NASA's Partnerships to Observe the Ocean

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Exploring Our Ocean Planet from Space

NASA Oceanography

oceans.nasa.gov

Ocean Observations

Status of remote sensing technologies to observe geophysical variables of Earth's oceans:

- Sea surface temperature - operational -> research
- Ocean surface wind research to operational
- Ocean surface topography research to operational
  - high resolution OST (wide swath ocean altimeter)- research
- Ocean mass/gravity - research
- Sea surface salinity - research
- Mixed Layer Depth - research
- Ocean color - chlorophyll-a research to operational
- Fluorescence - research

Established Partnerships With Other Space Agencies

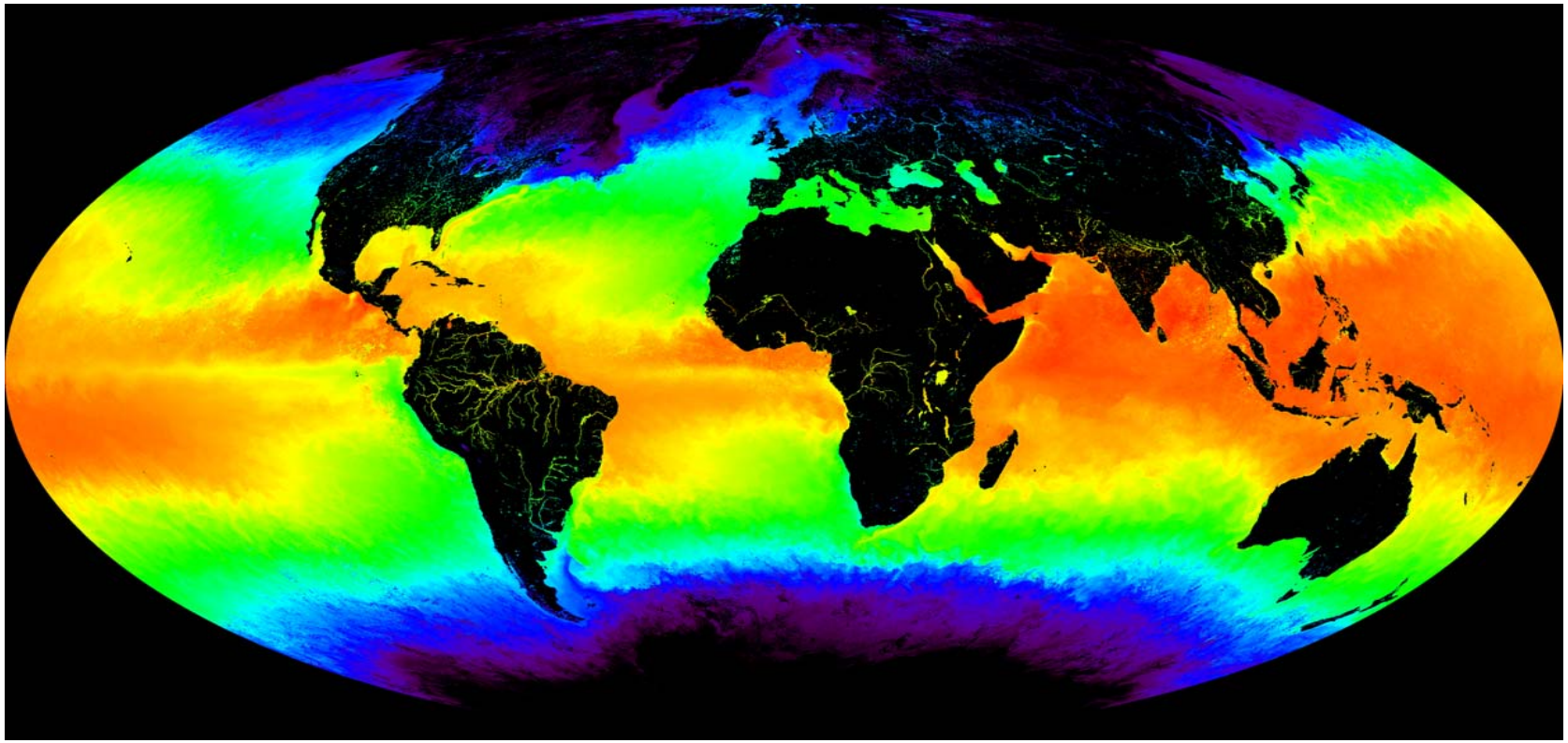
- Ocean surface wind - NSCAT - QuikSCAT/SeaWinds - JAPAN
- Ocean surface topography - TOPEX/Poseidon - JASON -OSTM - FRANCE
- Gravity - GRACE - GERMANY
- Sea surface salinity - Aquarius/SAC-D - ARGENTINA - -
  - Collaboration with HYDROS- NASA and SMOS - ESA
- Sea surface temperature - GHRSST-PP (Global High-Resolution SST Pilot Project) - International effort

Sea Surface Temperature (SST)

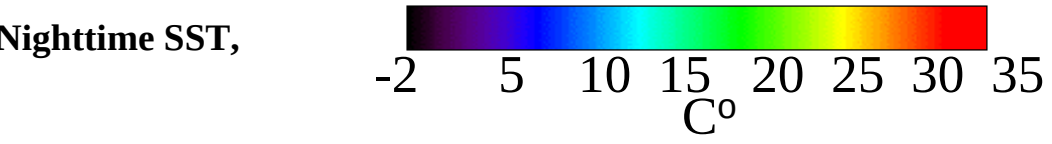
SST measurements reflect air and sea interactions, a key factor in understanding climate and climate change:

- Modern Heritage: AVHRR technologies developed at NASA and used operationally by NOAA.
- Next Generation: All-weather microwave SST (e.g. TRMM Microwave Imager and Aqua-AMSR-E) and high resolution infrared (e.g. MODIS on Terra and Aqua satellites.)
- Research activity (GHRSST) to understand the signal from infrared and microwave instruments :
  - intercomparison and validation across temporal and spatial scales
  - target resolution of 1-2km in coastal zones, 5-10km in open ocean, with accuracy of 0.3-0.4ºC

MODIS Sea Surface Temperature



MODIS Terra Nighttime SST, 4am, May 2001



Ocean Surface Vector Wind

Allows for better weather analysis and provides accurate forcing for ocean models:

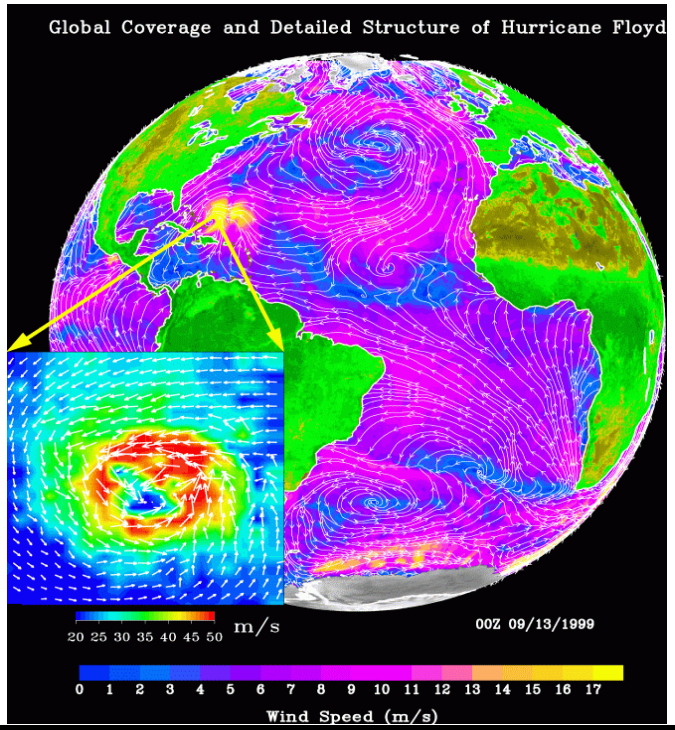
- Modern Heritage: NSCAT mission followed by SeaWinds on QuikSCAT.
- Successive missions targeted toward measurement and technology that can be used operationally.
- Next Generation - Ocean Vector Winds Mission will be smaller and lighter.

Wind Vector: Scatterometry

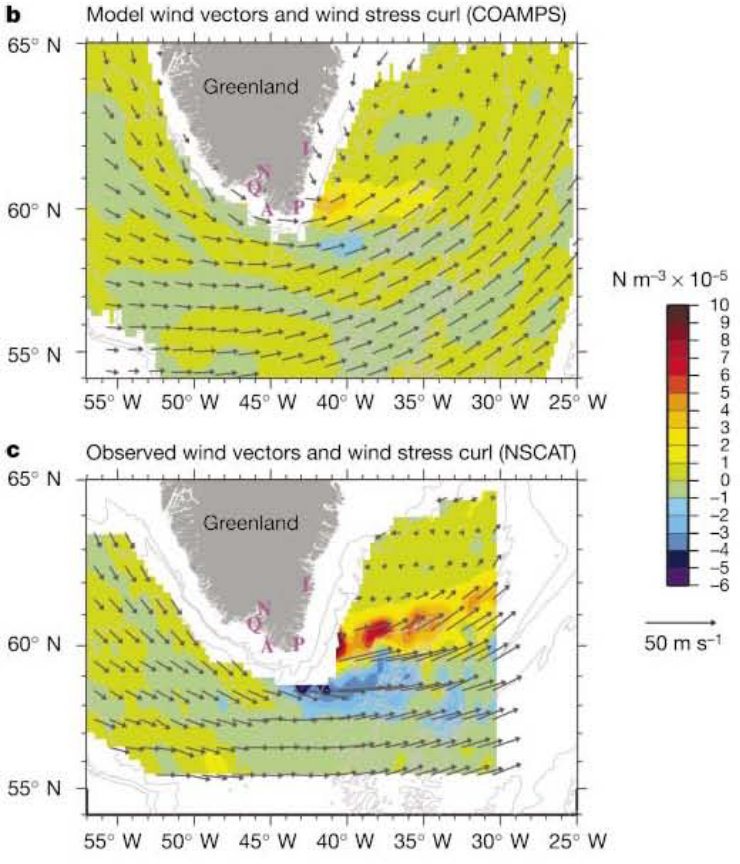
Global Weather and Marine Storms

- Synoptic view of the winds over global ocean
- Improved weather forecast
- Detailed structure of marine storms
- Wind-driven ocean circulation and ecological changes

Hurricane Floyd, 1999



Greenland Tip Jet,
Pickart et al, *Nature*, July, 2003

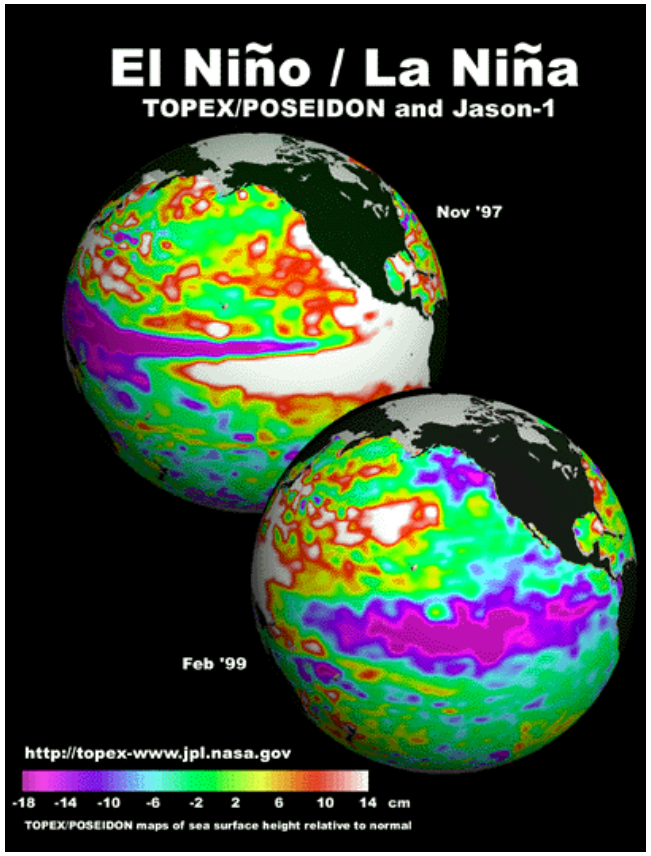


Ocean Surface Topography

Used to explore the ocean's response to wind and buoyancy forcing:

- Modern Heritage: TOPEX/Poseidon development and improvement of altimetry in cooperation with the French space agency.
- Next Generation:
  - Jason-1 (launched 12/7/2001.)
  - Ocean Surface Topography Mission (circa 2007-8)
- Numerous applications: Improves global climate predictions, fish harvesting, circulation simulation.

Ocean Topography From Altimetry



El Niño / La Niña

The early detection of the 1997-98 El Niño was a great success **of the mission. The loss of lives and property from the strongest El Niño on record was kept to a minimum owing to the early warnings.** The data have been routinely used by NOAA to improve the forecast of El Niño and other climatic events.

