Combined studies of altimetric and subsurface data

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Satellite altimetric measurements of sea surface height, together with subsurface temperature and salinity (T/S) profiles and reference level velocities, form a dynamically complete description of the physical state of the ocean. We will combine TOPEX/POSEIDON and Jason-1 altimetric data with T/S profiles and reference velocities from the Argo Project as well as from ongoing High Resolution XBT/XCTD transects. Our goal is to study the role of the ocean in the climate system and to provide appropriate tests for data assimilation models that synthesize similar datasets.

Introduction and Objectives

The height of the sea surface is determined by the mass of water at a given location and by the water's density (a function of temperature, salinity and pressure). The altimeter measures changes in sea surface height due to both of these factors – redistribution of mass and changes in density (steric height). On seasonal to interannual time-scales, density changes are the largest contributor to sea level variability. In the tropics they are the dominant one.

Our project is aimed at an improved understanding of sea surface height variability and its causes through studies of altimetric sea level *in combination* with subsurface data. Models are not yet capable of accurately decomposing sea level variability into its components or of describing the vertical structure of the underlying density changes. By studying altimetric data together with subsurface data we can:
• Understand the relative contributions of mass and steric height variability to sea level change over a broad range of space and time-scales and geographic regimes.
• Verify the performance of models that assimilate altimetric data through direct comparison of subsurface model fields with data.
• Produce combined datasets that have the high spatial and temporal resolution of the altimeter, but that include the subsurface structure of temperature and salinity.
These datasets will be used for studies of ocean circulation and dynamics, especially the role of the ocean in the climate system – including heat transport and storage and the hydrological cycle.

Subsurface Datasets

High Resolution XBT/XCTD (HRX) transects

Throughout the TOPEX/POSEIDON era, temperature and salinity profile data have been collected along a set of repeating commercial ship tracks (figure 1) spanning the Pacific Ocean.

Transects are obtained quarterly along each track by a scientist or technician, consisting of temperature profiles (XBT) to 800 m at 10 - 40 km

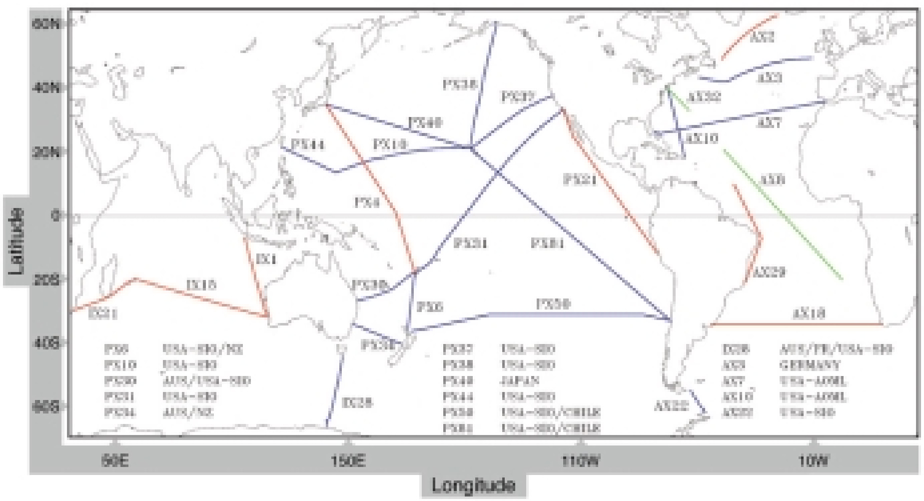

Figure 1: Ship tracks in the High Resolution XBT/XCTD Network. Blue lines indicate present quarterly sampled lines; red and green lines are planned.

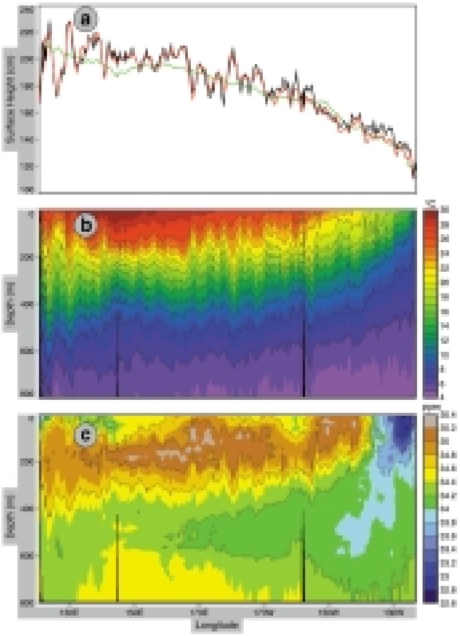

Figure 2: Temperature (b), salinity (c) and sea surface height (a) from a single XBT/XCTD transect along PX37/10/44 (figure 1) in May 1996. The black line is steric height and the red line is TOPEX/POSEIDON altimetric height, plotted as the deviation from the mean steric height (green).

