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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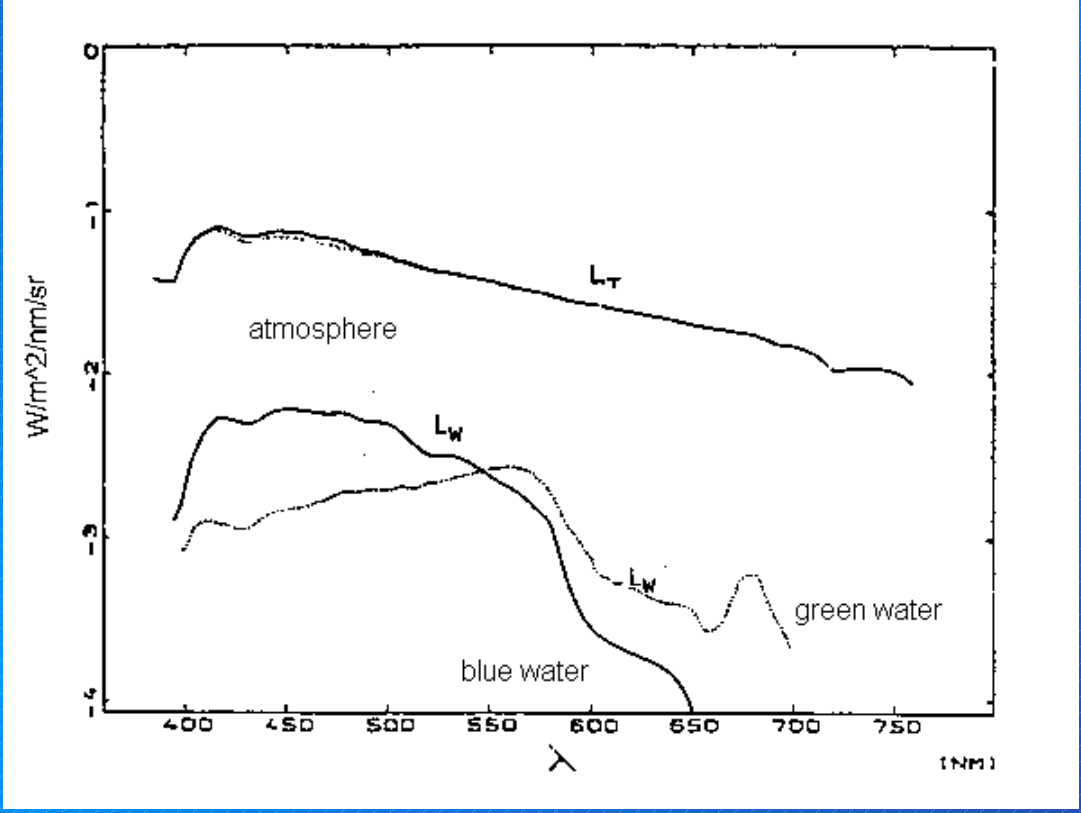
Introduction to Ocean Color

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

MODIS Band	SeaWiFS Band	MODIS Wavelength	SeaWiFS Wavelength
8	1	412	412
9	2	443	443
10	3	488	490
11	4	531	510
12	5	551	555
13	6	667	670
15	7	748	765
16	8	869	865

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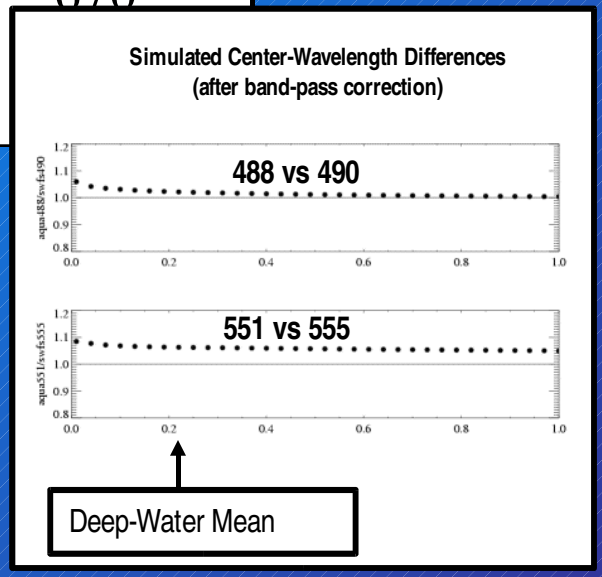
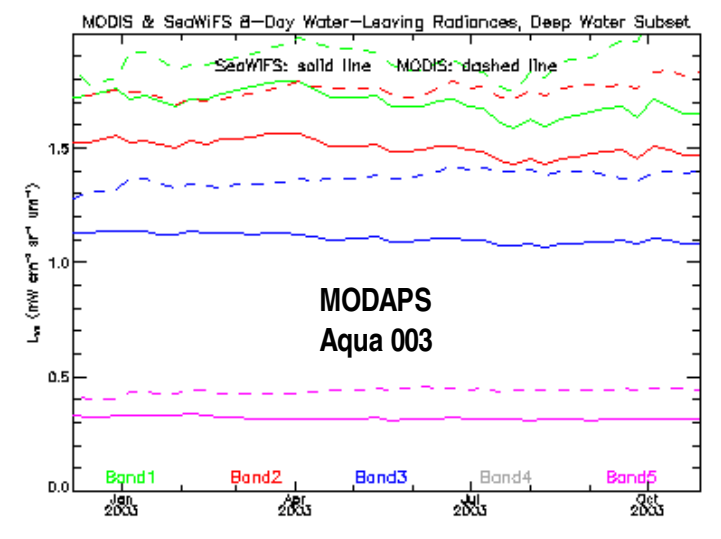
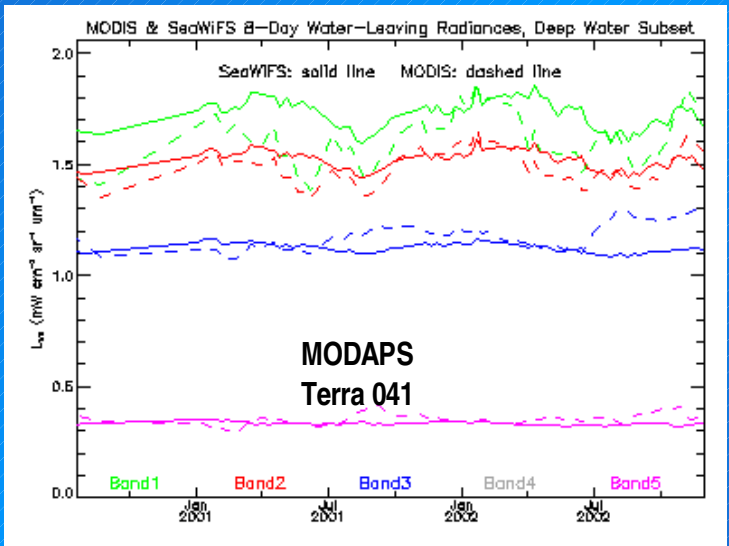


nLw: MODIS vs SeaWiFS at OBPG Transition

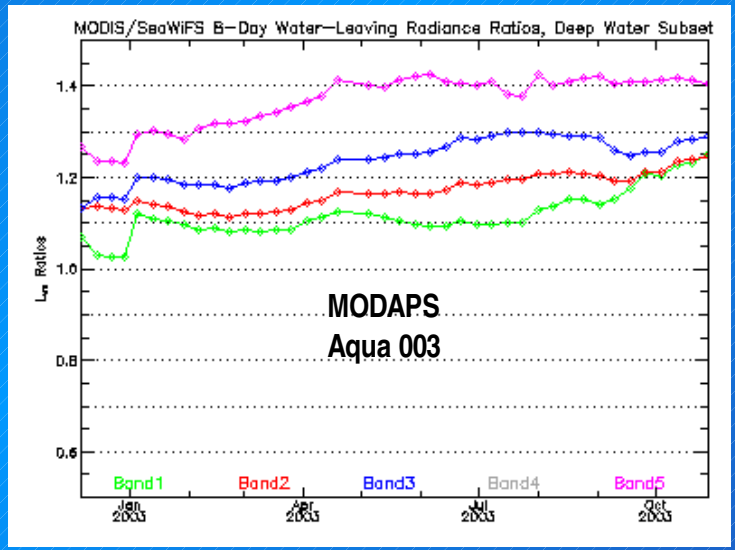
Deep-Water (global mean > 1000m)

