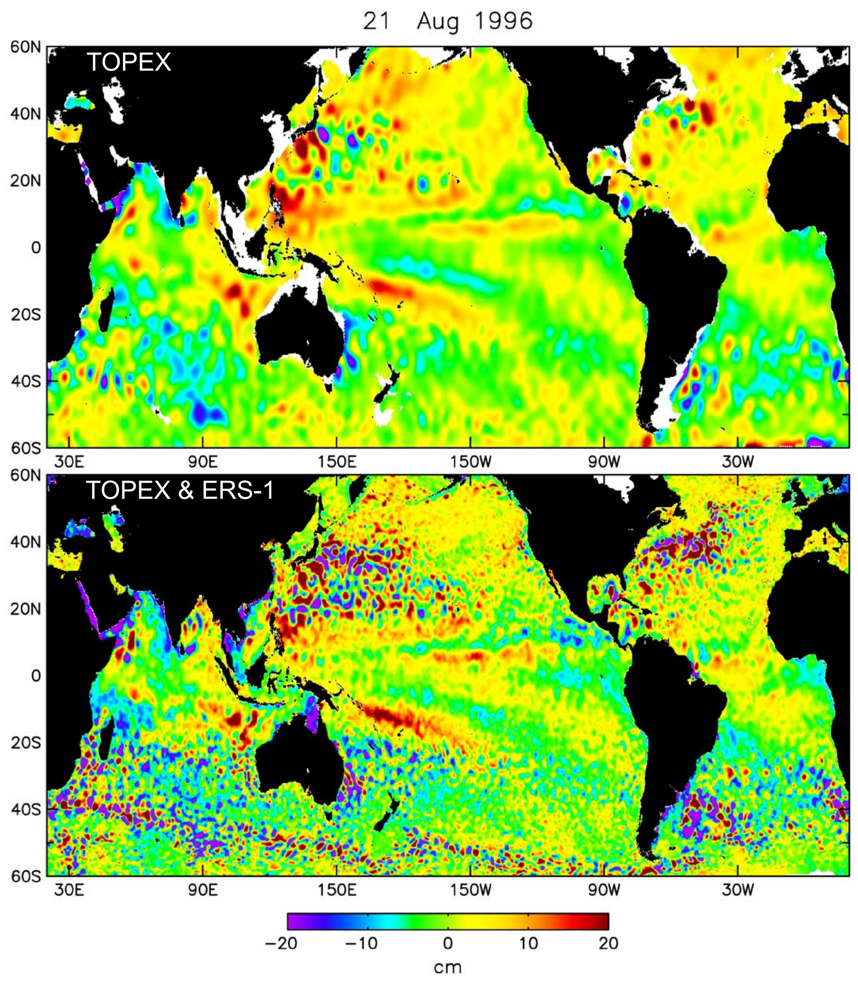
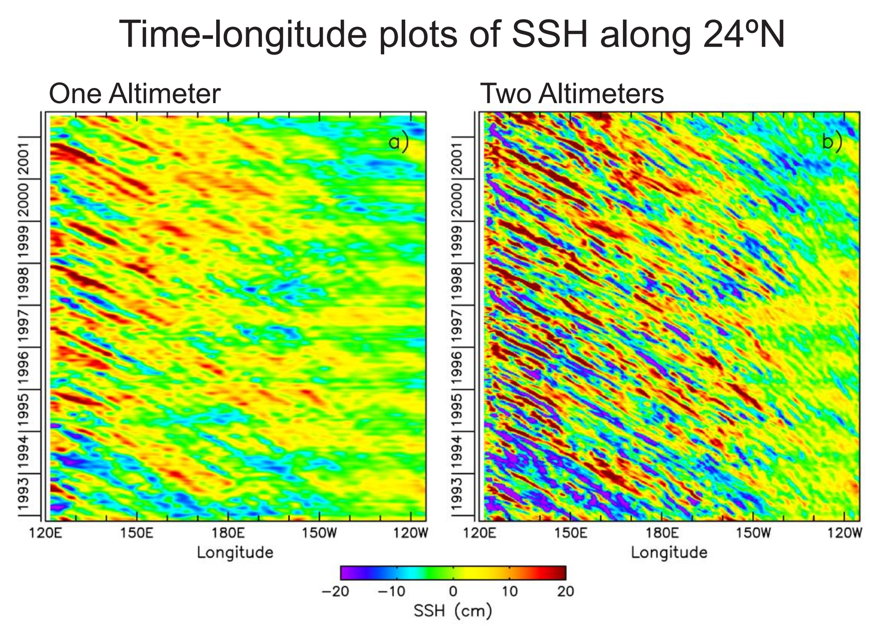
An Investigation of Global Mesoscale Variability

