Towards Paleo-climatic constraints on abrupt climate change

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Outline

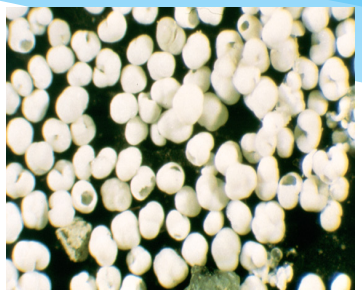
* Background of study,
* Scientific questions,
* Preliminary results and
* Summary and future plan overview.

Background of study

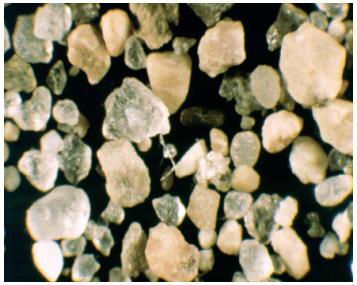
* Abrupt climate change shows in the last glacial, e.g. Heinrich event 1 (HE1, ~17 ka BP) and Bølling-Allerød (BA, ~14.5 Ka BP),
* Abrupt climate change is at least hemispheric, if not global, in extent,
* Abrupt climate change is caused by changes in ocean circulation, e.g. by fresh water release as a result of disrupted icebergs melting or diminished North Atlantic Deep-water (NADW) formation, *tight correlate with Atlantic Meridional Overturning Circulation (AMOC)*

Ocean sediment records during Heinrich events (HEs)

