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Building Ensemble-Based Data Assimilation Systems for Coupled Models

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PDAF Parallel Data Assimilation Framework

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Overview

How to simplify to apply data assimilation?

1. Extend model to integrate the ensemble
2. Add analysis step to the model
3. Then focus on applying data assimilation

PDAF: A tool for data assimilation

PDAF Parallel Data Assimilation Framework

PDAF - Parallel Data Assimilation Framework

- a program library for ensemble data assimilation
- provide support for parallel ensemble forecasts
- provide fully-implemented & parallelized filters and smoothers (EnKF, LETKF, NETF, EWPF … easy to add more)
- easily useable with (probably) any numerical model (applied with NEMO, MITgcm, FESOM, HBM, TerrSysMP, …)
- run from laptops to supercomputers (Fortran, MPI & OpenMP)
- first public release in 2004; continued development
- ~200 registered users; community contributions

Open source:
Code, documentation & tutorials at

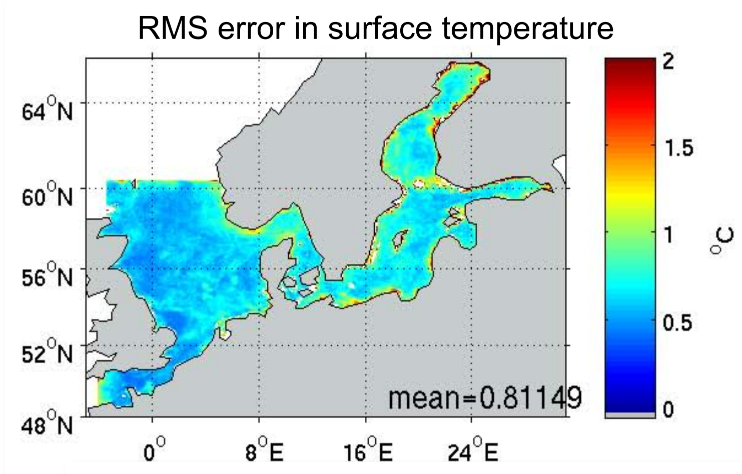
http://pdaf.awi.de

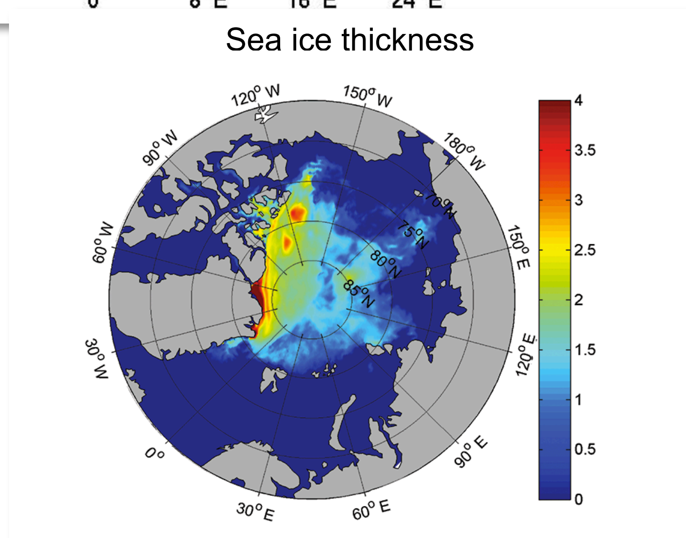
L. Nerger, W. Hiller, Computers & Geosciences 55 (2013) 110-118

AWI

Application examples run with PDAF

- FESOM: Global ocean state estimation (Janjic et al., 2011, 2012)
- NASA Ocean Biogeochemical Model: Chlorophyll assimilation (Nerger & Gregg, 2007, 2008)
- HBM-ERGOM: Coastal assimilation of SST & ocean color (S. Losa et al. 2013, 2014)
- MITgcm: sea-ice assimilation (Q. Yang et al., 2014-16, NMEFC Beijing)

