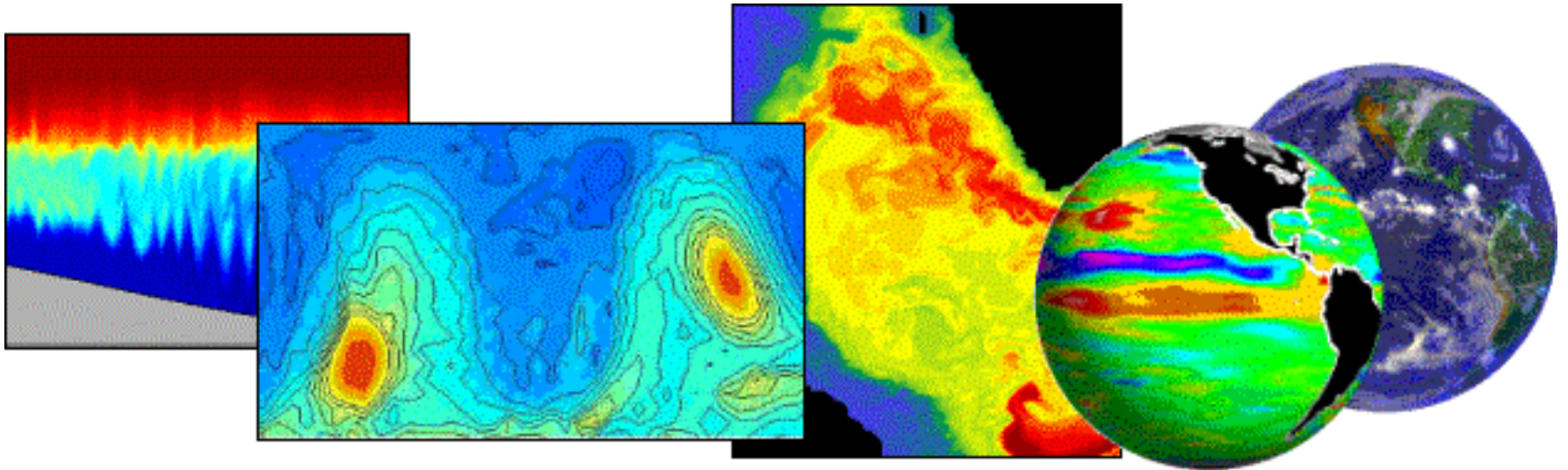


Satellite Oceanography Lab

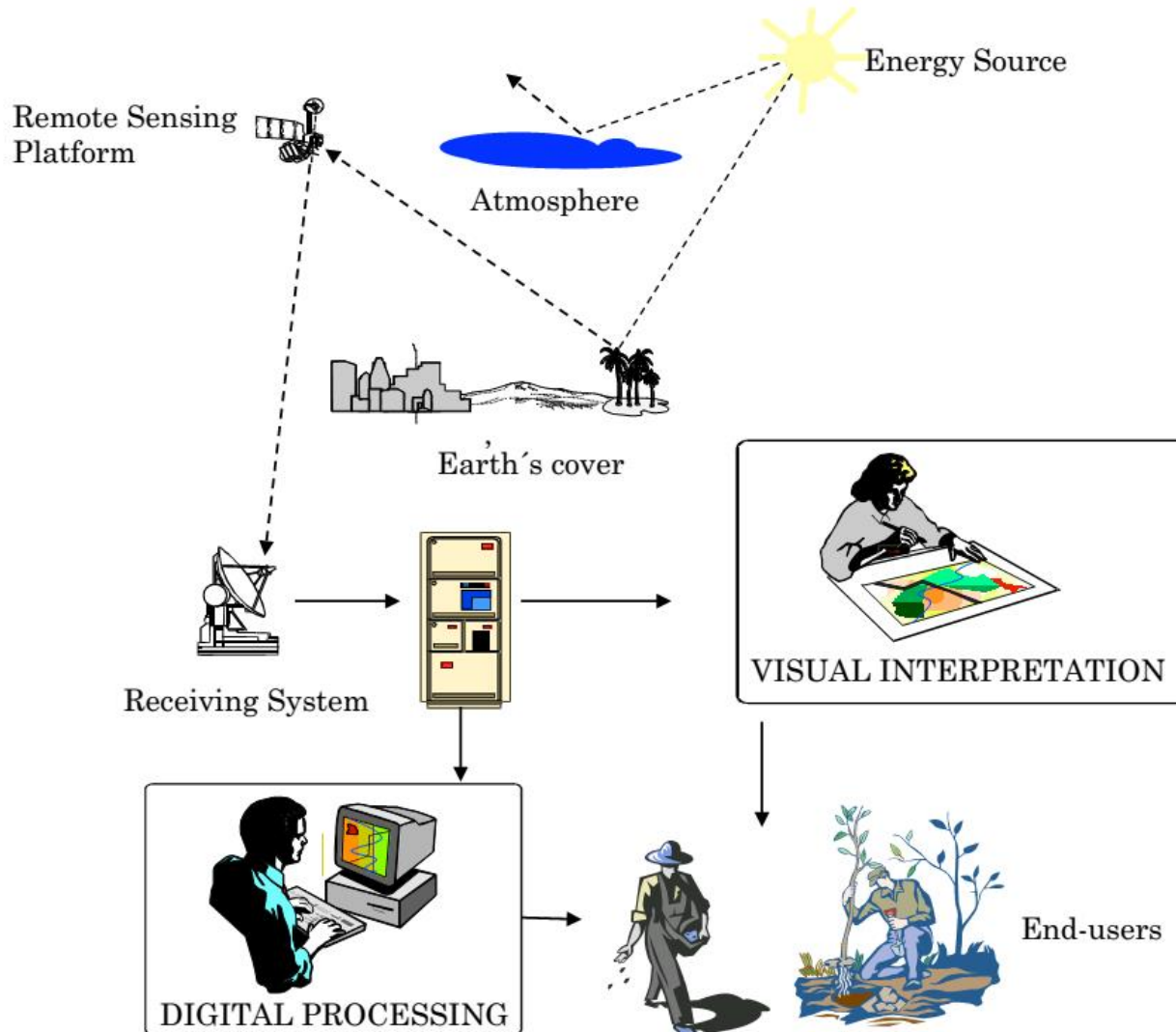
Ebenezer Nyadjro

**US Naval Research Lab/
University of New Orleans**



UG-DMFS Summer Program (AUGUST 1-5, 2016)

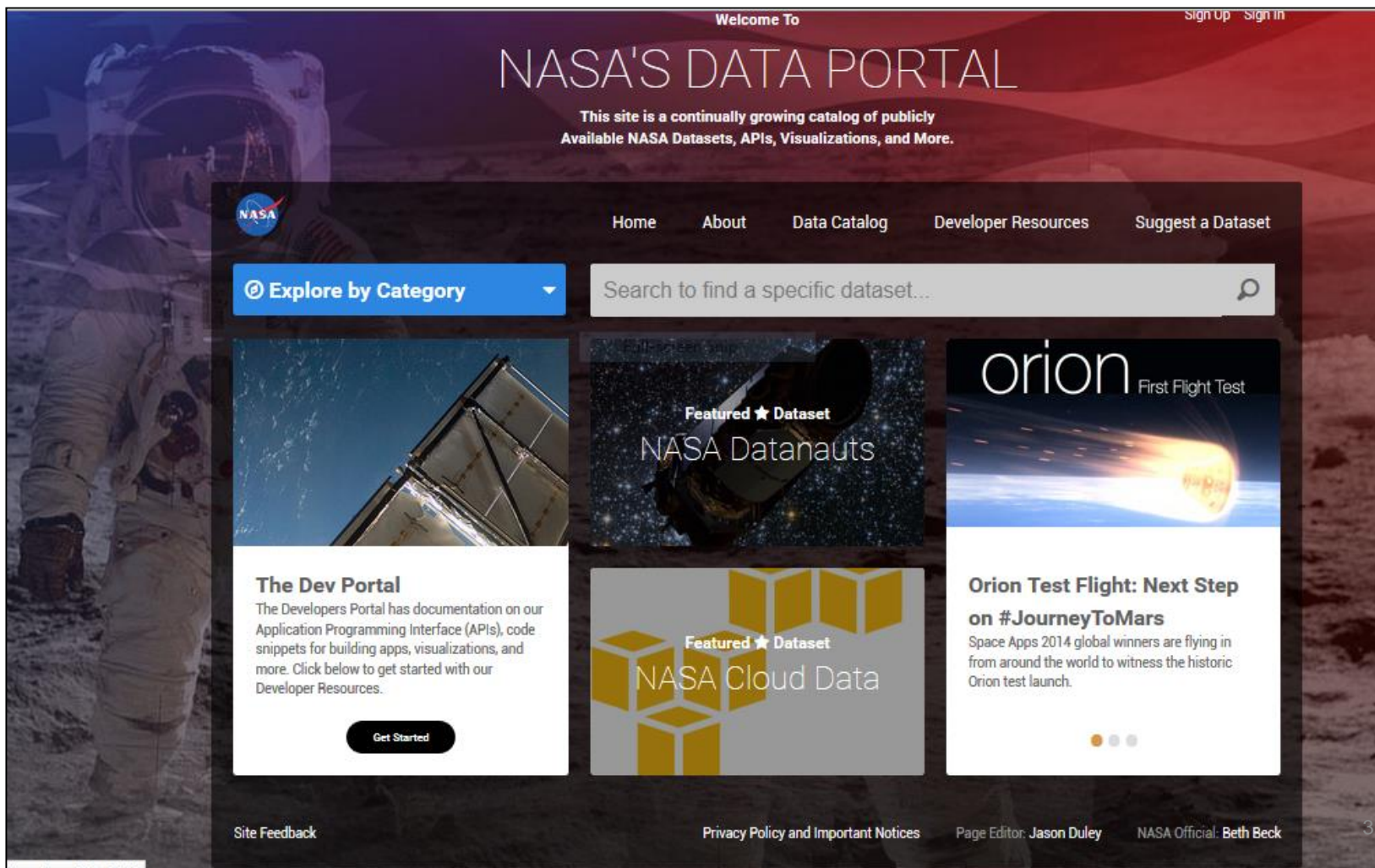
Remote Sensing: Primary components



- A. Energy Source
- B. Radiation and Atmosphere
- C. Interaction with target
- D. Energy recorded by sensor
- E. Transmission, reception, processing
- F. Interpretation and analysis
- G. Application of information

Data Sources

- ✓ National institutions that manage satellite data
 - National Aeronautics and Space Administration (NASA)



The screenshot shows the NASA's Data Portal homepage. At the top, it says "Welcome To" and "NASA'S DATA PORTAL". Below this, it states "This site is a continually growing catalog of publicly Available NASA Datasets, APIs, Visualizations, and More." The navigation menu includes "Home", "About", "Data Catalog", "Developer Resources", and "Suggest a Dataset". There are links for "Sign Up" and "Sign In" in the top right corner. A search bar is present with the text "Search to find a specific dataset...". A blue button labeled "Explore by Category" is on the left. The main content area features three featured datasets: "The Dev Portal" (with a "Get Started" button), "NASA Datanauts" (labeled "Featured ★ Dataset"), and "Orion Test Flight: Next Step on #JourneyToMars" (with a "Get Started" button). The footer contains "Site Feedback", "Privacy Policy and Important Notices", "Page Editor: Jason Duley", "NASA Official: Beth Beck", and a page number "3".

Data Sources

- ✓ National institutions that manage satellite data
 - National Oceanic and Atmospheric Administration (NOAA)



NOAA SATELLITE AND INFORMATION SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Home About NESDIS Satellites Offices Data Centers Resources

Rectangular Snip

When Solar Storms Attack: Space Weather and our Infrastructure
On a cold night on March 13, 1989 Quebec, Canada and the surrounding areas went dark. Within 90 seconds, and warning, six million people were left without power for nine hours, many for days. [Read more »](#)

About Satellites Imagery and Data NESDIS News Education



NOAA NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Formerly the National Climatic Data Center (NCDC)... [more about NCEI »](#)

Home Climate Information Data Access Customer Support Contact About

NOAA's National Centers for Environmental Information (NCEI) is responsible for preserving, monitoring, assessing, and providing public access to the Nation's treasure of climate and historical weather data and information. [Learn more about NCEI »](#)

How may we assist you?

- I want to search for data at a particular location.
- I want quick access to your products.
- I want to see your monthly climate reports.
- I want to find a specific dataset.
- I want to know about climate change and variability.

STATE OF THE CLIMATE IN 2014

State of the Climate in 2014 Report Released
We're announcing the release of the State of the Climate in 2014 report, an assessment of the world's climate system.

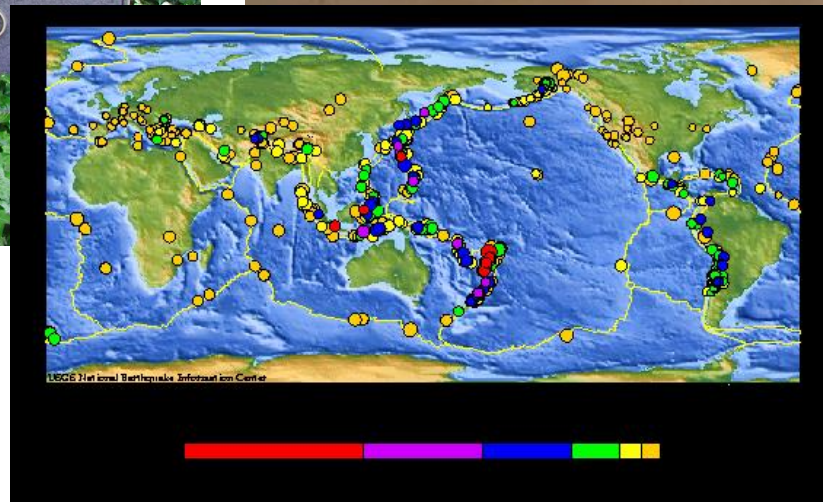
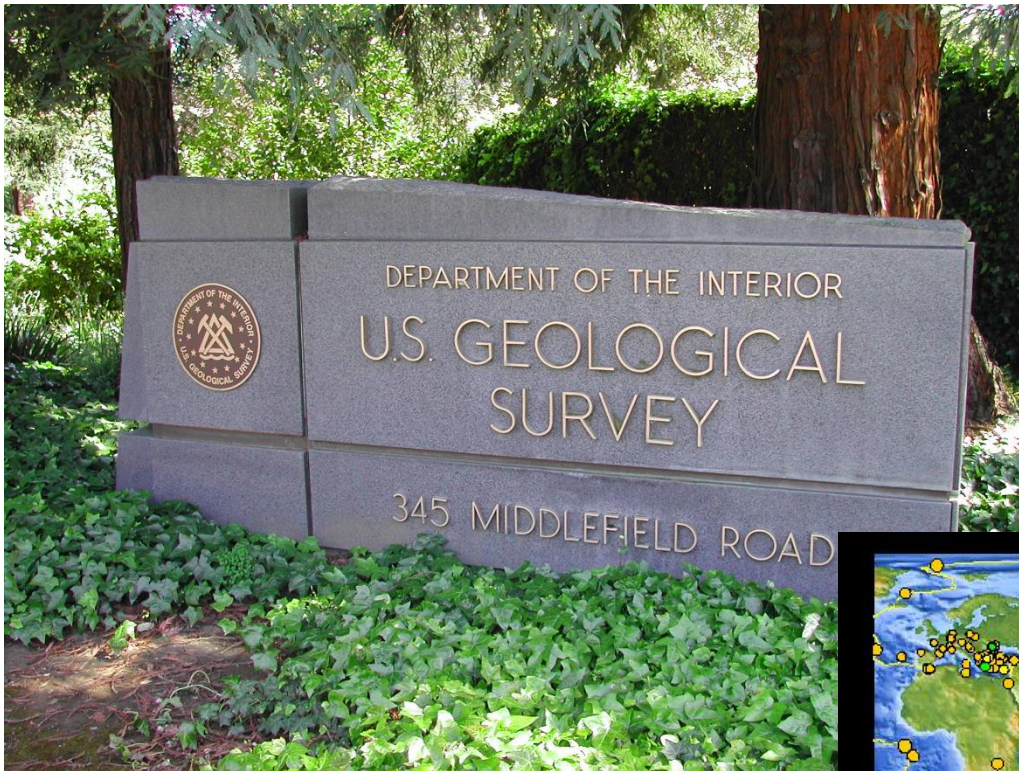
HIGHLIGHTS Upcoming Events, Products, and Services [View a complete listing of the](#)

NEWSROOM USCRN Implements New Approach to Precipitation
On August 17, 2015, the U.S. Climate Reference Network (USCRN) will change how it processes precipitation observations.

