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Study of mesoscale and sub-mesoscale processes in a shear-stratified regional ocean using Modular Ocean Model

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Meso and sub-mesoscale processes are important drivers that define the regional scale weather dynamics, which in turn impact the large-scale ocean circulation. Mesoscale processes range from 10 km to 100 km (e.g. waves, gyres, meso-eddies), while sub-mesoscale processes (e.g. filaments, plumes, small-scale eddies and vortices) are of the order of 1 km. They actively play a role in determining the ocean properties, such as the mixed layer depth (MLD), sea surface temperature (SST), and sea surface salinity (SSS) that govern the local ocean dynamics by balancing the exchange of mass, momentum and energy between the atmosphere and ocean. The objective of this study is to model the effect of these processes on the ocean surface properties, and sub-surface characteristics using different vertical mixing schemes available in the Modular Ocean Model version 5 (MOM5). For better accuracy in climate models, it is important to consider the realistic ocean dynamics for which proper vertical mixing scheme should be implemented. Here, three different vertical mixing schemes are taken into account, namely, constant mixing, Packnowski and Philander (PP), and K-profile parameterization (KPP). As a toy problem, a regional domain in the Bay of Bengal (BoB) is selected whose dynamics are important for understanding the Indian summer and winter monsoon seasons and the associated weather patterns. The BoB experiences wind reversals, change in precipitation patterns and vertical stratification over the year, introducing a host of mixing processes in this region. Further, these seasonal winds have varying intensities, which is a proxy for the wind shear.

A regional ocean modelling approach is adopted using MOM5, developed by NOAA's Geophysical Fluid Dynamics Laboratory (GFDL). Numerical experiments are designed with multiple horizontal grid sizes (1/4°, 1/8°, and 1/12°) while maintaining the vertical grid-size as 1m near the surface region which increases with depth. For the regional domain, open boundary condition (OBC) is implemented on all the four sides of the domain, based on the technique proposed by Orlanski (1976). The SST and SSS are restored to climatological values with a timescale of 30 days. The model is started from a state of rest, and annual average climatological temperature and salinity from World Ocean Atlas dataset is given as the initial conditions. Simulations are carried out for a period of 10 years using monthly mean wind forcing from Data Assimilation System of KIOST (DASK). After five years of model spin-up, the last five years of simulated output data is considered for the analysis to ensure the efficacy of the results. It shows that the higher grid resolution captures the impacts of the regional processes more prominently. Implementation of KPP scheme enhances mixing in the upper ocean layers with more realistic thermocline formation. Sub-surface turbulent kinetic energy (TKE) is higher in KPP. Comparing the results with observations, it is found out that KPP reduces the cold surface temperature bias compared to the other mixing schemes. Further, the spatial distribution of SST reveals comparatively cooler mid-region in case of the finer resolution.