TOPEX/Poseidon Ocean topography of the Pacific Ocean during El Niño and La Niña.
- Red and orange represent highs;
- Purple and blue represent lows.

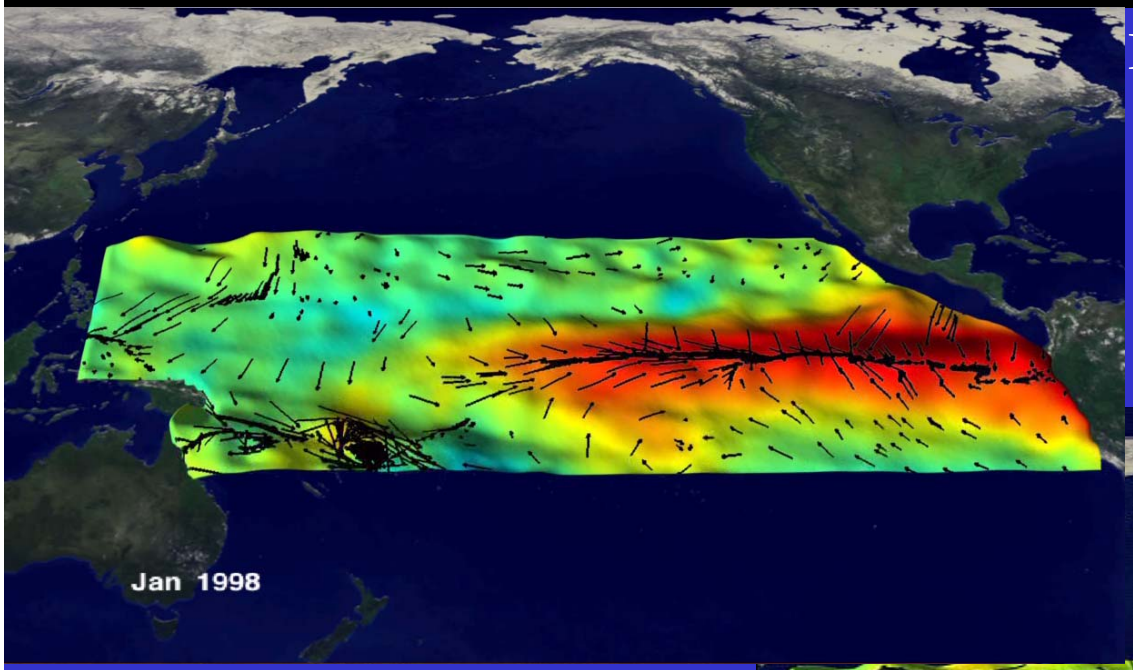
SSH from TOPEX/Poseidon and Anomalous Wind Vectors from SSM/I

(Courtesy of D. Adamec/GSFC)

