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Construction of a reduced-order model for real-time hydrodynamic forecast

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Due to the highly non-linear and dynamical nature of oceanic and coastal phenomena, the predictive capability of various hydrodynamic models depends on the assumptions and availability of operational data. Currently established computationally intensive method to improve the accuracy of the hydrodynamic forecast is to use a data assimilation methodology to combine in-situ measured and remotely acquired data with numerical forecast models of the physical environment. Such models are usually run at supercomputers before or during a mission; but small autonomous surface and underwater vehicles (ASVs and AUVs) are not capable of utilizing the technology due to limitations of onboard resources. Nevertheless, packed with various sensors for exploring and sampling the water column, ASVs and AUVs require on-board capabilities for an adaptive sampling strategies and real-time data assimilation.

We are conducting a research on applying a Model Order Reduction (MOR) technique to construct a Reduced-Order Model (ROM) which is expected to work in the vehicle's environment and to provide real-time forecasts of hydrodynamic fields. There are advantages of using a real-time forecast in the water vehicle: (1) the instantaneous forecast of hydrodynamic fields could be used to improve the vehicle's operation such as navigation and update of its objectives; (2) the ROM could be coupled with a data assimilation model on-board to enhance the forecast of the hydrodynamic fields.

At the first stage of the study, the ROM is constructed using a projection framework, in which the set of Nonlinear Shallow Water Equations (NSWEs) is projected on a reduced basis to form a small set on nonlinear Ordinary Differential Equations (ODEs). The reduced basis is constructed by applying the Proper Orthogonal Decomposition (POD) method on a large dataset of pre-computed hydrodynamic snapshots (by solving the full NSWEs). Solving the nonlinear ODEs is much lighter than solving the full NSWEs. The hydrodynamic fields are reconstructed from the solutions of the nonlinear ODEs.

At the development stage the MOR methodology is applied for various types of equations ranging from a simple 1D diffusion to a complex 2D NSWEs. Interesting results and discussions will be presented.