NCEI PARTNERS 

Data Sources

- ✓ National institutions that manage satellite data
 - US Geological Survey (USGS)



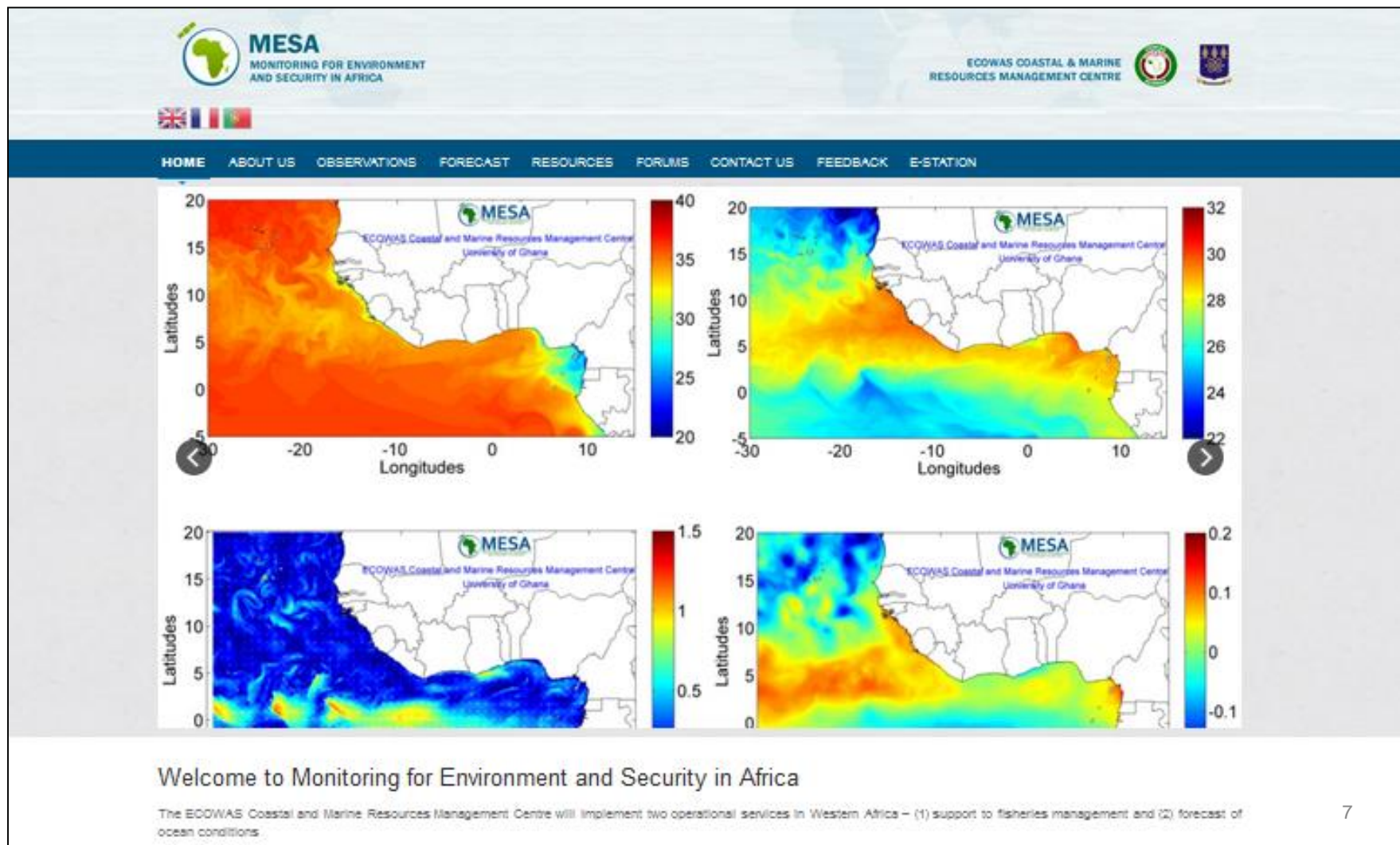
Data Sources

- ✓ National institutions that manage satellite data
 - European Space Agency (ESA)

The screenshot shows the ESA website homepage. At the top, there is a navigation bar with links: EUROPEAN SPACE AGENCY, ABOUT US, OUR ACTIVITIES, CONNECT WITH US, FOR MEDIA, FOR EDUCATORS, and FOR KIDS. Below this is a dark blue header with the text "space for europe" and the ESA logo. A "HOME" button is visible on the left. The main content area features a large image of the CBRERSO deep-space tracking station at night, reflecting light. A blue button labeled "→ LIGHTLY THRU SPACE" is overlaid on the image, with text below it: "Human spaceflight and operations image of the week: ESA's Cbreros deep-space tracking station reflecting environmentally friendly light". Below the main image is a "LATEST NEWS" section with four news items, each with a small image and a date: "13 August 2015 Rosetta's big day in the Sun", "12 August 2015 Thrusty, not rusty, pipelines owe a debt to space", "12 August 2015 Ariane 5 and Vega C begin development", and "11 August 2015 Comet's firework display ahead of perihelion". To the right of the news section is a search bar and a section titled "ESA IN YOUR COUNTRY" with flags for Germany, Spain, France, and the UK. At the bottom right, there is a "LATEST PRESS RELEASE" section with a "previous" link.

Data Sources

- ✓ National institutions that manage satellite data
 - Monitoring for Environment and Security for Africa (MESA)

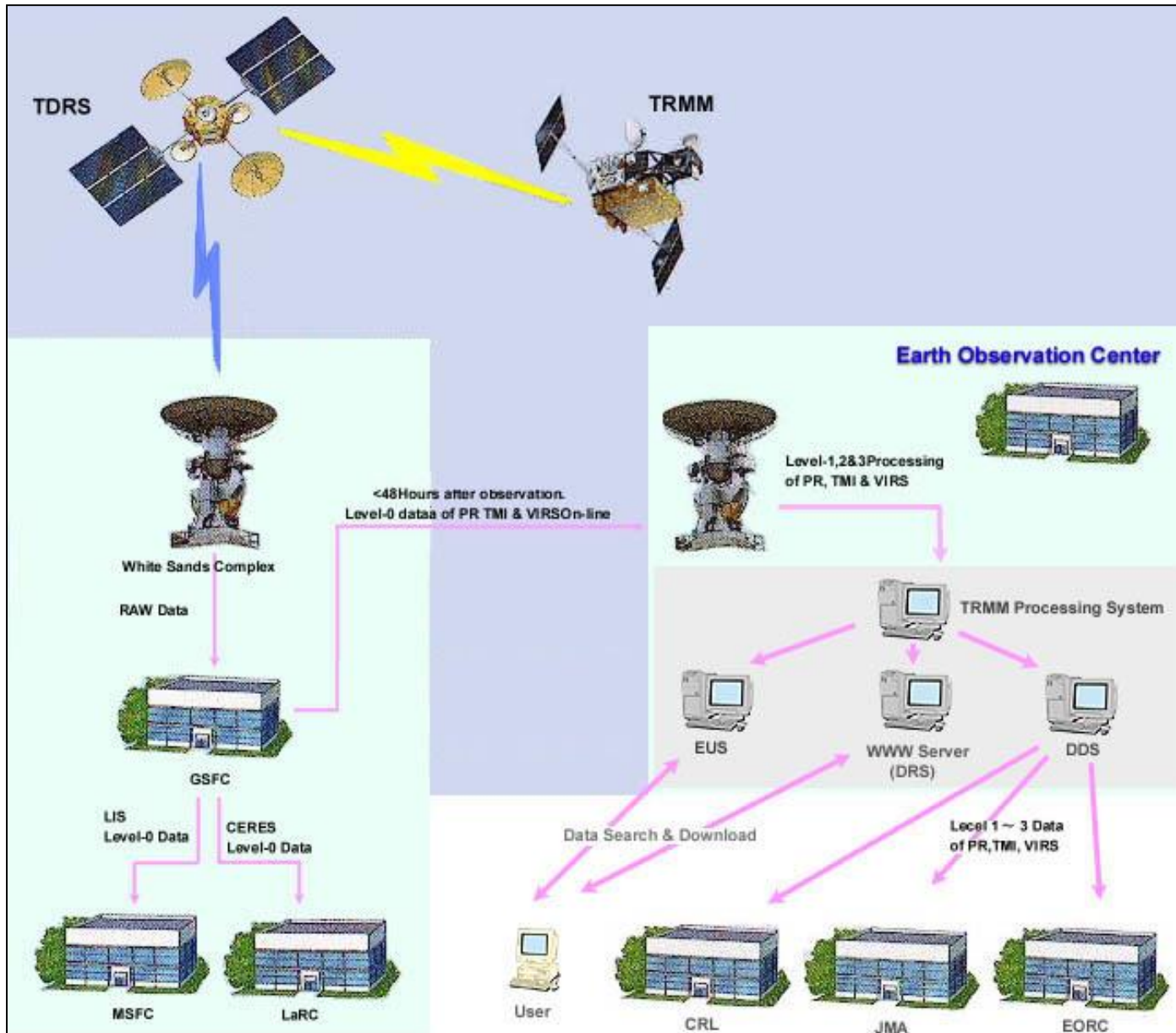


The screenshot displays the MESA website interface. At the top left is the MESA logo with the text "MONITORING FOR ENVIRONMENT AND SECURITY IN AFRICA". To the right is the logo for the ECOWAS Coastal & Marine Resources Management Centre. Below the logos are navigation links: HOME, ABOUT US, OBSERVATIONS, FORECAST, RESOURCES, FORUMS, CONTACT US, FEEDBACK, and E-STATION. The main content area features four satellite data maps of the West African coast, arranged in a 2x2 grid. Each map shows a color-coded data field over a geographic area from 20°N to 0°N latitude and -30°E to 10°E longitude. The top-left map has a color scale from 20 to 40. The top-right map has a color scale from 22 to 32. The bottom-left map has a color scale from 0.5 to 1.5. The bottom-right map has a color scale from -0.1 to 0.2. Each map includes the MESA logo and the text "ECOWAS Coastal and Marine Resources Management Centre, University of Ghana".

Welcome to Monitoring for Environment and Security in Africa

The ECOWAS Coastal and Marine Resources Management Centre will implement two operational services in Western Africa – (1) support to fisheries management and (2) forecast of ocean conditions.

Satellite Data Processing



MSFC : Marshall Space Flight Center
LaRC : Langley Research Center

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

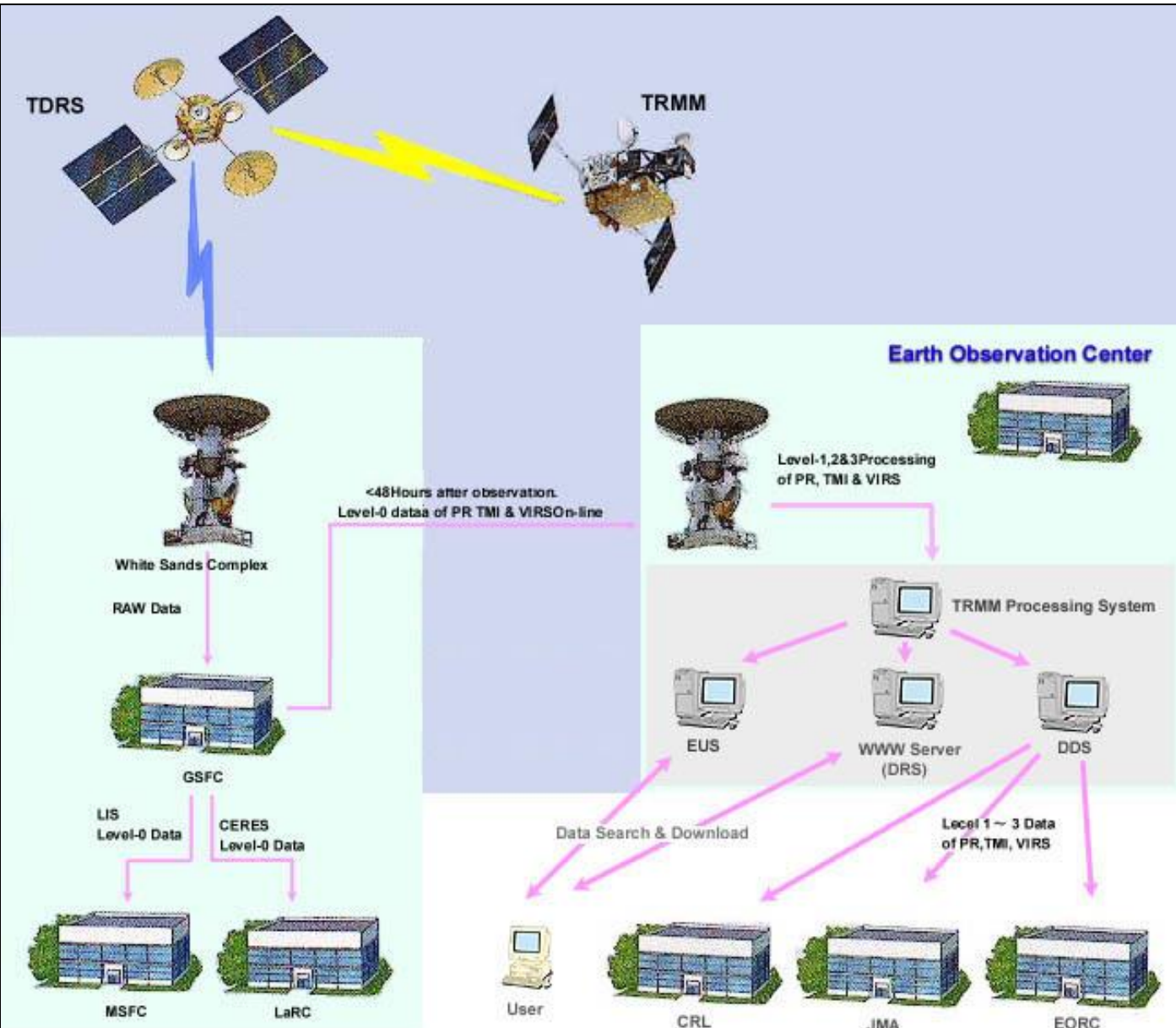
The storage capacity of magnetic media on board the satellite is crucial if a long time period is passed between the measurements and the transmission of obtained information to Earth.

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 1/6-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



MSFC : Marshall Space Flight Center
LaRC : Langley Research Center

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;

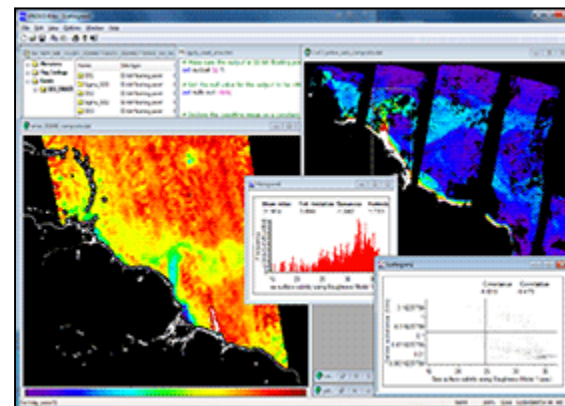
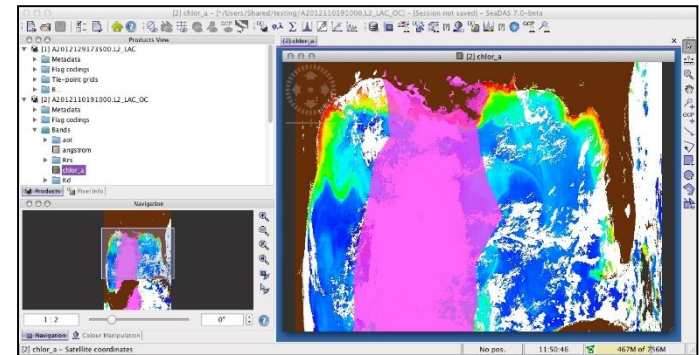
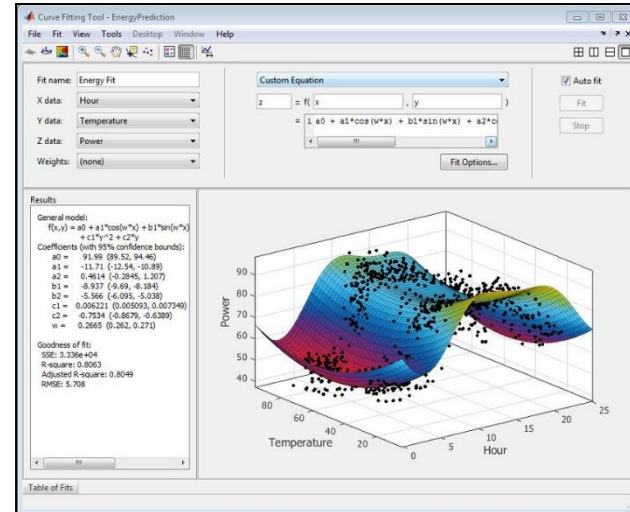
Level 2 – Derived oceanic variable, atmospherically corrected and geolocated, but presented in sensor coordinates;

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.

Satellite Data Processing

- ✓ Computer programming software: Matlab, Python, Ocean Data View,
- ✓ 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.