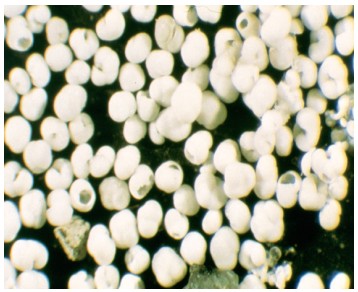
after H-Event



during H-Event

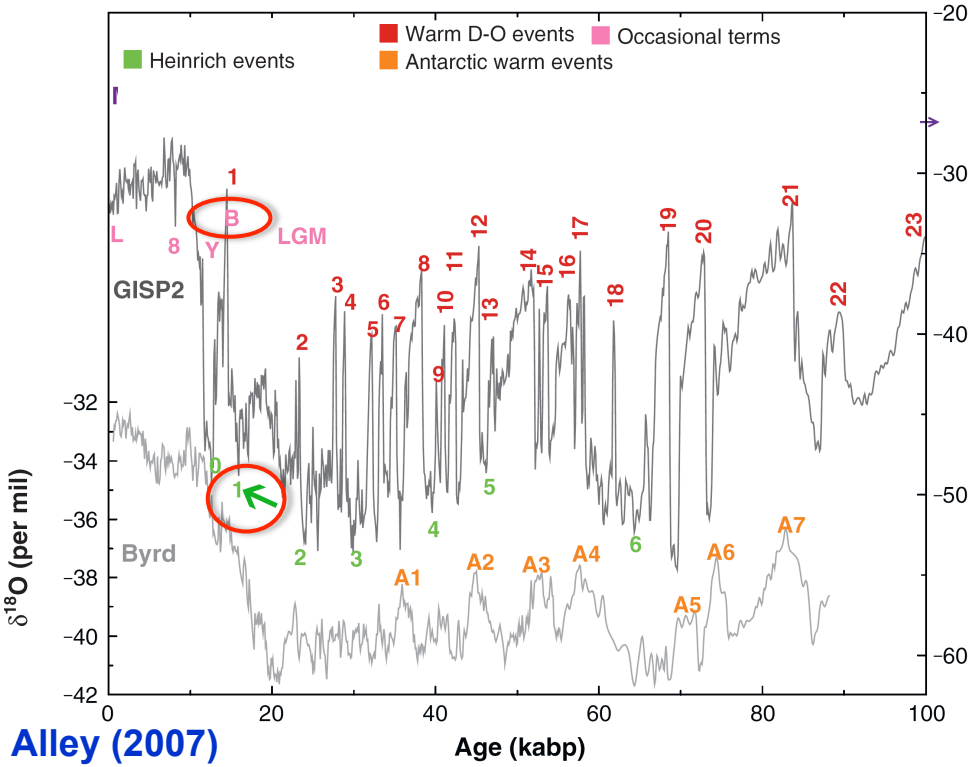


before H-Event

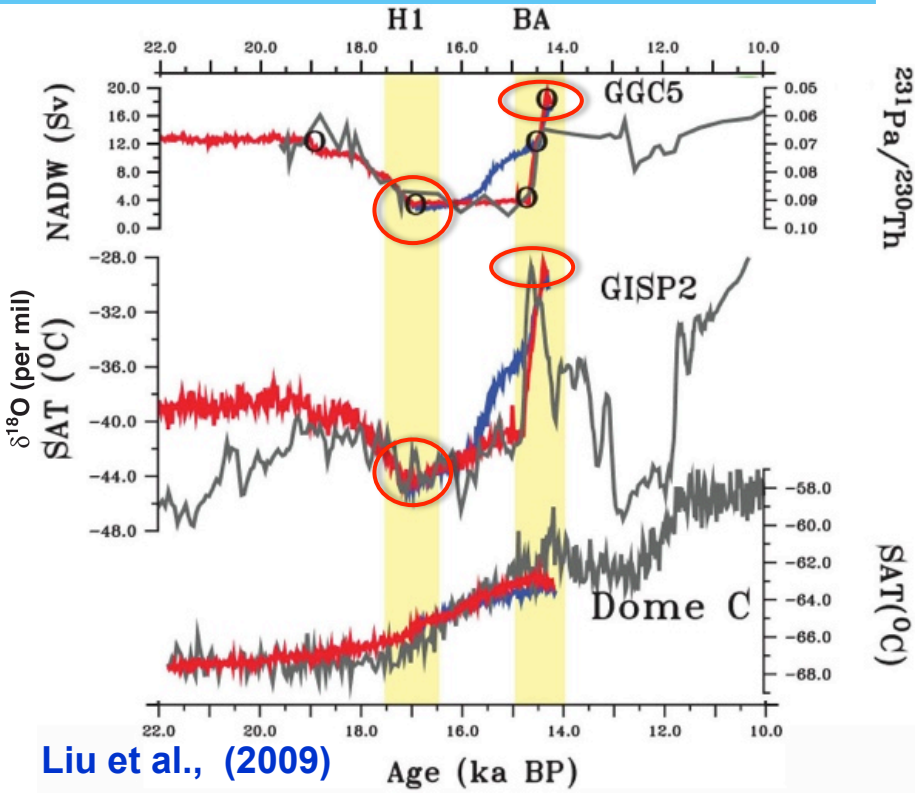


Andrews et al., *Paleoclimatology Slide Set "Heinrich Events"; Core site HU87033-009, Hudson Strait*

Ice-core records in high latitude



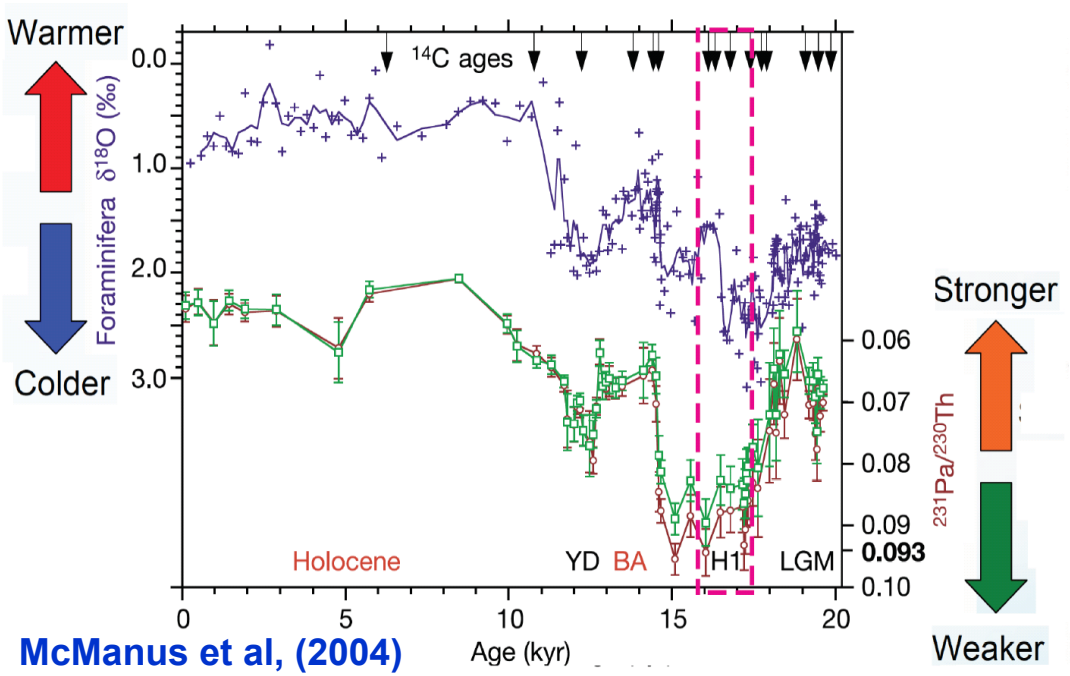
Alley (2007)



