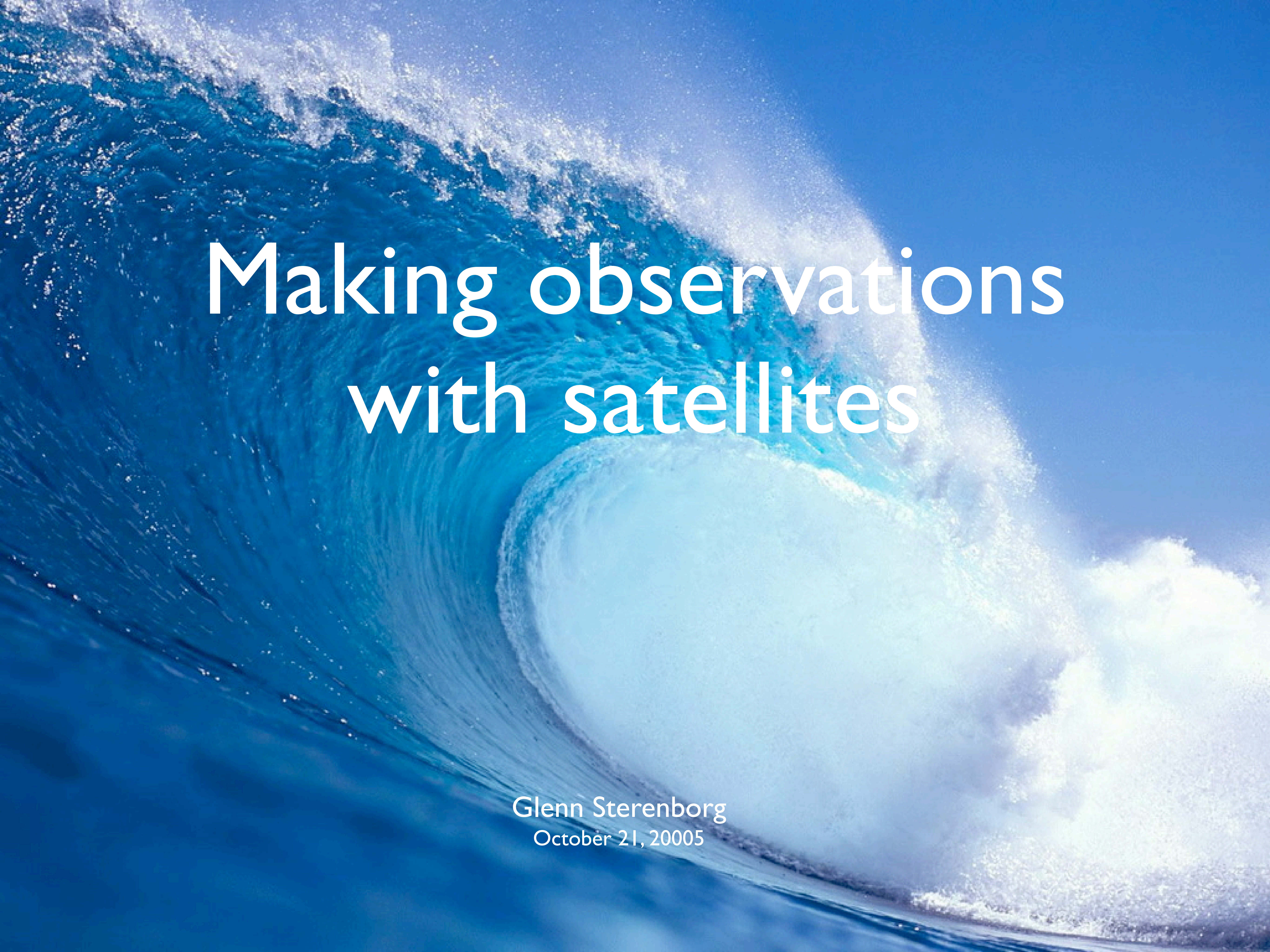


Making observations with satellites

Glenn Sterenborg
October 21, 20005

Number of ways to approach this subject:

- electromagnetic spectrum
- techniques
- satellites/instruments in use
- observables

what do we want to know?

what do we want to know?

- o sea surface height
- o currents
- o bathymetry
- o gravity
- o wind speed
- o wind direction
- o sea surface temperature
- o sea surface salinity
- o chlorophyll-a detection
- o depth

- o p, T, water vapour
- o liquid water content
- o electron density

what do we want to know?

- sea surface height
- currents
- bathymetry
- gravity

} altimetry

- wind speed
- wind direction

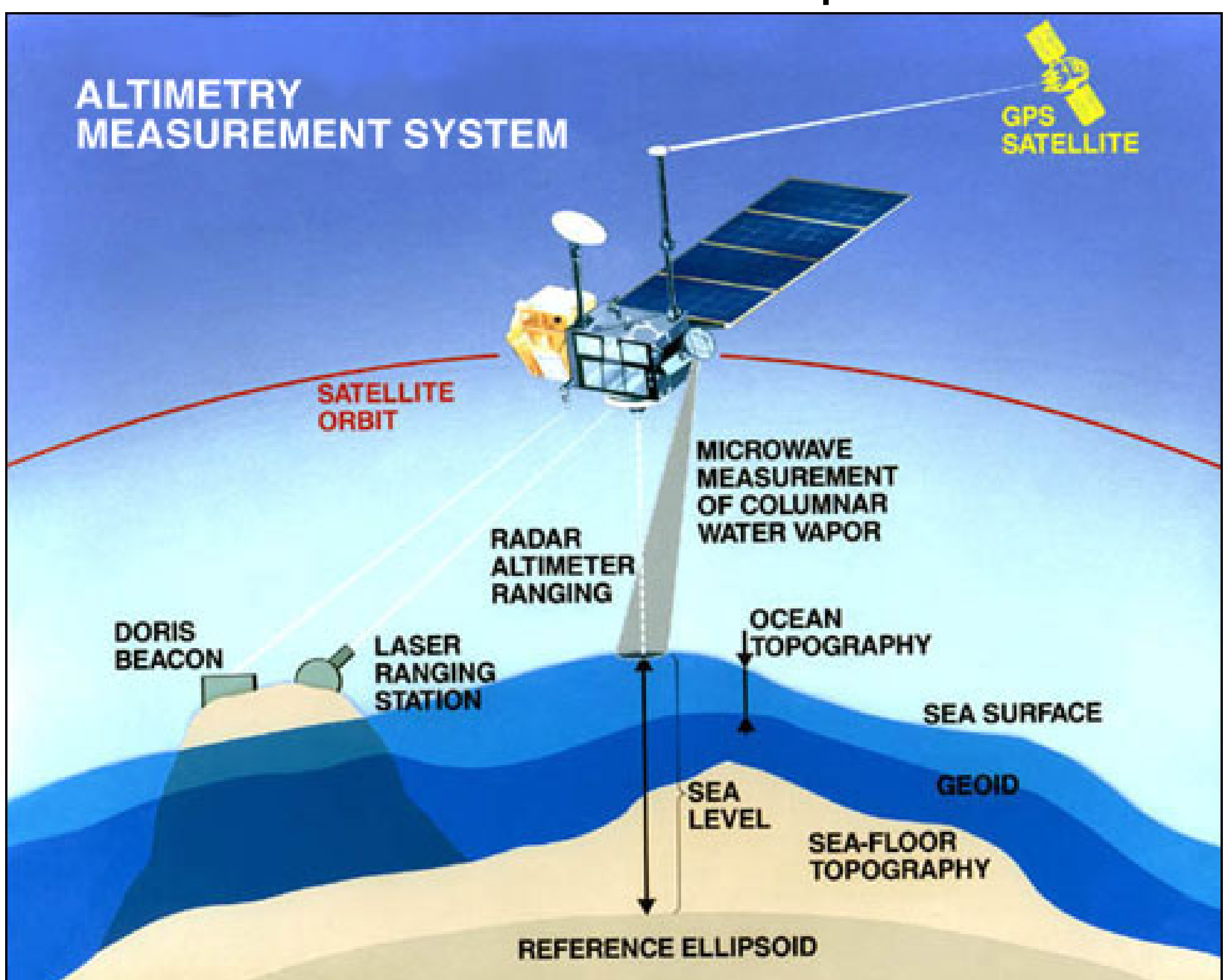
} scatterometry

- sea surface temperature — infrared
- sea surface salinity — radiometry
- chlorophyll-a detection — visible
- depth

Sea Surface Height

Altimeters send self-generated (active) signals to reflecting surfaces and collect the reflected signal. Then they measure the total roundtrip times from the targets (solid land, tree tops, ice, or water) over which they move. The signals can be either radio pulses (radar included) or light pulses (laser).

One of the most famous examples is TOPEX/POSEIDON.