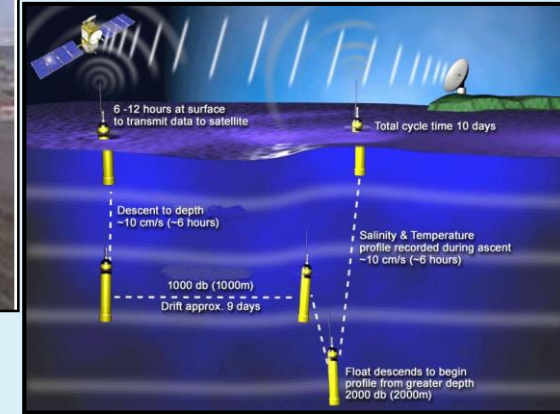
Remote sensing of the sea: Data usage

1. Sensor calibration



2. Atmospheric correction

3. Positional registration



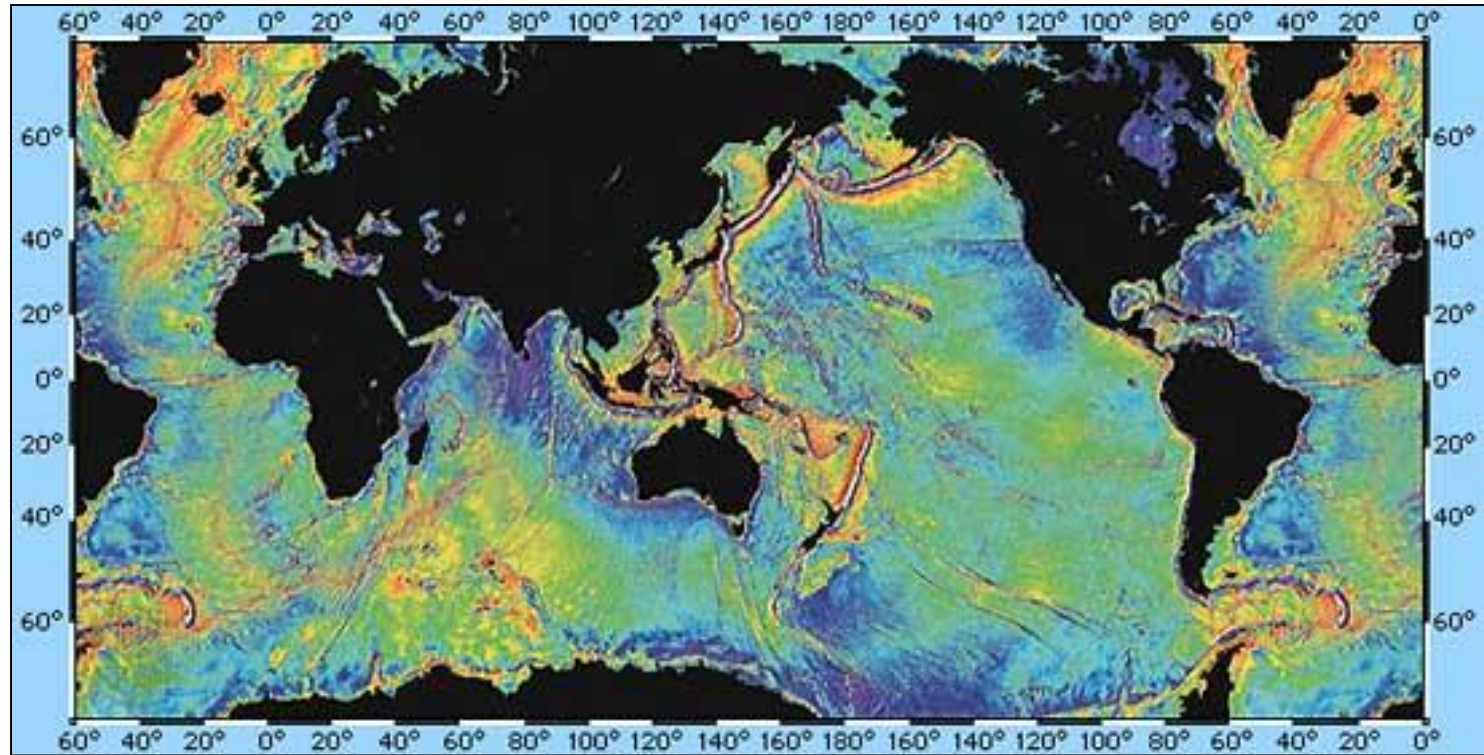
4. Oceanographic sampling for “sea truth”

5. Image processing

6. Oceanographic applications of satellite Remote sensing

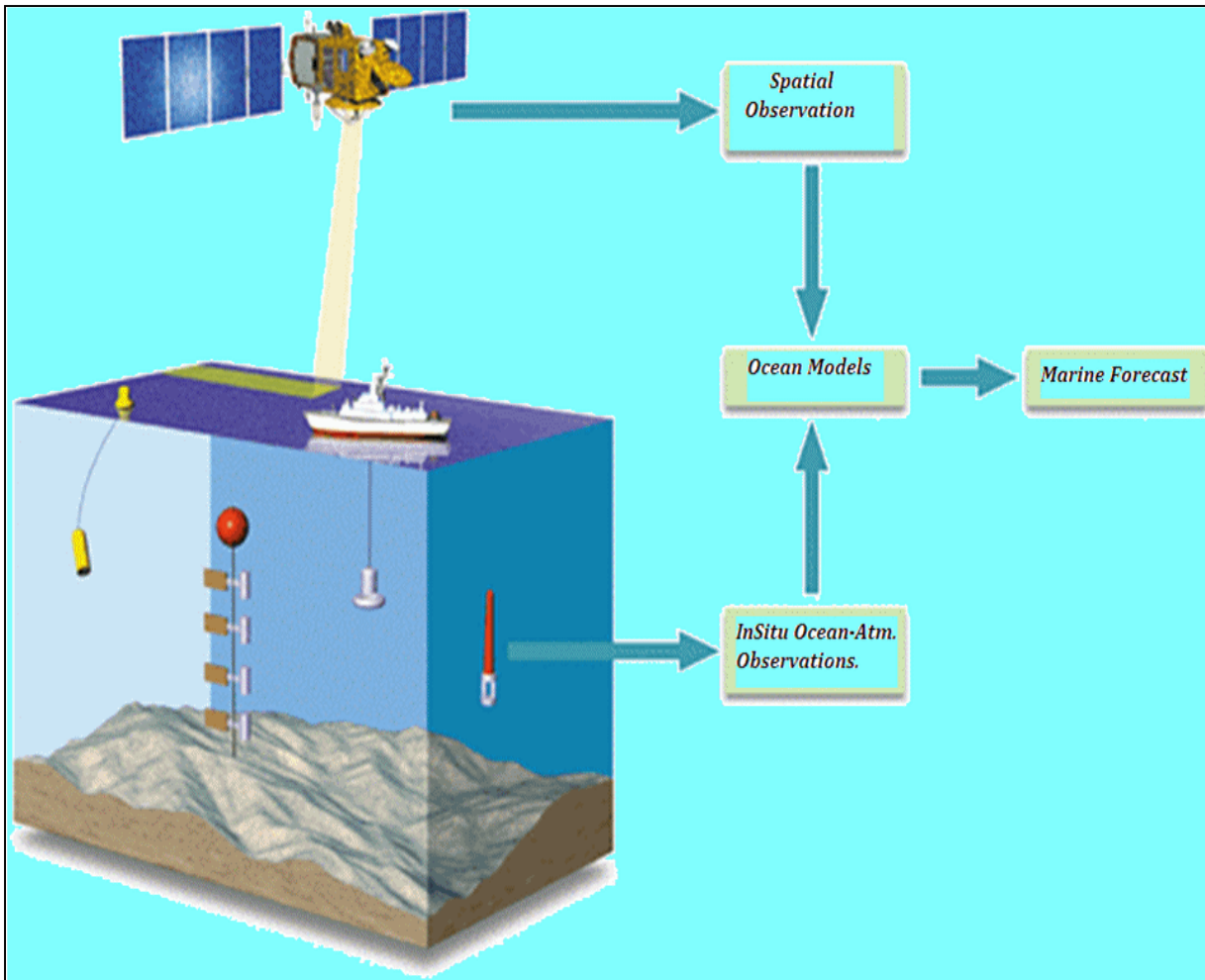


Application: Bathymetry and Navigation



- 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



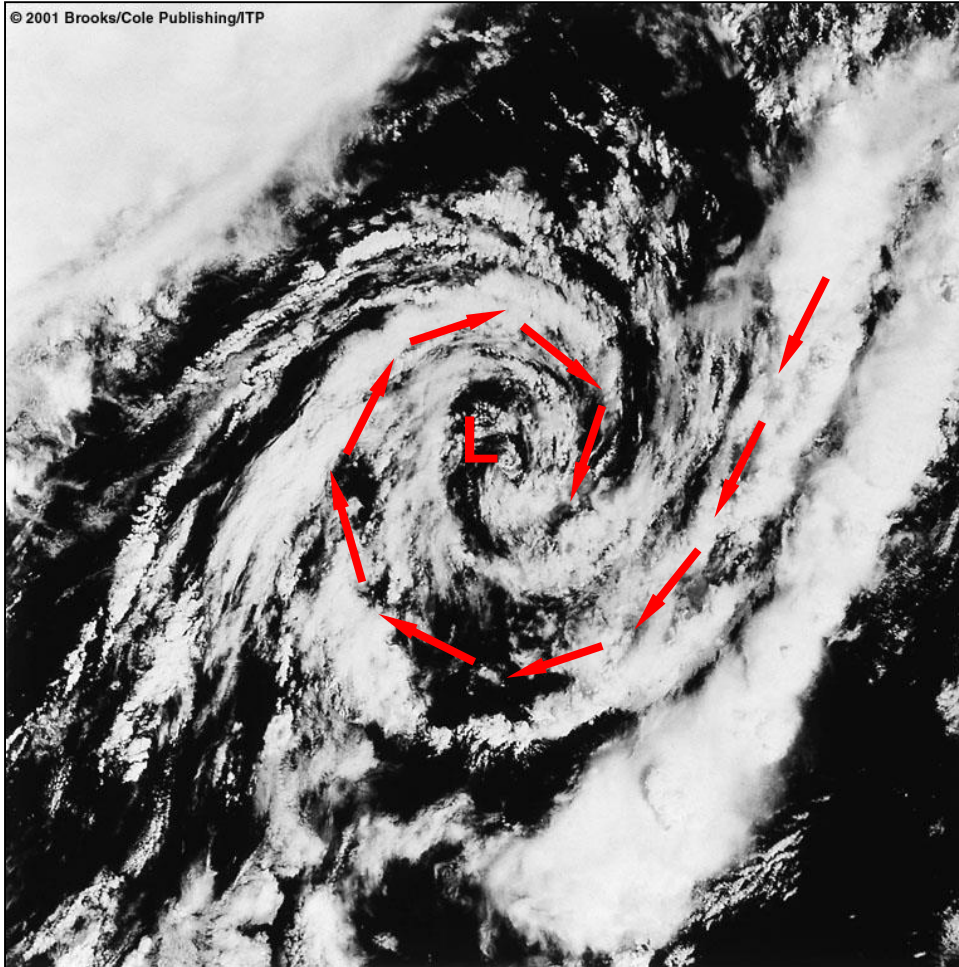
Marine weather info needed for

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

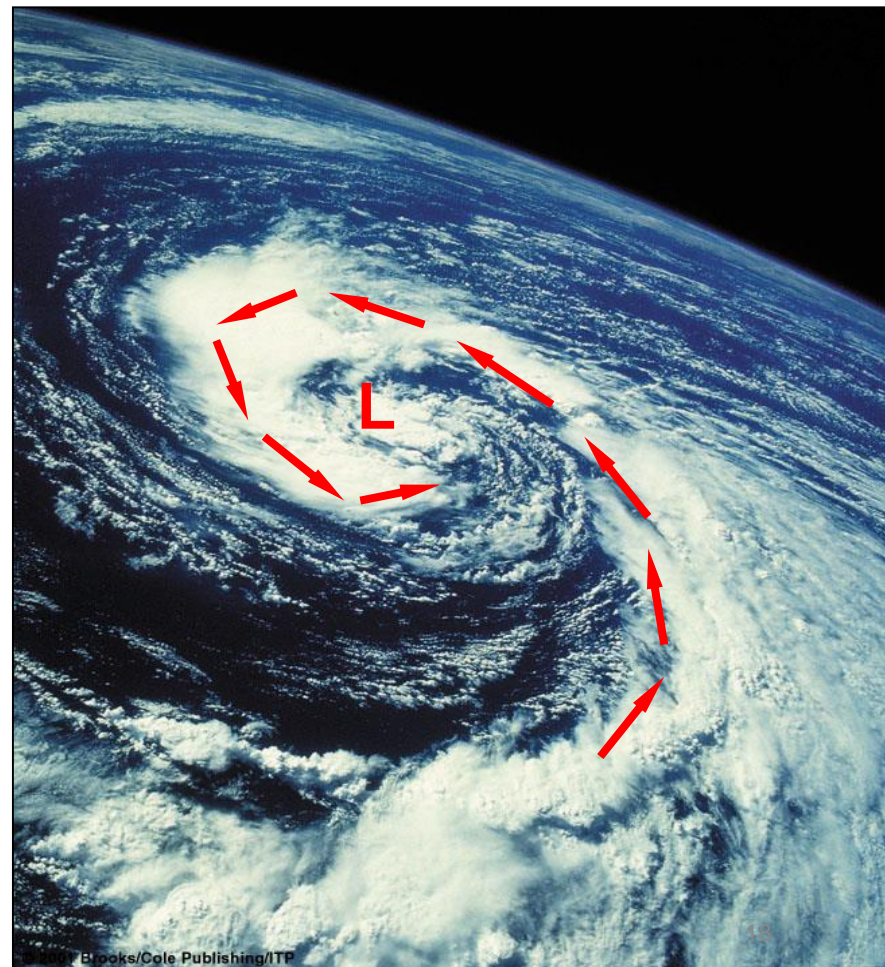
Maps of ocean currents, eddies, and winds are used in commercial shipping to optimize routes.

Cyclonic Flow: (flow around a low pressure center)

Clockwise in SH

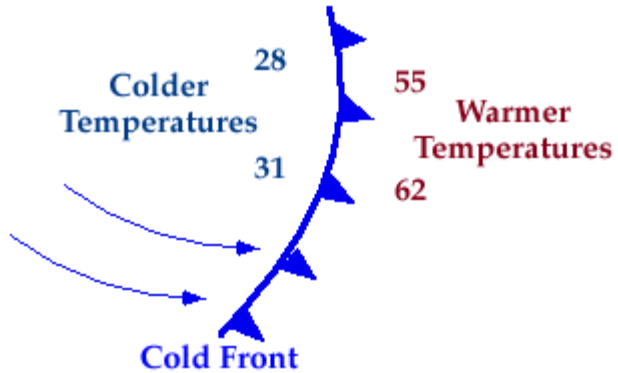


Counterclockwise in NH

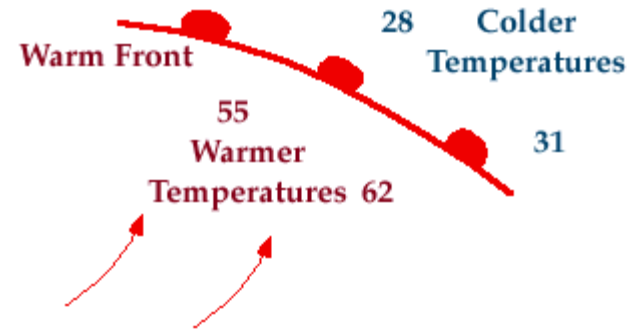


Fronts: air masses

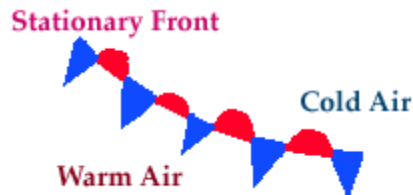
- **Cold front:** cold, dry stable air is replacing warm, moist unstable air.



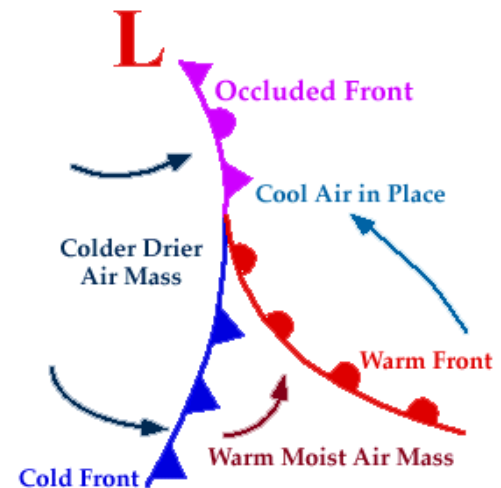
- **Warm front:** warm, moist unstable air is replacing cold dry stable air.



