Overview of Sea Ice Data Assimilation Activities and System Development at NOAA-NCEP

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As Earth-observing systems continuously evolve, various data assimilation methodologies and algorithms have been exploited to make better use of observation data and computational resources. Under a joint effort for data assimilation integration (JEDI) at the Joint Center for Satellite Data Assimilation (JCSDA) and the National Centers for Environmental Prediction of the National Ocean and Atmospheric Administration (NOAA-NCEP), a seaice-ocean coupled assimilation system (SOCA) of the Modular Ocean Model version 6 (MOM6, https://www.gfdl.noaa.gov/mom-ocean-model) and the Community Ice Code version 5 (CICE5, https://github.com/CICE-Consortium/CICE) are integrated into the hybrid Global Ocean Data Assimilation System (GODAS) for new operational applications. We summarize the seaice data assimilation activity in the GODAS project with a brief introduction of the JEDI frame work.

In the JEDI software structure, an object oriented prediction system (OOPS) provides a core framework of algorithms that combine generic building blocks for data assimilation application algorithms. The object-oriented programming approach of the OOPS system, mostly written by C++, does not require knowledge of actual implementations of specific application model structures or observation data information. In the JEDI interface-based programming method, application calls are made with a list of the pre-defined OOPS abstract interfaces, rather than by direct calls of any unitary application routines or classes. A few articles (Trémolet, 2020, Holdaway et al., 2020, Honeyyager et al., 2020) introduce a key concept of the JEDI software system, to highlight how different data assimilation systems can be seamlessly established through the same software infrastructure and components. As a core JEDI application project, the SOCA data assimilation system has been implemented with the interface classes of Geometry, State, Increment, Model, LinearModel, and VariableChange. A C++ traits technique is applied to connect the SOCA application interfaces to the OOPS abstract interfaces and generic algorithms. In addition to developing the MOM6-CICE5 model interfaces, generic marine observation operators and data handling capabilities of the JEDI unified observation (forward) operator (UFO) and interface for observation data access (IODA) systems are also utilized in the SOCA project. The SOCA model interfaces have mainly been built for a coupled data assimilation system of MOM6-CICE5 [4,5]. However, a SOCA-CICE6 system has been demonstrated for a standalone data assimilation capability in CICE version 6 as well. The SOCA interfaces have been tested with a combination of variational and ensemble data assimilation cases: 3DVar, 3DEnVar, and 3D-FGAT and their hybrid variants. A high-resolution 1/4 degree cycled experiment has been conducted with an extensive set of observation data: see details in the paper (Holdaway et al., 2020). More information about the SOCA system is available at https://www.jcsda.org/jcsda-project-soca.

When a broad range of marine observation data sets are used to set initial conditions of the MOM6-CICE5, the SSMI seaice concentration data from DMSP F-15 (https://polar.ncep.noaa.gov/seaice/Analyses.shtml) is also utilized to set the initial conditions of the seaice category concentration variable of the CICE model. As ocean and sea ice are thermodynamically coupled, assimilation of seaice concentration data clearly serves as a good test case for assessing the benefits of a strongly coupled SOCA data assimilation system over weakly coupled data assimilation cases. Here we summarize a preliminary experimental result of the SOCA system of using seaice concentration data. The experiment was done using 3DVar and a 24-hour assimilation window. During the experiment, various observation filters of the JEDI UFO system were applied: bounds check, background check, and thinning. Figure 1 shows seaice concentration analysis and increment (analysis-minus-background) fields obtained from the test of the hybrid GODAS system for the assimilation of the SSMI observation data. The assimilation process produces positive and negative increments in different areas. A positive increment to model background is a dominant feature in the Weddell Sea and Ross Sea. Negative increment is found over a broad range of the seaice boundary in the Southern Ocean. At this stage, we are not systematically applying a post-processing tool for quantification of analysis verification. However, we are still able to observe that analysis and increment fields produced from the experiment match well with patterns in the observation data. A few articles (Barth et al. 2015, Massonet et al., 2015) note that bias can be introduced with the data assimilation approach of multi-category seaice variables with aggregated ice observation data. As the GODAS system evolves, our priority will be focused on the scientific benefits of the SOCA-based data assimilation system with systematically tuned experiment sets.

The JEDI-based data assimilation framework and applications continuously evolve to be adopted for both existing and emerging operational data assimilation systems. With the recent release of the SOCA, MOM6, and CICE5/6 interfaces to NOAA-NCEP, future efforts will be focused on replacing the variational component of the current GODAS system with SOCA. In doing so, important aspects of the SOCA system to be investigated in the coming months are tuning up cycled experiments with robust quality control of observation data, verification of assimilation results with robust post-processing tools, and improving the system efficiency with a hybrid 3DVar and 3DEnVar approach.

References

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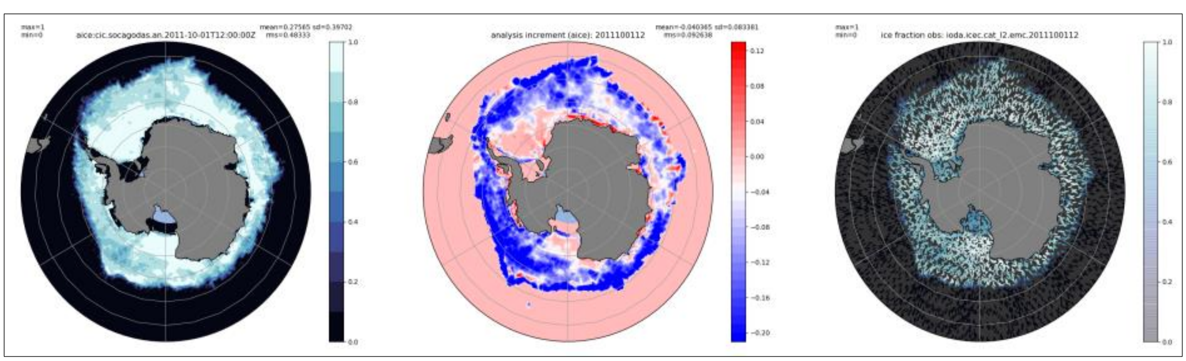

Figure 1: Seaice concentration analysis (left) and increment (middle) fields produced from a data assimilation experiment for the SSMI observation (right) data: 2011-10-01-12:00.