Satellite Remote Sensing of Coastal and Inland Water Quality: Toward a Global Water Quality Monitoring and Forecasting Service

4th Annual CICS-MD Science Meeting
23-24 November 2015
College Park, MD USA

Paul M. DiGiacomo
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NOAA-NESDIS Center for Satellite Applications & Research

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

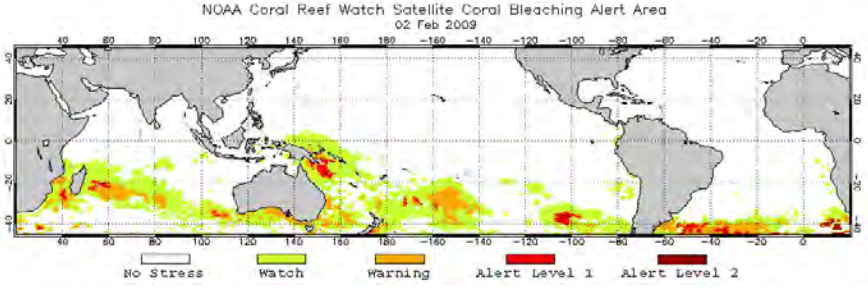
Laboratory for Satellite Altimetry

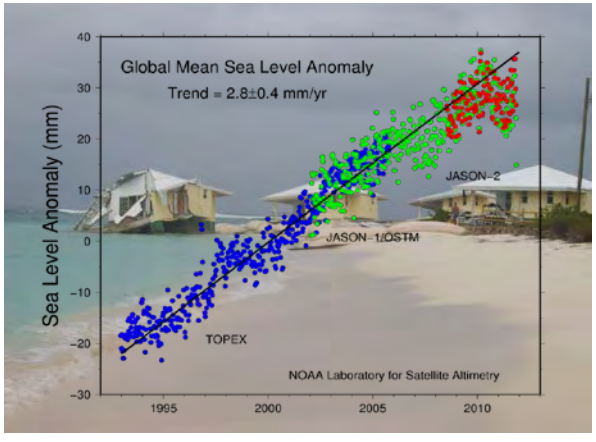
Chief: *Dr. Laury Miller*

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

Science Teams: R&O

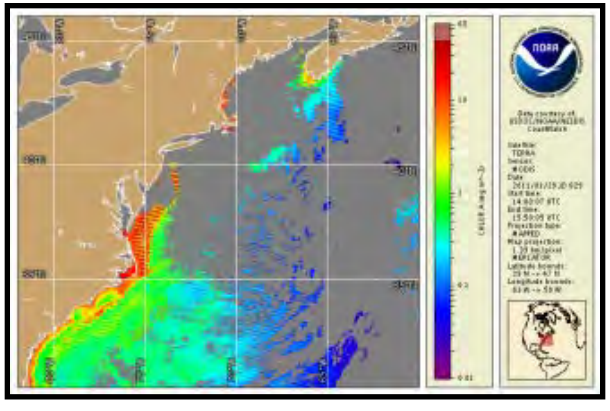
- Sea Surface Height
- Sea Surface Roughness
- Sea Surface Salinity
- Sea Surface Temperature
- Ocean Color Radiometry
- Ocean Surface Vector Winds
- CoastWatch/OceanWatch
- Coral Reef Watch
- Sea Ice and Polar Dynamics

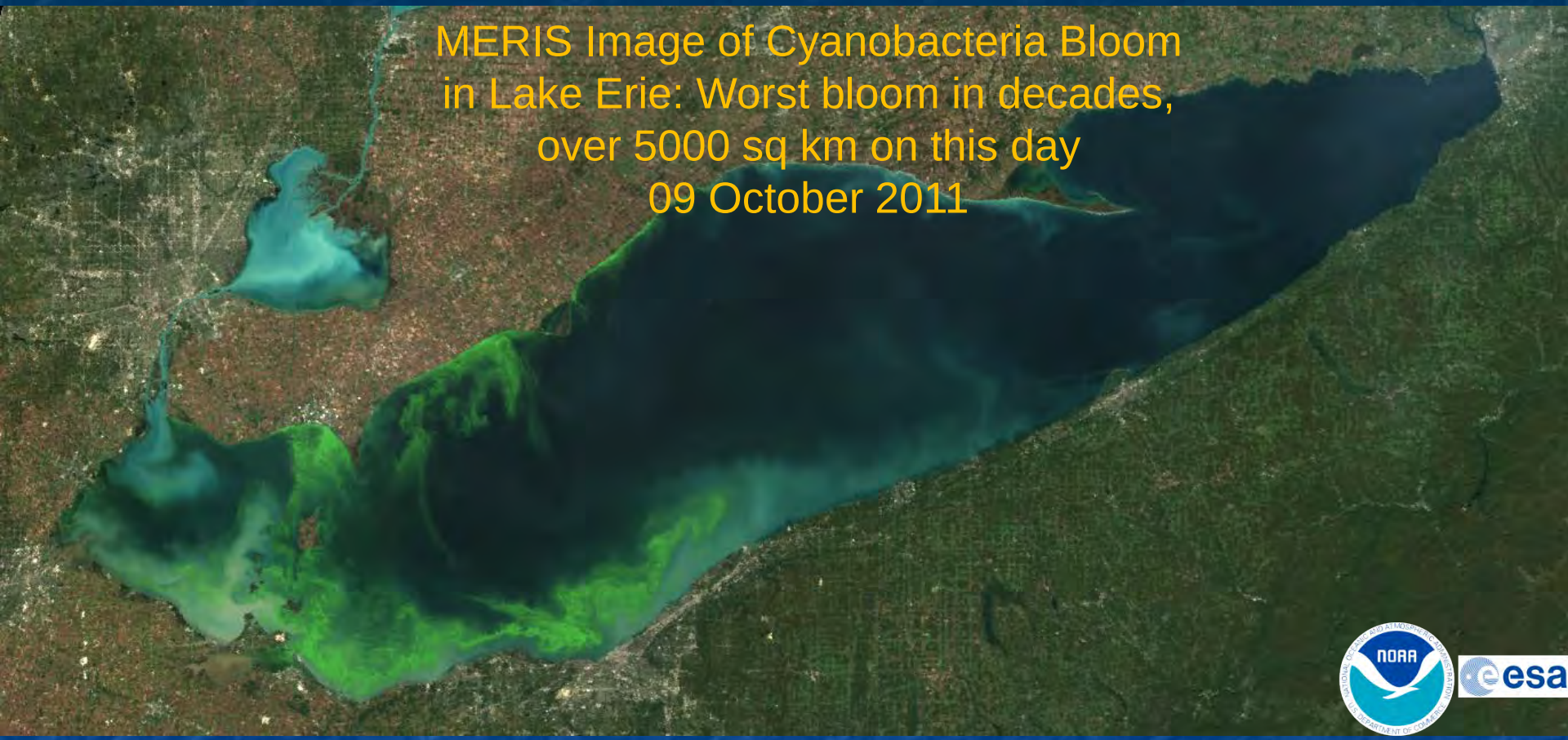




Major Programs/Activities

- 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/OceanWatch & Coral Reef Watch




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

WEATHER

Mostly cloudy 74°

Complete Forecast→

THE BLADE

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Print Story

Scenes like this were common this morning as area residents traveled all over in search of bottled water.
THE BLADE/ JETTA FRASER

Enlarge | Buy This Photo

Published: Saturday, 8/2/2014 - Updated: 1 year ago

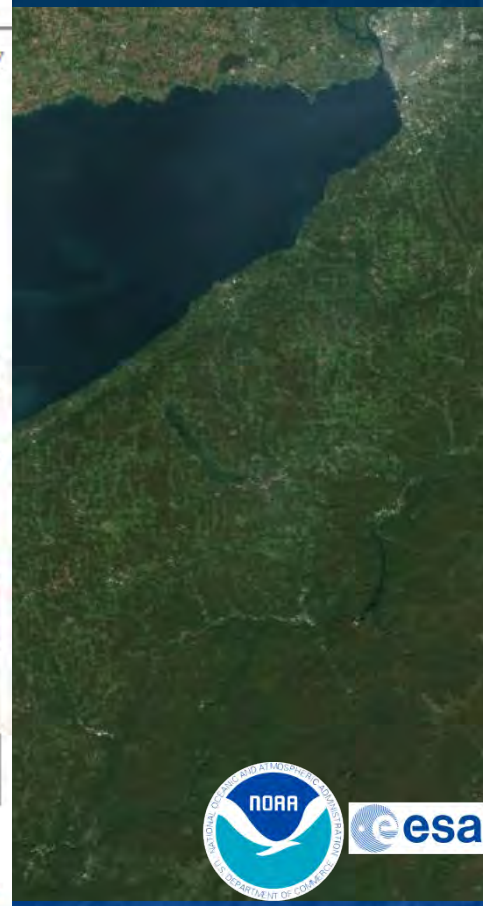
08/02/2014

Toledo-area water advisory expected to continue through Sunday as leaders await tests; water stations to remain open

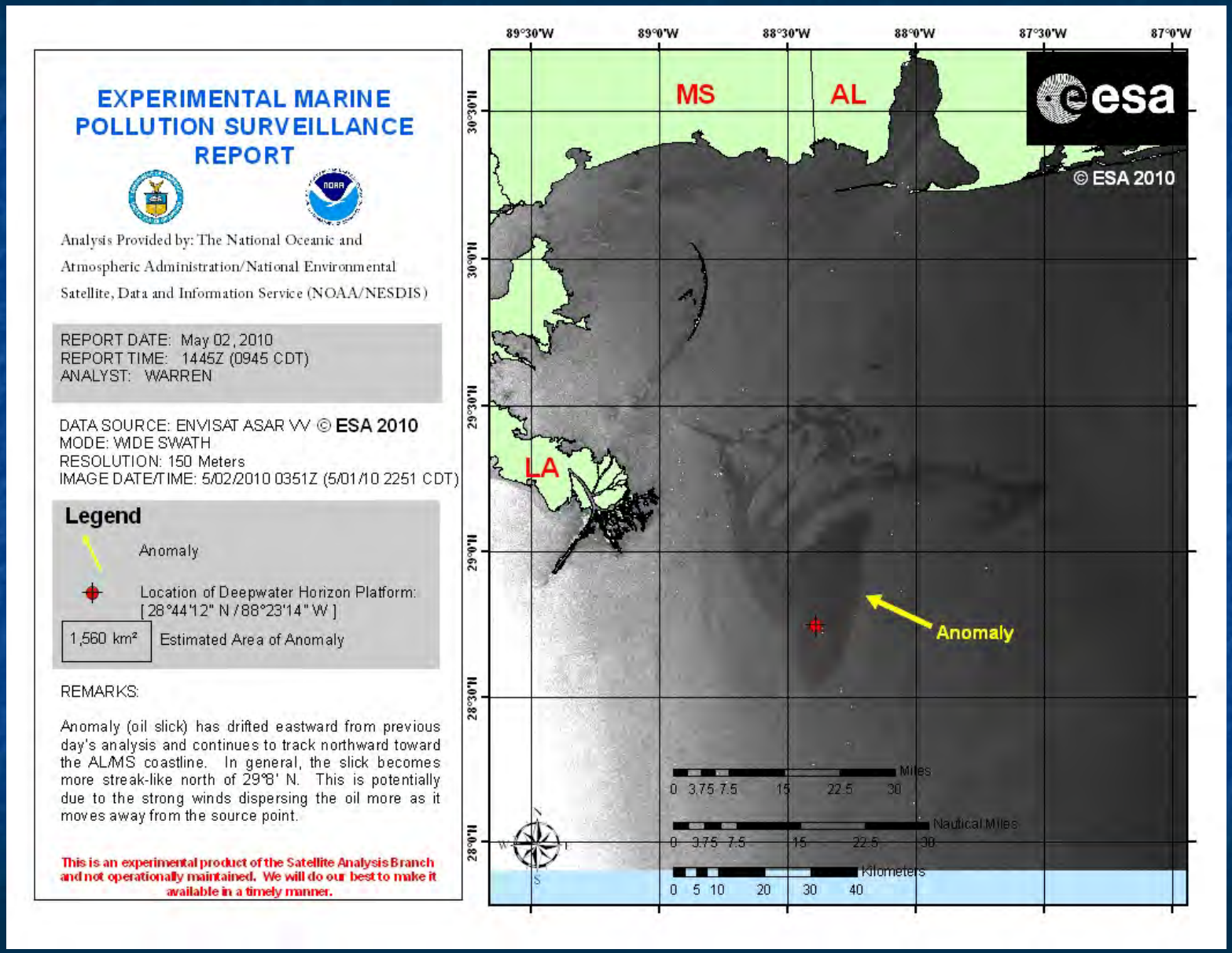
Microcystin found in samples; boiling not recommended

BY TAYLOR DUNGJEN AND DAVID PATCH
BLADE STAFF WRITERS

Toledo's public water will remain under a do-not-drink advisory until at least 6 a.m. Sunday pending the return of results from test samples sent out to three different laboratories, Mayor D. Michael Collins said during an evening news conference.



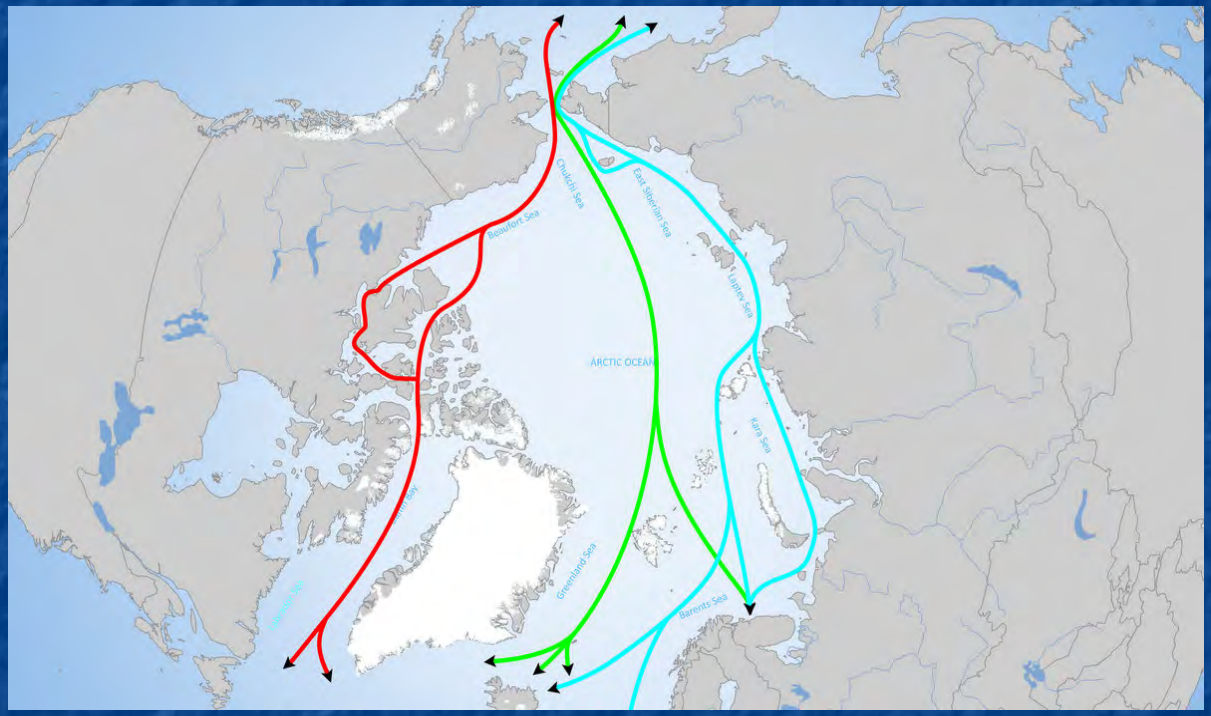
Oil spill and marine pollution monitoring



Polar Navigation Routes

"The remoteness of the Polar Regions limits the amount of direct observation of sea ice. Hence, more than 95% of the data used in sea ice analyses are derived from the remote sensors on polar-orbiting satellites. Sea ice analyses and forecasts are primarily prepared using satellite imagery and ice reconnaissance."

- U.S. National Ice Center



Map: The Arctic Institute

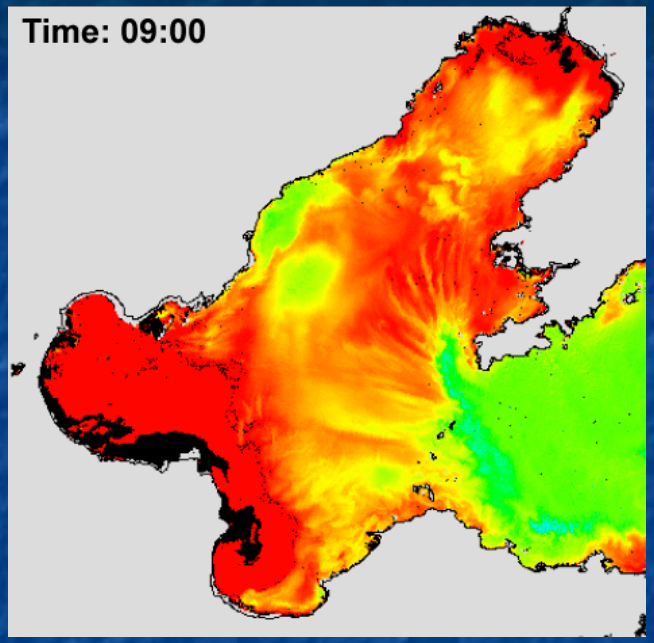
Remote Sensing of Water Quality in Inland & other Coastal Waters

- Declining water quality has become a global issue of significant concern as anthropogenic impacts increase and climate change leads to major alterations to the hydrological cycle

- Globally, water quality monitoring is receiving inadequate attention particularly in developing countries and in countries in transition where existing water quality monitoring networks are deficient

- Even developed nations can better leverage satellite and other remote sensing data to a much greater extent.

- Improved coastal and inland water monitoring capabilities are essential for providing socio-economic benefits



GOCI $K_d(490)$ (Turbidity), 2012-03-25

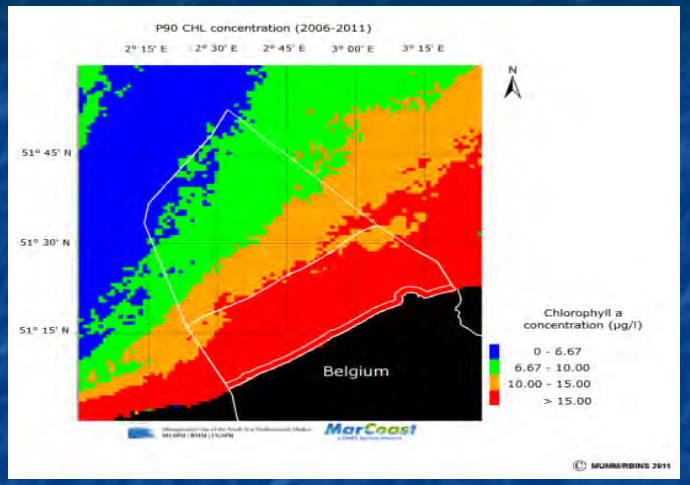
Courtesy S. Greb

Earth Observations in Support of Global Water Quality Monitoring

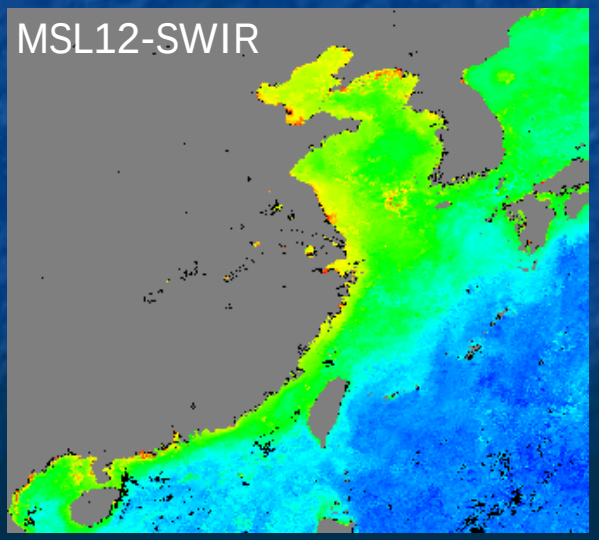
- Since the 2007 *Group on Earth Observations (GEO) Inland & Nearshore Coastal Water Quality Remote Sensing Workshop* in Geneva, there have been significant advances in our ability to monitor and forecast water quality on a global basis,

- This includes integrating observations (satellite & in situ), modeling and data assimilation, and development of fit for purpose user-driven products, indicators, applications and services

- We are working to build a stronger linkage between water resources management end users and data providers to fully realize current and future Earth Observation products.



North Sea Coast Chl.a (MarCoast Project)



China East Coast Chl.a (M. Wang)

Monitoring & Forecasting Global Water Quality via Earth Observations

• NOAA, through partnerships between its satellite service (NESDIS), and the end-user driven ocean, weather, and fisheries services, is working to improve monitoring and forecasting of water quality (especially for U.S. coastal & inland waters). Some examples of NOAA satellite data, applications and product portals (spanning developmental to operational) are shown here, including:

- Remotely sensed Ocean/Aquatic color from multiple satellite sensors (e.g., JPSS VIIRS, MERIS/OLCI, MODIS, GOCI) addressing harmful algal bloom (HAB), terrestrial runoff et al. events, with significant socio-economic impacts

- Synthetic Aperture Radar (SAR) observations of sea surface roughness, addressing key aspects such as high resolution coastal winds, oil spills and other pollution events in regions including the Arctic, Gulf of Mexico, S. Cal et al.

- These and other related data are/will be distributed by the existing NOAA CoastWatch/OceanWatch Data Portal (coastwatch.noaa.gov), as well as the emerging PolarWatch Portal, being jointly developed by NMFS/NESDIS, which will make satellite ocean data for the Arctic, sub-Arctic & Antarctic available to diverse users/applications (polarwatch.noaa.gov)

• Finally, highlights/status of various international water quality monitoring & forecasting activities will be provided (e.g., GEO/GEOSS Blue Planet Initiative).

Ocean (Aquatic) Color

Ocean Color Radiometry and Water Quality Applications

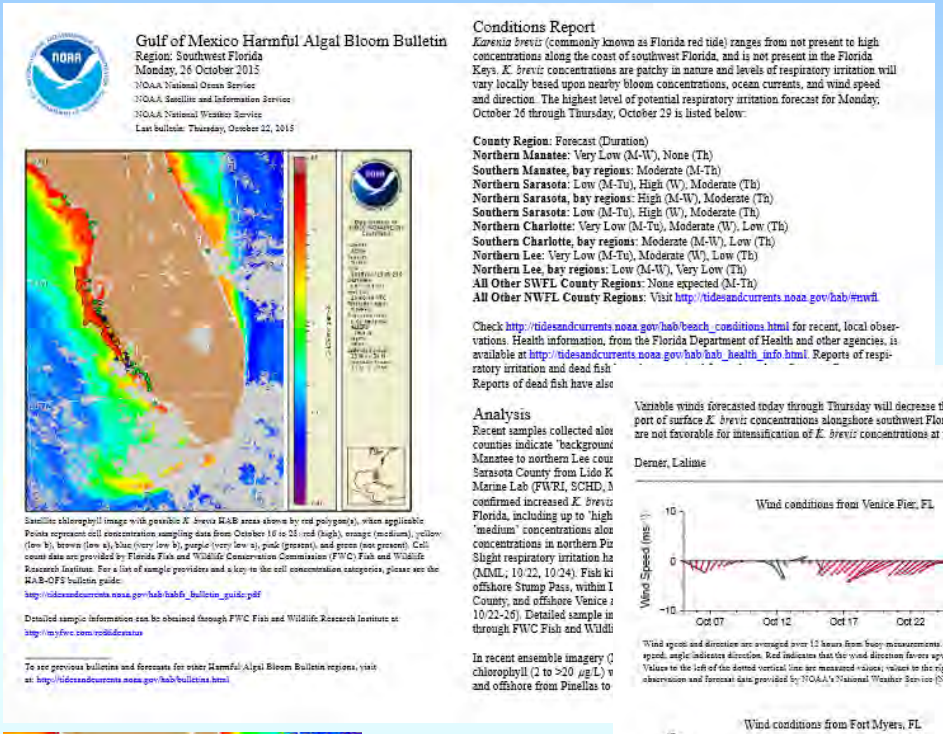
Table 7.1 Products or state indicators and their applications.

Product Name	Standard and Advanced Product Requirement	Application
Transparency / Secchi disk depth	Pigments, total suspended matter (TSM), light attenuation coefficient, dissolved organic matter (DOM),	Water quality monitoring
Primary production	Pigments, TSM, DOM, inherent optical properties of water constituents, SST, surface irradiance	Water quality monitoring, ecosystem and habitat assessment
Differential biomass/ phytoplankton community structure	Pigments, chemotaxonomic equations	Water quality monitoring, ecosystem assessment, hazards
Eutrophication index	Chlorophyll, primary production , nutrients, SST	Water quality monitoring, hazards
Turbidity index	Transparency, phytoplankton biomass	Water quality monitoring
Submerged benthic vegetation index	Pigments, sediment, dissolved organic matter, bathymetry, albedo data base	Aquaculture, water quality monitoring, impact assessment
Bloom/ plume dynamics	Chlorophyll, TSM , DOM	Hazards, ecosystem and habitat assessment

Hoepffner et al., “Ocean Colour Radiometry and Water Quality”, in, *Why Ocean Colour?* IOCCG Report #7, 2008

NOAA/NOS Operational Harmful Algal Bloom Bulletins

Gulf of Mexico Harmful Algal Bloom Bulletin
Region: Southwest Florida
Monday, 26 October 2015
NOAA National Ocean Service
NOAA Satellite and Information Service
NOAA National Weather Service
Previous bulletin: Thursday, October 22, 2015



Gulf of Mexico Harmful Algal Bloom Bulletin
Region: Southwest Florida
Monday, 26 October 2015
NOAA National Ocean Service
NOAA Satellite and Information Service
NOAA National Weather Service
Last bulletin: Thursday, October 22, 2015

Satellite chlorophyll image with possible *K. brevis* HAB areas shown by red polygon(s), when applicable. Points represent cell concentration sampling data from October 16 to 23: red (high), orange (medium), yellow (low b), brown (low a), blue (very low b), purple (very low a), pink (present), and green (not present). Cell count data are provided by Florida Fish and Wildlife Conservation Commission (FWC) Fish and Wildlife Research Institute. For a list of sample providers and a key to the cell concentration categories, please see the HAB-OFS bulletin guide:
http://tidesandcurrents.noaa.gov/hab/habfs_bulletin_guide.pdf

Detailed sample information can be obtained through FWC Fish and Wildlife Research Institute at:
http://myfwc.com/redtidestatus

To see previous bulletins and forecasts for other Harmful Algal Bloom Bulletin regions, visit at: http://tidesandcurrents.noaa.gov/hab/bulletins.html

Conditions Report

Karenia brevis (commonly known as Florida red tide) ranges from not present to high concentrations along the coast of southwest Florida, and is not present in the Florida Keys. *K. brevis* concentrations are patchy in nature and levels of respiratory irritation will vary locally based upon nearby bloom concentrations, ocean currents, and wind speed and direction. The highest level of potential respiratory irritation forecast for Monday, October 26 through Thursday, October 29 is listed below:

County Region: Forecast (Duration)
Northern Manatee: Very Low (M-W), None (Th)
Southern Manatee, bay regions: Moderate (M-Th)
Northern Sarasota: Low (M-Tu), High (W), Moderate (Th)
Northern Sarasota, bay regions: High (M-W), Moderate (Th)
Southern Sarasota: Low (M-Tu), High (W), Moderate (Th)
Northern Charlotte: Very Low (M-Tu), Moderate (W), Low (Th)
Southern Charlotte, bay regions: Moderate (M-W), Low (Th)
Northern Lee: Very Low (M-Tu), Moderate (W), Low (Th)
Northern Lee, bay regions: Low (M-W), Very Low (Th)
All Other SWFL County Regions: None expected (M-Th)
All Other NWFL County Regions: Visit http://tidesandcurrents.noaa.gov/hab/#nwfl

Check http://tidesandcurrents.noaa.gov/hab/beach_conditions.html for recent, local observations. Health information, from the Florida Department of Health and other agencies, is available at http://tidesandcurrents.noaa.gov/hab/hab_health_info.html. Reports of respiratory irritation and dead fish
Reports of dead fish have also

Analysis

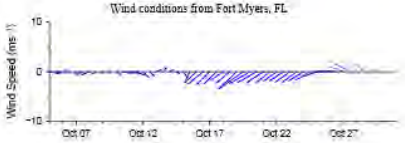
Recent samples collected also
counties indicate "background
Manatee to northern Lee coun
Sarasota County from Lido K
Marine Lab (FWRI, SCHD, M
confirmed increased *K. brevis*
Florida, including up to "high
"medium" concentrations also
concentrations in northern Pin
Slight respiratory irritation ha
(MML; 10/22, 10/24). Fish ki
offshore Stump Pass, within I
County; and offshore Venice
10/22-26). Detailed sample in
through FWC Fish and Wildli

In recent ensemble imagery (
chlorophyll (2 to >20 μg/L)
and offshore from Pinellas to

Variable winds forecasted today through Thursday will decrease the potential for transport of surface *K. brevis* concentrations alongshore southwest Florida. Forecasted winds are not favorable for intensification of *K. brevis* concentrations at the coast.

