NASA Support for MODIS Direct Broadcast: Level-0 to Standard Ocean Products

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Direct Broadcast Meeting
3-6 October 2005
Benevento, Italy

The Ocean Biology Processing Group

A Component of NASA's Missions-to-Measurements Initiative

- Designated NASA team responsible for the processing and distribution of ocean color measurements and SST from various spaceborne instruments.

Ocean Color: CZCS, OCTS, SeaWiFS, MODIS

SST: MODIS/Aqua MODIS/Terra

- Designated Product Evaluation & Test Element (PEATE) for ocean color and SST on NPP/VIIRS.

Ocean Color & SST PEATE: NPP/VIIRS

- Heritage: SeaWiFS, SIMBIOS, SeaBASS, SeaDAS

Recent Developments in MODIS Ocean Color

- Transition from MODAPS / DAAC to OBPG in 2004.
- MODIS processing integrated into the OBPG's Multi-Sensor Level-1 to Level-2 (msl12) code.
  - common code for MODIS, SeaWiFS, OCTS, CZCS
  - common Level-2 format
  - no more PGE09, no more radcor files
- Reviewed all aspects of MODIS/Aqua Calibration
  - prelaunch characterization, on-orbit temporal cal, vicarious
- Updated common atmospheric correction and retrieval algorithms

nLw: MODIS vs SeaWiFS at OBPG Transition

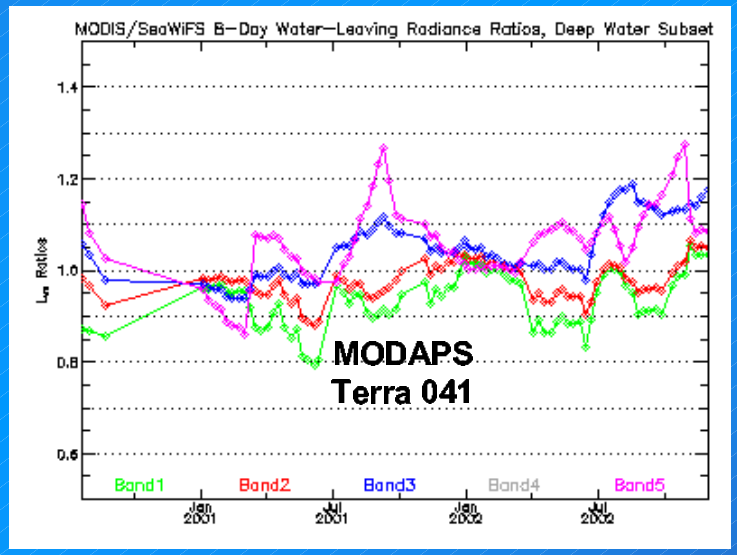
Deep-Water (global mean > 1000m)

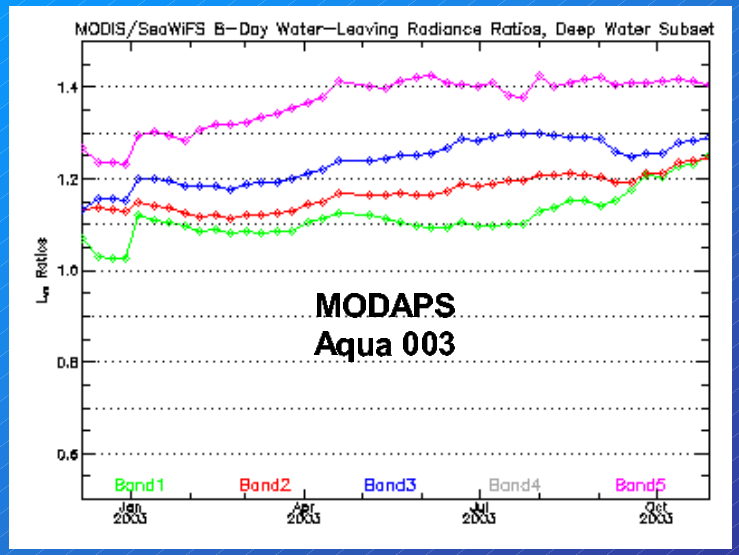
MODIS / SeaWiFS

MODIS on Terra shows significant temporal instability

MODIS on Aqua shows large bias, but better temporal stability in ocean color

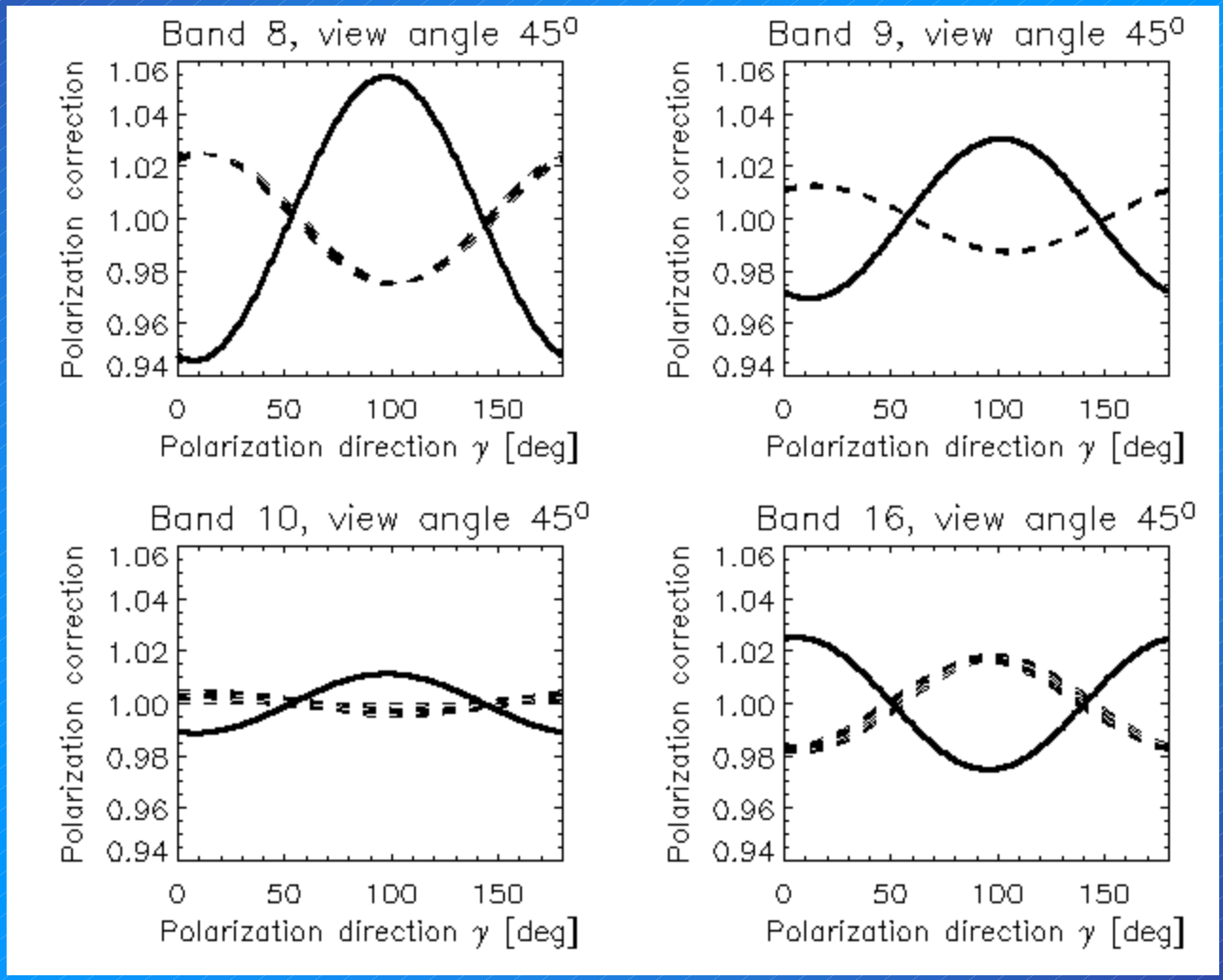
OBPG efforts concentrated on MODIS/Aqua ocean color





Revised Polarization Correction

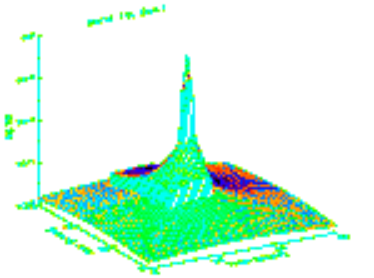
Solid line = OBPG, Dashed line = original correction



Added Masking for Straylight

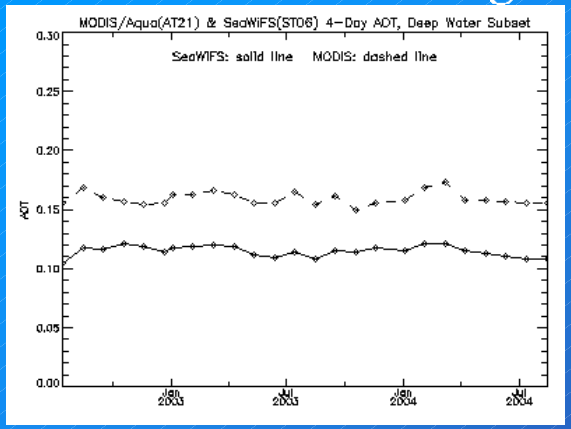
- SeaWiFS already includes correction & masking for straylight.
- Modeled point-spread function (PSF) for MODIS indicates significant sensitivity to straylight from adjacent sources.
- 7 x 5-pixel masking around bright pixels removes significant contamination.
- Fixes AOT discrepancy (excess NIR radiance)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

