Geophysical Research Abstracts
Vol. 13, EGU2011-3517, 2011
EGU General Assembly 2011

A North Atlantic 3D coupled physical-biogeochemical model: a stochastic approach to estimate biogeochemical parameters from ocean color data using a nonlinear and non-Gaussian framework

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A realistic 3D physical model of the North Atlantic is implemented at 1/4° resolution in a Drakkar configuration (Barnier et al. 2006) and is coupled online with a biogeochemical model including six biogeochemical variables, among which the phytoplankton concentration (LOBSTER, Lévy et al. 2005). Although coupled physical-biogeochemical models skills have been steadily increasing in the past years, there are still some discrepancies between the model results and the observations of phytoplankton concentrations obtained with ocean color remote sensing, generally expressed in terms of chlorophyll a concentrations. Our assumption in the present study is that the main source of uncertainty, and thus of error, lies in the biogeochemical parameterization. For instance, it is commonly spatially uniform at the basin scale, although the existence of ecological provinces has been long recognized (Longhurst 1995). A sensitivity study was performed with a Monte Carlo experiment, introducing regional perturbations on three main parameters of the biogeochemical model (the phytoplankton growth and mortality rates and the zooplankton grazing rate). The set-up included 200 members and simulations lasted 30 days during the 1998 spring bloom. The ensemble showed that the phytoplankton concentration is sensitive to the parameterization, with strong spatial heterogeneity, combined to a nonlinear and non-Gaussian behavior. Within the Kalman filter theory, parameter estimation can be done, in the framework of optimal estimate with Gaussian assumptions and reduced rank approximation, when the state vector is augmented with the uncertain parameters. Twin data assimilation experiments, using surface phytoplankton as observations, were performed either in the linear framework or introducing a nonlinear local monovariate transformation (anamorphosis). Nonlinear parameter estimation performed better than linear estimation: on the 39 estimated biogeochemical parameters, there is a reduction in the variance obtained with the nonlinear analysis, compared to the variance obtained with the linear analysis, except for 2 parameters. The reduction is better than 60% in 80% of these cases. The anamorphosis is also useful to define an objective error norm for the biogeochemical variables. These experiments opens the way to perform the estimation of uncertain biogeochemical parameters at a global scale from ocean color. Further work will deal with data assimilation of real ocean color data.