Satellite Ocean Biogeochemistry (OB) Climate Data Records

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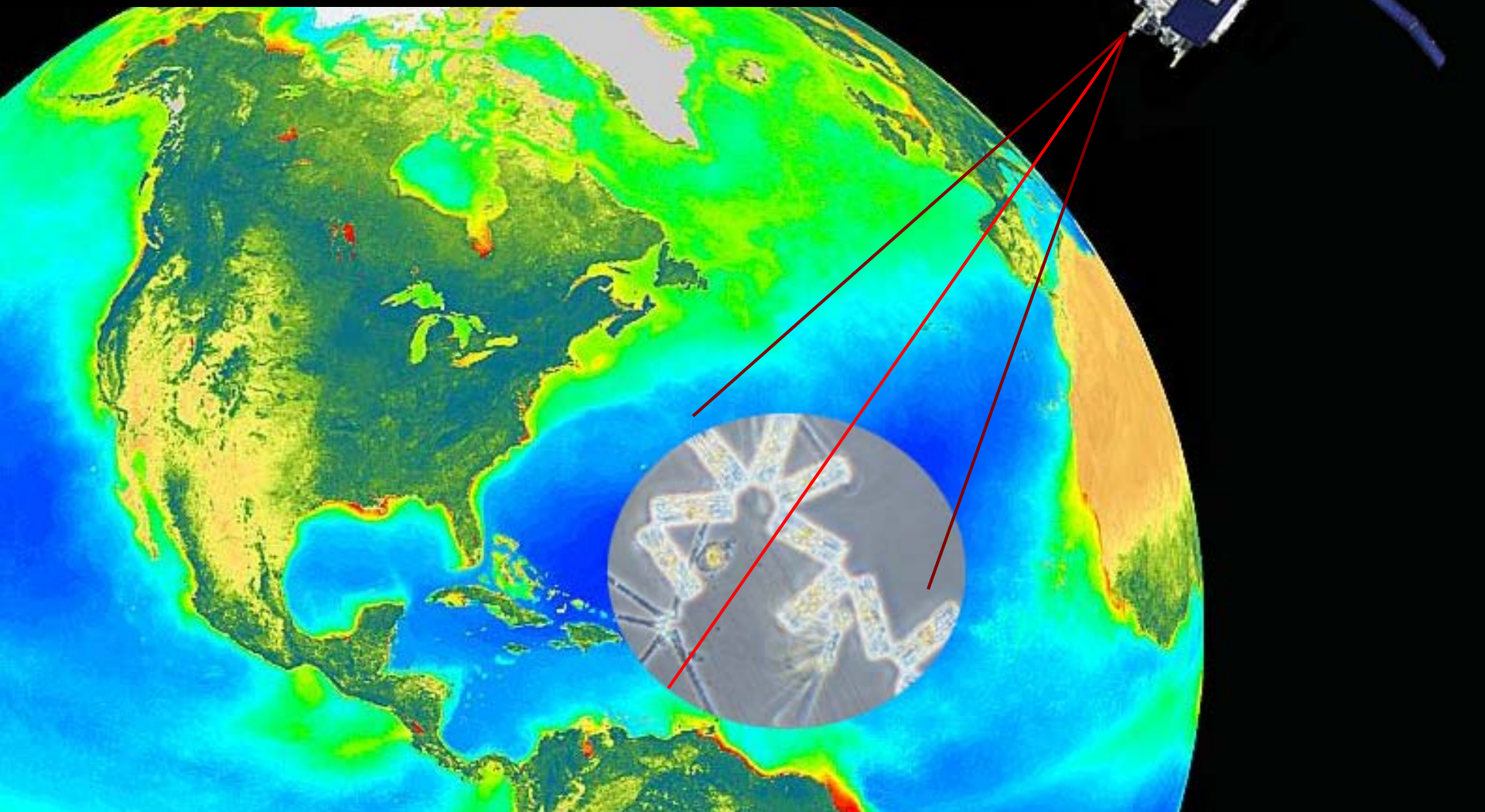


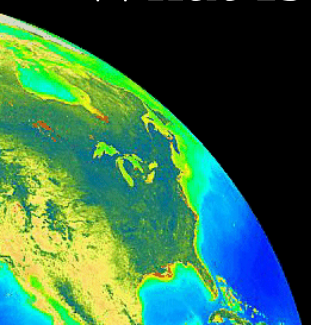
Climate Data Records

"A climate data record is a time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change."

NRC, *Climate Date Records from Environmental Satellites*, 135 pp., 2004.

What is sufficient time series length?

What is the magnitude of the climate variability (parameter dependent) to be measured?



OB CDRs: What's required

- Well-conceived sensor performance specifications
  - Polarization sensitivity, out-of-band response, temperature sensitivity, response vs. scan angle, stray light, cross-talk, etc.
- Thorough prelaunch sensor characterization
  - Mature/established test procedures and facilities
- Vicarious calibration facilities & support infrastructure
- Performance monitoring throughout mission lifetime
  - Monthly lunar calibrations (preferably at constant 7^{o} phase angle)
- Consistent algorithms across sensors/missions
  - Backward compatible with earlier sensors (includes compatible bands)
- Adequate in situ validation data
  - Accuracy, data volume, global distribution
  - Affordable & robust field instrumentation, calibration & measurement protocols
- Periodic data reprocessing with improved algorithms
- Overlap between missions time series
- Close collaboration between processing group, cal/val team, & science community
- Open data & processing software access (sensor & in situ)

