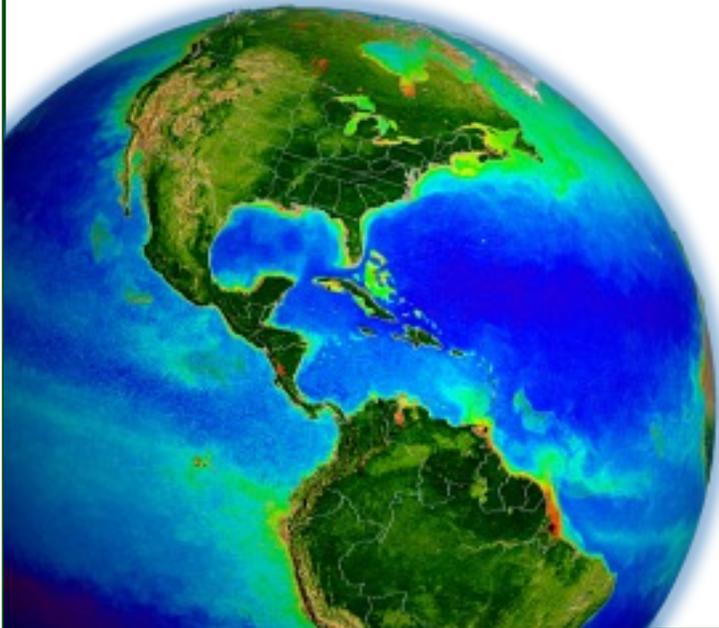# Quality of the MODIS and VIIRS ocean color time series following the R2022 reprocessing

Bryan Franz

Ocean Ecology Laboratory
NASA Goddard Space Flight Center

MODIS/VIIRS Science Team Meeting

2-4 May 2023

College Park, MD

NASA Ocean Biology Processing Group & OB.DAAC

calibration, validation, software development, (re)processing, and distribution for a multitude sensors
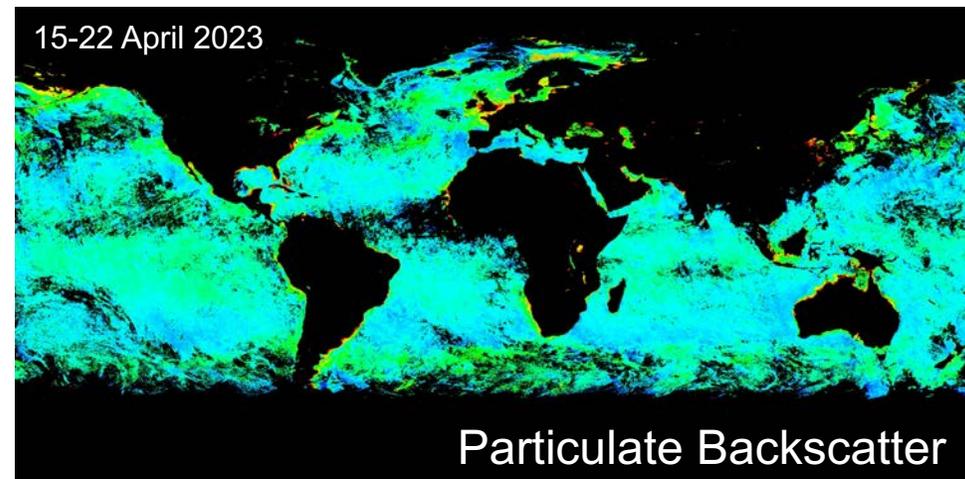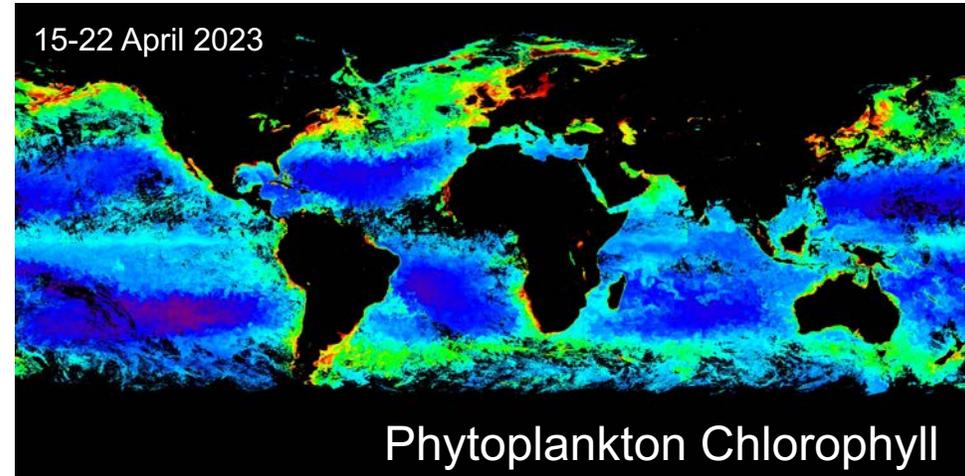
Global Processing & Distribution

- **VIIRS/JPSS2**   (USA)
- **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)

JPSS-2 VIIRS Ocean Color Products Now Available!

15-22 April 2023

Phytoplankton Chlorophyll

15-22 April 2023

Particulate Backscatter

R2022 Multi-mission Ocean Color Reprocessing

Missions:

VIIRS (SNPP, J1, J2), MODIS (Aqua, Terra), OLCI (S3A, S3B), 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 flagging/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.

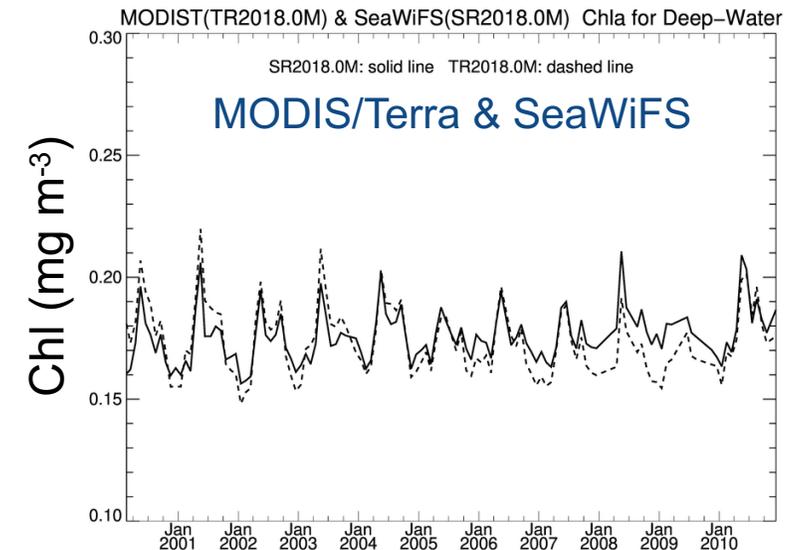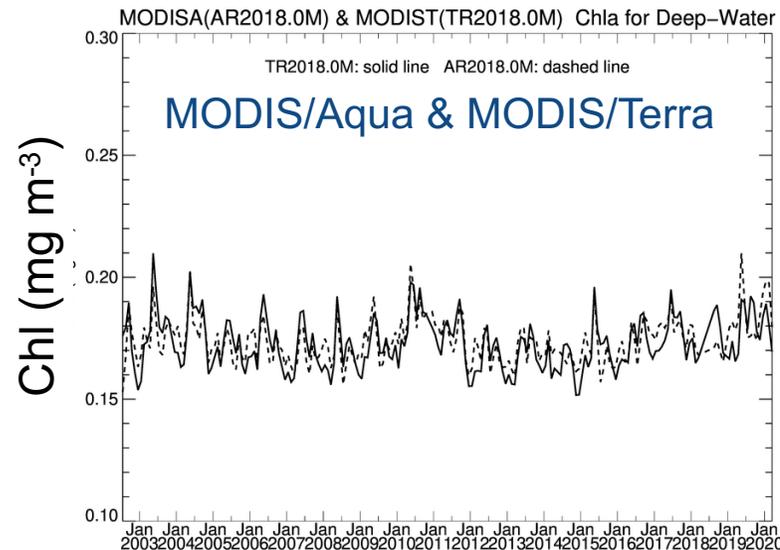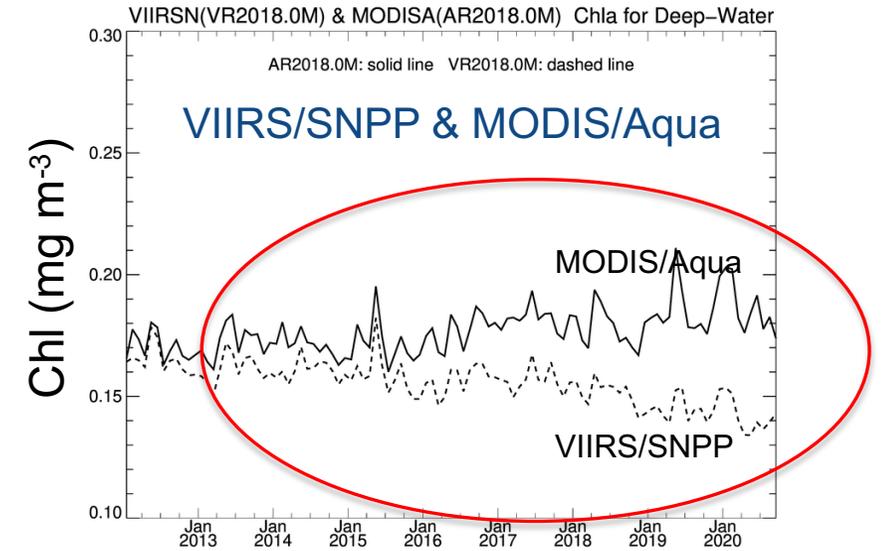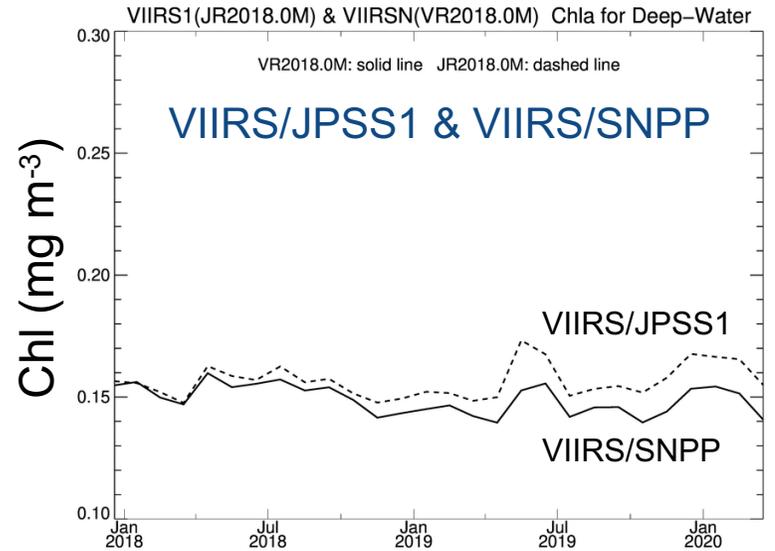# Seasonal Mean Chlorophyll Concentration for 2022
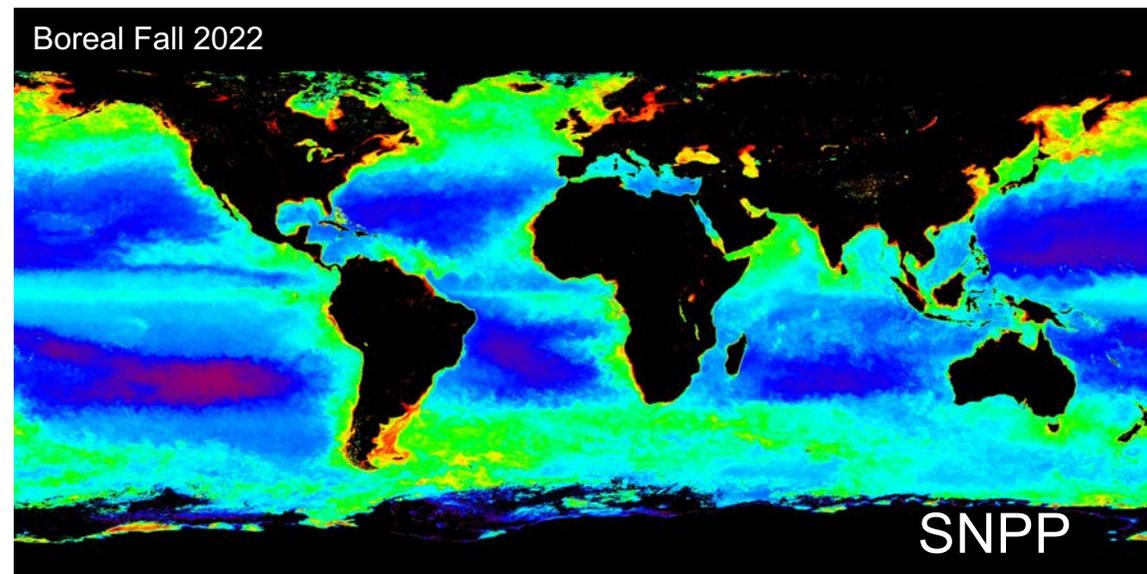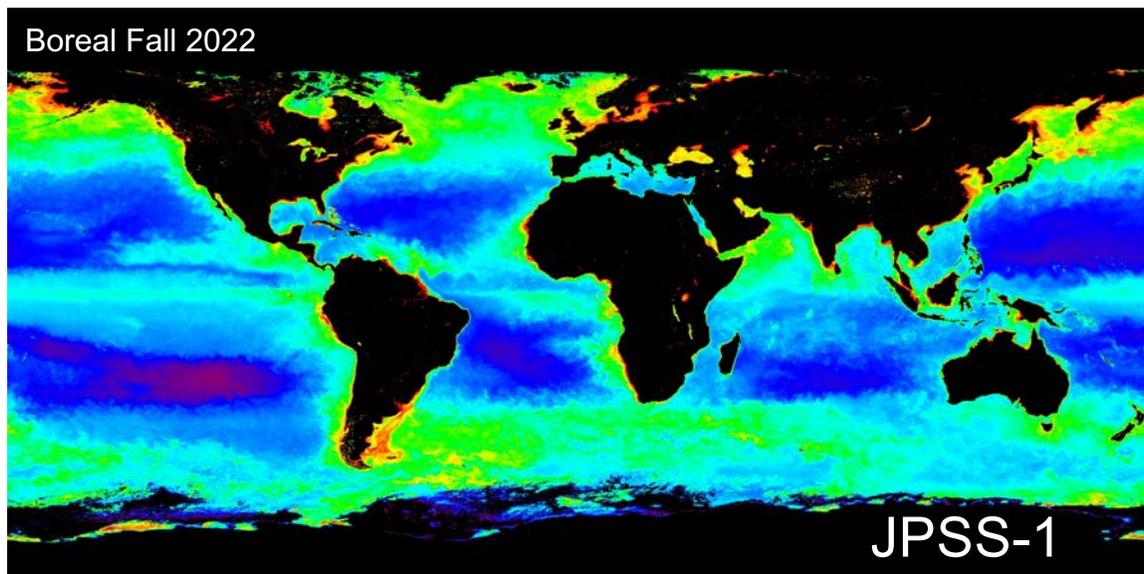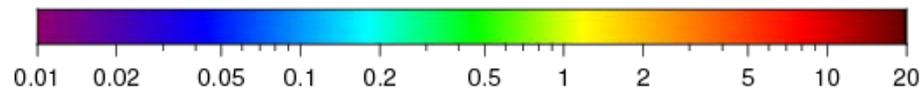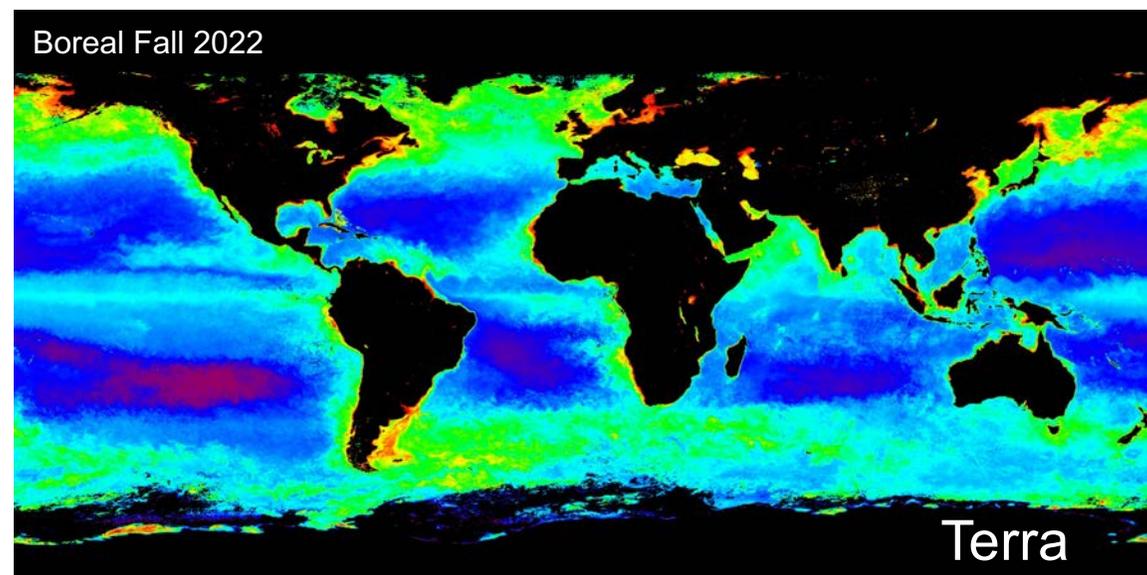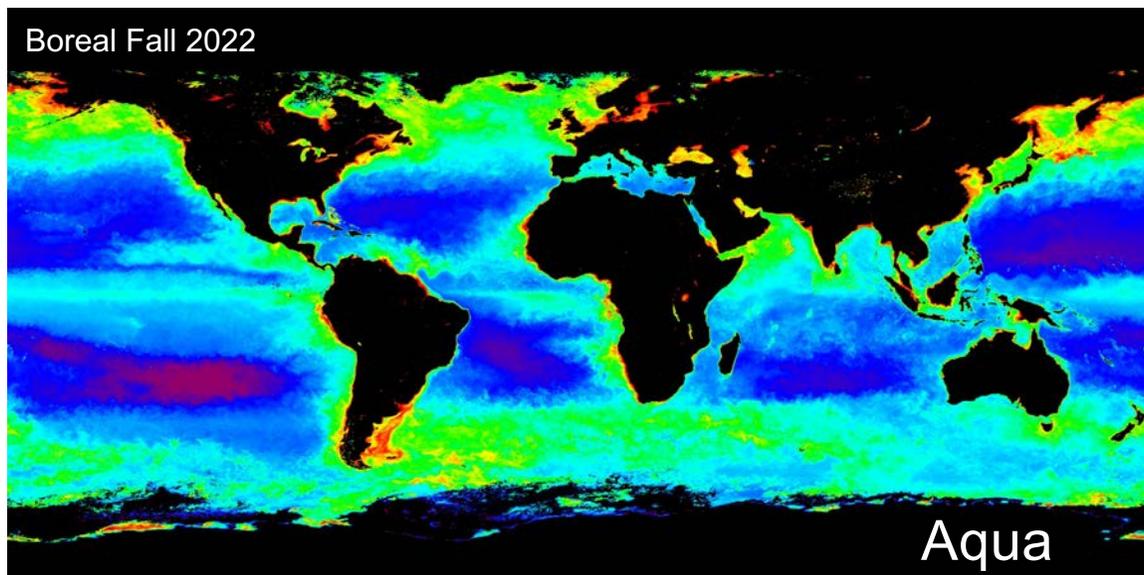
R2018 Global Deep-Water Chlorophyll Trends

