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Formation process of intermediate water in the baroclinic ocean under surface cooling

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The formation process of intermediate water in baroclinic current (such as Kuroshio) under surface cooling is investigated using a nonhydrostatic numerical model.

At first, surface cooling drives intense vertical convection in the surface layer to mix water vertically. Soon later, baroclinic instability develops into finite amplitude and forms an intense density front. Strong downdrafts with a horizontal scale of 1 km are generated near the density front and flows along stably (though weakly) stratified isopycnal layers, transporting surface water to depths (400 m). As a result, patches of ventilated water of 10 - 20 km horizontal scale with anticyclonic circulation are formed at intermediate depths, which is often observed in the baroclinic ocean.

Combined effects of baroclinic instability and convection are key dynamics for these phenomena. Convection acts as an initiator for baroclinic instability at the onset and accelerates its subsequent growth by reducing stratification. Developed baroclinic wave initiates frontogenetic process, which induces downdraft along isopycnals. Density change due to convection intensifies this frontal downdraft by strengthening the geostrophic forcing (tendency to destroy the geostrophic balance) and by reducing potential vorticity (static stability). Further, symmetric instability, induced by the density change due to convection and intensified by the frontogenetic process, drives slantwise convection along isopycnal surface. Consequent downward velocity becomes 20 times as large as that of the frontal downdraft without cooling and twice larger than that of pure convection.

The role of convection (cooling) in the formation process of intermediate water in this context is not only to mix water vertically and deepen the mixed layer but also to enhance the frontal downdraft and subduction of surface water into intermediate depth.