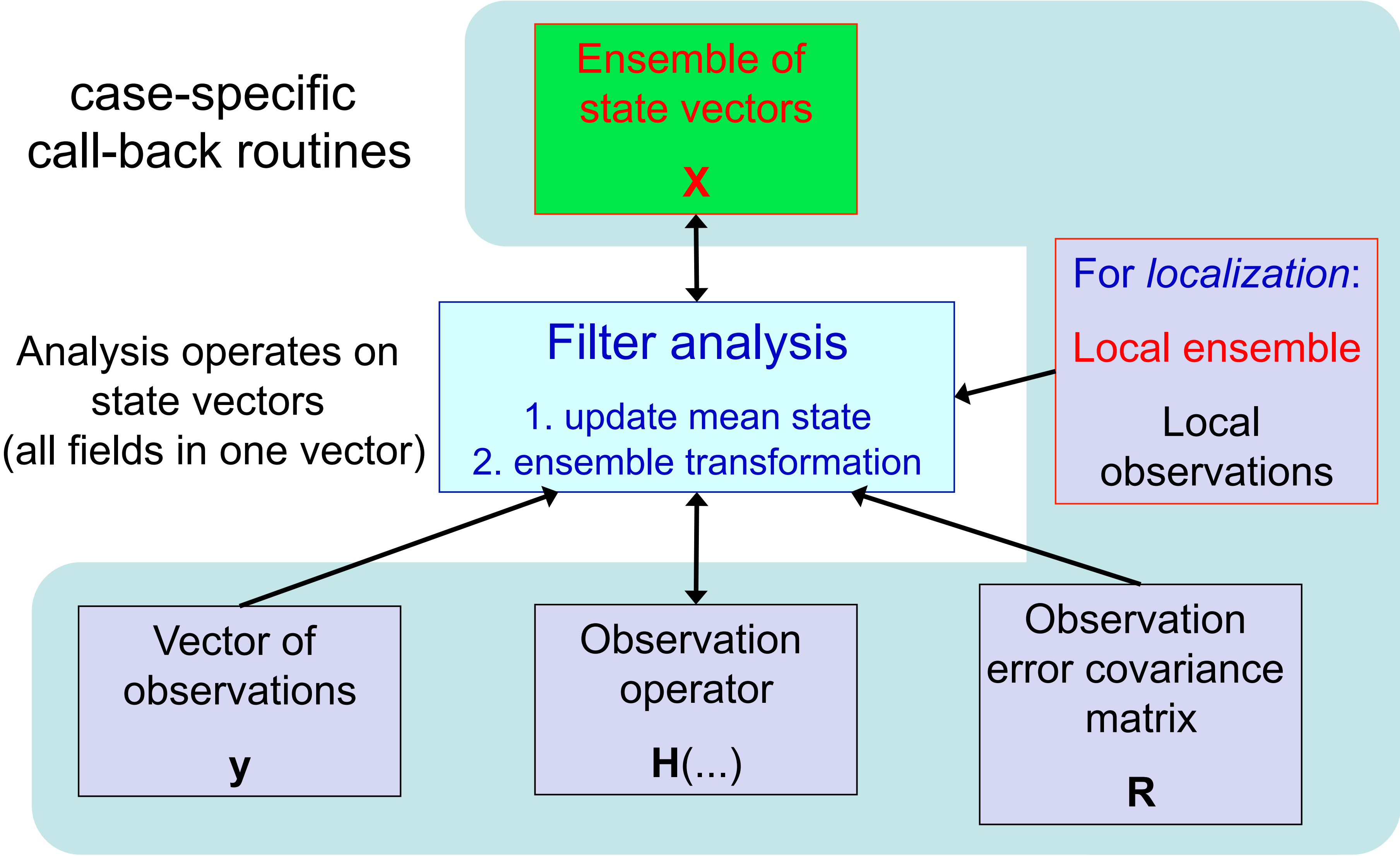




\+ external applications & users, e.g.

