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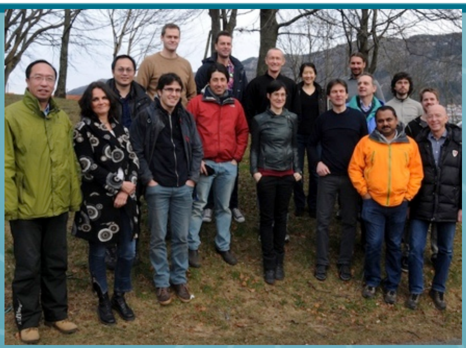
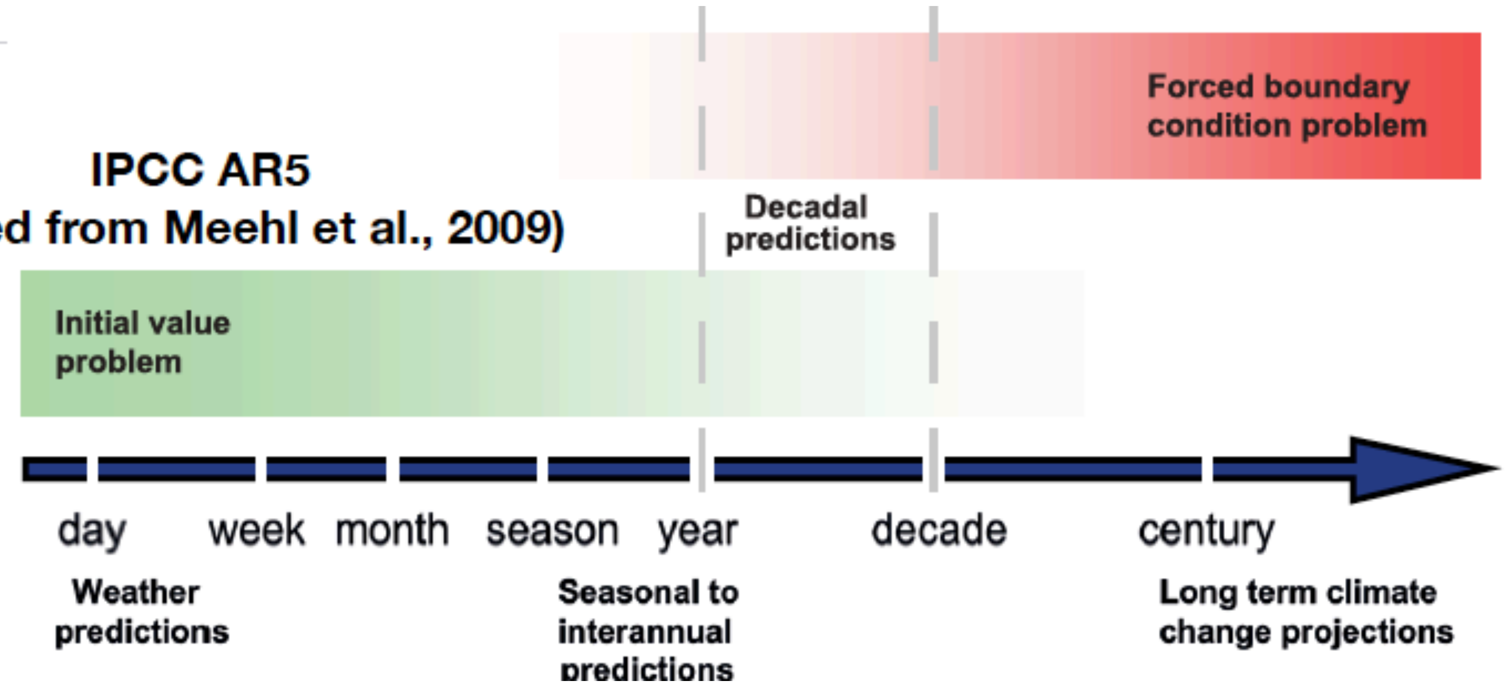


Seasonal-decadal prediction with the Norwegian Climate Prediction Model

"getting ready for CMIP6 DCPP"

F. COUNILLON, Y. WANG, I. BETHKE, N. KEENLYSIDE, M-L SHEN

Seasonal-decadal prediction



IPCC AR5
(adapted from Meehl et al., 2009)

- Seasonal-decadal prediction depends on initialization & Forcing
- Most of the predictability is in the ocean (larger inertia and heat capacity)
- Prior attempt showed potential using simple initialisation method (Keenlyside 08, Smith 08, Pohlman 09)

Can advanced data assimilation method improve predictability ?

NorCPM

Norwegian Climate Prediction Model

NorCPM = NorESM + data assimilation (EnKF)

Objectives:

- Long term reanalysis
- Seasonal-to-decadal prediction
  - Regional focus into the Nordic Seas & Scandinavia

Only SST available for a sufficiently long period of time (1850-present) to demonstrate skill for decadal time scale

Outlines:

- Twin-experiment (Counillon et al. 2014)
- First test with real observation 1980-2005
- How to avoid assimilation drift in isopycnal model (*Wang et al.*)

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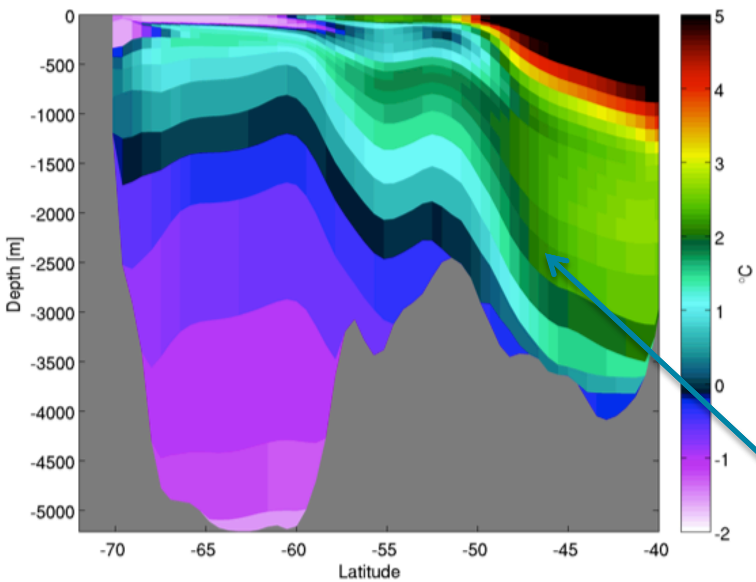
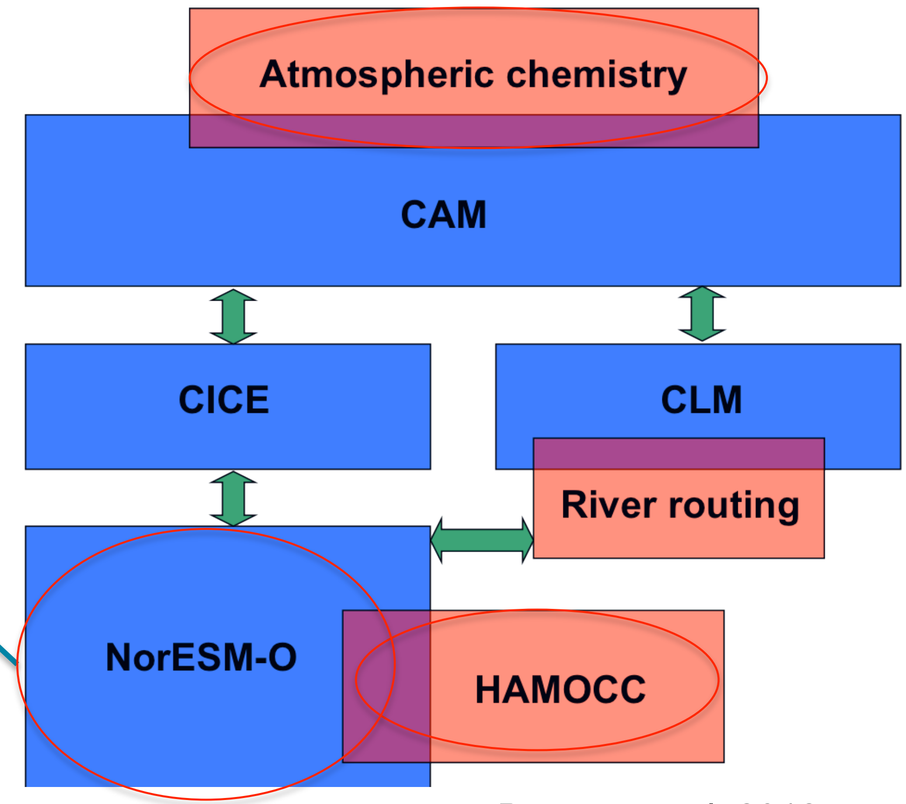
Norwegian Earth System Model (NorESM)

Based on NCAR's Community Earth System Model version 1 (CESM1)

Temperature section through Southern Ocean



Isopycnic coordinate ocean model with a bulk mixed layer on top



Bentsen et al. 2012

CMIP5 version:

NorESM1-ME (Tjiputra et al 2013, GMD)