Derner, Lalime

Wind speed and direction are averaged over 12 hours from buoy measurements. Length of line indicates speed, angle indicates direction. Red indicates that the wind direction favors upwelling, west the coast. Values to the left of the dotted vertical line are measured values; values to the right are forecasts. Wind observation and forecast data provided by NOAA's National Weather Service (NWS).



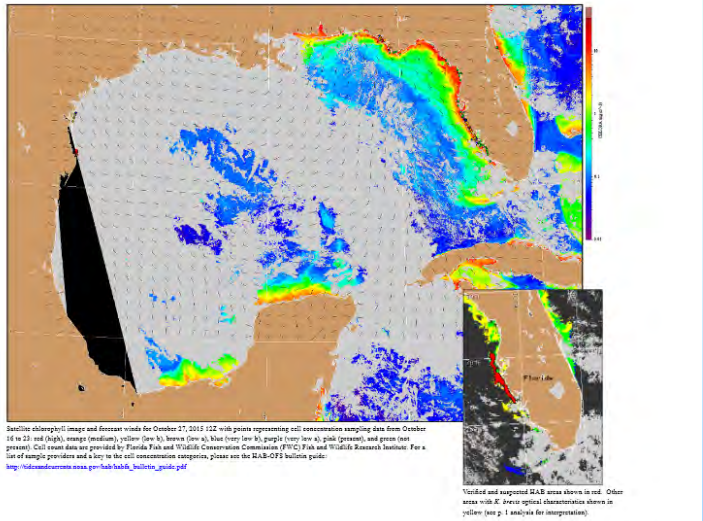
-2-

Wind Analysis

Englewood to Tarpon Springs (Venice): Southeast winds (10-20kn, 5-10m/s) today through Tuesday becoming south (10-15kn, 5-8m/s) Tuesday night through Wednesday. Southwest winds (10kn, 5m/s) in the afternoon becoming west winds (5kn, 3m/s) Wednesday night. Northwest winds (5kn) Thursday.

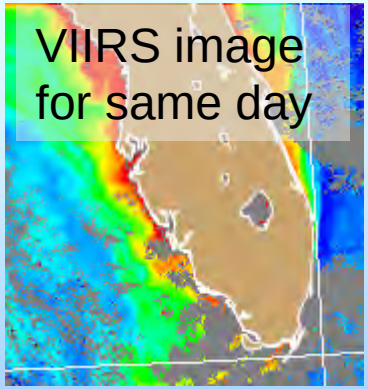
Bonita Beach to Englewood (Fort Myers): Southeast winds (10-20kn) today through Tuesday. South winds (15kn) Wednesday becoming southwest (5-10kn, 3-5m/s) in the afternoon through Wednesday night. West winds (5kn) Thursday.

-3-



Satellite chlorophyll image and forecast winds for October 27, 2015 12Z with points representing cell concentration sampling data from October 16 to 23: red (high), orange (medium), yellow (low b), brown (low a), blue (very low b), purple (very low a), pink (present), and green (not present). Cell count data are provided by Florida Fish and Wildlife Conservation Commission (FWC) Fish and Wildlife Research Institute. For a list of sample providers and a key to the cell concentration categories, please see the HAB-OFS bulletin guide:
http://tidesandcurrents.noaa.gov/hab/habfs_bulletin_guide.pdf

Verified and suspected HAB areas shown in red. Other areas with *K. brevis* optical characteristics shown in yellow (see p. 1 analysis for interpretation).



Sample of Gulf of Mexico Operational HAB-OFS Bulletin using Aqua MODIS OC data

WEATHER

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

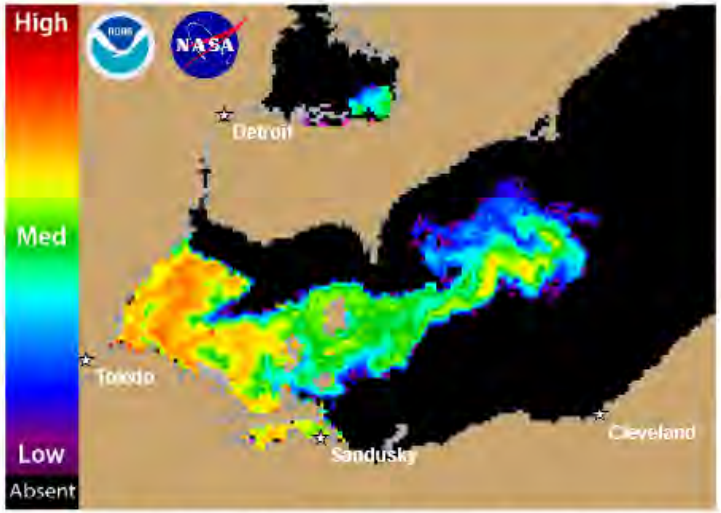


Figure 1. Cyanobacterial Index from NASA's MODIS- Aqua data collected 22 August, 2015 at 13:10 EST. Grey indicates clouds or missing data. Black represents no cyanobacteria detected. Colored pixels indicate the presence of cyanobacteria. Cooler colors (blue and purple) indicate low concentrations and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

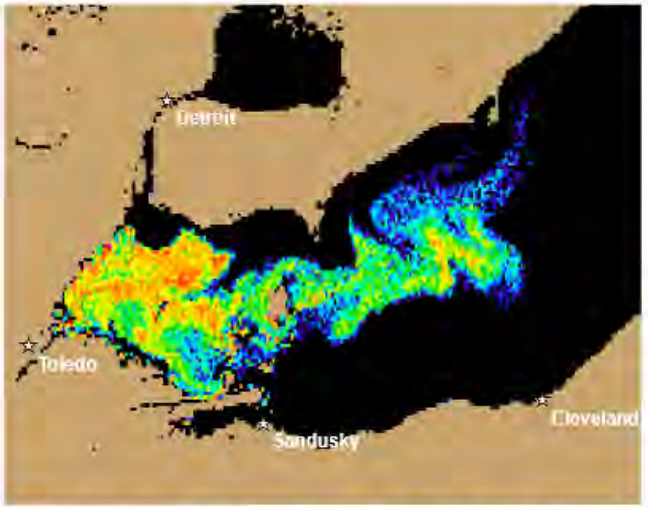


Figure 2. Nowcast position of bloom for 24 August, 2015 using GLCFS modeled currents to move the bloom from the 22 August, 2015 image.

Courtesy: NOAA/NOS

NOAA/NOS/CO-OPS

said during an evening news conference.

NOAA Lake Erie HAB Bulletin (MERIS 2009-2011, now MODIS, soon Sentinel-3/OLCI)

Experimental
Lake Erie Harmful Algal Bloom Bulletin
2011-008
08 September 2011
National Ocean Service
Great Lakes Environmental Research Laboratory
Last bulletin: 22 July 2011

Bloom from MERIS

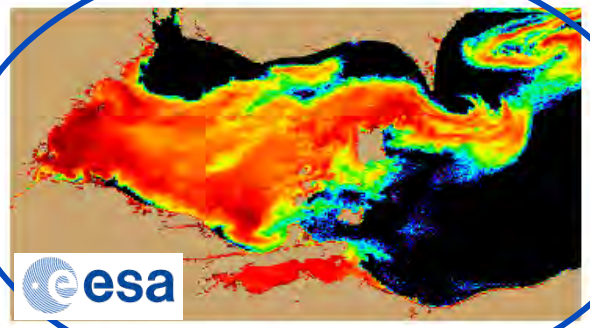


Figure 1. MERIS image from the European Space Agency. Imagery shows the spectral shape at 681 nm from September 03, where colored pixels indicate the likelihood of the last known position of the *Microcystis* spp. bloom (with red being the highest concentration). *Microcystis* spp. abundance data from shown as white squares (very high), circles (high), diamonds (medium), triangles (low) , + (very low) and X (not present).

Forecast (with Great Lakes CFS)

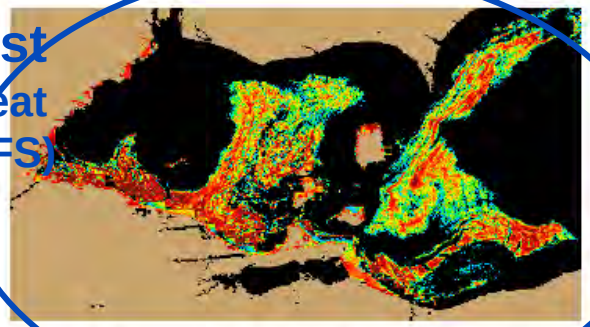


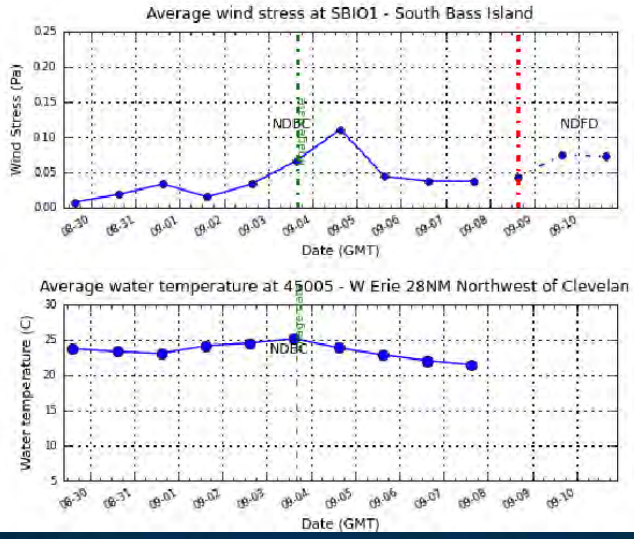
Figure 2. Nowcast position of *Microcystis* spp. bloom for September 08 using GLCFS modeled currents t move the bloom from the September 03 image.

Conditions: A massive *Microcystis* bloom persists throughout most of Lake Erie's Western Basin.

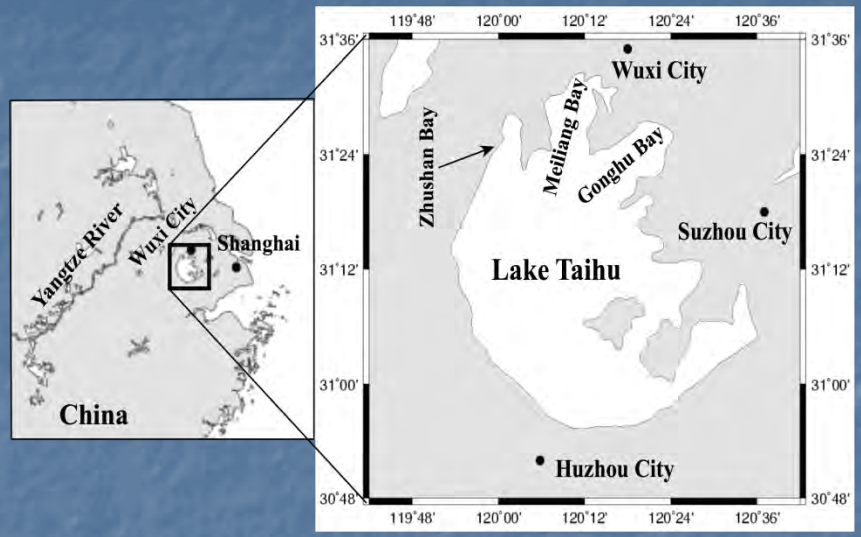
Analysis: As indicated in satellite imagery from Saturday (9/3/2011), an enormous *Microcystis* bloom was present in western Lake Erie. The southern extent of the bloom was remotely observed along the coast of Ohio from Maumee Bay to Catawba Island. The northern extent of the bloom was observed to be consistent along the Michigan coast from Northern Maumee Bay to the mouth of the Detroit River. The eastern-most portion of the bloom was observed past Point Pelee and to the northeast up in to Rondeau Provincial Park.

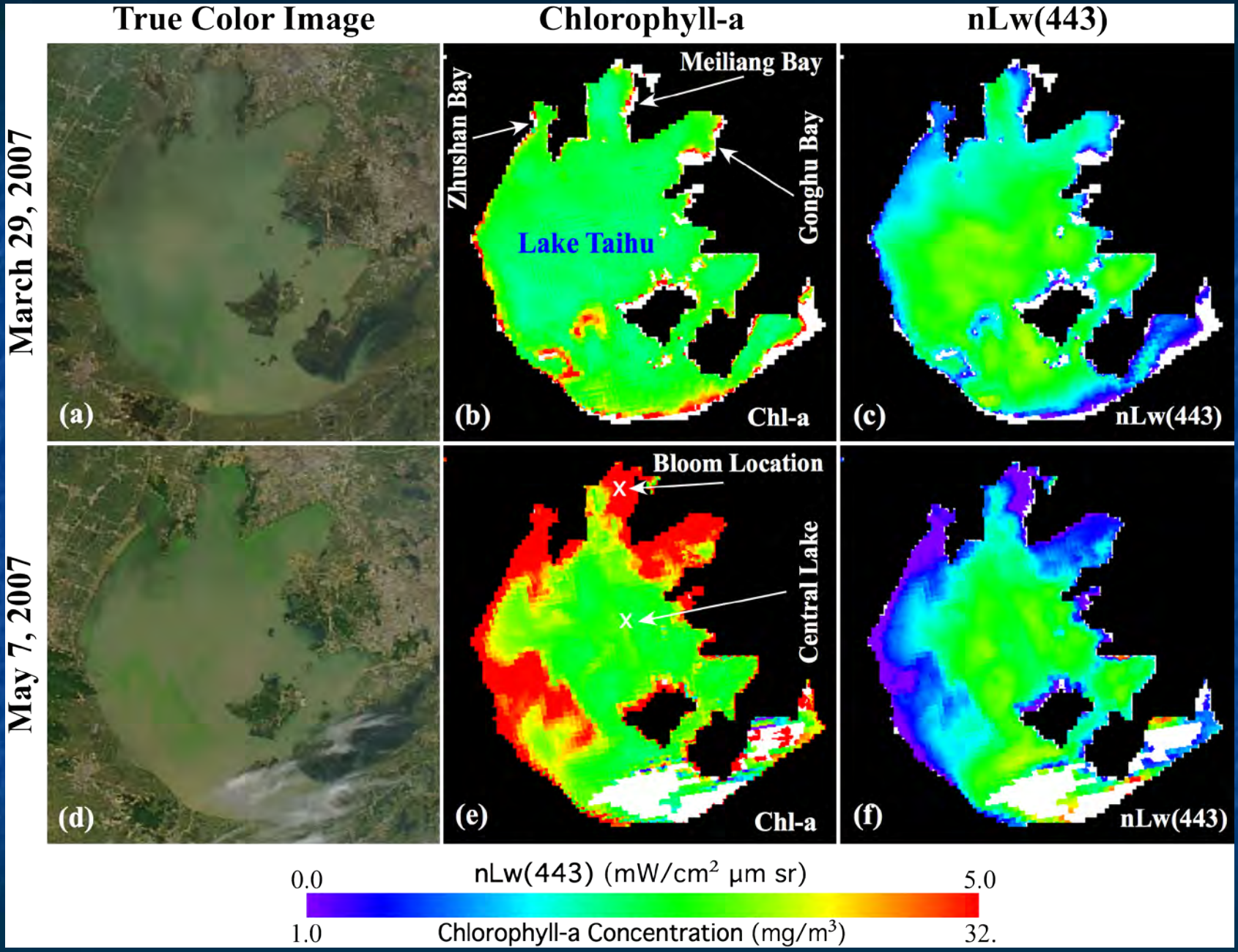
At the mouth of the Detroit River, a five day nowcast shows a southward suppression of the western-most portions of the bloom. However, the bloom is likely to still persist in much of the Western Basin. The nowcast also suggest the bloom has spread to the east of Sandusky and into the Cleveland area. **(Note: Due to a lack of clear imagery the bloom has not been remotely observed in the Cleveland area.)** A three day forecast also suggests that the bloom will persist to the north of Cleveland through the weekend. Water temperatures remain above 20 degrees Celsius and are forecast to decrease into the weekend; however, conditions remain favorable for bloom growth.

Briggs Wynne



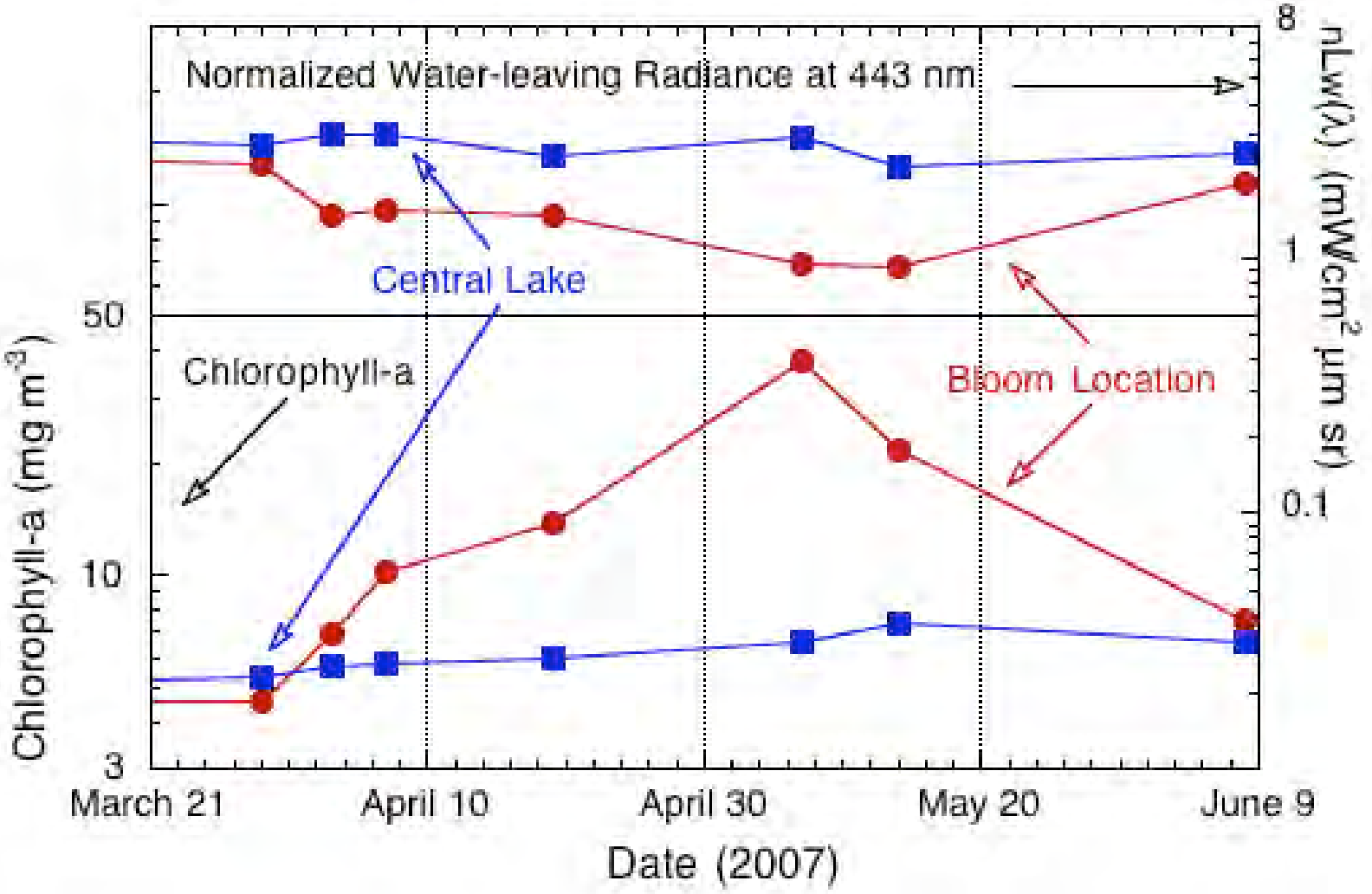
Blue-Green Algae (Microcystis) Bloom Crisis in Lake Taihu (Spring 2007), China



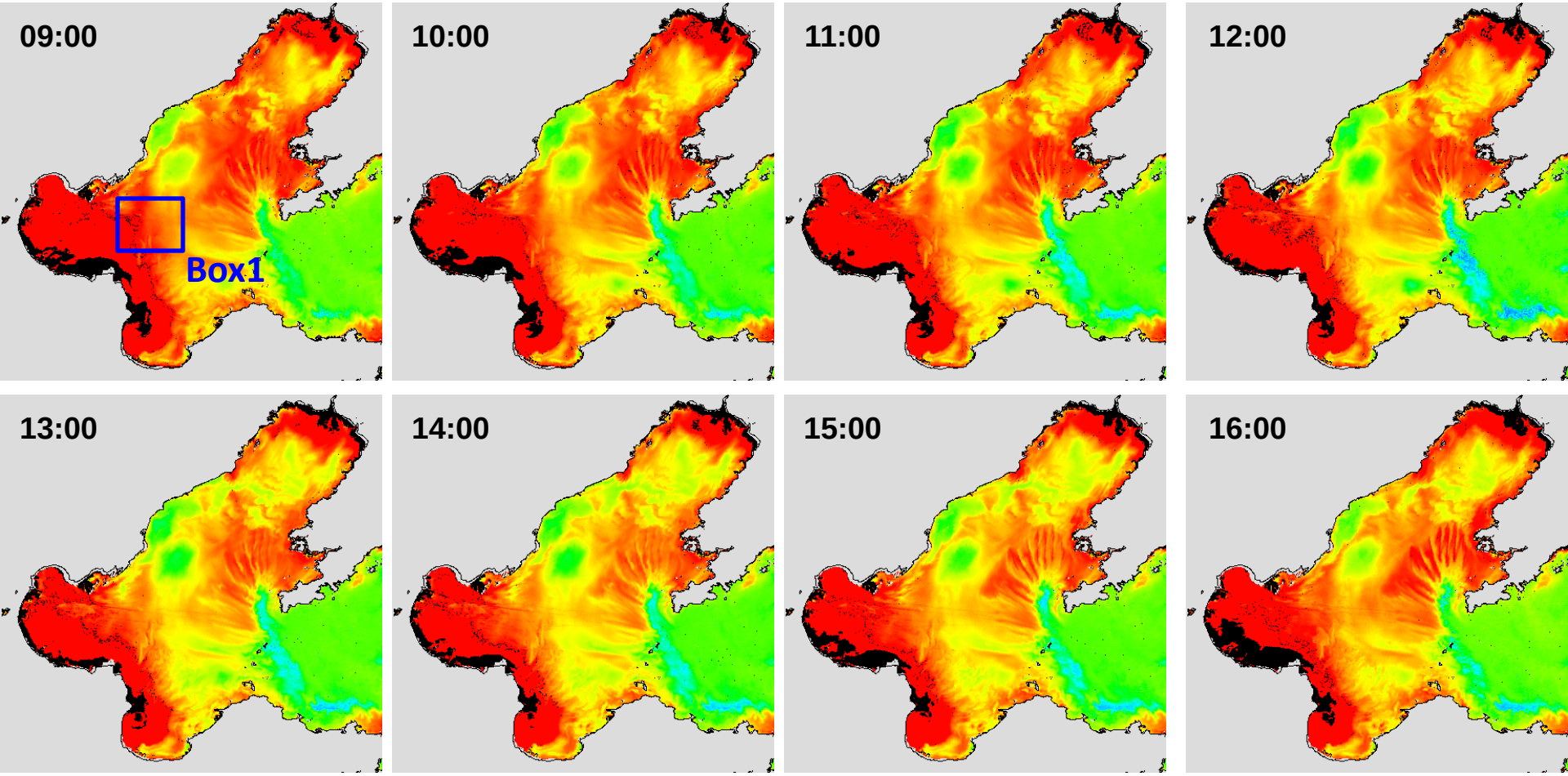


Wang, M., W. Shi, and J. Tang (2011), "Water property monitoring and assessment for China's inland Lake Taihu from MODIS-Aqua measurements," *Remote Sens. Environ.*, **115**, 841–845.

