Ocean and atmosphere changes in the North Atlantic over the last millennium

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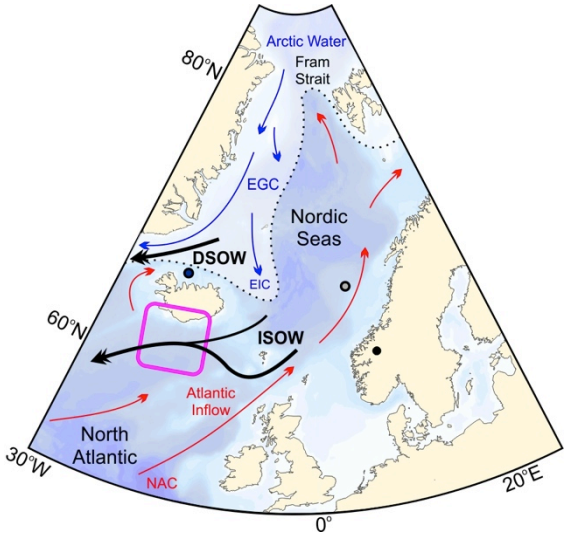
- Long-term trends in Holocene AMOC components
- Climate of the last millennium
- Temperature and salinity variability of the NAC
- Comparison to model simulations
- Conclusions

Long-term changes in Iceland-Scotland Overflow strength



Long-term variations in Iceland–Scotland overflow strength during the Holocene

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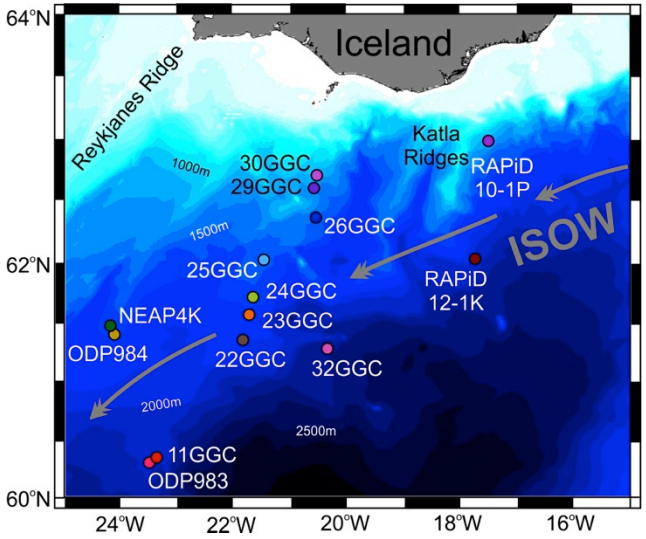
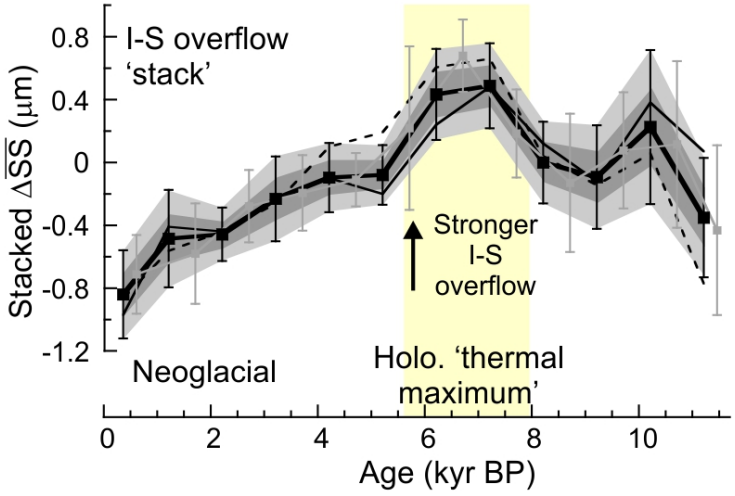
Clim. Past Discuss., 9, 1627–1656, 2013



