Institut Pierre Simon Laplace
Sciences de l'environnement

LSCE
LABORATOIRE DES SCIENCES DU CLIMAT ET DE L'ENVIRONNEMENT

cnrs dépasser les frontières

Influence of volcanic eruptions on the bi-decadal variability in the North Atlantic

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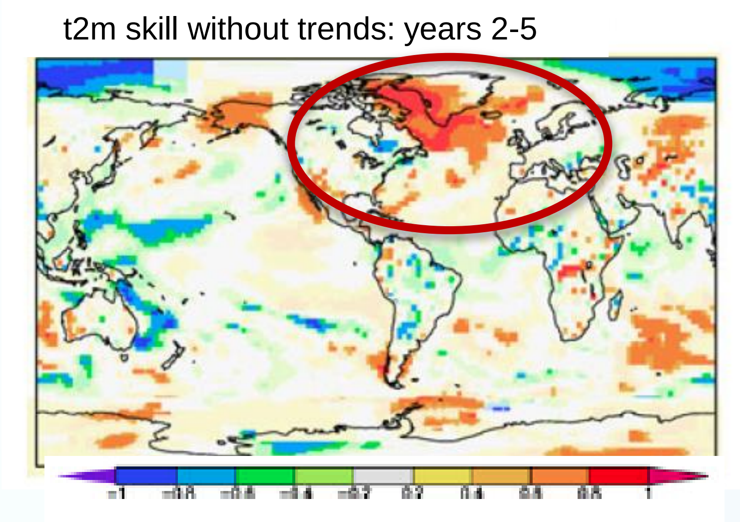
SPECS
Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

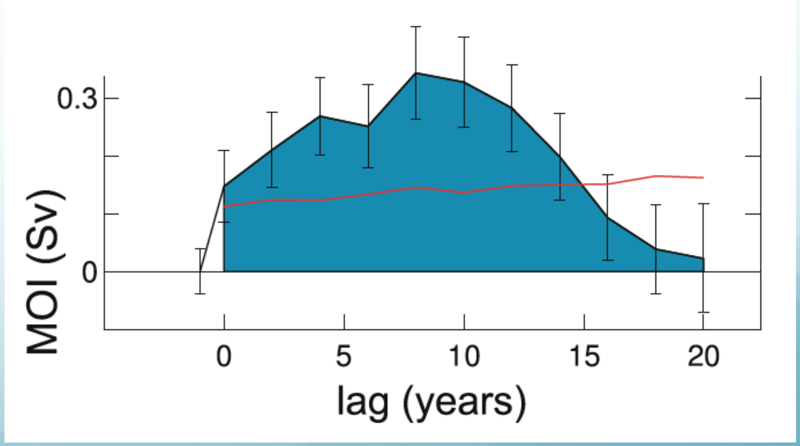
EPIDOM
Evaluation of Interannual to decennial predictability starting from observations and models

Background

- AMOC: a key player for decadal prediction
- Volcanic impact on AMOC
  (Ottera et al. 2011, Iwi et al. 2010, Mignot et al. 2011…)
- Bi-decadal variability in the North Atlantic:
  - in several models
    (Frankcombe et al. 2010…)
  - and in data
    (Chylek et al. 2011, Sicre et al. 2008, Divine et al. 2006…)



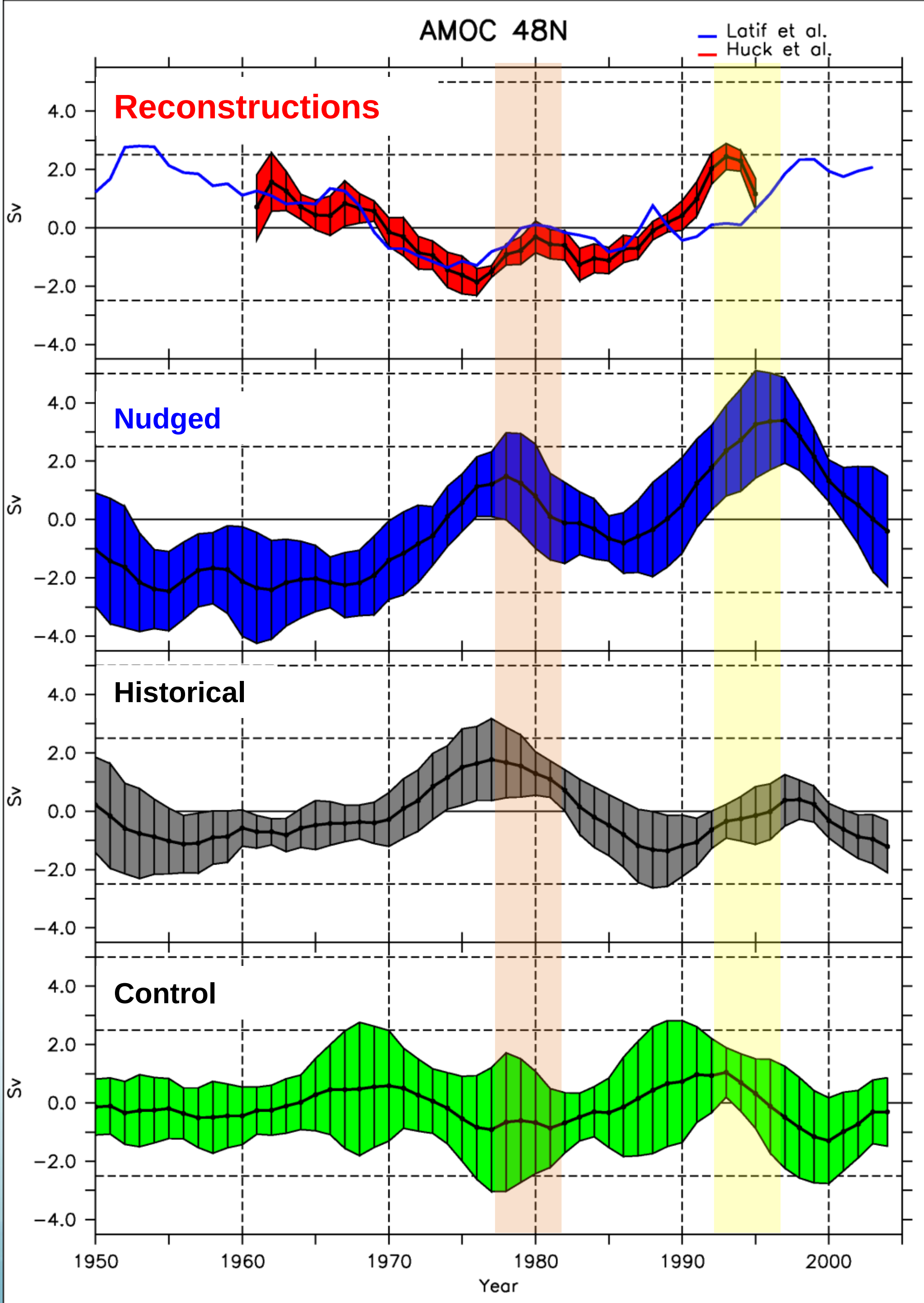
Van Oldenborgh et al. 2012



Zanchettin et al. 2012

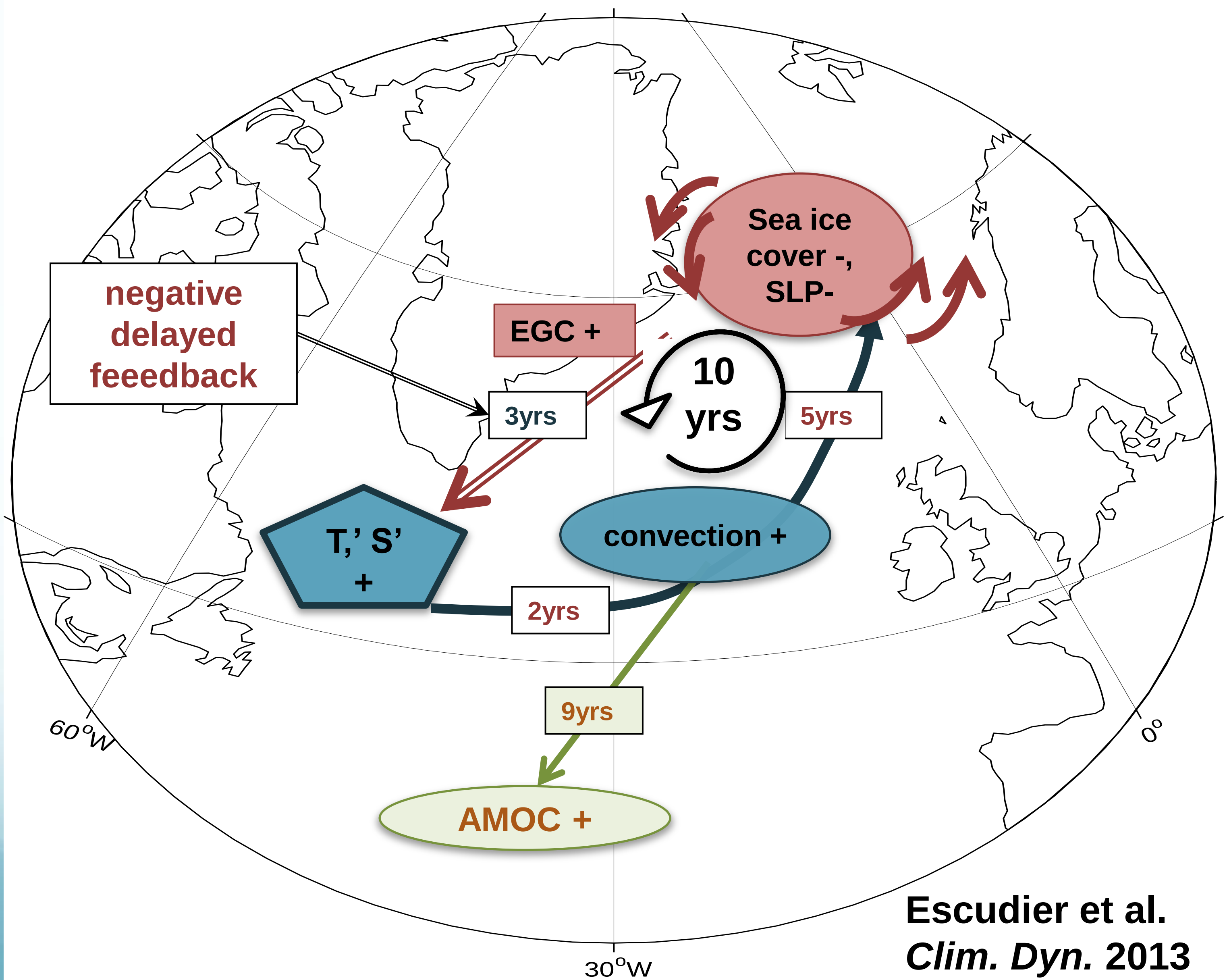
AMOC Initialisation

- IPSLCM5A-LR simulations nudged or free (with observed external forcings)
- Two reconstructions of the AMOC
- Agreement between nudged and reconstructions
- Synchronisation also in the historical simulations