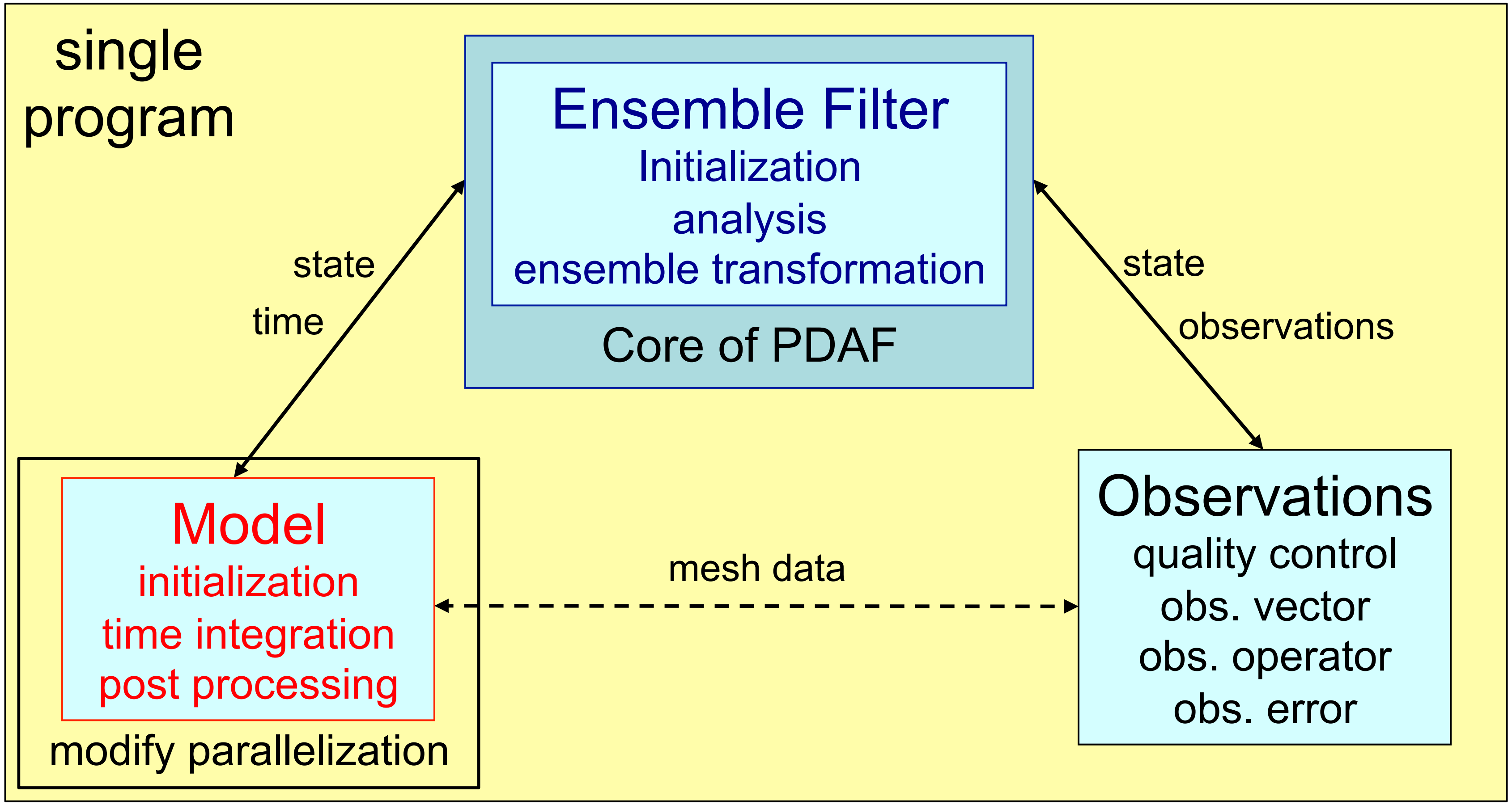
- Geodynamo (IPGP Paris, A. Fournier)
- MPI-ESM (coupled ESM, IFM Hamburg, S. Brune) *-> talk tomorrow*
- CMEMS BAL-MFC (Copernicus Marine Service Baltic Sea)
- TerrSysMP-PDAF (hydrology, FZJ)

Ensemble filter analysis step



Logical separation of assimilation system

PDAF Parallel Data Assimilation Framework



⟷ Explicit interface

⇠- - -⇢ Indirect exchange (module/common)