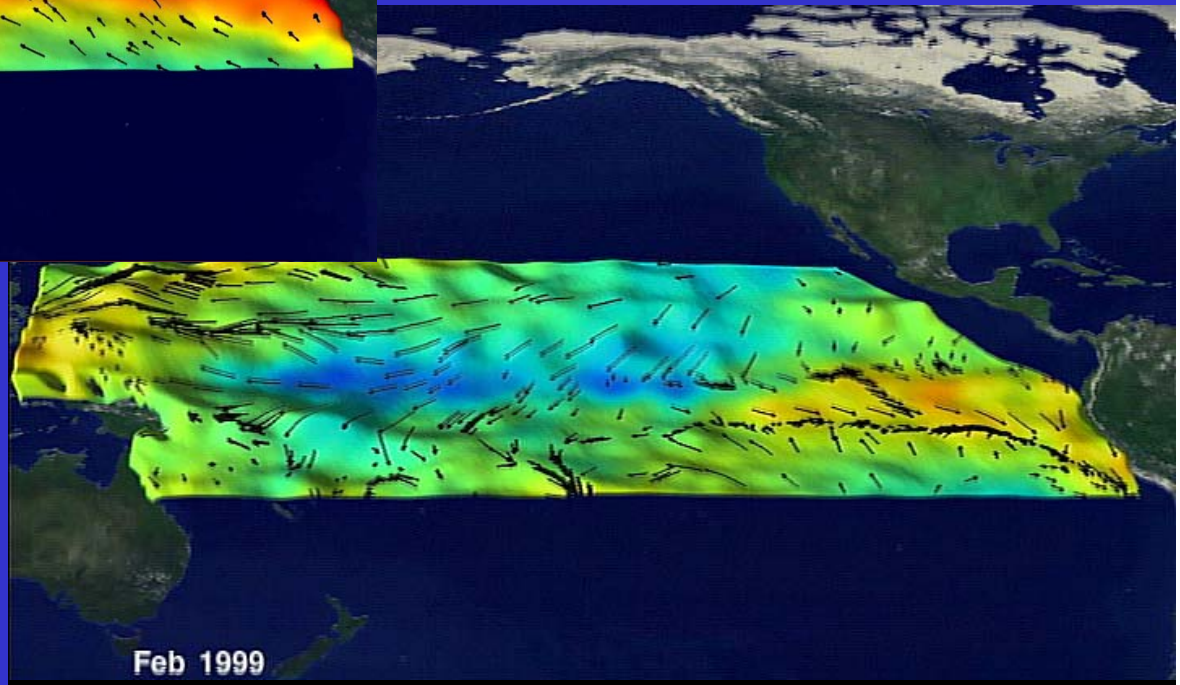
Earth Science Enterprise

National Aeronautics and Space Administration

El Nino 1997-1998



La Nina 1999



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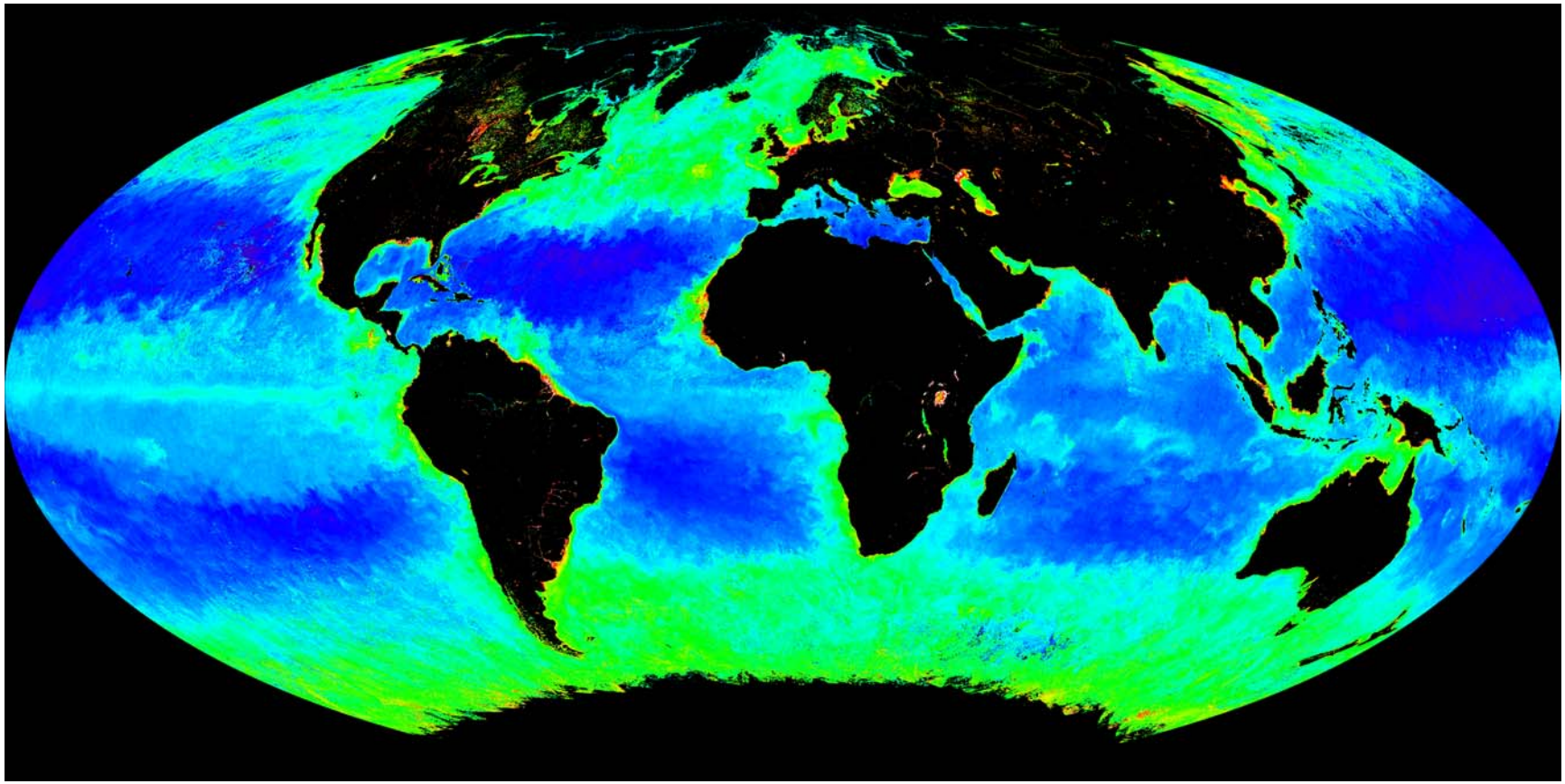
Ocean Color

Used to estimate the chlorophyll-a in the ocean and investigate the global carbon cycle:

- Modern Heritage: SeaWiFS and MODIS on Terra.
- Next Generation: Sensors with finer resolution, better algorithms, and more spectral resolution.
- Numerous applications: Ocean productivity, fisheries, plankton dynamics.

MODIS Chlorophyll-a

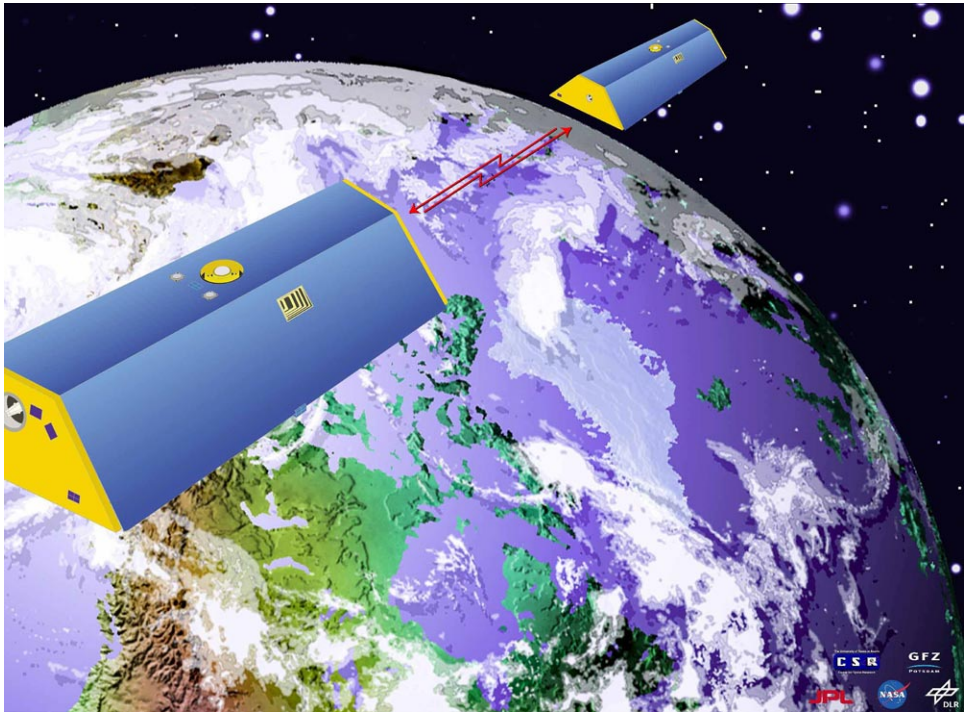


MODIS Terra, May 2001

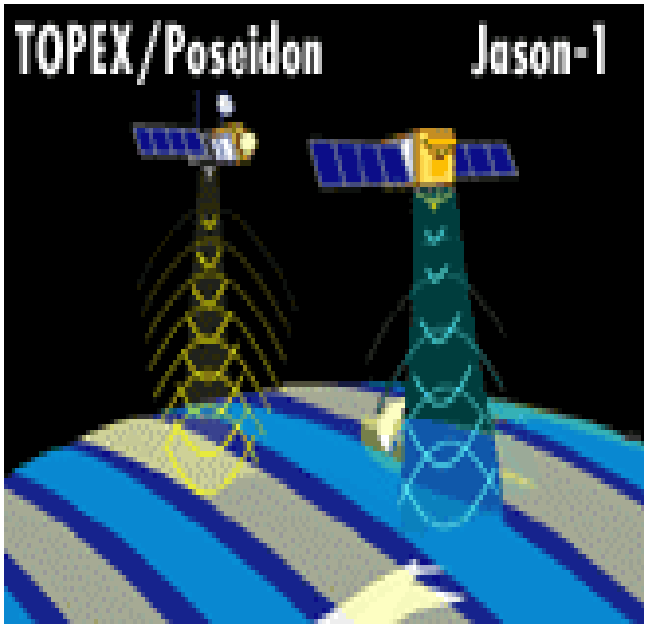
Ocean gravity and mass

GRACE

- **measuring the changing mass of polar ice caps;**
- **measuring changes in water resources on land**
- **understanding shallow and deep ocean current transport;**
- **understanding sea level change resulting from ocean temperature and water mass changes;**
- **understanding atmosphere-ocean mass exchange**

