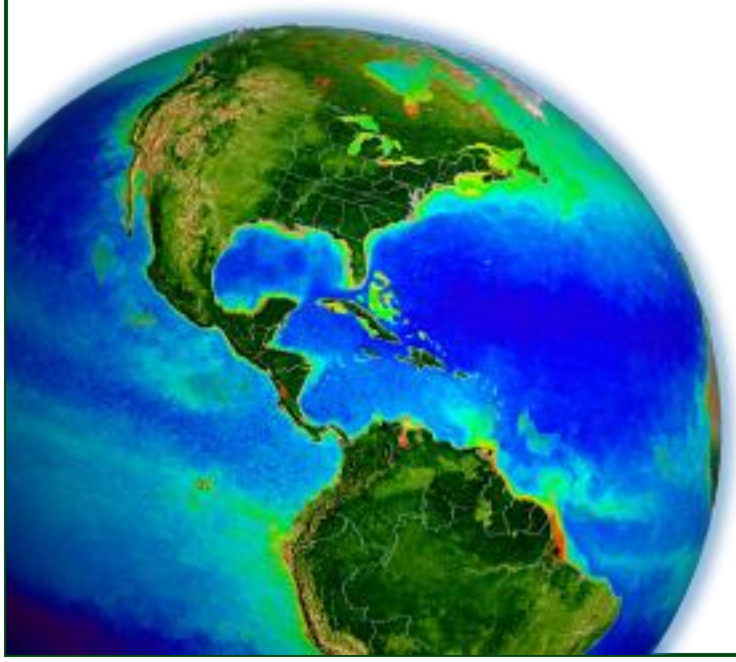
NASA Satellite Ocean Color Timeseries



Bryan Franz

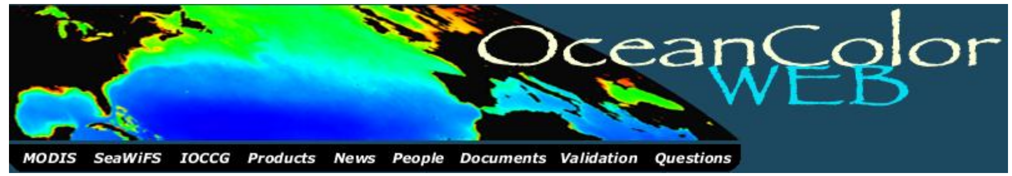
and the

NASA Ocean Biology Processing Group

International Ocean Color Science Meeting

6-8 May 2013

Ocean Biology Processing Group



oceancolor.gsfc.nasa.gov

Multi-mission Ocean Color

SST for MODIS, GHRSST

Salinity and Ocean Winds from Aquarius

+ Mission Operations

Ocean Color End-to-End

- Sensor calibration/characterization
- Processing software & algorithms
- Product validation (SeaBASS)
- Algorithm development (NOMAD)
- User processing and display (SeaDAS)
- User support (Ocean Color Forum)

Ocean Data Processing System

automated data acquisition, distributed processing, data management

Data archive and distribution

~3 PB online storage (RAID)

Missions Supported

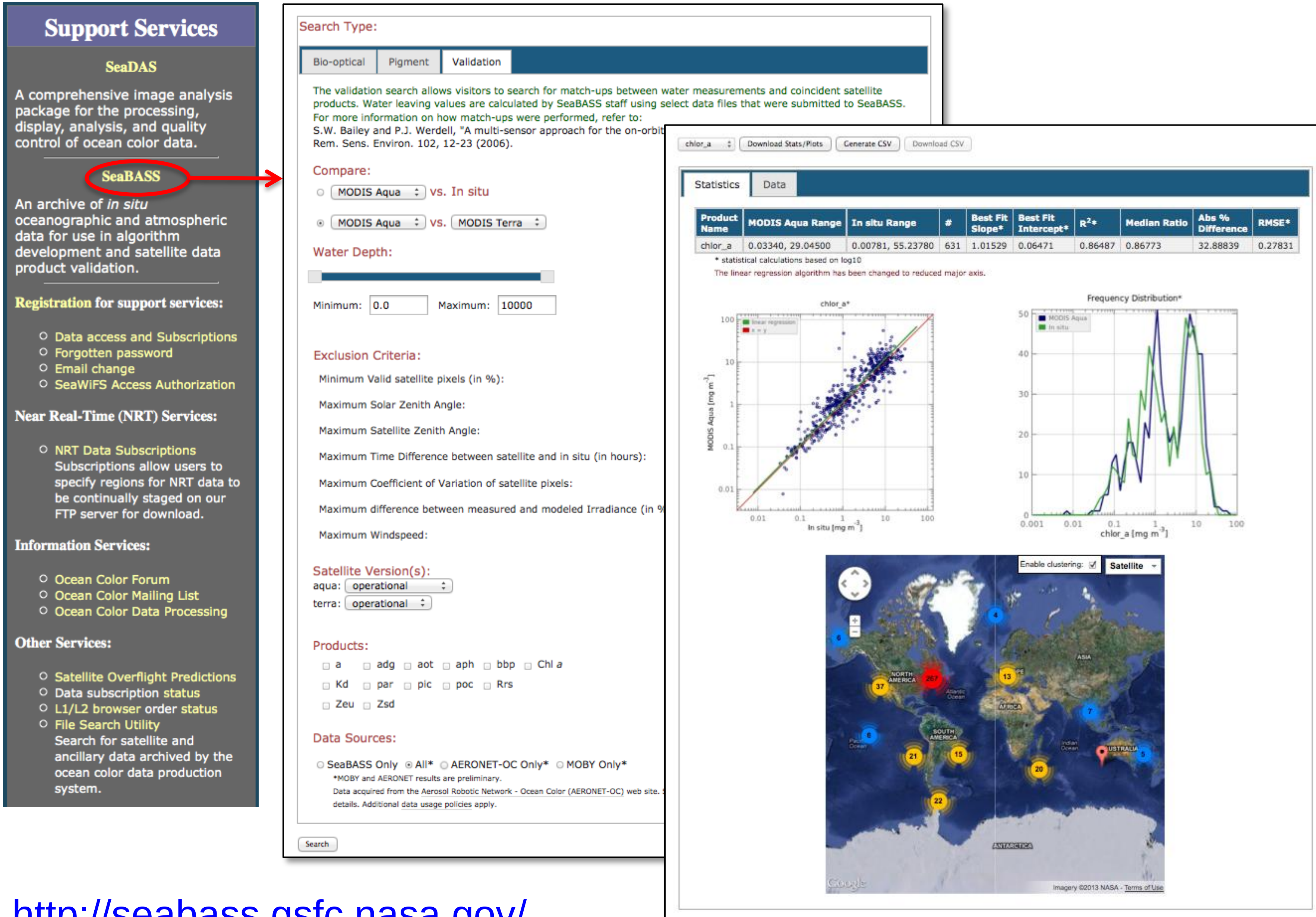
Aquarius/SAC-D : 2011-present

VIIRS/NPP: 2011-present
MODIS/Aqua: 2002-present
MODIS/Terra: 1999-present
SeaWiFS/Orbview-2: 1997-2010
CZCS/NIMBUS-7: 1978-1986

MERIS/Envisat: 2002-2012
OCM-2/Oceansat-2: 2009-present
MOS/IRS-P3: 1996-2004
OCTS/ADEOS: 1996-1997
OSMI/Kompsat: 1999-

Splinter 11

SeaBASS In Situ Validation Tool

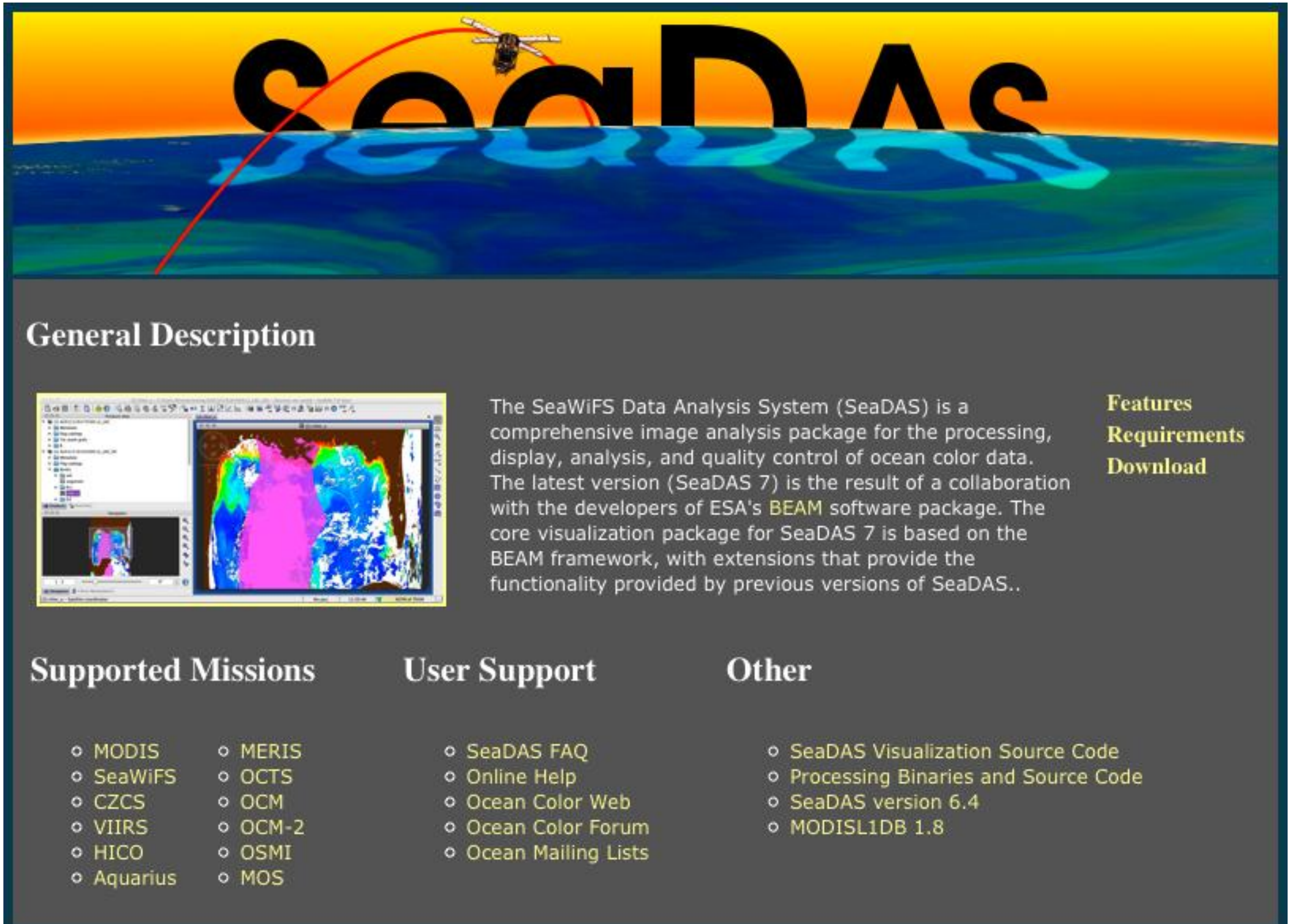


http://seabass.gsfc.nasa.gov/

Splinter 11

SeaDAS 7 Release

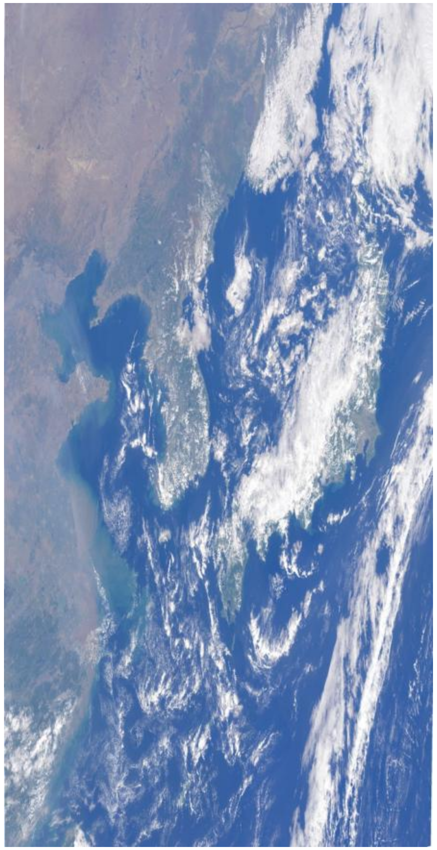
SeaDAS processing capabilities and BEAM Analysis and Display

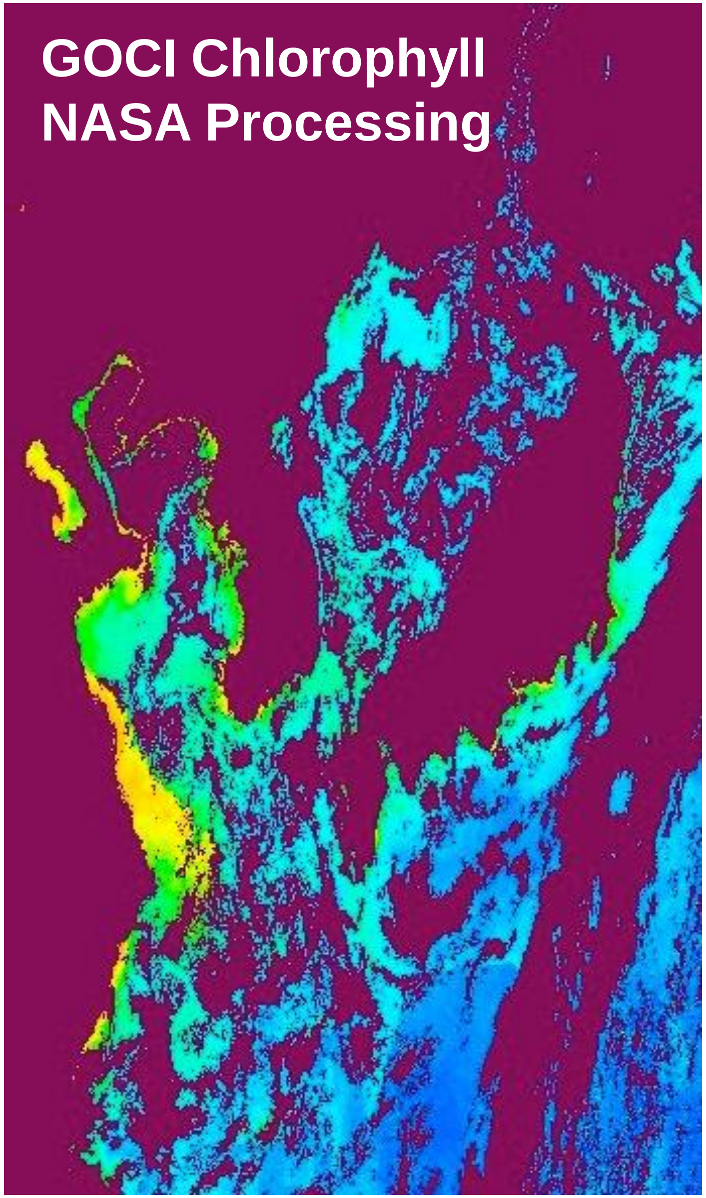


http://seadas.gsfc.nasa.gov/

GOCI Collaboration with KIOST

distribution through ocean color web
SeaDAS analysis and display
NASA processing implementation
collaboration on calibration & algorithms





Coming Soon!

HICO

Hyperspectral Imager for Coastal Oceans

operating on ISS since 2009

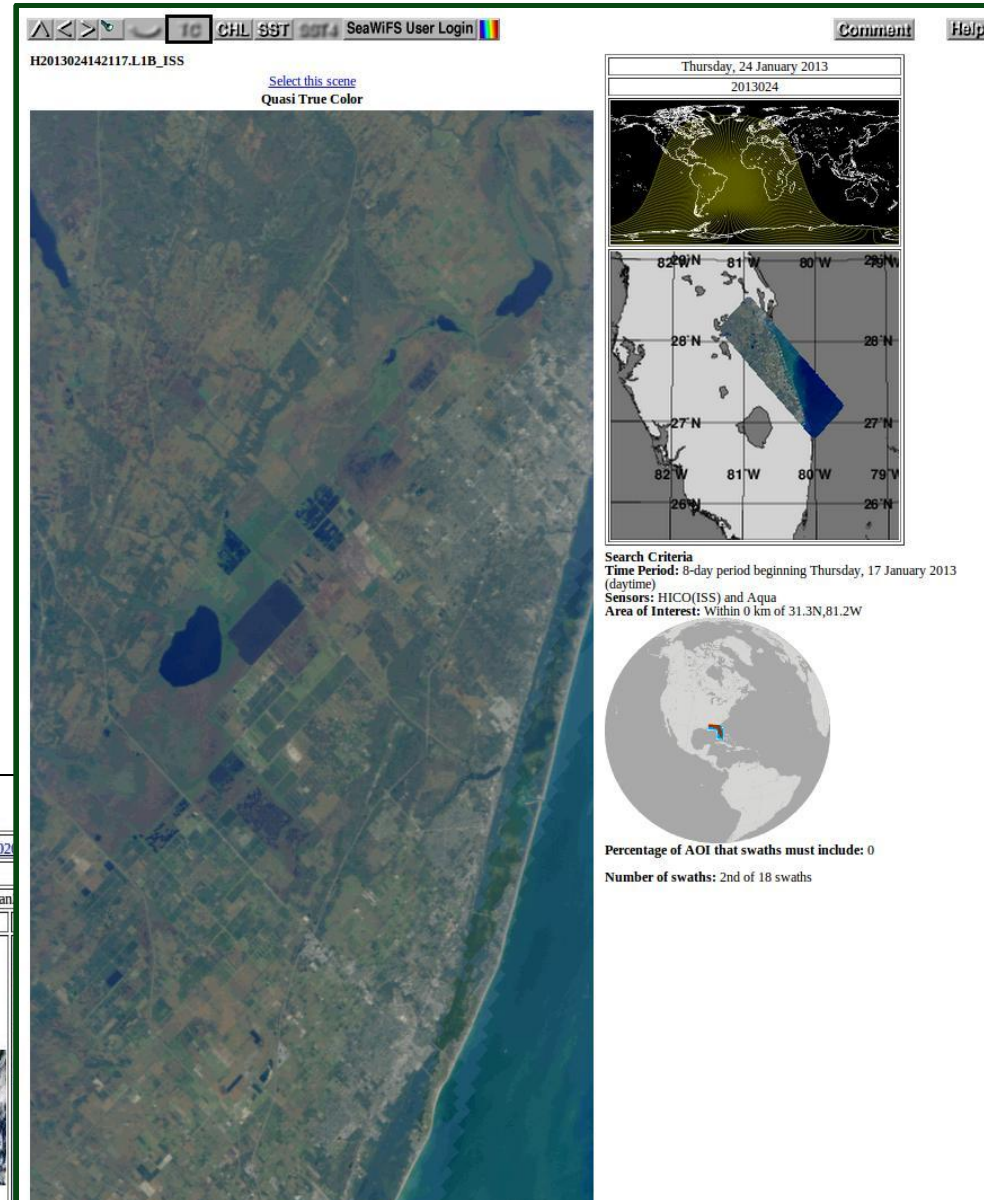
128 spectral bands 350-1080nm

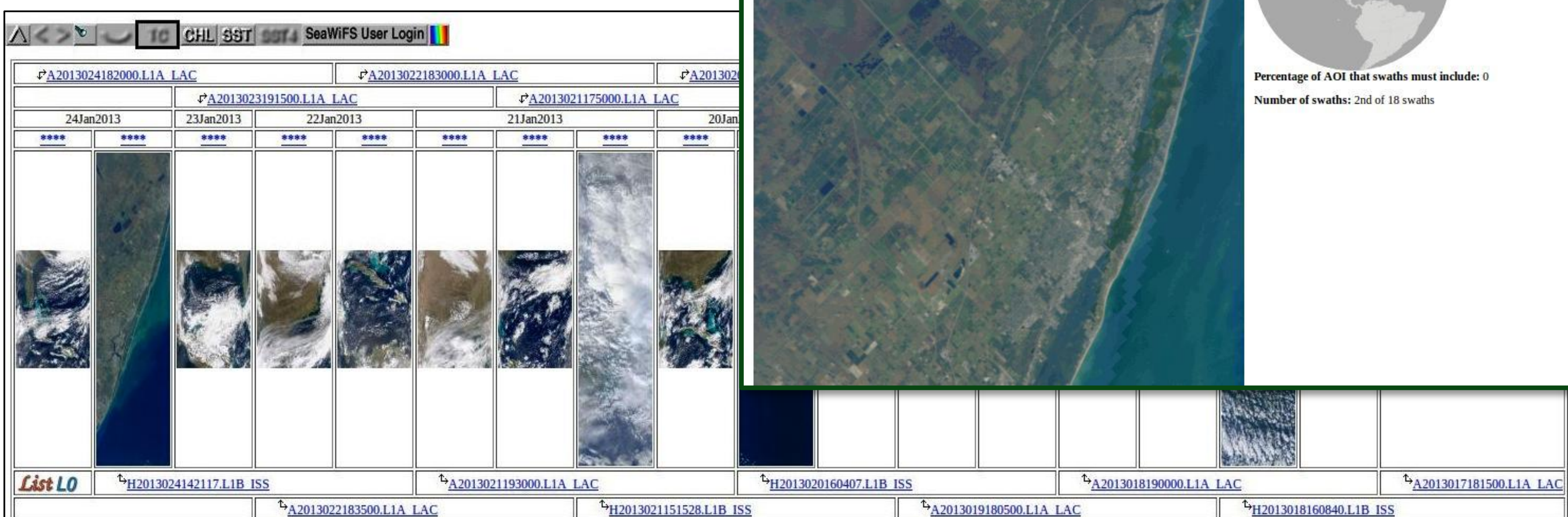
2000 scenes per year

coming very soon:

distribution through OCW

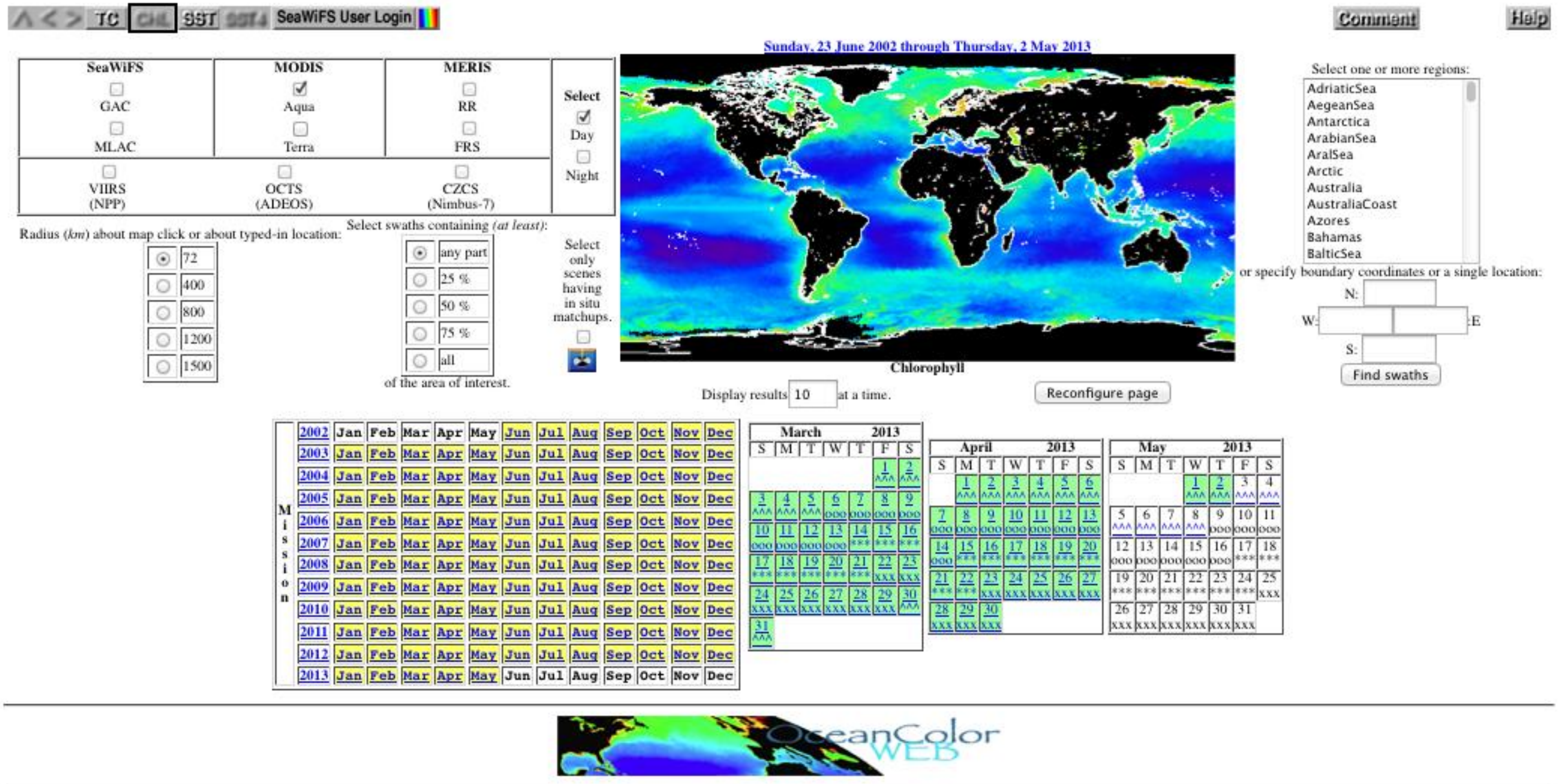
SeaDAS support





Multi-Mission Data Distribution

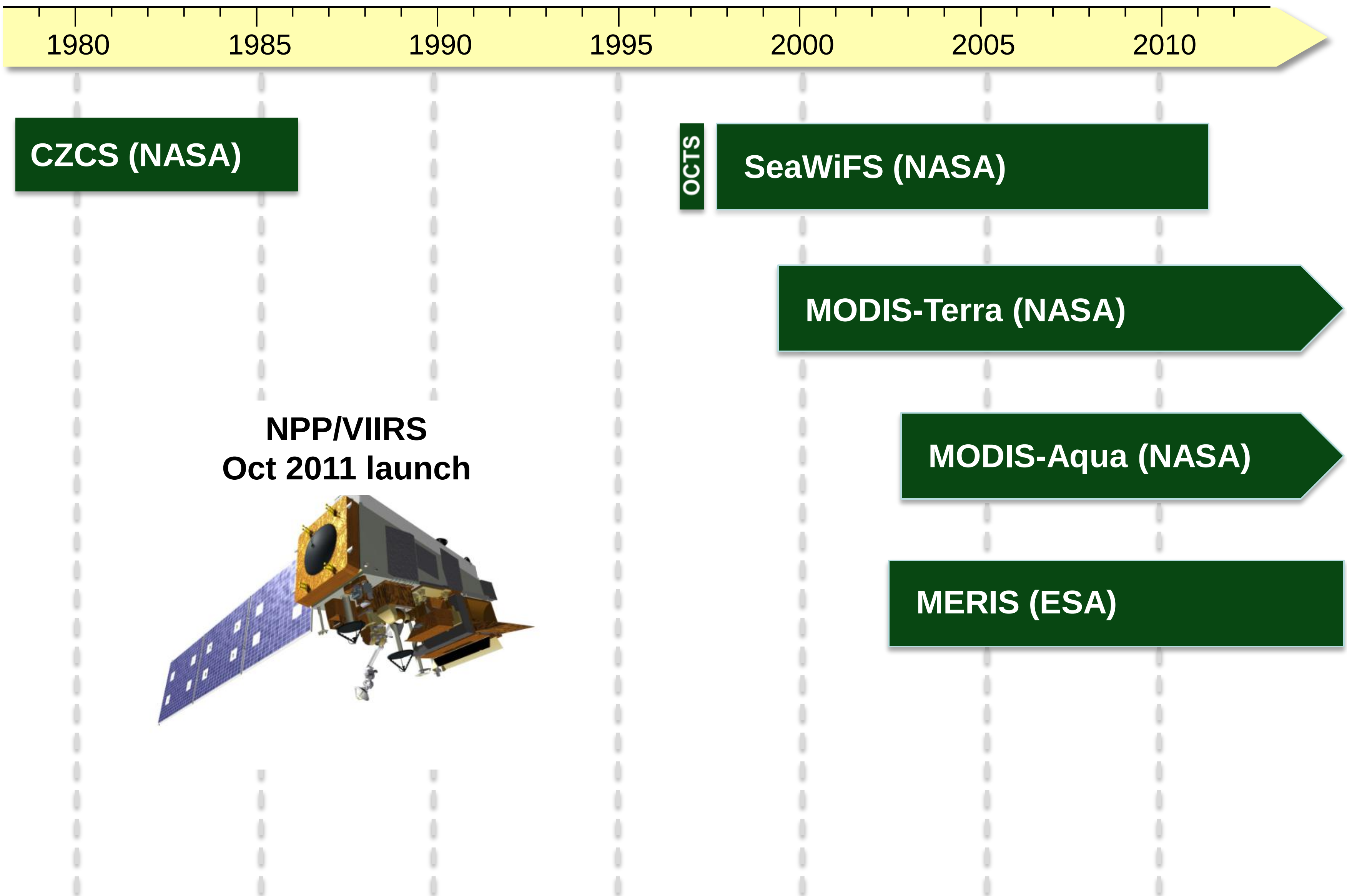
now serving MERIS and VIIRS



http://oceancolor.gsfc.nasa.gov/

Global Multi-Mission Ocean Color Timeseries

the man with two watches doesn’t know what time it is ...

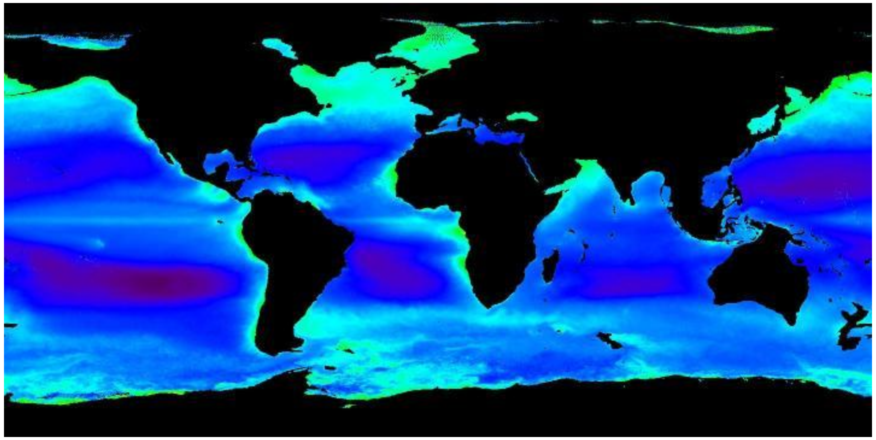


How do we achieve consistency?

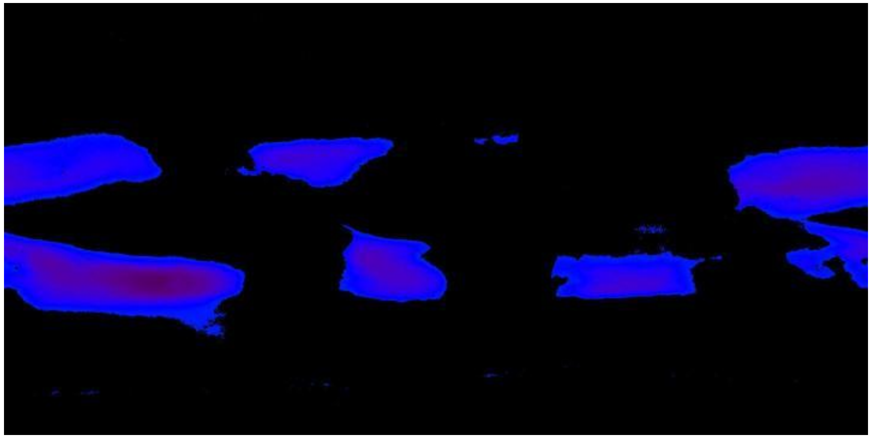
- Focus on instrument calibration
  - establishing temporal and spatial stability within each mission
- Apply common algorithms
  - ensuring consistency of processing across missions
- Apply common vicarious calibration approach
  - ensuring spectral and absolute consistency of water-leaving radiance retrievals under idealized conditions
- Reprocess multi-mission timeseries
  - incorporating new instrument knowledge and algorithm advancements
- Perform detailed trend analyses
  - assessing temporal stability & and mission-to-mission consistency

Global Trophic Subsets

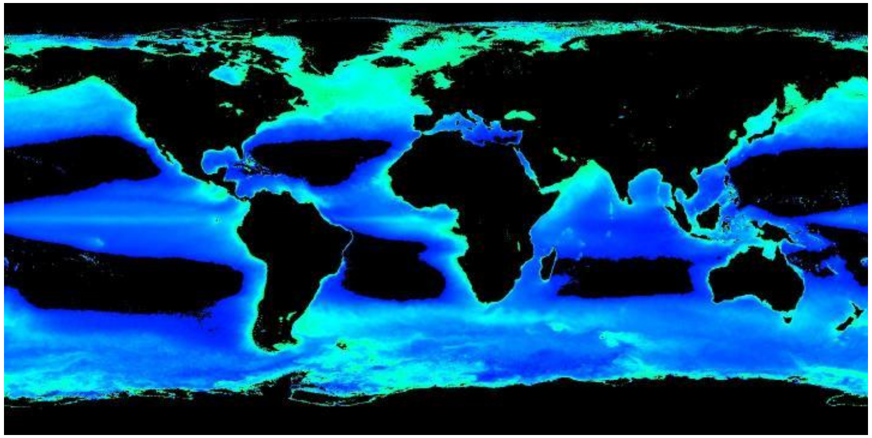
Deep-Water (Depth > 1000m)



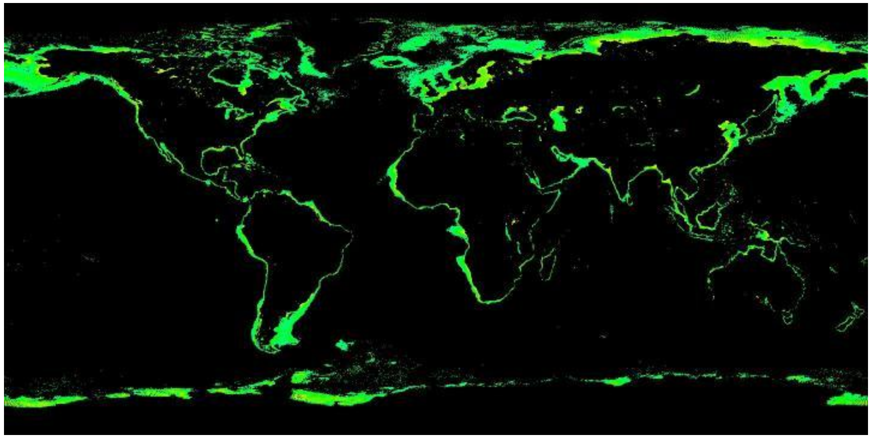
Oligotrophic (Chlorophyll < 0.1)



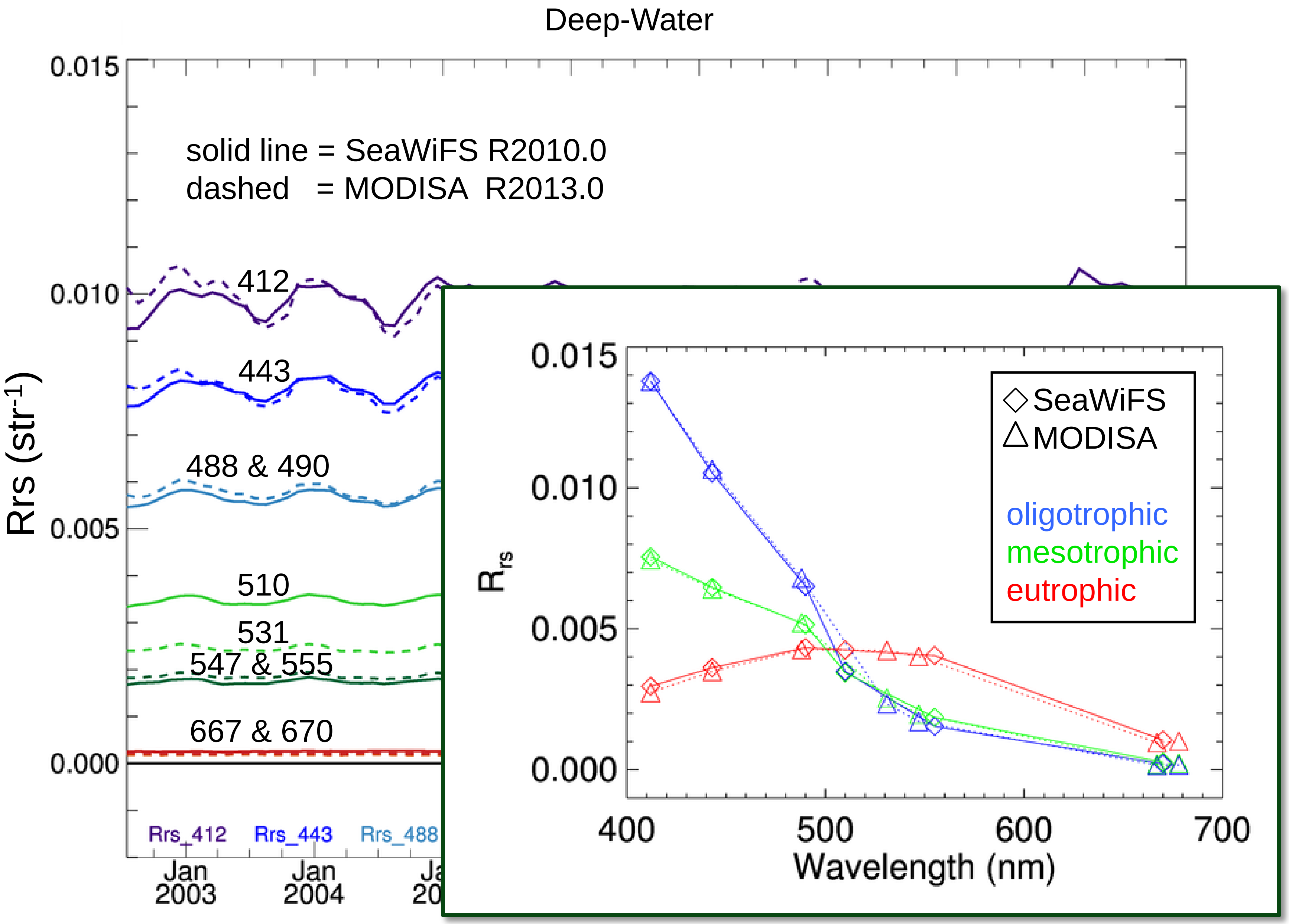
Mesotrophic (0.1 < Chlorophyll < 1)



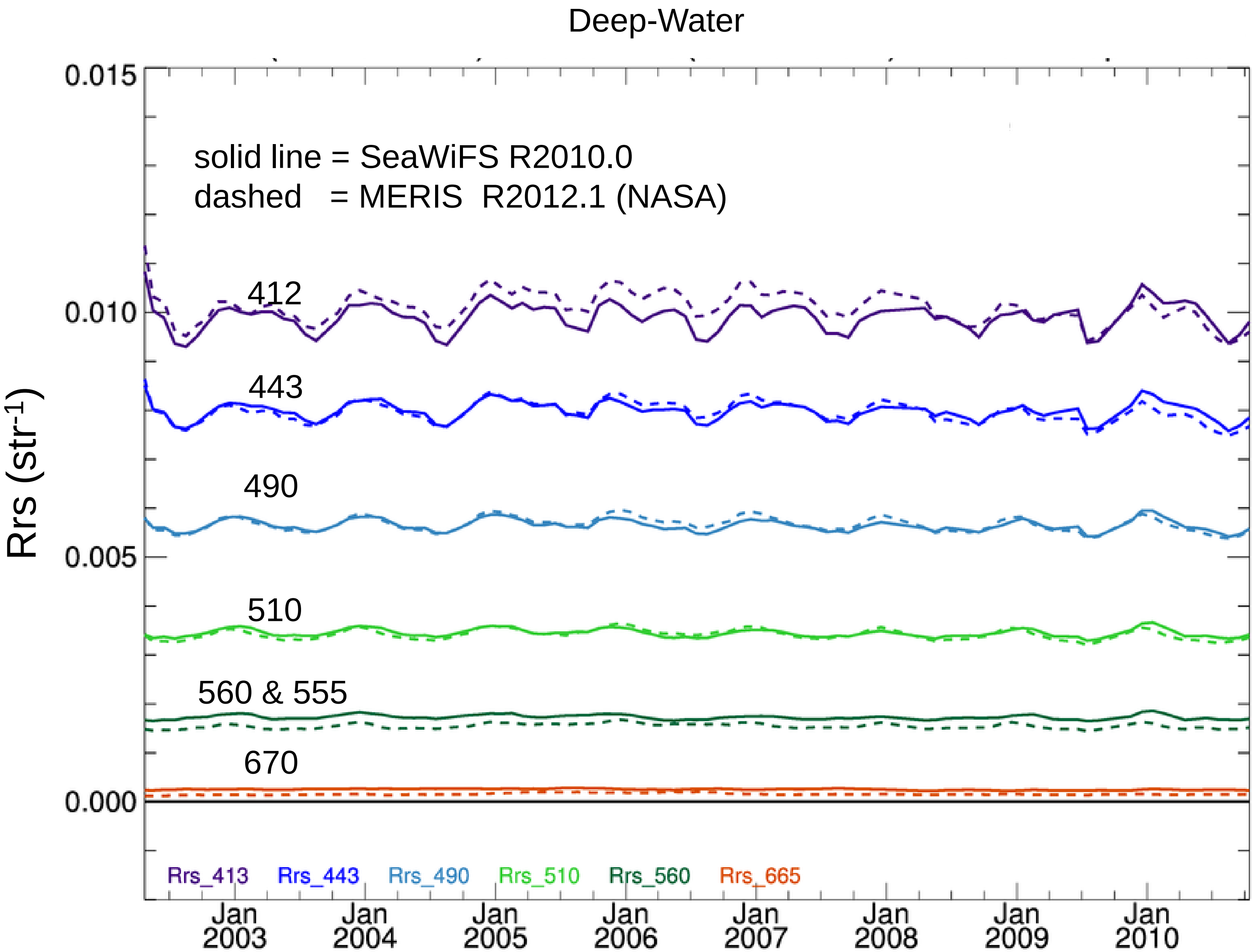
Eutrophic (1 < Chlorophyll < 10)



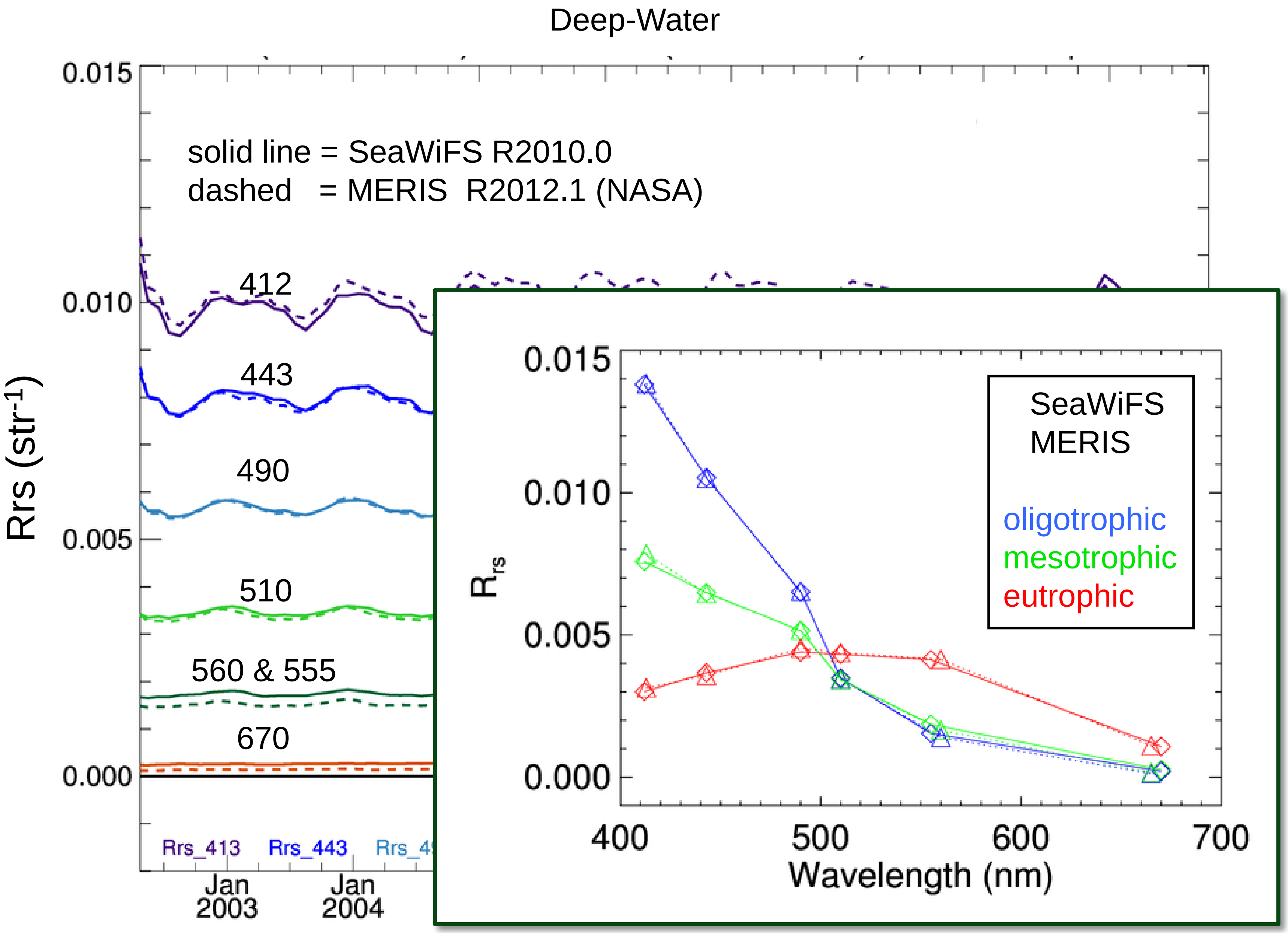
Radiometric Consistency of MODISA & SeaWiFS



