Satellite Oceanography and Applications 3

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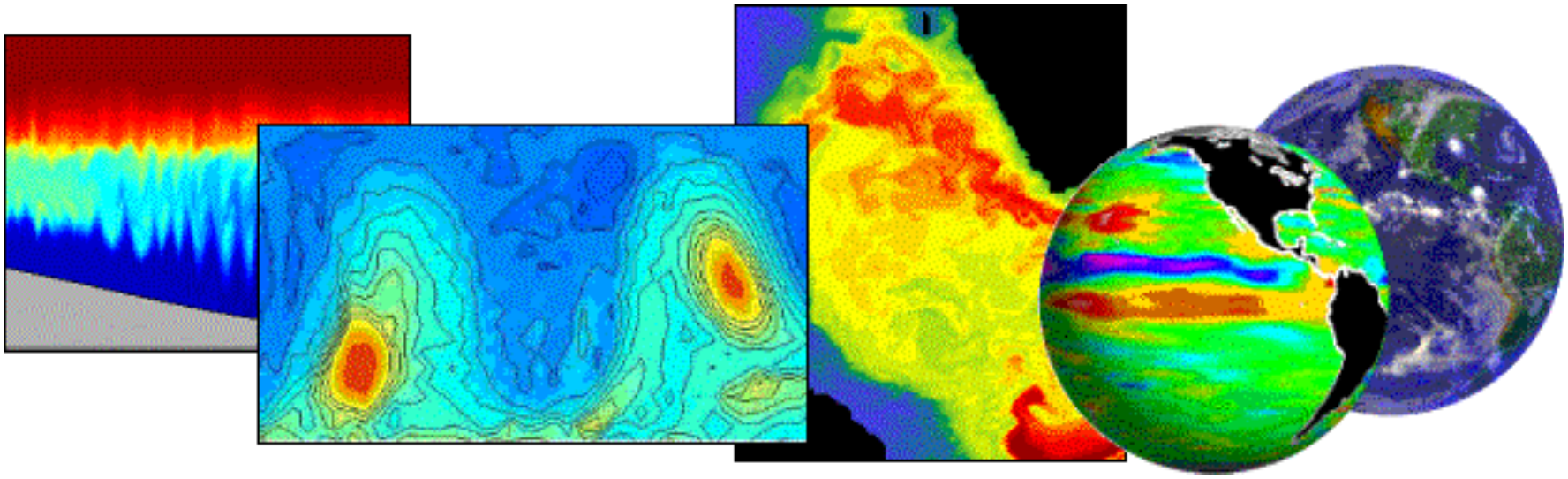
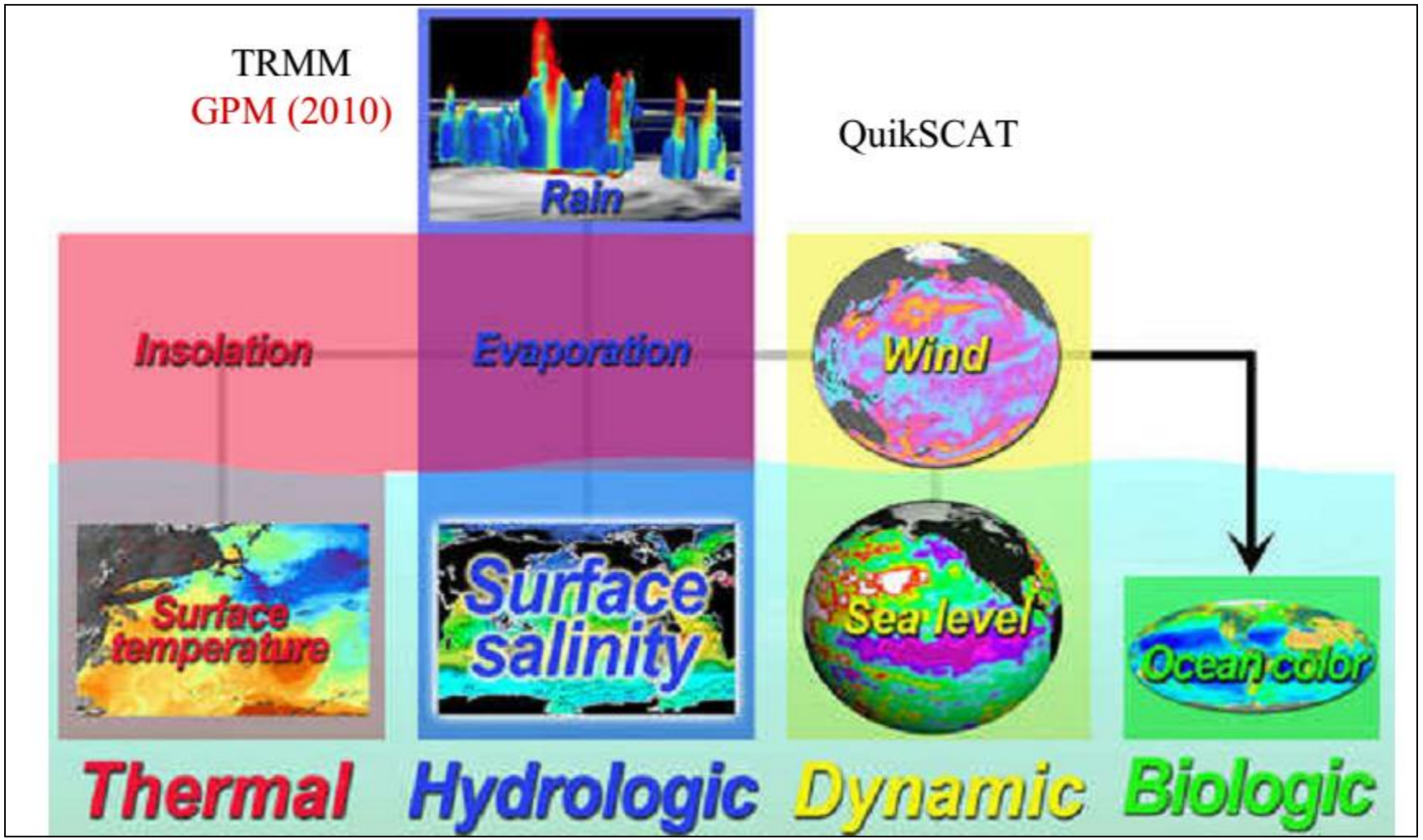


RMU Summer Program (AUGUST 24-28, 2015)

Global Ocean Observing Systems from Space



AVHRR TMI, AMSR GOES	Aquarius (2009)	TOPEX/Poseidon Jason OSTM (2008)	SeaWiFS MODIS

RECAP: Satellite data sources

- **Radiometers:** sea surface temperature

  -- Envisat (AATSR) -- NOAA (AVHRR)

- **Spectral sensors:** ocean color and water quality

  -- Envisat (MERIS) -- Aqua (MODIS)

  -- Proba (CHRIS) -- Quickbird

- **Altimeters:** SSH, SWH, surface wind speed, ocean currents

  -- Envisat -- Jason-1 -- Jason-2

  -- GFO -- ERS-2

RECAP: Satellite data sources

- **Scatterometers:** surface wind speed and direction.

  -- QuikSCAT -- ASCAT -- ERS-2

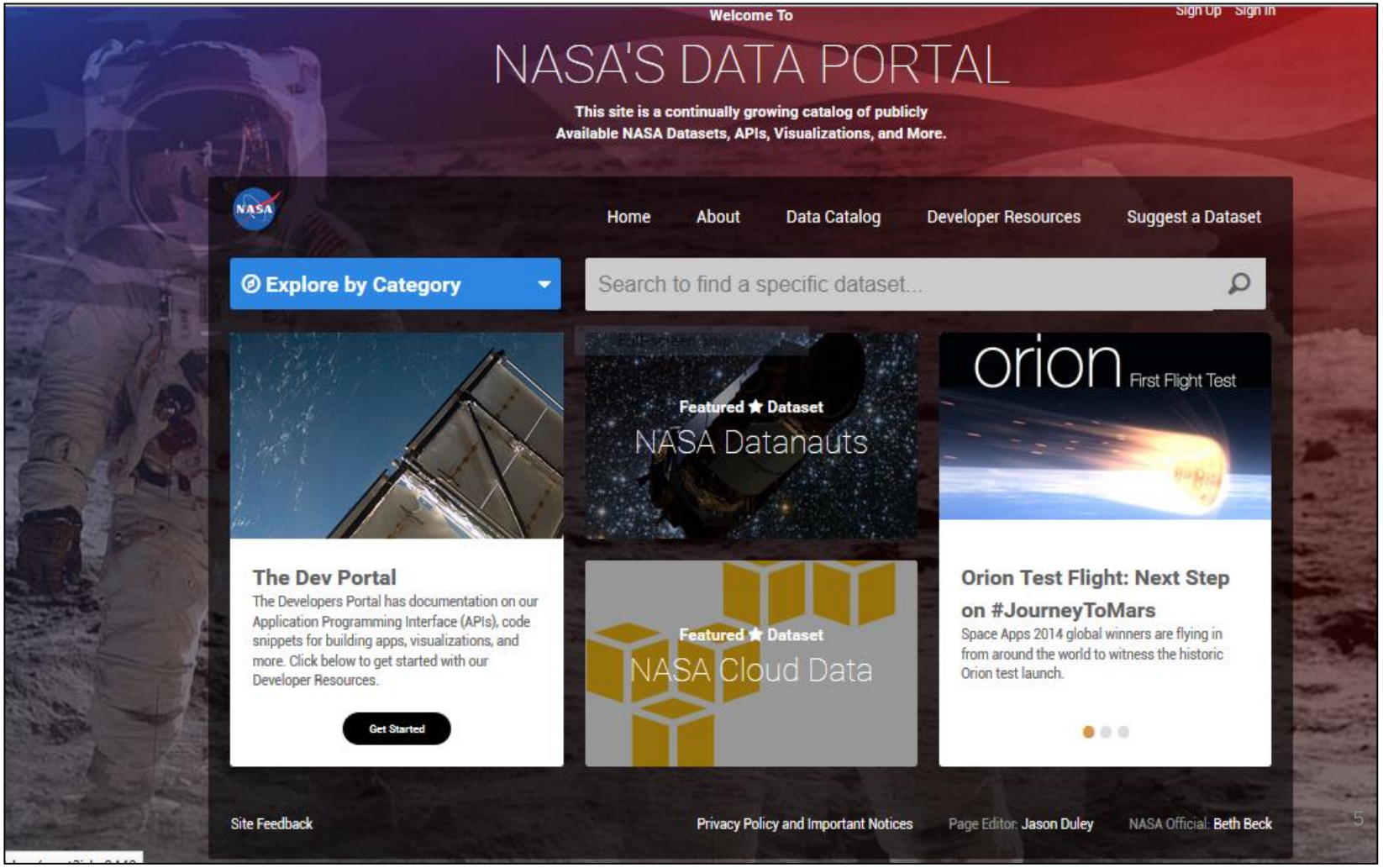
- **Synthetic Aperture Radars** (SAR): for radar imagery that gives surface features including information on winds, waves, currents, oil slicks and ship detection.

  -- Envisat (ASAR) -- Radarsat -- TerraSAR-X

Data Sources

- ✓ National institutions that manage satellite data

--- National Aeronautics and Space Administration (NASA)



Data Sources

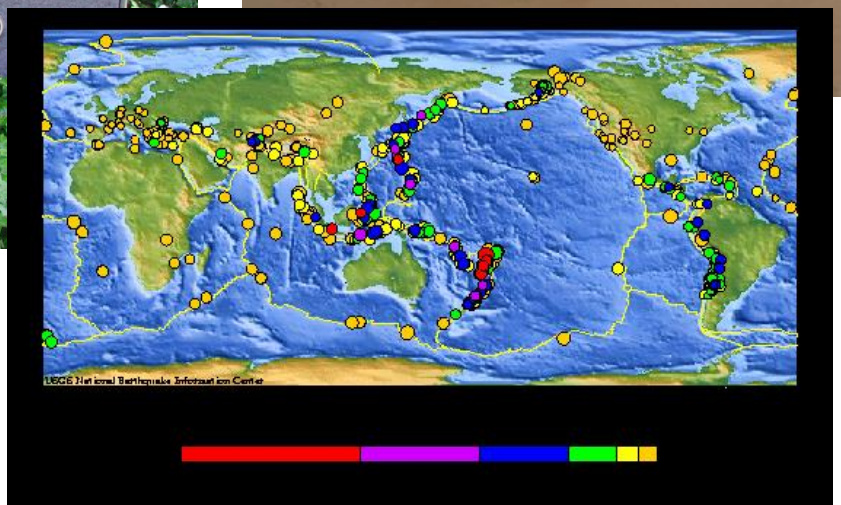
- ✓ National institutions that manage satellite data

--- National Oceanic and Atmospheric Administration (NOAA)

Data Sources

- ✓ National institutions that manage satellite data

--- US Geological Survey (USGS)



Data Sources

- ✓ National institutions that manage satellite data

--- European Space Agency (ESA)

Data Sources

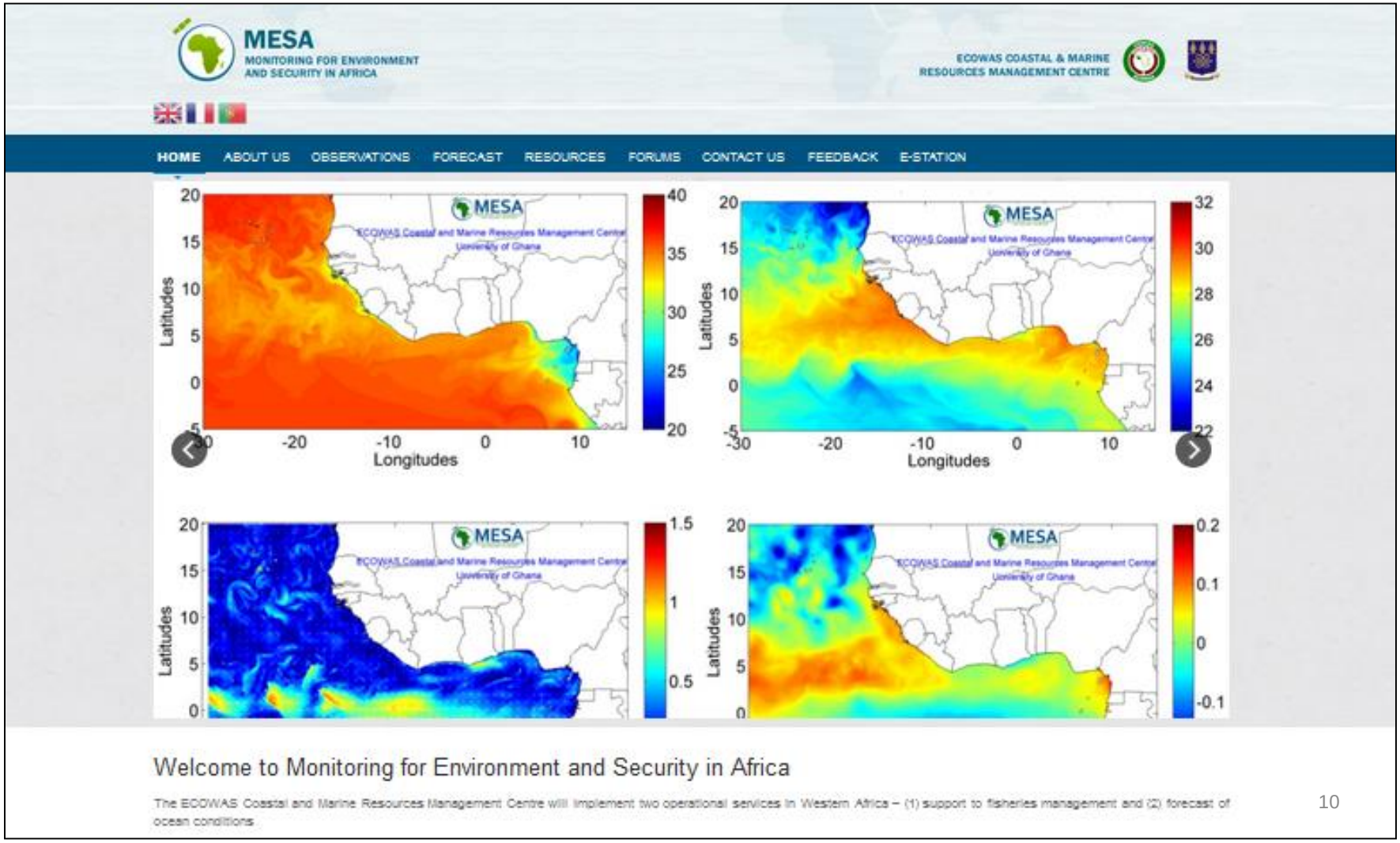
- ✓ National institutions that manage satellite data

--- South African Space Agency (SANSA)

Data Sources

- ✓ National institutions that manage satellite data

--- Monitoring for Environment and Security for Africa (MESA)



Data Sources

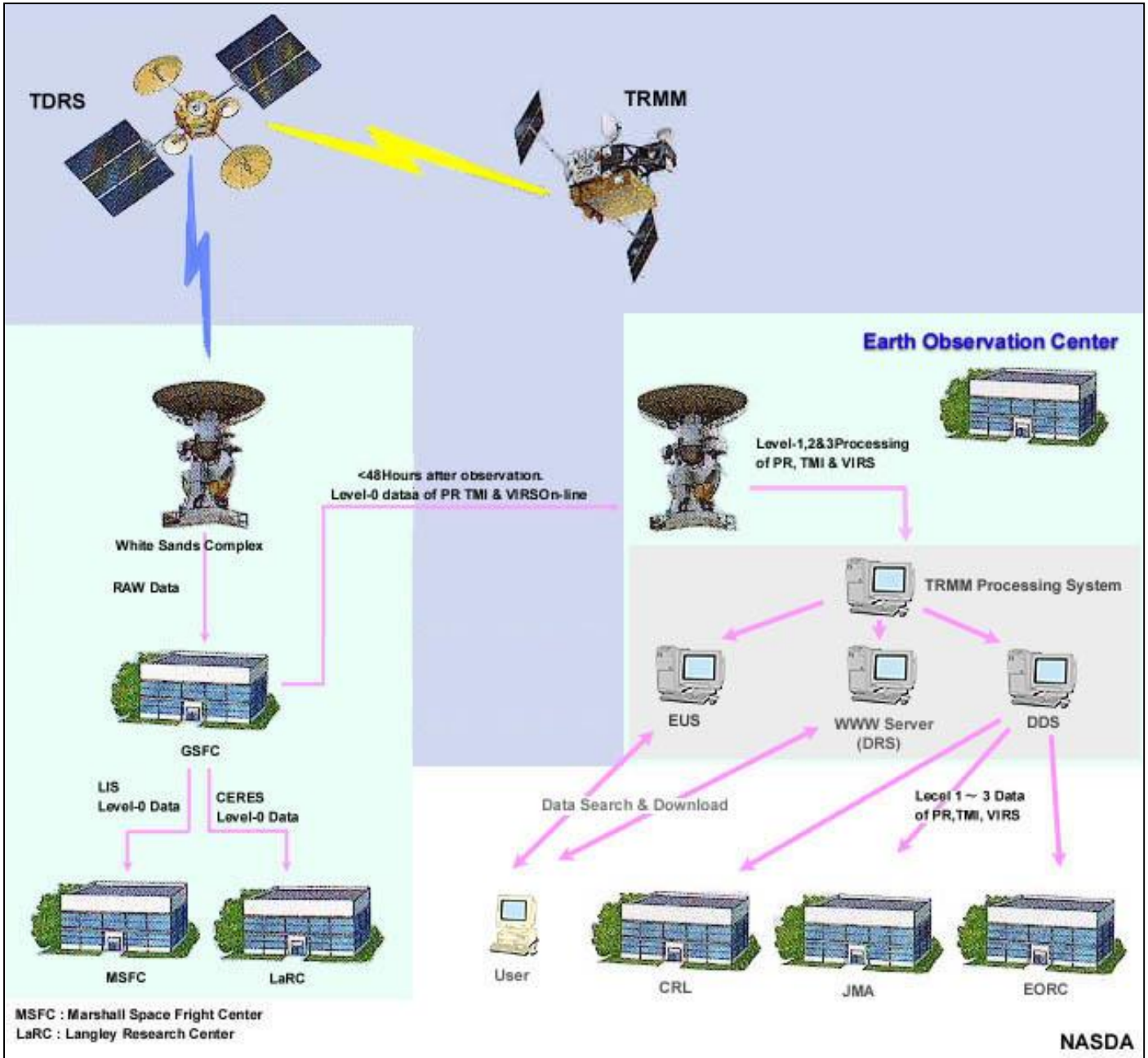
- ✓ National institutions that manage satellite data

--- Universities and Labs

http://apdrc.soest.hawaii.edu/data/data.php

NOAA PMEL

Satellite Data Processing



Data Transmission

The information measured by a sensor is

- converted into digital format,
- stored on magnetic media, and
- transmitted to the ground receiving stations.