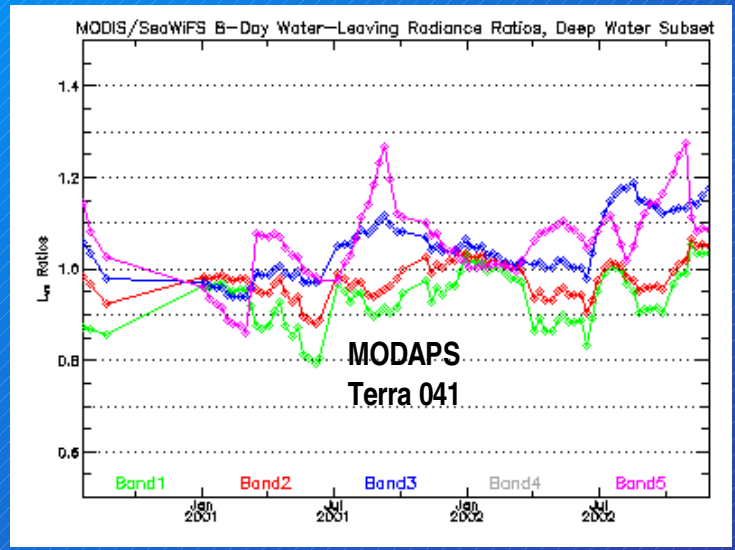
MODIS & SeaWiFS





MODIS / SeaWiFS

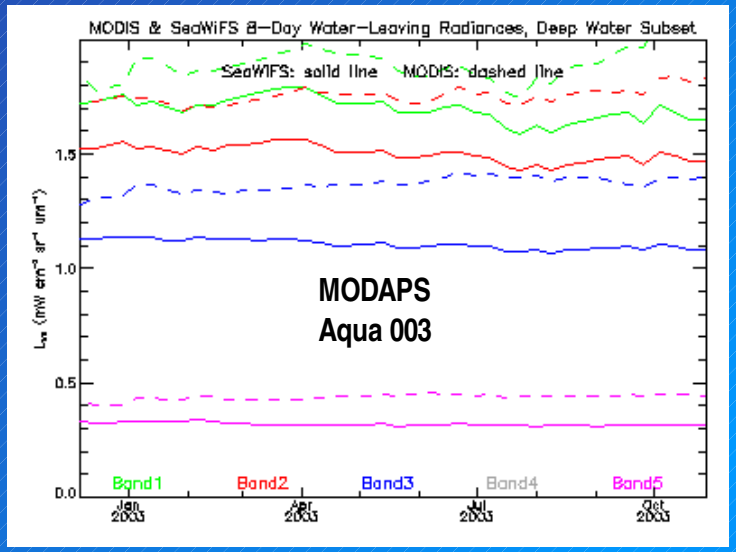




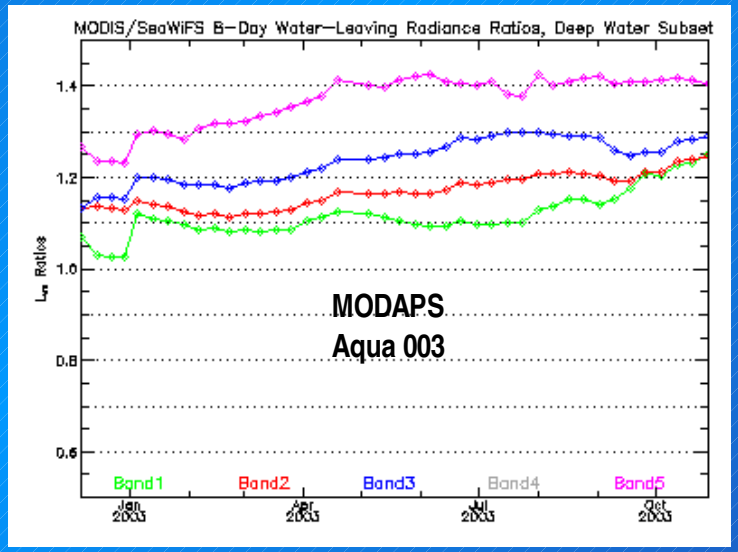
nLw: MODIS/Aqua vs SeaWiFS

Deep-Water

MODIS & SeaWiFS



MODIS / SeaWiFS

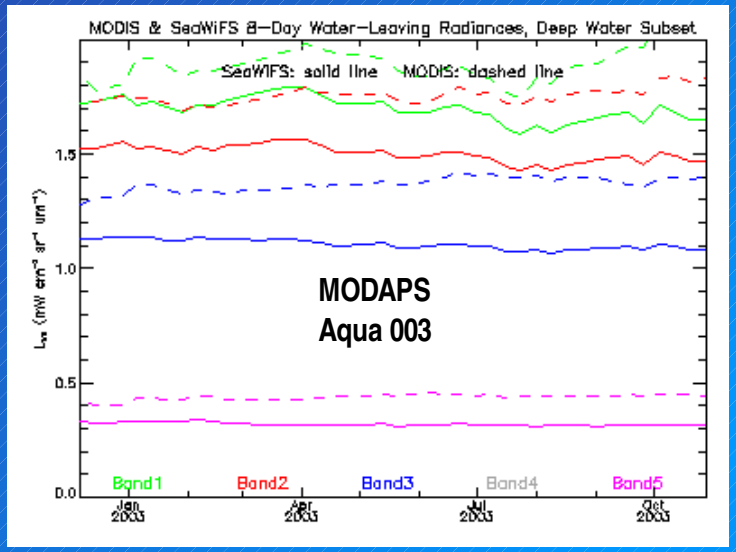


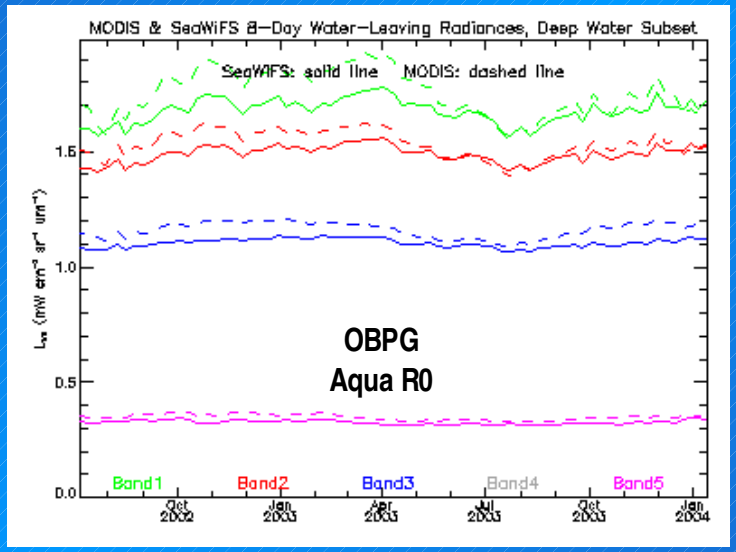
- Concentrate on MODIS/Aqua (more stable than Terra)
  - step 1: integrate MODIS processing into common (SeaWiFS) software
  - step 2: update to best available instrument calibration from MCST
  - step 3: apply standard vicarious calibration using MOBY *in situ* data
  - Initial OBPG processing of MODIS/Aqua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

