Development of New Techniques for Assimilating Satellite Altimetry Data into Ocean Models

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1. Introduction

State of the art fully three-dimensional ocean models are very computationally expensive, and the adjoint of them can be even more resource intensive, typically with ten times the computational cost or so. However, many features of interest can be approximated by the first baroclinic mode over much of the ocean, especially in the lower-mid latitude region. In order to fully take advantage of this characteristic and design a more efficient data assimilation system, a new type of data assimilation scheme, a reduced-space adjoint data assimilation technique, is developed, through the application of vertical normal mode decomposition (Philander 1990). To test this technique, the Navy Coastal Ocean Model (NCOM) (Martin 2000 and Morey et al. 2004) is used in the Gulf of Mexico as the forward model. The results indicate that the first baroclinic mode SSH represents the full SSH field very well. Twin experiments are run to test this method, and the dynamical field is recovered as expected and as fast as in around five iterations

2. Methods and Data

The assimilation procedure works by minimizing the cost function, which generalizes the misfit between the observations and their model counterparts (Ghil et. 1991), sea surface height (SSH) in this study, in a least-square sense. The model governing equations are integrated forward in time within the period during which the data are assimilated. Vertical normal mode decomposition is conducted to retrieve the first baroclinic mode, and the data misfit between the model outputs and observations is calculated. Adjoint equations based on a one active layer reduced gravity model, which approximates the first baroclinic mode, are integrated backward in time using the data misfit as the forcing to get the gradient of the cost function with respect to the control variables (velocity and SSH of the first baroclinic mode). The gradient is then input into an optimization algorithm, the limited memory BFGS method in this study, to determine the new first baroclinic mode velocity and SSH fields, which are used to update the NCOM model variables at the initial time.

SSH data from a forward NCOM run are sampled along Topex/POSEIDON (T/P) tracks to simulate the T/P observations. An EOF-based mapping method (Yu et. 2004) is then applied to produce a gridded dataset. The assimilated model fields are compared with the "truth" fields supplied by the twin experiment.

3. Results

The cost function reduces much faster after the first two iterations, and converges after five iterations (Figure 1).

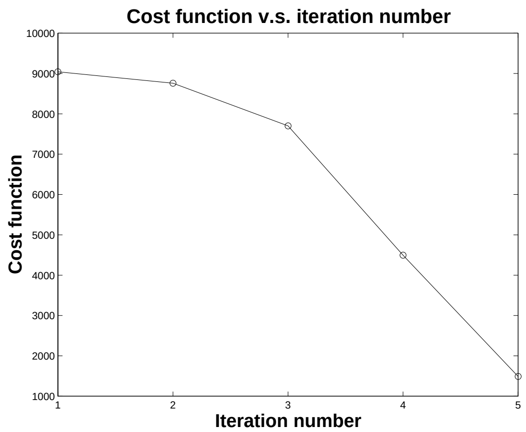

Fig. 1. Cost function v.s. iteration number for twin experiment.

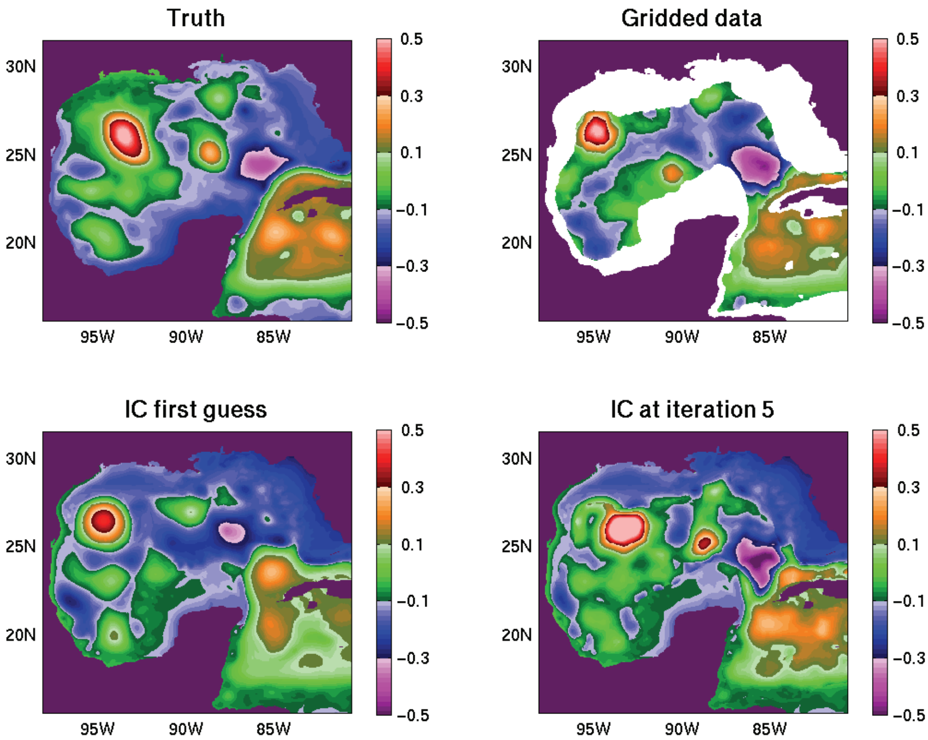

Fig 2. Sea surface height (SSH) field at model initial time. Upper left: The initial SSH field of "truth". Upper right: Gridded SSH data from the simulated Topex/POSEIDON data sampled from the truth field. Lower left: First guess of initial SSH field. Lower right: Initial SSH field after five iterations.

Figure 2 shows that after five iterations, the main features of the SSH field at initial time are very well recovered. Further studies show the comparison between other model variables and the "truth" fields is good, which indicates that this reduced-space adjoint technique is a powerful and efficient tool to improve the model initialization. Since the adjoint model has only one vertical layer compared to sixty vertical layers in the forward NCOM model, the computational cost is much lower.

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