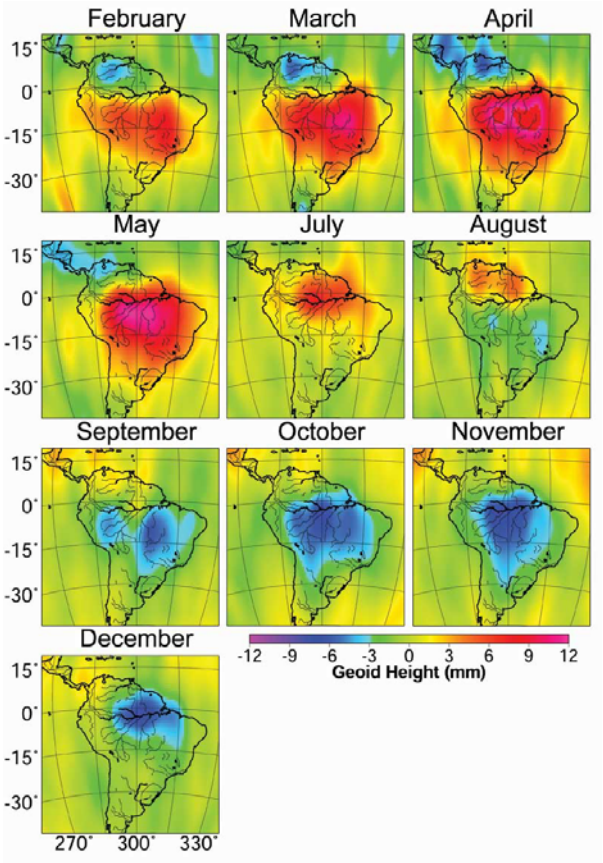


TIDE GAUGES AND ALTIMETRY

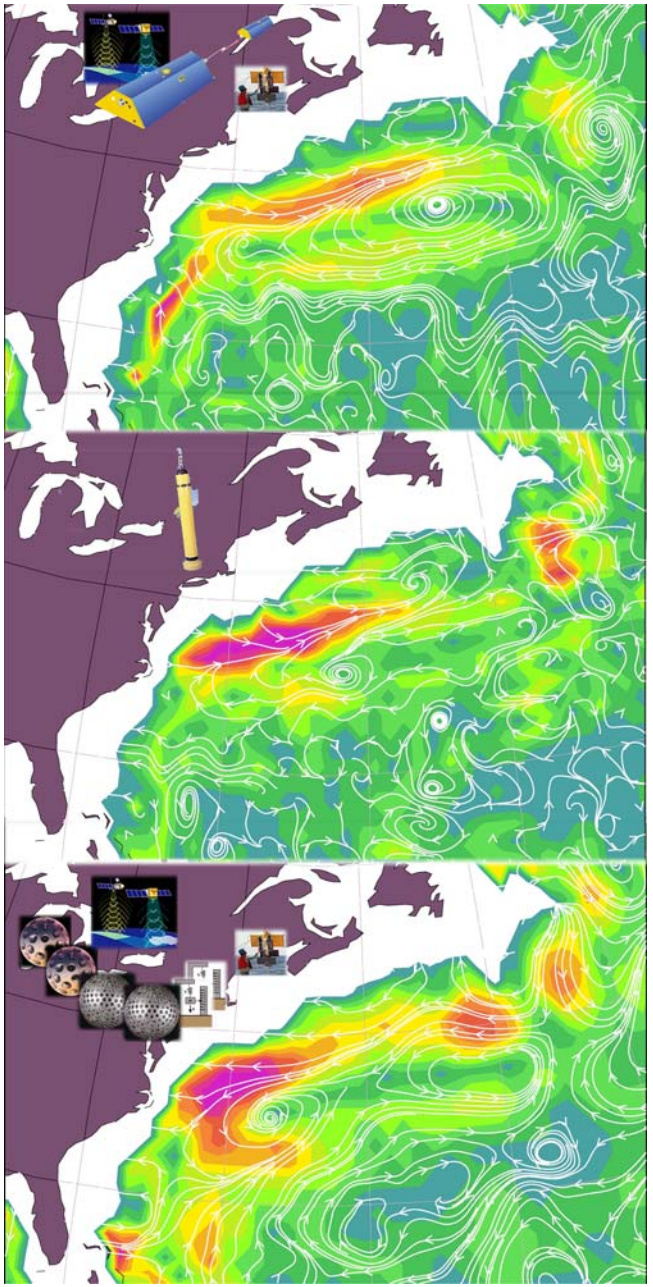


Results from GRACE:

Below: Seasonal change in ground water storage in South America,
from Tapley et al, *Science*, July 2004



Right: Gulf Stream currents at 1000 meter depth
Top: Derived from altimetry, GRACE gravity model and ship measurements
Middle: From in situ measurements (floats)
Bottom: Same as top but earlier Gravity model information
Credit: NASA JPL



Sea Surface Salinity

Future mission- Aquarius: Aims to explore the variability of surface salinity in the oceans.

