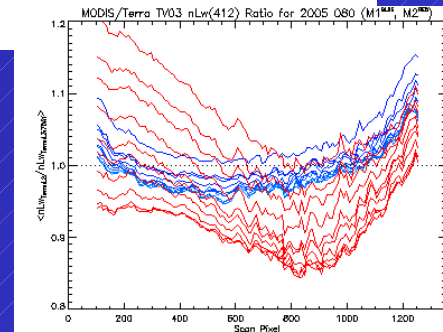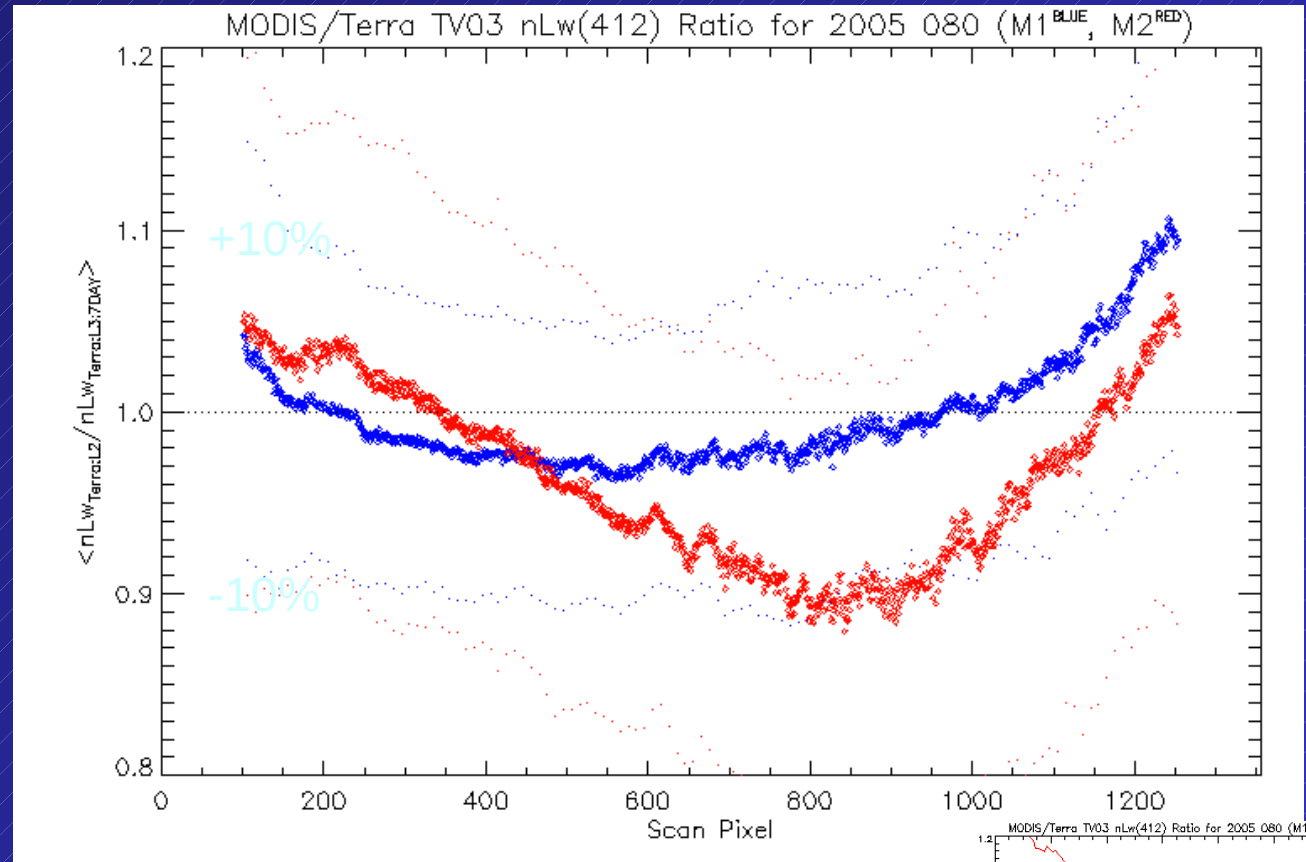L_{wn} Ratio of MODIS Missions (Terra/Aqua)

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

TOA sensor cross-calibration

Goal

- Extract MODIS-Terra
  - RVS, and
  - polarization sensitivity
- For all ocean-color bands, per mirror side and detector
- Through the entire Terra mission
- Optionally, derive temporal calibration change

Approach

- Vicarious calibration / cross-calibration using SeaWiFS
- SeaWiFS – stable spatially and temporally
- SeaWiFS – insensitive to polarization

TOA sensor cross-calibration

MODIS – measured

TOA radiance
$$L_t(\lambda)$$

MODIS – vicarious

TOA   air   aerosol   whitecap   glint   water   gas   polariz

$$\mathbf{L'_t(\lambda)} = [\, L_r(\lambda) + L_a(\lambda) + tL_f(\lambda) + TL_g(\lambda) + t_d(\lambda)L_w(\lambda)\,] \cdot t_g(\lambda) \cdot f_p(\lambda)$$

$\lambda' \longrightarrow \lambda$ (fit in the ln-ln space)

$\lambda' \longrightarrow \lambda$ (fit based on bio-optical models)

$AOT(\lambda')$

SeaWiFS

$nL_w(\lambda')$

Current implementation

MODIS – vicarious

TOA   air   aerosol   whitecap   glint   water   gas   polariz

$$L'_t(\lambda) = [\, L_r(\lambda) + L_a(\lambda) + tL_f(\lambda) + TL_g(\lambda) + t_d(\lambda)L_w(\lambda) \,] \cdot t_g(\lambda) \cdot f_p(\lambda)$$

MODIS operational
assuming accuracy of MODIS NIR band calibration

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

SeaWiFS

$nL_w(\lambda')$

Polarization f_p

- Polarization correction

    $f_p = I_m / I_t$

    $I_m = M_{11}I_t + M_{12}(Q_t\cos2\alpha - U_t\sin2\alpha) + M_{13}(Q_t\sin2\alpha + U_t\cos2\alpha)$

- I_t – Stokes vector exiting the TOA
- Mueller matrix $\mathbf{M}$ – instrument characterization, including polarization
- $\forall$ α - rotation angle
- I_m – Stokes vector measured by a sensor

    $I_m = \mathbf{M}\,\mathbf{R}(\alpha)\,I_t$

$$I_m = \begin{bmatrix} M_{11} \dots M_{14} \\ M_{21} \dots M_{24} \\ M_{31} \dots M_{34} \\ M_{41} \dots M_{44} \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos2\alpha & -\sin2\alpha & 0 \\ 0 & \sin2\alpha & \cos2\alpha & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I_t \\ Q_t \\ U_t \\ 0 \end{bmatrix}$$