~20±20% decline



Long-term changes in Iceland-Scotland Overflow strength

Decaying ice-sheets

Insolation

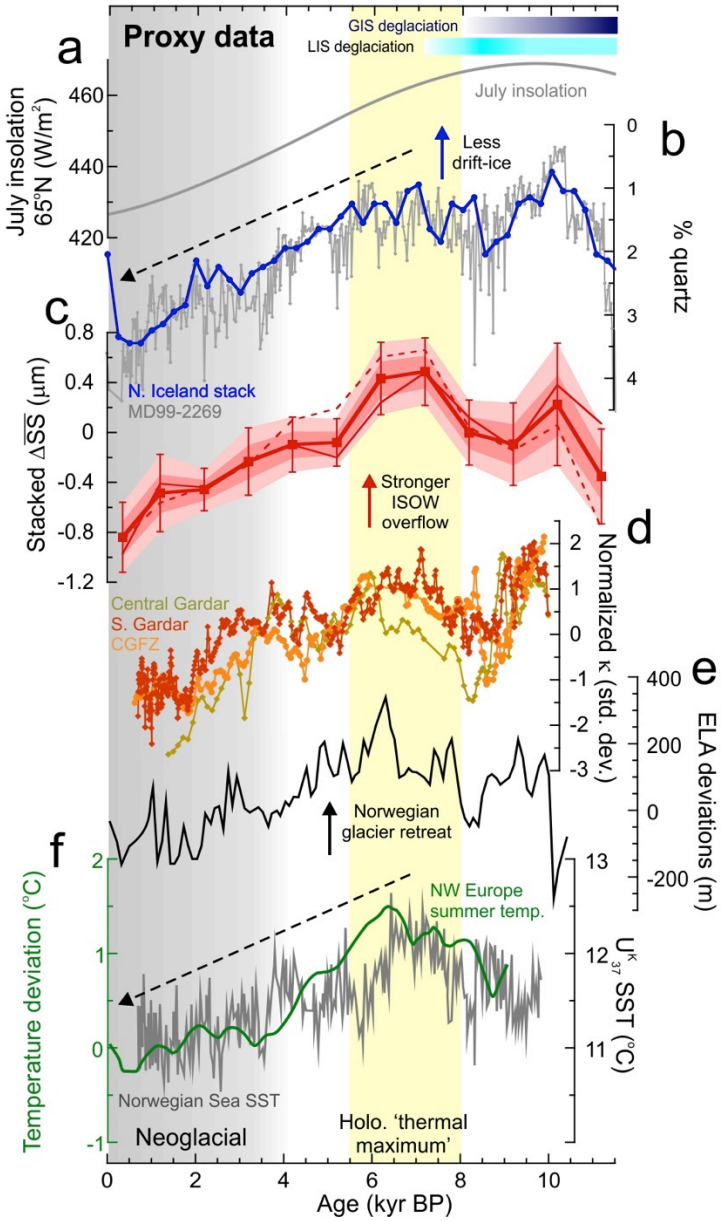
Nordic Seas sea-ice

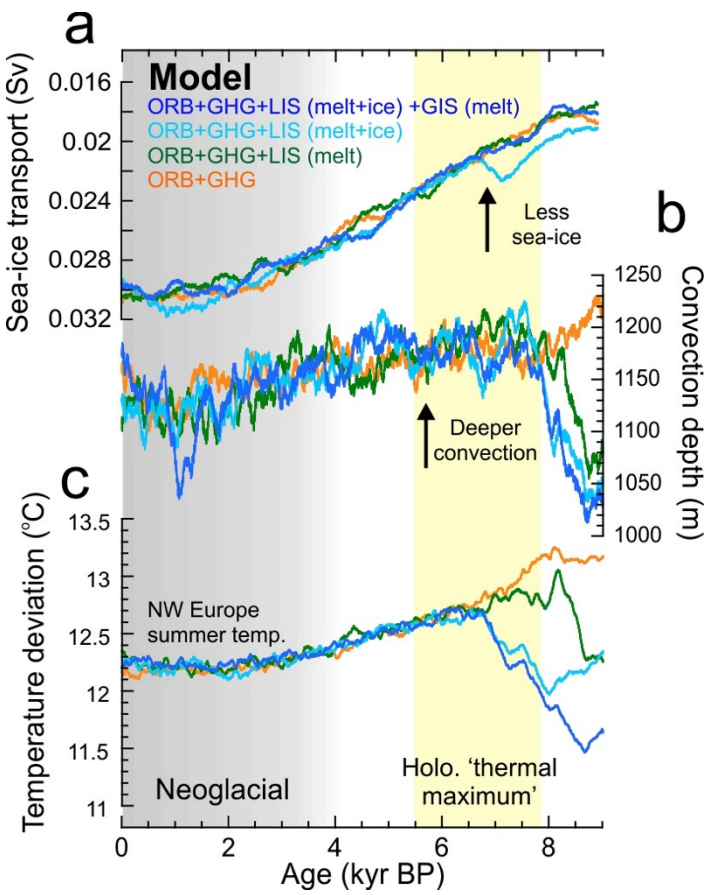
I-S overflow strength

I-S overflow strength

Glacier retreat

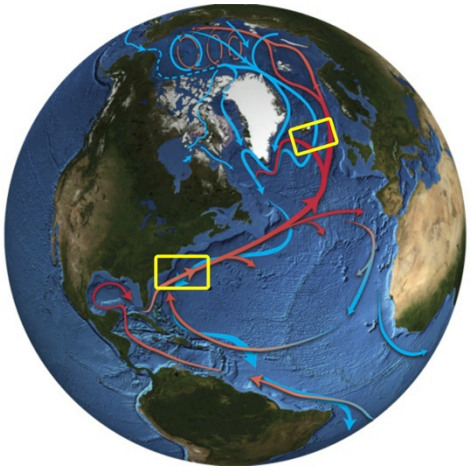
NW European temperature

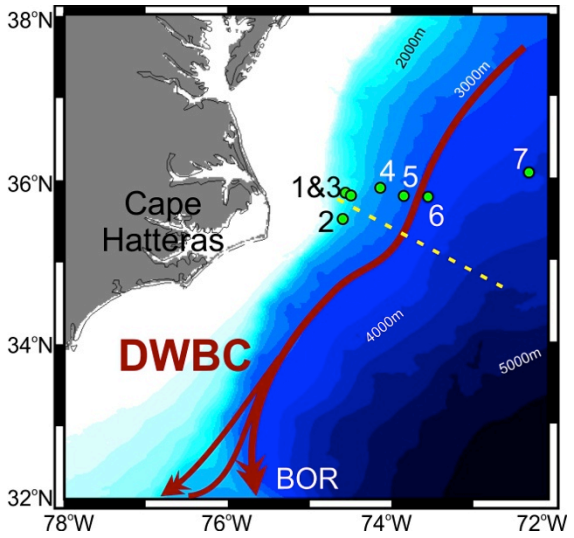


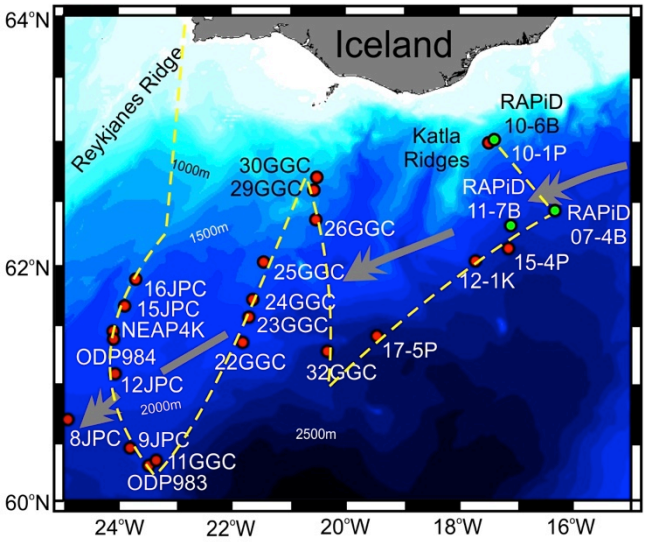


"Holocene reconstructions of Iceland-Scotland Overflow and the Deep Western Boundary Current"
Oppo, Thornalley & Keigwin

- I-S overflow changes over past 2000 years – focus on LIA-to-modern
- Long-term and last 2000 years changes in DWBC
- Changes in DSOW/LSW compensate ISOW?





