Salinity, Wind, Altimetry

NOAA CoastWatch Satellite Course

Last Updated: 10/20/2020

coastwatch.info@noaa.gov

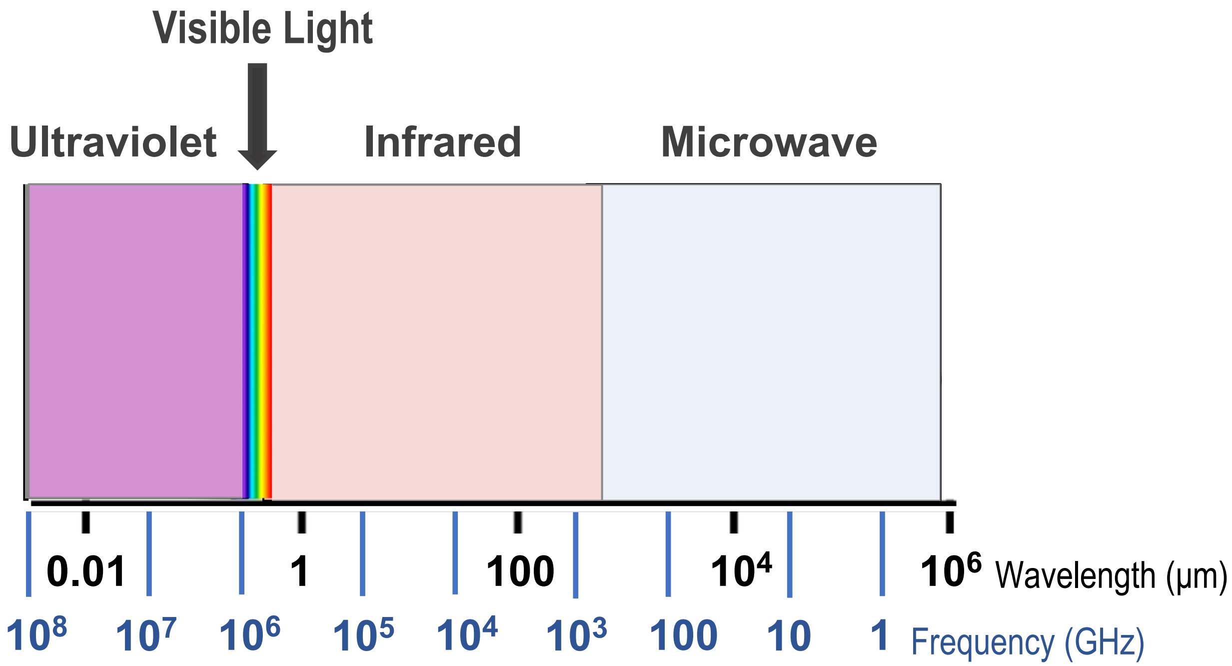
The presentation will cover the following topics

MICROWAVE TRANSMISSION IN THE ATMOSPHERE

PASSIVE AND ACTIVE SATELLITE SENSORS

SSS, WIND, AND SSH MEASUREMENTS AND PRODUCTS

Sea surface height, sea surface salinity, and wind are measured in the microwave bands



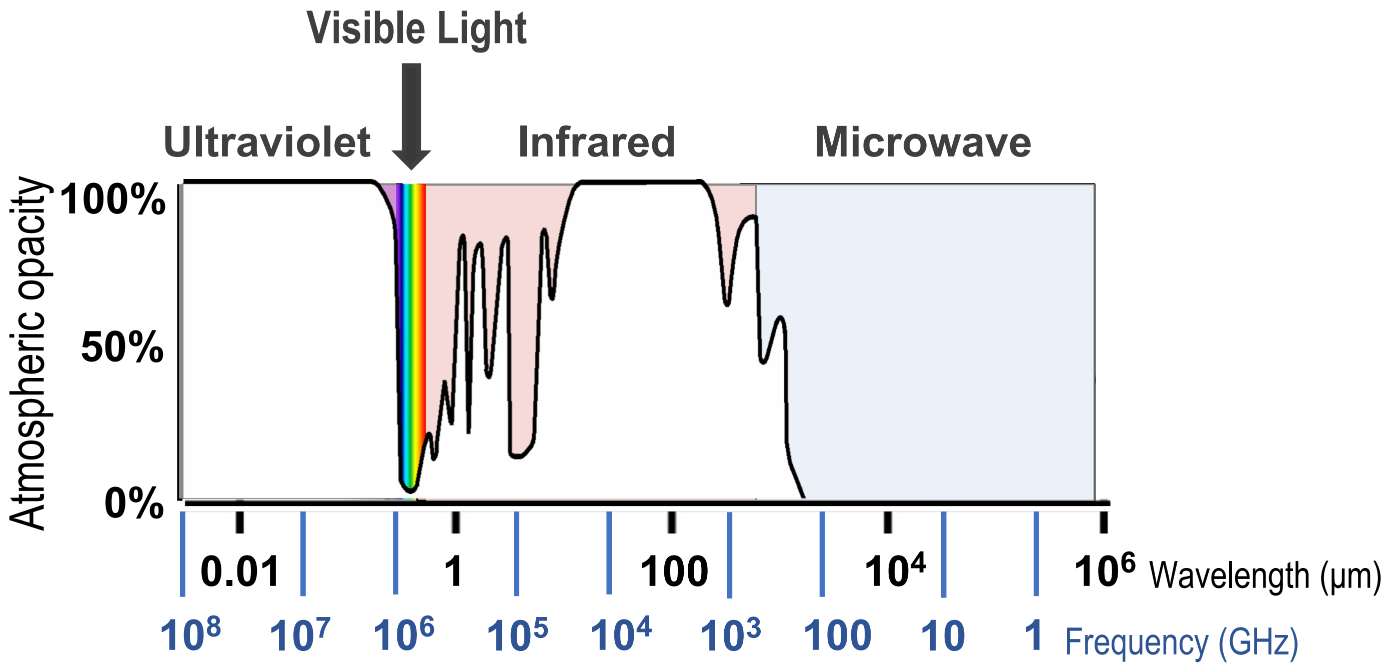
Characteristics of microwaves

Microwaves are at longer wavelengths than visible and infrared light

Usually measured in frequency not wavelength (300 GHz to 0.3 GHz)

Band	Freq. (GHz)
Ka	40–27
K	27–18
Ku	18–12
X	12.5–8
C	4–8
S	4–2
L	2–1
P	1–0.3

Atmosphere is very transparent to microwaves



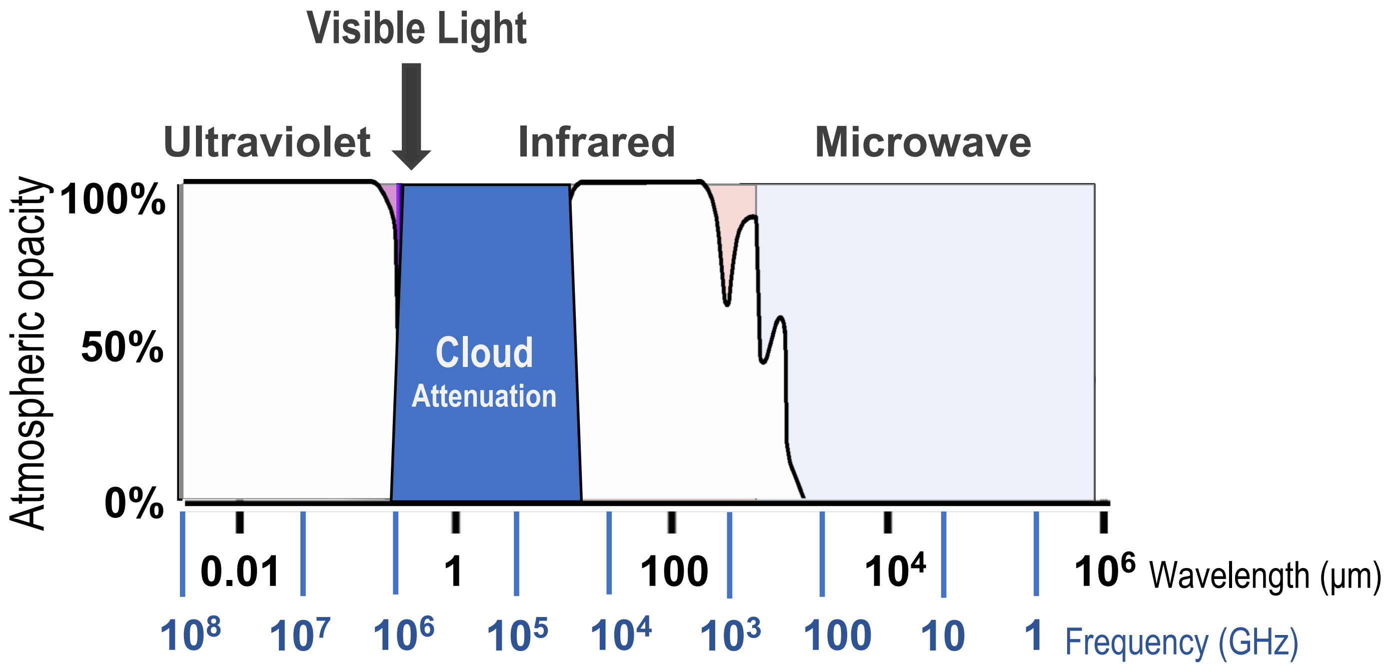
Characteristics of microwaves

Microwaves are at longer wavelengths than visible and infrared light

Usually measured in frequency not wavelength (300 GHz to 0.3 GHz)

Atmospheric "window" covers most of the microwave range

Microwaves can see through clouds



Characteristics of microwaves

Microwaves are at longer wavelengths than visible and infrared light

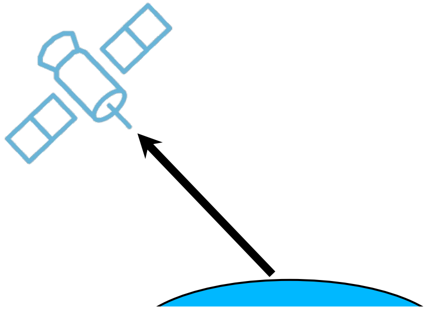
Usually measured in frequency not wavelength (300 GHz to 0.3 GHz)

Atmospheric “window” covers most of the microwave range

Clouds do not block transmission of microwaves

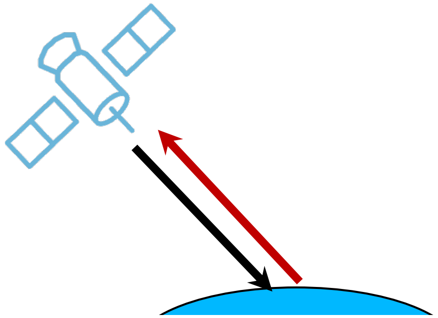
Satellite sensors measure naturally occurring or instrument-generated microwave signals

