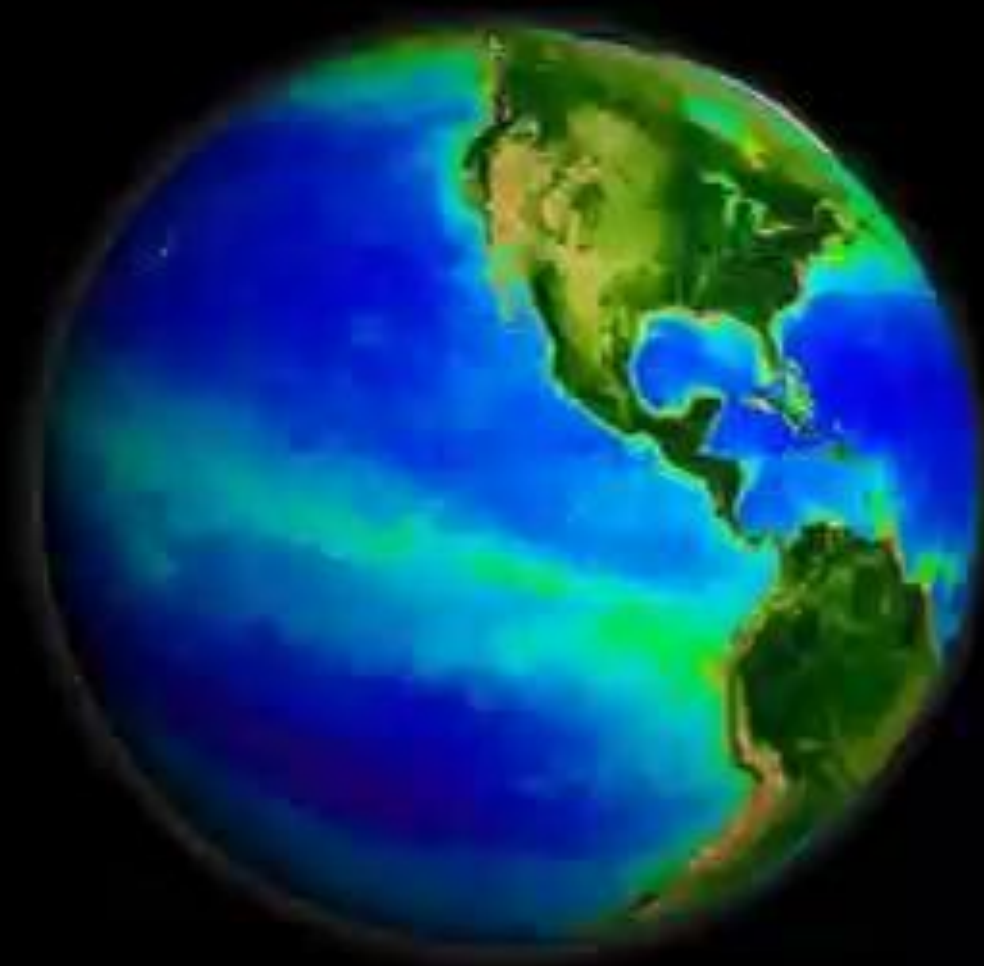
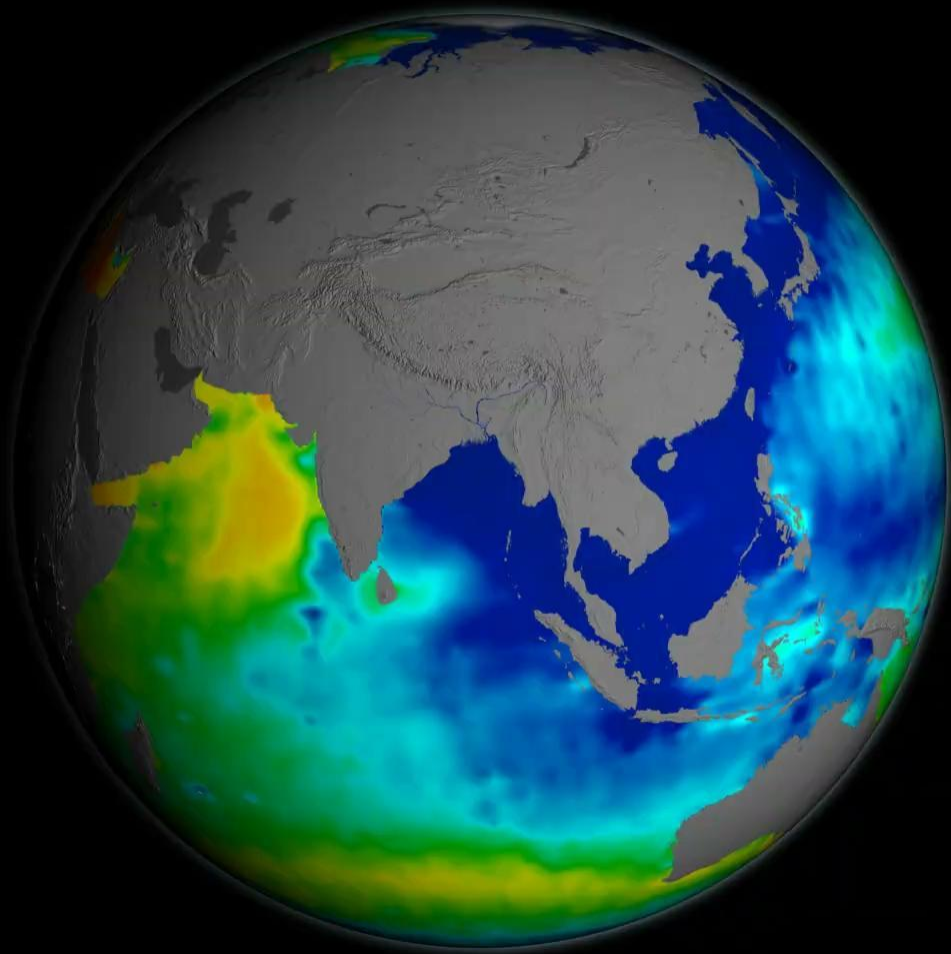






Sep 02, 2011



Brief Overview of Oceanographic Satellite Data

Cara Wilson¹ and the CoastWatch Training Team

¹NOAA Southwest Fisheries Science Center, Monterey CA

ATN Animal Telemetry Data Course - Aug 14 & 15 2025

coastwatch.info@noaa.gov



For how long have these measurements been made?



- Sea Ice
- Sea Surface Temperature (SST)
- Sea Surface Height (SSH)
- Chlorophyll (ocean color)
- Rainfall
- Surface Vector Winds (SWV)
- Sea Surface Salinity

For many applications we want to know how the oceans are changing over time, so we need long timeseries of consistent measurements



For how long have these measurements been made?



- Sea Ice since 1978¹
- Sea Surface Temperature (SST) since 1981
- Sea Surface Height (SSH) since 1992
- Chlorophyll (ocean color) since 1997²
- Rainfall since 1997
- Surface Vector Winds (SWV) since 1999³
- Sea Surface Salinity since 2011

For many applications we want to know how the oceans are changing over time, so we need long timeseries of consistent measurements

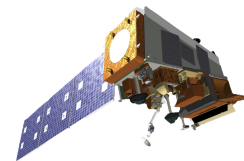
¹The *consistently processed* satellite passive microwave record of sea ice concentration begins in 1978, but other data extends to 1966.

²The continuous record of ocean color sensors extends back to 1997, but the CZCS mission flew from 1979-1986.

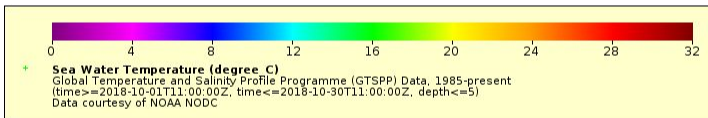
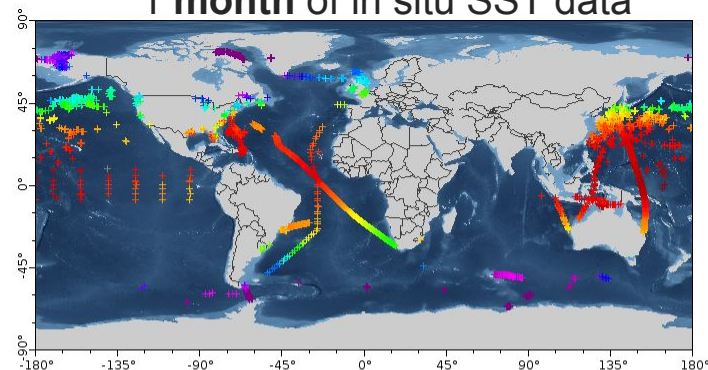
³Wind speed, without direction, dates back to 1988



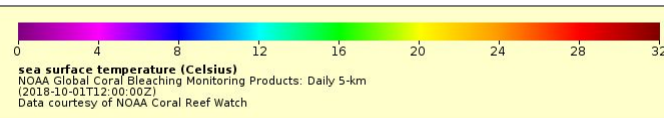
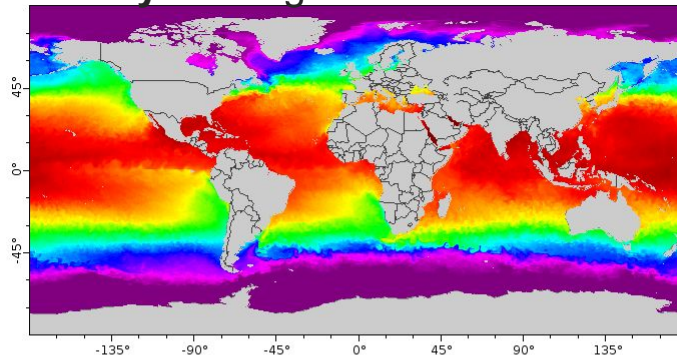
Benefits of satellite data