- **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

Beaufort Wind Force Scale



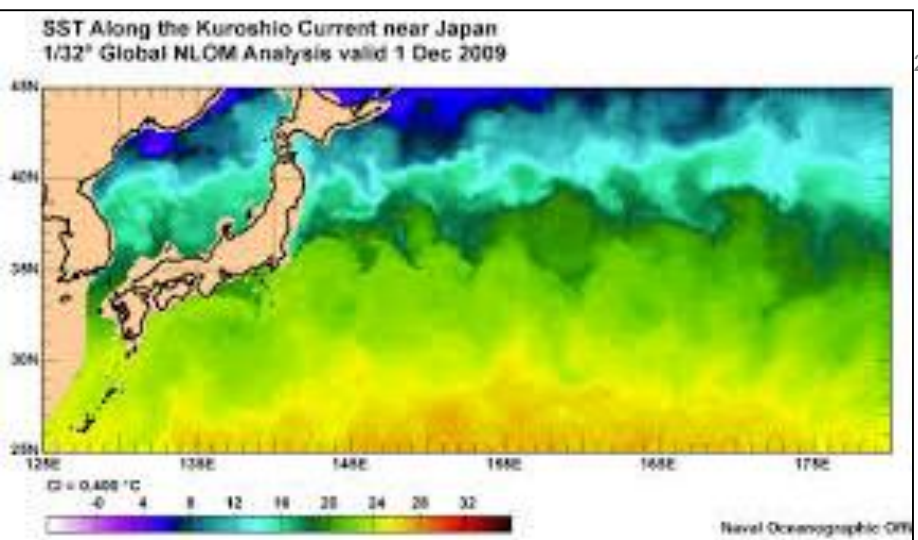
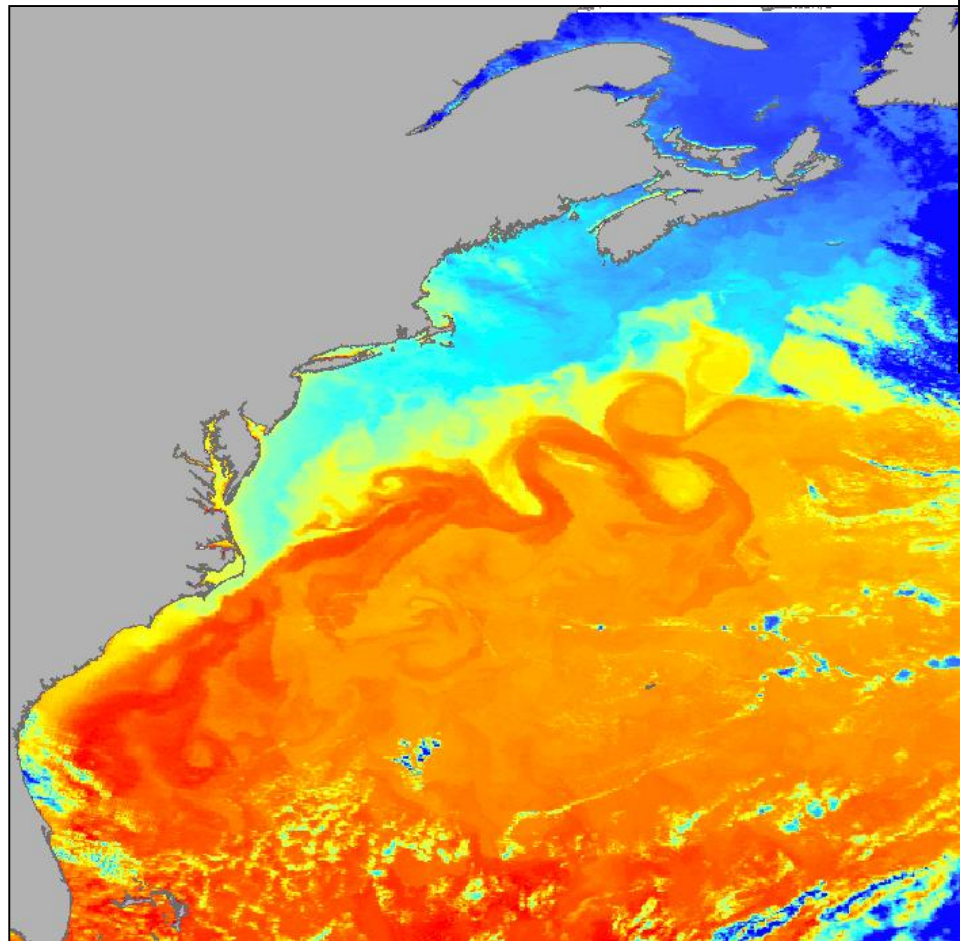
The Beaufort scale (pronounced bay-foor) is an empirical measure for describing wind speed. It was originally based on observed sea conditions, in the early 19th Century, British naval officers made regular weather observations, but there were no standard terms, and one captain's "giff breeze" might be another's "soft breeze". Sir Francis Beaufort, a British admiral and hydrographer, created the scale in 1805. It was made a standard for ship-log entries on Royal Navy vessels in the year 1827. The first modification was introduced in 1840. It borrowed actual wind speeds. Four years later the scale was revised to include trees. The growth of steam power led to a major revision in 1876. The original descriptions were based on observation of the sea. They were changed to describe the conditions of the sea. The scale was also expanded to include conditions on land. Today the terms and the scale are used by meteorologists and farmers worldwide. The information presented on this poster makes it possible for anyone to determine wind speed based on nothing more than visual observations. The original Beaufort scale included sail setting instructions for each condition. This poster follows that example.

Adapted by Francis Beaufort

Force	Name	Wind Speed (MPH)	Wind Speed (Knots)	Wind Speed (km/h)
0	"Calm"	<1	0.0	0.0
1	"Light Air"	1-3	0.3-0.8	0.5-1.3
2	"Light Breeze"	4-7	0.8-1.6	1.3-2.6
3	"Gentle Breeze"	8-12	1.6-3.2	2.6-5.1
4	"Moderate Breeze"	13-17	3.2-4.7	5.1-7.4
5	"Fresh Breeze"	18-24	4.7-6.3	7.4-10.4
6	"Strong Breeze"	25-30	6.3-8.2	10.4-14.0
7	"Near Gale"	31-38	8.2-10.4	14.0-18.5
8	"Fresh Gale"	39-46	10.4-12.5	18.5-24.1
9	"Strong Gale"	47-54	12.5-14.6	24.1-31.3
10	"Storm"	55-63	14.6-17.3	31.3-40.7
11	"Violent Storm"	64-72	17.3-19.8	40.7-52.1
12	"Hurricane"	>73	>19.8	>52.1

Each cell of the poster contains an illustration of a coastal scene with a house, a pier, and a sailboat, showing the increasing severity of wind and waves from calm to hurricane. Each cell also includes a small text box with additional details or historical notes.

Fronts: water masses



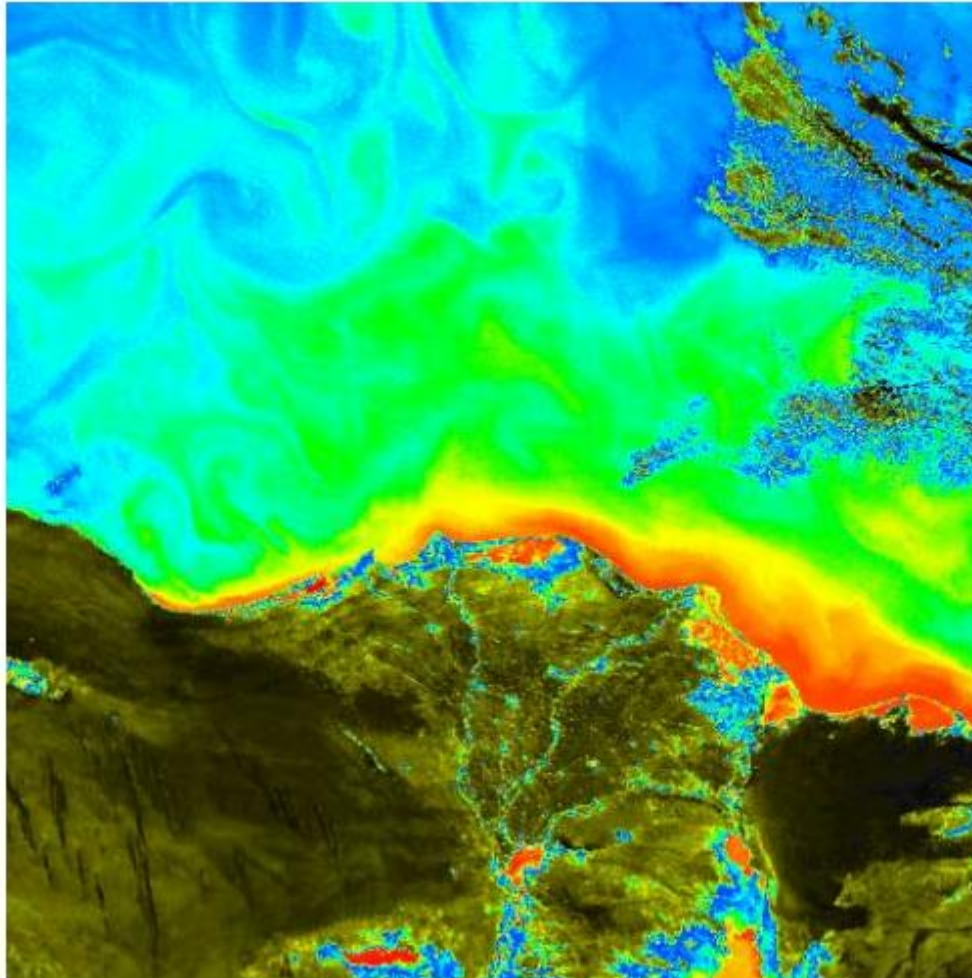
SST fronts provide information on a variety of processes in the ocean:

--- Enhanced gradients of:

- temperature
- density

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

Application: ATSR image of the Nile Delta

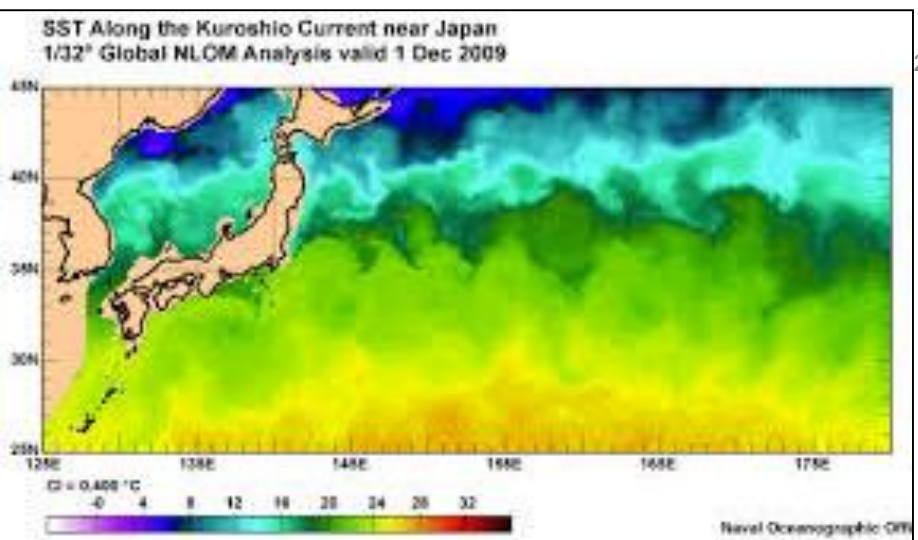
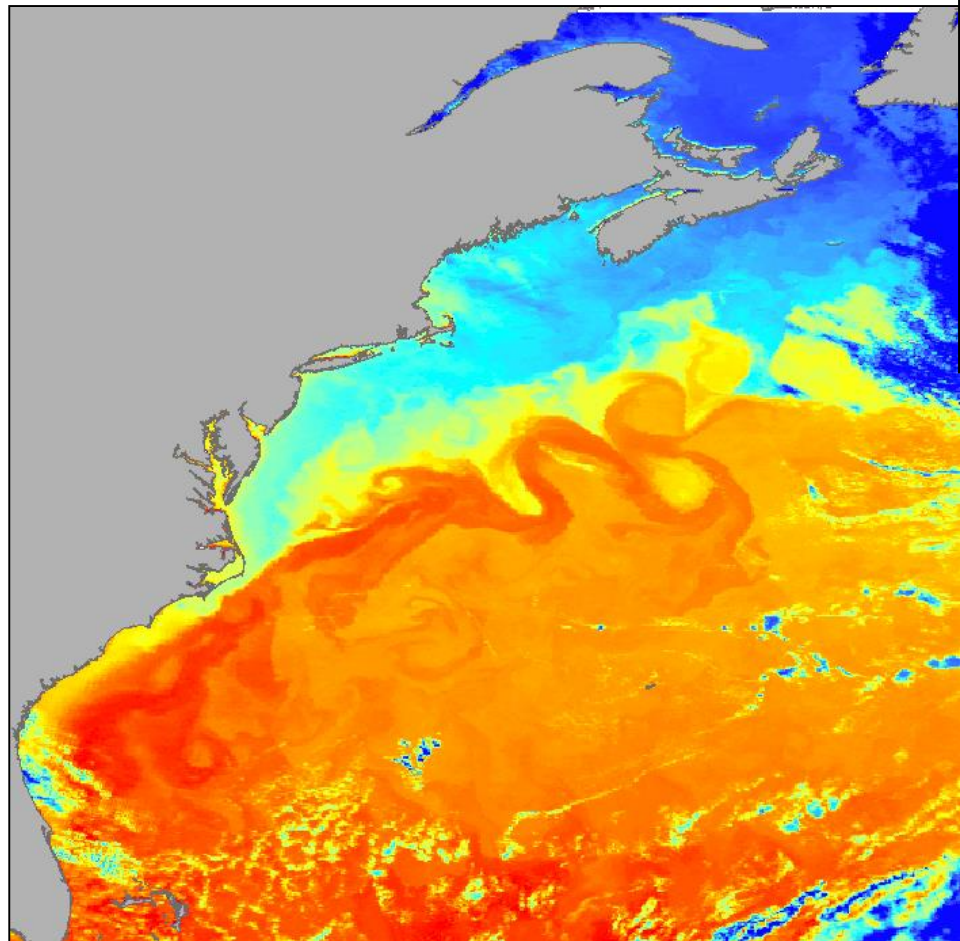


clouds

warm shallow
water at a
temperature of
around 17 °C

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

Fronts: water masses

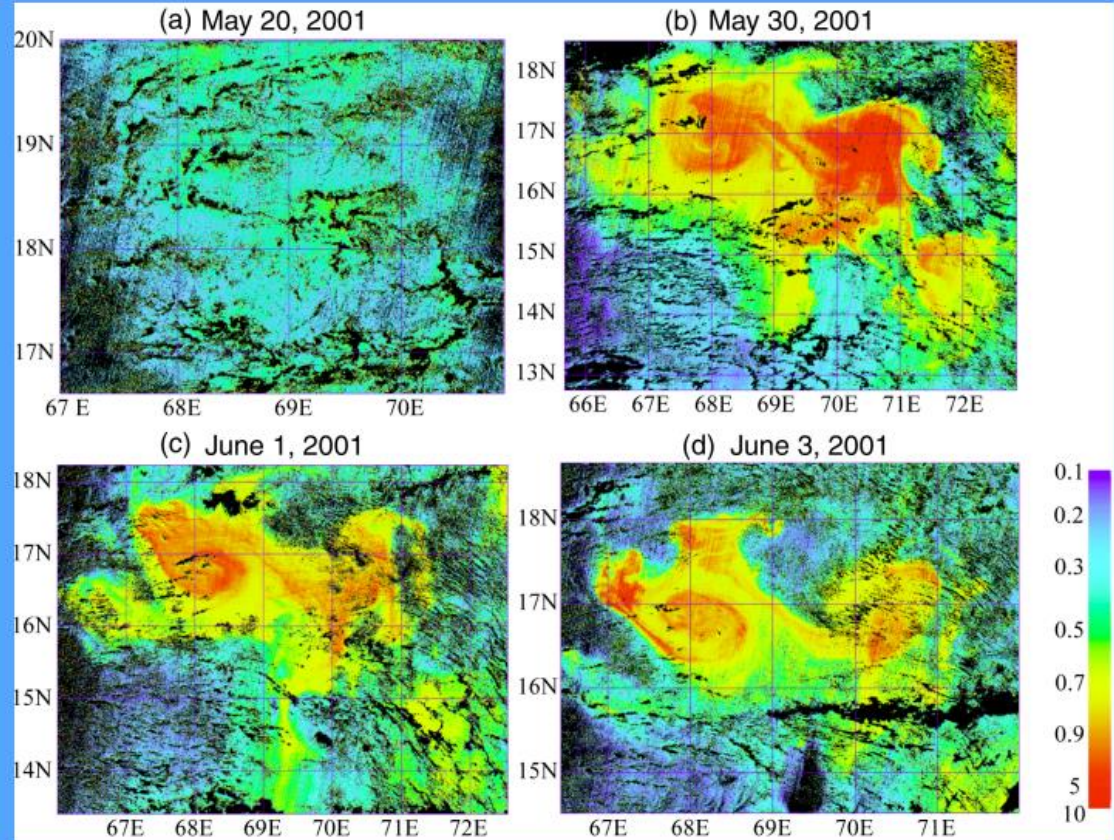
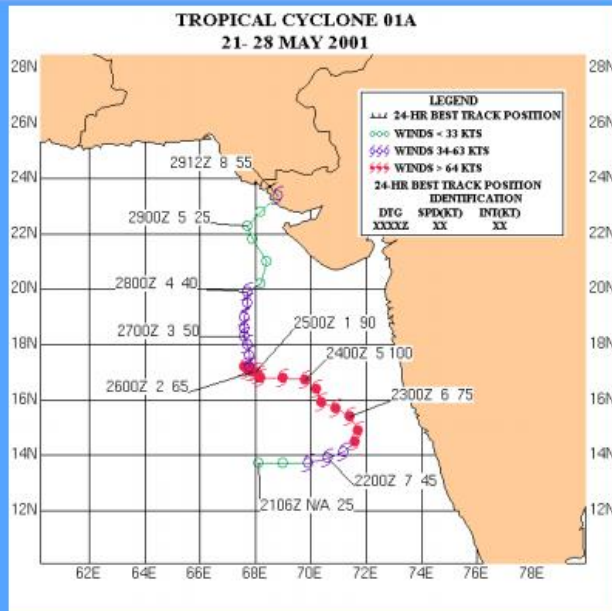


SST fronts provide information on a variety of processes in the ocean:

- Enhanced gradients of:
- temperature
- density

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

Influence of tropical cyclones on Chlorophyll-a



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

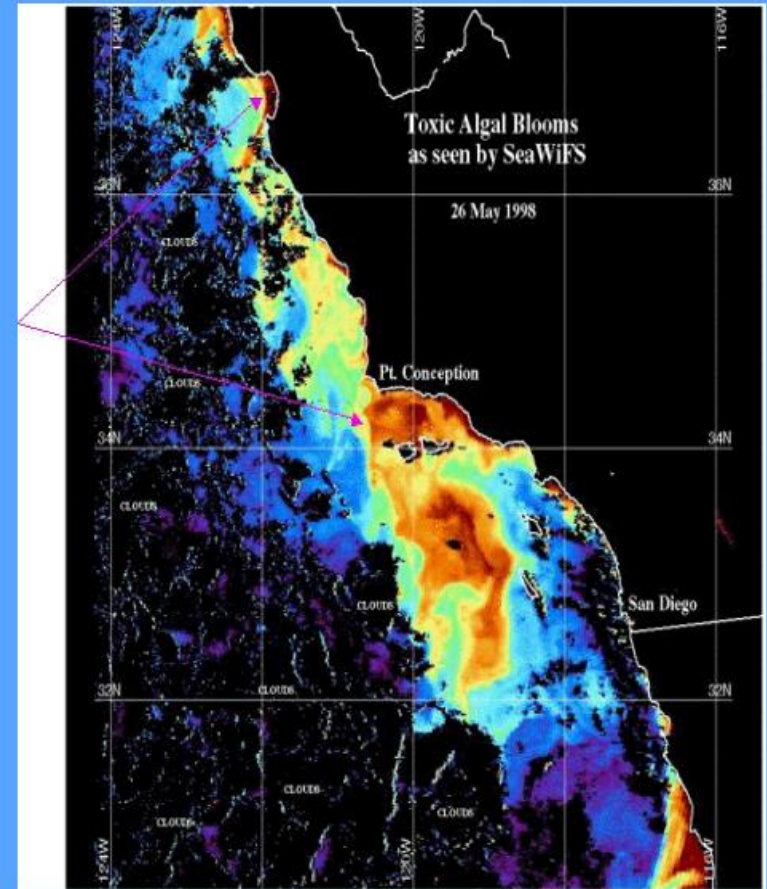
Water quality: Algal blooms

Coccolithophore blooms and Toxic algal blooms from SeaWiFS

Coccolitho-
phore
blooms
shown via
SeaWiFS

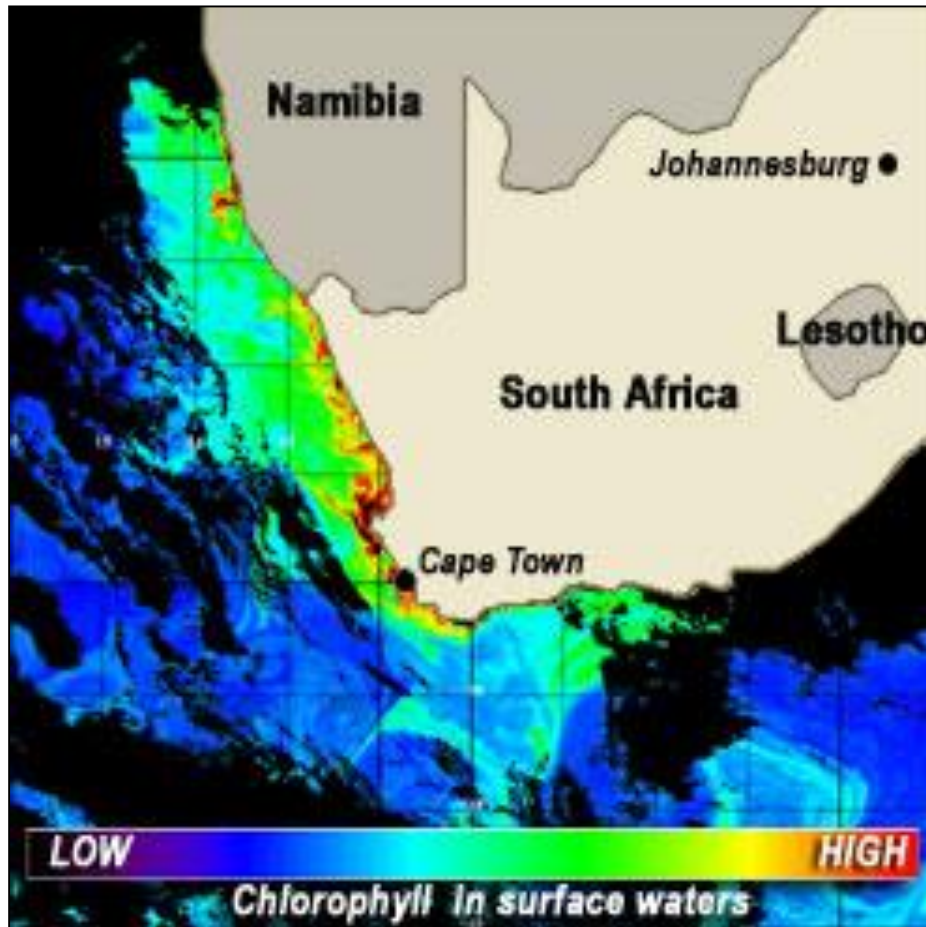


Extensive
patches of
high
reflectance
blooms



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

Water quality: Algal blooms



Bloom in southern Africa

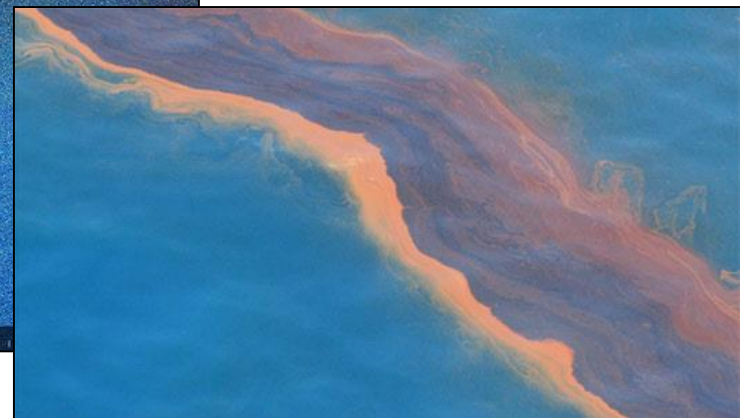
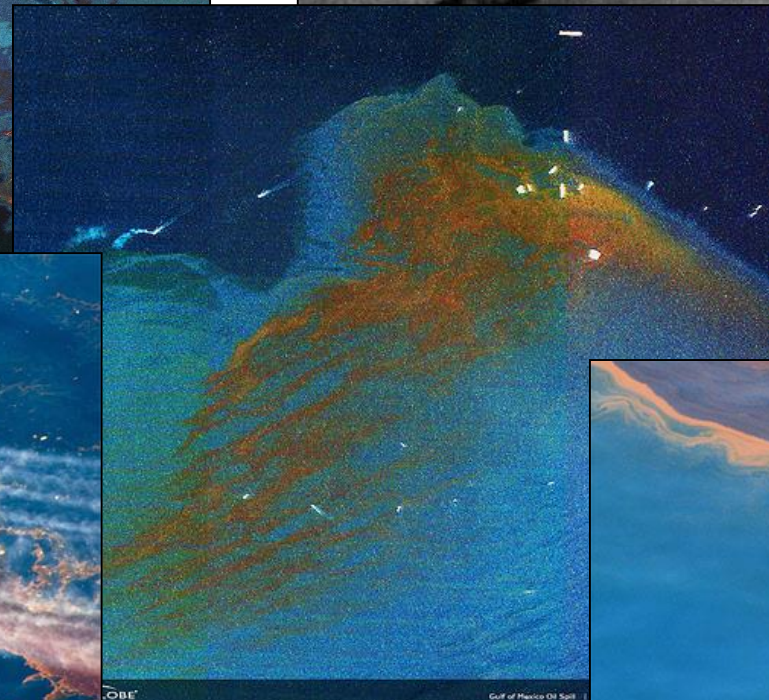
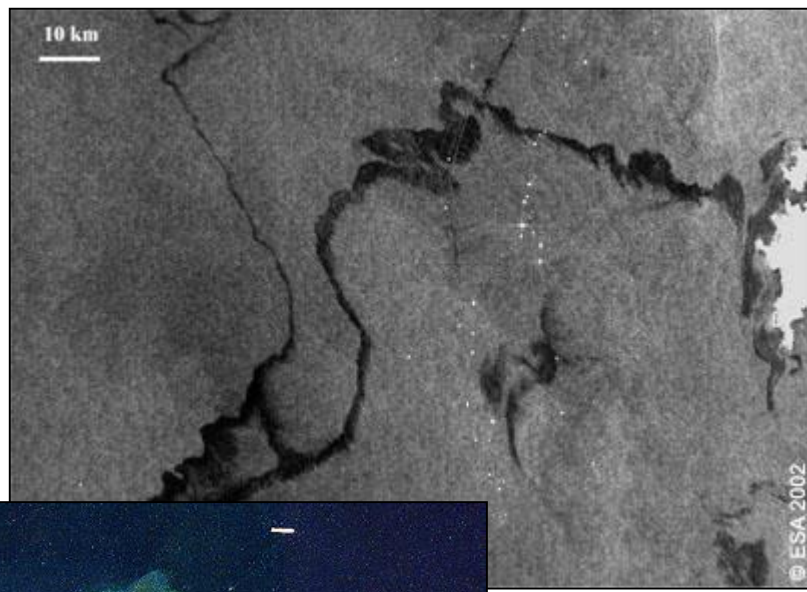


An algae bloom off the southern coast of England in 1999 as observed from satellite

Water quality: Oil spill

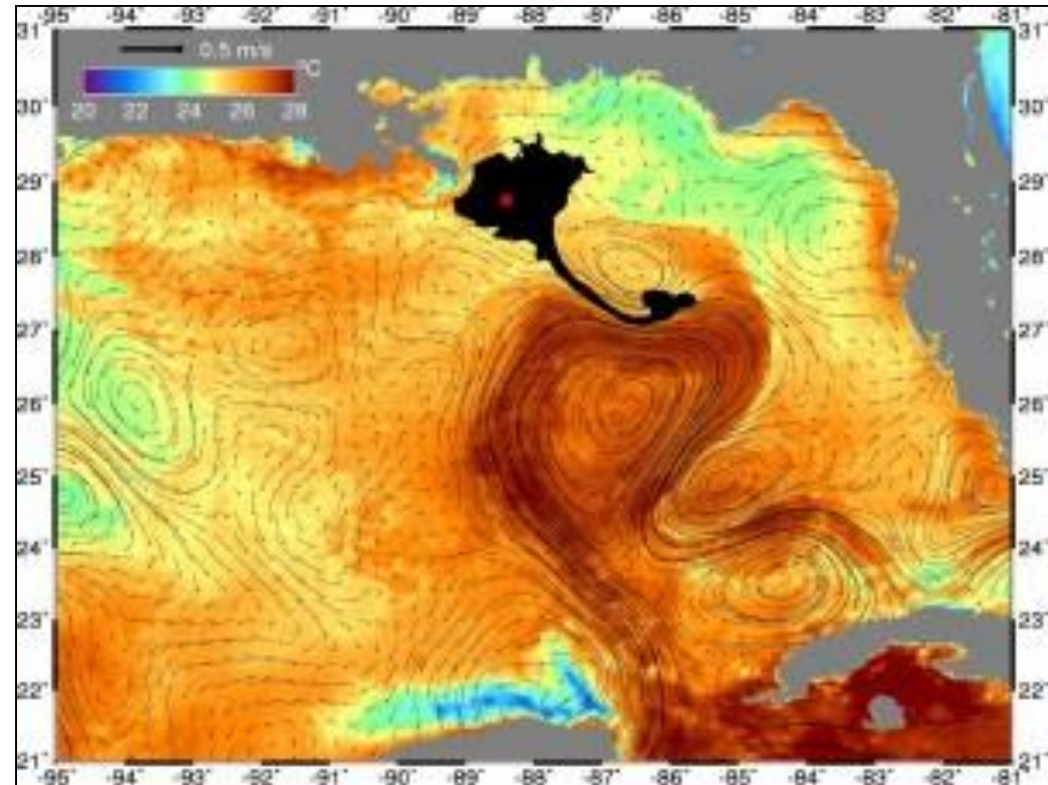
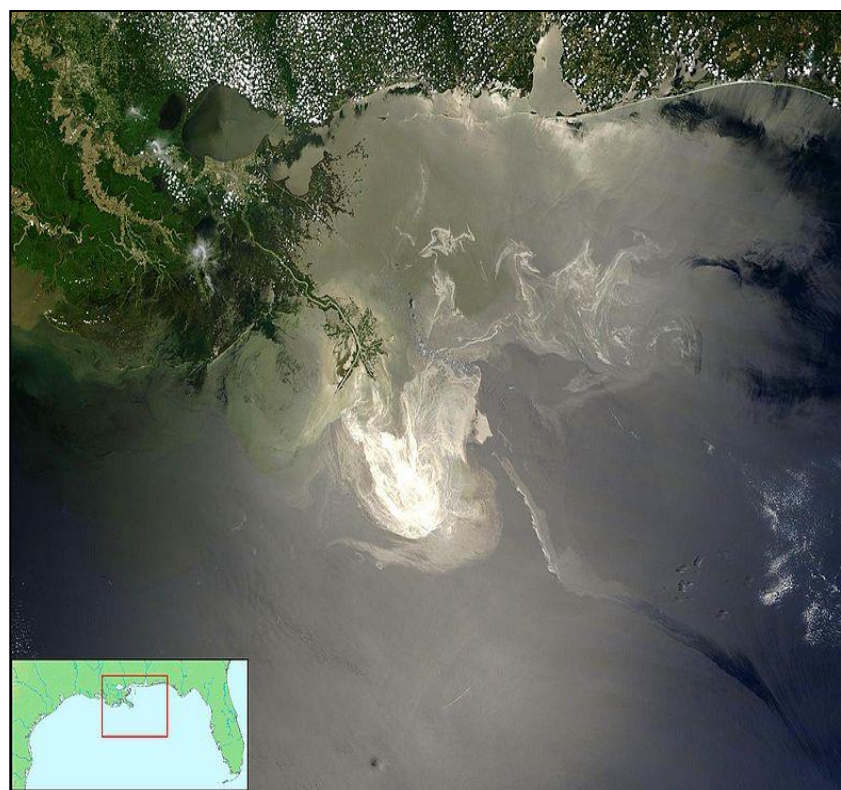
Country : USA
Area : Transocean Deepwater
Horizon Drilling Oil Slick
Clean Up - Gulf of Mexico
Sensor : WorldView-2
Acquisition Date : June 15, 2010
Resolution (GSD) : 0,5 Meter

Burning off oil on surface
different sensor bands
from WorldView-2
satellite to highlight the
oil and dispersant