Passive sensors



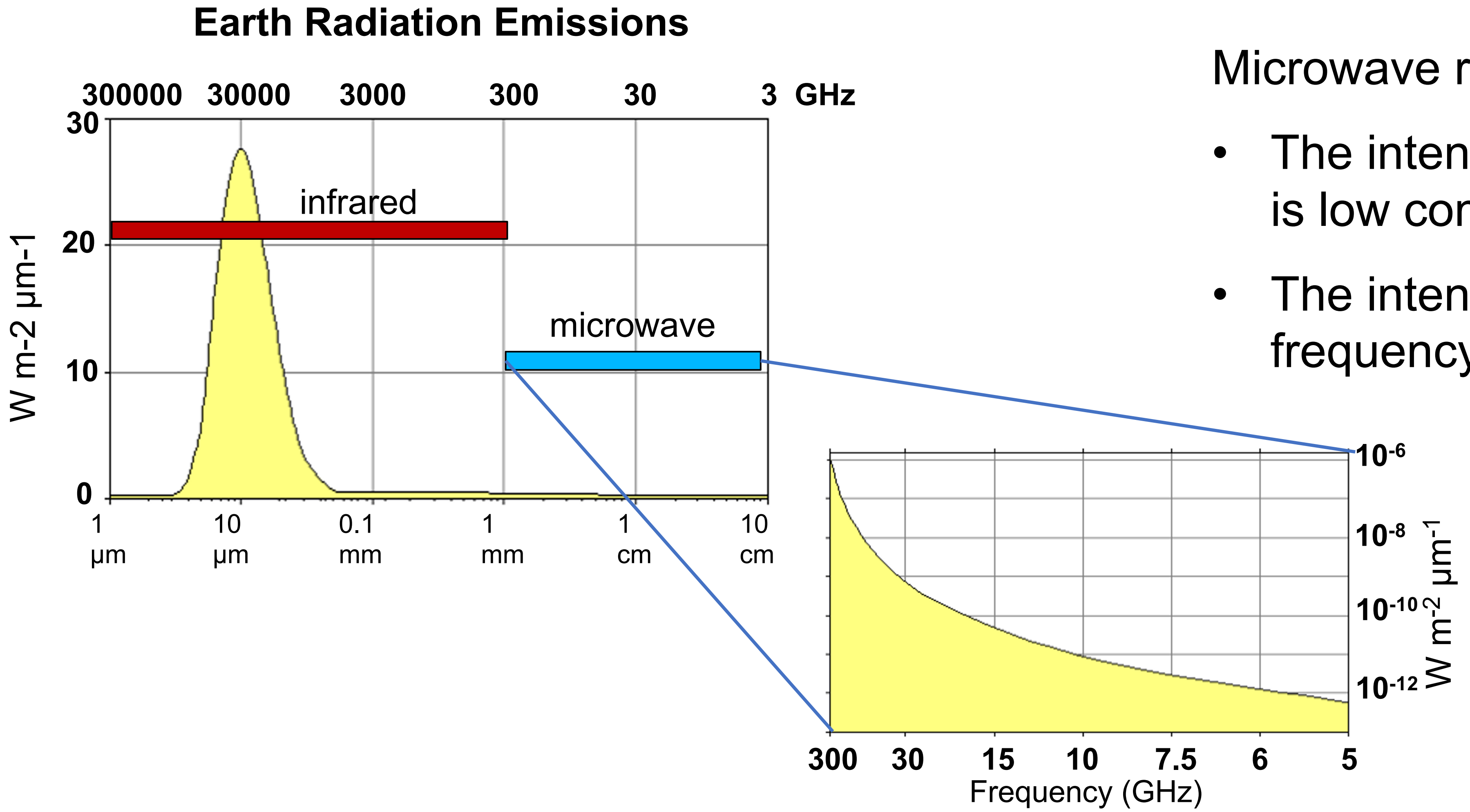
- The sensors measure microwave radiation naturally emitted from the sea.

Active sensors



- Microwave signals generated by the satellite are sent to the sea surface.
- The sensors measure the signal that is reflected back to the sensor.

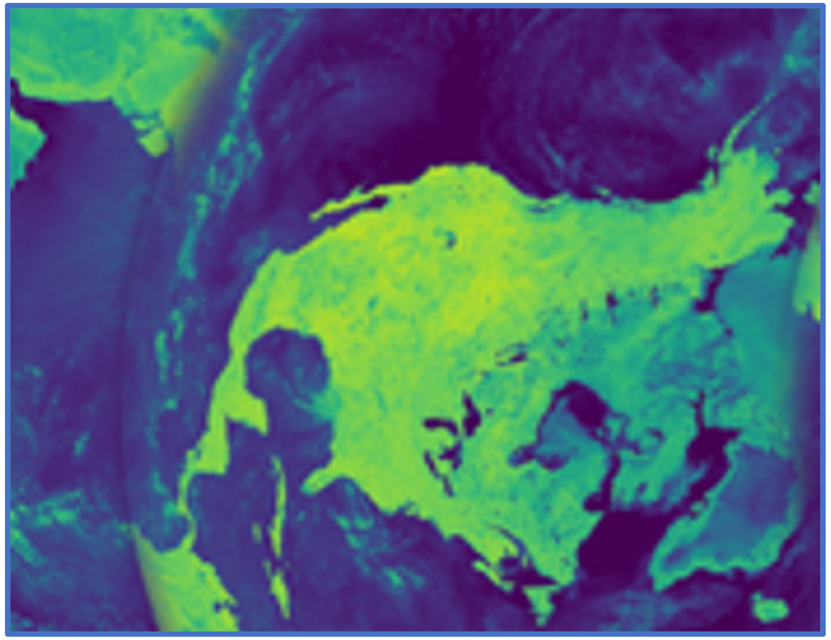
Passive microwave radiometers measure blackbody radiation naturally emitted by the sea



Microwave radiation

- The intensity of the emissions is low compared to the infrared
- The intensity decreases with frequency

The Earth is a less efficient emitter than a blackbody



37 GHz Microwave Channel
Land Emissivity 0.95
Sea Water Emissivity 0.45

$$\textbf{Emissivity } (e) = \frac{\text{Emitted Radiation}}{\text{Blackbody Radiation}}$$

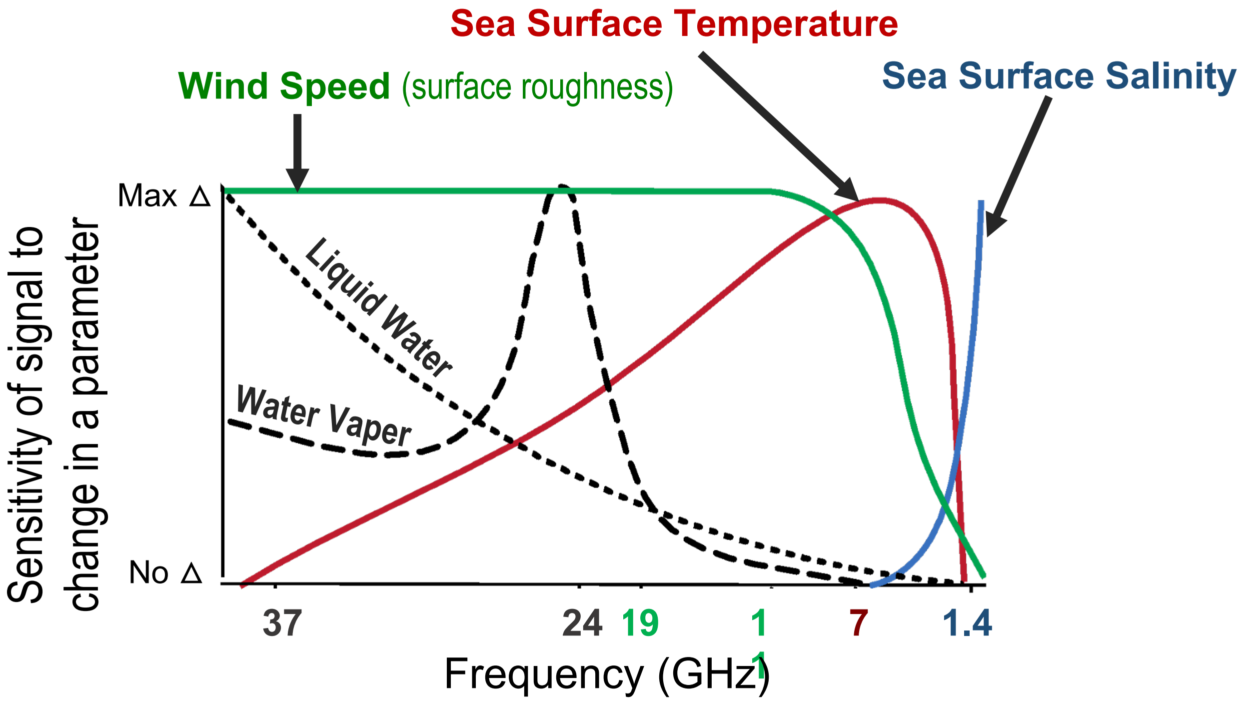
Real objects have emissivity values less than 1.0 that vary with frequency.

Emissivity can be changed by physical properties of the emitting surface, e.g. land vs. water.

Changes in physical properties of sea water can change emissivity and the strength of the signal e.g. salinity, temperature, and surface roughness.

Passive emissions respond uniquely to the change in each parameter

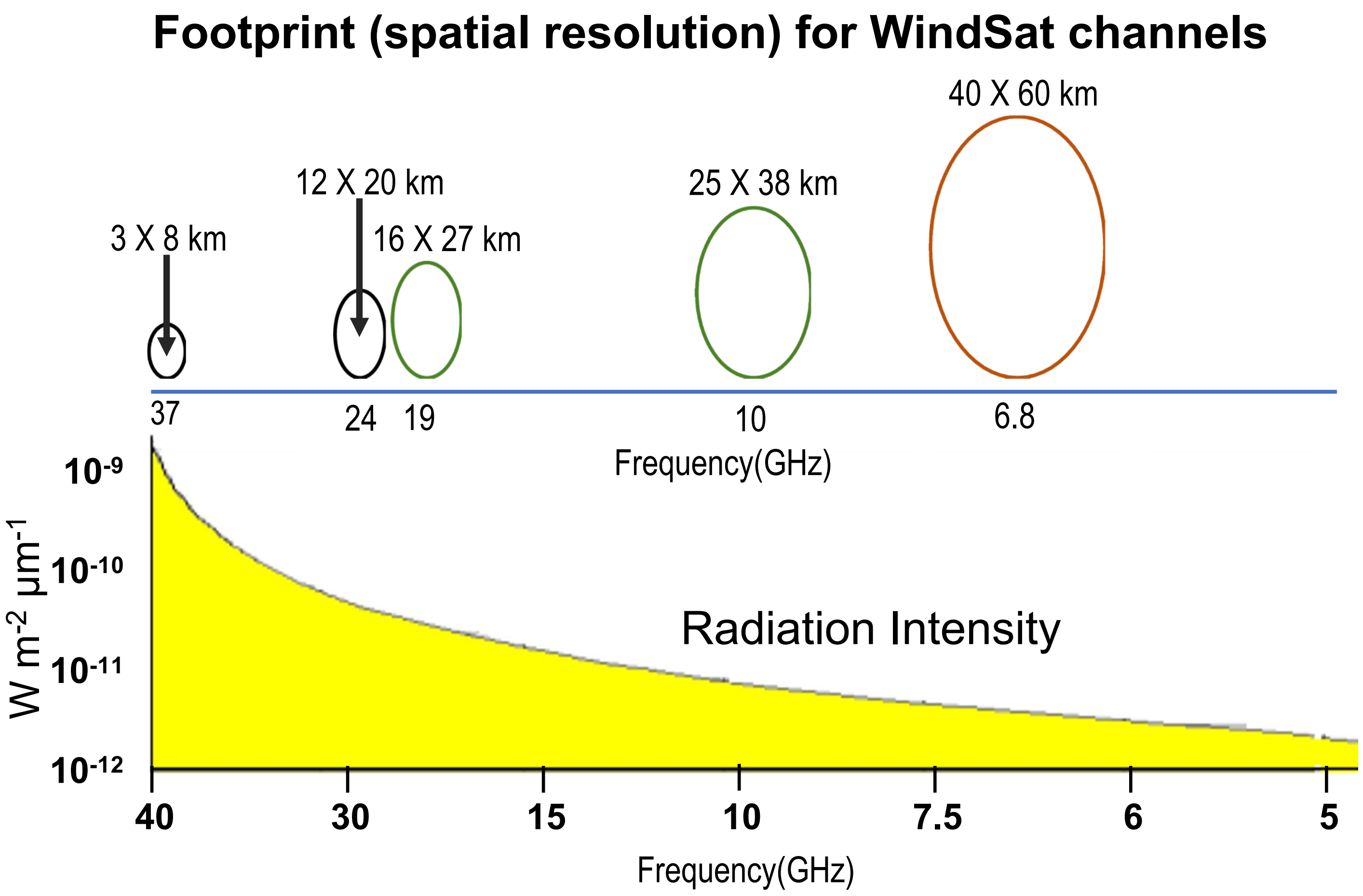
VALID MEASUREMENTS FOR ONE PARAMETER REQUIRES CORRECTION FOR THE INFLUENCE OF THE OTHER PARAMETERS