- 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

VIIRS1(JR2018.0M) & VIIRSN(VR2018.0M) Chla for Deep-Water

VR2018.0M: solid line   JR2018.0M: dashed line

VIIRS/JPSS1 & VIIRS/SNPP

VIIRSN(VR2018.0M) & MODISA(AR2018.0M) Chla for Deep-Water

AR2018.0M: solid line   VR2018.0M: dashed line

VIIRS/SNPP & MODIS/Aqua

MODISA(AR2018.0M) & MODIST(TR2018.0M) Chla for Deep-Water

TR2018.0M: solid line   AR2018.0M: dashed line

MODIS/Aqua & MODIS/Terra

MODIST(TR2018.0M) & SeaWiFS(SR2018.0M) Chla for Deep-Water

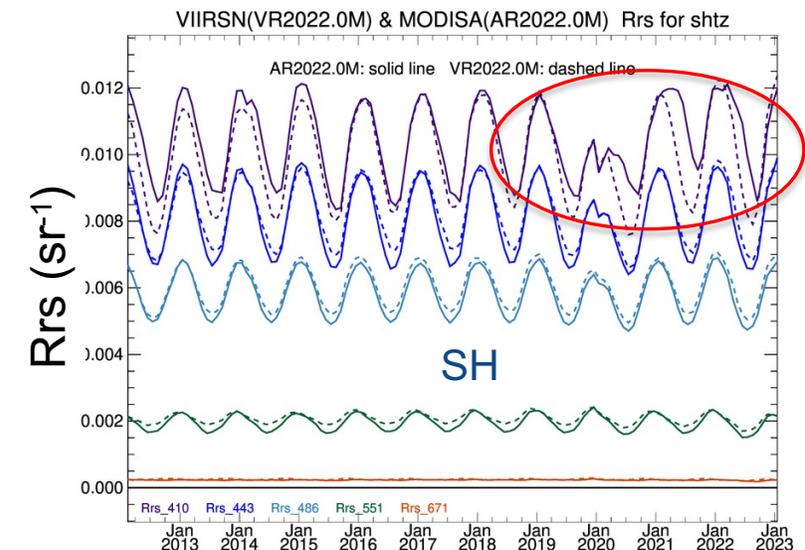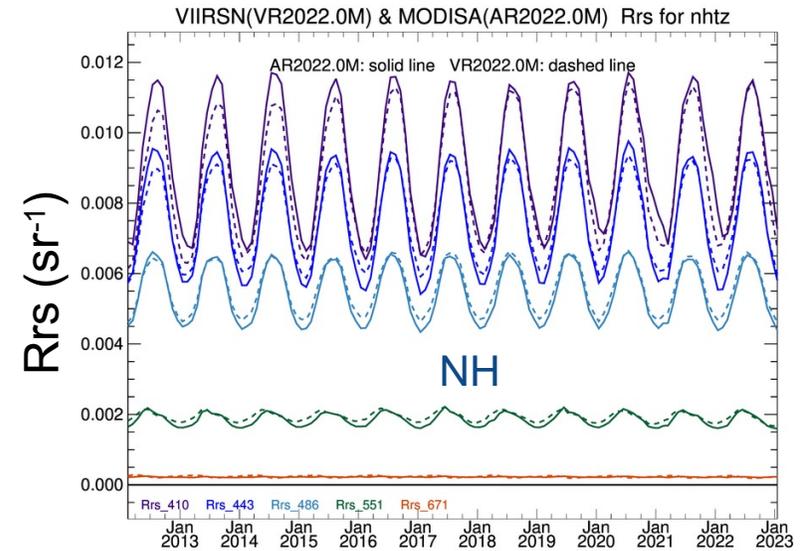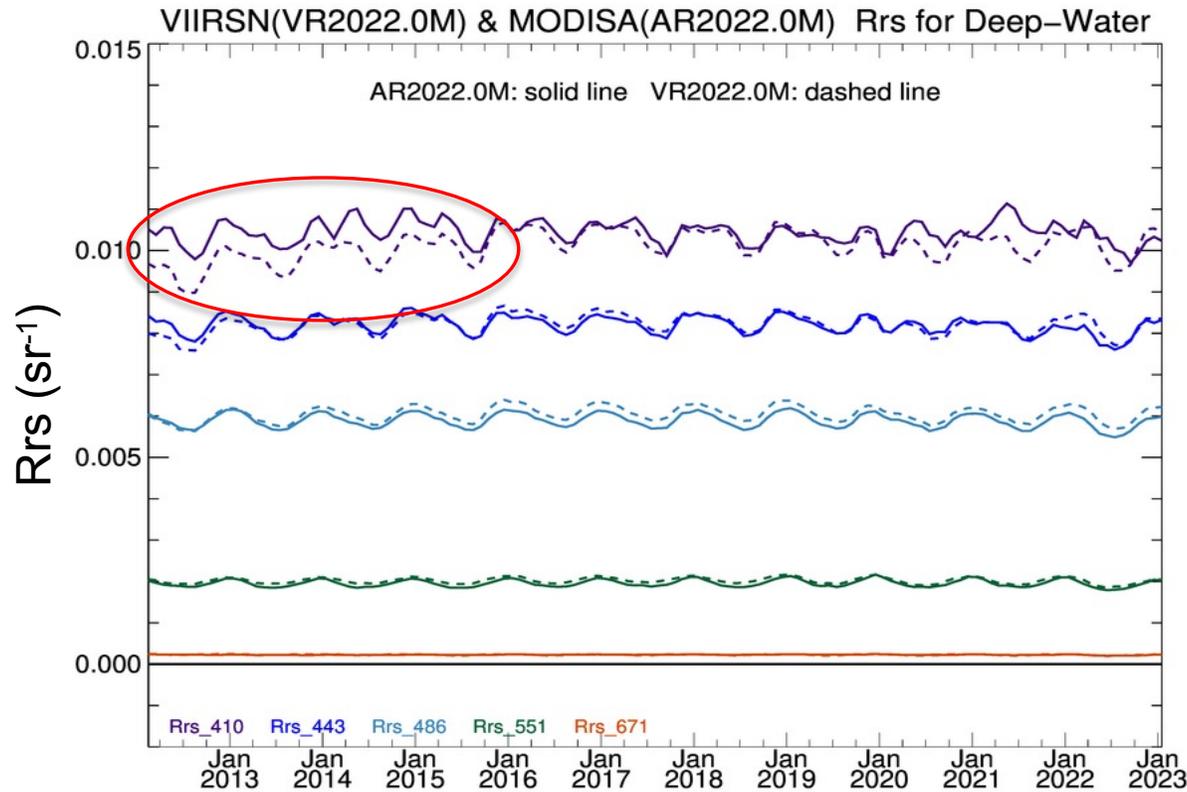SR2018.0M: solid line   TR2018.0M: dashed line

MODIS/Terra & SeaWiFS

R2022 Global Deep-Water Chlorophyll Trends

- Comparison trends over common mission lifetime

- VIIRS/SNPP now in good agreement with VIIRS/JPSS1 & MODIS/Aqua

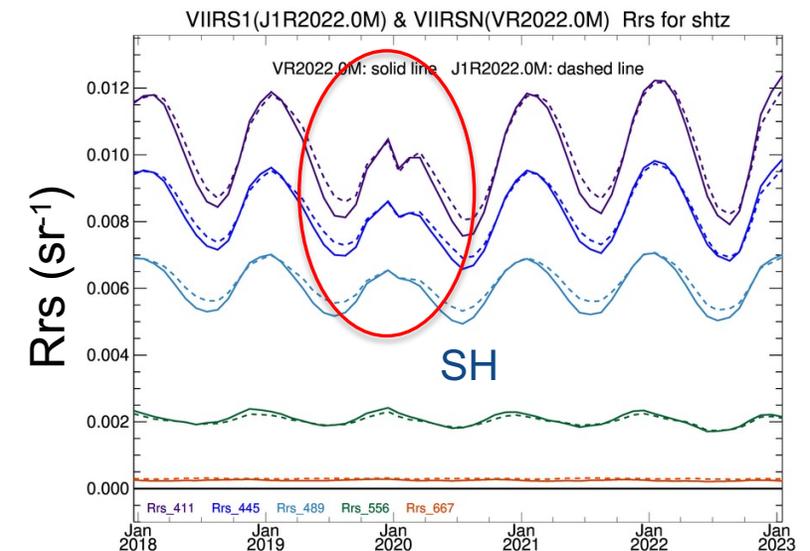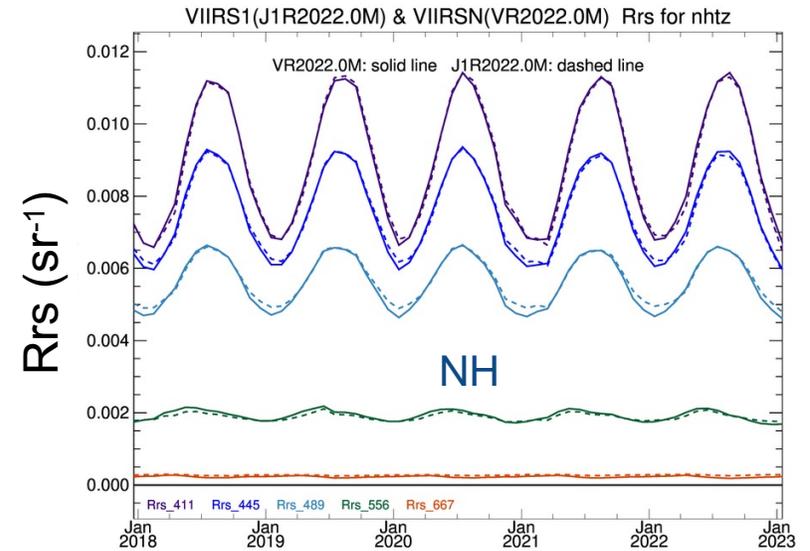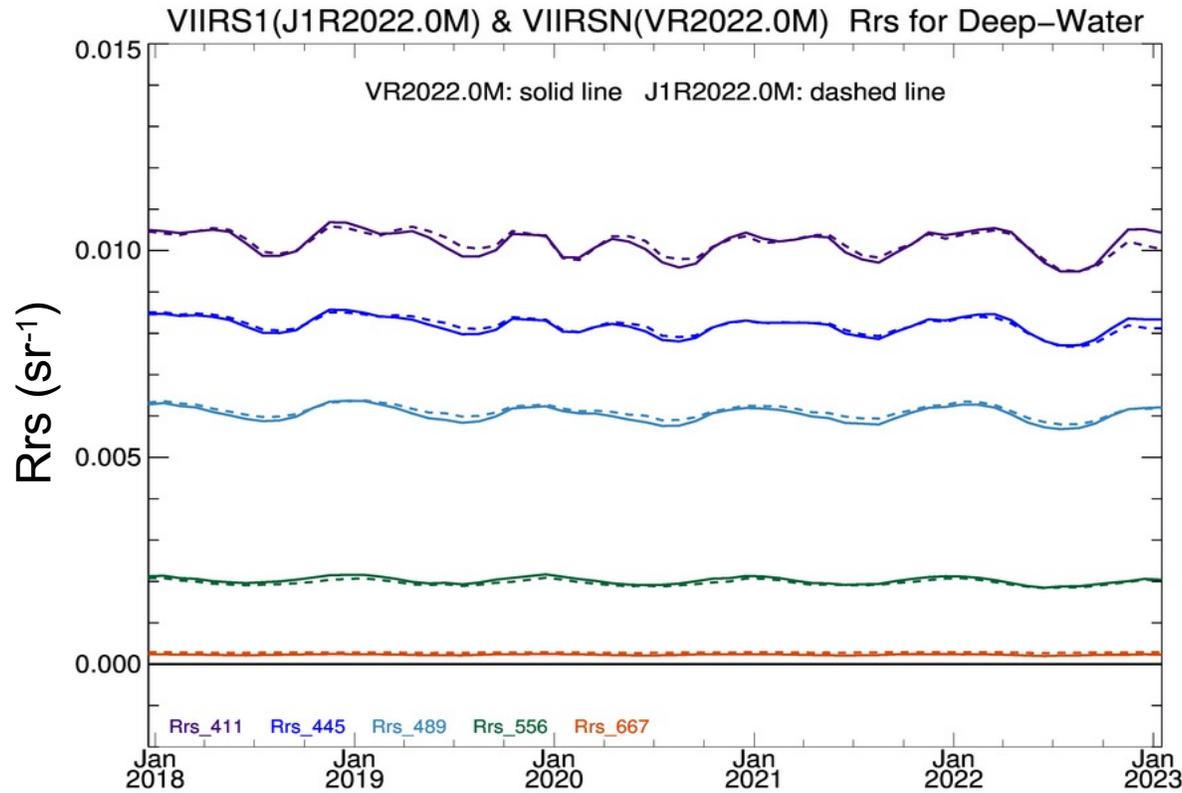- SeaWiFS, MODIS/Terra, MODIS/Aqua still in good agreement, with short-term deviations
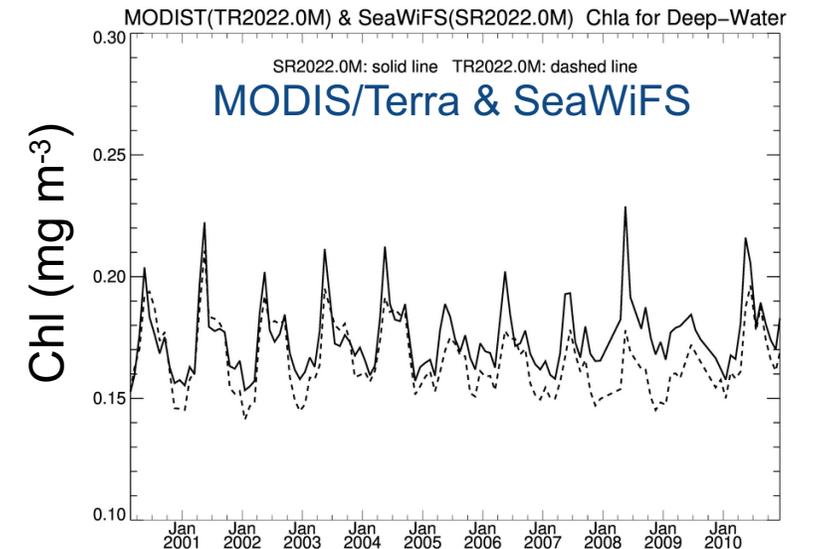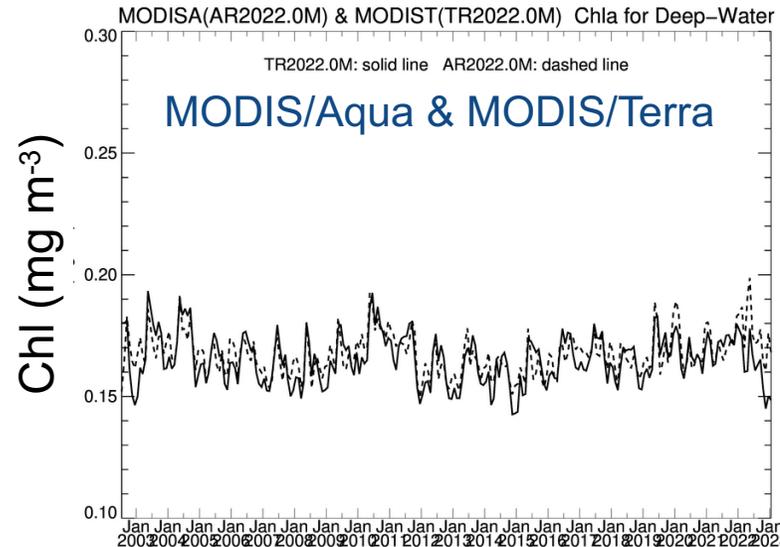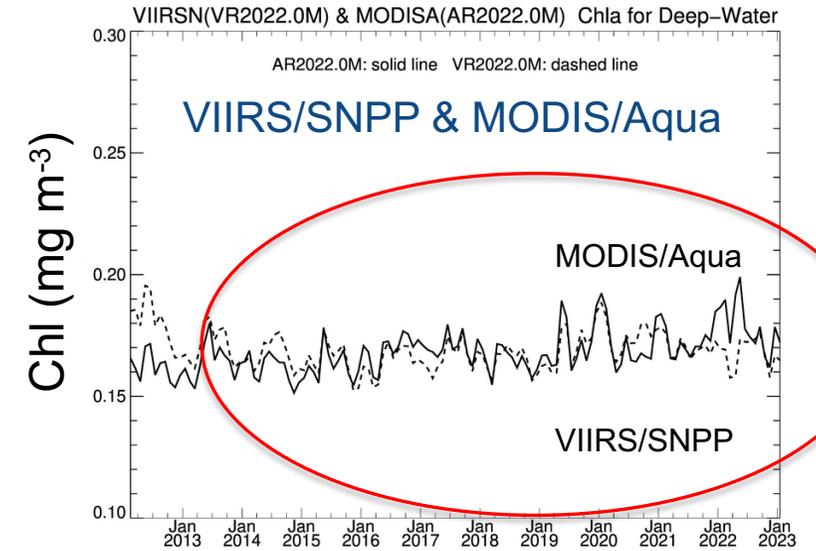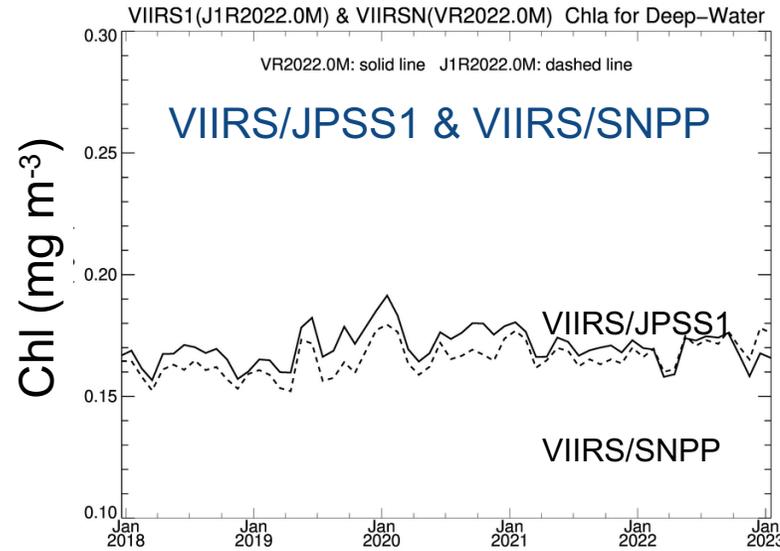
R2022 Deep-water Rrs, MODIS/Aqua & SNPP/VIIRS
+Northern & Southern Hemisphere Temperate Zone