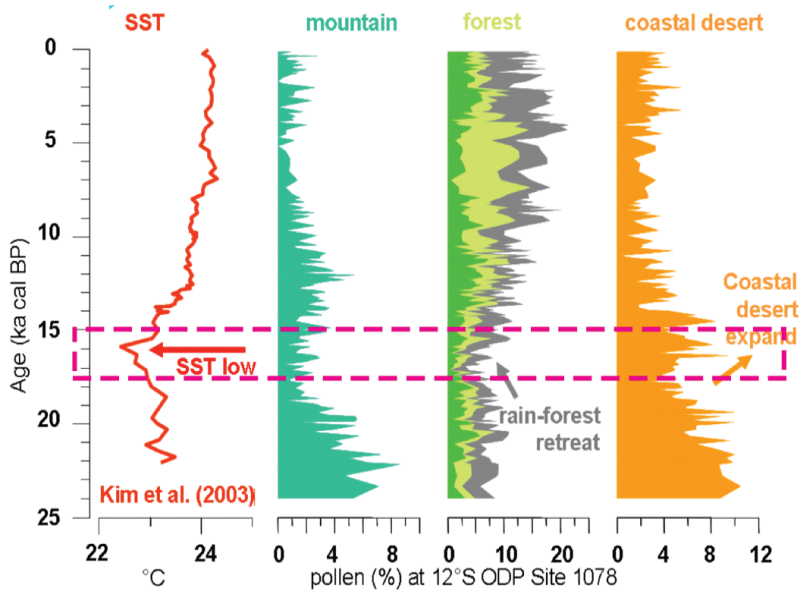
Liu et al., (2009)

- Surface air temperature from proxy records in Greenland (GISP2) and Antarctic (Byrd) over the past 100,000 years show an abrupt climate change, e.g. HE1 and BA event.
- SAT on GISP2 decreases by 4^{o}C at HE1 and increases by 15^{o}C at BA, all changes occurring in less than 200 years. The changes correlate to changes in NADW formation. The red circles indicate these events and changes.

Ocean sediment records in the tropics



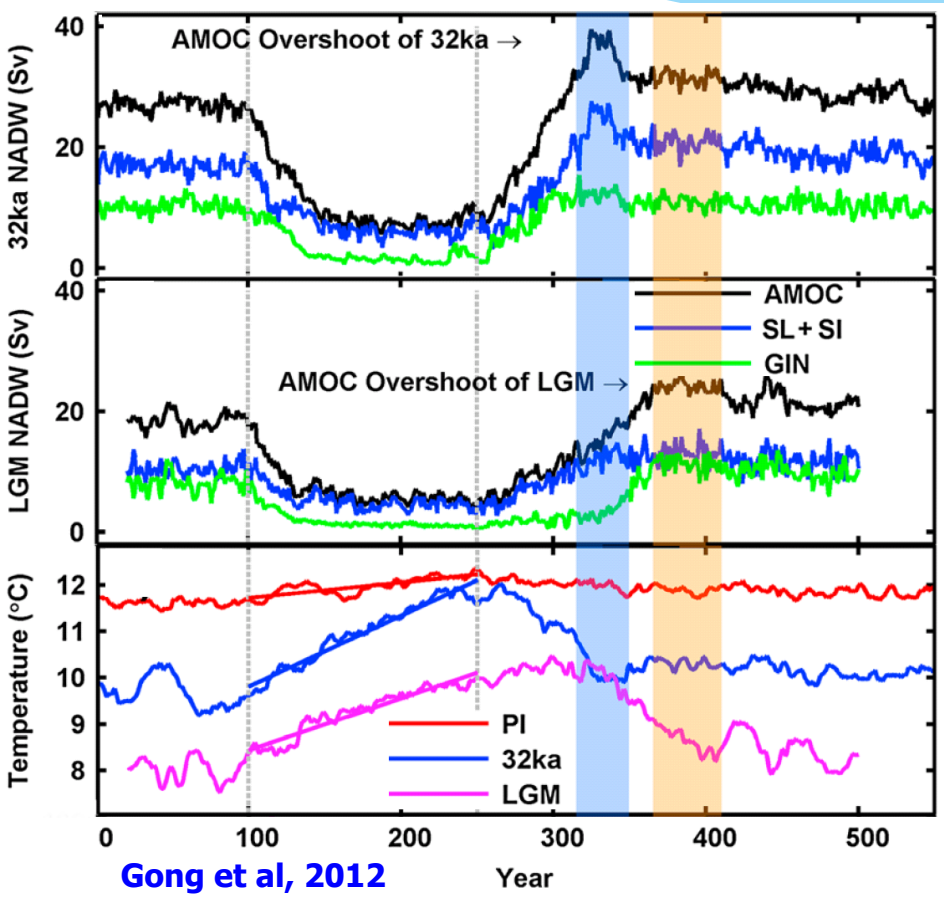
McManus et al, (2004)



