MODIS OCEAN COLOR DATA QUALITY ISSUES with relevance to VIIRS & Ocean Color EDR Performance

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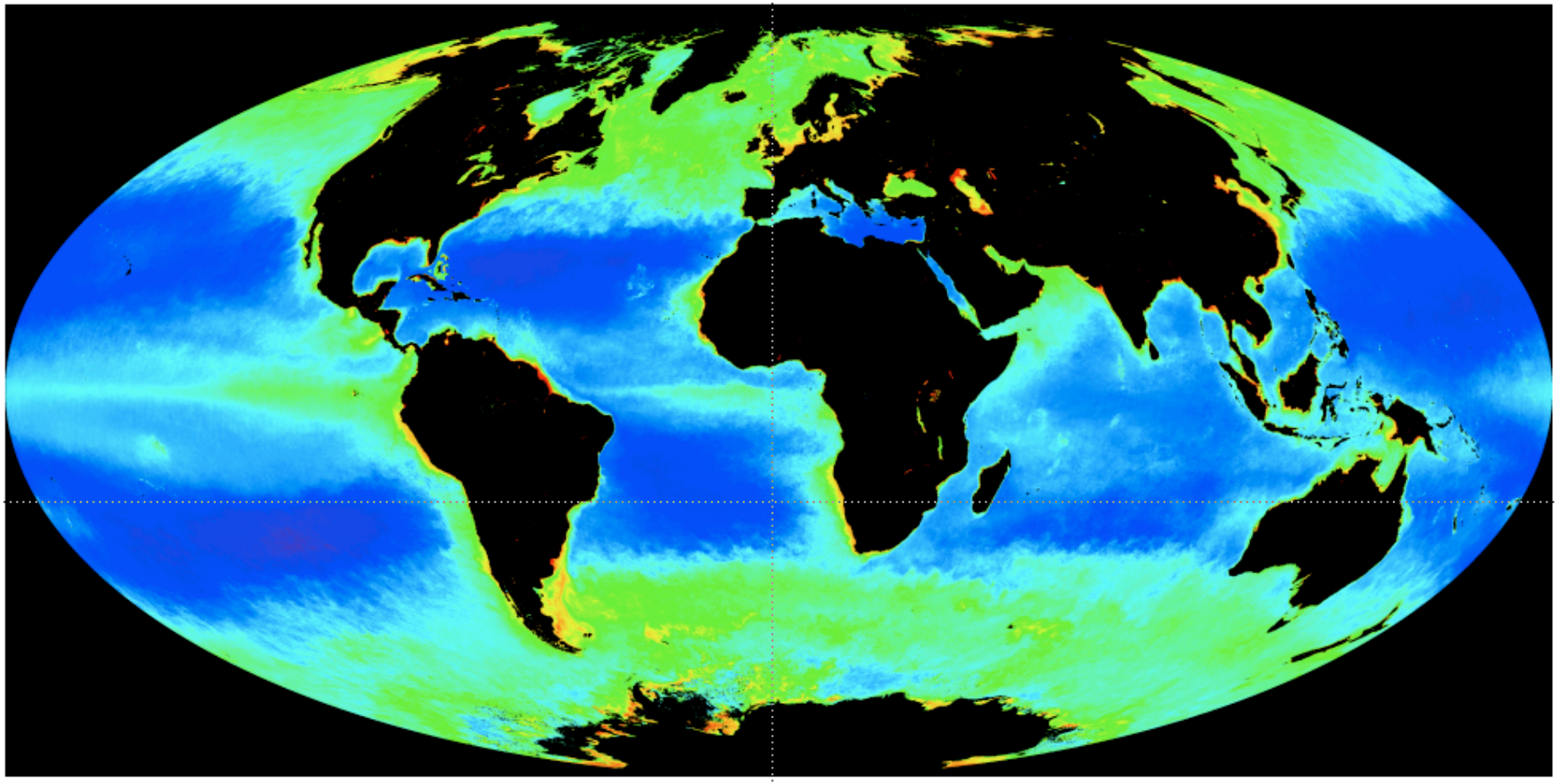
MODIS Science Team, NPP Science Team

MODIS TERRA Collection 041 MODIS Chlorophyll (Semi-analytic)



Yearly Average 2001

Quality Levels 0 and 1

0.01 0.1 1.0 10

mg/m3

Maximum Ocean Color signal is only 0.01 to .1 of TOA Radiance

This places a premium on precision and calibration stability over time, band-to-band, across the swath (RVS).

Precision of <0.001 (.1%) must be achieved. The approach has been to remove biases and trends retrospectively, via vicarious techniques. This requires superior instrument performance, stability, and does not substitute for it.

Ocean color is particulary sensitive to instrumental biases with time scales which are intrinsic to geophysical variability of concern -
local to global, daily to seasonal to decadal.

VIIRS INSTRUMENT CONCERNS

Calibration Stability (short term, long term)
SD performance
Stray Light Characterization Include Out of Band
Polarization Sensitivity and Stability
    Half angle mirror, dichroic, spectral changes
RVS
Electronic stability

VIIRS EDR Performance & Testing Concerns

Correlation of errors and biases are not properly assigned to determine effects on EDRs.
IPO, NGST lack capability to determine impact of instrument test results on EDR performance (This is beyond present role of NPP ST).

Mechanism for jointly determining and updating L1 and L2 calibrations quickly, throughout the mission is needed.
It took the MCST and MODIS Ocean Team about 4-5 months to respond to a given instrument performance change, and the trends were unpredictable.

A reliable, continuing source of high quality water-leaving radiance observations is essential (like MOBY), but is not presently assured.
MOBY funding currently expires 1/05.
A strong argument could be made for second time series in the southern ocean.

EDR requirements are for end of life, and at the pixel level (not global).

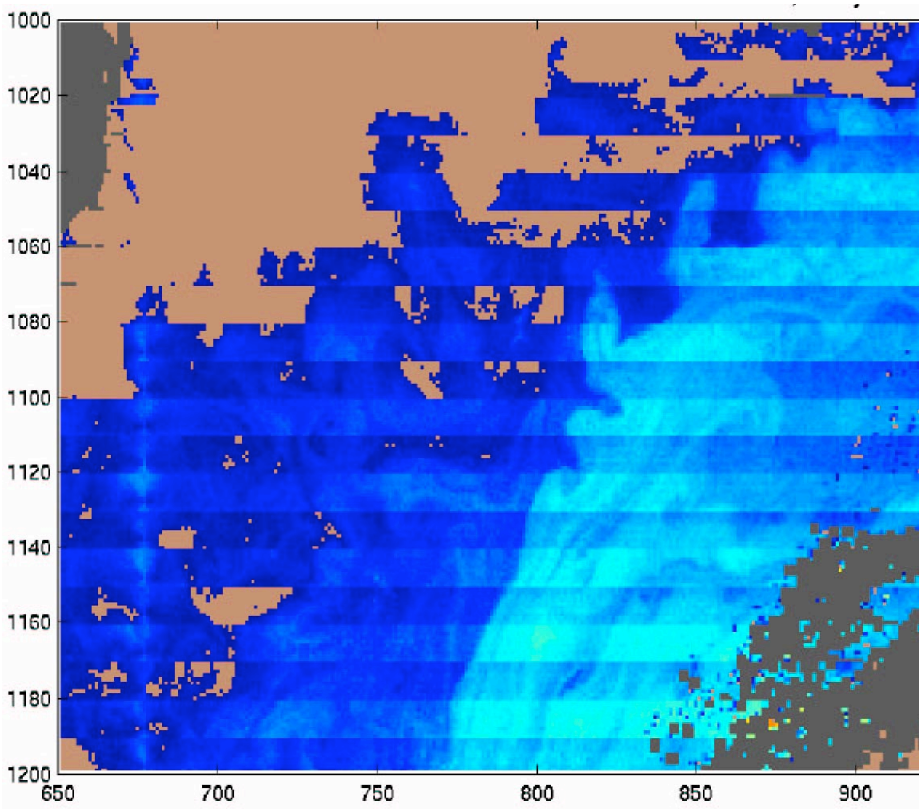


Figure 1a. Mirror Side Banding, nLw 412 before corrections. November 1,2000 v3.0.1 Level 1b

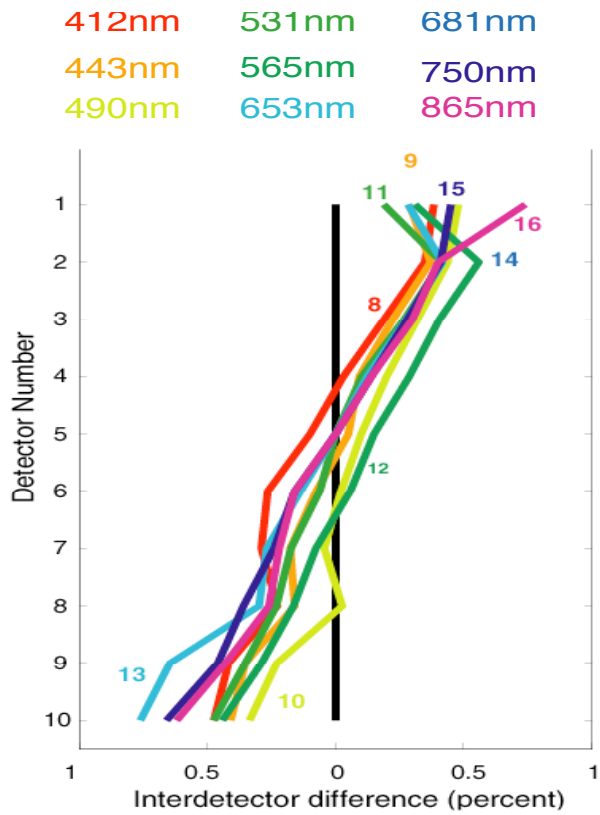
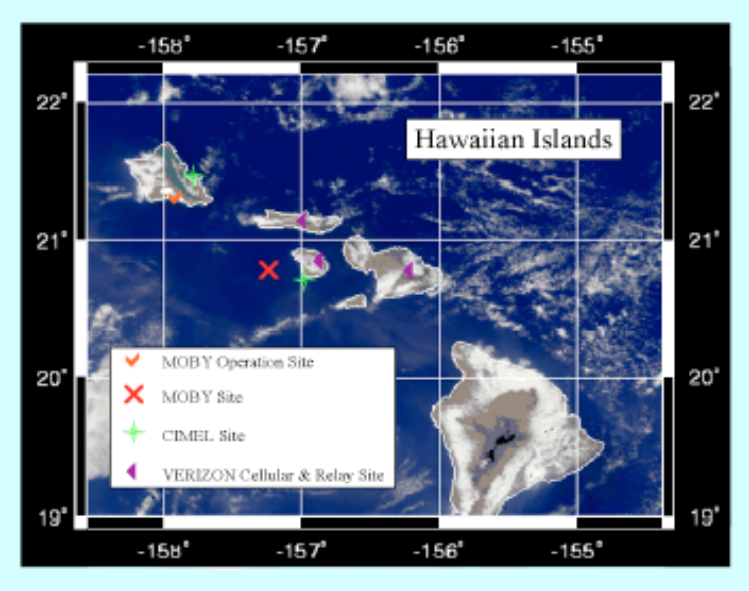


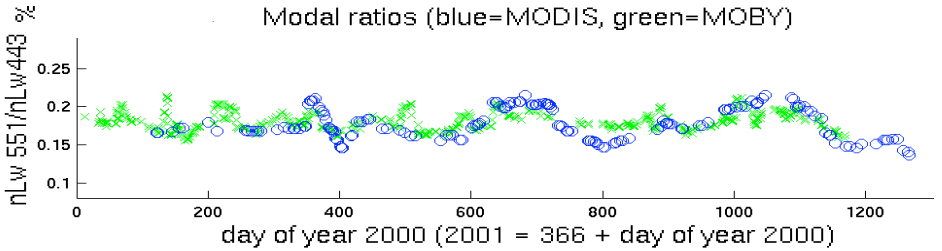
Figure 1b. Detector Corrections to minimize detector to detector banding by spectral band for oceans, additional to L1 corrections

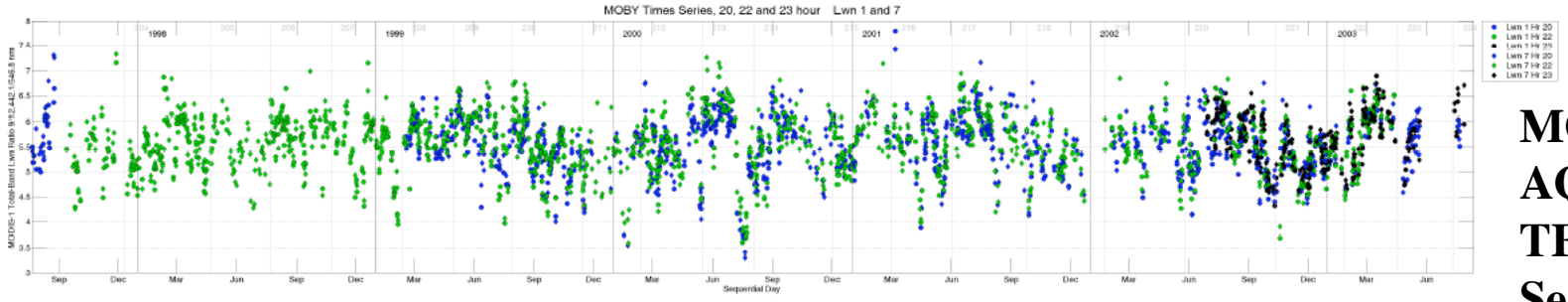
MOBY (443/551) and MODIS (551/443) blue/green ratios

MOBY Calibration Site
at Hawaii
(Dennis Clark)



