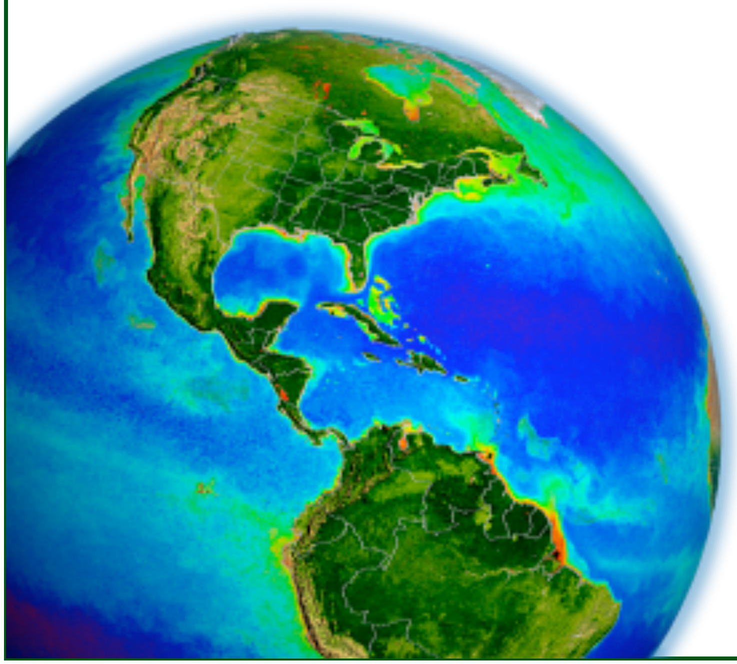
NASA Ocean Color Calibration & Validation

Bryan A. Franz

and the

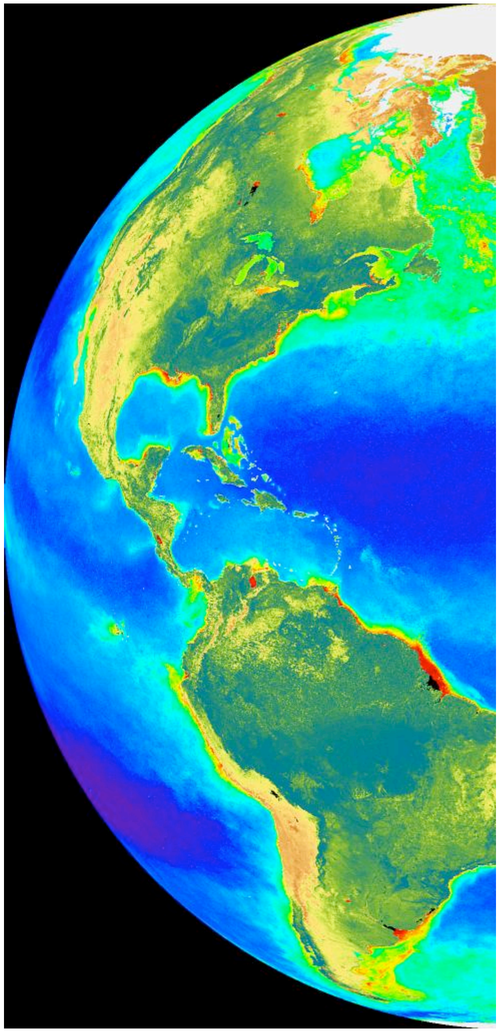
NASA Ocean Biology Processing Group



AERONET-OC Workshop

24 February 2011 – Greenbelt, MD

Three ways we use in situ OC radiometry



algorithm development (NOMAD)

vicarious calibration (MOBY)

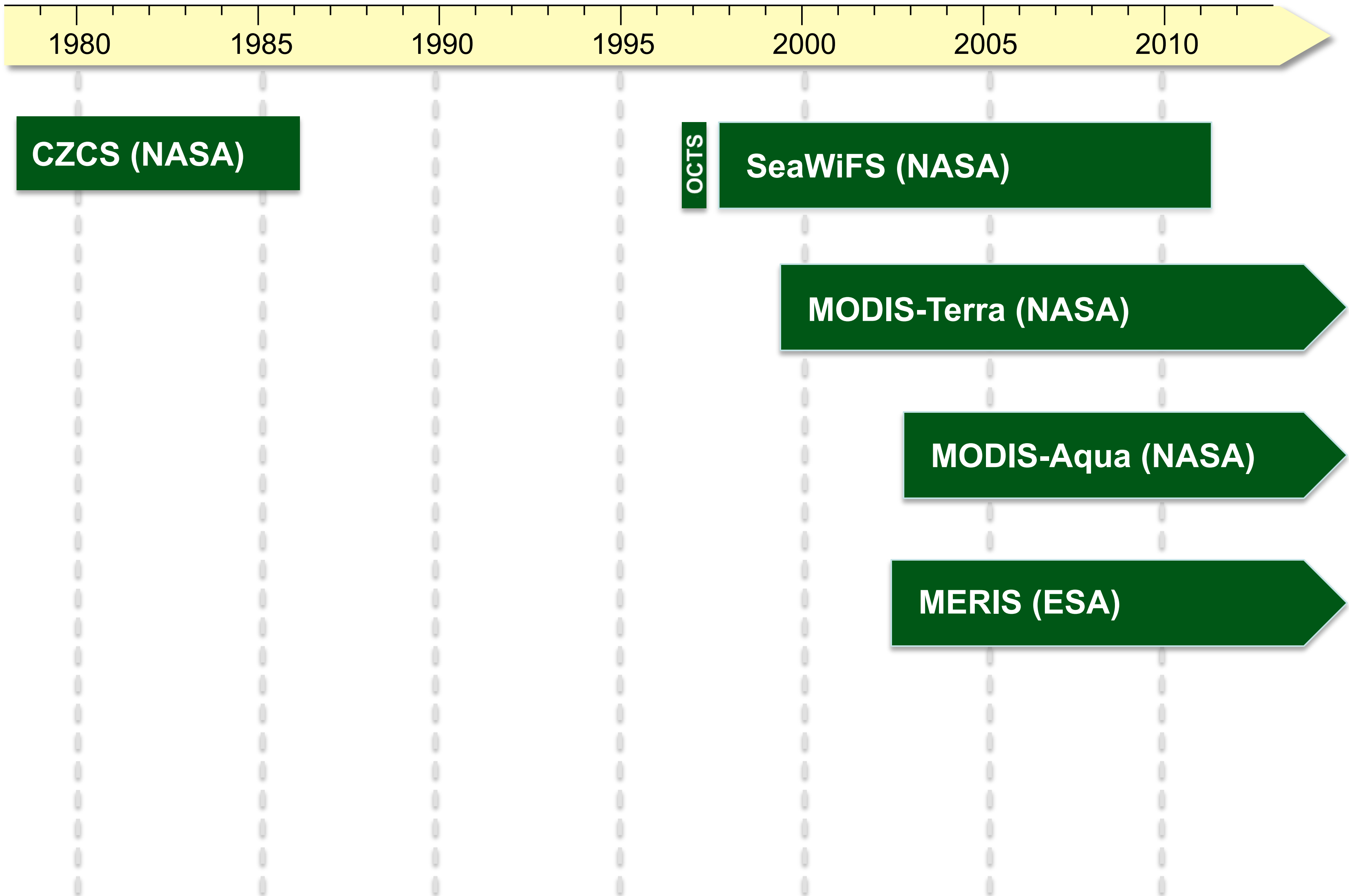
product validation (SeaBASS)

Our primary goal is to produce global climate data records for ocean color radiometry and derived products.

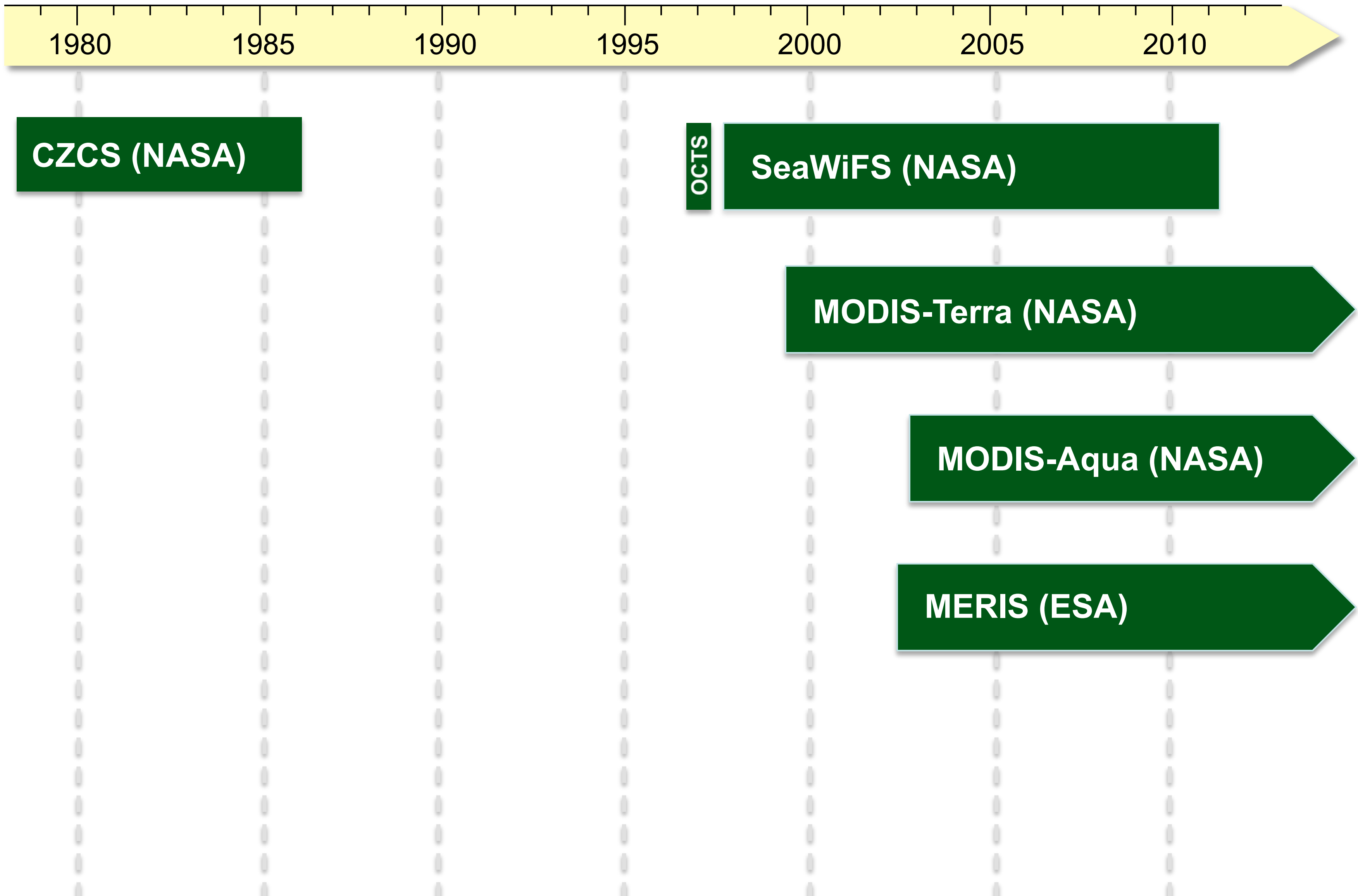
A climate data record is a time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change.

