Ocean EDRs and Initiatives: Overview

VIIRS ocean data products responding to operational user needs and applications

Paul M. DiGiacomo and Veronica P. Lance

WE HAVE HEARD FROM OUR USERS

Our users are sensor-agnostic;

In addition to high-quality Level 2 EDRs from VIIRS, they have expressed the critical need for:

- *Consistently* processed data sets for *multiple* sensors (NOAA and non-NOAA, including foreign, data)
  - **NOAA ACSPO** for SST: VIIRS, AVHRR, MODIS, ABI, AHI;
  - **NOAA MSL12** for Ocean Color: VIIRS, OLCI, S-GLI;
  - **PGRR funded**: Gladkova et al., Multi-sensor high-resolution gridded (super)-collated SST ACSPO L3C/L3S products

- Even better, a fully merged/integrated multi-sensor (not only JPSS) time series extending as far back into the past as possible (e.g., complete retrospective for MODIS, AVHRR, SeaWiFS et al.)

HOW DO WE GET THIS DONE?

WE HAVE HEARD FROM OUR USERS

- New product development
  - Phytoplankton Functional Types
    - SOCD funded projects:
      - Zheng and DiGiacomo (2018) Detecting phytoplankton diatom fraction based on the spectral shape of satellite-derived algal light absorption coefficient, Limnology and Oceanography, 63(S1), S85-S98 https://doi.org/10.1002/lno.10725
      - Joaquim Goes (LDEO, U. Columbia);
      - Dariusz Stramski and Rick Reynolds (Arctic) (SIO, UCSD)
      - Chris Brown and Tim Moore (NOAA, UNH)
      - Andrea Vander Woude and Sherry Palacios (NOAA/GLERL, NASA/BAERI)
    - **PGRR funded**: Hyde et al., Optimization of phytoplankton functional type algorithms for VIIRS ocean color data in the Northeast US Continental Shelf Ecosystem
    - **PGRR funded**: Ahmed et al., Extending and evaluating VIIRS ocean color neural network retrievals of harmful algal blooms and IOPs (inherent optical properties) to complex inshore, bay and inland waters and examining their applicability to different bloom types.
  - Ocean Heat Content
  - Ocean Acidification/primary productivity, etc.

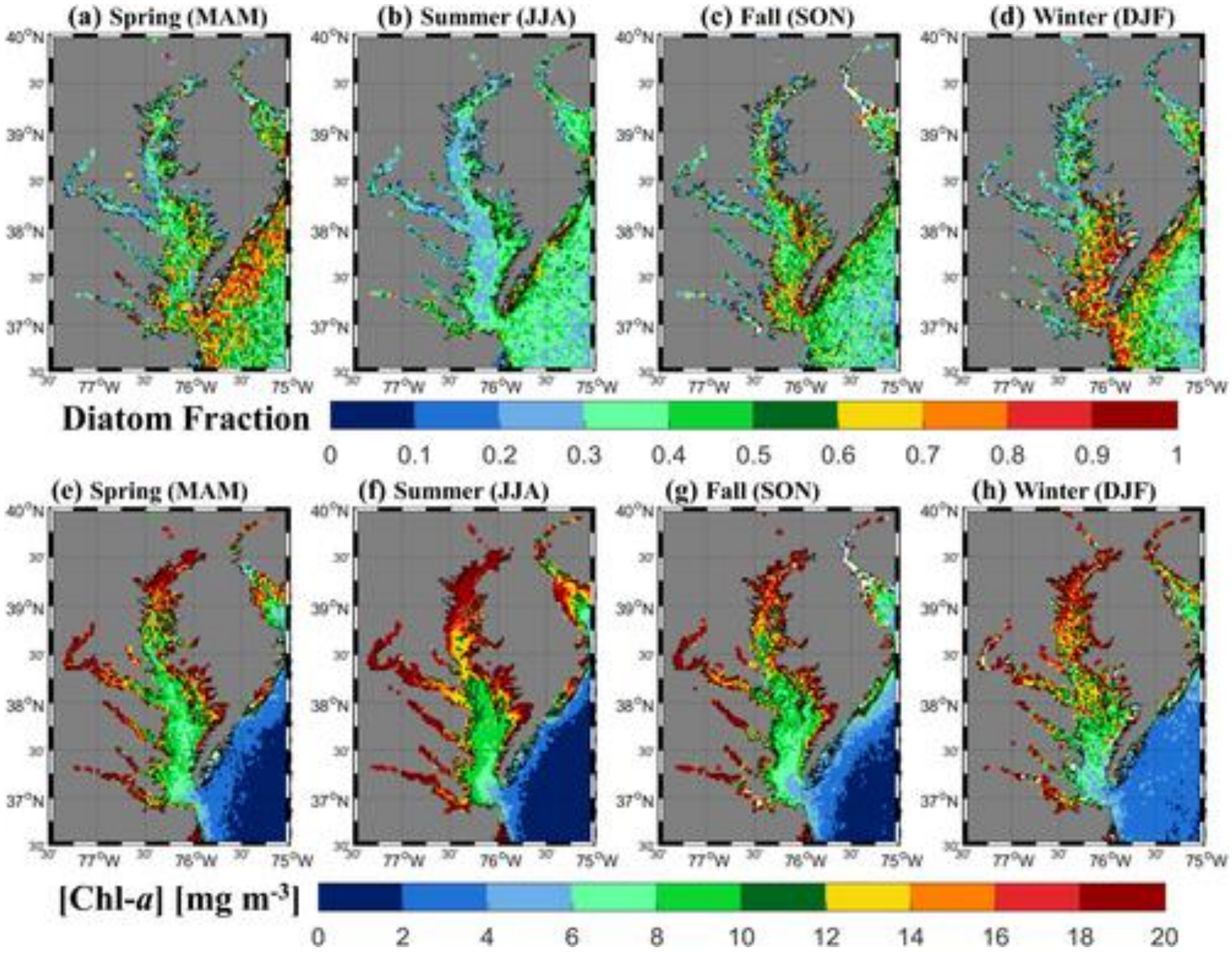


Fig. 5 from paper: Seasonal climatology of diatom fraction (a–d) and [Chl a] (e–h) in the Chesapeake Bay derived from VIIRS data during the period of 2012–2016. The diatom fraction is calculated from GSCM-derived aph(670)/aph(440) ratio using Eq. 1. The [Chl a] is calculated based on GSCM-derived aph(670) using Eq. 2.

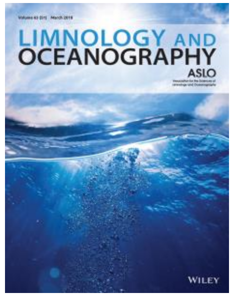


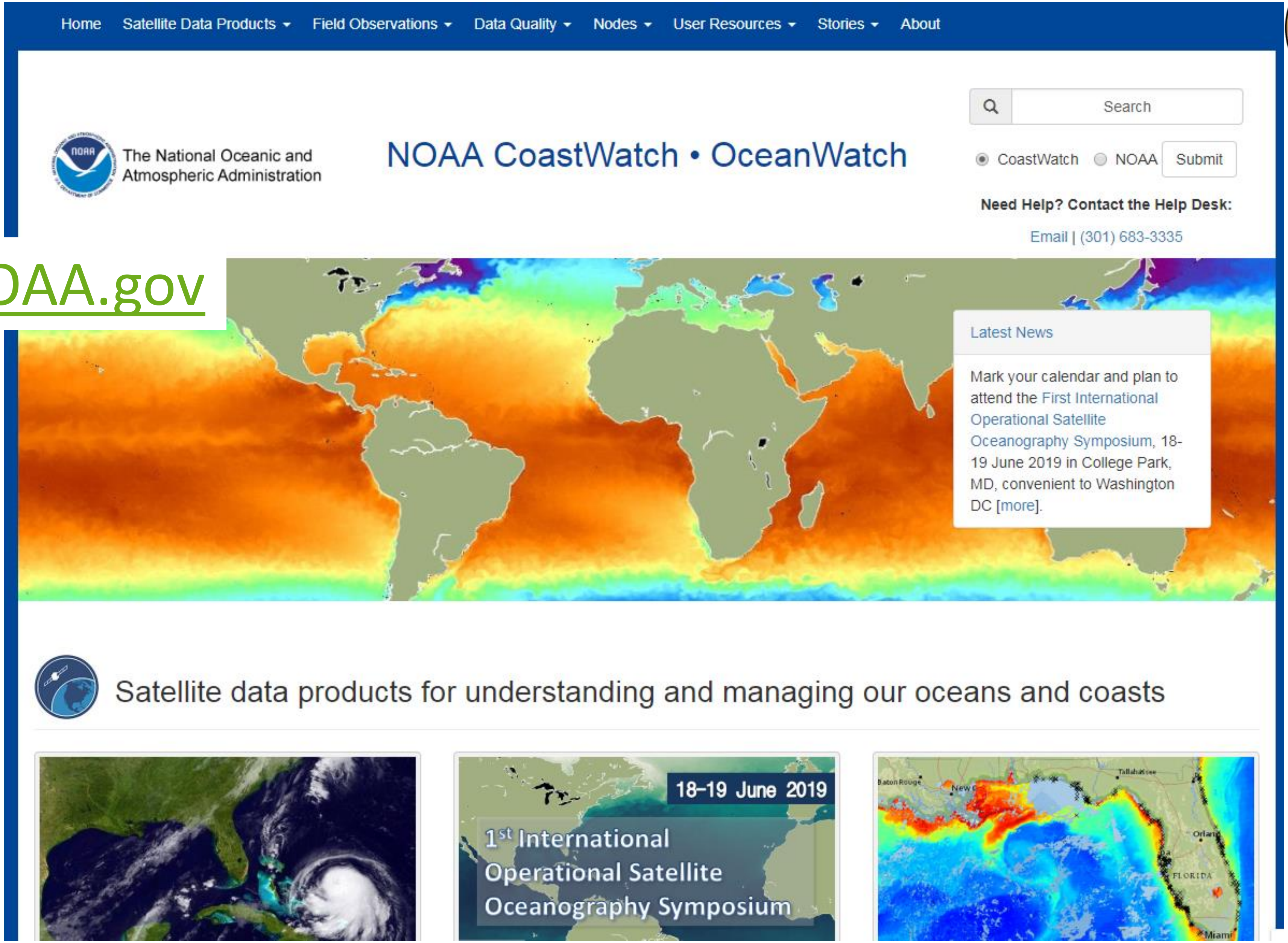
Fig. 5 from Zheng and DiGiacomo, Detecting phytoplankton diatom fraction based on the spectral shape of satellite-derived algal light absorption coefficient, Volume: 63, Issue: S1, Pages: S85-S98, First published: 23 October 2017, DOI: (10.1002/lno.10725)

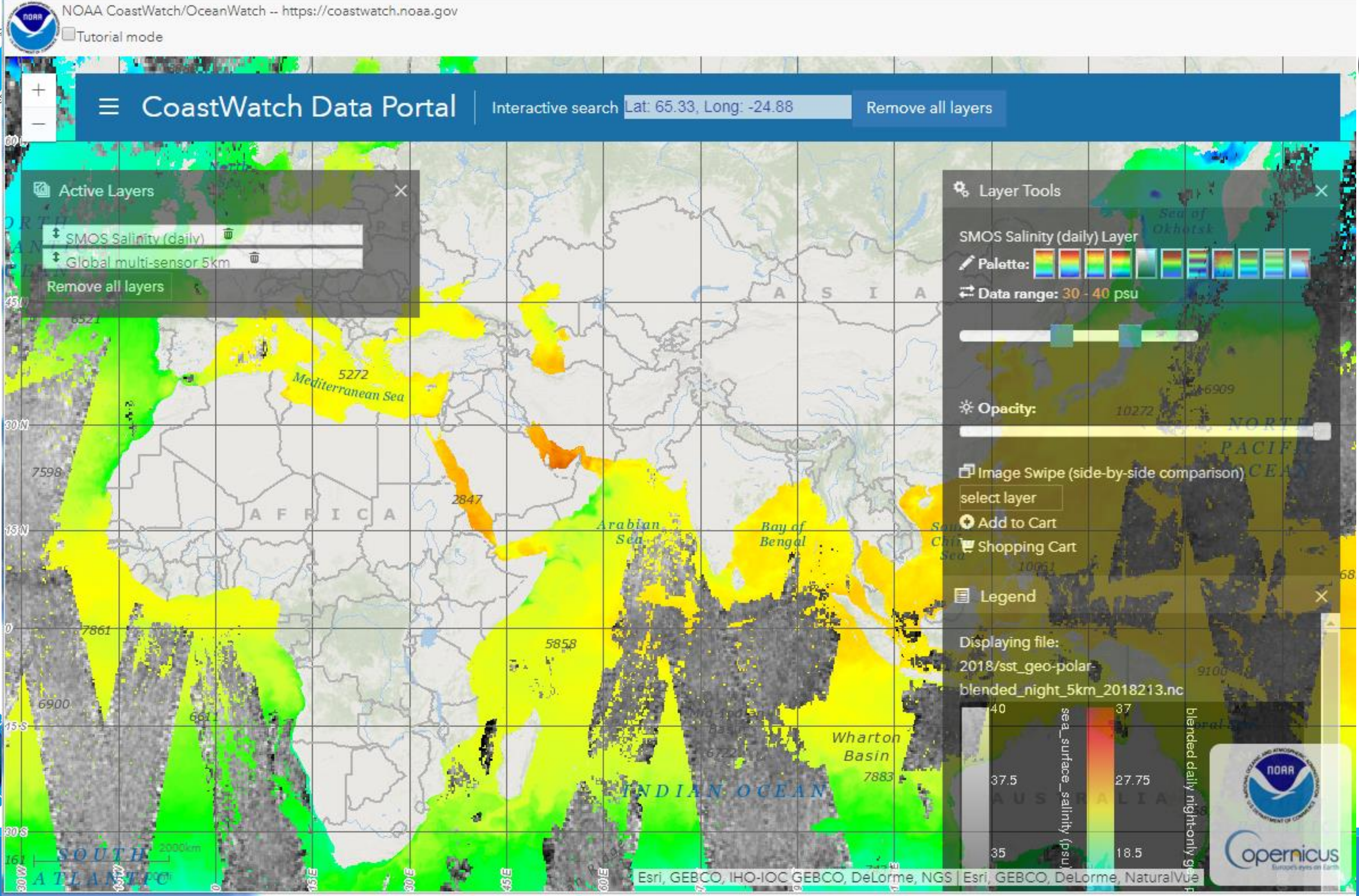
WE HAVE HEARD FROM OUR USERS

- Downstream services: Improved data discovery, access and multi-sensor interpretation
  - **PGRR funded:** DiGiacomo et al., NOAA CoastWatch/OceanWatch – Implement, process and serve JPSS program ocean products tailored for downstream user needs.
    - Includes Data Portal
    - Serving chlorophyll anomaly and DINEOF gap-filled chlorophyll and K_d (downwelling attenuation coefficient) products derived from MSL12 EDRs by the ocean color science team
    - *VIIRS common-gridded products (MSL12 Ocean Color and ACSPO SST in common grid) was cut*
  - PolarWatch Data Portal (VIIRS, AMSR-2 et al.)
  - Access to higher resolution data sets: Sentinel-2, Landsat-8; GCOM-C SGLI
  - CW/OW: additional complementary in situ measurements for validation, environmental context etc.
  - Ocean monitoring (both intra- and inter-themed comparison tools)
  - Use VIIRS in fisheries models:
    - **PGRR funded:** Elliot Hazen, et al., Using VIIRS to operationalize dynamic EBFM (ecosystem-based management) tools on the US East and West Coasts
    - **PGRR funded:** Michael Jacox, et al., Assimilating NOAA VIIRS data into near real-time ocean models to support fisheries applications off the US West Coast.

CoastWatch.NOAA.gov

Facilitate the use of ocean /aquatic satellite data in the value chain from observations to decision-making





NOAA CoastWatch/OceanWatch -- https://coastwatch.noaa.gov
Tutorial mode
CoastWatch Data Portal
Interactive search
Lat: 65.33, Long: -24.88
Remove all layers
Active Layers
SMOS Salinity (daily)
Global multi-sensor 5km
Remove all layers
Layer Tools
SMOS Salinity (daily) Layer
Palette:
Data range: 30 - 40 psu
Opacity:
Image Swipe (side-by-side comparison)
select layer
Add to Cart
Shopping Cart
Legend
Displaying file:
2018/sst_geo-polar-blended_night_5km_2018213.nc
40
37.5
35
sea_surface_salinity (psu)
37
27.75
18.5
blended daily night-only
Mediterranean Sea
Arabian Sea
Bay of Bengal
INDIAN OCEAN
Wharton Basin
AFRICA
ASIA
AUSTRALIA
SOUTH ATLANTIC
NORTH PACIFIC OCEAN
Sea of Okhotsk
Esri, GEBCO, IHO-IOC GEBCO, DeLorme, NGS | Esri, GEBCO, DeLorme, NaturalVue

National Oceanic and Atmospheric Administration
U.S. Department of Commerce

Oceanwatch Monitor (OM)

Satellite data products for understanding and managing our oceans and coasts

Oceanwatch | Ocean Color | Sea Surface Height | Sea Surface Salinity | Sea Surface Temperature | Sea Surface Wind | About

Oceanwatch > OM > SSH Home

- Oceanwatch Monitor
- Data and Regions 3
  - Satellite Products
  - Reference Data
  - Regions of Interest
- Intra-thematic Plots 4
  - Maps
  - Histograms
  - Timeseries Graphs
  - Dependence Series
- Inter-thematic Plots 3
- Event Media (future)
- On-Demand (future)
- 20-min Quickstart Guide

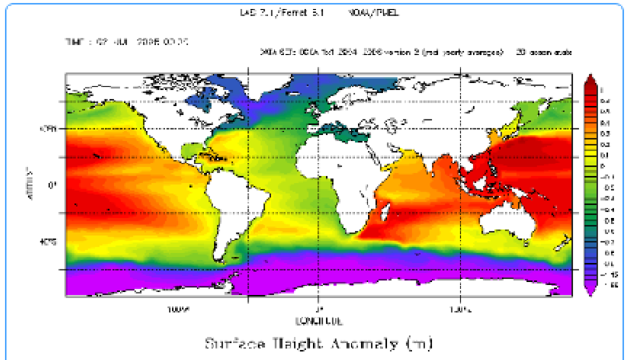
Partners & collaborators

NOAA SOCD Enterprise Oceanwatch Monitor (OM)

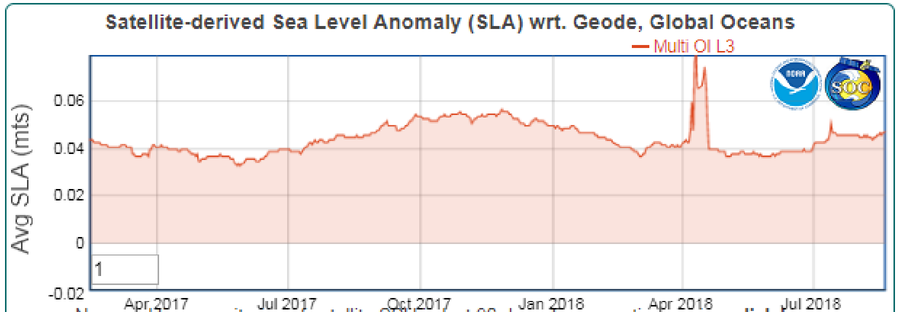
The Oceanwatch Monitor **(OM)** provides a first look at the performances of products ingested in the Oceanwatch systems. These remotely sensed products include: **Sea Surface Temperature (SST)**, **Ocean Color (OC)**, **Sea Surface Height (SSH)**, **Sea Surface Salinity (SSS)** and **Sea Surface Wind (SSW)**.

Sea Surface Height

Satellite altimeters use active radar to observe the surface height of the ocean which is not smooth or flat. Fluid hills and valleys deviate from a reference (mean geoid) height at the ocean surface. These vertical gradients are of interest for sea level rise, storm predictions, ocean currents, ecosystem ecology and other applications.



Latest SSH (click on image to enlarge). More maps, click here.



Near-real time monitoring of satellite SSH in last 90 days. For more time-series, click here.

Ocean Monitor will be incorporated into CoastWatch.NOAA.gov website

The First Operational Satellite Oceanography Symposium

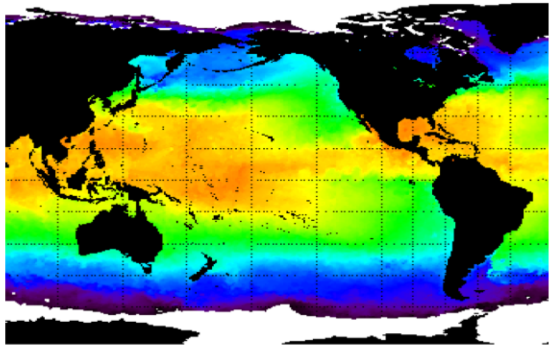
18 & 19 June 2018 here at NCWCP

Aims to

- enable the understanding the barriers (perceived or actual) and
- facilitate the widespread incorporation of satellite ocean observations into the value chain from data to useful information across the range of operational applications.

Satellite operators, information producers and users will exchange facts and ideas to

- understand user needs and expectations, and
- develop interoperability standards and establish best practices that will lead to more universal use of ocean satellite data.



18 to 19 June 2019
Washington, DC Area
FIRST INTERNATIONAL OPERATIONAL SATELLITE OCEANOGRAPHY SYMPOSIUM

Satellite remote sensing of ocean properties is a technology of continuously increasing maturity and scope. Sea surface temperature, sea surface height, ocean color, sea ice, ocean winds, roughness-derived parameters (e.g., oil spills) and other measurements are now available on a routine and sustainable basis. Some of these products are integral to operational applications for routine and event-driven environmental assessments, predictions, forecasts and management. Yet ocean satellite data are still underutilized and have a huge potential for contributing further to societal needs and the "blue economy".

The First Operational Satellite Oceanography Symposium aims to enable the understanding the barriers (perceived or actual) and facilitate the widespread incorporation of satellite ocean observations into the value chain from data to useful information across the range of operational applications. In this symposium, an international community of satellite operators, information producers and users will exchange facts and ideas to 1) understand user needs and expectations, and 2) develop interoperability standards and establish best practices that will lead to more universal use of ocean satellite data.

EUMETSAT

NOAA Center for Weather and Climate Prediction

18 & 19 June 2019
College Park, MD USA

Convenient access from Washington DC

HTTPS://CoastWatch.NOAA.gov/OSOSymposium

STEERING COMMITTEE
Bojan Bojkov (EUMETSAT)
Christopher Brown (NOAA)
Paul DiGiacomo (NOAA)
Veronica Lance (NOAA)
Francois Montagner (EUMETSAT)

Posted 24 May 2018 – More details to follow

Prior to the symposium, an ocean satellite data training course for users will also be held!

AquaWatch
The GEO Water Quality Community of Practice

What: Global Water Quality Service for Inland & Coastal Waters

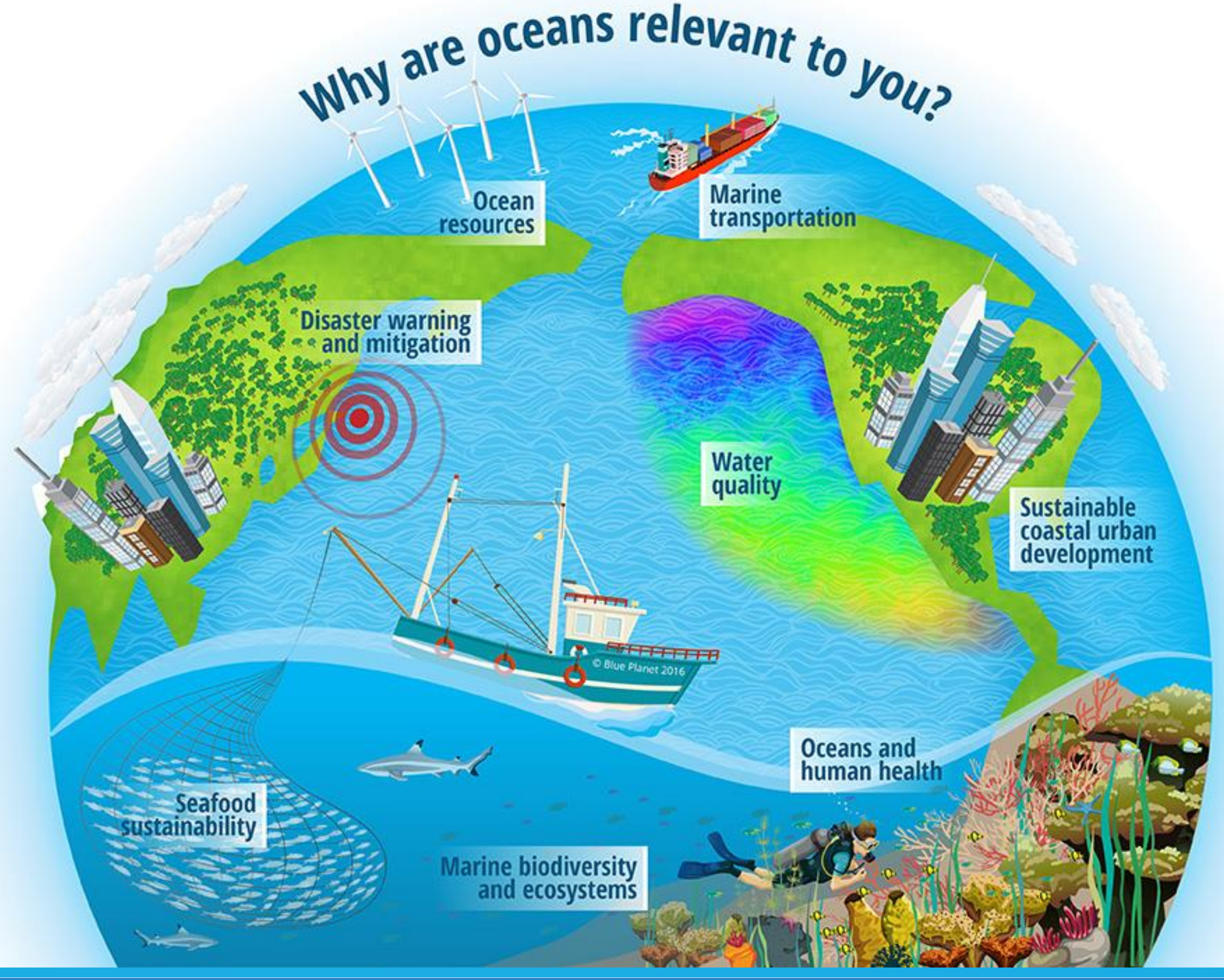
Mission Statement: Deliver, on a routine and sustained basis, timely, consistent, accurate and fit-for-purpose water quality data products & information to support water resource management and decision making in coastal and inland waters.

How: Develop, implement and maintain a global inland and coastal water quality monitoring and forecasting service, via a system of systems approach.

Who: This task will be facilitated by the recently implemented GEO Water Quality Community of Practice.

Ocean and Coastal Information for Societal Benefit

http://geoblueplanet.org/



GROUP ON EARTH OBSERVATIONS

BLUE PLANET Oceans and Society

JPSS SST 2018 UPDATE

NOAA STAR

**Alexander Ignatov, John Sapper,
Yury Kihai, Irina Gladkova, Matthew Pennybacker,
Olafur Jonasson, Boris Petrenko, Xinjia Zhou**

STAR, OSPO, GST, CICS-CREST, CSU-CIRA

Outline

- Cal/Val Team
- Sensor/Algorithm Overview
- SNPP/N20 Products Performance
- Major Risks/Issues and Mitigation
- Milestones and Deliverables
- Future Plans/Improvements
- Summary: Users, FY18 Accomplishments, FY19 Work

Cal/Val Team Members

Name	Organization	Tasks
Ignatov, Sasha	STAR	JPSS Algorithm & Cal/Val Lead
DiGiacomo, Paul	STAR	JPSS Ocean Lead/CoastWatch
Lance, Veronica	STAR – GST	Coast Watch / JPSS Ocean Coordinator
Sapper, John	OSPO	NDE/OSPO Operations, Data distribution & Archival
Kihai, Yury	STAR – GST	ACSPO SW/HW; Preprocessor; L2P Code; In situ match-ups ACSPO Regional Monitor for SST (ARMS) – back end; L3U product
Pennybacker, Matthew	STAR – GST	L3U/C/S Code/Algorithms (U=Uncollated; C=Collated; S=Super-Collated); Resampling; Pattern Recognition; Ocean Fronts; ARMS
Jonasson, Olafur	STAR – GST	VIIRS SST Reanalysis (RAN); RDR-to-SDR; SST Quality Monitor (SQUAM); Monitoring IR Clear-sky Radiances for SST (MICROS)
Petrenko, Boris	STAR – GST	ACSPO Algorithms: Clear-Sky Mask/SST/Error Characterization
Zhou, Xinjia	STAR – CIRA	SST Quality Monitor (SQUAM); Monitoring IR Clear-sky Radiances Oceans for SST (MICROS); In Situ Quality Monitor (*i*Quam)
Gladkova, Irina	STAR–CCNY CREST/GST	L3U/C/S Code/Algorithms (U=Uncollated; C=Collated; S=Super-Collated); Resampling; Pattern Recognition; Ocean Fronts; ARMS

SST Algorithm

- NOAA enterprise Advanced Clear-Sky Processor for Ocean (ACSPO) system
- ACSPO is a stand-alone system (does not the Enterprise Cloud Mask, etc)

Night M12/14/15/16 (3.7/8.6/10.8/12 µm)

$$T_S = a_0 + a_1 T_{11} + a_2(T_{11}-T_{3.7}) + a_3(T_{11}-T_{8.6}) + a_4(T_{11}-T_{12}) + [a_5 + a_6 T_{11} + a_7(T_{11}-T_{3.7}) + a_8(T_{11}-T_{8.6}) + a_9(T_{11}-T_{12})]S_\theta + [a_{10}(T_{11}-T_{3.7}) + a_{11}(T_{11}-T_{8.6}) + a_{12}(T_{11}-T_{12})]T_S^0$$

Day M14/15/16 (8.6/10.8/12 µm) + M5/7 (0.68/0.86 µm)

$$T_S = a_0 + a_1 T_{11} + a_3(T_{11}-T_{8.6}) + a_4(T_{11}-T_{12}) + [a_5 + a_6 T_{11} + a_8(T_{11}-T_{8.6}) + a_9(T_{11}-T_{12})]S_\theta + [a_{11}(T_{11}-T_{8.6}) + a_{12}(T_{11}-T_{12})]T_S^0$$

$T_{3.7}, T_{8.6}, T_{11}, T_{12}$	BTs at 3.7, 8.6, 11 and 12 µm
$S_\theta = 1/\cos(\theta) - 1$	θ is VZA
T_S^0	L4 SST in °C (currently by Canadian Meteorological Center – CMC)
a's	regression coefficients, trained against drifters and mooring buoys

- Regression coefficients are trained against *in situ* SST & stabilized by taking special steps to keep only significant eigenvectors/values of the covariance matrix
- Error characterization (Single Scanner Error Statistics, SSES) significantly reduces errors in retrieved SSTs (due to aerosols, residual cloud, etc) & improves consistency with *in situ*

Performance of SNPP/N20 Real-Time SST

- Regression SST

Product	L1RDS APU Thresholds	SNPP Performance	N20 Performance
L2P/L3U (Night)	Accuracy: ±0.20 K Precision: 0.6 K	Accuracy: ±0.15 K Precision: 0.35 K	Accuracy: ±0.15 K Precision: 0.35 K
L2P/L3U (Day)	Accuracy: ±0.20 K Precision: 0.60 K	Accuracy: ±0.20 K Precision: 0.45 K	Accuracy: ±0.20 K Precision: 0.45 K

- SSES Bias Corrected SST

Product	L1RDS APU Thresholds	SNPP Performance	N20 Performance
L2P/L3U (Night)	Accuracy: ±0.20 K Precision: 0.6 K	Accuracy: ±0.10 K Precision: 0.30 K	Accuracy: ±0.10 K Precision: 0.30 K
L2P/L3U (Day)	Accuracy: ±0.20 K Precision: 0.60 K	Accuracy: ±0.15 K Precision: 0.35 K	Accuracy: ±0.15 K Precision: 0.35 K

- Performance is expected to improve in the reprocessed (RAN) products

Major Risks/Issues and Mitigation

Risk/Issue	Description	Impact	Action/ Mitigation
1 – WUCD anomalies remain unresolved	Quarterly/Annual WUCDs exercises	VIIRS SST off specs for 2-3 days per quarter/year	Quarterly reduced to annual. SDR plans to correct
2 – ACSPO Updates in NDE	NDE implementation takes a little too long	Negative impact on users, producers, archive	Working with PO to address
3 – Parallel Testing	Need both data streams for at least two weeks	Negative impact on users, producers, archive	Working with PO to address
4 – OSPO/NDE Integration	OSPO has no access to NDE to help with builds	Negatively affects implementation time	Working with PO to address

FY19 Milestones & Deliverables

Task Category	Task/Description	Start	Finish	Deliverable
Development (D)	ACSPO 2.61 (update N20, GFS 0.50/ 0.25; optimize); 2.70 (improve clear-mask/SST in support of data fusion)	Jun'18	Aug'19	V2.61: deliver in Dec 2018 V2.70: deliver in Aug 2019 (Versions may be combined)
Integration & Testing (I)	Continue testing/Improving N20 SST. Improve SST/clear mask/ocean fronts. Iterate based on users' feedback.	Jun'18	Jun'19	N20 SST archived PO.DAAC & evaluated by users. Improved ACSPO algorithms integrated
Calibration & Validation (C)	Support N20 and SNPP Cal/Val & fixes. Work on N20 RAN1 & SNPP RAN2. Archive N20 w/PO.DAAC.	Jun'18	May'19	JPSS SST meets specs/users' needs. N20 RAN1 complete. SNPP RAN2 advanced.
Maintenance	Maintain ACSPO, SQUAM, *i*Quam, ARMS, match-up codes, RAN infrastructure. Improve & optimize	Ongoing	Ongoing	ACSPO, SQUAM, *i*Quam, ARMS, match-up, RAN codes functional, stable & optimal
LTM & Anomaly Resolution (L)	Work w/VIIRS SDR Team to fix WUCD anomalies. Sustain SQUAM, *i*Quam, and ARMS monitoring & optimize	Ongoing	Ongoing	Real-Time/RAN performance stats available online in SQUAM, *i*Quam, ARMS

Future Plans/Improvements

- **Algorithm Improvements**
  - Improved SST, Clear-Sky Mask/QC, and Error Characterization Algorithms in support of users and data fusion
  - Pattern Recognition and Front Detection Algorithms
- **J2 and Beyond**
  - Support J2/N21 Algorithm Updates and Cal/Val
  - Support J3/4 Algorithm Updates and Cal/Val
- **Reprocessing Plans/Status**
  - SNPP RAN2 underway. Expected completion: Dec 2019
  - N20 RAN1 underway. Expected completion: Dec 2018
- **Long Term Monitoring/Website links**
  - SQUAM (satellite monitor) www.star.nesdis.noaa.gov/sod/sst/squam/
  - *i*Quam (in situ monitor) www.star.nesdis.noaa.gov/sod/sst/iquam/
  - ARMS (regional monitor) www.star.nesdis.noaa.gov/sod/sst/arms/

Users' Feedback & Summary

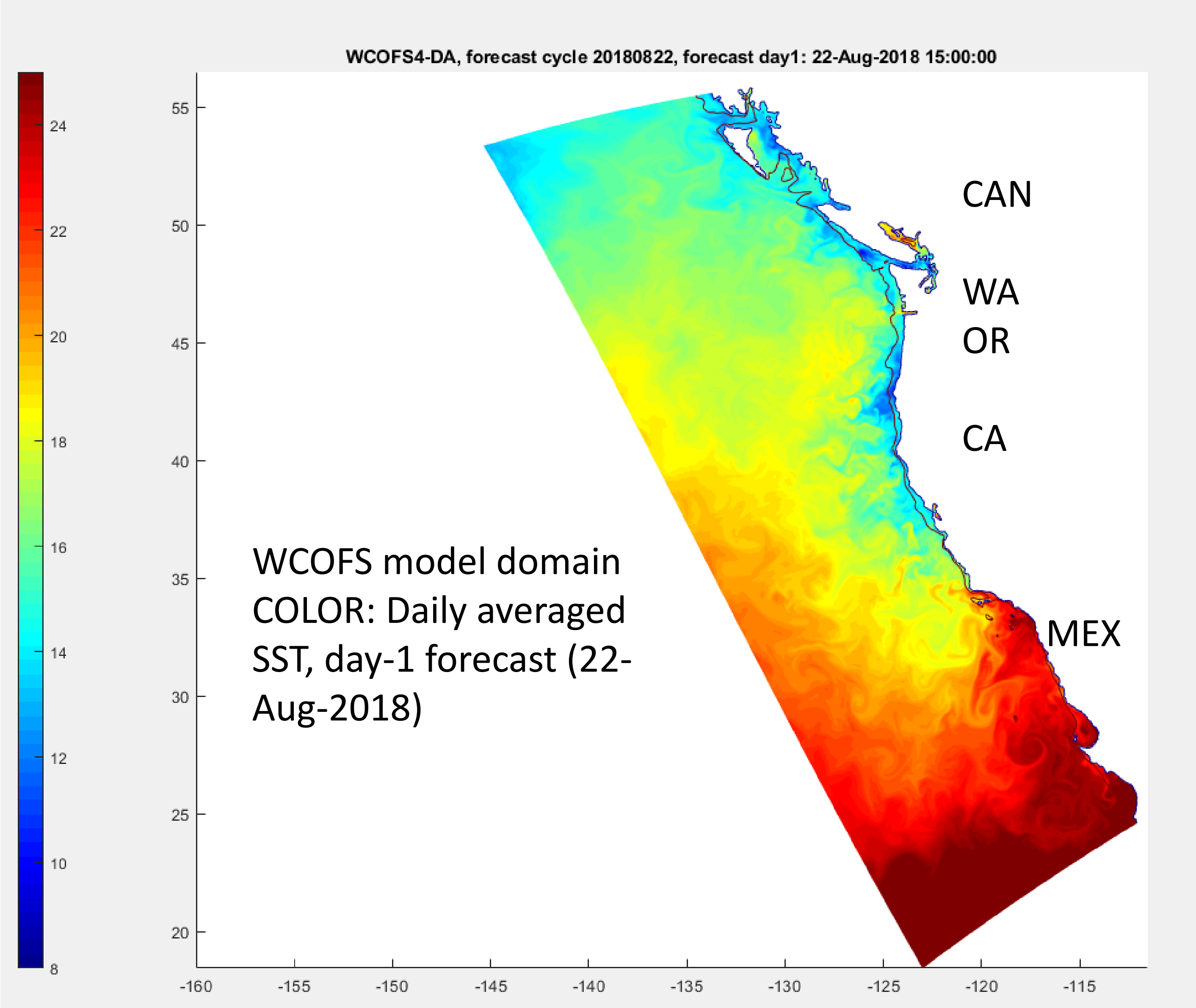
- Users' Feedback: Generally Positive
  - NOAA: NESDIS (CW, CRW, GPB), NOS, OAR, NCEP, NMFS
  - Int'l: CMC, EUMETSAT, Met Office, BoM, DMI, JMA, U. Melbourne
  - Academia: OSU, URI, UMD
  - Private Industry: Digital Globe, ESR
- Summary FY18 Accomplishments
  - ACSPO: 2 versions released, 2.50 & 2.60
  - N20 SST: Declared provisional (pending implementing ACSPO 2.60 in NDE)
  - SNPP RAN2: Infrastructure set up in STAR, underway with 2.60
  - Validation systems: SQUAM, *i*Quam, ARMS all upgraded to v2.0/2.1
  - PGRR SST fusion project: Will aggregate individual L3Us into L3C/S
- Major Focus in FY19
  - Development: ACSPO v2.61 (GFS/improved N20) & 2.70 (Improved SST/Mask)
  - Integration: Archive N20 w/PO.DAAC. Evaluate 2.61/2.70 improvements w/Users
  - Cal/Val: Support N20 & SNPP Cal/Val. Perform N20 RAN1. Advance SNPP RAN2
  - Maintenance: Sustain ACSPO, SQUAM/*i*Quam/ARMS, match-up codes, RAN's
  - LTM/Anomaly: Sustain SQUAM/iQuam/ARMS. Resolve anomalies (WUCD)