VIIRSN(VR2022.0M) & MODISA(AR2022.0M) Rrs for Deep-Water

AR2022.0M: solid line   VR2022.0M: dashed line

Rrs_410   Rrs_443   Rrs_486   Rrs_551   Rrs_671

VIIRSN(VR2022.0M) & MODISA(AR2022.0M) Rrs for nhtz

AR2022.0M: solid line   VR2022.0M: dashed line

NH

Rrs_410   Rrs_443   Rrs_486   Rrs_551   Rrs_671

VIIRSN(VR2022.0M) & MODISA(AR2022.0M) Rrs for shtz

AR2022.0M: solid line   VR2022.0M: dashed line

SH

Rrs_410   Rrs_443   Rrs_486   Rrs_551   Rrs_671

- MODIS/Aqua & VIIRS/SNPP in very good agreement!
- Deviation in blue prior to 2016 likely residual error from tungsten oxide contamination on VIIRS mirror
- Deviation in blue post 2020 in SH are TBD (MODIS issue)

R2022 Deep-water Rrs, SNPP/VIIRS & J1/VIIRS
## +Northern & Southern Hemisphere Temperate Zone

VIIRS1(J1R2022.0M) & VIIRSN(VR2022.0M) Rrs for Deep–Water

VR2022.0M: solid line   J1R2022.0M: dashed line

Rrs_411   Rrs_445   Rrs_489   Rrs_556   Rrs_667

VIIRS1(J1R2022.0M) & VIIRSN(VR2022.0M) Rrs for nhtz

VR2022.0M: solid line   J1R2022.0M: dashed line

NH

Rrs_411   Rrs_445   Rrs_489   Rrs_556   Rrs_667

VIIRS1(J1R2022.0M) & VIIRSN(VR2022.0M) Rrs for shtz

VR2022.0M: solid line   J1R2022.0M: dashed line

SH

Rrs_411   Rrs_445   Rrs_489   Rrs_556   Rrs_667

- VIIRS/SNPP & J1 in exellent agreement
- Artifact near Jan 2020 in SH is Australian fires

R2022 Hemispherical Deep-water Chlorophyll Trends
Northern & Southern Hemisphere Temperate Zone

- Excellent agreement demonstrates that the consistently-processed VIIRS time-series can be used to extend the ocean color data record established with SeaWiFS and MODIS for many key parameters.
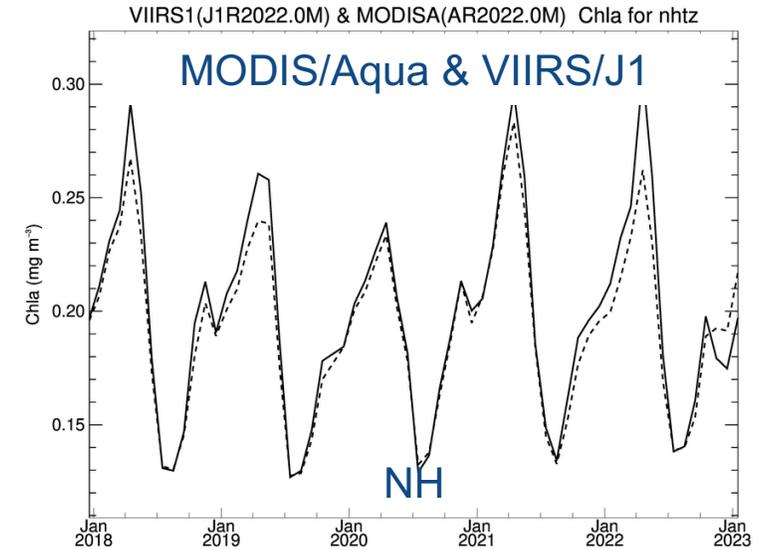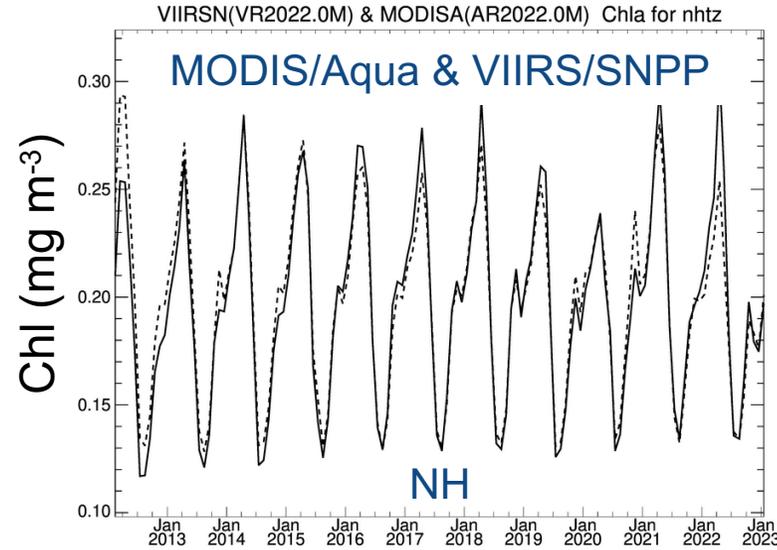
- SH peak in Jan 2020 captures phytoplankton blooms generated by Australian fires.
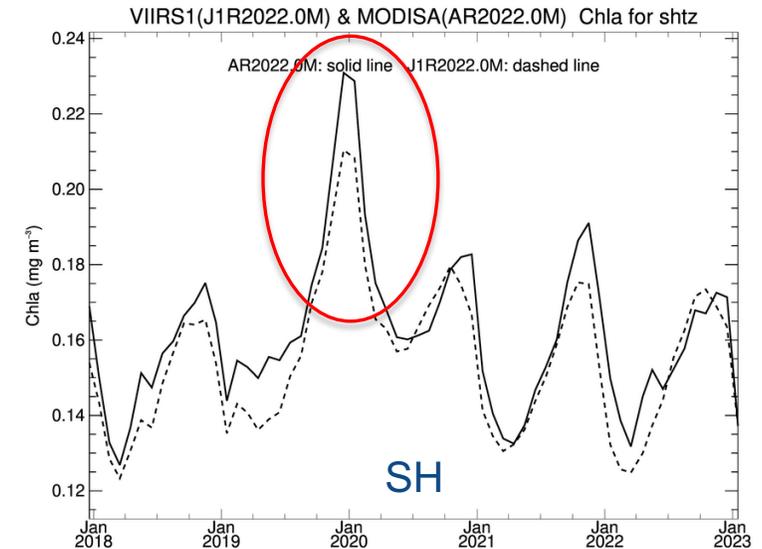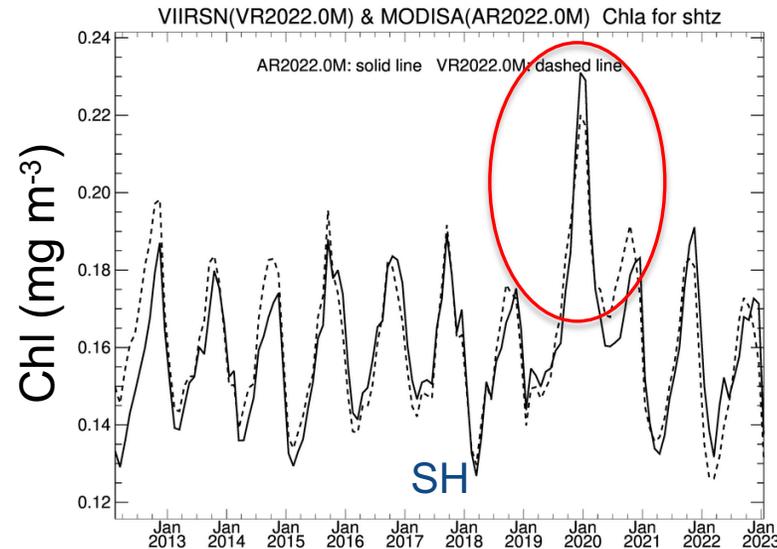
R2022 MODIS/Aqua Rrs Validation

- Comparison against AERONET-OC and SeaBASS in situ measurements.

- Very good agreement in most bands.

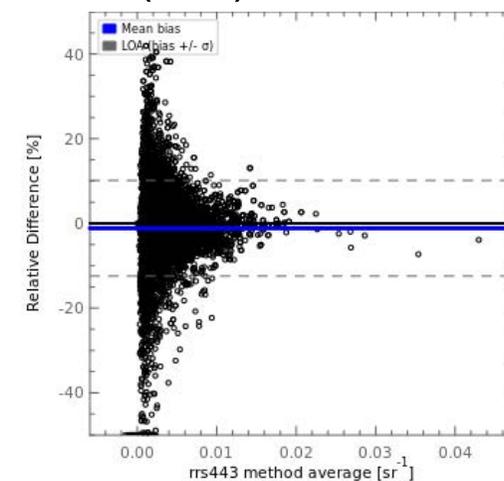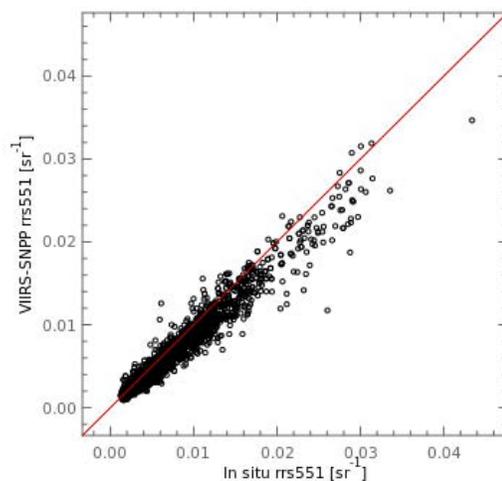- Negative mean relative bias of < 5% in most bands (Bland Altman).
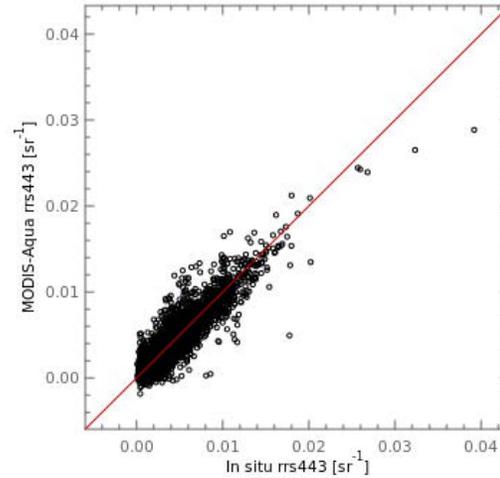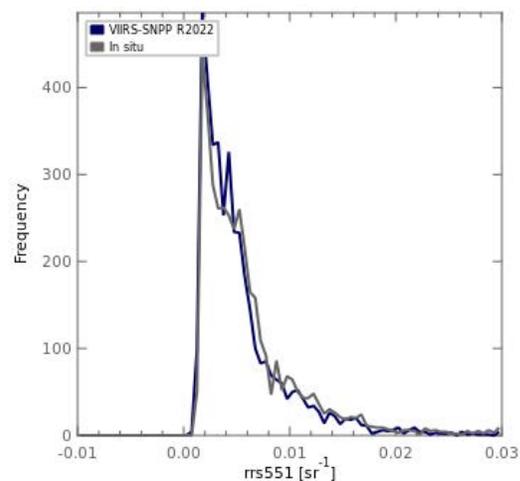

Rrs (443) Scatter
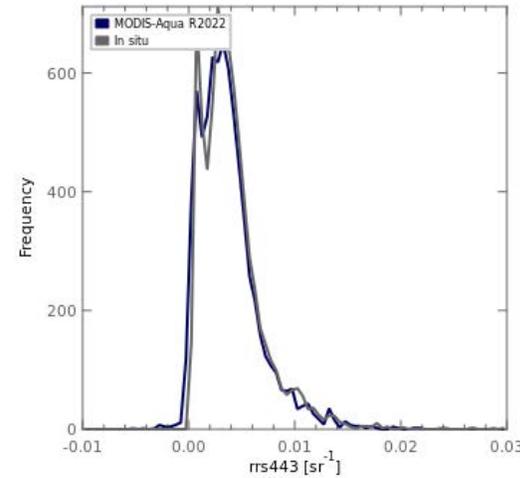
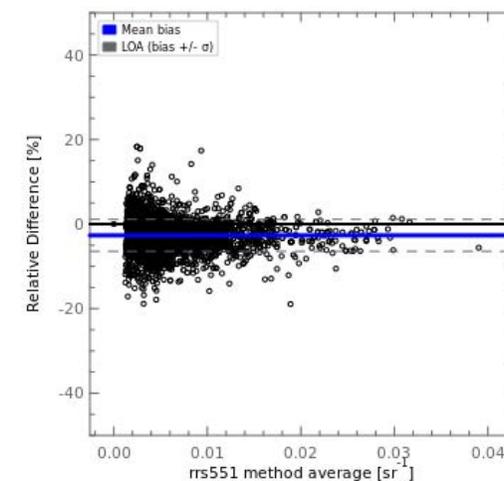
Rrs (443) Freq. Dist.

