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

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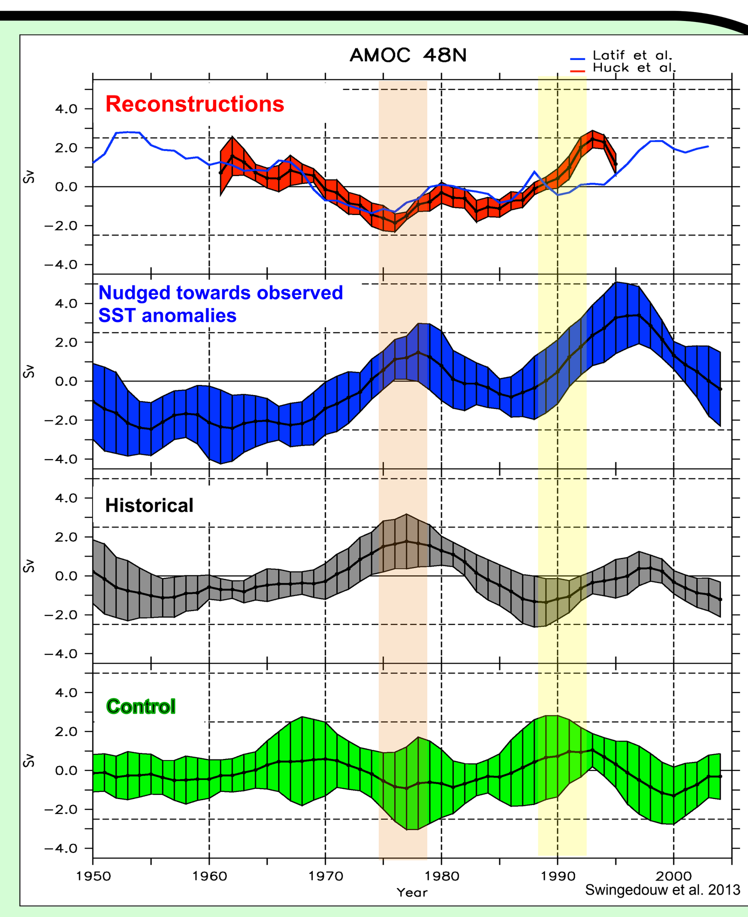
Background

- Volcanoes can play the role of a pacemaker for the climatic variability (Otterå et al. 2011) and the Atlantic Meridional Overturning Circulation (AMOC)
- Clues for a 20-yr preferential variability in Greenland ice cores data (Chylek et al. 2011) in oceanic sediment data north of Iceland (Sicre et al. 2008) and in models (Frankcombe et al. 2010)
- In the IPSLCM5A-LR climate model: Mt Agung reset a 20-yr preferential variability in the North Atlantic (Swingedouw et al. 2013)



Aim of this work

1. Evaluate the timing of AMOC changes in CMIP5 simulations with respect to **Mt Agung eruption**
2. Evaluate the simulated processes using **North Atlantic in situ salinity data**
3. Evaluate the robustness of model response to volcanic events using **last millennium** simulations against **Greenland ice core data**
4. Investigate **interference patterns** due to the impacts of El Chichon and Pinatubo eruptions on ocean circulation

