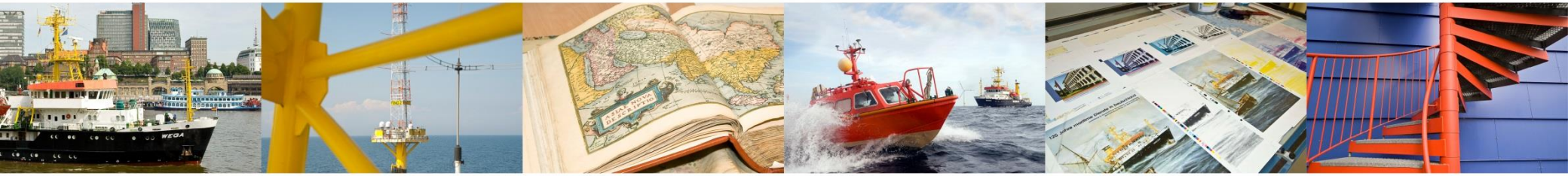
A comparison of data assimilation experiments in an operational model system for the North and Baltic Sea

Xin Li[1], Thorger Brüning[1], Eefke van der Lee[1], Friederike Lempe[1], Tabea Rebekka Panteleit[1], Lars Nerger[2]

[1] Federal Maritime and Hydrographic Agency (BSH), Germany,
[2] Alfred-Wegener-Institute (AWI), Germany

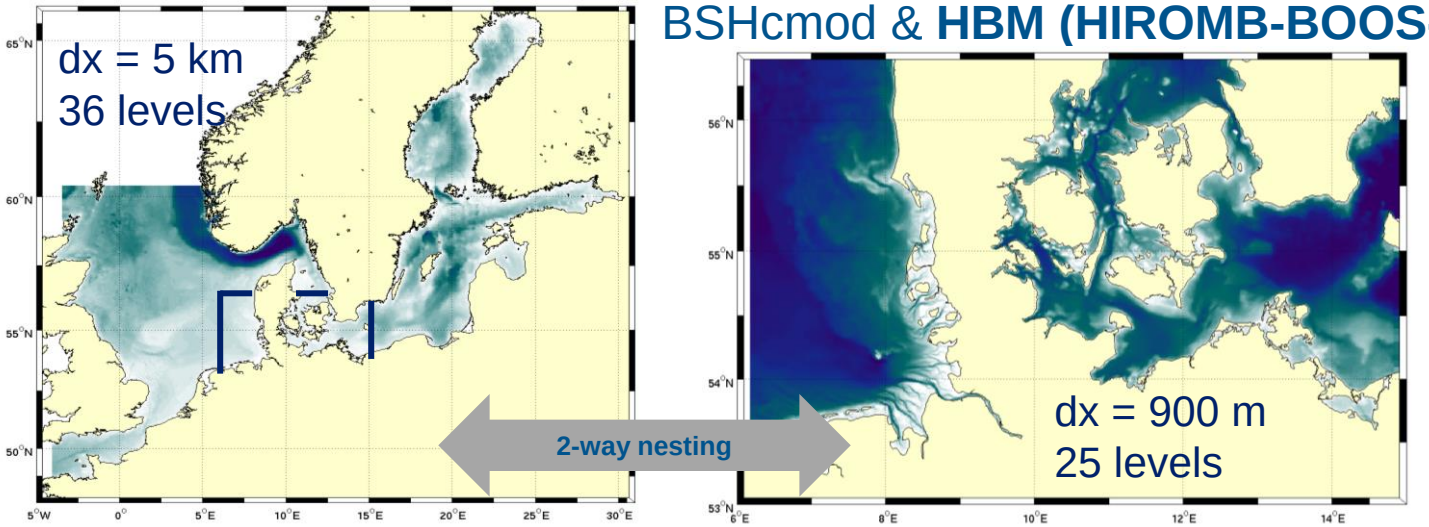


EuroSea/OceanPredict, 2022/06/30

General overview: Operational model system

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

3D (& 2D) ocean circulation models based on BSHcmod & **HBM (HIROMB-BOOS-MODEL)**



- **ice model used for ice service at the BSH**

- Arakawa-C-Grid
- 2-way dynamical nesting
- wetting & drying
- dynamical vertical coordinates Kleine, 2003
- dynamical ice module Hibler,1979
- highly efficient code (OMP & MPI) Berg and Poulsen, 2012

- Advection by flux-corrected transport scheme
- k-ω-turbulence model Berg, 2012
- Open boundary:
  - Tides (14 constituents)
  - Surge (from internal NOA-surge model)
  - Temperature/Salinity Janssen et al., 1999
- NetCDF output

Brüning et al., 2014: Operational Ocean Forecasting for German Coastal Waters
Brüning et al., 2021: An operational, assimilative model system for hydrodynamic and biogeochemical applications for German coastal waters

Data assimilation component

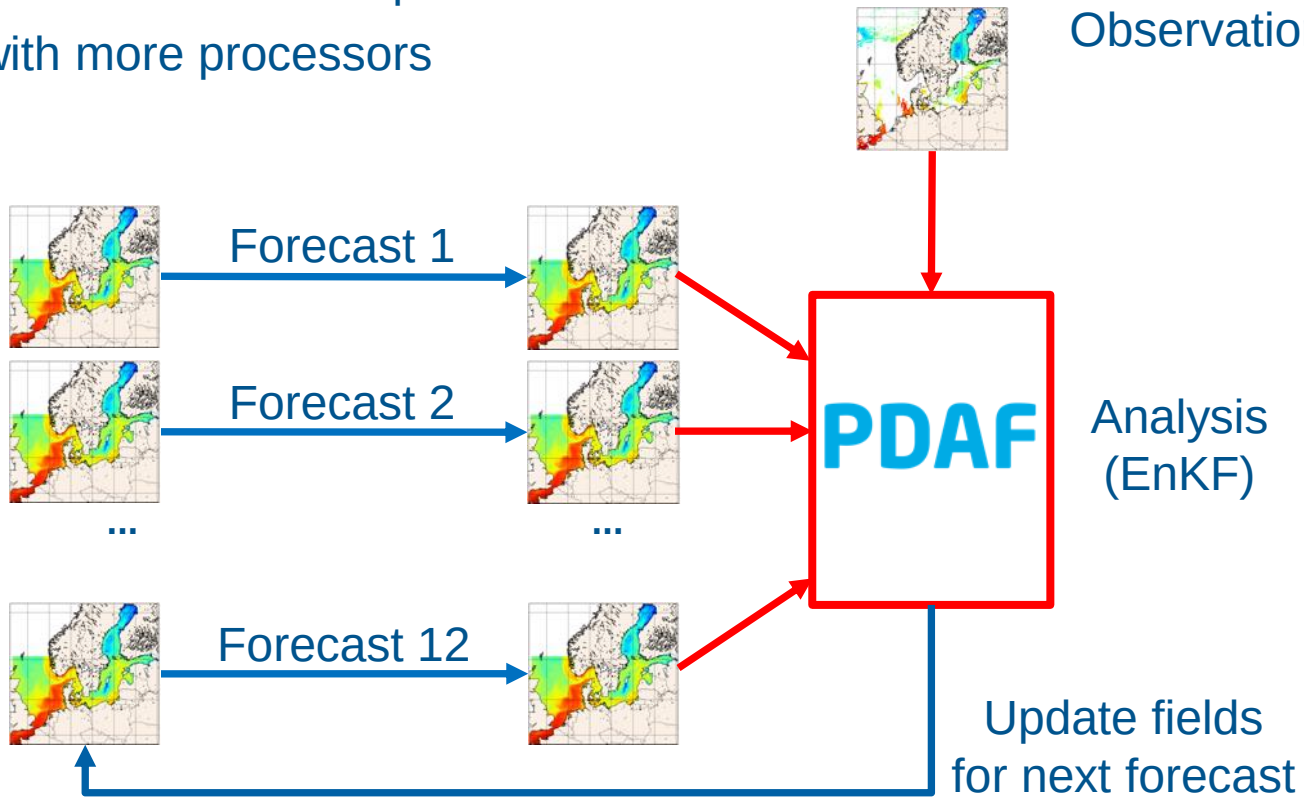
BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