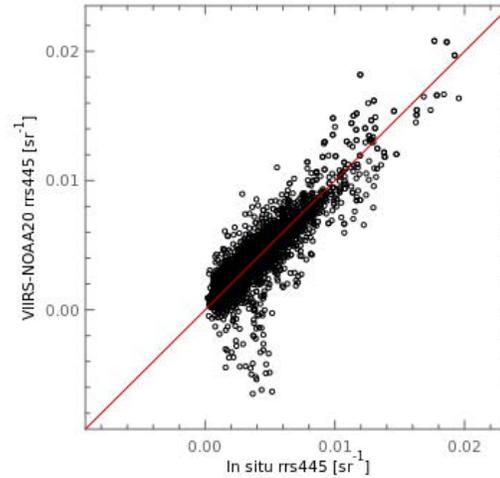Rrs (443) Bland Altman
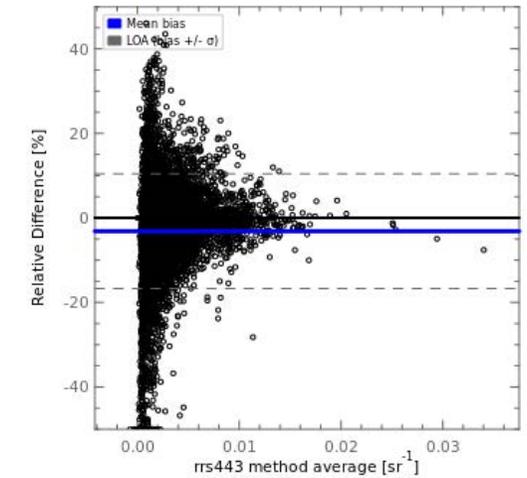
Rrs (547) Scatter
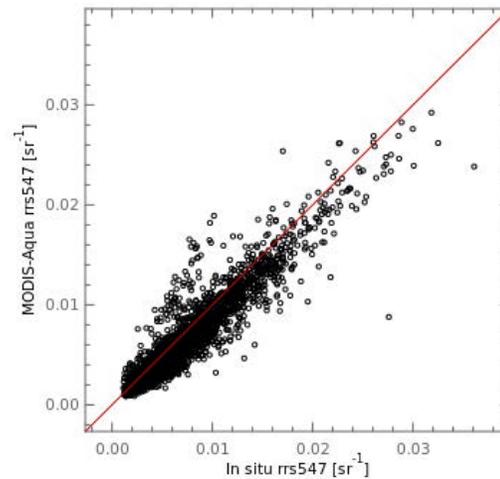
Rrs (547) Freq. Dist.

Rrs (547) Bland Altman

https://seabass.gsfc.nasa.gov/search_results/val
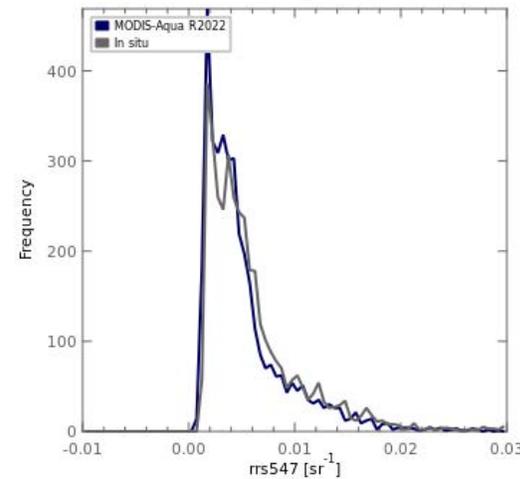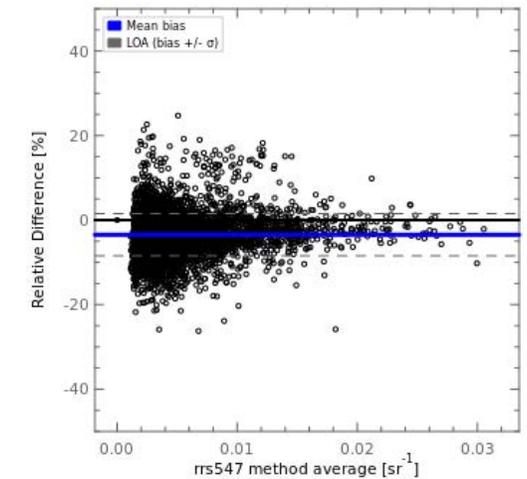
R2022 VIIRS/SNPP Rrs Validation

- 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).
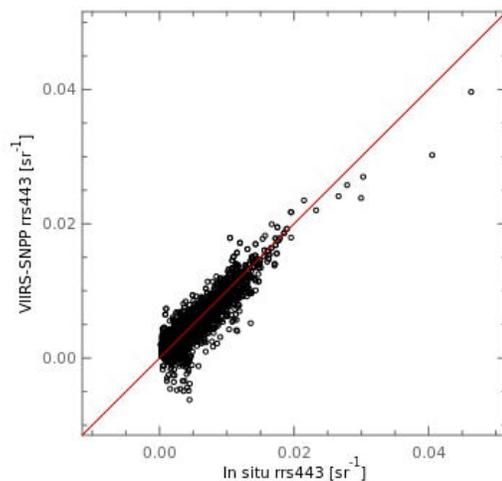
Rrs (443) Scatter
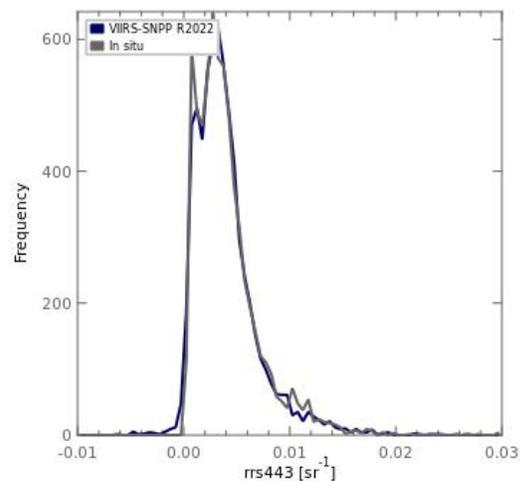
Rrs (443) Freq. Dist.

Rrs (443) Bland Altman

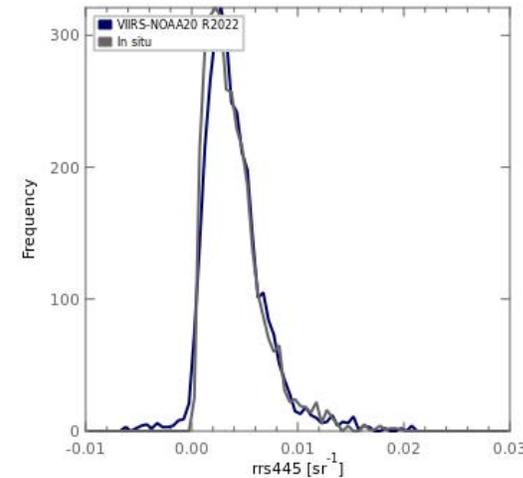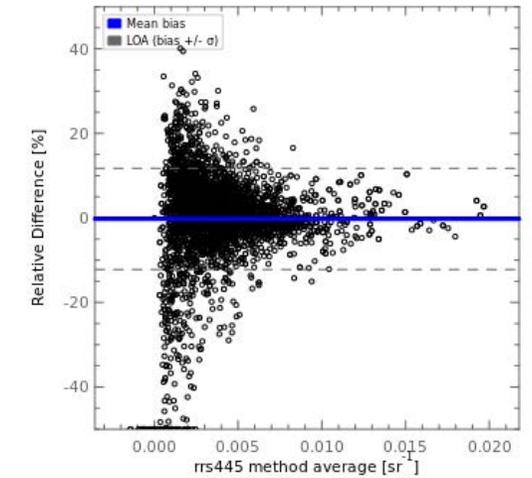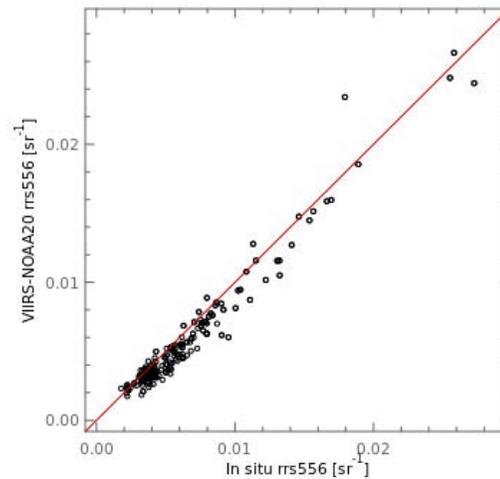Rrs (551) Scatter

Rrs (551) Freq. Dist.

Rrs (551) Bland Altman

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

R2022 VIIRS/JPSS1 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 (445) Scatter

Rrs (445) Freq. Dist.
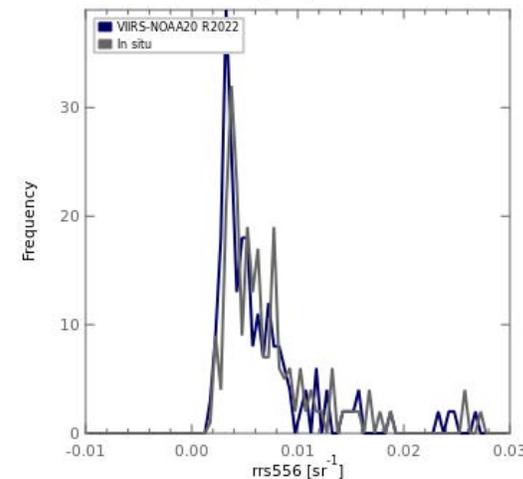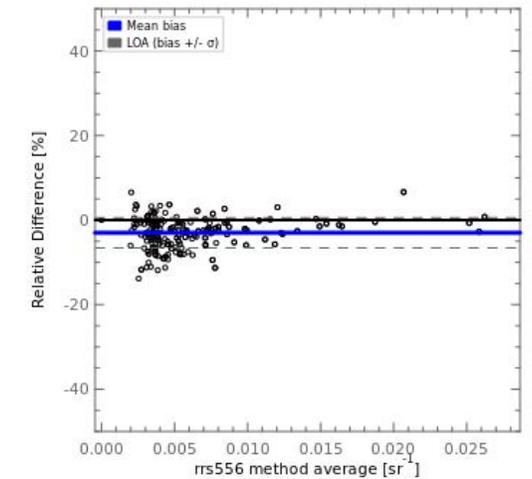
Rrs (445) Bland Altman

Rrs (556) Scatter

Rrs (556) Freq. Dist.

