The propagation of spiciness anomalies in the upper North Pacific

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The density-compensated temperature and salinity anomalies, referred to as spiciness anomalies, measure the variations of water mass properties on isopycnals. With the improvement of observing systems, spiciness anomalies have been detected in global ocean, and some recent studies discovered the propagation of spiciness anomalies, but limited to certain regions and relatively short periods. Some numerical models separated and quantified different processes in propagating spiciness signals. However, the quantitative interpretation of the propagation of spiciness anomalies by observational study is still lacking.

Using Argo float observations during 2004~2015, this study investigates spiciness anomalies in the upper North Pacific on neutral density surfaces. Firstly, we explored three major water masses in the upper North Pacific, Subtropical Mode Water (STMW), Eastern Subtropical Mode Water (ESTMW), and Central Mode Water (CMW). Interannual or decadal variability of spiciness are detected, as well as their propagation. To explain the propagation of spiciness anomalies, we calculated the geostrophic velocity on neutral density surfaces, and trace the spiciness anomalies along the mean geostrophic streamlines in the subtropical gyre. Despite high-frequency spiciness variability near the outcrop region, low-frequency spiciness signals of each phase propagate and decay downstream the mean geostrophic streamlines. The propagation paths of spiciness anomalies are highly consistent with the mean flows, but the propagation speeds of spiciness signals are faster than those of the mean advection, especially in regions where the zonal component of geostrophic current is westward. This difference of speeds implies the influences of anomalous advection and other processes.

Furthermore, to quantify the different processes in propagating spiciness signals, we used a conservation equation for salinity anomalies on isopycnal surfaces, and integrated each term along the geostrophic streamlines. As a result, the mean advection of the anomalous spiciness gradient is dominant along the propagation paths, the anomalous advection of the mean salinity gradient is important in generating local signals, and there are also influences of the covarying velocity and spiciness anomalies fields. The total sum of above terms should equal to the spiciness anomaly variability in an eddy-resolving model. However, there is a meaningful difference, which could be caused by estimating the advection only by geostrophic currents in $1^\circ\times1^\circ$ observation resolution, suggesting the effects of processes such as mesoscale/submesoscale eddies. Here, we could interpret this difference in terms of bolus velocity and others.

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