Polarization of the atmosphere

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

polarization correction f_p
pre-launch MODIS characterization
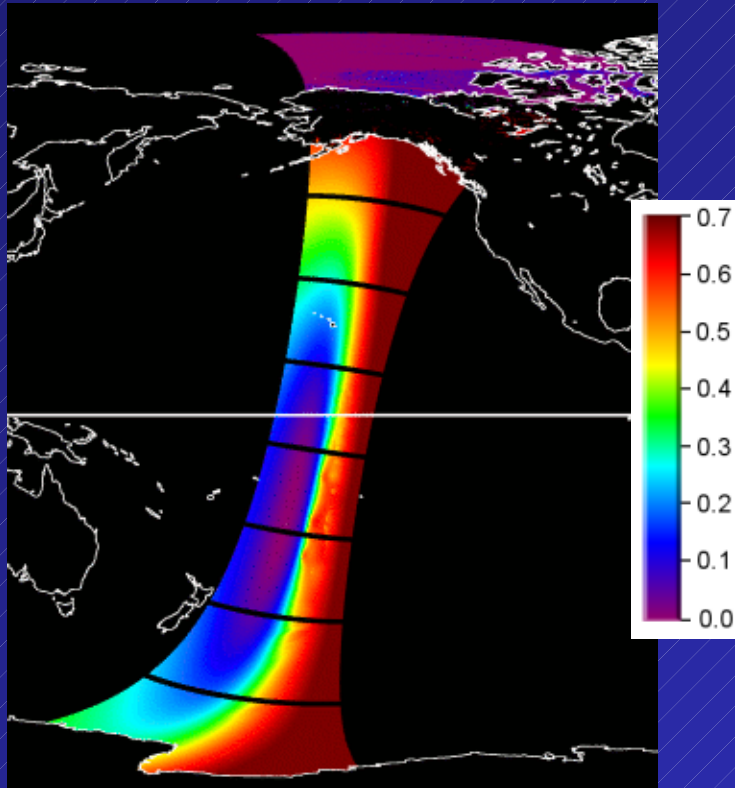
MODIS Terra swath

412nm band 8
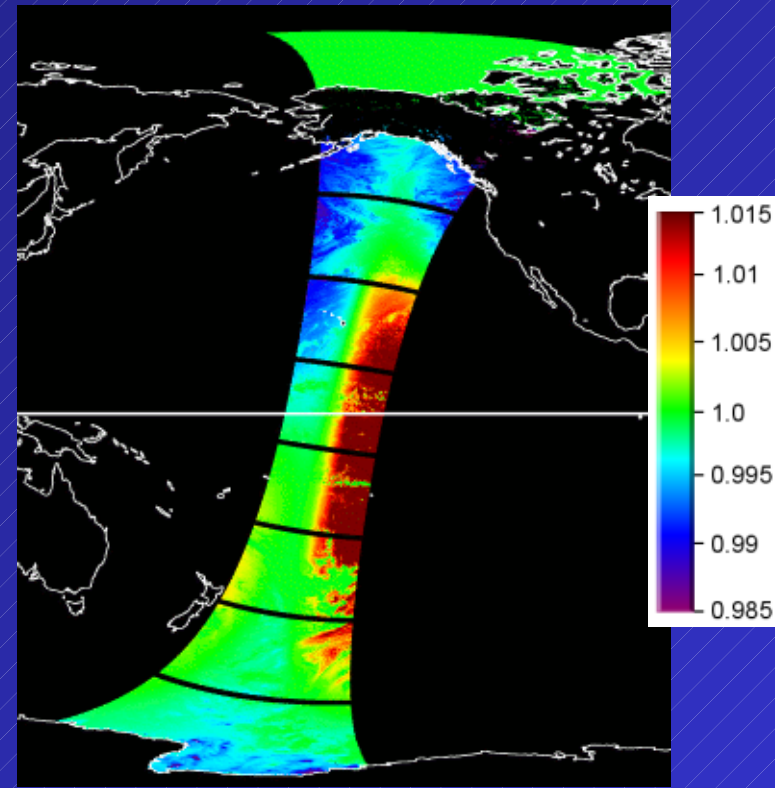
$$d_p = \frac{\sqrt{Q^2 + U^2}}{I}$$

Time series and global optimization

- Global time series throughout the entire Terra mission
  - MODIS Terra – one day a month global set of granules (90 days)
  - SeaWiFS – 9-day global L3s centered on each month's day from MODIS
  - Strict screening criteria for SeaWiFS L3 bins and MODIS L2 pixels

$$L_t = M_{11}L'_t + M_{12}(Q_t\cos2\alpha - U_t\sin2\alpha) + M_{13}(Q_t\sin2\alpha + U_t\cos2\alpha)$$

Known:

- L_t – MODIS-measured
- L'_t – MODIS-vicarious
- Q_t and U_t – atmospheric molecular and glint polarization, Rayleigh tables, glint derivation
- $\forall$ α – theoretical calculation

Unknown:

- M_{11} – RVS and absolute calibration
- M_{12} and M_{13} – polarization sensitivity

- Global optimization for each day to derive M_{11}, M_{12}, and M_{13}

- M_{11}, M_{12}, M_{13} = fn(mirror AOI)