HRPT (High Resolution Picture Transmission) format enables transmission of raw information to the receiving stations located on the Earth's surface.

Each station includes receiving antenna and computer for processing and storage of information.

HRPT format is used in IR sensors AVHRR (Advanced Very High Resolution Radiometer) and optical scanners (e.g., SeaWiFS/ MODIS).

Satellite Data Storage

The storage capacity of magnetic media on board the satellite is crucial if a long time period is passed between the measurements and the transmission of obtained information to Earth.

For example, in the case of SeaWiFS (launched in 1997) the satellite continuously transmits information in HRPT format to ground stations located along its orbit.

The capacity of its "memory" is insufficient to store all the data collected during one day. That is why only 16-th part of information (each 4-th pixel in each 4-th row) is stored, transmitted to GSFC, processed there and disseminated to users.

In more recently launched satellites (e.g., MODIS-Terra and MODIS- Aqua) the onboard storage capacity is much better.

Satellite Data Processing

Levels of data processing:

Level 0 – Raw data received from satellite, in standard binary form;

Level 1 – Image data in sensor coordinates, contain individual calibrated channels;

Level 2 – Derived oceanic variable, atmospherically corrected and geolocated, but presented in sensor coordinates;

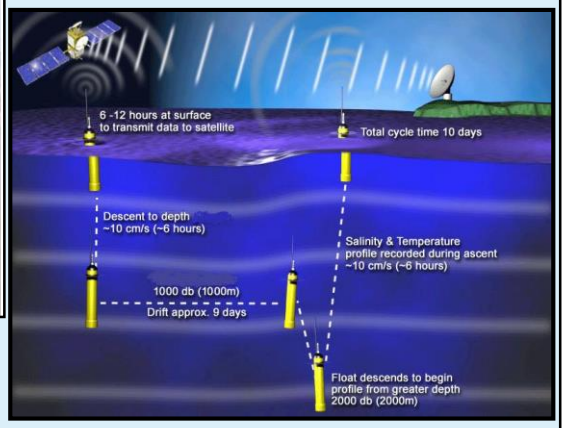
Level 3 – Composite images of derived ocean variable resampled onto standard map base and averaged over a certain time period (may contain gaps);

Level 4 – Image representing an ocean variable averaged within each grid cell as a result of data analysis, e.g., modeling.

Remote sensing of the sea: Data usage

1. Sensor calibration

2. Atmospheric correction



3. Positional registration

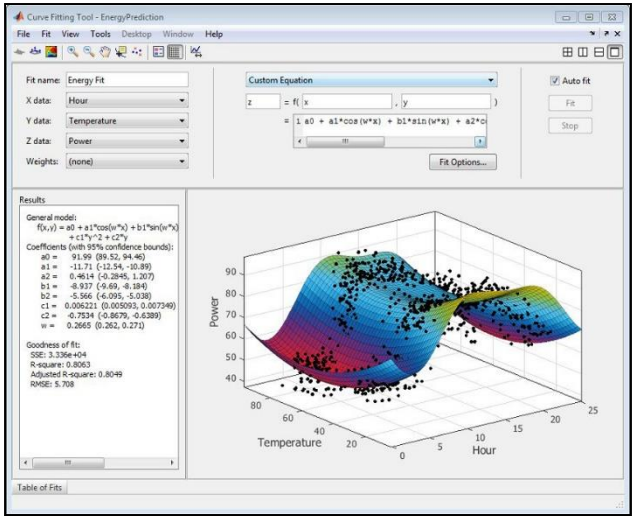
4. Oceanographic sampling for "sea truth"

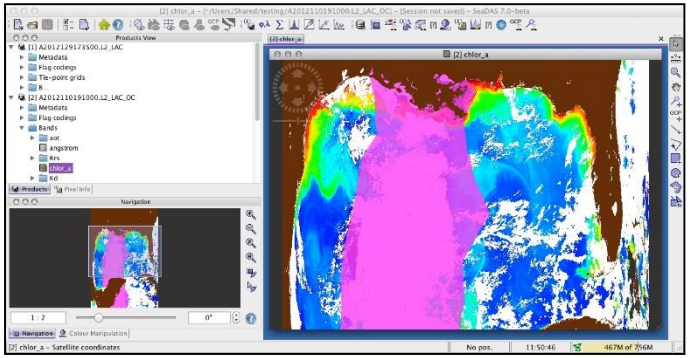
5. Image processing

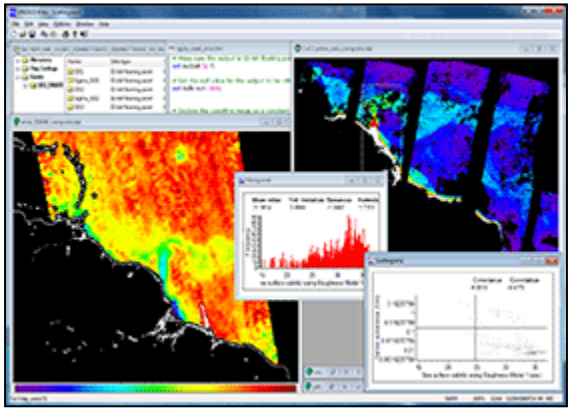
6. Oceanographic applications of satellite Remote sensing

Satellite Data Processing

- ✓ Computer programing software: Matlab, Python, Ocean Data View, ArcGIS
- ✓ Specialized data software:
  - -- NASA's SeaDAS: ocean color
  - -- ESA's BEAM – ocean color, SAR, etc
  - -- UNESCO's Bilko - ocean color, SMOS







Data dissemination

The method of data dissemination depends the purpose (commercial or research) they will be used.

In the first case (commercial use) the data are transmitted directly to ships and coastal receiving stations and then processed and analyzed there.

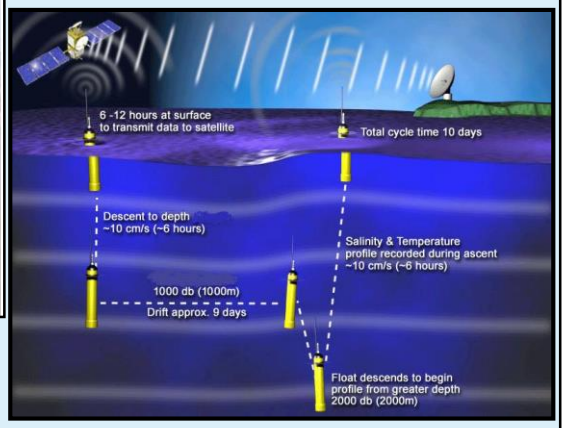
In the second case (scientific use) the data are processed in the large scientific centers of and disseminated via Internet.

The processing requires sophisticated procedures of atmospheric correction, calibration and interpolation.

Remote sensing of the sea: Data usage

1. Sensor calibration

2. Atmospheric correction



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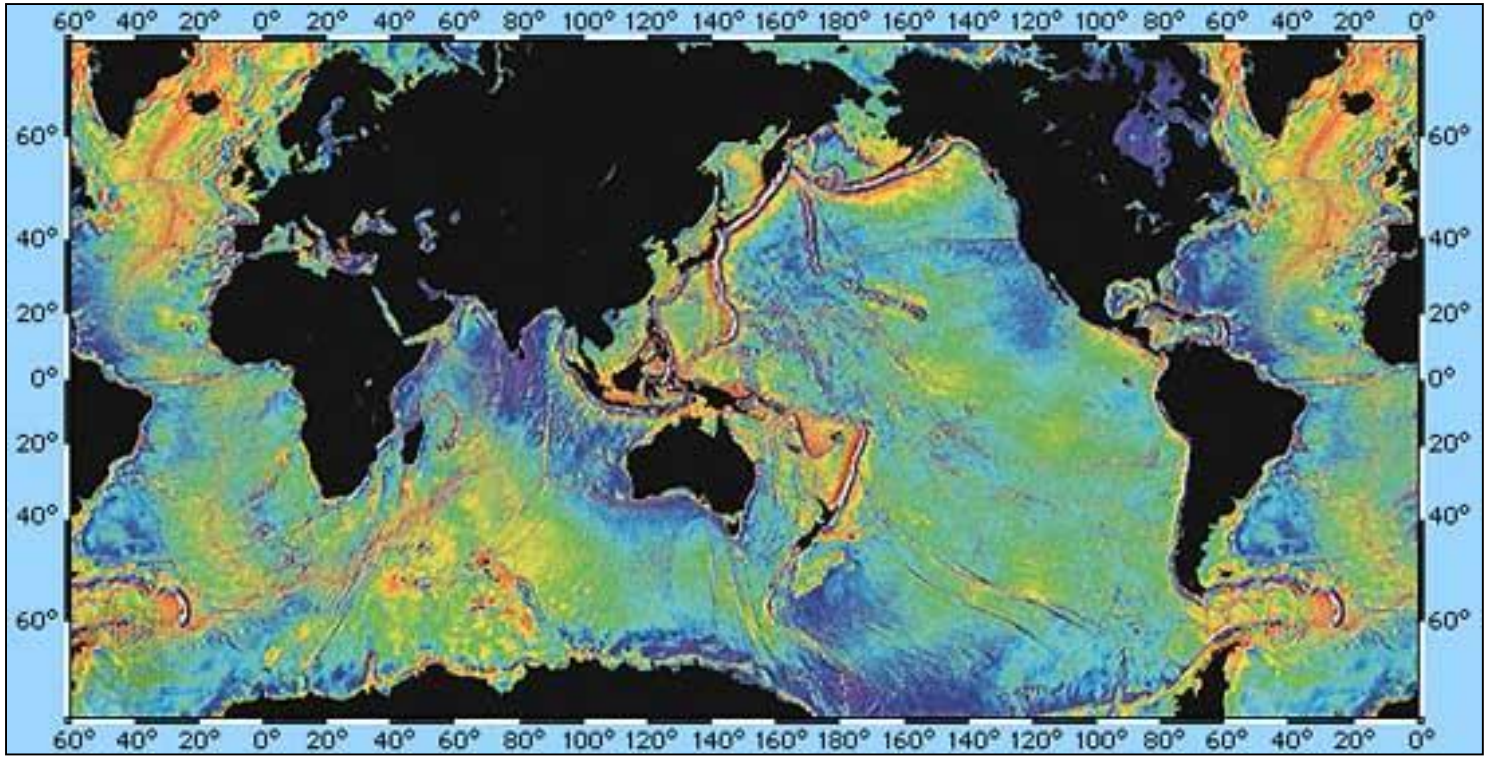
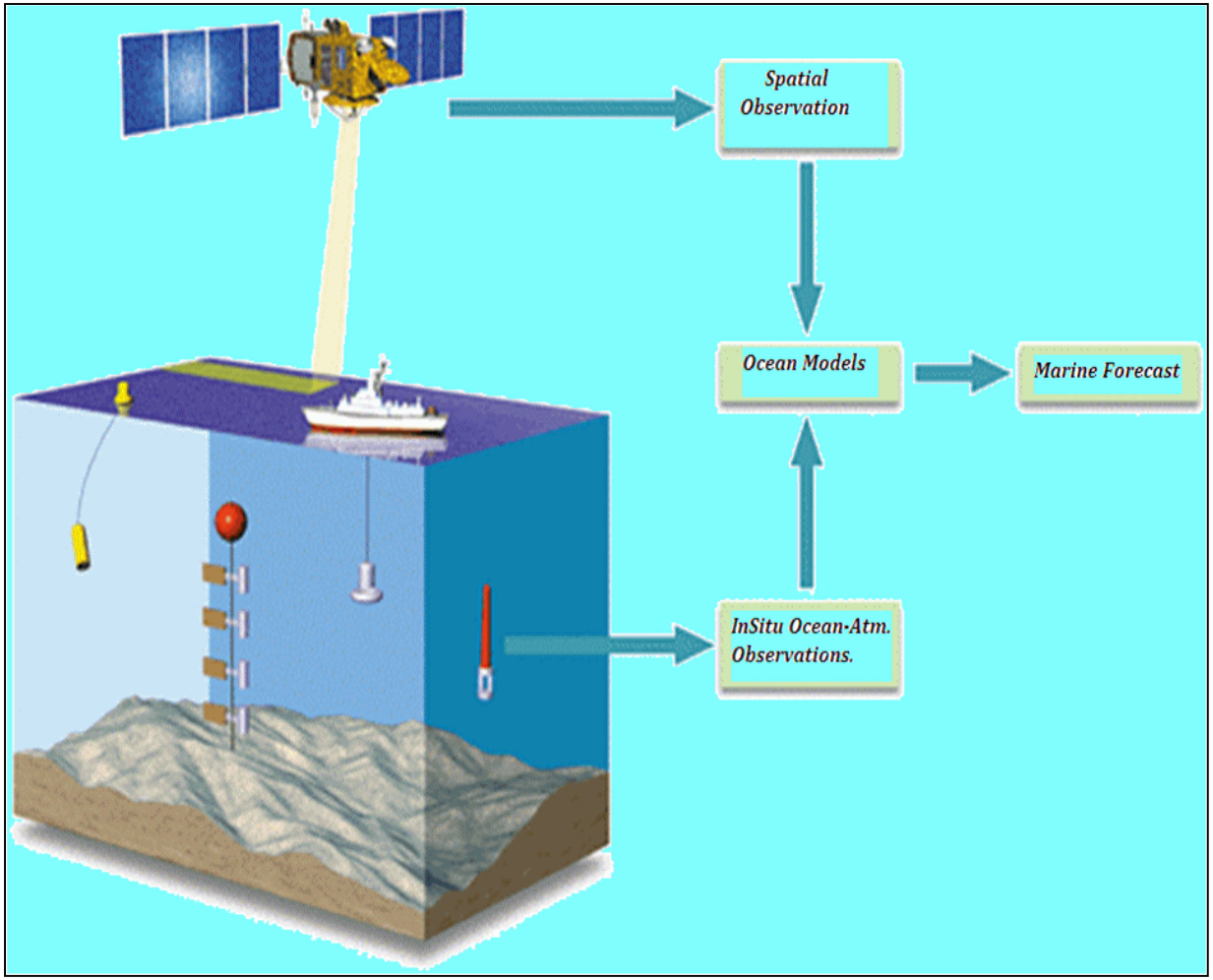
Application: Bathymetry and Navigation



- gravity map of ocean surface, computed from *radar-altimetry* and *GRACE* measurements.
- ocean surface is deformed by the varying gravitational attraction of the underlying marine topography
- such maps sensitively mirror seafloor features and have been valuable in finding previously uncharted seamounts, ridges, and fracture zones.

Application: Marine Meteorology



Marine weather info needed for

- Vessel navigation
- Fishing
- Coastal protection
- Oil and gas industry
- Tourism
- Military operations
- Aviation industry

Maps of ocean currents, eddies, and winds are used in commercial shipping to optimize routes.

Marine Meteorology: ingredients

- State of the Sea: wave height
  - Slight: Wave Height of 0.6 – 1.0 m ……. (≈ 1.8 – 3.0 ft)
  - Slight-Moderate: Wave Height of 1.0 – 1.9 m .(≈ 3.0 – 5.7 ft)
  - Moderate: Wave Height of 2.0 – 2.9 m …….. (≈ 6.0 – 8.7 ft)
  - Rough: Wave Height of 3.0 – 4.0 m …….. (≈ 9.0 – 12.0 ft)
  - Very Rough: Wave Height of 4.1 – 5.5 m …..(≈ 12.3 – 16.5 ft)

- Wind Speed:
  - Light Breeze: Wind speed of 1.5 – 3.3 m/s
  - Gentle Breeze: Wind speed of 3.4 – 5.4 m/s
  - Moderate Breeze: Wind speed of 5.5 – 7.9 m/s
  - Fresh Breeze: Wind speed of 8.0 – 10.7 m/s

- Visibility
  - Poor: Between 1,000 - 4,000 m
  - Moderate: Between 4,000 – 9,000 m
  - Good: More than 9,000 m

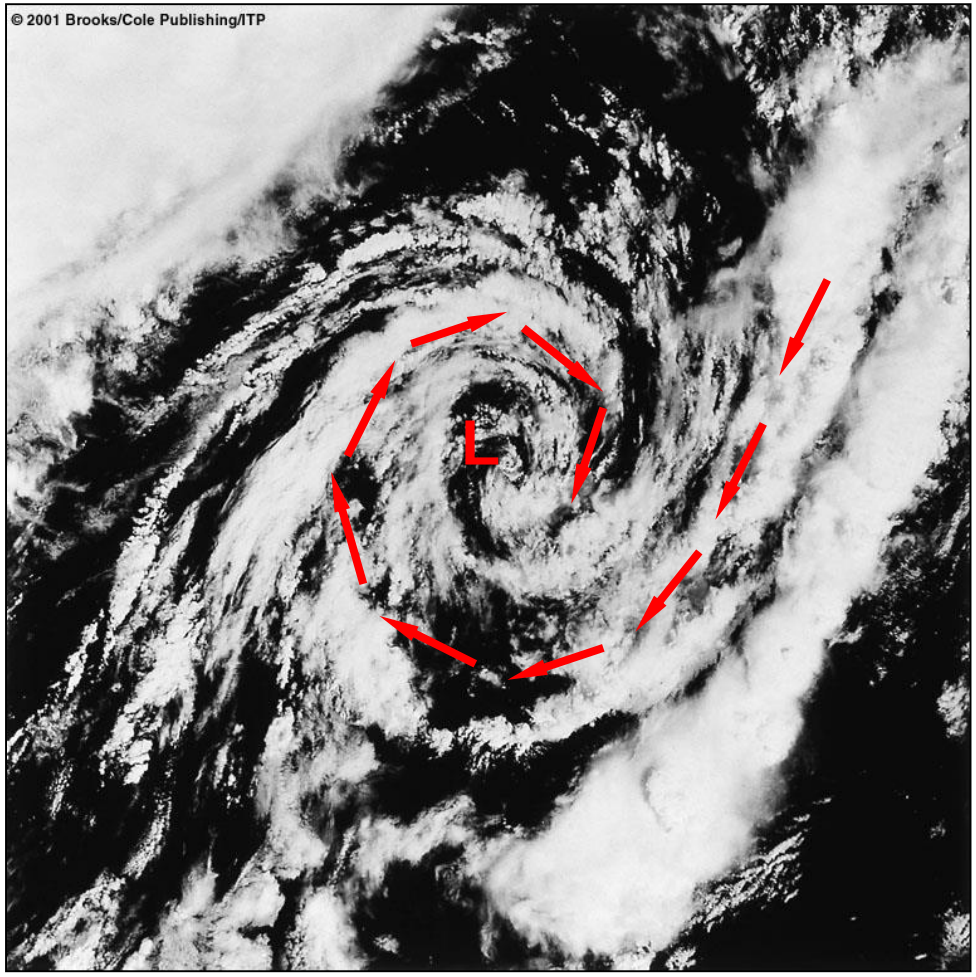
Marine Meteorology: ingredients

Salinity and currents forecast:

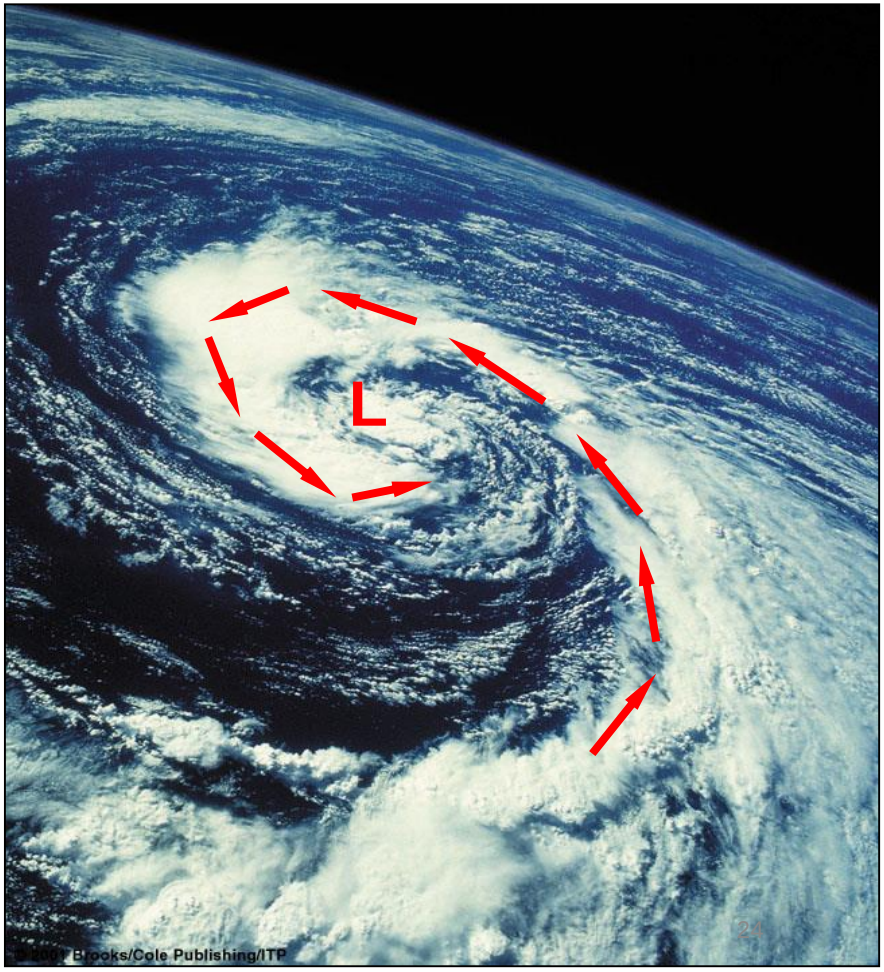
- The salinity and currents over the coastal ocean can be used as a proxy for wind strengths
- Strong winds imply high evaporation of fresh water leaving behind more saline waters
- Strong winds drag the water over the ocean surface to force the coastal currents
- This information is used to validate model products of wind and significant wave heights

Cyclonic Flow: (flow around a low pressure center)

Clockwise in SH

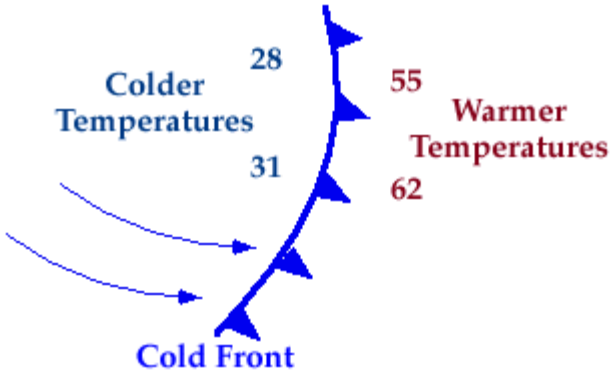


Counterclockwise in NH

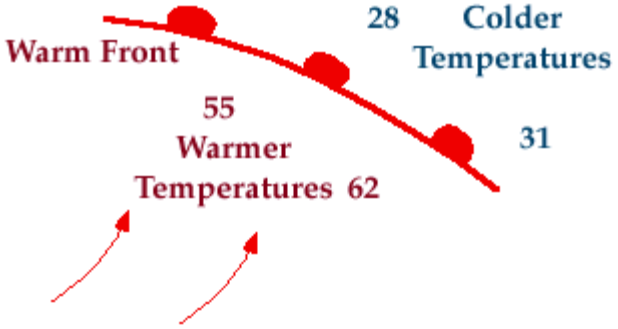


Fronts: air masses

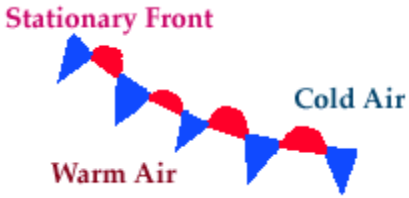
- **Cold front**: cold, dry stable air is replacing warm, moist unstable air.



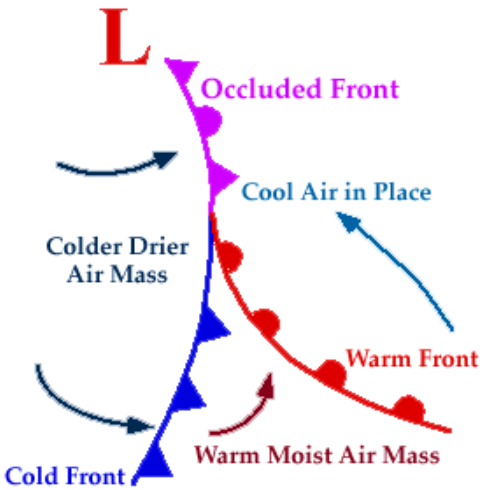
- **Warm front**: warm, moist unstable air is replacing cold dry stable air.



- **Stationary front**: boundary between the two air masses is not moving.

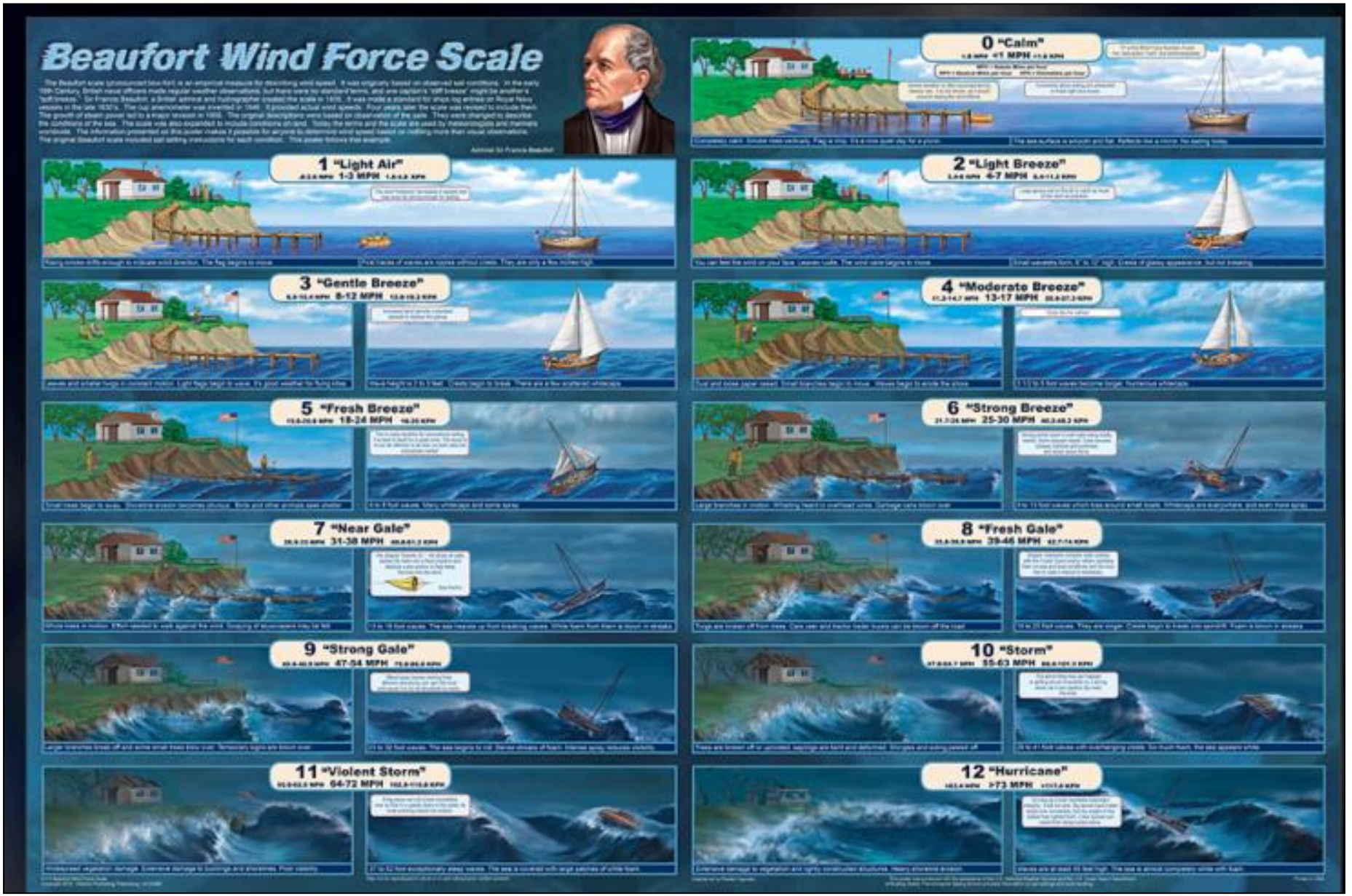


- **Occluded front**: when a cold front catches up with a warm front

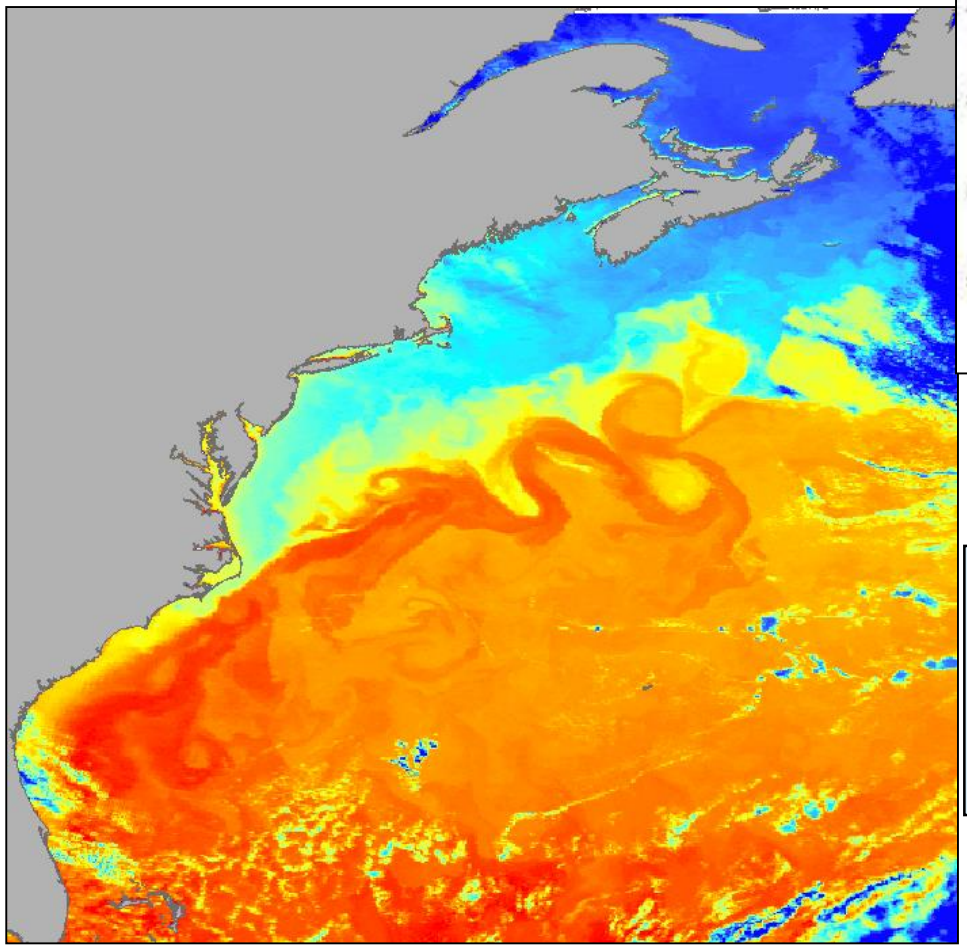


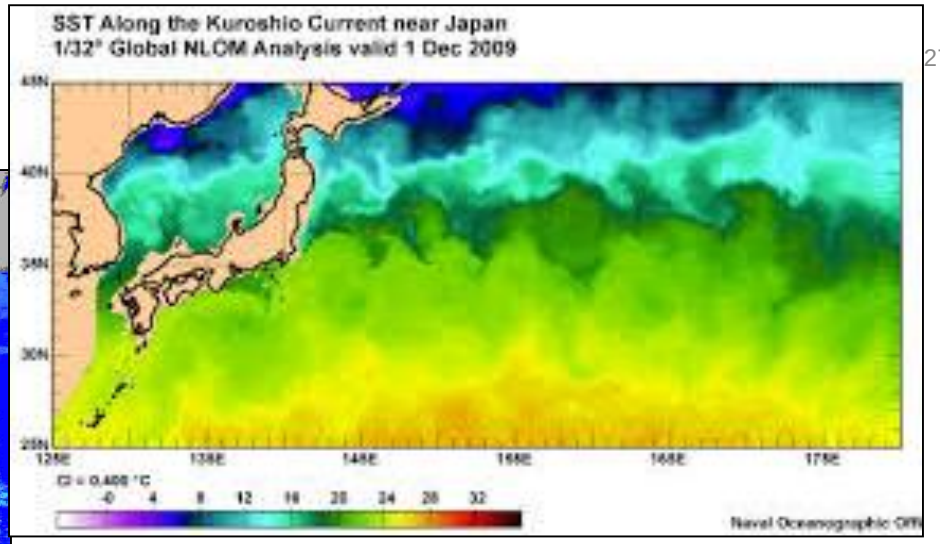
- The **symbols** on a map are in the direction of the air mass motion.

Marine Meteorology: ingredients



Fronts: water masses





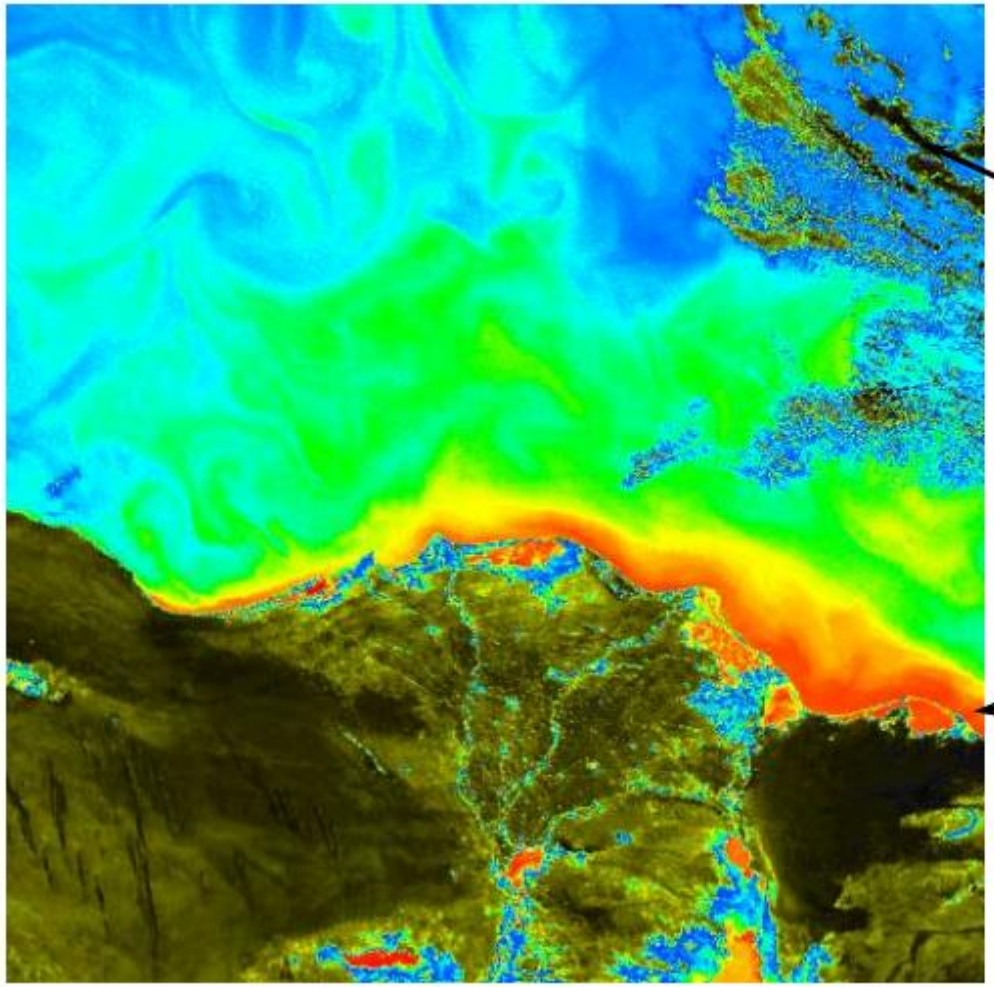
SST fronts provide information on a variety of processes in the ocean:

--- Enhanced gradients of:

- temperature
- density

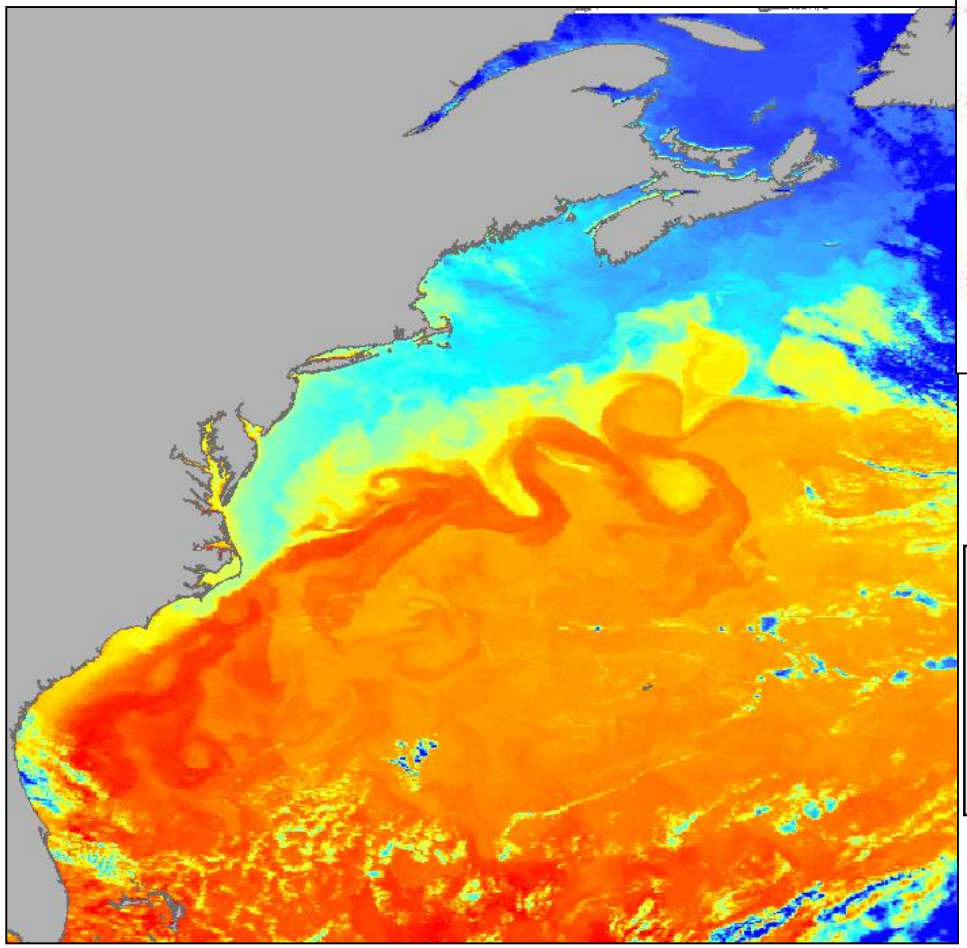
- affects air-sea interaction
- heat and salt transport
- ecosystem functioning

