NASA Ocean Biology Processing Group Satellite Ocean Color Update

Bryan Franz

NASA Goddard Space Flight Center

bryan.a.franz@nasa.gov

NASA Ocean Biology Processing Group

calibration, validation, software development, (re)processing, and distribution for a multitude of ocean color sensors

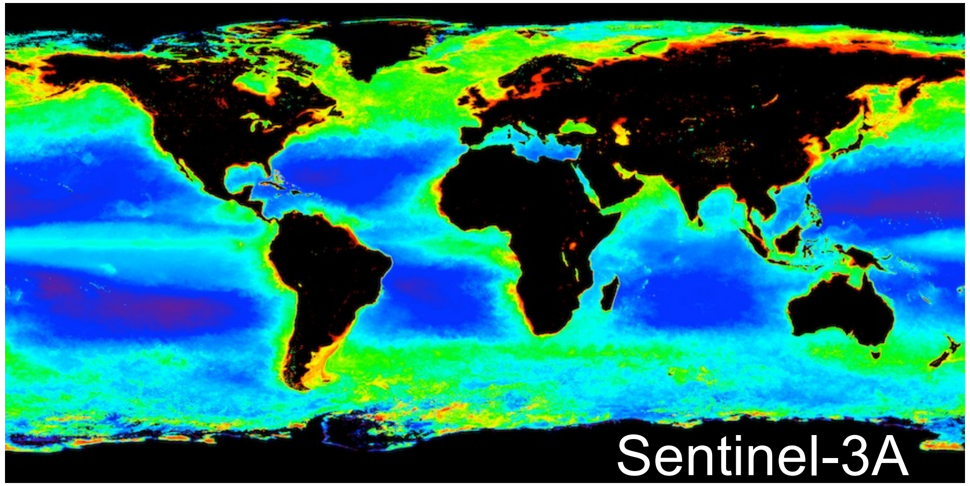
Global Processing & Distribution

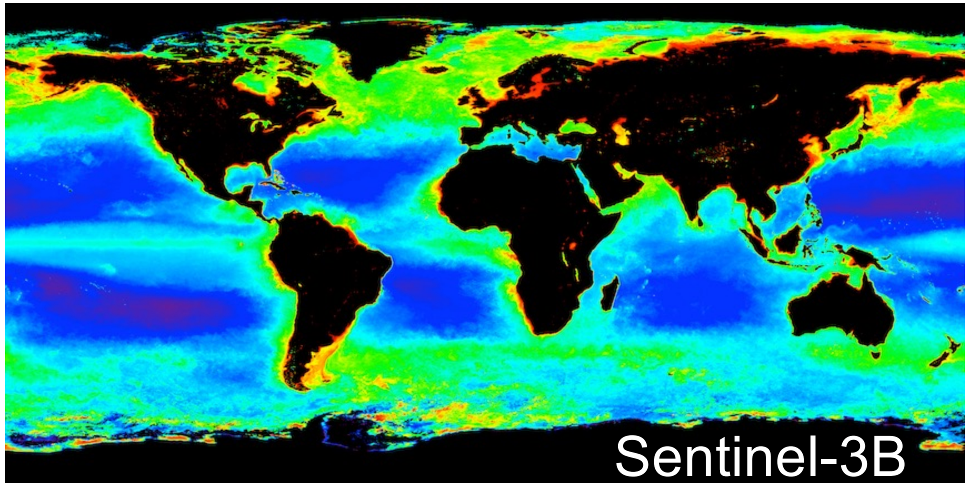
- **VIIRS/JPSS1** (USA)
- **VIIRS/SNPP** (USA)
- **MODIS/Aqua** (USA)
- **MODIS/Terra** (USA)
- **OLCI/S3A** (Europe)
- **OLCI/S3B** (Europe)
- SeaWiFS (USA)
- MERIS (Europe)
- OCTS (Japan)
- CZCS (USA)

Regional Processing & Distribution

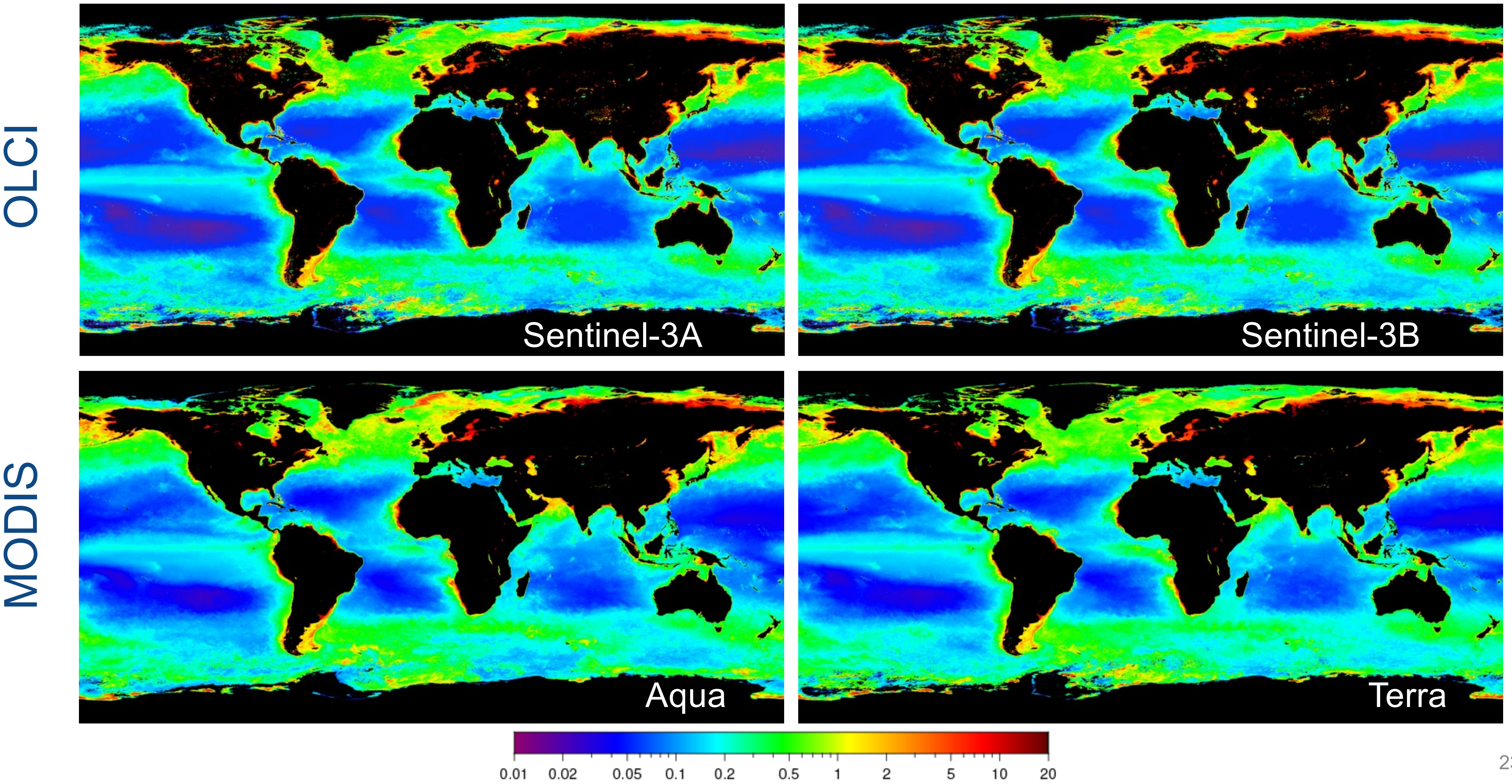
- **Hawkeye** (USA)
- GOCI (South Korea)
- HICO (USA)