6 March 2000

polynomial across scan
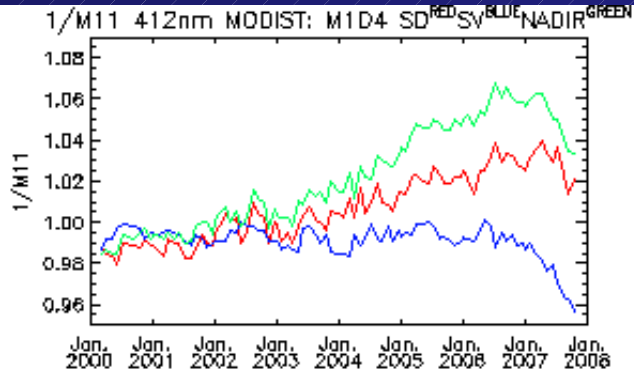
RVS   M12   M13

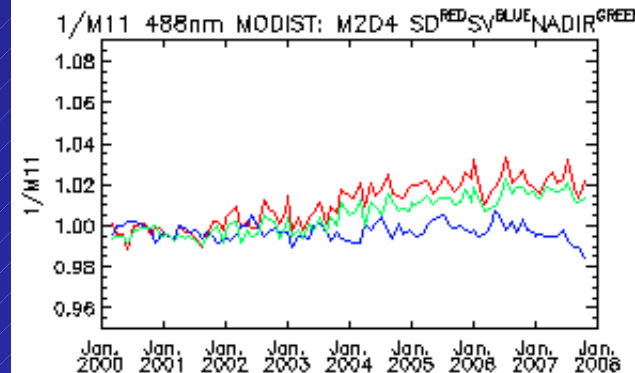3-rd degree   linear   linear

Detector 4

Mirror side 1
Mirror side 2

412nm
443nm
488nm
531nm
551nm
667nm
678nm

1-1.5%
1-2%
2%
2%
1.5%
1%
1%
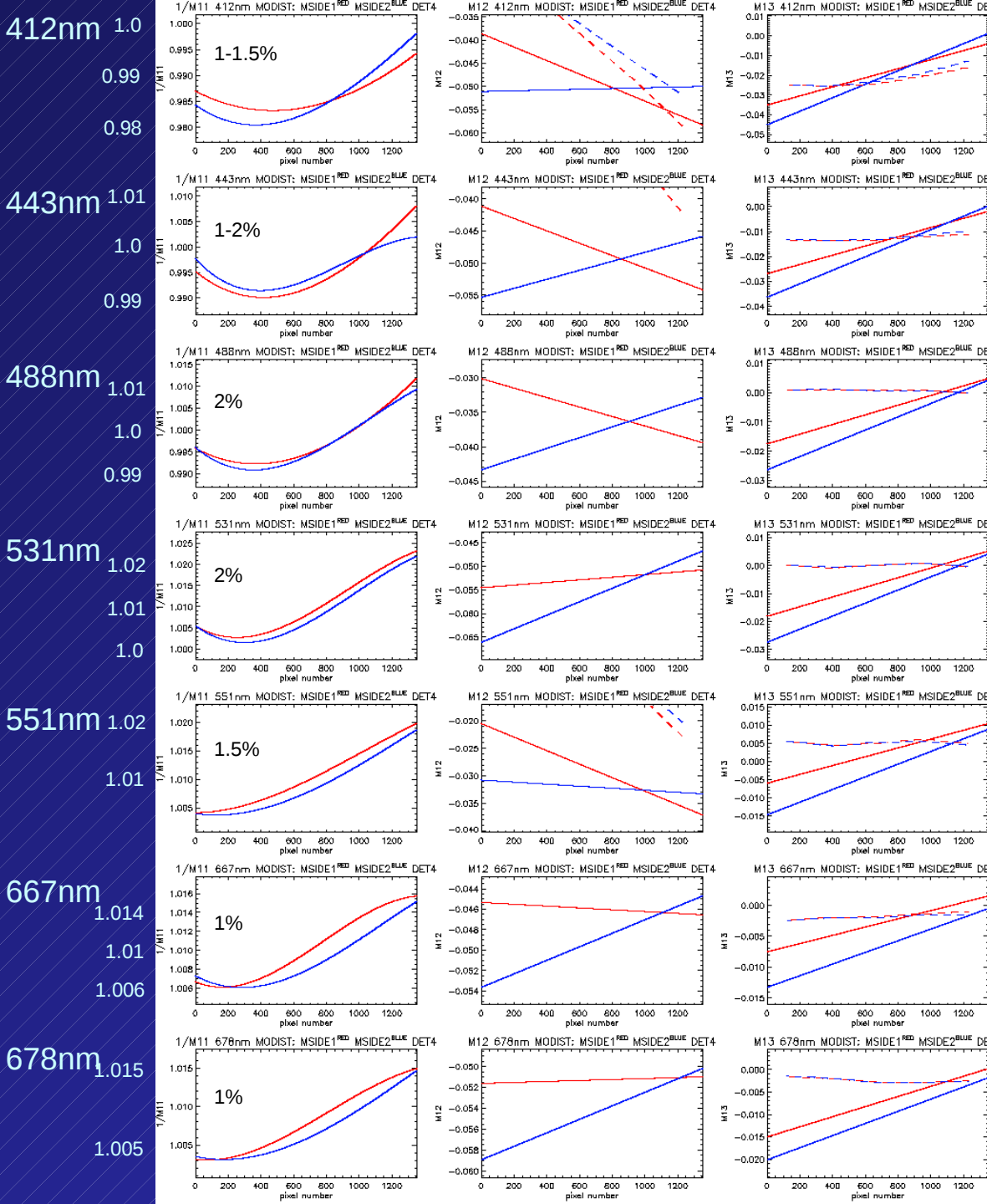
16 October 2007

polynomial across scan

RVS   **M12**   **M13**

3-rd degree   linear   linear

Detector 4

Mirror side 1
Mirror side 2
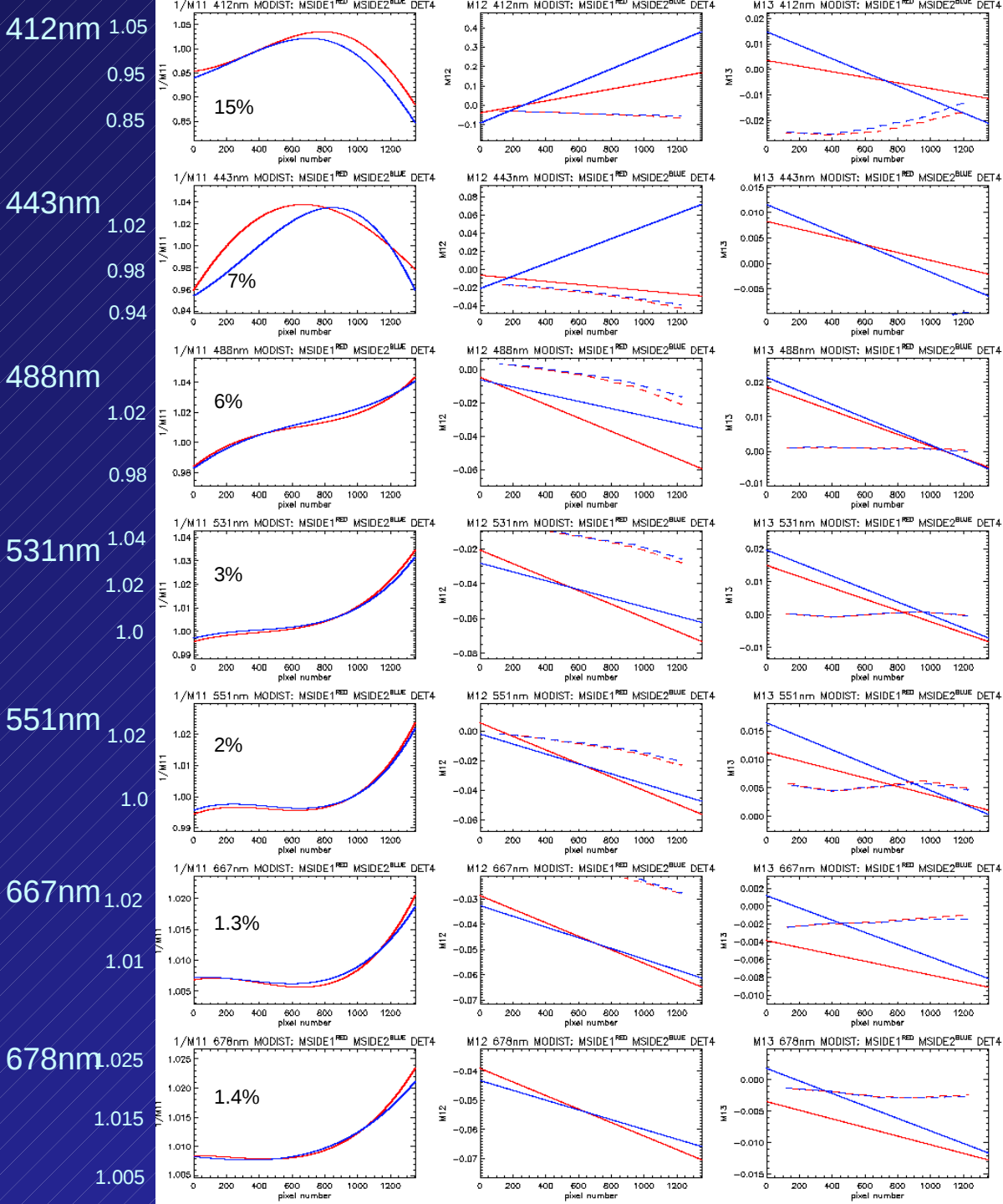
Blue band temporal trends
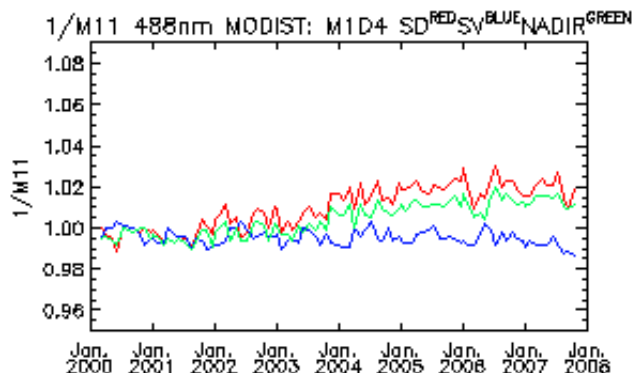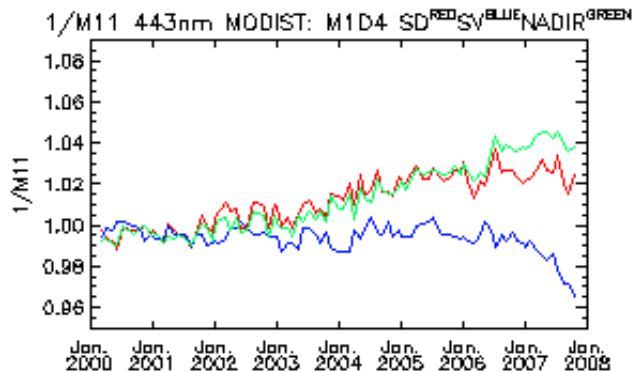
Mirror side 1
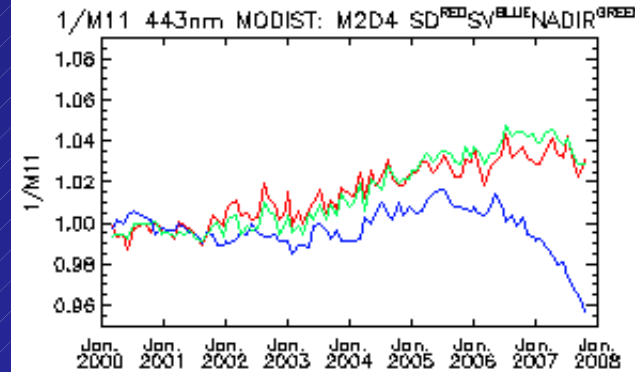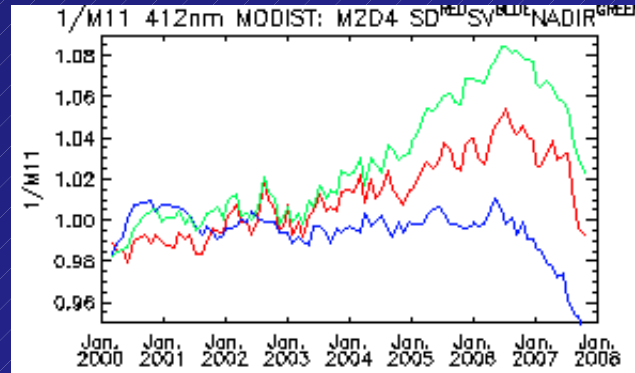
Mirror side 2