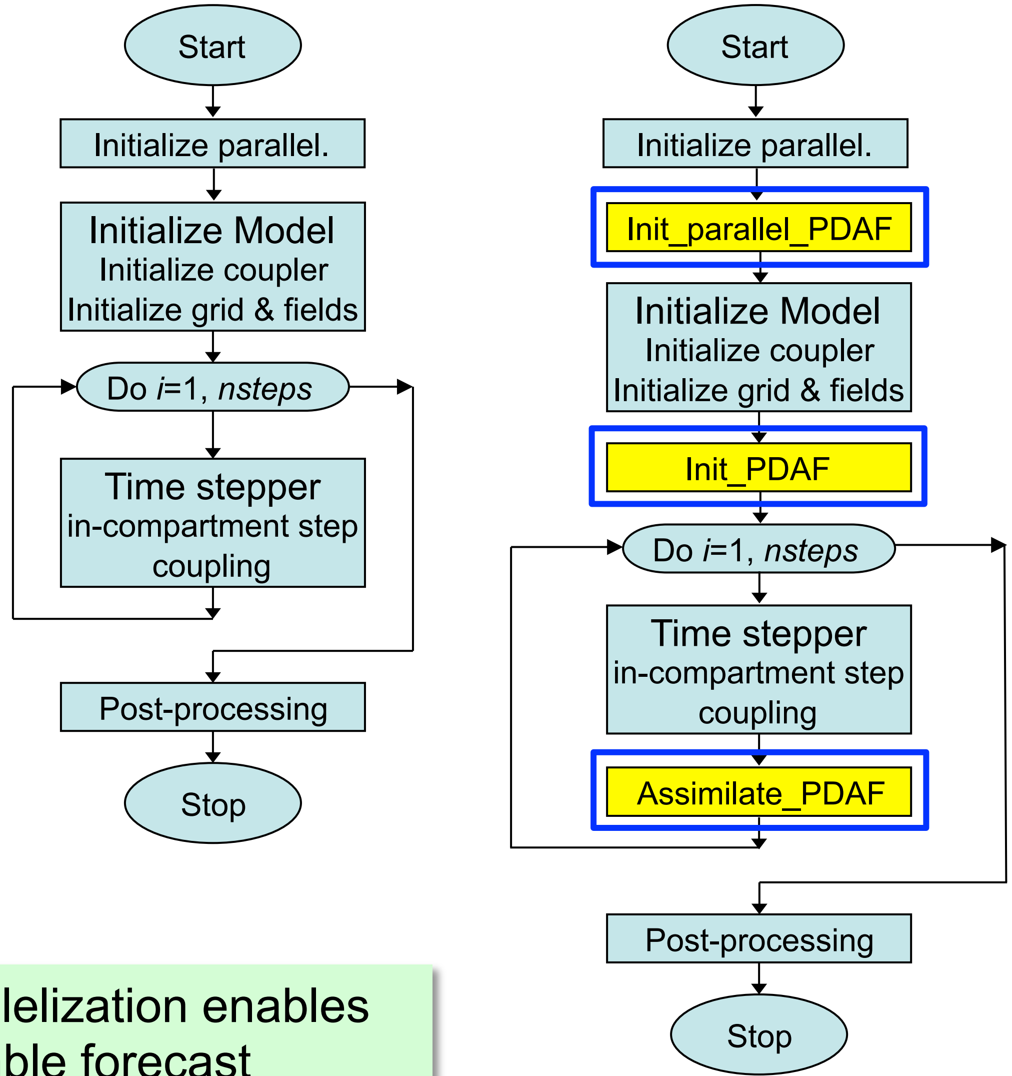
Nerger, L., Hiller, W. Software for Ensemble-based DA Systems – Implementation and Scalability. Computers and Geosciences 55 (2013) 110-118