OLCI L2 & L3 products now available

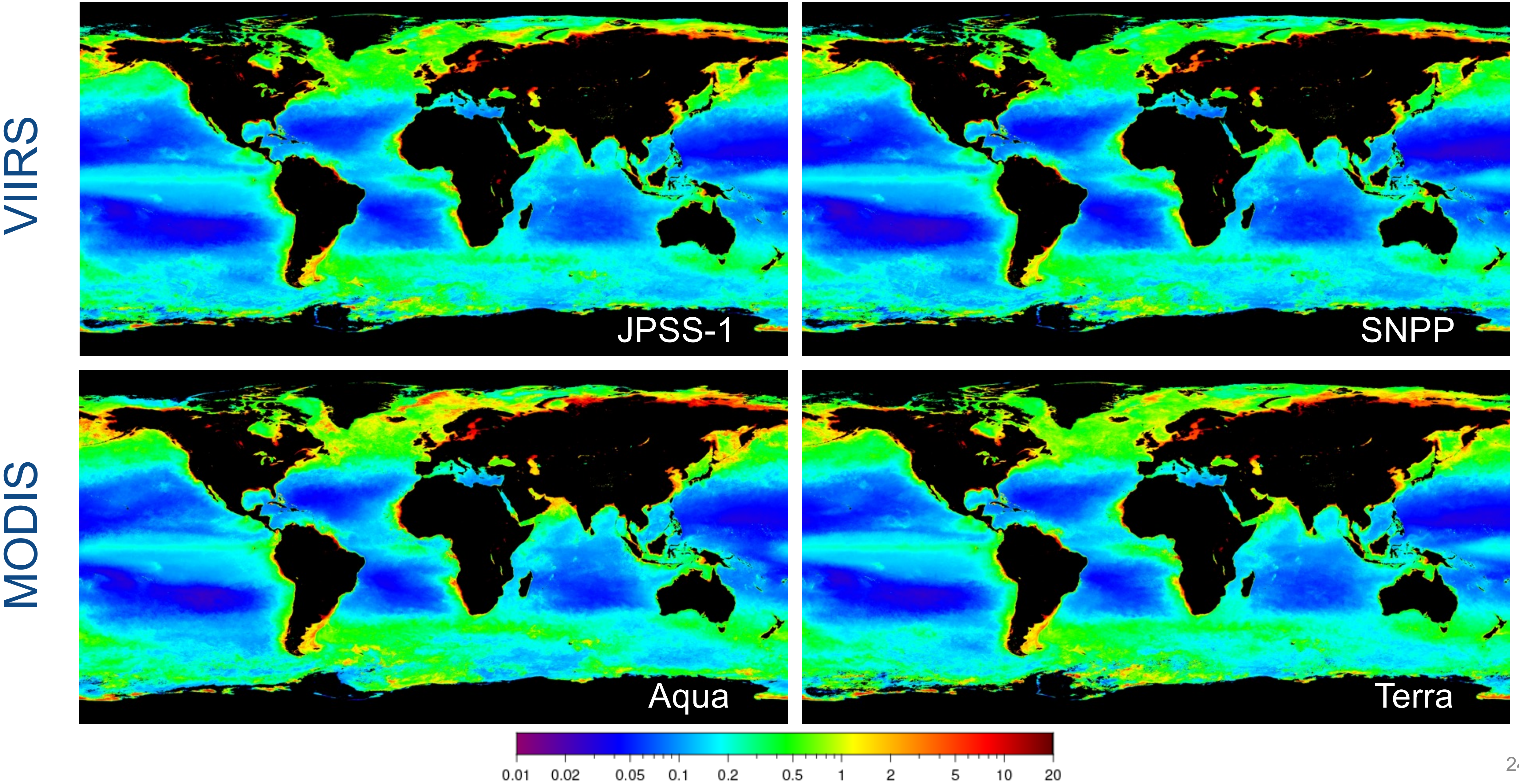




Annual Mean Chlorophyll Concentration for 2020

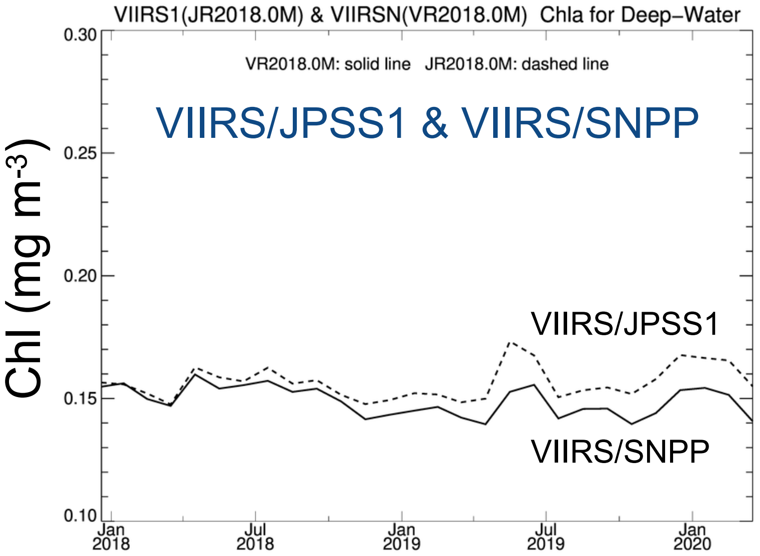


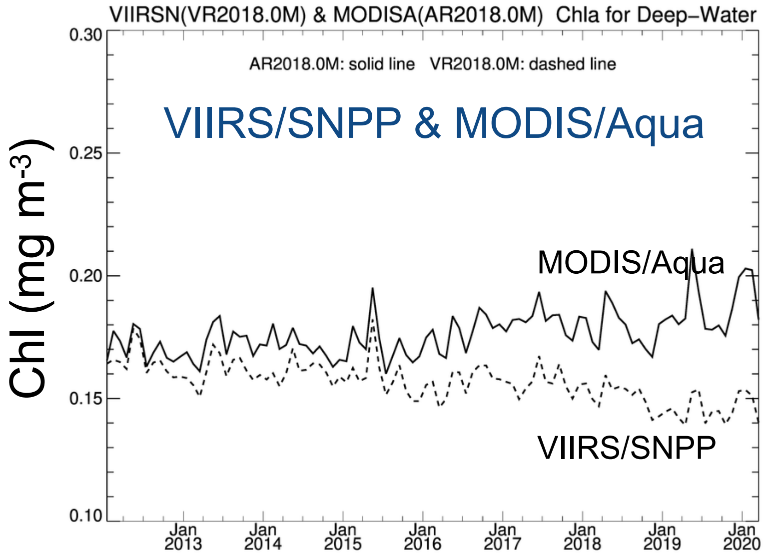
Annual Mean Chlorophyll Concentration for 2020

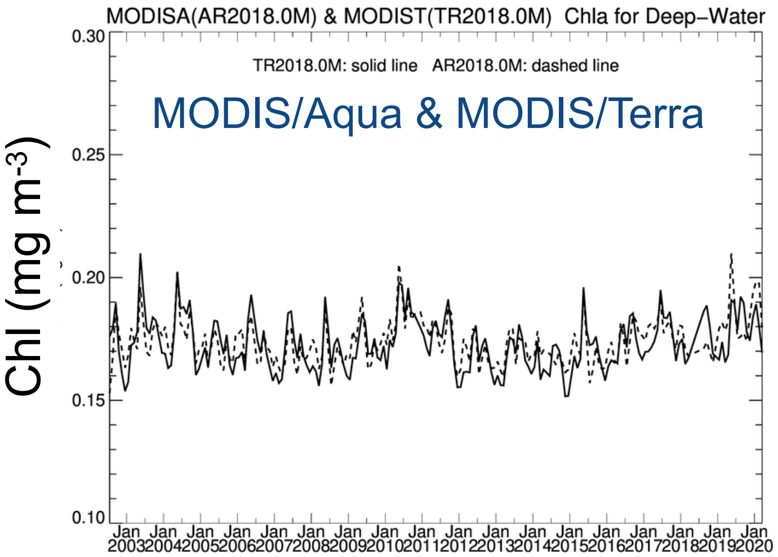


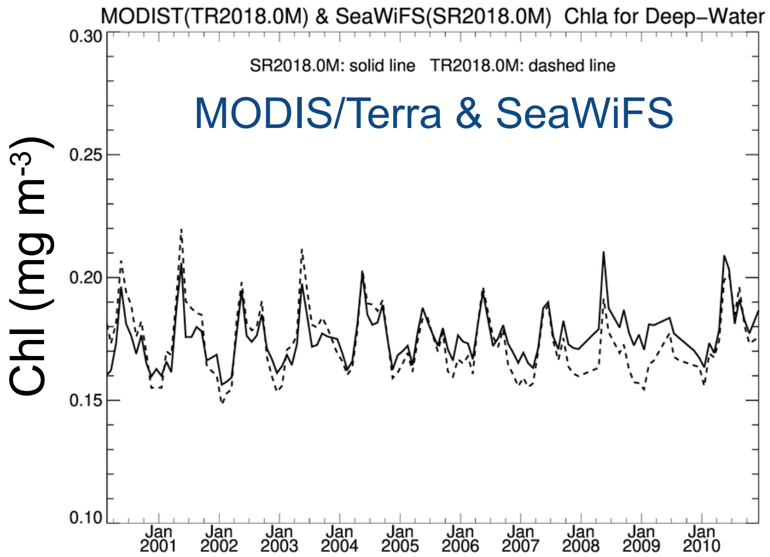
R2018 Global Deep-Water Chlorophyll Trends

- Comparison trends over common mission lifetime
- VIIRS/SNPP shows negative trend relative to VIIRS/JPSS1 & MODIS/Aqua
- SeaWiFS, MODIS/Terra, MODIS/Aqua in good agreement, with short-term deviations









