NASA Pathfinder

Ocean Altimeter

Research Activities

at

GSFC

NASA Ocean Altimeter Pathfinder Project

The First Four Years

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Improved Satellite Altimeter Data Sets for Oceanography:

The NASA Ocean Altimeter Pathfinder Program

TOPEX/POSEIDON & Jason Science Working Team Meeting

October 25 - 27, 1999

Saint Raphael, France

BACKGROUND

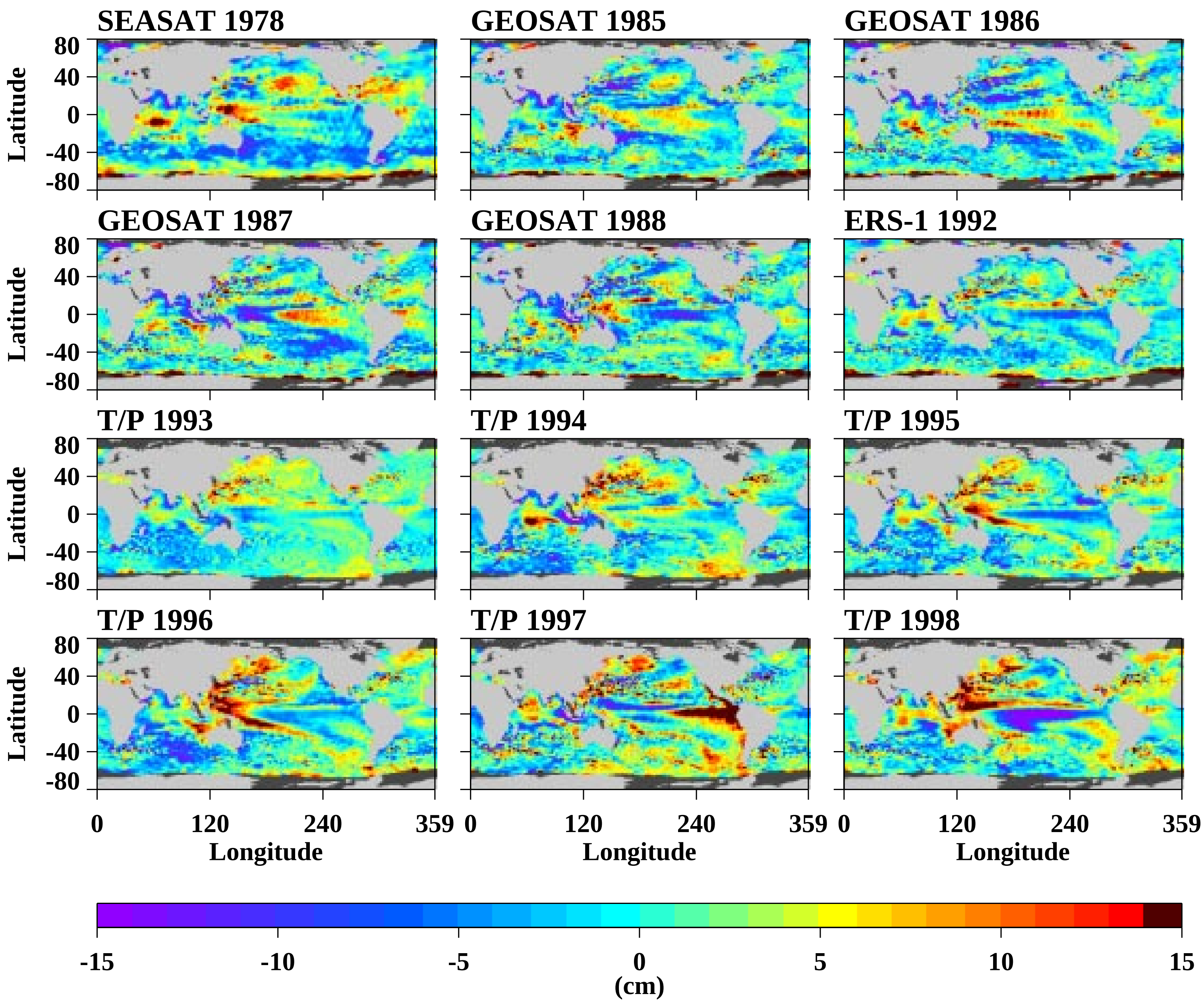
Over the past decade, satellite altimeter data sets have been invaluable to the NASA physical oceanography program and the ocean science community, in general. The need for high quality, documented, and easy-to-use global measures of ocean topography, provided in a consistent reference frame and processing environment, has grown for scientific research, environmental monitoring, and academic applications.

The NASA Ocean Altimeter Pathfinder Project was initiated at GSFC in 1995 to create such a data base for all altimeter satellites, which exploits the TOPEX/Poseidon experience. The altimeter data sets have been reprocessed within a consistent reference frame and set of algorithms based on T/P results. Details are presented in two NASA technical reports:

Report 1: Data Processing Handbook NASA/TM-1998-208605

Report 2: Data Set Validation NASA/TM-1999-209230

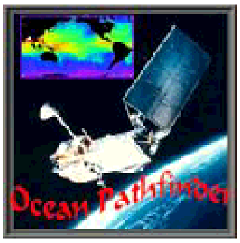
Summer Sea Surface Height Anomalies 1978 - 1998



The reprocessing of all ocean related mission altimetry employing the latest algorithms from the TOPEX/POSEIDON experience has resulted in a geodetically consistent data set for climate research.

NASA/GSFC Ocean PATHFINDER

Reprocessing of Altimeter Data for Oceanography:



http//:neptune.gsfc.nasa.gov/ocean.html

NEW

- **Monthly and 10 day SSH Anomaly Grids and Animations**
- **Version 6.0 Colinear Sea Surface Heights**
  TOPEX/POSEIDON (cycles 1 - 254)
- **Merged ERS-1,2 Colinear Sea Surface Heights**
- **Ocean Altimeter Pathfinder Documentation**
  Report 1: Data Processing Handbook (NASA TM-1998-208605)
  Report 2: Data Set Validation (NASA TM-1999-209230)

Earth Observing System	Global Change Master Directory	Mission to Planet Earth	NASA Homepage	Pathfinder Program

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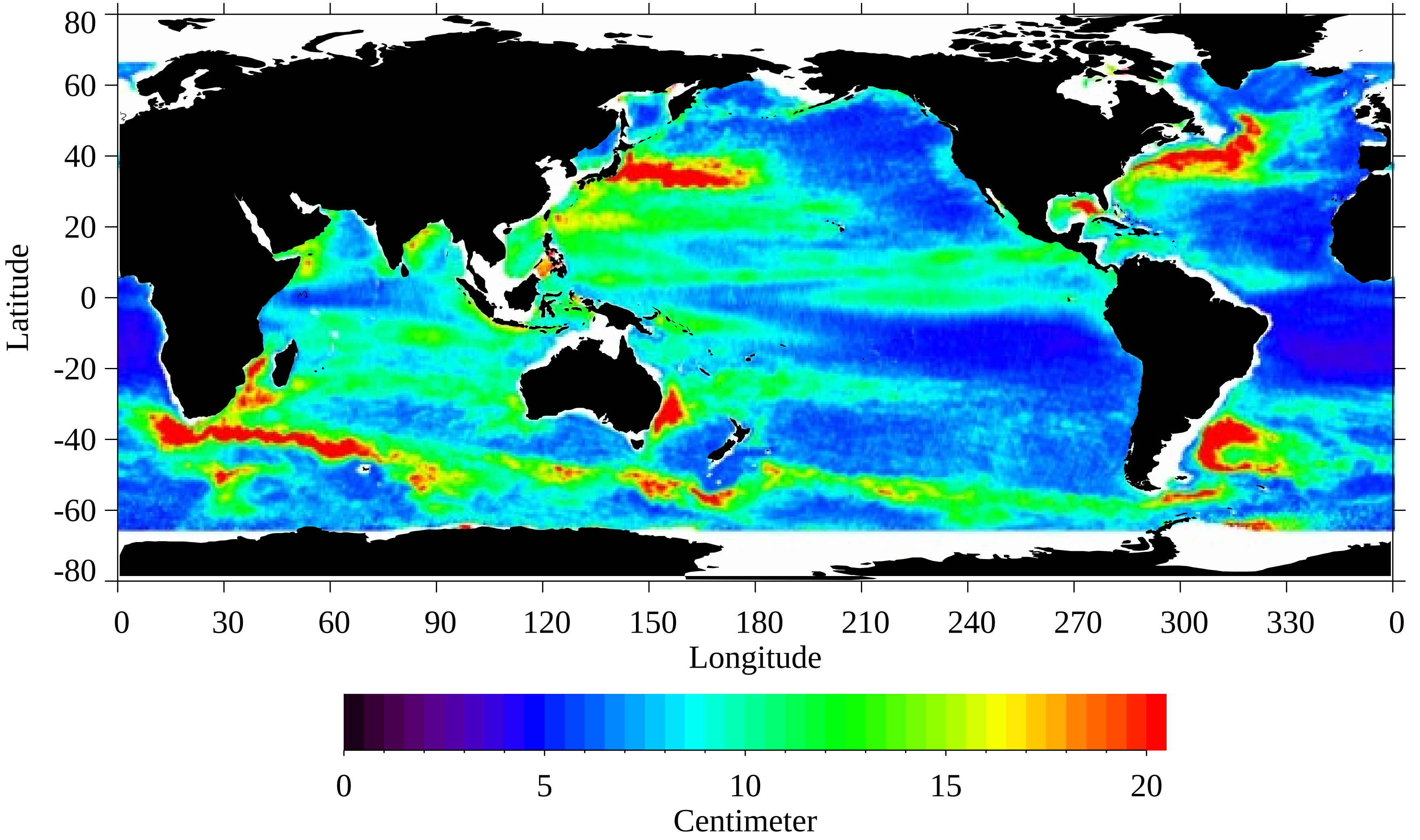
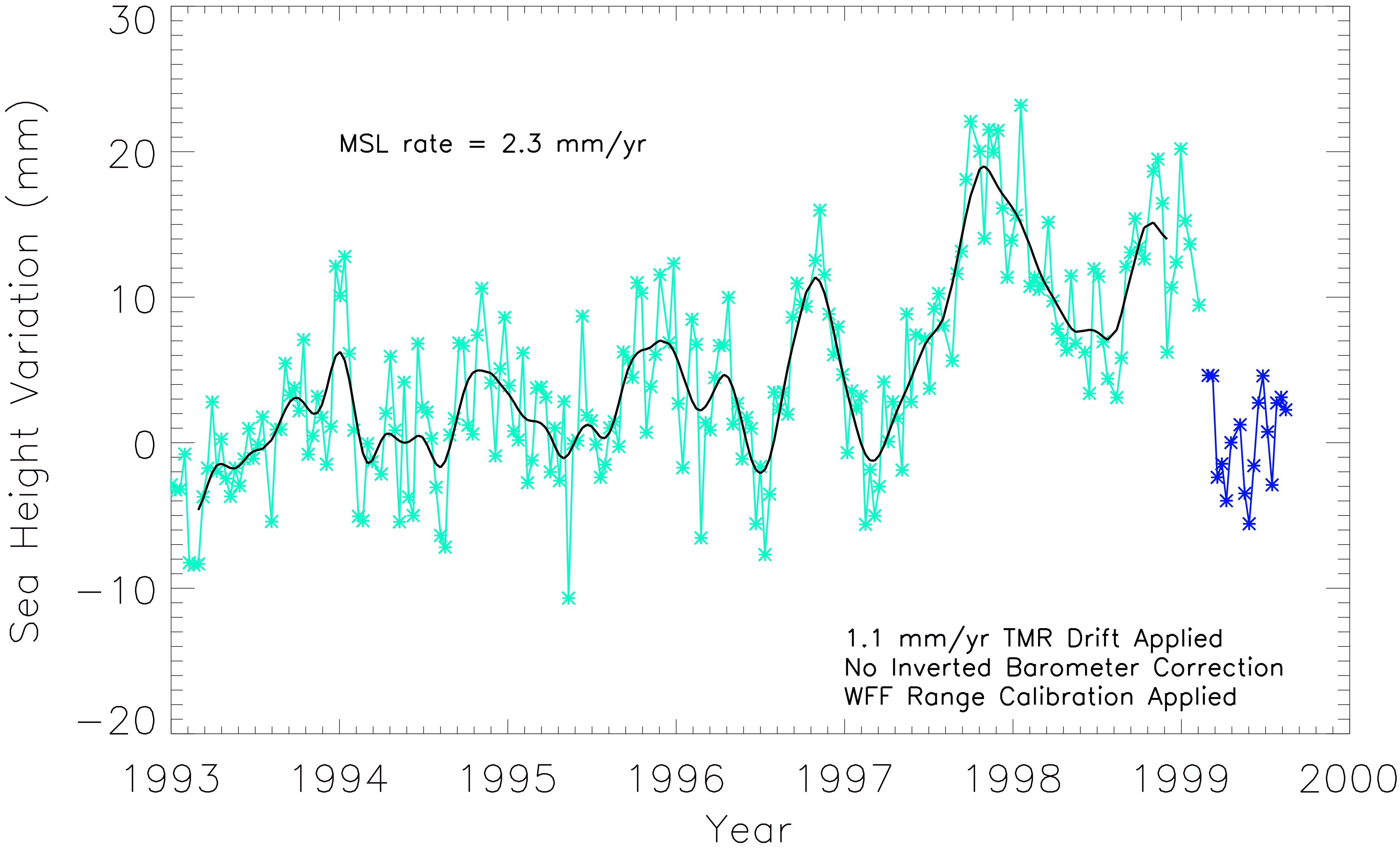
T/P + ERS Sea Surface Height Variability