U.S. National Research Council, 2004

Length & continuity achieved via multiple missions



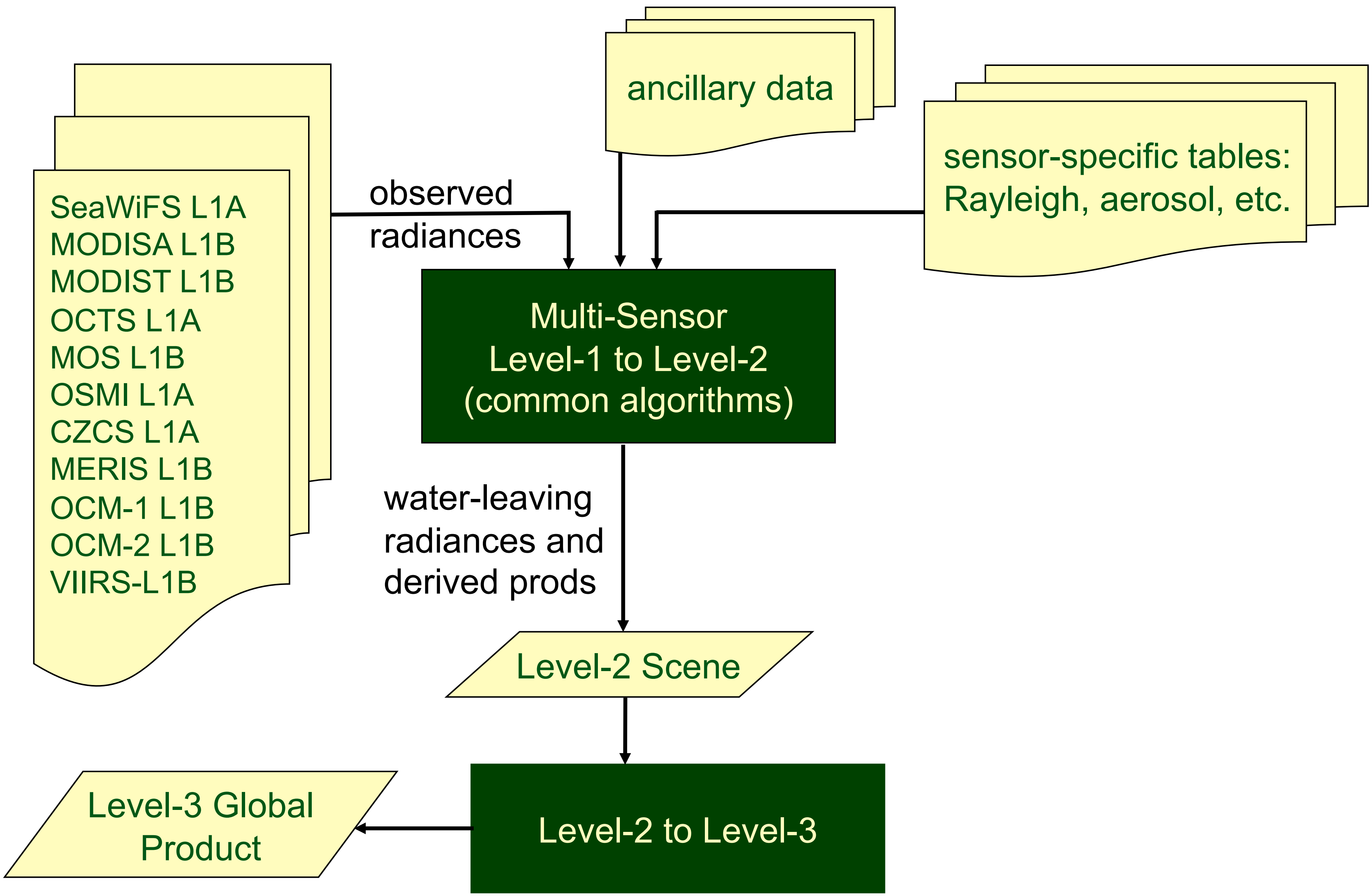
Length & continuity achieved via multiple missions



How do we achieve consistency?

- Concentrate on instrument calibration
  - establishing temporal and spatial stability within each mission
- Apply common algorithms
  - ensuring consistency of processing across missions

Sensor-Independent Approach



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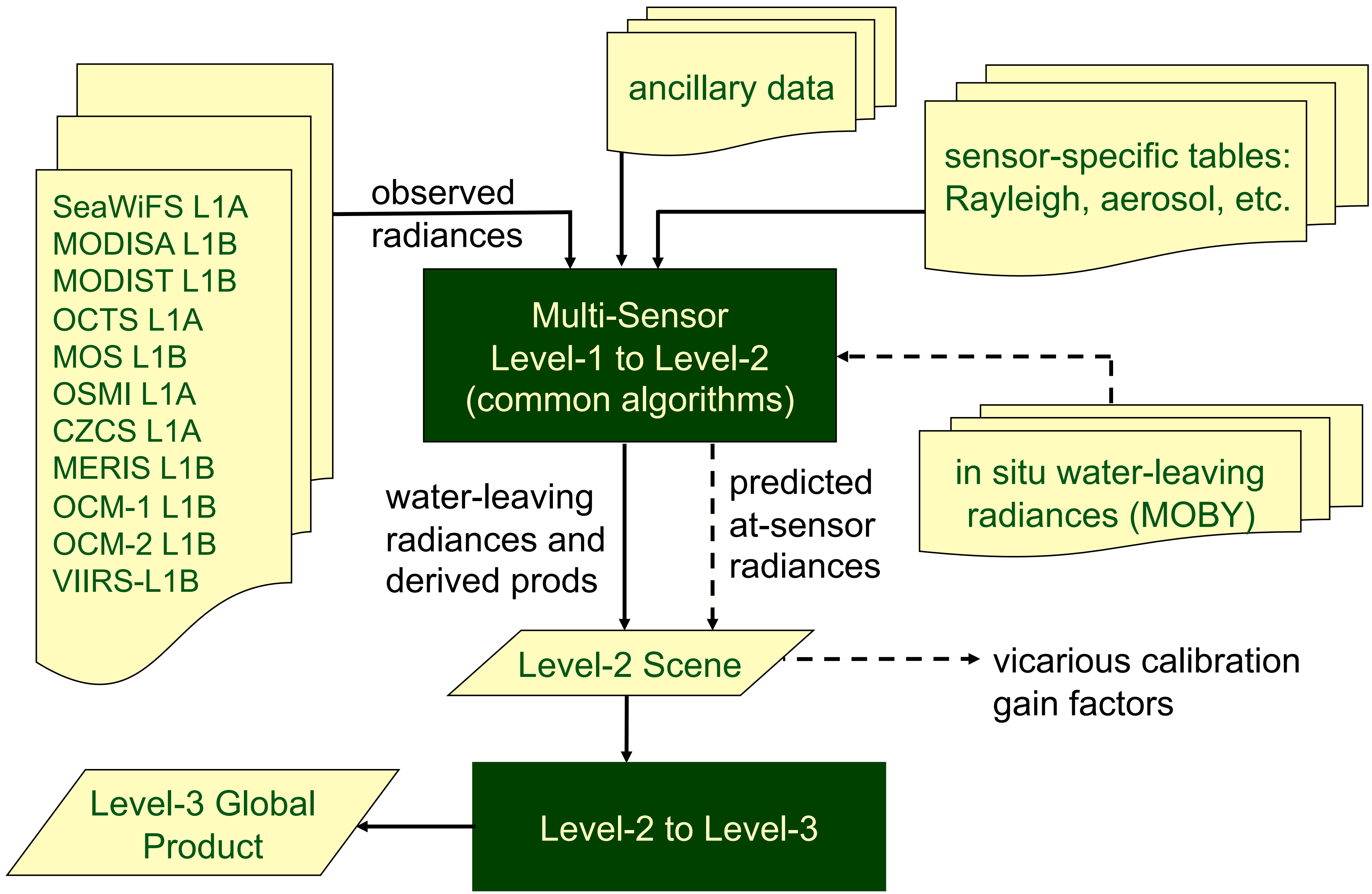
  - ensuring spectral and absolute consistency of water-leaving radiance retrievals under idealized conditions

Sensor-Independent Approach



Vicarious Calibration (Vicarious Adjustment)

derive adjustment factors, one per sensor band, to minimize mean bias between in situ calibration source and satellite R_{rs}(l) retrievals.