R2022 Multi-mission Ocean Color Reprocessing

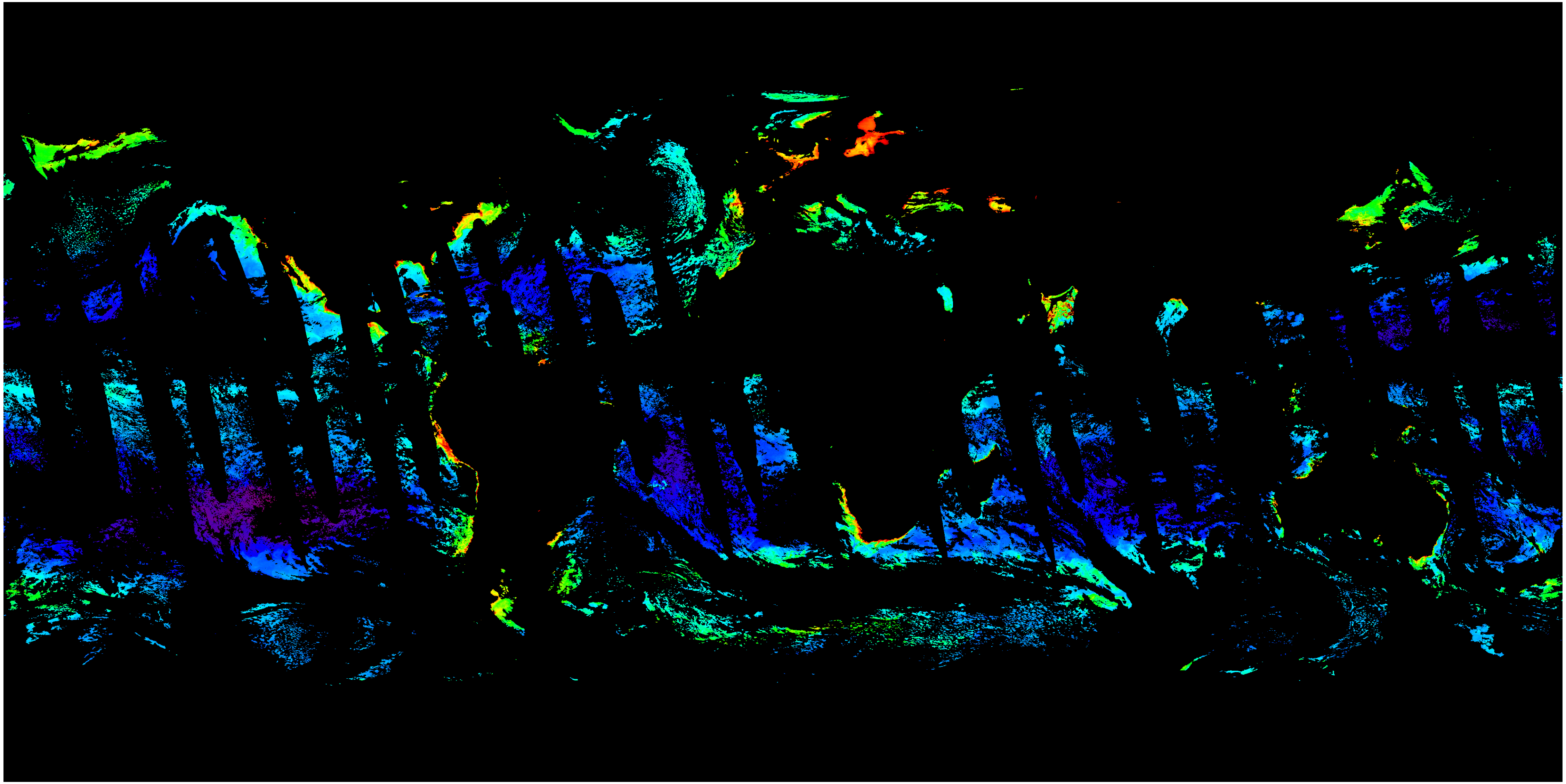
Missions:

OLCI (S3A, S3B), **MODIS (Aqua**, Terra), VIIRS (SNPP, JPSS1), SeaWiFS, **MERIS**, OCTS, CZCS

Changes:

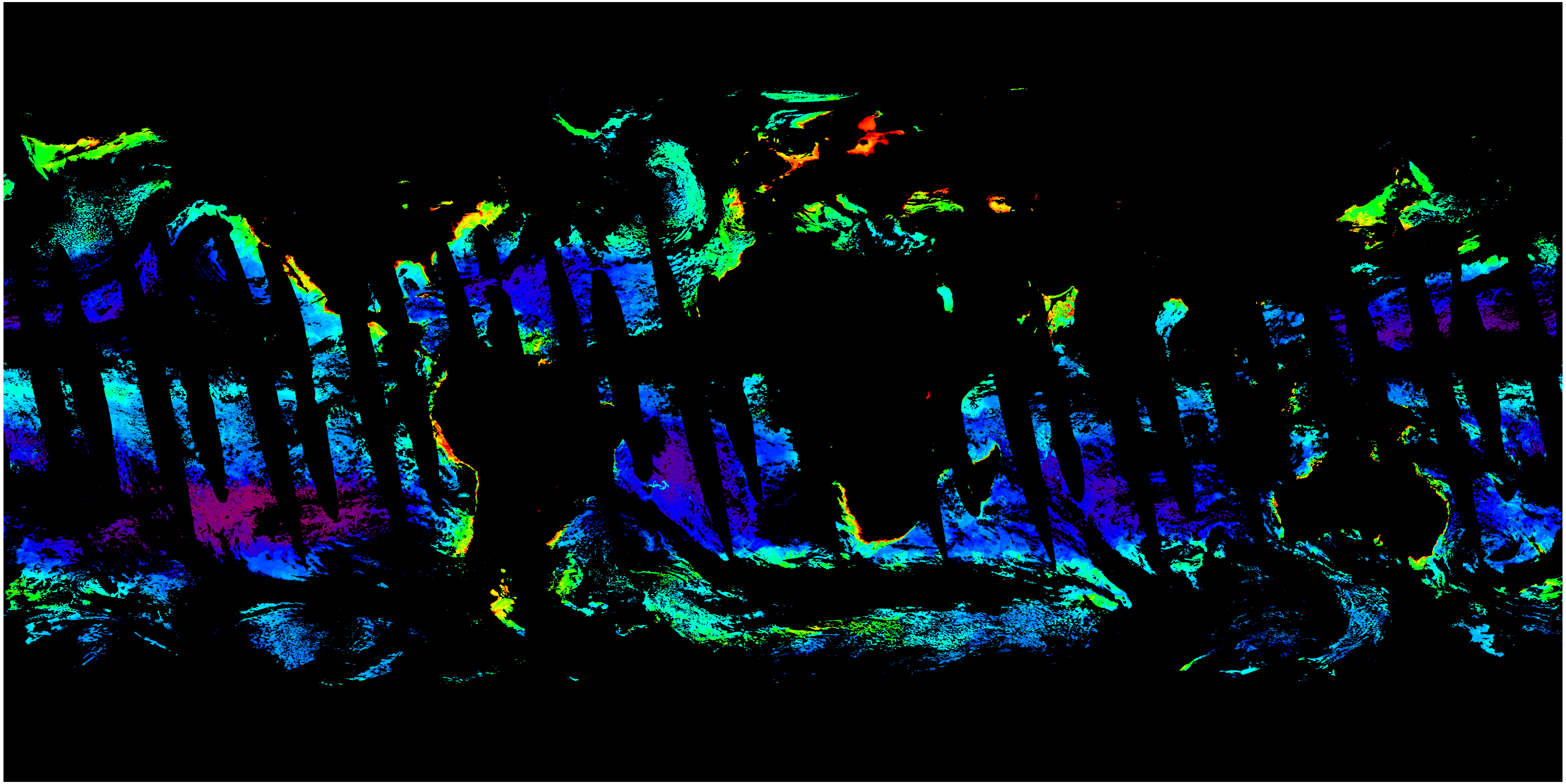
1. instrument and vicarious calibration updates
2. updates to ancillary data sources
   - from NCEP/TOMS-OMI/etc. to MERRA-2 assimilation product
3. updates to atmospheric correction methods and tables
   - multi-scattering aerosol selection, extended AOT range, improved/expanded absorbing gas corrections, Rayleigh hi-solz bug
4. updates to pure seawater optical properties (nw, aw, bbw)
   - apply temperature & salinity dependence (e.g., Werdell et al. 2013), bug in pure-water aw/bbw (off by few nm)
5. updates to masks and flags
   - reduced straylight masking (Hu et al. 2019, JGRO), absorbing aerosol flag based on MERRA-2 transport model
6. updates to derived product algorithms
   - Chl coefficient update (Hu et al. 2019, JGRO; O'Reilly and Werdell, 2019), PIC, PAR, etc.