1 month of in situ SST data



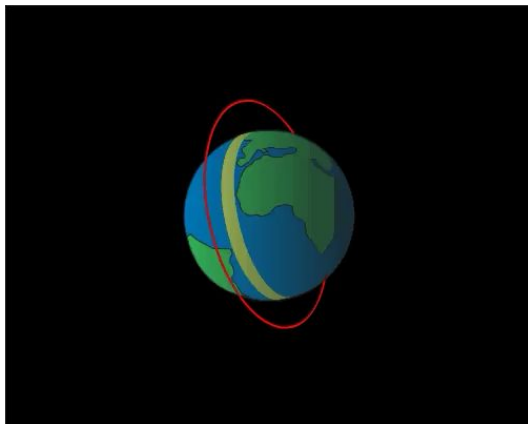
1 day of merged SST satellite data



- Satellite data provides observations of the ocean at temporal and spatial scales that are impossible to achieve with traditional in situ measurements
- Timeseries of satellite data make it possible to detect anomalous conditions and 'observe' past events

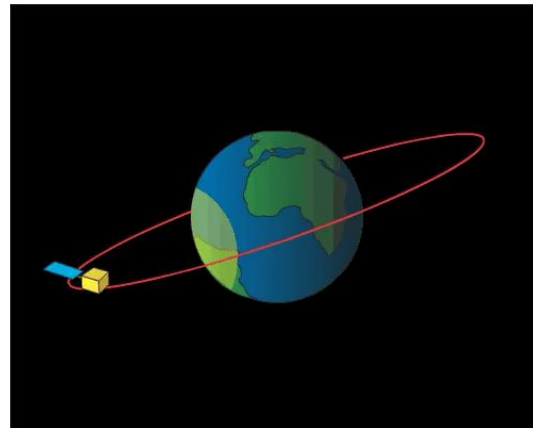


Satellite orbits



Polar-orbiting satellites view most of the earth once a day

Altitude: 700-800 km



Geostationary satellites view a limited region of the earth, but do so continuously throughout the day

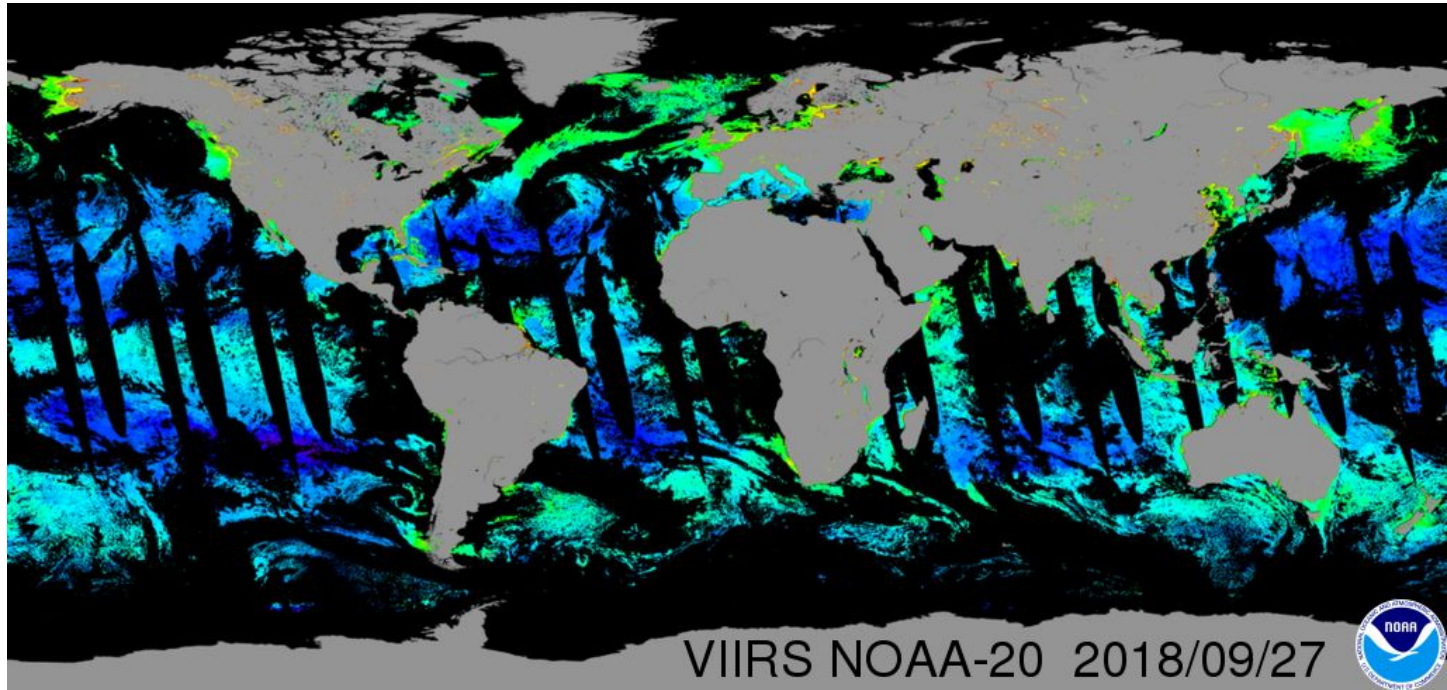
Altitude: 35,800 km

- Most oceanographic satellite measurements come from polar-orbiting satellites
- Some SST measurements are made from geostationary satellites
- South Korea has an ocean color sensor on a geostationary satellite.

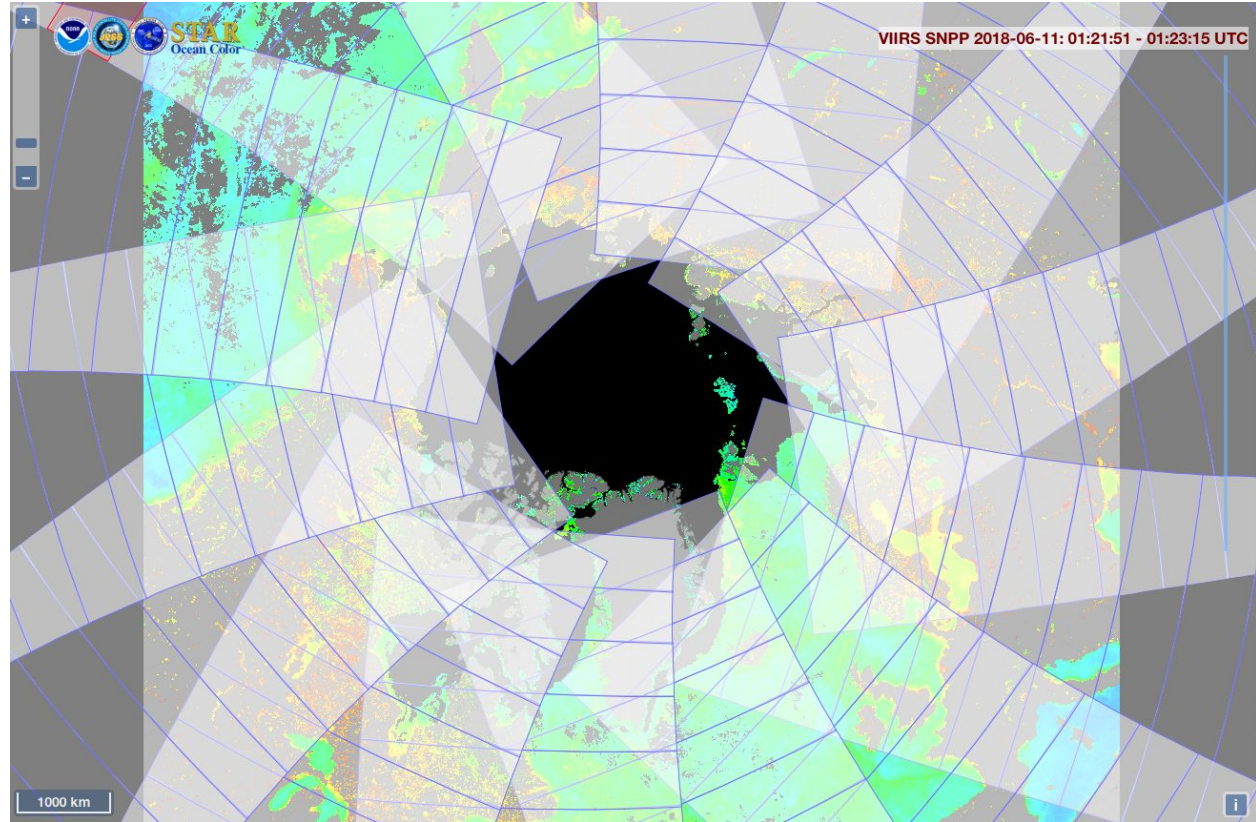
might
US ~~will~~ be getting ocean color on GEO!
NASA to launch GLIMR ~2027
NOAA to launch GEO-XO ~2032



