OceanPredict '19
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Theme 4: Data Assimilation

Session 4: Biogeochemical and coupled ocean-atmosphere data assimilation

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Assimilation of vertical chlorophyll and oxygen profiles using the lognormal four dimensional variational method: A case study in Osaka Bay, Japan

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While assimilation of biogeochemical data in oceanography is often conducted with surface chlorophyll, assimilation of vertical profiles of chlorophyll and oxygen remains rare. When the assimilation is carried out in a productive and hypoxic estuary or coastal sea, the concentrations of chlorophyll and dissolved oxygen (DO) vary considerably in vertical and the concentration of DO is sometimes close to zero near the bottom. While the value of DO must be non-negative, the assimilated DO could be lower than zero when the normal distribution is assumed for its probability distribution. In this presentation, we show a case study to clarify the effect of the normal and lognormal four dimensional variational assimilation (G4DVar and L4DVar) on the calculation of vertical chlorophyll and DO profiles.

Hourly observations of vertical chlorophyll and DO have been obtained in Osaka Bay by Ministry of Land, Infrastructure, Transportation and Tourism of Japan since 2010. The bay is a semi-enclosed and oval coastal sea with the length of 60 km and the width of 30 km, adjacent to Japans second largest urban area, and affected by freshwater with the loadings of nutrient and organic matters from the bay head. At the head of the bay, phytoplankton blooms in spring and in rainy months, and hypoxia is formed during the period from early summer to late autumn, resulting in almost anoxic condition on the bottom in the innermost area. We developed tangent linear and adjoint codes of the biogeochemical model coupled with the Regional Ocean Modeling System. The biogeochemical model considered 11 variables for nitrogen, phosphorus and oxygen cycles. After a seven-month setup run for the initial setting, hourly chlorophyll and DO data with the vertical interval of 1 m was assimilated using the normal and lognormal distributions for those state variables for a week starting from August 1, 2012. In the case of L4DVar, the area where DO was negative on the bottom in the case of G4DVar successfully disappeared. However, the surface distribution of chlorophyll and the vertical profiles of DO agreed better with observations in the G4DVar case than in the L4DVar case.

Keywords: DA - Biogeochemical data assimilation, DA - Data assimilation applications

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Assimilation of phytoplankton functional group data into a global coupled ocean-ecosystem model

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Satellite data of phytoplankton functional groups are assimilated into a global configuration of the coupled ocean circulation-ecosystem model MITgcm-REcoM2. REcoM2 simulates small phytoplankton and diatoms, which are both updated by the assimilation using a local ensemble Kalman filter. The assimilation is performed for the years 2008 and 2009 with an analysis update at each 5th day. The phytoplankton group data for the two groups of REcoM2 are provided by the satellite products OC-PFT, PhytoDOAS, and SynSenPFT, which is a synergistic product combining OC-PFT and PhytoDOAS. Assessed is the separate assimilation of each of these satellite products but also a joint assimilation of OC-PFT and PhytoDOAS data. The results are compared with the assimilation of total chlorophyll data from the ESA Ocean-Color Climate Change Initiative (OC-CCI), which is an alternative to constrain both phytoplankton groups through multivariate assimilation.

The assimilation leads to significant improvements of the concentration of the two phytoplankton groups and of total chlorophyll. While the assimilation of total chlorophyll already improves both groups separately, the assimilation of group data further improves the representation of the phytoplankton community. Here, the assimilation of either OC-PFT or SynsenPFT, and the joint assimilation of OC-PFT and PhytoDOAS data leads to very similar results, while the assimilation of PhytoDOAS data alone leads to higher concentrations of diatoms. However, the joint assimilation of both OC-PFT and PhytoDOAS data improves the representation of the phytoplankton groups, in particular the diatoms, compared to the assimilation of OC-PFT.

Keywords: DA - Biogeochemical data assimilation, DA - Data assimilation applications, DA - Ensemble data assimilation

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Towards the assimilation of ocean color data into a physical-biogeochemical ensemble simulation for the North Atlantic

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Estimating the biogeochemical state of the ocean has become fundamental under the current climate change context due to its key role in mediating the global stocks of carbon. The generation of synthetic products that provide the best possible description of the biogeochemical ocean state is indeed one of the core projects of the Copernicus Marine Environment Monitoring Service (CMEMS). With the objective of contributing to this task, a 1-year experiment from a novel biogeochemical data assimilation method is presented. The method relies upon the daily integration of ocean color data into a probabilistic simulation of a three-dimensional online-coupled physical-biogeochemical model for the North Atlantic. Since any description of the true state of a system involves uncertainties, it is indispensable to identify the structure of the errors that affect the model and the observations in order to build an appropriate assimilation system. In this sense, ensemble methods provide a statistical description of the inaccuracies associated with a complex model system by drawing the evolution of the probability density function (pdf). The ensemble used here includes 24 trajectories that are daily updated by a square root algorithm based on the SEEK filter. To ensure the marginal pdfs are close to Gaussian, anamorphosis transformations are apply both to each variable of the multivariate state vector and to the observations prior to the ensemble analysis step. The corresponding inverse transformations to come back into the original model space are performed after analysis. We aim to evaluate the impacts of using the proposed methodology on analyses and forecast, and to provide guidelines for a new generation of data assimilation methodologies based on ensemble simulations. The results show the ensemble assimilation system is sensitive to the assumptions made for describing the uncertainties. Surface chlorophyll is overestimated on regions with nutrient-depleted mixed layers. By contrast, the assimilation improves the surface analysis and forecast chlorophyll concentrations displayed by the assimilated data where nutrients are not at limiting concentrations. The relevance of the nutrient vertical mixing is indeed evidenced from a diagnosis of the systems performance over the main biogeochemical provinces of the North Atlantic. In this presentation, we will introduce this original approach, and discuss its performance.