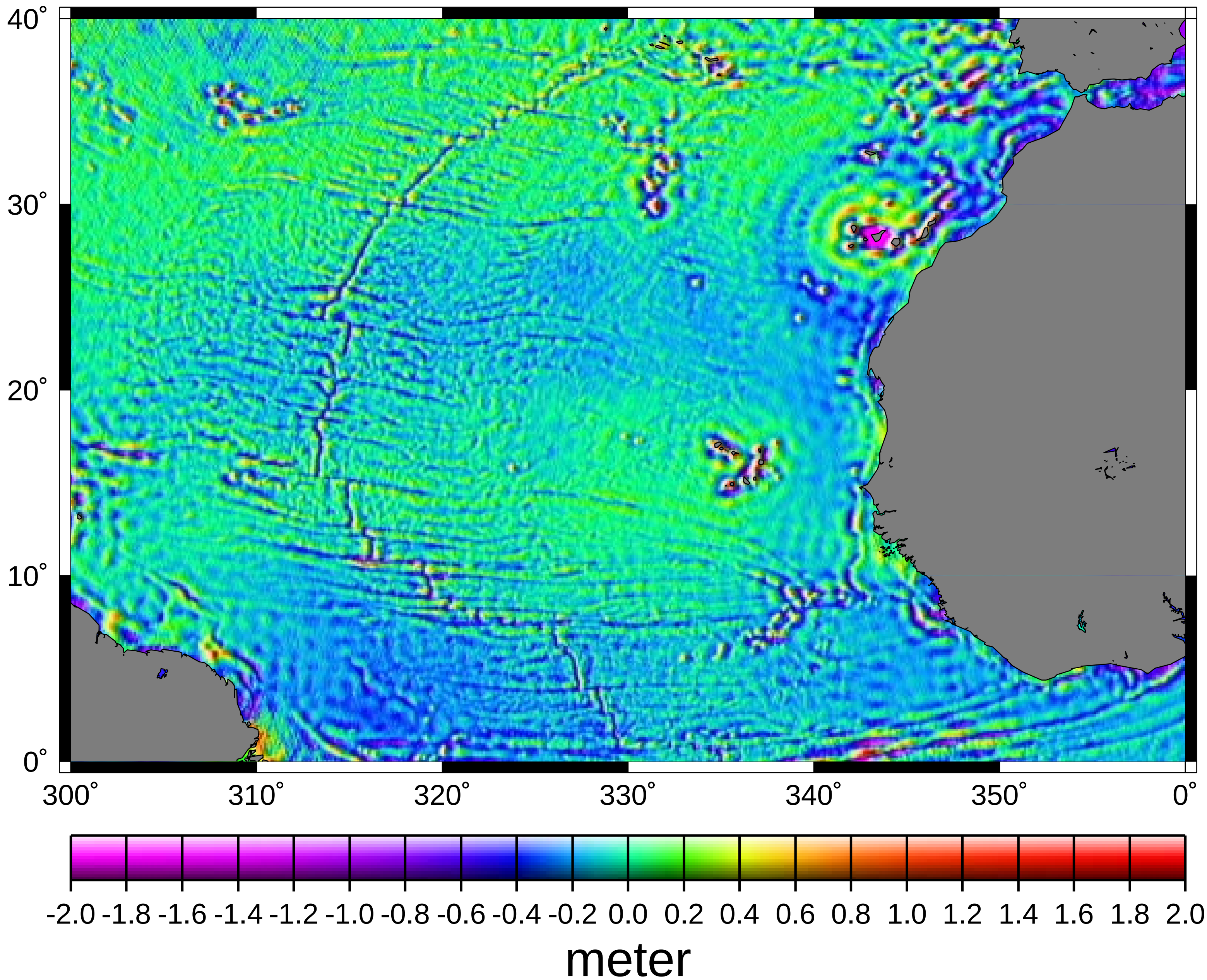
Data Range : (3.79607 , 41.6204)   Contour Range : (0.00000 , 20.0000)   Number of Valid Points : 516159   Number of Excluded Points : 405441

