Monitoring the Arctic with TOPAZ system: status & future perpectives

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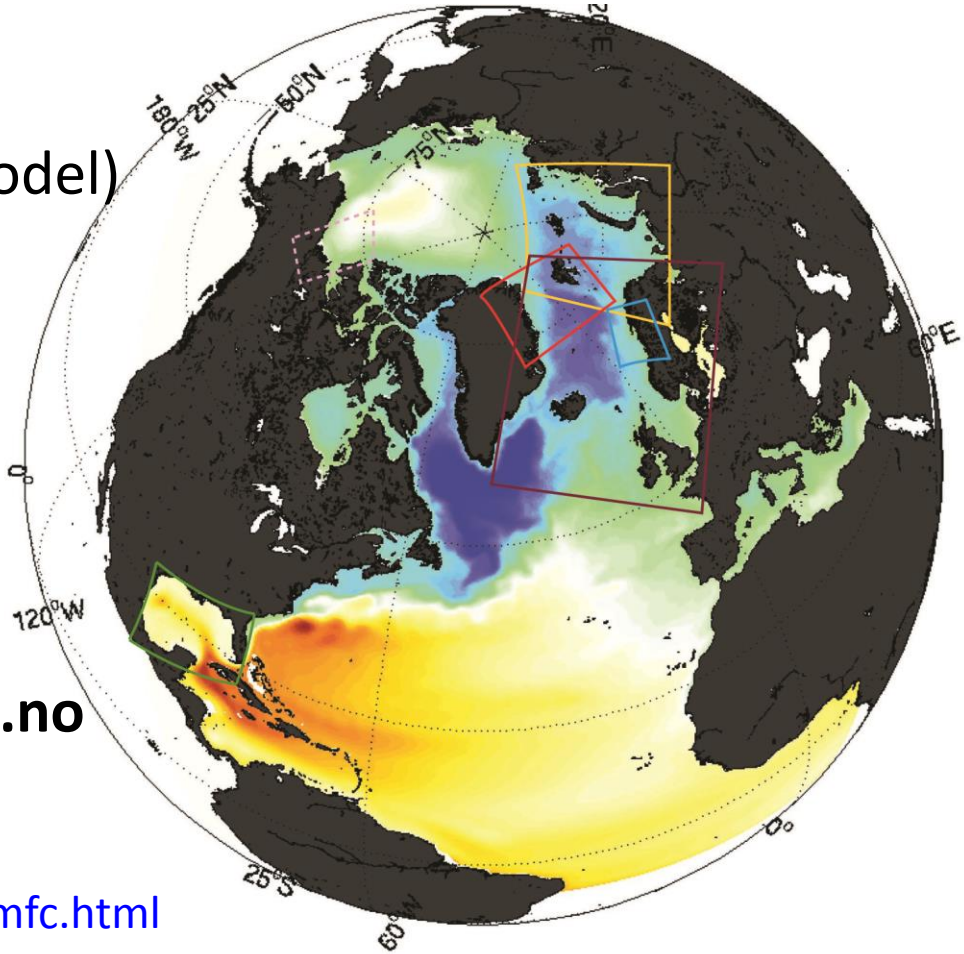
TOPAZ system

TOPAZ system is a forecasting system responsible for Arctic in MyOcean
MyOcean intends to set up a pan-European capacity for ocean monitoring and forecasting
Challenges in the Arctic:

- Mesoscale ~2-4 km (Nested model)
- Few observations
- Non-linearity of ice dynamic

→ Advanced data assimilation



- System is run operationally at **Met.no**
  - 10 day forecast (with ecosystem)
- Reanalysis at NERSC (1990-2010)

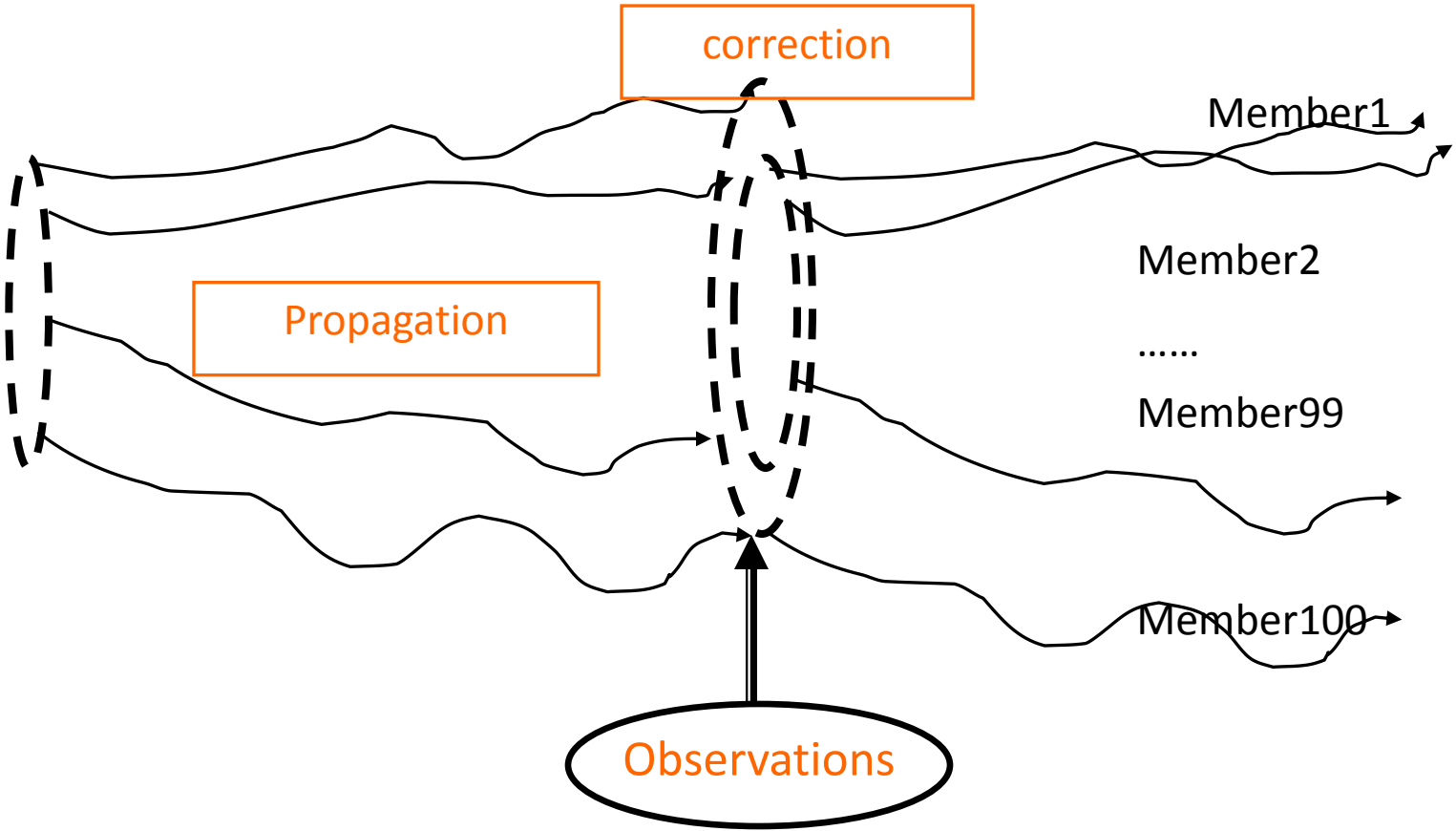
http://thredds.met.no/thredds/myocean/arc_mfc.html

Ensemble Kalman Filter

Statistic method based on ensemble (Monte-Carlo methodology)

