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

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With contributions from SOCD science teams, including: Eric Bayler, Paul Chang, Mark Eakin, Sinead Farrell, Sasha Ignatov, Eric Leuliette, Eileen Maturi, Frank Monaldo, Menghua Wang, Guangming Zhang

OAR/CPO and STAR/JPSS Technical Interchange Meeting:
Using JPSS Products for Earth System Data Assimilation
Monday, 30 January, 2017, NCWCP College Park, MD

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 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.

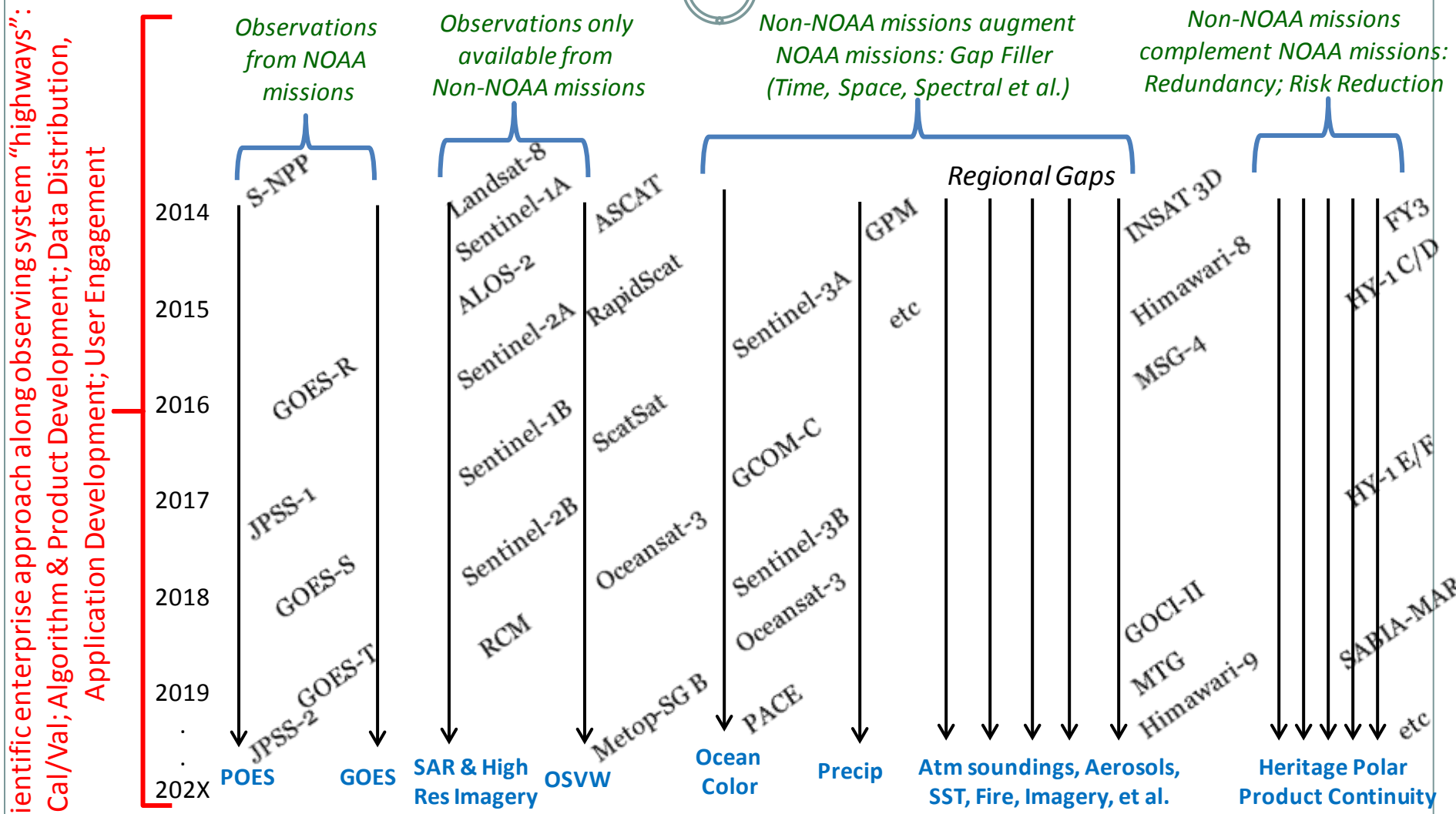
Supports the calibration and validation of all satellite sensors used in NOAA's satellite operations, and develops **methods and maintains systems for inter-calibrating NOAA satellite data with other satellites** in the international constellation of research and operational satellites.

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.

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

- 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)

Division Organization and Branch Chiefs

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. Eric Leuliette (Acting)*

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

SOCD Science Teams By Parameters

- 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
- Foreign Sensors: Winds, SAR, etc
- Marine Optical BuoY (MOBY)
- Coast/Ocean/PolarWatch & Coral Reef Watch

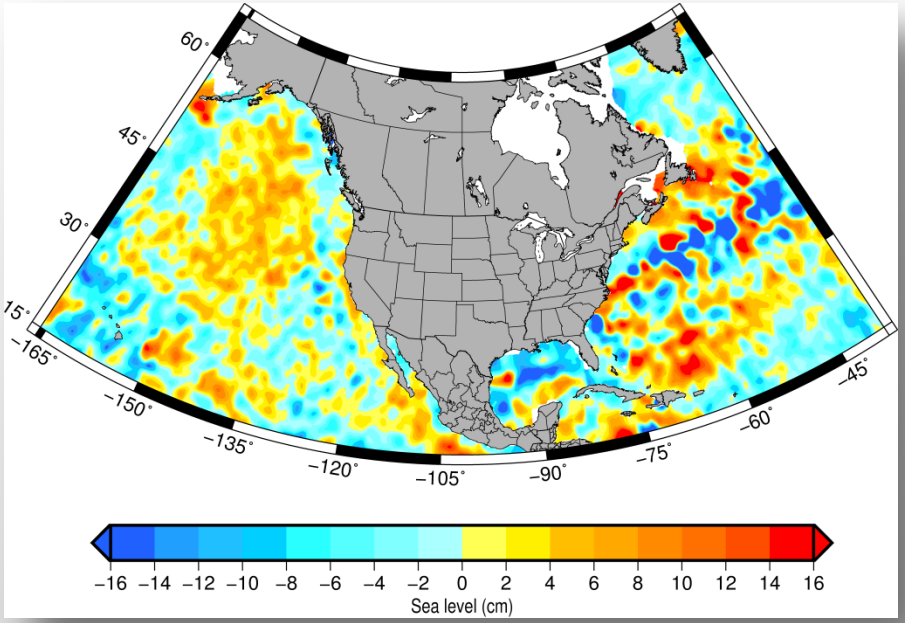
Jason Satellite Radar Altimeter Program

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.

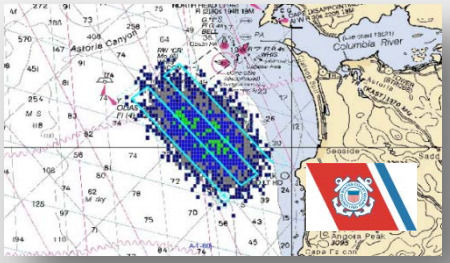
Jason Applications & End Users

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

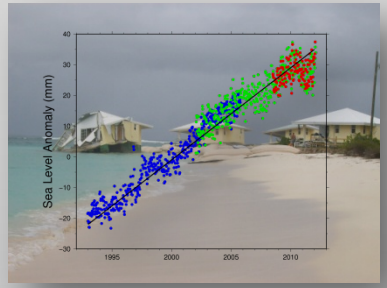


High Wave Forecasting

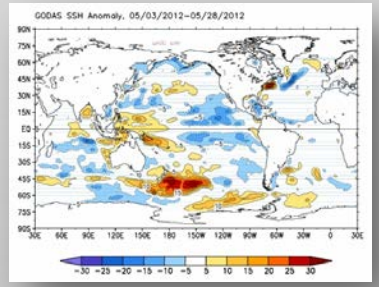
Coast Guard Search & Rescue



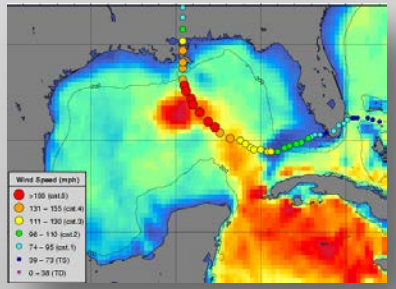
Global & Regional Sea Level Rise



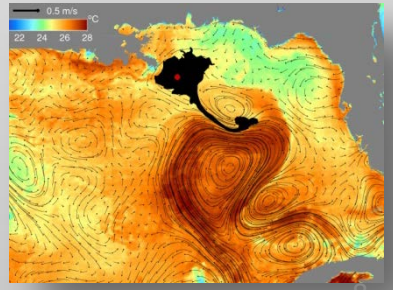
El Nino Forecasting



Hurricane Intensity Forecasting



Oil Spill Monitoring



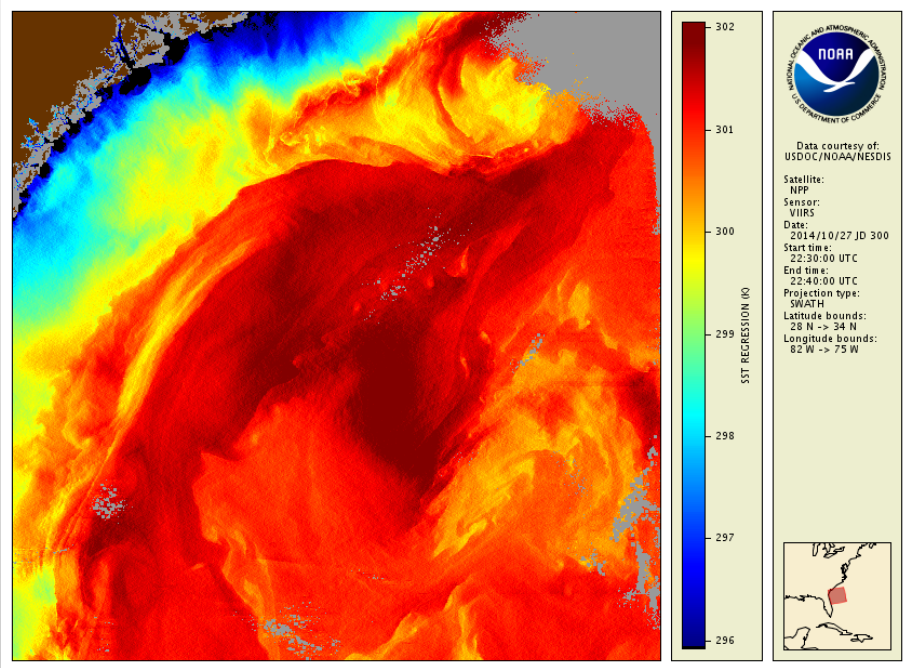
Real-Time S-NPP SST Products

ACSPO VIIRS L2P real-time product

- podaac.jpl.nasa.gov/dataset/VIIRS_NPP-OSPO-L2P-v2.4
- data.nodc.noaa.gov/cgi-bin/iso?id=gov.noaa.nodc:GHRSST-VIIRS_NPP-OSPO-L2P