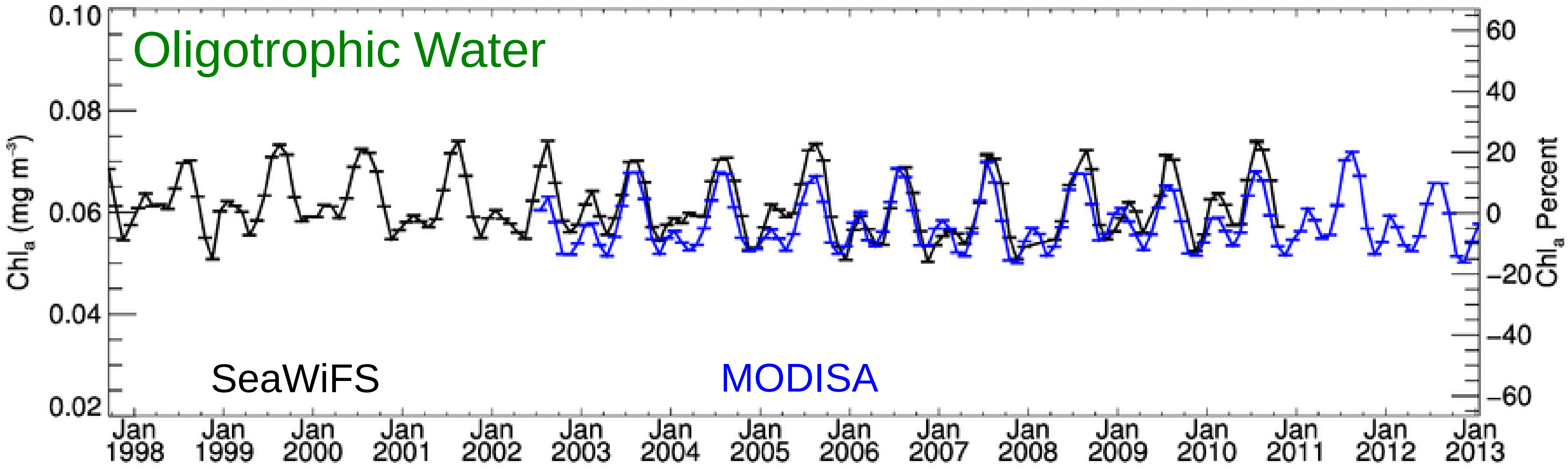
Radiometric Consistency of MERIS & SeaWiFS



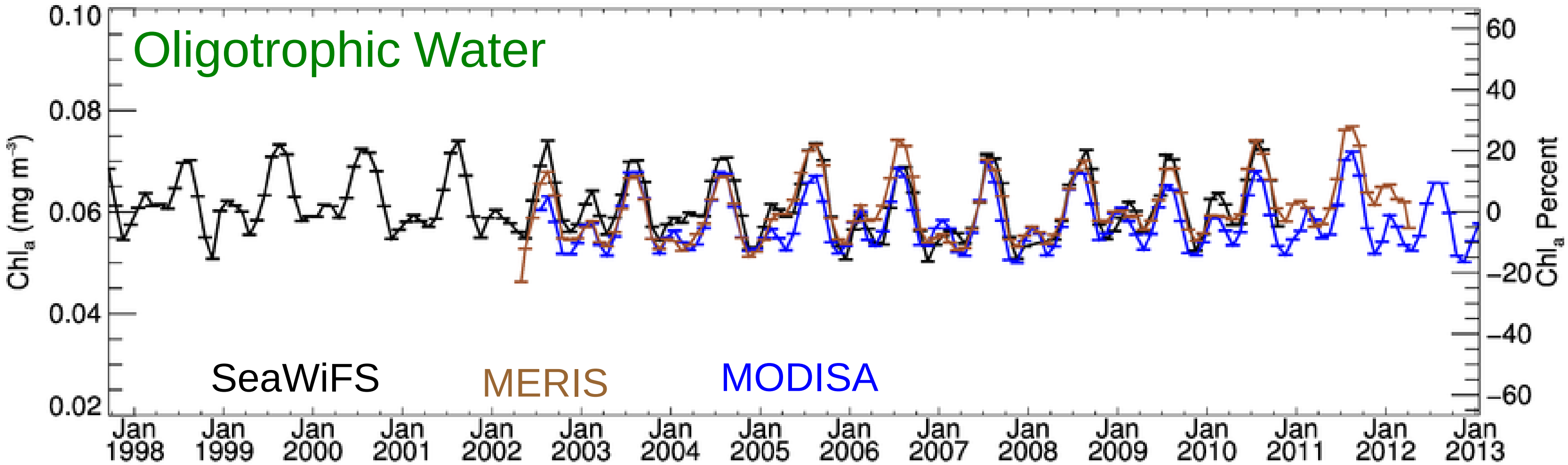
Radiometric Consistency of MERIS & SeaWiFS

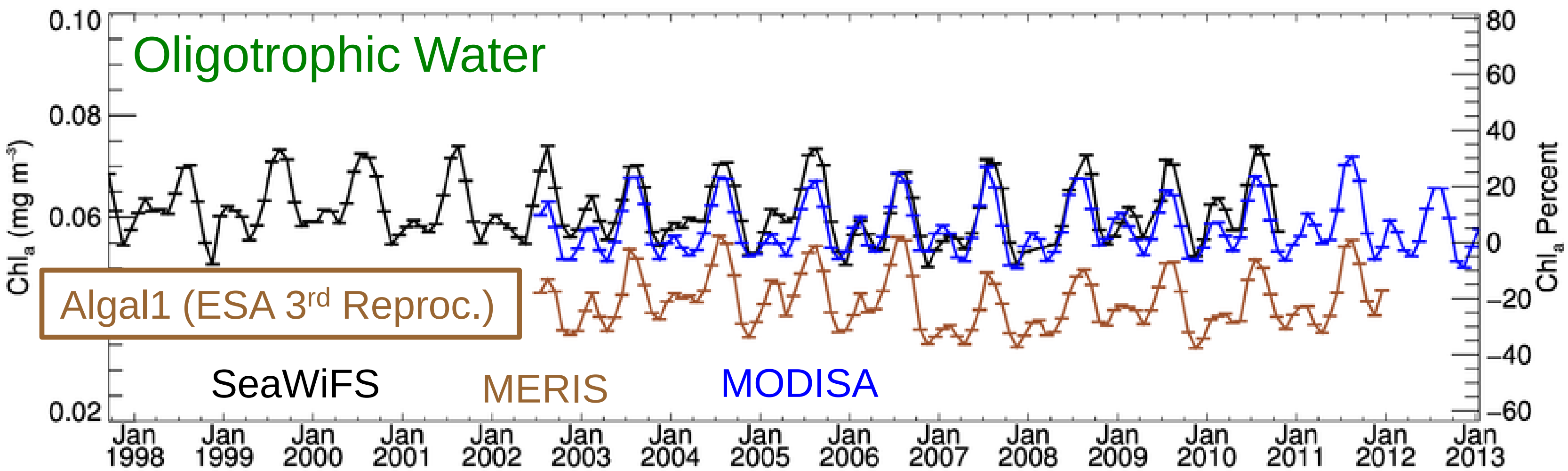


Multi-mission Chlorophyll Record

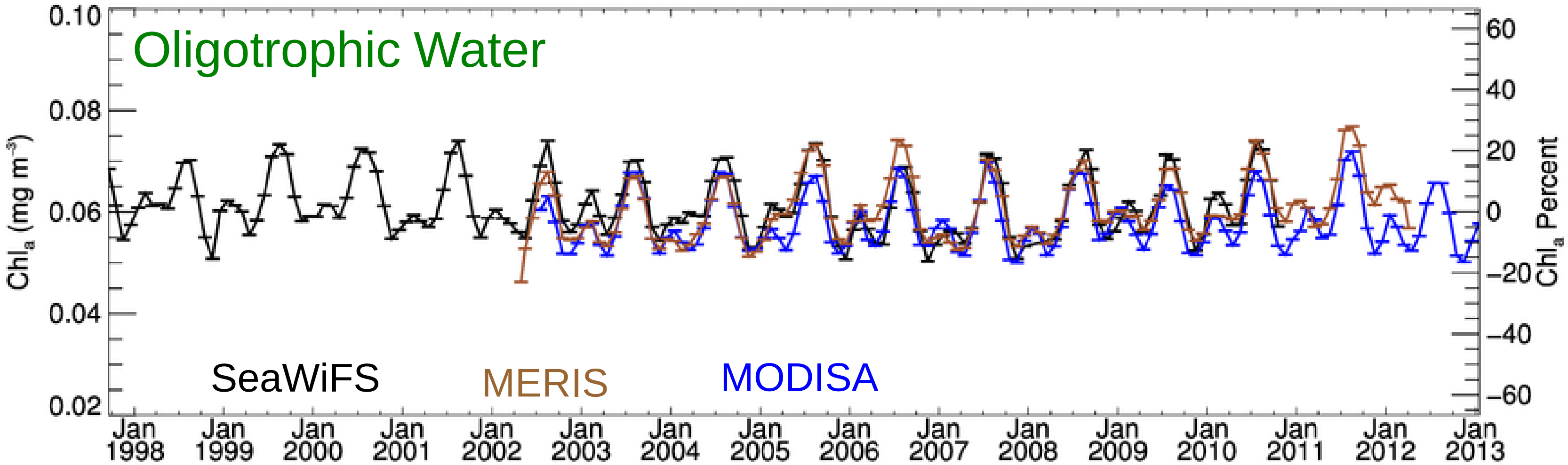


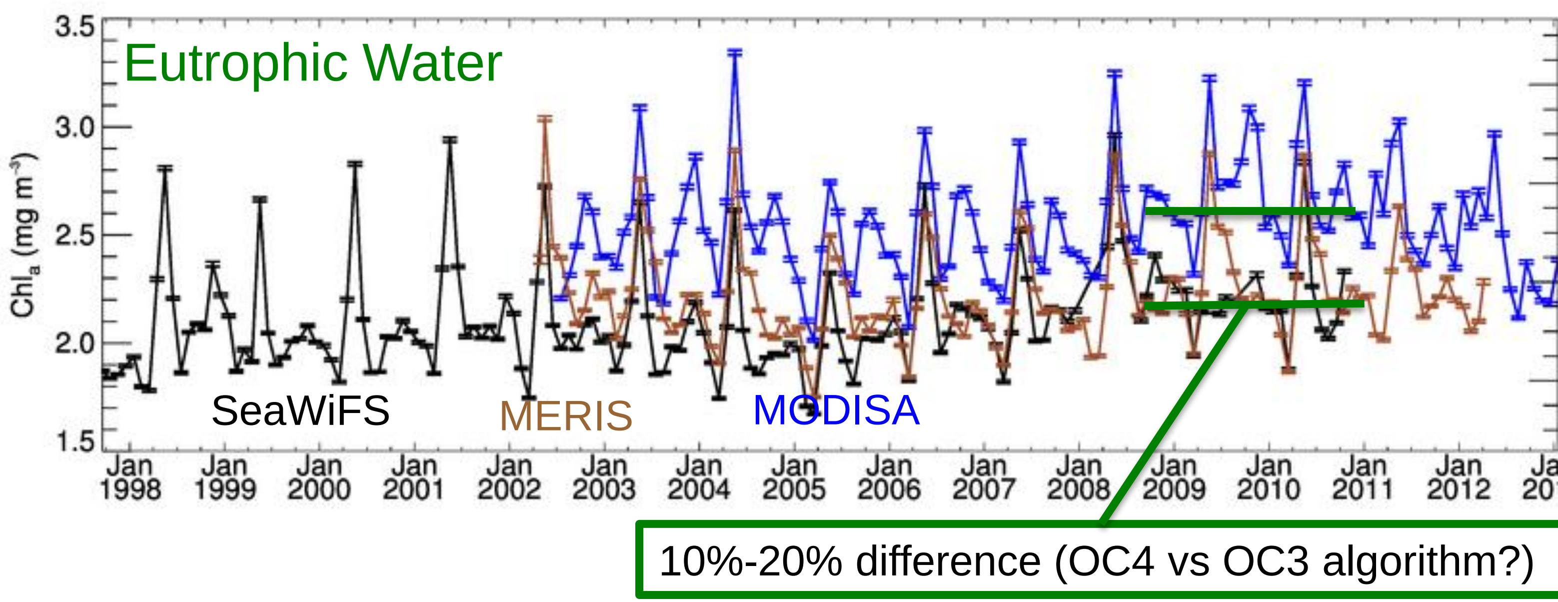
Multi-mission Chlorophyll Record





Multi-mission Chlorophyll Record





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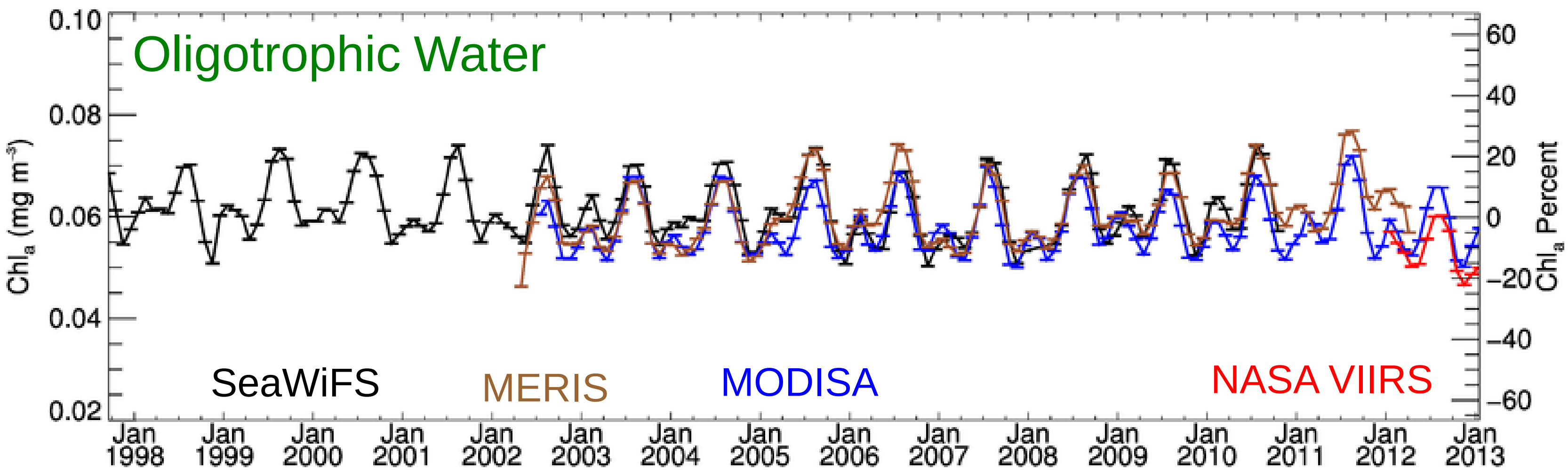
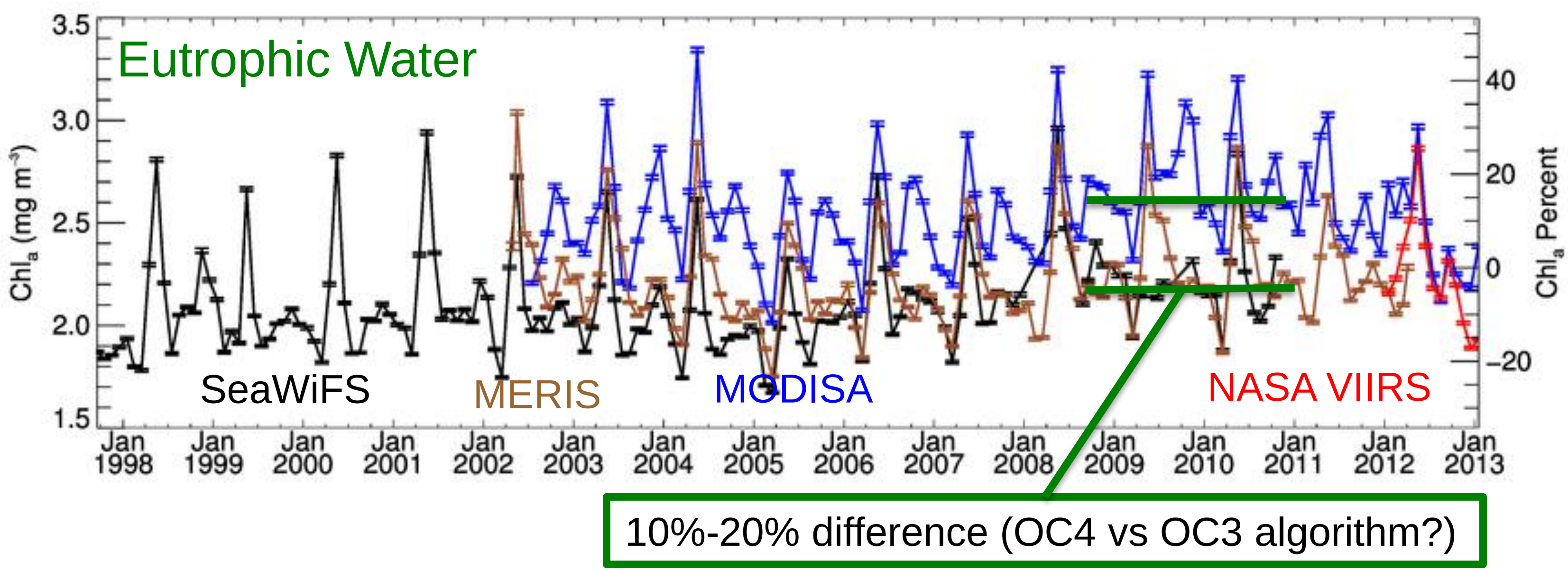
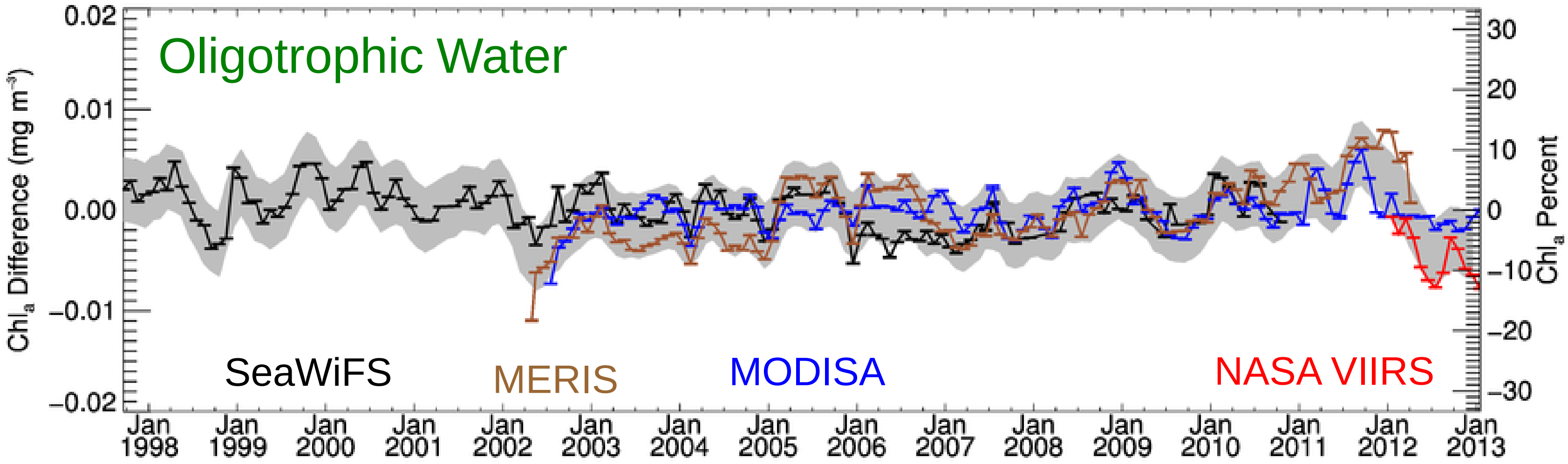
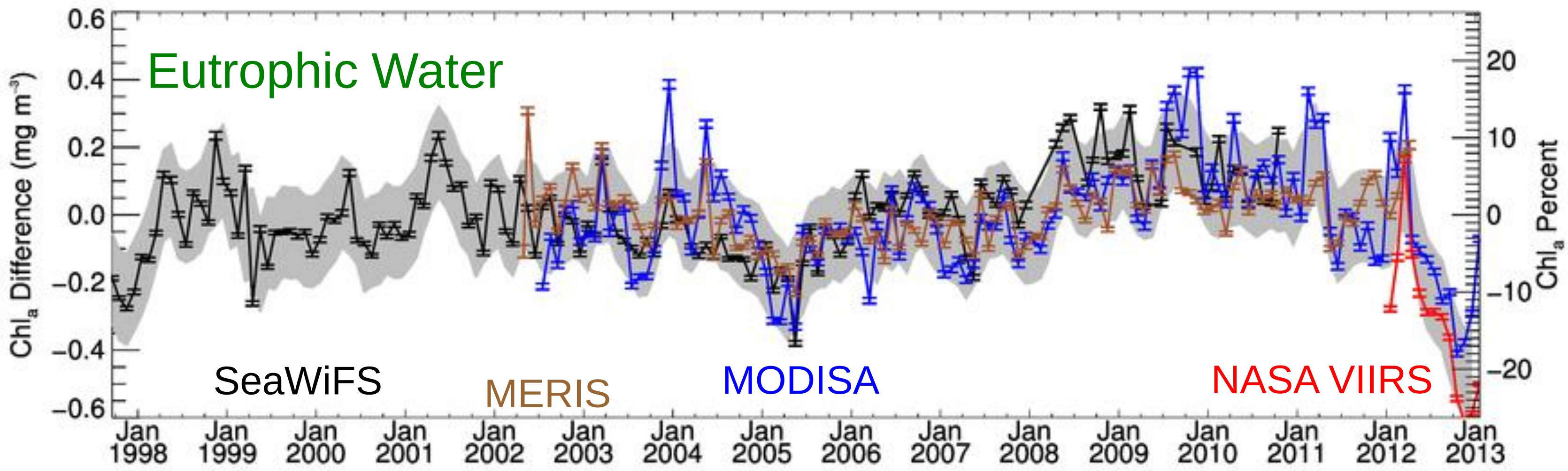




