Performance of a 23 years TOPAZ reanalysis

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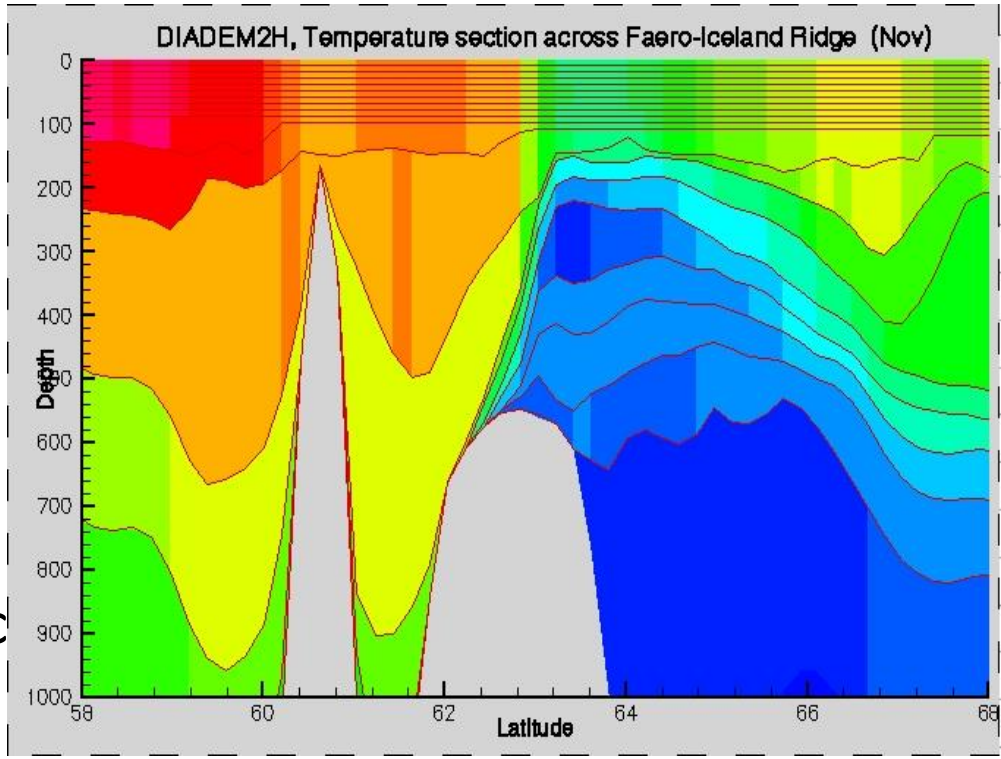
Outline

- Presentation of the TOPAZ4 system
  - Choice of modeling and assimilation tools
- The 23-years physical reanalysis
  - “Good health” of an Ensemble Kalman Filter
  - Ocean variables
  - Sea ice variables
- Plans for TOPAZ5 /perspectives

The HYCOM model at NERSC

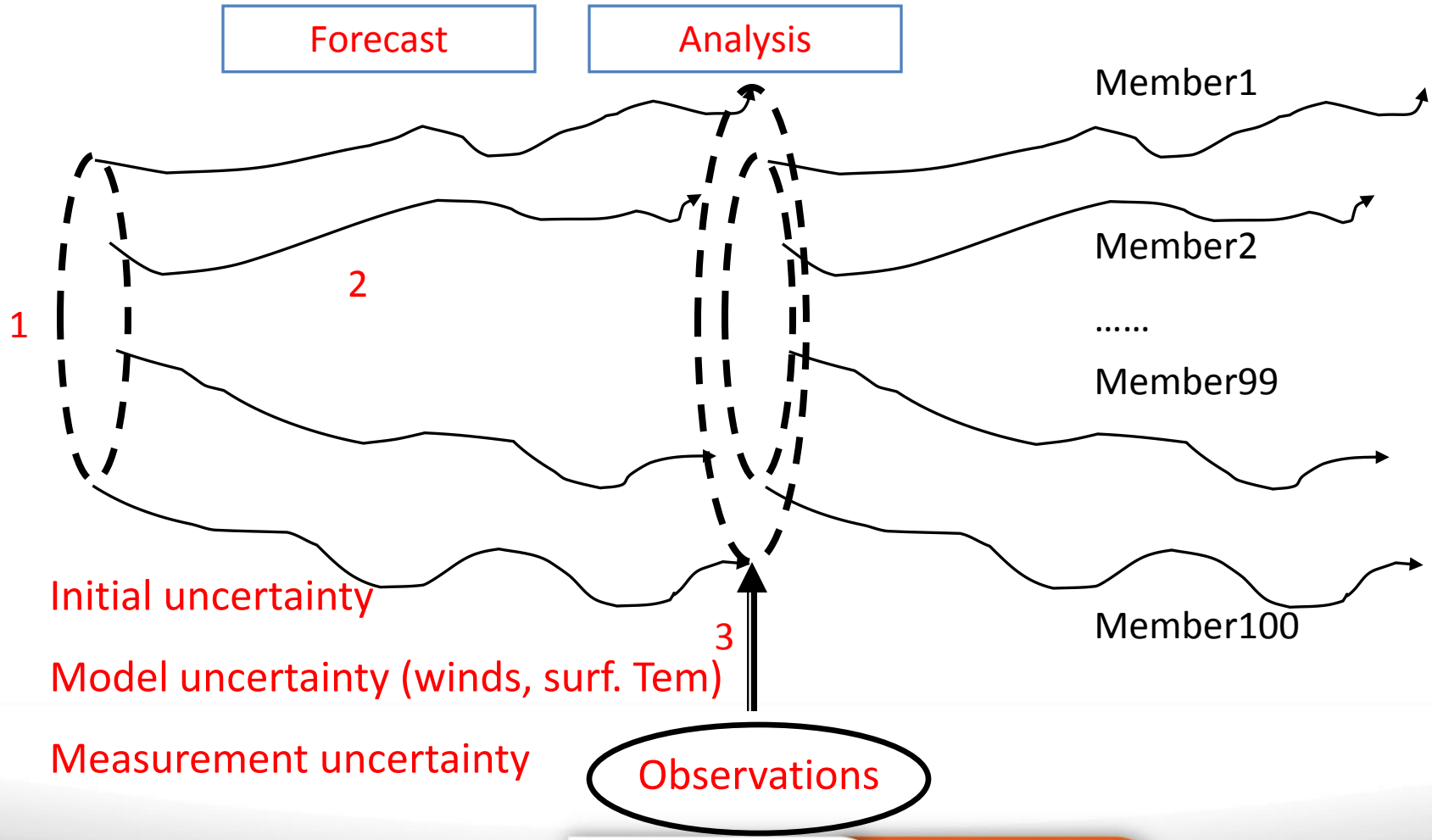
- 3D numerical ocean model
  - Hybrid Coordinate Ocean model, HYCOM (U. Miami)
  - Horizontal resolution 12 km
    - Conformal mapping: uniform
- Hybrid vertical coordinate
  - Isopycnal in the interior
  - Z-coordinate at the surface
  - No sigma layers
  - TOPAZ4 uses 28 layers
- Hybrid coordinates in the Arctic
  - Sharp pycnocline
  - Less spurious diapycnal mixing (critical at high model resolution)



Local HYCOM settings

- 4th Order scheme, momentum advection
  - Used in near real time, but not in this reanalysis
- Sea ice coupled with HYCOM
  - CICE V3, NERSC thermo
  - No coupler, same code
- Still using sigma-0
- Rivers using ERA-Interim + TRIP
- No SSS relaxation if Delta S > 0.5 psu

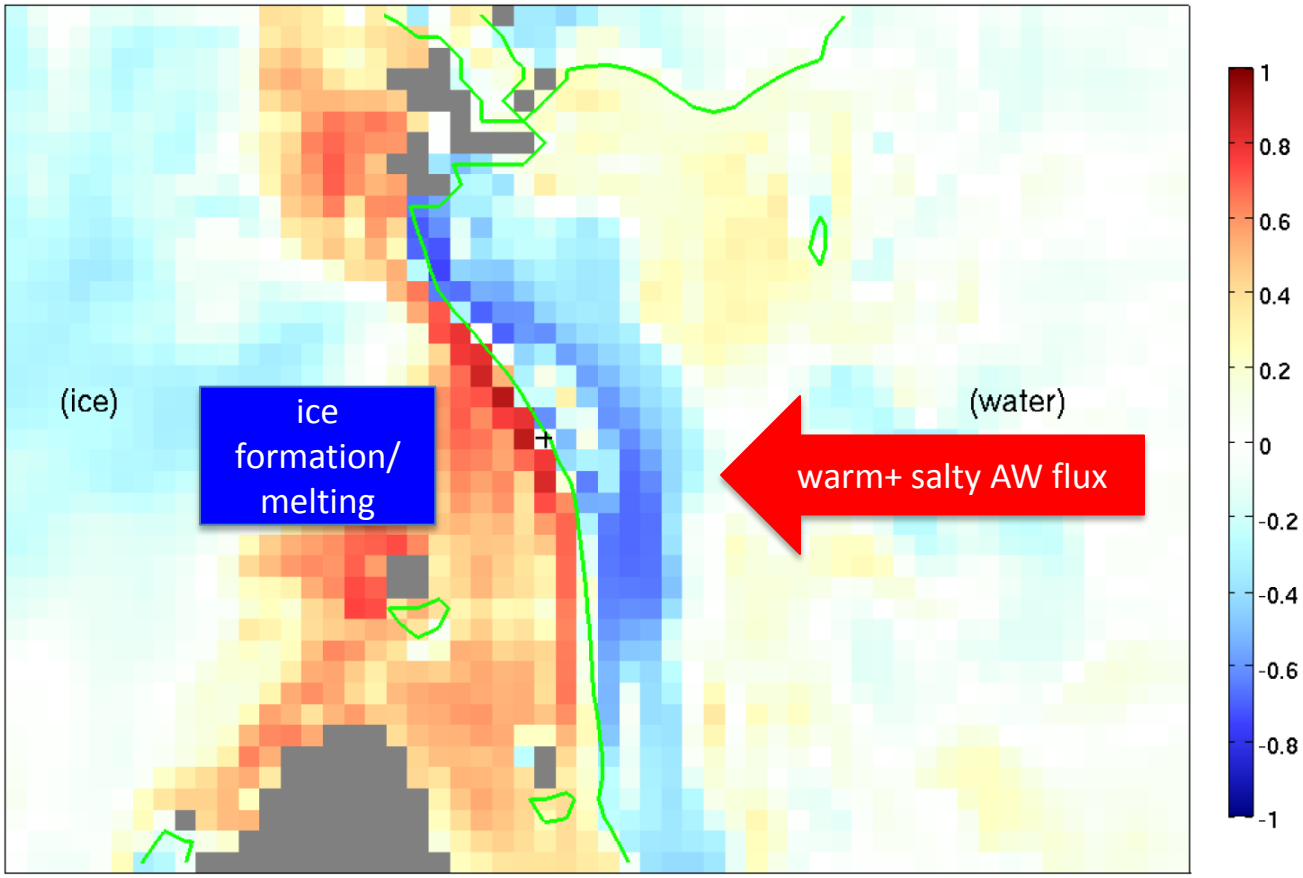
Ensemble Kalman filtering



1. Initial uncertainty
2. Model uncertainty (winds, surf. Tem)
3. Measurement uncertainty

Why dynamic Data Assimilation in the Arctic?