MODIS-Aqua Daily Chlorophyll – R2018



Includes 5 X 7 STRAYLIGHT masking of Level-2 pixels around bright targets

MODIS-Aqua Daily Chlorophyll – R2022



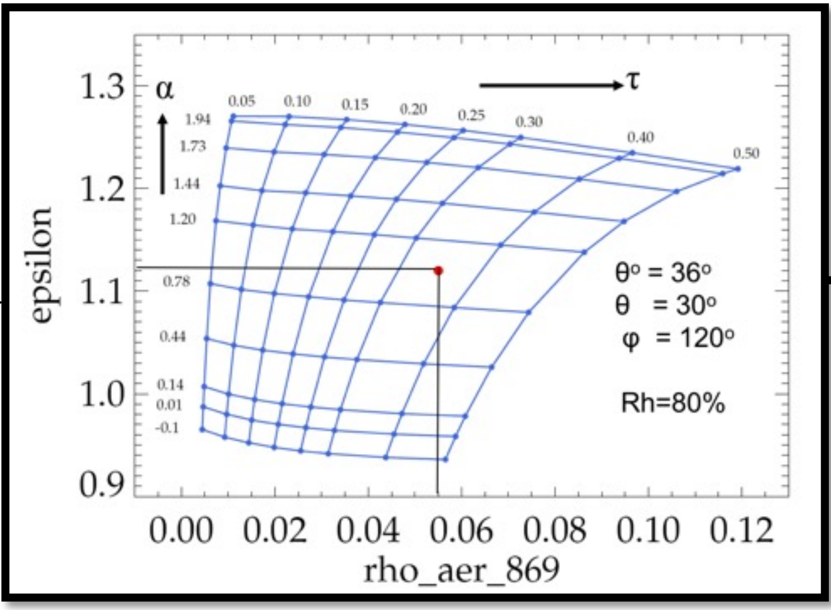
Includes 3 X 3 STRAYLIGHT masking of Level-2 pixels around bright targets

Multi-Scattering Epsilon (MSEPS) Atmospheric Correction

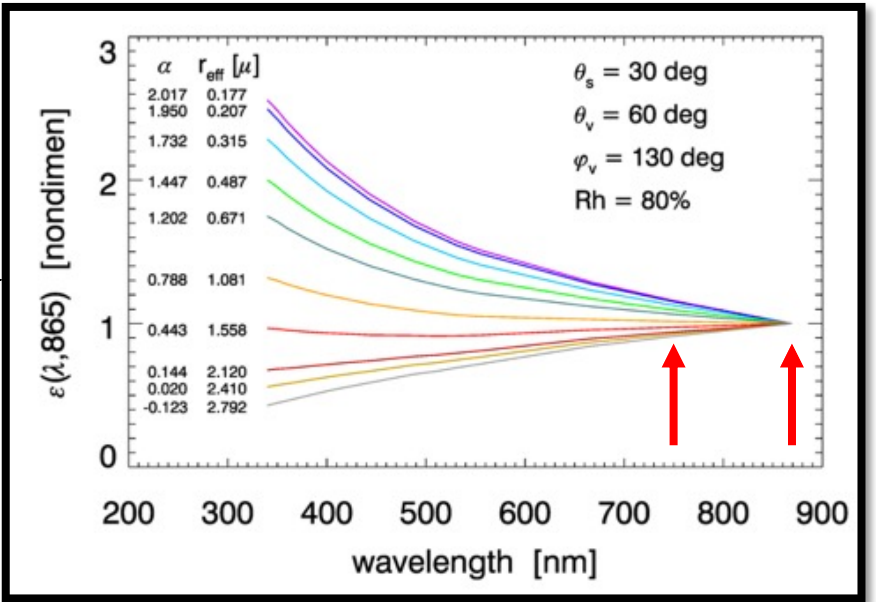
TOA reflectance

Step 1
Rayleigh, gas, and glint correction

Step 2
Estimate the optical depth at the longest high radiometric quality band for each relative humidity aerosol model set



Step 3
From (multi-scattering) Epsilon, find the closest aerosol fine mode fractions (FMF).



Step 4
Calculate the spectral aerosol reflectance for the closest models in relative humidity and FMF space

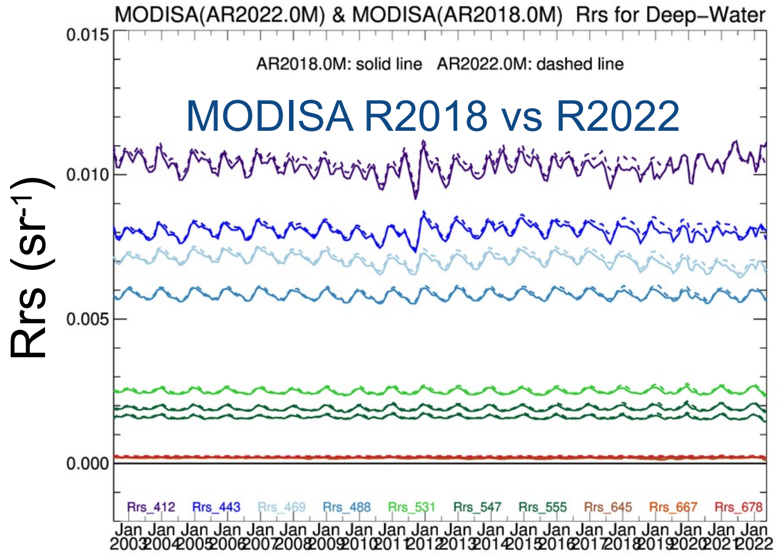
Step 5
Calculate the weighted mean of the models to get the final aerosol reflectance and diffuse transmittance

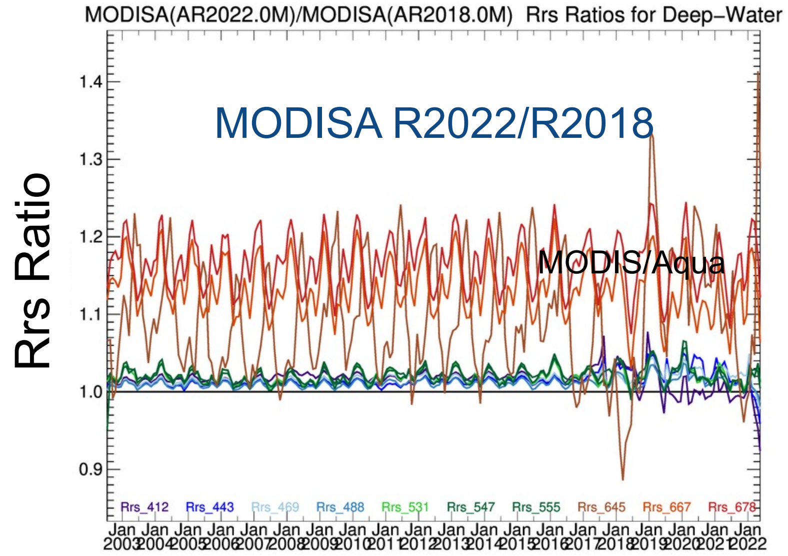
R_{rs}, τ_a, Ångström

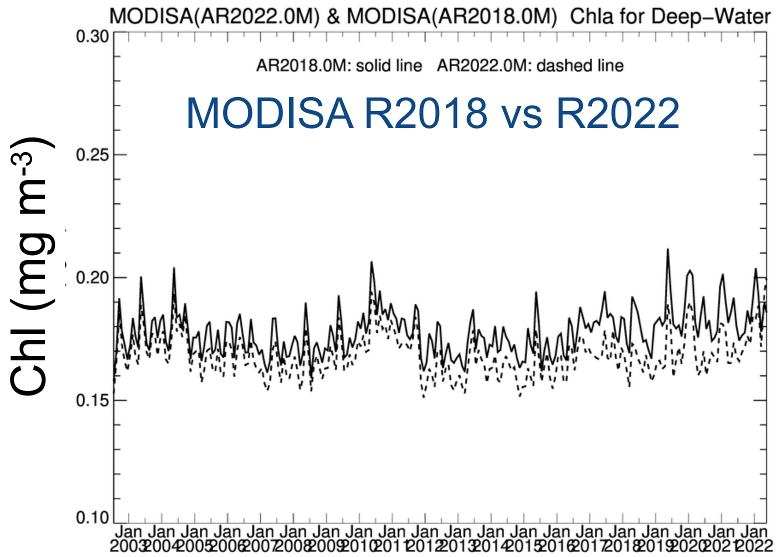
Ahmad, Z. and B. Franz (2018), Uncertainty in aerosol model characterization and its impact on ocean color retrievals, in PACE Technical Report Series, Volume 6: Data Product Requirements and Error Budgets (NASA/TM-2018 - 2018-219027/ Vol. 6).