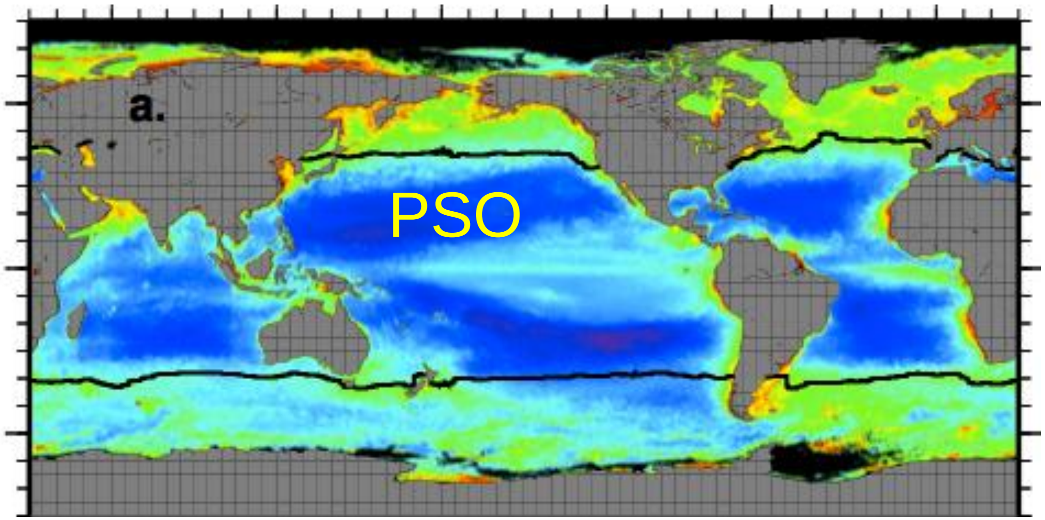
Multi-mission Chlorophyll Anomaly Record



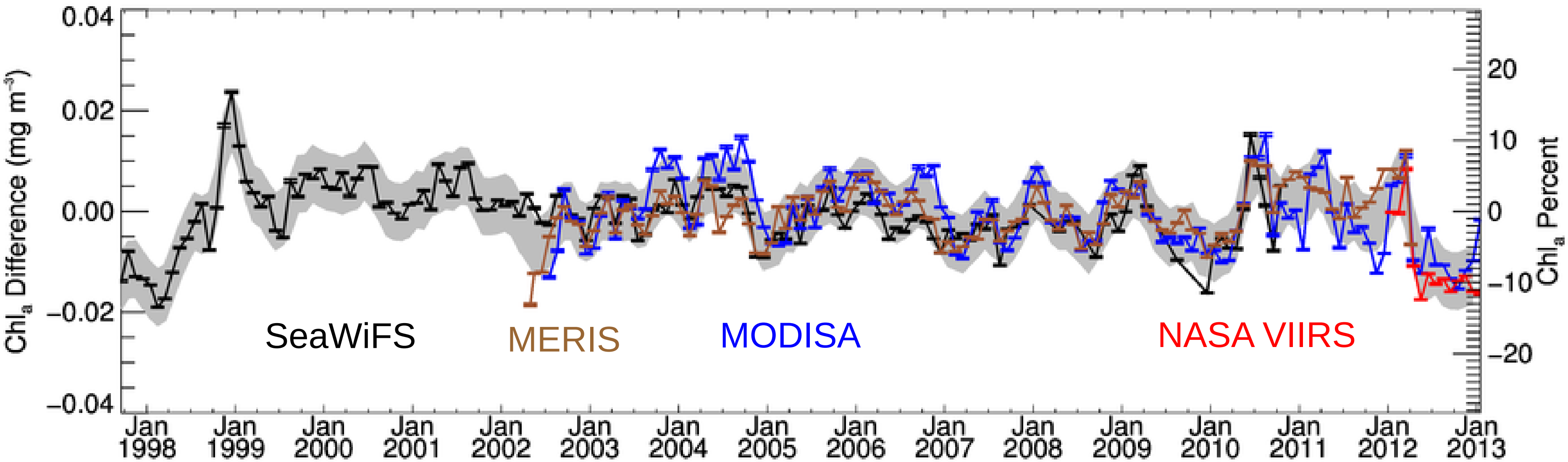


Multi-mission Chlorophyll Anomaly Record

Following
Berenfeld et al. 2006
Mean SST > 15C



PSO Anomaly



Franz, B.A., D.A. Siegel, M.J. Behrenfeld, P.J. Werdell (2013). Global ocean phytoplankton [in State of the Climate in 2012]. Bulletin of the American Meteorological Society (submitted)

Multi-mission Chlorophyll Anomaly Record

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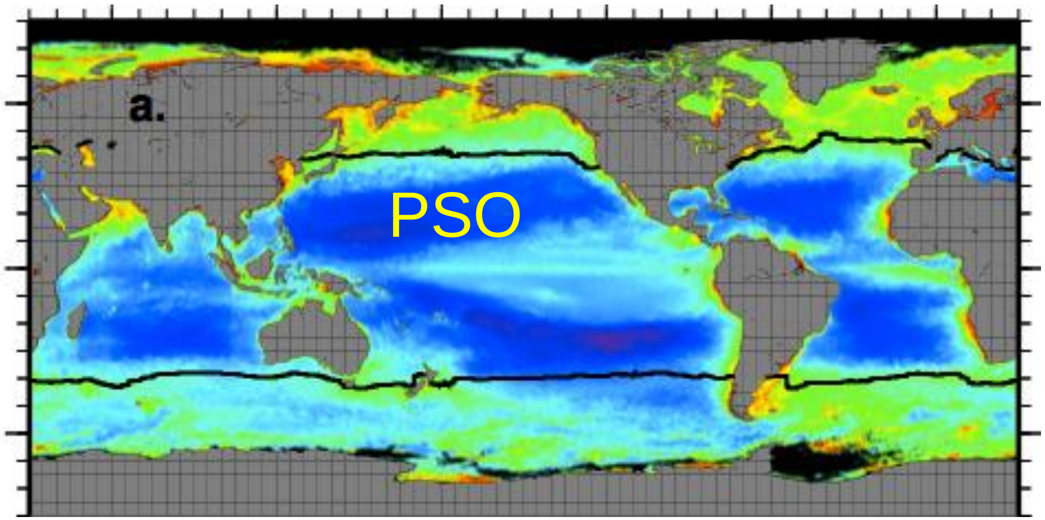
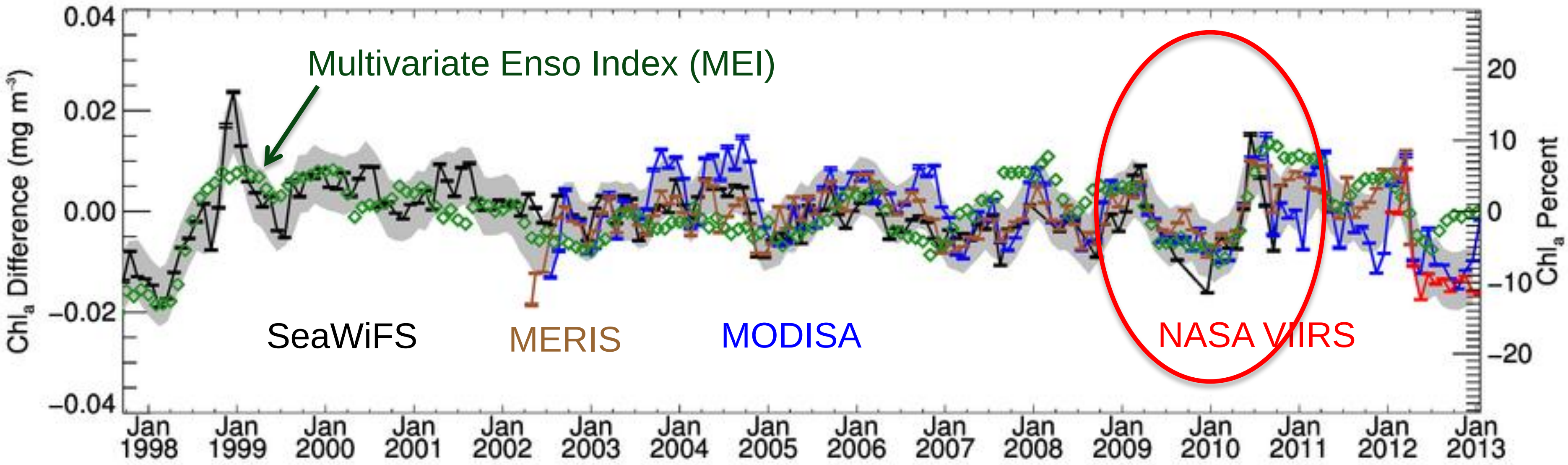


PSO Anomaly



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Multi-mission Chlorophyll Anomaly Record

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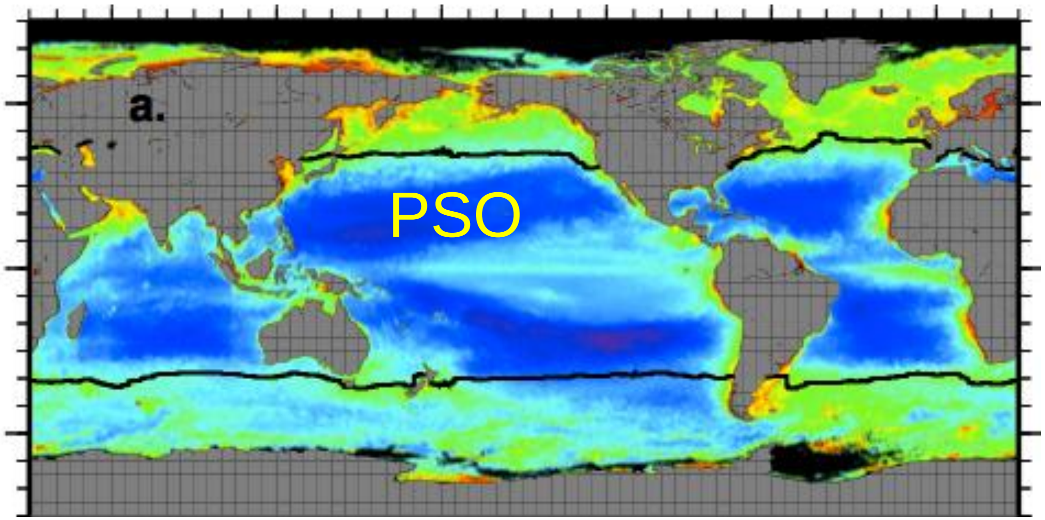
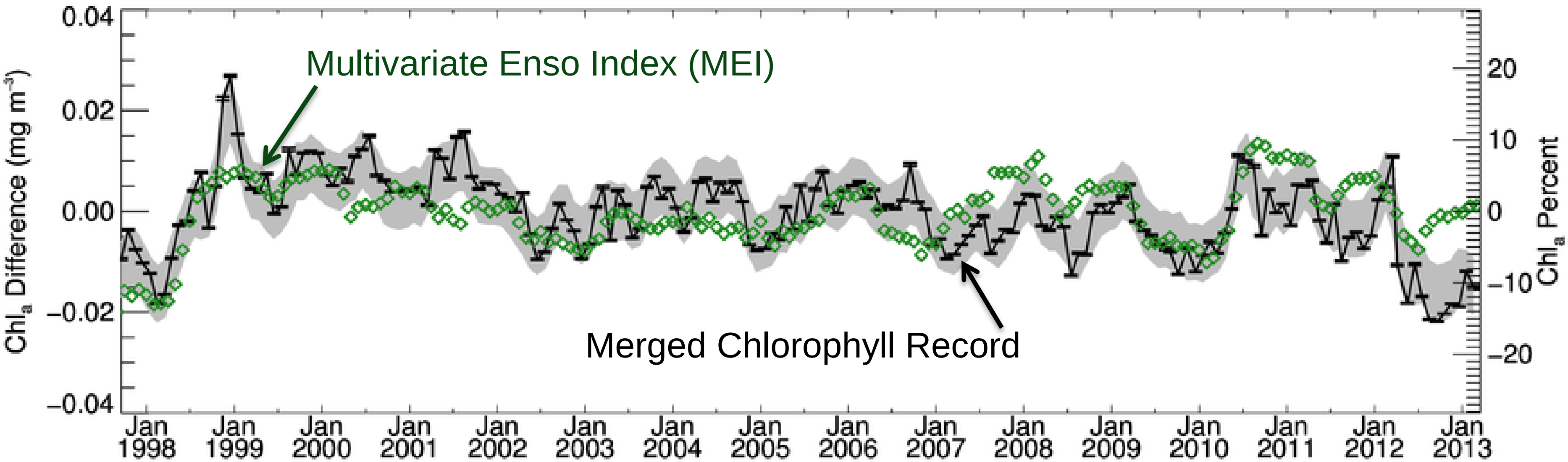


PSO Anomaly

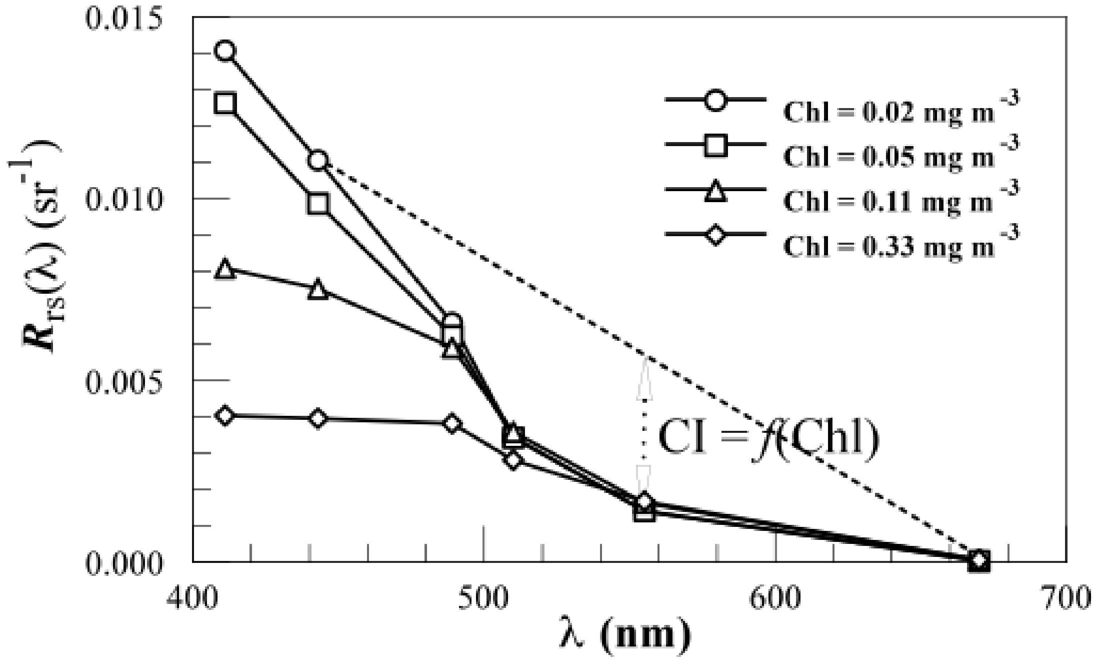


Chlorophyll Algorithm Refinement

Chlorophyll Algorithm Refinement (OCI)

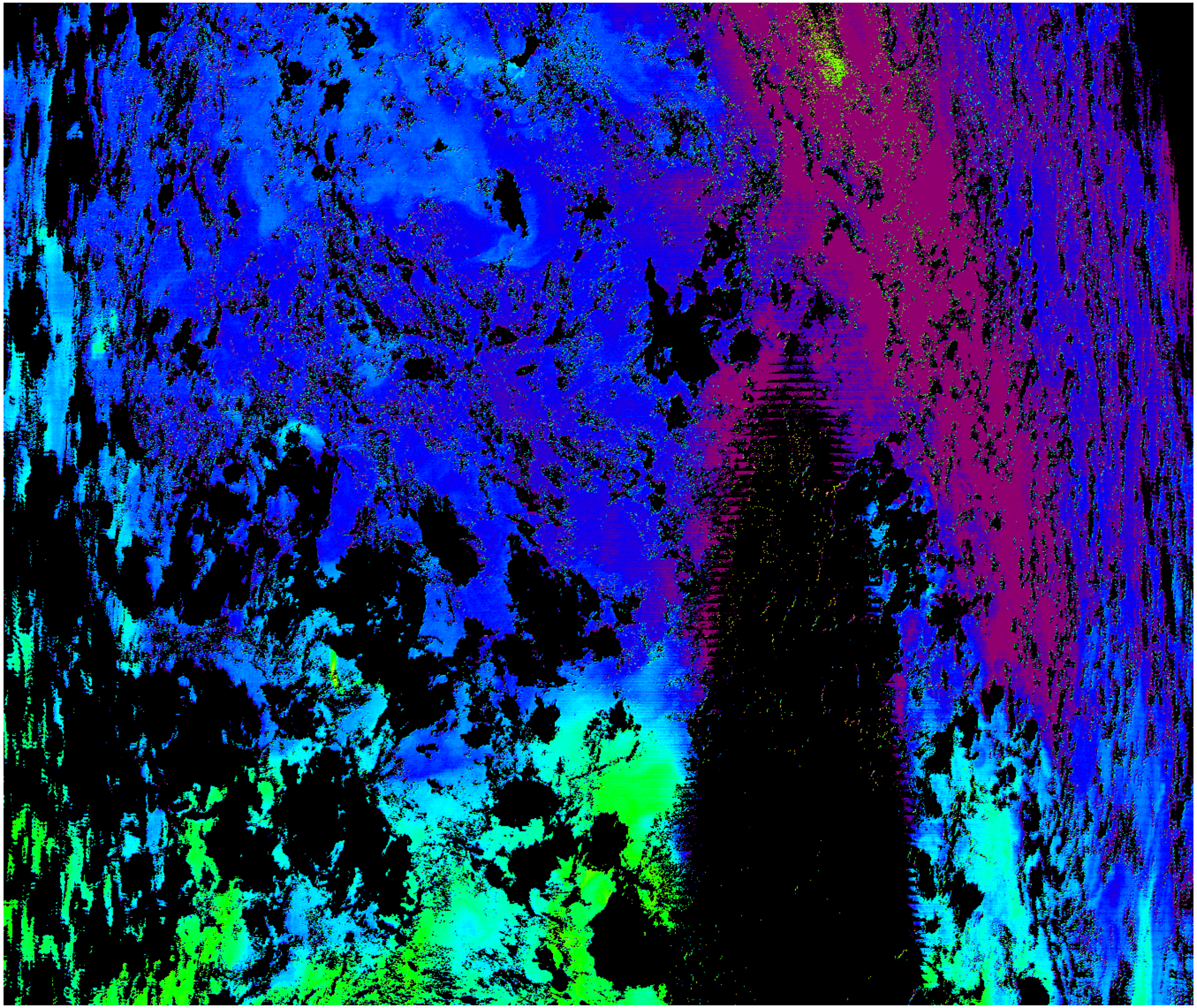
for low-chlorophyll water only

OCI algorithm: Line height algorithm for chlorophyll < 0.25 mg m^{-3}, merged with OC3/OC4 max band ratio algorithm for chlorophyll > 0.3 mg m^{-3}.

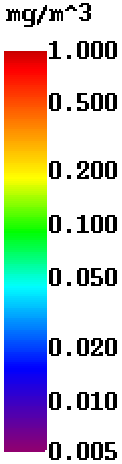


Hu, C., Z. Lee, and B.A. Franz (2012). Chlorophyll-a algorithms for oligotrophic oceans: A novel approach based on three-band reflectance difference, J. Geophys. Res., 117, C01011, doi:10.1029/2011JC007395.