nLw: MODIS vs SeaWiFS

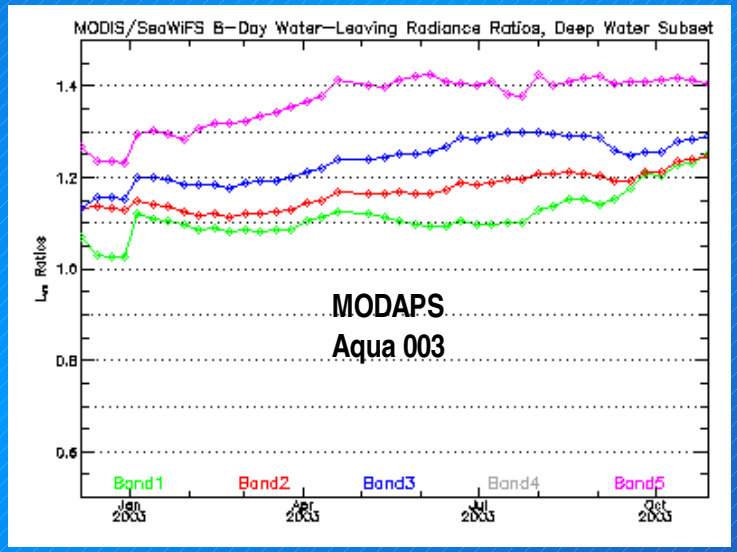
Deep-Water

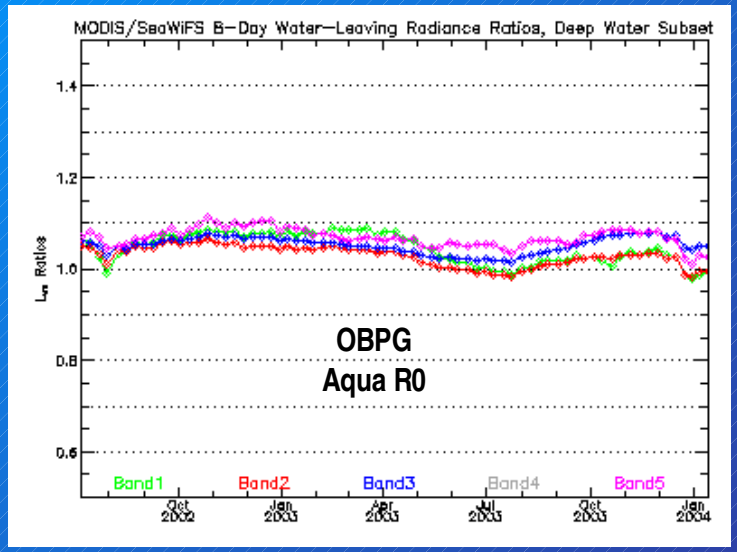
MODIS & SeaWiFS





MODIS / SeaWiFS





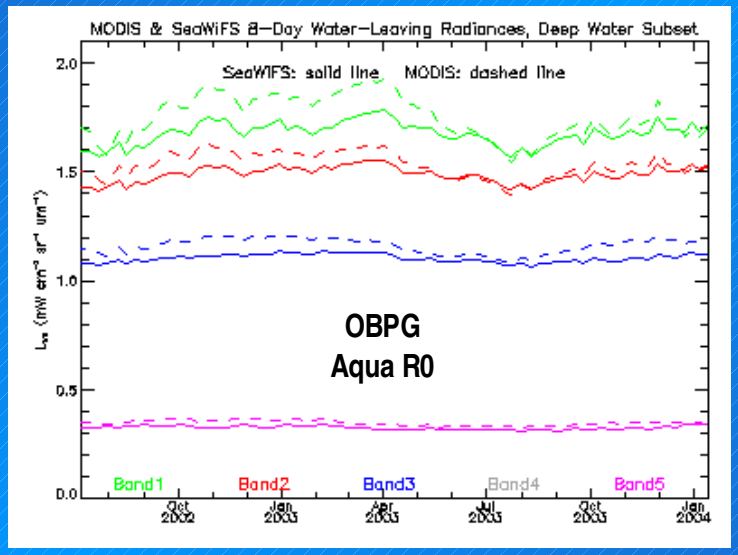
nLw: MODIS vs SeaWiFS

Deep-Water

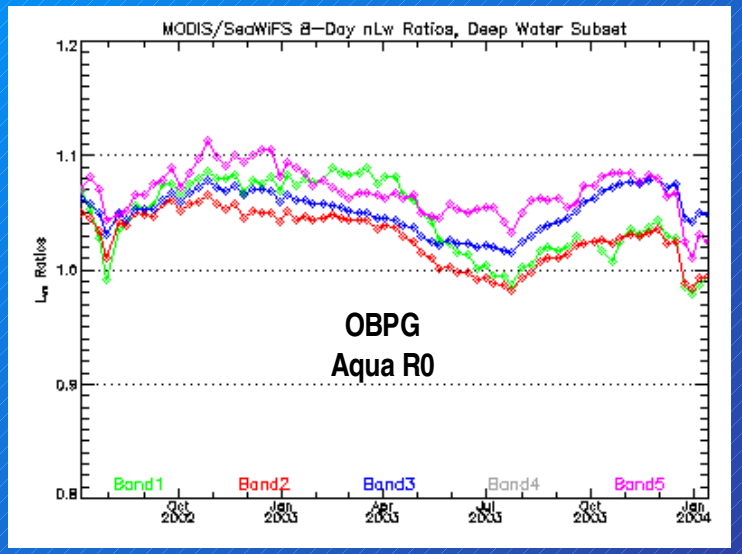
After Initial OBPG Processing of MODIS

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

MODIS & SeaWiFS



MODIS / SeaWiFS

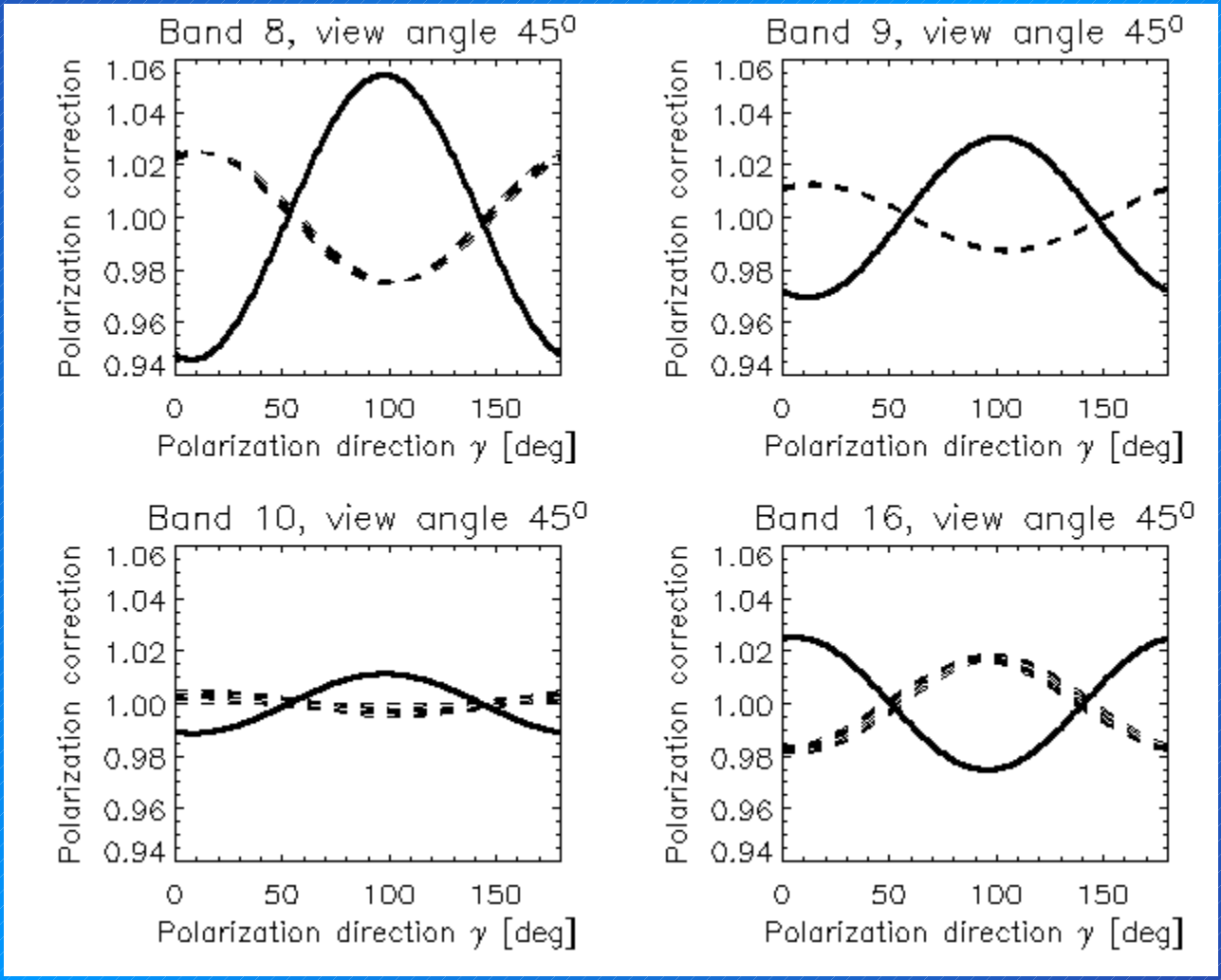


Polarization Correction

- 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 sensitivty results had been misinterpreted in the original implementation (Collection 3 & OBPG R0).

Polarization Correction

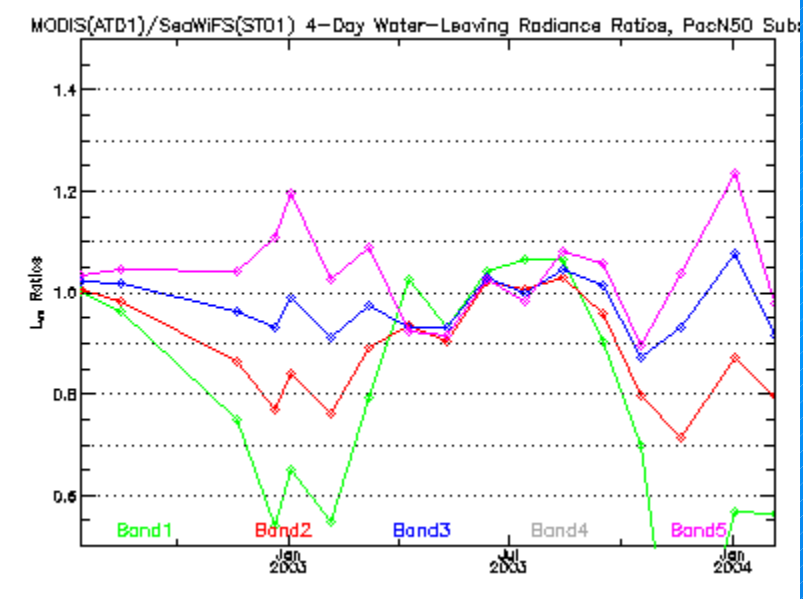