SeaWiFS, MODIS, & VIIRS

- **SeaWiFS**
  - Rotating telescope
  - 412, 443, 490, 510, 555, 670, 765, 865 nm bands
  - 12 bit digitization truncated to 10 bits on spacecraft
  - 4 focal planes, 4 detectors/band, 4 gain settings, bilinear gain configuration
  - Polarization scrambler: sensitivity at 0.25% level
  - Solar diffuser (daily observations)
  - Monthly lunar views at 7° phase angle via pitch maneuvers

- **NPP/VIIRS (Ocean Color)**
  - SeaWiFS-like rotating telescope
  - MODIS-like focal plane arrays (16 detectors/band)
  - 12 bit digitization
  - No polarization scrambler
  - Solar diffuser with stability monitor
  - 7 OC bands (412, 445, 488, 555, 672, 746, 865 nm)
    - Dual gains except 746 nm (single gain)
  - Monthly lunar views at 55° phase angle via space view port with roll maneuvers (feasible, but not approved)

- **MODIS (Ocean Color)**
  - Rotating mirror
  - 413, 443, 488, 531, 551, 667, 678, 748, 870 nm bands
    - Single gain (NIR saturation)
  - 12 bit digitization
  - 4 focal planes (7-11 bands each)
    - OC Visible: 412-547 nm (5 bands-10 detectors each)
    - OC NIR: 667-869 (4 bands-10 detectors each)
  - No polarization scrambler: sensitivity at ~3% level
  - Spectral Radiometric Calibration Assembly (SRCA)
  - Solar diffuser (observations every orbit), Solar Diffuser Stability Monitor (SDSM)
  - Monthly lunar views at 55° phase angle via space view port

Sensor designs & performance are never identical.

Historical Ocean Color Accuracy Goals

- **Sensor radiometric calibration**

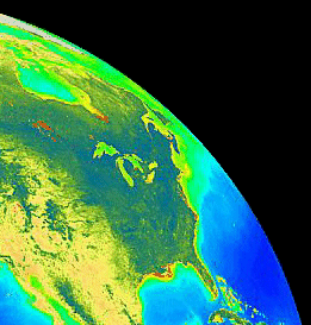
  ±0.5% absolute

- **Water-leaving radiances**

  ±5% absolute

- **Chlorophyll-a**

  ±35% over range of 0.05-50.0 mg/m^3



NASA Ocean Biogeochemistry Derived Products

- Normalized water-leaving radiances (±5%)
- Chlorophyll-a (± 35%)
- Diffuse attenuation coefficient (490 nm)

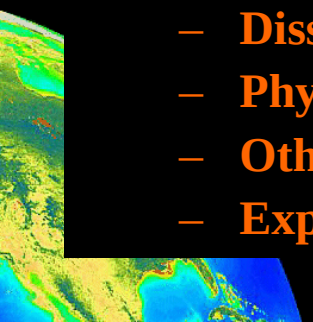
Current OBB CDRs

- Primary production
- Inherent optical properties (IOPs; spectral absorption & scattering coefficients)
- Particulate organic carbon concentration (POC)
- Calcite concentration (PIC)
- Colored dissolved organic matter (CDOM)
- Photosynthetically available radiation (PAR)
- Fluorescence line height (FLH)

Candidate OBB CDRs

- Particle size distributions & composition (biogenic, mineral, etc.)
- Functional/taxonomic group distributions
- Phytoplankton carbon
- Dissolved organic matter/carbon (DOM/DOC)
- Physiological properties (e.g., C:Chl, fluorescence quantum yields)
- Other plant pigments (e.g. carotenoids)
- Export production

