Sea Surface Height, Wind, and Salinity

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NOAA Satellite Workshop

Anchorage, Alaska

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Versioning

-Robinson, 2020, WCN

-Tomlinson and Vogel, 2018, ECN

-Abecassis and Howell, 2018. PIN

-Robinson, 2019, WCN

SSH, wind and salinity are measured with microwave sensors

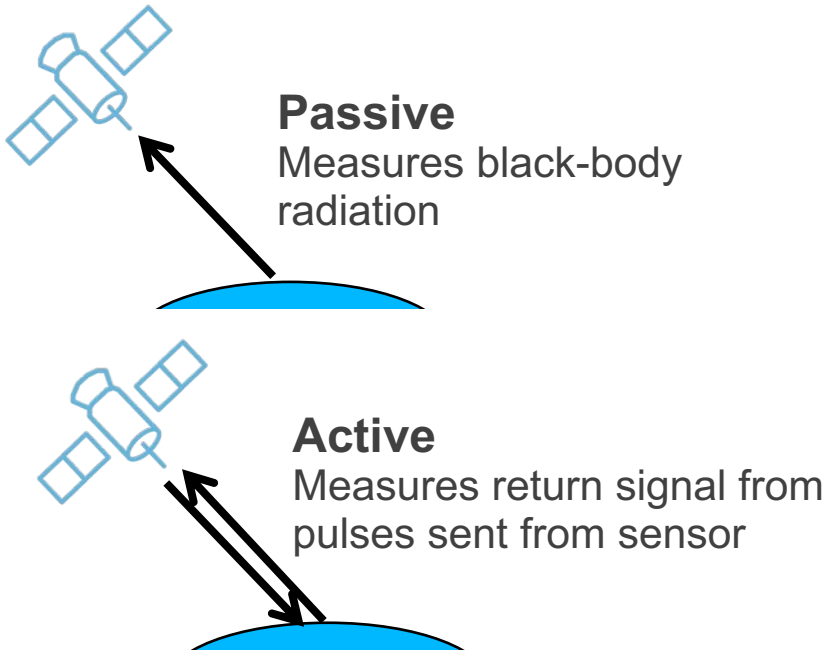
REVIEW OF MICROWAVE SENSORS AND THEIR PROPERTIES

FOR EACH MEASUREMENT [SSH, WIND, AND SSS] DISCUSS

- **How measurements are made**
- **Spatial and temporal resolution and coverage**
- **Where to download the data**

A quick review of microwave sensors

Passive and active sensors



Passive
Measures black-body radiation

Active
Measures return signal from pulses sent from sensor

Properties compared to ocean color

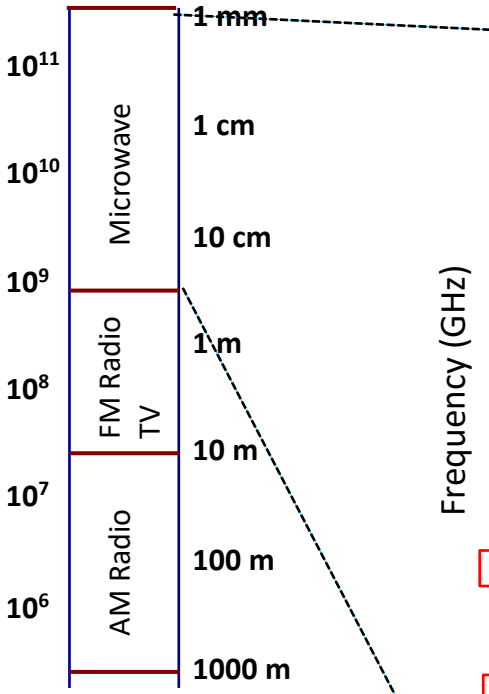
Lower spatial resolution:
12 km – 100 km (1/8º – 1º)
Usually 25-50 km (1/4º – 1/2º)

Can see through clouds

Can measure at night

Passive cannot measure near land or sea ice

Many uses compete for microwave bands



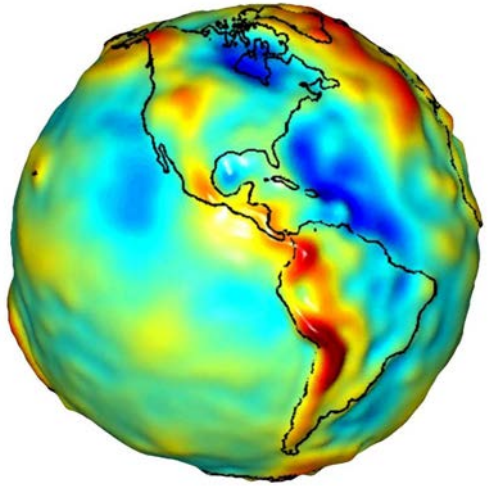
Frequency (GHz)	
170-110	radio astronomy, high-frequency microwave radio relay, microwave remote sensing, amateur radio, directed-energy weapon, millimeter wave scanner
100-75	satellite communications, millimeter-wave radar research, military radar targeting and tracking applications, and some non-military applications, automotive radar
75-50	millimeter wave radar research and other kinds of scientific research
60-40	terrestrial microwave communications, satellite communications, millimeter-wave radar research
50-33	satellite communications, terrestrial microwave communications, radio astronomy, automotive radar
40-25	satellite communications
25-18	radar, satellite communications, astronomical observations, automotive radar
18-12	satellite communications
8-4	satellite communications, radar, terrestrial broadband, space communications, amateur radio
	long-distance radio telecommunications
4-2	weather radar, surface ship radar, and some communications satellites (microwave ovens, microwave devices/communications, radio astronomy, mobile phones, wireless LAN, Bluetooth, GPS, amateur radio)
2-1	military telemetry, GPS, mobile phones (GSM), amateur radio

*Worries that the new 5G cellular phone band near 24 GHz could bleed over to the water vapor band used for weather satellites

Sea surface height (SSH): the ocean surface is not flat

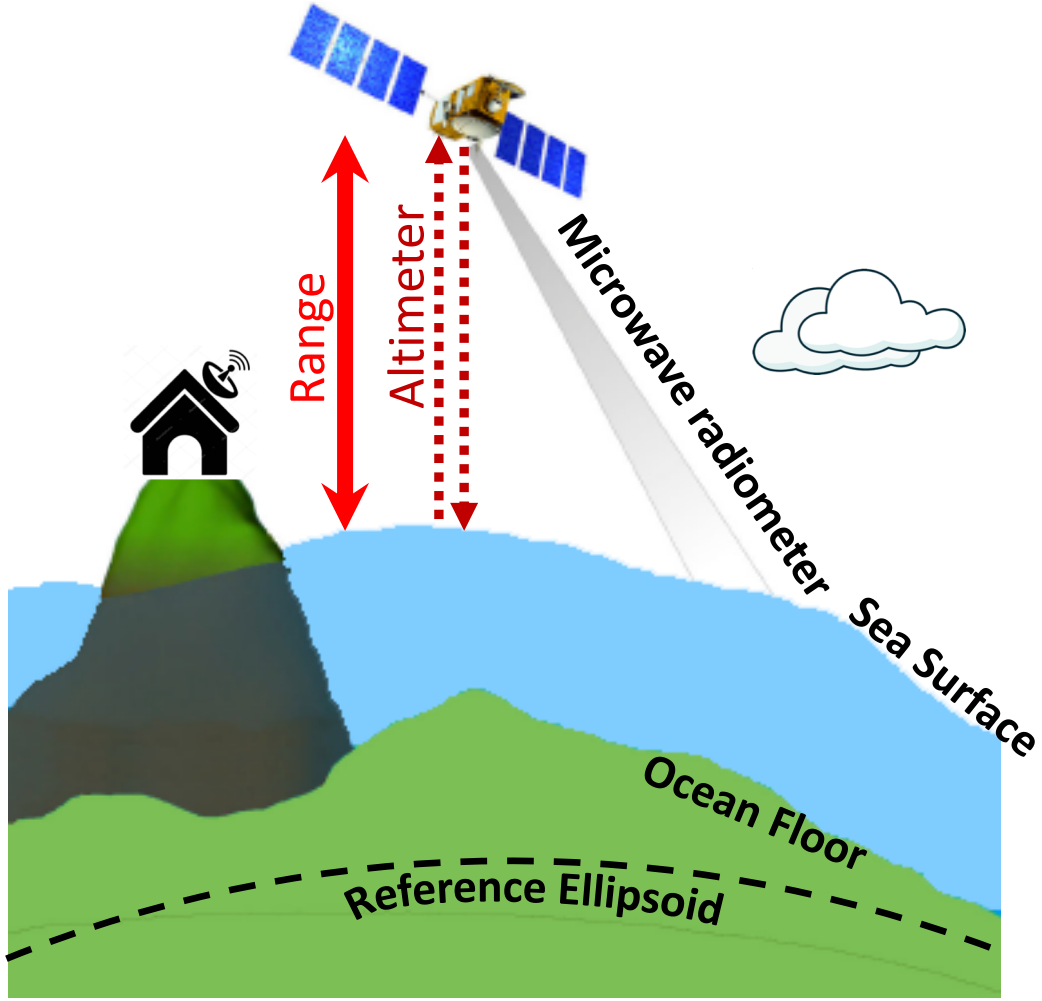
THE OCEAN'S BUMPINESS (SSH) IS MEASURED WITH ALTIMETRY (active sensors)

Idealized Earth Globe



Bumpy Earth

Altimeters measure the distance of the satellite to the ocean



Altimeters measure distance to the ocean surface

- Measures **Return Time**: the time for microwave pulses to travel to the ocean surface and back
- **Range -** the distance to the ocean surface is calculated from **Return Time** of the signal

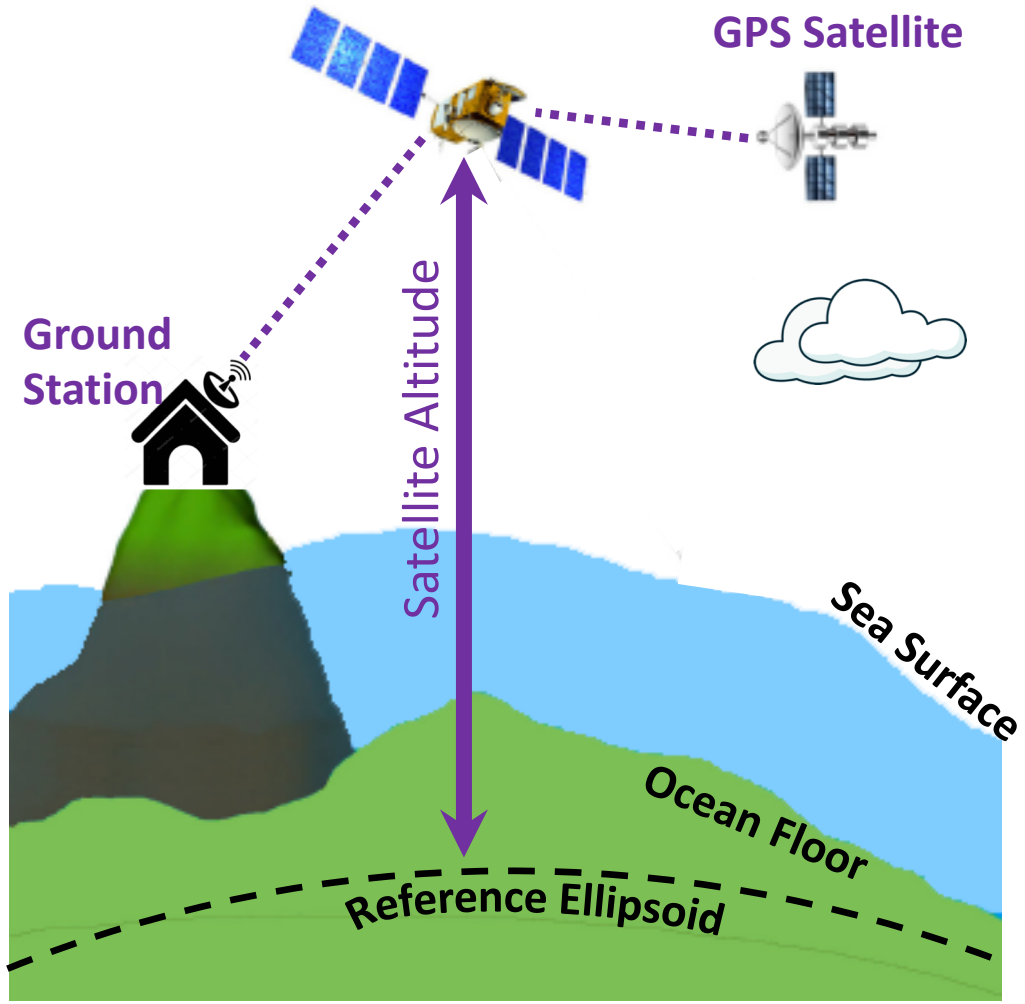
Range (m) = Speed of Light (m/s) x Return Time (s) / 2