VIIRS SST assimilation in the US West Coast Ocean Forecast System (WCOFS)

Alexander Kurapov (NOAA CSDL)
Jiangtao Xu (NOAA COOPS)
Alexander Ignatov (NOAA NESDIS)
Eric Bayler (NOAA NESDIS)
Ed Myers (NOAA CSDL)

WCOFS:
- provides daily updates of 3-day forecasts (SST, currents, total sea level, etc.)
- is based on a high-resolution 3D ocean circulation model and 4DVAR data assimilation
- assimilates VIIRS SST to improve forecast accuracy (both SST and currents)

Users:
- navigation
- fisheries
- environmental hazard response (incl. oil spills)
- search and rescue
- base for coupled physical-bio-geo-chem forecasts



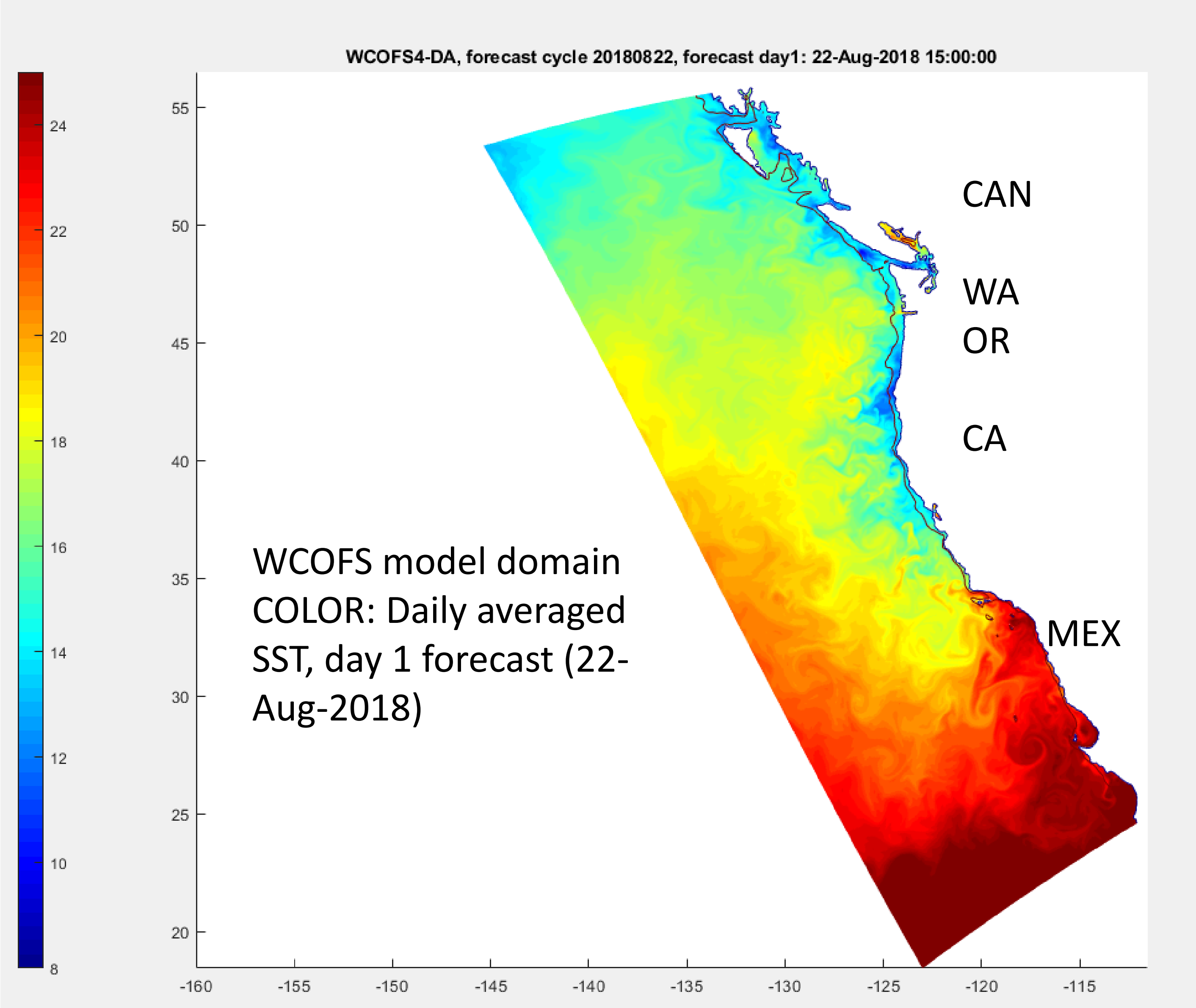
WCOFS, system design:

Regional Ocean Modeling System (ROMS)
2-km horizontal resolution*
NAM atmospheric forcing [NCEP]
RTOFS Boundary Conditions [NCEP] + TPXO tides
Rivers (Columbia, Fraser, small rivers in Puget Sound)

Assimilated data sets:

- SST VIIRS L3U [NESDIS/STAR]
- HFR surface currents [IOOS, NDBC]
- (planned) alongtrack altimetry [NESDIS/STAR]

** This is the target resolution. The model was initially tested without assimilation at the 2-km resolution. Data assimilation and real-time forecasts are currently performed at the 4-km resolution.*



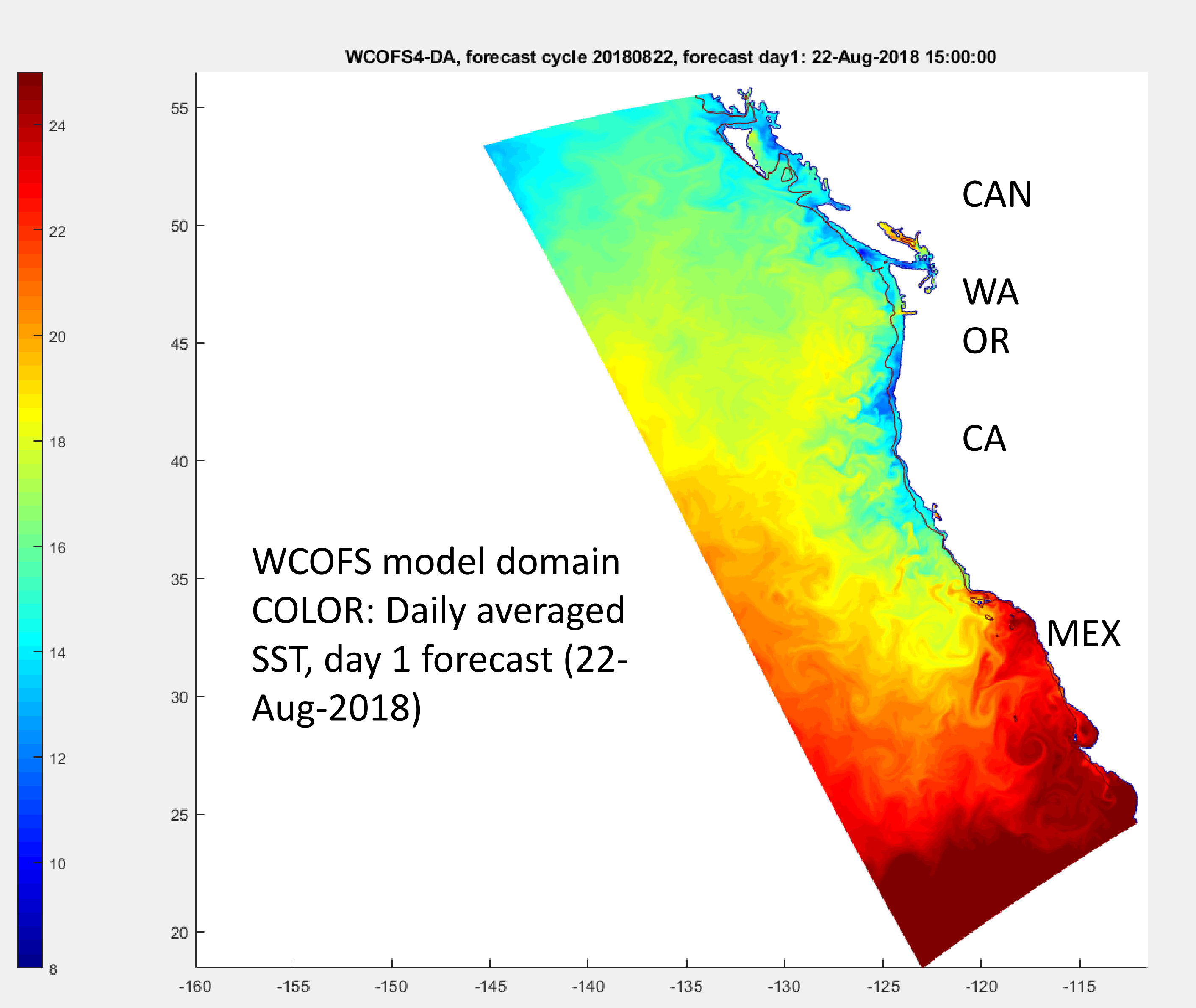
WCOFS skill assessment (no DA):

Kurapov, A. L., N. A. Pelland, and D. L. Rudnick, 2017: Seasonal and interannual variability in along-slope oceanic properties off the US West Coast: Inferences from a high-resolution regional model, J. Geophys. Res. Oceans, 122, 5237–5259, doi:10.1002/2017JC012721.

Kurapov, A.L., S. Y. Erofeeva, and E. Myers, 2017: Coastal sea level variability in the US West Coast Ocean Forecast System (WCOFS), Ocean Dynamics, 67: 23. doi:10.1007/s10236-016-1013-4.

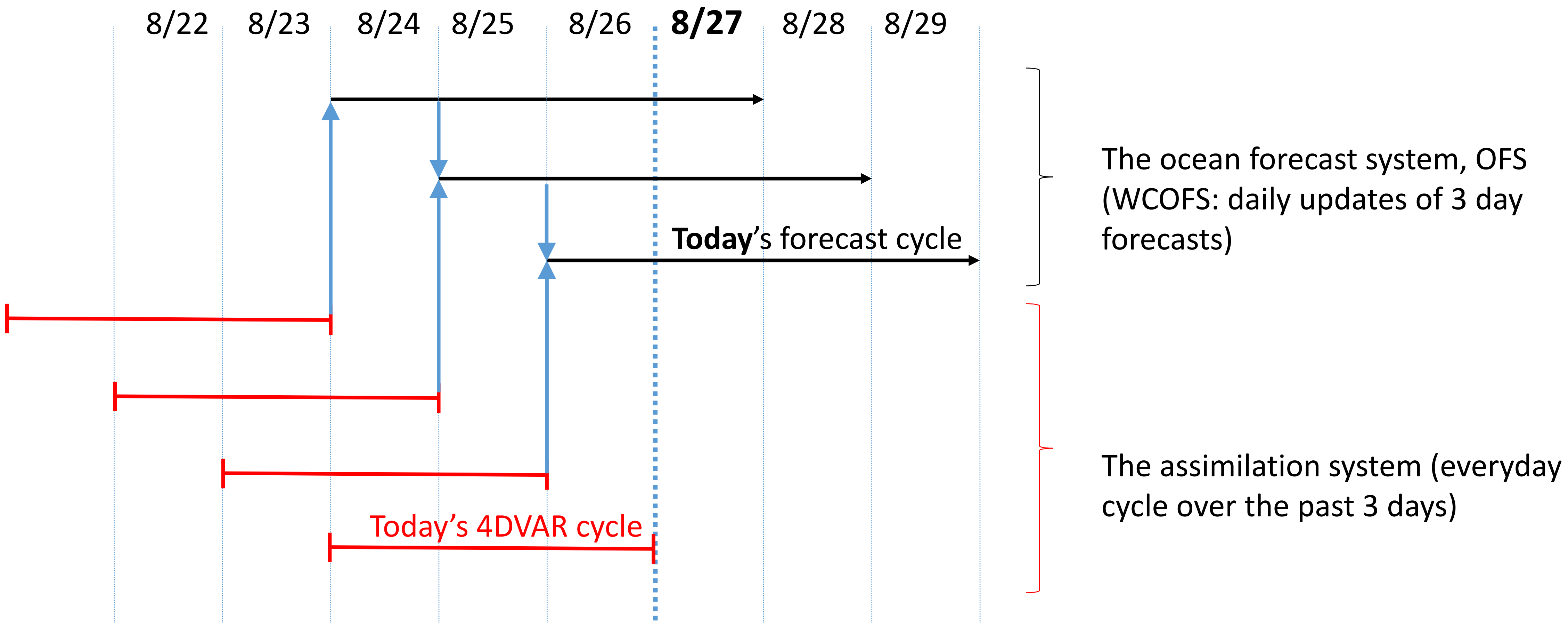
WCOFS, present status:

- developed and tested at CSDL and transitioned to NOS/COOPS for real-time testing
- run routinely in the near-real-time regime with data assimilation since 2 Aug 2018 (still in the “developmental mode”)
- intermediate 4-km resolution for assimilation and forecasts (target is 2-km resolution forecasts)
- assimilates VIIRS L3U SST and High-Frequency Radar (HF) surface currents; altimetry assimilation will be added in the future
- 3-day forecasts are updated daily

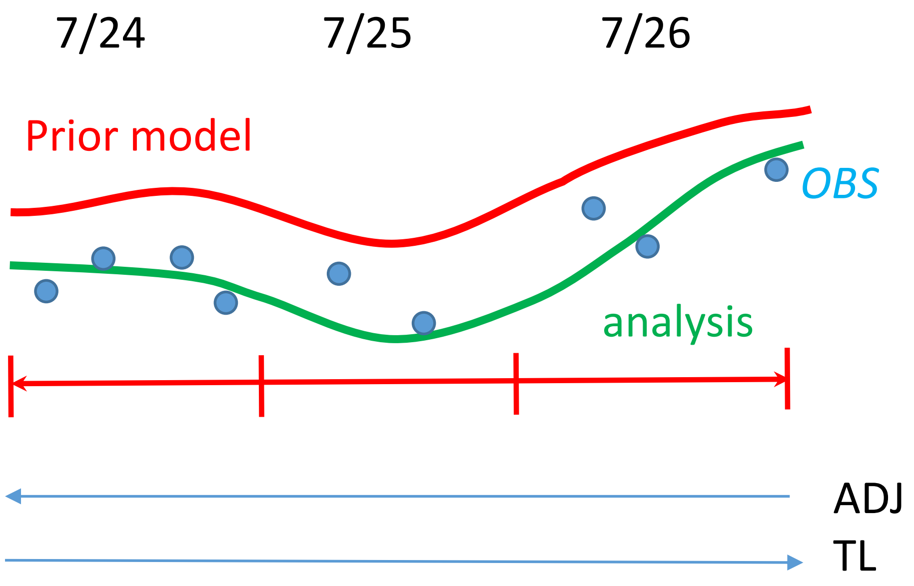


DA methodology: 4-dimensional variational DA (4DVAR)

Every day, the ROMS 4DVAR is run to improve the ocean state estimate at the beginning of the 3-day window. Then the 3-day nonlinear analysis is run over the same period. **Initial conditions for the forecasts are sampled from the DA analysis**



The 4DVAR cycle:



(VIIRS L3U: we assimilate data from individual granules, at their respective times)

(a) Over a given time interval (here, 3 days) use available observations to correct initial conditions for the analysis

(b) The cost function is minimized:

$$J(u) = \|u - u^{PRIOR}\|^2 + \|OBS - HM(u)\|^2$$

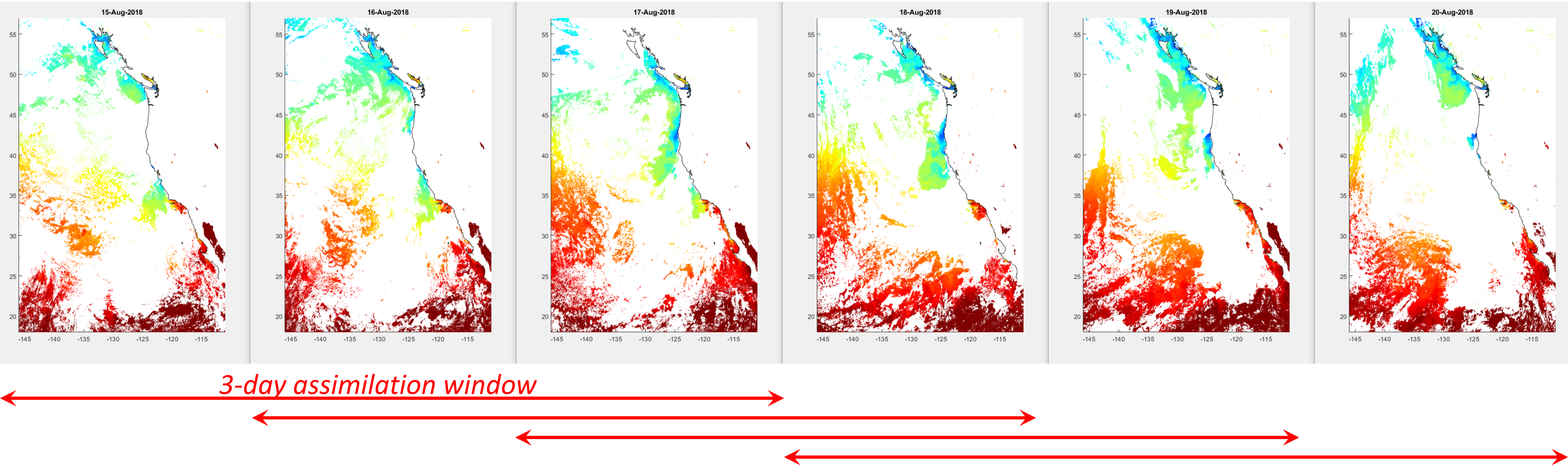
where

u: improved initial conditions on 7/24
u^{PRIOR}: prior initial conditions
M: model, propagating initial conditions in time
H: data functionals (sampling the model solution at obs. locations and times)

(c) The minimizer is found iteratively, using repeatedly the tangent linear (TL) model and its adjoint (ADJ) counterpart

The advantage of using the 4DVAR system (*shown are VIIRS L3U daily mozaics, 15-20 Aug 2018*):

- dynamically-based time and space interpolation
- the estimate is close to the prior where data are not available



- opportunity to include data from multiple satellites

(*not implemented here*)

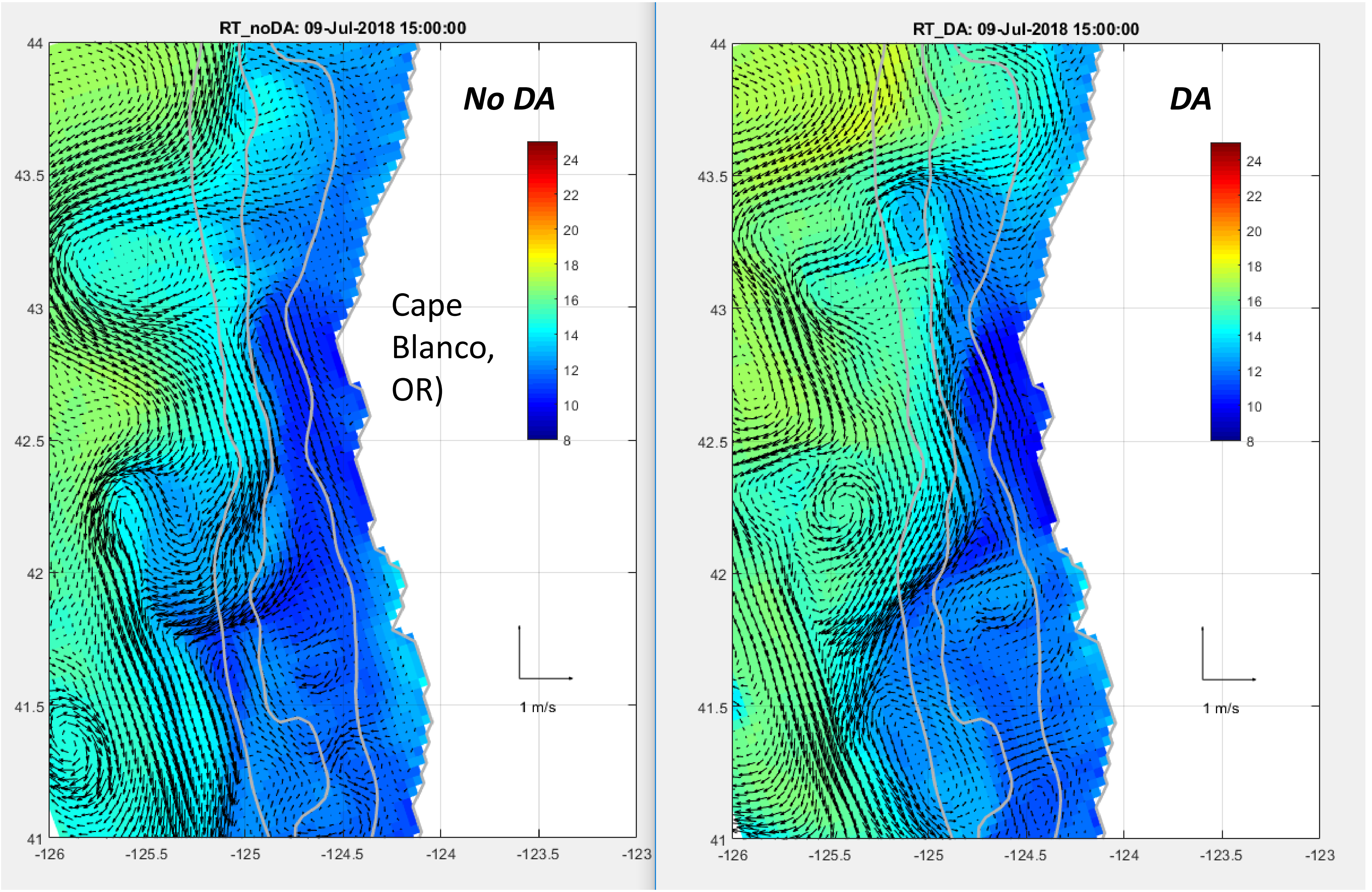
(potential challenges: DA convergence, biases between different sets)

- synthesis of observations from different platforms (SST, u-v, SSH, etc.) to obtain the best available ocean estimate

Impact on surface transports and SST (daily-averaged, day 3 forecasts):

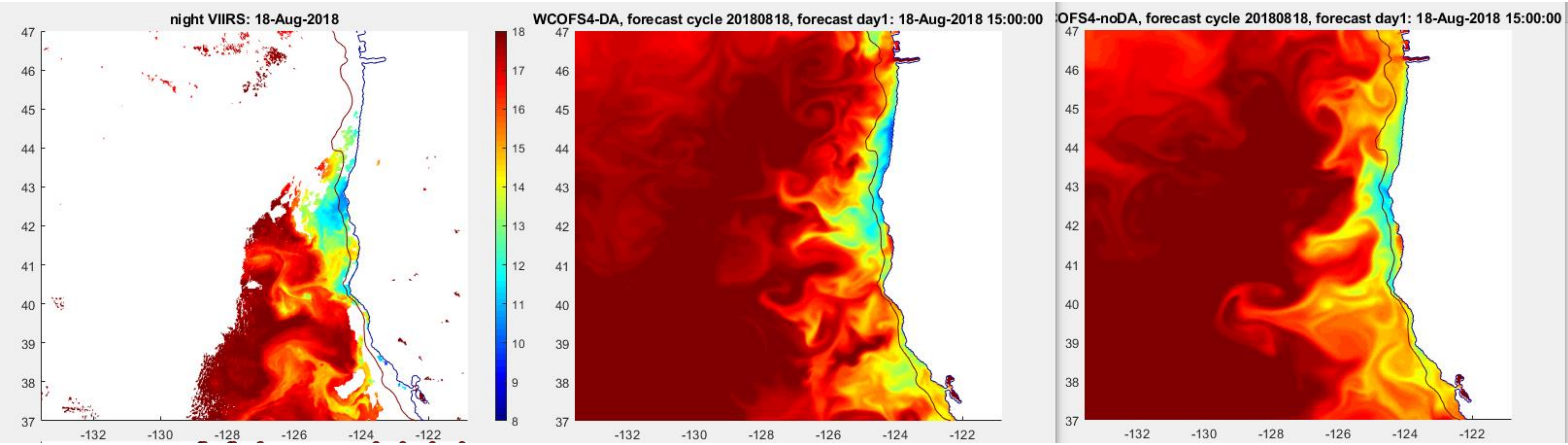
Coastal jets follow closely the SST fronts

DA changes in SST yield changes in surface currents



Assimilation of SST improves the upwelling front geometry in forecasts

18-Aug-2018: nighttime VIIRS | WCOFS4 DA (Day 1 forecast) | WCOFS4 , no DA

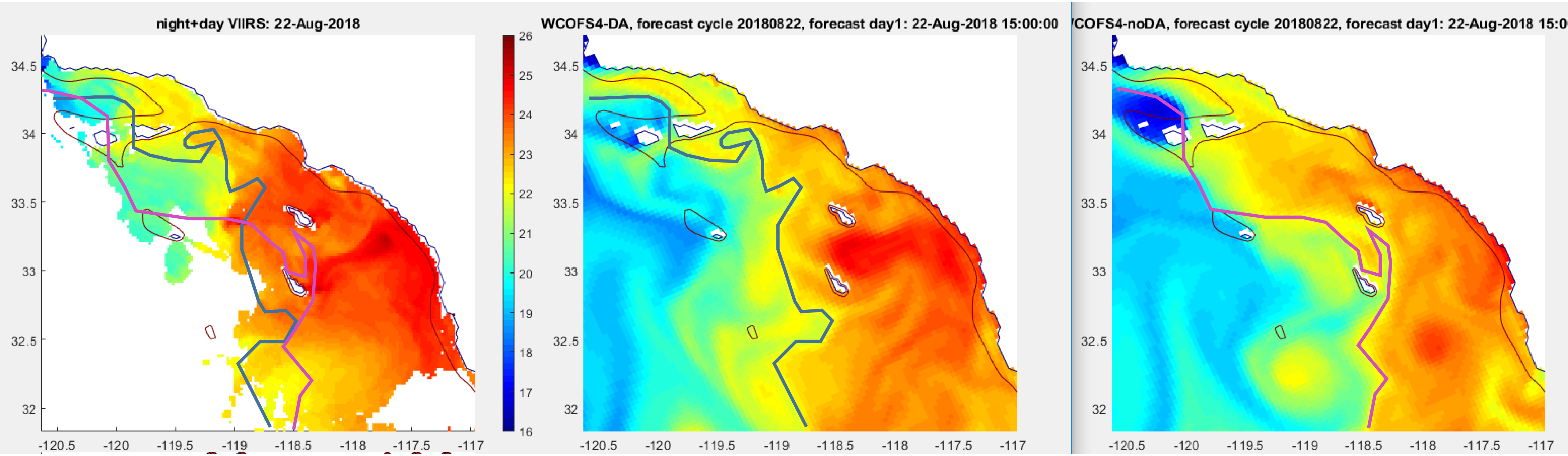


In Southern CA Bight:

18-Aug-2018: night+day VIIRS

WCOFS4 DA (Day 1 forecast)

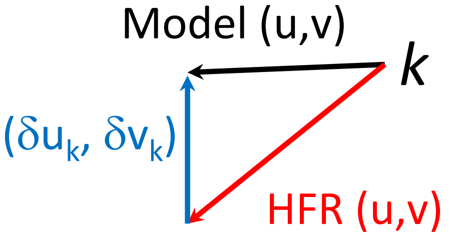
WCOFS4 , no DA



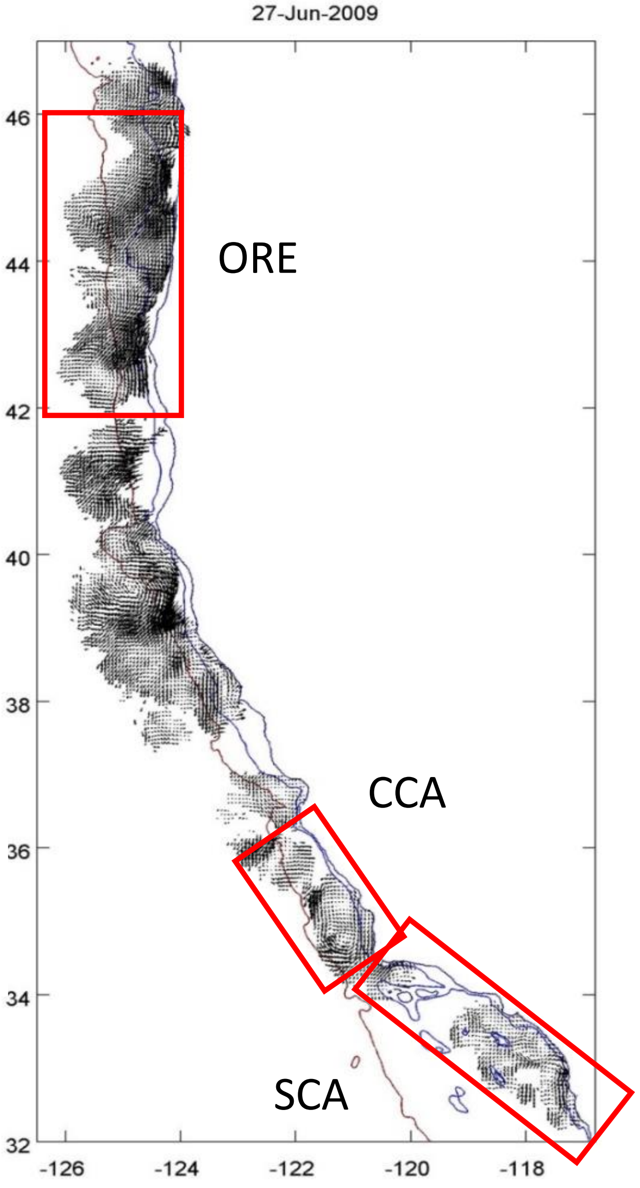
The geometry of the upwelling front is improved qualitatively, compared to the case without assimilation

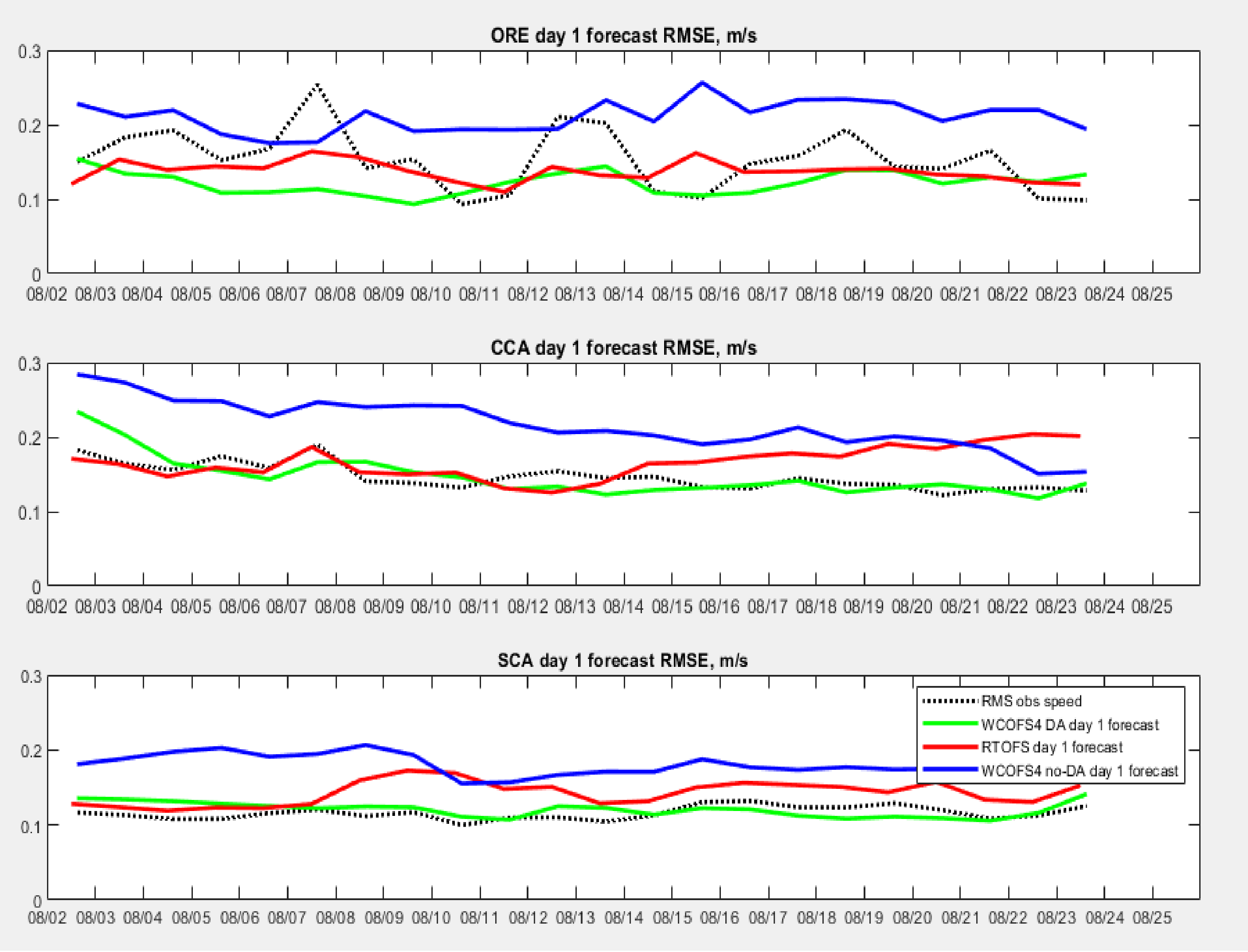
HFR – model RMSE,
Daily averaged (u,v), area-averaged in 3 regions
Day 1 forecasts

WCOFS4 no DA
Global RTOFS
WCOFS4 DA



$$RMSE = \left[\frac{1}{K}\sum_k (\delta u_k^2 + \delta v_k^2)\right]^{1/2}$$





Pre-assimilation data quality control (QC):

It does not matter how good the data are, we need to look at the data before they are assimilated

- to pick out outliers
- to identify new situations where QC flags can be raised
- to learn about the ocean and satellite technology

For example:

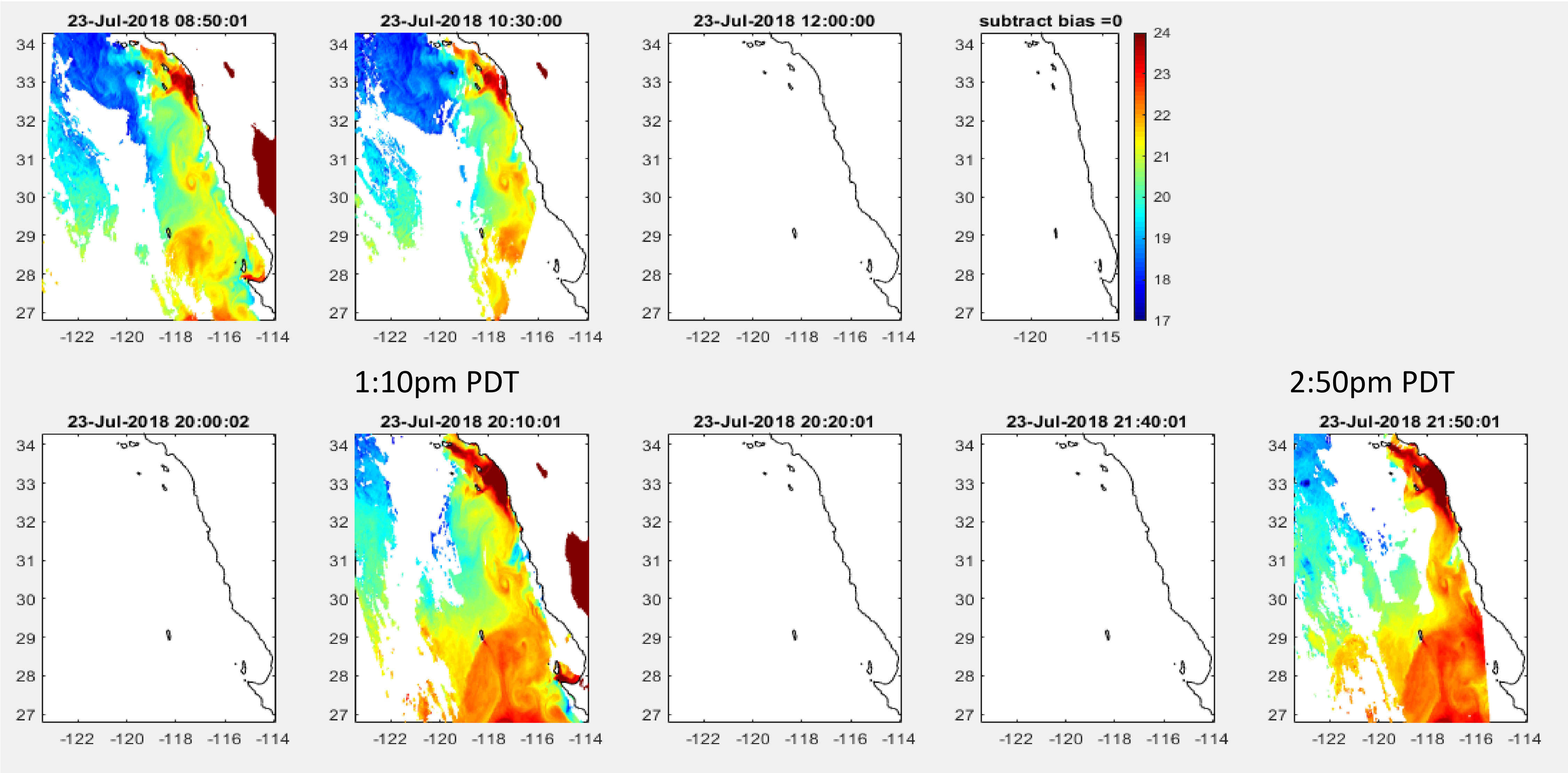
We assimilate L3U “sea_surface_temperature” minus “sses_bias”.
Looking closely at the data, we identify non-standard situations with either field
(*see graphics in the next slides*)

VIIRS L3U SST: no *sses_bias* subtracted. Separate granules over Southern CA and MEX

Night

Day

(times are UTC)