Dudley B. Chelton (chelton@coas.oregonstate.edu)
and Roger M. Samelson (rsamelson@coas.oregonstate.edu)
College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR, 97331-5503 USA

1. High-Resolution SSH Fields from Two Altimeters

Maps of the SSH fields constructed from measurements by two simultaneously operating altimeters (one in a 10-day orbit and the other in a 35-day orbit) reveal the eddy-like character of the variability (below left). Time-longitude plots (below right) show little indication of dispersion, as expected for nonlinear eddies, but inconsistent with linear Rossby waves.

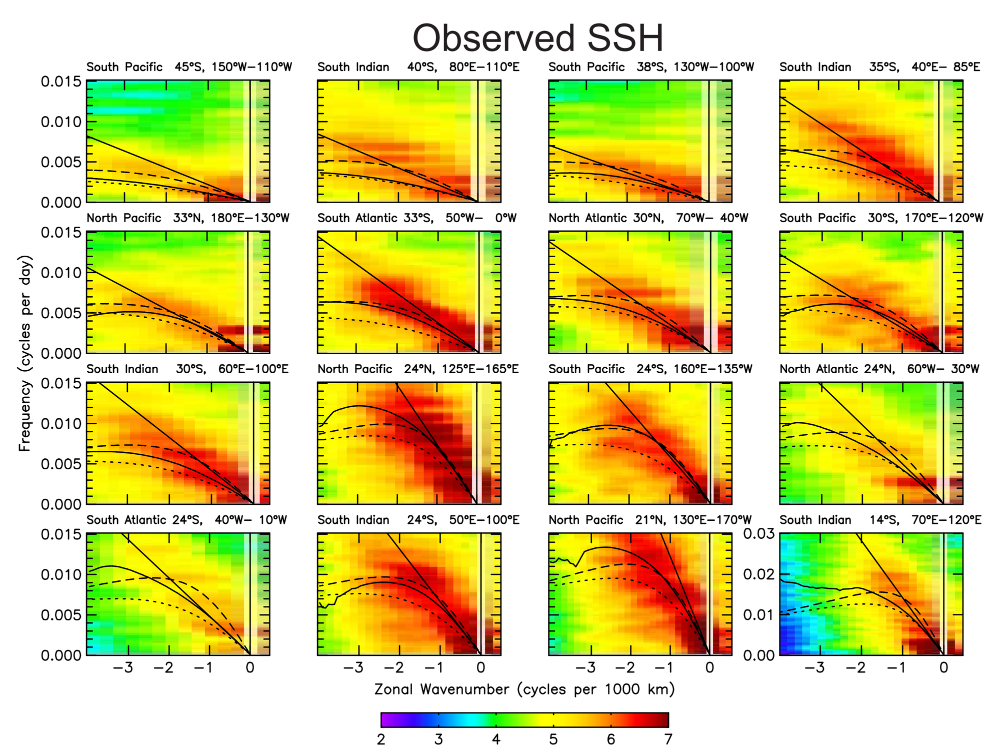