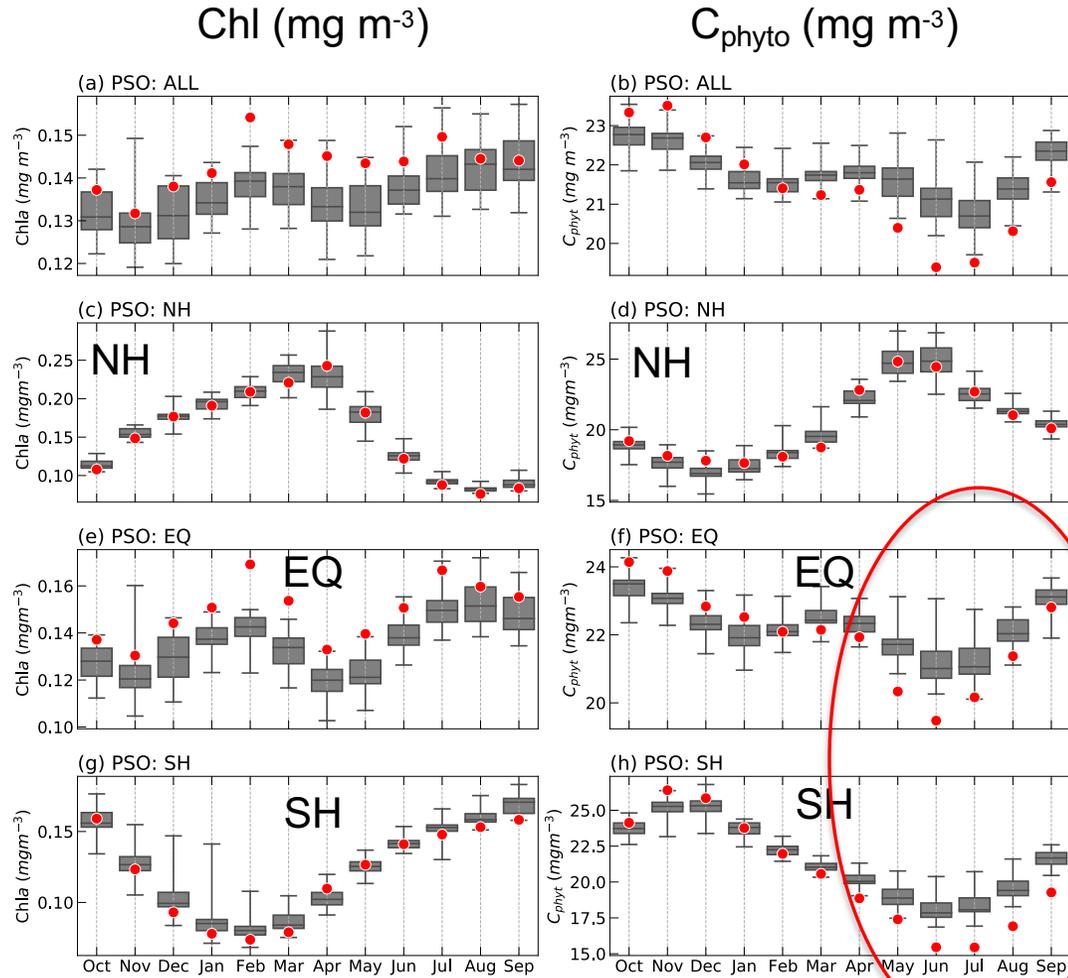Rrs (556) Bland Altman

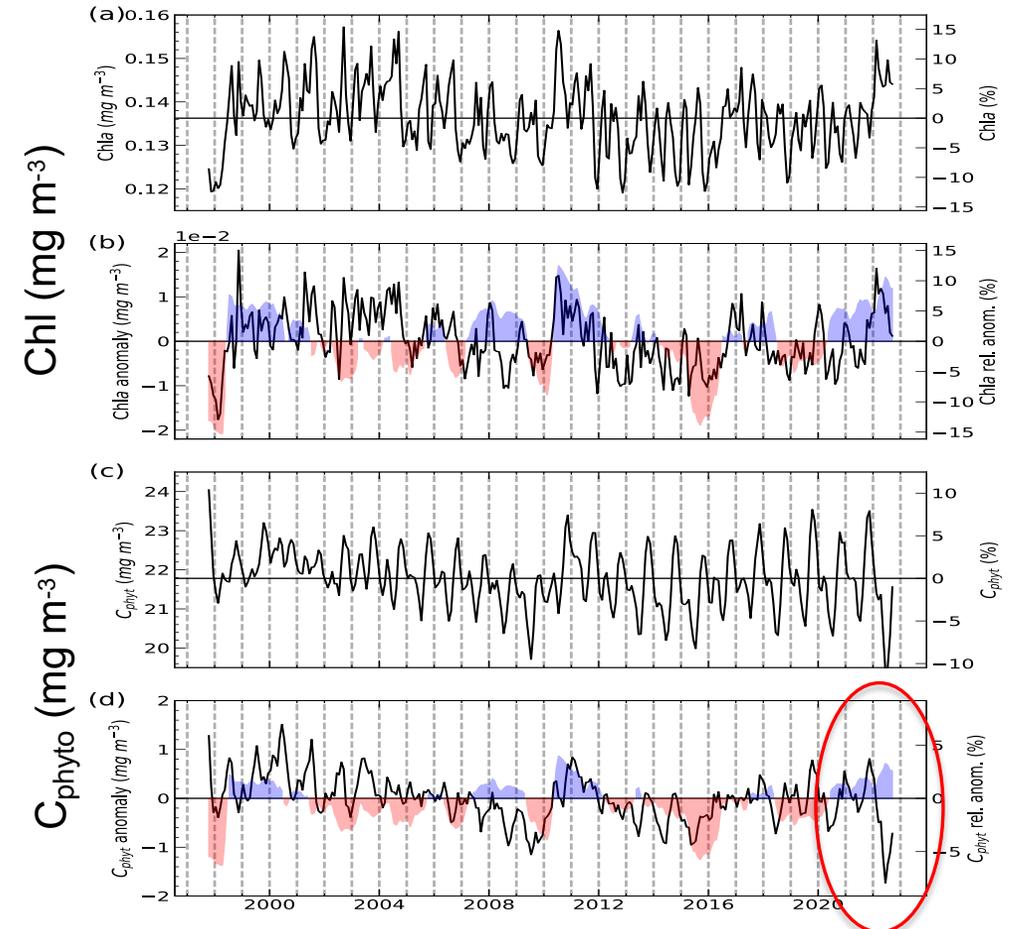https://seabass.gsfc.nasa.gov/search_results/val

Anomalous results observed in 2022

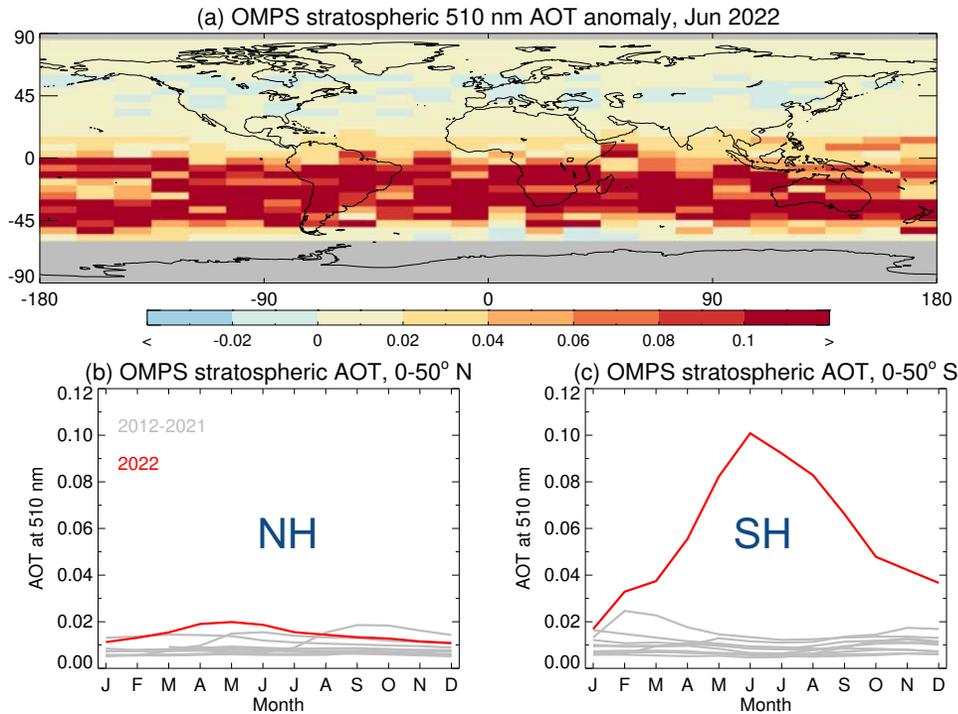2022 Seasonal Cycle and SeaWiFS-MODISA Climatology

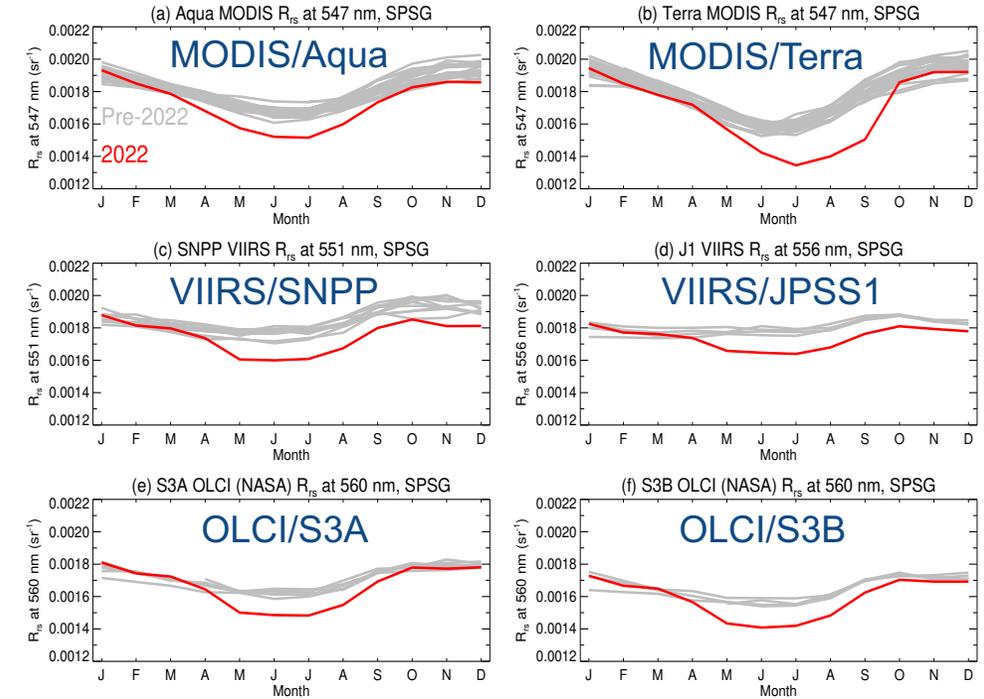SeaWiFS-MODISA Time-Series and De-seasonalized Anomalies

B.A. Franz, I. Cetinic, M. Gao, D.A. Siegel, and T.K. Westberry (2023). Global ocean phytoplankton [in State of the Climate in 2022]. BAMS, in review.

# Impact of 2022 Hunga Tonga Eruption

OMPS Stratospheric Aerosol

(a) OMPS stratospheric 510 nm AOT anomaly, Jun 2022

(b) OMPS stratospheric AOT, 0-50° N — NH

2012-2021 / 2022

(c) OMPS stratospheric AOT, 0-50° S — SH

Rrs (green) Seasonal Cycles in South Pacific Gyre

(a) Aqua MODIS R_{rs} at 547 nm, SPSG — MODIS/Aqua (Pre-2022 / 2022)

(b) Terra MODIS R_{rs} at 547 nm, SPSG — MODIS/Terra

(c) SNPP VIIRS R_{rs} at 551 nm, SPSG — VIIRS/SNPP

(d) J1 VIIRS R_{rs} at 556 nm, SPSG — VIIRS/JPSS1

(e) S3A OLCI (NASA) R_{rs} at 560 nm, SPSG — OLCI/S3A

(f) S3B OLCI (NASA) R_{rs} at 560 nm, SPSG — OLCI/S3B

- All ocean color missions showing large deviation in Rrs through 2022, largest % diff in green-red.
- Issue believed to be atmospheric correction error due to unmodeled stratospheric aerosols.
- Operating assumption is that ocean reflectance (Rrs) is underestimated because the correction for ozone absorption does not account for scattering by high-altitude aerosols.

B.A. Franz, A. Sayer, I. Cetinic, A. Ibrahim, manuscript in development
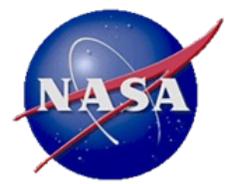
Summary
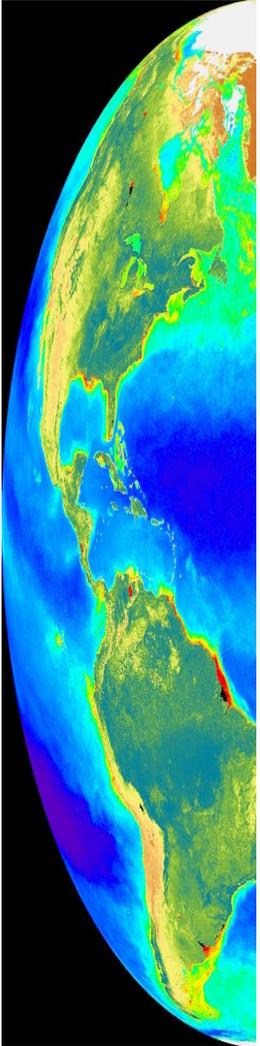
- JPSS-2 VIIRS ocean color products are now available through OB.DAAC.

- R2022 ocean color reprocessing completed for all missions. VIIRS Rrs time series from SNPP and JPSS-1 in good agreement with MODIS, indicating that VIIRS can be used to extend the SeaWIFS-MODIS time series for many key OC parameters.

- R2022 Rrs (and Chl) results are in good agreement with in situ measurements for all missions, with Rrs bias < 5% (typically negative) in all bands.

- All ocean color missions are showing anomalous trends in Rrs through 2022 that appear to be due to atmospheric correction error associated with unresolved stratospheric aerosols from the Hunga Tonga eruptions of Jan 2022. Detailed analyses underway; mitigation strategy in development.

MODIS-Aqua Daily Chlorophyll – R2018
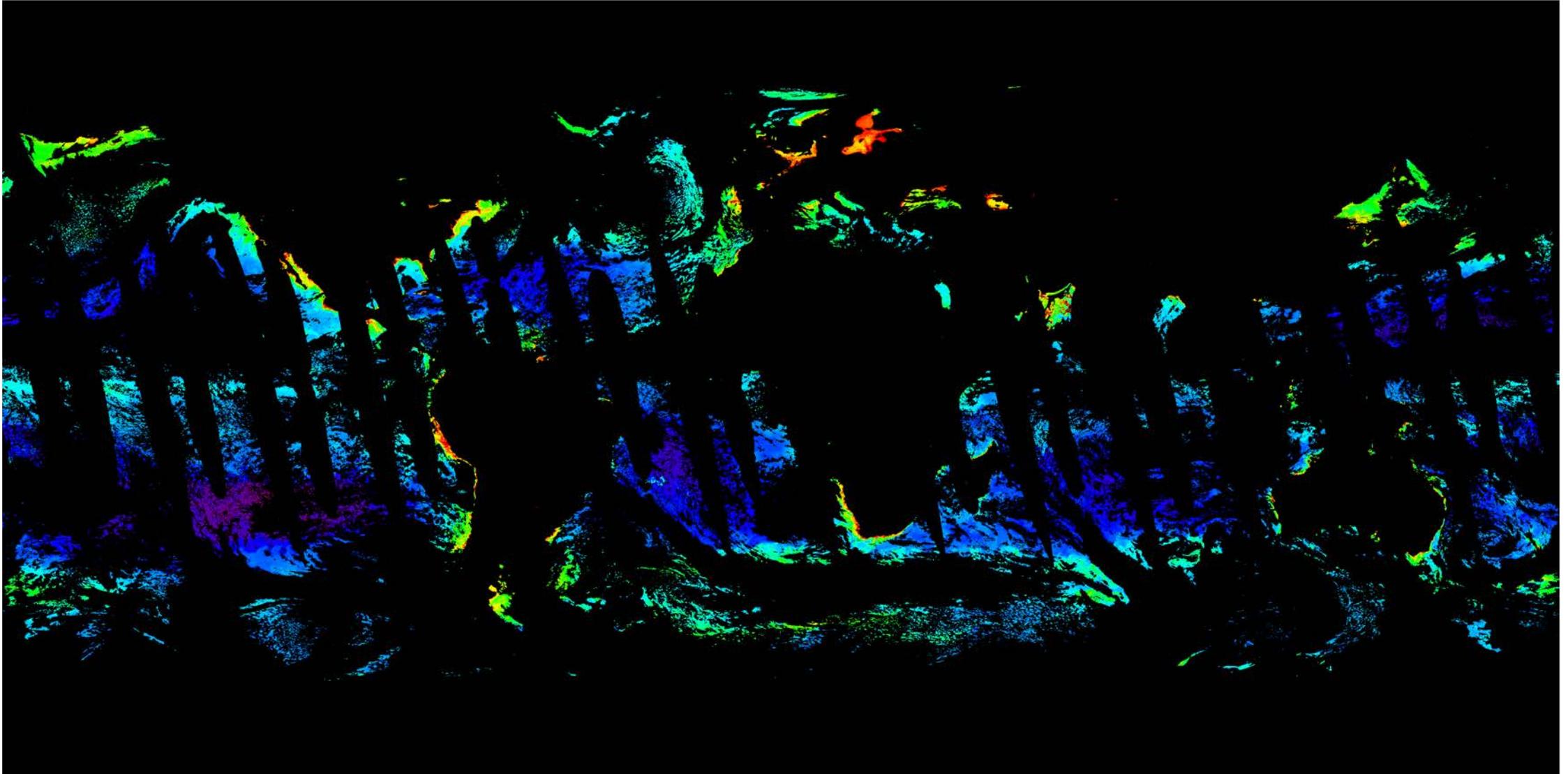
Includes 5 X 7 STRAYLIGHT masking of Level-2 pixels around bright targets

MODIS-Aqua Daily Chlorophyll – R2022
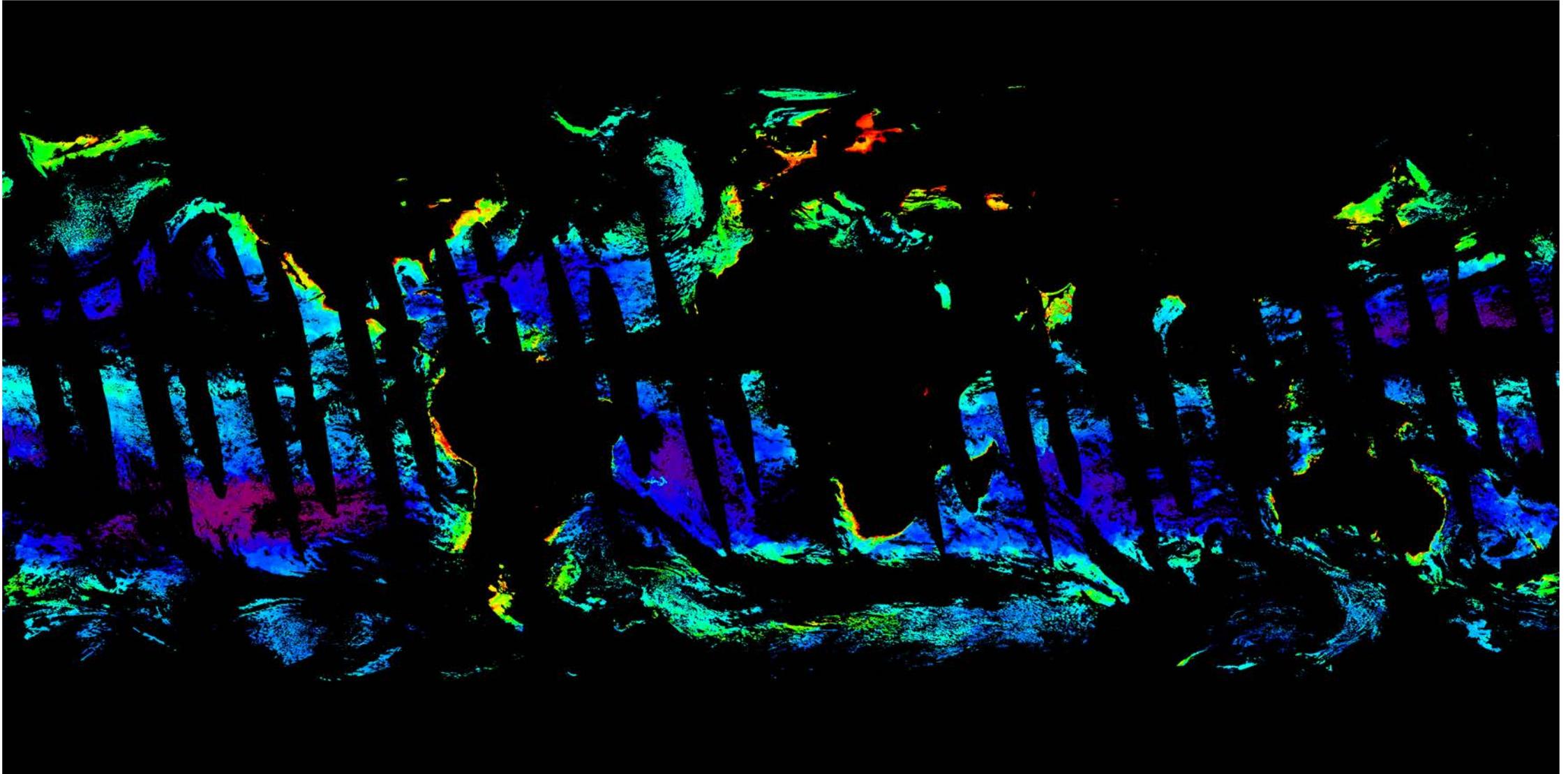
Includes 3 X 3 STRAYLIGHT masking of Level-2 pixels around bright targets

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).