Global Mean Sea Level Variations from TOPEX/POSEIDON

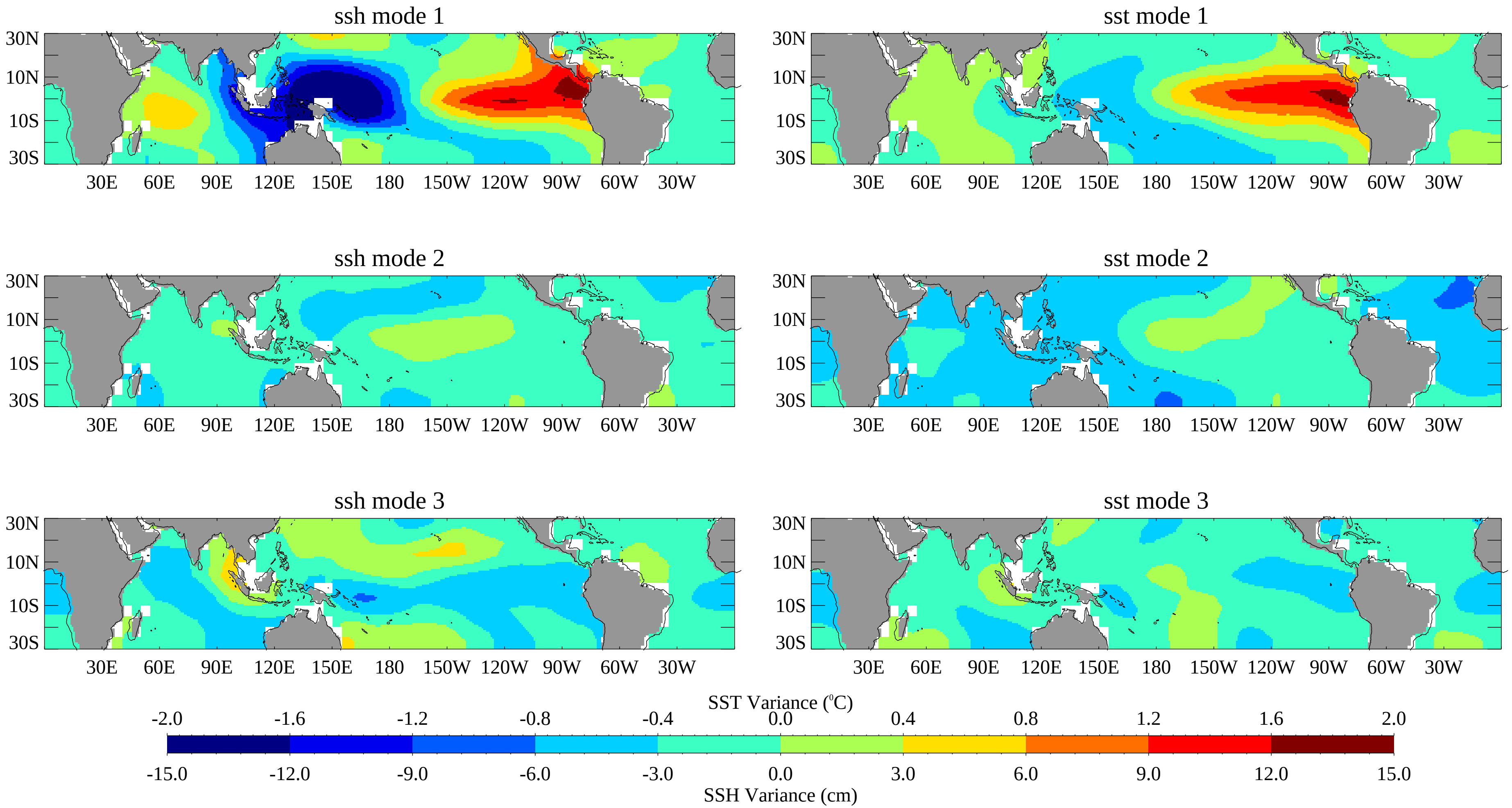


Global mean sea level variations are computed from TOPEX/POSEIDON altimetry for cycles 10 - 254. Each asterick represents a 10 day estimate of the global mean sea level variation with repect to a 1993-1996 average. The solid black line is a 60-day Hanning filter. The dark blue points identify the transition to ALT B that is currently being validated.

Mean Sea Surface Residual wrt EGM96 Geoid

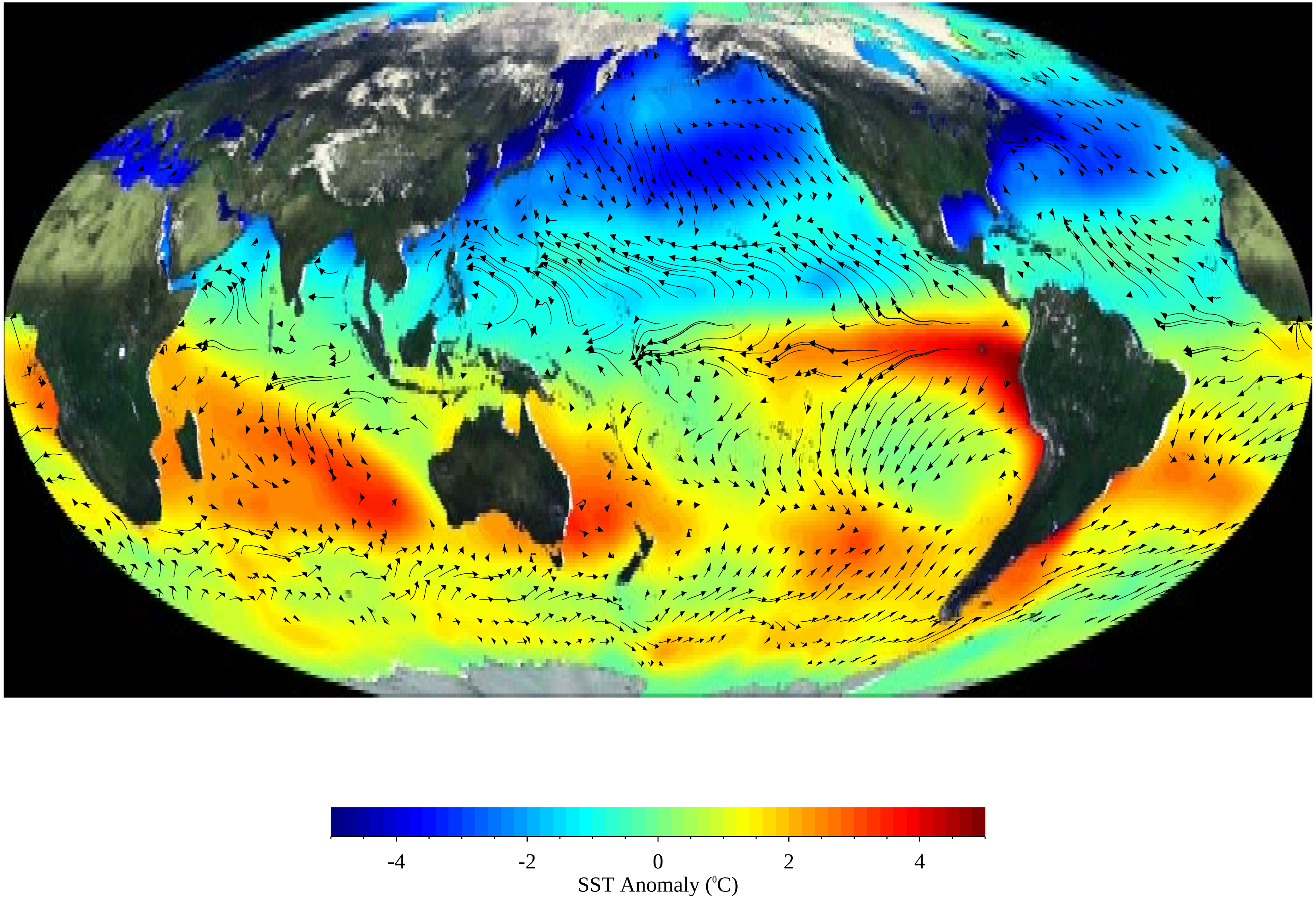


Coupled Mode Analysis Between SSH and SST



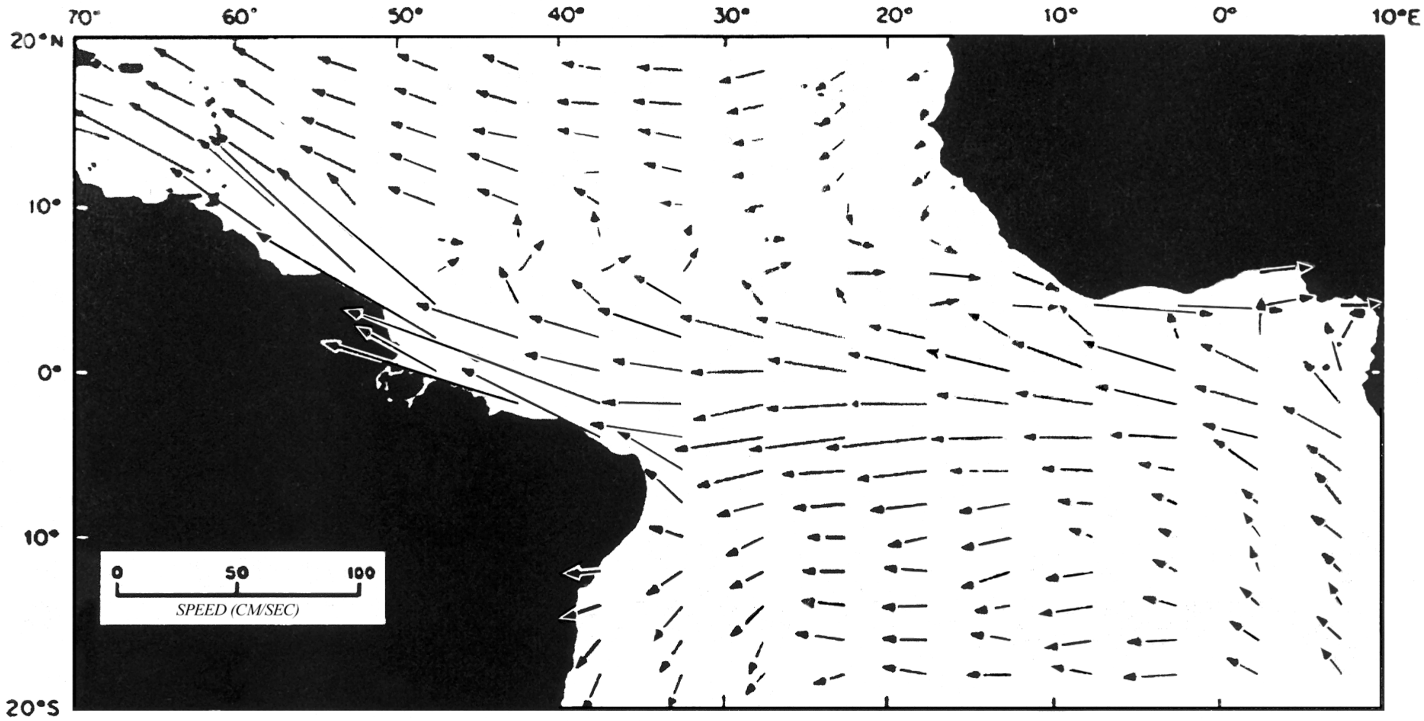
The coupled modes of SSH and SST are computed employing the Singular Value Decomposition (SVD) algorithm. SSH fields are derived from TOPEX/Poseidon altimetry and the temperature data are from Reynolds SST fields.