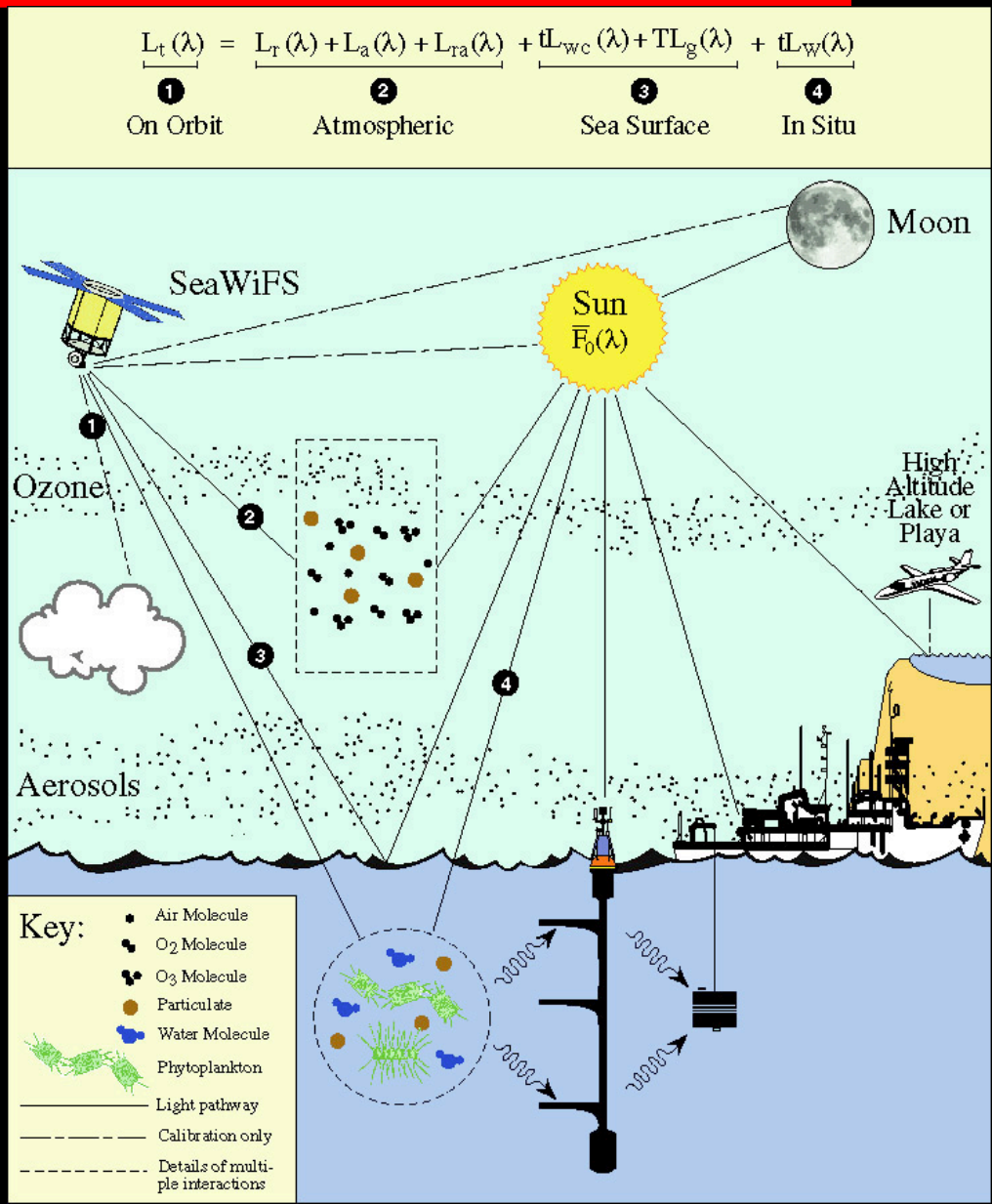
Research products



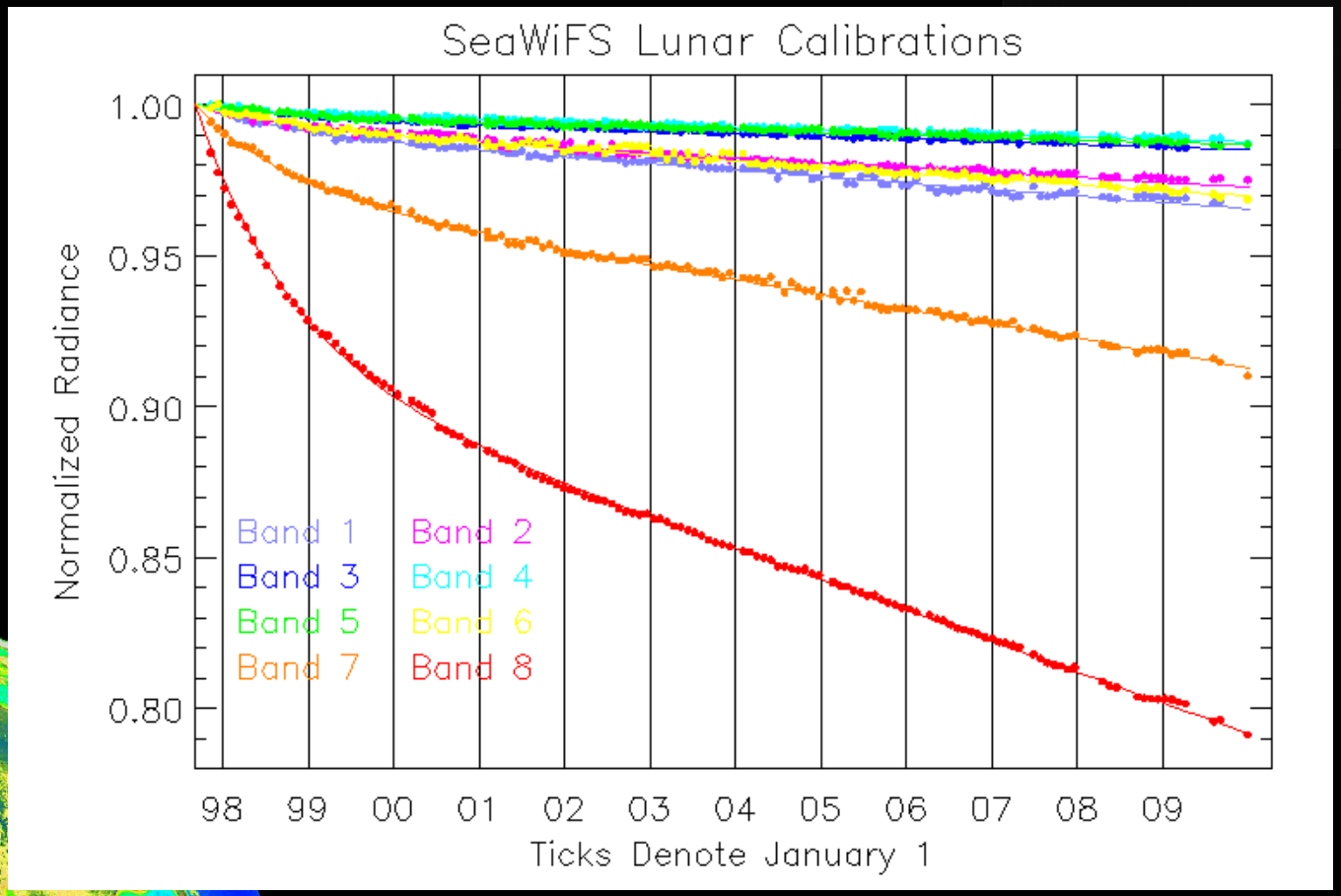
Calibration/Validation Paradigm

Program Elements:

- **Laboratory** - prelaunch sensor calibration & characterization
- **On-orbit** - solar and lunar observations used to track changes in sensor response
- **Field** - comparison of satellite data retrievals to in-water, above-water and atmospheric observations
  - Vicarious calibration - adjust instrument gains to match water-leaving radiances
  - Product validation (water-leaving radiances, chl-a, etc.)