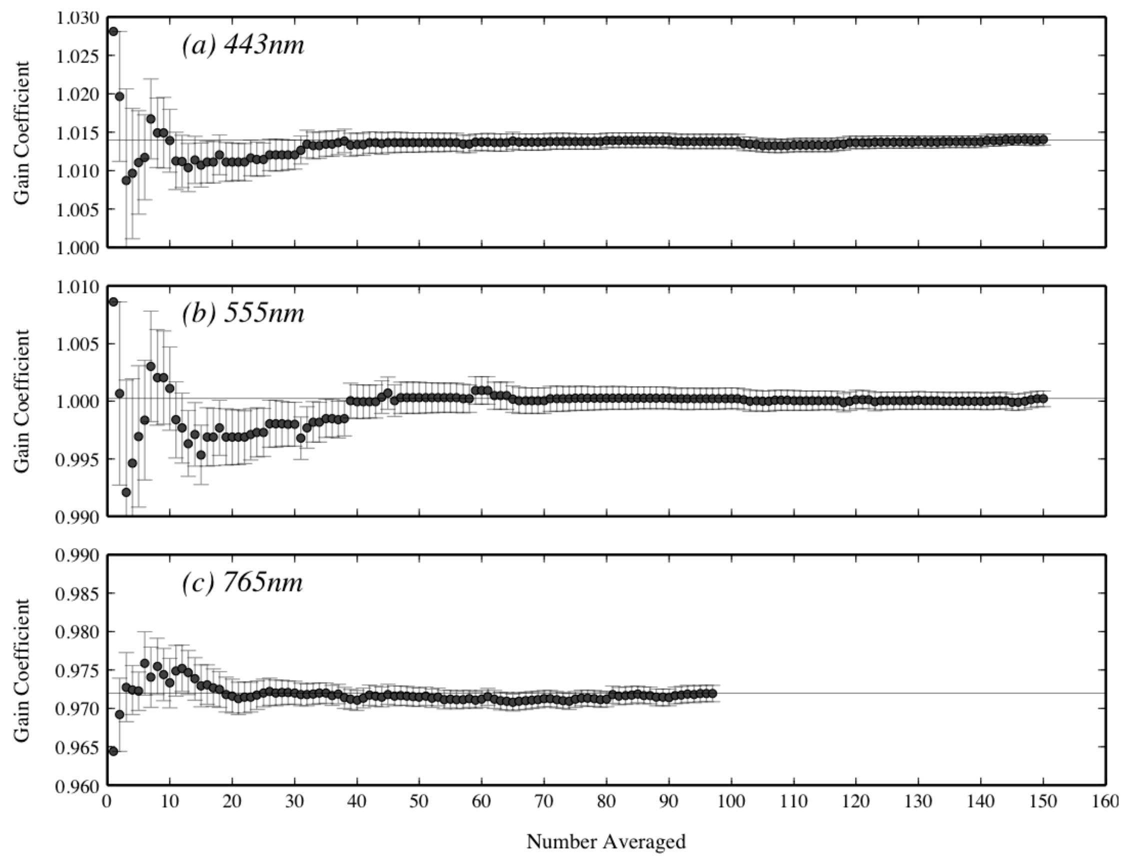
- system calibration
  - compensates for both instrument calibration and algorithm biases
- two step process:
  - calibrate NIR bands to improve aerosol retrieval
  - calibrate visible using calibrated aerosol retrieval and in situ radiometry
- calibration site considerations
  - prefer clear water location to minimize heterogeneity and R_{rs} (NIR)
  - prefer stable (known) aerosol type
  - prefer open ocean to minimize adjacency effects

$$g(\lambda) = \frac{1}{n} \sum_{i=1}^{n} g_i(\lambda) \qquad g_i(\lambda) = \frac{L_t^{predicted}}{L_t^{observed}}$$

Cumulative mean vicarious gain

It requires many samples to reach a stable vicarious calibration, even in clear (homogeneous) water with a well maintained instrument (MOBY)

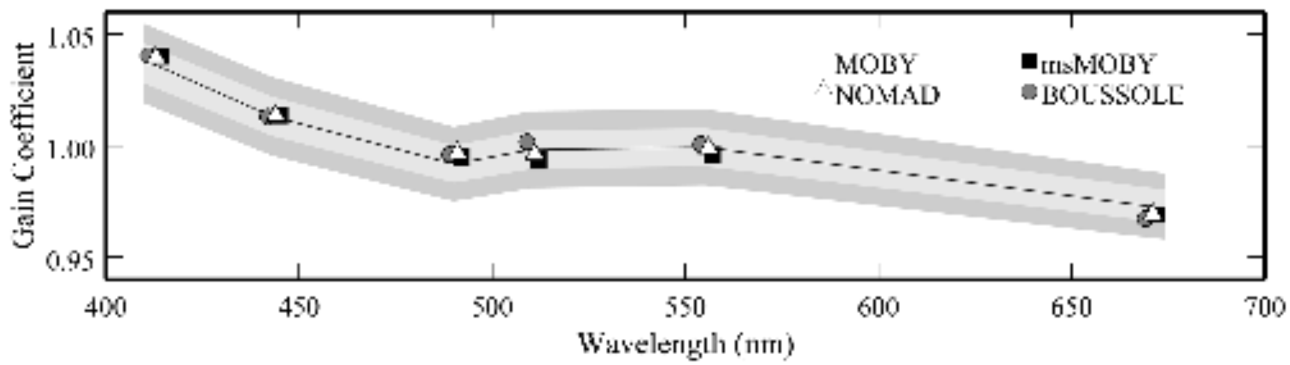
SeaWiFS to MOBY



Franz, B.A., S.W. Bailey, P.J. Werdell, and C.R. McClain, F.S. (2007). Sensor-Independent Approach to Vicarious Calibration of Satellite Ocean Color Radiometry, Appl. Opt., 46 (22).

Alternative calibration sources, similar results

SeaWiFS Gains



Validation of Satellite Retrievals

Band	N	MOBY		msMOBY			NOMAD/BOUSSOLE		
		Ratio	% Diff.	Ratio	% Diff.	Abs. UPD	Ratio	% Diff.	Abs. UPD
$L_{WN}(412)$	154	1.005	11.762	1.005	11.83	0.814	0.997	11.49	0.713
$L_{WN}(443)$	236	0.938	15.96	0.936	16.10	0.324	0.924	16.32	0.313
$L_{WN}(490)$	236	0.918	13.62	0.929	12.77	0.706	0.933	12.74	1.235
$L_{WN}(510)$	127	0.953	11.97	0.948	12.01	0.815	0.985	12.26	1.636
$L_{WN}(555)$	236	0.961	15.95	0.950	17.45	1.223	0.988	16.25	1.572
$L_{WN}(670)$	233	1.719	87.21	1.218	81.18	12.69	1.091	85.49	15.42
C_a	383	1.001	27.80	0.988	27.90	1.569	1.060	29.42	3.636

Bailey, S.W., Hooker, S.B., Antoine, A., Franz, B.A., and Werdell, P.J. (2008). Sources and assumptions for the vicarious calibration of ocean color satellite observations, Appl. Opt., 47 (12).

How do we achieve consistency?

- Concentrate on instrument calibration
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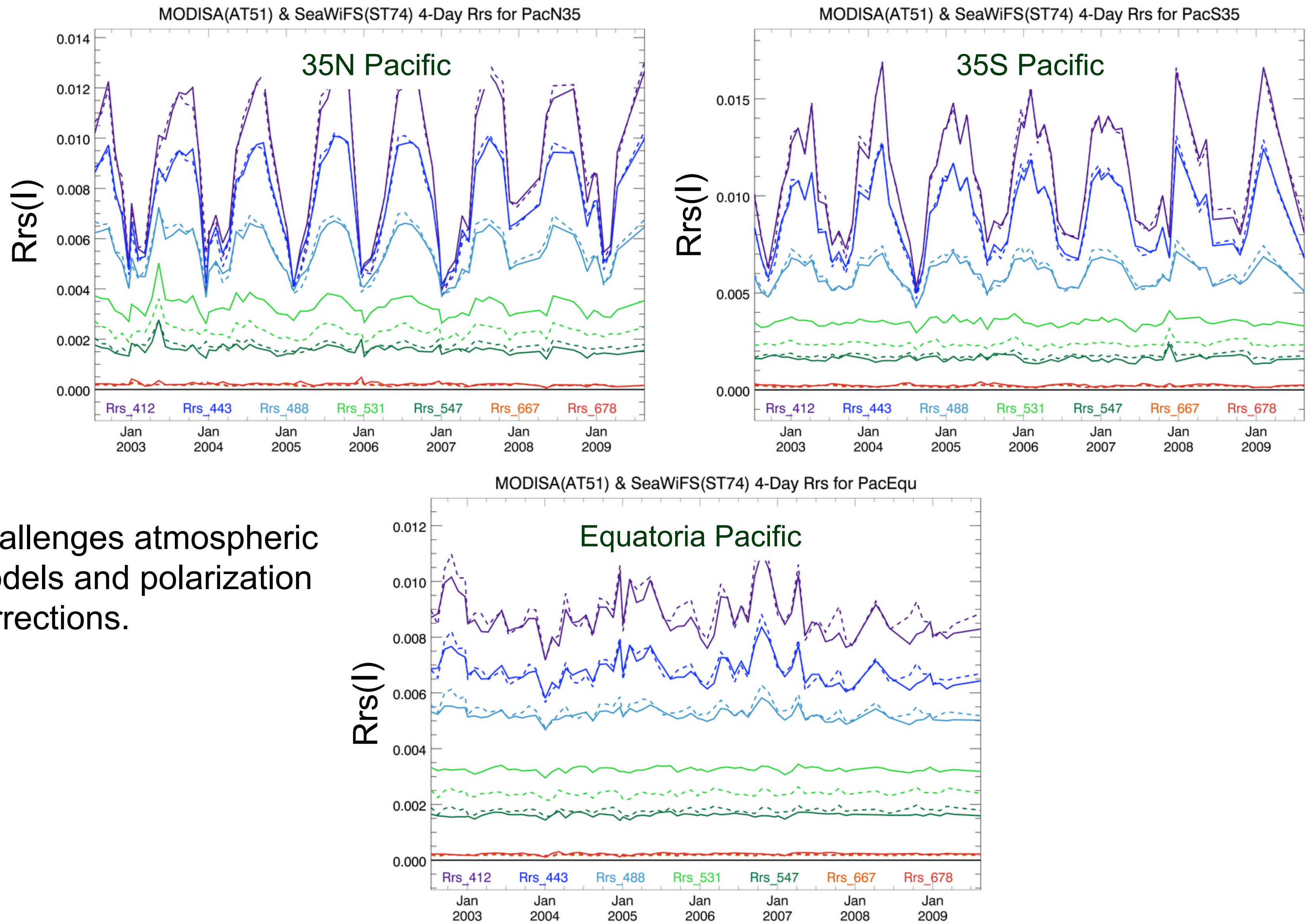
- Apply common algorithms
  - ensuring consistency of processing across missions
- Apply common vicarious calibration approach
  - ensuring spectral and absolute consistency of water-leaving radiance retrievals under idealized conditions
- Perform detailed trend analyses (hypothesis testing)
  - assessing temporal stability & and mission-to-mission consistency

