The Continuity of Ocean Color Measurements from SeaWiFS to MODIS

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SPIE Earth Observing Systems X
31 July - 4 August 2005
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We want to measure the "color" of the ocean, as defined by the spectral distribution of upwelling radiance just above the sea surface, but we observe ocean + atmosphere. The atmosphere is approximately 90% of the signal, and it must be accurately modeled and removed. A 1% error in atmospheric correction or calibrated (Level-1B) radiance will result in a 10% error in water-leaving radiance retrieval.
Introduction

• As a component of NASA’s “Missions to Measurements” initiative, the OBPG was formed from the former SeaWiFS & SIMBIOS Projects to consolidate the processing and distribution efforts required to retrieve ocean color measurements from various spaceborne instruments.
  – CZCS, SeaWiFS, MODIS, NPP/VIIRS (MOS, OSMI, OCTS)

• In February 2004 the OBPG assumed responsibility for MODIS ocean color processing and distribution.

• This presentation will cover
  – Approach to multi-mission integration
  – Changes implemented to improve quality & consistency
  – Comparison of results
Multi-Mission “Measurement-Based” Processing

• Common software for Level-1 through Level-3
  – eliminates potential for algorithm and implementation differences
  – sensor-specific issues consolidated in i/o function and external tables

• Mission-independent, distributed processing system
  – 200x global reprocessing for MODIS, 1600x for SeaWiFS
  – mission-long test processing for calibration & algorithm evaluation

• Standard procedures for calibration and validation
  – temporal calibration via On-Board Calibration system (OBC)
  – vicarious calibration to MOBY (instrument + algorithm calibration)
  – validation against SeaBASS in situ archive
  – temporal trending analysis of Level-3 products
## Sensor Spectral Bands

<table>
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<tr>
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**Simulated Center-Wavelength Differences (after band-pass correction)**

- **488 vs 490**
- **551 vs 555**

**Deep-Water Mean**
nLw: MODIS vs SeaWiFS at OBPG Transition
Deep-Water (global mean > 1000m)

MODIS & SeaWiFS

MODIS / SeaWiFS
nLw: MODIS/Aqua vs SeaWiFS
Deep-Water

MODIS & SeaWiFS

MODIS / SeaWiFS

• Concentrate on MODIS/Aqua (more stable than Terra)
  – step 1: integrate MODIS processing into common (SeaWiFS) software
  – step 2: update to best available instrument calibration from MCST
  – step 3: apply standard vicarious calibration using MOBY *in situ* data
  – Initial OBPG processing of MODIS/Aqua completed May 2004
nLw: MODIS vs SeaWiFS
Deep-Water

MODIS & SeaWiFS

MODAPS
Aqua 003

MODIS & SeaWiFS 8-Day Water-Leaving Radiance, Deep Water Subset

SeaWiFS: solid line  MODIS: dashed line

MODAPS
Aqua 003

MODIS / SeaWiFS

MODAPS
Aqua 003

MODIS/SeaWiFS 8-Day Water-Leaving Radiance Ratios, Deep Water Subset

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OBPG
Aqua R0

MODIS/SeaWiFS 8-Day Water-Leaving Radiance Ratios, Deep Water Subset

SeaWiFS: solid line  MODIS: dashed line

OBPG
Aqua R0
After Initial OBPG Processing of MODIS

10% peak-to-peak seasonal variability between MODIS/Aqua and SeaWiFS global mean nLw
Polarization Correction

- The atmospheric signal reaching the sensor is polarized.

- SeaWiFS has a polarization scrambler.

- MODIS has significant polarization sensitivity, especially in the blue.

- H. Gordon developed an algorithm to derive the polarization components of the atmospheric signal and correct for the polarization response, given the instrument polarization sensitivity.

