Data-driven improvement of coarse-resolution QG models

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Geophysical turbulence remains a serious theoretical challenge, and its parameterizations are needed for practical modelling purposes. In this work we focus on oceanic mesoscale eddies, which can be viewed as 'oceanic weather'; for the foreseeable future, their parameterizations will remain indispensible for climate prediction models and other applications. The classical parameterization approach for this class of motions is via turbulent eddy diffusion, but it has many limitations involved. The new and powerful research trend is to aim at stochastic parameterizations of various geophysical processes, including the mesoscale eddies, and our approach is within this category. The stochasticity means that one makes use of random processes with prescribed correlations, which can be either inferred from the first principles or treated as data-driven. The latter is the main novelty of our approach, as it is data-driven in the sense that we aim to emulate the mesoscale eddies statistically and constrain them with all the available and relevant data. This approach takes advantage of not only rapidly growing amount of the real observations, but also of the available machine-learning technologies. Within the data-driven approach for improving coarse-resolution ocean models, we engaged in systematic analyses of the underlying dynamical interactions and the roles played by the smaller scales, which are to be parameterized. We considered an intermediate-complexity, classical, eddy-resolving, double-gyre ocean circulation model as the benchmark, and used its coarse-resolution equivalent as the test ground for a novel, data-driven eddy parameterization framework. The unresolved scales in the coarse-resolution model are associated with fast and small-scale motions (eddies) predicted by and extracted from the eddy-resolving benchmark solution, viewed as the high-resolution truth. First, the eddies are filtered out and characterized by standard statistical analyses. Second, as the essential step towards the eddy parameterization, the inferred spatio-temporal history of the eddy fields is nonlinearly coupled with the self-sustained coarse-resolution dynamics --- this results in significantly improved circulation solution.
However, this solution still lacks some important large-scale characteristics. We argued that using additional information (related to the large scales) from the benchmark reference solution can mitigate the discrepancies and further improve the coarse-resolution solution. Along this line we demonstrated that spatial resolution of the eddy fields is important and should be consistent with the spatial resolution of the non-eddying model, as affects the essential nonlinearities of the eddy/large-scale interactions. Our final goal is to investigate whether data-driven, statistically emulated eddy fields, rather than those statistically extracted from the eddy-resolving solutions, can be nonlinearly coupled to the coarse-gridded dynamics, as a successful eddy parameterization. In this talk we discuss challenges and caveats along this route and provide a research perspective.

Keywords: Oceanic Eddies, Eddy Forcing, Eddy Parameterisation