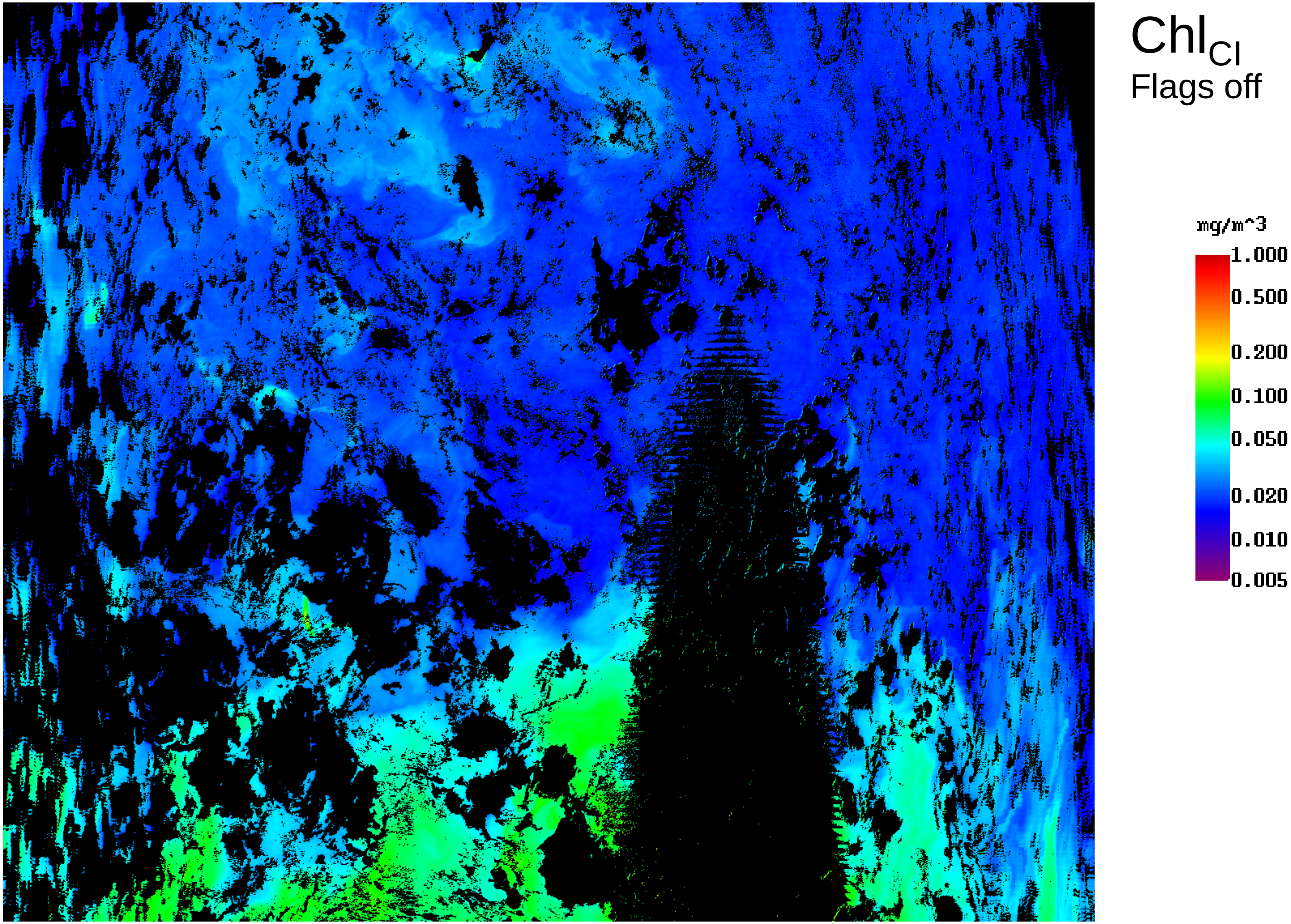
MODISA Standard OC3 Chlorophyll



Chl$_{OC3}$
Flags off

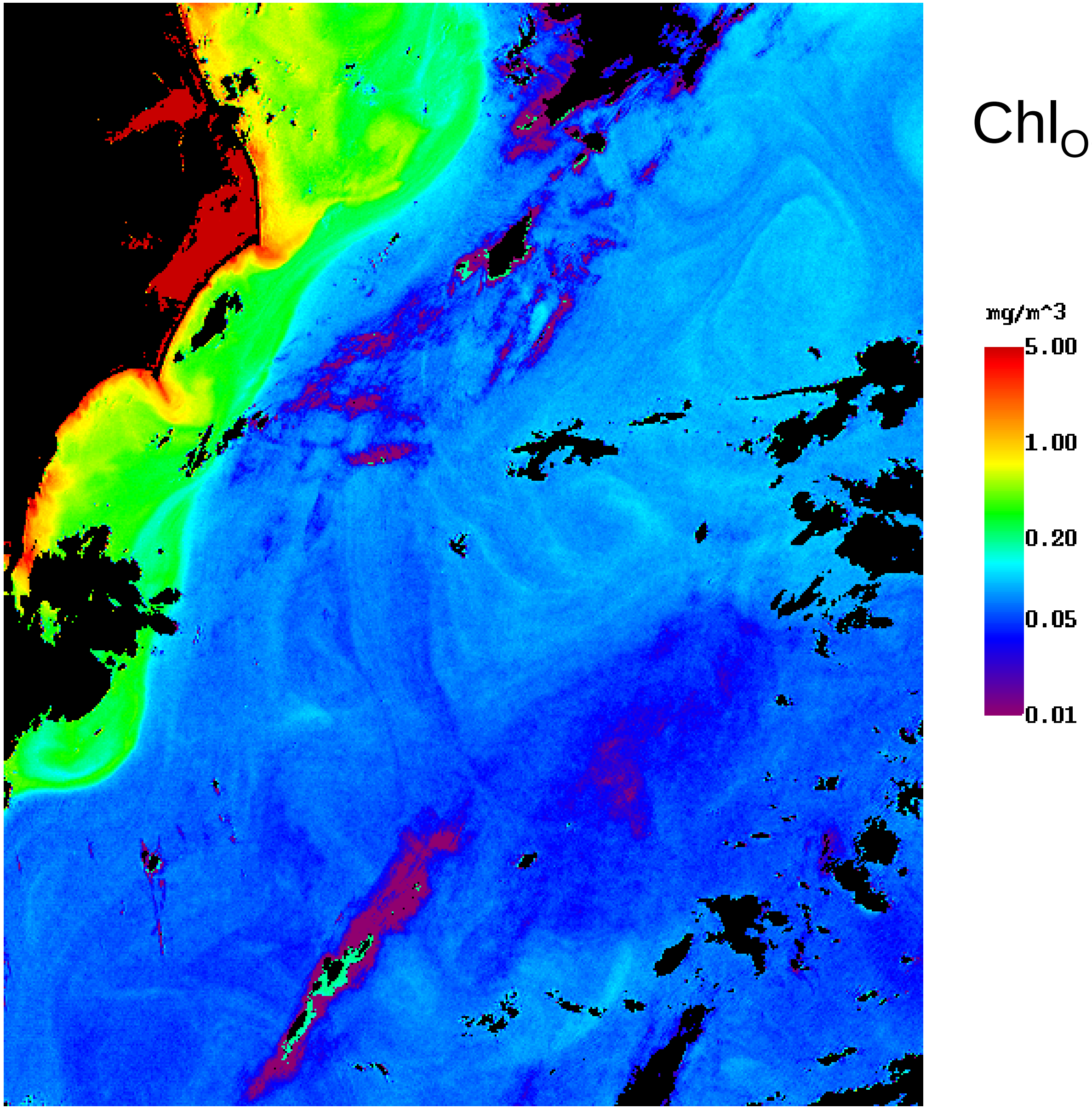


MODISA Evaluation OCI Chlorophyll



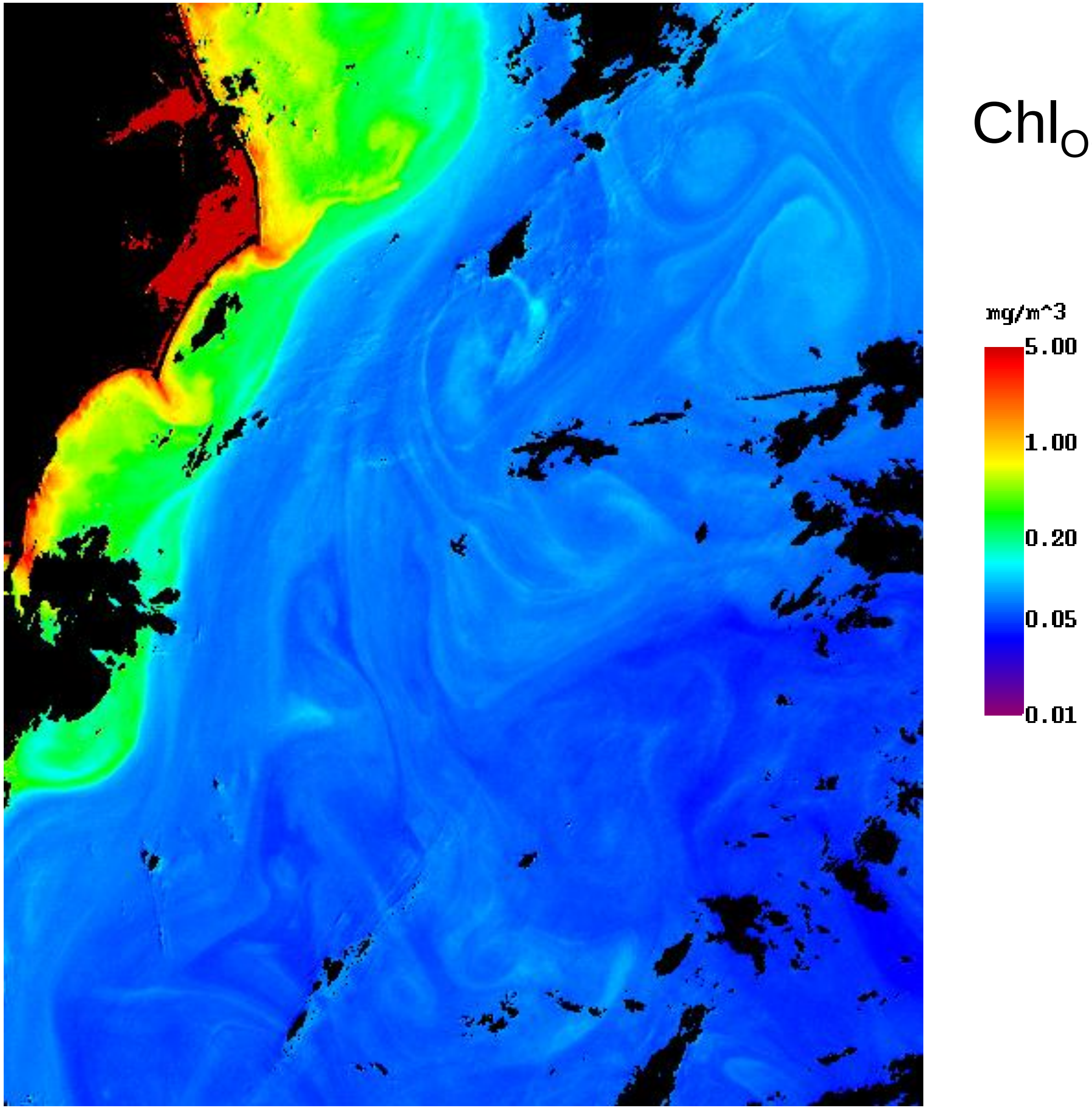
Chl_{CI}
Flags off

SeaWiFS Standard OC4 Chlorophyll



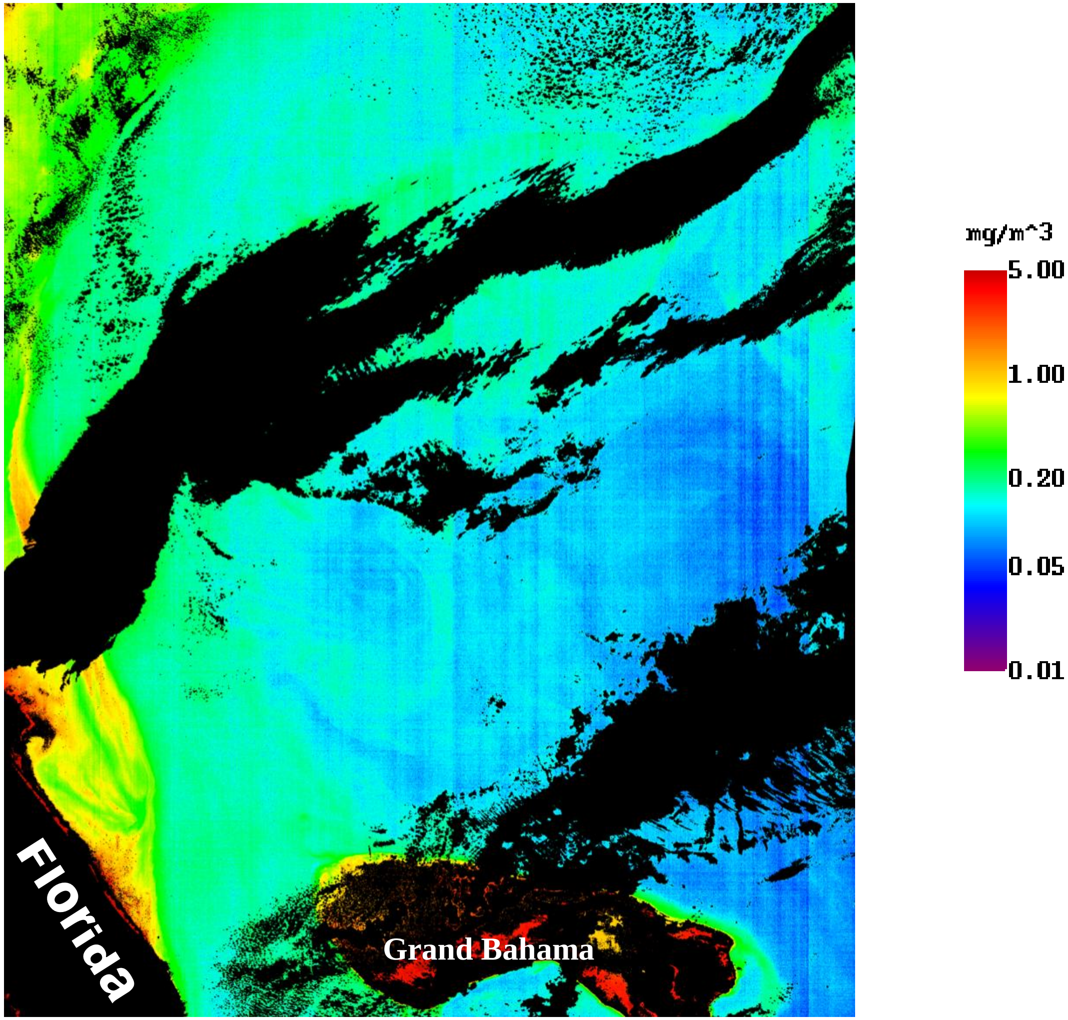
Chl_{OC4}

SeaWiFS Evaluation OCI Chlorophyll

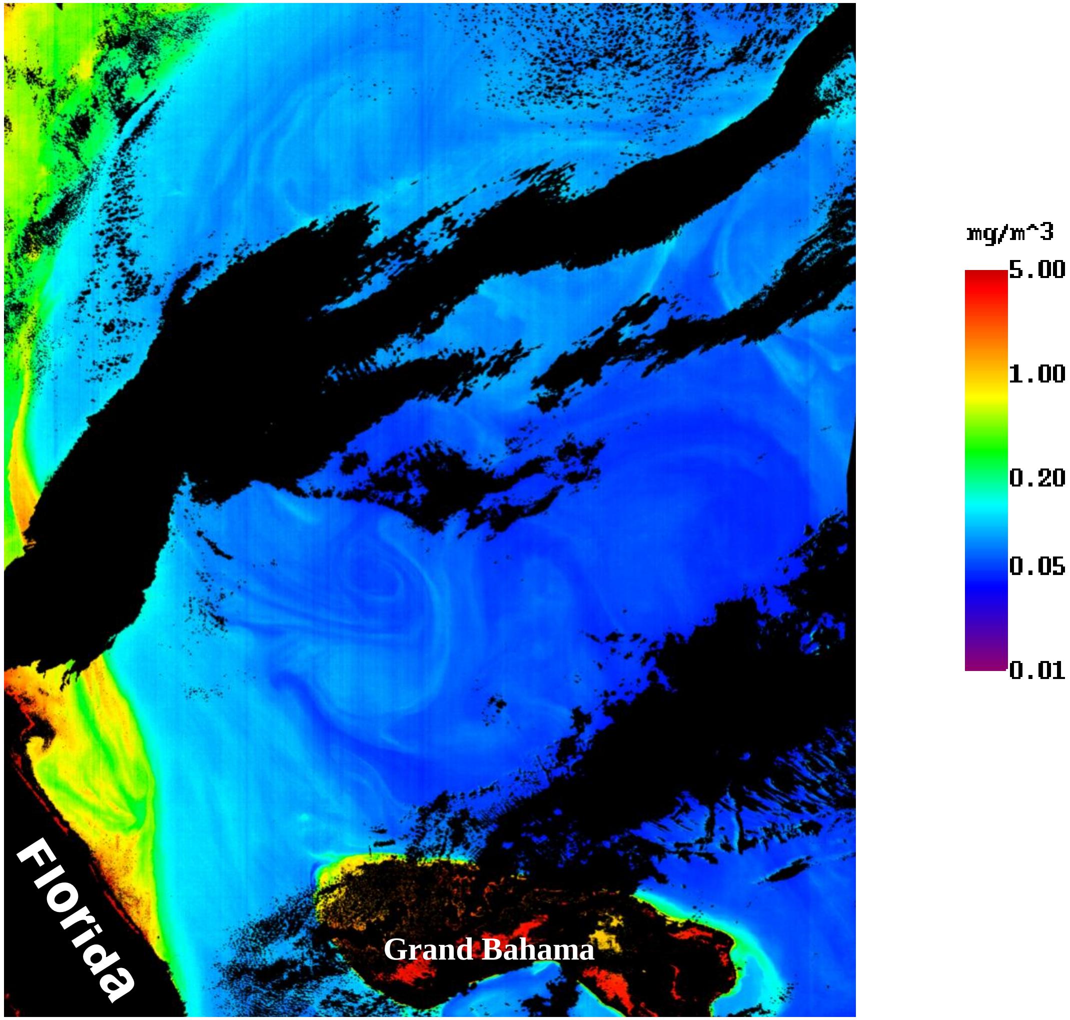


Chl_{OCI}

MERIS Standard OC4 Chlorophyll



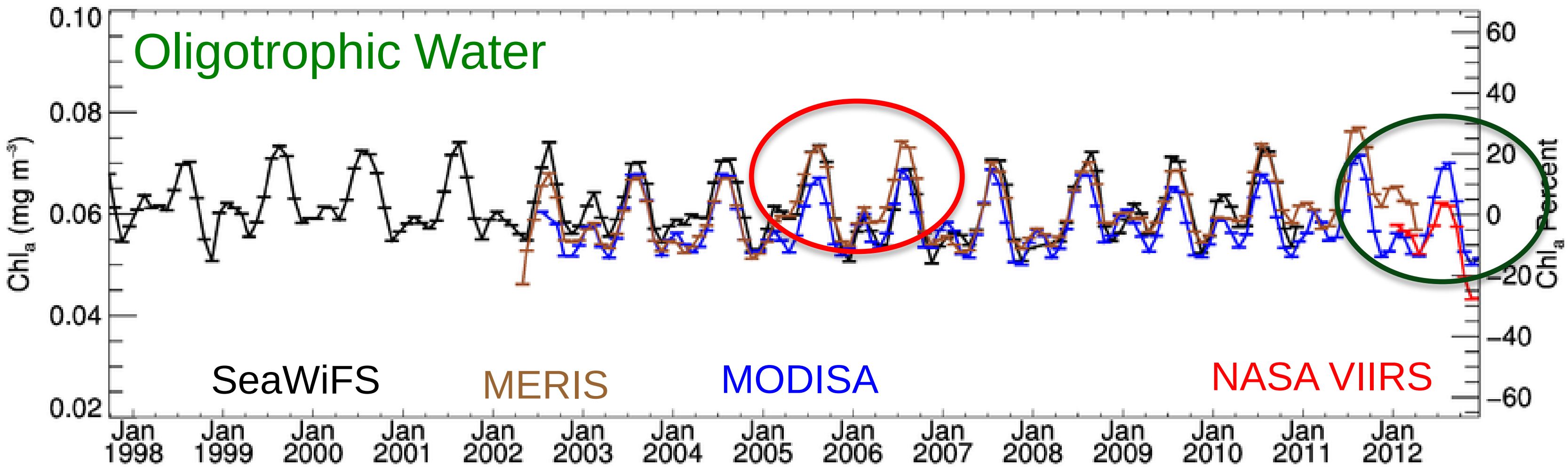
MERIS Evaluation OCI Chlorophyll



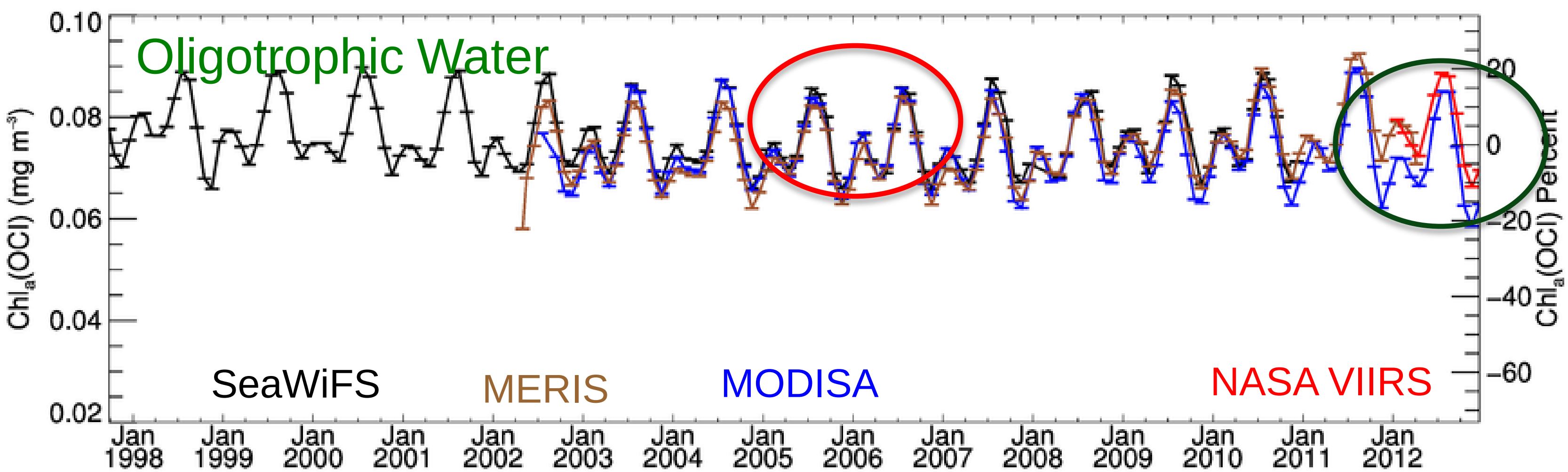
Chlorophyll Algorithm Refinement

improved agreement between sensors in clear water

OC3 & OC4



OCI



Future Plans

Next multi-mission reprocessing anticipated 2013-2014

Incorporate algorithm refinements

- advancements in atmospheric correction
- new chlorophyll algorithm likely
- updates to PIC algorithm
- updates to PAR algorithm

Expand standard product suite

- IOP products (algorithm TBD)
- Uncertainties (method TBD)

Change data formats

- moving to CF-compliant netCDF4

Splinter 11

Conclusions

A high degree of consistency has been achieved between SeaWiFS, MODIS, MERIS (and VIIRS).

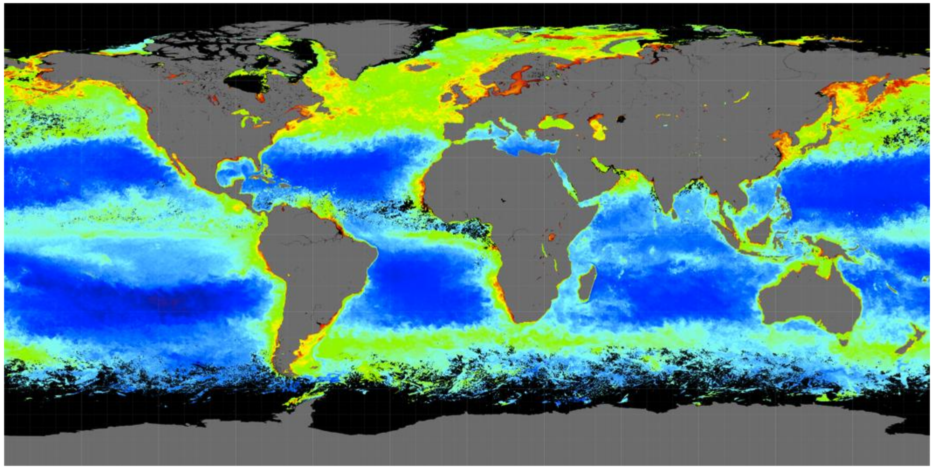
Multiple overlapping missions, consistently processed and calibrated, provide insight into trend uncertainty and truth.

We do chlorophyll pretty well (and we can still do it better), but chlorophyll is a rough proxy for phytoplankton abundance.