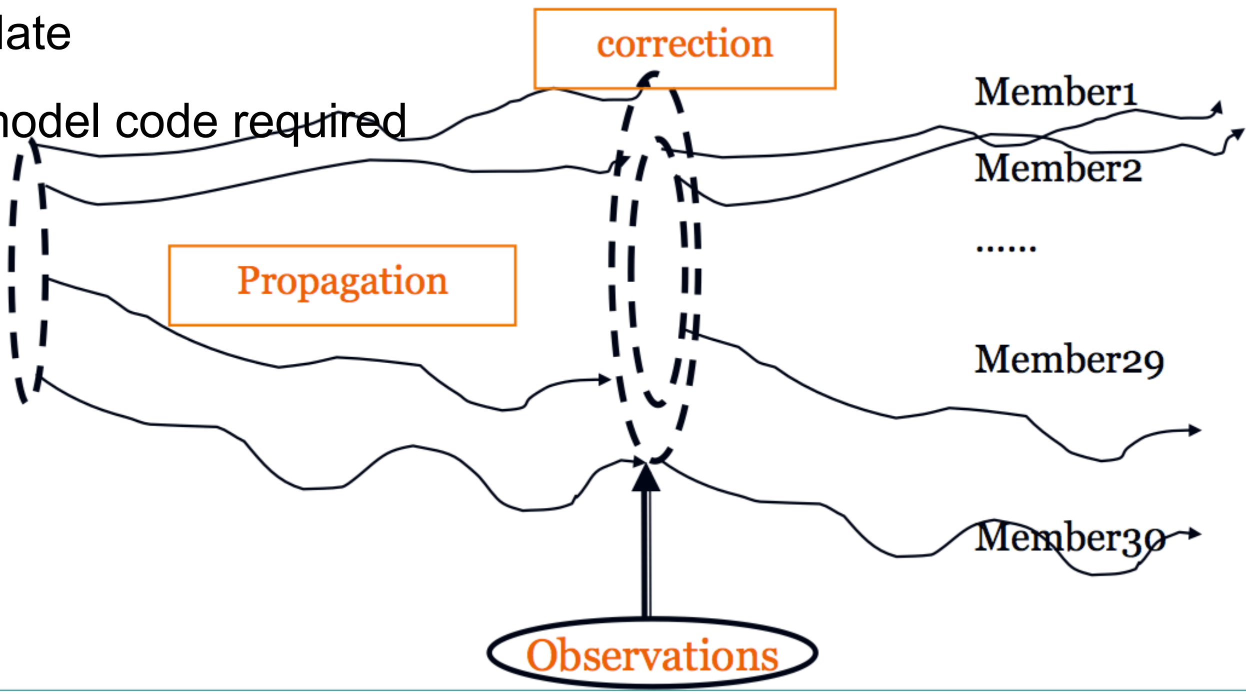
atmosphere: CAM4-OSLO on 1.9°x2.5°, 26 levels

ocean: MICOM on 1°, 53 levels

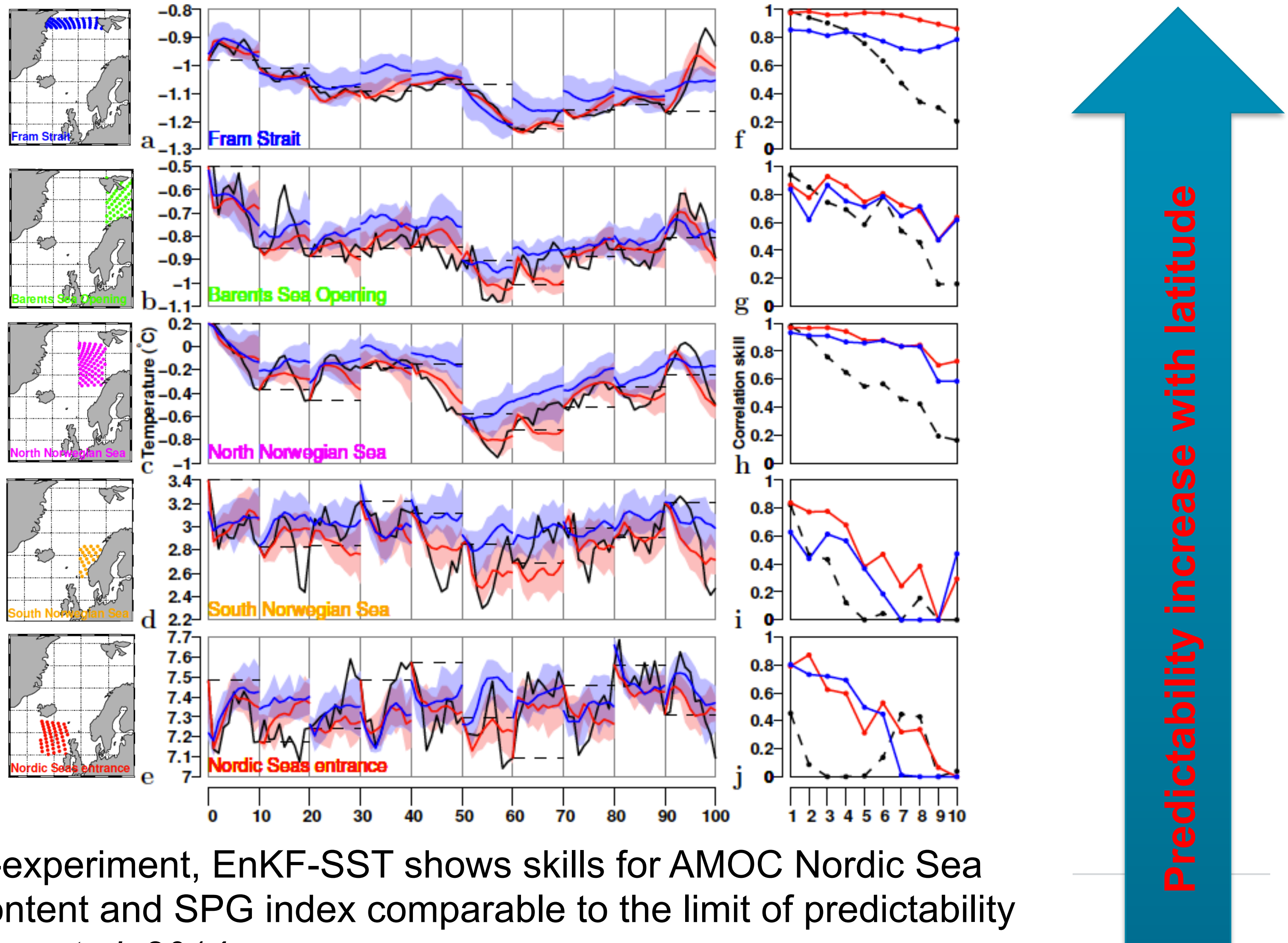
Ensemble Kalman Filter (EnKF)

Sequential Monte-Carlo method with **propagation** and **correction** step

- Forecast = Ensemble mean, Forecast uncertainty = ensemble std deviation
- Ensemble covariance used to update the **full water column** from the obs (e.g., SST)
  - **More information extracted** from sparse observations
  - Consistency in the update
  - No knowledge of the model code required



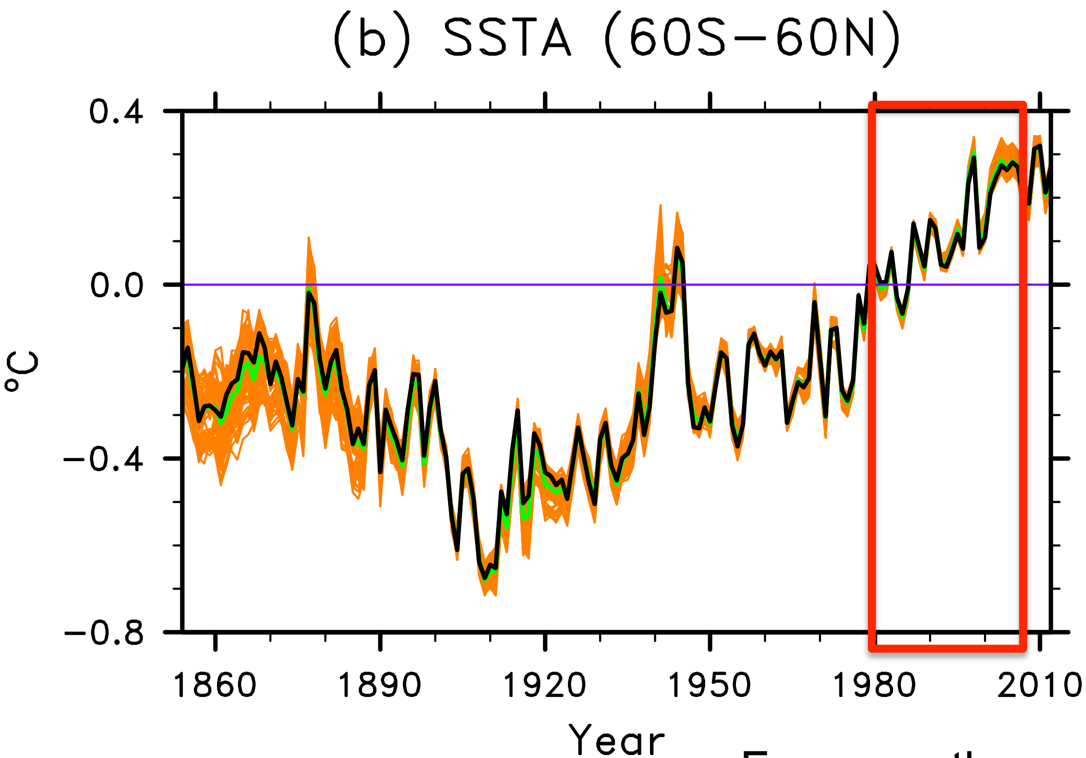
Nordic Seas heat content (0—300m)
Predictability 1—10 lead-year