Polar Orbit



Polar Orbit

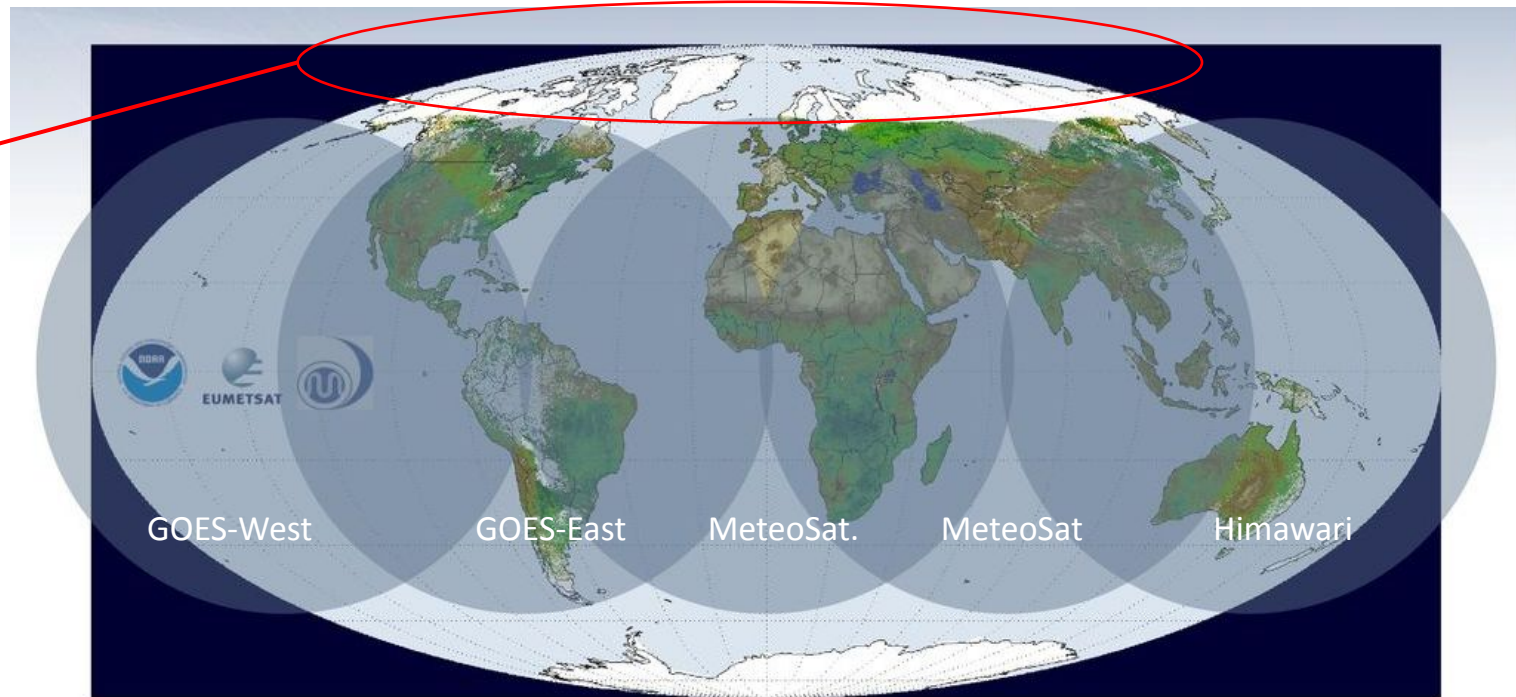


from <https://www.star.nesdis.noaa.gov/sod/mecb/color/ocview/ocview.html>



Geostationary coverage

Geostationary satellites aren't much use in polar regions!



GOES-West (US), GOES-East (US), MeteoSat x2 (Europe), Himawari (Japan)
-> 5 satellites for global coverage



Polar vs Geo Orbits

Polar

- Altitude: 700-800 km
- ~ 14 orbits a day
- Global coverage
- High spatial resolution (< 1 km)
- Low temporal resolution (≥ 1 day)

Geo

- Altitude: 35,800 km
- Poor coverage of the poles
- Regional coverage only
- Low spatial resolution (2-4 km)
- High temporal resolution ($< \text{hour}$)

Higher spatial resolution generally means lower temporal resolution, and vice-versa.

You can't have everything!



What Resolution?



- **Spatial resolution** is the pixel size of the image. The resolution of oceanographic satellite products ranges from 250 m – 25 km.
- **Temporal resolution** is the amount of time that passes between subsequent images at the same point.
- **Spectral resolution** refers to how many bands the sensor has.
- **Swath width** refers to the width of the area observed by the satellite (polar-orbiting). Satellites with larger swath widths will take less time to acquire global spatial coverage.



High Spatial Resolution Satellites



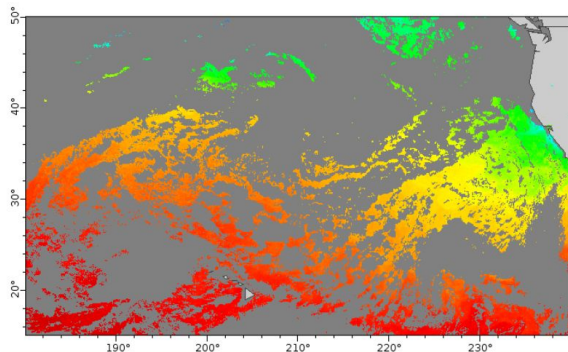
- There are a number of high spatial resolution imaging sensors, ~1-30 m, e.g. SPOT, QuickBird, IKONOS, OrbView-3, Hyperion, WorldView
- The trade-off is temporal resolution, and these sensors generally have very long repeat-times. Some don't have regular repeat times, but rather work on a system of scheduled, on-demand acquisitions.
- These data are generally better suited for land applications than for ocean applications.
- Traditionally these data had to be purchased, and are generally more difficult to access. However in recent years access has been granted to federal scientists to use these data without charge.
- These data are generally not offered as part of this course.



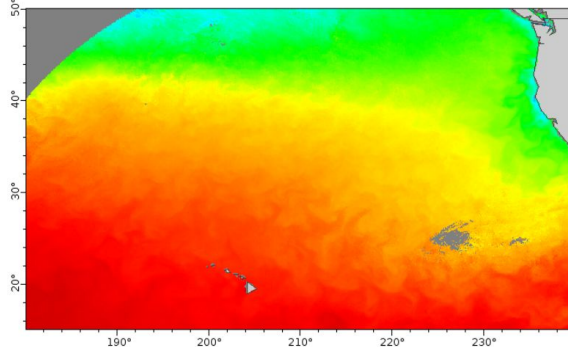
Example of Temporal Compositing

GOES West SST – September 2018

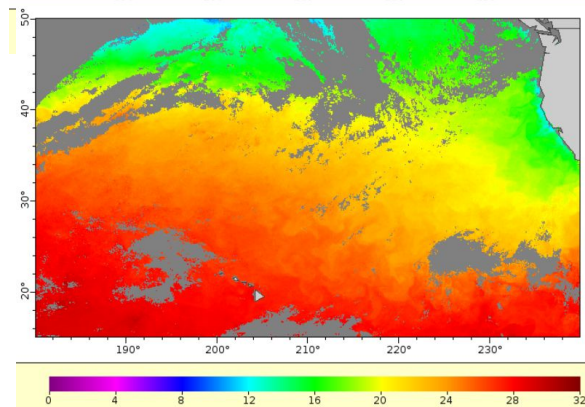
Sept 15
Hourly
Image



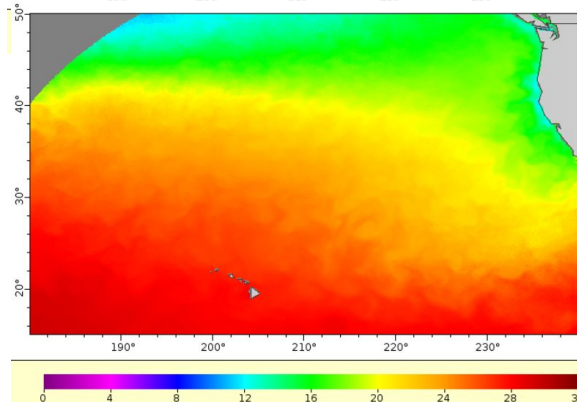
Sept 12-18
Weekly
Composite



Sept 15
Daily
Composite



Sept
Monthly
Composite



Cloud Masking

- Cloud masks are necessary for measurements that can't see through clouds, such as SST and ocean color
- Since cloud masks are usually made from visible imagery, cloud masks for nighttime retrievals of SST are less accurate than for daytime retrievals
- Different agencies and different satellite product producers use different cloud masks.



Anomaly Products and Climatologies

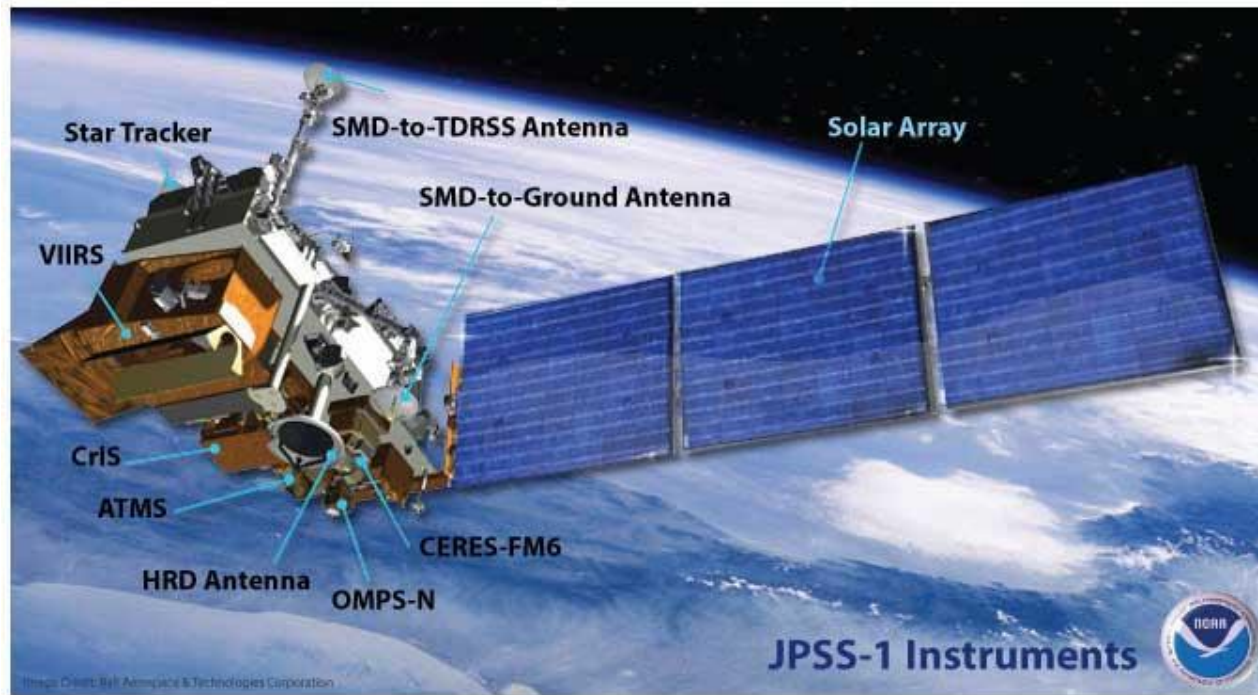
- For many applications an anomaly is more useful than the actual parameter. Anomalies are generated by subtracting a climatology of that parameter.
- We have a limited number of products with anomalies:

	MUR	NOAA Global Coral Bleaching
Temporal Coverage	2002 - now	1985 - now
Temporal Resolution	Daily & Monthly	Daily
Spatial Resolution	1 km	5 km
Products	SST	SST
ERDDAP link	https://coastwatch.pfeg.noaa.gov/erddap/griddap/jplMURSST41anommday.graph	https://coastwatch.pfeg.noaa.gov/erddap/griddap/NOAA_DHW.graph?CRW_SSTANO_MALY



Satellite vs Sensor

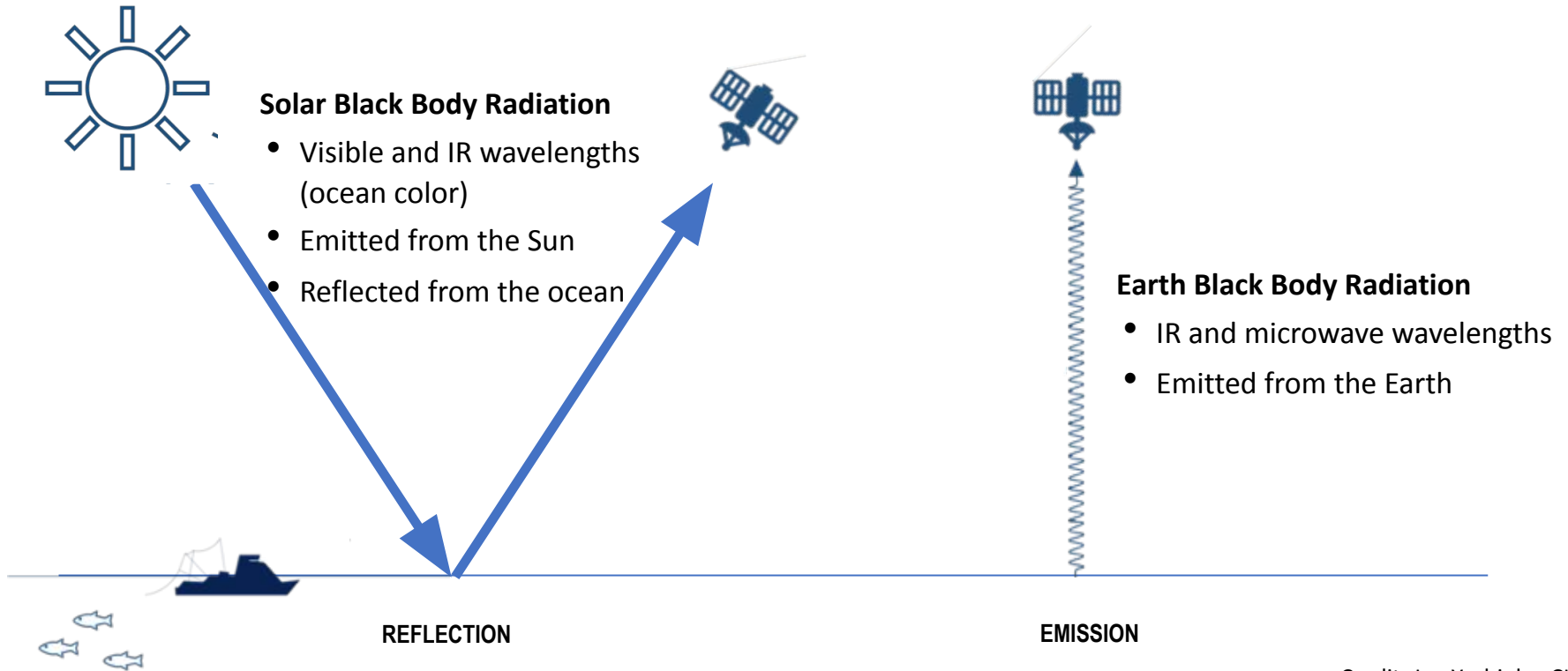
VIIRS:
Visible
Infrared
Imaging
Radiometer
Suite



Some satellites are single-mission, carrying only one sensor, e.g. the SeaWiFS sensor on the GeoEye/OrbImage satellite. Other satellites have multiple sensors on them, as the JPSS satellites do. The same sensor can be on multiple satellites, ie VIIRS on SNPP, NOAA-20 and NOAA-21



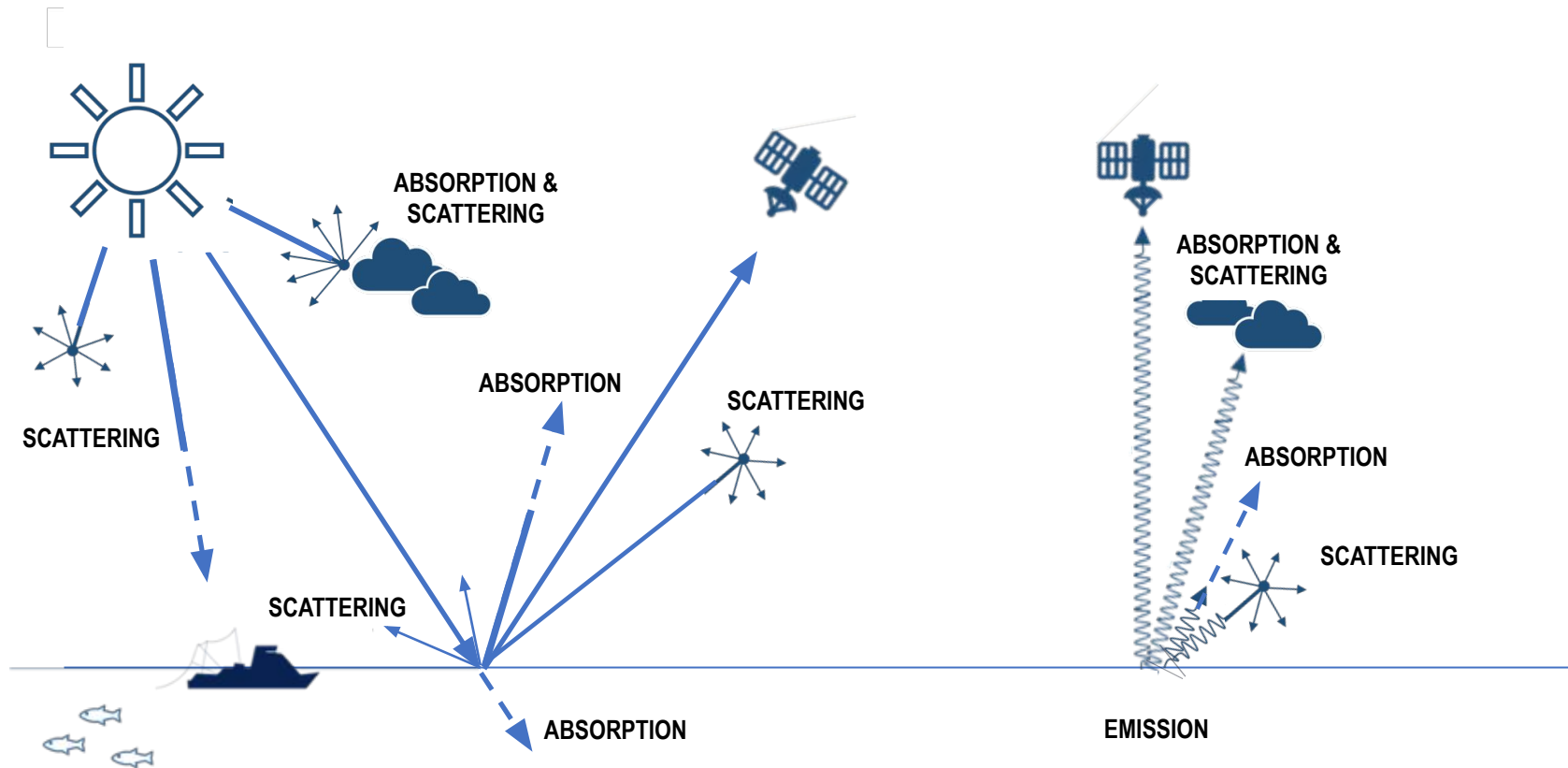
Satellite measure electromagnetic radiation (EMR)



Credit: Jan Yoshioka, CI



Processes alter the EMR signal as it passes through the atmosphere



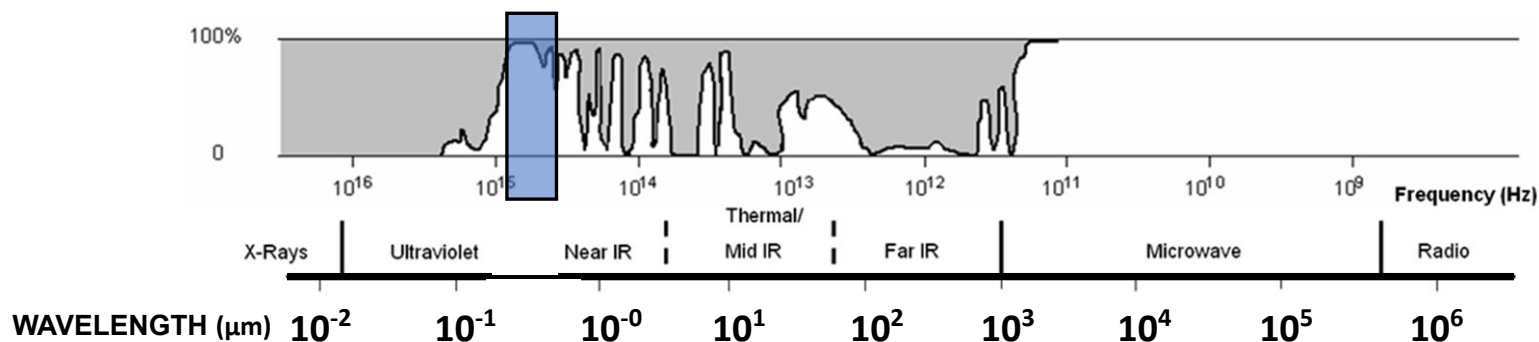
Credit: Jan Yoshioka, CI



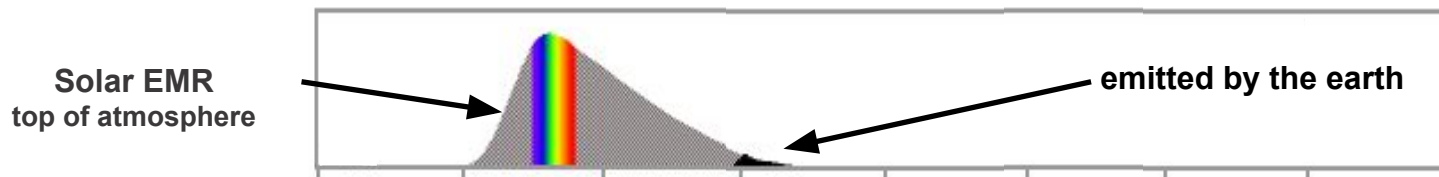
Visible light passes through the atmosphere without much attenuation