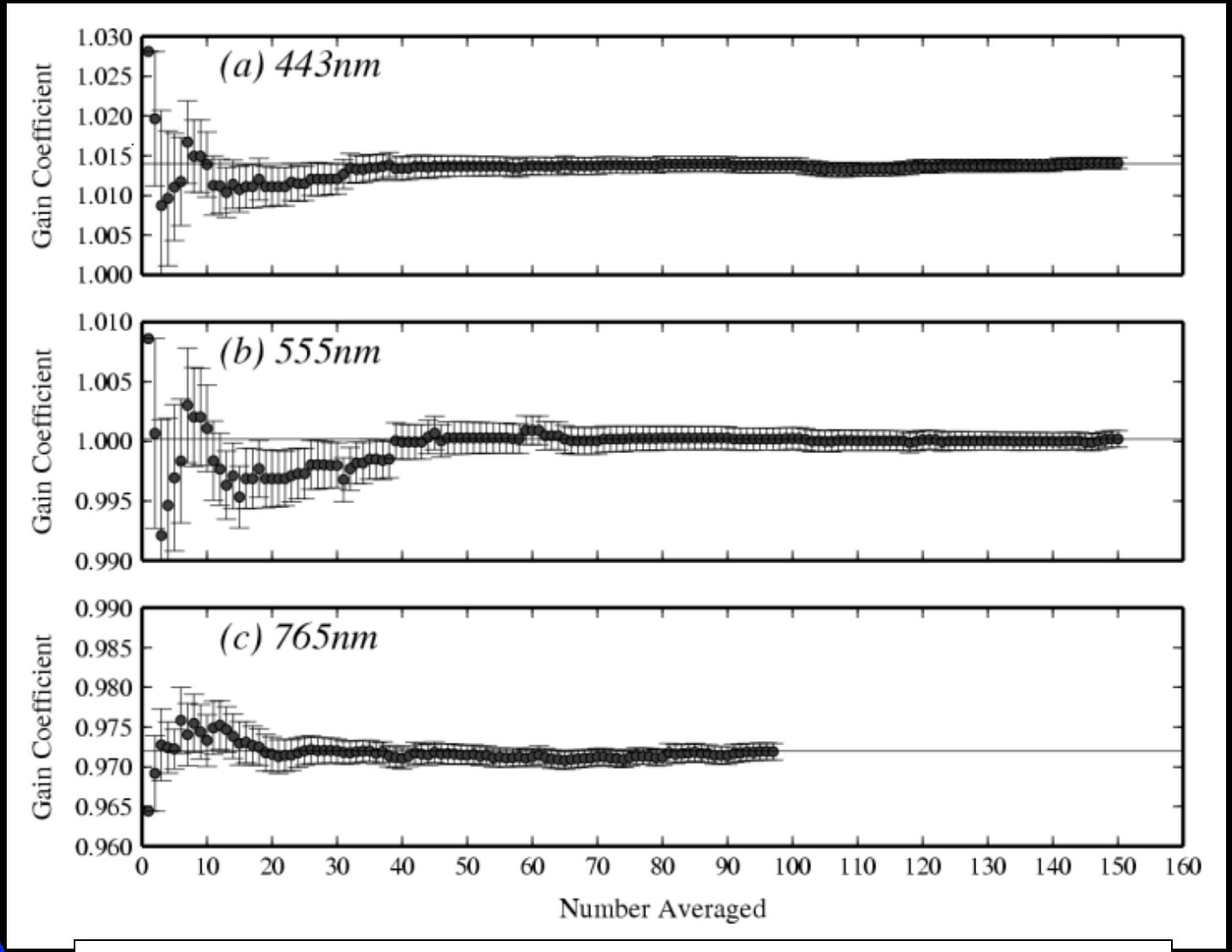


SeaWiFS Temporal Calibration



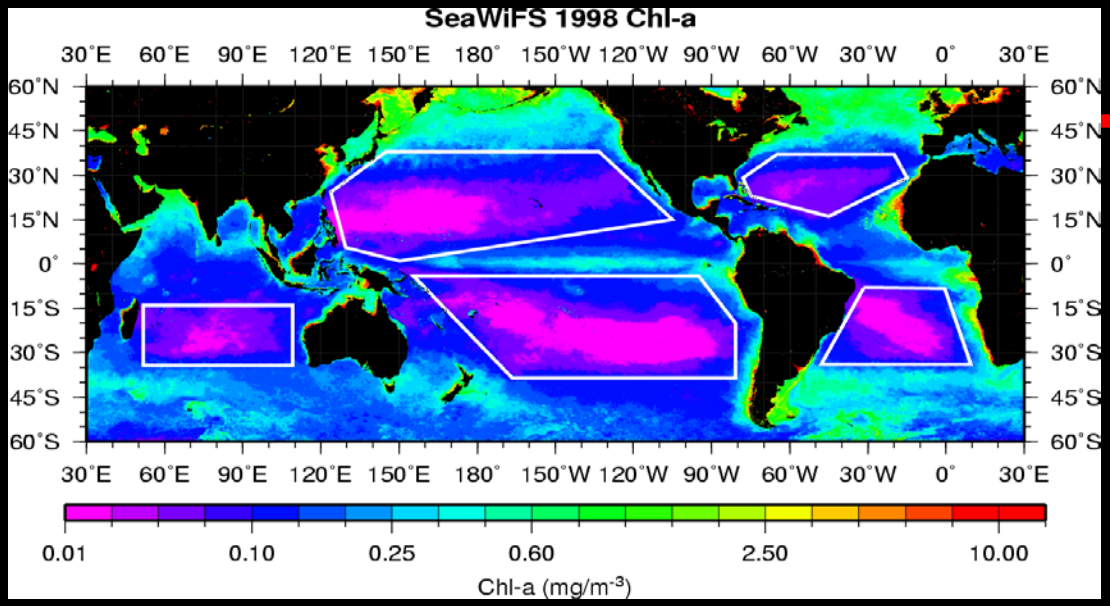
SeaWiFS Band	SeaWiFS λ (nm)
1	412
2	443
3	490
4	510
5	555
6	670
7	765
8	865