MODISA & SeaWiFS Water-Leaving Reflectance

zonal analysis over duration of mission overlap



Challenges atmospheric models and polarization corrections.

How do we achieve consistency?

- Concentrate on instrument calibration
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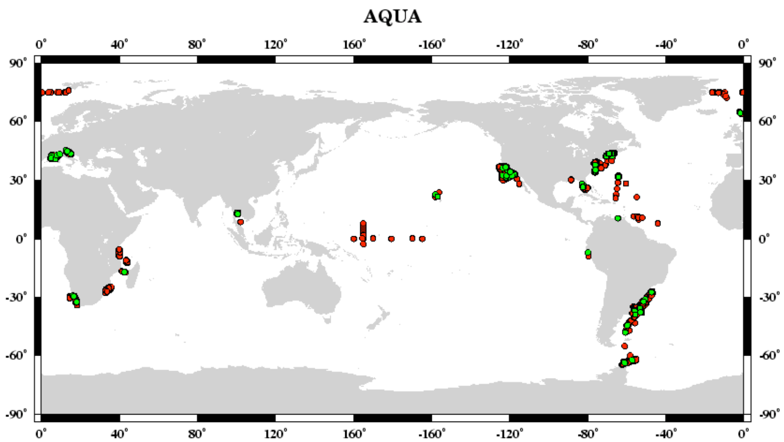
- Apply common vicarious calibration approach
  - ensuring spectral and absolute consistency of water-leaving radiance retrievals under idealized conditions
- Perform detailed trend analyses (hypothesis testing)
  - assessing temporal stability & and mission-to-mission consistency
- Reprocess multi-mission timeseries
  - incorporating new instrument knowledge and algorithm advancements

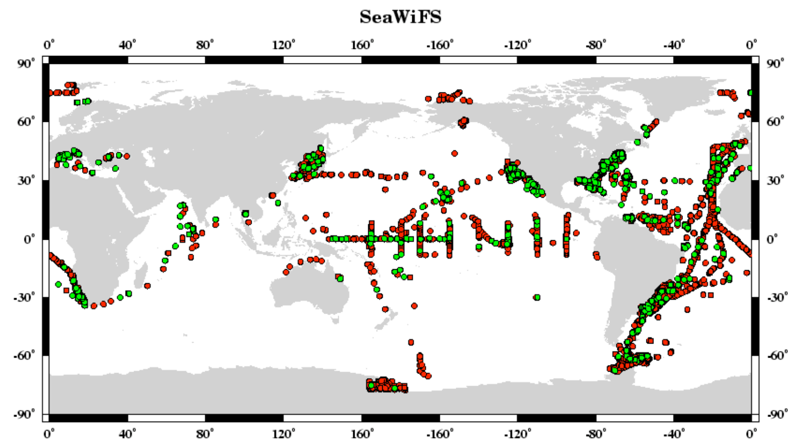
Validation & Results

SeaBASS In Situ Match-ups by Sensor

MODIS-Aqua
July 2002 - Present

SeaWiFS
Sept 1997 - Present



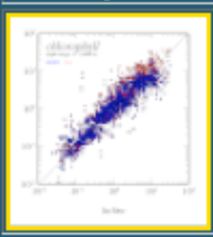
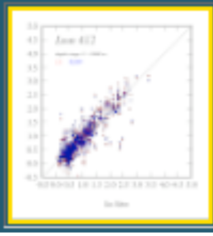
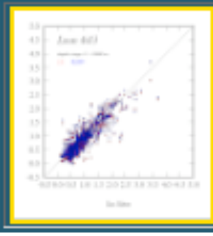
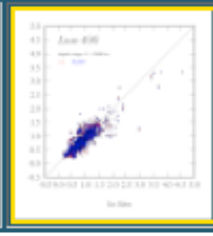
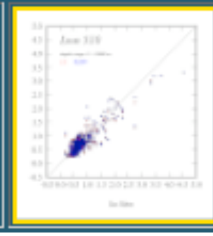
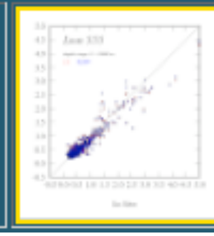
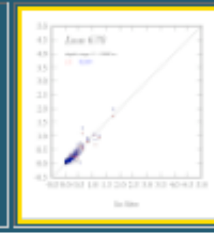
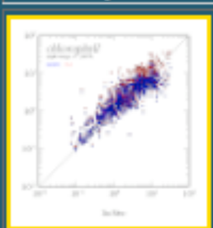
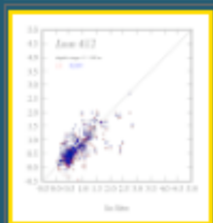
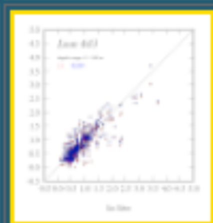
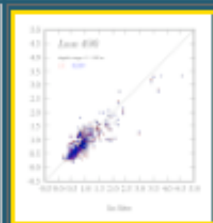
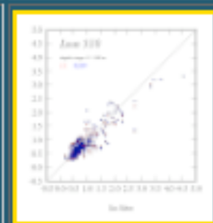
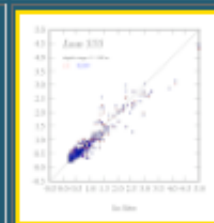
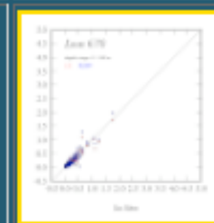
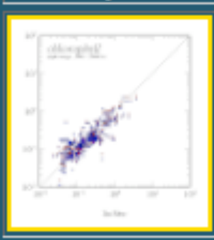
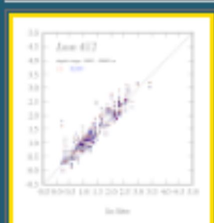
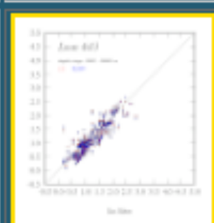
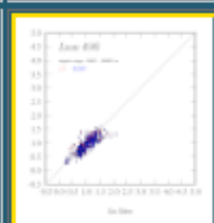
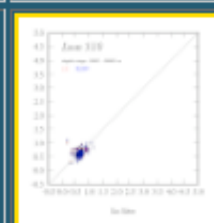
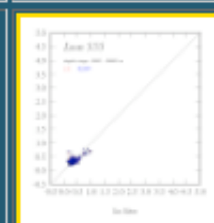
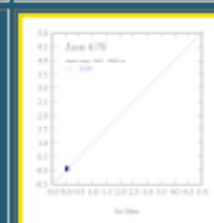


