TECHNICAL REPORT

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"Decadal Predictability Study using a Global Coupled Model"

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The Atlantic thermohaline circulation (THC), by its key role in the transport of heat from the Tropics to high latitudes, is essential in the maintenance of the current climate over the North Atlantic Europe region. A 200-year simulation performed using the coupled general circulation model ORCALIM2/ARPEGE3 has shown decadal to multi-decadal fluctuations of the strength of the THC (for more details about this experiment, see "Climatology and Interannual to Decadal Variability diagnosed from a 200-year Global Coupled Experiment", CERFACS Technical Report TR/CMGC/03/30). This work took place in the framework of the PREDICATE project. The main goal of this project was to assess the potential predictability of such fluctuations and to examine the extent to which such predictability may lead to predictable variations in climate that may be relevant to society. Two 25-year long ensembles of predictability experiments were conducted from this simulation, contrasting opposite phases of the low frequency fluctuations of the thermohaline circulation (THC). In the following, the experimental set-up is presented, together with the different predictability diagnostics used. Results are then commented briefly.

1. <u>Data and method</u>

1.1. Methodology

The predictability of THC variations is studied using a "perfect model" or "perfect ensemble" approach. By perturbing the initial conditions of an AOGCM and measuring the spread of initially near-by model trajectories, the limit of first-kind or initial condition predictability may be assessed. The experiments represent an upper limit of the predictability characteristics based on having a perfect model and perfect initial conditions. While this situation is never likely to be achieved in practice, perfect ensemble studies are useful in identifying the potential for climate predictability that may, one day, be realized through the development of operational systems.

To measure the spread of model trajectories, three different diagnostics are used. The first one is called the Anomaly Correlation Coefficient (ACC), which measures the correlation between the predictability experiments and the control run. A value of 1 indicates a perfect forecast, a value of 0 no skill. For historical reasons, a value of 0.6 is taken as a threshold. The second diagnostic is the Root Mean Square Error (RMSE), which measures the deviations of model trajectories from the control run, summing up the measurements, and then taking the square root of the sum. The forecast is accurate while the RMSE remains less than $\sqrt{2}$ times the climatological RMS. The last diagnostic is a normalized ratio of variance, which measures the ratio of the variance of model trajectories and the control simulation variance. The score is 0 for a perfect forecast and 1 is the predictability threshold.

1.2. Experimental set-up

Two 25-year long predictability experiments have been carried out. Each experiment contains 6 individual trajectories. The first experiment (Figure 1) starts from an initial oceanic state corresponding to a high phase of the THC (hereafter RP experiment). The second experiment starts from a low phase of the THC (hereafter RM experiment).

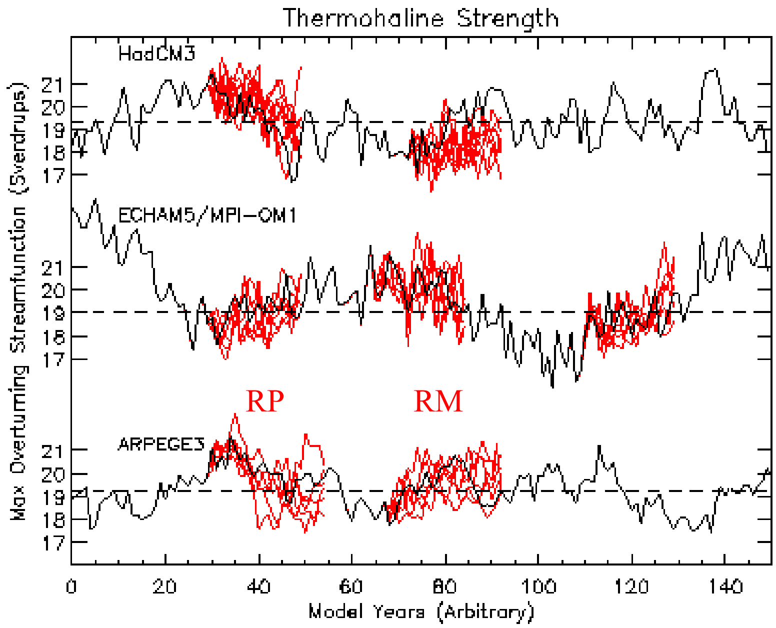

Figure 1: THC strength for three models of the PREDICATE project. The lowermost is the ARPEGE3/ORCALIM2 coupled model. Individual trajectories for each predictability experiment are shown (red lines). Figure taken from *Collins et al (2003).*

2. Results: potential predictability of the modelled climate system in the North Atlantic region

Figure 2a shows that, for all predictability indexes, when taking a strengthened THC as initial condition, the forecast remains accurate for about 10 years. After this period, there's a rapid drop-off in less than one year. Concerning North Atlantic Sea Surface Temperature (SST), the resulting forecast index doesn't vary very much with the averaging region (Figure 2b and 2c). In both cases, when looking at the ACC, the predictability falls down very quickly the first year but returns to high values of predictability the following years. Moreover, there seems to be predictability for longer when averaging over the whole North Atlantic than over the 40°N-60°N band. On the other hand, when looking at the RMSE and the ratio of variance plots, the opposite conclusion is drawn: there's more predictability when the averaging region is the 40°N-60°N band than when it is the whole North Atlantic. In any case, the predictability of the North Atlantic SSTs is weak and strongly depends on the index chosen to measure it. For Tropical SSTs (Figure 2d), predictability is even weaker when looking at the ACC. With the other indexes, there's some predictability the first year and occasionally after.