Approximate sensor frequencies used for measurements:

- Salinity 1.4 GHz
- SST 6.6 GHz
- Wind 10.7 &19 GHz
- Water Vapor 21 GHz
- Liquid Water 37 GHz

A drawback to passive microwave sensors is low spatial resolution

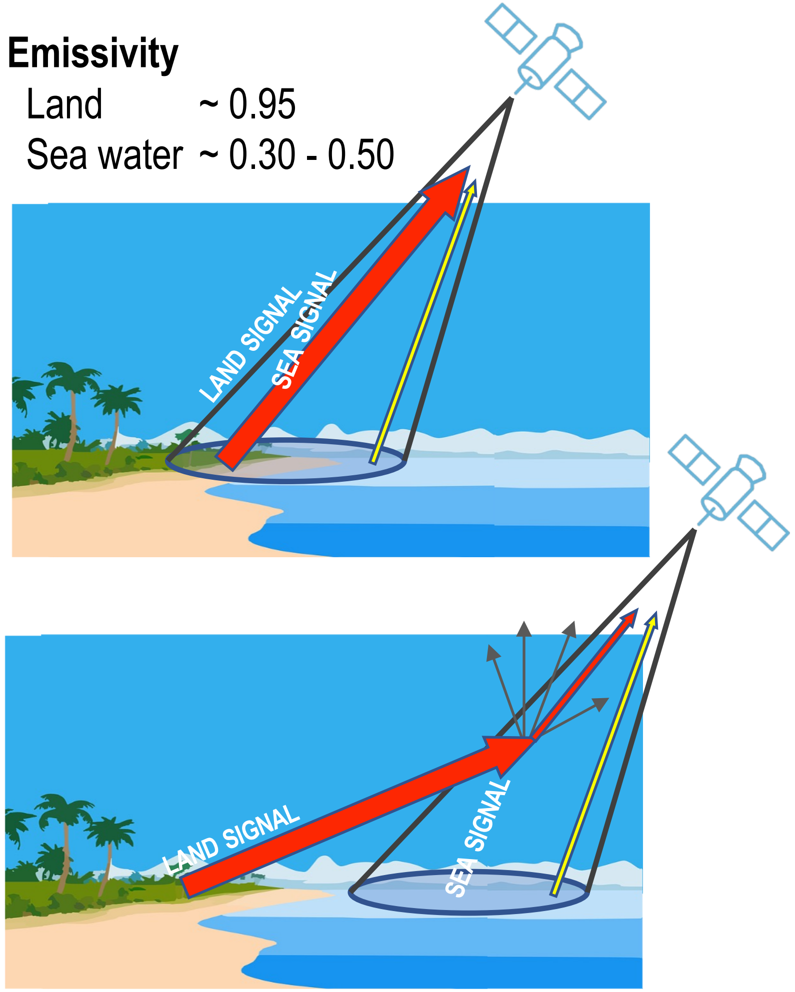


Microwave blackbody radiation by the sea is very low compared to infrared

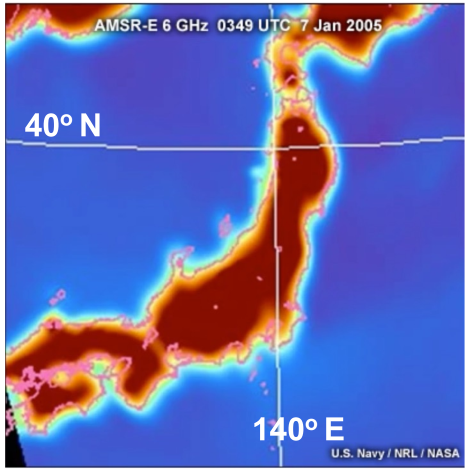
To collect enough energy for measurements, microwave sensors require:

- Larger antennas and/or larger footprints
- Microwave spatial resolution: ~5km - 100 km

Passive microwave measurements cannot be made close to the coast



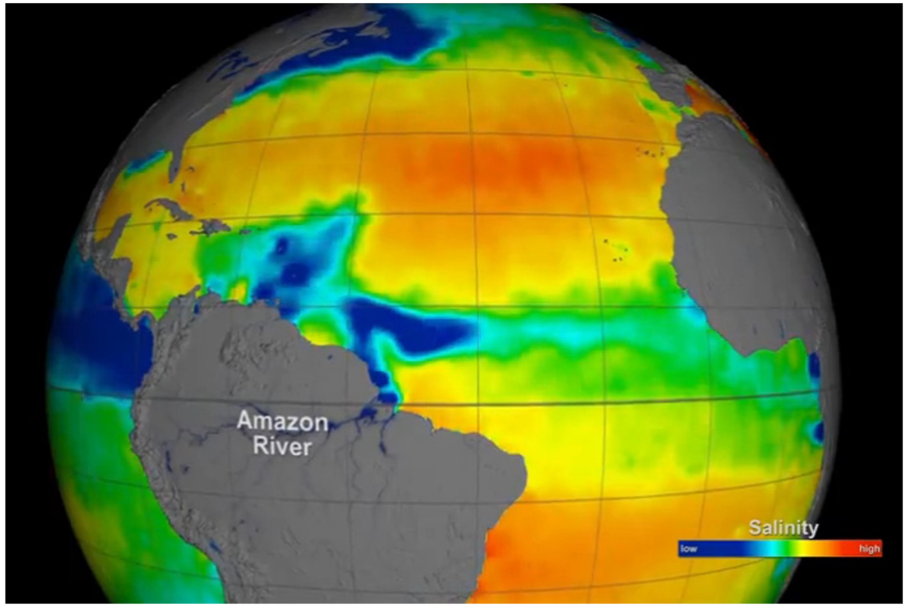
Coastline of Japan
6 GHz channel



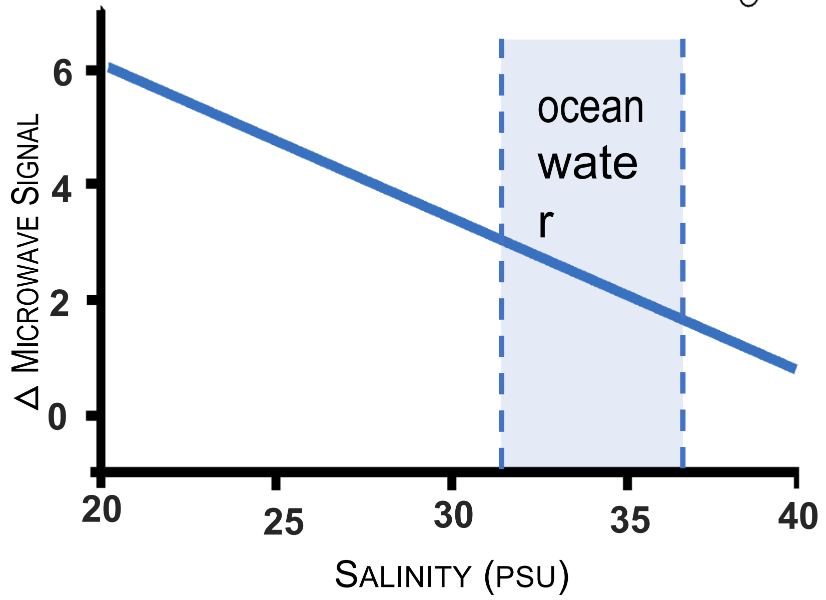
Near the coast, the strong microwave emissions from land contaminate the signal from the sea.

Data within ~50 km of the coast are removed from satellite products to eliminate bad values.

Sea Surface Salinity is measured with passive sensors

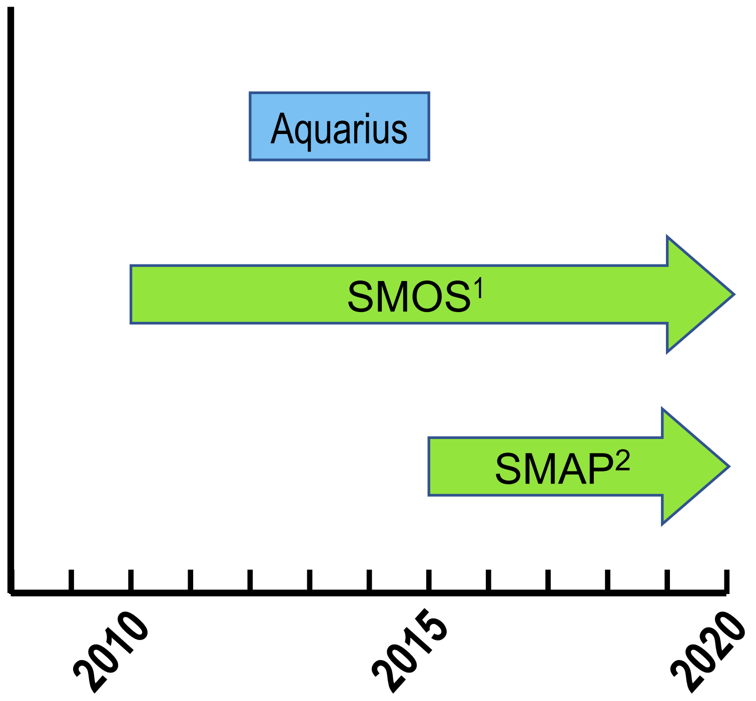


Salinity changes the brightness of the microwave signal emitted by the ocean



Radiometers measure salinity at 1.4 GHz

Satellite salinity is a relatively new measurement



[1]Soil Moisture and Ocean Salinity mission
[2]Soil Moisture Active Passive mission