Extending a Model for Data Assimilation

Model

single or multiple executables

coupler might be separate program



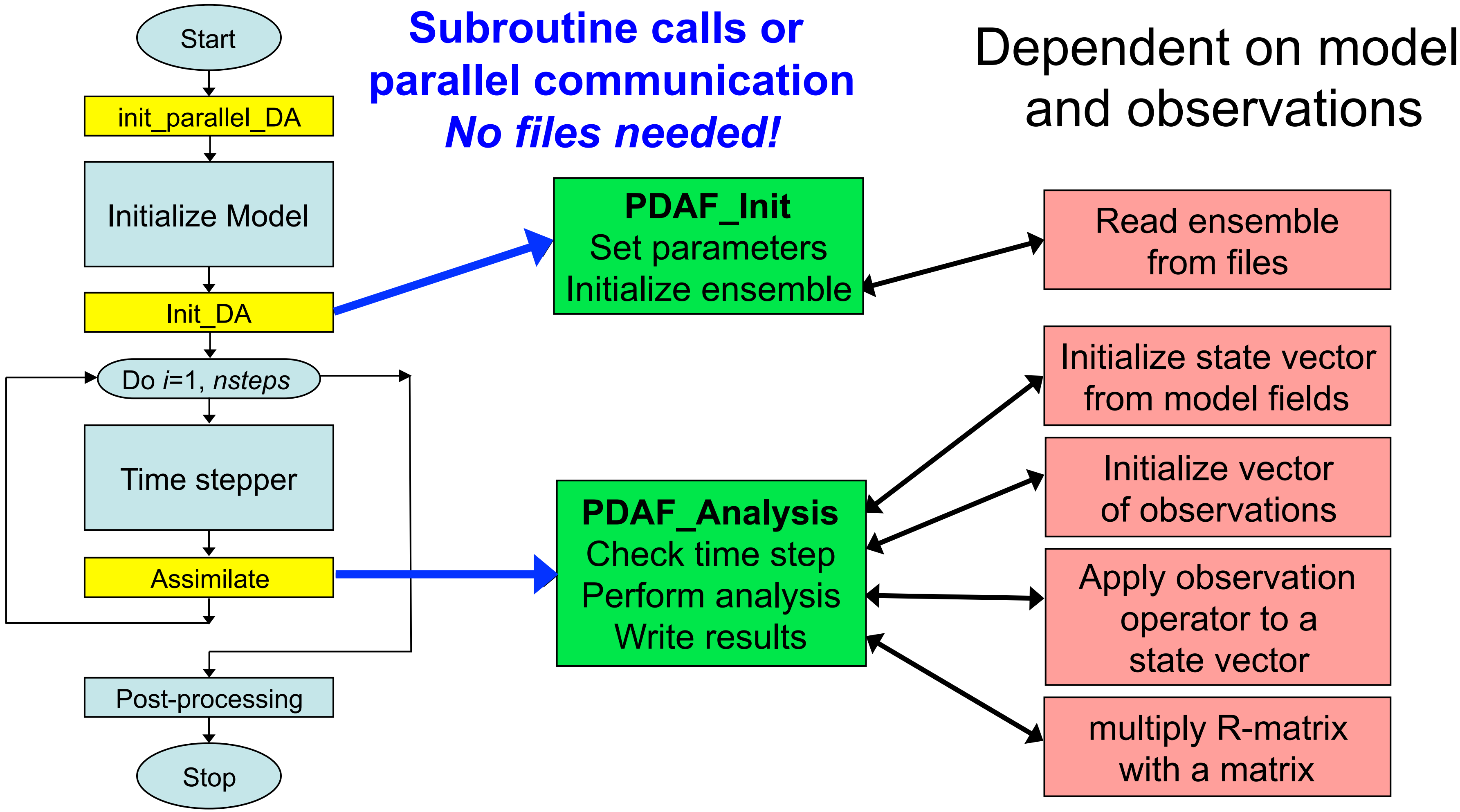
Extension for data assimilation

plus:
Possible model-specific adaption

Possible adaption of coupler (e.g. OASIS3-MCT)