RVS

Detector 4

Space View (lunar) frame
Nadir frame
Solar Diffuser frame

Blue band temporal trends
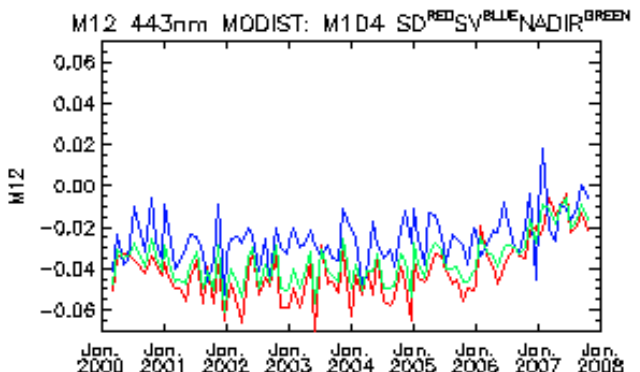

Mirror side 1

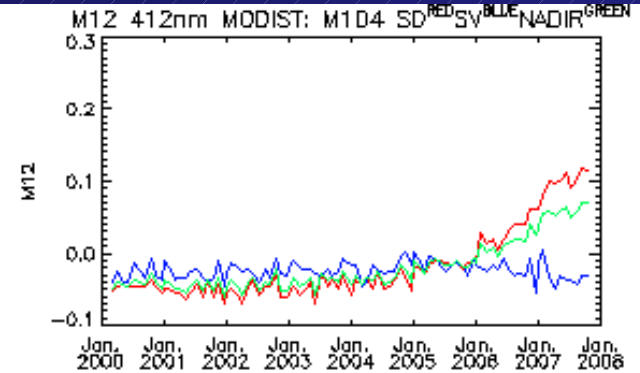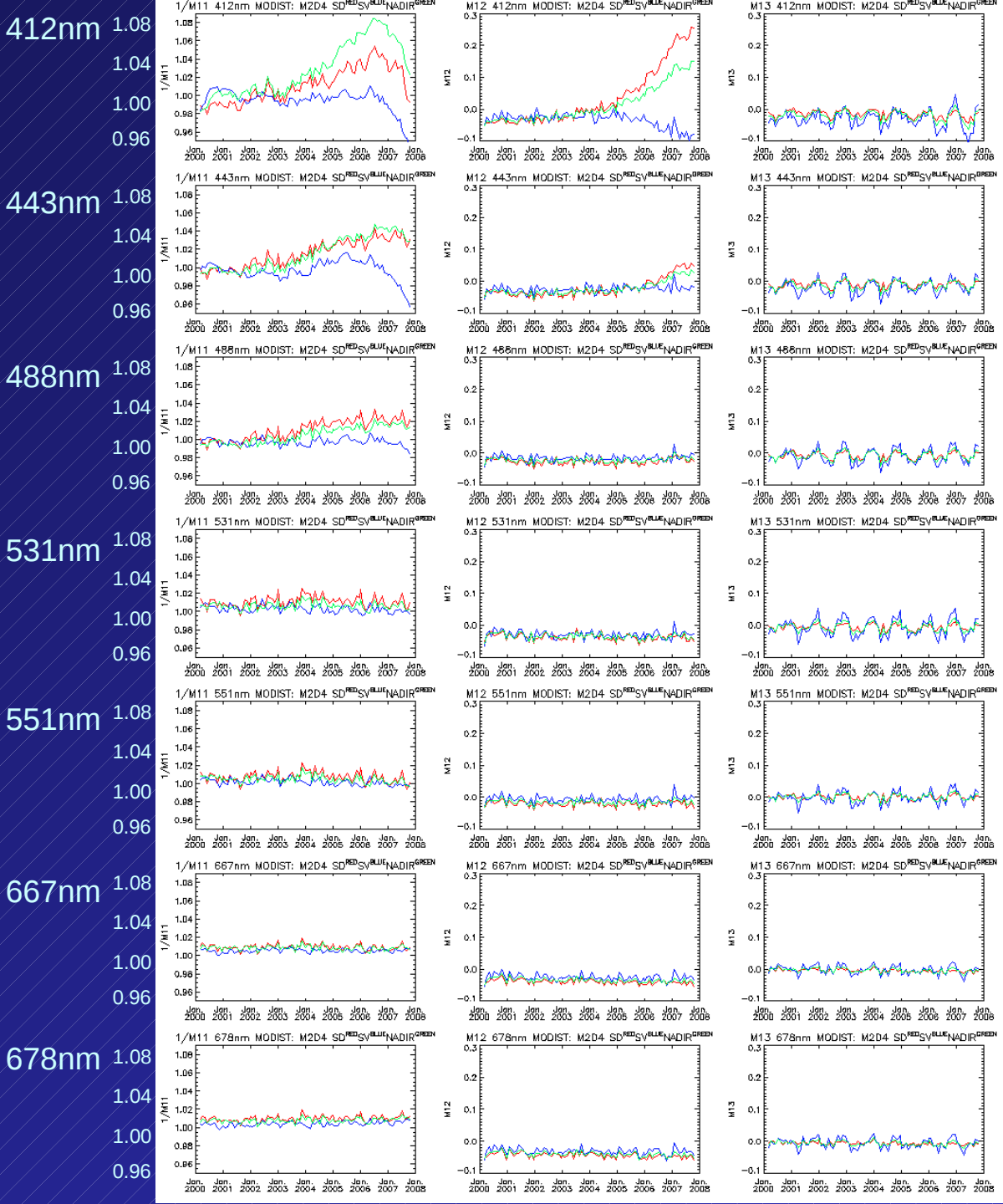Mirror side 2