ACSPO VIIRS L3U real-time product

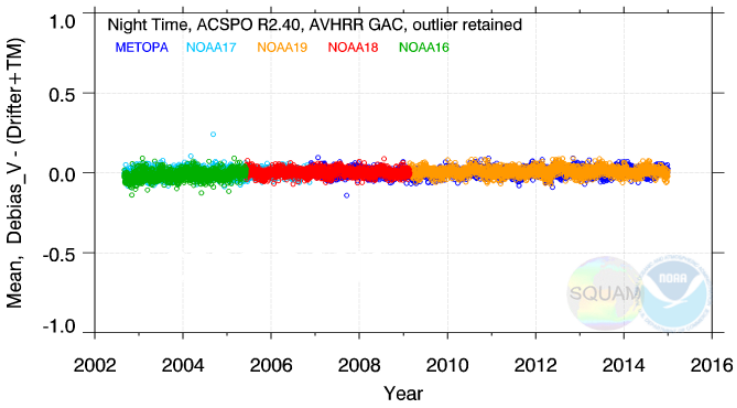
- podaac.jpl.nasa.gov/dataset/VIIRS_NPP-OSPO-L3U-v2.4
- data.nodc.noaa.gov/cgi-bin/iso?id=gov.noaa.nodc:GHRSST-VIIRS_NPP-OSPO-L3U

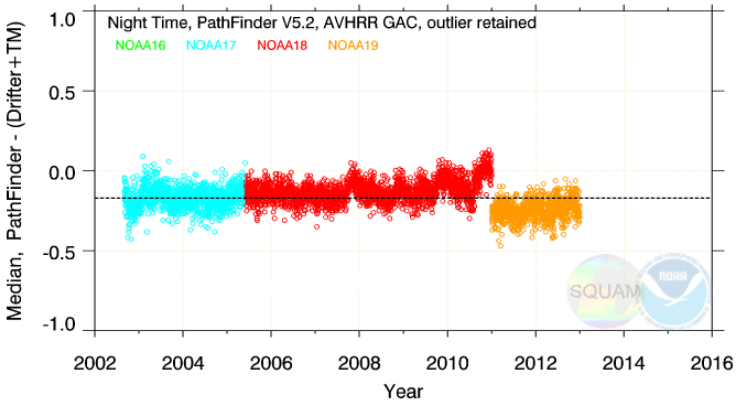


- Currently operational: ACSPO v2.40 (May 2015)
  - Redesigned Single Scanner Error Statistics (uncertainty estimates in each pixel)
  - Destriped imagery (important for pattern recognition and ocean dynamics analyses)
  - New ACSPO L3U product generated
- ACSPO enhancements underway: geo-capable (Himawari-8, GOES-R) (2.41); Improved imagery (2.50); Pattern analyses (2.60); Explore new bands in SST retrievals; Improve/Add L3 products
- **Initial reprocessing Mar 2012 – Dec 2015 with ACSPO 2.40 done at UW (Gumley et al.)**

