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Lagrangian connectivity of near-surface ocean studied with in situ and satellite observations

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Abstract

Presented are preliminary results of the study, in which feasibility for floating matter to travel between a pair of selected locations is characterized on a global scale, using trajectories of Lagrangian drifting buoys. Low-connectivity areas are identified and role of major fronts, strong currents, and the equator as barriers are discussed. Lagrangian time scales of the exchange are assessed and shown to be much larger than Lagrangian velocity time scales in the mesoscale eddy field. Empirical SCUD (Surface CUrrents from Diagnostic) model, forced by satellite altimetry and QuikSCAT and ASCAT winds, is used to study Lagrangian trajectories longer than the characteristic life time of a drifter. Applied to the problem of marine debris, generated by the 2011 tsunami in Japan, the study suggests that pathway, linking the source to a particular destination, may be narrower than one might expect from the advection-diffusion model. Knowing these pathways could help optimize the use of limited resources available to monitor safety of critical sites (such as Midway Islands or big harbors).

Cross-frontal exchange

Complexity of processes of fluid transport by ocean eddies and difficulty of eddy flux parameterization are well recognized. In addition to high spatial heterogeneity and anisotropy, connectivity of some regions may be enhanced or reduced by features in the ocean circulation.

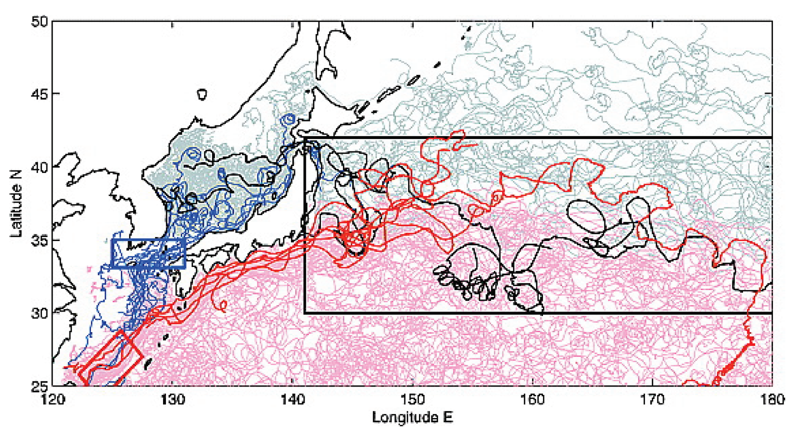

Figure 1. Drifters deployed north and south of the Kuroshio Extension do not mix. (Niiler et al., 2003)

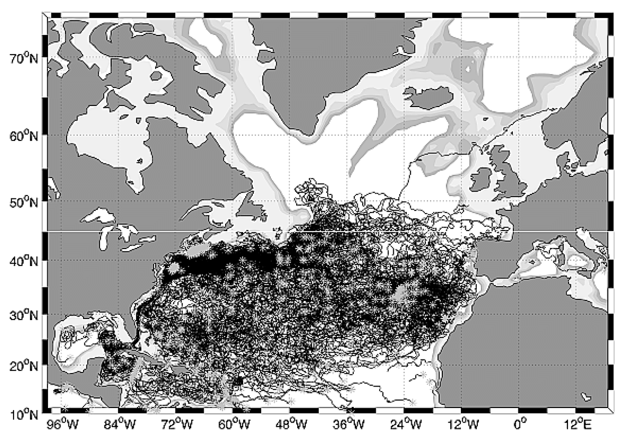

Figure 2. Same applies to the North Atlantic subpolar/subtropical drifter exchange (Brambila & Talley, 2006).