Solid line = OBPG, Dashed line = original correction



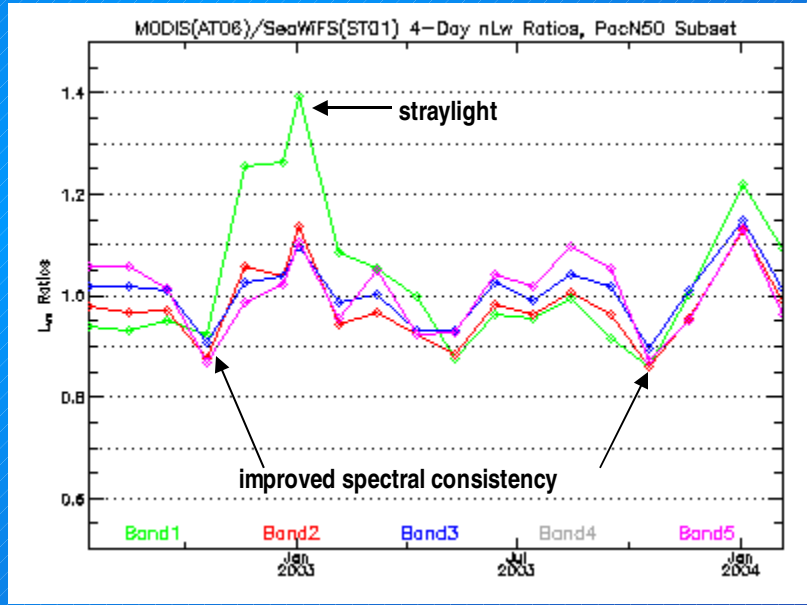
nLw Ratio: MODIS/Aqua vs SeaWiFS

50N-40N, 150W-170W

Before Polarization Correction



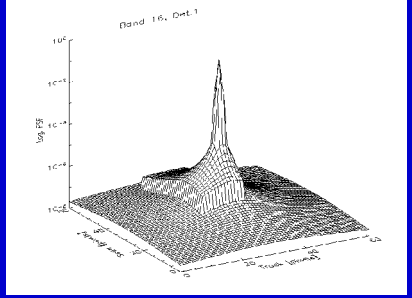
After Polarization Correction



MODIS Straylight Masking

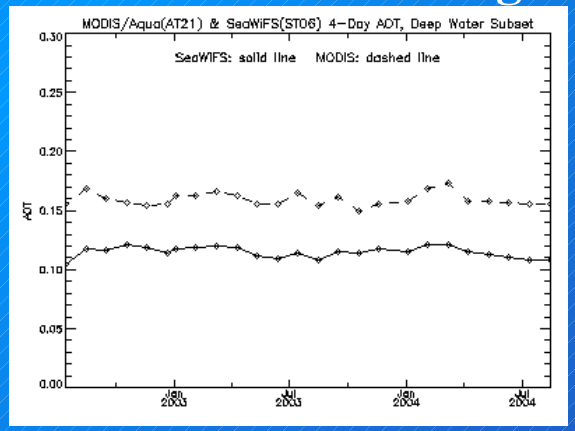
- SeaWiFS already includes correction & masking for straylight.
- Modeled point-spread function (PSF) for MODIS indicates significant sensitivity to straylight from adjacent sources.
- 7 x 5-pixel masking around bright pixels removes significant contamination.
- Fixes AOT discrepancy (excess NIR radiance)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

