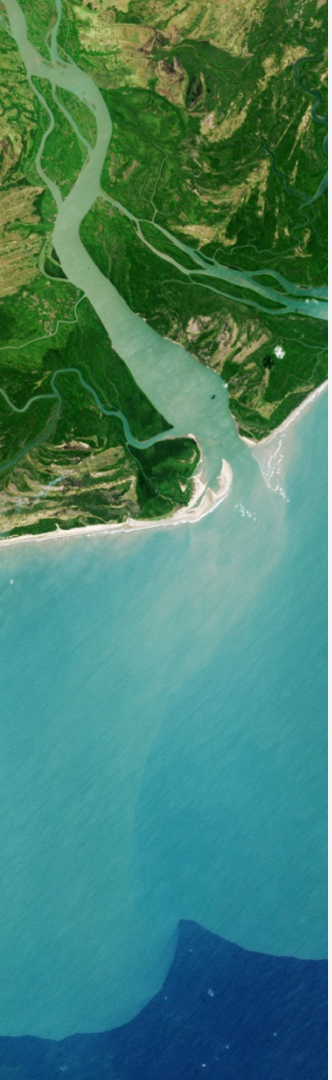


National Aeronautics and Space Administration

ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

@NASAARSET

Introduction to Remote Sensing for Ocean and Coastal Applications

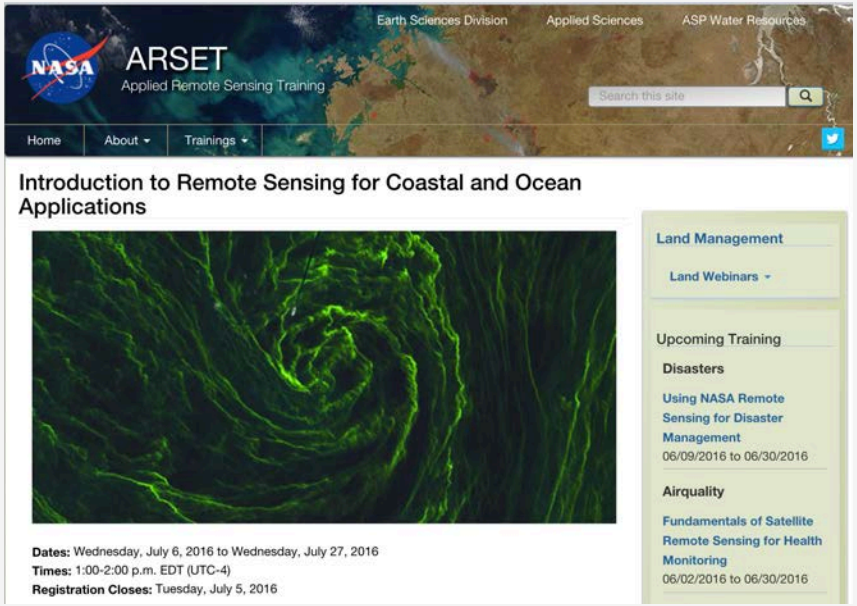
Week 2: Platforms and Sensors for Ocean Observations, Data Access, and Processing Tools

Course Structure

- One lecture per week – every Wednesday July 6 – July 27
- 1:00 – 2:00 PM EDT (UTC-4)
  - Lectures
  - In-class demonstration
  - Homework exercises, due August 10th
- Webinar recordings, presentations, and homework assignments can be found after each session at:
  - http://arset.gsfc.nasa.gov/land/webinars/coastal-oceans-2016
- Q/A: Following each lecture and/or by email (sherry.l.palacios@nasa.gov)

Accessing Course Materials

http://arset.gsfc.nasa.gov/land/webinars/coastal-oceans-2016



Course Agenda:

Agenda.pdf

Session One: Overview of Satellite Remote Sensing of Aquatic Environments

July 6, 2016

An overview of themes in coastal and ocean applied science, how remote sensing is used for coastal and ocean applied science, fundamentals of remote sensing (spatial, temporal, spectral resolutions), and the advantages and limitations of remote sensing in aquatic environments. View the recording »

- Presentation Slides »

Session Two: Platforms and Sensors for Ocean Observations, Data Access, and Processing Tools

July 13, 2016

Satellites and sensors for coastal and ocean applications, satellite data processing levels, NASA satellite data access tools and data processing tools. View the recording »

- Presentation Slides »

Your Course Instructors

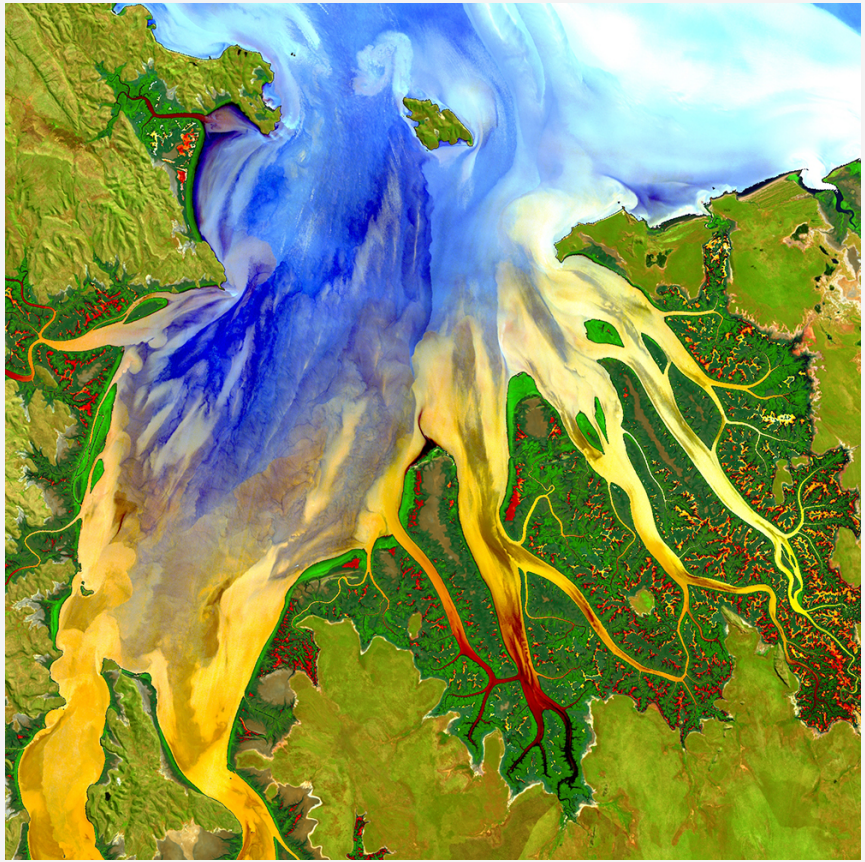
- Sherry Palacios: sherry.l.palacios@nasa.gov
- Amber McCullum: amberjean.mccullum@nasa.gov
- Cindy Schmidt: cynthia.l.schmidt@nasa.gov

- Guest Speakers:
  - Mitchell Roffer, Roffer's Ocean Fishing Forecast Service (Week 3)
  - Mark Eakin, NOAA Coral Reef Watch (Week 4)

- General ARSET Inquiries
  - Ana Prados: aprados@umbc.edu

Course Objectives

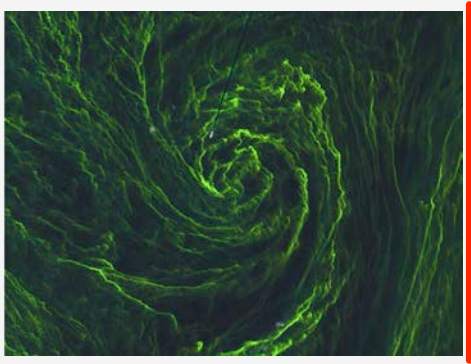
- Overview of NASA Earth Observation resources available for open ocean and coastal applications including:
  - A basic understanding of remote sensing of aquatic systems
  - How to access and visualize NASA Earth science data
  - How to use NASA Earth science data, tools, and products for ocean and coastal applied science issues
- Conduct live demonstrations of useful ocean and coastal applied science tools



Credit: NASA/USGS Landsat; Geoscience Australia

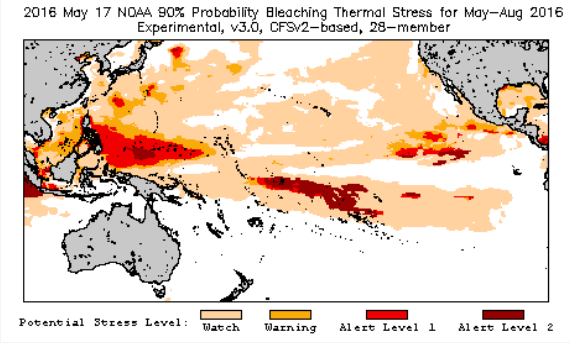
Course Outline

Week 1
Overview of
Satellite
Remote Sensing



Week 2
Platforms
and Sensors
for Ocean
Observations

Week 3
Animal
Movement



Week 4
Coral Reefs

Week 2 Agenda

- Brief Review of Last Week
- Satellites and sensors for coastal and ocean applications
- Satellite data processing level
- NASA satellite data access tools
- NASA satellite data processing tools

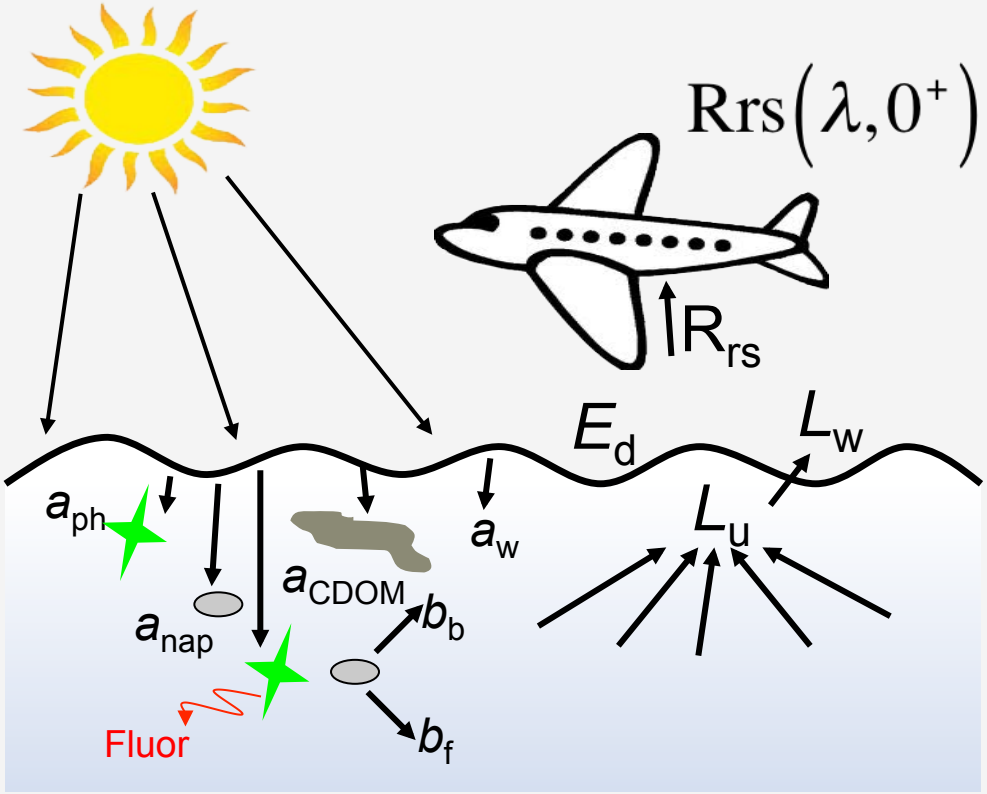
Review of Week 1

Coastal and Open Ocean Applied Science Thematic Areas

- Marine Protected Areas
- Marine Fisheries
- Animal Migrations
- Water Quality
- Harmful Algal Blooms (HABs)
- Eutrophication
- Coral Reef Health
- Marsh Subsidence
- Coastal Development
- Coastal Hazards – flooding, sea level rise

How Light Interacts with the Water

Defining Remote Sensing Reflectance (Rrs) – or 'Ocean Color'



$$Rrs(\lambda,0^+) \cong C\,\frac{b_b(\lambda)}{a(\lambda)+b_b(\lambda)} = \frac{L_w(\lambda)}{E_d(\lambda,0^+)}$$

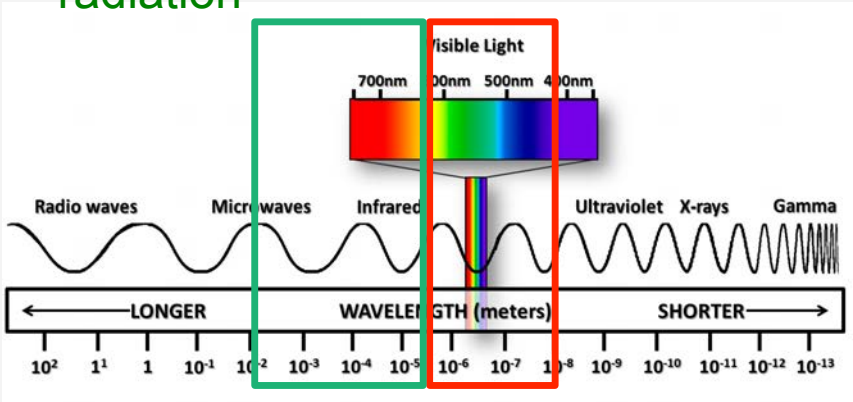
a = absorption
b = scattering

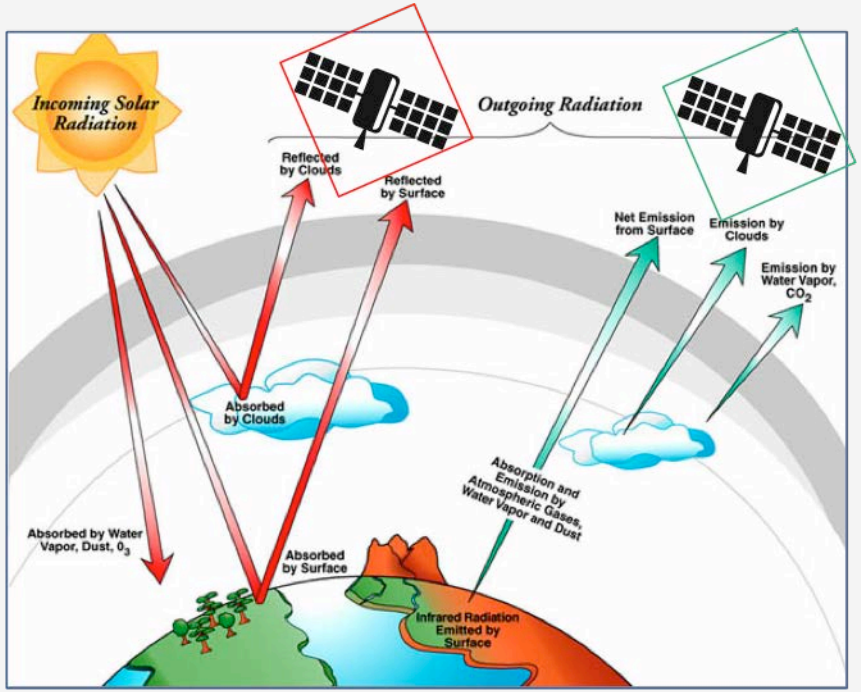
L_w = water leaving radiance
E_d = downwelling irradiance

An Overview of Satellite Remote Sensing

Satellites carry instruments/sensors to measure:

- reflected solar radiation
- emitted infrared and microwave radiation





Satellites and Sensors for Coastal and Open Ocean Applications

Overview of NASA Satellites & Sensors for Water Quality Monitoring

- Currently several satellites observe water surface properties in:
  - *the open ocean*
  - *coastal oceans and estuaries*
  - *many inland lakes*
- A number of water quality parameters are operationally available from these satellites
  - (e.g. temperature, chlorophyll-a)

NASA Satellites & Sensors for Ocean and Coastal Systems

Satellite	Sensor	Parameter
Landsat Series (7/1972 - present)	• Thematic Mapper (TM) • Enhanced Thematic Mapper (ETM+) • Operational Land Imager (OLI)	• Spectral Reflectance
Terra (12/1990-present)	Moderate Resolution Imaging Spectroradiometer (MODIS)	• Spectral Reflectance • Chlorophyll-a Concentration • Temperature • Colored Dissolved Organic Matter (CDOM) • Turbidity • Euphotic Depth
Aqua (5/2002-present)		
Terra (12/1999 – present)	Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)	• Spectral Reflectance • Temperature

NASA Satellites & Sensors for Ocean and Coastal Systems

Satellite	Sensor	Parameter
National Polar Partnership (NPP) (11/2011-present)	Visible Infrared Imaging Radiometer Suite (VIIRS)	• Spectral Reflectance • Chlorophyll Concentration
International Space Station	Hyperspectral Imager for the Coastal Ocean (HICO) (2009 – 2014)	• Spectral Radiance • Spectral Remote Sensing Reflectance
Plankton, Aerosols, Clouds, ocean Ecosystems, PACE (proposed for 2022 or 2023)	Ocean Color Instrument	• Spectral Reflectance • Optional Polarimeter being considered

Landsat Satellites and Sensors

http://landsat.gsfc.nasa.gov/

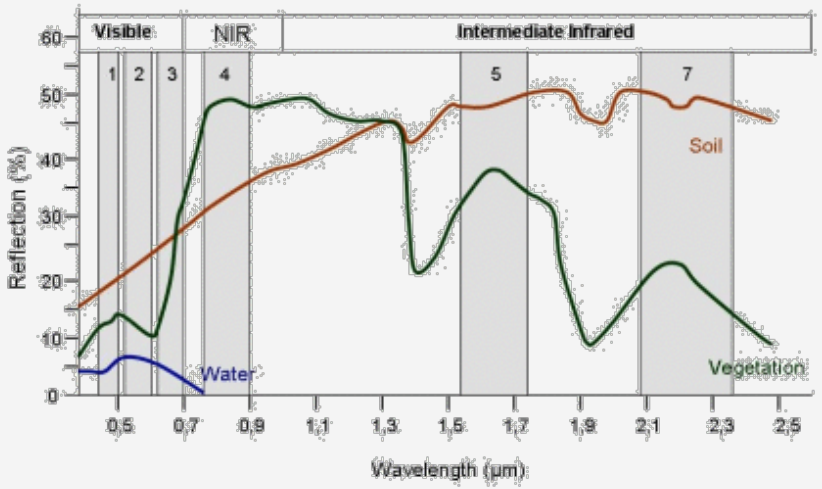
http://landsat.usgs.gov//about_mission_history.php

- Near-polar orbit
- 10 a.m. equator-crossing time
- Global coverage
- July 1972 – present
- 16 day revisit time
- Sensors
  - MSS
  - TM
  - ETM+
  - OLI
  - TIRS

Landsat-7 Enhanced Thematic Mapper (ETM+)

http://geo.arc.nasa.gov/sge/landsat/l7.html

- Flying on-board Landsat 7 polar orbiting satellites
- Spatial Coverage and Resolution:
  - Global, swath 185km
  - Spatial Resolution: 15m, 30m, 60m
- Temporal Coverage and Resolution
  - April 15, 1999 – present
  - 16 day revisit time
- Spectral Bands
  - 8 bands (major bands include: blue-green, green, red, reflected and thermal IR, and panchromatic)