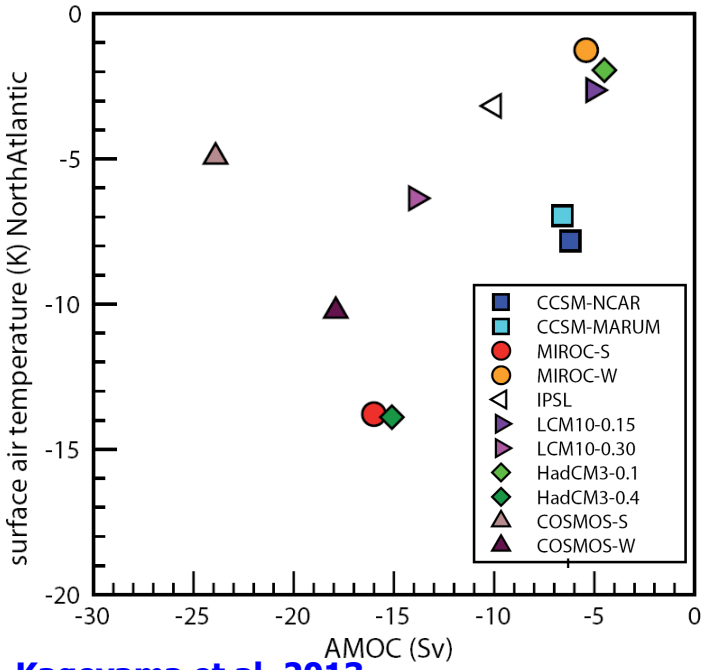
Kim et al., (2003); Dupont et al., (2008)

- Heinrich events are likely associated with a slowdown of the AMOC, in sub-tropical Atlantic has cold and fresh surface water condition (3º-4ºC cooling),
- The vegetation pattern also occurs in west tropical Africa (Angola) rain forest cover decreases, while coastal desert cover increases.