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

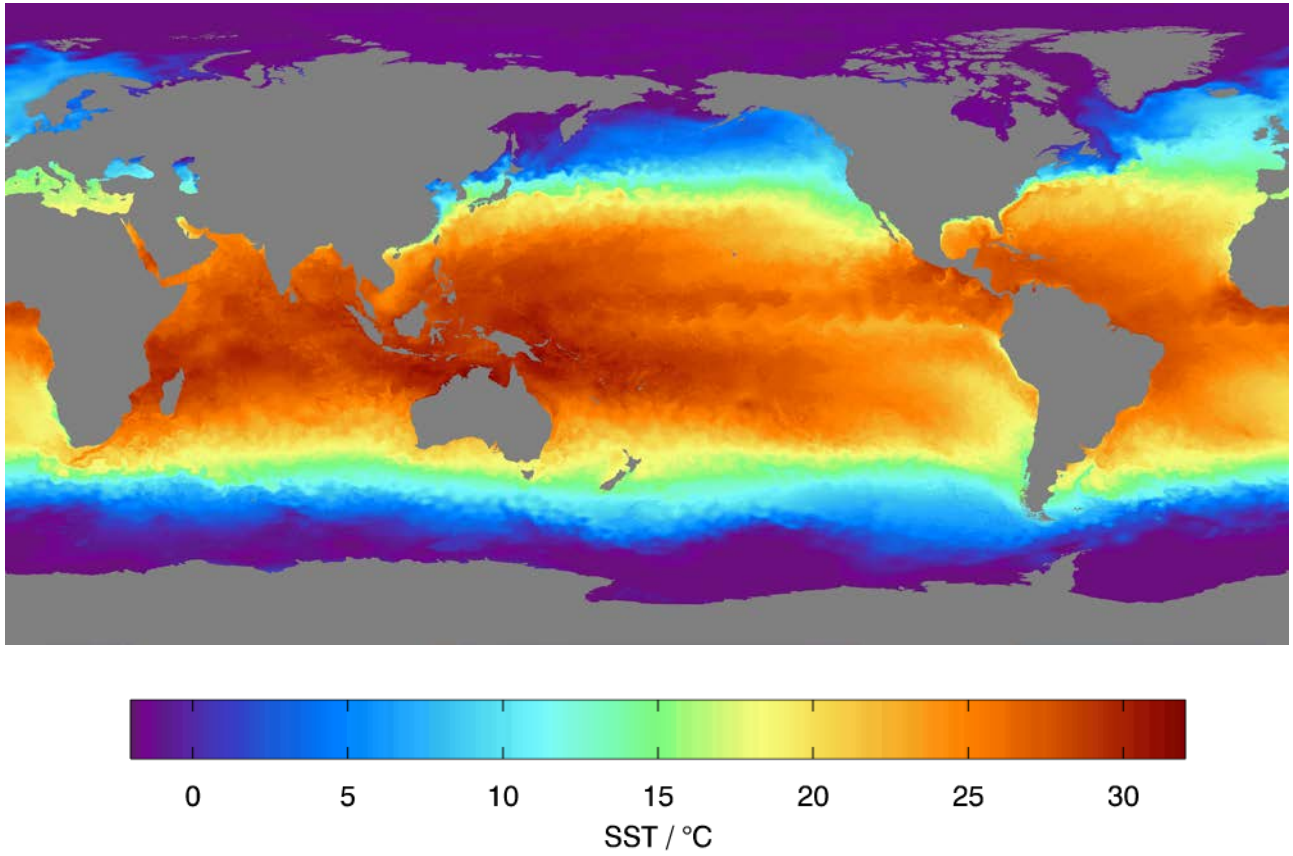
Global Bias with respect in situ SSTs





- 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

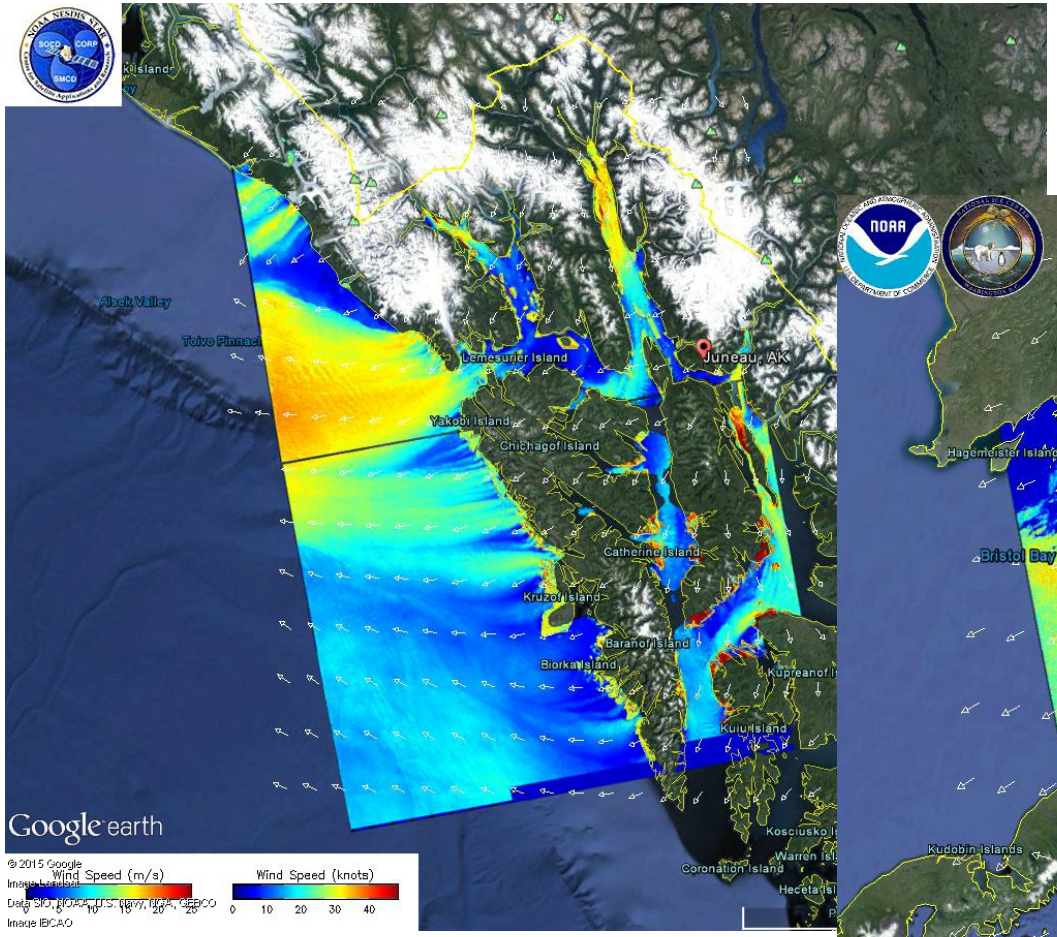
5-km Global Blended SST Analysis



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

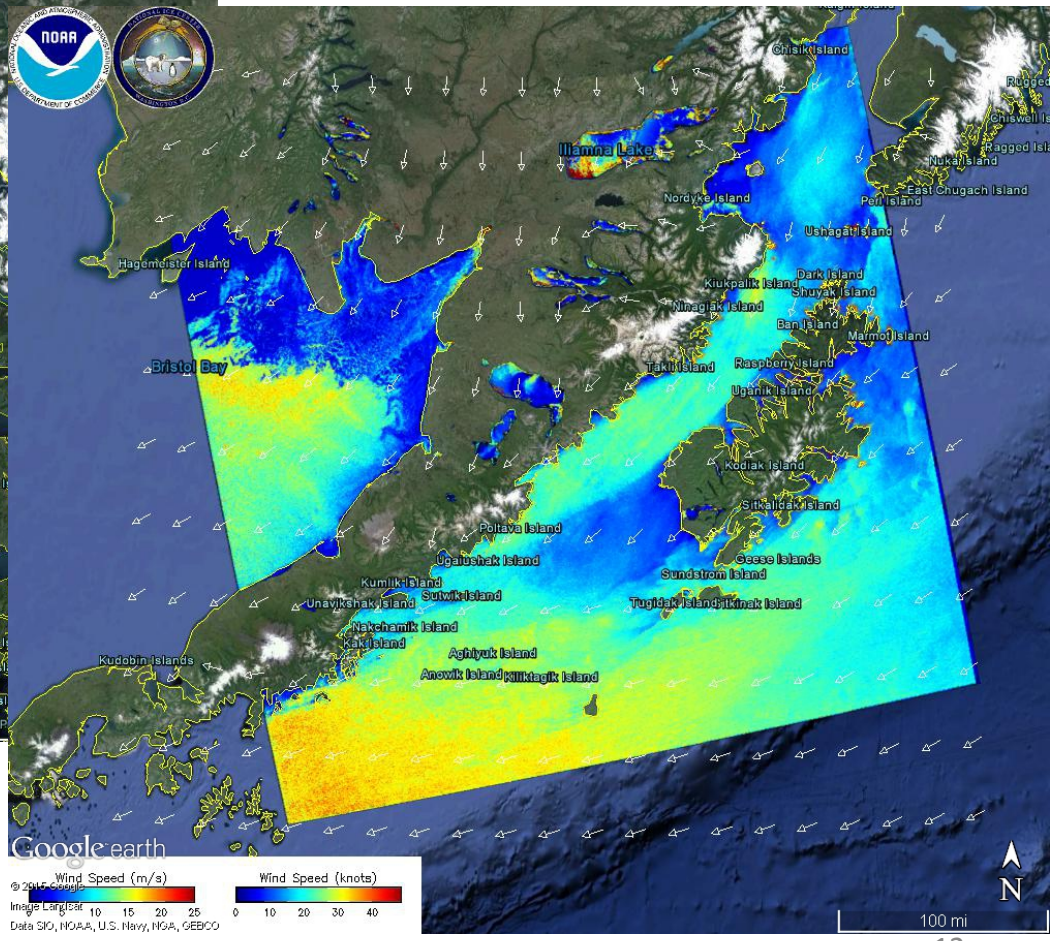
http://www.ospo.noaa.gov/Products/ocean/sst/contour/index.html

High-Resolution SAR-Derived Wind Speed Products



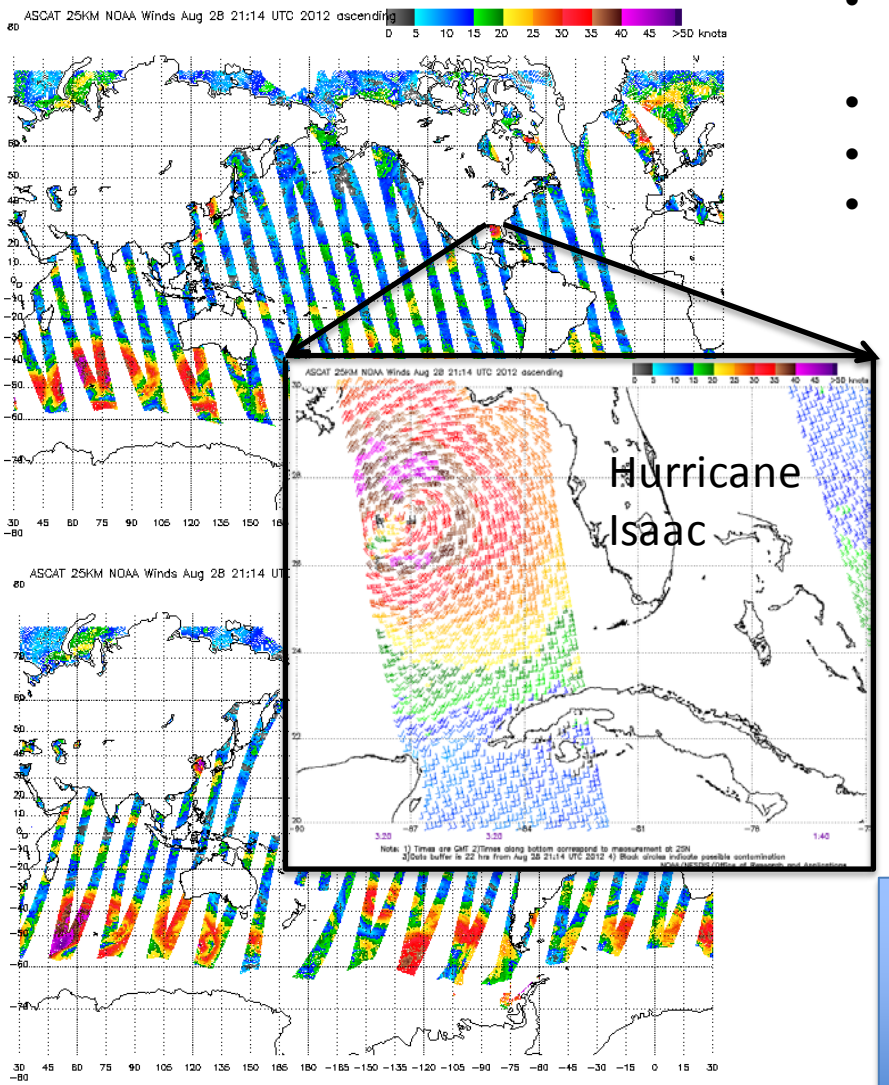
Pre-operational Sentinel-1A wind speed
2015-01-08 02:46 UT

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

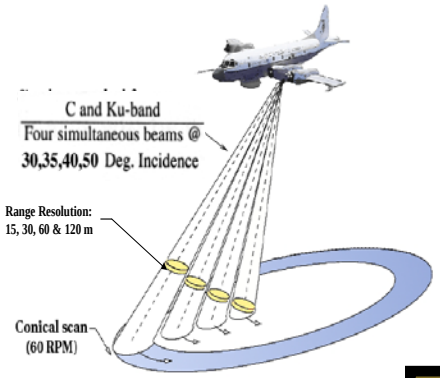


Satellite Ocean Surface Vector Winds

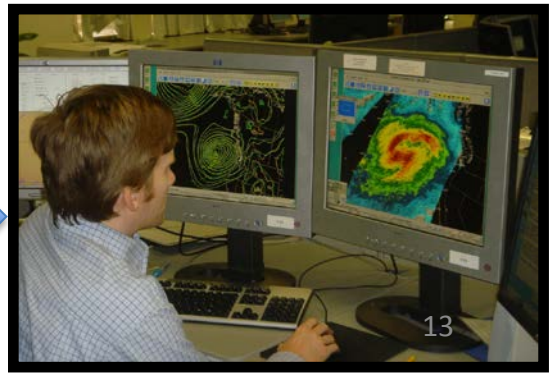
ASCAT Daily Coverage Example



- 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

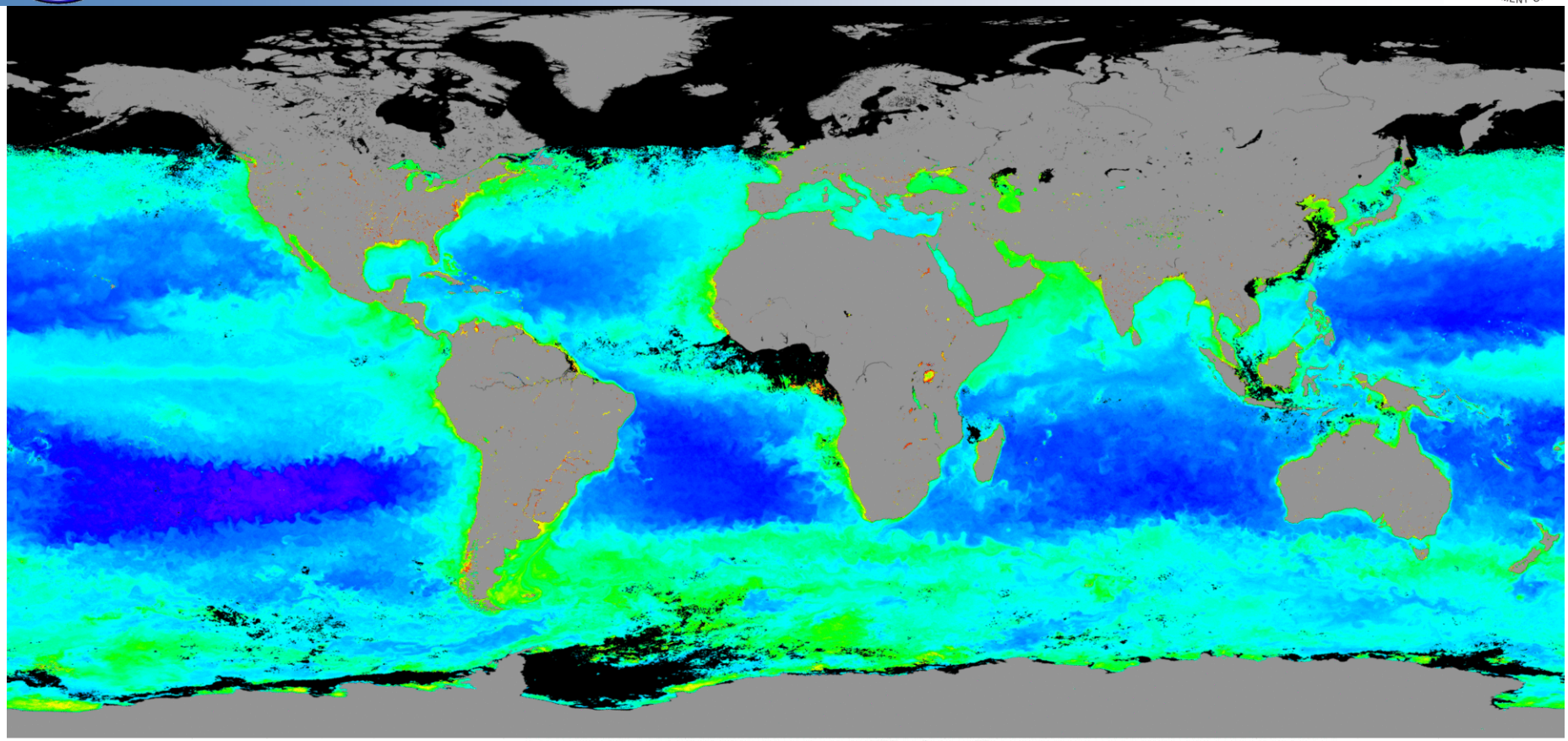


Goal: Provide the best possible product and training to end users



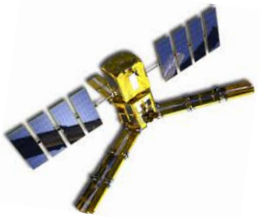
NOAA Satellite Ocean Surface Winds Science Team
http://manati.star.nesdis.noaa.gov/