Couple HBM with PDAF

- Modify model to simulate ensemble of model states
- Insert analysis step/solver to be executed at prescribed interval
- Run model as usual, but with more processors

PDAF Parallel Data Assimilation Framework

https://pdaf.awi.de



Data assimilation component

DA method:

- Local Error Subspace Kalman Transform Filter (**LESKTF**) algorithm of the PDAF

Ensemble model states:

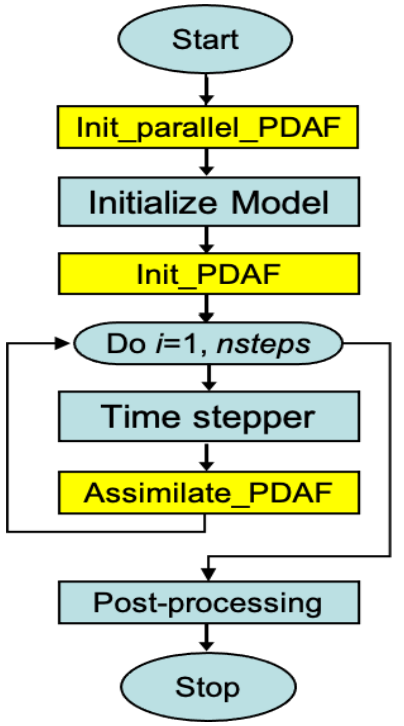
- Temperature, salinity, current velocities and sea surface elevation, layer thickness of dynamical vertical coordinates
- Sea ice thickness, sea ice concentration, snow thickness, surface temperature of snow ice and sea ice velocities

Observations:

- **SST observations:**
  1) AVHRR data
  2) CMEMS multi-sensor SST
- **Ice observations:**
  CMEMS ice chart L4 product for the Baltic Sea
- Salinity + Temperature profile from CMEMS in-situ TAC
- BGC observations

HBM-PDAF
Online mode

DA-augmented model



Data assimilation component

- **Operational set up : SST assimilation**
  - Running 2 times on a daily basis (12-hour forecast from 00 and 12 UTC)
  - Ensemble size: 12
  - SST observations:

    1) AVHRR data:

    - Processed, gridded and quality controlled by the BSH satellite data service
    - Assimilated two times daily (00 und 12 UTC)

    2) CMEMS multi-sensor SST:

    - Resolution: 0.02 x 0.02 degrees
    - Assimilated once daily (00 UTC)
  - Lineally vertical localization for salinity

- **Ice assimilation experiments:**
  - On the basis of the operational SST assimilation set up
  - Sea ice assimilation on a daily basis (12 UTC)
  - 3 month experiments (from Nov. 2017 to Jan 2018)
  - Sea ice concentration (SIC) and sea ice thickness (SIT) observations:

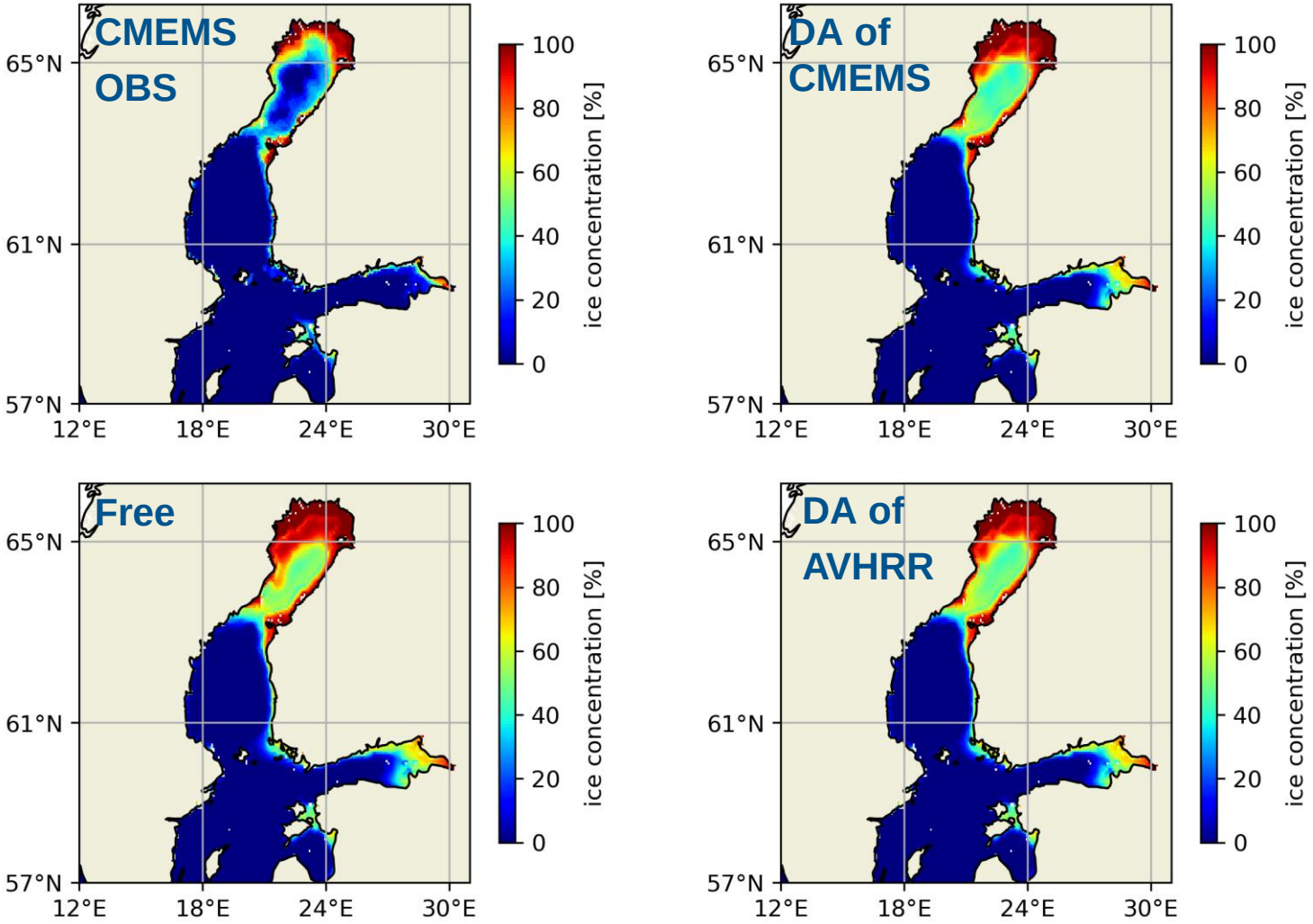
    ✓ **CMEMS SIC L4 product** + CMEMS SST