MODIS Band 16 PSF

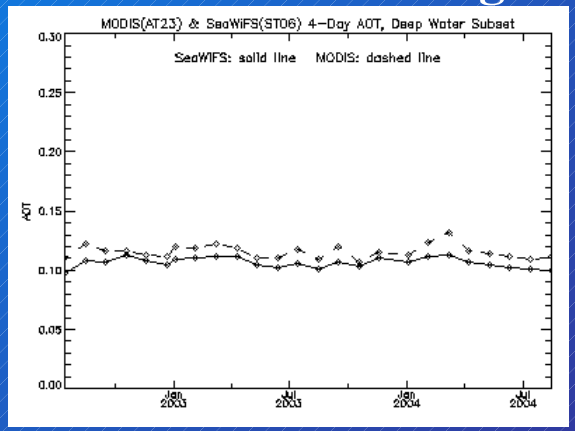


MODIS & SeaWiFS Deep-Water AOT Comparison

Before SL Masking



After SL Masking

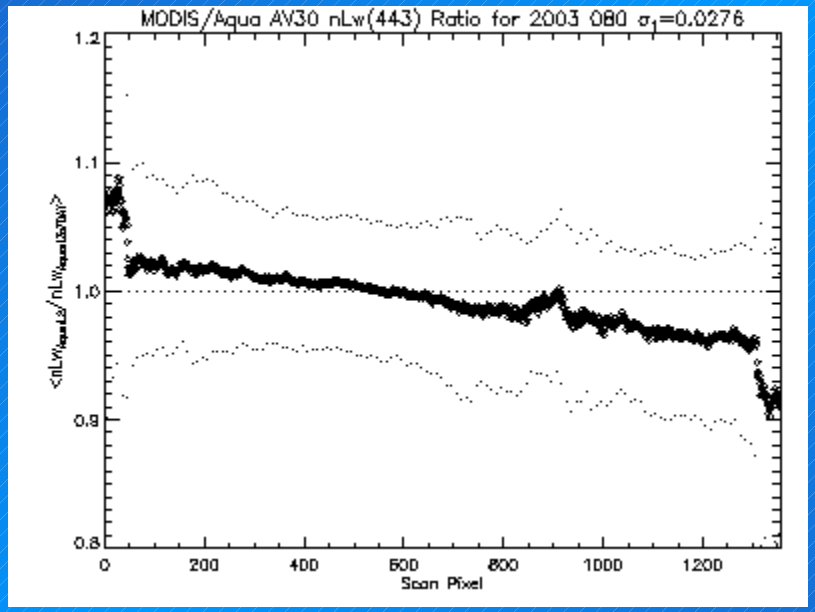


Bidirectional Reflectance at Surface

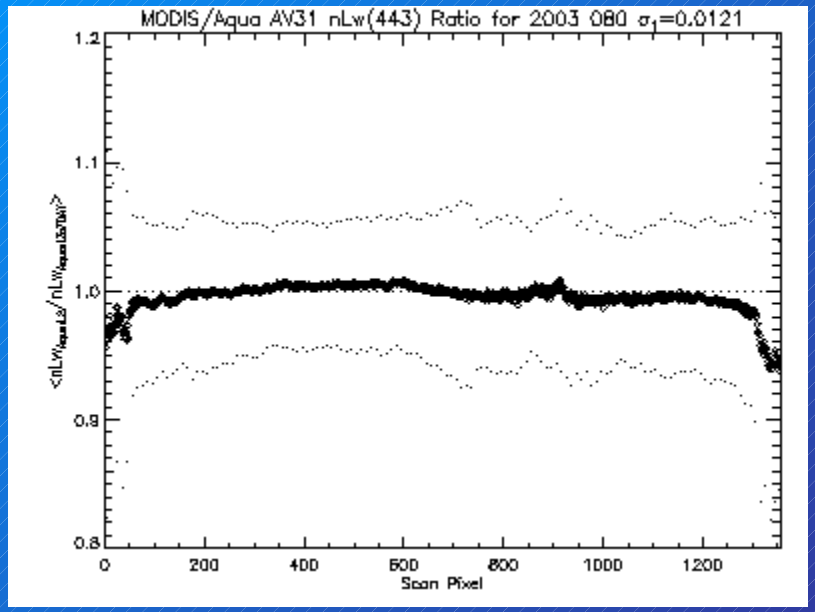
- Each sensor views the same location on earth from different view angle and at different time of day (solar angle).
- The angular distribution of upwelling radiance varies with solar illumination angle and the scattering properties of the water body.
- A. Morel developed a correction for this effect,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

Residual Scan Dependence in MODIS nLw(443)

Before BRDF



After BRDF



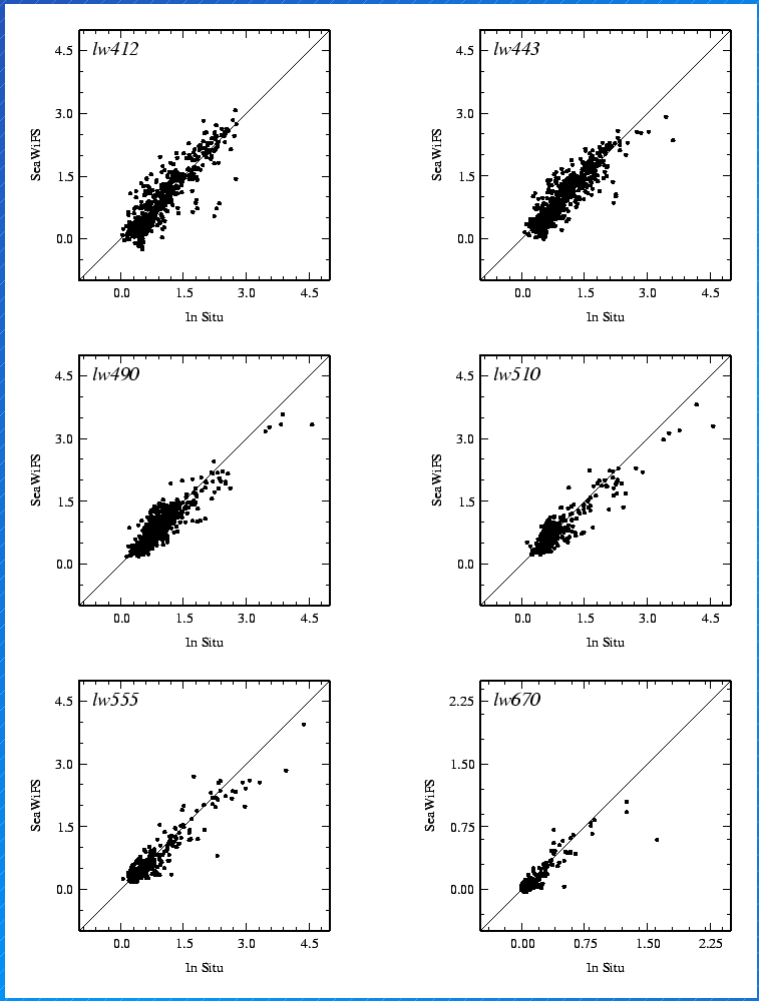
Reprocessing

- MODIS Reprocessing 1 completed February 2005
- SeaWiFS Reprocessing 5 completed March 2005