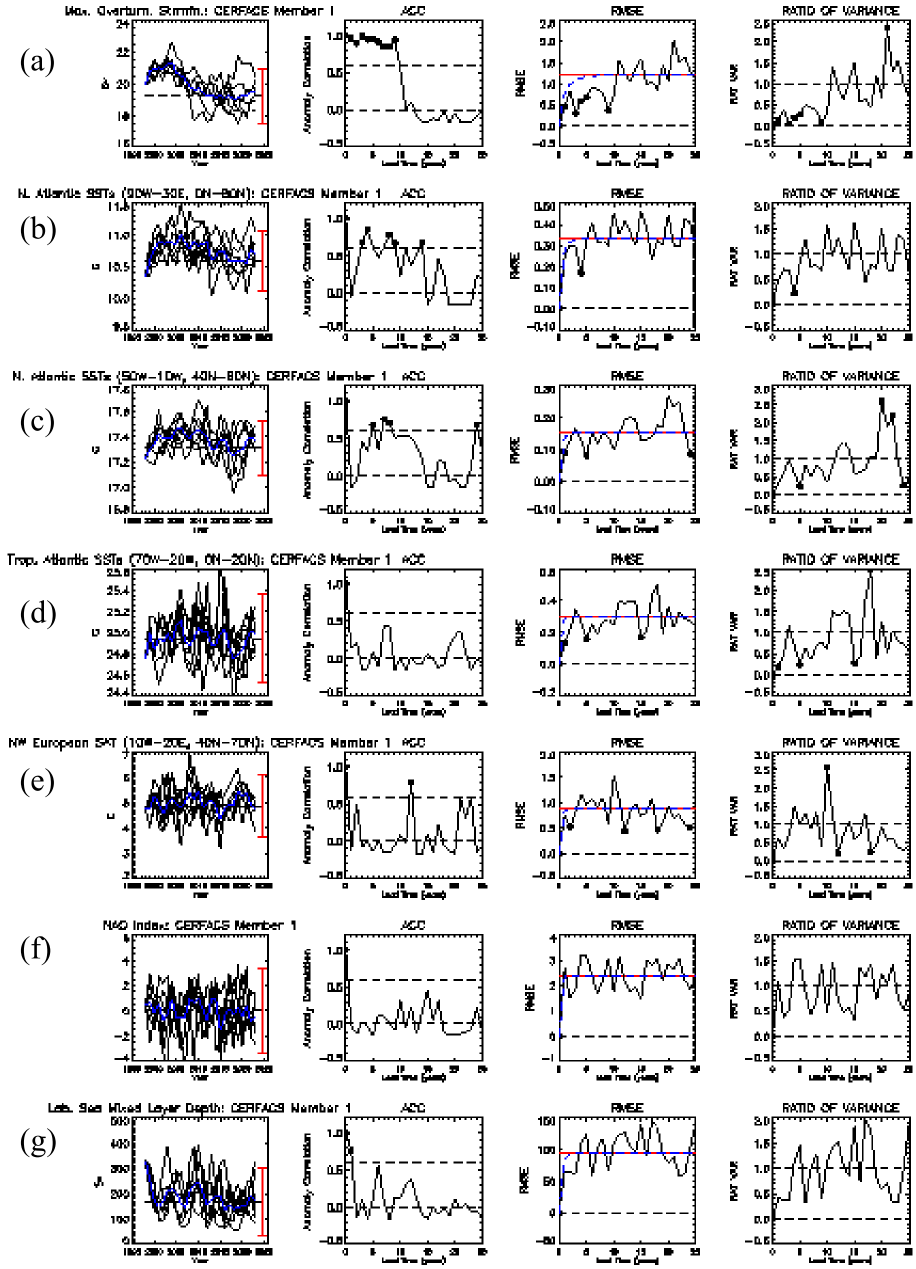

Figure 2: Annual mean RP predictability indexes as defined in section 1.1 for (a) the THC, (b) the North Atlantic SST averaged in the region 0°N-80°N, 90°W-30°E, (c) the North Atlantic SST averaged in the region 40°N-60°N, 50°W-10°W, (d) the Tropical Atlantic SST averaged in the region 0°N-20°N, 70°W-20°W, (e) the North West European land SAT averaged in the region 40°N-70°N, 10°W-20°E, (f) the NAO index, and (g) the Labrador Sea Mixed Layer Depth. Significant values are marked by a black filled circle. Figure was taken from *Collins et al (2003).*

For atmospheric variables such as the North West Europe Surface Air Temperature (SAT) and the NAO index (Figure 2e and 2f), the predictability remains very weak, except by chance. The Labrador Sea Mixed Layer Depth (Figure 2g) is predictable for about 2 years.