    ✓ **CMEMS SIT L4 product** + AVHRR SST

Impact of DA on sea ice concentration

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

Monthly averaged SIC (Jan 2018)



- Large differences between models and observation
- SIC in the Gulf of Bothnia and Gulf of Finland are overestimated in the HBM
- Improvements through the DA

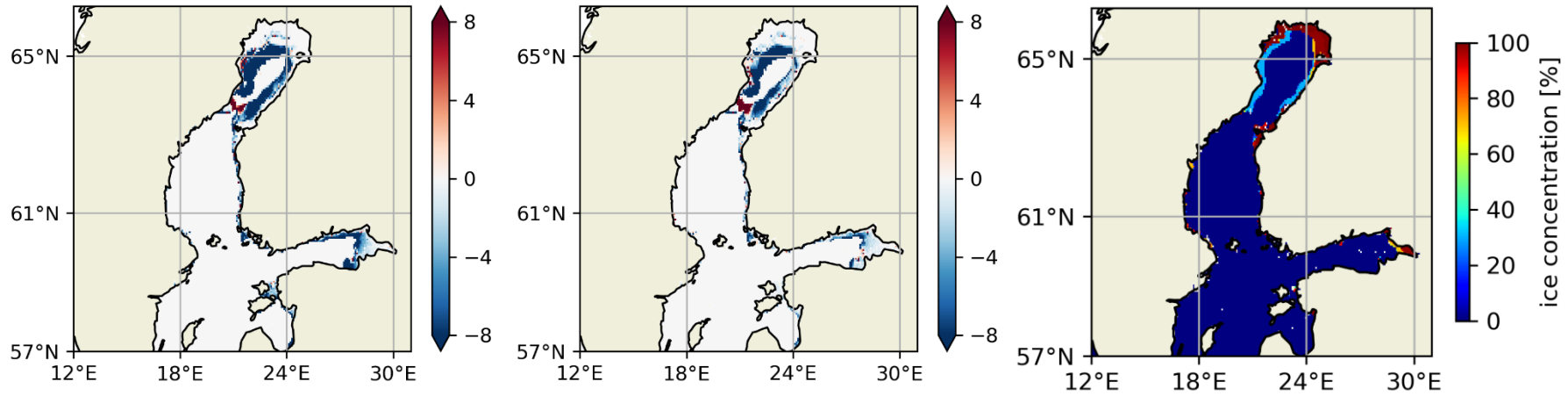
Impact of DA on sea ice concentration

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

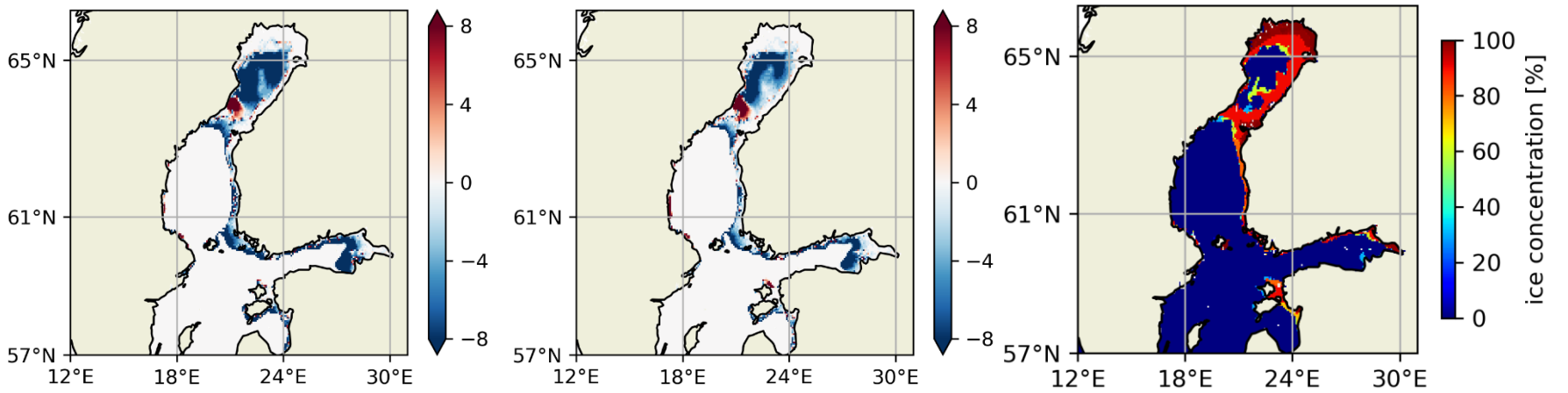
Generally negative increment from DA runs