Models of freshwater hosing in past climate

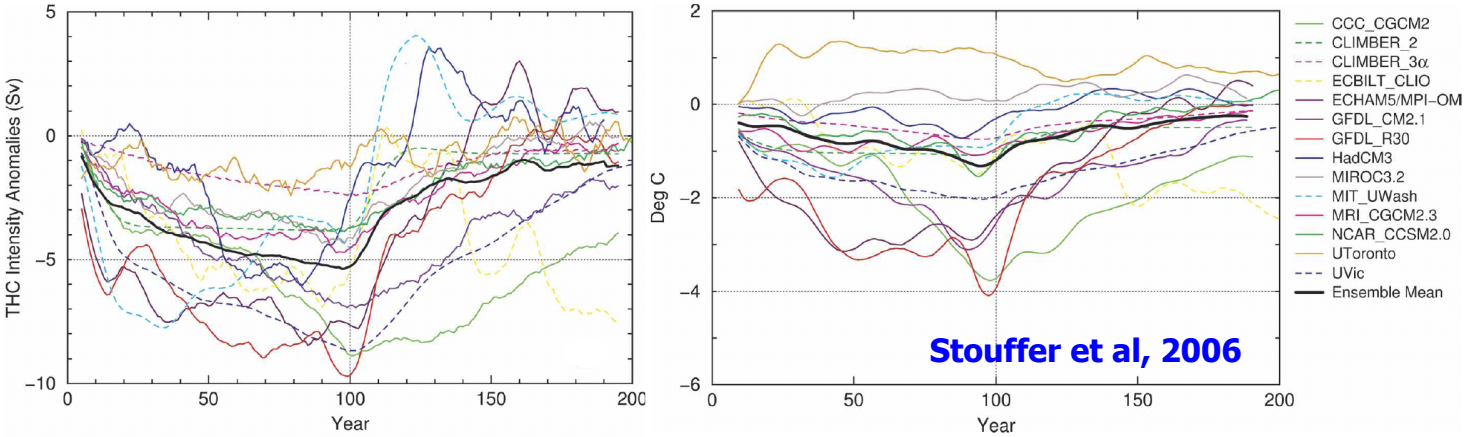


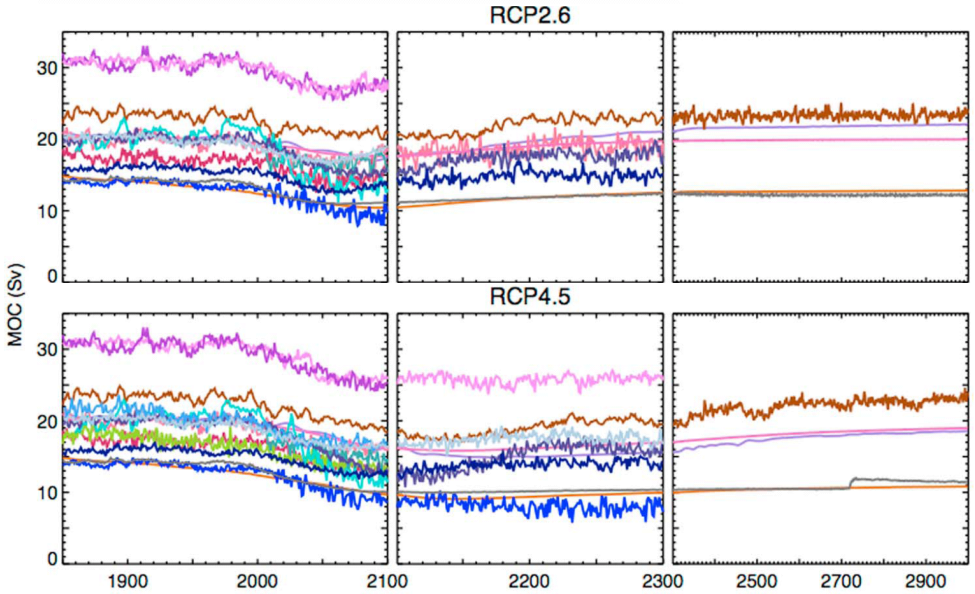
Gong et al, 2012



Kageyama et al, 2013

Models of AMOC responses to freshwater hosing and RCP's scenario





Weaver et al, 2012

ACCESS1.0
BCC-CSM1.1
Bern3D
CanESM2
CCSM4
CESM1-BGC
CESM1-CAM5
CMCC-CM
CNRM-CM5
CSIRO-Mk3.6.0
GFDL-CM3
GFDL-ESM2G
GFDL-ESM2M
HadCM3
HadGEM2-A0
HadGEM2-ES
INMCM4
IPSL-CM5A-LR
IPSL-CM5A-MR
LOVECLIM
MESMO
MIROC5
MIROC-ESM-CHEM
MIROC-ESM
MIROC-Lite-LCM
MPI-ESM-LR
MPI-ESM-MR
NorESM1-M
NorESM1-ME
UVic

- AMOC and temperature response to freshwater forcing under pre-industrial climate is much smaller than the results obtained from glacial climate,
- AMOC strength reduces over RCPs scenario experiment.

Research questions

* What is causing the difference responses of AMOC in the models?

  →to investigate the possible mechanisms,

  →to tune parameters and improve the models,

* How likely is abrupt climate change in future causing from AMOC changes?

Models with freshwater hosing experiments

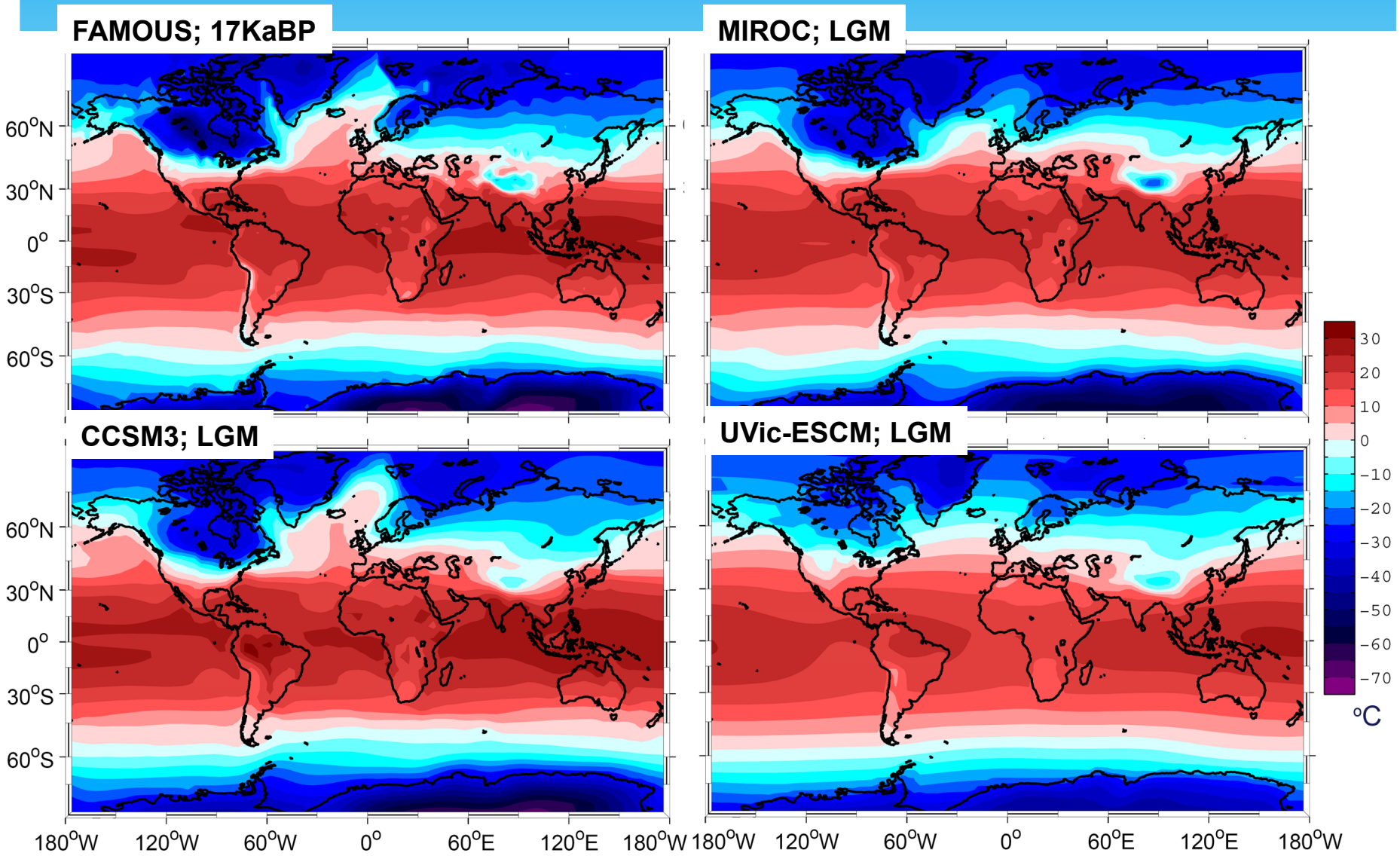