MODAL Analysis
Green - MOBY
Blue - MODIS

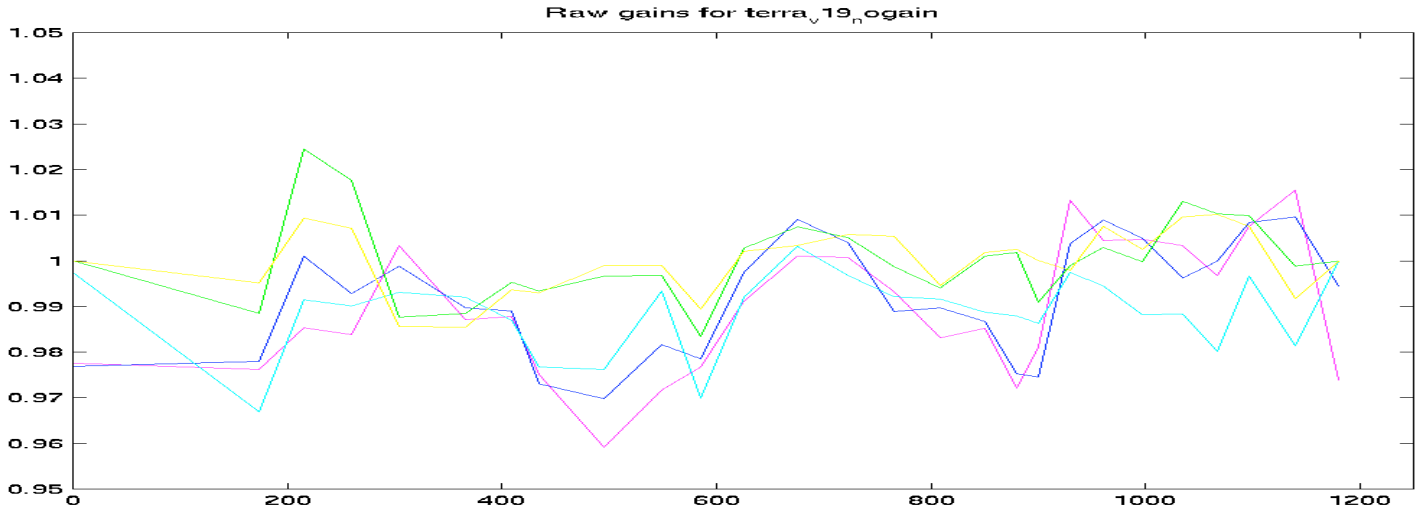




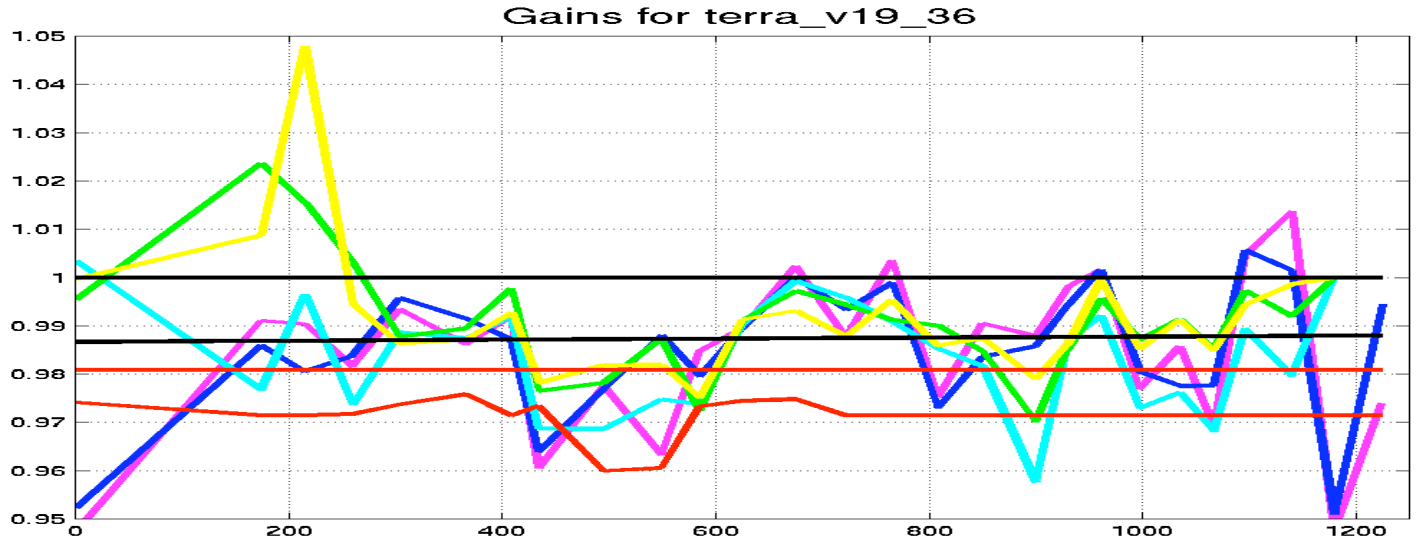
MOBY for AQUA, TERRA, SeaWiFS

Temporal adjustment to blue and green band m1 required to produce MODIS nLw that match MOBY Ocean Lt adjustments are of order 3-4%

Gain adjustments calculated from per granule MOBY, MODIS differences



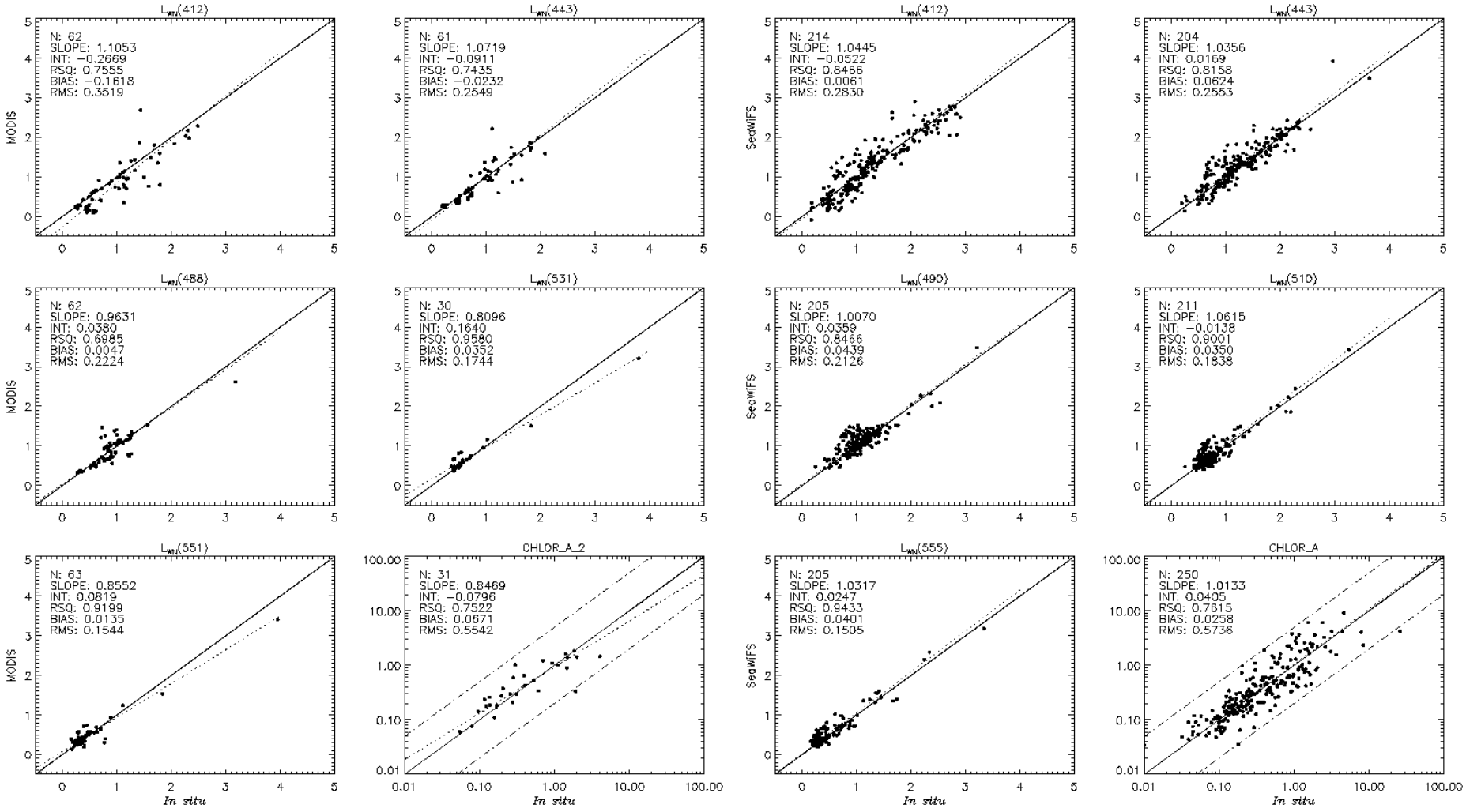
Gain factors with temporal trends removed, smoothing applied



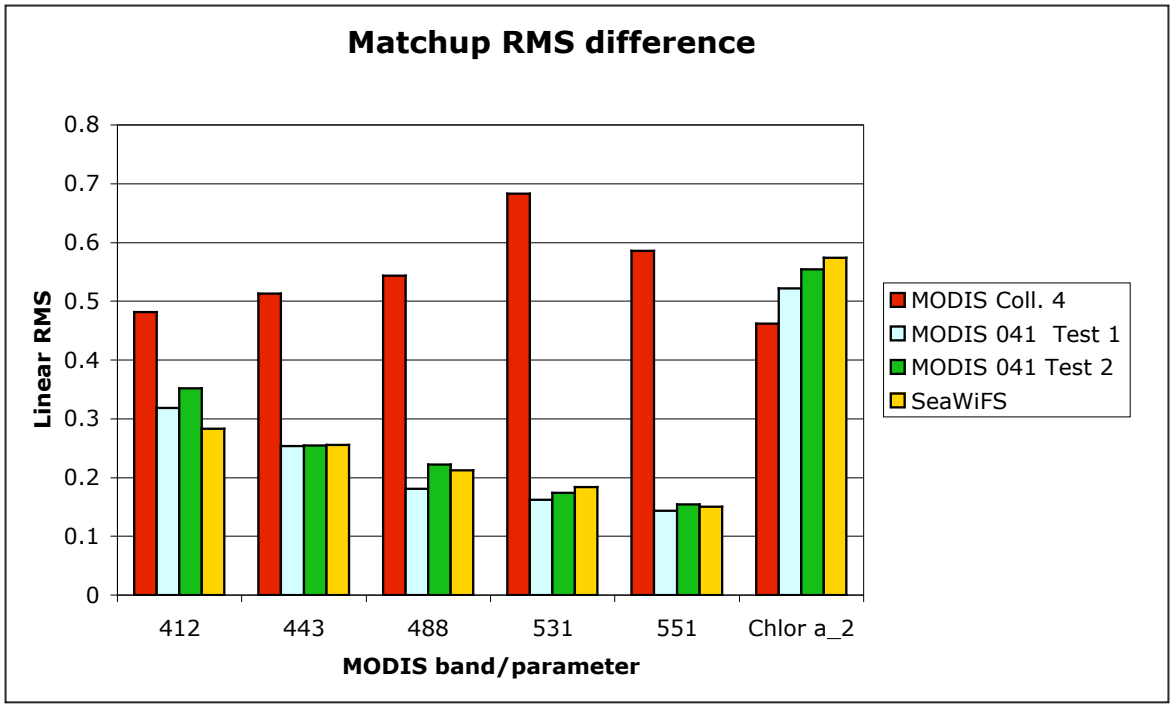
CHLOROPHYLL Satellite-In-situ Matchups

MODIS 041

SeaWiFS
Repro 4



Franz, Bailey



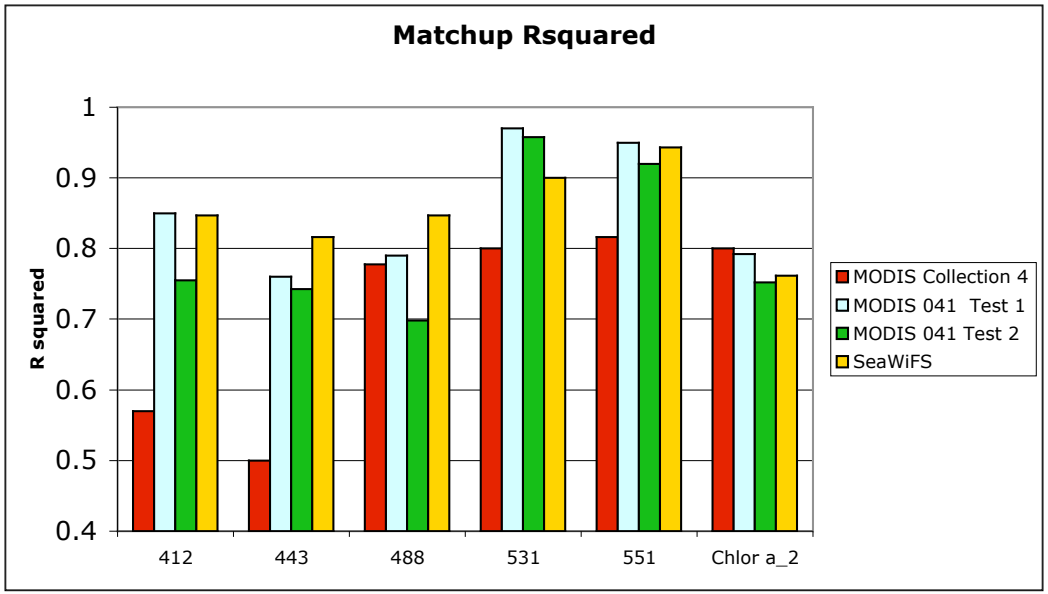
Satellite and in-situ data Match-ups - Global

