

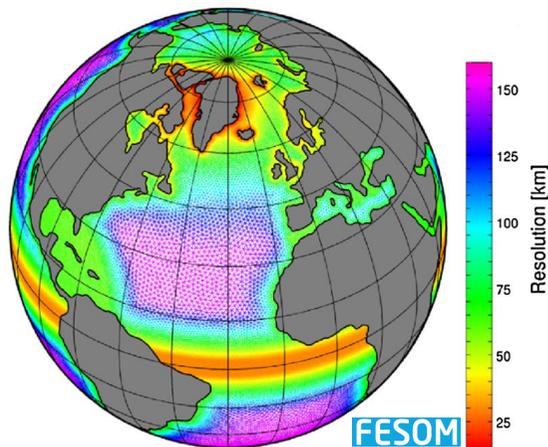
Data Assimilation Developments with FESOM and PDAF

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Earth System Data Assimilation

Models



Observations

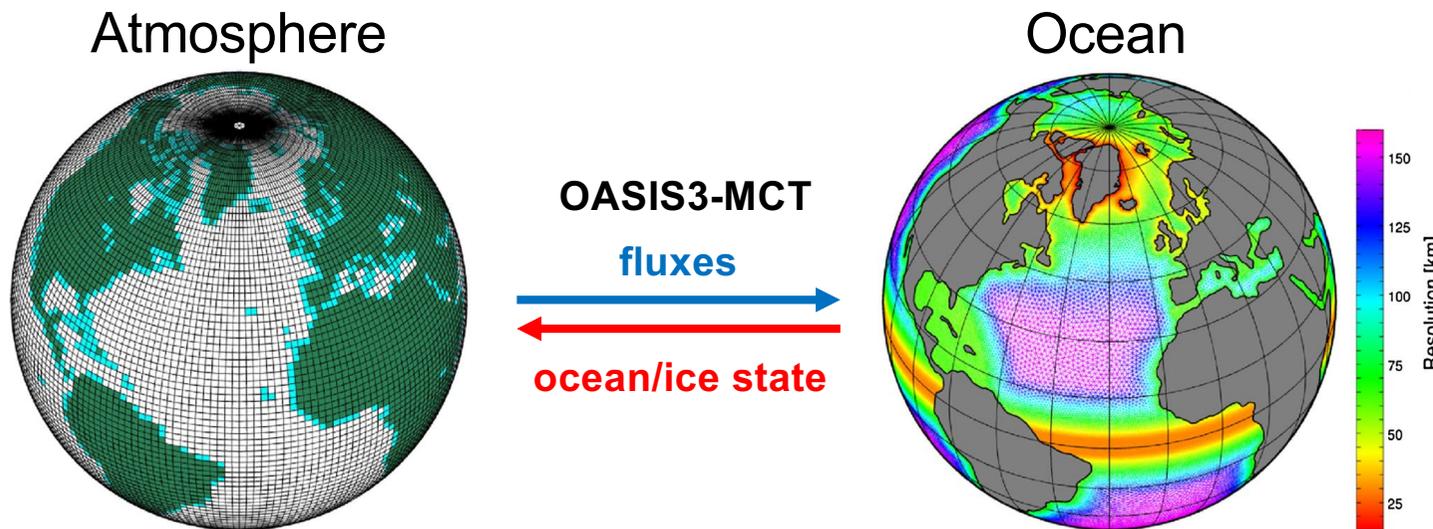


Data Assimilation

Combine both sources of information quantitatively

- Provide direct link between observations and models
- Allow models to learn from data
 - Detect model errors
 - Estimate initial conditions
 - Optimize parameters driving model processes
 - Perform reanalysis

Assimilation into coupled model: AWI-CM



- Atmosphere**
- ECHAM6
 - JSBACH land

Coupler library
OASIS3-MCT

- Ocean**
- FESOM
 - includes sea ice

SSIP Version (AWI-CM3)

