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Meso 4D-VAR data assimilation system using a coupled atmosphere-ocean model

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Mesoscale data assimilation schemes have recently been developed as important components in operational forecasting, particularly for high-impact weather events. This development is driven by the significant advances in computing resources. For example, the Japan Meteorological Agency (JMA) has incorporated an adjoint-based four-dimensional variational (4D-Var) method in their regional forecast system that is based on the JMA nonhydrostatic model (JMA-NHM). This JMA Nonhydrostatic model based Variational data Assimilation system (hereafter, JNoVA) has been used operationally by JMA to construct a mesoscale objective analysis dataset and for regional forecasts since April 2009.

The JNoVA optimizes the fitting of time trajectories to observational records by controlling the initial conditions of an assimilation window. It has substantially improved the forecast skill. However, further improvements are likely around a tropical cyclone since the impact of ocean mixing along with the typhoon passage has not been considered so far.

The aim of this study is to enhance the skill of JNoVA by developing a coupled atmosphere- ocean model. As a first step toward constructing the sophisticated coupled model, a simple one-dimensional mixed layer model proposed by Price et al. (1986) is used. The initial condition of sea surface temperature at the first data assimilation cycle is set to the same as used in the JNoVA. Ocean temperature (except the sea surface temperature) and salinity is taken from World Ocean Atlas 2009. The experiment is initiated at the state of rest, for simplicity. At this moment, the sea surface temperature is restored toward that originally used in JNoVA in a time-scale of one day since the ocean model is too simple to represent the long-term features.

The data assimilation experiment was conducted for the case of Typhoon Talas (2011) (from August 31 to Sep 2, 16 data assimilation cycles). The result exhibits the sea surface temperature decrease around the tropical cyclone. The temperature decrease is maximized in the right of the tropical cyclone pathway with the values of 1-2 K, which is consistent with the observation. The total cost function, which quantifies the misfit in a whole domain between the model results and observations and between the first-guess and the updated initial state, is decreased by 1-3% after coupling the ocean mixed layer model. It is an encouraging evidence to illustrate that the skill of sophisticated data assimilation system can be further enhanced thanks to the coupling to the ocean model.

The typhoon intensity during the data assimilation period in the original JNoVA is improved by the ocean coupling but it is only a slight amount. This is because the use of typhoon bogus results in the reasonable estimate of tropical cyclone intensity in the both data assimilation experiments. In contrast, the forecast skill of typhoon intensity is improved very much according to the coupling to the mixed layer model. The typhoon intensity is overestimated in the original experiment, while the sea surface cooling in a coupled model brings about the closer estimate of typhoon intensity.

Keywords: data assimilation, typhoon, coupled atmosphere-ocean model