COBE Gulf of Mexico Oil Spill

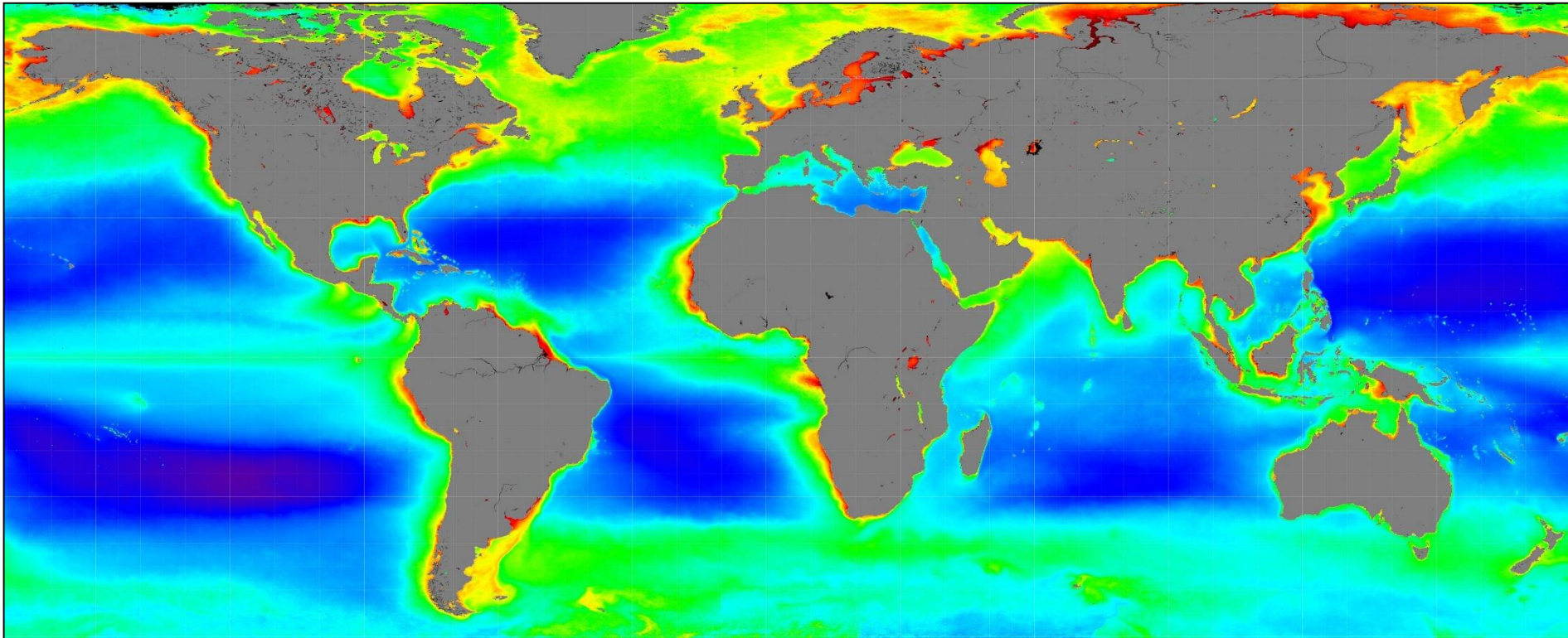
Multi-satellite application: Oil spill



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

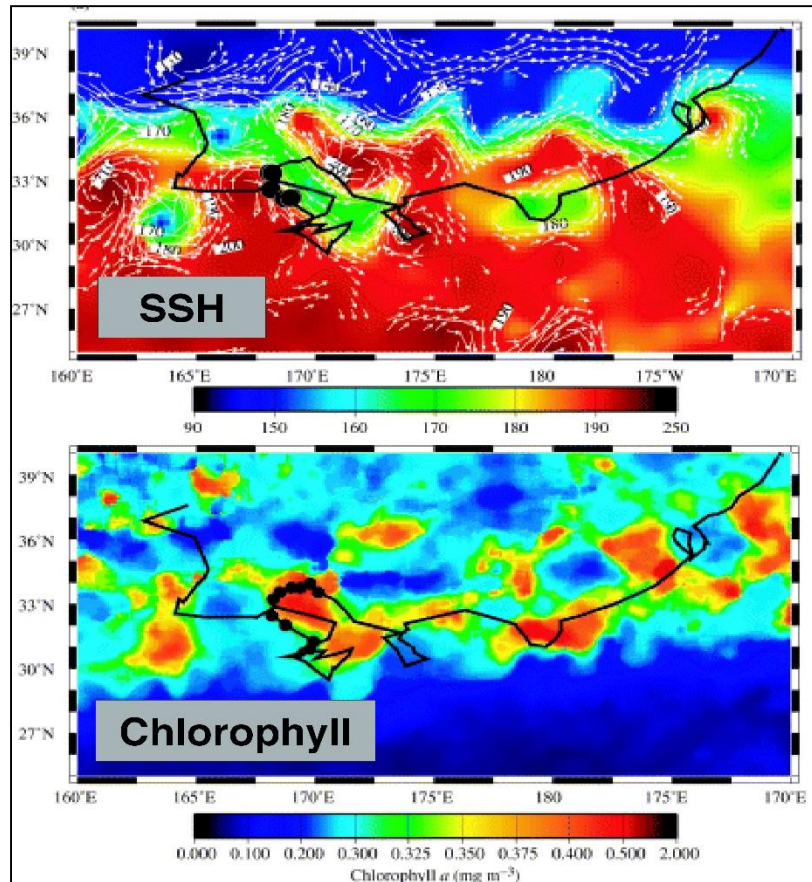
- Habitat Classification: SST, SSH, ocean color, ocean winds and sea ice
- Info: ocean fronts, eddies, convergence zones, river plumes and coastal regions,



Chl map: potential productive zones

Satellite data and fisheries

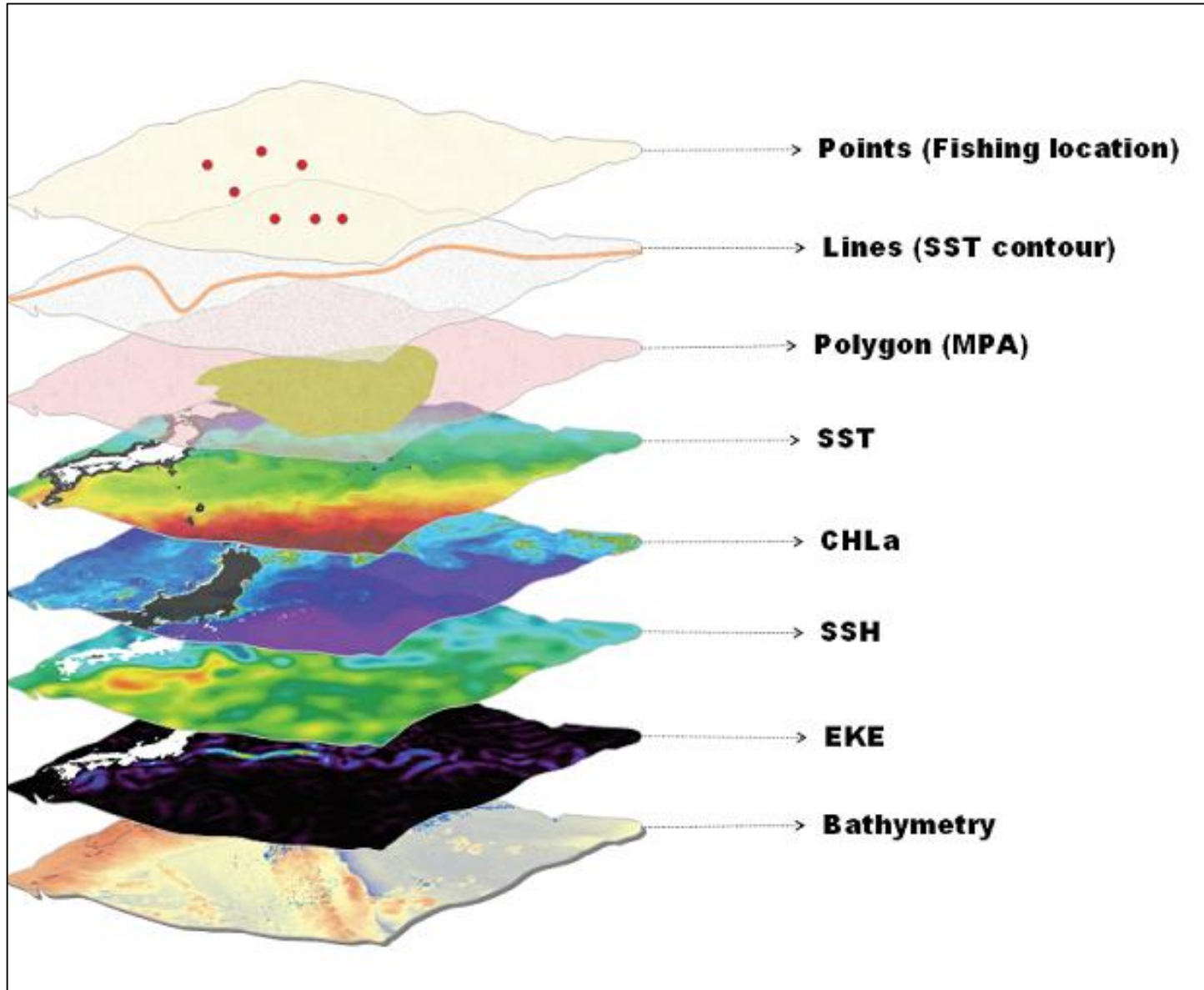
- Habitat Classification: SST, SSH, ocean color, ocean winds and sea ice
- Info: ocean fronts, eddies, convergence zones, river plumes and coastal regions,



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

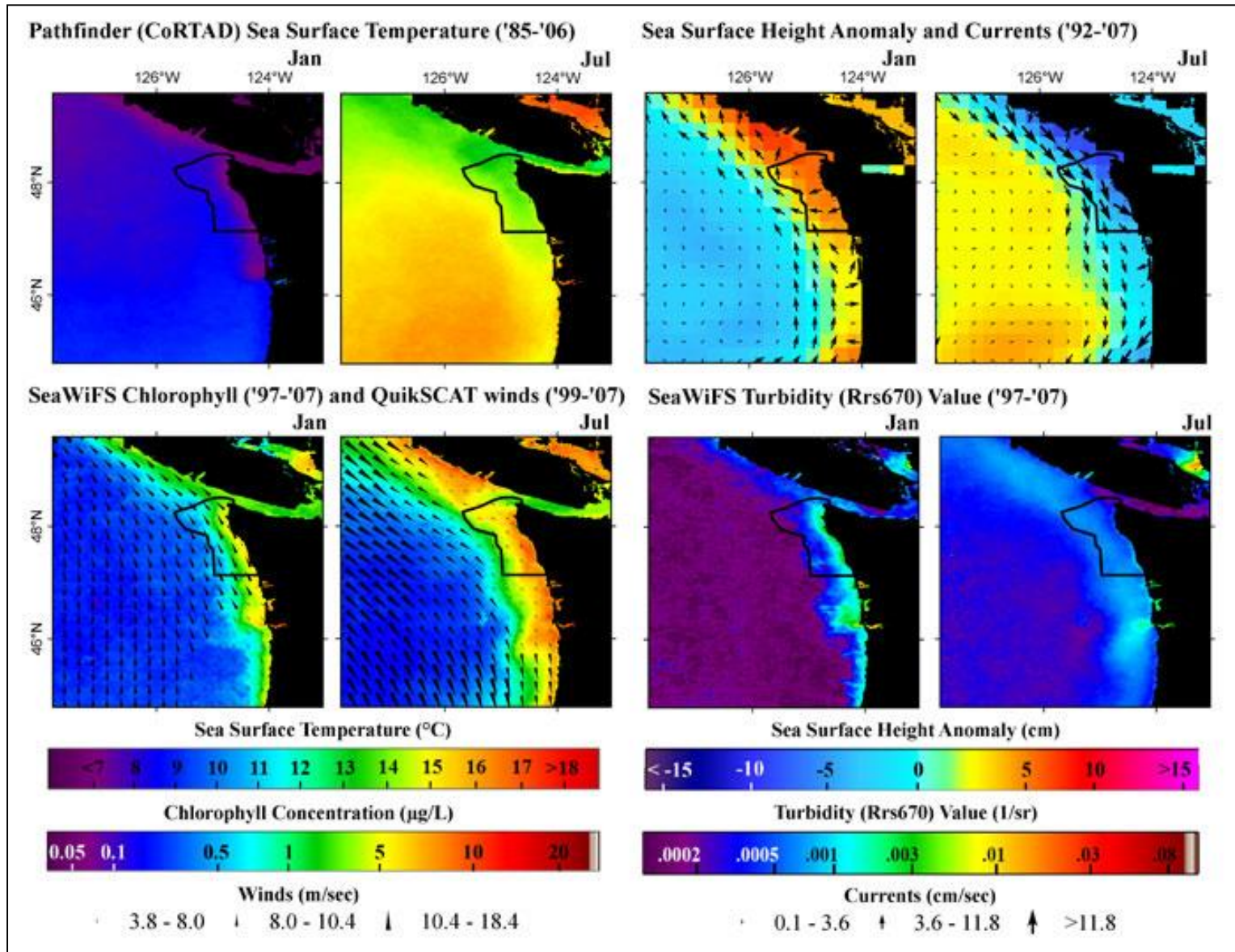


Satellite data and fisheries



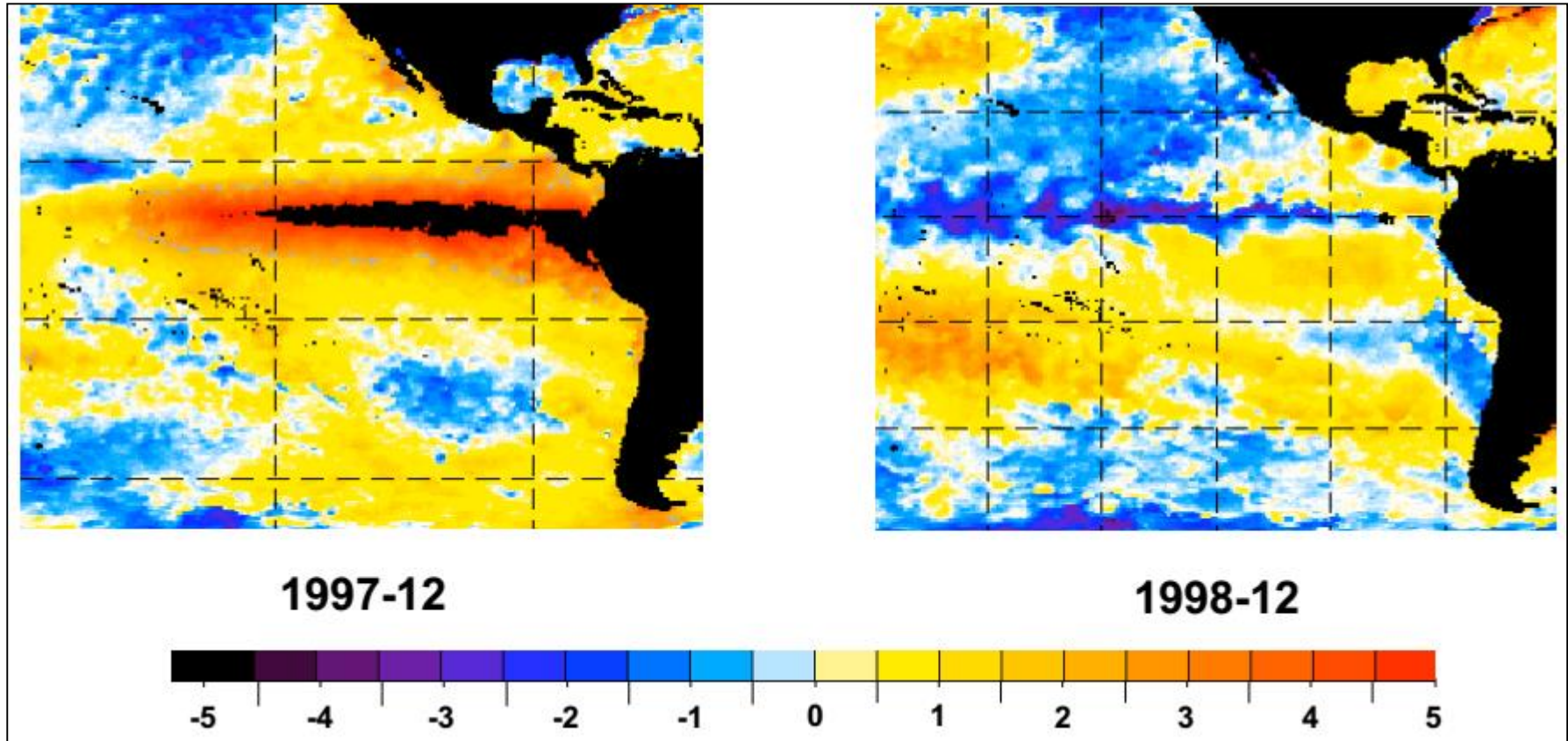
Assessing the viability of a fishing ground