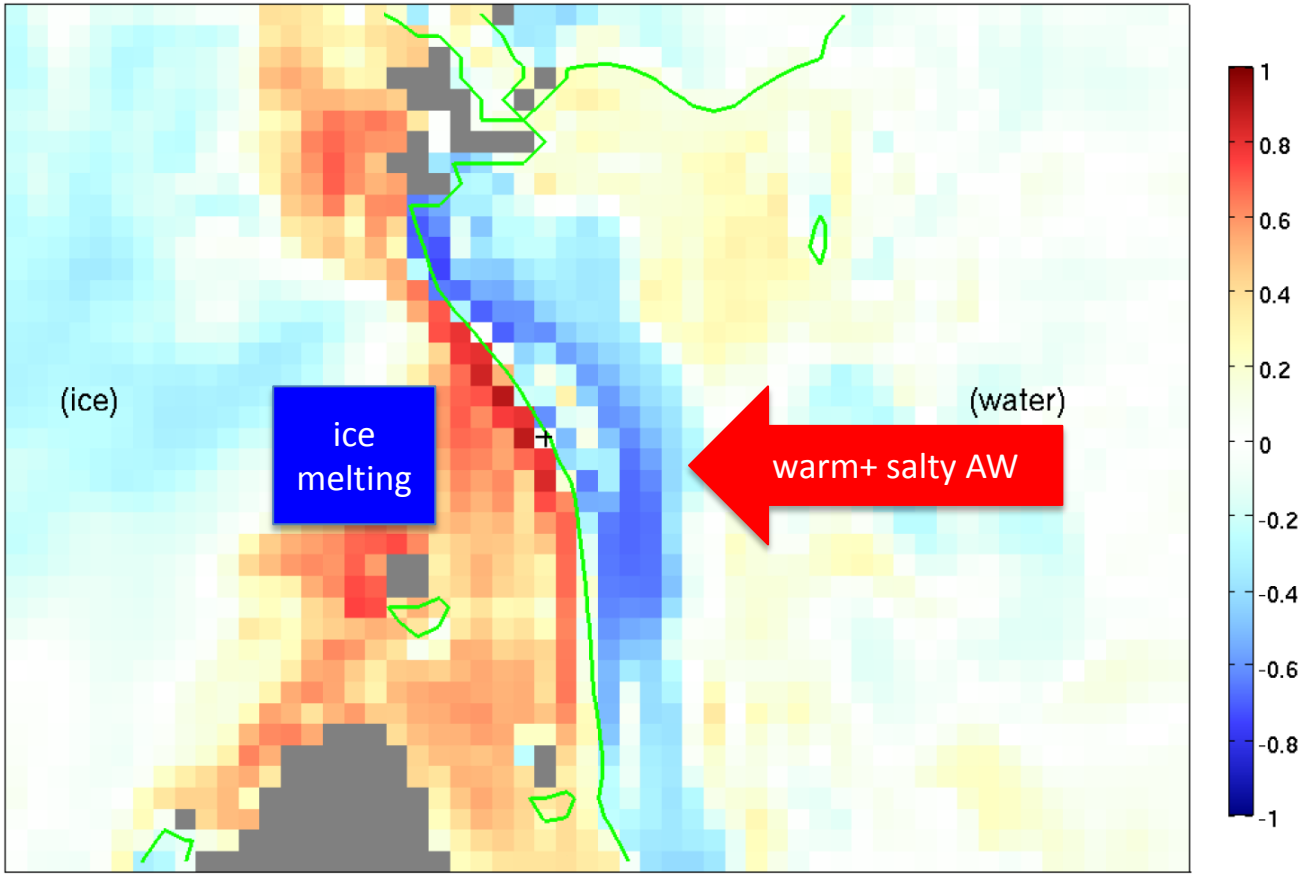
Sequential data assimilation method:

- Propagation step (Ensemble spreads in chaotic region → proxy for error)
- Correction step (Estimate optimal model state from [model, error] [obs, error])



Multivariate flow dependency
Ice concentration/salinity

Can observation of ice concentration be useful to correct salinity ?



Need flow dependencies to obtain meaningful multivariate update

System configuration

MODEL :

- HYCOM 2.2.37 (reanalysis is 2.2.12)
- Real time uses the quick scheme
- KPP (GISS in reanalysis)
- 12-16 km horizontal resolution
- 28 layers
- ECMWF forcing
- Barotropic inflow in Bering Straits
- Rivers discharge (TRIP+ERA-I)
- Single category EVP
- Thermodynamic (*Dange & Simonsen 96)*

Perturbations:

- Atmospheric forcing field with Gaussian Red noise (space and time): taux,tauy, precip, clouds …
- Sea ice model parameter (coeff e in EVP)

ASSIM :

- DEnKF (Square root filter scheme)
- 100 members
- Assimilation window 1 week
- Asynchronous assimilation
- Localization (300 km; tapering with G&C)
- Parameter estimation (SSH, SST)
- Inflation

Observations :

- TSLA
- SST
- Ice concentration
- Profile (ARGO+ITP)
- Ice drift

Realtime Validation

SST

Nowcast

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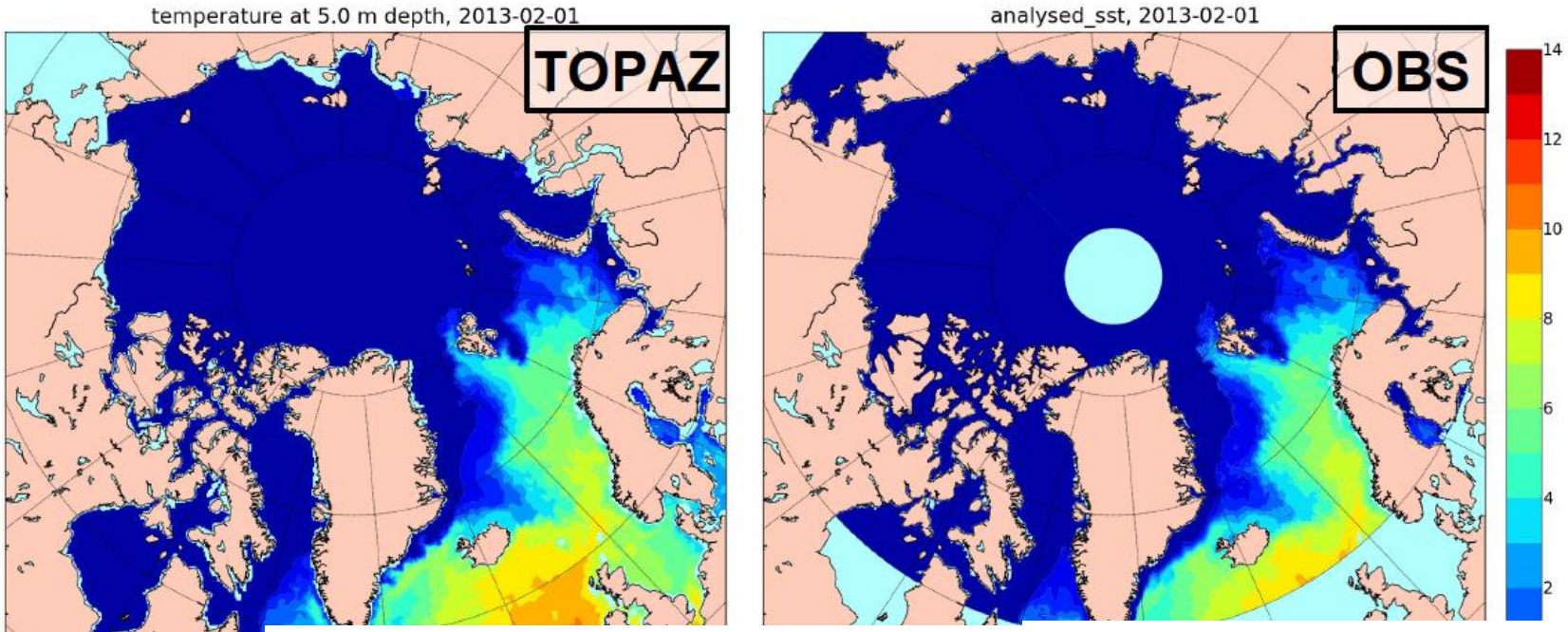