- Atmosphere**
- Open-IFS

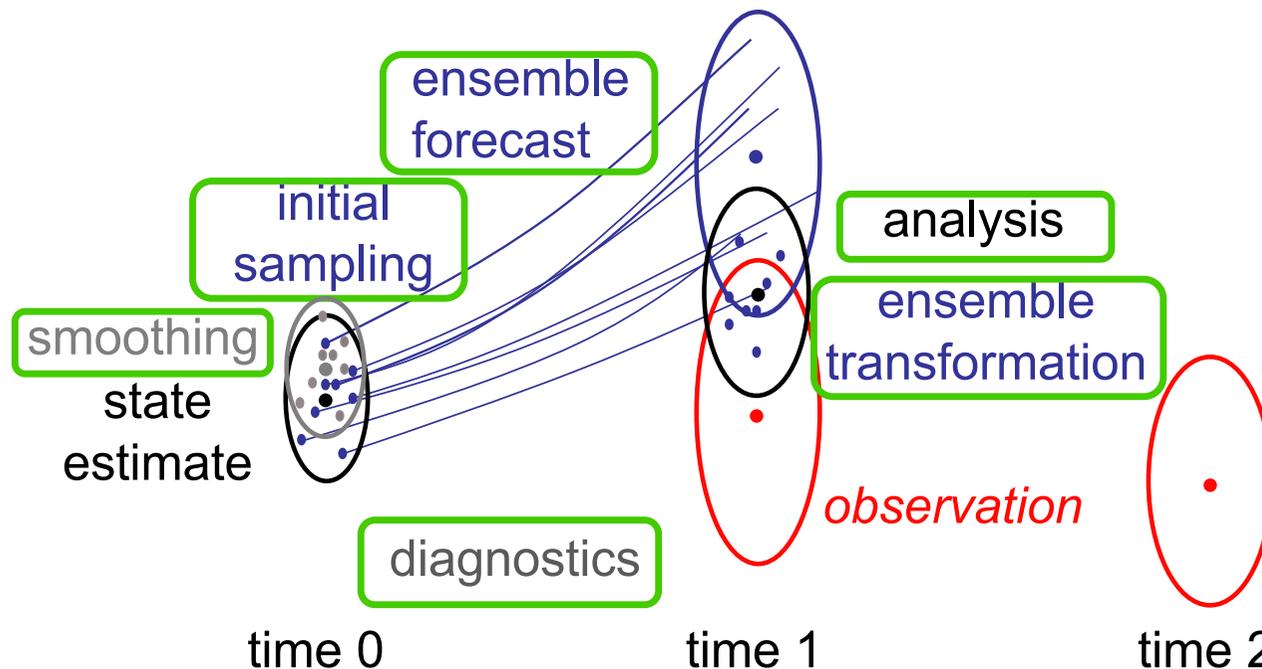
Coupler library
OASIS3-MCT

- Ocean**
- FESOM2

PDAF – Community Ensemble Data Assimilation Software

Ensemble Kalman Filters & Particle Filters

- Use ensembles to represent state and uncertainty
- Propagate ensemble using numerical model
- Use observations to update ensemble



