Current and Emerging Science (R&D to Users!) Activities in STAR's Satellite Oceanography and Climatology Division

Paul M. DiGiacomo, Ph.D.
Chief, SOCD & CoastWatch/OceanWatch Program Manager

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CoastWatch/OceanWatch Program Scientist

CICS Science Meeting
30 November 2016

NOAA: Making Science Matter

Environmental Intelligence

Observations → Monitoring → Assessment → Modeling → Tools & Services

NOAA's long-term goals

1. Climate Adaptation and Mitigation
2. Weather-Ready Nation
3. Healthy Oceans
4. Resilient Coastal Communities and Economies

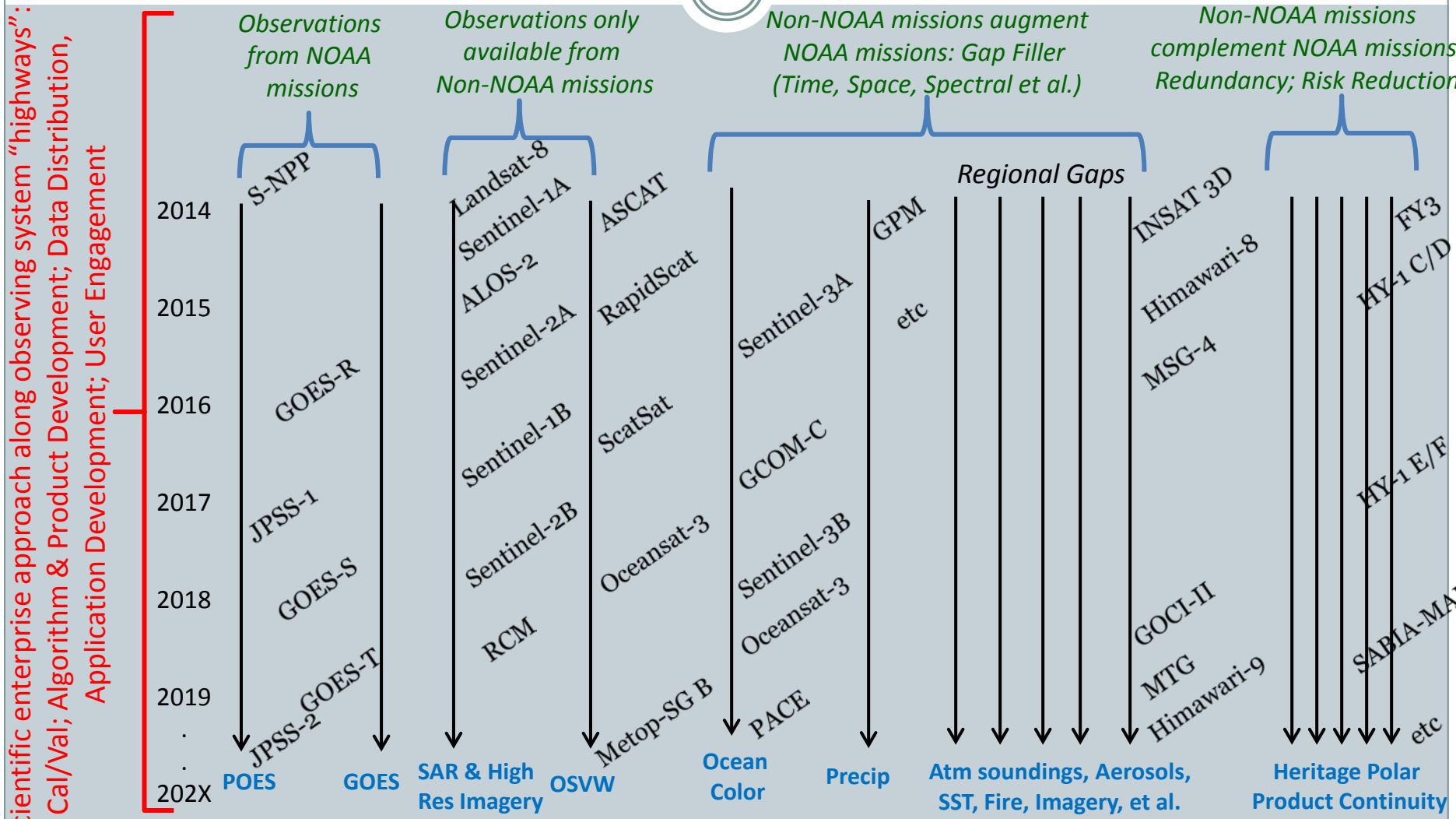
NOAA/NESDIS Center for SatelliteApplications & Research (STAR):

To advance remote sensing science and technology to better inform the American public and safeguard the environment .

- Active engagement of users (*science-based understanding of requirements*)
- Facilitate end-to-end value chain for satellite observations (“*translate” obs to info*)
- Pursue measurement-based approach (*mission-agnostic, ensure continuity for users*)
- Generate data of highest possible quality (*no short-cuts!*)
- Provide satellite data products that are fit for purpose (*new operational paradigm*)
- Ensure user satellite data needs are met (*existing as well as emerging/evolving*)

- NB: the value of our (environmental data) products is zero until they are used to improve societal outcomes (Jeff Adkins, NOAA social scientist).

Mission Agnostic, Measurement-based approach in support of users: Ensuring continuity & coverage



Courtesy: Paul DiGiacomo & Paul Chang

STAR Satellite Oceanography & Climatology Division (SOCD)

SOCD Organization

SOCD Chief: *Dr. Paul M. DiGiacomo*

Ocean Sensors Branch

Chief: *Dr. Alexander (Sasha) Ignatov*

- Sea Surface Temp, Ocean Winds, Ocean Optics & Water Quality (e.g. Chesapeake Bay)

Marine Ecosystems & Climate Branch

Chief: *Dr. Menghua Wang*

- Ocean Color, Coral Reefs, Sea Ice, Synthetic Aperture Radar, Blended SST

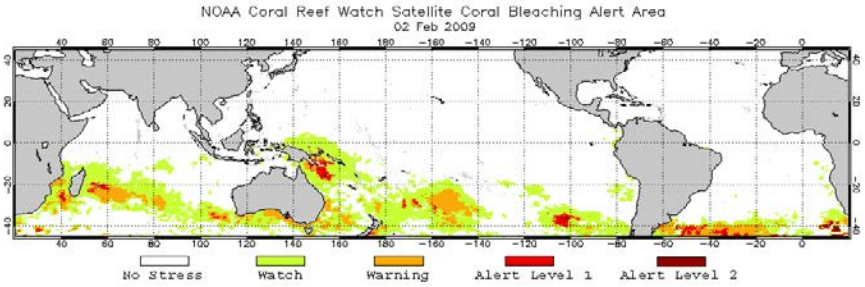
Laboratory for Satellite Altimetry

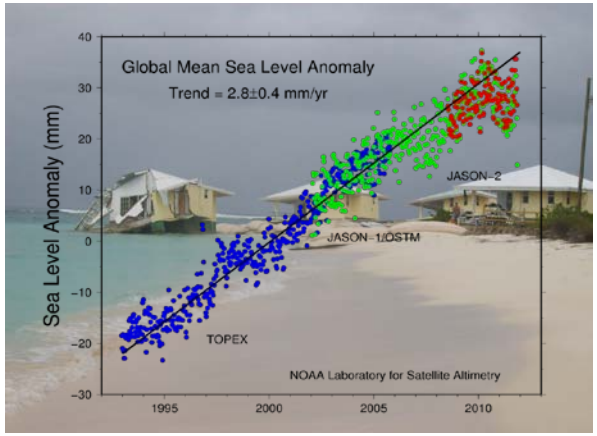
Chief: *Dr. Laury Miller*

- Sea Level, Bathymetry, Waves, Sea Ice/Climate

Science Teams: R&O

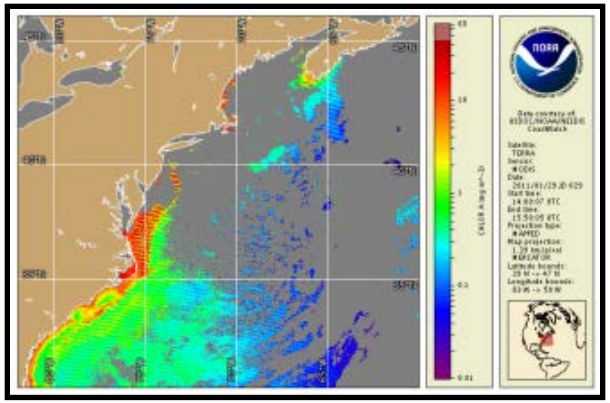
- Sea Ice
- Sea Surface Height
- Sea Surface Roughness
- Sea Surface Salinity
- Sea Surface Temperature
- Ocean Color Radiometry
- Ocean Surface Vector Winds
- CoastWatch/OceanWatch
- Coral Reef Watch
- PolarWatch





Major Programs/Activities

- JPSS: Ocean Color & SST EDRs
- GOES-R: SST (& Ocean Dynamics)
- JASON Satellite Radar Altimeter Program
- NOAA GCOM Program Scientist
- National Ice Center Chief Scientist
- Foreign Sensors: Winds, SAR, etc
- Marine Optical BuoY (MOBY)
- Coast/Ocean/PolarWatch & Coral Reef Watch



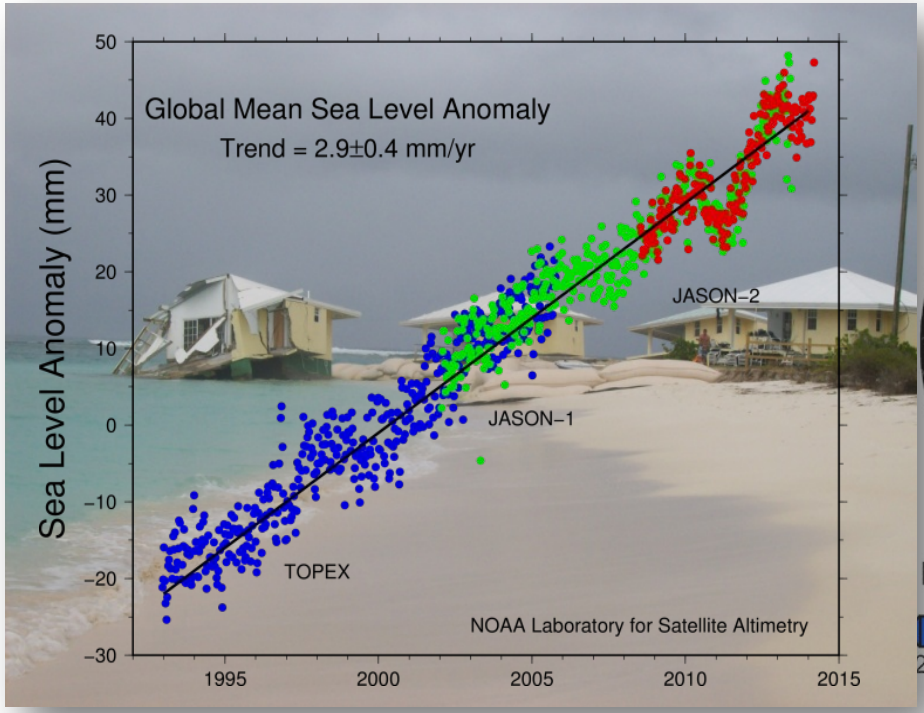
Jason Satellite Radar Altimeter Program

24+ year CEOS global reference record of sea level

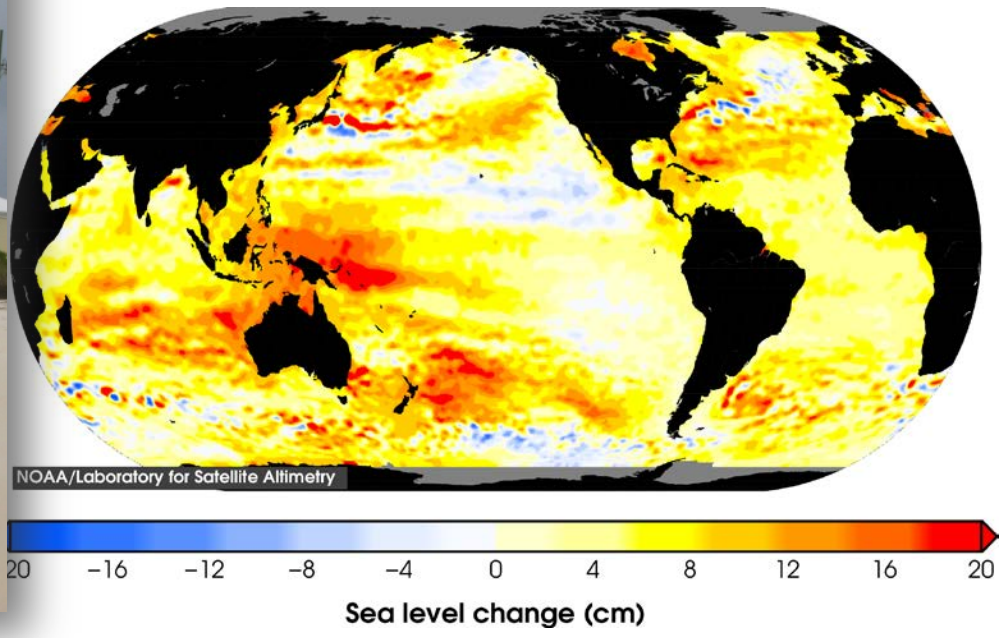
Led by NOAA and its operational partner, EUMETSAT, in collaboration with NASA, CNES, and soon ESA and the EC for Jason-CS in 2020.

STAR Laboratory for Satellite Altimetry

Global mean sea level anomaly:
TOPEX/Poseidon, Jason-1, Jason-2



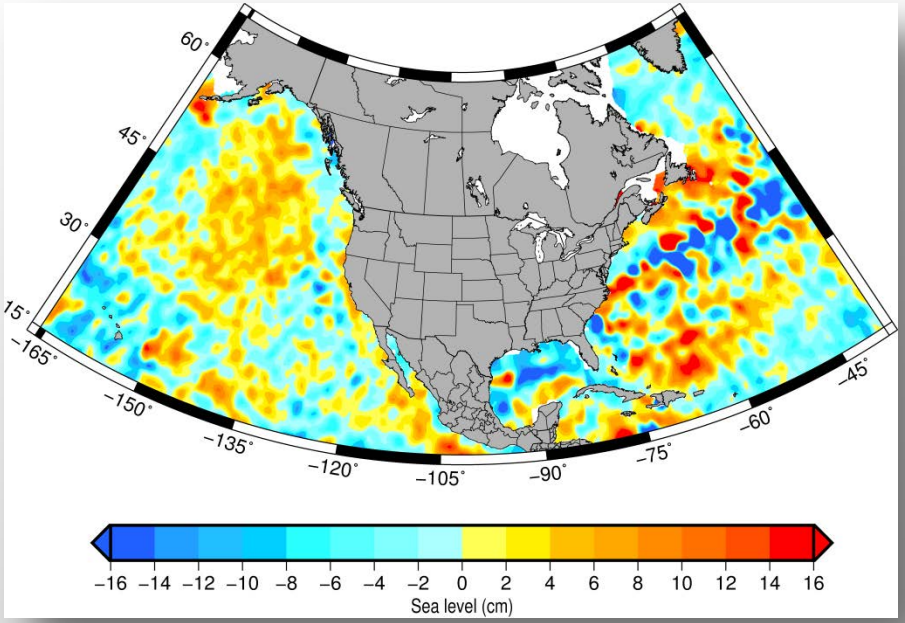
Total sea level change since 1993



Jason Applications & End Users

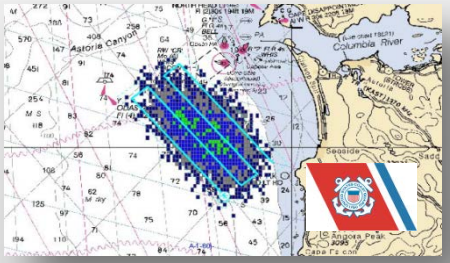
Laboratory for Satellite Altimetry
NOAA·NESDIS·STAR