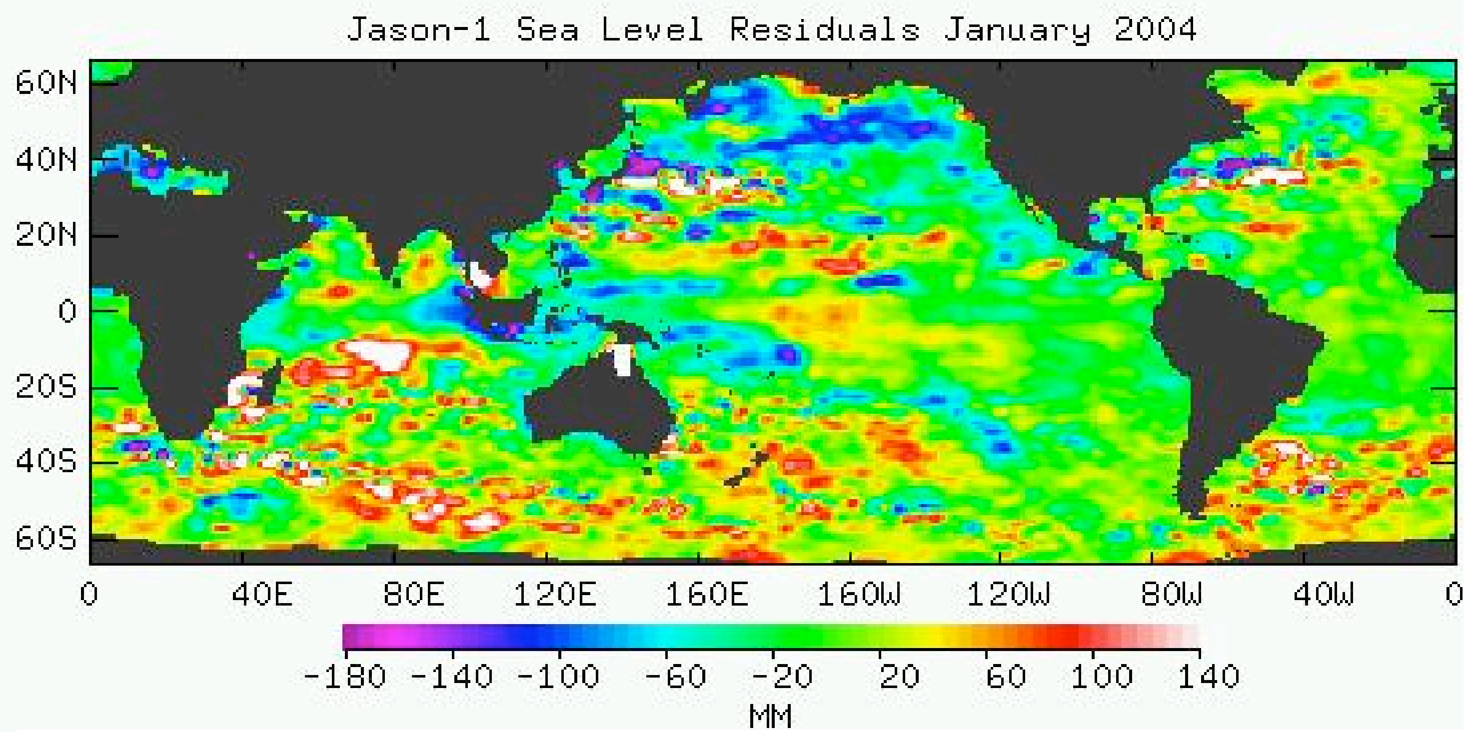
www.nasa.gov

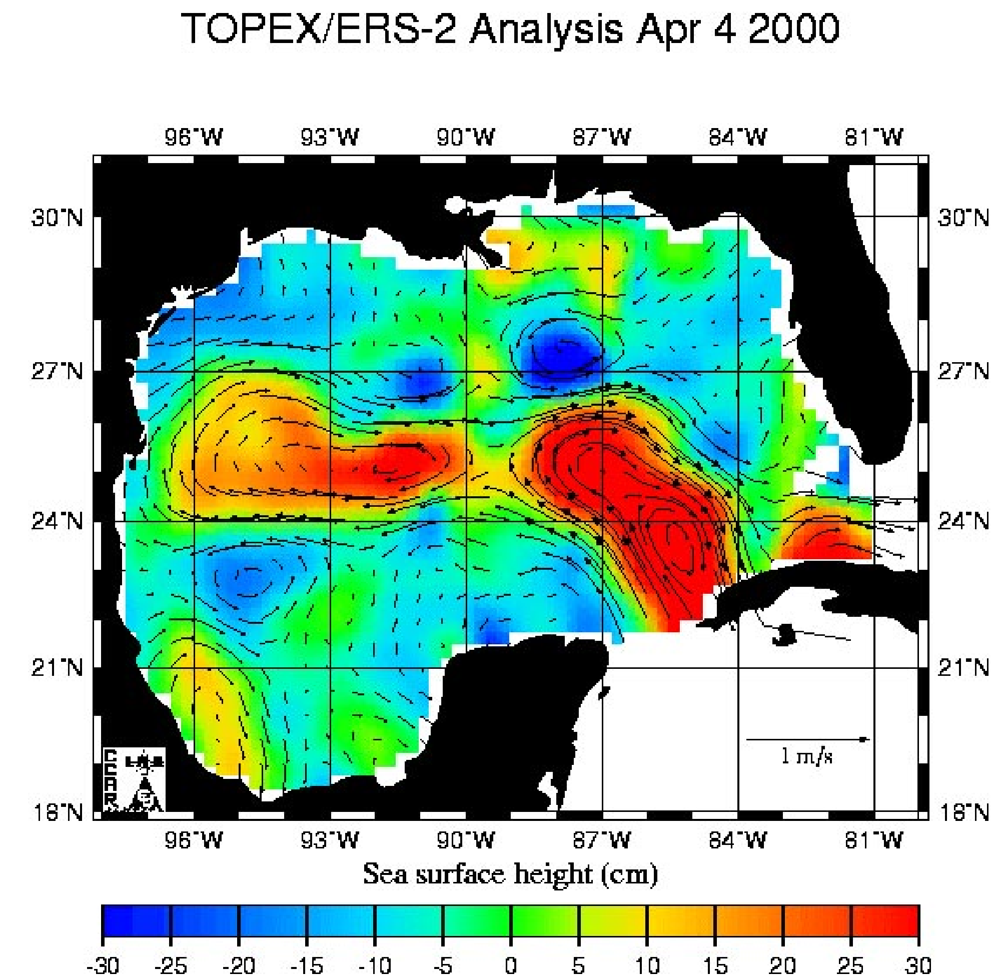
o It can measure the height of the ocean surface directly underneath the satellite with an accuracy of 4-5 centimeters (better than 2 inches). It covers the global oceans every 10 days.

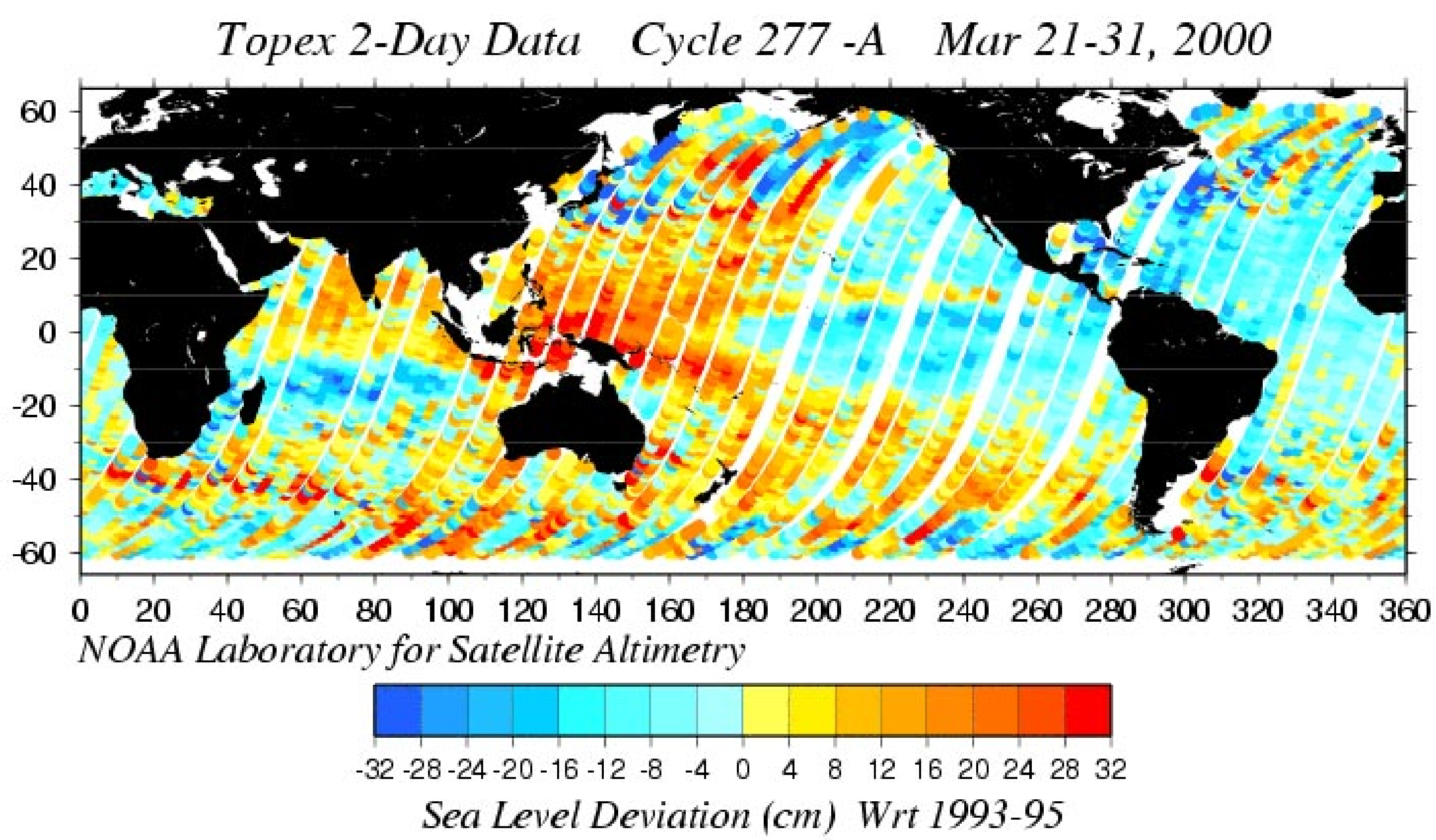
o Precise Orbit Determination (POD) plays a key role here.

o By averaging the many measurements made by the satellite over this period the global mean sea level can be determined within mm's.