SST Anomaly and Ocean Current, January 1998

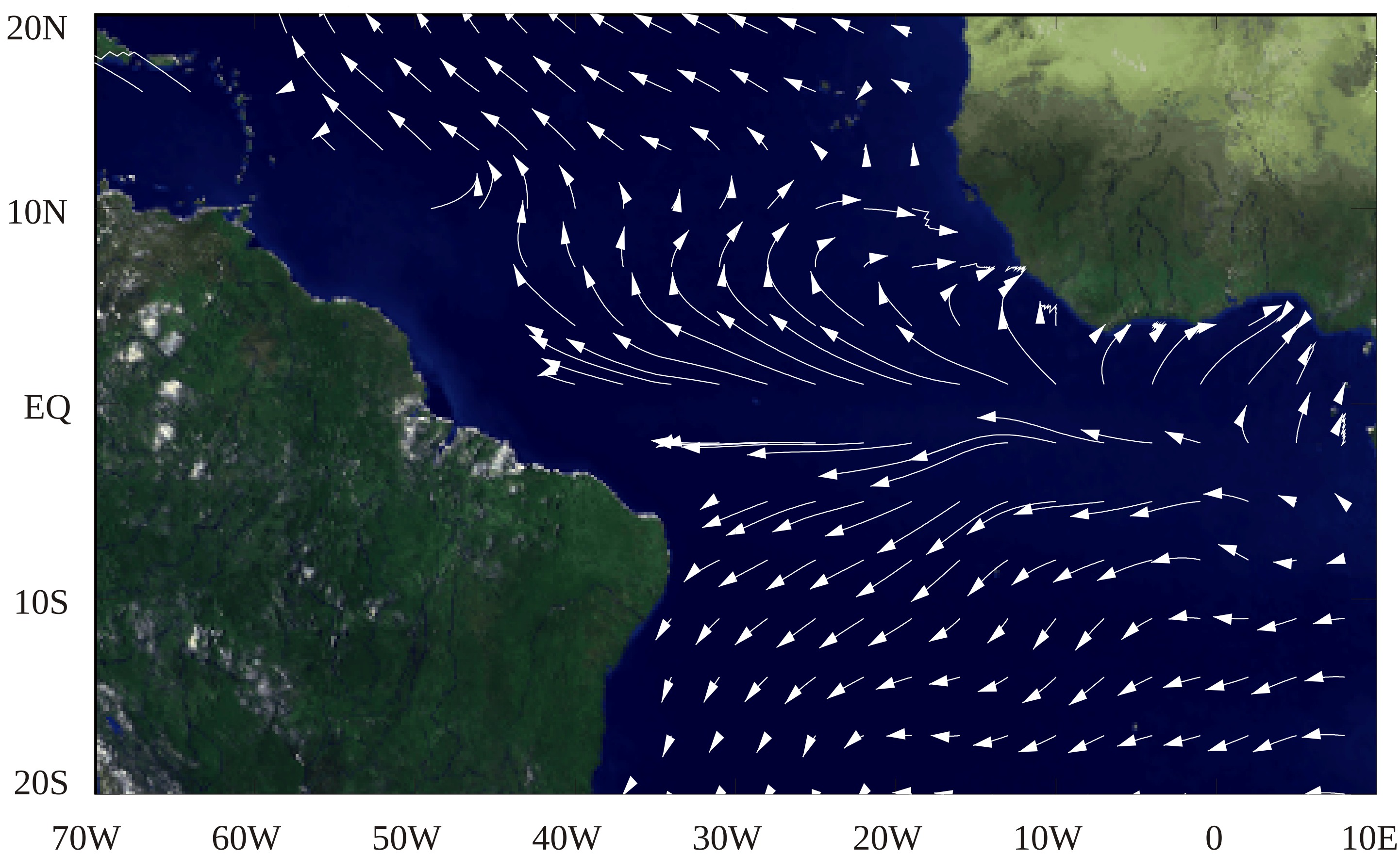


The ocean current velocity field is a combination of the geostrophic component computed from T/P altimeter data, and the wind driven Ekman drift component derived from SSMI wind data. The SST anomaly in the background is estimated using Reynolds SST field.

ANNUAL AVERAGE VELOCITY



Altimeter Derived Mean Current, 1992-1998

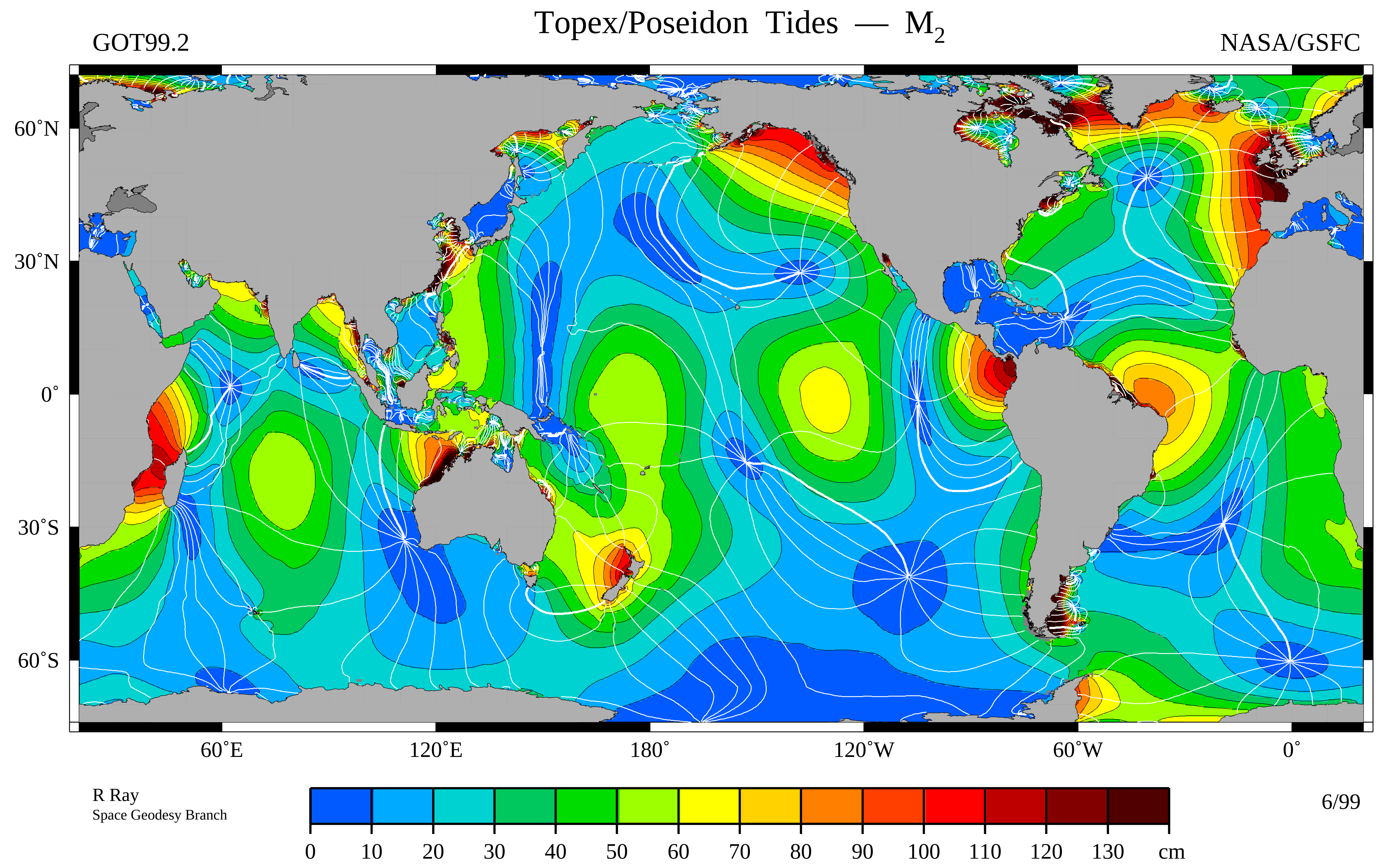


The top image is a mean ocean surface velocity obtained by ship drift data (Richardson and Walsh [1986]).The bottom image shows a similar ocean surface velocity field derived from TOPEX/POSEIDON altimeter data and SSMI wind data.

Altimetry Upgrades

While significant progress has been made in providing a consistent, cross-mission data set, further improvements to the complete data set are proposed. Progress continues in model development and instrument validation which in some cases, significantly improves our ability to isolate subtle, yet highly significant long period signals. These include:

- improved tidal models, especially through embedding regional models in shallow and enclosed seas within the global T/P-based model
- IRI-2000 ionosphere corrections for single frequency instruments
- Radiometer drift monitoring with VLBI and GPS
- improved orbits (GFO)
- barotropic dealiasing

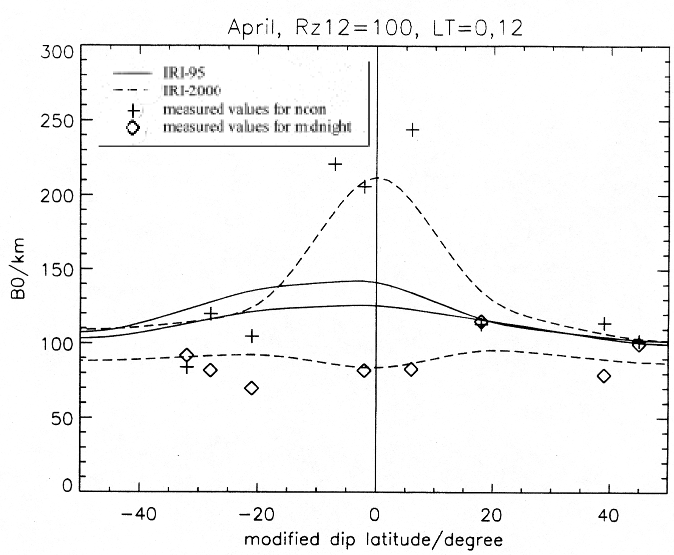


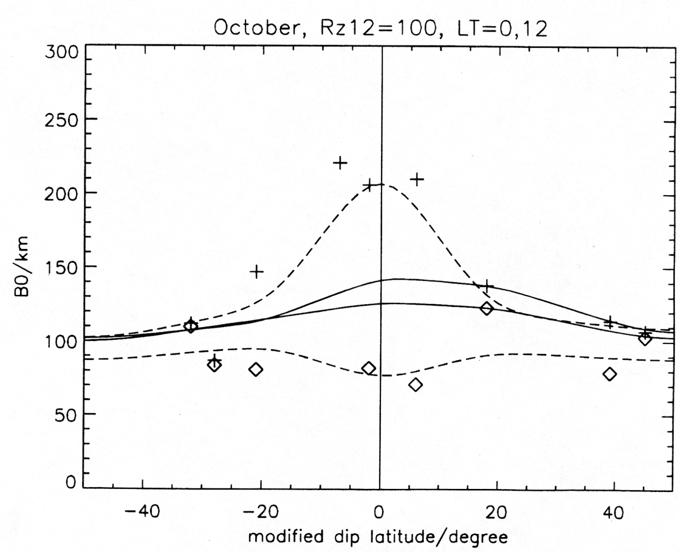
Global cotidal chart of amplitude and Greenwich phase lag for the M2 constituent.
Solution based on 232 cycles of T/P altimetry, plus FES94.1 and regional prior models.