DA with CMEMS - Free | DA with AVHRR - Free | OBS

15 Jan



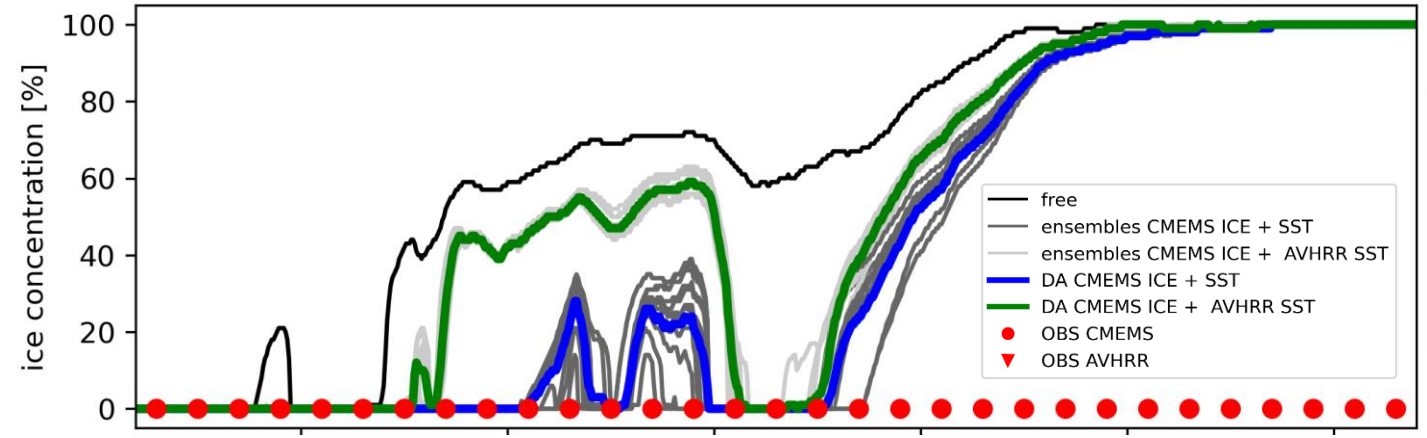
20 Jan



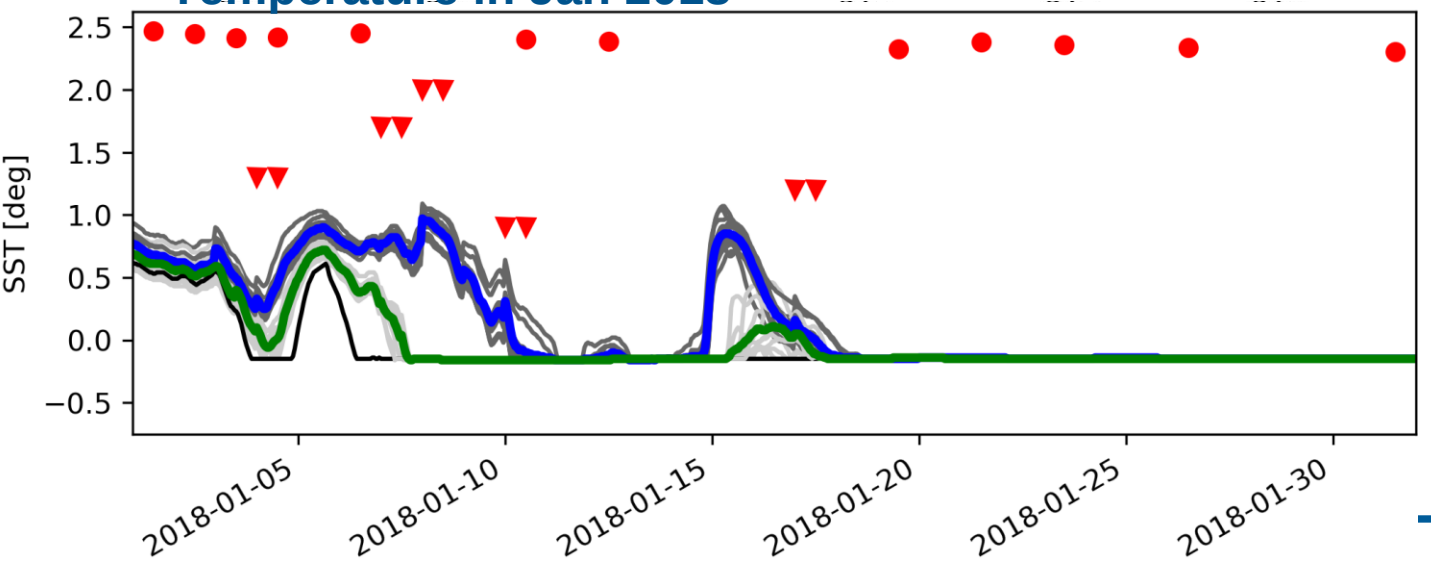
Impact of DA on sea ice concentration

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

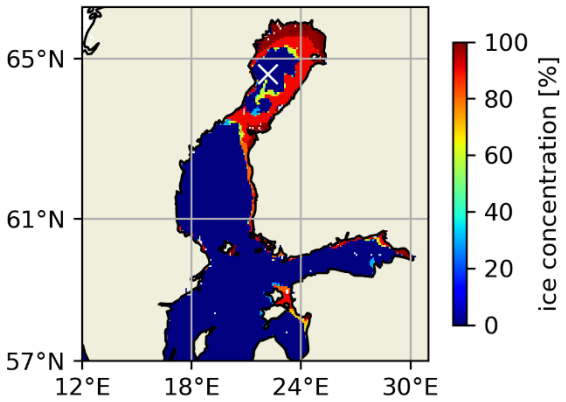
SIC in Jan 2018



Temperature in Jan 2018



- Overestimation of ice formation in HBM can be reduced by SST DA
- Large differences of SIC from 2 DA runs
- CMEMS-SST is higher than AVHRR SST -> SIC from DA using CMEMS-SST reduced more significantly



