RECONSTRUCTIONS OF THE CLIMATE STATE OVER LAST CENTURIES USING PARTICLE FILTERING

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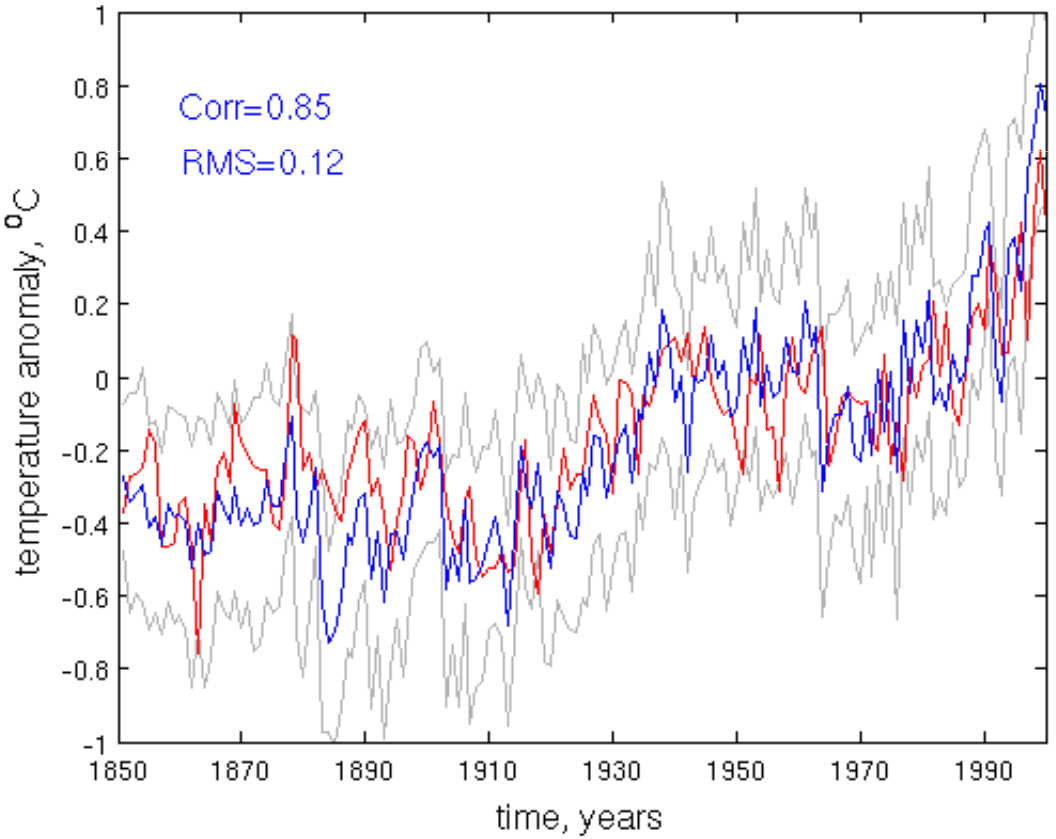
Background

- Particle filter with sequential importance resampling (the SIR method) was used with the climate model of intermediate complexity LOVECLIM employing only **96** particles (e.g., Goosse et al. 2011, Dubinkina et al. 2010).

Plot of surface air temperature anomalies averaged over 90N-30N from Dubinkina et al. 2010

- The time series of the instrumental records HADCRUT3 (Brohan et al. 2006) is in red.
- The ensemble average is in blue.
- Mean plus and minus one standard deviation is in grey.



Why did the SIR method work?

- The observations were very sparse: for example, only 7 observations were given in the area 90N-60N for year 1850 and 86 for year 2000.
- The number of degrees of freedom was reduced by performing spatial and temporal averages before computing the particles weights.
- As a result, we were able to reconstruct large-scale features averaged over one or few years.

What now?

- Now, we would like to have more detailed reconstructions, to study interannual variability of the past climate states.
- So, we will investigate how the SIR method (particle filter with sequential importance resampling) performs these tasks.
- And compare the SIR method to an extremely efficient particle filter and to a nudging.

Data-assimilation methods

- **Nudging**

is widely used in GCMs for initializing predictions.

- **Particle filter with sequential importance resampling (SIR)**

is degenerative when ensemble size is small and the system has many degrees of freedom but showed a good performance for paleoclimate applications.

