Symmetric and Mixed Layer Instability at a Sharp Ocean Front

*Yuki Tanaka[1]

1. Graduate School of Science, The University of Tokyo

Submesoscale processes at ocean fronts play a crucial role in transferring buoyancy, momentum, and tracers in both the horizontal and vertical directions, as well as in cascading energy from large to small scales. Although symmetric instability and mixed layer instability are believed to be two major types of submesoscale instability, clear evidence of them has not yet been obtained in the real ocean. This is partly because theoretical prediction of the dispersion and polarization relations of these submesoscale instability processes in the real ocean is still incomplete; most of the theoretical studies have assumed an infinite ocean with homogeneous negative potential vorticity sustaining the existence of symmetric instability. This idealized situation is quite different from the actual one where negative potential vorticity is confined within a narrow region centered at a front.

Here, we examine symmetric and mixed layer instability created at a realistic front in the surface mixed layer. For this purpose, we performe a linear stability analysis on a meridional–vertical plane with a zonally uniform background field characterized by a sharp front with a narrow region of negative potential vorticity. The analysis shows that symmetric instability is the most unstable mode when the zonal wavenumber of the disturbance is small enough. The symmetric instability is characterized by wave patterns mostly confined within the negative potential vorticity region and nearly aligned with the background isopycnals. As the zonal wavenumber of the disturbance becomes large, the dominant unstable mode is replaced by mixed layer instability. The meridional scale of the mixed layer instability is much larger than that of the symmetric instability, even larger than the width of the front. Furthermore, the zonal phase speed of the mixed layer instability is much smaller than that of the symmetric instability. These clear differences enable us to easily distinguish between the two types of instability even though they are continuous in the dispersion diagram. The results will be useful for identifying the symmetric and mixed layer instability in the real ocean.

Keywords: Submesoscale Processes, Symmetric Instability, Mixed Layer Instability, Ocean Fronts, Linear Stability Analysis