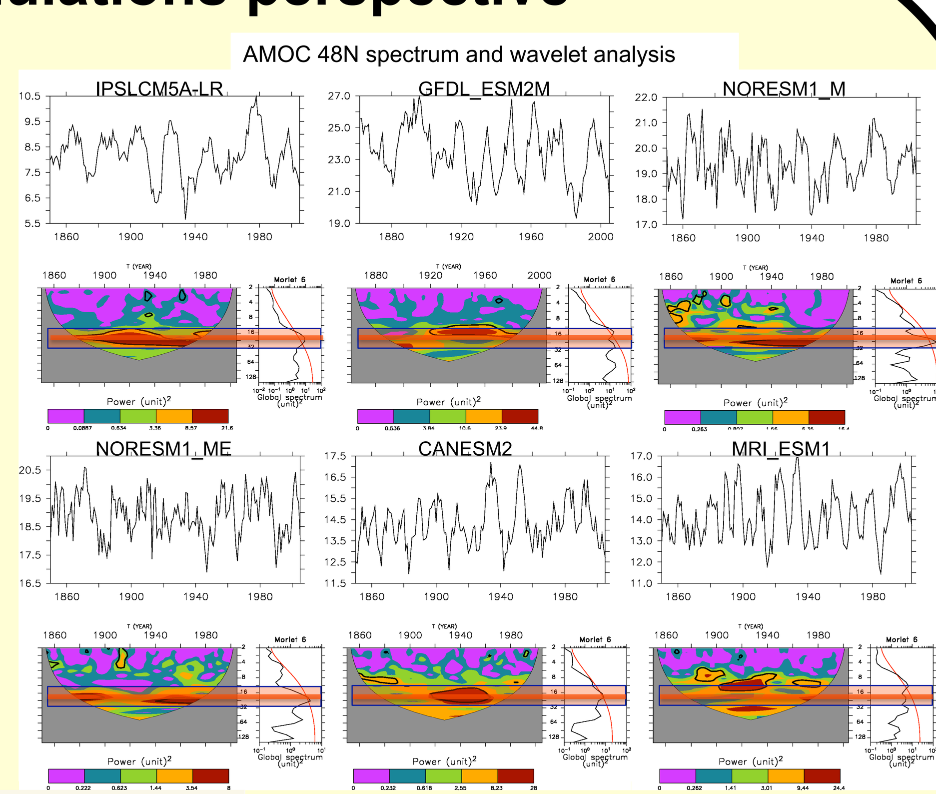
1) CMIP5 historical simulations perspective

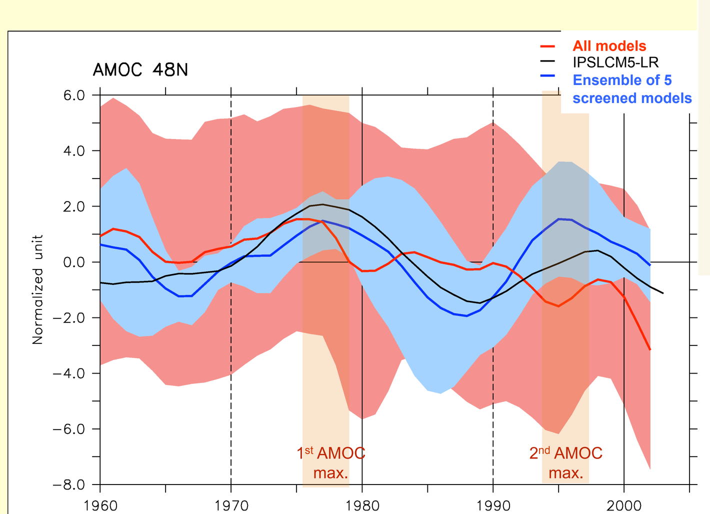
Experimental Design:

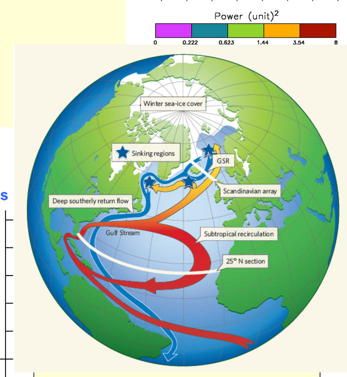
- Screening of 16 models for which the AMOC is available
- Selection of models for which the AMOC has a preferential variability at 12 to 30 yrs