Atmospheric correction

Microwave radiometer corrects for changes in the **Speed of Light**

(due to atmospheric conditions)

The altimeter position is determined by GPS and ground stations



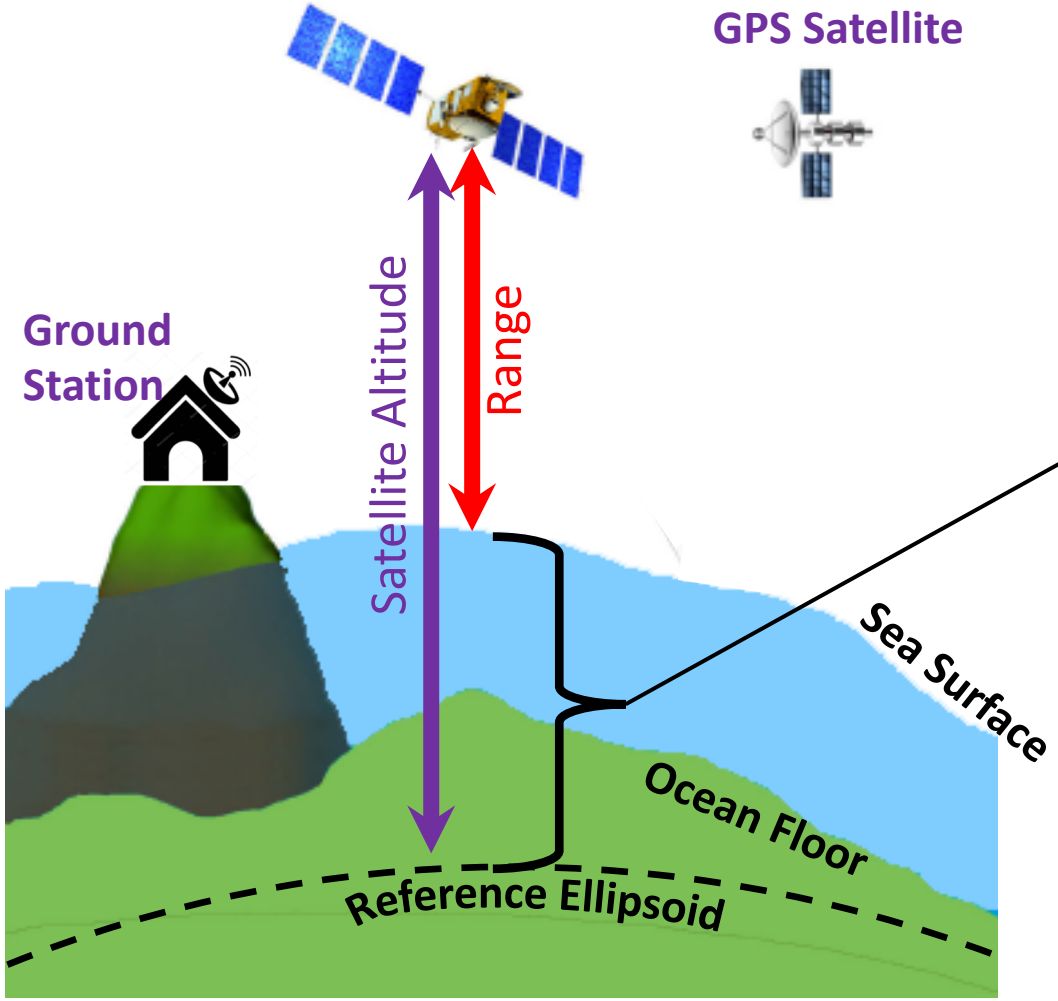
GPS satellites and/or ground stations determine the satellite's position in 4D

- Altitude above the reference

Plus

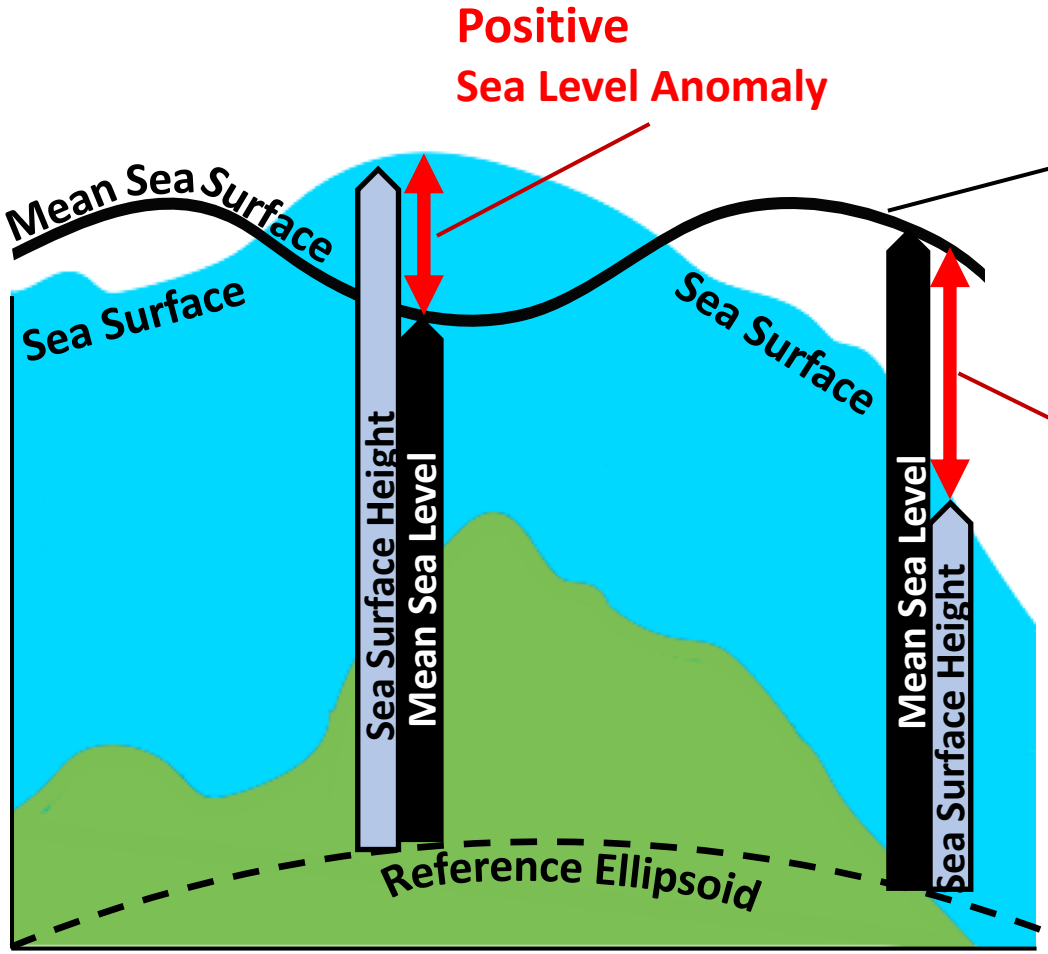
- Latitude
- Longitude
- Time

Put all it all together to determine SSH and other parameters



Sea Surface Height = Satellite Altitude – Range

Sea level anomaly is the difference from a long-term sea level mean



Long-term sea level mean

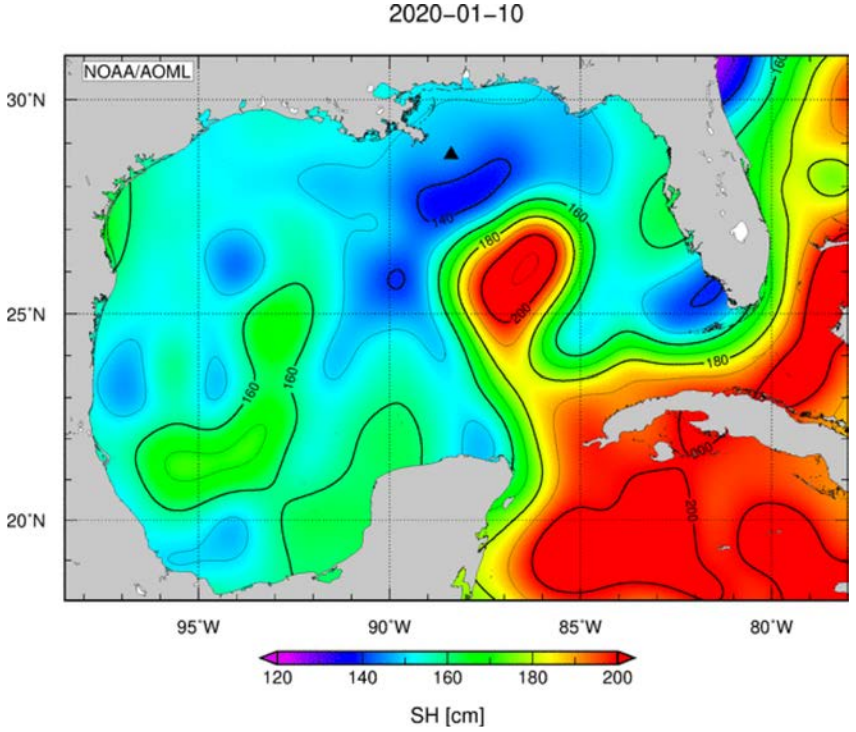
currently the reference period is 1993-2012

Negative
Sea Level Anomaly

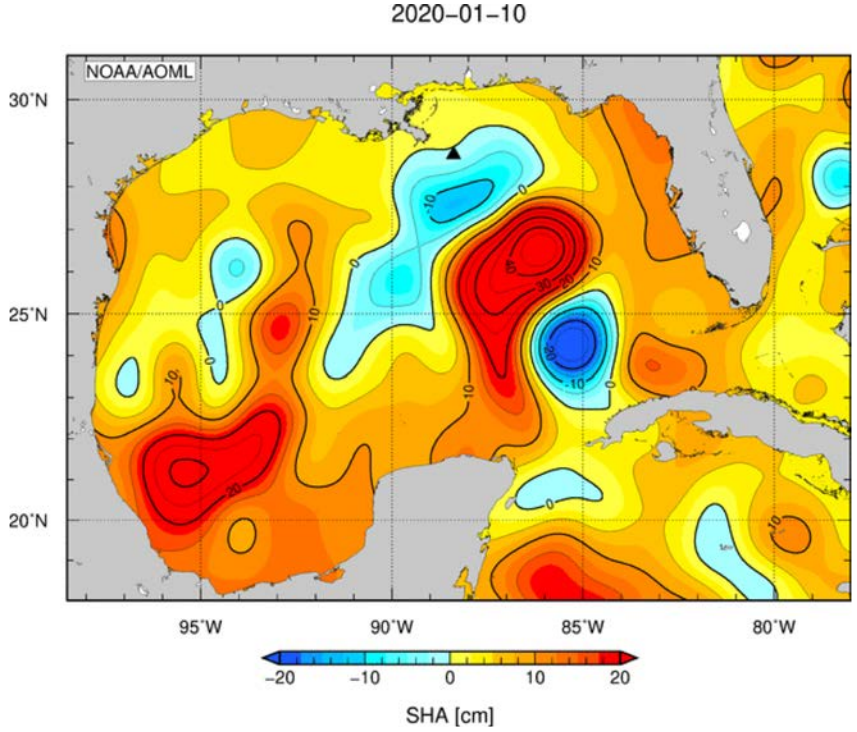
Sea Level Anomaly = Sea Surface Height - Mean Sea Level