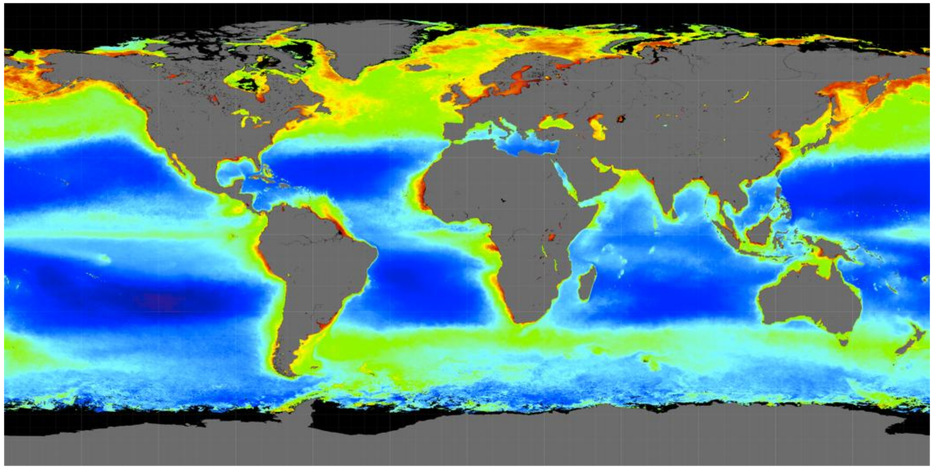
We need to focus equivalent effort on IOP trends (separation of CDOM from chlorophyll) and push into phytoplankton community structure,

… leading to requirements for global hyperspectral (PACE Mission)

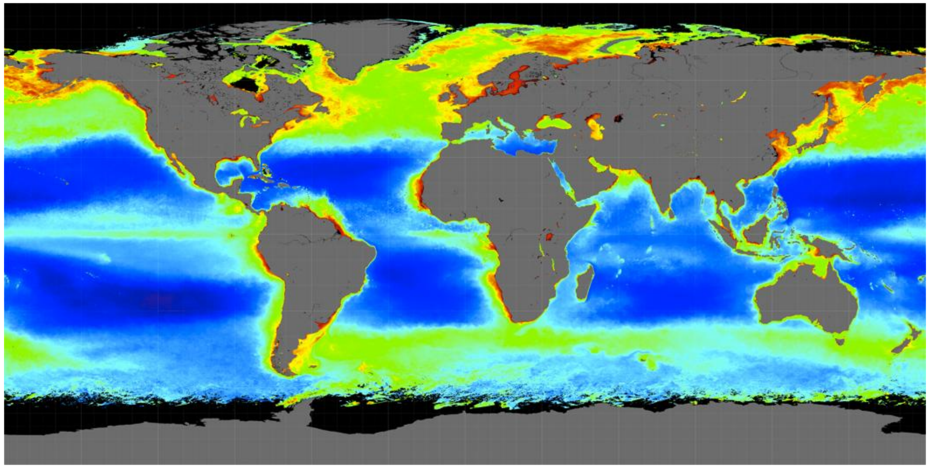
Questions?



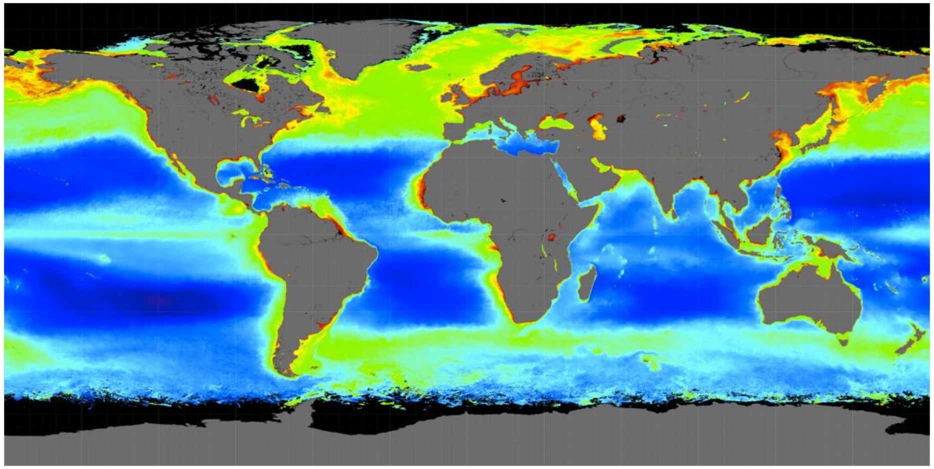
Spring 2012 - VIIRS



Spring Climatology - SeaWiFS

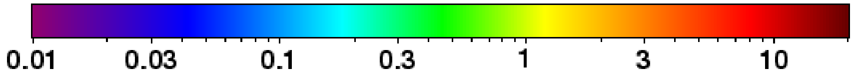


Spring Climatology - Aqua/MODIS



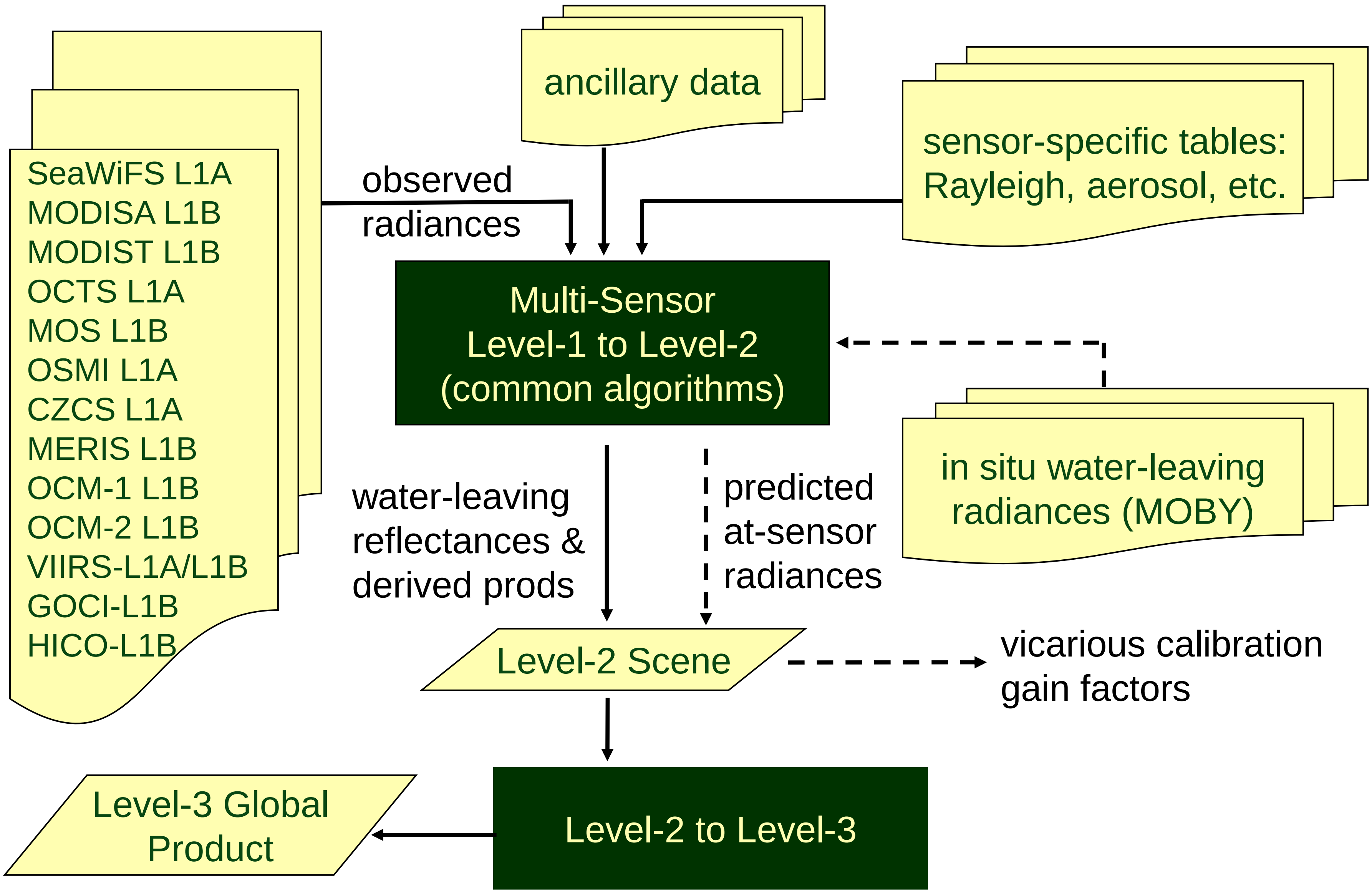
Spring Climatology - Terra/MODIS

Chlorophyll a concentration (mg / m^3)



Thank You

Common Processing Approach



Recent Ocean Color Reprocessings

Multi-Mission Reprocessing (2010-2011)

R2010.0 all missions with consistent algorithms and calibration approach

MODISA, MODIST, SeaWiFS, OCTS, CZCS

MODISA Calibration Updates (2012 & 2013)

R2012.0 full-mission revised instrument temporal calibration

R2013.0 partial-mission instrument calibration update (2011-2013)

VIIRS Ingest and Reprocessing (2011-2013)

R2013.0 latest version of VIIRS processing with consistent algorithms and MOBY vicarious calibration (NASA VIIRS)

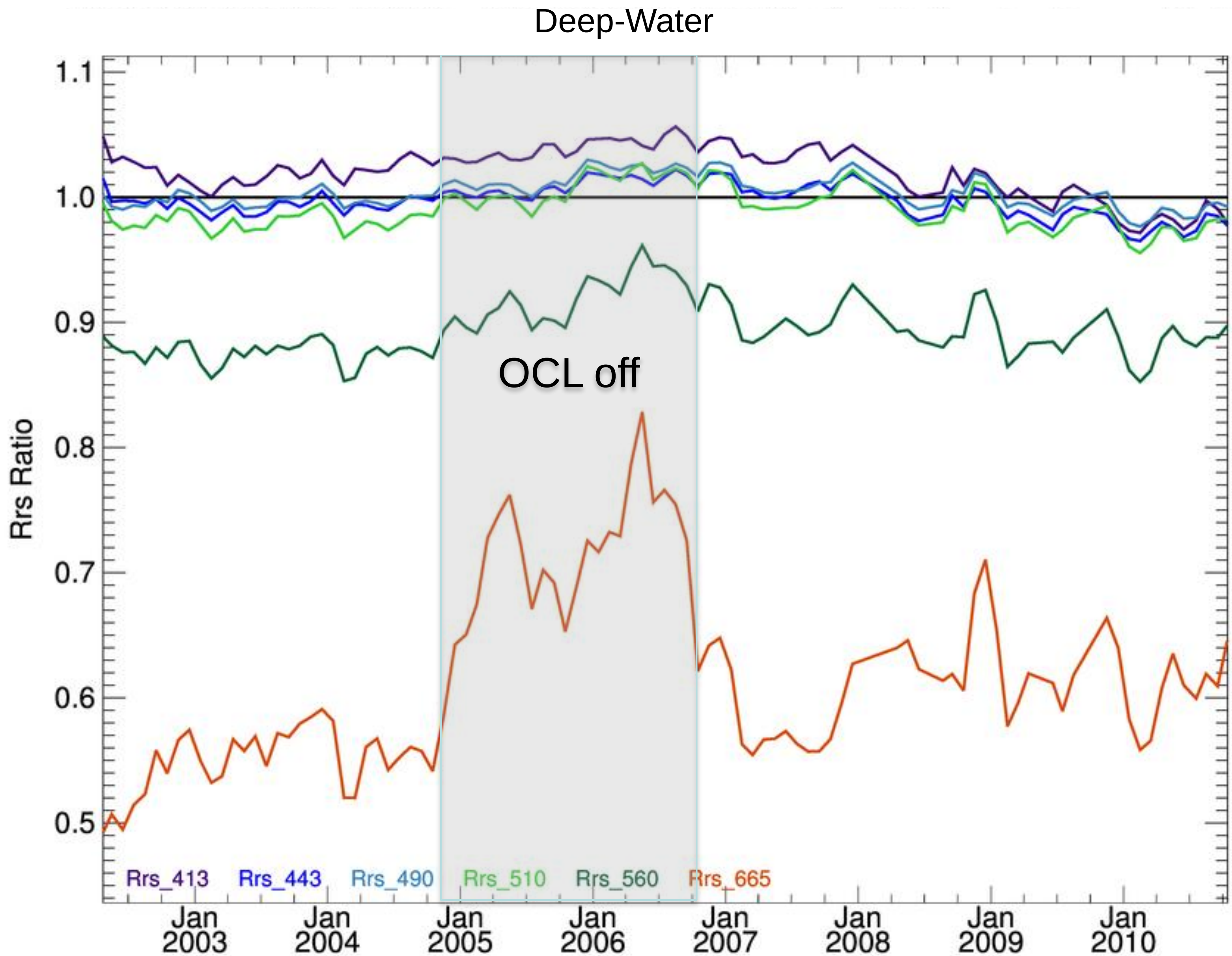
MERIS RR Ingest and Reprocessing (2012-2013)

R2012.1 full mission reprocessing with consistent algorithms and MOBY vicarious calibration

MODIST Calibration Update (expected May 2013)

http://oceancolor.gsfc.nasa.gov/WIKI/OCReproc.html

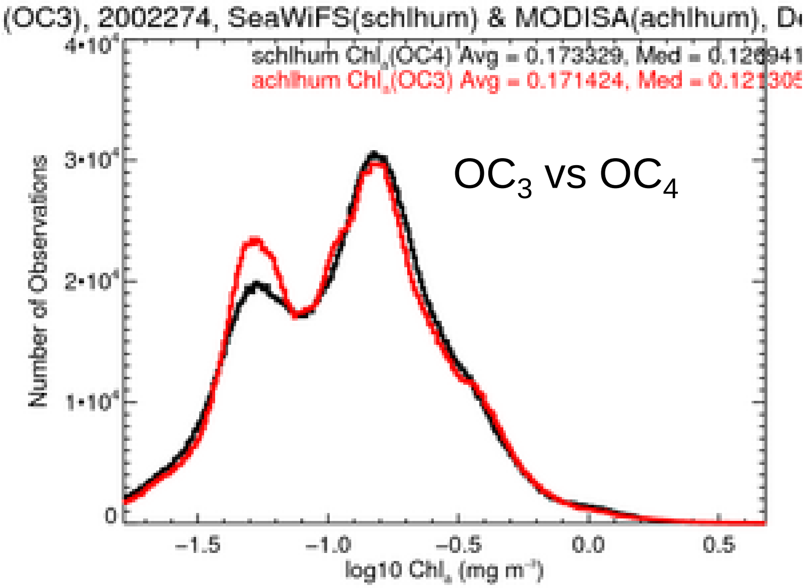
MERIS/SeaWiFS Rrs Ratios

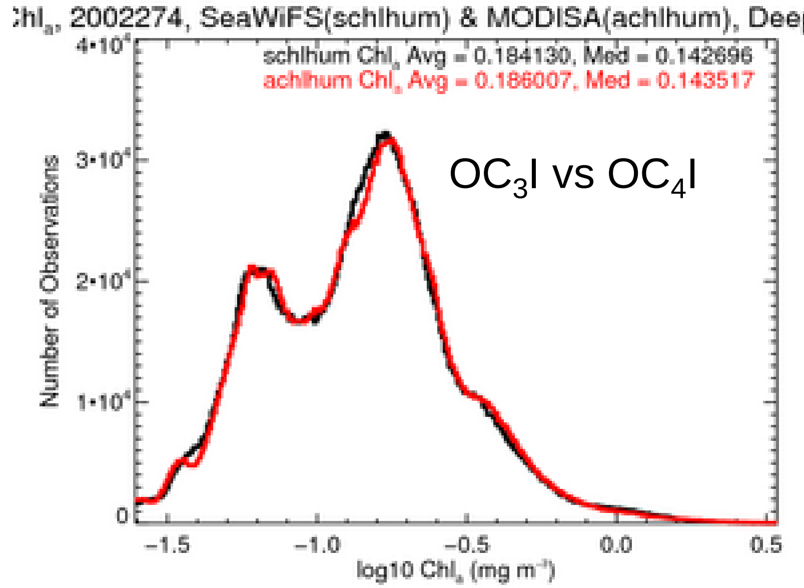


Improved Agreement in Chl Distribution

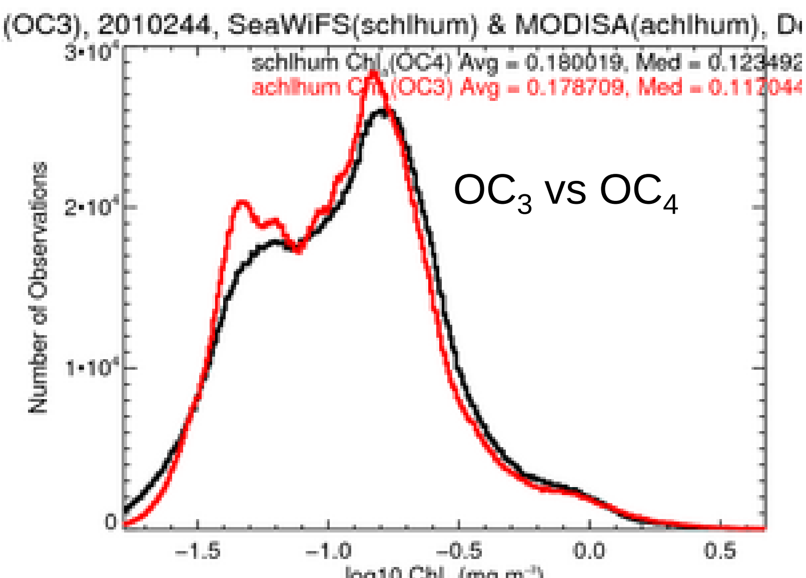
Deep-Water Monthly Mean, MODISA (red) & SeaWiFS (black)

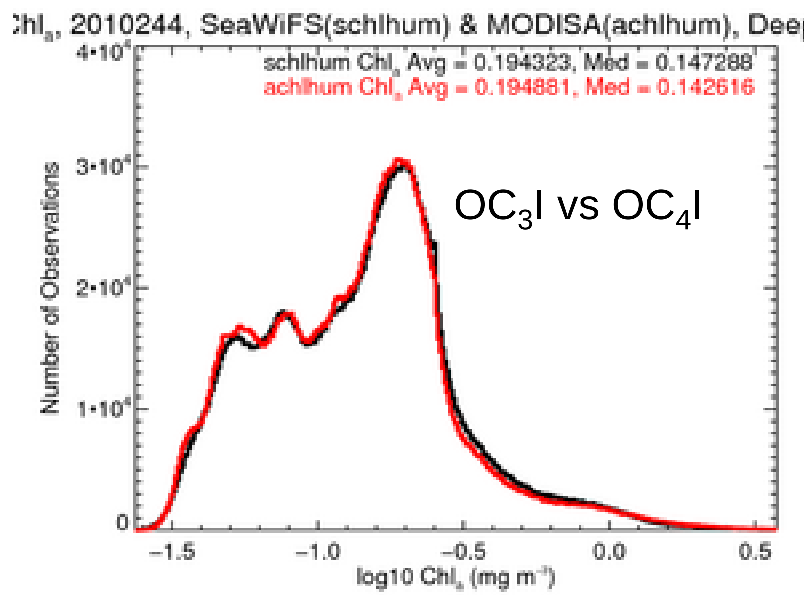
Fall 2002





Fall 2010





VIIRS

Generating Continuity Products

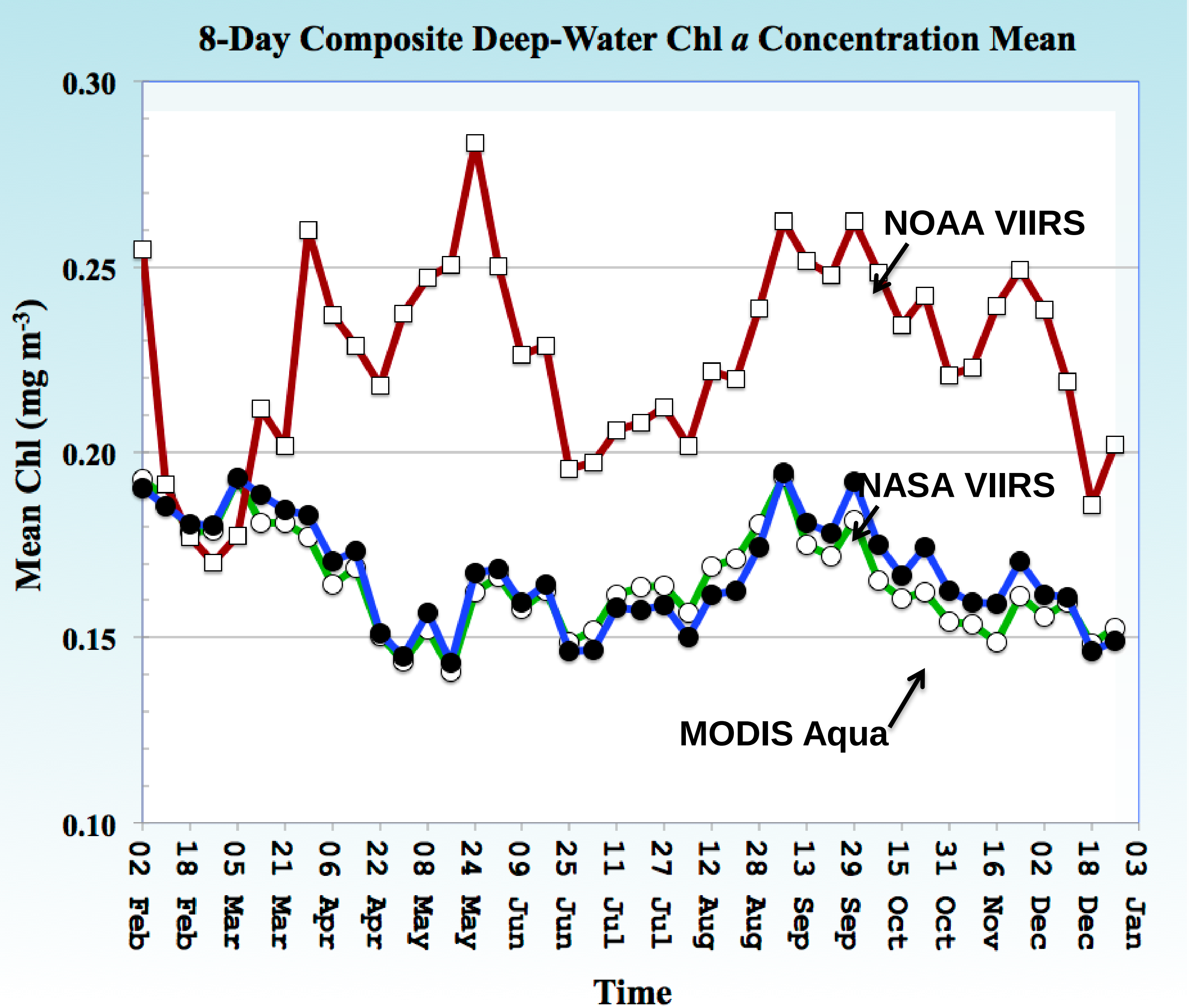
	MODISA L2	NASA VIIRS L2	NOAA VIIRS EDR
1.	$R_{rs}(\lambda)$	$R_{rs}(\lambda)$	$nLw(\lambda)$
2.	Ångstrom	Ångstrom	
3.	AOT	AOT	
4.	Chlorophyll *a*	Chlorophyll *a*	Chlorophyll *a*
5.	$K_d(490)$	$K_d(490)$	
6.	POC	POC	
7.	PIC	PIC	
8.	PAR	PAR	
9.	iPAR		
10.	nFLH		

VIIRS lacks fluorescence capability (items 9–10)

Chlorophyll Bands

λ (nm)					
	SeaWiFS	412 **443 490 510**		**555** 670	
	MODIS	412 **443 488**	531	**547** 667 678	
	VIIRS	412 **443 486**		**555** 671	