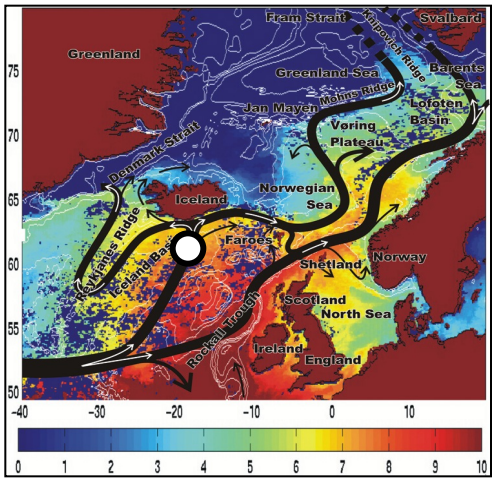


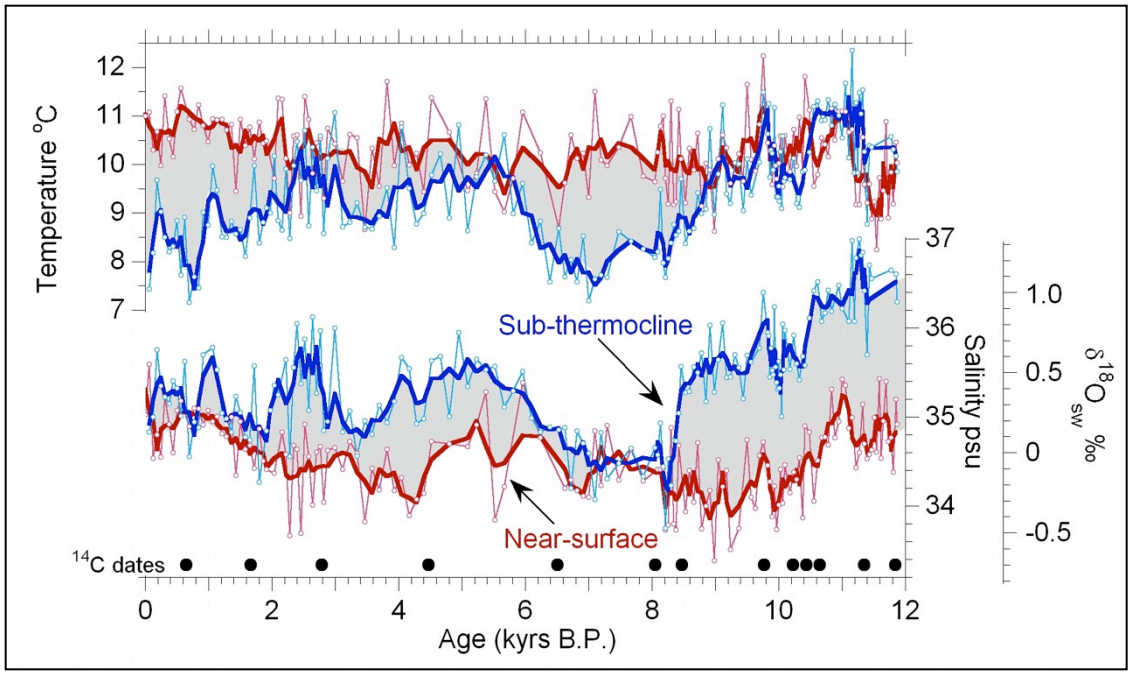
National Science Foundation
WHERE DISCOVERIES BEGIN

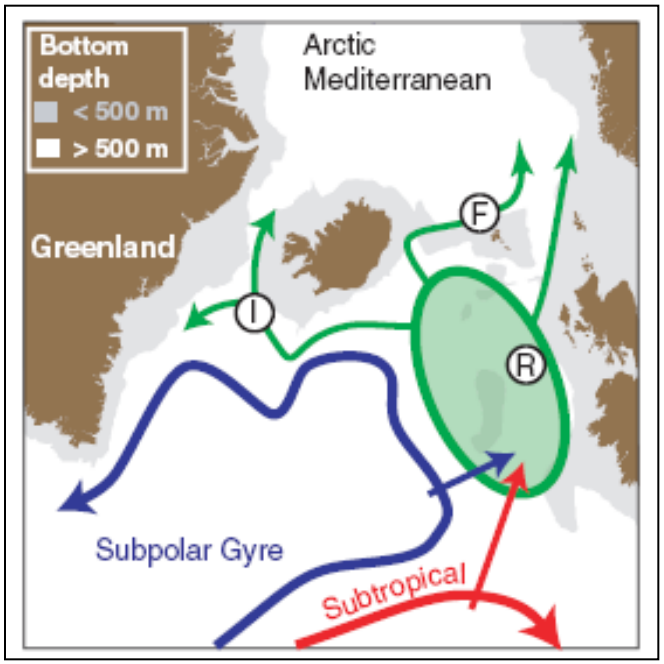
Holocene oscillations in temperature and salinity of the surface subpolar North Atlantic

David J. R. Thornalley[1]†, Harry Elderfield[1] & I. Nick McCave[1]