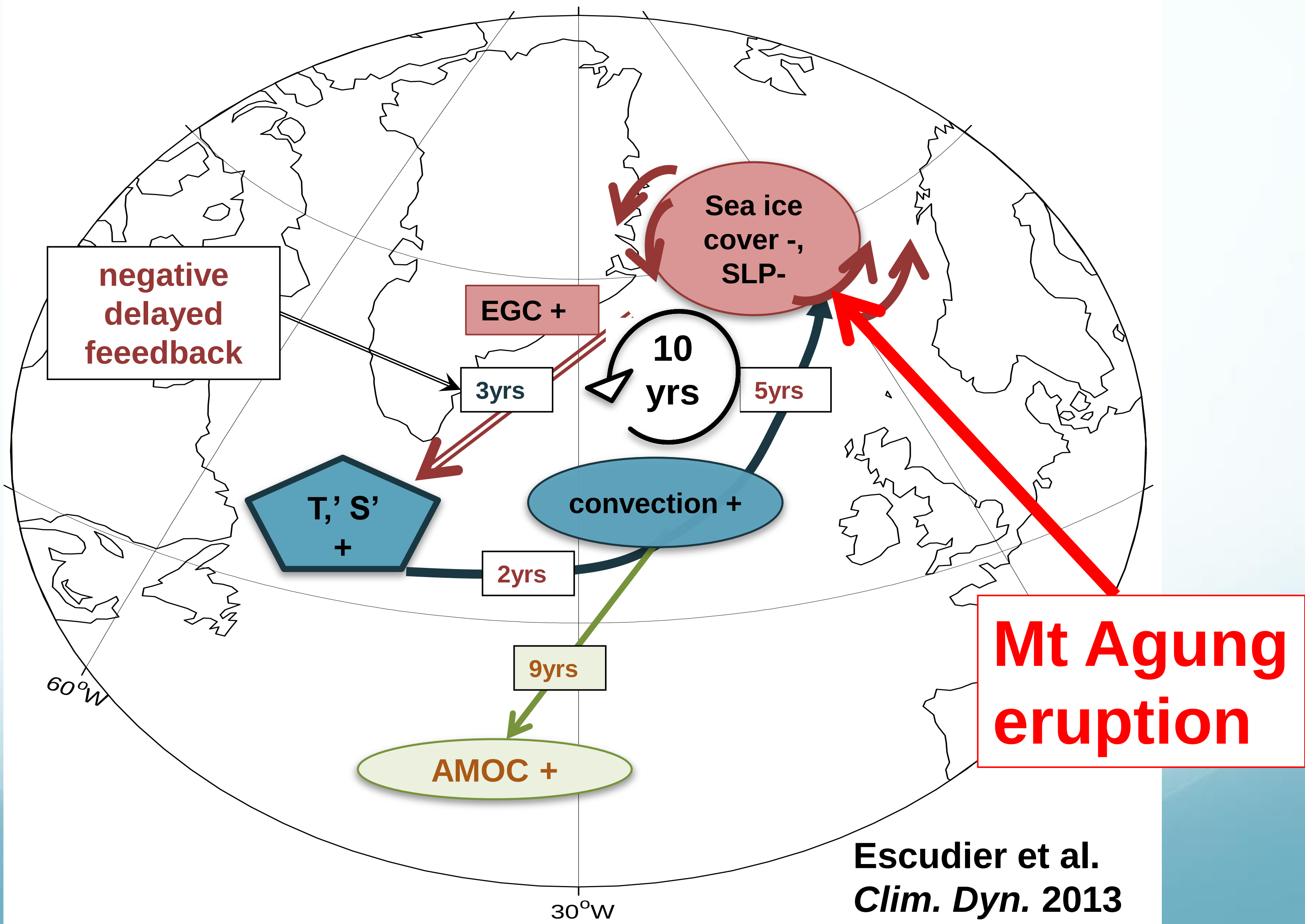
Swingedouw et al., *Clim. Dyn.* 2013

20-yr cycle in IPSL-CM5A-LR



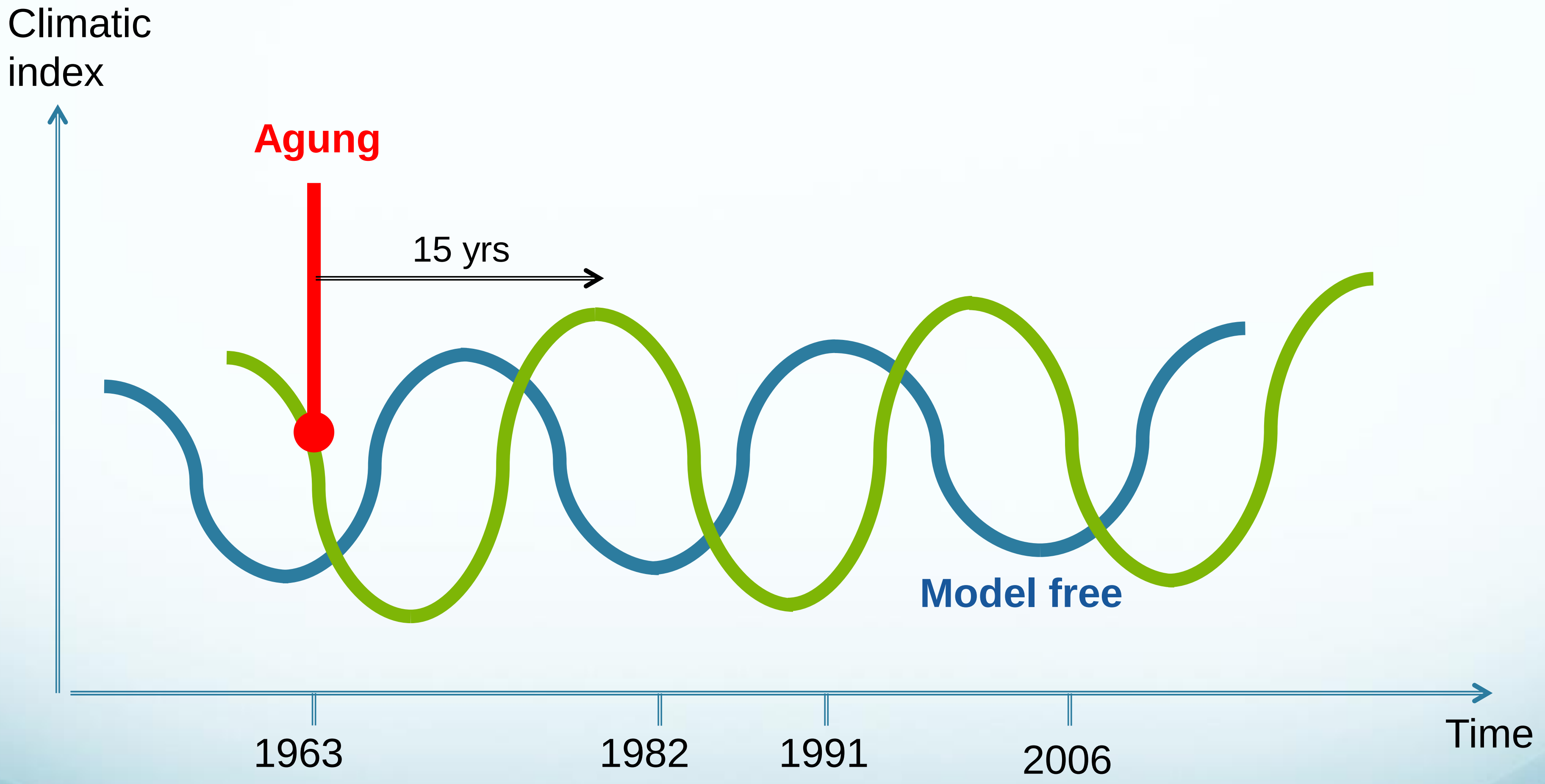
Escudier et al. *Clim. Dyn.* 2013

20-yr cycle in IPSL-CM5A-LR

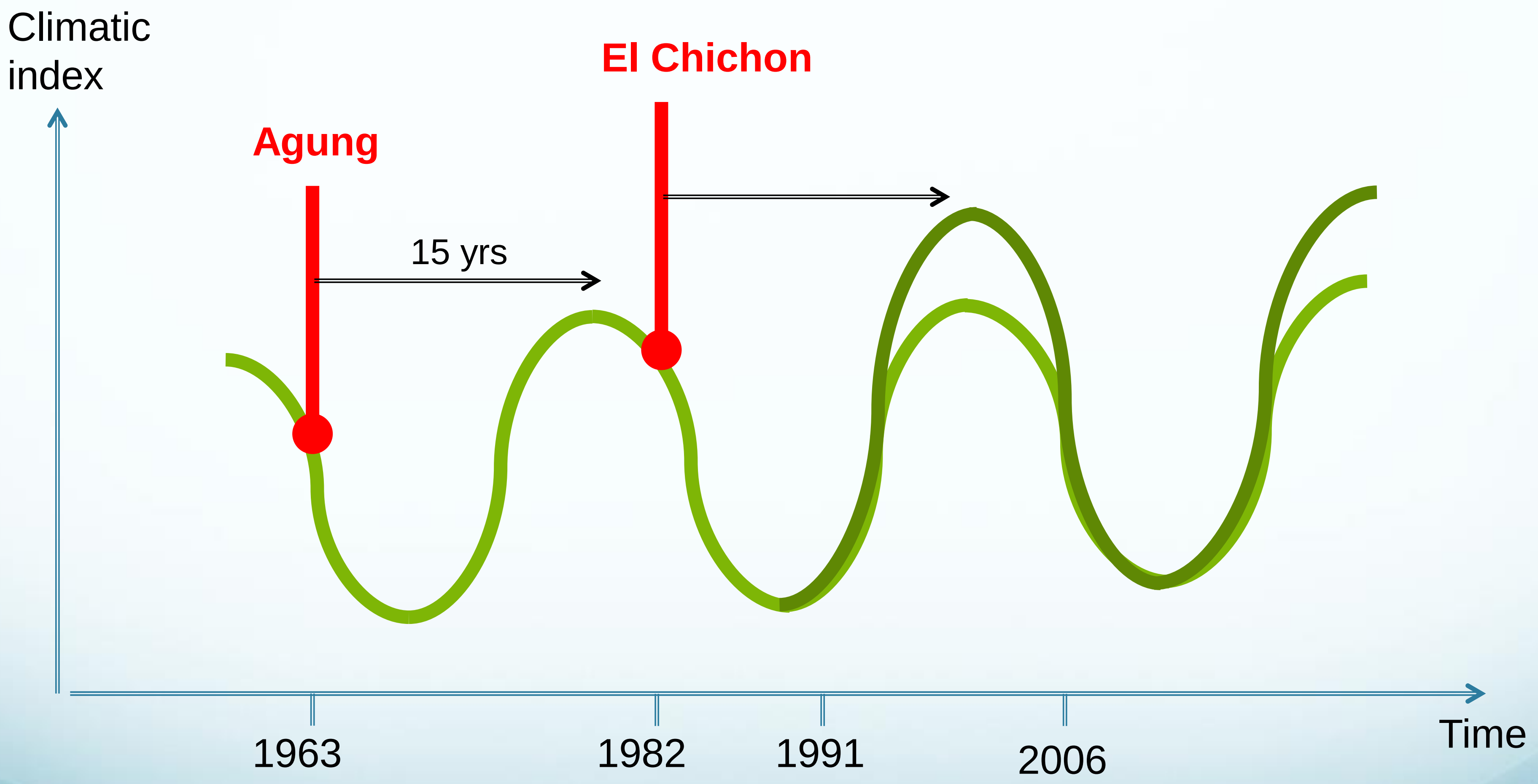


Escudier et al.
Clim. Dyn. 2013

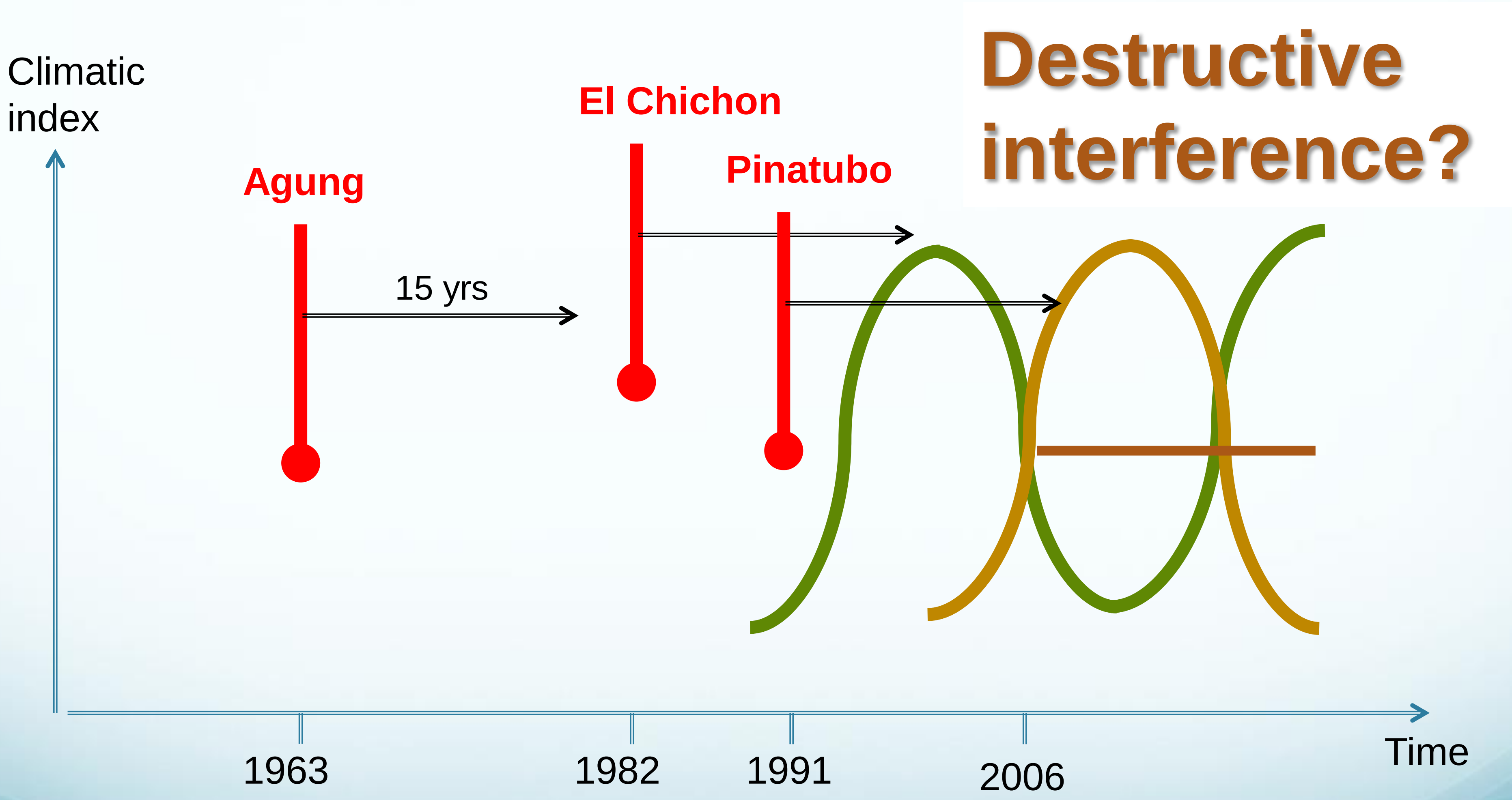
Impact of volcanic forcing



Impact of volcanic forcing

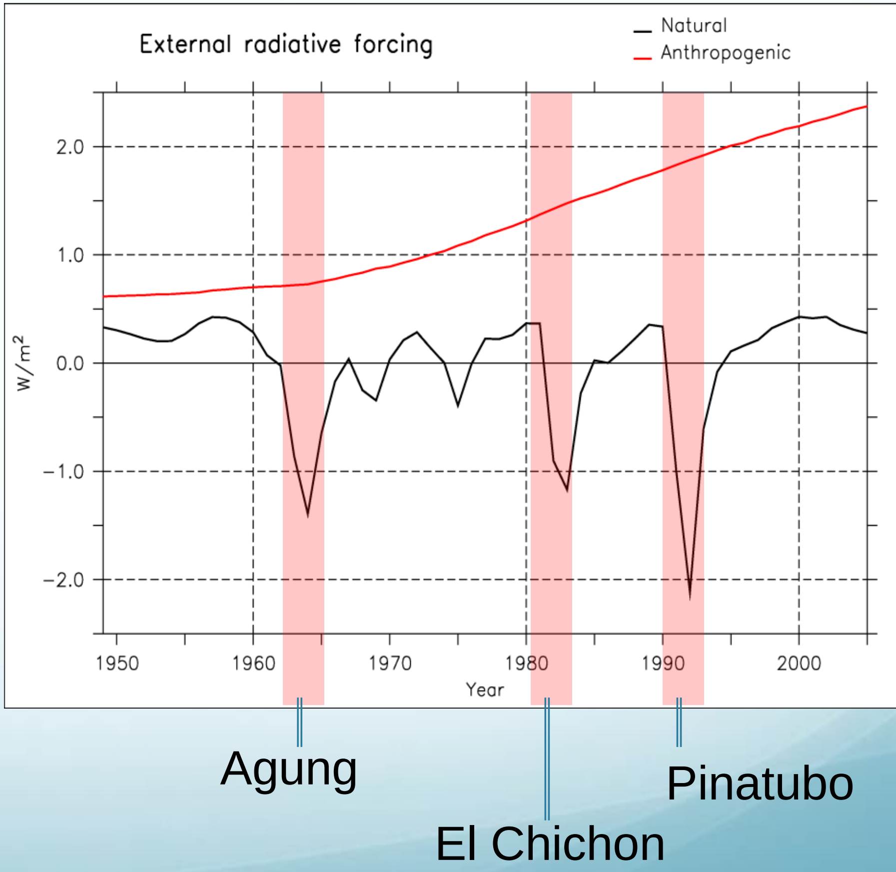


Impact of volcanic forcing



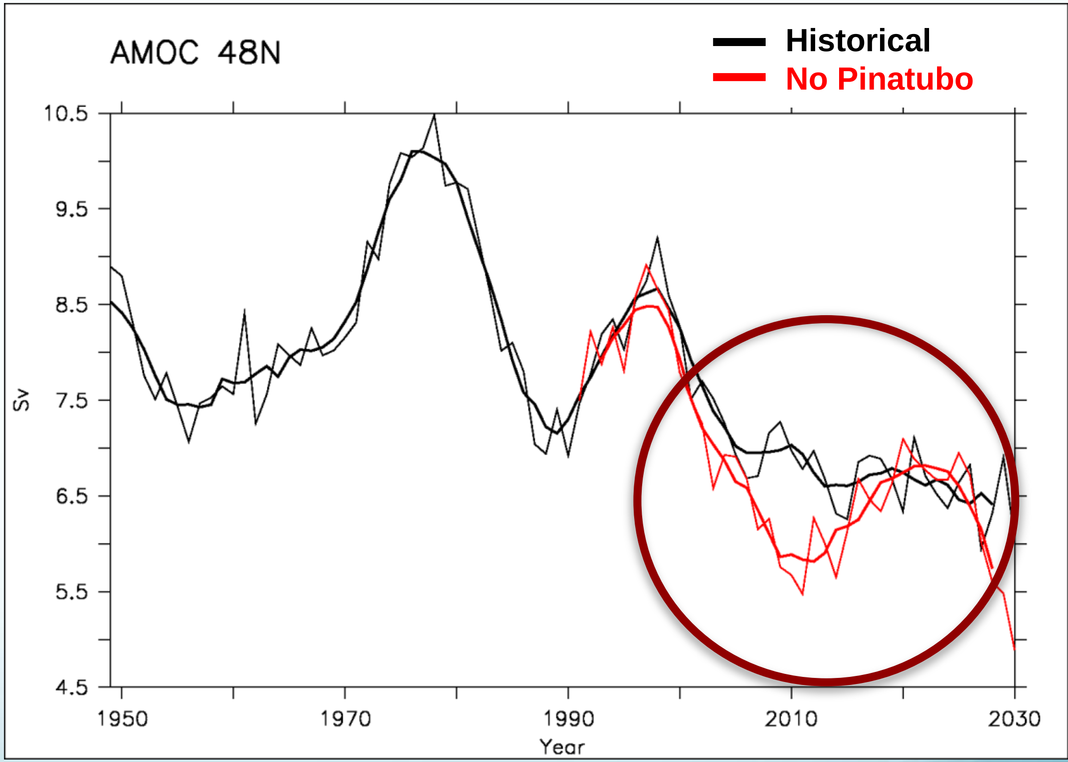
Experimental design

- IPSL-CM5A-LR climate model
- 5-member **historical** ensemble (natural and anthropogenic forcing)
- 5-member **initialised** ensemble nudged with SST anomalies
- 5-member sensitivity ensemble **without Pinatubo**
- **CMIP5** ensemble
- Comparison with existing **in situ SSS data**
- A **paleo-climate** perspective



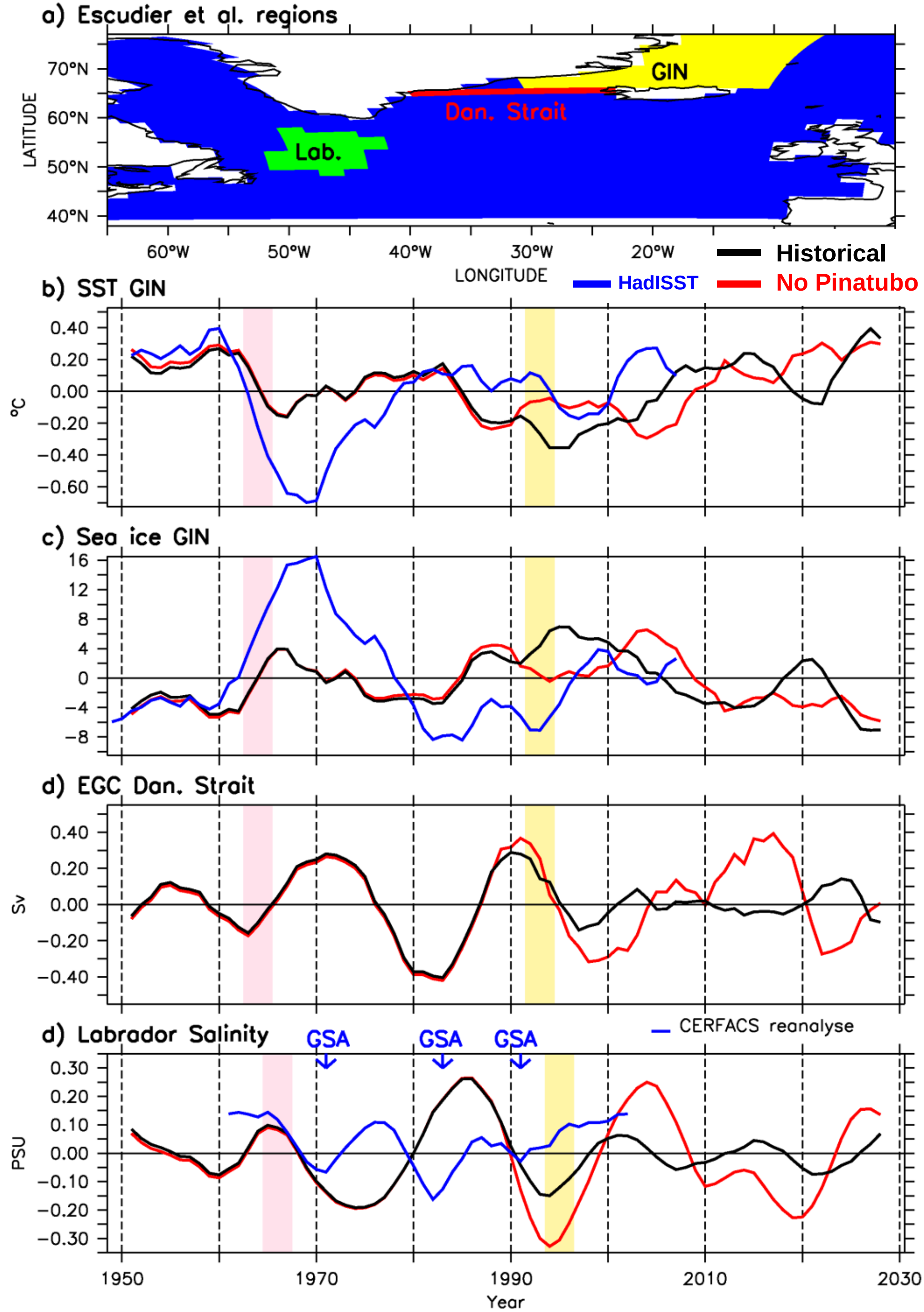
AMOC response in the IPSL-CM5A-LR model

- The sensitivity ensemble **without Pinatubo** shows a larger decrease in the early 2000's as compared to **historical** ensemble