Time Series of Chlorophyll-a (index) and $nL_w(443)$ at Wuxi Station (bloom) and Central Lake (non-bloom)

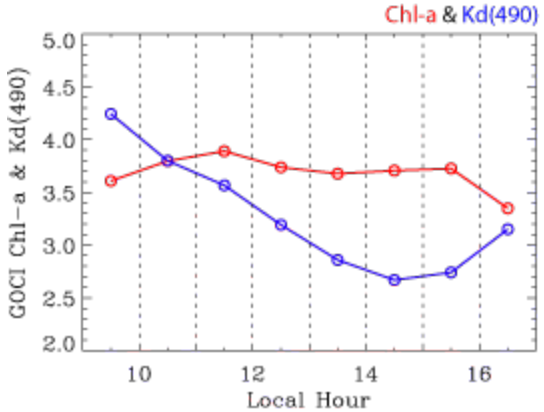


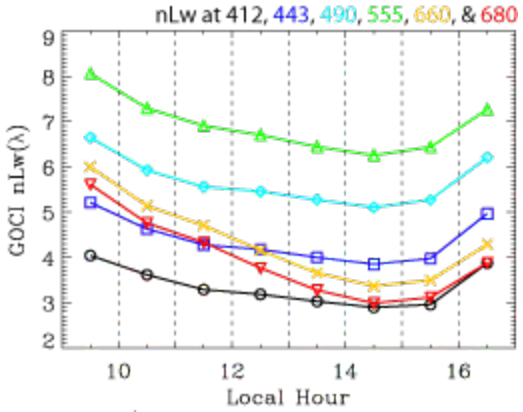
Geostationary Ocean Color Imager (GOCI) $K_d(490)$ (3-25-2012)



Diurnal Changes (Box1)

Bohai Sea





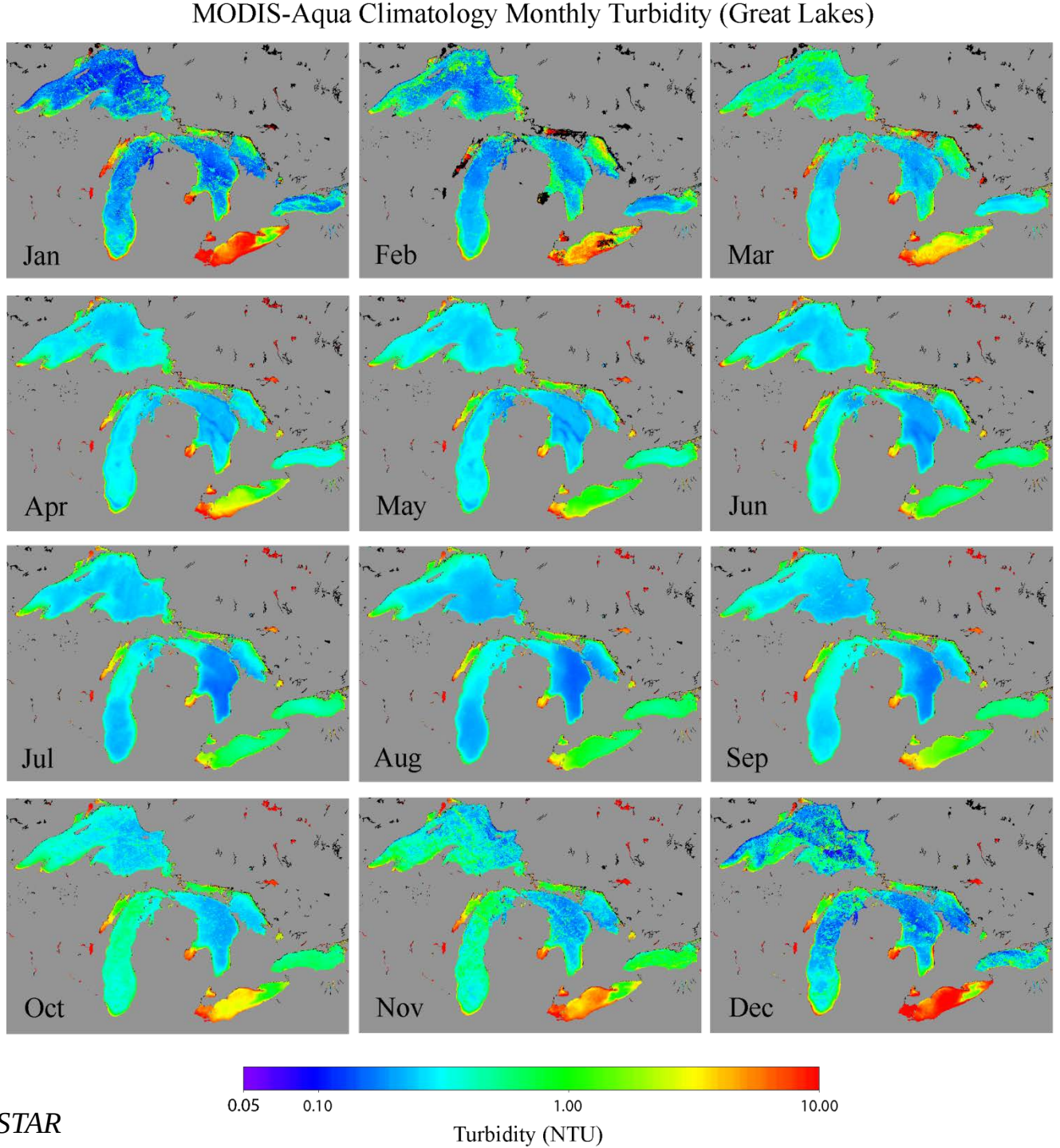
Derived from

NOAA-MSL12

Wang et al. (2012; 2013)

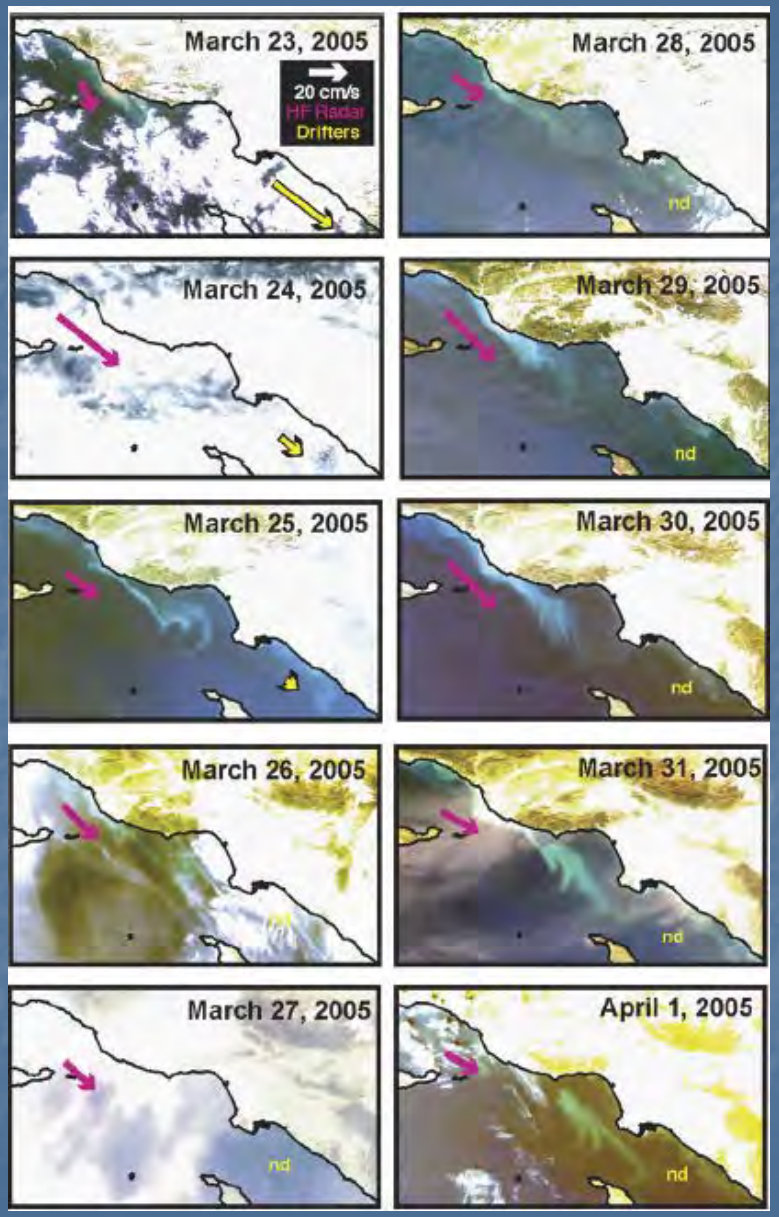
- MODIS-Aqua-measured seasonal climatology water turbidity (NTU) images in Great Lakes.
- Highly turbid waters in winter and in Lake Erie, somewhat turbid in Lake Ontario, and part of Lakes Huron, Michigan, etc.

The NIR-SWIR Data Processing (NOAA-MSL12)

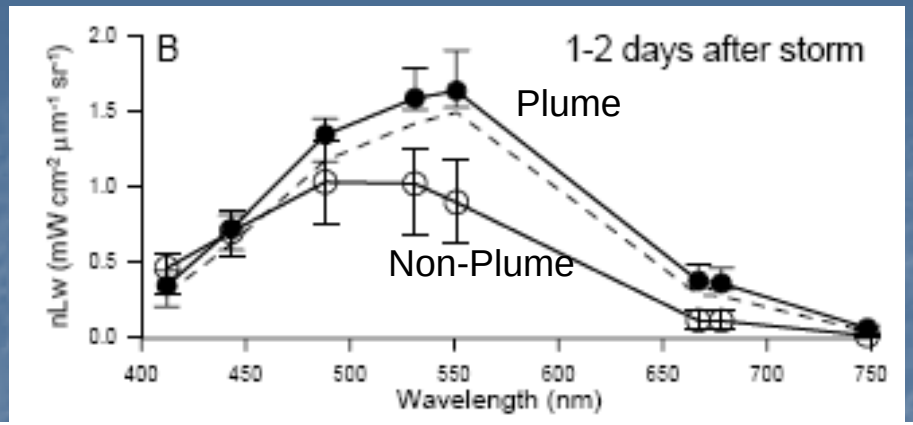


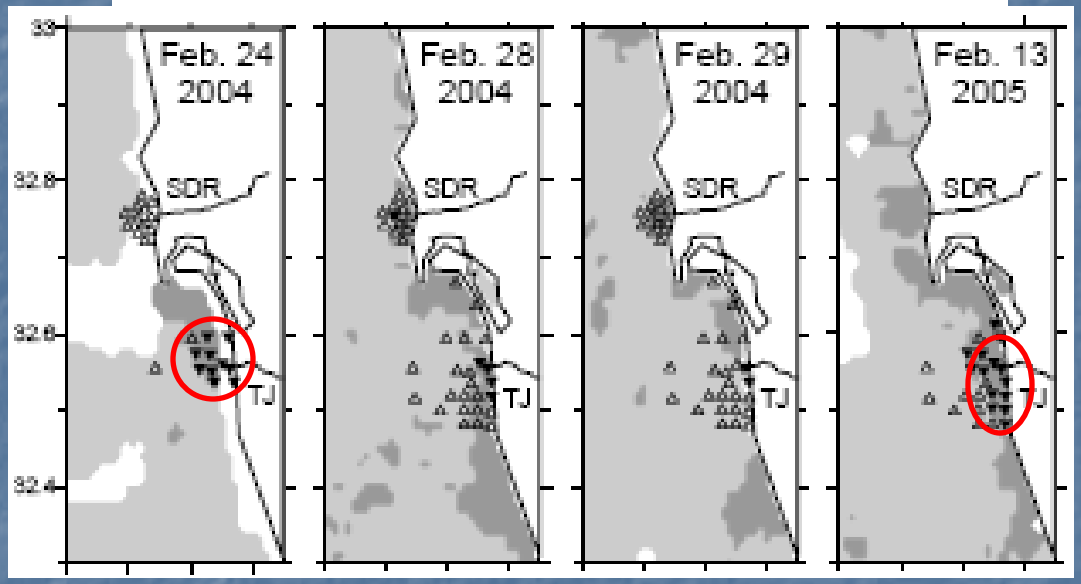
Menghua Wang, NOAA/NESDIS/STAR

Satellite Observations of Urban Stormwater Runoff *Plumes*



Warrick et al., CSR, 2007

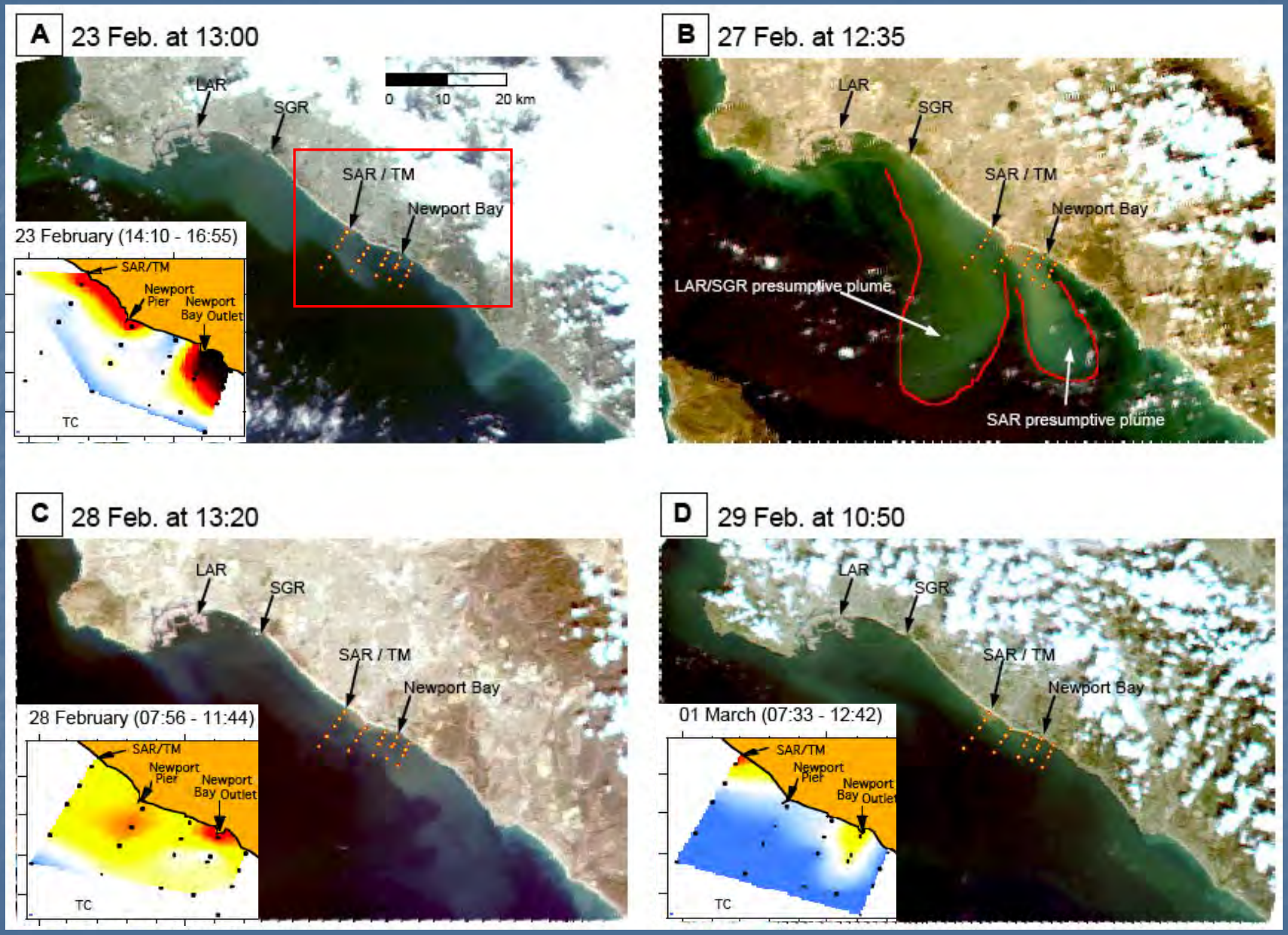




Nezlin et al., ECSS, 2008

- Runoff plumes are dynamic, episodic features, and can move 20-40 km/day
- Cloud cover limits their observation

Pollutant and Pathogen-laden Urban Stormwater Runoff

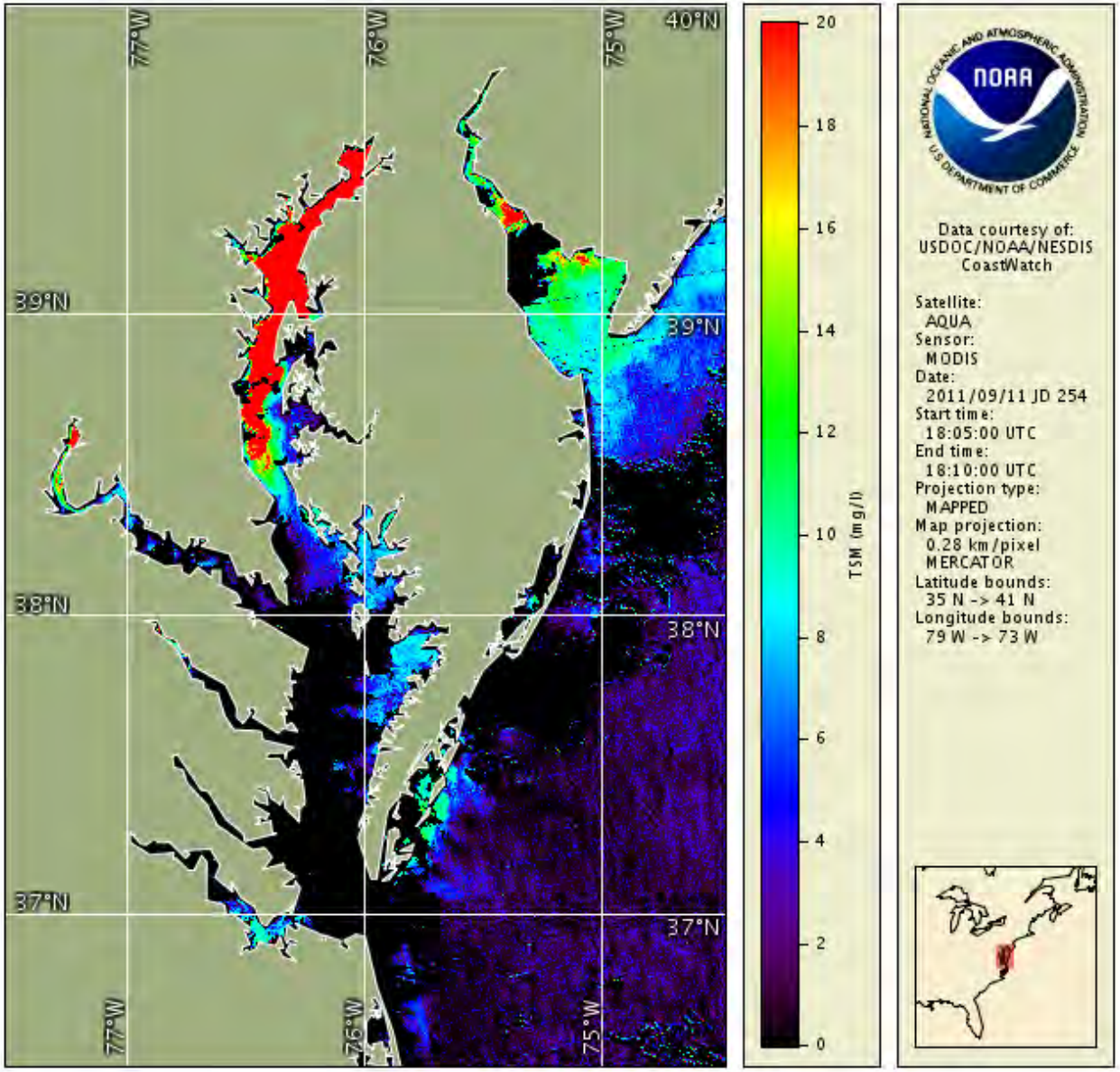


Ahn et al., Environmental Science and Technology, 2005.

Satellite Monitoring of Post-Storm Coastal Sediment Plumes

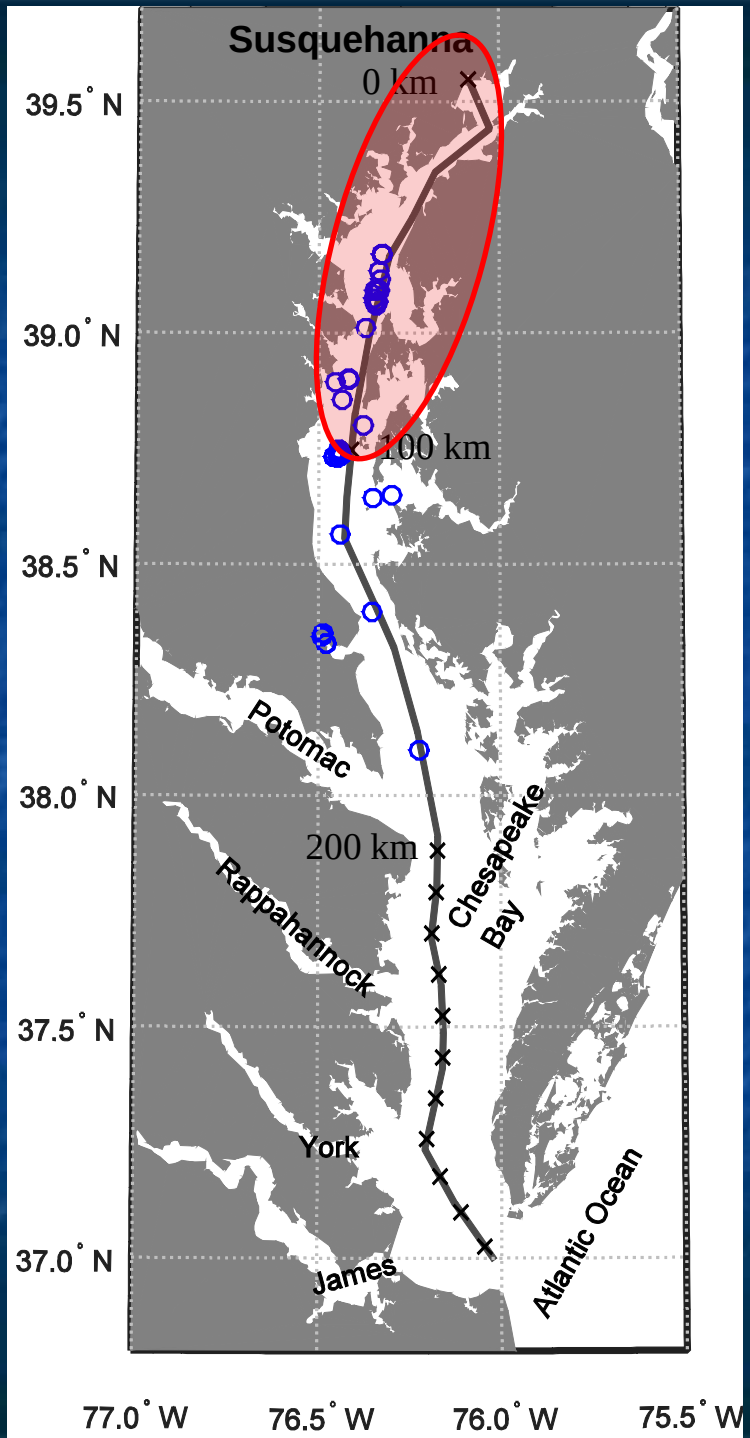
Sediment plume in Chesapeake Bay following 2011's Tropical Storm Lee

- Satellites can measure concentration of sediment in the surface water
- Red indicates high sediment concentration as a result of storm runoff from land

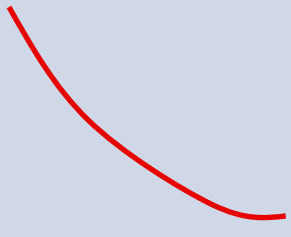
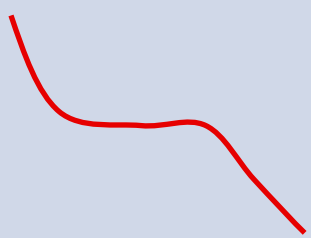
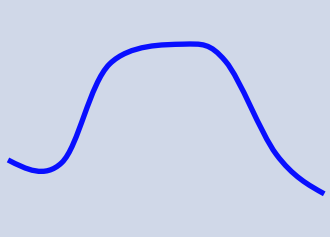
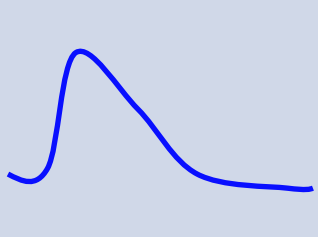


Evolution of sediment plumes in the upper Chesapeake Bay

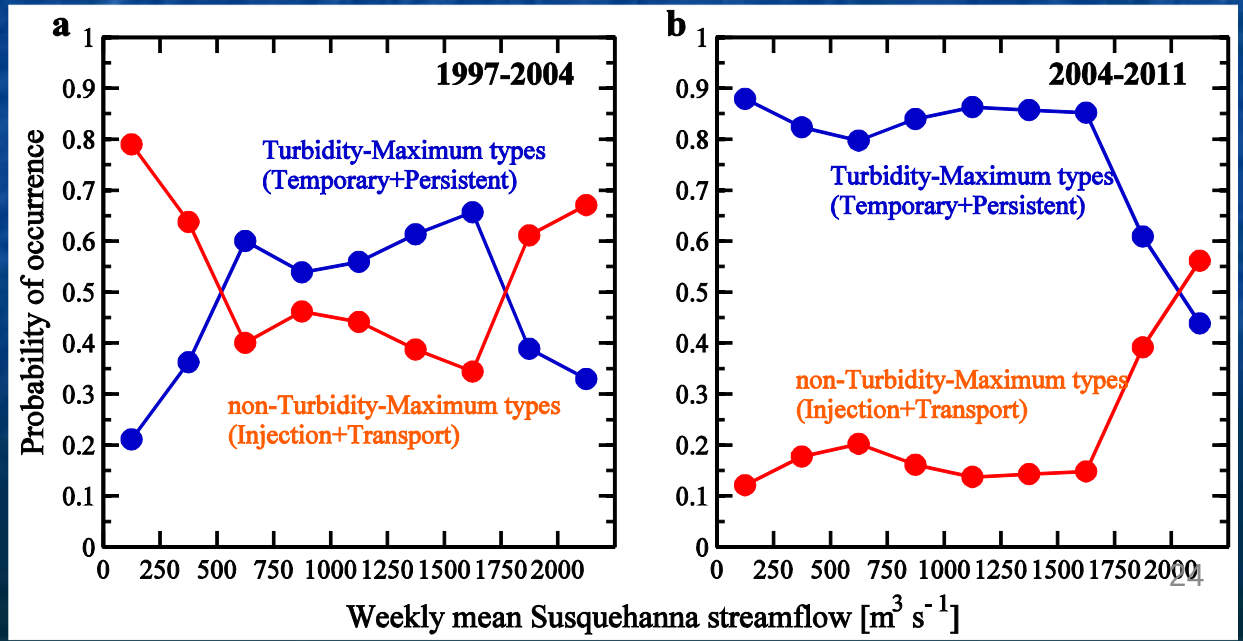
Zheng, G., P. M. DiGiacomo, S. S. Kaushal, M. A. Yuen-Murphy, and S. Duan (2015a), Evolution of sediment plumes in the Chesapeake Bay and implications of climate variability, *Environmental Science & Technology*, 49(11), 6494–6503, doi: 10.1021/es506361p.