Temporal coverage: 2010 - Present

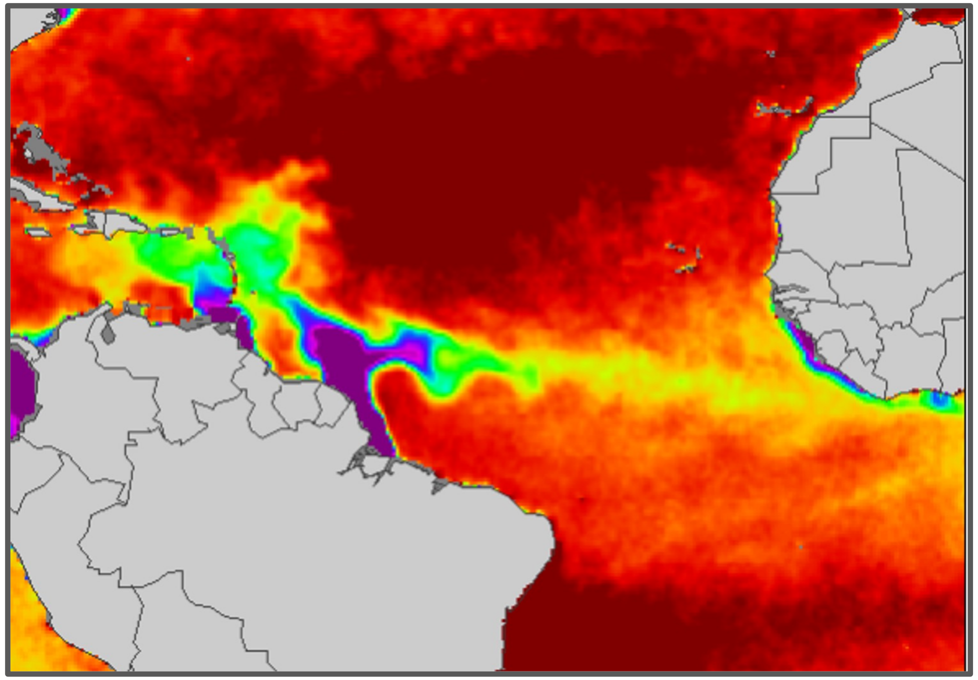
Spatial resolution: 0.25 – 1 degree

Global coverage: 3 – 8 days

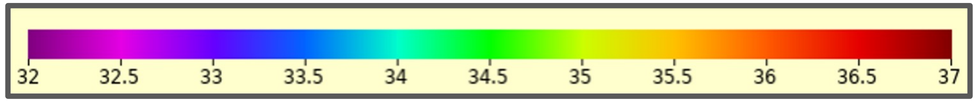
Accuracy: 0.15-0.25 PSS

Depth: 1– 2 cm

Uses for satellite salinity



SMOS data – 0.25^{o} resolution



Practical Salinity Scale

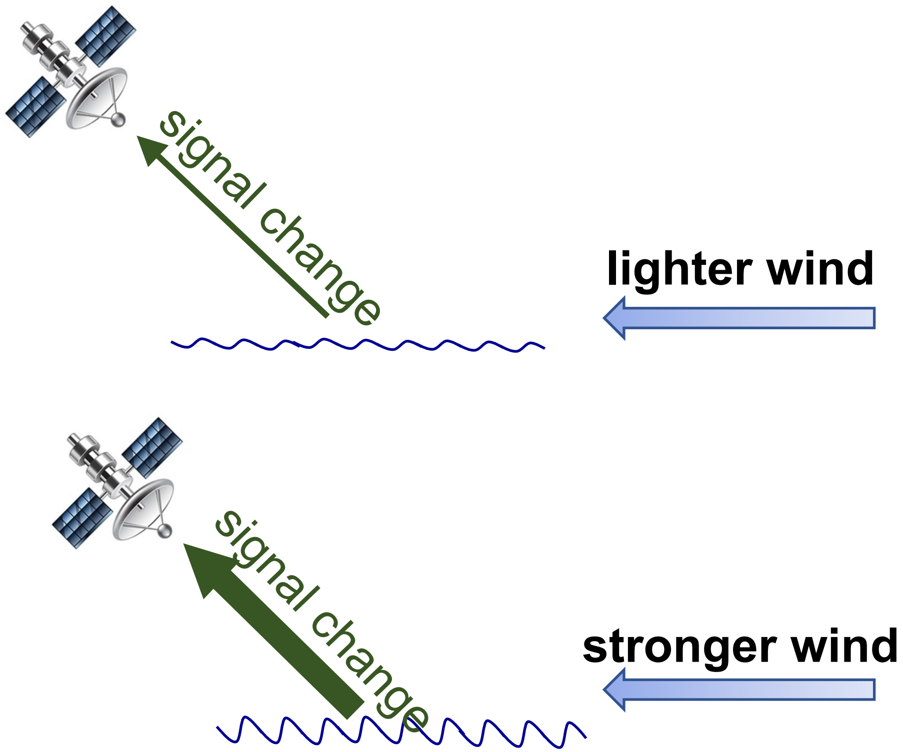
Global thermohaline circulation

Dynamic ecosystem modeling

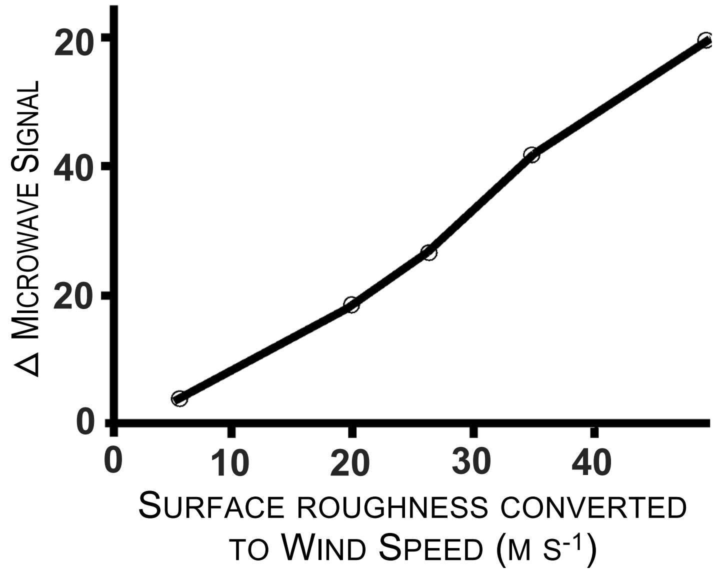
Tracking surface salinity events

Wind speed (not direction*) is measured with passive radiometer sensors

RADIOMETERS MEASURE SEA SURFACE ROUGHNESS AND USE IT AS A PROXY FOR WIND SPEED



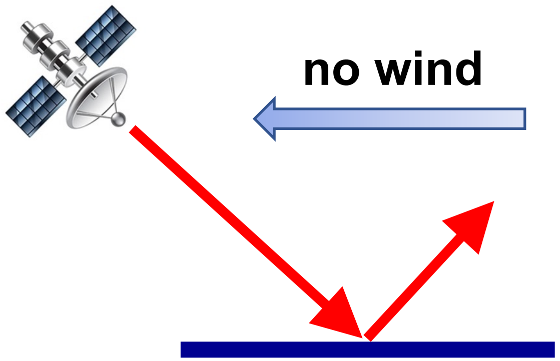
Sea surface roughness changes the brightness of the microwave signal emitted by the ocean

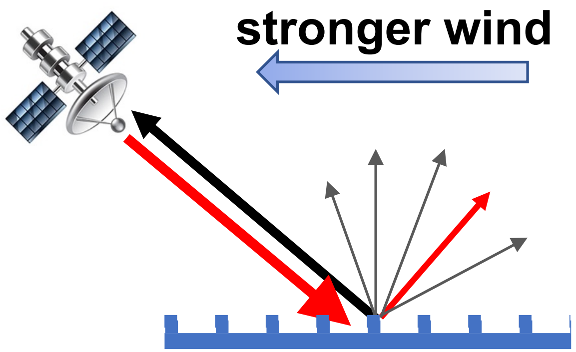


Radiometers measure roughness at ca. 10.7 GHz

*WindSat radiometer can measure wind direction using polarization

Wind speed and direction are measured with active scatterometer sensors





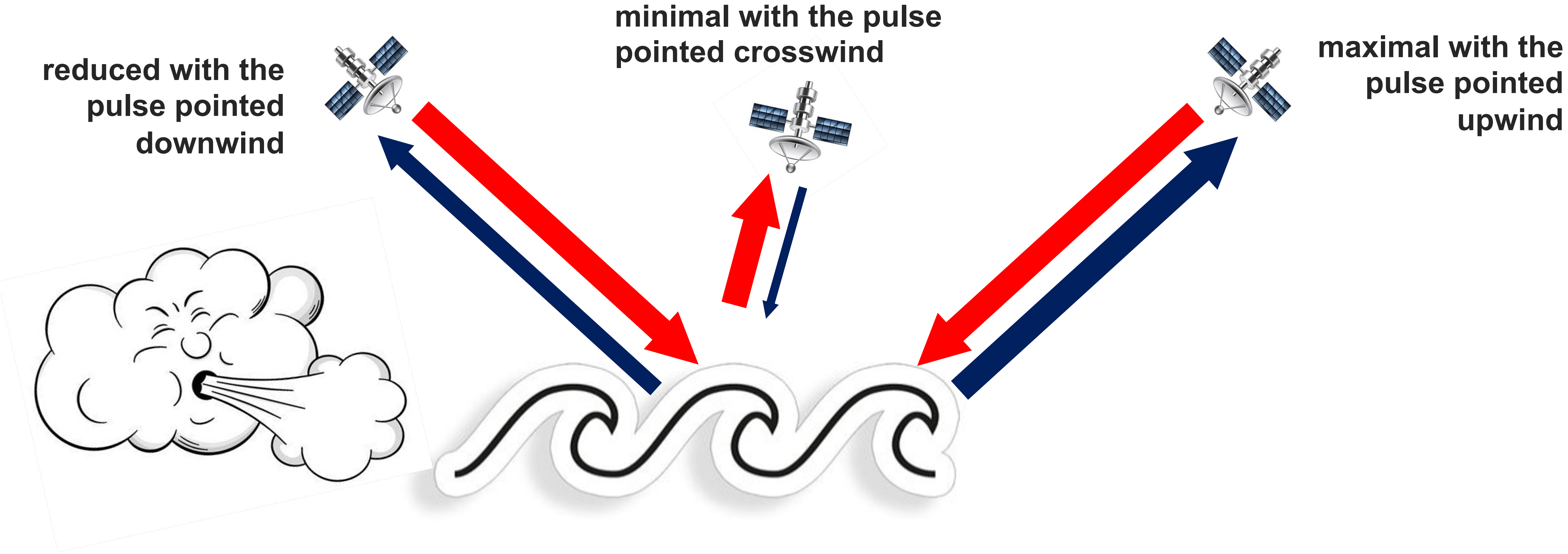
Scatterometers send a microwave pulse to the sea surface

The strength of the signal backscattered to the sensor is measured

Higher wind speed increases backscatter by increasing ripples (capillary waves)

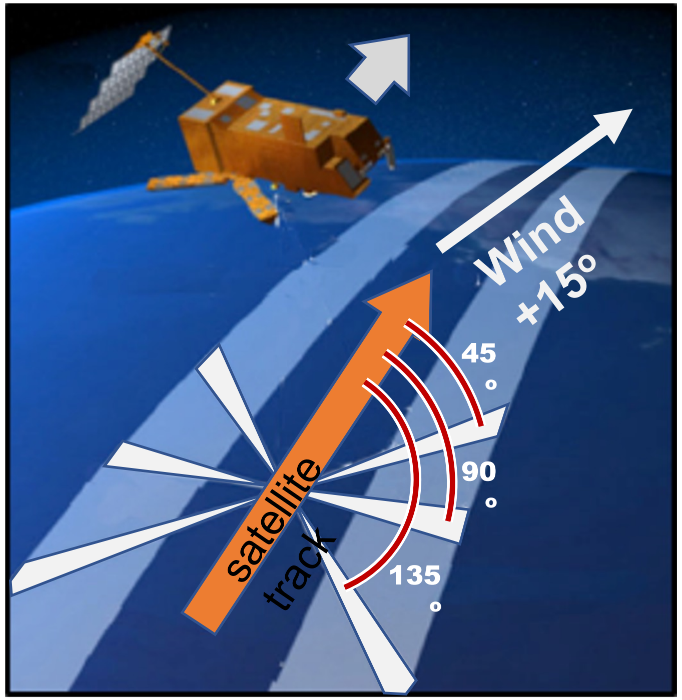
Signal backscatter is also dependent on wind direction