Sea Surface Height







http://topex-www.jpl.nasa.gov/science/data-noaa-lab.html

http://topex-www.jpl.nasa.gov/science/data-ccar-altimetry.html

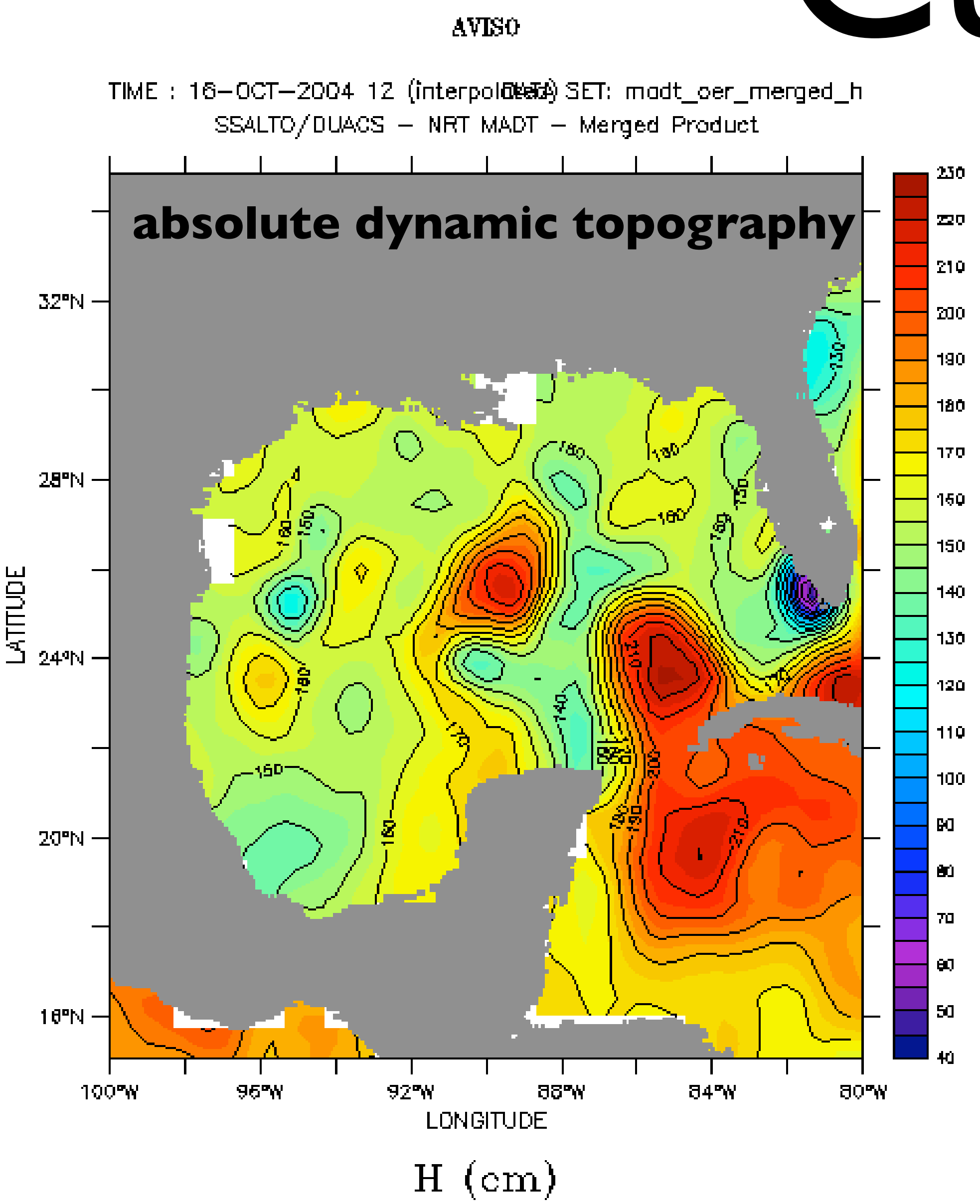
http://topex-www.jpl.nasa.gov/science/timeseries/200401_G.html

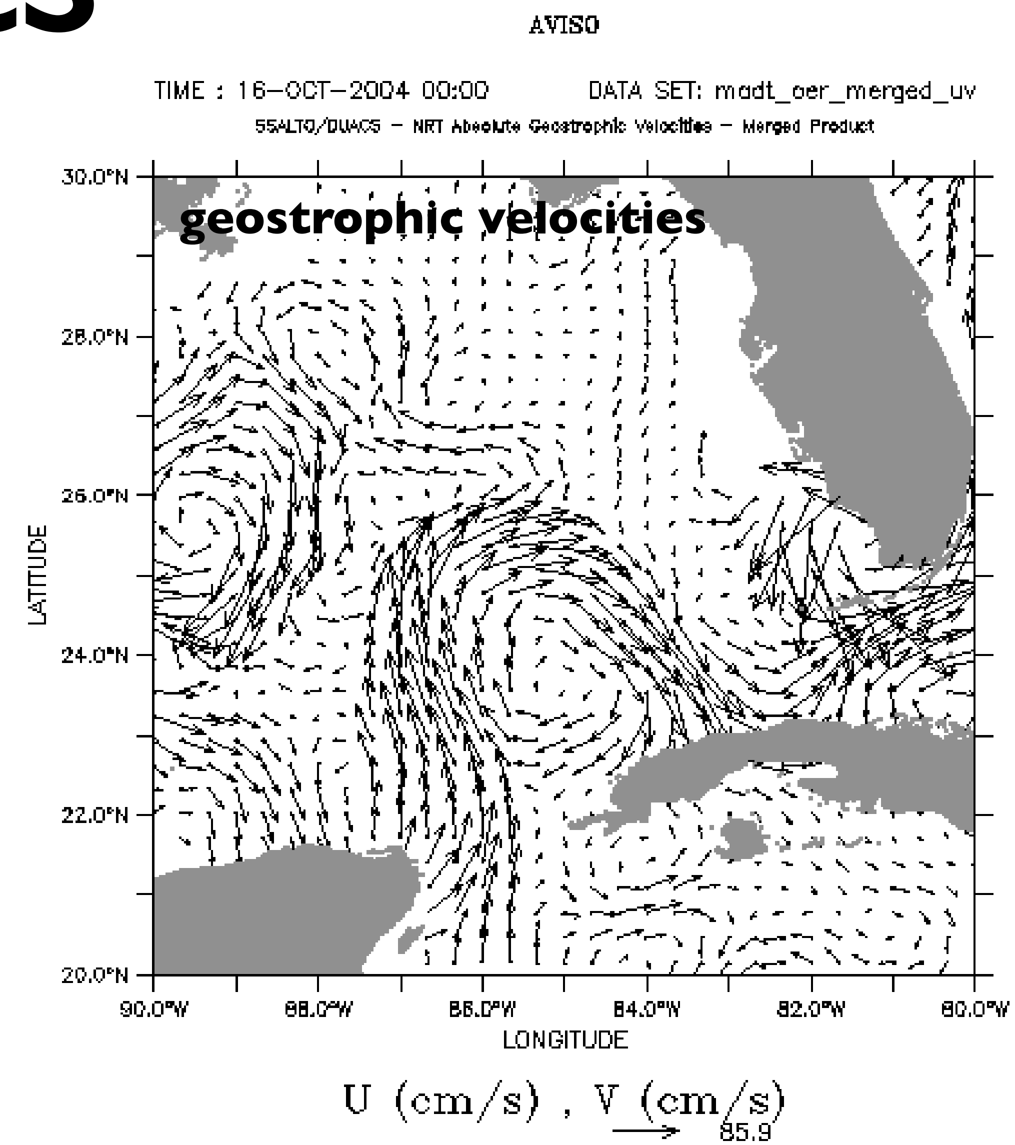
Sea Surface Height

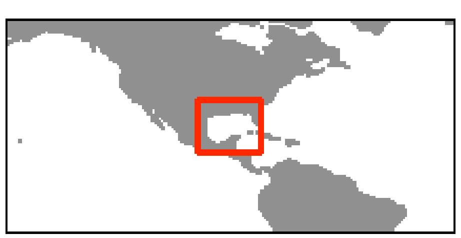
changes in sea level measured from space using data from the TOPEX/Poseidon and Jason satellites

