Evolutions of water mass anomalies in the upper North Pacific based on Argo data, in STMW, ESTMW, and CMW.

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Under the background of climate changes, long-term trends and interannual to decadal variations of water masses have been discovered in recent studies. However, how they evolved in space and time is still not fully investigated, partly due to the insufficiency of observation. With spatially and temporally unbiased data available through Argo floats recently, this study describes three-dimensional evolutions of water mass anomalies during 2004-2015, focusing on three typical water masses in the upper North Pacific: North Pacific Subtropical Mode Water (STMW), Eastern Subtropical Mode Water (ESTMW), and North Pacific Central Mode Water (CMW).

In order to preserve the water mass characteristics as much as possible, the analysis in this study is mainly on neutral density surfaces, along which the advection and mixing of water masses dominantly occur. Because of the compensation between temperature and salinity on isopycnal surfaces, this study mainly investigates salinity as a proxy of spiciness. The main results are listed as follows:

In STMW:
The temporal variations of spiciness are dominated by interannual or longer variations. There is a long-term freshening trend at 0.005/year generally as well as strong decadal variations. The former is related to global warming; the latter are caused by the decadal variations of Kuroshio Extension path stability. These anomalies show rapid southwestward propagations in STMW, and the directions can be explained by geostrophic currents, but the propagation speed are 2-3 times higher than geostrophic currents, which indicates other processes involved. The origins of anomalies are most likely to be the STMW formation region. Another possible origin is found in the subtropics of the central North Pacific through statistical analysis, which needs further verification and explanation. Strikingly, the Eulerian temporal changes of spiciness are preserved well during the large distance propagation, implying the existence and persistence of large-scale spiciness fronts.

In ESTMW:
The temporal variability of ESTMW is higher than STMW and CMW, and interannual or longer variations are dominant. The long-term trend in northeastern ESTMW shows freshening, while the southwestern ESTMW is in salinification. There is an obvious 5-6-year oscillation cycle. The anomalies shift between positive and negative rapidly at the ESTMW formation region, spread to the whole ESTMW along its subduction path in each period, and propagate southwestward to the central subtropics and the western tropics by geostrophic flow.

In CMW:
Both spiciness and its total variations are smaller than the other two water masses, but the seasonal variations are higher, being comparable with interannual or longer variations in the northern CMW. With regard to trends, the northern CMW is in salinification, with the anomalies propagating eastward on both monthly scale and annual mean. However, the majority of CMW shows freshening almost uniformly, with weak but recognizable southward propagations.

In conclusion, this study provides a comprehensive description of the evolutions of water mass anomalies in the upper North Pacific for the first time. The regional variations that have been found by limited observations are confirmed and complemented with three-dimensional presentations. The evolutions occurred in earlier years and documented by previous studies are updated by the present analysis. Furthermore, the new phenomena that should be investigated in future are also raised.

Keywords: Argo float data, Subtropical Mode Water, Eastern Subtropical Mode Water, Central Mode Water, Spiciness anomaly