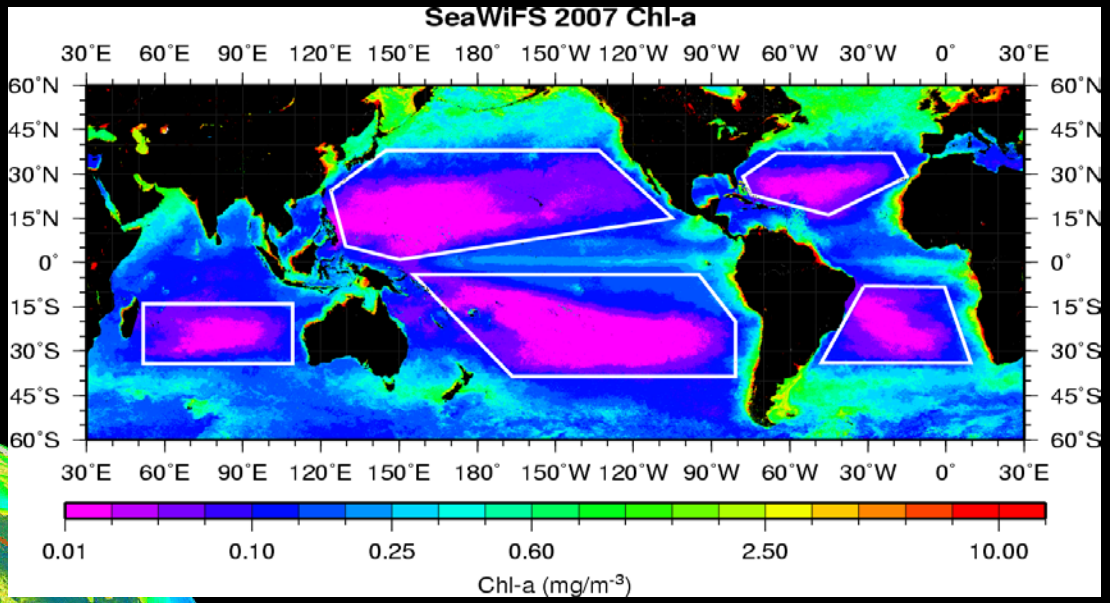
Vicarious Calibration Gain Convergence

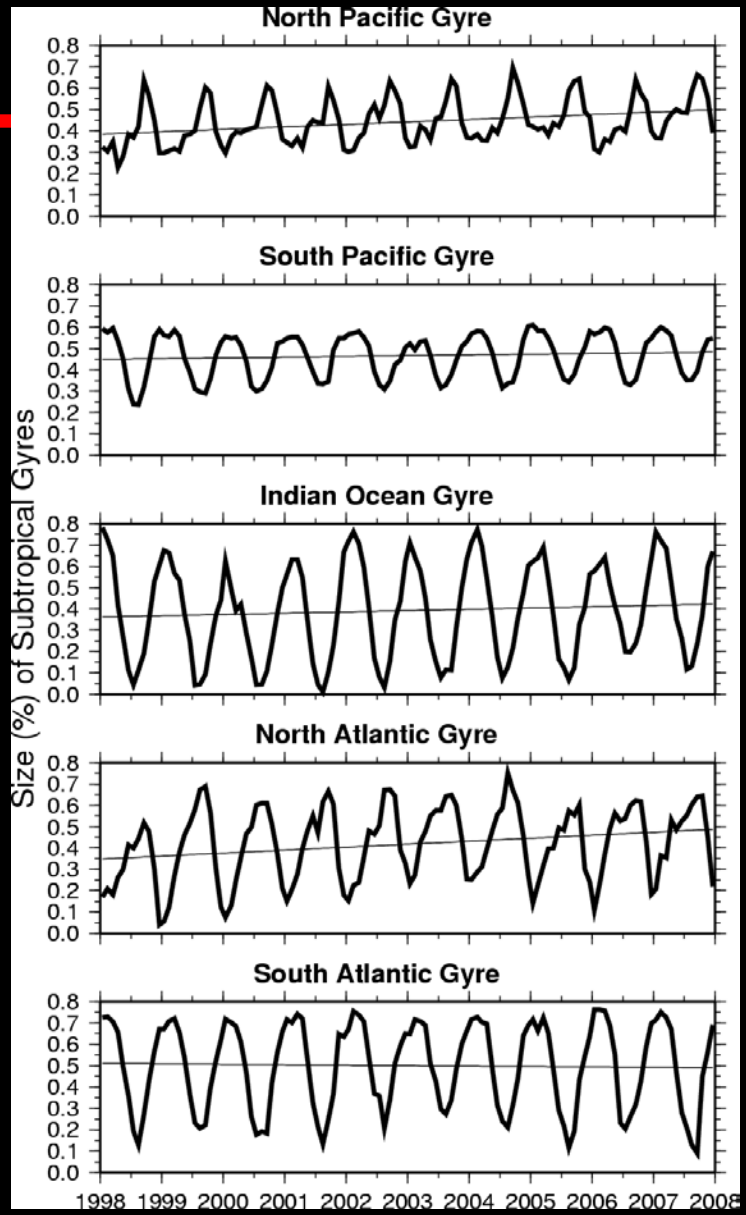


B. A.Franz, S. W. Bailey, P. J. Werdell, and C. R. McClain, "Sensor-independent approach to the vicarious calibration of satellite ocean color radiometry," Appl. Opt. 46, 5068-5082 (2007)