No.	Boundary conditions			Freshwater hosing experiment										Group of ensembles
	Insolation and ice sheet			Rates (Sv)					Location	Years simulation (years)				
	Preindustrial (1850 AD)	LGM (21 KaBP)	17 KaBP	0.1	0.2	0.4	0.5	1.0	50-70N	100	300	500	940	
1		X												Control
2		X		X					X				X	✦
3		X						X	X	X				✦
4	X													▲
5	X			X					X			X		▲
6		X												Control
7		X			X				X			X		✦
8	X													Control
9	X			X					X			X		▲; ■
10	X					X			X			X		■
11	X						X		X			X		■
12	X							X	X			X		■
13		X												Control
14		X		X					X			X		✦
15			X											Control
16			X	X					X	X				■
17			X	X					X		X			■
18			X	X					X			X		■
19			X			X			X	X				■
20			X			X			X		X			■
21			X			X			X			X		■
22			X					X	X	X				■
23			X					X	X		X			■
24			X					X	X			X		■
25	X													Control
26	X			X					X			X		▲; ■
27	X					X			X			X		■
28	X							X	X			X		■
29			X											Control
30			X	X					X	X				■
31			X	X					X		X			■
32			X	X					X			X		✦; ■
33			X			X			X	X				■
34			X			X			X		X			■
35			X			X			X			X		■
36			X					X	X	X				■
37			X					X	X		X			■
38			X					X	X			X		■