VIIRS Mission Monthly Chlorophyll-a



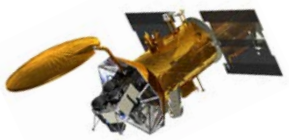
Generated using NOAA MSL12 for VIIRS ocean color data processing

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



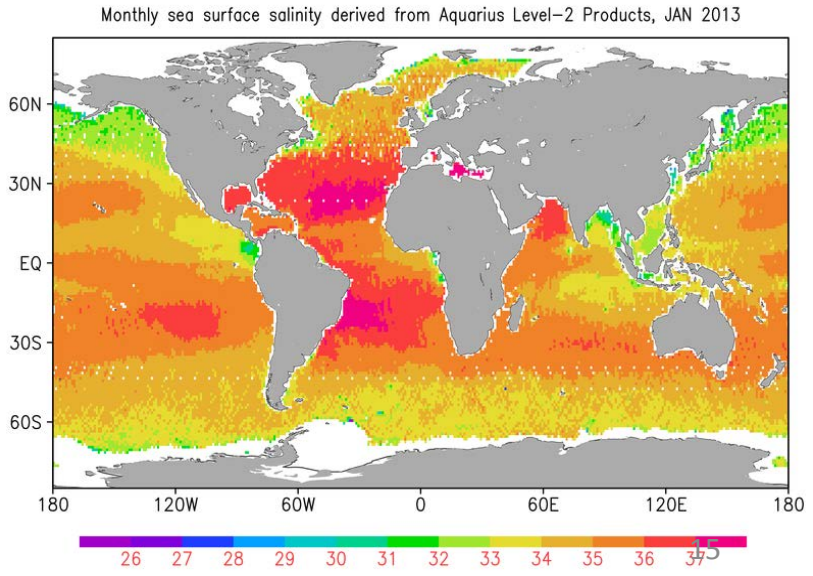
Satellite Sea-Surface Salinity Science Team

Current & Emerging Efforts

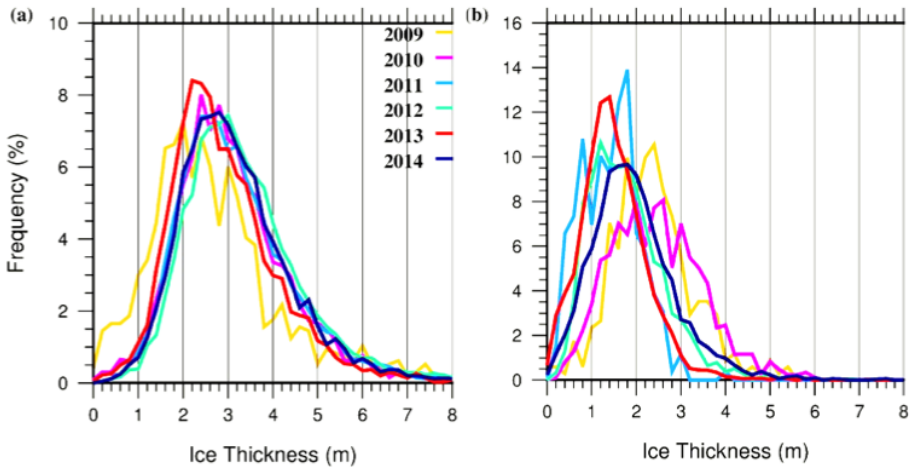


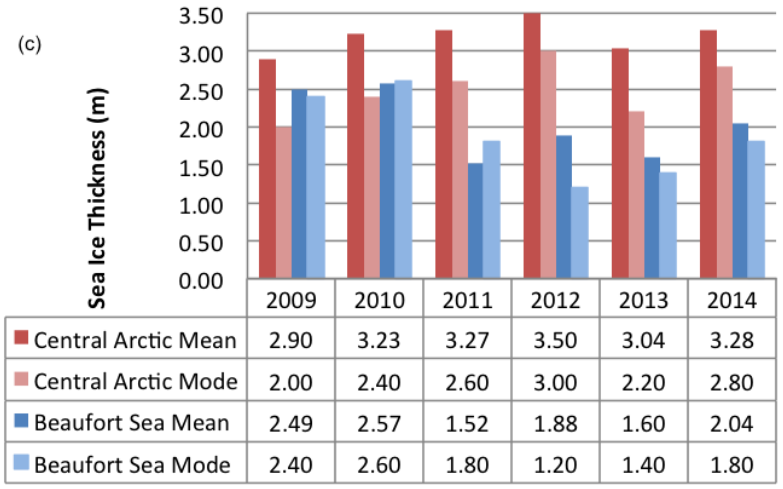
- **Data**
  - SSS Level-2 /3 data records acquired for NASA's Aquarius & ESA's SMOS missions
  - Data set development in support of applications and climatology
  - Ocean color radiometry for coastal/estuarine areas
- **Quality**
  - Online quality monitoring and assessment - automation, statistics,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



Sea Ice





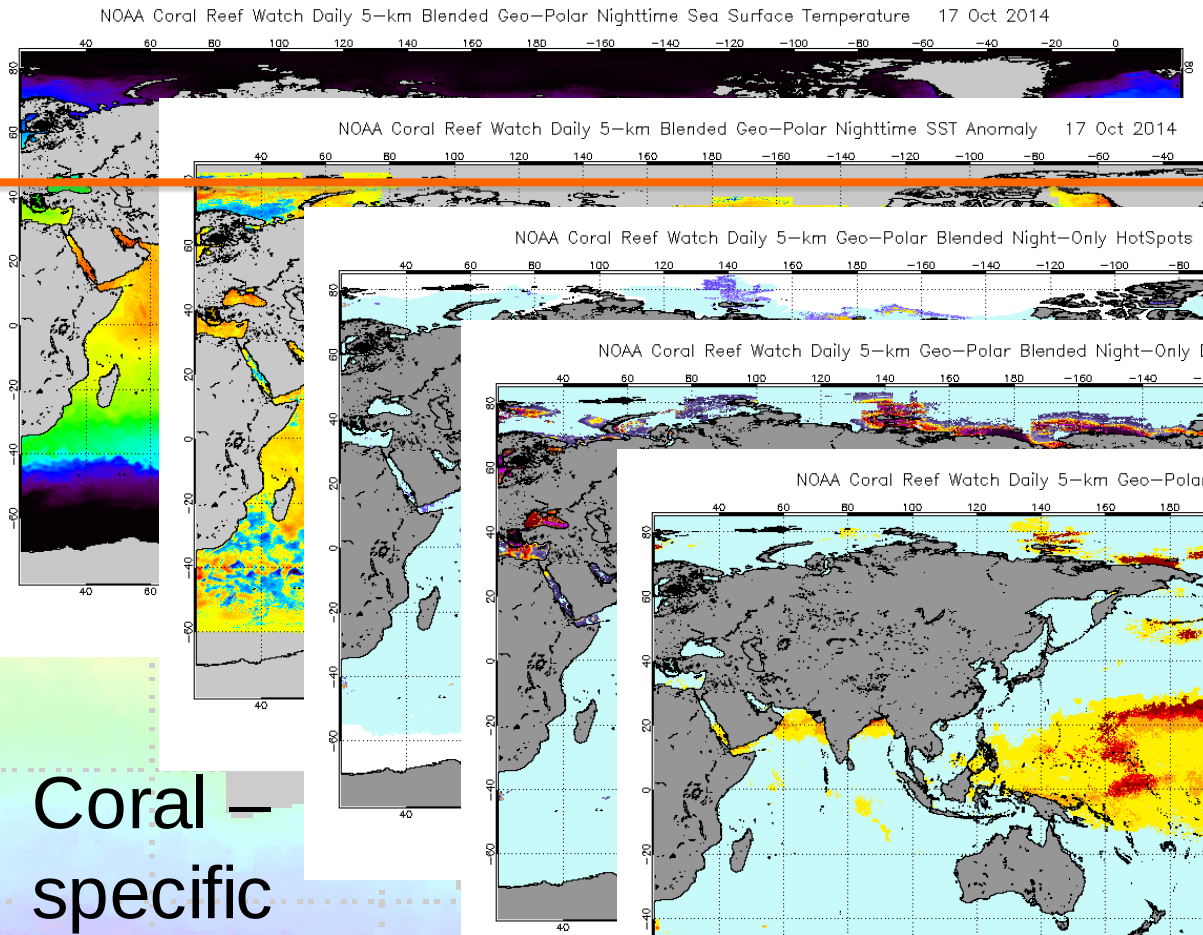
	2009	2010	2011	2012	2013	2014
Central Arctic Mean	2.90	3.23	3.27	3.50	3.04	3.28
Central Arctic Mode	2.00	2.40	2.60	3.00	2.20	2.80
Beaufort Sea Mean	2.49	2.57	1.52	1.88	1.60	2.04
Beaufort Sea Mode	2.40	2.60	1.80	1.20	1.40	1.80

