Initialisation and predictability of the AMOC over the last 50 years in a climate model

Didier Swingedouw[1], Juliette Mignot[2], Sonia Labetoulle[2], Eric Guilyardi[2,3], Gurvan Madec[2,4]

[1]LSCE/IPSL, Gif-sur-Yvette, France [2]LOCEAN/IPSL, Paris, France [3]NCAS-Climate, University of Reading, UK [4]NOCS, Southampton, UK

Mailto: didier.swingedouw@lsce.ipsl.fr ; Web site :http://dods.ipsl.jussieu.fr/dssce/public_html/

Background

- IPCC 2013: A new chapter on **decadal predictability**
- **AMOC:** a key player for the decadal variability and predictability
- **Initialisation** of the AMOC: a challenge for models
- A **20-yr cycle** of variability suggested in paleo-reconstructions (Sicre et al. 2008, Chylek et al. 2011) of the last millennium around the subpolar gyre
- Similar 20-yr timescale in a few **climate models**, including IPSLCM5A and in HadISST (Fig. 1)

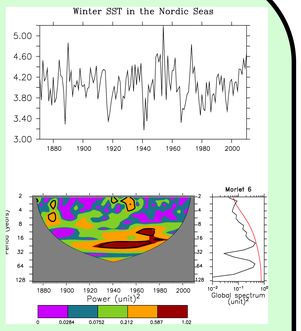

Fig.1: Wavelet analysis

Aim of this work

- Evaluate the **initialisation of the AMOC in the IPSLCM5A** decadal prediction system
- Analyse the **mechanisms** leading to such an initialisation
- Evaluate the **performance** of the predicting system for the AMOC

Experimental design

We use the **IPSL-CM5A-LR** coupled model:

- Ocean ORCA2: 2° x (0.5-2°) x L31
- Sea-ice LIM2: dynamic-thermodynamic
- Atmophere LMDz: 1.875° x 3.75° x L31
- Land model ORCHIDEE

The "Nudged" simulations are initialized by restoring to anomalous Reynolds et al. (2007) SST over the period 1948-2005.

We add this term to the SST equation:

$Q=-\gamma\,(SST'_{mod}-SST'_{obs})$

With γ=40 W.m^{-2}/K , physically based and 15 times smaller than for other studies (Keenlyside et al. 2008, Dunstone and Smith 2010, *ect.*)

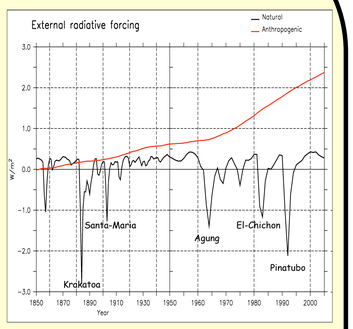

Fig.2: External forcings used in the simulations

	# Ensemble	Initial conditions	Forcing	Restoring	Years of simulation
Control	1	Spin-up simulation	Preindustrial	No	1x1000
Historical	5	Start in 1850 every 10 years from a preindustrial simulation	Natural + Anthropogenic	No	5x156
Nudged	5	Start in 1948 from each associated historical simulation	Natural + Anthropogenic	SST anomalies from Reynolds et al. (1948-2005)	5x57
Hindcast	3	Start every 5 years from the 1st Jan. 1961 from a nudged simulation plus a spatial white noise on SST	Natural + Anthropogenic and RCP4.5	No	3x10x10
Natural	3	Start in 1850 every 10 years from a preindustrial simulation	Natural	no	3x156
Anthropogenic	3	Start in 1850 every 10 years from a preindustrial simulation	Anthropogenic	no	3x156

Table1: list of the simulations

AMOC initialisation

- The AMOC time series exhibit two local maxima after 1970 in historical and nudged simulations as in the two reconstructions
- The nudged runs better capture the amplitude of large maximum in the 1990s
- The natural runs are also synchronized with historical, nudged and observations; not the anthropogenic simulations

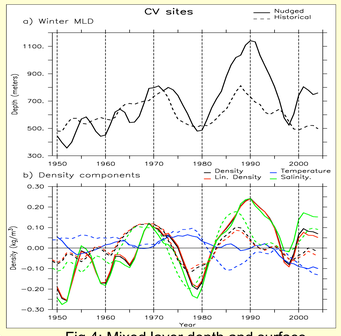

Fig.4: Mixed layer depth and surface density in the convection sites

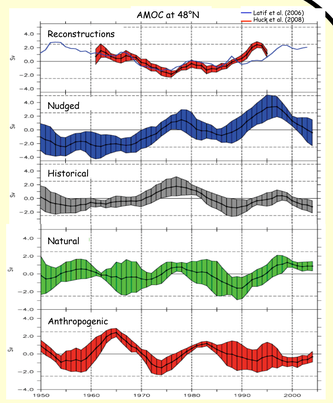

Fig.3: AMOC variations

- Convective variability precedes AMOC variation by 5-10 years
- It shows a synchronized max. around 1970 in historical and nudged runs
- This maximum is driven by SSS, while SST damps the changes, except in the 1980s in the nudged runs : an effect of positive NAO at that time

Proposed mechanisms

- The reset starts with Agung eruption (1963)
- It cools the Nordic Seas
- This increases the EGC
- Salinity anomalies accumulate in the Labrador Sea 3 years later
- This leads to the intensification of the convective activity 3 years later
- And the AMOC maximum 15 years after the beginning of the eruption