Sea surface height and anomaly from the Gulf of Mexico

sea surface height



sea surface height anomaly

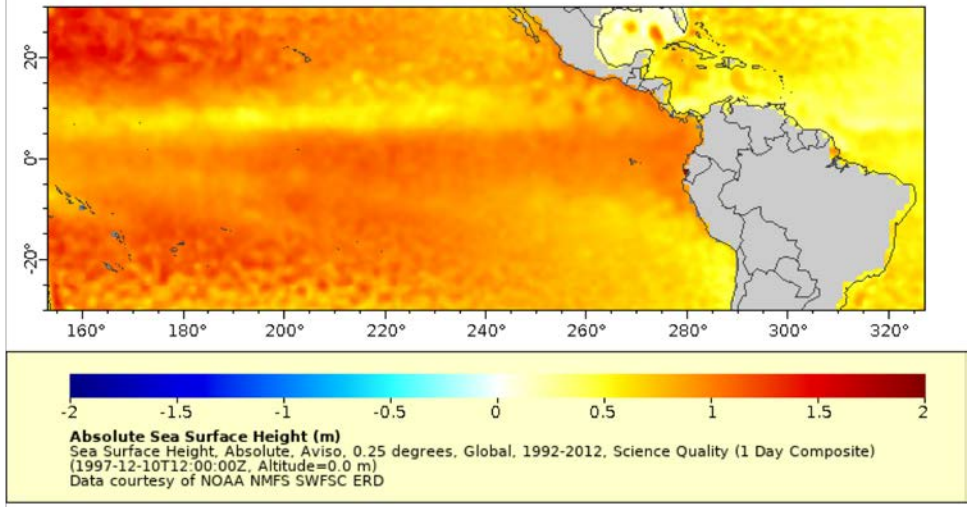


https://www.aoml.noaa.gov/phod/dhos/altimetry.php

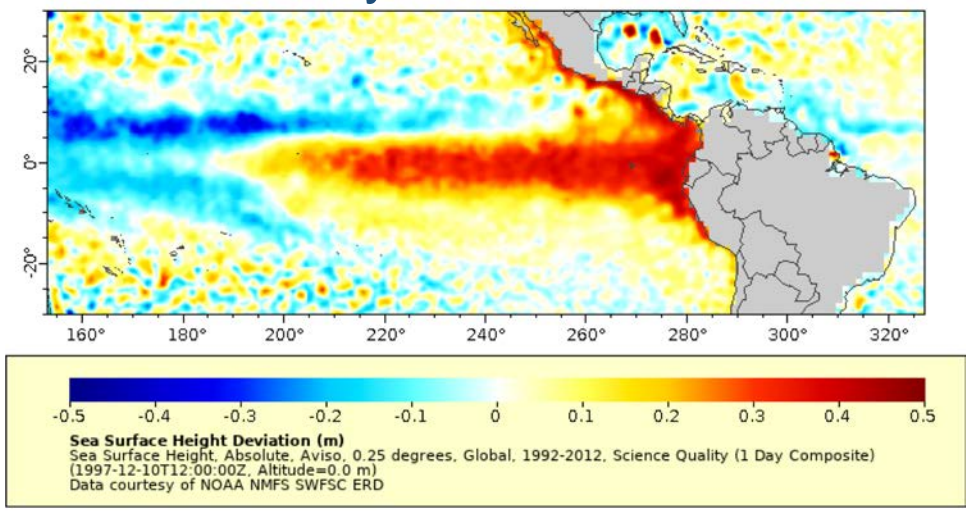
Visualize an El Niño with the SSH anomaly

1997-1998 El Niño

SSH



SSH Anomaly

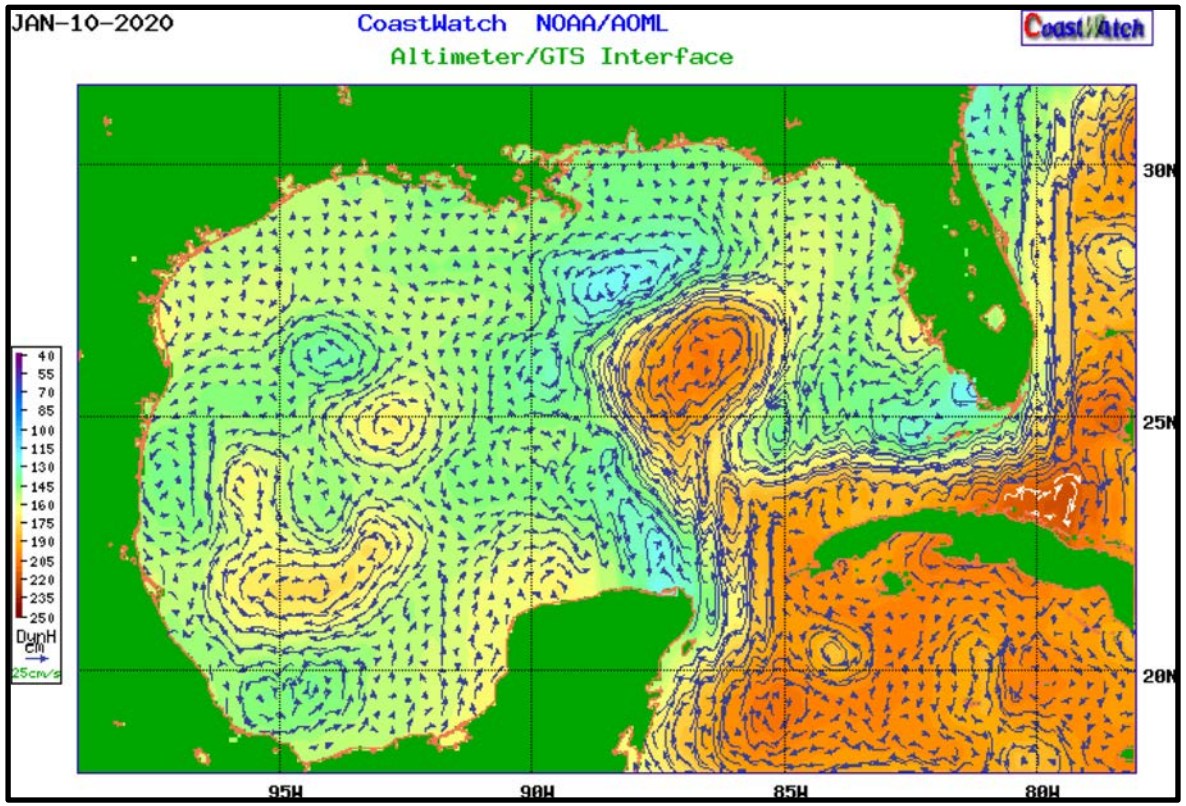


- Winds push warm water to the east against the west coast of Peru
- As the water warm it expands, increasing SSH beyond what is typically observed
- SSH anomaly help to visualize the non-typical SSH values

Geostrophic currents are calculated from SSH information

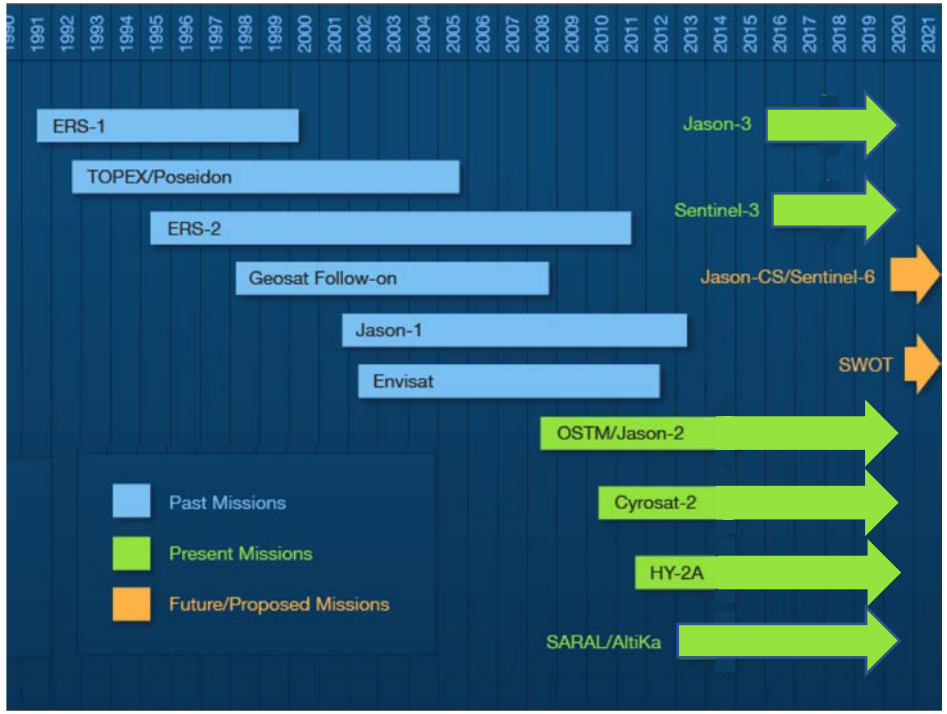
CURRENTS THAT ARE DRIVEN BY A SEA LEVEL GRADIENT

Geostrophic Currents Jan 10, 2020



https://www.aoml.noaa.gov/phod/dhos/altimetry.php

Satellite altimetry dates back to the early 1990s



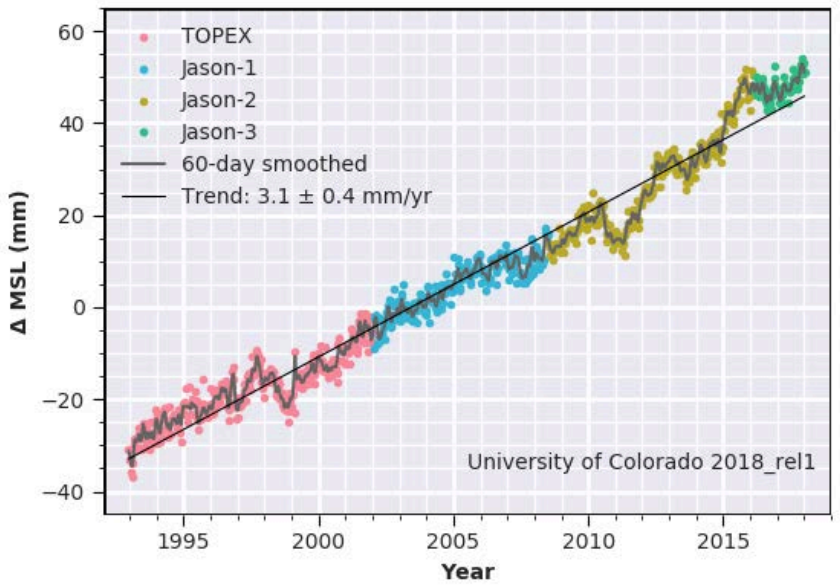
Many missions, always with some overlap

Blending the sensor data together allows:

- Creating long timeseries
- Getting better spatial coverage at any one time

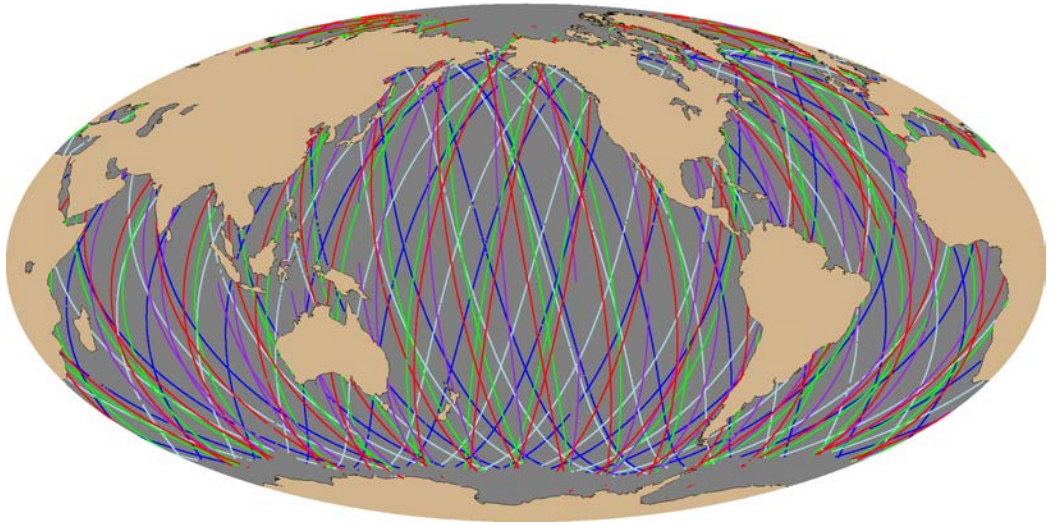
Blended missions gives improved temporal and special coverage

Blended Product
Mean Sea Level 1993–2018



TOPEX Jason-2
Jason-1 Jason-3

Altimeter Spatial Coverage
(Aug 1, 2018)



Jason-2 AltiKa
Jason-3 Cryosat-2
Sentinel-3A

Blended sea surface height datasets available on ERDDAP

	Time Range	Resolution	Composite	Quality	Parameters
[a,c] **NOAA CoastWatch**	2017-Now	0.25º (25 km)	Daily	NRT	SSH Anomaly Geostrophic Currents
[b,c] **NOAA CoastWatch**	2012-Now	0.25º (25 km)	Daily	SQ (delayed)	SSH anomaly Geostrophic Currents
AVISO	1993 – 2012 [d] 1993 – Now [e]	0.25º (25 km)	Daily	SQ (delayed)	SSH, SSH Anomaly, Geostrophic Currents
[f,g] **HYCOM Model**	2012 – Now	0.08º (8 km)	Daily	SQ (months-years)	SSH, SSH Anomaly, SST, Salinity, Currents

[a] coastwatch.pfeg.noaa.gov/erddap/griddap/nesdisSSH1day.graph

[b] coastwatch.noaa.gov/erddap/griddap/noaacwBLENDEDSQsshDaily

[c] coastwatch.noaa.gov/cw/satellite-data-products/sea-surface-height/sea-level-anomaly-and-geostrophic-currents-multi-mission-global-optimal-interpolation-gridded.html

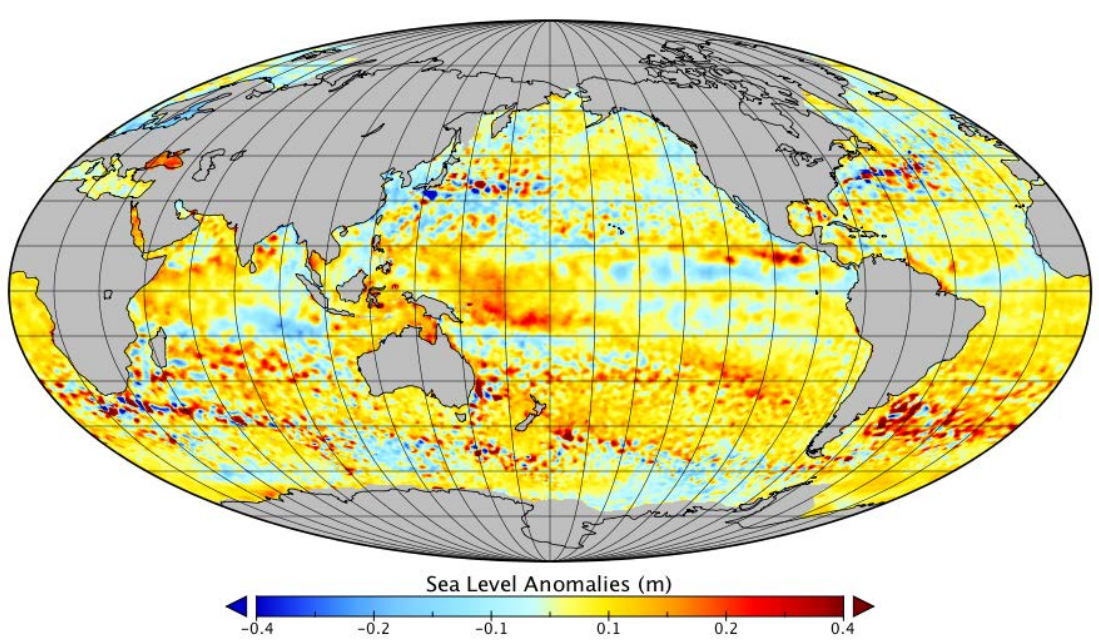
[d] coastwatch.pfeg.noaa.gov/erddap/search/index.html?page=1&itemsPerPage=1000&searchFor=erdTA

[e] marine.copernicus.eu/services-portfolio/access-to-products/

[f] coastwatch.pfeg.noaa.gov/erddap/search/index.html?page=1&itemsPerPage=1000&searchFor=nrlHycom+surface

[g] www.hycom.org/

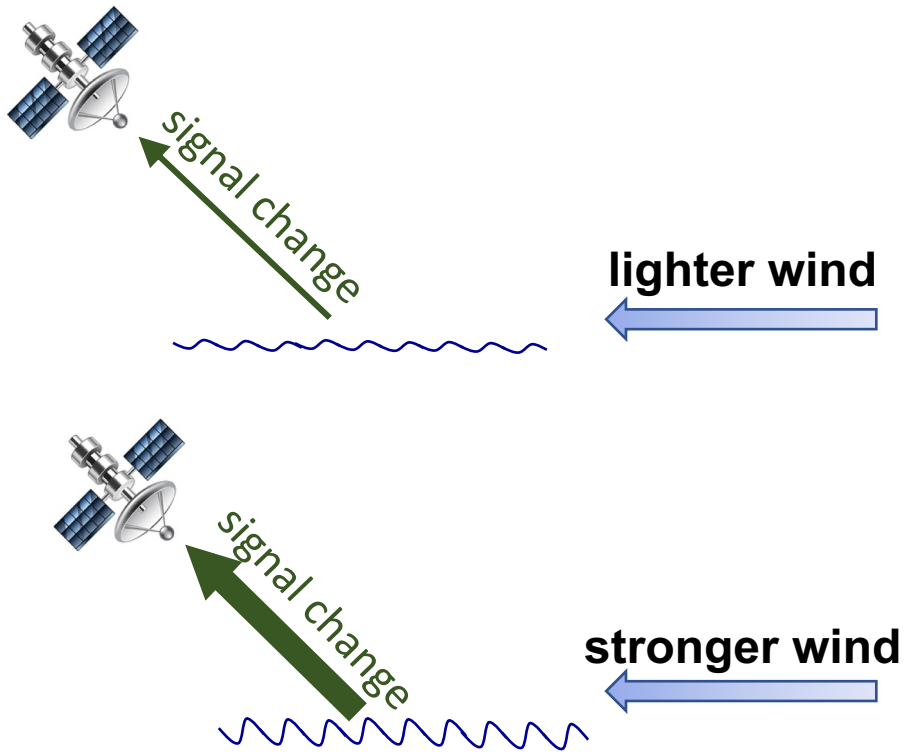
Questions before moving on to wind measurements?



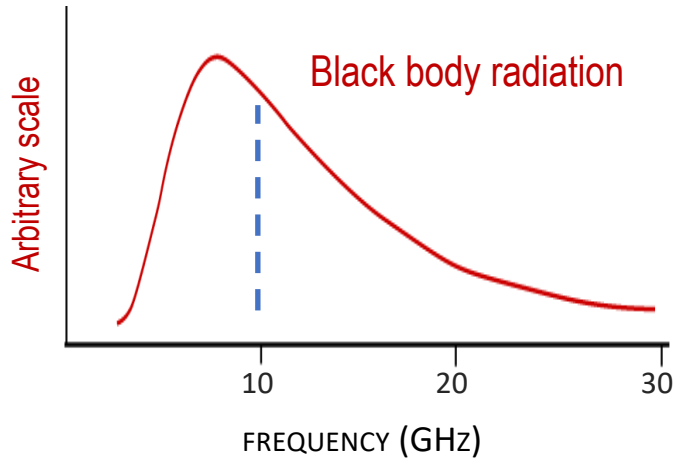
Sea Surface Height Anomalies from Altimetry
NOAA CoastWatch

Winds measured with radiometers (passive) and scatterometers (active)

RADIOMETERS (PASSIVE) MEASURE WIND SPEED (NOT DIRECTION), USING SEA ROUGHNESS AS A PROXY



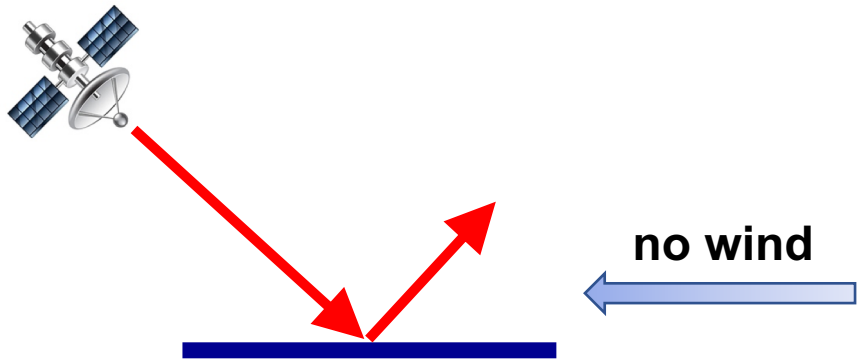
roughness changes the black body signal emitted by the ocean

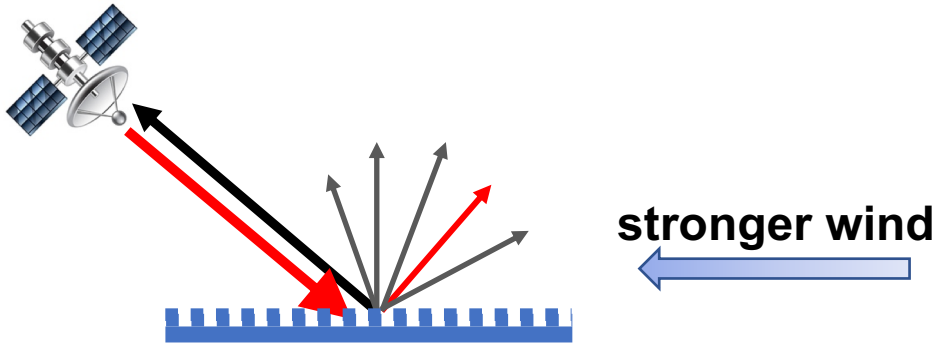


Radiometers measure roughness at ca. 10 GHz

Scatterometers (active) measure wind speed and direction

WIND SPEED IS MEASURED VIA BACKSCATTER FROM SEA SURFACE RIPPLES (CAPILLARY WAVES)





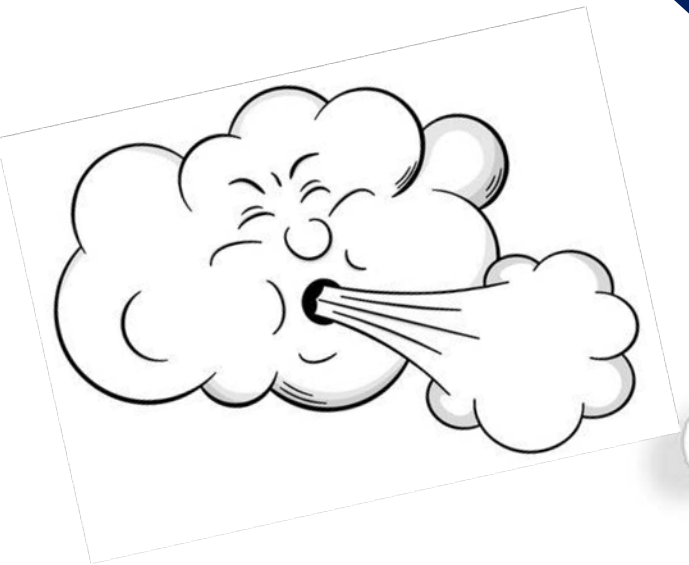
Wind direction is also determined from backscatter

