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Uncertainty in ocean biogeochemical simulation: Application of ensemble data assimilation to a one-dimensional model

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Marine biogeochemical (BGC) models are important tools in the hands of scientists and policymakers when assessing the impacts of climate change. Therefore, including an ocean BGC component in Earth System Modeling efforts is essential for climate simulation and predictions. However, current BGC models, used to simulate and thus better understand the marine ecosystem processes, are associated with large undefined uncertainties. Similar to other geoscientific models, complex biological and chemical processes are converted to simplified schemes in BGCs, a methodology known as parameterization. However, these parameter values can be poorly constrained and also involve unknown uncertainties. In turn, the uncertainty in the parameter values translates into uncertainty in the model outputs. Therefore, a systematic approach to properly quantify the uncertainties of the parameters is needed. In this study, we apply an ensemble data assimilation method to quantify the uncertainty arising from the parameterization within BGC models. We apply an ensemble Kalman filter provided by the parallel data assimilation framework (PDAF) into a one-dimensional vertical configuration of the biogeochemical model Regulated Ecosystem Model 2 (REcoM2) at two BGC time-series stations: the Bermuda Atlantic Time-series Study (BATS) and the Dynamique des Flux Atmosphériques en Méditerranée (DYFAMED). Satellite chlorophyll-a concentration data and in situ net primary production data are assimilated to estimate ten selected biogeochemical parameters and the model state. We present convergence and interdependence features of the estimated parameters in relation to the major biological processes and discuss their uncertainties. The major improvements on the parameters involved changes in phytoplankton photosynthesis rate, chlorophyll degradation, and grazing. In general, the change in the estimates of these parameters results in improvements in the model prediction and reduced prediction uncertainty.