color key: valid match excluded

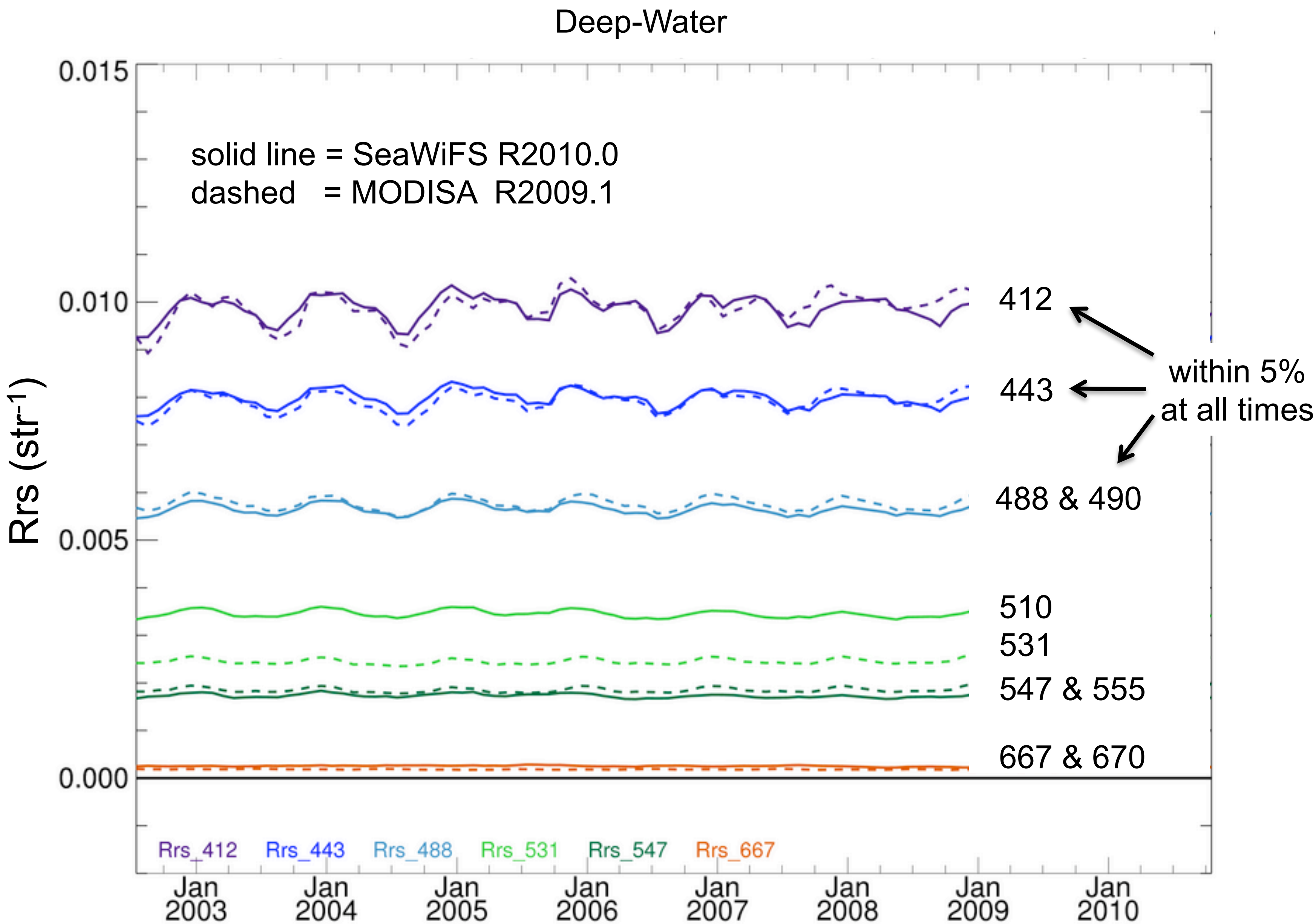
"match-up" defined as:
(1) in situ measurement collected within +/- 3 hours of satellite overpass
(2) 5x5 satellite pixel box centered on in situ lat/lon target
(3) homogeneity and sensor/solar geometry tests applied
(4) filtered median of valid (non-flagged) pixels, if >50% remain

Bailey, S.W., Hooker, S.B., Antoine, A., Franz, B.A., and Werdell, P.J. (2008). Sources and assumptions for the vicarious calibration of ocean color satellite observations, Appl. Opt., 47 (12).

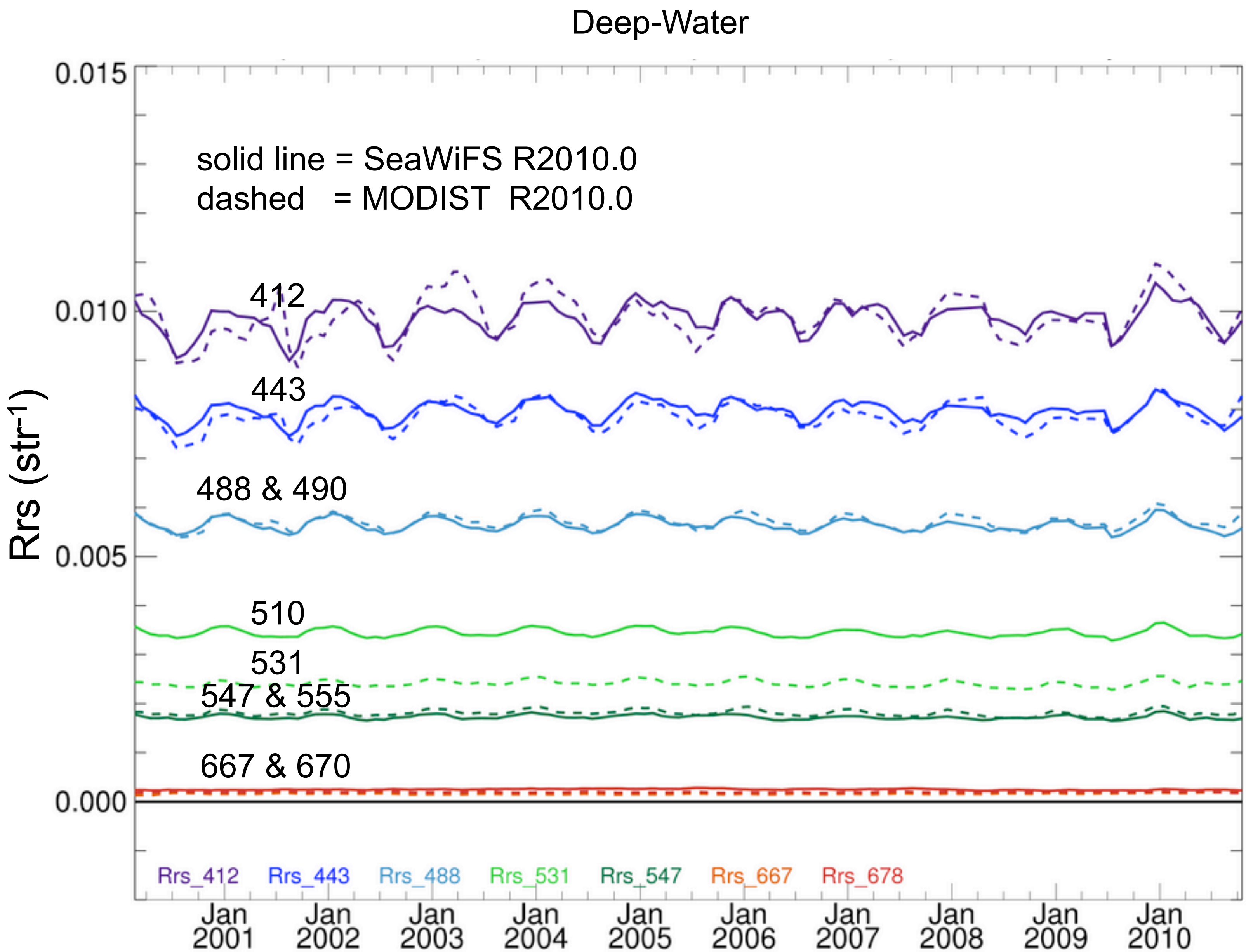
SeaWiFS In Situ Validation

	Chlorophyll	Lwn 412	Lwn 443	Lwn 490	Lwn 510	Lwn 555	Lwn 670
Global							
R2007	1.202 (38.25%)	0.895 (24.51%)	0.906 (19.98%)	0.901 (16.58%)	0.915 (15.24%)	0.911 (17.60%)	1.015 (42.30%)
R2009	0.980 (36.67%)	0.953 (21.2%)	0.964 (18.23%)	0.936 (15.09%)	0.940 (16.09%)	0.957 (17.07%)	1.032 (34.83%)
							
Coastal (< 200 m)							
R2007	1.322 (42.03%)	0.824 (33.92%)	0.902 (22.43%)	0.908 (19.79%)	0.936 (15.61%)	0.918 (17.16%)	0.865 (33.93%)
R2009	0.994 (38.42%)	0.957 (28.07%)	1.001 (22.03%)	0.963 (16.28%)	0.979 (15.30%)	0.976 (16.53%)	0.981 (34.67%)
							
Deep Water (> 1000 m)							
R2007	1.012 (30.54%)	1.020 (12.57%)	0.947 (16.62%)	0.922 (13.62%)	0.956 (13.80%)	0.955 (16.46%)	1.683 (79.88%)
R2009	0.980 (31.58%)	0.995 (13.40%)	0.947 (14.85%)	0.935 (13.64%)	0.940 (14.91%)	0.999 (15.77%)	1.186 (35.44%)
							