- G. Meister (OBPG) reviewed the laboratory set-up and determined that the MODIS polarization sensitivity results had been misinterpreted in the original implementation (Collection 3 & OBPG R0).
Polarization Correction

Solid line = OBPG, Dashed line = original correction
nLw Ratio: MODIS/Aqua vs SeaWiFS
50N-40N, 150W-170W

Before Polarization Correction

After Polarization Correction

- Improved spectral consistency
- Straylight
MODIS Straylight Masking

- SeaWiFS already includes correction & masking for straylight.
- Modeled point-spread function (PSF) for MODIS indicates significant sensitivity to straylight from adjacent sources.
- 7 x 5-pixel masking around bright pixels removes significant contamination.
- Fixes AOT discrepancy (excess NIR radiance) between sensors.

MODIS & SeaWiFS Deep-Water AOT Comparison

Before SL Masking

After SL Masking
Bidirectional Reflectance at Surface

- Each sensor views the same location on earth from different view angle and at different time of day (solar angle).
- The angular distribution of upwelling radiance varies with solar illumination angle and the scattering properties of the water body.
- A. Morel developed a correction for this effect, which was incorporated into the common processing software for both sensors.

Residual Scan Dependence in MODIS nLw(443)

Before BRDF

After BRDF
Reprocessing

• MODIS Reprocessing 1 completed February 2005
• SeaWiFS Reprocessing 5 completed March 2005
Results from Reprocessing
Comparison with Field Data

SeaWiFS R5

MODIS/Aqua R1
Results from Reprocessing
Sensor-to-Sensor nLw Comparison
Deep-Water Trends

• Sensor agreement to within 7% for global mean deep-water nLw retrieval.
• Some long-term trend, bias is still evident.

MODIS & SeaWiFS

MODIS / SeaWiFS
Results from Reprocessing

Sensor-to-Sensor nLw Ratios, Latitudinal Effects

35 North

nLw Ratios, Zonal Pacific, 150W-170W

25 North

Seasonal, latitudinally-dependent differences reduced.

15 North
Results for Reprocessing
Consistency in Annual Cycle of nLw

SeaWiFS R5

MODIS/Aqua R1
Multi-Mission Browse & Distribution
Back-up Slides
Abstract

The Ocean Biology Processing Group (OBPG) at NASA’s Goddard Space Flight Center is responsible for the processing and validation of oceanic optical property retrievals from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and the Moderate Resolution Imaging Spectroradiometer (MODIS). A major goal of this activity is the production of a continuous ocean color time-series spanning the mission life of these sensors from September 1997 to the present time. This paper presents an overview of the calibration and validation strategy employed to optimize and verify sensor performance for retrieval of upwelling radiances just above the sea surface. Substantial focus is given to the comparison of results over the common mission lifespan of SeaWiFS and the MODIS flying on the Aqua platform, covering the period from July 2002 through December 2004. It will be shown that, through consistent application of calibration and processing methodologies, a continuous ocean color time-series can be produced from two different spaceborne sensors.
Atmospheric Correction Equation

\[ L_t = L_r + L_a + tL_{wc} + TL_g + t L_w \]

- \( L_w \) is the quantity we wish toretrieve at each wavelength.
- \( TL_g \) is Sun glint, the direct reflectance of the solar radiance from the sea surface. This effect is avoided through tilting.
- \( tL_{wc} \) is the contribution due to "white"-capping, estimated from statistical relationship with wind speed.
- \( L_r \) is the contribution due to molecular (Rayleigh) scattering, which can be accurately computed.
- \( L_a \) is the contribution due to aerosol and Rayleigh-aerosol scattering, estimated in NIR from measured radiances and extrapolated to visible using aerosol models.
Deep-Water Chlorophyll Images

common-bin 12-day composite, Winter 2002

0.01-1 mg/m$^3$

SeaWiFS
R5

MODIS/Aqua
R1
Effect of BRDF Correction to MODIS/SeaWiFS Ratios

Deep Water nLw Ratio
MODIS/SeaWiFS

Before BRDF

After BRDF

Southern Pacific nLw Ratio
MODIS/SeaWiFS