NOAA Operational Ocean Color Products from the CoastWatch Okeanos System: A Potential Application to NWP Model

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OUTLINE

- Background
- Ocean Color Operational Product System (CoastWatch Okeanos System)
- Operational and Developmental Ocean Color Products
- Spatial and Temporal Characteristics of Chlorophyll Concentration
- Summary and Conclusions

Why Is Ocean Color (OC) So Important?

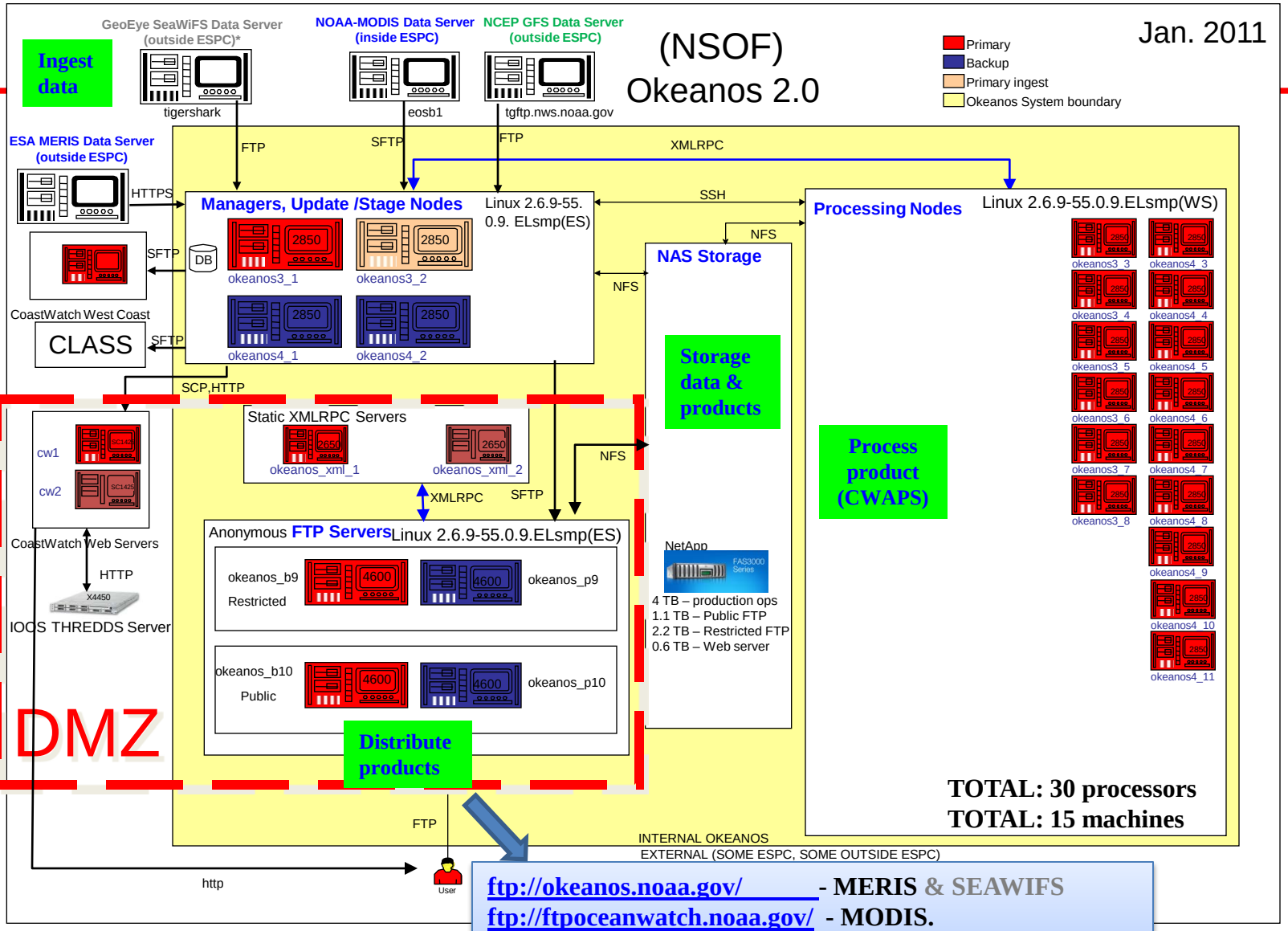
- OC is the water hue due to the presence of tiny plants containing the pigment chlorophyll, sediments, and colored dissolved organic material.
- Upwelling radiance scattered from chlorophyll, and other colored DOM is a key parameter for remote sensing of chlorophyll
- OC play a key role in marine ecosystem (see figure)

NOAA Ocean Color Operational Product System (CoastWatch Okeanos System) Concept

Okeanos is a flexible, expandable Linux-based system capable of processing multiple satellite streams into multiple CoastWatch ocean color products.

- CoastWatch Automatic Processing Software (CWAPS) :
  - Process manager and control module
  - File ingesting module
  - CWAPS (Coast Watch Automated Processing Software)
  - Merge module
  - Disk space control module
  - Publication module I (for cw webserver)
  - Publication module II (for okeanos ftp server)

Okeanos Operational Product System Architecture



*SeaWifs observations were over in Feb. 14, 2011

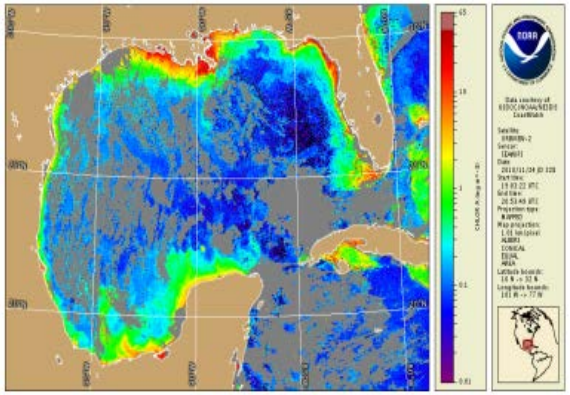
Ocean Color Operational Products

- Daily mean, Bi-Monthly Mean and Anomaly of 1 km Chlorophyll concentration (MERIS and MODIS/Aqua) (http://www.osdpd.noaa.gov/ml/ocean/index.html):
- Harmful Algal Bloom Bulletins (National Ocean Service and NESDIS) (http://tidesandcurrents.noaa.gov/hab/)
- Daily, Bi-Monthly Mean and Anomaly of 1 km MODIS/Aqua Ocean Color (Remote Sensing Reflectance at 667 nm) (http://www.osdpd.noaa.gov/ml/ocean/index.html):