MODIS Band 16 PSF

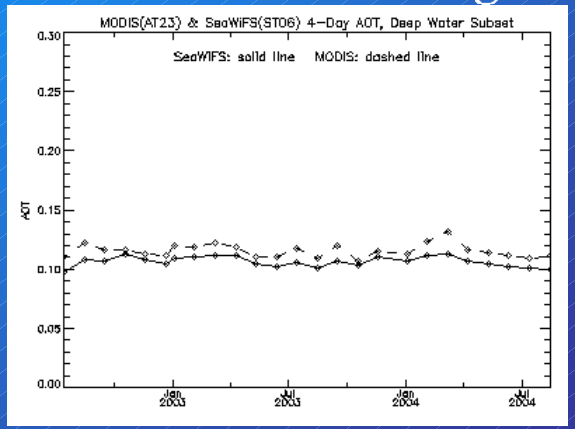


Improved Agreement with SeaWiFS AOT

Before SL Masking

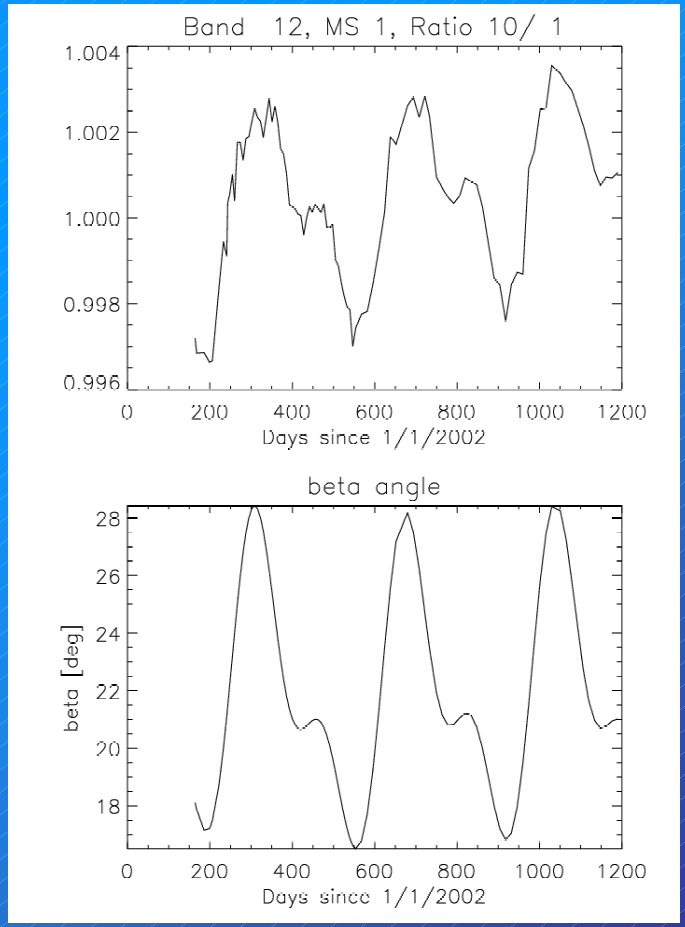


After SL Masking



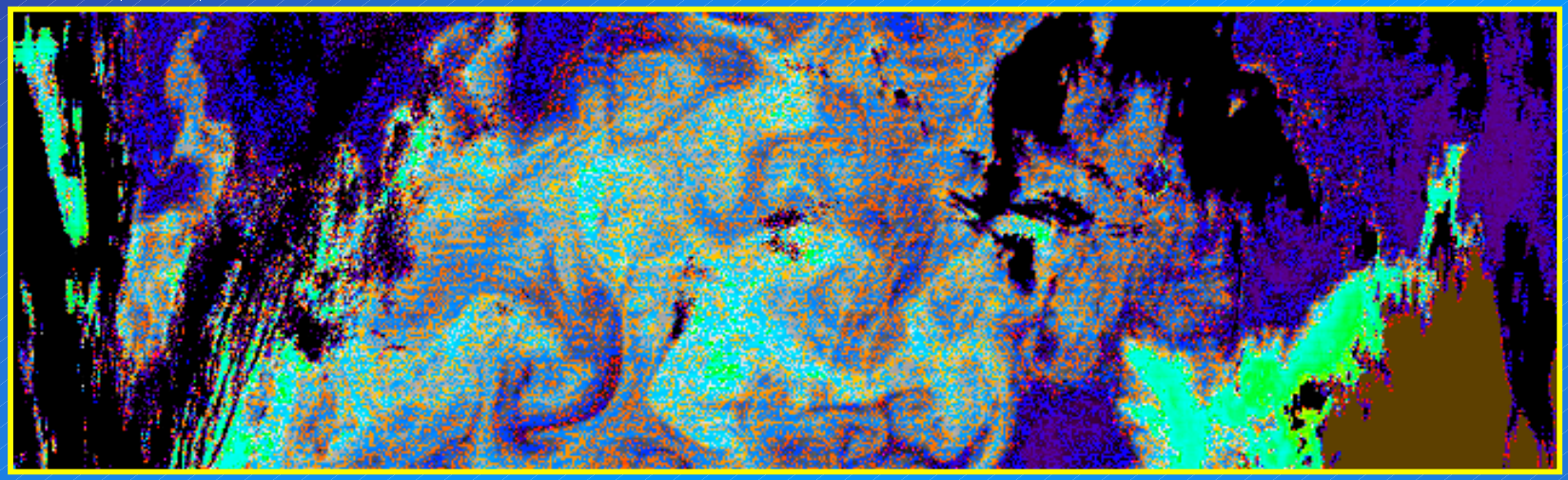
Revised Temporal Calibration
Reflected Solar Bands

- In collaboration with MCST
- Reanalyzed Onboard Calibration (OBC) Data (solar, lunar)
- Removed residual correlations associated with diffuser screen
- Refit solar diffuser trends to double exponential model
- Improved model extrapolation

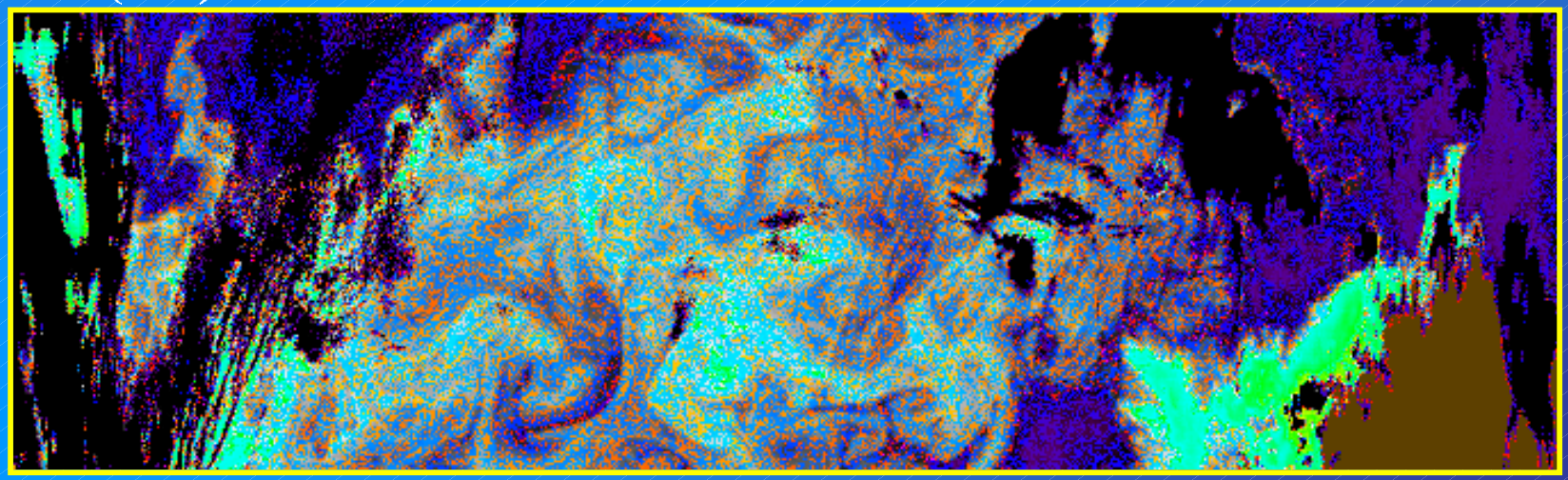


Added Correction for Residual Detector Striping

nLw(412) Before Correction



nLw(412) After Correction

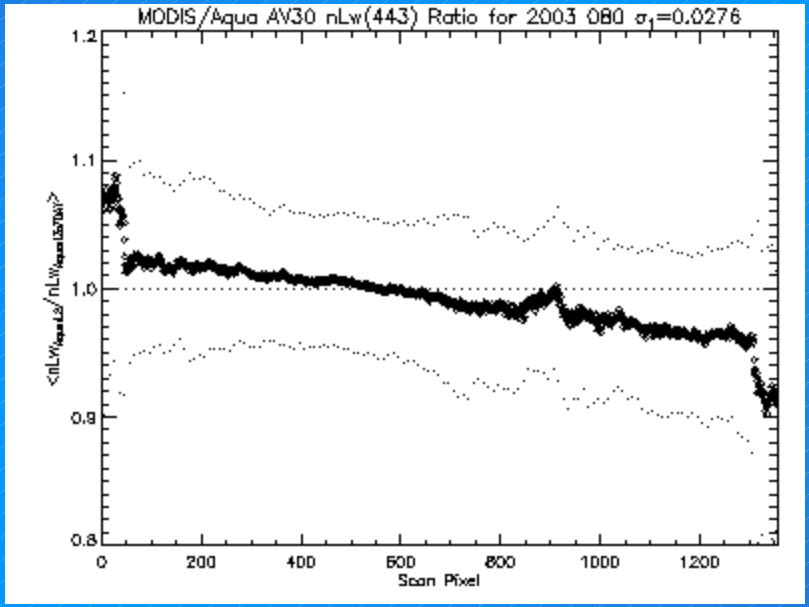


Bidirectional Reflectance at Surface

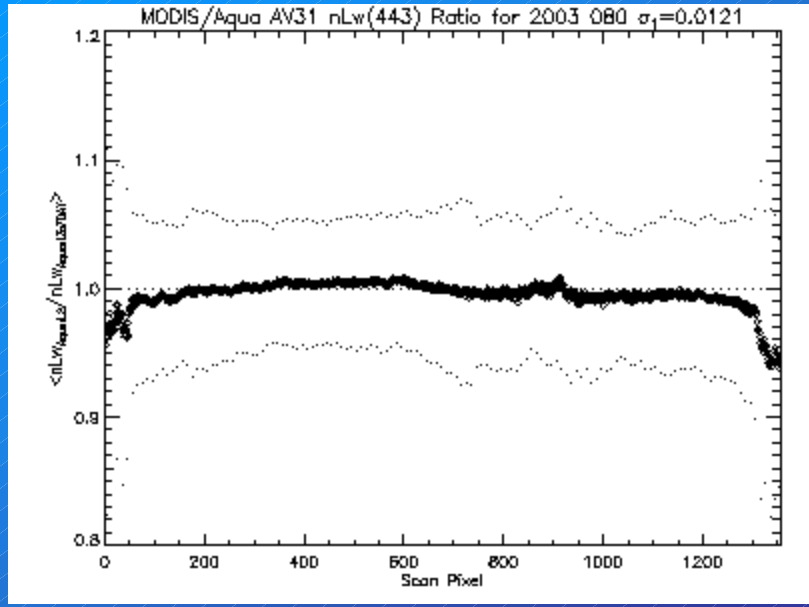
- Each sensor views the same location on earth from different view angle and at different time of day (solar angle).
- The angular distribution of upwelling radiance varies with solar illumination angle and the scattering properties of the water body.
- A. Morel developed a correction for this effect,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

Residual Scan Dependence in MODIS nLw(443)