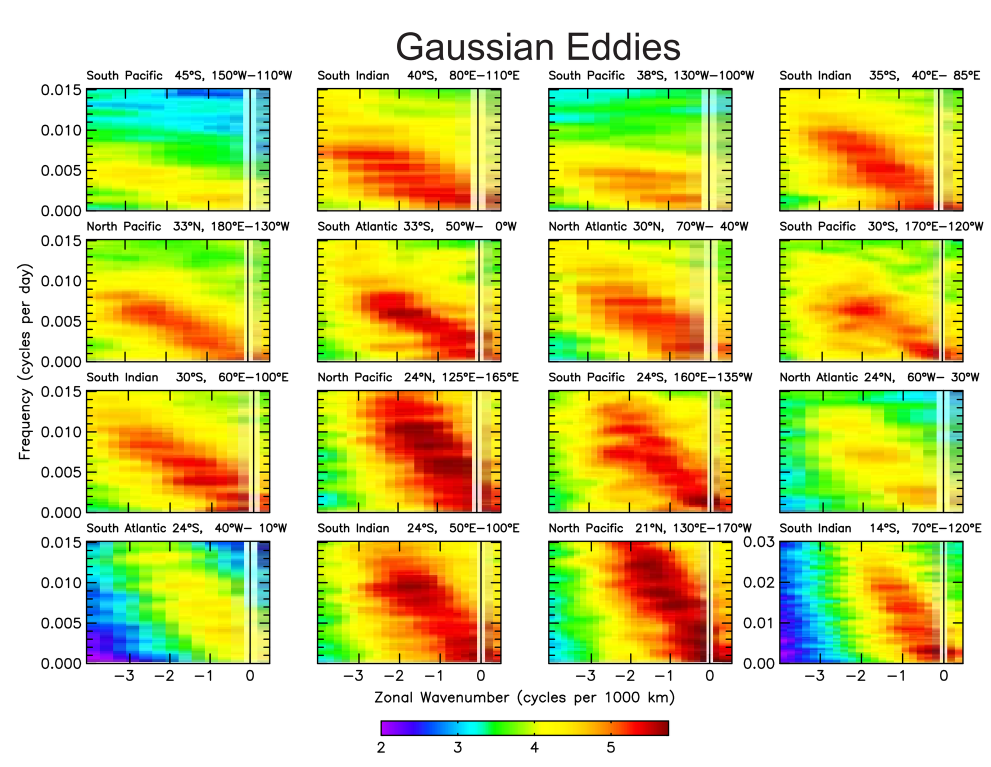


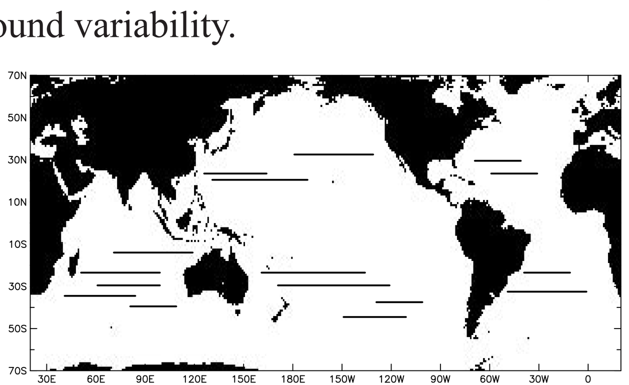
2. Zonal Wavenumber-Frequency Spectral Analysis

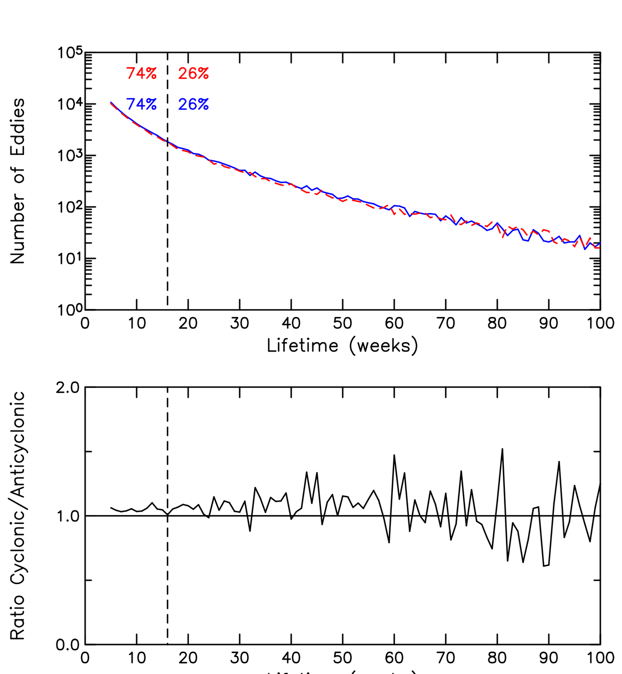
Wavenumber-frequency spectra were computed along the 16 sections shown below. The variance is concentrated along a straight line in wavenumber-frequency space (upper right), corresponding to nondispersive westward propagation. There is considerable variance at frequencies higher than can be accounted for by the standard theory for Rossby waves (dotted lines) or by the modified theories that include the effects of vertical shear (solid lines) or rough bottom topography (dashed lines).