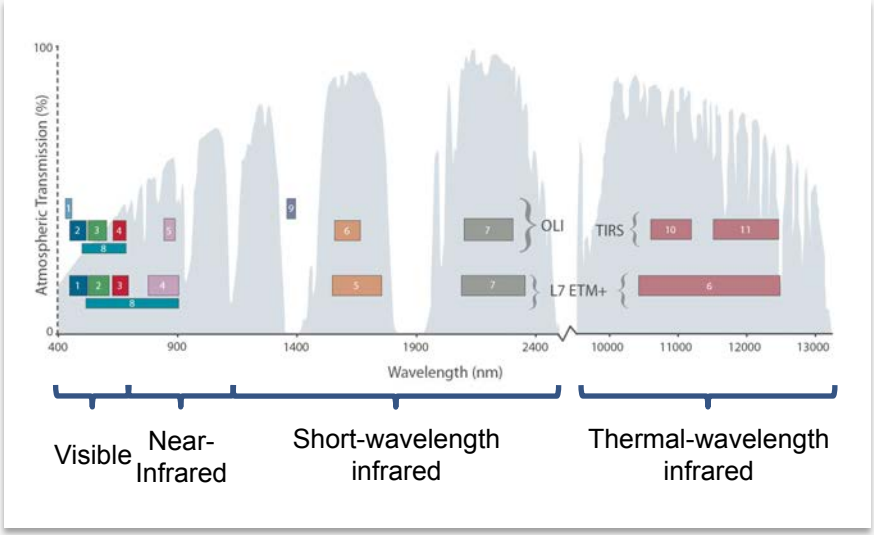


- Spectral Bands
  - Bands 1-5, 7: 30m
  - Band 6: 60m
  - Band 8: 15m

Landsat-8 Operational Land Imager (OLI)

http://landsat.usgs.gov/landsat8.php; http://landsat.gsfc.nasa.gov/?p=5779

- Flying on-board Landsat 8 (Landsat Data Continuity Mission – LDCM) polar orbiting satellite
- Spatial Coverage & Resolution:
  - Global, Swath 185km
  - Spatial Resolution: 15m, 30m
- Temporal Coverage & Resolution:
  - February 11, 2013 – present
  - 16 day revisit time
- Spectral Bands
  - 9 bands (major bands include blue-green, red, near IR, shortwave and thermal IR, panchromatic)



- Spectral Bands
  - Bands 1-7, 9: 30m
  - Band 8: 15m

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  - 9 bands (major bands include blue-green, red, near IR, shortwave and thermal IR, panchromatic)

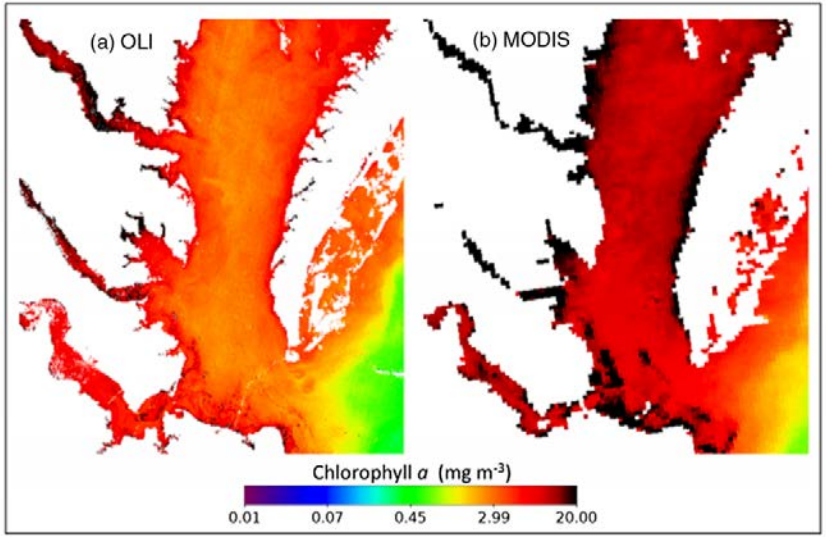


Fig. 3 Images of chlorophyll *a* concentration retrieved from OLI and MODIS Aqua over Chesapeake Bay on September 5, 2013. The MODIS data were collected on the same day, about 3 h later. The chlorophyll *a* concentration was retrieved using standard NASA ocean color processing in SeaDAS.

Franz et al. 2015
http://oceancolor.gsfc.nasa.gov/cmsdocs/papers/franz_et_al_2015_jars.pdf

Terra and Aqua

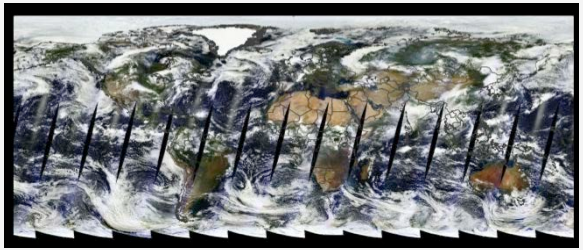
http://terra.nasa.gov/; http://aqua.nasa.gov/

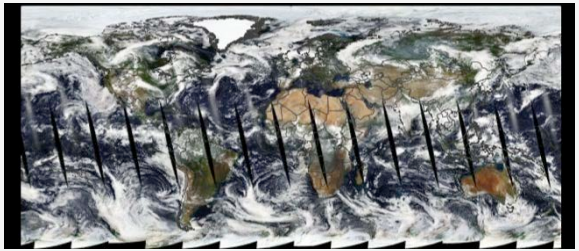
Terra

- Polar orbit, 10:30 a.m. equator crossing time
- Global Coverage
- December 18, 1999 – present
- 1-2 observations per day
- Sensors:
  - ASTER, CERES, MISR, MODIS, MOPITT

Aqua

- Polar orbit, 1:30 p.m. equator crossing time
- Global Coverage
- May 4, 2002 – present
- 1-2 observations per day
- Sensors:
  - AIRS, AMSU, CERES, MODIS, AMSR-E

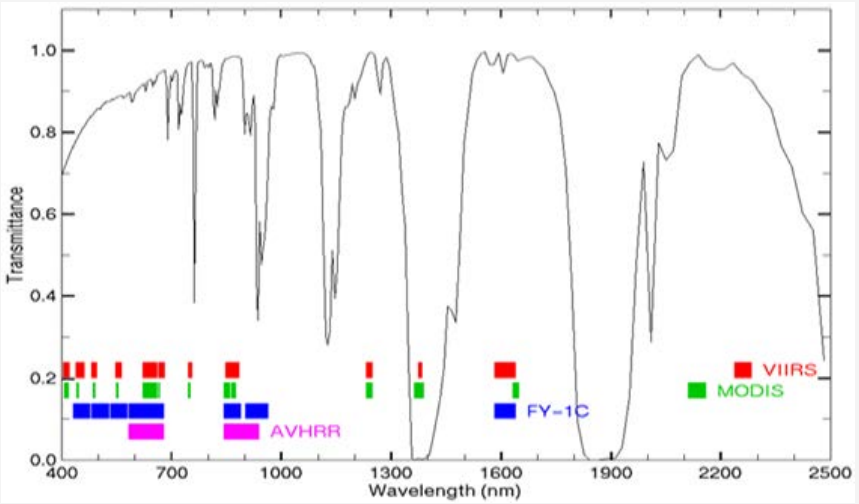




MODerate Resolution Imaging Spectroradiometer (MODIS)

http://modis.gsfc.nasa.gov

- Flying on-board Terra and Aqua – polar orbiting satellites
- Designed for land, atmosphere, ocean, and cryosphere observations
- Spatial Coverage & Resolution
  - Global, swath width 2300km
  - Spatial resolution: 250m, 500m, 1km
- Temporal Coverage and Resolution
  - 2000 – present
  - 2 times per day
- Spectral Bands
  - 36 bands (major bands include red, blue, IR, NIR, MIR)

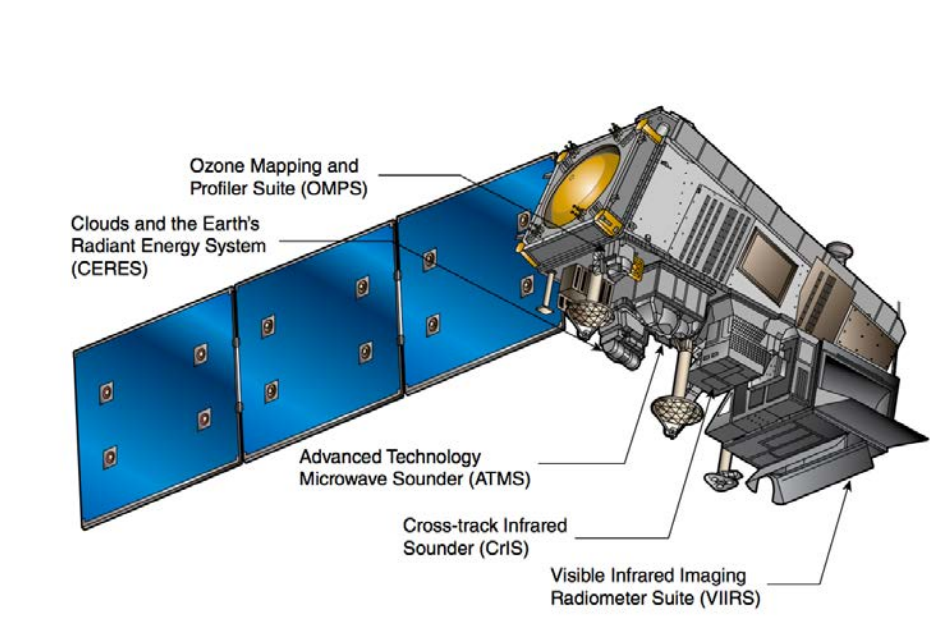


Paul Menzel, http://cimss.ssec.wisc.edu/

- Spectral Bands
  - Bands 1-2: 250m
  - Bands 3-7: 500m
  - Bands 8-36: 1000m

National Polar Partnership (NPP)

http://www.nasa.gov/mission_pages/NPP



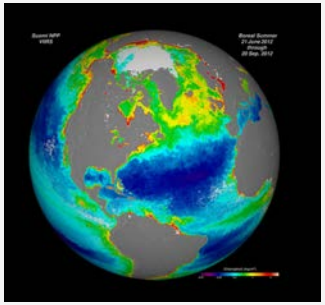
NASA/NOAA

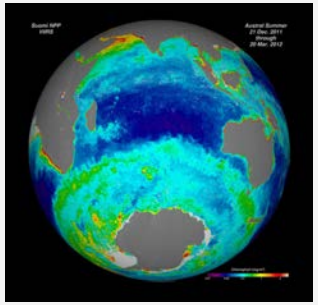
- Polar orbit
- 1:30 p.m. equator crossing time
- Global coverage
- November 21, 2011 – present
- 1-2 observations per day
- Sensors
  - VIIRS
  - ATMS
  - CrIS
  - OMPS
  - CERCES

Visible Infrared Imaging Radiometer Suite (VIIRS)

http://npp.gsfc.nasa.gov/viirs.html

- Flying on-board NPP, polar-orbiting satellite
- Designed to collect measurements of clouds, aerosols, ocean color, surface temperature, fires, and albedo
- Spatial Coverage and Resolution:
  - Global, swath width: 3,040 km
  - Spatial resolution: 375m – 750m
- Temporal Coverage
  - October 2011 – present
  - 2 times per day



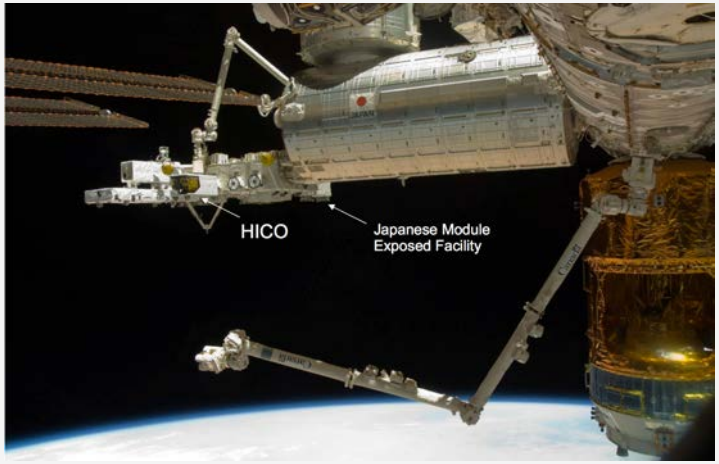


- Spectral Bands
  - 15 bands (major bands include visible, red, blue, green, short, middle, and long-wave IR)
  - Ocean Color Bands 1-7: 0.402-0.682µm
  - Sea Surface Temperature Bands 12-13: 3.660-4.128µm

Hyperspectral Imager for the Coastal Ocean (HICO)

http://hico.coas.oregonstate.edu/ ; http://oceancolor.gsfc.nasa.gov/cms/data/hico

- Partnership with US Naval Research Lab, Office of Naval Research, Oregon State University, and NASA
- Active 2009 – 2014 aboard the International Space Station (ISS)
- 380 nm to 960 nm at 5.7 nm spectral resolution
- 90 m^2 spatial resolution
- Targeted data collection

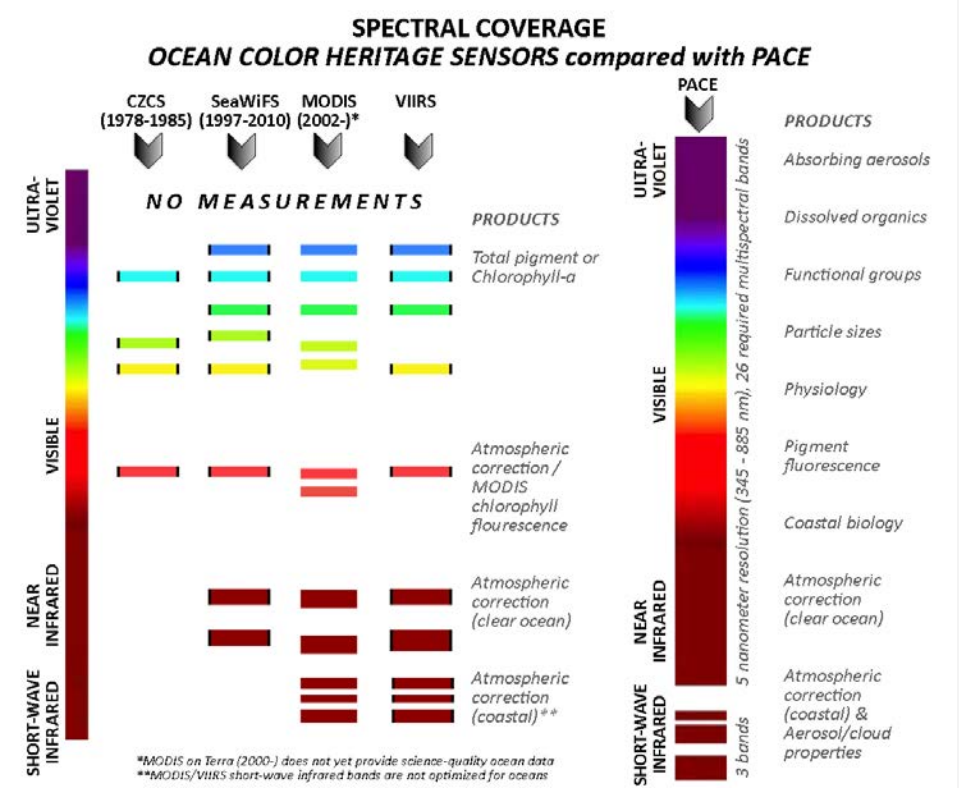


http://www.ioccg.org/sensors/Davis_HICO_IOCCG-15.pdf

Plankton, Aerosol, Clouds, ocean Ecosystem (PACE)

http://pace.gsfc.nasa.gov/

- Polar orbiting, 2-day revisit
- High spectral resolution
- 1 km ground sample distance
- Optional polarimeter being considered for cloud and aerosol study and to aid in atmospheric correction



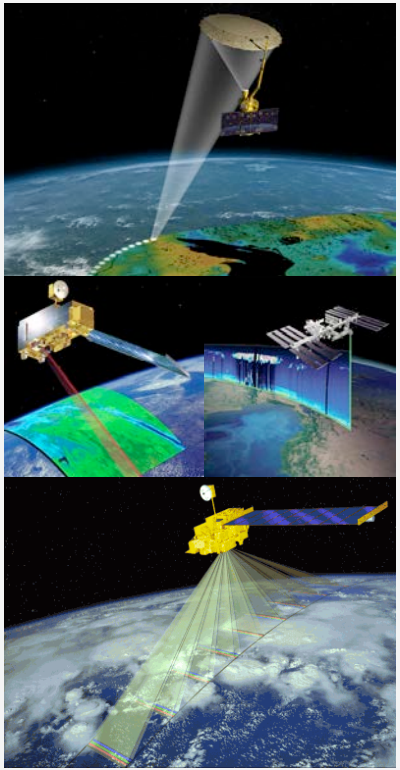
From: http://pace.gsfc.nasa.gov/

Satellite Data Processing Level

Levels of Data Processing

http://oceancolor.gsfc.nasa.gov/cms/products

- Level 0: unprocessed instrument data at full resolution, rawest format available
- Level 1A: reconstructed and unprocessed instrument data at full resolution, Level 1B: L1A data with instrument/radiometric calibrations applied
- Level 2: Derived geophysical variables at same resolution as L1 data
- Level 3: L2 projected onto a well defined spatial grid over a well-defined time period
- Level 4: model output or results from analyses of lower level data (e.g., Primary Productivity)



Data Processing Levels

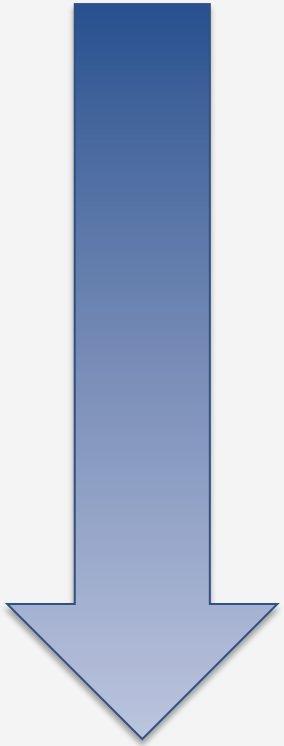
L0: Raw instrument data

L1: Geolocated and calibrated

L2: Products derived from L1B

L3: Gridded and quality controlled

L4: Model output: derived variables



Harder to Use

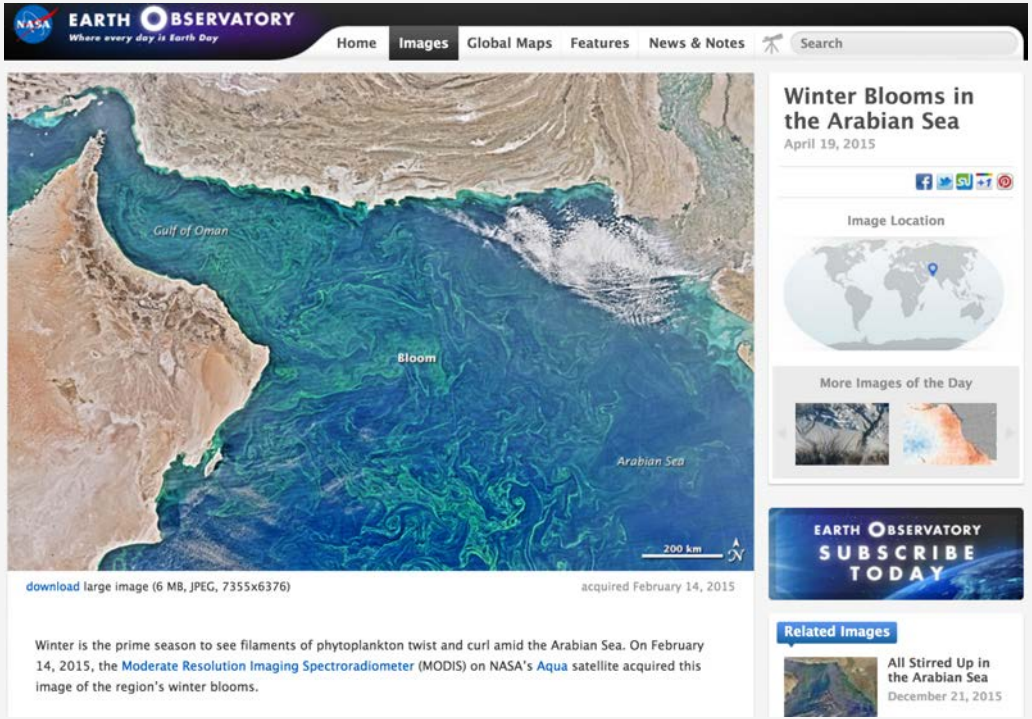
Easier to Use

NASA Satellite Data Access Tools

Phytoplankton Bloom in the Arabian Sea

http://earthobservatory.nasa.gov/IOTD/view.php?id=85718

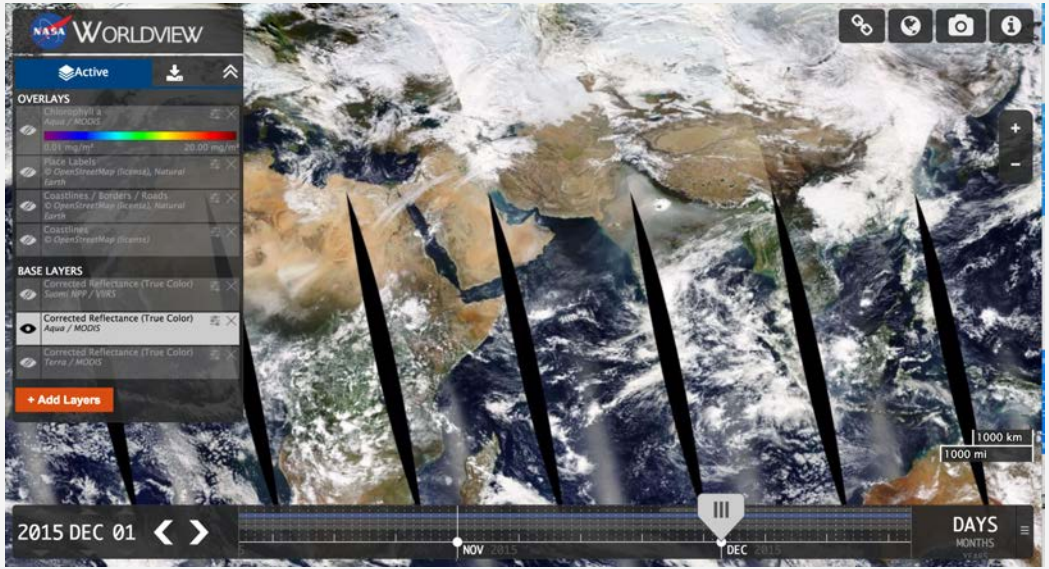
- Winter is the prime season for phytoplankton blooms due to monsoon wind shifts that bring more nutrients to the surface
- A recent phase shift from diatoms to dinoflagellates may have an impact on the food web
- The phase shift is due to changing surface oxygen concentrations