Before BRDF



After BRDF



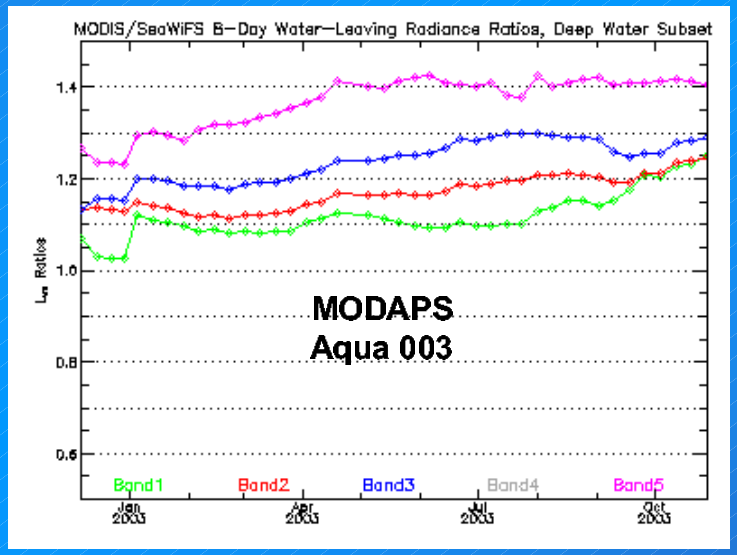
nLw: MODIS vs SeaWiFS
Deep-Water

After OBPG Reprocessing of MODIS/Aqua

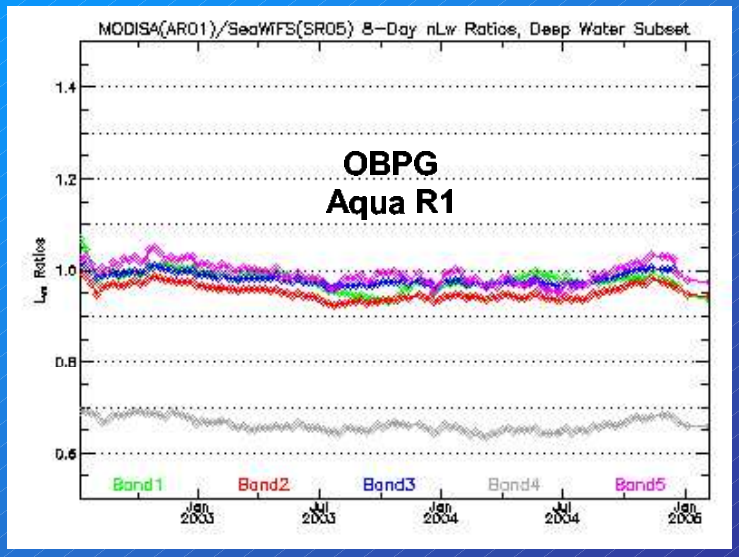
Significantly improved agreement with

SeaWiFS global mean nLw

MODIS / SeaWiFS

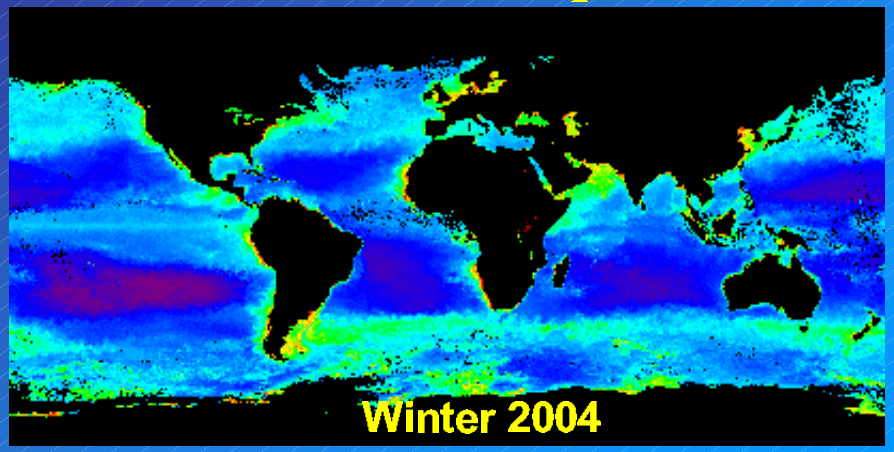


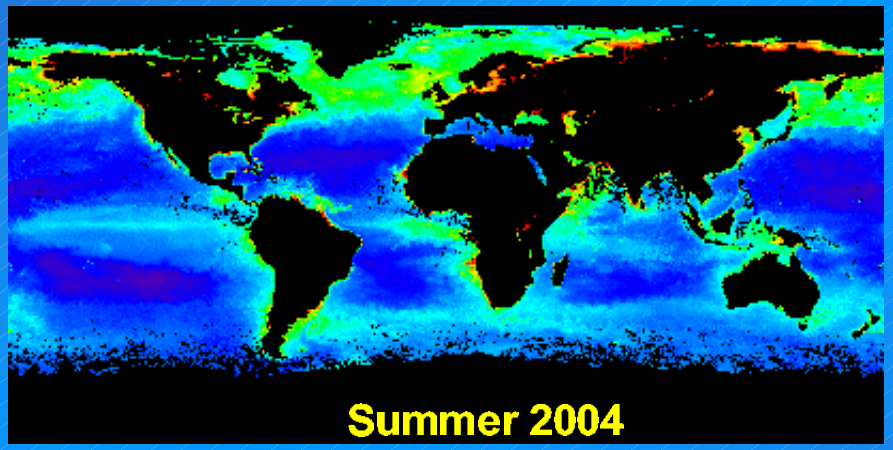
MODIS / SeaWiFS



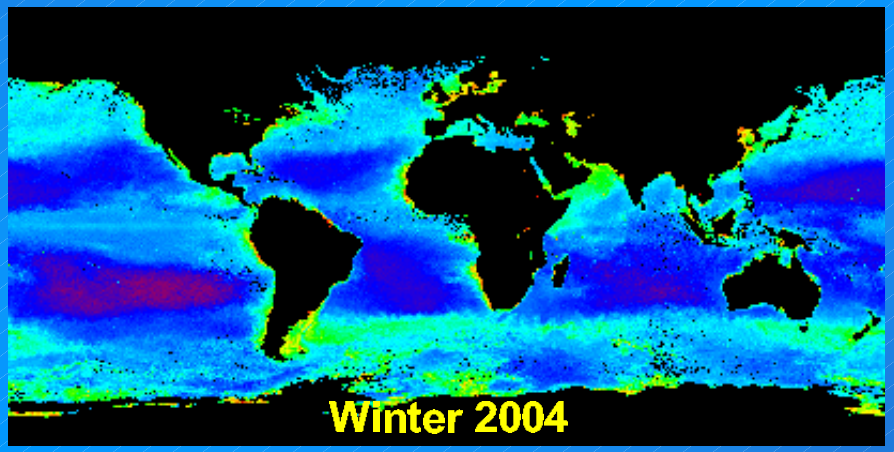
Seasonal Chlorophyll Images

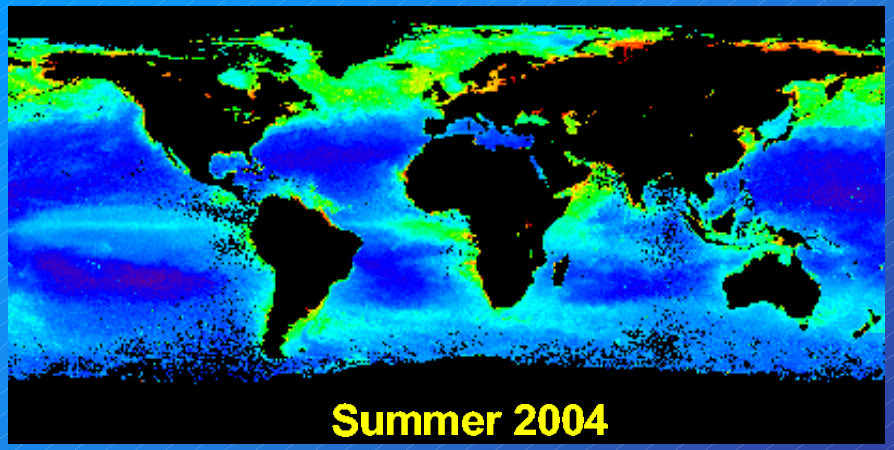
MODIS/Aqua

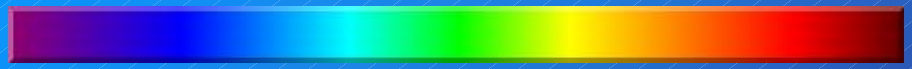




SeaWiFS





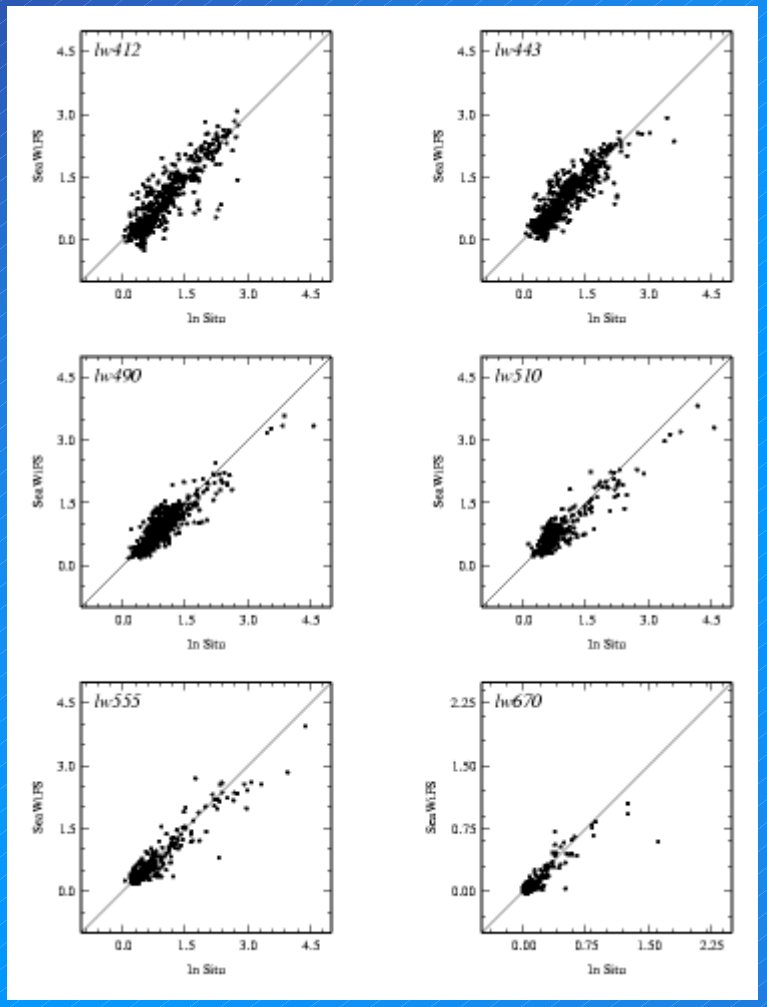


0.01-64 mg m^{-3}

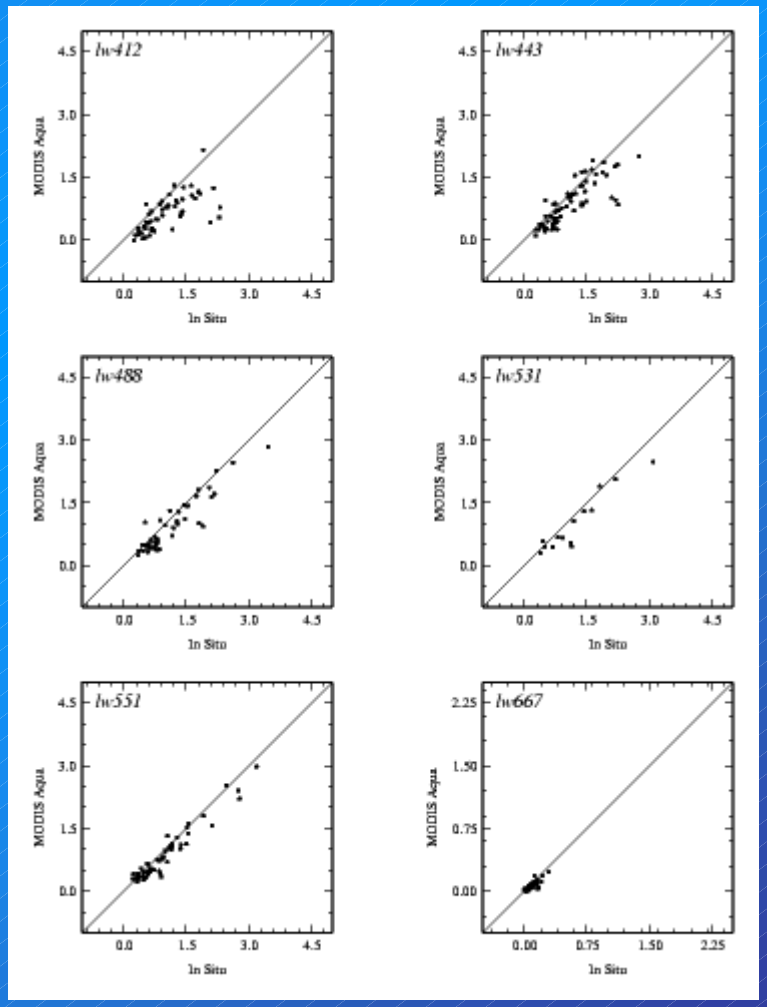
Results from Reprocessing

Comparison with Field Data

SeaWiFS R5



MODIS/Aqua R1



Important for Direct Broadcast

- OBPG modifies the Aqua LUTs generated by MCST, replacing the temporal trends and detector-relative corrections of the reflected solar bands 8-16.
- OBPG distributes the LUTs for Terra and Aqua through the oceans ftp site (oceans.gsfc.nasa.gov).
- OBPG distributes all processing software for Level-0 through Level-3 via the SeaDAS distribution (source and binaries).


OBPG!