Impact of DA on sea ice concentration

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

Increment of DA runs on 20. 01. 2018

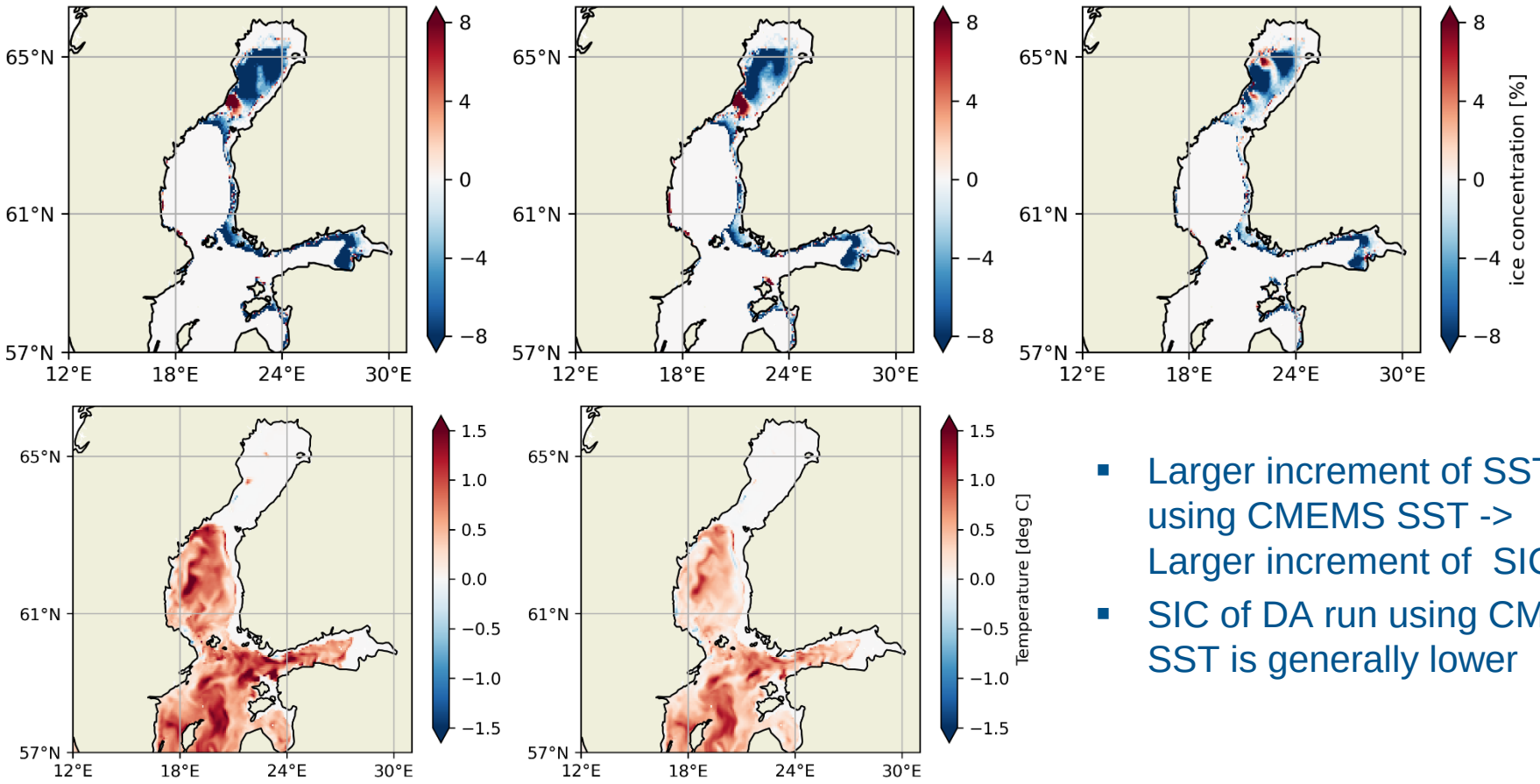
DA with CMEMS - Free

DA with AVHRR - Free

DA with CMEMS – DA with AVHRR

Ice concentration

Temperature

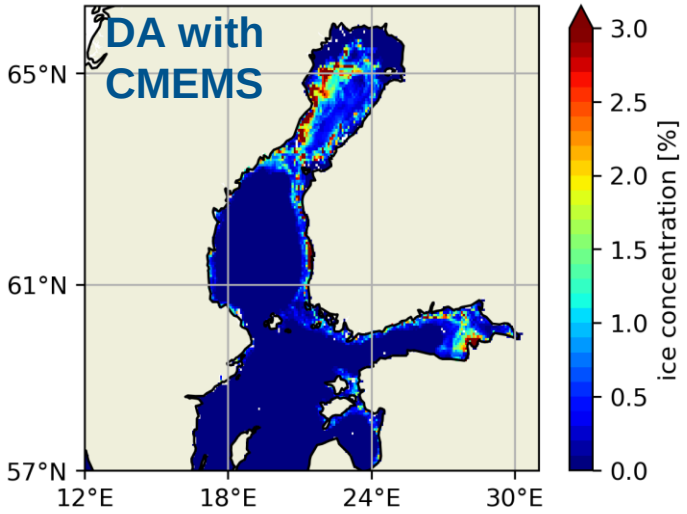


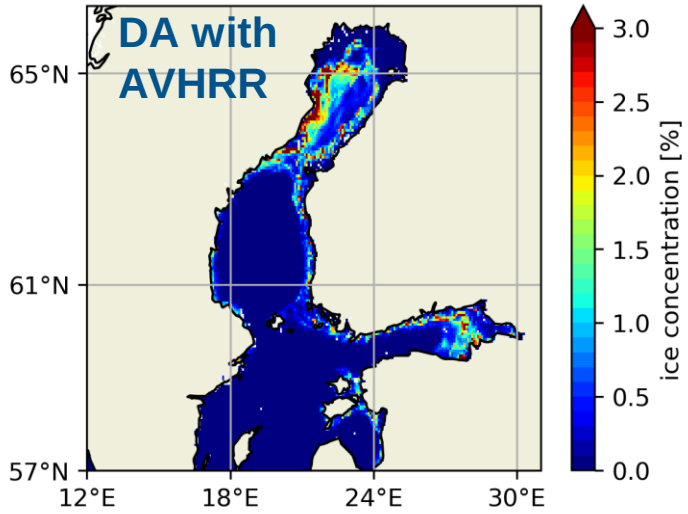
- Larger increment of SST using CMEMS SST -> Larger increment of SIC
- SIC of DA run using CMEMS SST is generally lower

Impact of DA on sea ice concentration

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

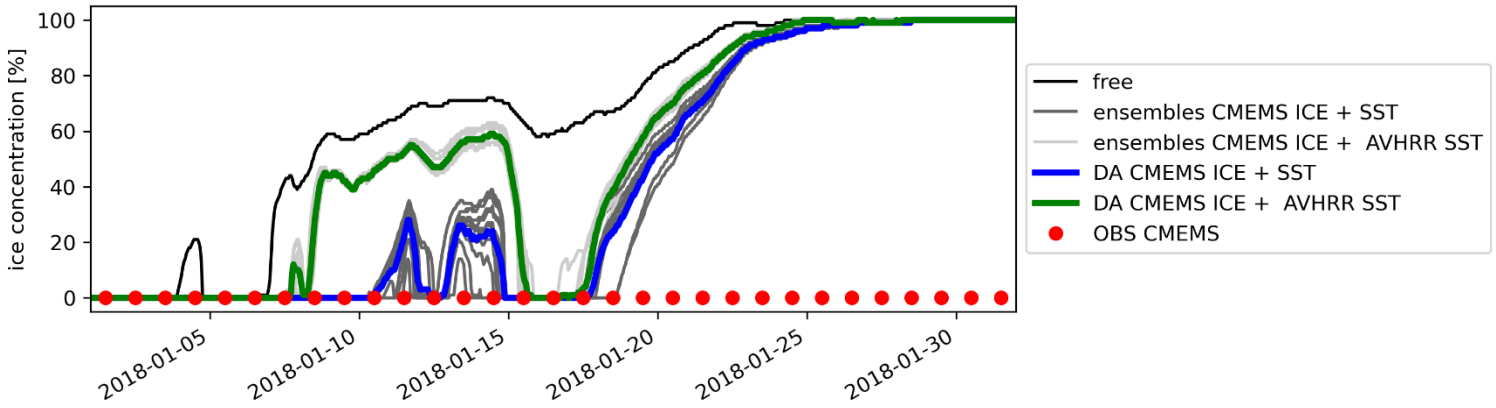
Averaged of STD of ensembles (Jan 2018)

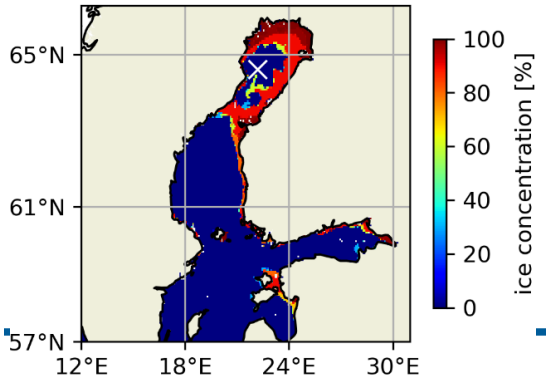




- Using different SST observations makes different ensemble spread
- Ensemble spread in DA using CMEMS-SST is larger than that from using AVHRR
- Larger ensemble spread makes larger improvement
- Ensemble spread is still not large enough