M12

Detector 4

Space View (lunar) frame
Nadir frame
Solar Diffuser frame
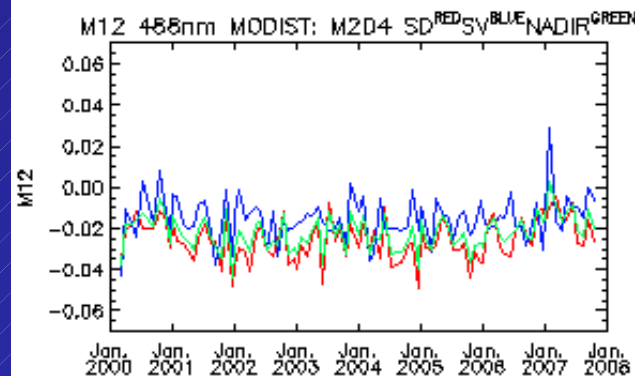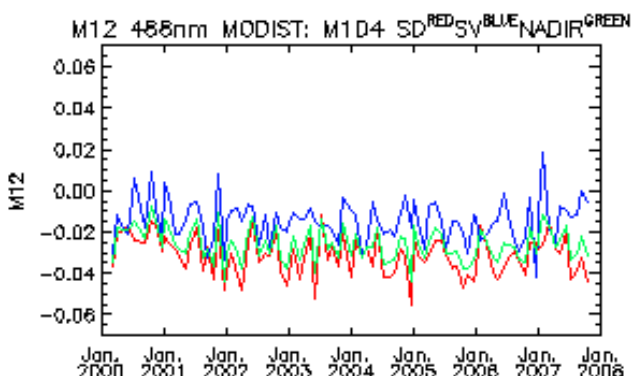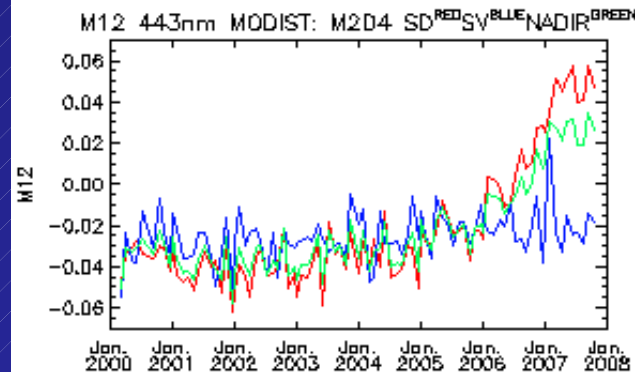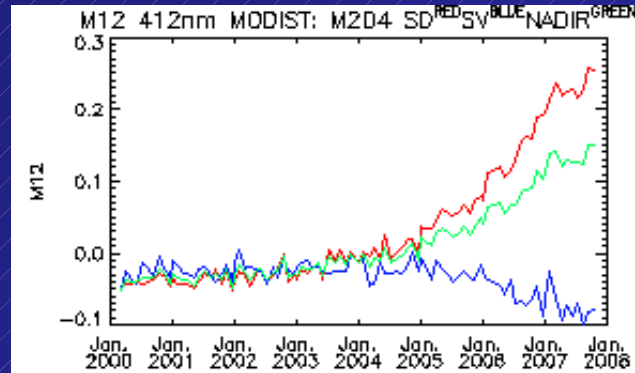
Temporal trends