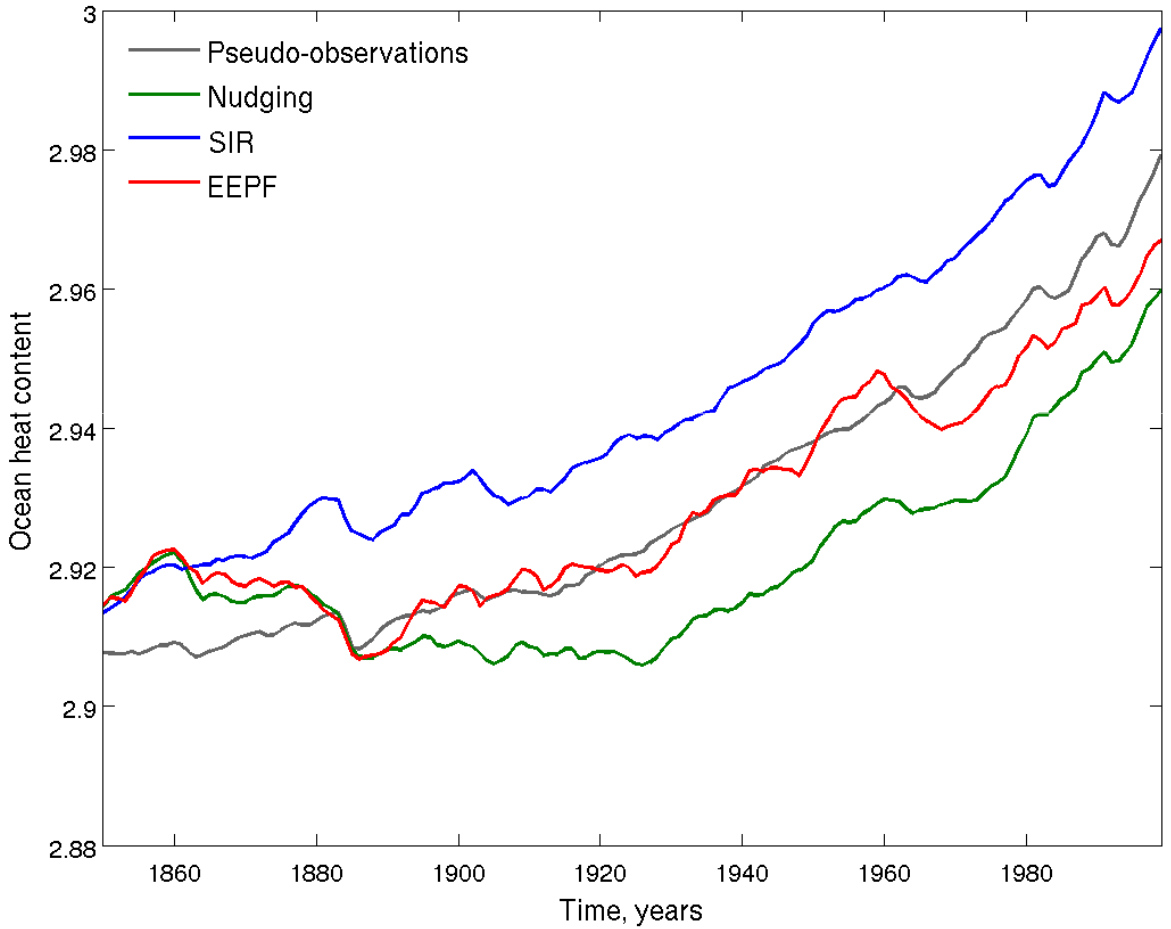
- **Extremely efficient particle filter (EEPF)**

by nudging the particles during the model simulations and adjusting the particles weights avoids the filter degeneracy problem. (P.J. van Leeuwen 2010)