Example of ice-salinity correlations in the Barents Sea

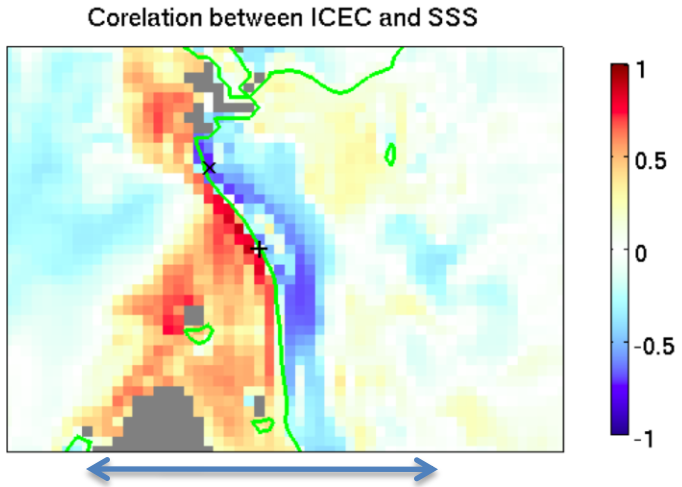


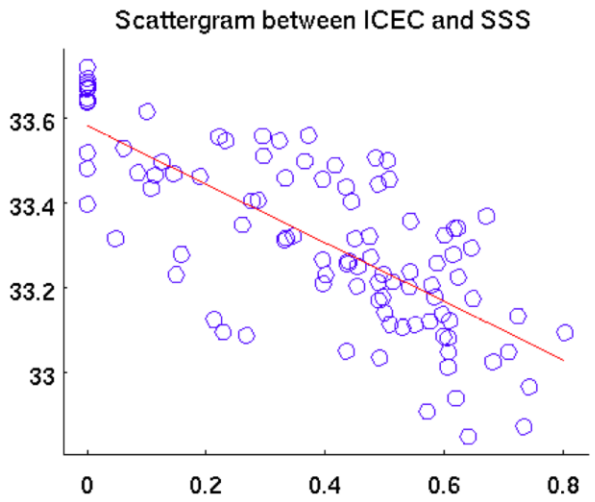
Sakov et al., the TOPAZ4 system, OS 2012

Also see *Lisæter et al.* Oc. Dyn. 2003

Comparison of dynamical to static / climatological covariances

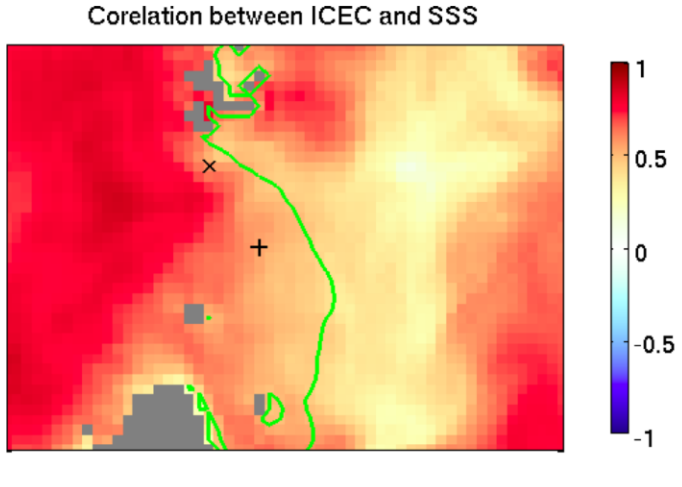
Dynamic ensemble

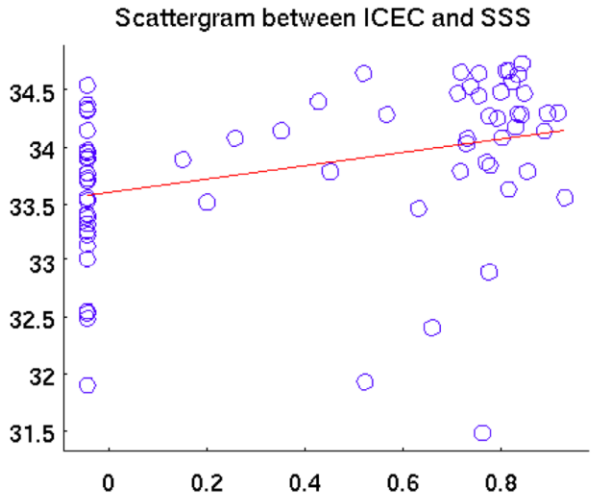




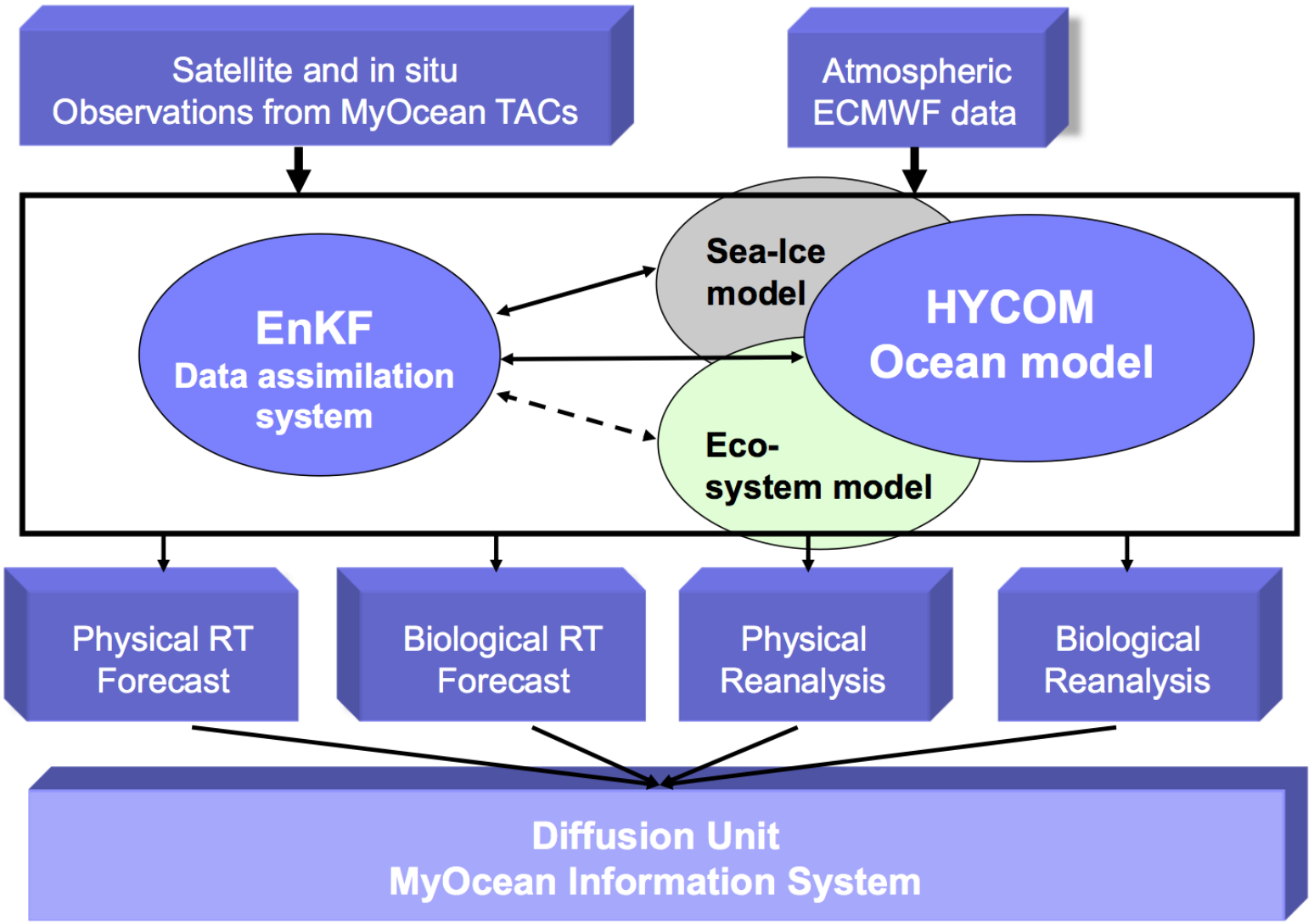
Mobile ice edge = mobile covariances

Static ensemble



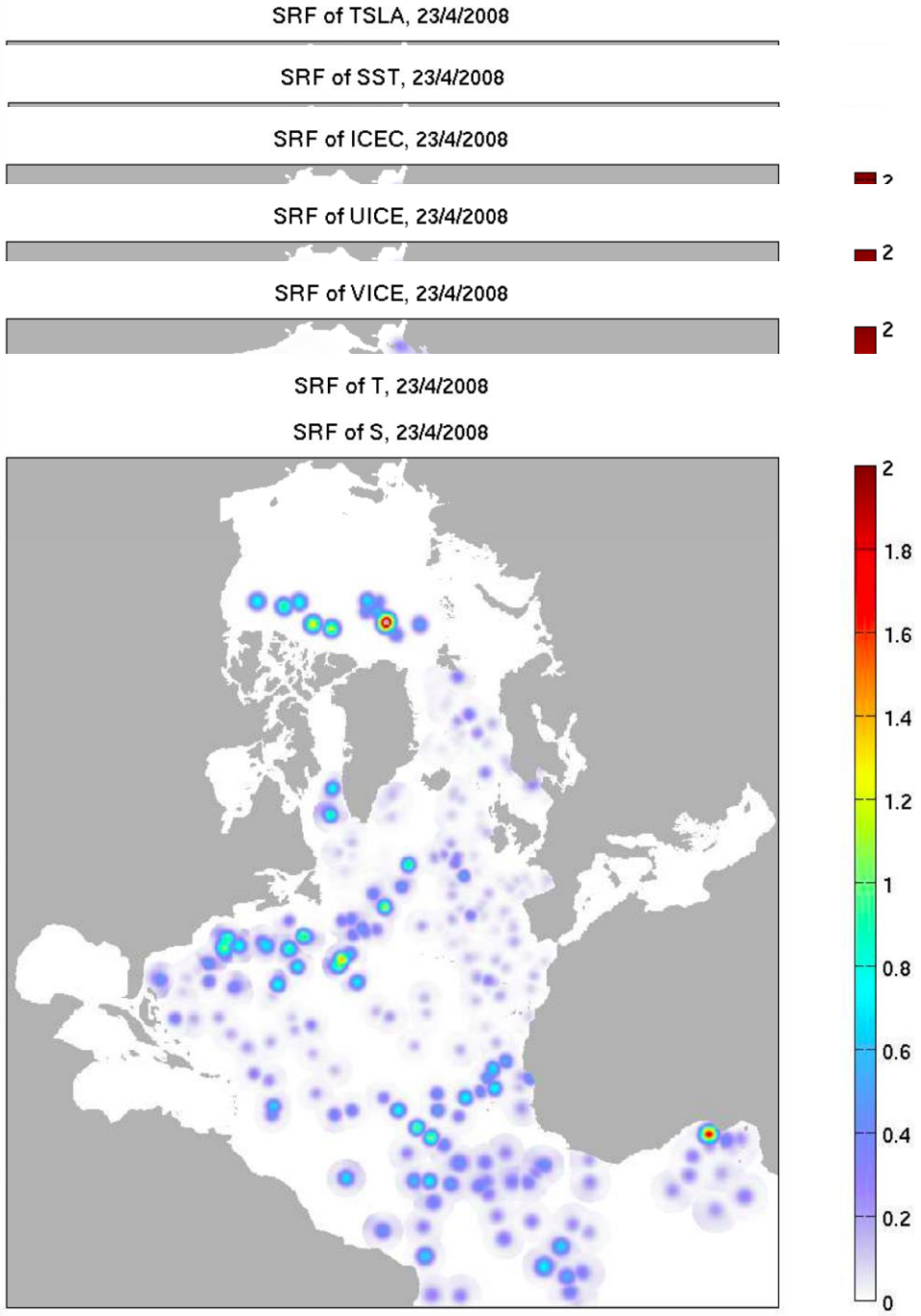


The TOPAZ system at a glance



Assimilation

- DEnKF, asynchronous
  - 100 members
  - Local analysis (~90 km radius)
  - Ensemble inflation by 1%
- Observations:
  - Sea Level Anomalies (CLS)
  - SST (NOAA, then UK Met)
  - Sea Ice Concentr. (OSI-SAF)
  - Sea ice drift (CERSAT)
  - T/S profiles (Coriolis, IPY)
  - **400.000 observations** per week
  - ~100 in each local radius

