Ocean Variations Along the Eastern Gulf of Alaska Due to ENSO

Steven D. Meyers[1], **Arne Melsom**[2], and **James J. O'Brien**[1]
[1]Center for Ocean-Atmospheric Prediction Studies, The Florida State University, Tallahassee, FL USA
[2]Norwegian Meteorological Institute, Oslo, Norway

Key Words: El Niño, Gulf of Alaska, eddies

Interannual variability in the coastal upwelling and upper ocean circulation in the eastern Gulf of Alaska (GOA) is linked to the El Niño/Southern Oscillation (ENSO) phenomenon in the tropical Pacific Ocean, largely via coastal Kelvin waves. Results from a high-resolution six layer, isopycnal, wind-forced Pacific basin model provided by the Naval Research Laboratory, Stennis, MS (NRL) are examined within the GOA. ENSO warm events are found to produce downwelling equatorial Kelvin waves that propagate into the GOA as coastally trapped waves. These waves suppress upwelling along the western coast of North America. Sufficiently large waves destabilize the Alaska Current, creating multiple strong anticyclonic eddies along the coast that slowly propagate into the GOA, where they survive for more than one year. The typical diameter of the anticyclonic eddies is <=200 km. These eddies are strongly baroclinic, with a typical value for the velocity difference between layers 1 and 2 of 15 cm/s. Cold El Viejo (La Niña) events generally suppress eddy formation in the GOA by stabilizing the coastal circulation. Observed sea level variations are similar to model results.

The numerical model used in this study is the NRL Pacific basin multi-layer model (Wallcraft 1991), which is based on the semi-implicit, free surface model of Hurlburt and Thompson (1980). The model is formulated using an Arakawa C-grid. The daily 1981-1995 surface windstress product from the European Center for Medium Range Forecasting, with the monthly climatology replaced by the Hellerman-Rosenstein climatology, drives the ocean circulation. Recent results from this class of models and additional model description is given by Hurlburt et al. (1996).

The 1/12-degree ETOPO5 bottom topography data set is used in order to include effects of realistic bathymetry. The topography data set was first interpolated to the model grid and then smoothed with a 9-point smoother. This is to reduce the energy generation at small scales, which are poorly resolved by the model. In the model integration, the amplitude of the topography above the maximum depth of 6500 m was multiplied by 0.78 to confine it to the lowest layer. The model includes realistic coastline geometry, determined by the 200-m depth contour of the ETOPO5 topography, which is the minimum depth in the model and represents the shelf break. The model domain extends from 20°S to 70°N latitude and has a horizontal resolution of 0.0625-degree in latitude and about 0.083-degree in longitude.

Model results indicate anticyclonic eddy formation along the eastern GOA nearly every winter of the 1981-1995 run. The eddies drift westward. The non-ENSO year eddy amplitude is about a +15 cm deviation of the sea surface height (SSH). The nominal diameter of these eddies is 60 km, and their lifetime is 1 to 1.5 years. Following the 1982/83 El Niño, eddy amplitudes reached roughly a +45 cm deviation with diameters of nearly 200 km (Fig. 1). These eddies are also long-lived, lasting over 1.5 years. These are large compared to the net SSH change across the model GOA of 80 cm, and much greater than the change across the Alaska Current. Therefore the large eddies represent a disruption of the Alaska Current by ENSO.

No anticyclonic eddies were found following the 1988/89 cold event, but cyclonic patches with amplitudes around -20 cm were found in the model. This suggests an asymmetry between the warm and cold ENSO events. The downwelling waves of the warm event strengthen the Alaska Current, steepening the isopycnals until instability occurs. The upwelling cold events flatten the isopycnals and stabilize the system. Sufficiently strong along-shore wind events associated with ENSO can have a similar effect (Ramp et al. 1997).

A match-filter technique is employed to detect eddies from TOPEX/Poseidon (satellite instrument) altimetery along a single track in the eastern GOA during late 1992 through 1996 (Meyers and Basu 1998). Anticyclonic and cyclonic eddies have similar spatial distributions, with most occuring between 50°N and the northern limits of the GOA. Anticyclonic eddies have a broad distribution of amplitudes (5-20 cm) compared to cyclonic features, which are almost normally distributed over 5-13 cm. The average amplitude of anticyclonic eddies increases following the 1994/95 El Niño and decreases following the 1995/1996 El Viejo. A similar result was found by Matthews et al. (1992).

