Atmospheric constrain in NorCPM

Lilian Garcia-Oliva[1], François Counillon[2], Ingo Bethke[1], Noel Keenlyside[1] and Lea Svendsen[1]

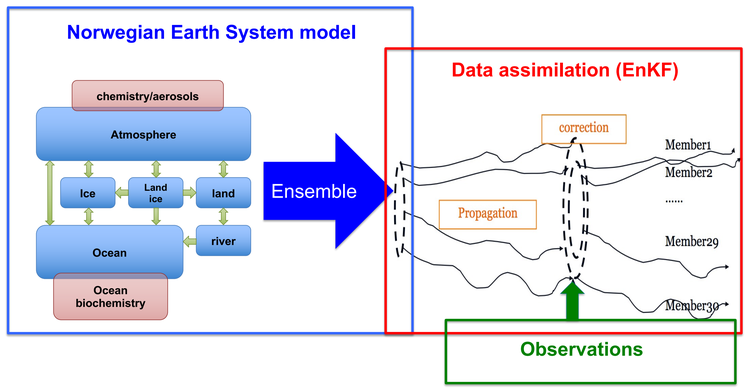
[1]University of Bergen and Bjerknes Centre for Climate Research [2]Nansen Environmental and Remote Sensing Center and Bjerknes Centre for Climate Research

Introduction

Seasonal-to-decadal (S2D) prediction depends predominantly on the initialisation of the ocean component. The Norwegian Climate Prediction Model combines the Norwegian Earth System Model and the Ensemble Kalman Filter data assimilation and is currently tailored for S2D by assimilating data in the ocean and sea ice component. However, subseasonal-seasonal (S2S) predictions rely also partly on the initialisation of the atmosphere and land component of the Earth System. Using an assimilation cycle sufficiently short to constrain the atmosphere (typically **6 h**) is computationally out of reach with NorCPM. We aim to test the potential of atmospheric nudging to enhance the accuracy of the ocean data assimilation by better constraining the atmospheric state within the ensemble so that errors in the linear analysis update are reduced.

NorCPM: Norwegian Climate Prediction Model

NorCPM[1;2] combines the Norwegian Earth System Model (NorESM) and the Ensemble Kalman filter[3]. It performs monthly anomaly assimilation of SST, salinity and temperature vertical profiles in the version tested. A schematic of the system is shown below:



Experimental design

We use anomaly nudging of (U, V, T). The prescribed data is ERA-interim. Maximum nudging strength varies with height, as in Figure 1. The impact of different nudging strength τ on the performance of reanalyses with monthly ocean assimilation is compared for the 1980 - 1990 period. ODA using SST, (T, S) using 30 ensemble members. Table 1 summarizes the settings and experiments.

Figure 1. Nudging strength with height.

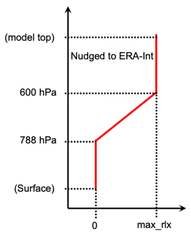
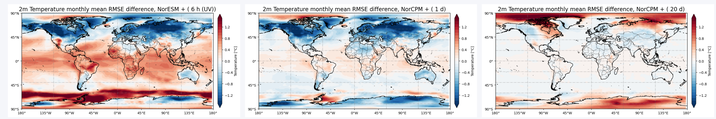


Table 1. Setting for experiments.

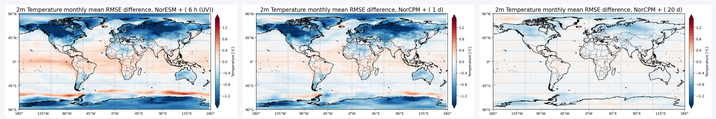
Case	ODA	Atmo. nudging	τ
NorCPM-00	yes	no	–
NorCPM-6h	no	yes	**6 h**
NorCPM-1d	yes	yes	**1 d**
NorCPM-20d	yes	yes	**20 d**

Results

RMSE difference (a) - (c), and bias free RMSE difference (d)-(f) for **2 m** temperature in °C. Difference with respect to NorCPM-00. Red/blue: increase/decrease of error.

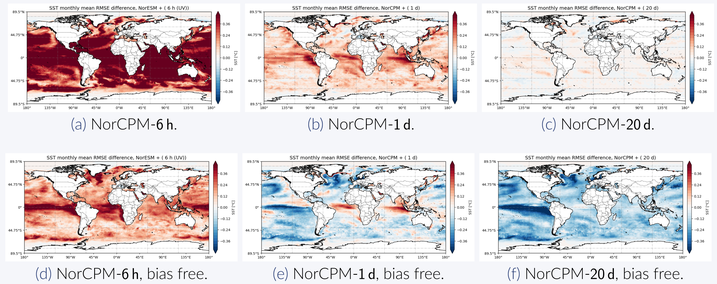


(a) NorCPM-**6 h**. (b) NorCPM-**1 d**. (c) NorCPM-**20 d**.