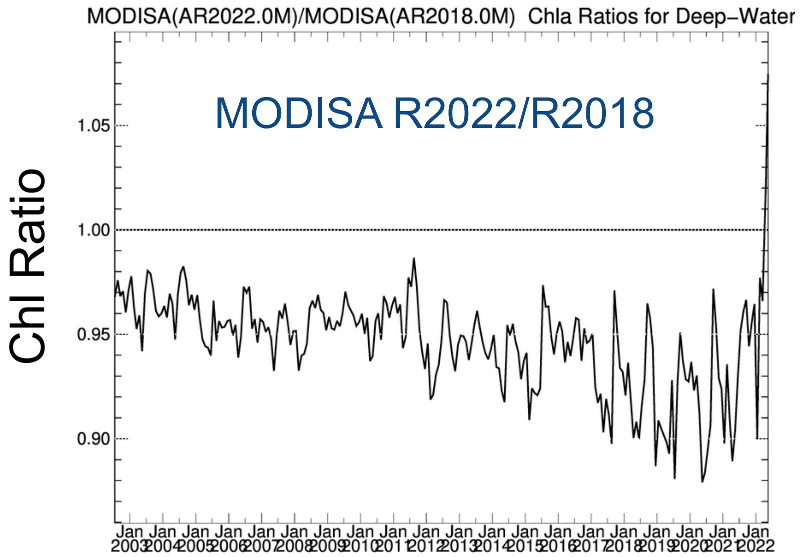
MODIS-Aqua R2022 vs R2018, Global Deep-Water Trends

- Comparison trends over mission lifetime
- Rrs changes of a few percent in blue & green, larger in red.
- Chl decrease of ~0.01 mg/m^3 (-5% in global mean deep water), with slightly higher decreases after 2017.
- Effects of instrument and vicarious cal.





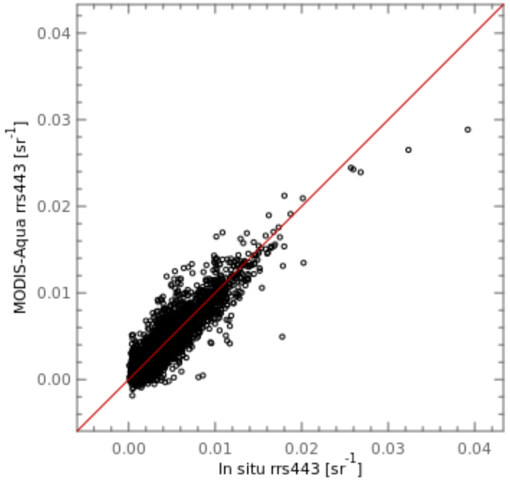




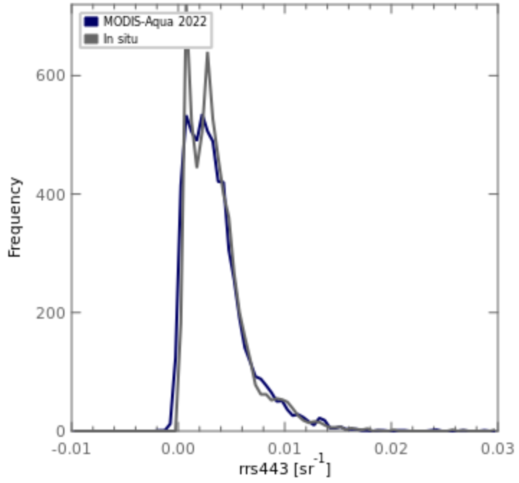
MODIS-Aqua R2022 Rrs Validation

- Comparison against AERONET-OC and SeaBASS in situ measurements.
- Very good agreement in most bands.
- Negative mean relative bias of < 5% in most bands (Bland Altman).

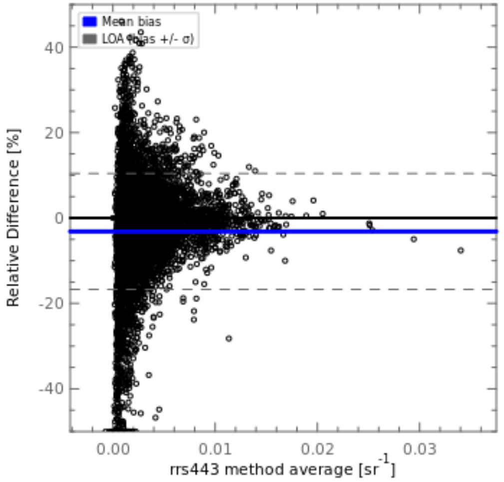
Rrs (443) Scatter



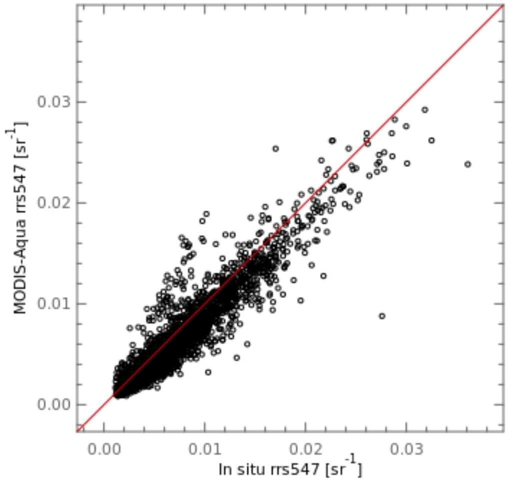
Rrs (443) Freq. Dist.



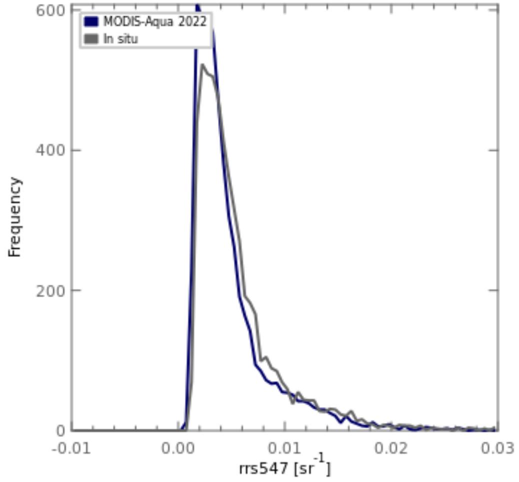
Rrs (443) Bland Altman



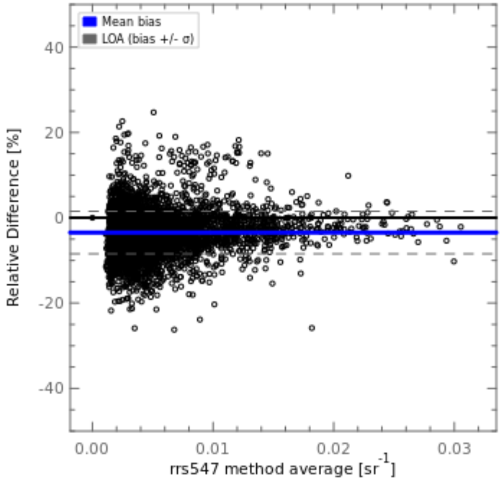
Rrs (547) Scatter



Rrs (547) Freq. Dist.