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

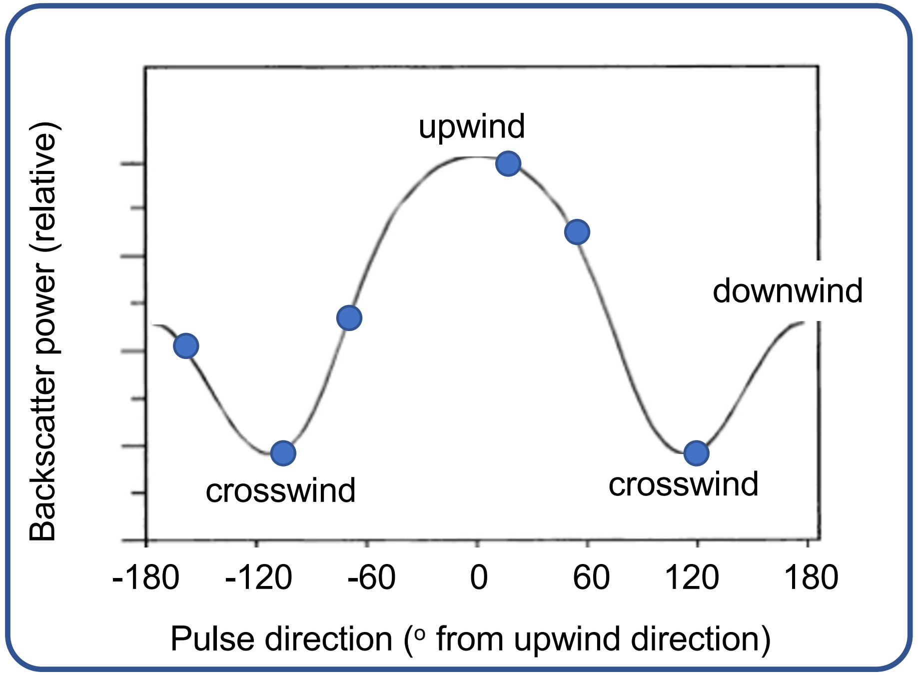


Scatterometers measure backscatter at several pulse directions

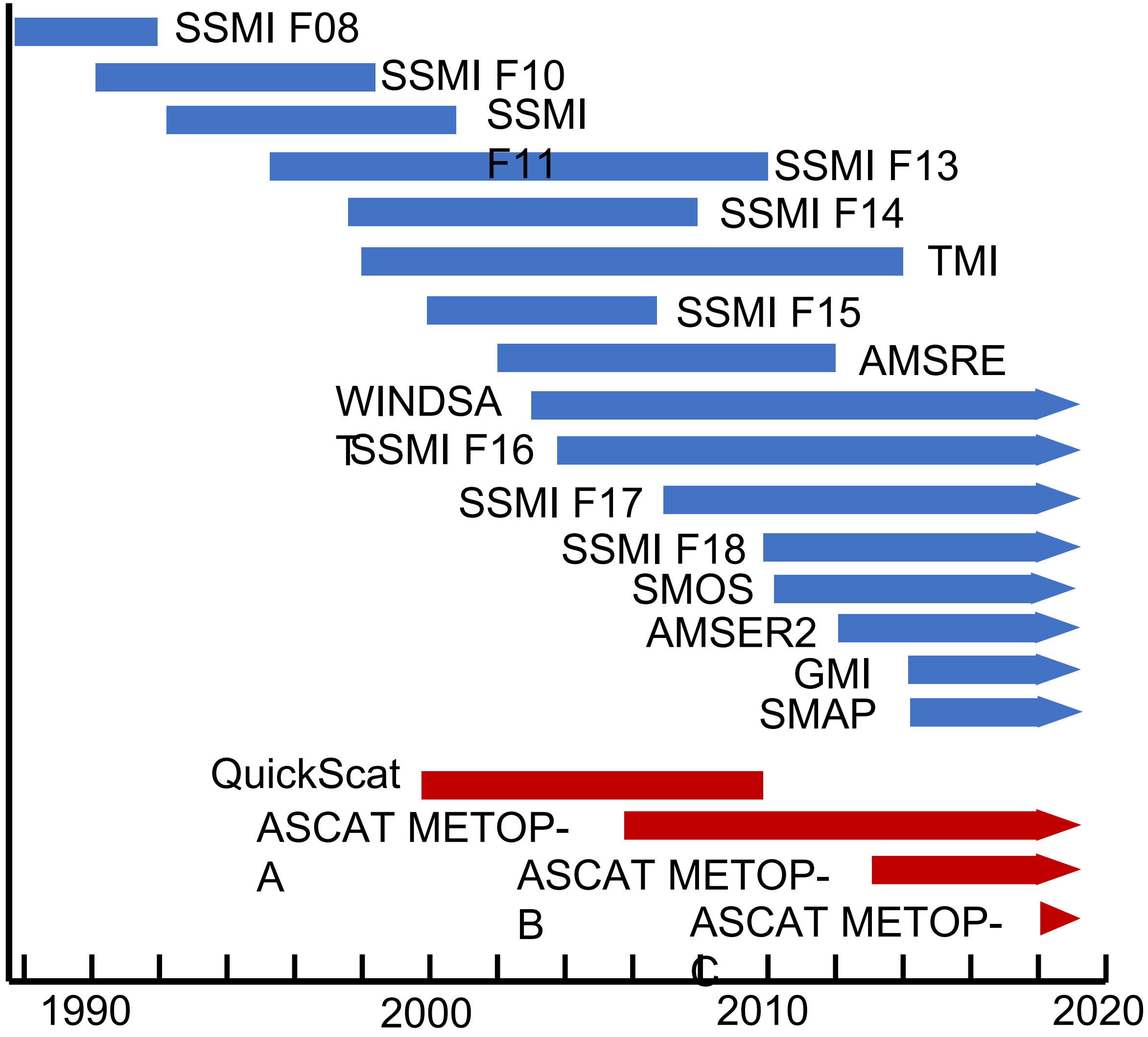
SOLVE FOR THE WIND SPEED AND DIRECTION THAT BEST FITS ALL OF THE MEASUREMENTS



backscatter values at 15° pulse direction



Wind measurements date back to the late-1980s



Passive sensors (wind speed only)

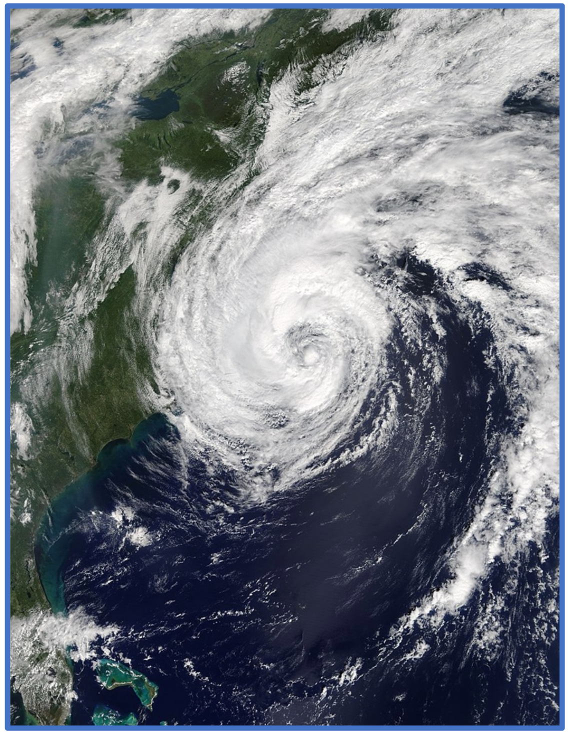
Time span:	1987 - Present
Global coverage:	ca. 6 hours - 3 days
Spatial resolution:	$1/8^{o} – 1^{o}$ (12–100km)

Active sensors (wind speed & direction)

Time span:	1999 - Present
Global coverage:	ca. 1 - 3 days
Spatial resolution:	$0.25^{o} – 1^{o}$ (25-100 km)

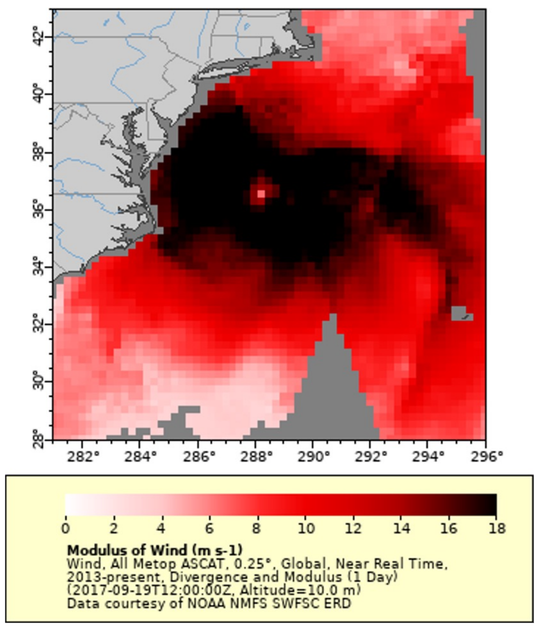
Ocean features can be tracked with wind data

Hurricane Jose September 5, 2017

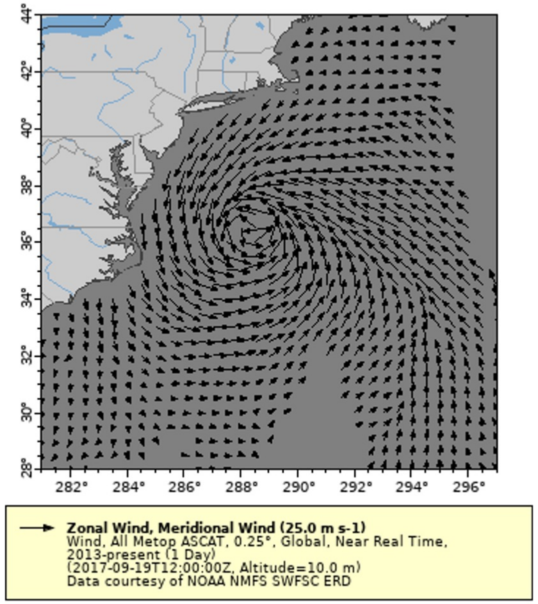


MODIS true color image

Wind Speed
(black is high winds)



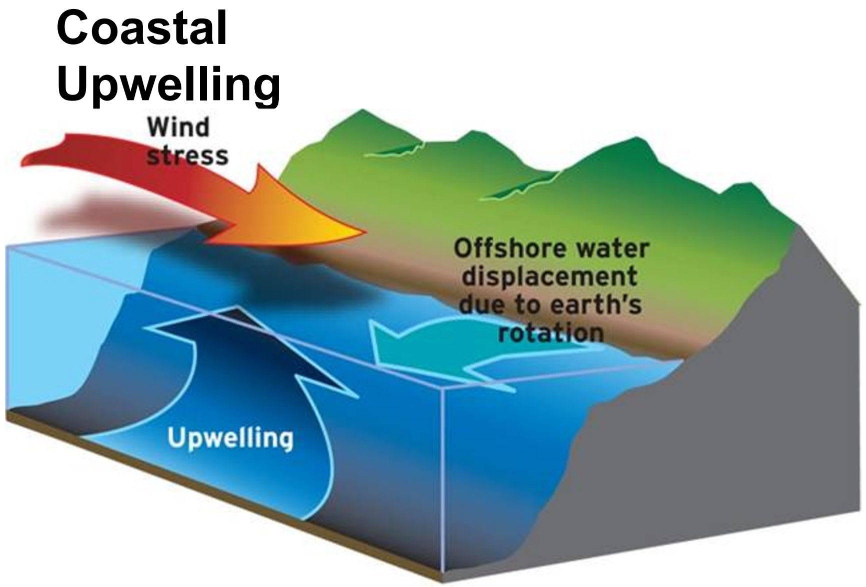
Wind Vectors
(direction and speed)