In twin-experiment, EnKF-SST shows skills for AMOC Nordic Sea heat content and SPG index comparable to the limit of predictability

Counillon et al. 2014

Assimilation of real observation



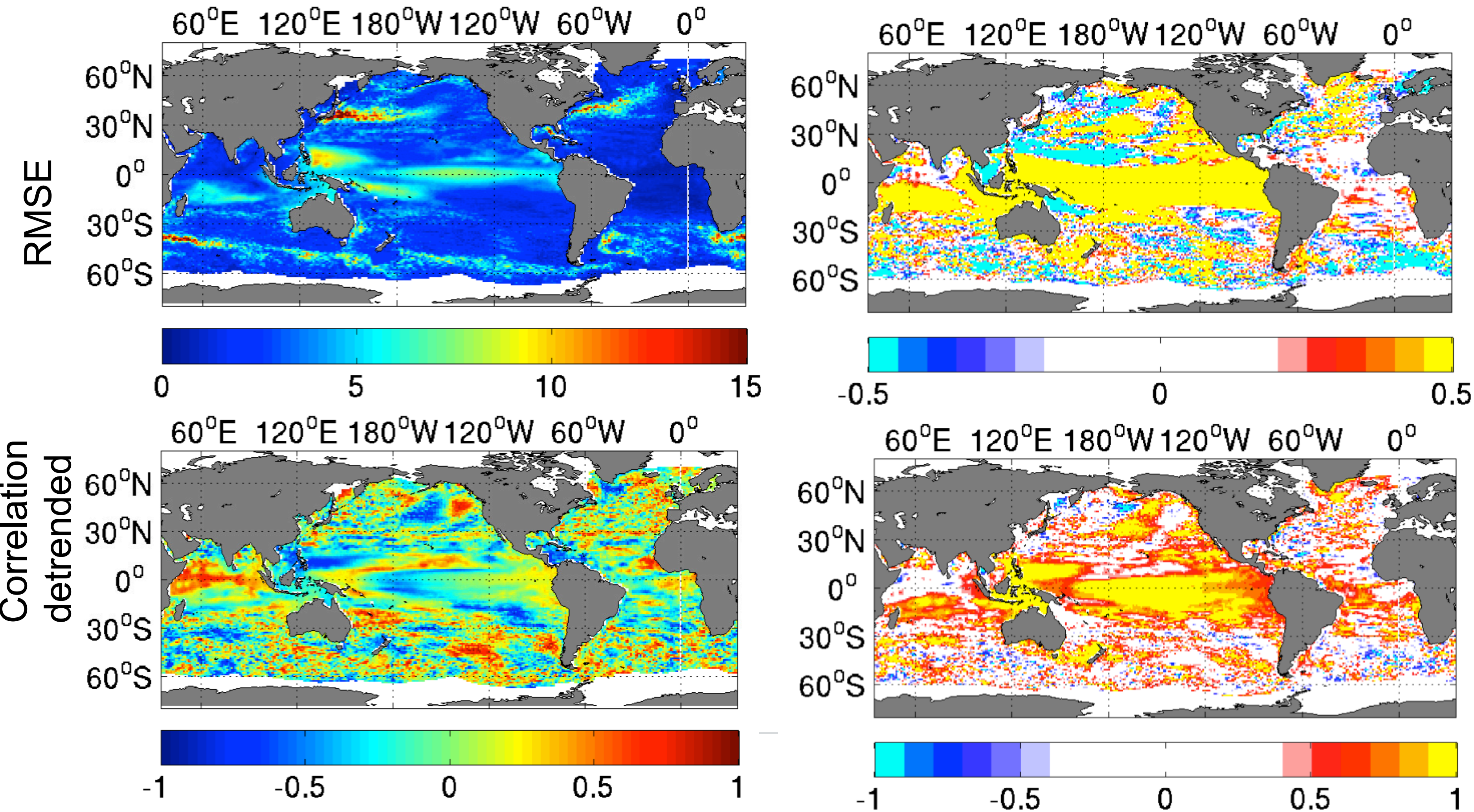
- HadISST2 1850-2007
- 1° resolution, monthly
- Obs error varies space & time

Assimilate anomaly w.r.t. 1980-2000

Focus on the period 1980-2005 first:
➔ plenty of independent obs for validation

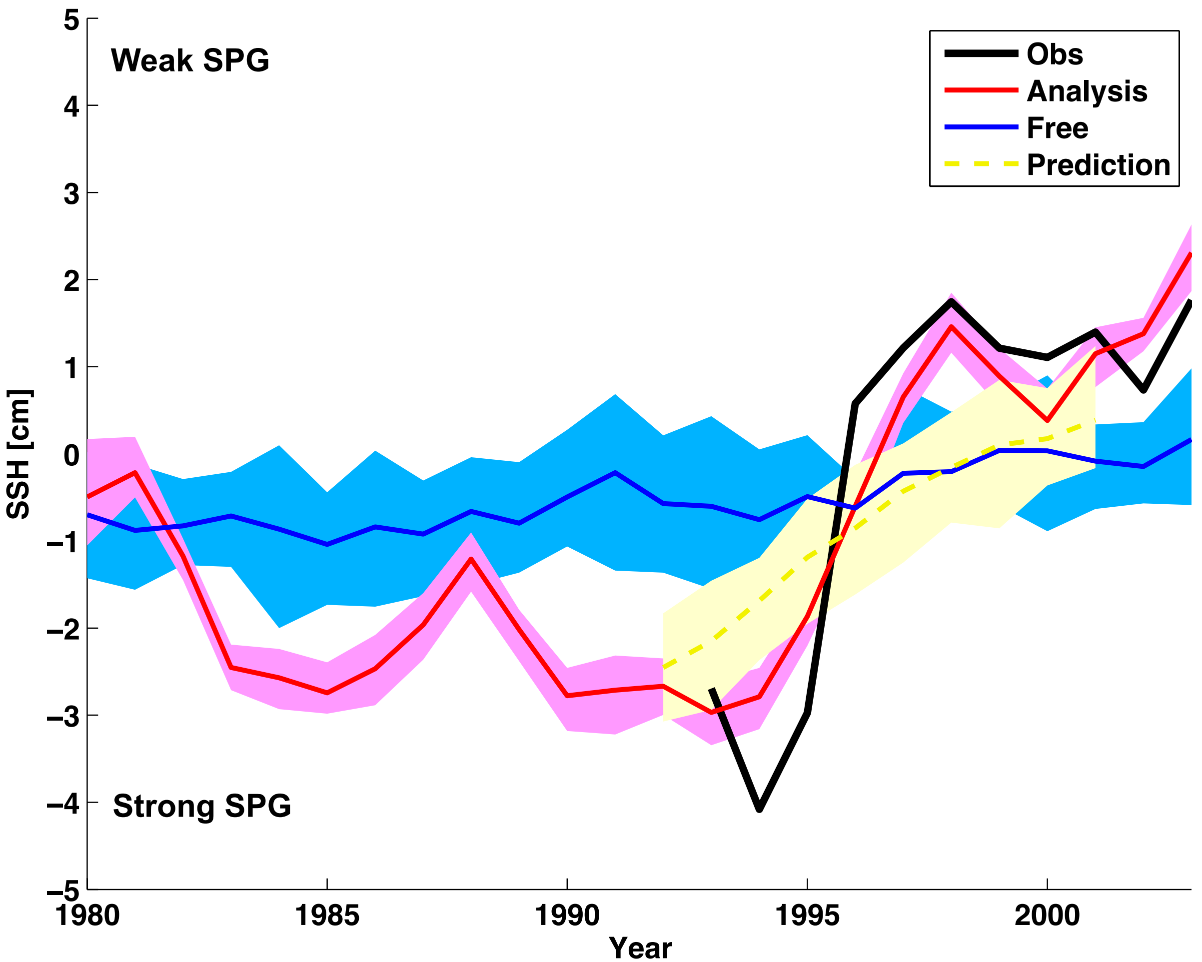
Validation with SSH data

Free run | **Free run – EnKF**



SPG index

- SPG index is box-averaged SSH [60W-15W,48N-65N]