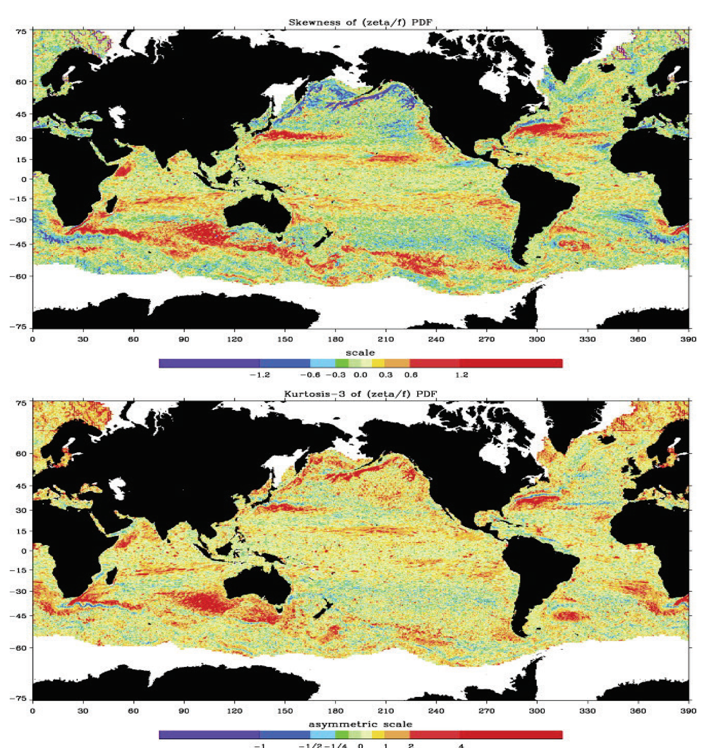

Figure 3. Hughes et al. (2010) suggest that contours of zero vorticity skewness (top), coinciding with low Kurtosis (bottom), can outline mixing barriers. The identify a number of such barriers, all associated with frontal jets.

Agulhas Retroflection

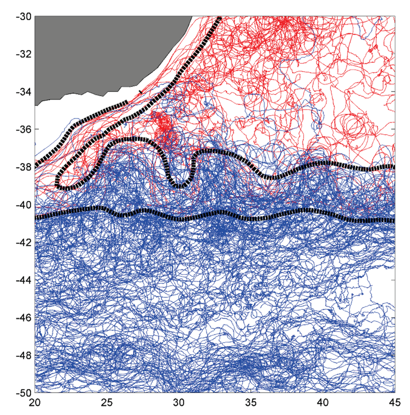

Figure 10. Trajectories of northern and southern drifters with start positions separated by 50 dyn. Cm.

Kuroshio Extension

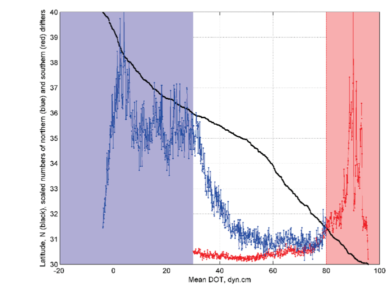

Figure 9. Density of fixes of northern and southern drifters as a function of the mean dynamic topography.

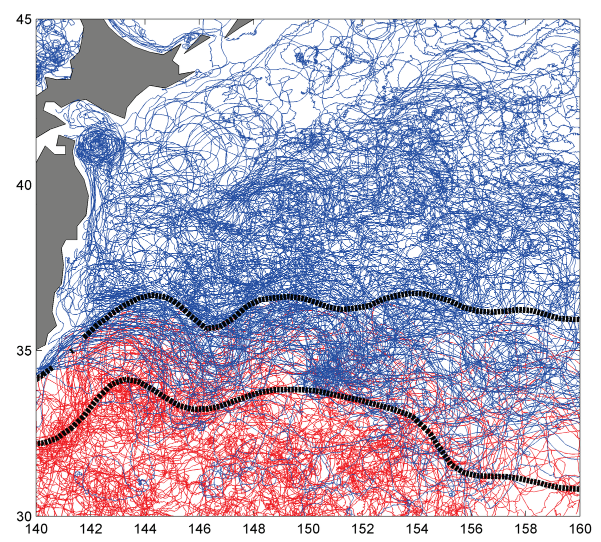

Figure 8. Trajectories of northern and southern drifters with start positions separated by 50 dyn. Cm.