R2022 MODIS-Aqua Chl Validation

Chl Scatter
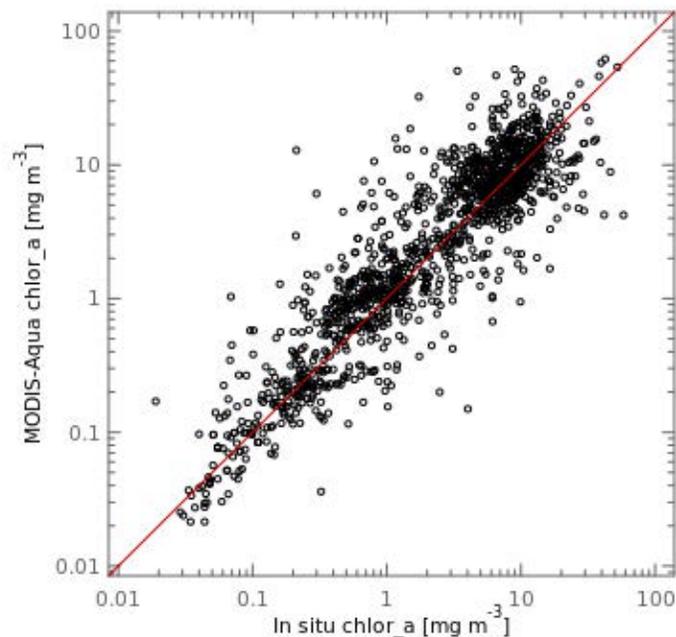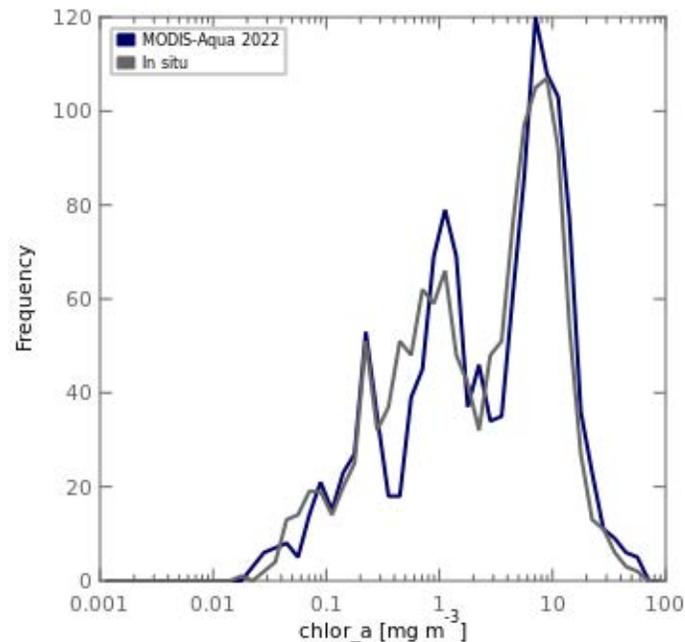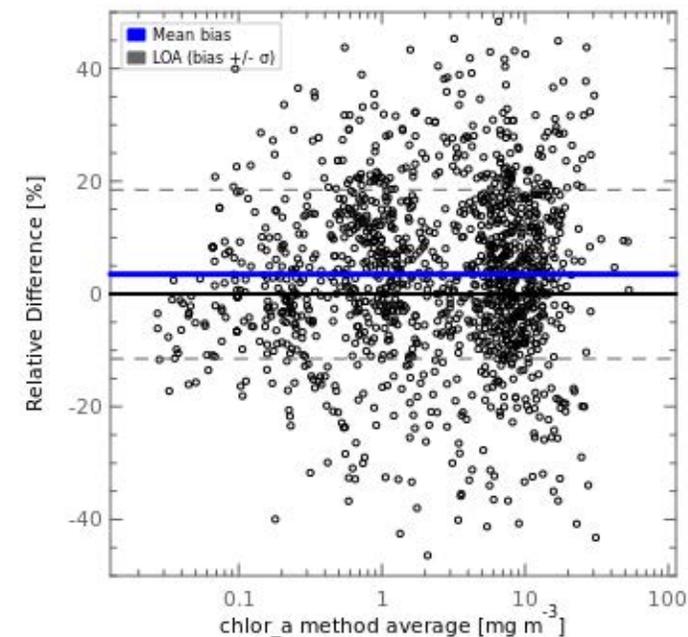
Chl Freq. Dist.

Chl Bland Altman

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

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

R2022 VIIRS-SNPP Chl Validation

Chl Scatter   Chl Freq. Dist.   Chl Bland Altman
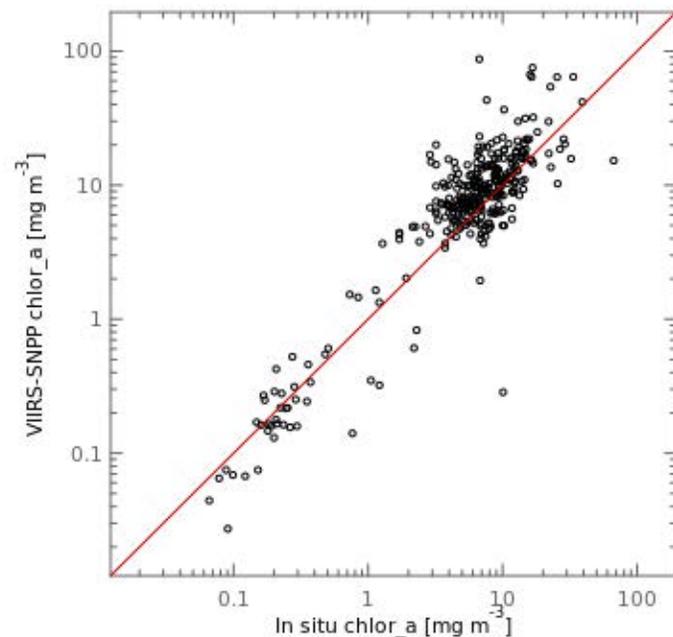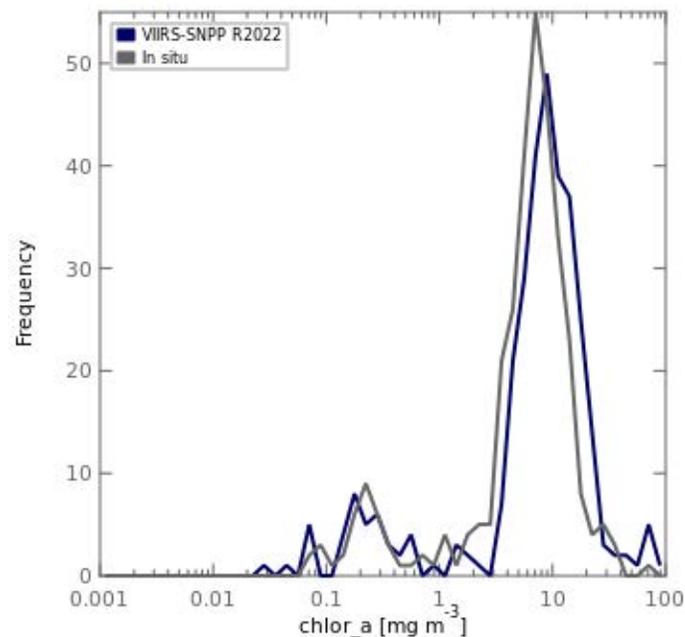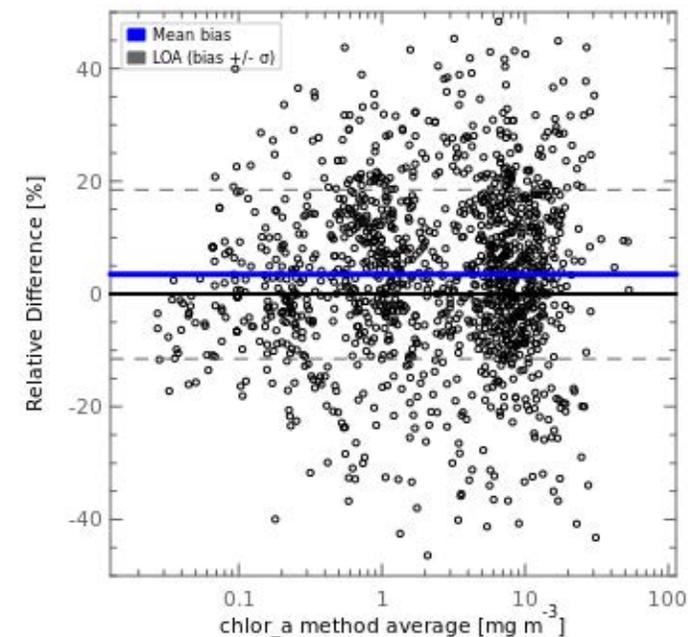
- MODIS-Aqua Chlorophyll in good agreement with in situ measurements
- Mean positive relative bias < 5%