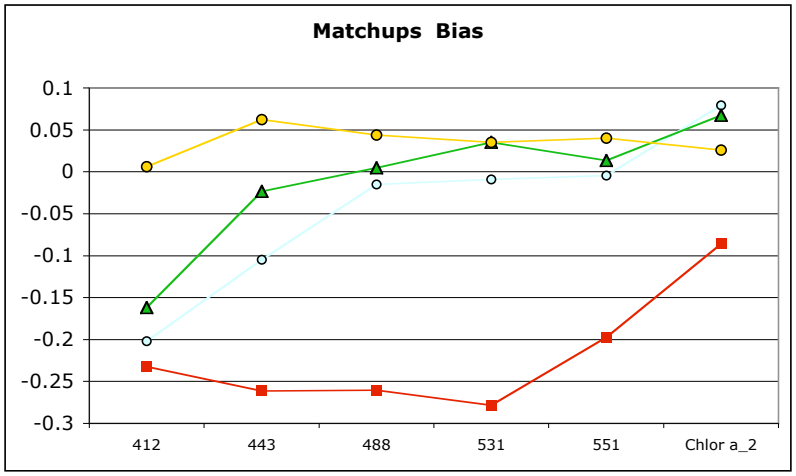
Analysis by Sean Bailey SIMBIOS group

MODIS data provided by MODAPS and Miami

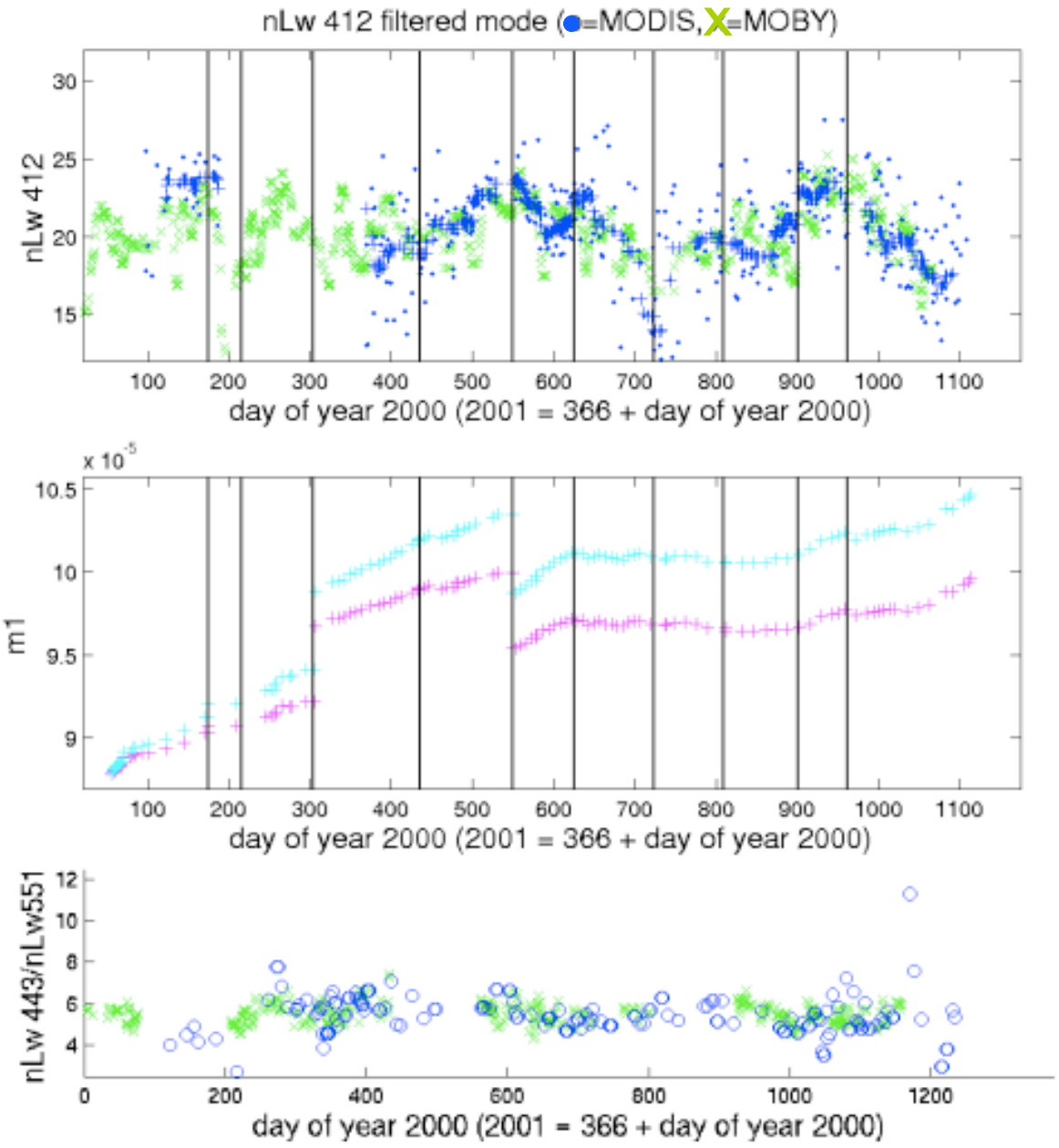
results available at:

http://seabass.gsfc.nasa.gov/matchup/MODIS/041/





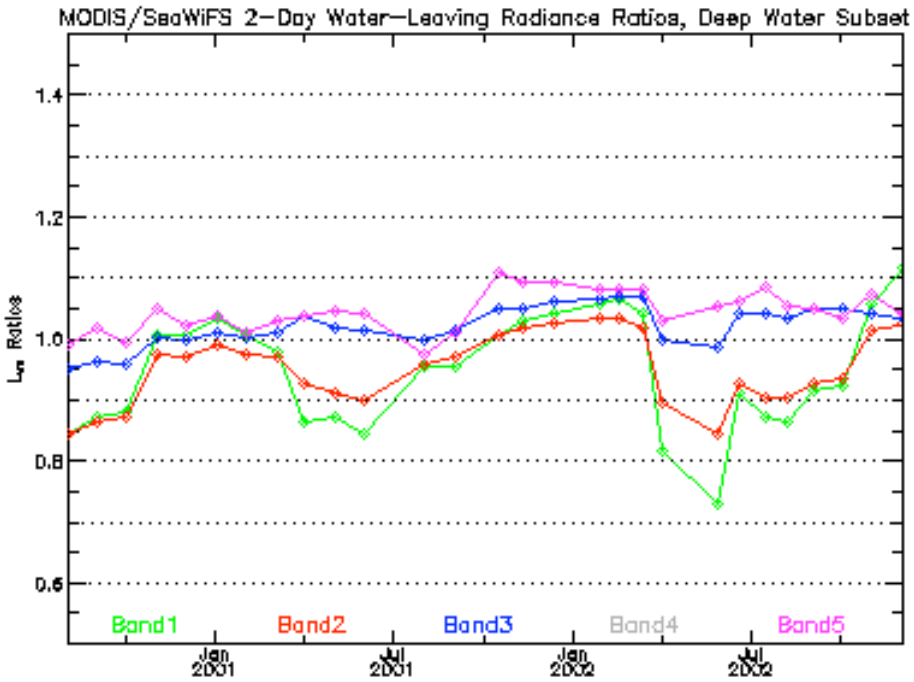
Now, Looking at “epoch” regional performance...



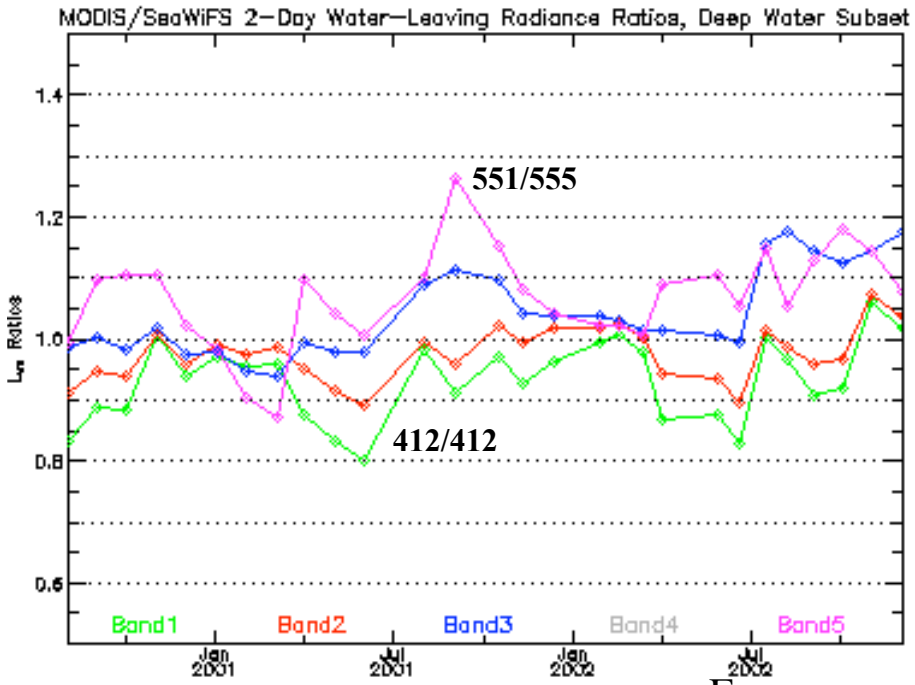
MODIS/SeaWiFS nLw Ratios

MODIS Temporal Subset vs SeaWiFS 4th Reprocessing Deep-Water Means

Collection 4.0



Collection 4.1



Franz

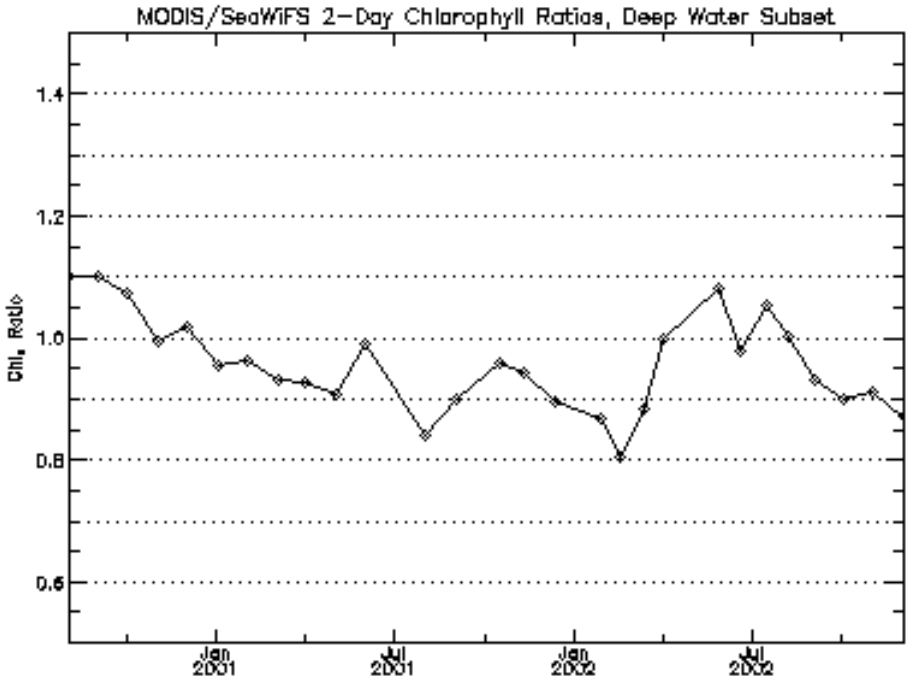
Deviations between sensors generally larger, some improvement in blue bands (412,443), larger deviations in green bands.

MODIS/SeaWiFS Chlorophyll Ratios

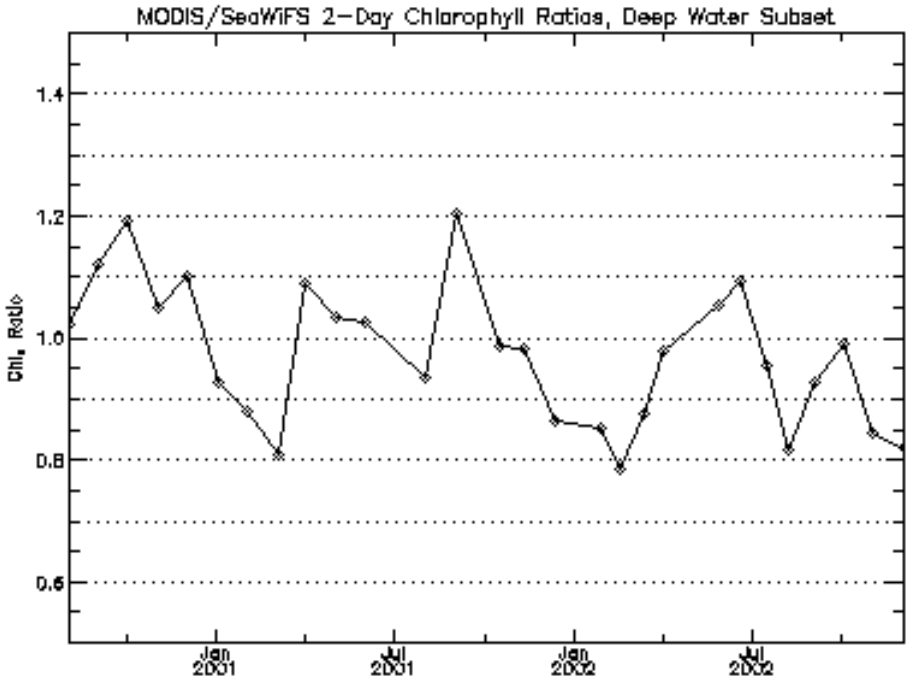
MODIS Temporal Subset vs SeaWiFS 4th Reprocessing

Deep-Water Means

Collection 4.0



Collection 4.1

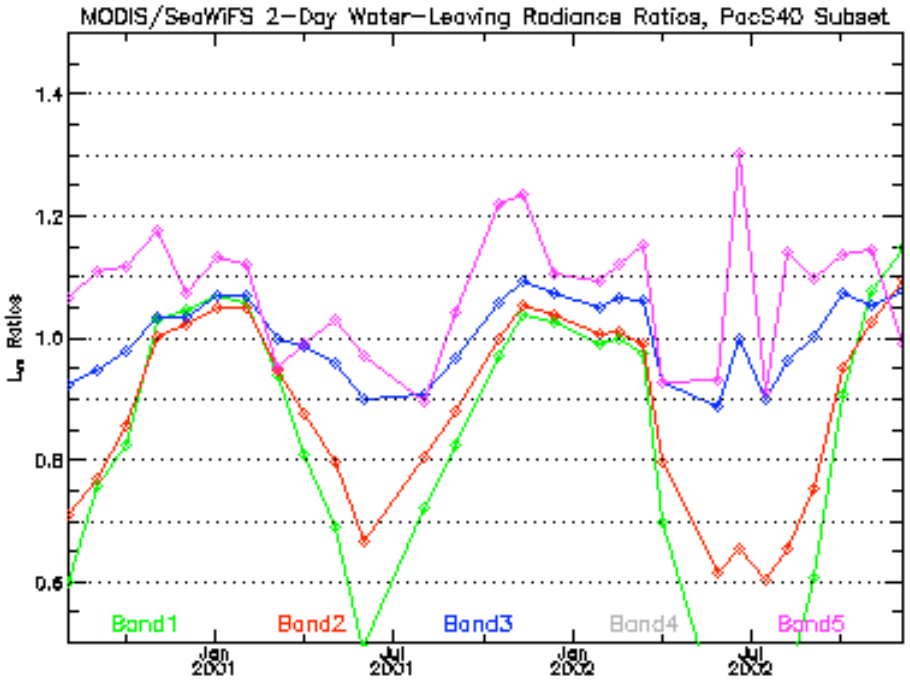


Deviations between chlorophyll products have also increased, likely related to the increased variability in the green. Agreement very good on average (SeaWiFS = 0.185 +/0.02, MODIS = 0.179+/- 0.02 mg/m^3)

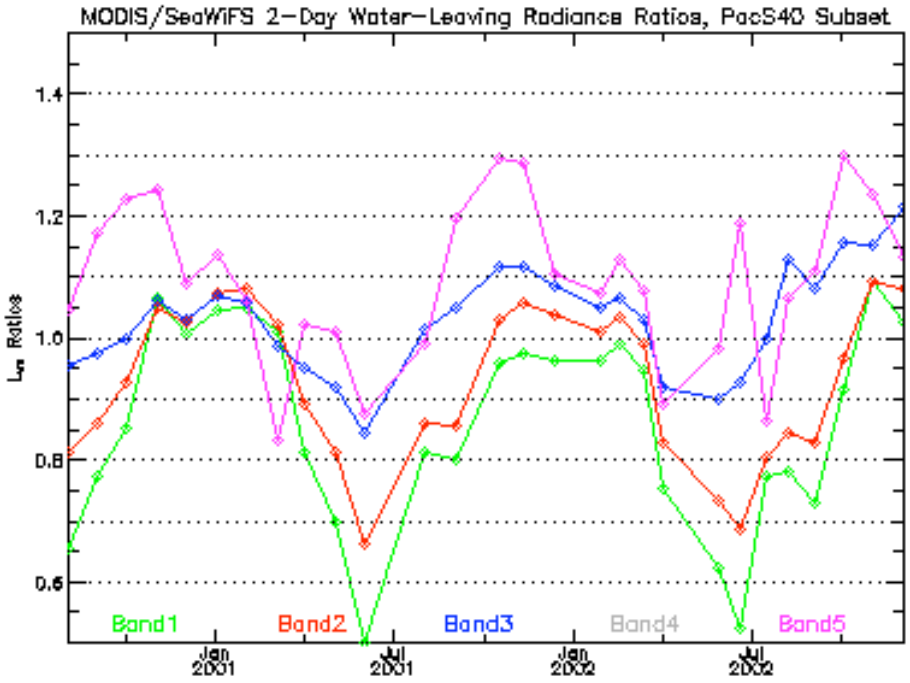
MODIS/SeaWiFS nLw Ratios

MODIS Temporal Subset vs SeaWiFS 4th Reprocessing
PacS40 (30S-40S, 150W-170W) Means

Collection 4.0



Collection 4.1



Franz

MODIS radiances still show seasonal low in the austral winter, relative to SeaWiFS. No major change was expected.