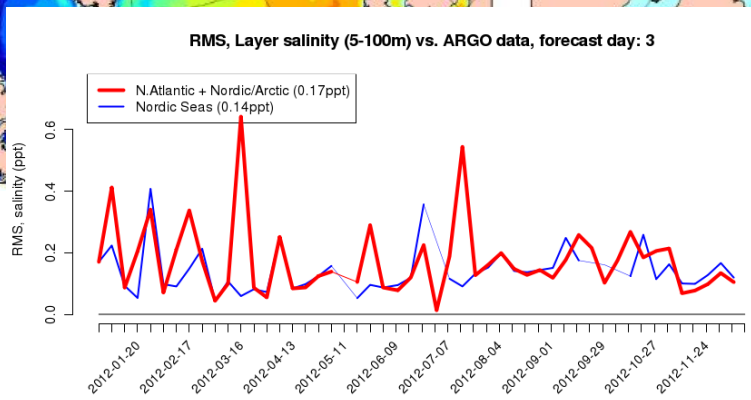

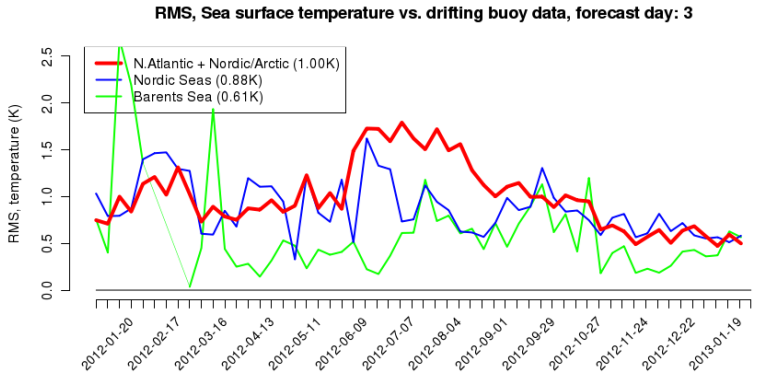

Ice-drift validation

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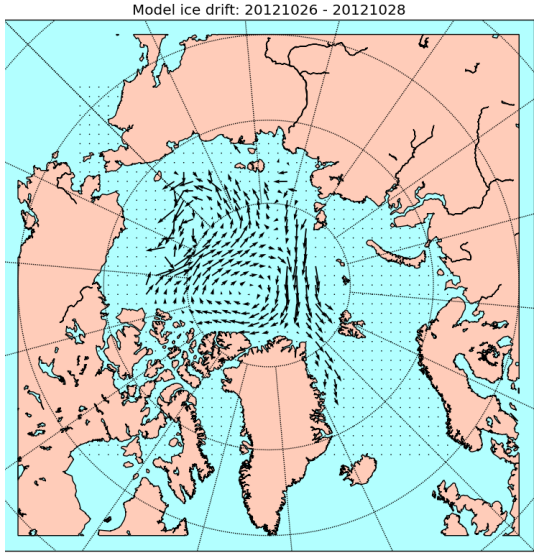
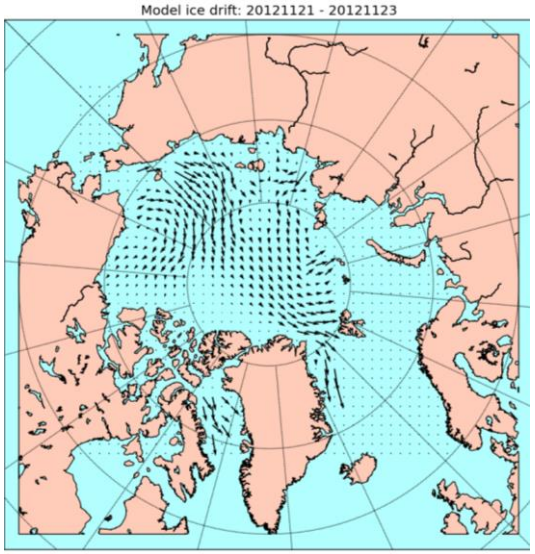
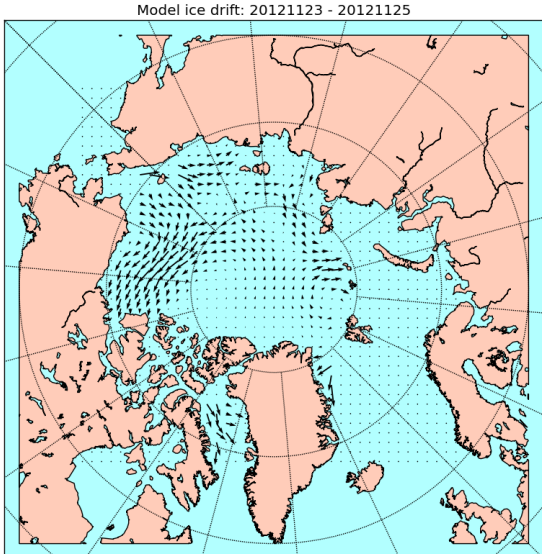
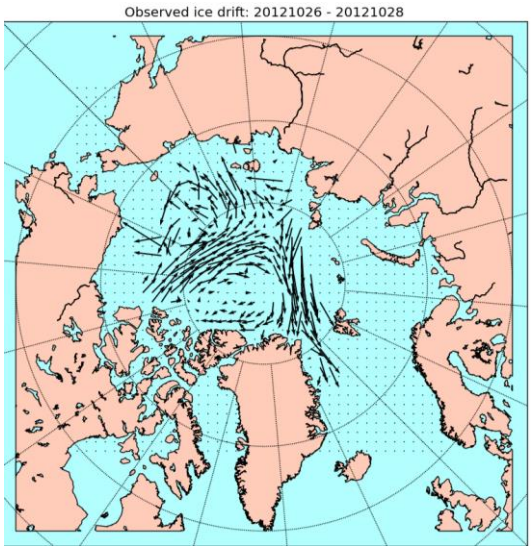
TOPAZ 1-day drift