TC CHL SST SeaWiFS User Login

Comment Help

SeaWiFS

GAC	LAC	MLAC
☐	☐	☑

OCTS (ADEOS)	MODIS (Aqua)	CZCS (Nimbus-7)
☑	☑	☑

Radius (*km*) about map click or typed-in location:

○ ○ ○ ○ ○

36 400 800 1200 1500

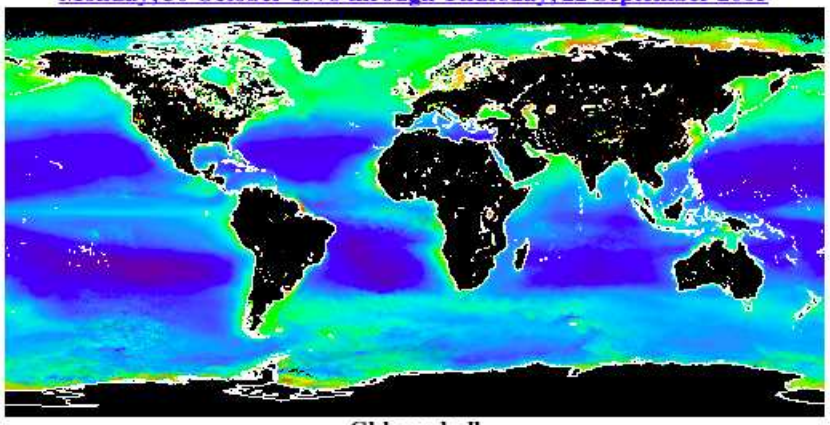
Select swaths containing *(at least)*:

○ ○ ○ ○ ○

any part 25 % 50 % 75 % all of the area of interest.

Display results 10 at a time.

Monday, 30 October 1978 through Thursday, 22 September 2005



Chlorophyll

Select one or more regions:

AdriaticSea
AegeanSea
Antarctica
ArabianSea
AralSea
Australia
Azores

or specify boundary coordinates or a single location:

N:

W: :E

S:

or check this box ☐ to select all of this time period's scenes.

Find swaths

Reconfigure page

Mission	J	F	M	A	M	J	J	A	S	O	N	D
1978	J	F	M	A	M	J	J	A	S	O	N	D
1979	J	F	M	A	M	J	J	A	S	O	N	D
1980	J	F	M	A	M	J	J	A	S	O	N	D
1981	J	F	M	A	M	J	J	A	S	O	N	D
1982	J	F	M	A	M	J	J	A	S	O	N	D
1983	J	F	M	A	M	J	J	A	S	O	N	D
1984	J	F	M	A	M	J	J	A	S	O	N	D
1985	J	F	M	A	M	J	J	A	S	O	N	D
1986	J	F	M	A	M	J	J	A	S	O	N	D
1996	J	F	M	A	M	J	J	A	S	O	N	D
1997	J	F	M	A	M	J	J	A	S	O	N	D
1998	J	F	M	A	M	J	J	A	S	O	N	D
1999	J	F	M	A	M	J	J	A	S	O	N	D
2000	J	F	M	A	M	J	J	A	S	O	N	D
2001	J	F	M	A	M	J	J	A	S	O	N	D
2002	J	F	M	A	M	J	J	A	S	O	N	D
2003	J	F	M	A	M	J	J	A	S	O	N	D
2004	J	F	M	A	M	J	J	A	S	O	N	D
2005	J	F	M	A	M	J	J	A	S	O	N	D

July 2005

S	M	T	W	T	F	S
					1 XXX	2 XXX
3 XXX	4 ^^^	5 ^^^	6 ^^^	7 ^^^	8 ^^^	9 ^^^
10 ^^^	11 ^^^	12 000	13 000	14 000	15 000	16 000
17 000	18 000	19 000	20 ***	21 ***	22 ***	23 ***
24 ***	25 ***	26 ***	27 ***	28 XXX	29 XXX	30 XXX
31 XXX						

August 2005

S	M	T	W	T	F	S
	1 XXX	2 XXX	3 XXX	4 XXX	5 ^^^	6 ^^^
7 ^^^	8 ^^^	9 ^^^	10 ^^^	11 ^^^	12 ^^^	13 000
14 000	15 000	16 000	17 000	18 000	19 000	20 000
21 ***	22 ***	23 ***	24 ***	25 ***	26 ***	27 ***
28 ***	29 XXX	30 XXX	31 XXX			

September 2005

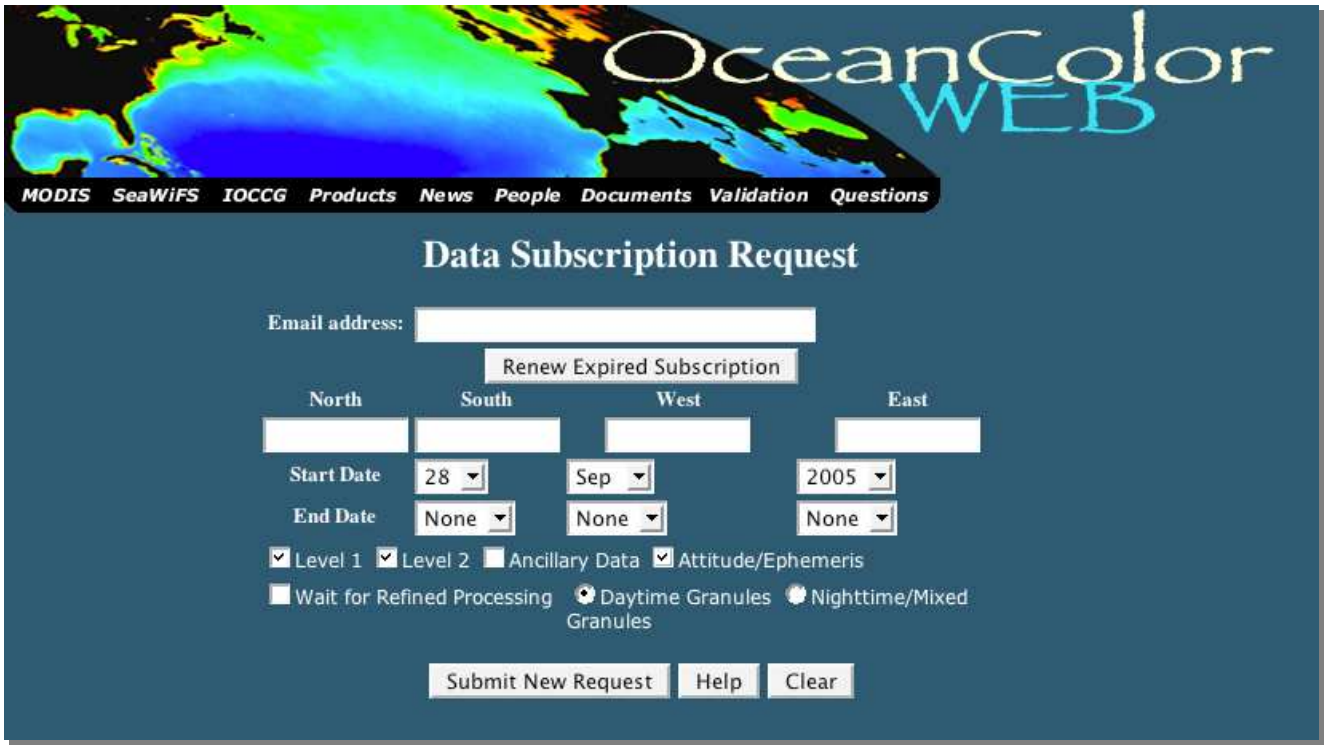
S	M	T	W	T	F	S
				1 XXX	2 XXX	3 XXX
4 XXX	5 XXX	6 ^^^	7 ^^^	8 ^^^	9 ^^^	10 ^^^
11 ^^^	12 ^^^	13 ^^^	14 000	15 000	16 000	17 000
18 000	19 000	20 000	21 000	22 ***	23 ***	24 ***
25 ***	26 ***	27 ***	28 ***	29 ***	30 XXX	

Data Distribution

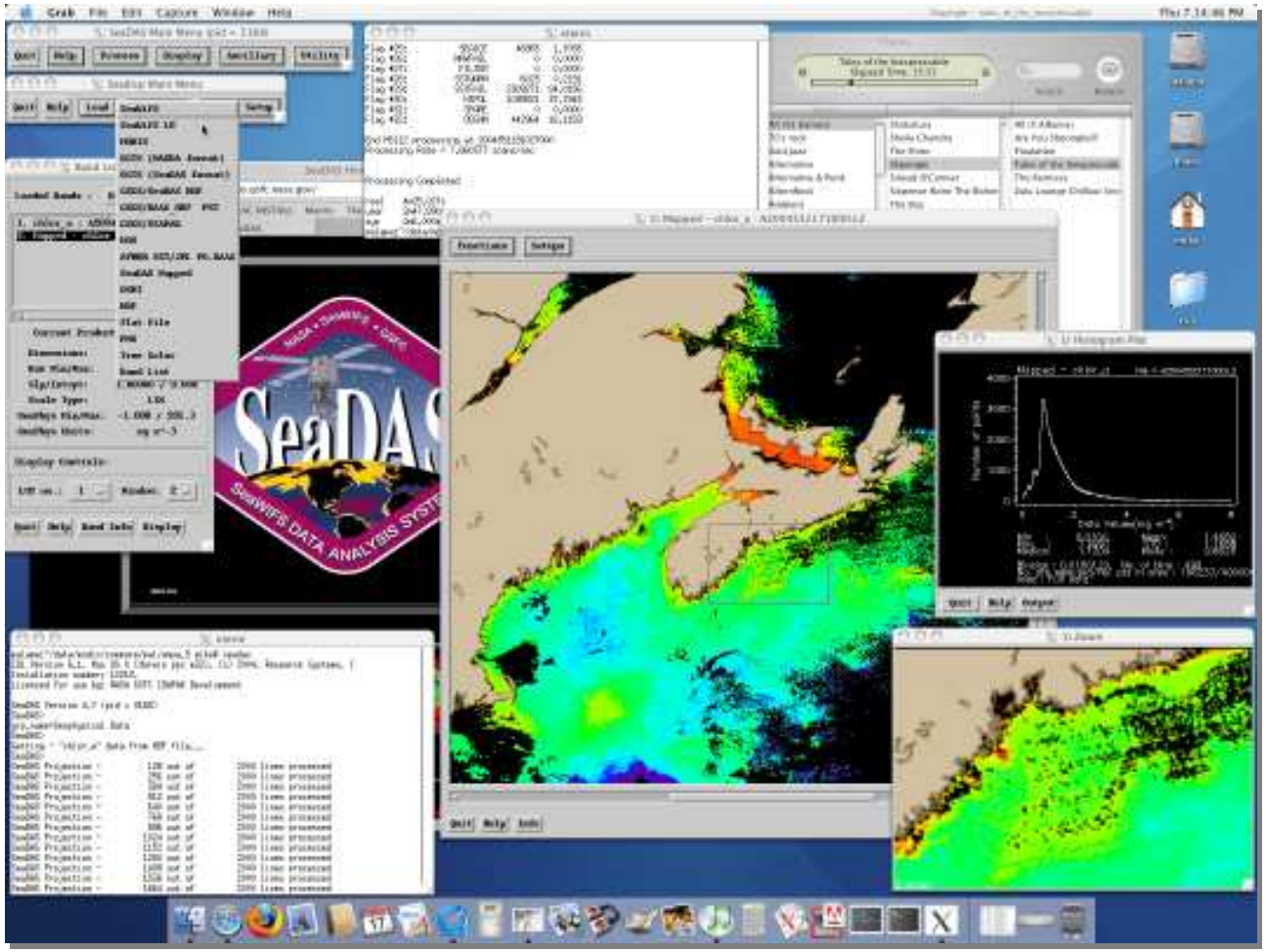
- **Instant access:** entire archive of Level-1A through Level-3 data for all missions is stored online
- **Minimal latency:** MODIS L1A/GEO/L1B/L2 data available 2-5 hours after satellite observation
- **Web-based browser:** simple viewing/order/download tool for the entire multi-mission data set
- **Data subscriptions:** automatic staging of new data products to user-specific ftp accounts

Virtual ground station concept

Data subscriptions can be created for a limited geographic region, allowing users to receive Level-1A, Level-1B, and Level-2 data for their area(s) of interest within 2-5 hours of satellite observation.