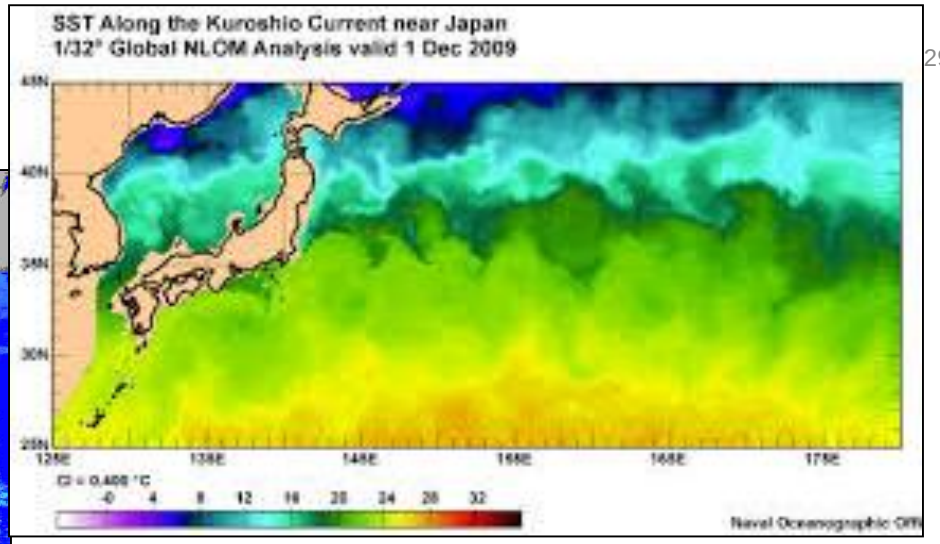
Application: ATSR image of the Nile Delta



The Nile Delta, Egypt, and the Mediterranean Sea on 9th May 1992

Fronts: water masses





SST fronts provide information on a variety of processes in the ocean:

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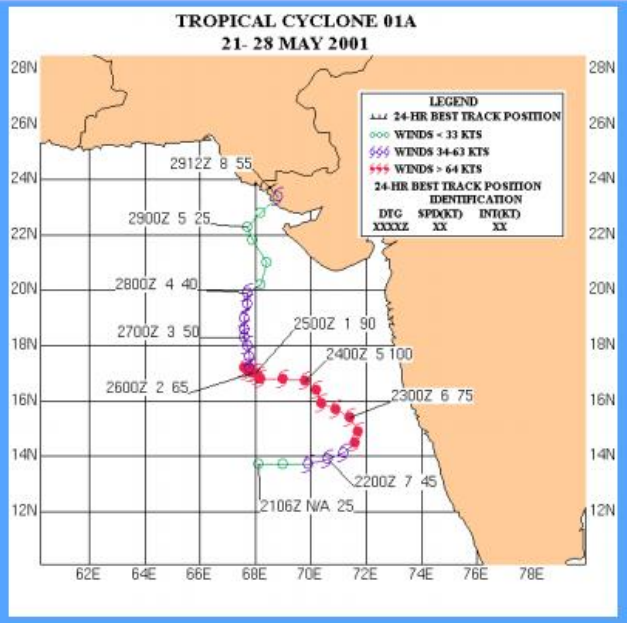
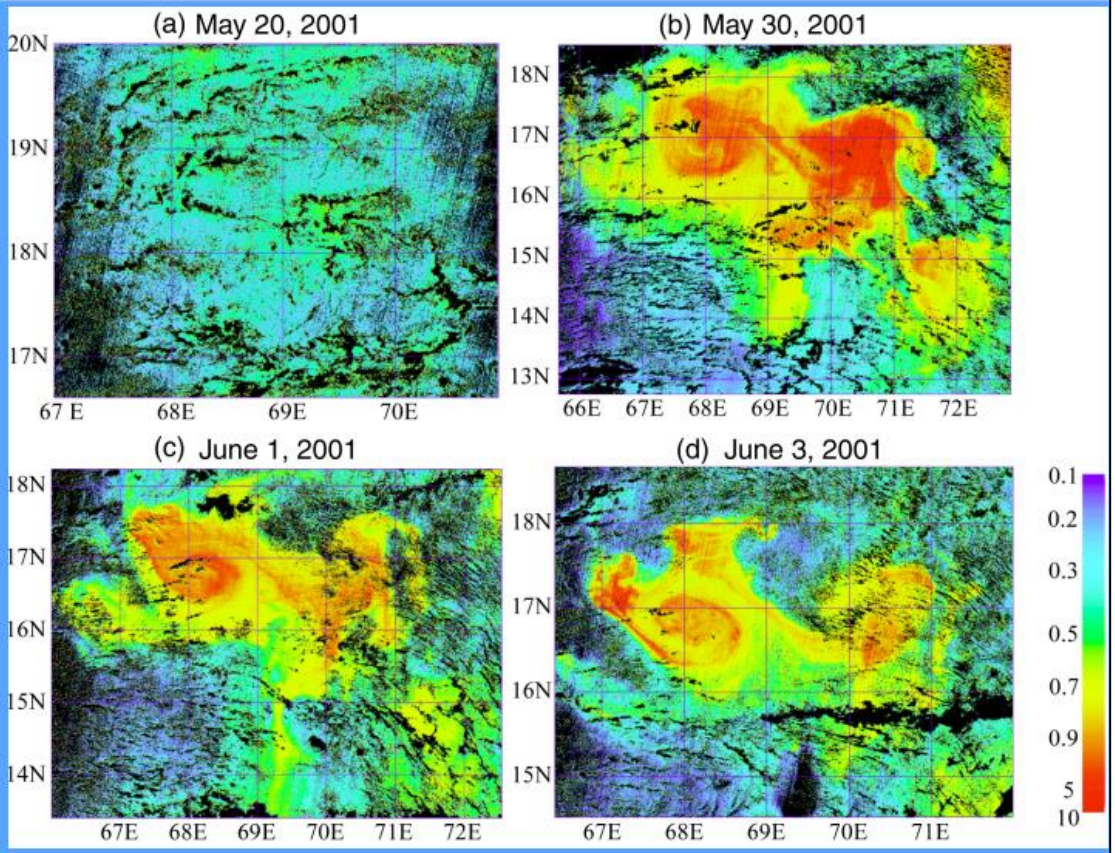
Influence of tropical cyclones on Chlorophyll-a





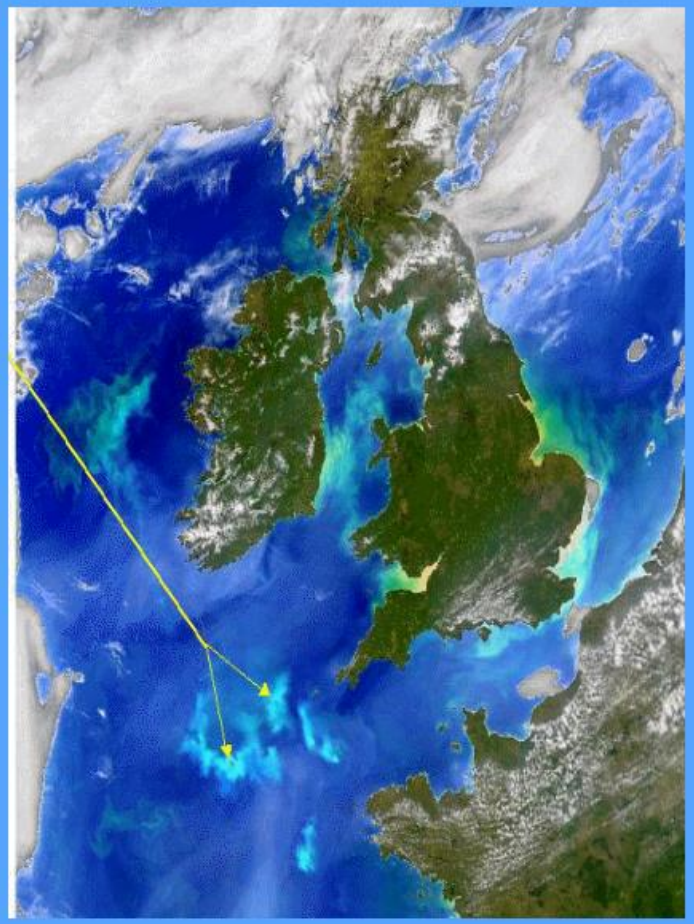
Chlorophyll-*a* concentrations (mg m^{-3}) from IRS-P4 (OCEANSAT-1) Ocean Color Monitor (OCM)

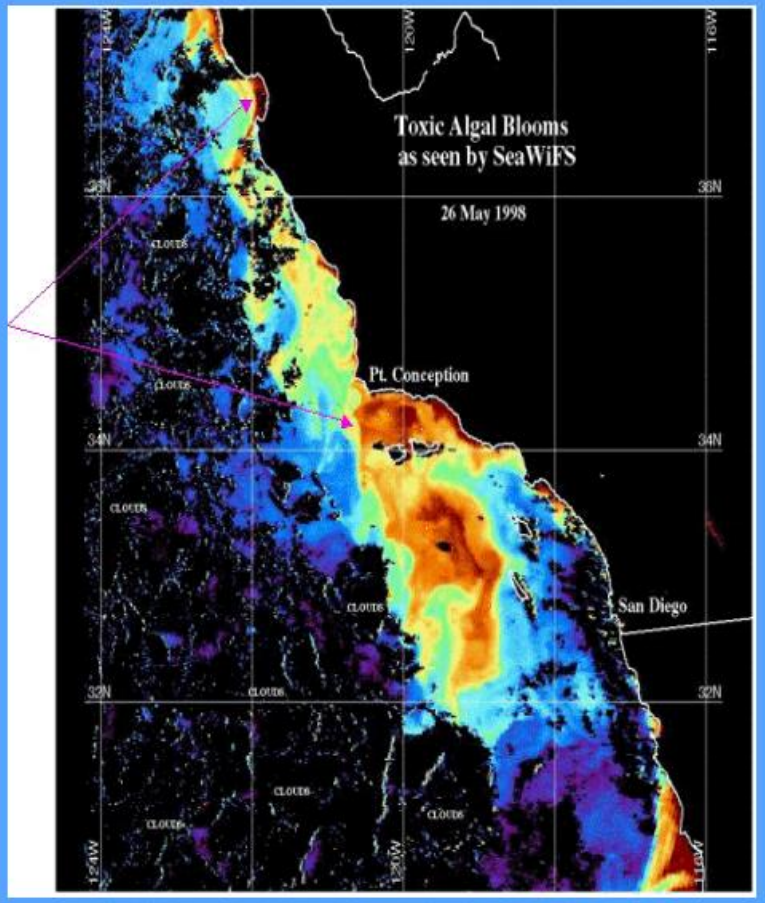
Water quality: Algal blooms

Coccolithophore blooms and Toxic algal blooms from SeaWifs

Coccolitho-phore blooms shown via SeaWiFS

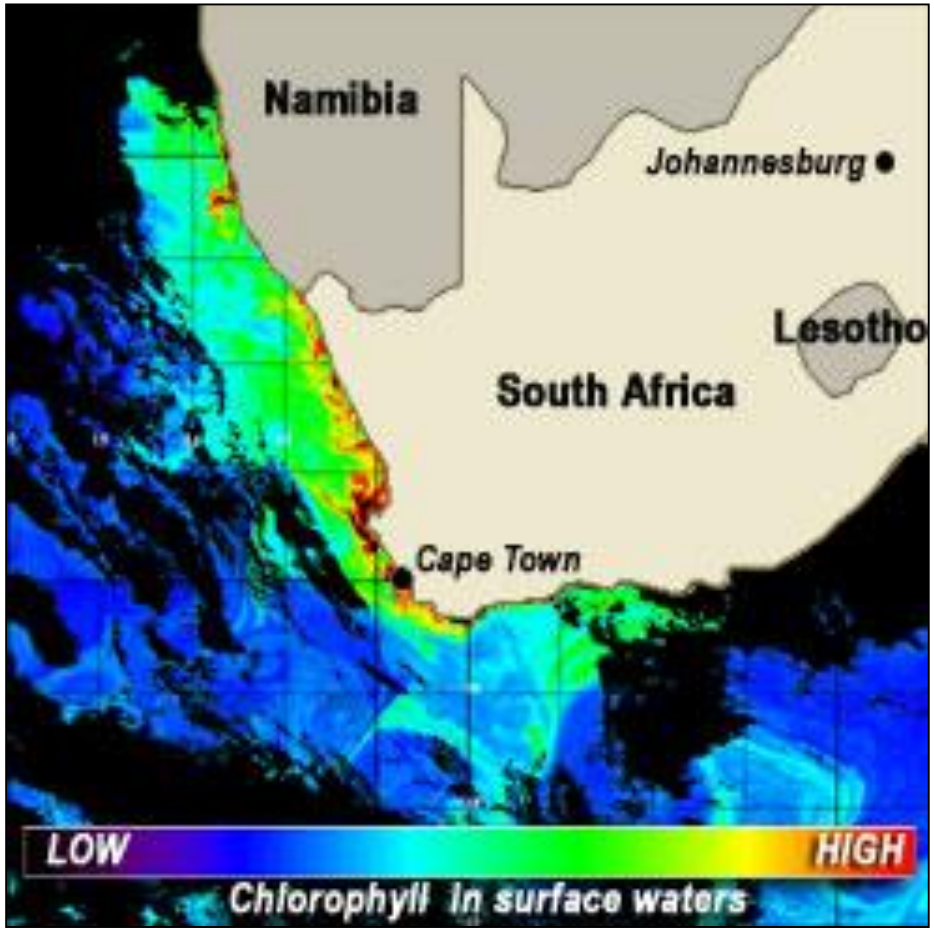
Extensive patches of high reflectance blooms





source: SeaSpace (http://www.seaspace.com/main/derived_samples/oceanographic.html)

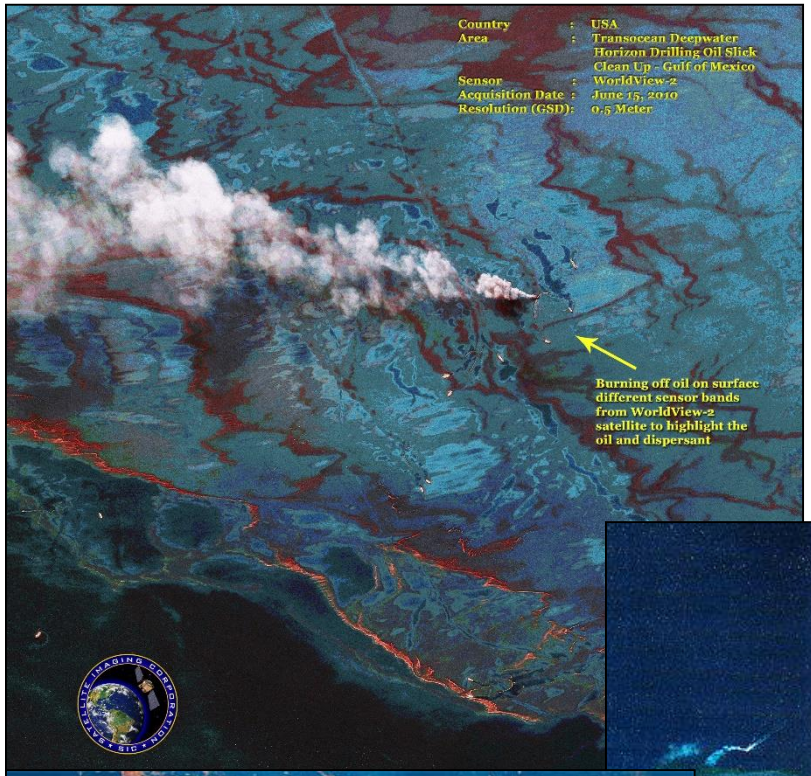
Water quality: Algal blooms

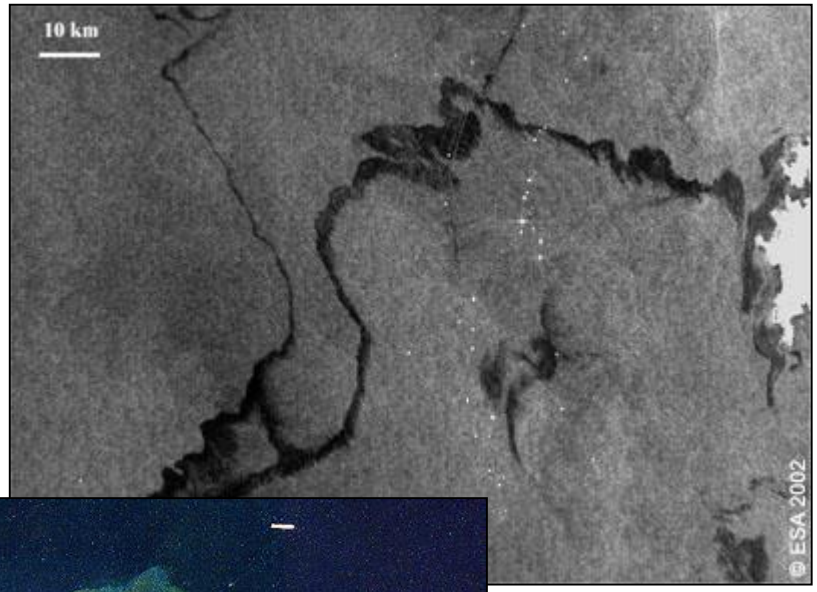


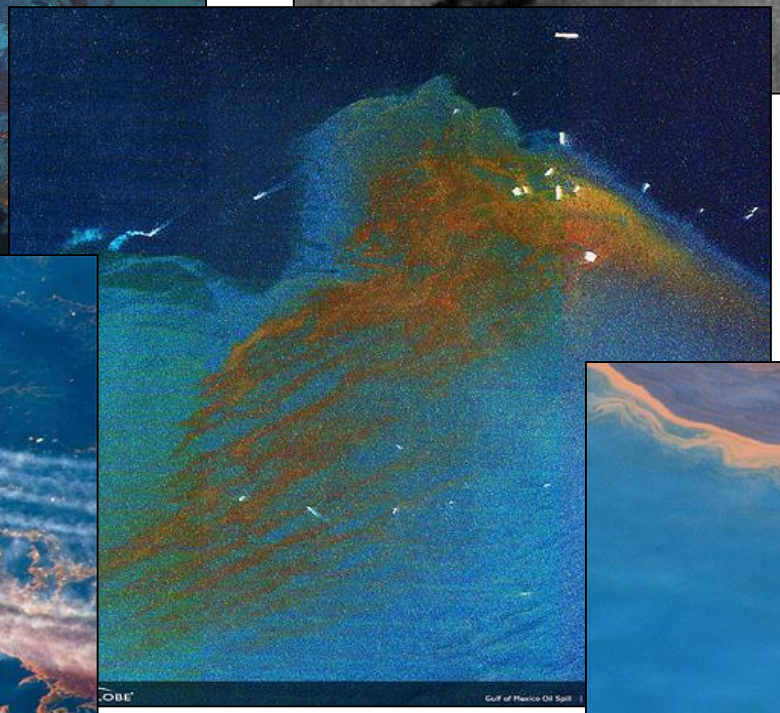
Bloom in southern Africa

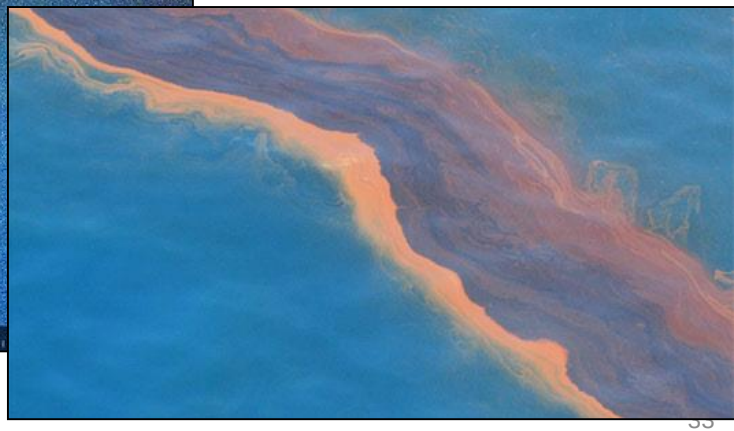
An algae bloom off the southern coast of England in 1999 as observed from satellite

