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

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Outline

• 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

~20±20% decline

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

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Long-term changes in Iceland-Scotland Overflow strength

- Decaying ice-sheets
- Insolation
- Nordic Seas sea-ice
- I-S overflow strength
- Glacier retreat
- NW European temperature
Long-term changes in AMOC components

“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?
Long-term changes in the NAC

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

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From Hátún et al., 2005
Climate of the last millennium
Climate of the last millennium

NH temperature reconstructions

Temperature anomaly (°C wrt 1961-1990)

Years AD

Medieval Climatic Anomaly

Little Ice Age

Modified from IPCC 2007
The most favoured explanation...

External Forcings

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 3.5°C 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°N, 17°W): Large amplitude (~2°C, 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.