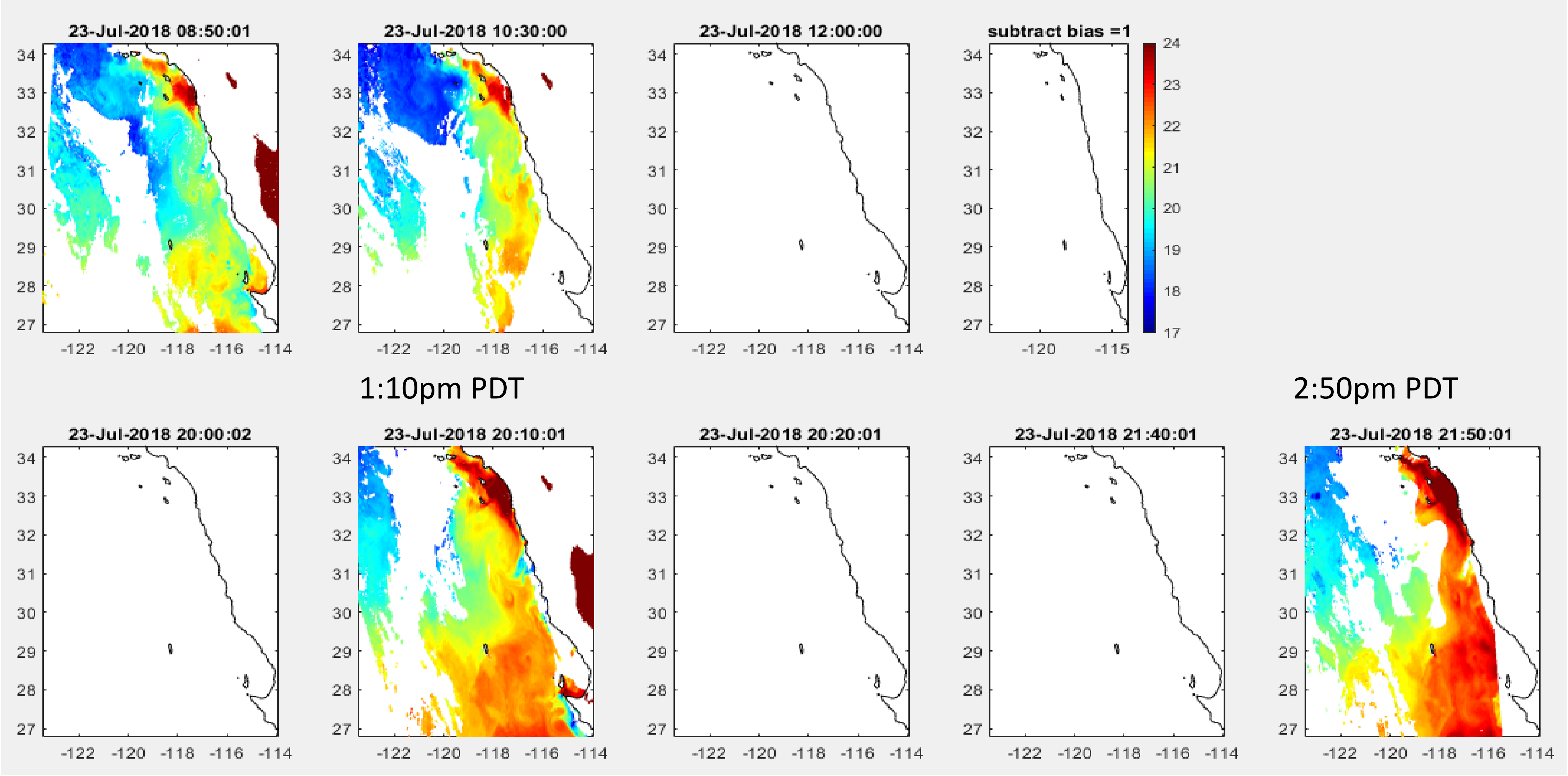


VIIRS L3U SST: **with** *sses_bias* subtracted. Separate granules over Southern CA and MEX

Night

Day

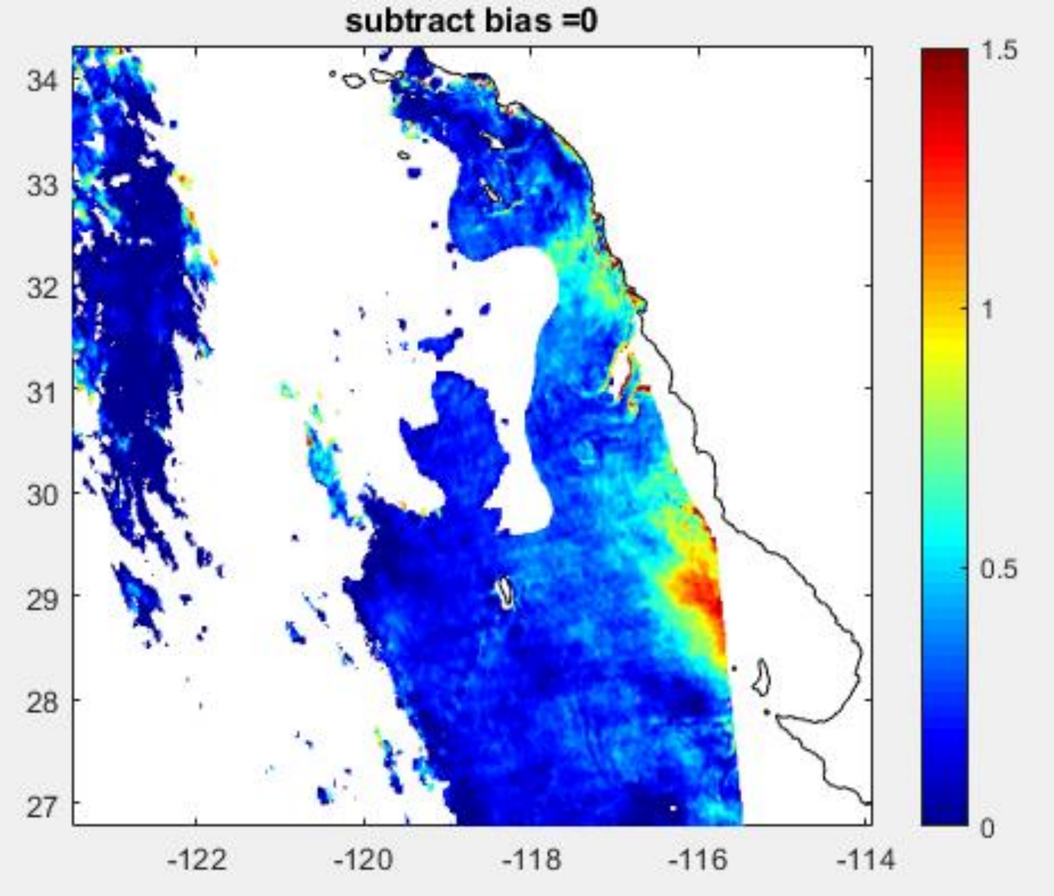
(times are UTC)

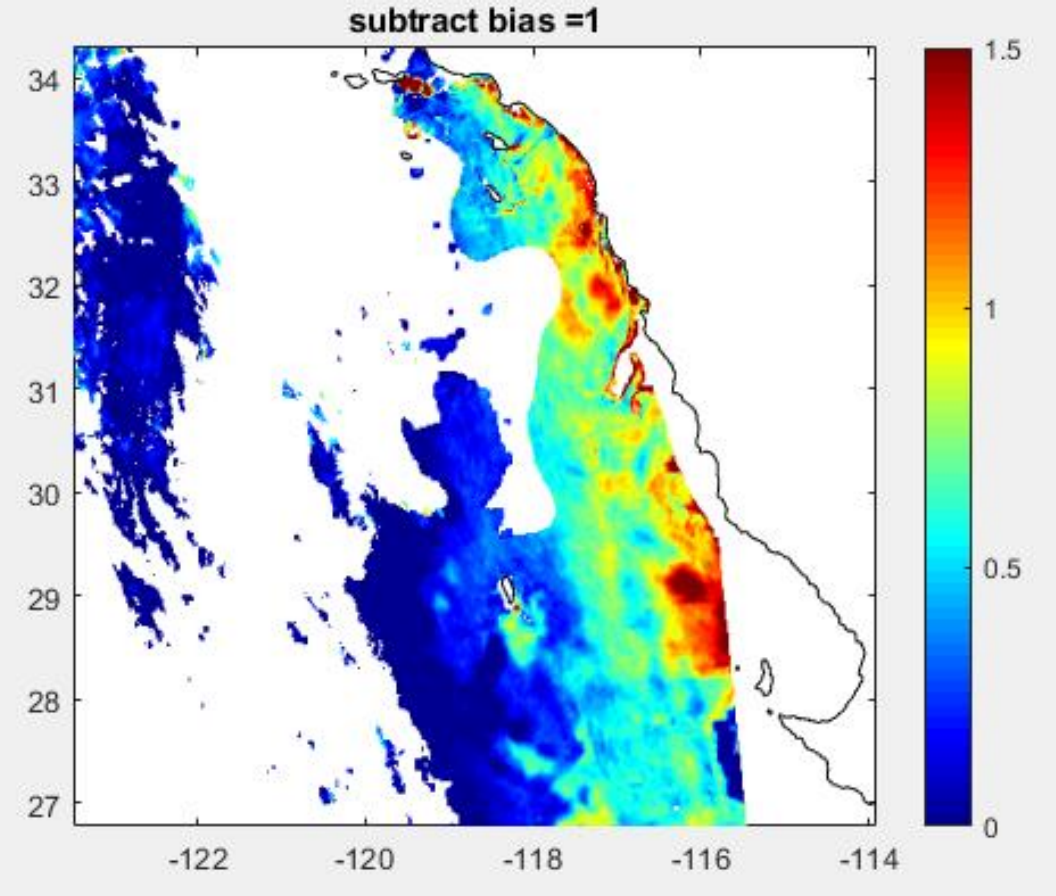


SST difference between two VIIRS granules obtained during the day, 1½ hours apart, 21:50 and 20:10 UTC (2:50 and 1:10pm local time)

no sses_bias correction

w/ sses_bias correction





0.7-1.5°C increase in SST over 90 min?
Enforced by sses_bias?

Mooring - VIIRS SST L3U comparison

https://www.ndbc.noaa.gov/station_page.php?station=46232

Solar Radiation & Ph | Mobile Protection In | Makefile learning tut | Jetdocs | New Tab | start [Jet Docs] | Using BBCP

Station 46232 - Point Loma South, CA (191)

Information submitted by Scripps Institution of Oceanography
Waverider Buoy
32.530 N 117.421 W (32°31'47" N 117°25'17" W)

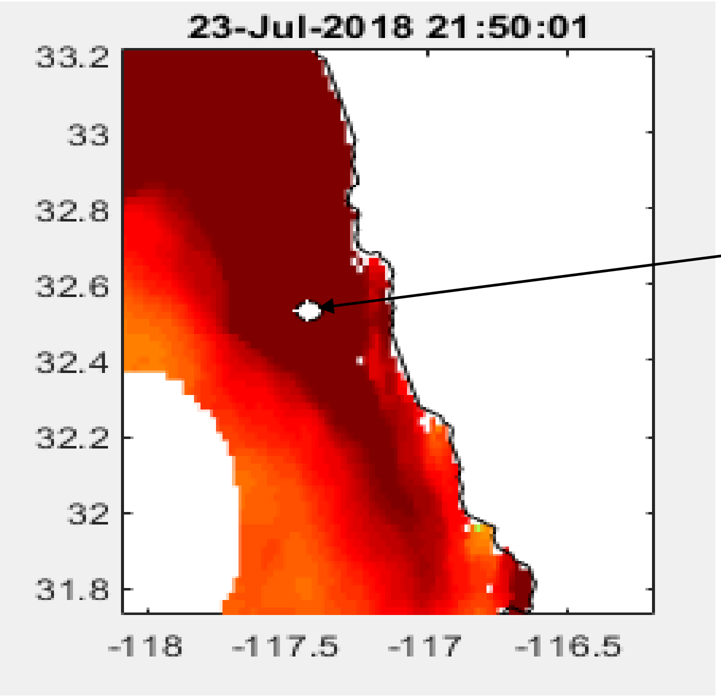
Site elevation: sea level
Sea temp depth: 0.46 m below water line
Water depth: 1143 m

Latest NWS Marine Forecast

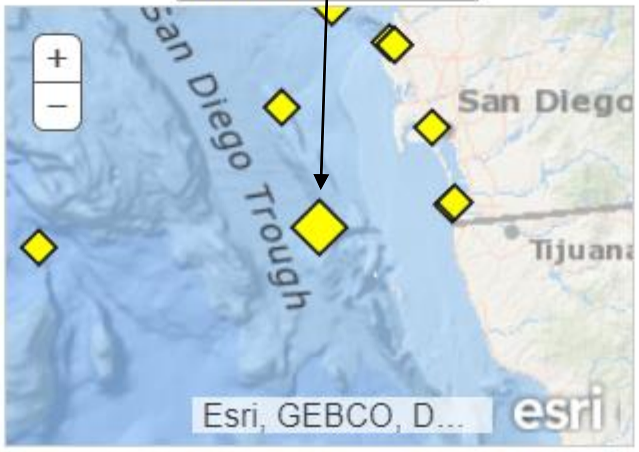
Search And Rescue (SAR) Data

Meteorological Observations from Nearby Stations and Ships

Regional HF Radar Surface Current Observations

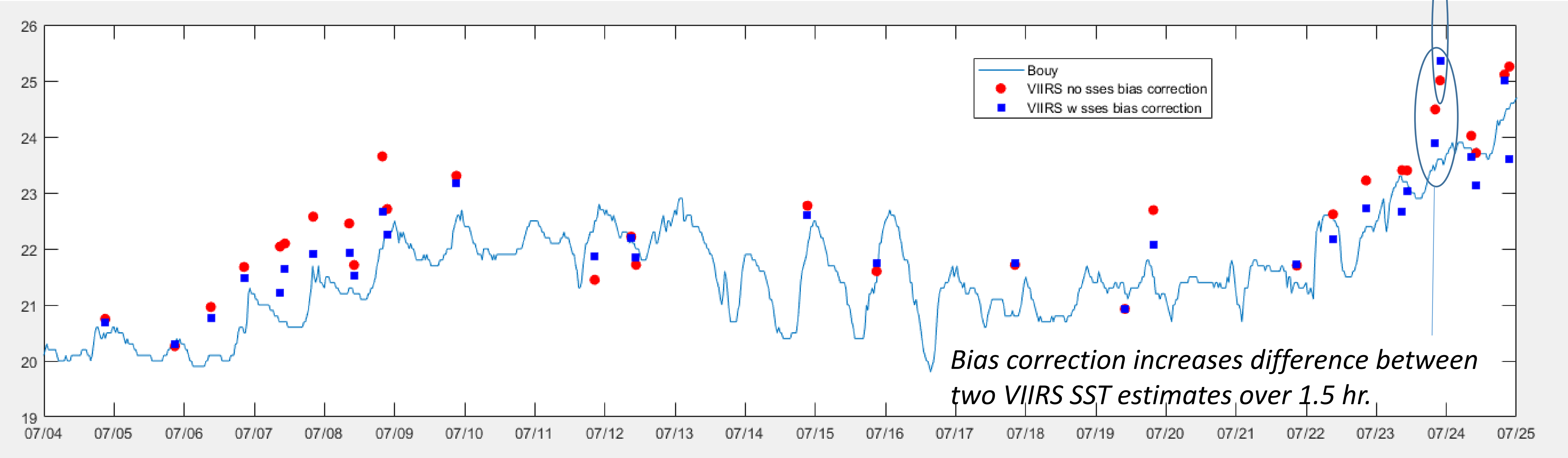


Oceans



Line: Mooring temperature time-series (@0.46 m below surface)

7/23 20:30 UTC (as discussed in previous slide)



Bias correction increases difference between two VIIRS SST estimates over 1.5 hr.

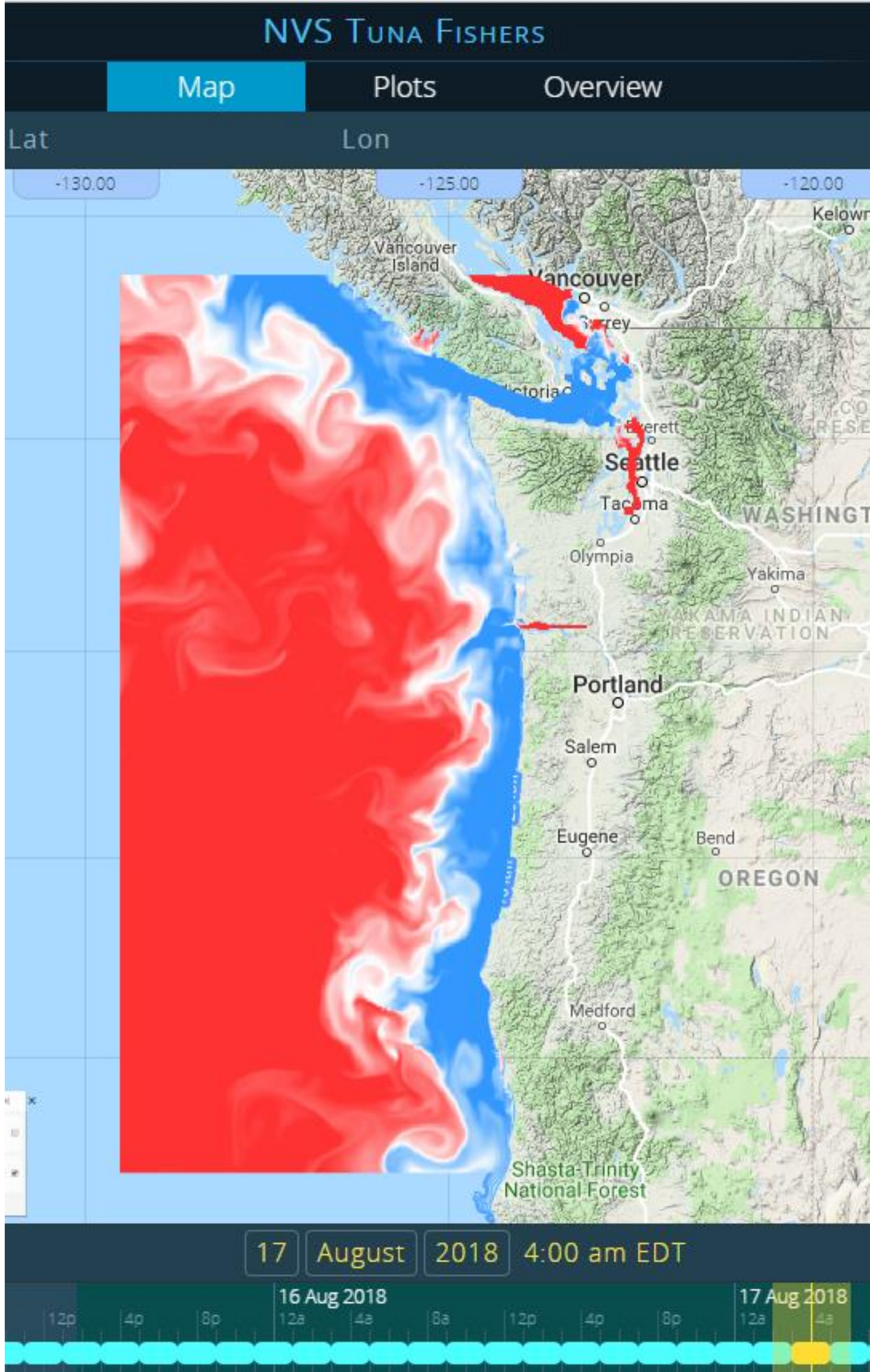
Statistics
(ΔT = sat SST – mooring T)

	No sses_bias	With sses_bias
mean(ΔT)	0.572	0.257
RMSE ($[\text{mean}(\Delta T)^2]^{1/2}$)	0.829	0.620

Stats are better with sses_bias subtracted

Outreach and Engagement:

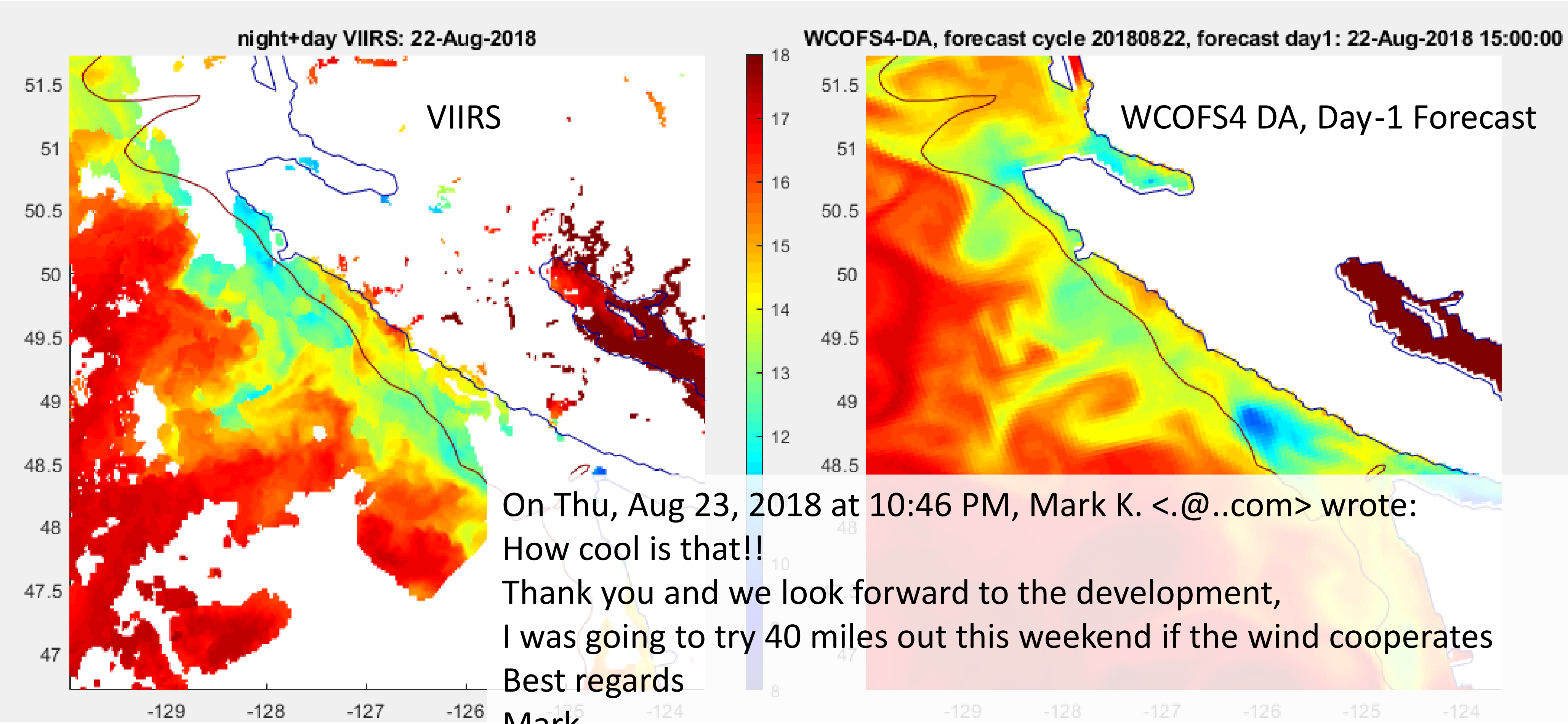
- NOAA ORR would love to use accurate surface velocity forecasts
- Fishermen (esp. tuna along the West Coast) love to see SST forecasts



Tuna forecast at NANOOS Visualization System (NVS), using OSU OR-WA OFS
NANOOS = IOOS Regional Association @ Pacific NW

On Wed, 22 Aug 2018 at 19:42, Mark K. <...@....com> wrote:
From: Mark K.
Subject: NANOOS: Map

How do I get the tuna map to move north to include all of Vancouver Island?



On Thu, Aug 23, 2018 at 10:46 PM, Mark K. <.@..com> wrote:
How cool is that!!
Thank you and we look forward to the development,
I was going to try 40 miles out this weekend if the wind cooperates
Best regards
Mark

SUMMARY:

JPSS VIIRS SST assimilation in the WCOFS helps to improve oceanic forecasts (SST fronts, currents)

4DVAR assimilation = time and space interpolation of sparse data sets using dynamically consistent covariances, provided by the solution of the TL and ADJ models

The DA-enabled forecast system provides SST and currents in the future

Pre-assimilation data QC and post-assimilation solution QC are essential components of any DA system

The forecasts of SST and currents will have their user base (thousands of fishermen, NOAA ORR, fishery managers, USCG etc.)

Many steps to improve WCOFS:
- improved resolution
- improved DA algorithm and implementation (more iterations needed to fit the data better)
- combine data from several radiometers
- better model error covariance
- include assimilation of altimetry (5 nadir satellites... information on surface geostrophic currents)

VIIRS Ocean Color Products and Updates

Menghua Wang &

Ocean Color EDR and Cal/Val Teams

NOAA/NESDIS Center for Satellite Applications and Research (STAR)
E/RA3, 5830 University Research Ct.
College Park, MD 20740, USA

STAR JPSS 2017 Annual Science Team Meeting
NCWCP, College Park, Maryland, August 27-29, 2018

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

Acknowledgements: This work has been supported by JPSS/VIIRS funding. We thank MOBY team for in situ optics data, VIIRS Cal/Val PIs and their collaborators in support of VIIRS Cal/Val activities.

VIIRS Ocean Color EDR & Cal/Val Teams

EDR	Name	Organization	Funding Agency	Task
Lead	**Menghua Wang (OC EDR & Cal/Val Lead),** L. Jiang, X. Liu, W. Shi, S. Son, L. Tan, X. Wang, J. Sun, K. Mikelsons, M. Chu, V. Lance, **M. Ondrusek,** E. Stengel, C. Kovach	NOAA/NESDIS/ STAR	JPSS/NJO	Leads – Ocean Color EDR Team & Cal/Val Team OC products, algorithms, SDR, EDR, Cal/Val, vicarious cal., refinements, data processing, reprocessing, algorithm improvements, software updates, data validations and analyses
Ocean Color	**Robert Arnone** Sherwin Ladner, Adam Lawson, Jen Bowers	U. Southern MS, NRL, QinetiQ Corp., SDSU	JPSS/NJO	Satellite matchup tool (SAVANT) – Golden Regions, Cruise participation and support WAVE_CIS (AERONET-OC site) operation
	Carol Johnson	NIST	JPSS/NJO	Traceability, AERONET Uncertainty
	Nicholas Tufillaro, Curt Davis	OSU	JPSS/NJO	Ocean color validation, Cruise data matchup West Coast
	Burt Jones, Matthew Ragan	USC	JPSS/NJO	Eureka (AERONET Site)
	Alex Gilerson, **Sam Ahmed**	CUNY	JPSS/NJO	LISCO (AERONET site), Cruise data and matchup
	Chuanmin Hu	USF	JPSS/NJO	NOAA data continuity, OC data validation
	Ken Voss & **MOBY** team	Miami	JPSS/NJO	Marine Optical Buoy (MOBY)
	Zhongping Lee, Jianwei Wei	UMB	JPSS/NJO	Ocean color IOP data validation and evaluation Ocean color optics matchup

Working with: **NOAA CoastWatch**, VIIRS SDR team, DPA/DPE, Raytheon, NOAA OC Working Group, NOAA various line-office reps, NOAA NCEI, NOAA OCPOP, IOCCG, NASA, ESA, EUMETSAT, etc.

Collaborators: D. Antoine (BOUSSOLE), B. Holben (NASA-GSFC), G. Zibordi (JRC-Italy), R. Frouin (for PAR), and many others.

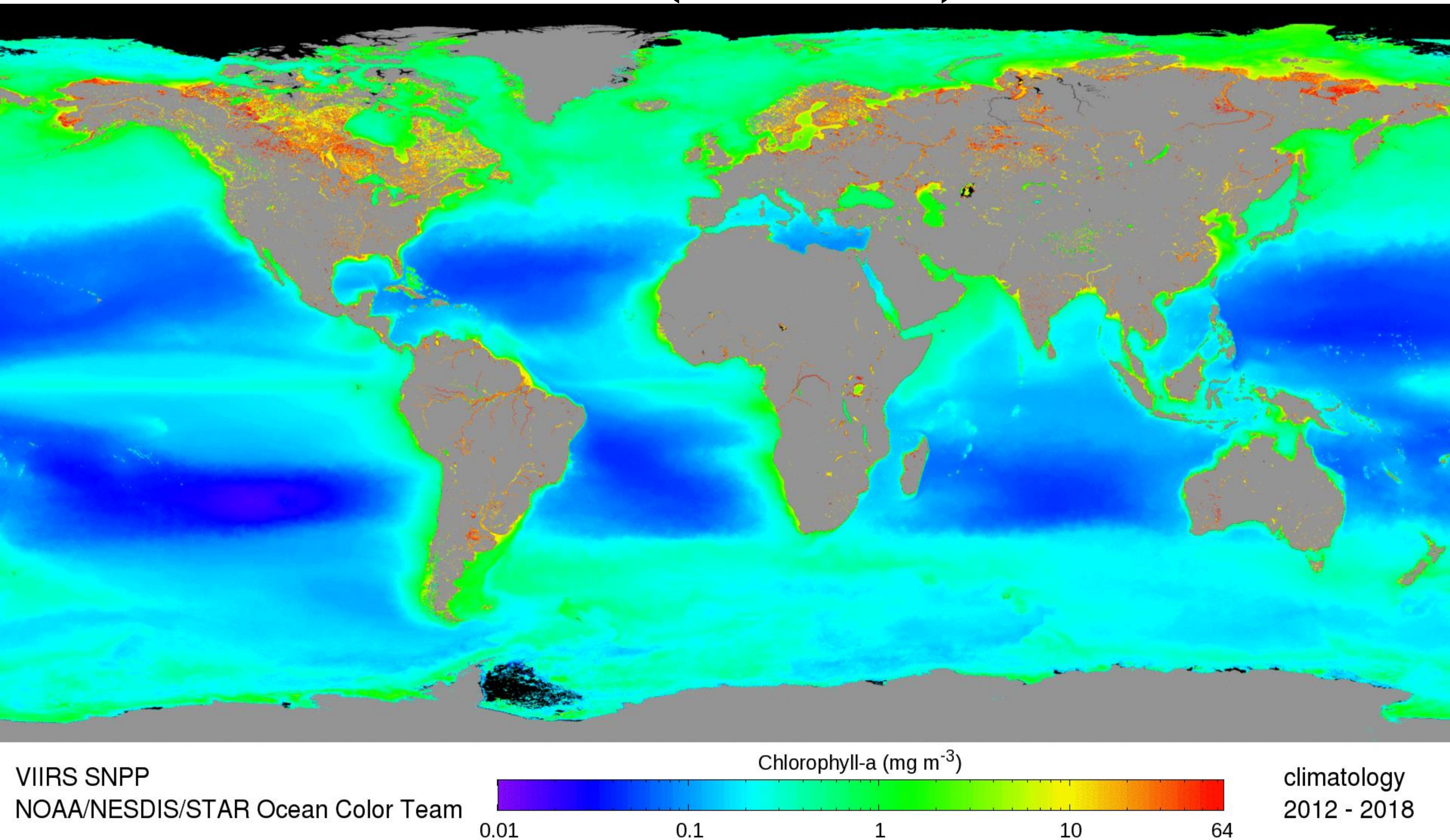
Summary of VIIRS Ocean Color EDR Products (Updates)

- **Inputs**:
  - VIIRS M1-M7, I1, and the **SWIR** M8, M10, and M11 bands SDR data
  - Terrain-corrected geo-location file
  - Ancillary meteorology and ozone data
- **Operational (Standard) Products** (**10**):
  - Normalized water-leaving radiance (nL_w's) at VIIRS visible bands M1-M5, and **I1 (638 nm)**
  - Chlorophyll-a (Chl-a) concentration
  - Diffuse attenuation coefficient for the downwelling spectral irradiance at the wavelength of 490 nm, K_d(490)
  - Diffuse attenuation coefficient of the downwelling photosynthetically available radiation (PAR), K_d(PAR)
  - **QA Score** for data quality ($nL_w(\lambda)$ spectra) (*Wei et al.*, 2016)
  - Level-2 quality flags
- **Experimental Products (29):**
  - Inherent Optical Properties (IOP-a, IOP-a_{ph}, IOP-a_{dg}, IOP-b_b, IOP-b_{bp}) at VIIRS M2 or other visible bands (M1-M5) from the Quasi-Analytical Algorithm (QAA) (*Lee et al.*, 2002)
  - Photosynthetically Available Radiation (PAR) (*R. Frouin*)
  - Chl-a from ocean color index (OCI) method (*Hu et al.*, 2012; *Wang and Son*, 2016)
  - Others, e.g., user specific products (e.g., **Chl-a anomaly** and **Chl-a anomaly ratio**)

➢ Data quality of ocean color EDR are extremely sensitive to the SDR quality. It requires **~0.1%** data accuracy (degradation, band-to-band accuracy…)!

VIIRS Climatology Ocean Color Product Image

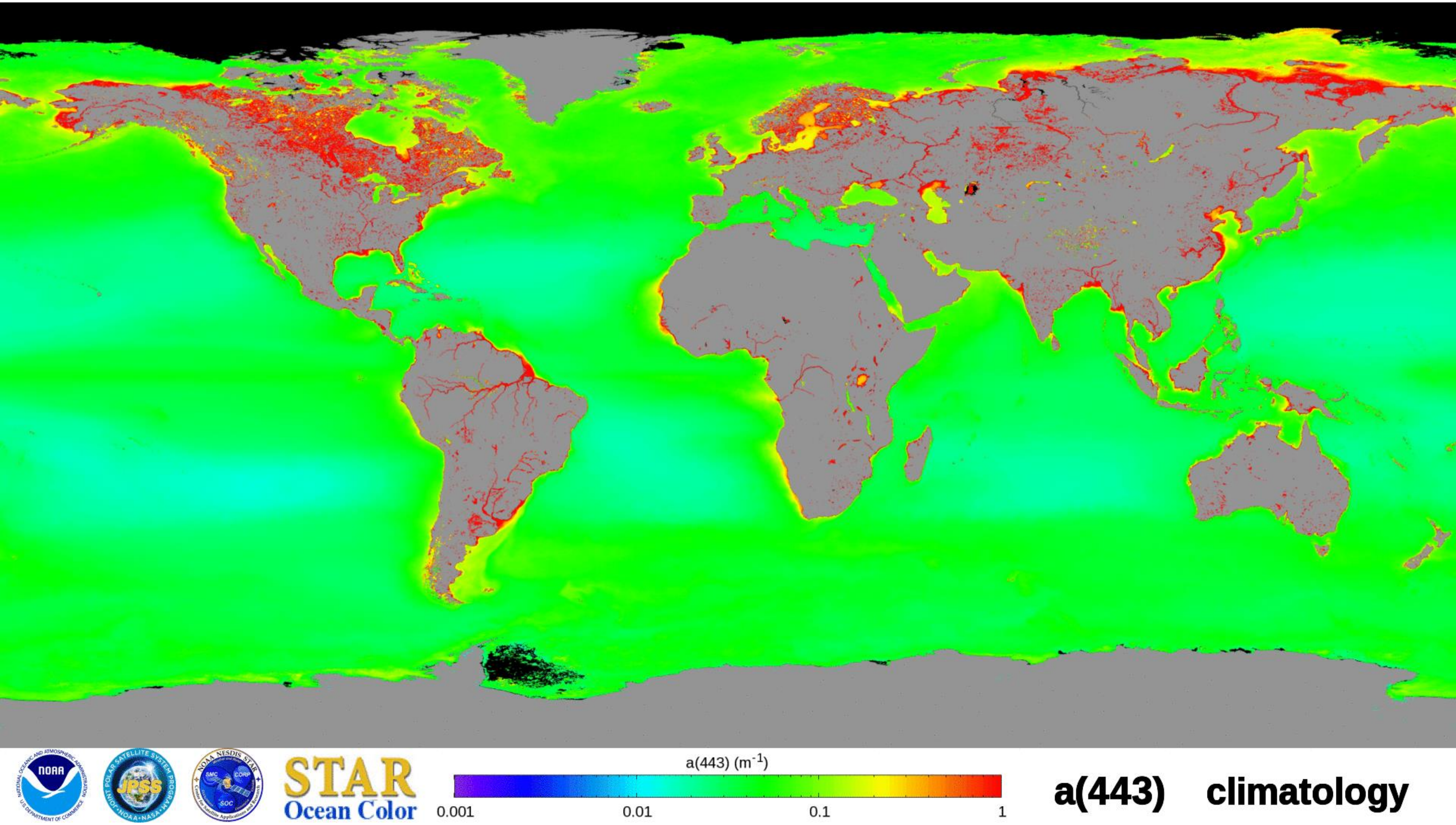
SNPP (2012–2018)



MSL12 with the NIR-SWIR data processing system is used for VIIRS

Menghua Wang, NOAA/NESDIS/STAR

Experimental Ocean Color Product Image (Selected)
SNPP (2012–2018)