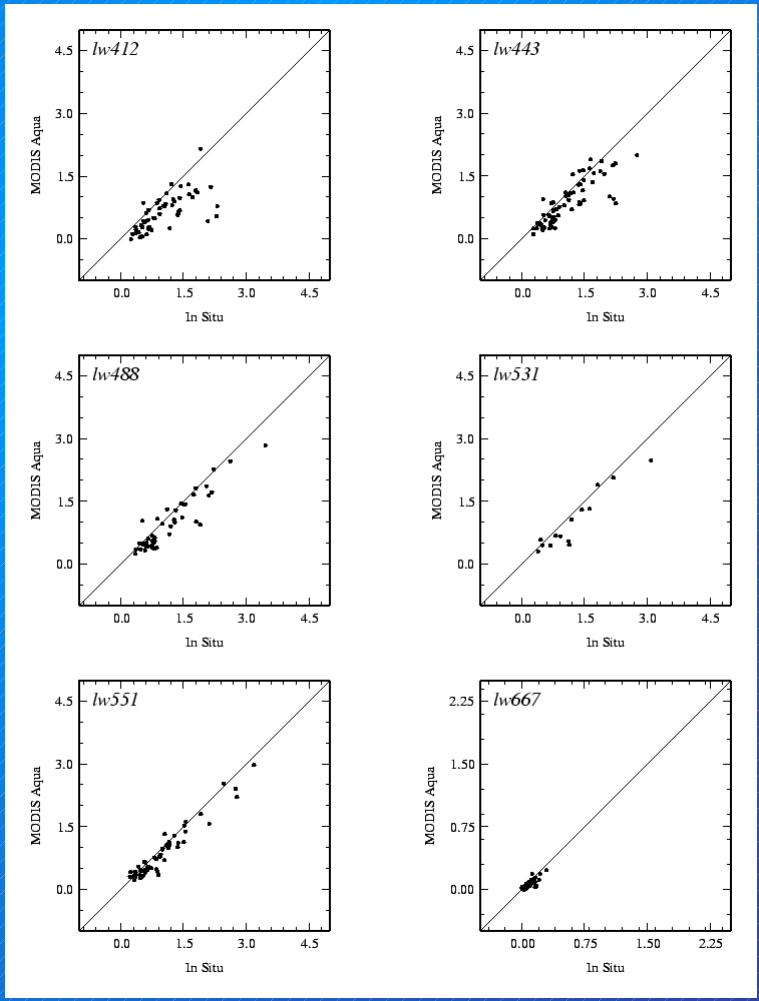
Results from Reprocessing

Comparison with Field Data

SeaWiFS R5



MODIS/Aqua R1



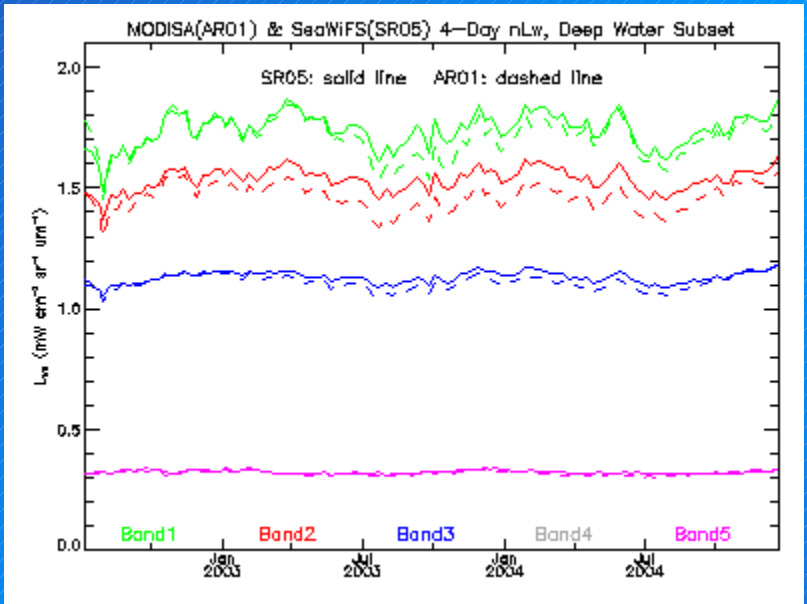
Results from Reprocessing

Sensor-to-Sensor nLw Comparison

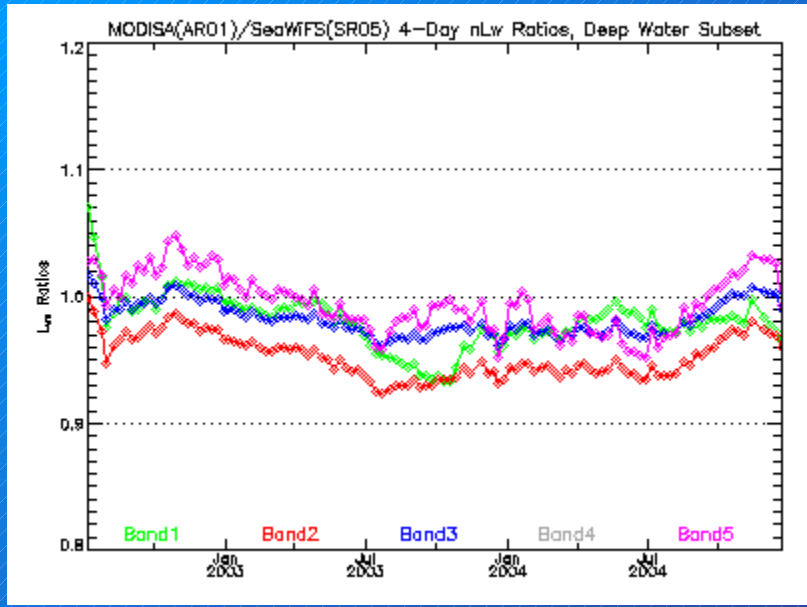
Deep-Water Trends

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

MODIS & SeaWiFS



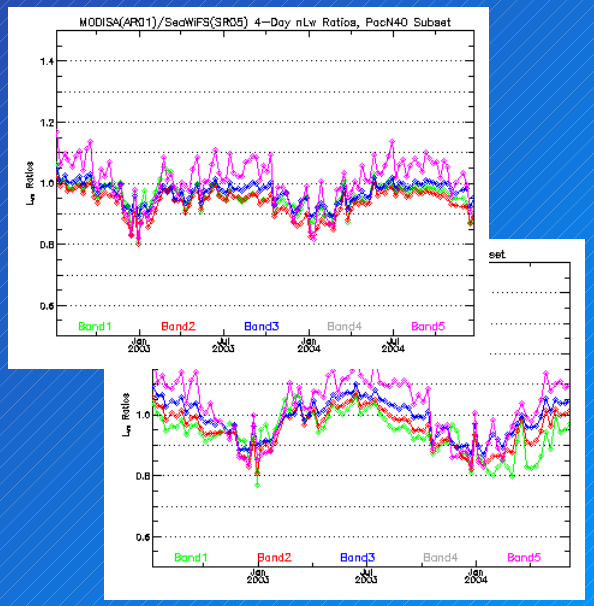
MODIS / SeaWiFS



Results from Reprocessing

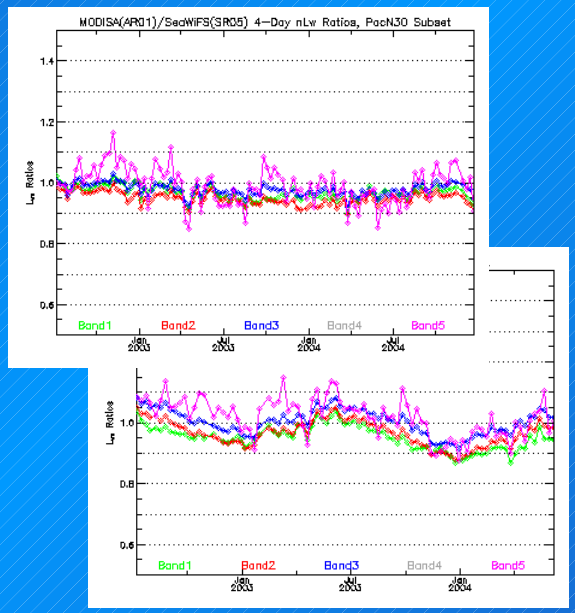
Sensor-to-Sensor nLw Ratios, Latitudinal Effects