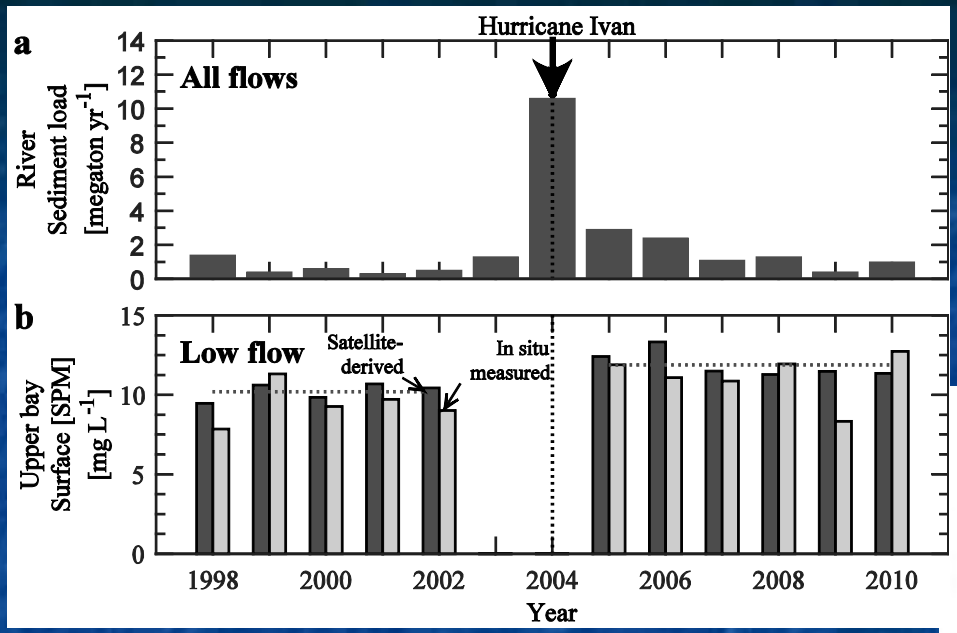


Short-term evolution of sediment plumes after discharge events

Types	Injection	Transport	Temporary Turbidity Max	Persistent Turbidity Max
Spatial shape of [SPM]				
Timing (days)	0–5	3–10	5–30	>13

Long-term regime shift of typology

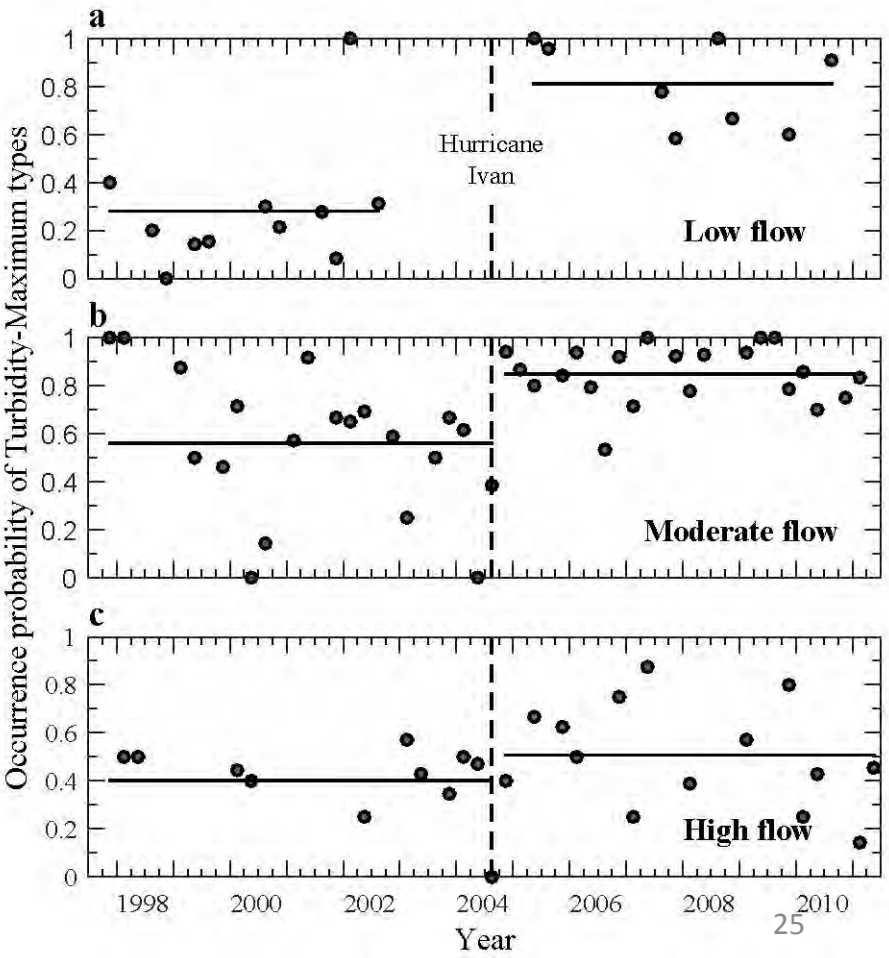




• The regime shift is likely associated with Hurricane Ivan (2004)

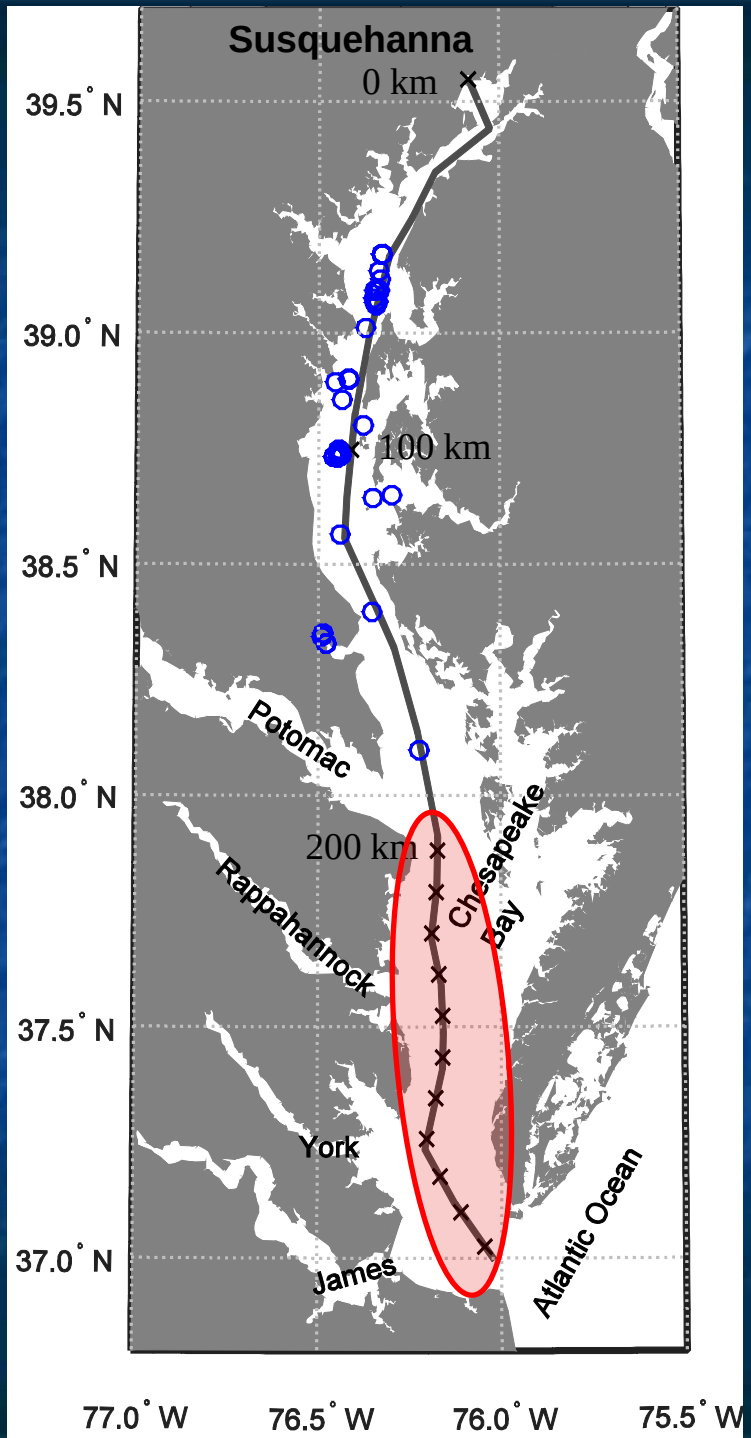
• Hurricane Ivan (2004) triggered a discharge of sediments equivalent to the total amount discharged over the preceding 10 years

• The shift in typology occurred in an abrupt manner after Hurricane Ivan

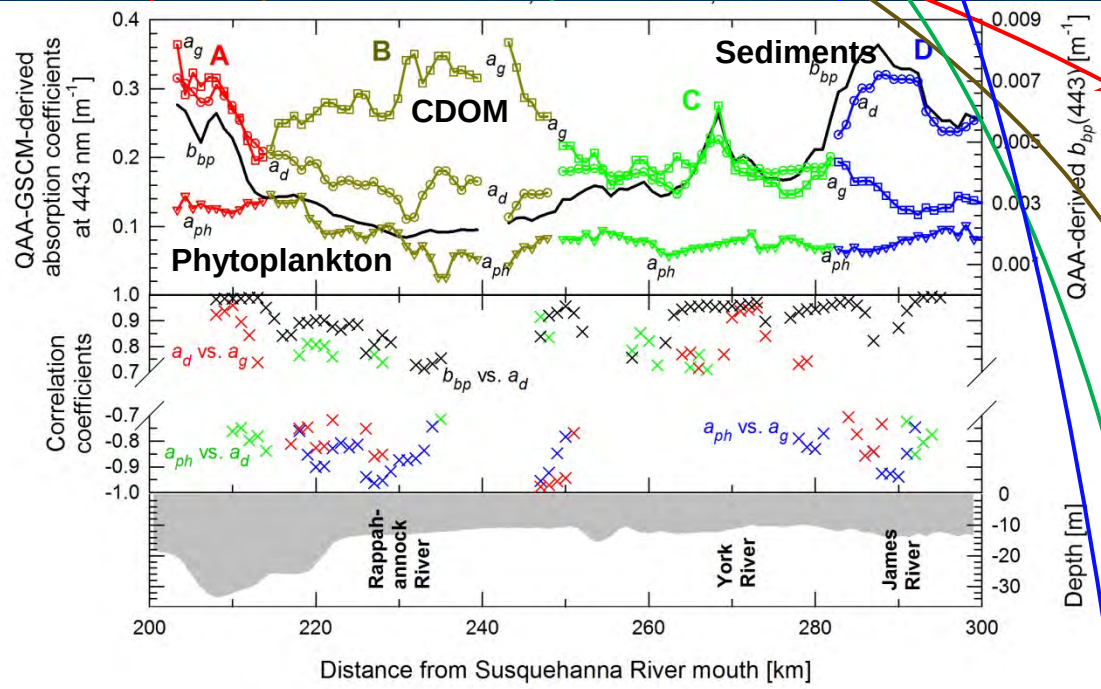


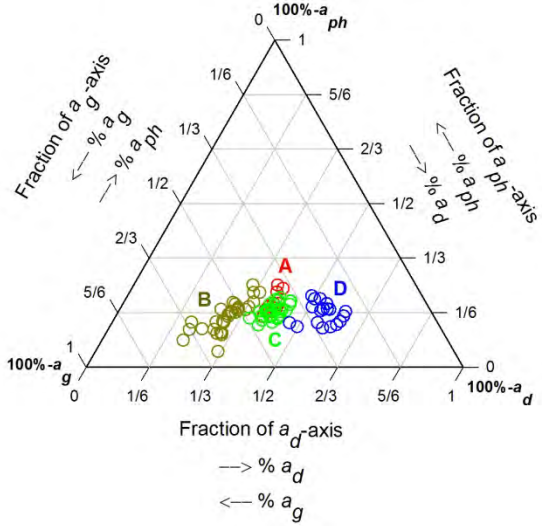
Optical identification of water mass in the lower Chesapeake Bay

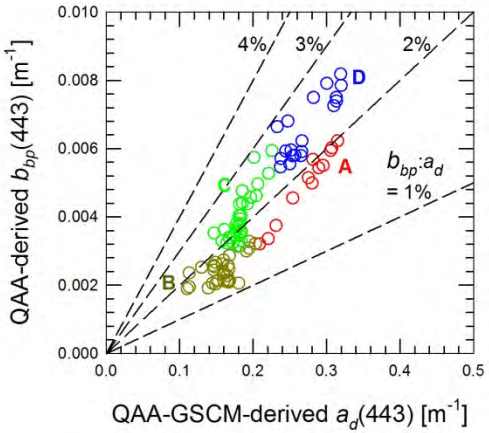
Zheng, G., P. M. DiGiacomo, and M. Yuen-Murphy, Dissociated absorption coefficients of phytoplankton, non-algal particles, and colored dissolved organic matter in the Chesapeake Bay from MODIS, *in prep*.



Fall 2002





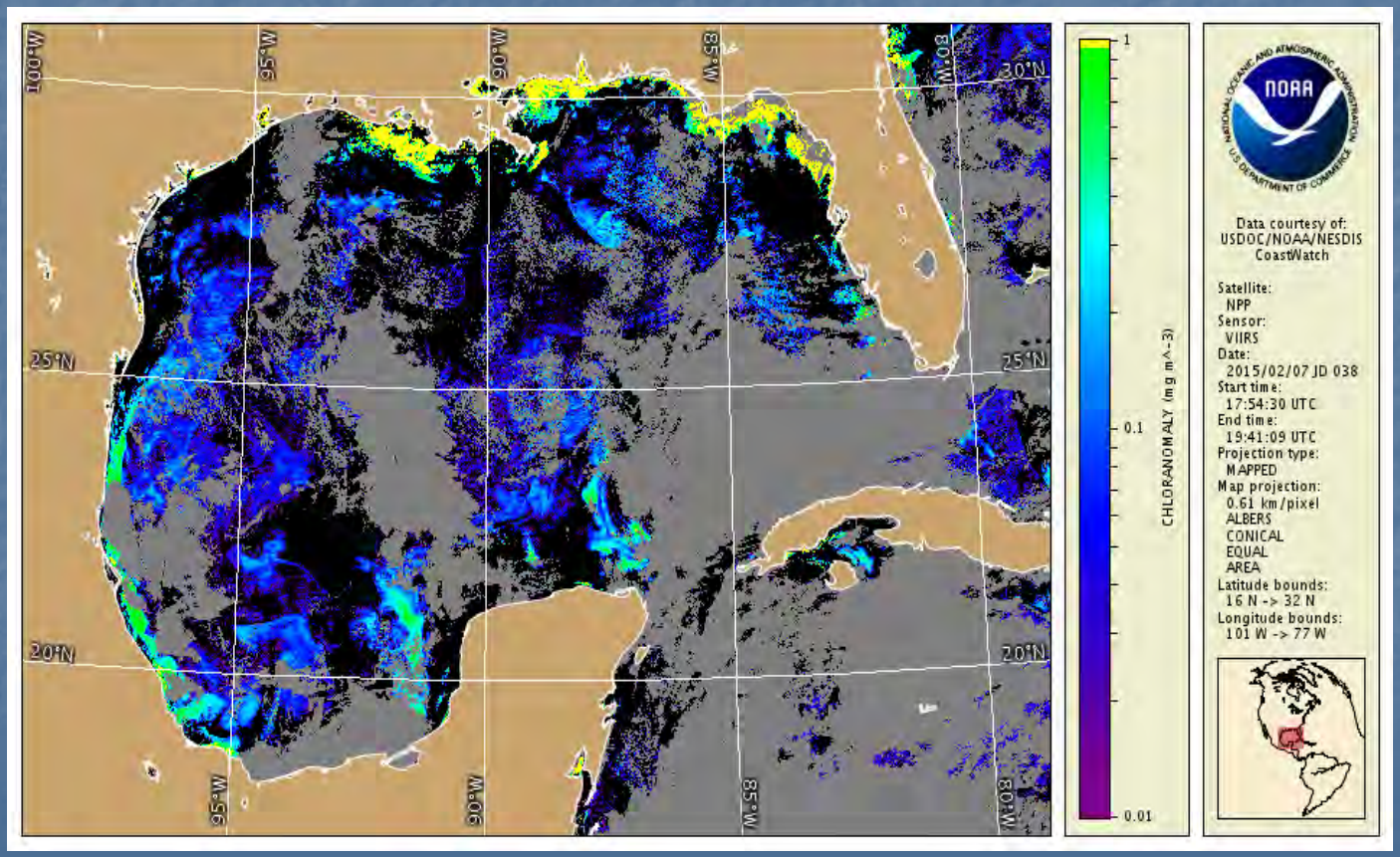


- Water mass **A**:
  - Potomac River plume
  - CDOM and NAP dominated
  - $b_{bp}(443):a_d(443) = 1.8 \pm 0.2$ %
  - CDOM-NAP mixed plume
- Water mass **B**:
  - Rappahannock River plume
  - CDOM dominated
  - $b_{bp}(443):a_d(443) = 1.5 \pm 0.2$ %
  - "Tea-colored" plume
- Water mass **C**:
  - York River plume
  - CDOM and NAP dominated
  - $b_{bp}(443):a_d(443) = 2.2 \pm 0.3$ %
  - CDOM-NAP mixed plume
- Water mass **D**:
  - James River plume
  - NAP dominated
  - $b_{bp}(443):a_d(443) = 2.5 \pm 0.2$ %
  - "Turbid" plume

Ecological Forecasting

Representative products supporting Ecological Forecasting

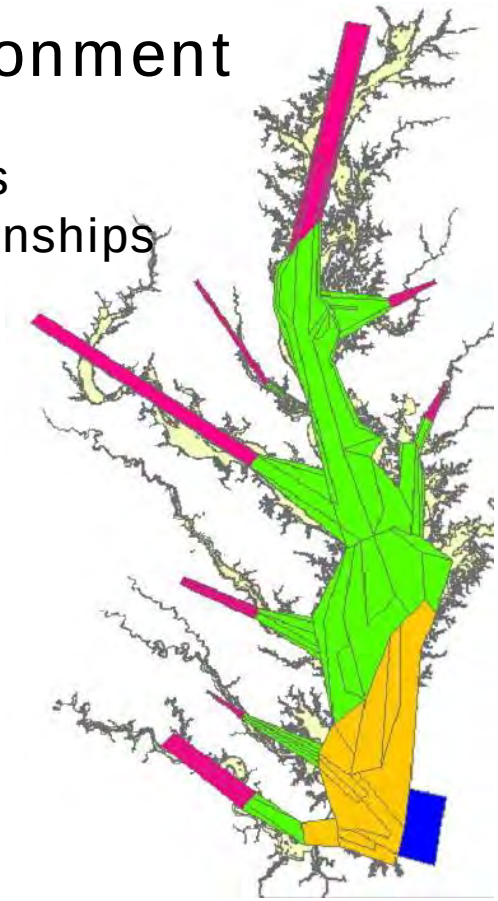
VIIRS Chlorophyll Anomaly Product for NOAA/NOS HAB Bulletin: Gulf of Mexico



NMFS/NCBO
The Chesapeake Atlantis Model (CAM)
A Holistic Ecosystem Model
Incorporating:

Biological environment
- ✓Primary production
- ✓Trophic interactions
- ✓Recruitment relationships
- ✓Age structure
- ✓Size structure
- ✓Life History

Fisheries
- ✓Multiple sectors
- ✓Gears
- ✓Seasons
- ✓Spatially explicit

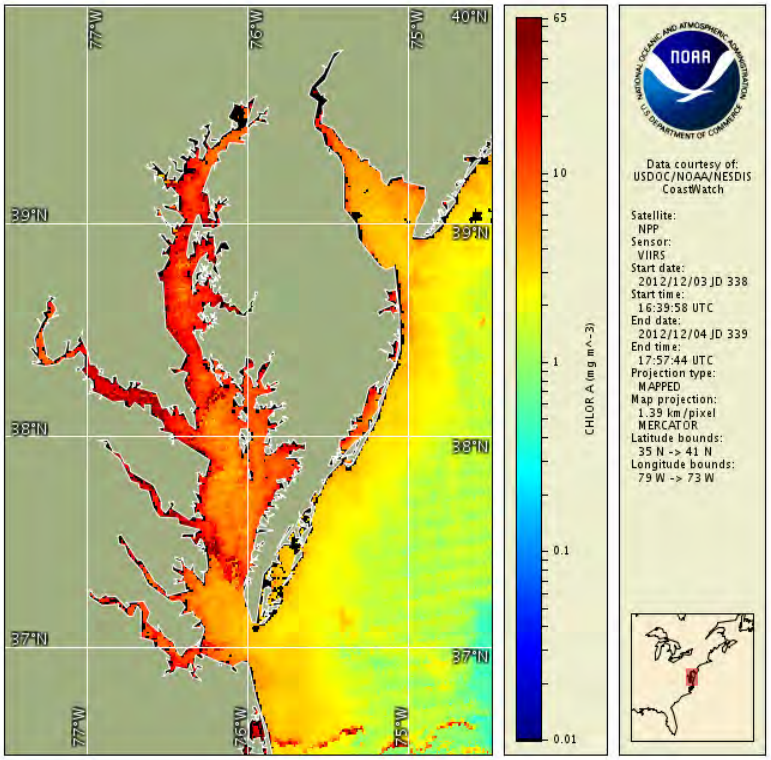


Physical environment
- ✓Geology
- ✓Chemistry
- ✓Circulation & currents
- ✓Temperature
- ✓Salinity
- ✓Water clarity (TSS)
- ✓Climate variability

Nutrient Inputs
- ✓Currency is Nitrogen
- ✓Oxygen
- ✓Silica
- ✓3 Detrital forms
- ✓Bacteria-mediated recycling

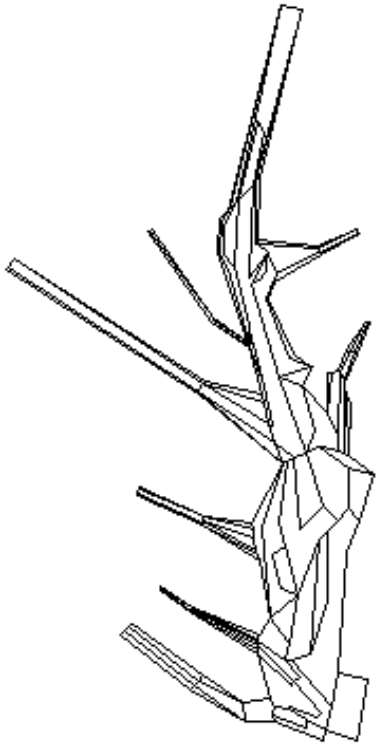
Conversion of VIIRS data to Ecosystem Model Grid

VIIRS satellite chlorophyll → **Georeferenced grid** → **Ecosystem model grid**



S-NPP VIIRS chlorophyll
CoastWatch 2-day avg (Dec 3-4, 2012)
Raster data: UTM coordinates

Chesapeake Bay Program
Georeferenced polygonal grid
8,282 polygons



NOAA/NMFS/NCBO
Atlantis Ecosystem Model
97 polygons
Aggregated from 8,282

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)

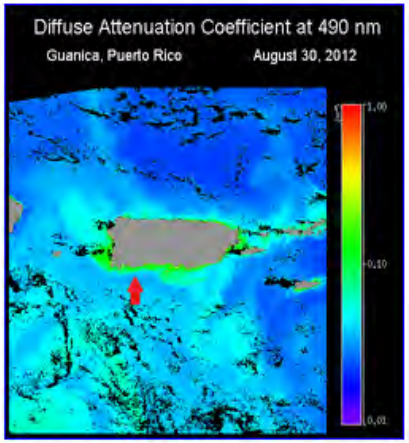
DOC > NOAA > NESDIS > STAR > CRW

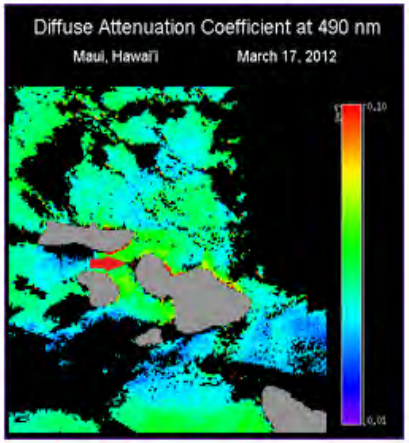
Coral Reef Watch

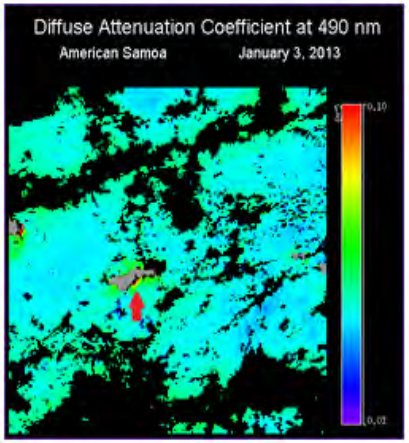
CRTF | CRCP | CREIOS | CoRIS

- 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





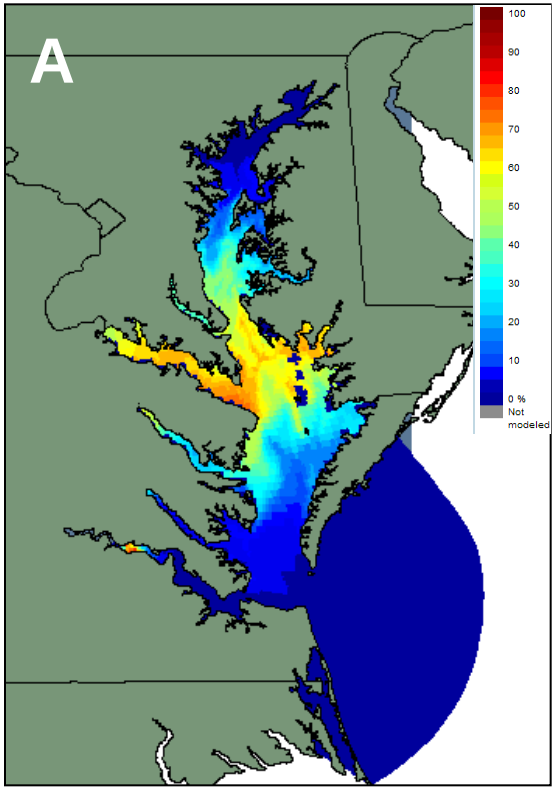


NOAA Coral Reef Watch and NOAA/NESDIS' Ocean Color Team are working closely with partners in the U.S. Coral Reef Task Force (USCRTF) Watershed Working Group (WWG) to develop pilot satellite ocean color products using data from the Visible Infrared Imaging Radiometer Suite (VIIRS) aboard the Suomi National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

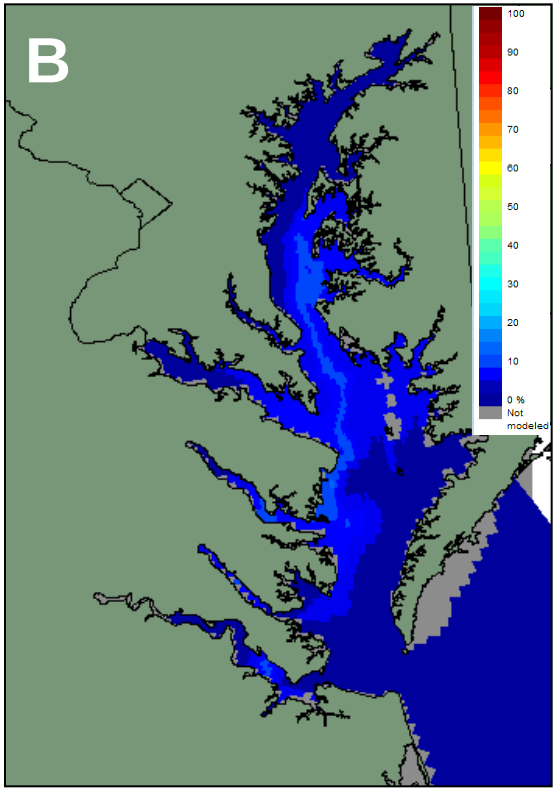
*From **Coral Reef Watch***

Examples of Chesapeake Bay Species Forecasts

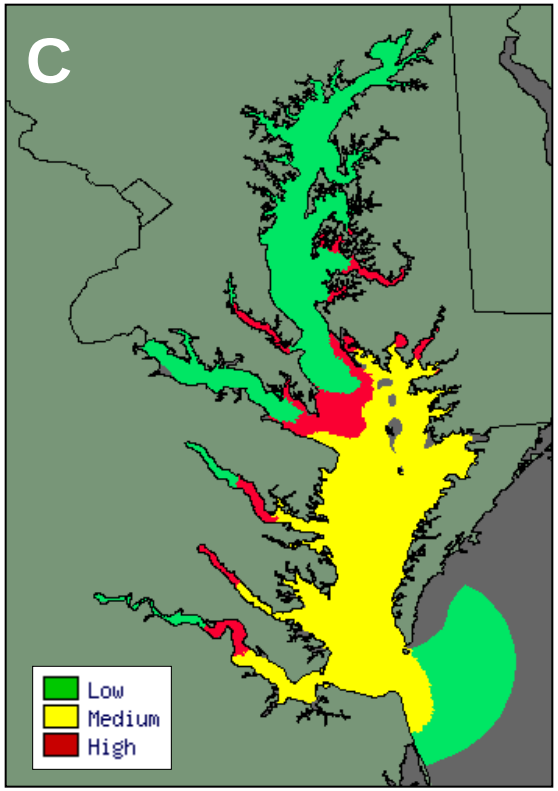
Sea Nettle ***Water-borne Pathogen*** ***Harmful Algal***



Predicted likelihood of encountering sea nettles on 17 August 2007.



