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Data-driven parameterization of transient features in a low-resolution double-gyre ocean flow

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Studying oceanic flows poses a great challenge because their dynamics often comprise multi-scale motions featuring highly nonlinear, persistent structures such as jets and vortices. The most demanding problem is that such transient features couple in a non-trivial way with large-scale components of the flows thus modifying the evolution of the latter. Therefore, in order to reliably model the large-scale components of the oceanic flows, one still needs to resolve these evanescent transient features (with typical length scales of 10-100 kilometers depending on the latitude). The feedback of the transient features on the large-scale components manifests itself in a number of ways, for instance, it amplifies the distinct low frequency variability characteristic of the large-scale – small-sale coupling. This makes it vital to resolve these intense transient features to model correctly the large-scale circulation. Brute-forcely resolving the meso-scale features is still out of question even despite significantly increased capabilities of modern high performance computing systems.

To overcome the problem, one may attempt to parameterize the effect of the transient features on the large-scale components. This presentation will focus on a data-driven approach to the problem. The classic double-gyre flow is addressed as its dynamics is known to be heavily affected by the multi-scale interactions. Given a relatively short dataset produced by a high-resolution model that resolves all the necessary scales resulting in the correct coupling between the transient features and large-scale components, we extract information relating to the coupling from this dataset and augment the low-resolution model with this information. As a result, the augmented low-resolution model demonstrates similar to the corresponding high-resolution model spectral characteristics. The geometric structure of the double-gyre flow in the augmented model becomes much more realistic. The large-scale structure of the double-gyre flow featuring a persistent eastward-jet barrier between the gyres, which is characteristic of the high-resolution model and absent in the low-resolution model, is satisfactory restored in the augmented model. The influence of the transient eddy-like features is then parameterized by a stochastic process in order to emulate the influence of the transient features. The stochastic process incorporates memory effects to produce reliable simulations.