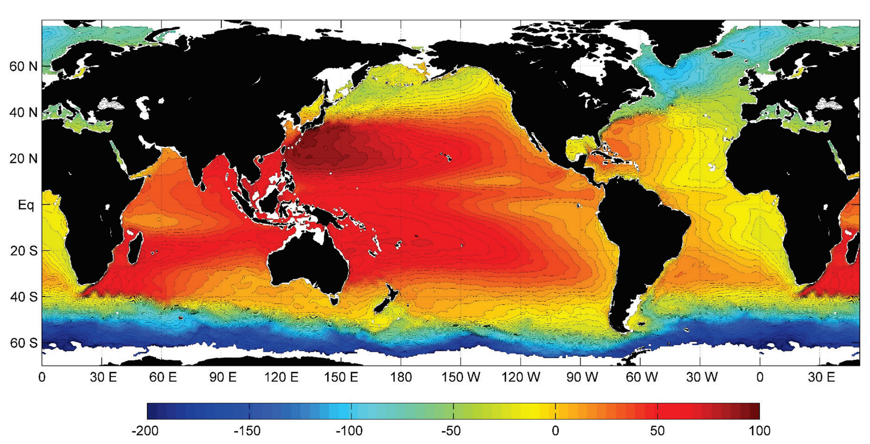

Figure 7. Mean dynamic ocean topography of Maximenko et al. (2008), used to Identify axes of frontal jets.

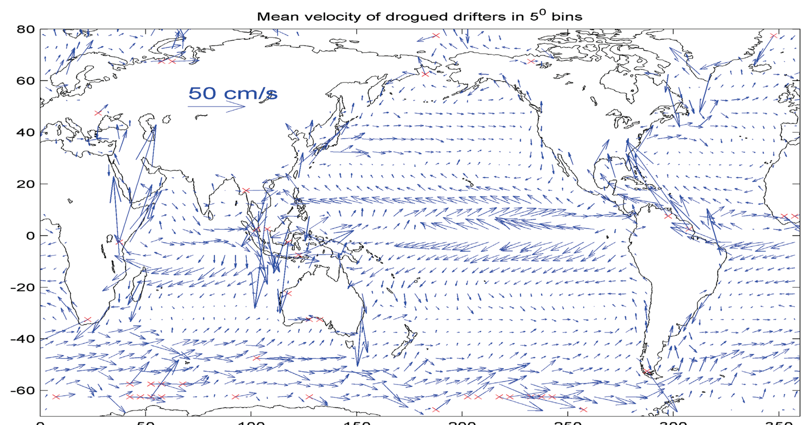

Figure 6. Mean drifter velocity vectors.

Surface drifters

In this study we use data of >16,500 drifting buoys, collected by SVP/GDP. Only drifters with the drogue present at 15 m depth are used.

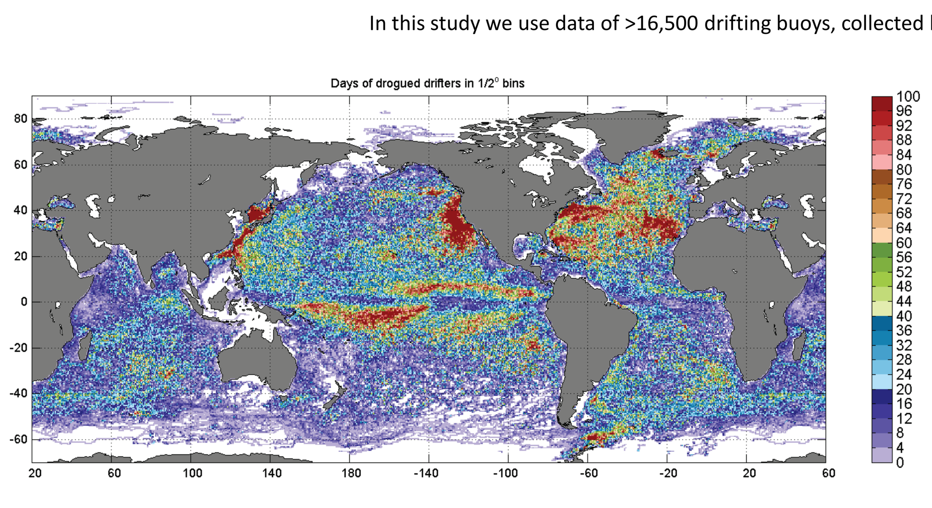

Figure 4. Number of drifter 6-hourly fixes in ¼-degree bins.