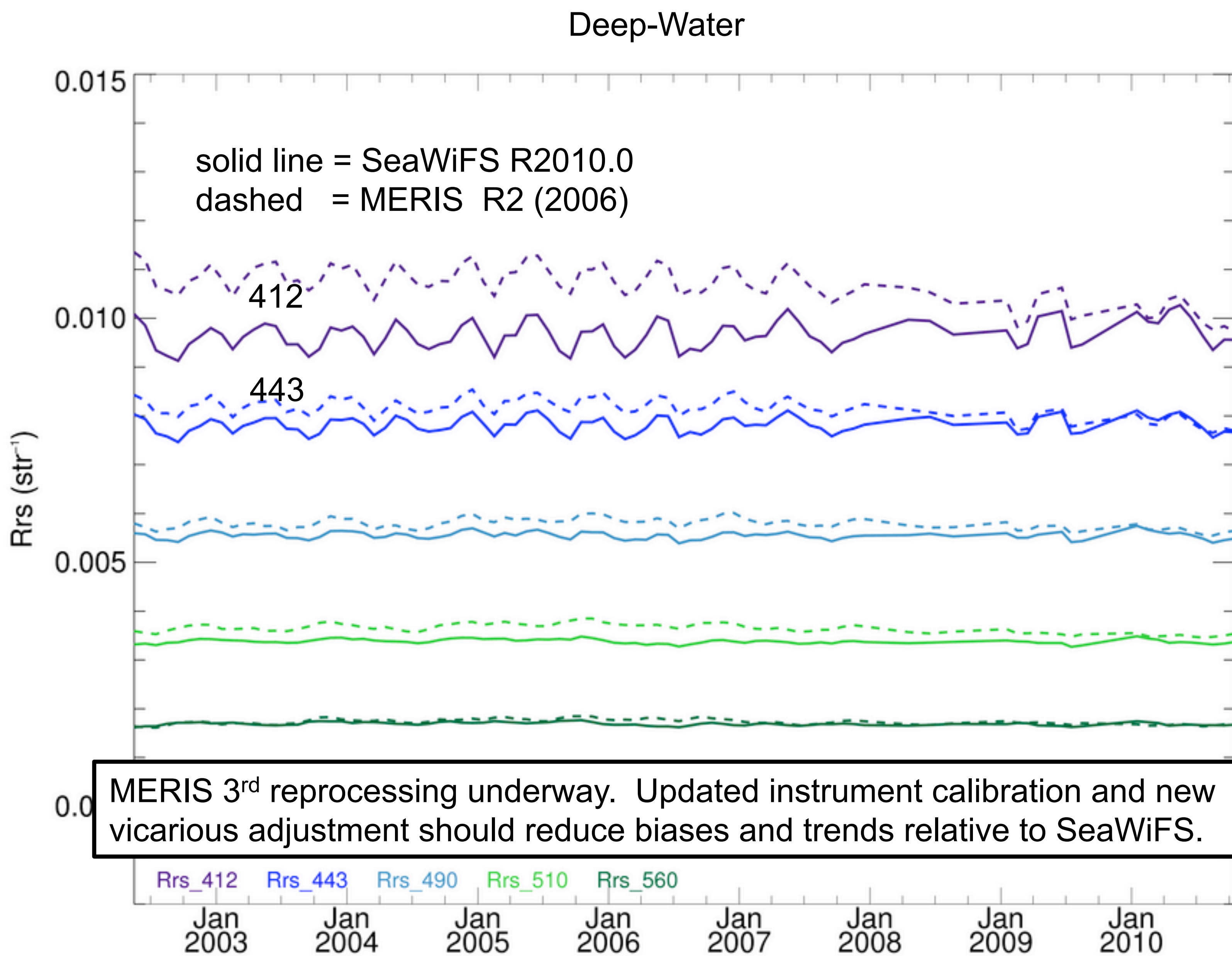
SeaWiFS & MODISA Rrs in good agreement



MODIST Rrs in good agreement with SeaWiFS

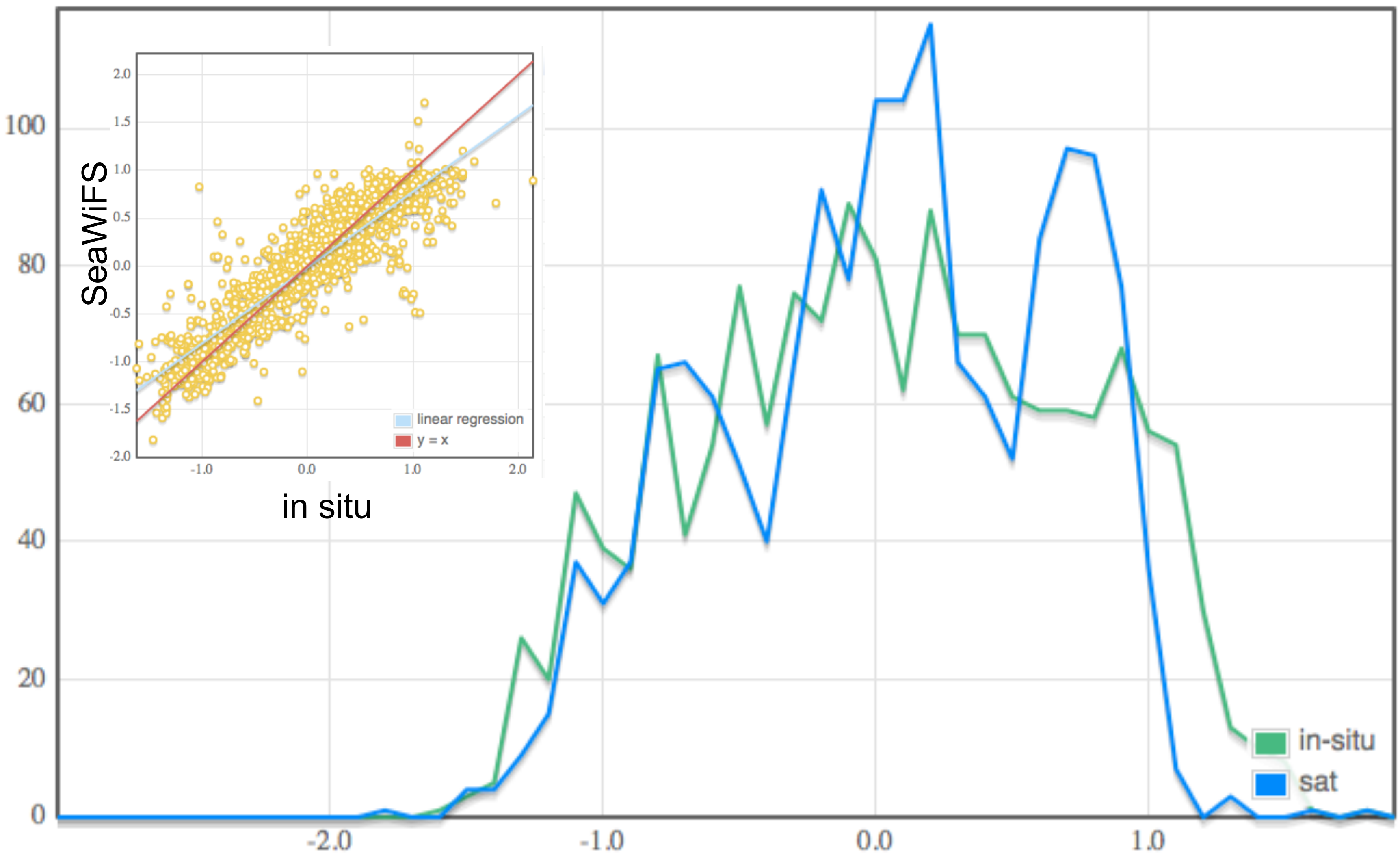


MERIS Rrs is biased relative to SeaWiFS



MERIS 3rd reprocessing underway. Updated instrument calibration and new vicarious adjustment should reduce biases and trends relative to SeaWiFS.

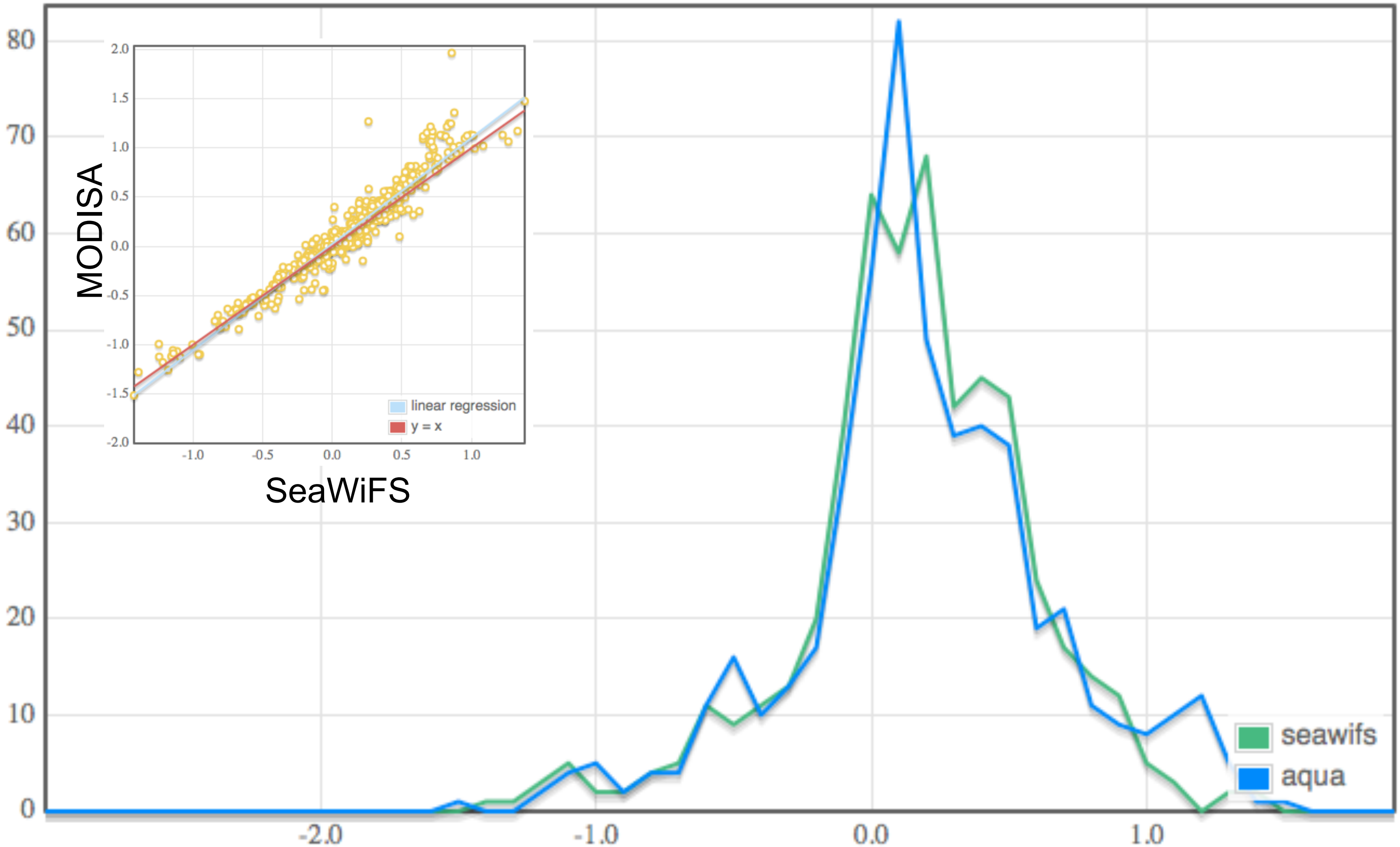
SeaWiFS Chl_a: Good Agreement with Global In situ