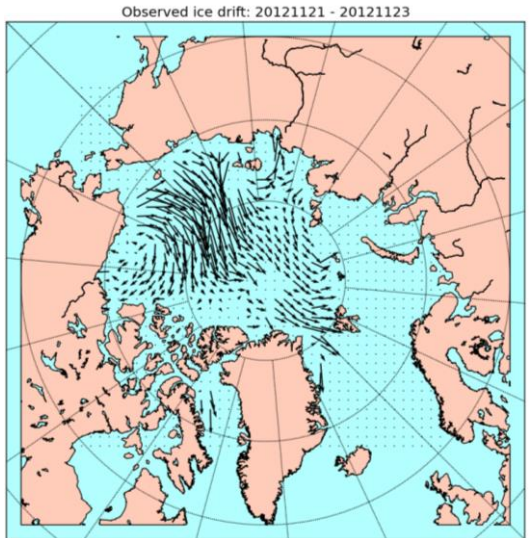


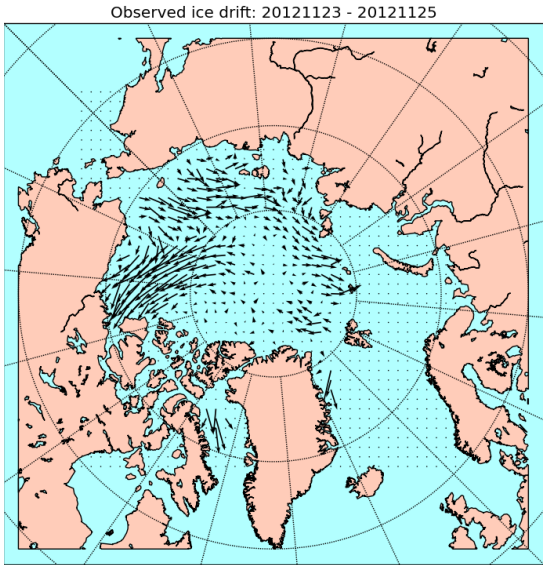




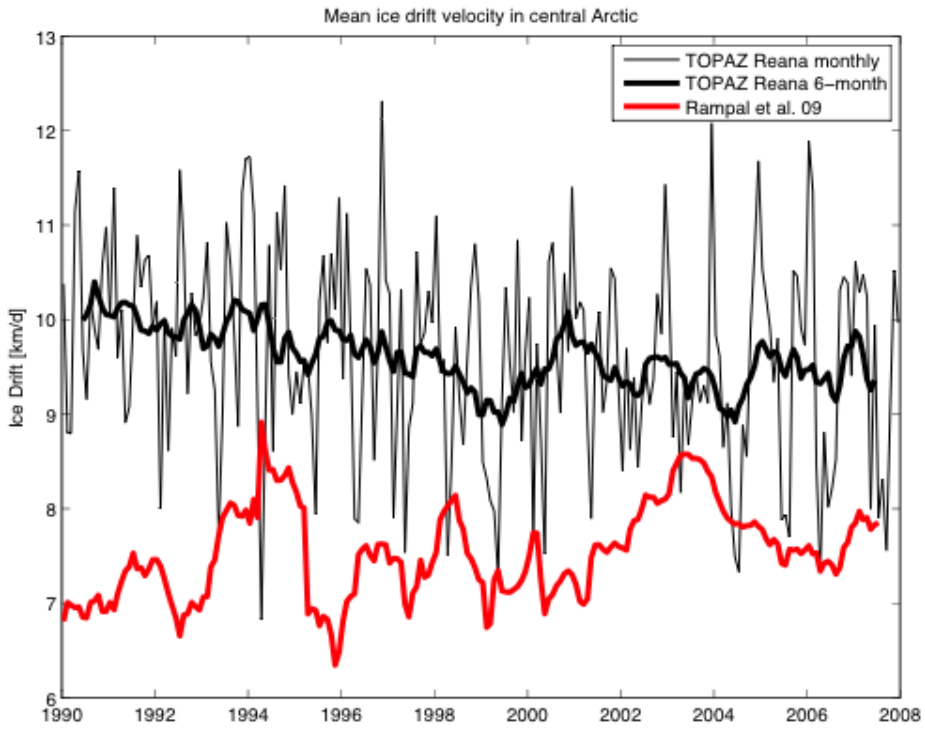
OSISAF 2-day drift

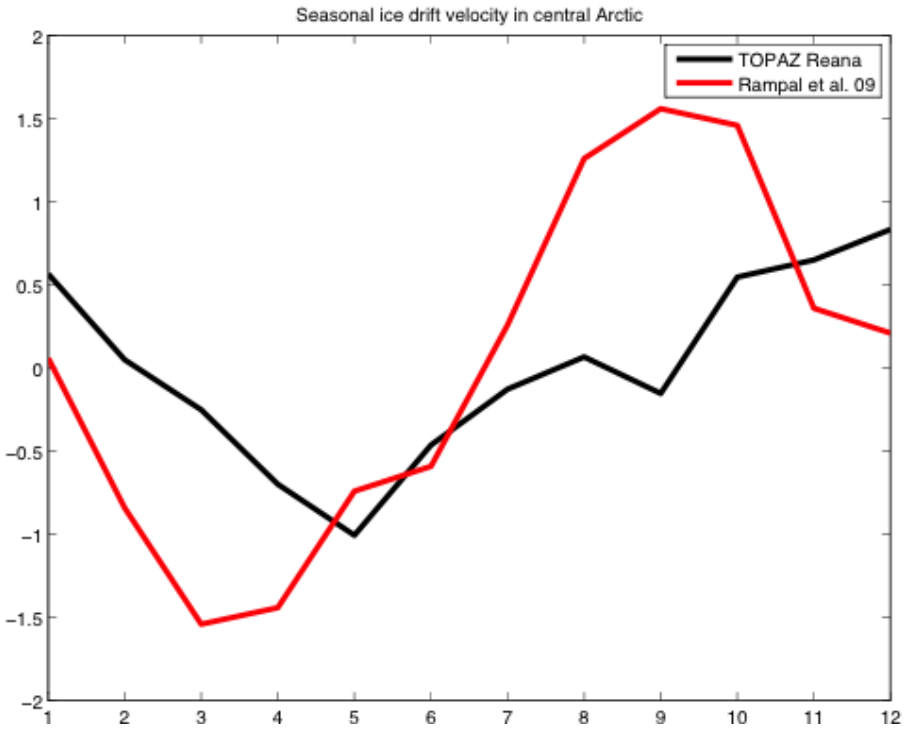






Ice Drift validation



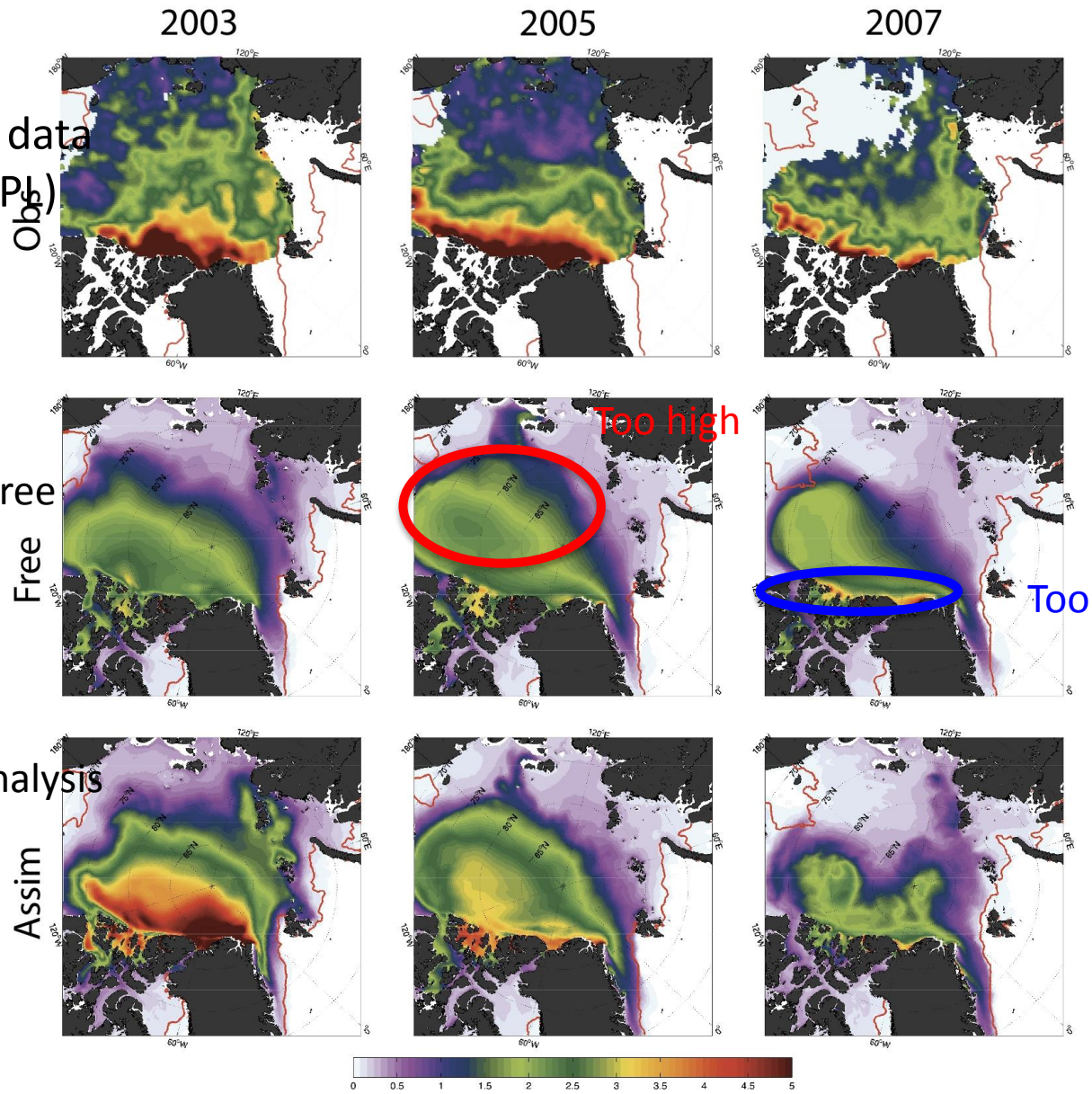


Comparing the ice drift with buoys show that TOPAZ currently overestimate the velocity:

- Model overestimate the drifting speed by ~2km/day (can tune the drag coefficient)
- Trend not represented