NASA Worldview

https://worldview.earthdata.nasa.gov/

- Interactive web-based tool for browsing satellite imagery
- Imagery is generally available within four hours of observation
- Daily imagery from May 2012 to present
- Data can be downloaded
- Image output in JPEG, PNG, GeoTIFF, and KML formats



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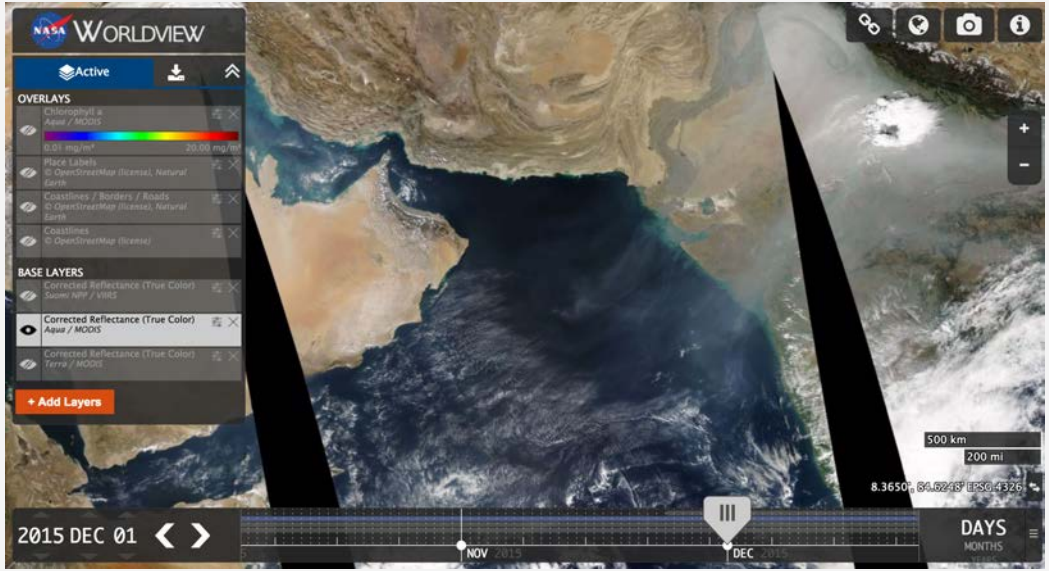

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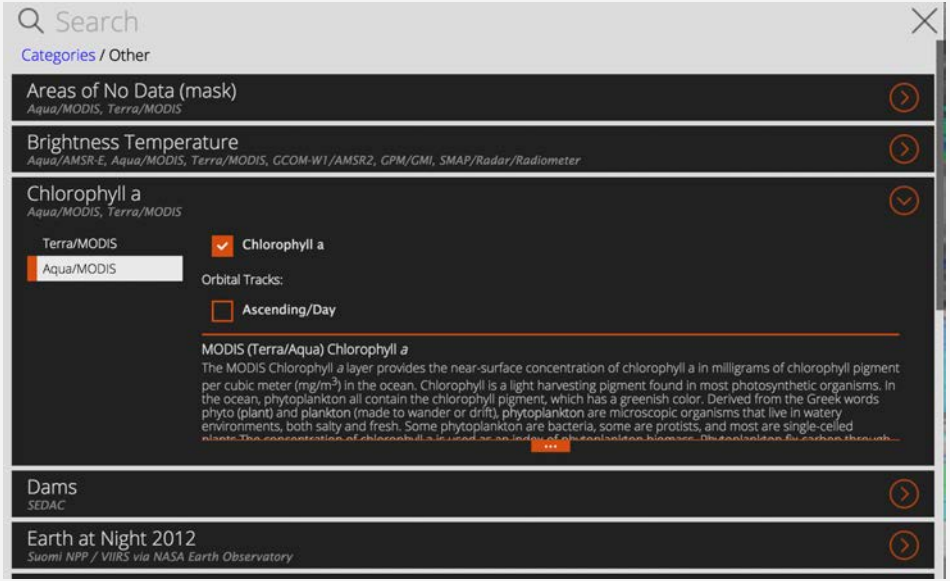

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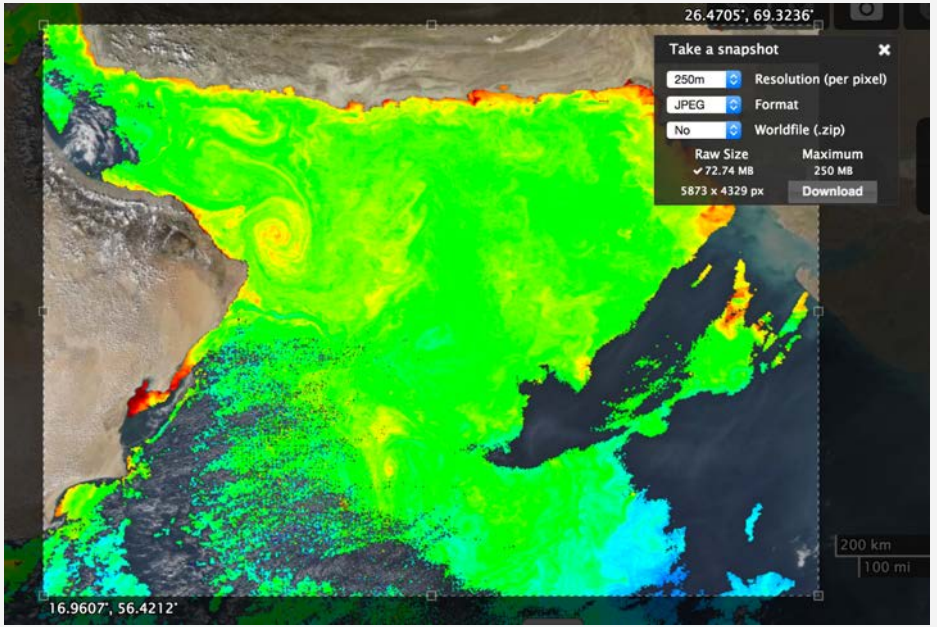
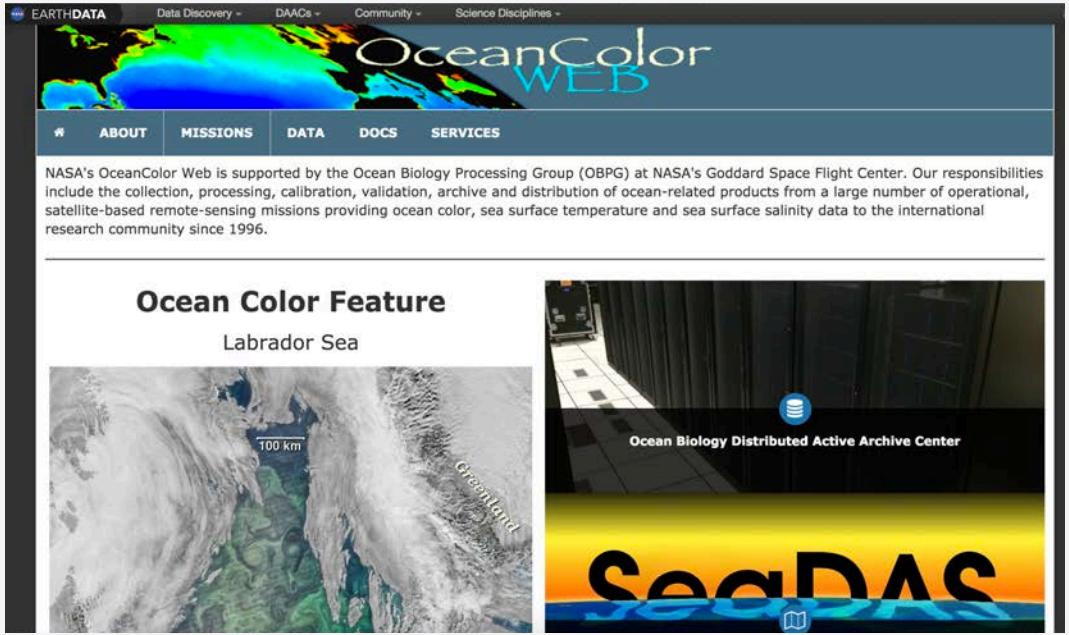


NASA OceanColor Web

http://oceancolor.gsfc.nasa.gov/

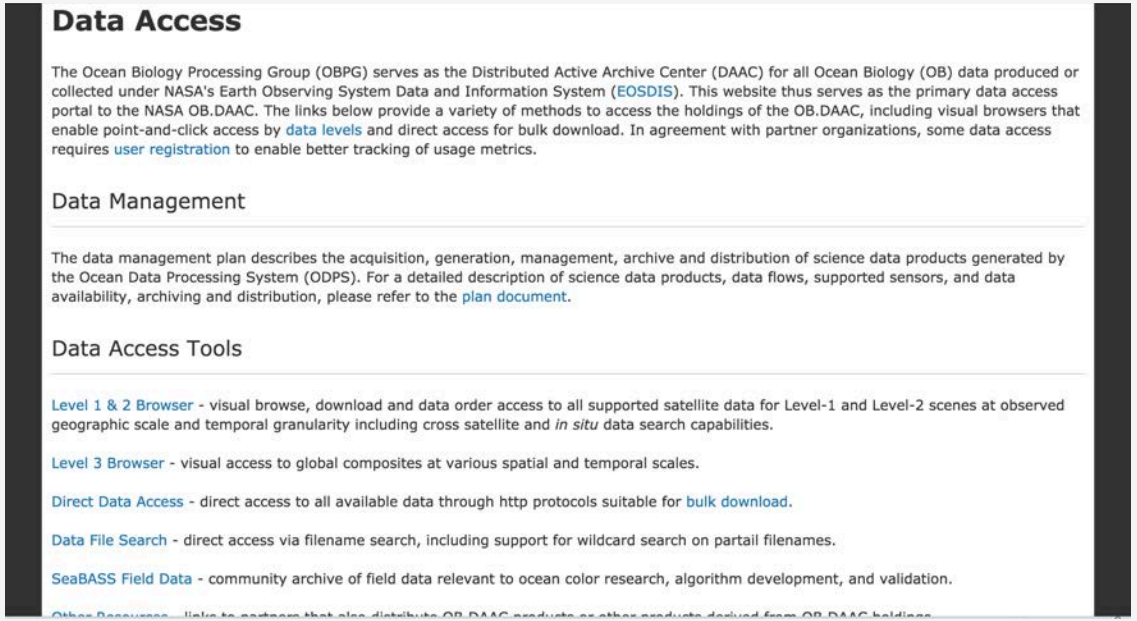
- OceanColor Web is supported by the Ocean Biology Processing Group (OBPG) at NASA Goddard
- OBPG's duties include collection, processing, calibration, validation, archive, and distribution of ocean-related data products from a large number of satellite missions



NASA OceanColor Web – Data Access

http://oceancolor.gsfc.nasa.gov/cms/dataaccess

- Level 1 & 2 Browser
- Level 3 Browser
- Direct Data Access
- Data File Search
- SeaBASS Field Data



Data Access

The Ocean Biology Processing Group (OBPG) serves as the Distributed Active Archive Center (DAAC) for all Ocean Biology (OB) data produced or collected under NASA's Earth Observing System Data and Information System (EOSDIS). This website thus serves as the primary data access portal to the NASA OB.DAAC. The links below provide a variety of methods to access the holdings of the OB.DAAC, including visual browsers that enable point-and-click access by data levels and direct access for bulk download. In agreement with partner organizations, some data access requires user registration to enable better tracking of usage metrics.

Data Management

The data management plan describes the acquisition, generation, management, archive and distribution of science data products generated by the Ocean Data Processing System (ODPS). For a detailed description of science data products, data flows, supported sensors, and data availability, archiving and distribution, please refer to the plan document.

Data Access Tools

Level 1 & 2 Browser - visual browse, download and data order access to all supported satellite data for Level-1 and Level-2 scenes at observed geographic scale and temporal granularity including cross satellite and *in situ* data search capabilities.

Level 3 Browser - visual access to global composites at various spatial and temporal scales.

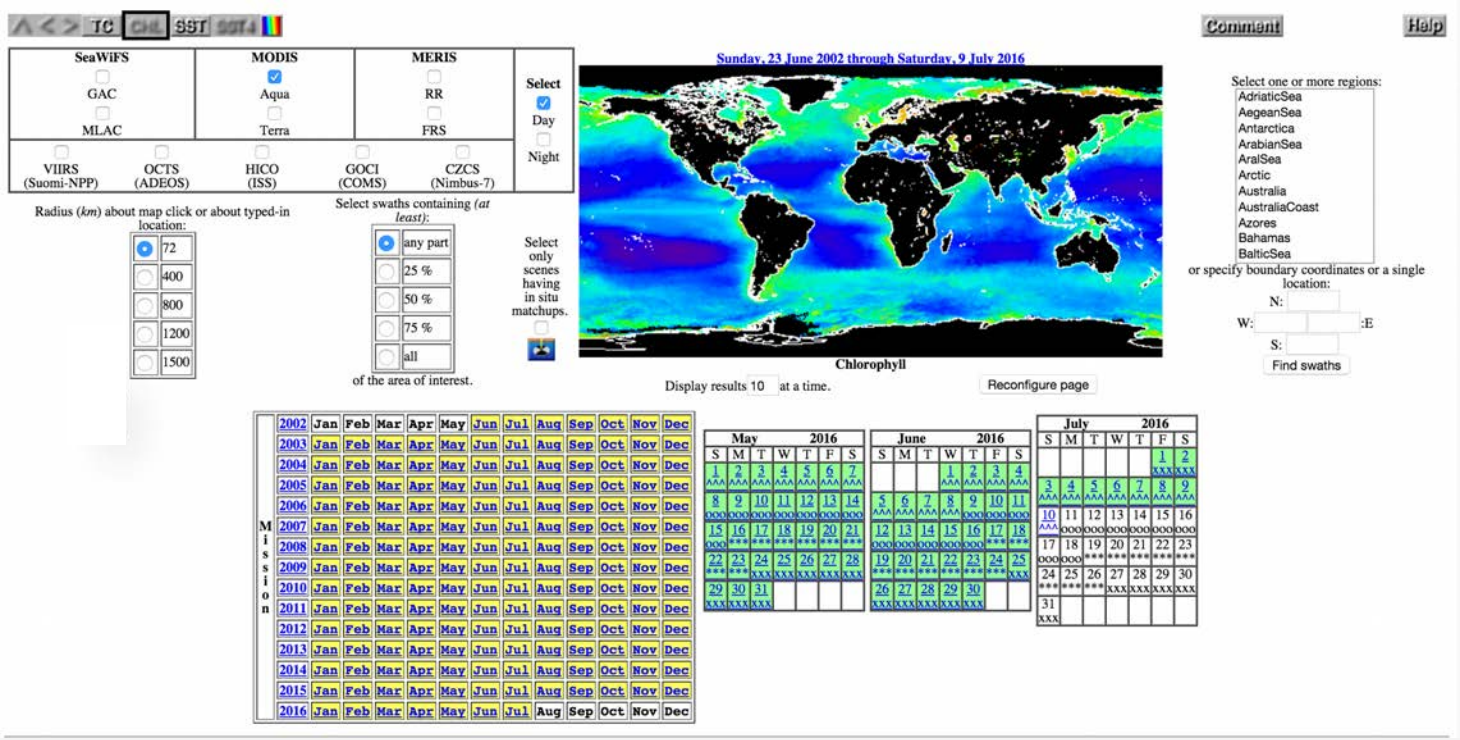
Direct Data Access - direct access to all available data through http protocols suitable for bulk download.

Data File Search - direct access via filename search, including support for wildcard search on partail filenames.

SeaBASS Field Data - community archive of field data relevant to ocean color research, algorithm development, and validation.