35 North

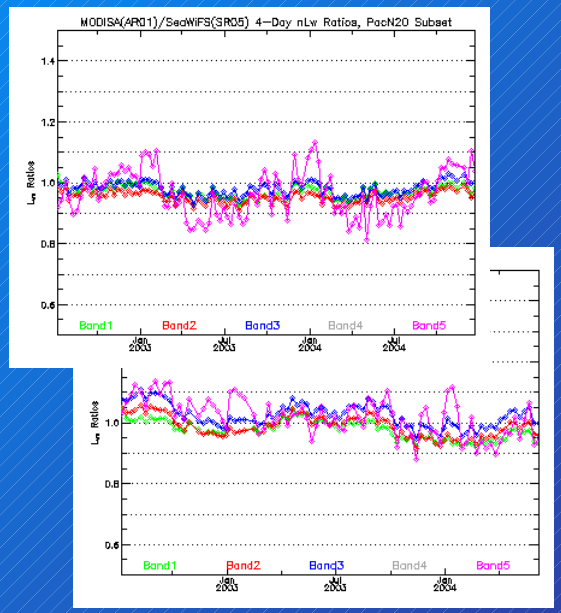


nLw Ratios, Zonal Pacific, 150W-170W

25 North



15 North

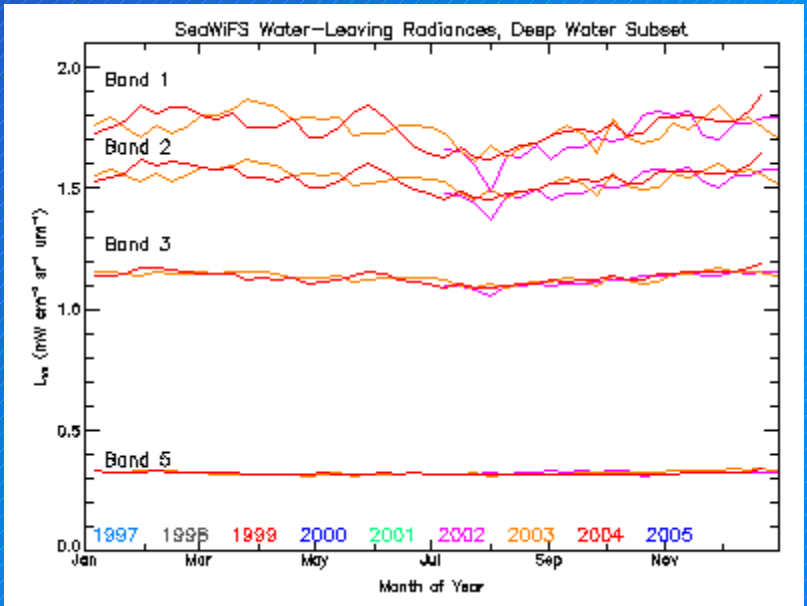


Seasonal, latitudinally-dependent differences reduced.