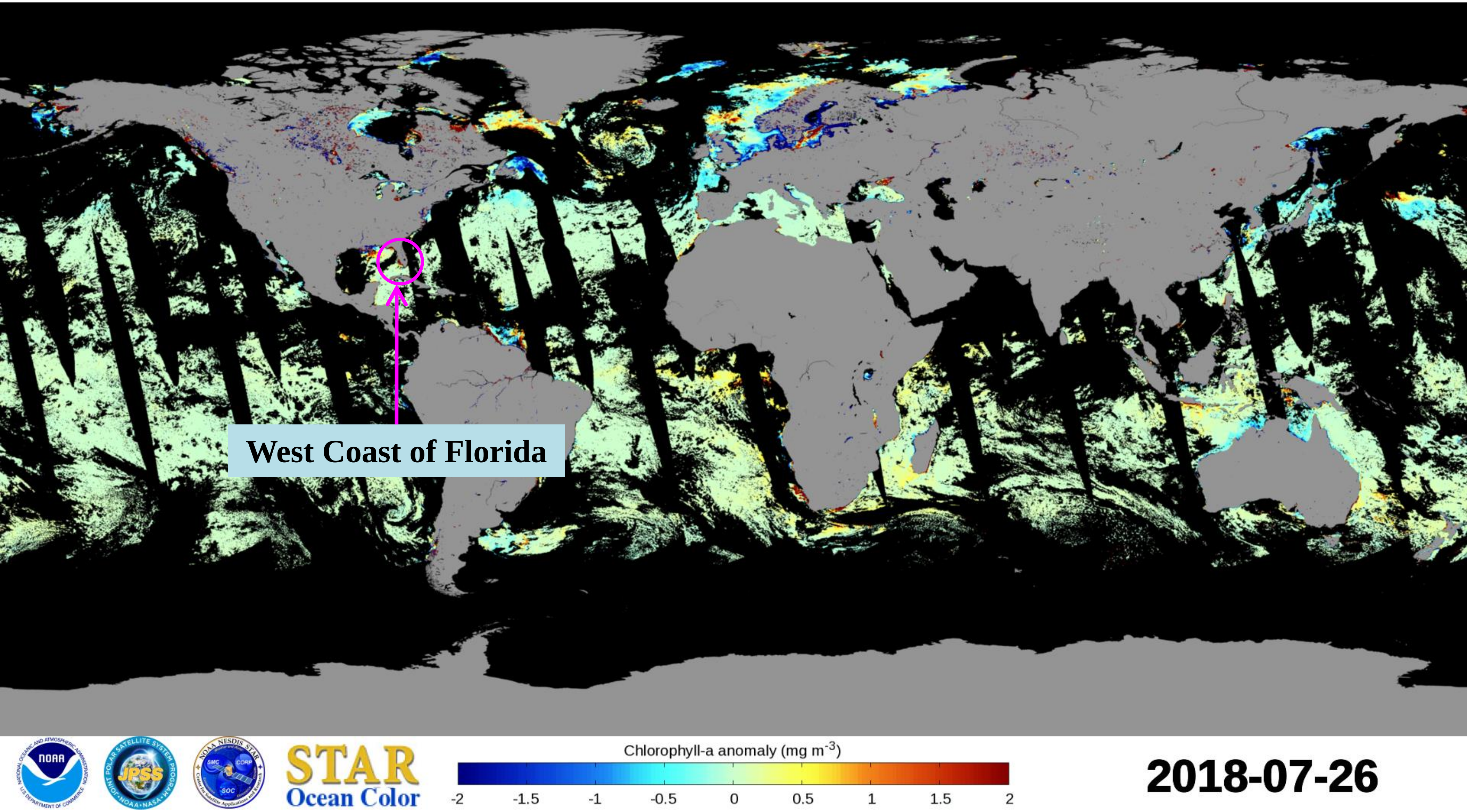


a(443) climatology

MSL12 with the NIR-SWIR data processing system is used for VIIRS

Menghua Wang, NOAA/NESDIS/STAR

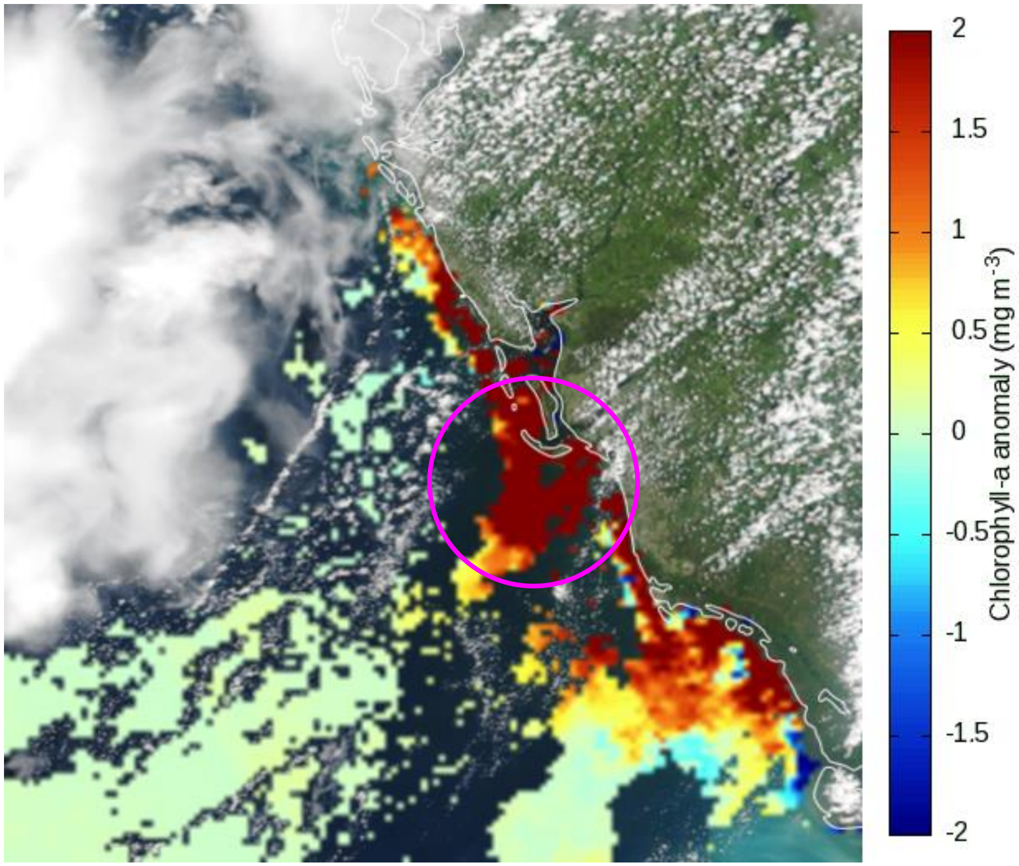
VIIRS-SNPP Chl-a Anomaly
(July 26, 2018)



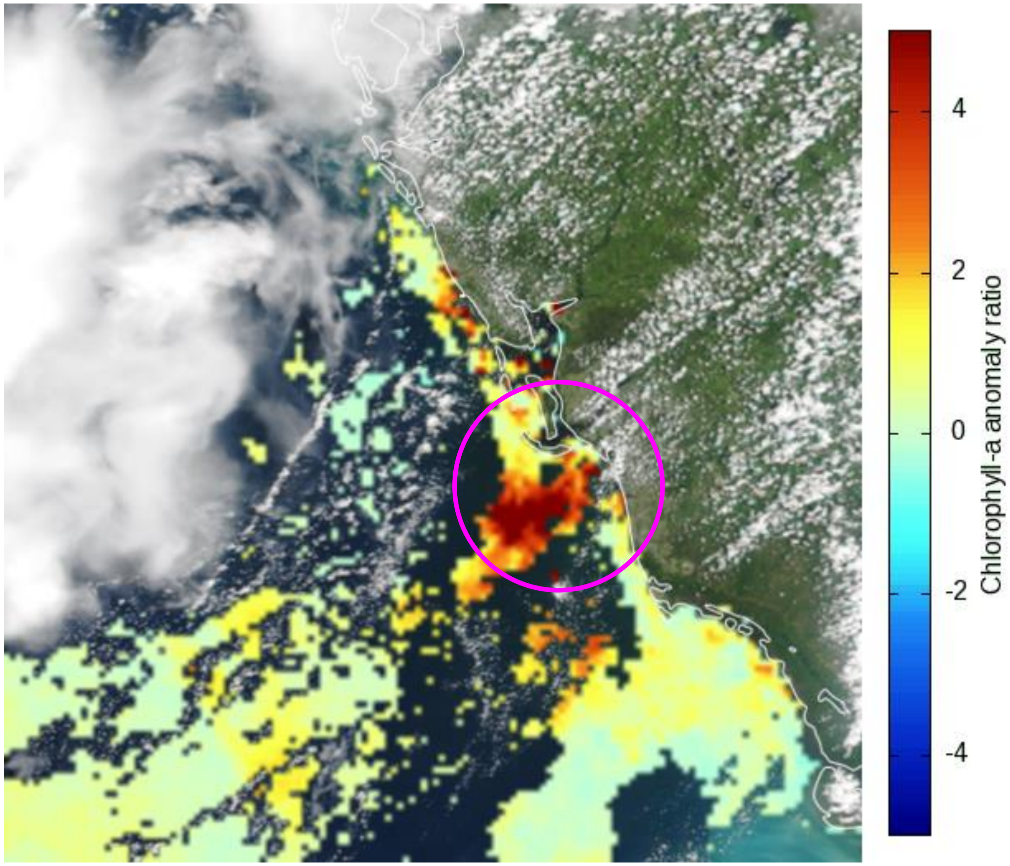
Global daily NRT Chl-a anomaly and anomaly ratio are *Routinely* produced

Menghua Wang, NOAA/NESDIS/STAR

High Chl-a Anomaly Linked to HAB in the West Coast of Florida (July 26, 2018)



Chl-a Anomaly



Chl-a Anomaly Ratio

Global NRT Chl-a anomaly and anomaly ratio are routinely produced

Menghua Wang, NOAA/NESDIS/STAR

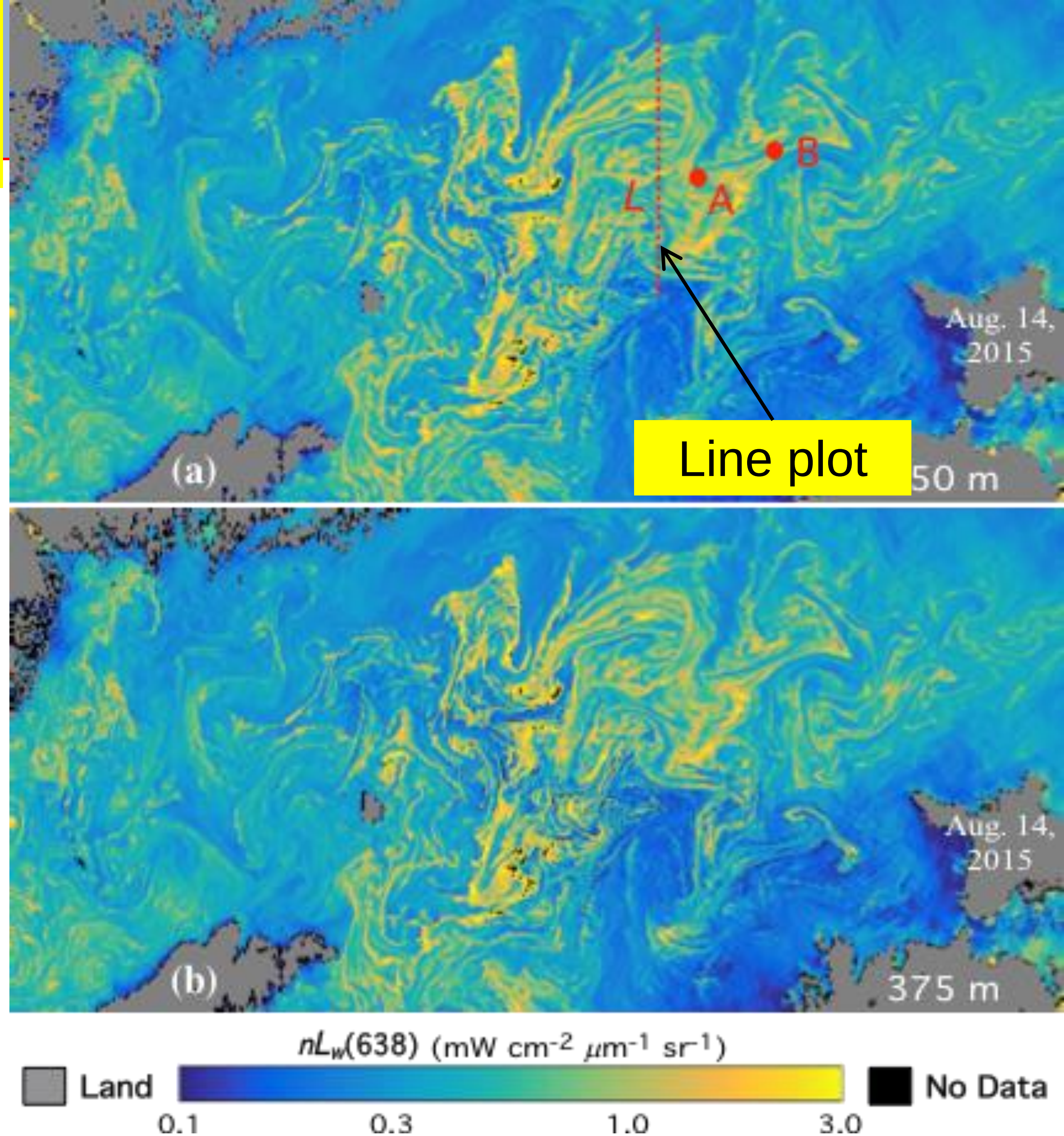
New VIIRS nL_w(638) with Imaging Bands

(Resolution at 375 m)

Example:

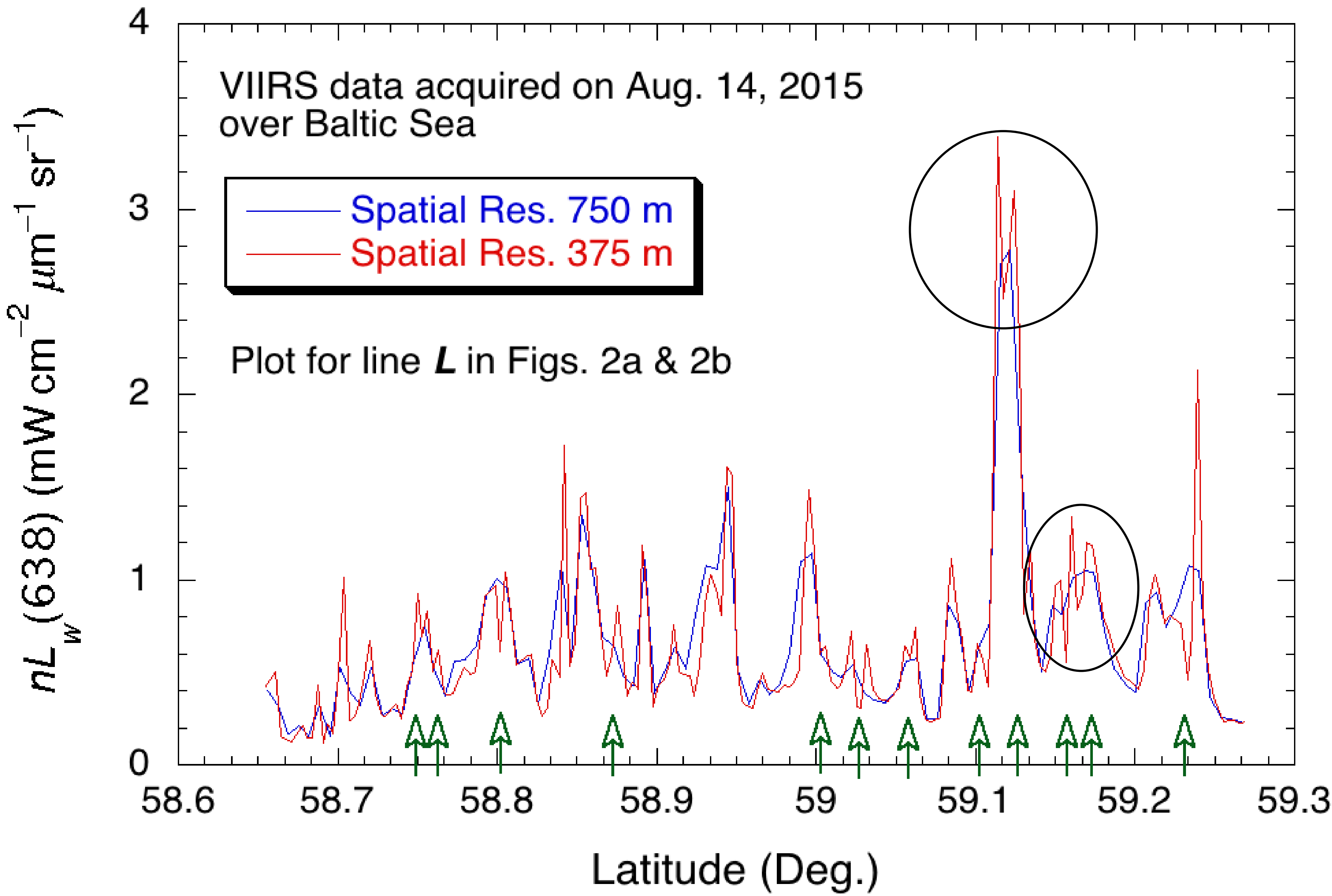
Algae Bloom in the Baltic Sea on August 14, 2015

One can see differences between two images for bloom size < ~500 m, showing high spatial resolution data providing more details for bloom spatial distribution/features

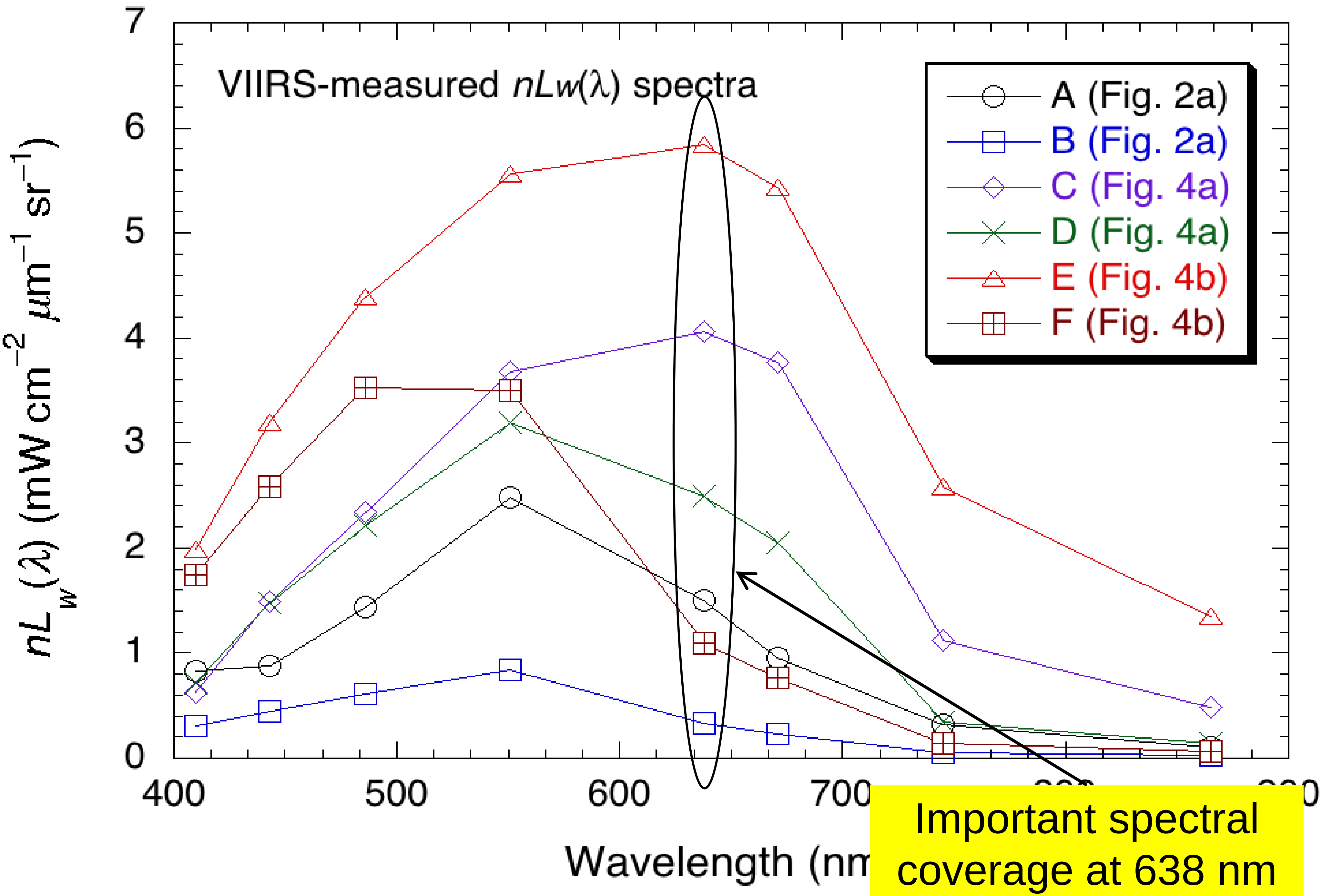


Wang, M. and L. Jiang (2017), "VIIRS-derived ocean color product using the imaging bands", *Remote Sen. Environ.*, **206,** 275–286, 2018. http://dx.doi.org/10.1016/j.rse.2017.12.042

More Detailed Algae Bloom Information Provided by VIIRS High Spatial Resolution (375 m) $nL_w(638)$ Data



Increased spectral coverage with VIIRS new $nL_w(638)$ data, providing important spectral information



Important spectral coverage at 638 nm

Two Data Streams for VIIRS Ocean Color EDR

To meet requirements from **All** users (operational, research, modeling, etc.), we have been routinely producing VIIRS global ocean color products in **two data streams**: Near-Real-Time (NRT) and Delayed Science-Quality data.

Attribute	Near-Real Time (NRT)	Delayed Science-Quality
Latency:	Best effort, as soon as possible (~12-24h)	Best effort, on 1-2-week delay
Processing System:	MSL12	MSL12
SDR:	IDPS Operational SDR	OC-Improved SDR
Ancillary Data:	Global Forecast System (GFS) Model	Science quality (assimilated; GDAS) from NCEP
Coverage:	May have gaps due to various issues	Complete global coverage
Processed by:	NOAA CoastWatch, transferring to OSPO (operational)	NOAA/STAR
Distributed by:	NOAA CoastWatch, OSPO	NOAA CoastWatch, NCEI
Archive Plans:	Yes, from OSPO to NCEI	Yes, from CoastWatch to NCEI
Full Mission Reprocessing:	No	Yes, every ~2-3 years or as needed

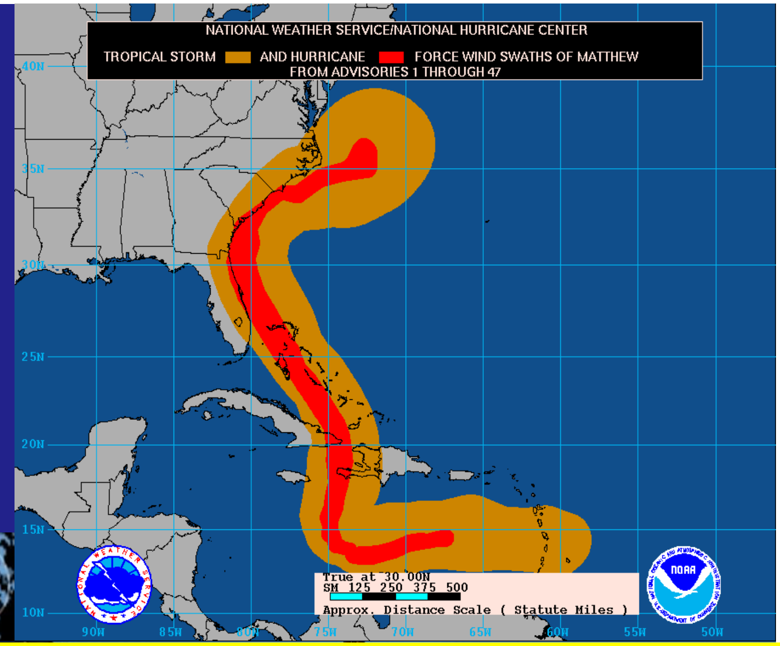
NOAA Capability of End-to-End Ocean Color Data Processing

- 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) using the Multi-Sensor Level-1 to Level-2 (MSL12) ocean color data processing.**
  - 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 (3 sites operation, added **Lake Erie site**), **NOAA dedicated Cal/Val cruises** (2014, 2015, 2016, **2018, 2019** …..,)
- **On-orbit instrument calibration (solar and lunar) for ocean color data processing:**
  - 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.
- **On-orbit vicarious calibration using MOBY in situ data:**
  - M. Wang, W. Shi, L. Jiang, and K. Voss, "NIR- and SWIR-based on-orbit vicarious calibrations for satellite ocean color sensors," *Opt. Express*, **24**, 20437-20453, 2016.
- **RDR (Level-0) to SDR (Level-1B) data processing** (efficient RDR to SDR 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.
- **Ocean Color Viewer (OCView)**—Online display and monitoring of ocean color product imagery.
- Ocean Color Data Analysis and Processing System (**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.
- **Work with users to meet their requirements.**

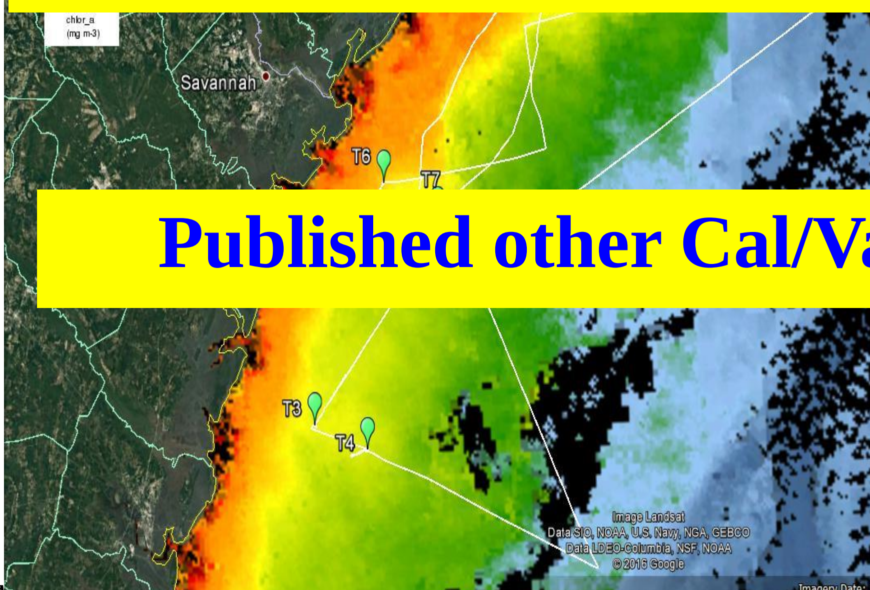
Dedicated VIIRS Cal/Val Cruise III
NOAA Ship *Nancy Foster*
5-18 October 2016

NOAA, NRL, NASA, USF, UMB, CUNY, lDEO, OSU

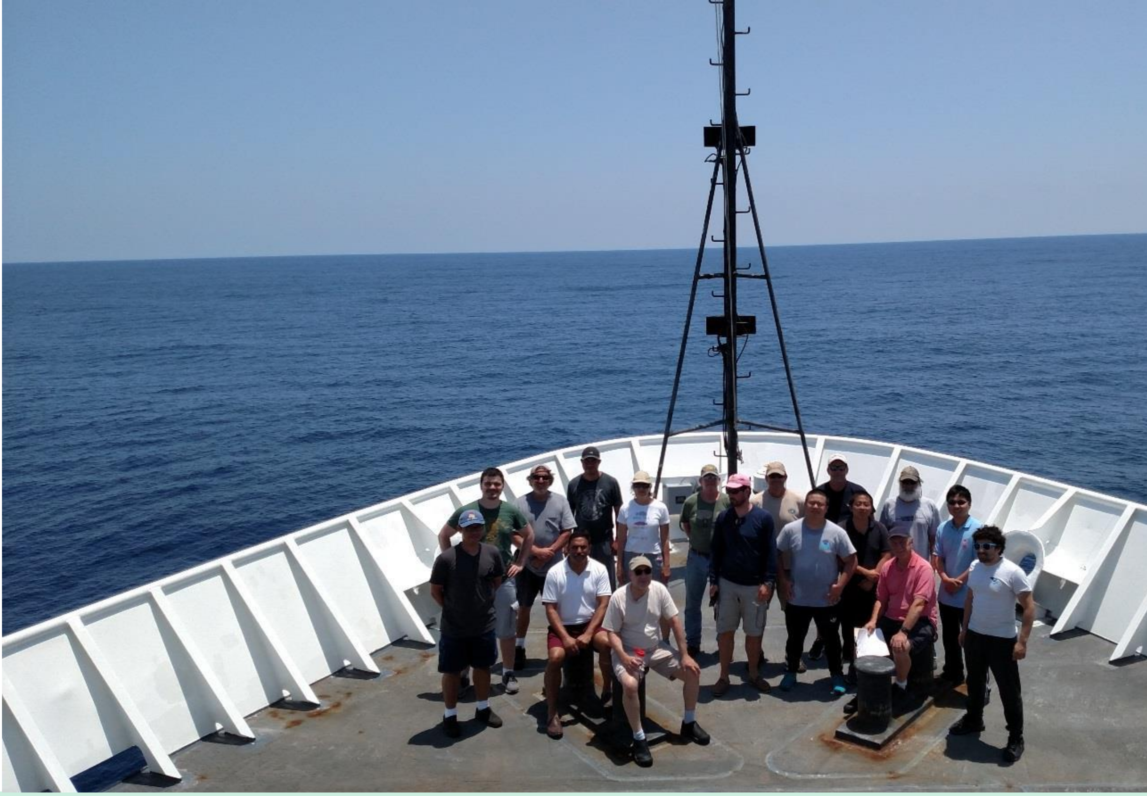
Measurements done just after Hurricane Matthew in the region **13-18 October 2016**.

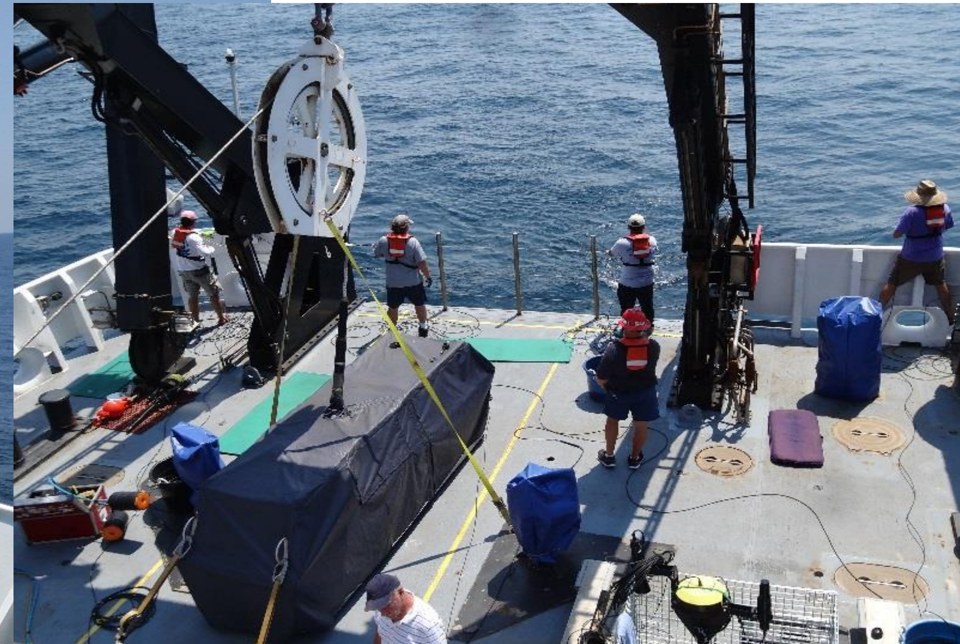


Ondrusek, M., V. P. Lance, M. Wang, E. Stengel, C. Kovach, R. Arnone, S. Ladner, W. Goode, A. Gilerson, S. Ahmed, A. El-Habashi, R. Foster, M. Ottaviani, J. I. Goes, H. Gomes, K. McKee, J. W. Kang, C. Hu, J. Cannizzaro, S. Sun, D. English, B. C. Johnson, Z. P. Lee, L. Zoffoli, J. Lin, N. Tufillaro, I. Lalovic, J. Nahorniak, C. O. Davis, M. Twardowski, N. Stockley, and K. J. Voss, "Report for Dedicated JPSS VIIRS Ocean Color Calibration/Validation Cruise October 2016," *NOAA Technical Report NESDIS 151*, V. P. Lance (ed.), NOAA National Environmental Satellite, Data, and Information Service, Silver Spring, Maryland, 2017. http://dx.doi.org/10.7289/V5/TR-NESDIS-151

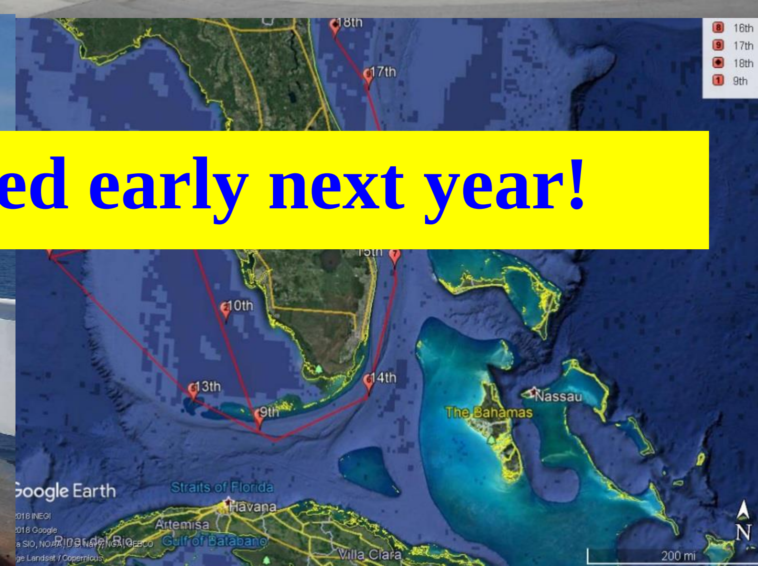


Published other Cal/Val cruise reports (2014 and 2015)





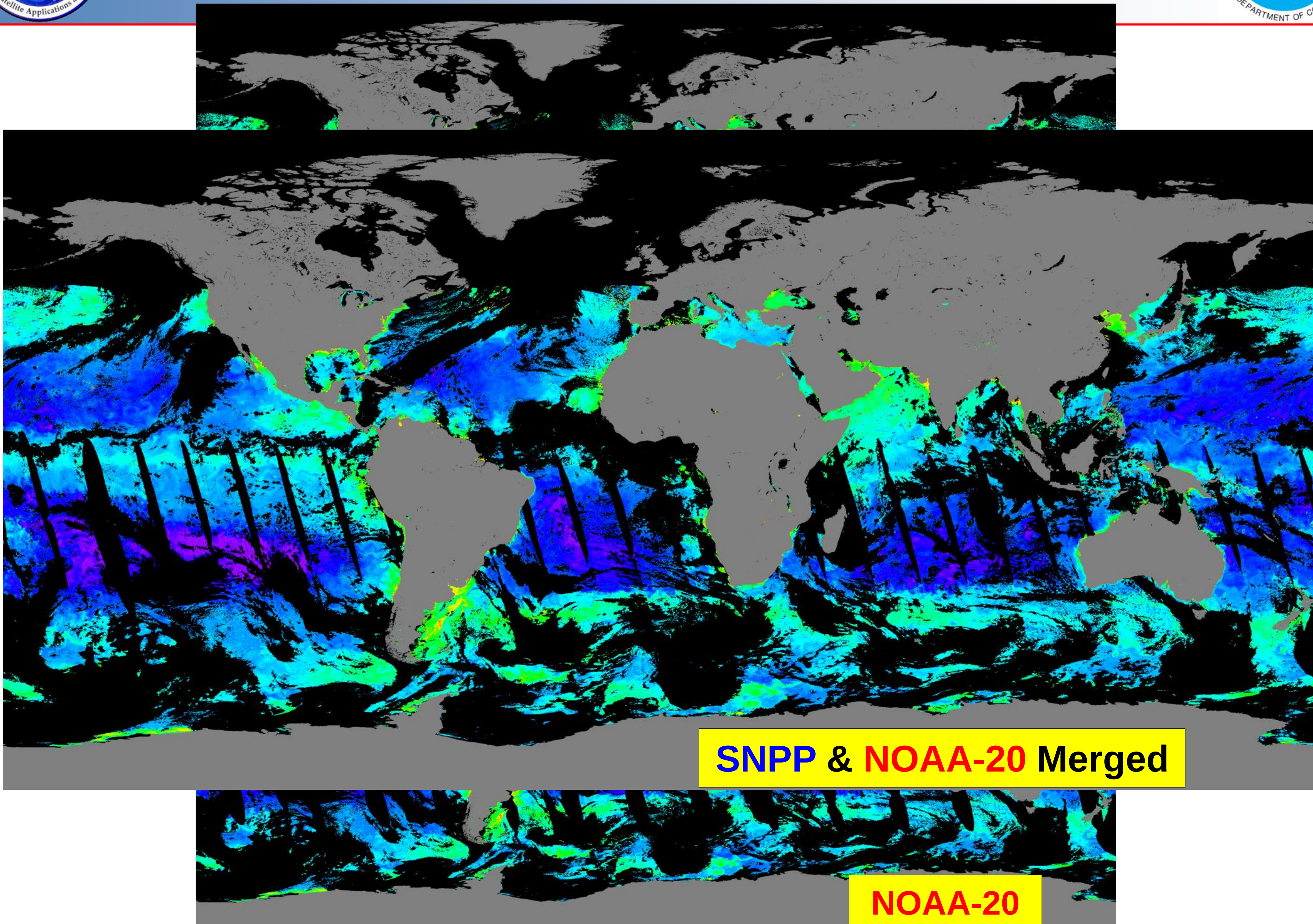
Dedicated VIIRS Cal/Val Cruise IV
NOAA Ship *Okeanos Explorer*
9-18 May 2018



Cal/Val cruise report will be published early next year!

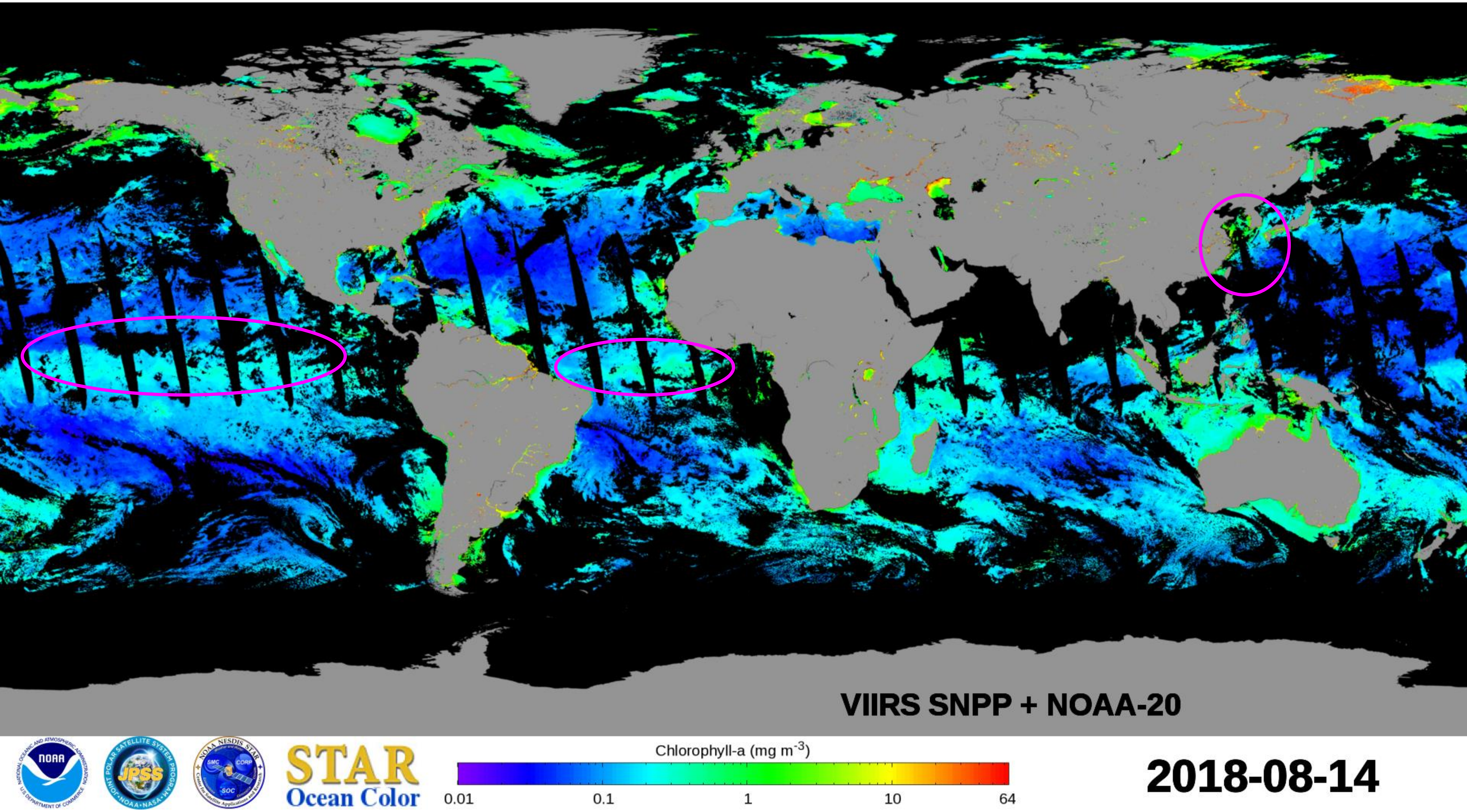
VIIRS-SNPP and NOAA-20 Chl-a Images

(January 6, 2018)



Menghua Wang, NOAA/NESDIS/STAR

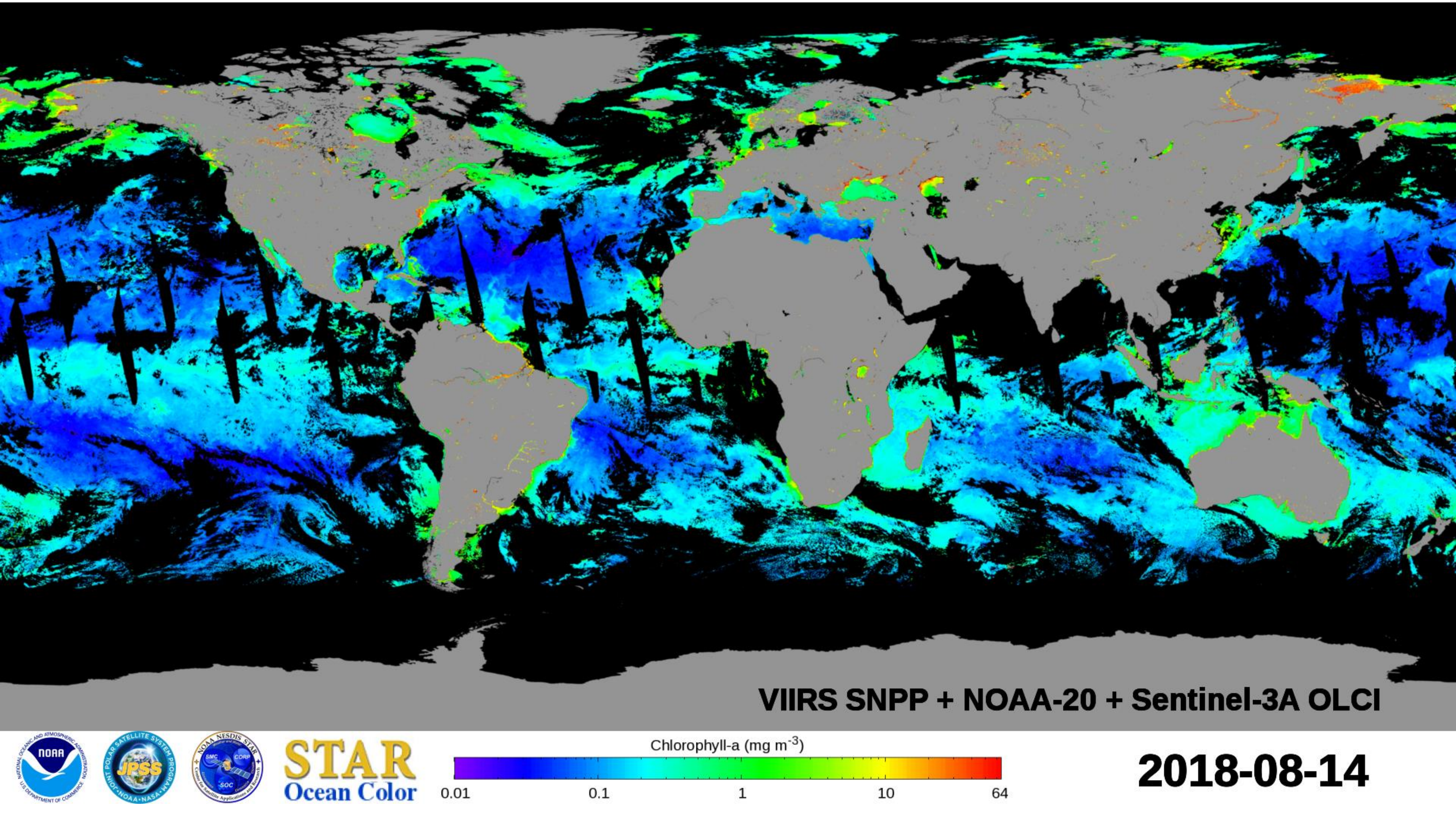
VIIRS SNPP and NOAA-20 Merged Global Chl-a
(August 14, 2018)



Global VIIRS merged Chl-a from SNPP/NOAA-20 are routinely produced

Menghua Wang, NOAA/NESDIS/STAR

VIIRS SNPP, NOAA-20, Sentinel-3A OLCI Merged Global Chl-a (August 14, 2018)



Ocean color data from the THREE sensors are all derived using the same MSL12!