VIIRS and MODIS lack 510 nm band for high Chla case



8-Day Composite Deep-Water Chl a Concentration Mean
Mean Chl (mg m-3)
0.30
0.25
0.20
0.15
0.10
NOAA VIIRS
NASA VIIRS
MODIS Aqua
02 Feb
18 Feb
05 Mar
21 Mar
06 Apr
22 Apr
08 May
24 May
09 Jun
25 Jun
11 Jul
27 Jul
12 Aug
28 Aug
13 Sep
29 Sep
15 Oct
31 Oct
16 Nov
02 Dec
18 Dec
03 Jan
Time

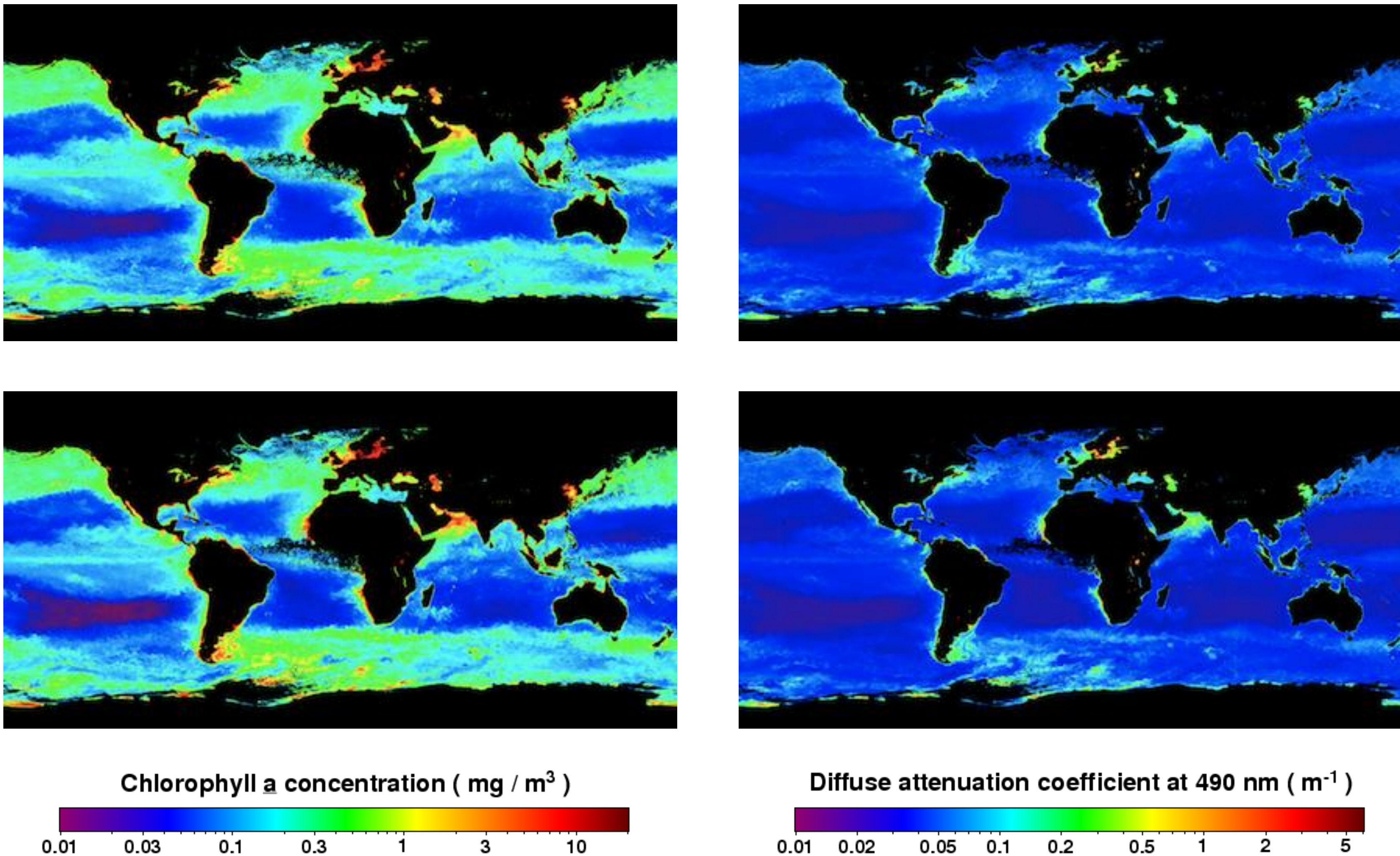
VIIRS & MODISA Winter 2012

NASA/OBPG Calibration & Processing

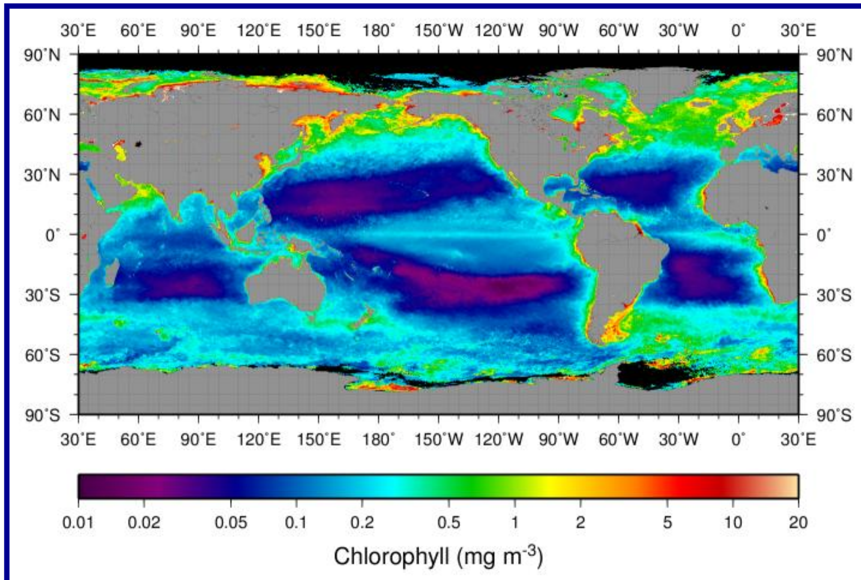
Chlorophyll | Kd(490) Diffuse Attenuation

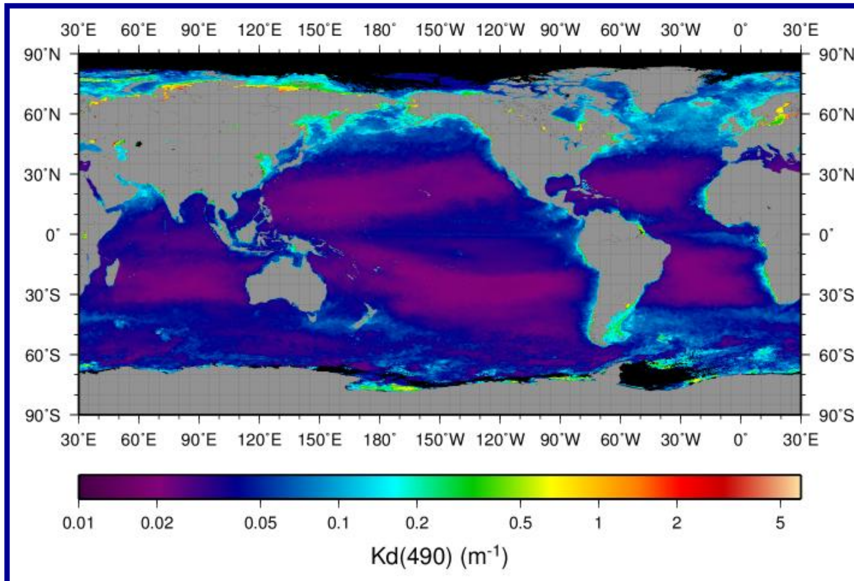
VIIRS

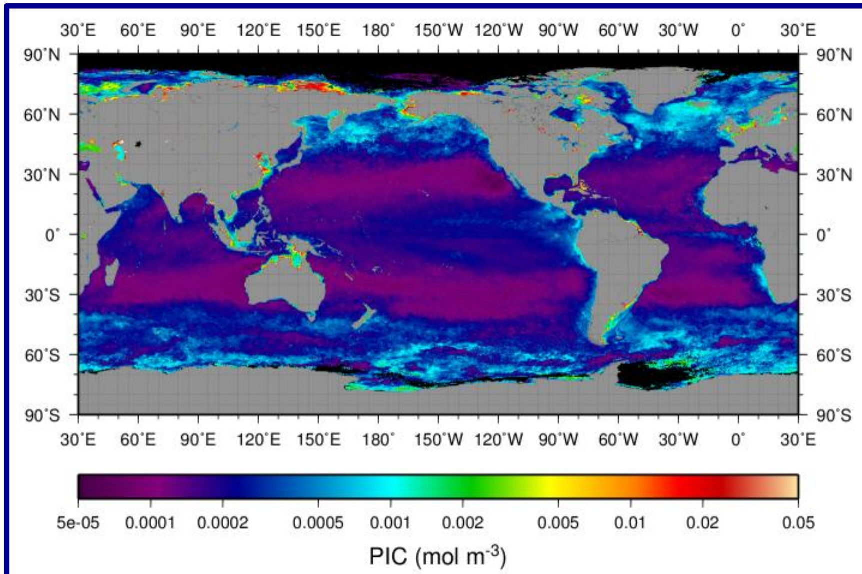
MODISA

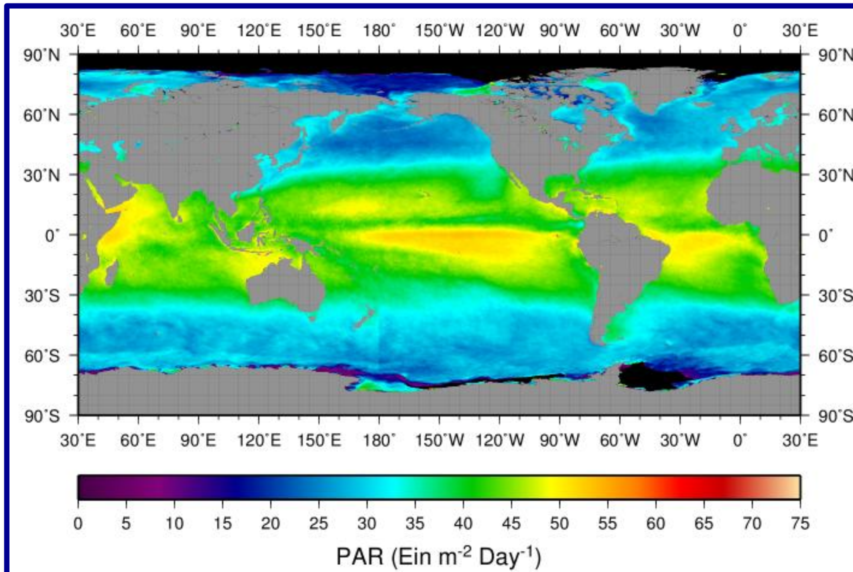


Generating Continuity Products



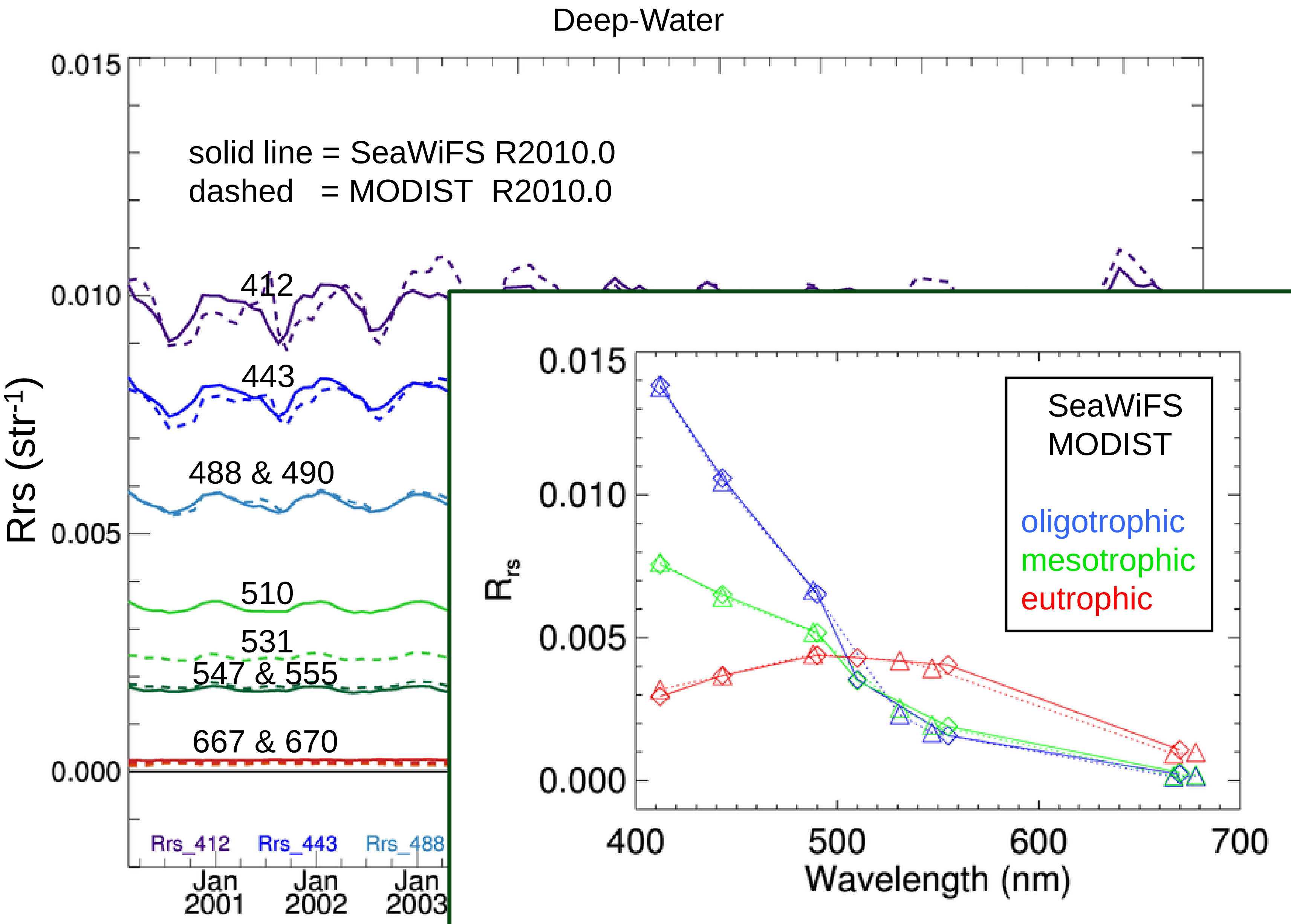




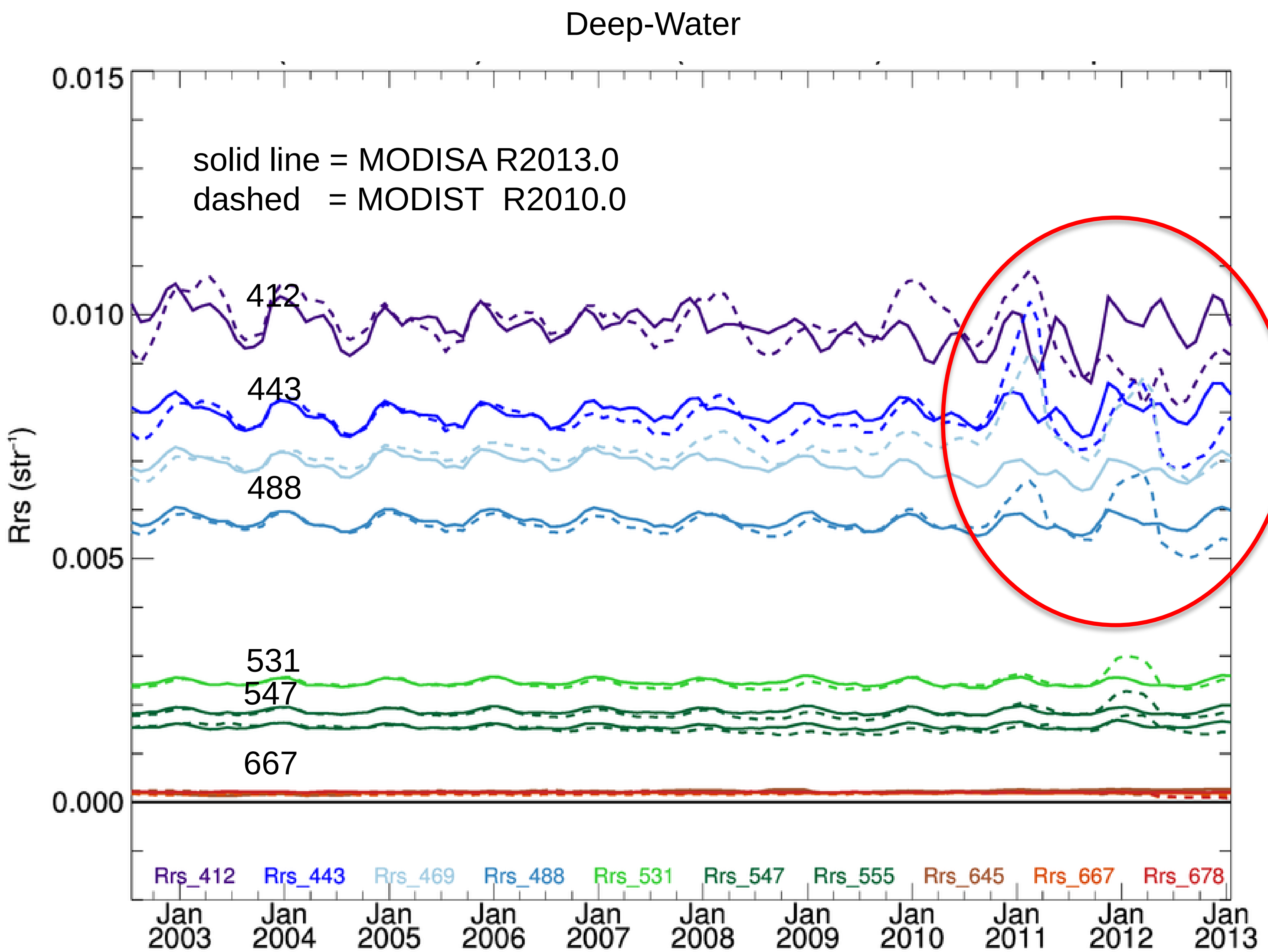


MODIST

Radiometric Consistency of MODIST & SeaWiFS



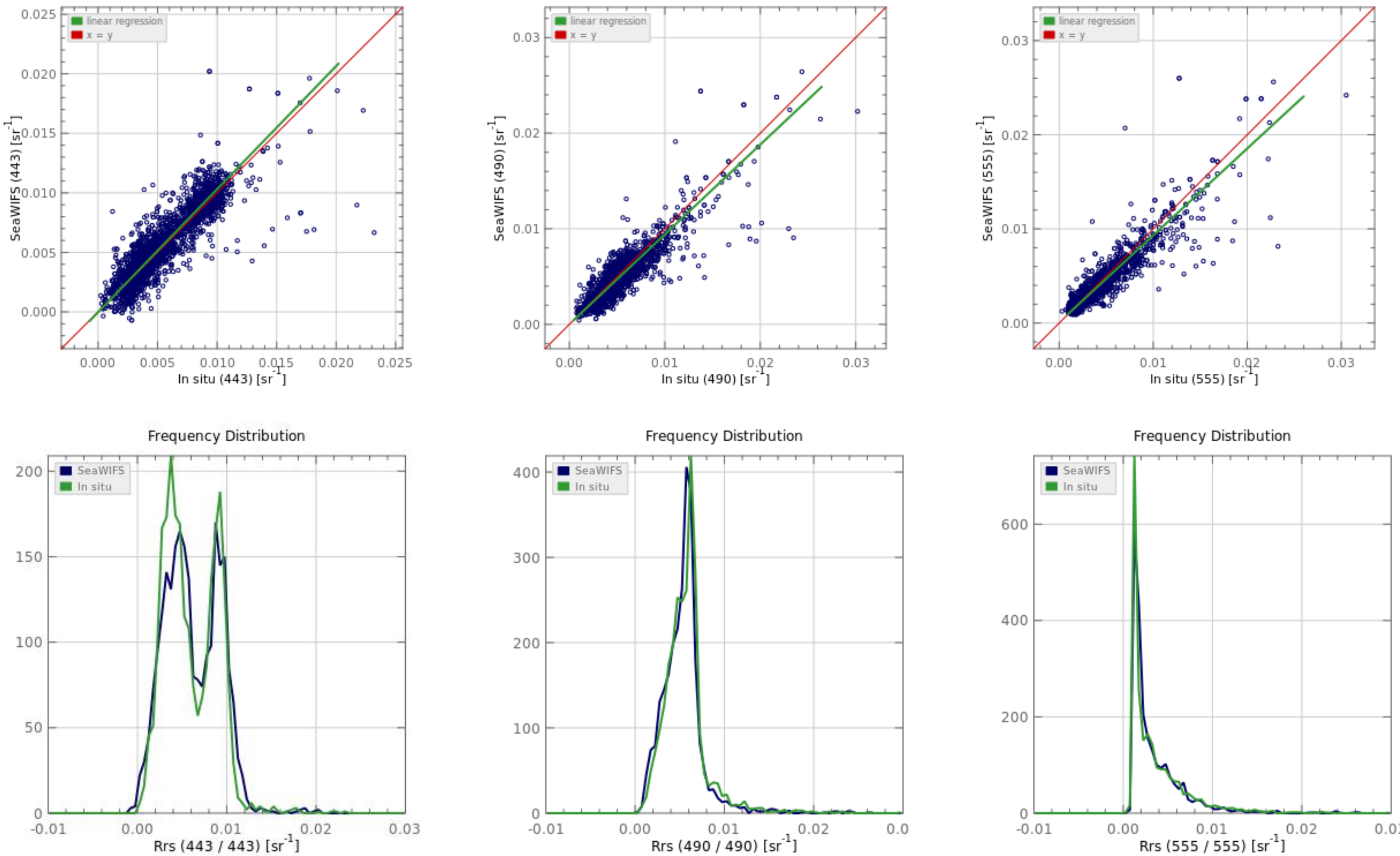
Degrading Radiometric Stability of MODIST



In situ Validation

SeaWiFS (R2010.0) Rrs vs Field Measurements

Rrs(443) Rrs(490) Rrs(555)