RVS   M12   M13

Mirror side 2
Detector 4

Space View (lunar) frame
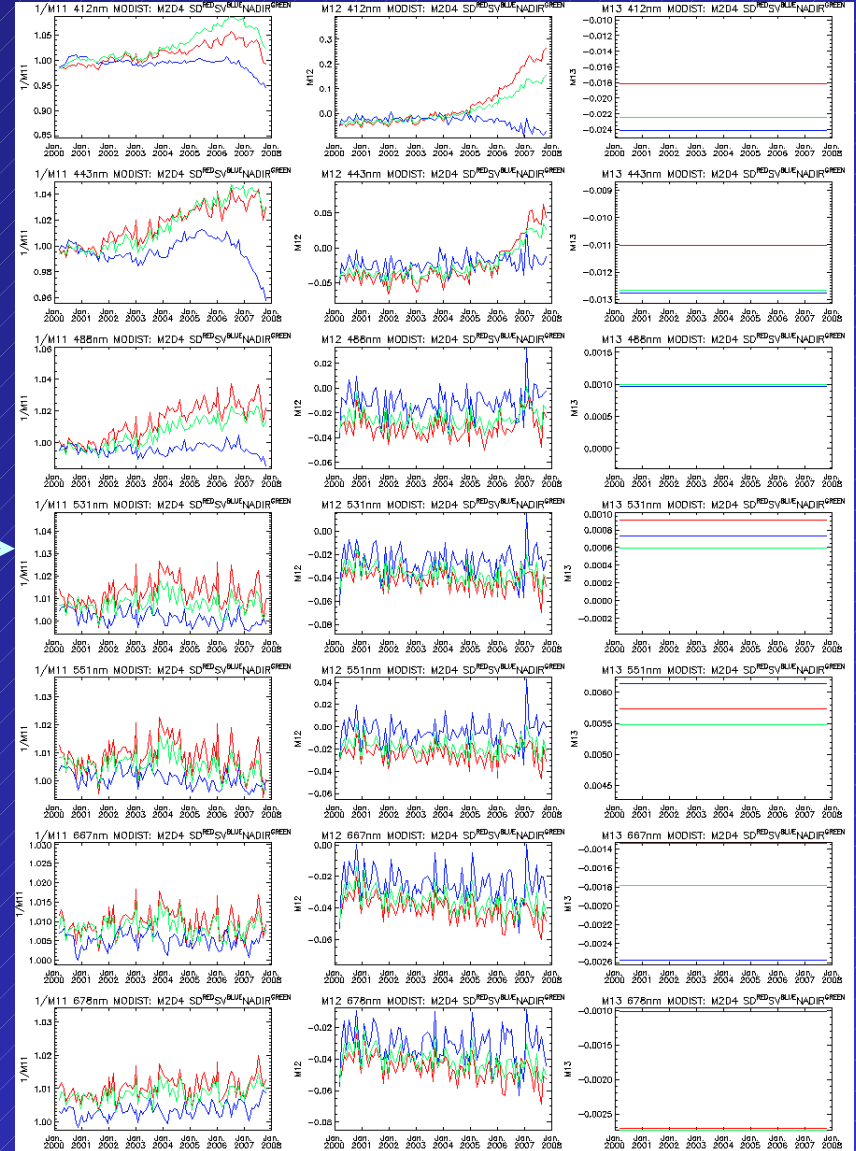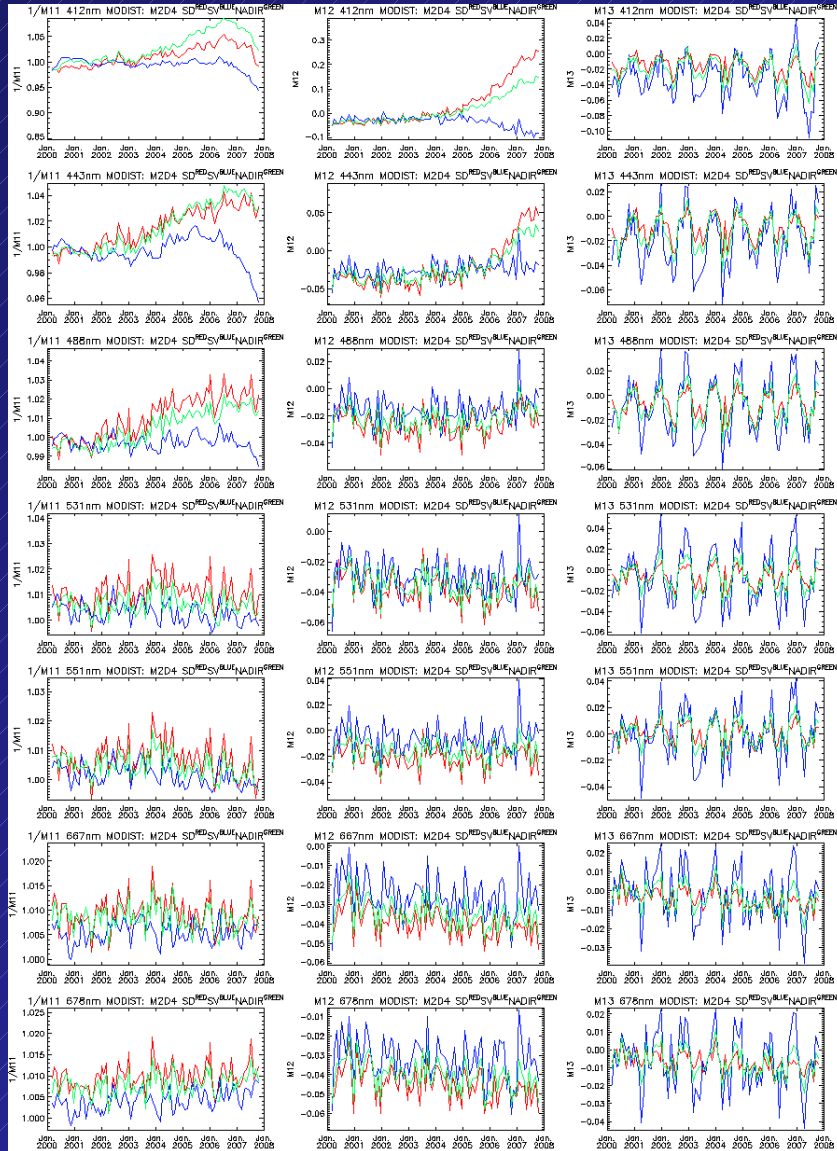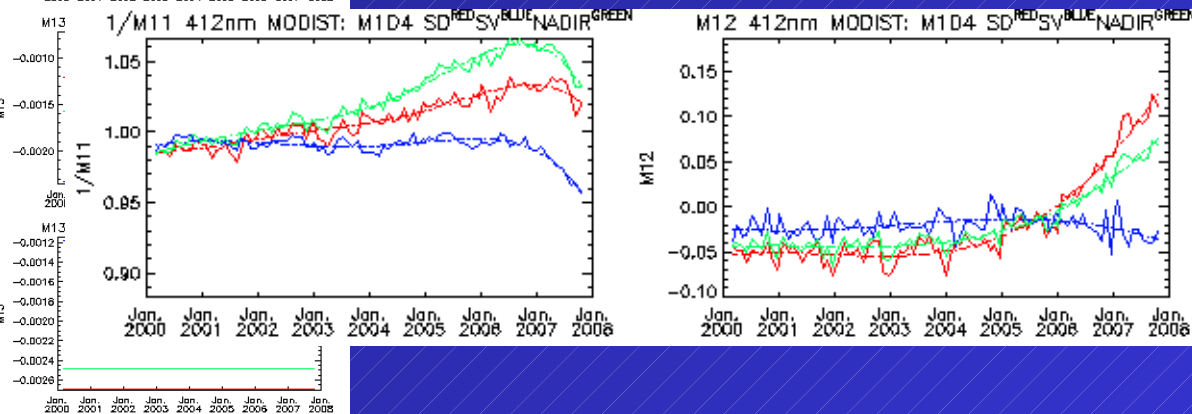Nadir frame
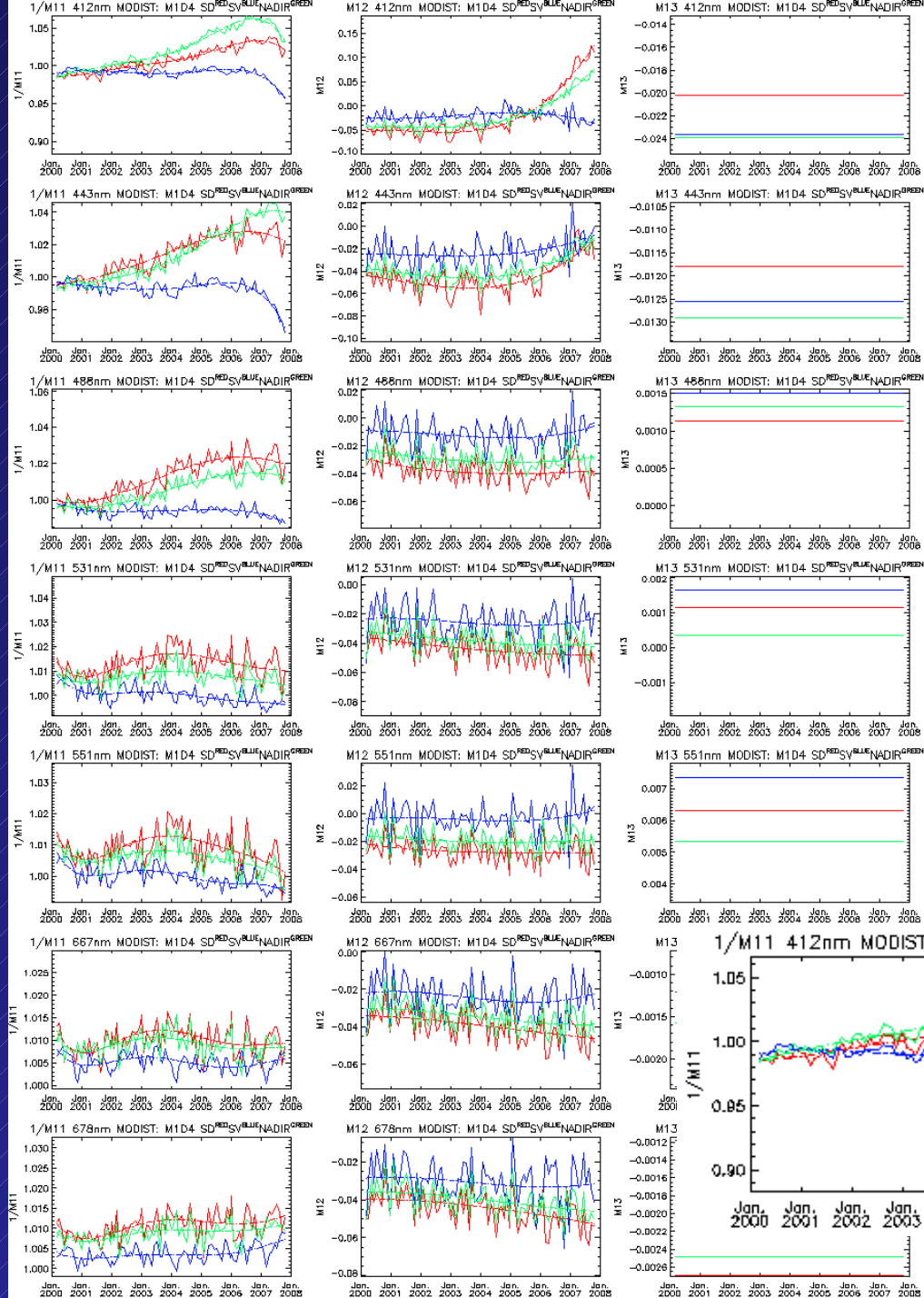Solar Diffuser frame