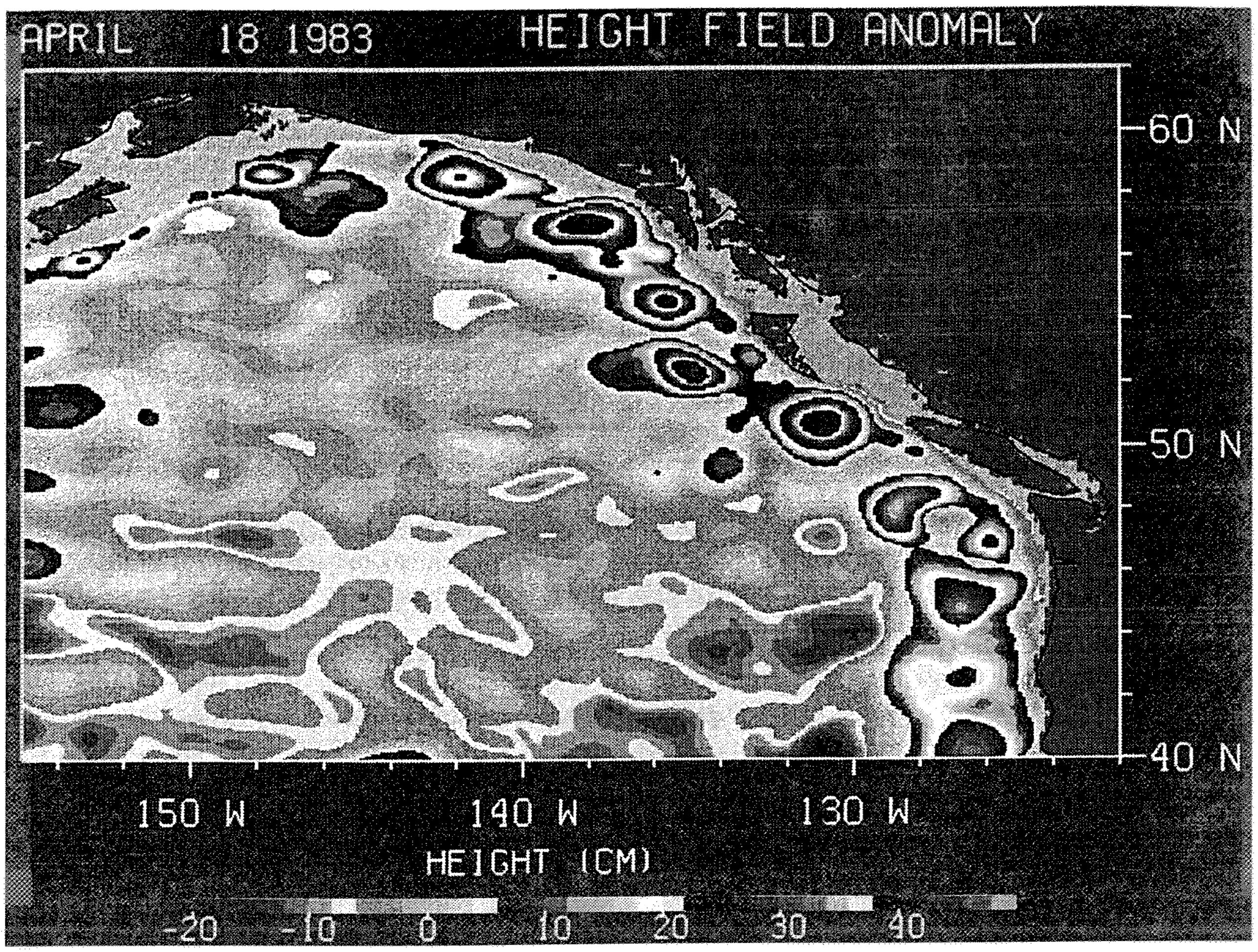

Fig. 1. Sea surface height anomaly (minus the 1981-1995 mean) following the 1982/83 El Niño. Eddies for due to the destabilization of the Alaska Current by a coastal Kelvin wave.

REFERENCES

Hurlburt, H.E., and J.D. Thompson. 1980. A numerical study of loop current intrusions and eddy shedding. J. Phys. Oceanogr. 10:1611-1651.

Hurlburt, H.E., A.J. Wallcraft, W.J.S. Jr., P.J. Hogan, and E.J. Metzger. 1996. Dynamics of the Kuroshio/Oyashio current system using eddy-resolving models of the North Pacific Ocean. J. Geophy. Res. 101C:941-976.

Matthews, P.E., M.A. Johnson, and J.J. O'Brien. 1992. Observation of mesoscale ocean features in the Northeast Pacific using Geosat radar altimetry data. J. Geophy. Res. 97:17829-17840.

Meyers, S.D., and S. Basu. 1998. Eddies in the eastern Gulf of Alaska from TOPEX/POSEIDON altimetry. J. Geophy. Res. (Manuscript).

Ramp, S.R., J.L. McClean, C.A. Collins, A.J. Semtner, and A.S. Hayes. 1997. Observations and modeling of the 1991-1992 El Niño signal of central California. J. Geophy. Res. 102C:5553-5582.

Wallcraft, A.J. 1991. The Navy layered ocean model users' guide. Tech. Rep.35, NOARL, Naval Res. Lab., Stennis Space Center