Predicted likelihood of *Vibrio vulnificus* on 20 April 2011.



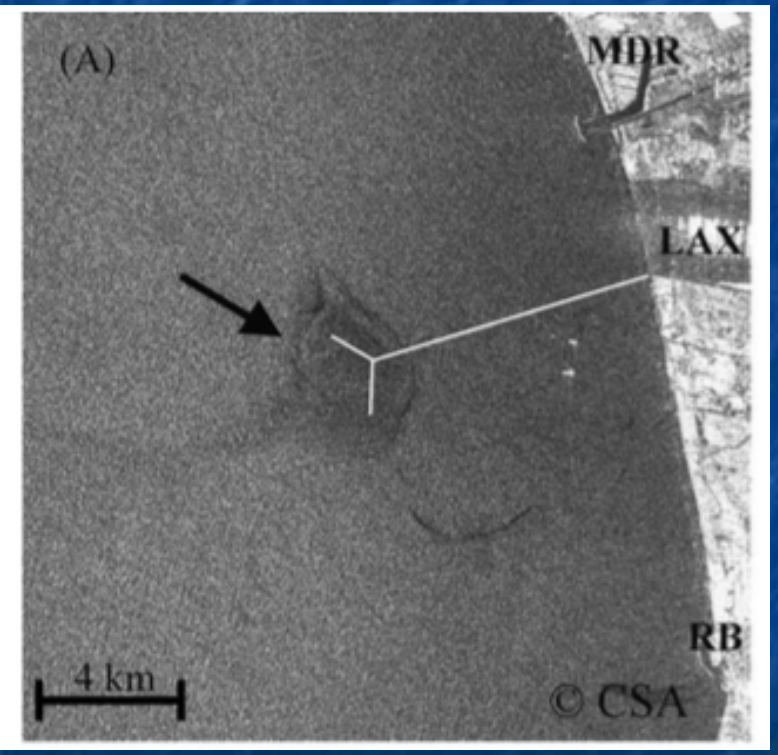
Predicted relative abundance of *Karlodinium veneficum* on 20 April 2005

Courtesy, Chris Brown

Synthetic Aperture Radar (SAR)

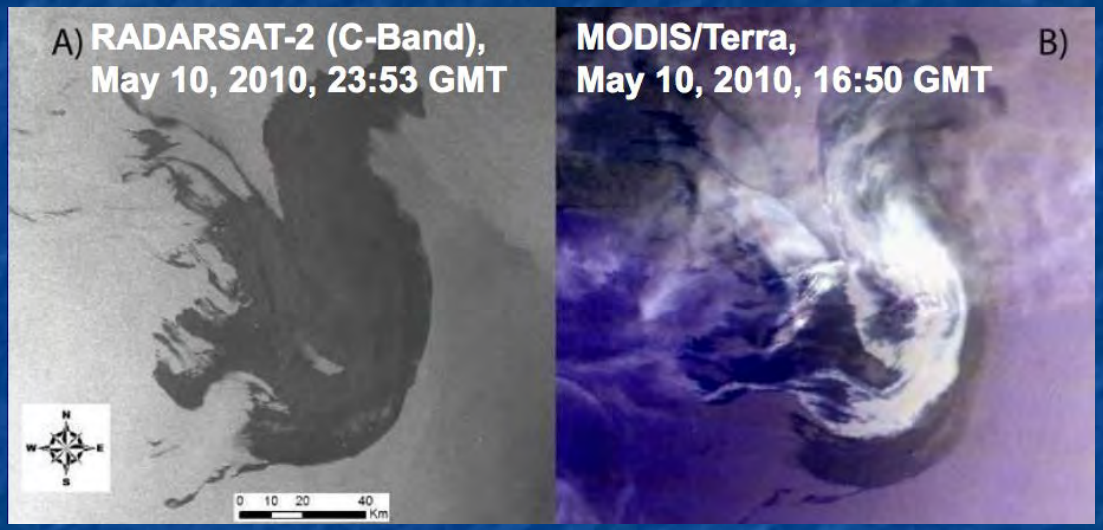
Coastal SAR Water Quality

Surface roughness on the scale of the radar wavelength (2-20 cm depending on the radar) cause high backscatter or bright SAR images. Surfactants reduces backscatter.

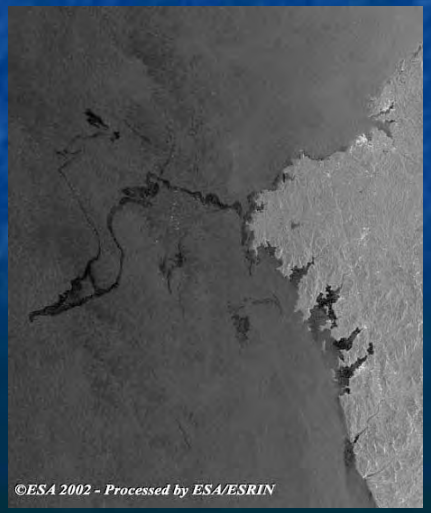


Radarsat-1 SAR image showing surface signature of municipal wastewater, 1997 Dec 27[1]

[1]DiGiacomo et al, *Marine Pollution Bull. 49* (2004)

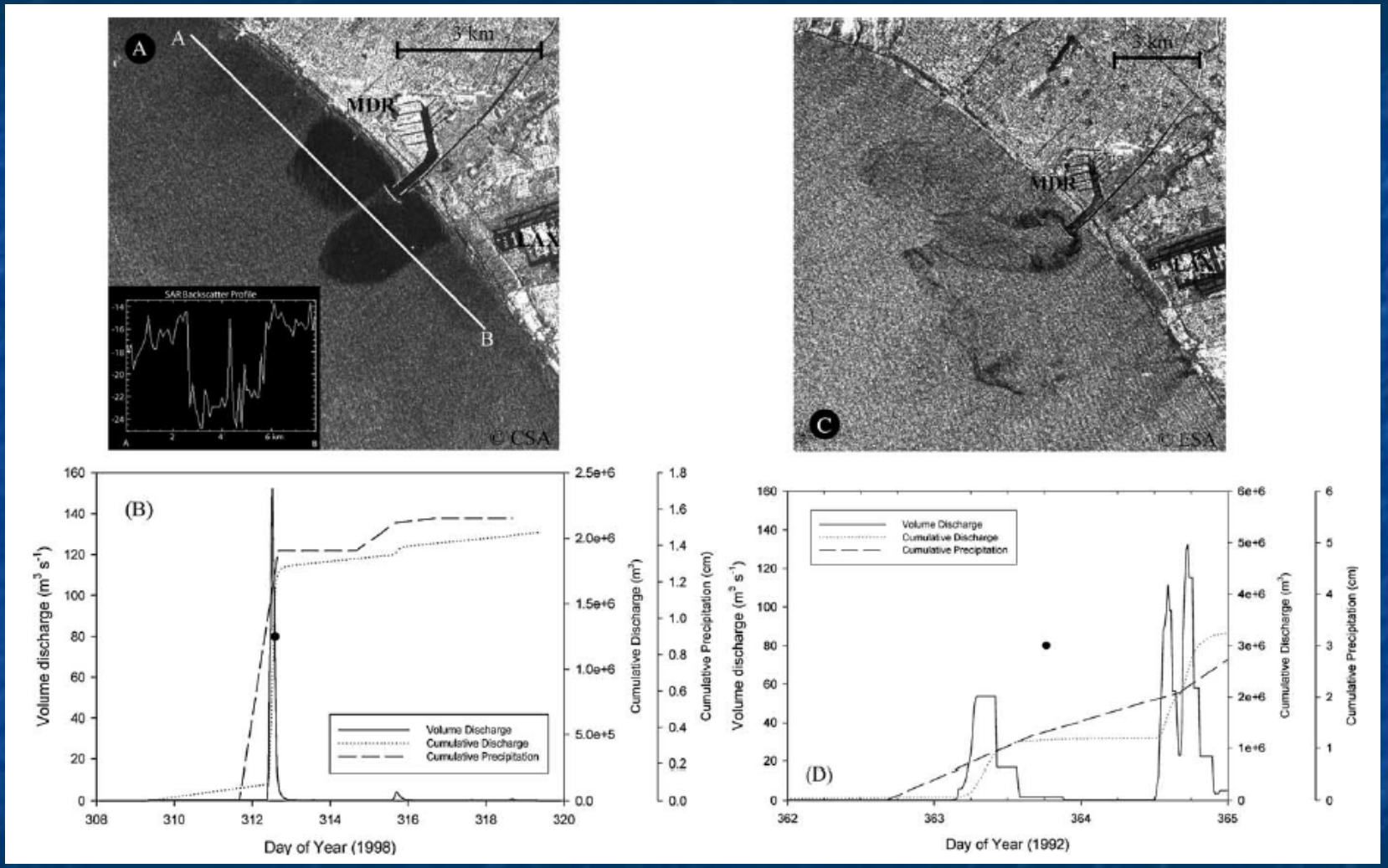


Deepwater Horizon oil spill observed rom Radarsat-2 and MODIS



Prestige oil spill off the coast of Portugal from Envisat, 2002 Nov 11

Coastal SAR Water Quality

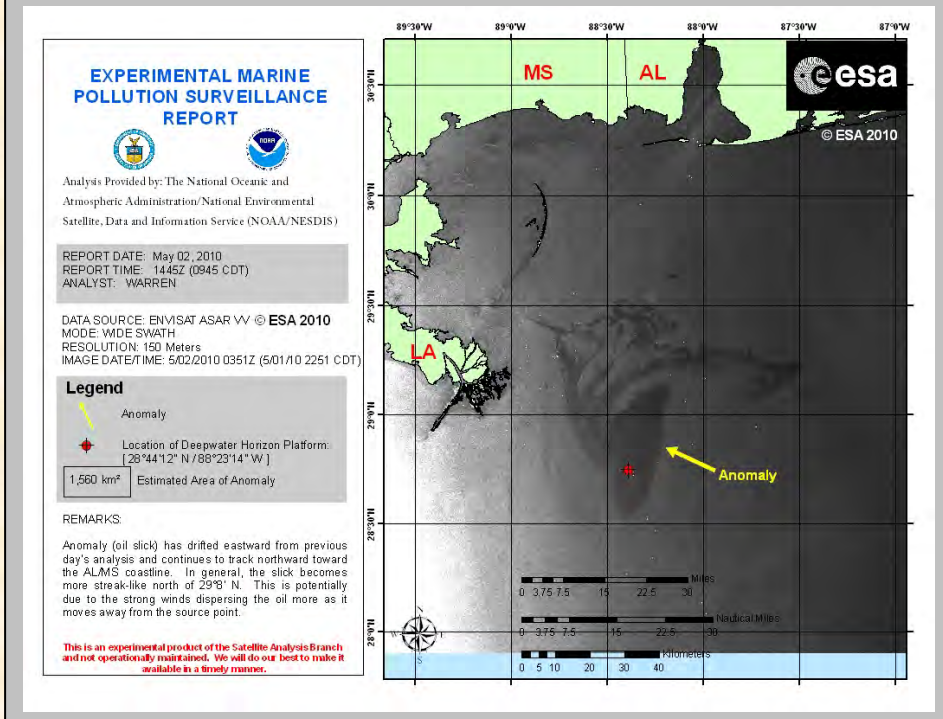


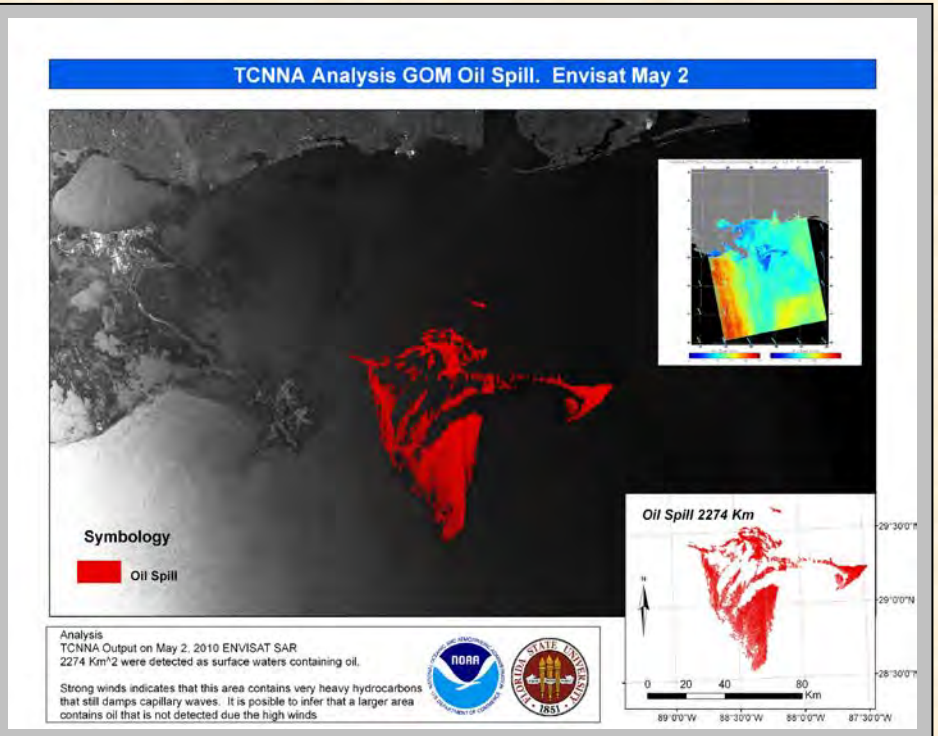
SAR imagery of stormwater plumes from Ballona Creek, Santa Monica Bay, Left: RADARSAT-1 SAR image; Right: ERS-1 SAR image.

[1]DiGiacomo et al, *Marine Pollution Bull. 49* (2004)

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

Deepwater Horizon Fire 4/21/2010

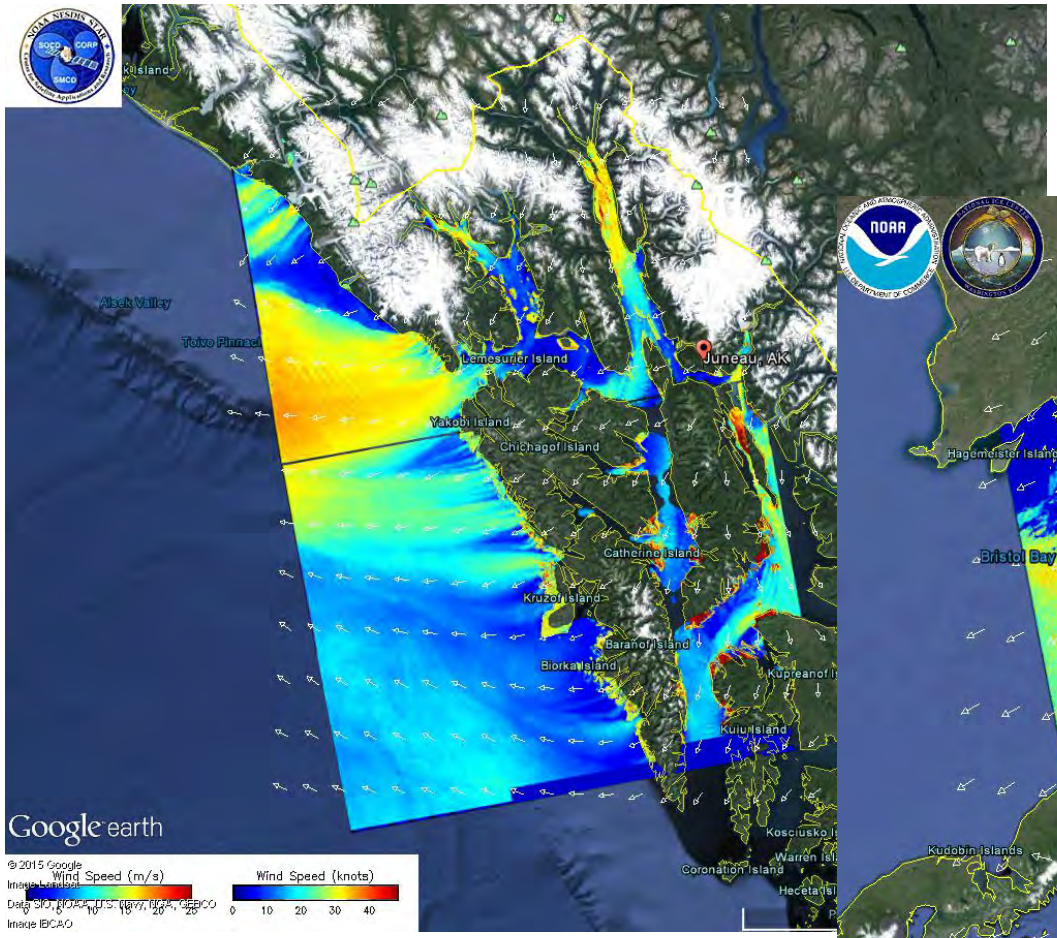




Interactively derived Marine Pollution Surveillance Report issued by NESDIS/OSPO Satellite Analysis Branch for May 2, 2010, during the Deepwater Horizon incident.

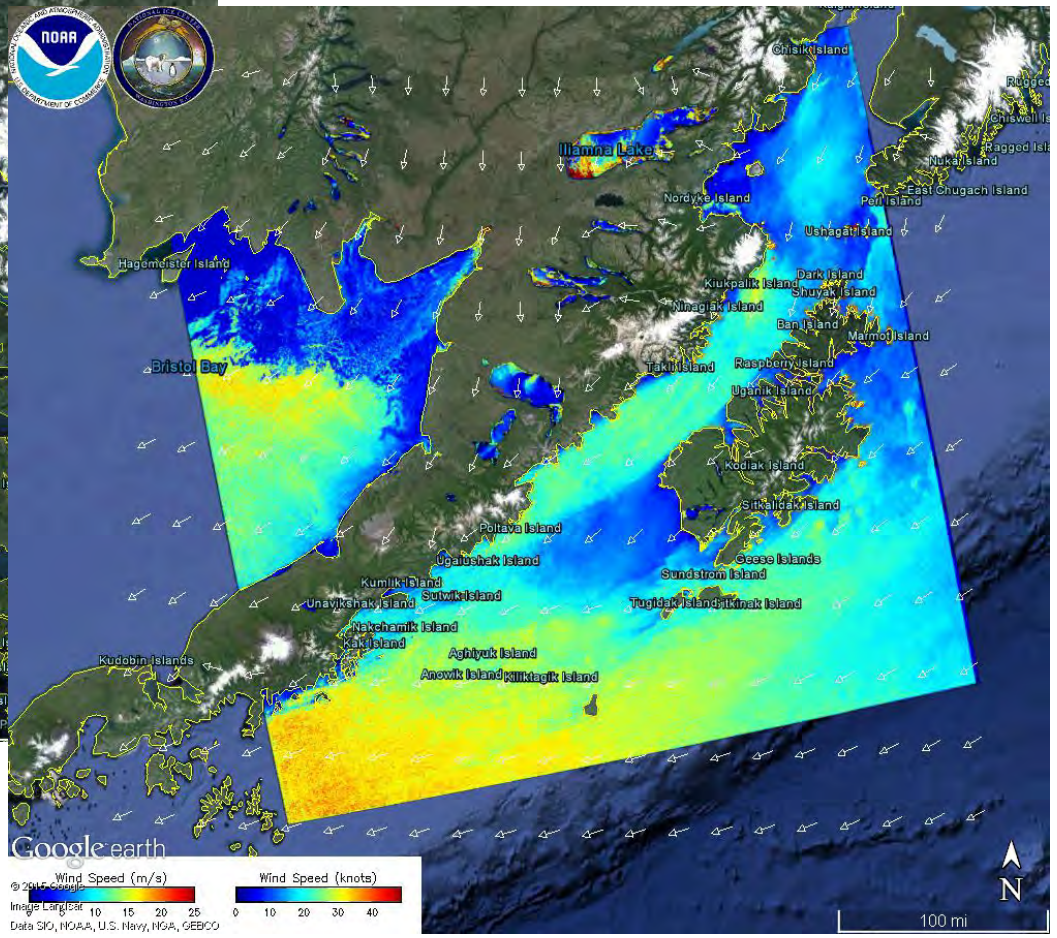
Automated Texture Classifying Neural Network (TCNNA) oil spill map for the same day. This algorithm is being developed in a collaboration between NESDIS/STAR and Florida State Univ. for future use as an automated oil spill mapping tool.

High-Resolution SAR-Derived Wind Speed Products



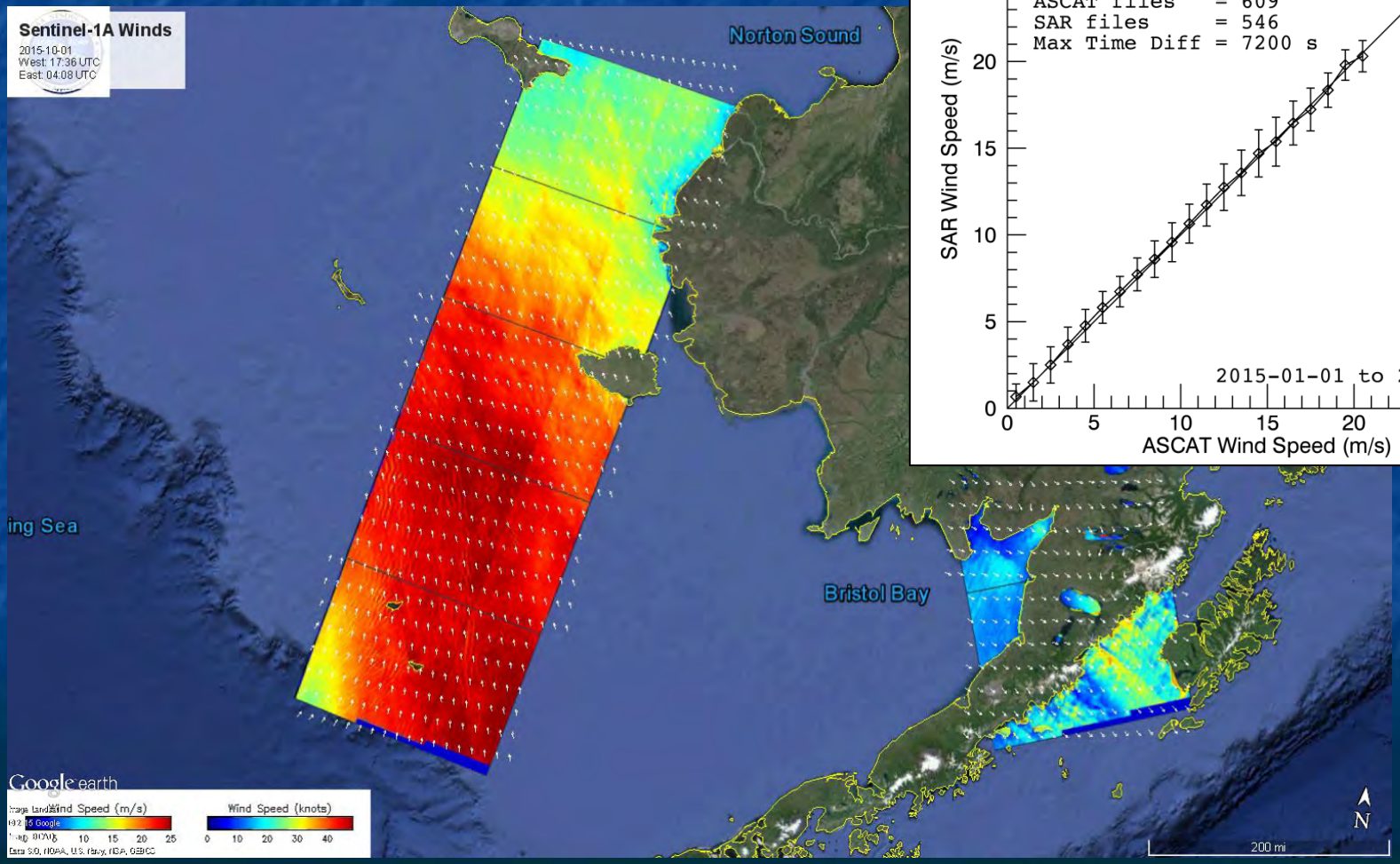
Pre-operational Sentinel-1A wind speed
2015-01-08 02:46 UT