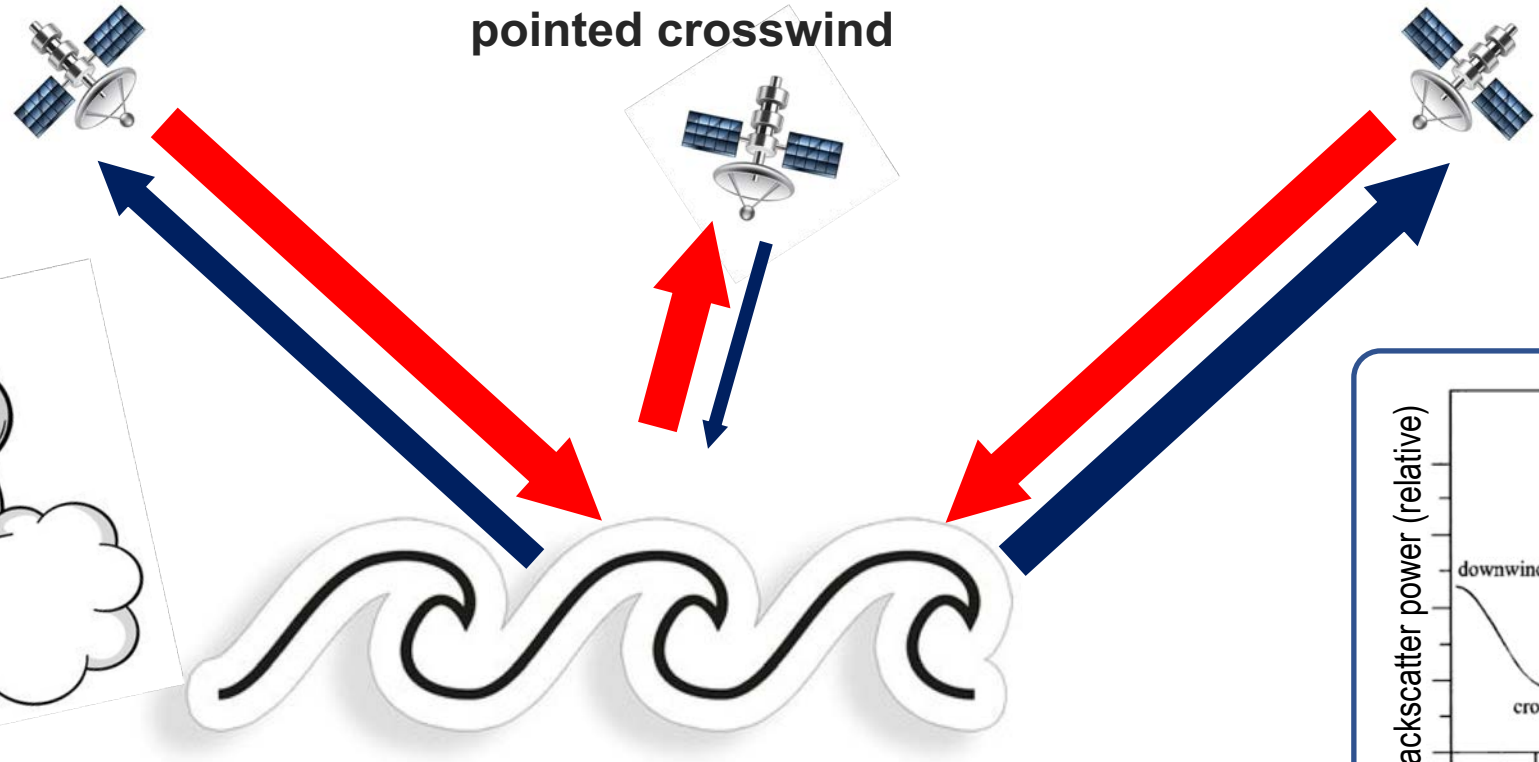
FOR A SINGLE WIND SPEED, BACKSCATTER IS SENSITIVE TO THE PULSE DIRECTION RELATIVE TO THE WIND DIRECTION

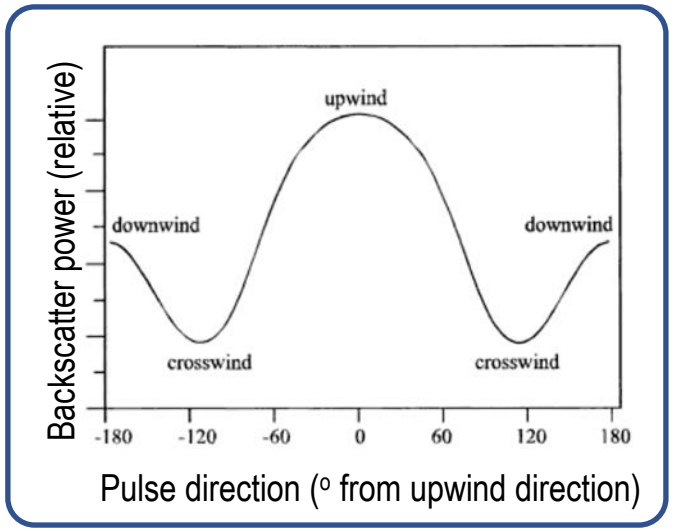
reduced with the pulse pointed downwind

minimal with the pulse pointed crosswind

maximal with the pulse pointed upwind

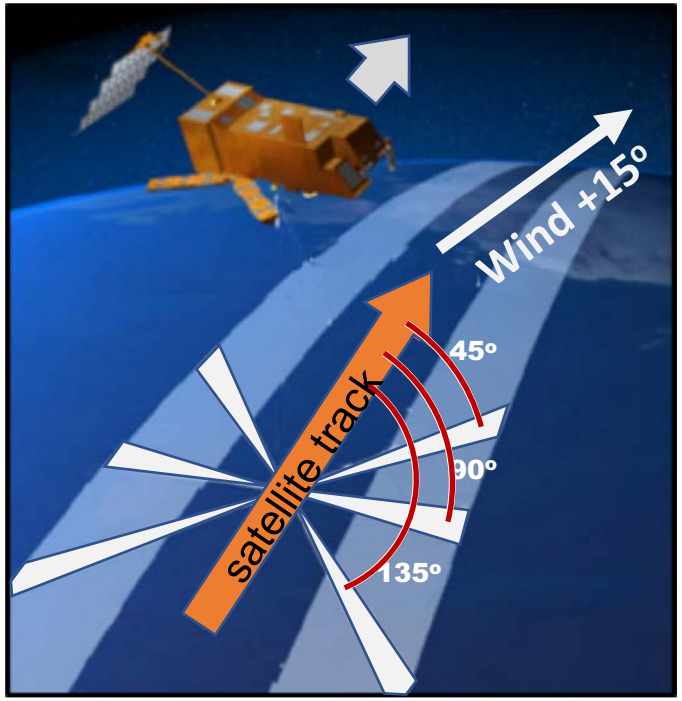




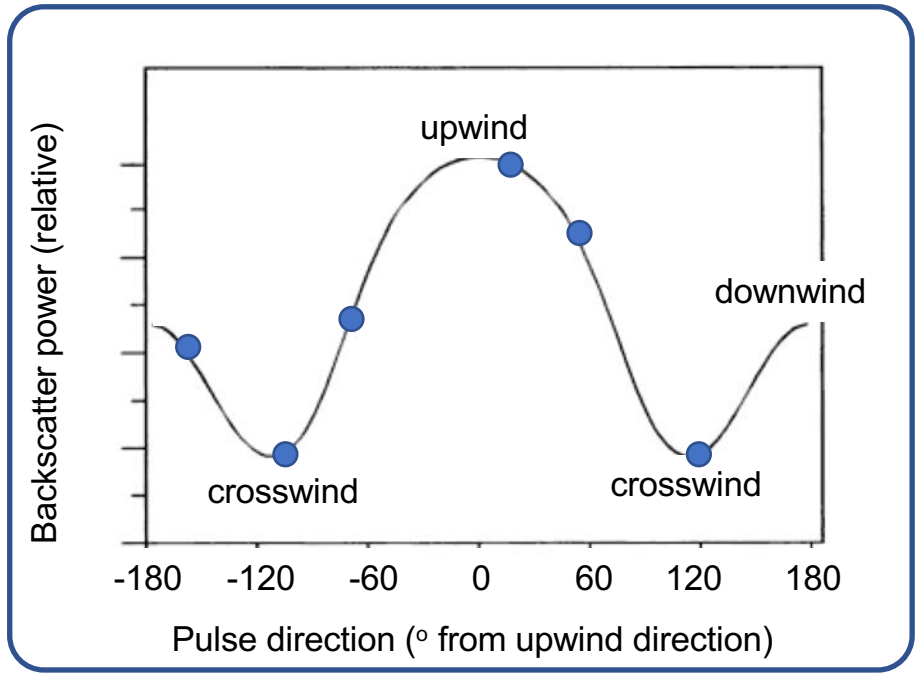


Measure backscatter at several pulse directions

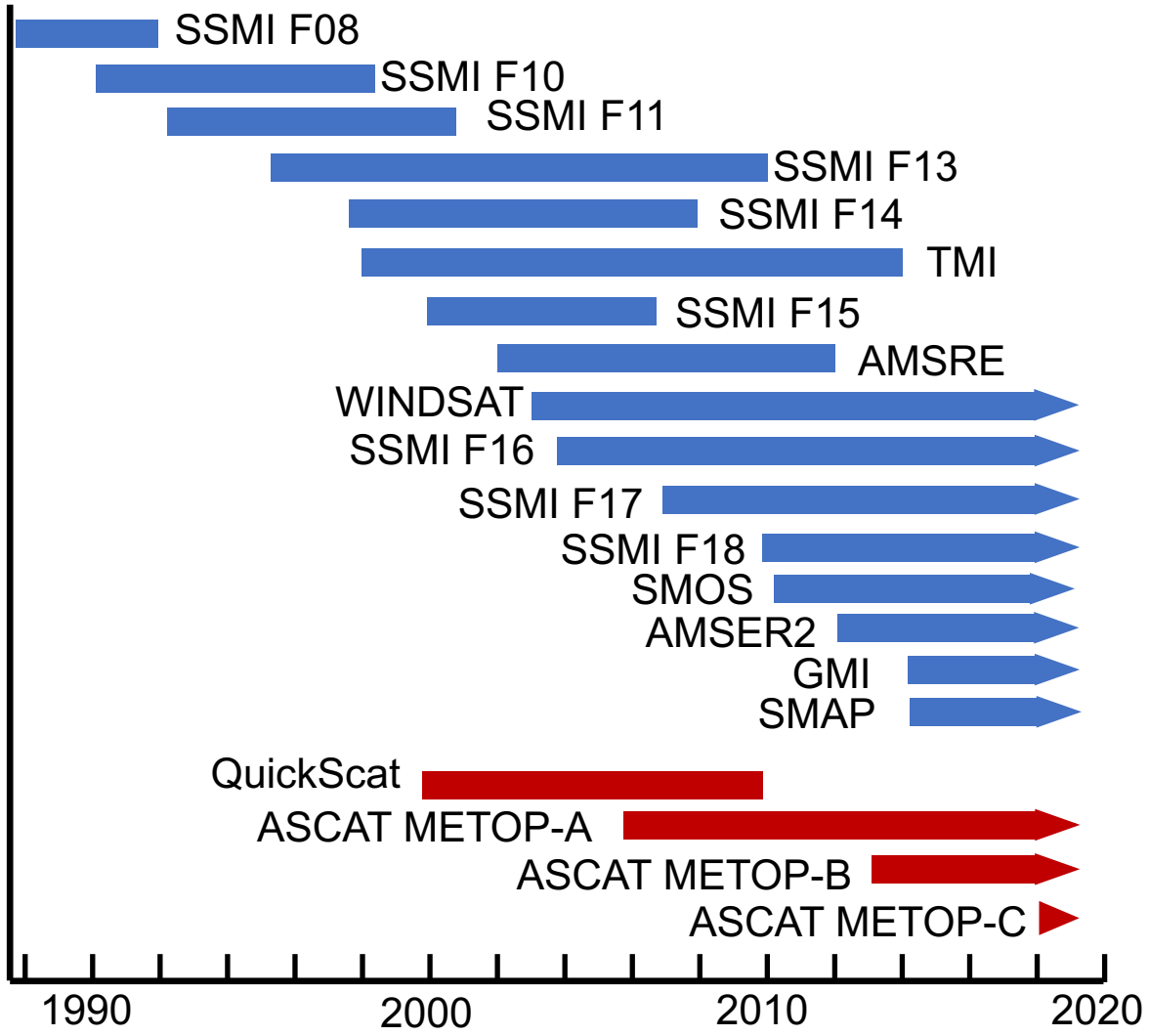
SOLVE FOR THE WIND SPEED AND DIRECTION THAT BEST FITS ALL OF THE MEASUREMENTS



backscatter values at 15° pulse direction



Wind measurements date back to the late-1980s



Passive sensors (wind speed only)