Sea Level Anomaly –"Ocean Weather"- Feb 3-13, 2014

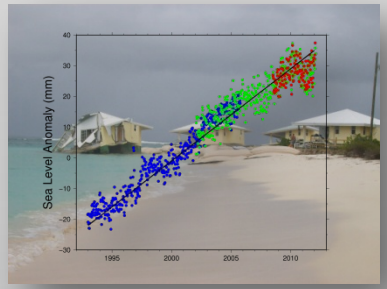


High Wave Forecasting

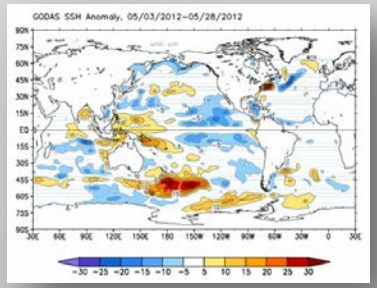
Coast Guard Search & Rescue



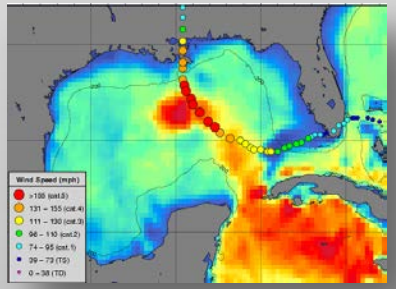
Global & Regional Sea Level Rise



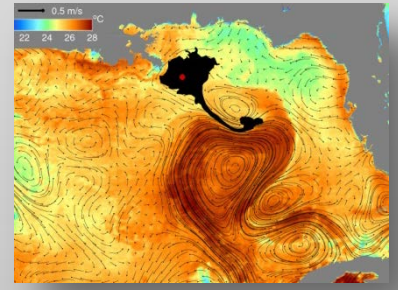
El Nino Forecasting



Hurricane Intensity Forecasting

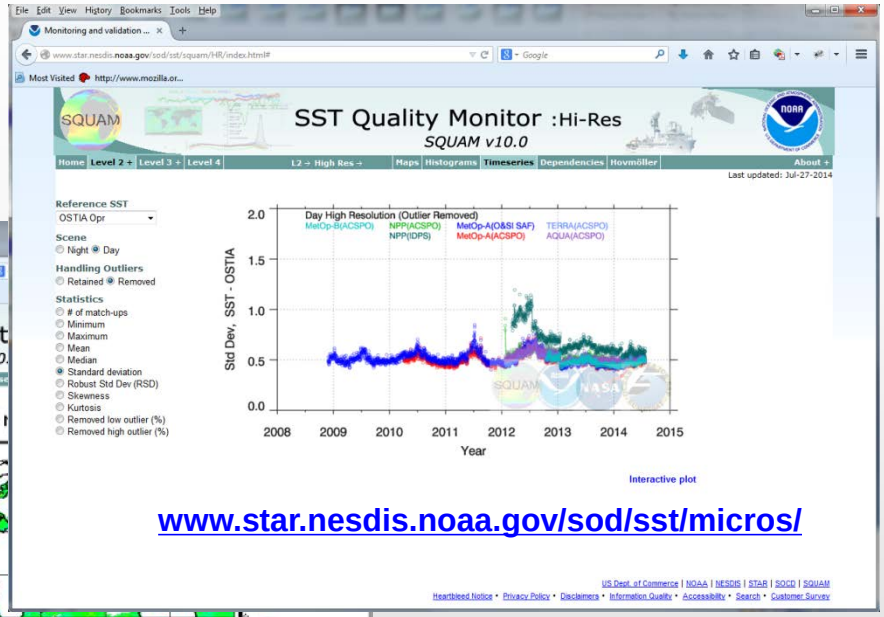


Oil Spill Monitoring

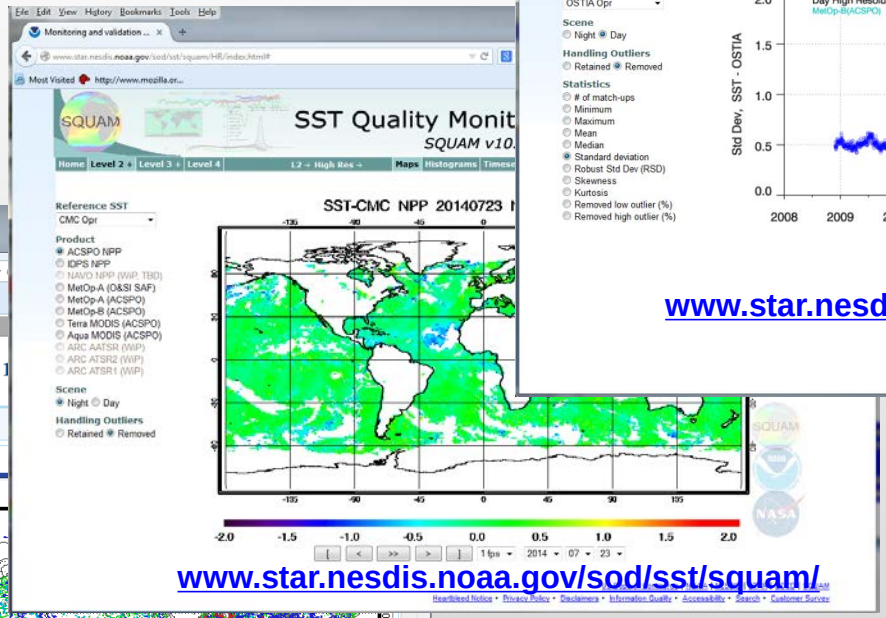


NOAA SST Monitoring: Bringing Community Together

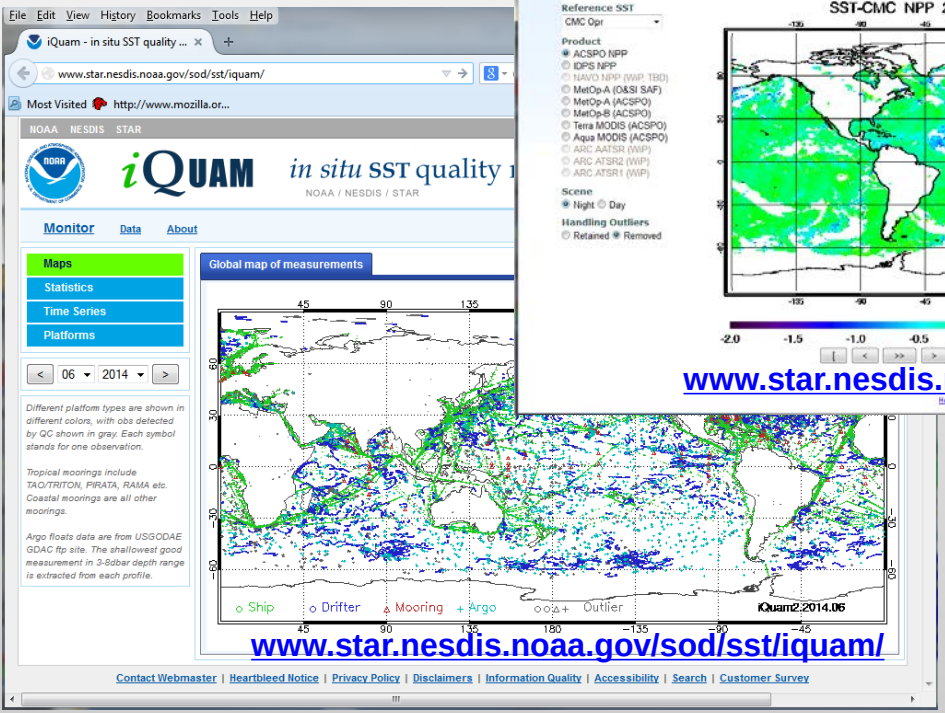
Today, STAR leads community efforts and brings together NOAA and partners' SST products



www.star.nesdis.noaa.gov/sod/sst/micros/



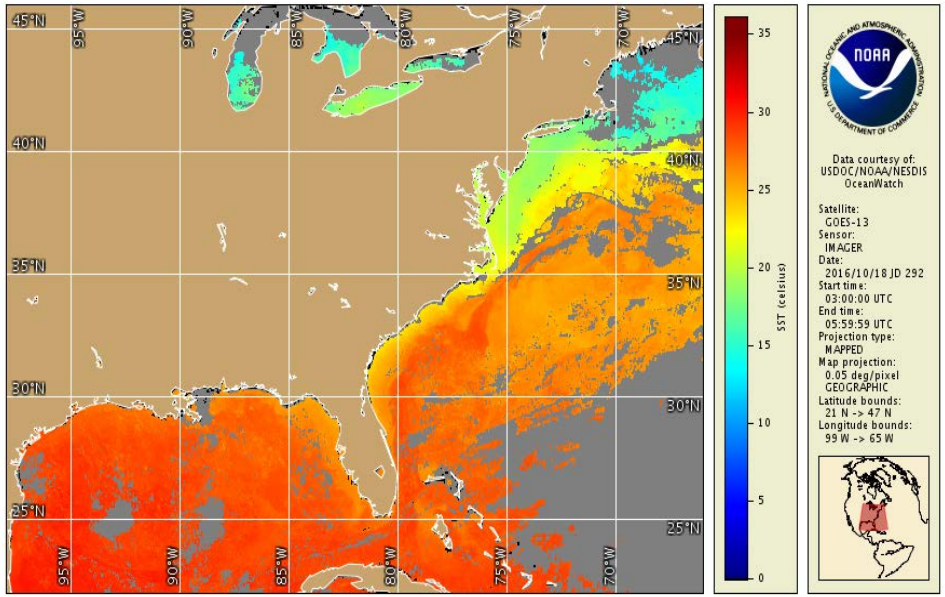
www.star.nesdis.noaa.gov/sod/sst/squam/



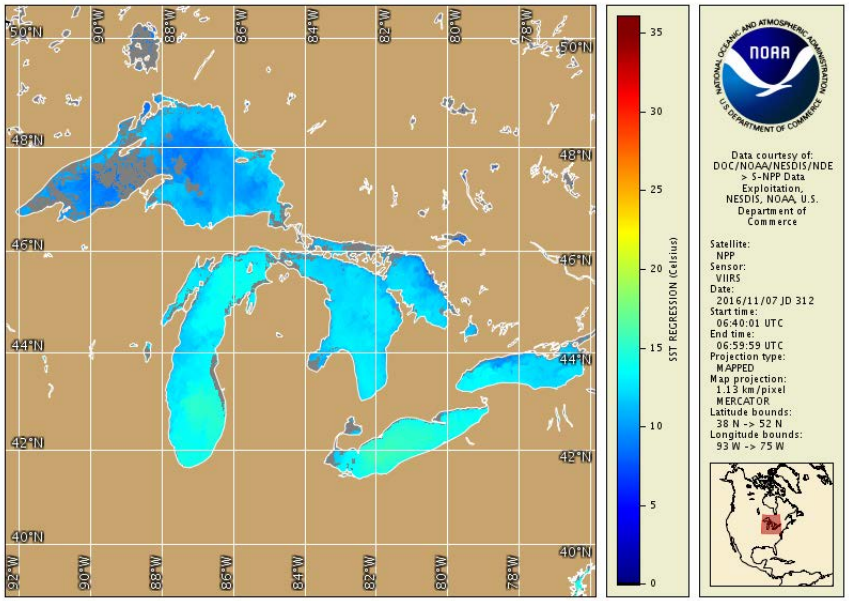
www.star.nesdis.noaa.gov/sod/sst/iquam/

Products are monitored online in near-real time, to ensure high quality & consistency, to support and facilitate SST applications

Local & Regional SST Products (LEO & GEO)



GOES SST, 17 Oct 2016



VIIRS SST, 7 Nov 2016

Polar SST Production and Monitoring Systems at NESDIS/STAR

ACSPO* - *Advanced Clear-Sky Processor for Oceans

- ✓ Used for AVHRR Operations & Reprocessing
- ✓ Used for VIIRS Operations & to be used for reprocessing
- ✓ Can be potentially used for MODIS (re)processing

SQUAM* - *SST Quality Monitor* *www.star.nesdis.noaa.gov/sod/sst/squam/

- ✓ Monitor SST Products (L2, L3, L4) for Self- and Cross-Consistency; Validate against *in situ* SSTs (*iQuam*)

MICROS* - *Monitoring IR Clear-sky Radiances over Oceans for SST
www.star.nesdis.noaa.gov/sod/sst/micros/

- ✓ Monitor Clear-sky ocean radiances for Self- and Cross-Consistency; Validate against CRTM simulations

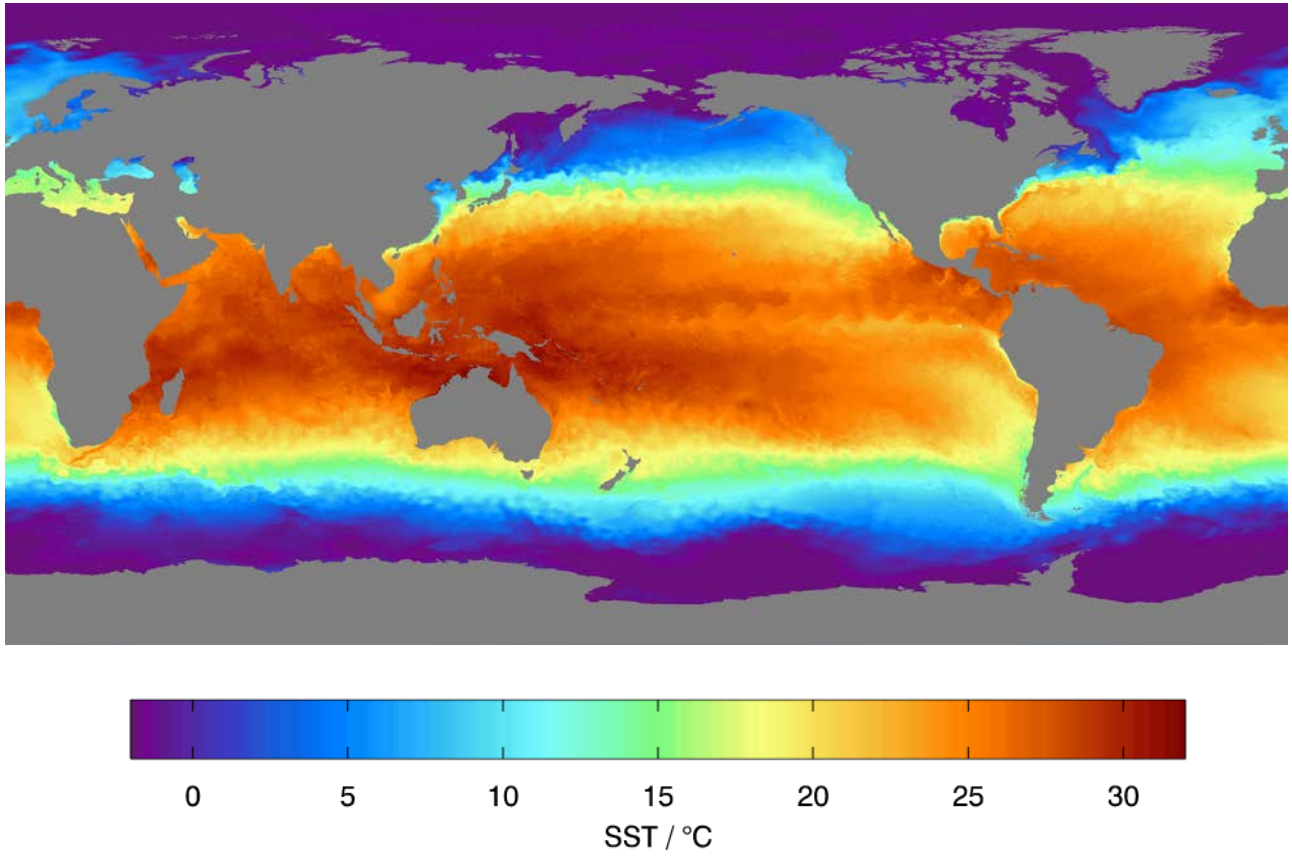
iQuam* - *In situ Quality Monitor* *www.star.nesdis.noaa.gov/sod/sst/iquam/

- ✓ QC *in situ* SSTs, Monitor on Web, Distribute to users

ARMS* - *ACSPO Regional Monitor of SST* *http://www.star.nesdis.noaa.gov/sod/sst/arms/

- ✓ Global SST monitoring in SQUAM is supplemented by ARMS system, focusing on geographical regions of interest, e.g., US coastal regions and other regions worldwide

5-km Global Blended SST Analysis

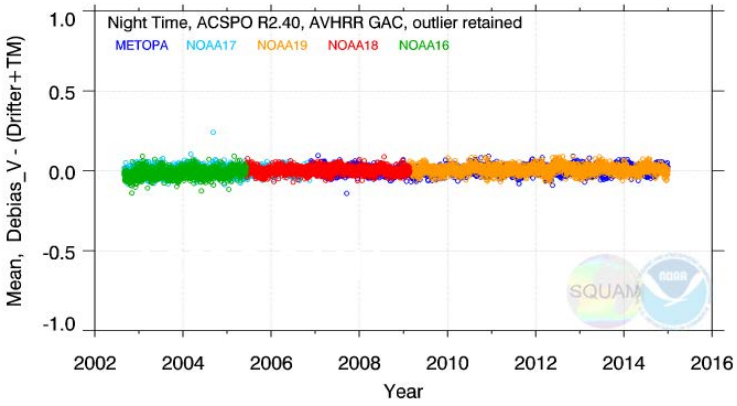


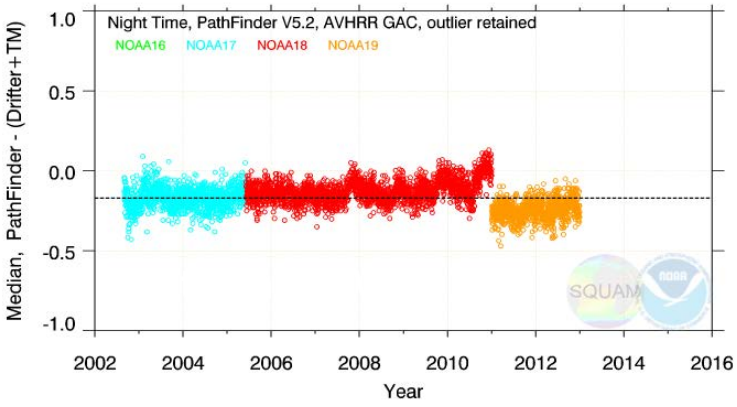
- **Produced daily from operational Polar and Geo-SST data.**
- **Product benefits from available non-NOAA SST data, especially for other basins**

http://www.ospo.noaa.gov/Products/ocean/sst/contour/index.html

AVHRR Reanalysis v1 (2002-pr)
Ignatov et al., *Remote Sens.*, 2016

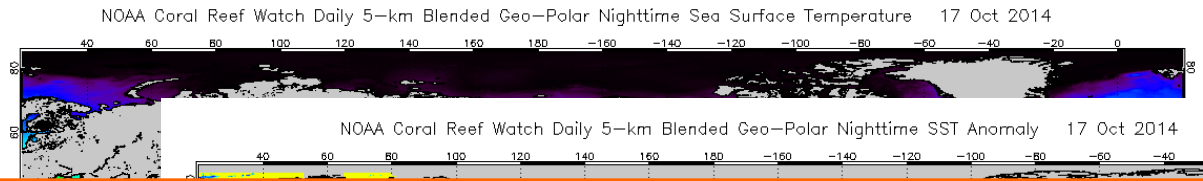
Global Bias with respect in situ SSTs

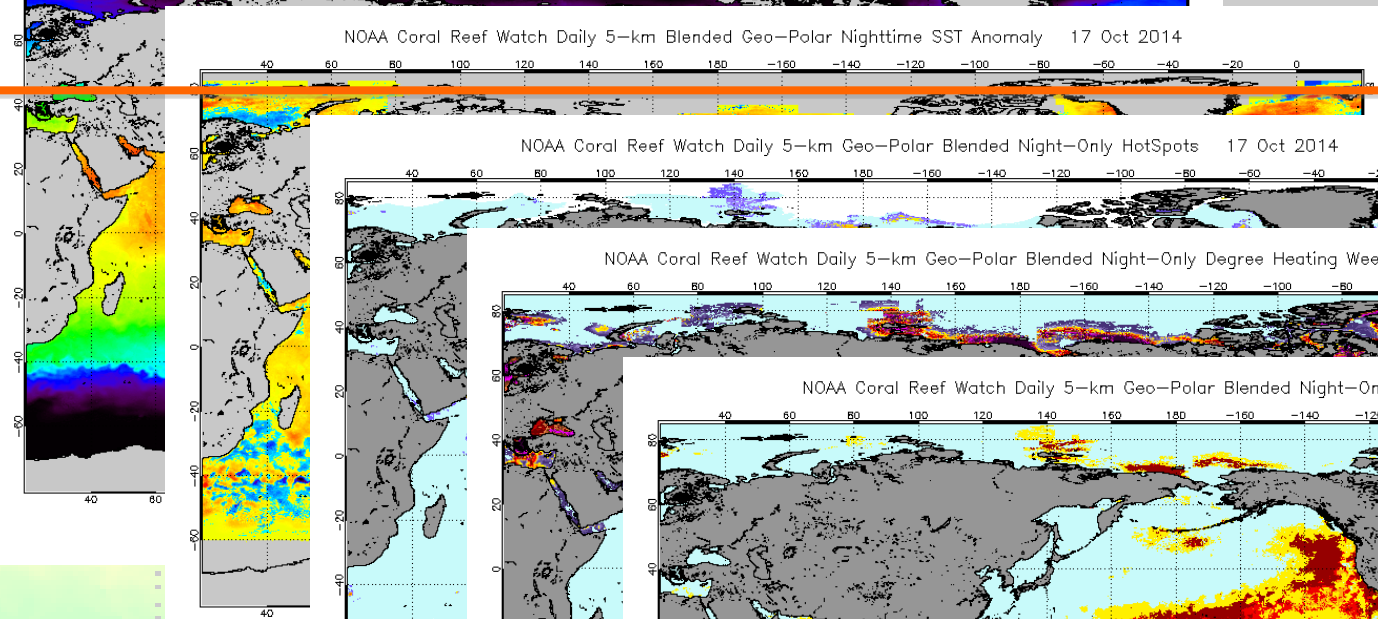


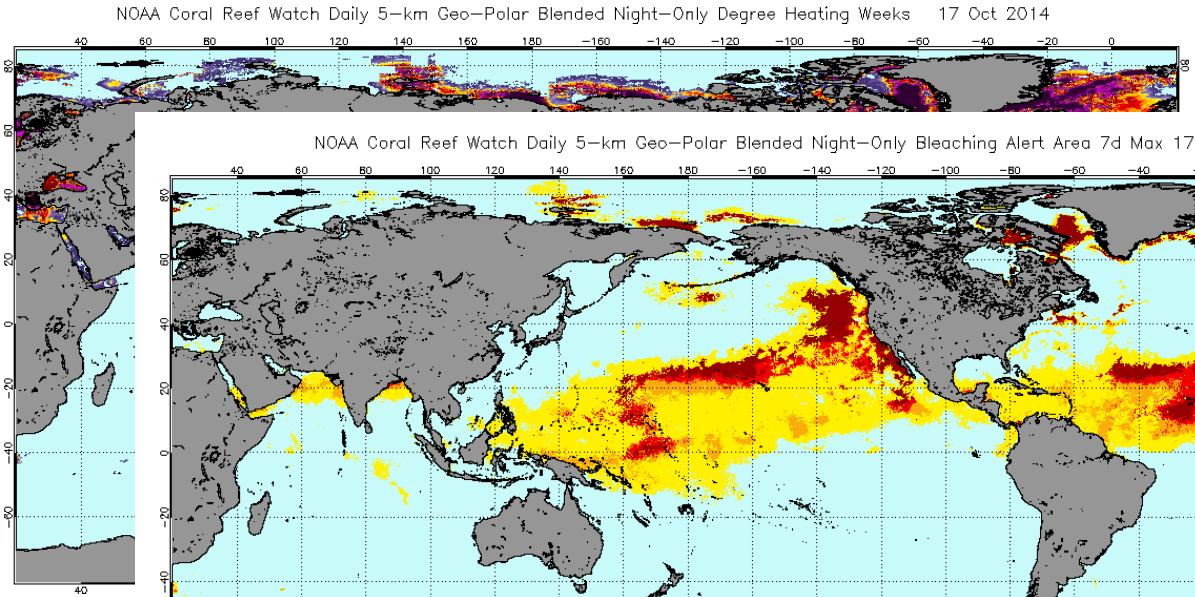


- 13+ years of AVHRR data (2002-pr) reprocessed from 7 satellites using NOAA ACSPO system
- Delivered to STAR geo-polar blended SST team for use by NOAA Coral Reef Watch
- Product is more accurate and uniform than the widely used Pathfinder SST dataset
- Work is underway to archive with JPL PO.DAAC and NCEI