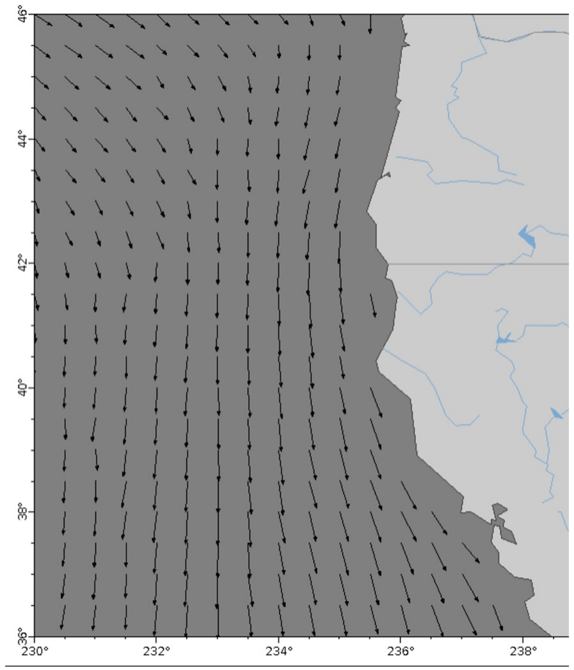
You can make these maps. Follow the instructions in Chapter 6 of the ERDDAP tutorial.

https://coastwatch.pfeg.noaa.gov/projects/erddap/vectors.html

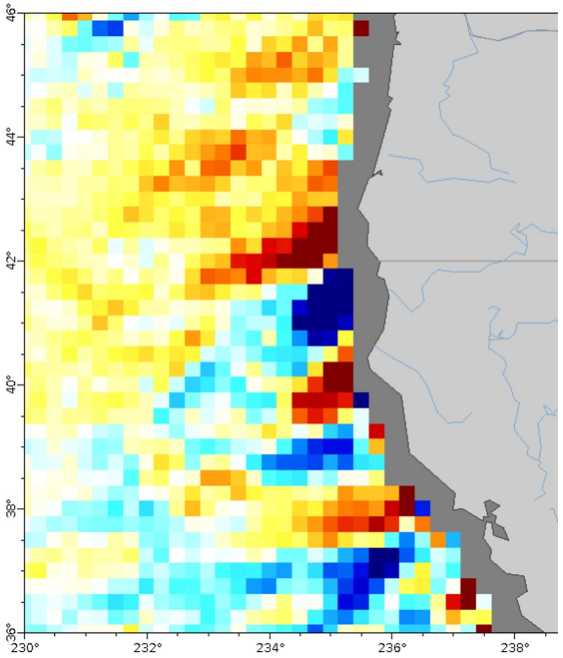
Coastal upwelling can be derived from wind speed and direction



Wind Vectors
(direction and speed)

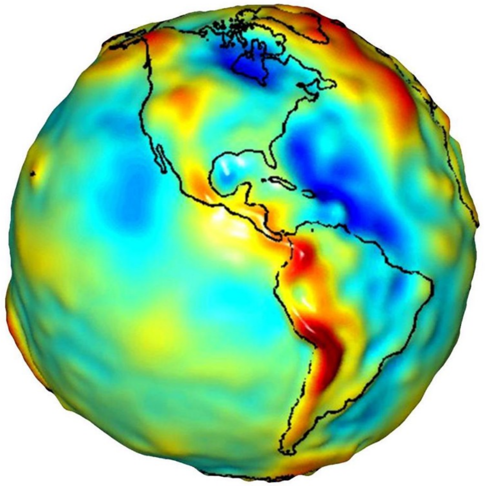


Ekman Upwelling
(red is up)

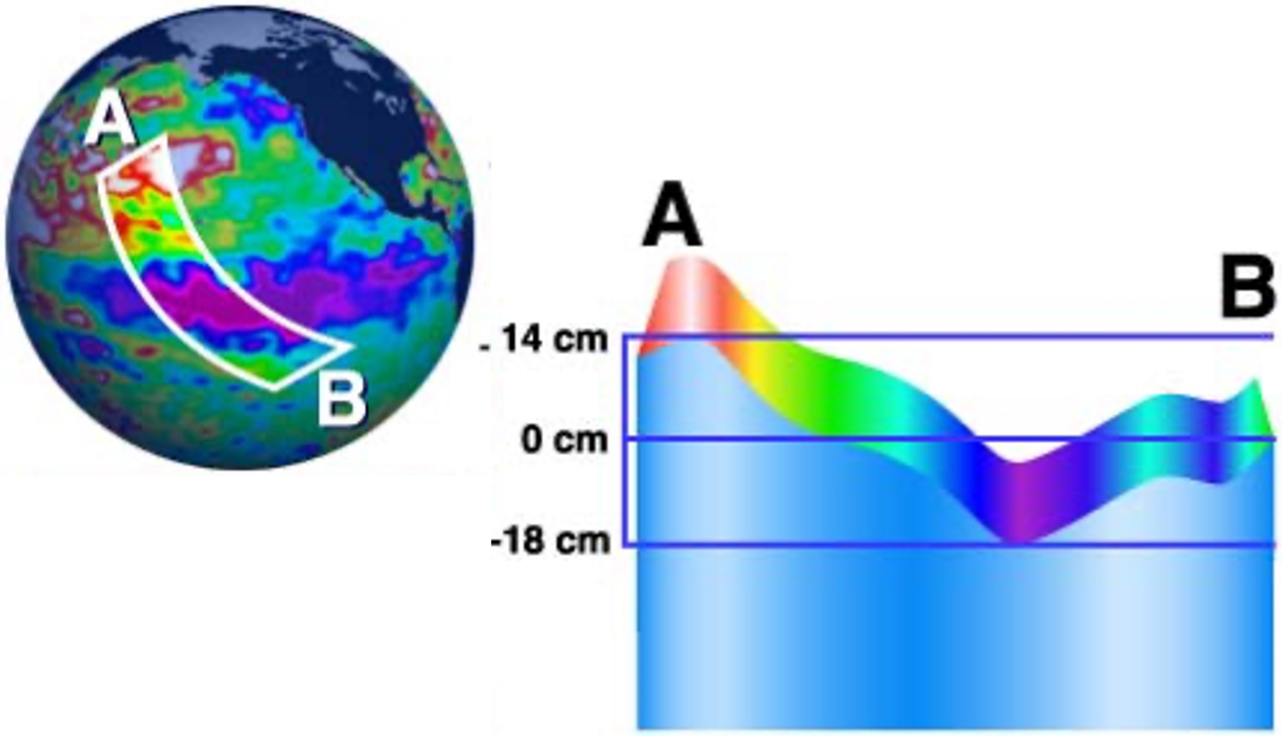


Sea surface height (SSH): the ocean surface is not flat

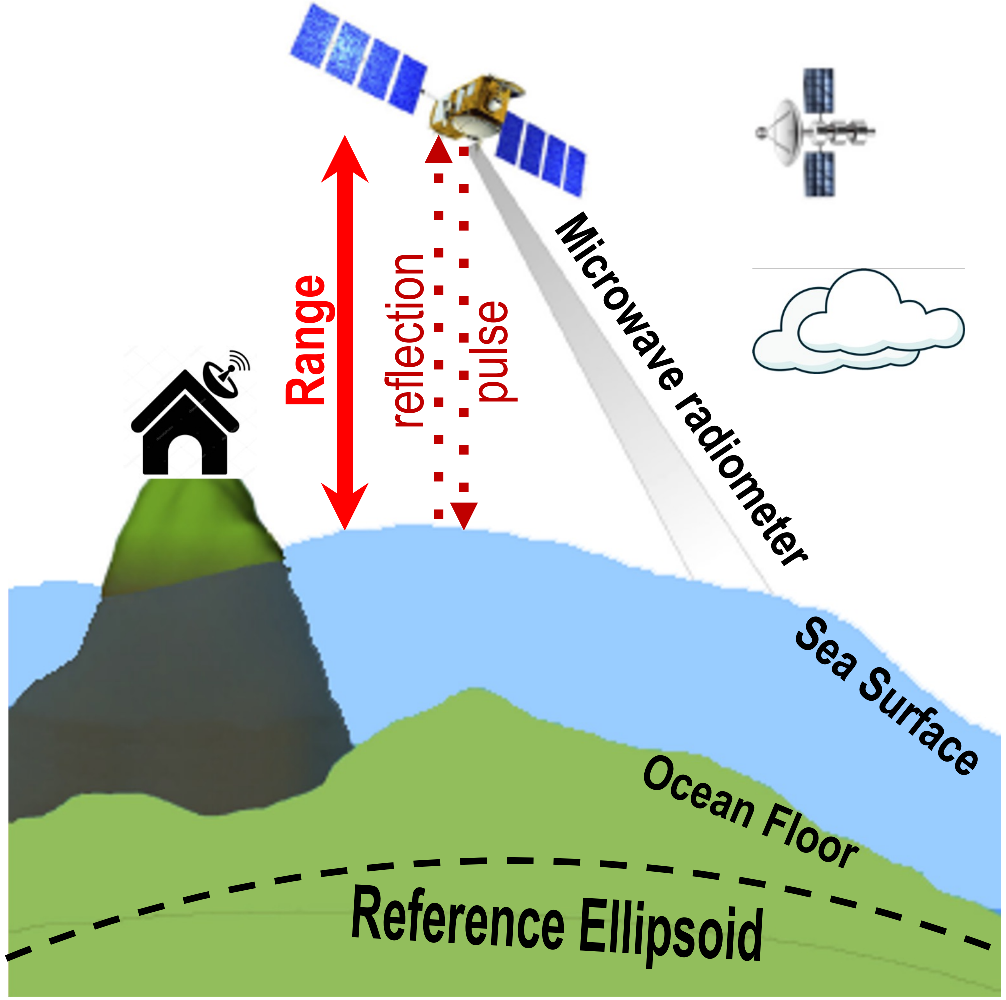
THE OCEAN'S BUMPINESS (SSH) IS MEASURED WITH ALTIMETRY (active sensors)



Bumpy Earth



Sea surface height measurements are made with satellite altimeters



Altimeters measure the distance from altimeter to sea surface (Range)