The spectra of observed SSH variability are well reproduced by substituting simple Gaussian eddies for the times and locations of all of the tracked eddies with lifetimes ≥ 16 weeks (see Section 3). Note the different color bar; the variance of the simulated eddy fields is necessarily biased low because of discretization of the contours of SSH used to define eddy perimeters, the existence of eddies that are either not tracked or have lifetimes < 16 weeks, and the existence of broad-banded non-eddy background variability.







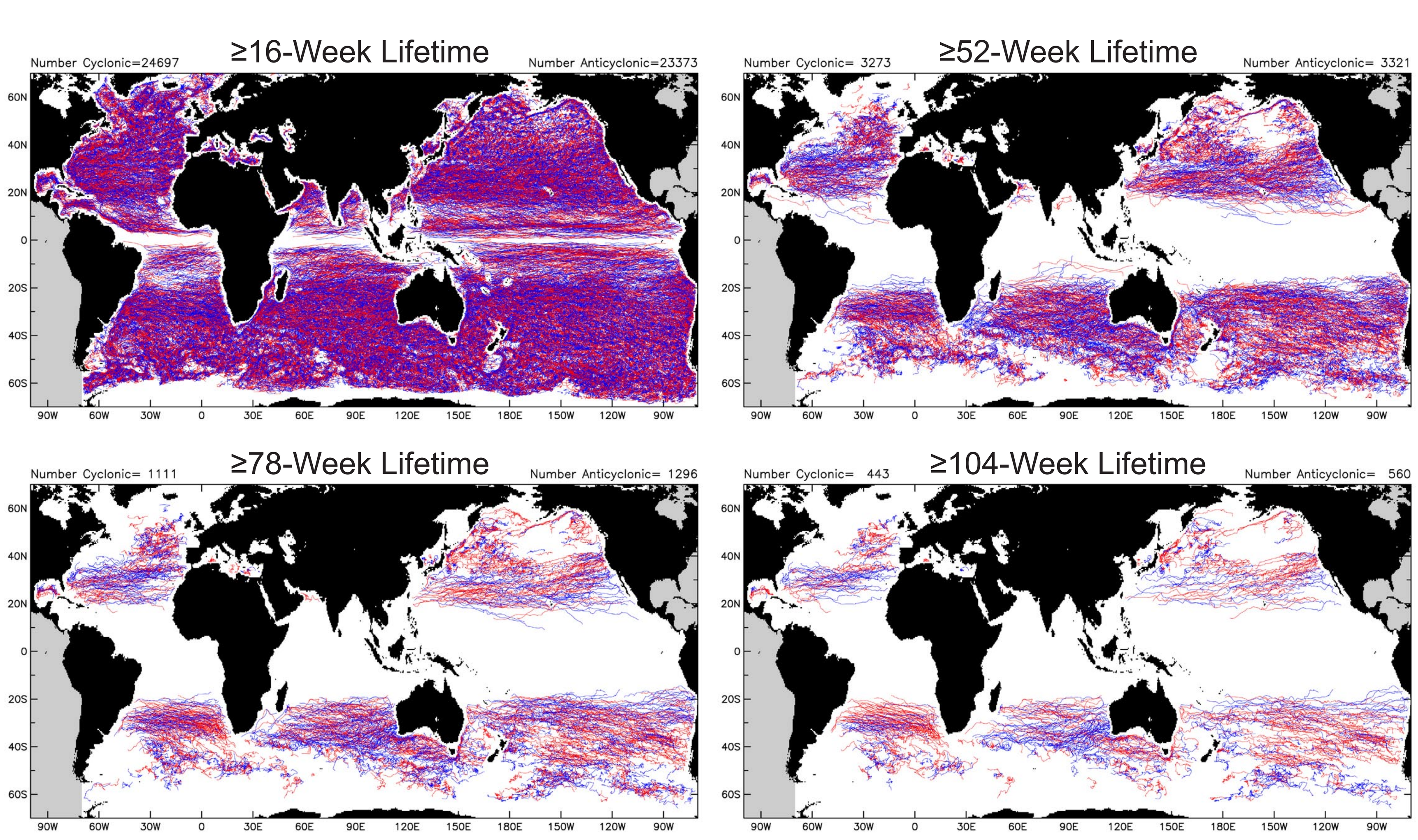


3. Automated Eddy Tracking