Keywords: DA - Biogeochemical data assimilation, DA - Ensemble data assimilation, DA - Fundamentals and methodologies of data assimilation,

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Evaluation of the impact of multivariate assimilation on Mediterranean Sea biogeochemistry

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The currently available near-real time multi-platform measurements of different variables, namely vertical profiles of nutrient and chlorophyll concentrations from BGC-Argo floats besides satellite surface chlorophyll concentration, provide the opportunity to integrate additional information into biogeochemical forecasting systems. In the framework of the European Copernicus Marine Environment Monitoring Services (CMEMS) an operational system for the short-term forecast of Mediterranean Sea biogeochemistry is in place and already includes the assimilation of ocean color satellite observations over both open ocean and coastal areas.

The existing 3D variational assimilation scheme, where the background error covariance matrix is decomposed in different operators, accounts for the covariance among biogeochemical variables through the operator Vb. An update of the operators has been designed for the assimilation of nutrient and chlorophyll vertical profiles of BGC-Argo floats, and different combinations of assimilated and updated variables have been tested. Novel metrics have been developed to evaluate the impact of the different sets of observations on the forecast skill and persistency of the updates.

Covariances between biogeochemical variables calculated on a model simulation have been inserted in the new Vb operator. The covariances are imposed to be variable in time and space to account for the different processes driving biogeochemical dynamics, that would be not properly described by constant and uniform covariances. Results show that the assimilation of satellite chlorophyll and the consequent update of both chlorophyll and nutrients may positively impact the forecast skill performances increasing the persistency of the chlorophyll updates. Furthermore, BGC-Argo floats data assimilation has local but very positive impacts on the vertical dynamics of phytoplankton and nutrients (e.g., deep chlorophyll maximum and nutricline time evolution). However, when float and satellite chlorophyll data are simultaneously assimilated, skill and persistency metrics appear to be affected by some inconsistency between satellite and float data, probably related to the different spatial observation scales and different measurement techniques (i.e., fluorescence-derived vs radiance-derived chlorophyll).

Keywords: DA - Biogeochemical data assimilation, DA - Assimilation of new observation types, DA - Variational data assimilation, Models - Ecosystem/BGC modelling,

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Development of weakly coupled atmosphere-ocean data assimilation system and the evaluation of the coupled reanalysis in JMA/MRI

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JMA/MRI have developed a weakly-coupled Data Assimilation (DA) system, MRI-CDA1, based on JMAs operational systems. MRI-CDA1 is composed of the global atmosphere Four-Dimensional Variational (4DVAR) system for numerical weather predictions, the global Three-Dimensional Variational (3DVAR) system for seasonal predictions named MOVE-G2, and the coupled atmosphere-ocean model for seasonal predictions. The coupled atmosphere-ocean model is adopted as the outer model of the atmospheric 4DVAR routine although the uncoupled atmospheric model is used as the inner model. While the atmospheric 4DVAR analysis is performed every 6 hours, the oceanic 3DVAR analysis is performed every 10 days and the oceanic analysis increments are applied in the integrations of the outer (coupled) model.

Coupled reanalysis experiments based on MRI-CDA1 are conducted for the period from November 2013 to December 2015. Comparison of the reanalysis results with Japanese 55-year Reanalysis (JRA-55) indicates that the overestimate of the sea surface latent heat flux found in JRA-55 disappears in the reanalysis of MRI-CDA1. The system also effectively suppresses the excess rainfall in the tropics in JRA-55, particularly in the Intertropcal Convergence Zone (ITCZ) in the Pacific. We also confirmed that the coupled DA system properly reproduces the lagged-correlated variations of Sea Surface Temperature (SST) and precipitation in the far western tropical North Pacific which is not reproduced by a regular uncoupled DA system. The variation of the precipitation is improved in the coupled reanalysis over the uncoupled one when only conventional data and oceanic data are assimilated. But the coupled DA system adjusts SST to the change of precipitation, instead of correcting the precipitation field, when atmospheric data from satellite are additionally assimilated.

Keywords: DA - Coupled data assimilation for various earth system components, Systems - Coupled systems, Systems - Ocean reanalysis, Applications - Climate change research,

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Coupled Ocean-Atmosphere 4D-Var: Formulation and sensitivity analysis

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The US Navy is currently developing the first coupled ocean-atmosphere four-dimensional variational (4D-Var) data assimilation system to be used for short-term regional forecasting. This project merges the 4D-Var capabilities of the atmospheric component of the Coupled Ocean/Atmospheric Mesoscale Prediction System (COAMPS(c)) with the Navy Coastal Ocean Model (NCOM) through the Earth System Modeling Framework (ESMF). This will provide the coupled ocean-atmosphere forecast with a fully balanced analysis that accounts for all combined observations in both primary fluids (i.e. ocean and atmosphere). In this present work, the formulation of the system is presented in detail along with a series of adjoint sensitivity analysis results using the coupled ocean-atmosphere adjoint model. The sensitivity of the atmosphere (ocean) to each ocean (atmosphere) model variable is analyzed in detail in order to illustrate the usefulness of this approach in the coupled data assimilation system.

Keywords: DA - Coupled data assimilation for various earth system components, DA - Variational data assimilation, DA - Data assimilation applications, ,

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