Coral Reef Watch
5-km Satellite-Based Products





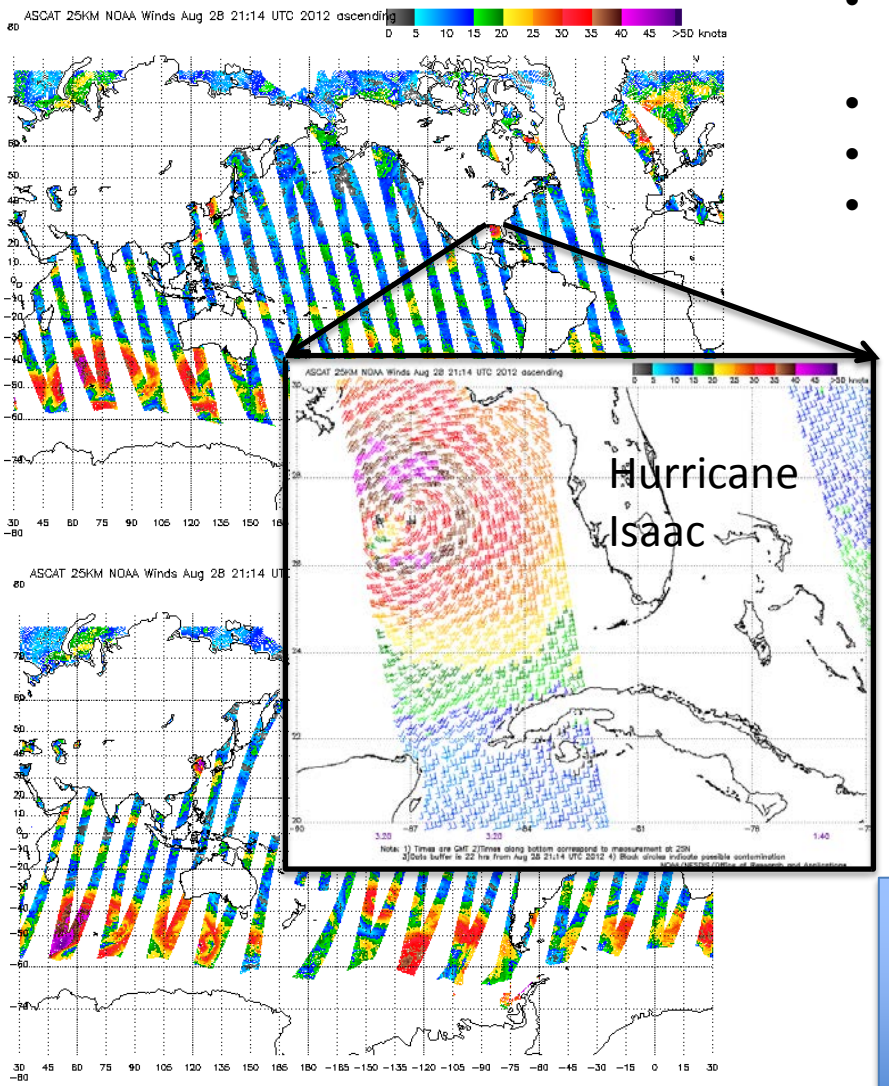


Coral – specific

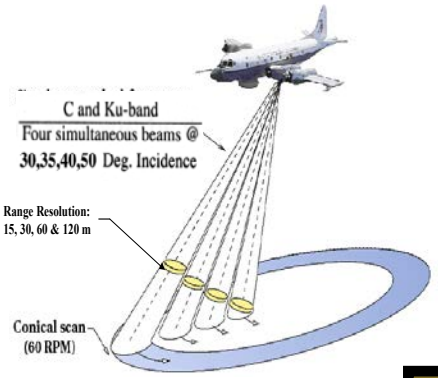
http://coralreefwatch.noaa.gov

Satellite Ocean Surface Vector Winds

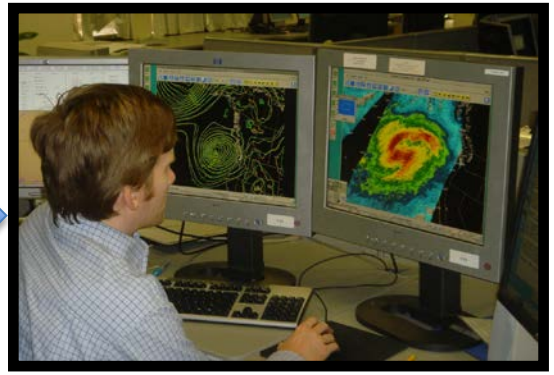
ASCAT Daily Coverage Example



- OSVW data supports wind and wave warning and forecasting
- ASCAT data from EUMETSAT operational at NOAA
- SCATSCAT data from ISRO next up for implementation
- NOAA P-3 used to fly a profiling scatterometer system (IWRAP) for validation and improvement of satellite algorithms in tropical (hurricanes) and extratropical cyclone conditions

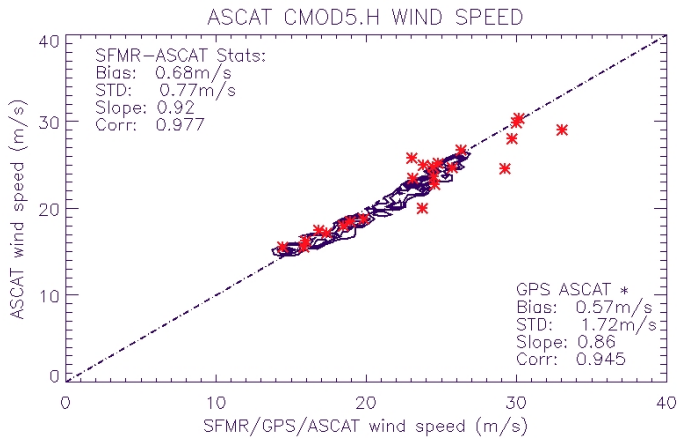


Goal: Provide the best possible product and training to end users

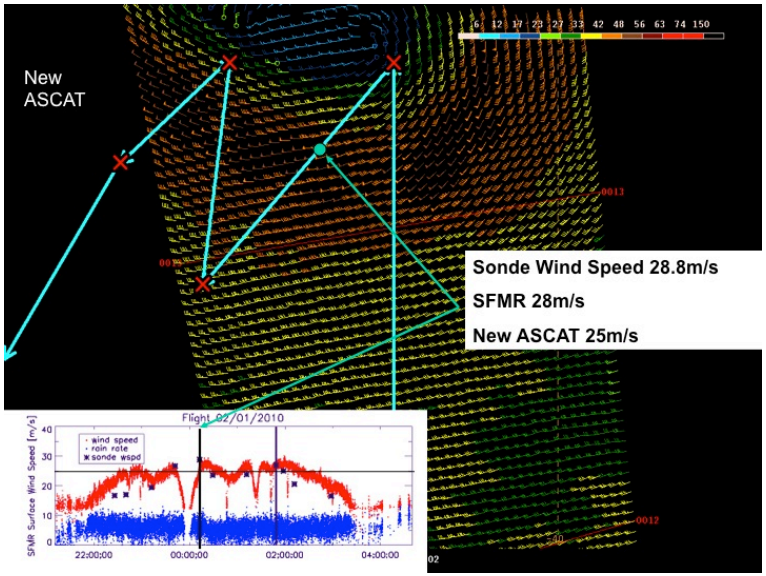


NOAA Satellite Ocean Surface Winds Science Team
http://manati.star.nesdis.noaa.gov/

ASCAT High Wind Speed Retrieval Improvement

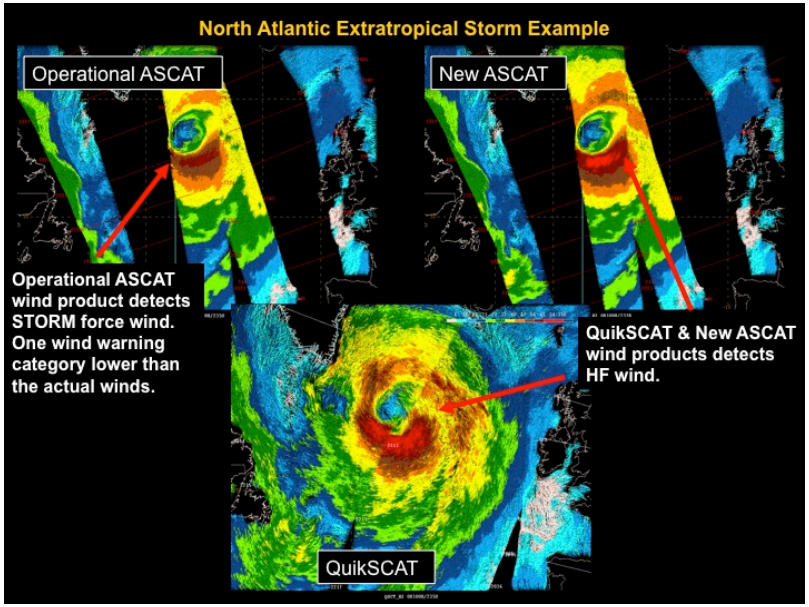


New ASCAT winds versus SFMR and GPS dropsonde winds



Flight track overlaid on ASCAT swath

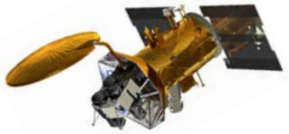
- ASCAT high wind speed improvements developed utilizing aircraft and satellite data



Hurricane force wind observations with NOAA's QuikSCAT and original and new ASCAT wind products

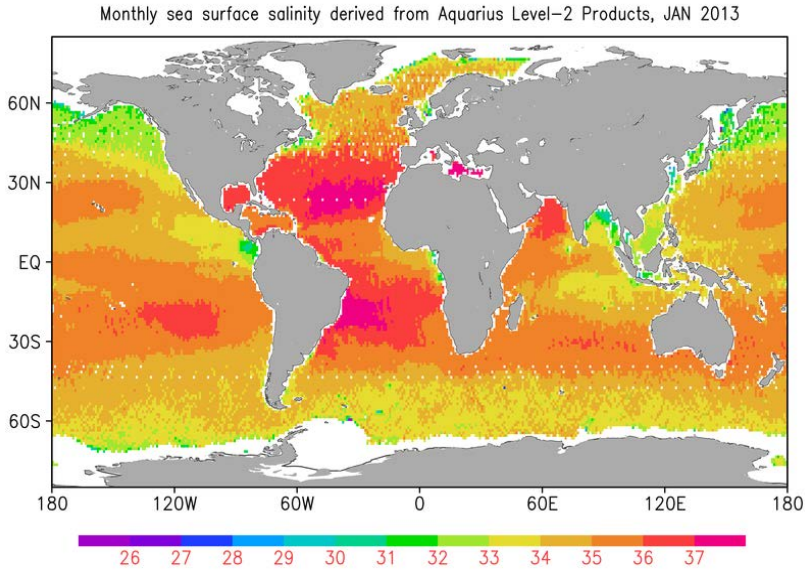
Satellite Sea-Surface Salinity Science Team

Current & Emerging Efforts

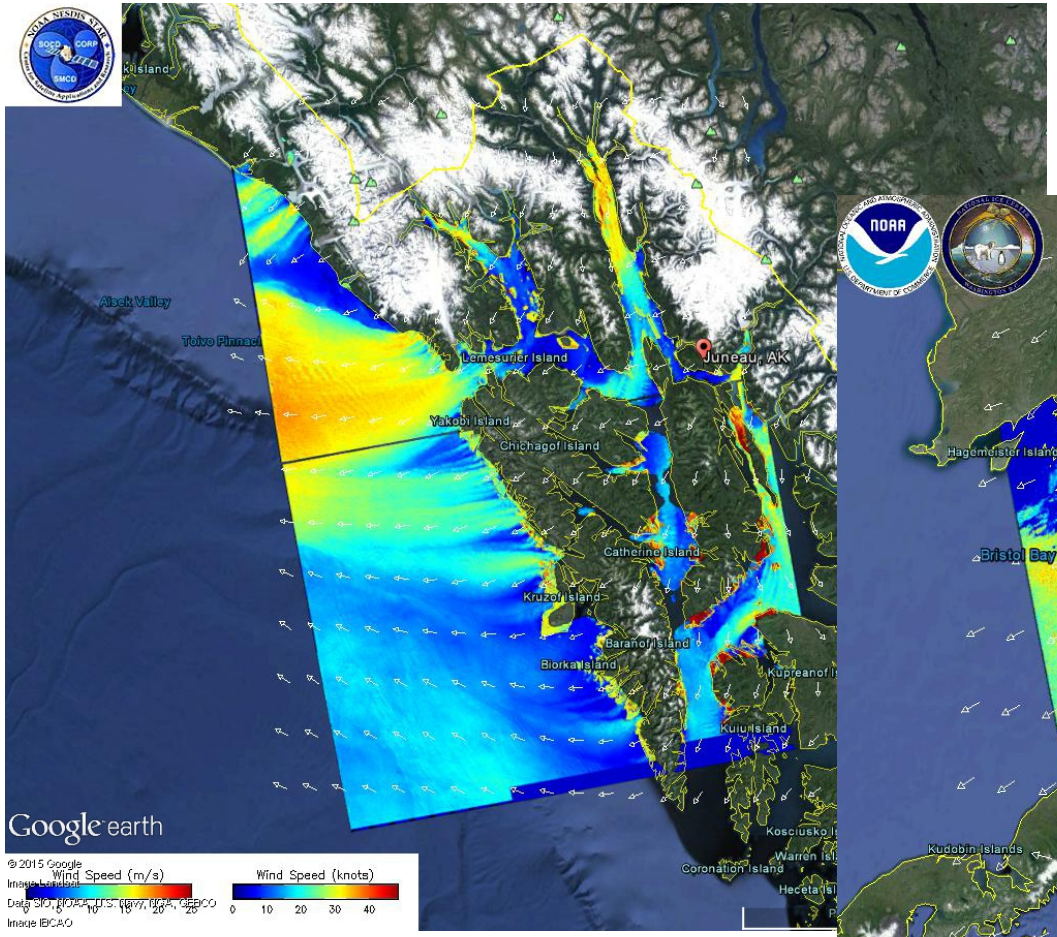


- **Data**
  - SSS Level-2 /3 data records acquired for NASA's Aquarius & ESA's SMOS missions
  - Data set development in support of applications and climatology
  - Ocean color radiometry for coastal/estuarine areas
- **Quality**
  - Online quality monitoring and assessment - automation, statistics, visualization:
    Satellite Sea-Surface Salinity Quality Monitor (4SQM)
  - NESDIS/Center for Satellite Applications and Research (STAR)
  - NESDIS/National Centers for Environmental Information (NCEI) / CICS
- **Assimilation**

  Working with users to incorporate SSS data
  - National Weather Service (NWS):
    Real-Time Ocean Forecast System (RTOFS)
  - NWS seasonal-interannual:
    Global Ocean Data Assimilation System / Coupled Forecast System (CFS)

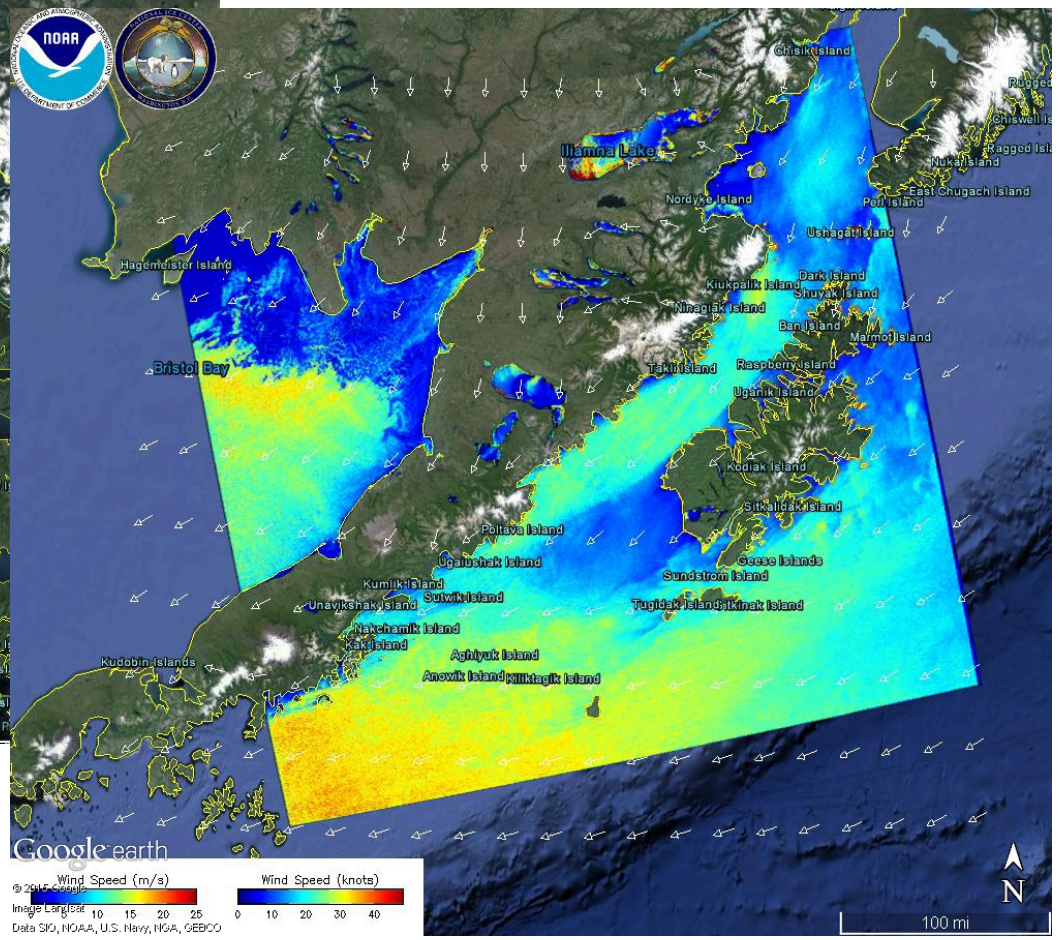


High-Resolution SAR-Derived Wind Speed Products



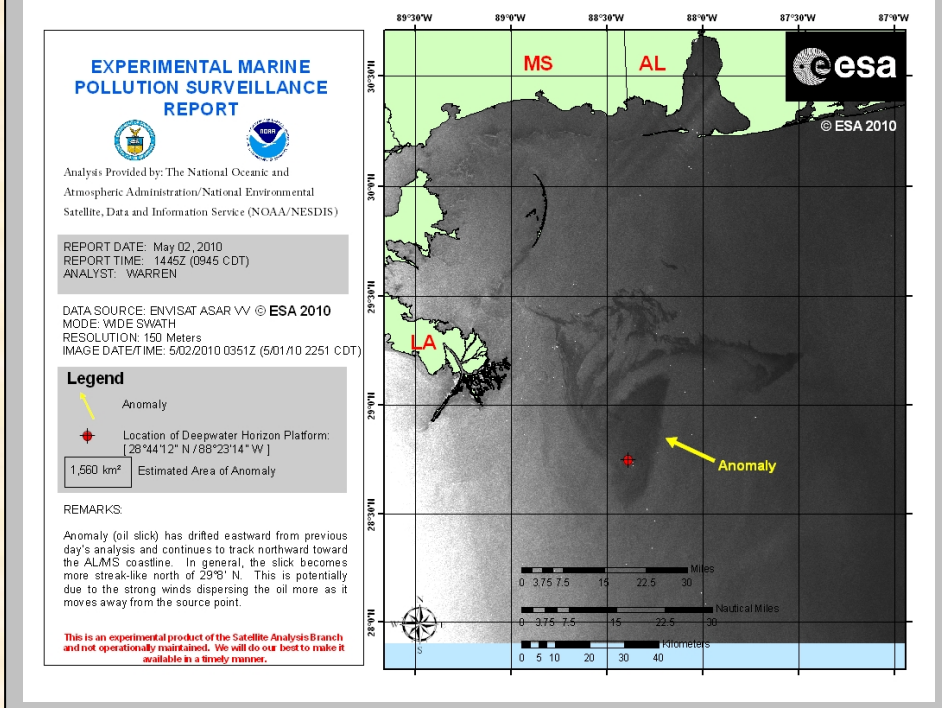
Pre-operational Sentinel-1A wind speed
2015-01-08 02:46 UT

