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

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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
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
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

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

SeaWiFS
4-day mean

from MODIS NIR
assumes MCST NIR band characterization

\[ \lambda' \rightarrow \lambda \]

fit based on bio-optical models
Crosscalibration approach:

\[ \frac{L_m}{M_{11}} = L_t + m_{12}Q + m_{13}U \]

- \( L_m \): 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:

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

Color coding: Frames (pixels) 22 675 989, 1250 (out of 1354)

Solid line is a fit to the measurements of each month (diamonds)
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)
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)
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)

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)
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
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 OBPG 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

Band 8: 412nm

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
Chlorophyll trends: similar to SeaWiFS
RVS issues resolved: red bands (not EOM)
Backup
MCST coll. 6 resolves temporal issue for 678nm, FLH:
MCST coll. 6 reduces temporal variation for 488-547nm:
MCST coll. 6 increases trend in 412nm, improves angstrom:
Vicarious TOA MODIS total signal

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

air molecule (Rayleigh) and glint scattering

pre-launch MODIS characterization

$\sqrt{Q_{\|}} + U_{\perp}$

MODIS Terra swath

412nm band 8

polarization correction $f$

$f_{p} = \frac{L_{m}}{L_{t}}$
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)