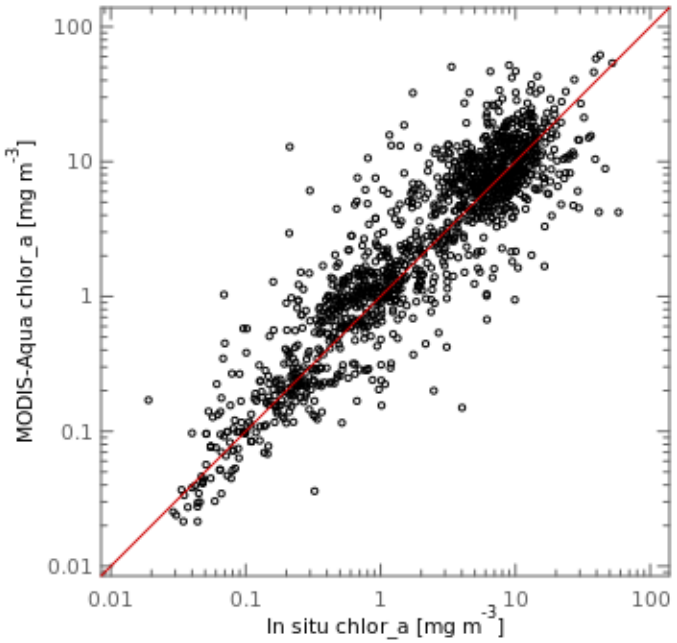
Rrs (547) Bland Altman



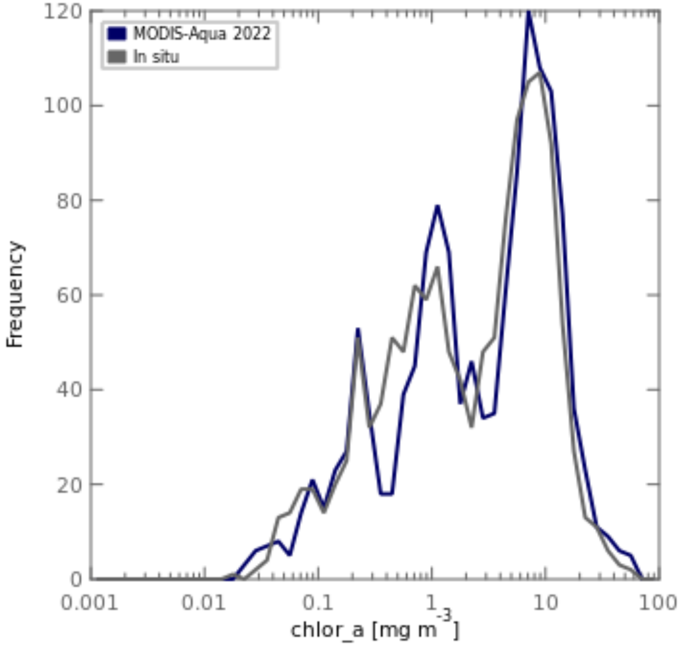
https://seabass.gsfc.nasa.gov/search_results/val

MODIS-Aqua R2022 Chl Validation

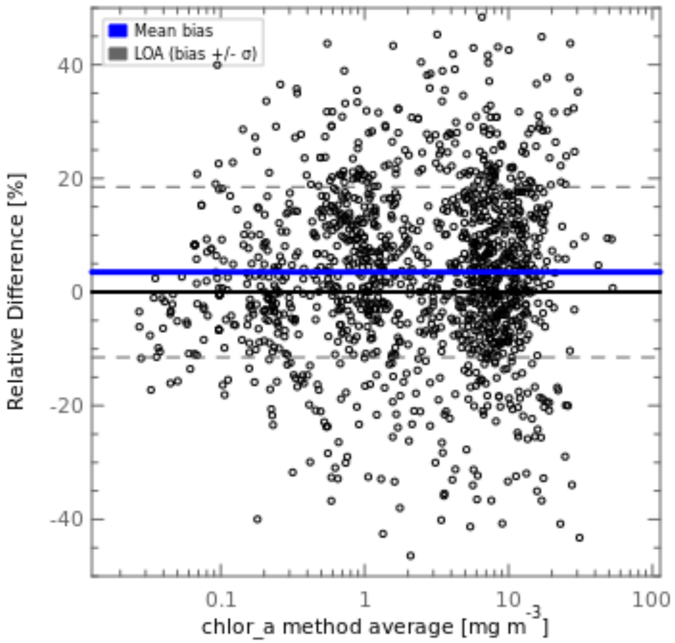
Chl Scatter



Chl Freq. Dist.



Chl Bland Altman

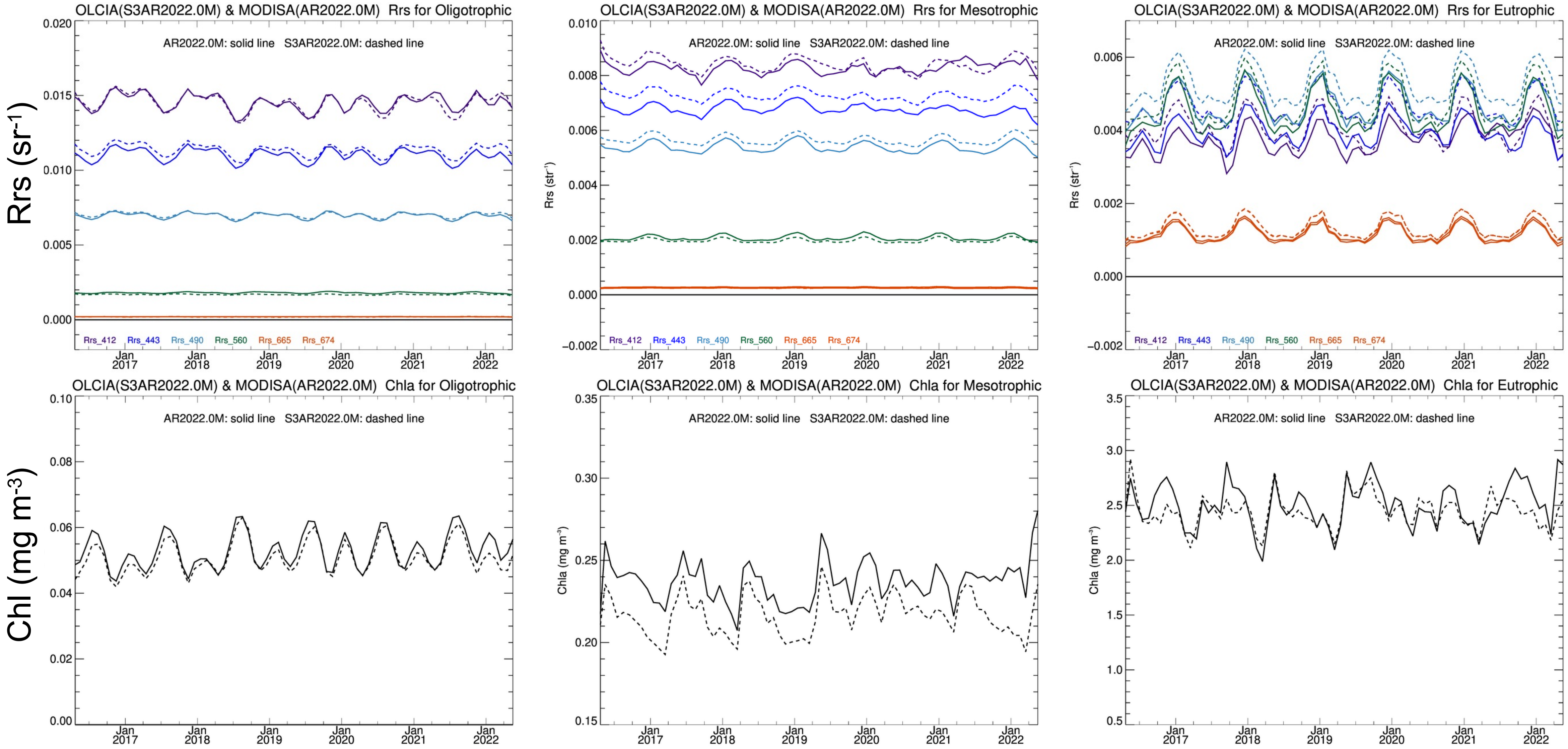


- MODIS-Aqua Chlorophyll in good agreement with in situ measurements
- Mean relative bias < 5%