SIC in Jan 2018

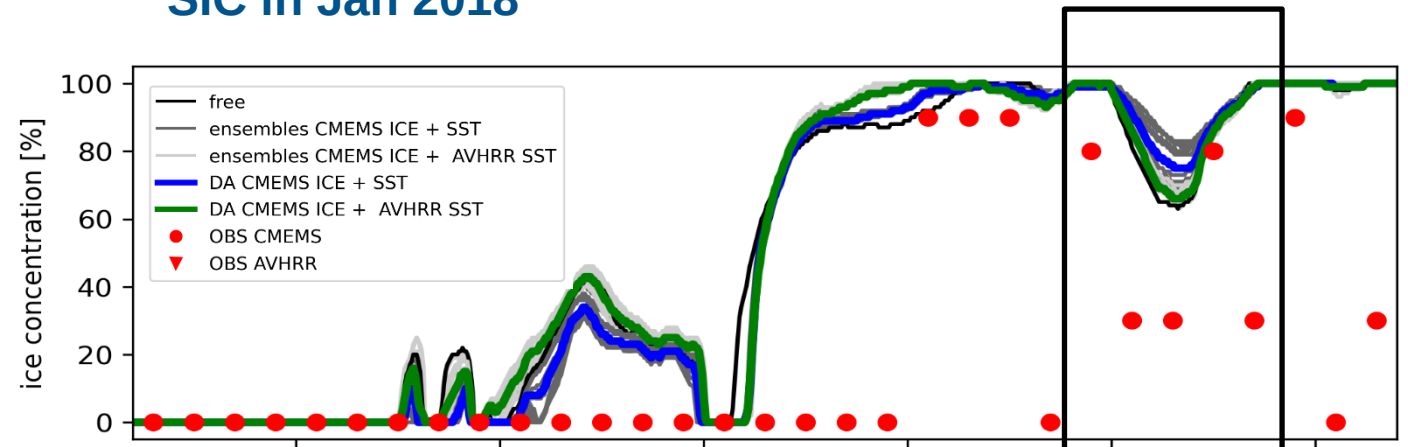




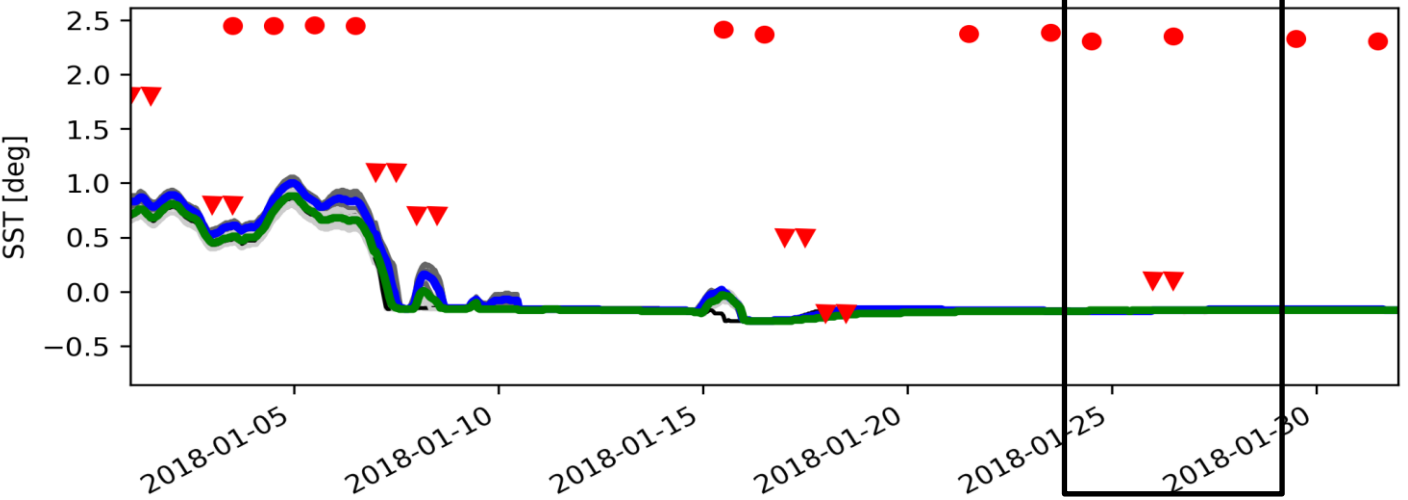
Impact of DA on sea ice concentration

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

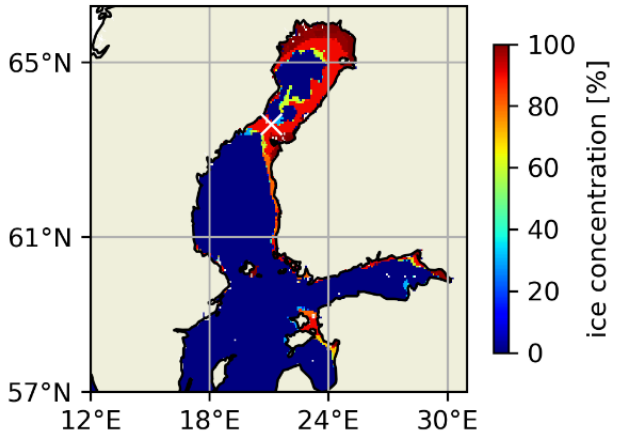
SIC in Jan 2018



Temperature in Jan 2018



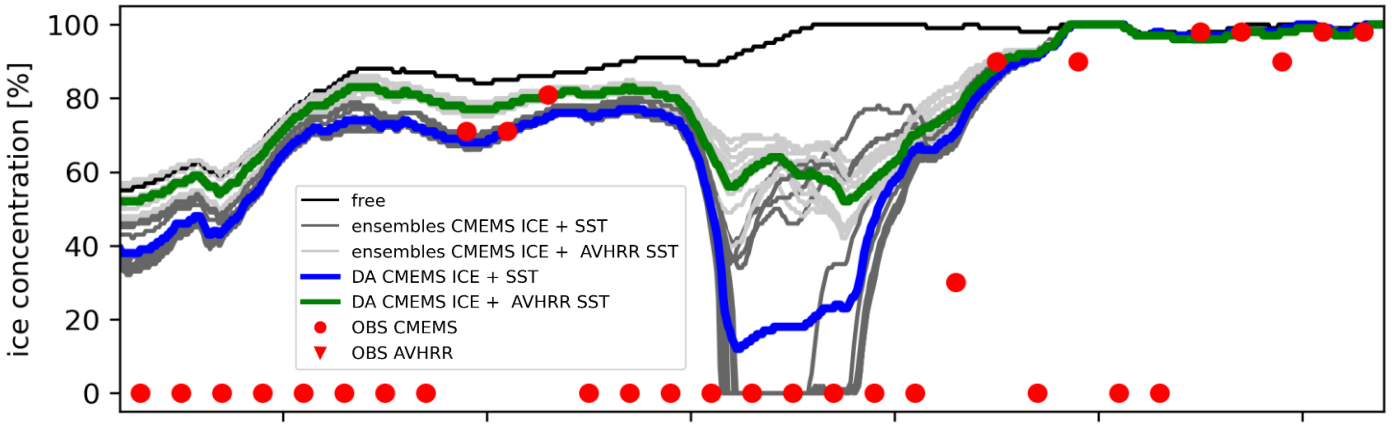
- CMEMS SST are larger than 2° C in the ice area at the location
- Quality of AVRHH SST is controlled by the BSH satellite data service
- SIC in DA using better quality SST is closer to observations