- Requires improved antennas, signal processing, and algorithms.
- Remotely sensed salinity data will greatly improve our knowledge of an important driver of significant climate signals.
- Joint mission with CONAE: NASA will provide the L-band radiometer/scatterometer and launch vehicle, CONAE will provide the integrated satellite platform with SAC-D science instruments
- Planned launch date September 2008

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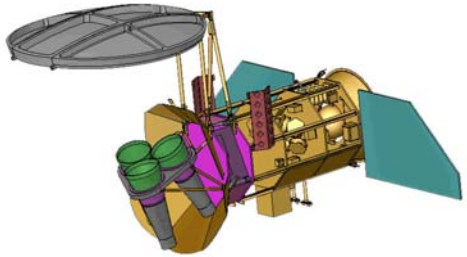
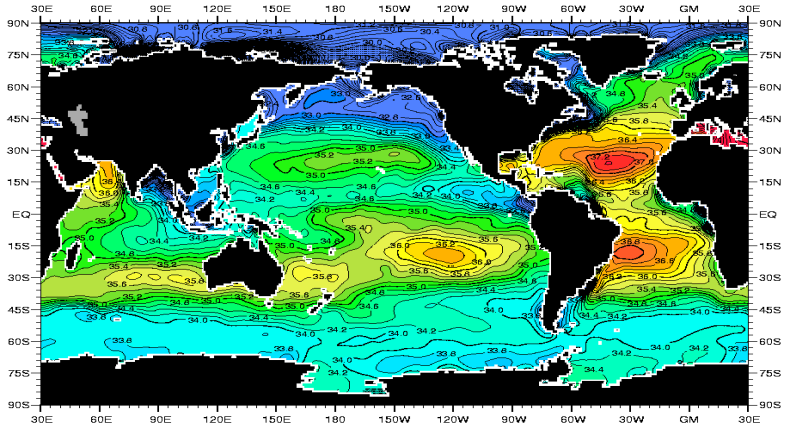
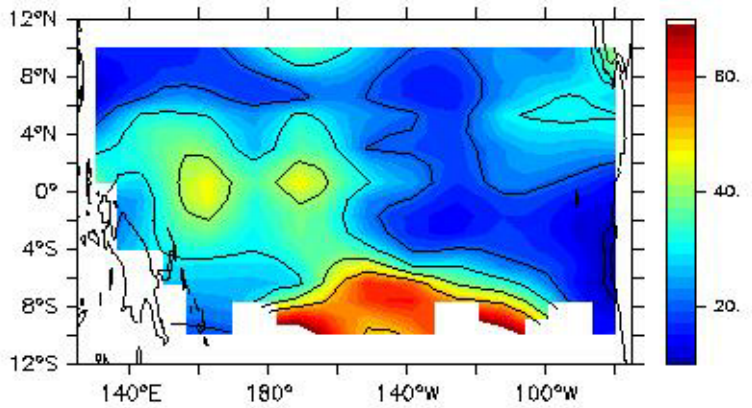
/SAC-D







Percentage of dynamic height variability due to salinity (Maes and Behringer, 2000).

Science Themes

Hydrological cycle

- Salinity is the key variable to understand the fresh water cycle in the ocean

Ocean & Climate

- Salinity is a key variable to determine the density that drives ocean circulation to impact climate

Measurement requirements

- 0.2 PSU, 100-km footprint, weekly

Science Rationale

- The effect of salinity is comparable to the effect of temperature.
- Salinity can be used to improve El Nino prediction

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are needed to see this picture.

GSFC JPL

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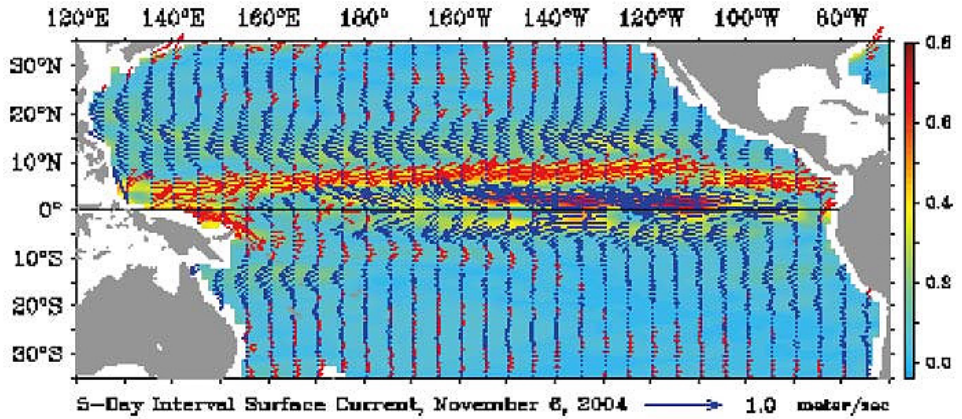
Derived Products : Multi-Sensor and Merged Satellite and In Situ Data Sets

•Ocean surface currents

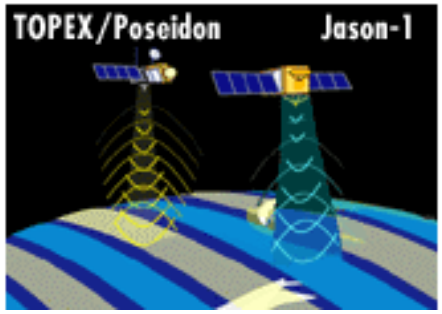
- altimetry, drifters, ARGO floats (OSCAR-product)

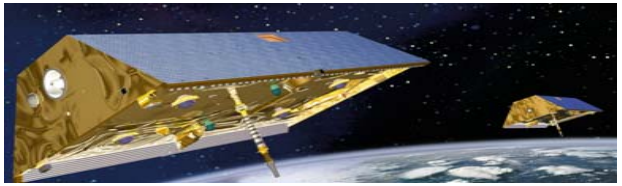


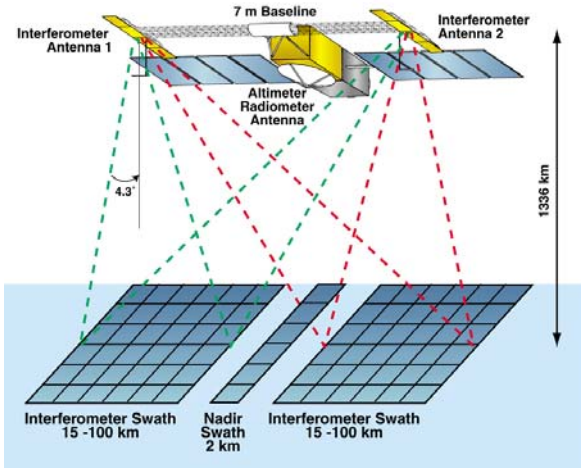
•Ocean deep currents

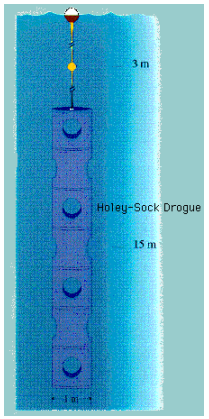
- altimetry, GRACE gravity, in situ hydrography, ARGO floats

Ocean Currents :