Technical details

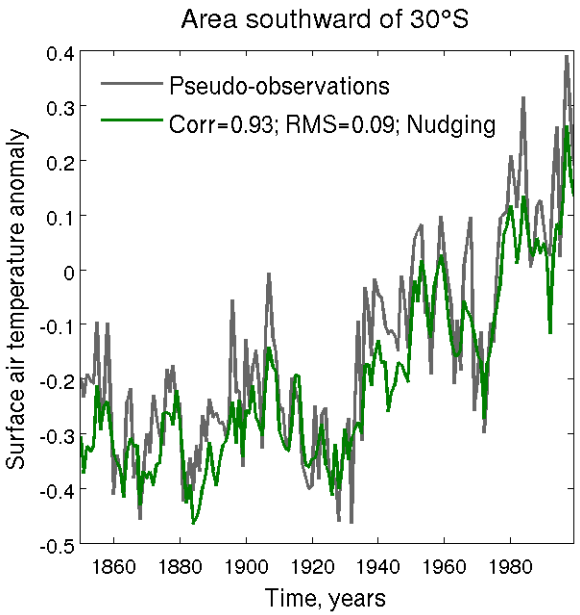
- The climate model LOVECLIM (atmosphere, ocean, sea ice, vegetation) is a fast model with coarse resolution.
- 96 particles (meaning 96 states of the climate model which were obtained by perturbing the initial conditions)
- Pseudo-observations of surface air temperature; surface air temperature is the variable observations of which, either instrumental or proxy reconstructions, appear to be the most disposable for the last centuries.
- Assimilation of seasonal averages
- Nudging is done over the ocean by adjusting heat fluxes from the atmosphere to the ocean

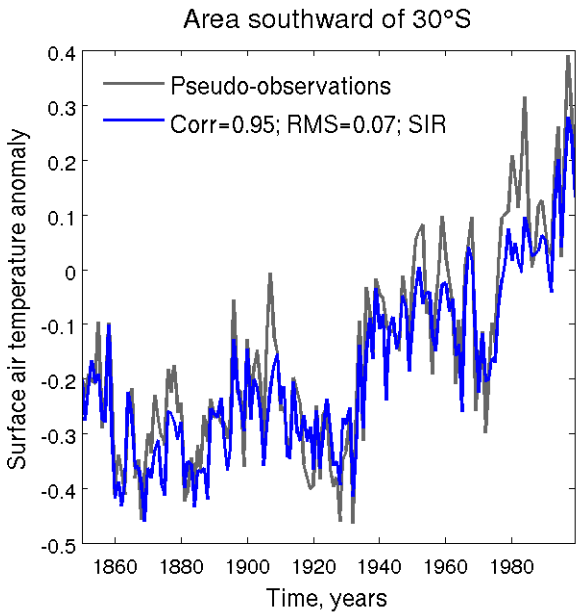
Reconstructions of ocean heat content

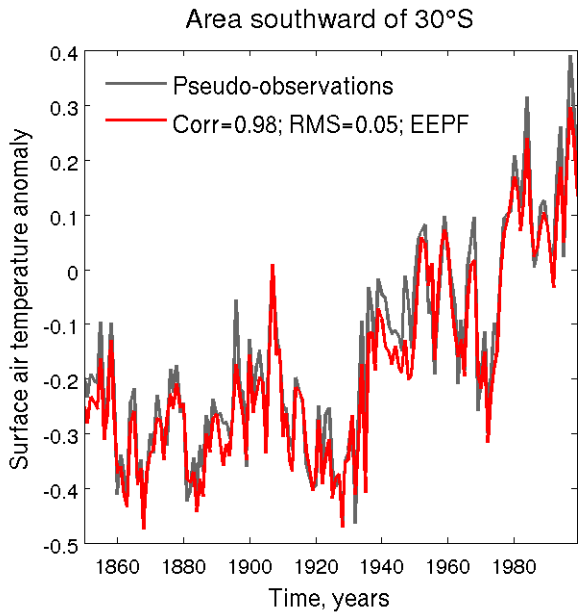


Ocean heat content obtained by the EEPF appears to be the closest to the pseudo-observations.

Reconstructions of surface air temperature averaged over the area southward of 30S