Atmospheric transmittance is high in **visible bands**, where solar EMR emission is highest

ATMOSPHERIC TRANSMISSION



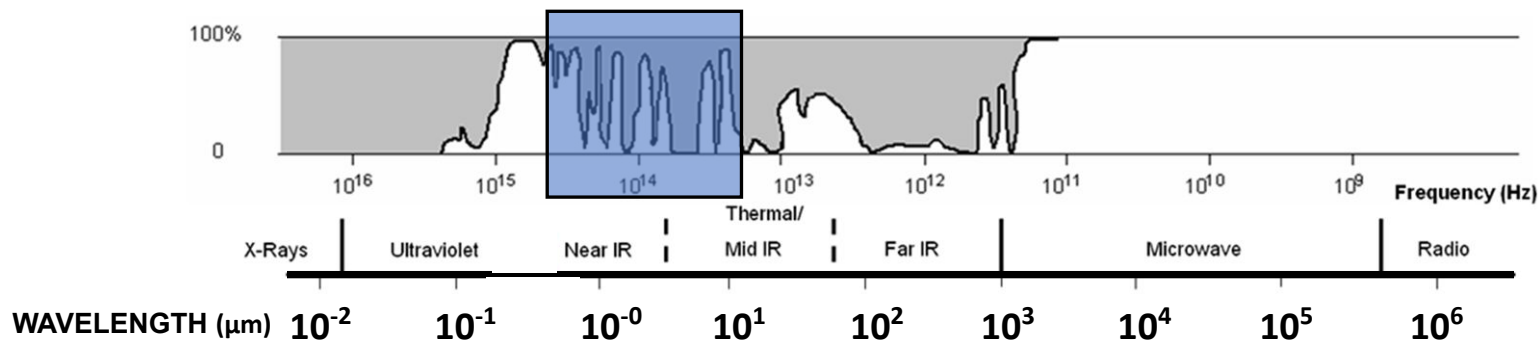
EMITTED EMR INTENSITY



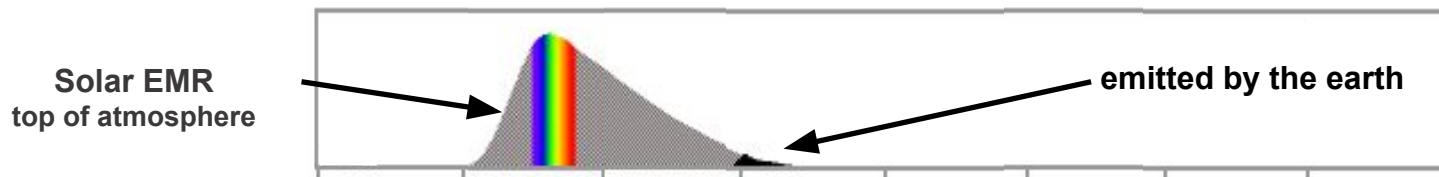
Infrared passes through narrow atmospheric windows

In the infrared, high transmittance occurs in narrow bands. This includes the optical windows in the thermal **infrared**, where the Earth's surface emits radiation.

ATMOSPHERIC TRANSMISSION



EMITTED EMR INTENSITY

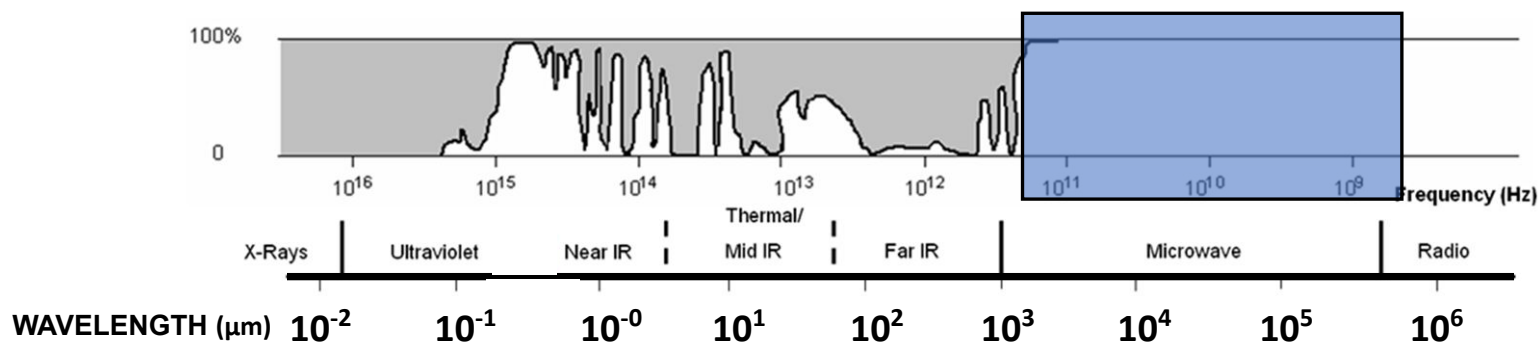


Microwaves pass through the atmosphere without much attenuation

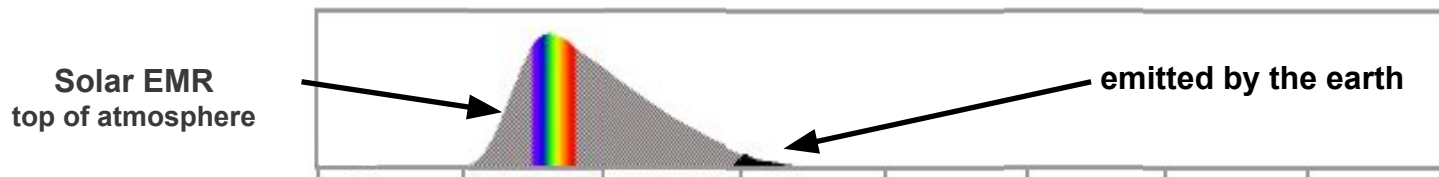
In the **microwave**, atmosphere transmission is near 100%.

But emission in the **microwave** by are relatively weak, so large antennas and large sensor footprints are needed to collect enough radiation for measurements.

ATMOSPHERIC TRANSMISSION



EMITTED EMR INTENSITY



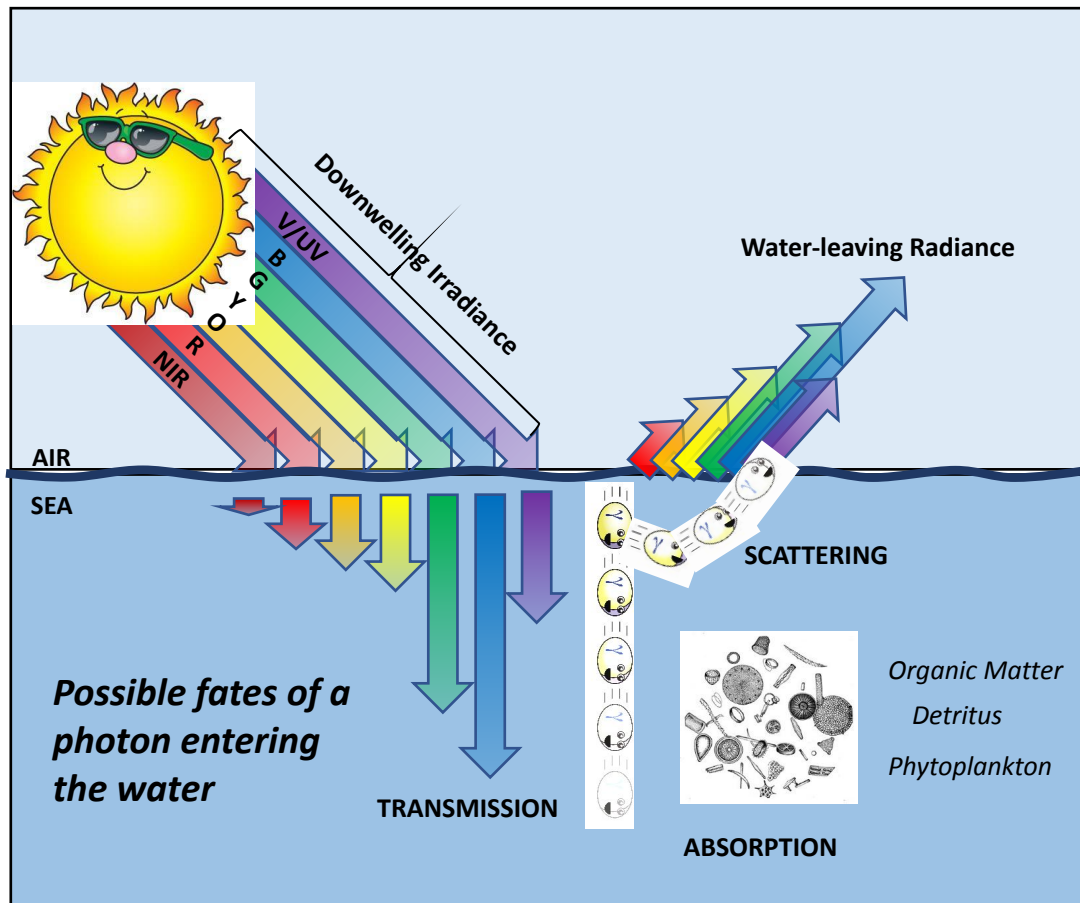
EMR is also affected by the water properties

EMR emitted by the sun is transmitted through the atmosphere to the ocean.