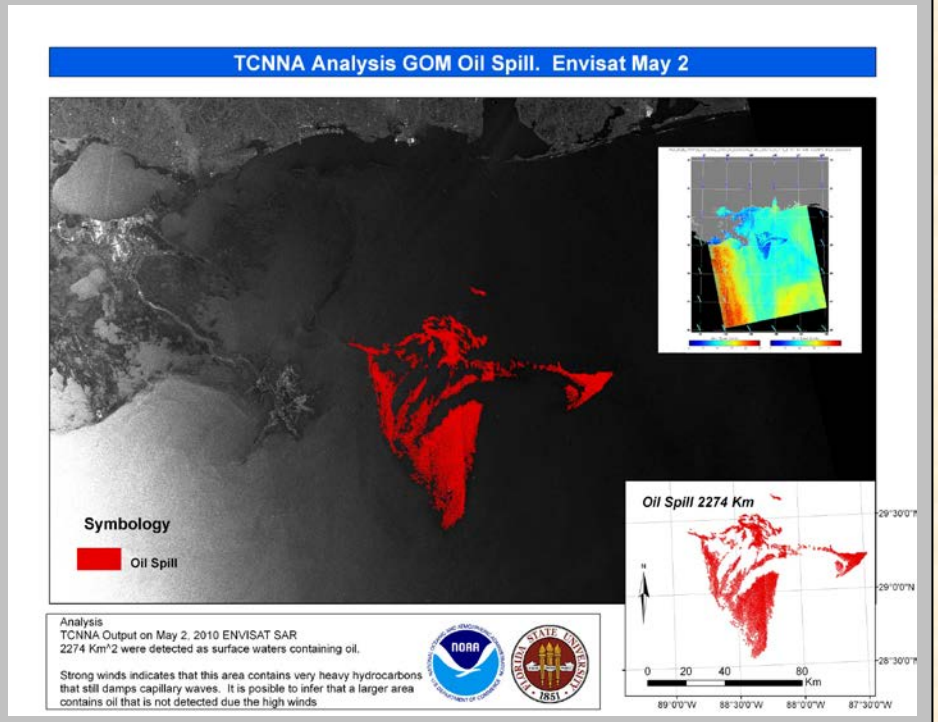
Operational Radarsat-2 wind speed
2015-02-04 04:05 UT



Interactive and Automated Techniques for Oil Spill Analysis Using (SAR) Imagery

Deepwater Horizon Fire 4/21/2010

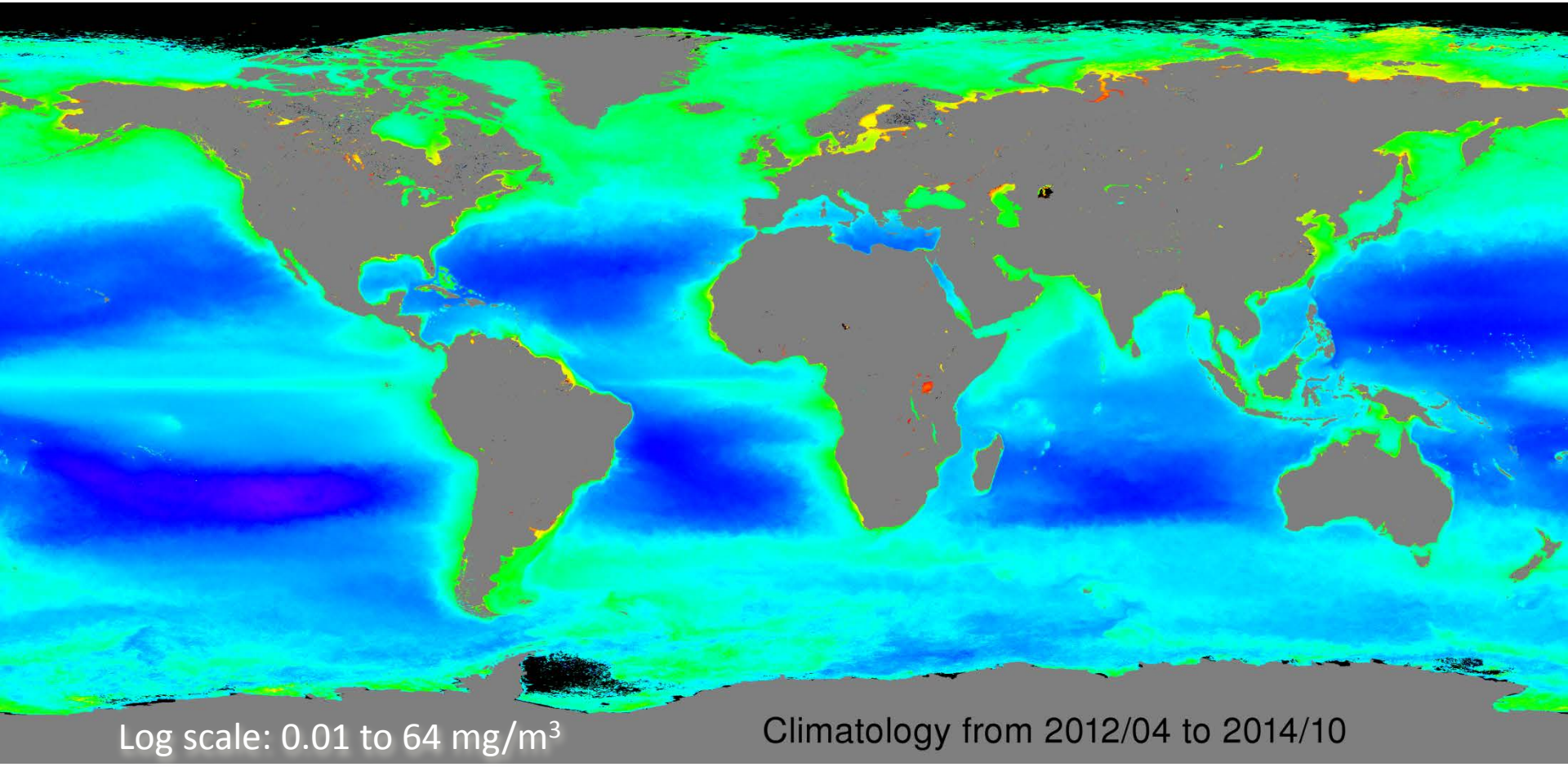




Interactively derived Marine Pollution Surveillance Report issued by NESDIS/OSPO Satellite Analysis Branch for May 2, 2010, during the Deepwater Horizon incident.

Automated Texture Classifying Neural Network (TCNNA) oil spill map for the same day. This algorithm is being developed in a collaboration between NESDIS/STAR and Florida State University for possible use as an automated oil spill mapping tool.

VIIRS Climatology Chlorophyll-a Image

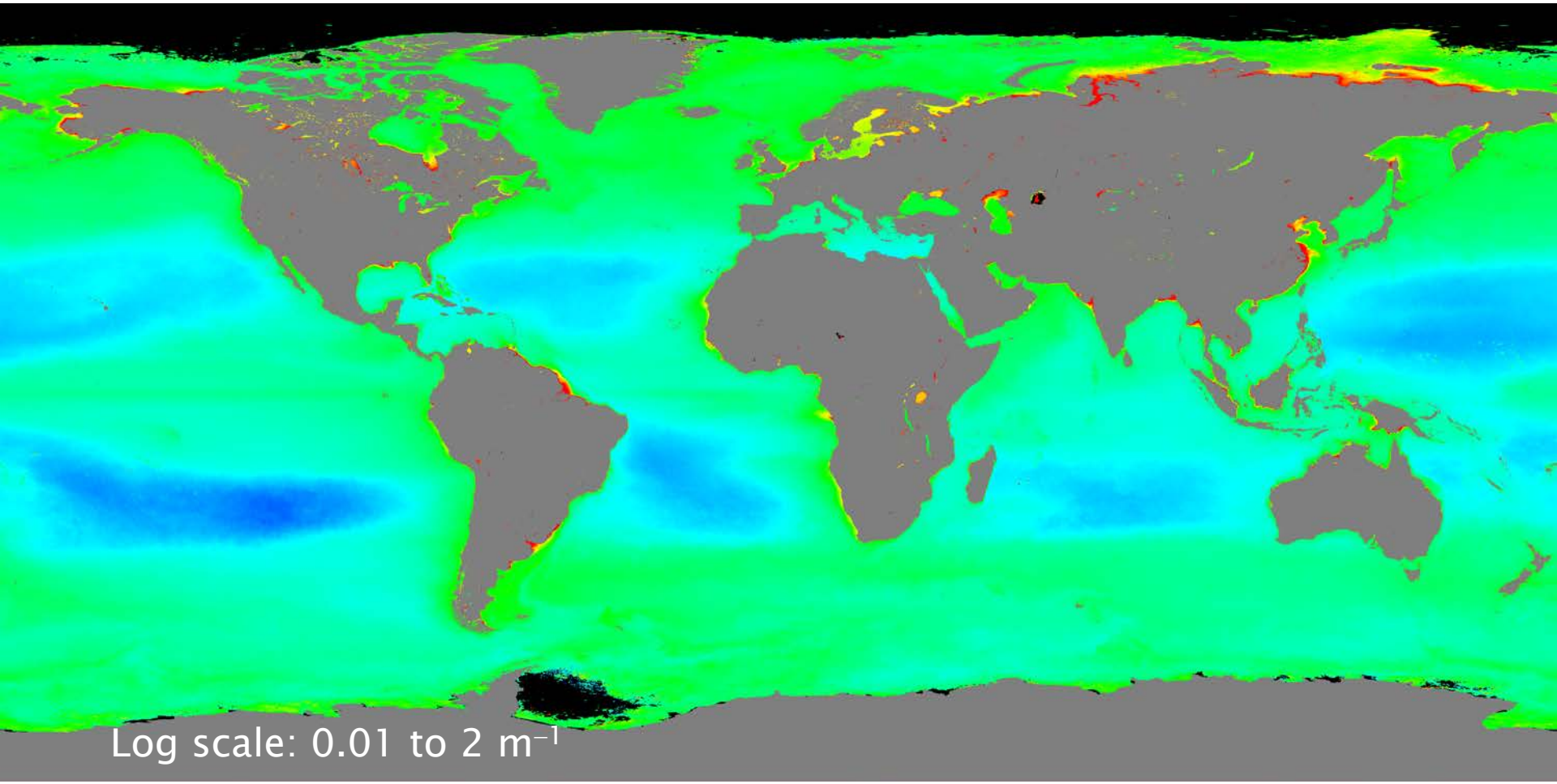


Generated using NOAA MSL12 for VIIRS ocean color data processing

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

New VIIRS OC Product: Satellite-derived K_d(PAR) Data

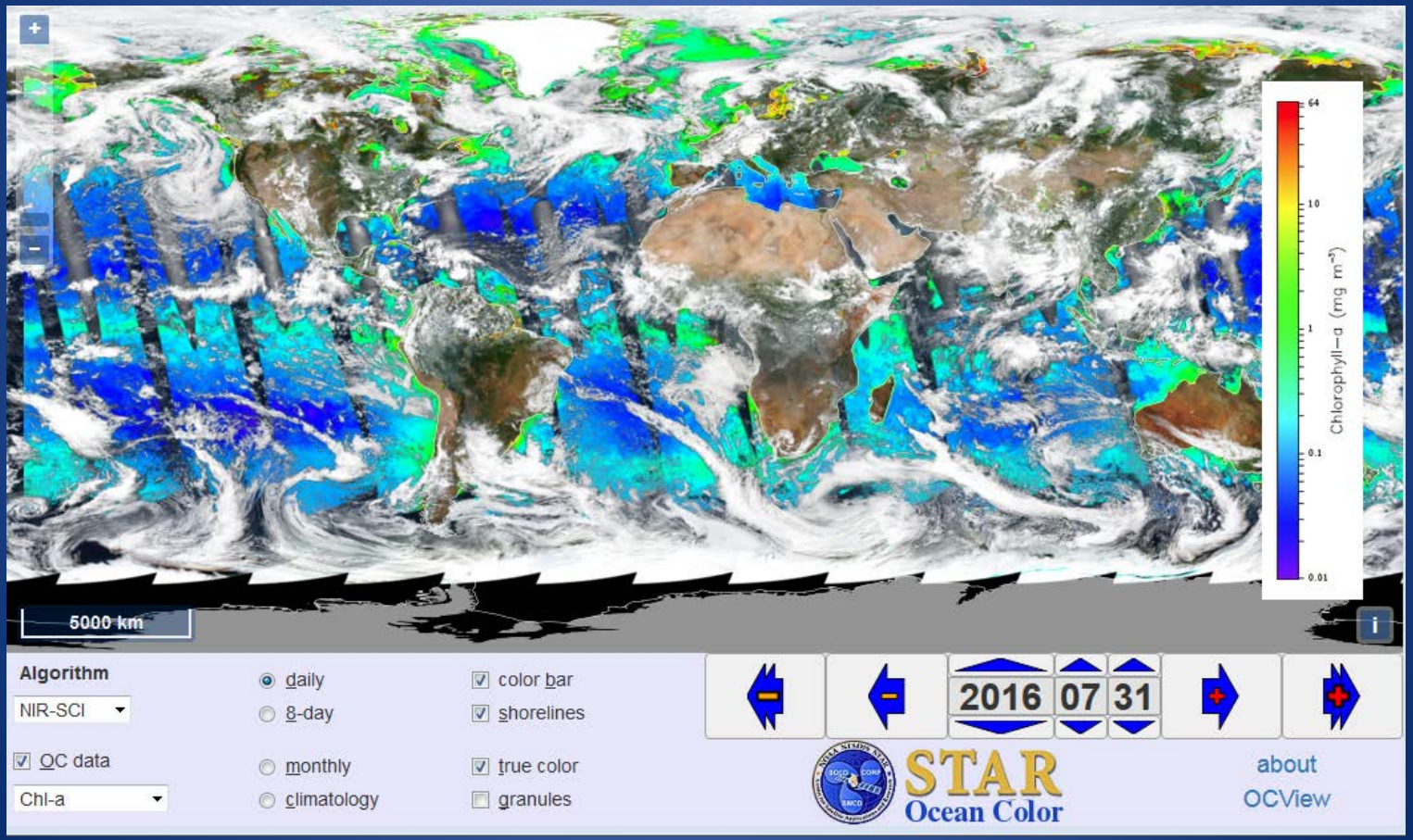
VIIRS Climatology K_d(PAR) Image
(March 2012 to February 2015)



Son, S. and M. Wang, "Diffuse attenuation coefficient of the photosynthetically available radiation K_d(PAR) for global open ocean and coastal waters", *Remote Sens. Environ.*, **159**, 250-258 (2015).

NOAA/STAR Ocean Color

VIIRS Ocean color EDR Team: Introduced OCView tool for easy, interactive image monitoring



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

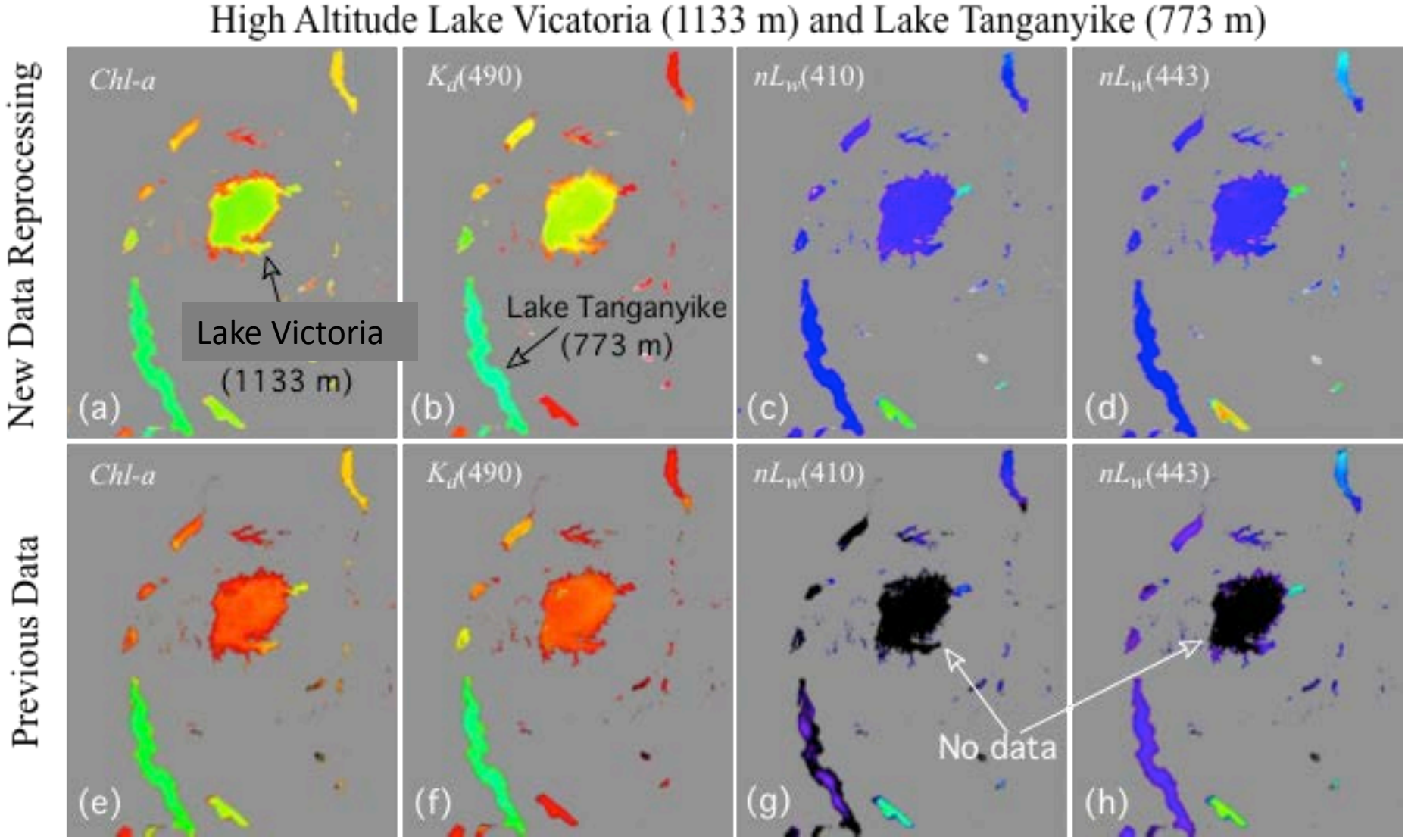
NOAA/STAR VIIRS Ocean Color

Multi-Sensor Level 1 to Level 2 Processing System (MSL12) Both NRT and mission -long science quality data

Attribute	Near-Real Time	Science Quality Delayed Mode
Processing System	MSL12	MSL12
Latency:	Best effort, as soon as possible (~12-24h)	Best effort, ~1-2 week delay
SDR:	IDPS Operational SDR	OC-improved IDPS SDR
Ancillary Data:	Global Forecast System (predicted)	Science quality (assimilated)
Spatial Coverage:	May be gaps due to various issues	Complete global coverage
Processed by:	CoastWatch, transferring to OSPO	NOAA/STAR
Distributed by:	CoastWatch	CoastWatch, NCEI
Archive Plans:	Yes, NCEI, via OSPO	Yes, NCEI, via CoastWatch
Reprocessing:	No	Yes, ~2-3 years or as needed

Menghua Wang

Significantly Improved VIIRS Water Property Data Over High Altitude Lakes



VIIRS mission-long ocean color data have been successfully reprocessed using improved MSL12. VIIRS ocean color data over open oceans and coastal/inland waters have been significantly improved, in particular, over high altitude lakes. This is a significant progress for remote sensing of inland water quality.