An automated eddy identification and tracking procedure was developed based on defining eddies by outermost closed contours of SSH. This was found to yield eddies with significantly more robust structures than the Okubo-Weiss parameter that is often used to define eddies.

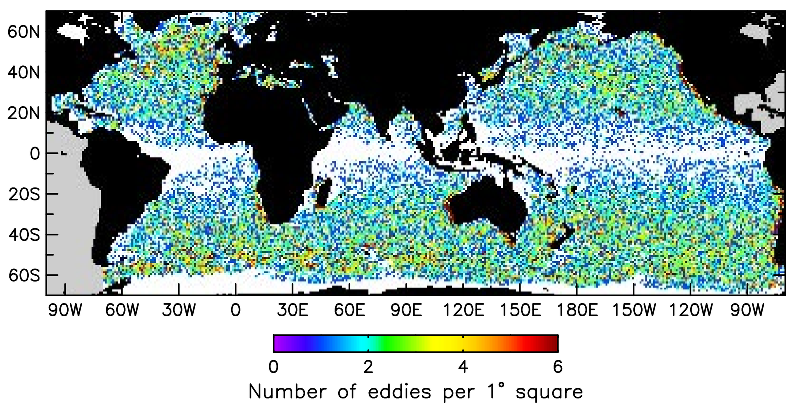
As shown to the left, there is a slight preference for cyclonic eddies globally for lifetimes up to about a year, beyond which the ratio becomes noisy because of limited sample sizes. Regionally, either polarity can be dominant.

Eddies exist throughout the World Ocean. The trajectories of cyclonic (blue) and anticyclonic (red) eddies with various lifetime thresholds are shown below. The longest-lived eddies occur in the subtropical latitudes.