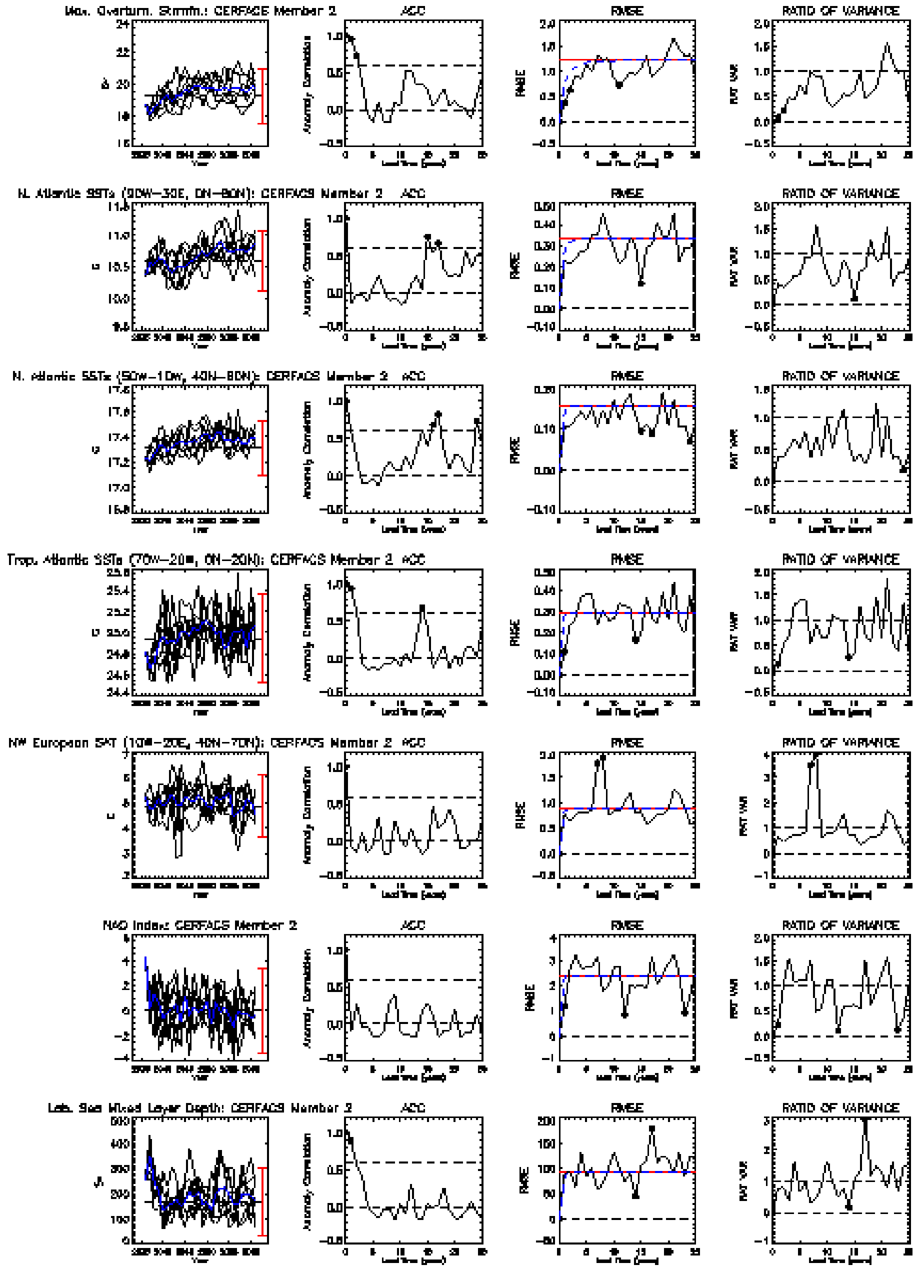

Figure 3: As in Figure 2 but for RM experiment.

In the case of the ensemble experiment starting from a low value of the THC index, the predictability is weaker than in the RP experiment for all variables (Figure 3), except the Tropical Atlantic SSTs where predictability remains at one year, and the Labrador Sea Mixed Layer Depth where predictability remains at 2 years. The predictability of the THC index drops off to 2-3 years.

All the forecasts presented before were made using annual means. When looking at seasonal means (not shown), there's no improvement of the predictability.

3. Conclusion

Two ensemble experiments were conducted from a 200-year long global coupled simulation. The two ensembles contrasted two phases of the Atlantic THC. Preliminary results concerning the potential predictability of different fields of the North Atlantic Europe climate system leads to the following assertions: the strength of the THC is potentially predictable for about 10 years in the best case (e.g. a high THC phase); this predictability doesn't imply predictability on SSTs nor on atmospheric fields; some predictability arises from the Labrador Sea mixed layer depth.