IRI-2000

Upgrades Relevant for Single Frequency Altimeter Range Corrections

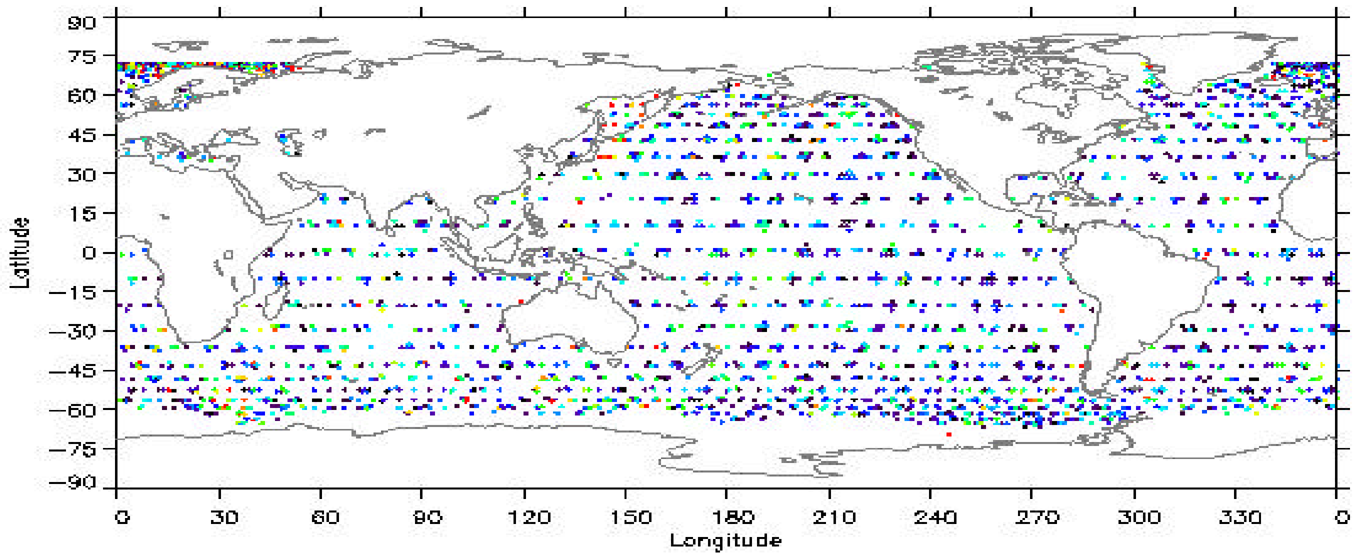
Bottomside (ICTP Task Force Activity)	Radicella /ICTP, Reinisch /USA, Bilitza / USA, Adeniyi /Nigeria, Mosert /Argentina, Zhang/ China, Zolesi , Spalla /Italy, Buresova /Czech R., et al.
Topside (ICTP TFA)	Bilitza /USA, Leitinger /Austria, Titheridge /New Zealand
Stormtime Updating	Kishcha /Russia, Fuller- Rowell /USA, Condrescu /USA
Realtime Updating with GPS Data	Komjathy /Hungary, Hernandez/Spain,

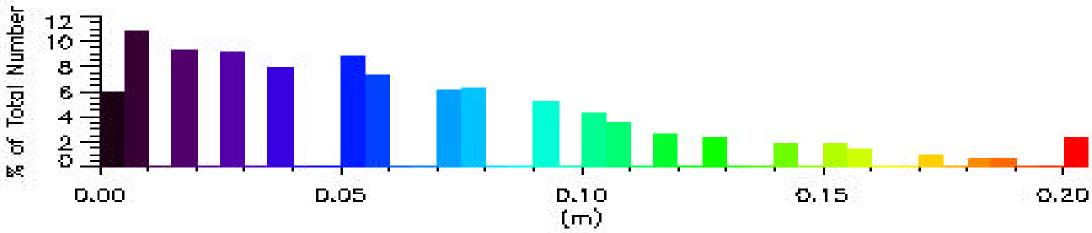




The above figures show the bottomside thickness B0 plotted against modified dip latitude for high solar activity (Rz12=100) for the spring and fall equinox. B0 determines the IRI electron density profile below the F peak and thus about 35 to 50 % of the Total Electron Content (TEC). The ionospheric correction of altimeter measurements is directly proportional to the ionospheric Total Electron Content (TEC) between the satellite and the ground.

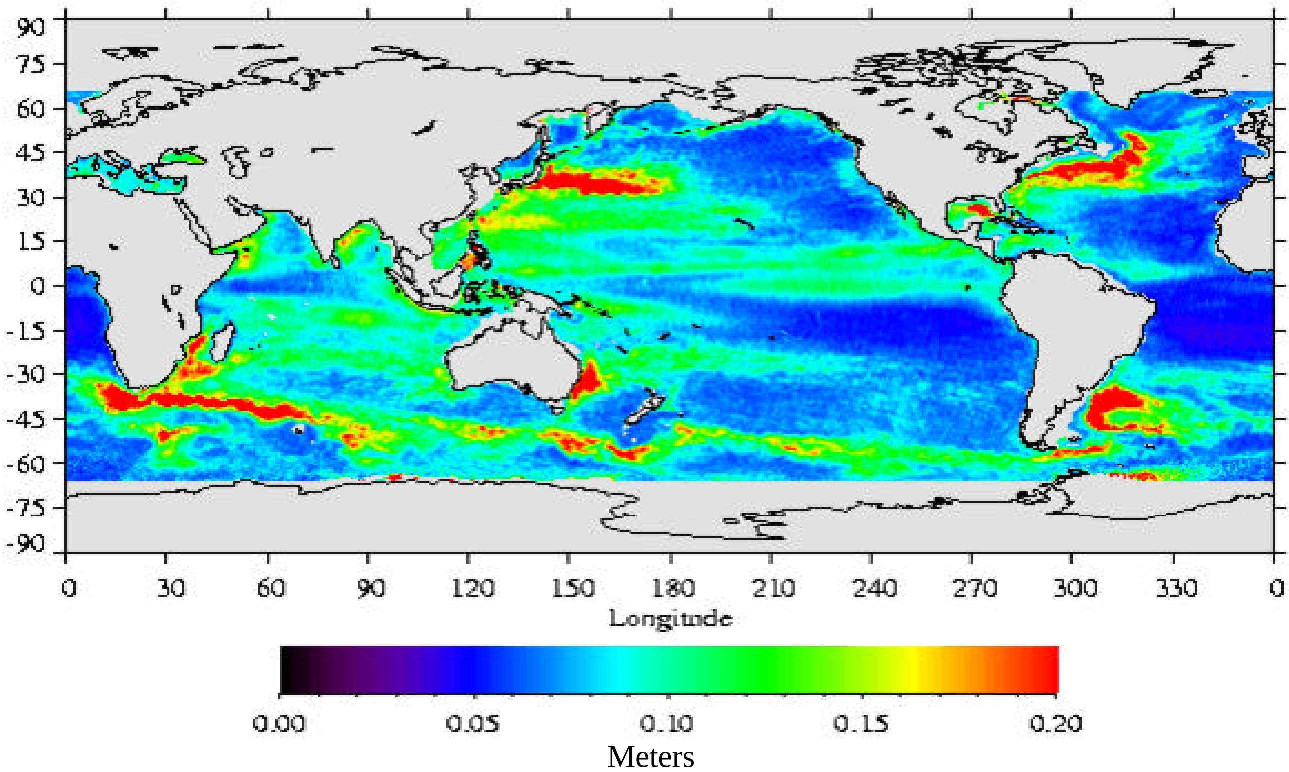
GFO Altimeter Dynamic Crossover Residuals (990616 – 990703)





RMS: 0.082 (m)   Mean: 0.064   Number Points: 3060

TP+ERS Sea Surface Height Variability



Calibration of Altimeter Microwave Radiometers with GPS and VLBI Wet Tropospheric Delays

- Monitor the long-term drift of the Topex and Jason-1 microwave radiometers

- The drift of the Topex radiometer has been estimated to contribute about 1-2 mm/year to global mean sea level rate of change

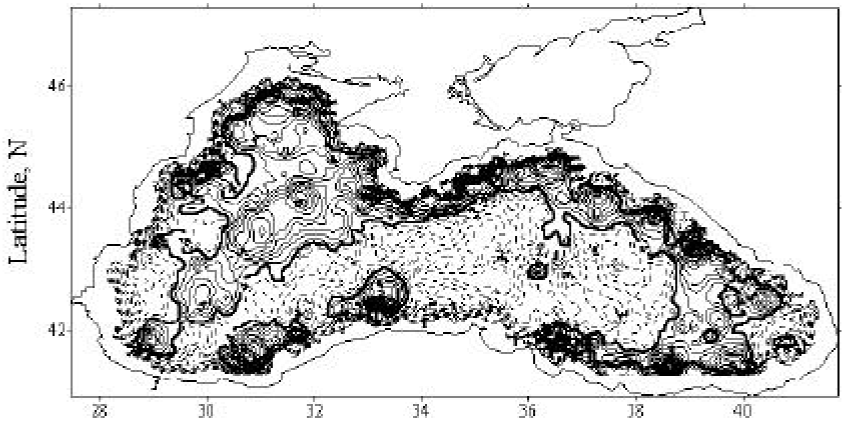
- We are using wet zenith delays estimated with the geodetic techniques of GPS (global positioning system) and VLBI (very long baseline interferometry)