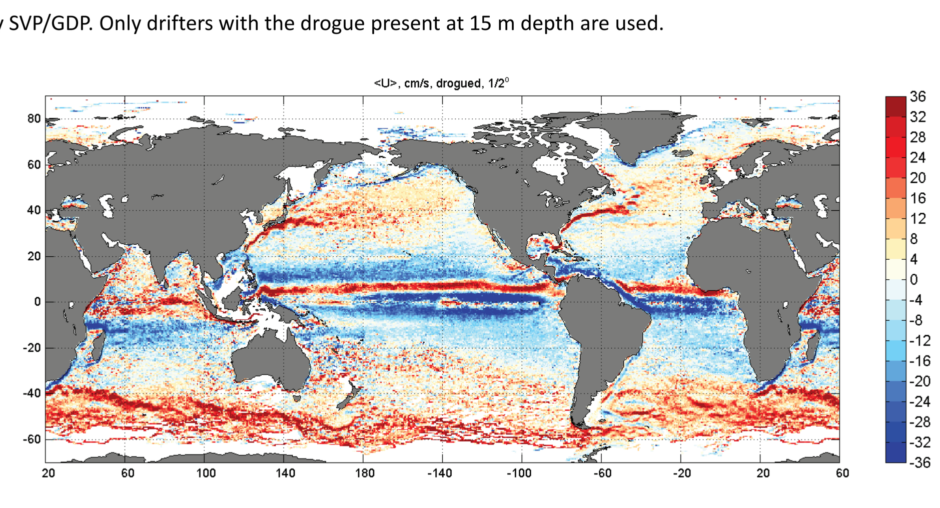

Figure 5. Mean zonal drifter velocity (inertial and higher frequencies are filtered.

Gulf Stream

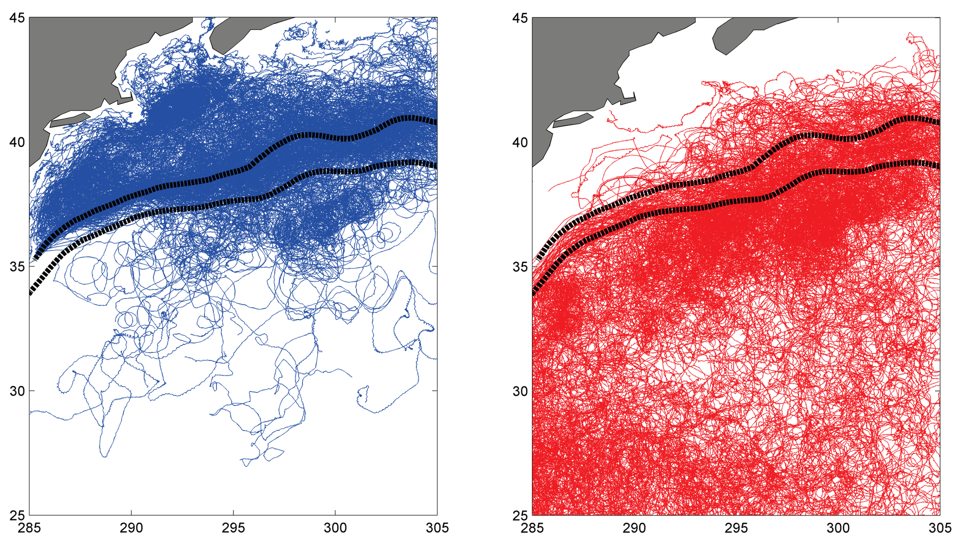

Figure 11. Trajectories of northern and southern drifters with start positions separated by 50 dyn. Cm.