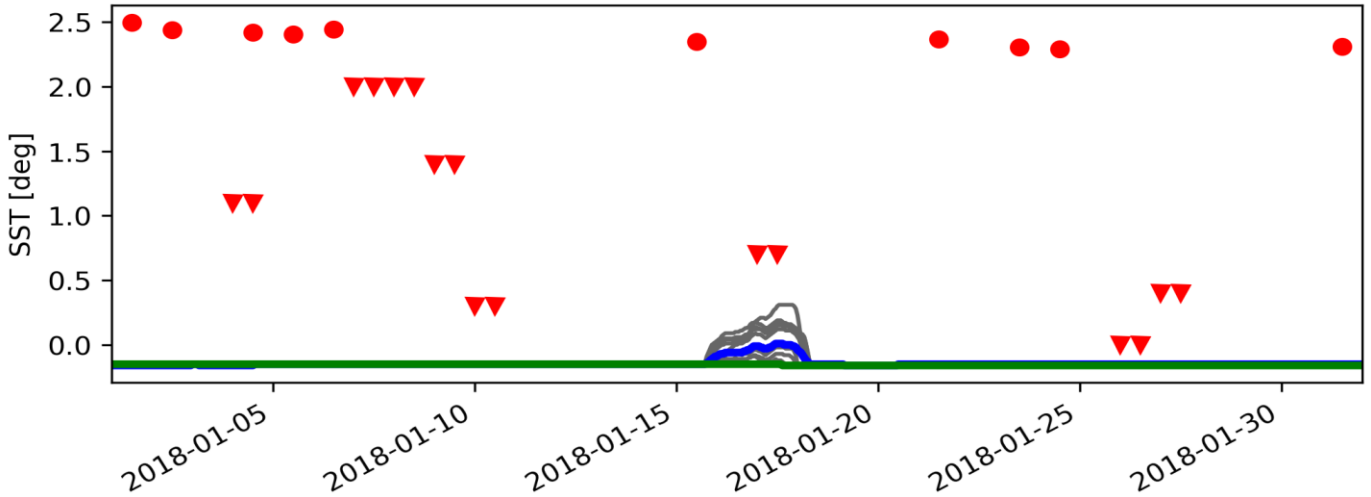
Impact of DA on sea ice concentration

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

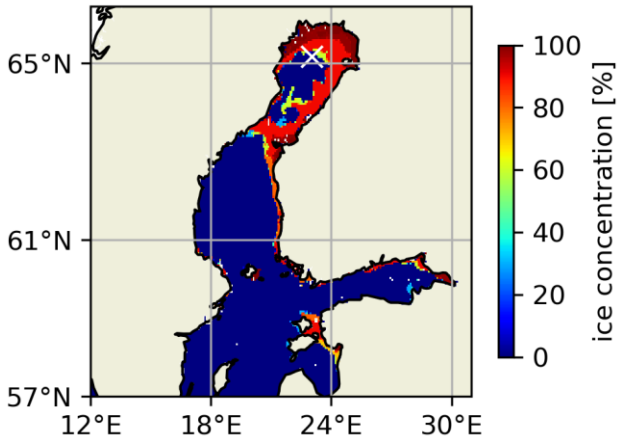
SIC in Jan 2018



Temperature in Jan 2018

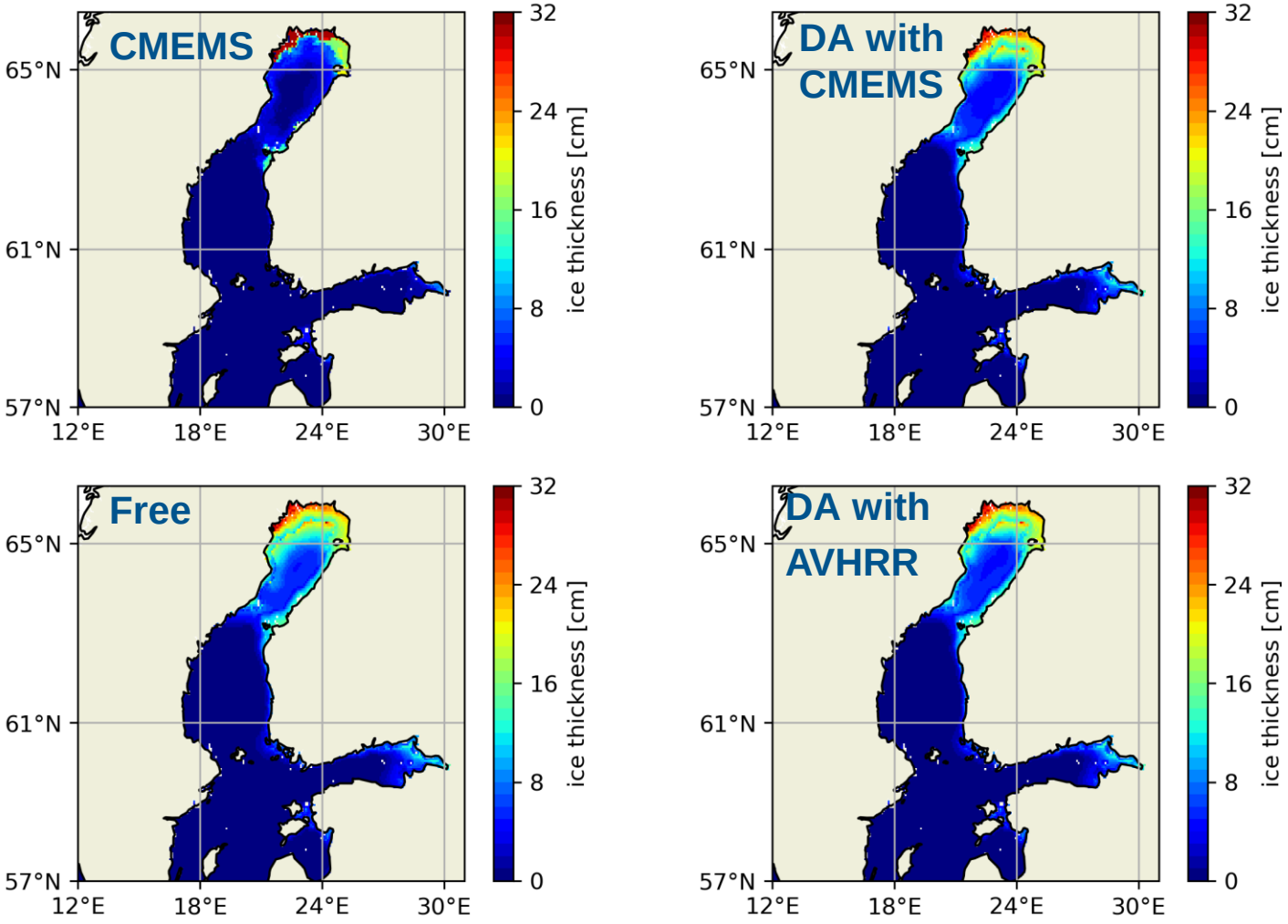


- More than 50% difference of SIC between 2 experiment can be found
- Ice DA has also influences on SST
- Large negative increment in DA run using CMEMS ice chart results in the increment in SST



Impact of DA on sea ice thickness

Monthly averaged (Jan 2018)



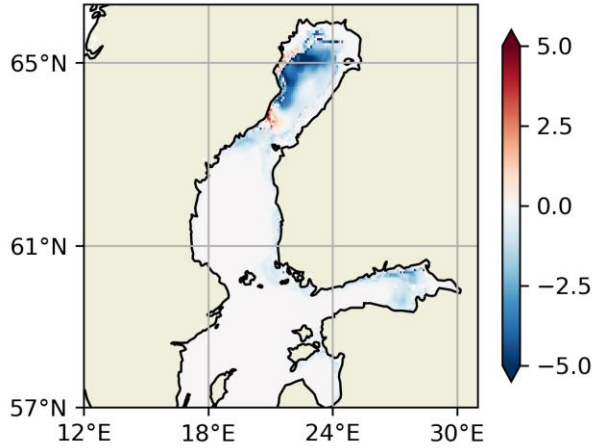
- DA has similar influences on SÍT
- Thickness is reduced in the DA runs, especially in the Gulf of Bothnia and Gulf of Finland

Impact of DA on sea ice thickness

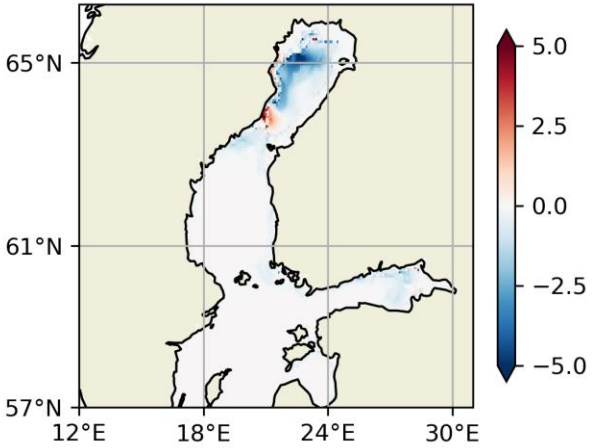
BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

Averaged differences between runs (Jan 2018)

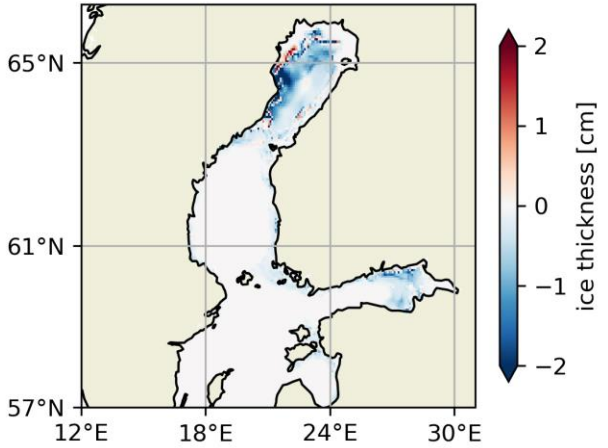
DA with CMEMS - Free