Menghua Wang, NOAA/NESDIS/STAR

Matchup of

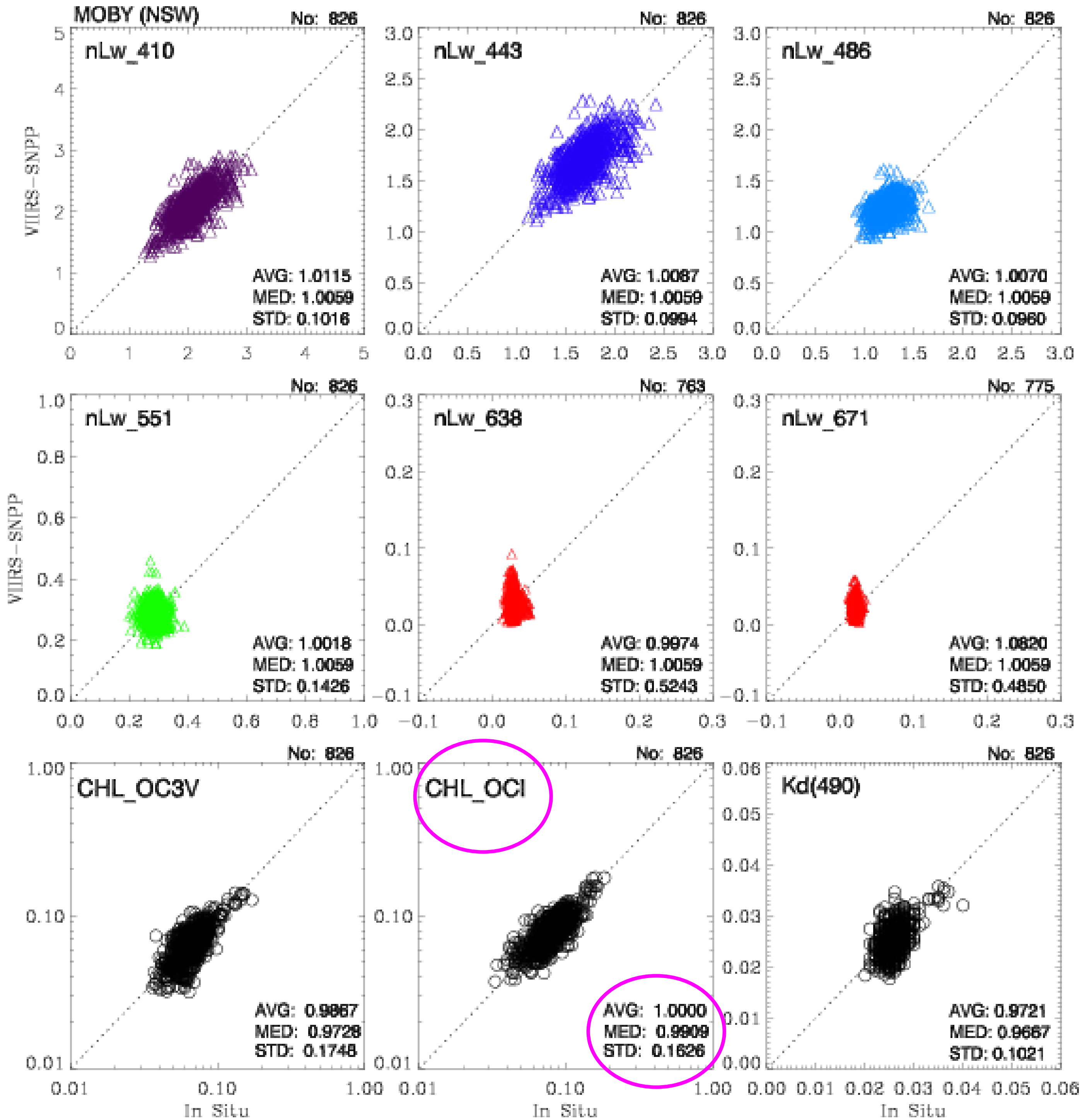
MOBY In Situ

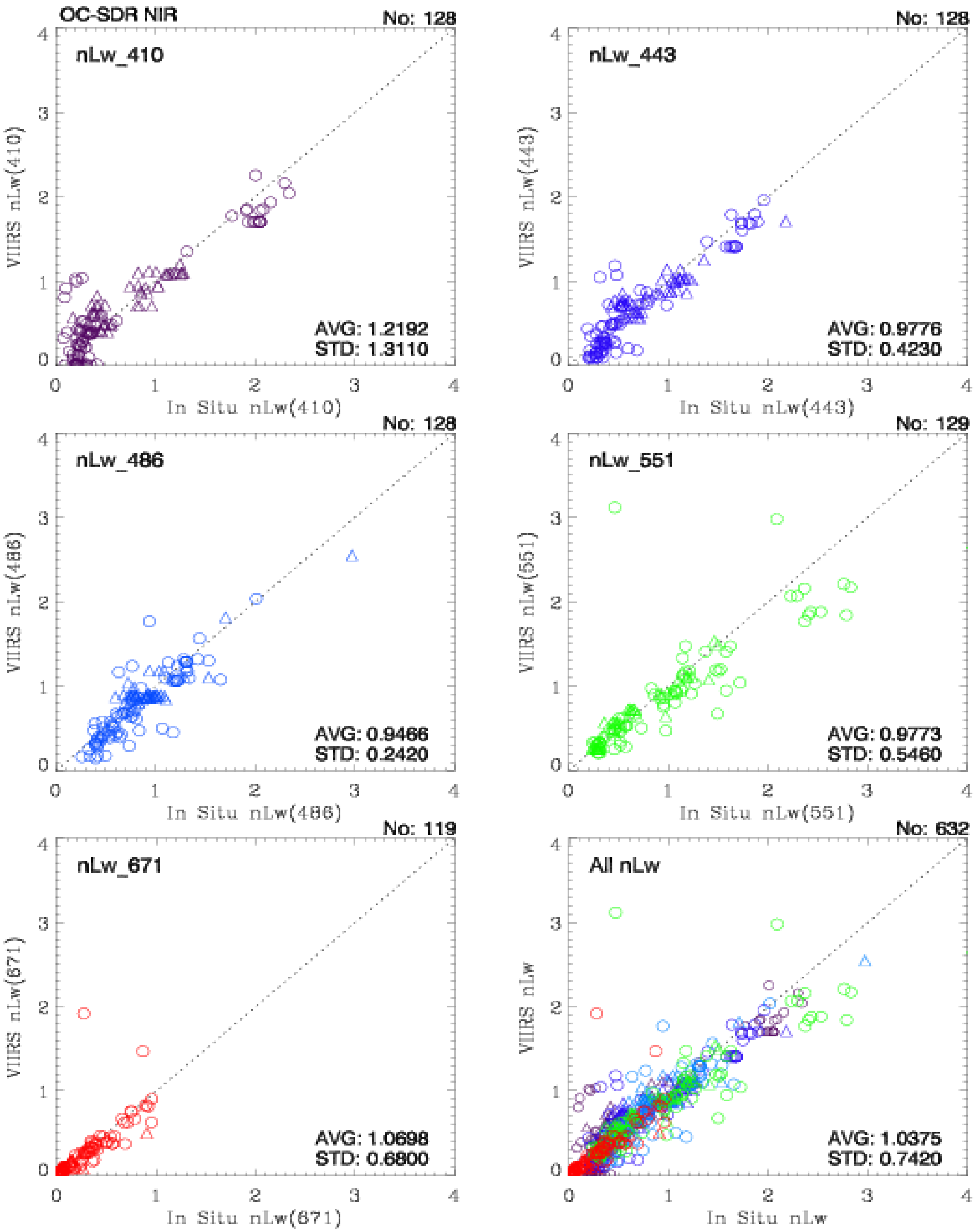
&

VIIRS-SNPP

(NIR-SWIR)

MOBY





Validation Effort

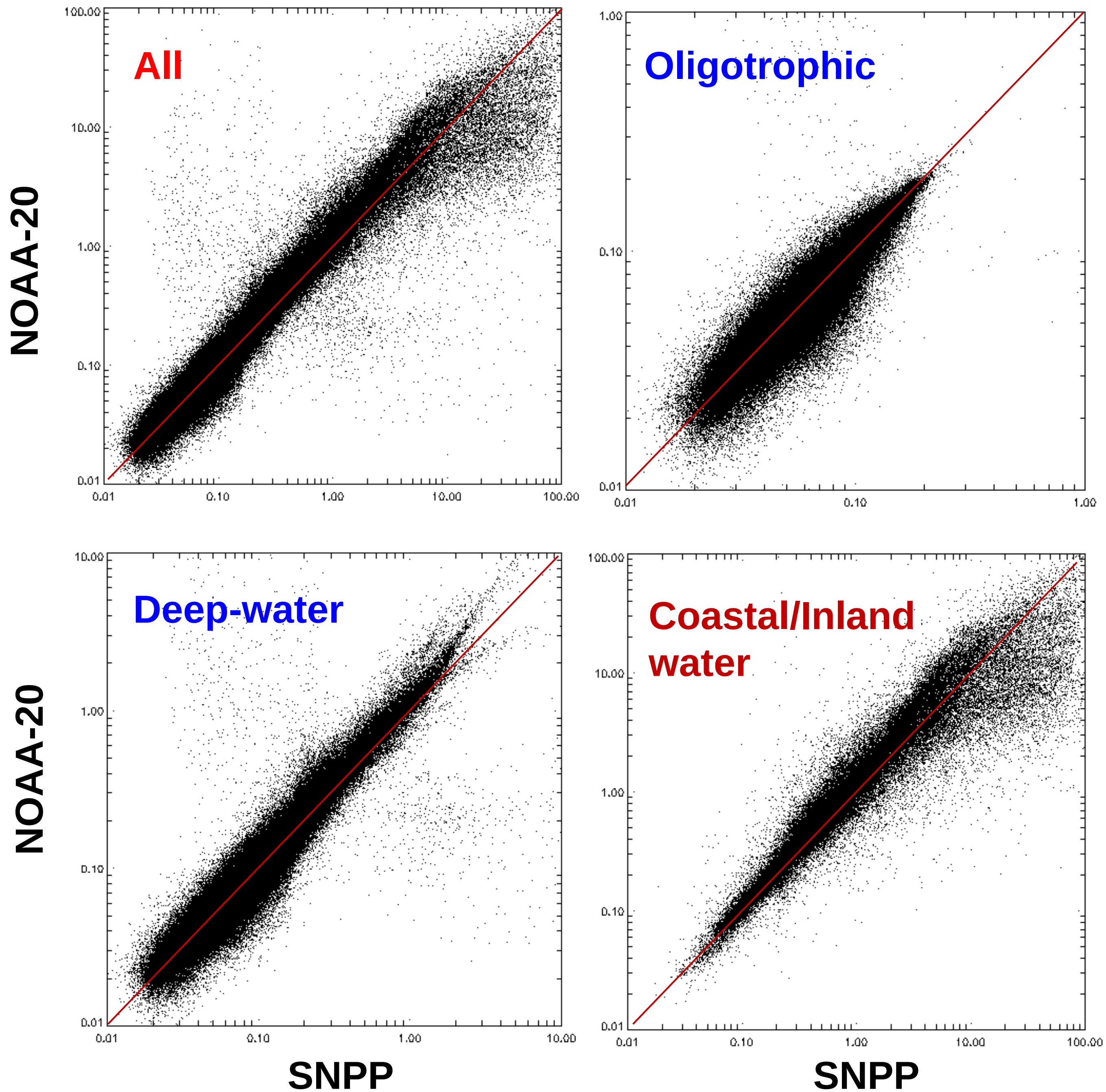
VIIRS-SNPP vs. In Situ Data

In Situ Data Sources:

R. Arnone (U. South Miss.)
C. Davis (Oregon State U.)
C. Hu (U. South Florida)
Z. Lee (U. Mass. Boston)
M. Ondrusek (NOAA/STAR)
G. Zibordi (JRC)

- ➢ Three dedicated Cal/Val cruises (2014-2016) and
- ➢ Various in situ measurement opportunities

VIIRS Global Chl-a Comparisons of NOAA-20 vs. SNPP (June 1, 2018)



VIIRS Ocean Color Side Meeting

Tuesday, 28 August 2018,

NCWCP 1st Floor Conference Room (A+B)

	Ocean Color - OC VIIRS EDR			Blue text = Update as needed
0915-1045		*Duration (min)*		
	915	30	Wang, Menghua	Welcome and Overview of MSL12 and Ocean Color EDR Team activities
	945	15	Sun, Junqiang	VIIRS OC calibration update
	1000	15	Liu, Xiaoming	New merged products
	1015	15	Mikelsons, K.	New capabilities of OCView--Online display and monitoring of ocean color product imagery
	1030	15	Zhaohui Cheng	Operational (near real-time) OC update
	1045	15	**BREAK (15 min)**	
1100 - 120	*Ocean Color - VIIRS EDR Cal/V*			*PI's should include status of publications related to VIIRS cruises*
	1100	15	Voss, K. (U. Miami)	Update on MOBY-Refresh and MOBY products
	1115	15	Ondrusek, M. (NOA	Cruise(s) Overview and Optical in situ Validation
	1130	15	Arnone, R. (Stennis)	Evaluation of VIIRS ocean color products and development of enhanced ocean products and applications
	1145	15	Gilerson, A. (CCNY)	CCNY VIIRS validations at the Long Island Sound Coastal Observatory (LISCO) and on cruises
1200-131	**LUNCH (75 min)**			
1315 - 14	*Ocean Color - VIIRS EDR Cal/V*			*PI's should include status of publications related to VIIRS cruises*
	1315	15	Hu, C. (USF)	Evaluation of VIIRS performance in coastal waters and in its capacity to detect dark water and harmful algal blooms
	1330	15	Lee, Z. (UMB)	Towards consistent VIIRS AOP and IOP products
	1345	15	Tufillaro, N. (OSU); Jones, B./Ragan, M. (USC)	Validation of VIIRS ocean color products for the US West Coast
	1400	15	Carol Johnson (NIST)	NIST update
	1415	15	Joaquim Goes (LDEO)	Phytoplankton physiology/functional types
1430-151	*Ocean Color- OC VIIRS in situ program*			
	1430	20	Lance, V-	Cruise reports, Cruise data sharing policy at NOAA; NCEI archiving of cruise data (by cruise); in situ Ocean Color Optical Database at NOAA
	1450	25	Facilitator: Ondrusek, M. (NOAA/STAR)	Group Discussion: May 2019 (FY19) cruise planning/ lessons learned from previous cruises.
1515-153	**BREAK (15 min)**			
1530 - 17	*Ocean Color - Users, New Applications, Data Distribution*			
	1530		Daniel Tong, OAR/ARL	Isoprene emissions from VIIRS ocean color informs air quality forecasts
	1545	15	Eric Geiger, Coral Reef Watch	Coral Reef Watch use and applications for ocean color data products
	1600	15	Yongsheng Zheng	NCEI Scientific Stewardship on NOAA MSL12 Ocean Color EDR Products
	1615	15	Lance, V. (CoastWatch)	Ocean Color Data distribution through NOAA CoastWatch/OceanWatch and NCEI
	1630	30	Menghua Wang	Questions, discussion, plans for next year
1700	**ADJOURN SJASM**			

Conclusions

- VIIRS-SNPP and VIIRS-NOAA-20 global ocean color products have been routinely produced using the **NIR**-, **SWIR**-, and **NIR-SWIR**-based atmospheric correction algorithms, providing necessary satellite data for various applications in open oceans, coastal and inland waters, as well as for further improving data quality.
- Our evaluation results show that VIIRS-SNPP can produce high quality ocean color data over global open oceans and reasonable data quality over coastal and inland waters.
- VIIRS-NOAA-20 can also produce reasonable ocean color data quality, and ocean color results are generally comparable to those from VIIRS-SNPP.
- However, there are still some issues/problems, including NOAA-20 SDR calibration problems that significantly impact VIIRS ocean color data quality.
- VIIRS-NOAA-20 mission-long ocean color data **reprocessing** is current underway due to IDPS SDR calibration errors and error in early polarization correction.
- Significant effort is still needed for improving ocean color data quality over turbid coastal and inland waters.

VIIRS Images and Cal/Val:
https://www.star.nesdis.noaa.gov/sod/mecb/color/

VIIRS Ocean Color Data:
https://coastwatch.noaa.gov/

Thank You!

VIIRS Marine Isoprene:
From Research to Air Quality Forecasting Operation

Daniel Tong and Pius Lee
NOAA Air Resources Laboratory (ARL), College Park, MD

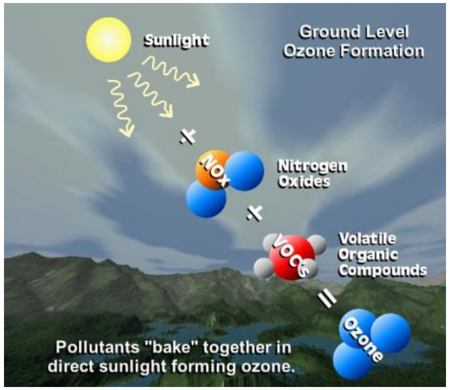
Menghua Wang and Xiaoming Liu
NOAA Center for Satellite Applications and Research (STAR), College Park, MD

Acknowledge: NOAA JPSS Program for funding support;

What is isoprene

Isoprene (CH2=CH-C(CH3)=CH2) is a biogenic hydrocarbon emitted by trees, grasses and ocean phytoplankton.

- **Purpose of emission:** combat abiotic stresses;
- **Ozone formation:**

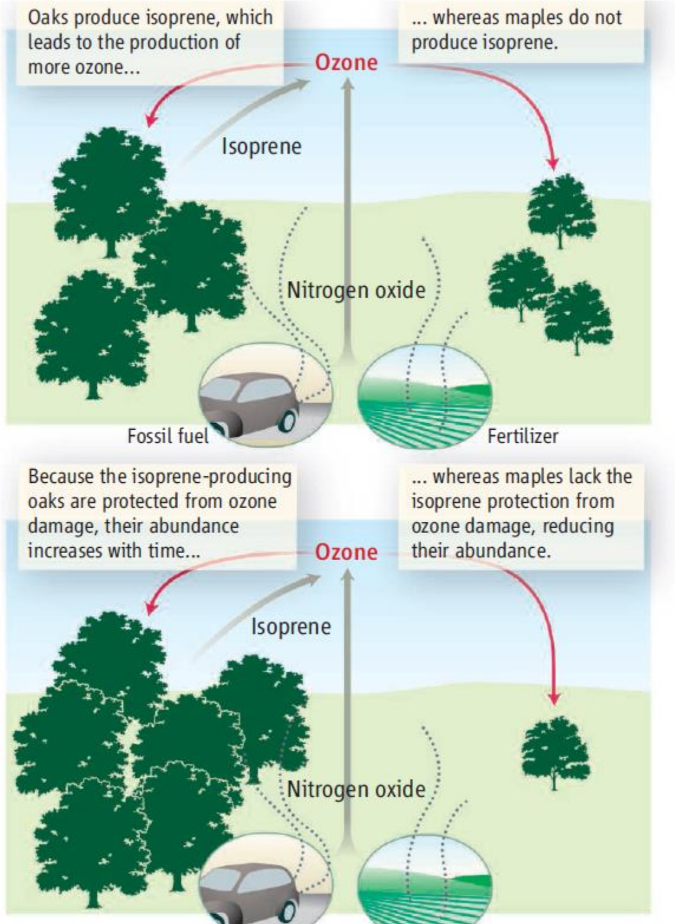


- **Aerosol formation:**

$$\mathrm{VOC} + \mathrm{OX} \rightarrow \sum_{i=1}^{N} \alpha_i \times P_i \rightarrow \mathrm{SOA}$$

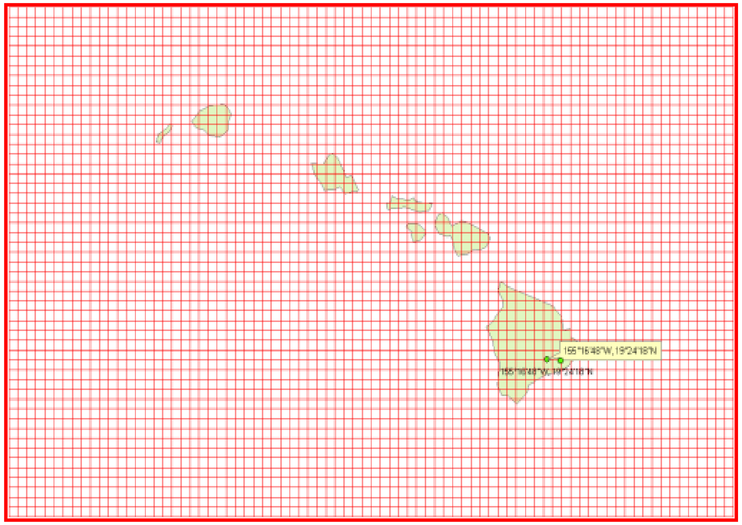
- **Cloud formation:** Cloud Condensation Nuclei (CCN);

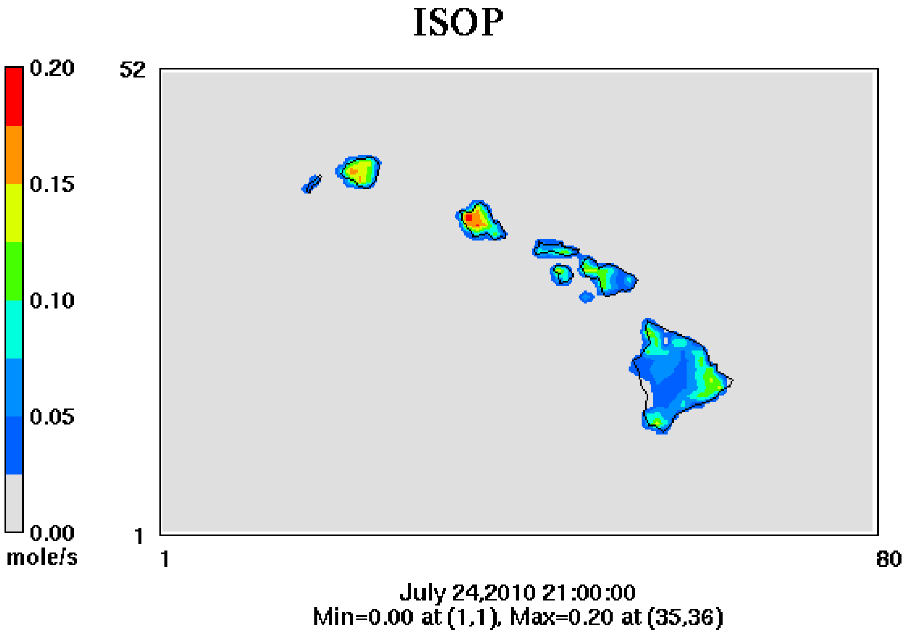
Ozone, Aerosol, cloudiness all at the central stage of climate change debate



(Lerdau, *Science*, 2007)

National Air Quality Forecast over Hawaii

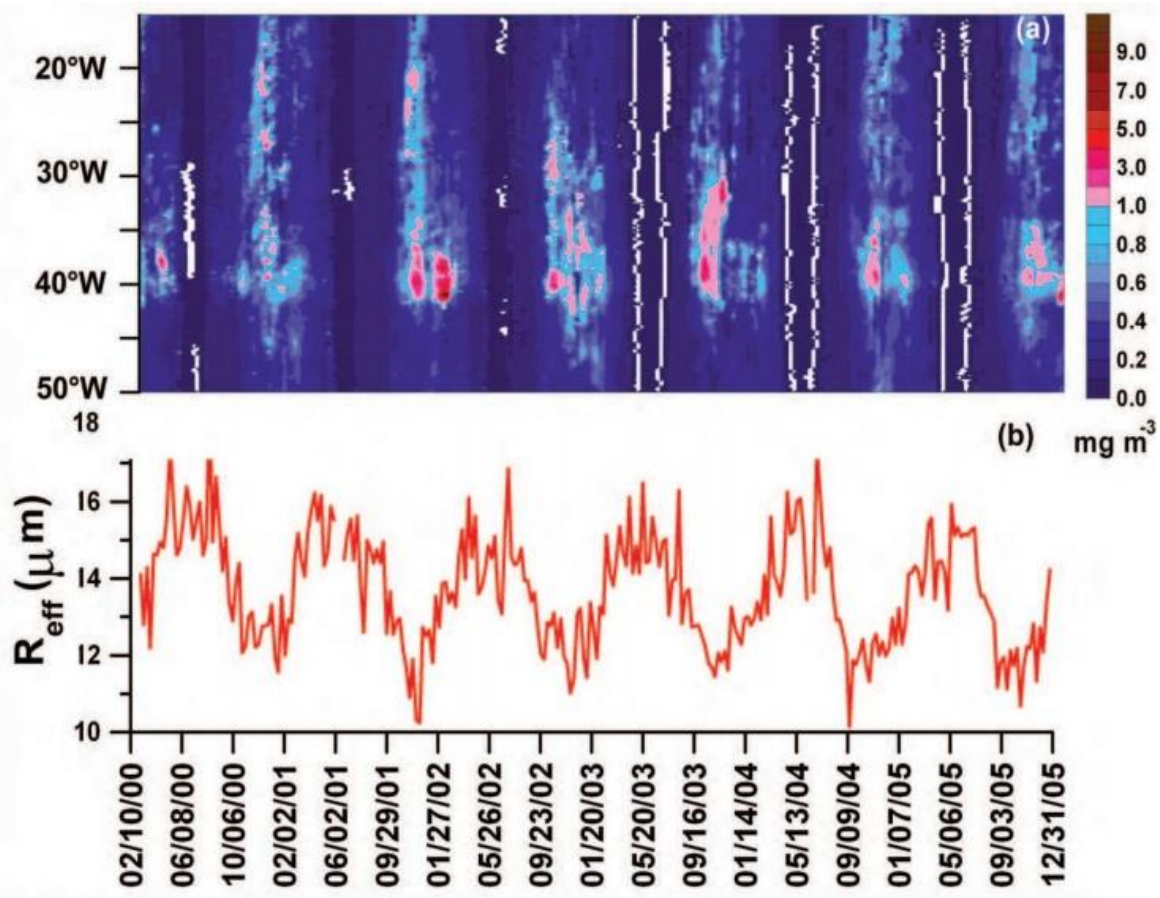




A suite of reactive gases and aerosols emitted from the Ocean:

- **Isoprene;**
- **Dimethyl Sulfide (DMS);**
- **Organic Aerosols;**

Algae Bloom and Ocean Cloudiness



(Meskhidze and Nenes, Science, 2006)

JPSS marine Isoprene algorithm (V1.0)

- **Built upon several pioneering works:**

$$F = a \times [Chl] \times \sum_{i=1}^{N} (EF_i \times f_i) \times H_{max} \times \gamma$$

JPSS Products Used:

- **[Chl-a]**
- **Kd490**
- **PAR**

Euphotic zone height (Gantt et al., 2009)

$$H\max = (-\ln(\frac{2.5}{I_0})/K_{490})$$

I_0 – ground radiation; K490 – defuse attenuation coefficient in water

Phytoplankton Functional Types (PFTs) (Arnold et al., 2009)

Determine emission factor (EF) and abundance (f);
No data available from JPSS, using SeaWiFS climatological data

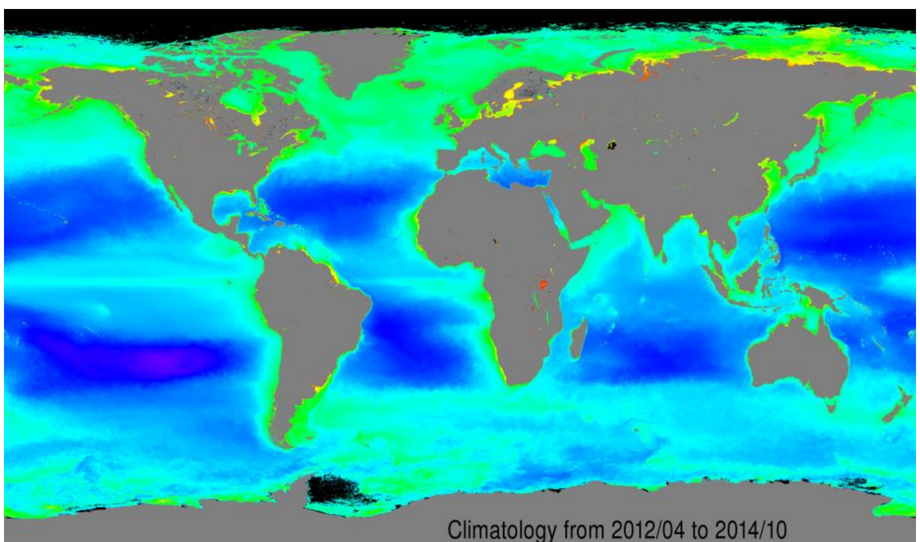
Chlorophyll-a and $K_d(490)$

- **Sensor/Satellite**: Visible Infrared Imaging Radiometer Suite (VIIRS) on SNPP
- **Ocean Color Data Processing:**

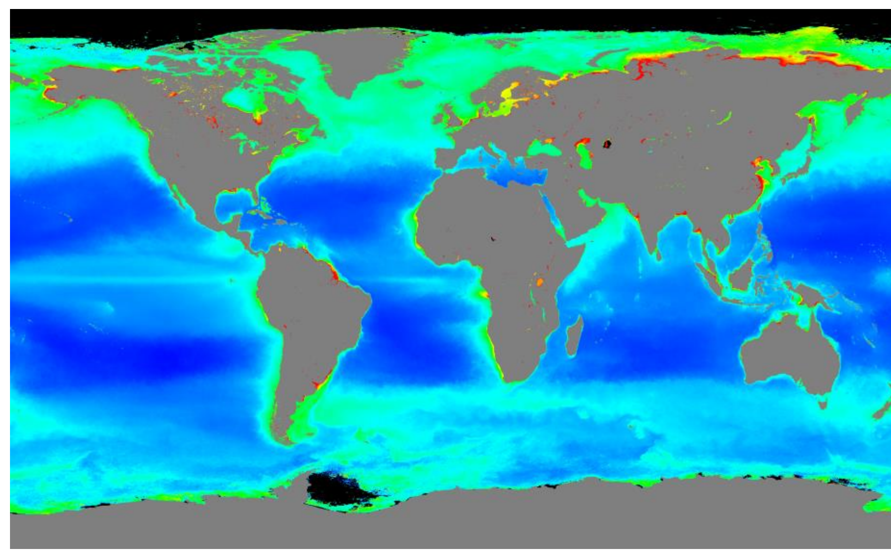
  - Multi-Sensor Level-1 to Level-2 (MSL12) is used for VIIRS ocean color data processing

  - Routine ocean color data production from SDR (Level-1B) to ocean color EDR (Level-2), and to global Level-3 data, including nL_w, chlorophyll-a, and $K_d(490)$.

  - Level 3: Products are mapped to the CoastWatch geographic regions
- **Algorithms (Ocean Color EDR Team):**
  - Chlorophyll-a concentration: VIIRS OC3 algorithm
  - Diffuse attenuation coefficient at 490 nm $K_d(490)$: *Wang et al.* (2009) algorithm

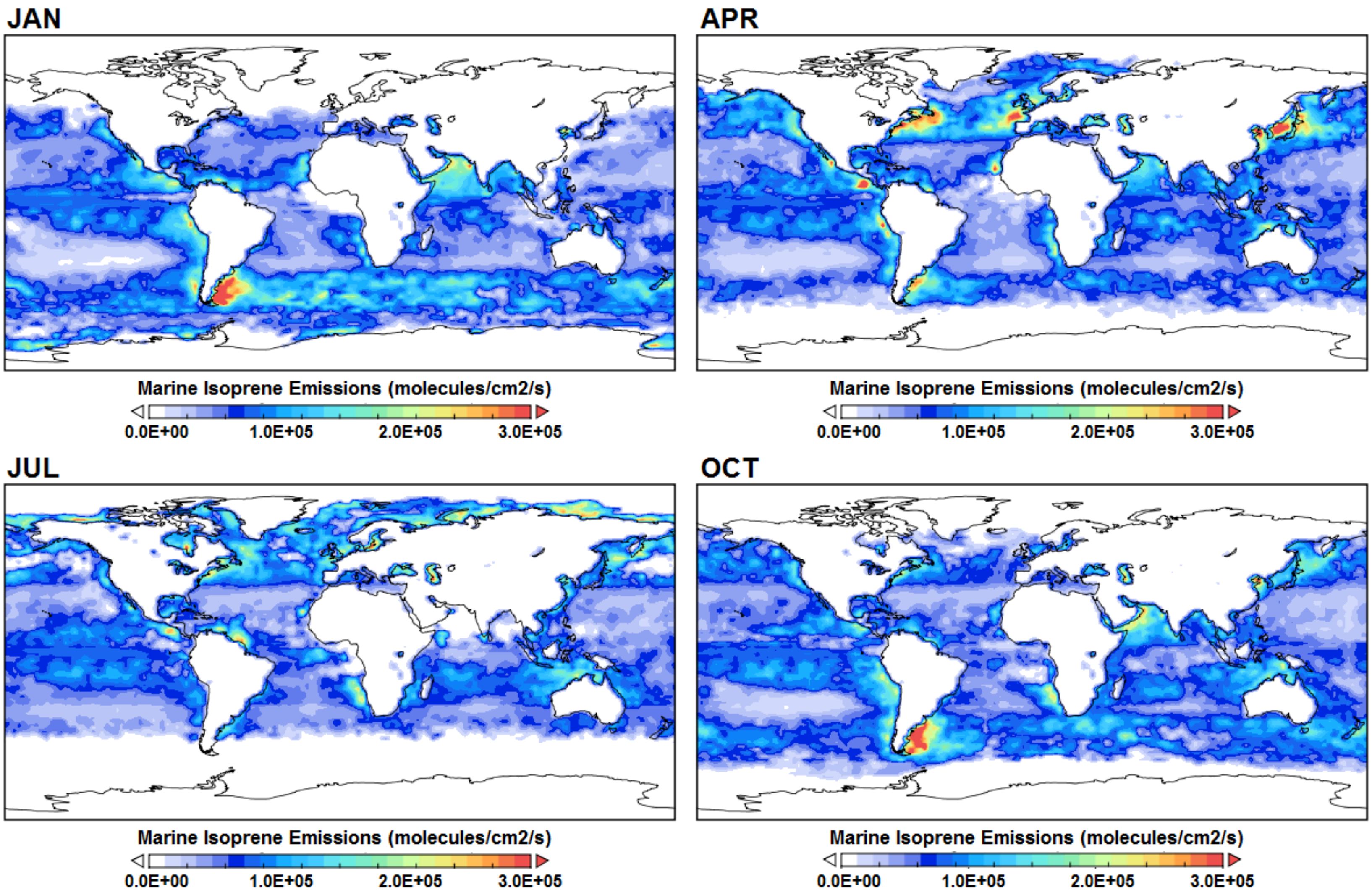


Chlorophyll-a



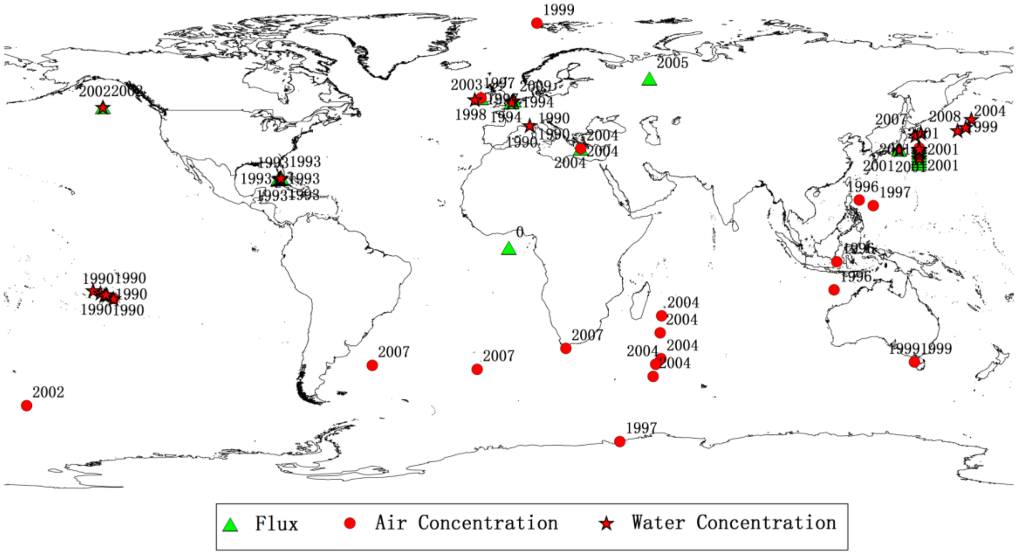
$K_d(490)$

Global Distribution of Marine Isoprene



Isoprene Observations and Reprocessing

Issue: Some data can not be directly used for product validation.
Reprocessing Approach: Air-sea mass transfer.



Convert seawater conc into flux:

$$E_{iso} = K_{AS} * (C_W - H * C_A)$$

k$_{AS}$ – exchange coeff.;

C$_W$ – isop. conc. in water

C$_A$ – isop. conc. in the air

H – Henry's law constant;

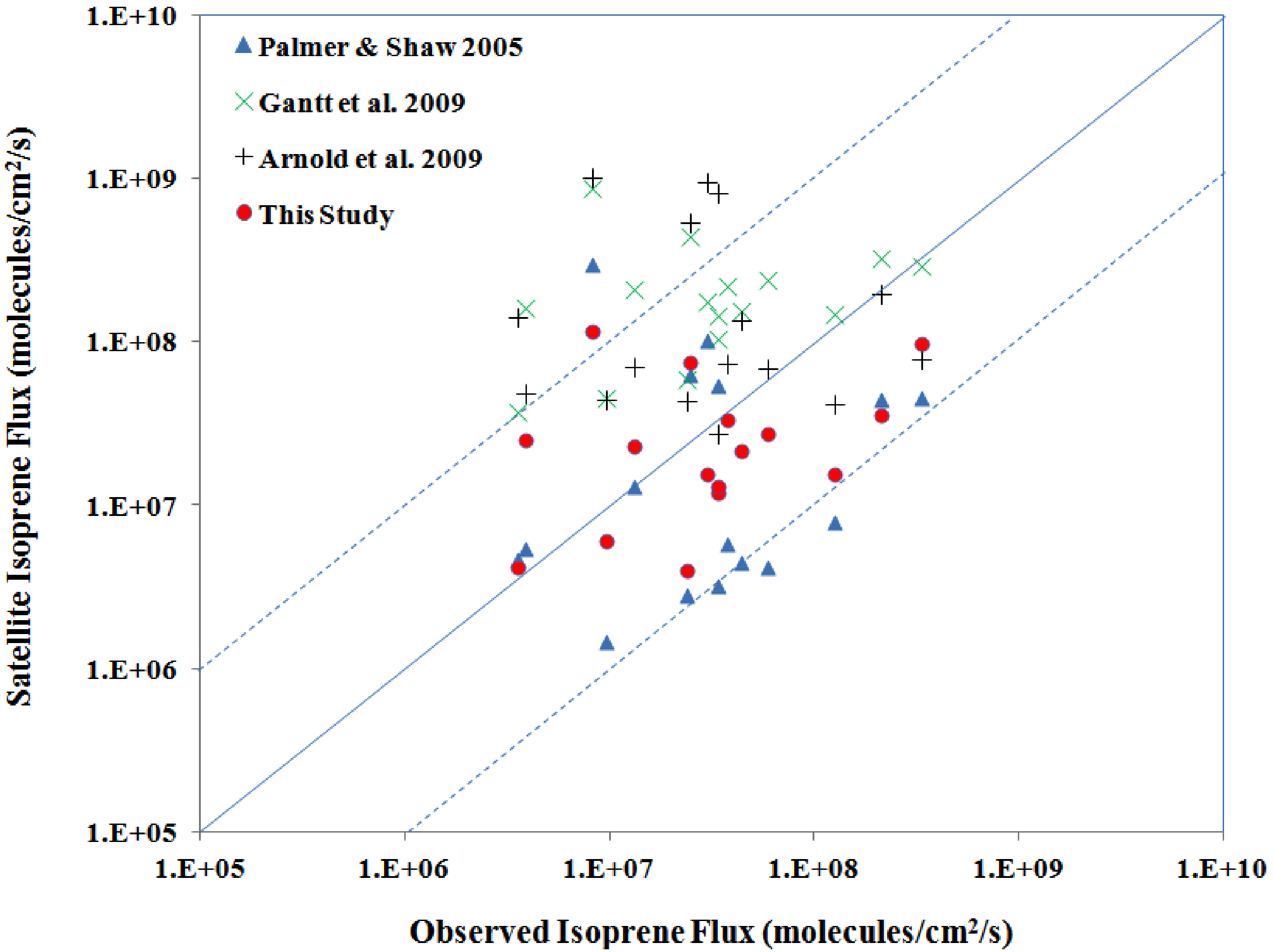
Calculate exchange coeff based on wind speed:

$$K_{AS} = 0.31 * U^2 ((391315 - 16213T + 2.67T^2 - 0.012T^3)/660)^{-0.5}$$

U – surface wind speed; **T** – Sea surface Temperature

(Wanninkhof et al., 2004)

Isoprene Product Validation (Cont.)

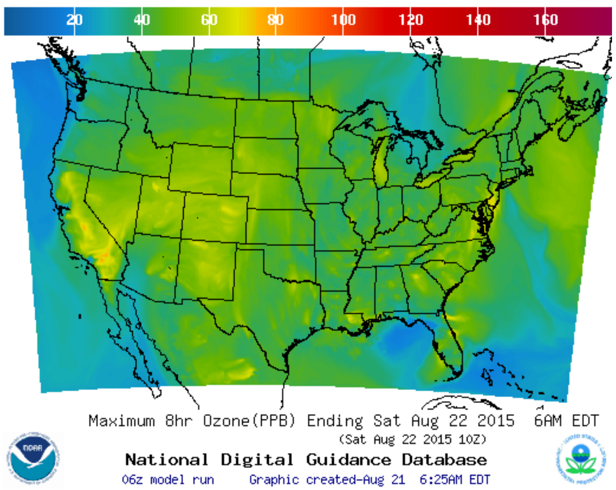


NOAA National Air Quality Forecast Capability (NAQFC)

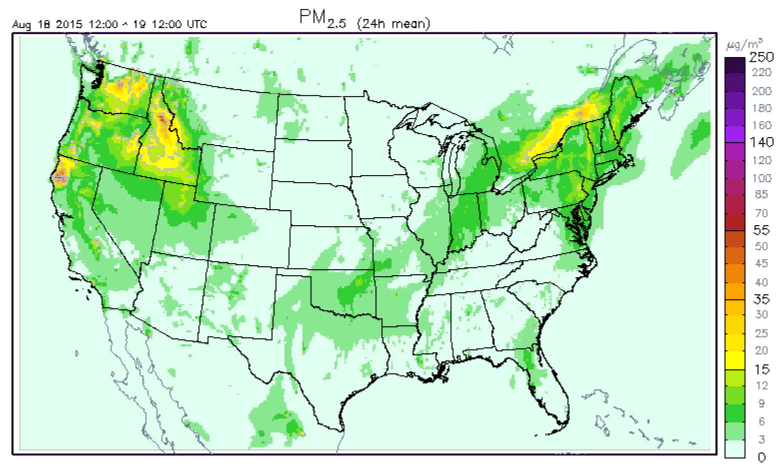
- **Developed by OAR/Air Resources Laboratory; Operated by National Weather Service (NWS) (PM: I. Stajner).**

- **Provides national numeric air quality guidance for ozone (operational product) and $PM_{2.5}$ (particulate matter with diameter < 2.5 μm);**

O_3 Forecasting



$PM_{2.5}$ Forecasting

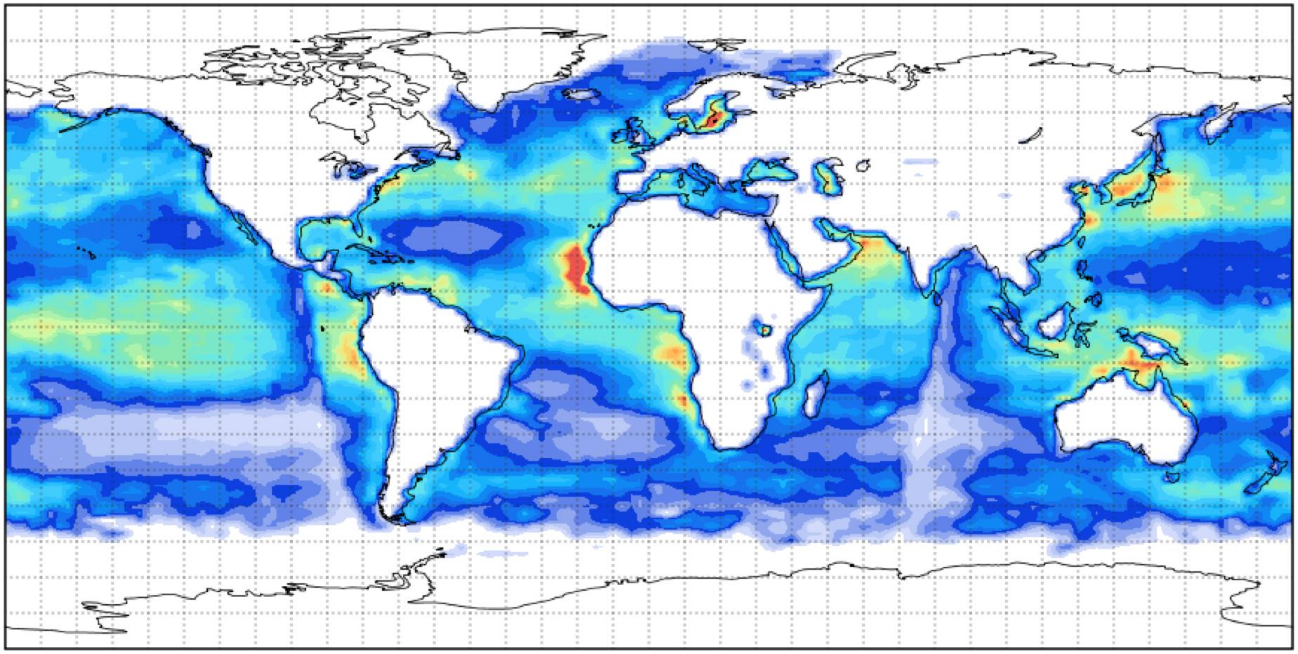


http://airquality.weather.gov/

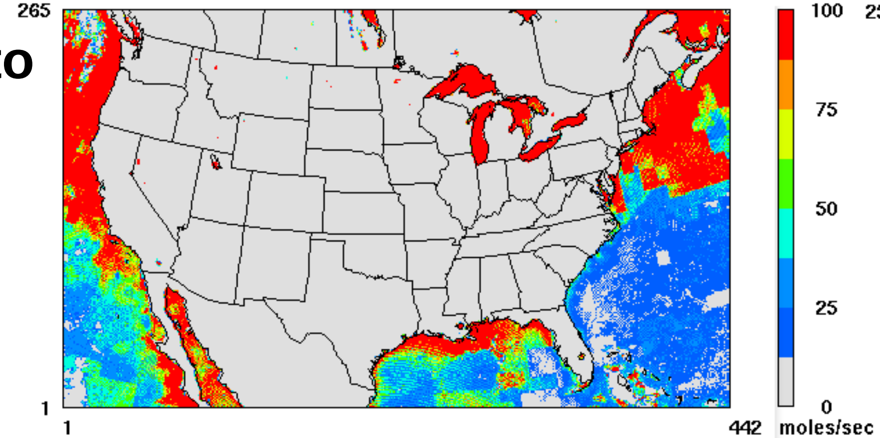
NAQFC is one of the major gateways to disseminate NOAA satellite observations and model prediction of air quality to the public.

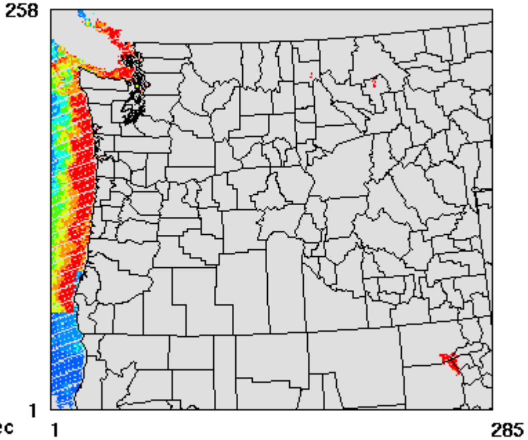
VIIRS Isoprene applications: National and regional air quality forecasting

Global Isoprene (April 2014)



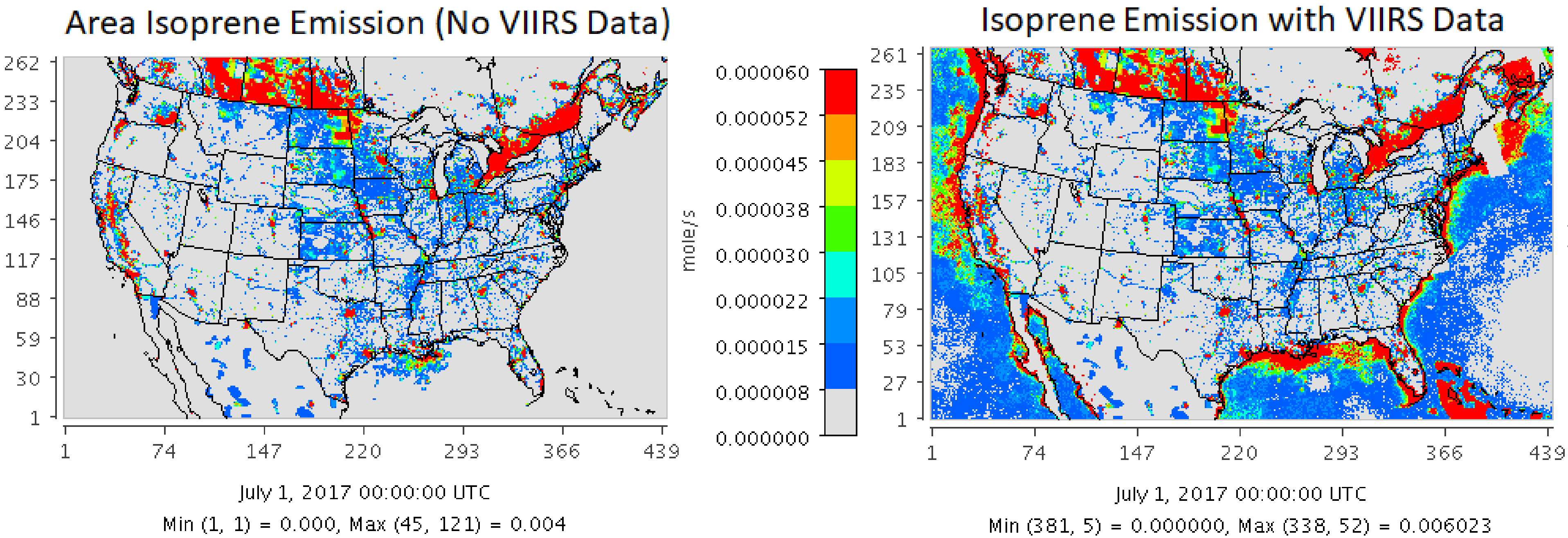
Isoprene into model domains





Application of VIIRS Isoprene in NAQFC

Since June 2018, VIIRS Isoprene product has been incorporated into ARL emission data to support NWS NAQFC operation.

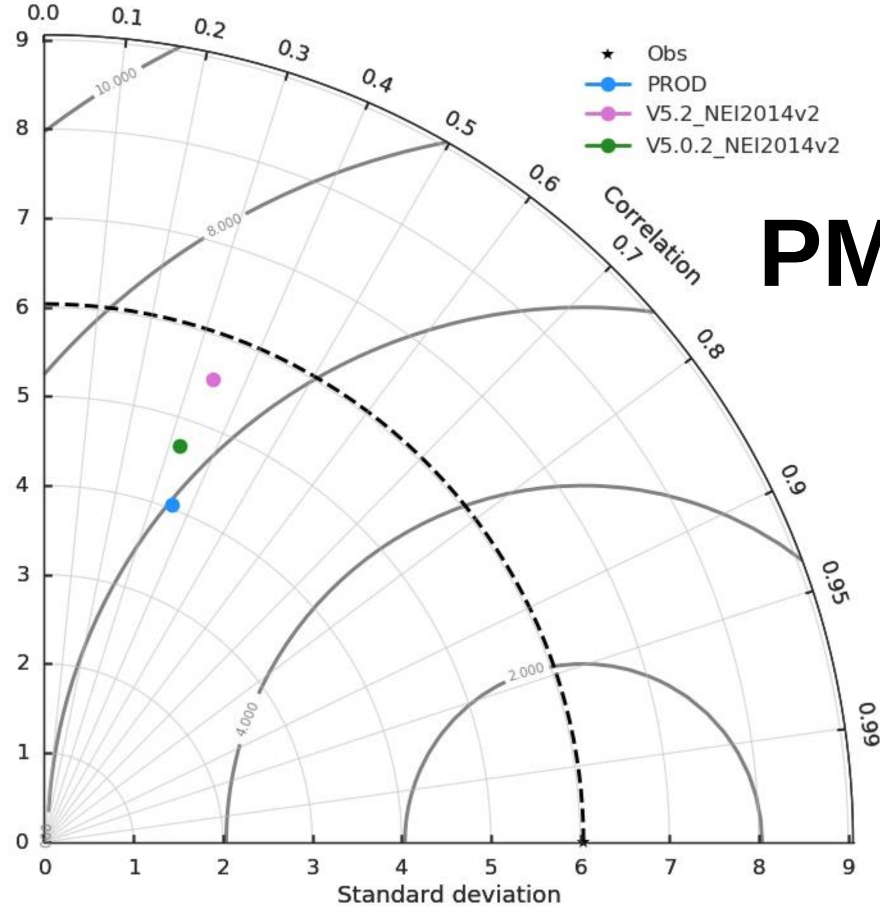


VIIRS marine isoprene is complementary to terrestrial and anthropogenic emissions currently used in NAQFC.

NAQFC 2018 Updates

Updates from the NEI2011 (Op.)

- **Agriculture: NH_3 expanded with all related species;**
- **Mobile sources: MOVES2014v2.**
- **Marine emissions (VIIRS) and Halogen chemistry.**
- **Model updates: from Version 5.0.2 to V5.2**



$PM_{2.5}$

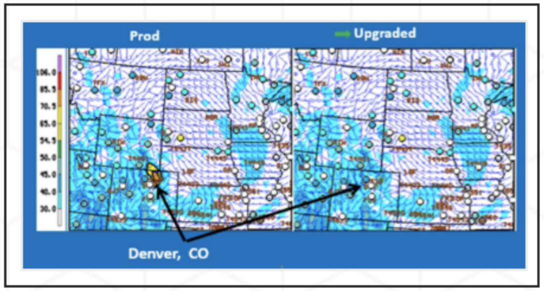
(Courtesy of Pius Lee, Youhua Tang and Barry Baker)

Search

ARL Updates NWS Forecast Model to Resolve High Wintertime Ozone Issue

April 2018

The atmospheric chemistry group within NOAA's Air Resources Laboratory (ARL) delivered new model packages and emission data to the National Weather Service (NWS) that, among other upgrades, resolved a long-term ozone forecasting issue: high wintertime ozone bias over oil/gas fields.



A Code Orange bad air quality forecast due to an erroneous ozone plume north of Denver on a winter day. Credit: NOAA

The operational forecasting system that provides real-time prediction of ozone and aerosols to our nation is the NWS's National Air Quality Forecast Capability, or NAQFC. For several years, forecasters have been

Serving the broad community

VIIRS Isoprene product released to "early adopter" users at a user workshop hosted by ARL, JPSS and NESDIS/STAR.

(Mitch Goldberg greeting users)

Workshop participants:

- NWS, OAR, NESDIS;
- Environment Canada
- World Meteorological Organization
- US Environmental Protection Agency,
- National Center for Atmospheric Research
- Department of Energy
- National Institute of Standards and Technology
- New York Department of Environmental Conservation
- Meteorological Agencies from Mexico, Japan, South Korea, India, and Chile.
- Universities (Georgia Tech, University of Iowa, University of Alabama, UMD etc);
- Private sector.

Summary & Future Plan

- JPSS offers unique marine emission products derived from VIIRS-SNPP ocean color data;

- VIIRS isoprene product has been incorporated into OAR/ARL emission data to support NWS NAQFC operations;

- Marine emission products, including isoprene, dimethyl sulfide (DMS), organic aerosols, are needed to support NWS Next-Generation Global Prediction System (NGGPS).

STAR JPSS 2018
Annual Science Team Meeting

Oceans EDRs and Initiatives
Monday, 27 August 2018

Dedicated NOAA/JPSS Cal/Val Cruises

Michael Ondrusek, Eric Stengel, Charle Kovach, Bob Arnone, Zhongping Lee, Sherwin Ladner, Scott Freeman, Wesley Goode, Chuanmin Hu, David English, Jianwei Wei, Junfang Lin, Alex Gilerson, Sam Ahmed, Ahmed El-Habashi, Robert Foster, Nick Tufillaro, Curt Davis, Matteo Ottaviani, Michael Twardowski, Carlos Carrizo, Eder Herrera, Giuseppe Zabordi, Yingjun Zhang, Xialolong Yu, Zhehai Shang, Chih-Wei, Carol Johnson, Ivan Lalovic, Laura Zoffoli, Shaojie Sun, Nicole Stockley, Scott Freeman, Guoqing Wang, Joaquin Chaves, Ryan Vandermeulen, Amir Ibrahim, Marco Talone, Aimee Neeley, Ken Voss, Veronica Lance, Menghua Wang.

International, Interagency and Academic Collaborations

US Agencies

- NOAA/NESDIS/STAR (NOAA)
- Naval Research Laboratory, Stennis Space Center (NRL)
- NASA/Goddard Space Flight Center (NASA)
- National Institute of Standards and Technology (NIST)

European Union

- Joint Research Center of the European Commission (JRC)

Universities

- City University of New York, Long Island; Crest
- Lamont-Doherty Earth Observatory, Columbia University
- University of Massachusetts, Boston
- University of Miami
- University of South Florida
- University of Southern Mississippi
- Florida Atlantic University

Background

- **NESDIS STAR/ORA has been conducting shipboard validation measurements since the CZCS days.**

- **During SeaWiFS there were several dedicated validation cruises and many tied to the Marine Optical Buoy Operations.**

- **More recently, up until 2014, our team and most other ocean color investigators were conducting Cal/Val measurements aboard cruise of opportunity.**

- **NOAA Office of Marine and Aviation Operations Ship-time requests have resulted in the use of NOAA ships for dedicated validation cruises in FY 2015, 2016, 2017, 2018 and coming up in 2019.**

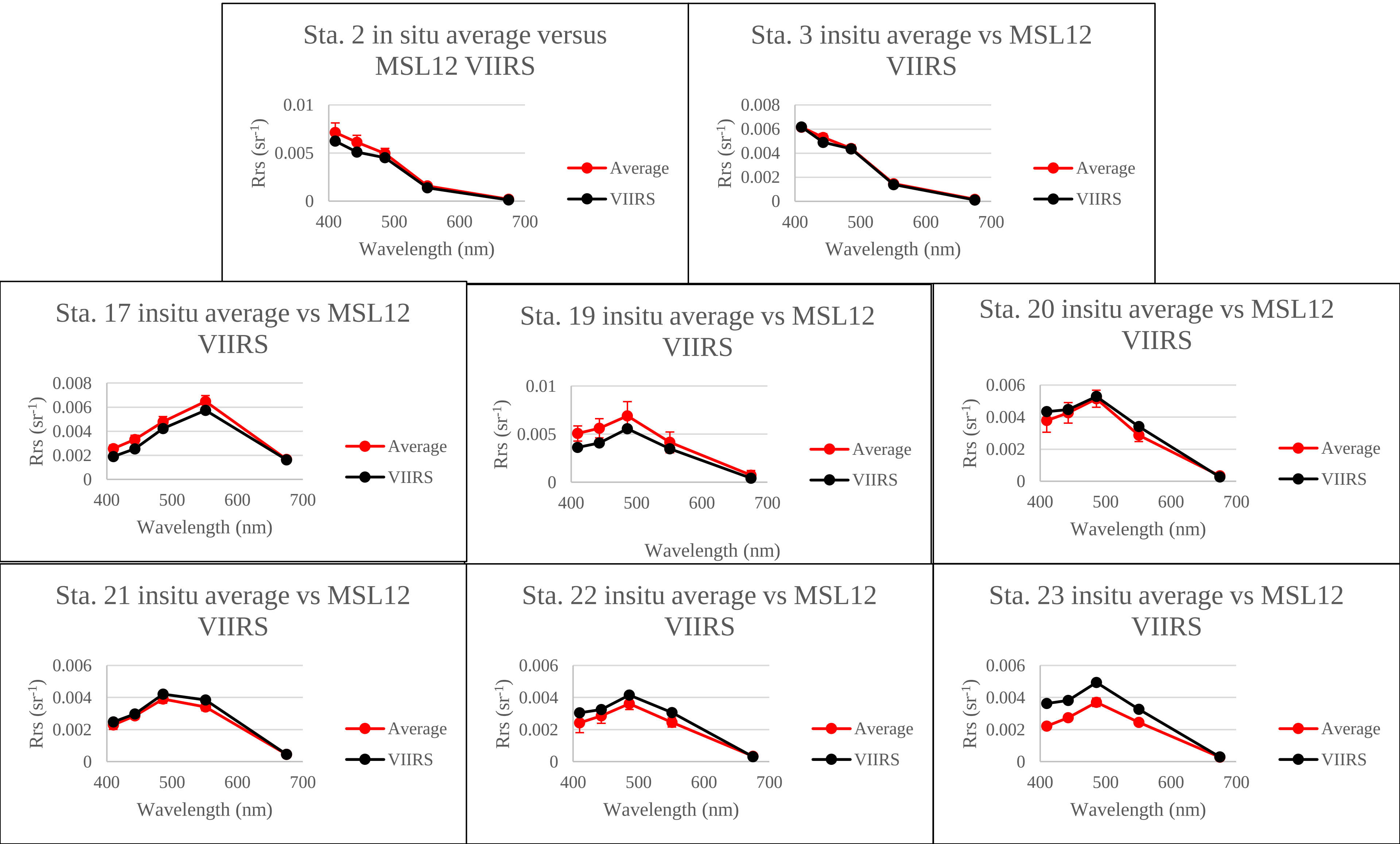
Science Objectives for the Cruise

Goals

1) Validation of VIIRS JPSS Satellite Ocean Color products - Ground truth ocean color sensors and product

- **Occupied optical stations over four cruises to collect the best in situ matchups with VIIRS and other ocean color sensors used by NOAA.**
- **Water-Leaving Radiance** - HyperPro, HyperTSRB, C-OPS, GER, Spectral Evolution, SBA, HyperSAS, ASD Handheld 2.
- **Conducted pre- and post-cruise inter-cals**
- **Chlorophyll** - HPLC, Fluorometric, (in situ and extracted)
- **Absorption** - ACS, AC9, Spectrophotometric
- **Backscatter** - BB9, BB7, BB3, ECO Puck
- **Phytoplankton Physiology and Functional Types -** Imaging FlowCytobot, Alfa
- **Carbon** - POC and DOC water analysis; plus CDOM
- **Total Suspended Matter** - Gravimetric
- **Aerosol Optical Depth** - Microtops
- **Bi-directional radiance distribution** - NURADS

2014 MSL12 VIIRS 5x5 avg vs avg of all Rrs measurements

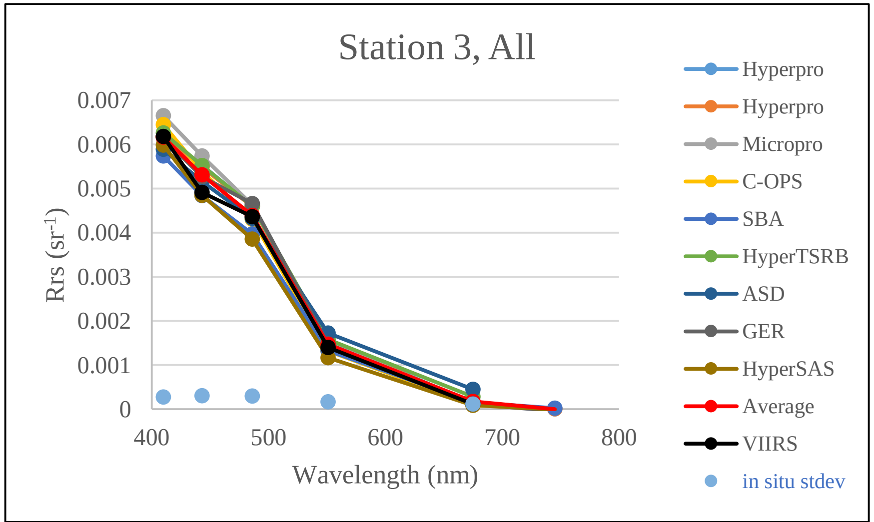


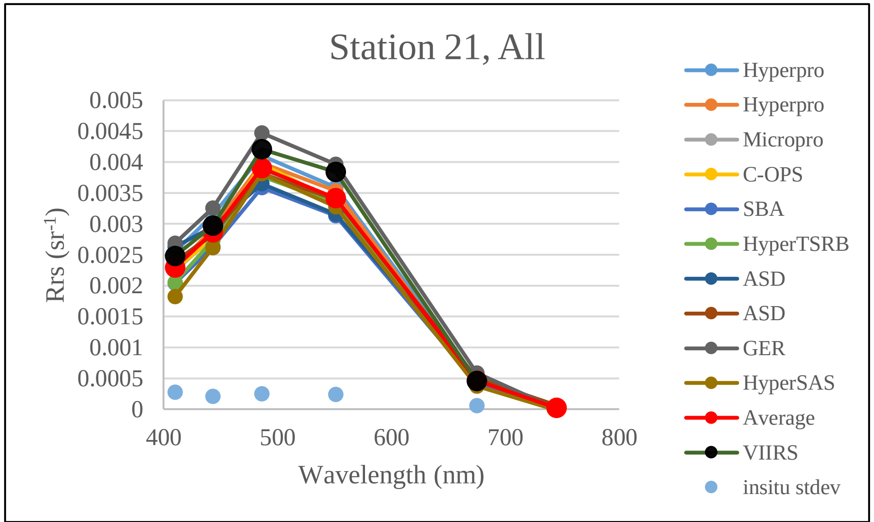
Science Objectives for the Cruise

Goals (cont.)

2) Characterization of uncertainties among the in situ ocean color measurements

a) replicate observations from multiple identical (same model) instruments deployed in parallel;
b) observations of the same in situ parameters but using different types of instruments;
c) different deployment protocols for sample collection;
d) different post-processing methods for the in situ data; and
e) spatial and temporal variability of the ocean waters.
f) Protocol analysis and recommendations.



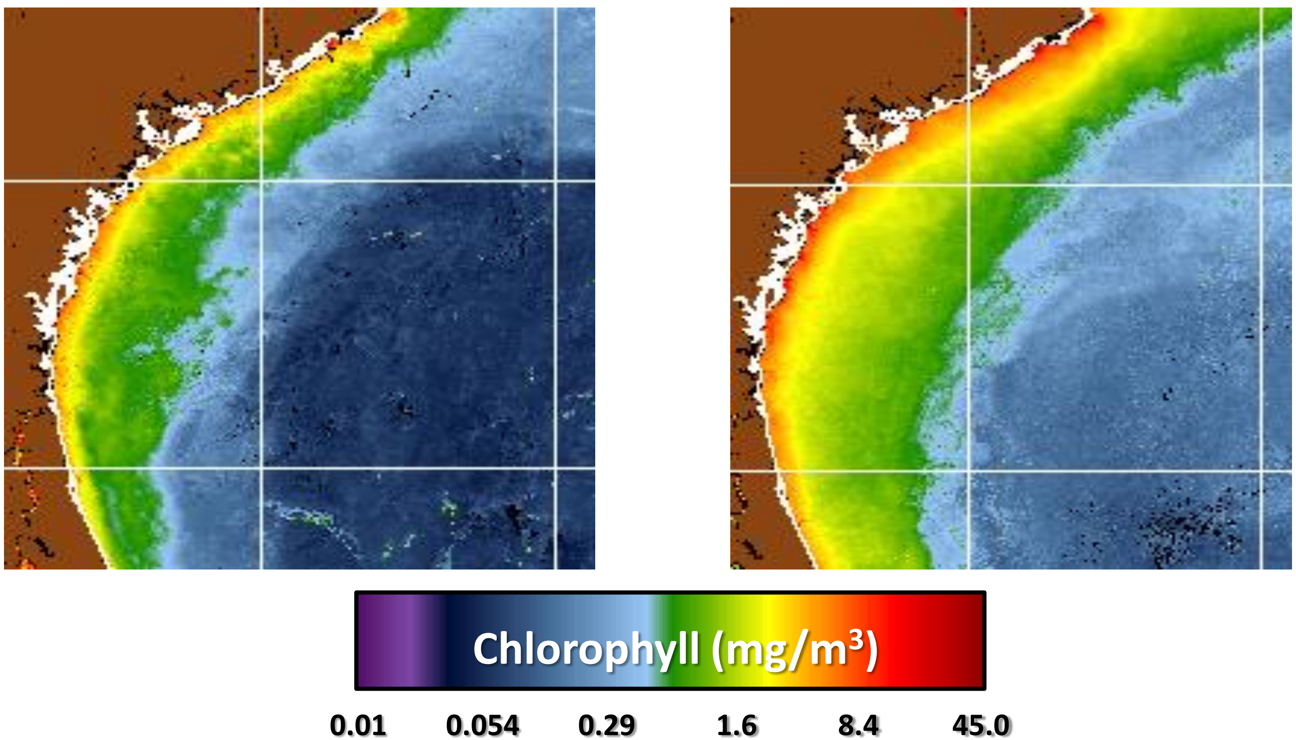


Science Objectives for Cal/Val Cruises

Goals (cont.)

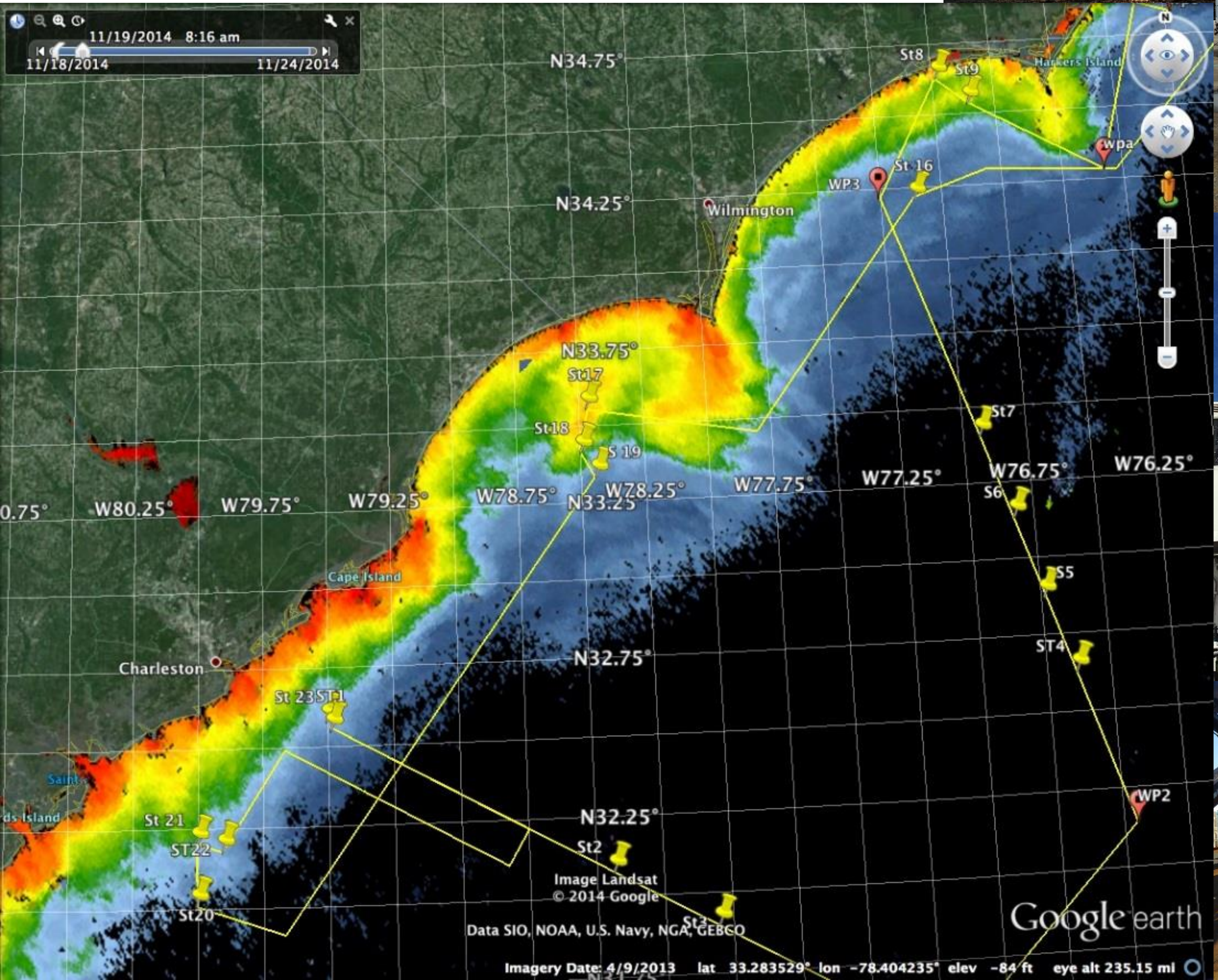
3) Optical characterization of oceanic processes (i.e. coastal, near-shore, cross-shelf, eddies, fronts, filaments, blue water)

Influence of Hurricane Matthew on the Coastal waters

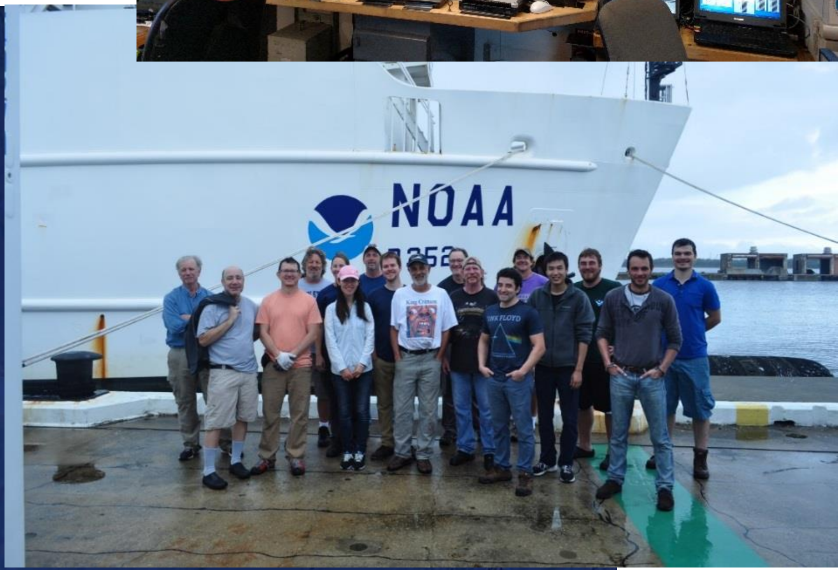


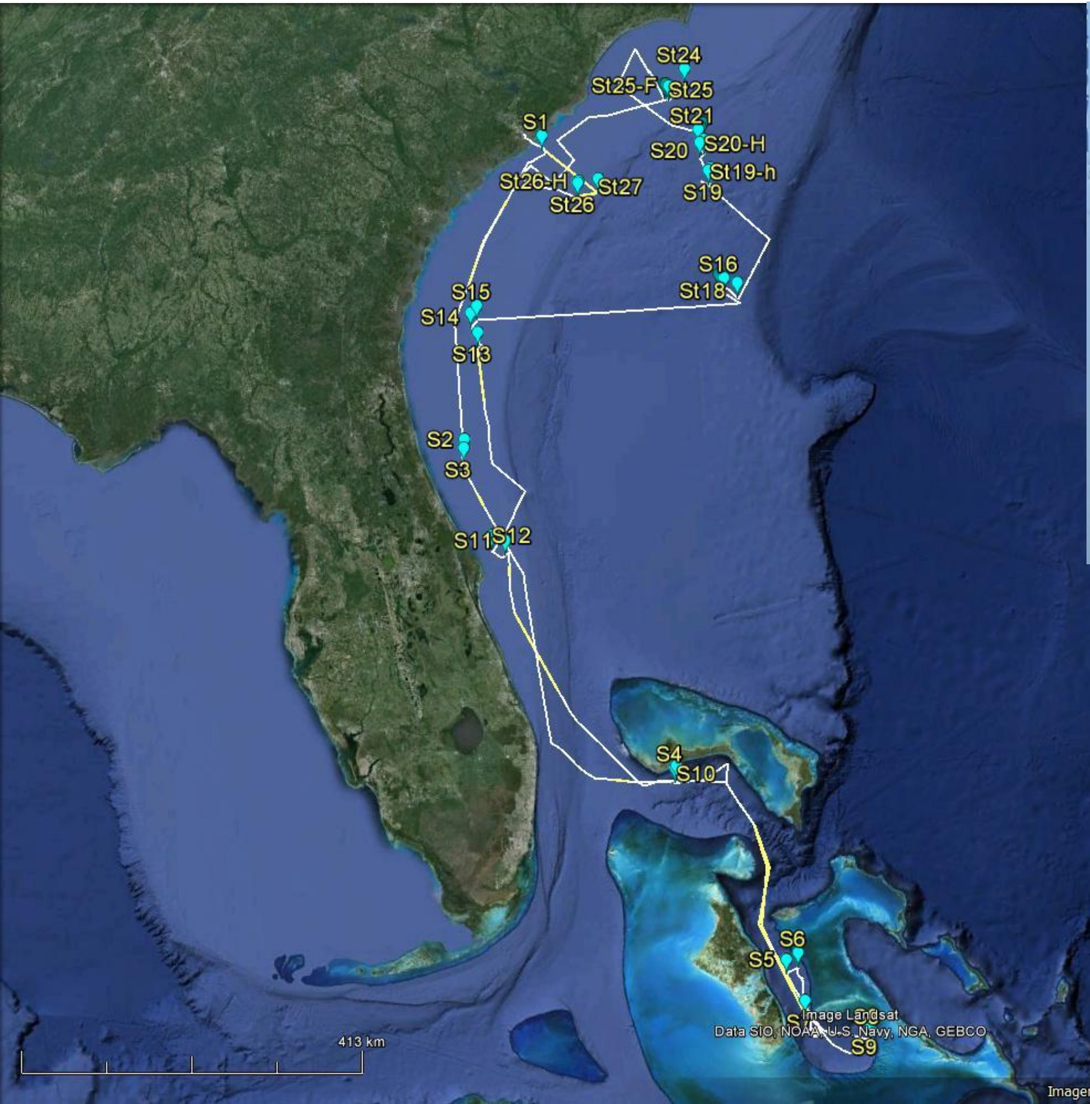
-Can water mass characterization of the representing different bio-physical processes be defined using VIIRS bio-optical products in the a dynamic system?