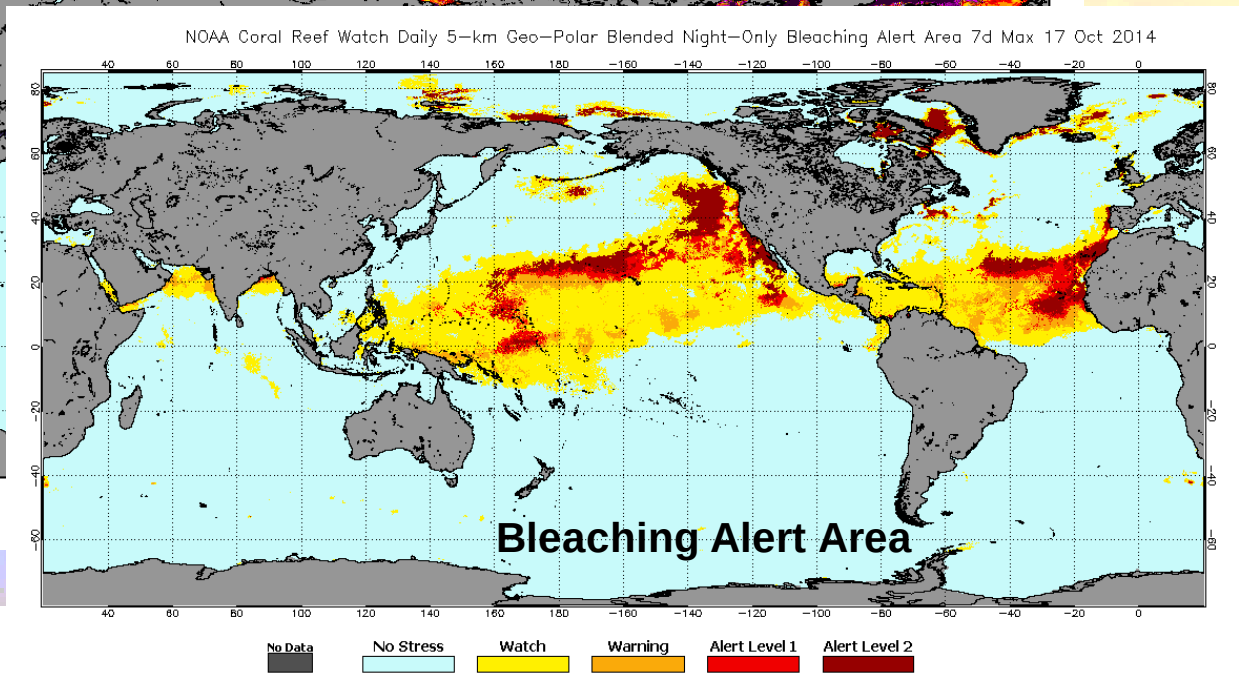
Wintertime Arctic sea ice thickness distributions spanning six years (2009-2014) for (a) Central Arctic, and (b) the Beaufort/Chukchi Seas, derived from the Operation IceBridge Sea Ice Thickness product (IDCSI2). Mean and modal sea ice thickness (m) over six years for regions (a) and (b) is shown in (c). Reference: Richter-Menge and Farrell (2013), updated 2014.

Sea ice in the Beaufort Sea, off the coast of Barrow, AK. Photo credit: Sinead L. Farrell, NOAA/Univ. Maryland

Some Applications

Coral Reef Watch
5-km Satellite-Based Products





Coral – specific

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)

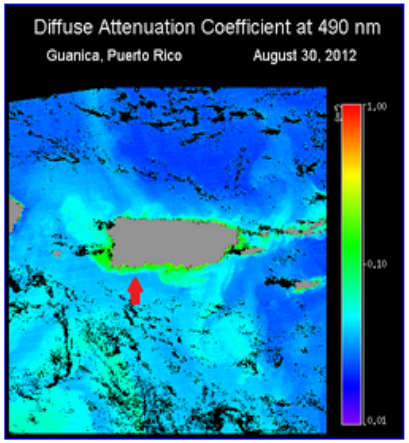
DOC > NOAA > NESDIS > STAR > CRW

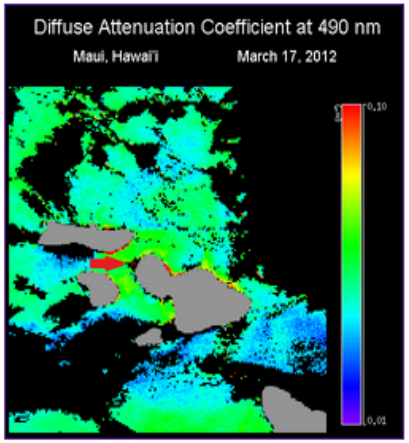
Coral Reef Watch

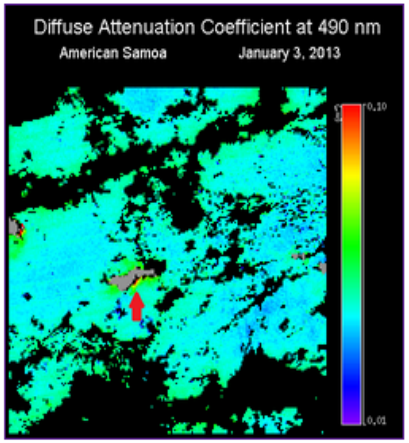
CRTF | CRCP | CREIOS | CoRIS

- 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



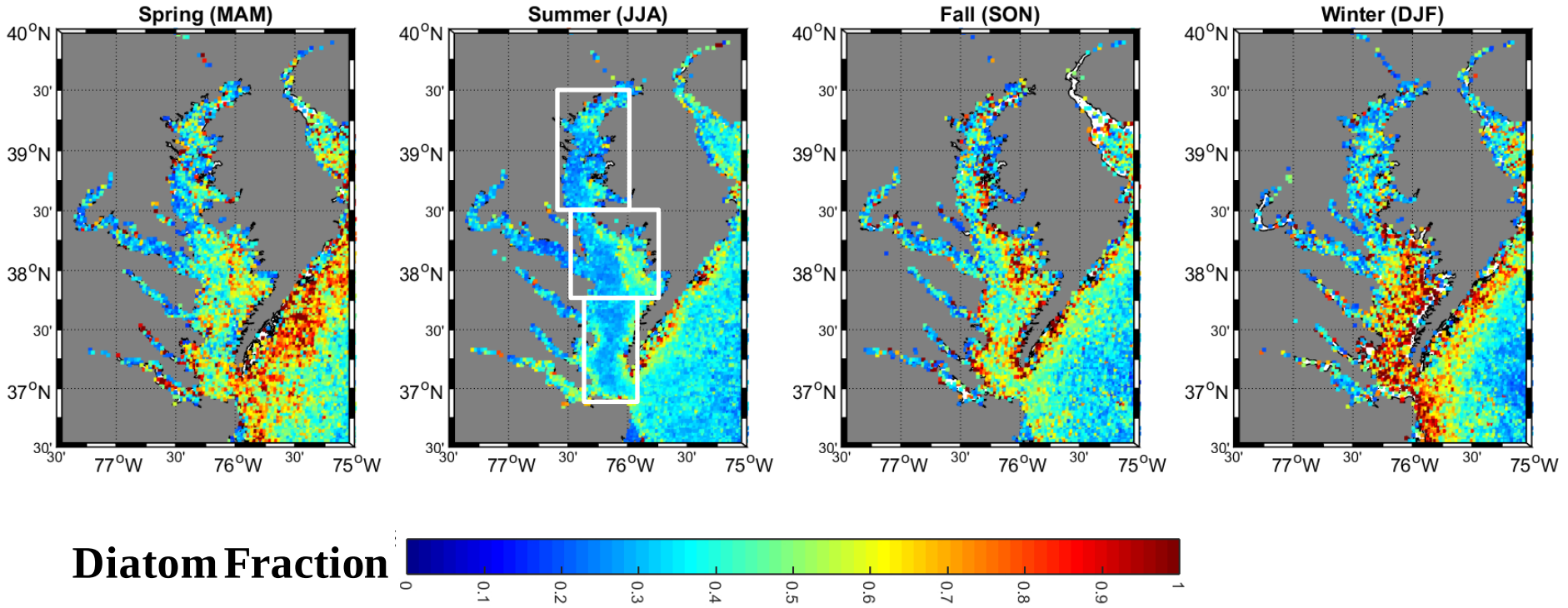




NOAA Coral Reef Watch and NOAA/NESDIS' Ocean Color Team are working closely with partners in the U.S. Coral Reef Task Force (USCRTF) Watershed Working Group (WWG) to develop pilot satellite ocean color products using data from the Visible Infrared Imaging Radiometer Suite (VIIRS) aboard the Suomi National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



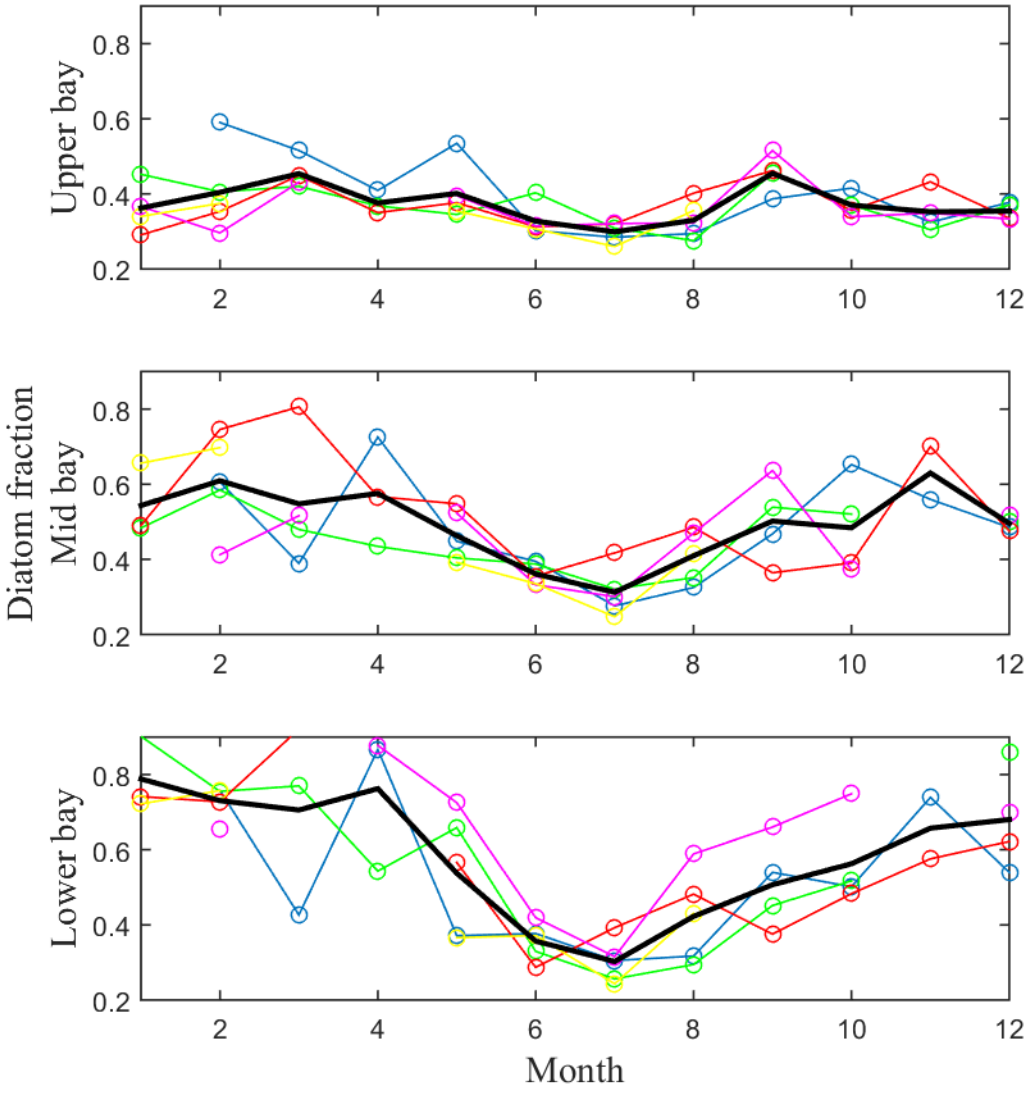
- Lowest diatom fraction occurs in summer, a well known feature in this region.
- Diatom-dominated spring bloom is most evident in coastal waters outside of the bay.
- Strongest diatom domination in the lower bay during winter?