Water quality: Oil spill

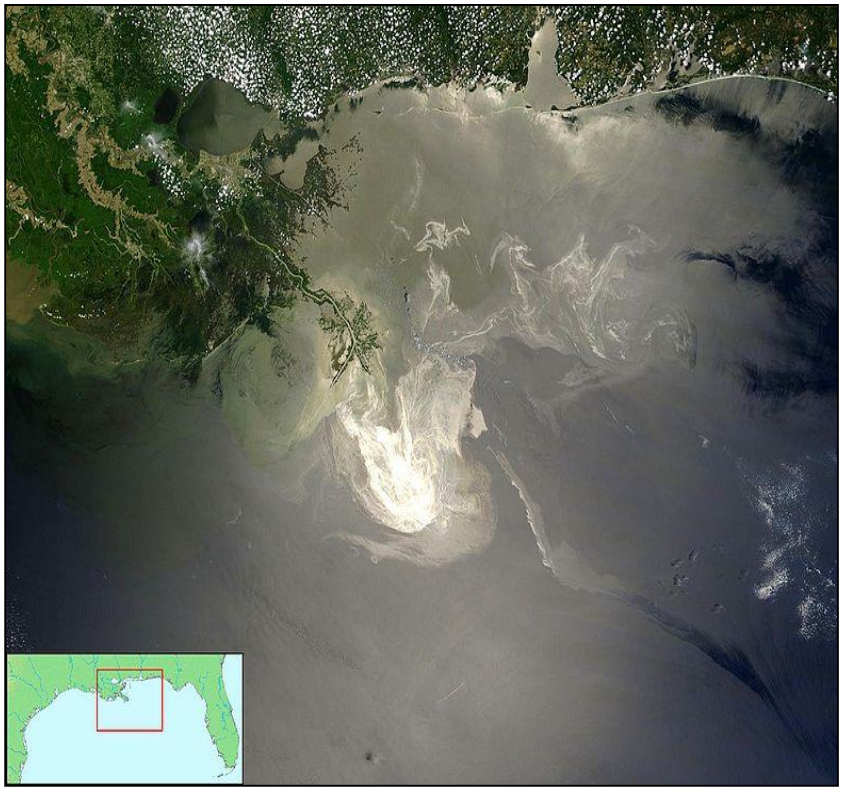


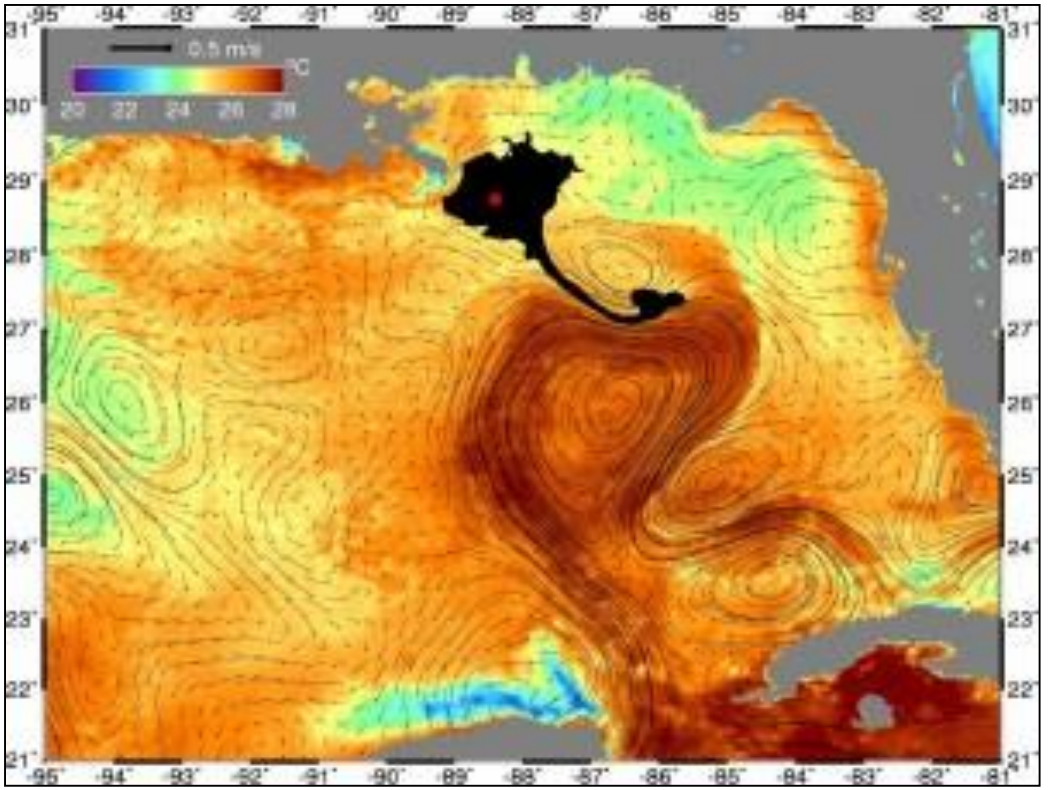






Multi-satellite application: Oil spill

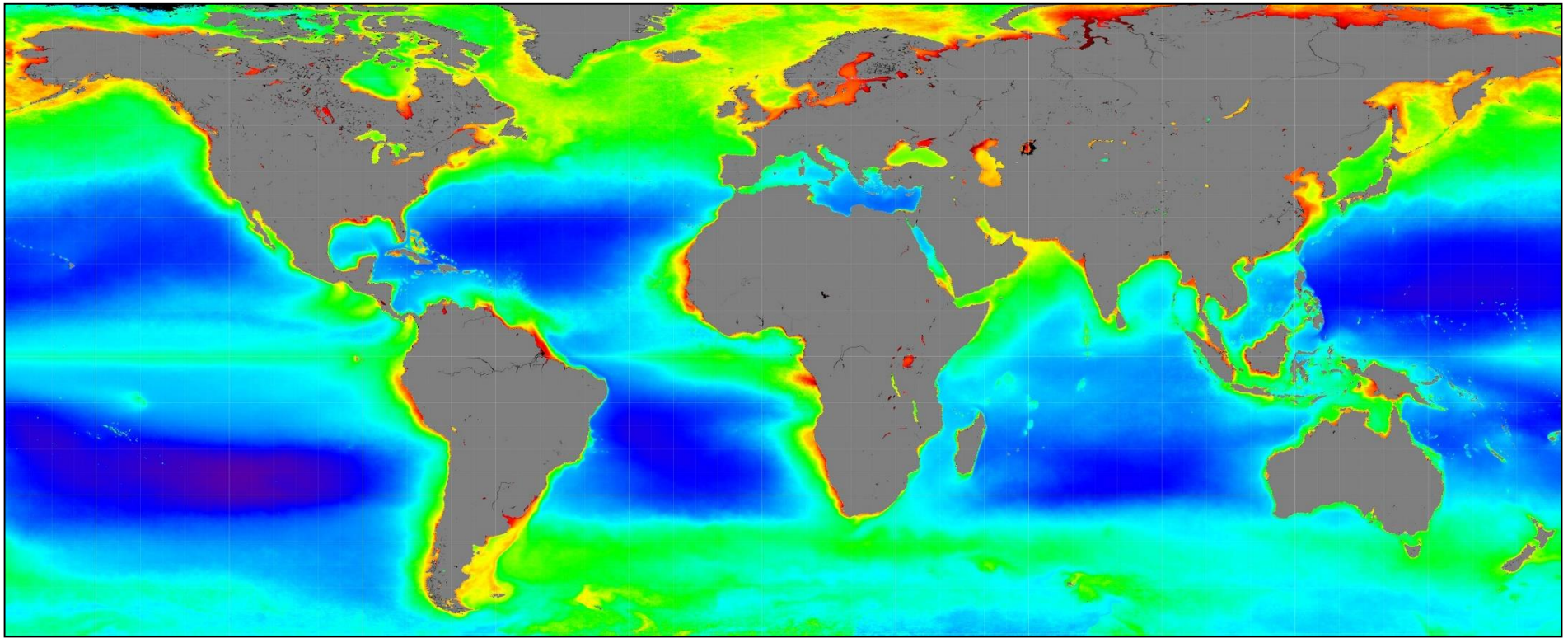




Gulf of Mexico Deepwater Horizon oil spill (Apr-Jul 2010): SST (background image), oil spill (black stain) from SAR sensors on Radarsat-2 satellite, pumped away by the Loop Current from altimetry (black arrows).

Satellite data and fisheries

- Habitat Classification: SST, SSH, ocean color, ocean winds and sea ice
- Info: ocean fronts, eddies, convergence zones, river plumes and coastal regions,



Chl map: potential productive zones

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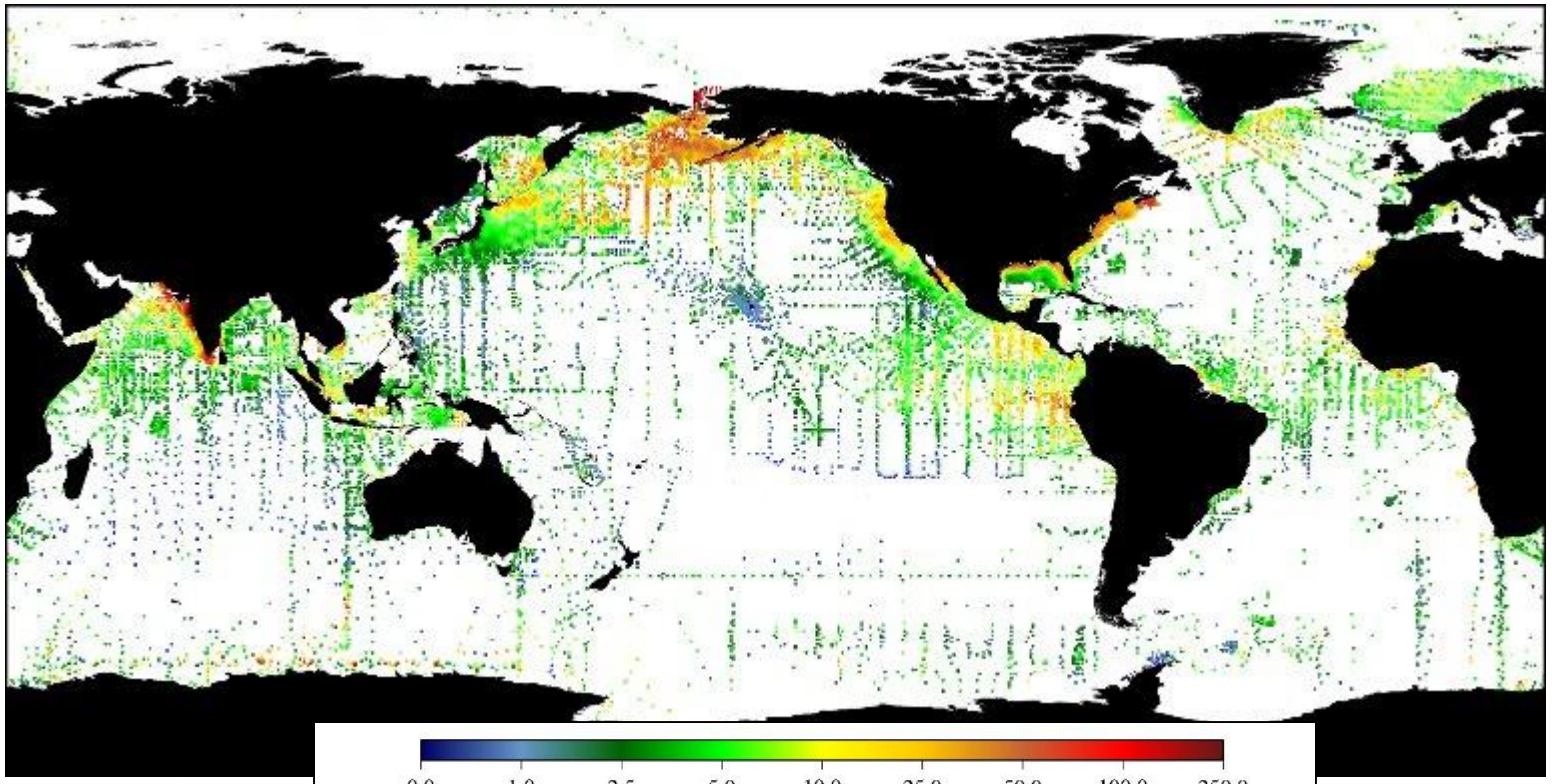

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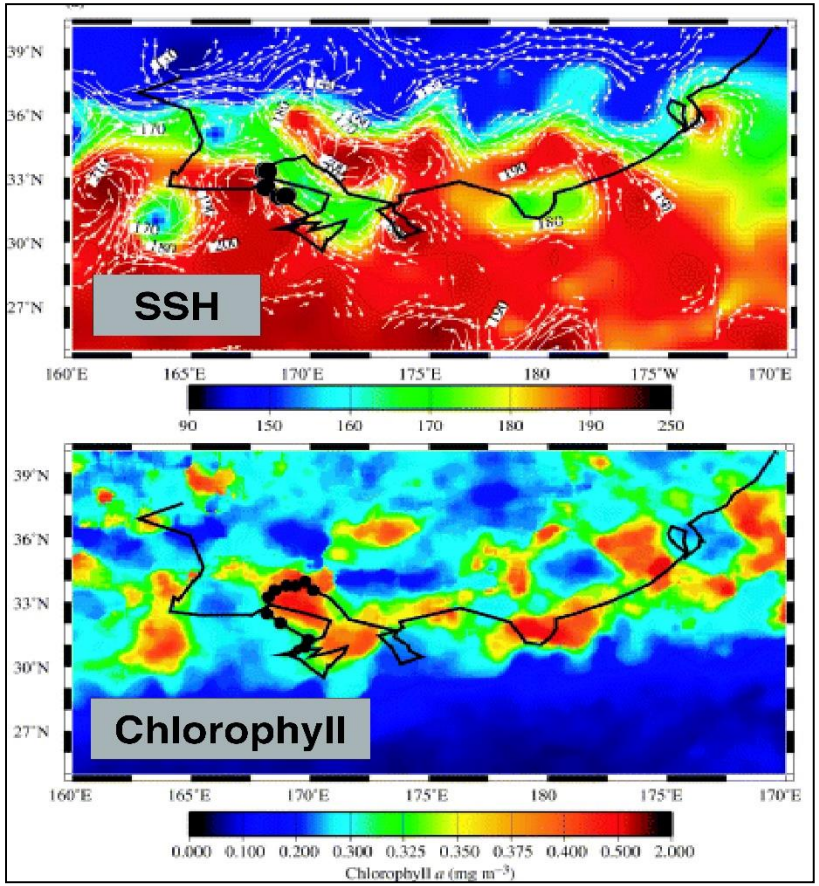
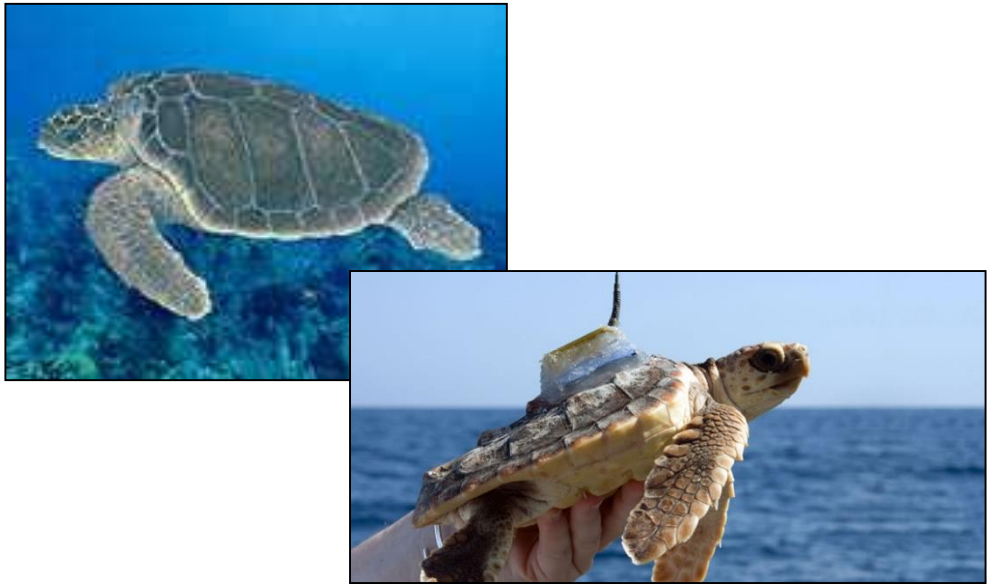
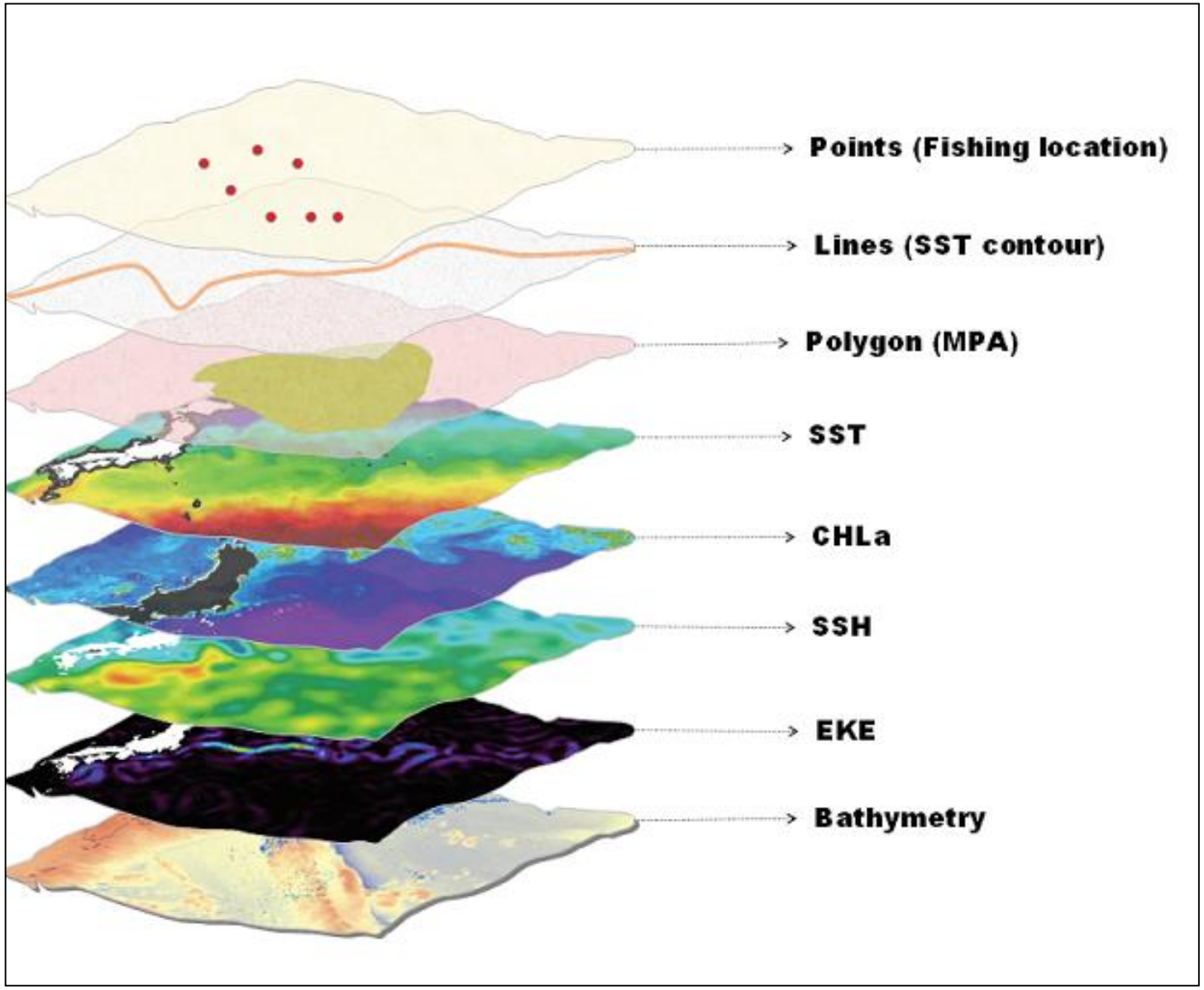