Reasons for the SeaWiFS MODIS differences:

Atmospheric Correction Impacted by Characterization

MODIS - off noon, is more sensitive to Polarization and ocean BRDF effects

Both Pol and BRDF are strong functions of solar angles, scan angles, as is MODIS calibration. MODIS lacks unambiguous characterization/knowledge of these terms. For MODIS, correlation of errors must be better understood and minimized.

Stray Light and out - of - band contributions are questionable, and vary as latitude and sun angle as well.

SeaWiFS exhibits a well defined and stable calibration change with time.
Polarization is very small, and unchanging.
BRDF effects are symmetrical across swath.

This enables band/band gains and RVS to be adjusted for the full mission by comparison with MOBY independently, in a single step.

MODIS exhibits multiple epochs in band to band gain characteristics, with changing RVS, (and polarization). BRDF is larger, and convolved with sun angles similar to polarization and seasonal SD variations.

Final adjustment has required epoch by epoch adjustments to a known location - MOBY. Delays and accuracy are unacceptable.

Candidate Sources for Differences

Calibration/Characterization

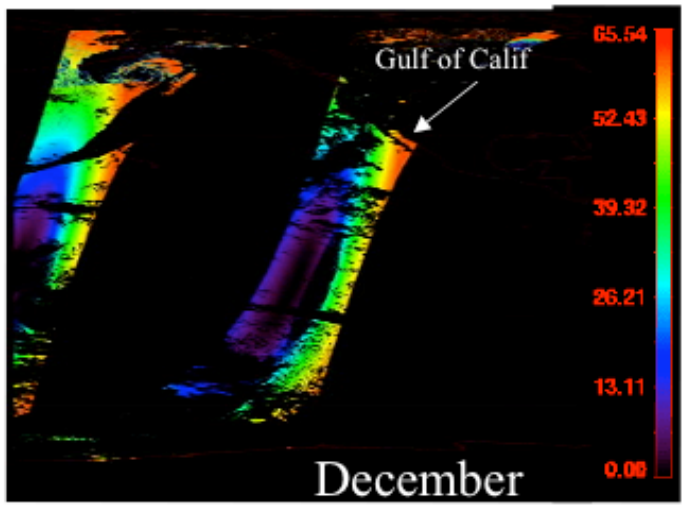
- RVS
- Polarization
- Oceanic in water BRDF
  - has latitude, biological, roughness dependencies
- Stray Light

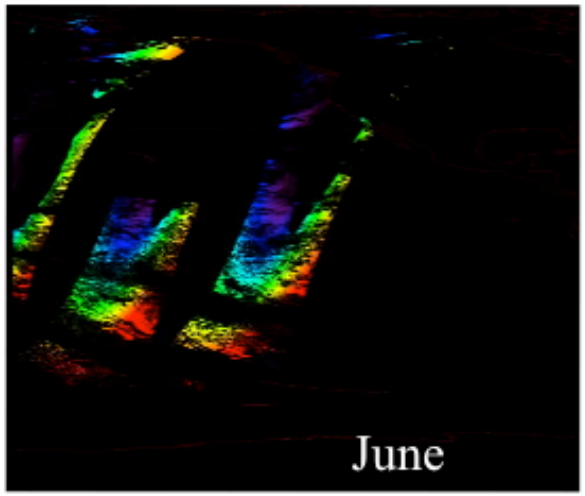
Stability

Correction Algorithms

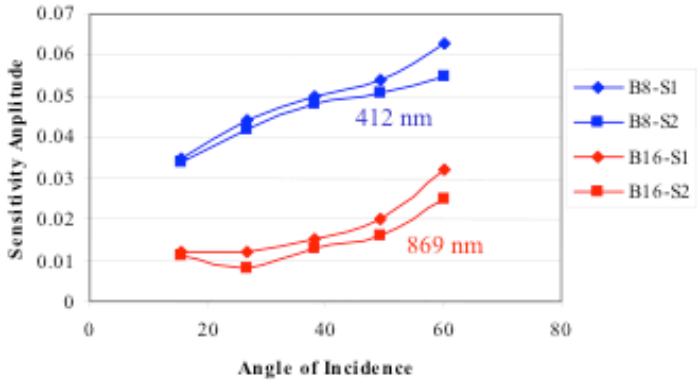
Degree. of Polarization P (%)

(Pure Rayleigh Atmosphere)





MODIS Polarization Sensitivity Amplitude a



Maximum error in measurement of the top-of-atmosphere radiance due to polar. sensitivity is $\pm aP$.

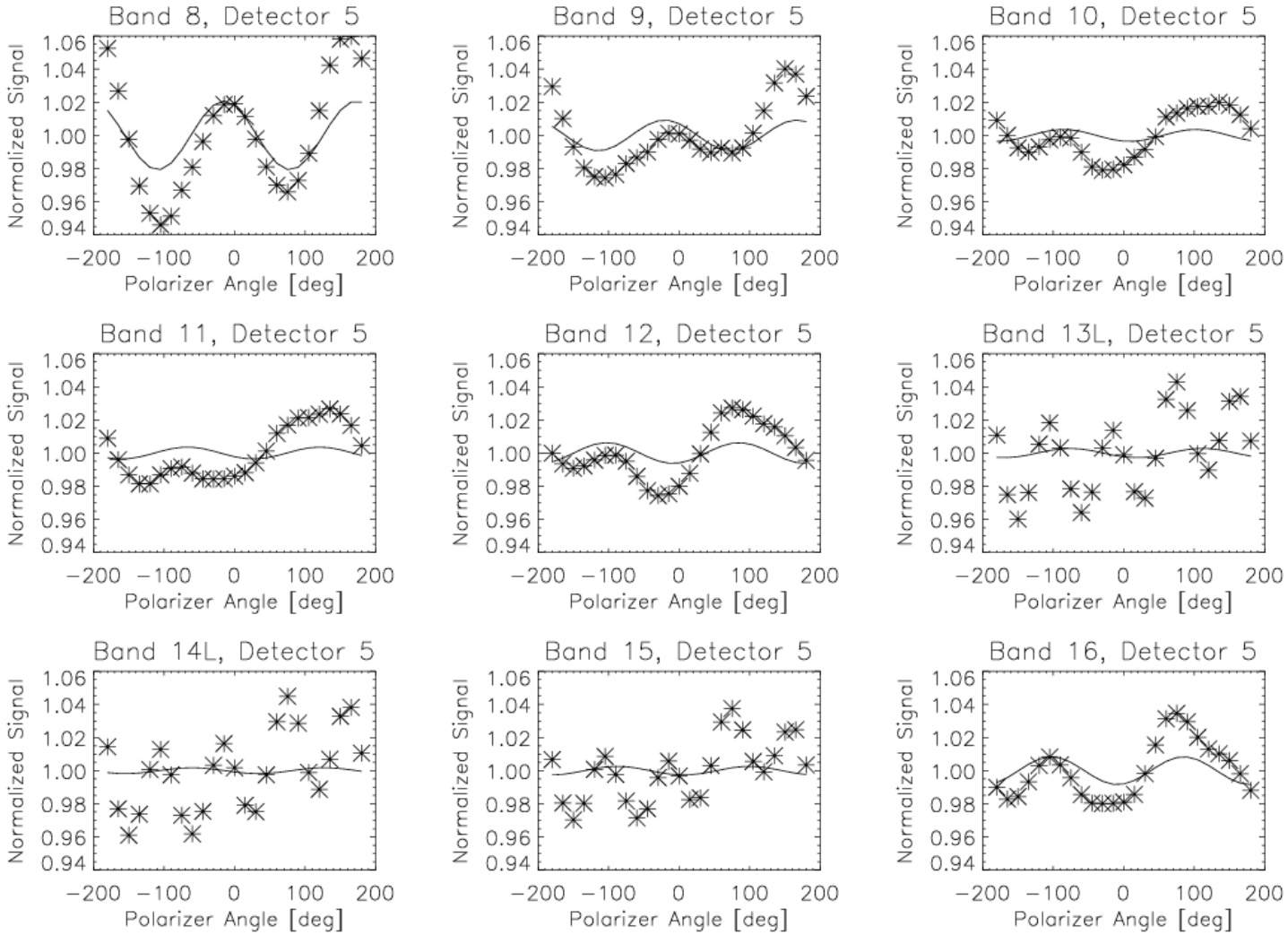
$\pm 4\%$

Note: a radiance error of 1% at 412 nm results in a water-leaving radiance error of ~ 10%.

MODIS Aqua Polarization Test Results

Trends

4 cycles

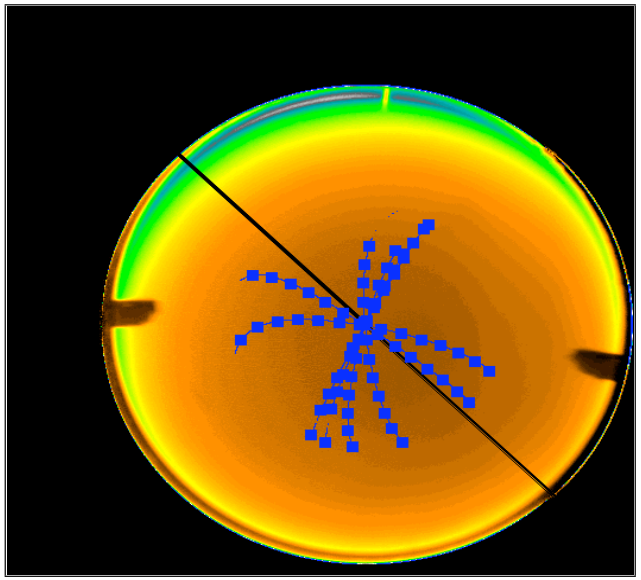


The proper cos2 response must be derived by Fourier analysis of the measurements, which is degraded by the coarse resolution, trends, and poor SNR. Changes on orbit are expected, but uncontrolled.

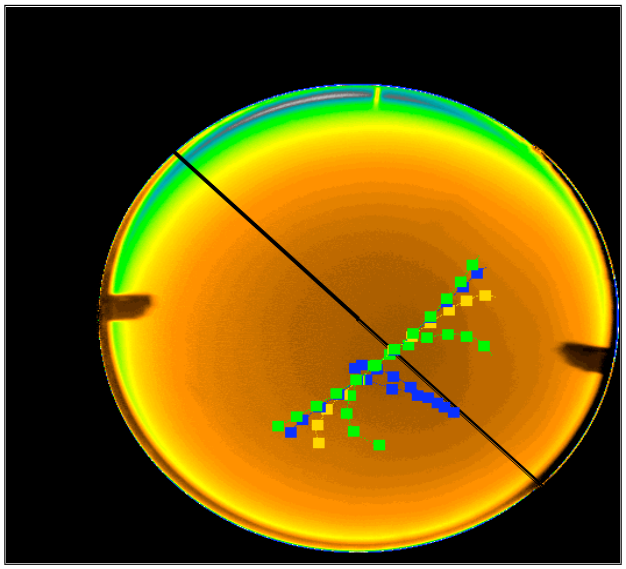
In-Water BRDF

A view along representative swaths in Northern Hem.

MODIS (Terra), 0-80N



SeaWiFS, 0-80N



- MODIS vs. SeaWiFS scan geometries displayed with an upwelling radiance distribution image.
- SeaWiFS tends toward scan lines oriented perpendicular to the principal plane, while MODIS actually has some oriented along the principal plane (very large variation in BRDF).
- The in-water BRDF correction currently has large uncertainties.