The FY15 cruise (Nov. 10-20, 2014) went in and out of Charleston SC aboard the Nancy Foster. In 10 days occupied 24 stations resulting in 9 good matchups with VIIRS

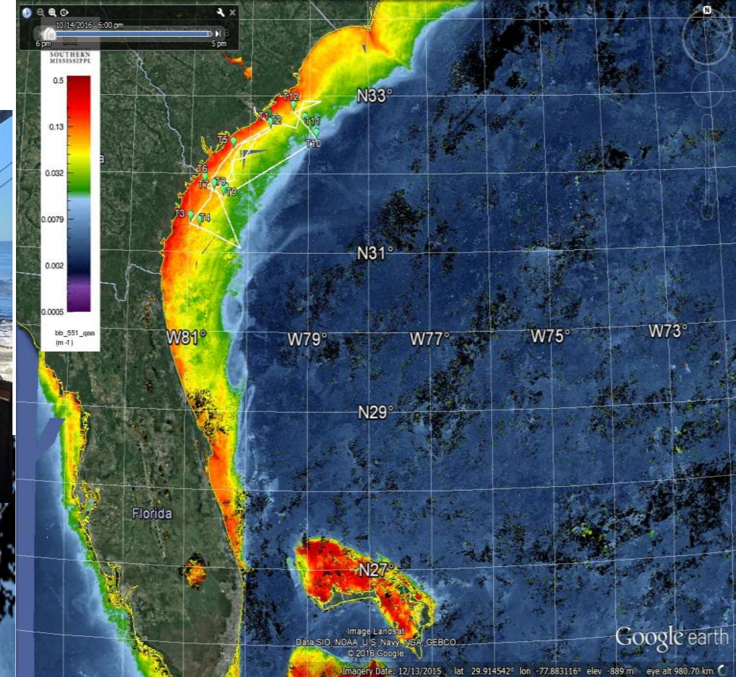


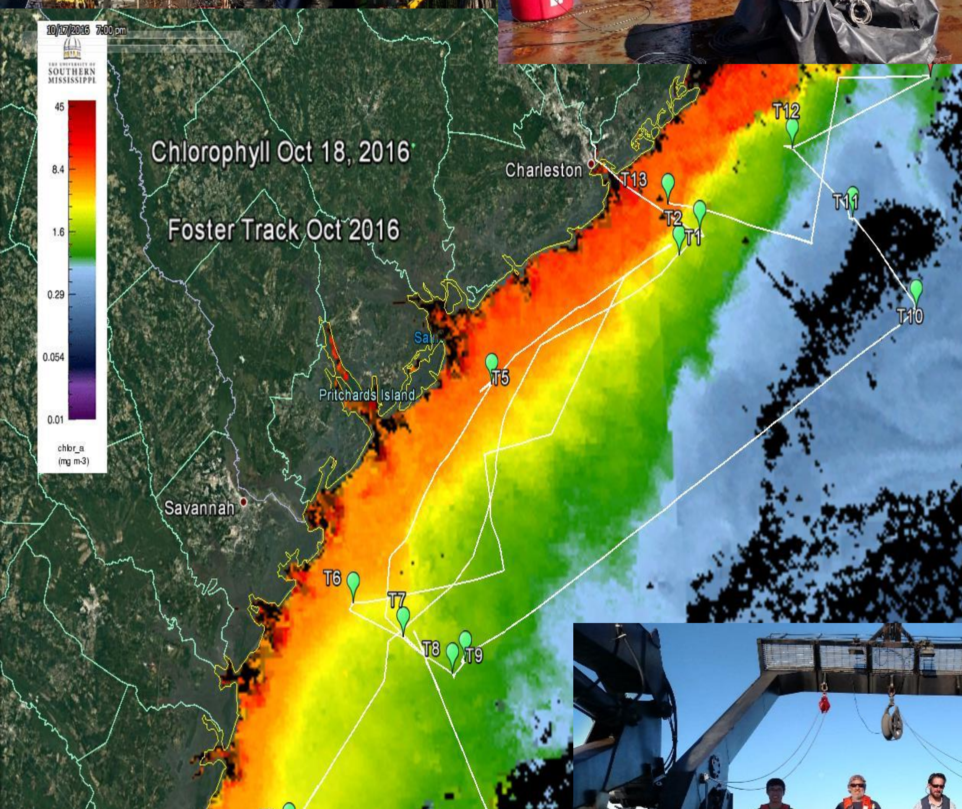
The FY16 cruise (Dec. 2-13, 2015) went in and out of Charleston SC aboard the Nancy Foster. In 12 days occupied 27 stations resulting in 9 good matchups with VIIRS

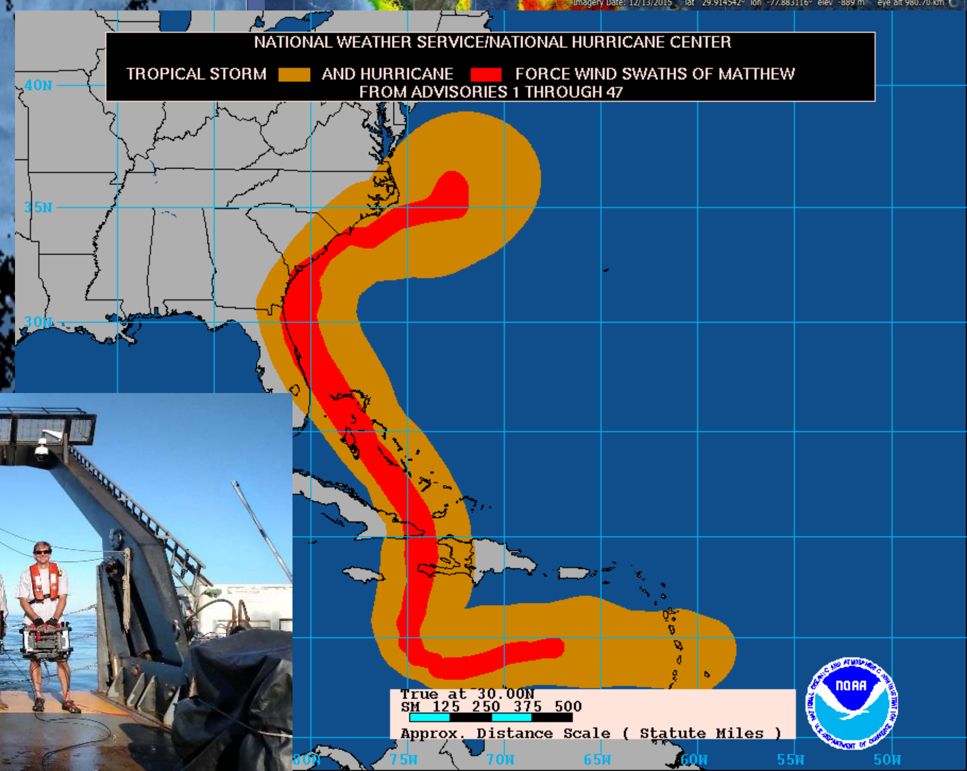




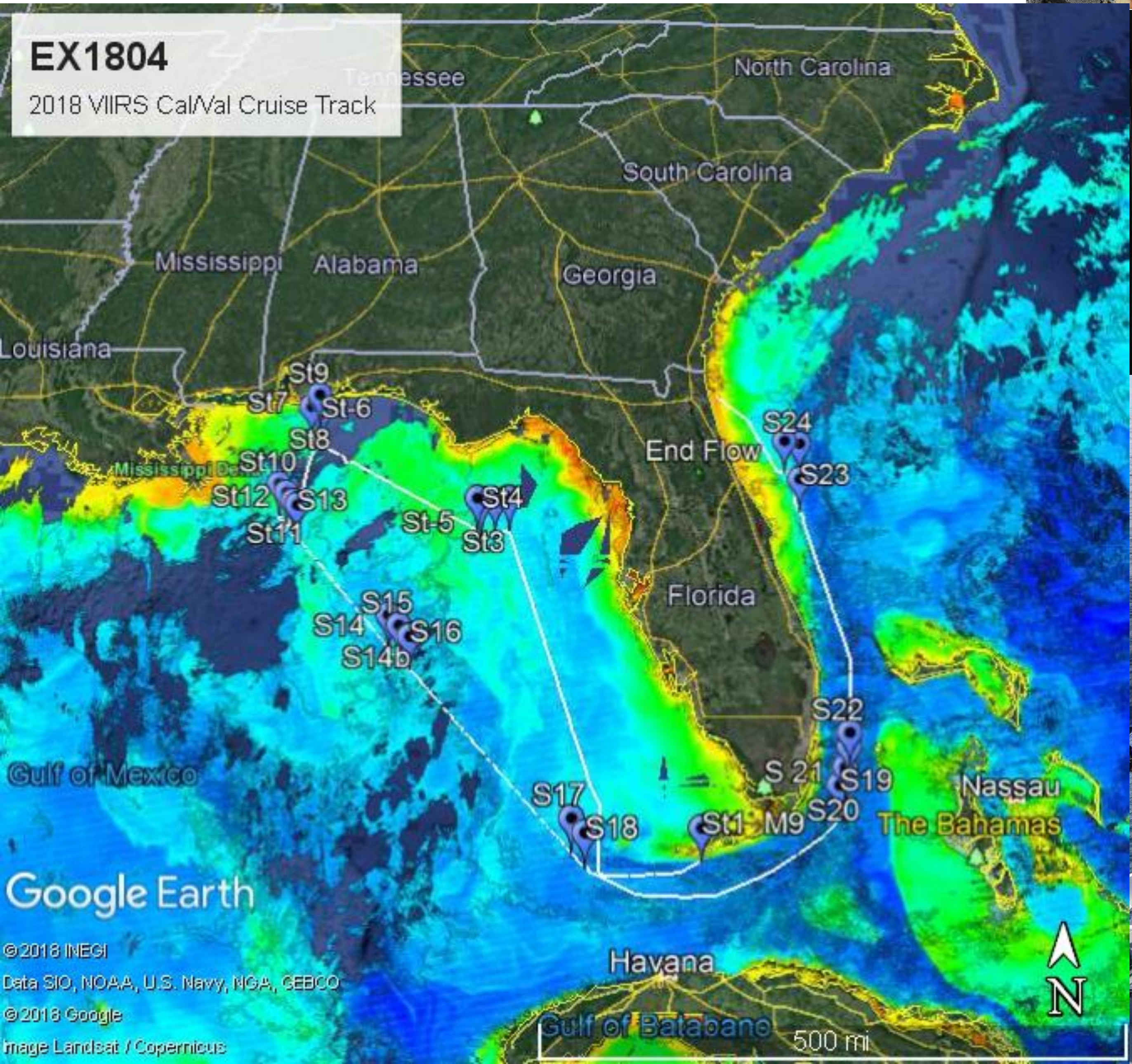
FY 17 VIIRS Cal/Val Cruise III (NF-16-08), October 13 to 18, 2016 aboard the NOAA Vessel Nancy Foster. In and out of Charleston, SC. 13 st.

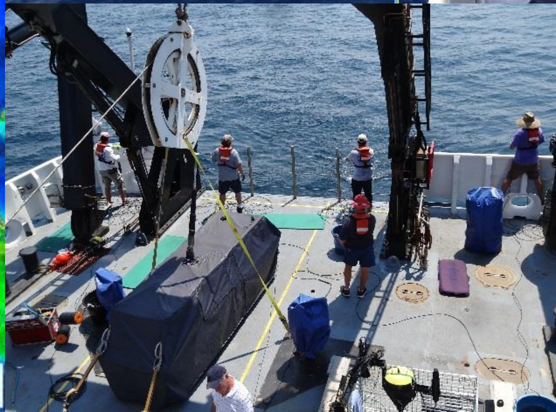






FY18 Cal/Val cruise. May 9 – 18, 2018. NOAA Ship Okeanos Explorer. Miami to Jacksonville. 24 stations, potential 18 matches





Instrument Percent difference relative to average of all instruments

2014 VIIRS Validation Cruise

Band	Hyperpro	Hyperpro	Micropro	C-OPS	SBA	HyperTSRB	ASD	ASD	GER	HyperSAS
410	4.83	-0.41	1.93	-1.49	-9.01	-4.29	6.47	-1.82	4.04	-0.75
443	6.84	3.12	-0.35	-4.21	-8.90	-0.28	1.34	-3.30	6.19	-1.31
486	4.83	3.81	-0.37	-2.19	-9.86	1.01	-4.71	-2.21	10.38	-0.75
551	5.22	4.14	-1.86	-7.24	-9.12	5.52	-0.11	-4.75	8.53	-1.16
675	-9.18	-14.02	-14.91	-17.22	-8.57	36.15	38.47	0.24	5.46	-11.25
All	2.51	-0.67	-3.11	-6.47	-9.09	7.62	8.29	-2.37	6.92	-3.04

2015 VIIRS Validation Cruise

Band	Hyperpro	Hyperpro	Spec Evo	SBA	HTSRB 1	HTSRB 2	ASD 1	ASD 2	ASD 3	GER	HyperSAS
410	3.88	13.32	14.46	-1.04	-0.97	-1.68	-6.04	2.29	-12.15	-7.30	-17.42
443	4.97	10.15	10.09	0.48	-1.31	0.41	-10.97	-3.32	-12.94	-4.97	-4.86
486	6.45	9.93	4.84	1.37	-2.34	3.36	-15.05	-8.95	-14.12	1.09	0.92
551	7.39	3.18	6.46	-2.70	-2.06	6.48	-10.68	-2.11	-8.75	-5.98	-3.61
675	-5.43	-17.26	-3.61	-33.49	50.99	72.27	-5.04	9.29	-7.03	-44.38	-35.22
Average	3.45	3.86	6.45	-7.08	8.86	16.17	-9.56	-0.56	-11.00	-12.31	-12.04

2016 VIIRS Validation Cruise

Band	Hyp 1	Hyp 2	Hyp 3	Float 1	Float 2	SBA	Spec. Evo	GER	HyperSAS	ASD 1	ASD 2	ASD 3	ASD 4
410	6.80	7.56	17.28	-21.40	-8.72	-4.86	13.96	-16.20	12.09	-10.46	-2.70	-6.48	2.52
443	8.62	9.46	17.59	-10.49	-5.03	-1.72	9.17	-9.93	5.19	-6.61	-6.72	-8.32	-2.58
486	10.32	10.44	16.13	-4.61	-2.25	-0.31	6.16	-5.71	3.23	-4.06	-9.32	-9.91	-6.56
551	10.72	10.20	15.33	-3.37	2.38	3.61	5.84	-4.66	0.52	-7.57	-8.89	-11.63	-6.62
675	14.03	5.24	23.49	17.86	12.49	30.87	-2.98	-7.06	-7.12	-25.26	-3.56	-40.01	4.69
avg all	10.10	8.58	17.96	-4.40	-0.22	5.52	6.43	-8.71	2.78	-10.79	-6.24	-15.27	-1.71

MSL12 VIIRS Percent difference relative to in situ

2014 VIIRS Cal/Val Cruise

Band	Hyperpro	Hyperpro	Micropro	C-OPS	SBA	HyperTSRB	ASD	ASD	GER	HyperSAS	Average
410	-6.73	-3.36	-5.39	-2.15	10.31	1.57	-8.17	-8.73	3.33	3.85	**-3.79**
443	-13.15	-10.87	-7.45	-3.93	4.15	-7.42	-8.53	-9.38	-8.44	-3.90	**-8.31**
486	-6.49	-5.70	-1.44	0.45	11.28	-2.84	3.67	-2.83	-8.83	0.35	**-2.30**
551	-3.58	-2.71	4.05	10.21	14.65	-2.89	2.89	3.18	-2.82	5.52	**1.17**
675	-10.37	-0.44	1.06	1.70	-3.34	-28.45	-25.91	-9.02	-22.89	-4.94	**-17.04**
All	-8.07	-4.62	-1.83	1.26	7.41	-8.01	-7.21	-5.36	-7.93	0.18	**-6.05**

2015 VIIRS Cal/Val Cruise

Band	Hyperpro	Hyperpro	Spec Evo	SBA	HTSRB	HTSRB	ASD 1	ASD 2	ASD 3	GER	HyperSAS	Average
410	-10.71	-33.17	-32.44	0.69	-17.95	-2.30	-5.63	-13.05	-6.59	11.00	33.56	**-6.96**
443	-18.16	-31.21	-29.54	-8.79	-22.38	-11.47	-4.18	-11.97	-8.68	-4.17	-4.42	**-14.09**
486	-10.39	-19.94	-14.26	-0.97	-12.37	-5.97	13.50	4.83	4.68	-2.64	-2.58	**-4.19**
551	-20.75	-24.85	-24.76	-7.82	-24.11	-18.53	-0.83	-12.52	-11.21	-6.12	-7.59	**-14.46**
675	-5.97	-7.69	1.95	82.36	-45.75	-40.02	0.21	-15.49	-9.78	82.26	56.15	**8.93**
Average	-13.20	-23.37	-19.81	13.09	-24.51	-15.66	0.62	-9.64	-6.32	16.07	15.02	**-6.16**

2016 VIIRS Cal/Val Cruise

Band	**Hyp 1**	**Hyp 2**	**Hyp 3**	**Float 1**	**Float 2**	**SBA**	**Spec. Ev**	**GER**	**HyperSA**	**ASD 1**	**ASD 2**	**ASD 3**	**ASD 4**	Average
410	-21.14	-13.021	-14.58	-8.6991	-10.169	-5.1651	-17.349	9.41287	-13.086	-9.5444	-13.751	-15.726	-14.526	-11.33
443	-23.637	-18.248	-16.385	-9.1118	-12.199	-9.3288	-13.487	-6.5252	-10.053	-9.5982	-6.3806	-4.6875	-12.335	-11.6
486	-19.977	-19.423	-10.79	-8.2182	-5.8882	-8.393	-12.214	-8.6991	-9.2464	-3.9016	-0.0429	-8.7008	-4.4225	-9.224
551	-20.499	-16.072	-14.42	-5.4567	-10.169	-12.975	-13.573	-4.5217	-7.5895	-5.0782	-7.3789	0.5504	-1.7808	-9.150
675	-9.0381	23.9794	8.34418	8.53912	6.38464	-10.026	10.6155	13.2666	12.936	30.5061	10.9994	18.1037	0.3017	9.6085
avg all	-18.858	-8.5568	-9.5662	-4.5893	-6.4082	-9.1776	-9.2014	0.58669	-5.4078	0.47673	-3.3107	-2.0921	-6.5525	-6.358

Summary:

- Bring together JPSS ocean color cal/val team investigators from many agencies and universities to test the consistency in validation measurements being provided to processing centers.

- In four cruises we have occupied 88 stations with 48 matchup stations.

- Provided best in situ validation data to NOAA and other agencies responsible for ocean color processing and quality control.

- Identified sampling uncertainties and problems areas and are constantly working to lower the uncertainties and resolve sampling errors.

- Will continue annual validation cruises. Next expedition is in May 2019 aboard the NOAA Ship Nancy Foster along the east coast.

- More information and complete list of measurements can be found in the Cruise Reports-
  - FY2015 - NOAA Technical Report NESDIS 146, DOI:10.7289/V52B8W0Z
  - FY2016 - NOAA Technical Report NESDIS 148, DOI:10.7289/V5/TR-NESDIS-148
  - FY2017 - NOAA Technical Report NESDIS 151, DOI: 10.7289/V5/TR-NESDIS-151

Thank you

Science, Service, Stewardship

Satellite Oceanography: NMFS Vantage Point

Mike Ford
Oceanographer

NOAA Fisheries
Smithsonian Environmental Research Center

August 2018

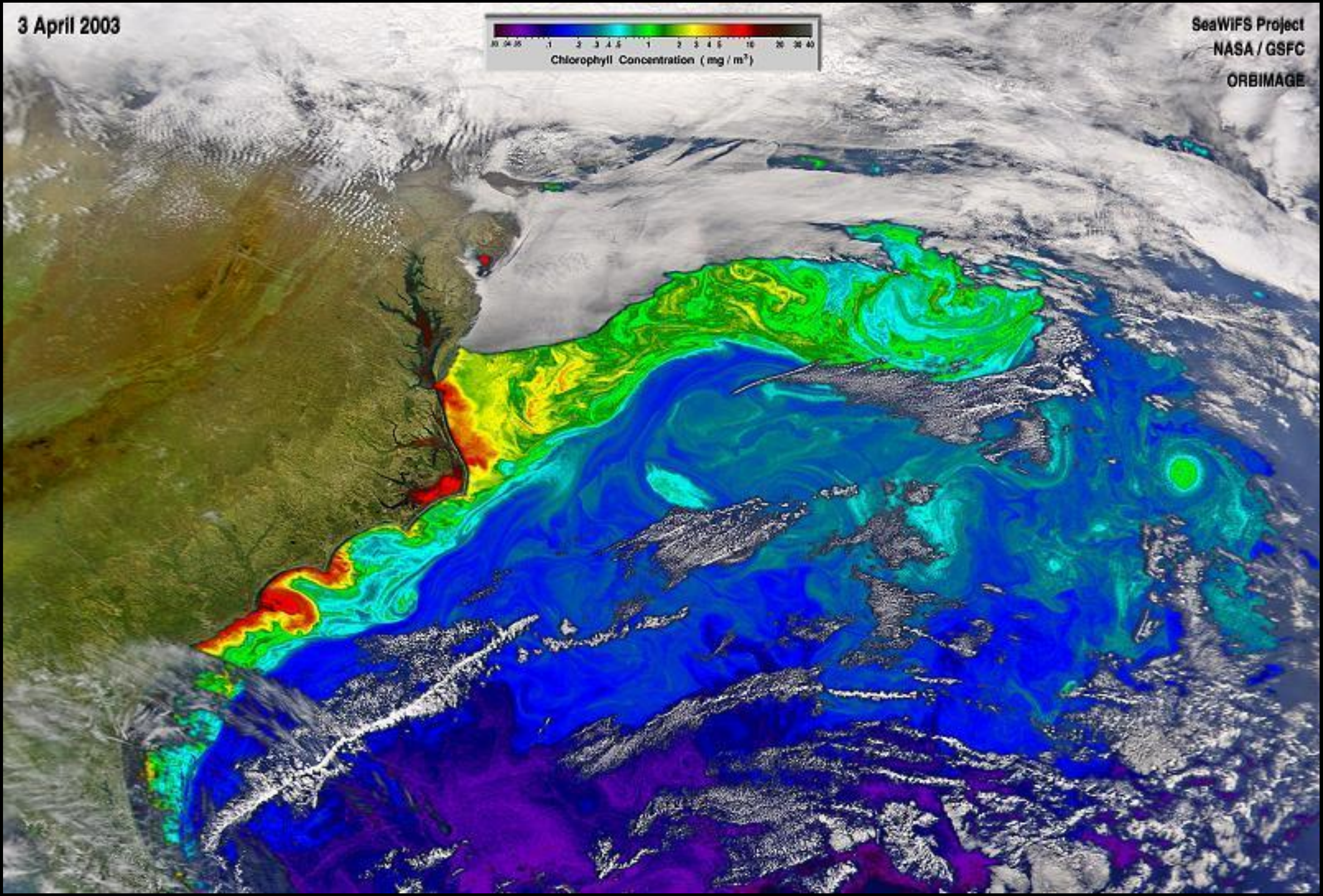
NOAA FISHERIES SERVICE

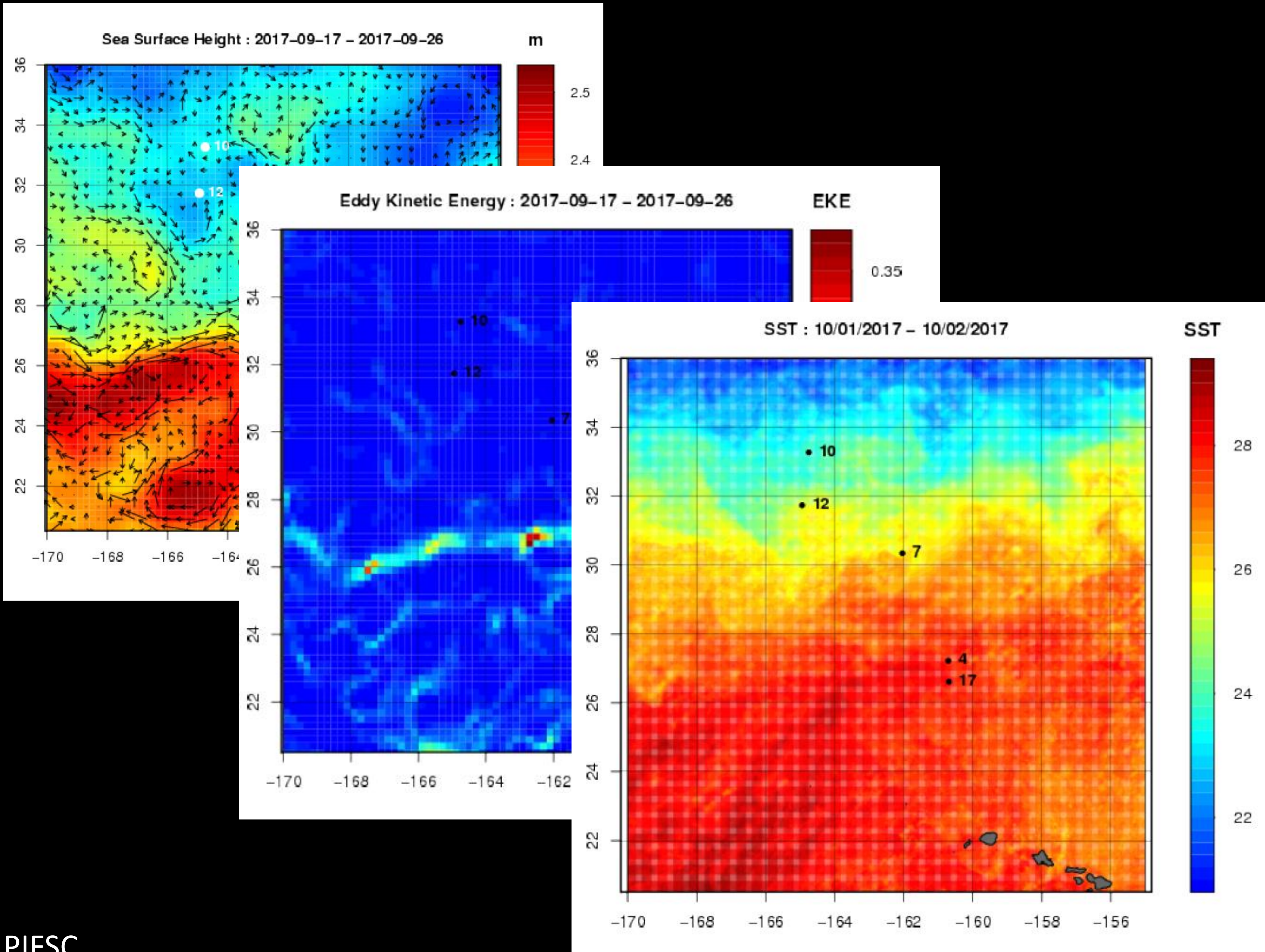
1.6 million jobs and $208 billion in sales

3 million square miles of
open-ocean and more than
95,000 miles of coastline

474 fish stocks; 46 fishery management plans

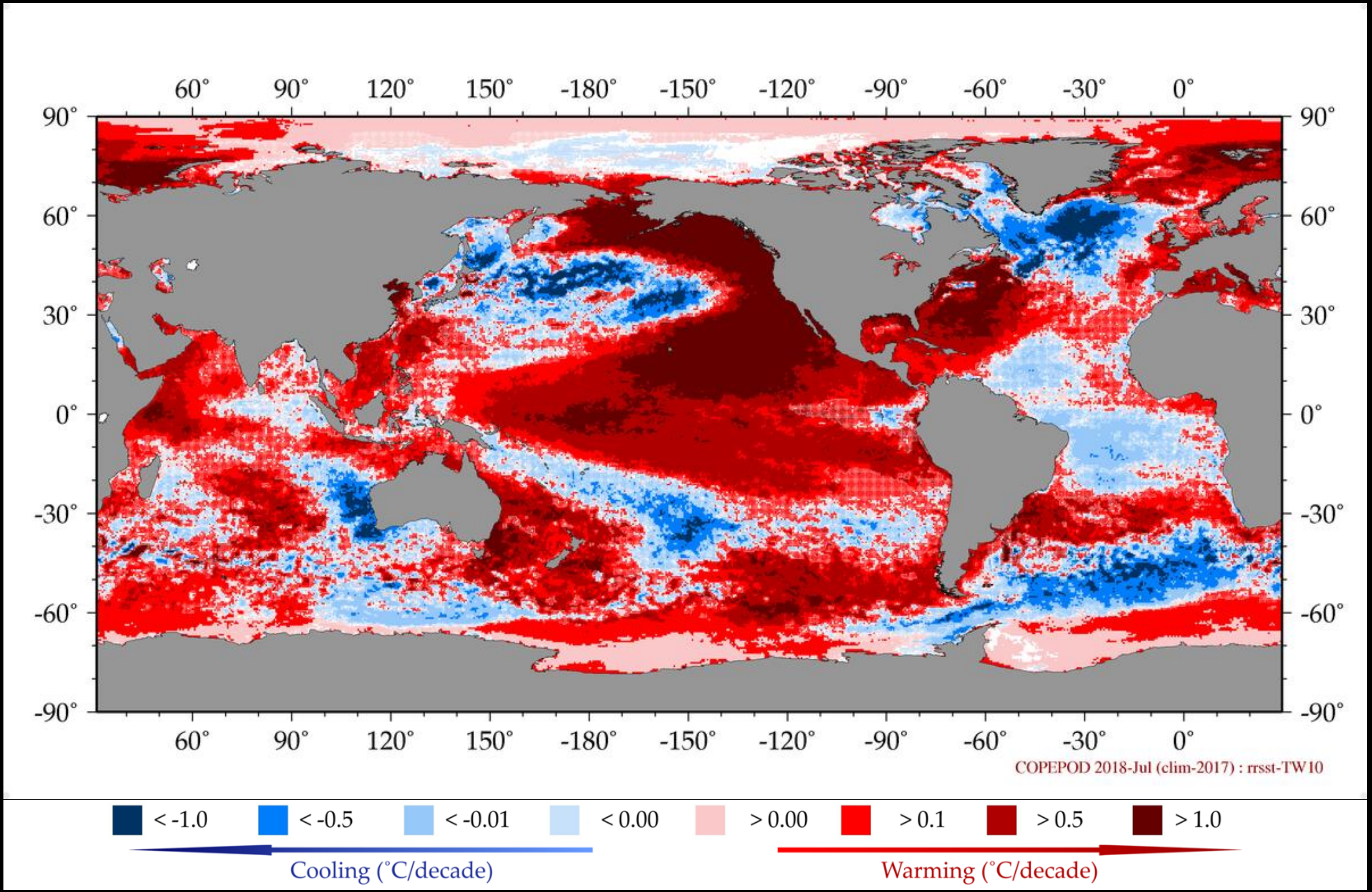
157 endangered and threatened species


3 April 2003
.1 .2 .3 .4 .5 1 2 3 4 5 10 20 30 40
Chlorophyll Concentration (mg / m³)
SeaWiFS Project
NASA / GSFC
ORBIMAGE


Sea Surface Height : 2017-09-17 – 2017-09-26
m
2.5
2.4
Eddy Kinetic Energy : 2017-09-17 – 2017-09-26
EKE
0.35
SST : 10/01/2017 – 10/02/2017
SST
28
26
24
22
10
12
7
4
17
36
34
32
30
28
26
24
22
−170
−168
−166
−164
−162
−160
−158
−156

PIFSC

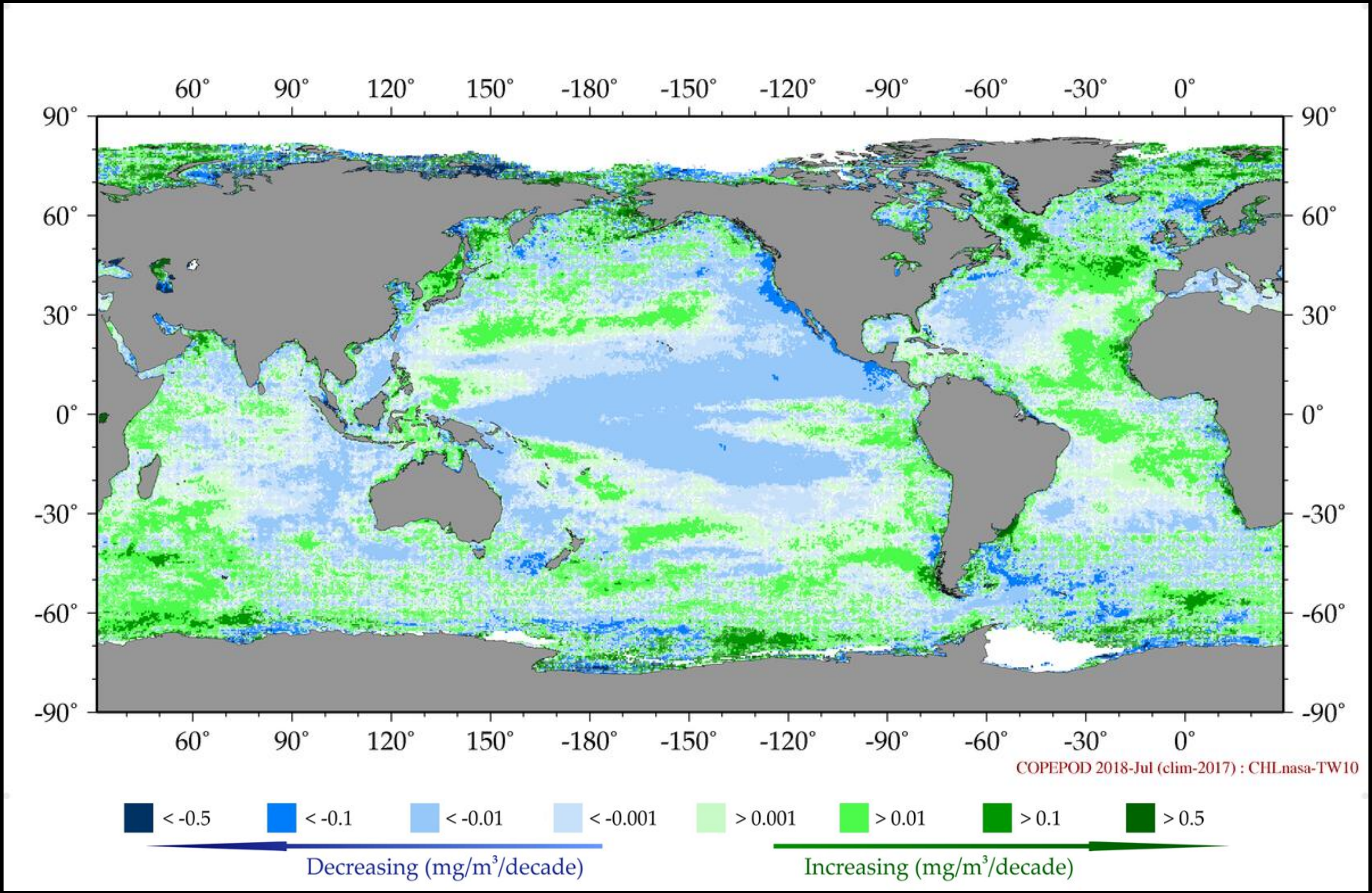
- Maintain highest quality long-term time series (preferably hyperspectral)
- Advance all capabilities to measure phytoplankton functional groups/size classes on the continental shelf – sensors & algorithms
- Develop products that resolve mesoscale features (e.g. Lagrangian Coherent Structures, Chlorophyll fronts)
- Cross-platform integration of Chl products (e.g., GHRSST, ROMS)



10-year (2008-2017) SST trends (C/decade)

In this figure, 72% of the ocean surface has a warming trend, with 8% warming at > 0.5 C/decade!