Ocean Color Tools for Reef Managers

http://coralreefwatch.noaa.gov/satellite/research/oceancolor.php

NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)

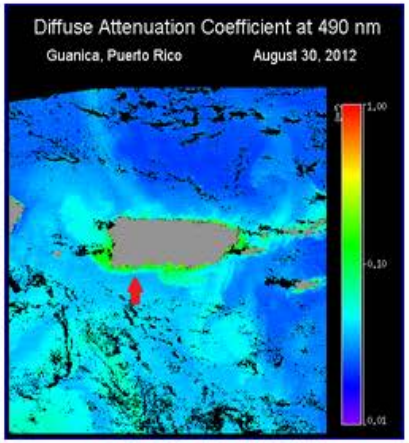
DOC > NOAA > NESDIS > STAR > CRW

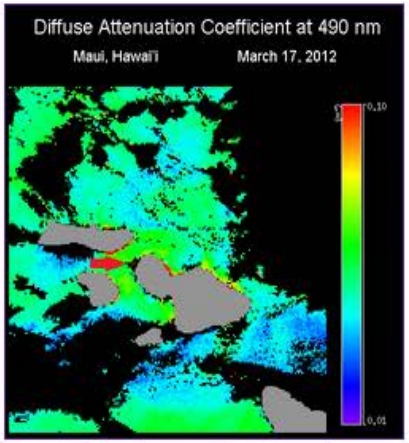
Coral Reef Watch

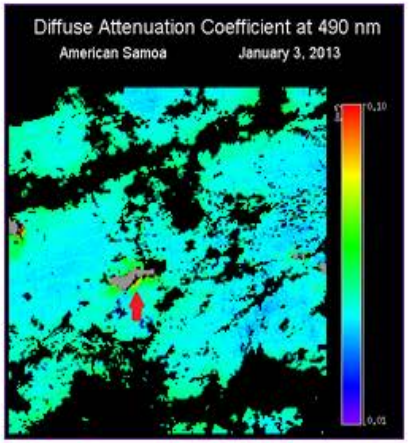
CRTF | CRCP | CREIOS | CoRIS

- CRW Home
- Product Overview
- Near-Real-Time Data
- Experimental Products
- Research Activities
  - Ocean Color
  - Projections: OA/Bleaching
  - Ocean Acidification
  - Hydrodynamic Modeling
  - Paleoclimatology
  - High-resolution SST
  - Decision Support System
  - QCed Bleaching Obs
- Outreach/Education

Satellite Ocean Color Product Development



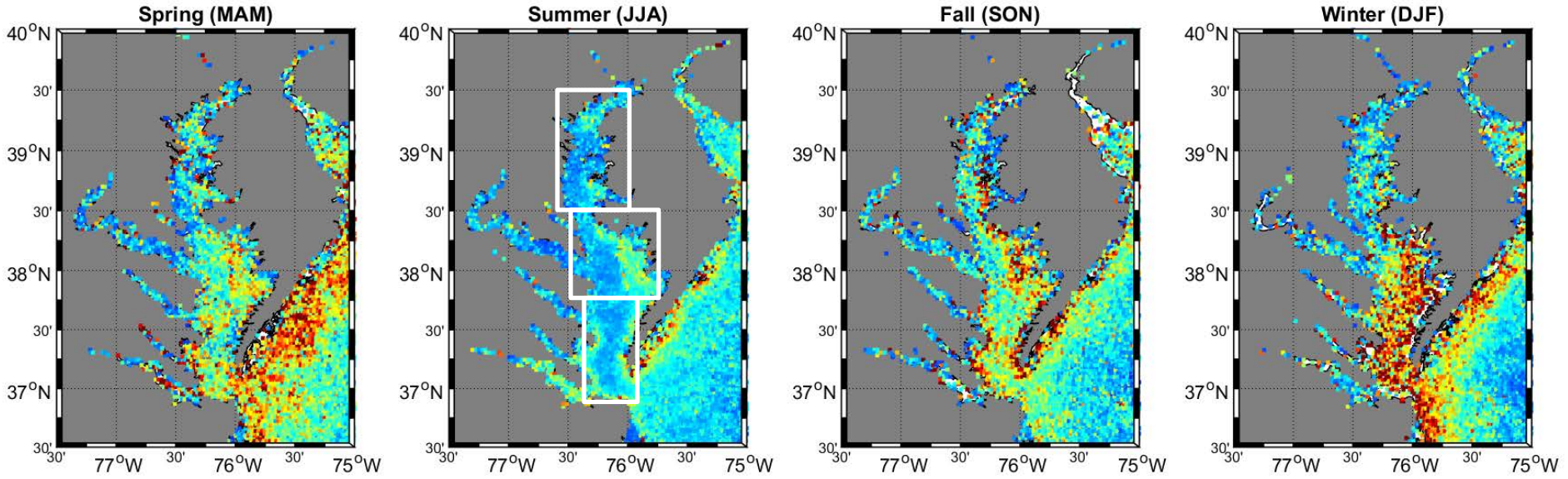




NOAA Coral Reef Watch and NOAA/NESDIS' Ocean Color Team are working closely with partners in the U.S. Coral Reef Task Force (USCRTF) Watershed Working Group (WWG) to develop pilot satellite ocean color products using data from the Visible Infrared Imaging Radiometer Suite (VIIRS) aboard the Suomi National Polar-orbiting Partnership (S-NPP) satellite operated by the NASA-NOAA Joint Polar Satellite System (JPSS).

*From **Coral Reef Watch***

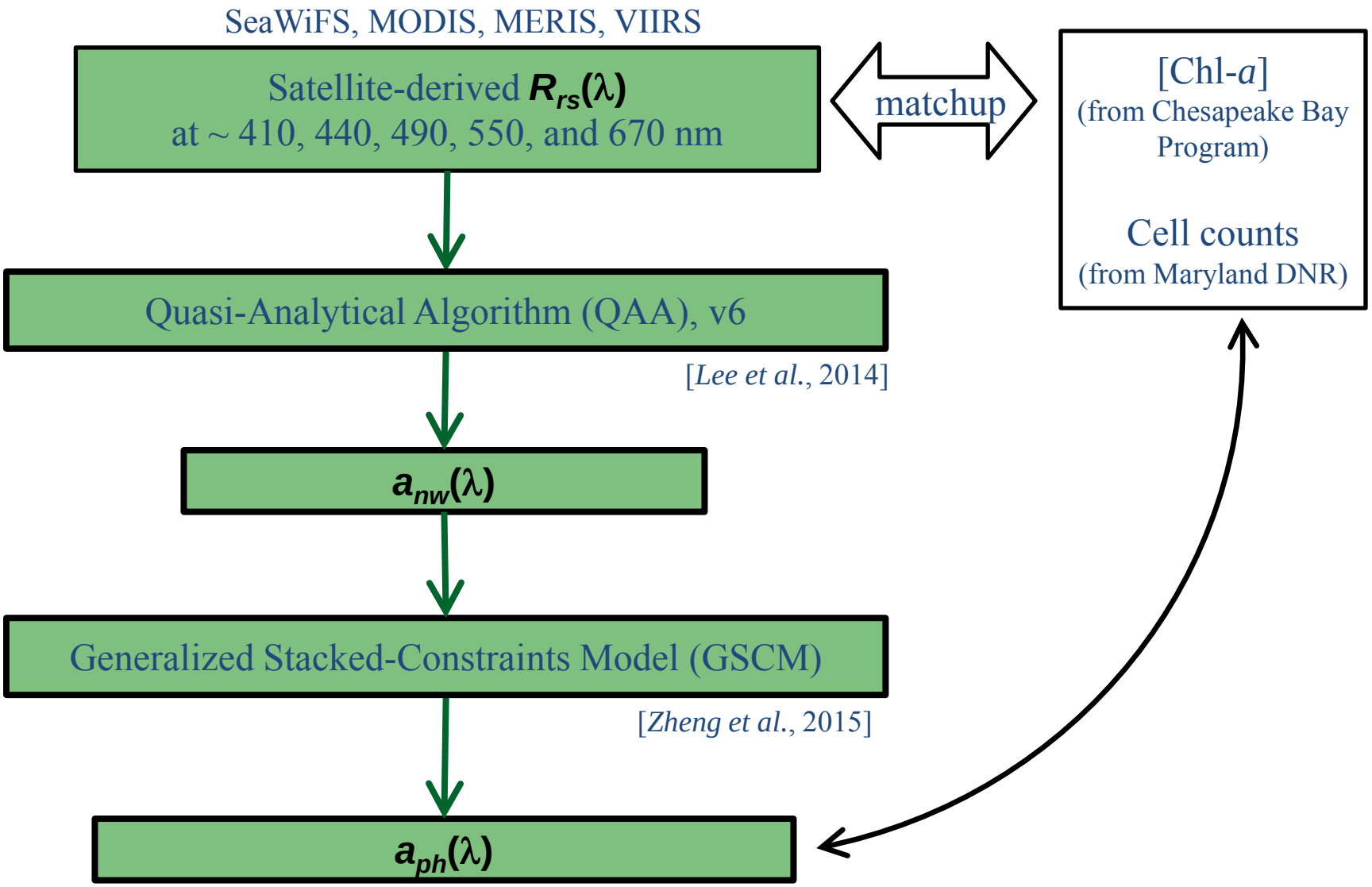
Diatom fraction based on $a_{ph}(670)/a_{ph}(440)$: VIIRS Seasonal Climatology (2012-2016)



- Lowest diatom fraction occurs in summer, a well known feature in this region.
- Diatom-dominated spring bloom is most evident in coastal waters outside of the bay.
- Strongest diatom domination in the lower bay during winter?

G. Zheng and P. DiGiacomo, 2016 Ocean Optics Meeting

Flowchart of data processing



G. Zheng and P. DiGiacomo,
2016 Ocean Optics Meeting

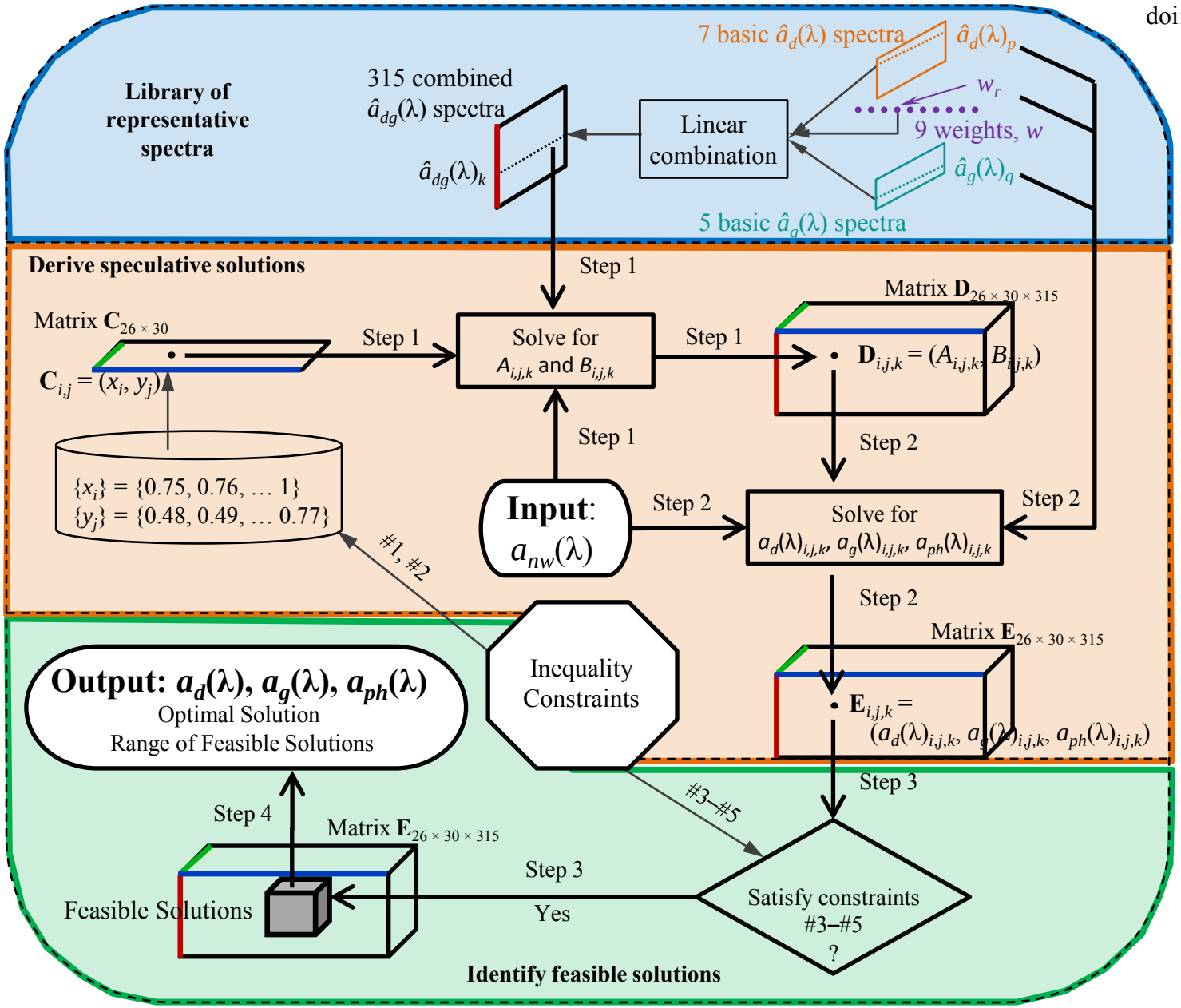
Generalized Stacked-Constraints Model (GSCM)

Reference:
Zheng et al. (2015), *J. Geophy. Res.*, 120, 2601–2621, doi:10.1002/2014JC010604.

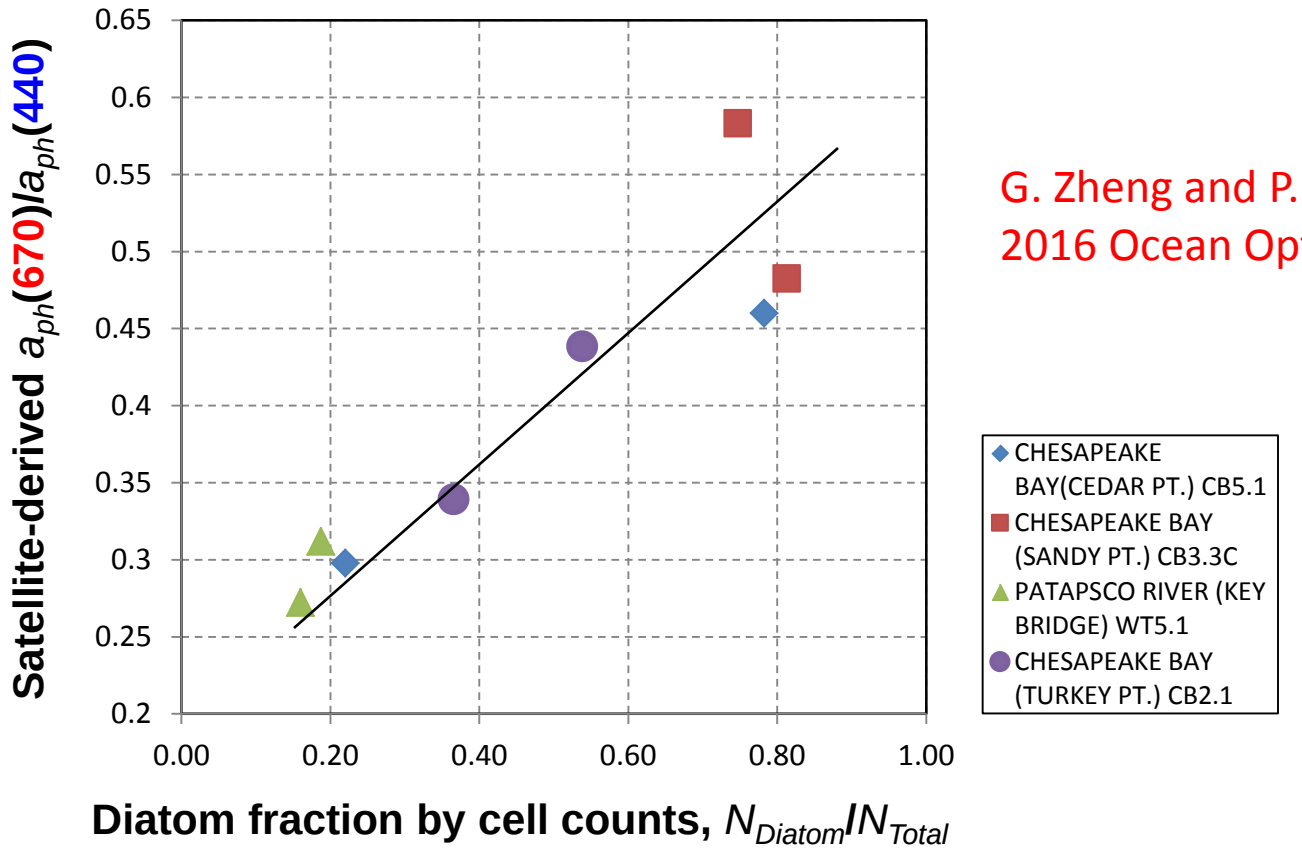
End members of spectral shapes to capture the variability of various absorption components.

Obtain a comprehensive set of candidate solutions.

Identify feasible solutions and estimate optimal solutions.