NATURE | Vol 457 | 5 February 2009



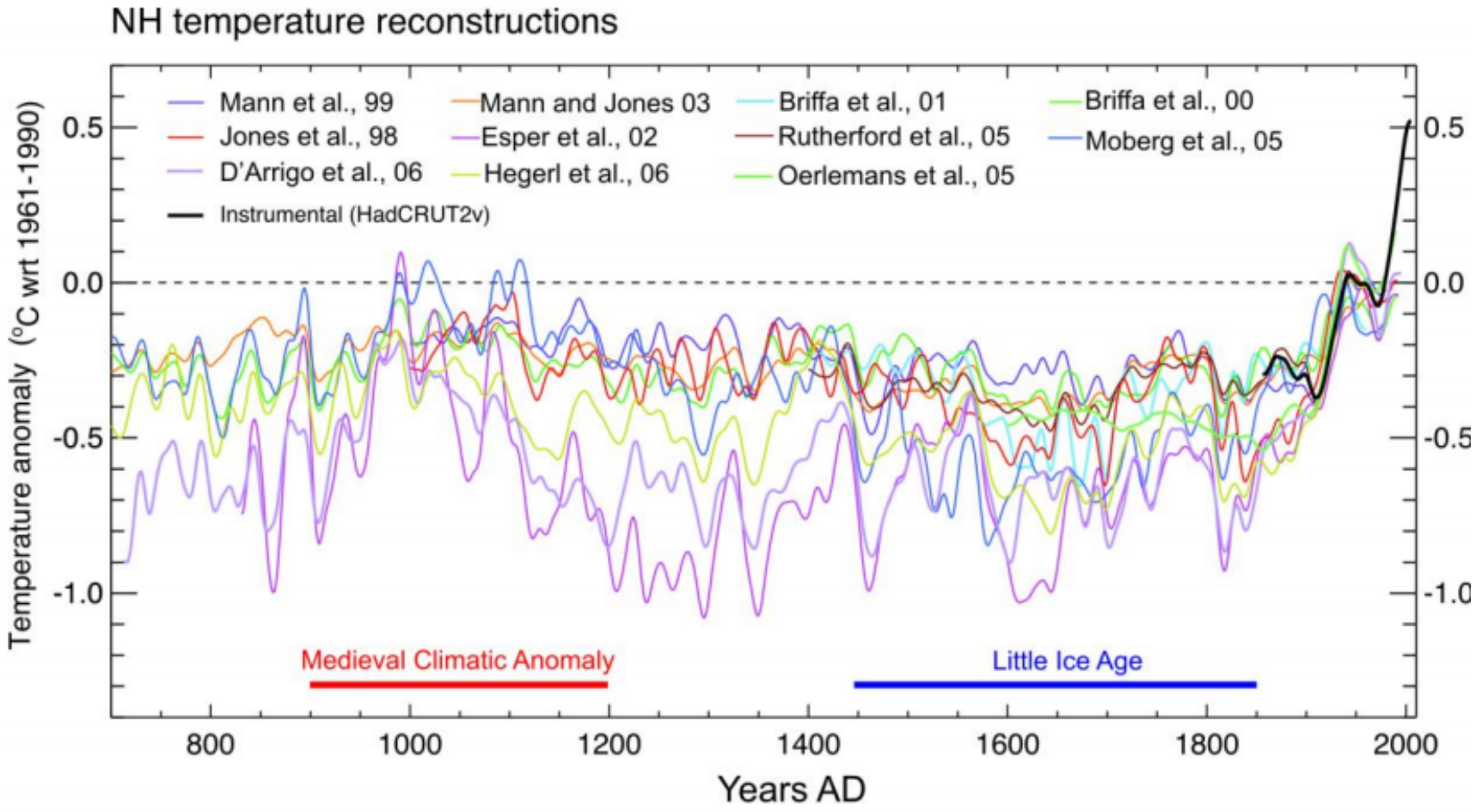




From Hátún *et al.*, 2005

Climate of the last millennium

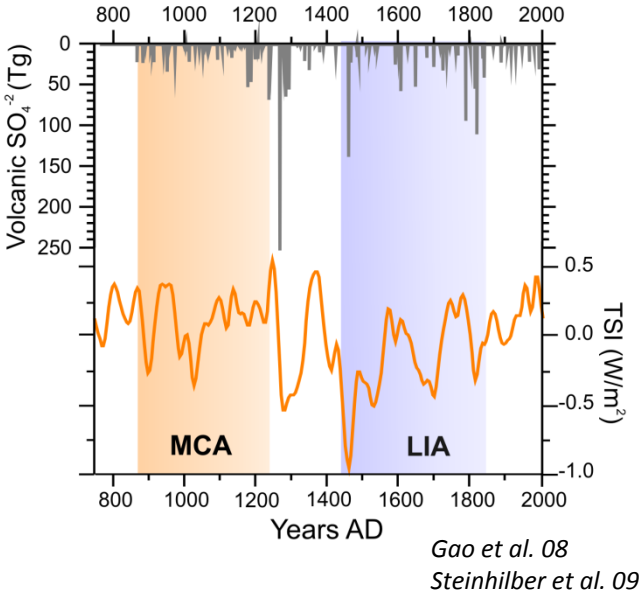
Climate of the last millennium



Modified from IPCC 2007

The most favoured explanation…

External Forcings



Gao et al. 08
Steinhilber et al. 09

Climate Feedbacks

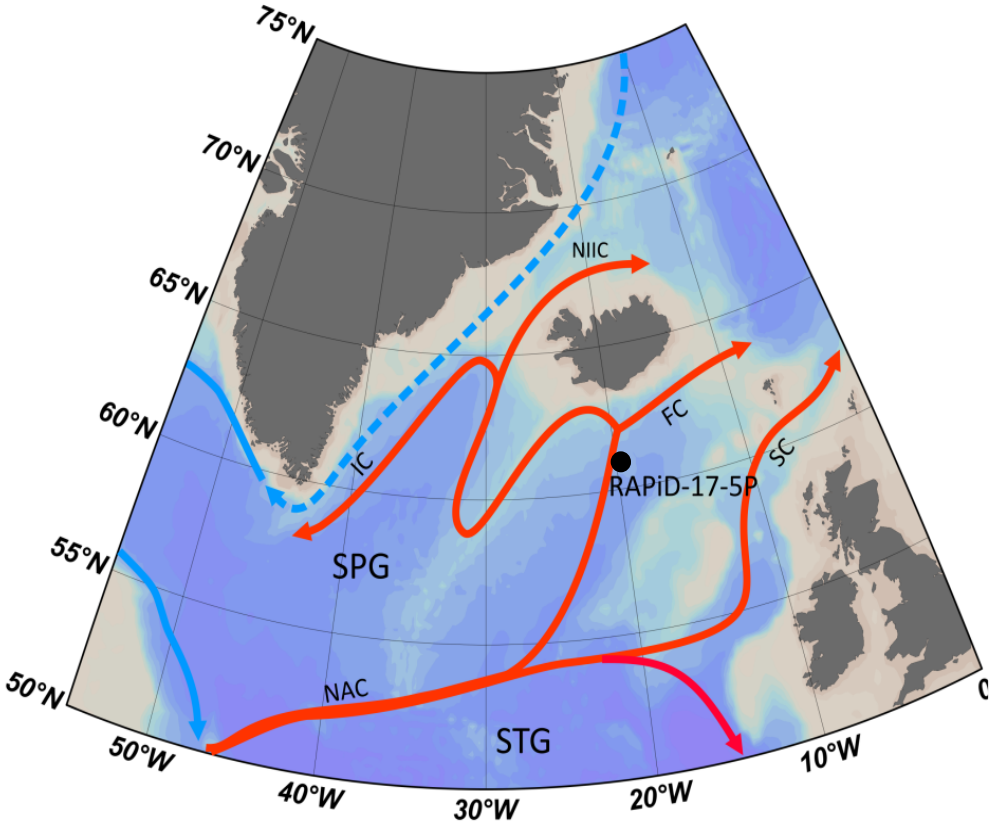
AMOC

NAO

Teleconnections (Indo-Pacific SST, ENSO, Asian Monsoon)