Spatial resolution:	1/8° – 1° (12–100km)
Global coverage:	ca. 6 hours - 3 days
Time span:	1987 - Present

Active sensors (wind speed & direction)

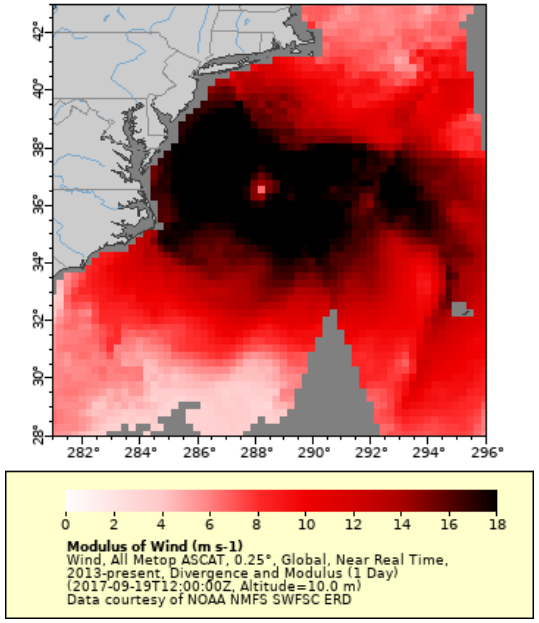
Spatial resolution:	0.25° – 1° (25-100 km)
Global coverage:	ca. 1 - 3 days
Time span:	1999 - Present

Tracking features with wind data

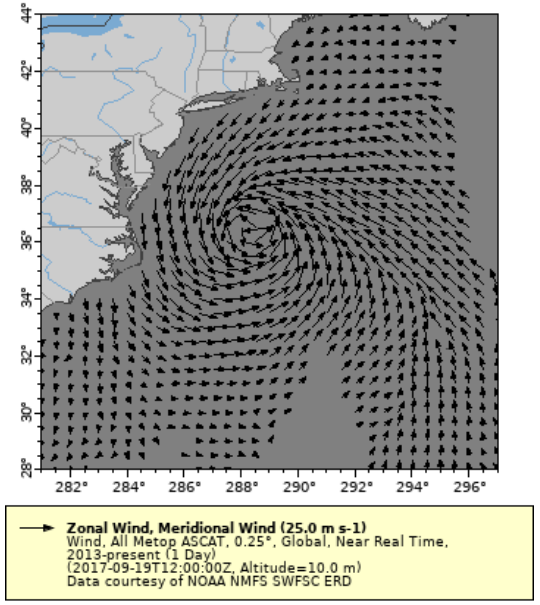
MODIS true color image

You can make these maps. Follow the instructions in Chapter 6 of the ERDDAP tutorial
https://coastwatch.pfeg.noaa.gov/projects/erddap/vectors.html

Wind Speed
(black is high winds)

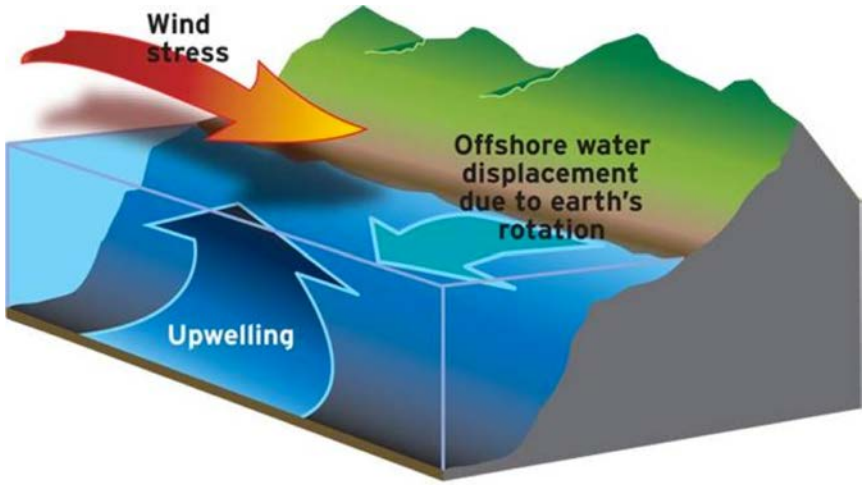


Wind Vectors
(direction and speed)

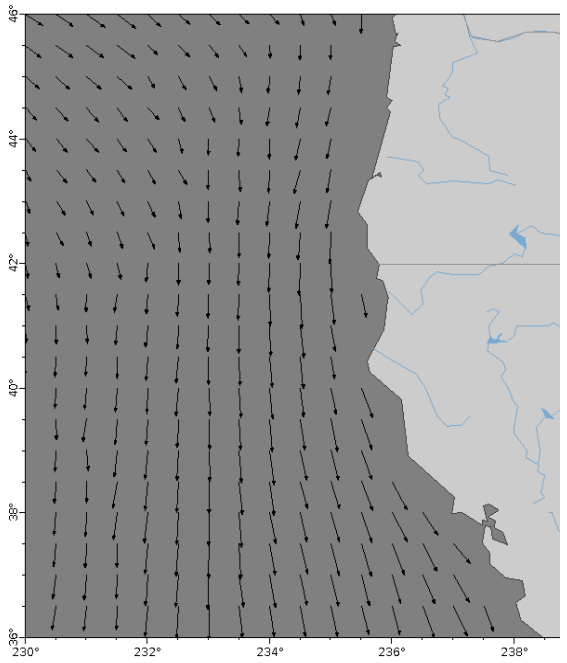


Additional parameter derived from wind speed and direction

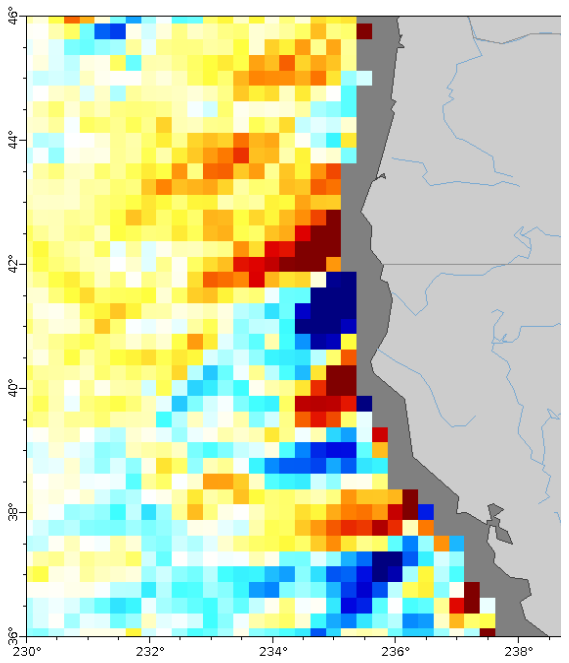
Coastal Upwelling



Wind Vectors
(direction and speed)



Ekman Upwelling
(red is up)



Datasets: Wind products from scatterometers (active sensors)

	Time Range	Resolution	Composite	Quality	Parameters
[a,c] **QuickScat**	1999-2009	1.0º (100 km)	1-day, 3-day, 8-day, 14-day, month	NRT	Wind speed, direction ➤ divergence, stress, curl, and Ekman upwelling
[b,c] **ASCAT METOP-A**	2009-Now	0.25º (25 km)	1-day, 3-day, 8-day, 14-day, month	NRT	Wind speed, direction ➤ divergence, stress, curl, and Ekman upwelling
[d,e] **ASCAT METOP-B**	2013-Now	0.25º (25 km)	1-day, 3-day, 8-day, 14-day, month	NRT	Wind speed, direction ➤ divergence, stress, curl, and Ekman upwelling

[a] coastwatch.pfeg.noaa.gov/erddap/search/index.html?page=1&itemsPerPage=1000&searchFor=erdQS
[b] podaac.jpl.nasa.gov/QuikSCAT
[c] coastwatch.pfeg.noaa.gov/erddap/search/index.html?page=1&itemsPerPage=1000&searchFor=erdQA
[d] coastwatch.pfeg.noaa.gov/erddap/search/index.html?page=1&itemsPerPage=1000&searchFor=erdQB
[e] www.ospo.noaa.gov/Products/atmosphere/ascat/

Datasets: Wind products from radiometers (passive sensors)

	Time Range	Resolution	Composite	Quality	Parameters
[a,b] **NOAA Blended Winds**	2011-2015	0.25º (25 km)	6 hr, 1-day, month	SQ	Wind speed (direction: models & active)
[c,d] **CCMP Ocean Winds**	1987-2011	0.25º (25 km)	6 hr, 5-day, month	SQ	Wind speed (direction: models & active)
[e,f] **SMAP Wind Speed**	2015-Now	0.25º (25 km)	8-day, month	SQ	Wind speed

CCMP = Cross-Calibrated Multi-Platform Ocean Winds

SMAP = Soil Moisture Active Passive

[a] coastwatch.pfeg.noaa.gov/erddap/search/index.html?page=1&itemsPerPage=1000&searchFor=ncdcOw

[b] www.ncdc.noaa.gov/data-access/marineocean-data/blended-global/blended-sea-winds

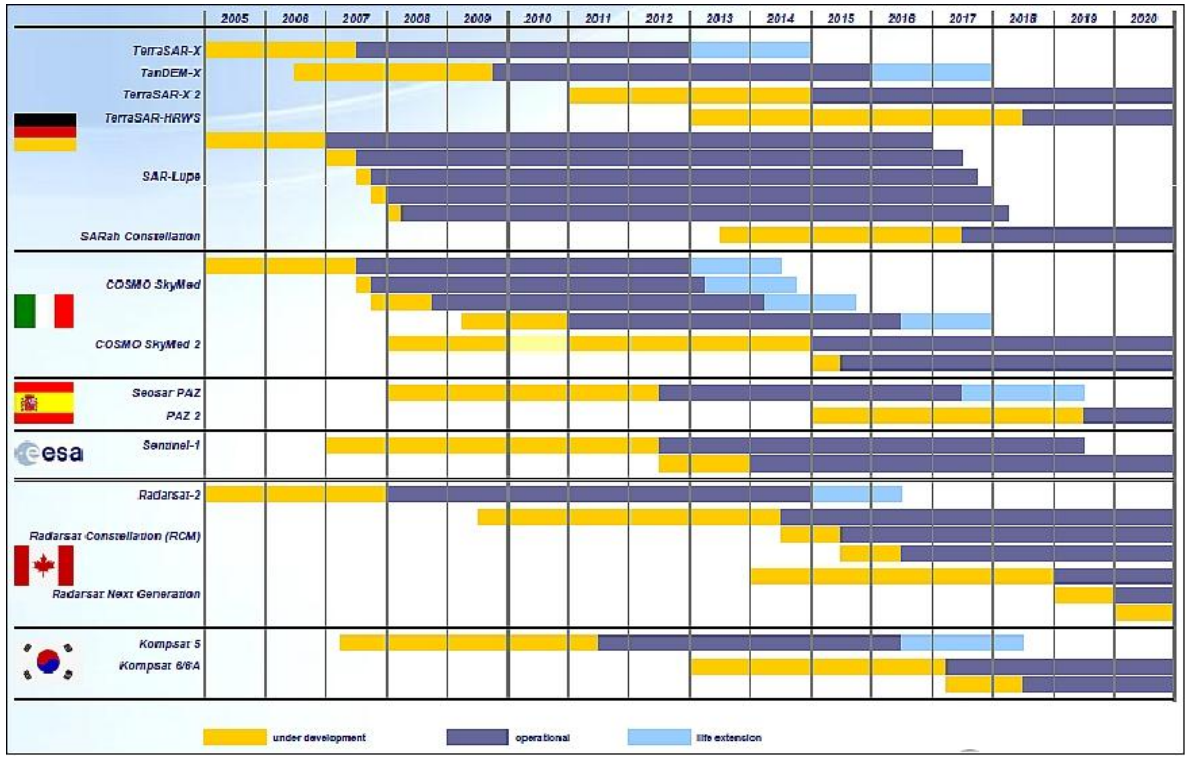
[c] coastwatch.pfeg.noaa.gov/erddap/search/index.html?page=1&itemsPerPage=1000&searchFor=ccmp