- Then a partial recovery in the late 2010's



Mechanisms

- Pinatubo decreases SST and increases sea-ice cover in the GIN Seas
- This interferes with variability of the EGC
- This removes the salinity anomalies in the Labrador Sea
- And then the convection and the AMOC variations

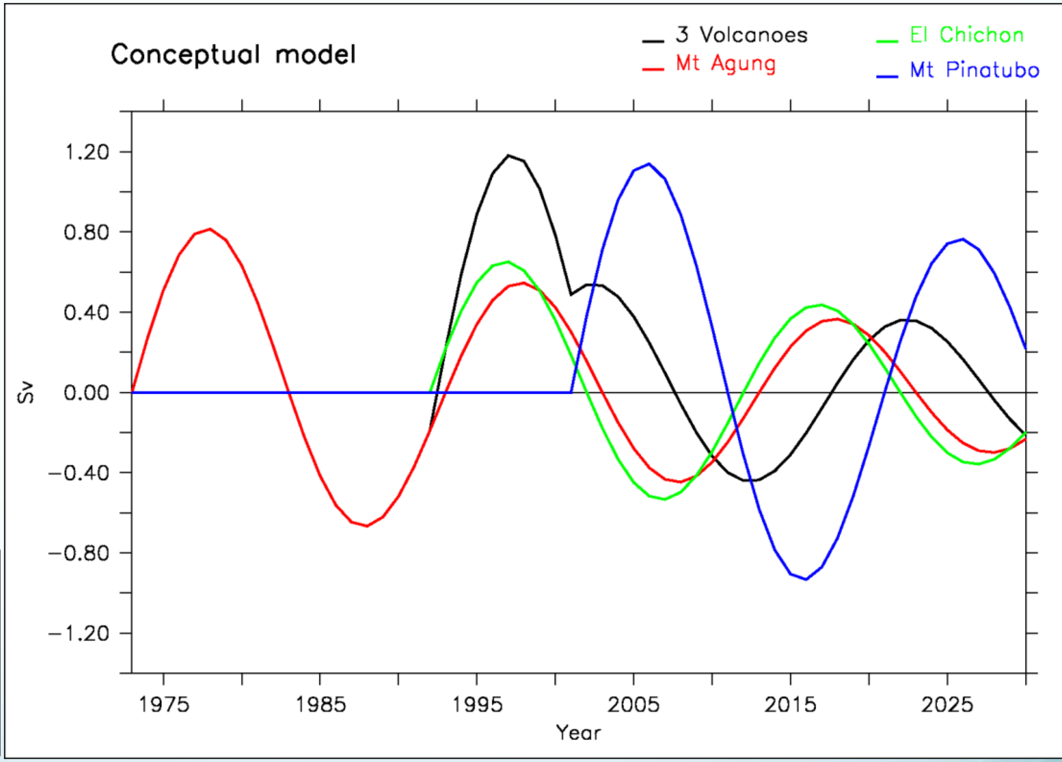


A conceptual model to explain AMOC variability in the model

We propose a conceptual model based on:

- harmonic response to volcanoes
- Linear response to radiative forcing (GHG)

$$f(t) = \sum_{i=1}^{3} a_i H(t - t_i)\sin\left(\frac{2\pi}{20}t\right)e^{-\frac{t-t_i}{D}} - b \times RF(t)$$

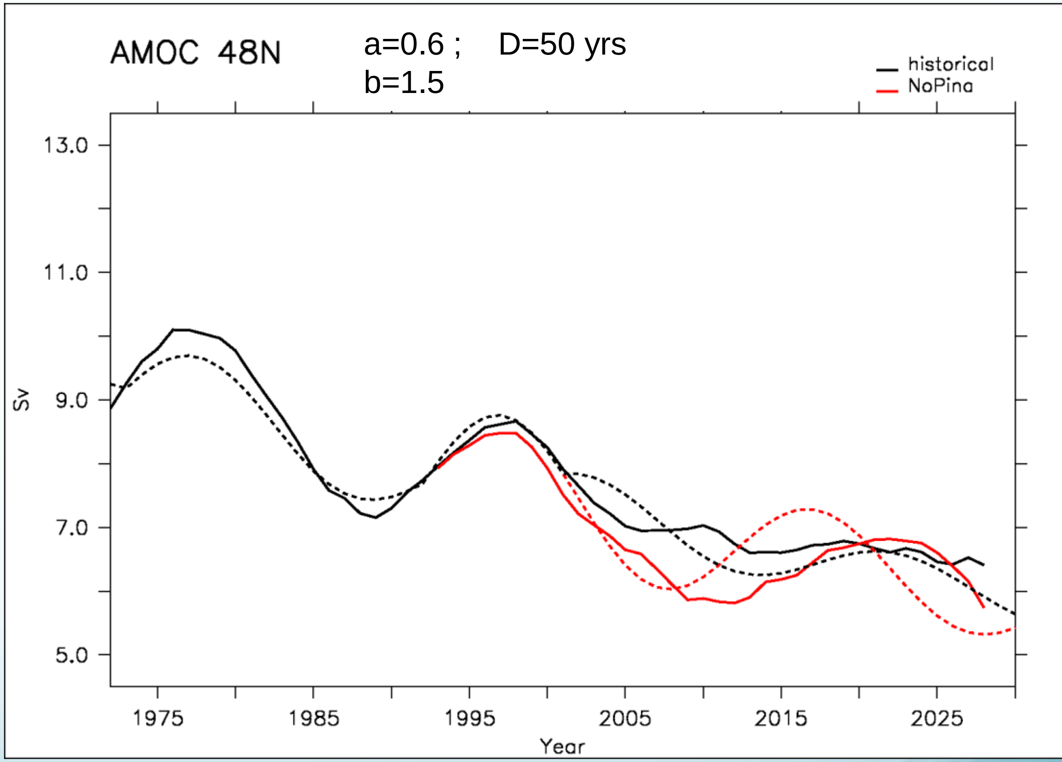


Comparison with IPSL-CM5-LR

We compare the conceptual model and the simulations

$$f(t)=\sum_{i=1}^{3} a_i H(t-t_i)\sin\left(\frac{2\pi}{20}t\right)e^{-\frac{t-t_i}{D}} - b\times RF(t)$$

$$f(t)=\sum_{i=1}^{2} a_i H(t-t_i)\sin\left(\frac{2\pi}{20}t\right)e^{-\frac{t-t_i}{D}} - b\times RF(t)$$