Equator

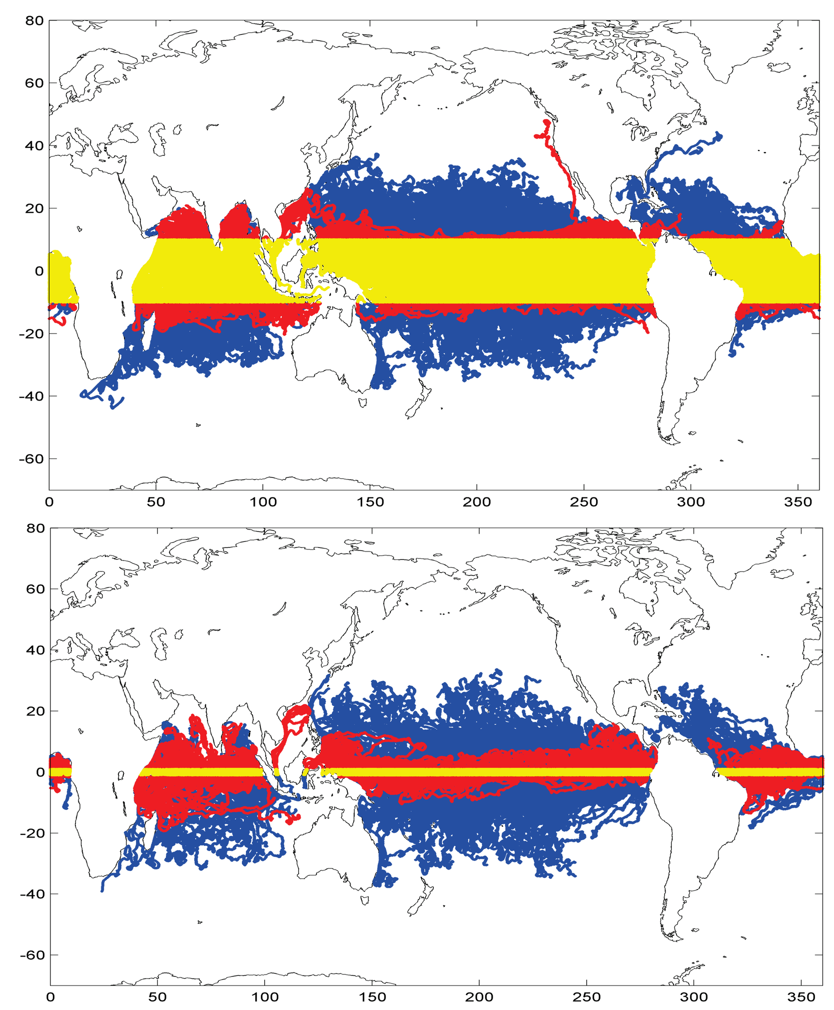

Figure 12. Trajectories of drifters that start from (blue) or end in (red) yellow regions.

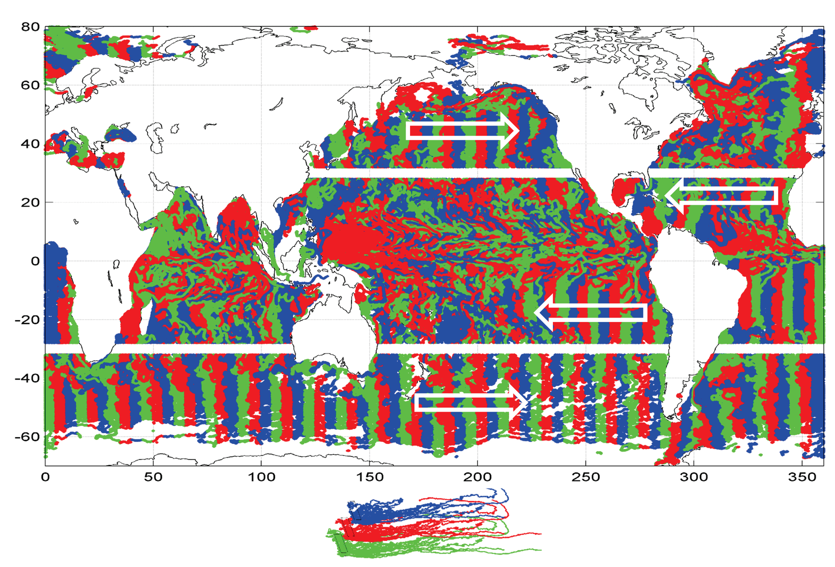

Figure 13. Trajectories of drifters, starting from 20-degree longitude wide meridional Bands. Order of the bands is downstream the mean currents.