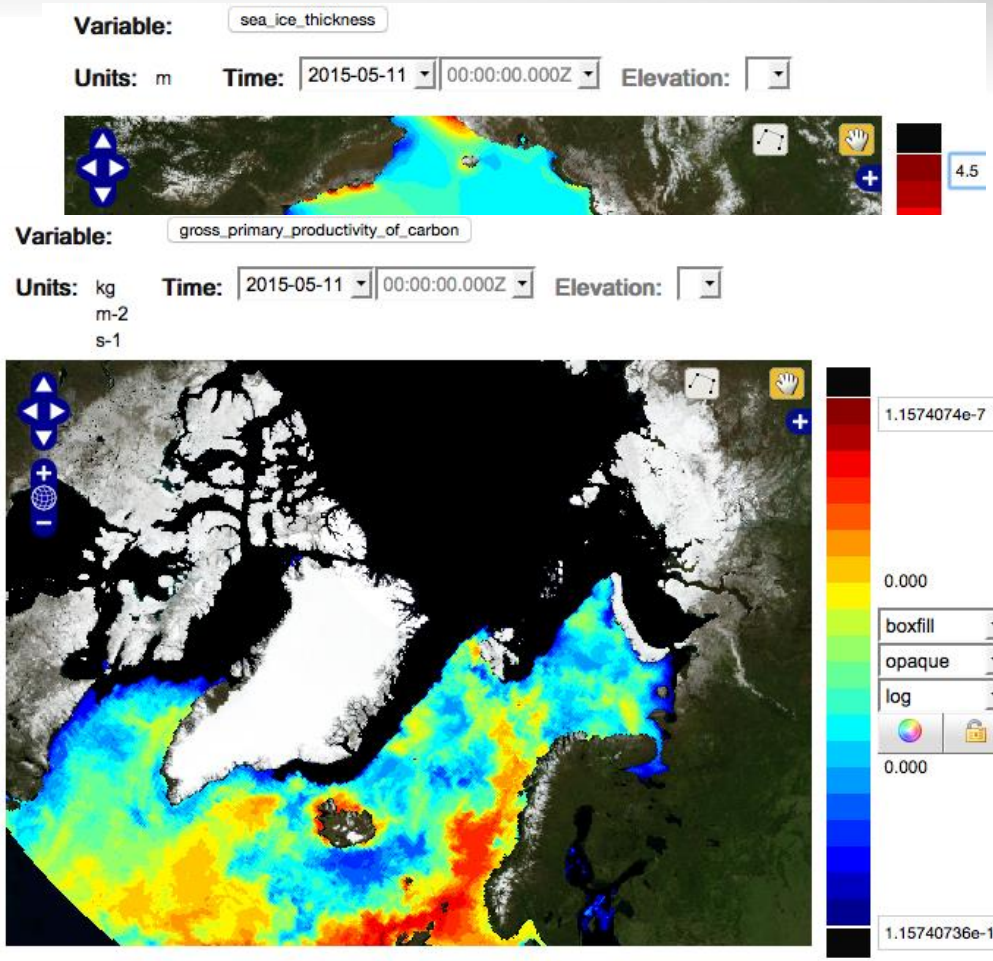


SRF: local spread reduction factor

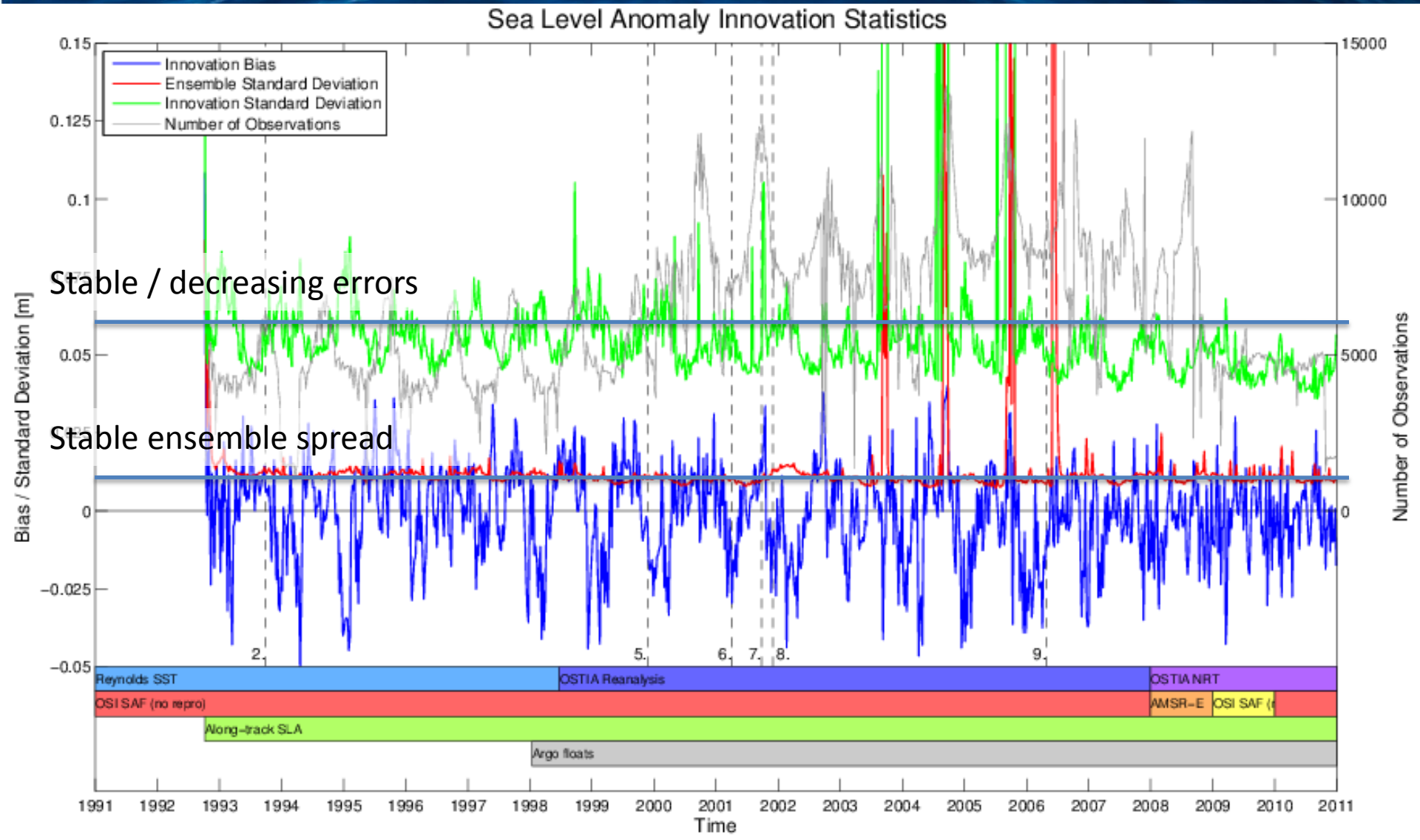
$$\mathrm{SRF} = \sqrt{\frac{\mathrm{tr}(\mathbf{H}\mathbf{P}^{f}\mathbf{H}^{\mathrm{T}}\mathbf{R}^{-1})}{\mathrm{tr}(\mathbf{H}\mathbf{P}^{a}\mathbf{H}^{\mathrm{T}}\mathbf{R}^{-1})}} - 1$$

The TOPAZ system again

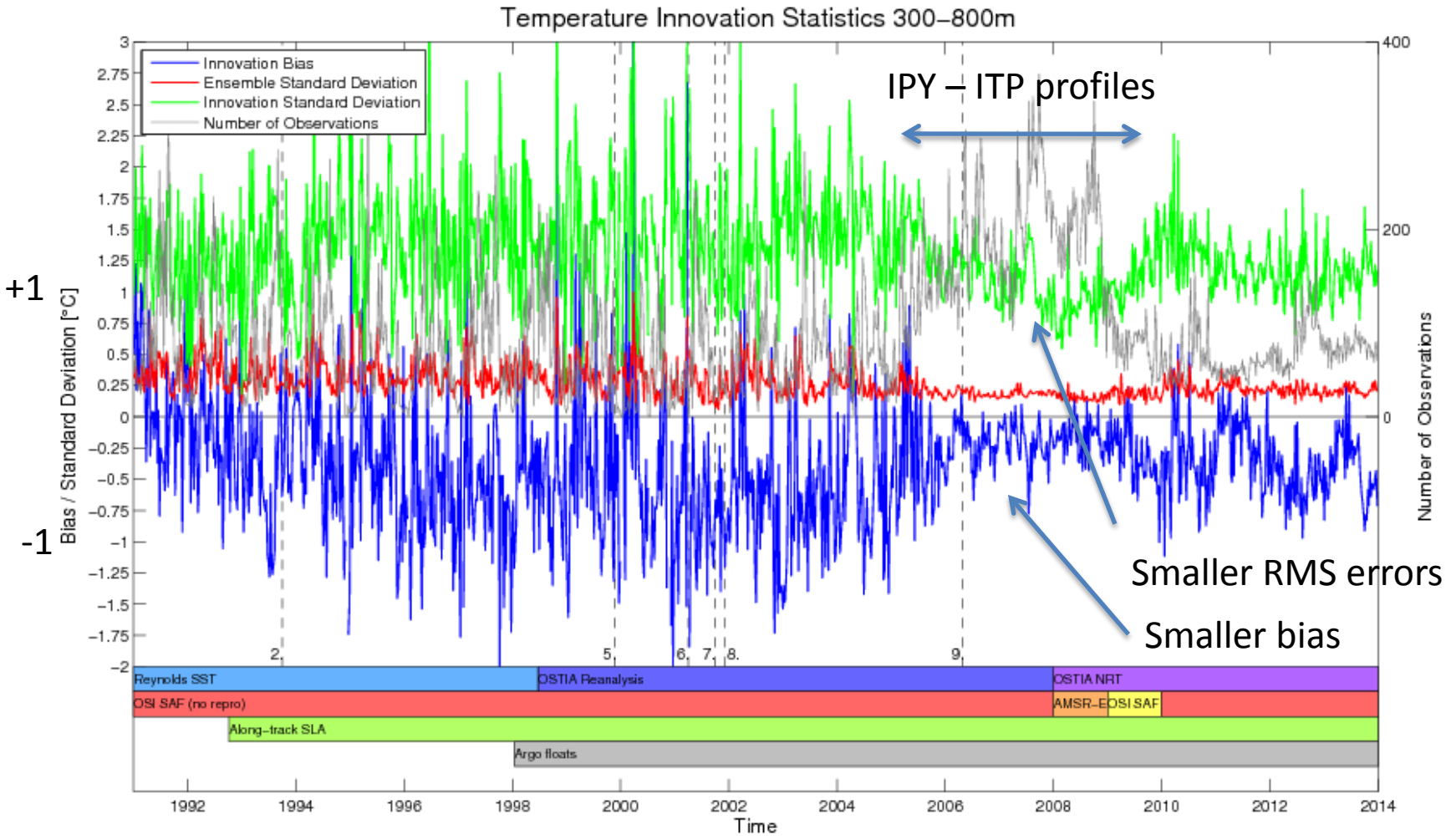
- Exploited operationally at MET Norway
  - Since 2008
  - Ecosystem coupled online
- 20 years reanalysis at NERSC
  - Took 2 years to produce
- 3-years ecosystem reanalysis
  - Assimilation of both physical and ocean colour data
- MyOcean/Copernicus
  - Arctic MFC
  - Free distribution of data
- RT Data used by ECMWF wave forecast model
  - Surface currents