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



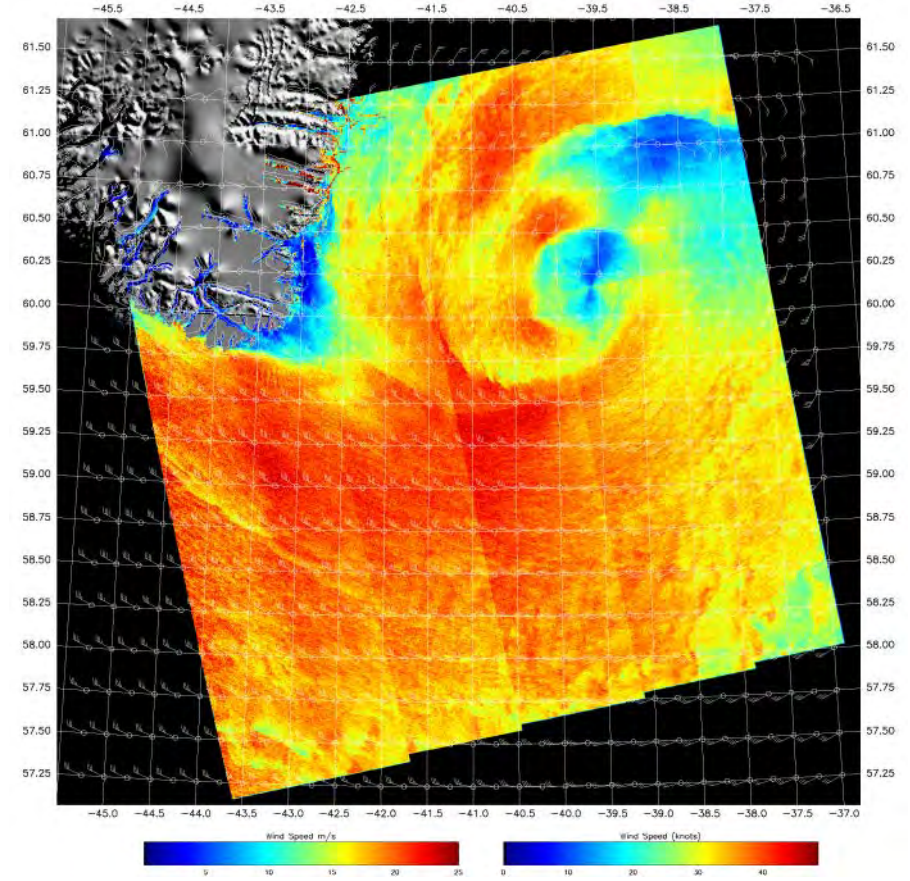
Operational Sea Surface Winds from SAR

Sea surface roughness correlated with wind speed

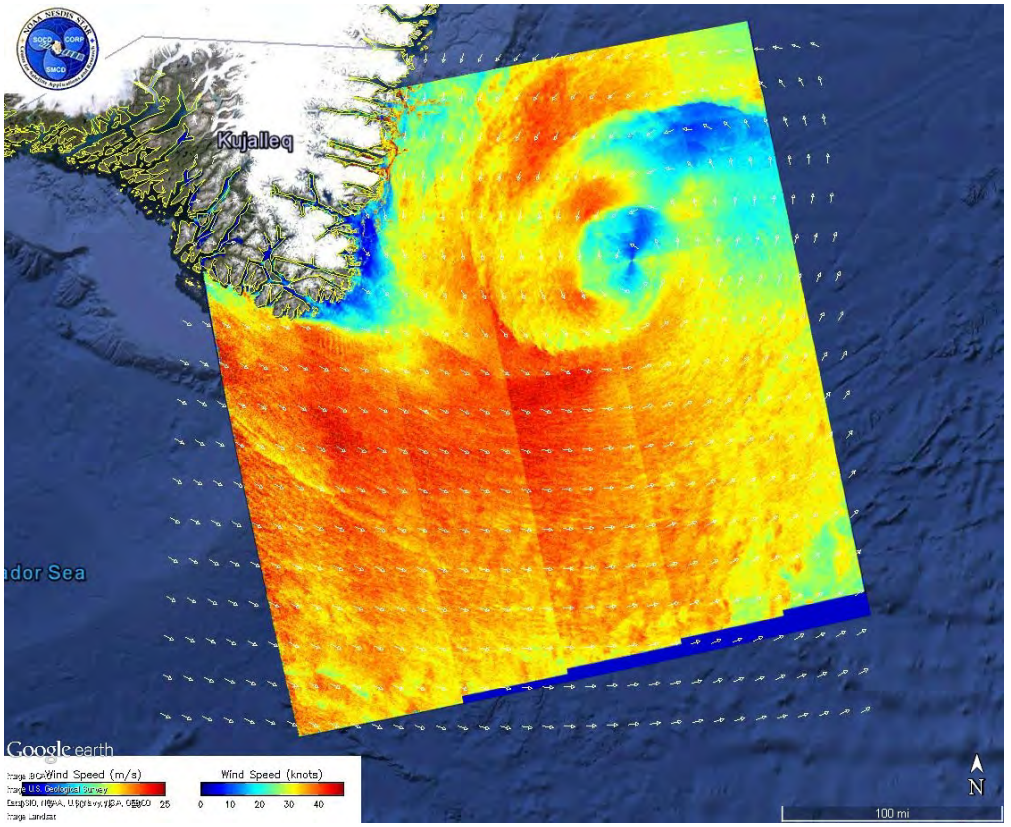


Sentinel-1A SAR vs ASCAT winds

Sentinel-1A wind images: 2014-12-31 20:19:38 UTC

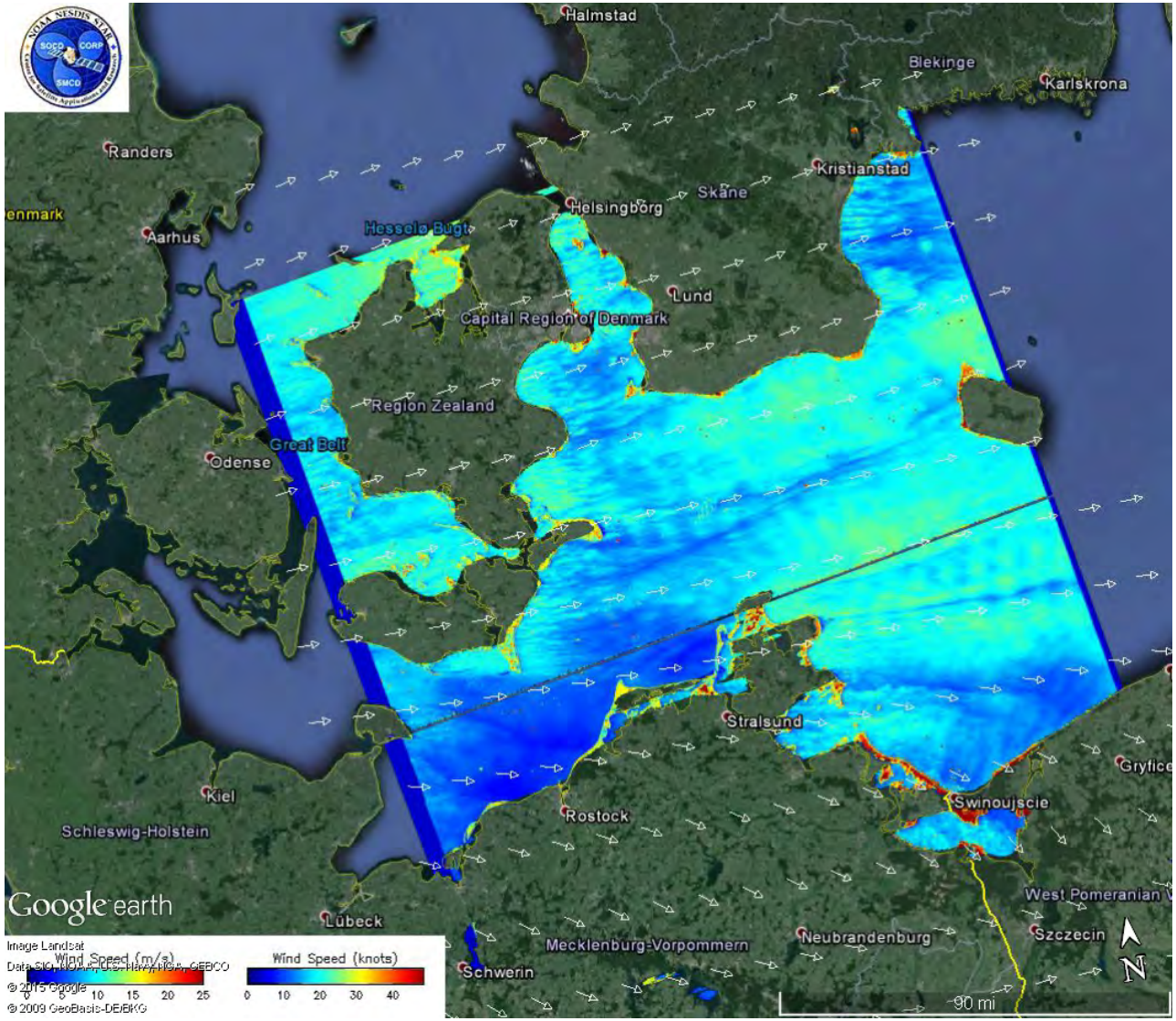


PNG Image



KMZ File

Sentinel-1A Wind Speed Retrieval Baltic Sea

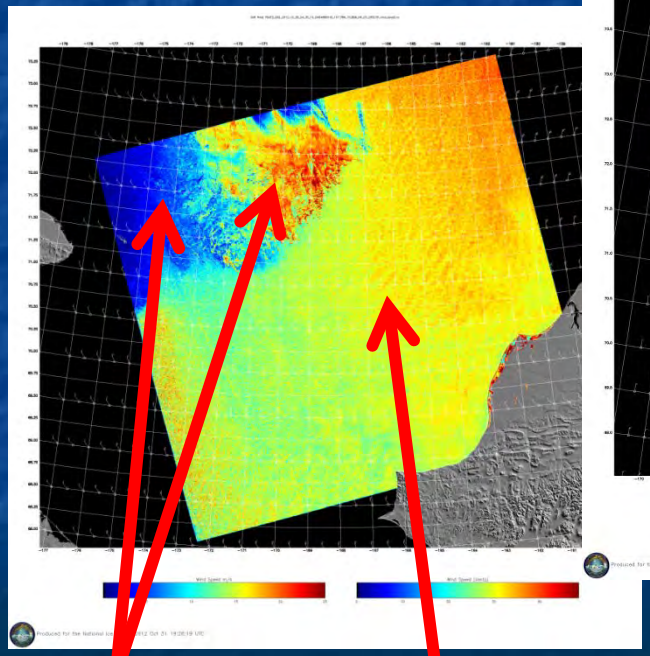


July 6, 2015, 1652

Wind speed imagery makes other phenomena more visible.
Example: Fast Freeze-up at Drilling Site from RADARSAT-2 SAR Surface Winds

NIC RADARSAT-2 Synthetic Aperture Radar (SAR) Surface Winds Products

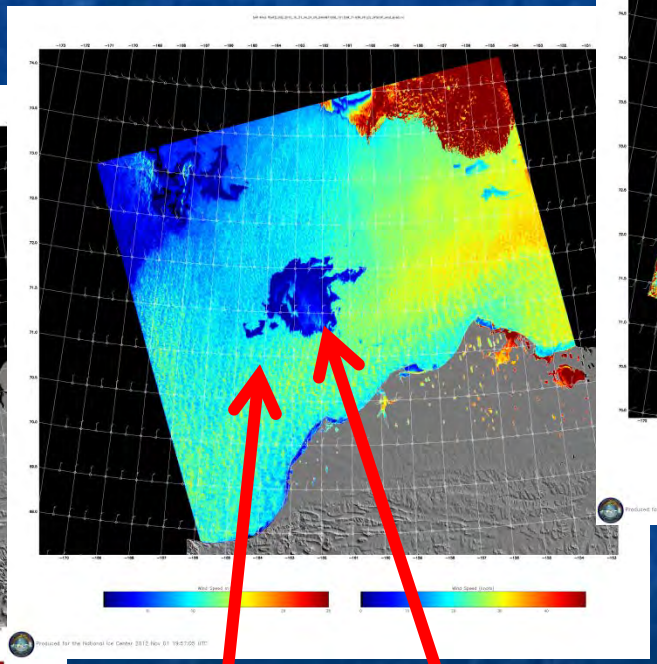
October 30th 0430Z



Sea Ice

No Ice
Winds > 30 knots

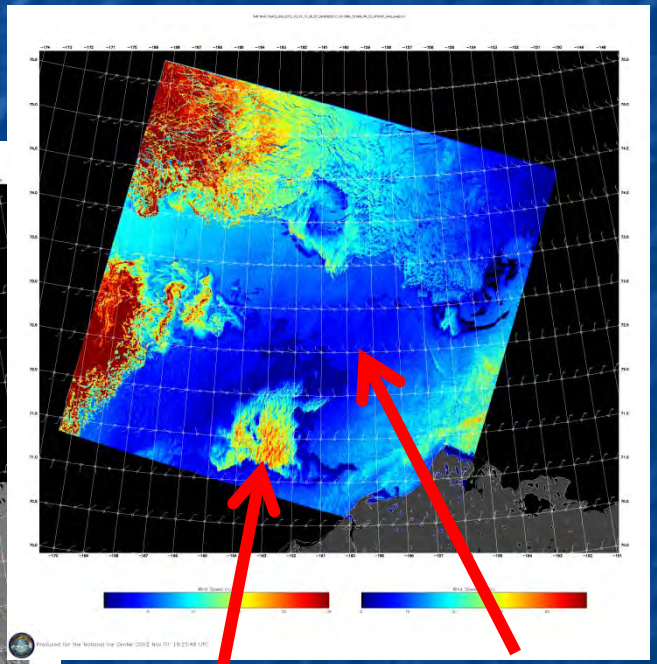
October 31st 0401Z



Lower
Wind Speeds

Grease Ice

October 31st 1736Z



Nilas and
Pancake Ice

Very Low
Wind Speeds

NOAA CoastWatch

- Home
- History
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- Data Access
- Data Products
- Applications
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- Reports
- Resources

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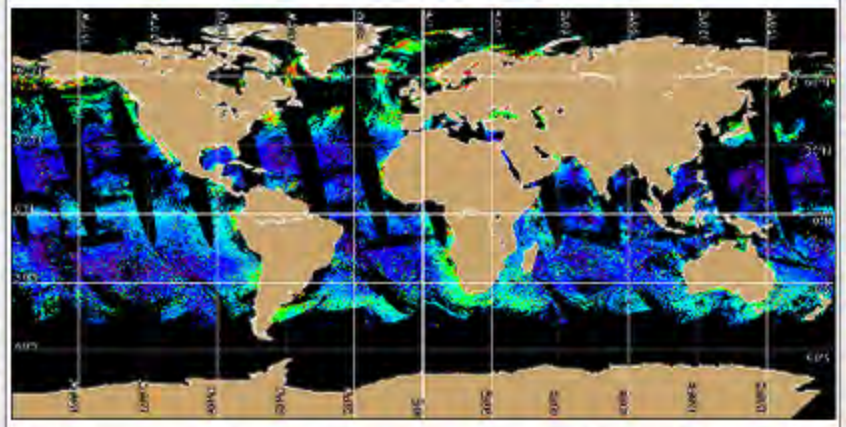
CoastWatch NOAA

NOAA CoastWatch
NCWCP E/RA3
College Park, MD 20740
301.683.3335
coastwatch.info@noaa.gov

Central Operations & Regional Nodes



VIIRS ocean color data products are being processed by NOAA CoastWatch on an experimental basis.

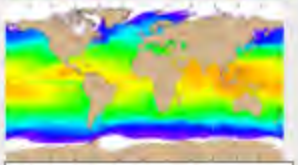
Global 4km chlorophyll-a (single file) and 750m (24 sector tiles) and CONUS (CoastWatch regions) are produced daily. Both CONUS and GLOBAL 750m (L2,L3) products are available through the CoastWatch THREDDS Server.

Level-2 granules can be browsed by using the CoastWatch Granule Selector. The selector allows visualization of a granule's geographic coverage with quick access to the Level-2 dataset.

Sentinel-3

NOAA OceanWatch and other US partners are in discussions with EUMETSAT to develop pre-operational support for Sentinel-3 data and products. [more]

Featured Image



Global daily 5km SST product is now available. More Information

Applications

News

GOES SST filenames have changed to be consistent with other geostationary products. Files now include the satellite in the filename: sst3b_[goes,mtsat,msg]_YYYY [DEC 2014]

MODIS ~250m True Color and GOES SST products are now available on ftpcoastwatch.noaa.gov. [FEB 2014]

NOAA Satellites and Information
National Environmental Satellite, Data, and Information Service

PRIVACY | CONTACT US

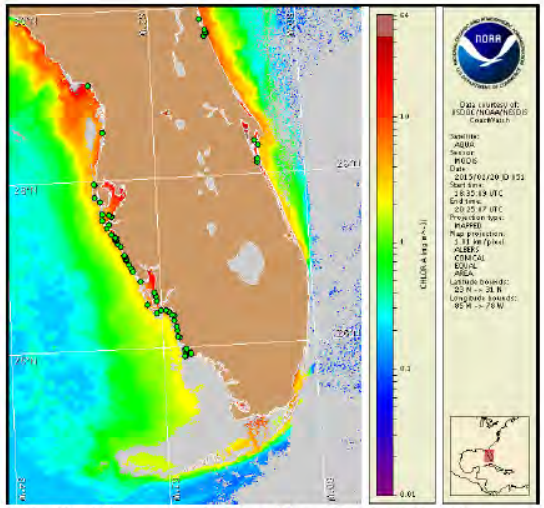
Department of Commerce

http://coastwatch.noaa.gov/

CoastWatch/OceanWatch Support for NOS Harmful Algal Bloom Bulletins

Gulf of Mexico Harmful Algal Bloom Bulletin

Region: Southwest Florida
Monday, 23 February 2015
NOAA National Ocean Service
NOAA Satellite and Information Service
NOAA National Weather Service
Last bulletin: Tuesday, February 17, 2015



Satellite chlorophyll image with possible *K. brevis* HAB areas shown by red polygon(s), when applicable. Points represent cell concentration sampling data from February 13 to 20: red (high), orange (medium), yellow (low b), brown (low a), blue (very low b), purple (very low a), pink (present), and green (not present). Cell count data are provided by Florida Fish and Wildlife Conservation Commission (FWC) Fish and Wildlife Research Institute. For a list of sample providers and a key to the cell concentration categories, please see the HAB-OFS bulletin guide:
http://tidesandcurrents.noaa.gov/hab/habfs_bulletin_guide.pdf

Detailed sample information can be obtained through FWC Fish and Wildlife Research Institute at:
http://myfwc.com/redtidestatus

To see previous bulletins and forecasts for other Harmful Algal Bloom Bulletin regions, visit at: http://tidesandcurrents.noaa.gov/hab/bulletins.html

Conditions Report

There is currently no indication of *Karenia brevis* (commonly known as Florida red tide) along the coast of southwest Florida, including the Florida Keys. No respiratory irritation is expected alongshore southwest Florida Monday, February 23 through Monday, March 2.
Check http://tidesandcurrents.noaa.gov/hab/beach_conditions.html for recent, local observations.

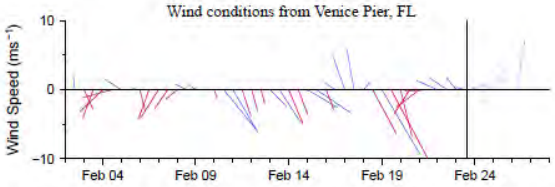
Analysis

The most recent samples received from along- and offshore southwest Florida, from Pinellas to Collier counties, all indicate that *Karenia brevis* is not present (FWRI, MML, SCHD, CCPCPD; 2/14-19).

Recent MODIS Aqua imagery (2/20, shown left) is obscured by clouds from alongshore Collier County to the Florida Keys, limiting analysis. Elevated chlorophyll (2-4 μg/L) is visible along- and offshore the coast of southwest Florida from Pinellas to Collier counties.

Harmful algal bloom formation at the coast of southwest Florida is not expected today through Monday, March 2.

Kavanaugh, Davis



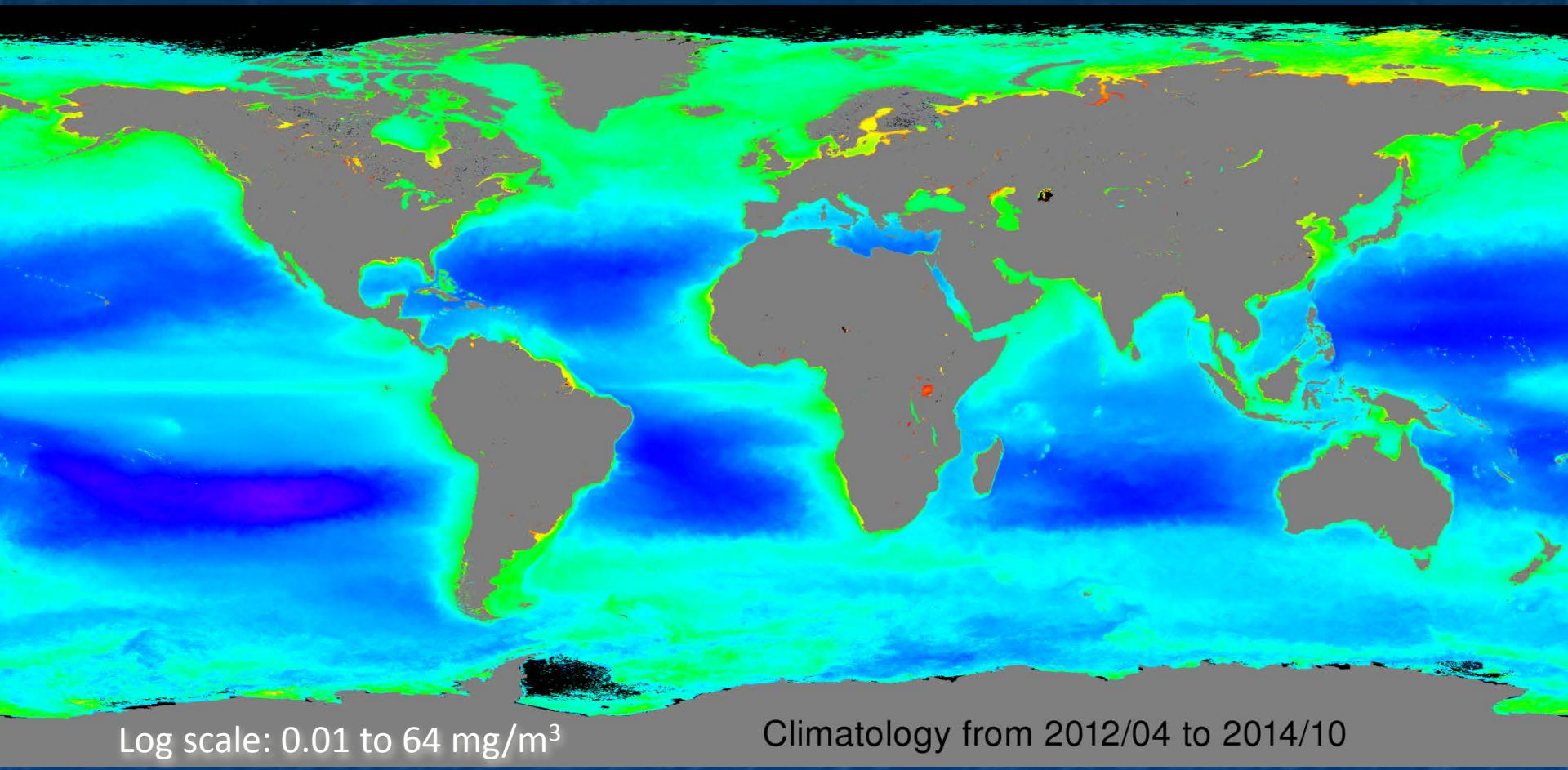
Wind speed and direction are averaged over 12 hours from buoy measurements. Length of line indicates speed; angle indicates direction. Red indicates that the wind direction favors upwelling near the coast. Values to the left of the dotted vertical line are measured values; values to the right are forecasts. Wind observation and forecast data provided by NOAA's National Weather Service (NWS).

Wind Analysis

Englewood to Tarpon Springs (Venice): Variable winds (5-10kn, 3-5m/s) today through Tuesday. Southerly winds (5-20kn, 3-10m/s) Wednesday becoming northerly winds (10-15kn, 5-8m/s) Thursday through Friday.