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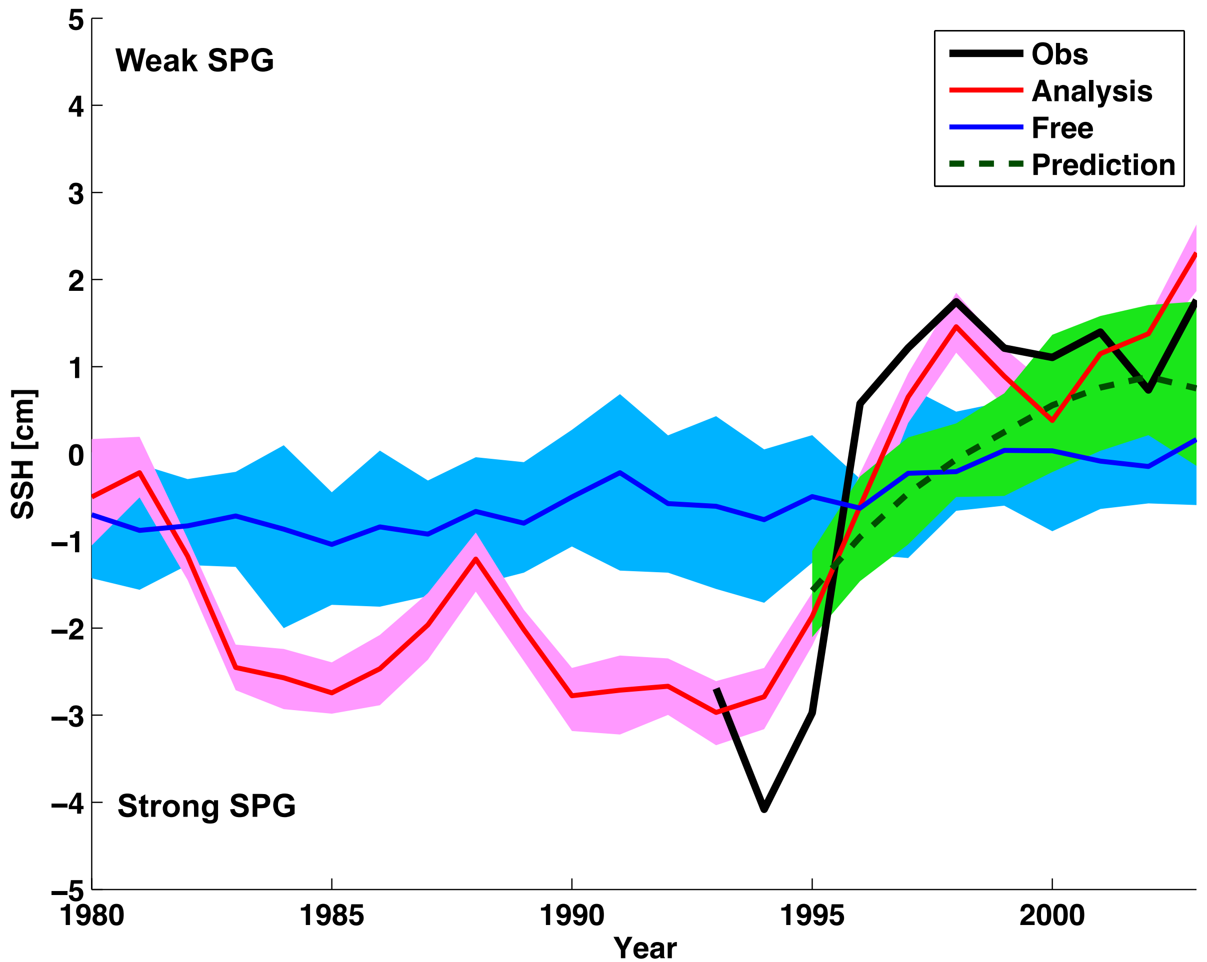

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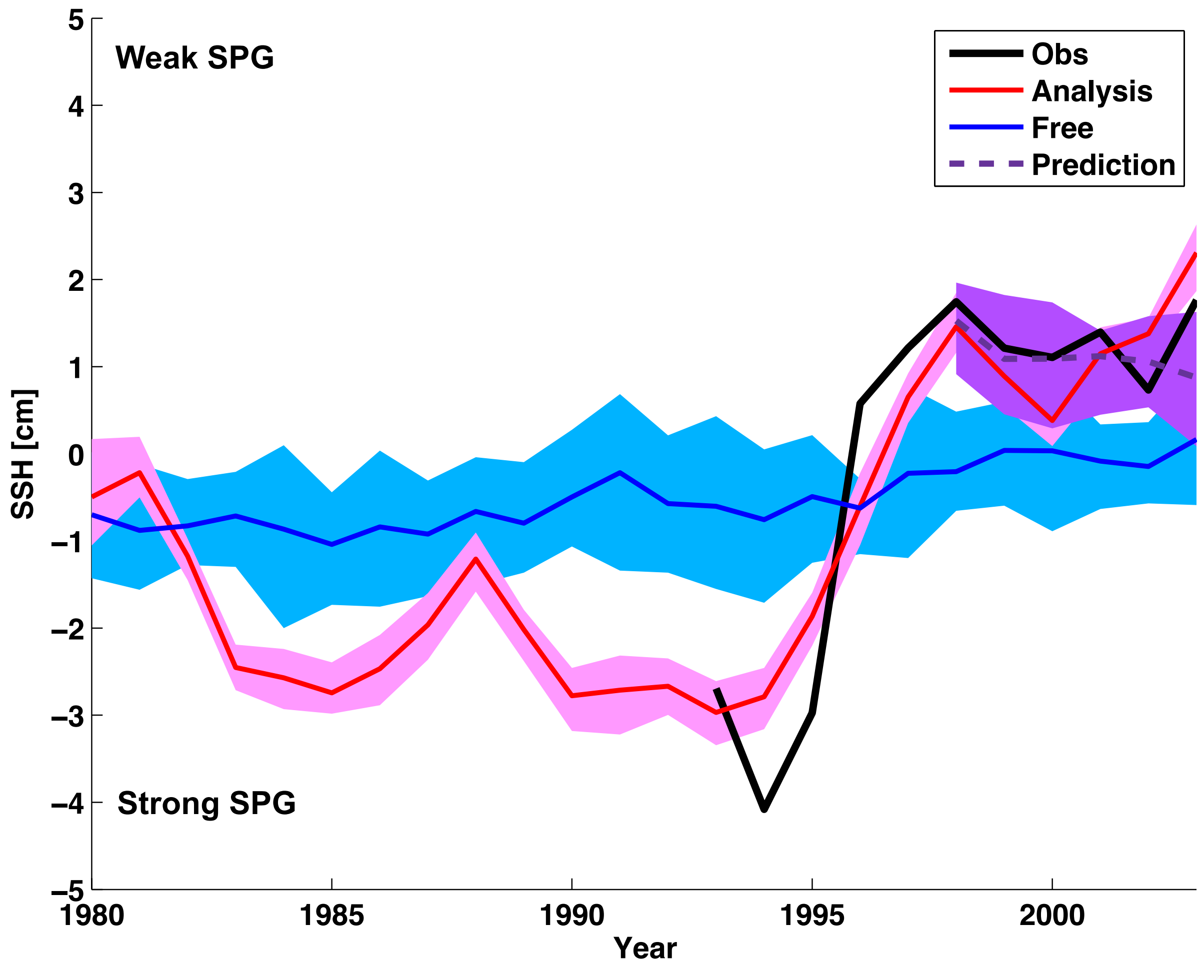
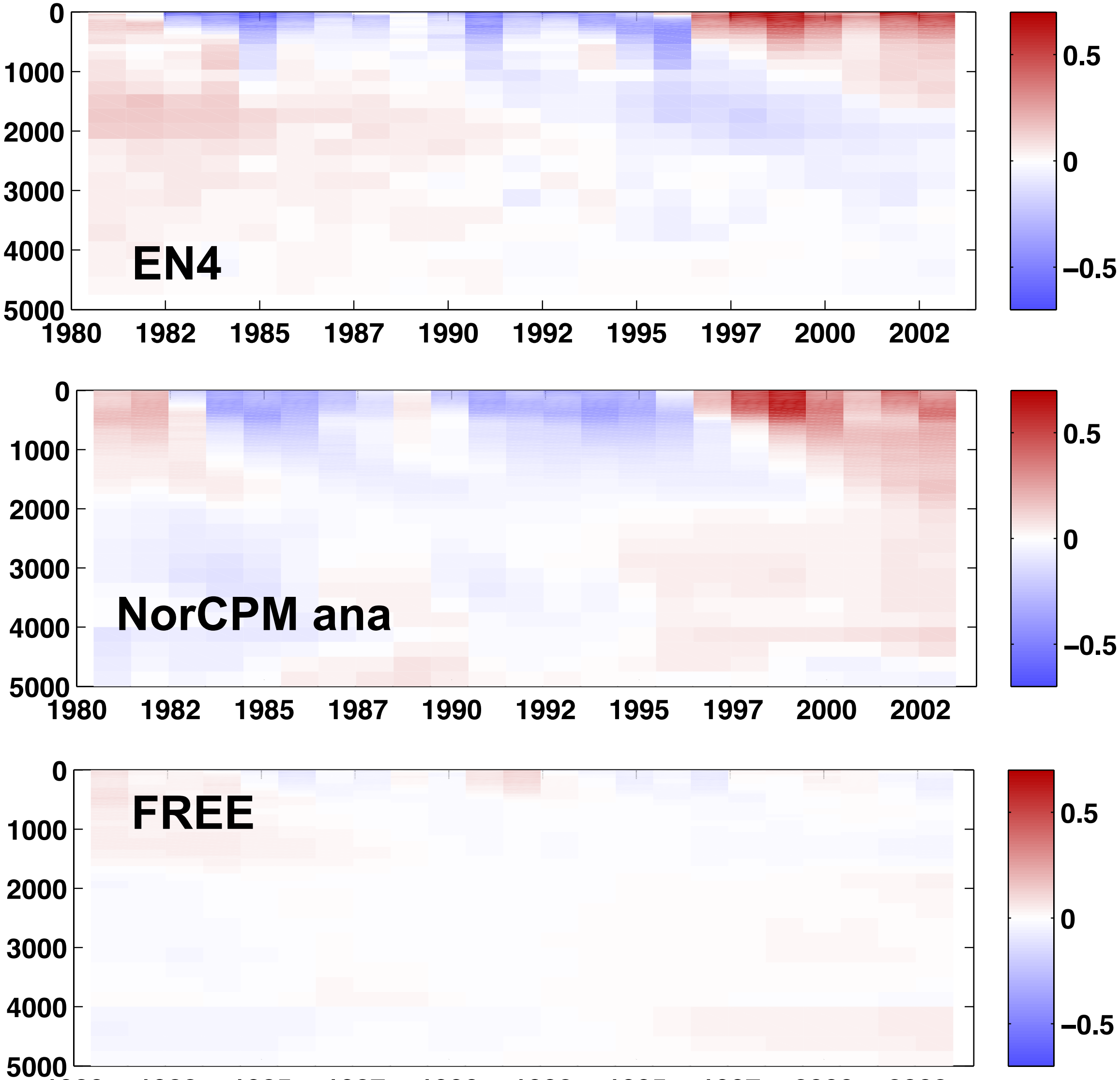