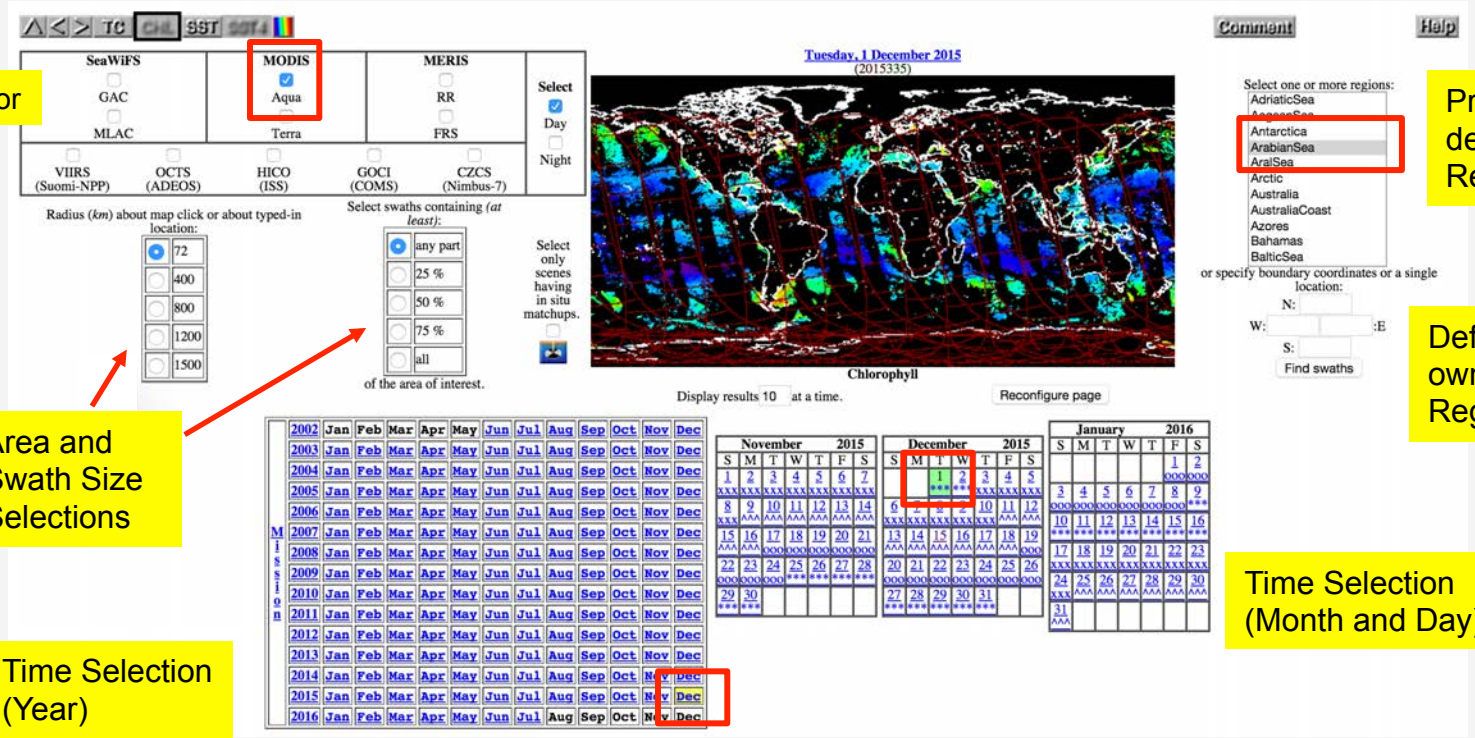
NASA OceanColor Web – Level 1 & 2 Browser

http://oceancolor.gsfc.nasa.gov/cgi/browse.pl



NASA OceanColor Web – Level 1 & 2 Browser

http://oceancolor.gsfc.nasa.gov/cgi/browse.pl



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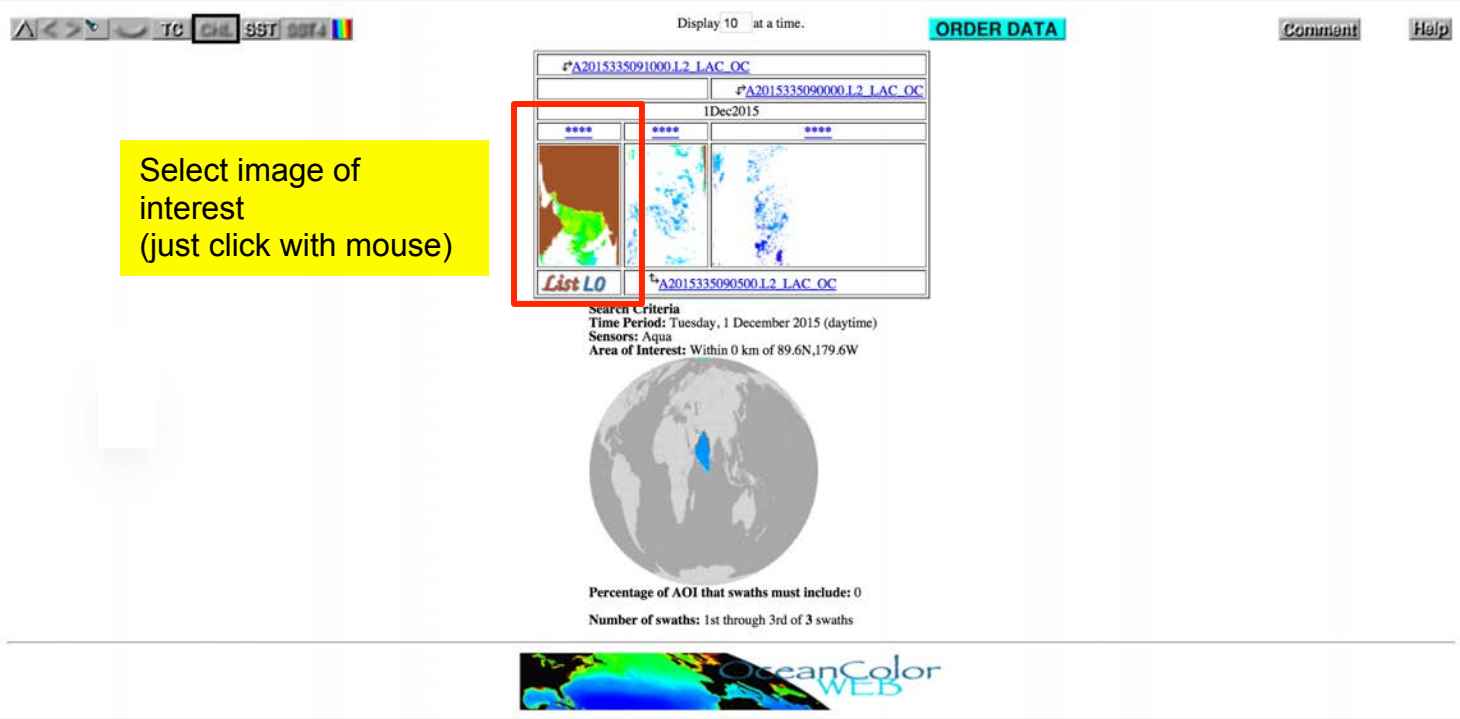

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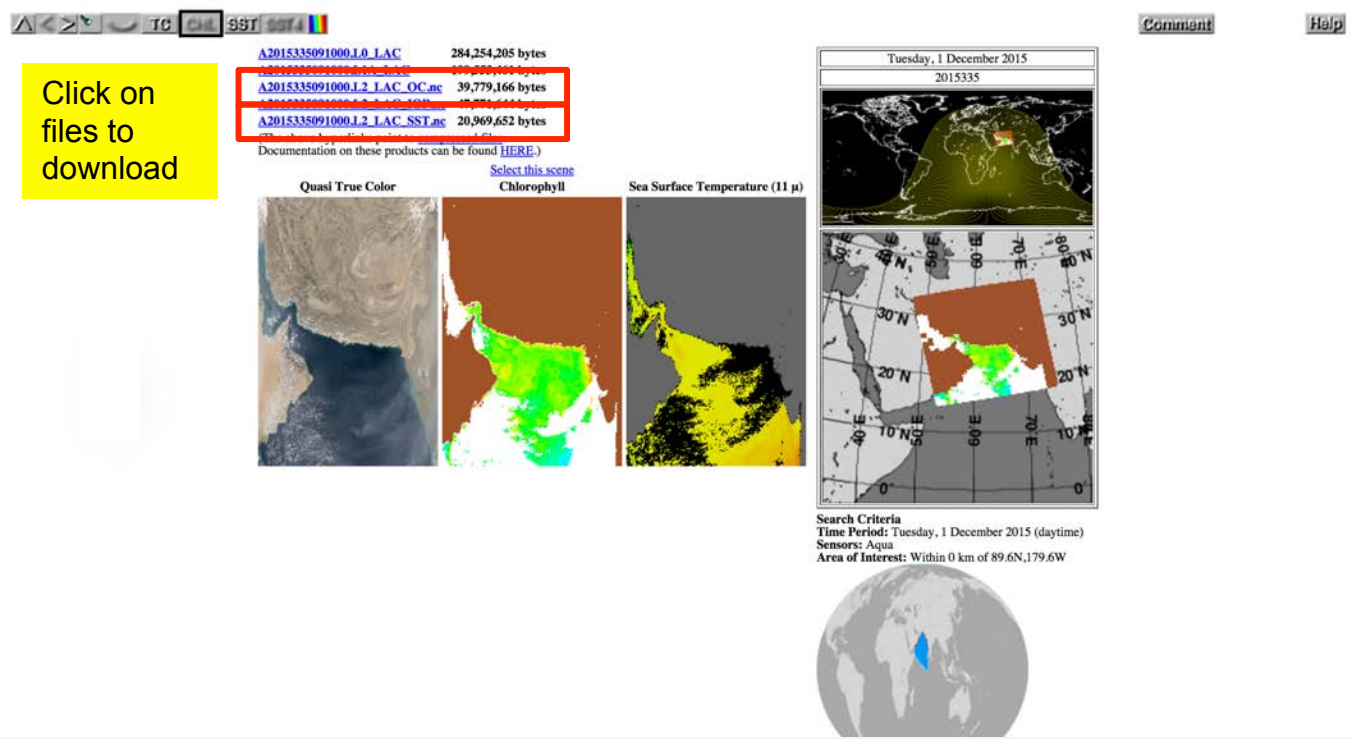

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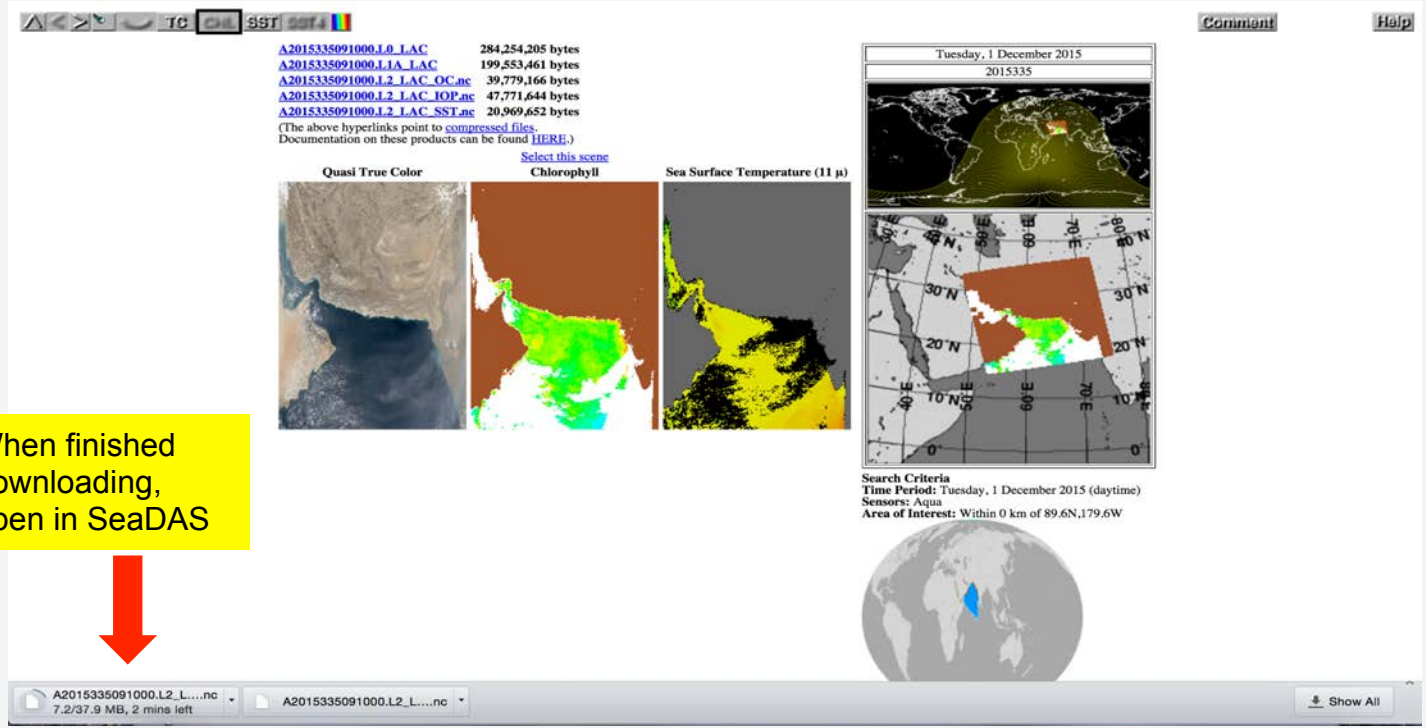
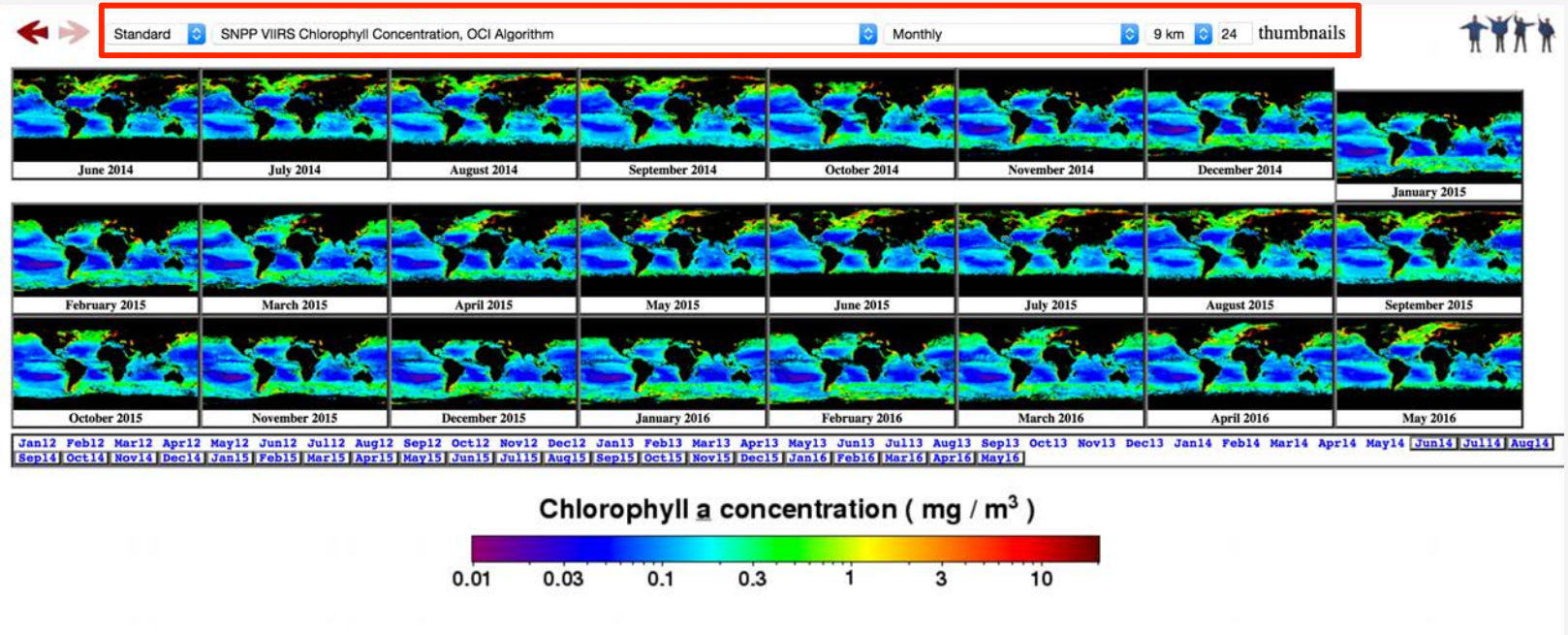


NASA OceanColor Web Level 3 Browser

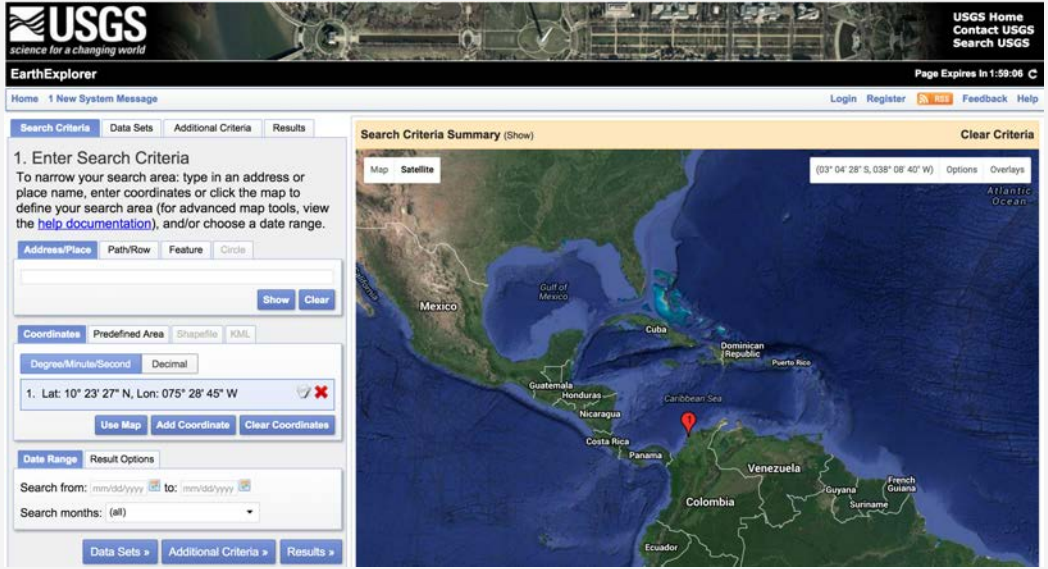
http://oceancolor.gsfc.nasa.gov/cgi/l3

Data Product, Time Selections, and Spatial Resolution Selections



Some Other Data Access Tools

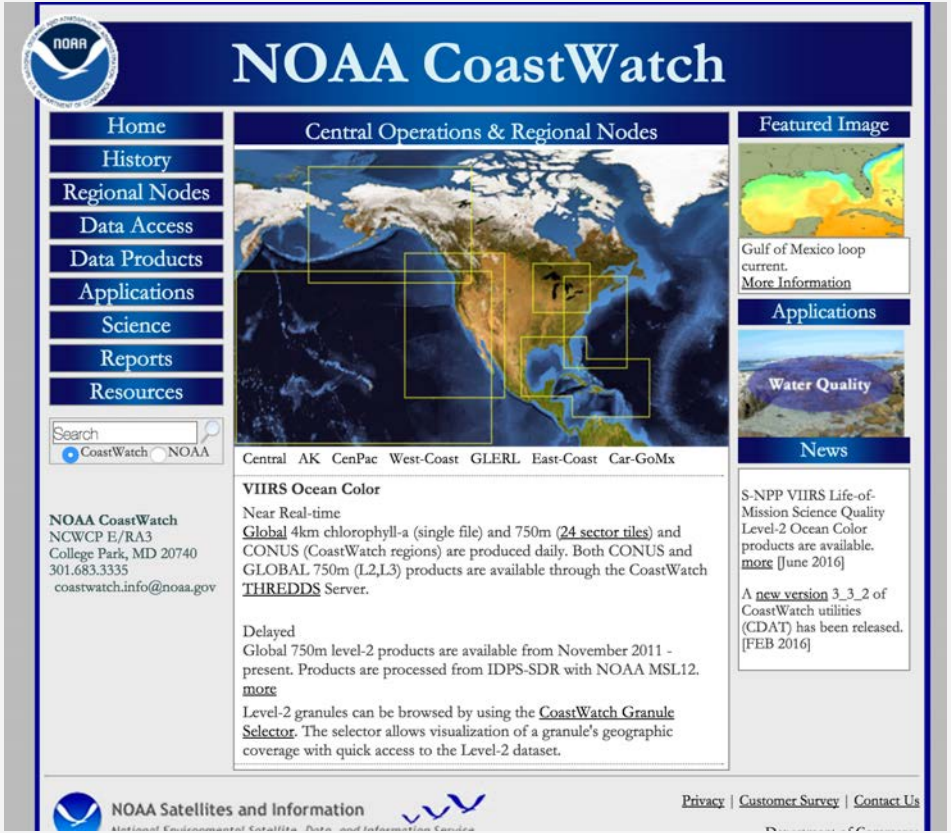
- NOAA CoastWatch
  - http://coastwatch.noaa.gov/
- NASA Giovanni
  - http://giovanni.gsfc.nasa.gov/giovanni/
- USGS Earth Explorer
  - http://earthexplorer.usgs.gov/



NOAA CoastWatch

http://coastwatch.noaa.gov/

- CoastWatch is organized into regional nodes (USA only at this time)
- Each node serves needs of regional user community
- Serves image data from a variety of satellite sensors
- Download to work with image processing software such as SeaDAS or CoastWatch Utilities software