Data assimilation statistics SLA

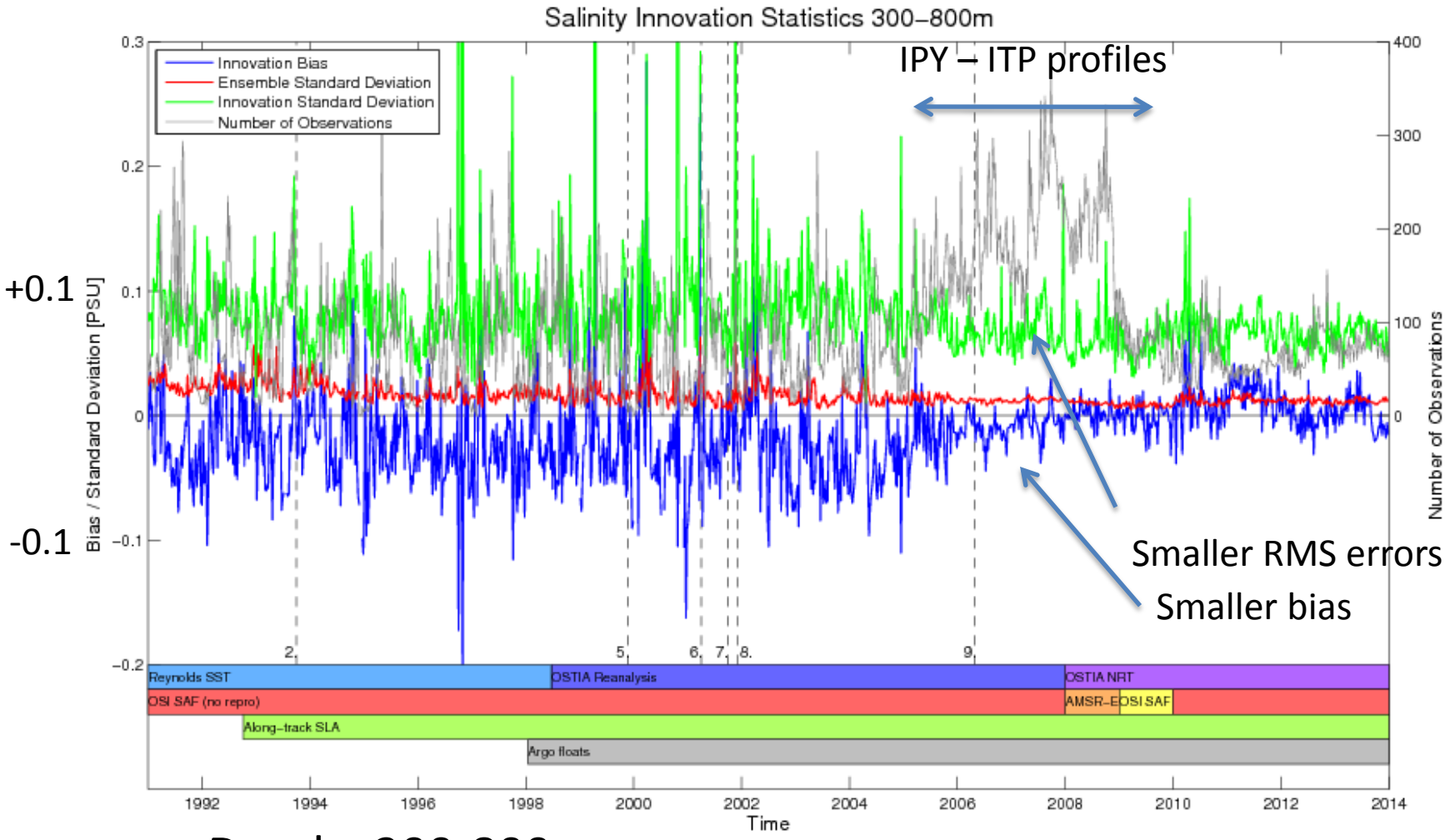


In situ TEM innovation statistics



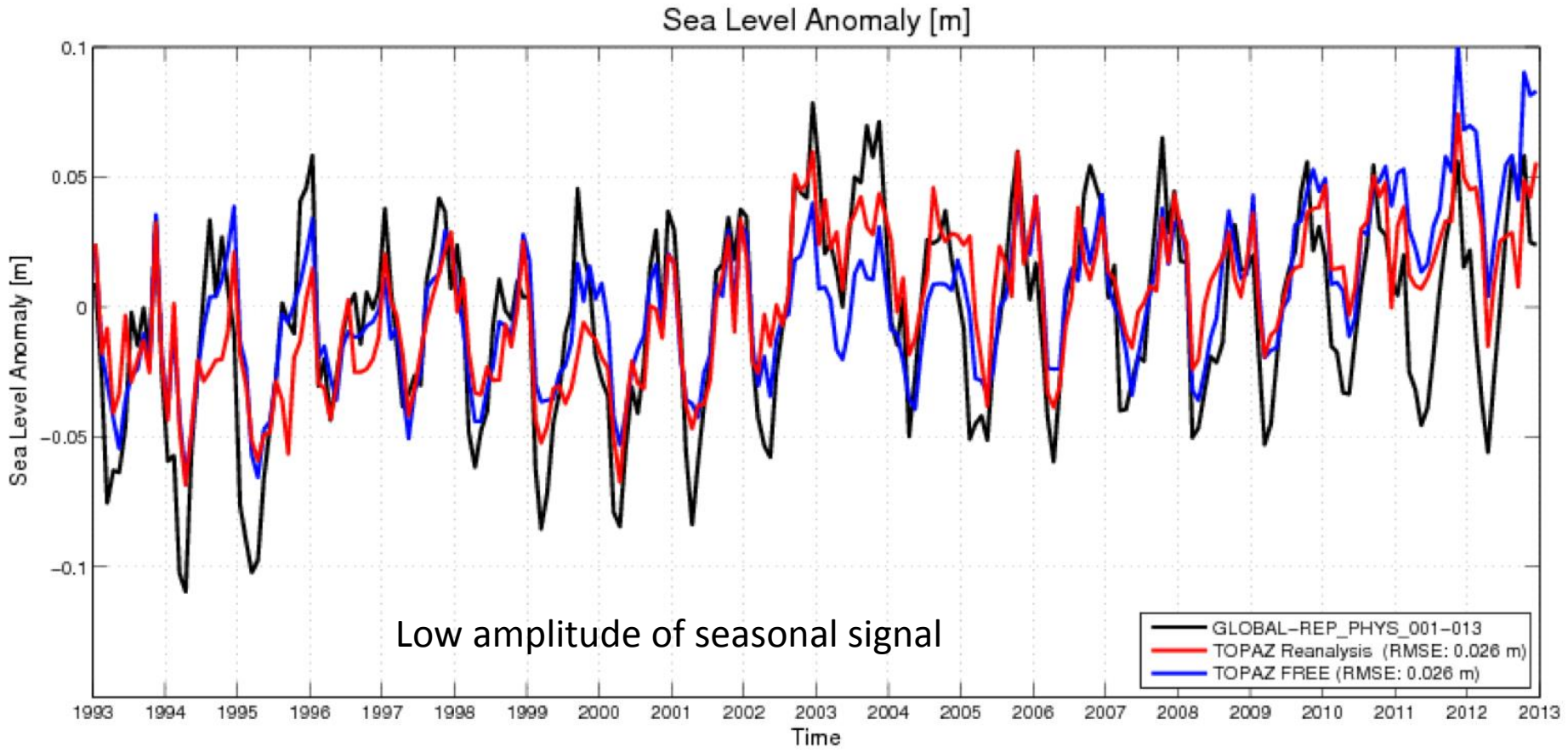
Depths 300-800 m

In situ SAL innovation statistics



Depths 300-800 m

Arctic-wide sea level change

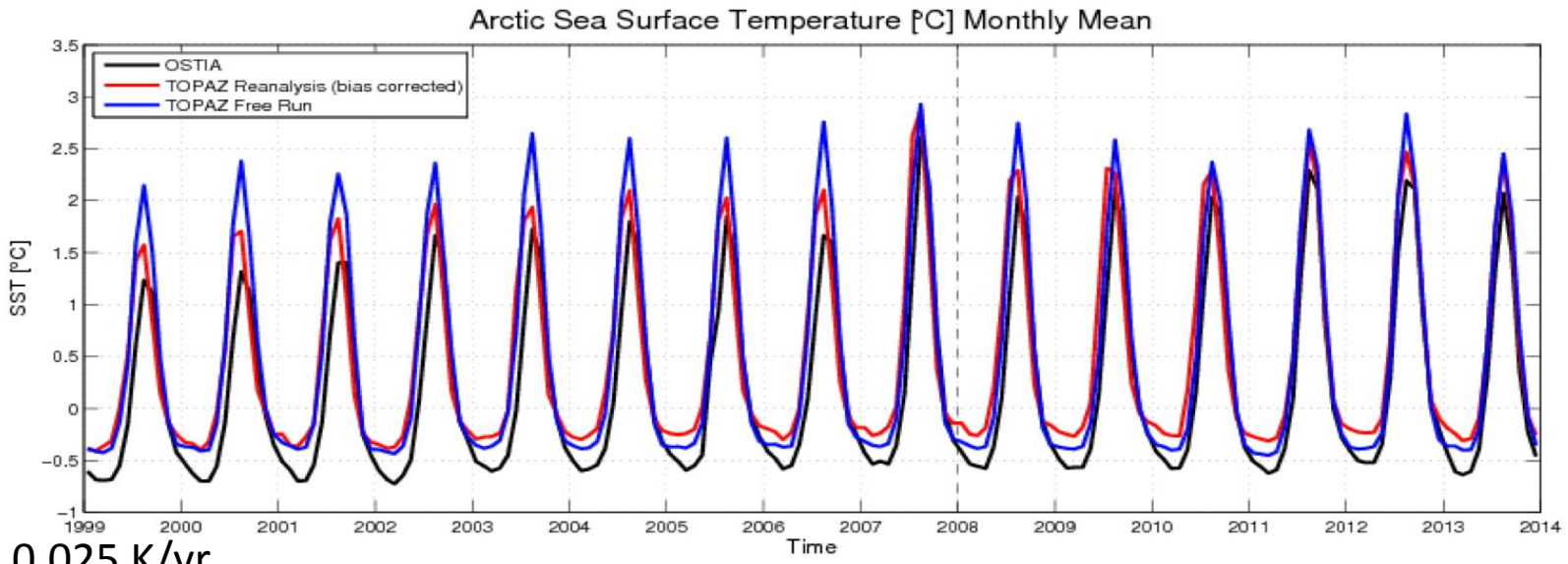


Same trend: 2mm/yr

Same performance wrt tide gauges

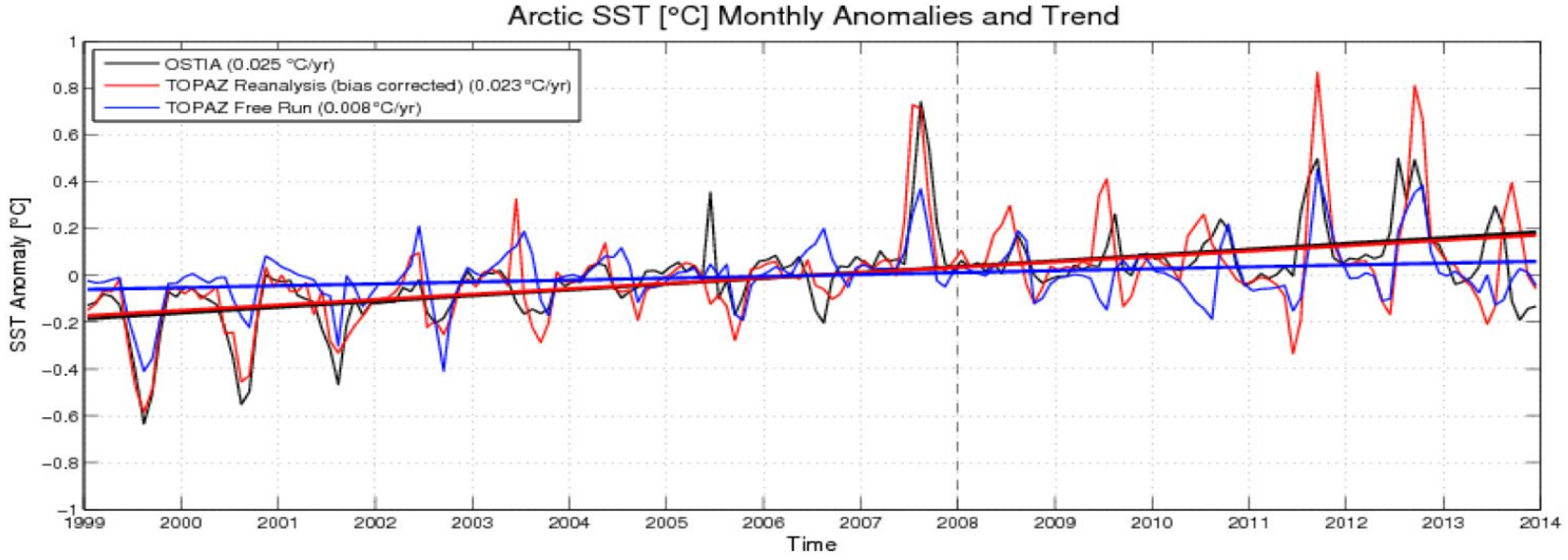
No improvements, no degradation

Arctic SST trend

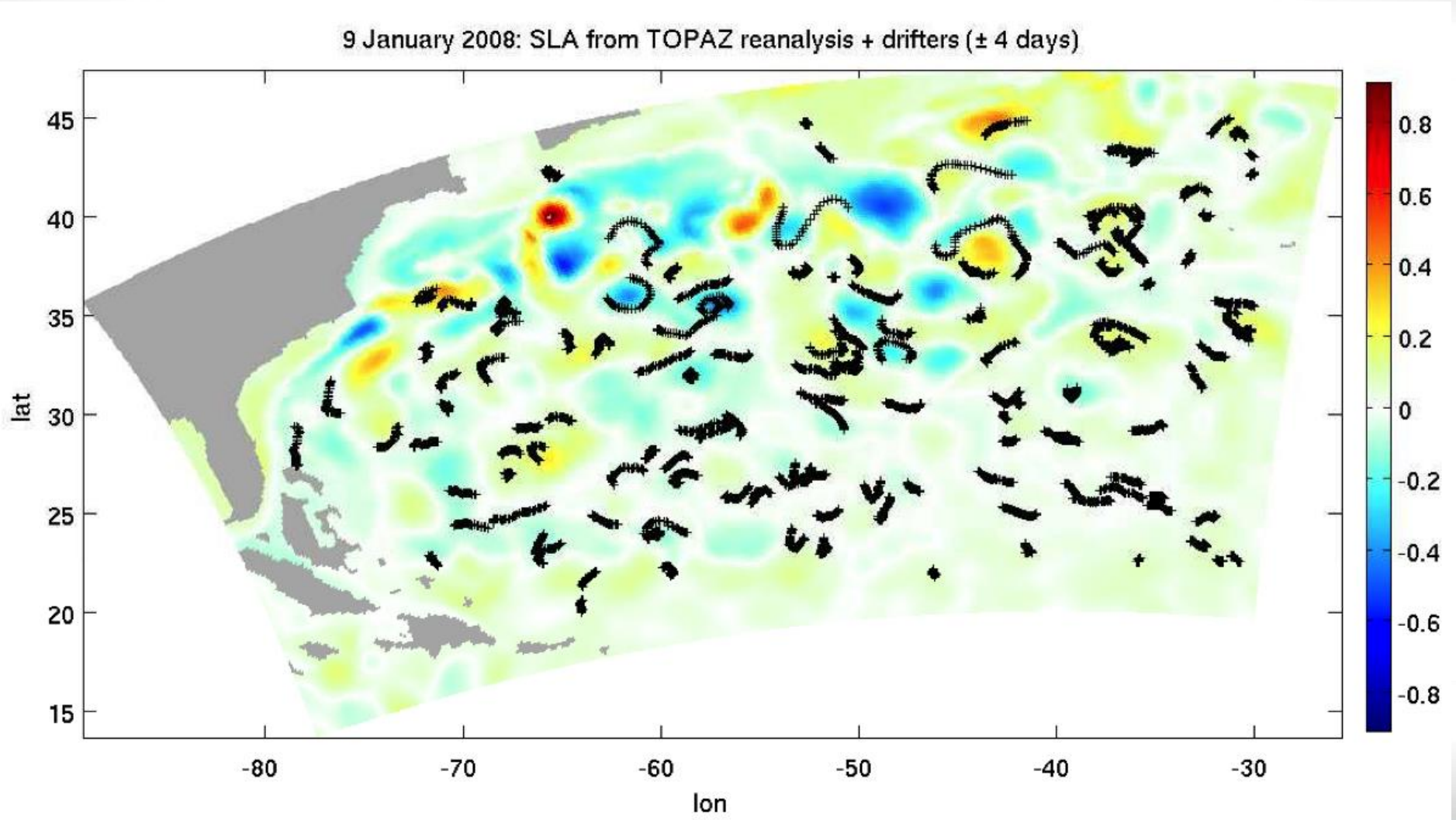


Trend: 0.025 K/yr

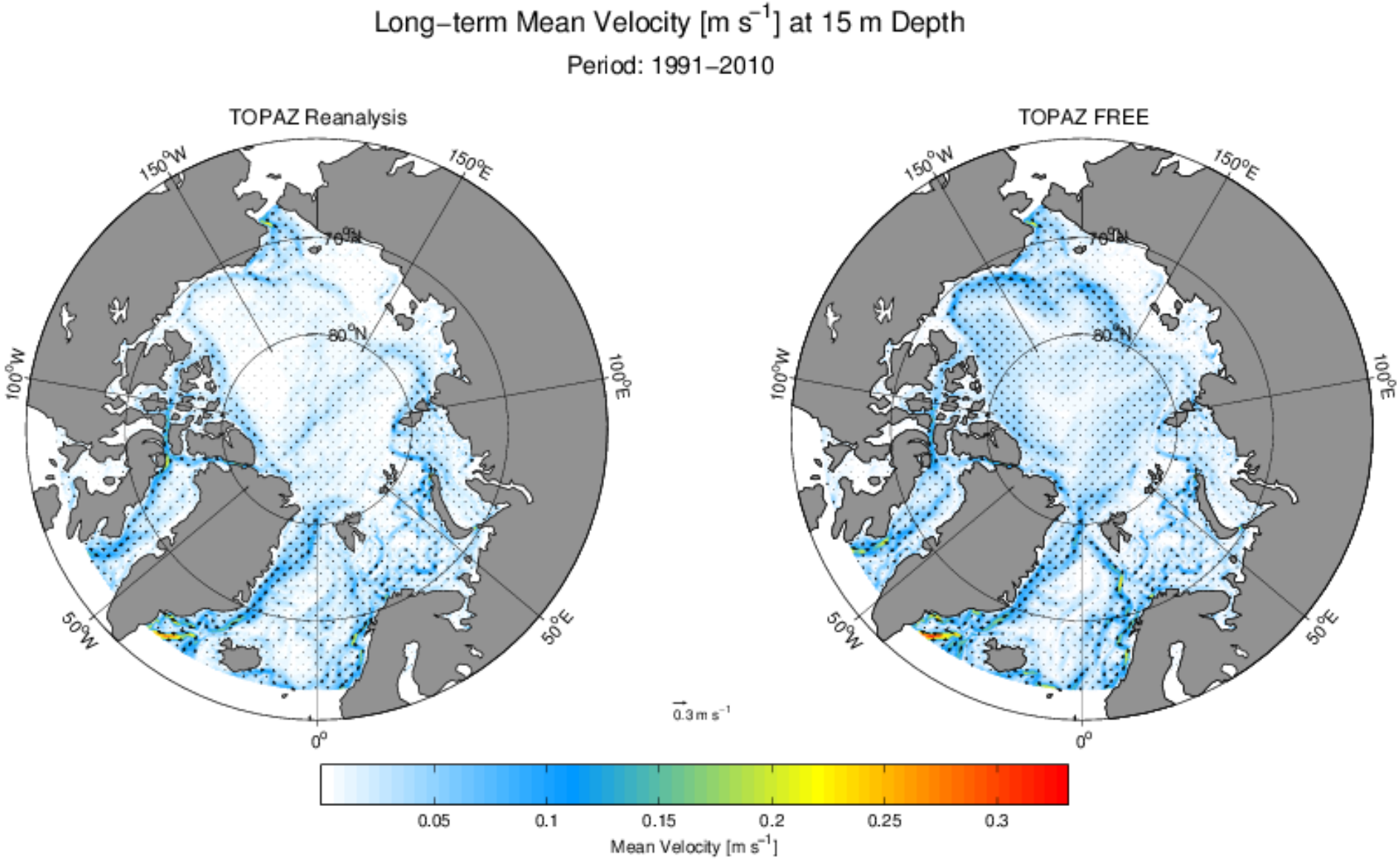
Improved by assimilation (of SST or of sea ice?)