- Currently we are analyzing data at about 25 globally distributed island or coastal GPS and VLBI sites

- Several years of geodetic data should determine the drift rate with a precision of about 0.5-1.0 mm/year at each site

Science Contributions

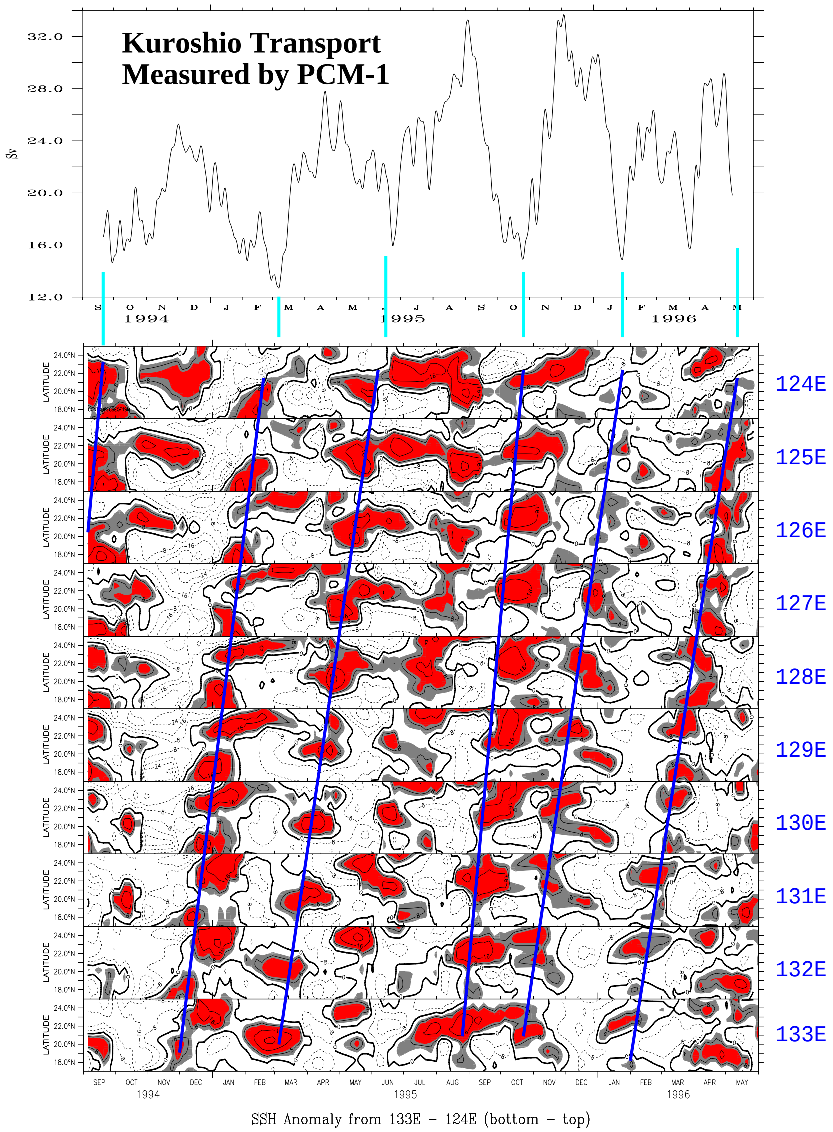
Applications of the Pathfinder data have been over a wide range of subject areas from large scale ocean changes to inland water variations. Some examples of recent results developed by investigators that have employed the Pathfinder data sets in their research activities are displayed.



Root mean square sea level deviation based on ERS-1 altimetry. Values smaller than 4 cm are denoted by a dotted line; contour intervals are 0.25 cm. Korotaev, G.K., Saenko, O.A., Koblinsky, C.J., "Satellite Observations of the Black Sea Level", submitted to Journal of Geophysical Research.

Pathfinder Project and WOCE PCM-1 Current Meter Array in Observing Kuroshio Variability at 24°N

Contribution by RSMAS University of Miami

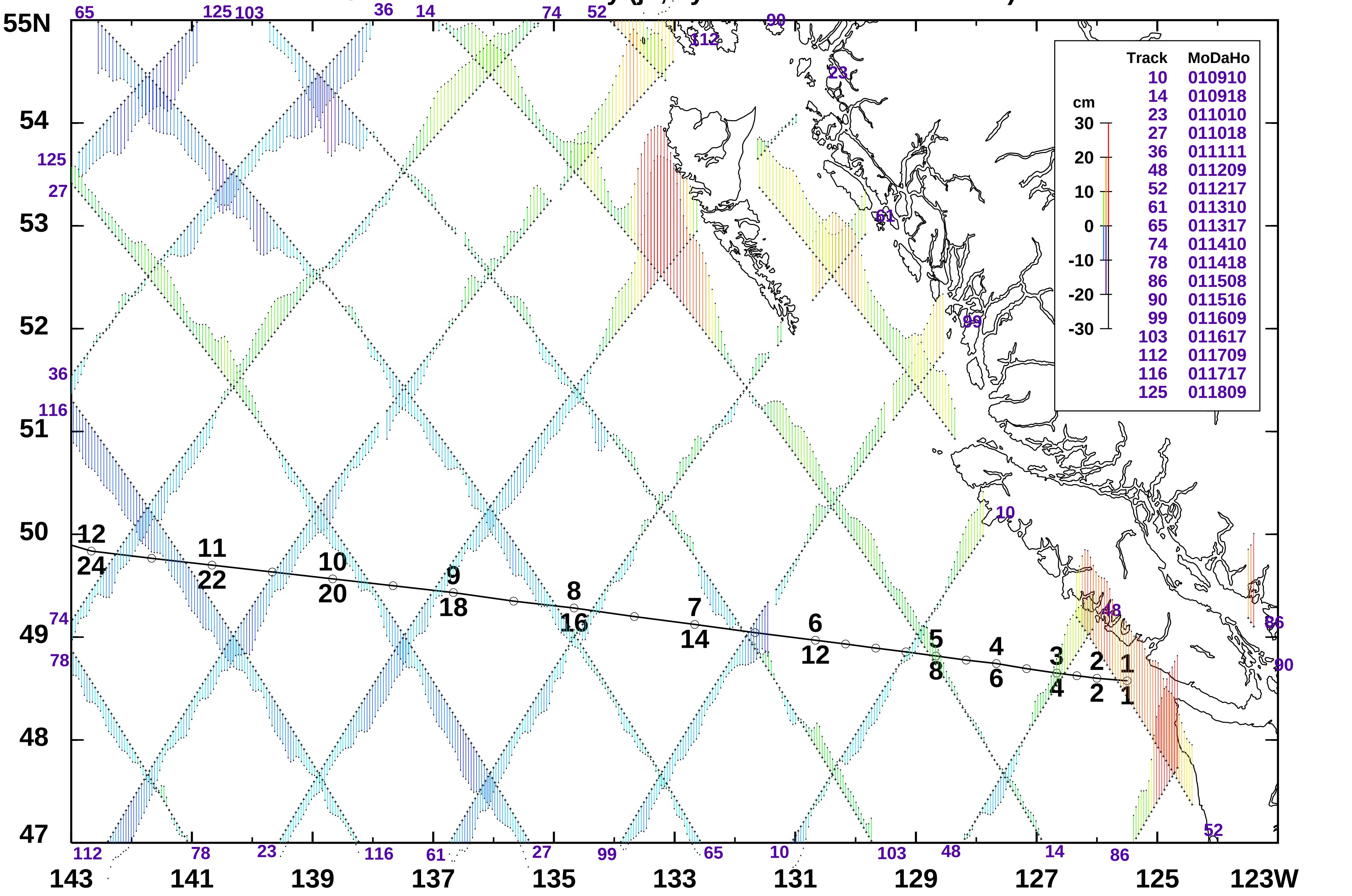


Bottom: latitude-time plots of T/P SSHA indicating westward propagation of anticyclonic eddies.

The Kuroshio transport entering the East China Sea has recently been shown by the WOCE PCM-1 moored current meter array to have strong variability on several month time scales. These strong transport fluctuations are found to be coincident with the arrival of mesoscale eddies at the western boundary from the interior ocean that cause the Kuroshio to undergo a large meander east of Taiwan. These large meanders steer part of Kuroshio water to flow northward off the Ryukyus.