Variety of different:
→models,
→climate background and,
→amount of freshwater forcing

GCM models:
→FAMOUS (x), **Singarayer and Valdes., 2010**
→MIROC (x), **Chikamoto et al., 2012** and
→CCSM3 (x), **Merkel et al., 2010**,

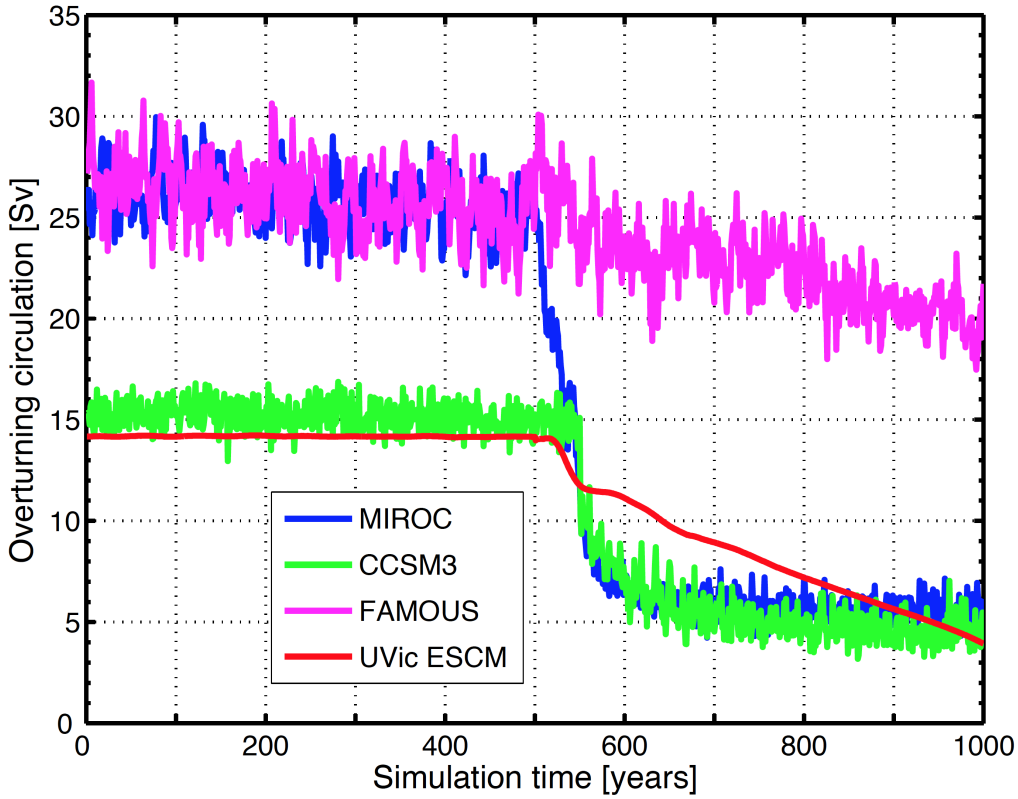
EMIC models:
UVic ESCM (x), **Weaver et al., 2001**