- Seasonal signal poorly matching the observation

Common flaws of all VP based model

Not observed: Ice thickness



IceSAT satellite data (Kwok, JPL)

TOPAZ4 free run

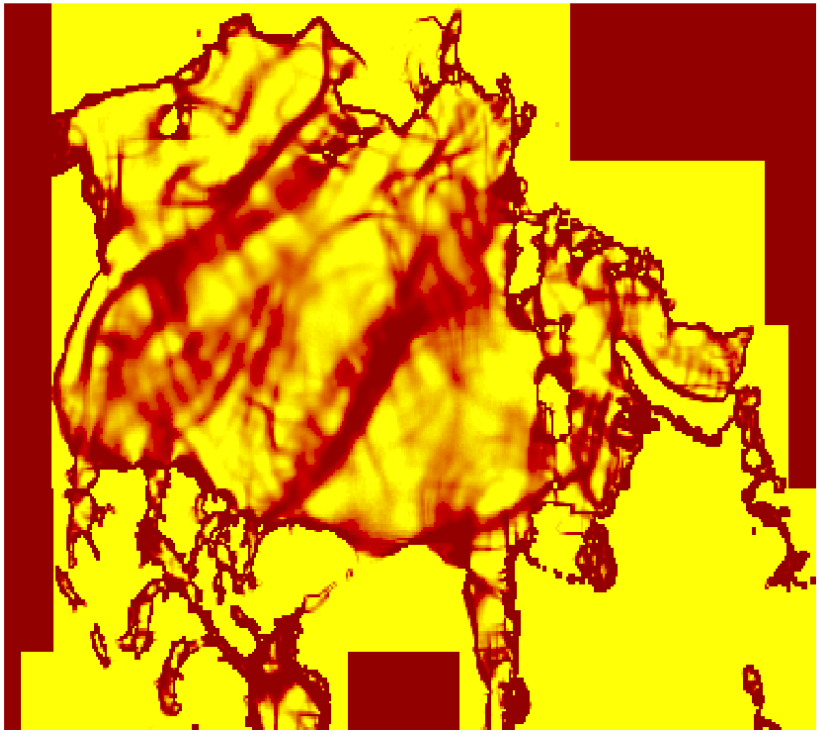
Pilot reanalysis

Again a common flaws to all VP based rheology model

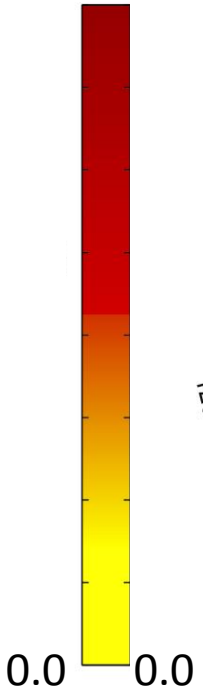
Little improvement by DA

Simulated deformation fields are not similar to observations.

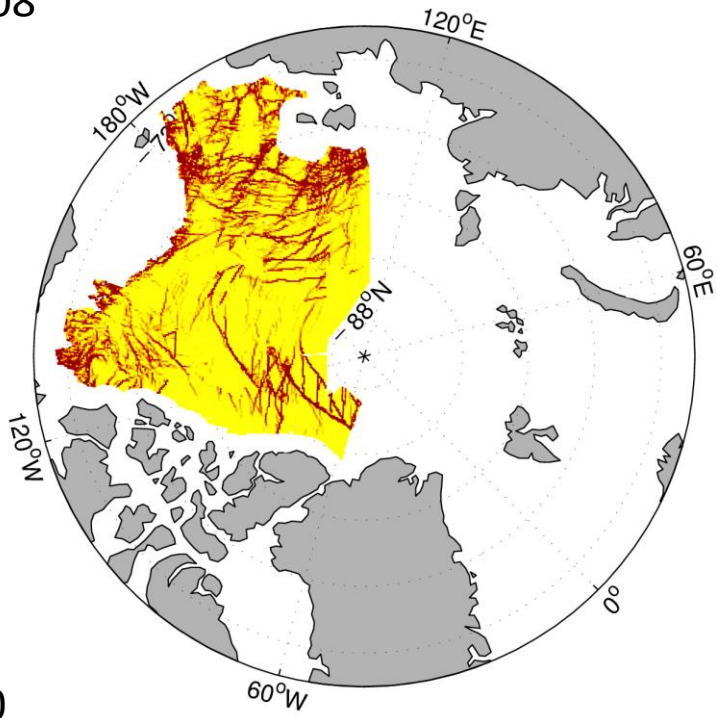
New EVP



Shear rate (day^{-1})