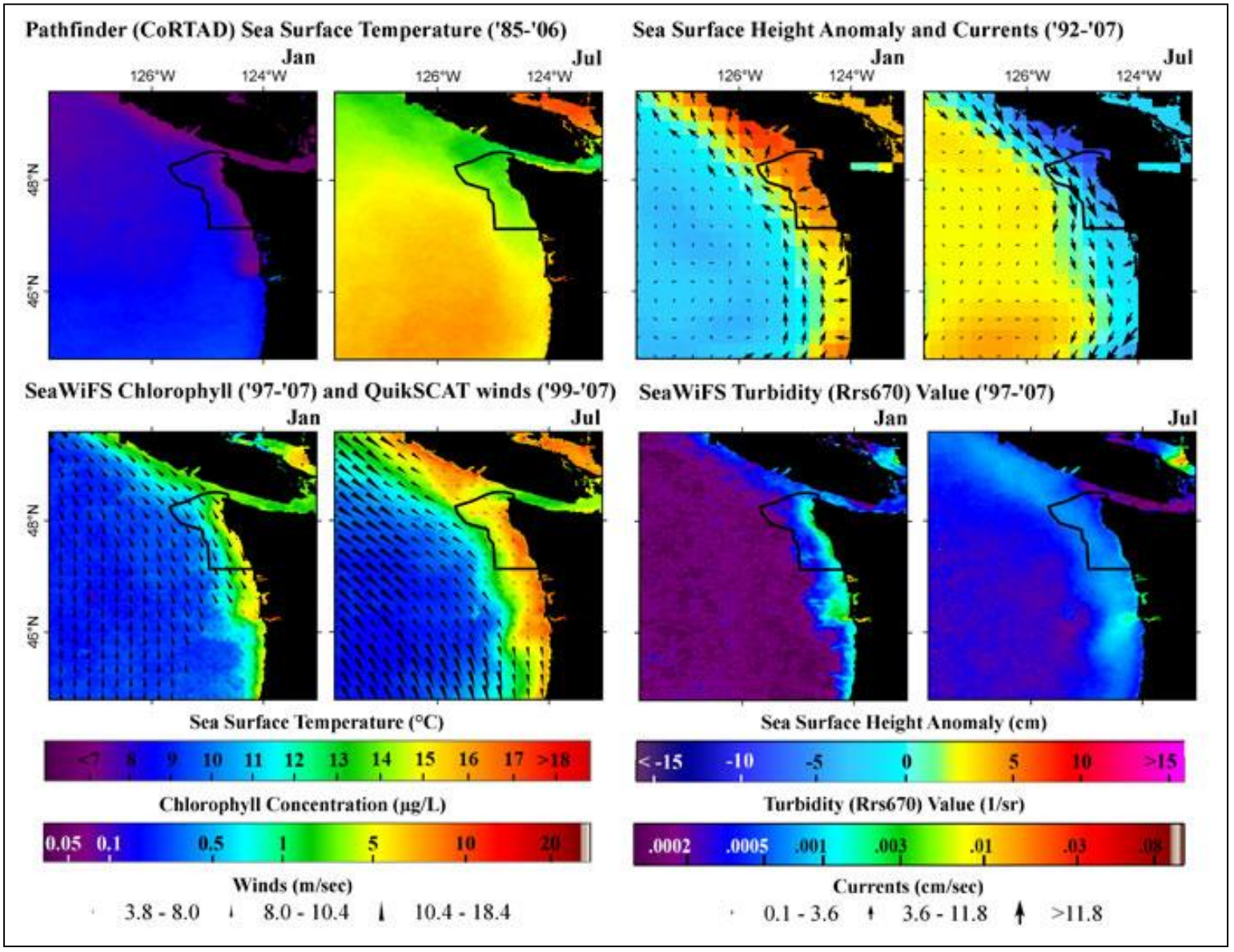
Loggerhead turtle tracks along the TZCF during Feb. 2001. Polovina et al. (2000), Fisheries Oceanography, 9, 71-82.

Satellite data and fisheries



Assessing the viability of a fishing ground

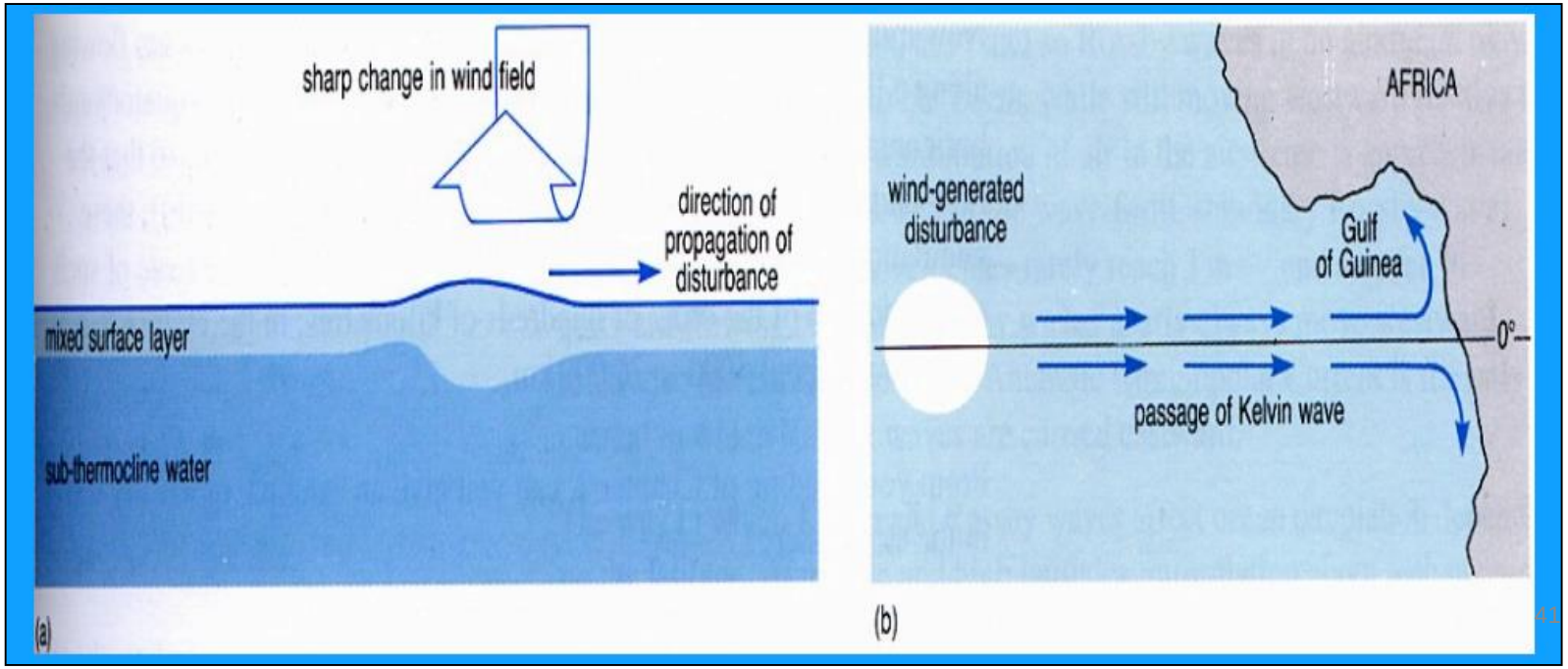
Multi-satellite application



NW Pacific biophysical info from multiple satellite products

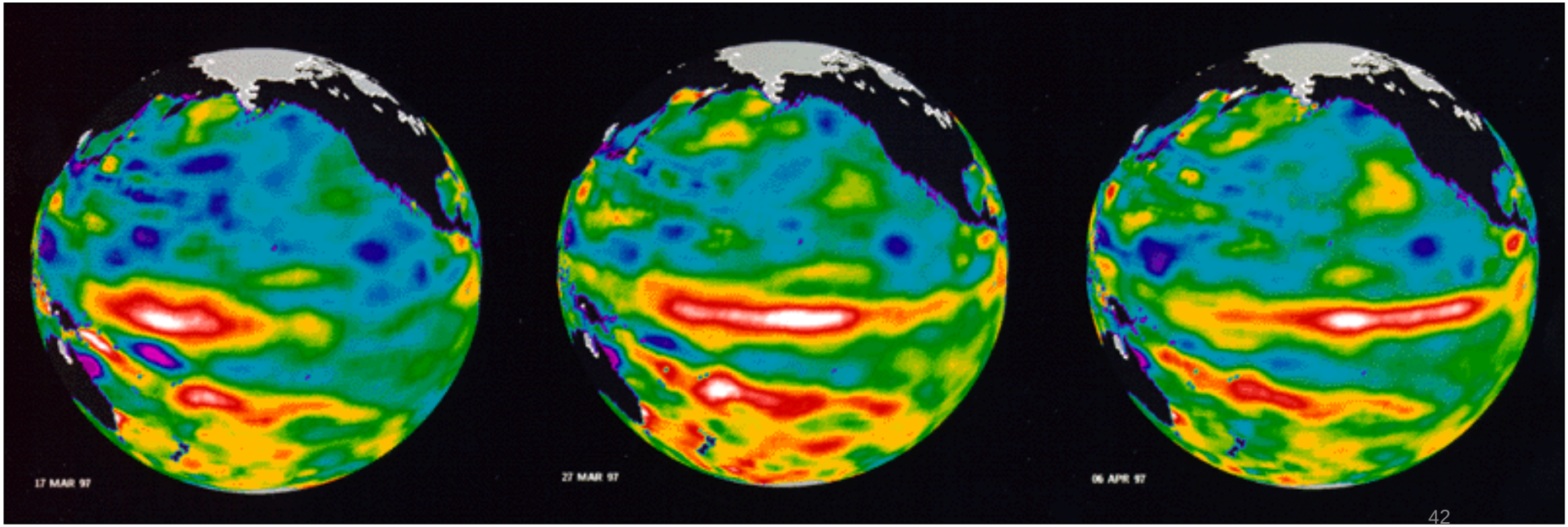
Kelvin Waves

- Kelvin waves are similar to surface wind waves in that the principal maintaining force is gravity.
- The necessary condition for propagating Kelvin waves is that the horizontal pressure gradient force and Coriolis force act in opposite direction.
- Along the equator f=0 , hence equator serve as a wave guide.



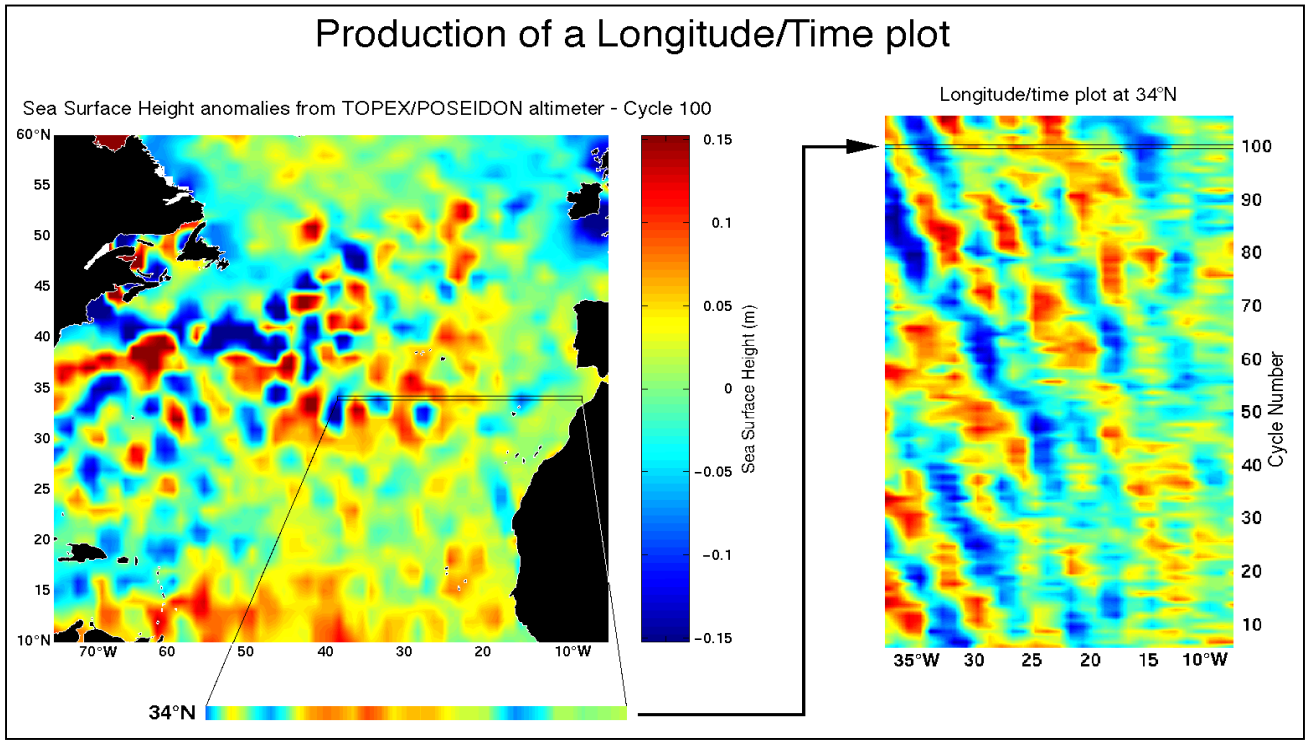
Equatorial Kelvin Waves

- Satellite altimetry from TOPEX/Poseidon
- Scenes are 10 days apart

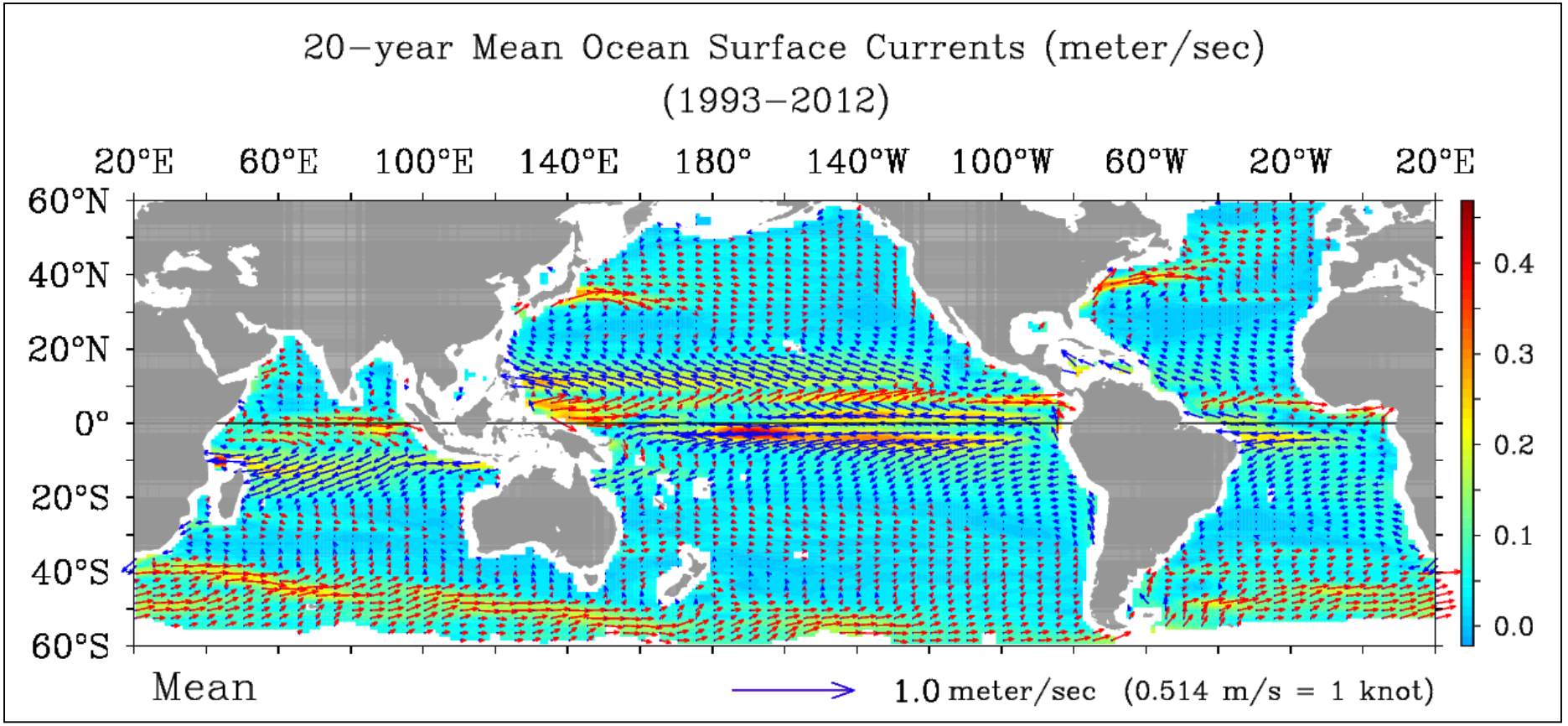


Rossby waves

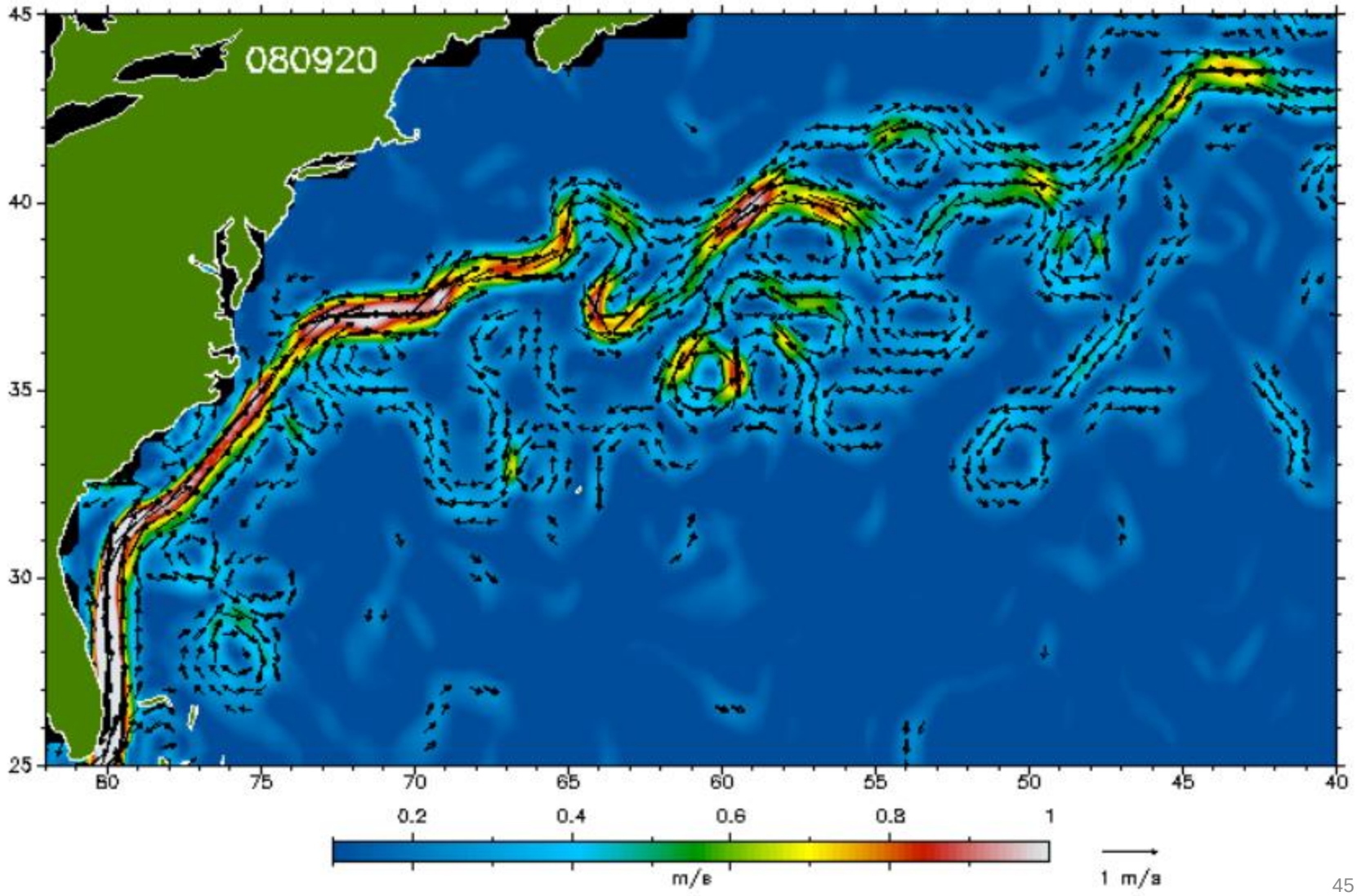
- Rossby waves, or planetary waves are a special class of large-scale waves which occur in both the atmosphere and the ocean.
- They arise because of the latitudinal variation of the Coriolis parameter.
- Long wavelength (100s-1000s of Km). Wave amplitude < 10 cm