» Voss Gordon

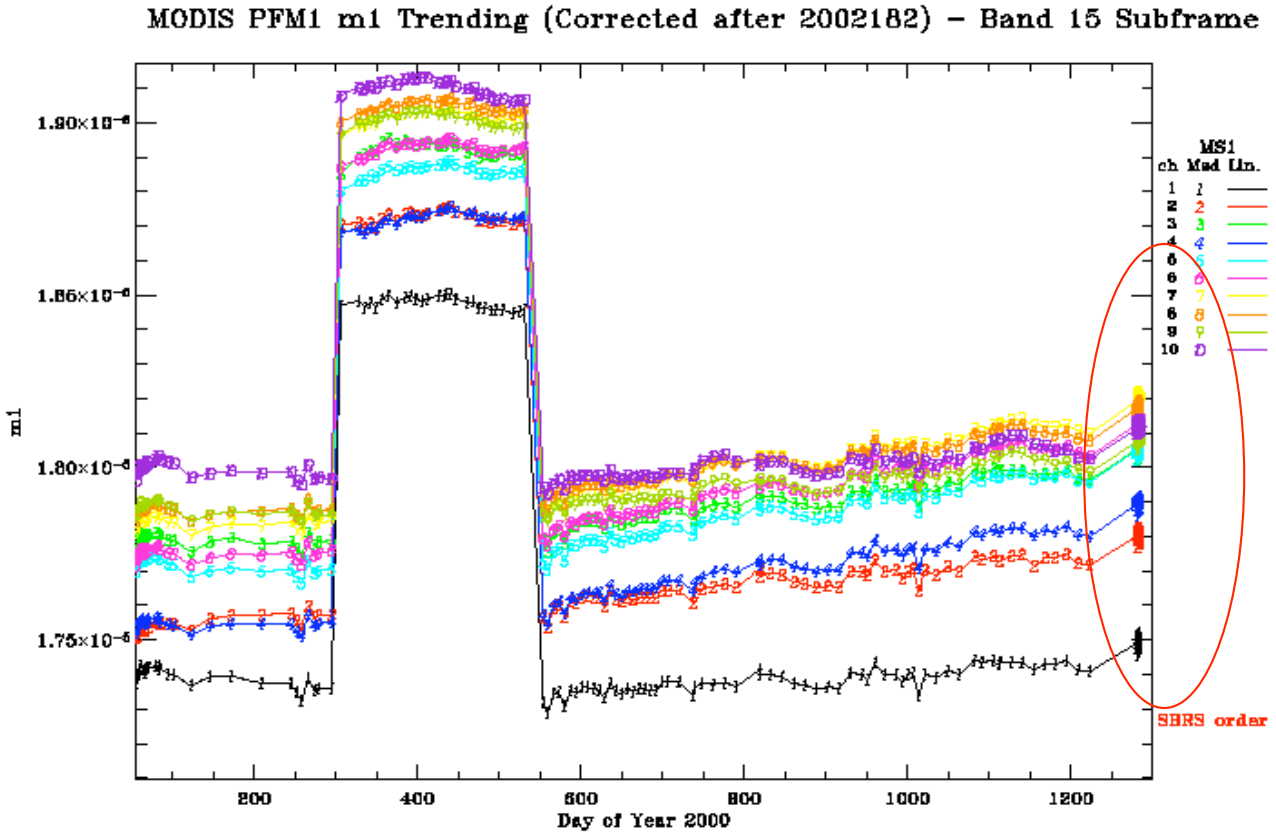
Physics

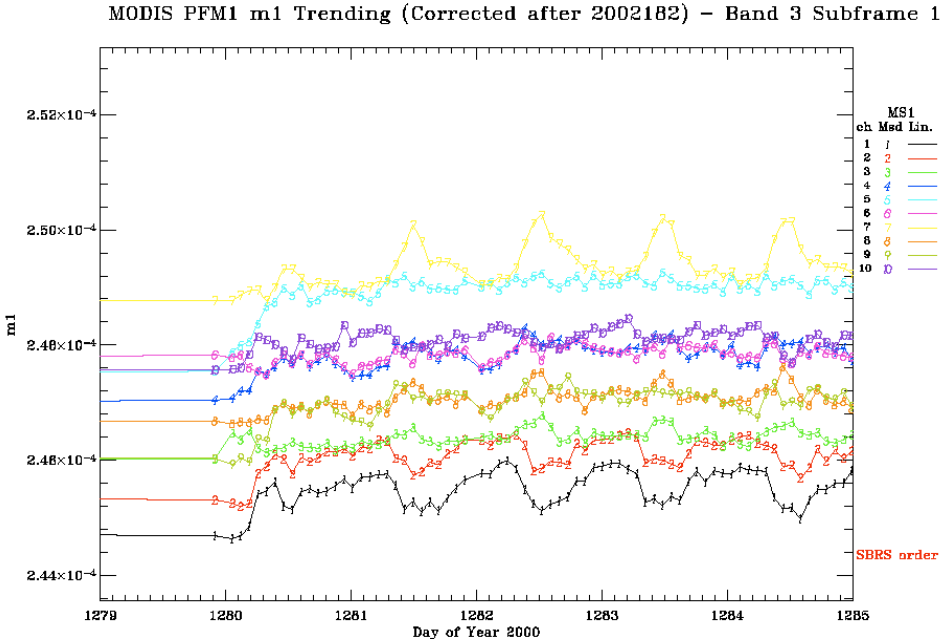
Solar Diffuser Performance

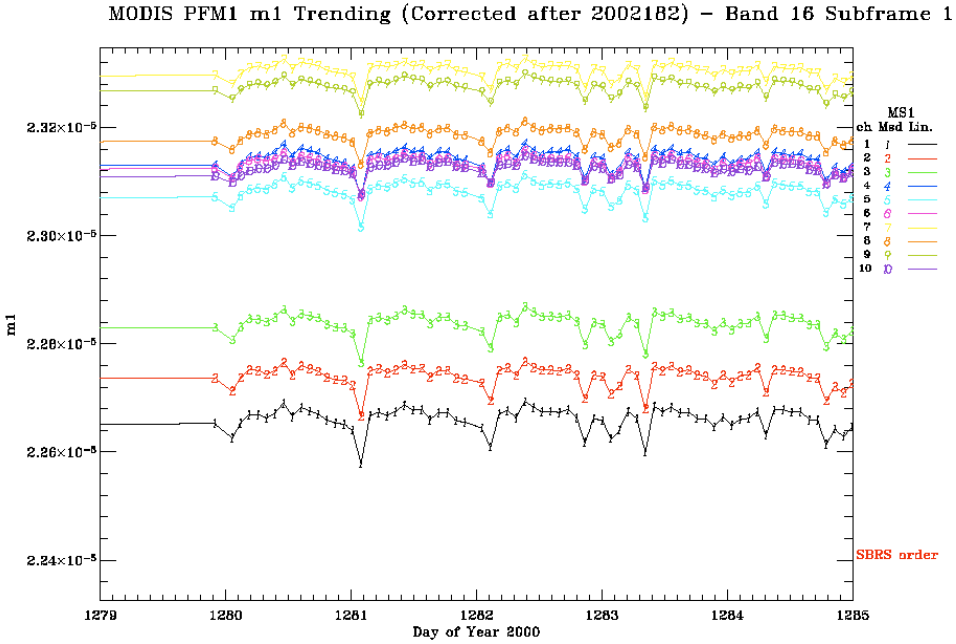
1. Use of a pinhole attenuation screen has not been documented to yield precise unbiased results with MODIS.
2. SD signal is contaminated (needlessly?) with Earthshine, for which a correction/solution is lacking.
3. Manifests itself as an additive signal, with an orbital and seasonal variation of $> 0.3\%$ to 3%.
4. Degree of contamination of VIIRS would seem to be greater than MODIS due to the larger opening.

5. The response over the field of regard must be mapped, and, if at all possible, the Earthshine needs to be blocked completely.

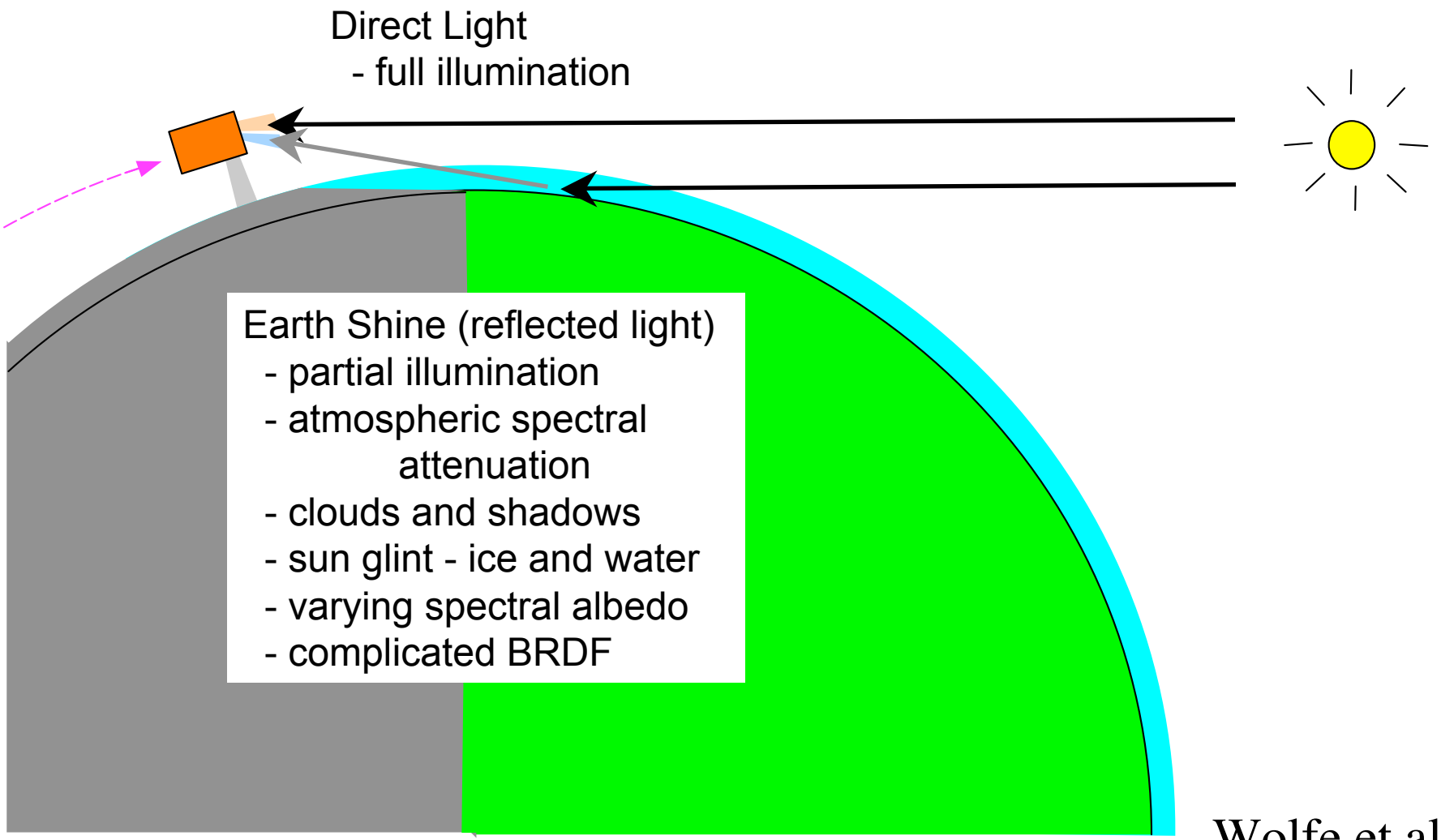
Understanding SD measurement variation – What is the Earth shine contribution?




MODIS PFM1 m1 Trending (Corrected after 2002182) - Band 3 Subframe 1
m1
2.52×10⁻⁴
2.50×10⁻⁴
2.48×10⁻⁴
2.46×10⁻⁴
2.44×10⁻⁴
1279
1280
1281
1282
1283
1284
1285
Day of Year 2000
MS1
ch Msd Lin.
1 1
2 2
3 3
4 4
5 5
6 6
7 7
8 8
9 9
10 10
SBRS order

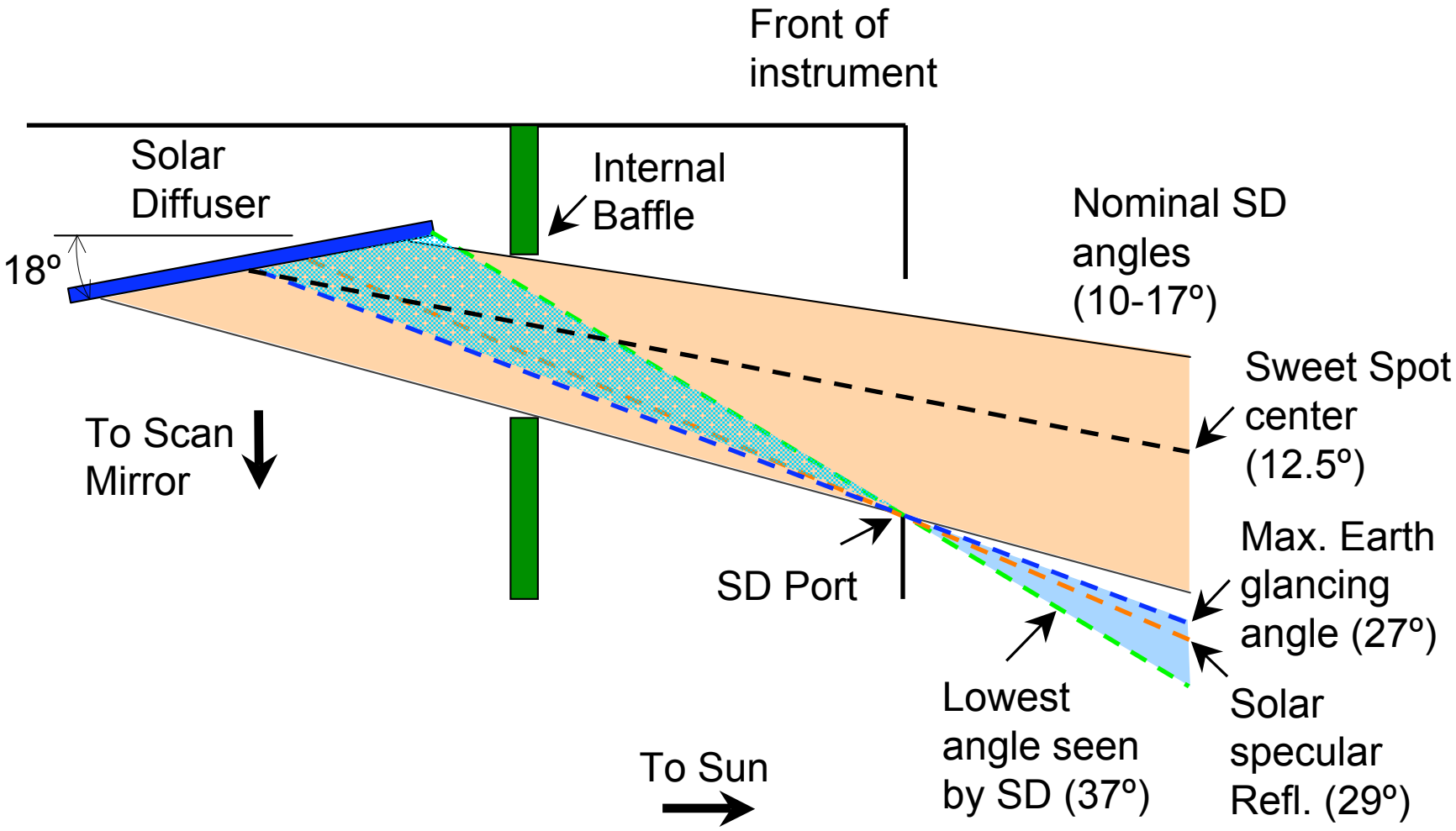

MODIS PFM1 m1 Trending (Corrected after 2002182) - Band 16 Subframe 1
m1
2.32×10⁻⁵
2.30×10⁻⁵
2.28×10⁻⁵
2.26×10⁻⁵
2.24×10⁻⁵
1279
1280
1281
1282
1283
1284
1285
Day of Year 2000
MS1
ch Msd Lin.
1 1
2 2
3 3
4 4
5 5
6 6
7 7
8 8
9 9
10 10
SBRS order