SPG temperature anomaly 1980-1995



Objective analysis of independent observation (Good et al. 2013)

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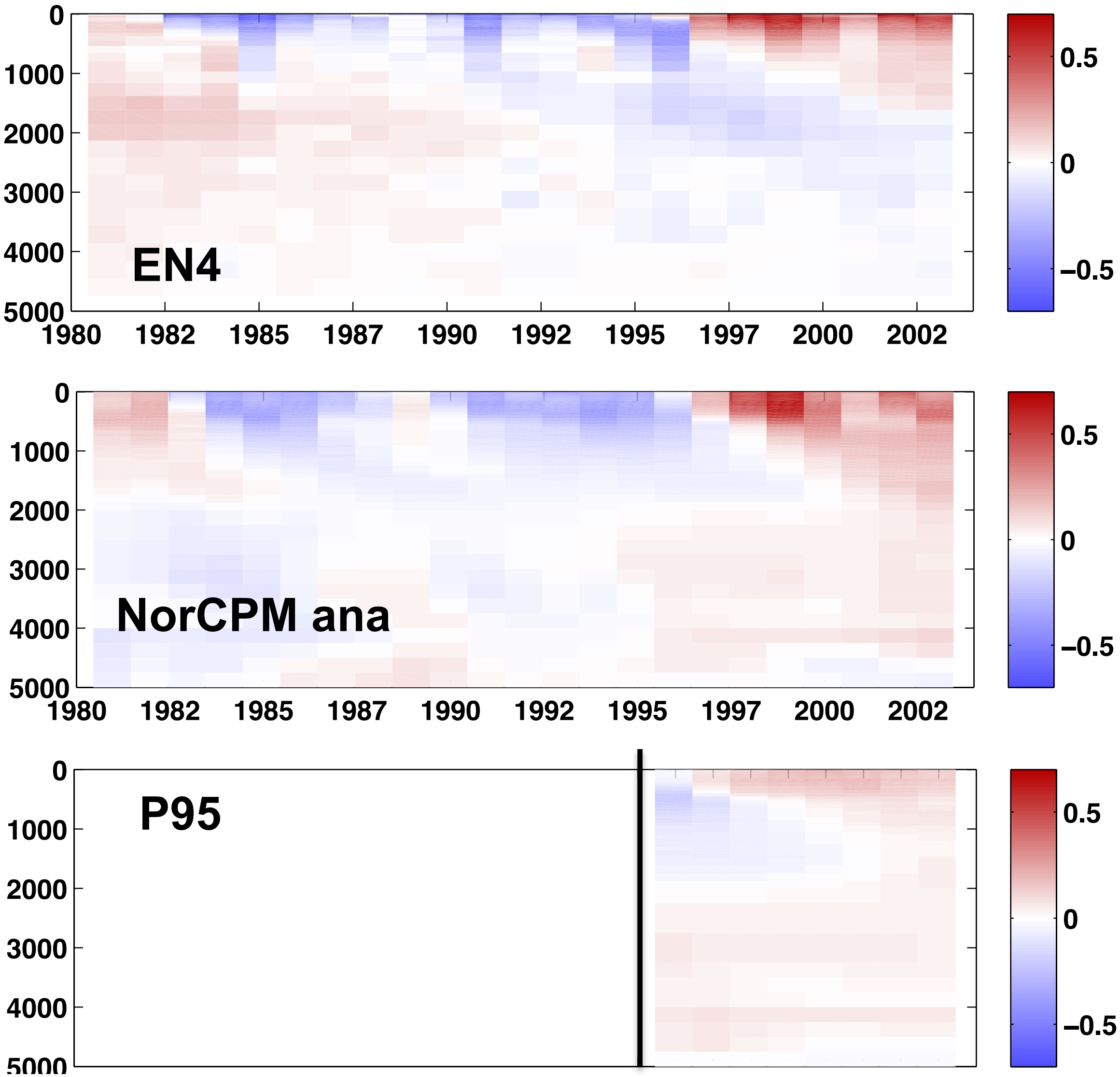
SPG temperature anomaly 1980-1995



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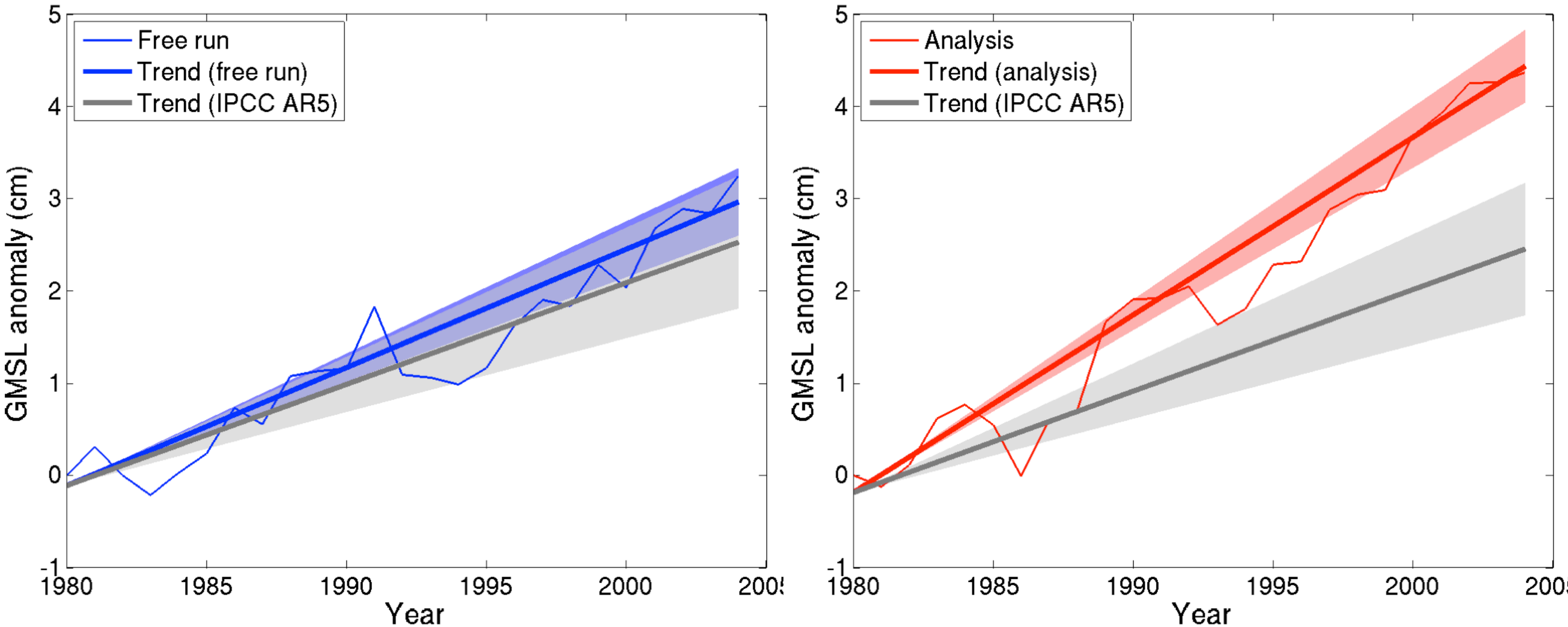
Data assimilation introduces a drift