revised parallelization enables ensemble forecast

Framework solution with generic filter implementation

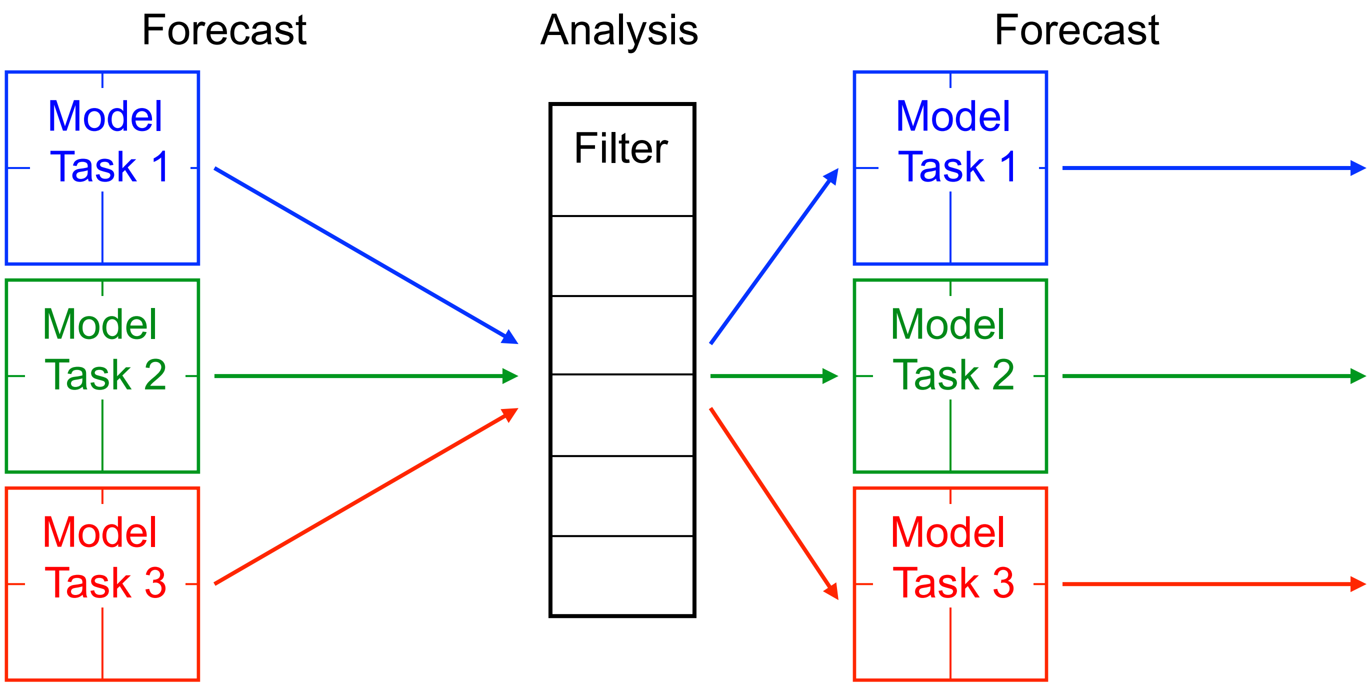


Model with assimilation extension

Core-routines of assimilation framework

Case specific call-back routines

2-level Parallelism



1. Multiple concurrent model tasks
2. Each model task can be parallelized

- Analysis step is also parallelized

- Configured by “*MPI Communicators*”

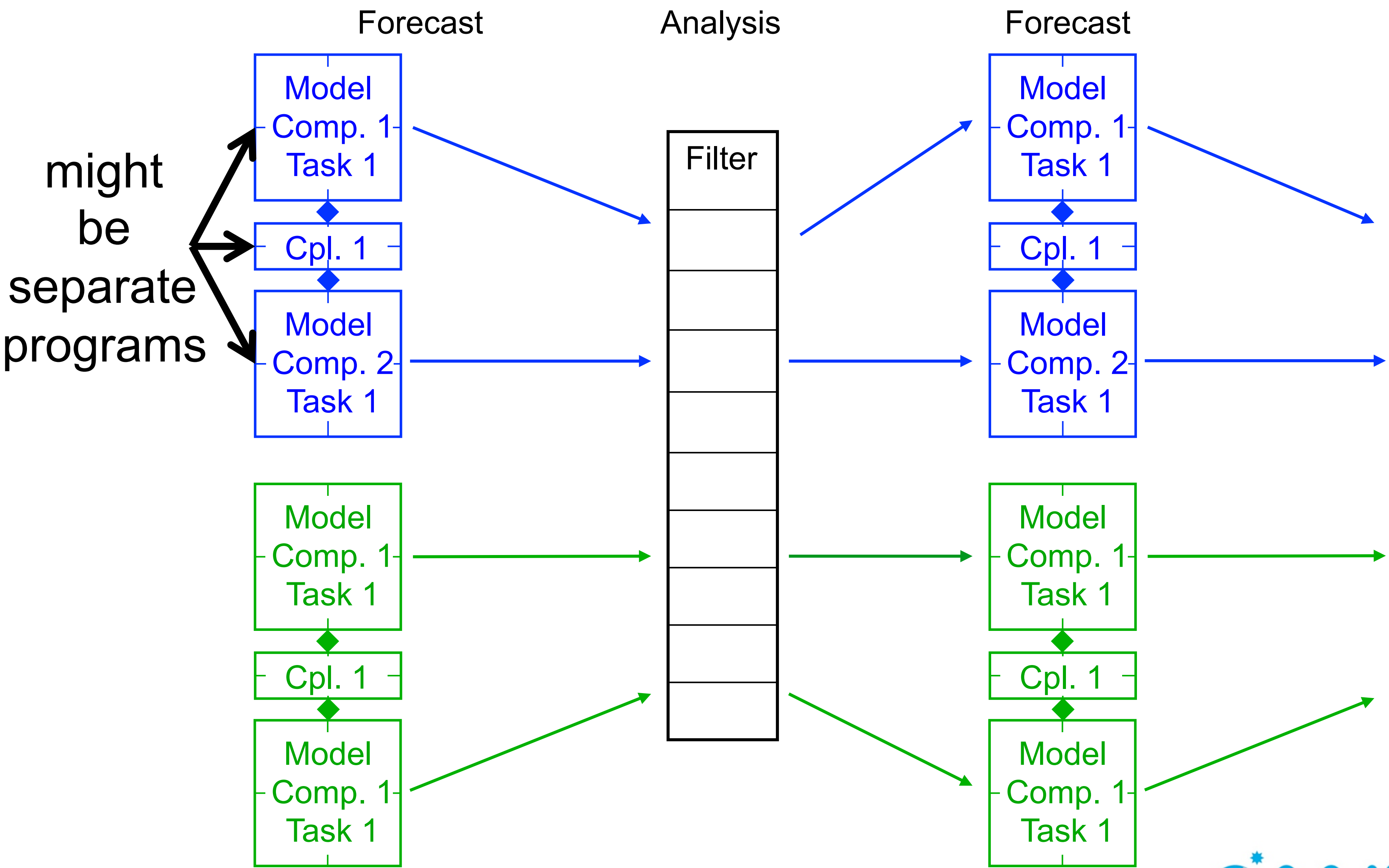
Building the Assimilation System

Problem reduces to:

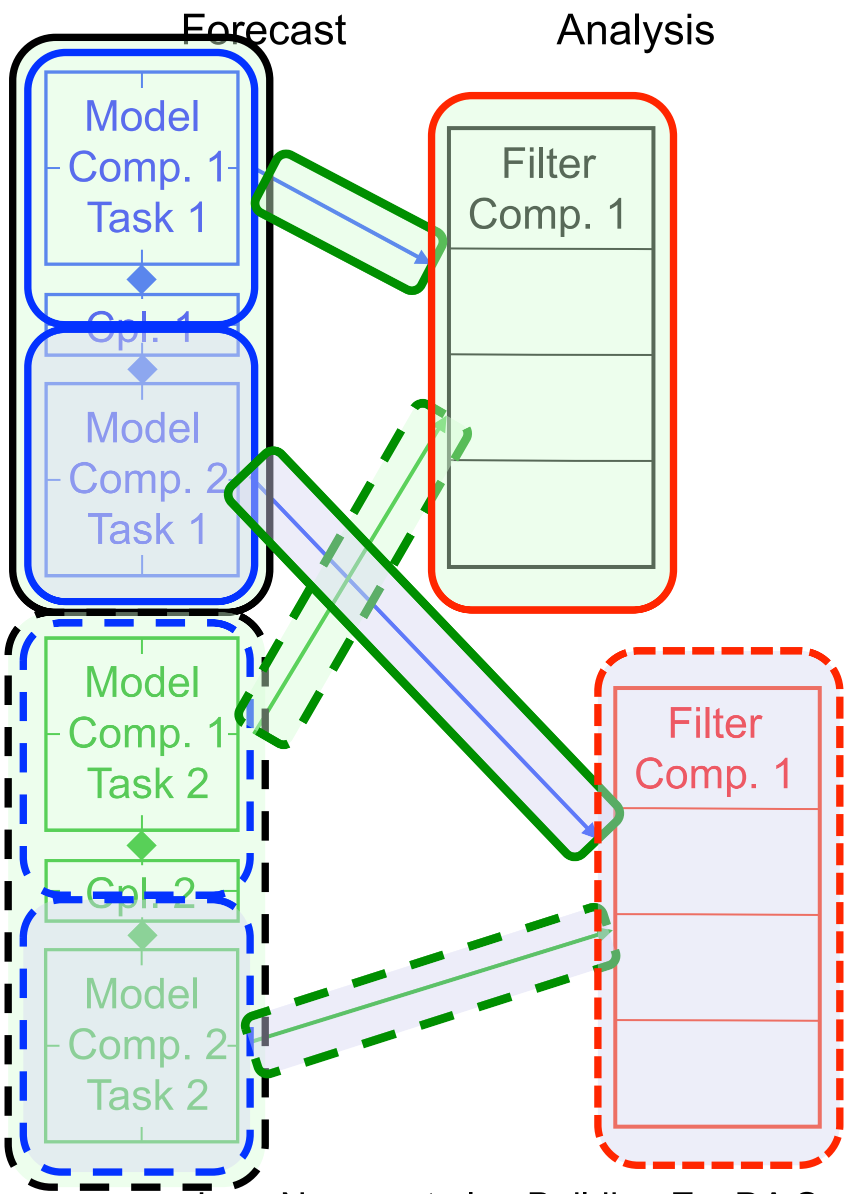
1. Configuration of parallelization (MPI communicators)

2. Implementation of compartment-specific user routines and linking with model codes at compile time

2 compartment system – strongly coupled DA



Configure Parallelization – weakly coupled DA



Logical decomposition:

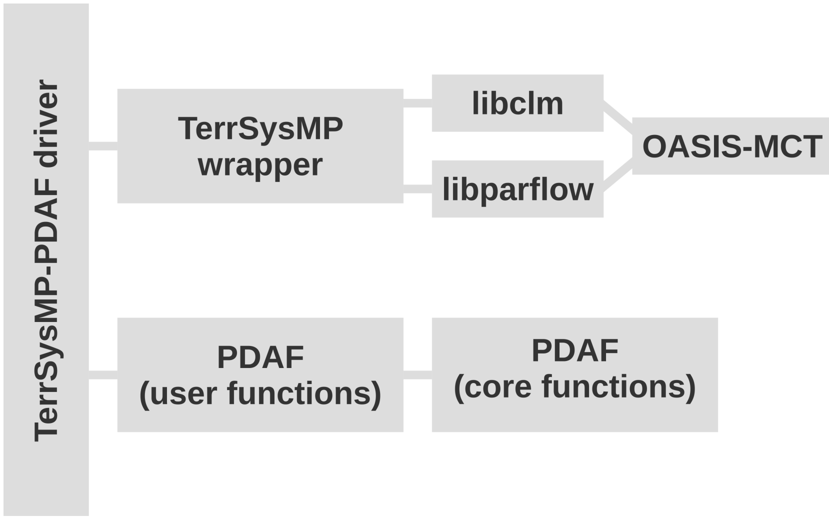
- Communicator for each
  - Coupled model task
  - Compartment in each task (init by coupler)
  - (Coupler *might want to split MPI_COMM_WORLD*)
  - Filter for each compartment
  - Connection for collecting ensembles for filtering