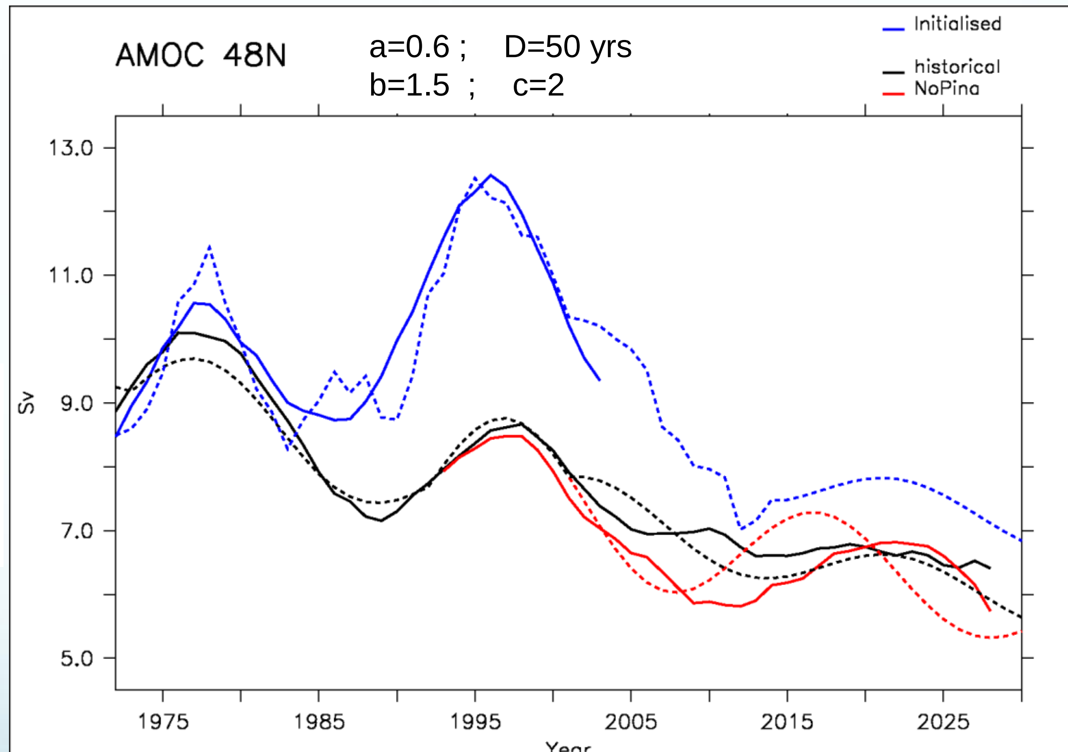


Role of observed NAO in the initialised ensemble

We add a term corresponding to observe NAO to explain AMOC variation in the initialised simulation

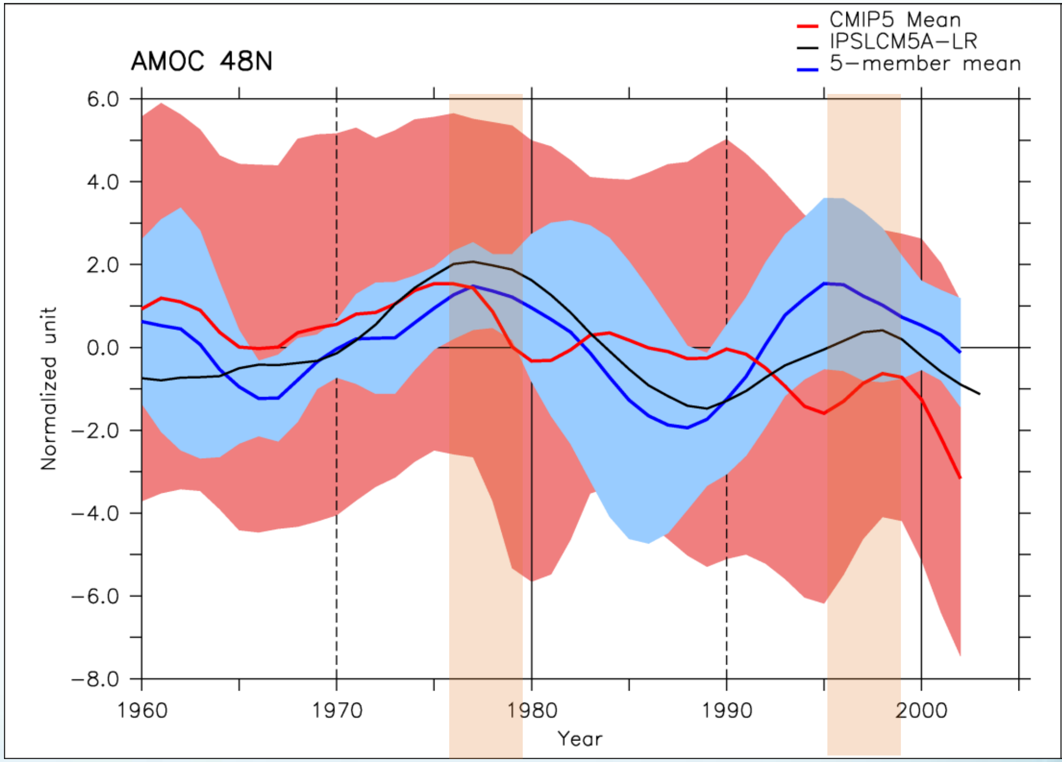
$$f(t) = \sum_{i=1}^{3} a_i H(t - t_i)\sin\left(\frac{2\pi}{20}t\right)e^{-\frac{t-t_i}{D}} - b \times RF(t)$$

$$+ c \times NAO(t+T)$$

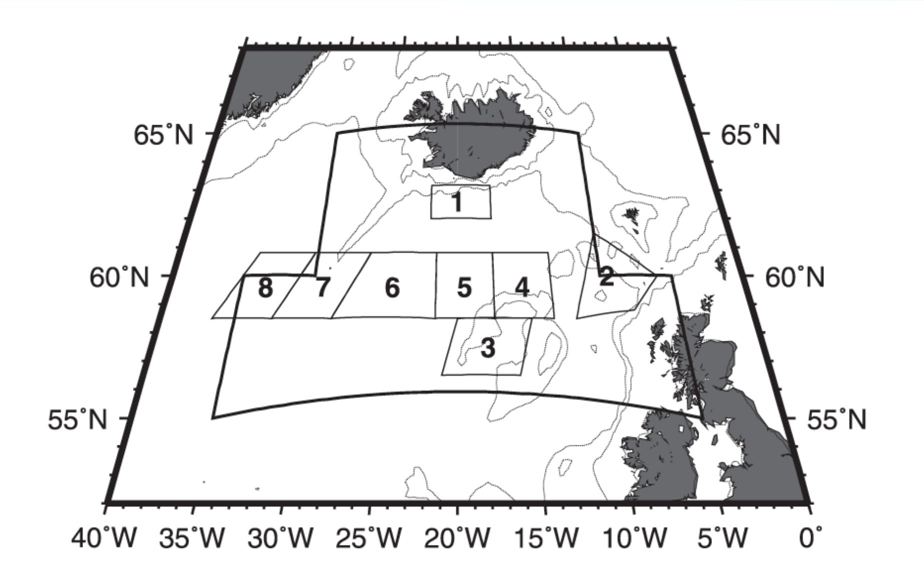


A CMIP5 multi-model confirmation?

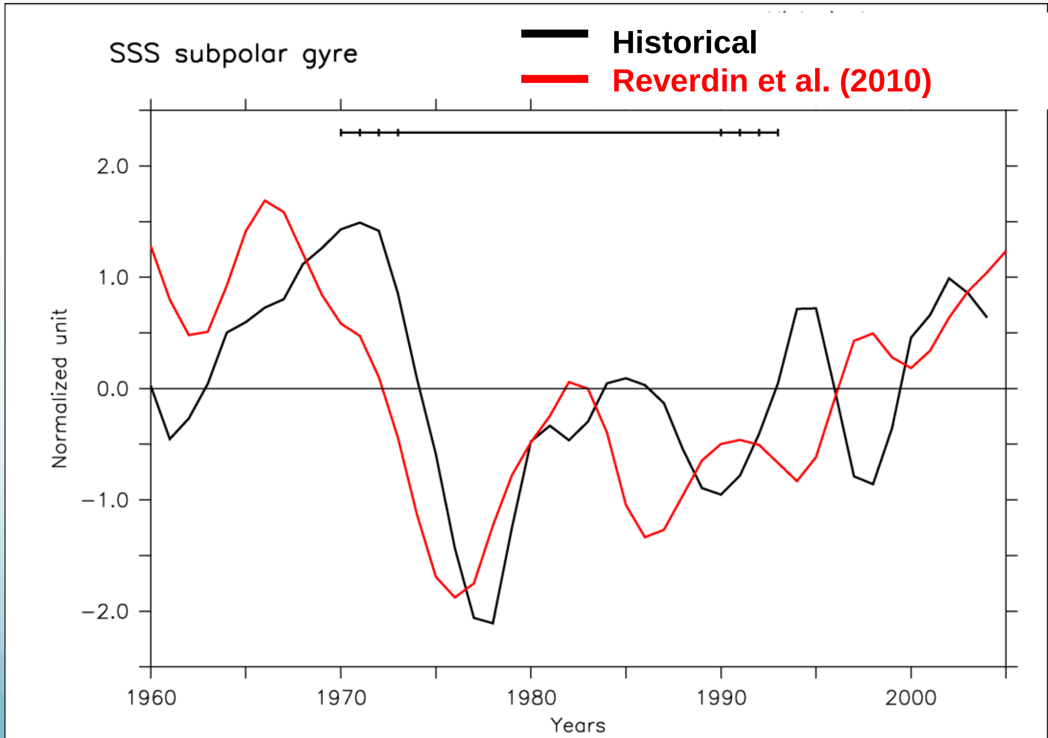
- 11 individual models (not different versions) from **CMIP5 WITHOUT** IPSLCM5A
- The ensemble mean shows a maximum in AMOC just before 1980 as in IPSLCM5A
- Large spread
- **5 models** show a maximum of energy in the **12-30 yrs spectral band**. Strong similarity of the response in these 5 models



Comparison with in situ SSS in the subpolar gyre

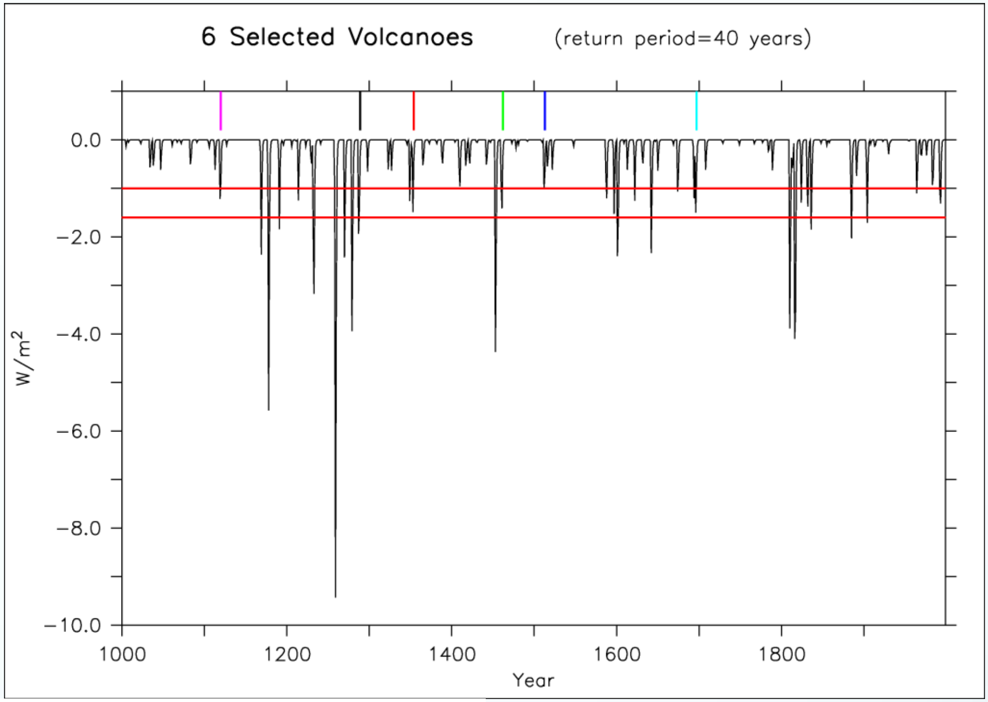


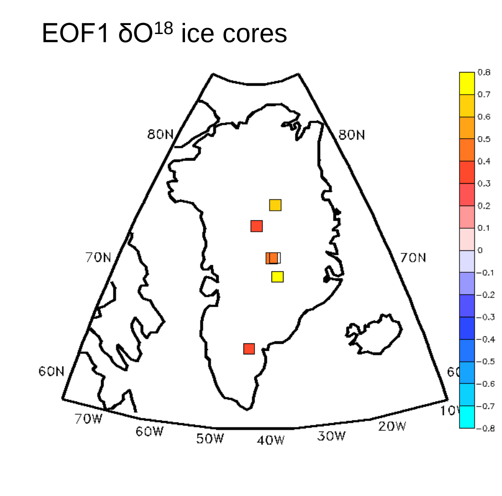
- Reverdin et al. (2010) reconstruction of SSS variability over the east subpolar gyre
- Too strong variance in the model (2 times)
- Agreement between **historical** and **data** from 1970 to 1994 (20-yr sliding window correlation, p<0.1)

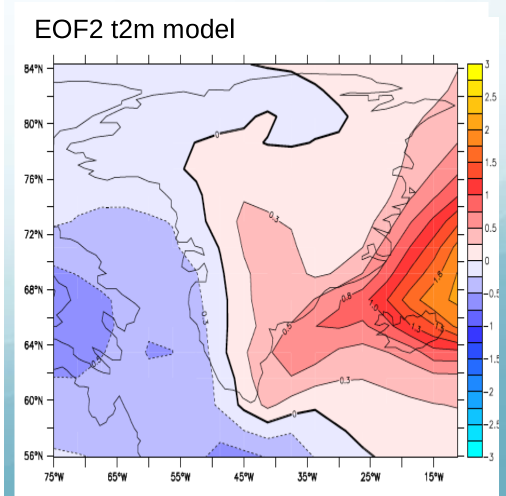


A paleo-perspective

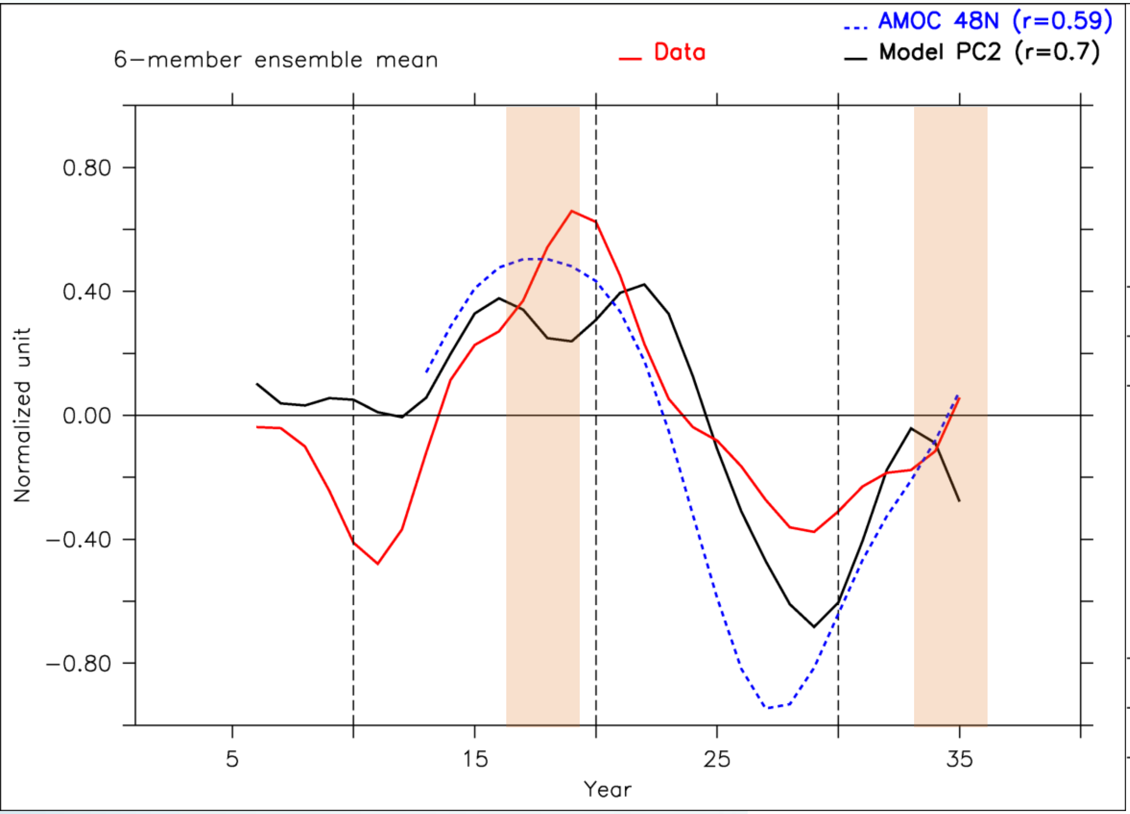
- Last millennium simulation from IPSLCM5A-LR (Khodri et al. in prep.)
- We select all the volcanoes from preindustrial era that are larger than Agung but not too large
- 6-member ensemble
- EOF1 of Compilation of 6 ice cores reconstructing Greenland O^{18} over the last millennium (Ortega et al. in prep.)