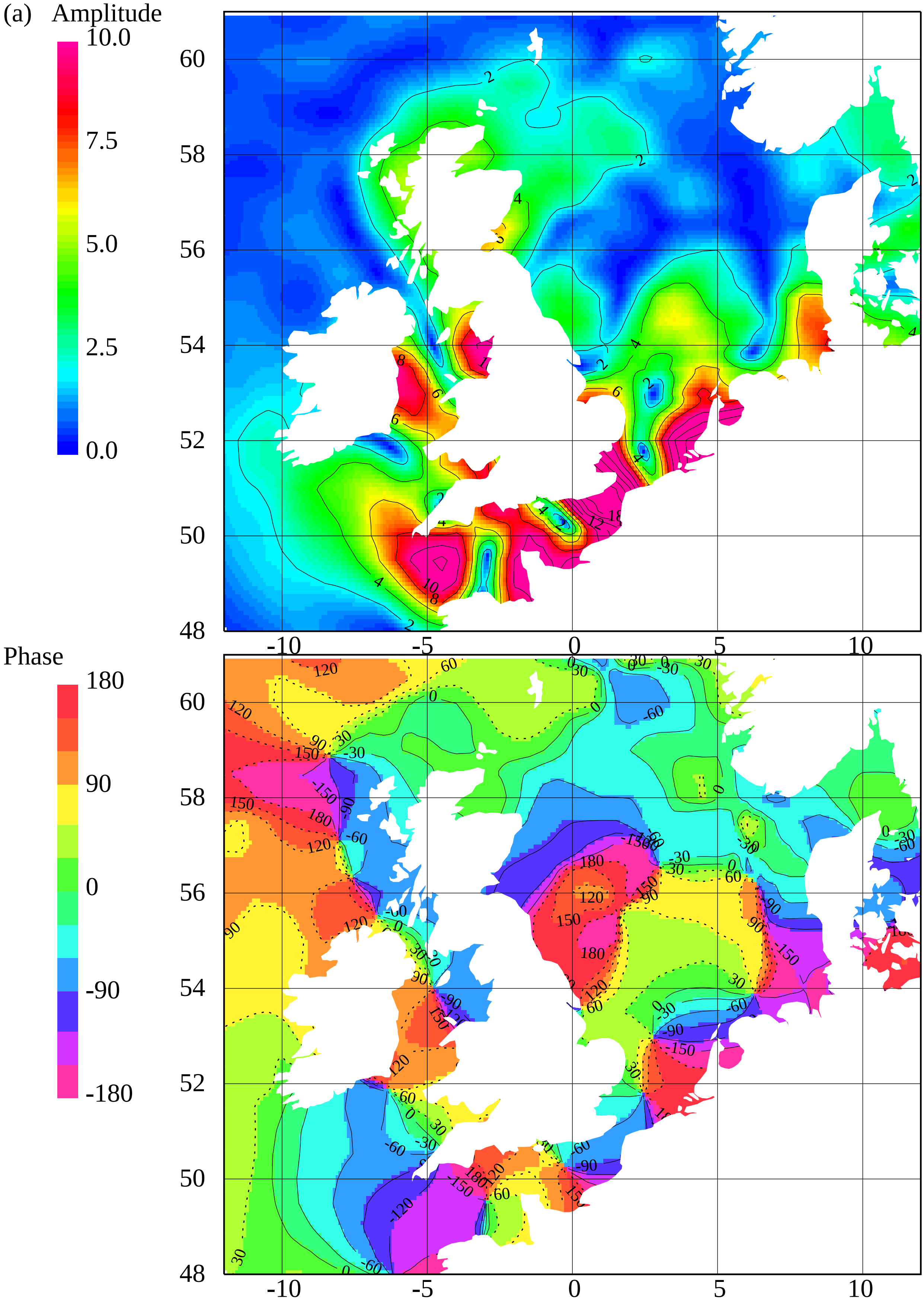
For detail, see Zhang, D., T.N. Lee, W.E. Johns, C-T Liu, and R. Zantopp, 1999: The Kuroshio East of Taiwan - Modes of Variability and Relationship to Interior Ocean Mesoscale Eddies. Submitted to J. of Phys. Oceanogr.
OR contact Dr. Bill Johns wjohns@rsmas.miami.edu

T/P Sea Level Anomaly (j5; cycle 196: 980109 - 980118)



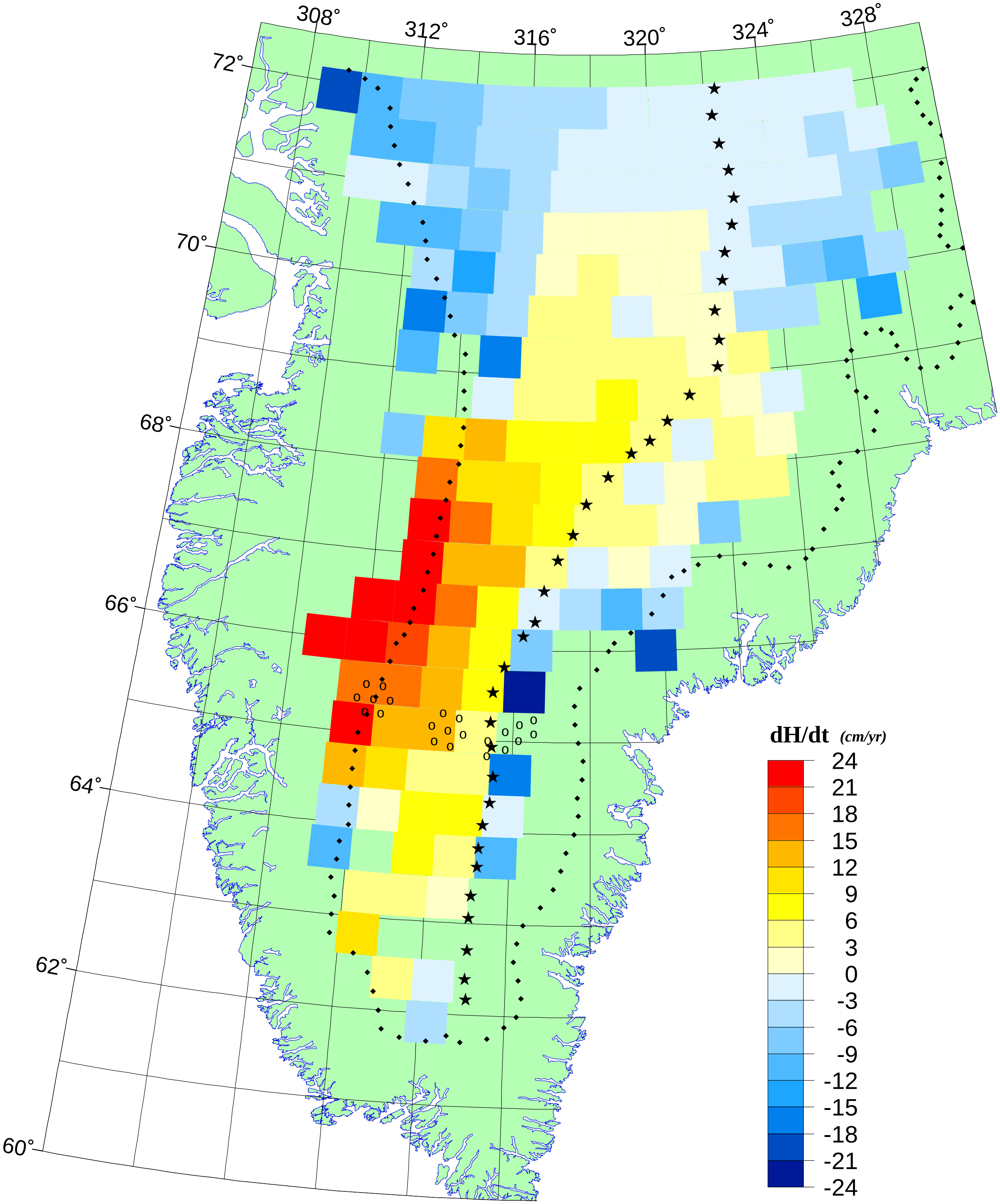
The early stages of eddy Haida while it was forming off the west coast of the Queen Charlotte Islands in early January, 1998. This image provides support for the mechanism of baroclinic instability as the generation process. Crawford, W.R., J.Y. Cherniawsky and M.G. Foreman, "Multi-year meanders and eddies in Alaskan Stream as observed by TOPEX/POSEIDON"

Shallow Water Tides from TOPEX/POSEIDON

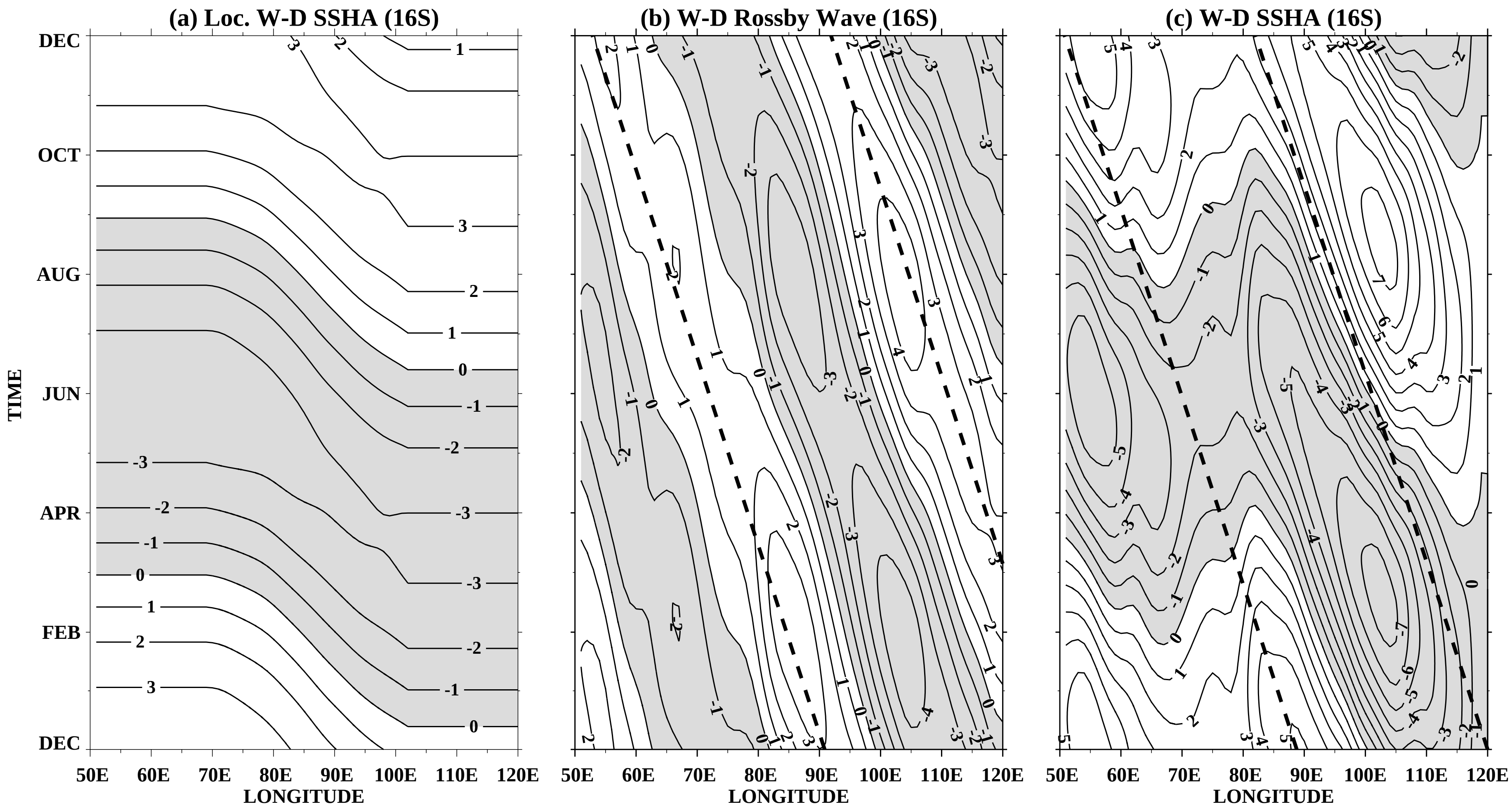


The shallow water M4 constituent in the northwest European shelf region derived from T/P data. Amplitudes are in centimeters, and phases are in degrees with respect to Greenwich. Note the ability of the T/P data to resolve high frequency shallow water tides. Reference:
O.B. Andersen, Shallow water tides in the northwest European shelf region from TOPEX/POSEIDON altimetry, Journal of Geophysical Research, Vol 104, C4, April 15, 1999.