Match up between phytoplankton cell counts and satellite-derived $a_{ph}(670)/a_{ph}(440)$



G. Zheng and P. DiGiacomo, 2016 Ocean Optics Meeting

$$\text{Diatom fraction} = 2.353\ a_{ph}(670)/a_{ph}(440) - 0.459$$

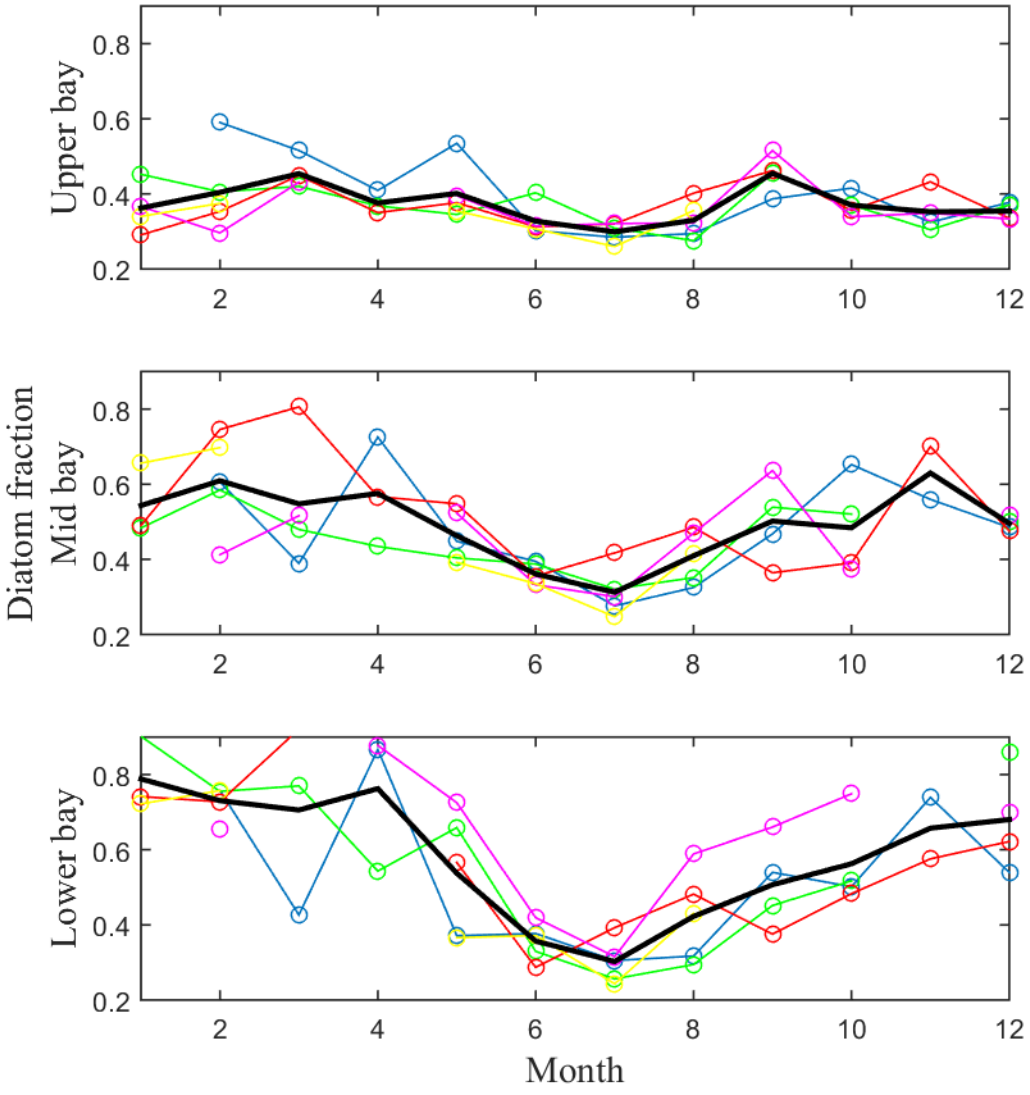
$$R^2 = 0.8534$$

NB: The blue-to-red phytoplankton absorption band ratio is a promising indicator of diatom fraction in the Chesapeake Bay.

Spatial trend in seasonal variability

2012 – 2016

2012 2013 2014 2015 2016 Median



1996 – 2000

Table 3
ANOVAs of seasonal differences in the magnitude of $a^*_{ph}(\lambda)$ in the Bay. ANOVAs were performed on the spectral average $a^*_{ph}(\lambda)$ between 400 and 700 nm, $\langle a^*_{ph} \rangle$

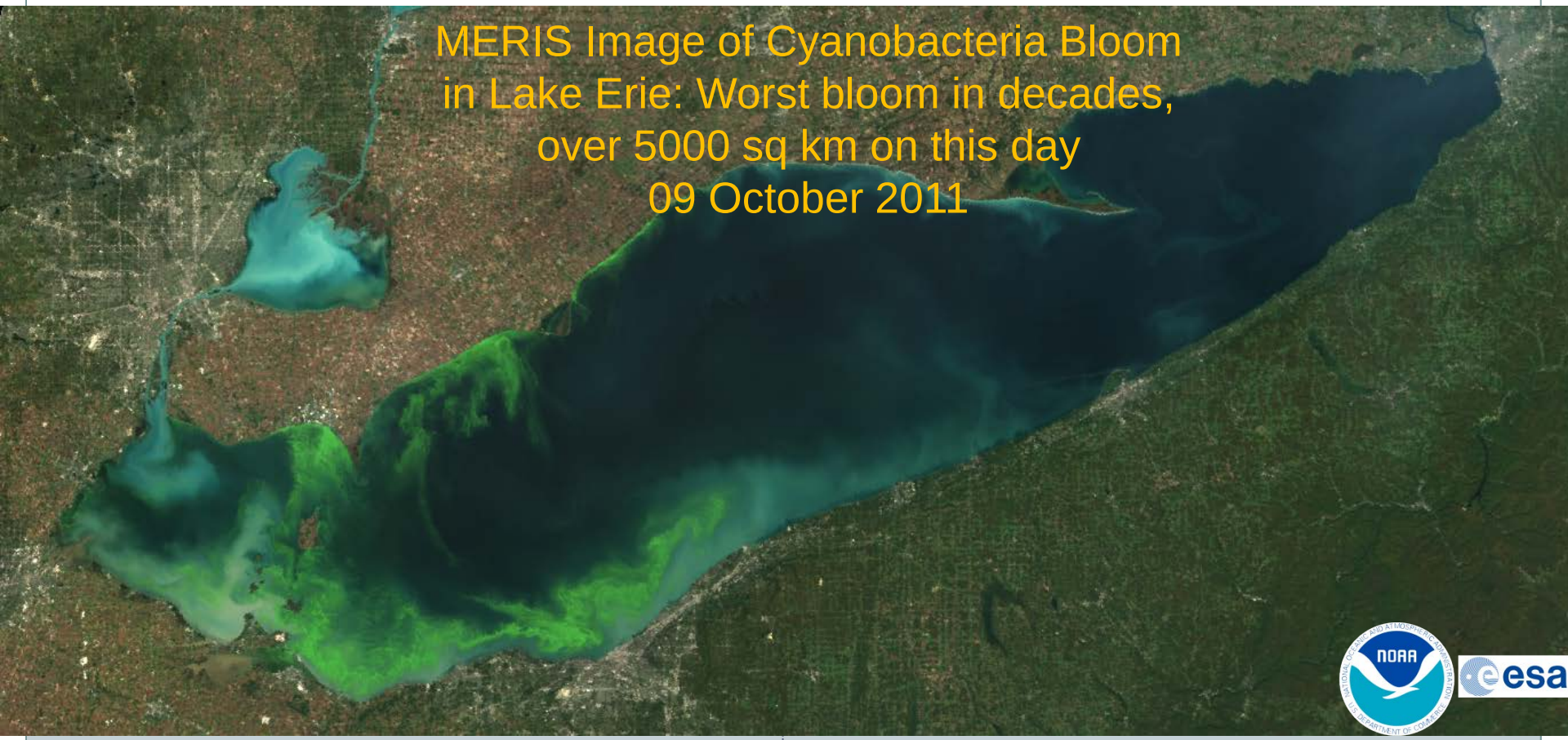
Region	n	ANOVA of seasonal differences in $\langle a^*_{ph} \rangle$		
		F	F_{crit}	P
Upper Bay	$n_{spring} = 2$; $n_{summer} = 36$; $n_{fall} = 13$	0.45	3.19	0.64
Mid-Bay	$n_{spring} = 21$; $n_{summer} = 39$; $n_{fall} = 28$	5.92	3.10	0.0039
Lower Bay	$n_{spring} = 18$; $n_{summer} = 34$; $n_{fall} = 25$	19.47	3.12	0.00000016

[Magnuson et al., *Estuar. Coast. Shelf Sci.*, 2004]

- Seasonal variability of diatom fraction increases from upper to lower bay.

- This trend is consistent with the increasing variability of chlorophyll-specific a_{ph} reported previously based on field data.

G. Zheng and P. DiGiacomo, 2016 Ocean Optics Meeting


MERIS Image of Cyanobacteria Bloom
in Lake Erie: Worst bloom in decades,
over 5000 sq km on this day
09 October 2011
NOAA
esa

THE BLADE

Experimental Lake Erie Harmful Algal Bloom Bulletin

National Centers for Coastal Ocean Science and Great Lakes Environmental Research Laboratory

24 August, 2015, Bulletin 13

The *Microcystis* cyanobacteria bloom continues across a large part of the western basin along the Michigan and Ohio coasts and into the central basin. The recent southwesterly winds have pushed the bloom northward along the Michigan coast. Moderate to high concentrations extend eastward to midway between Cleveland and Rondeau, Ontario. Scum has been scattered in the last few days. Microcystin toxins are still present in the bloom, but the concentration has decreased in general. However, scum areas remain a significant risk.

Strong, westerly winds are expected through Tuesday, creating strong mixing. A possible shift to NW winds on Wed and Thursday may favor southward movement. Milder winds on Thursday may reduce mixing, giving greater potential for scum formation. The persistent bloom in Sandusky Bay continues. No other blooms are evident in the central and eastern basins.

Please check for updates on Ohio State Parks at Ohio EPA's site, http://epa.ohio.gov/habalgae.aspx. Keep your pets and yourself out of the water in areas where scum is forming.

-Stumpf, Tomlinson

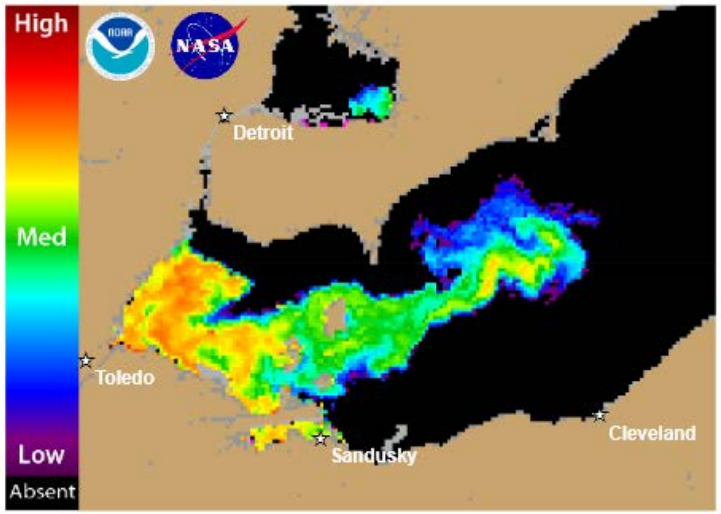


Figure 1. Cyanobacterial Index from NASA's MODIS- Aqua data collected 22 August, 2015 at 13:10 EST. Grey indicates clouds or missing data. Black represents no cyanobacteria detected. Colored pixels indicate the presence of cyanobacteria. Cooler colors (blue and purple) indicate low concentrations and warmer colors (red, orange, and yellow) indicate high concentrations. The estimated threshold for cyanobacteria detection is 20,000 cells/mL.

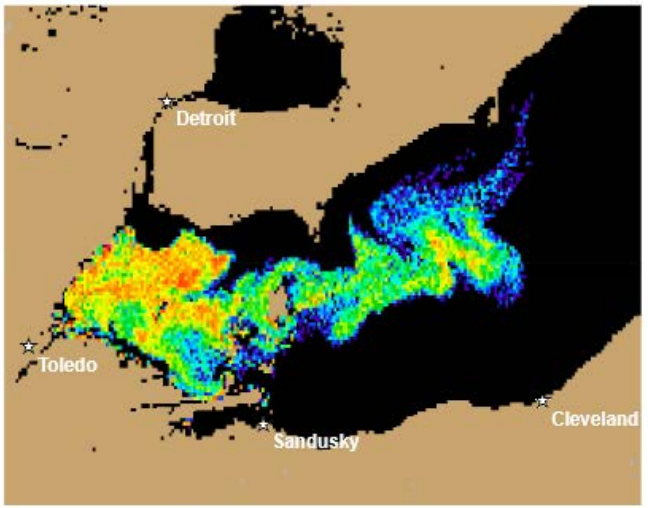


Figure 2. Nowcast position of bloom for 24 August, 2015 using GLCFS modeled currents to move the bloom from the 22 August, 2015 image.

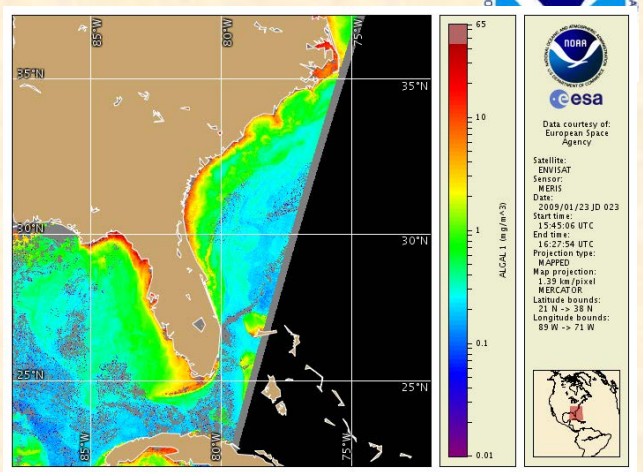
NOAA/NOS/CO-OPS

esa

the return of results from test samples sent out to three different laboratories, Mayor D. Michael Collins said during an evening news conference.

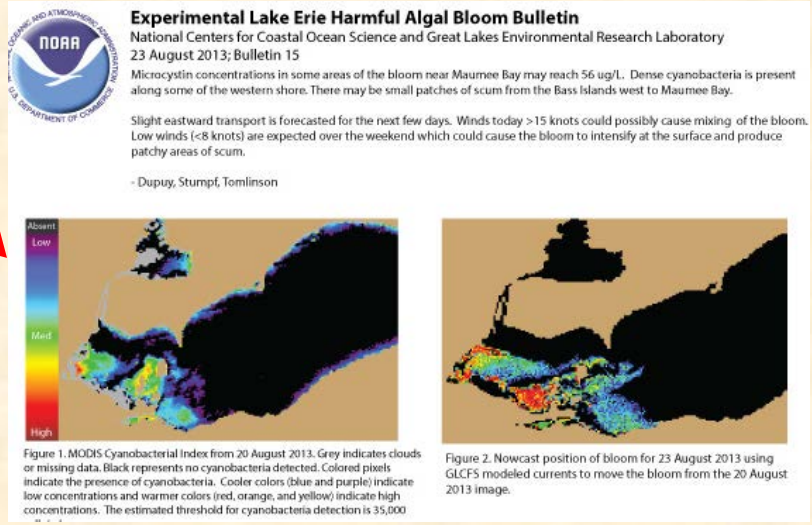
NOAA Utilization of European Ocean Color Data: Way forward for Sentinel-3/OLCI

- ESA's MERIS data declared operational by NOAA in Jan 2009 Chlorophyll-a/anomalies were generated from MERIS amongst other ocean color products, supporting NOS et al. users. However, Envisat failed in 2012.
- STAR and others in NESDIS are now actively working to facilitate acquisition of the follow-on Sentinel-3 (OLCI et al.) data to support NOAA and other U.S. user needs.
- Sentinel-3/OLCI, like Envisat/MERIS, provides higher spatial resolution (300 m) than VIIRS, useful for coastal/inland waters, and also has additional spectral bands – and as such is a vital complementary capability.
- STAR is supporting ESA/EUMETSAT as part of the Sentinel-3 Validation Team (3 projects)
- NOAA (STAR) has the responsibility for distribution of Sentinel-3 data in the U.S.



http://coastwatch.noaa.gov

STAR's efforts have resulted in the generation and flow of NOAA experimental and operational ocean color products to the Coastwatch user community.



Experimental Lake Erie Harmful Algal Bloom Bulletin

National Centers for Coastal Ocean Science and Great Lakes Environmental Research Laboratory

23 August 2013; Bulletin 15

Microcystin concentrations in some areas of the bloom near Maumee Bay may reach 56 ug/L. Dense cyanobacteria is present along some of the western shore. There may be small patches of scum from the Bass Islands west to Maumee Bay.

Slight eastward transport is forecasted for the next few days. Winds today >15 knots could possibly cause mixing of the bloom. Low winds (<8 knots) are expected over the weekend which could cause the bloom to intensify at the surface and produce patchy areas of scum.

- Dupuy, Stumpf, Tomlinson

Figure 1. MODIS Cyanobacterial Index from 20 August 2013. Grey indicates clouds or missing data. Black represents no cyanobacteria detected. Colored pixels indicate the presence of cyanobacteria. Cooler colors (blue and purple) indicate low concentrations and warmer colors (red, orange, and yellow) indicate high concentrations. The estimated threshold for cyanobacteria detection is 35,000

Figure 2. Nowcast position of bloom for 23 August 2013 using GLCFS modeled currents to move the bloom from the 20 August 2013 image.

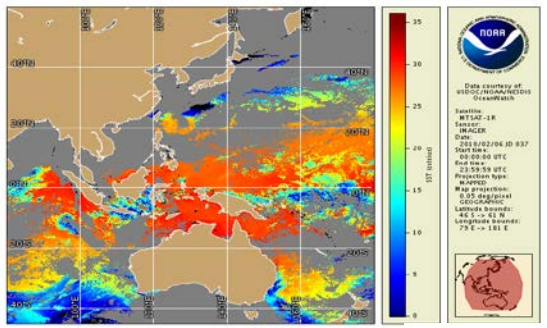
NOAA CoastWatch/OceanWatch

- STAR leads the NOAA CoastWatch/ OceanWatch Program, supporting users (both *research & applied*) within NOAA as well as nationally & globally

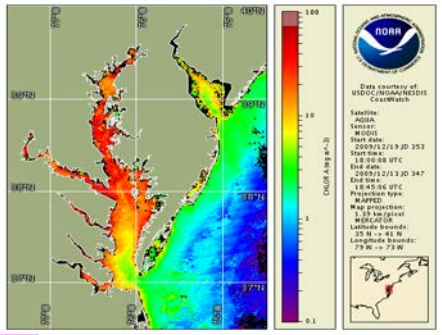
- CW/OW facilitates development and transition of satellite ocean remote sensing experimental data products from ***research into operations*** and supports user-driven coastal and ocean ***applications*** through the dissemination of ***fit for purpose data.***

- CoastWatch/OceanWatch partnership:
  - NMFS, NOS, OAR, NWS/NCEP
  - NESDIS offices

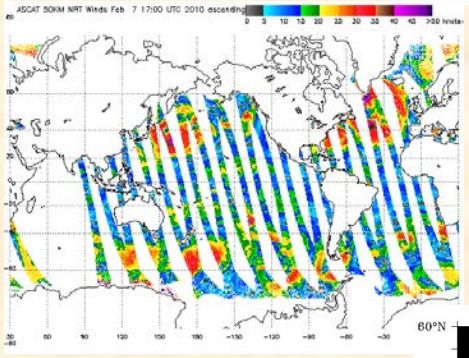
- Supports a number of regional U.S., basin-scale and international coastal and oceanic activities and applications
  - Chesapeake Bay, Gulf of Mexico, Mediterranean Sea, Atlantic & Pacific Basins, Australia et al.



