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Analysis of Lagrangian Potential Vorticity Balance and Lateral Displacement of Water Parcels in Gulf Stream Meanders

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ABSTRACT

The balance of potential vorticity components following fluid parcel motion in Gulf Stream meanders was studied using RAFOS float data from the SYNOP Experiment. By introducing curvature dependent variations to the velocity and density fields, the authors relaxed the rigid field assumption used in earlier studies and examined closely 61 floats in the upper layers (13°–16°C) of the main thermocline. Float trajectories were segmented according to transition from crest to trough and trough to crest, and grouped by their positions relative to the current center. A total of 154 segments were collected to estimate the horizontal divergence and the mean lateral displacement of parcels under two distinct regimes: growing and decaying meanders.

Both spatial and temporal changes in curvature affect the regions of divergence in a meandering stream. On the one hand, horizontal divergence increases with increasing curvature magnitude, while on the other hand, the divergence pattern itself changes going from growing to decaying meanders. The growing amplitude meanders (i.e., cases where the magnitude of curvature increases in time) are found to be associated with divergence (convergence) upstream, and convergence (divergence) downstream of crests on the anticyclonic (cyclonic) side. This pattern is reversed for decaying meanders.

A parcel's cross-stream motion is found to be consistent with the pattern established earlier: upwelling/onshore from trough to crest and downwelling/offshore from crest to trough. When referenced to the locus of the velocity maximum, which itself is curvature dependent, the mean cross-stream displacements of parcels on the cyclonic and anticyclonic sides appear to be opposite in direction relative to the current center and hence result in difluence (confluence) up- (down) stream of crests for growing amplitude meanders and vice versa for decaying ones.

Cross-frontal fluid exchange is enhanced by changes in meander amplitude. The growth and decay of a meander are found to affect both the pathways and the intensity of fluid exchange. Comparisons of satellite IR imagery with RAFOS float trajectories suggest that the detraining of water associated with Gulf Stream meandering process occurs in both growing and decaying regimes.

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