Independent data: surface drifters

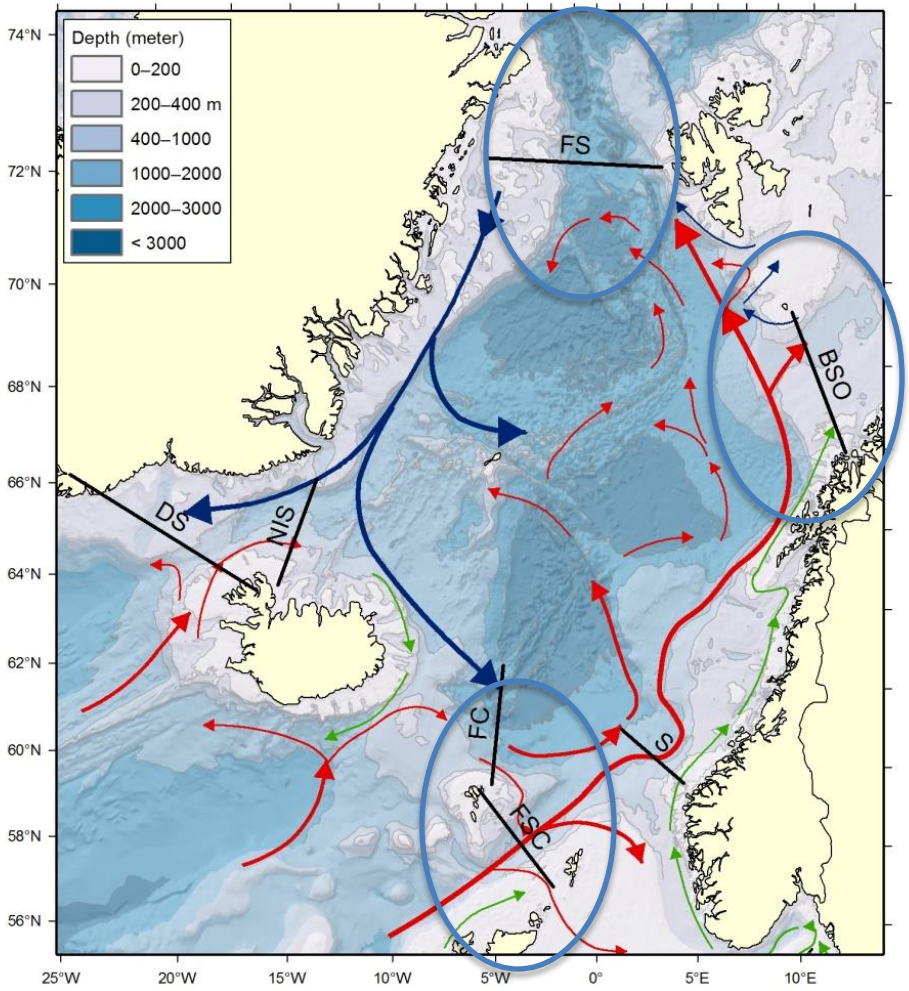


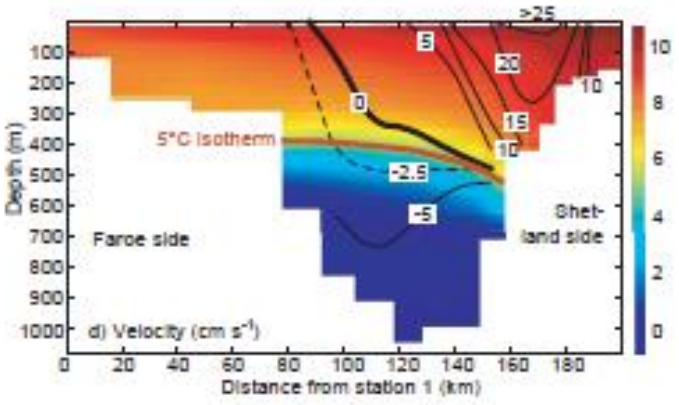
Current velocities near surface

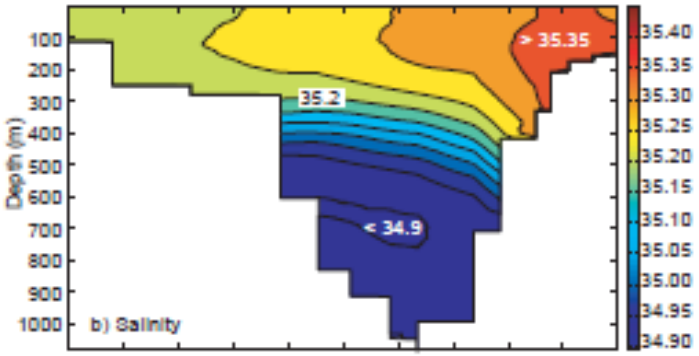


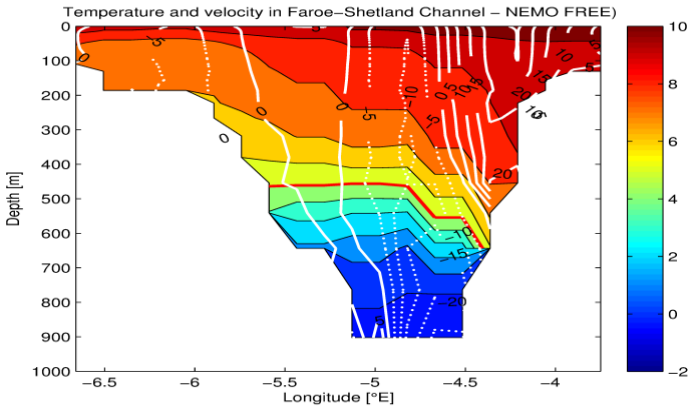
Validation of 1993-2009 reanalyses

- Validation of 1993-2009 reanalyses, focus on vol & heat fluxes, hydrography in the Nordic Seas
- Global / Arctic MFC
- NEMO / TOPAZ
- Monthly means ,both free runs and assimilated runs
- Mean, std, seasonal cycle and trends
- *Lien V., S. Hjøllo, M. Skogen, H. Wehde, E. Svendsen, G. Garric, M. Chevallier, F. Counillon, L. Bertino (in progress)*



