Statistical Survey of Mesoscale Eddies and their Impacts on Station ALOHA

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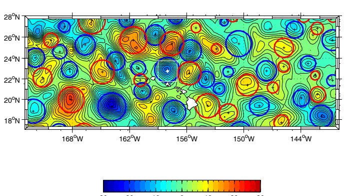
Introduction & Methods

Eddies have important consequences for physical phenomena and significant influences on biogeochemical properties (Robinson, 1983). The objective of this work is to understand the characteristics of eddies and their impacts on the waters north of Oahu, Hawaii, by developing a catalog of the eddies that pass through this region. We focus on the region surrounding Station ALOHA, the deep-ocean site of the Hawaii Ocean Time-series (HOT) Program.

Station ALOHA is a 10 km radius circle centered on 22°45' N and 158° W, 100 km north of Oahu. The HOT Program has been conducting monthly shipboard sampling at this site since 1988. Eddies have noticeably affected the physics and biogeochemistry measured during some cruises (Letelier et al. 2000).

Eddies are detected and tracked using a variation on an algorithm developed by Chelton et al. (2007). This method isolates areas of closed sea surface height (SSH) anomaly contours from unfiltered gridded AVISO satellite altimetry data during OCT 1992 - DEC 2006. Eddies are then identified from these isolated regions by stepwise partitioning the SSH field in 1 cm increments at each time step. Amplitude, effective radius, translation speed and axial speed are also calculated. This method limits the effective radius to about 200 km and the minimum lifetime is 4 weeks.



A snapshot of unfiltered AVISO sea level anomalies (cm) overlaid with eddy algorithm output on 22 February 2006. Station ALOHA is marked as the white cross and the surrounding 2°x2° square represents the region of focus.

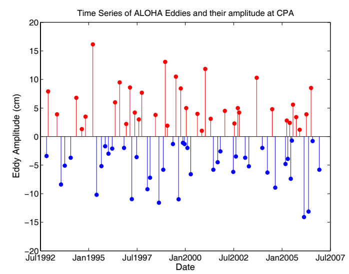
Information about the vertical structure of some of these eddies is provided by data from HOT cruises. HOT data include temperature, salinity, dissolved oxygen and inorganic nutrients (nitrate & nitrite, phosphate and silicate).

A detailed visual analysis comparing the algorithm output with unfiltered SSH AVISO data was also done to describe the behavior of ALOHA eddies as they progressed through the eddy stages of development, maturation and dissipation. Descriptions include possible interactions with other features including topography, and changes in direction during translation.

Conclusions

24% of the variance of select water mass properties at Station ALOHA is described by the first EOF mode in potential density space & most of the significant events of this mode are associated with eddies that formed east of ALOHA. Eddies pass through the 2°x2° square region surrounding Station ALOHA every 10 weeks (on average) and intersect ALOHA during 68 of 136 select HOT cruises. ALOHA eddies have no bias for rotation, average amplitude of 7 cm, average translation speed of 6 cm/s & average radius of 100 km.

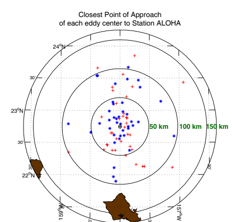
ALOHA Eddy Characteristics



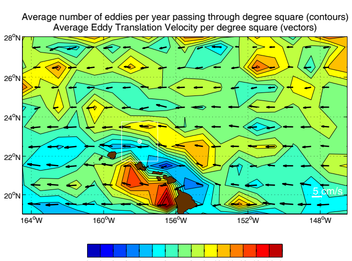
Time series of eddy events and the amplitude at their Closest Point of Approach (CPA) to ALOHA. Blue stems indicate cyclonic eddies and red indicate anticyclonic eddies.

Seventy six (36 anticyclonic and 40 cyclonic) eddies were found to intersect Station ALOHA. All of these eddies had lifetimes of at least 4 weeks, a center that passed through the 2°x2° square surrounding ALOHA and a radius that overlapped Station ALOHA.

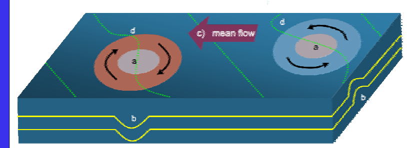
CPA of the eddy center to Station ALOHA. Eddies move from east to west, but several dissipated before reaching Station ALOHA and a few formed west of the station. Eddies that passed south of ALOHA appeared to have strong interaction with the islands.



These eddies have an average amplitude of 7 cm, average radius of 100 km and an average translation speed of 6 cm/s. The figure below shows the spatial distribution of eddy activity north of the Hawaiian islands.

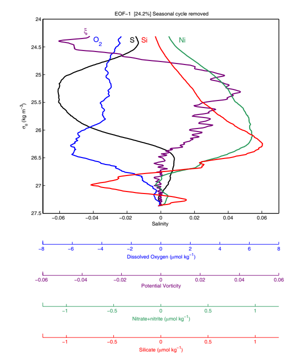


Impacts at ALOHA

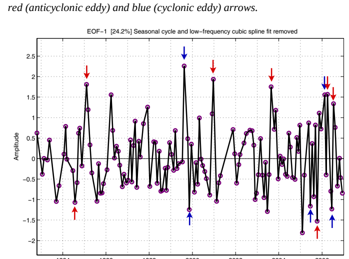


The mechanisms by which an anticyclonic(left) eddy and a cyclonic (right) eddy advect anomalous water properties: a) bolus transport, b) vertical advection, c) advection through the mean flow, and d) lateral entrainment.

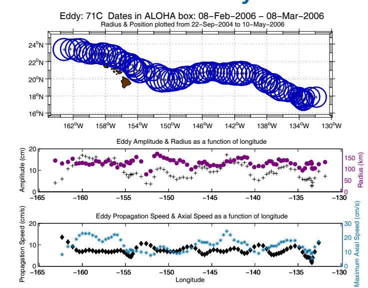
The first EOF mode of Station ALOHA water mass variability describes 12 eddies, all of which formed well east of the Hawaiian islands. These anomalous water properties are indicative of bolus transport, though some eddies appear in several modes, indicating multiple types of variability, such as lateral entrainment.



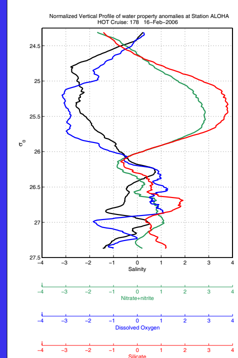
EOF mode-1 spatial structure (above) and time series (below) with large amplitudes (abs[amplitude>1]) that correspond to eddy events annotated with red (anticyclonic eddy) and blue (cyclonic eddy) arrows.



Case Study



After spinning up, this cyclonic eddy travelled northwest until reaching 22N, then moved directly westward until it reached the Hawaiian islands. At that point, it moved northwest until it cleared Kauai, then moved west again. The figure in the far left column shows this eddy as it passed over ALOHA, along with other eddies that were tracked on 2/22/2006.



The vertical profile of normalized water property anomalies has the mean of the 3 previous HOT cruises removed and is normalized by the standard deviation in each density interval for all HOT cruises. The normalized anomalies are plotted versus potential density to remove the effects of vertical advection.

The eddies in this study are extremely dynamic and difficult to characterize. Subjective analysis showed that eddy-eddy and eddy-island interactions are an important part of eddy dynamics, in both the physical and the biogeochemical realms.

References

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