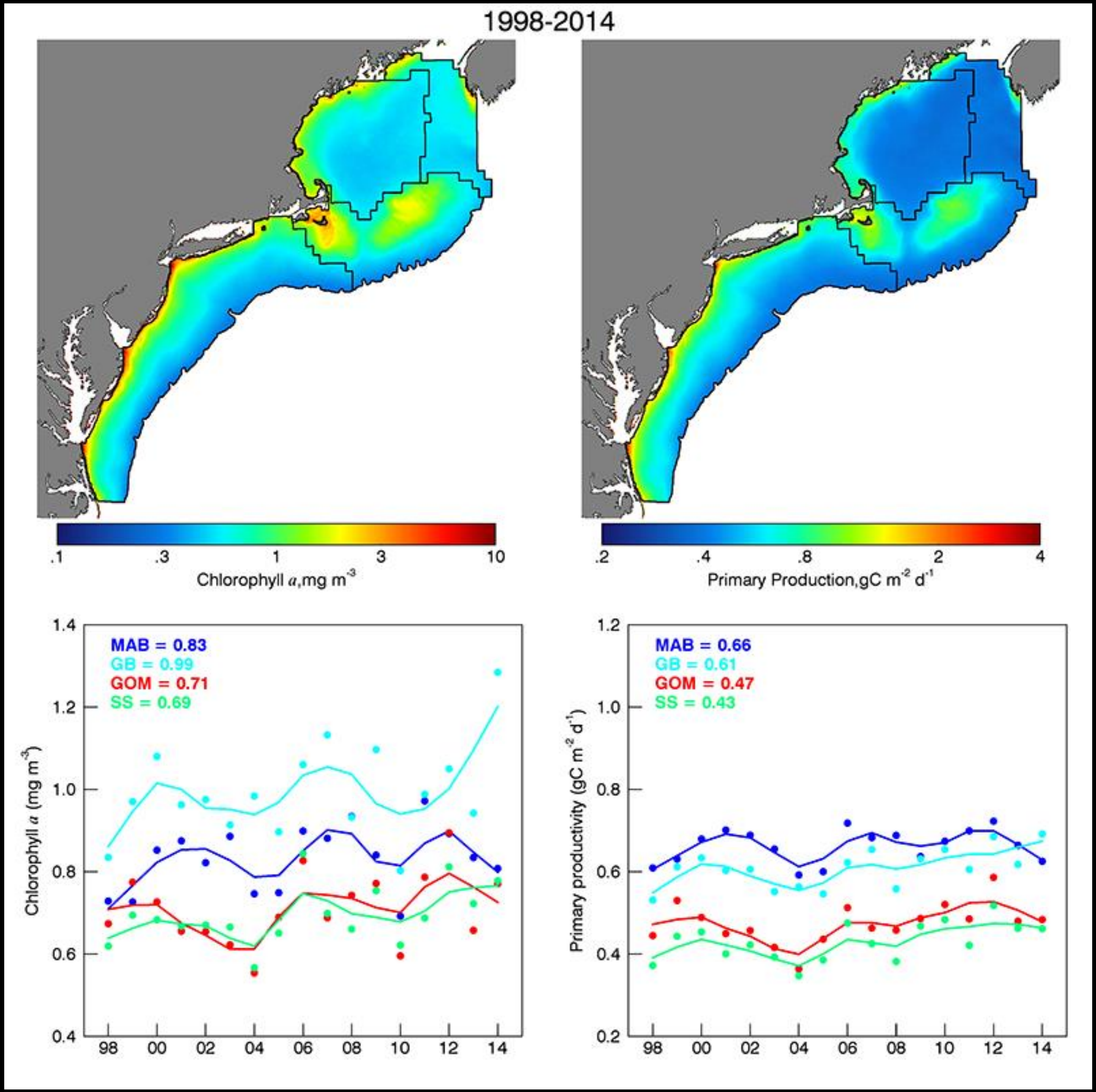
O'Brien et al. NMFS S&T; IGMETS



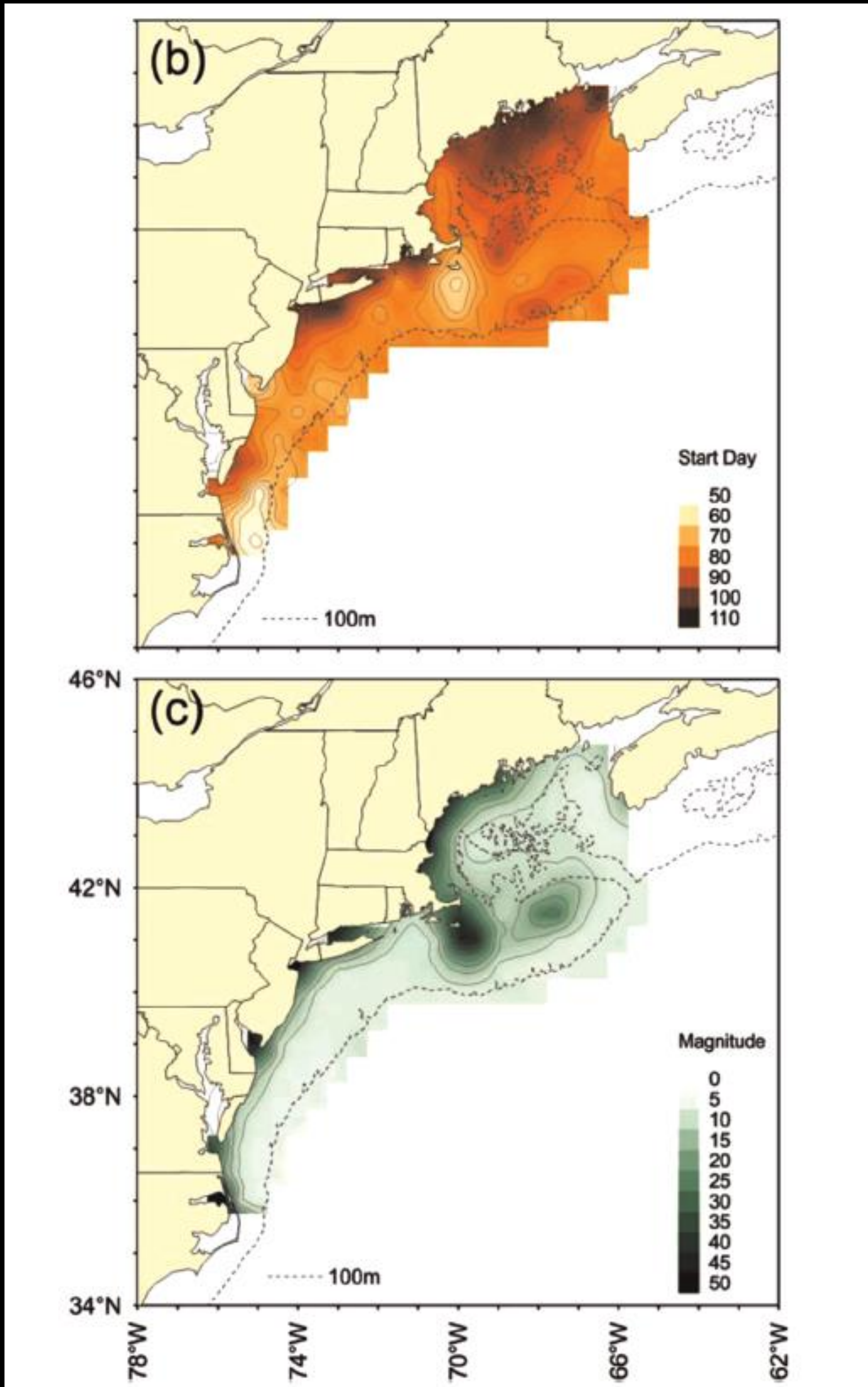
10-year (2008-2017) Chlorophyll trends (mg/m^3/decade)

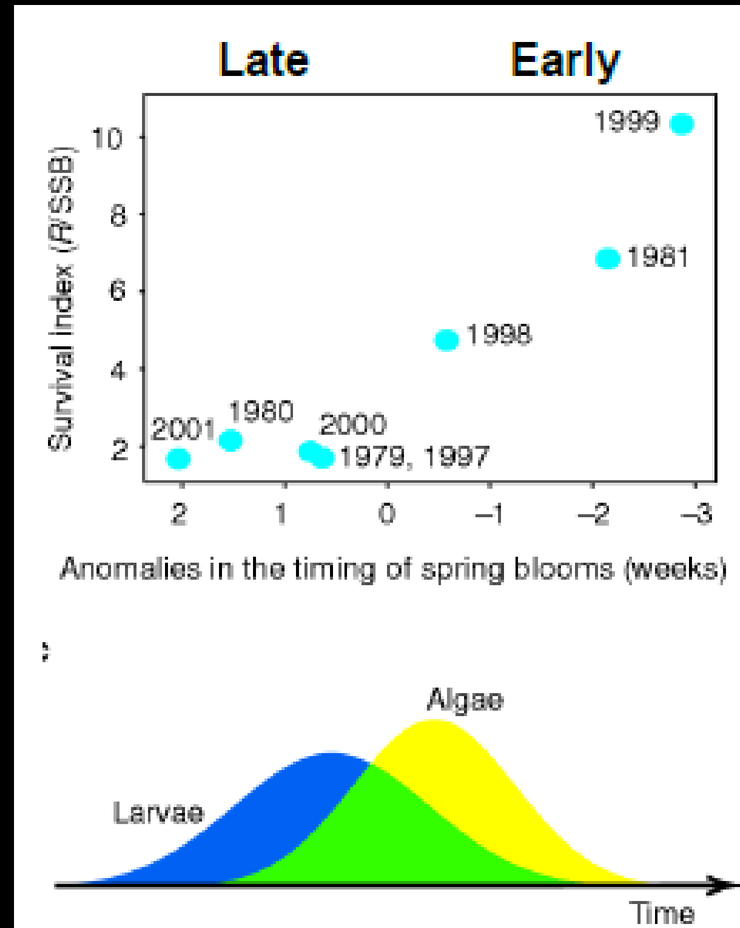
In this figure, 53% of the ocean surface has a negative (decreasing biomass) trend.

O'Brien et al. NMFS S&T; IGMETS


1998-2014
.1
.3
1
3
10
Chlorophyll a,mg m-3
.2
.4
.8
2
4
Primary Production,gC m-2 d-1
MAB = 0.83
GB = 0.99
GOM = 0.71
SS = 0.69
Chlorophyll a (mg m-3)
MAB = 0.66
GB = 0.61
GOM = 0.47
SS = 0.43
Primary productivity (gC m-2 d-1)
98 00 02 04 06 08 10 12 14

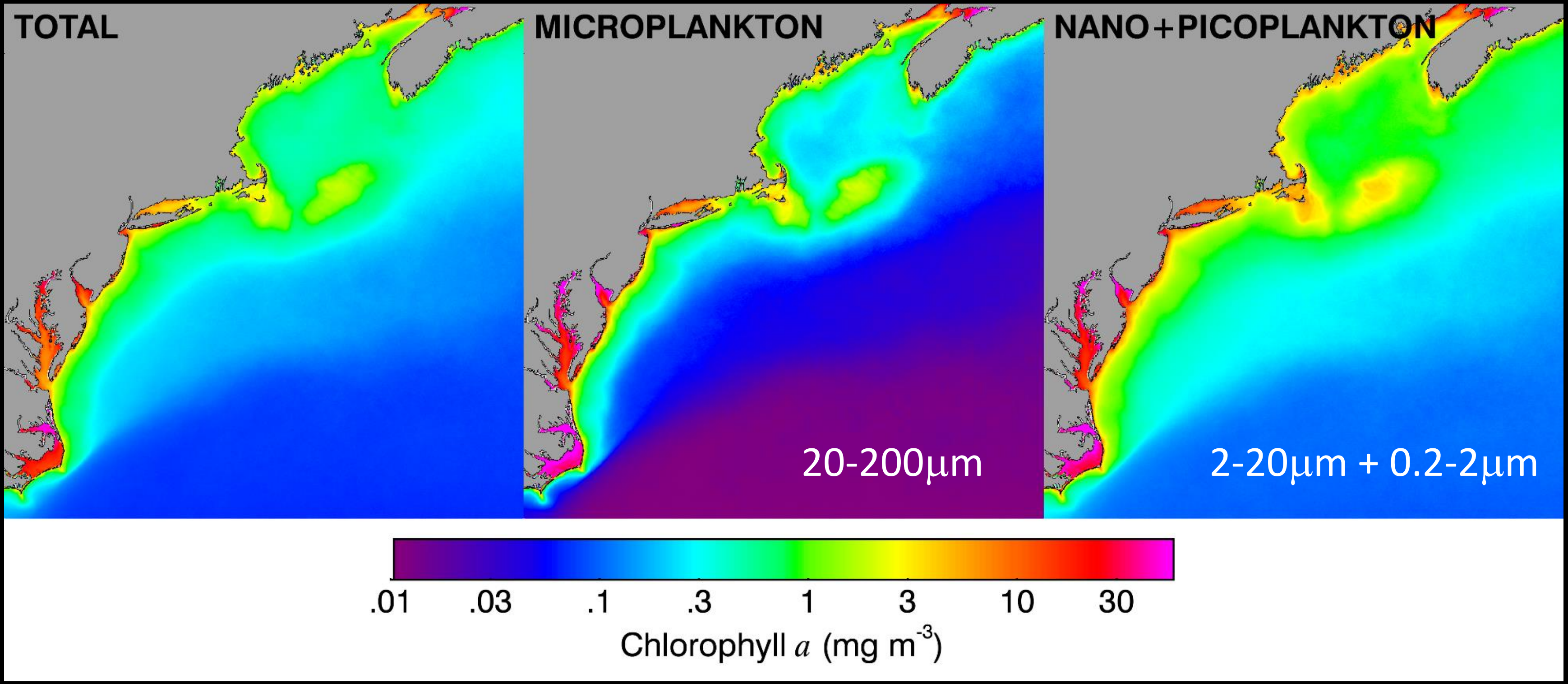
NEFSC


(b)
Start Day
50
60
70
80
90
100
110
100m
(c)
Magnitude
0
5
10
15
20
25
30
35
40
45
50
100m
46°N
42°N
38°N
34°N
78°W
74°W
70°W
66°W
62°W

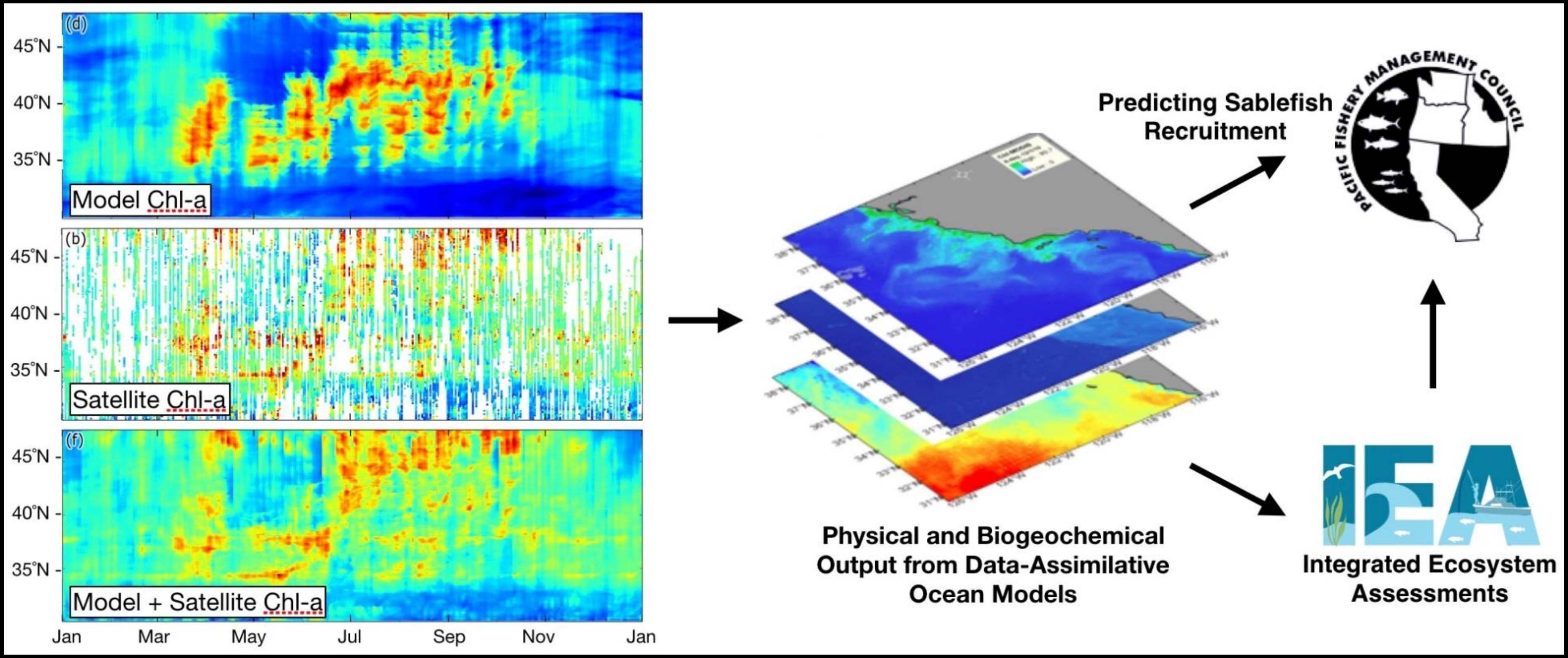

Late
Early
Survival Index (R/SSB)
10
8
6
4
2
1999
1981
1998
2001
1980
2000
1979, 1997
2
1
0
−1
−2
−3
Anomalies in the timing of spring blooms (weeks)
Algae
Larvae
Time

NEFSC

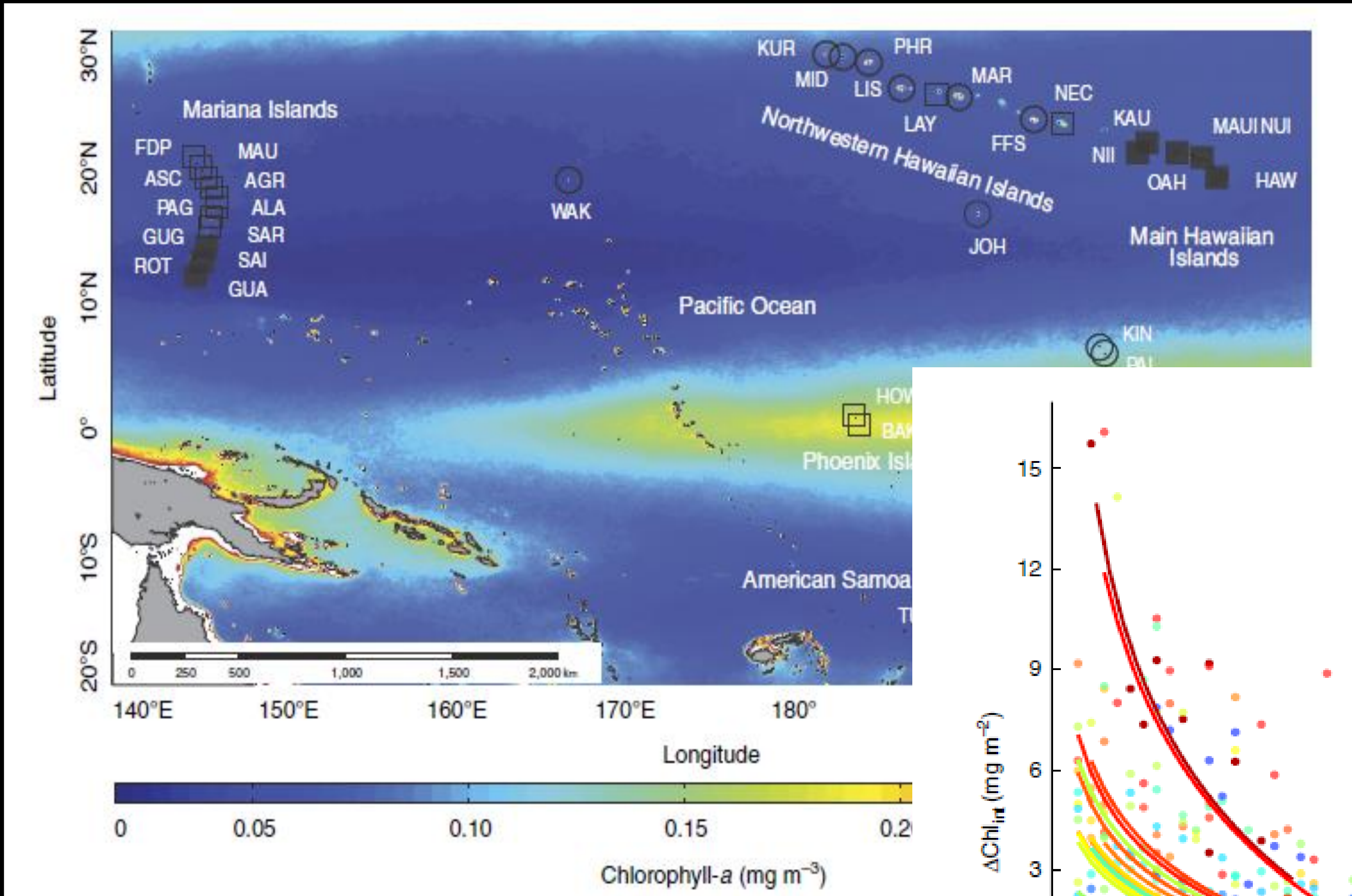
Satellite ocean color data is used to derived phytoplankton functional groups a series of Remote Sensing Reflectance (R_{RS}) band ratio algorithms at 490, 555 and 670 nm.

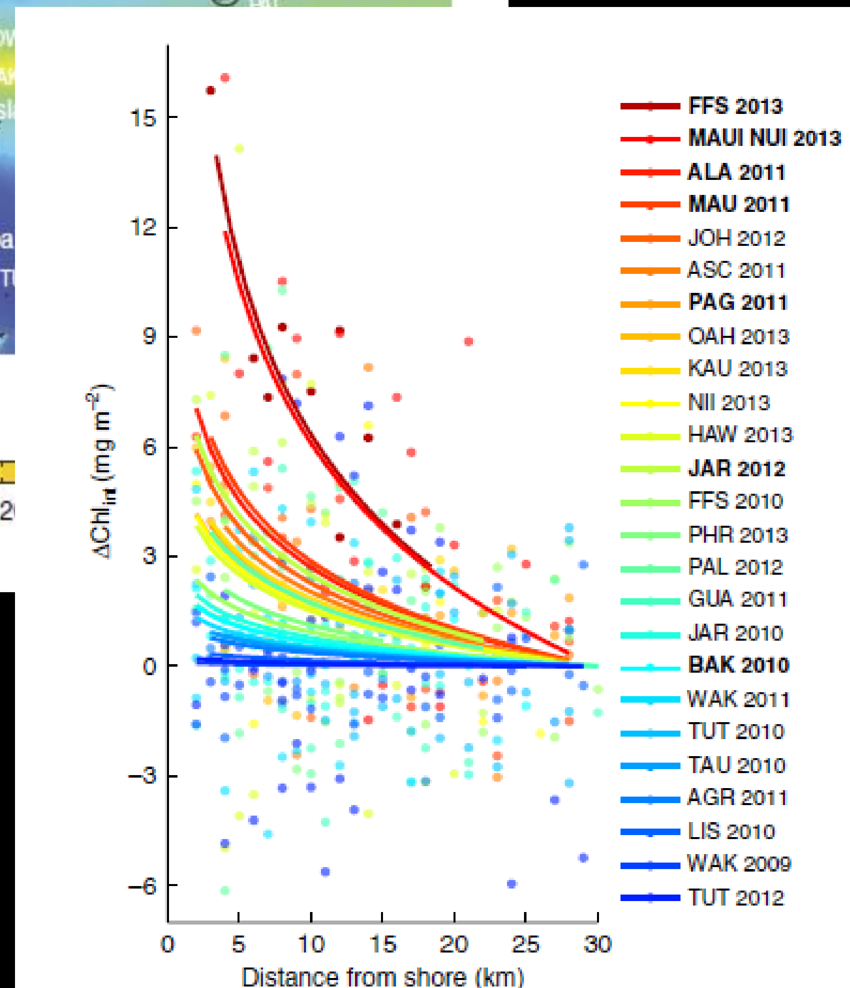


Hyde at al. (JPSS) with STAR



Satellite Ocean Color in models for U.S. West Coast (Jacox et al. JPSS)





Gove at al. PIFSC

EcoCast
An Eco-informatic Tool for Fisheries Sustainability
Experimental Product

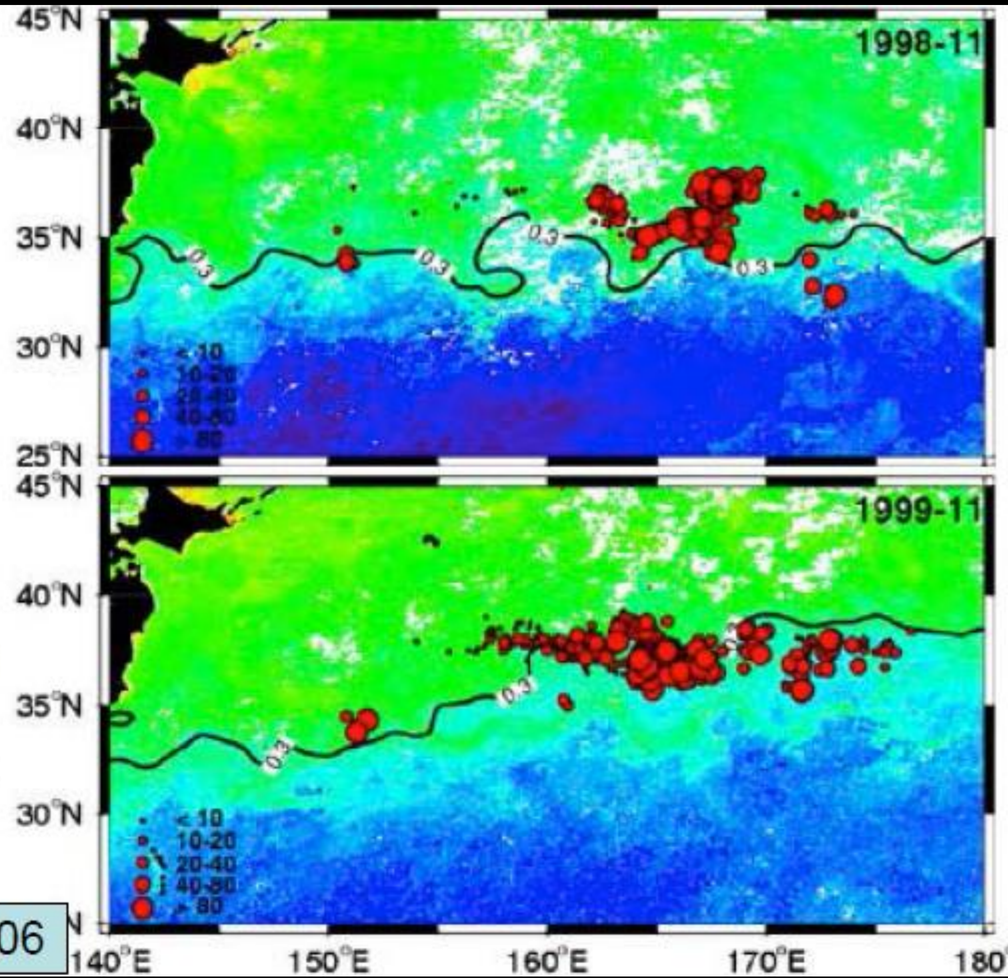
Fishing zones predicted based on ocean features, catch potential, and weighted by bycatch risk

Hazen et al. 2018 *Science Advances*

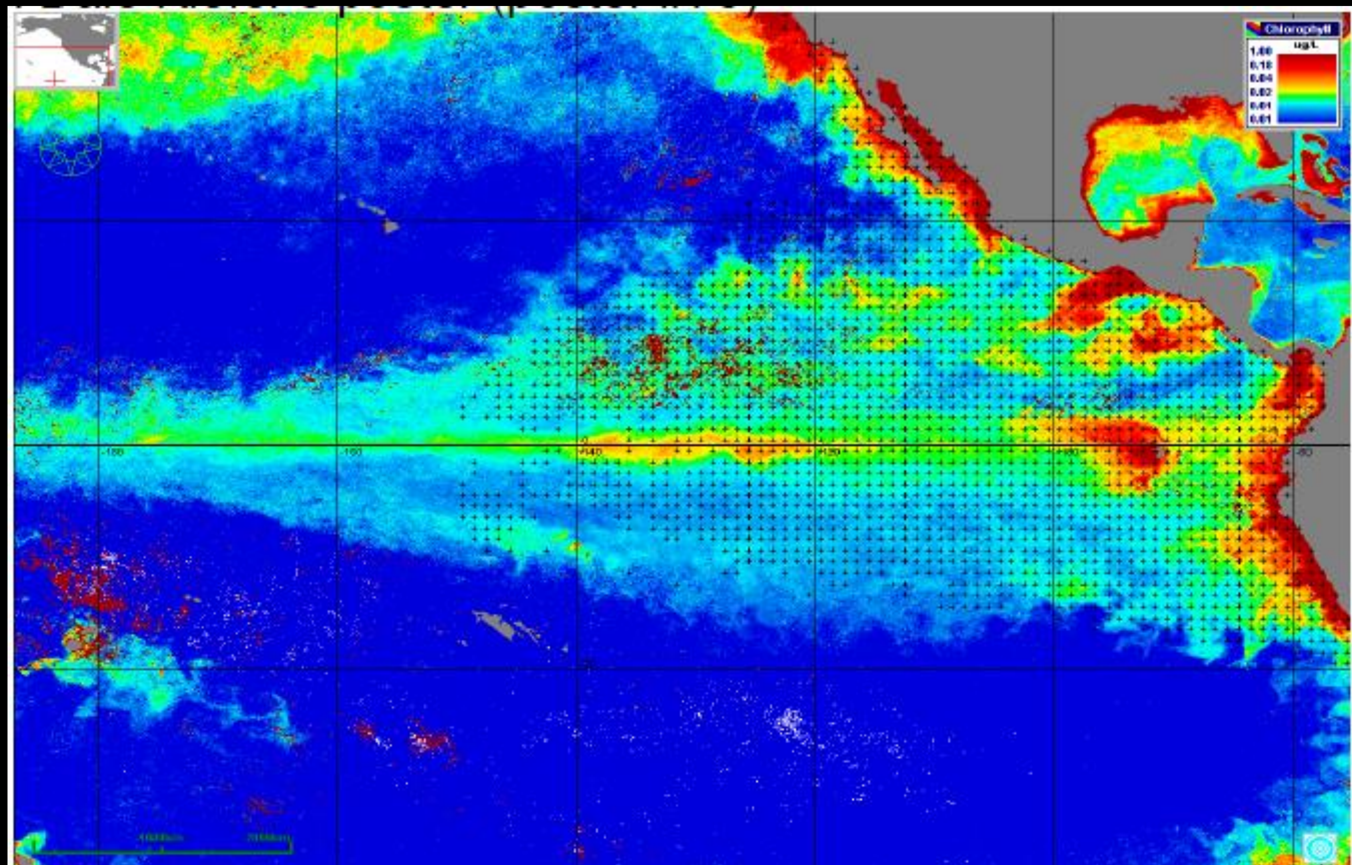
Drew Briscoe

Hazen et al. SWFSC

Albacore CPUE (catch per unit effort) overlain on SeaWiFS chlorophyll, showing that the longline fishery largely operates along the transitional zone chlorophyll front (TZCF)



Zainuddin et al., DSR-II, 2006



PIFSC

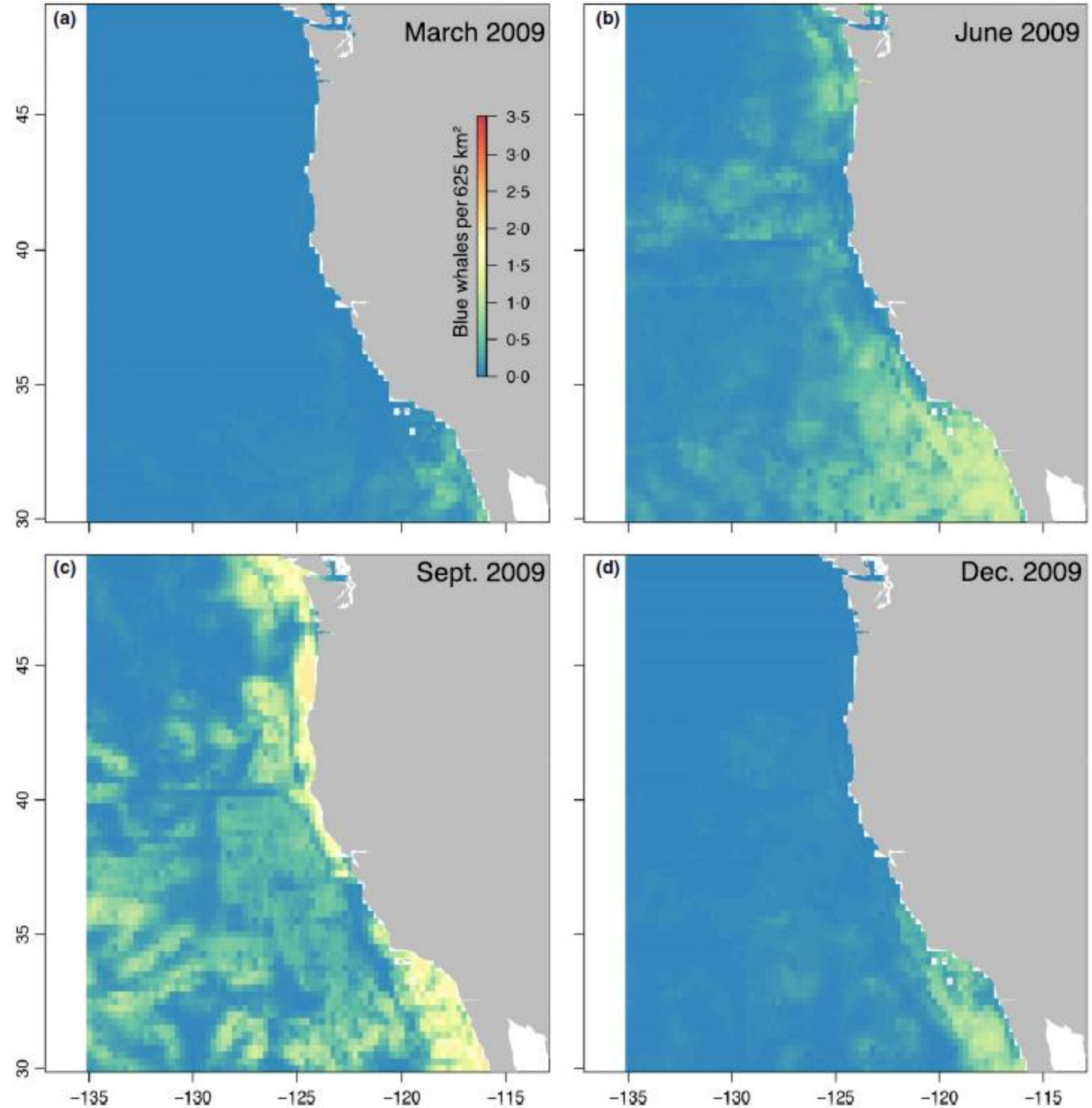
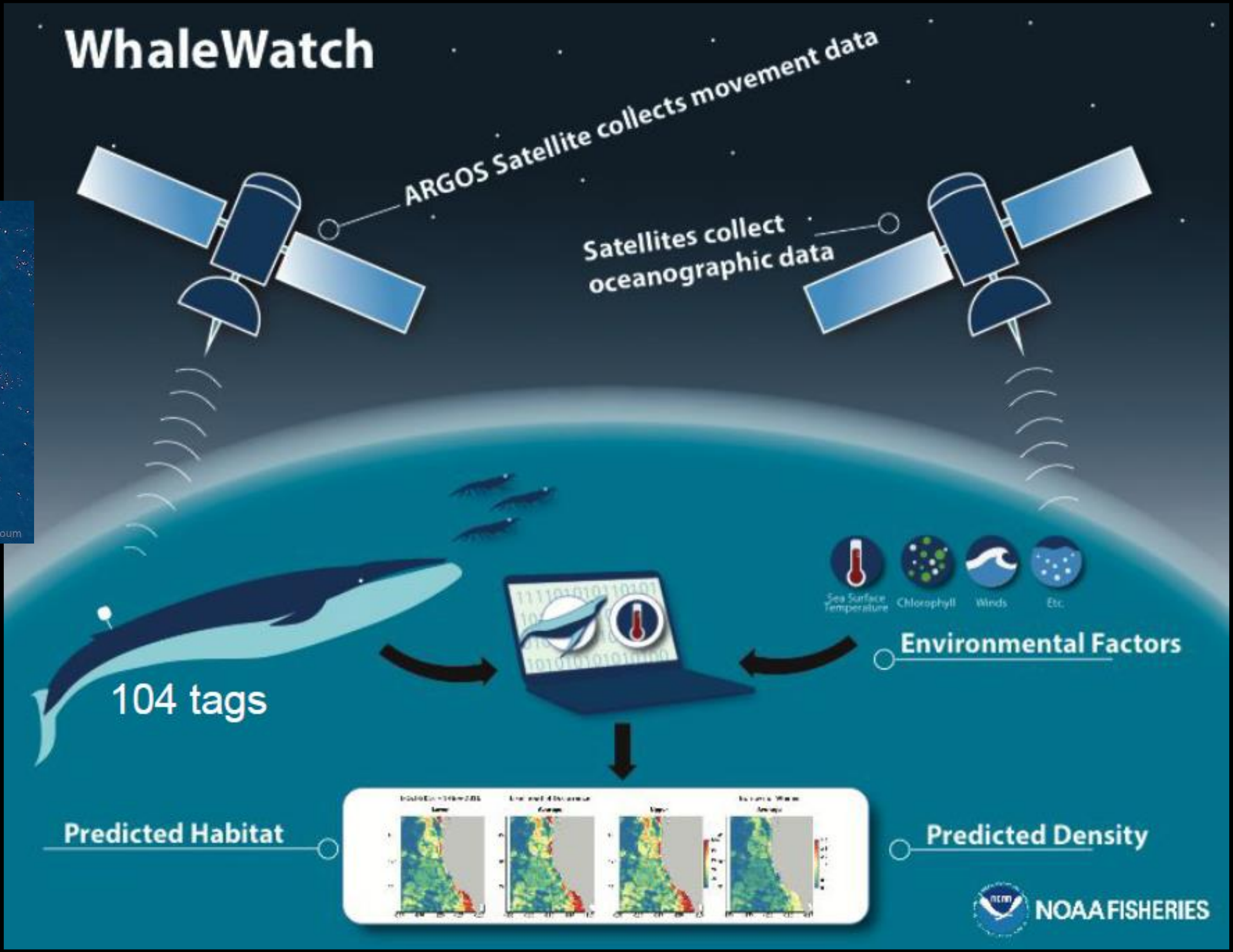


Fig. 4. (a–d) Blue whale habitat predictions from seasonal GAMMs for March, June, September and December of 2009. Density is included as number of whales per 625 km^2.



Hazen at al. SWFSC

- Maintain highest quality long-term time series (preferably hyperspectral)

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