PDAF Parallel
Data Assimilation
Framework

PDAF provides
methods for each of the
steps

Open-source:
<http://pdaf.awi.de>

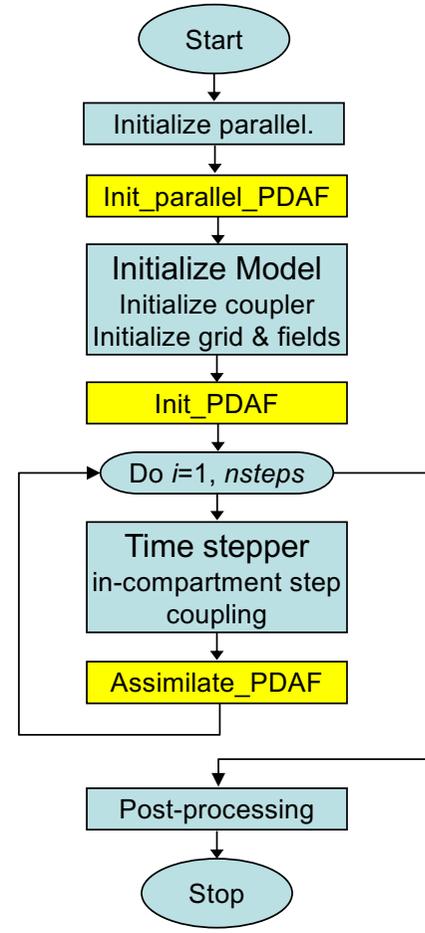
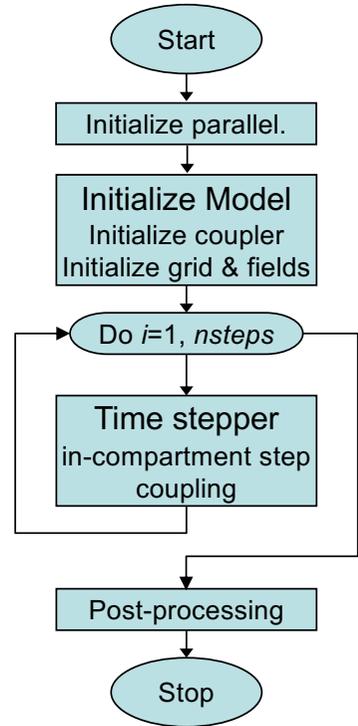
Developed at AWI –
used at AWI, other
Helmholtz Centers
and world wide

Augmenting a Model for Data Assimilation

Model
single or multiple executables
coupler might be separate program

Augment both
ECHAM & FESOM
or
IFS & FESOM

revised parallelization enables
ensemble forecast

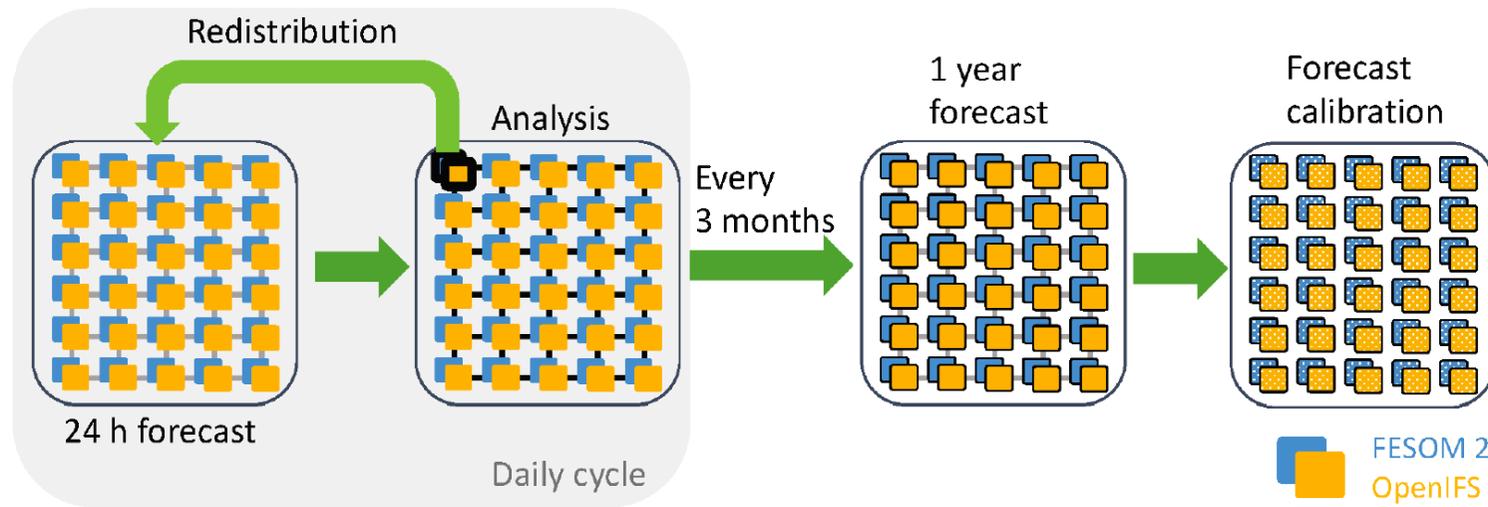


Extension for
data assimilation

plus:
Possible
model-specific
adaption

e.g. in
ECHAM: treat
leap-frog
time stepping
and adaption
in OASIS-MCT

Seamless Sea Ice Prediction System (L. Mu, H. Gößling)



Filter	LESTKF in PDAF
Ensemble size	30
State vector	SIC, SIT, SIU, SIV, SSH, T, S

Coupled model (AWI-CM-3), but...