Multi-satellite application



NW Pacific biophysical info from multiple satellite products

Application: Special Events - El Nino and La Nina



AVHRR Ocean pathfinder SST anomalies

Normal conditions

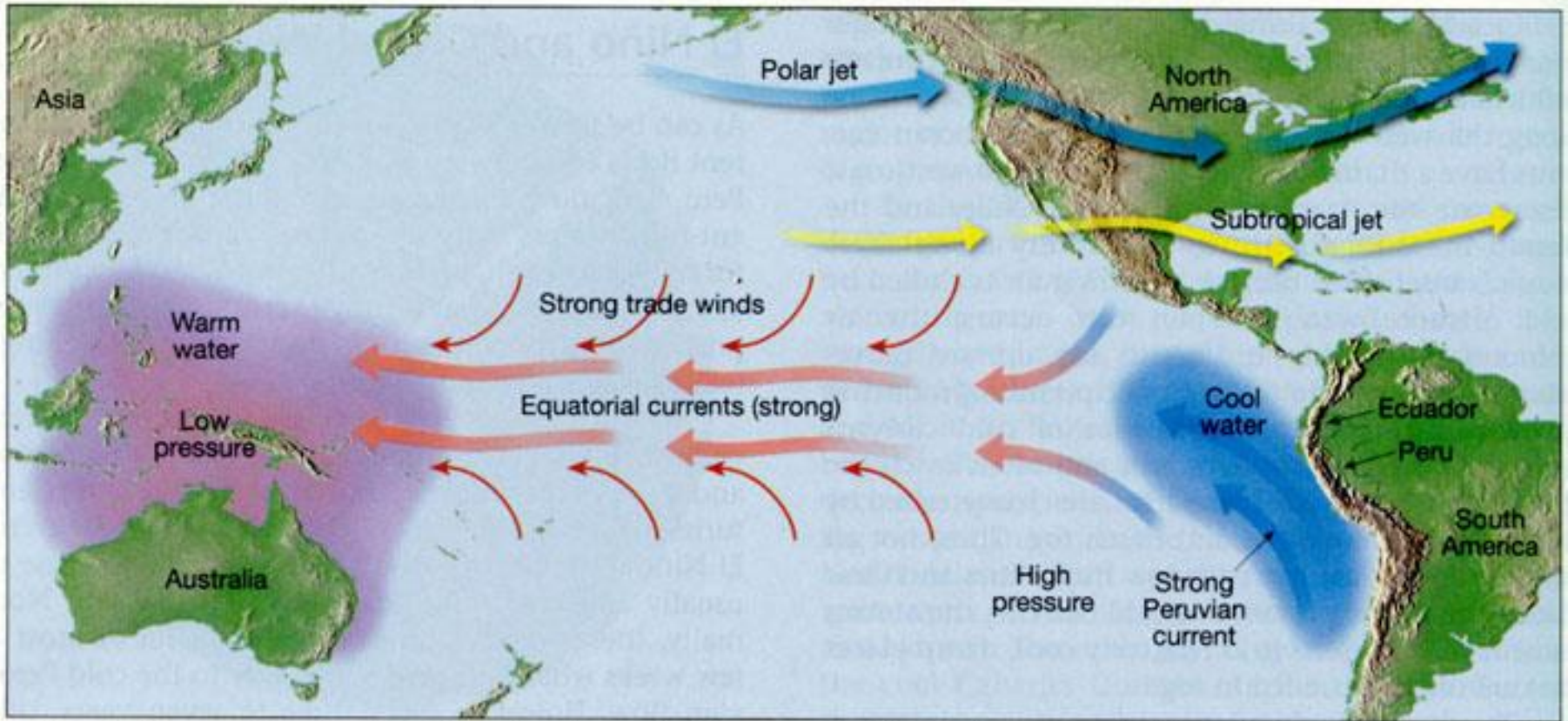
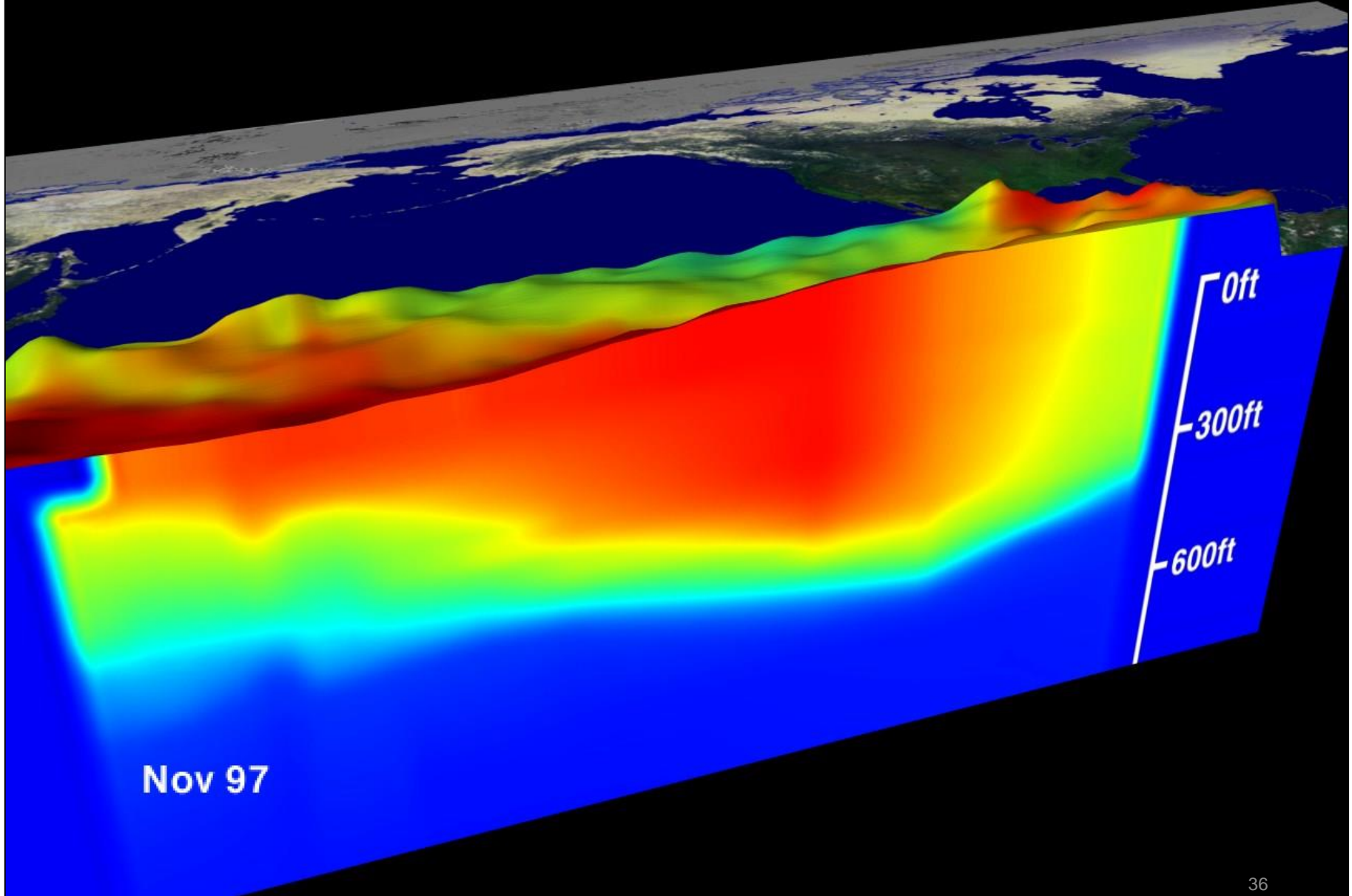
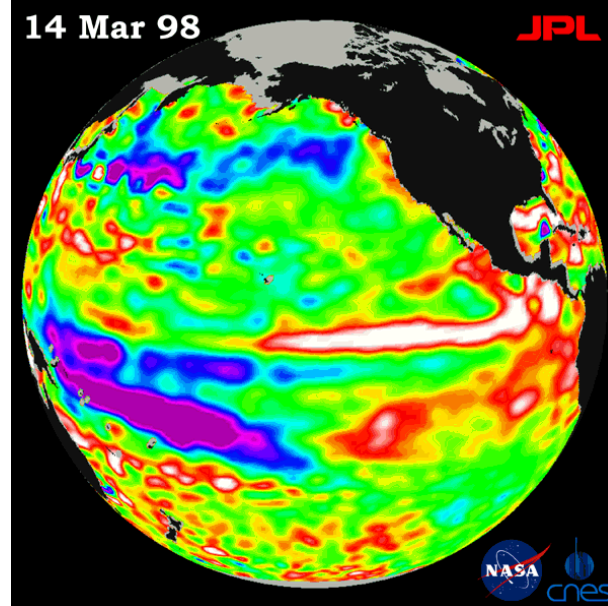
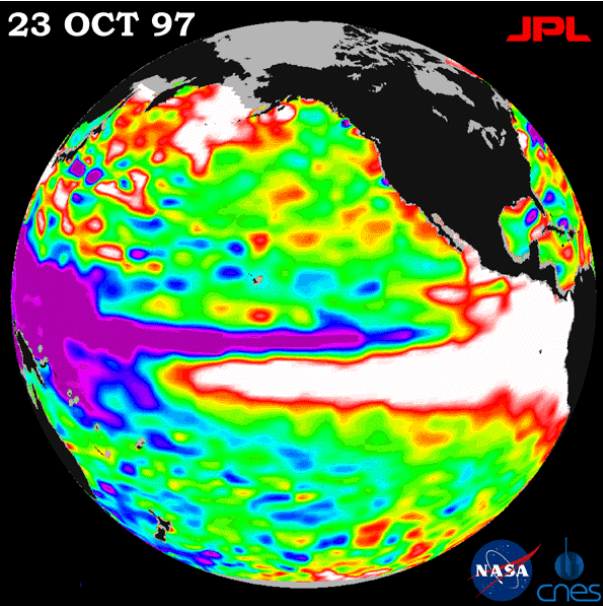


Fig.6 Normally, the trade winds and strong equatorial currents flow toward the west. At the same time, an intense Peruvian current causes upwelling of cold water along the west coast of South America.

El Niño – Southern Oscillation (ENSO)



ENSO: stages

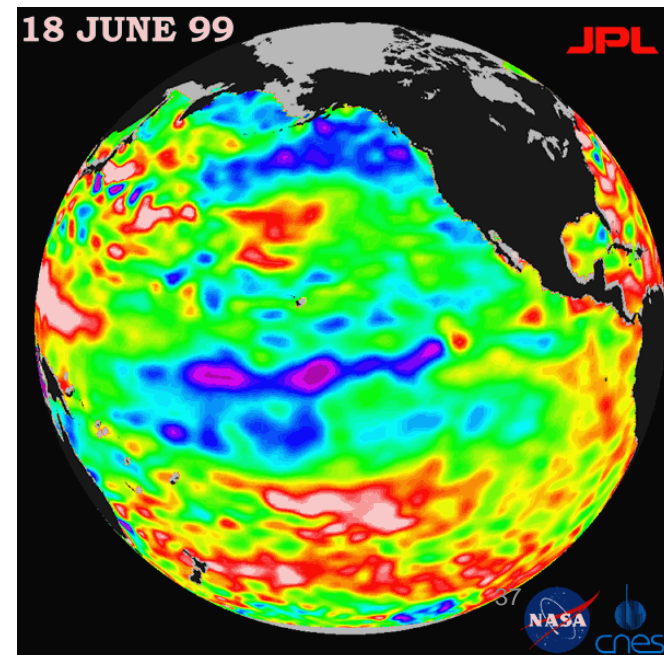
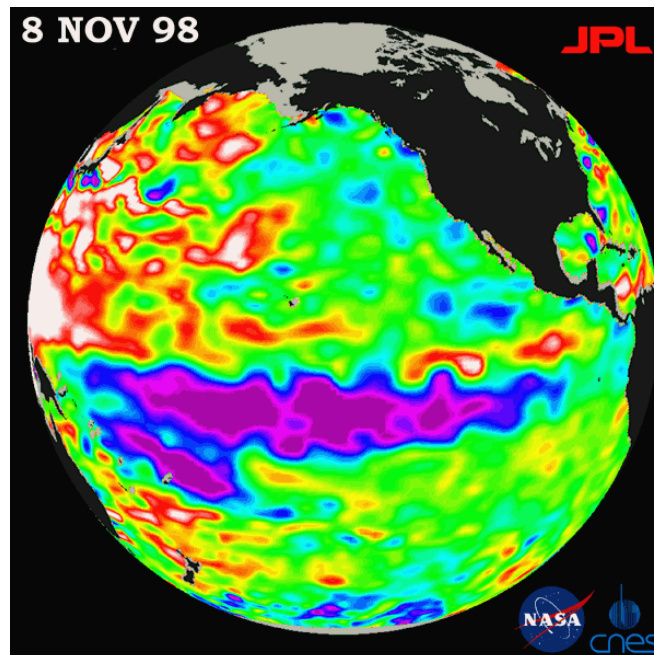