Main Results

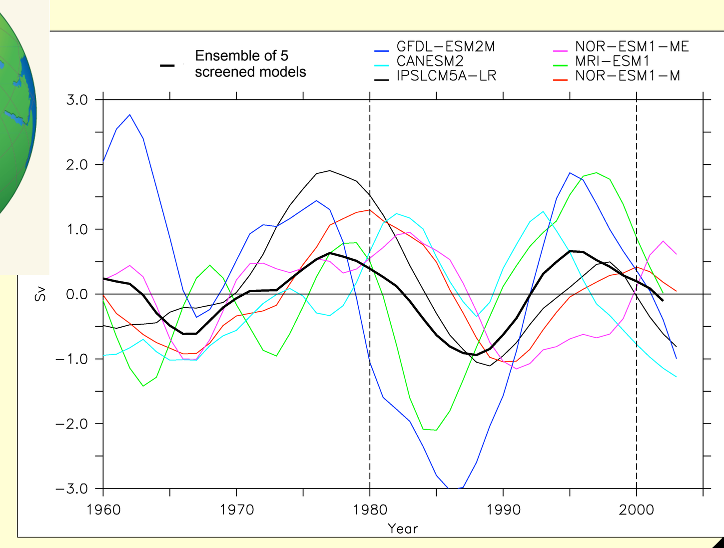
- Only 5 models + IPSLCM5A-LR pass the selection test
- Robust timing: in these 6 models, AMOC is maximum in 1978 (15 years after Agung) and in the 1990s (20 year after the previous maximum)







Scheme of the Atlantic Meridional Overturning Circulation (AMOC) from Quadfasel (2005)



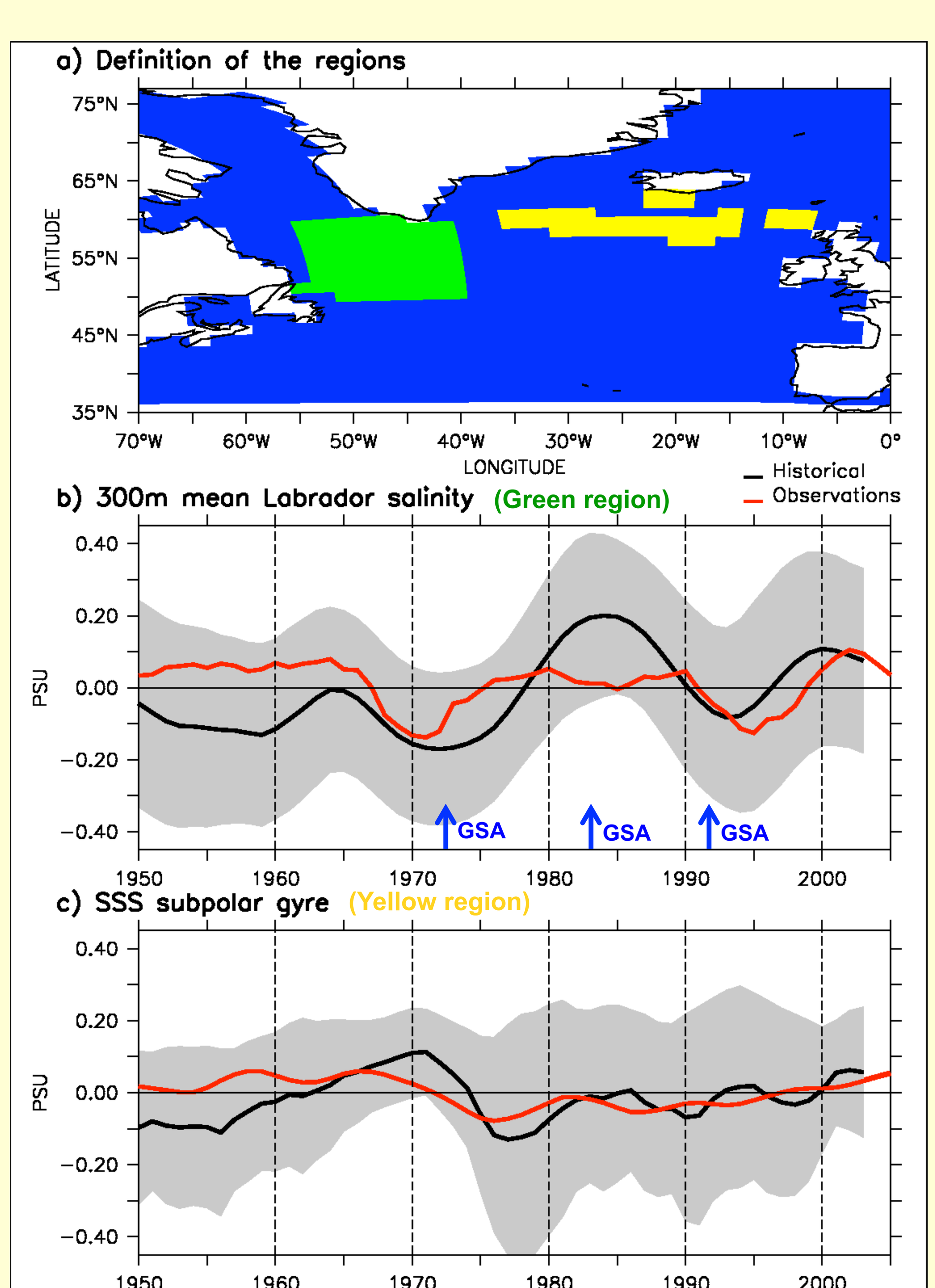
2) *In situ* salinity observations perspective