EMR interacts with elements in the ocean, where the spectral characteristics are changed

EMR reflected from the ocean is transmitted through the atmosphere and reaches the sensor

Image Credit: jeremy.werdell@nasa.gov



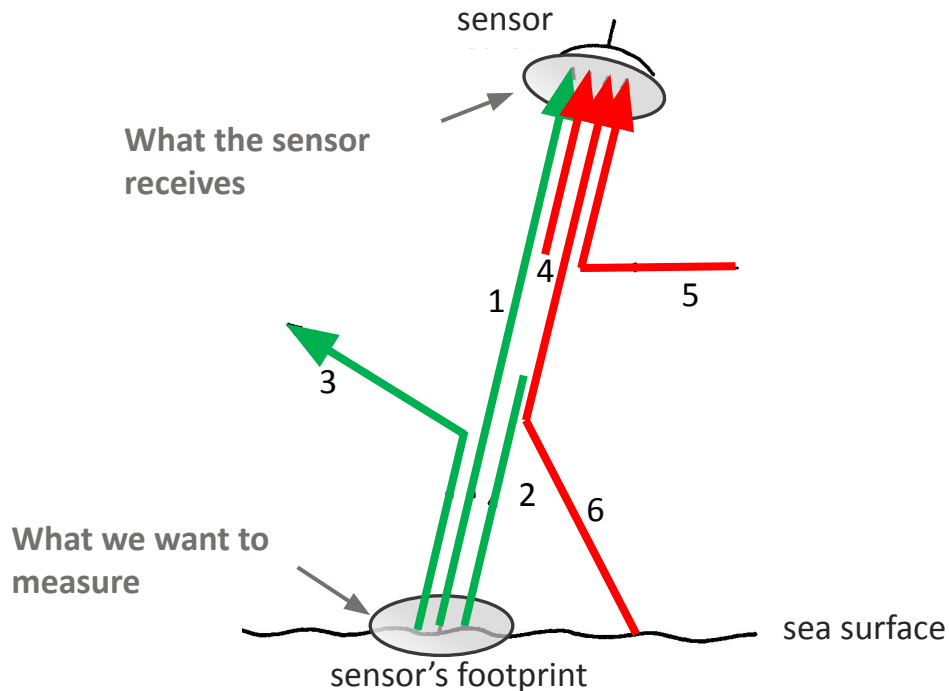
Atmospheric Pathways of EMT between the ocean and the satellite

Emitted from the sea within the sensor's footprint

- Ray 1** - the useful signal, radiation leaving the ocean and measured by the sensor
- Ray 2** - radiation leaving the ocean that is absorbed by the atmosphere
- Ray 3** - radiation that is scattered by the atmosphere out of the sensor field of view

Reaching sensor from sources outside its footprint

- Ray 4** - radiation emitted by the constituents of the atmosphere
- Ray 5** - radiation reflected by scattering into the field of vision of the sensor
- Ray 6** - radiation from the ocean but from outside the field of view.



ATMOSPHERIC CORRECTIONS ARE NECESSARY TO DERIVE ACCURATE SATELLITE DATA PRODUCTS.



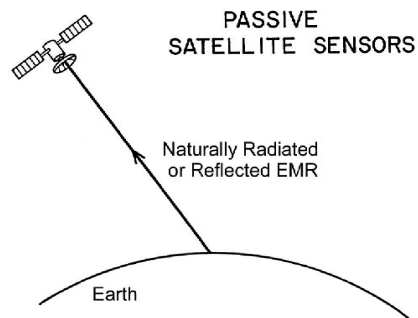
Atmospheric Correction

- Most of the absorption/re-emission of IR in the atmosphere is caused by a few gases (O_2 , N_2 and trace gases) that are relatively well-mixed, and by water vapor, ozone and aerosols, that are not well mixed.
- The well-mixed components cause a constant difference in temperature between the surface and the satellite.
- The variable components must be detected and corrected for using multiple wavelengths.

Atmospheric correction is necessary to derive accurate satellite data products.

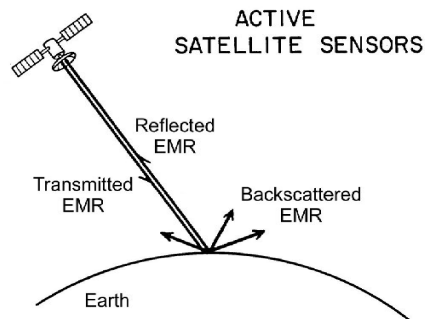


Passive vs Active Sensors



Passive Remote Sensing

- Reception of EMR signals from natural source
- Either EMR from the Sun that is reflected off of the earth or EMR emitted by the Earth



Active Remote Sensing

- Reception of EMR signals from a pulse emitted by a satellite
- The pulse is directed to the earth and the reflected signal is captured by the satellite sensor

Sea Surface Temperature

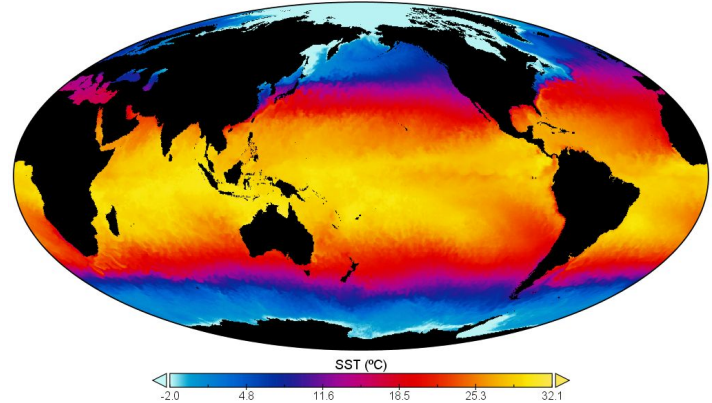
Continuous satellite data record goes back to 1981

Infrared instruments:

- SST_{skin} – the top ~ 20 μm
- High spatial resolution
- Measurements blocked by clouds
- Sensors in both polar and geo orbit

Microwave instruments:

- SST_{subskin} top ~ several mm
- Reduced spatial resolution
- Sees through clouds (fuller coverage)
- No measurements close to land (50-100km)
- Sensors only in polar orbit



Blended Products:

- Data from multiple satellites and/or multiple passes of the same satellite are combined
- Often data-gaps are filled by interpolation

Products Selection

- There are many SST products to choose from
- Before picking a product, select a few and compare them for several time steps and regions.

Ocean Color

Continuous satellite data record goes back to 1997

Measurements are made in the visible wavelengths and can not be made through clouds or at night.

Atmospheric correction is extremely important!

There are a suite of products measured by “ocean color” satellites:

- Chlorophyll (most commonly used)
- CDOM (Colored Dissolved Organic Matter)
- Primary Productivity
- Fluorescence,
- Photosynthetically Available Radiation (PAR)
- Water Clarity

Algorithms were developed for Case-1 (open ocean) waters.

- Care must be taken when using data from Case-2 (coastal) waters.

The most recently launched U.S. OC sensors are VIIRS

- Joint NASA/NOAA missions were launched Oct. 2011 (SNPP), Nov 2017 (NOAA-20) and Nov 2022 (NOAA-21)

Primary US satellites: • SeaWiFS 1997-2010 • MODIS/Aqua 2002- 2016-present • VIIRS 2011-present

European satellites: • MERIS 2002-2012 • OLCI April 2016-present



Sea Surface Salinity, Surface Winds, and Altimetry

Characteristics of microwave measurements

Measured with passive and active microwave sensors

Measurements are taken day and night,
and in nearly all-weather conditions

Spatial resolution (~ 25km) is lower than visible and infrared.