Observation vector

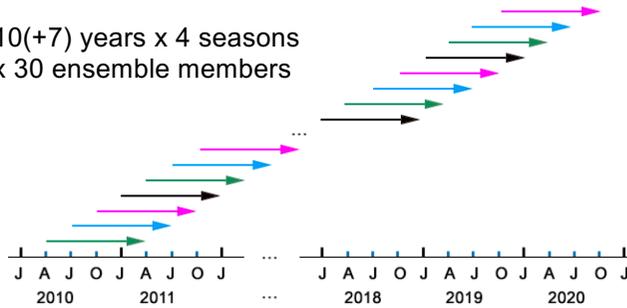
	SIC	SIT	SID	SSH	SST	SSS	T/S profiles
Source	OSI-450	CS2SM OS/Envi Sat	OSI-405-c/NSIDC	SEALEV EL_GLO_PHY_L3	OSTIA	SMOS (L2OS)	EN4
Temporal resolution	Daily	Daily	2 days	Daily	Daily	Daily	Daily
Spatial resolution	25km/10km	25km	62.5km	Along track	0.054°	Along track	profiles
Provider	OSI SAF	AWI	OSI SAF	CMEMS	UKMO	ESA	Met-Office

...assimilation only in the ocean/ice component -> atmospheric relaxation planned

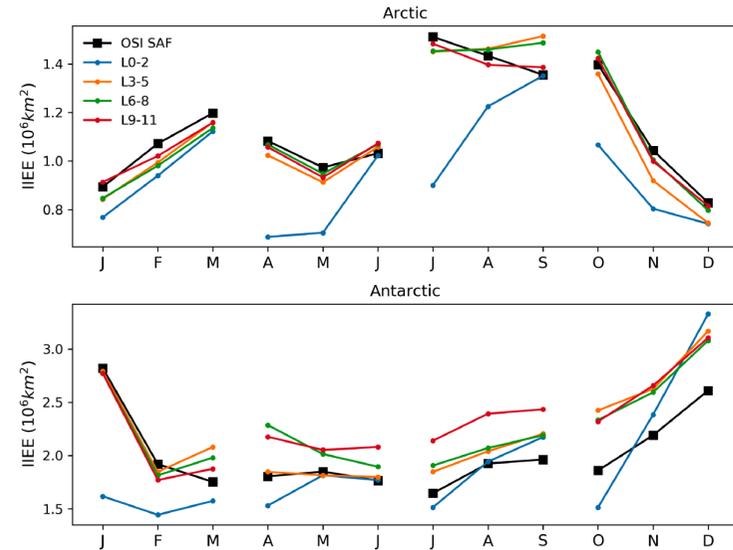
Some Results

Re-forecast setup

10(+7) years x 4 seasons
x 30 ensemble members



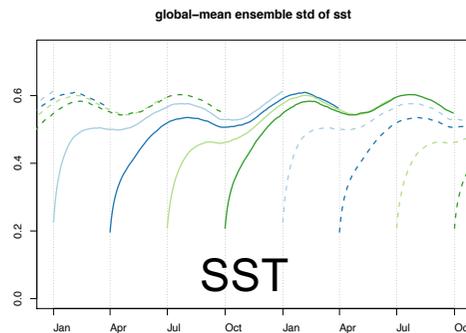
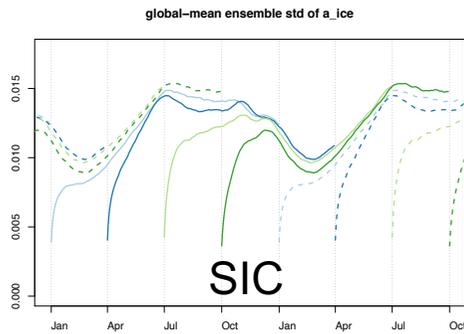
Forecast skill (ice-edge error, calibrated)