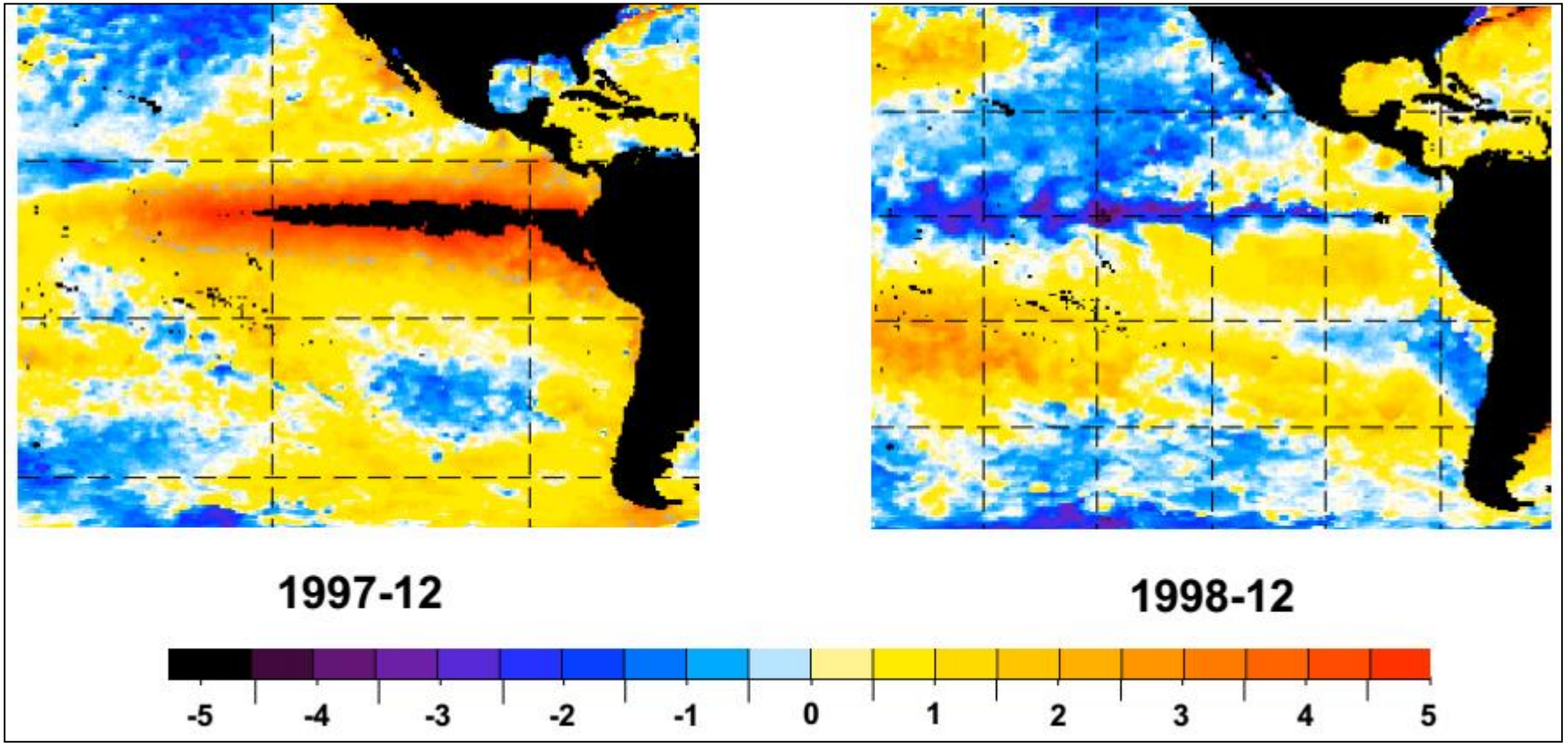
Surface currents from satellites



Gulf Stream position from altimetry



Application: Special Events - El Nino and La Nina



AVHRR Ocean pathfinder SST anomalies

Normal conditions

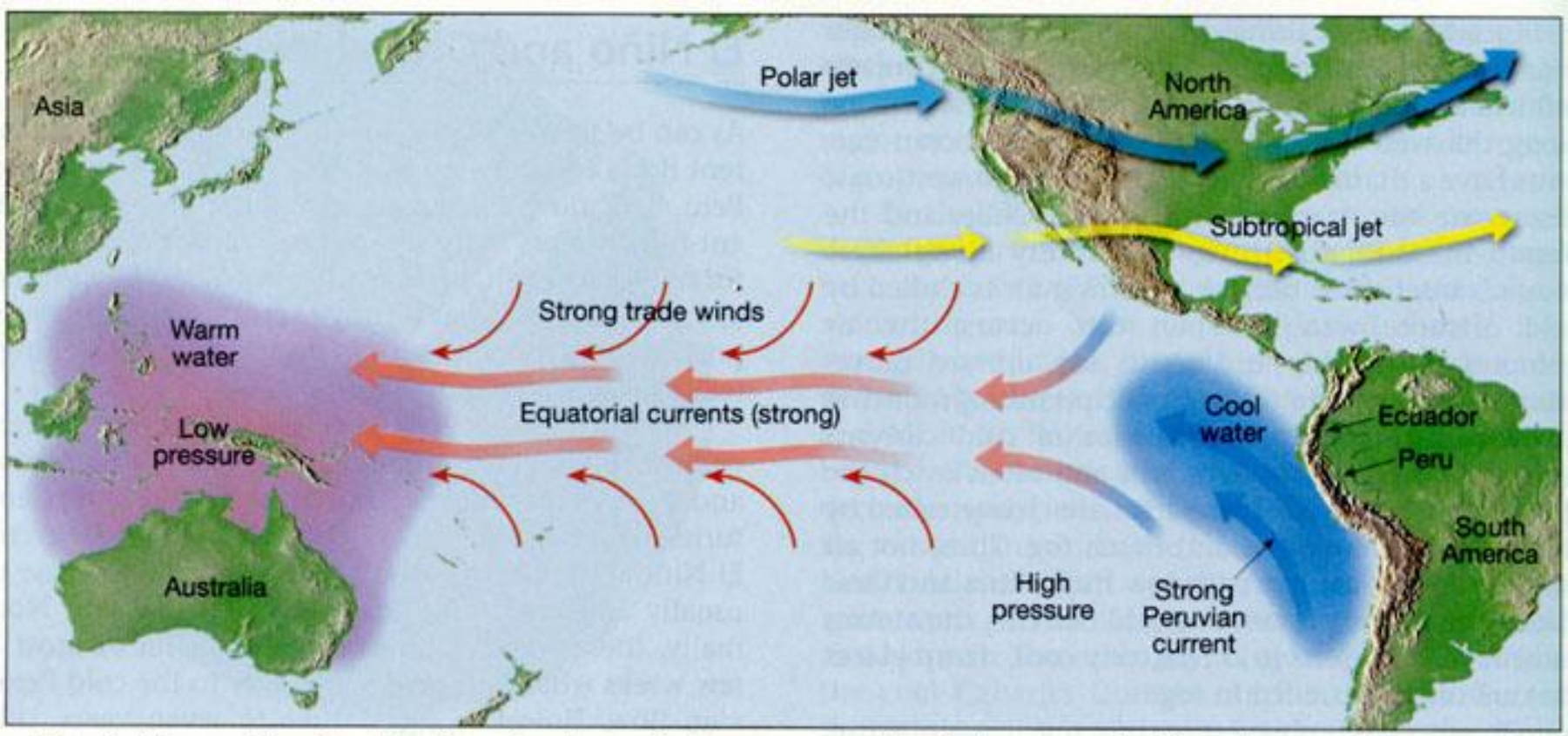
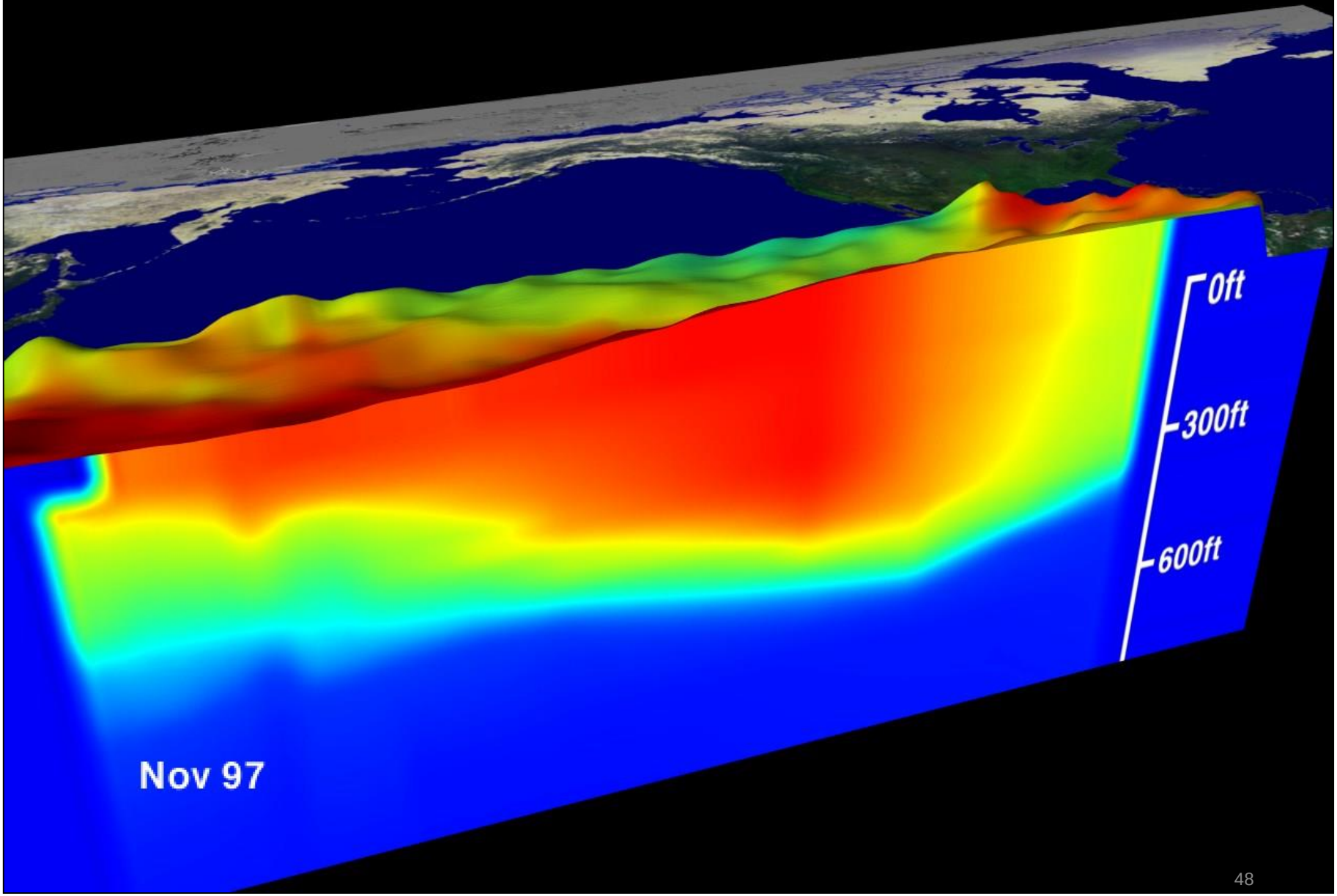
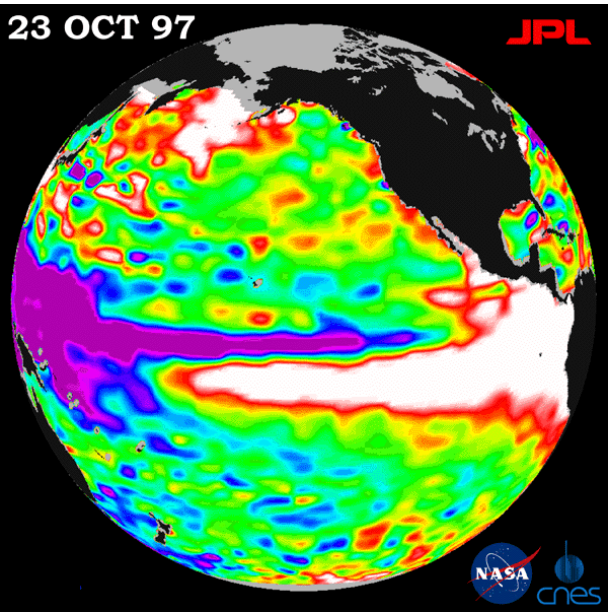


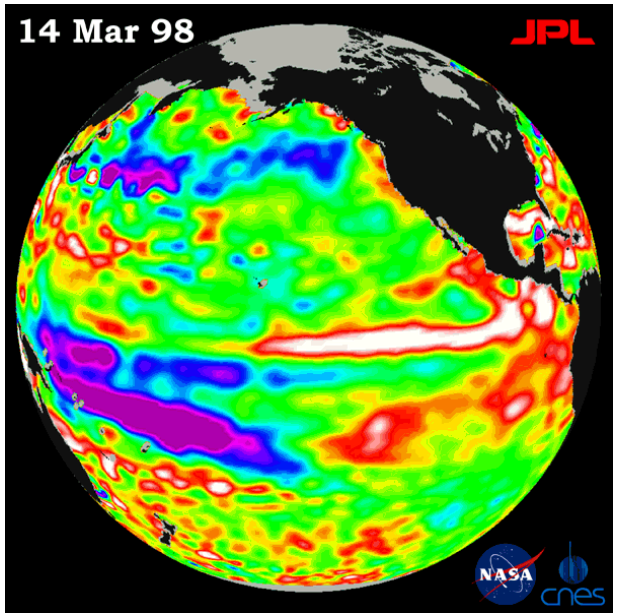
Fig.6 Normally, the trade winds and strong equatorial currents flow toward the west. At the same time, an intense Peruvian current causes upwelling of cold water along the west coast of South America.

El Niño – Southern Oscillation (ENSO)