Experimental Design:

- *In situ* SSS data from Reverdin et al. (2010) for the east subpolar gyre
- *In situ* salinity data from Labrador obtained from the Canadian « Ocean Science Hydrographic Climate Database » from the Bedford Institute of Oceanography
- 5-member historical simulations from the IPSLCM5A-LR climate model.

Main Results

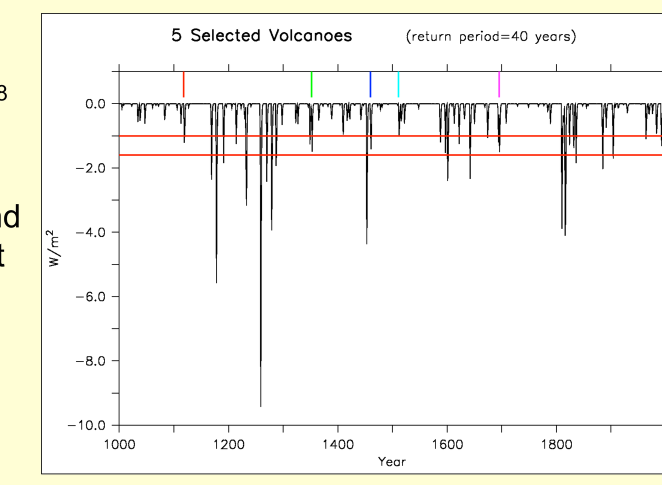
- Consistent pattern of changes in the ensemble of simulations and the salinity observations since the late 1960s
- Large salinity anomalies observed in the 1970s and 1990s well simulated (corresponding to the so-called Great Salinity Anomalies, GSA, Belkin et al. 1998)
- 1980s GSA not represented in the model and appears as very small in the data used as compared to the two other GSAs
- In the model, the 1990s GSA is due to excitation of the 20 year cycle in the North Atlantic by the Mt Agung eruption



3) Last millennium perspective

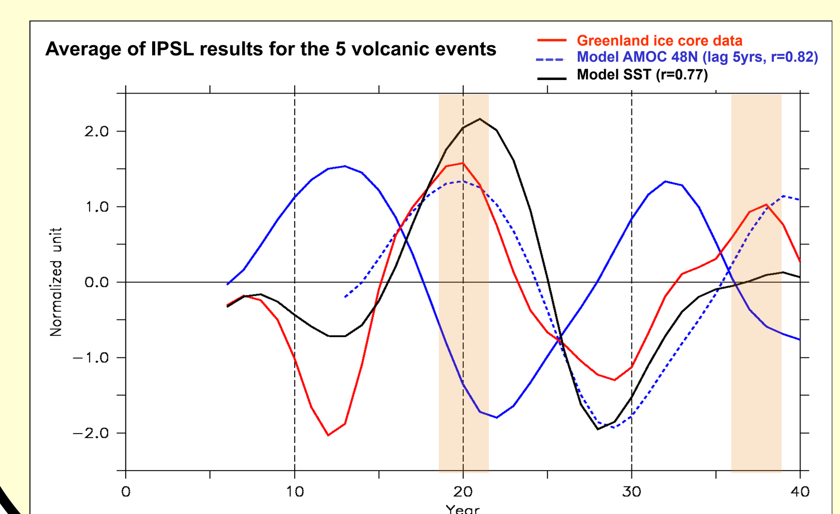
Experimental Design:

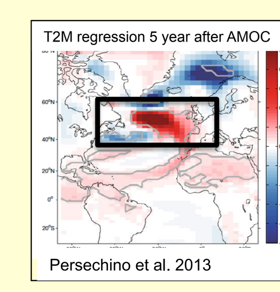
- Model: Last millennium simulation from IPSLCM5A-LR (Khodri et al., in prep.)
- Paleoclimate record: 1st principal component of Greenland ice core δO^{18} data selected due to accurate chronology and demonstrated link with North Atlantic SST during the instrumental period (Ortega et al., sub.)
- Focus on the 5 volcanic eruptions with amplitude similar to Mt Agung and not followed by major eruptions in the coming 40 years using the Gao et al. (2008) volcanic forcing

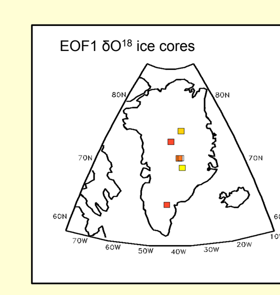


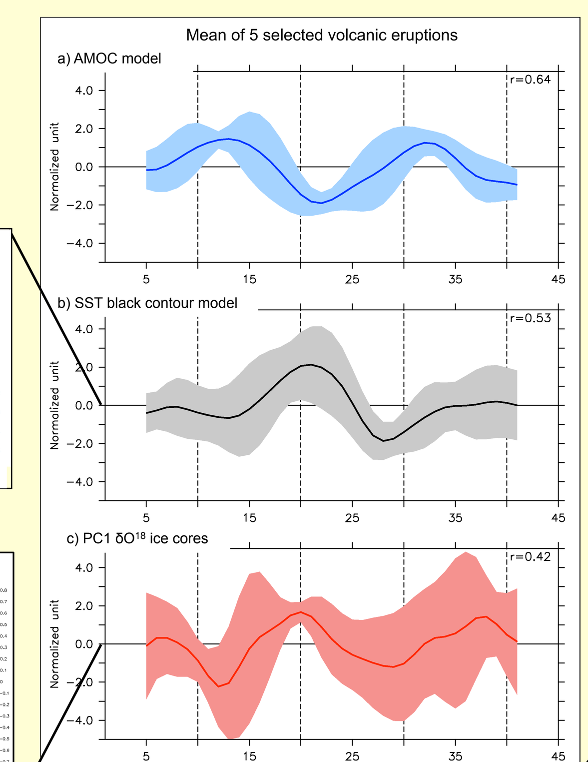
Main Results

- Ice core data:
  1. 20-yr periodicity
  2. Isotopic maximum (warming) 20 years after volcanic events
- Simulations:
  1. Systematic AMOC maximum 15 years after the volcanic events
  2. AMO-like pattern with peak SST in the North Atlantic 20 years after the volcanic events
  3. Development of a second oscillation 20 years after the AMOC peak