Line colors indicate lead time in months

- Forecast ensemble spread behaves reasonably
- Calib. forecasts outperform climatology up to three months ahead

Ensemble spread



Weakly and Strongly Coupled DA: Effect on the ocean (Qi Tang)

Relative RMSE of SST, subsurface T and S

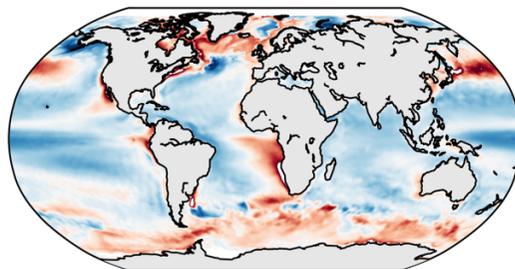
	Free_run	WCDA	SCDA	SCDA_vert
RMSE(SST)	1.00	0.34	0.37	0.34
RMSE(proT)	1.00	0.80	0.80	0.81
RMSE(proS)	1.00	0.95	0.97	0.96

Assimilate only SST and subsurface profiles (T and S)

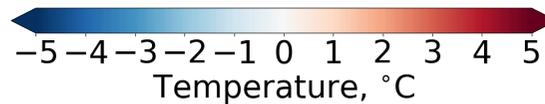
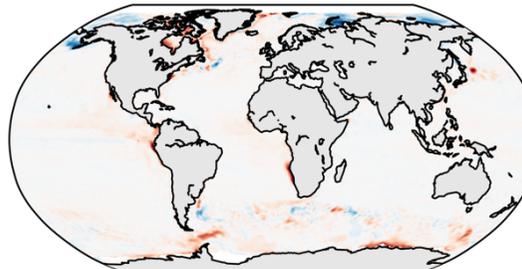
In general, SCDA gives similar RMSEs to WCDA

SST difference

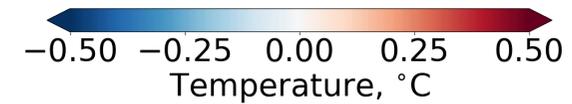
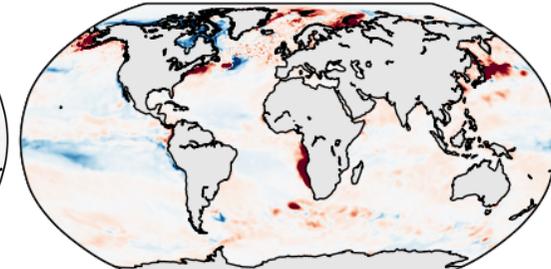
Free run-obs