SeaDAS



SeaDAS Features

- Most widely used ocean color software package in the world
- Process/display/analyse MODIS, SeaWiFS, CZCS, OCTS, MOS
- Will support NPP/VIIRS in the future
- Reproduces identical OBPG standard ocean color & SST products
- Runs on Linux, Macintosh OS X, Sun Solaris, SGI IRIX
- Extremely active user support forums

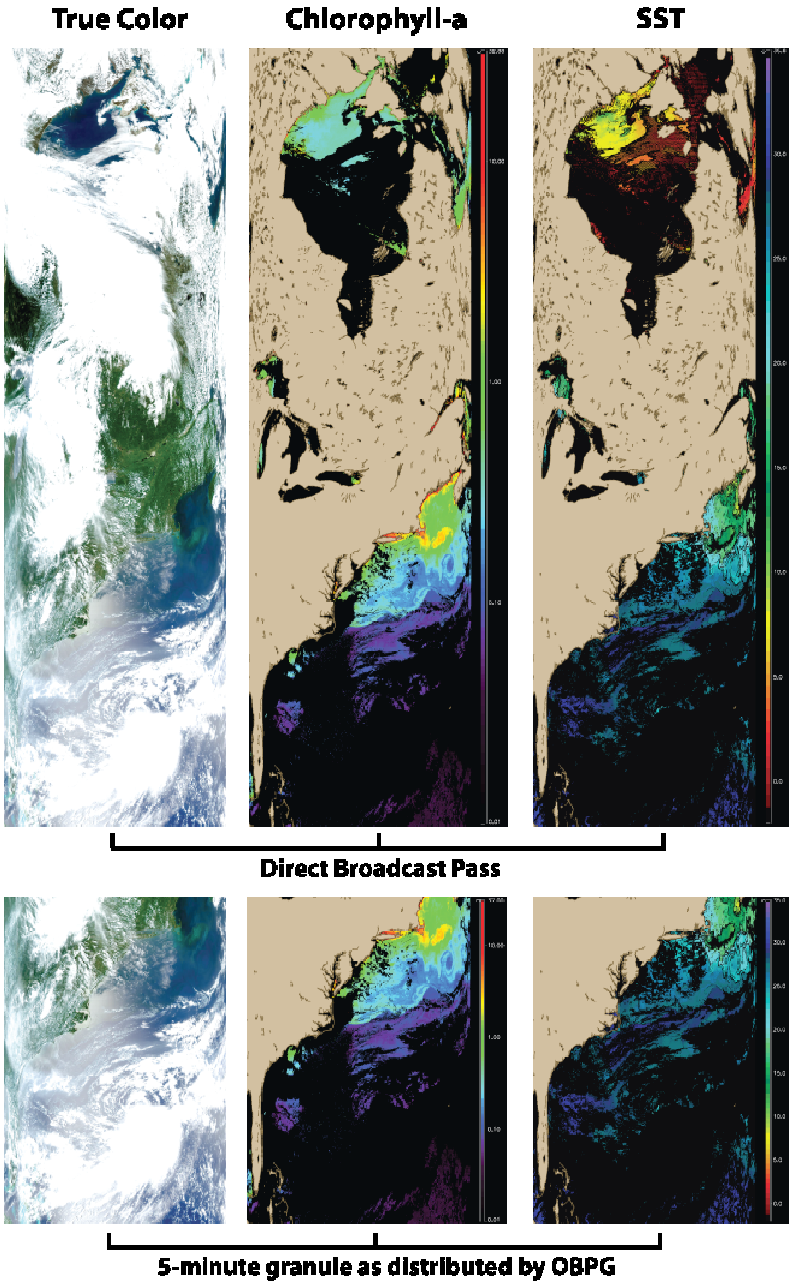
msl12

- converts sensor measured radiances (Level-1B) to geophysical products
- processes MODIS, SeaWiFS, OCTS, MOS, OSMI, POLDER, and CZCS
- default products generated are identical to those distributed by the OBPG
- customizable run-time parameters control processing options and determine output products
- source code/build environment allow users to implement custom algorithms

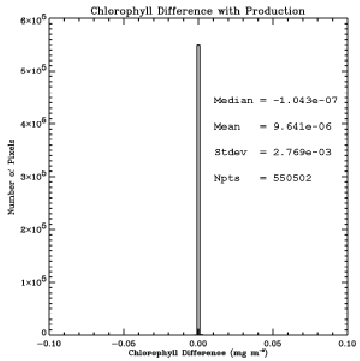
- **The flexibility of msl12 allows SeaDAS users to investigate alternative processing options and to generate a host of additional output products beyond the standard suite.**

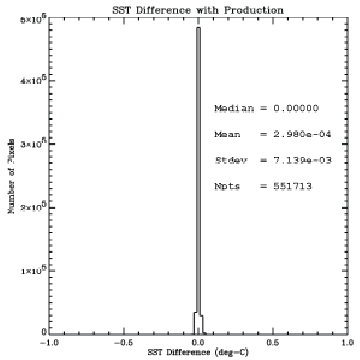
msl12: example products

- water-leaving radiances
- remote sensing reflectance
- SST (thermal and short-wave IR)
- chlorophyll (8 algorithms)
- diffuse attenuation of sea water
- IOP (GSM01, Carder, QAA):
  - -absorption (total, phaeophytin, dissolved & detrital)
  - -backscatter (total, particulate)
- particulate organic carbon
- total suspended matter
- calcite concentration
- fluorescence line height
- photosynthetically active radiation
- aerosol products (AOT, Angstrom)
- intermediate products (Lr, La, anc. fields, etc.)



These images and histograms show pixel-for-pixel comparisons between MODIS/Aqua products generated from a Level-0 scene (UWisc DB station) using SeaDAS, and the overlapping 5-minute granule processed by the OBPG. Using SeaDAS, it is possible to exactly reproduce the standard products distributed by the OBPG, as well as a host of additional products.





MODISL1DB

MODISL1DB

- Direct Broadcast software package for processing MODIS Aqua and Terra Level-0 data to Level-1A and Level-1B
- Unifies SeaDAS, MCST, IMAPP
- Runs on Linux, Macintosh OS X, Sun Solaris
- Very simple to install and use (and integrate into existing processing systems)
- New ‘MODIS Direct Broadcast Support’ forum as well as direct support from developers

MODISL1DB 1.0 Features

- processing binaries compiled with MCST Version 5 source
- Code and LUTs will remain synchronized with MCST
- processing mechanism to auto-download latest MCST LUTs (and optional custom OBPG Aqua LUTs)
- processing mechanism to auto-download definitive or real-time attitude and ephemeris, or use GBAD-generated att/eph
- MCST source code and build environment (available via SeaDAS) allow users to implement custom features

MODISL1DB directory structure

```
bin/ - - - - - - - - - - - Processing and utility binaries

data/  - - - - - - - - - - Supporting data files
     modis/
           atteph/ - - - Attitude and ephemeris files
           dem/  - - - - Digital elevation maps
           static/ - - - Common ancillary files
     modisa/
            cal/ - - - - Aqua calibration LUTs and ancillary files
            mcf/ - - - - Aqua metadata configuration files
            pcf/ - - - - Aqua process control files
     modist/
            cal/ - - - - Terra calibration LUTs and ancillary files
            mcf/ - - - - Terra metadata configuration files
            pcf/ - - - - Terra process control files

scripts/ - - - - - - - - - Main wrapper scripts and utility scripts
```

Level-0 to Level-1A wrapper script:

```
Usage: modis_L0_to_L1A_GEO.csh MODIS_L0_PDS_file [OPTIONS]

Options:

  -o L1A_file                Output MODIS L1A HDF filename
  -g GEO_file                Output MODIS GEO HDF filename
  -a1 attitude_file1         Input attitude file 1 (chronological)
  -a2 attitude_file2         Input attitude file 2 (chronological)
  -e1 ephemeris_file1        Input ephemeris file 1 (chronological)
  -e2 ephemeris_file2        Input ephemeris file 2 (chronological)
  -disable-definitive        Disable use of definitive attitude/ephemeris
  -disable-definitive-ftp    Disable auto-downloading of definitive att/eph
  -disable-predicted         Disable use of real-time attitude/ephemeris
  -disable-predicted-ftp     Disable auto-downloading of real-time att/eph
  -verbose-ftp               Enable verbose auto-download messages
  -disable-dem               Disable terrain elevation correction
  -startnudge n              Level-0 start-time offset (seconds)
  -stopnudge n               Level-0 stop-time offset (seconds)
  -geocheck_threshold n      % of geo pixels required to pass validation test
  -satellite aqua            Only required if non-standard filename
  -satellite terra           Only required if non-standard filename
  -save-log                  Save Level 1A and geolocation processing log files
```

MODISL1DB 1.0 Online Installation

Select a MODISL1DB ftp download site:

USA (Goddard Space Flight Center, Maryland)

Select your operating system:

Fedora Core 2

Select your UNIX shell environment: (execute "echo $SHELL" to determine your shell)

Bourne-Again shell (bash)

- [x] Required Digital elevation maps for MODIS geolocation terrain correction (seadas_dem_modis.tar.gz, 565MB)
- [ ] Sample MODIS Aqua L0 Direct Broadcast file (seadas_demo_modis_db.tar.gz, 770MB)

CONTINUE


OBPG!
Good for yo

Back-up Slides

Multi-Mission Approach

- Common software for Level-1 through Level-3
  - reduces potential for algorithm and implementation differences
  - sensor-specific issues consolidated in i/o function and external tables
- Mission-independent, distributed processing system
  - controls staging/sequencing of processing jobs for max through-put
  - 150x global reprocessing for MODIS, 1600x for SeaWiFS
- 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

The Ocean Biology Processing Group

- **Heritage:**
  - **SeaWiFS Project** (calibration, validation, processing, and distribution)
  - **SIMBIOS Project** (field campaigns, international collaboration, sensor intercomparison, multi-mission support)
  - SeaWiFS Bio-optical Analysis and Storage System (**SeaBASS**), archive of in situ ocean bio-optical measurements
  - SeaWiFS Data Analysis System (**SeaDAS**), public domain software package for the display, analysis, and processing of ocean color and SST products.

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

$$L_t = L_r + L_a + tL_{wc} + TL_g + t\,L_w$$

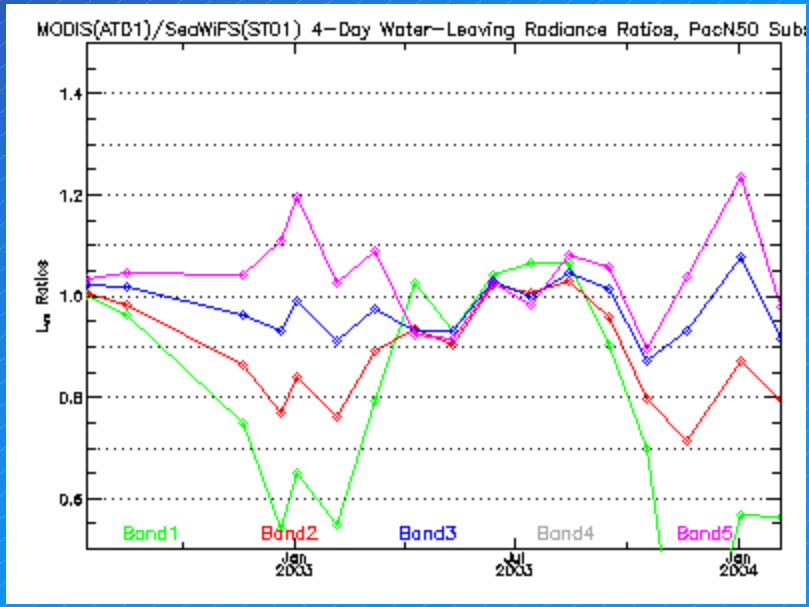
- L_w is the quantity we wish to retrieve at each wavelength.

- 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.