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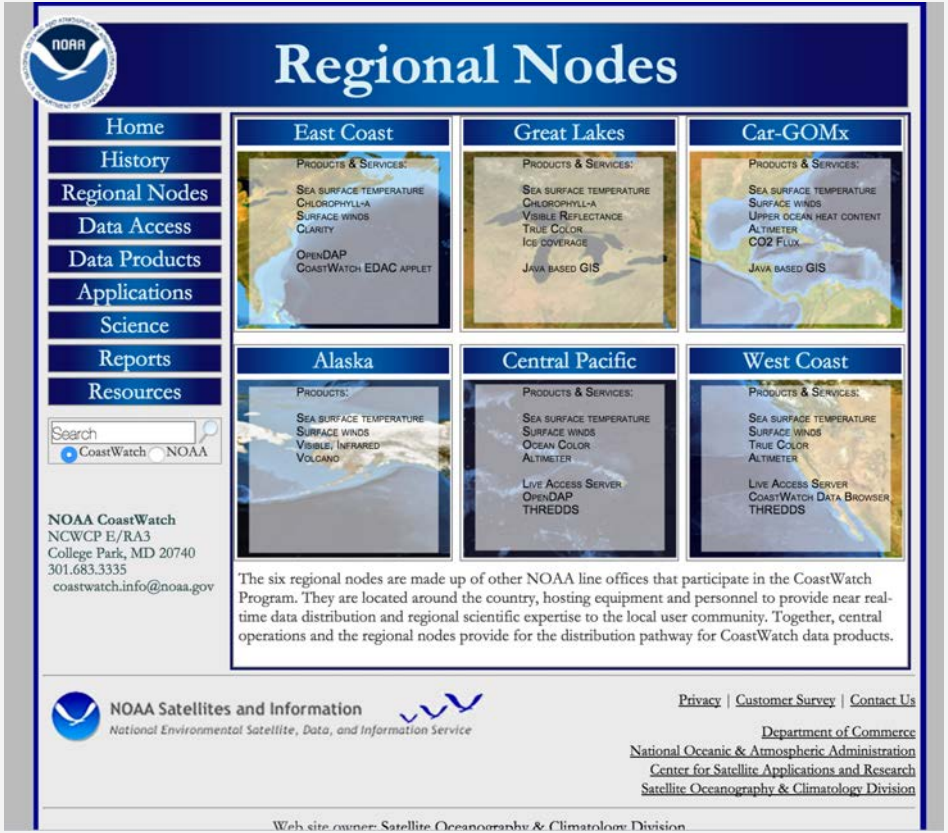

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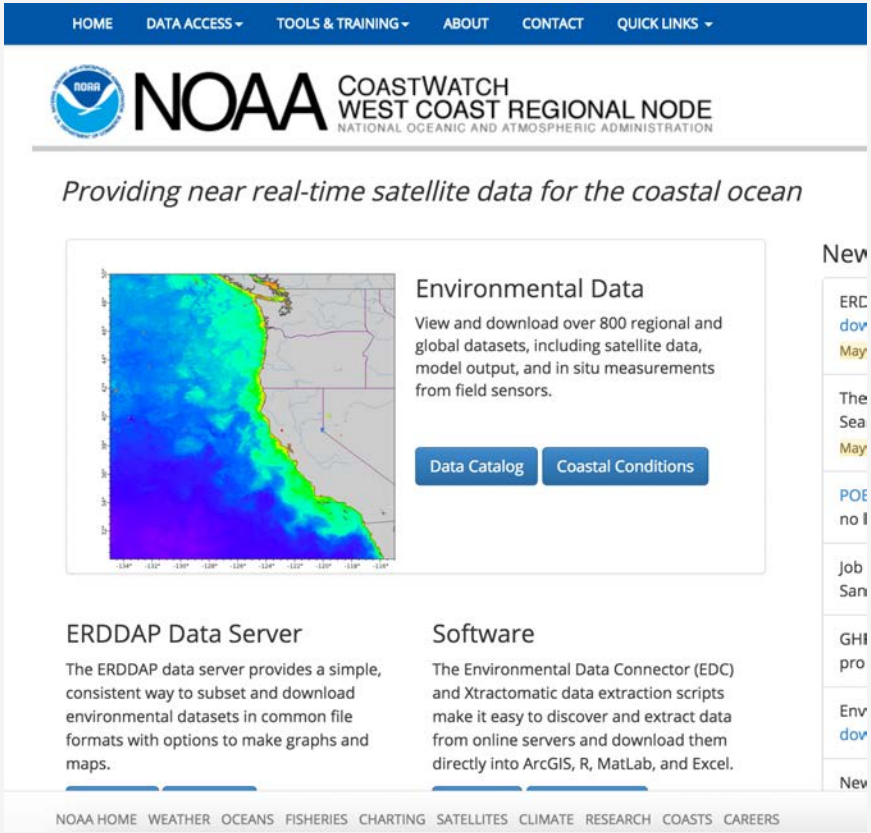

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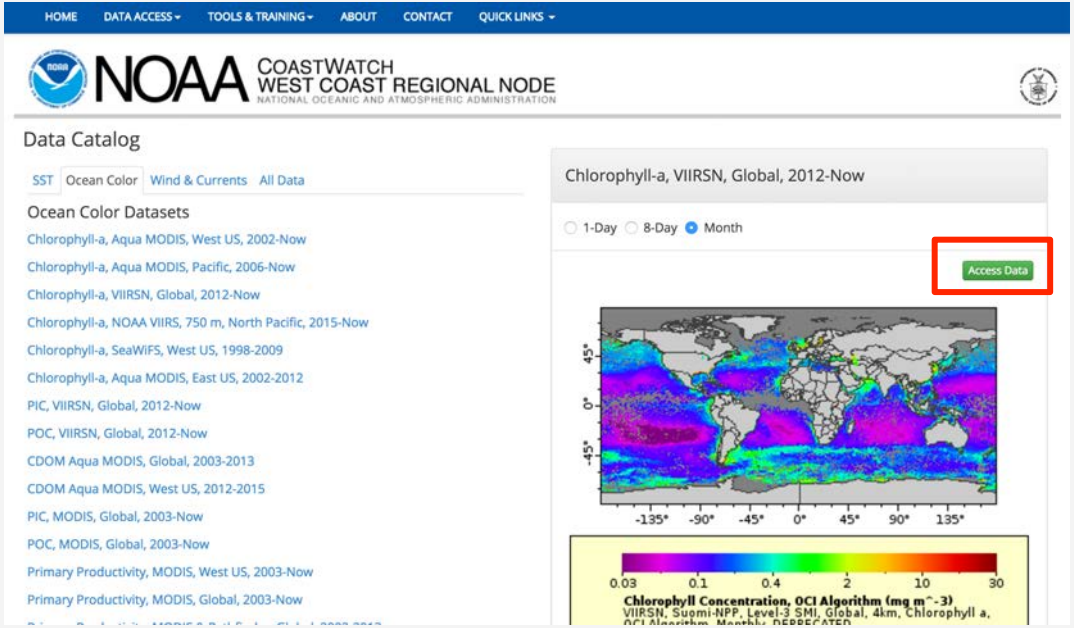

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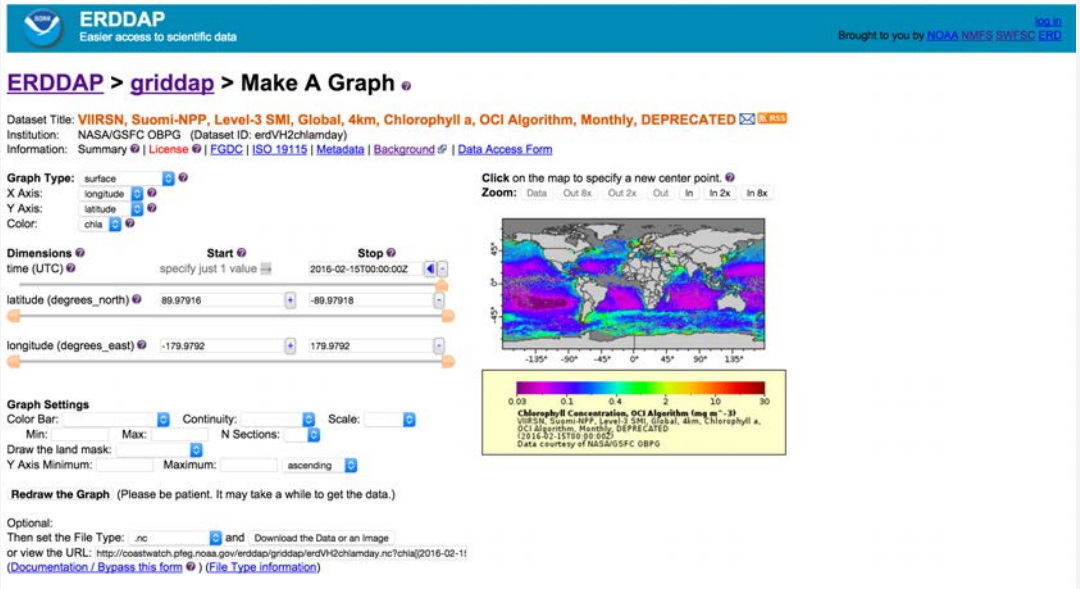

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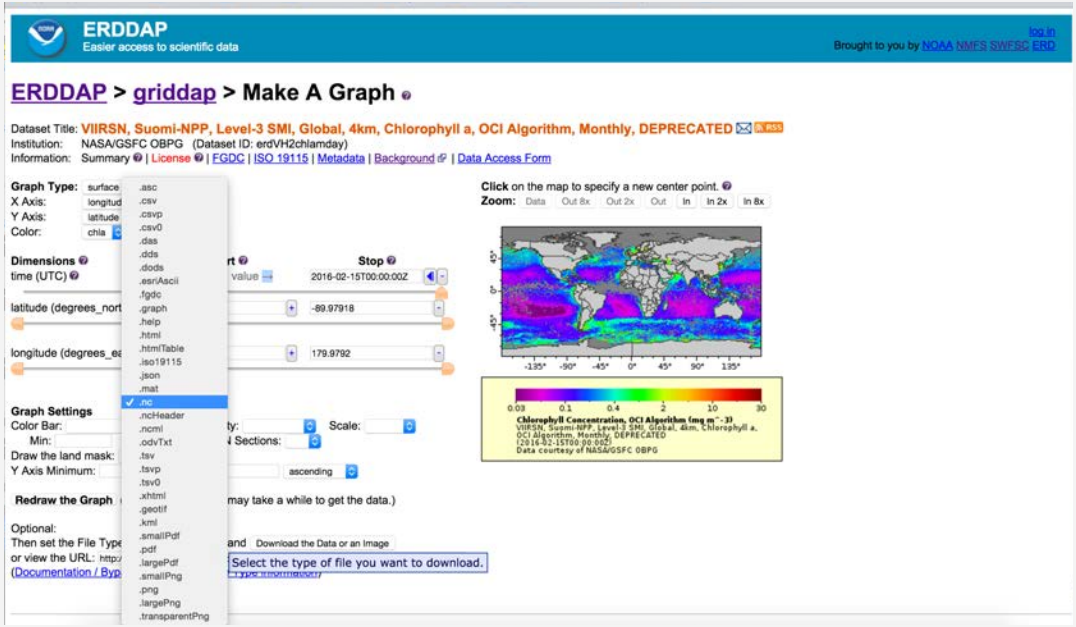


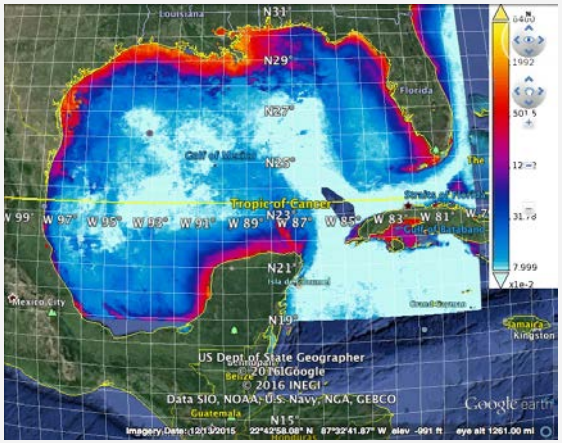
Giovanni

http://giovanni.gsfc.nasa.gov/giovanni

- Giovanni: **G**eospatial **I**nteractive **O**nline **V**isualization **AN**d a**N**alysis **I**nfrastructure
- A web-based application developed by Goddard Earth Sciences Data & Information Services Center (GES DISC)
- Provides a simple and intuitive way to visualize, analyze, and access vast amounts of Earth science remote sensing data without having to download the data

Available Data

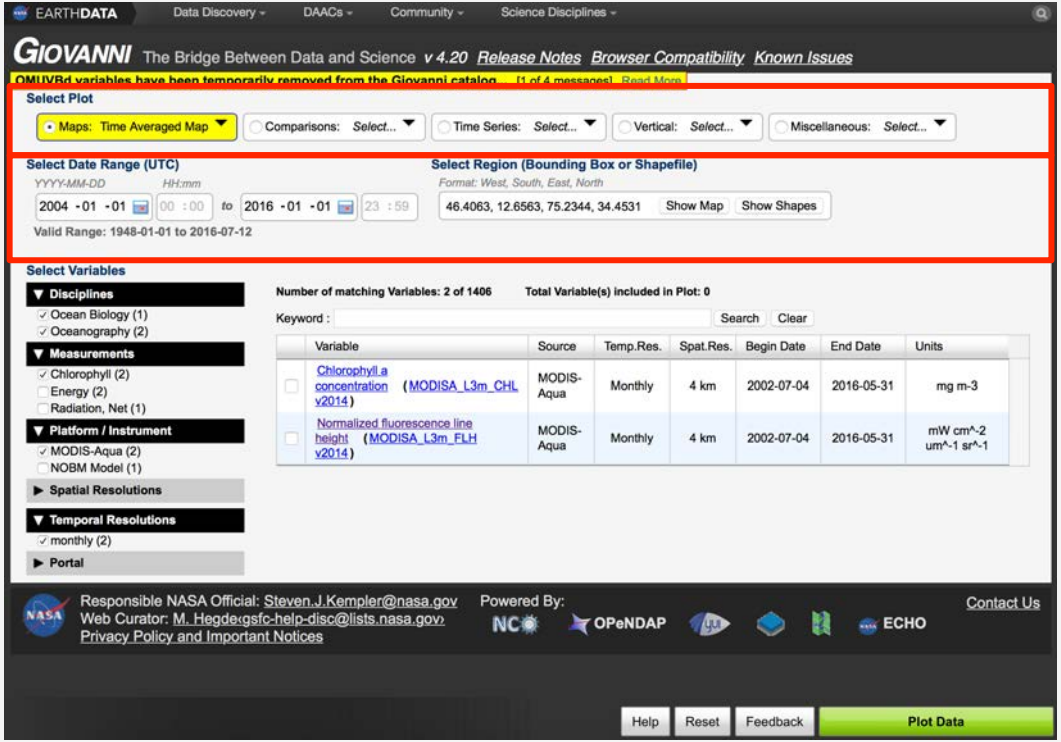
- MODIS-Aqua Chlorophyll Concentration
- Monthly, 4km (7/2002-2/2016)