Simplified SD Geometry



Wolfe et al

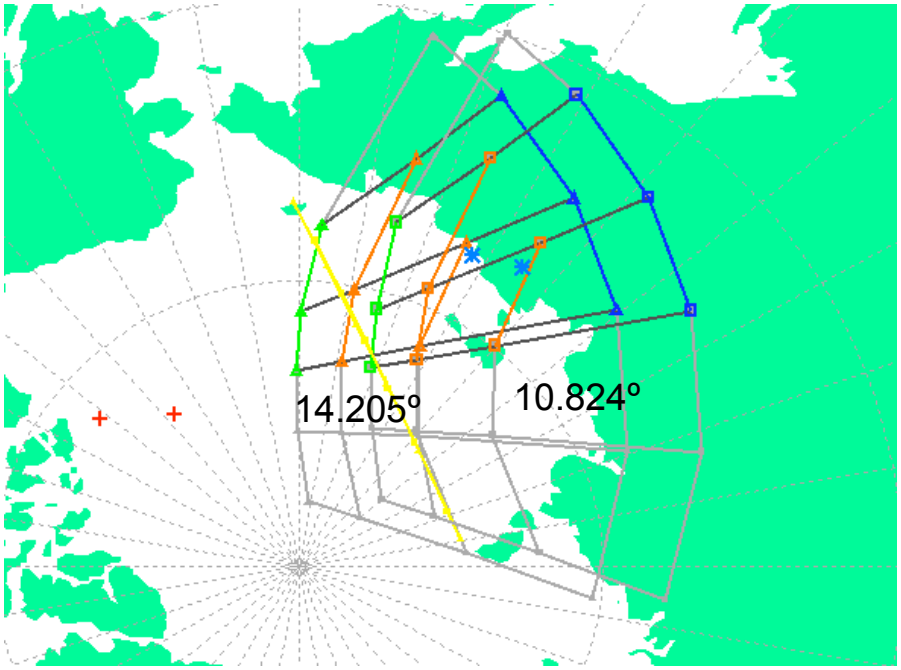
MODIS Solar Diffuser Geometry

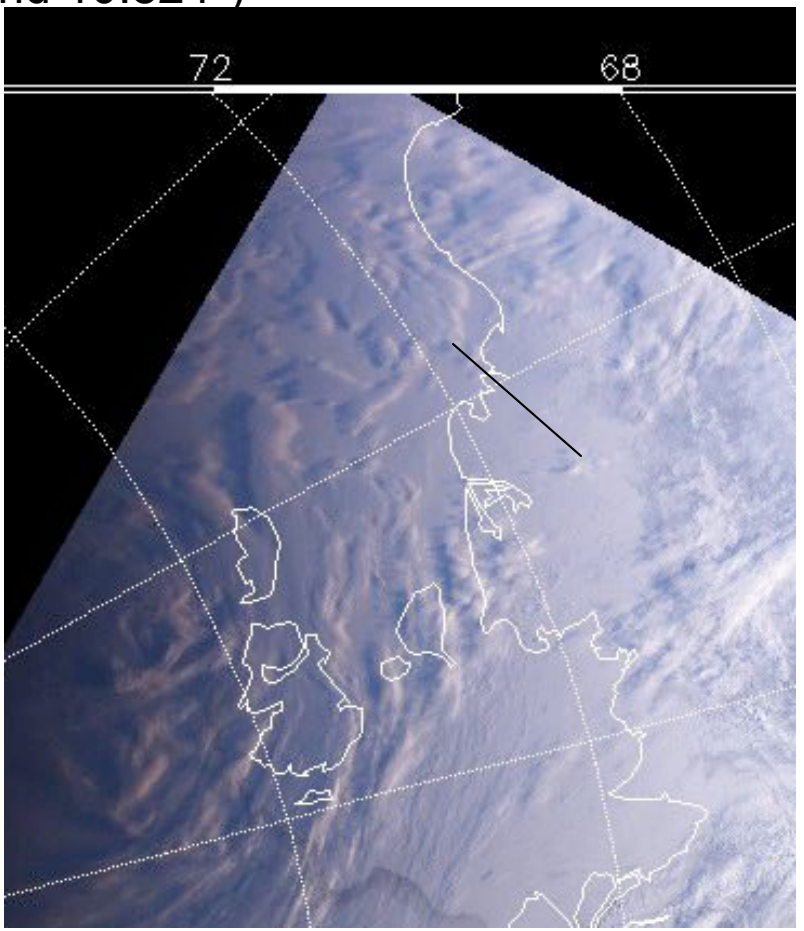


Wolfe et al

Solar Diffuser Stray Light from Earth Surface

2000/059.0435.91 and 0436.92 (14.205º and 10.824º)





Key:
- Red plus – Sub-satellite point
- Yellow line – Terminator
- Green line – Lowest angle seen by SD (37.2º)
- Orange lines – 4º and 8º above lowest SD angle (33.2º and 29.2º)
- Dark blue line – Earth limb (glancing angle, 27º to 32º)
- Light blue star – Specular reflection angle (view zenith == solar zenith, relative azimuth == 180º)
- Light gray line – Stray light from sides

Wolfe et al

ISS photo of sunrise over the Pacific

Wolfe et al

Pacific Ocean 07/21/2003 ISS007E 377 km Alt.

The MODIS SD Uncertainty Budget needs reworking

- SD Characterization Uncertainties (SBRS):
  - NIST reference: 0.5%
  - Characterization of SBRC scattering goniometer: 0.7%
  - Transfer of NIST BRF scale to MODIS SD: 0.5% *
  - Solar diffuser characterization: 0.5%
  - Solar diffuser spatial non-uniformities: 0.7% *
  - Interpolation angular / spectrally: 0.1% *
  - Prelaunch to orbit insertion BRDF change: 0.5%
  - Characterization of 8.5% SD screen: 0.2%
  - SDSM solar 2% attenuation and SDS impact: 0.5%
  - On-orbit stray light elements during the use of the illuminated SD *
  - Solar illumination of the SD surrounds 0.3%
  - Earthshine through the SD door 0.3% *
  - Earthshine through nadir aperture door 0.1% *

Errors can be different at different illumination/viewing angles

RSS = 1.6% *

* = solar angle or seasonal components are present, effects can be additive, not random.

Recommendation

Restrict SD elevation FOV to exclude L_{earth}.

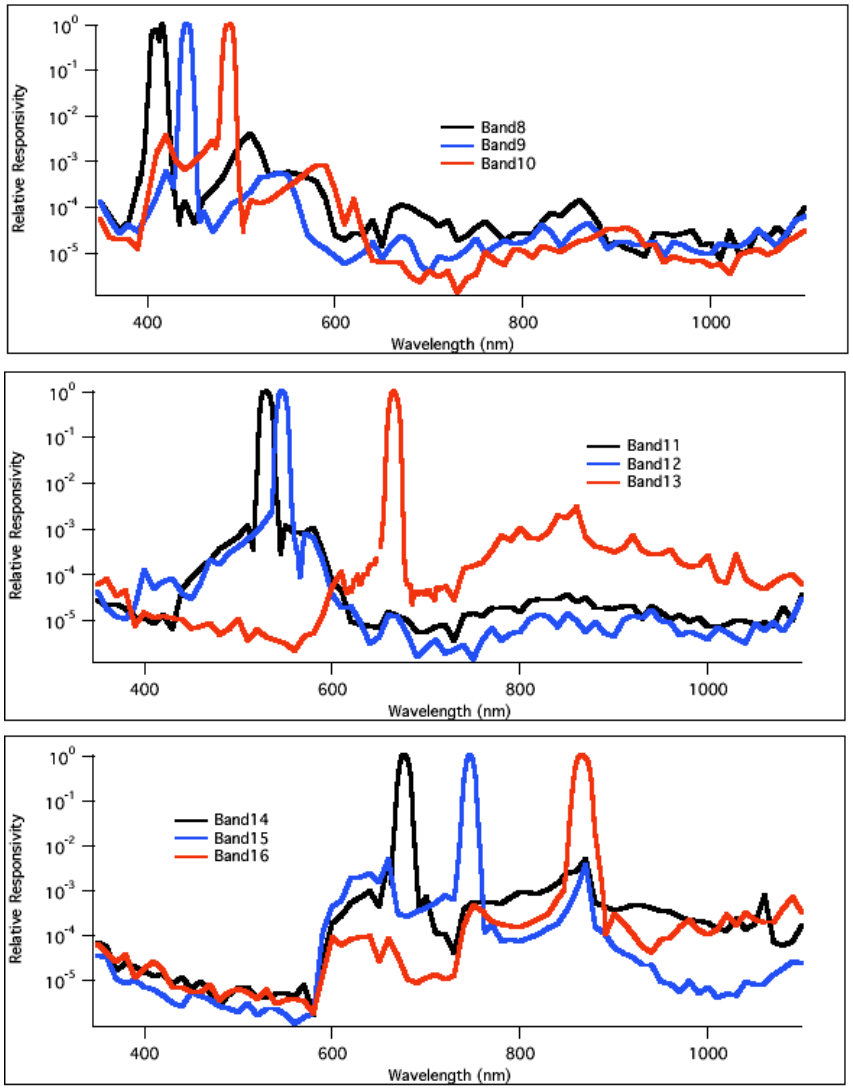
Map the spatial response of the SD assembly for all view angles, and try to develop a robust correction basis and algorithm.

Otherwise the SD will provide at best, only a long term Annual Average stability assessment, assuming that the instrument itself is stable over a 12 month period.

Redo the Uncertainty Budget.

Out of Band Spectral Response

MODIS total band RSR



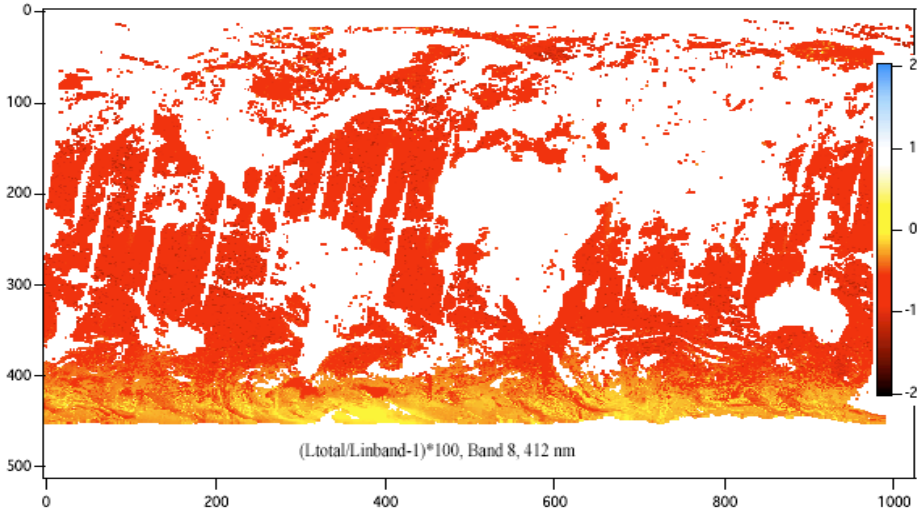
The total band responses are not included in MODIS calibrations, or L1 data. The test data are of questionable quality. Correction is required.

K. Voss & MCST

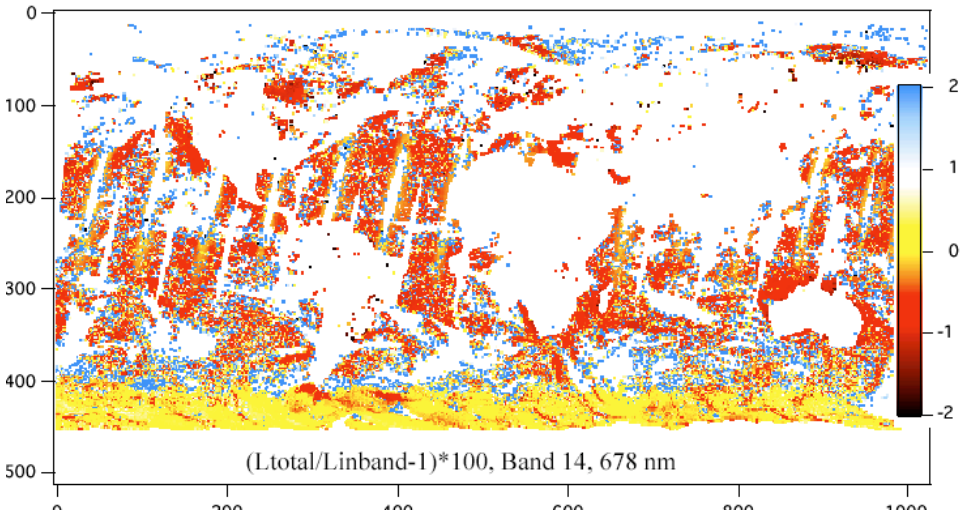
% Ltotal/Linband shows structure with geographical and seasonal variation.