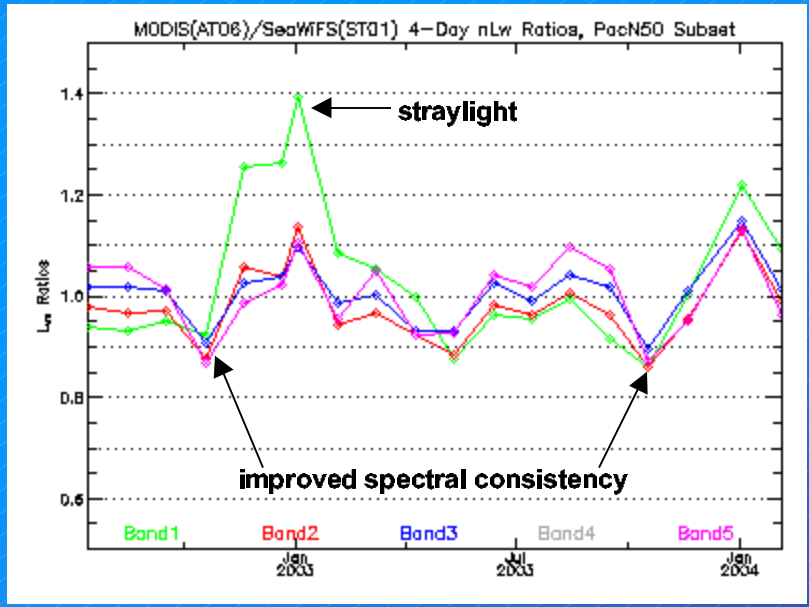
nLw Ratio: MODIS/Aqua vs SeaWiFS

50N-40N, 150W-170W

Before Polarization Correction



After Polarization Correction



Polarization Correction

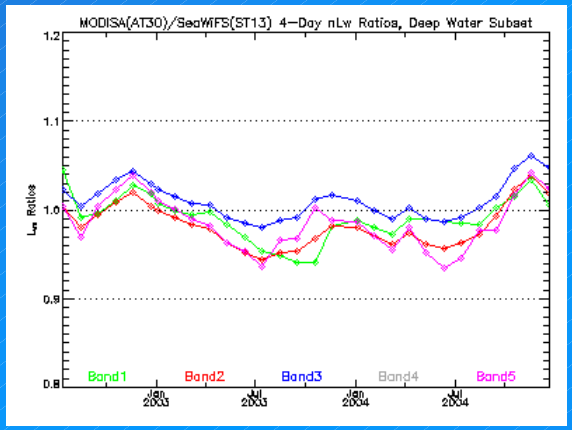
- The atmospheric signal reaching the sensor is polarized.
- SeaWiFS has a polarization scrambler.
- MODIS has significant polarization sensitivity, especially in the blue.
- H. Gordon developed an algorithm to derive the polarization components of the atmospheric signal and correct for the polarization 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).

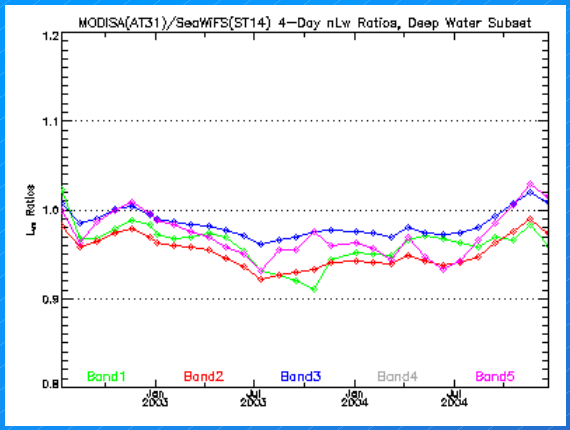
Effect of BRDF Correction to MODIS/SeaWiFS Ratios