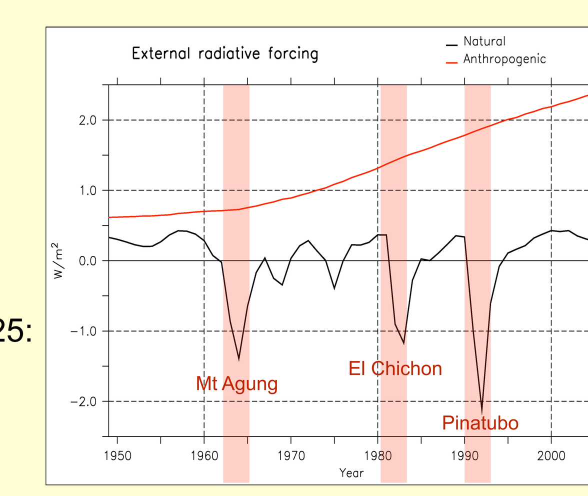




4) Interference pattern over the recent period

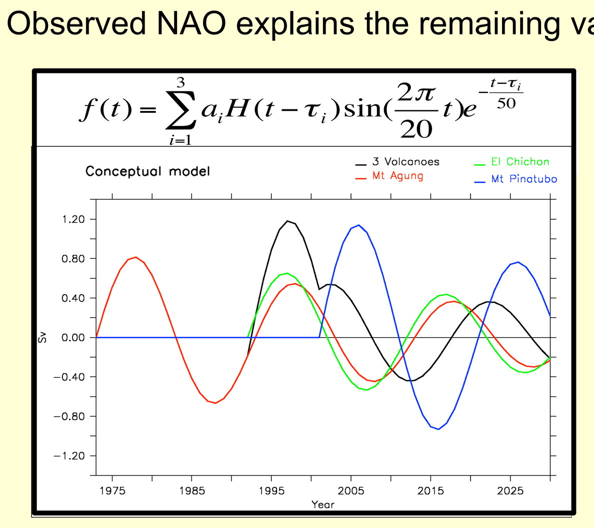
Experimental Design

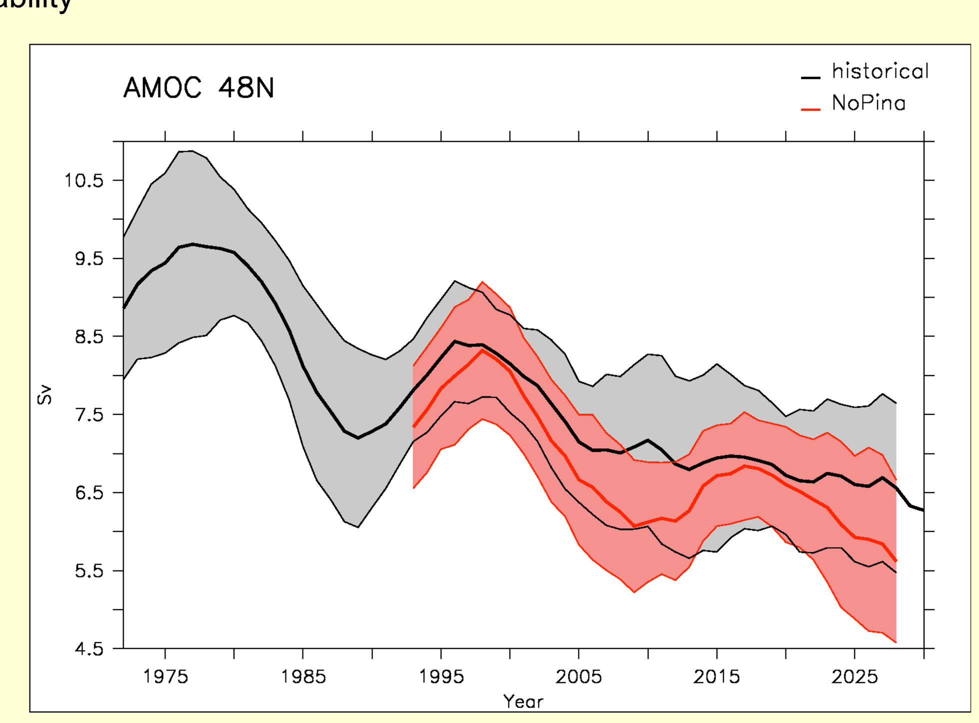
- 5-member ensemble of historical simulations from IPSLCM5A-LR climate model
- 5-member ensemble of historical simulations without Pinatubo eruption