Multidecadal-scale climate variability

Reconstruction of past surface ocean variability



-Top 600m at core-location bathed by NAC waters

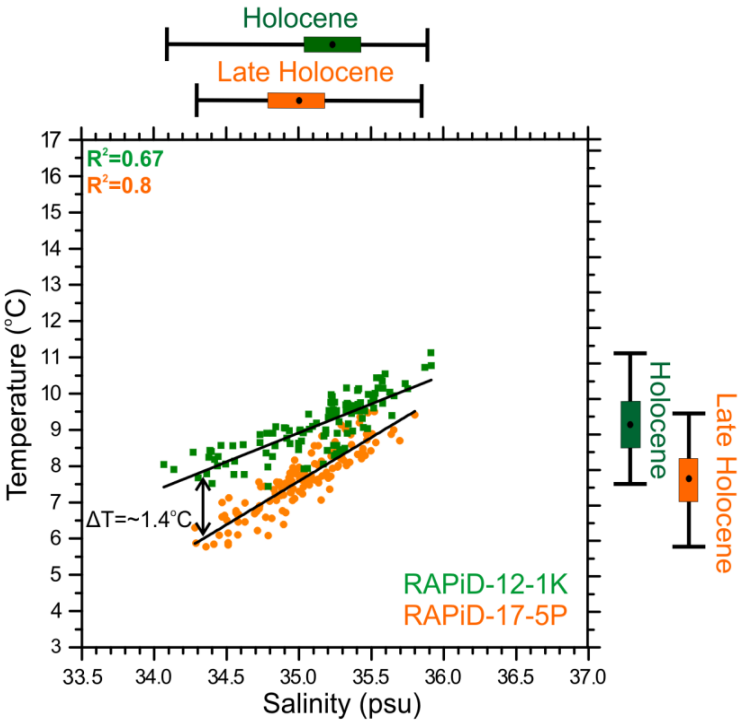
-We use paired Mg/Ca and $\delta^{18}O$ in *G. inflata* to reconstruct T/S at ~*200m*

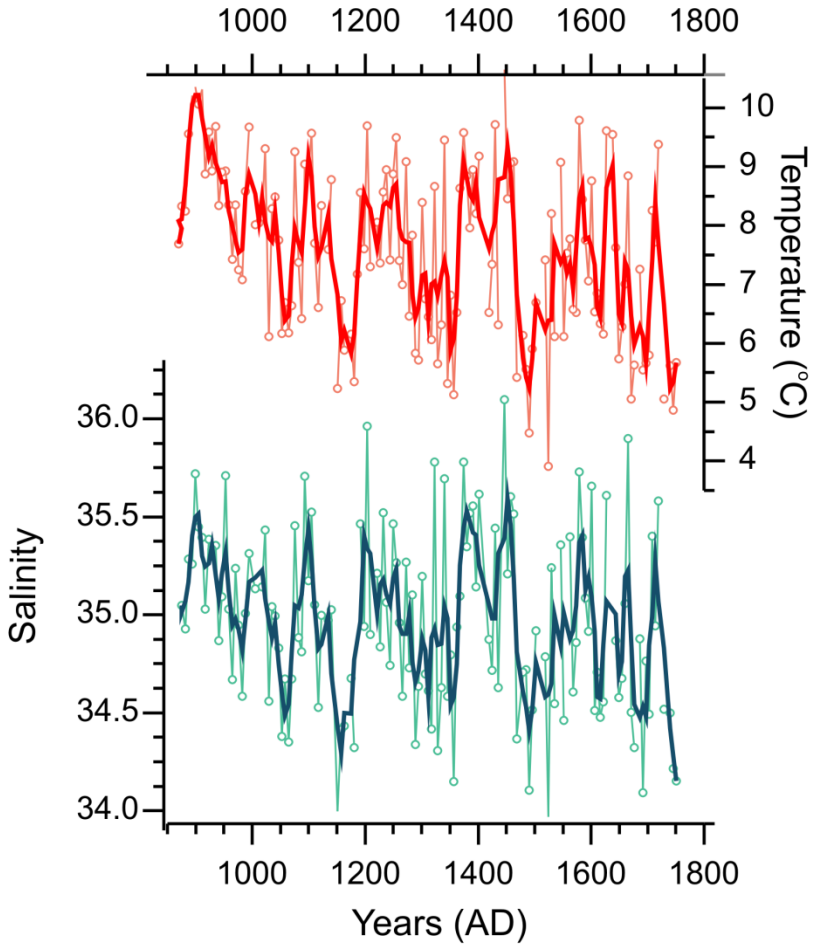
-Age model constructed based on 14C dates

-Average resolution of ~6 years per sample (750-1750 years AD)

Temperature and Salinity changes over the last 1000 years

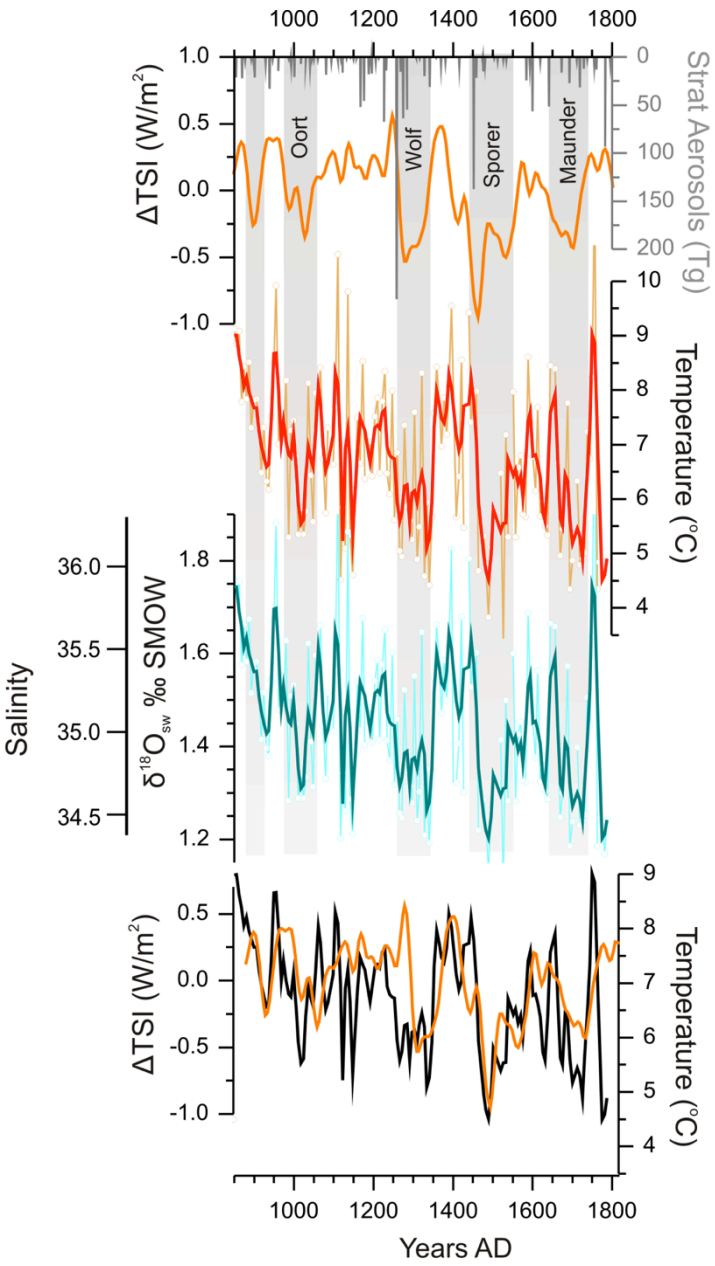
- Abrupt T/S changes of 3.5ºC and 1.5 psu
- Similar variability to that of the last 11,000 yrs
- Spectral analysis reveals 200 year cyclicity between 1200-1700 yrs AD.



