Influence of Initialization Method on the Quality of Decadal Climate Predictions

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1. Introduction

The results presented here are part of a project whose aim is to test and develop methods in order to **improve** the **quality** and the **reliability** of **decadal climate predictions**.

We are currently focusing on the **estimate of the initial condition (IC).** Indeed, optimal estimate of the IC is required in order to perform accurate and reliable decadal predictions. **Data assimilation (DA)** methods can provide an optimal estimate of the initial state given inaccurate and incomplete observations and imperfect model equations.

2. Methodology

Different methods are being tested with the coupled climate model **LOVECLIM** [1] which

- is a 3D Earth system model of intermediate complexity;
- presents a lower level of complexity and a coarser resolution than general circulation model (GCM);
- has a lower computational cost than GCM.

➡ allows us to realize a large number of tests within a reasonable computational time.

Hindcast experiments spanning the last 70 years are performed. 2 data assimilation methods are used to provide initial condition for hindcasts. The accuracy of these hindcasts is assessed by comparing their results with available observations.

In order to take into account uncertainties on the estimate of the initial state, **ensemble simulation** method is used.

3. Data Assimilation Methods

Particle Filter with Resampling

The particle filter with resampling [2] has been used for seasonal DA of the surface temperature, over a 2D box spanning the area northward of 30°N.

Starting from some initial conditions, an ensemble of 96 simulations (the *particles*) is propagated with the model for a period of 3 months. Then, a weight is calculated following the likelihood of each particle. The closer to the observations the particle is, the higher the weight is.

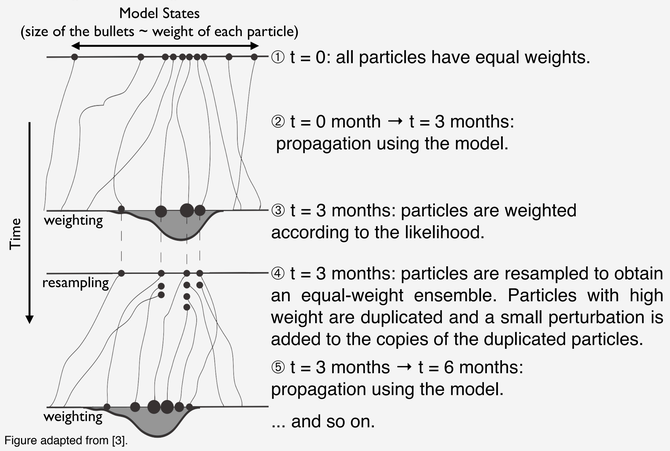


Figure adapted from [3].

Nudging

It consists of adding to the model equations a term that nudges the solution towards the observation.

In LOVECLIM, this is done by adding to the heat flux between the atmosphere and the ocean the following term (for each grid point of the ocean free of sea ice):

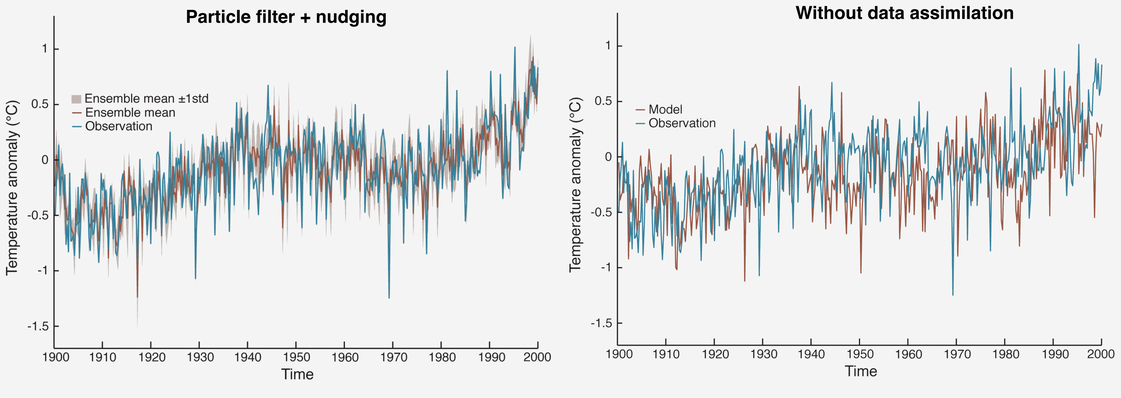
$$-k(T_{mod} - T_{obs})$$

where T_{mod} is the surface temperature calculated by the model and T_{obs} is the observed surface temperature, k is the relaxation coefficient. Here, this coefficient has been chosen such that it corresponds to a relaxation time of 6 months. The nudging term has been limited to a maximum flux of 50 Wm^{-2}.

4. Reconstruction of the Surface Temperature between 1900 and 2000

Observed surface temperature anomalies are taken from the HadCRUT3 [4] dataset.

Seasonal mean of the surface temperature anomaly averaged over the area northward of 30°N.

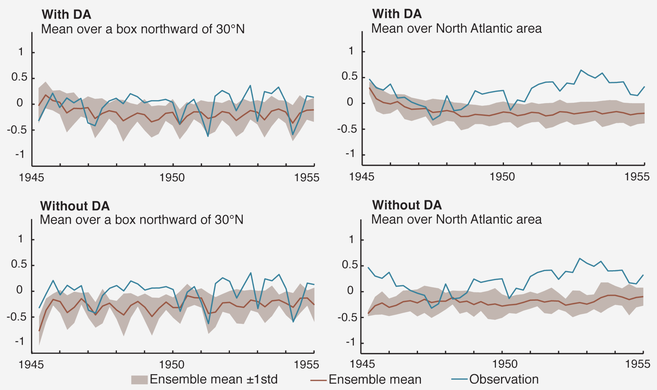


Data assimilation provides better results for surface temperature reconstruction, especially in summer.

5. Hindcasts Experiments

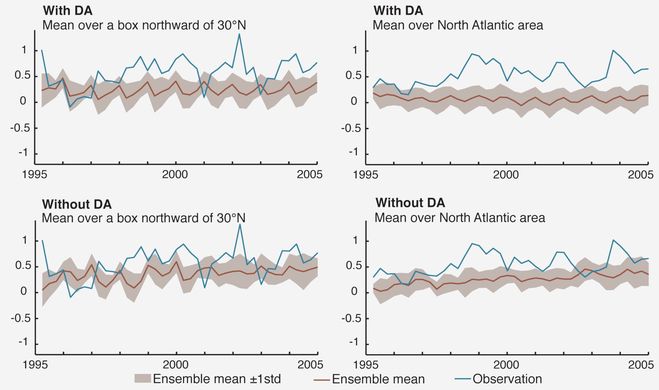
Hindcasts are performed for a 10-years period and start in January every 5 years from 1940 to 2000. For each time period, 2 hindcasts are run: one whose initial condition has been extracted from the simulation with data assimilation (**hindcasts with DA**) and the other one which is initialized from a run without data assimilation (**hindcasts without DA**). For hindcasts with DA, 96 members are chosen in function of their weights calculated by the particle filter.

1945-1955 hindcast for the surface temperature anomaly (°C)



Hindcast with DA starts with a state close to the observation and follows it towards the model climatology during 3 years. Then, the observations roll away from the model climatology while the hindcast oscillates around it. Without DA, IC is too far from the observed state to provide any predictability.

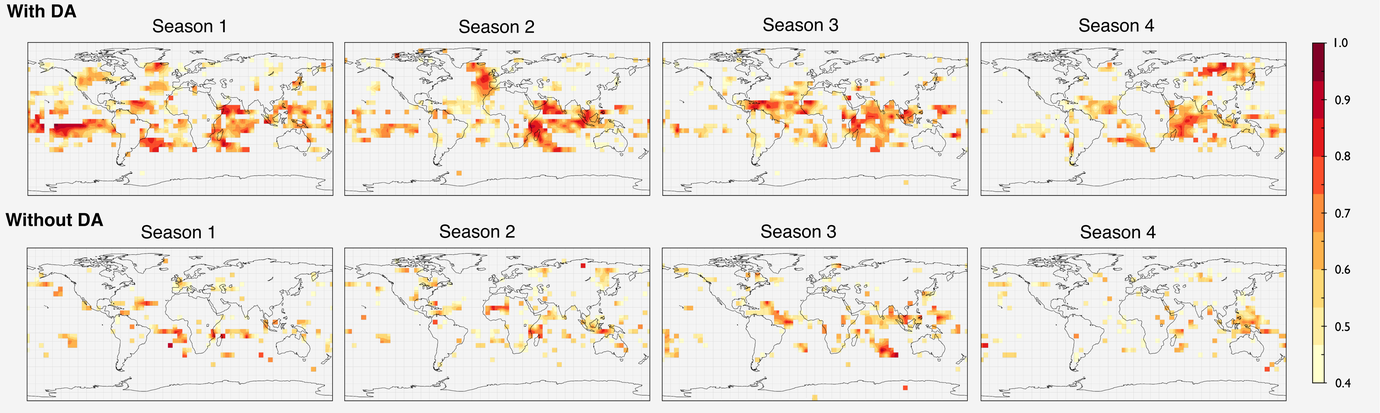
1995-2005 hindcast for the surface temperature anomaly (°C)



Both IC with and without DA are too far from the observed state. Hindcasts oscillate around the model climatological mean. Observation presents important anomalies that the model is not able to reproduce. Here, none of the IC is able to provide any predictability.

Spatial Distribution of the Correlation between Observations and Hindcasts [5]

Only significant (95% level) correlations are shown on the figures below.



During the 4 first seasons, correlation for hindcasts initialized with DA is higher and significant in wider area than the one of hindcasts initialized without DA, especially in the Atlantic and in the Indian Ocean.

6. Discussion

The quality of the predictions performed with LOVECLIM using initial conditions obtained thanks to the assimilation of observed surface temperature is not very high.

Hindcasts performed with these initial conditions show that the model tends to drift toward its climatology and its dynamics is not able to create anomalies such as those appearing in the observations.

7. Next Steps

- Improvement of the data assimilation method.
- Assimilation of 3D temperature in the ocean.

References

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[2] Dubinkina S. et al., 2011. Testing a particle filter to reconstruct climate changes over the past centuries, Int. J. Bifur. Chaos (to appear).
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[4] Brohan P. et al., 2005. Uncertainty estimates in regional and global observed temperature changes: a new dataset from 1850. J. Geophys. Res, 111, D12106, 10.1029/2005JD006548.
[5] Pohlmann, H. et al., 2009. Initializing Decadal Climate Predictions with the GECCO Oceanic Synthesis: Effects on the North Atlantic. J. Climate, 22, 3926–3938, 10.1175/2009JCLI2535.1