Full El Niño
condition

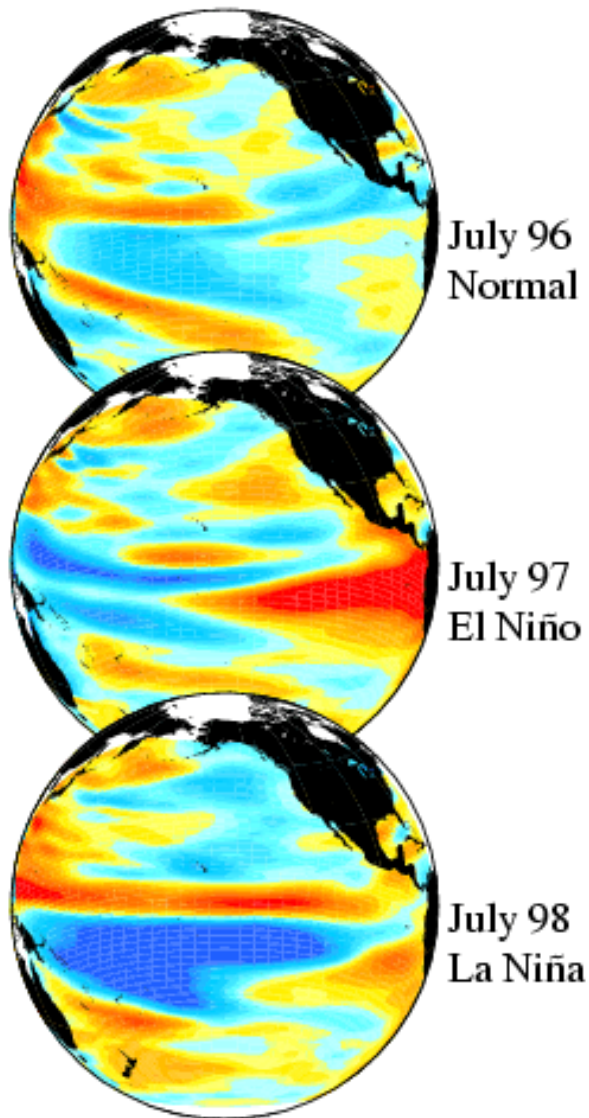
El Niño retreating

Full La Niña
condition

La Niña fading

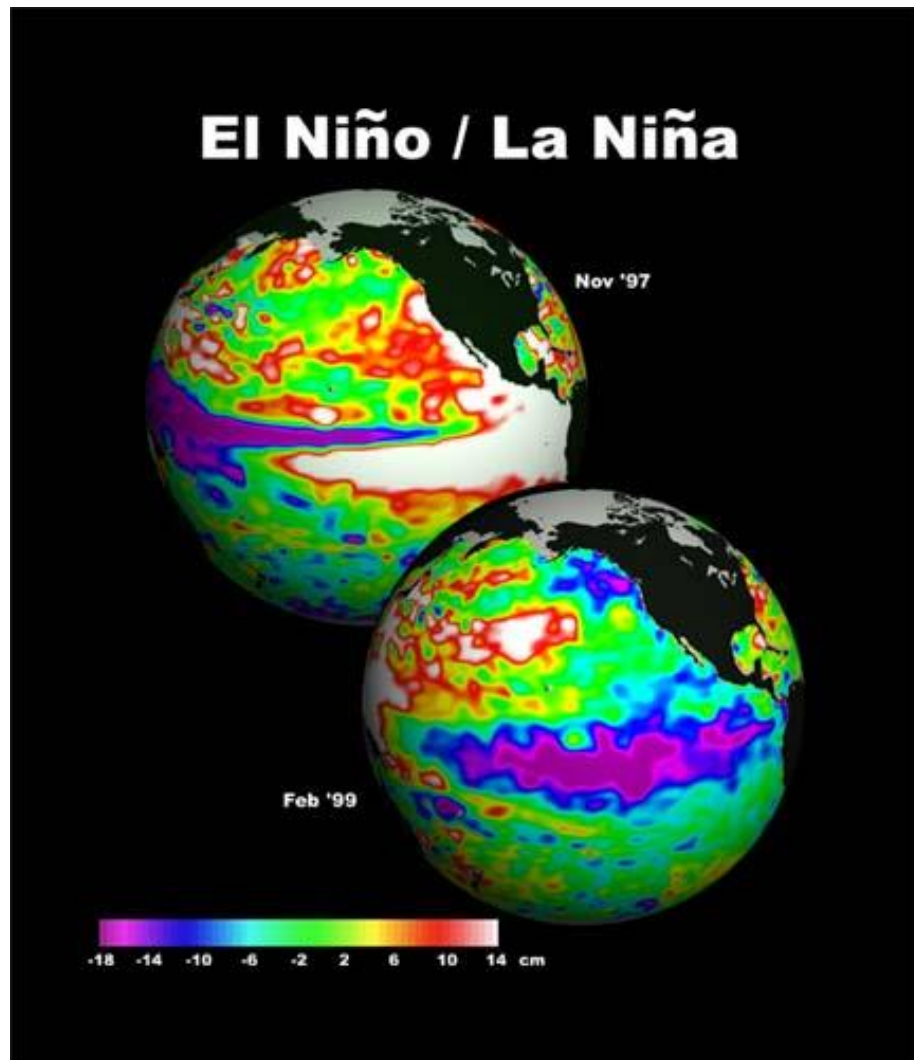


Topex/Poseidon Sea Level Deviation

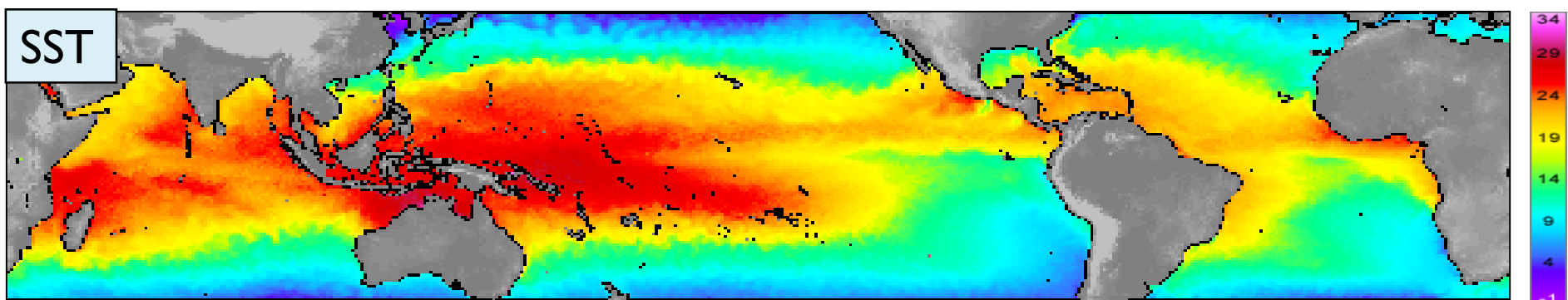
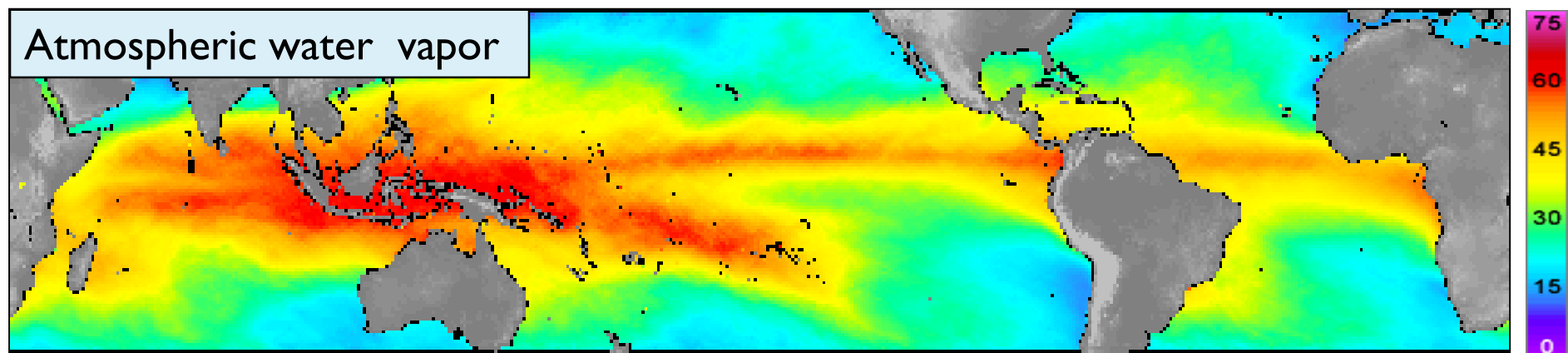
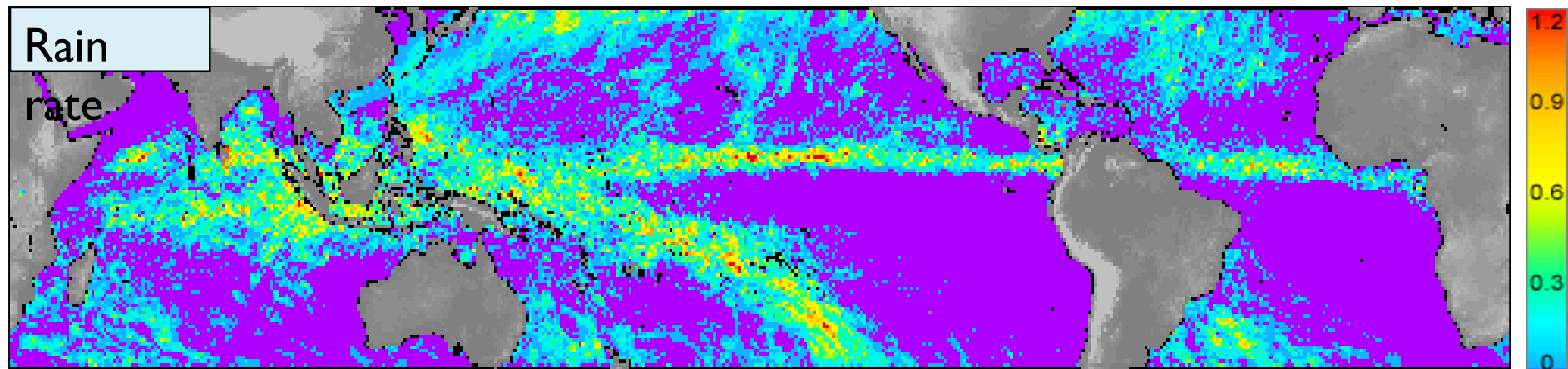


ENSO

- Topex-Poseidon Sea-Surface Height Anomaly



TRMM Satellite-Rain measurements



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

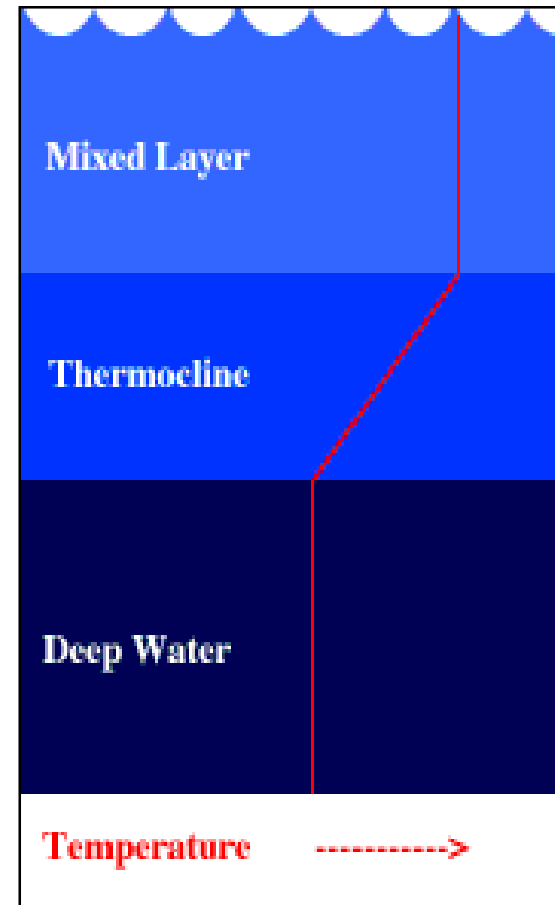
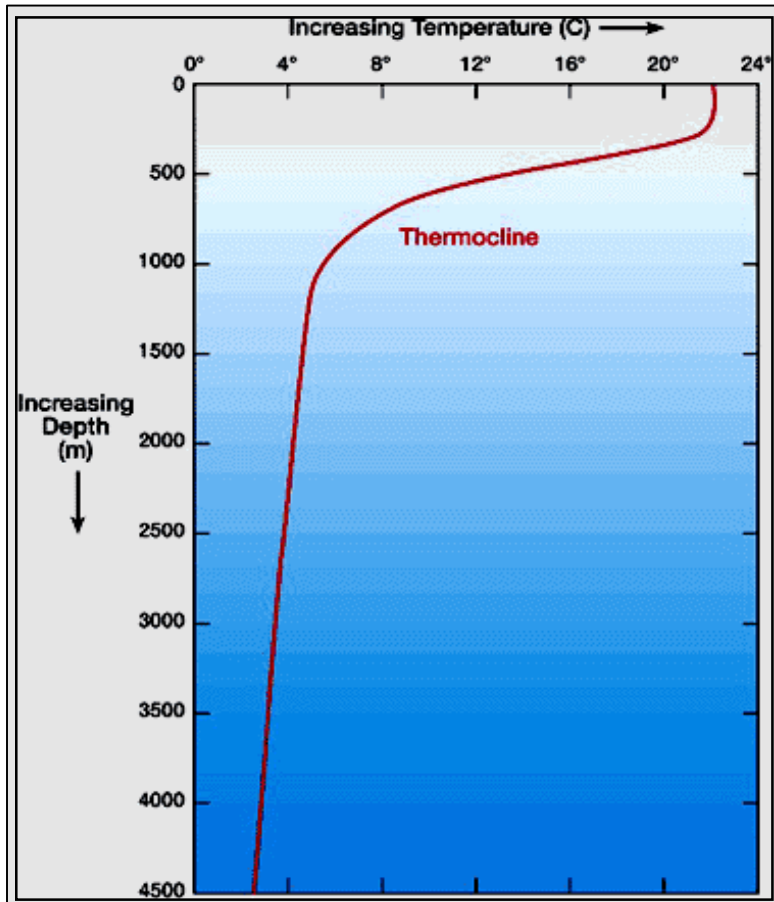
e.g. University of Hawaii

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

Upwelling

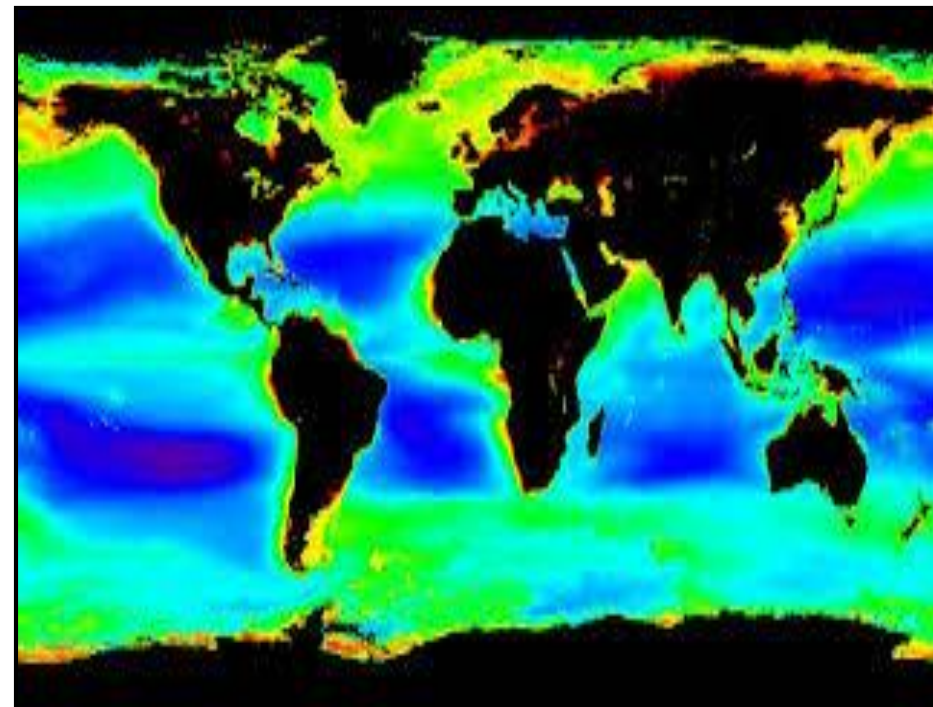
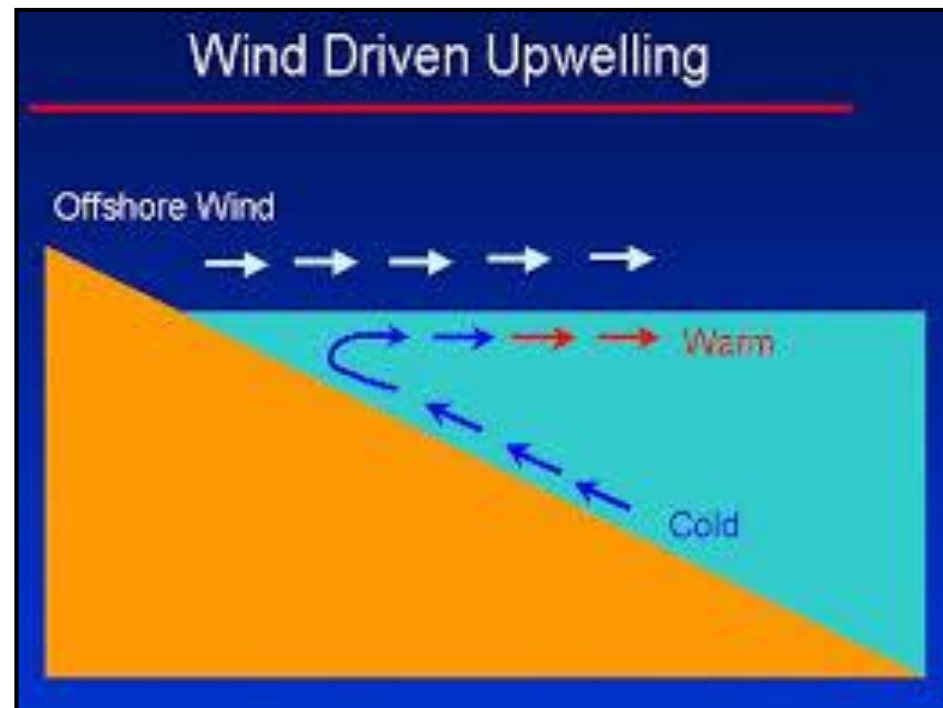
Background: Upwelling

- Thermocline inhibits exchange of surface and subsurface waters.
- High nutrient-rich waters are locked up in subsurface waters.



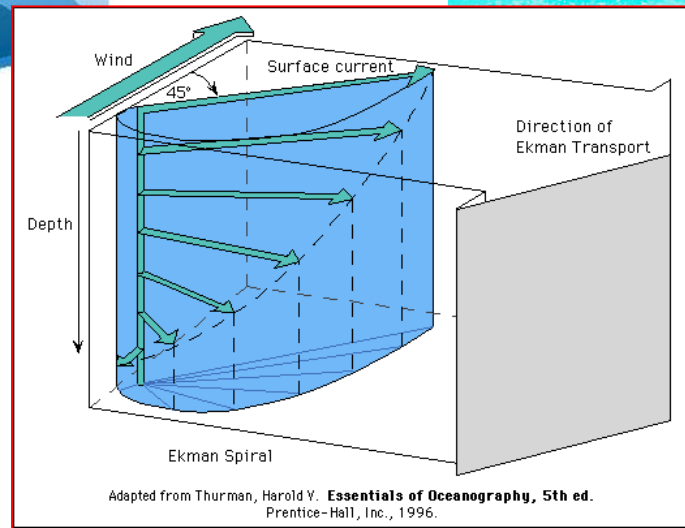
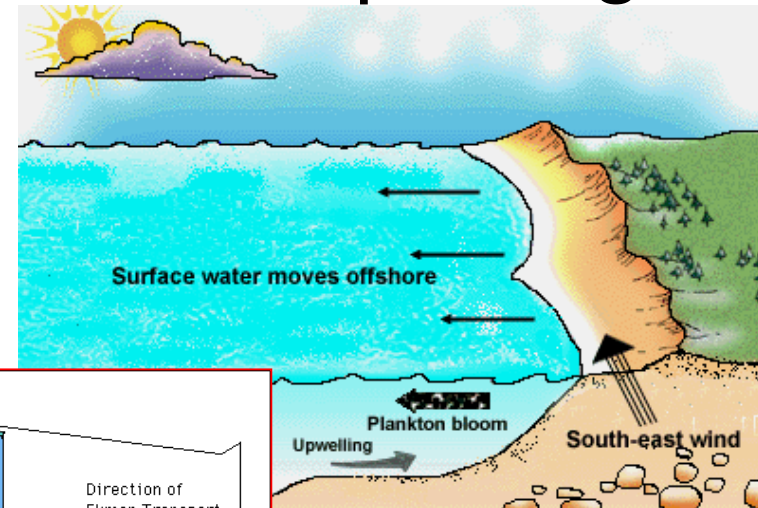
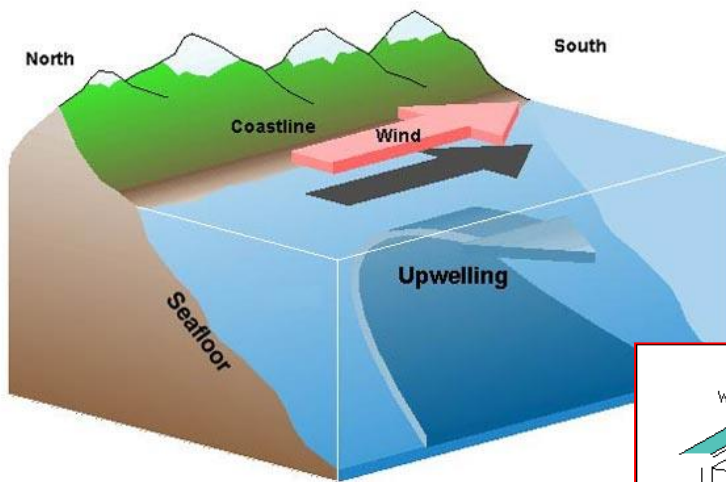
Background: Upwelling

- Cold nutrient-rich waters are brought into the surface ocean through upwelling.
- Indicators: low SST, low oxygen, high nutrients and increased primary productivity.



How it works

- Wind + Coriolis force
- N-hemisphere: right of wind direction
- S-hemisphere: left of wind direction
- “gaps” are filled with water from below: upwelling



Methods:

Ekman transport:

$$\mathbf{M} = \frac{\boldsymbol{\tau}}{\rho_0 f}$$

units = $\text{m}^2 \text{s}^{-1}$

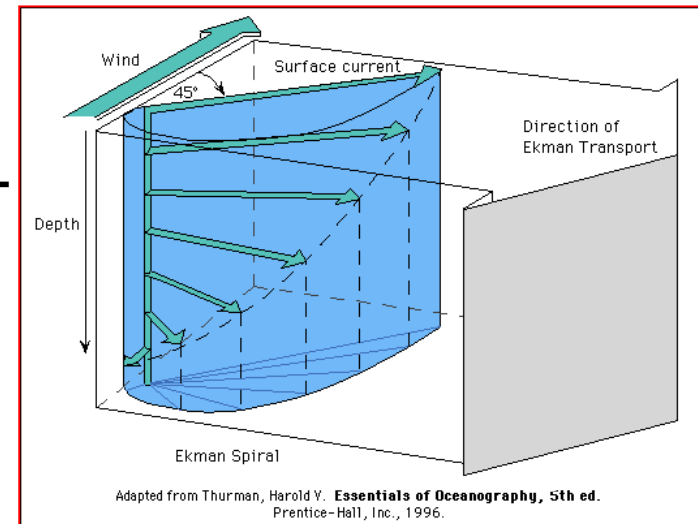
Ekman pumping velocity:

$$w_e = \frac{1}{\rho_0 f} \nabla \times \boldsymbol{\tau}$$

units = m s^{-1}

Compare the two: \mathbf{M}/R ; $R \sim 70\text{-}100 \text{ km}$

Upwelling Index: UI_{ET} and UI_{SST}



Methods:

Ekman pumping velocity:

$$w_e = \frac{1}{\rho_0 f} \nabla \times \boldsymbol{\tau} \quad \text{units} = \text{m s}^{-1}$$

Wind stress curl $\nabla \times \boldsymbol{\tau} = \partial \tau^y / \partial x - \partial \tau^x / \partial y$