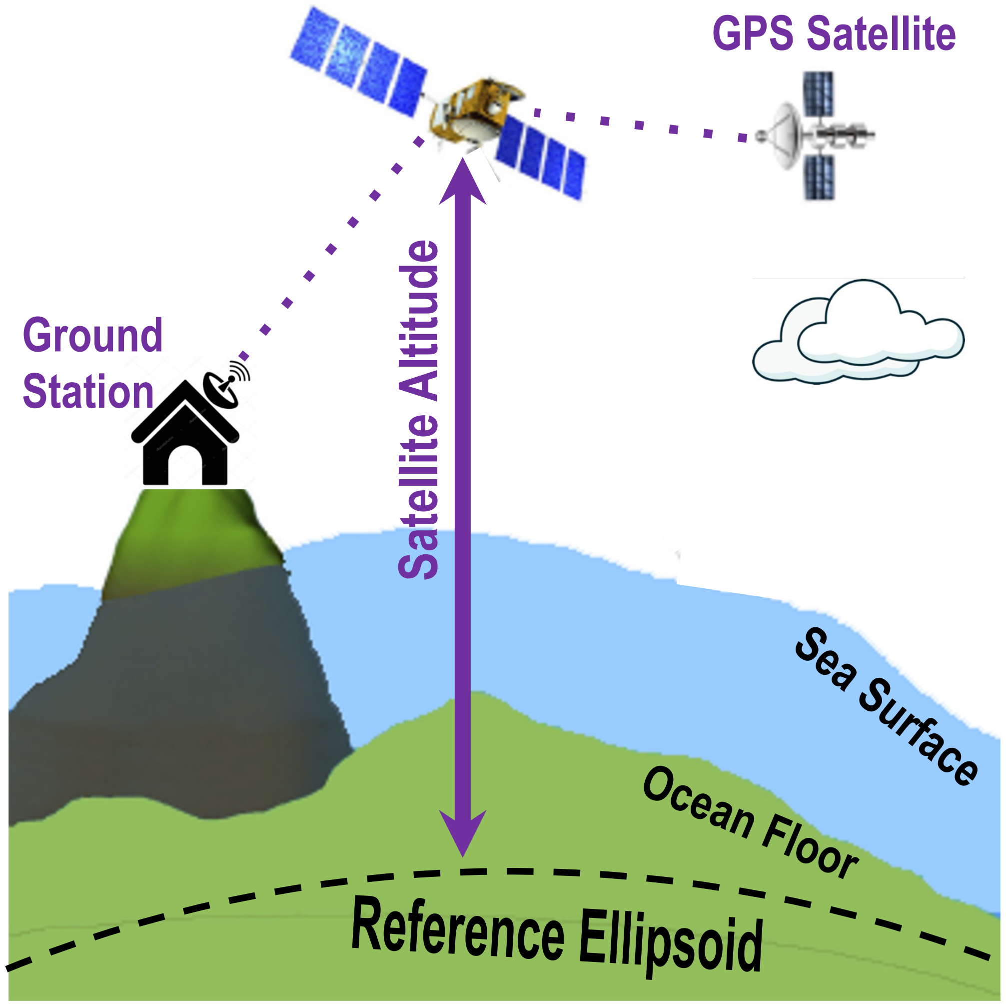
- Signal pulses sent by the altimeter are reflected off the sea surface and returned to the altimeter.
- **Range** is calculated from the return time.

$$\boxed{Range \;=\; \frac{return\ time}{2} + speed\ of\ light}$$

Atmospheric correction

- A microwave radiometer corrects for **Speed of Light** changes in the atmosphere.

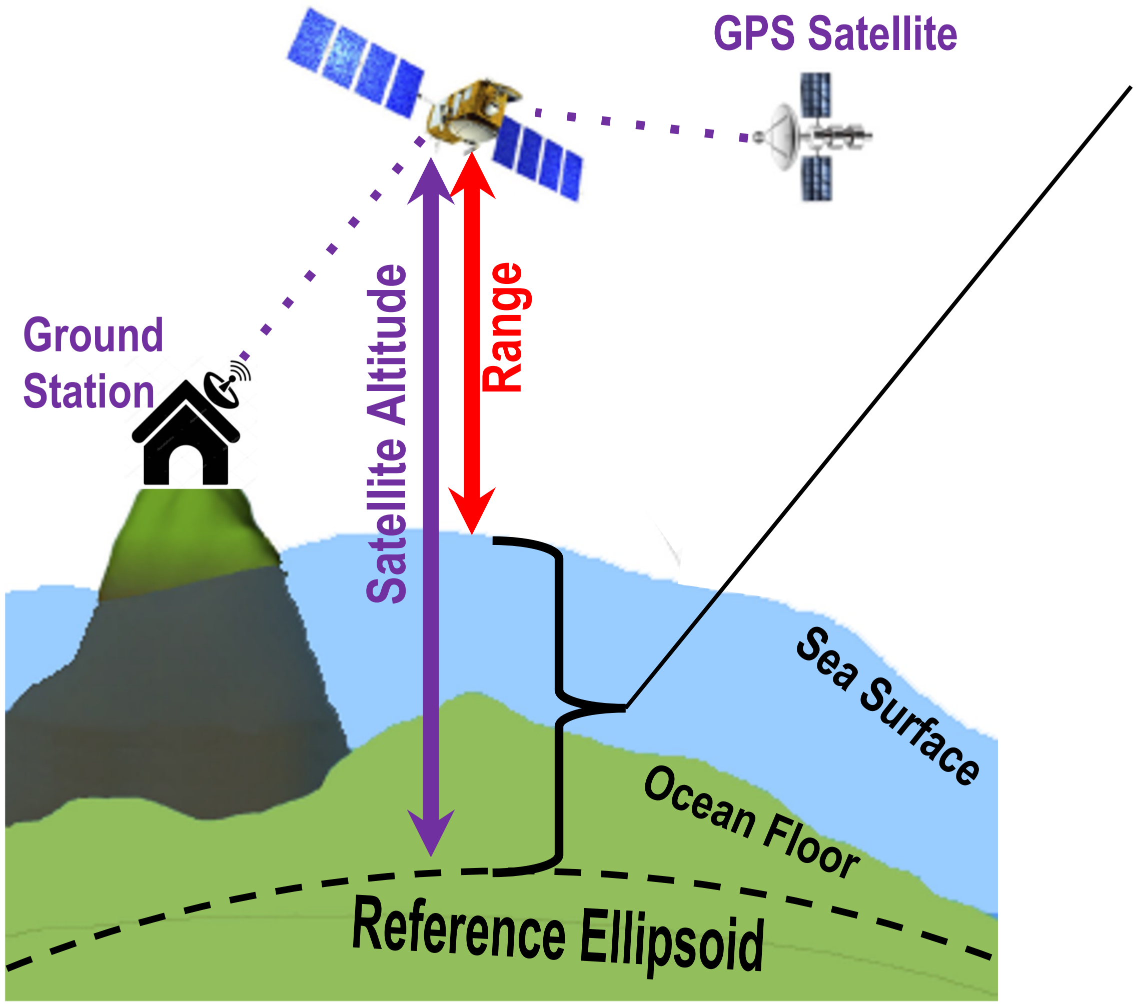
The altimeter position is determined in four dimensions



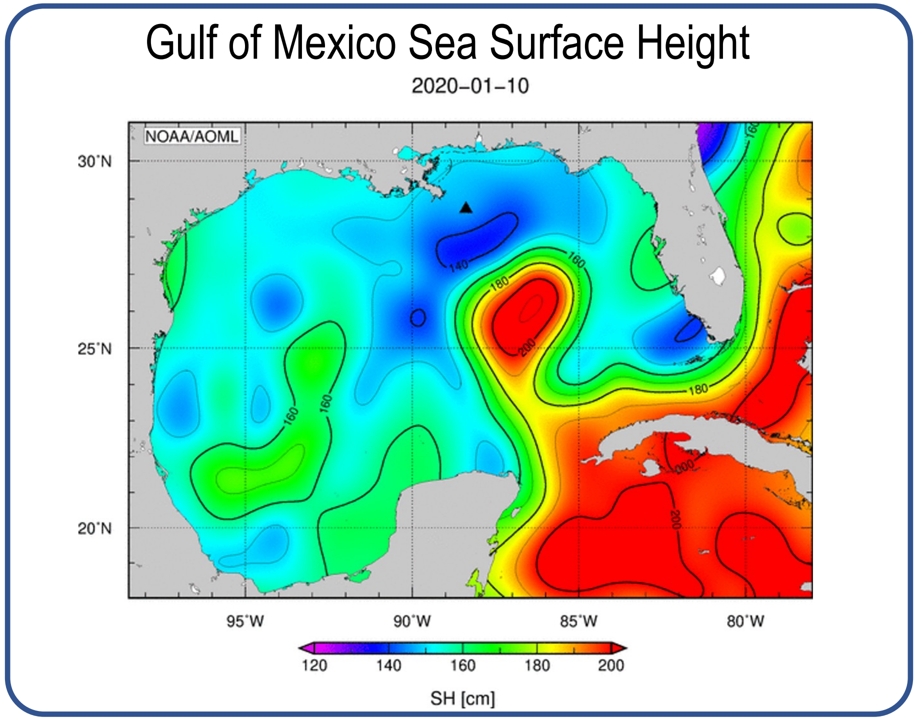
GPS satellites and ground stations determine the altimeter's position

- Altitude above the reference
- Latitude, longitude, time

Put it all together to determine SSH and other parameters

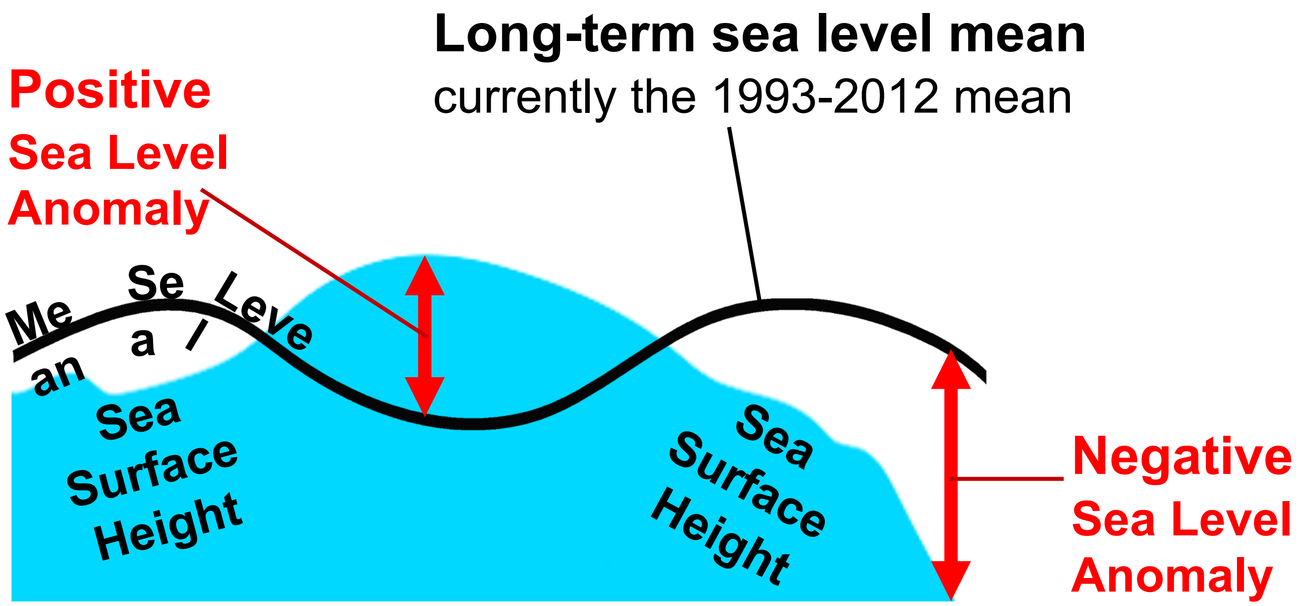


Sea Surface Height = Satellite Altitude – Range



Sea Level Anomaly (SLA) is a derived product of SSH

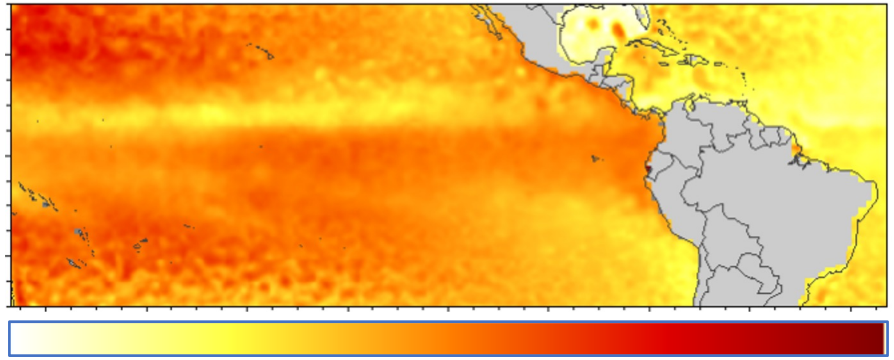
DERIVED FROM SUBTRACTING THE LONG-TERM MEAN SEA LEVEL FROM MEASURED SSH



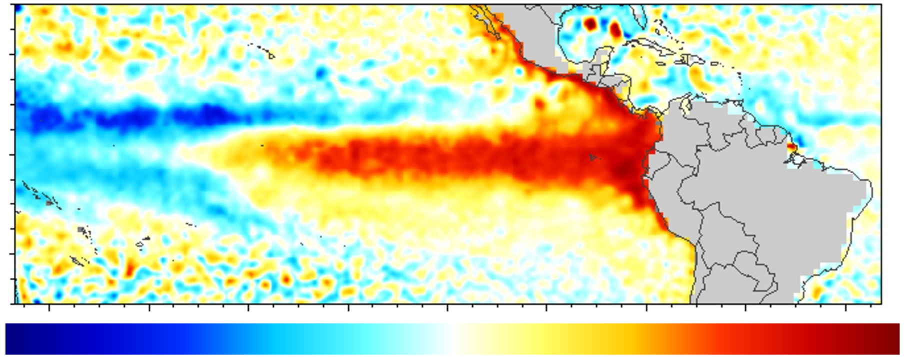
SLA helps detect ocean phenomena from subtle changes in SSH