T/P and Jason tandem mission, Wide Swath altimeter

Drifters, ARGO, GRACE

Application of Science

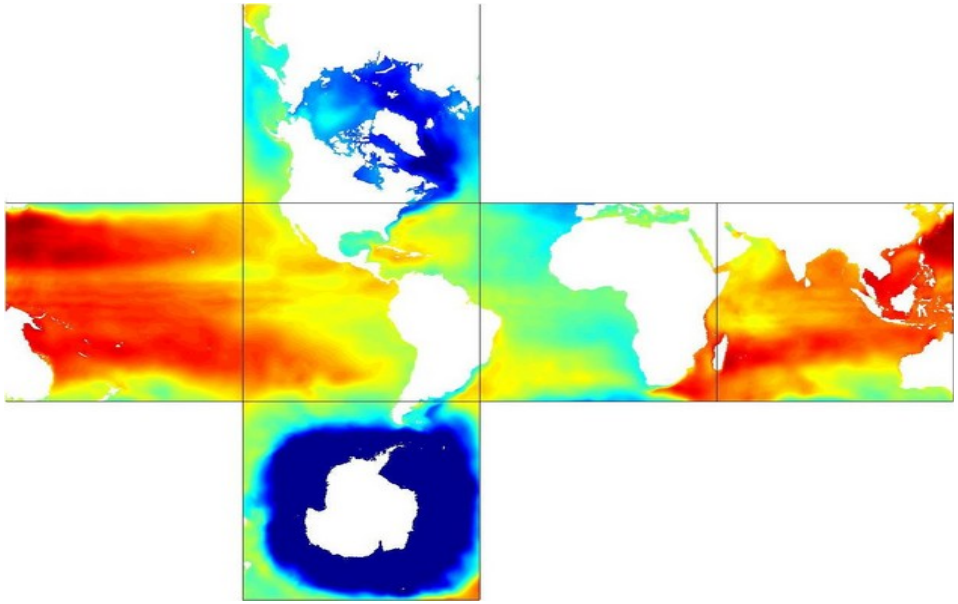
- NSIPP (NASA Seasonal-to-Interannual Prediction Project): a productive partnership of NASA GSFC and the University community to advance national climate prediction capabilities.

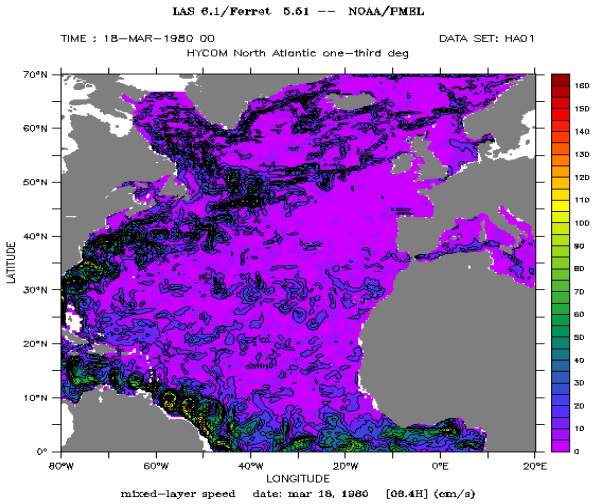
- NOPP (National Oceanographic Partnership Program): Data assimilation and climate prediction projects serving as pathfinders and tool developers for a wide array of applications.
  - ECCO consortium for ocean state estimation

- IGOS (Integrated Global Observing Strategy): An international partnership enabling development of an integrated ocean observing system.
  - Global Ocean Data Assimilation Experiment (GODAE) a practical demonstration of near-real-time, global ocean data assimilation.

Data Assimilation: Integrated Products

GODAE – ECCO, HYCOM, MERCATOR





NASA Interests in Technology Development

- Instrument development beyond exploratory missions:
  - Salinity , mixed layer depth
  - High resolution measurements: SST, OST, time variable gravity
- Improved numerical models of the ocean.
- Data assimilation techniques.
- High-performance supercomputer applications.
- Enabling access to large data sets

Frameworks for International Collaboration

- The development of a **global** network for ocean observing platforms, products, and services - IGOS

- Ocean state analysis - GHRSST - GODAE

- The ocean **research** enterprise **and** the development of "**operational**" oceanography are tightly linked
  - creation of research quality data sets - creation of the climate record - through reprocessing and
  - VALIDATION


NASA
Earth Science Enterprise
National Aeronautics and Space Administration
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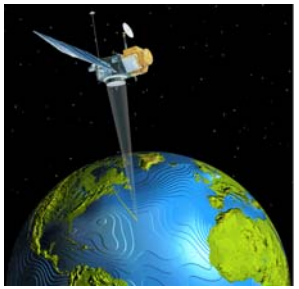
Data Assimilation : The Ultimate Synthesis

Data assimilation is the conduit of information between the observing systems and the user community.