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

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

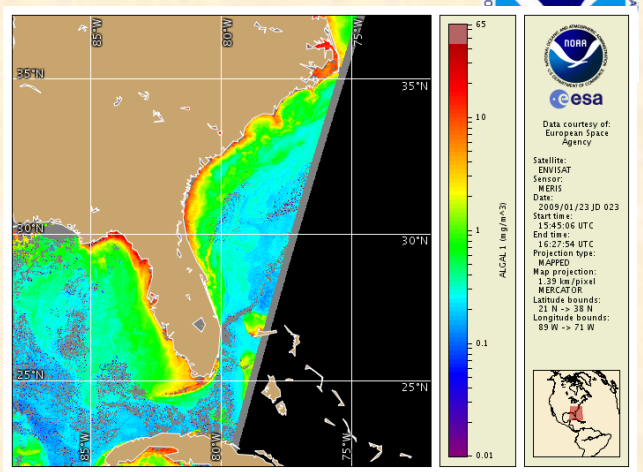
[Magnuson et al., *Estuar. Coast. Shelf Sci.*, 2004]

- 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

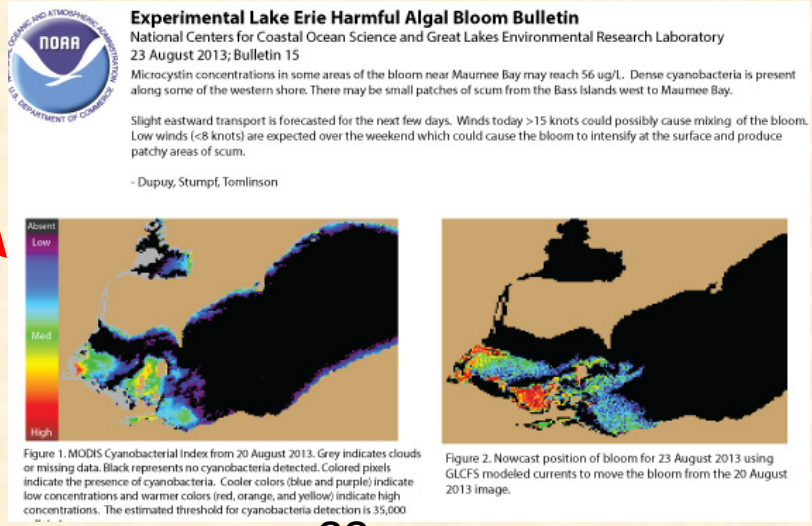
NOAA Utilization of European Ocean Color Data: Way forward for Sentinel-3/OLCI

- 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.

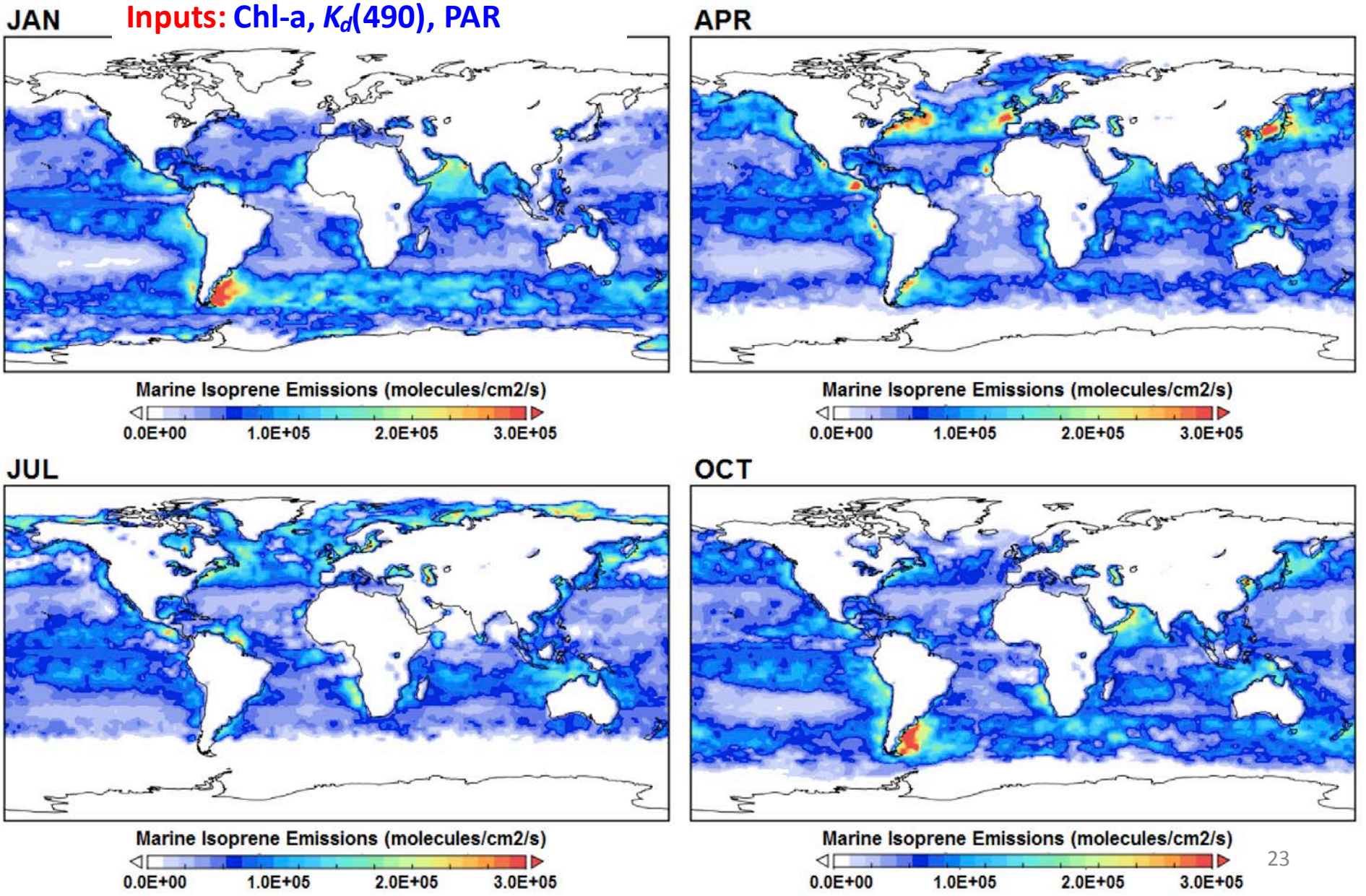
Slight eastward transport is forecasted for the next few days. Winds today >15 knots could possibly cause mixing of the bloom. Low winds (<8 knots) are expected over the weekend which could cause the bloom to intensify at the surface and produce patchy areas of scum.

- Dupuy, Stumpf, Tomlinson

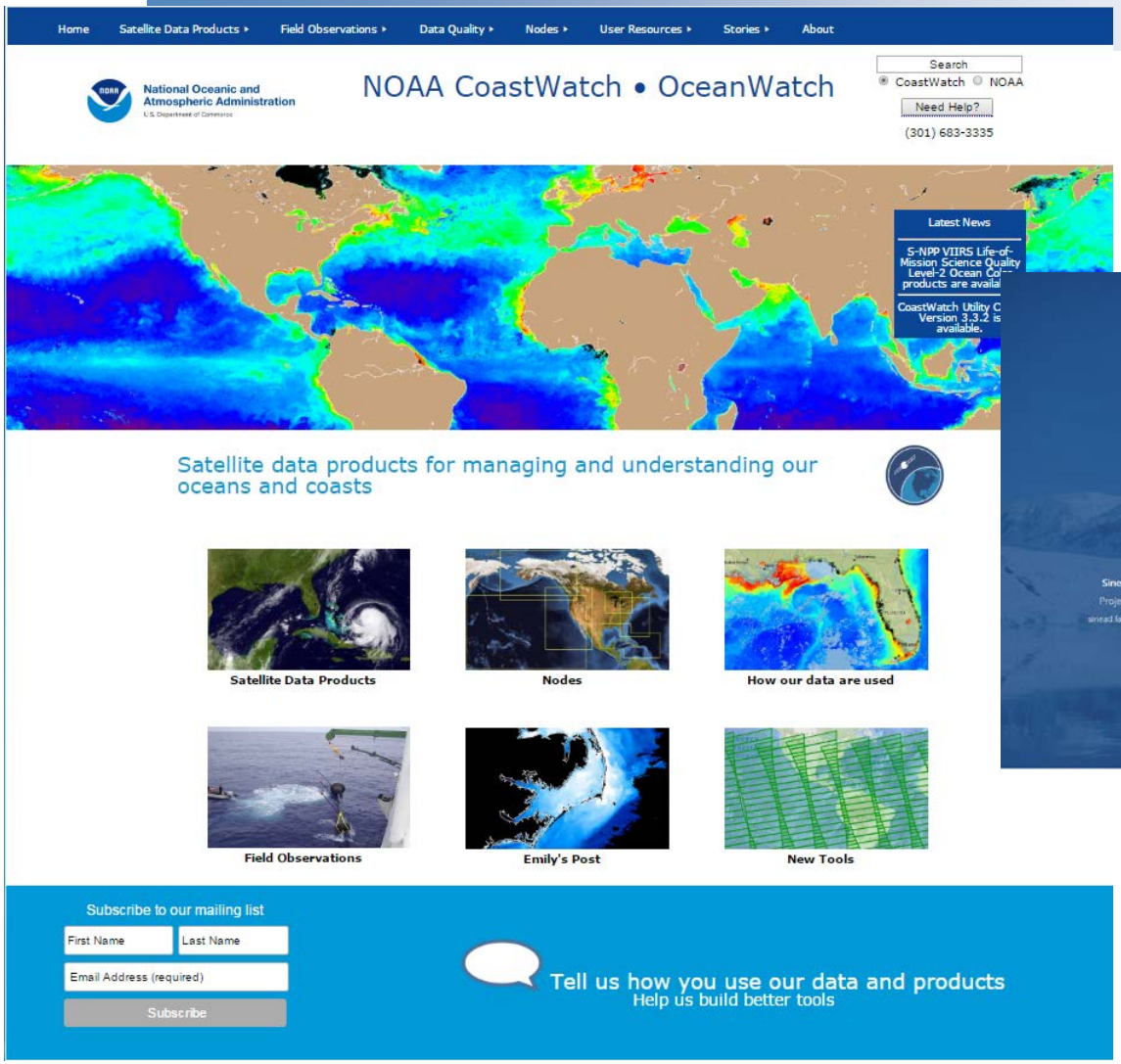
Figure 1. MODIS Cyanobacterial Index from 20 August 2013. Grey indicates clouds or missing data. Black represents no cyanobacteria detected. Colored pixels indicate the presence of cyanobacteria. Cooler colors (blue and purple) indicate low concentrations and warmer colors (red, orange, and yellow) indicate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