spacing plus sparse salinity profiles (XCTD). These data allow comparison of steric height and altimetric height (figure 2) variability on seasonal to interannual time-scales and on spatial scales from those of fronts, eddies and boundary currents to the 10,000 km scale of the Pacific Ocean. A new 2000 m XBT with improved accuracy is being phased into use. We designed the Pacific HRX Network as a component of WOCE and CLIVAR, and we continue to implement it in collaboration with international partners.

Argo

A broadscale global array of 3000 CTD profiling floats, Argo (figure 3), is being implemented as part of CLIVAR and the Global Ocean Data Assimilation Experiment (GODAE). Once complete, the array will provide approximately 100,000 high quality temperature/salinity profiles per year, distributed randomly over the global ocean. It replaces the present broadscale XBT network, with deeper profiles, much better space-time coverage and the addition of salinity as well as temperature. In addition to profile data, Argo will obtain velocity measurements at a mid-depth reference level. Through the geostrophic relationship, velocity is proportional to the horizontal gradient of pressure and hence it is a measure of the mass distribution above the reference level. Argo was designed to be the subsurface counterpart to the Jason-1 altimeter, and the Jason-1/Argo combination measures sea level and its subsurface causes. Argo implementation has been started in 2000 by an international consortium of 12 float-providing nations, and the array will be complete by 2004. D. Roemmich was a co-designer of the Argo network and is chairman of the international Argo Science Team.

Interim Results

- Comparative studies of steric height and altimetric height have been carried out in both the North Pacific [Gilson et al, 1998] and South Pacific [McCarthy et al, 2000]. Steric height was shown to be the dominant component of sea level variability, with large-scale residuals that are due to the mass field. A correlation technique was developed for estimating subsurface temperature from altimetric data.
- Eddies observed concurrently by the TOPEX/POSEIDON altimeter and the HRX dataset in the tropical North Pacific were analyzed [Roemmich and Gilson, 2000] to reveal their surface (figure 4) and subsurface characteristics. Subsurface tilt of eddy centers was shown to result in substantial poleward heat transport and interannual variability in the equatorward transport of thermocline waters.
- Studies of the mean and interannual heat balance of the North Pacific [Roemmich et al, 2000a]

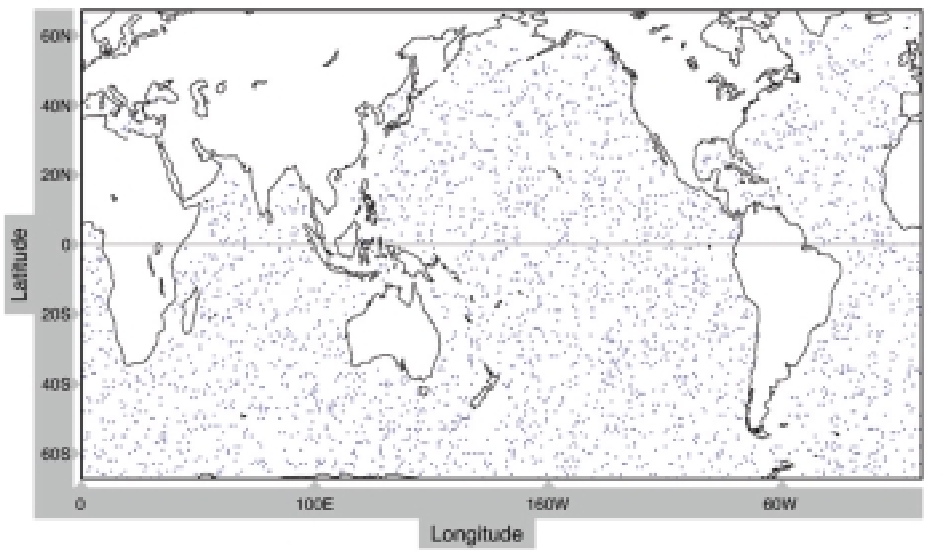

Figure 3: Schematic of the Argo array, showing 3000 randomly selected float locations. Each float will provide a T/S profile, nominally to 2000 m, and a reference level velocity, every 10 days.