The Ocean's Biological Deserts are Expanding

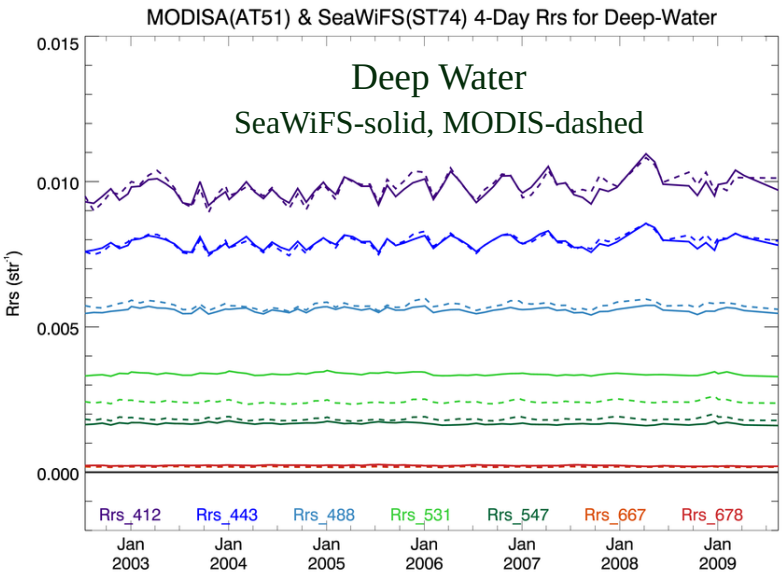


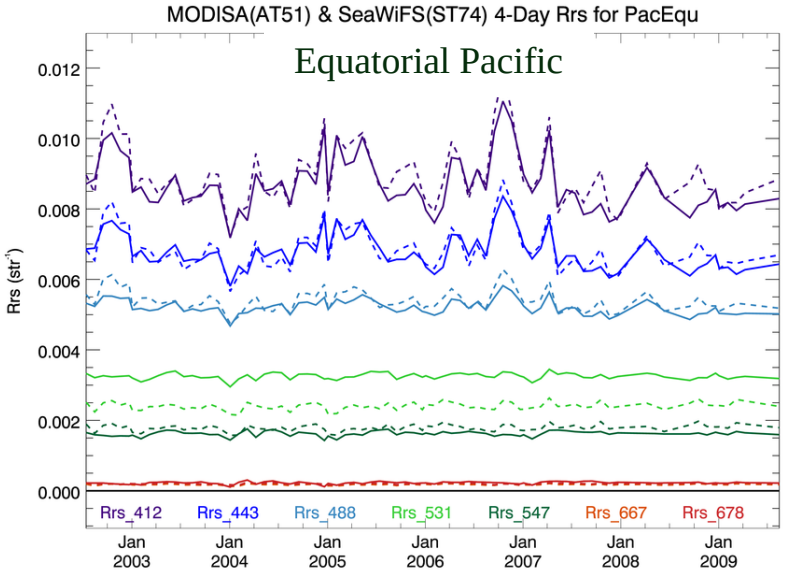


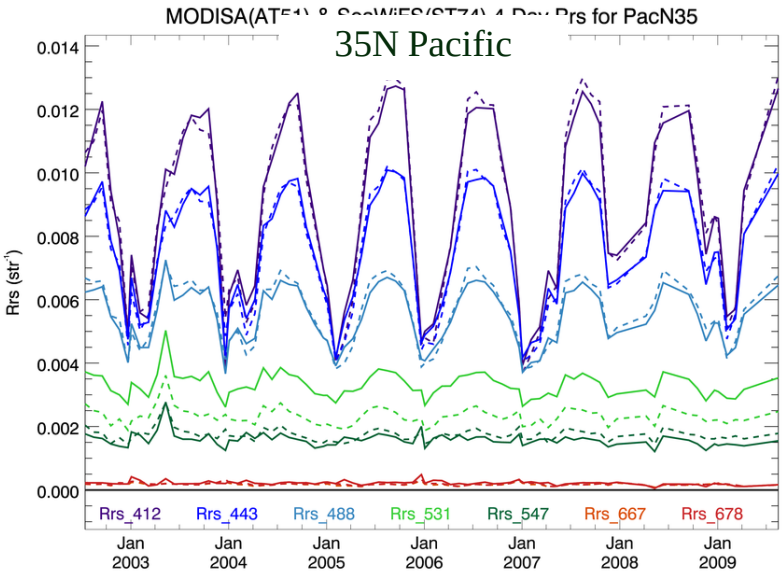


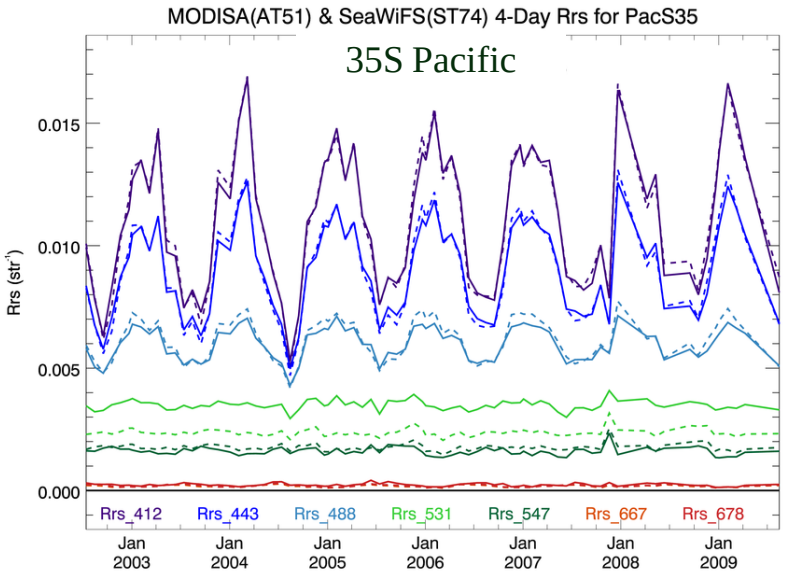
Percent of total area with Chl-a concentration < 0.07 mg/m^3