Before BRDF

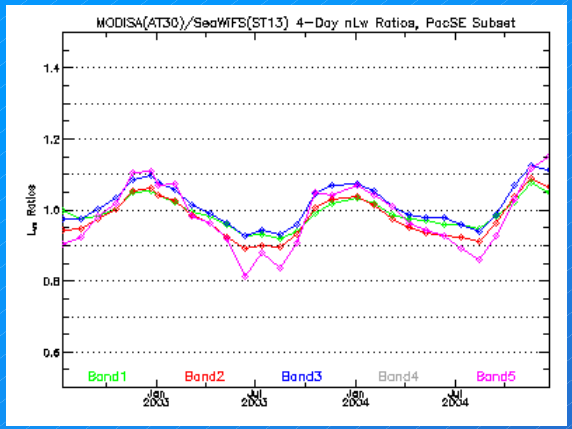
After BRDF

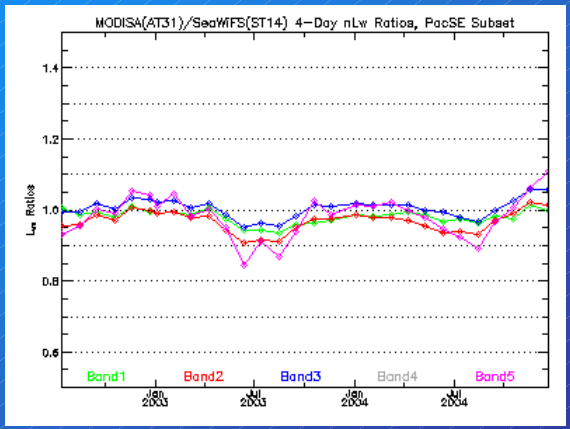
Deep Water nLw Ratio MODIS/SeaWiFS





Southern Pacific nLw Ratio MODIS/SeaWiFS





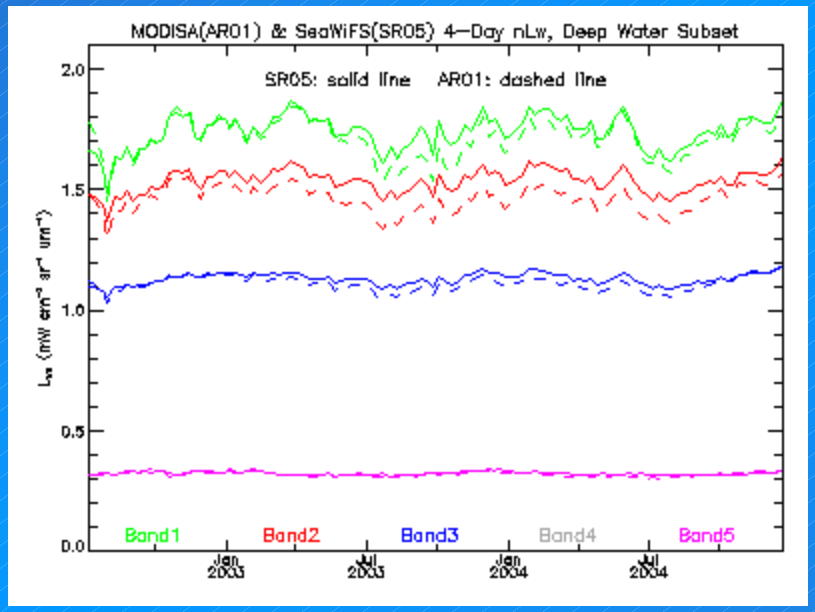
Results from Reprocessing

Sensor-to-Sensor nLw Comparison

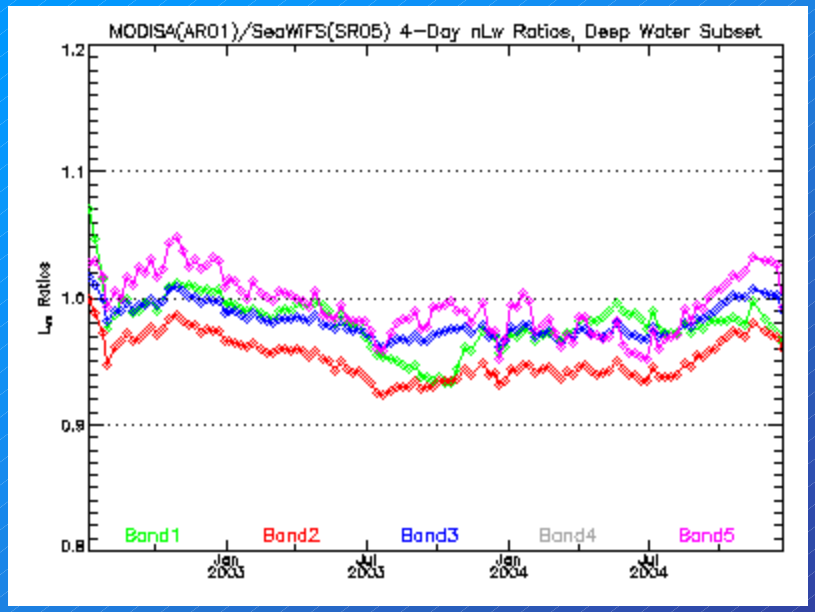
Deep-Water Trends

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

MODIS & SeaWiFS



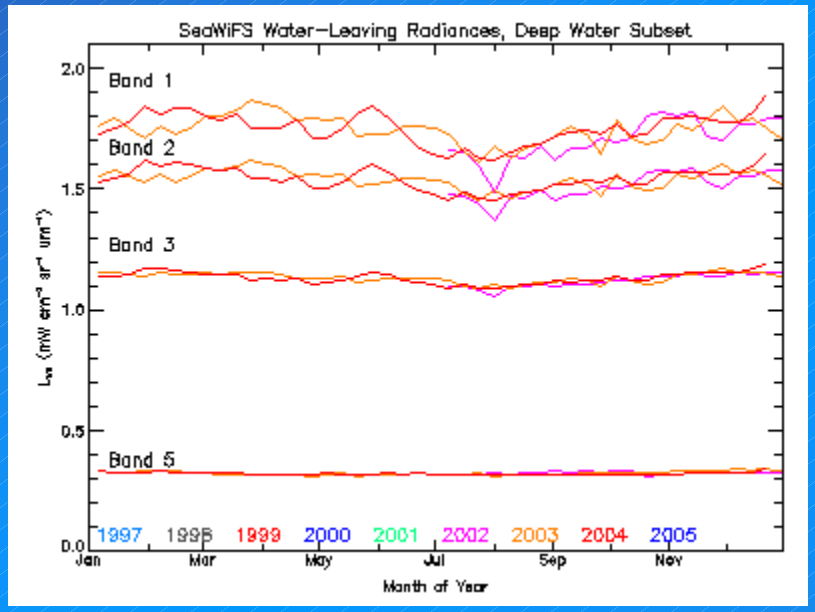
MODIS / SeaWiFS



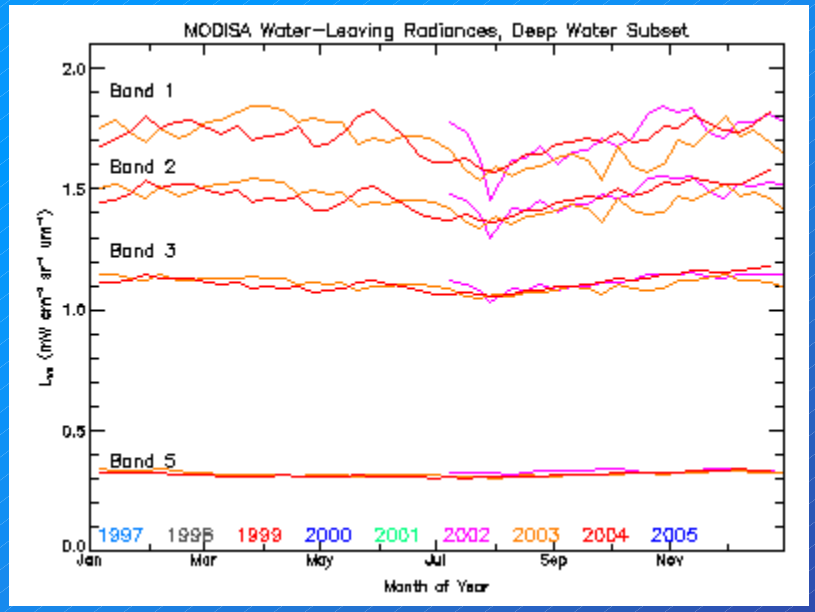
Results for Reprocessing

Consistency in Annual Cycle of nLw

SeaWiFS R5



MODIS/Aqua R1



Reprocessing

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

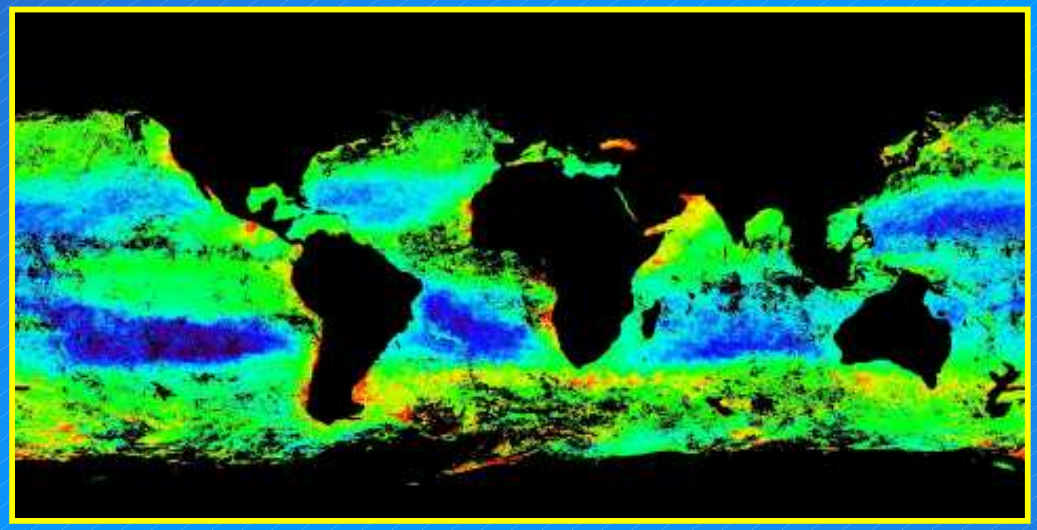
water-leaving radiances
remote sensing reflectance
sea surface temperature (thermal and short-wave IR)
chlorophyll (8 algorithms)
diffuse attenuation of sea water
inherent optical properties (3 algorithms)
    absorption (total, phaeophytin, disolved & detrital)
    backscatter (total, particulate)
particulate organic carbon
total suspended matter
calcite concentration
fluoresence line height
photosynthetically active radiation
aerosol products (type, AOT, Angstrom)
various intermediate products (Lr, La, ancillary fields, etc.)

Deep-Water Chlorophyll Images

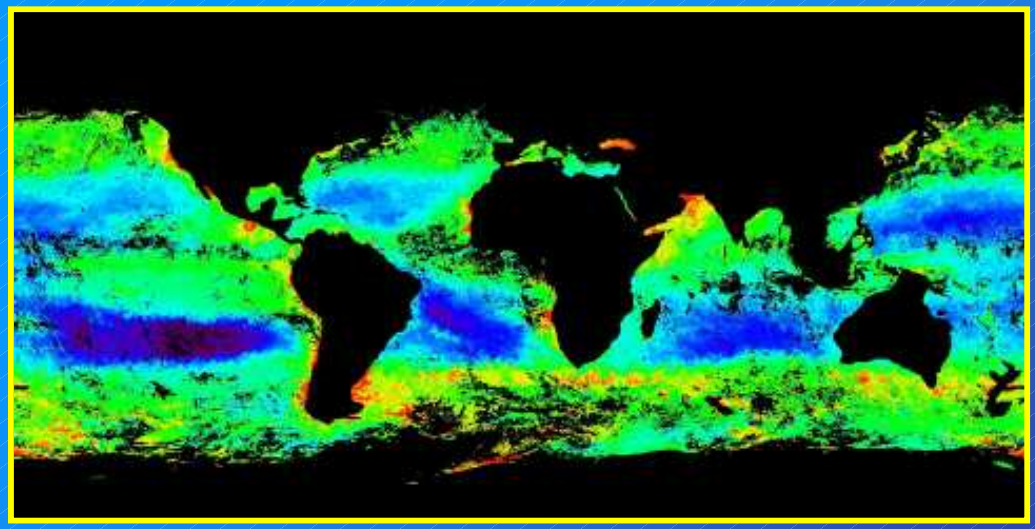
common-bin 12-day composite, Winter 2002

0.01-1 mg/m^3

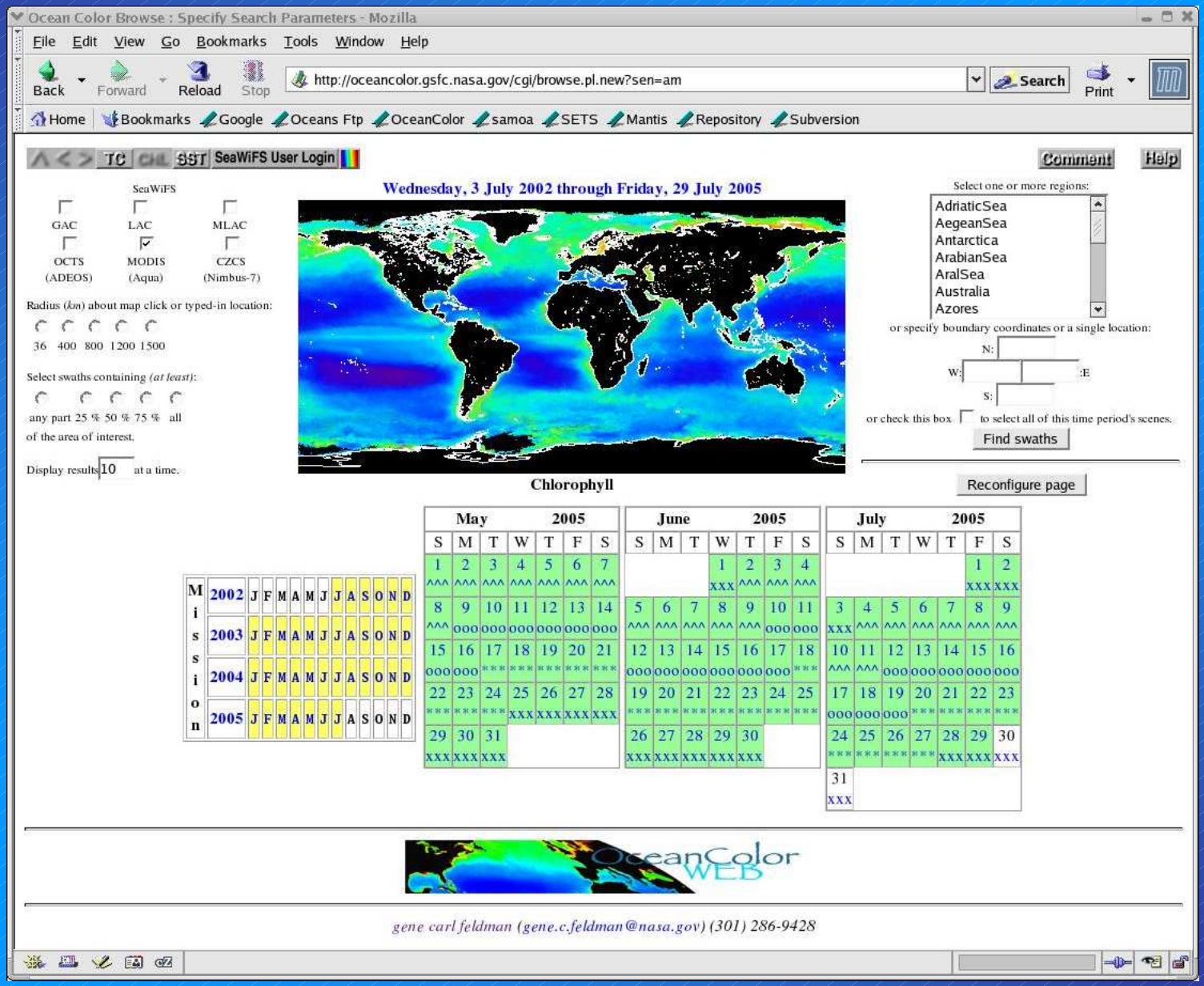
SeaWiFS R5



MODIS/Aqua R1

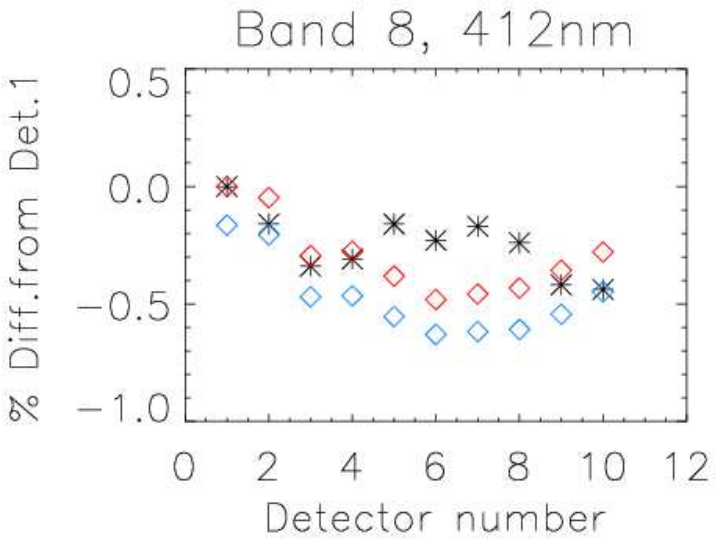


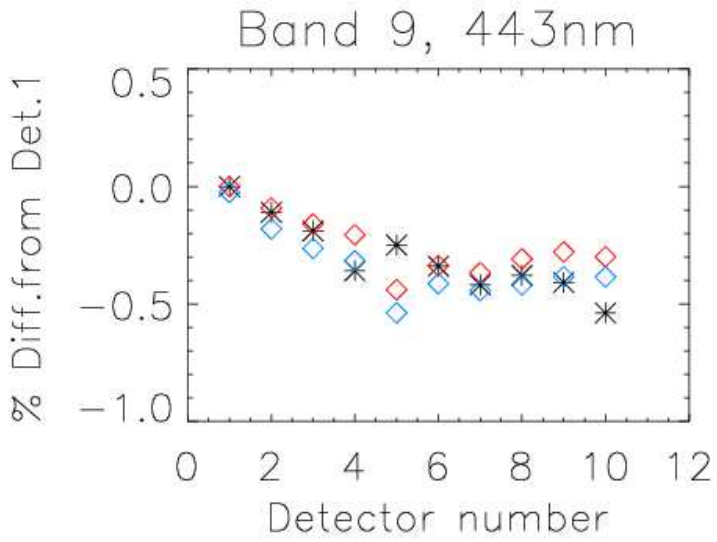
Multi-Mission Browse & Distribution

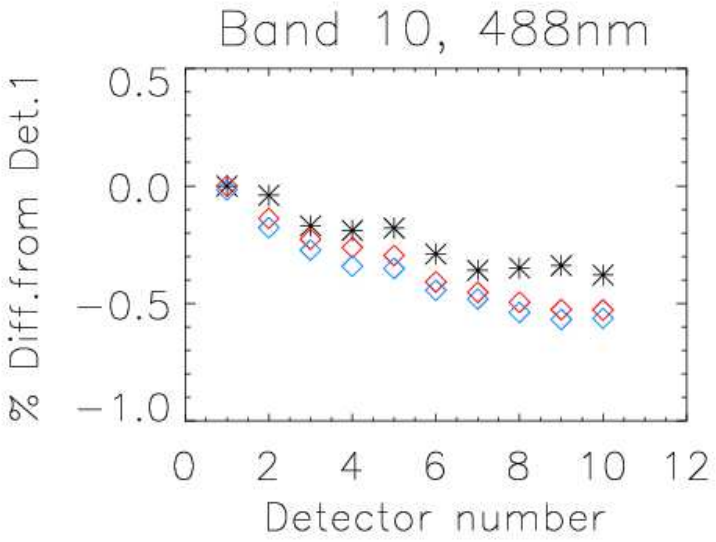


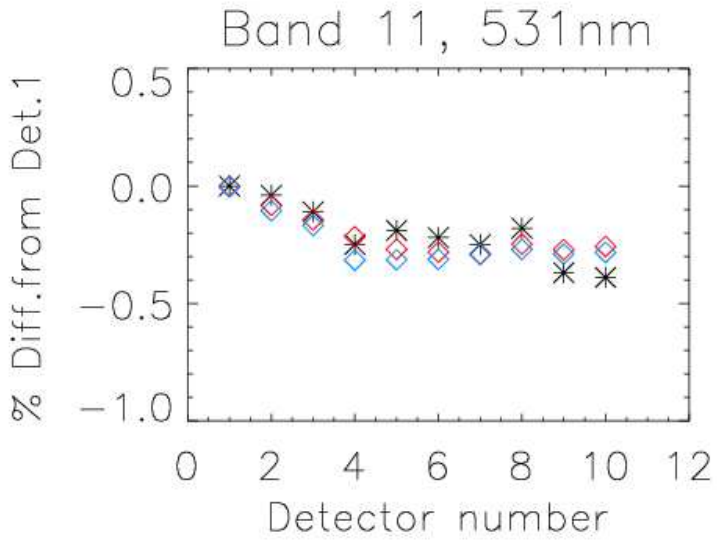
Identified and removed a residual detector trend in the reflected solar band calibration.