http://www.nasa.gov/vision/earth/environment/sealevel_feature.html

Currents



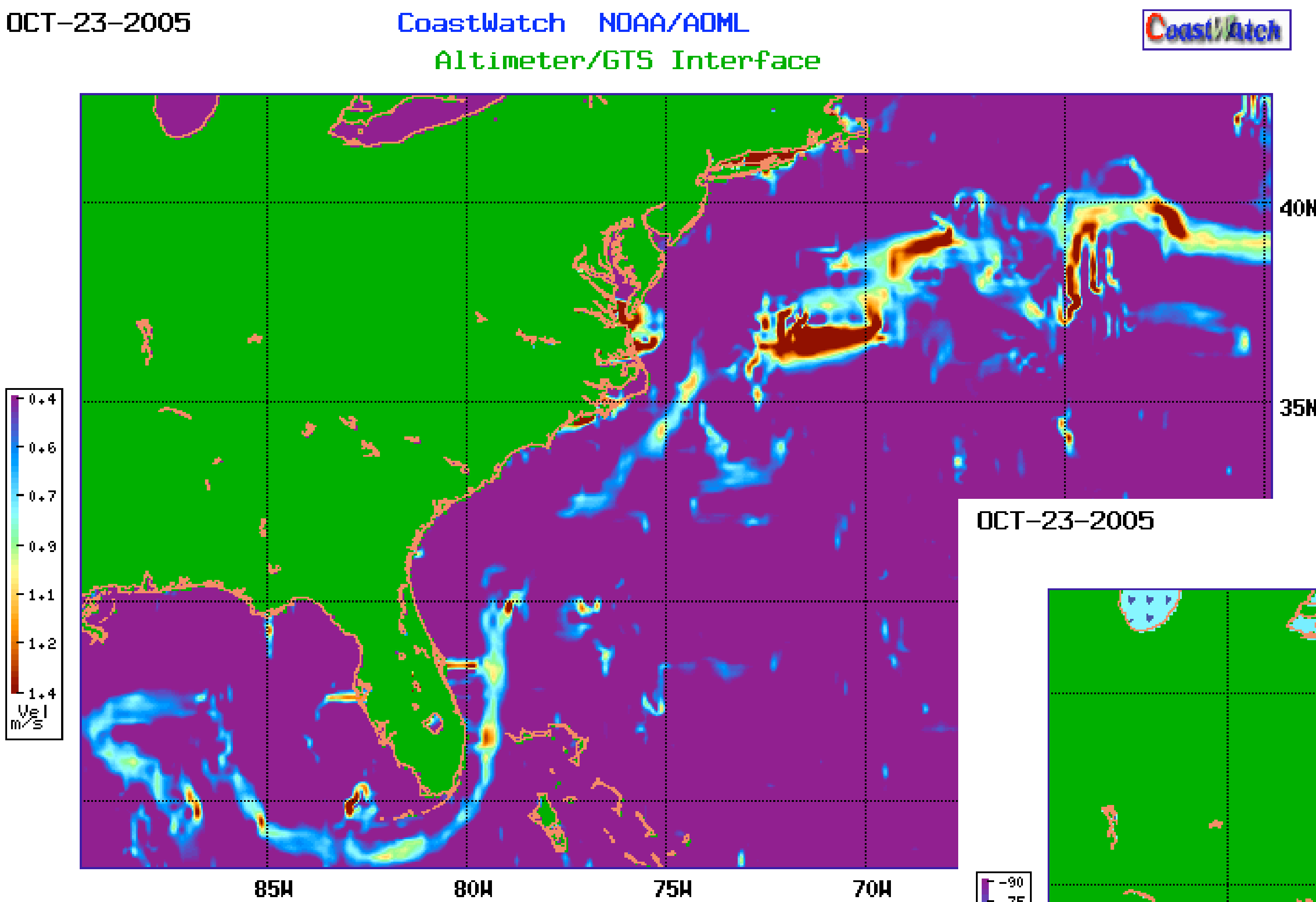




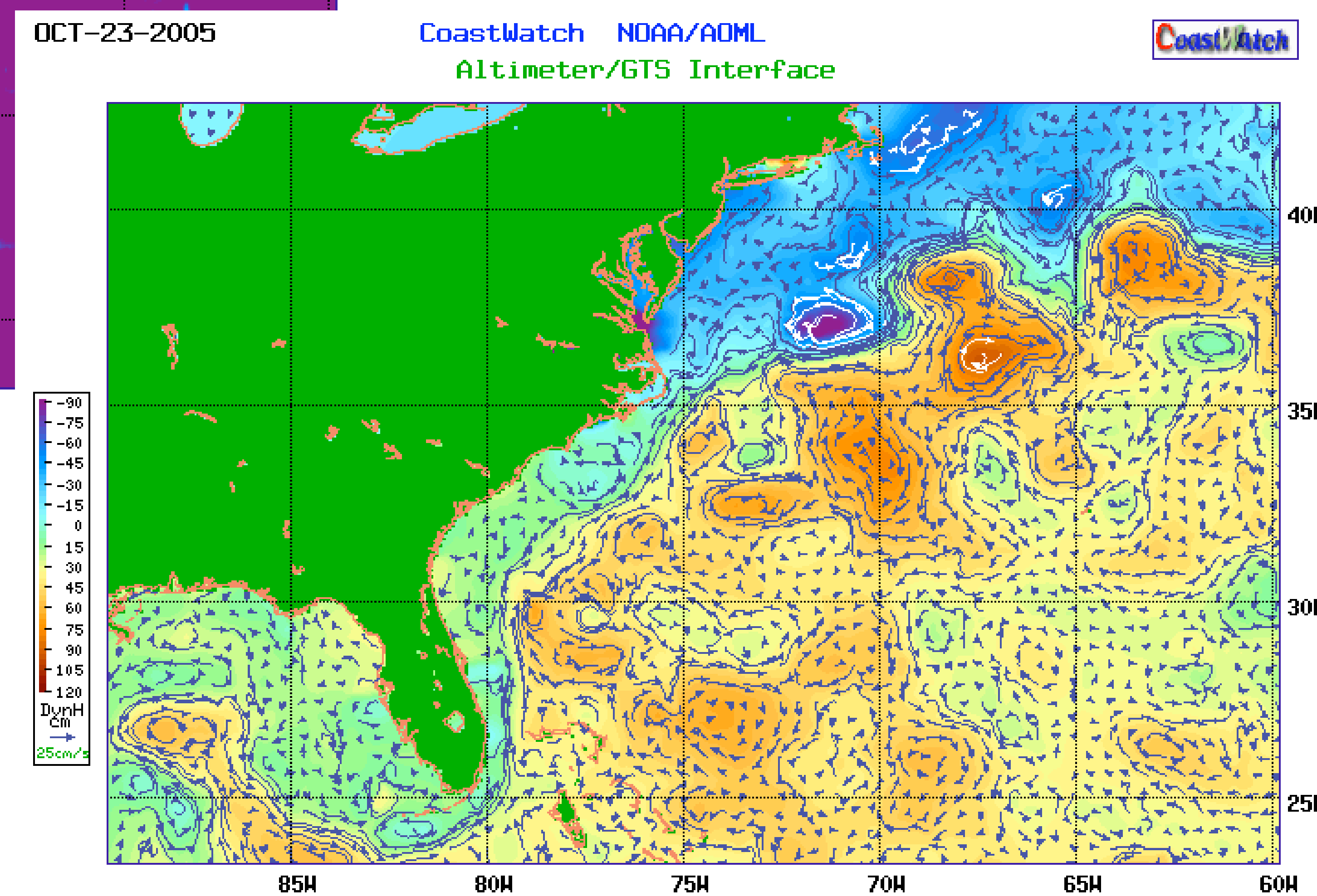
Currents are determined from altimetry data as well

http://www.jason.oceanobs.com/

Currents



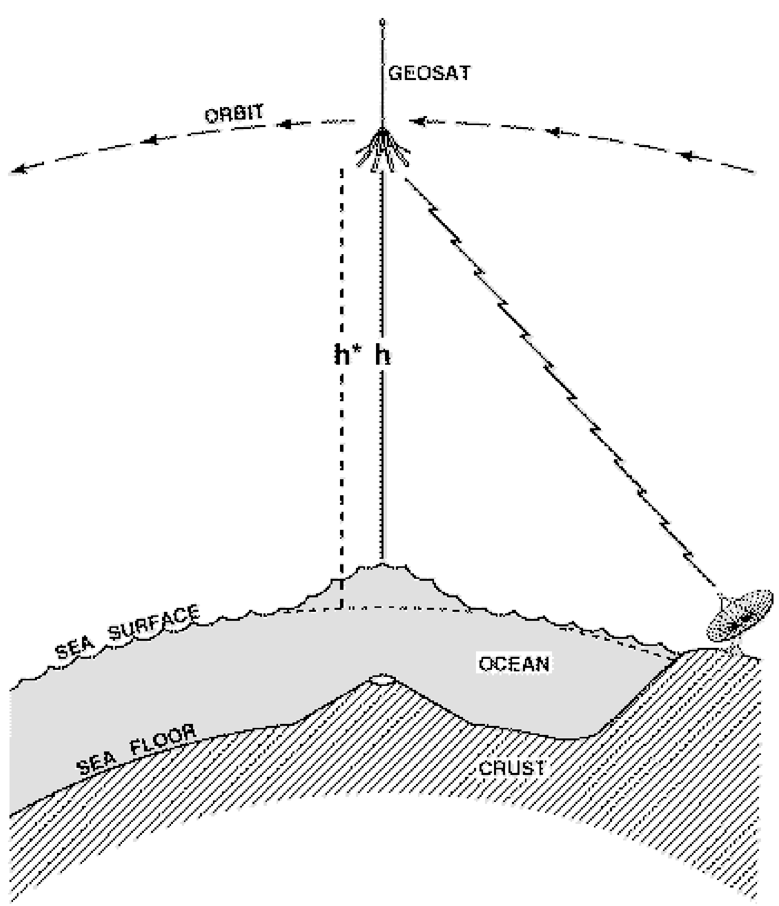
JASON-1, TOPEX, ERS-2, ENVISAT and GFO Sea Height Anomaly (SHA) and Significant Wave Height data are available here on a near-real time basis with a 2-day average delay. These data have been processed by the NRL site at the Stennis Space Center. The maps shown here are generated by interpolating SHA data corresponding to a 10-day period ending on the selected date.



http://www.aoml.noaa.gov/phod/altimetry/index.php

Bathymetry/Gravity

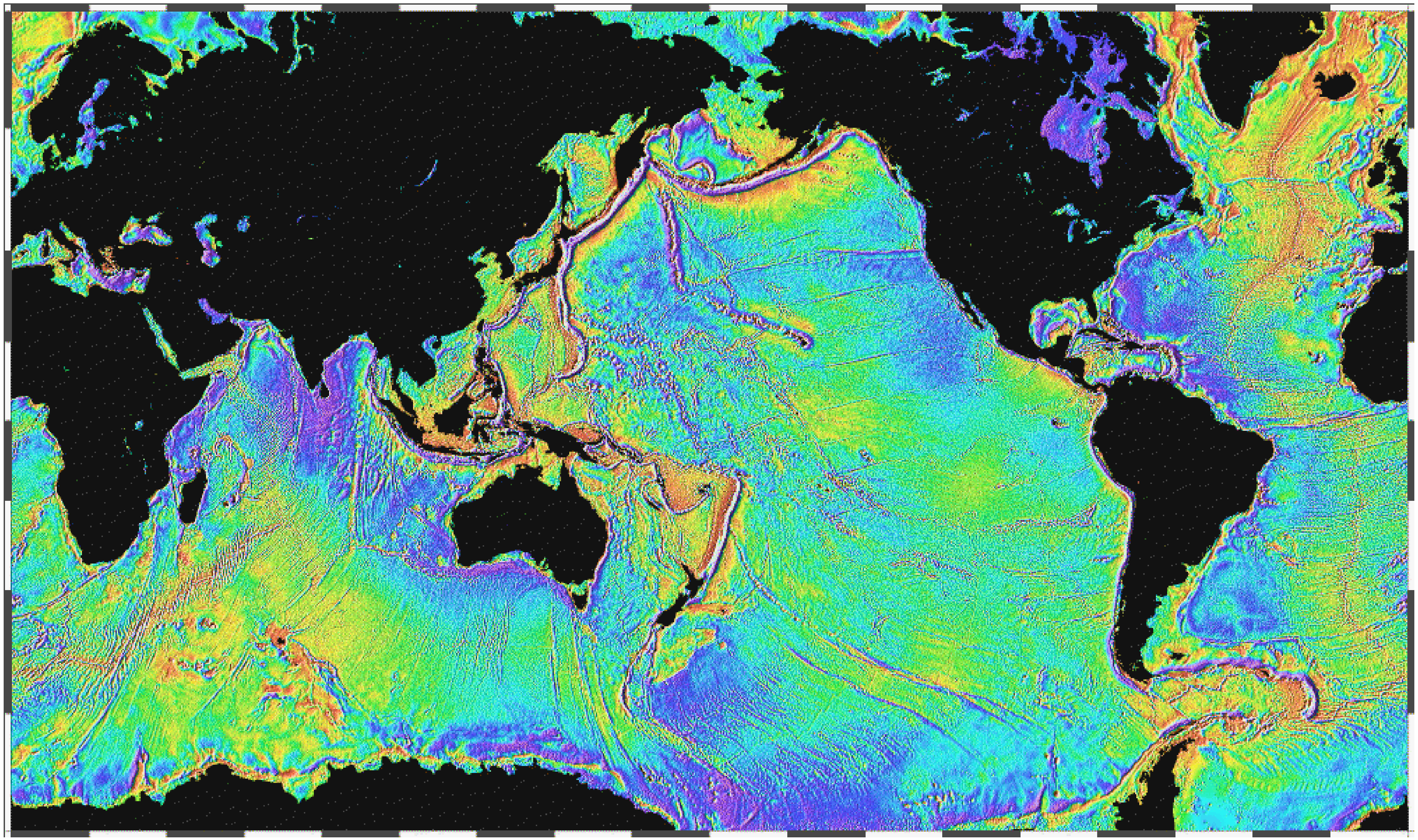
The surface of the ocean bulges outward and inward mimicking the topography of the ocean floor. The bumps, too small to be seen, can be measured by a radar altimeter aboard a satellite.



