Assessing the Impact of Initialization Methods on Seasonal-to-Decadal Climate Predictions: Comparing Atmosphere and Ocean Constraints

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Introduction

The challenge in developing reliable seasonal-to-decadal (S2D) climate predictions lies in finding the best combination of initialization methods that effectively constrain the atmospheric and/or oceanic states while also addressing the significant biases present in current models through full-field (FF) or anomaly-field (AF) initialisation. We focus on the atmospheric constraint and compare its benefit against ocean initialisation or their combination.

Experimental design

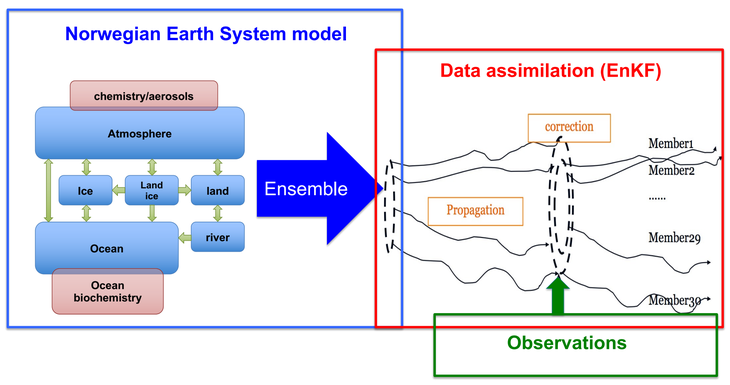
We evaluate the performance of each initialisation method to provide skilful reanalysis and good initial conditions for seasonal and decadal predictions. The reanalyses are done using a 30-member ensemble for 1980-2010. Seasonal hindcasts start each Feb, Mar, Aug and Nov (1985-2010). Decadal hindcasts start each November every other year (1985-2010). Each hindcast consists of 9-member ensemble runs.

Table 1. Configurations summary.

Configuration	Ocean DA	Atmo nud (6 h)	Assimilated variables[a]	E. F.[b]
NudF-UVT	-	FF	(U, V, T)	-
NudA-UVT	-	AF	(U, V, T)	-
NudA-UV	-	AF	(U, V)	-
NudA-UV (EF)	-	FF	(U, V)	yes
ODA	AF	AF	[SST, T, S]	-
ODA+NudA-UV	AF	AF	[SST, T, S] + (U, V)	yes
Free	-	-	-	-

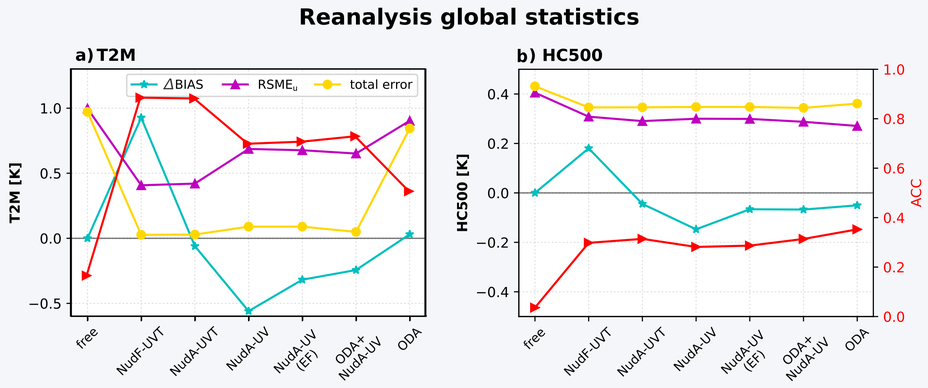
[a]Variables in squared brackets (parenthesis) denote ocean (atmosphere) observations.
[b]E. F. is for Energy Fix.

We performed our experiments in the context of the Norwegian Climate Prediction Model (NorCPM[1;2]). In the atmosphere, we use nudging towards ERA-interim. In the ocean, we use the Ensemble Kalman Filter (EnKF[3]). The data assimilated is the HadISST2 for the SST and EN4.2.1 for salinity and temperature profiles.



Results I: Reanalysis- Global statistics

Global statistics of reanalysis on the 1980-2010 period for a) T2M, b) HC500. Left hand y-axis (in black) corresponds to $RMSE_u$ (magenta), ΔBIAS (cyan) and total error (yellow). The red right-hand y-axis corresponds to ACC (red). The reanalyses are said to be reliable when the total error (yellow) and $RMSE_u$ (magenta) overlap.