In-Situ Range	Sat Range	N	Slope	Intercept	R Squared	Median Ratio	Abs % Difference
(-1.61979, 2.14003)	(-1.81612, 1.70704)	1560	0.79275	-0.0152278	0.81477005	0.98005764	36.67182

MODISA vs SeaWiFS Chl$_a$

at common in situ match-up locations

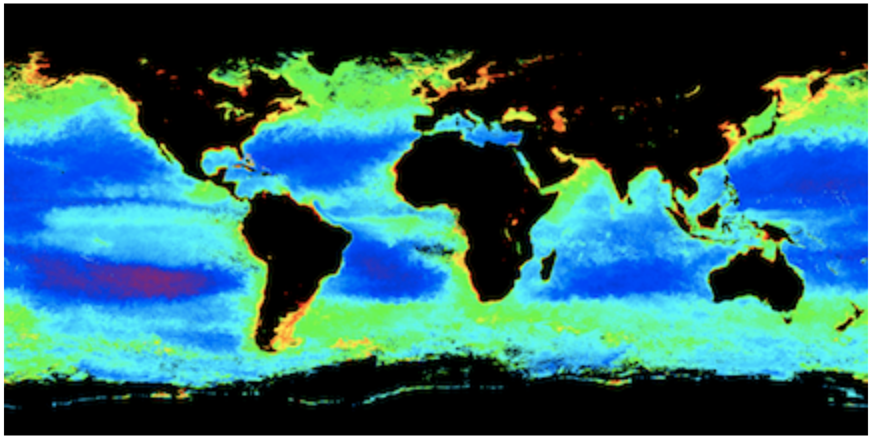


seawifs Range	aqua Range	N	Slope	Intercept	R Squared	Median Ratio	Abs % Difference
(-1.42248, 1.38101)	(-1.51267, 1.96563)	526	1.07836	0.0247077	0.92288022	1.0608265	13.805507

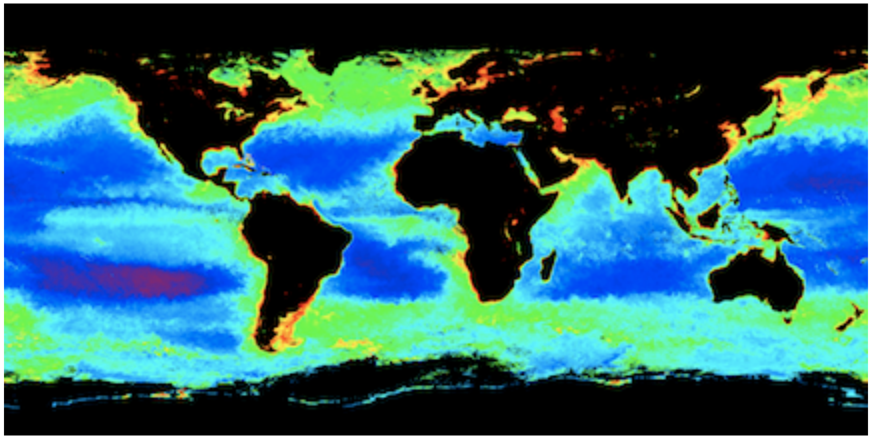
Chlorophyll spatial variation in good agreement

Fall 2002

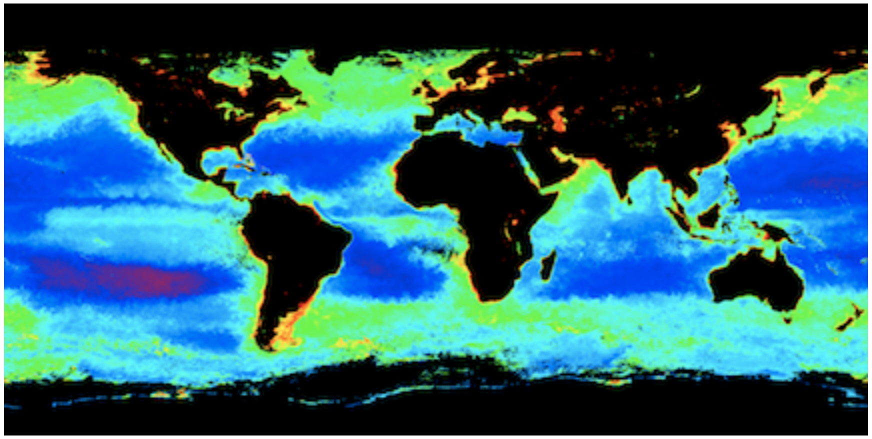
SeaWiFS

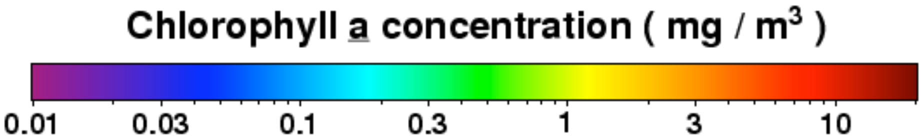


MODIS/Aqua



MODIS/Terra

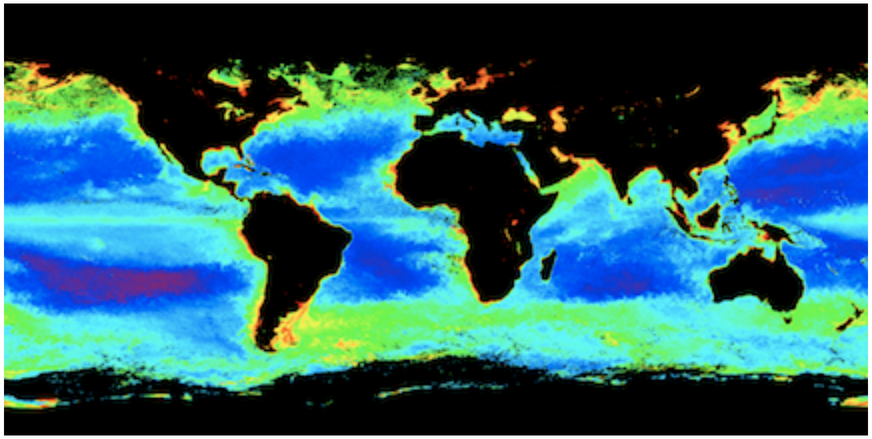




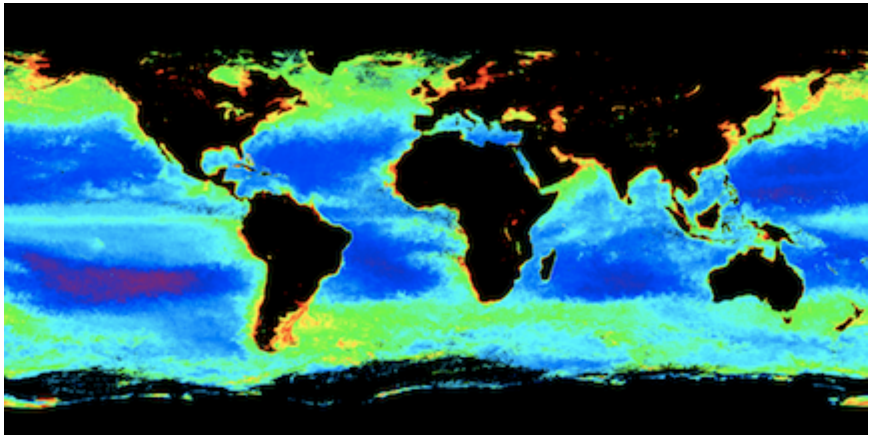
Chlorophyll spatial variation in good agreement