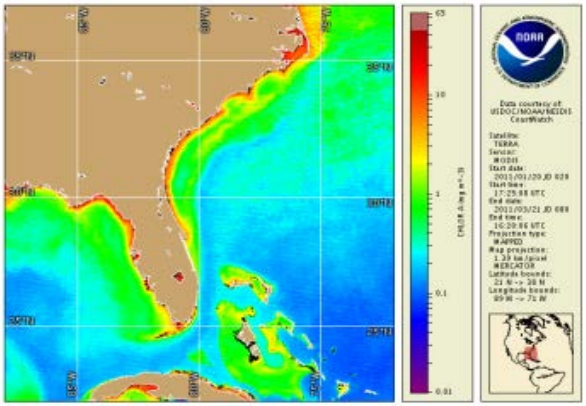
(Format: HDF 4.1, GeoTiff, PNG, NetCDF4 (2011))

Operational Ocean Color Products Example

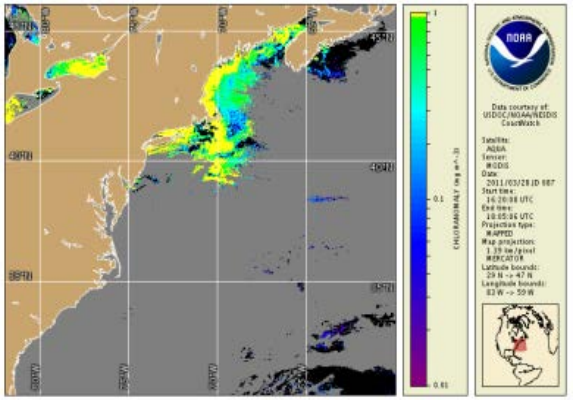
Daily chlorophyll concentration



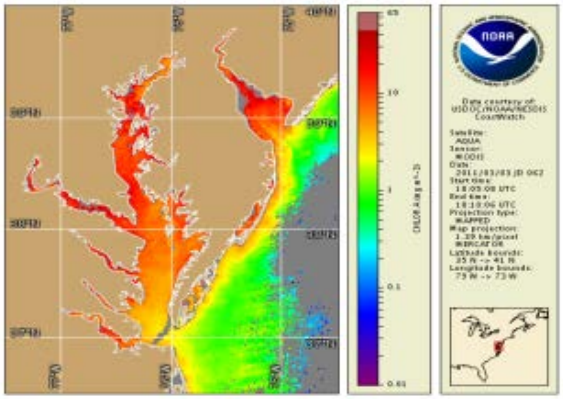
Bimonthly-mean chlorophyll concentration



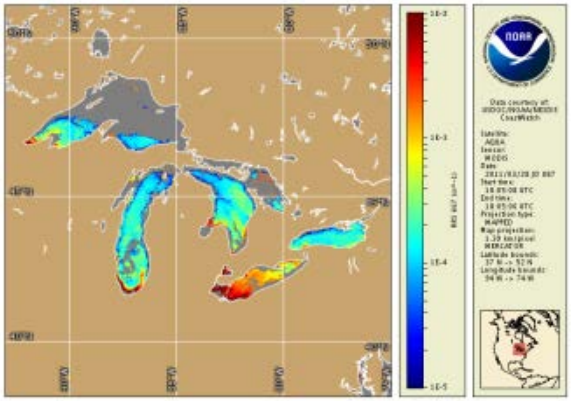
New algal growth (Positive chlorophyll concentration anomaly)



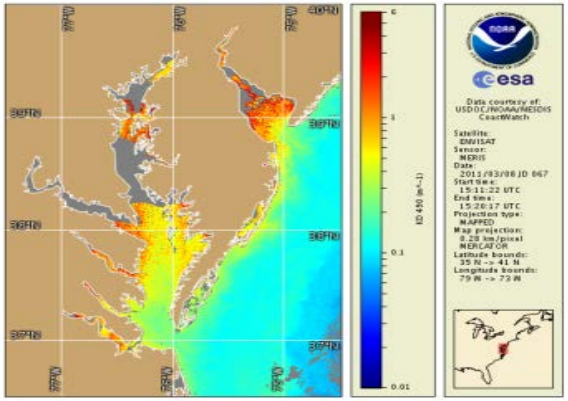
Chesapeake Bay daily chlorophyll concentration



Suspended sediment proxy (Remote sensing reflectance at 667 nm)

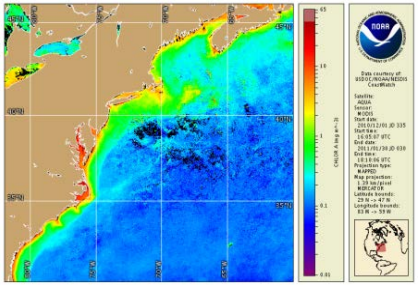


Water turbidity (Diffuse attenuation coefficient at 490 nm)