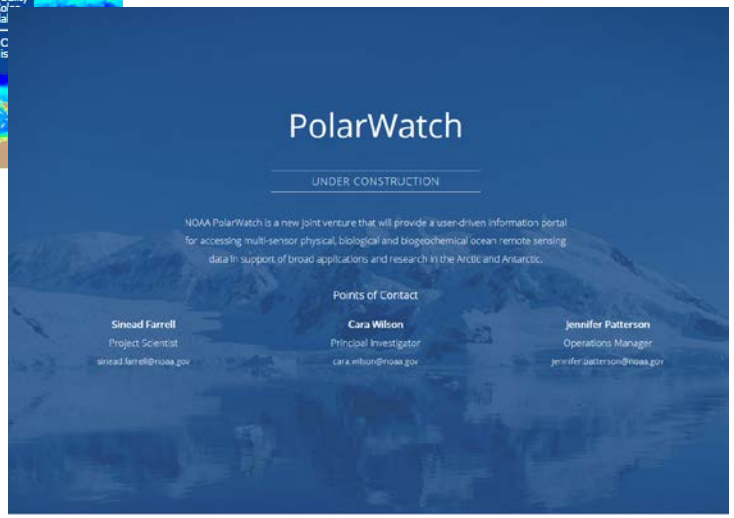
Figure 2. Nowcast position of bloom for 23 August 2013 using GLCFS modeled currents to move the bloom from the 20 August 2013 image.

OAR/ARL: Global Distribution of Marine Isoprene Emission

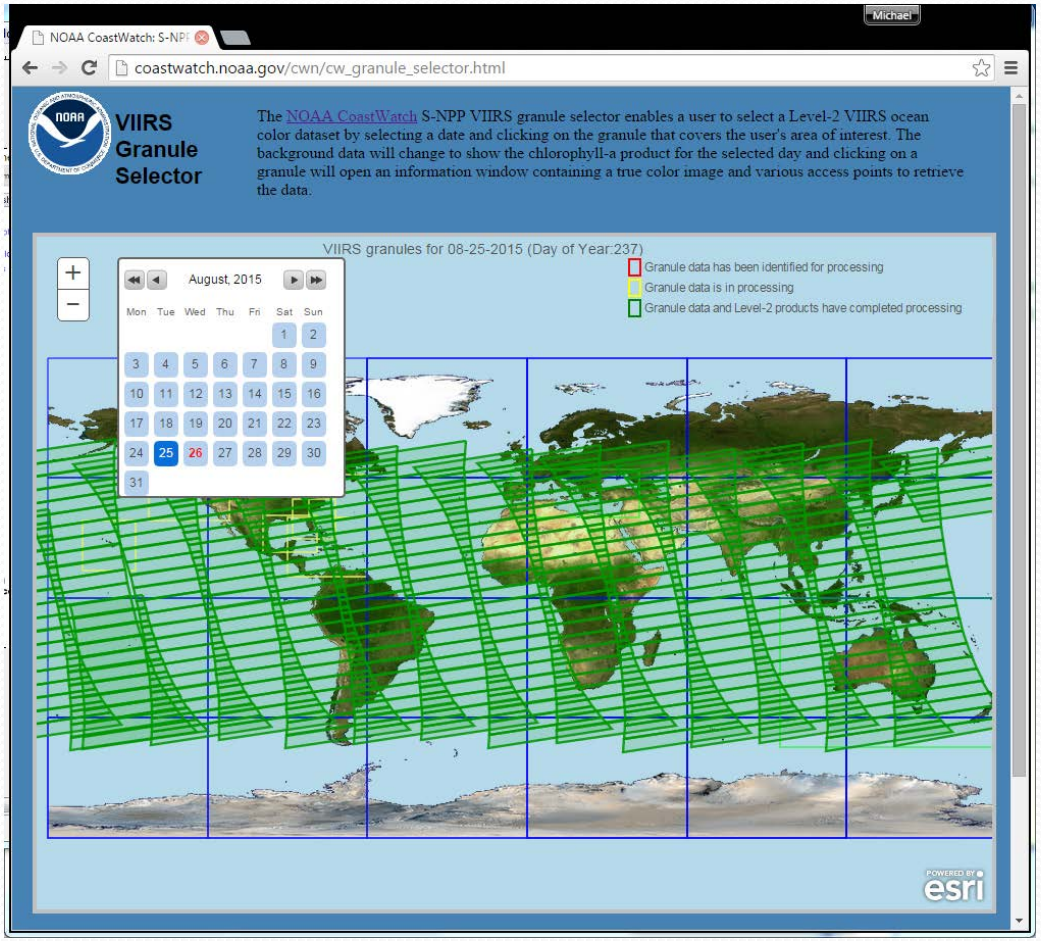


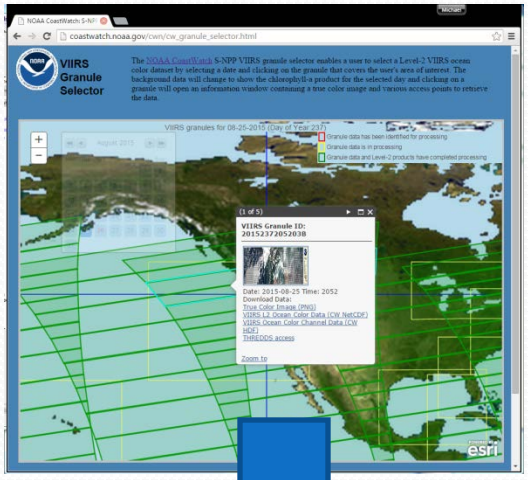
NOAA CoastWatch/OceanWatch/PolarWatch

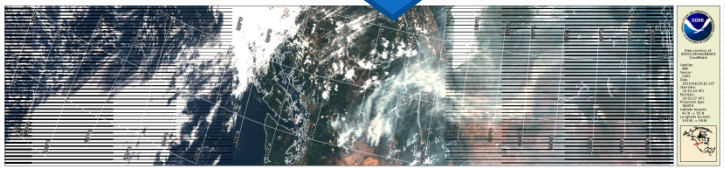




L2 Granule Selector







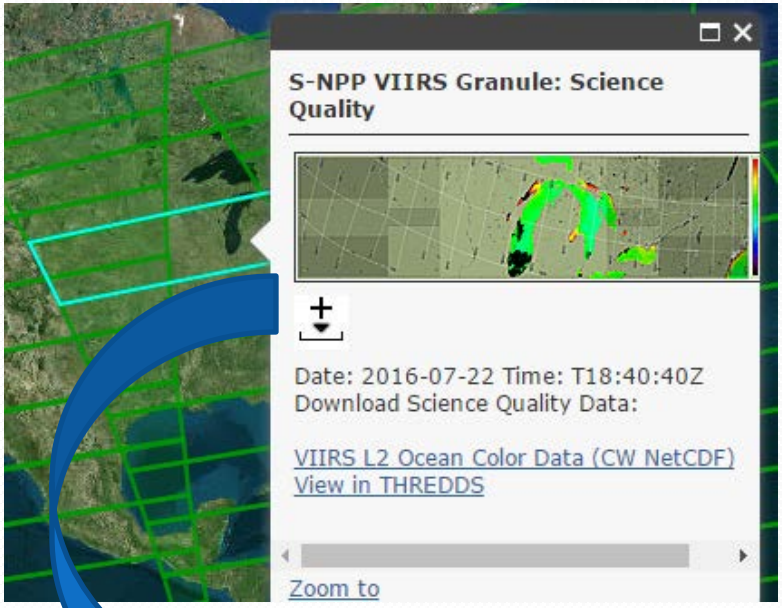
Date: 2015-08-25 Time: 2052
Download Data:
True Color Image (PNG)
VIIRS L2 Ocean Color Data (CW NetCDF)
VIIRS Ocean Color Channel Data (CW HDF)
THREDDS access

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

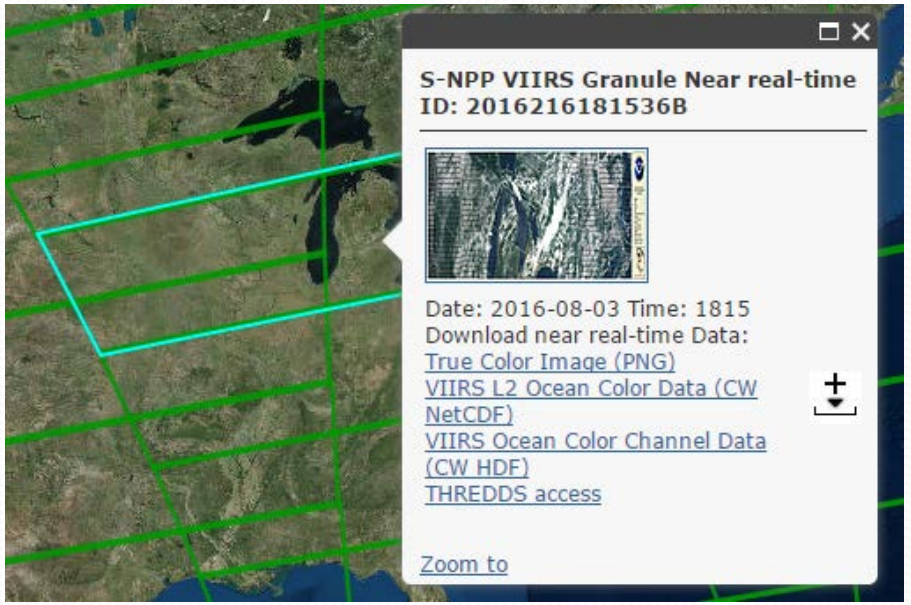
Thanks for Listening!
Now, Questions….