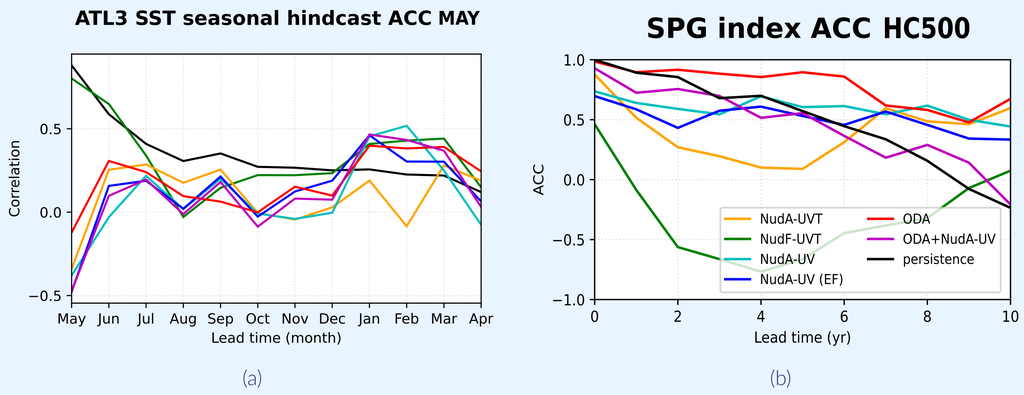


- Atmospheric nudging constrains well atmospheric variability; ODA is poor there.
- ODA performs best in the ocean (SST, HC, SC).
- Unlike anomaly nudging, Full-field nudging introduces a large climatological change (cyan lines).
- Energy fix only reduces the bias change with anomaly momentum nudging.
- Atmospheric nudging collapses the ensemble spread at the ocean surface and degrades ODA impact.

Full-field or Anomaly-field: When is bias correction beneficial?

(a) Seasonal hindcast SST skill of Atlantic Niño (ATL3). Line colour green corresponds to NudF-UVT, orange to NudA-UVT, cyan to NudA-UV, blue to NudA-UV (EF), red to ODA and magenta to ODA+NudA-UV, and persistence is the solid black line.

(b) ACC as a function of lead time in the SPG box for a) HC500 and b) SST. The line colour green corresponds to NudF-UVT, orange to NudA-UVT, cyan to NudA-UV, blue to NudA-UV (EF), red to ODA and magenta to ODA+NudA-UV, the black line is persistence.

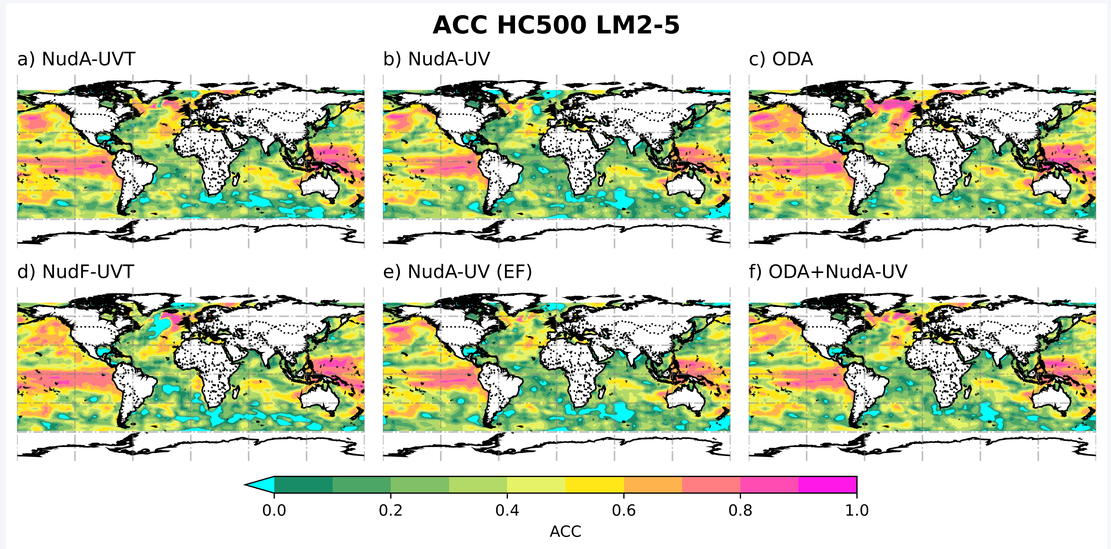


(a) (b)

It depends on the region and time scale: In the ATL3, the correction of the bias (using FF) improves the predictive seasonal skill (up to the 1st. lead month). However, the initialization introduces large drifts at longer scales, as in the SPG. For longer time scales (years), it is better to use AF.