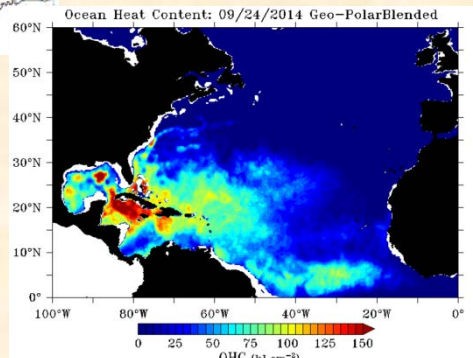
SST



Ocean Color



Ocean Surface Vector Winds

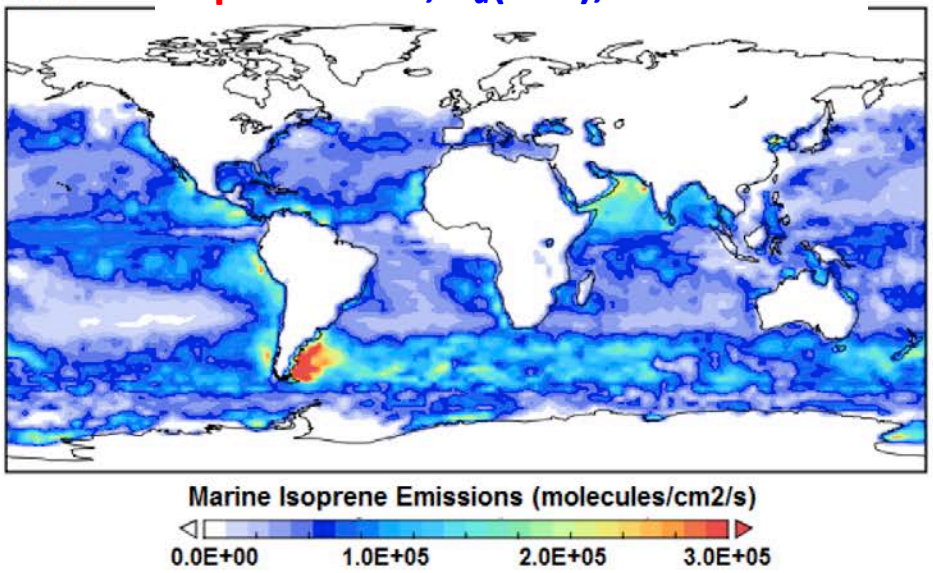


Ocean Heat Content

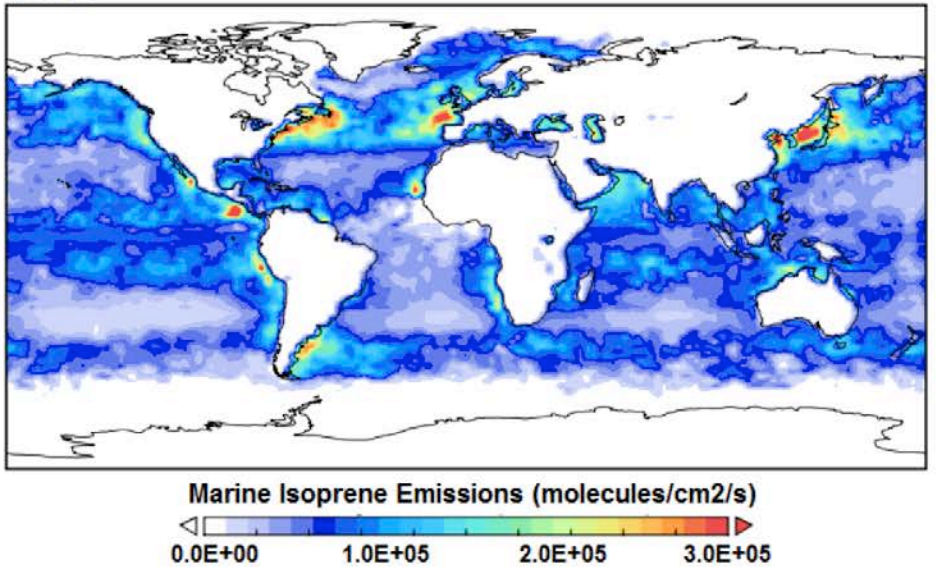
OAR/ARL: Global Distribution of Marine Isoprene Emission

JAN

Inputs: Chl-a, K_d(490), PAR



APR



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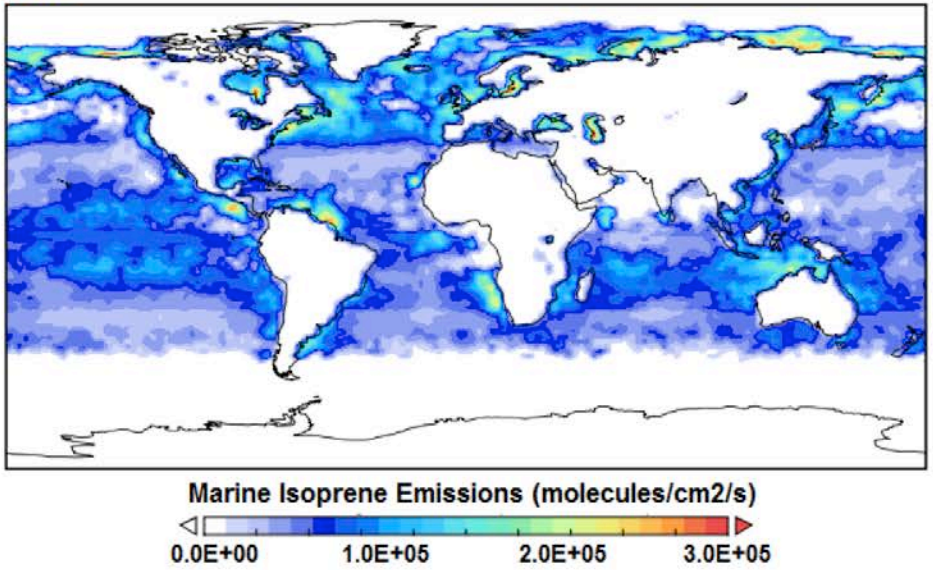
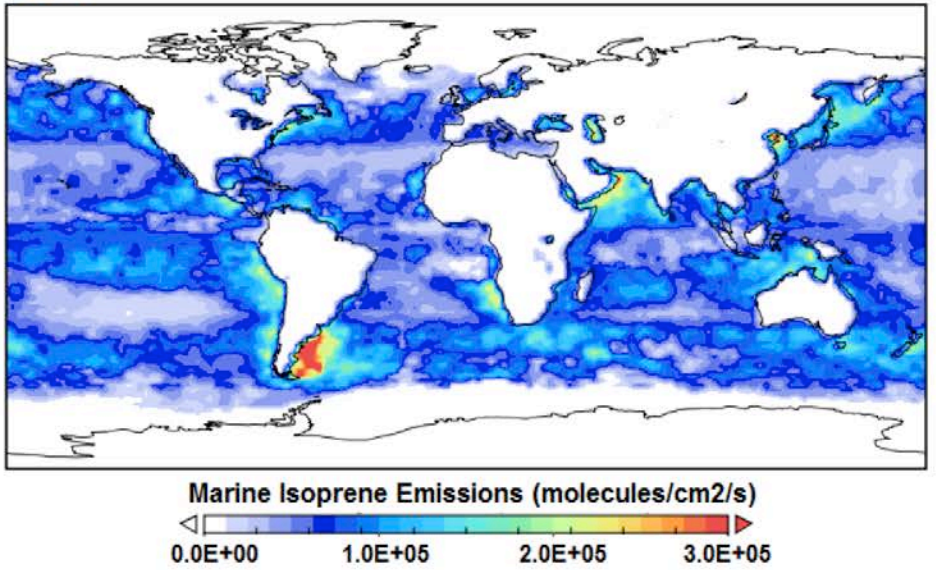
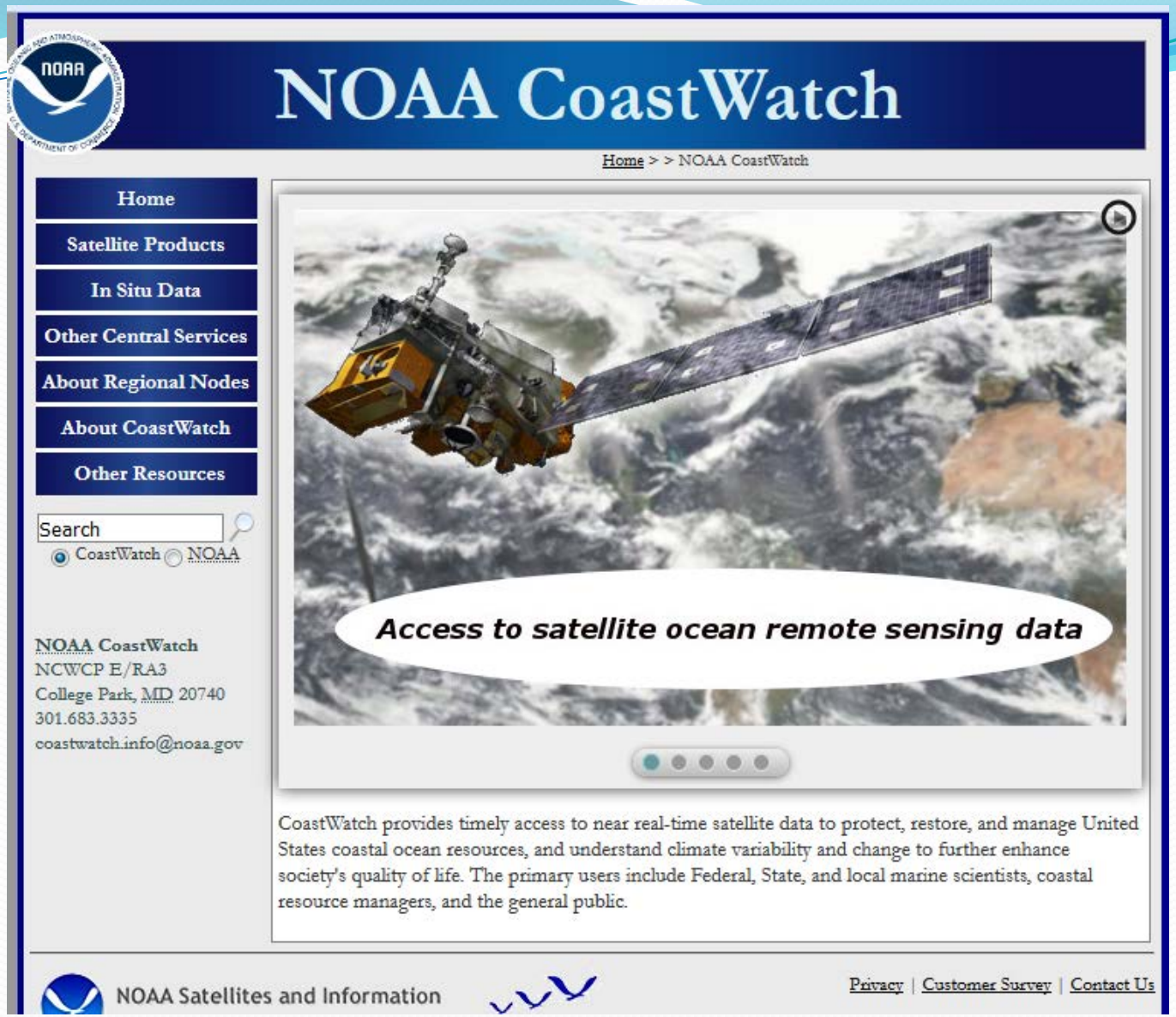


OCT

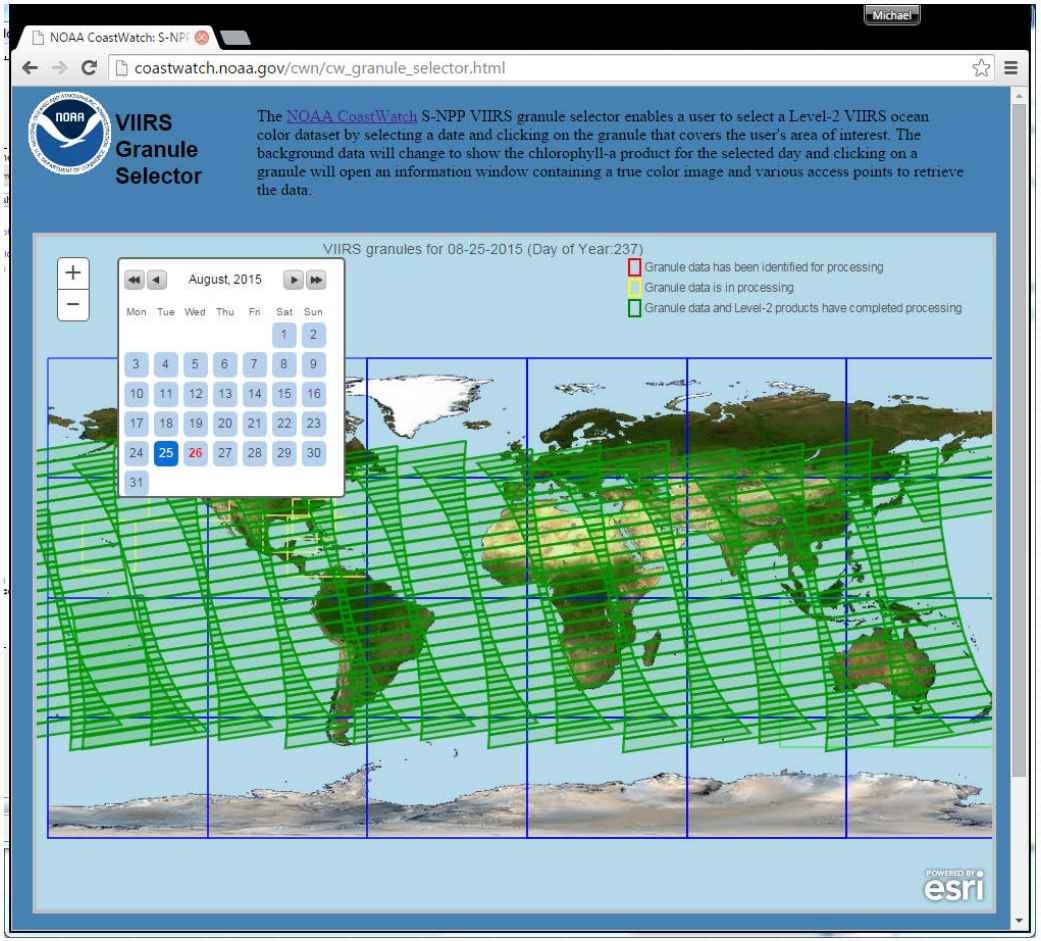


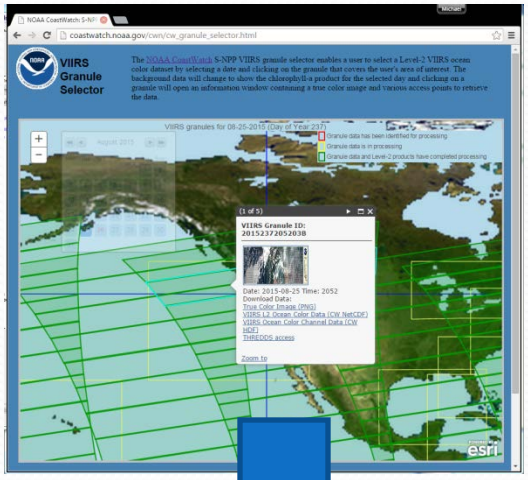


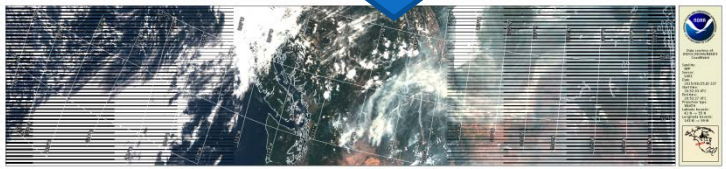
http://coastwatch.noaa.gov/

coastwatch.info@noaa.gov

L2 Granule Selector





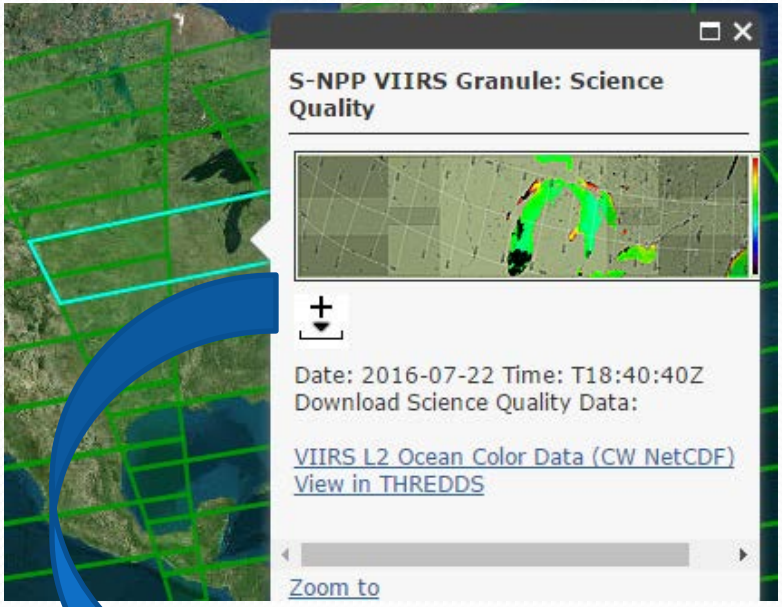


Date: 2015-08-25 Time: 2052
Download Data:
True Color Image (PNG)
VIIRS L2 Ocean Color Data (CW NetCDF)
VIIRS Ocean Color Channel Data (CW HDF)
THREDDS access

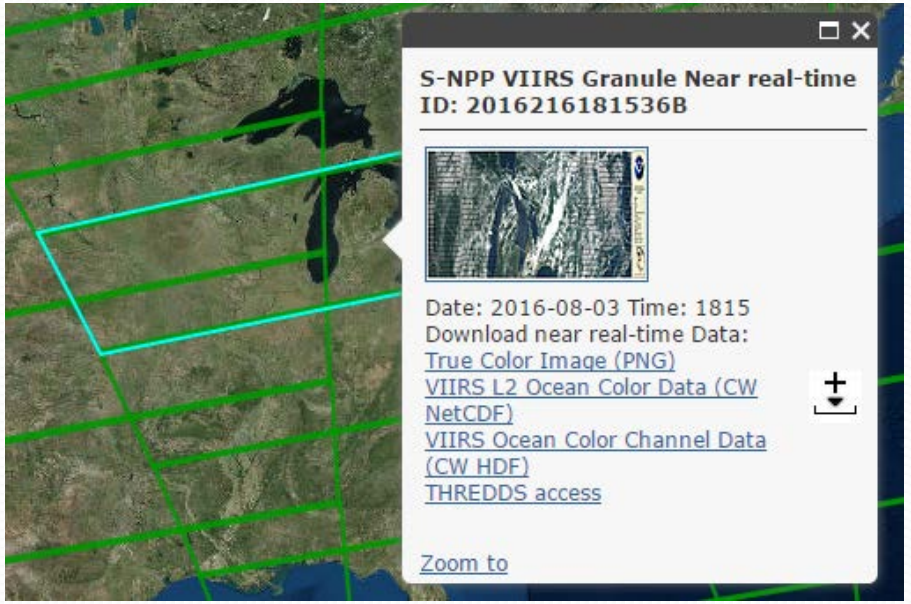
http://coastwatch.noaa.gov/cwn/cw_granule_selector.html

Example of VIIRS OC Data Cart

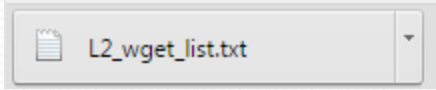
Science Quality (forward processing)