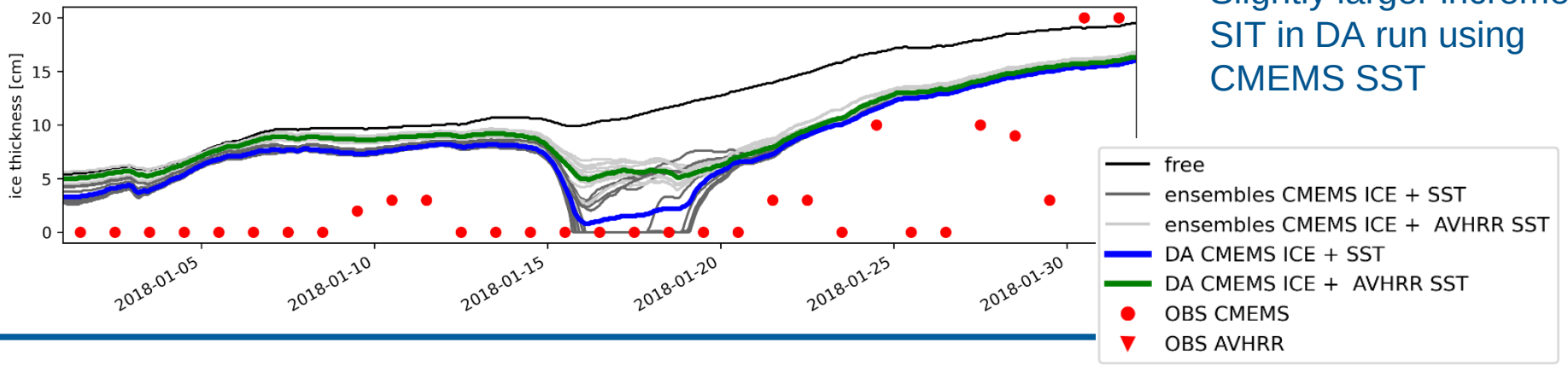
DA with AVHRR - Free



DA with CMEMS – DA with AVHRR



SIT in Jan 2018



- Slightly larger increment of SIT in DA run using CMEMS SST

Conclusion and Outlook

- **HBM model system** assimilates different observations including sea ice chart
- **Two different DA experiments**
  1) Ice DA + SST DA using CMEMS SST
  2) Ice DA + SST DA using AVRHH SST
- Larger differences in ice model between two experiments
- More or less **improvements** are shown in DA experiments
- SST assimilation has **large influences** on ice model
- Ice assimilation has also influences on SST

- **Ensemble perturbations should be large enough. Especially, in the area, where there is large differences between model results and observations.** This should be improved in HBM-PDAF for ice assimilation
- Ice forecasts using DA need both better ice and better SST satellite data

Thank you and Questions?

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE