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熱帯太平洋における水温躍層以浅の微細構造に伴う鉛直混合の役割
Role of Vertical Mixing Induced by Small Vertical Scale Structures above and within the Equatorial Thermocline in a CGCM

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Recent measurements of ocean currents available at high vertical resolution capture vertical scales down to the order of O(10m). These new measurements showed numerous small vertical scale structures (SVSs) are present in and above the thermocline in the western equatorial Pacific [Richards et al., 2012]. The estimated vertical diffusion coefficient was found to vary from 10^{-5} to 10^{-3} m^2s^{-1} from the core of the thermocline to the base of the surface mixed layer. This is in stark contrast to the estimated diffusion coefficients below the thermocline in equatorial waters, which is found to be as low as 10^{-6} m^2s^{-1} [Gregg et. al, 2003].

The vertical scale of the SVSs is such that they are unresolved in ocean general circulation models with conventional vertical resolution. The vertical mixing originating from the SVSs, therefore, needs to be parameterized and its impact investigated. In this study, as a first step towards gaining an understanding of the likely role of SVS induced mixing in the dynamics of the equatorial ocean we employ a simple method for parameterization of the SVS mixing, and focus on the impacts of the SVS mixing on the climatological state and El Nino/Southern Oscillation (ENSO) in the equatorial Pacific.

We have performed a total of three simulations with and without parameterized SVS mixing by using a coupled general circulation model. Only the elevated background vertical diffusivity coefficients which represent the SVSs are different between the simulations. For the control run (CTL: without SVS mixing), the background vertical diffusivity coefficient is set to be a constant 1.0×10^{-6} m^2s^{-1} throughout the water column in the whole computational domain. In the runs with SVS mixing, the enhanced mixing induced by SVSs in the equatorial Pacific is represented as the elevated background vertical diffusivity coefficient. To reflect the observations that the SVS enhanced mixing appears to occur in the upper water column down to the center of the thermocline [Richards et al., 2012], we introduce a run with SVS enhanced mixing (SVS_C: stratification-independent SVS mixing) in which background diffusivity in the upper water column down to the 20C isotherm is set to be a constant 5.0×10^{-5} m^2s^{-1}. Below the 20C isotherm, the background vertical diffusivity is set to the control value of 1×10^{-6} m^2s^{-1}. The enhanced diffusivity is applied to the tropical Pacific (5S-5N, 140E-70W). We perform an additional run with SVS enhanced mixing, SVS_N2 (stratification-dependent SVS mixing), in which the level of the enhanced mixing is inversely proportional to the square of the buoyancy frequency. This parameterization is prompted by the observation that variation of the level of the vertical diffusivity is caused by variation in the stratification [Richards et al., 2012].

It is found that the SVS-induced mixing leads to a reduced stratification above the thermocline. The reduced stratification leads to an increase in the vertical diffusivity which feeds back to further reduce the stratification and tighten the thermocline. The sharpened thermocline limits the exchange of heat across the thermocline and traps the surface heating above the thermocline. As a result, SST in the eastern equatorial Pacific is warmed by the SVS enhanced mixing. Furthermore, the warming of the SST is strengthened through the ocean-atmosphere feedbacks in the coupled system: Bjerknes feedback [Bjerknes, 1969] and SST-shortwave feedback [Klein and Hartman, 1993]. We also find that the SVS-induced mixing changes a few characteristics of ENSO. There is a reduction in the amplitude of ENSO brought about by a deepening of the thermocline. Moreover, stratification-independent SVS mixing reduces the skewness of ENSO, while stratification-dependent SVS mixing leads to a warming of the cold tongue and deepened thermocline during La Nina conditions, which increases the skewness of ENSO.

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