ENSO: stages



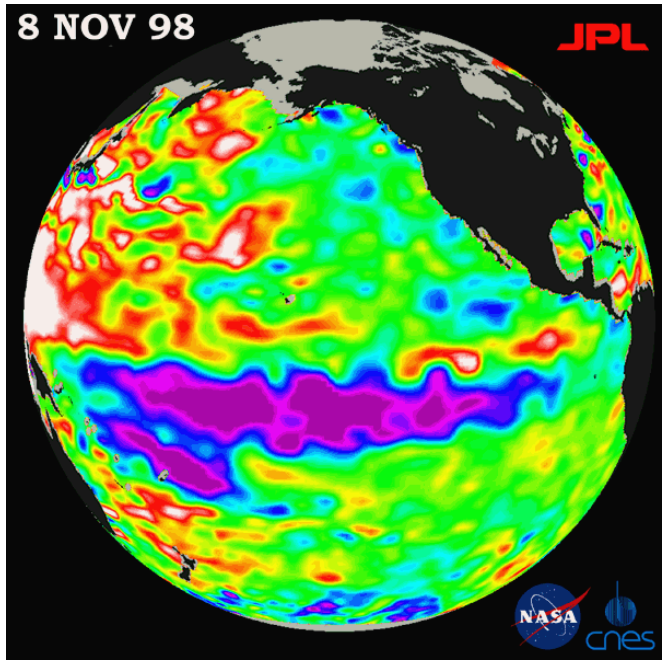


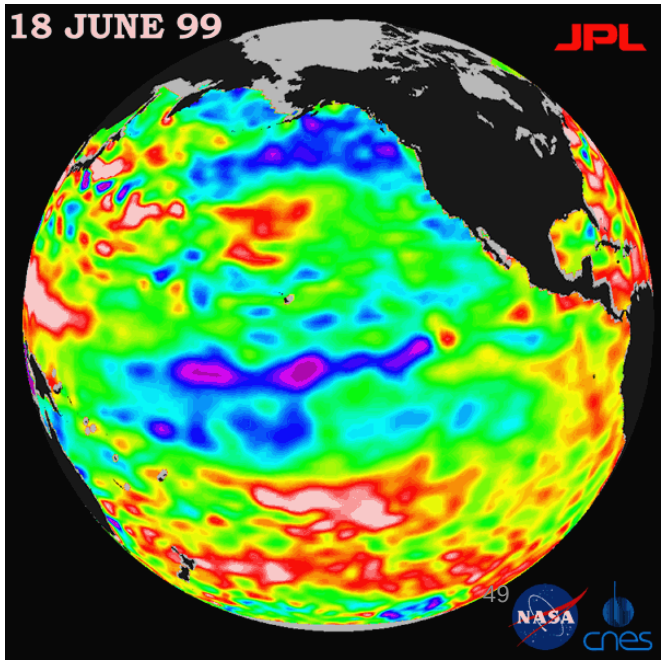
Full El Nino condition

El Nino retreating

Full La Nina condition

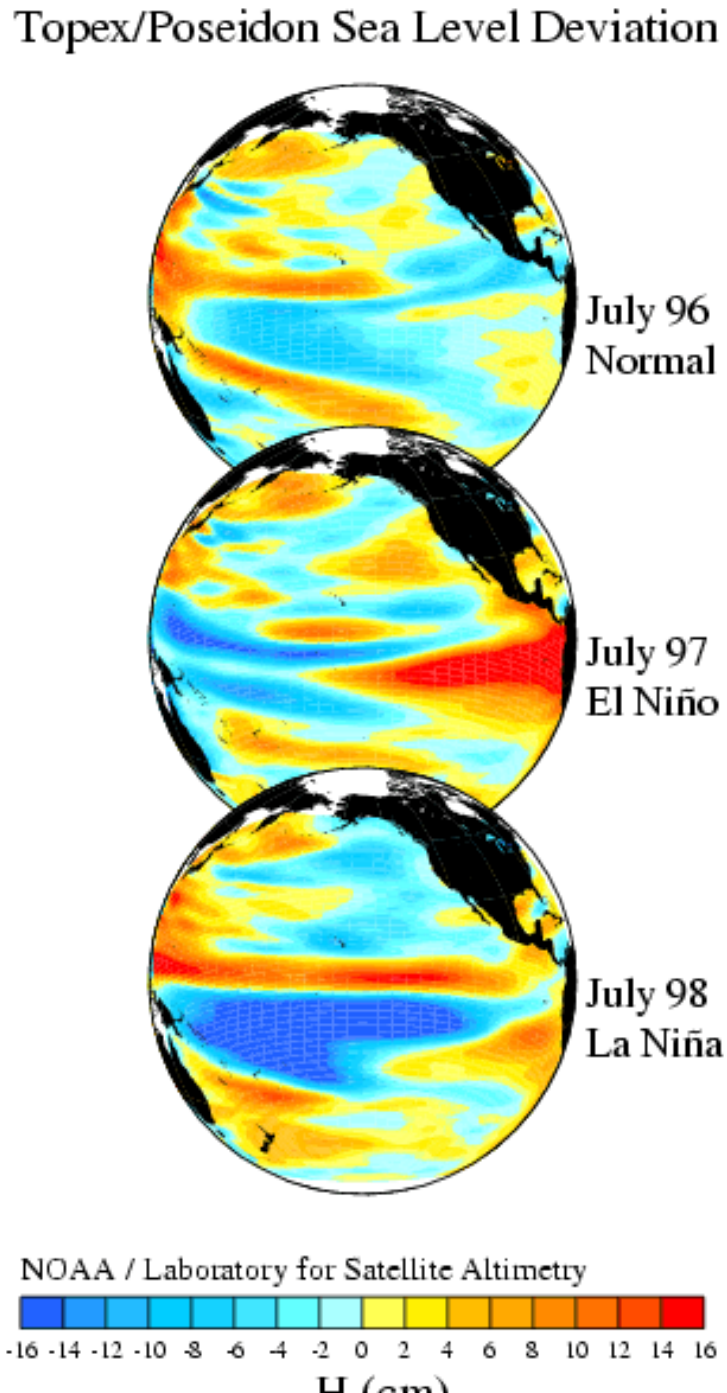
La Nina fading

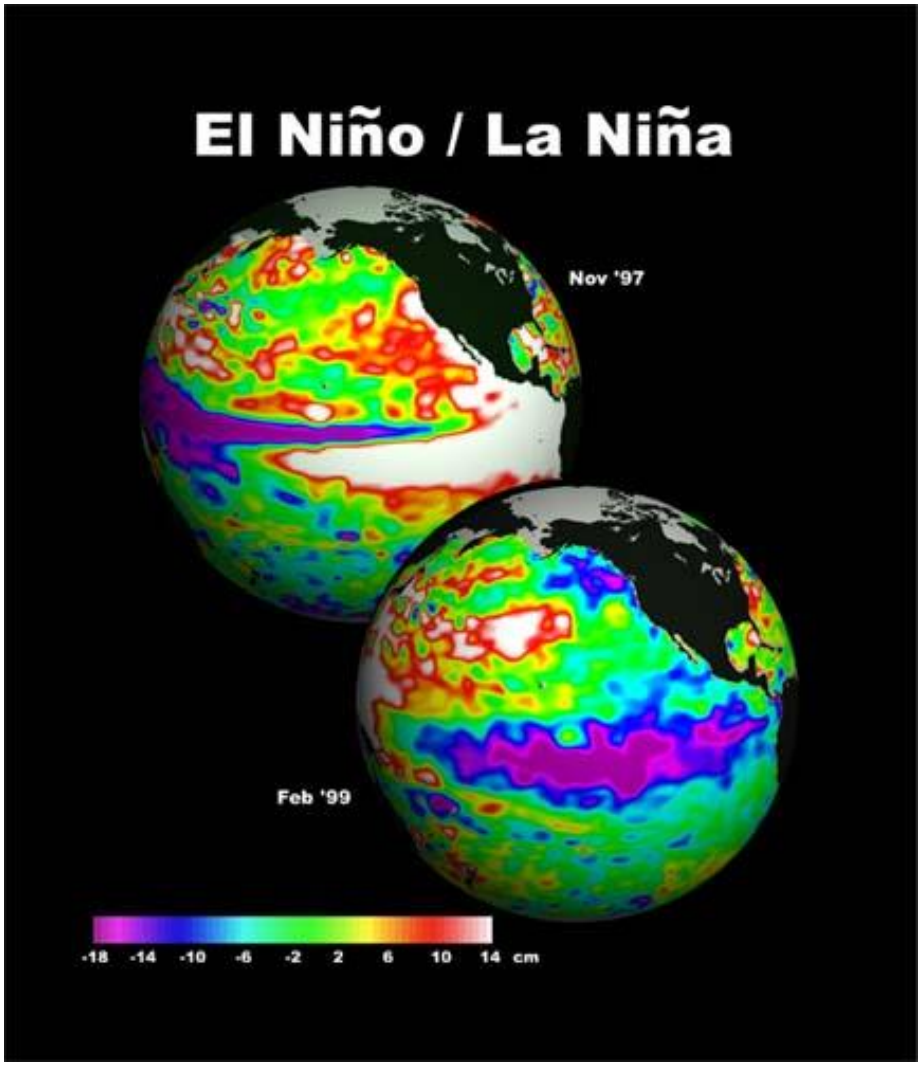




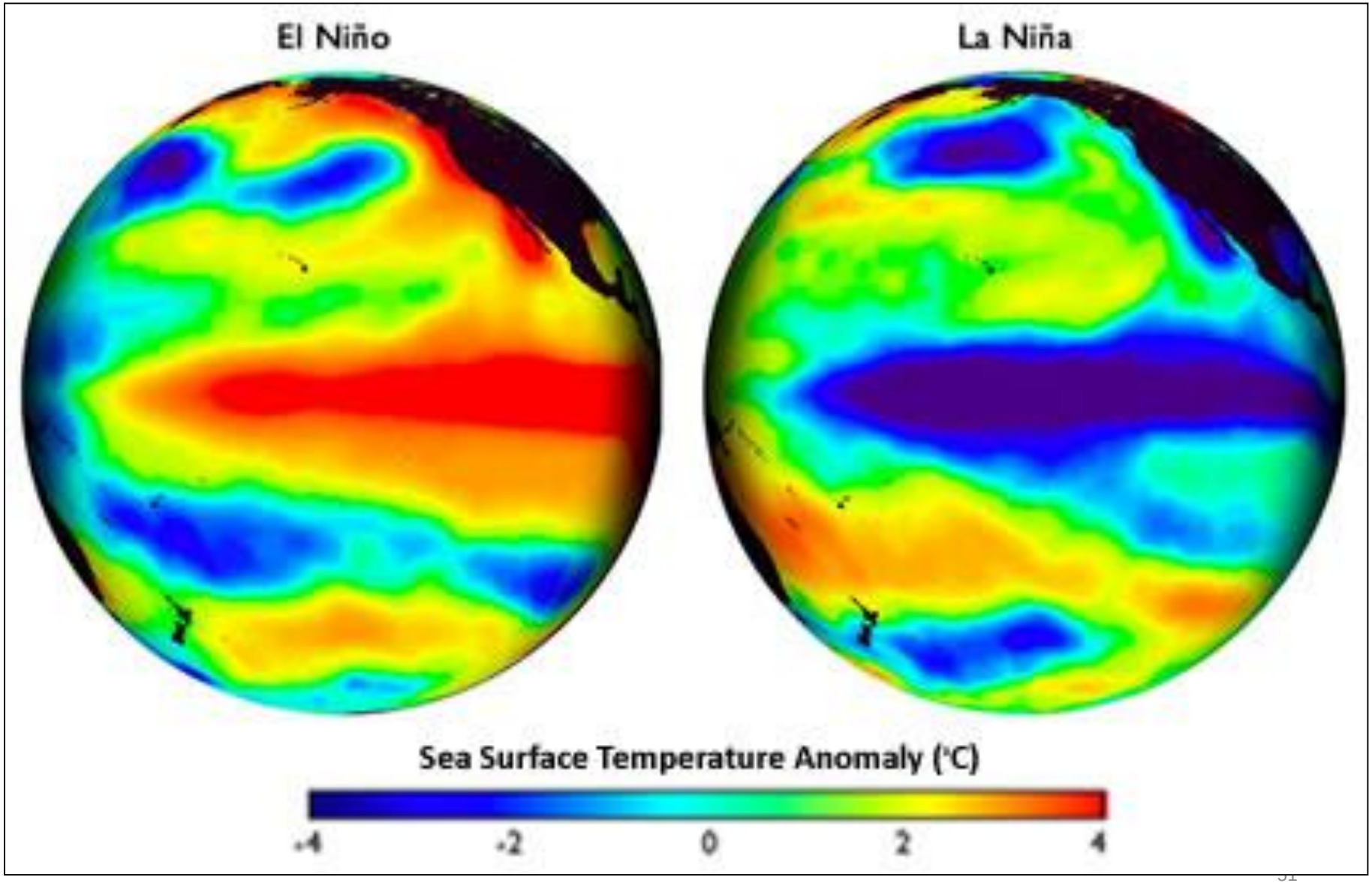
ENSO

- Topex-Poseidon Sea-Surface Height Anomaly

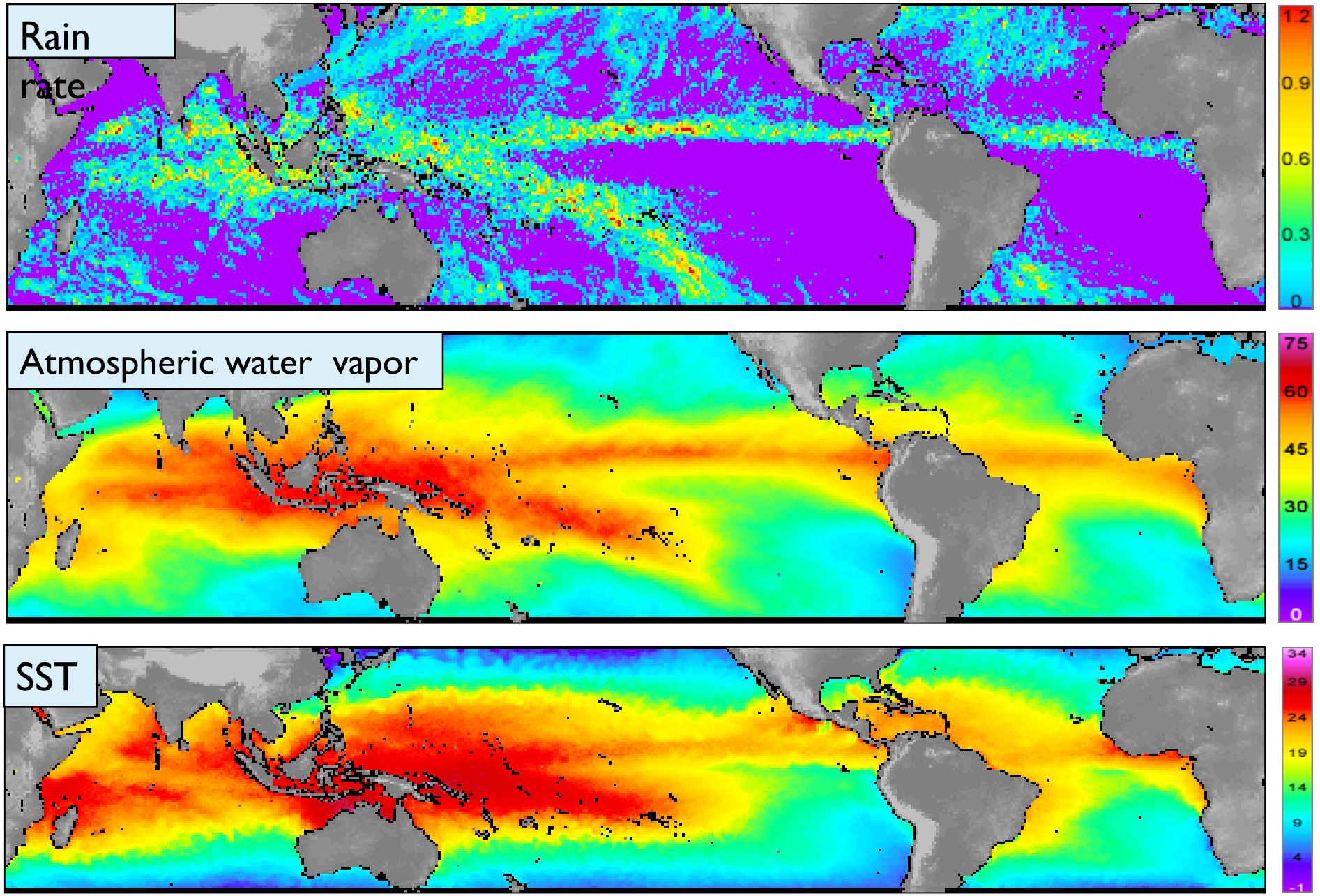




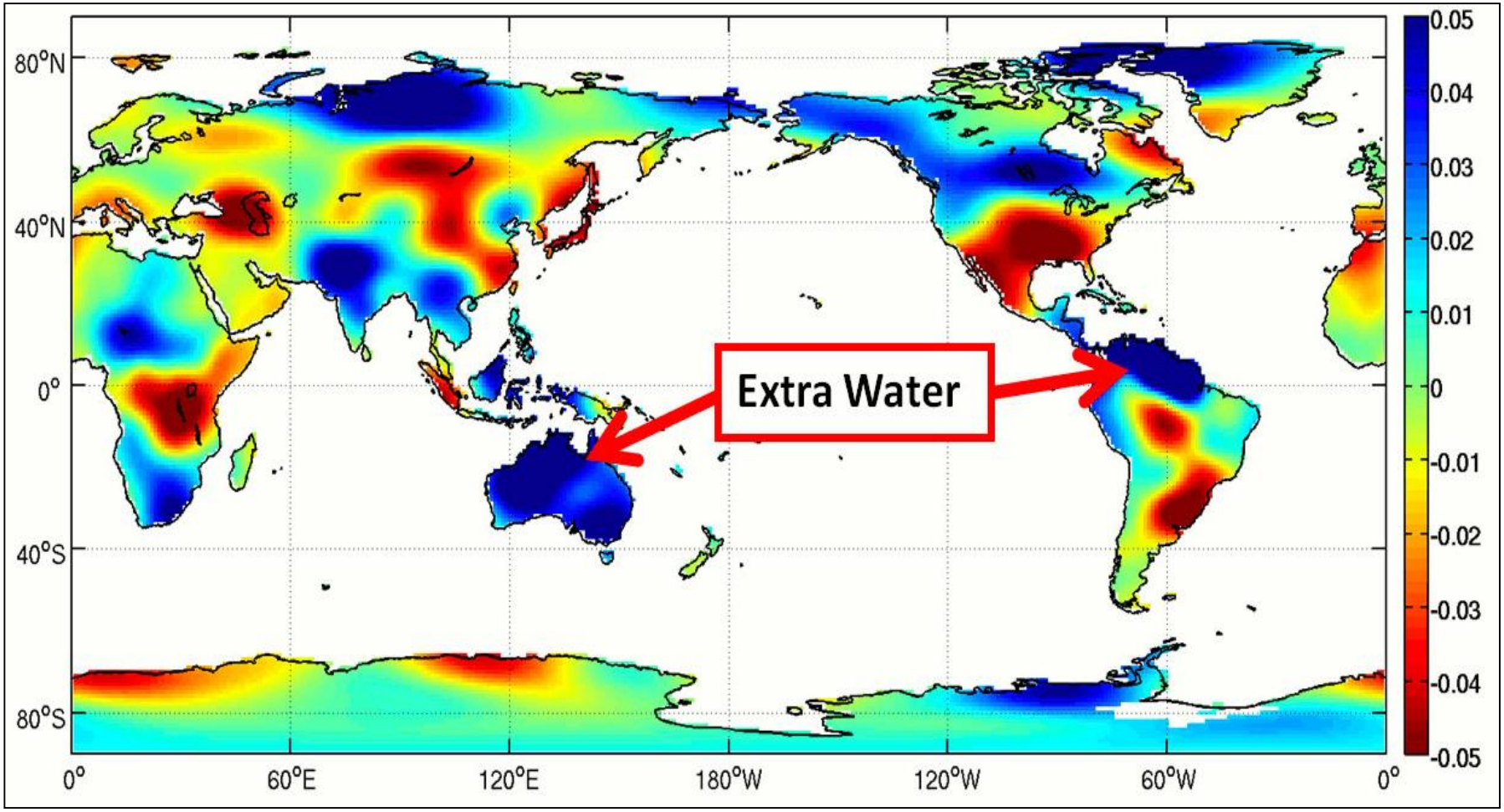
ENSO from SST



TRMM Satellite-Rain measurements

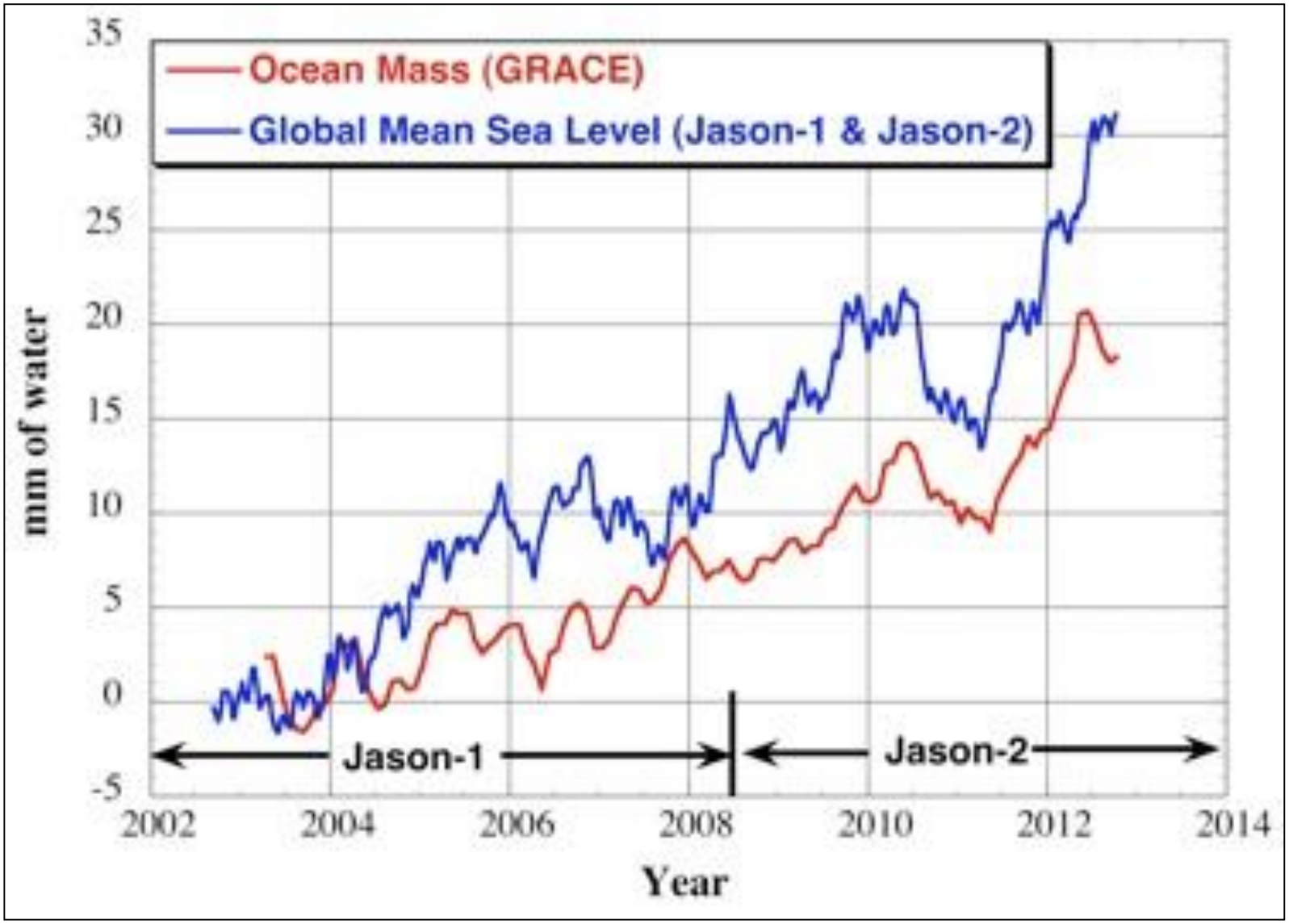


Application: Global change - Monitor changes in Earth's water



GRACE shows change in water from March 2010 to March 2011

Application: Global change - Monitor changes in Earth's water



Global mean sea level (GMSL) derived from GRACE and from altimetry.

NASA
ftp://podaac-ftp.jpl.nasa.gov/allData/

CNES
http://www.aviso.altimetry.fr/en/data/data-access.html

NOAA
http://www.ncdc.noaa.gov/data-access/satellite-data/satellite-data-access-datasets

ESA
http://marine.copernicus.eu/

IFREMER
http://wwz.ifremer.fr/institut_eng/Marine-science/French-facilities/Data-Centres/Coriolis

SANSA
http://www.sansa.org.za/

MESA
http://www.ug-mesa.org/

Individual Universities and Labs
e.g. University of Hawaii
http://apdrc.soest.hawaii.edu/data/data.php