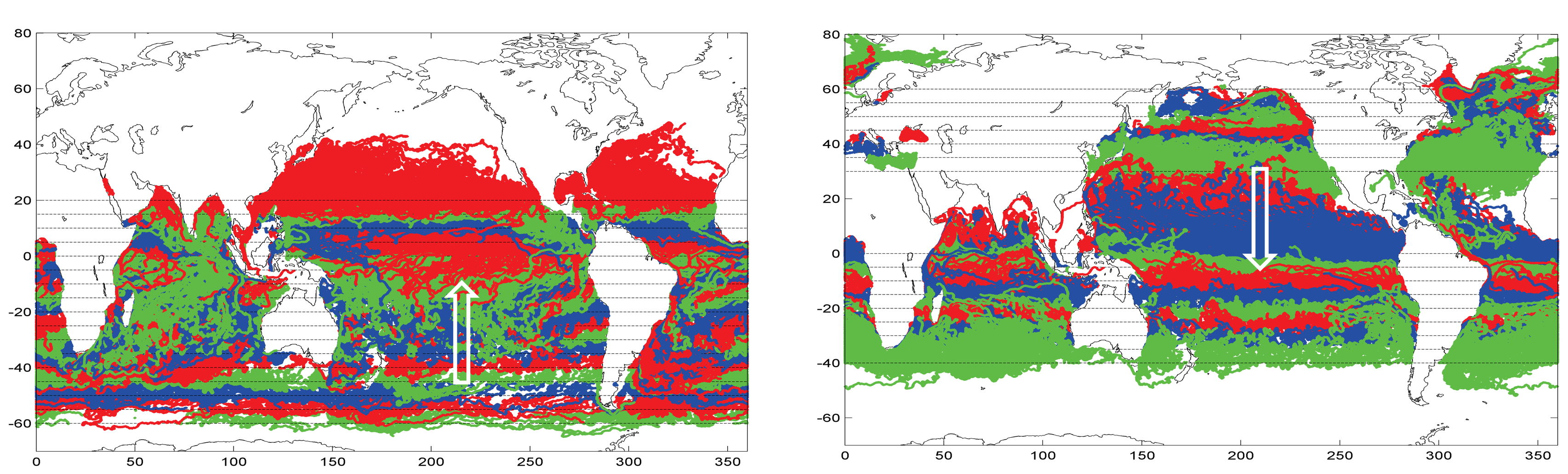

Figure 14. Trajectories of drifters, starting from 15-degree latitude wide zonal bands. Order of the bands is from south to north (left) and from north to south (right).

Note: Drifters do not travel far up the mean stream, even in the areas of high eddy activity.

Velocity anomaly statistics is skewed relative to the direction of the local mean vector

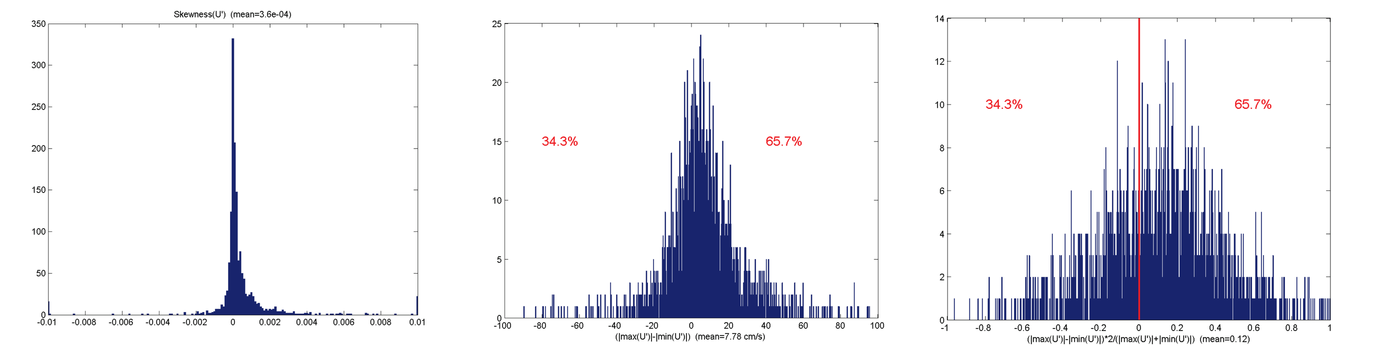

Figure 15. Skewness of velocity anomaly statistics along the local mean velocity vector (left), histogram of differences between minimum and Maximum anomalies in 3-degree bins (medium). Right panel is the same as medium but normalized by the local r.m.s. velocity anomaly.