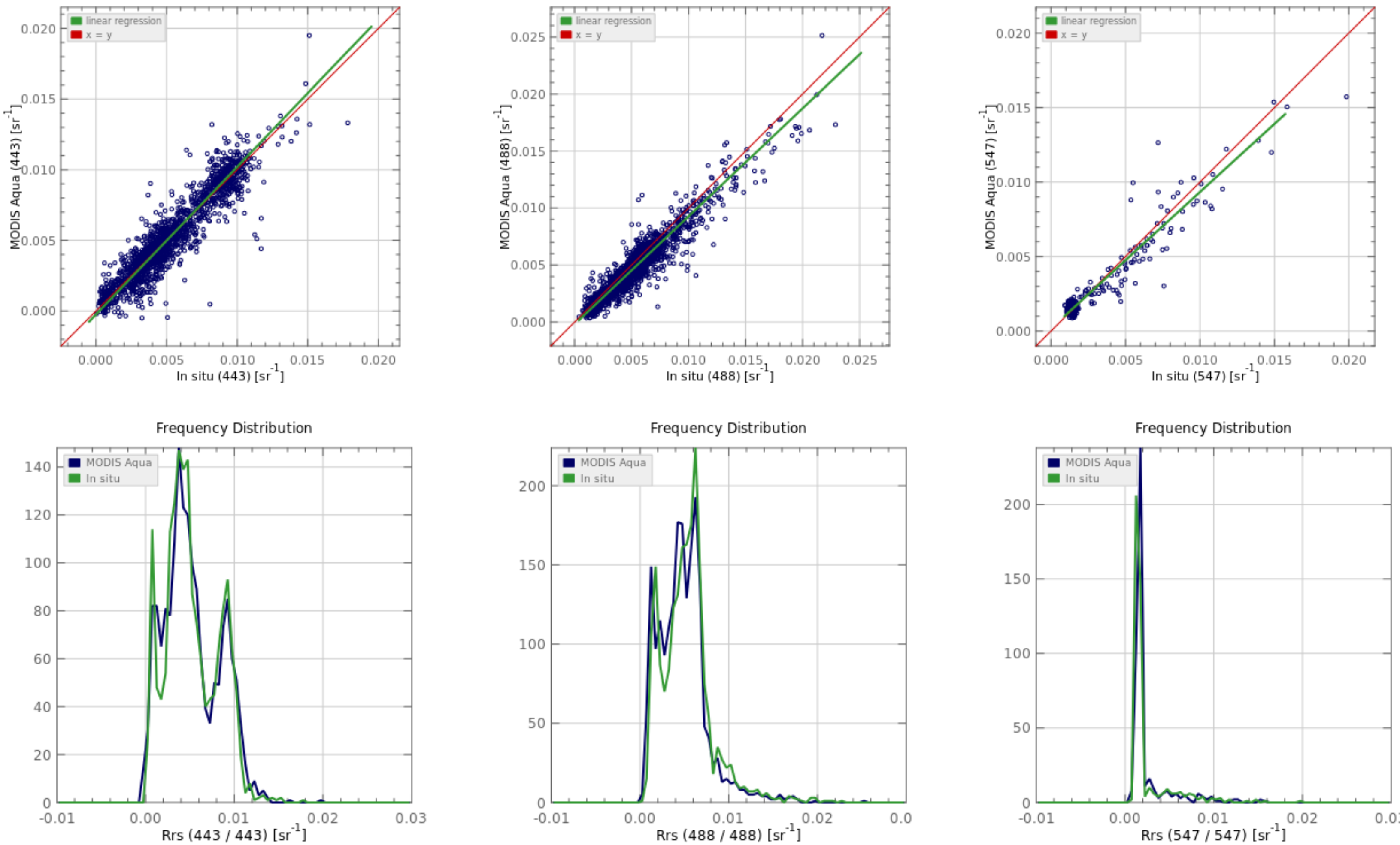


Mean APD < 14%, Mean Bias < 6%, R^2 > 0.8

SeaBASS + AERONET-OC

MODISA (R2013.0) Rrs vs Field Measurements

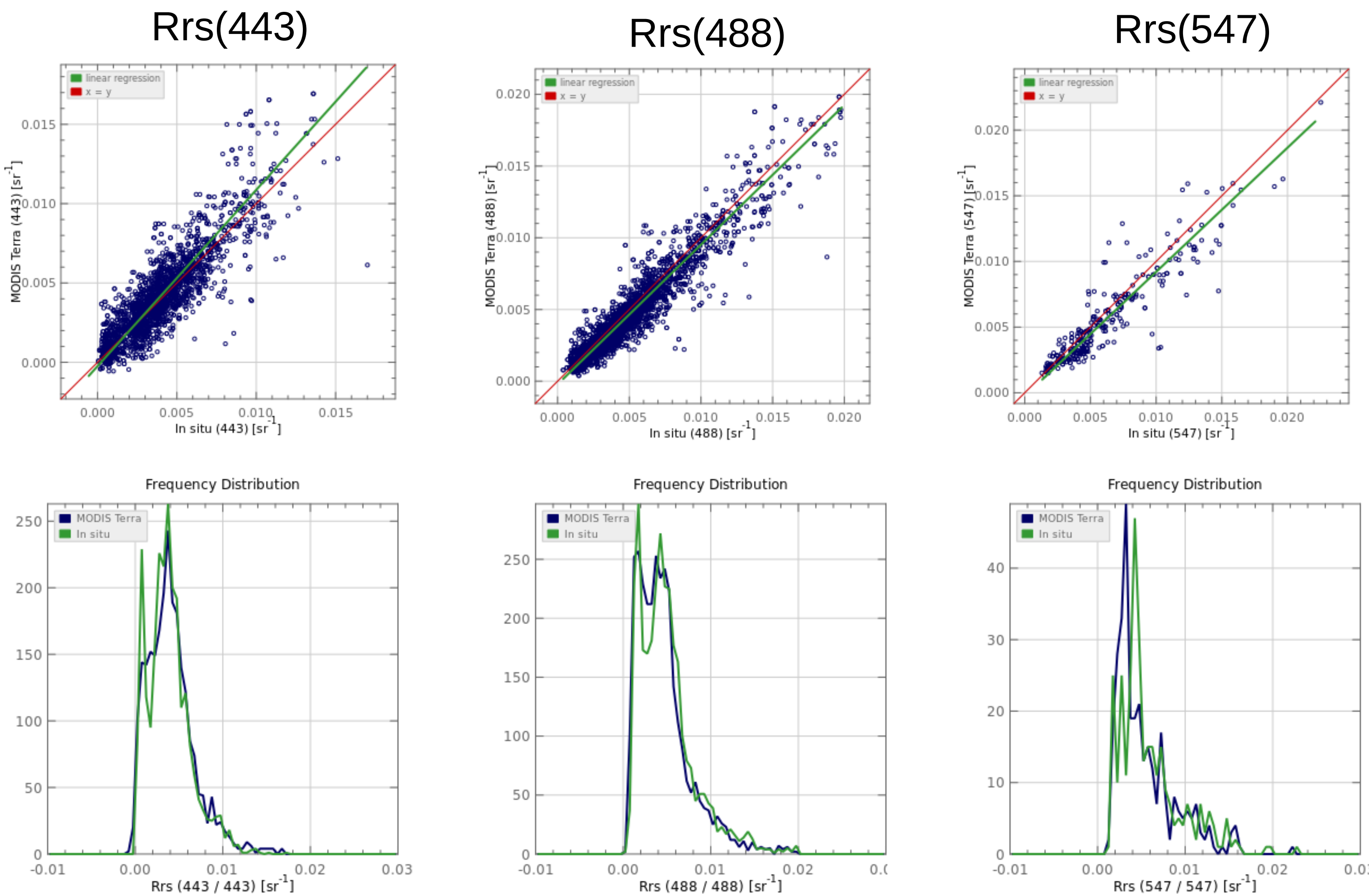
Rrs(443) Rrs(488) Rrs(547)



Mean APD < 13%, Mean Bias < 10%, R^2 > 0.9

SeaBASS + AERONET-OC

MODIST (R2010.0) Rrs vs Field Measurements

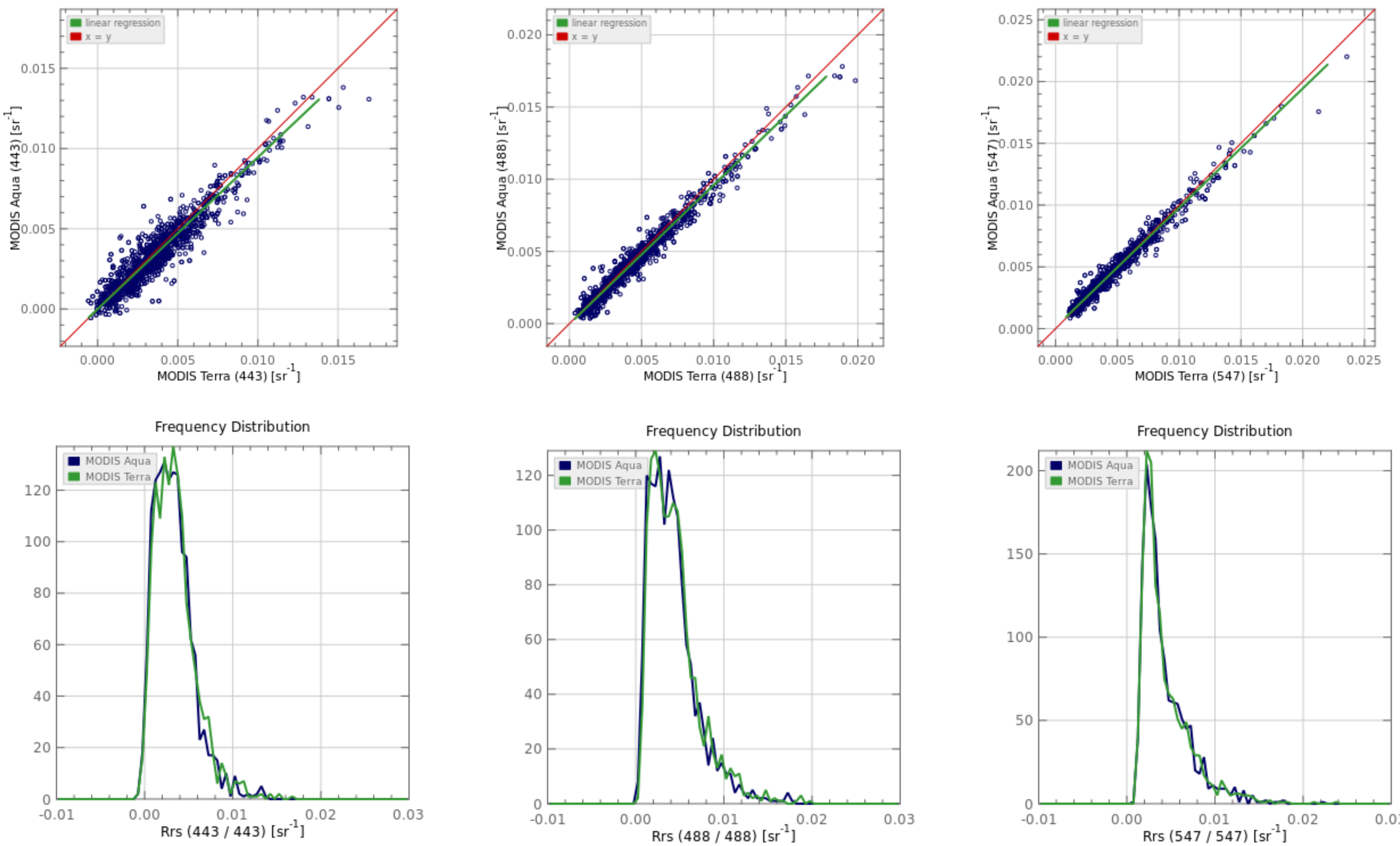


Mean APD 14-21%, Mean Bias < 11%, R^2 > 0.8

MODIST (R2010.0) vs MODISA (R2013.0)

common in situ match-up locations

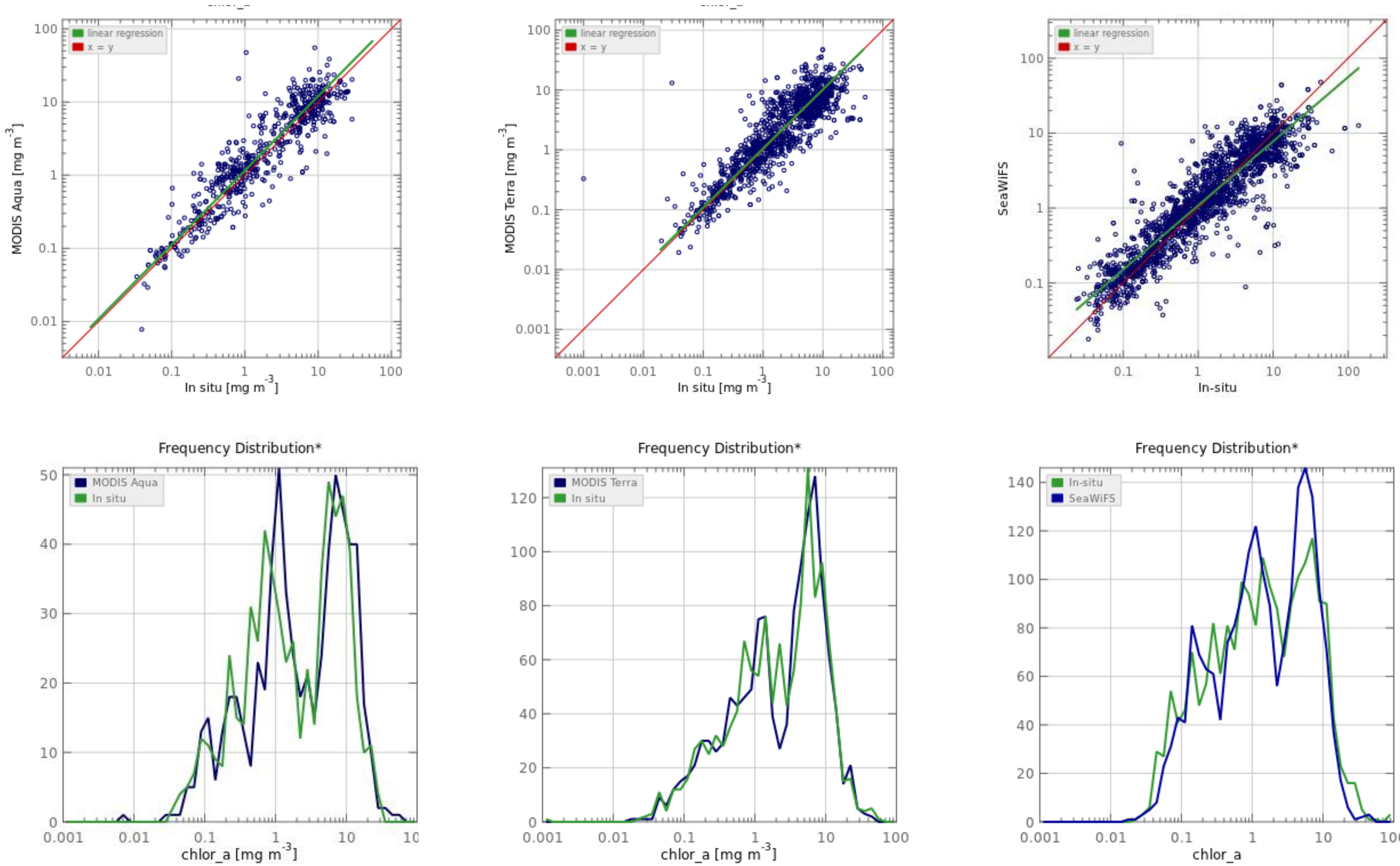
Rrs(443) Rrs(488) Rrs(547)



MODISA to MODIST scatter 1/2 the MODIS to in situ scatter!

Chl_a in Good Agreement with Field Measurement

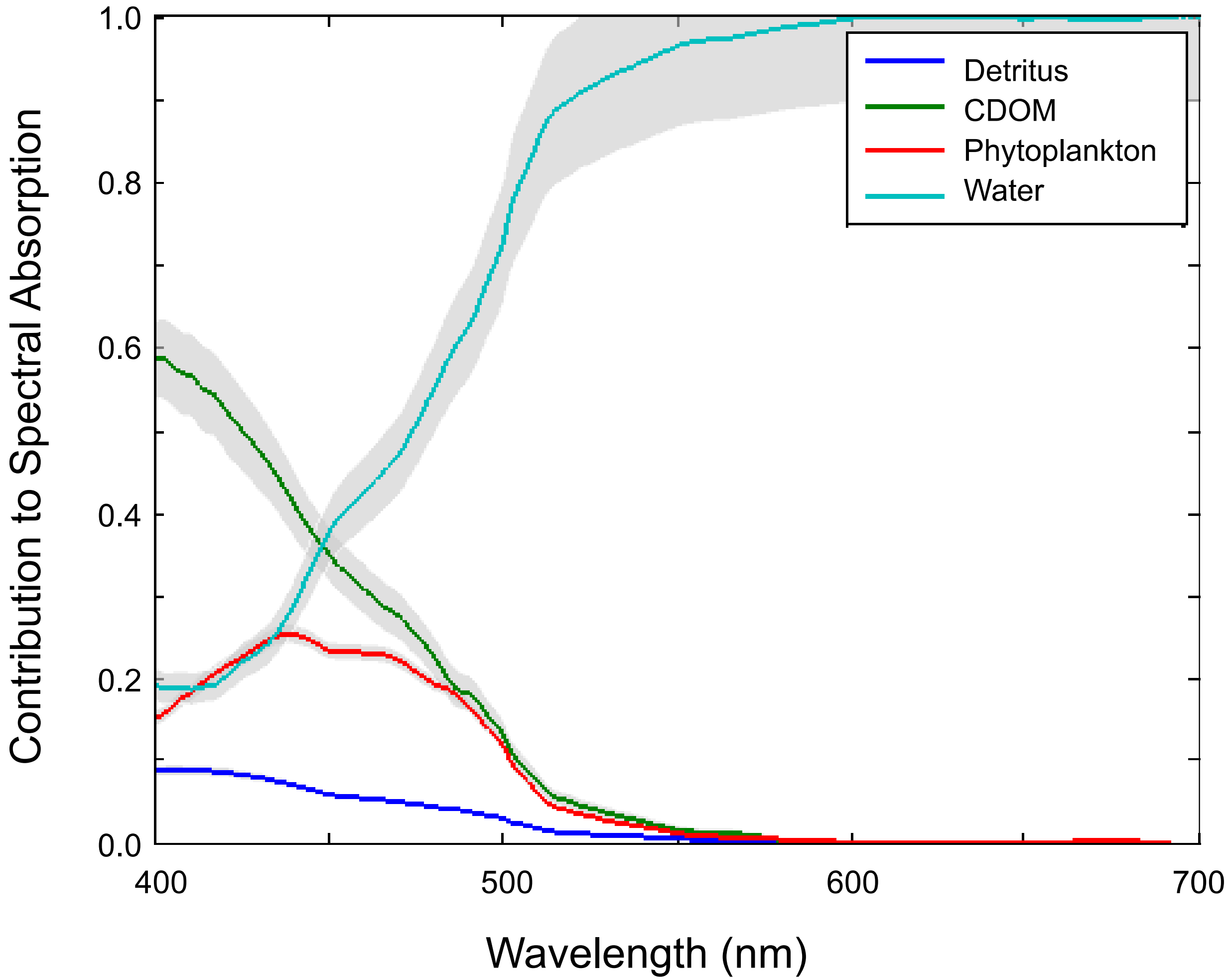
MODISA MODIST SeaWiFS



Mean APD 35%, Mean Bias < 15%, R^2 > 0.8

IOPs

Beyond Chlorophyll



Siegel et al. 2013, RSE

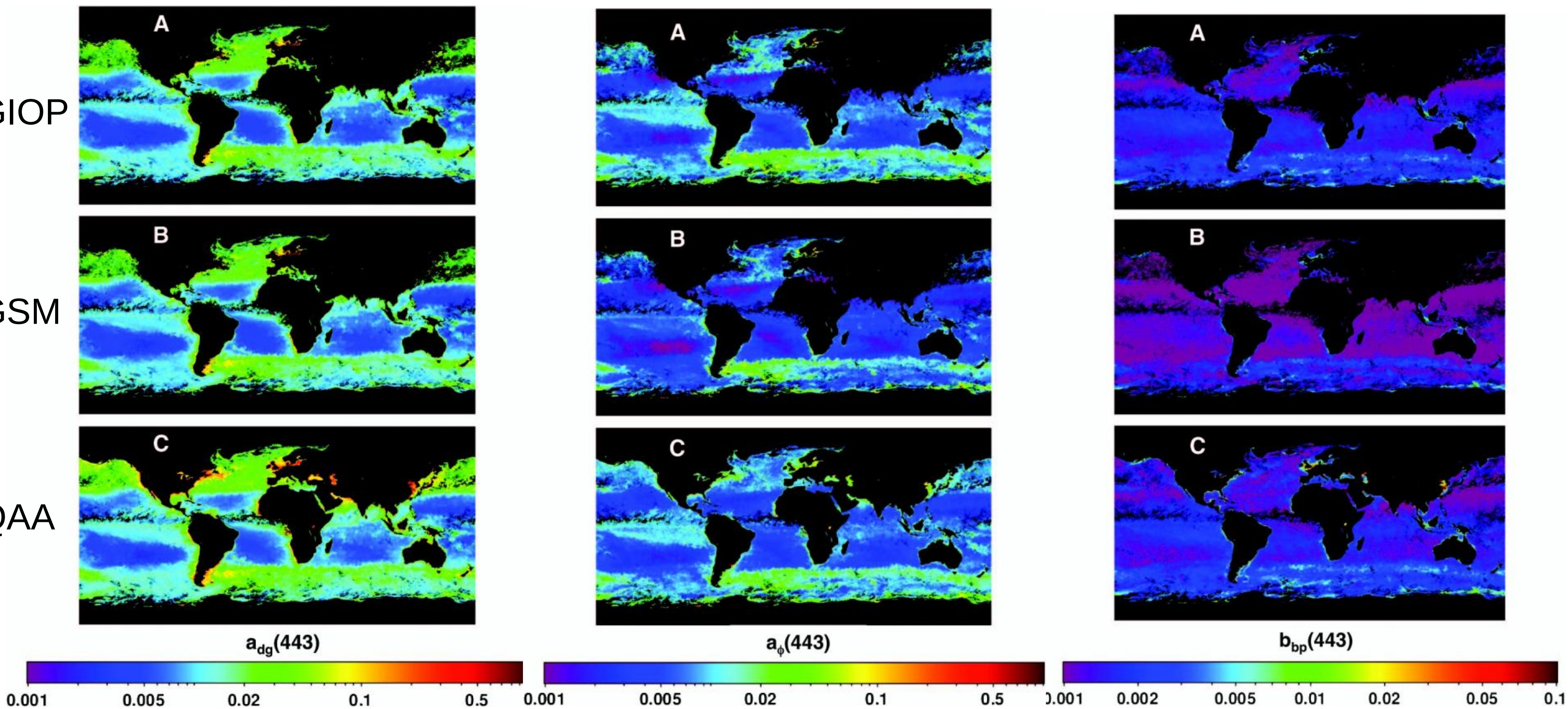
Separation of Constituent Absorption

CDOM & detritus | Phytoplankton | Particle Backscatter

GIOP

GSM

QAA



Werdell, P.J., B.A. Franz, S.W. Bailey, G.C. Feldman and 15 co-authors (2013). Generalized ocean color inversion model for retrieving marine inherent optical properties, Applied Optics 52, 2019-2037.

Beyond Chlorophyll