(d) NorCPM-**6 h**, bias free. (e) NorCPM-**1 d**, bias free. (f) NorCPM-**20 d**, bias free.

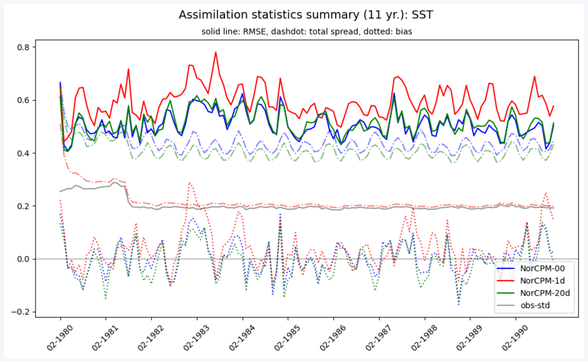
RMSE difference (a) - (c), and bias free RMSE difference (d)-(f) for SST in °C. Difference with respect to NorCPM-00. Red/blue: increase/decrease of error.



(a) NorCPM-**6 h**. (b) NorCPM-**1 d**. (c) NorCPM-**20 d**.

(d) NorCPM-**6 h**, bias free. (e) NorCPM-**1 d**, bias free. (f) NorCPM-**20 d**, bias free.

RMSE (solid line), ensemble spread (dashdot line) and bias (dotted) of experiments with ODA. We see NorCPM-00 (blue), NorCPM-1d (red) and NorCPM-20d (green). The solid gray line represents observations spread.

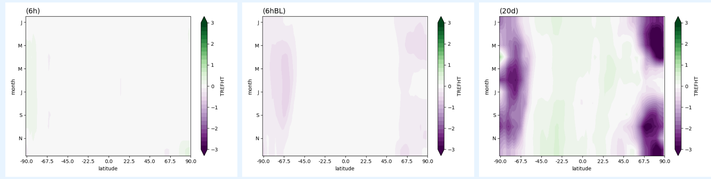


What causes the bias?

To diagnose the cause of the bias we performed a perfect framework experiment. One member simulations with full field nudging of (U, V, T). Use of perfect synthetic observations and different nudging strengths (i.e. τ = **6 h** –**20 d**). We checked also the role of boundary layer nudging. No ocean data assimilation. The climatology was compared for the period 1980 - 2000, compared to true run.

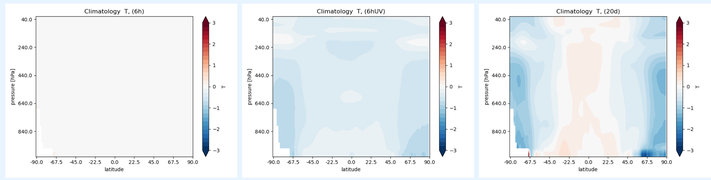
We identified that nudging introduces a cold bias in the atmospheric state. The maximum bias is over the poles. The zonal distribution of the bias is also present at all atmospheric levels.

Climatological bias of T2m in °C. Green/purple warm/cold bias with respect to true run.



(a) NorESM-**6 h**. (b) NorESM-**6 h** BL tapering. (c) NorESM-**20 d**.

Vertical distribution of Temperature in °C. Red/blue warm/cold bias with respect to true run.



(a) NorESM-**6 h**. (b) NorESM-**6 h** BL tapering. (c) NorESM-**20 d**.

Summary

- In general, ocean data assimilation alone provides a better initialization.
- Atmospheric nudging improves performance over land and over the ocean with weak nudging. It also preserves reliability.
- Atmospheric nudging introduces a bias in the climatology of both ocean and atmosphere.
- The bias is reproducible in perfect model framework.
- The origin of the bias is still unclear. Ongoing analysis of meridional heat transport and ocean overturning will be carried to identify its cause.

References

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[2] François Counillon, Noel Keenlyside, Ingo Bethke, Yiguo Wang, Sebastien Billeau, Mao Lin Shen, and Mats Bentsen. Flow-dependent assimilation of sea surface temperature in isopycnal coordinates with the Norwegian Climate Prediction Model. *Tellus, Series A: Dynamic Meteorology and Oceanography*, 68(1):32437, 2016.

[3] Geir Evensen. The Ensemble Kalman Filter: Theoretical formulation and practical implementation. *Ocean Dynamics*, 53(4):343–367, 2003.

Lilian.Garcia@uib.no