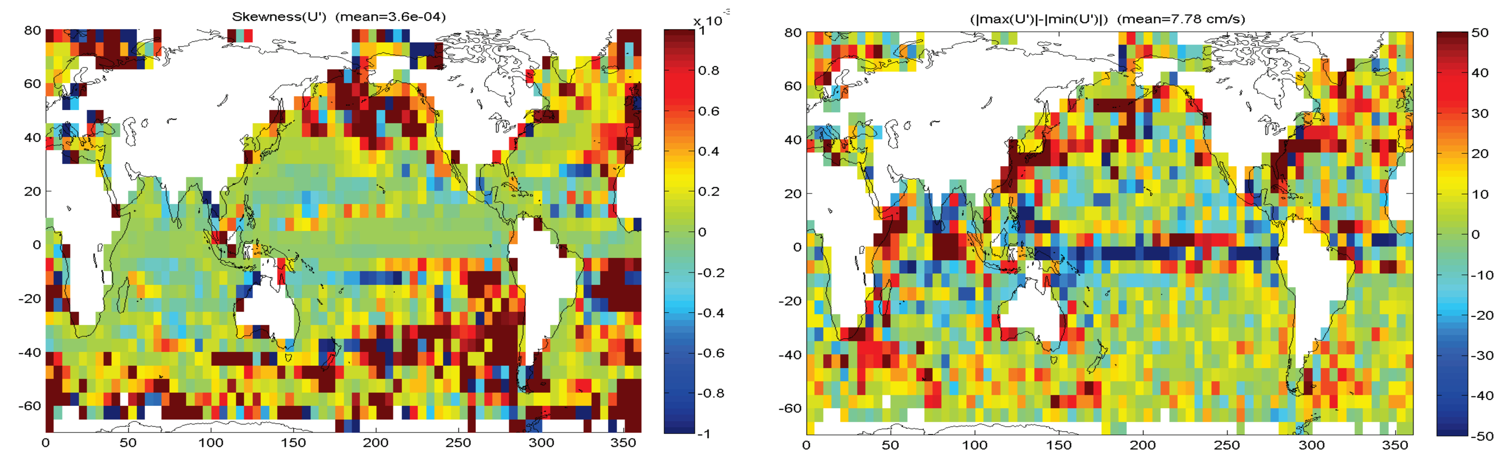

Figure 16. Maps of skewness of velocity anomaly statistics along the local mean velocity vector (left) and histogram of differences between minimum and maximum anomalies in 3-degree bins.