- o equipotential surface
- o satellite laser ranging (h*)
- o orbital mechanics (h*)
- o microwave radar altimeter (h)
- o large footprint (average out wave irregularities)

http://www.ngdc.noaa.gov/mgg/image/altimeter.gif

Bathymetry/Gravity



http://www.ngdc.noaa.gov/mgg/bathymetry/predicted/explore.HTML#sat_alt

Wind Speed/Direction

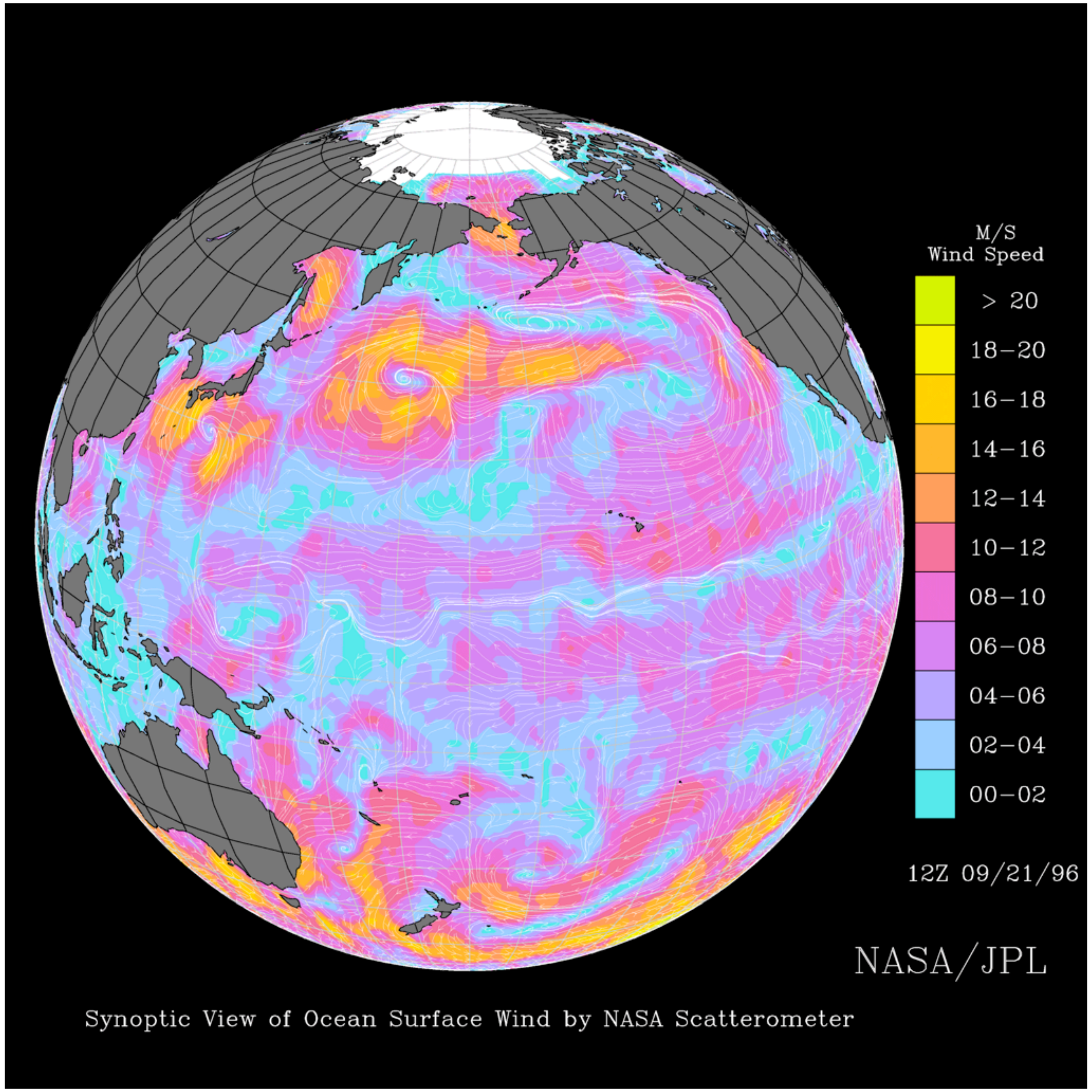
- Scatterometry: microwaves are scattered by short water waves; the fraction of energy returned to the satellite (backscatter) is a function of wind speed and wind direction. *The wind speed* can be determined from the strength of the backscatter signal

- *The wind direction*: the angle that is most likely to be consistent with the backscatter observed from multiple angles. In roughly 5 minutes, a satellite in a low polar orbit will move far enough to view a point on water surface from angles spanning 90°.

- Seasat-A Satellite Scatterometer
- (ERS)-1 & -2 Active Microwave Instrument (AMI) scatterometer
- NASA Scatterometer (NSCAT)
- NASA Quick Scatterometer (QuikSCAT)

Wind Speed/Direction

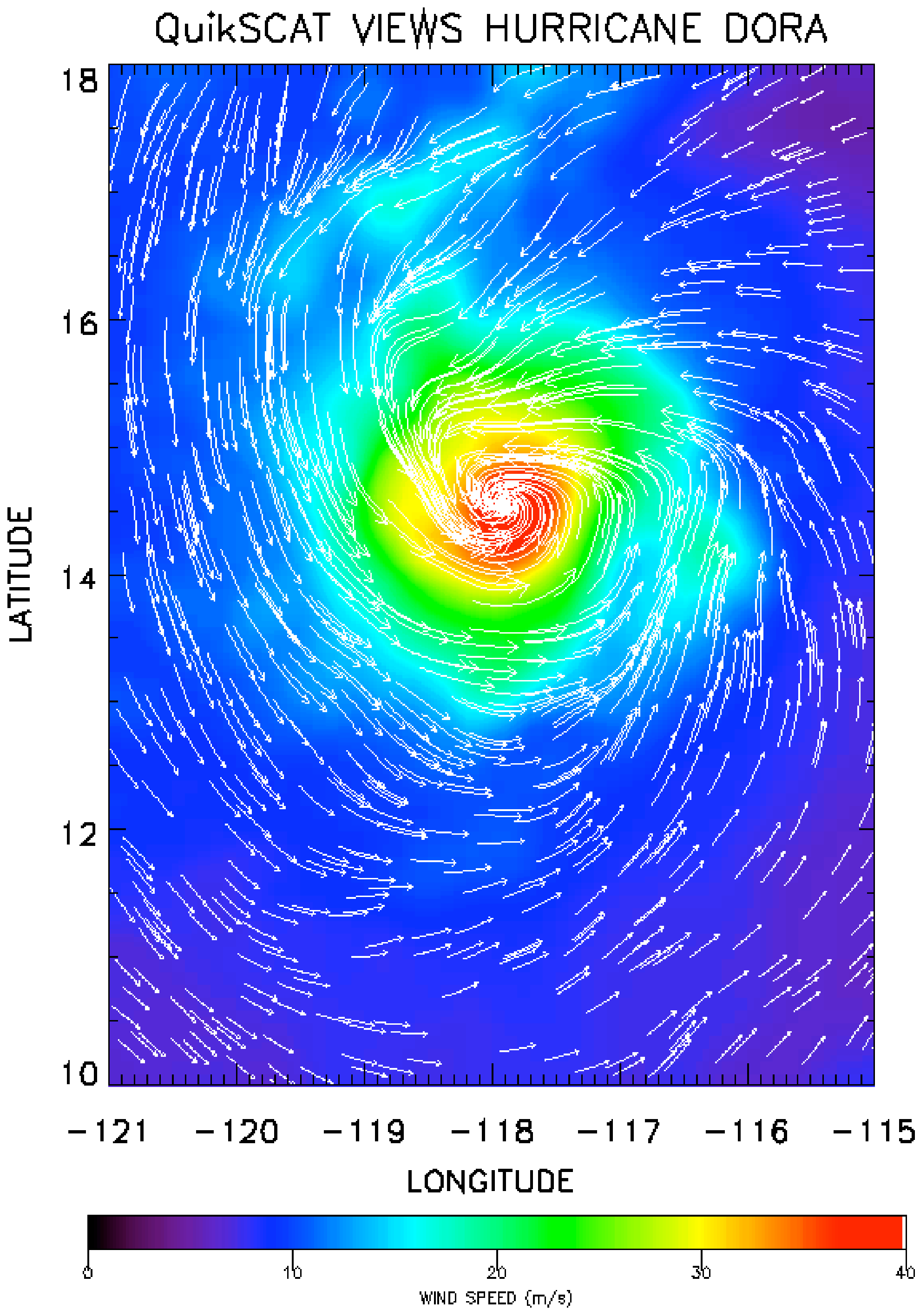
Ocean surface wind speeds and directions over the Pacific Ocean on 21 September 1996 as they were measured by the NASA Scatterometer (NSCAT)



http://winds.jpl.nasa.gov/imagesAnim/nscatdata.cfm

Wind Speed/Direction

JPL / NASA



L. Jones, UCF / M. H. Freilich, OSU

The SeaWinds instrument onboard NASA's new QuikScat ocean-viewing satellite captured this image of Hurricane Dora in the eastern tropical Pacific Ocean on August 10 2005, as it was blowing at speeds of nearly 40 meters per second (90 miles per hour).