*Reference: http://disc.sci.gsfc.nasa.gov/giovanni/

NASA Giovanni

http://giovanni.gsfc.nasa.gov/giovanni/

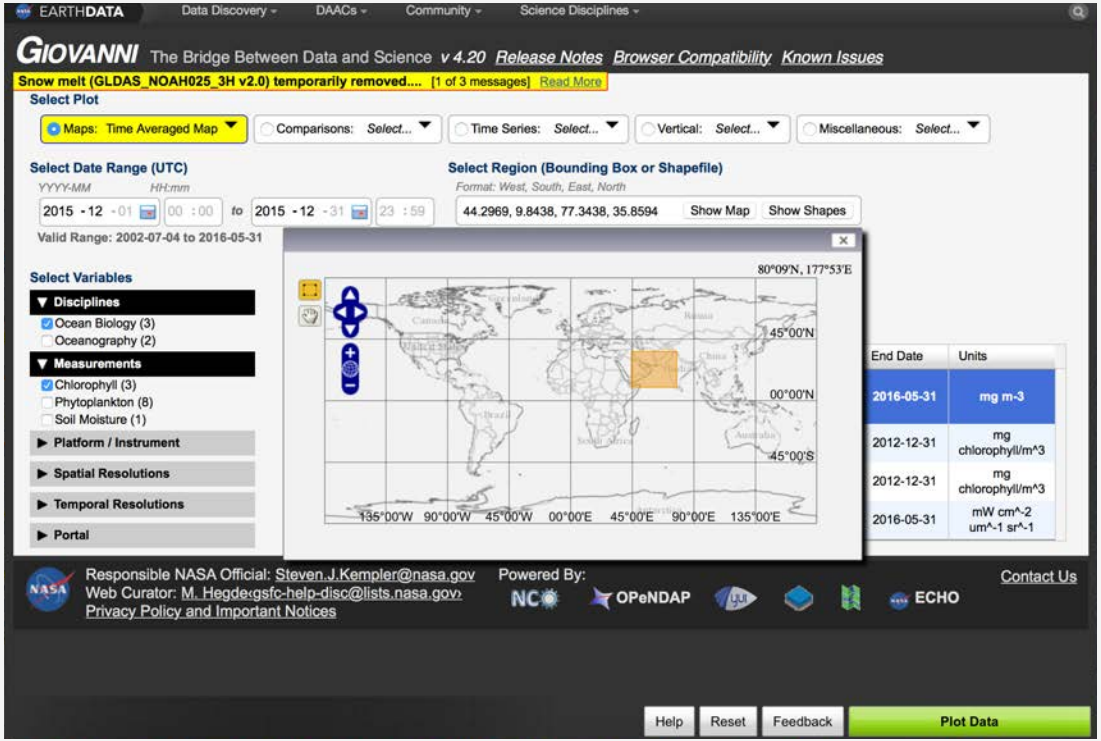


Analysis and Plot Selection

Start and End Date; and Spatial Selection by Map/Latitude-Longitude/Shapefile

NASA Giovanni

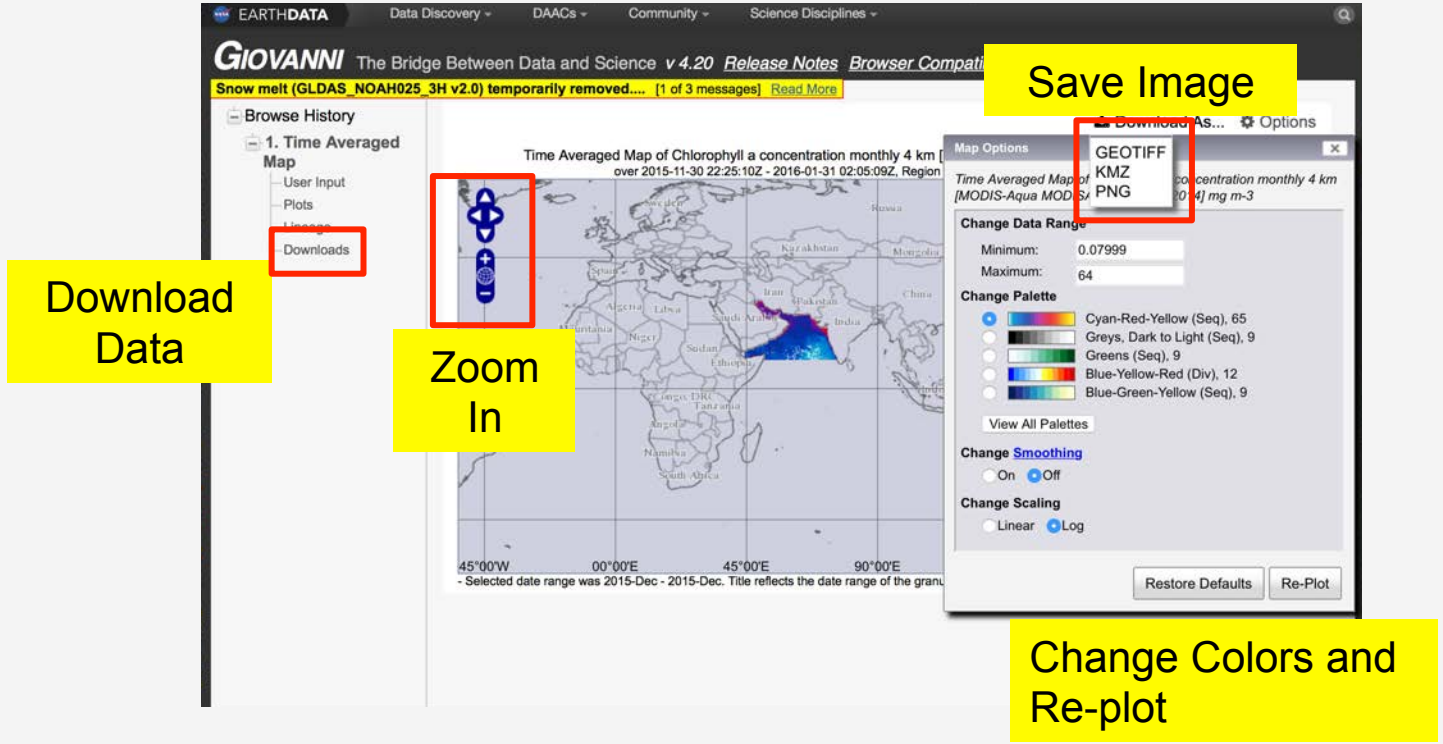
http://giovanni.gsfc.nasa.gov/giovanni/



MODIS-based Chlorophyll for Dec 2015 in the Arabian Sea

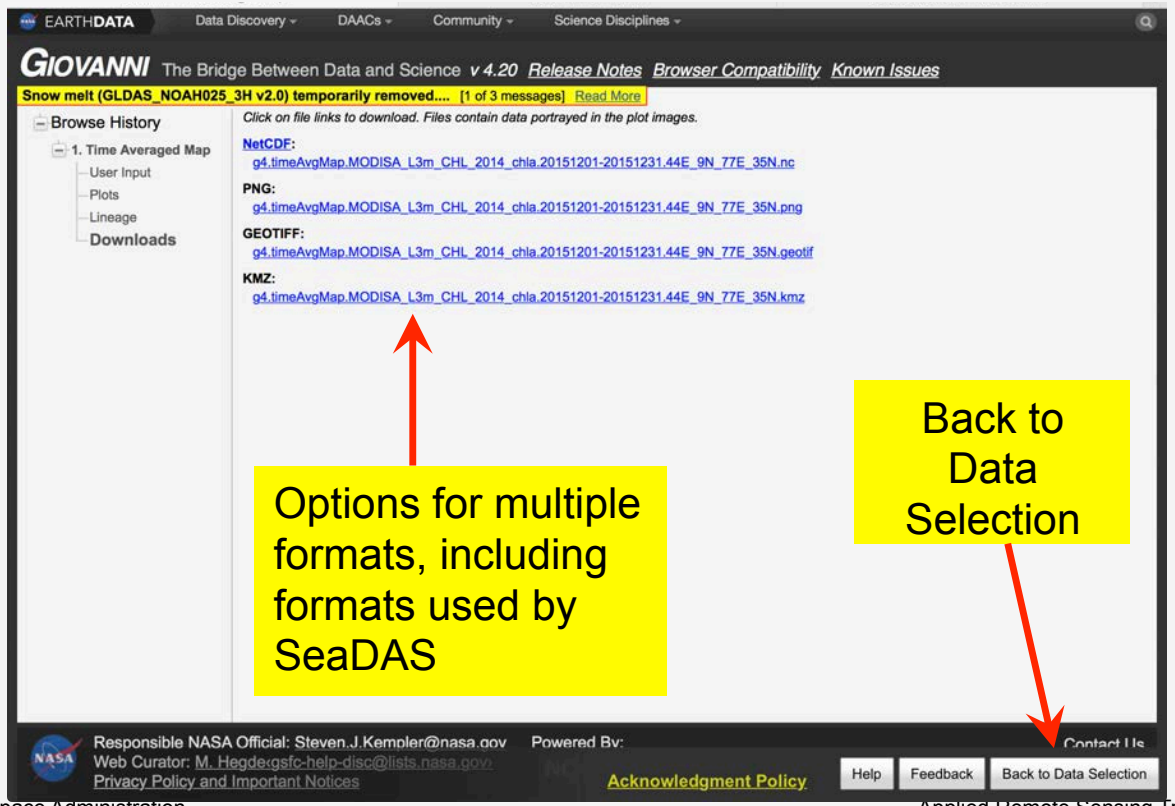
NASA Giovanni - Visualization

http://giovanni.gsfc.nasa.gov/giovanni/



NASA Giovanni – Data Download

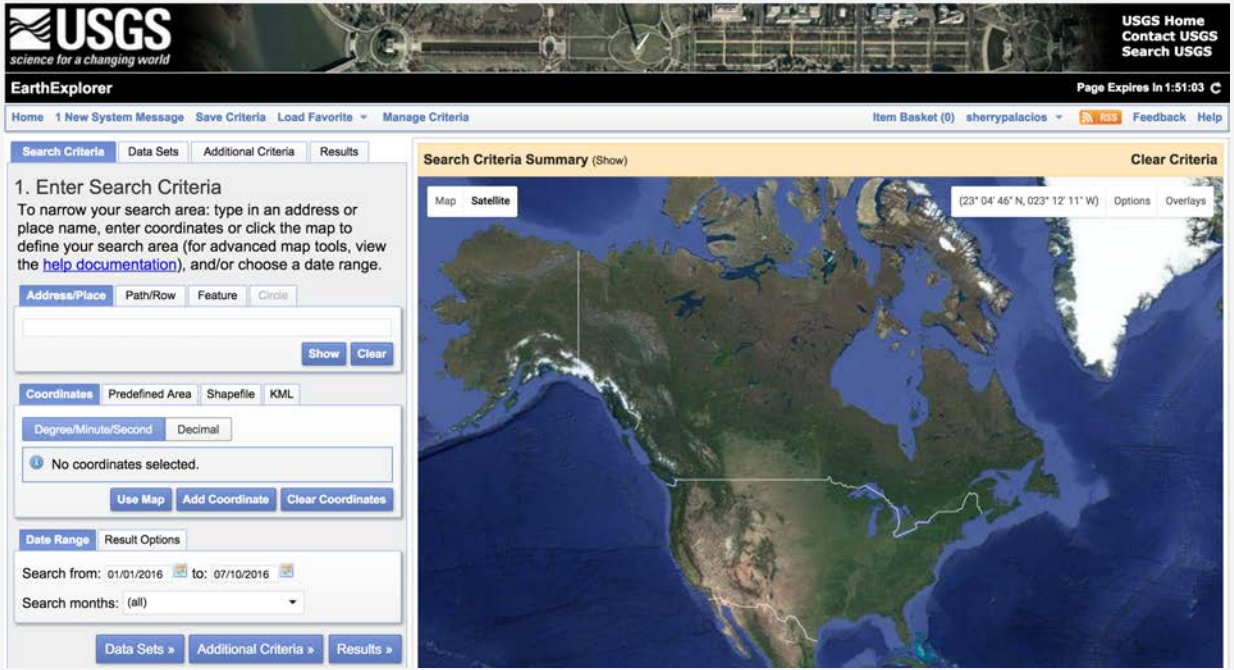
http://giovanni.gsfc.nasa.gov/giovanni/



USGS Earth Explorer

http://earthexplorer.usgs.gov/

- Search for Landsat and other satellite sensor data
- Download to work with image processing software such as SeaDAS



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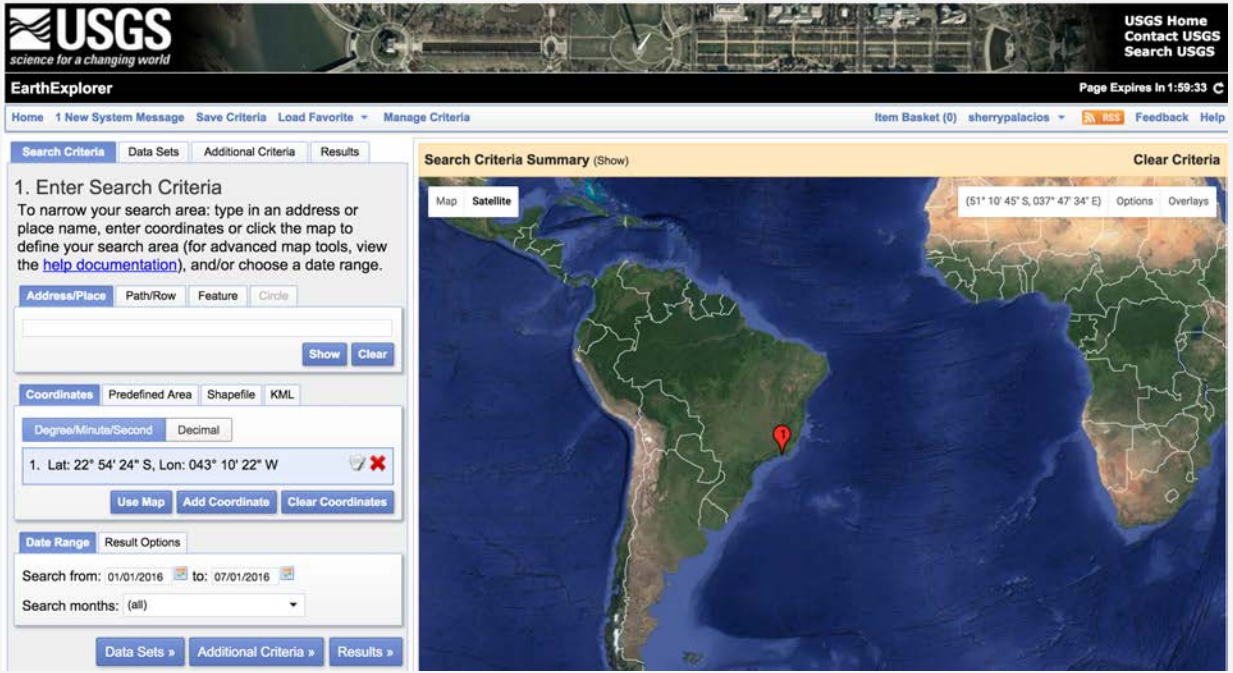

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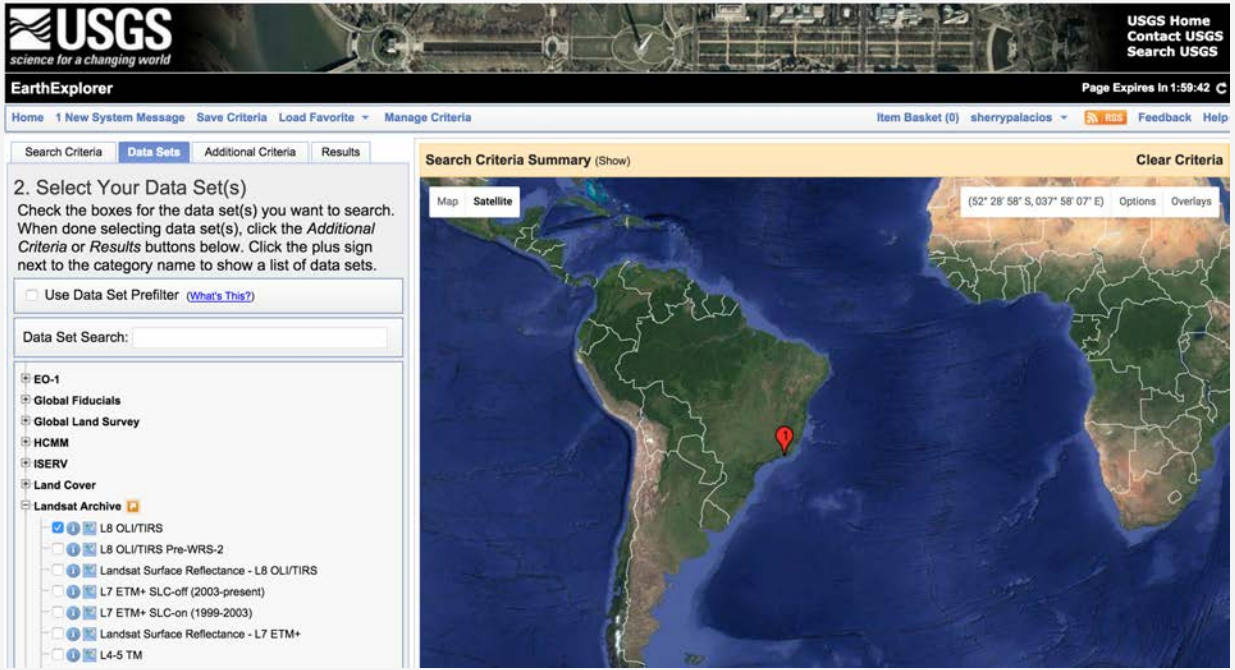

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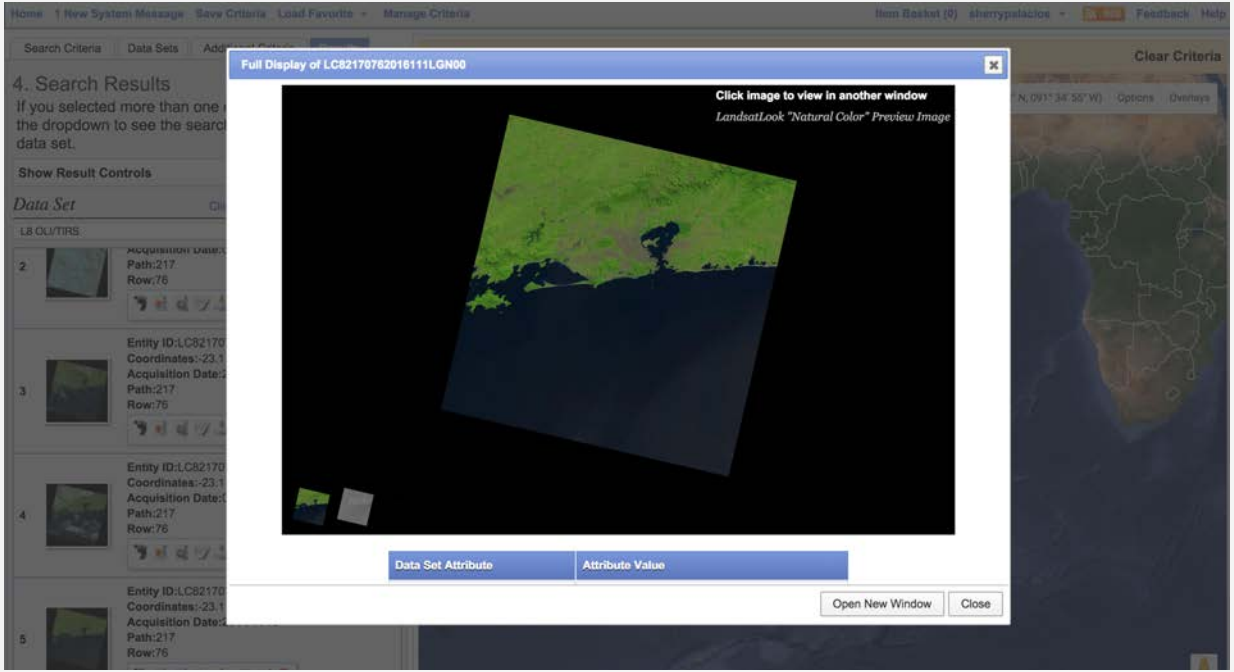

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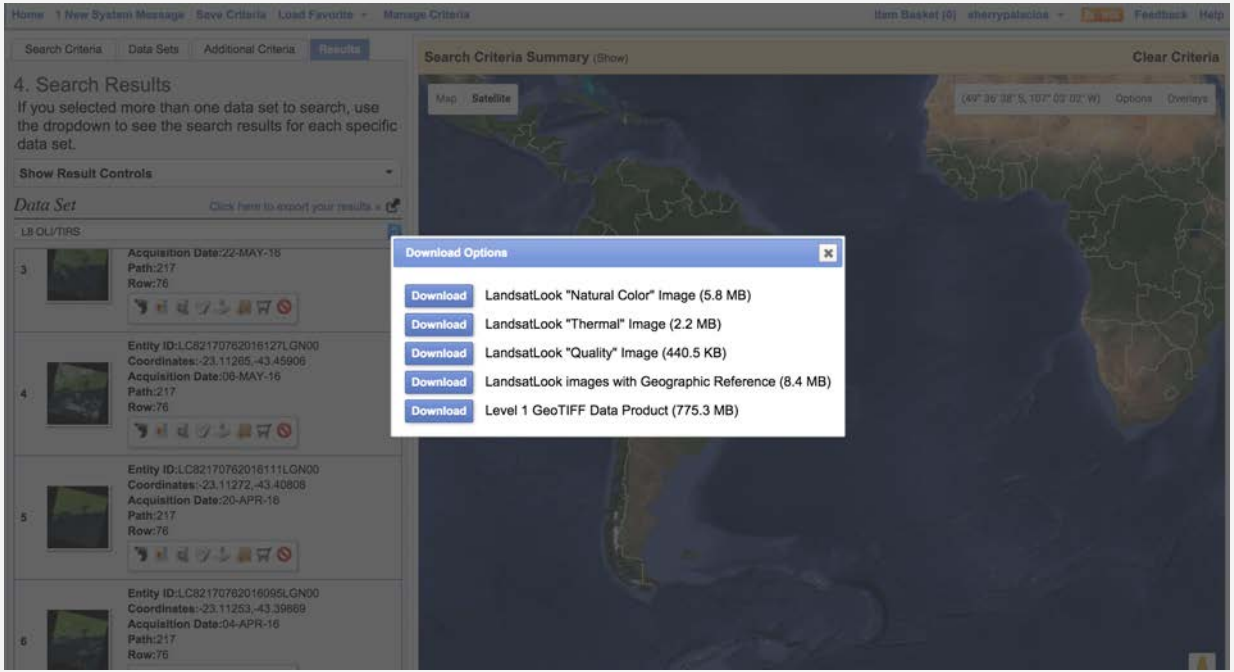


NASA Satellite Data Processing Tools

SeaWiFS Data Analysis System (SeaDAS)

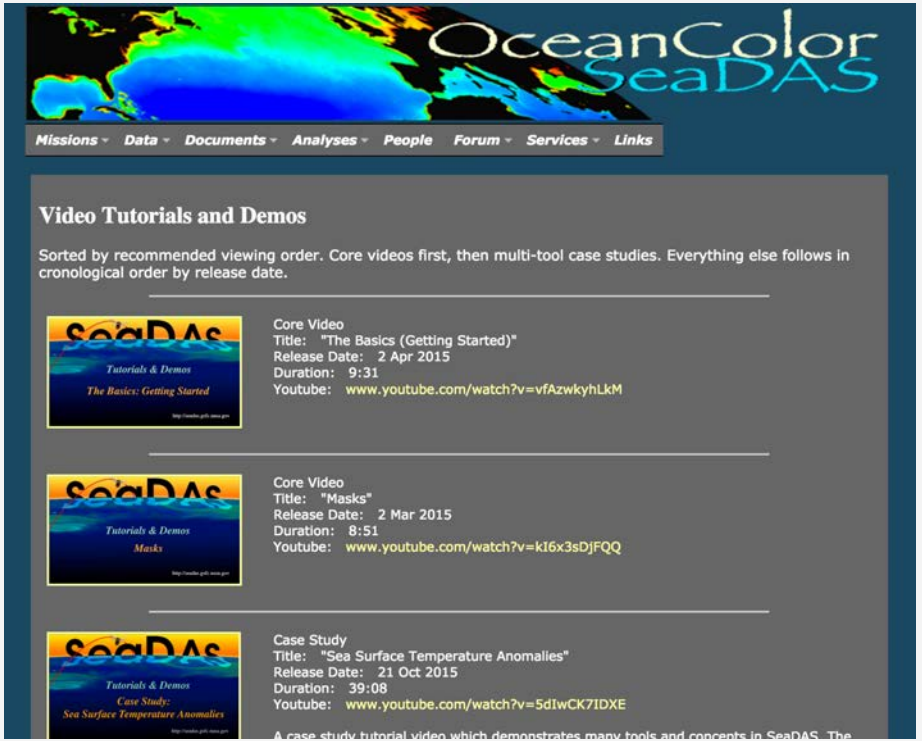
http://seadas.gsfc.nasa.gov/

- Image analysis package for the processing, display, analysis, & quality control of ocean color data
- Originally developed for SeaWiFS, but supports most U.S. and international ocean color missions
- Online tutorials, help pages, and an active user community in the Ocean Color Forum
- Attentive & friendly support team based at NASA Goddard

Online Tutorials and Webinars for SeaDAS

http://seadas.gsfc.nasa.gov/tutorial/

- Strongly recommend completing all of the on-demand tutorials listed on this webpage
- SeaDAS supports a wide variety of satellite sensors so your investment in learning it will be time well spent
- Check out SeaDAS webinar on June 15, 2016:
  - https://earthdata.nasa.gov/user-resources/webinars-and-tutorials



Features of SeaDAS

http://seadas.gsfc.nasa.gov/

SeaDAS Features

Visualization

- Very fast image display and navigation even of giga-pixel images
- Advanced layer management allows adding and manipulation of new overlays such as images of other bands, images from WMS servers or ESRI shapefiles
- Rich region-of-interest definitions for statistics and various plotting funtions
- Easy bitmask definition and overlay
- Flexible band arithmetic using arbitrary mathematical expressions
- Accurate reprojection and ortho-rectification to common map projections
- Geo-coding and rectification using ground control points
- Coastline, land/water masking for navigated data
- Store and restore the current session including all opened files, views and layers

Data Processing

SeaDAS offers the ability for users to process satellite data from a number of ocean color missions (both U.S. and International) through the various processing levels:

- Level 0 to Level 1 processing is offered for the MODIS sensors onboard the Terra and Aqua spacecraft
- Level 1 to Level 2 (l2gen)
- Level 2 to Level 3 binned (l2bin)
- Temporal binning of Level 3 (l3bin)
- Mapping of Level 1 data (l1mapgen)
- Mapping of Level 2 data (l2mapgen)
- Mapping of Level 3 binned data (smigen)
- Browse file creation (l1brsgen,l2brsgen)

System Requirements for SeaDAS

http://seadas.gsfc.nasa.gov/

- Visualization only version
- Visualization and data processing version
- Data from multiple missions can be analyzed

SeaDAS Configuration and Requirements

SeaDAS is currently available for Linux, Mac OS X, and Windows. The Windows version currently does not support the science data processing code. The SeaDAS source code is publicly available.