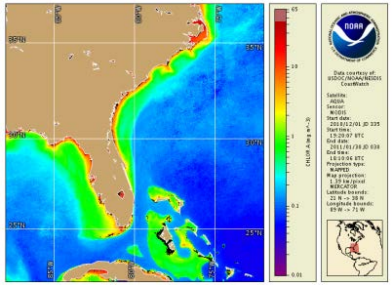


MODIS/Aqua OC Product Coverage

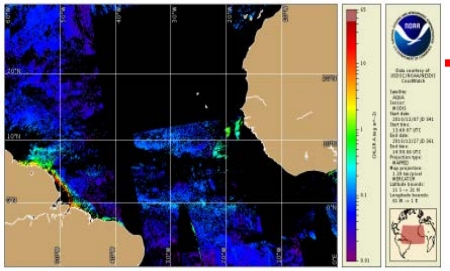
Northeast



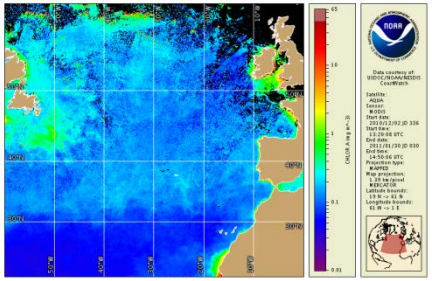
Southeast



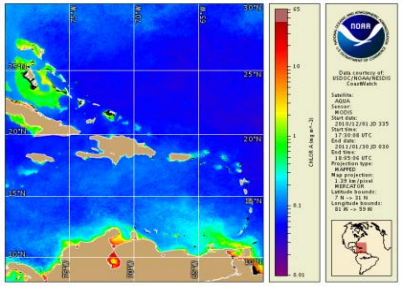
Equatorial Atlantic



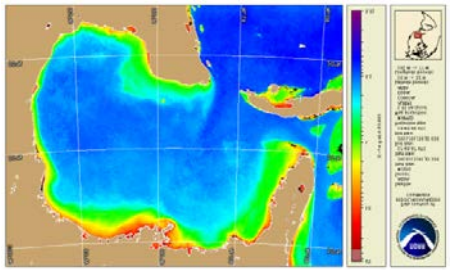
North Atlantic



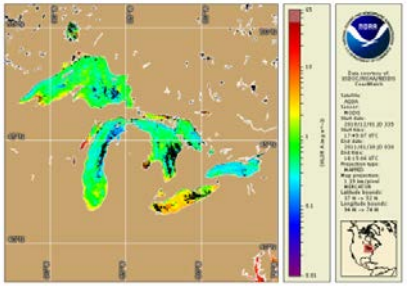
Caribbean



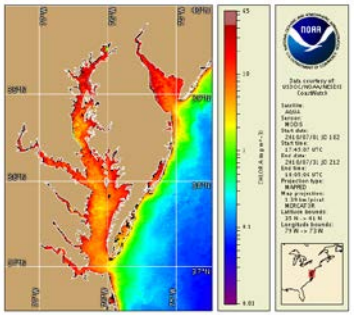
Gulf of Mexico



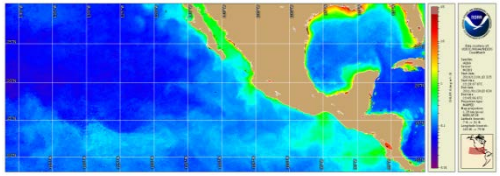
Great Lakes



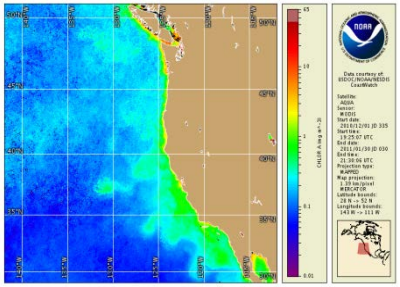
Chesapeake Bay



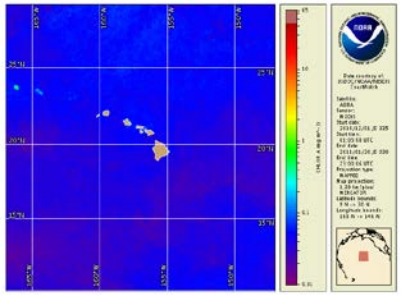
Eastern Tropical Pacific



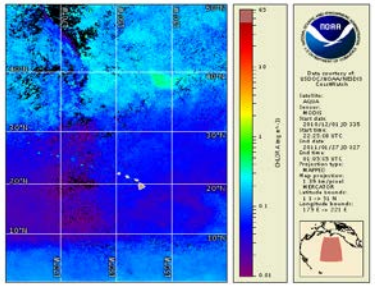
West Coast



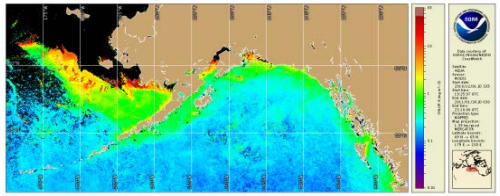
Hawaii



Pacific Basin



Alaska

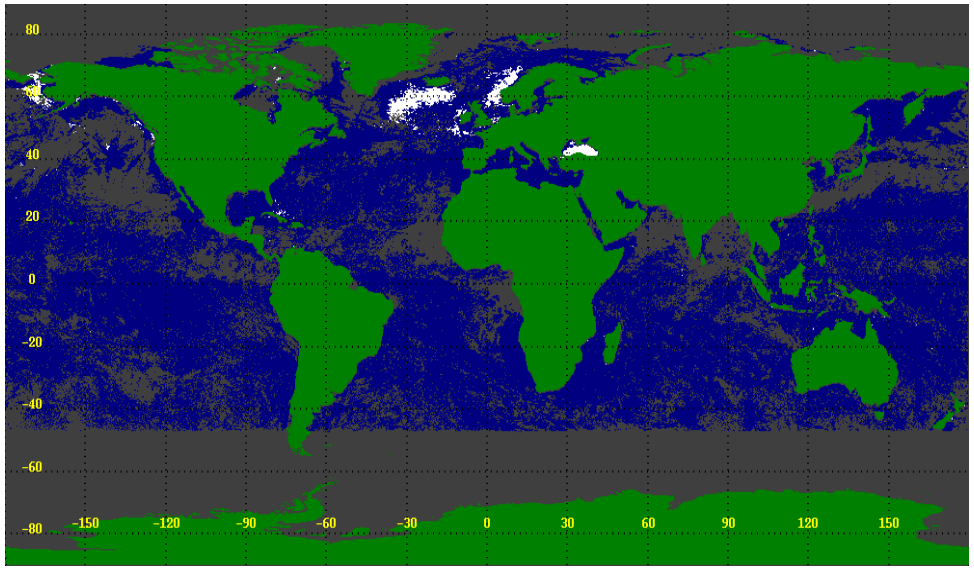


Ocean Color Developmental Products

- Chlorophyll concentration (MODIS/Terra)
- Ocean Color (Remote Sensing Reflectance at 665 for MERIS and at 667 nm for Terra)
- MODIS/Aqua SWIR OC products(USA coastal areas)
- Global MODIS/Aqua Ehux map (calcite + presence/absence)
- MODIS/Aqua chlorophyll frontal products

