Influence of Initialization Method and Systematic Model Errors on the Quality of Decadal Climate Predictions

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Introduction

Objectives
The aim of this project is on the one hand to test and develop methods in order to improve the quality and the reliability of decadal climate predictions, i.e. predictions for several years to a few decades ahead. On the other hand, this study will allow to identify processes capable of providing reliable sources of predictability.

Motivation
Decadal predictions are a recent topic in climate research. Several recent syntheses agree on the point that methods able to reduce the uncertainties on such predictions are at their very beginning. Moreover, decadal time-scale is widely recognized as a key planning horizon in the decision-making processes of several socio-economic sectors.

Decadal Climate Predictions

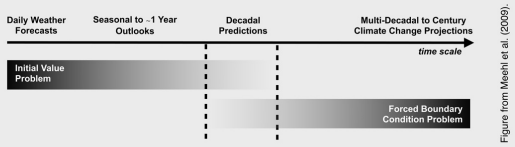


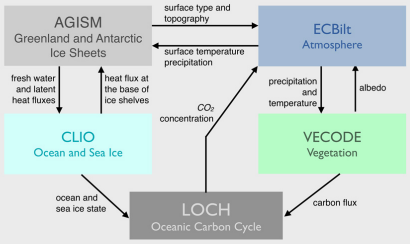
Figure from Meehl et al. (2009).

Decadal predictions bridge the gap between seasonal-to-interannual predictions and long-term projections. We face a mixed problem between two kinds of predictions in which we have to analyze at the same time changes due to natural climate variability and those resulting from external forcing (of natural and anthropogenic origin).

Methodology

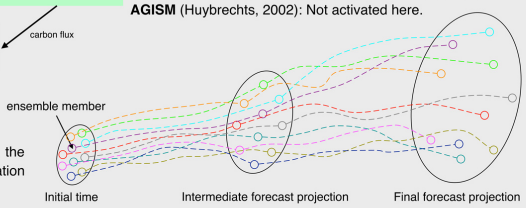
Here we are performing systematic tests for some available methods and for methods which haven't been used for decadal predictions yet. By comparing the quality and the accuracy of predictions based on the use of these methods, we will be able to point out the ones which are best suited and therefore to improve the current methodology.

The Model
Systematic tests for different methods are being performed with the coupled climate model **LOVECLIM**. It is a 3D Earth system model of intermediate complexity (EMIC). It presents a lower level of complexity and a coarser resolution than general circulation model but has a lower computational cost. This allow us to realize systematic tests with reasonable computational time.



LOVECLIM is made up of 5 interacting components:
ECBilt (Opsteegh et al., 1998): Quasi-geostrophic atmospheric model (prescribed cloudiness; T21, L3).
CLIO (Goosse and Fichefet, 1999): Ocean general circulation model coupled to a thermodynamic-dynamic sea ice model (3° x 3°, L20).
VECODE (Brovkin et al., 2002): Reduced-form model of the vegetation dynamics and of the terrestrial carbon cycle (same resolution as ECBilt).
LOCH (Mouchet and François, 1996): Not activated here.
AGISM (Huybrechts, 2002): Not activated here.

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



Three Important Sources of Uncertainties on Decadal Climate Predictions

Initial Condition Estimate
Observations are imperfect and incomplete but data assimilation methods can provide an optimal estimate of the initial condition given observations and model equations.

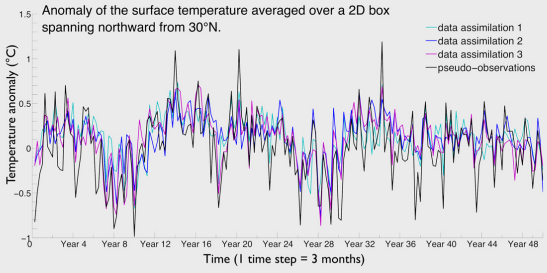
Perturbation of the Initial Condition
Initial spread of the ensemble impacts on the evaluation of the reliability of the prediction.

Systematic Model Errors
Models are approximation of the reality and present biases.

Preliminary Results

Twin Experiments
We have first performed seasonal data assimilation in twin experiments using a particle filter, i.e. assimilating pseudo-obervations extracted from the output of a particular simulation of the model (a 100 years run performed in preindustrial conditions).

Assimilation of Pseudo-Observations
The surface temperature was assimilated. These experiments differ by a scaling factor and a weight factor appearing in the error covariance matrix. Pseudo-observations are assimilated every 3 months during 100 years, over a 2D box spanning northward from 30°N. Results for the first 50 years are shown below.



Correlation between data assimilation results and pseudo-observations:

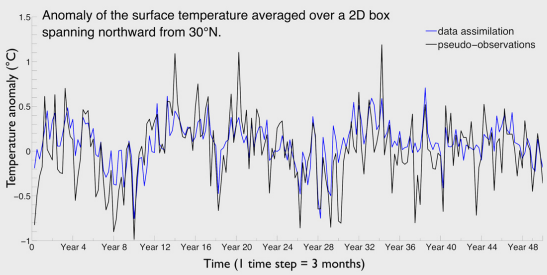
	Winter	Spring	Summer	Autumn
data assimilation 1	0,72	0,60	0,54	0,74
data assimilation 2	0,78	0,57	0,64	0,76
data assimilation 3	0,77	0,55	0,65	0,81

Correlation is always lower in spring and summer than in autumn and winter.

Root mean square error between data assimilation results and pseudo-observations:

	Winter	Spring	Summer	Autumn
data assimilation 1	0,36	0,25	0,13	0,29
data assimilation 2	0,33	0,26	0,12	0,28
data assimilation 3	0,33	0,26	0,12	0,26

Assimilation of Pseudo-Observations with Noise
A gaussian noise of variance 0.5 has been added on the pseudo-observations to mimic the error on observations. We used the scaling and weight factors which gave the best results for correlation in the previous twin experiments.



Correlation between data assimilation results and pseudo-observations:

Winter	Spring	Summer	Autumn
0,80	0,54	0,65	0,74

Even with imperfect pseudo-observations assimilated, results from data assimilation stay close to the 'true' surface temperature.

Root mean square error between data assimilation results and pseudo-observations:

Winter	Spring	Summer	Autumn
0,32	0,27	0,12	0,29

The Particle Filter with Resampling

In the framework of this project, the particle filter with resampling has been used for seasonal data assimilation.
Starting from some initial conditions, an ensemble of 96 simulations (the *particles*) is performed for a period of 3 months. Then a weight is calculated following the likelihood of each particle. The closer is the particle to the observations, the higher the weight is.

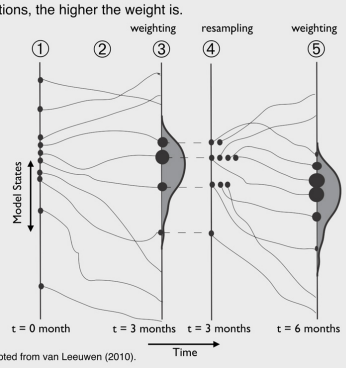


Figure adapted from van Leeuwen (2010).

The weight of each particle corresponds to the size of the bullets.

① t = 0: all particles have equal weight.

② t = 0 month → t = 3 months: propagation using the model.

③ t = 3 months: particles are weighted according to the likelihood.

④ t = 3 months: particles are resampled to obtain an equal-weight ensemble. Particles with high weight are duplicated and a small perturbation is added to the copies of the duplicated particle.

⑤ t = 3 months → t = 6 months: propagation using the model.

... and so on.

Next Steps

- Sesaonal assimilation with actual data observations.
- Monthly assimilation with pseudo-observations and actual data observations.
- Hindcast experiments over the last 50 years starting with initial condition provided by the particle filter method.

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