[d] podaac.jpl.nasa.gov/dataset/CCMP_MEASURES_ATLAS_L4

[e] coastwatch.pfeg.noaa.gov/erddap/search/index.html?page=1&itemsPerPage=1000&searchFor=jplSMAPSSSv42

[f] podaac.jpl.nasa.gov/dataset/SMAP_JPL_L3_SSS_CAP_MONTHLY_V42

We are entering the “Golden Age” of Synthetic Aperture Radar (SAR)



https://directory.eoportal.org/web/eoportal/satellite-missions/p/paz

Why you might be interested

Very high spatial resolution (<1m -500m)

Pros

Many sensors are flying or soon will be

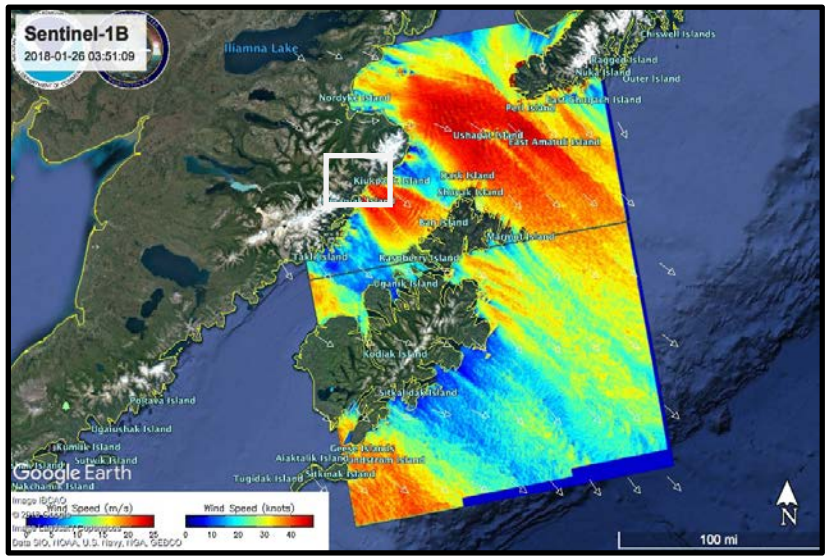
Many datasets are free

Challenges

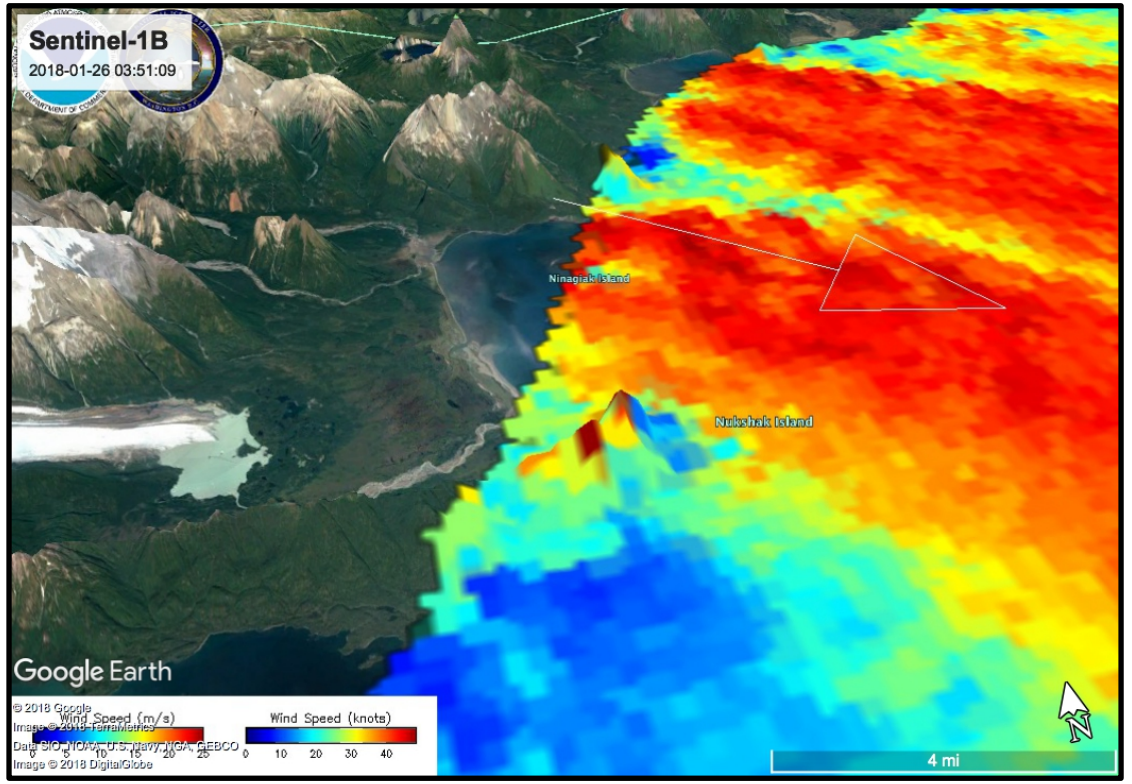
Small path width (temporal resolution is low)

Huge data volumes

High resolution Synthetic Aperture Radar (SAR) data are available



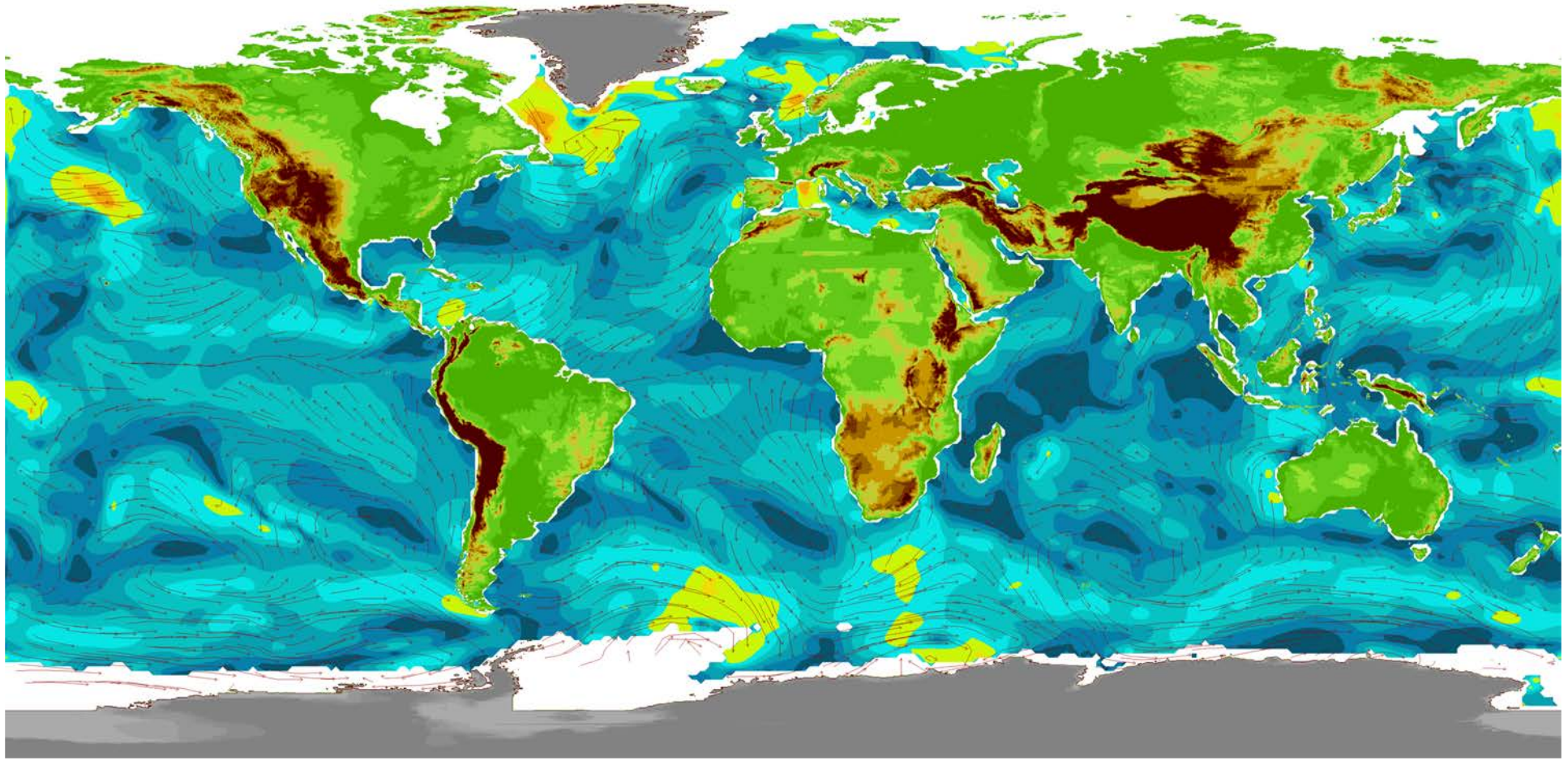
VERY HIGH RESOLUTION (<1M -500M)



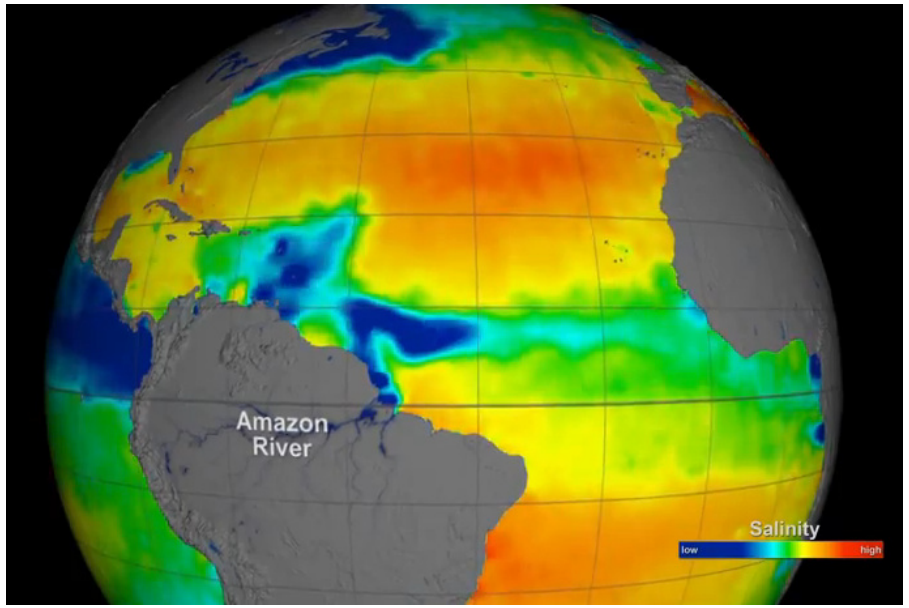
SAR data are not on ERDDAP servers,
but they are available at CoastWatch Central

https://coastwatch.noaa.gov/cw/satellite-data-products/synthetic-aperture-radar-surface-roughness/sar-winds.html

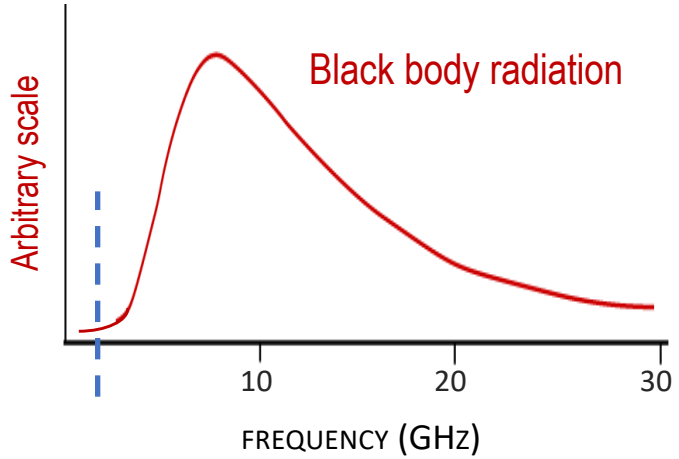
Questions before moving on to salinity?