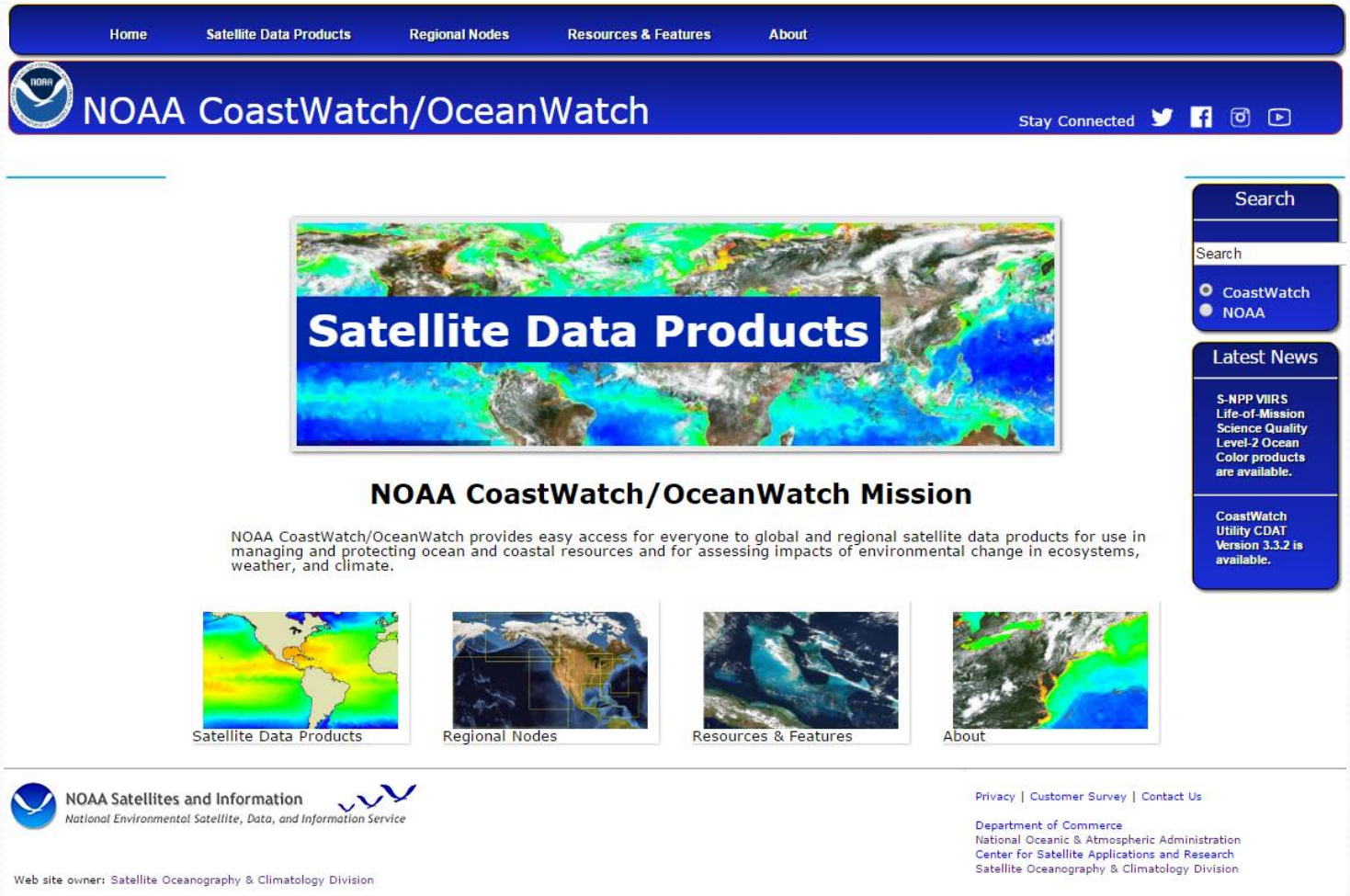
Near real-time



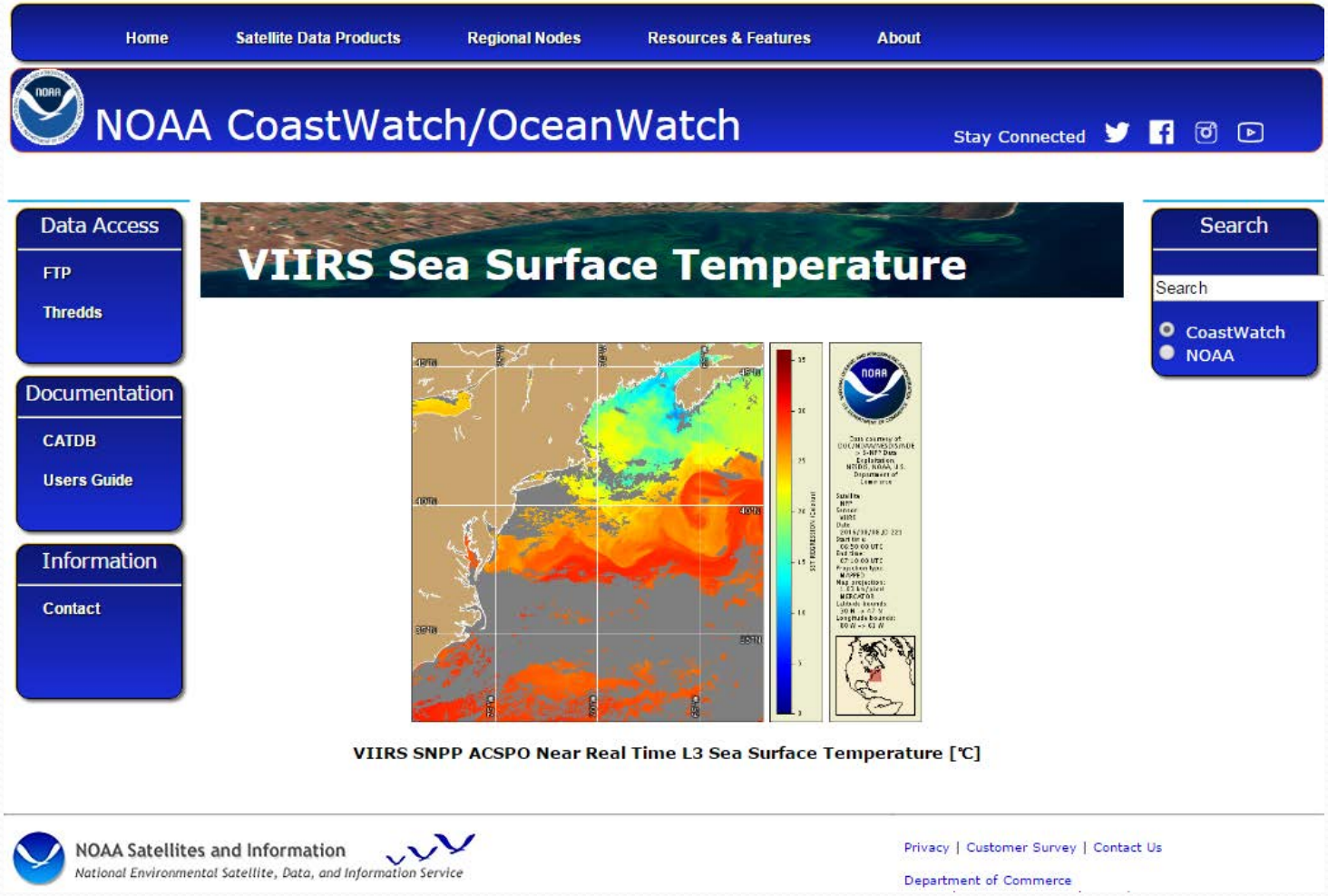
For batch download



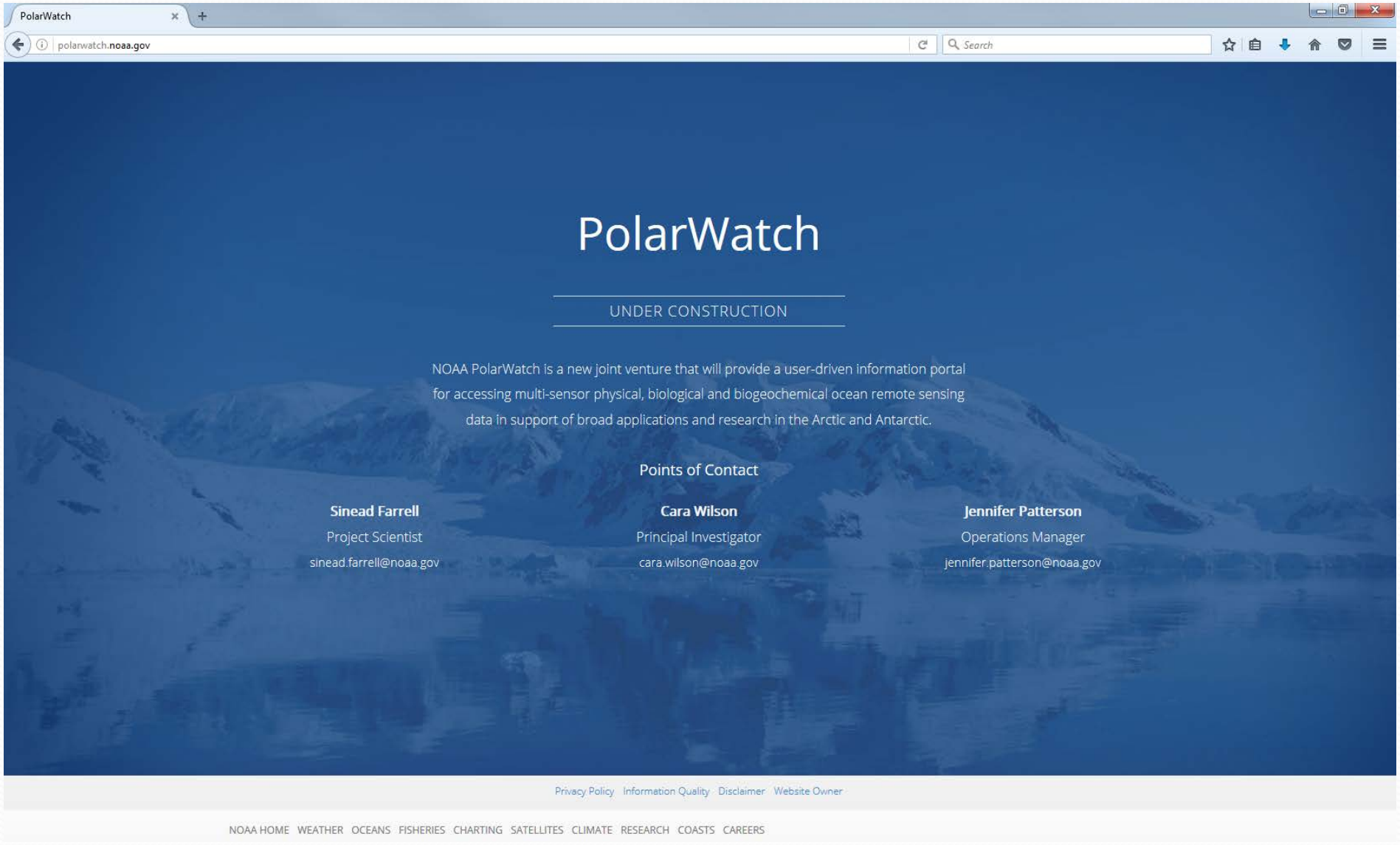
Website Revamp in Progress (1)



Website Revamp in Progress (2)



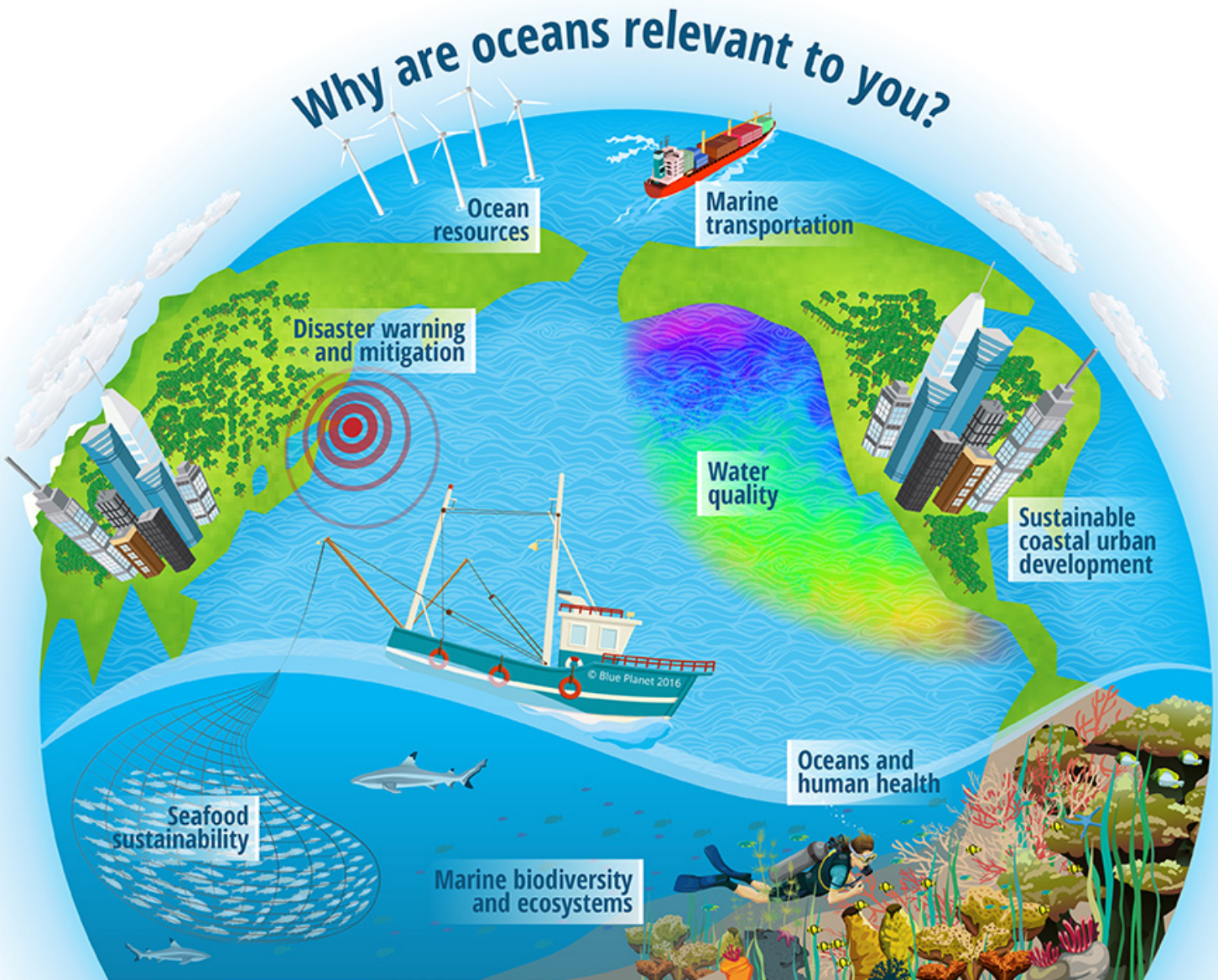
NOAA PolarWatch Portal



GROUP ON EARTH OBSERVATIONS

BLUE PLANET Oceans and Society

http://geoblueplanet.com/



THE ROLE OF THE OCEANS IN EARTH'S LIFE-SUPPORT SYSTEM

- The Blue Planet Symposium will serve as a forum for discussion of societal information needs resulting from the important role the oceans play in Earth's life-support system.

- The symposium will also be a platform for the participating communities to exchange information on their activities and identify potential pilot and prototype projects for Blue Planet to focus on in the coming years.

http://symposium.geoblueplanet.com/

AquaWatch

The GEO Water Quality Community of Practice

What: Global Water Quality Service for Inland & Coastal Waters

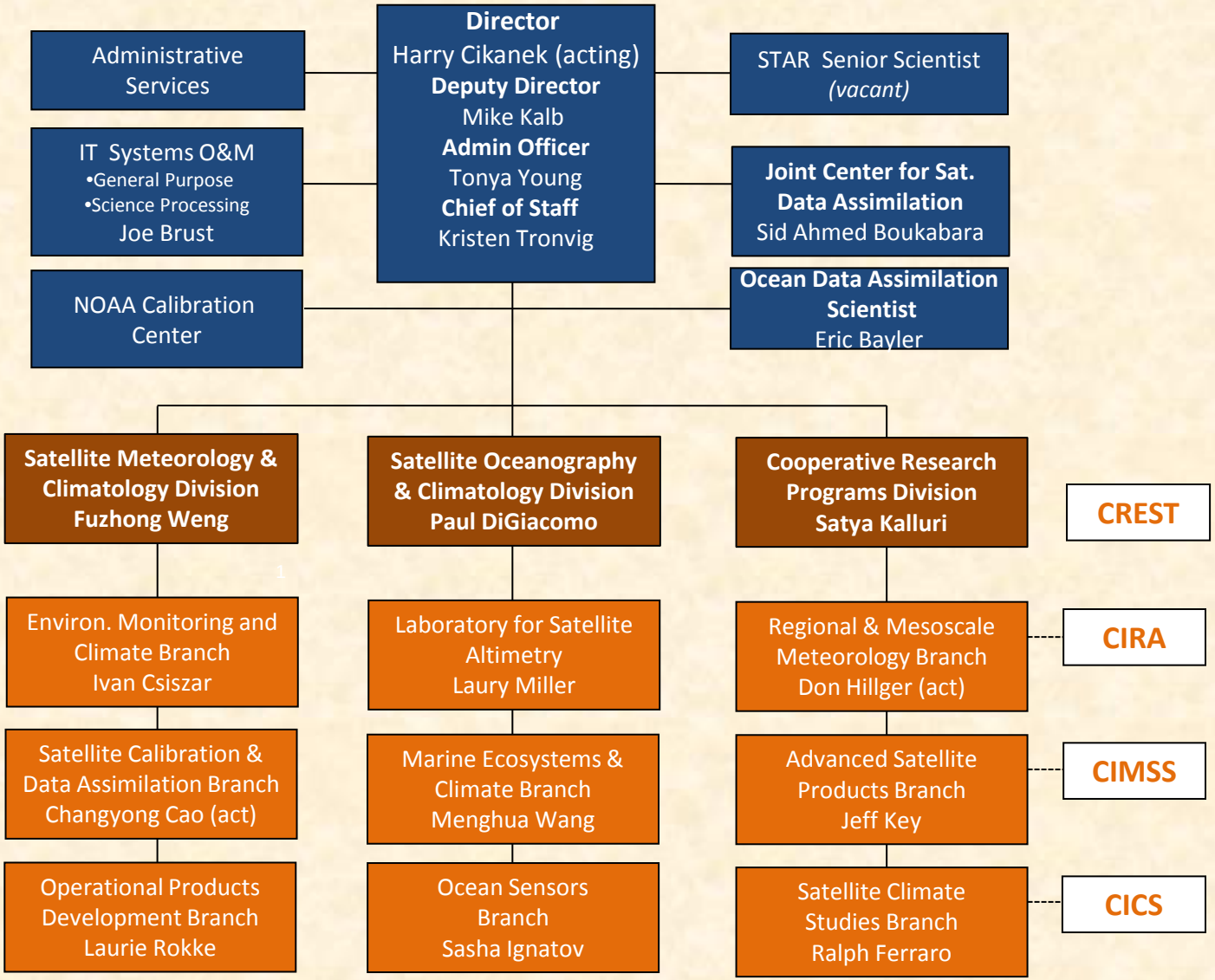
Mission Statement: Deliver, on a routine and sustained basis, timely, consistent, accurate and fit-for-purpose water quality data products & information to support water resource management and decision making in coastal and inland waters.

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.

Thanks for Listening!
Now, Questions….

NOAA/NESDIS Center for Satellite Applications and Research (STAR)



NOAA/NESDIS Center for Satellite Applications & Research (STAR):

Delivers leadership for NESDIS **research**, **development, validation and maintenance of satellite derived products and applications** from NOAA's operational geostationary and polar-orbiting satellites and from non-NOAA research and international satellites.

Develops new environmental **applications**, **techniques and algorithms for transforming raw satellite observations into scientifically meaningful**, quality assured and calibrated **environmental measurements and products**, and develops the pre-operational computer codes to implement them.

Supports the calibration and validation of all satellite sensors used in NOAA's satellite operations, and develops **methods and maintains systems for inter-calibrating NOAA satellite data with other satellites** in the international constellation of research and operational satellites.

Collaborates **with other NESDIS and NOAA offices, universities, NASA and other U.S. agencies**, and with international organizations on exchange and evaluation of operational and research satellite data and products.