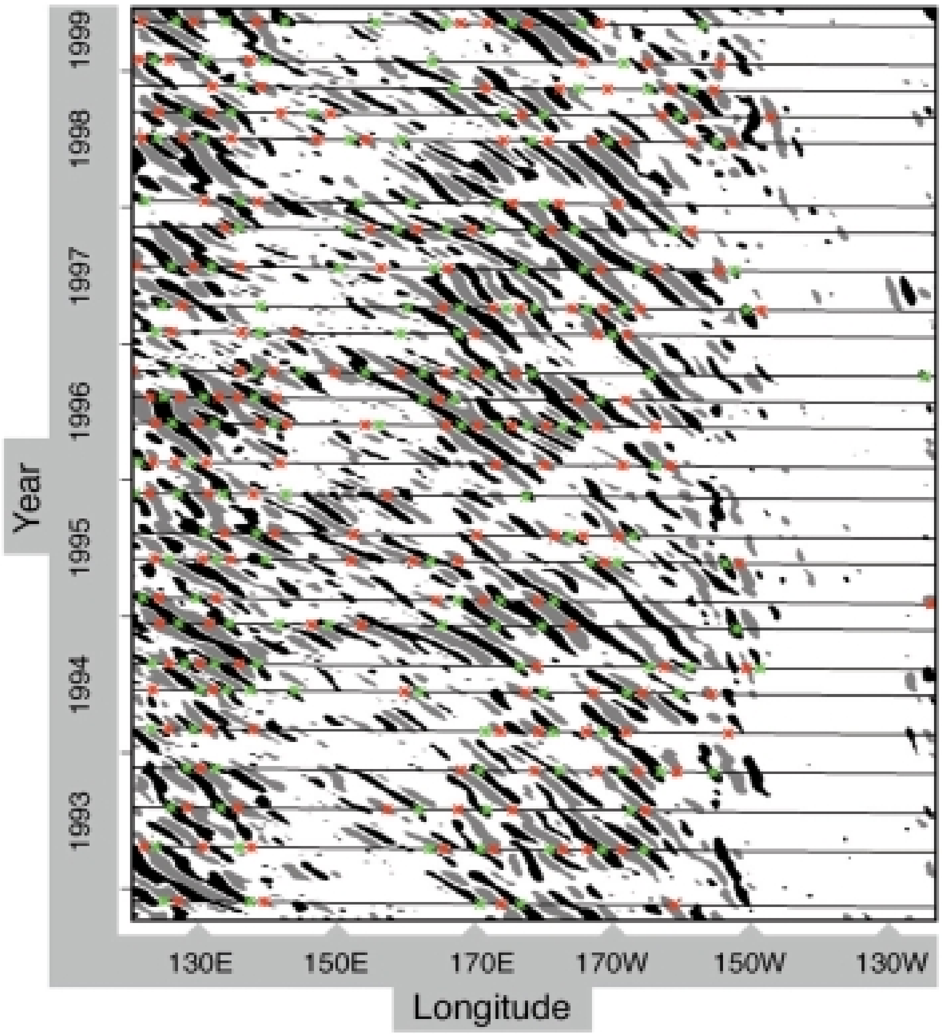

Figure 4: Eddy locations along the PX37/10/44 XBT track (see figure 1) in TOPEX/POSEIDON and XBT data, as a function of longitude and time. Warm-core eddies, with sea surface height maxima, are shown as red symbols for XBT data and gray shading for T/P data. Cold-core eddies are similarly indicated by green symbols (XBT) and black shading (T/P). From Roemmich and Gilson [2000].

and the tropical Pacific [Roemmich et al, 2000b] have been carried out using HRX data supplemented by TOPEX/POSEIDON altimetry.
The shallow overturning circulation, carrying warm water poleward and thermocline waters equatorward, is responsible for 1.2 pW of mean heat export from the tropical Pacific, with interannual variability of about 30%.

Approach and Future Plans

As Jason-1 and Argo come on line, we will continue to synthesize the combined altimetric and subsurface datasets. These studies will begin with, but not be limited to, the Pacific Ocean. They will focus broadly on the mass, heat and freshwater budgets of the ocean and on the large-scale circulation of the upper 2000 m. Our approach is complementary to data assimilating models, relying on statistical tools for dataset combination and interpolation, but without specifying the complete ocean dynamics.
The combined datasets are valuable in their own right for scientific studies of ocean circulation and transport, and as a tool for testing dynamical assimilations.
With assimilating models in their present rapidly developing state, analyses that are independent of the model dynamics and not subject to coarse model resolution are crucial for testing and verification of model results.

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