Pre-launch M13

Temporal smoothing

Polynomial fit through time into derived RVS and M12 per individual frame

Smoothed results

RVS   M12

Daily RVS and M12 use temporally smoothed values for all frames

412nm
443nm
488nm
531nm
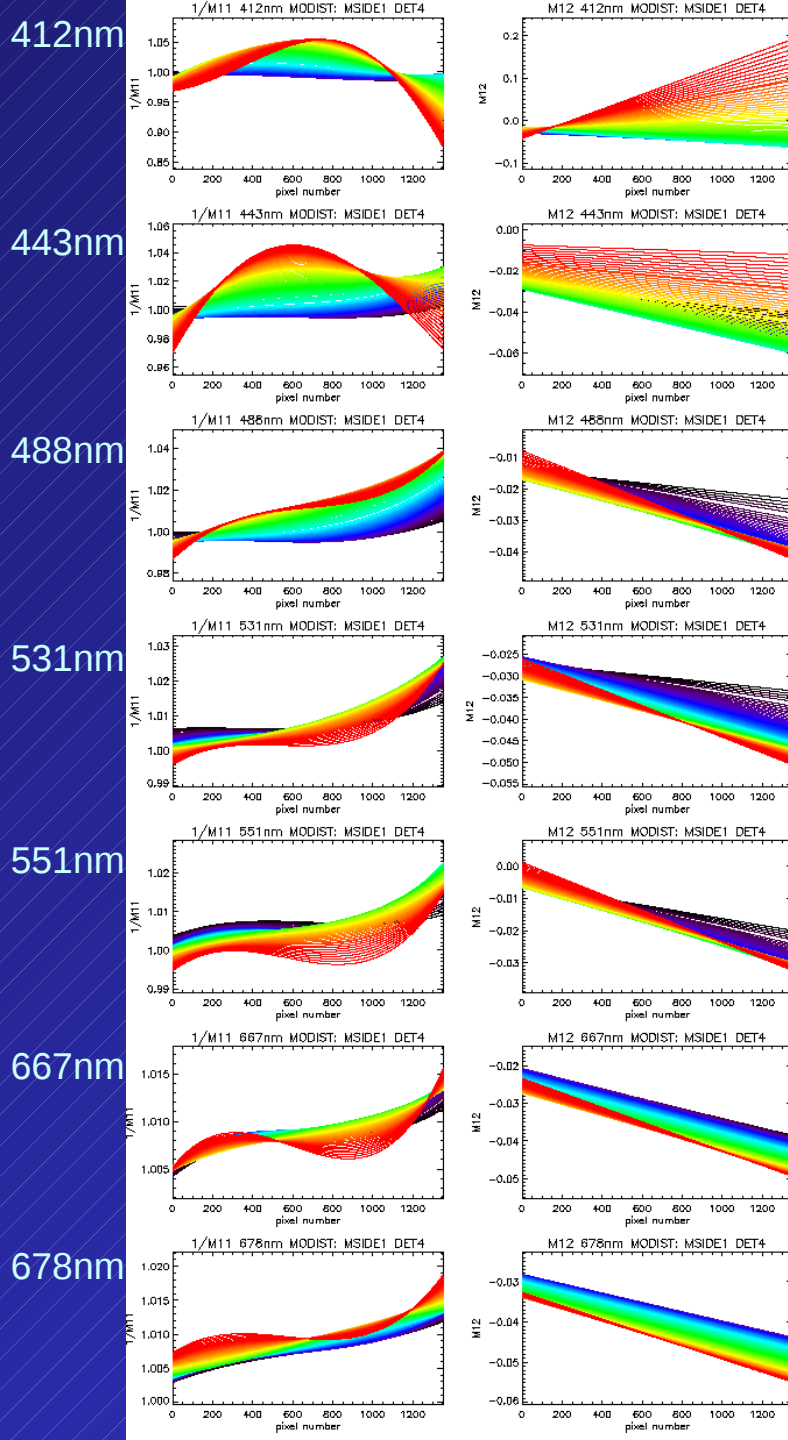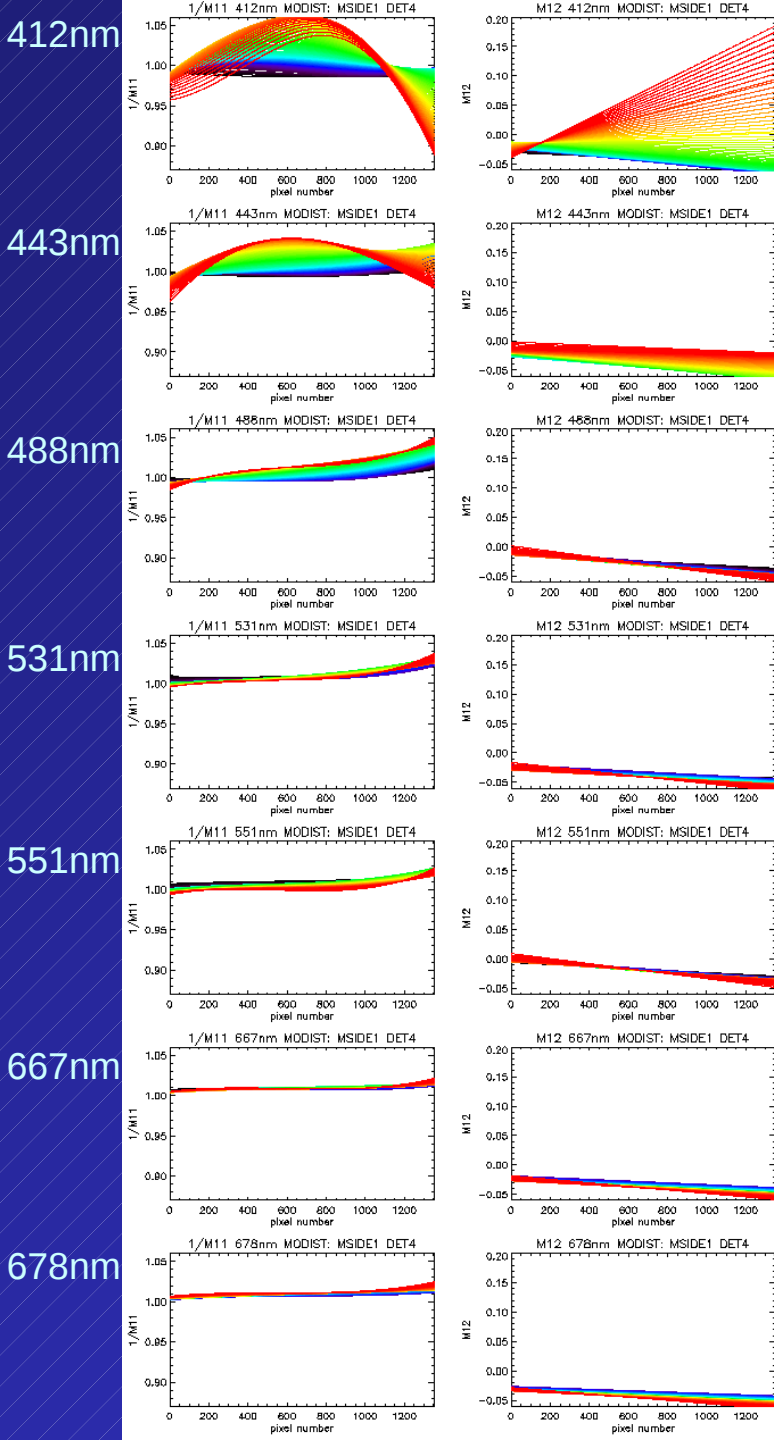551nm
667nm
678nm