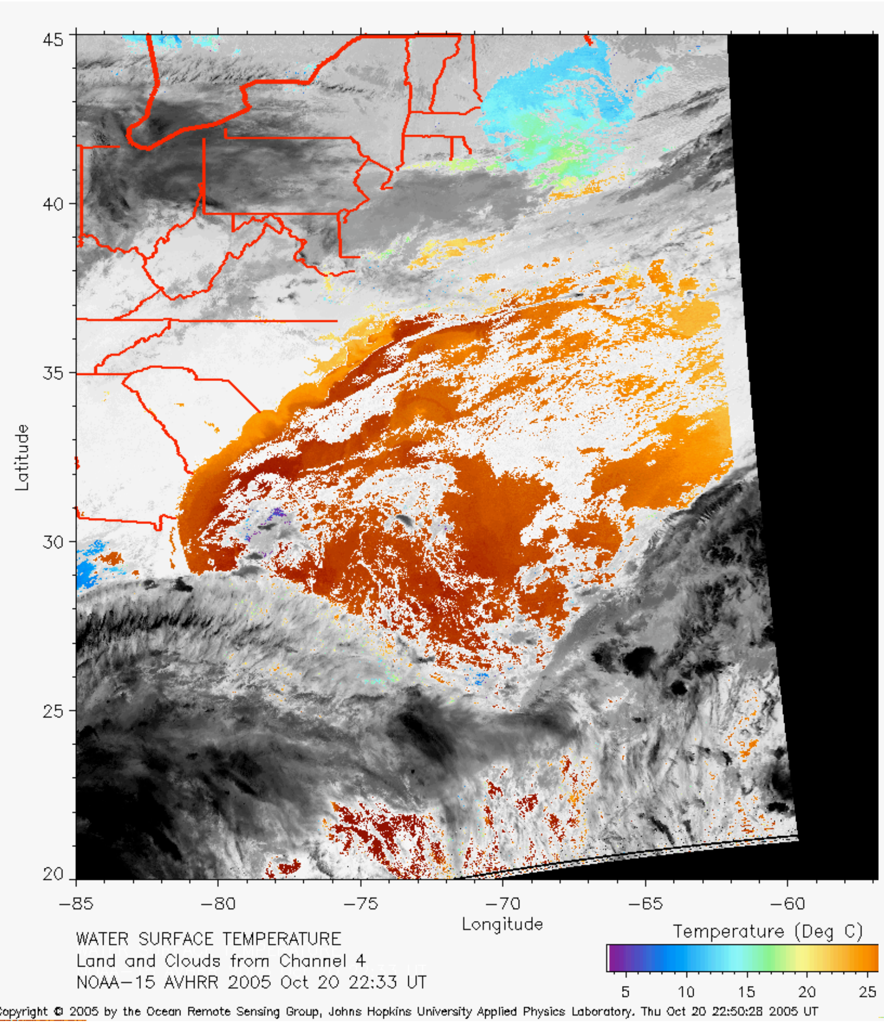
http://winds.jpl.nasa.gov/imagesAnim/quikscat.cfm

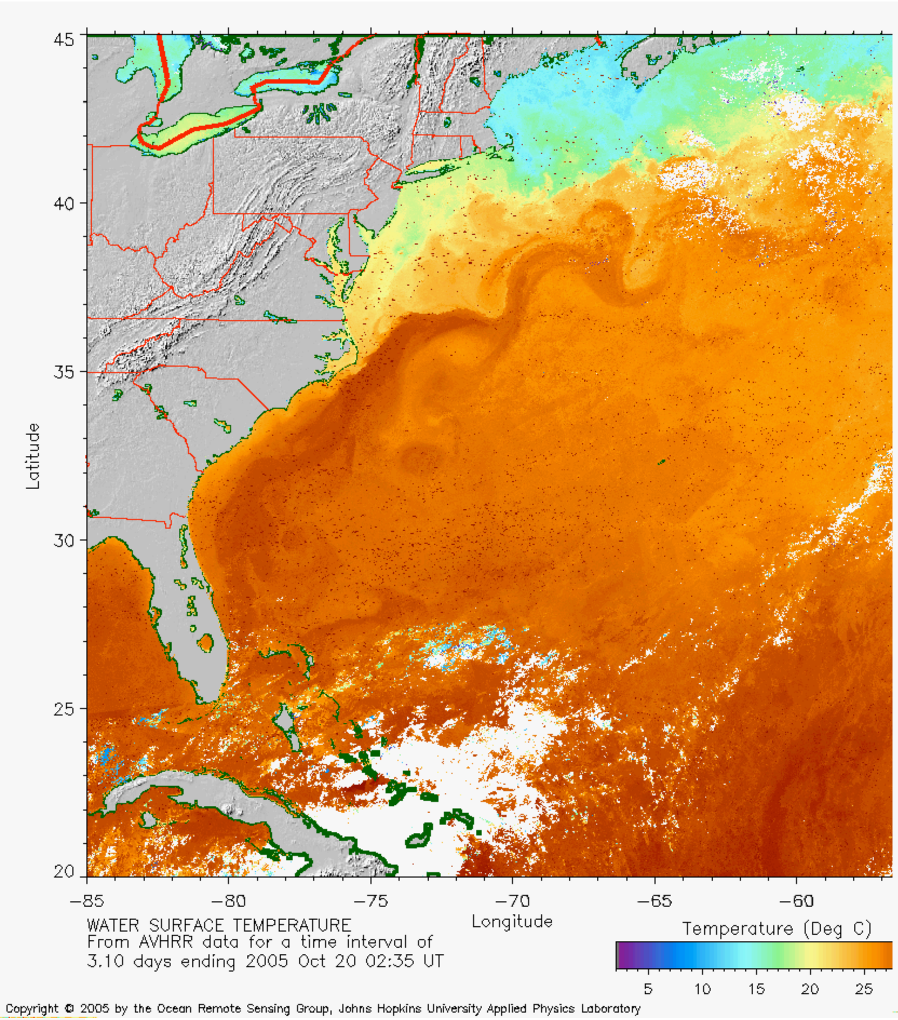
Sea Surface Temperature

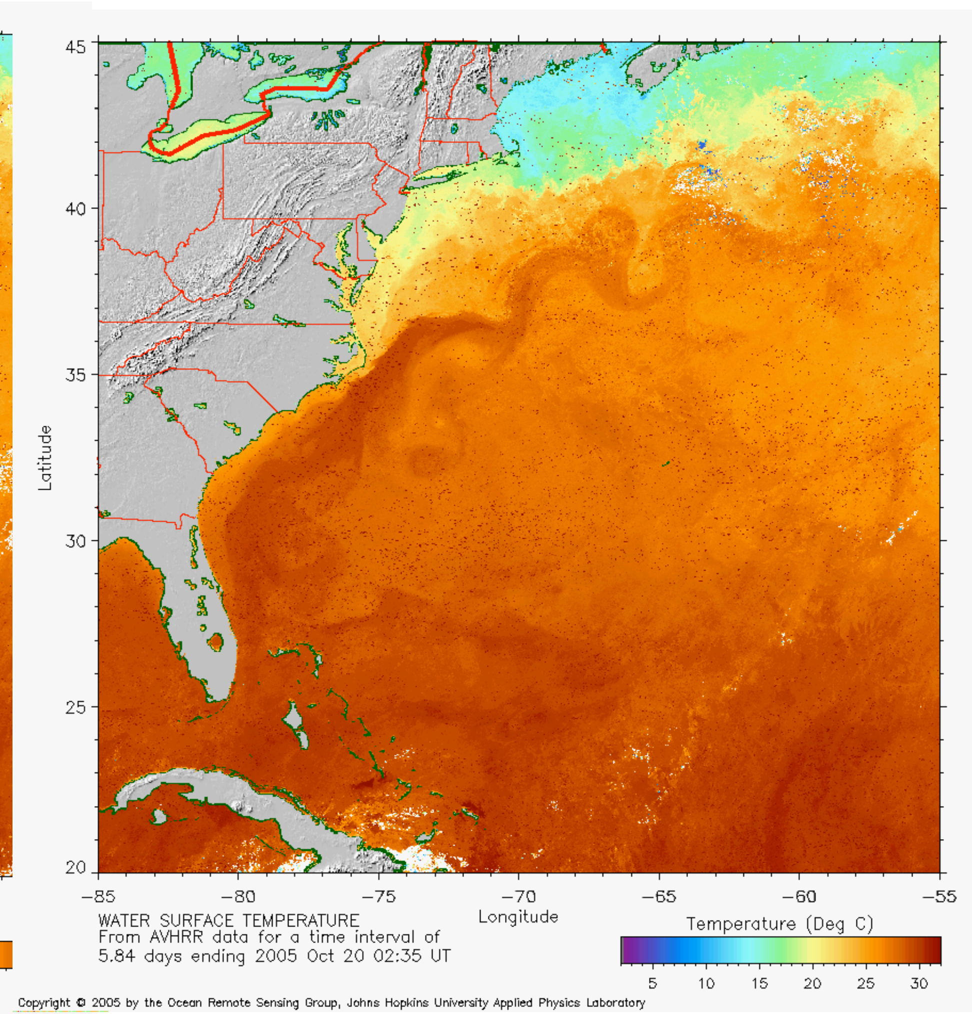
- A radiometer measures radiation over a finite wavelength window
- If emissivity of a body is known and the emitted radiance measured, the body's true surface temperature can be determined.
- Three problems:
  - clouds block some of the infrared radiation
  - atmosphere (*f*-dependent) absorbs radiation and emits some of its own
  - solar radiation reflected via surface to sensor
- Advanced High Resolution Radiometer on NOAA polar orbiter