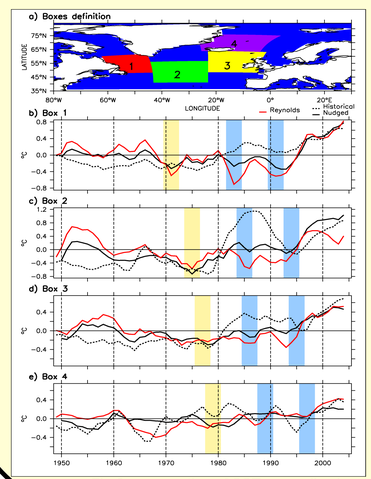

Fig.6: propagation of SST anomalies in the North Atlantic

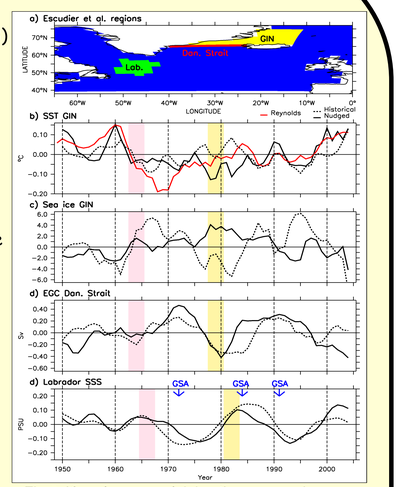

Fig.5: Key players explaining the proposed mechanism

- This synchronizes the 20-yr cycle and explain the second max. in the 1990s
- This 20-yr cycle is mainly based on propagation of tracers anomalies along the subpolar gyre (cf. Escudier et al.)
- We observe both in observations and models such a propagation of tracers anomalies, resembling what happens during GSAs

AMOC and climate predictability

- We launch every 5 years a 3-member ensemble from one of the initialized simulation
- We use 10-yr mean to compare hindcasts with initialised runs and reconstruction
- For the AMOC, hindcasts have a better correlation score than persistence and historical simulations as compared to reconstruction

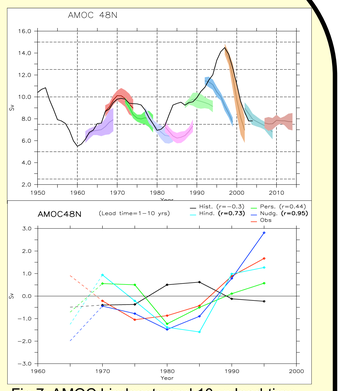

Fig.7: AMOC hindcasts and 10-yr lead-time average correlation skill score

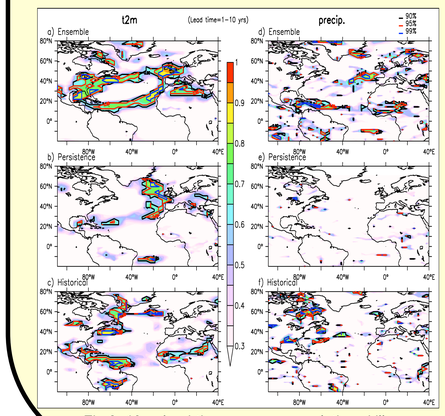

Fig.8: 10-yr lead-time average correlation skill score for temperature and precipitation

- The hindcasts also exhibit better correlation score for temperature and precipitation as compared to initialized runs than persistence and historical simulations in the Atlantic
- The regions of high score correspond to regions influenced by the AMOC: around the subtropical gyre for temperature and in the tropical Atlantic for precipitations

Discussions and conclusions

- New evidences of a **20-yr cycle in the North Atlantic** in a model (IPSLCM5A) and data (HadISSST)
- Weak nudging in SST-only succeeds in **initialising the AMOC**
- This is related to the **volcanoes acting as a pacemaker** for the 20-yr AMOC variability:
  - **Mount Agung** eruption **resets** the 20-yr cycle
  - **NAO modulates** AMOC variations when in phase with SSS 20-yr cycle variation
- **Hindcasts** have **better scores** than historical runs and persistence in several areas of the Atlantic Ocean

Outlooks

Analysis of the skill scores for other variables: cf. Ray et al. poster (P52, 3ICESM-276)

- Impact of **Pinatubo** on the more recent period and near future
- Test the use of **observed wind field and SSS** reanalysis in the initialisation procedure
- Impact of **higher resolution in the atmosphere** model for the decadal prediction system

References: Swingedouw D., Mignot J., Labetoule S., Guilyardi E., Madec G. : Initialisation and predictability of the AMOC over the last 50 years in a climate model

Escudier R., Mignot J. and Swingedouw D. : A 20-yrs coupled ocean-sea ice-atmosphere variability mode in the North Atlantic in an *AOGCM*,

Dunstone, N.J. and Smith, D.M. (2010) Impact of atmosphere and sub-surface ocean data on decadal climate prediction. *Geophysical Research Letters* 37

Keenlyside, N. et al. (2008), Advancing decadal scale climate prediction in the North Atlantic sector, *Nature*, 453, 84.

Reynolds, R. W.et al. (2007) Daily high-resolution blended analyses for sea surface temperature. *J. Climate*, **20**, 5473-5496.

Huck, T., A. Colin de Verdière, P. Estrade, and R. Schopp (2008) Low-frequency variations of the large-scale ocean circulation and heat transport in the North Atlantic from 1955-1998 in-situ temperature and salinity data. *Geophysical Research Letter*, **35**

Latif, M., Callins, M., Pohlmann, H. & Keenlyside, N. (2006) A review of predictability studies of the Atlantic sector climate on decadal time scales. *J. Clim.* 19, 5971-5987.

Chylek P., et al. (2011) Ice-core data evidence for a prominent near 20 year time-scale of the Atlantic Multidecadal Oscillation. *Geophysical Research Letters*, 38.

Sicre , M.-A. et al. (2008) Decadal variability of sea surface temperatures off North Iceland over the last 2000 years. *Earth and Planetary Science Letters* 268 137-142