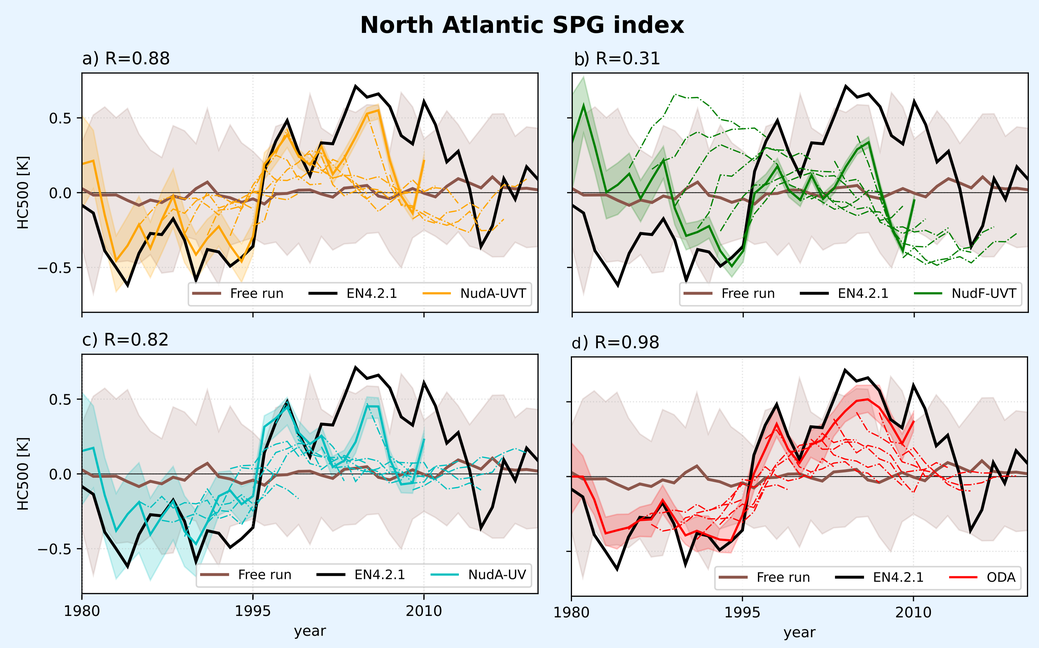
Results II: Seasonal hindcasts

Seasonal hindcast 2-5 lead-month HC500 ACC. Green-to-magenta colours indicate positive ACCs, and cyan colour indicates all negative ACCs.



Regional case: North Atlantic Subpolar Gyre

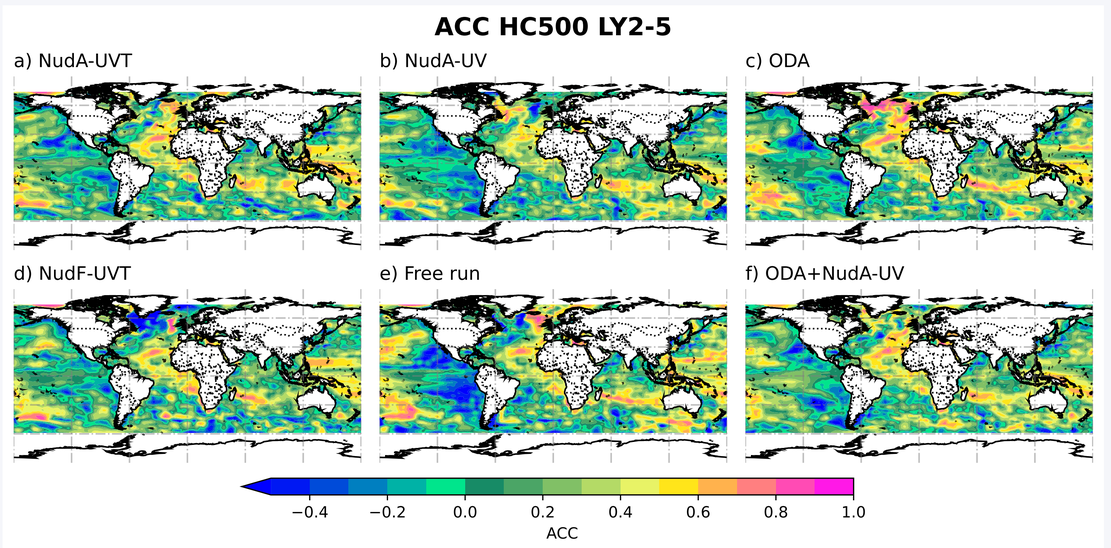
HC500 anomalies over the SPG box (48°-65°N, 60°-15°S). a) NudA-UVT, b) NudF-UVT, c) NudA-UV, d) ODA. Solid coloured lines represent the ensemble mean of reanalysis, dash-dot lines correspond to hindcast experiments, and the solid brown line is the free run. Shading denotes ensemble minima and maxima. The solid black line corresponds to EN4.2.1 observations.



- NudF-UVT performs poorer than NudA-UVT.
- ODA provides the best reanalysis, but using wind constraints better captures the 1995 shift.
- NudA-UVT provides a better reanalysis than NudA-UV; however, its hindcasts are poorer.

Results III: Decadal hindcasts

Decadal hindcast 2-5 lead year ACC for HC500. Green-to-magenta colours indicate positive ACCs, while cyan-to-blue colours indicate negative ACCs.



Summary

- ODA overall performs best, but each system has some assets in some regions.
- FF achieved the best skill in the tropical Atlantic where bias is important.
- Atmo nudging better captures the 1995 SPG shift (NAO pre-conditioning)
- Atmospheric full-field initialization introduces a large drift
- Nudging atmospheric momentum is important for decadal variability.
- Atmospheric nudging collapses ensemble spread at the ocean surface, making the ODA less effective.

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.

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