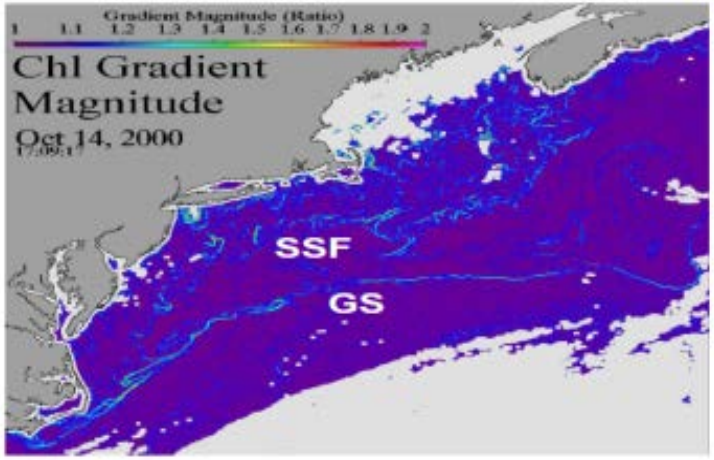
Developmental Ocean Color Products Example

Global 8-day, 9-km composite of E. huxleyi bloom presence
(Courtesy of Christopher Brown)

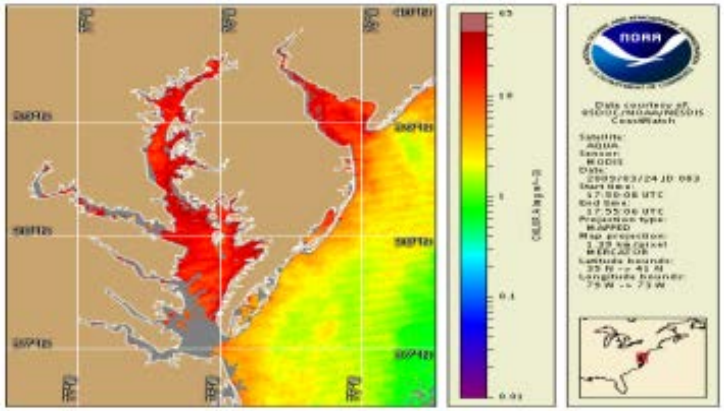


Global 8-day, 9-km composite of E. huxleyi bloom presence from SeaWiFS data for 10-17 June 1998. The *E. huxleyi* bloom class is white, the non-bloom class is blue, the land is green, and locations with no data are gray

Daily chlorophyll front distribution
(Courtesy of Igor Belkin)



Daily chlorophyll concentration using SWIR
(Courtesy of Menghua Wang)



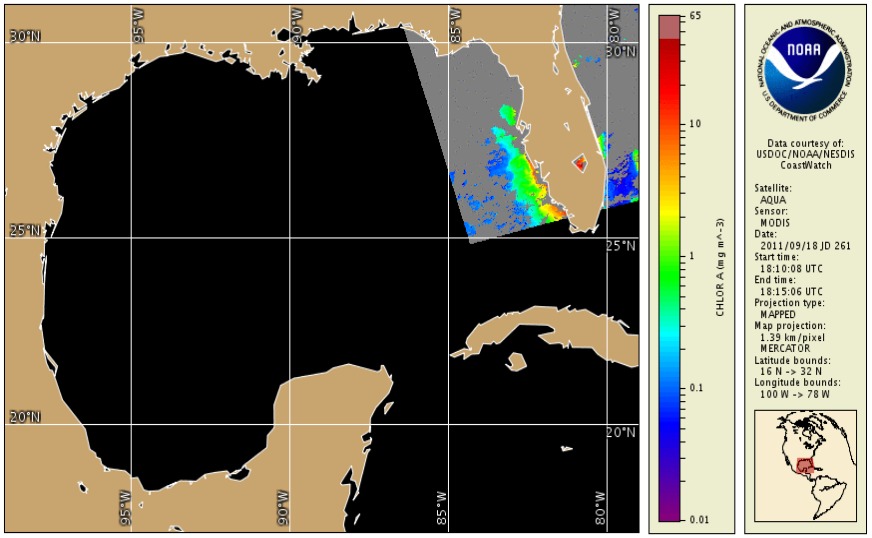
A Statistical Analysis of Ocean Color Products for NWP Application

Key Information of Chlorophyll Concentration for Ocean Color Data Assimilation:

- Dynamic range of chlorophyll concentration
- Spatial characteristics of chlorophyll concentration
- Temporal characteristics of chlorophyll concentration

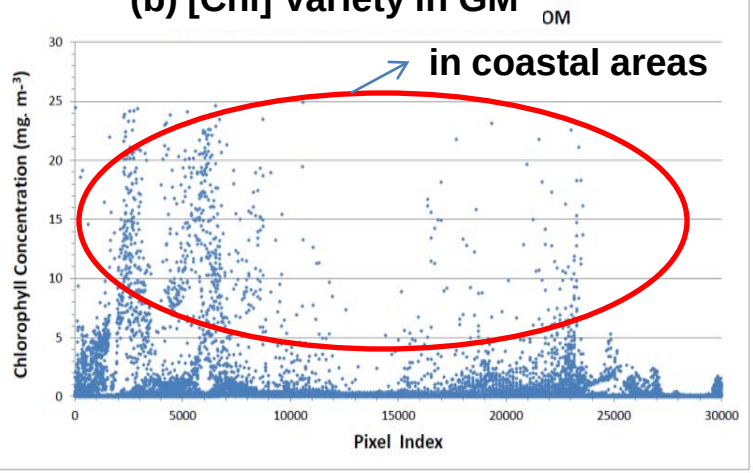
Daily Distribution Characteristics of Chlorophyll Concentration ([Chl])

(a) Distribution of Daily [Chl] in Gulf of Mexico (GM)