1997-1998 El Niño visualized with the SSH anomaly

SSH



Sea Level Anomaly

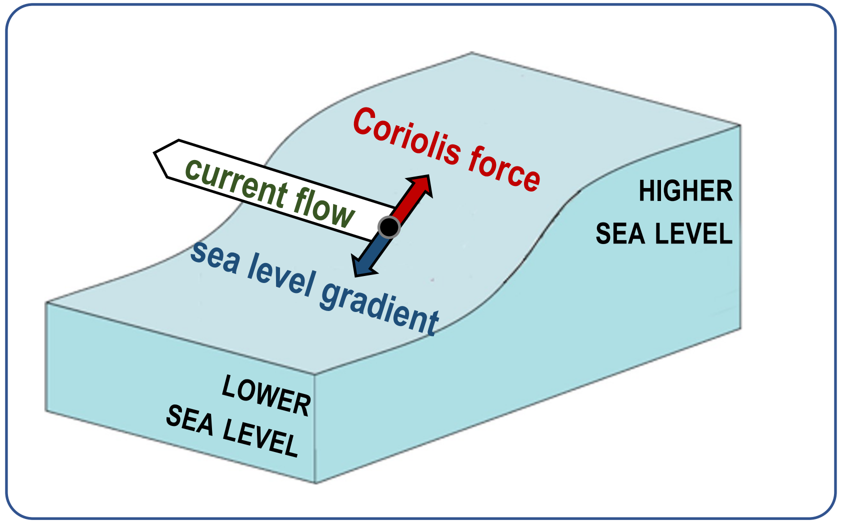


- During an El Niño, a shift in wind causes warm water to accumulate off the coast of Peru.
- The warming water expands, increasing SSH beyond what is typically observed.
- The SSH anomaly helps to visualize the non-typical SSH values.

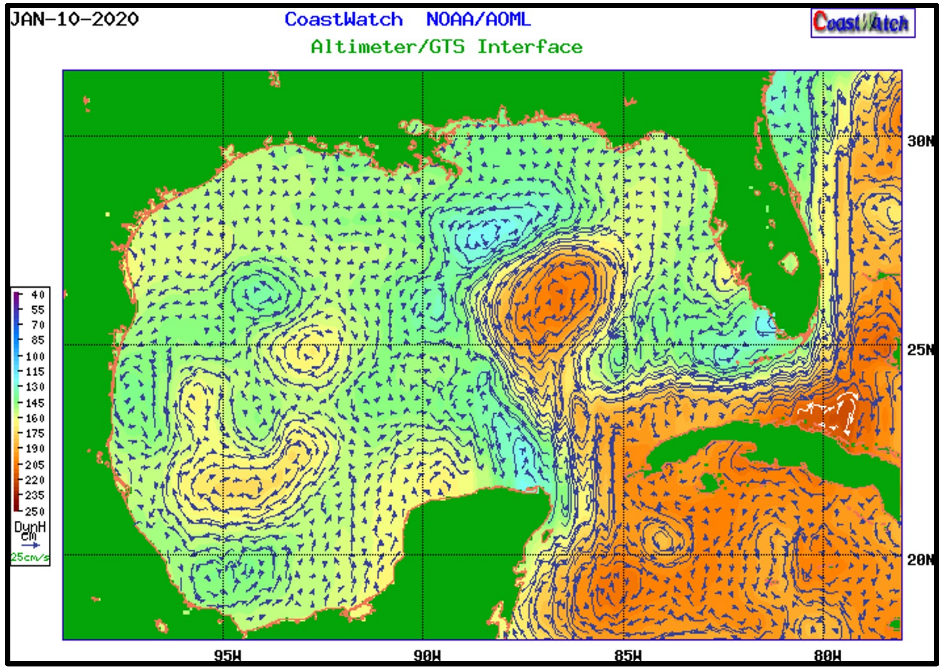
Geostrophic currents are derived from SSH information

GEOSTROPHIC CURRENTS ARE CURRENTS DRIVEN BY A SEA LEVEL GRADIENT

Geostrophic Currents Mechanism



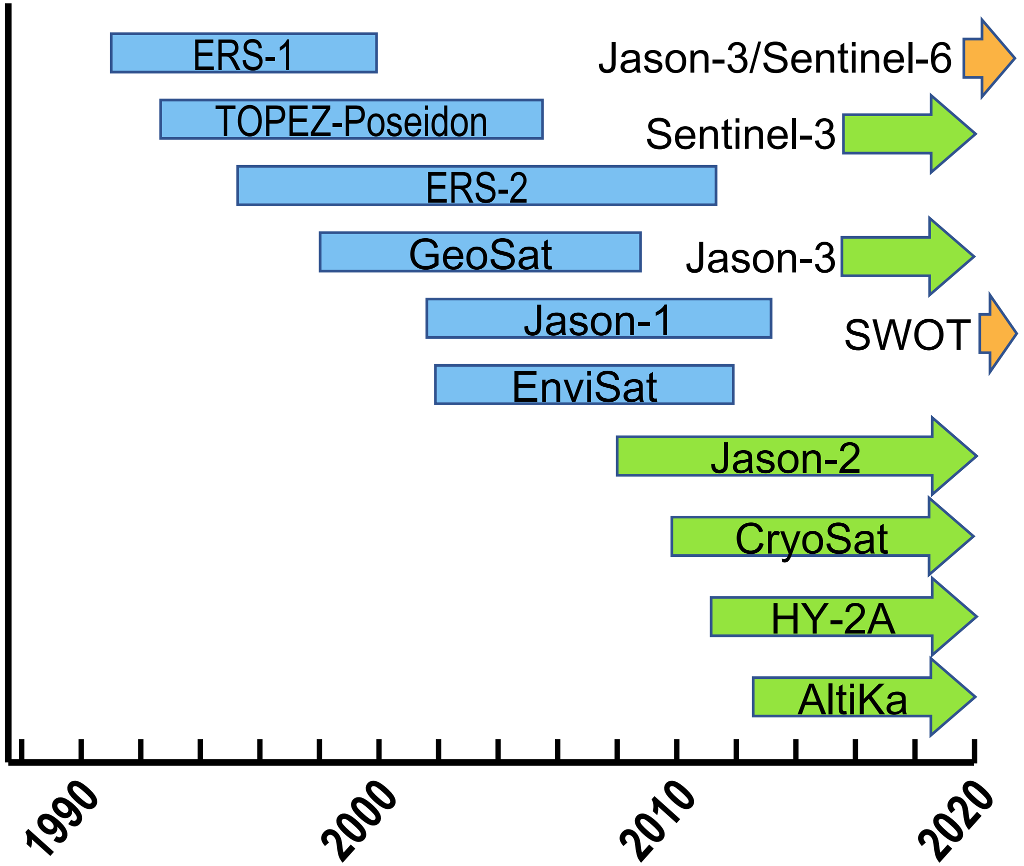
Geostrophic Currents in the Gulf of Mexico



Jan 10, 2020

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

Satellite altimetry dates back to the early 1990s



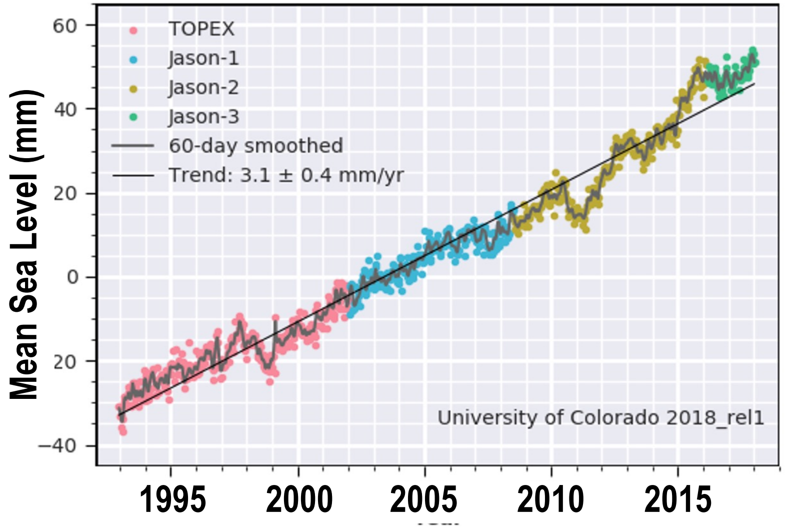
Many missions, always with some overlap

Blending the sensor data together allows:

Creating long timeseries

Getting better spatial coverage at any one time

Blended products give improved temporal and spatial coverage



Four sensor products extend the mean sea level timeseries back to 1993

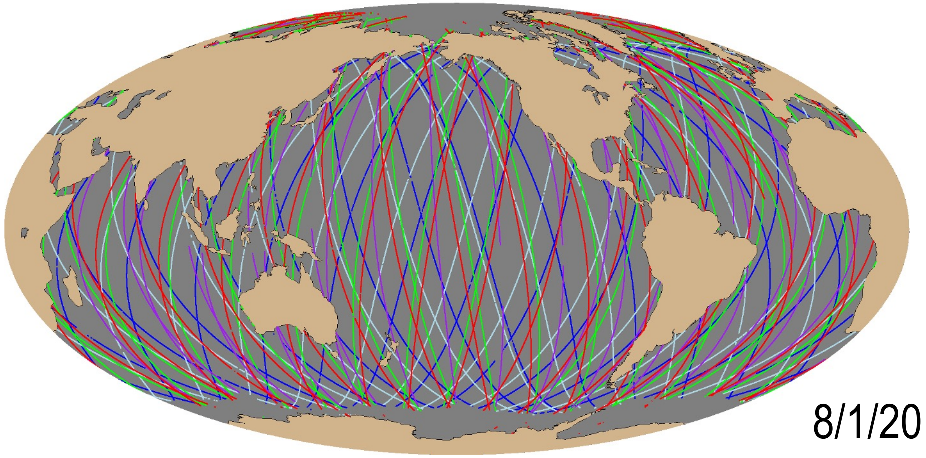
Satellites

TOPEX **Jason-2** **Jason-1** **Jason-3**

Combining data from five sensors improves daily spatial coverage

Satellites

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



8/1/2018

Review of SSS, Surface Winds, and SSH

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 that 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

SSH

1990 - present

Daily global coverage

Accuracy ~ 3 cm

NOAA CoastWatch Satellite Course - Narrated Presentations

- Satellite 101 – Part 1
- Satellite 101 – Part 2
- Fundamentals of Ocean Color
- Fundamentals of Sea-Surface Temperature
- **Fundamentals of Altimetry, Wind and Salinity**
- Introduction to ERDDAP
- What Dataset to Choose?
- Bringing Satellite Data into ARCGIS