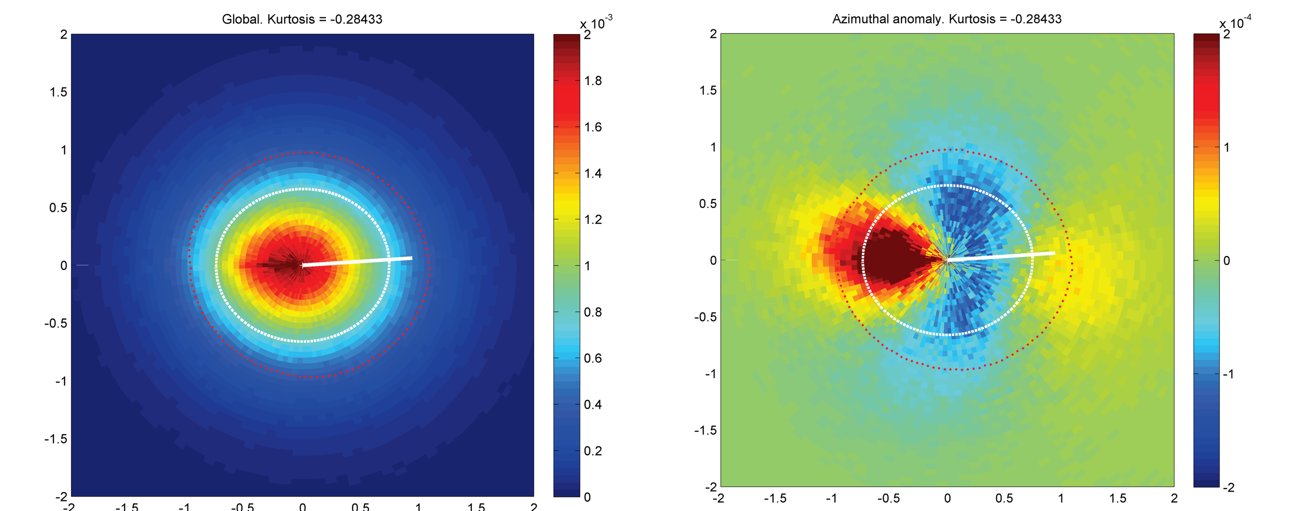

Figure 17. (left) Probability density of velocity anomaly relative to the mean vector and scaled with r.m.s values in 3-degree bins. Whiite ellipse visualizes Raynolds stress statistics and red dots represent directional r.m.s. velocity. White vector indicates vector skewness of the velocity anomaly Probability: **$\langle V \cdot V^2 \rangle / \langle V^2 \rangle^{3/2}$.** Right panel is same as left but with the azimuthal mean subtracted.

Possible explanation of the velocity anomaly statistics is that it combines eddies with lower-frequency modes of variability of the ocean circulation. This can be illustrated by comparing drifter diffusion under different decorrelation scales.

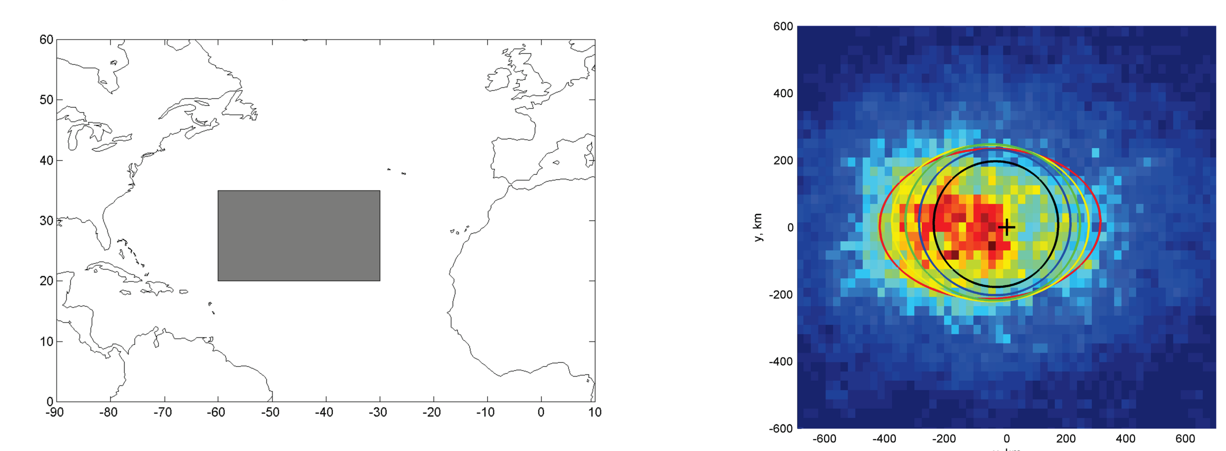

Figure 18. Colors on the right show probability density of drifter displacement In 80 days, averaged in a region, shown on the left panel. Red, yellow, green, blue and black ellipses characterize 30-day tracer dispersion for a singular source In the beginning of coordinates under assumption of 80, 40, 20, 10, and 5 days Lagrangian decorrelation scale.

Acknowledgments

We thank Luca Centurioni for providing us with most recent version of the krigged drifter dataset.

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