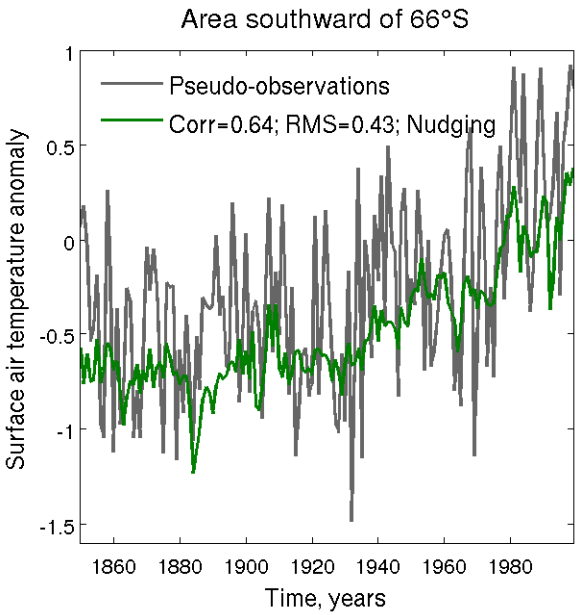


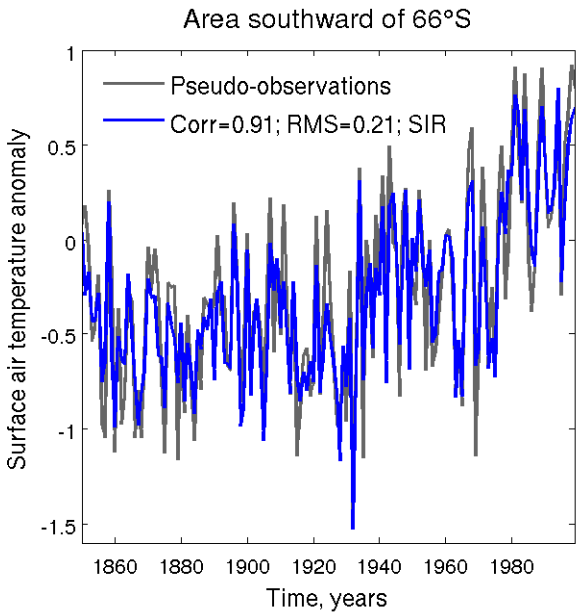


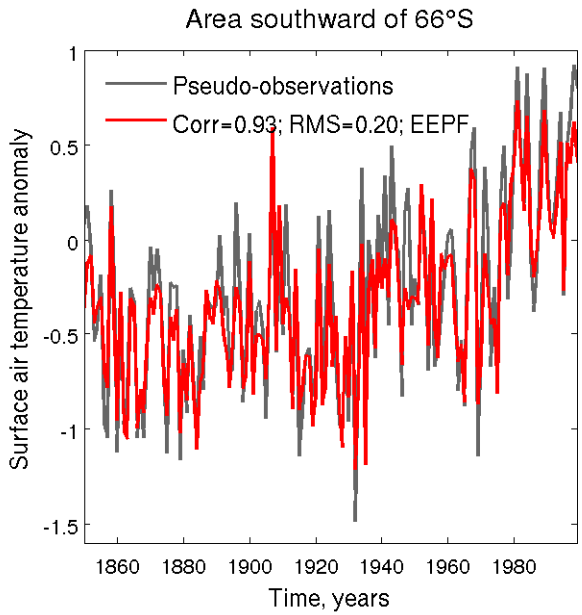


Over the area southward of 30S all three methods perform well.
The EEPF has slightly better fit than the SIR.

Reconstructions of surface air temperature averaged over the area southward of 66S







Over the area southward of 66S the nudging performance is weaker due to the fact that the ocean is less present there and that the nudging is done over the ocean only. The EEPF and the SIR methods have equivalent performances.

- So, what do we have?

Good reconstructions of annual averages of

– ocean heat content,

– surface air temperature averaged over wide domains.

- What about reconstructions of interannual variations?

We will look at variables averaged over May until October.