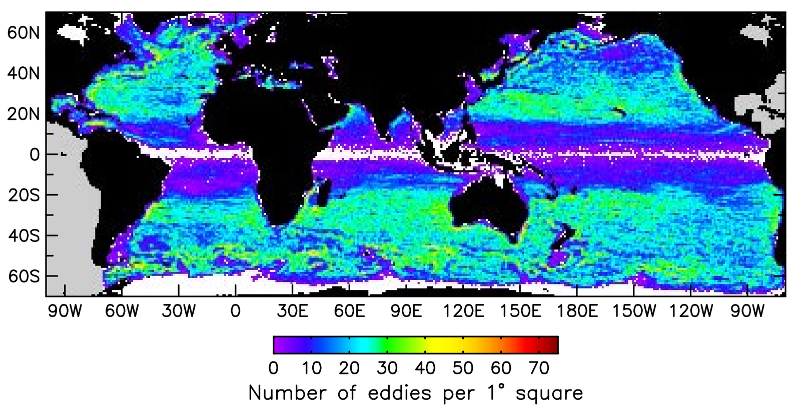


4. Characteristics of Eddies with Lifetimes ≥ 16 Weeks

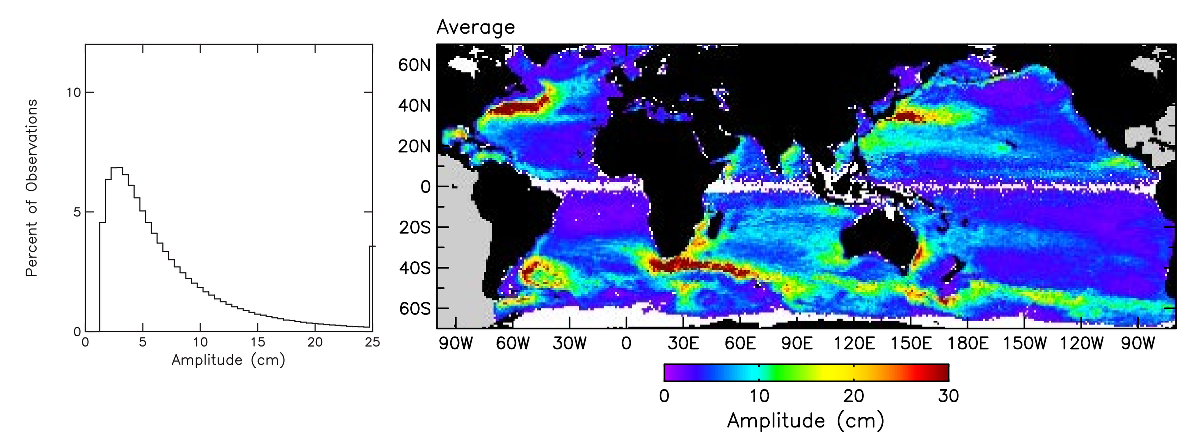
Eddy formation is most frequent along the eastern boundaries (upper right). Elsewhere, eddies form throughout most of the World Ocean. Notably fewer eddies form at latitudes below about 20º and in the northeast Pacific .

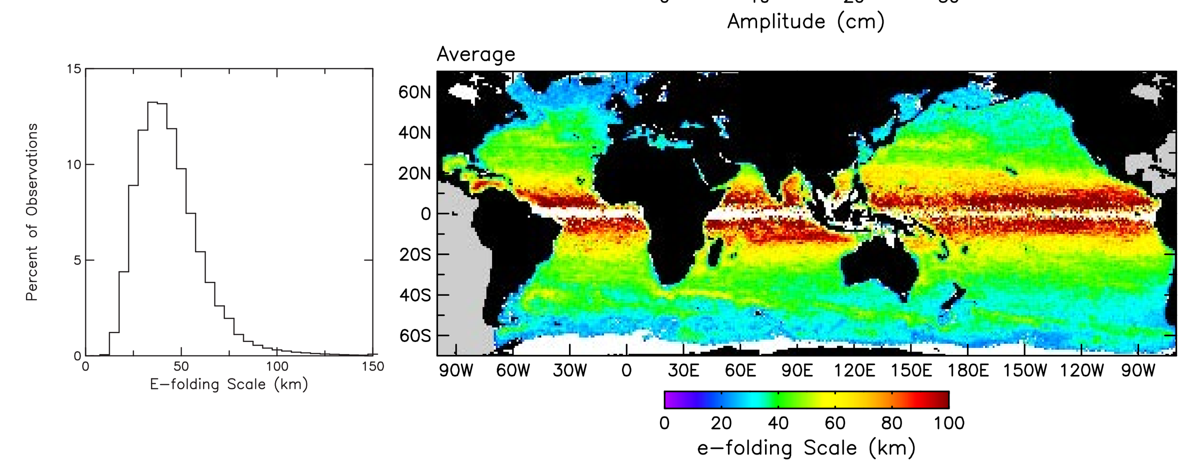


In the 14-year data record analyzed here, 2–3 eddy centers per year pass through 1º squares (lower right). About 10 eddy interiors (regions within one e-folding scale of the eddy center) per year pass through each 1º square (not shown here).