- *CoastWatch/OceanWatch has been providing tailored satellite ocean color products to NOS/NCCOS to generate Harmful Algal Bloom Forecast Bulletins since 2004, spanning SeaWiFS, MODIS, MERIS and now VIIRS ocean color data, and soon using Sentinel-3 OLCI data from EUMETSAT.*
- *In this context, CoastWatch is also actively supporting NOAA Ecological Forecasting infrastructure activities, working with NCEP/OPC as well as NOS/NCCOS and other partners.*

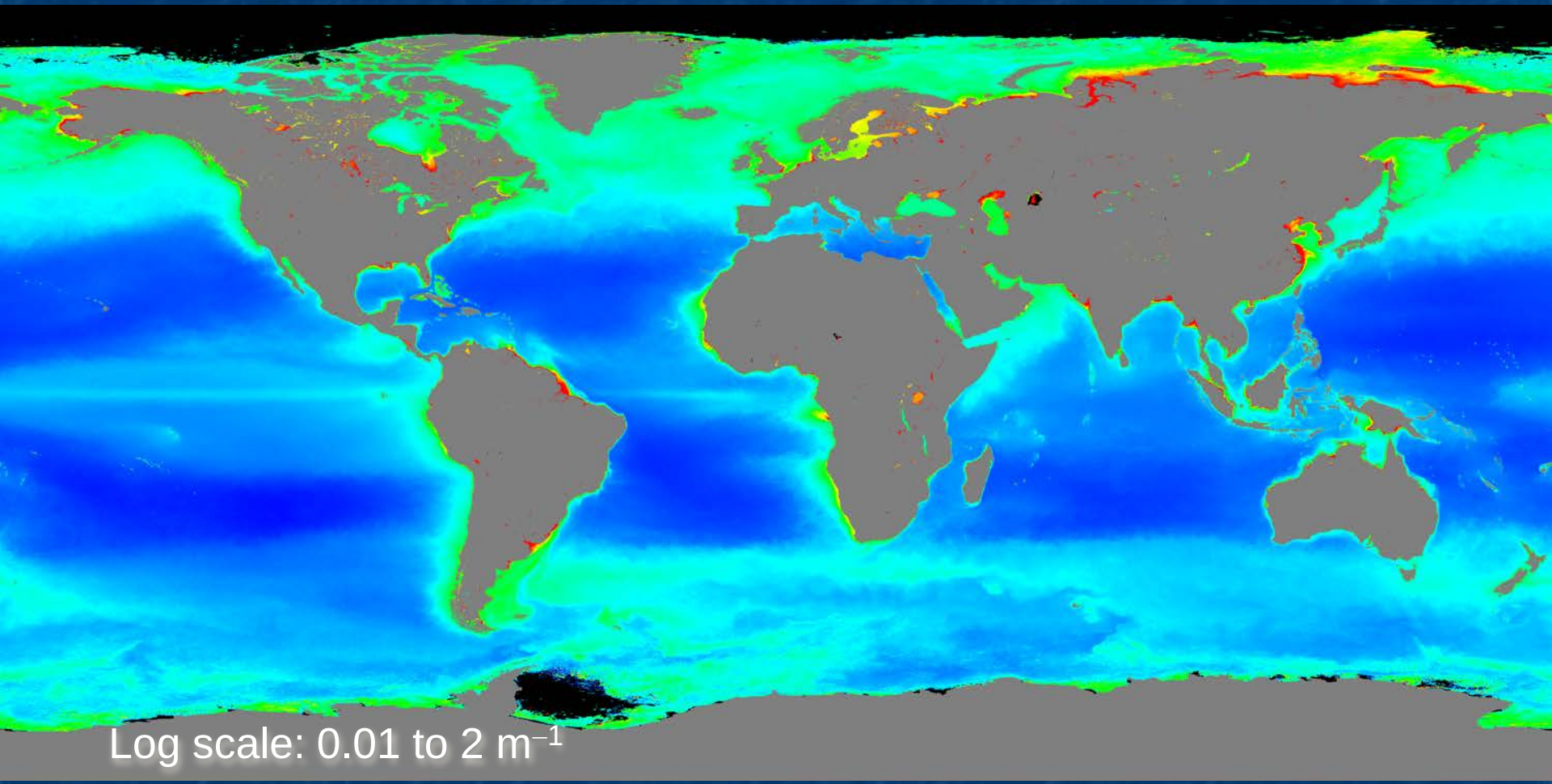
NOAA VIIRS Climatology Chlorophyll-a Image
(April 2012 to October 2014)



Generated using NOAA MSL12 for VIIRS ocean color data processing

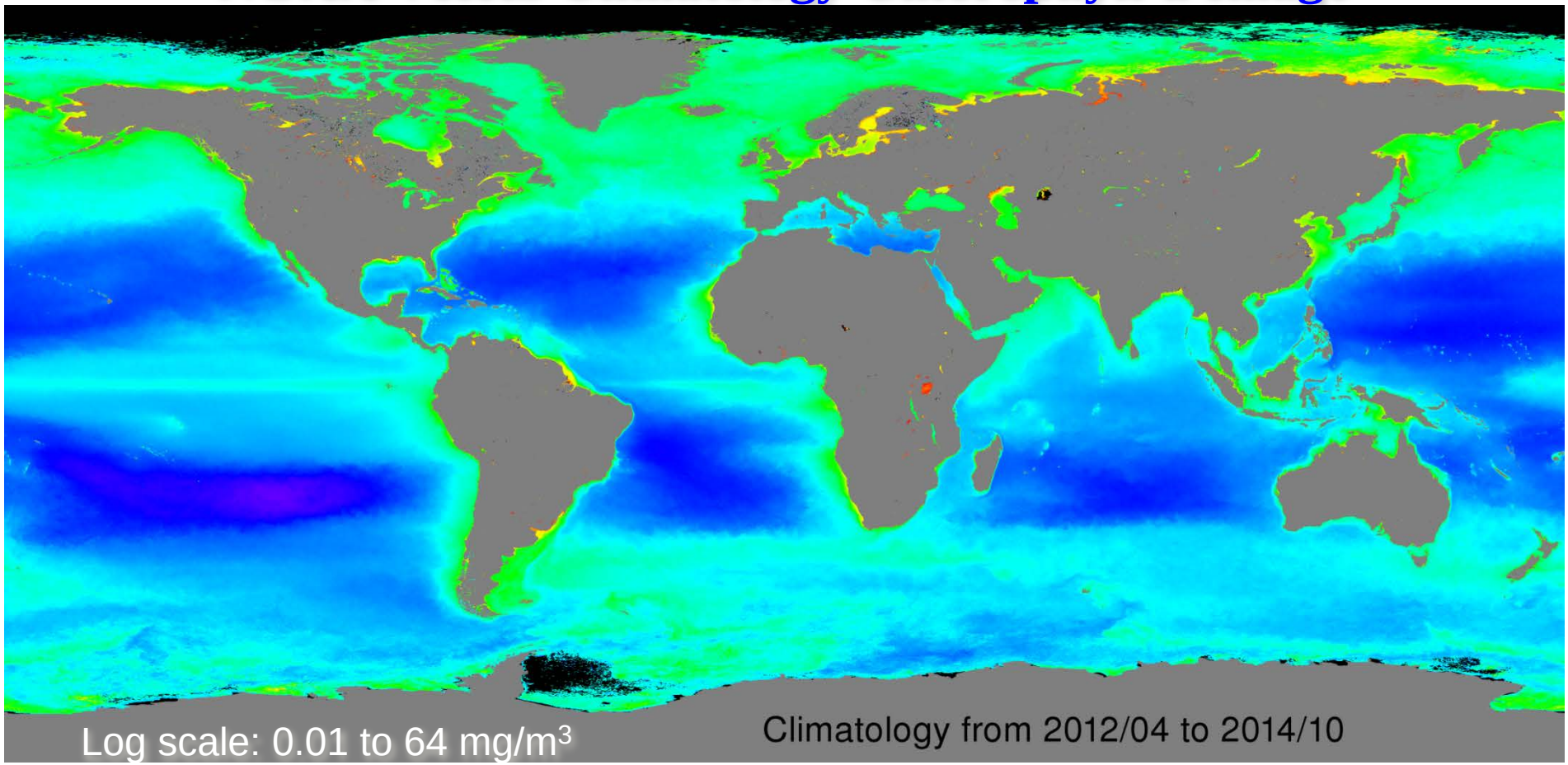
Wang, M., X. Liu, L. Tan, L. Jiang, S. Son, W. Shi, K. Rausch, and K. Voss, "Impacts of VIIRS SDR performance on ocean color products," *J. Geophys. Res. Atmos.*, **118**, 10,347–10,360, 2013. http://dx.doi.org/10.1002/jgrd.50793

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



Generated using NOAA-MSL12 for VIIRS ocean color data processing

NOAA VIIRS Climatology Chlorophyll-a Image



- NOAA Ocean Color Team has been developing/building the capability for the **End-to-End** satellite ocean color data processing including (**http://www.star.nesdis.noaa.gov/sod/mecb/color/**):
  - Level-0 to Level-1B (or Raw Data Records (RDR) to Sensor Data Records (SDR)).
  - Level-1B (SDR) to ocean color Level-2 (Environmental Data Records (EDR)).
  - Level-2 to global Level-3 (routine **daily**, **8-day**, **monthly**, and **climatology** data/images).
- Capability for on-orbit instrument calibration (MODIS, VIIRS, etc.).
- Support of in situ data collections for VIIRS Cal/Val activities, e.g., **MOBY**, **AERONET-OC** sites, **NOAA dedicated cruise**, etc.

NOAA Ocean Color Team

VIIRS Ocean Color EDR & Cal/Val Teams Members

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, P. Naik, J. Sun, K. Mikelsons, V. Lance, **M. Ondrusek,** E. Stengel	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, algorithm improvements, software updates, data validations and analyses
Ocean Color	**Robert Arnone** Sherwin Ladner, Ryan Vandermeulen Adam Lawson, Paul Martinolich, Jen Bowers	U. Southern MS NRL QinetiQ Corp. SDSU	JPSS/NJO	Look Up Tables – SDR-EDR impacts, vicarious calibration Satellite matchup tool (SAVANT) – Golden Regions Cruise participation and support WAVE_CIS (AERONET-OC site) operation
	Carol Johnson	NIST	JPSS/NJO	Traceability, AERONET Uncertainty
	Curt Davis, Nicholas Tufillaro	OSU	JPSS/NJO	Ocean color validation, Cruise data matchup West Coast
	Burt Jones, Matthew Ragan	USC	JPSS/NJO	Eureka (AERONET Site)
	Sam Ahmed, Alex Gilerson	CUNY	JPSS/NJO	LISCO (AERONET site) Cruise data and matchup
	Chuanmin Hu	USF	JPSS/NJO	NOAA data continuity
	Ken Voss & **MOBY** team	RSMAS –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** (C. Cao, F. DeLuccia, X. Xiong), DPA/DPE (R. Williamson, Neal Baker), Raytheon, NOAA -OC Working Group, NOAA various line-office reps, NASA OBPG (K. Turpie, et al.), NOAA OCPOP, 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

- **Inputs**:
  - VIIRS M1-M7 and the **SWIR** M8, M10, and M11 bands SDR data
  - Terrain-corrected geo-location file
  - Ancillary meteorology and ozone data
- **Operational (Standard) Products** (8):
  - Normalized water-leaving radiance (nL_w's) at VIIRS visible bands M1-M5
  - Chlorophyll-a (Chl-a) concentration
  - Diffuse attenuation coefficient for the downwelling spectral irradiance at the wavelength of 490 nm, $K_d(490)$ (New)
  - Diffuse attenuation coefficient of the downwelling photosynthetically available radiation (PAR), K_d(PAR) (New)
  - Level-2 quality flags
- **Experimental Products:**
  - 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)
  - Chlorophyll-a from ocean color index (OCI) method (Hu et al., 2012)
  - Others from users requests

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

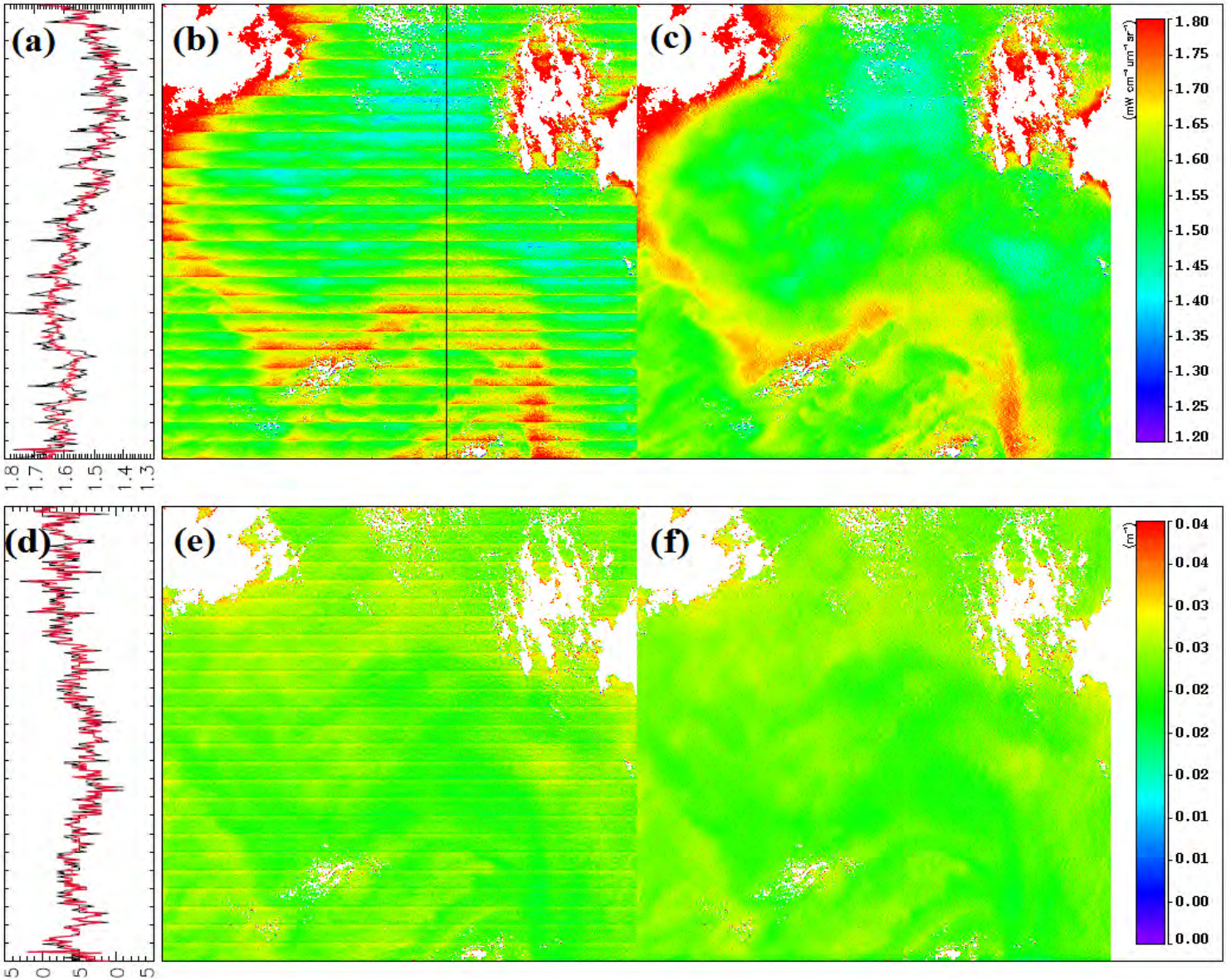
Multi-Sensor Level-1 to Level-2 (MSL12) Ocean Color Data Processing

- Multi-Sensor Level-1 to Level-2 (MSL12)
  - ✓ MSL12 was developed during NASA SMIBIOS project (1997-2003) for a consistent multi-sensor ocean color data processing (Wang, 1999; Wang and Franz, 2000), i.e., it is measurement-based ocean color data processing system.
  - ✓ It has been used for producing ocean color products from various satellite ocean color sensors, e.g., SeaWiFS, MOS, OCTS, POLDER, MODIS, GOCI, etc.
- NOAA-MSL12 Ocean Color Data Processing
  - ✓ NOAA-MSL12 is based on SeaDAS version 4.6.
  - ✓ Some significant improvements: (1) the SWIR-based data processing, (2) Rayleigh and aerosol LUTs, (3) algorithms for detecting absorbing aerosols and turbid waters, (4) ice detection algorithm, (5) improved straylight/cloud shadow algorithm, & others.
  - ✓ In 2014, some new algorithms (BMW–new NIR reflectance correction, Destriping, K_d(PAR), etc.)
- NOAA-MSL12 for VIIRS (and others) Ocean Color Data Processing
  - ✓ Routine ocean color data processing (daily, 8-day, monthly) since VIIRS launch.
  - ✓ Coastal turbid and inland waters from other approaches, e.g., the **SWIR approach**, results in the US east coastal, China's east coastal, Lake Taihu, Lake Okeechobee, Aral Sea, etc.
  - ✓ Capability for multi-sensor ocean color data processing, e.g., MODIS-Aqua, VIIRS, GOCI, and will also add J1, OLCI/Stentinel-3, and SGLI/GCOM-C data processing capability.

Destriping of VIIRS Ocean Color Products
(Examples)

$nL_w(412)$

$K_d(490)$



Mikelsons, K., M. Wang, L. Jiang, and M. Bouali, "Destriping algorithm for improved satellite-derived ocean color product imagery," *Opt. Express*, **22**, 28058-28070, 2014. http://dx.doi.org/10.1364/OE.22.028058

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

Welcome to VIIRS Ocean Color EDR Team Web Site

STAR Center for Satellite Applications and Research VIIRS Ocean Color EDR Team

The ocean color research team in the Center for Satellite Applications and Research (STAR) of NOAA/NESDIS seeks to develop improved ocean color products from the current and future ocean color satellite sensors including the Sea-viewing Wide Field-of-view Sensor (SeaWiFS), the Moderate Resolution Imaging Spectroradiometer (MODIS) on the both Terra and Aqua, and the Visible Infrared Imaging Radiometer Suite (VIIRS) on the Suomi National Polar-orbiting Partnership (SNPP) and the Joint Polar Satellite System (JPSS), as well as various satellite sensors from other countries, e.g., the Medium Resolution Imaging Spectrometer (MERIS), Geostationary Ocean Color Imager (GOCI), Ocean Land Colour Instrument (OLCI), Second-Generation Global Imager (SGLI), etc. The ocean color research team is currently focusing on (1) satellite ocean color instrument (e.g., VIIRS, MODIS) characterization and calibration, (2) understanding, evaluation, and refining satellite ocean color data processing system, (3) routine global ocean color data processing from Level-1, Level-2, and Level-3, (4) development and improvement of satellite retrieval algorithms in global open ocean and coastal and inland water regions, (5) in situ data processing, evaluation, and improvement, (6) implementing and transition research algorithms to the NOAA operational data system, and (7) various ocean color data applications in global open ocean and the inland and coastal waters.

Here we show results from VIIRS-SNPP.

Please select the page to visit:

VIIRS EDR Composite Images ← Link to composite image page

Calibration/Validation ← Link to calibration/validation page

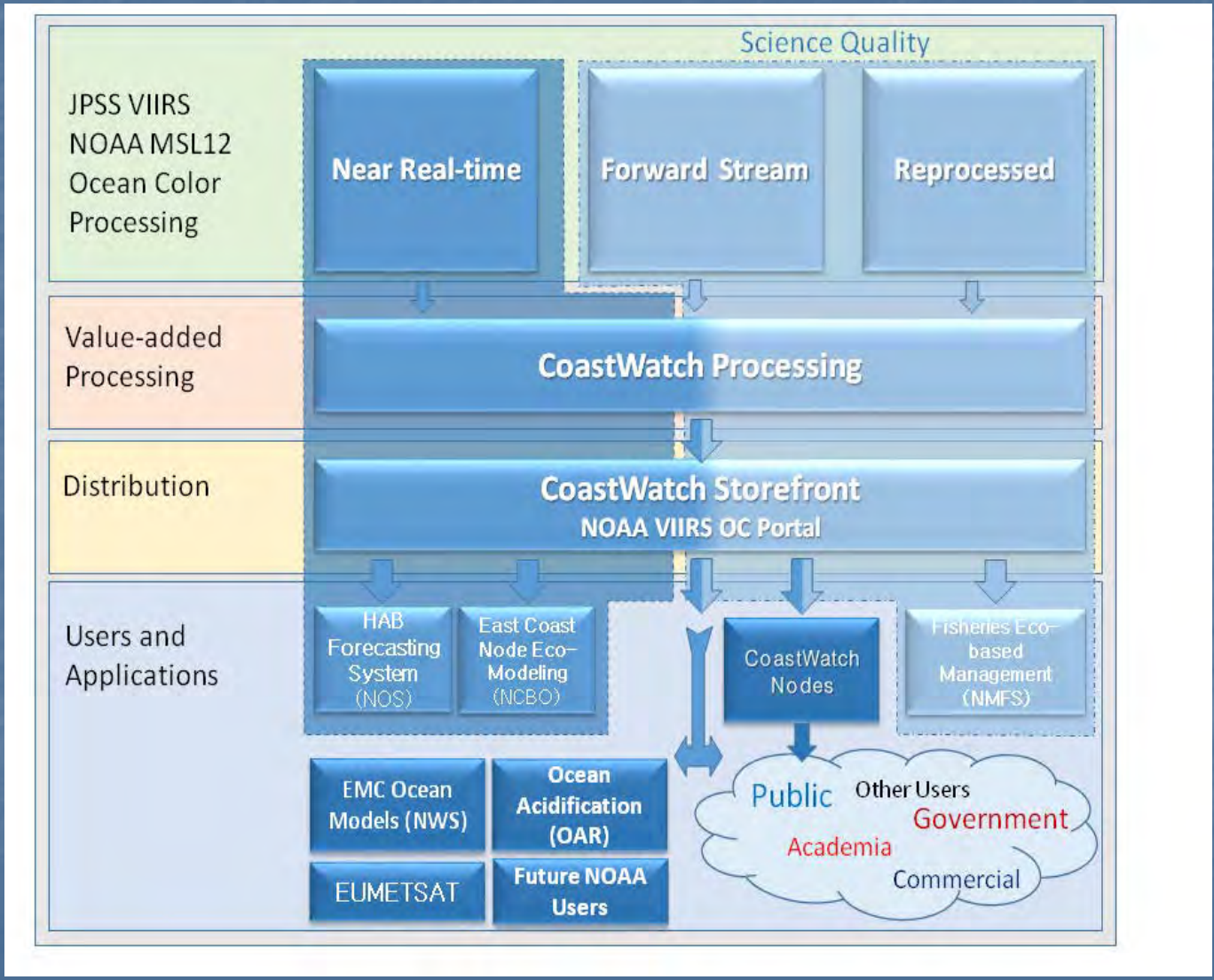
Team Publications ← List of the team publications

Software Download

Internal Access (password protected)

For detailed information about this site, please refer to the description pdf file. ← Website description

Evolving CoastWatch/OceanWatch VIIRS Ocean Color Data Flow



http://coastwatch.noaa.gov/

VIIRS OC Processing and User Engagements

- NOAA CoastWatch/OceanWatch is now generating and distributing global MSL12 VIIRS ocean color products
  - chlorophyll-a, Kd490, nLws for M1-5 bands
  - L2 granule files, 24 mapped global sector L3 files with 750m resolution (daily and weekly composite), and mapped global L3 files with 4km resolution (daily and weekly composites)
  - NetCDF format data products served via STAR/CoastWatch THREDDS Data Server (TDS)
  - Global 4km Chlorophyll-a and Kd490 netcdf data been used by EMC for their climate modeling development efforts.

http://coastwatch.noaa.gov/

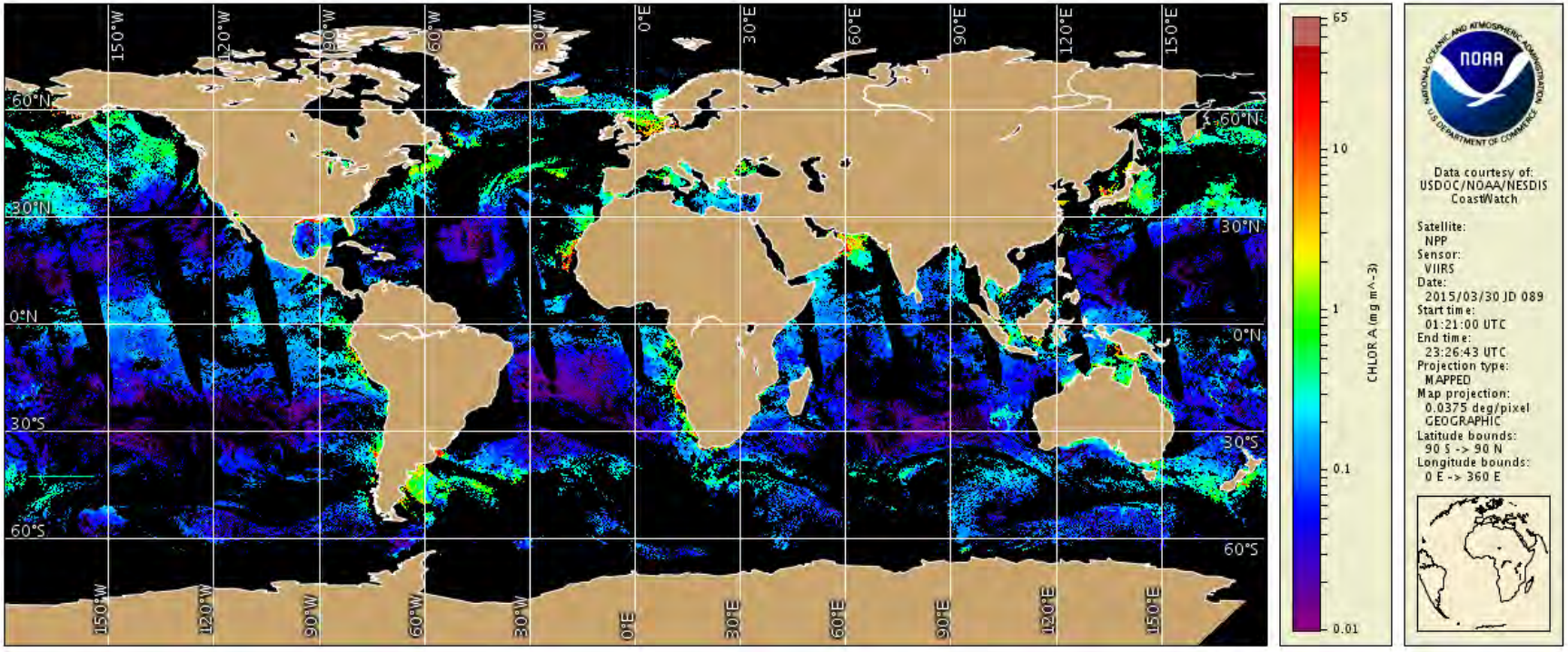
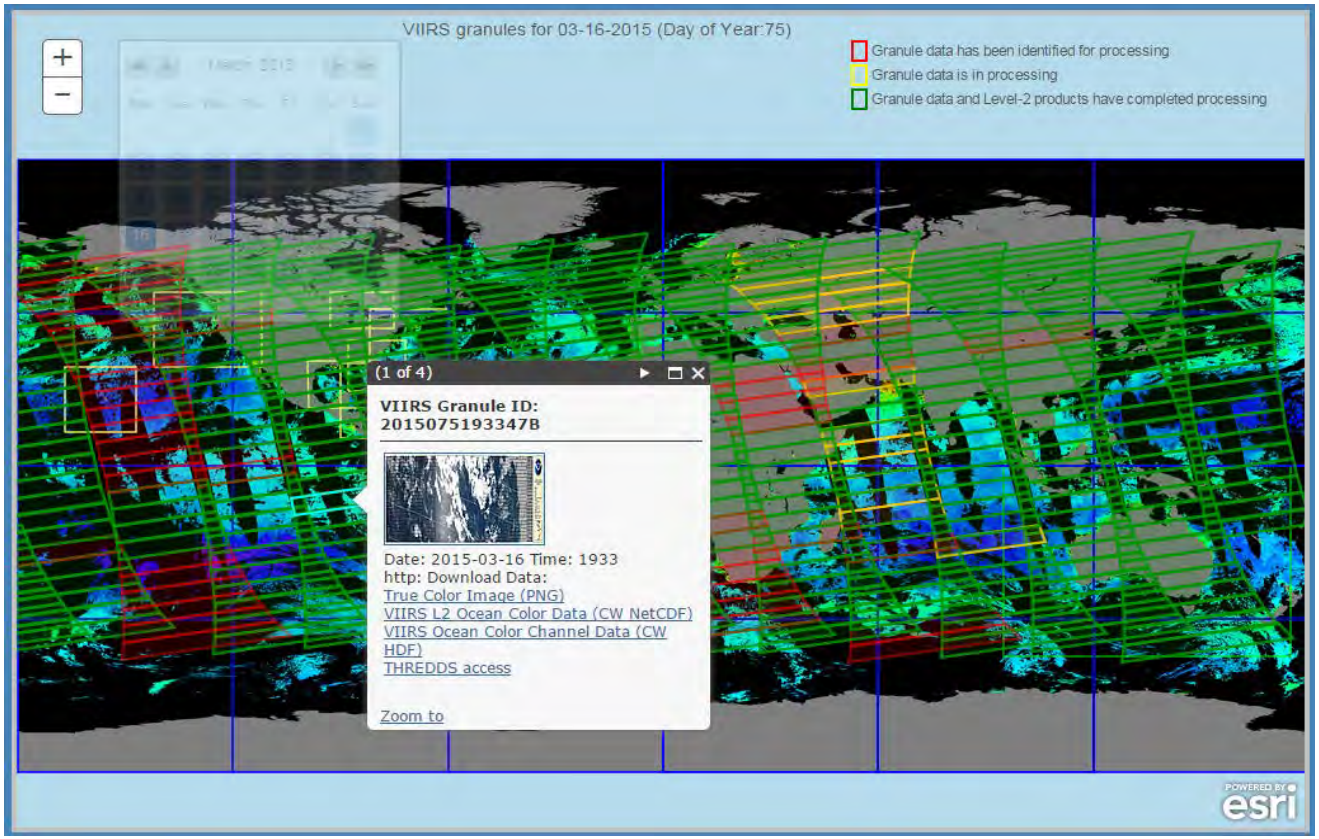


Figure 1. March 30, 2015 global Chlorophyll-a concentration image from SNPP VIIRS

CoastWatch VIIRS Ocean Color Portal

- CoastWatch/OceanWatch Global Map-based granule selector for VIIRS Ocean Color Data rolled out in March 2015
  - allows a user to quickly visualize and access a specific dataset based on time & geographic coverage
  - When finished, the portal will provide direct access to NRT, Science Quality, and Mission Reprocessed Level 2 data