Passive sensors cannot measure close to the coast

Salinity

2010 - present

Global coverage in 1-3 days

Accuracy ~0.2 PSS

Winds

1987 - present

Global coverage 6-hours

Accuracy ~ 0.1 m/s

Altimetry

1990 - present

Daily global coverage

Accuracy ~ 3 cm

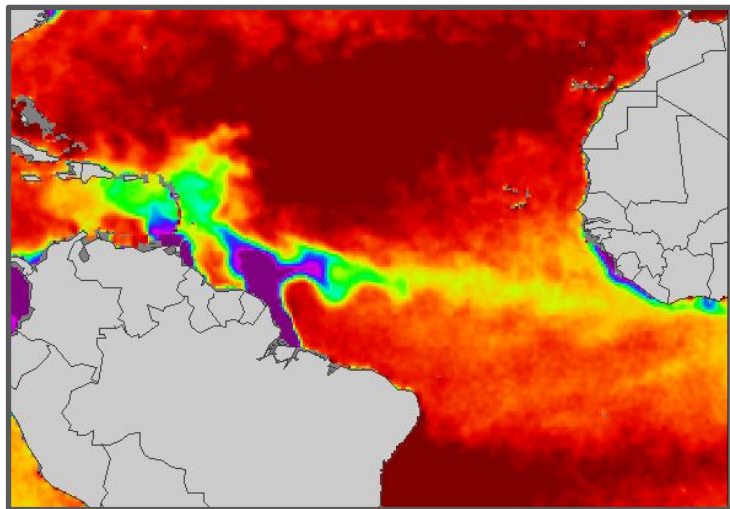


Uses for satellite salinity

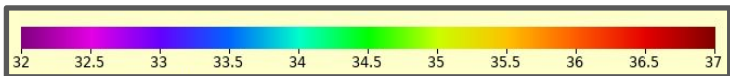
Global thermohaline circulation

Dynamic ecosystem modeling

Tracking surface salinity events



SMOS data – 0.25° resolution



Practical Salinity Scale

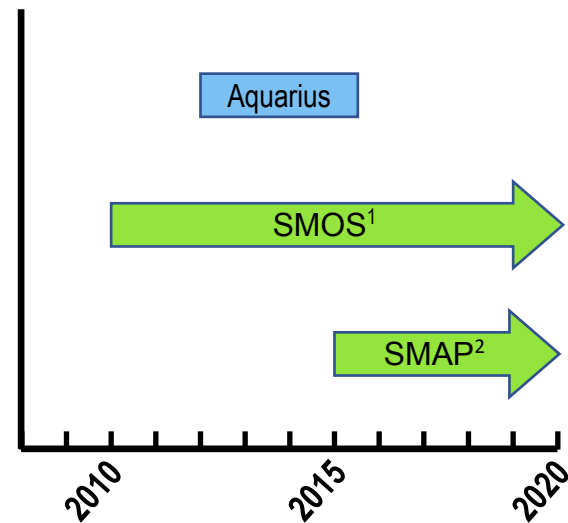
Temporal coverage: 2010 - Present

Spatial resolution: 0.25 – 1 degree

Global coverage: 3 – 8 days

Accuracy: 0.15-0.25 PSS

Depth: 1–2 cm

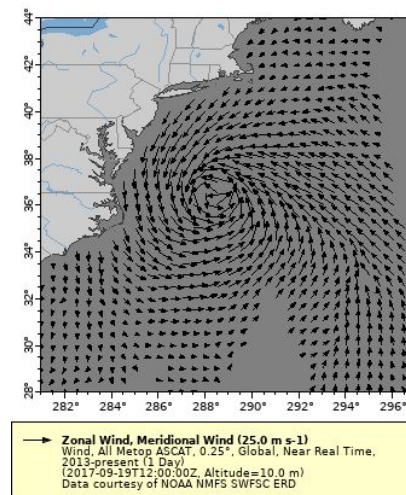
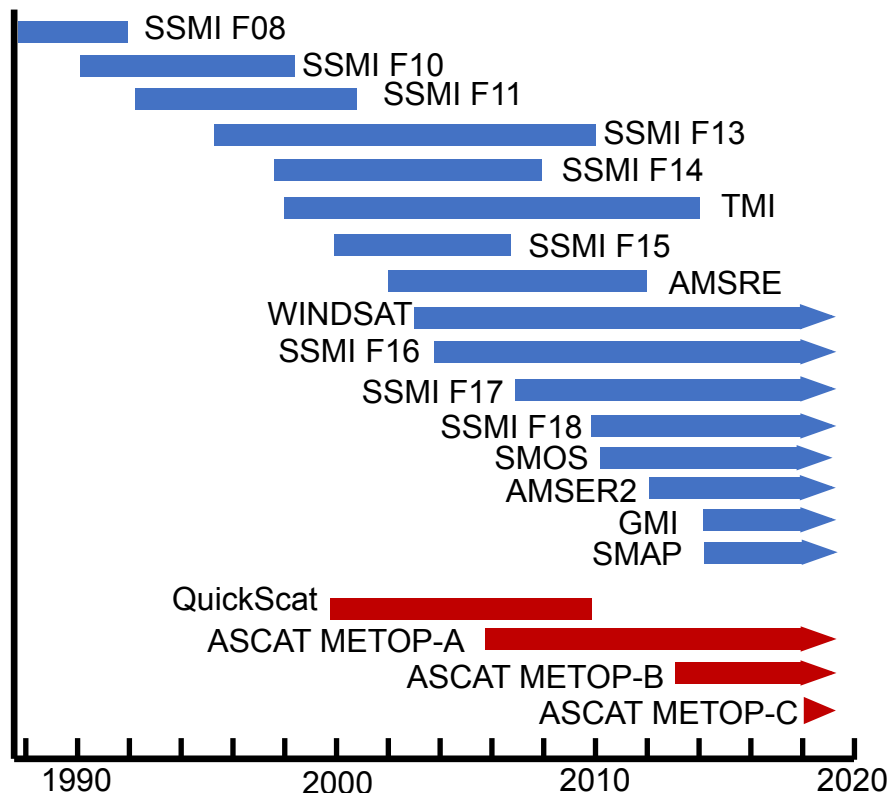


¹Soil Moisture and Ocean Salinity mission

²Soil Moisture Active Passive mission



Wind



Passive sensors (wind speed only)

Time span: 1987 - Present

Global coverage: ca. 6 hours - 3 days

Spatial resolution: 1/8° – 1° (12–100km)

Active sensors (wind speed & direction)

Time span: 1999 - Present

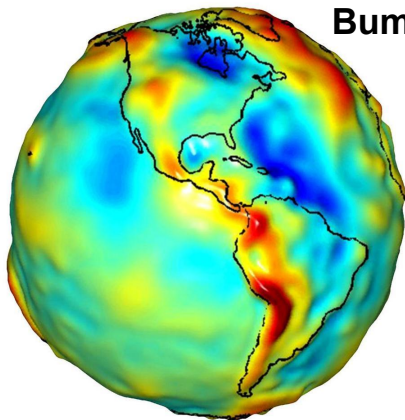
Global coverage: ca. 1 - 3 days

Spatial resolution: 0.25° – 1° (25-100 km)

Altimetry

Main variables:

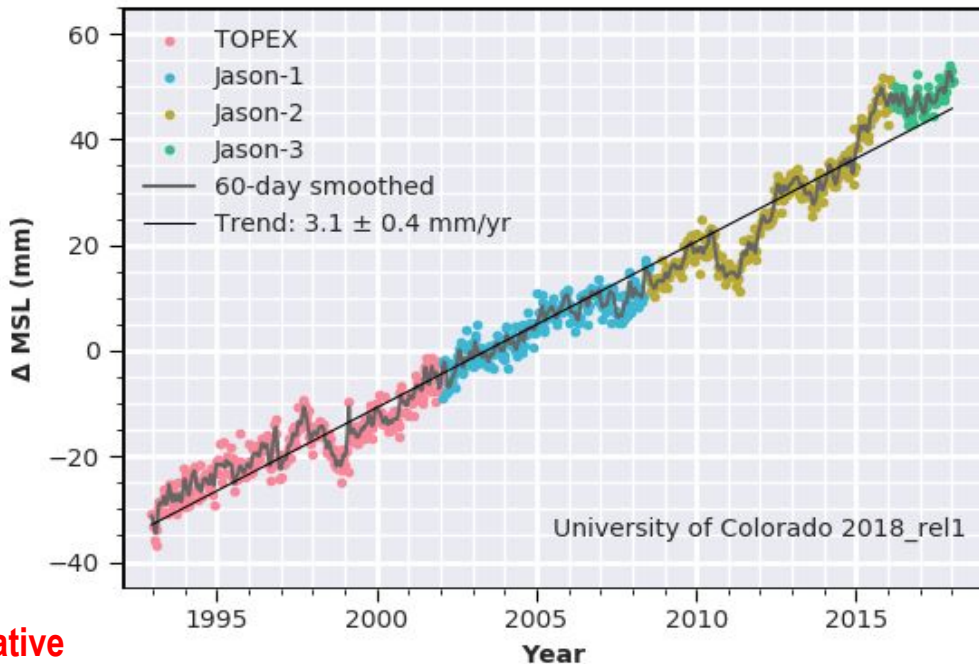
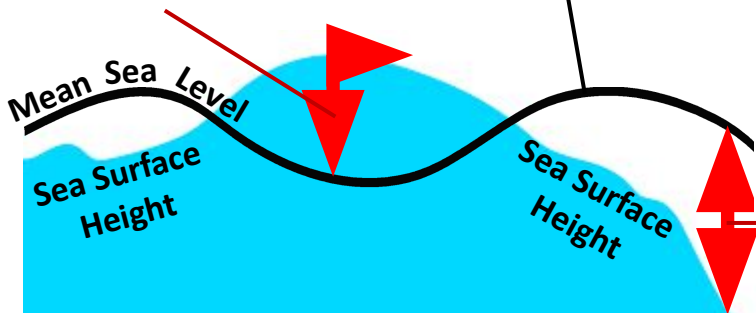
- Sea Surface Height
- Sea Level Anomaly
- Geostrophic Currents
- Eddy Kinetic Energy



Bumpy Earth

Long-term sea level mean
currently the 1993-2012 mean

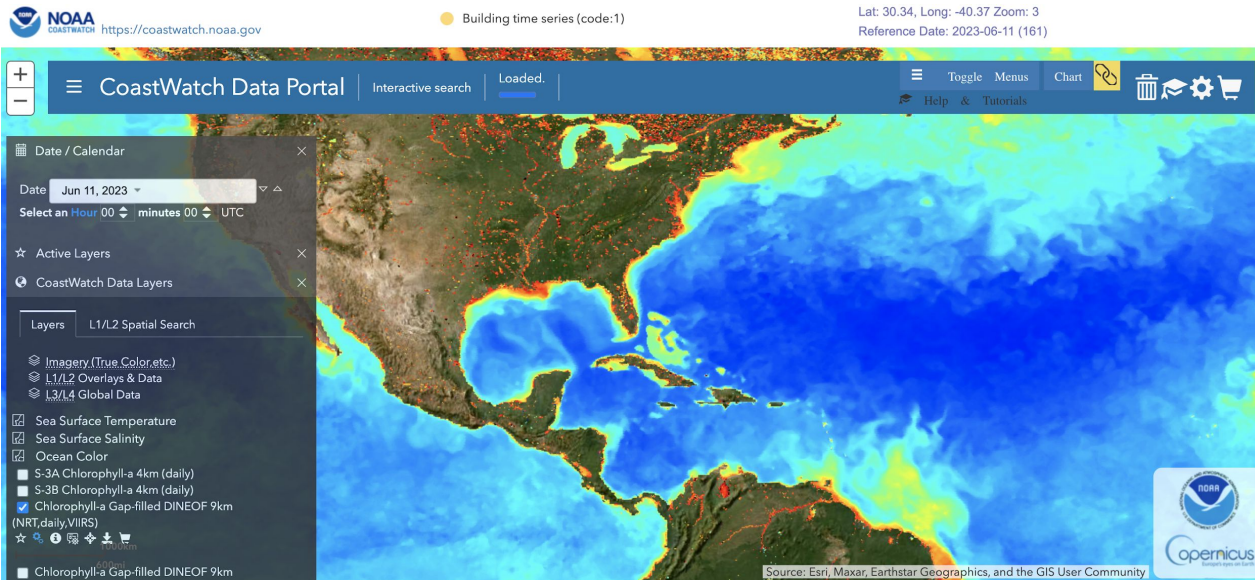
Positive
Sea Level Anomaly



Data Access/Discovery

- Websites:
 - CoastWatch (<https://coastwatch.noaa.gov>)
 - CoastWatch Regional Nodes (<https://coastwatch.noaa.gov/cw/nodes.html>)
- FTP Server:
 - <ftp://ftpcoastwatch.noaa.gov>
- THREDDS/ERDDAP:
 - <https://coastwatch.noaa.gov/thredds>
 - <https://coastwatch.noaa.gov/erddap>
 - CoastWatch West Coast Node ERDDAP Catalog of Catalogs:
 - https://oceanwatch.pfeg.noaa.gov/noaa_wide/erddap/index.html
 - erddap.com

CoastWatch Data Portal



- Visualize data layers
- Make time series
- Download data for region/range of dates
- Special user tools for specific applications

https://coastwatch.noaa.gov/cw_html/cwViewer.html



The web interface for the ERDDAP data catalog

ERDDAP at OceanWatch Central Pacific
Easier access to scientific data

ERDDAP > griddap

Griddap lets you use the OPeNDAP hyperslab protocol to request data subsets, graphs, and maps from gridded datasets (for example, satellite data and climate model data). For details, see [ERDDAP's griddap Documentation](#).