Mirror side 1
Detector 4

October 2007

March 2000

Smoothed results

RVS   M12

Daily RVS and M12 use temporally smoothed values for all frames

Mirror side 1
Detector 4

412nm
443nm
488nm
531nm
551nm
667nm
678nm

October 2007

March 2000

Verification of the vicarious cross-calibration with lunar measurements
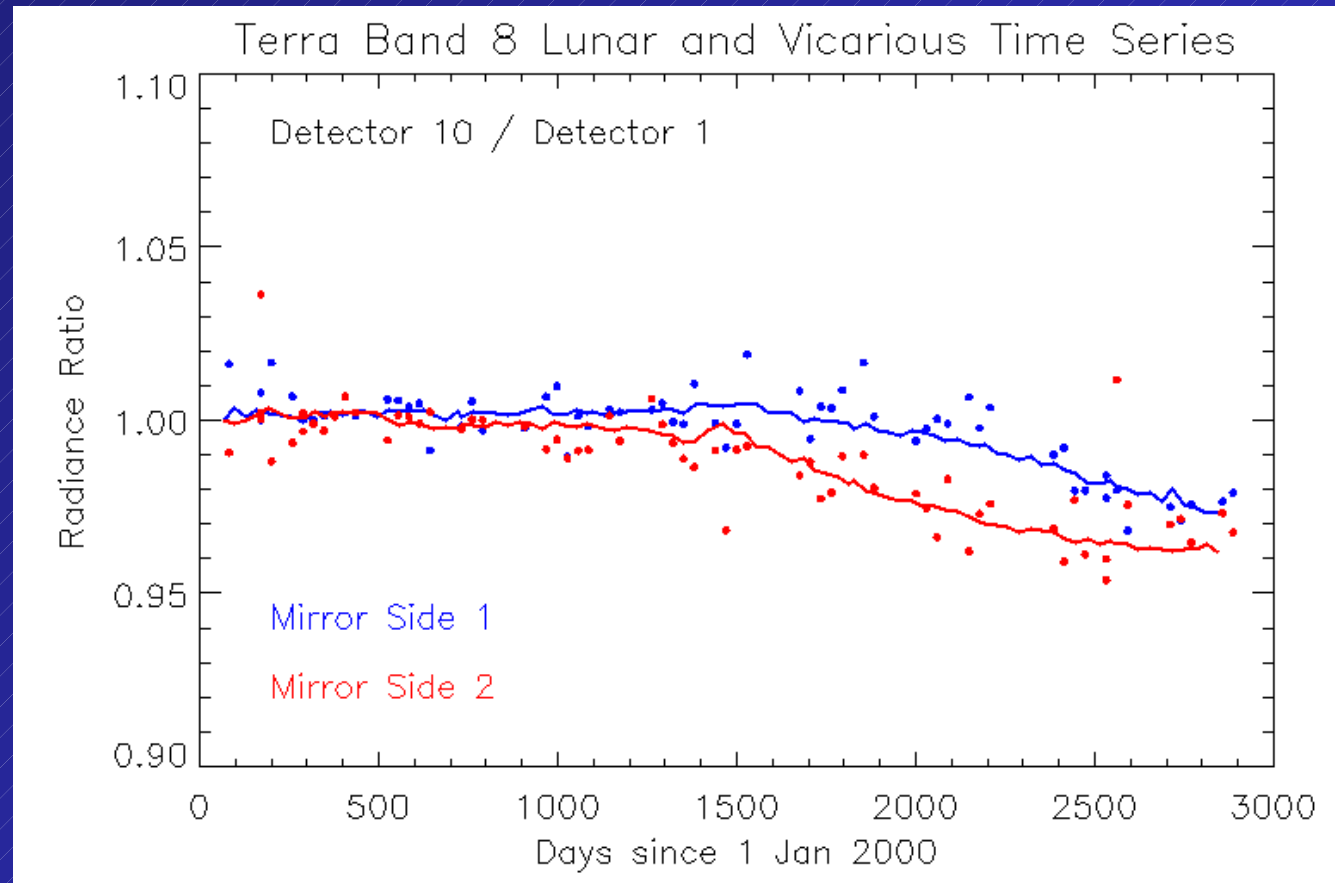# band 8 412nm

Terra detector ratios

detector 10 / detector 1

- lunar measurements
— vicarious cross-cal

412nm   band 8

Mirror side 1 MS1
Mirror side 2 MS2

Future plans

- Why seasonality in M13?

- Is extracted polarization sensitivity too large? RVS?

- Global time-series testing for water-leaving radiances

- Validation of RVS and detector calibration

- Application of the cross-calibration to Aqua