Comparison of TOA analysis (red and blue diamonds for two mirror sides) to lunar analysis of MCST (*):

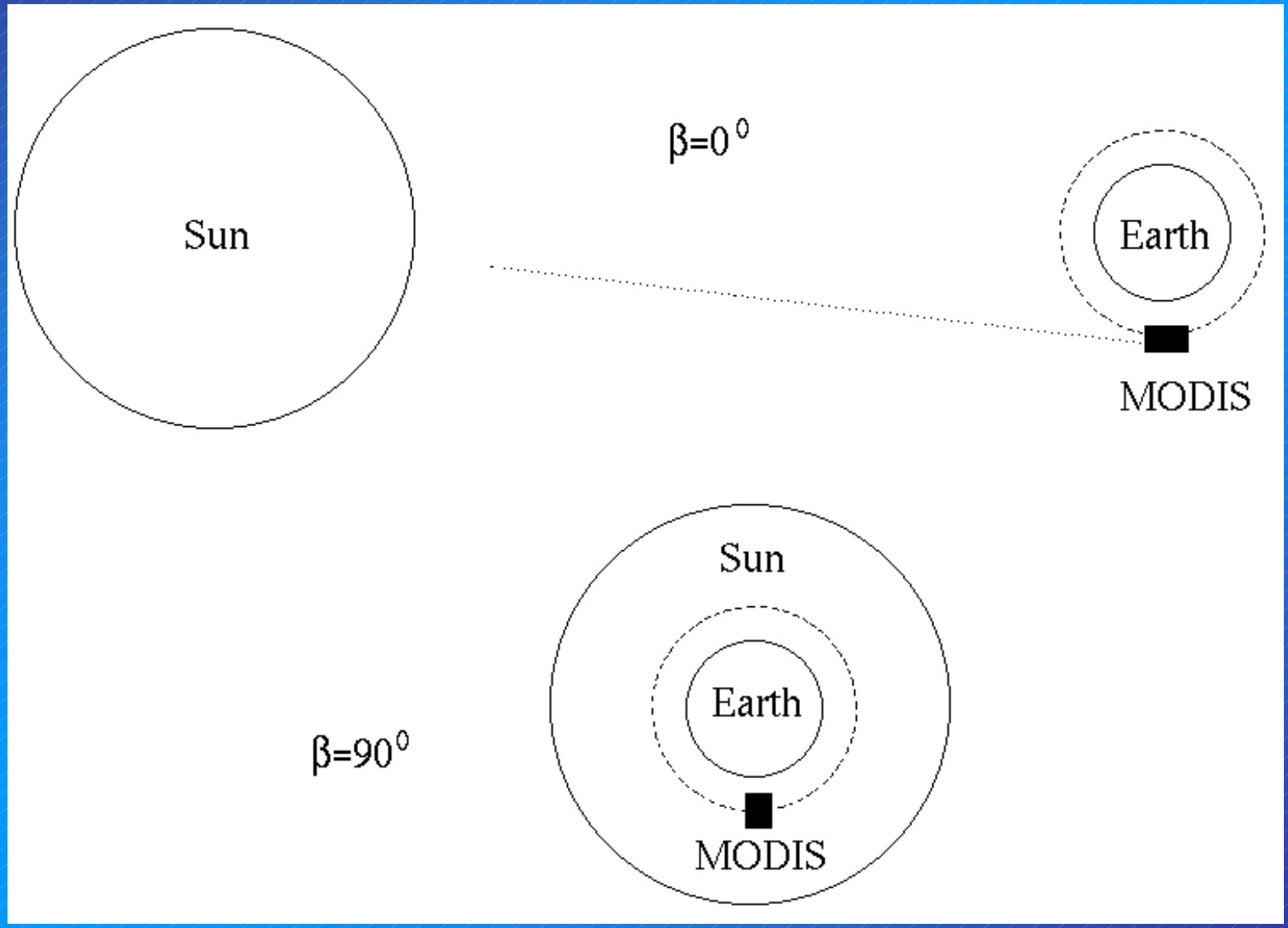








‘Sun-yaw’ or beta angle



MODIS SD Measurement Setup (Waluschka et al., 2004)

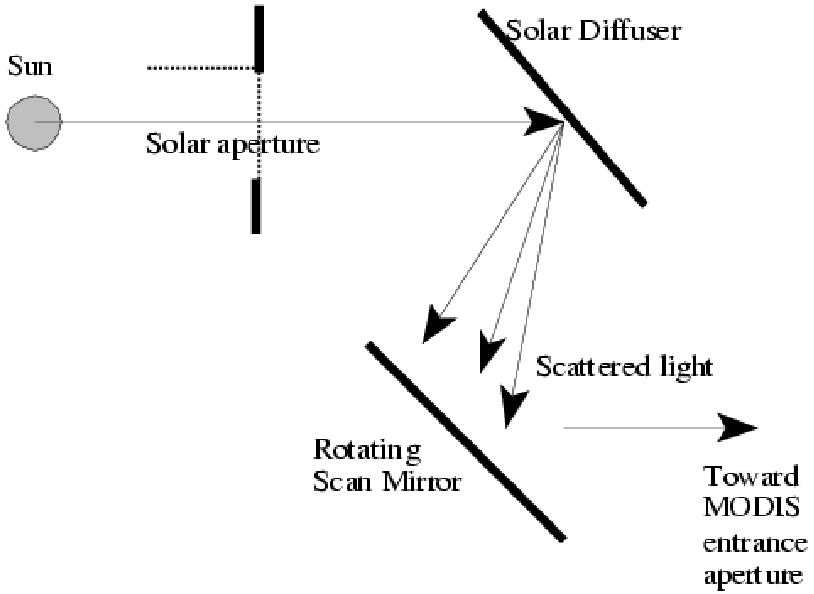


Fig. 4: Light path

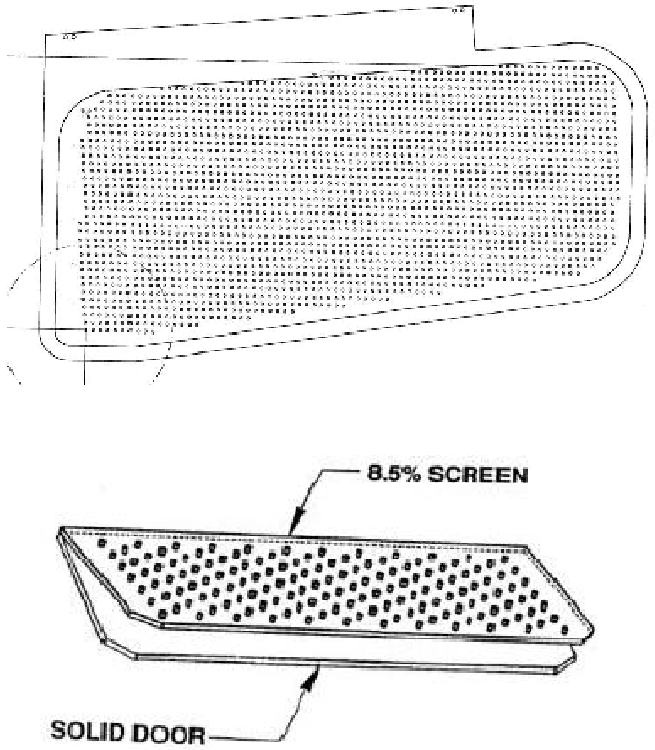
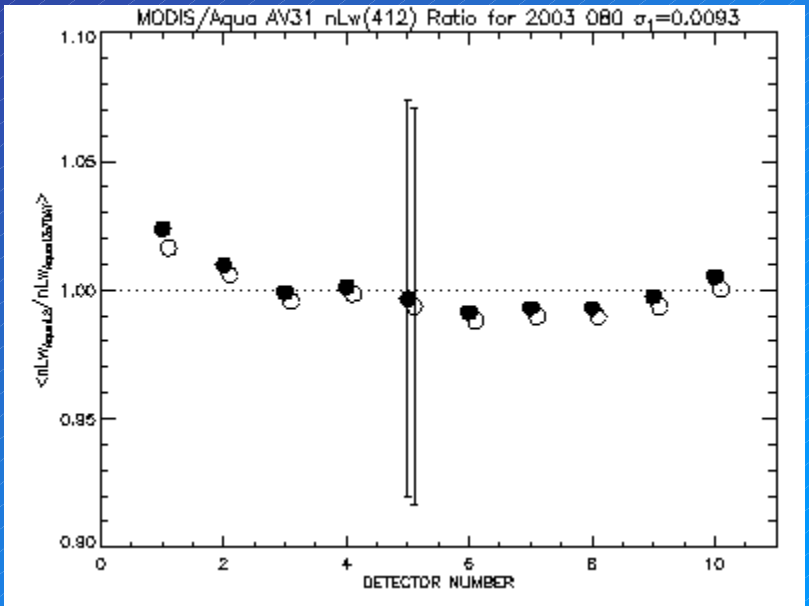


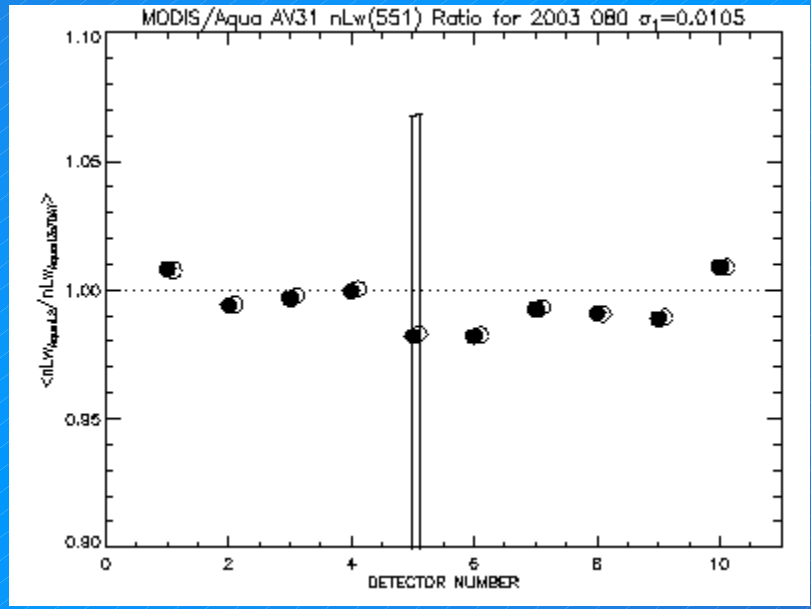
Fig. 5: Attenuation screen

Residual Striping

nLw(412)



nLw(551)



+10%

+5%

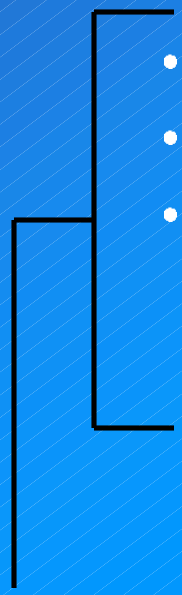
-5%

-10%

- Global mean residual striping at +/- 2% in nLw
- Consistent over life of mission (problem with SD cal?)

Reprocessing Results

- New LUT
- Straylight rejection
- RSR and pressure corrections
- Fresnel
- f/Q
- New MOBY vicarious cal



Also applied in SeaWiFS Reprocessing 5