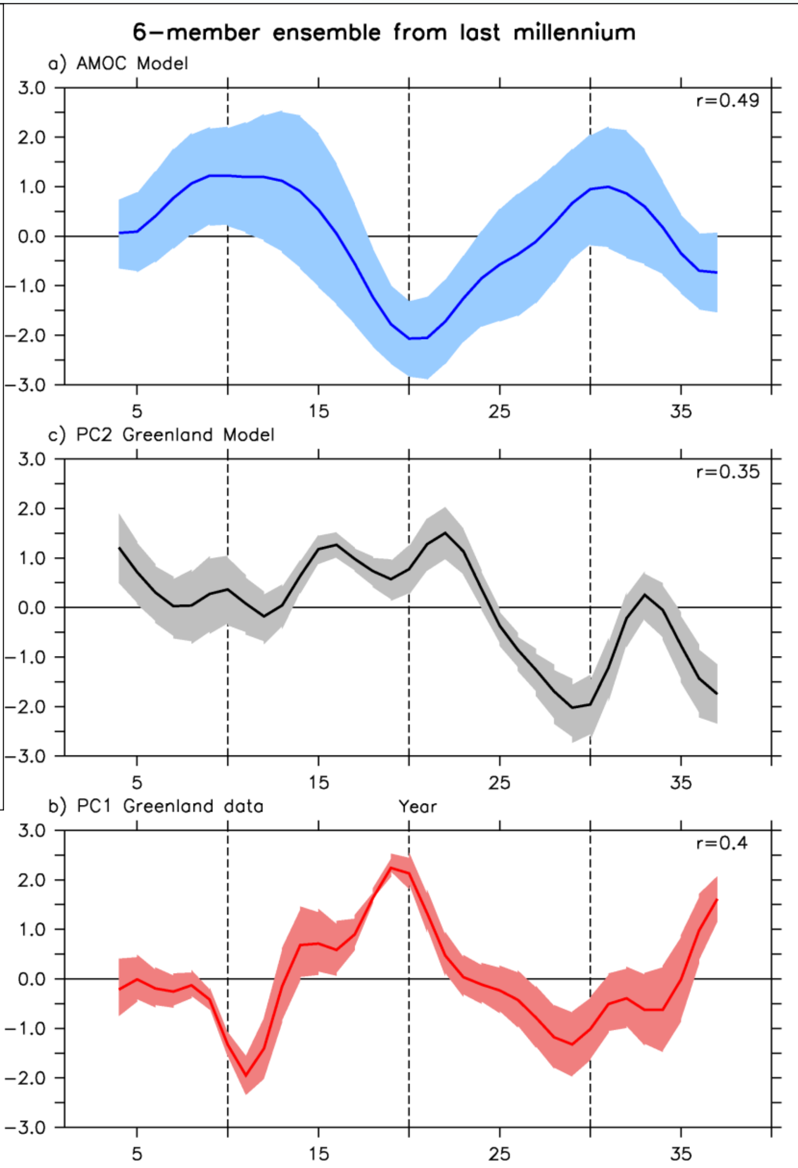


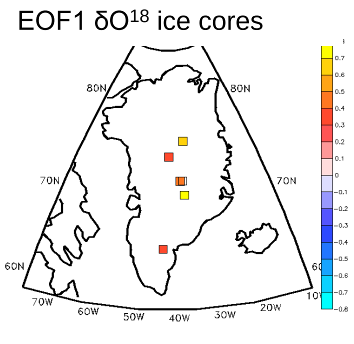




A paleo-perspective







Conclusions

- Volcanic eruption precedes an AMOC maximum by around 10-15 years
- Effect of Pinatubo: **destructive interference**!
- NAO still explains large amount of variance as compared to this mechanism of 20-yr cycle excitation by volcanoes
- Impact of volcanoes also very clear in a **5-member CMIP5** ensemble
- Consistent with **in situ SSS** in the subpolar gyre
- And data of Greenland over the **last millennium**

⇒ **large body of evidences** confirming potential reality of these processes in response to volcanic eruptions

Thank you

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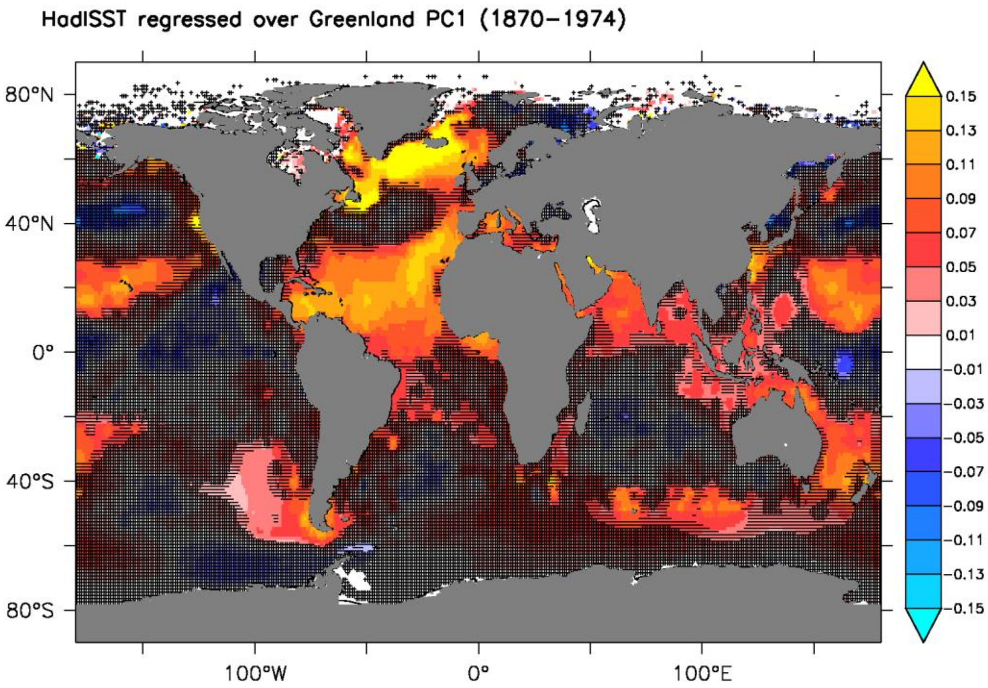
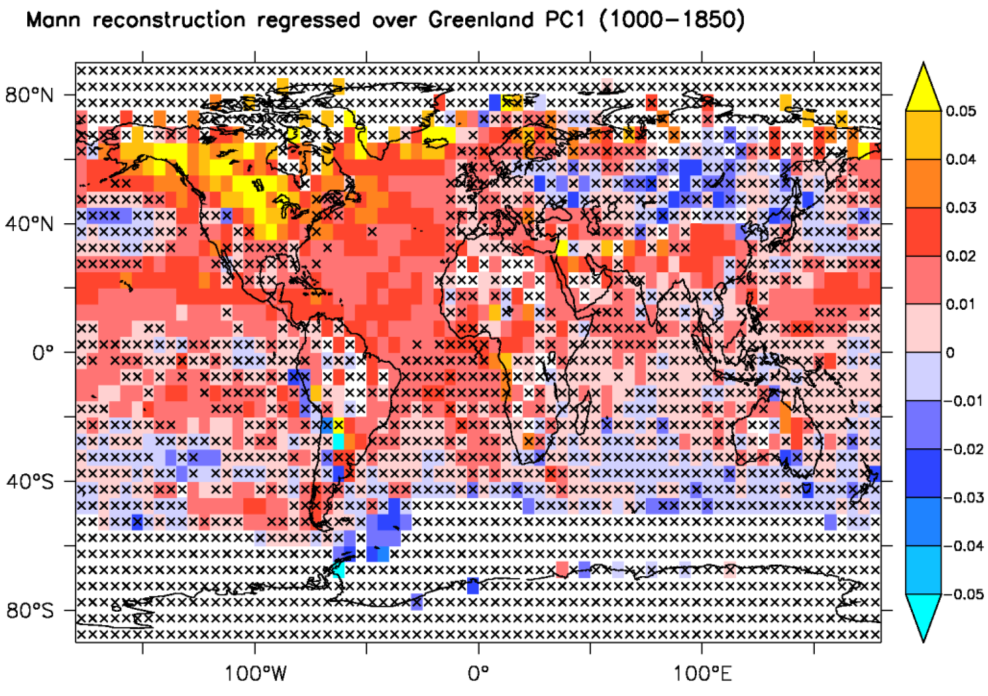
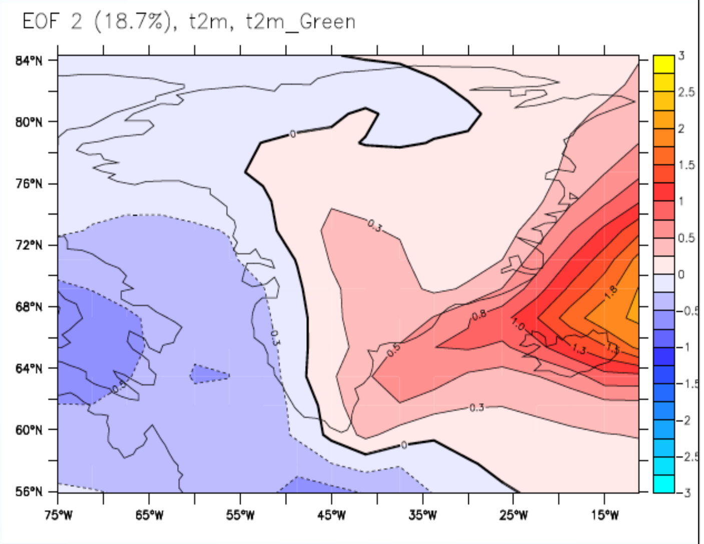
Courtesy of Bruno Ferron, OVIDE 2010

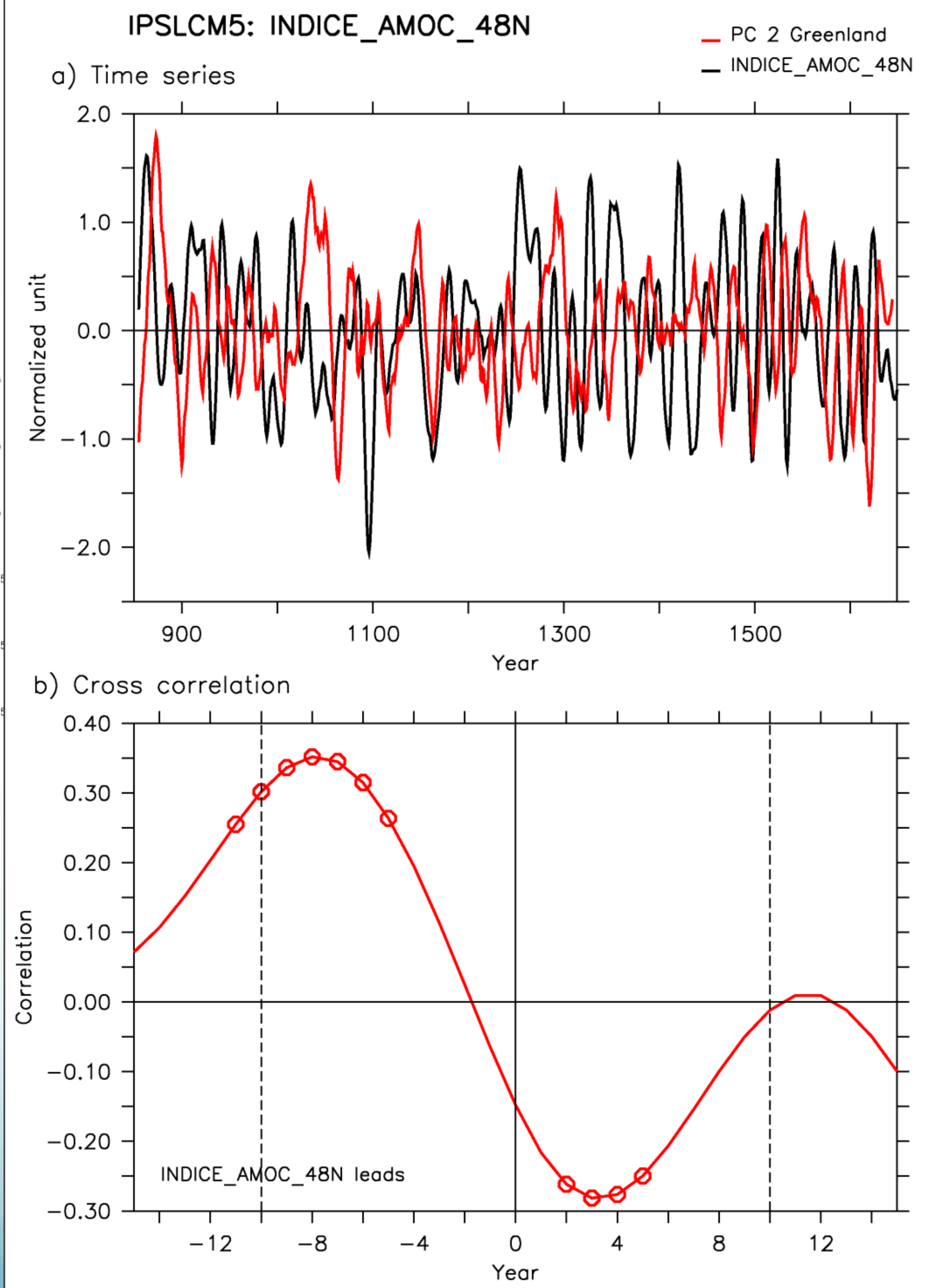
Link between PC1 over Greenland and the AMO





A paleo-perspective





In the model, the AMOC indeed leads by 7 years the PC2 of Greenland t2m for the whole simulation

A multi-model confirmation?

