Simulated cold events in the northern North Atlantic during the last millennium

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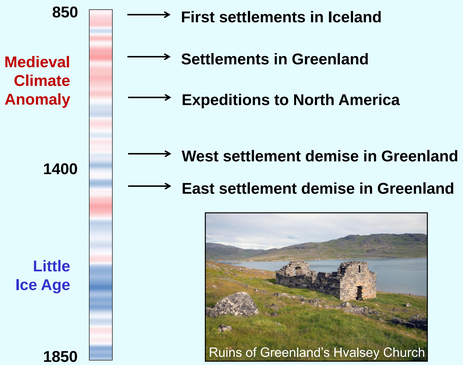
Leif Erikson and me

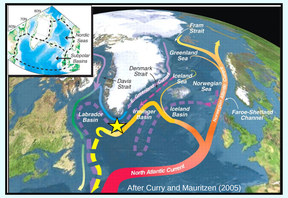
1. Vikings in the North Atlantic



Last-millennium NH surface-air temperature anomaly (Hegerl et al., 2006)

- The relatively mild climate conditions around year 1000 likely favoured the Viking expansion in the North Atlantic
- The loss of their Greenland settlements roughly coincides with the onset of the Little Ice Age and its shift towards colder NH climate conditions

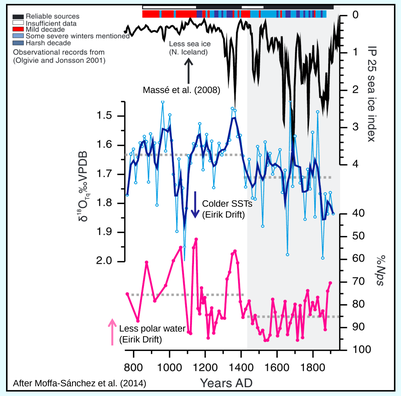
• Local oceanographic reconstructions to describe this shift in the environmental conditions



After Curry and Mauritzen (2005)

- The **Eirik Drift** ☆ is well situated to monitor and reconstruct variations in both the East Greenland and the Irminger currents, as well as changes in seawater properties within the deep bottom flow

- Periods of intense surface cooling over the Eirik Drift in a few decades around 1400
- Associated increase in the sea-ice extent at subpolar latitudes of the North Atlantic together with recorded years of severe winters over Iceland
- Both volcanism and solar irradiance changes as possible drivers of such events



After Moffa-Sánchez et al. (2014)

THREE QUESTIONS!

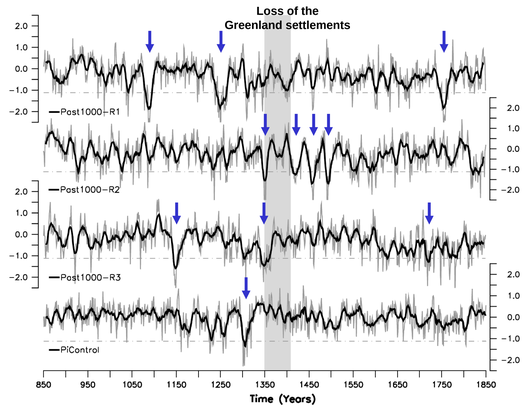
? Could these cold events have contributed to the demise of the Greenland settlements?
? What are their driving mechanisms?
? Are they part of the internal climate variability or can they only be triggered by external forcings?

2. Experimental set-up: MPI-ESM-P

- **Atmosphere GCM ECHAM6:** T63 horizontal resolution; 47 vertical levels
- **Ocean-sea ice GCM MPIOM:** 1.5º horizontal resolution (15 km near Greenland); 40 vertical levels

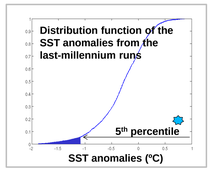
- **Simulations:** Ensemble of three last-millennium transient runs (CMPI5/PMIP3):
  Past1000-R1, -R2, and -R3
  Preindustrial 1000-year unperturbed control run:
  PiControl

3. All the simulations show decadal cold events in the northern North Atlantic



Eirik Drift SST anomalies (ºC)

- Averaged between 55-60N and 40-50W
- Filtered with an 11-year low-pass running mean



Decadal cold events: Periods with sustained SST anomalies below -1.1ºC during 5 or more years

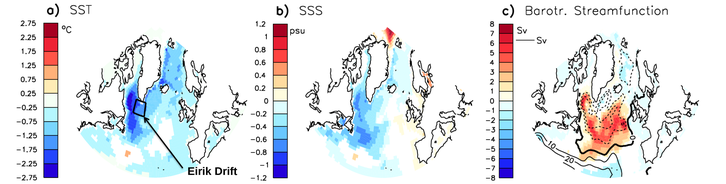
- ✓ Of similar amplitude (up to -2ºC) and duration (20-60 years) to those reconstructed within the northern North Atlantic during the last millennium
- ✓ Isolated in time or in series of several events
- ✓ Scattered distribution: no overlapping in time among events of different runs
- ✓ Outside periods of strong external forcings (e.g. major volcanic eruptions)
- ✓ Also present in the unforced PiControl simulation

The cold events can develop as a result of internal climate variability alone

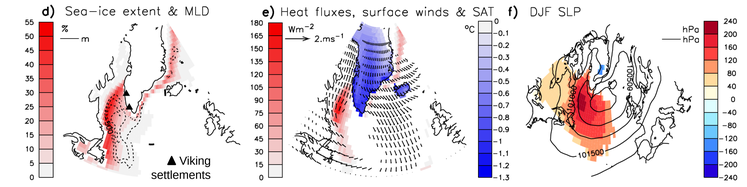
A series of cold events might have contributed to end the Greenland occupation by deteriorating the local environmental conditions. But, how? (see next)

4. The cold events are triggered by the weakening of the subpolar gyre

- The anomalies below compare the mean climate state of PiControl with an ensemble containing the coldest year in each cold event in the last-millennium runs
- Significance above the 99% confidence level based on the likelihood of a random occurrence of the signal

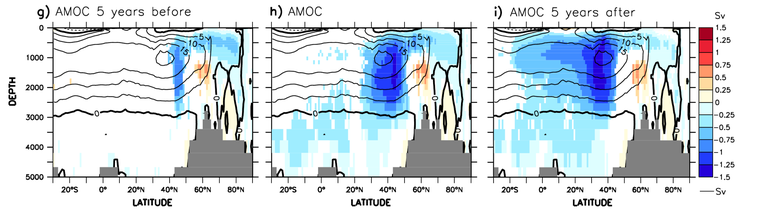


- ✓ Broad surface cooling and freshening over the northern North Atlantic, especially in the Labrador Sea, as a result, respectively, of the weaker advection of heat and salt westwards by the subpolar gyre



- ✓ Colder and fresher surface conditions favour larger sea-ice growth in the Labrador Sea, which results in a less efficient ocean heat transfer to the atmosphere and, eventually, in the cooling of the overlying surface-air during the wintertime
- ✓ Anomalous southerly wind advects colder air to South Greenland
- ✓ Blocking-like pressure in the sea-level pressure over the North Atlantic

Greenland settlers would have seen navigation hindered by expanded sea ice, blocking access from fjords to open sea, and suffered broad famines due to colder environmental conditions and shorter harvest seasons for more than one generation



- ✓ The Atlantic Meridional circulation weakens due to the reduced deep mixing in the Labrador Sea, thus responding to the changes in the subpolar gyre strength

References

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