Fall 2008

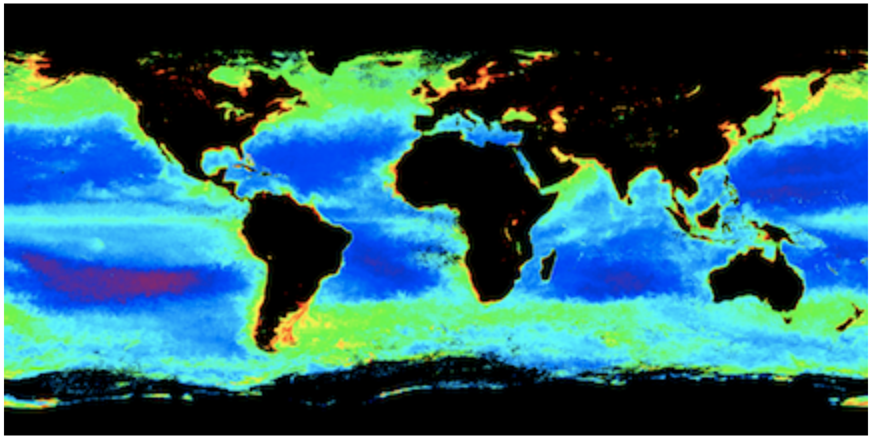
SeaWiFS

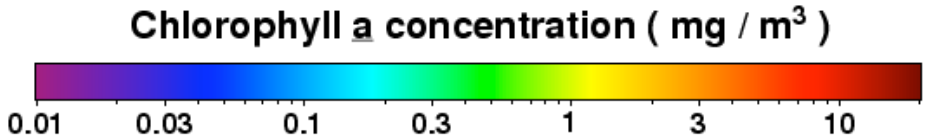


MODIS/Aqua

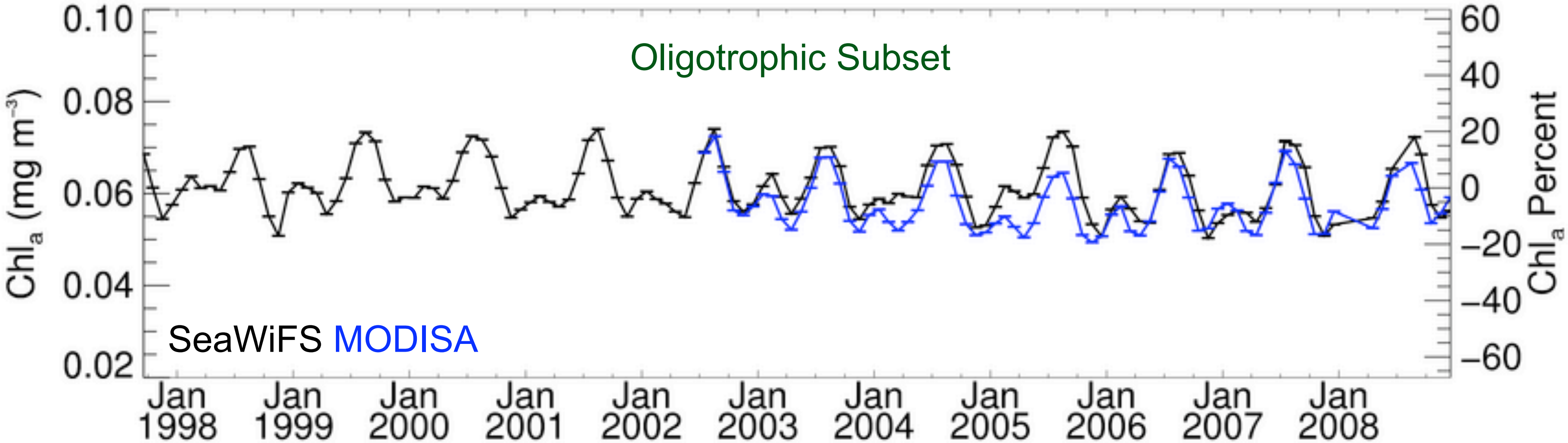


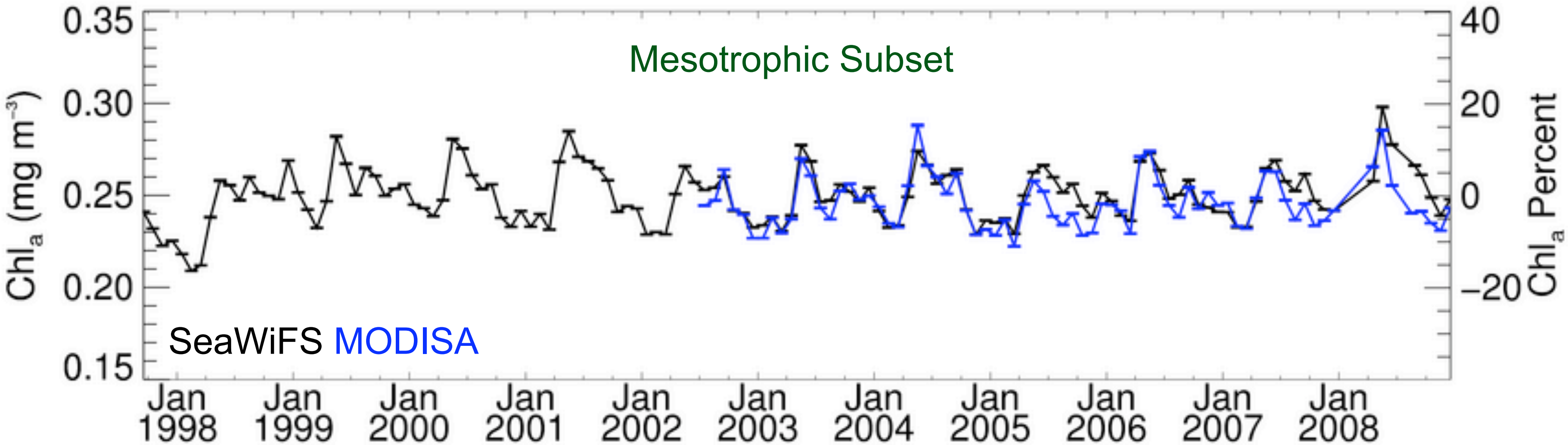
MODIS/Terra





Global Chlorophyll Timeseries





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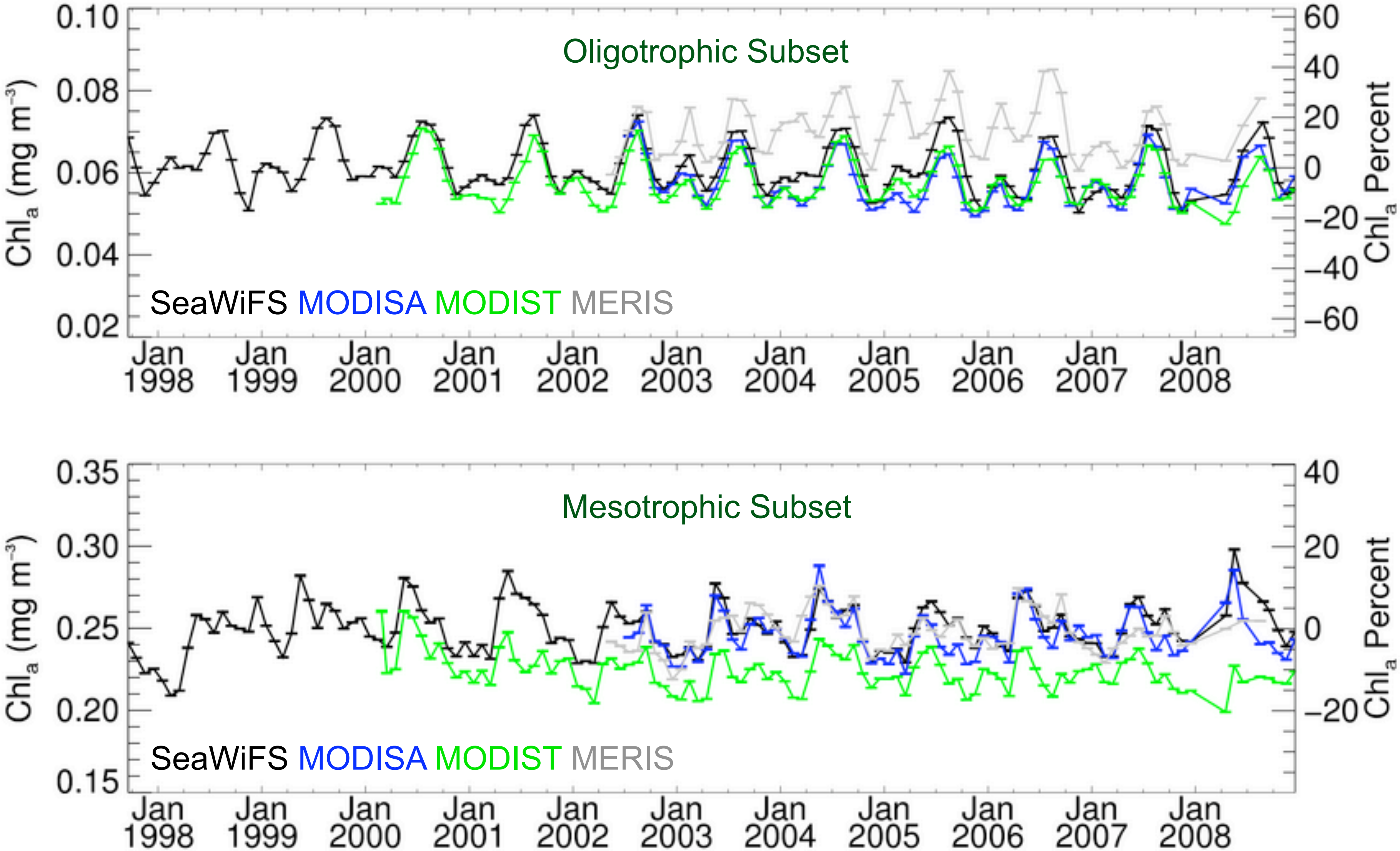
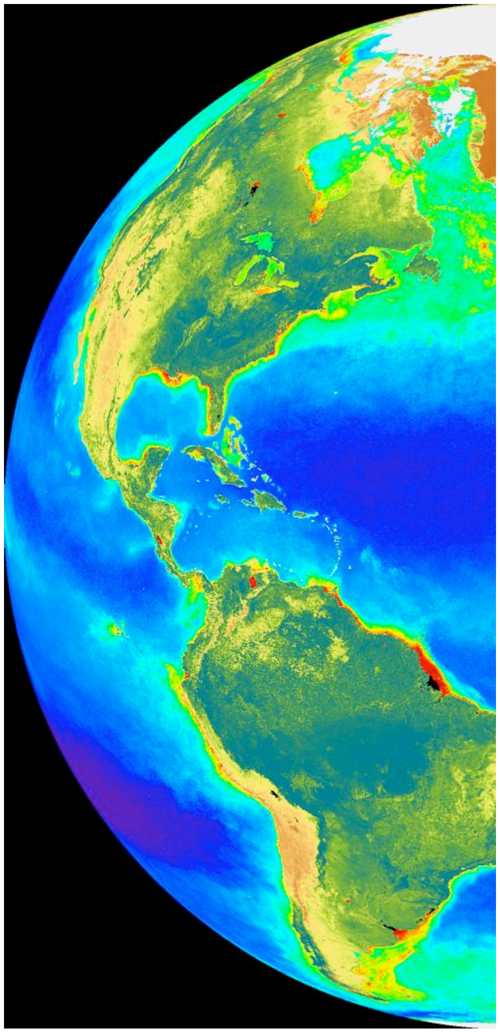


How we might use AERONET-OC



validation of satellite Rrs retrievals

- classic match-ups

verification of temporal trends in Rrs

- monthly mean Rrs trends


Thank You