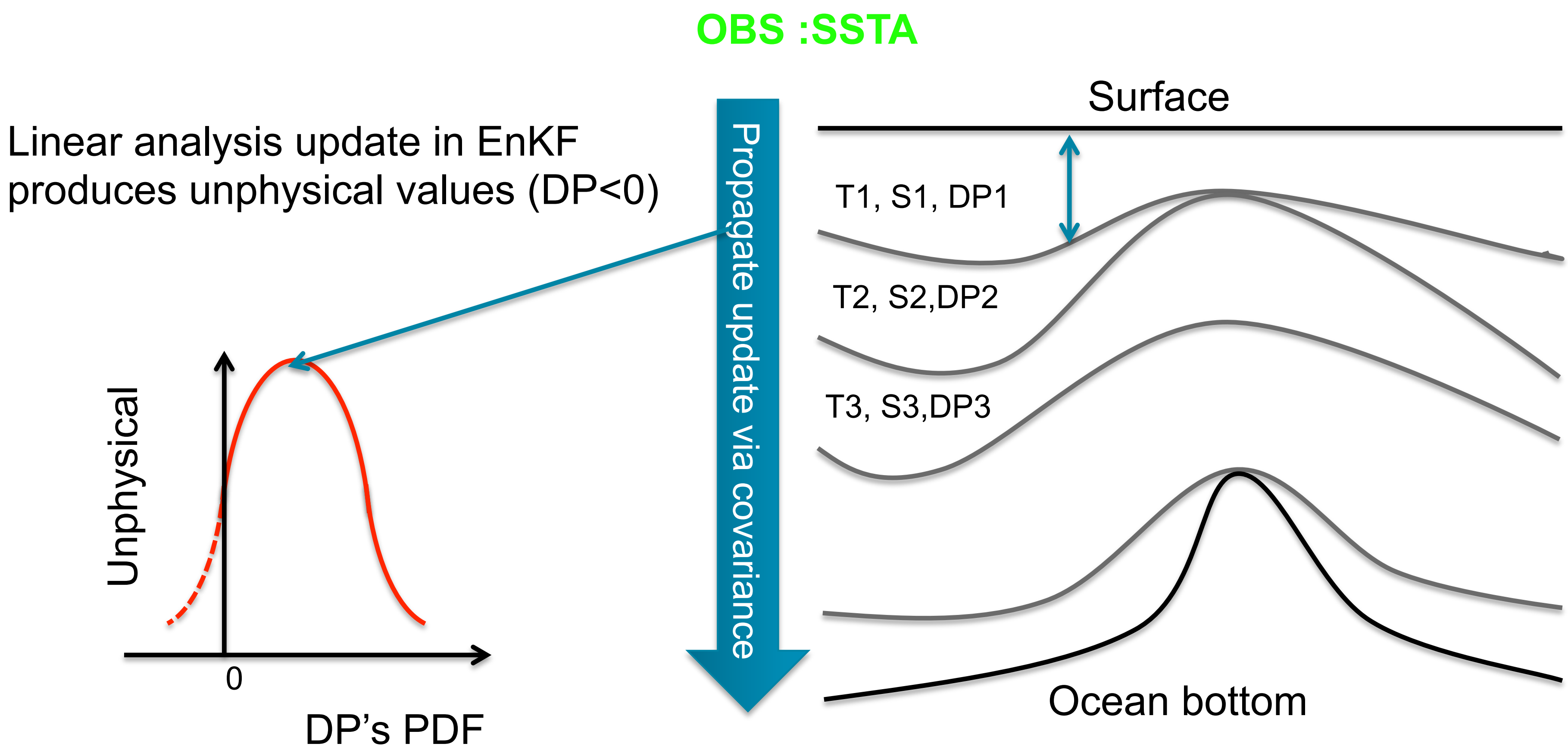
Assimilation of layer thickness is :

profitable but **introduces a drift**

Degradation of the water masses at intermediate depth induces an artificial drift in the steric mean sea Level



The Norwegian Climate Prediction model



Correcting for those unphysical value inevitably introduces a drift

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Physical constraints in NorCPM

–Non-negative layer:

$$\forall\ 1 \le i \le m,\ 1 \le j \le l\quad \mathrm{DP}_a^{i,j} \ge 0,$$

–unbiased estimator of mass in each layer:

$$\forall\ 1 \le j \le l\quad \mathrm{E}(a\rho^j \overline{\mathrm{DP}}_a^j) = \mathrm{E}(a\rho^j DP_t^j),$$

–unbiased estimator of heat in each layer:

$$\forall\ 1 \le j \le l\quad \mathrm{E}(ac_p\rho^j \overline{\mathrm{DP}}_a^j \overline{\mathrm{T}}_a^j) = \mathrm{E}(ac_p\rho^j DP_t^j T_t^j),$$

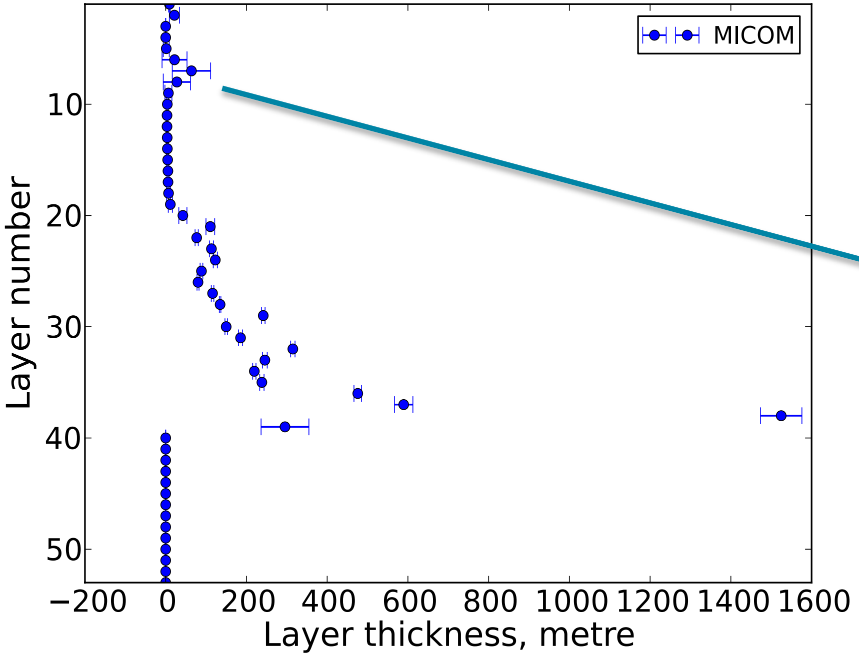
–unbiased estimator of salt in each layer:

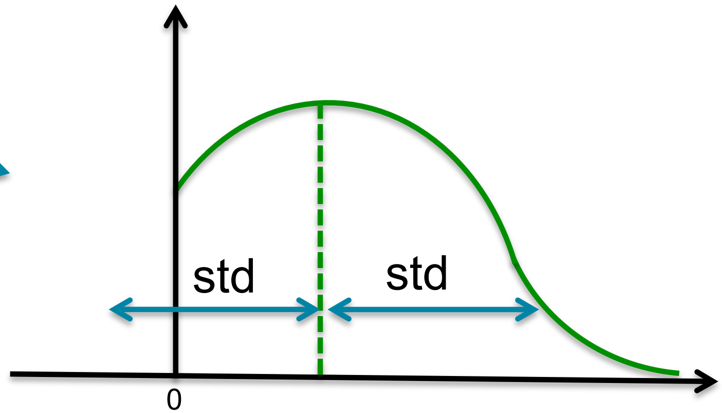
$$\forall 1 \le j \le l\quad \mathrm{E}(a\overline{\mathrm{DP}}_a^j \overline{\mathrm{S}}_a^j) = \mathrm{E}(aDP_t^j S_t^j),$$

t denote 'truth', m ensemble size; l nb of vertical layers; ***E(•)*** *expected value of a infinite number of assimilation*
a: grid cell area (m^2); ρ water density ($kg\ m^{-3}$), c_p: sea water specific heat capacity ($J\ kg^{-1}K^{-1}$)

Upscaling (aggregating) method:

Main idea

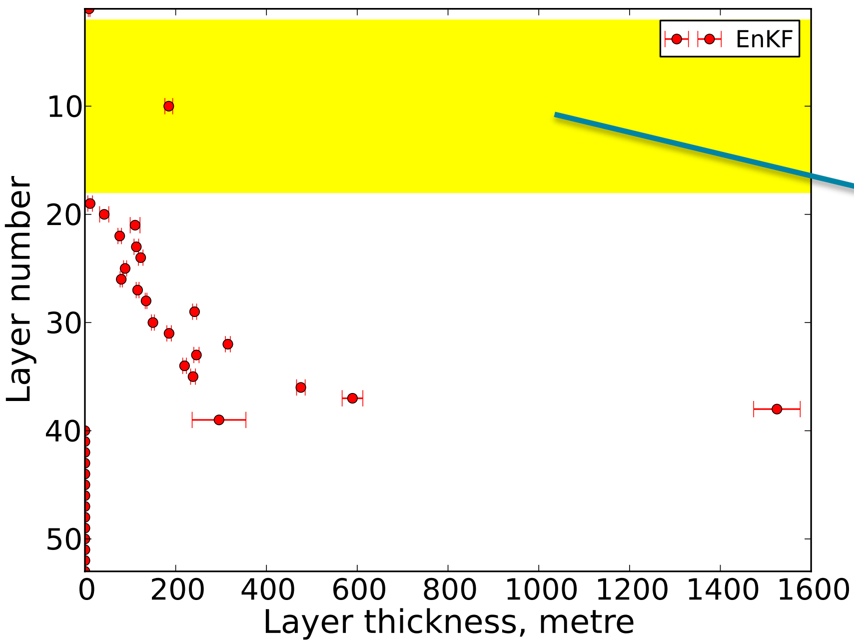


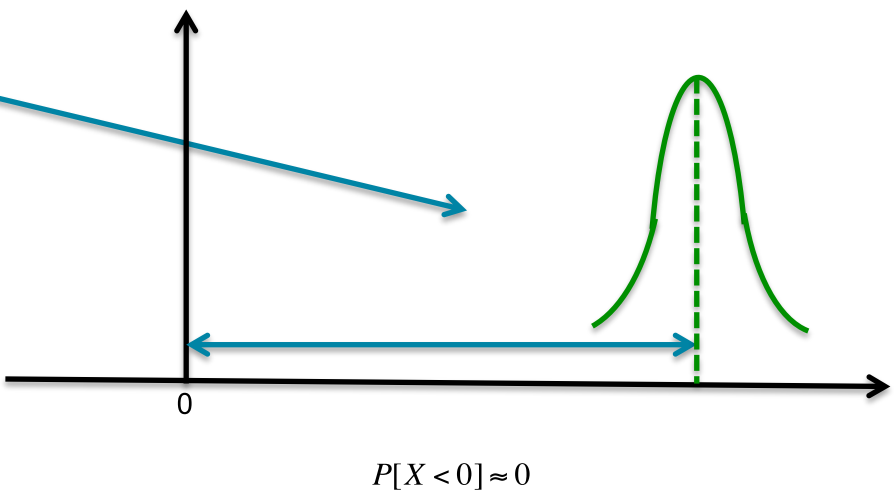


Upscaling (aggregating) method:

Main idea

By upscaling (or aggregating) we are moving the pdf away from the constraint and shrinking the spread ➔ risk of getting a unphysical value reduced

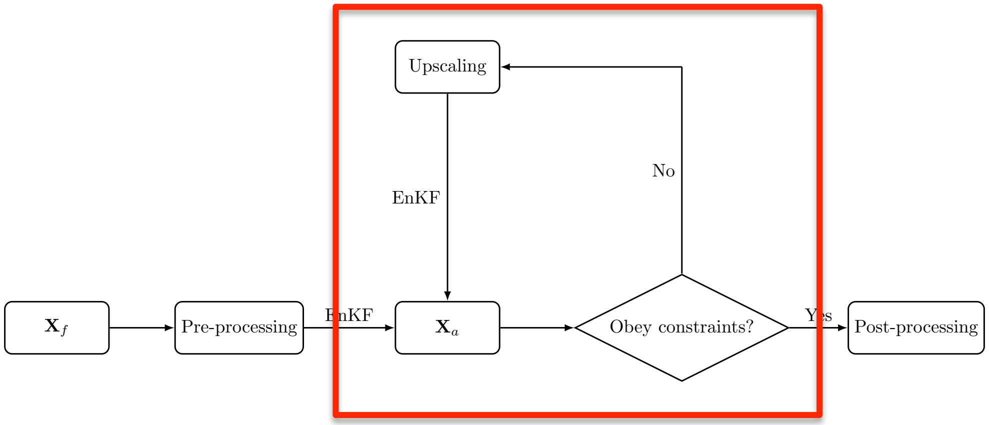


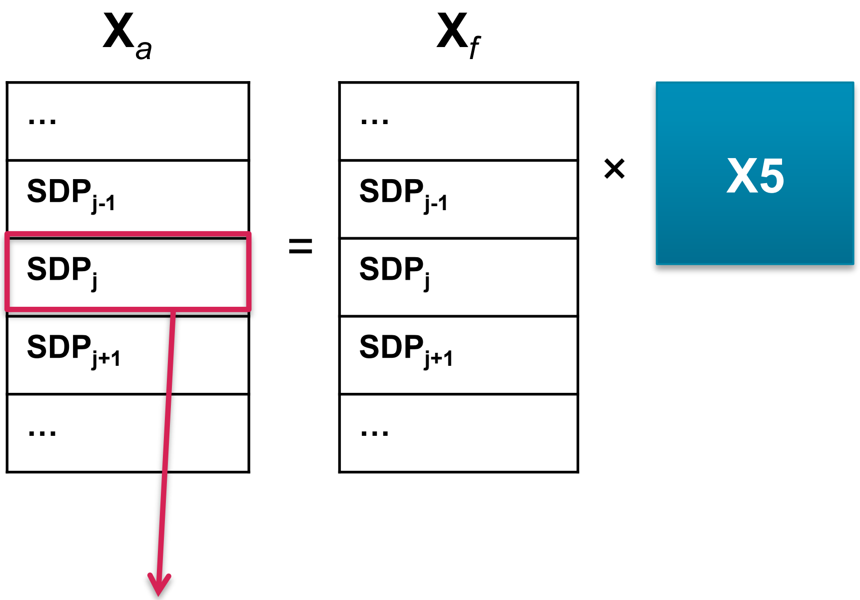


Upscaling (aggregating) method:

iterative method

Processing: updating of **T, S** and **SDP**



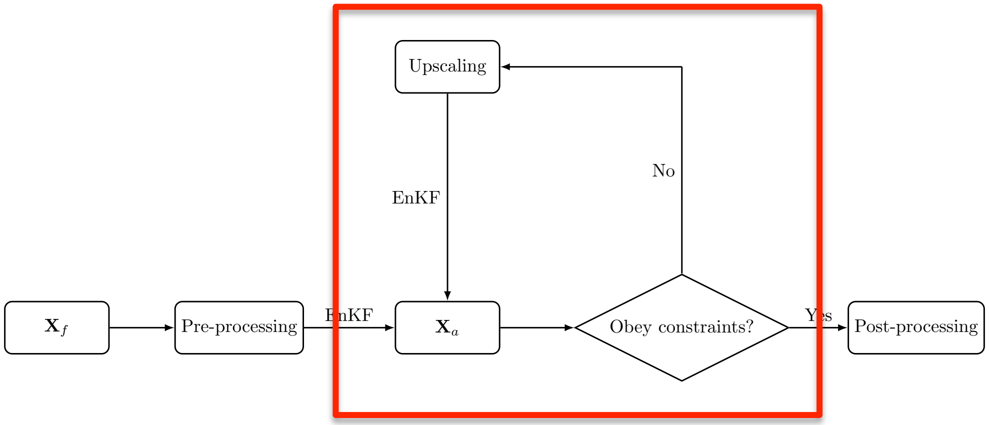


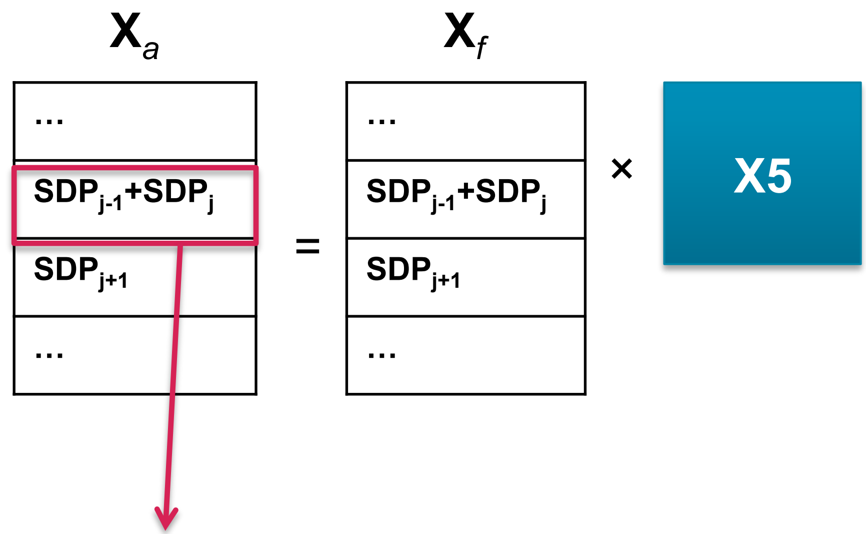
If negative ?

Upscaling (aggregating) method:

iterative method

Processing: updating of **T, S** and **SDP**

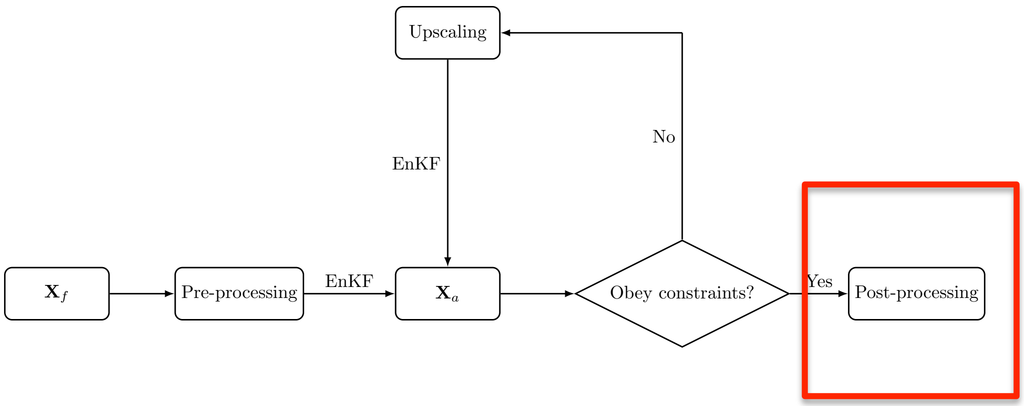




If not negative we redistribute the update

Upscaling (aggregating) method:

Post-processing



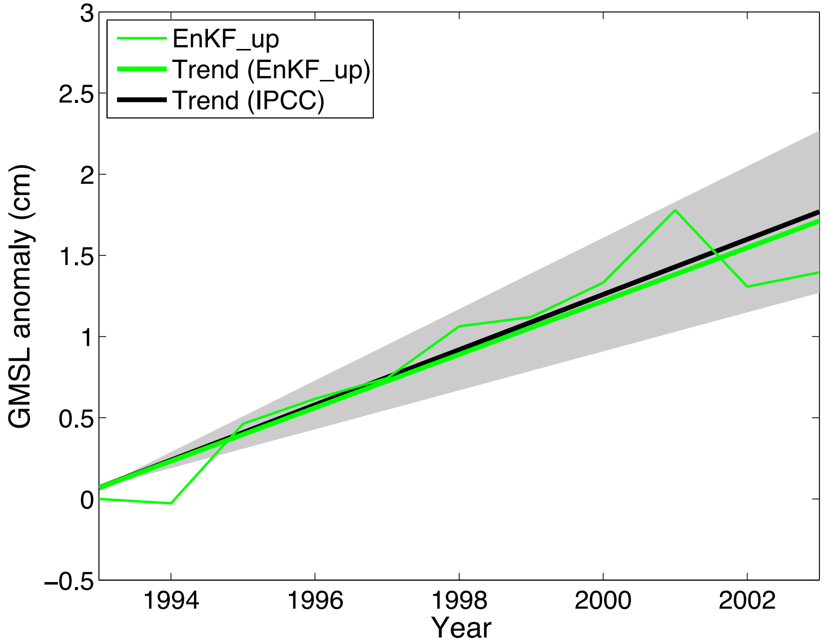
Post-processing: Distribution of **SDP**$_a$

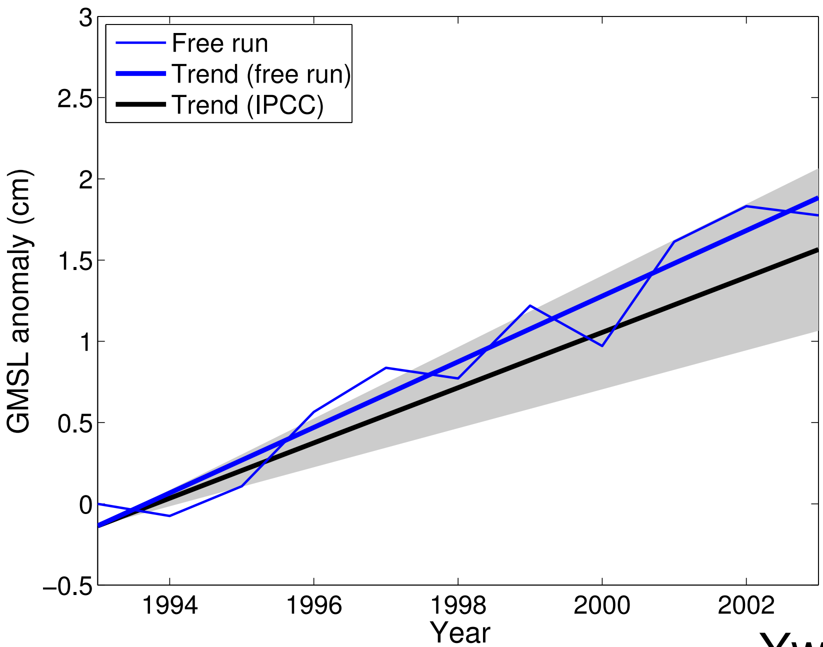
$$\forall\ 1 \le i \le m,\ j_0 \le j \le j_1,$$

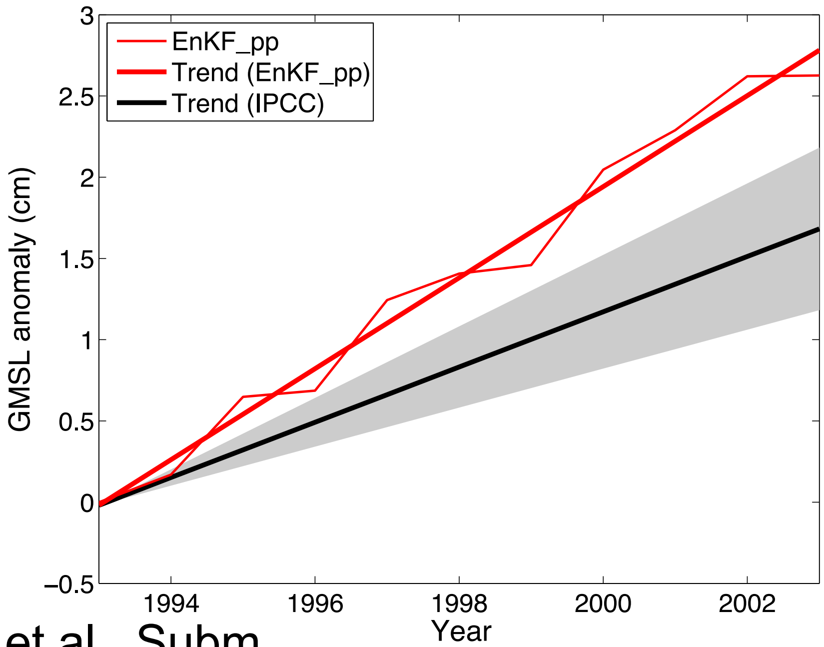
$$\mathrm{DP}_a^{i,j} = \frac{\mathrm{DP}_f^{i,j}}{\mathrm{SDP}_f^{i}} \times \mathrm{SDP}_a^{i},$$

Demonstration in real framework

Method demonstrated in real framework and reduces drift down by a factor 10

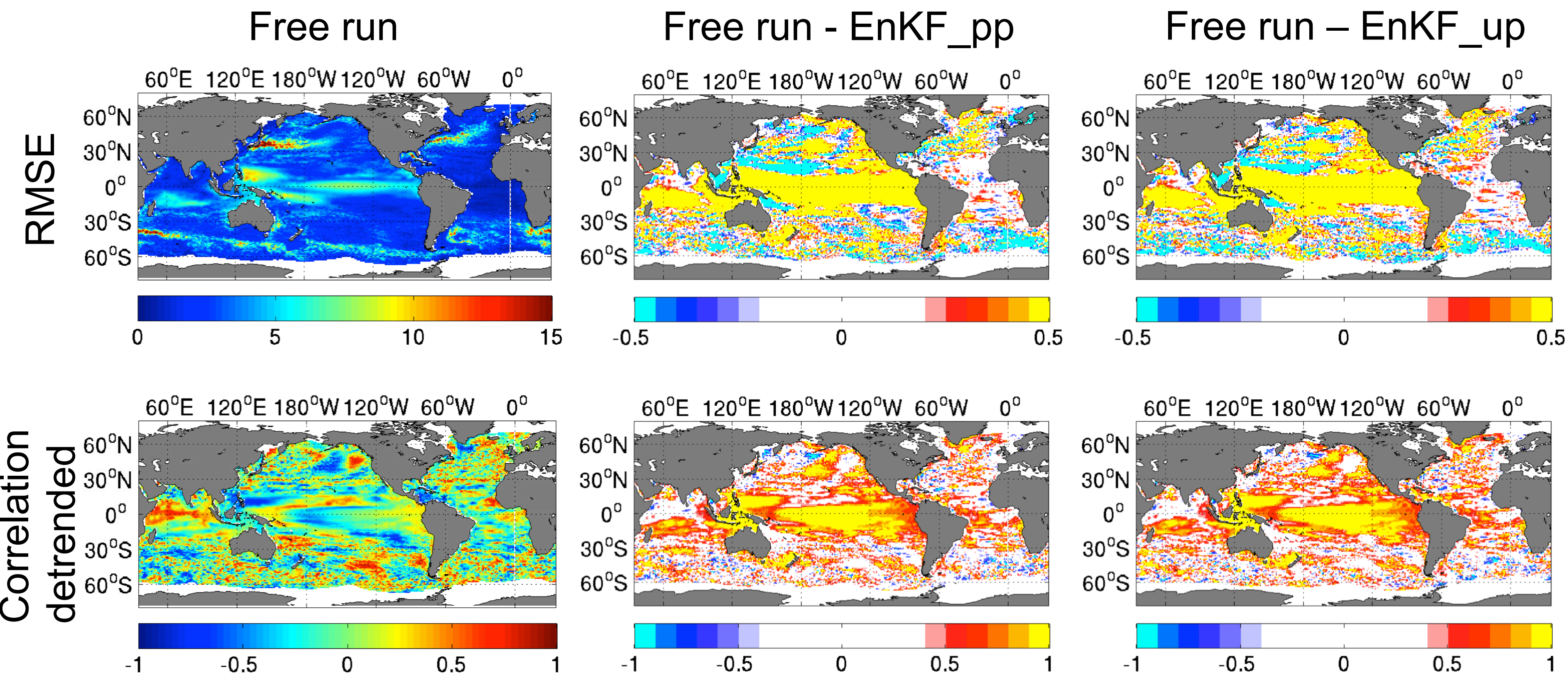






Ywang et al. Subm.

Validation with SSH data



Conclusion

- Assimilation of SST in twin experiment shows:
  - Decadal prediction skill (AMOC, SPG, Nordic HC)
  - Assimilation in isopycnal coordinate introduce drift

Counillon et al. 2014

- Assimilation of SST in real framework (1980-2005):
  - Shows skill against independent data (SSH, T-S profile)
  - Predictability reduced compare to twin exp
    - No skill for prediction in the Nordic Sea

Counillon et al. in prep

- The aggregation method handle drift caused by data assimilation for variable with a constrain:
  - Annihilates drift for DA with single member (3D-var, 4D var, EnOI) some drift remains for ensemble method (reduce by factor 10)
  - Methods does not impair predictive skill

Wang et al. subm.