SYMPOSIUM OP'24 ADVANCING OCEAN PREDICTION SCIENCE FOR SOCIETAL BENEFITS

Theme # (5)

# Enabling Ensemble Data Assimilation in NEMO using PDAF

## Overview

For efficient ensemble data assimilation in the NEMO ocean model, we coupled NEMO to the Parallel Data Assimilation Framework PDAF. The result is NEMO-PDAF with the following features:

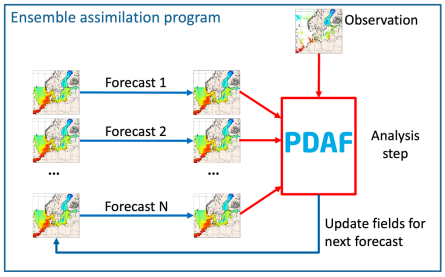
- NEMO is modified to run an ensemble of model states
- The program supports cycled data assimilation without the need to restart NEMO
- NEMO's ASM-module is used to apply assimilation increments
- The data exchange between NEMO and PDAF is done in memory without disk files
- The program is highly scalable for execution on supercomputers
- The different model variables, including sea ice and biogeochemistry, can be included in the data assimilation
- Further observations types can be easily added to the assimilation

### Conclusion

- We developed a highly efficient data assimilation framework for NEMO based on PDAF
- The code is open-source available at **github.com/PDAF/NEMO-PDAF**

## Ensemble Data Assimilation Program

The NEMO-PDAF program is an ocean model augmented by data assimilation functionality. It can also be used for pure ensemble modeling. NEMO-PDAF is run like a single instance of NEMO, but in separate directories with more processors and additional options for the data assimilation.




Sketch of the ensemble model with assimilation functionality

## PDAF

PDAF is a unified tool for interdisciplinary data assimilation …

Community open-source software | Coupled to wide variety of models | Easily usable with (probably) any model

**PDAF** Parallel **Data Assimilation** Framework

Provide data assimilation methods: ensemble Kalman filters & smoothers, particle filters, 3D-Var | Provide tools for observation handling and for diagnostics | Provide support for parallel ensemble forecasts

PDAF is a program library (PDAF-core) plus additional functions and templates | Can run from notebooks to supercomputers – use standards Fortran, MPI & OpenMP | Separation of concerns: model – DA method – observations – covariances

Documentation, and tutorials available at **pdaf.awi.de**

PDAF code release available at **github.com/PDAF/PDAF**

## Authors


**Lars Nerger**[1], Yuchen Sun[1], Wibke Düsterhöft-Wriggers[5], Yumeng Chen[2,3], Dale Partridge[4]

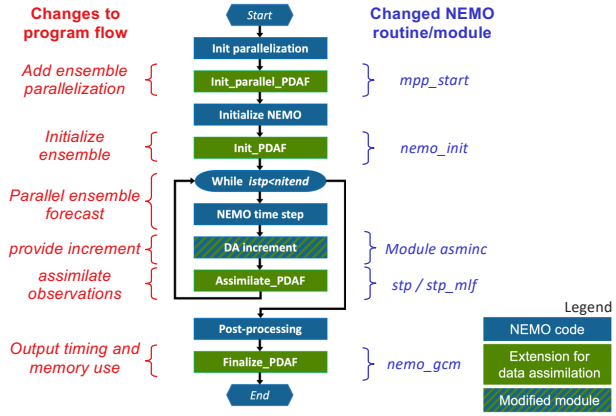
1 AWI 2 National Centre for Earth Observation 3 University of Reading 4 PML Plymouth Marine Laboratory 5 BSH Bundesamt für Seeschifffahrt und Hydrographie



This work has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004032.

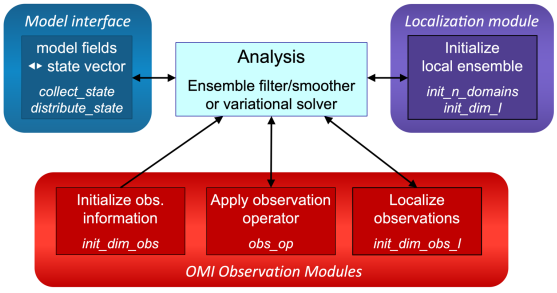

## Direct (Online) Coupling of NEMO and PDAF

Ensemble assimilation without model restarts is enabled by adding just four subroutine calls to the NEMO model code. This is done easily and transforms the model to an ensemble model with assimilation capability. Data transfers between the model and PDAF are performed in memory avoiding inefficient disk files. In addition, we adapt the NEMO's *ASM*-module to provide increments from PDAF.




## Implementing the Analysis Step

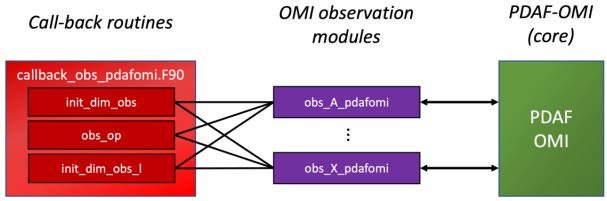
The assimilation methods in PDAF's core are generic. Call-back routines are used for operations specific to a model and observation. Observations are handled by PDAF-OMI. The different components ensure the separation for concerns. The call-back routines are implemented like model routines and utilize model information from NEMO's Fortran modules. The NEMO-PDAF code provides the call-back routines.




Call-back routines used in the PDAF analysis step are grouped in 3 categories

## PDAF-OMI: Observation Module Interface

PDAF-OMI provides an object-like handling for observations. It provides observation operators, and functionality for localization. The figure below shows the main structure of OMI. 'obs_op' and 'init_dim_obs_l' are short routines that only call a routine of PDAF-OMI.




Call-back routines build the interface to PDAF with separate call-back routines calling observation modules

Each observation type is encapsulated in a separate observation module that provides observation-specific functionality

PDAF-OMI provides core functionality for observation registration, observation operators, and localization

Ocean Predict In partnership with unesco Intergovernmental Oceanographic Commission

2021 2030 United Nations Decade of Ocean Science for Sustainable Development