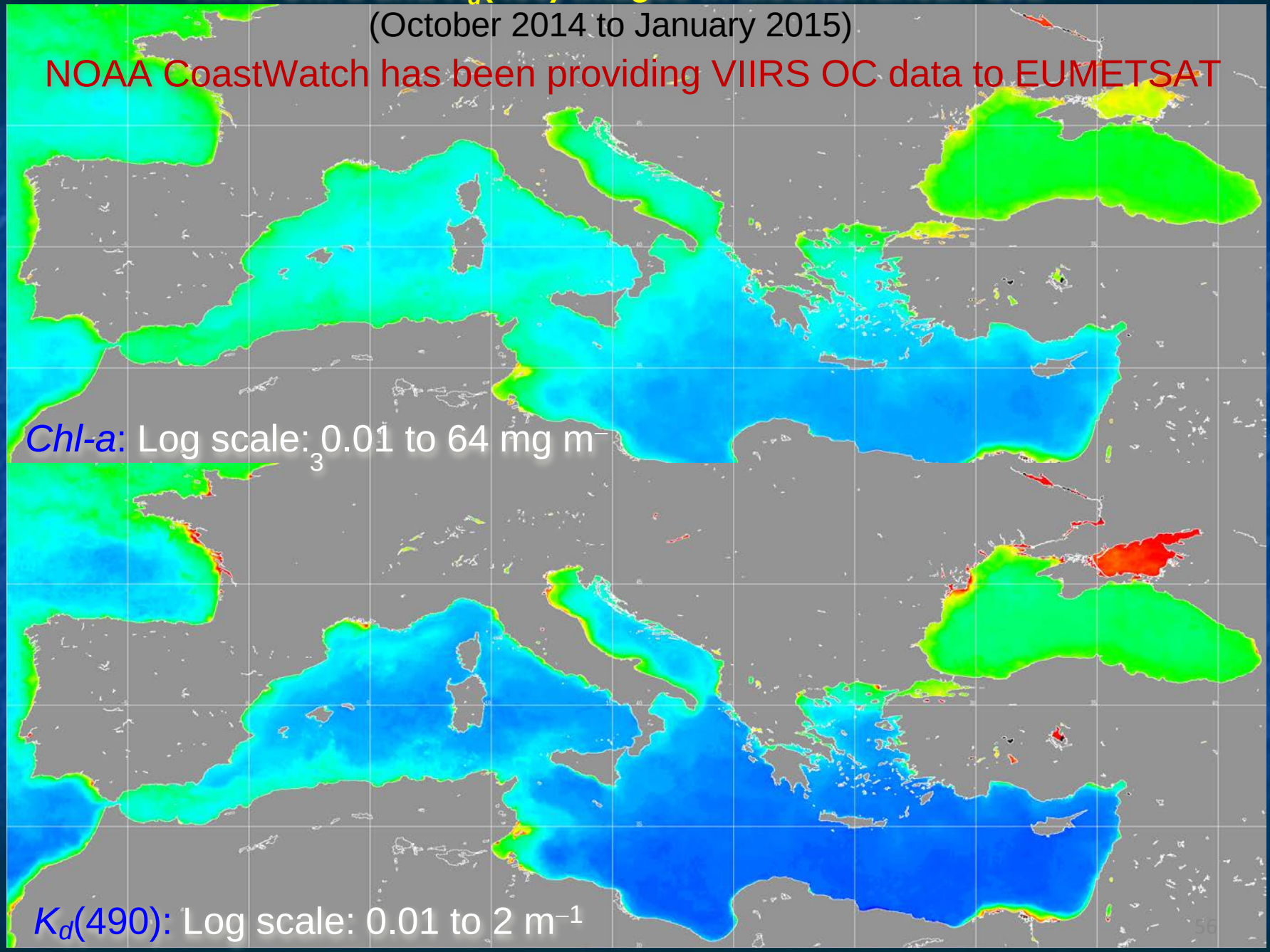
Global Map-based granule display of VIIRS true color images (granule selector)

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

VIIRS *Chl-a* and K_d(490) Images in Mediterranean Sea

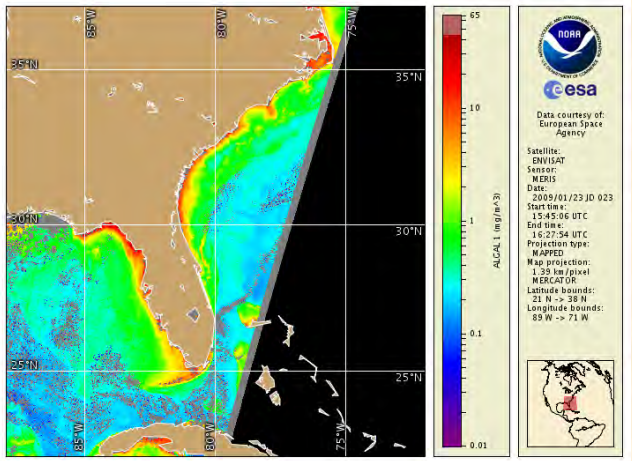
(October 2014 to January 2015)

NOAA CoastWatch has been providing VIIRS OC data to EUMETSAT



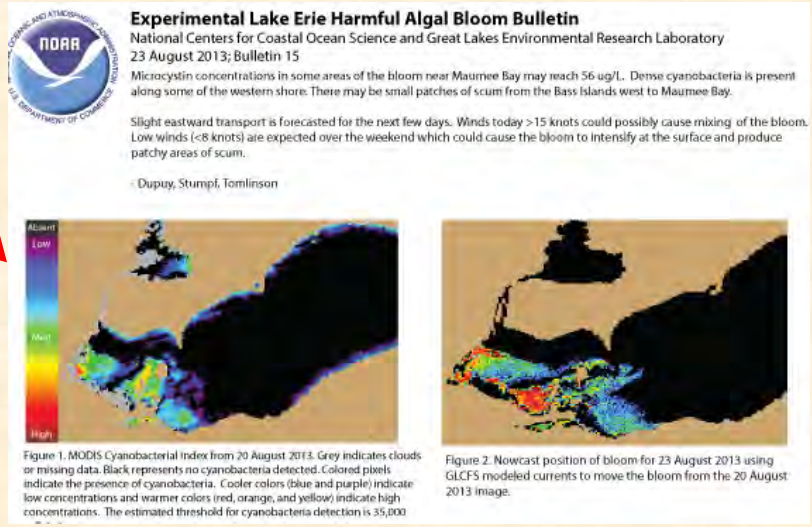
NOAA Utilization of European Ocean Color Data: Way forward for Sentinel-3/OLCI

- MERIS data declared operational by NESDIS in Jan 2009; however, Envisat failed in 2012.
- Chlorophyll-a/anomalies were generated from MERIS amongst other ocean color products, supporting NOS et al. users
- Coastwatch/NOAA was a “Champion User” for the ESA Coast Colour Project, supporting coastal users internationally.
- 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, has improved spatial resolution (300 m), useful for coastal/inland waters, and also has additional spectral bands – and as such is a vital complementary capability to VIIRS (especially as provides mid-morning orbit).
- STAR is supporting ESA/EUMETSAT as part of the Sentinel-3 Validation Team (3 projects)



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.

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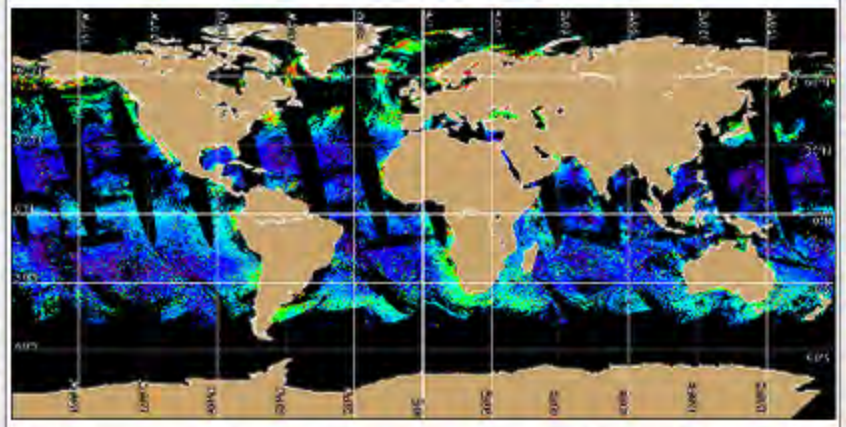
coastwatch.info@noaa.gov

Central Operations & Regional Nodes



VIIRS ocean color data products are being processed by NOAA CoastWatch on an experimental basis.

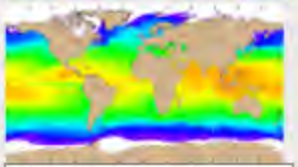
Global 4km chlorophyll-a (single file) and 750m (24 sector tiles) and CONUS (CoastWatch regions) are produced daily. Both CONUS and GLOBAL 750m (L2,L3) products are available through the CoastWatch THREDDS Server.

Level-2 granules can be browsed by using the CoastWatch Granule Selector. The selector allows visualization of a granule's geographic coverage with quick access to the Level-2 dataset.

Sentinel-3

NOAA OceanWatch and other US partners are in discussions with EUMETSAT to develop pre-operational support for Sentinel-3 data and products. [more]

Featured Image



Global daily 5km SST product is now available. More Information

Applications

News

GOES SST filenames have changed to be consistent with other geostationary products. Files now include the satellite in the filename: sst3b_[goes,mtsat,msg]_YYYY [DEC 2014]

MODIS ~250m True Color and GOES SST products are now available on ftpcoastwatch.noaa.gov. [FEB 2014]

NOAA Satellites and Information
National Environmental Satellite, Data, and Information Service

PRIVACY | CONTACT US

Department of Commerce

http://polarwatch.noaa.gov/ (in development)

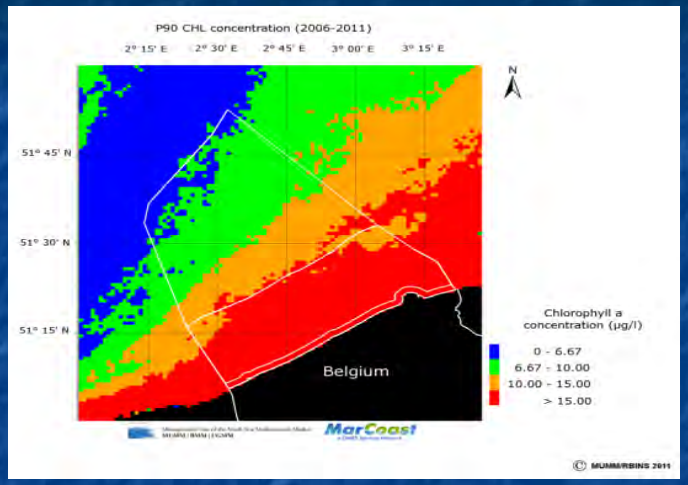
International Ocean Colour Coordinating Group Working Group: *Earth Observations in Support of Global Water Quality Monitoring*

- The measurement of water quality variables via radiometric measurements of the water's optical properties has rapidly grown over recent years.

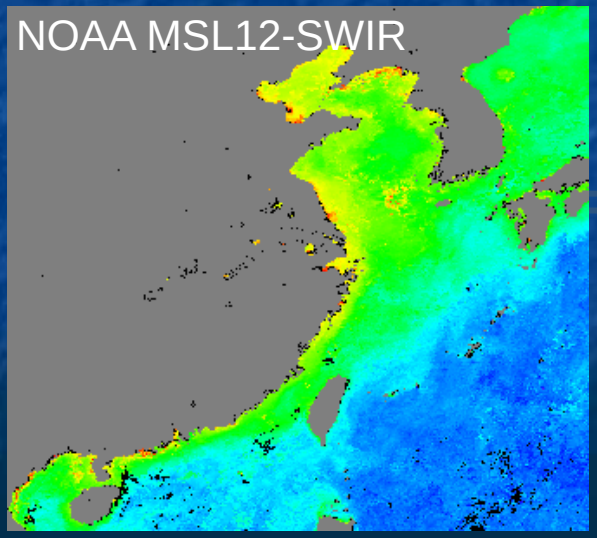
- This IOCCG working group seeks to build a stronger linkage between the water resources management end users and data providers to fully realize current & future Earth Observation products.

- IOCCG Working Group Chairs: *S. Greb, A. Dekker, P. DiGiacomo*

- Report Anticipated in 2016 timeframe



North Sea Coast Chl.a (MarCoast Project)



China East Coast Chl.a (M. Wang)

GROUP ON EARTH OBSERVATION

Report on the
Group on Earth Observation (GEO)
Water Quality Summit

World Meteorological Organization
Geneva, Switzerland 20-22, April, 2015

Under the auspices of GEO, we are now working to develop and implement a global water quality monitoring and forecasting service for coastal and inland waters

GEO Water Quality Service

What: Global Water Quality Service for Inland & Coastal Waters

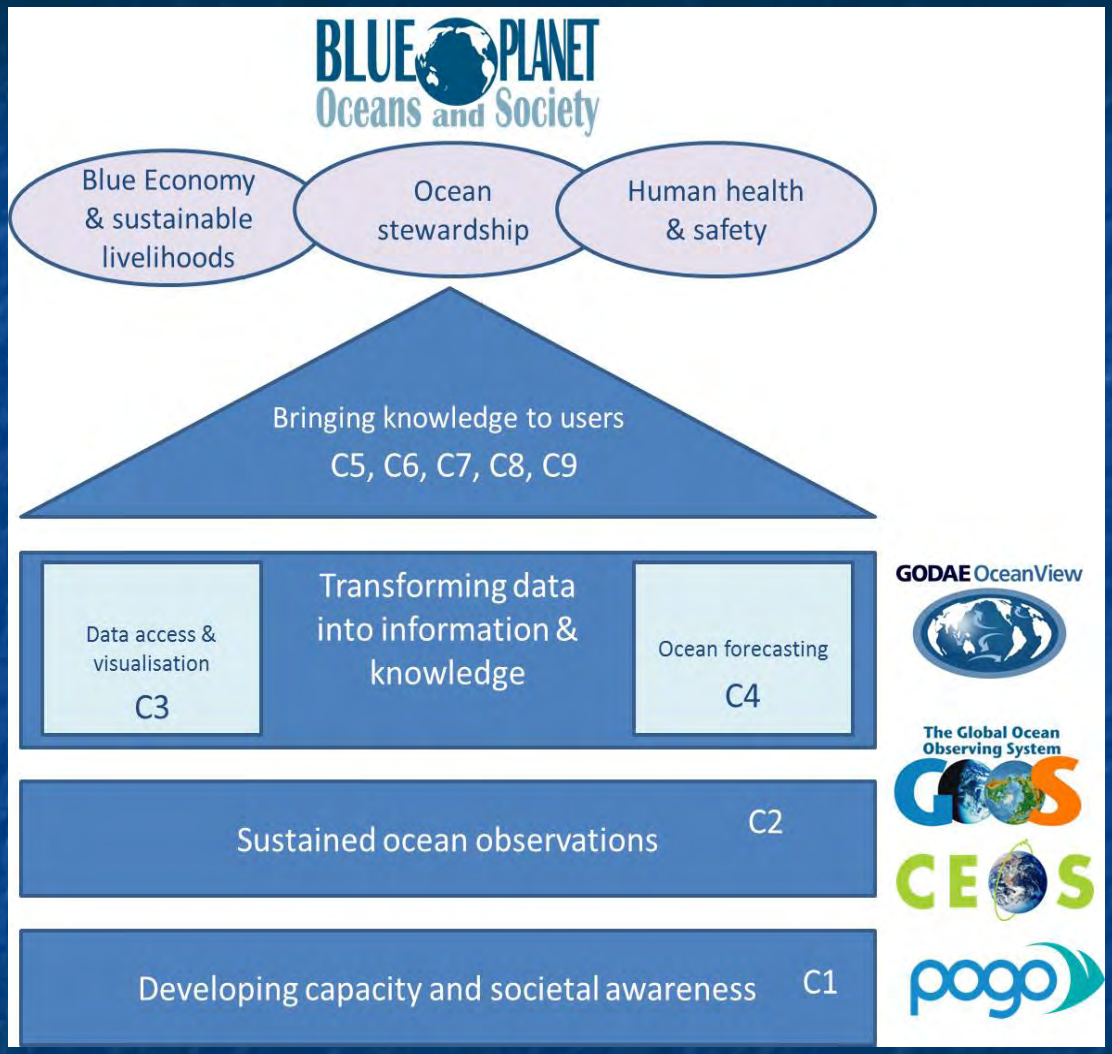
Mission Statement: Deliver, on a routine and sustained basis, timely, consistent, accurate and fit-for-purpose water quality data products & information to support water resource management and decision making in coastal and inland waters.

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 a newly implemented GEO Water Quality (GEO-WaQ) Community of Practice.

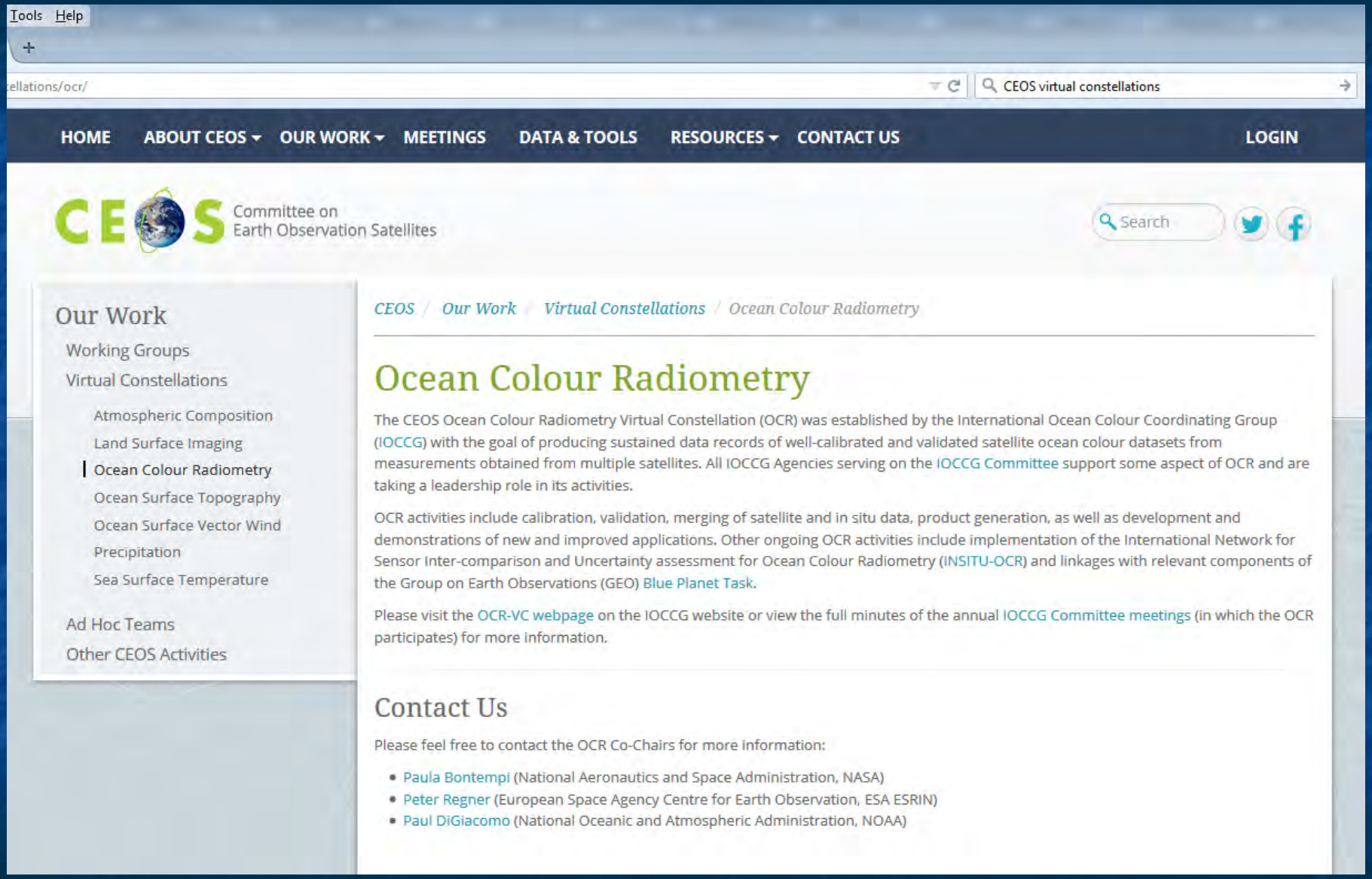
Details: Implementation plan forthcoming

GEO Blue Planet: Oceans & Society Initiative



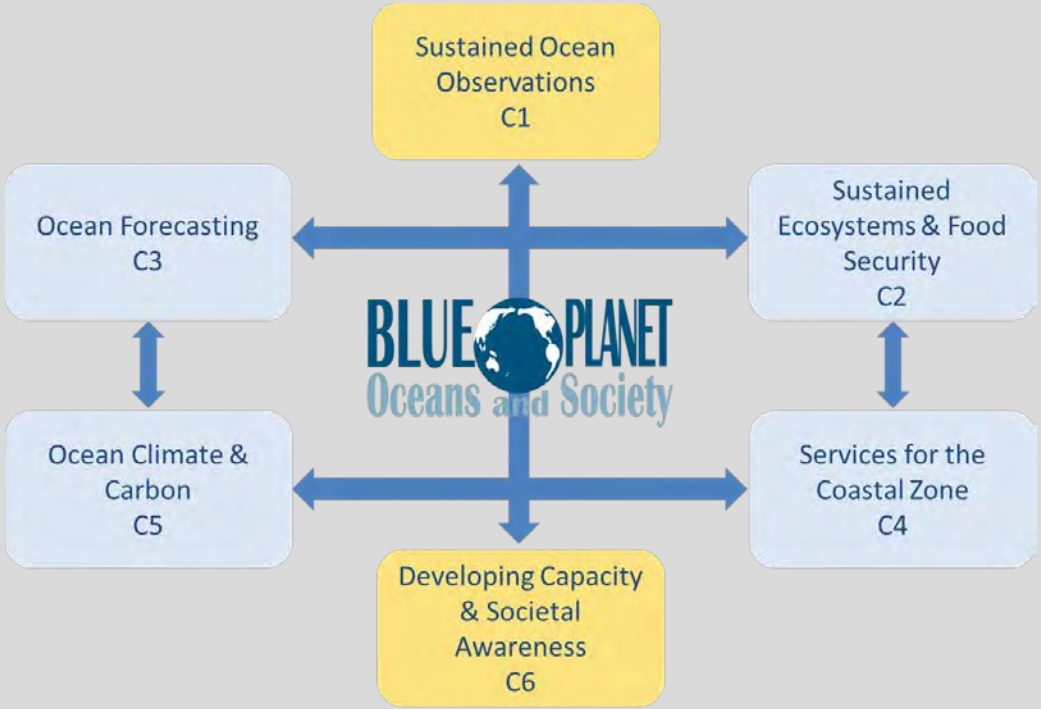
• NOAA and CSIRO (Australia) are jointly hosting the Group for Earth Observation's (GEO) newly established Blue Planet Secretariat, including NESDIS/STAR hosting the Science Officer/Coordinator position: Dr. Emily Smail

CEOS Ocean Colour Radiometry Virtual Constellation (OCR-VC)



http://ceos.org/ourwork/virtual-constellations/ocr/

BLUE PLANET
Oceans and Society

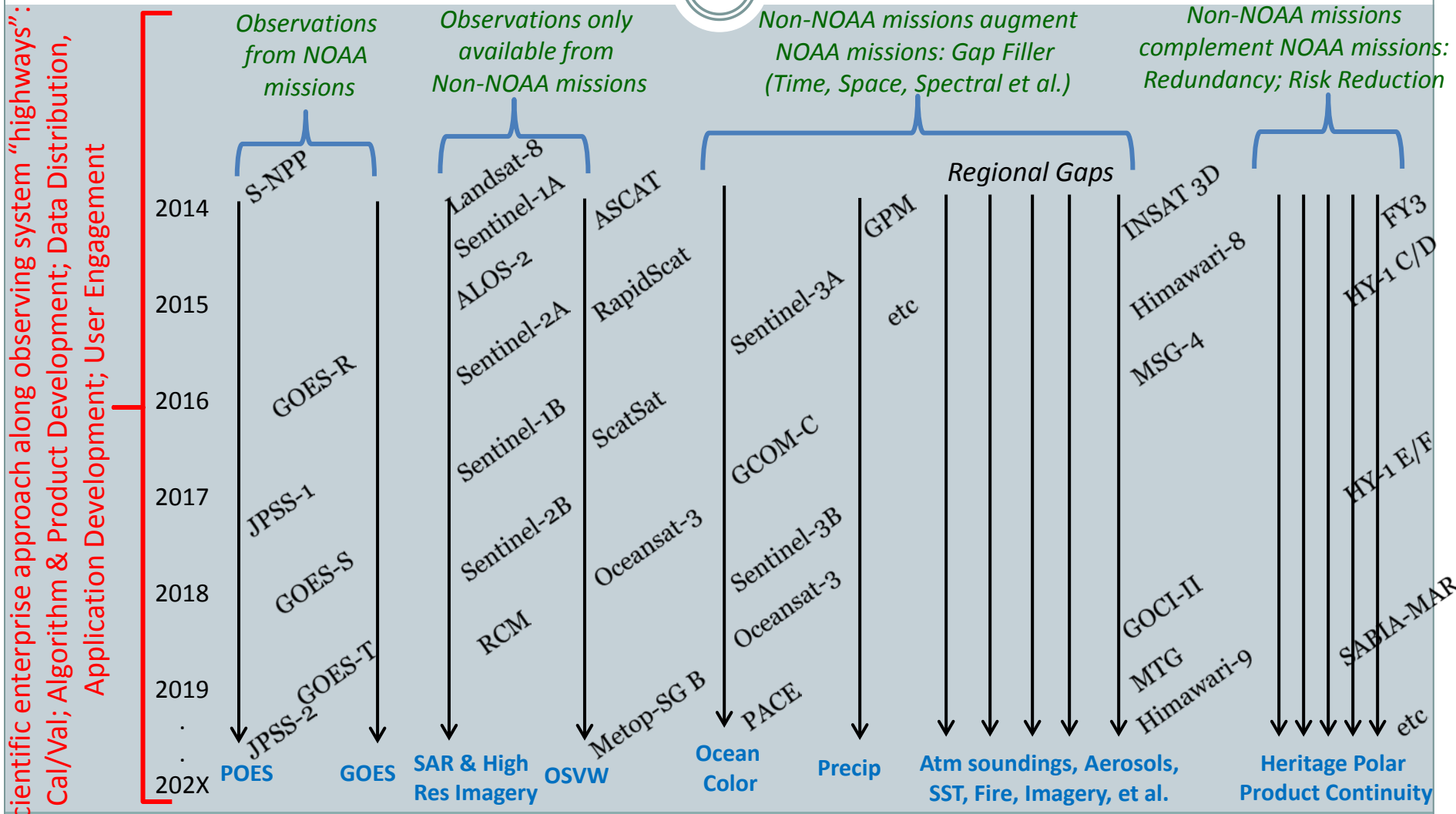


Thanks for listening!

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

Observing System Highways: Utilize satellite data from NOAA & non-NOAA missions

Leverages existing science, technical, programmatic et al. infrastructure in NESDIS



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