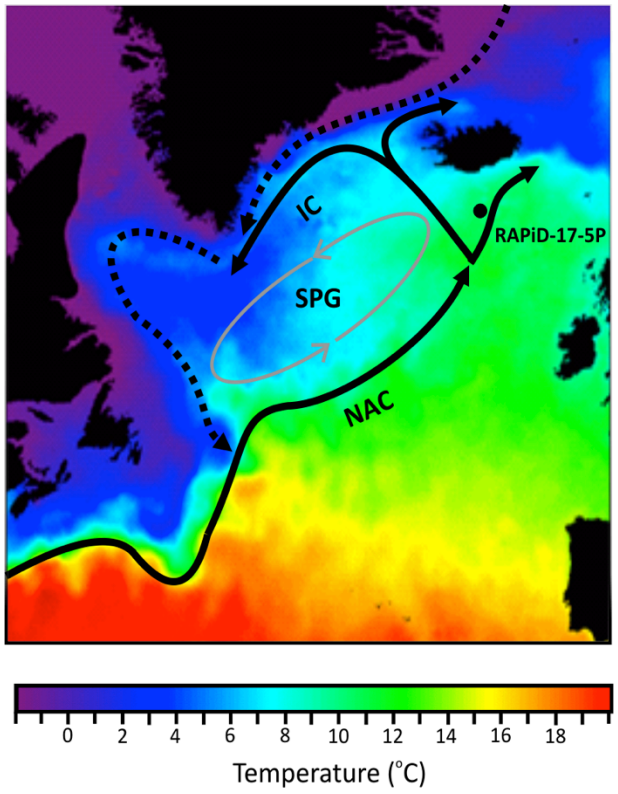


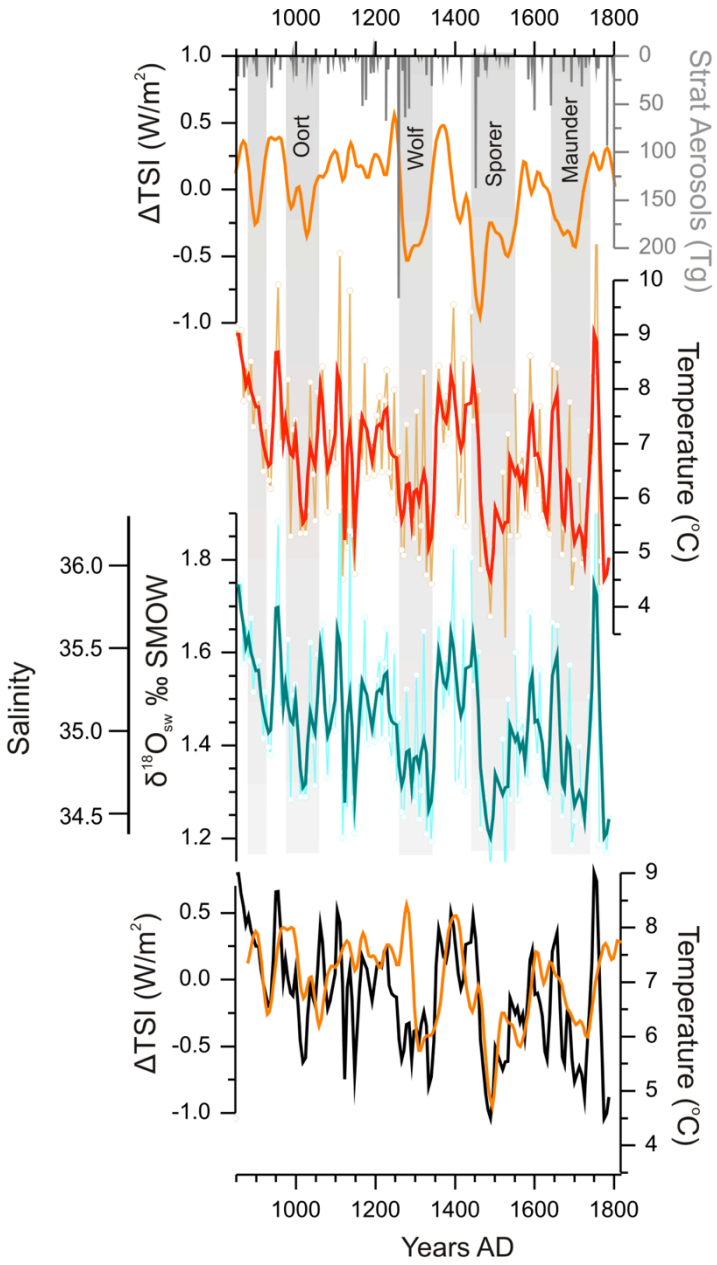
External forcing on the NAC hydrographic changes

- 200-yr cyclicity similar to deVries solar-cycles (210yrs).
- Cold/fresh NAC correspond to solar minima
- Pearson coeff=0.5 (95% conf. 0.3-0.7); R=0.6
- Potential additional effects of explosive volcanism