Observing Systems

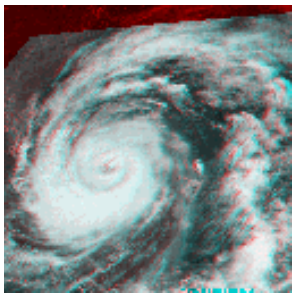


Data

Computer Ocean Models

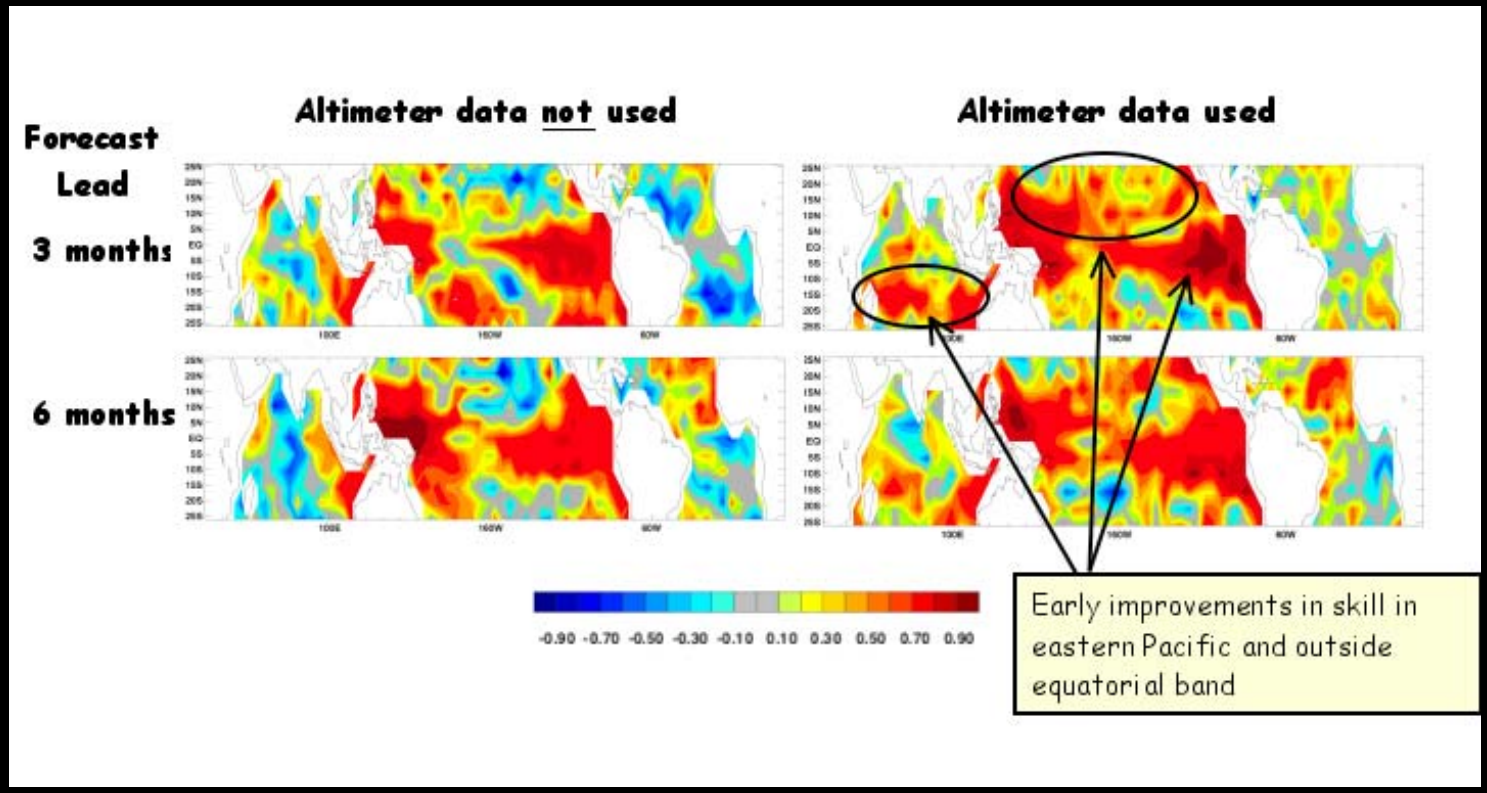
Synthesis Products

User Community



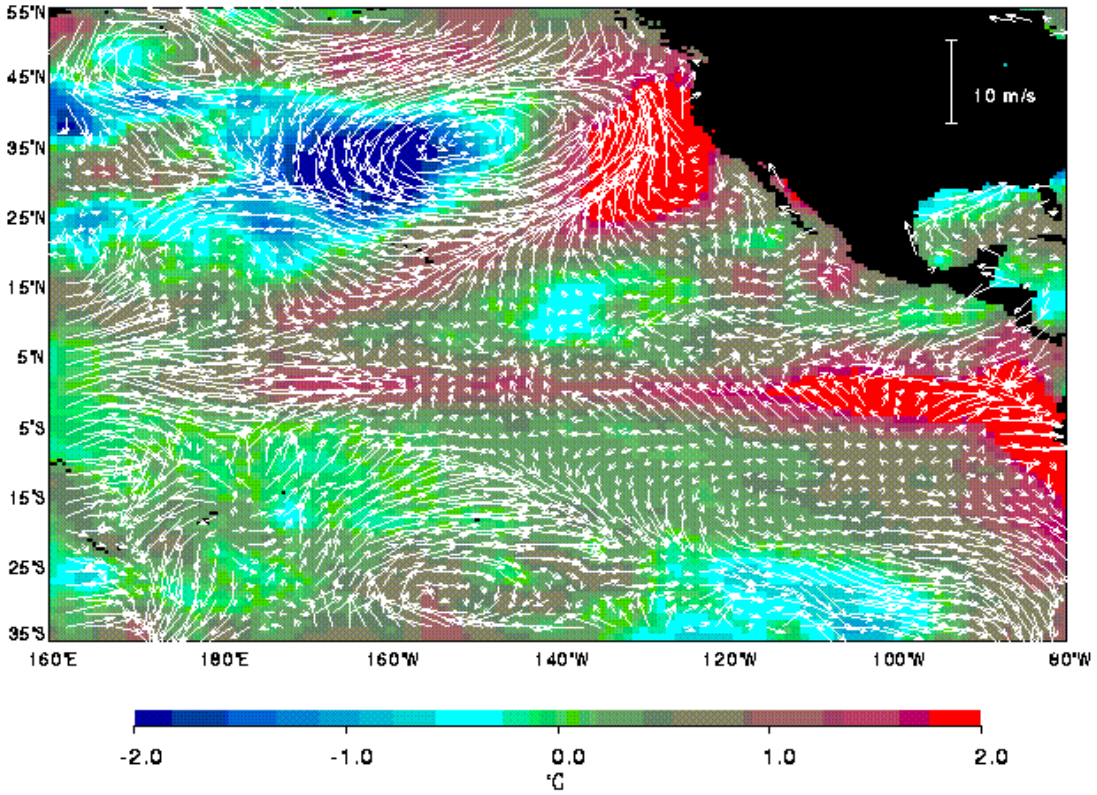
DATA ASSIMILATION: USE OF ALTIMETRY IN ENSO PREDICTION

(from D. Adamec/GSFC)



Wind, Air-Sea Interaction tie Timescales, Physics and Biology

- El Nino (equatorial Pacific warming, timescale: a few years) preceded by trade winds collapse, and westerly wind burst (timescale:a few days).
- Westerly wind burst is connected to super cloud clusters and convection. Timescale: sub-daily
- A branch of the equatorial winds, as part of the displaced anticlockwise flow, brings warm and moist air to the U.S. west coast
- The displacement of atmospheric circulation shifts the position of the decadal ocean temperature dipoles, with strong ecological effect to coastal water.



[Liu, W.T., W. Tang, and H. Hu, *Eos Trans. AGU, 79*, 249 & 252, 1998]

SST Research activity (GHRSST-PP)

- Characterize the quality of existing satellite and in situ SST data sources through validation exercises and identify differences between them by inter-comparison at local, regional and global spatial scales and for daily, weekly and monthly temporal scales.

- Develop data integration and assimilation methods that exploit existing SST datasets through data merging/fusion in order to generate improved multi-sensor SST products.

AVHRR

AMSR-E

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CTL= CONSTANT TEMPERATURE LAYER

Measurement Path From Research to Operational Use