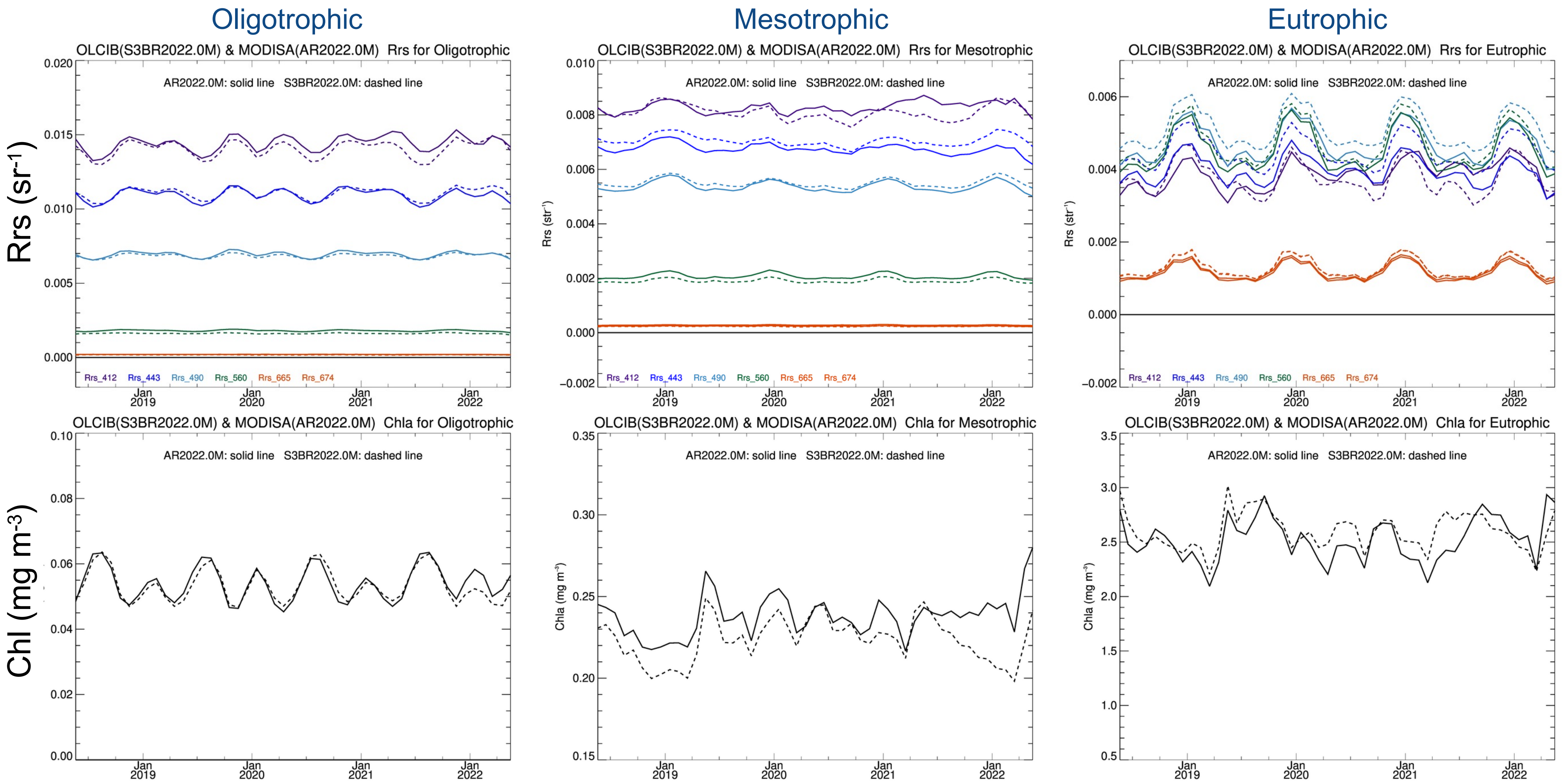
https://seabass.gsfc.nasa.gov/search_results/val

OLCI-S3A vs MODIS-A, R2022 Global Deep-Water Trends

Oligotrophic | Mesotrophic | Eutrophic



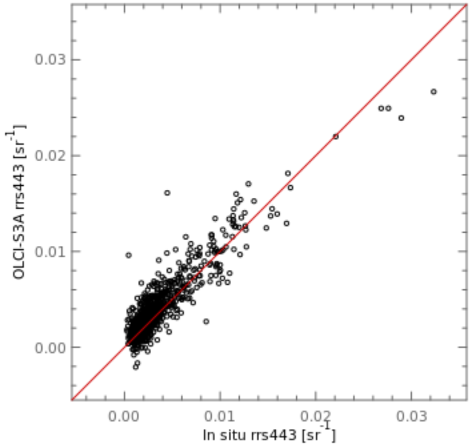
OLCI-S3B vs MODIS-A, R2022 Global Deep-Water Trends



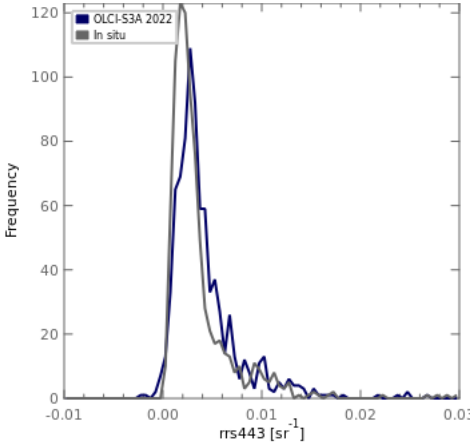
OLCI-S3A R2022 Rrs Validation

- Comparison against AERONET-OC and SeaBASS in situ measurements.
- Good agreement in most bands, with mean relative bias < 5%.
- Insufficient match-ups for OLCI-S3B yet, but looking similar.

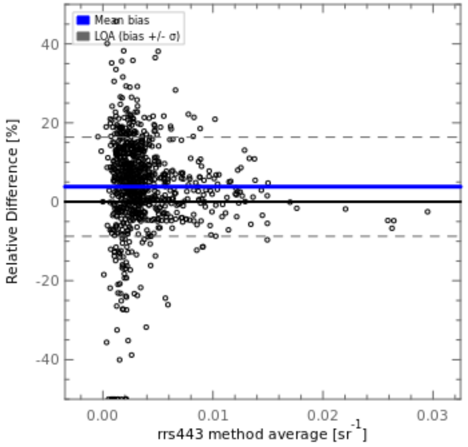
Rrs (443) Scatter



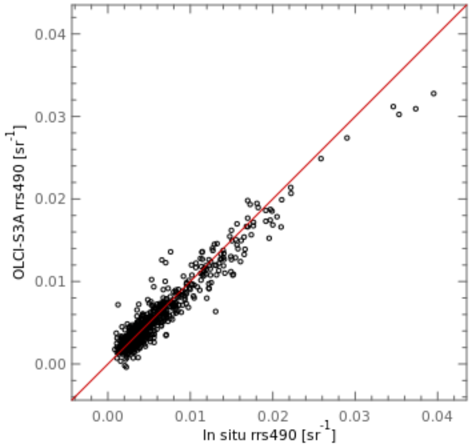
Rrs (443) Freq. Dist.



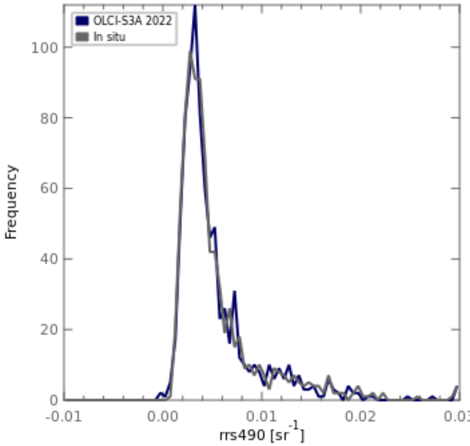
Rrs (443) Bland Altman



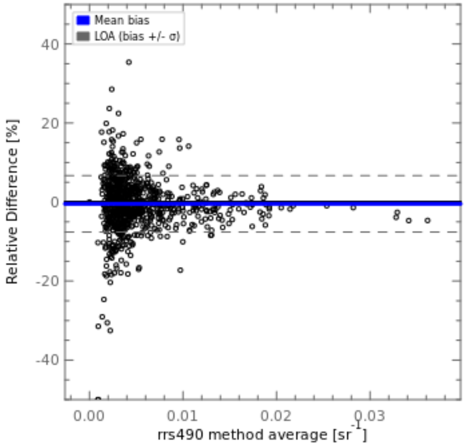
Rrs (490) Scatter



Rrs (490) Freq. Dist.



Rrs (490) Bland Altman



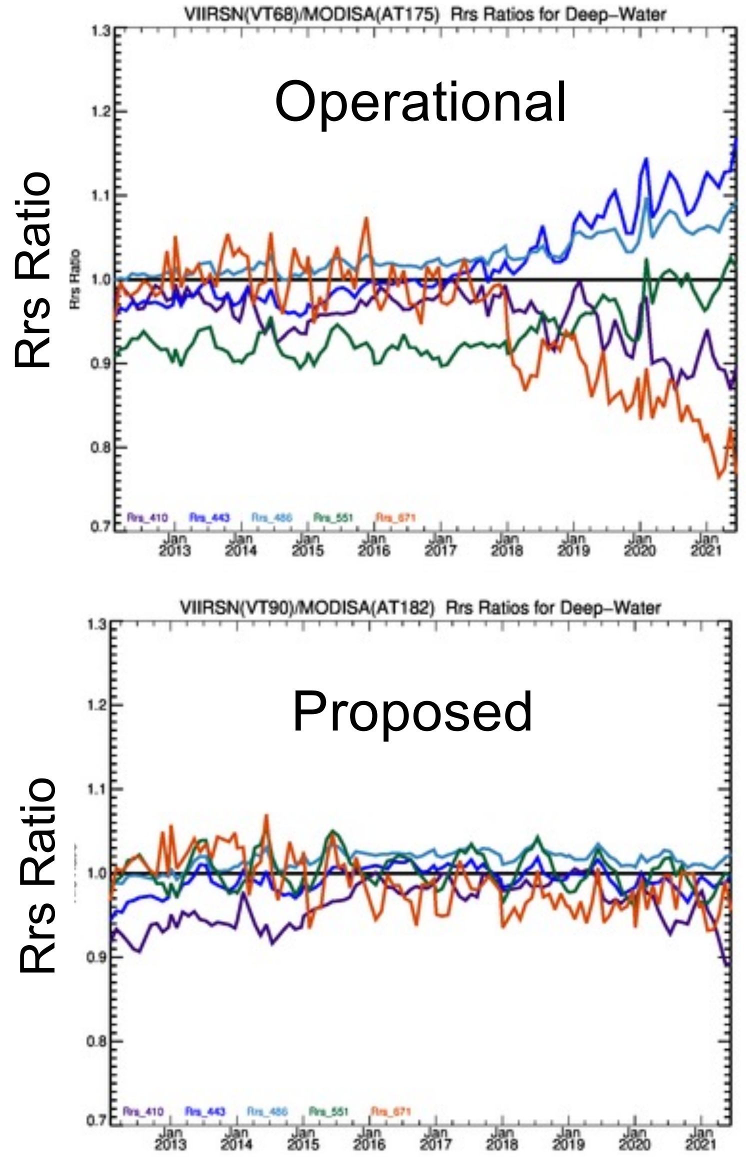
https://seabass.gsfc.nasa.gov/search_results/val