SeaWiFS-MODIS/Aqua Comparisons

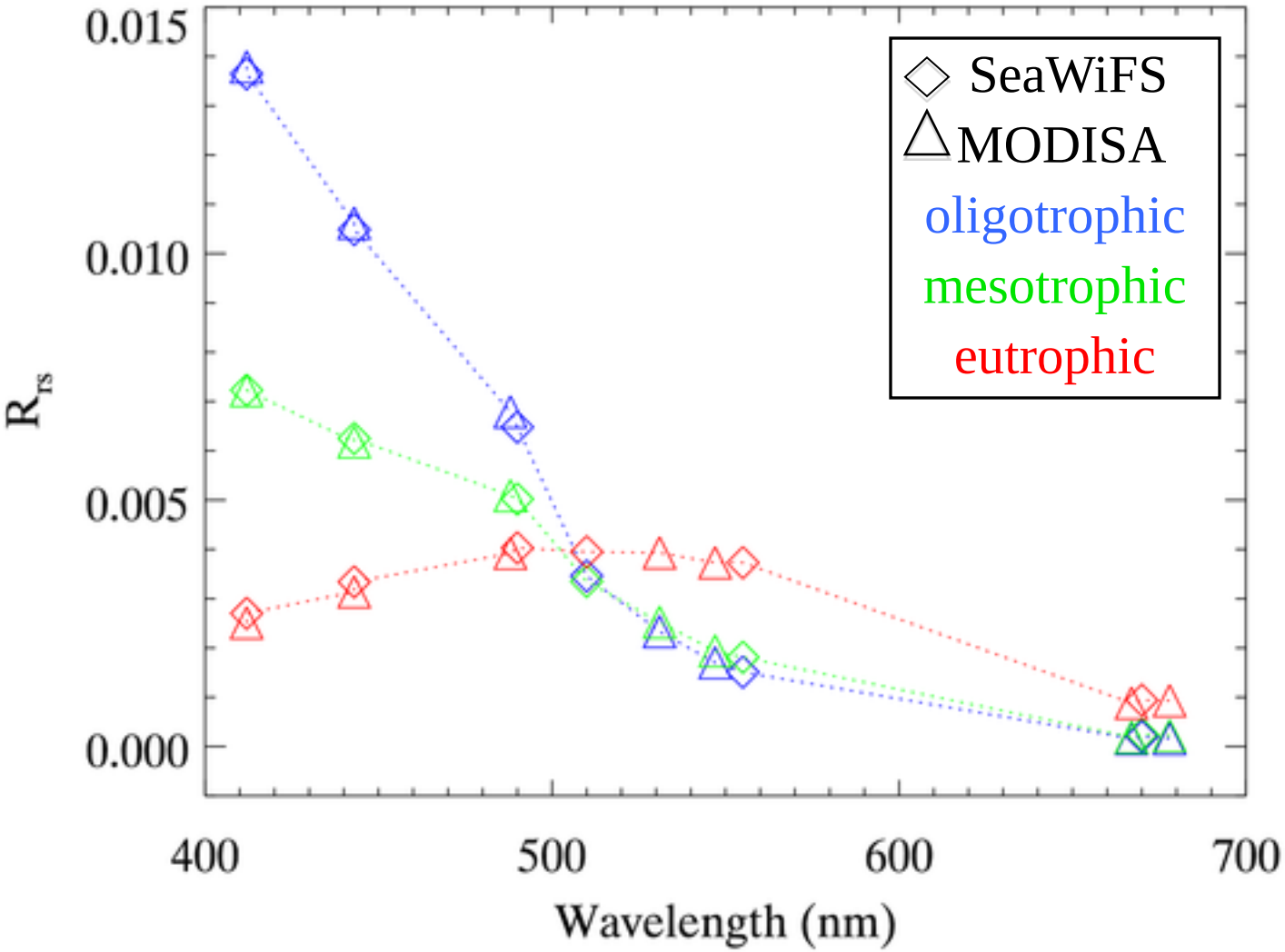








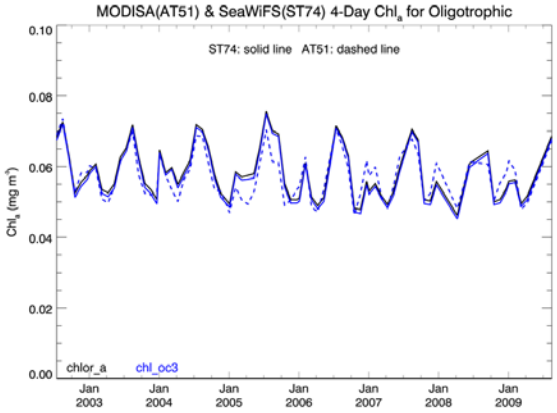
Global Mean Rrs Comparisons

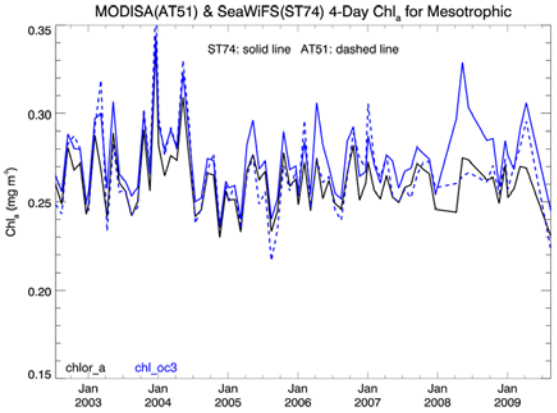


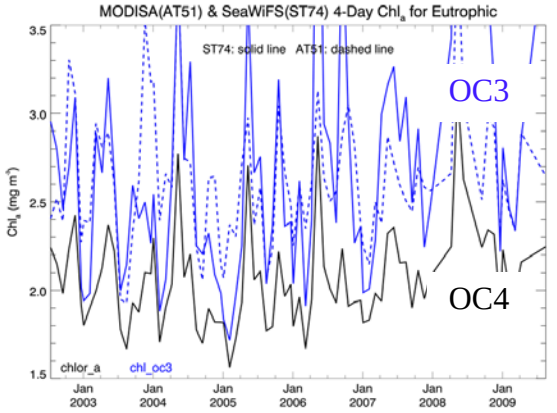
MODISA and SeaWiFS Chl_a

Oligotrophic — **Mesotrophic** — **Eutrophic**

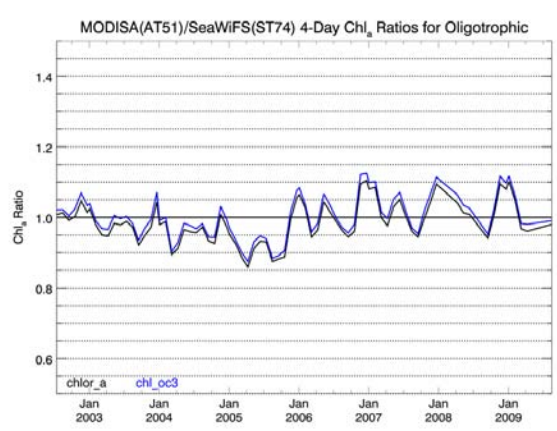
Comparison

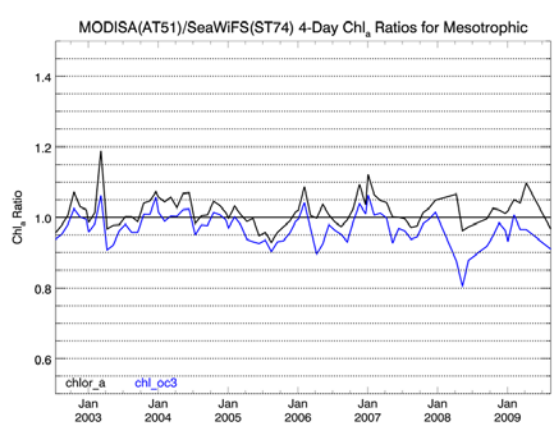


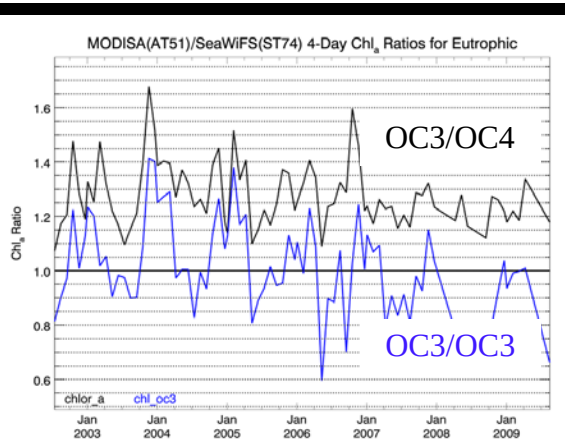




Ratio







<Ratio>	Std Dev
0.99	0.058
1.00	0.060

<Ratio>	Std Dev
1.02	0.042
0.97	0.045

<Ratio>	Std Dev
1.28	0.12
1.01	0.17

Concluding Statements

- Satellite ocean biogeochemical CDRs are very difficult to generate & verify.
- SeaWiFS and MODIS/Aqua are now consistent (after 6-7 years of effort).
  - Keeping them consistent will be an ongoing challenge
- Continuation of the existing CDRs without a gap is a major concern.
  - The NPOESS VIIRS (Visible-Infrared Imaging Radiometer Suite) data quality is TBD.
  - International mission (MERIS, OCM) data assess and quality issues are being worked, but remain TBD.