100 matching datasets, listed in alphabetical order. (Or, refine this search with [Advanced Search](#))

Grid DAP Data	Sub-set	Table DAP Data	Make A Graph	W M S	Source Data Files	Title	Summary	FGDC, ISO, Metadata	Background Info	RSS	E mail	Institution
data			graph	M		8_Day Global Seascapes (Lon:0_360)	?	F I M	background ?	RSS	✉	NOAA CoastWatch, ...
data			graph	M		Chlorophyll a Concentration, Aqua MODIS - 8-day, 2002-present. v.2018.0	?	F I M	background ?	RSS	✉	NASA/GSFC OBPB
data			graph	M		Chlorophyll a Concentration, Aqua MODIS - Cumulative Mean, January 2003 -February 2019. v. 2018.0	?	F I M	background ?	RSS	✉	NASA/GSFC OBPB
data			graph	M		Chlorophyll a Concentration, Aqua MODIS - Daily, 2002-present. v.2018.0	?	F I M	background ?	RSS	✉	NASA/GSFC OBPB
data			graph	M		Chlorophyll a Concentration, Aqua MODIS - Monthly, 2002-present. v.2018.0	?	F I M	background ?	RSS	✉	NASA/GSFC OBPB
data			graph	M		Chlorophyll a Concentration, ESA OC CCI - 8-Day, 1997-2019. v4.2	?	F I M	background ?	RSS	✉	Plymouth Marine L...
data			graph	M		Chlorophyll a concentration, ESA OC CCI - Cumulative Mean, 1998-2008. v4.2	?	F I M	background ?	RSS	✉	Plymouth Marine L...
data			graph	M		Chlorophyll a concentration, ESA OC CCI - Cumulative Mean, 1998-2018. v4.2	?	F I M	background ?	RSS	✉	Plymouth Marine L...
data			graph	M		Chlorophyll a concentration, ESA OC CCI - Cumulative Mean, 2009-2018. v4.2	?	F I M	background ?	RSS	✉	Plymouth Marine L...
data			graph	M		Chlorophyll a concentration, ESA OC CCI - Cumulative Mean, 2019. v4.2	?	F I M	background ?	RSS	✉	Plymouth Marine L...
data			graph	M		Chlorophyll a concentration, ESA OC CCI - Monthly, 1997-2019. v4.2	?	F I M	background ?	RSS	✉	Plymouth Marine L...

- Make simple graphs
- Download data for region/range of dates
- Use API in programming language to download data

For satellite data: Visit the NOAA CoastWatch data catalog pages

EACH OF THESE CATALOGS PROVIDE INFORMATION ABOUT DATASETS TO HELP YOU DECIDE WHICH TO USE



NOAA CoastWatch • OceanWatch

Central
Office

coastwatch.noaa.gov

NOAA COASTWATCH
WEST COAST REGIONAL NODE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
coastwatch.pfeg.noaa.gov/data.html

NOAA OCEANWATCH
CENTRAL PACIFIC NODE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
<https://oceanwatch.pifsc.noaa.gov/doc.html>

NOAA POLARWATCH
COASTWATCH REGIONAL NODE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
<https://polarwatch.noaa.gov/catalog/>

NOAA CoastWatch
Caribbean and Gulf of Mexico Regional Node
cwcarribbean.aoml.noaa.gov

NOAA CoastWatch
EAST COAST NODE
eastcoast.coastwatch.noaa.gov

NOAA CoastWatch
Great Lakes
coastwatch.glerl.noaa.gov

Preview sample images

Find out the geographical coverage

Find out the temporal range coverage

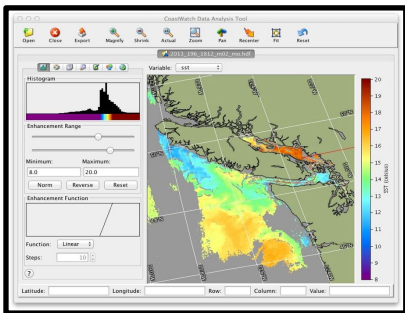
Review metadata for details about datasets



Tools for data processing

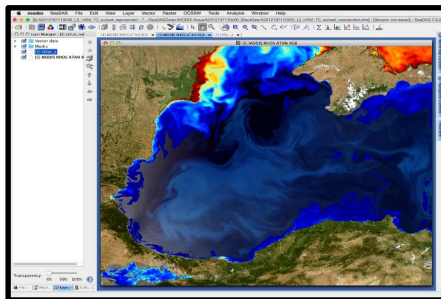
COMPREHENSIVE SOFTWARE PACKAGES

NOAA CoastWatch Utilities



[coastwatch.noaa.gov/cw/
user-resources/coastwatch-
utilities.html](https://coastwatch.noaa.gov/cw/user-resources/coastwatch-utilities.html)

NASA SeaDAS



seadas.gsfc.nasa.gov

Comprehensive software packages for satellite data:

- Processing
- Graphics and Visualization
- Analysis
- Format conversions
- Quality control

Not shown, ESA SNAP

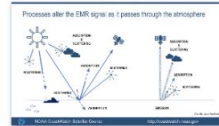


Recorded Lectures on the CoastWatch Learning Portal

Presently housed on the University of
Maryland learning management system :

<https://umd.instructure.com/courses/1336575/pages/all-lectures>

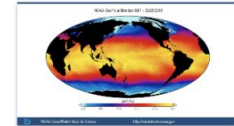
All lectures are available as audio-recorded PowerPoint files, videos or transcripts.



Satellite 101



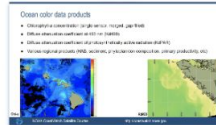
Ocean Color



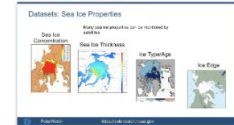
Sea Surface
Temperature



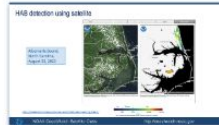
Sea Surface
Height, Winds,
Salinity



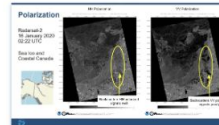
Water Quality



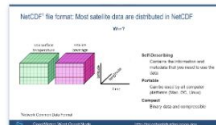
Sea Ice



HABs



Synthetic
Aperture
Radar (SAR)



Tools & Strategy



Selecting a
Dataset

Tutorials on the CoastWatch Learning Portal

Presently housed on the University of Maryland learning management system :

<https://umd.instructure.com/courses/1336575/pages/all-lectures>

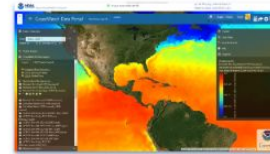
Tutorials And User Guides

Home Training Classes Lectures Tutorials Example Applications User Forums Help CoastWatch

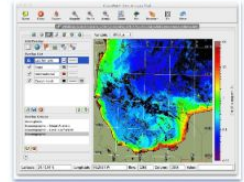
Step-by-step instructions, exercises, User Guides, and videos.



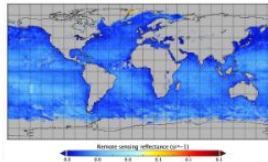
ERDDAP
also on GitHub



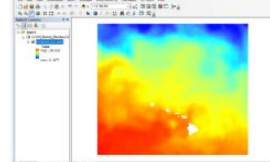
CoastWatch
Data Portal



CoastWatch
Utilities



also on GitHub
Panoply
netCDF viewer



ArcGIS



GitHub
R • Python • MATLAB



We will be using Slido to interact with participants:

Go to www.slido.com

#ATN2025



2025 CoastWatch & ATN Training

Aug 14 & 15, 2025 Virtual
10am - 1pm (Pacific Time)

Resources

- [Coastwatch Tutorials \(on GitHub\)](#)
- [Coastwatch Lecture series](#)
- [Animal telemetry Network](#)

Schedule

Thursday, August 14, 2025

Time (PST)	Topic	Presenter
10:00 - 10:15	Training Overview - CoastWatch, ATN and the workshop component	Cara Wilson
10:15 - 11:30	Coastwatch satellite datasets and data portals	Cara Wilson
11:30 - 11:45	Break	
11:45 - 12:15	Using the ERDDAP data server	Cara Wilson
12:15 - 12:45	Accessing ERDDAP using scripts (R, python)	Cara Wilson
12:45 - 1:00	Day 1 wrap-up	

Friday, August 15, 2025

Time (PST)	Topic	Presenter
10:00 - 10:30	Intro to ATN and the DAC	Megan McKinzie
10:30 - 11:00	Demo of ATN data portal	Megan McKinzie
11:00 - 11:30	Accessing public ATN datasets	Megan McKinzie
11:30 - 11:45	Break	
11:45 - 12:00	Workshop, part 1: Linking CoastWatch and ATN data using scripts	Daisy Shi
12:00 - 12:45	Workshop, part 2: Hand's on time	
12:45 - 13:00	Wrap up and final discussion	All



<https://coastwatch-training.github.io/CoastWatch-Workshops/courses/icft25.html>