VIIRS/SNPP Calibration Update for R2022

Calibration Changes

- extension of lunar/solar time-series with new observations
- revised model for fitting lunar time-series (exponential in time, linear in libration, applied to solar time-series)
- no lunar correction applied to M5,6,7 (no detectable trend)
- temporal gain adjustments for impact of modulated RSRs on ocean/atmosphere signal, for bands M1-M7
- relative detector corrections to reduce striping (flat fielding)
- model-based vicarious calibration using chlorophyll climatology (following *Werdell et al. 2007, Applied Optics*)

VIIRS/SNPP & MODIS/Aqua



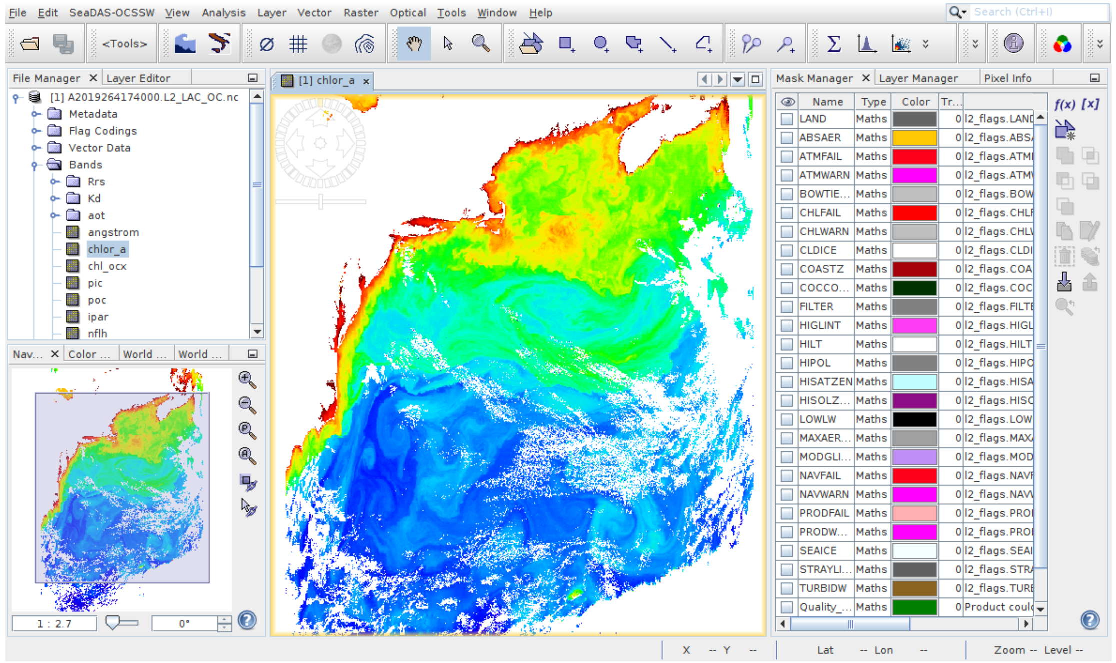
Other Work in Progress

- Developing Science Data Segment for PACE and GLIMR
- Preparing for JPSS-2 VIIRS (launching November 2022)
  - supporting prelaunch testing, refining Level-1 codes, and preparing algorithms and LUTs.
- Developing per-pixel Rrs uncertainties product
  - *Zhang, M., A. Ibrahim, B.A. Franz, Z. Ahmad, and A.M. Sayer (2022). Estimating pixel-level uncertainty in ocean color retrievals from MODIS, Opt. Express 30, 31415-31438.*
- Transitioning to TSIS for reference solar irradiance spectrum
  - *Coddington, O. M., Richard, E. C., Harber, D., Pilewskie, P., Woods, T. N., Chance, K., et al. (2021). The TSIS-1 hybrid solar reference spectrum. Geophysical Research Letters, 48, e2020GL091709.*
- Transitioning to Pengwang Zhai's vector radiative transfer code for AC LUTs
- Investigating seasonal bias issue
  - *Bisson,K.M., E. Boss, P. J. Werdell, A. Ibrahim, R. Frouin, and M. J. Behrenfeld (2021). Seasonal bias in global ocean color observations," Appl. Opt.* ***60****, 6978-6988.*

SeaDAS Status

Version 8.2

- Released: March 2022.
- Continues the open-source distribution of NASA ocean color processing codes.
- GUI built on SNAP framework, continues joint NASA-ESA development in visualization tools.
- Includes SeaDAS and Sentinel-3 Toolboxes, and SeaDAS-OCSSW client-server module (processing)



SeaDAS 8 GUI

Next Release

- Version 8.3 anticipated to capture changes associated with R2022 reprocessing.

Ocean Color Processing Support

Hawkeye, OCI/PACE, VIIRS (JPSS1, SNPP), MODIS(Terra, Aqua), OLCI(S3A, S3B), MERIS, SeaWIFS, GOCI, OLI(L8), ETM(L7), TM(L5), MSI(S2A,S2B), Aquarius, HICO, OCTS, CZCS, OSMI, OCM(1,2), MOS, SGLI

SNAP = Sentinel Application Platform (developed for ESA by Brockmann Consult)

OB.DAAC User Working Group

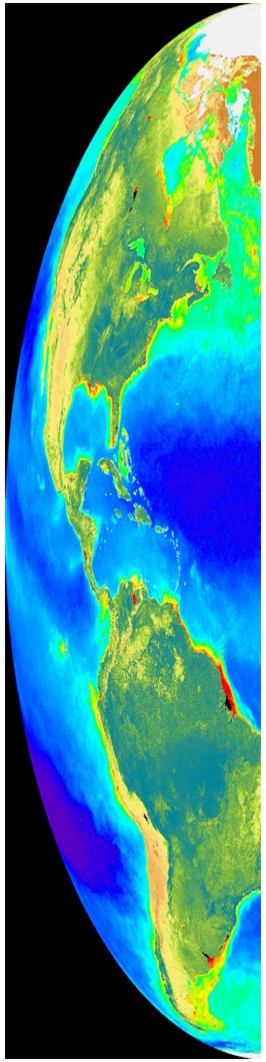
The OB DAAC User Working Group (UWG) is an external advisory group tasked to:

- Assess the quality of services provided by the OB.DAAC and provide a determination of the extent to which the products reflect the needs of the science community;
- Offer recommendations on the addition of new data sets
- Suggest improvements to enhance overall user experience
- Facilitate communications with the global ocean color user community and interested members of other communities
- Recommend new capabilities and guidance on suggested priorities
- Communicate with and document actions/input from the UWG to the NASA ESDIS Project and NASA ESD Data Systems Program
- Review previous recommendations for continued relevance and possible priority changes

The UWG meets once per year to review the status of OB DAAC operations and to provide recommendations. First meeting to take place 28 September 2022.

https://oceancolor.gsfc.nasa.gov/uwg/

Summary



- R2022 reprocessing underway. SeaWiFS and MODIS-Terra next.
- Consistently-processed L2/L3 OLCI products from S3A & S3B now available from OB.DAAC (also MERIS with updated ESA L1B calibration, netcdf4)
- R2022 results (MODIS-Aqua, OLCI, MERIS) looking good (+/- <5% Rrs biases). Some larger deviations between MODIS and OLCI post 2021. Still evaluating.
- SNPP VIIRS R2018.0 products show significant late-mission drifts, resolved through updated instrument calibration to be applied in reprocessing.
- JPSS1 VIIRS R2018.0 products available, instrument is very stable with no temporal calibration yet required, some detector striping will be corrected in reprocessing.
- JPSS2 VIIRS coming soon (November).
- Still supporting heritage missions (CZCS, GOCI, HICO, etc.), and leveraging OBPG facilities for CyAN, SeaHawk, PACE, and GLIMR.