Example of VIIRS OC Data Cart

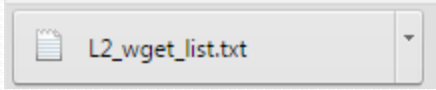
Science Quality (forward processing)



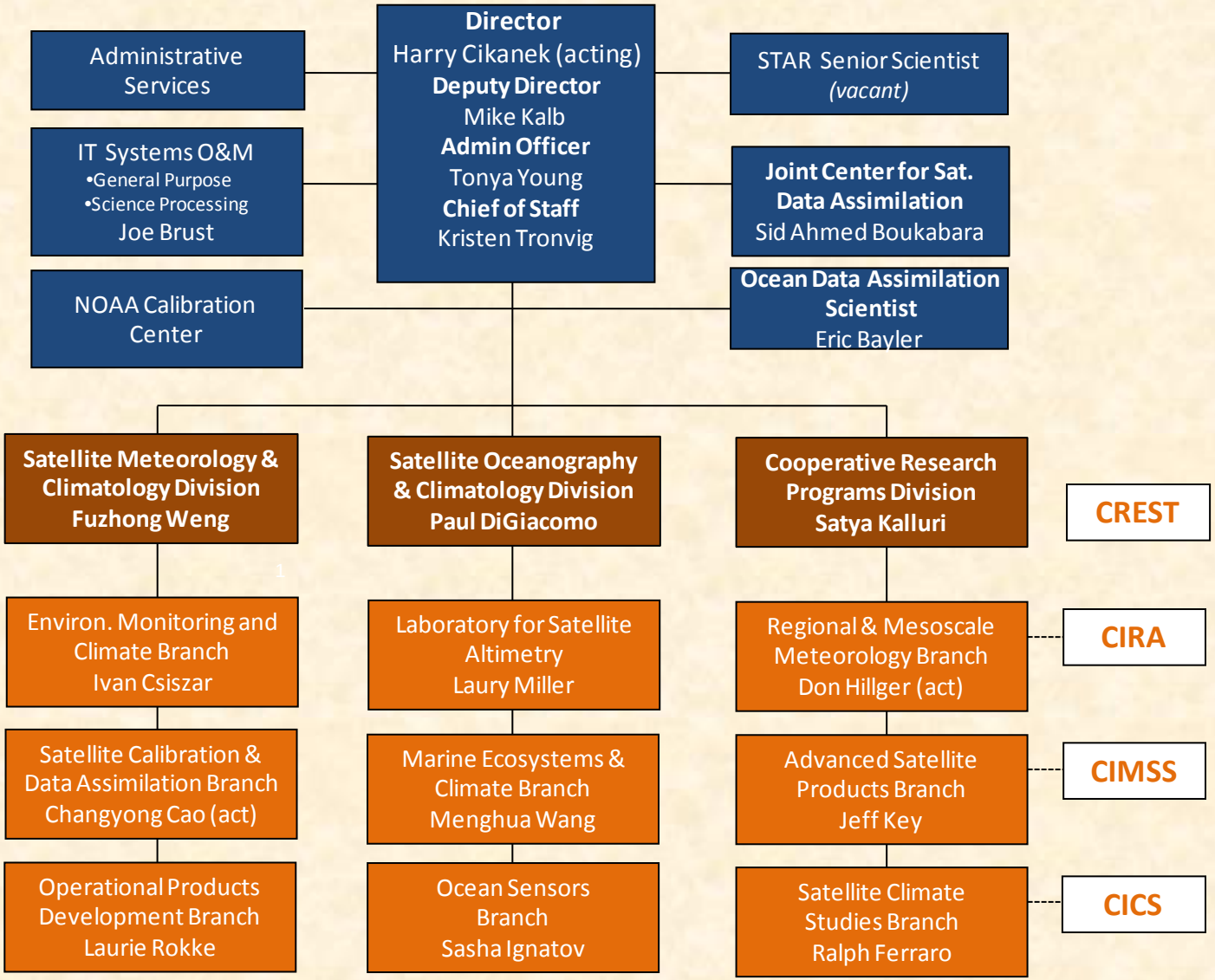
Near real-time



For batch download



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



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.

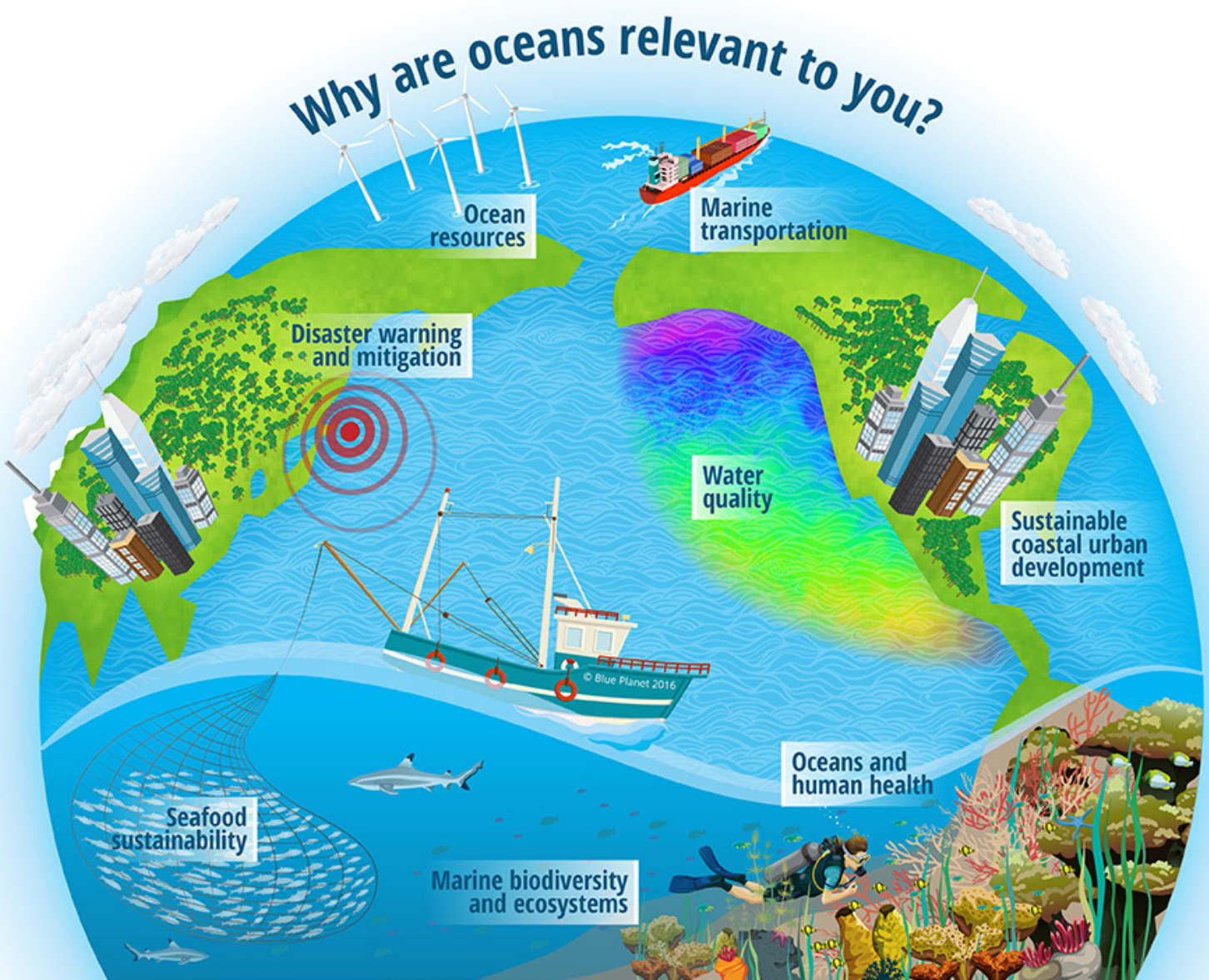
How: Develop, implement and maintain a global inland and coastal water quality monitoring and forecasting service, via a system of systems approach.

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

GROUP ON EARTH OBSERVATIONS

BLUE PLANET Oceans and Society

http://geoblueplanet.com/



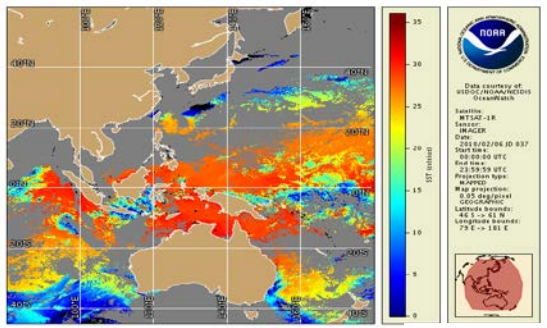
NOAA CoastWatch/OceanWatch

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

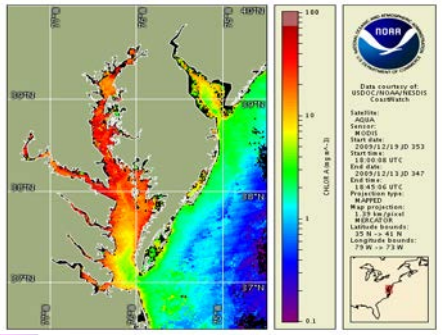
- CW/OW facilitates development and transition of satellite ocean remote sensing experimental data products from ***research into operations*** and supports user-driven coastal and ocean ***applications*** through the dissemination of ***fit for purpose data.***

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

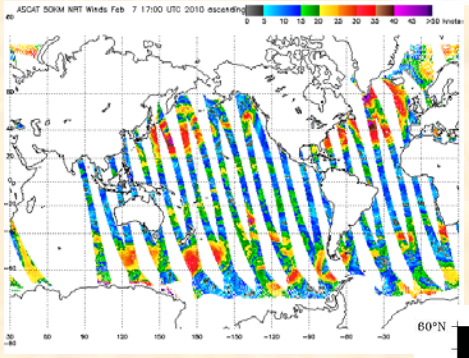
- Supports a number of regional U.S., basin-scale and international coastal and oceanic activities and applications
  - Chesapeake Bay, Gulf of Mexico, Mediterranean Sea, Atlantic & Pacific Basins, Australia et al.



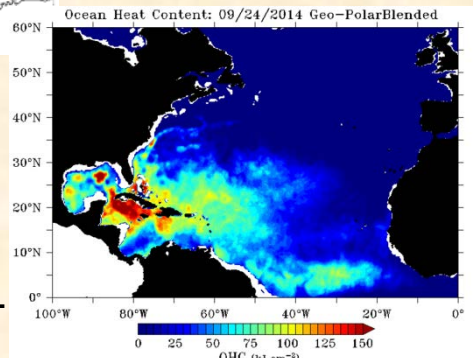
SST



Ocean Color



Ocean Surface Vector Winds



Ocean Heat Content