Geophysical Research Abstracts
Vol. 12, EGU2010-12373, 2010
EGU General Assembly 2010

Model-reduced 4D-Var data assimilation in ecological modeling

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Phytoplankton blooms, also called algal blooms, are important factors in ecological quality modeling. In order to model algal bloom, algal biomass has to be specified. A large portion of the algal biomass may be unidentifiable by most experts. However, measuring the concentration of chlorophyll-a is much easier and provides a reasonable estimate of algal biomass. To model chlorophyll-a concentration the generic ecological model (BLOOM/GEM) (Blauw et al., Hydrobiologia, 2008) is used. The model was developed to simulate nutrients cycle, primary production and ecosystem functioning. Moreover, it consists of detailed underlying hydrodynamics, suspended sediment and river loads, which are required for ecological modeling. A 2D version of this model is used to forecast chlorophyll-a concentration in the southern North Sea.

The ecological model consists of 25 state variables and more than 400 parameters, and it is defined on 8710 grid cells. Since many of the parameters are highly uncertain, the main task of this work is to update the parameters, such that better model predictions are obtained. Based on the sensitivity analysis 20 parameters have been chosen as the most significant (Salacinska et al., Ecological Modeling, 2009). In this paper, based on a number of simulations of the original model, proper orthogonal decomposition (POD) is used to obtain a reduced model (Vermeulen and Heemink, MWR, 2006). This reduced model carries out the most important information with respect to relation between the parameters and the dynamics of the model. Finally model-reduced 4D variational data assimilation is performed to estimate the parameters. Since model-reduced 4D-Var is performed in the reduced space, the implementation of the adjoint of the tangent linear approximation of the original model is not required. Instead it is approximated by the adjoint of the tangent linear approximation of the POD-reduced model.

The POD-reduced model technique, as well as the model-reduced 4D-Var technique, are explained and applied to the ecological model. The performance of the methods is tested by means of the twin experiment approach.