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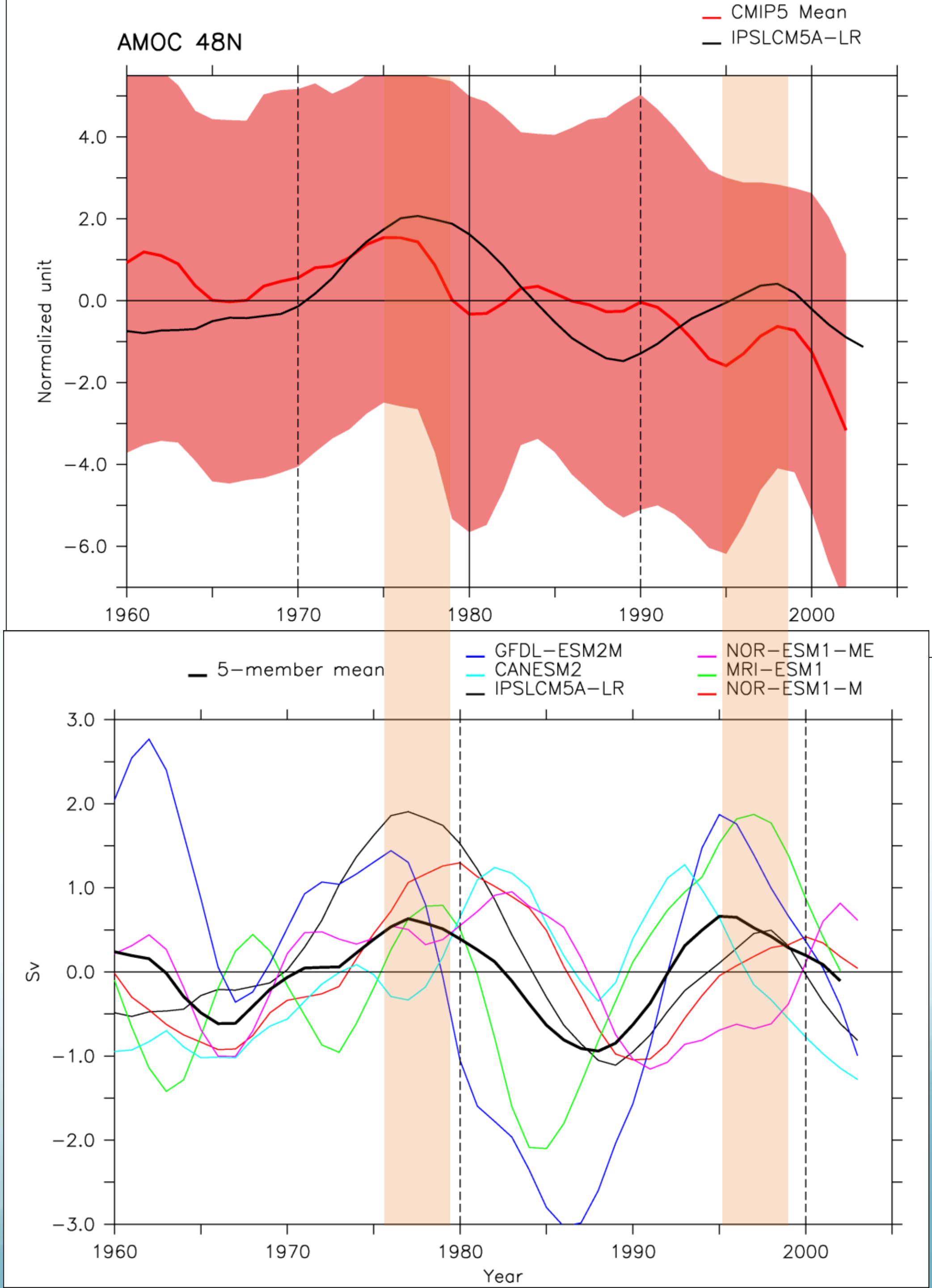
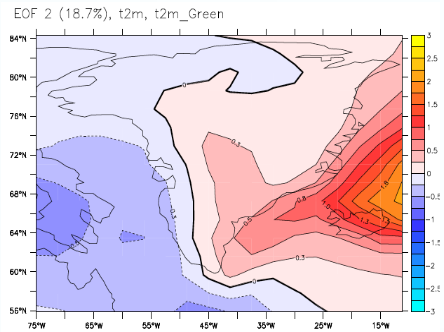
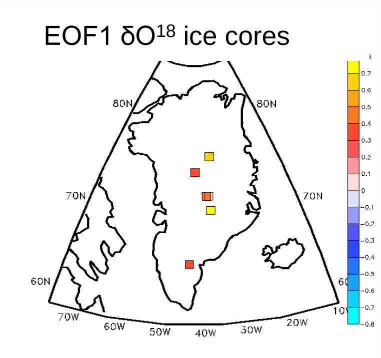
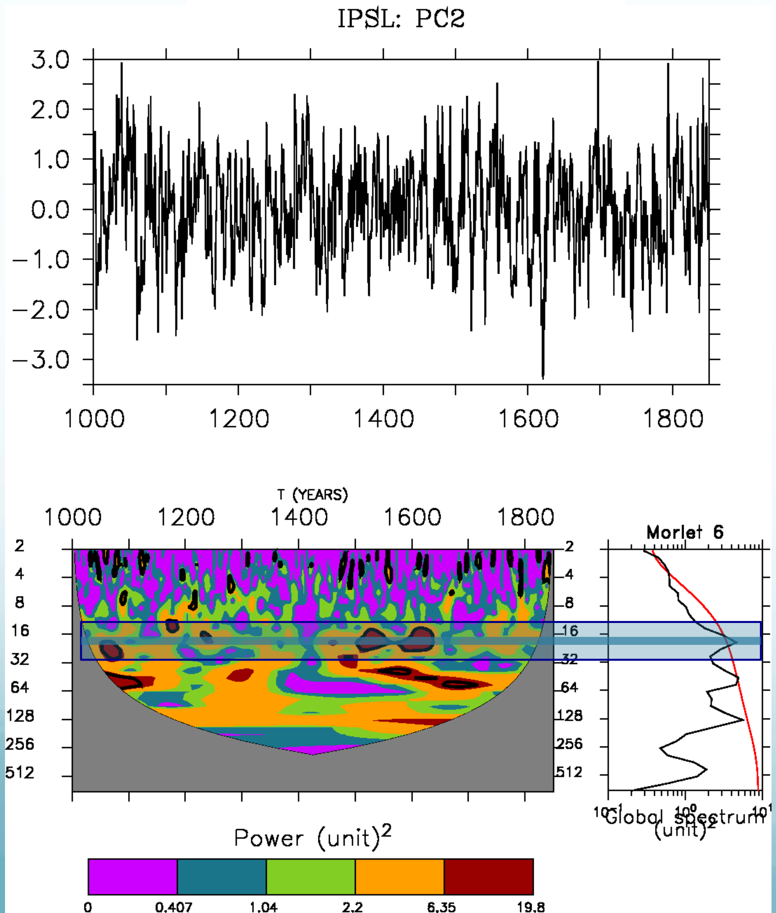
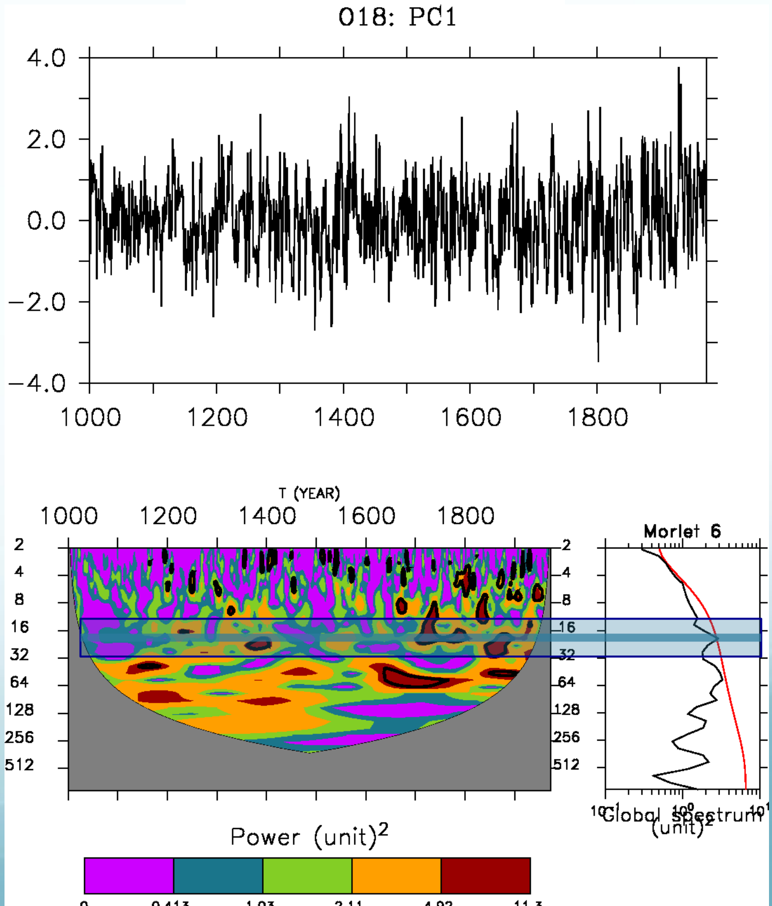