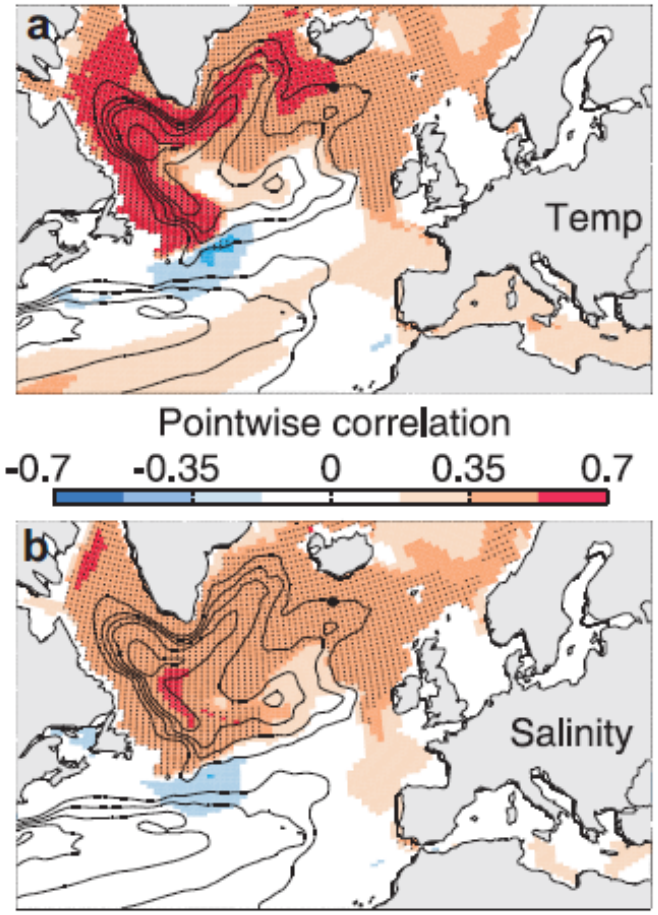


External forcing on the NAC hydrographic changes





Modelling results

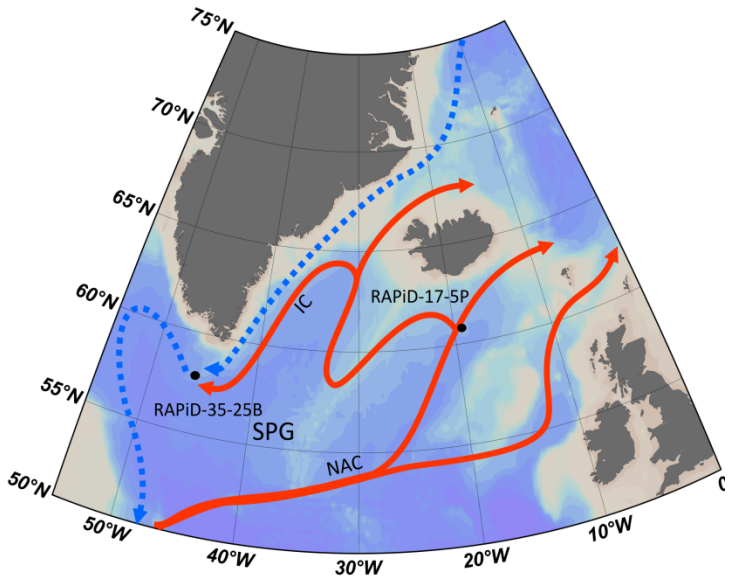


- CCSMv4 last millennium *(Landrum et al. 12)*

- Strong positive correlation T/S and TSI, particularly between temperature and TSI in the pathway of the IC

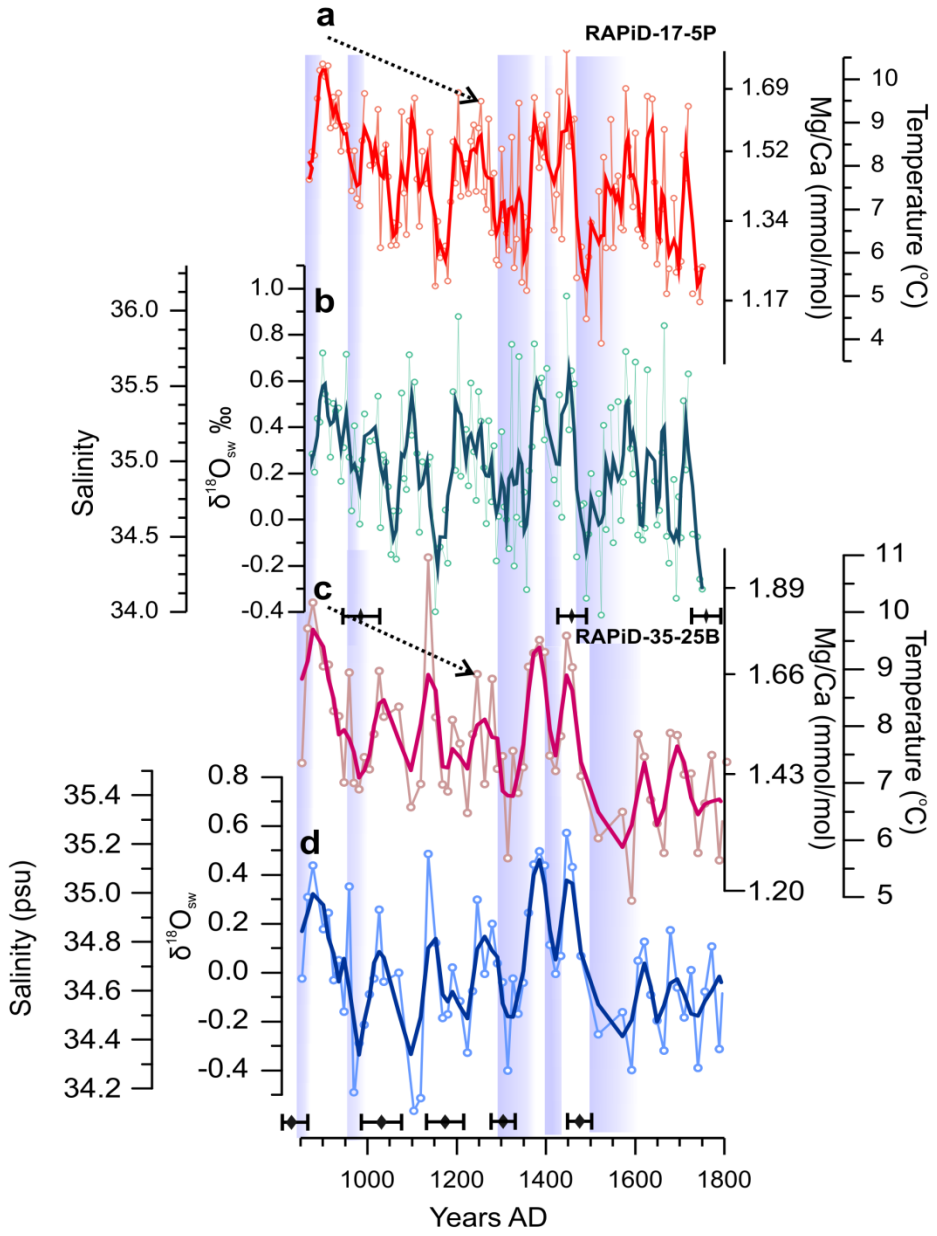
- This is in agreement with a core from South of Greenland