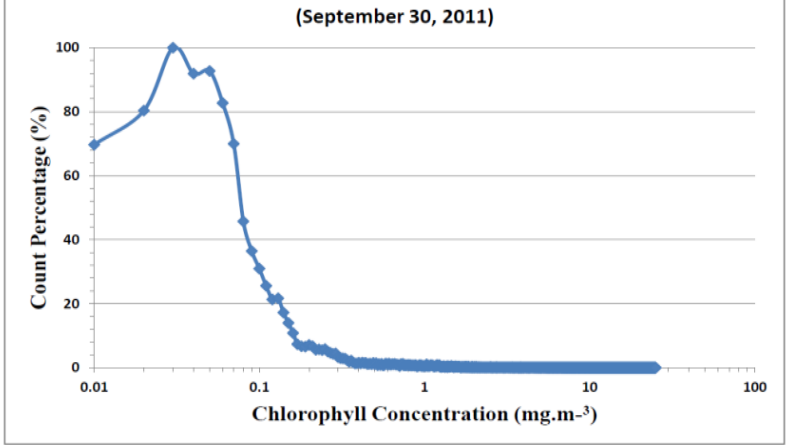


- [Chl] changes significantly with location
- [Chl] distributes primarily between 0.01 and 1 mg/m^3 over open oceans , while it can be up to 10 mg/m^3 in coastal areas
- [Chl] changes slowly with day

(b) [Chl] Variety in GM

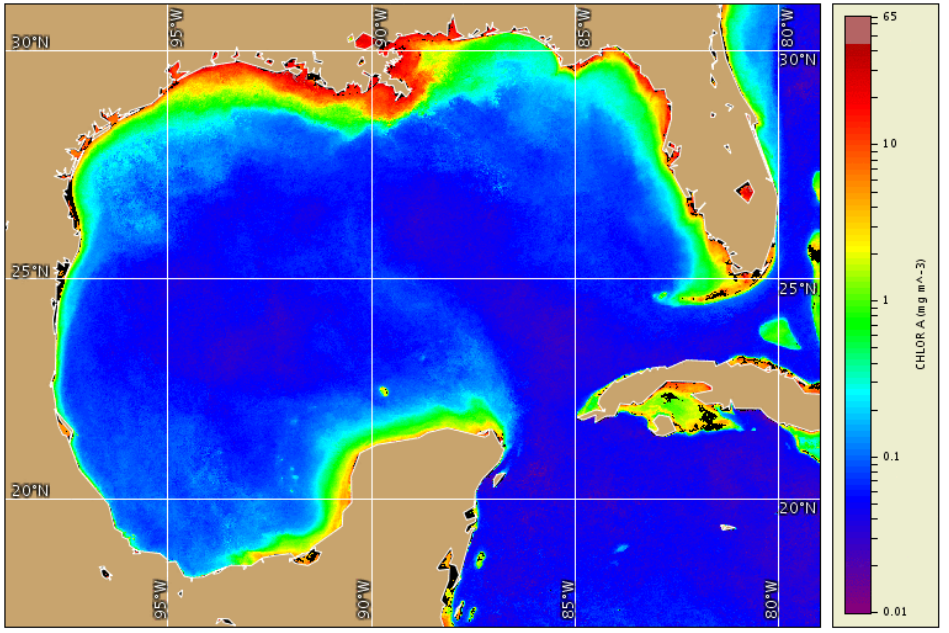


(c) [Chl] Histogram in GOM

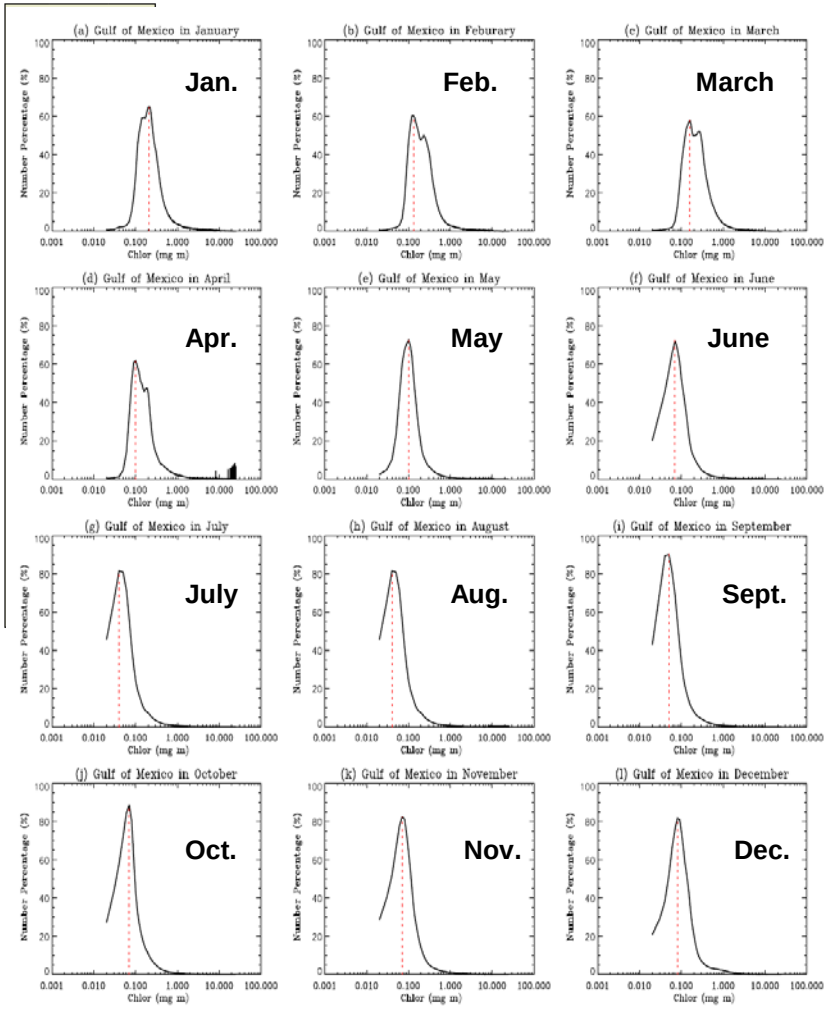


Bimonthly Mean Distribution of Chlorophyll Concentration in Gulf of Mexico

(a) Distribution of bimonthly-mean [Chl]