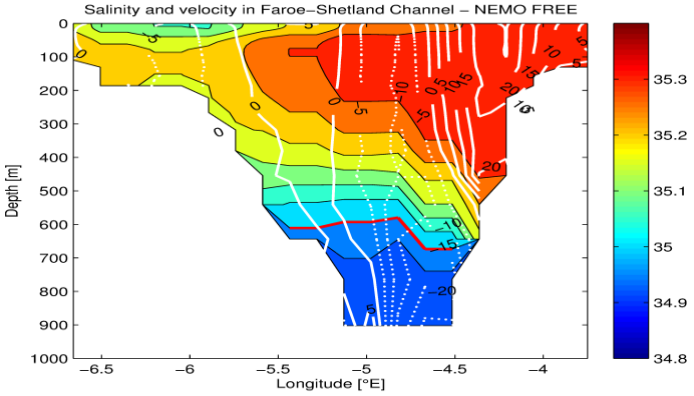


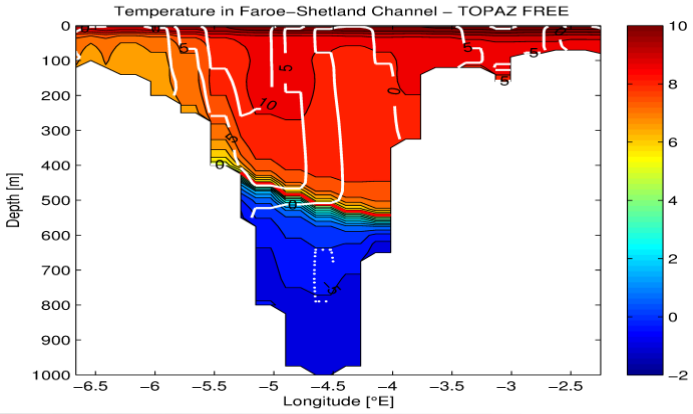




NEMO Free:

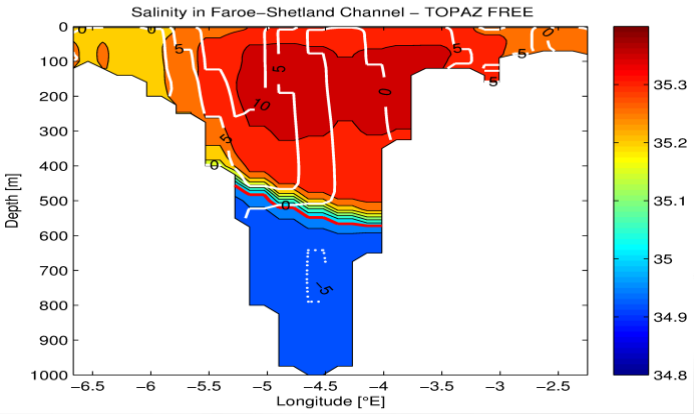
Slightly higher salinity, temperature and speed than in assimilated run

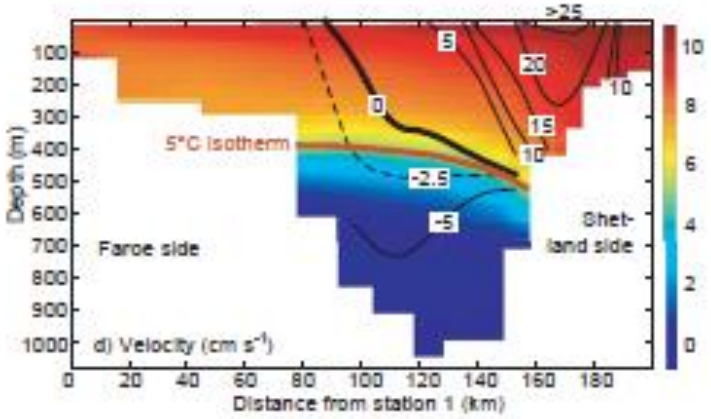


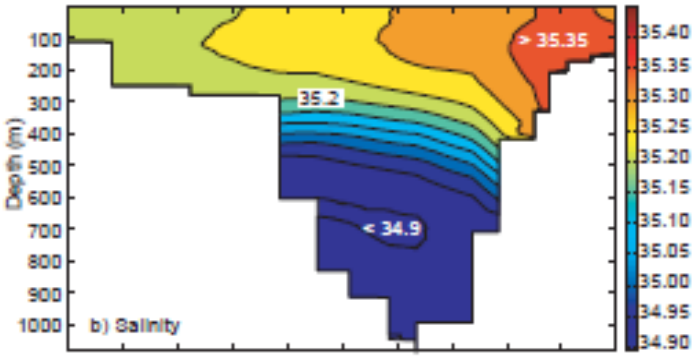


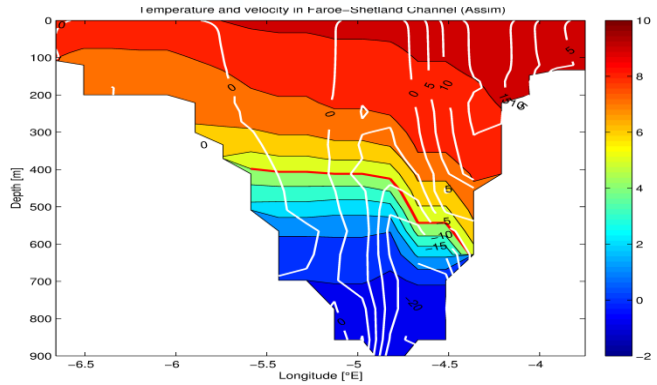
TOPAZ free:

More saline AW core than in assimilated run, but AW depth similar. Too weak currents.



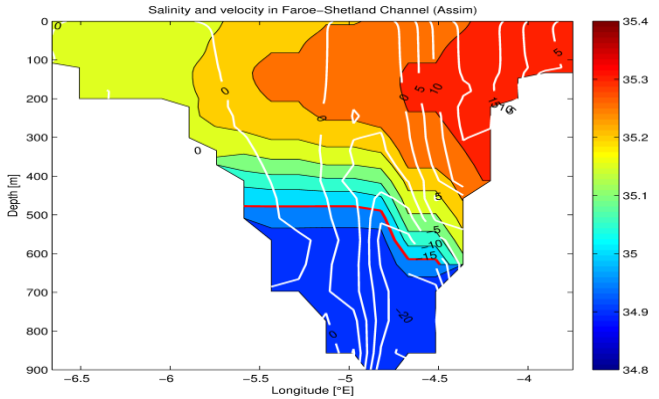


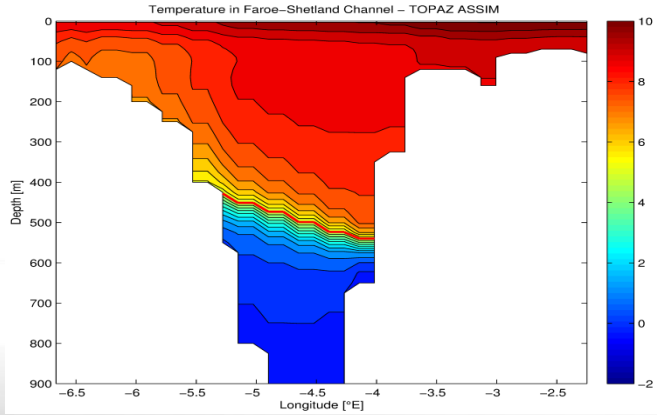




NEMO assim:

Realistic hydrography: AW core at Shetland shelf slope; sloping T and S surfaces; AW above ~500 m. Too weak currents





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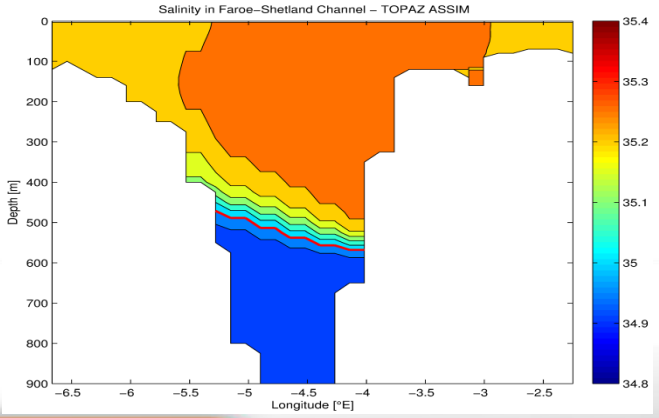
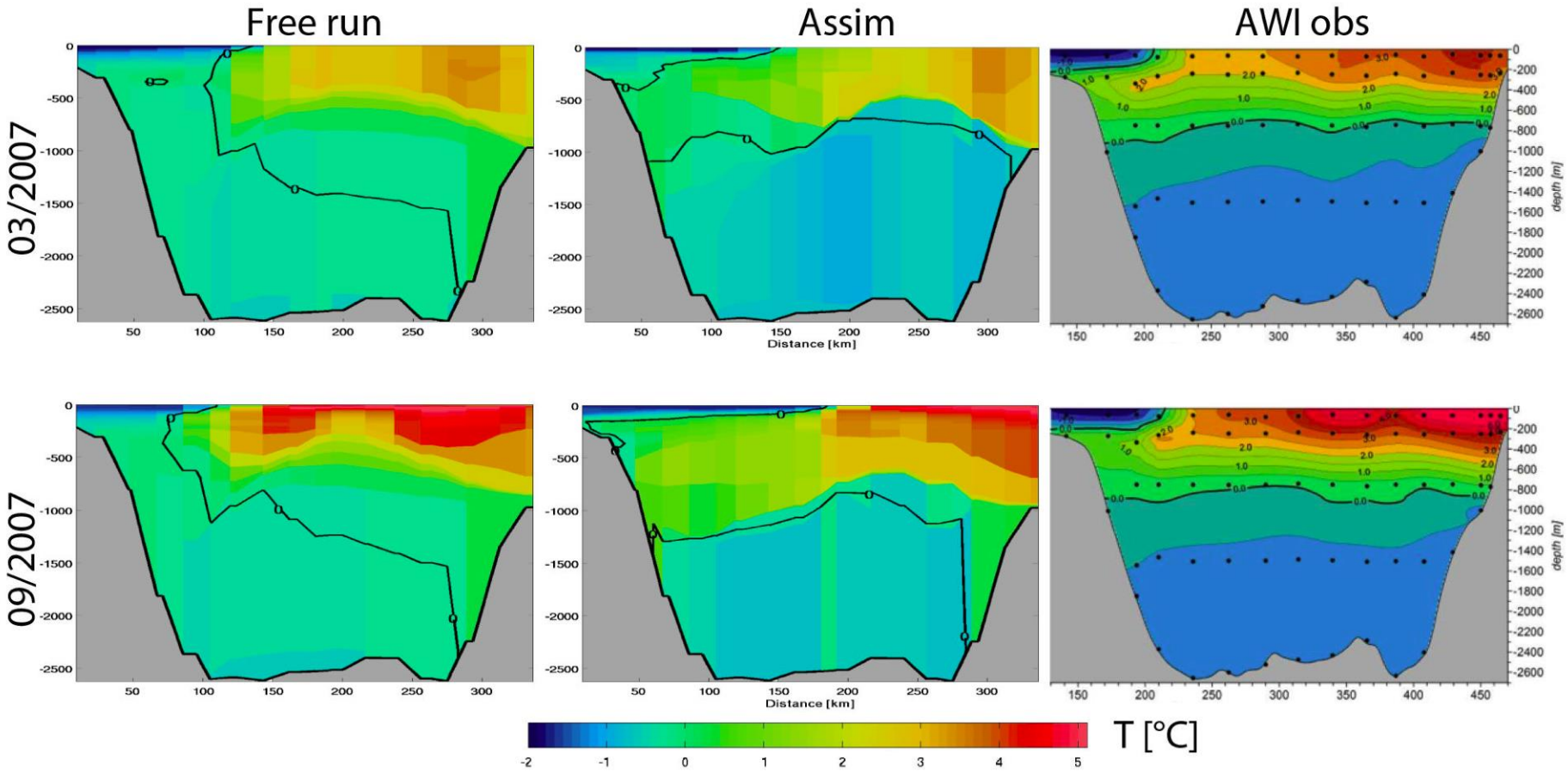
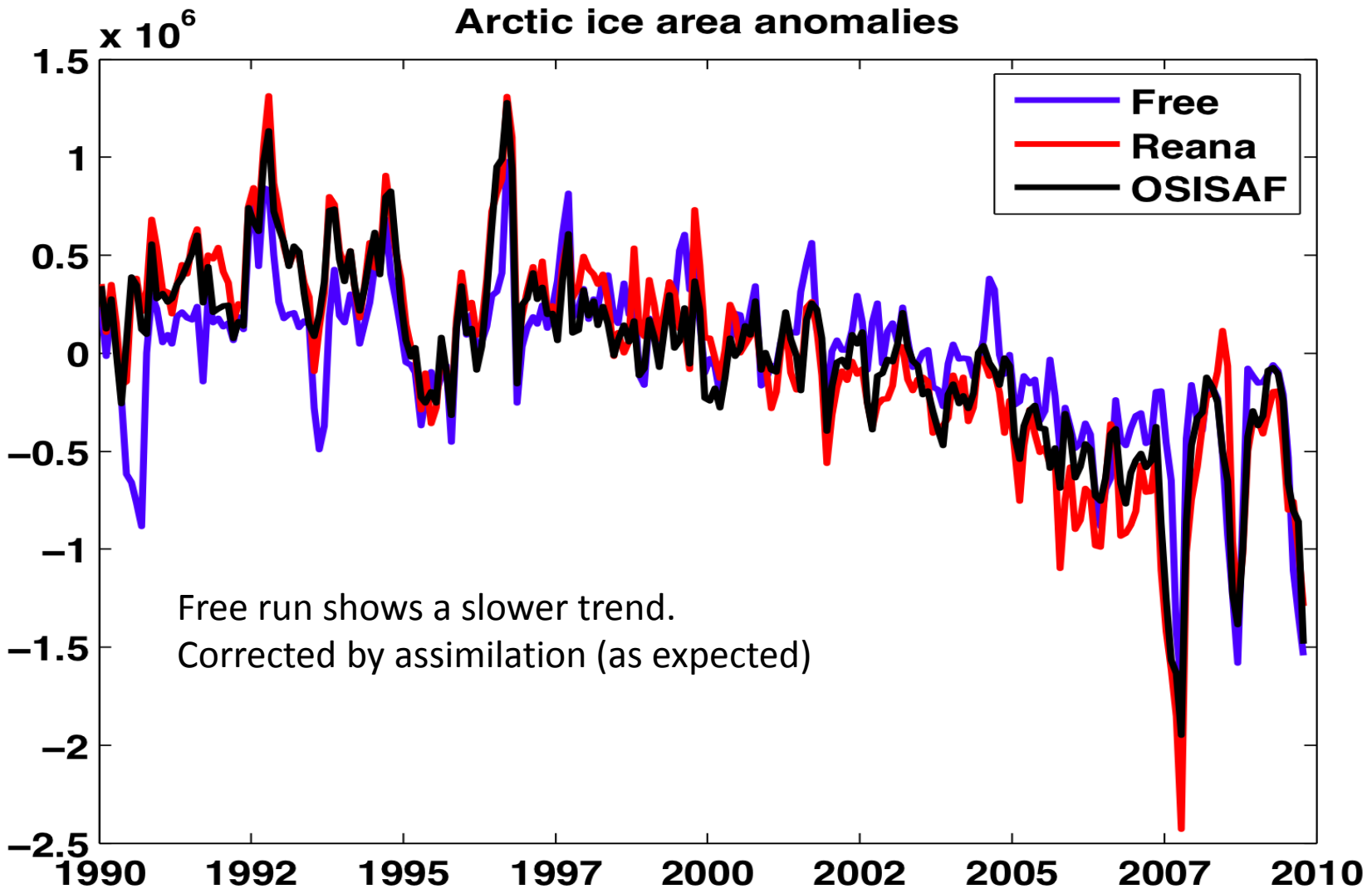


