Corrections to the calibration of MODIS Aqua ocean color bands derived from MODIS Aqua L3 data

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Calibration Breakout
Ocean Biology Processing Group:

- NASA Code 616, Ocean Sciences Research, Hydrospheric and Biospheric Sciences Research, Goddard Space Flight Center
- Responsible for producing Ocean Color (OC) products at NASA (CZCS, SeaWiFS, MODIS Aqua and Terra, MERIS, etc.)
- Website: oceancolor.gsfc.nasa.gov
Background:

- Previous: MCST lunar and SD trending (coll. 6, but Approach I)
- 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 (7-day L3)
- Only bands 8 and 9 (412nm and 443nm) needed temporal corrections, for bands 10-14 time-independent scan angle corrections are sufficient
- Method did not work after demise of SeaWiFS (end of 2010)
Globally averaged reflectances

Solid line: operational (old) using Approach I and xcal to SeaWiFS

50% increase in Rrs at 412nm
MCST Approach II:

- MCST lunar, SD, and desert (for bands 8 and 9) trending (coll. 6, Approach II)
- Largest difference to Approach I is in the center of the scan (between lunar and SD angles)
- Qualitatively, results are very similar to OBPG crosscalibration for SeaWiFS period
- OBPG derived a time-independent scan angle correction using a crosscalibration to a SeaWiFS climatology
- Approach II + time-independent scan angle correction: Temporal trends of global ocean color products look good even beyond SeaWiFS period, except for a downward trend in 412nm band (and possibly at the beginning of the mission for 443nm)
- The above is NOT our final approach
Globally averaged reflectances

Dashed line: Approach II and time-indep. xcal to SeaWiFS climatology

MODISA(AT82) & MODISA(AT78) Rrs for Deep-Water

50% increase in Rrs at 412nm eliminated, but now downward trend
Temporal anomaly for 412nm reflectance

Anomaly in MODISA(AT82) Rrs(412) for Deep-Water

![Graph showing temporal anomaly for 412nm reflectance]
Temporal anomaly for 443nm reflectance
Crosscalibration of MCST Approach II to SeaWiFS climatology: gain corrections for 412nm

Scan angles (frame): lunar (22), nadir (675), Solar diffuser (989), end-of-scan (1250)

3% change in M11 for end-of-scan
Crosscalibration of MCST Approach II to SeaWiFS climatology: gain corrections for 443nm

Scan angles (frame): lunar (22), nadir (675), Solar diffuser (989), end-of-scan (1250)
Crosscalibration of MCST Approach II to SeaWiFS climatology: gain corrections for 488nm

Scan angles (frame): lunar (22), nadir (675), Solar diffuser (989), end-of-scan (1250)
OBPG approach for MODISA 2012.0 reprocessing:

- Basis: MCST Approach II provides trending consistent with SeaWiFS climatology for central part of the scan (frames 300-1050)
- New approach: use Approach II to calculate MODIS Aqua L3 using only L2 from frames 300-1050, then derive crosscalibration coefficients for MODIS Aqua using these L3
- Resulting time series is independent of SeaWiFS trend, temporal trend is completely based on the MCST Approach II calibration for frames 300-1050
Crosscalibration of MCST Approach II to its central frames: gain corrections for 412nm

Scan angles (frame): lunar (22), nadir (675), Solar diffuser (989), end-of-scan (1250)
Crosscalibration of MCST Approach II to its central frames: gain corrections for 443nm

Scan angles (frame): lunar (22), nadir (675), Solar diffuser (989), end-of-scan (1250)
Crosscalibration of MCST Approach II to its central frames: gain corrections for 488nm

Scan angles (frame): lunar (22), nadir (675), Solar diffuser (989), end-of-scan (1250)
Crosscalibration of MCST Approach II to its central frames: gain corrections for 412-531nm

Color scale: black/blue=2002, red=2012
MODISA R2012.0: Rrs deep-water anomalies
MODISA R2012.0: Chlorophyll anomalies

Deep-water

Oligotrophic

Mesotrophic

Eutrophic
MODISA R2012.0: Scan angle dependency

nLw 412nm from C6:

MODIS/Aqua AV79 nLw(412) Ratio for 2010 353

nLw 412nm from C6+xcal:
MODISA R2012.0: Scan angle dependency

nLw 547nm from C6:

MODIS/Aqua AV79 nLw(547) Ratio for 2010 353

nLw 547nm from C6+xcal:

MODIS/Aqua AV85 nLw(547) Ratio for 2010 353
MODISA R2012.0: Scan angle dependency

nLw 678nm from C6:

nLw 678nm from C6+xcal:

AV results for 667nm and 678nm: better than ever
MODISA R2012.0: Land bands

- Pure MCST calibration
- Exception: Striping correction added (needs improvement)
- Mainly used in coastal areas
  => plots for eutr. regions
- Possibly a trend in 469nm
  (also in olig. Region, not shown)
MODISA R2012.0: Scan angle dependency

Land band scan angle dependency:
- Derived for first time
- Looks quite good (no corrections applied)
Summary:

- New MCST calibration approach (Approach II, desert site trending) results in reasonable trends for ocean color products (huge improvement compared to previous approach).

- OBPG applies time-dependent correction by adjusting the scan angle dependency (this modifies mainly the scan edges; overall trend is determined by MCST calibration for frames 300-1050).

- OBPG corrections result in small improvement to Rrs 412nm trend; scan angle dependency of most bands is improved, especially red bands.

- Land bands are not corrected by OBPG; scan angle dependency still quite reasonable.
Backup
Polarization trending for MODISA
MODISA R2012.0: Rrs(412nm) anomaly

Anomaly in MODISA(AT85) Rrs(412) for Deep-Water
Modeling of TOA Stokes vector over oceans

\[ \mathbf{L}_t(\lambda) = \left[ \mathbf{L}_r(\lambda) + \mathbf{L}_a(\lambda) + t\mathbf{L}_f(\lambda) + T\mathbf{L}_g(\lambda) + t_d(\lambda)L^w(\lambda) \right] \cdot t_g(\lambda) \]

from MODIS NIR
assumes MCST NIR band characterization

\[ \lambda' \rightarrow \lambda \]
fit based on bio-optical models

SeaWiFS
4-day mean
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)
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)
Comparison to 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)
Surface Effects

Sun Glint

White Caps

Corrections based on statistical models (wind & geometry)