http://fermi.jhuapl.edu/avhrr/primer/node1.html#SECTION00010000000000000000

Sea Surface Temperature



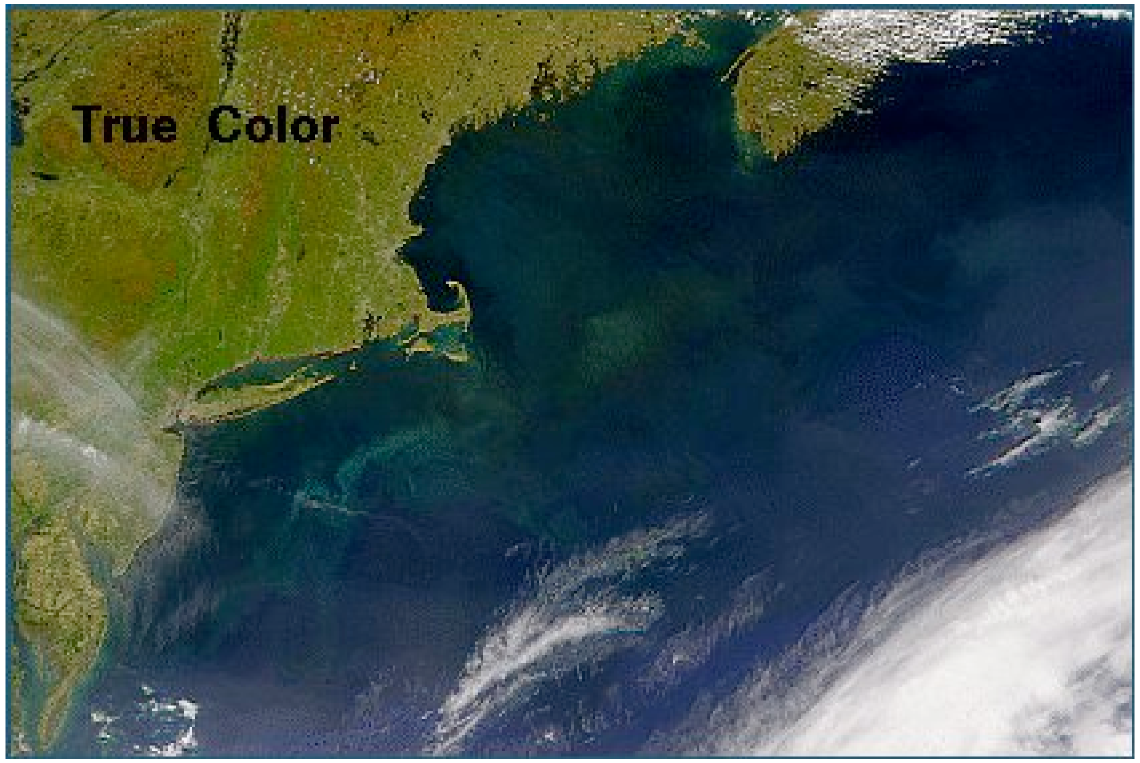


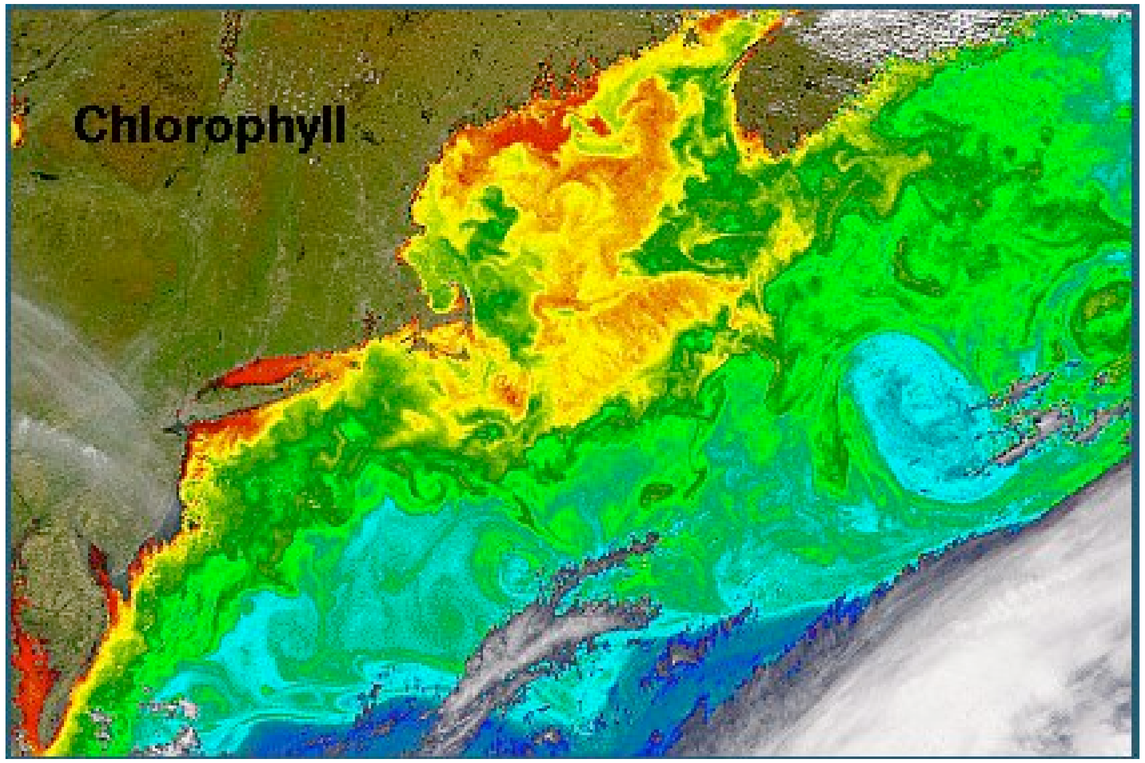


http://fermi.jhuapl.edu/avhrr/gs/05oct/index_thumb.html

Chlorophyll

- Sensors such as SeaWiFS can "see" the chlorophyll-bearing phytoplankton reflect predominantly green light back into space as opposed to the water itself which reflects predominantly blue wavelengths back to space.
- Sea-viewing Wide Field-of-view Sensor (SeaWiFS) uses an optical scanner looking at 8 different bands in the visible range

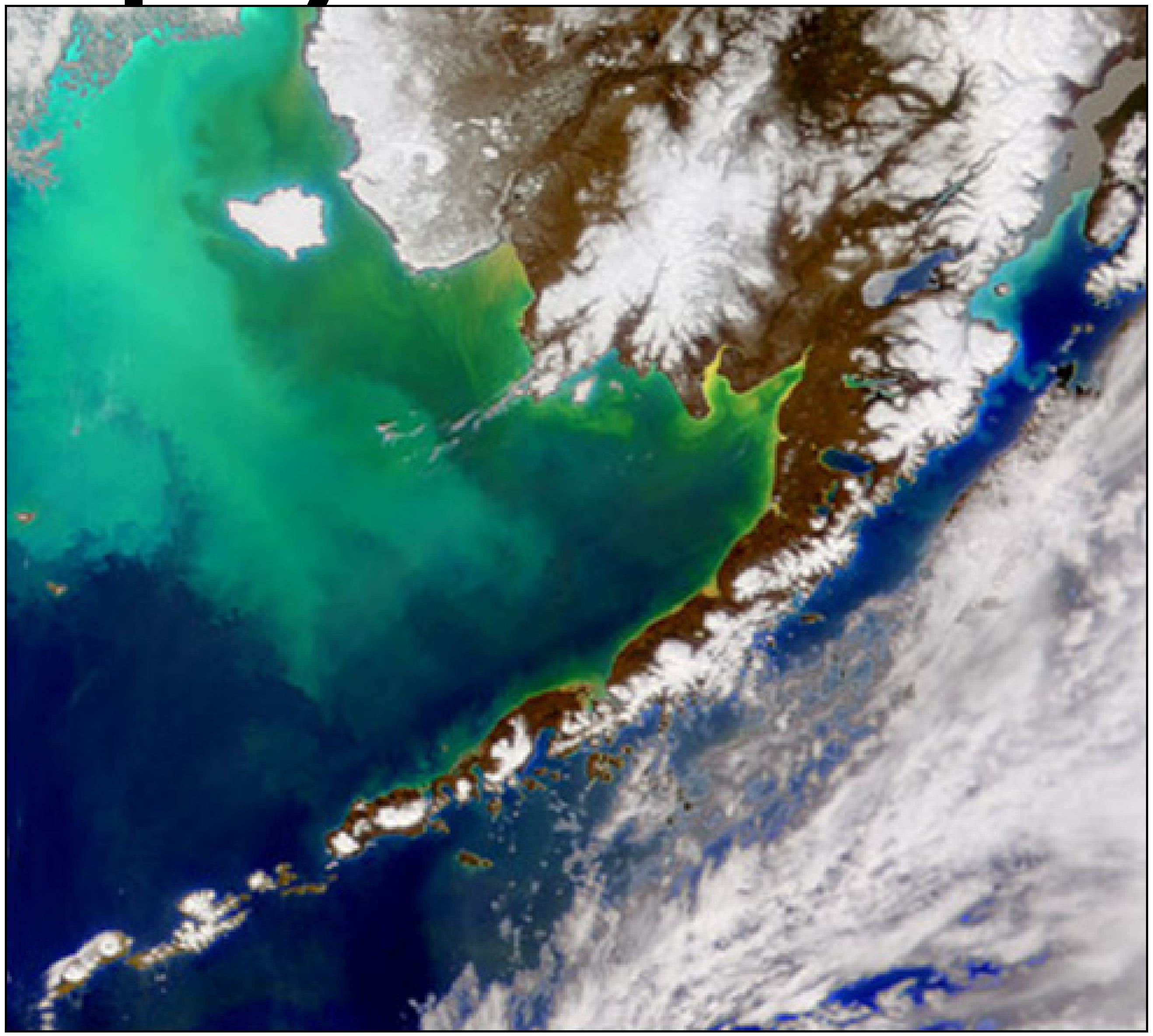




http://w3.mersea.eu.org/html/remote_sensing/oco_mission.html

Chlorophyll

Alaska and the Bering Sea observed by SeaWiFS on April 25, 1998. The bright aquamarine water is caused by the huge numbers of coccolithophores (type of phytoplankton)



Louisiana coast and the dynamic coastal region showing the suspended sediments, organic matter and phytoplankton.

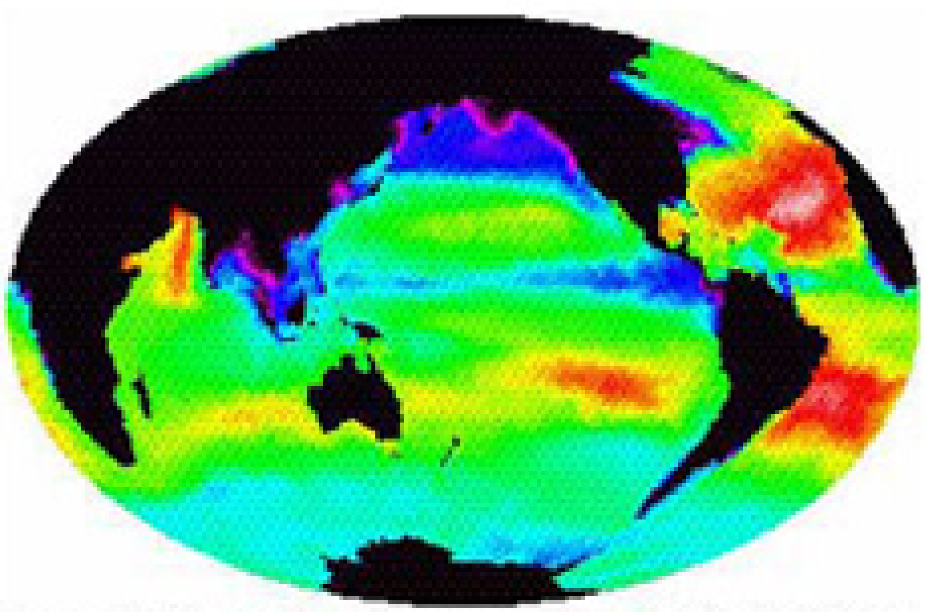
http://science.hq.nasa.gov/oceans/living/sensing.html