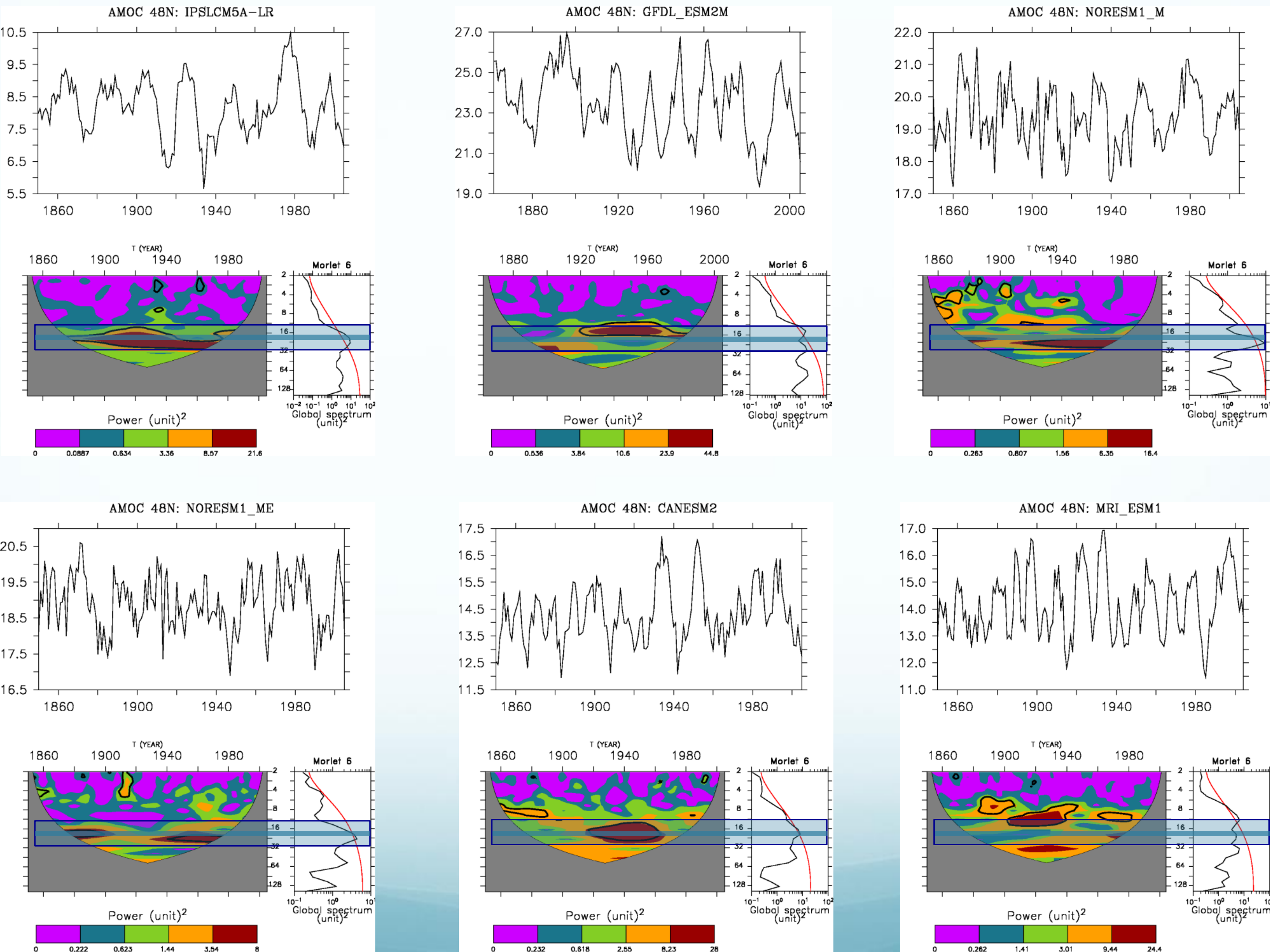
A paleo-perspective





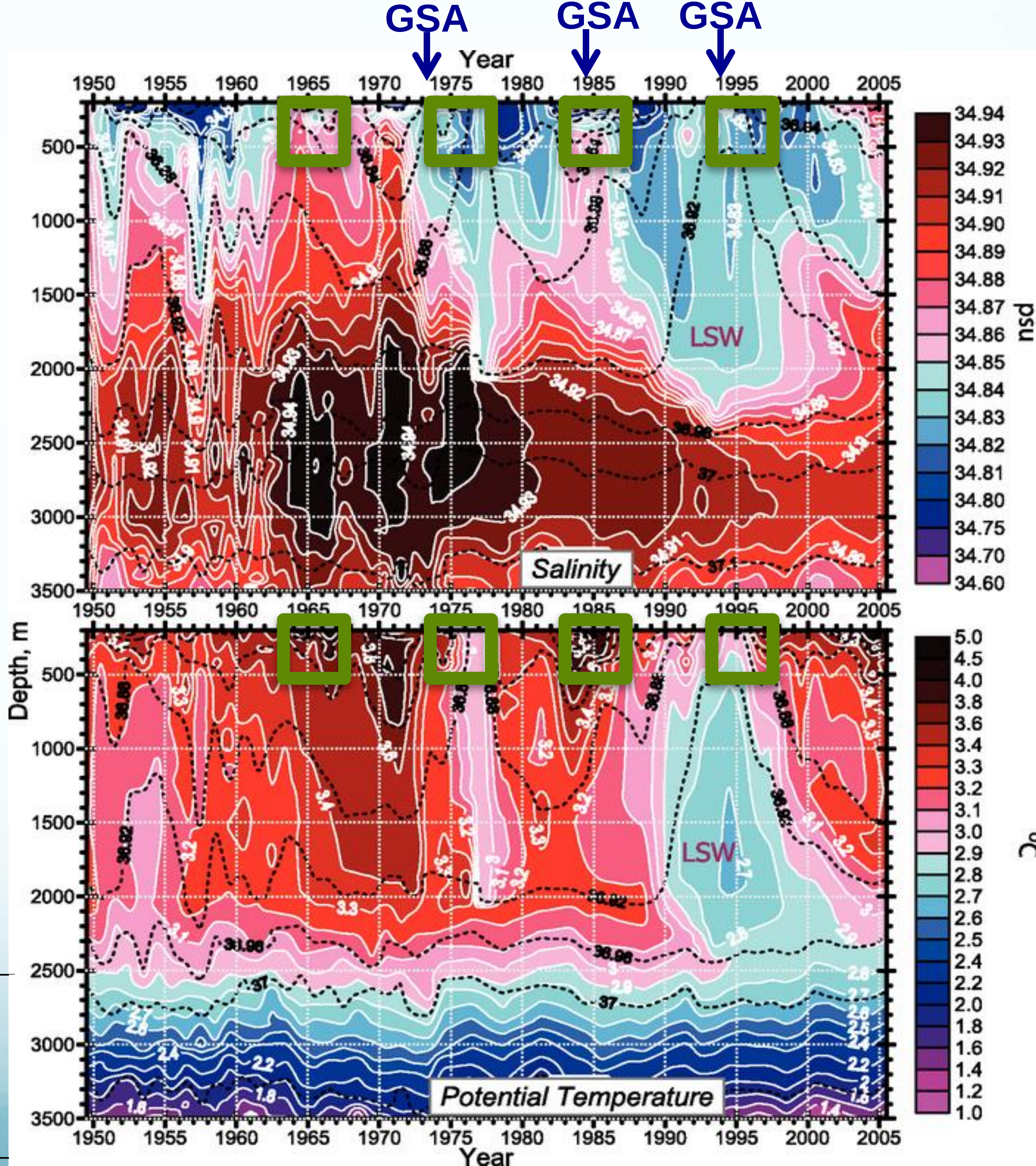





AMOC 48N: IPSLCM5A-LR
AMOC 48N: GFDL_ESM2M
AMOC 48N: NORESM1_M
AMOC 48N: NORESM1_ME
AMOC 48N: CANESM2
AMOC 48N: MRI_ESM1
T (YEAR)
Morlet 6
Power (unit)2
Global spectrum (unit)2
0 0.0887 0.634 3.36 8.57 21.6
0 0.536 3.84 10.6 23.9 44.8
0 0.263 0.807 1.56 6.35 16.4
0 0.222 0.623 1.44 3.54 8
0 0.232 0.618 2.55 8.23 28
0 0.262 1.41 3.01 9.44 24.4

In situ Labrador Sea variation

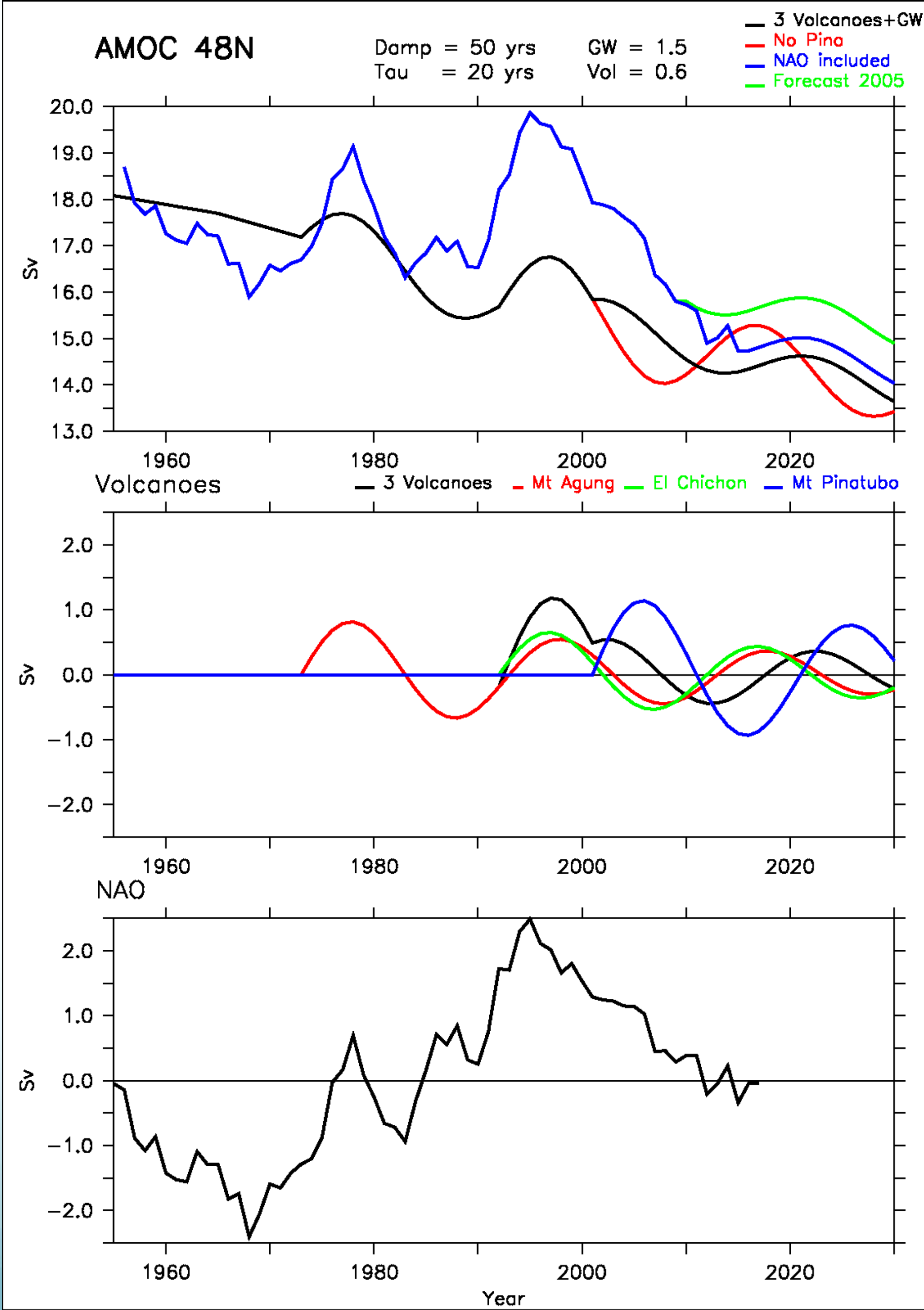
- The 1985 GSA is clearly different from 1972 and 1993 in the sense that there is a subsurface positive anomaly
- Belkin et al. (1998): two modes of GSA, one remote (Artic) and one more local (1980s)



Central Labrador Sea from 1949 to 2005 (updated from Yashayaev et al., 2003)
Source IPCC 2007

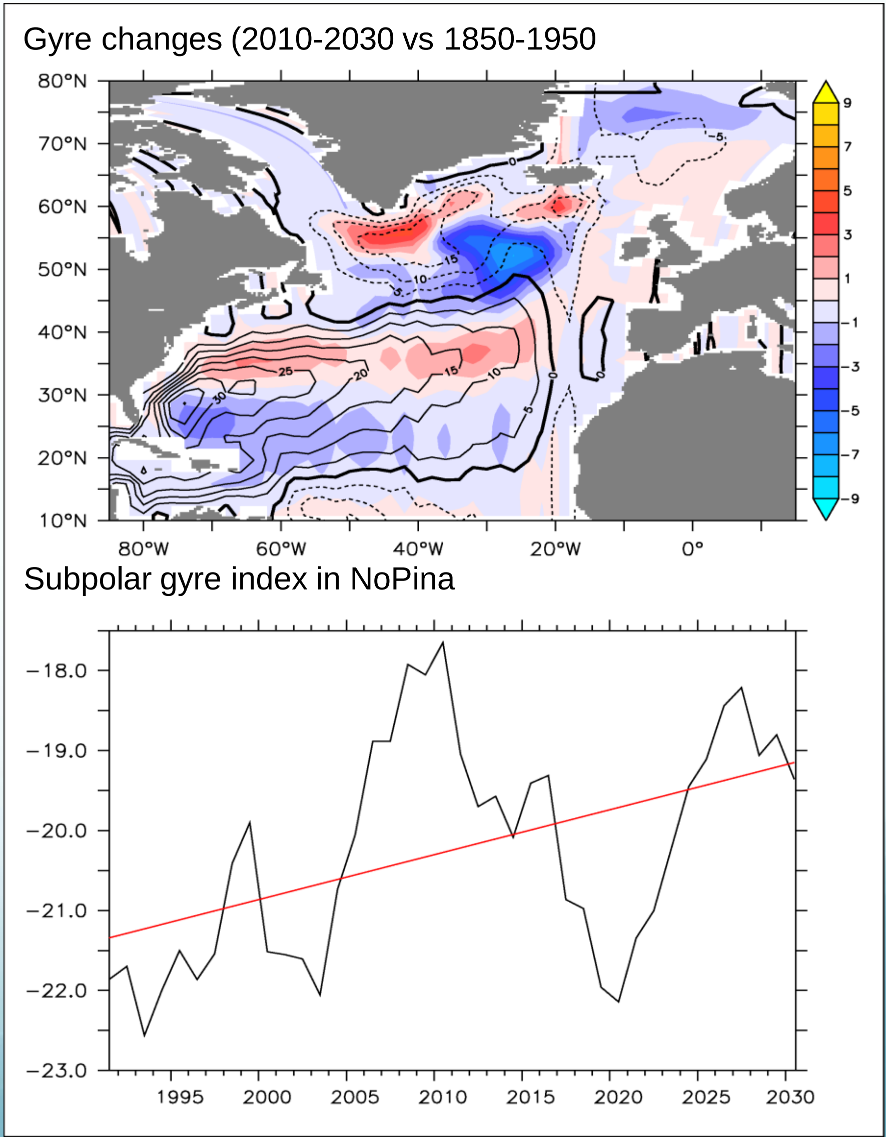
Comparison of the AMOC forcings

- NAO forcing is larger than that from volcanoes
- Over the period 1973-2018:
  - Std volcanoes =0.54 Sv
  - Std NAO = 0.93 Sv



Slow down of the subpolar gyre

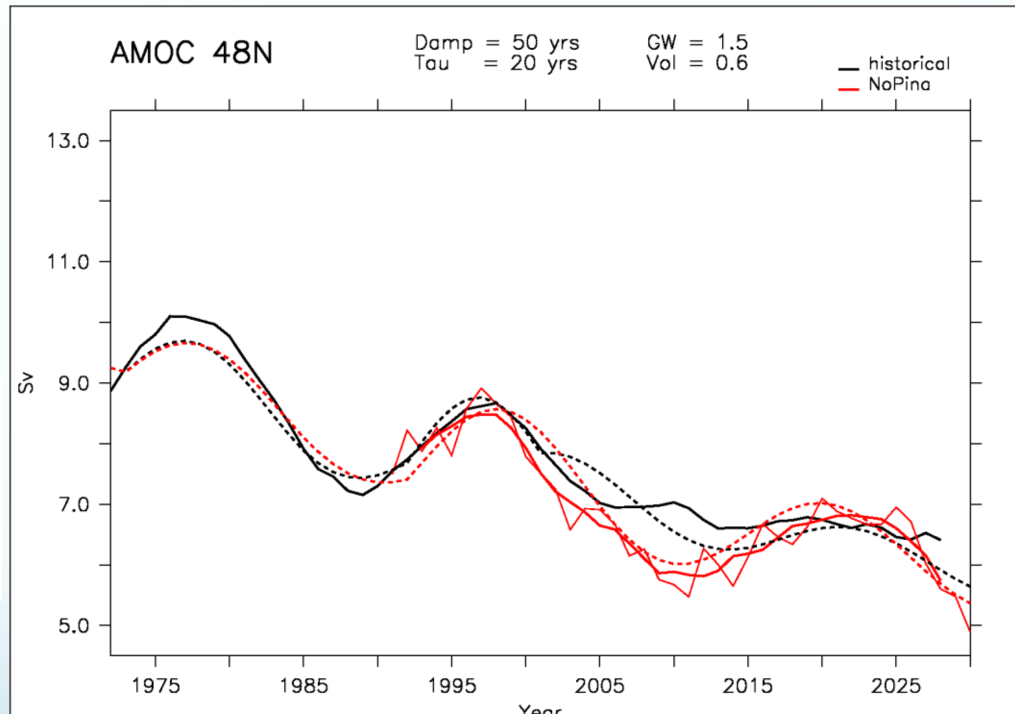
- The 20-yr cycle in the model is dependant on the subpolar gyre strength (anomalies propagation)
- The subpolar gyre is slowing down in the model (10% in 40 years)
- To improve the model we can take into account this slowing down