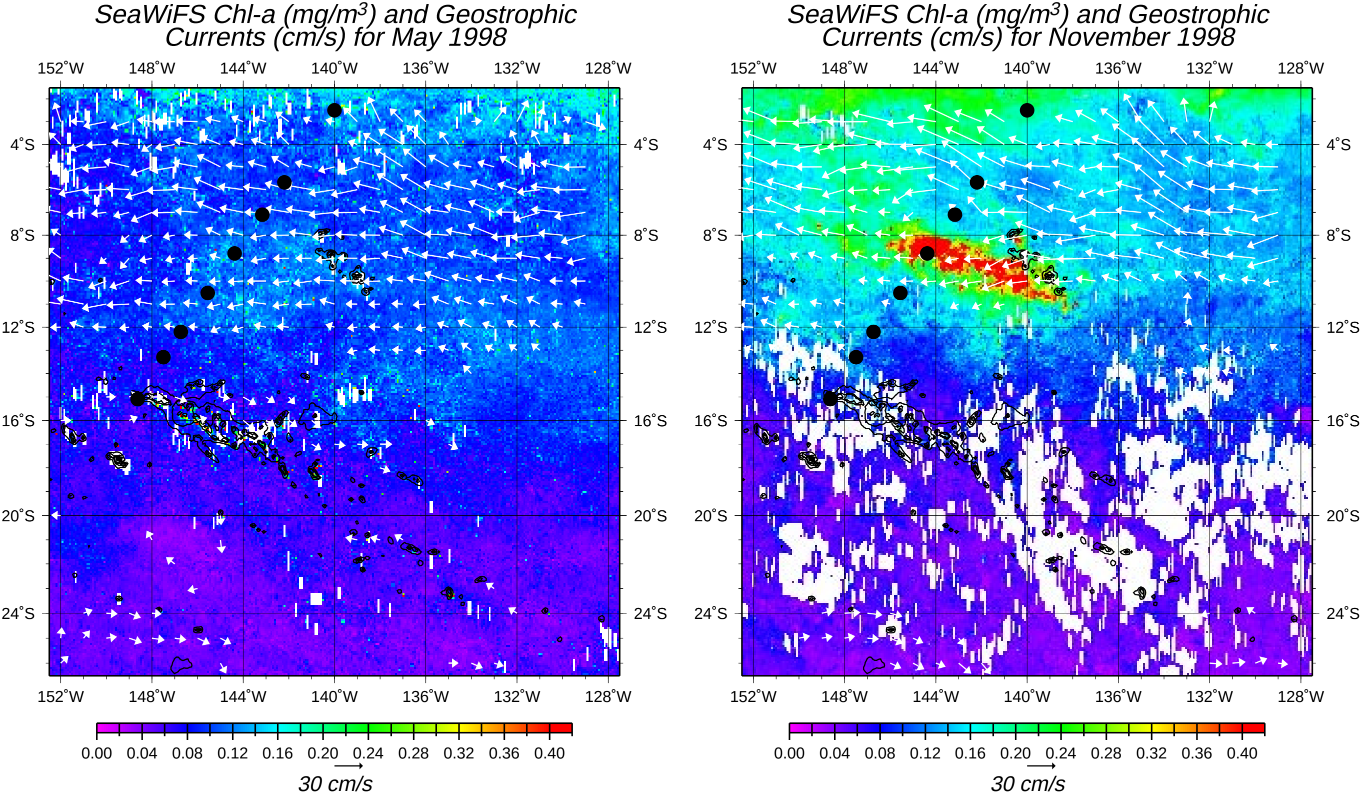
Ice Sheet Monitoring



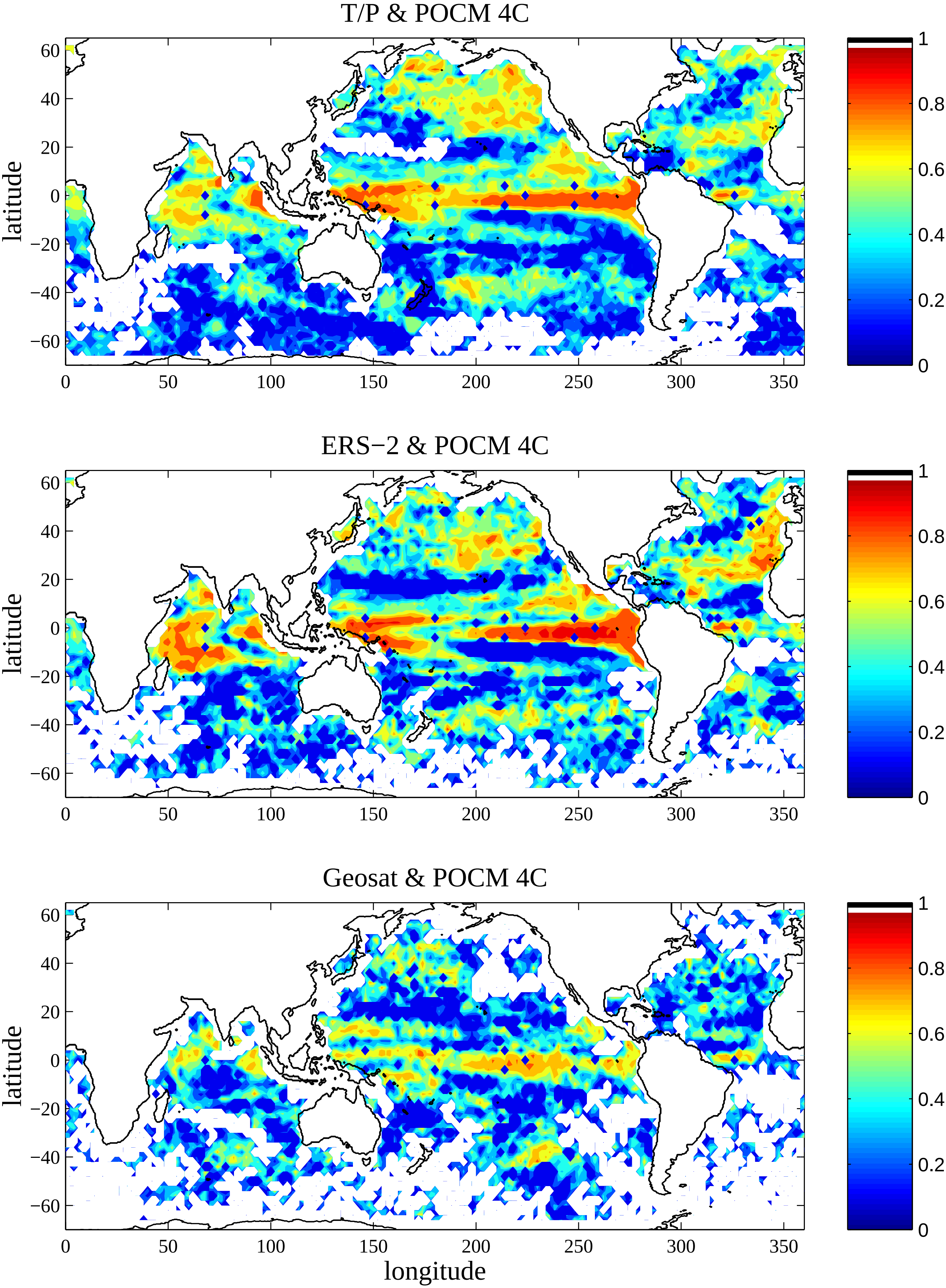
Elevation changes in the Greenland ice sheet are measured from the Geosat GM, ERM and Seasat altimetry. Courtesy of Davis, C.H., C.A. Kluever, B.J. Haines, C. Perez, and Y.T. Toon (1999), "Improved elevation change measurement of the Greenland ice sheet from satellite radar altimetry", IEEE Transactions on Geoscience and Remote Sensing, in press.



Separation of the T/P-observed wind-driven annual variability at 16S in the southern Indian Ocean, (c), into locally wind-driven response, (a), and wind-driven Rossby waves, (b), from Wang et al., (1999). The thick dashed lines in (b) and (c) show the theoretical phase lines with phase speed of 12.5 cm/s.



Average Chl a (mg m^{-3}) for May 1998 and November 1998 observed by SeaWiFS. Corresponding geostrophic surface currents derived from T/P altimeter data and dynamic height climatology are superimposed. Only speeds greater than 10 cm/s are shown. The black dots show the locations of the ALIZE II stations. The 500-, 1000-, and 2000-m bathymetry contours indicate the location of the Marquesas and other islands in the vicinity. Note that the phytoplankton bloom on the leeside of the Marquesas Islands (10^{o}N, 140^{o}W) intensifies in November 1998 when the South Equatorial Current grows in strength. This shows that the island blooms are coherent with strong flow events past the islands (from *Signorini et al.*,1999, *Geophys. Res. Lett.*, in press).


T/P & POCM 4C
ERS−2 & POCM 4C
Geosat & POCM 4C
latitude
longitude
60
40
20
0
−20
−40
−60
0
50
100
150
200
250
300
350
1
0.8
0.6
0.4
0.2
0