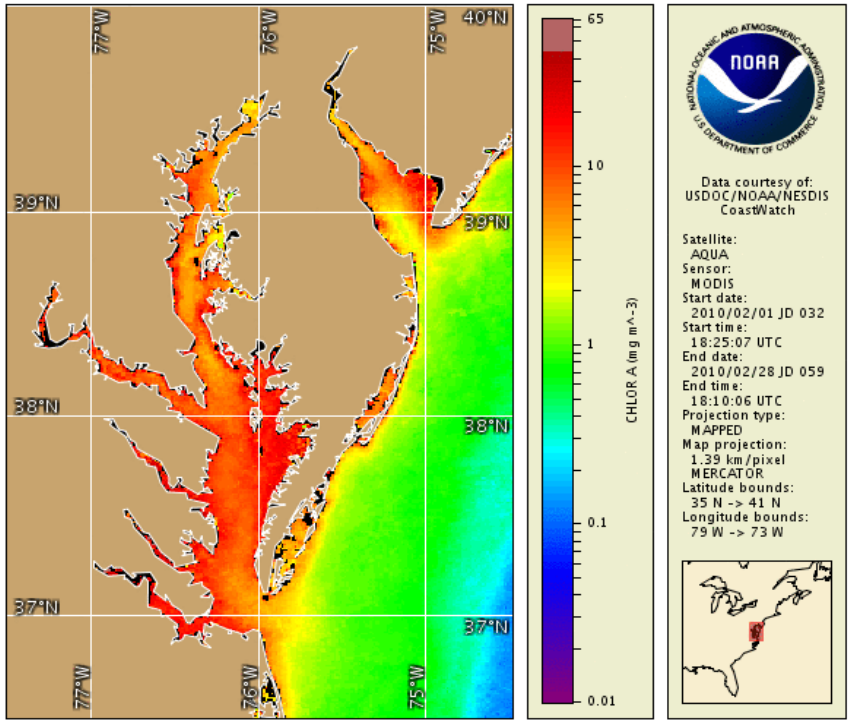
(b) Histogram of monthly-mean [Chl]



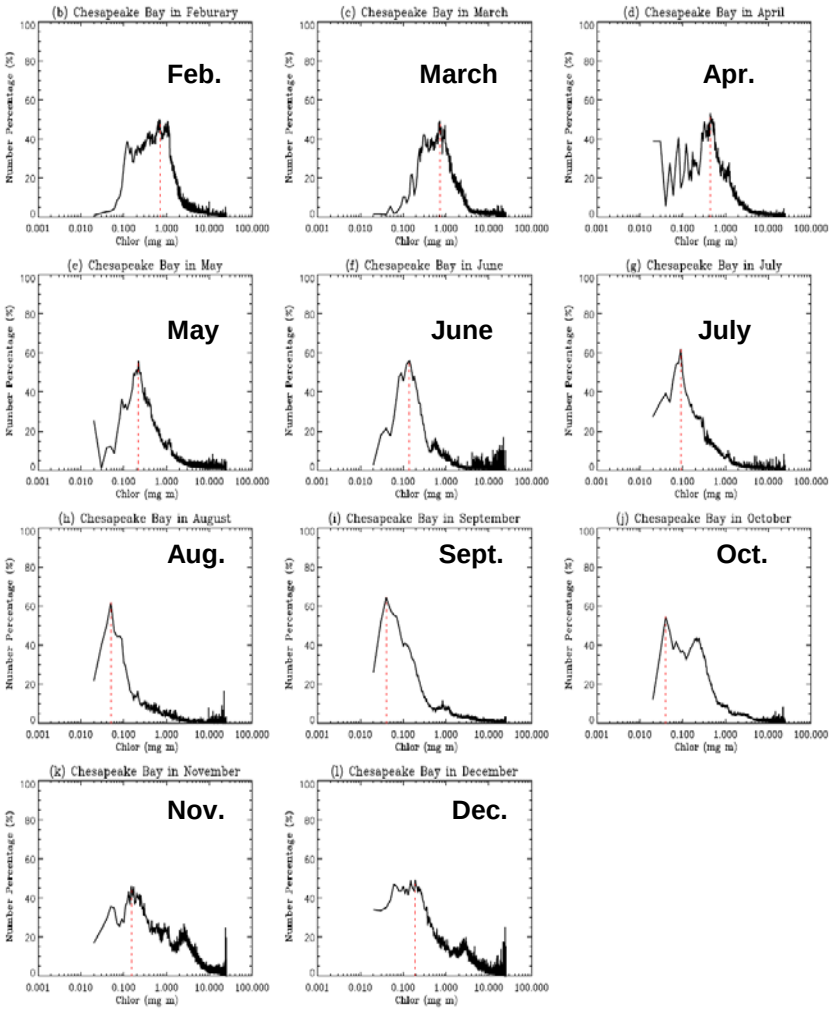
- [Chl] changes significantly with location
- [Chl] distributes primarily between 0.01 and 1 mg/m^3 over open oceans , while it can be up to 10 mg/m^3 in coastal areas
- Bimonthly-mean [Chl] in coastal areas changes obviously with time

Monthly Mean Distribution of Chlorophyll Concentration in Chesapeake Bay

(a) Distribution of monthly-mean [Chl]



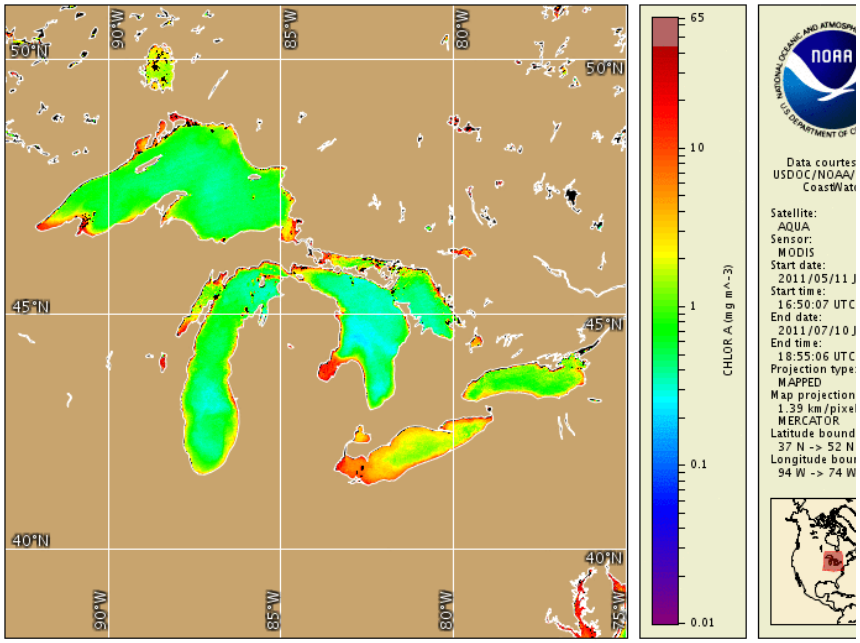
(b) Histogram of monthly-mean [Chl]