Sea Surface Salinity (SSS) is measured with passive sensors



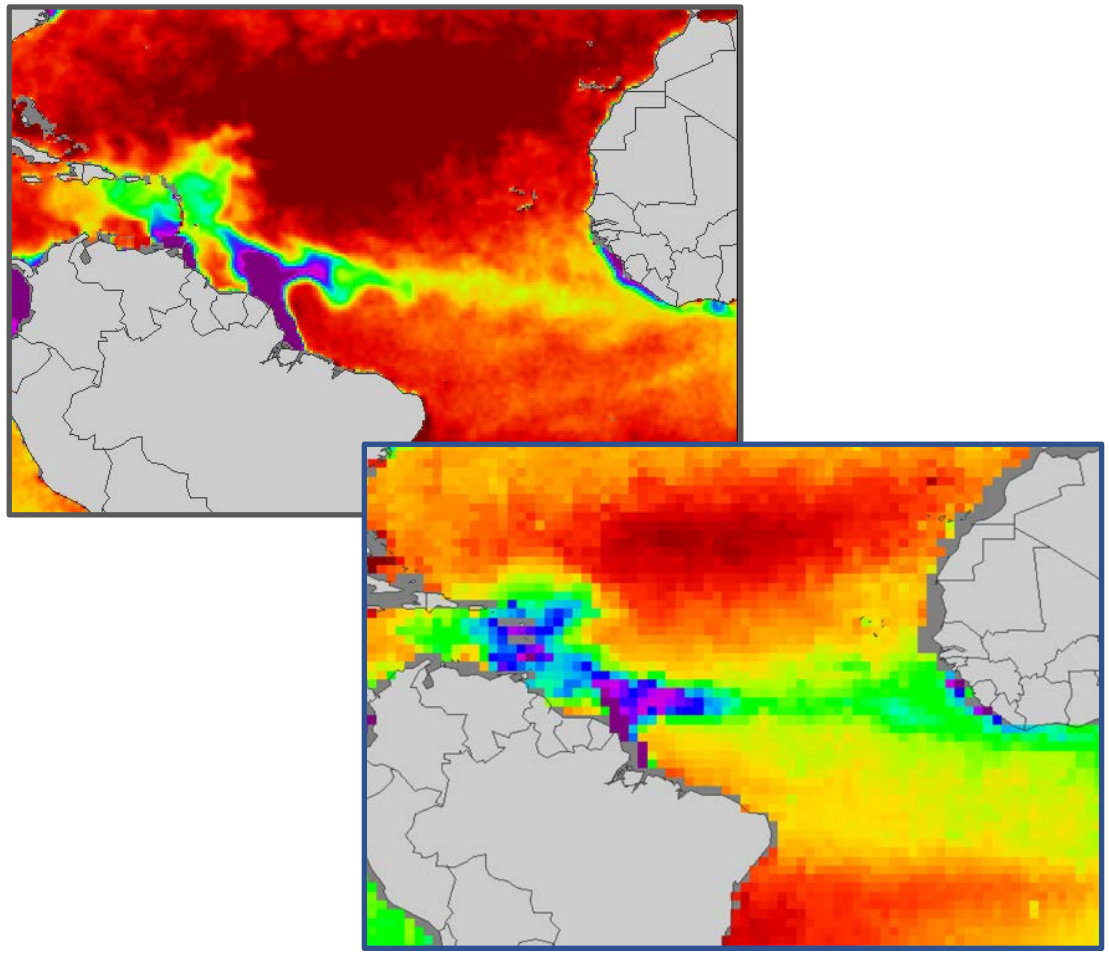
salinity changes the black body signal emitted by the ocean



Radiometers measure salinity at 1.4 GHz

Satellite SSS is a relatively new measurement

SMAP data – 0.25° resolution



Aquarius data – 1.0° resolution

Temporal coverage:	2010 - Present
Spatial resolution:	0.25 – 1 degree
Global coverage:	3 – 8 days

Datasets: WCN has data from 3 salinity sensors

	Time Range	Resolution	Composite	Quality	Parameters
[a,b] **Aquarius**	2011-2015	1.0º (100 km)	1-day, 7day, month, 3-month	SQ	Salinity
[c,d] **NOAA SMOS**	2010-Now	0.25º (25 km)	1-day, 3-day	NRT	Salinity
[e,f] **NOAA SMAP**	2015-Now	0.25º (25 km)	8-day	NRT	Salinity
[g] **NASA SMAP**	2015-2019	0.25º (25 km)	8-day, Month	SQ	Salinity

SMOS = Soil Moisture Ocean Salinity

SMAP = Soil Moisture Active Passive

[a] coastwatch.pfeg.noaa.gov/erddap/search/index.html?page=1&itemsPerPage=1000&searchFor=jplAquariusSSS

[b] podaac.jpl.nasa.gov/aquarius

[c] coastwatch.pfeg.noaa.gov/erddap/search/index.html?page=1&itemsPerPage=1000&searchFor=coastwatchSMOSv662SSS

[d] coastwatch.noaa.gov/cw/satellite-data-products/sea-surface-salinity/miras-smos.html

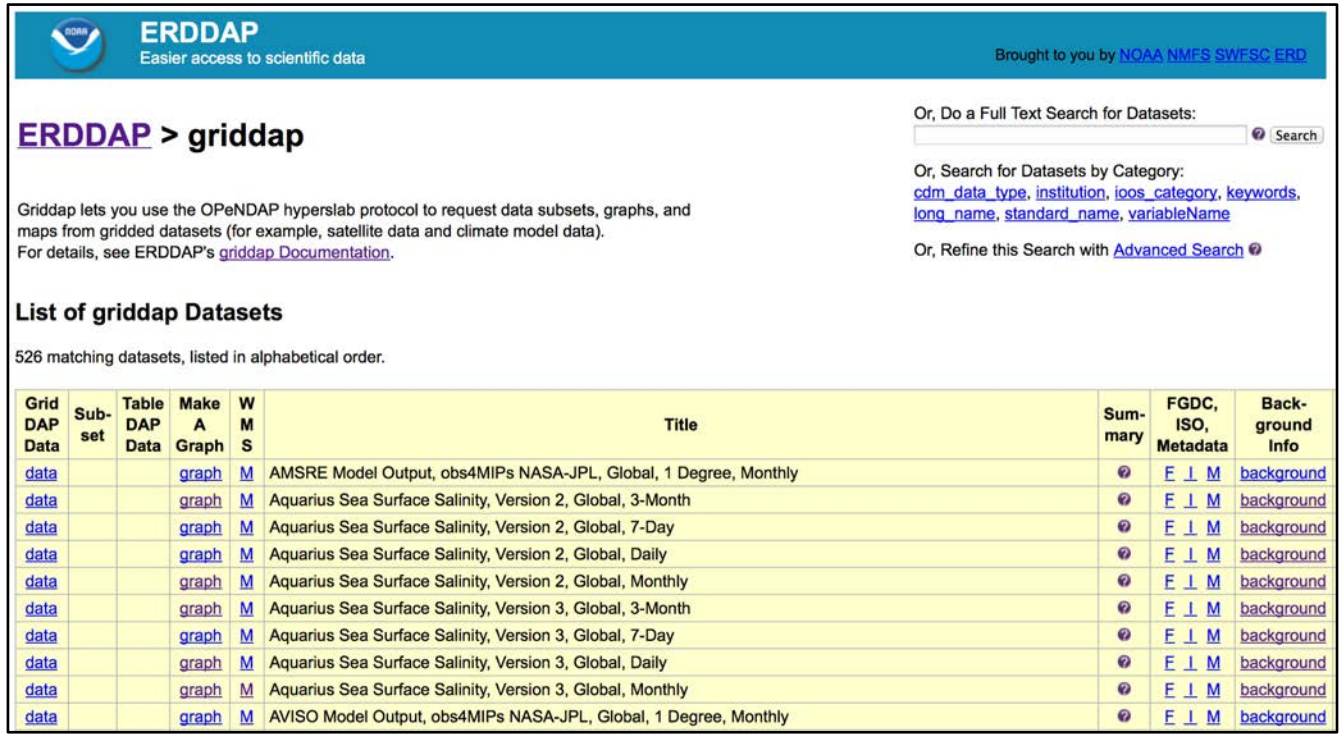
[e] coastwatch.pfeg.noaa.gov/erddap/griddap/coastwatchSMAPV42SSS1day.graph

[f] coastwatch.noaa.gov/cw/satellite-data-products/sea-surface-salinity/smap.html

[g] coastwatch.pfeg.noaa.gov/erddap/search/index.html?page=1&itemsPerPage=1000&searchFor=jplSMAPSSSv42

Questions?

FIND MOST OF THE PRODUCTS REVIEWED IN THIS PRESENTATION ON ERDDAP



ERDDAP
Easier access to scientific data

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ERDDAP > griddap

Or, Do a Full Text Search for Datasets: Search

Or, Search for Datasets by Category:
cdm_data_type, institution, ioos_category, keywords, long_name, standard_name, variableName

Or, Refine this Search with Advanced Search

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.

List of griddap Datasets

526 matching datasets, listed in alphabetical order.

Grid DAP Data	Sub-set	Table DAP Data	Make A Graph	WMS	Title	Sum-mary	FGDC, ISO, Metadata	Back-ground Info
data			graph	M	AMSRE Model Output, obs4MIPs NASA-JPL, Global, 1 Degree, Monthly		F I M	background
data			graph	M	Aquarius Sea Surface Salinity, Version 2, Global, 3-Month		F I M	background
data			graph	M	Aquarius Sea Surface Salinity, Version 2, Global, 7-Day		F I M	background
data			graph	M	Aquarius Sea Surface Salinity, Version 2, Global, Daily		F I M	background
data			graph	M	Aquarius Sea Surface Salinity, Version 2, Global, Monthly		F I M	background
data			graph	M	Aquarius Sea Surface Salinity, Version 3, Global, 3-Month		F I M	background
data			graph	M	Aquarius Sea Surface Salinity, Version 3, Global, 7-Day		F I M	background
data			graph	M	Aquarius Sea Surface Salinity, Version 3, Global, Daily		F I M	background
data			graph	M	Aquarius Sea Surface Salinity, Version 3, Global, Monthly		F I M	background
data			graph	M	AVISO Model Output, obs4MIPs NASA-JPL, Global, 1 Degree, Monthly		F I M	background

http://coastwatch.pfeg.noaa.gov/erddap/

Remote sensing by eye