Adjustment of atmospheric forcing parameters by Sea Surface Temperature data assimilation for multi-year simulations of the global ocean circulation.

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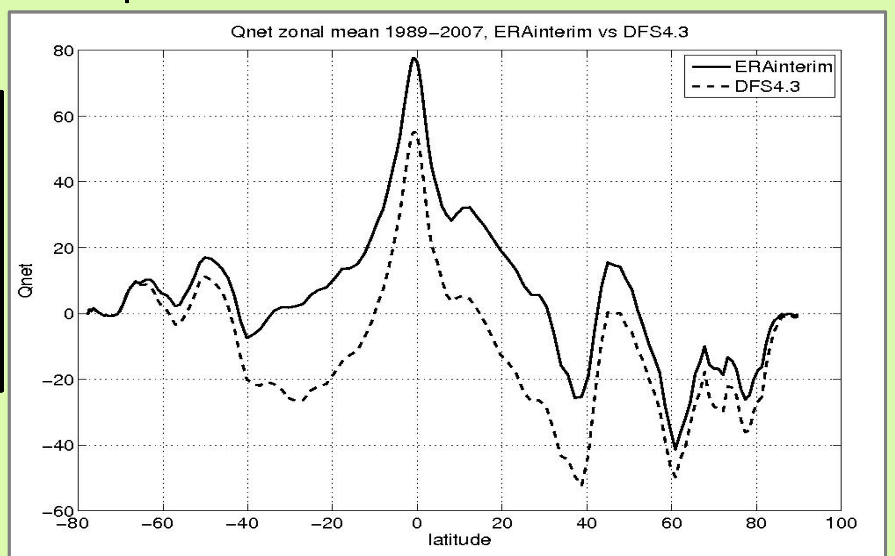
CONTEXT

Sea surface temperature (SST) is more precisely observed from space than near-surface atmospheric variables and air-sea fluxes. But ocean general circulation models used for simulations of the recent ocean variability use, as surface boundary conditions, bulk formulae which do not use the observed SST. In brief, **models do not use directly in their forcing one of the best observed ocean surface variable**, except when specifically assimilated.

The objective of this research is develop new approaches based on ensemble data assimilation methods that use SST satellite observations (and when available SMOS or AQUARIUS satellite sea surface salinity data) to constrain (within observation-based air-sea flux uncertainties) the surface forcing function (**surface atmospheric input variables**) of long-term ocean circulation simulations.

The problem of the **correction of atmospheric fluxes by data assimilation** has already been approached in other studies and projects (Skachko et Al., 2009, Skandrani et Al., 2009). The main goal of this work is to adapt the methodology to a different experimental context.

EXPERIMENTAL CONTEXT :
- Model : NEMO, 2° global simulation ORCA2
- First guess forcing : ERAinterim reanalysis atmospheric parameters (1989-2007)
- Objective : monthly forcing corrections

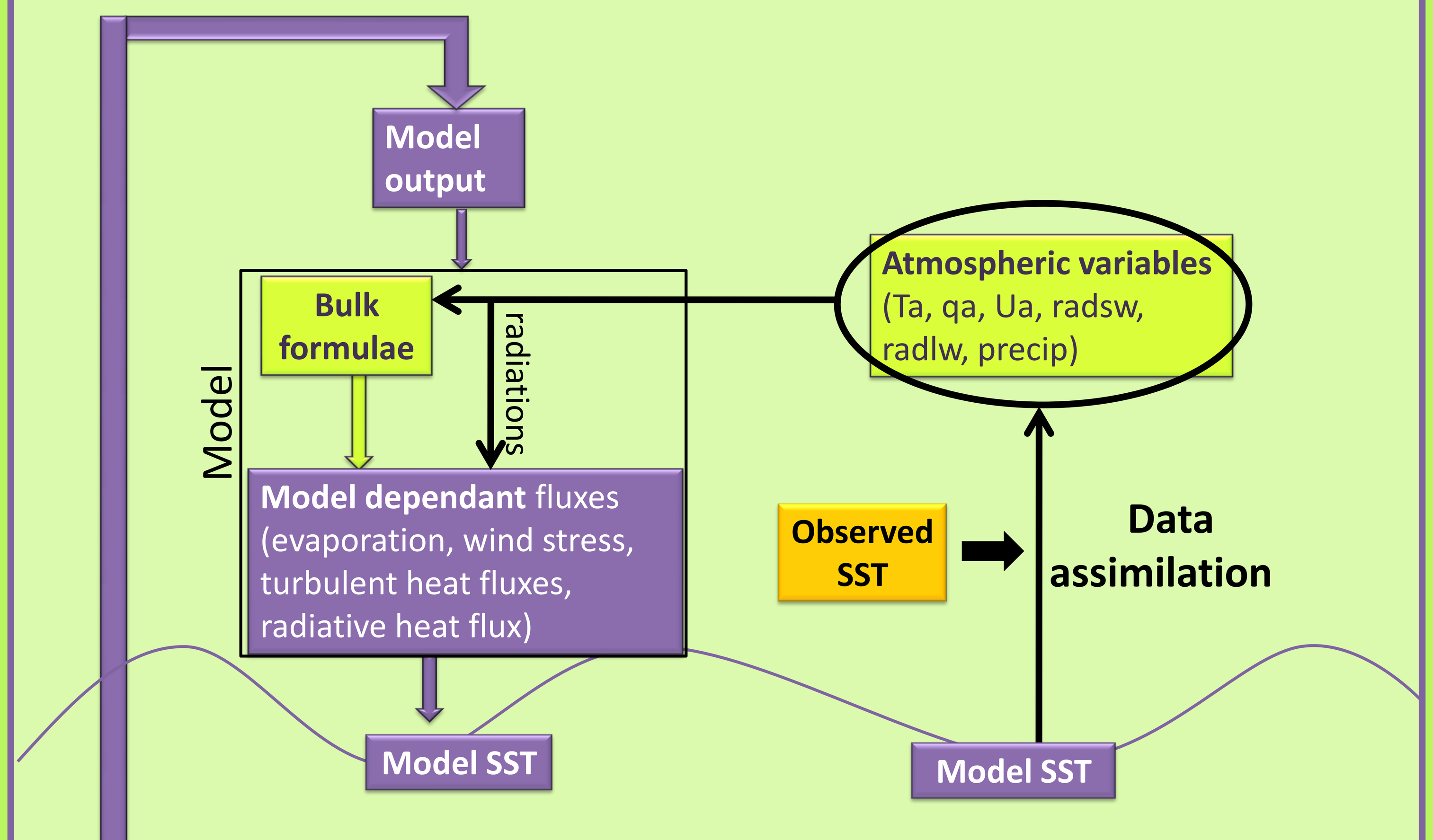


Net Heat Flux

ERAinterim > Drakkar Forcing Set (DFS4, Brodeau et Al., 2010)

CONCEPT

Correct the forcing function by SST data assimilation

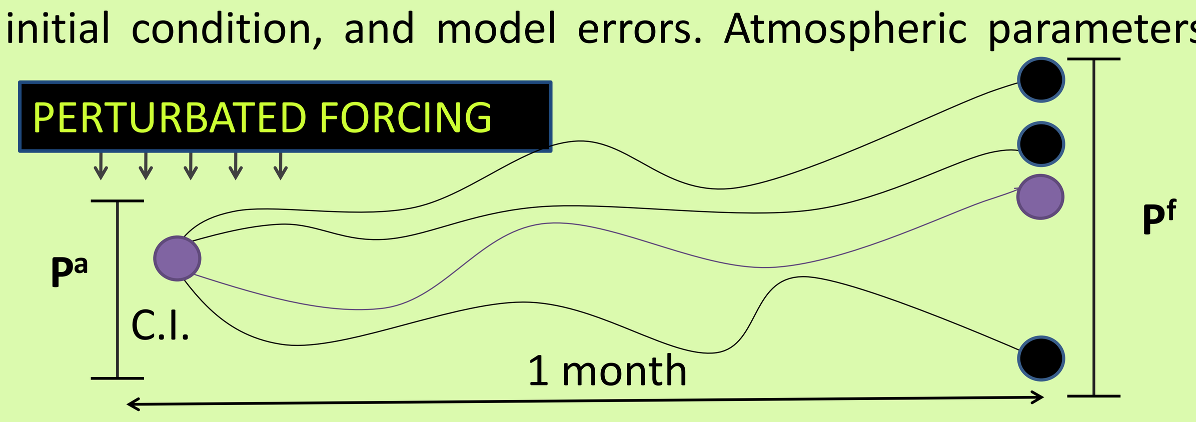


The idea is to evaluate a set of corrections for the atmospheric data of the ERAinterim reanalysis, that cover the period from 1989 to 2007, assimilating SST (Hurrel, 2008) and SSS (Levitus climatology) data. Model runs with these new atmospheric parameters are used for assesment.

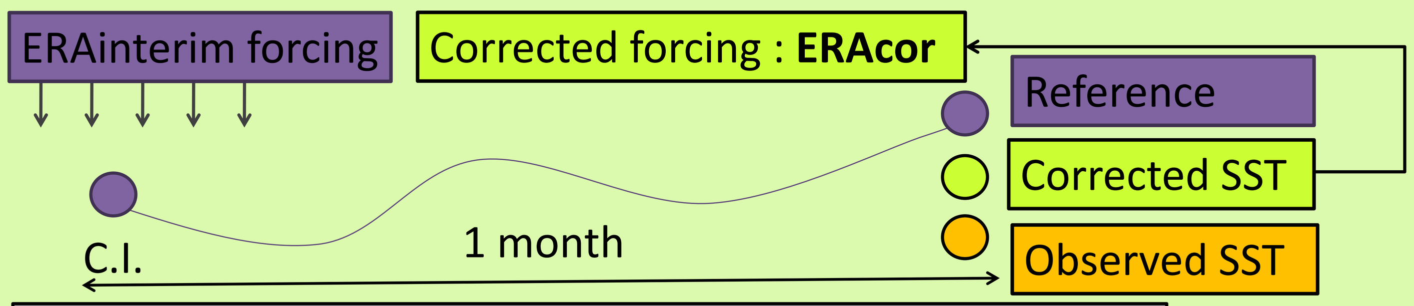
METHOD

We use a sequential method based on the SEEK filter, with an ensemble experiment of 200 members to evaluate parameter uncertainties. To better isolate forcing errors, we have to minimize the other sources of error such as initial condition, and model errors. Atmospheric parameters perturbations are calculated from multivariate EOF of monthly means parameters over the whole ERAinterim period.

The control vector is extended to correct forcing parameters (air temperature, air humidity, longwave and shortwave downward radiations, precipitation, wind velocity). The assimilation step is realized « off-line », that is to say that we don't correct the model state. We obtain atmospheric parameters corrections that we can apply to the model in free runs.



$$P^f = M P^a M^T + Q$$

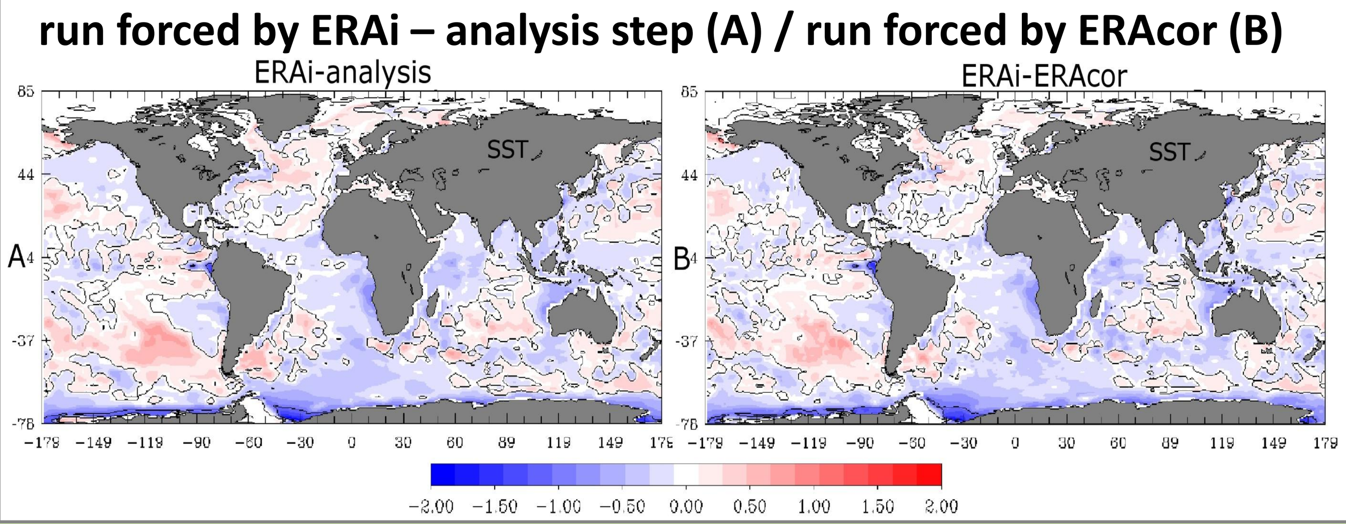


$$X^a = X^b + K(Y - HX^b)$$

METHOD STEPS :

1. **Ensemble forecast : model response to parameters uncertainties**
   - **Using reduced initial condition error**
   - **Using reduced model error**
   - ➡ **Forecast error covariance in augmented space**
2. **Parameter estimation : Kalman Filter for an augmented control vector**
   - **Small observation error**
   - **Truncation of the prior gaussian distribution**
   - ➡ **Correction of atmospheric parameters**
3. **Model run with new parameters : model response vs analysis efficiency**

January 2004 : SST monthly mean differences (°C)
run forced by ERAi – analysis step (A) / run forced by ERAcor (B)



The method permits to isolate the forcing errors minimizing other error sources.

Analysis step and direct application of corrected parameters in the model
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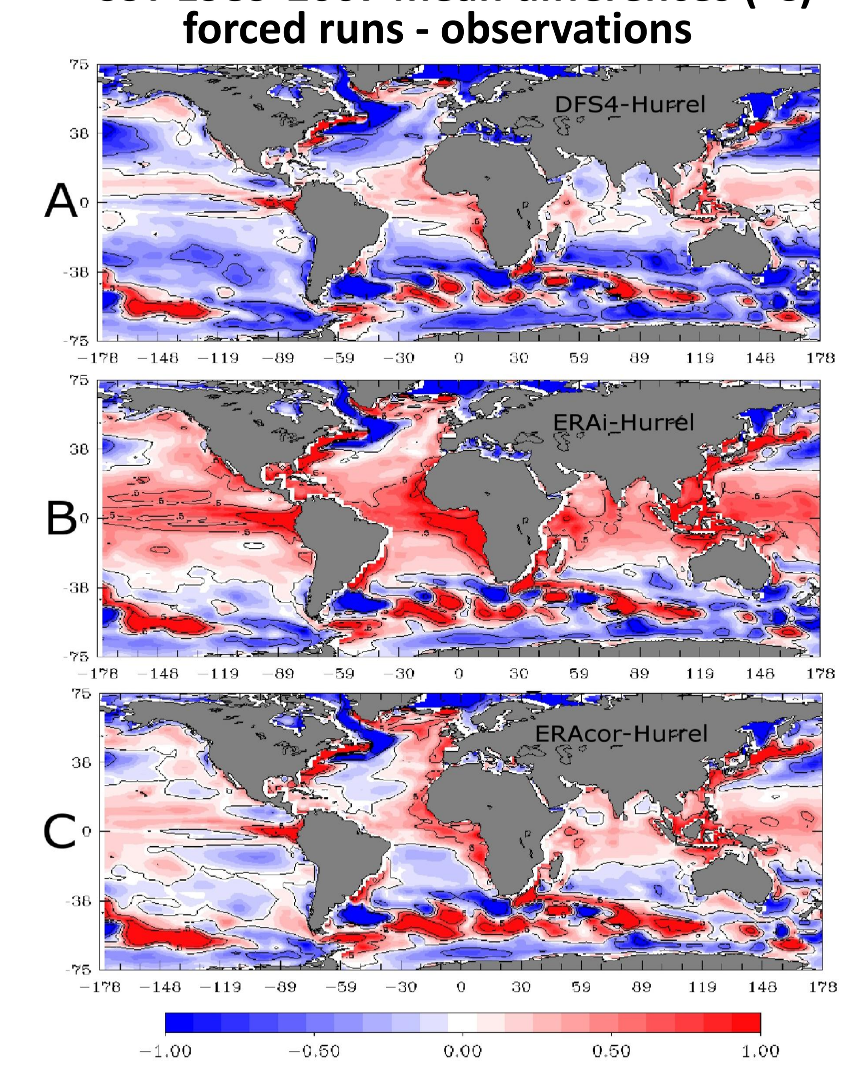
Comparable effects

RESULTS AND CONCLUSIONS

Assessment with forced model simulations
SST 1989-2007 mean differences (°C)
forced runs - observations



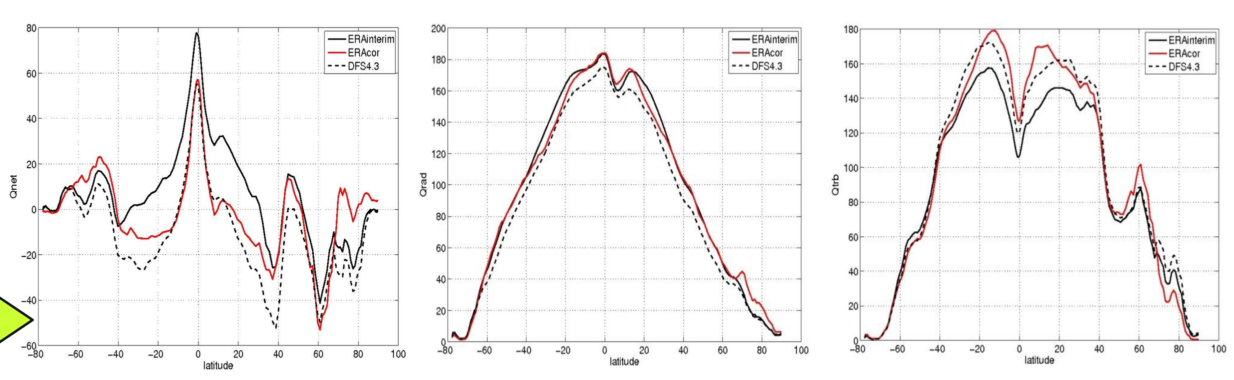
As DFS4 forcing does (A), our method reduces significantly the intertropical band warm bias (C) classically observable in forced simulations like the one forced by ERAinterim data (B).

- Forcing the model with corrected parameters (estimated for each month of 1989-2007) : reduced warm bias in the intertropical band with respect to observations.
- Diagnostic of the net heat flux computed with observed SST : sensible reduction as expected to correct ERAinterim forcing set, correction of the negative trend observed in ERAinterim dataset, better heat balance over the 1989-2007 period.

Impact in the model : Better agreement with SST observations.

Net heat flux : Same global result as DFS4

Qnet, Qrad, and Qtrb zonal mean (W.m^{-2})
1989-2007, DFS4 vs ERAi vs ERAcor



The partition between radiative and turbulent fluxes is different from empirical corrections applied to ERA40 to produce DFS4.

Mathematically optimal method
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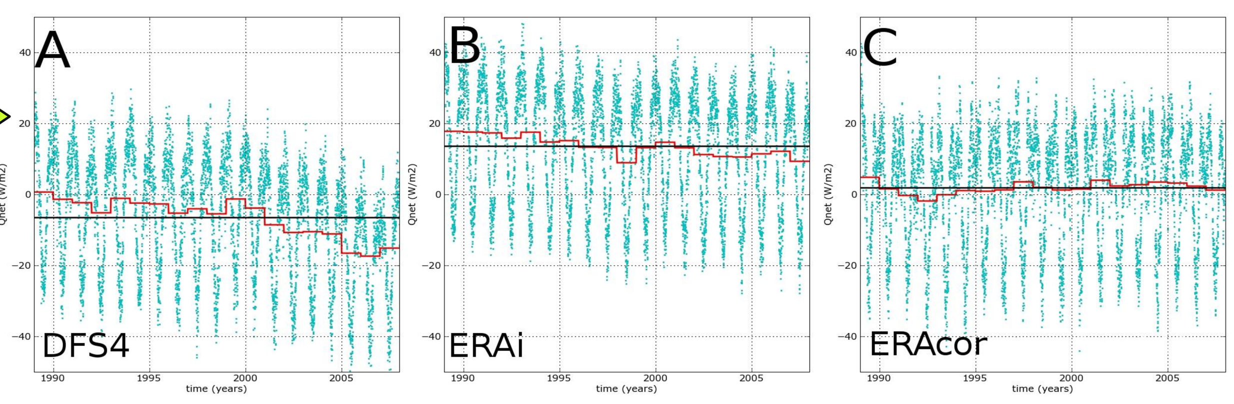
To guide classical empirical corrections

Net heat flux balance: Equilibrated budget

Qnet timeseries (W.m^{-2}) between 1989 and 2007
DFS4 vs ERAi vs ERAcor



The negative trend observed in both DFS4 and ERAinterim (over -1W/m²) which is inconsistent with the global warming observed in the 90s. Our method detrends the net heat flux.

Objective not explicitely prescribed in the method itself.
⬇
More realism in the forcing data

References : C. Skandrani et al., 2009 : Controlling atmospheric forcing parameters of global ocean models : sequential assimilation of sea surface Mercator-Ocean reanalysis data, Ocean Sci., 5,403-419.
S. Skachko et al., 2009 : Improved turbulent air-sea flux bulk parameters for the control of the ocean mixed layer : a sequential data assimilation approach, J.Atmos. Ocean. Tech.,26,538-555.
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