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

Seasonal Mean Chlorophyll Concentration for 2022
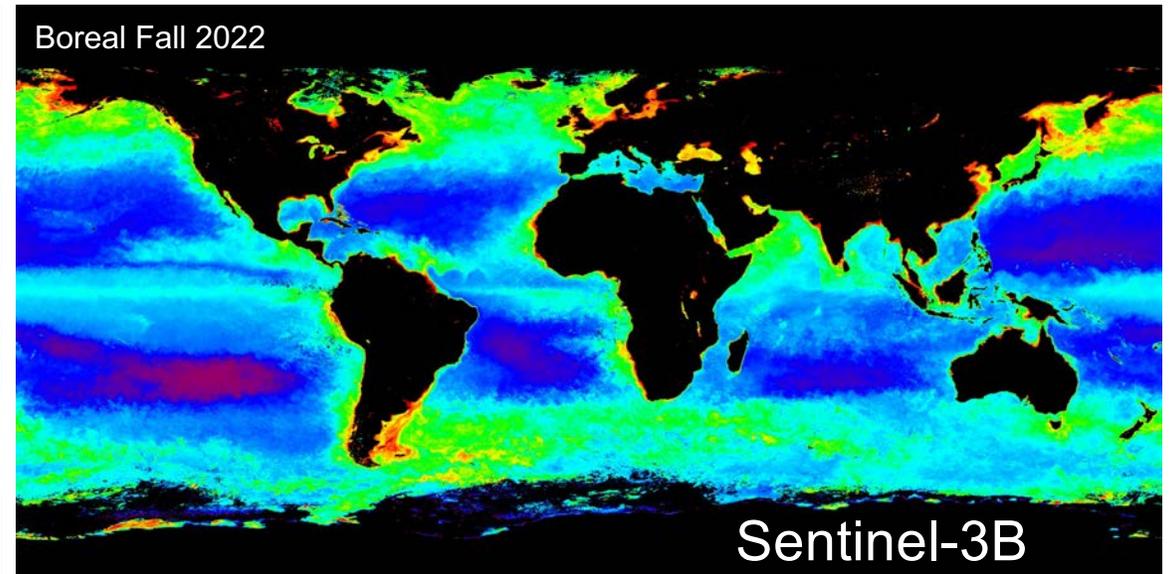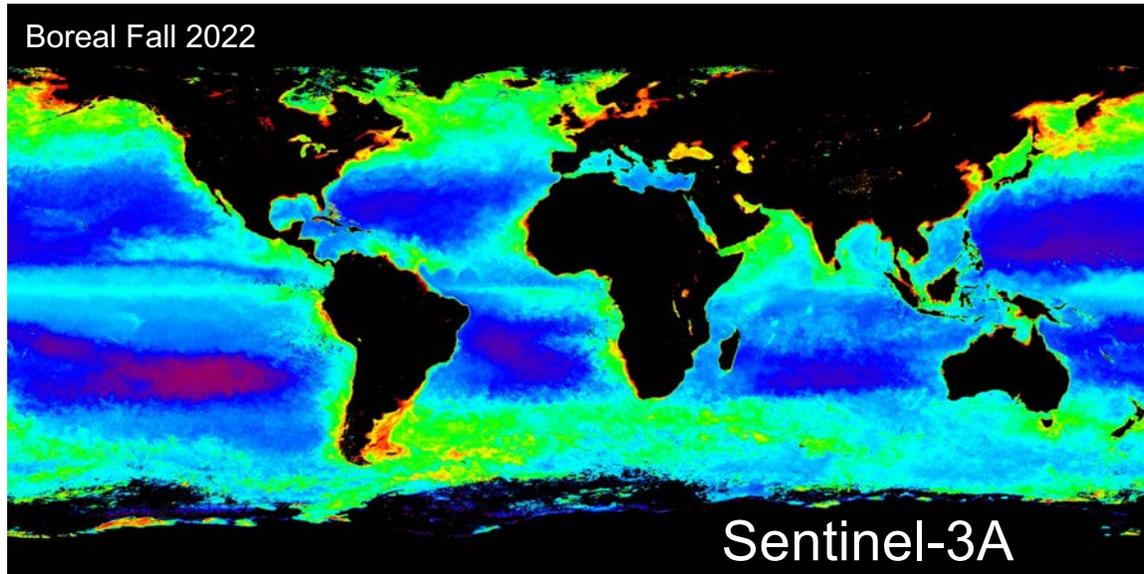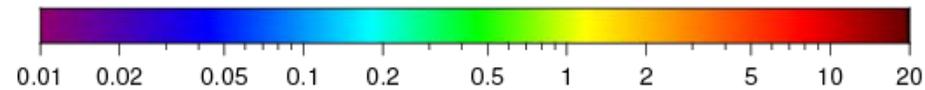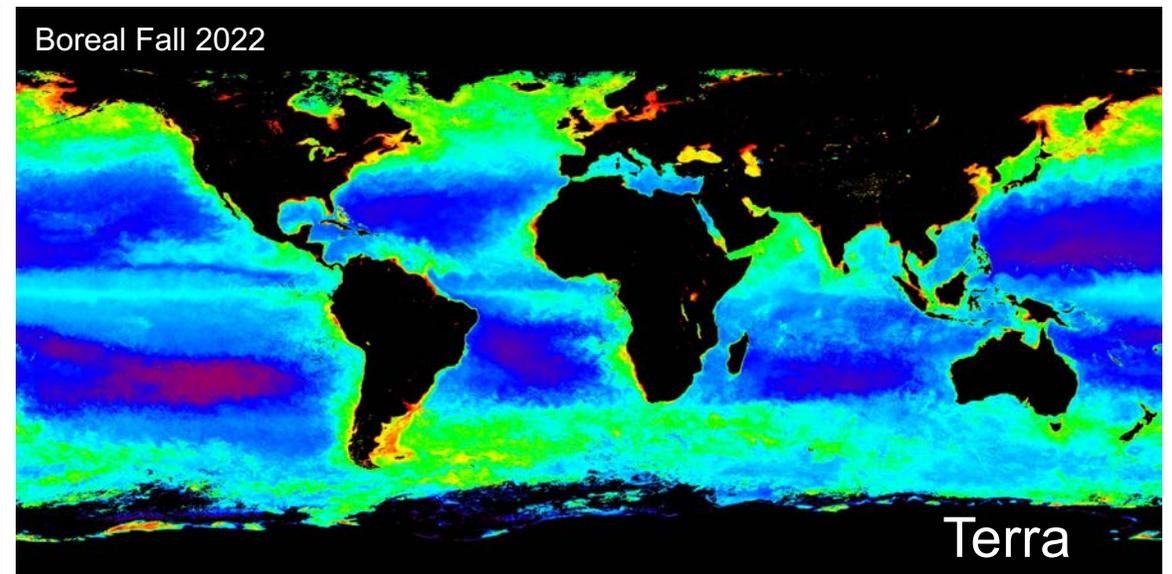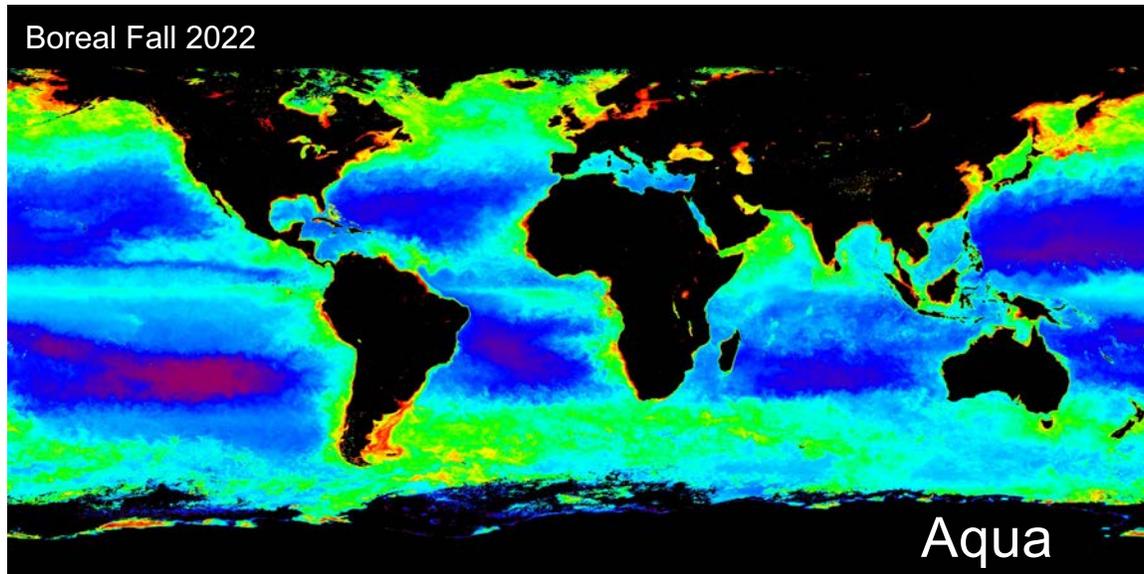
OLCI-S3A vs MODIS-A, R2022 Global Deep-Water Trends
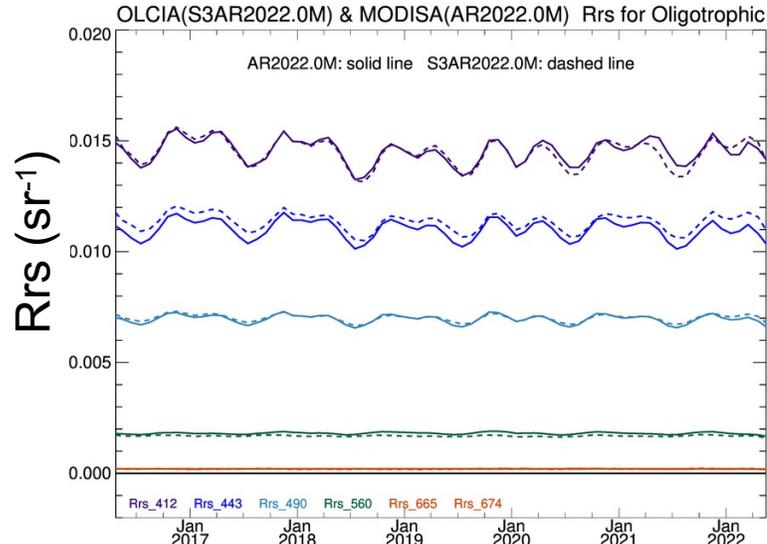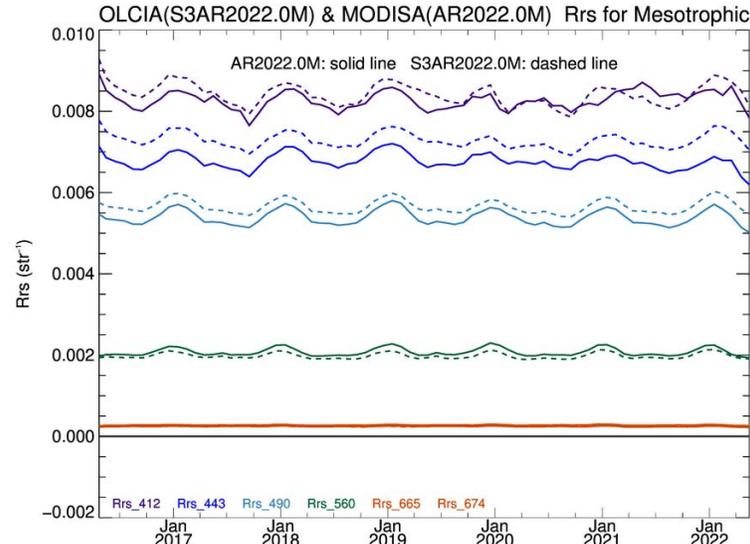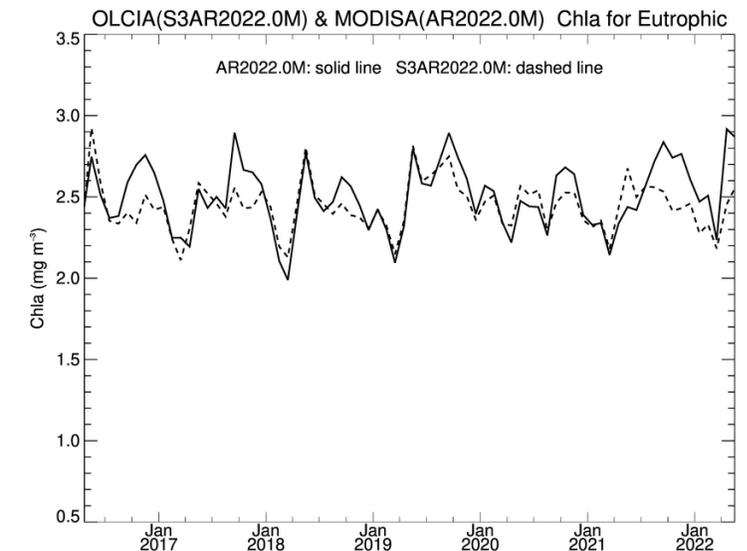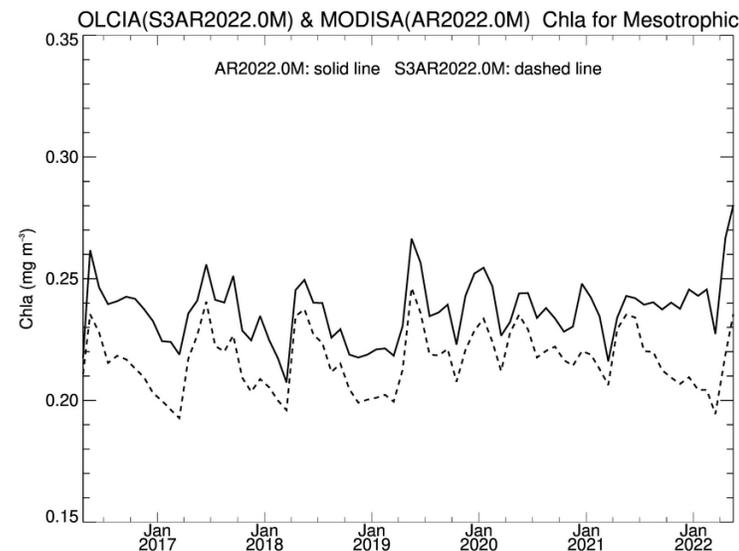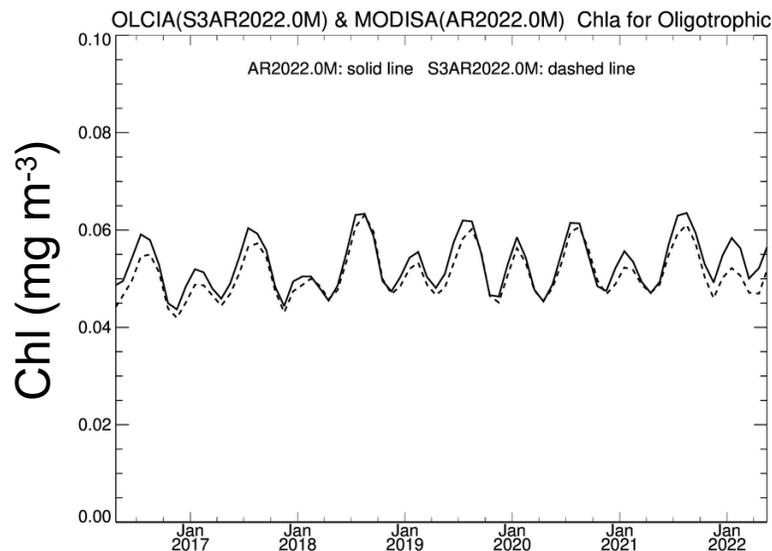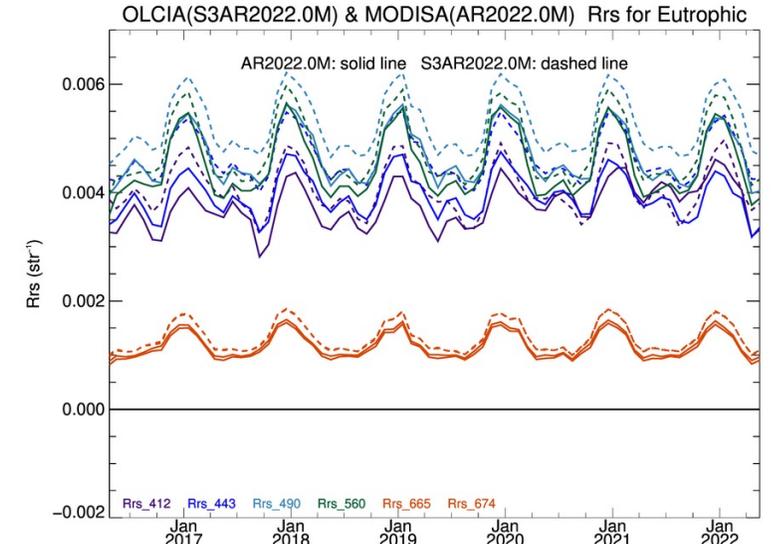
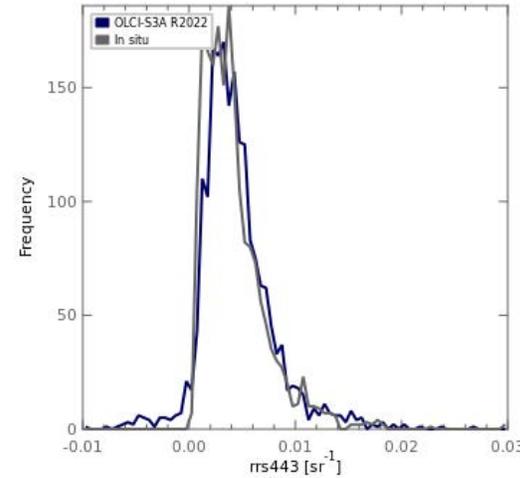# OLCI-S3B vs MODIS-A, R2022 Global Deep-Water Trends
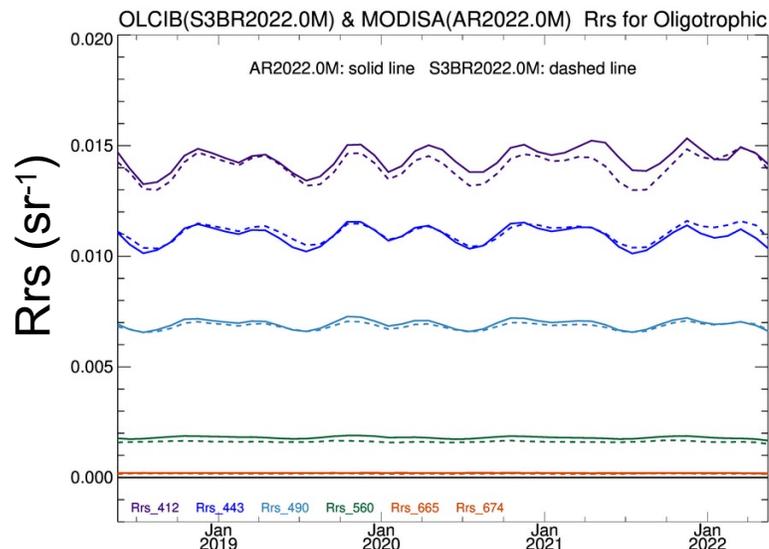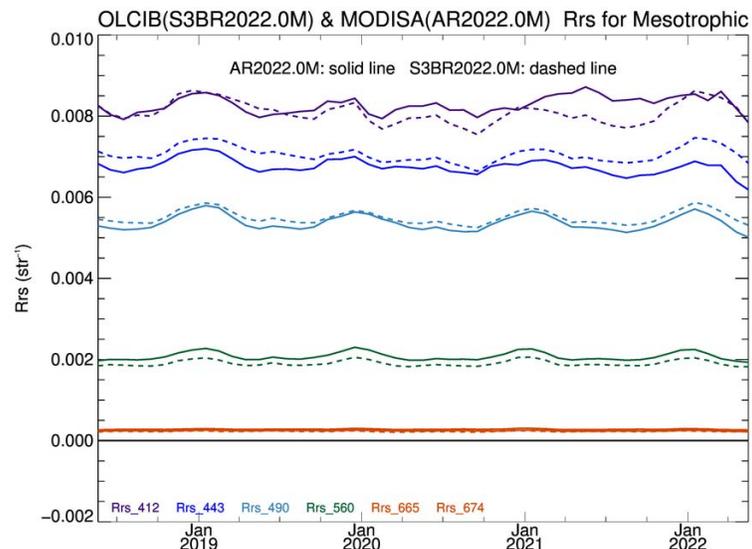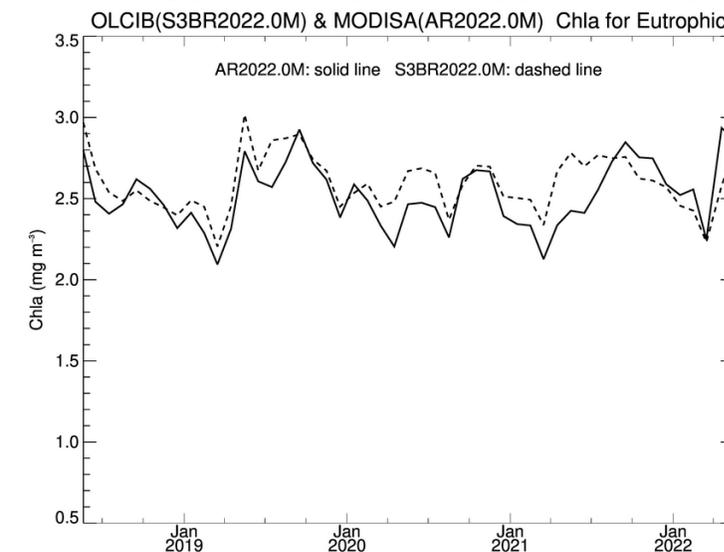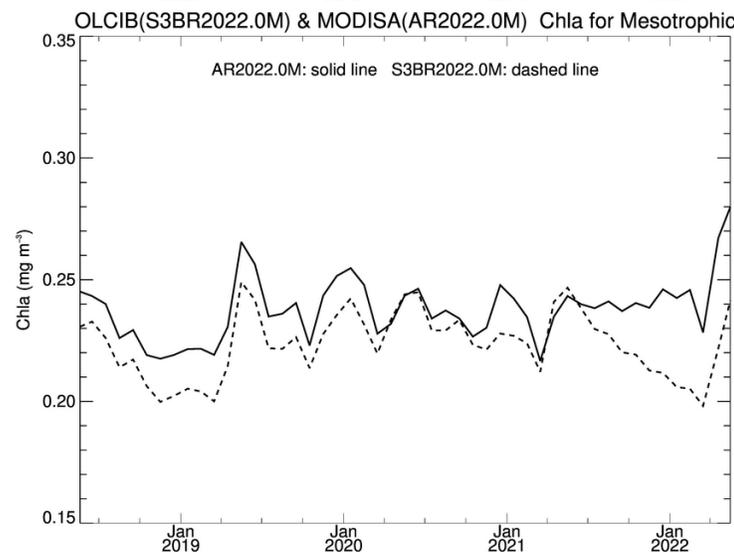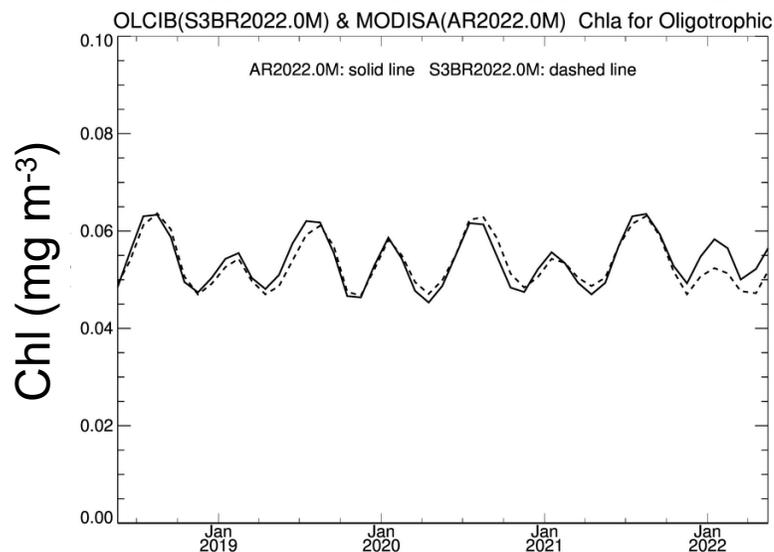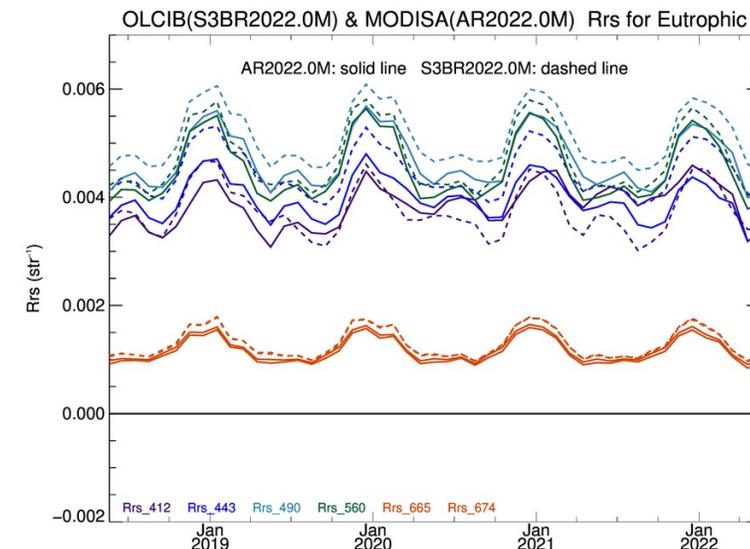
R2022 OLCI/S3A Rrs Validation

- Comparison against AERONET-OC and SeaBASS in situ measurements.

- Very good agreement in most bands.

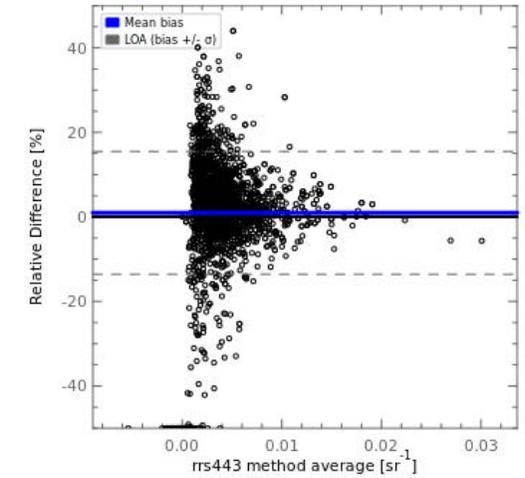- Negative mean relative bias of < 5% in most bands (Bland Altman).
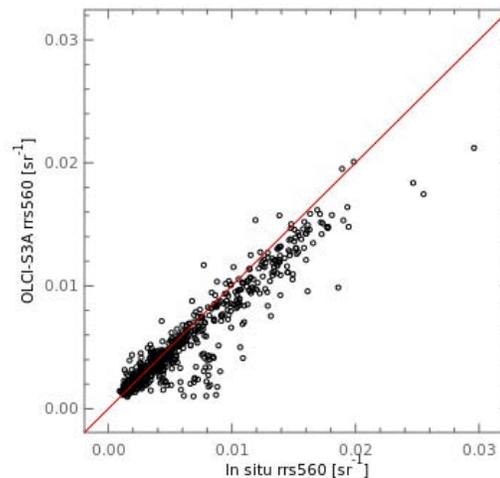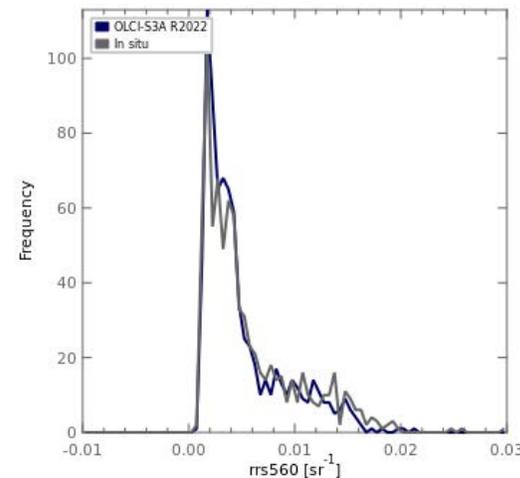

Rrs (443) Scatter
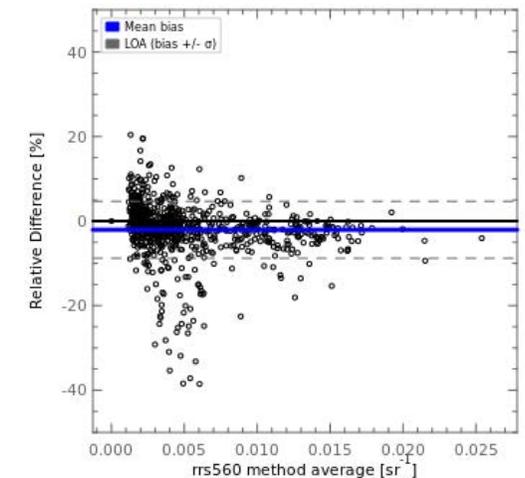
Rrs (443) Freq. Dist.

Rrs (443) Bland Altman

Rrs (560) Scatter

Rrs (560) Freq. Dist.

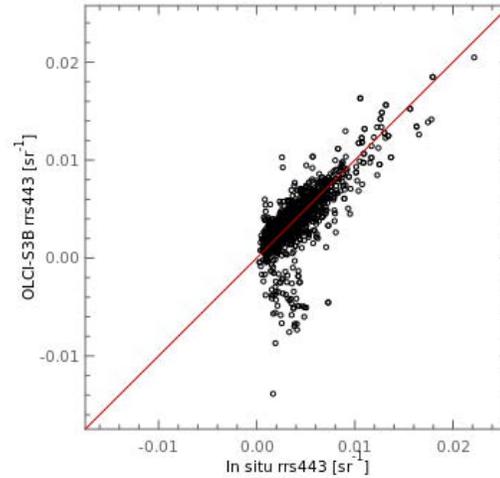Rrs (560) Bland Altman

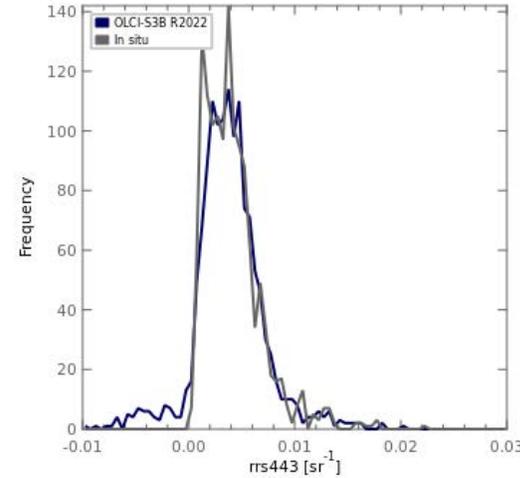https://seabass.gsfc.nasa.gov/search_results/val
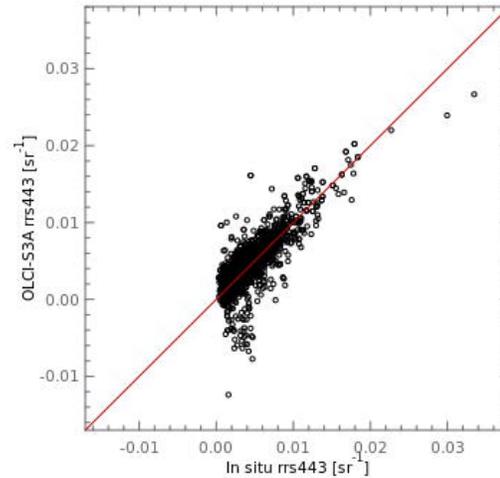
R2022 OLCI/S3B Rrs Validation

- Comparison against AERONET-OC and SeaBASS in situ measurements.

- Very good agreement in most bands.

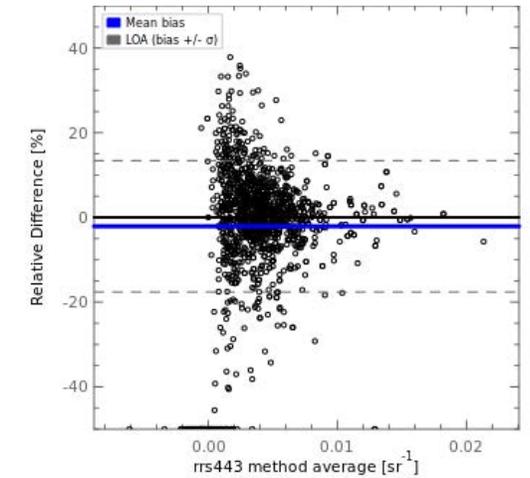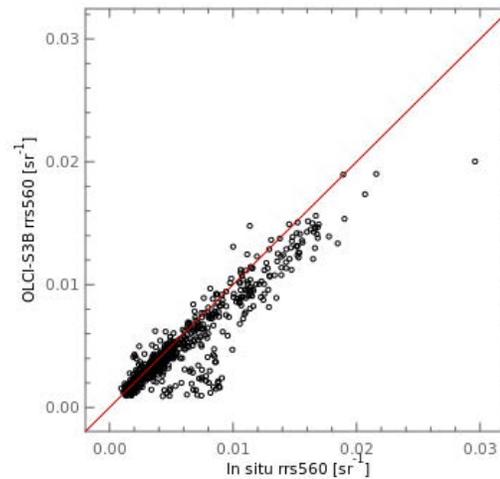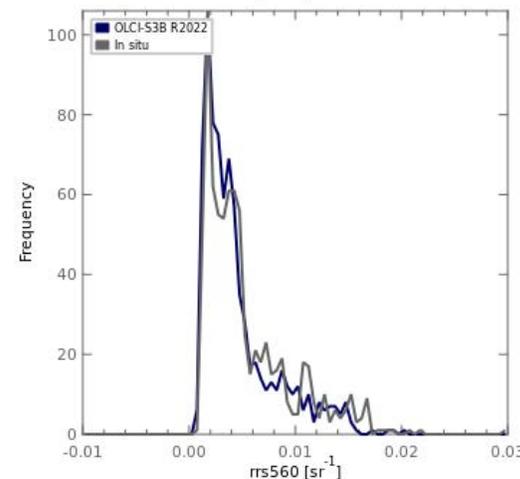- Negative mean relative bias of < 5% in most bands (Bland Altman).

Rrs (443) Scatter
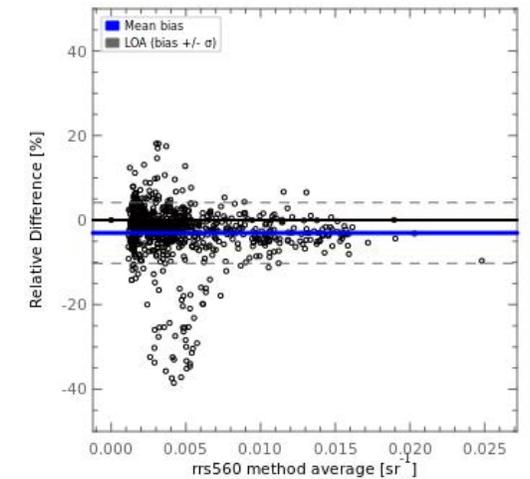
Rrs (443) Freq. Dist.

Rrs (443) Bland Altman

Rrs (560) Scatter

Rrs (560) Freq. Dist.

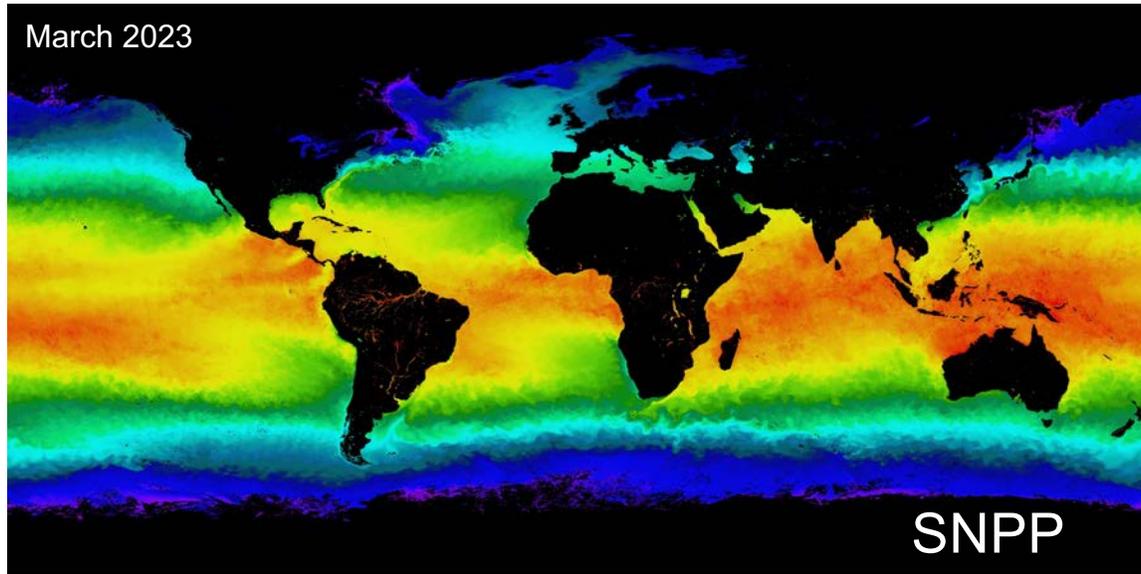Rrs (560) Bland Altman

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

Monthly Mean SST for March 2023

VIIRS

March 2023

SNPP

JPSS-1 VIIRS coming soon.

MODIS

March 2023

Aqua

March 2023

Terra

0   10   20   30   40