Suggested Hardware Requirements:

Platforms:	Linux Intel Mac OS X
Memory:	256MB minimum, 1GB+ suggested
Disk:	SeaDAS software package (display only version): ~200MB SeaDAS software package (with processing capabilities for all sensors): ~5GB 10GB of free space is also suggested for rudimentary data processing and storage.
Display:	15" Console or X-terminal with 20MB memory 1280x1024 resolution 24-bit X display plane depth 256 colors display minimum

Requirements:

The core visualization package of SeaDAS is written in Java. A minimum Java JRE of version 1.7 is required. A suitable JRE is packaged with the Windows and MacOSX distributions. Linux users will need to separately install a suitable JRE.

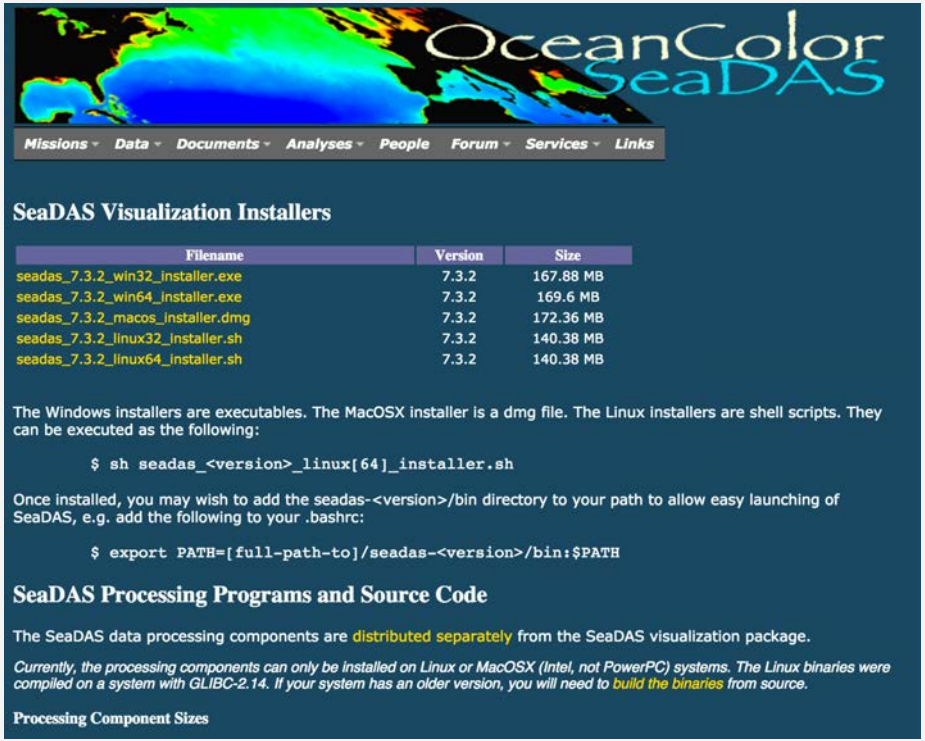
Operating Systems:	**Linux:** tested on various versions of CentOS, Fedora, and Ubuntu **Intel Mac:** OS X 10.10
Optional Compilers:	gcc/g++/gfortran (version 4.5 or higher) or Intel Compilers

Program	***Version***	***Notes***
Java	JRE 1.7 or above	Windows and MacOSX distributions come with a suitable JRE Linux users will need to separately install a suitable JRE
Bash	4.x	version 3.x should work, but not tested necessary only for science code, thus not required for Windows distributions
Python	2.6.5 or above	necessary only for science code, thus not required for Windows distributions; not (yet) compatible with version 3 and above
Git	1.7.9 or above	necessary only for science code install/update option, thus not required for Windows distributions
cURL	7.x or above	necessary only for science code install/update option, thus not required for Windows distributions

Downloading SeaDAS

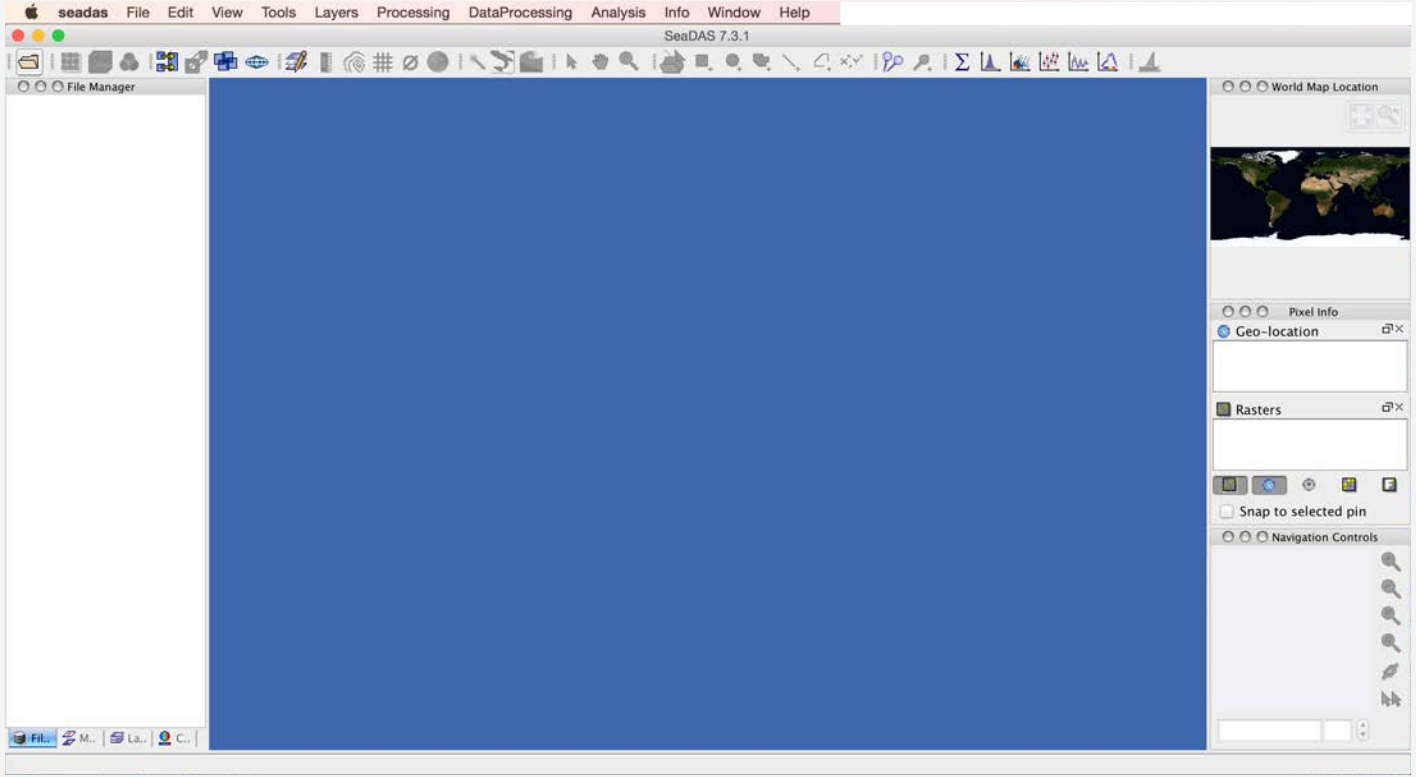
http://seadas.gsfc.nasa.gov/installers/

- Follow the instructions on the download webpage
- The "The Basics (getting started)" tutorial provides step-by-step directions on downloading and installing SeaDAS on your computer



Using SeaDAS

http://seadas.gsfc.nasa.gov/tutorial/



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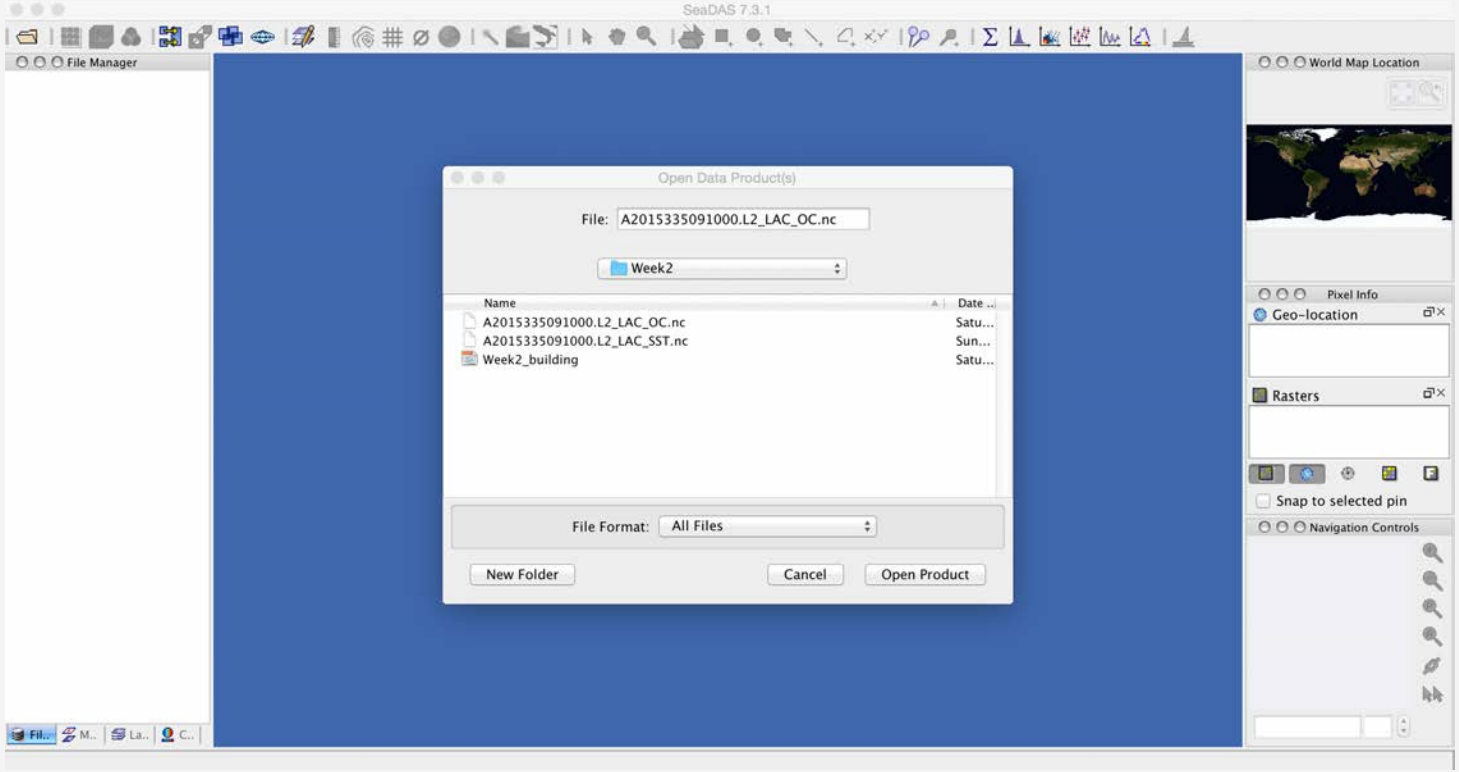

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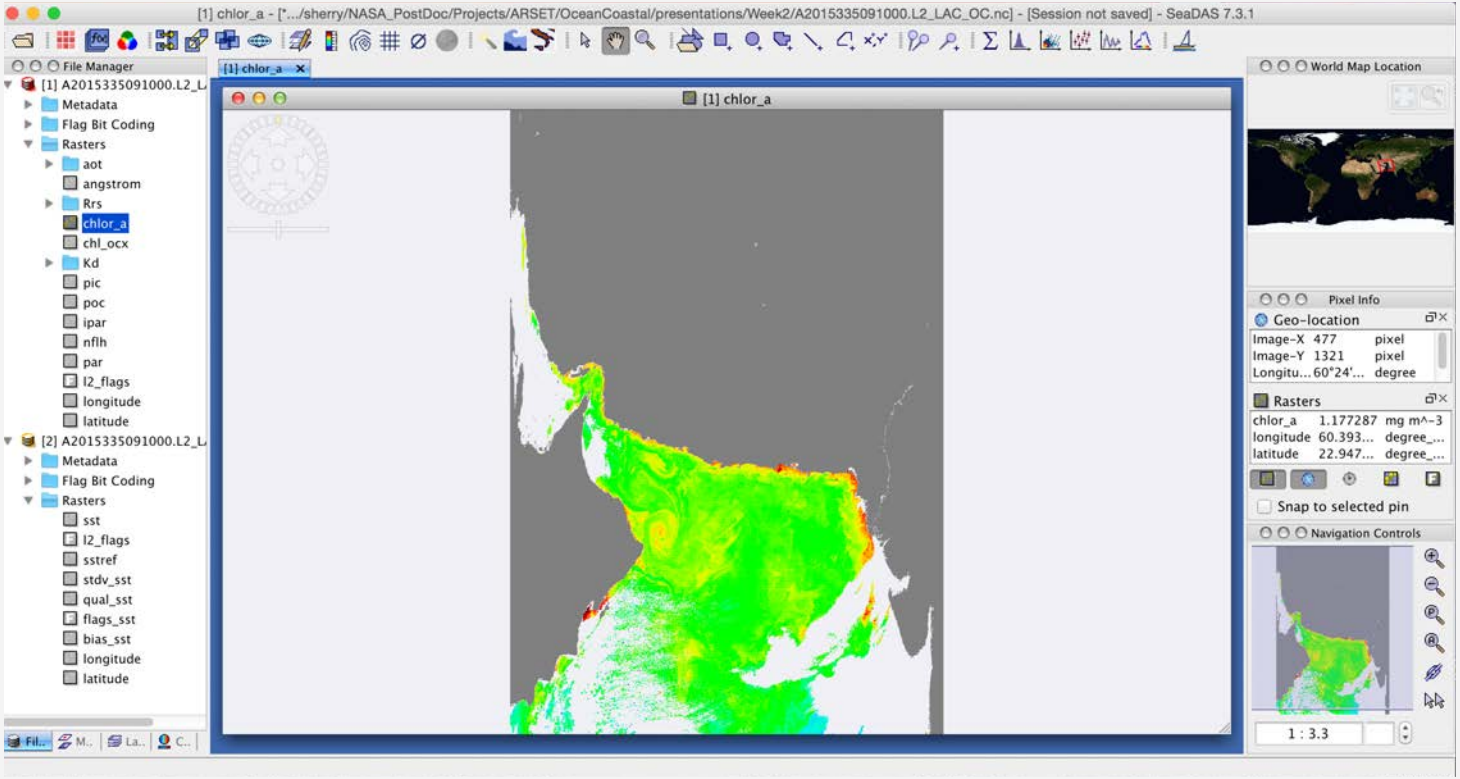

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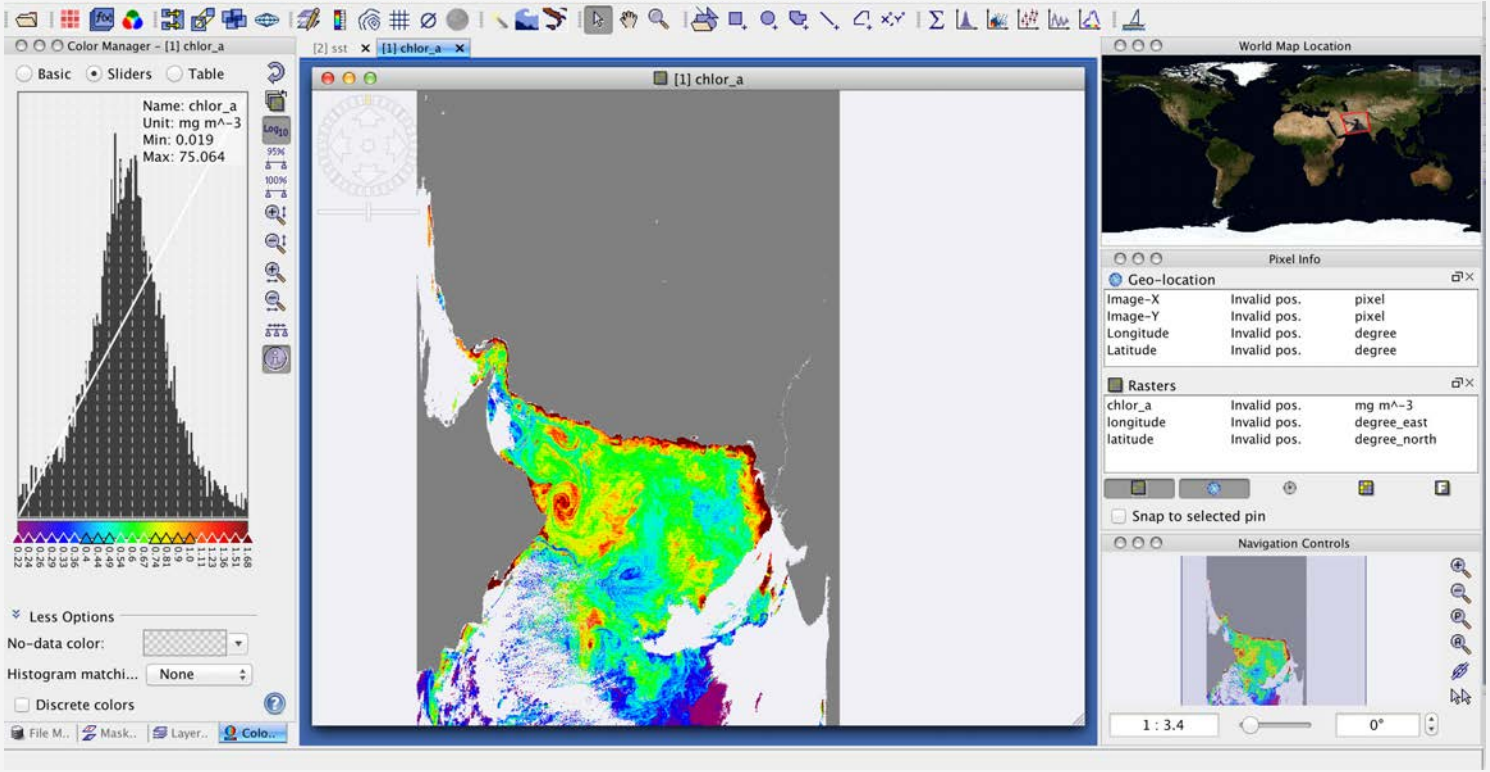