Physics

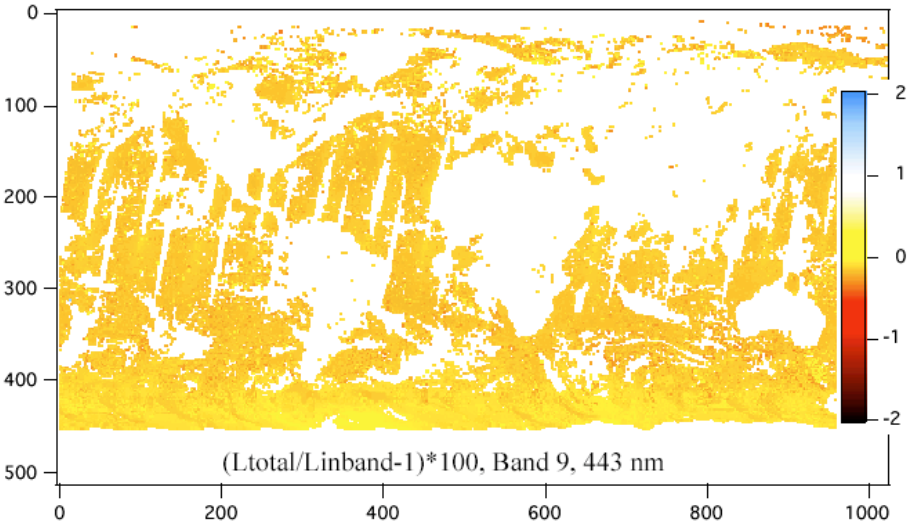
412 nm



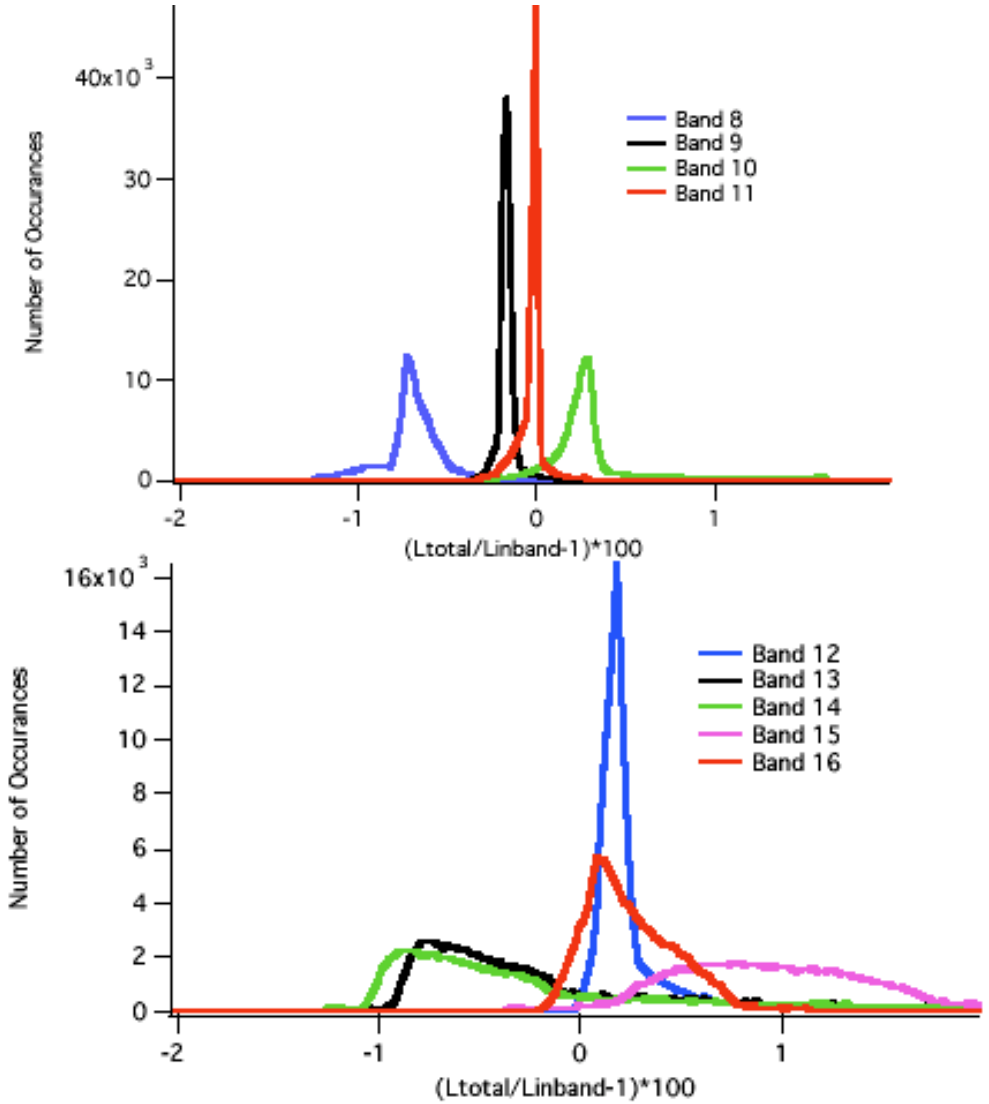
678 nm



443 nm



Global distributions of RSR are not uniform between bands, are poorly characterized.



Physics

MODIS Ocean Color Lessons for VIIRS

Improve performance and characterization of the Solar Diffuser and Stability Monitor.

Improve characterization of PSA.

SIRCUS testing is needed to characterize the out-of-band.

Improve characterization and analysis of stray light.

Optical modeling is required to address long term stability of polarization sensitivity on orbit.

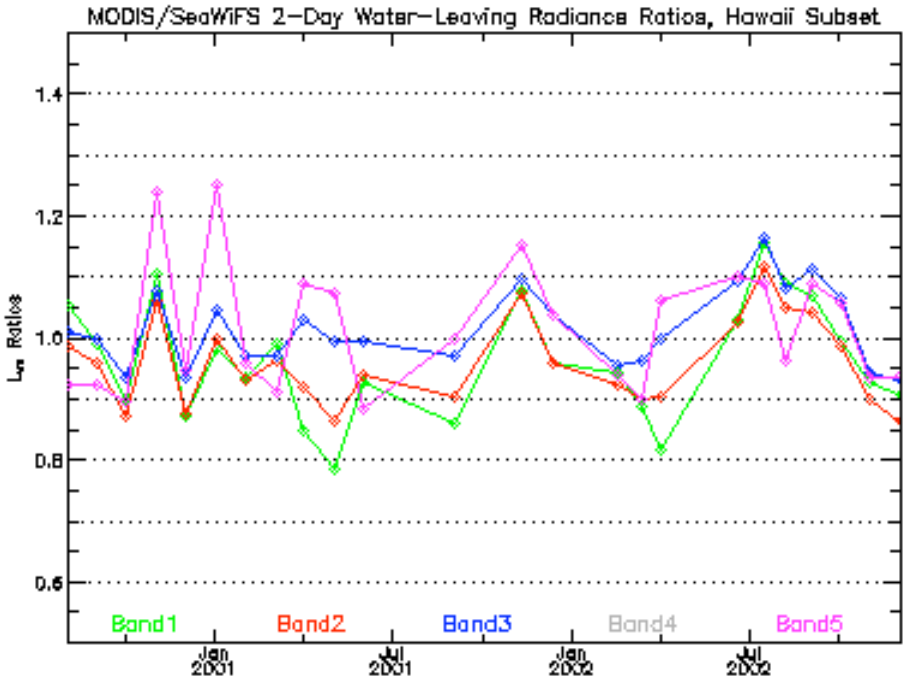
A greater level of effort, and greater coordination, will be needed post-launch to develop and implement the on-orbit corrections. They may not be successful without the recommended testing recommendations.

Backups

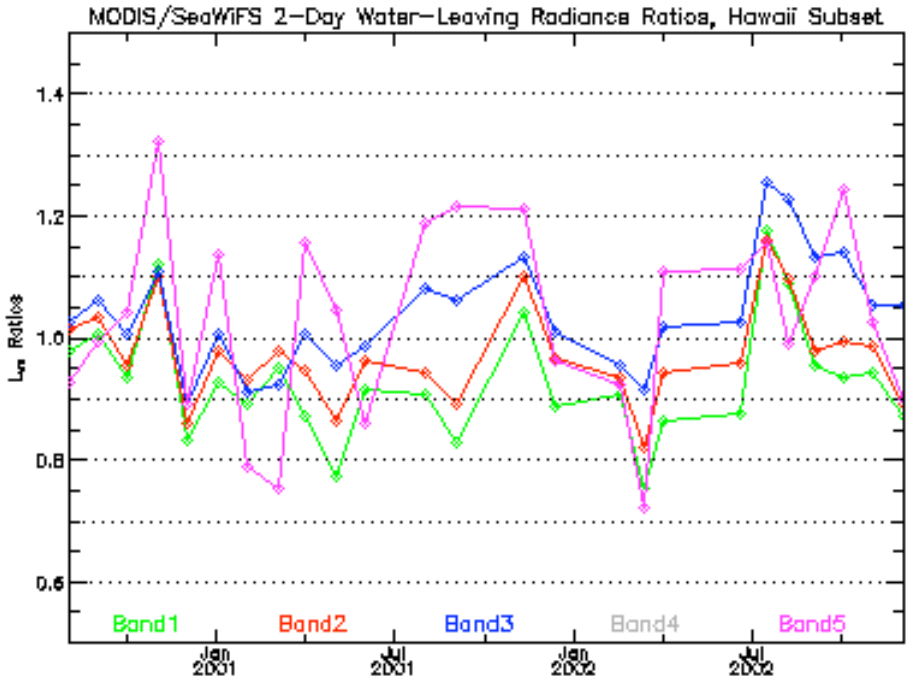
MODIS/SeaWiFS nLw Ratios

MODIS Temporal Subset vs SeaWiFS 4th Reprocessing
Hawaii Means

Collection 4.0



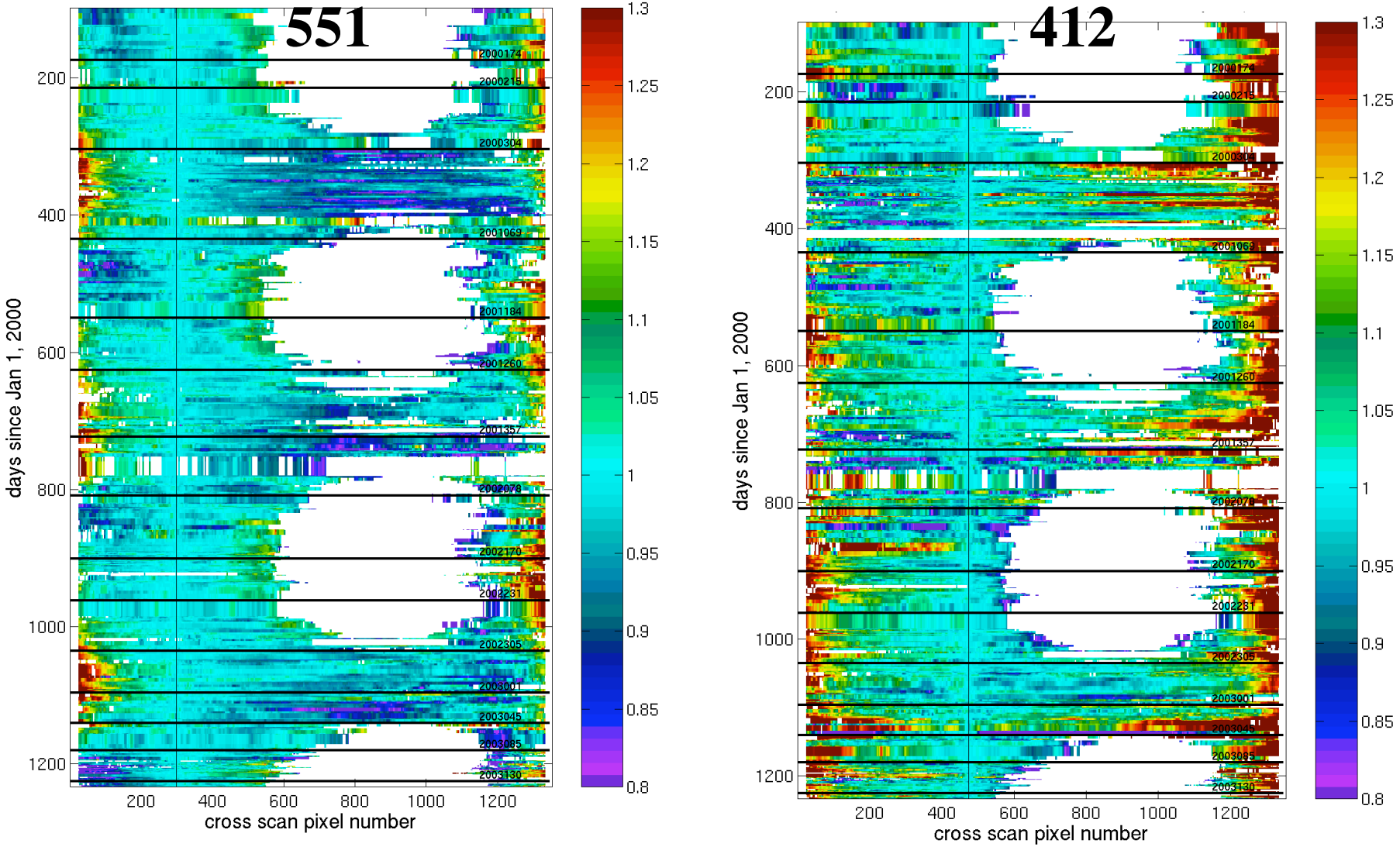
Collection 4.1



Franz

Mid-term variability has generally increased. This result was anticipated, given the use of measured SD/SDSM gains.

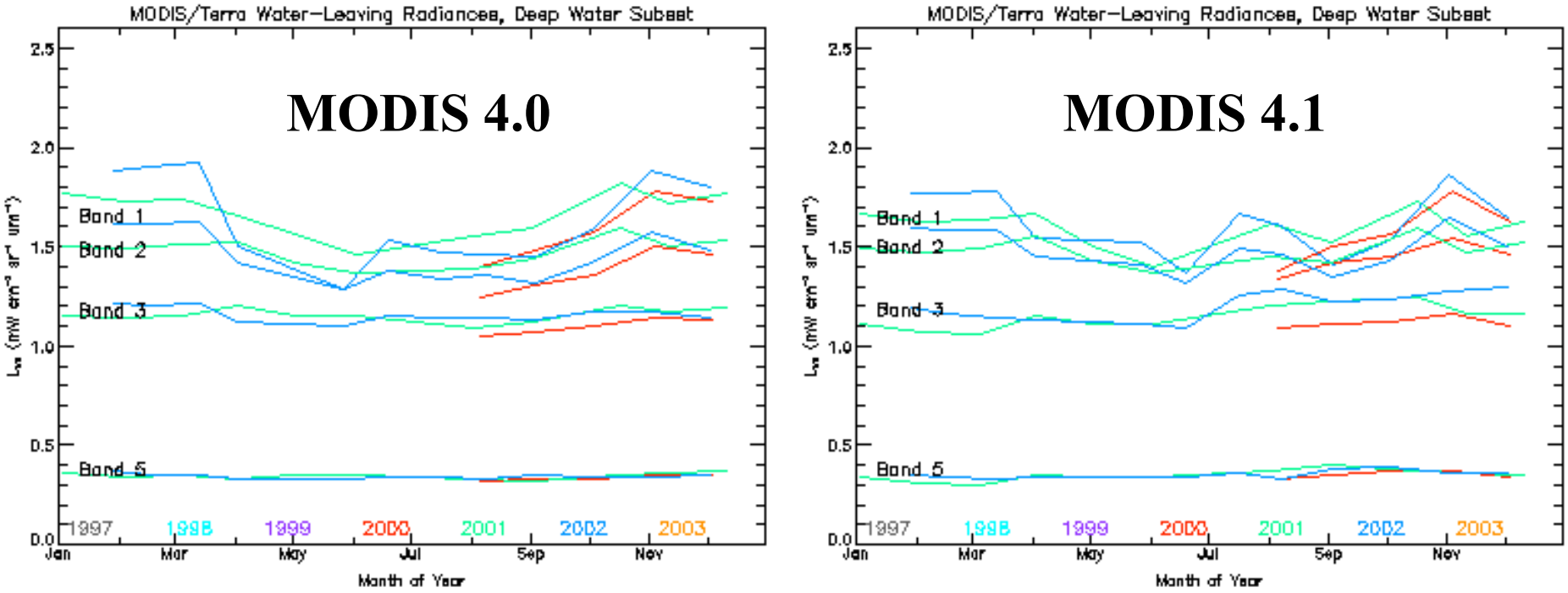
Cross Scan Difference - No Correction, Mirror Side 1
551 shows seasonal cross scan difference
412 difference more constant at scan edges