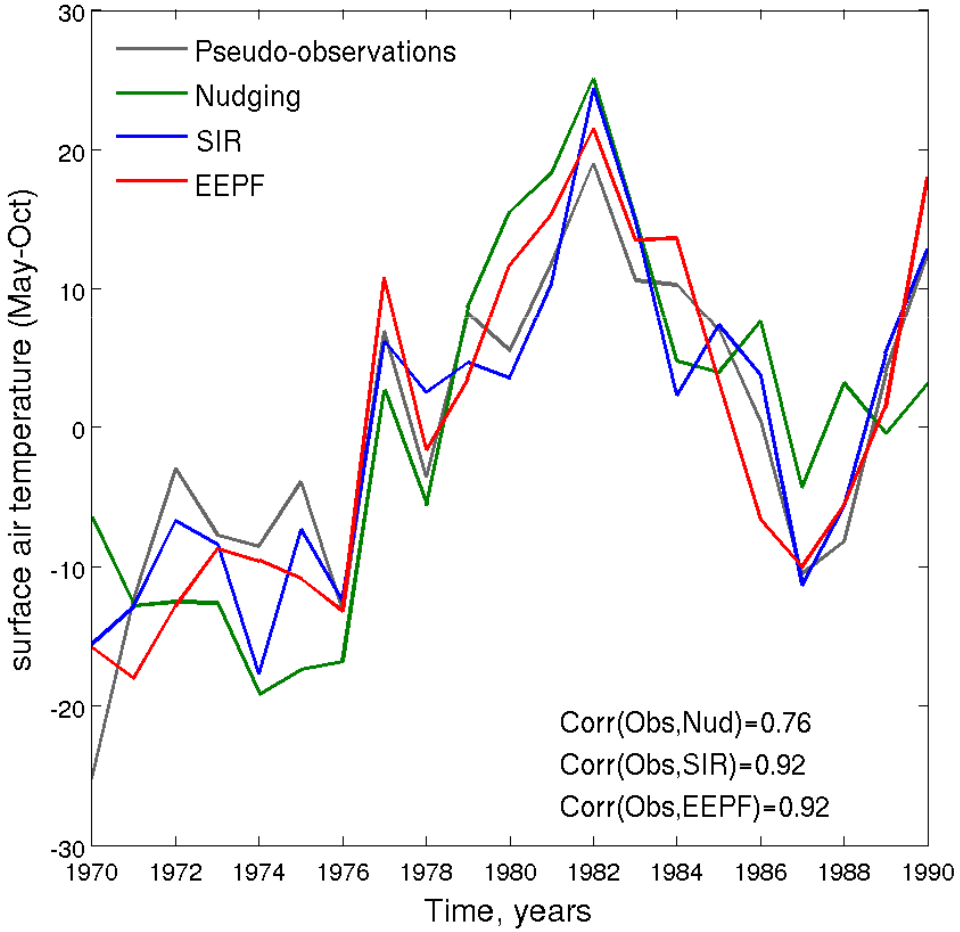
- What about reconstructions of spatial features?

We will compute the first principal components (PC) of the pseudo-observations and project the model simulations onto the corresponding first empirical orthogonal functions (EOF) of the pseudo-observations.

Surface air temperature EOF analysis

Plot of the first PC of the pseudo-observations and projections of the model simulations onto the corresponding first EOF of the pseudo-observations.

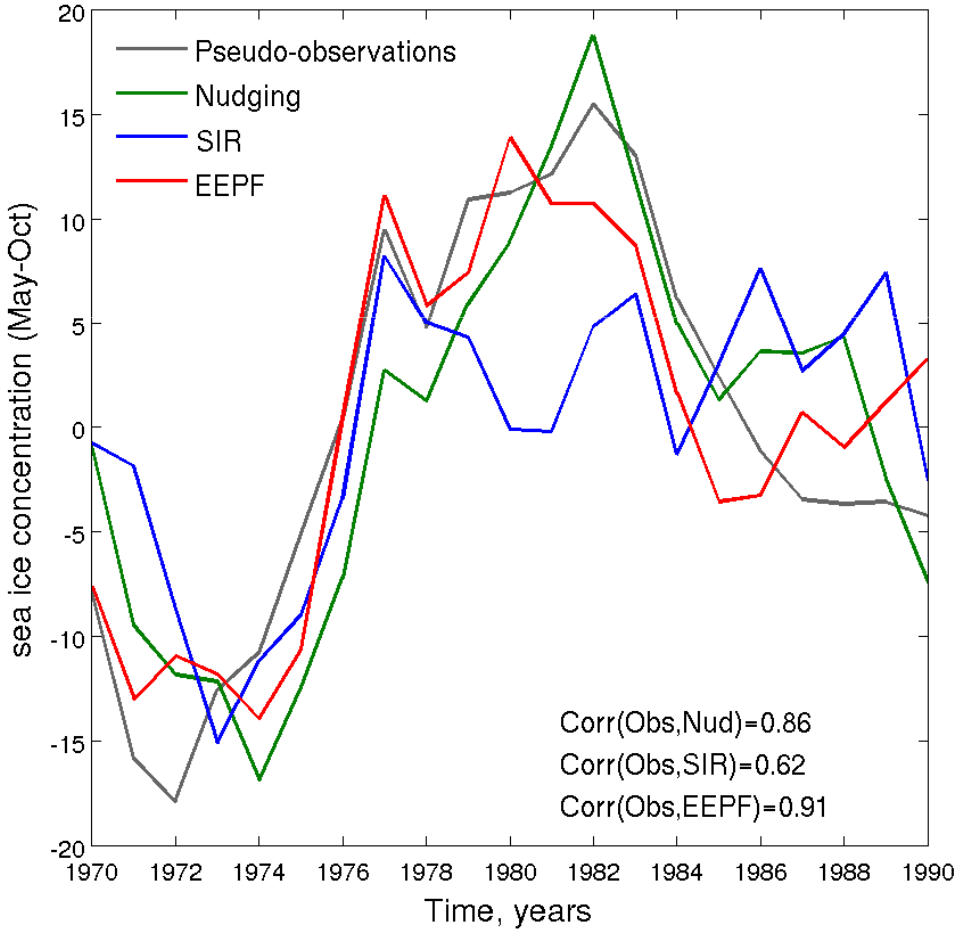
High correlations for the SIR and for the EEPF. The nudging also provides with reasonably high correlation.