The amplitudes and e-folding scales of the tracked eddies are broadly distributed (below left). The average amplitudes (upper right panel below) are largest in the western boundary currents and their eastward extensions, along subtropical fronts, and to the west of Central America. The average e-folding scales (lower right panel below) decrease from about 100 km near the equator to about 30 km at high latitudes.

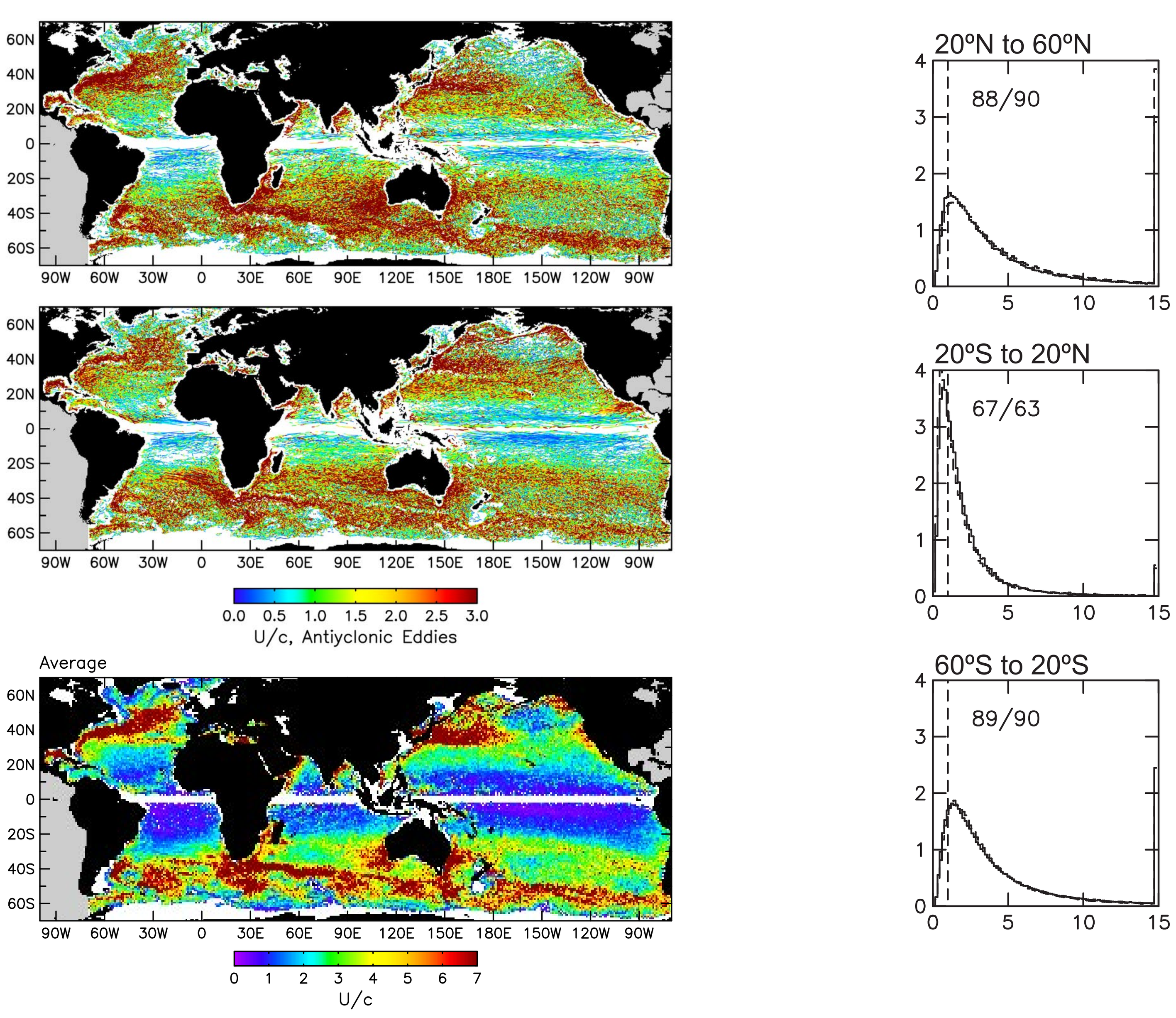




5. Nonlinearity of the Eddies

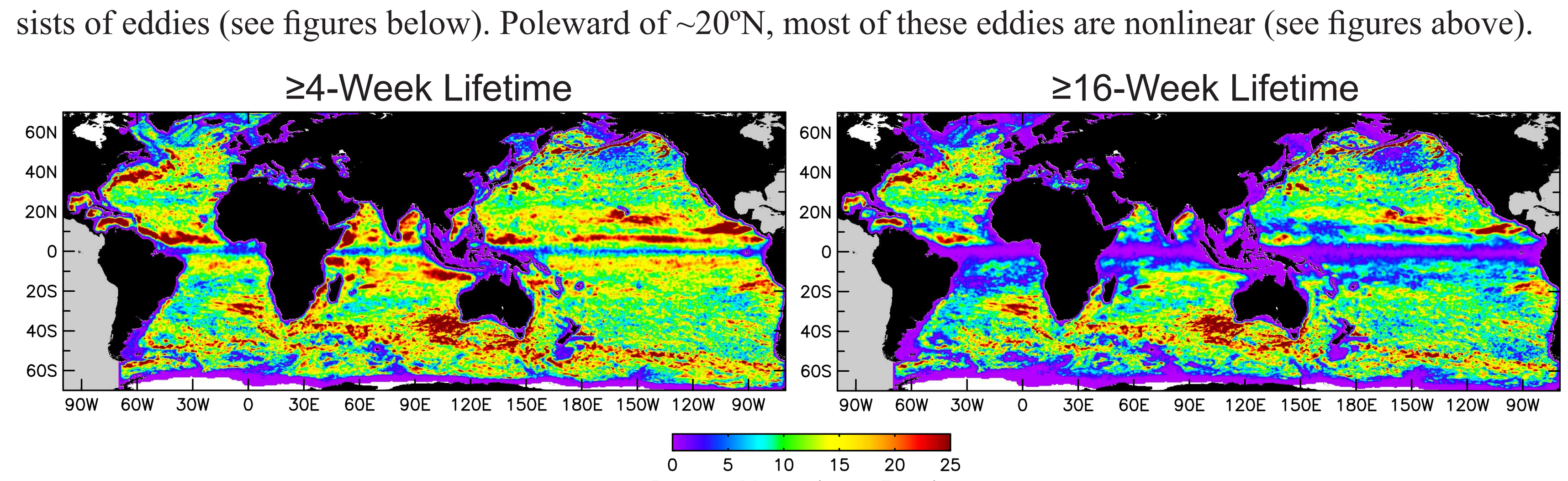
The trajectories of cyclonic and anticyclonic eddies with lifetimes of 16 weeks or longer are shown in the top and middle left panels below, respectively, color coded by the degree of nonlinearity, U/c, where U is the maximum rotational geostrophic speed within the eddy interior and c is the translational speed of the eddy center. The bottom left panel shows the average nonlinearity for both polarities combined. Corresponding histograms of U/c for the tracked eddies with lifetimes ≥ 16 weeks are shown in the right panels.

A ratio of $U/c \geq 1$ indicates that the eddy is nonlinear. Except at low latitudes and in the northeastern and southeastern Pacific, most of the eddies are nonlinear.



6. Conclusions

The higher resolution afforded by the merged altimeter data reveals that much of the observed SSH variance consists of eddies (see figures below). Poleward of ~20ºN, most of these eddies are nonlinear (see figures above).



7. Future Work

Much of our effort over the past 2 years has been devoted to developing a reliable automated eddy identification and tracking procedure designed to isolate propagating eddies in the presence of measurement and sampling errors. Future plans include investigations of:

- The growth rate and decay of eddies.
- Genesis of the observed eddies.
- Scale dependence of the meridional deflection of eddies.
- Dynamical analysis and modeling of nonlinear eddies.
- Lagrangian transport by the eddies.
- Potential vorticity transport by the eddies.
- Heat flux divergence by the eddies.
- The effects of eddies on the ability to detect quasi-zonal jets.