Gravity, bathymetry, and Mesoscale ocean circulation from altimetry

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Satellite altimeters provide data that are helpful for understanding both the ocean circulation (which varies in time) and the geophysical characteristics of the sea floor (which are invariant). The influence of sea floor bathymetry on ocean circulation is examined by jointly studying the time-varying and time-invariant components of altimeter measurements.

Over the last 15 years, satellite altimetry has enhanced our understanding of marine gravity, seafloor bathymetry and ocean circulation. The shape of the ocean's surface is determined by the Earth's gravity field. Bumps and wiggles in the time-averaged sea surface height measured by altimetry can tell us where the gravity field is particularly large or small [Sandwell and Smith, 1997]. In turn, the gravity field has been used to estimated the depth of the ocean. Anomalies in the gravity field are associated with seafloor ridges and troughs (as well as with differing densities of crustal material), so altimetric gravity estimates allow us to estimate ocean depth in regions not measured during past ship surveys [Smith and Sandwell, 1997]. Finally, since the Earth's gravity field is essentially constant over local time scales, variations in sea surface height from one satellite pass to the next tell us how the surface of the ocean is moving and allow us to infer changes in surface ocean currents.
The launch of the Jason-1 altimeter will extend the existing altimetric time series, providing better data to study year-to-year variability of the ocean and improving the accuracy of altimeter-derived estimates of geophysical quantities.

This study takes advantage of the excellent orbit accuracies of the TOPEX/POSEIDON and Jason-1 altimeters, which allow examination of sea surface height variations over distances as small as 10 to 20 km. Our goals are threefold: first to refine our knowledge of marine gravity and bathymetry, second to improve our understanding of eddy-scale ocean variability particularly in the poorly understood Southern Ocean, and finally to merge our geophysical analysis with studies of ocean circulation by asking how the specific features of bathymetry influence ocean circulation.

Our approach concentrates on using established techniques to retain small scale features measured in altimeter data [Yale, et al., 1995]. The same software is used for preliminary processing of all altimeter data, regardless of whether geophysical or physical oceanographic analyses are being carried out. With new data from Jason-1, we will update our altimeter databases, which will allow us to refine existing estimates of marine gravity and seafloor bathymetry and also to examine ocean surface variability on the lengthscale of ocean eddies (20 to 100 km).
We plan in particular to investigate how ocean variability in the ocean changes over the duration of the decade-long TOPEX/POSEIDON/ Jason-1 record.

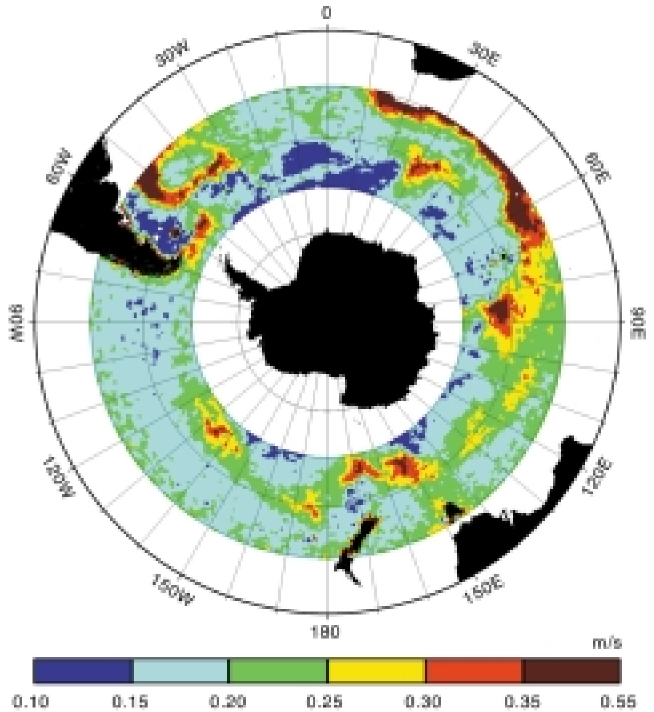

Figure 1: Southern Ocean eddy kinetic energy is high in the core of the Antarctic Circumpolar Current, both because the current meanders and because it spawns eddies. The path of the current is steered around ridges and bumps in the ocean floor.

This project focuses on the Southern Ocean, where small eddies interact with the meandering Antarctic Circumpolar Current. Figure 1 shows eddy energy in the Southern Ocean. By assuming that the Circumpolar Current consists of multiple meandering jets, we are able to separate ring-shaped transient eddies from the jet like structures that comprise the Circumpolar Current [Gille, 1994]. One challenge in interpreting ocean variability from altimetry stems from the fact that TOPEX/POSEIDON and Jason-1 return to each ocean location only once every 10 days, while the ocean itself can vary on time scales that are much shorter than 10 days [Stammer et al., 2000; Tierney et al., 2000; Gille and Hughes, 2001]. In order to study variability we will first need to determine how best to treat errors introduced by sampling once every 10 days. Ultimately we will examine how water moves through the Southern Ocean and how these motions evolve over the duration of our data record.

Finally, we will cross-compare our bathymetry and eddy variability datasets to examine the interactions between bathymetry and ocean circulation. Our early results show that on a global scale, high bottom roughness correlates with low eddy variability [Gille et al., 2000]. This implies that a strongly corrugated bottom may help dissipate surface eddy kinetic energy. During the TOPEX/POSEIDON and Jason-1 tandem mission, higher spatial resolution will be obtained, and we will be able to examine the geographic details of this interaction more closely. By studying the Southern Ocean circulation along with bathymetry, we hope to unravel the dynamics behind ocean/ bathymetry interactions.

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