- Different compartments
  - Initialize distinct assimilation parameters
  - Use distinct user routines

Example: TerrSysMP-PDAF (Kurtz et al. 2016)

TerrSysMP model

- Atmosphere: COSMO
- Land surface: CLM
- Subsurface: ParFlow
- coupled with PDAF using wrapper
- single executable
- driver controls program



- Tested using 65536 processor cores

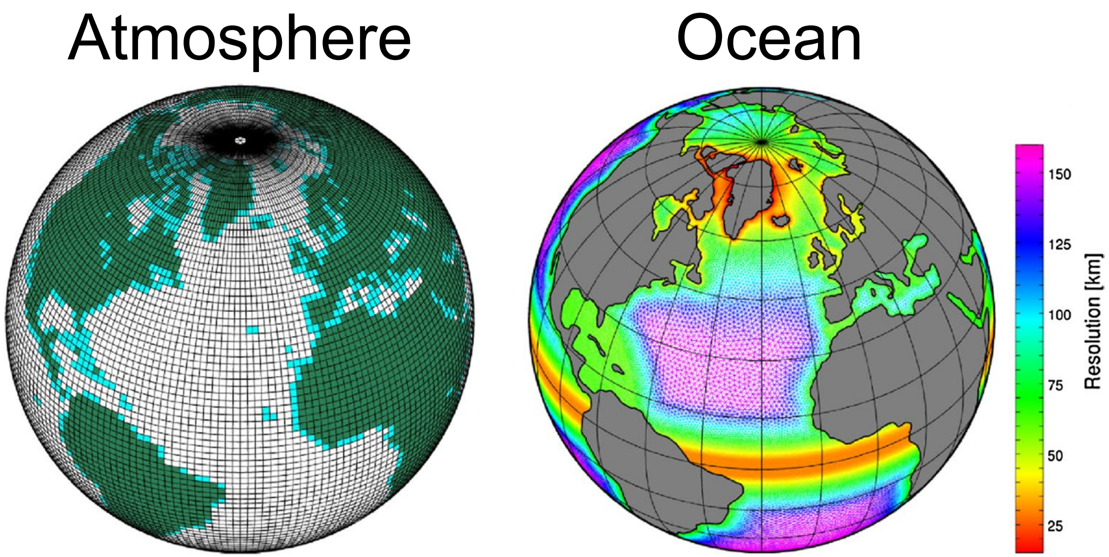
W. Kurtz et al., Geosci. Model Dev. 9 (2016) 1341

Example: ECHAM6-FESOM

Atmosphere
- ECHAM6
- JSBACH land

Ocean
- FESOM
- includes sea ice

Coupler library
- OASIS3-MCT



Separate executables for atmosphere and ocean

Data assimilation (FESOM completed, ECHAM6 in progress)
- Add 3 subroutine calls per compartment model
- Replace MPI_COMM_WORLD in OASIS coupler
- Implement call-back routines

Model: D. Sidorenko et al., Clim Dyn 44 (2015) 757

Summary

- Software framework
  simplifies building data assimilation systems
- Efficient online DA coupling
  with minimal changes to model code
- Setup of data assimilation with coupled model
  1. Configuration of communicators
  2. Implementation of user-routines
     - for interfacing with model code and
     - observation handling

References

- http://pdaf.awi.de

- Nerger, L., Hiller, W. *Software for Ensemble-based DA Systems – Implementation and Scalability*. Computers and Geosciences 55 (2013) 110-118

- Nerger, L., Hiller, W., Schröter, J.(2005). *PDAF - The Parallel Data Assimilation Framework: Experiences with Kalman Filtering*, Proceedings of the Eleventh ECMWF Workshop on the Use of High Performance Computing in Meteorology, Reading, UK, 25 - 29 October 2004, pp. 63-83.

Thank you !