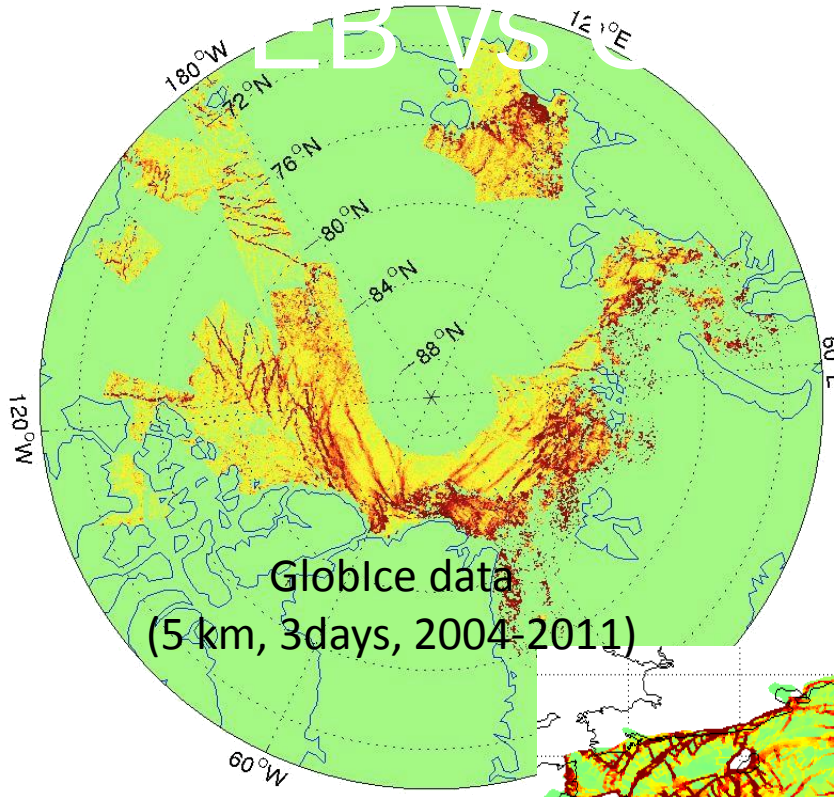


Observations

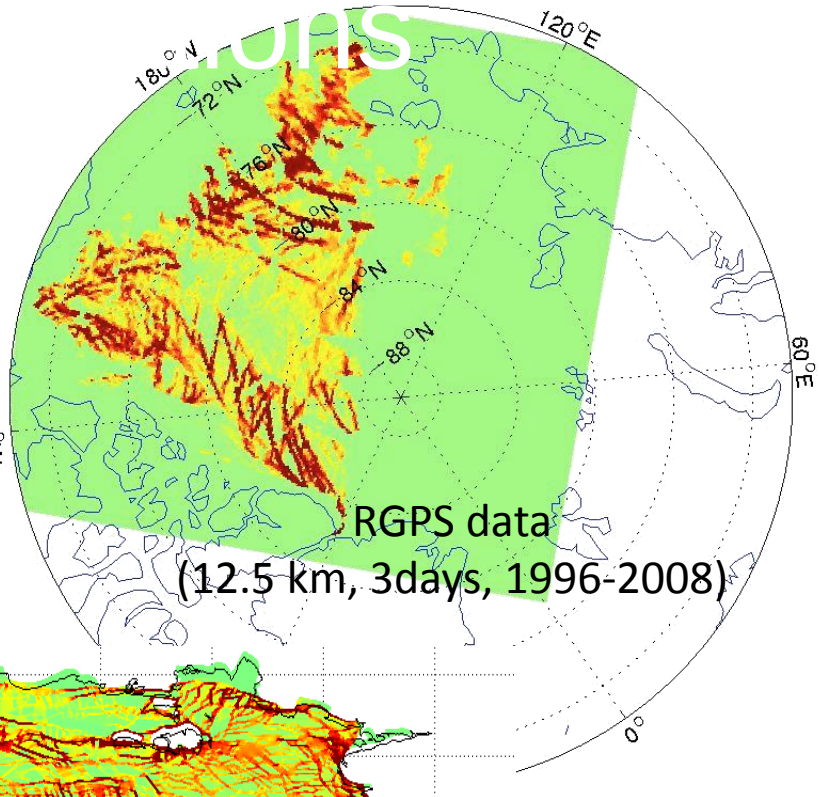


A new rheology is being developed based on the Elasto-Brittle framework (EB)

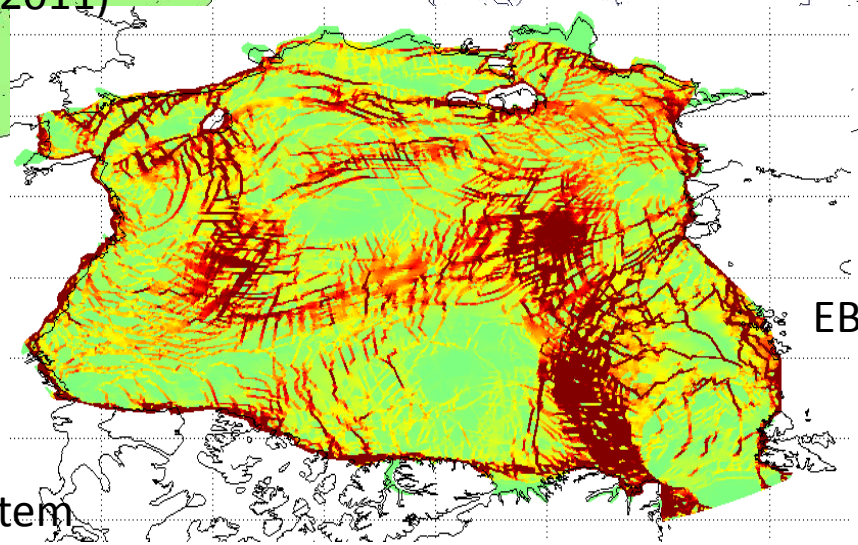
EB vs observations



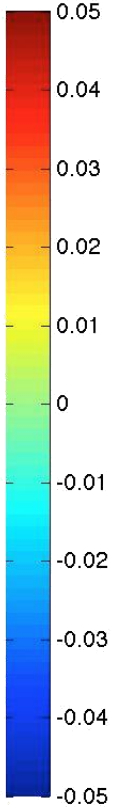
GlobIce data
(5 km, 3days, 2004-2011)



RGPS data
(12.5 km, 3days, 1996-2008)



EB model (preliminary)
(10 km, 3days)



Remaining task:

Implement EB within TOPAZ system

Run long simulation and analyze whether it improves flaws in :

- Ice thickness
- Ice drift (trends+ seasonal signal)