- [Chl] distributes primarily between 0.01 and 10 mg/m^3
- [Chl] changes significantly with location
- Monthly-mean [Chl] changes obviously with time

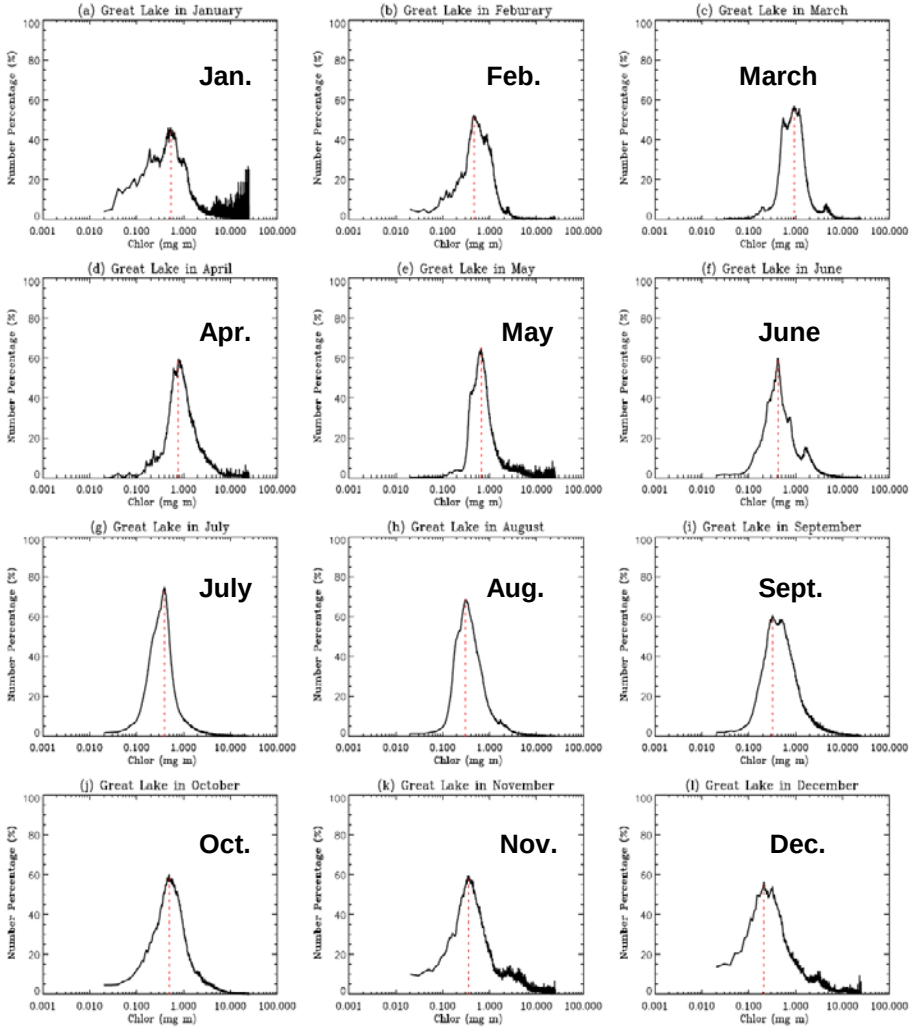
Bimonthly Mean Distribution of Chlorophyll Concentration in Great Lakes

(a) Distribution of bimonthly-mean [Chl]



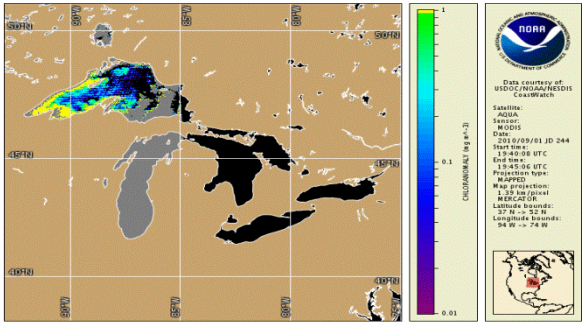
- [Chl] distributes primarily between 0.001 and 10 mg/m^3
- [Chl] changes significantly with location
- [Chl] distribution is relatively stable with time

(b) Histogram of Monthly-mean [Chl]

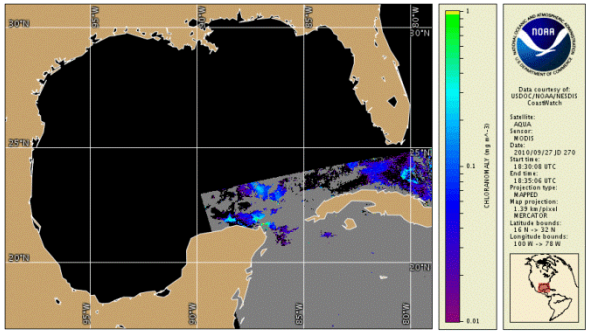


Chlorophyll Concentration Change Relative to Bimonthly Mean (Daily – Bimonthly)