MODIS and SeaWiFS Annual Repeatability

MODIS Collection 4.0 vs MODIS Collection 4.1

Deep-Water Subset, 2-Day Bins

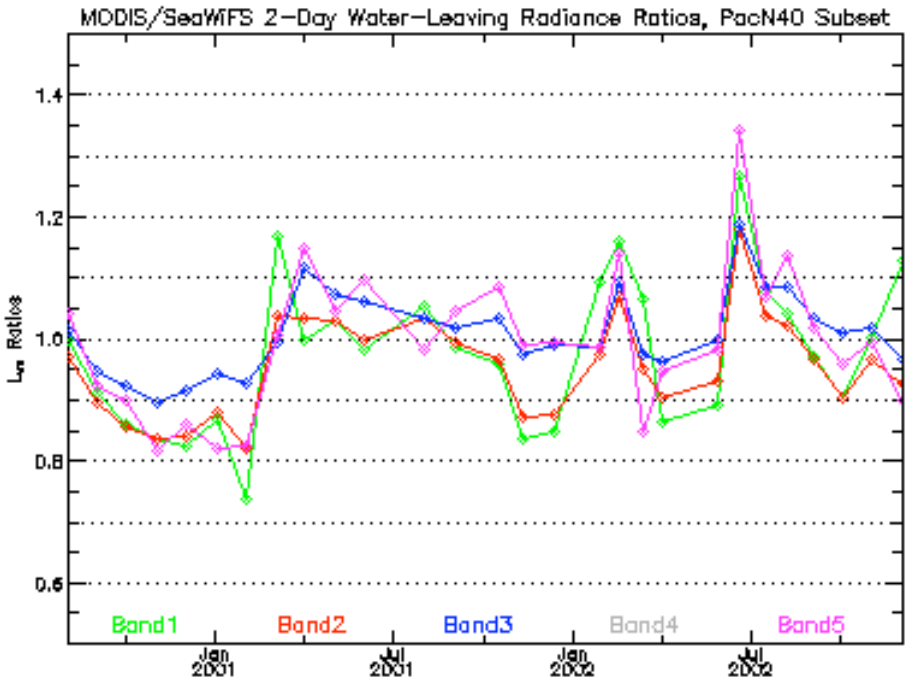


Temporal and spatial coverage is limited, but collection 4.1 shows evidence of improved repeatability in blue bands, degraded repeatability in green.[this results from the radcor procedure used]

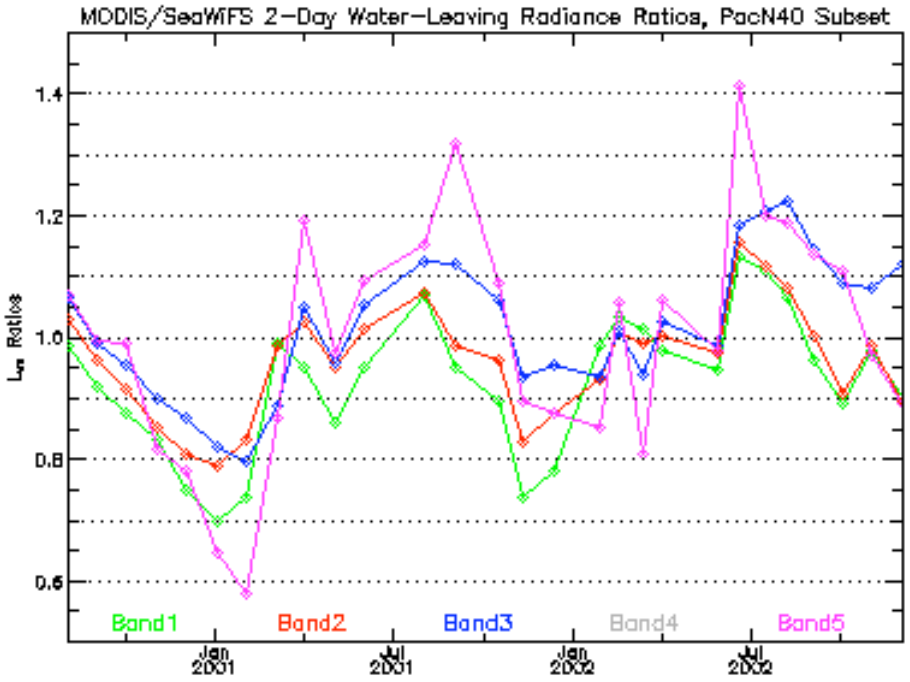
MODIS/SeaWiFS nLw Ratios

MODIS Temporal Subset vs SeaWiFS 4th Reprocessing
PacN40 (30N-40N, 150W-170W) Means

Collection 4.0



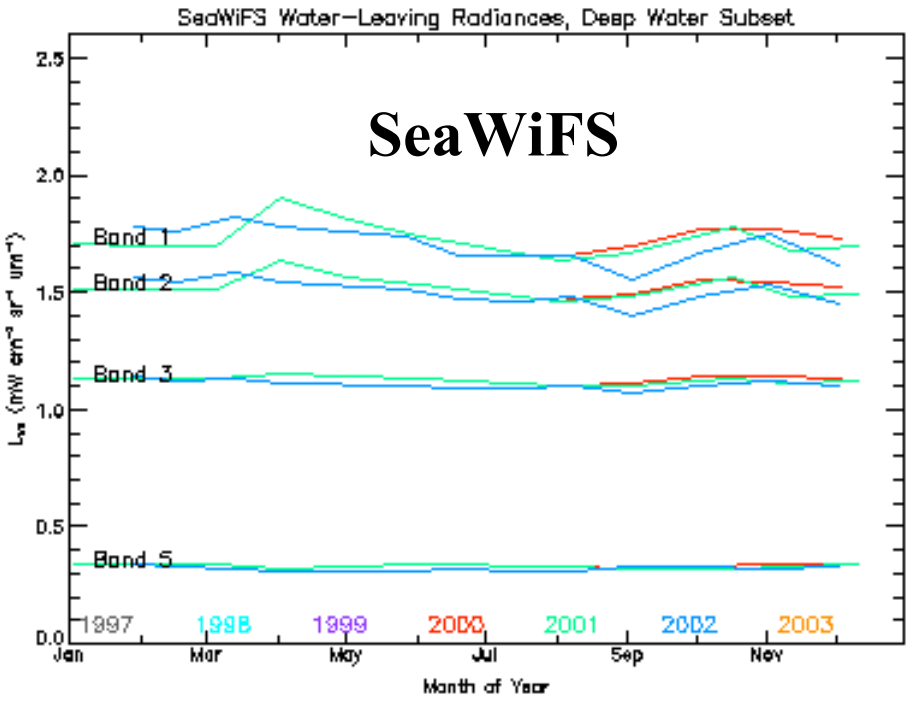
Collection 4.1

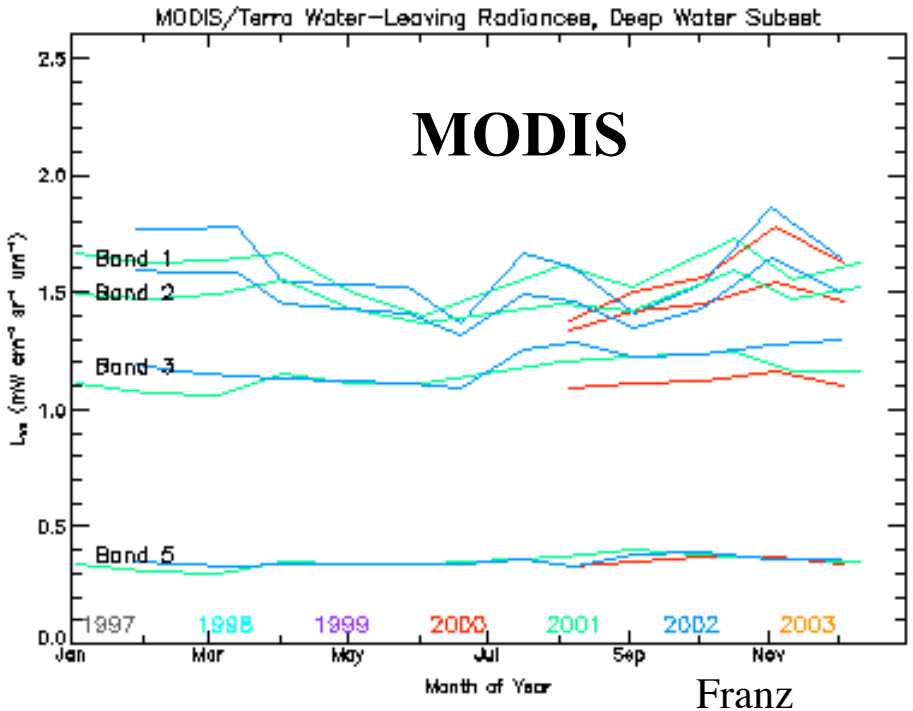


Deviations between MODIS and SeaWiFS radiances have increased in the northern latitudes. Seasonality appears opposite to SH.

MODIS and SeaWiFS Annual Repeatability

MODIS Collection 4.1 vs SeaWiFS 4th Reprocessing
Deep-Water Subset, 2-Day Bins





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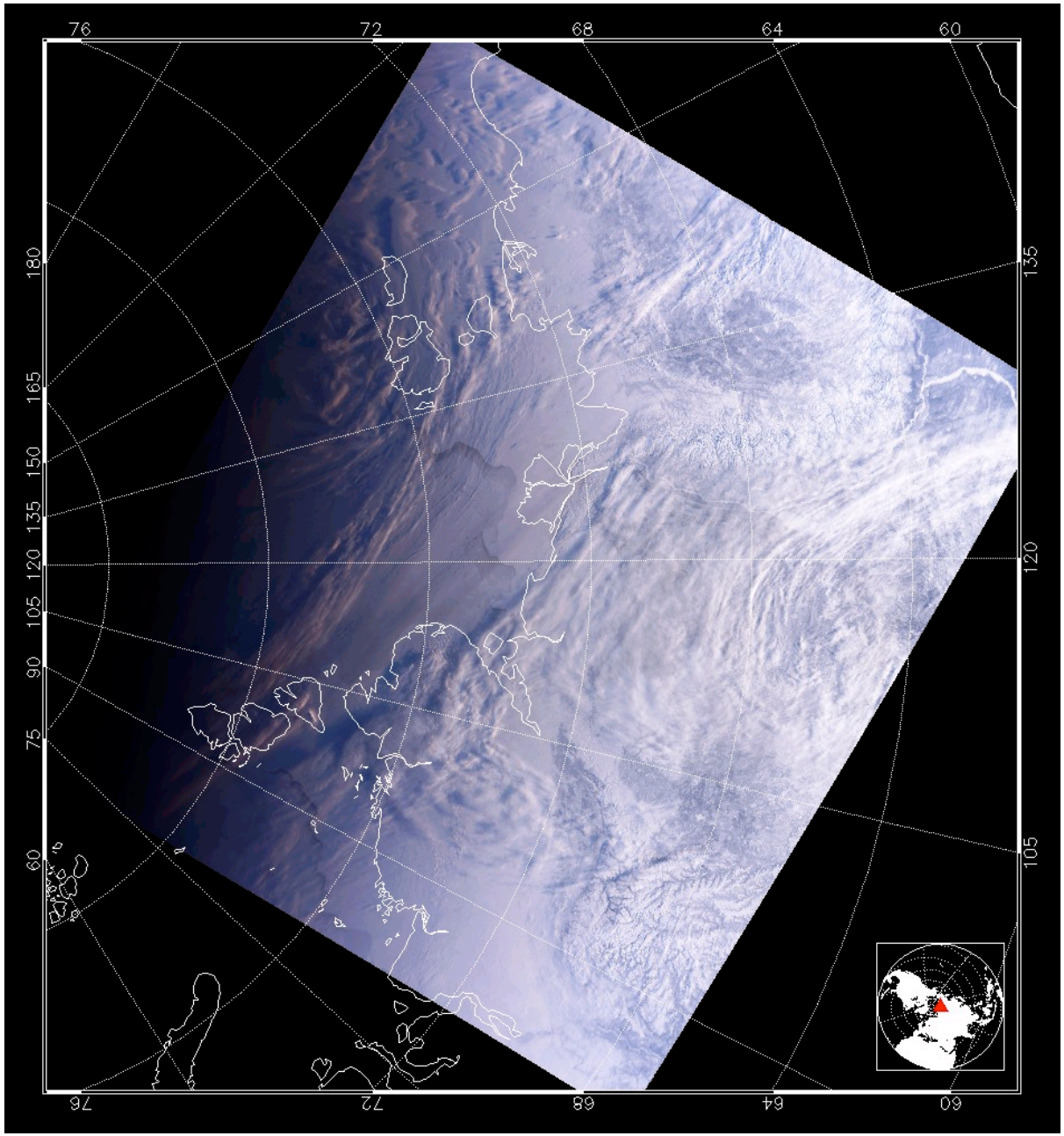
For exactly the same region, annual repeatability of deep-water subset for MODIS 4.1 is not at the level observed with SeaWiFS.

L1B image 2000/059.0440 (seen from nadir track direction, not near grazing geometry)



$L_{SD} = L_{sun} + L_{earth}$

$L_{earth} = f$ (Lsun, SD EFOV, grazing albedo (clouds, geography))

Determining Learth will be very difficult

$L_{SD} = L'_{sun} + \Delta L_{screen} + L'_{earth} + \Delta L_{earth}$

ΔL_{earth} (1day) ~ .3% (Wolfe, for one day in January for MODIS Terra)

L'_{earth}, ΔL_{earth} seasonal, (AM, PM) are still unevaluated
could be > 0.3 seasonally, and different for Aqua

SD FOV for VIIRS is larger than for MODIS, L earth will be larger.

If the earth limb was not seen by the SD, there would be no problem.