Sea Surface Salinity

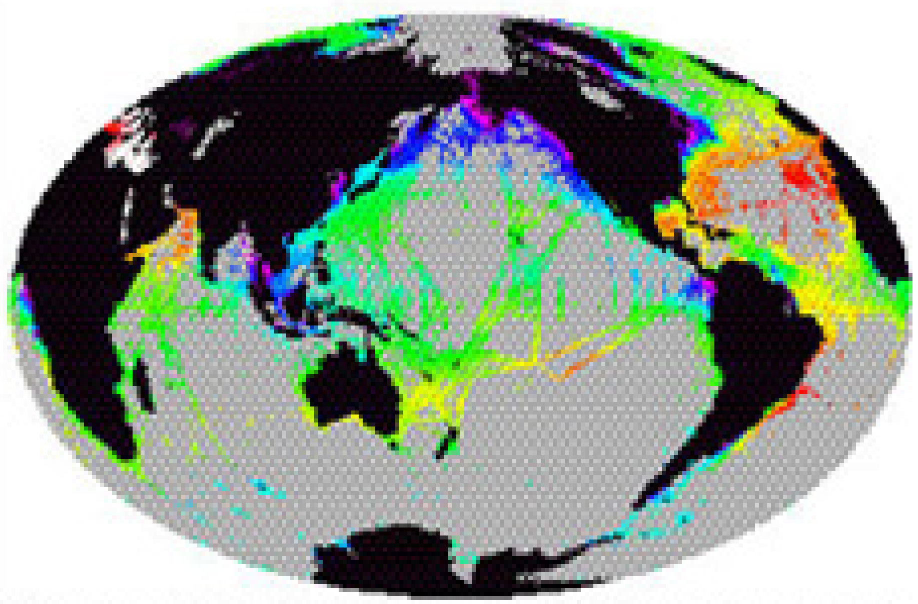
The SMOS mission (Soil Moisture and Sea Salinity) supported by ESA (European Space Agency) will be launched in early 2007 to provide the first satellite measurement of salinity at the oceanic surface. A novel instrument has been developed that is capable of observing both soil moisture and ocean salinity by capturing images of emitted microwave radiation around the frequency of 1.4 GHz (L-band). SMOS will carry the first-ever, polar-orbiting, space-borne, 2-D interferometric radiometer

Starting in 2009, Aquarius mission will measure global SSS with unprecedented resolution. The science instruments will include a set of three radiometers that are sensitive to salinity (1.413 GHz; L-band) and a scatterometer that corrects for the ocean's surface roughness.

The emissivity of the ocean's surface depends on the sea water conductivity (determined by its salinity and temperature) and the surface roughness (induced by waves and whitecaps).



Example 8 days of Aquarius Sea Surface Salinity (SSS) data

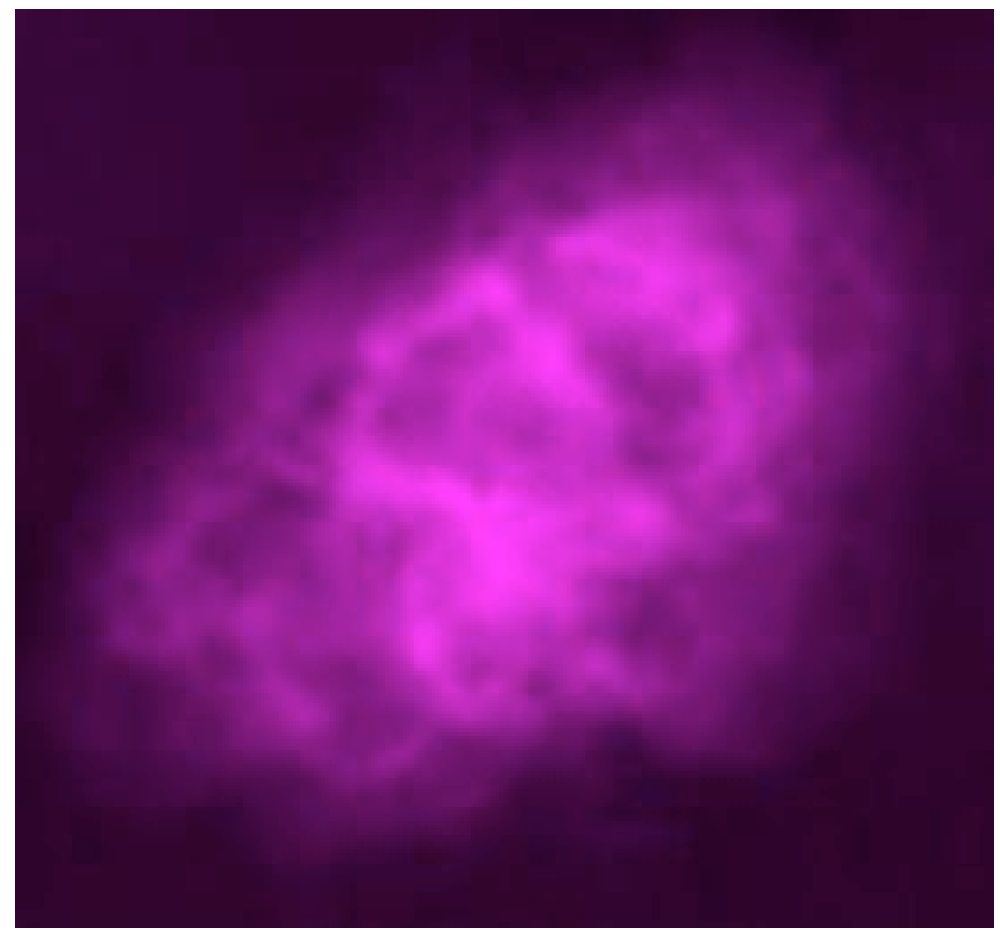


100 years of Sea Surface Salinity (SSS) measurements

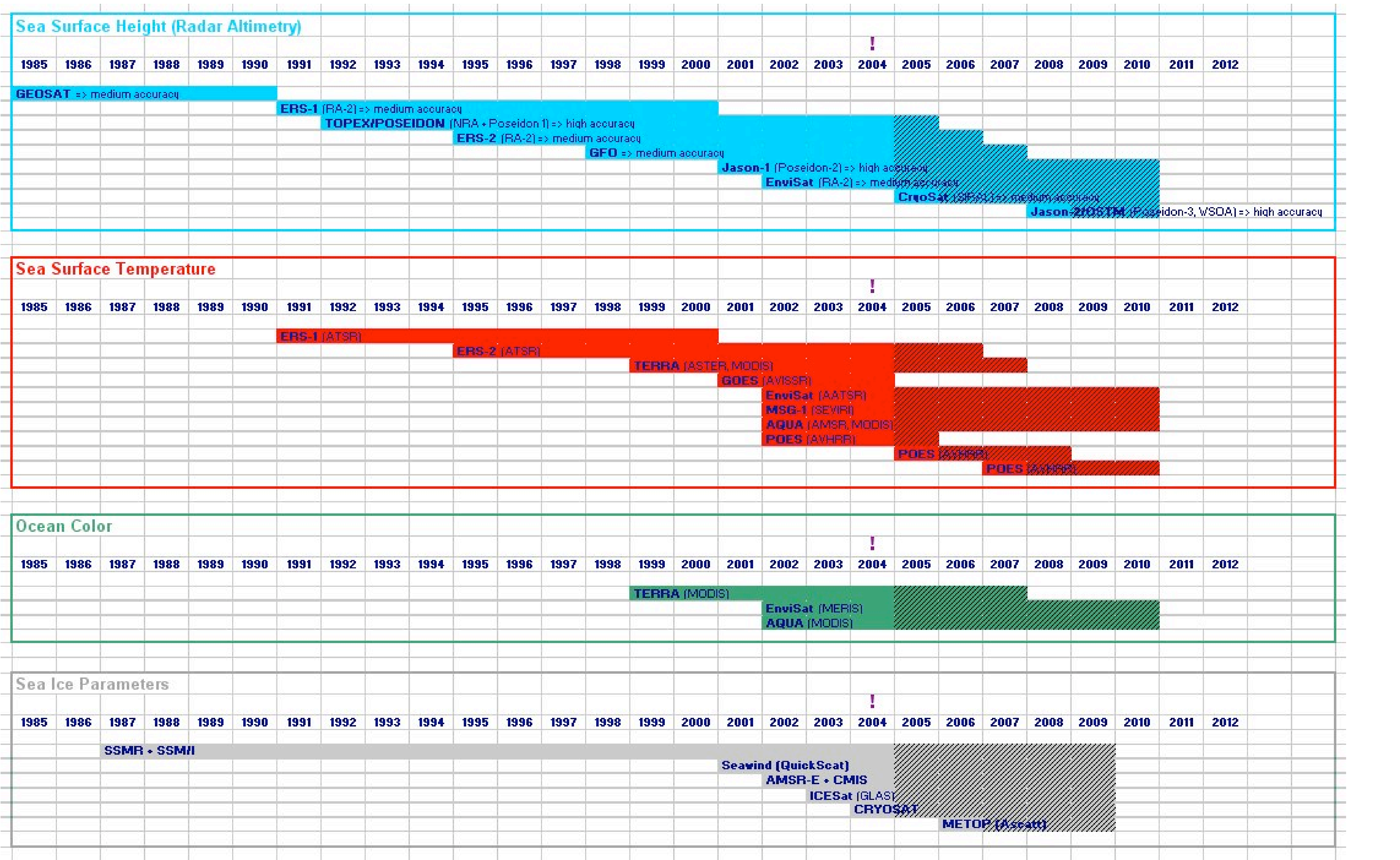
Error sources

- positioning (where is the sat)
- orientation (how is the sat pointed)
- instrument bias (calibration)
- noise (internal/external)
- viewing conditions (atmospheric errors)
- timing (aliasing)
- interpretation (models/processing)



http://rst.gsfc.nasa.gov/Intro/Part2_4.html



http://w3.mersea.eu.org/html/remote_sensing/alt_mission.html

Questions

?

Resources

- Remote Sensing Tutorial: http://rst.gsfc.nasa.gov/Front/tofc.html
- Altimetry: http://www.ngdc.noaa.gov/mgg/bathymetry/predicted/explore.HTML#sat_alt
- http://aquarius.gsfc.nasa.gov/techops.html
- http://oceancolor.gsfc.nasa.gov/SeaWiFS/
- http://oceancolor.gsfc.nasa.gov/SeaWiFS/TEACHERS/
- http://podaac-www.jpl.nasa.gov/catalog/
- http://topex.ucsd.edu/marine_topo/mar_topo.html
- http://www.jason.oceanobs.com
- http://www.esa.int/esaLP/ESAMBA2VMOC_LPsmos_0.html