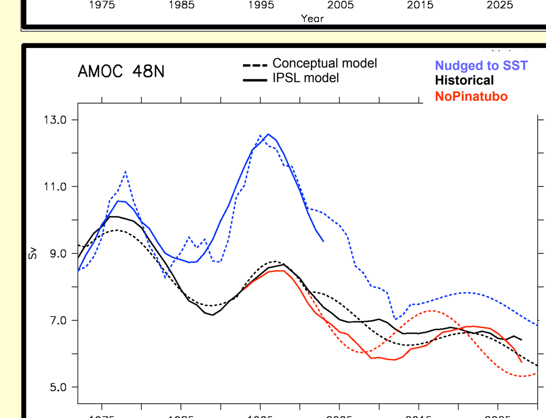


Main Results

- Without Pinatubo eruption, AMOC peak in the 2015s
- With Pinatubo eruption, destructive interference and flat AMOC in 2005-2025: due to the timing of El Chichon (19 yrs after) and Pinatubo (28 yrs after)
- Consistent with result from a simple conceptual model of delayed interferences
- Observed NAO explains the remaining variability





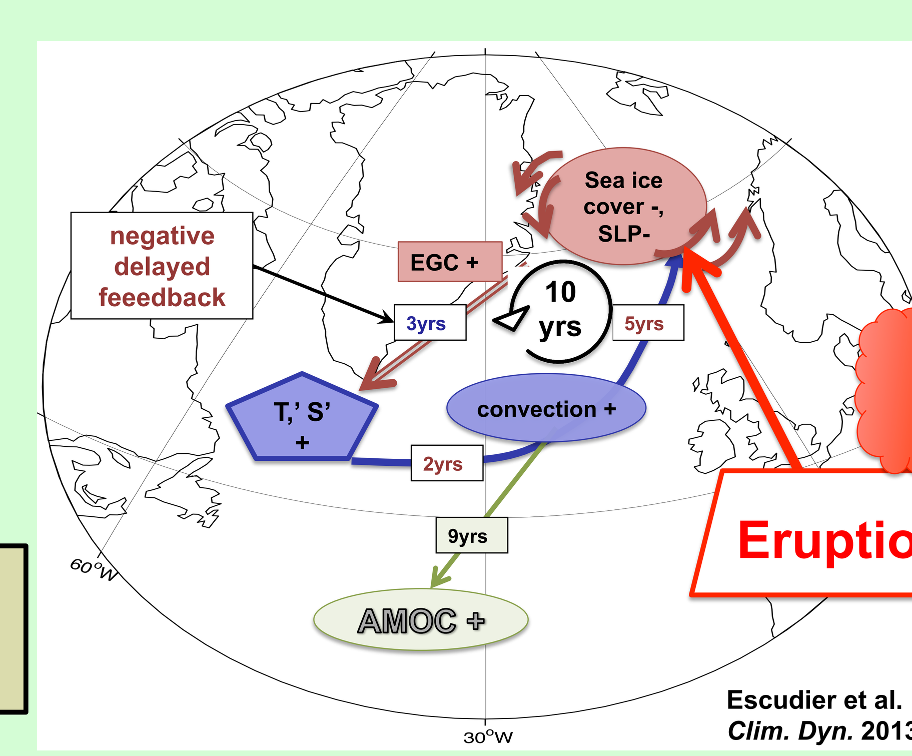


$$f(t)=\sum_{i=1}^{3} a_i H(t-\tau_i)\sin\left(\frac{2\pi}{20}t\right)e^{\frac{t-\tau_i}{50}} - b\times GW(t) + c\times NAO(t+5)$$

Discussions and conclusions

- Agung or Pinatubo-like eruptions precede an AMOC maximum by ~15 years
- Consistent with ***in situ* salinity data** from the subpolar gyre for the last 60 years
- Shown by IPSL historical simulations and selected periods of a last millennium simulation, and in a **subset of CMIP5 simulations**
- Consistent with **Greenland** temperature changes inferred from **ice core data** over the last millennium
- Importance of the pacing between medium size volcanic eruptions: **destructive interference** due to the Pinatubo eruption

⇒ **A large body of evidence** supports long lasting impacts of volcanic eruptions on ocean circulation and explains recent decadal AMOC variations



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