Fram Strait – Water masses

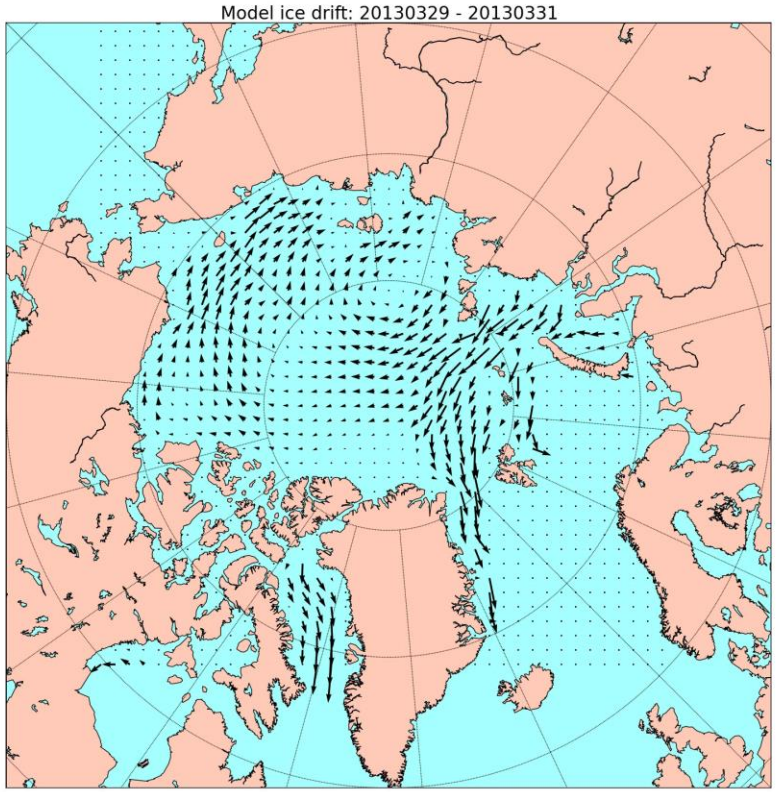


Icea area anomalies

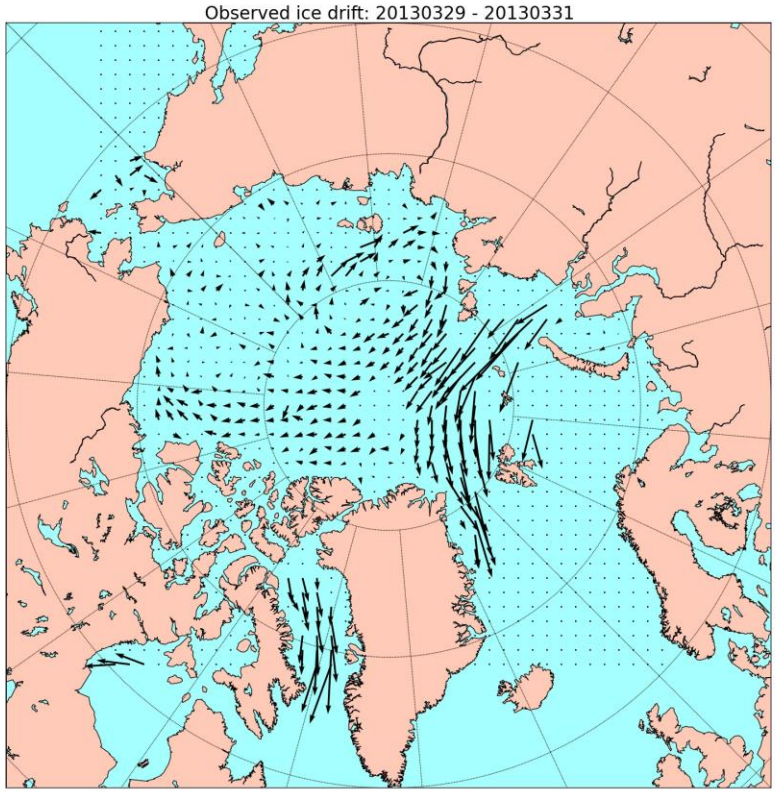


Ice drift in the model

Example 3-days end of March 2013

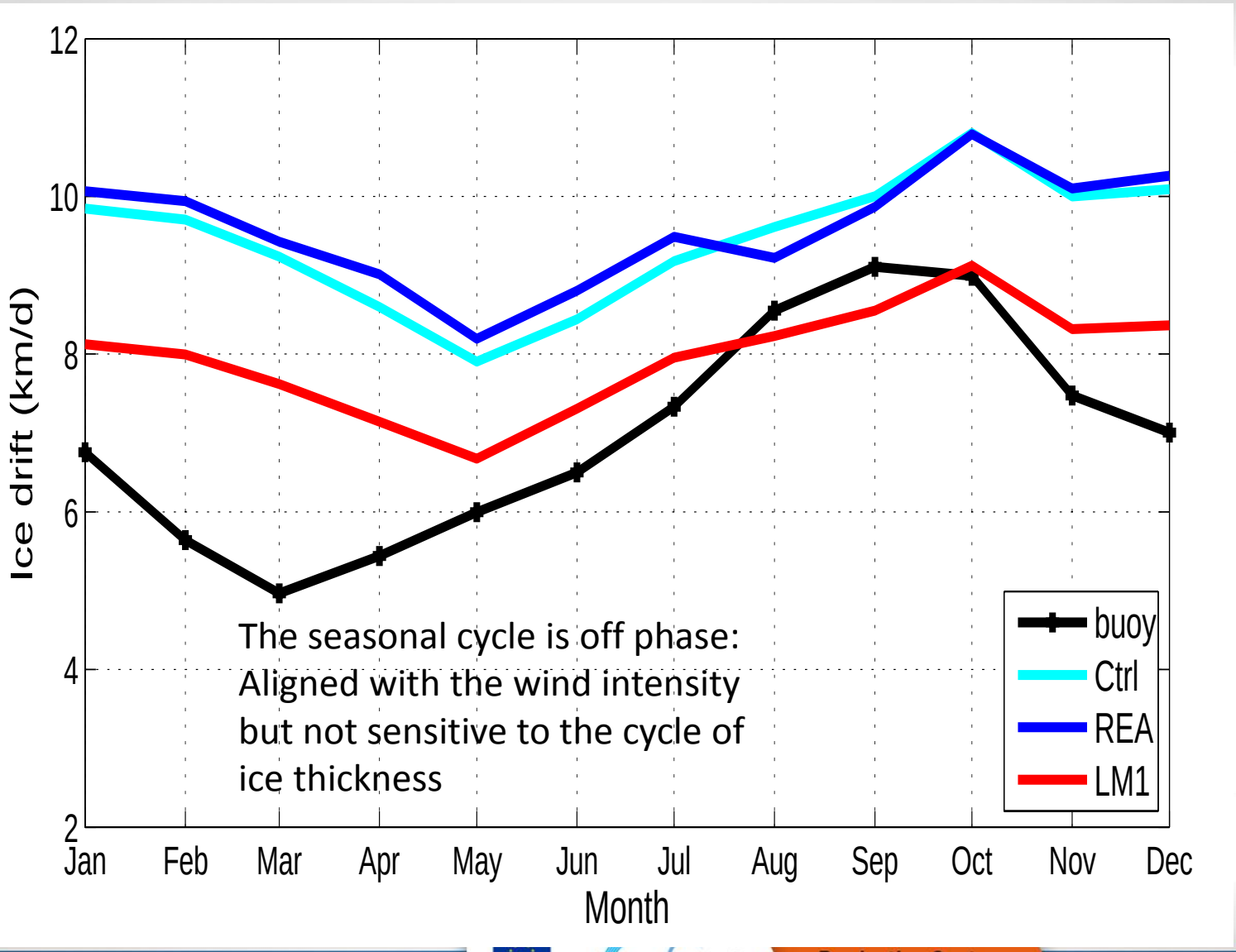


TOPAZ

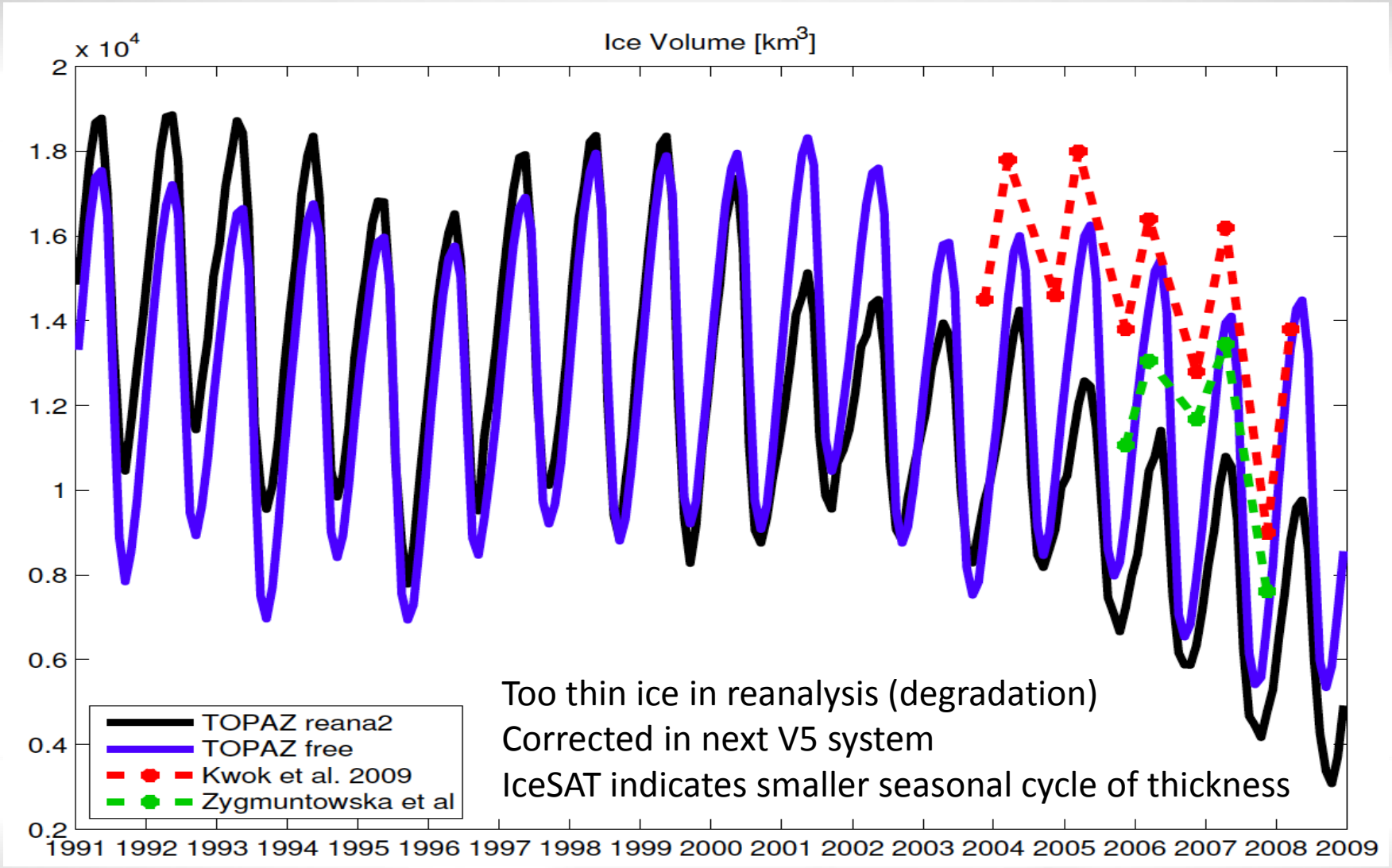


OSI-SAF

Ice drift seasonality shortcoming of the EVP rheology



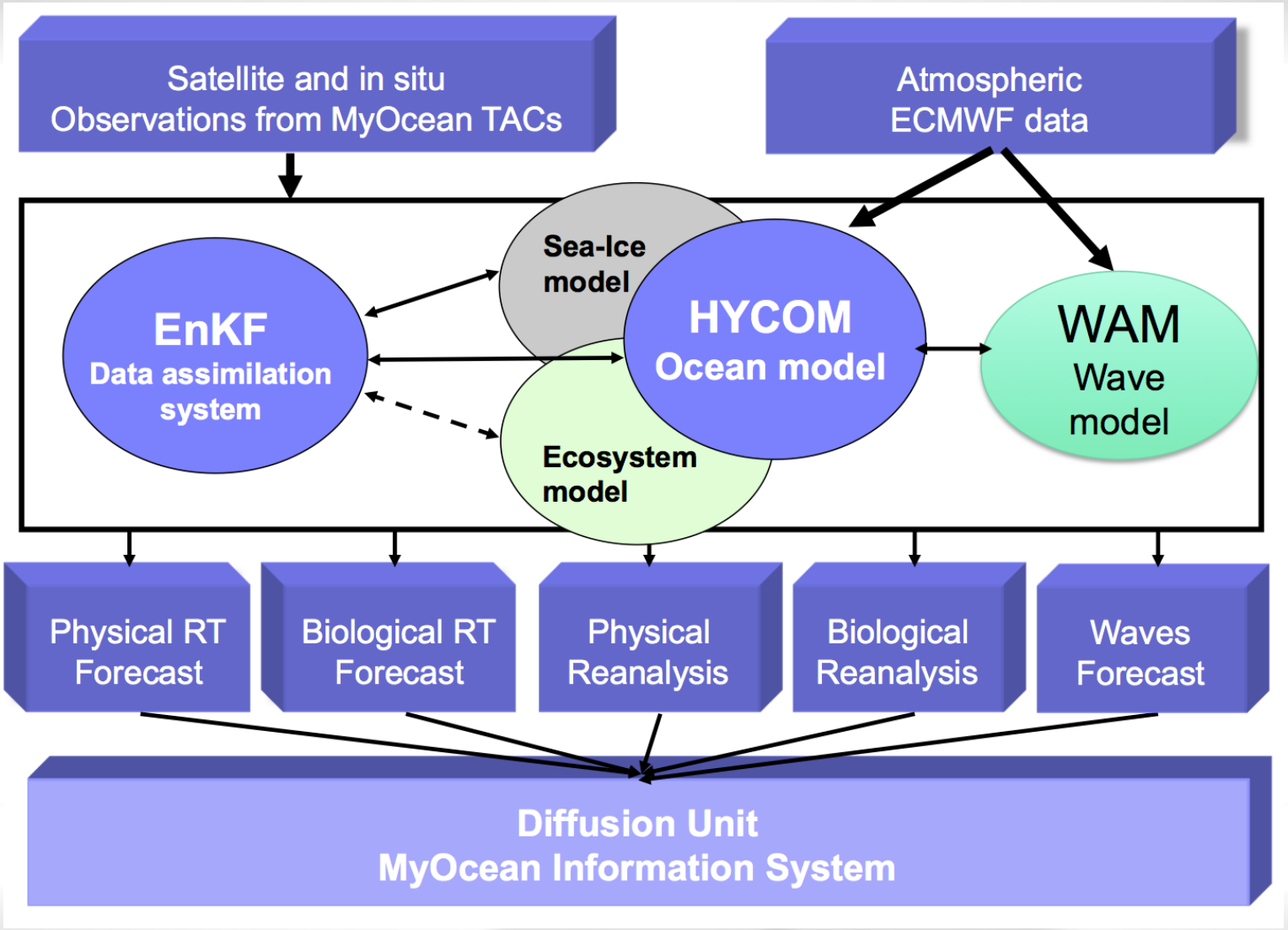
Ice thickness validation



Summary performance

- The Good:
  - Constraint of ice edge within +/- 50km
  - Processes related to presence of ice (mixing, blooms)
  - Most input data respected simultaneously
  - Useful for planning field experiments
- The Bad:
  - Heavy computational burden
  - Not yet eddy-resolving (planned for 2017)
  - Insufficient advection of Atlantic Water to Arctic
  - Sea ice too thin
- The Ugly:
  - The sea ice model needs a new rheology to improve the drift
  - Absence of sea ice biogeochemistry model