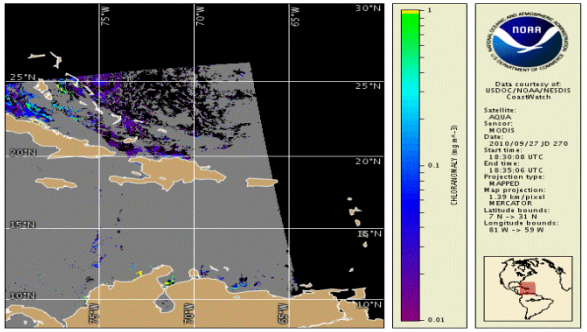
Great Lakes



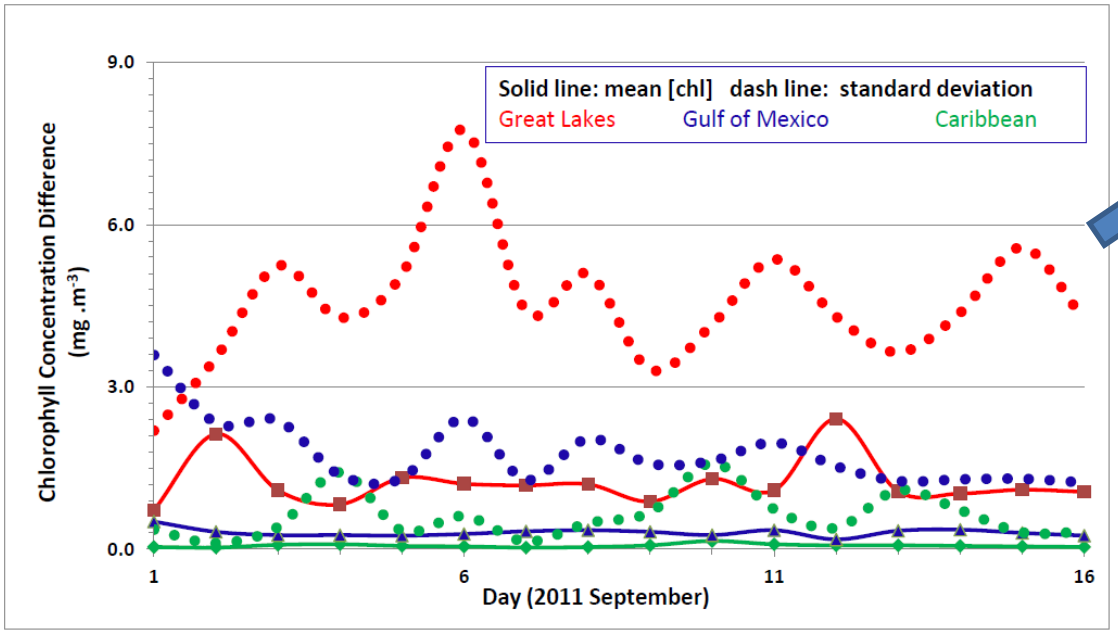
Gulf of Mexico



Caribbean

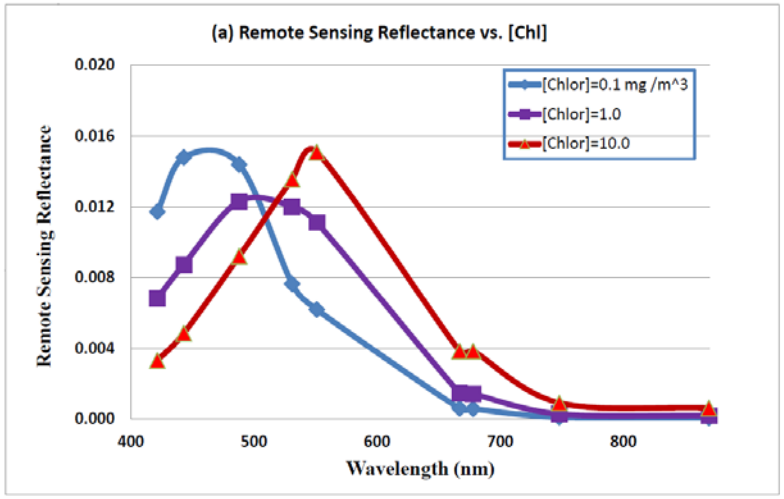


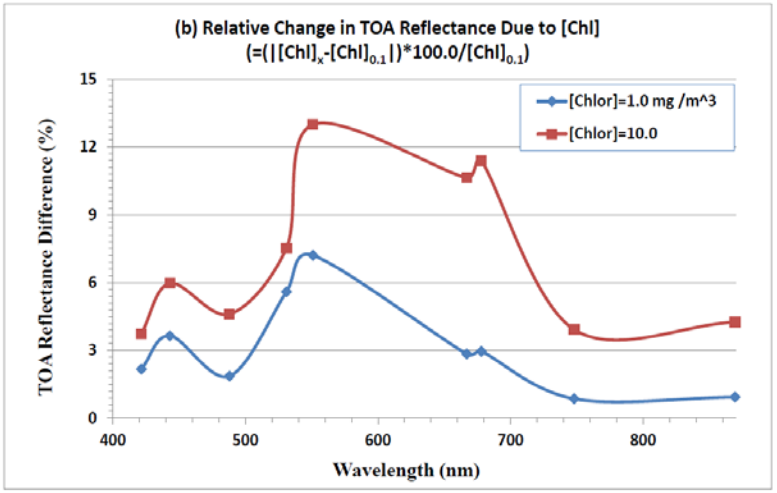
Chlorophyll Concentration Changes Relative to Bimonthly Mean



[Chl] changes relative to bimonthly-mean [Chl] is up to 10 mg/m^3

Impact of Chlorophyll Concentration Change on Satellite Reflectance





- Chlorophyll concentration affects remote sensing reflectance (Rrs) in the ocean surface: Rrs as [Chl] = 10.0 mg/m^3 is almost triple as that as [Chl] = 0.1 mg/m^3
- Resultant satellite reflectance change is primarily between 3% and 10 % depending on wavelength and the highest change occurs at 551 nm for MODIS channels
- Spatial and temporal distributions of chlorophyll concentration needs to be account for in assimilation of satellite ocean color data in NWP model

Summary and Conclusions

- NOAA Okeanos system provides high resolution of ocean color operational products along US oceans, e.g., remote sensing reflectance, diffuse attenuation coefficient at 490 nm, chlorophyll concentration, chlorophyll concentration anomaly, and (bi)monthly-mean chlorophyll concentration
- Chlorophyll concentration distributes primarily between 0.01 and 1 mg/m^3 over open oceans, while it can be between 1 and 10 mg/m^3 or higher in coastal areas which can cause a non-trivial change in satellite radiance especially at the visible channels
- Chlorophyll concentration changes also with time: its variety relative to (bi)month can be a few mg/m^3 which can result in non-trivial change in satellite radiance at the visible channels

Therefore, spatial and temporal distributions of chlorophyll concentration need to be account for in assimilation of satellite ocean color data in NWP model. An option is to use the NOAA CoastWatch Okeanos ocean color Products for this purpose.