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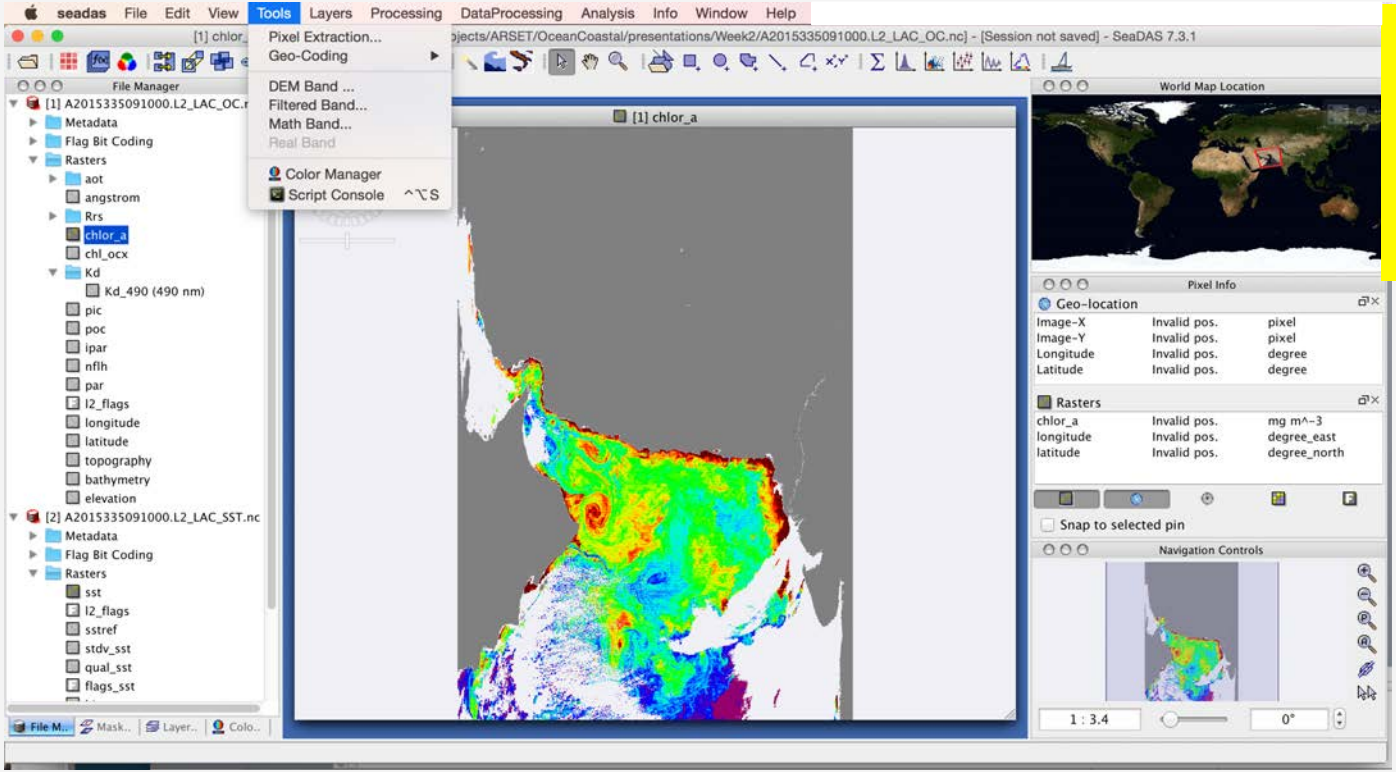

The tutorials and webinar review the functionality of SeaDAS in more depth

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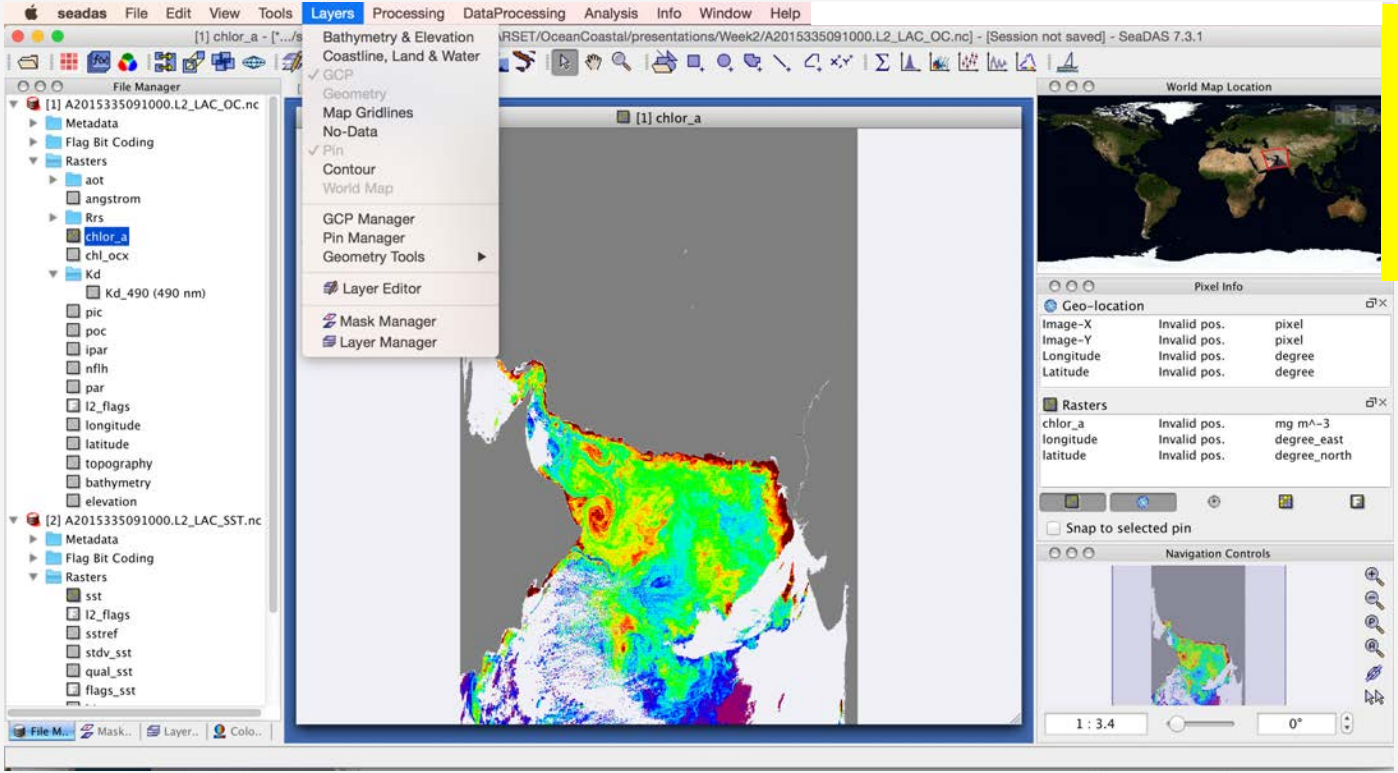

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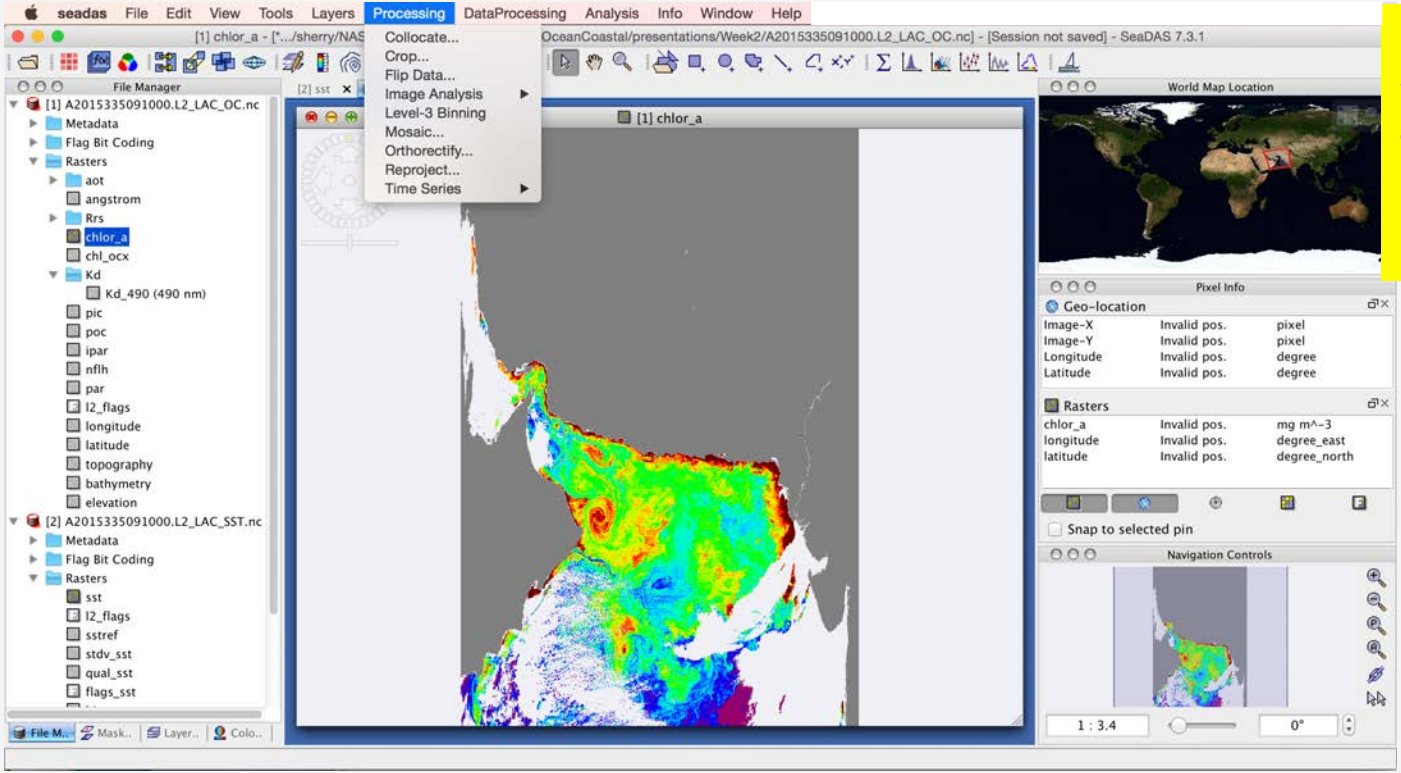

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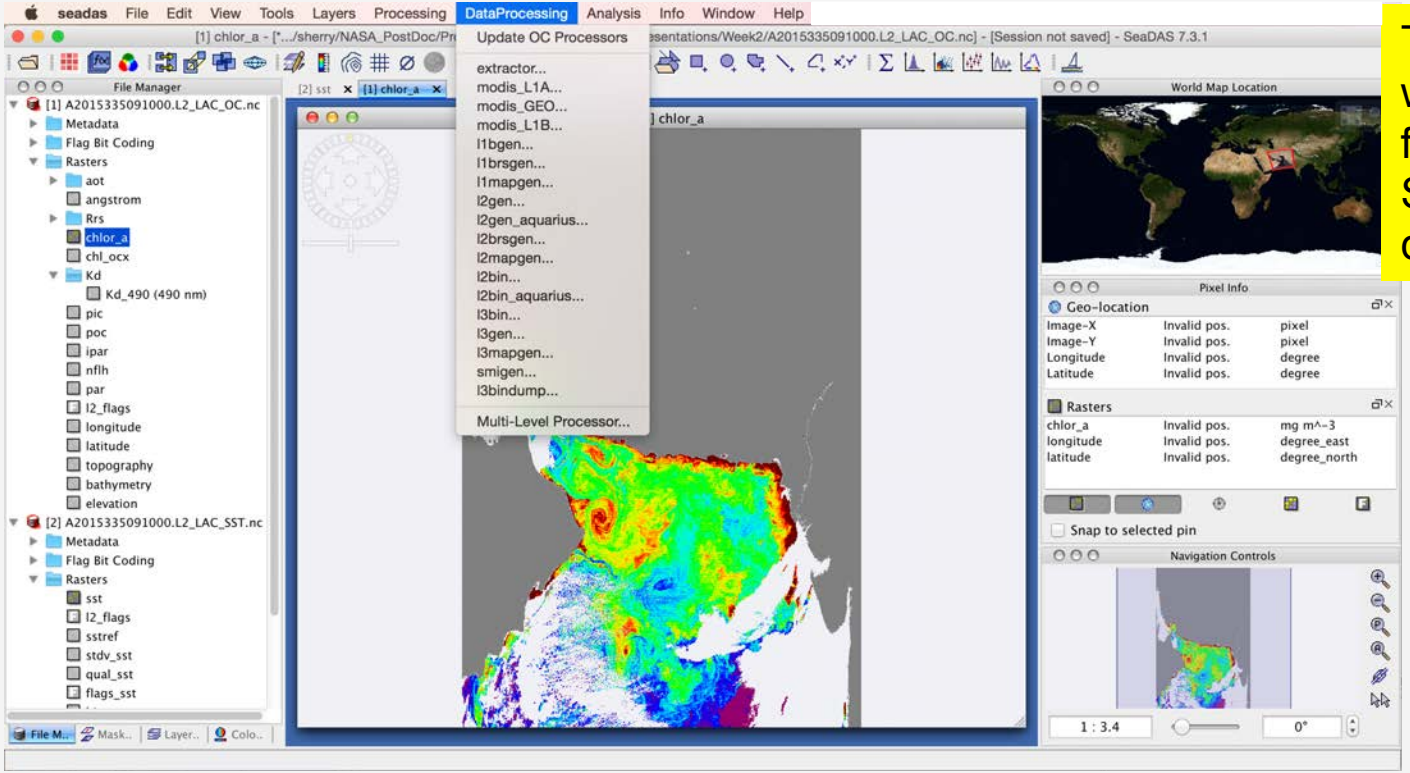

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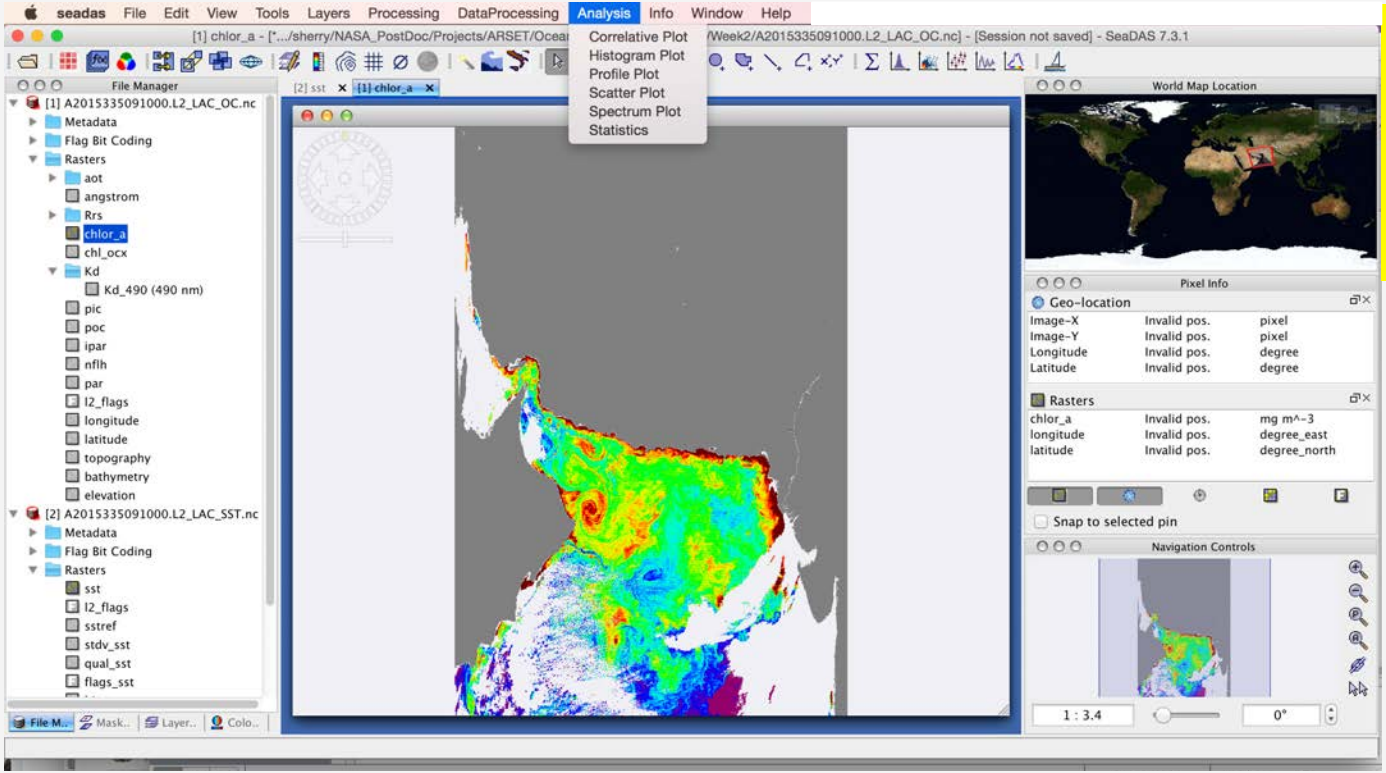

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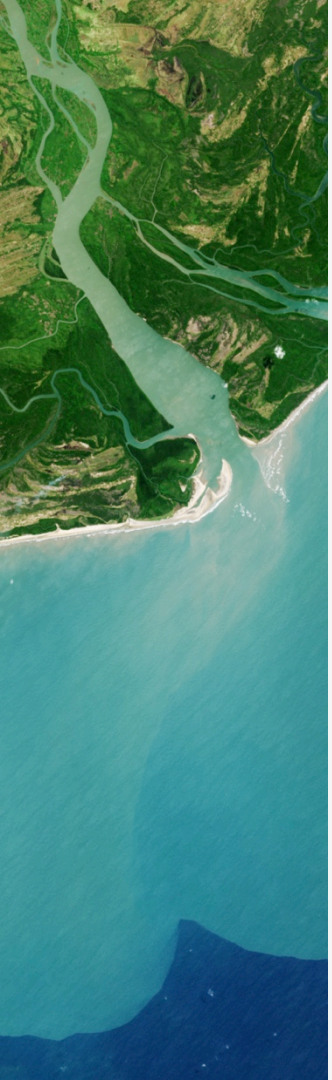
Week 2 Summary

Week 2 Review

- Brief Review of Last Week
- Satellites and sensors for coastal and ocean applications
- Satellite data processing level
- NASA satellite data access tools
- NASA satellite data processing tools



National Aeronautics and Space Administration

ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

@NASAARSET

Thank you!

Next Week:

Animal Movement and Migration