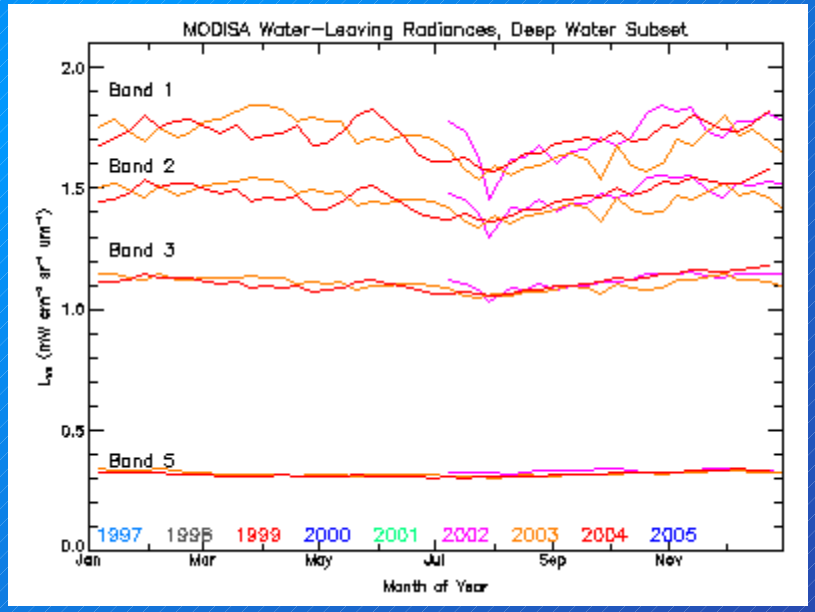
Results for Reprocessing

Consistency in Annual Cycle of nLw

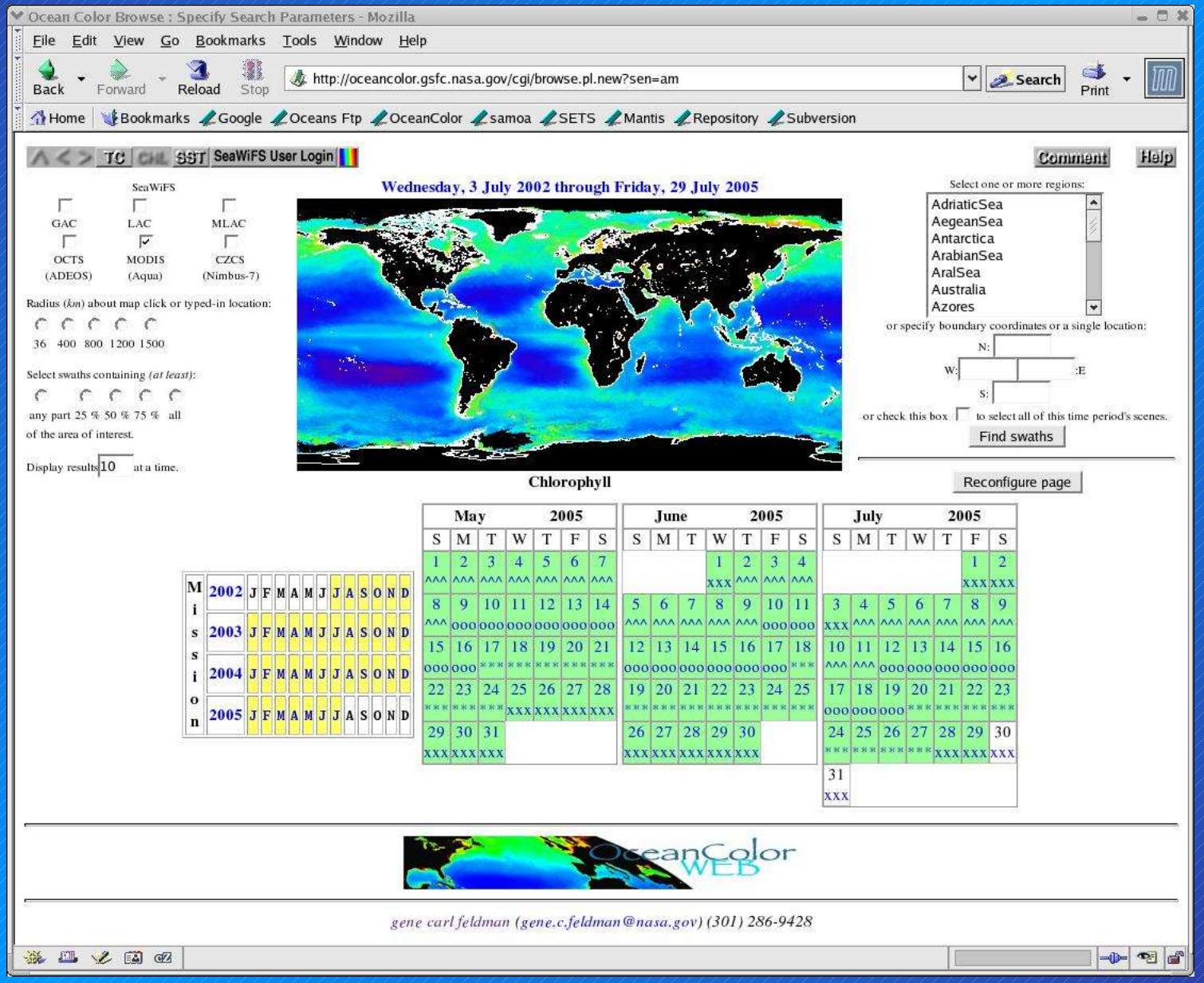
SeaWiFS R5



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 to retrieve at each wavelength.

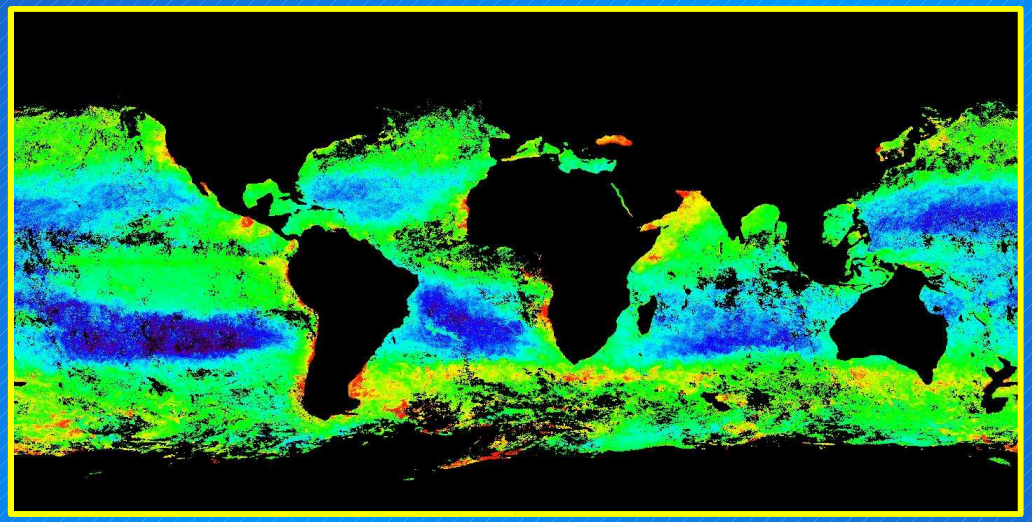
- TL_g is Sun glint, the direct reflectance of the solar radiance from the sea surface. This effect is avoided through tilting.
- tL_{wc} is the contribution due to "white"-capping, estimated from statistical relationship with wind speed.
- L_r is the contribution due to molecular (Rayleigh) scattering, 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

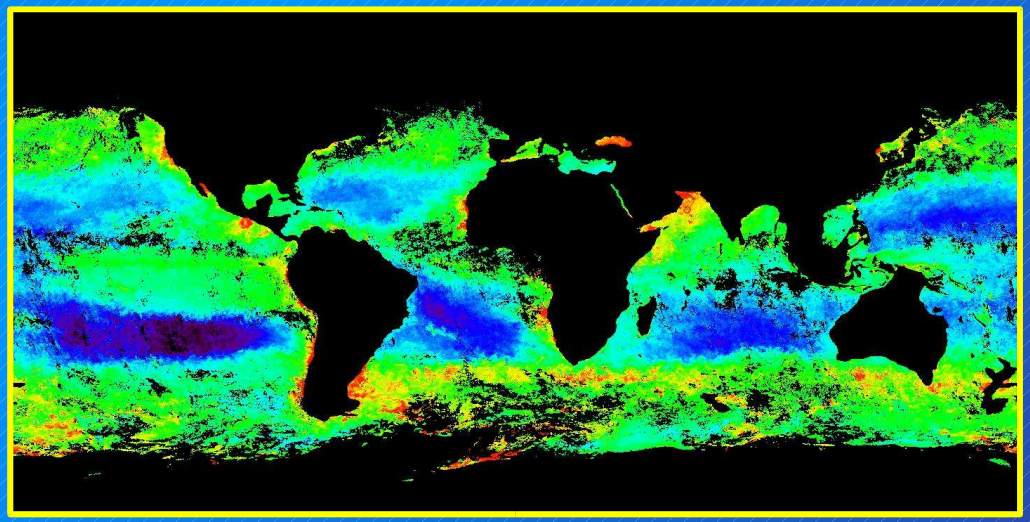
common-bin 12-day composite, Winter 2002

0.01-1 mg/m^3

SeaWiFS R5



MODIS/Aqua R1

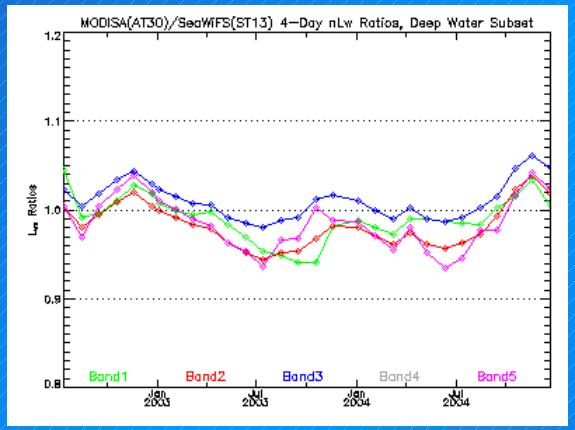


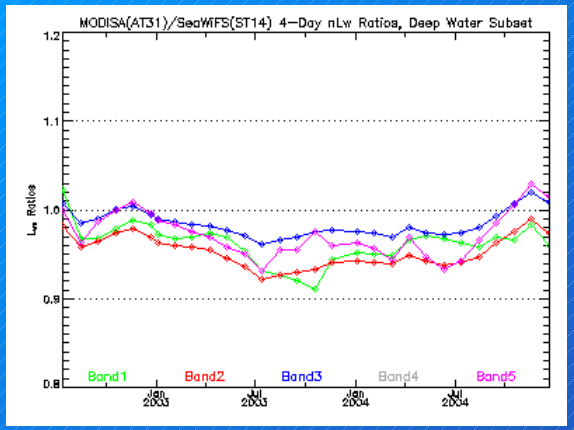
Effect of BRDF Correction to MODIS/SeaWiFS Ratios

Before BRDF

After BRDF

Deep Water nLw Ratio
MODIS/SeaWiFS





Southern Pacific nLw Ratio
MODIS/SeaWiFS