WCDA-obs

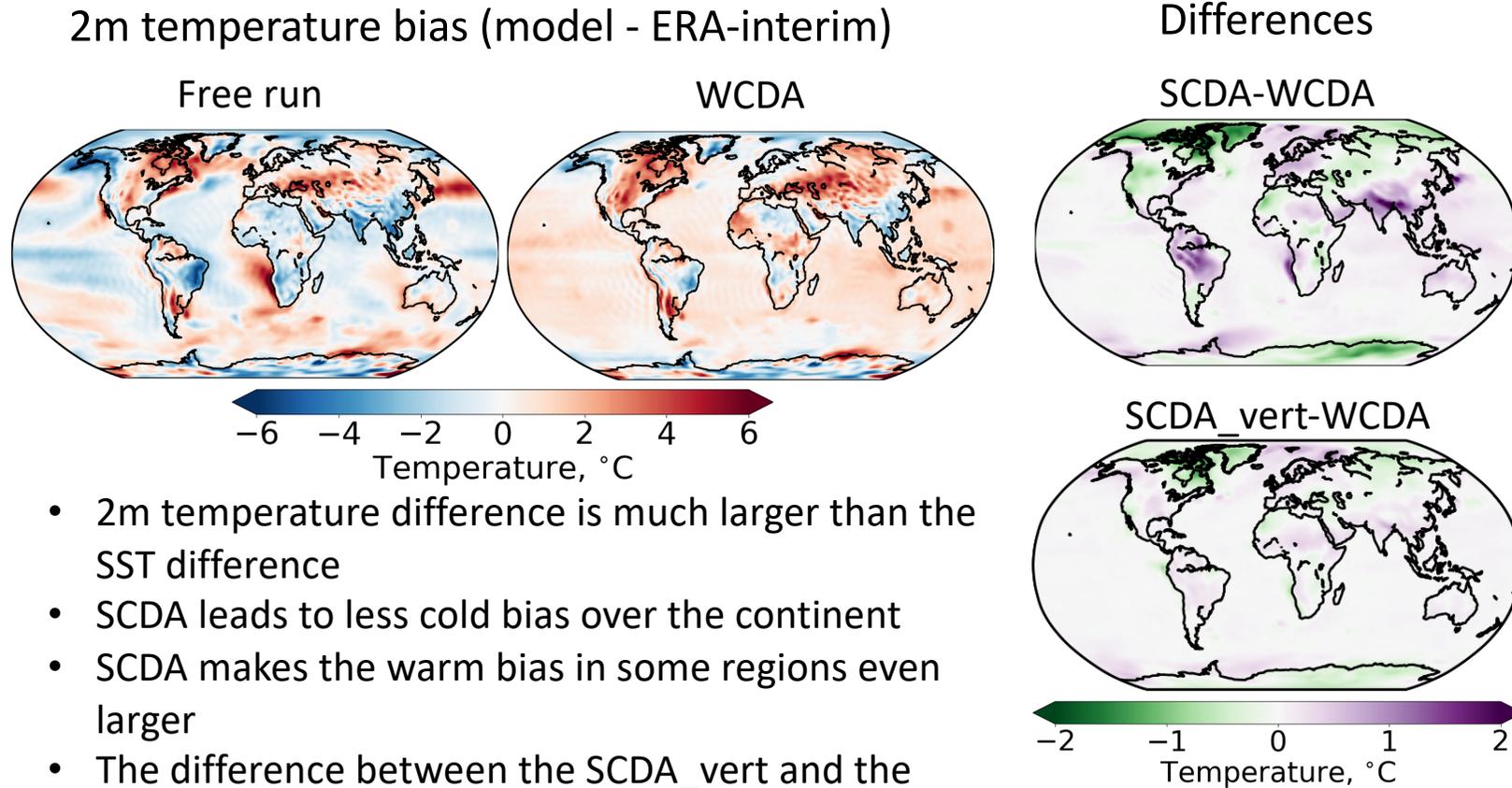


SCDA-WCDA



- The bias patterns for the SCDA and WCDA are similar
- Differences between the SCDA and WCDA in some regions are large, e.g. the west of South Africa, east of Japan, the Gulf Stream, etc.

Weakly and Strongly Coupled DA: Effect on the Atmosphere



- 2m temperature difference is much larger than the SST difference
- SCDA leads to less cold bias over the continent
- SCDA makes the warm bias in some regions even larger
- The difference between the SCDA_vert and the WCDA is relatively small

Summary

- Combined FESOM and FESOM2 (AWI-CM1/AWI-CM3) with PDAF for data assimilation
 - Current applications
 - Seamless sea ice prediction
 - Development of strongly-coupled DA capacity
 - Efficient assimilative coupled model
 - by combining coupled model with PDAF (“online-coupling”)
 - bypass the model coupler/avoid excessive file IO and model restarts
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- Current work:
Prepare assimilation into AWI-CM3 with HR mesh (1.3 mio 2D nodes)
 - Upcoming developments:
Assimilation into FESOM-REcoM (projects UQ and SOCRA)