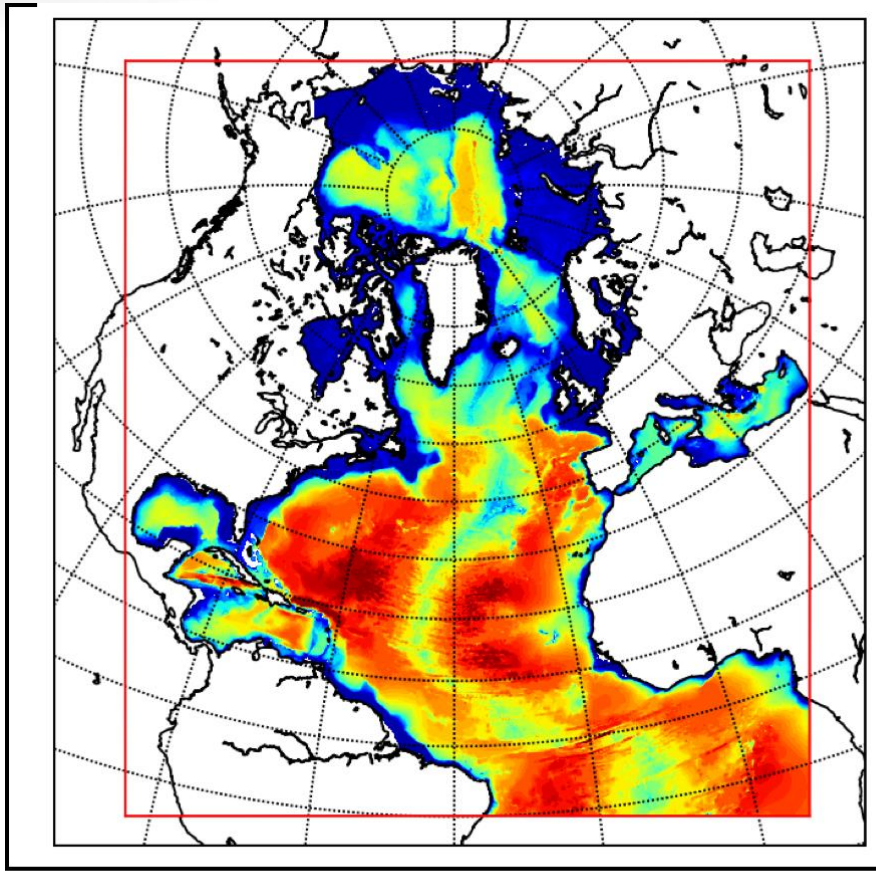
Evolution until 2018

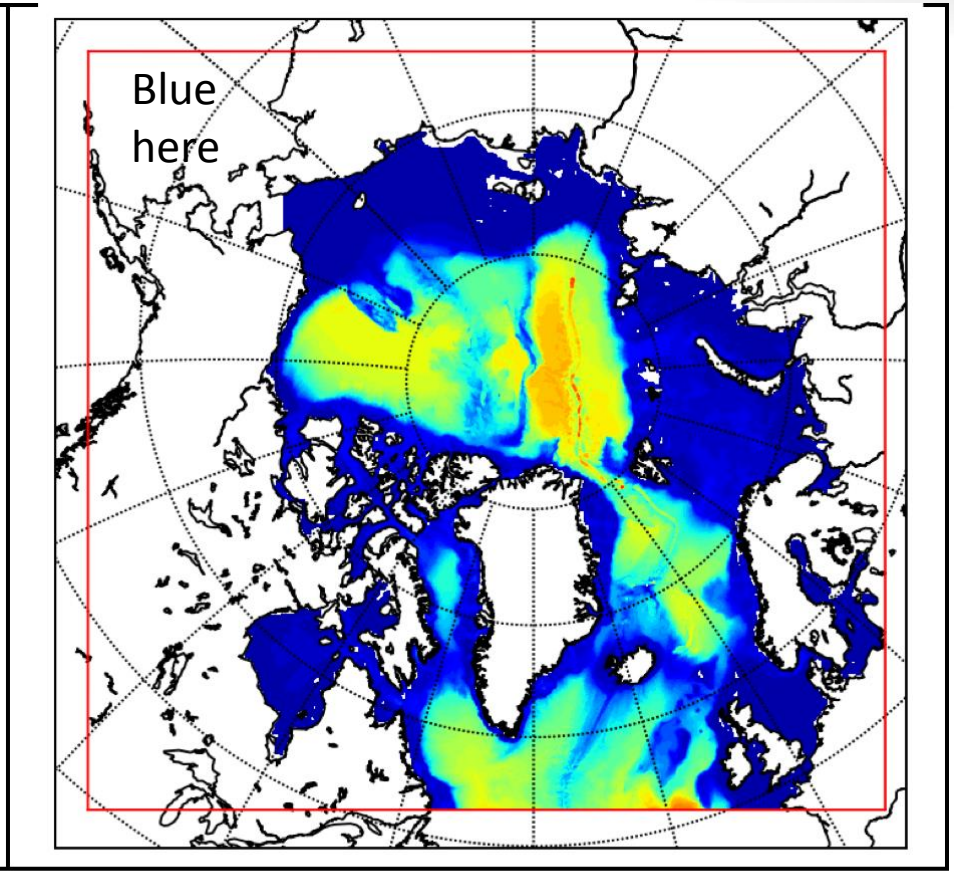


Next steps TOPAZ5 (2018)

- Wave-induced mixing in KPP
  - Hourly output in real-time / daily in reanalysis
  - 1 post-doc position soon opened
- Double horizontal resolution (6 km)
- Double vertical resolution (50 z-rho layers)
- Sigma-2*
- Nesting in global NEMO model
- Biological model ECOSMO

Increased horizontal resolution





V1: TOPAZ4 (12 km)

V4: TOPAZ5 (6 km)

Even further steps

- Sea ice model in (horizontal) Lagrangian coordinates
  - Consistent with solid mechanics (elastic-brittle rheology)
  - neXtSIM model (Rampal and Bouillon, OM 2015)
  - Coupling through ESMF.
- Wish list for HYCOM developments:
  - I/O to NetCDF (r/w access water columns) would make assimilation code much simpler.
  - Better cold halocline representation

A new generation of sea ice models First steps

Barents Sea regime

Kara Sea regime

MIZ regime ?