Accounting for the slow down of the subpolar gyre

To improve the model we take into account the slowing down of the subpolar gyre (10% in 40 years)

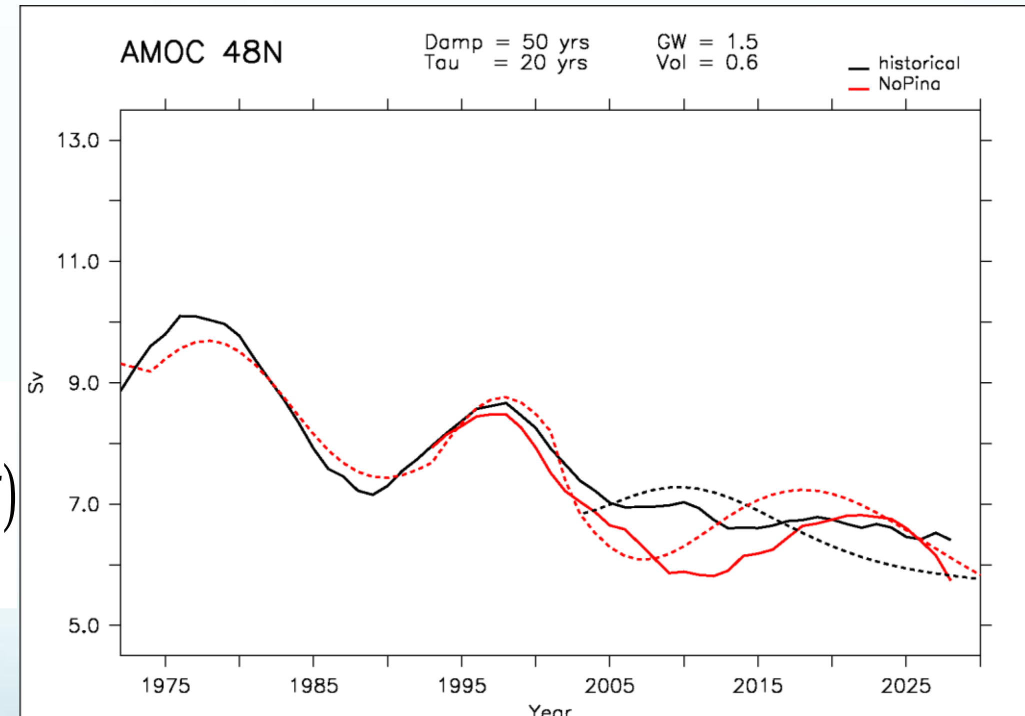
$$f(t) = \sum_{i=1}^{3} a_i H(t - t_i) \sin\left(\frac{2\pi}{22} t\right) e^{-\frac{t - t_i}{D}} - b \times RF(t)$$



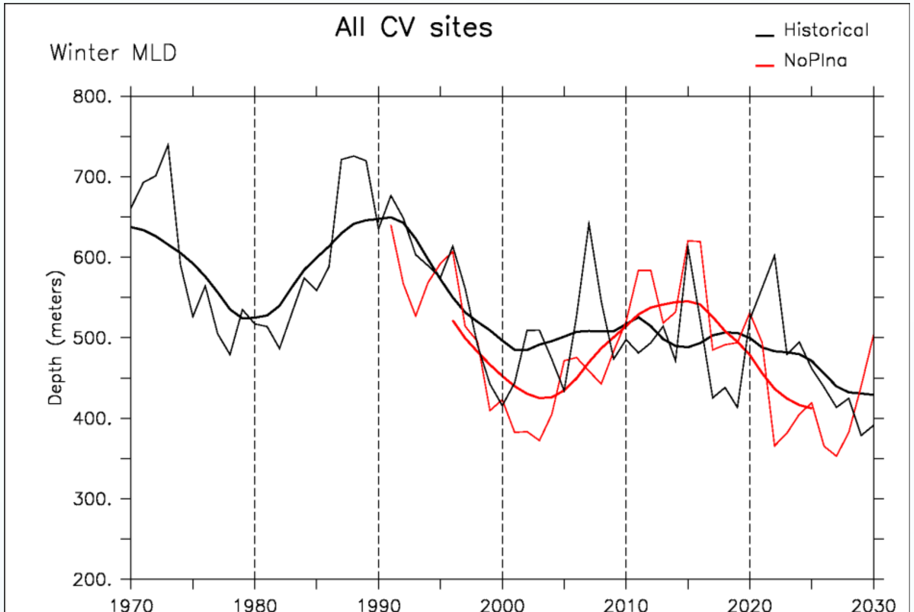
Accounting for the slow down of the subpolar gyre

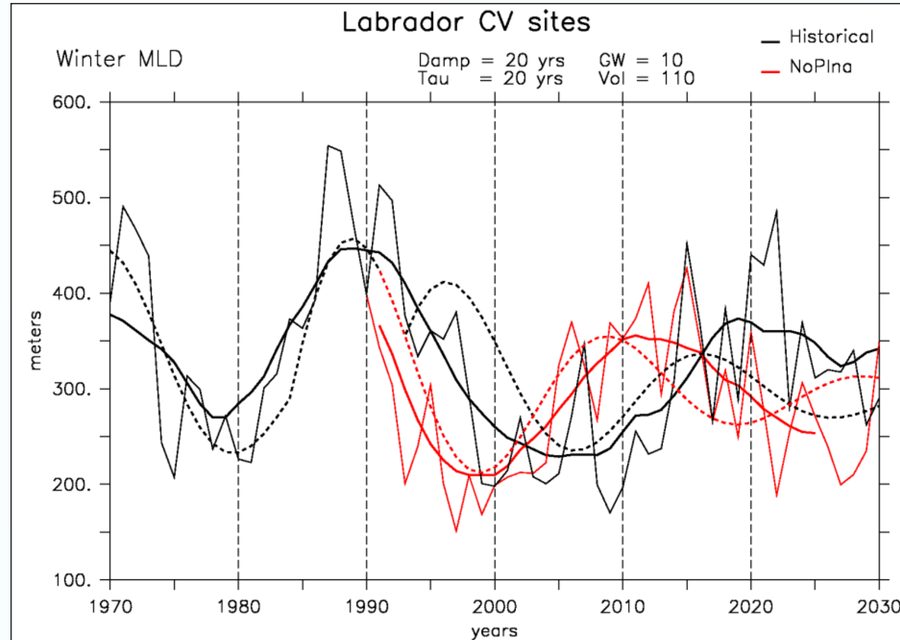
To improve the model we take into account the slowing down of the subpolar gyre (20% in 20 years from 1990 to 2010)

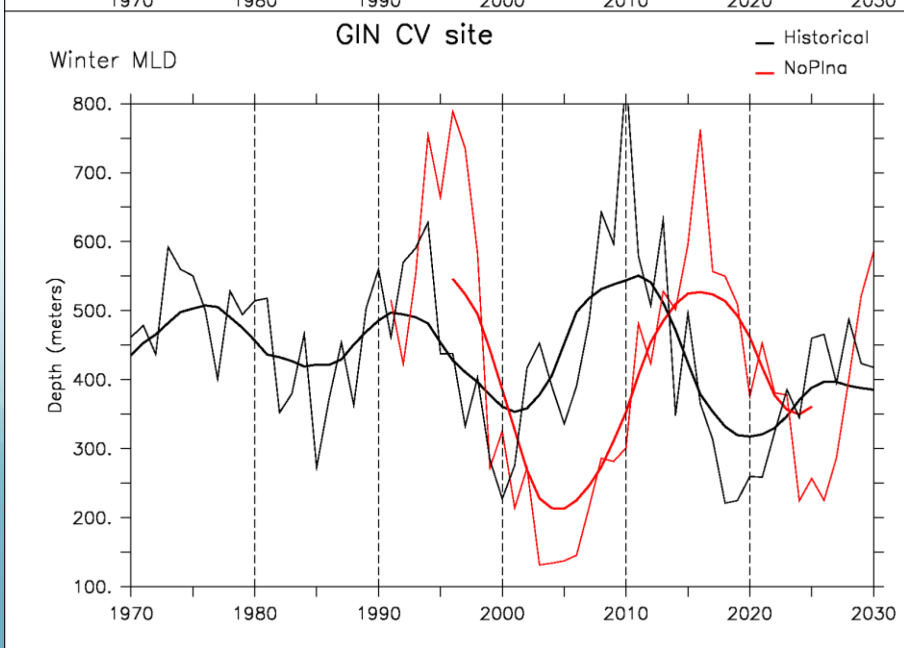
$$f(t)=\sum_{i=1}^{3} a_i H(t-t_i)\sin\left(\frac{2\pi(1-0.01t)}{20}t\right)e^{-\frac{t-t_i}{D}} - b \times RF(t)$$

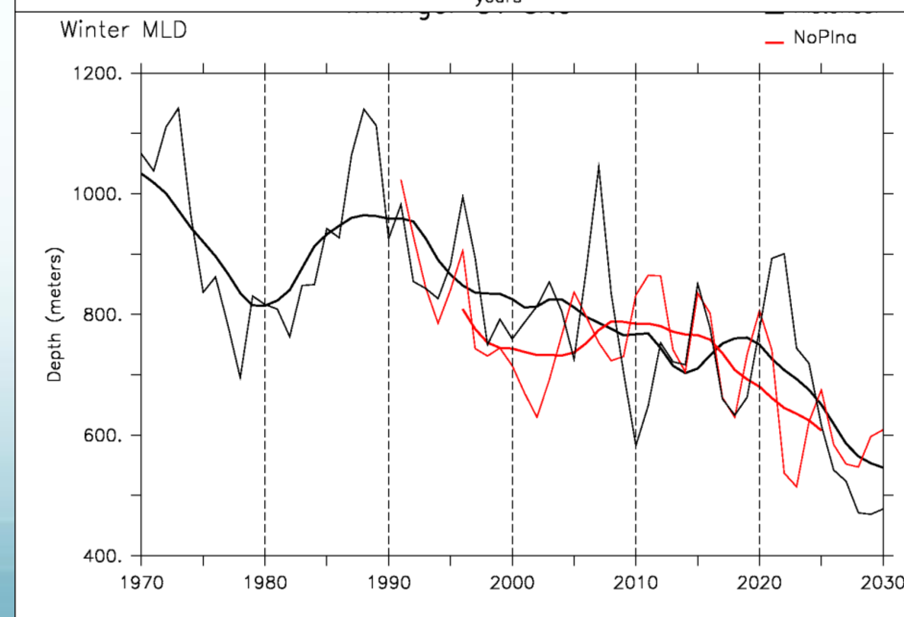


Convection sites response

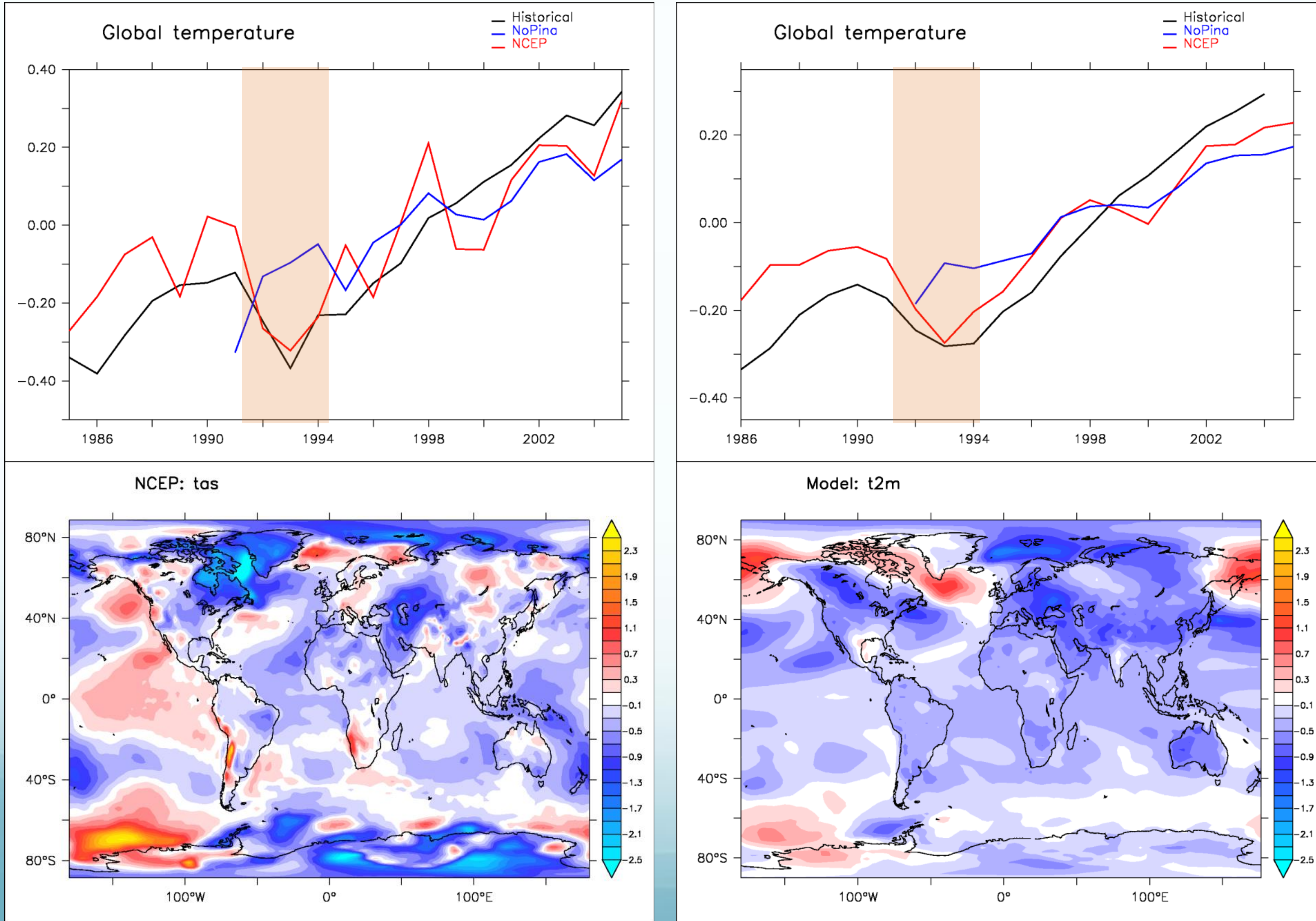








Pinatubo direct impact



Is volcanic impact on the NAO so clear in data?