T/S changes in the pathway of the Irminger Current

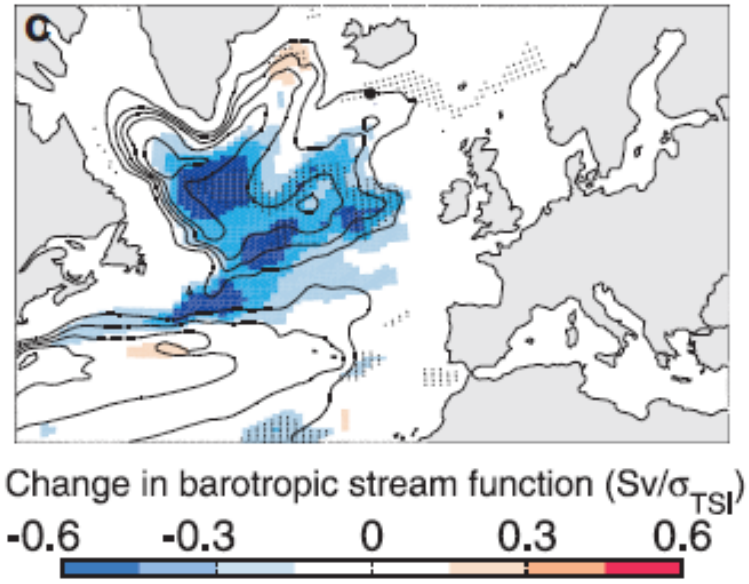


- Broad similarities of T/S patterns from S of Iceland and S Greenland

- Confirms the westward propagation of these anomalies as recorded in CCSM4



Subpolar Gyre circulation changes over the last millennium



•Volume transport analysis indicates that warmer/saltier conditions during high TSI conditions correspond to periods of strong SPG circulation

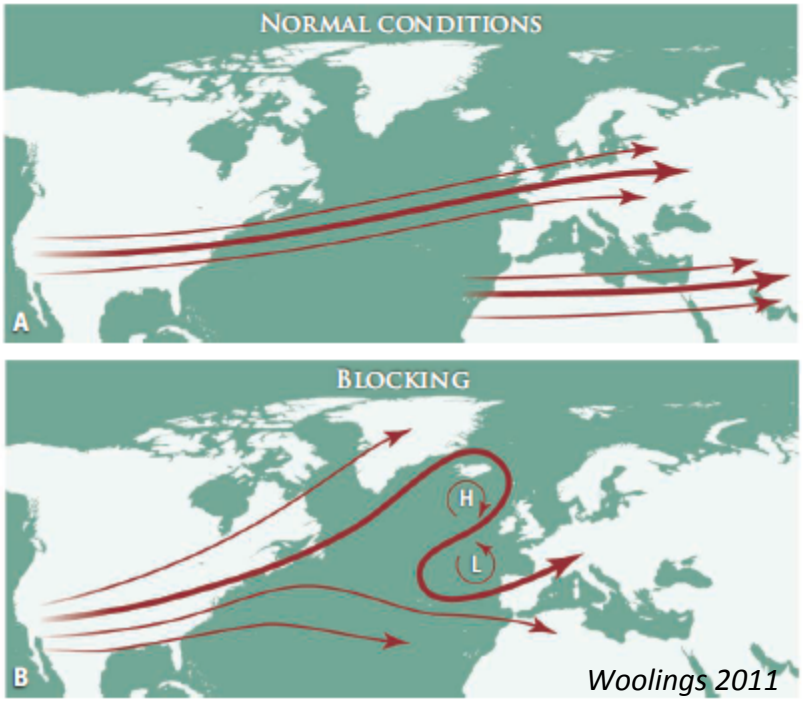
Atmospheric forcing on SPG circulation

•Small-scale atmospheric patterns in E Atlantic can affect surface ocean circulation *(Hakkinen et al. 11, Condron and Renfrew 13)*

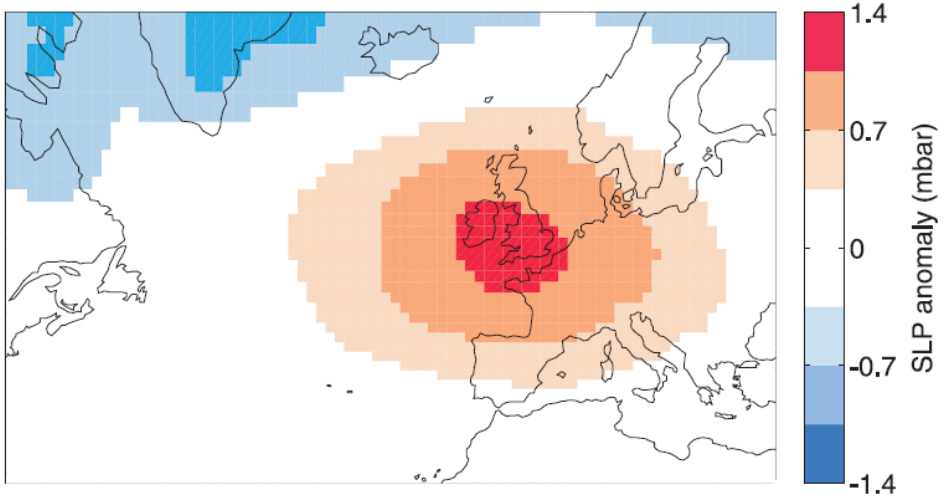
•Atmospheric blocking events, more prevalent during solar minima, have been responsible for recent harsh winters in Europe

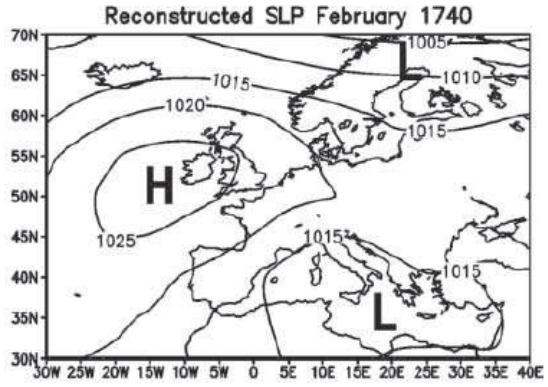
•SLP analysis in the last millennium CCSM4 run show a HP system over the British Isles during periods of solar minima

•This corresponds to slow SPG and cold/fresh conditions from CCSM4



Woolings 2011





Lutherbacker and Xoplaki 2002

Conclusions

1. **Long term decline in I-S overflow strength caused by increased export of Arctic sea-ice.** How has I-S behaved since the LIA? Compensated by other deep components of AMOC?

2. **S. Iceland (62^{o}N, 17^{o}W): Large amplitude (~2oC,1 psu) , millennial-scale, changes in T & S at base of seasonal thermocline (~200m depth).**

3. **Similar variability observed on multi-decadal timescales over last 1000 years**

4. **Coupled to total solar irradiance (low TSI = cold & fresh)**

5. CCSM4 simulations suggests increased atm blocking events and weaker SPG circulation during low TSI, causing reduced northward transport of heat and salt.