Realtime Validation

ice concentration

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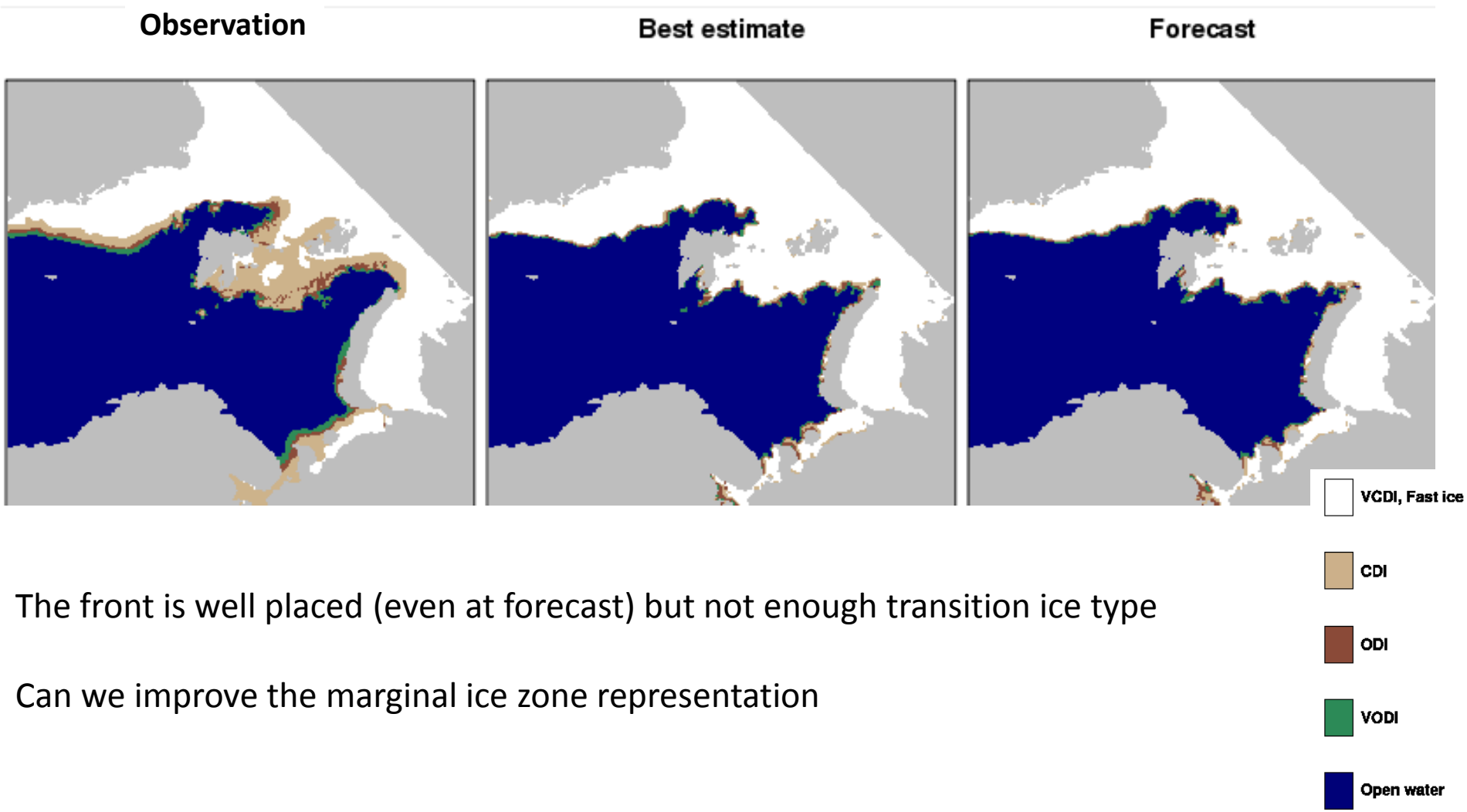
Date: 2013-01-30:



The front is well placed (even at forecast) but not enough transition ice type

Can we improve the marginal ice zone representation

Modeling the Marginal ice Zone

Rheology in the marginal ice zone in different than in the ice pack
A rheology based on random collisions of solid ice floes rheology proposed for the **MIZ (Shen et al. 1986 and 1987)**

How to estimate the transition between EVP and MIZ:

- Based on ice concentration + ice thickness

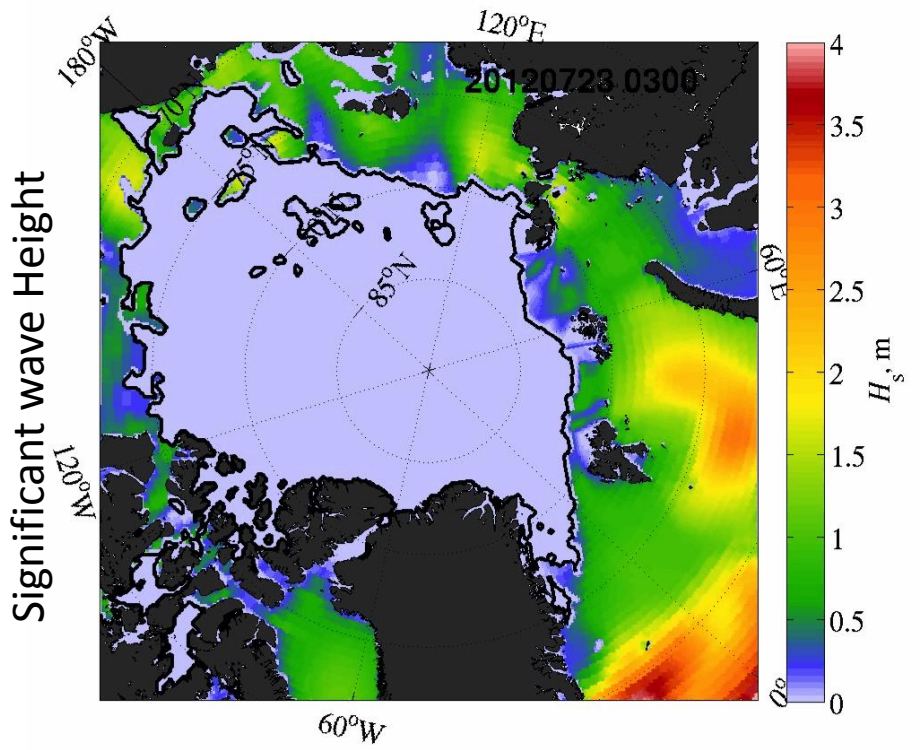
→Not optimal because the rheology should change with the floe size

A criteria based on the floe size is used to transit from EVP to MIZ

- Dumont et al. 2011 estimated the floe size in a 1D case using wave field
  - Provides realistic MIZ width
  - Updated by Williams et al (Part 1 & 2, submitted): improved breaking criteria based on wave statistics
- Williams et al. (2012) initialize wave from WW3 (IFREMER) at the model boundary. Waves are advected into HYCOM, attenuate under sea ice (with fice and hice) and change the floe size

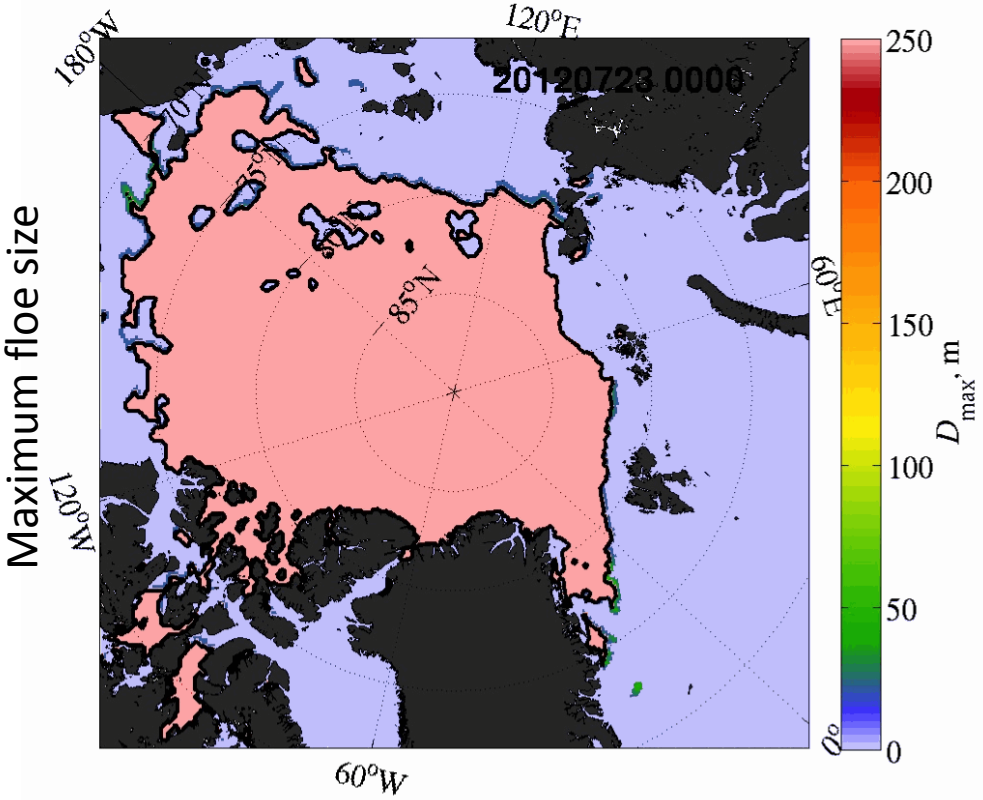
Example into TOPAZ free run summer 2012

Significant wave Height



➔Propagate and attenuate (2D) under sea ice and break the floes

Maximum floe size



➔Estimate boundary between the two rheologies

Marginal ice zone
Further development

Impact in ice concentration ➔ seems tiny

How can we better use info about MIZ:

- Improved thermodynamic (lateral melting, *Steele 2005*)
- Different drag coefficient (currently cte; *Lupkes and Birnbaum 2005*)
- Increase ocean mixing from wave dissipation

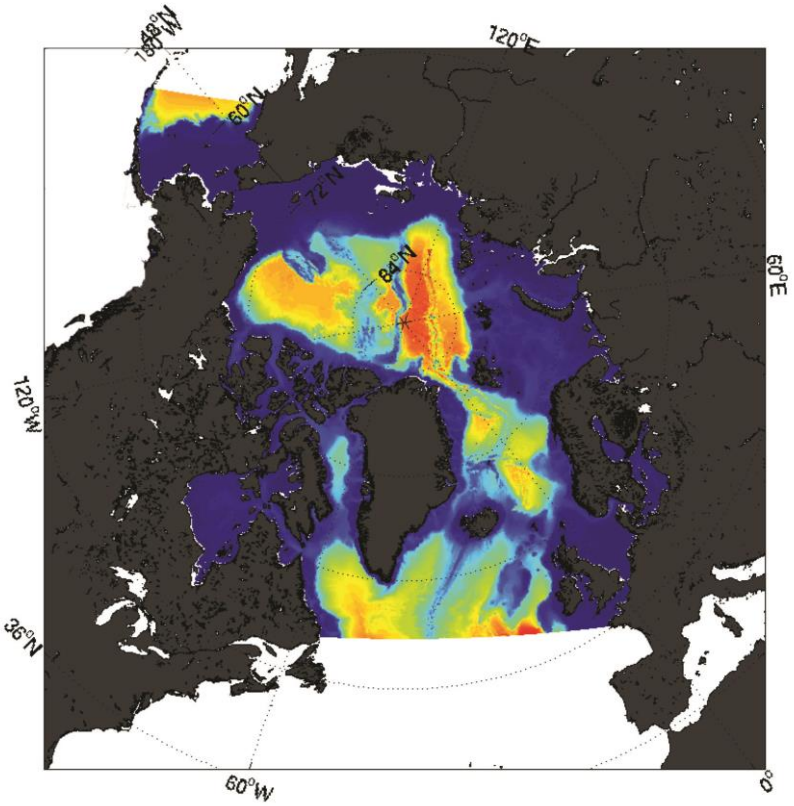
What is next to do :

- Implement a healing of floes
- (Making the implementation faster)

TOPAZ 5
new system at work

- Reduce the model domain
- Nesting taken from either:
  - MyOCEAN (Mercator, FOAM)
  - TOPAZ4
  - HYCOM global ?

- Resolution of 5-7 km ?
- Increase the number of layer to 36 ?
- Improved bathy; combined IBCAO v3.0 & GEBCO1'
- WOA2009 climatology (initialization, SSS relax)
- HYCOM version (depending on the release)
- Ice model:
  - multicategory
  - If ready (transition from VP -> EB)



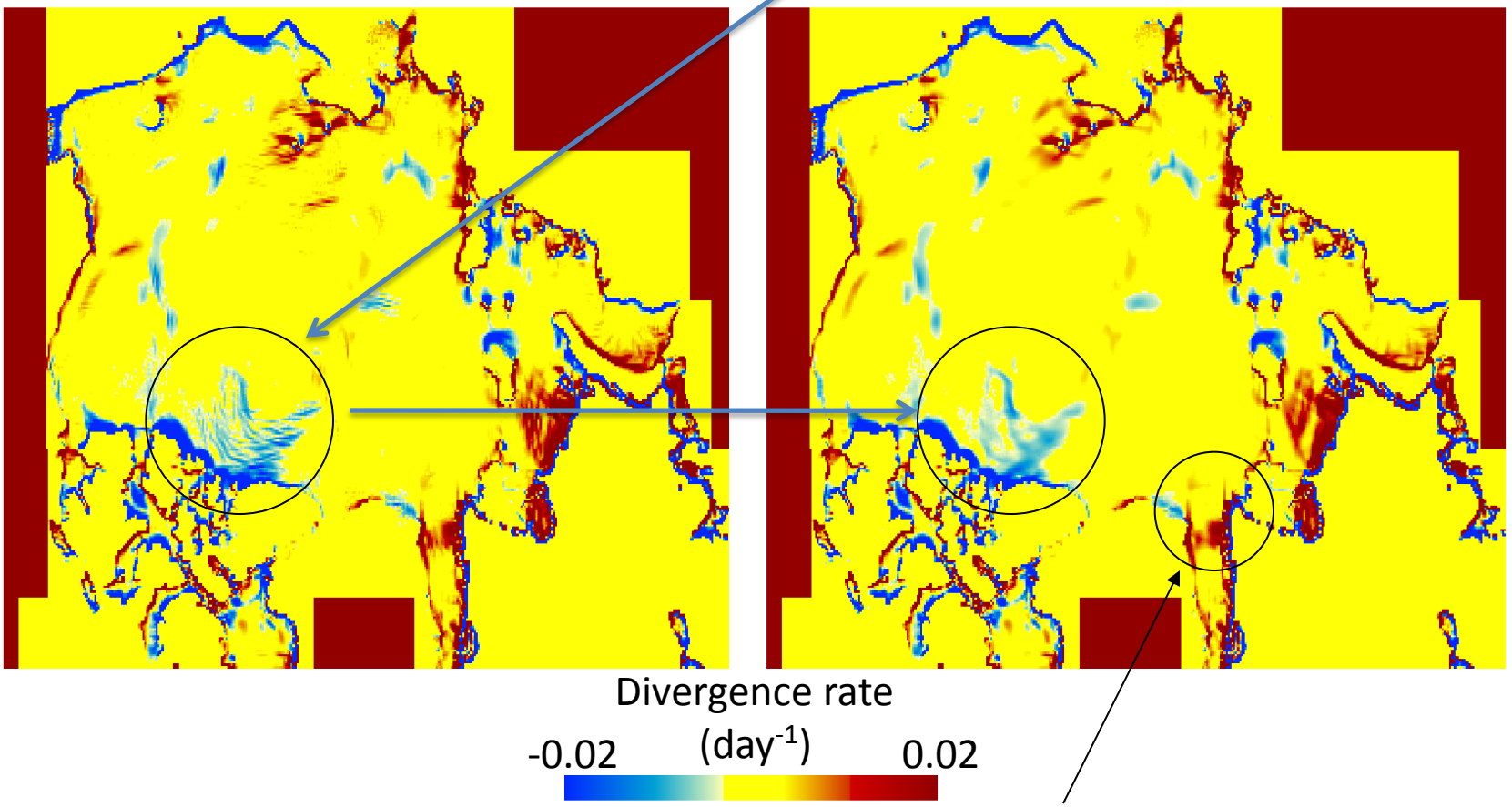
Looking for a ocean modeler that could help with this development (laurent.bertino@nersc.no)

Sylvain Bouillon has identified a numerical bug in all EVP formulation

Old EVP

The correction removes **artificial deformation stripes.**

New EVP



Questions: Remaining deformation bands aligned with the grid?
How to improve the numerical convergence of the EVP method?