Ocean Color Data Processing System: Multi-Sensor Level-1 to Level-2 (MSL12)

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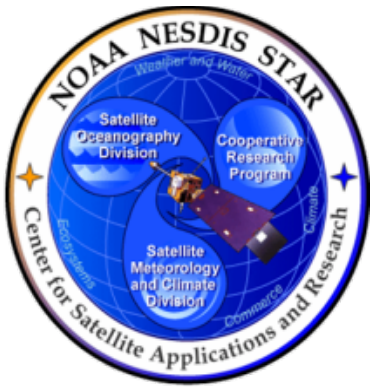
The Enterprise Algorithm Workshop, NCWCP, Maryland, March 30-31, 2016

Website for VIIRS ocean color images, data and Cal/Val:
http://www.star.nesdis.noaa.gov/sod/mecb/color/



VIIRS Spectral Bands for Ocean Color

VIIRS (Visible Infrared Imaging Radiometer Suite) on
Suomi National Polar-orbiting Partnership **(SNPP)**
VIIRS-**SNPP**, Oct. 28, **2011**, VIIRS-Joint Polar Satellite System (**JPSS**) **J1**, **2017**, VIIR-**J2**,
2021, and J3 & J4 (up to ~2038)

VIIRS (SNPP)†		MODIS		SeaWiFS
Ocean Bands (nm)	Other Bands (nm)	Ocean Bands (nm)	Other Bands (nm)	Ocean Band (nm)
410 (M1)	640 (I1)	412	645	412
443 (M2)	865 (I2)	443	859	443
486 (M3)	1610 (I3)	488	469	490
—		531	555	510
551 (M4)	*SWIR Bands*	551	*SWIR Bands*	555
671 (M5)	1238 (M8)	667	1240	670
745 (M6)	1610 (M10)	748	1640	765
862 (M7)	2250 (M11)	869	2130	865

†VIIRS nominal center wavelength

Spatial resolution for VIIRS M-band: 750 m, I-band: 375 m

Nominal Center Wavelength for VIIRS

SNPP & JPSS-1

VIIRS Nominal Center Wavelength (nm)		
Band	**SNPP**	**JPSS-1**
M1	410	411
M2	443	445
M3	486	489
M4	551	556
M5	671	667
M6	745	746
M7	862	868
I1	640	642
I2	865	867

Multi-Sensor Level-1 to Level-2 (MSL12) Ocean Color Data Processing System (1)

➢ Multi-Sensor Level-1 to Level-2 (MSL12)

- ✓ MSL12 was developed during NASA SMIBIOS project (1997-2003) for a consistent multi-sensor ocean color data processing for international satellite ocean color sensors (*Wang*, 1999; *Wang and Franz*, 2000; *Wang et al.*, 2002).
- ✓ It has been used for producing global and regional ocean color products from various satellite ocean color sensors, e.g., the Sea-viewing Wide Field-of-view Sensor (**SeaWiFS**), the Modular Optoelectronic Scanner (**MOS**), the Ocean Color and Temperature Scanner (**OCTS**), the Polarization and Directionality of the Earth's Reflectance (**POLDER**), the Moderate Resolution Imaging Spectroradiometer (**MODIS**), the Geostationary Ocean Color Imager (**GOCI**), and the Visible Infrared Imaging Radiometer Suite (**VIIRS**), etc.
- ✓ MSL12 will be used for all other satellite ocean color sensors, including future VIIRS on the JPSS series, e.g., JPSS-1, JPSS-2, …, as well as sensors from international agencies, e.g., the Ocean Land Colour Instrument (**OLCI**) on Sentinel-3, the Second-generation Global Imager (**SGLI**) on GCOM-C, etc.

Multi-Sensor Level-1 to Level-2 (MSL12) Ocean Color Data Processing System (2)

➢ NOAA-MSL12 Ocean Color Data Processing

- ✓ NOAA-MSL12 is based on SeaDAS version 4.6.
- ✓ Some significant improvements: (1) the SWIR-based ocean color data processing for coastal and inland waters, (2) improved Rayleigh and aerosol LUTs, (3) algorithms for detecting absorbing aerosols and turbid waters, (4) ice detection algorithm, (5) improved straylight and cloud shadow algorithm, (5) improved NIR water reflectance correction algorithm, (6) new destriping algorithm, and others.

➢ MSL12 for VIIRS Ocean Color Data Processing

- ✓ Routine ocean color data processing (daily, 8-day, monthly) since VIIRS launch.
- ✓ Routine global VIIRS ocean color data productions for the two data streams: Near-Real-Time (NRT) and Science Quality ocean color data processing.
- ✓ Coastal turbid and inland waters from other approaches, e.g., the **SWIR approach**, results in the US east coastal, China's east coastal, Lake Taihu, Lake Okeechobee, Aral Sea, etc.

MSL12 Ocean Color Algorithms, Improvements, and Updates

- **Algorithms used in the ocean color EDR data processing:**
  - Atmospheric corrections:
    - Gordon & Wang (1994) (and Wang et al. (2005)) for open ocean using the NIR bands
    - Wang (2007) and Wang and Shi (2007) using the SWIR bands
    - The NIR reflectance correction algorithm using **BMW** (Jiang and Wang, 2014) for costal/inland waters (New)
  - Operational chlorophyll-a: OC3V algorithm
  - K_d(490) algorithm: Wang et al. (2009) algorithm (New)
  - K_d(PAR) algorithm: Son and Wang (2015) (New)
  - Destriping algorithm: Mikelsons et al. (2014) (New)
  - Stray light/Cloud shadowing effects: Jiang and Wang (2013) (New)
- **Updates**
  - Polarization correction algorithm (errors are corrected)
- **Experimental Products**
  - IOPs: Quasi-Analytical Algorithm (QAA) (Lee et al., 2002)
  - PAR: Frouin et al. (2003)
  - Chlorophyll-a data from the OCI method: Hu et al. (2012) and implemented in VIIRS using Wang and Son (2016)

Satellite-Measured Ocean Color Products

➢ Ocean Color Products:

- **Normalized Water-leaving Radiance $nL_w(\lambda)$** in mW cm^{-2} μm^{-1} sr^{-1}.
- **Chlorophyll-a** Concentration (Chl-a) in mg m^{-3}.
- Water **Diffuse Attenuation Coefficient** at 490 nm ***K_d*(490)** in m^{-1}, which is related to light penetration and availability in aquatic systems.
- Water Diffuse Attenuation Coefficient for Photosynthetically Available Radiation (PAR) ***K_d*(PAR)** in m^{-1}. Both are two new VIIRS products.
- Inherent Optical Properties (**IOPs**) (using QAA).
- Photosynthetically Available Radiation (PAR).
- Others, e.g., **Total Suspended Sediment** (TSS) in mg l^{-1}, water **Turbidity** in NTU, etc.

➢ Ocean biological and biogeochemical properties, e.g., Chl-a, K_d(490), K_d(PAR), TSS, Turbidity, etc., are derived from satellite-measured $nL_w(\lambda)$ spectra.

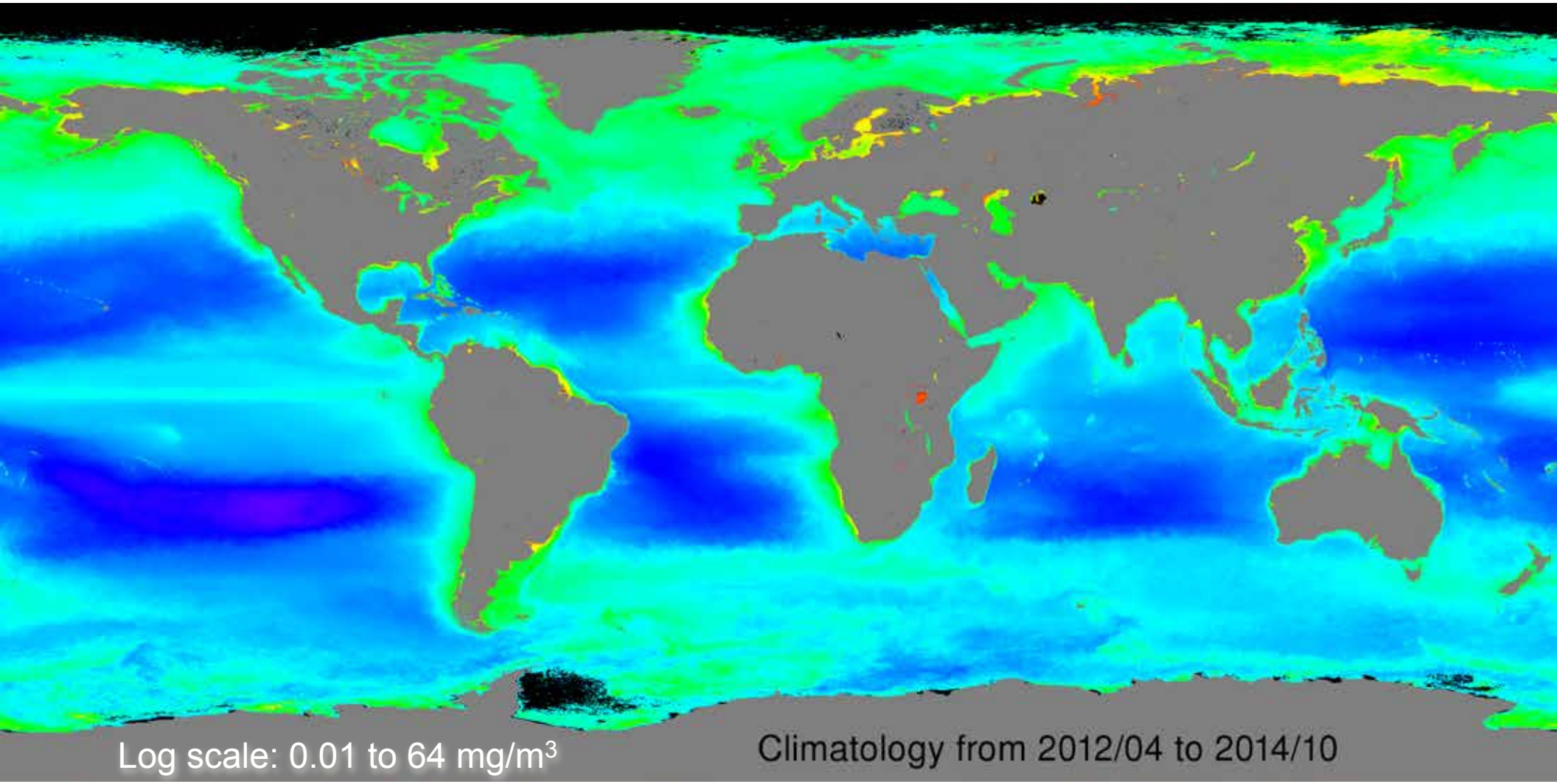
➢ Ocean color data processing:

- NOAA Multi-Sensor Level-1 to Level-2 (**MSL12**), which is the NOAA VIIRS **official ocean color data processing system**.

End-to-End Ocean Color Data Processing

- NOAA Ocean Color Team has been developing/building the capability for the **End-to-End** satellite ocean color data processing including:
  - Level-0 (or Raw Data Records (RDR)) to Level-1B (or Sensor Data Records (SDR)).
  - Level-1B (SDR) to ocean color Level-2 (Environmental Data Records (EDR).
  - Level-2 to global Level-3 (routine daily, 8-day, monthly, and climatology data/images).
  - Validation of satellite ocean color products (in situ data and data analysis capability).
- Support of in situ data collections for VIIRS Cal/Val activities, e.g., **MOBY**, **AERONET-OC** sites, **NOAA dedicated cruises (2014, 2015, 2016, ….,)**
- On-orbit instrument calibration (solar and lunar) for ocean color data processing:
  - J. Sun and M. Wang, "Visible Infrared Imaging Radiometer Suite solar diffuser calibration and its challenges using solar diffuser stability monitor," *Appl. Opt.,* **53**, 8571-8584, 2014.
  - J. Sun and M. Wang, "On-orbit characterization of the VIIRS solar diffuser and solar diffuser screen," *Appl. Opt.*, **54**, 236-252, 2015.
  - J. Sun and M. Wang, "On-orbit calibration of Visible Infrared Imaging Radiometer Suite reflective solar bands and its challengers using a solar diffuser," *Appl. Opt.*, **54**, 7210-7223, 2015.
  - J. Sun and M. Wang, "Radiometric calibration of the VIIRS reflective solar bands with robust characterizations and hybrid calibration coefficients," *Appl. Opt.*, **54**, 9331–9342, 2015.
- RDR (Level-0) to SDR (Level-1B) data processing:
  - Sun, J., M. Wang, L. Tan, and L. Jiang, "An efficient approach for VIIRS RDR to SDR data processing," *IEEE Geosci. Remote Sens. Lett.*, **11**, 2037–2041, 2014.
  - L. Tan, M. Wang, J. Sun, and L. Jiang, "VIIRS RDR to SDR Data Processing for Ocean Color EDR," *Proc. SPIE* 9261*, Ocean Remote Sensing and Monitoring from Space,* October 13-16, 2014.
- **O**cean **C**olor **D**ata **A**nalysis and **P**rocessing **S**ystem (**OCDAPS**)—IDL-based VIIRS ocean color data visualization and processing package
  - Wang, X., X. Liu, L. Jiang, M. Wang, and J. Sun, "VIIRS ocean color data visualization and processing with IDL-based NOAA-SeaDAS", *Proc. SPIE 9261*, 8 Nov. 2014.

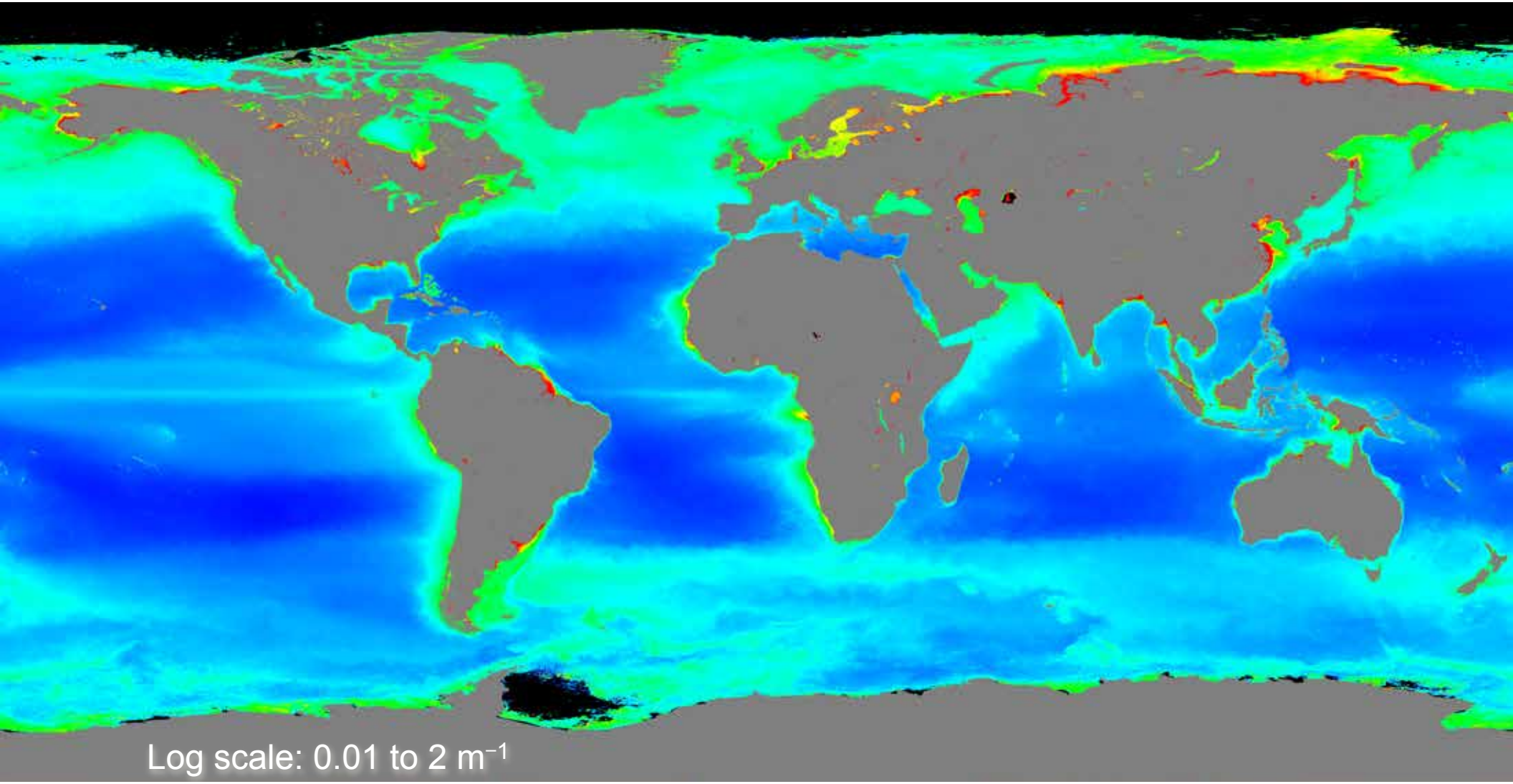
VIIRS Climatology Chlorophyll-a Image
(April 2012 to October 2014)



Generated using MSL12 for VIIRS ocean color data processing

Wang, M., X. Liu, L. Tan, L. Jiang, S. Son, W. Shi, K. Rausch, and K. Voss, "Impacts of VIIRS SDR performance on ocean color products," *J. Geophys. Res. Atmos.*, **118**, 10,347–10,360, 2013. http://dx.doi.org/10.1002/jgrd.50793

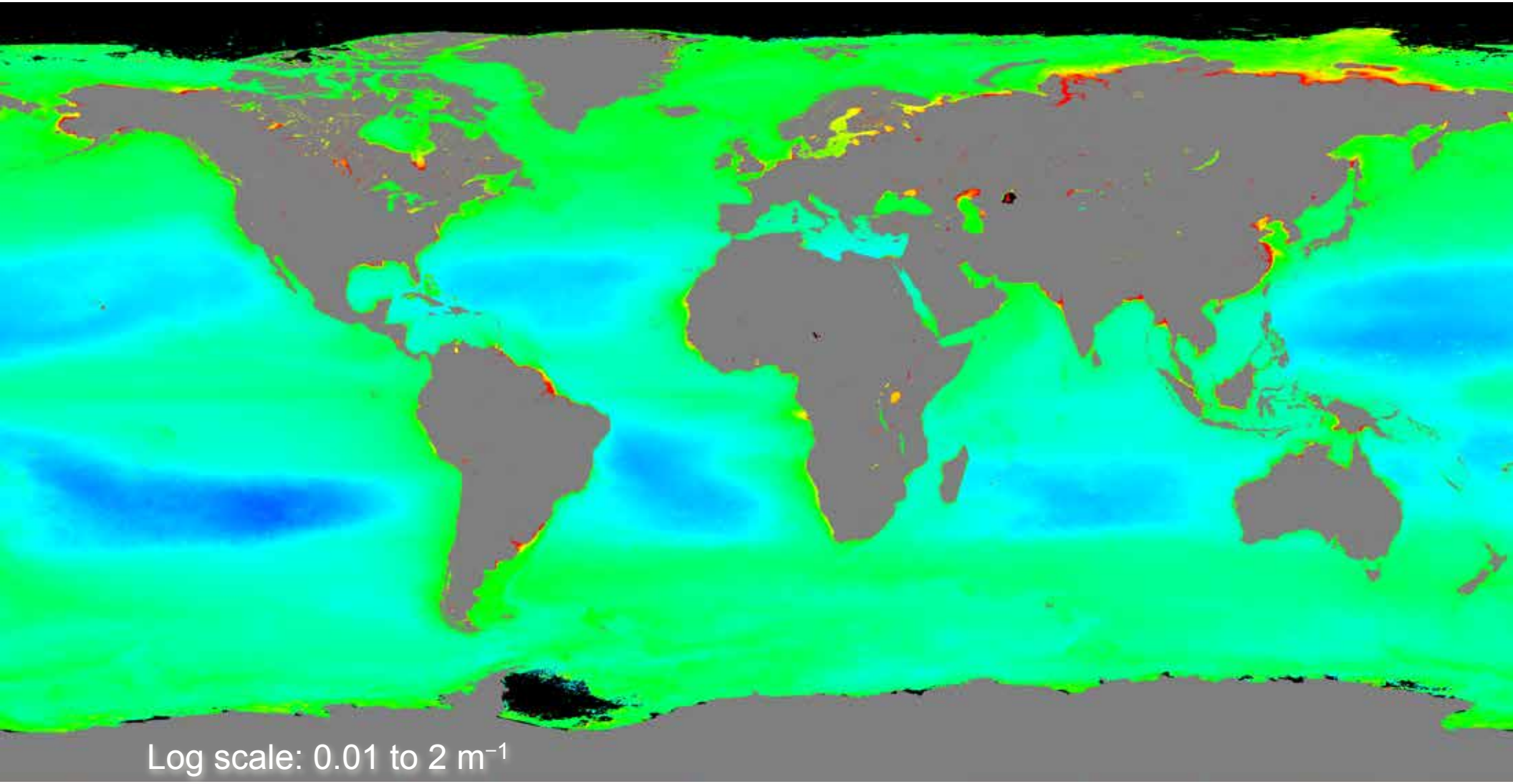
VIIRS Climatology $K_d(490)$ Image
(March 2012 to February 2015)



Generated using MSL12 for VIIRS ocean color data processing

Wang, M., S. Son, and L. W. Harding Jr., "Retrieval of diffuse attenuation coefficient in the Chesapeake Bay and turbid ocean regions for satellite ocean color applications," *J. Geophys. Res.*, **114**, C10011, 2009. http://dx.doi.org/10.1002/2009JC005286

VIIRS Climatology K_d(PAR) Image
(March 2012 to February 2015)



Generated using MSL12 for VIIRS ocean color data processing

Son, S. and M. Wang, "Diffuse attenuation coefficient of the photosynthetically available radiation Kd(PAR) for global open ocean and coastal waters," *Remote Sens. Environ.*, **159**, 250–258, 2015. http://dx.doi.org/10.1016/j.rse.2014.12.011

Website: http://www.star.nesdis.noaa.gov/sod/mecb/color/

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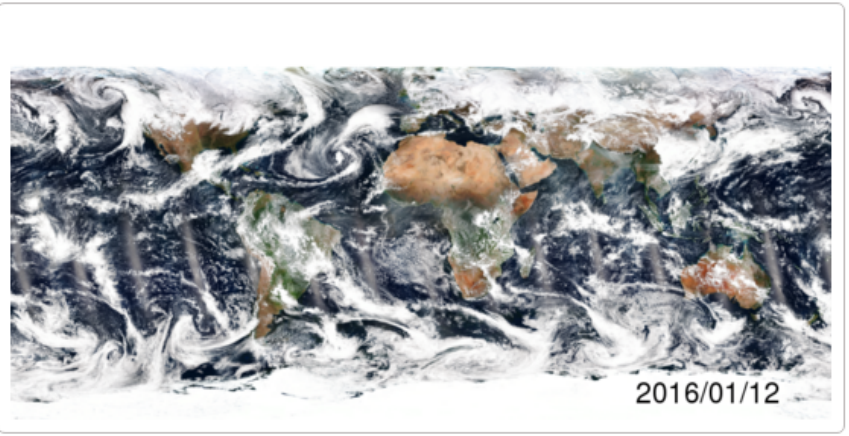
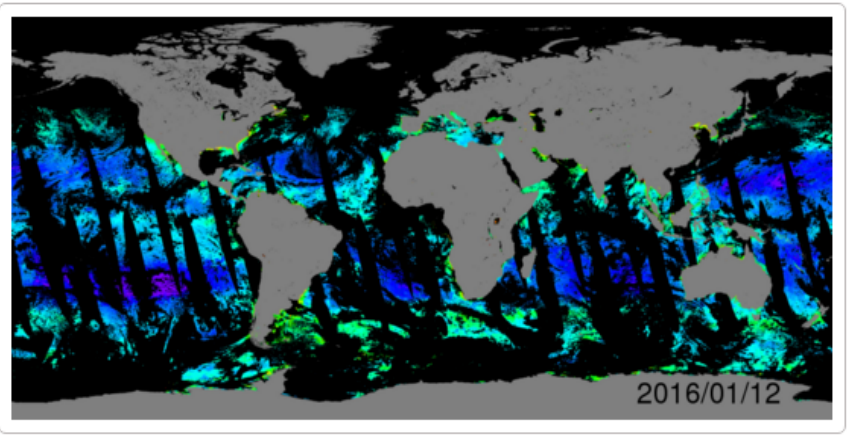
NOAA STAR Ocean Color Research Team

The ocean color research team in the Center for Satellite Applications and Research (STAR) of NOAA/NESDIS seeks to develop improved ocean color products from the current and future ocean color satellite sensors including the Sea-viewing Wide Field-of-view Sensor (SeaWiFS), the Moderate Resolution Imaging Spectroradiometer (MODIS), and the Visible Infrared Imaging Radiometer Suite (VIIRS) on the Suomi National Polar-orbiting Partnership (SNPP) and the Joint Polar Satellite System (JPSS), as well as various satellite sensors from other countries, e.g., the Medium Resolution Imaging Spectrometer (MERIS), Korean Geostationary Ocean Color Imager (GOCI), Sentinel-3 Ocean Land Colour Instrument (OLCI), GCOM-C Second-Generation Global Imager (SGLI), etc. The ocean color research team is currently focusing on:

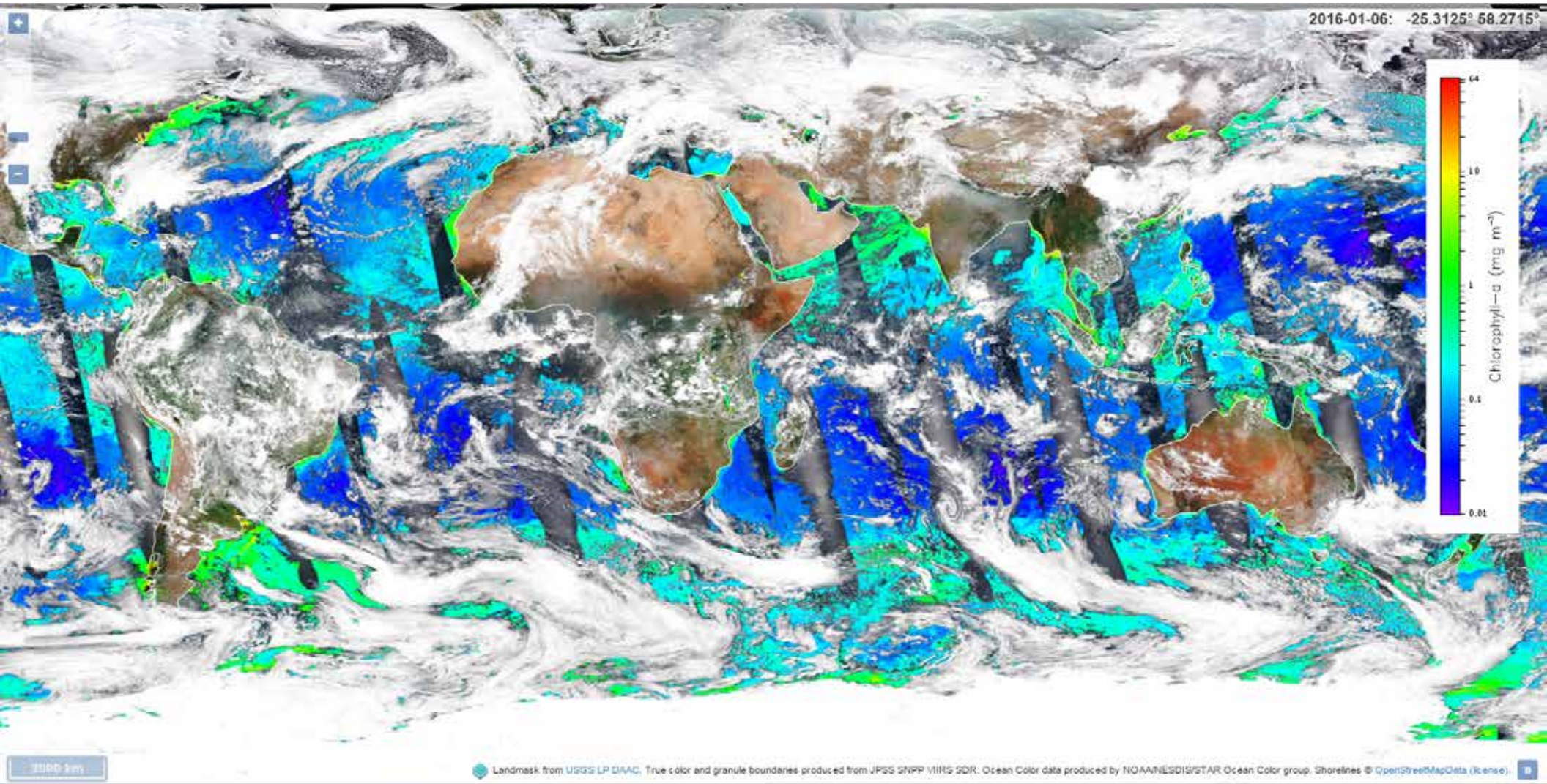
- Characterization and calibration of satellite ocean color instrument (e.g., VIIRS, MODIS);
- Satellite on-orbit vicarious calibration using in situ measurements;
- Understanding, evaluating, and refining satellite ocean color data processing system (i.e., MSL12);
- Routine global ocean color data processing from Level-0 to Level-1B, Level-1B to Level-2, and Level-2 to Level-3;
- The end-to-end satellite ocean color data processing capability and system;
- Development and improvement of satellite retrieval algorithms in global open ocean and coastal and inland water regions;
- In situ data processing, evaluation, and improvement;
- Implementing and transitioning research algorithms to the NOAA operational data system;
- Various ocean color data research and applications in global open ocean and coastal and inland waters.



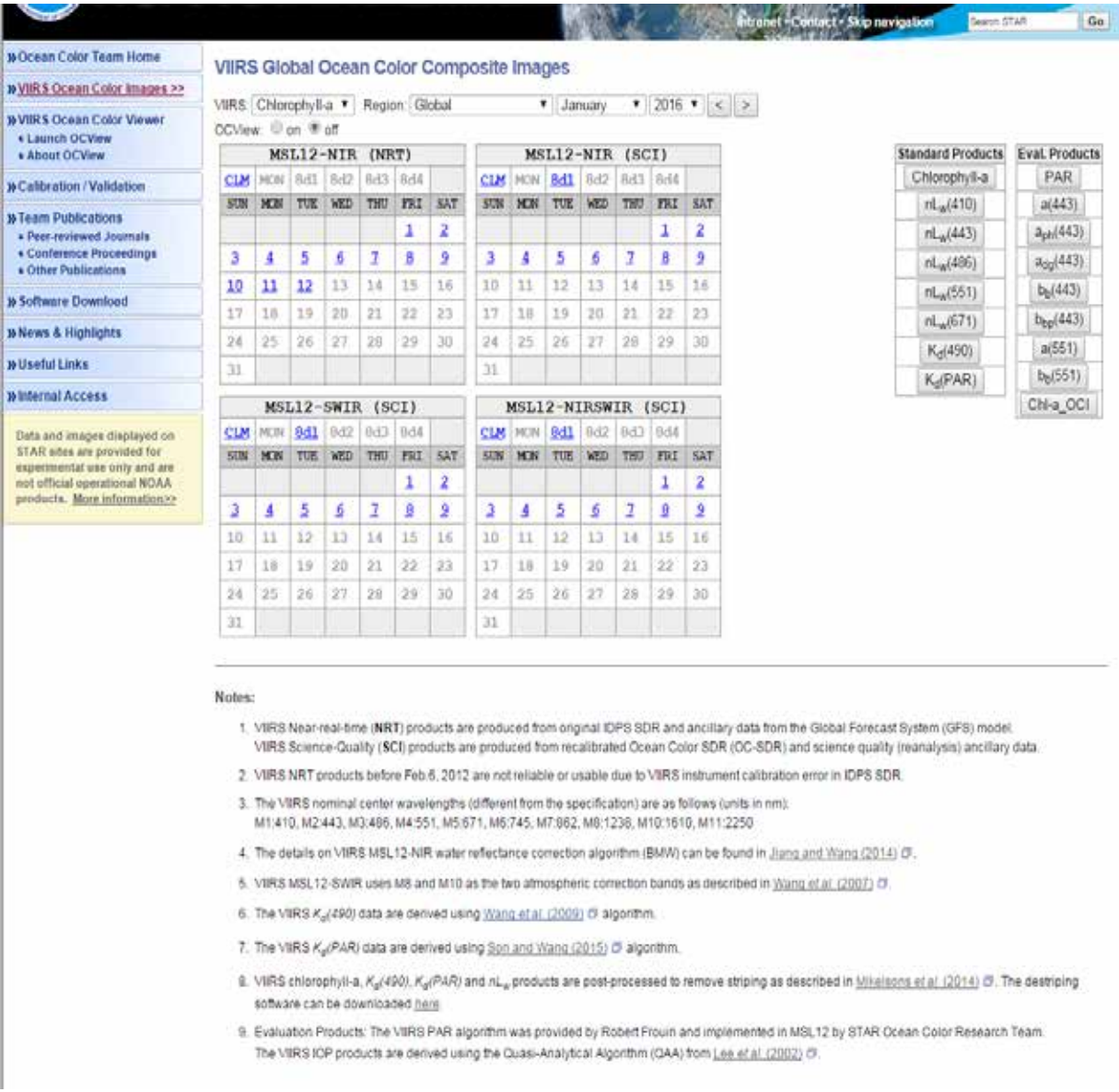


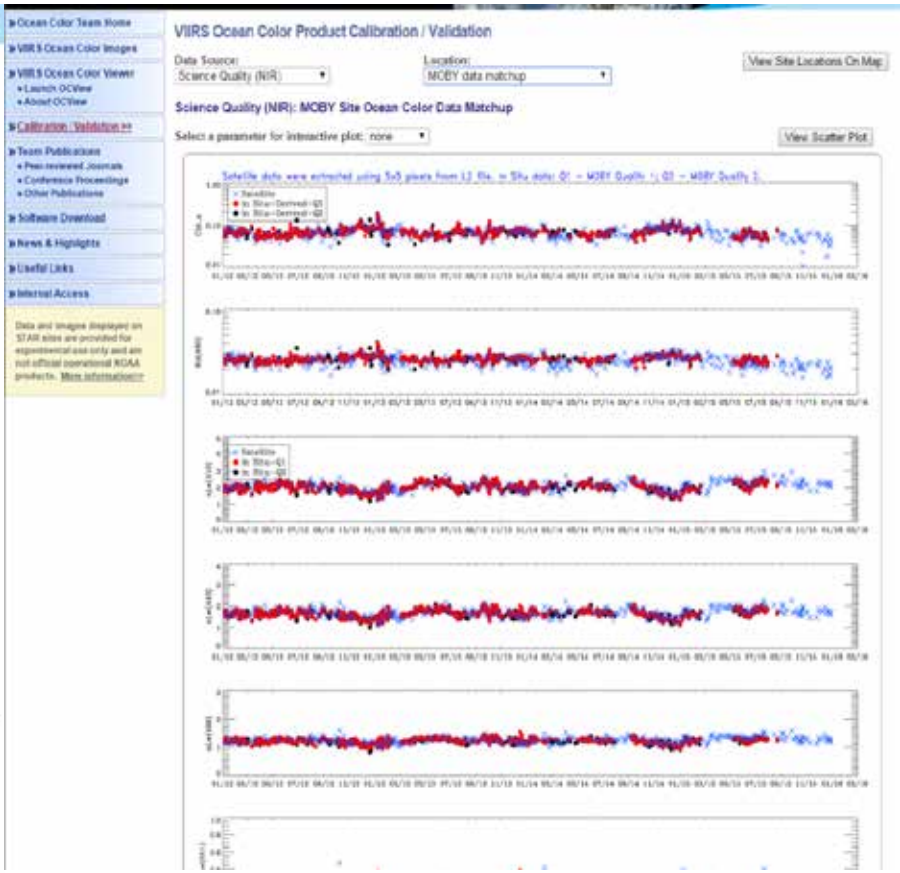
The STAR Ocean Color Research Team is also the NOAA VIIRS Ocean Color Environmental Data Records (EDR) Team, responsible for providing high quality VIIRS global ocean color products. Here we show results from VIIRS-SNPP.

OCView: Seamless Global Coverage



Composite Images & Cal/Val





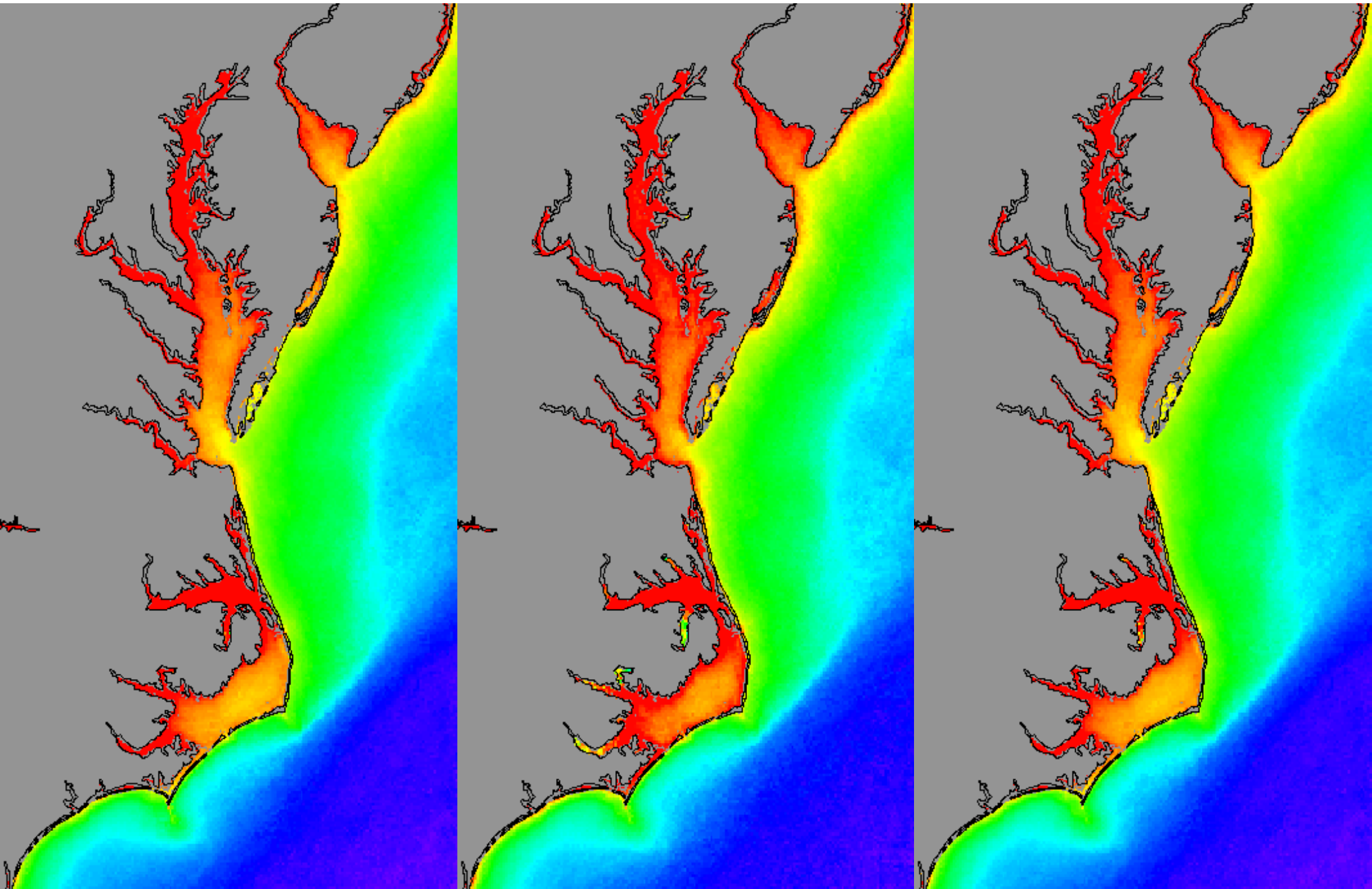
Routinely producing VIIRS global ocean color products (**daily**, **8-day**, **monthly**, **climatology**) using the **MSL12** with the **NIR**, **SWIR**, and **NIR-SWIR** atmospheric correction algorithms.

VIIRS (OC-SDR) Climatology Images (2012–2015)

Chl-a (0.1−16.0 mg/m^3 in log scale)

US East Coast

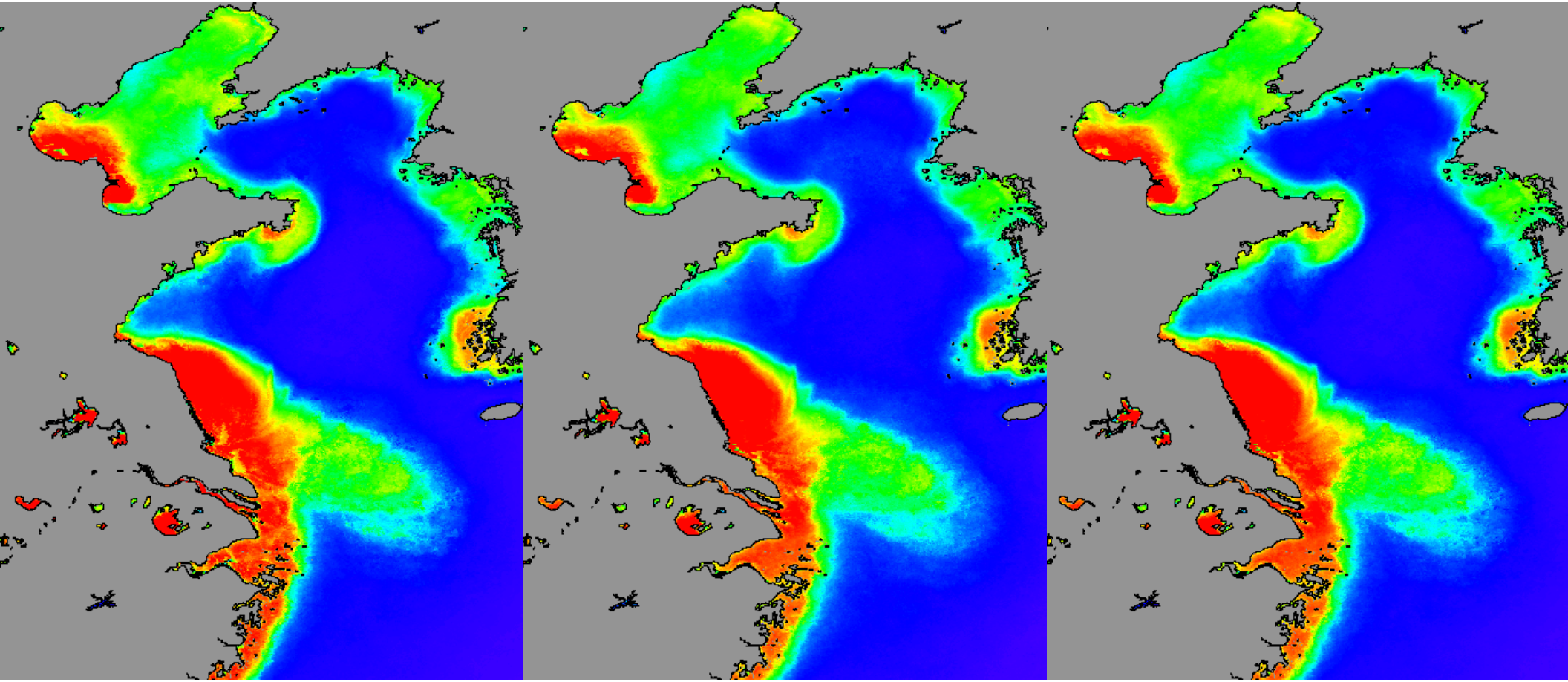
NIR | **SWIR** | **NIR-SWIR**



VIIRS (OC-SDR) Climatology Images (2012–2015)

$nL_w(551)$ (0.0−5.0 mW/cm^2 μm sr in linear scale)

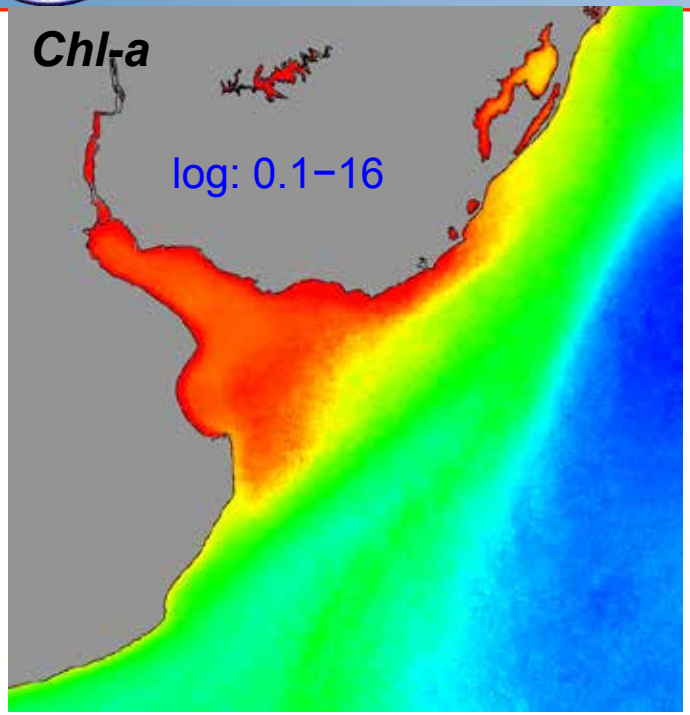
NIR | SWIR | NIR-SWIR

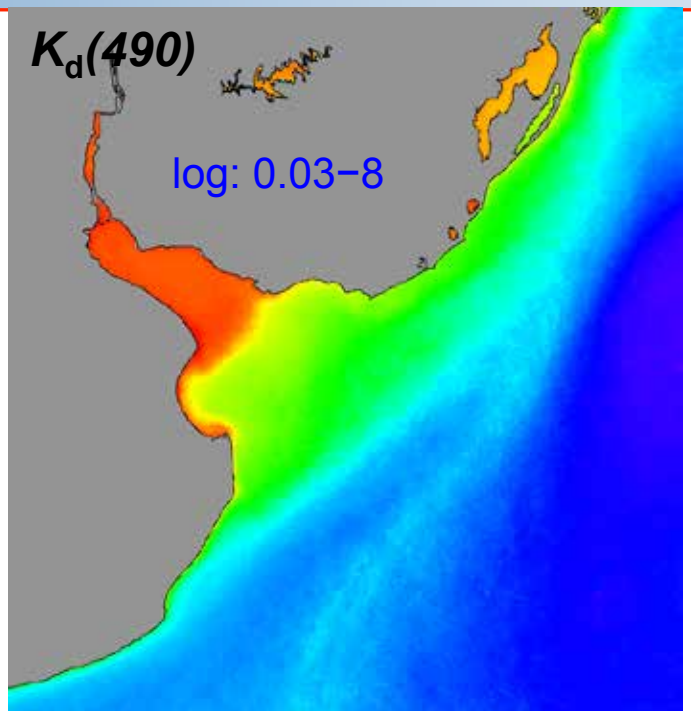


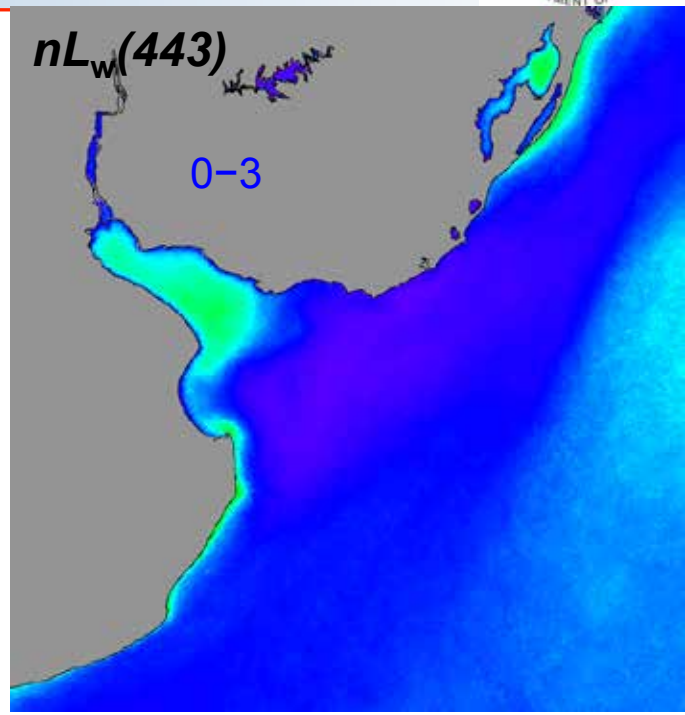
China East Coast

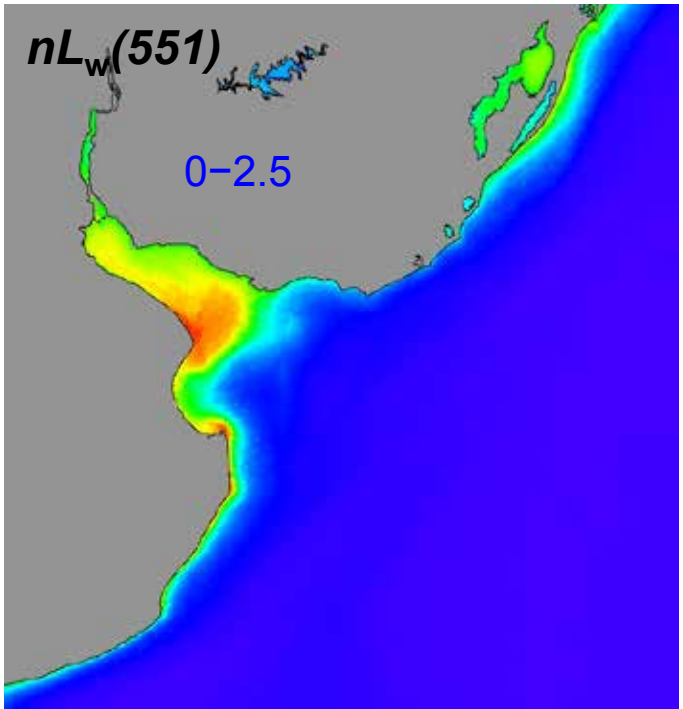
VIIRS Climatology (2012-2015) using the NIR-SWIR Approach

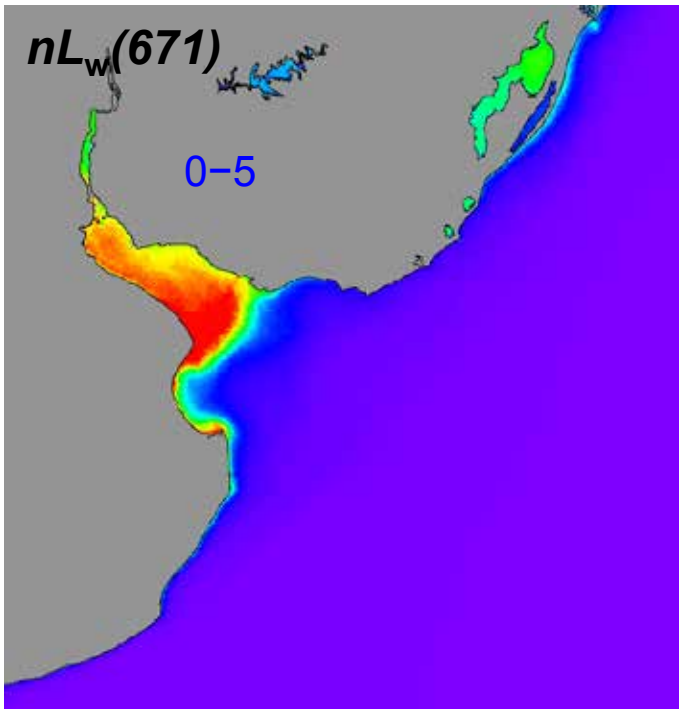
La Plata

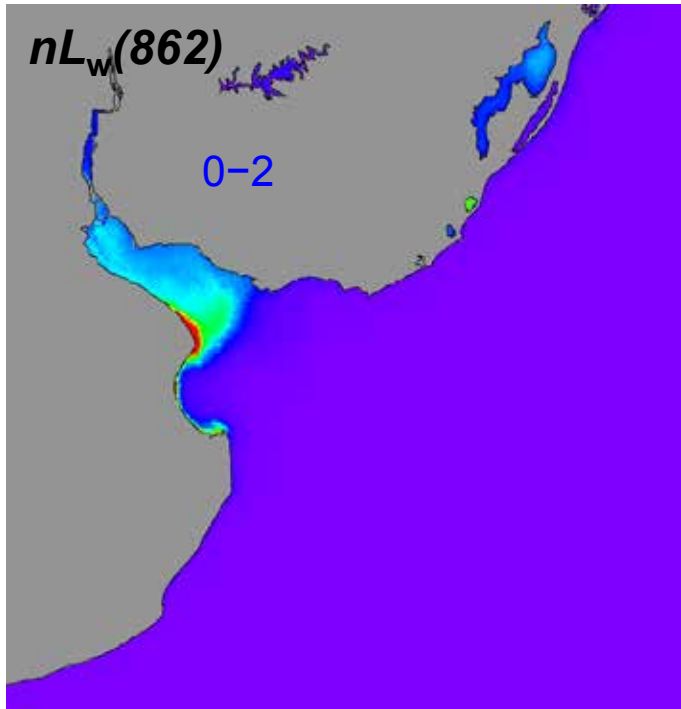












Conclusions

- MSL12 is the measurement-based satellite ocean color data processing system (i.e., enterprise algorithm), which can be used for all satellite ocean color data processing. MSL12 will be used for all VIIRS ocean color data processing, including VIIRS on SNPP and JPSS series, JPSS-1 to JPSS-4.

Thank You!

Website:
http://www.star.nesdis.noaa.gov/sod/mecb/color/