Sea ice concentration EOF analysis

Plot of the first PC of the pseudo-observations and projections of the model simulations onto the corresponding first EOF of the pseudo-observations.

Here, the nudging and the EEPF give higher correlations than the SIR method.

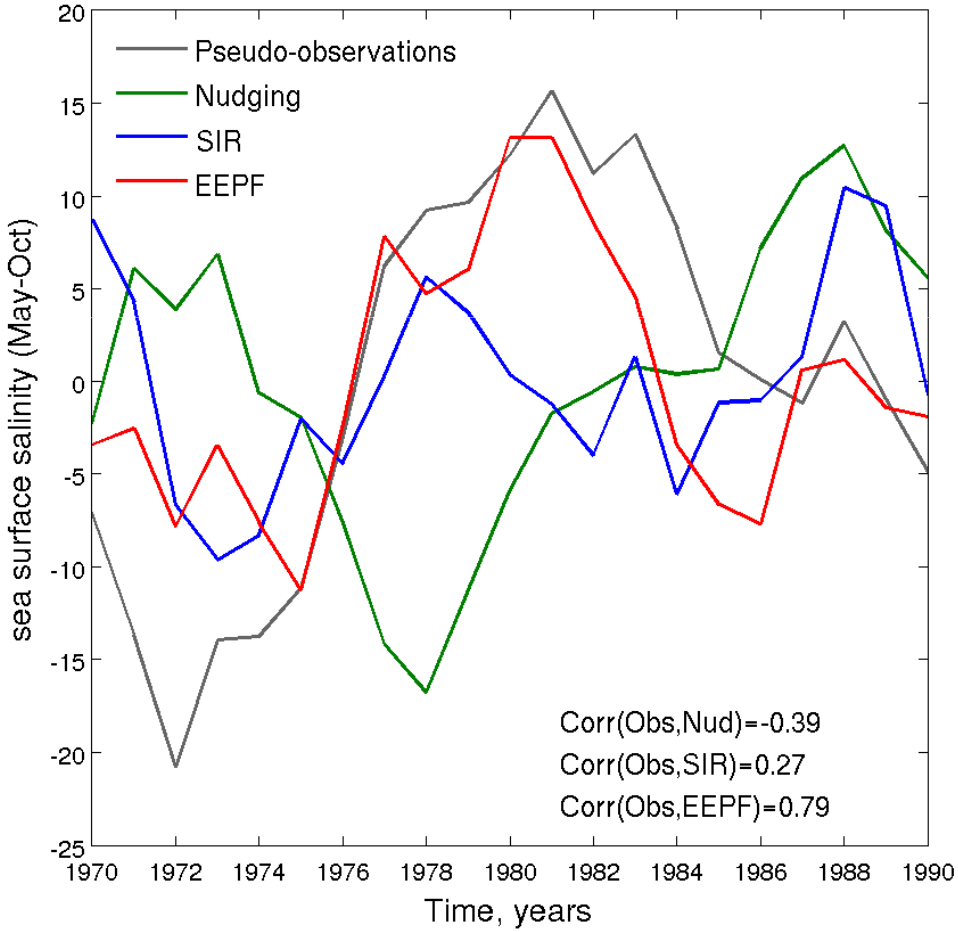


Sea surface salinity EOF analysis

Plot of the first PC of the pseudo-observations and projections of the model simulations onto the corresponding first EOF of the pseudo-observations.

Negative correlation for the nudging.

- **Is this result robust?**
- **What is the reason for negative correlation?**

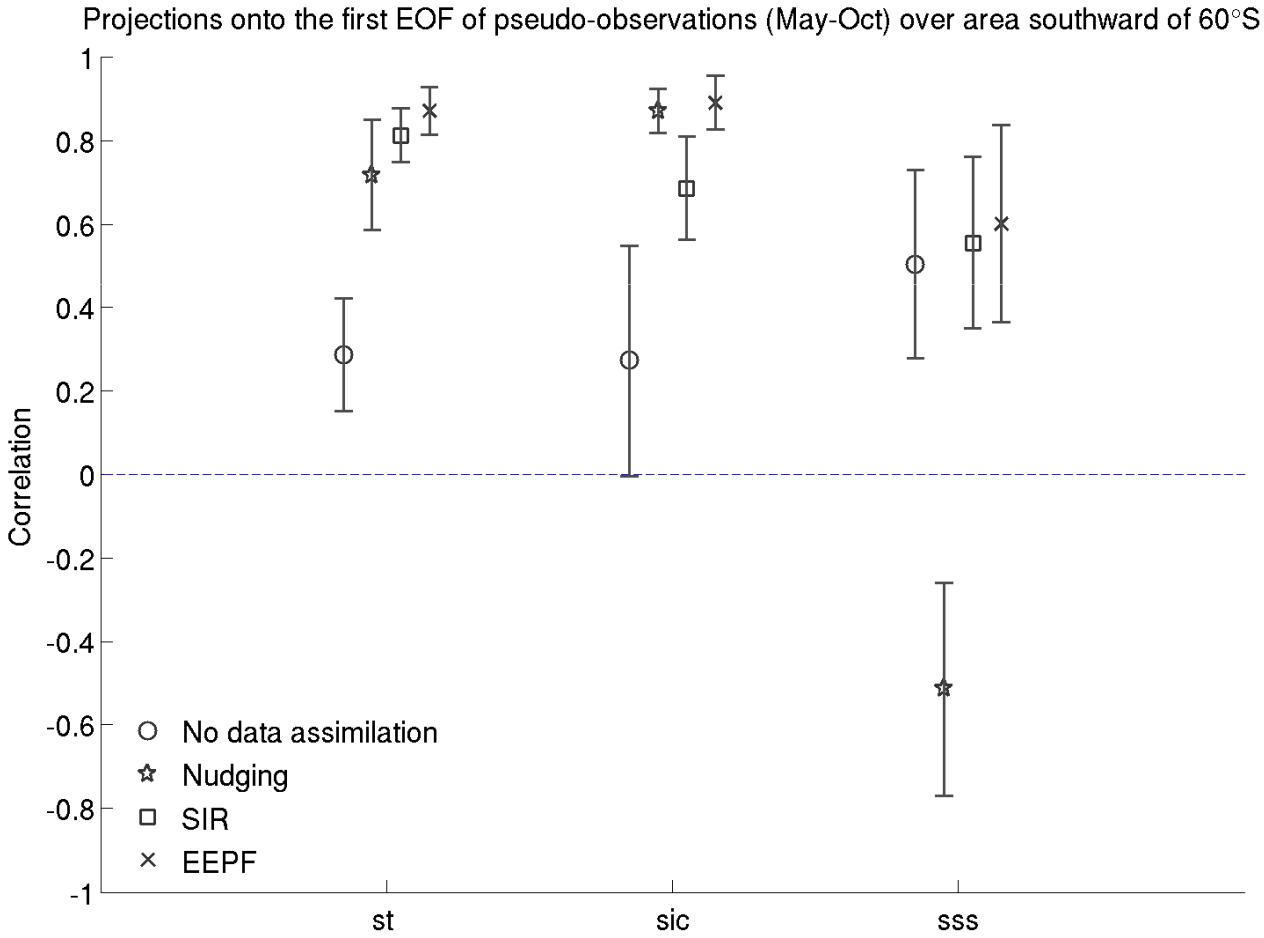


Robustness

Mean plus and minus one standard deviation over six 21-year periods.
st for surface temperature, sic for sea ice concentration, sss for sea surface salinity

Positive correlations for variables obtained without any data assimilation (circle). This is due to the same forcing used when deriving the pseudo-observations.

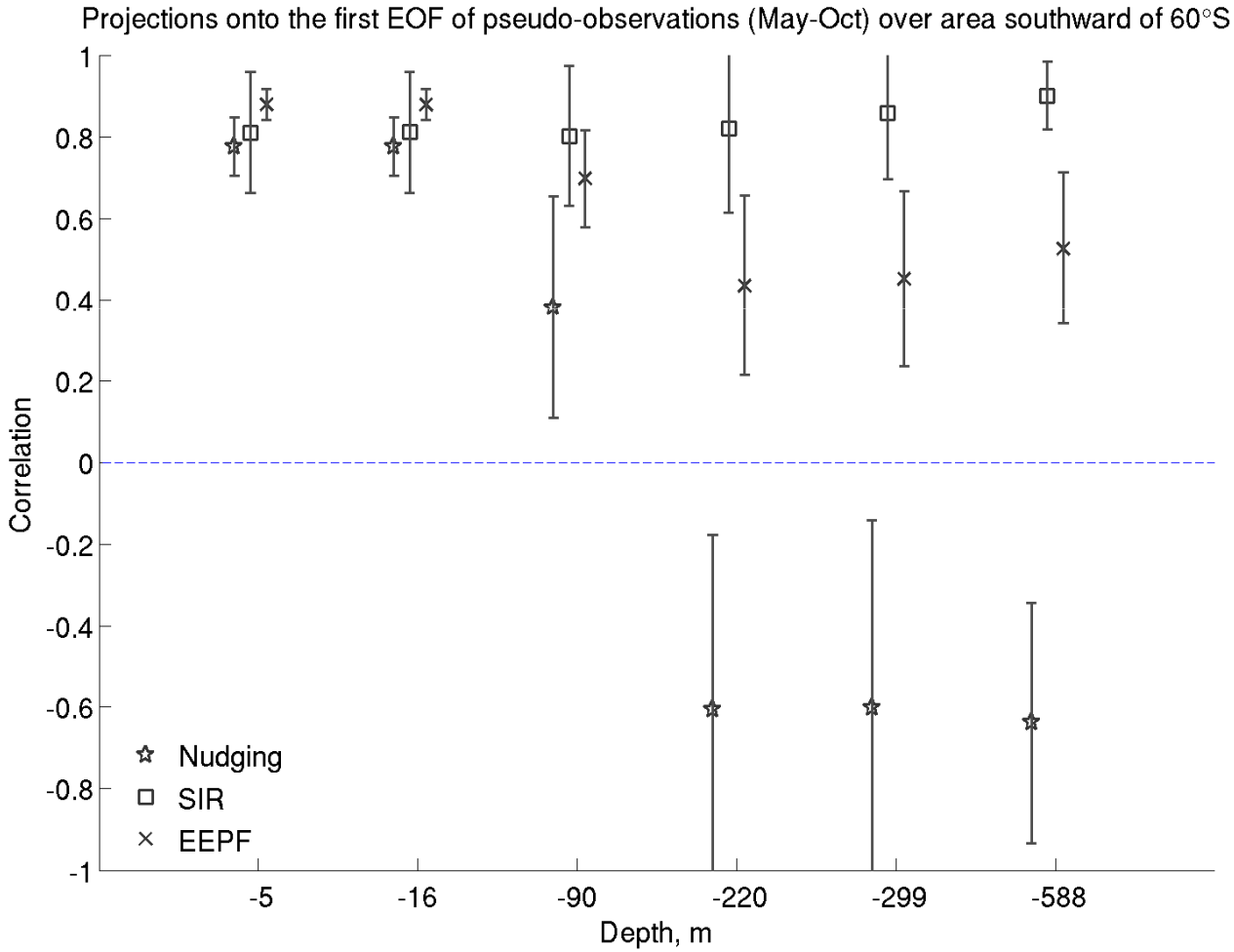
Sea surface salinity obtained by the nudging has always negative correlations.



Ocean temperature as a function of depth

Mean plus and minus one standard deviation over six 21-year periods.

The nudging adjusts surface temperature but does not respect the dynamics of the system. Therefore, we get negative correlations for ocean temperature at deep layers. And consequently, this wrong vertical ocean temperature profile leads to wrong salinity.



Conclusions

- The nudging corrects quite well surface temperature and sea ice concentration – variables directly linked to the pseudo-observations of surface temperature. But, it does not respect the dynamics of the system. So we get wrong deep ocean temperature, and consequently, wrong salinity.
- The EEPF method under the influence of the nudging performs better than the SIR method. But the EEPF in this form is not sufficient for our planned goals.
- Therefore, we still need a data-assimilation method that is sufficient for detailed reconstructions.

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Thank you for your attention!

Questions?

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