Glacial “control” climates

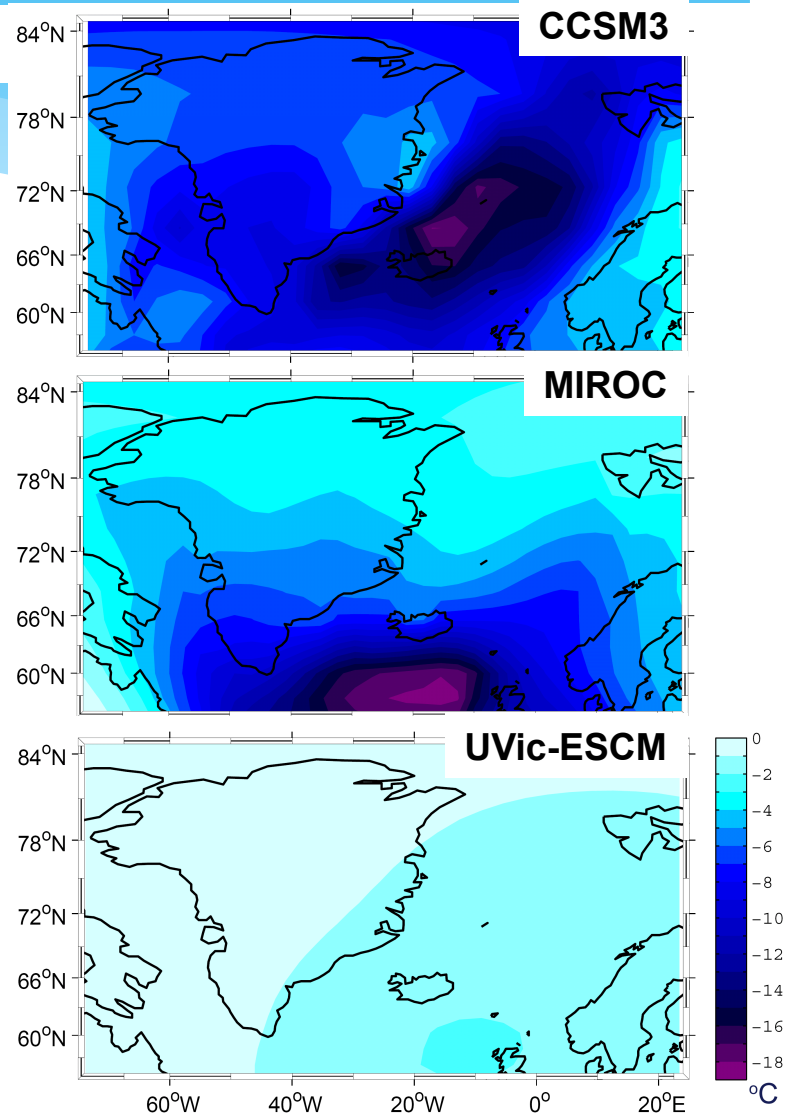


Models result from freshwater hosing experiment in glacial climate

AMOC strength

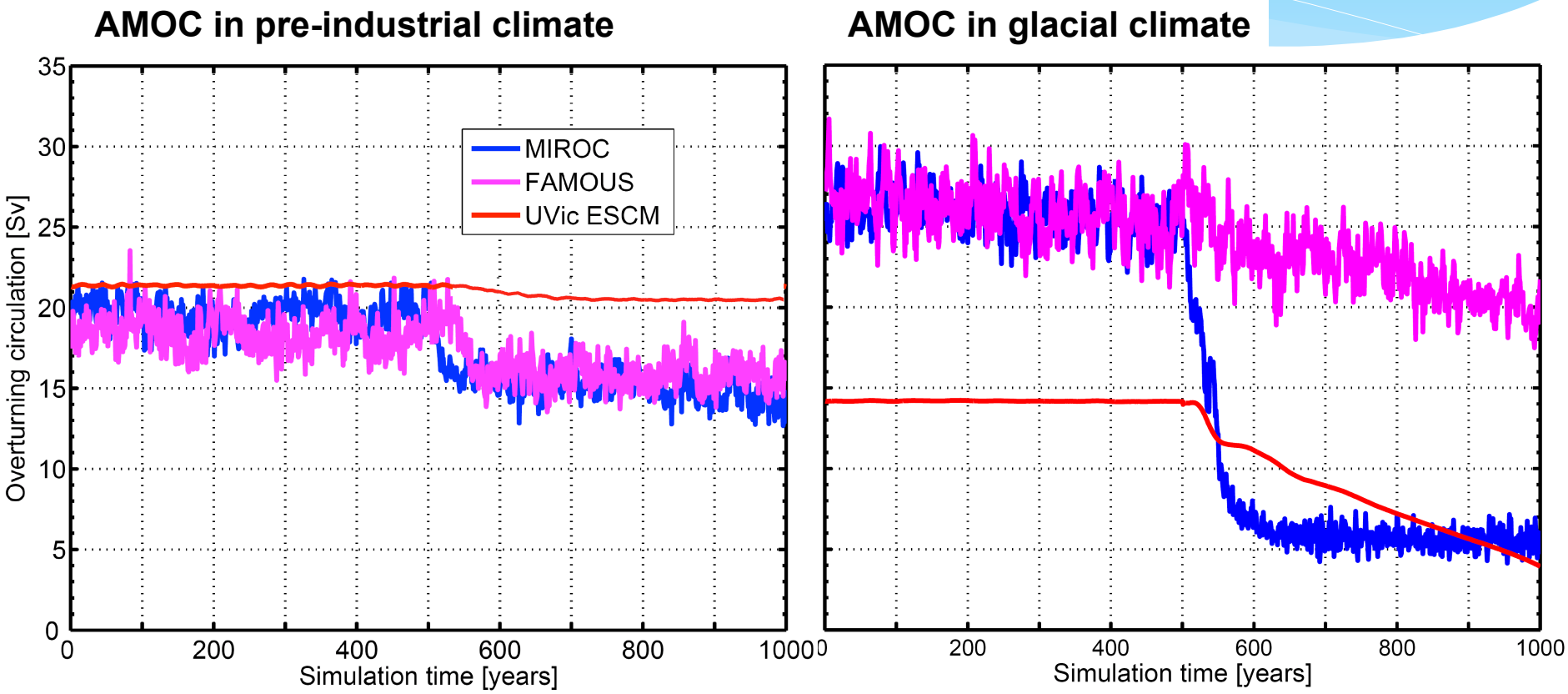


Temperature

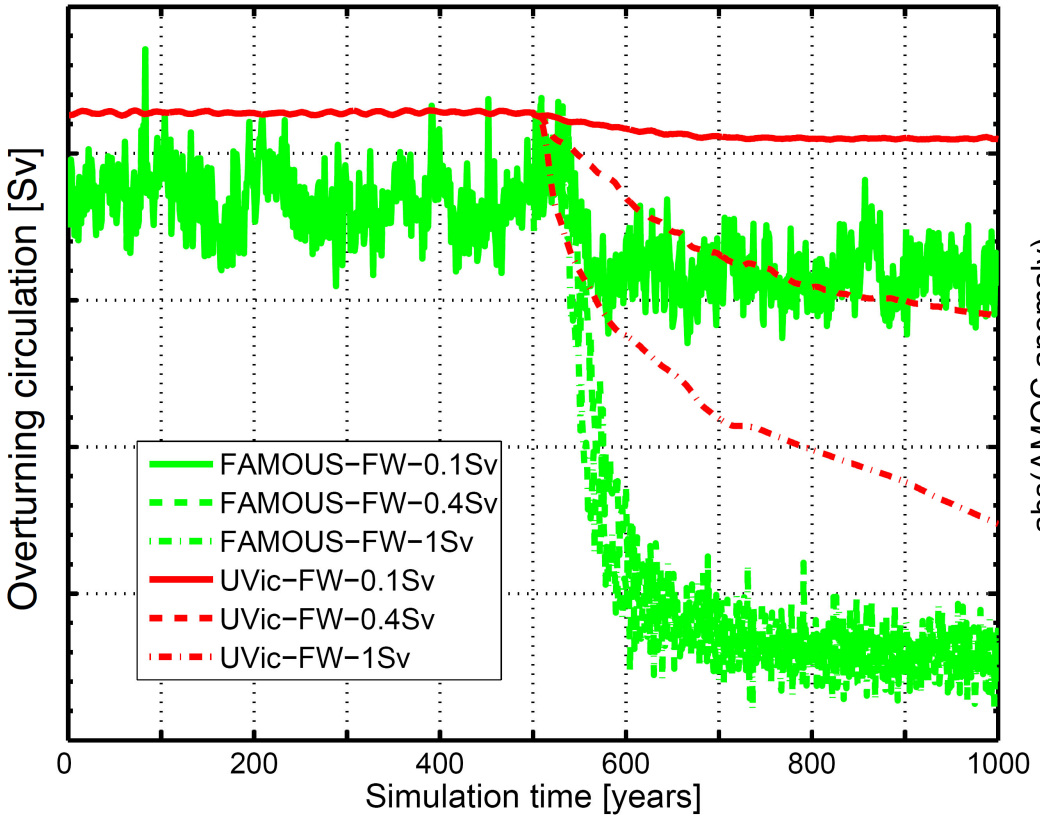


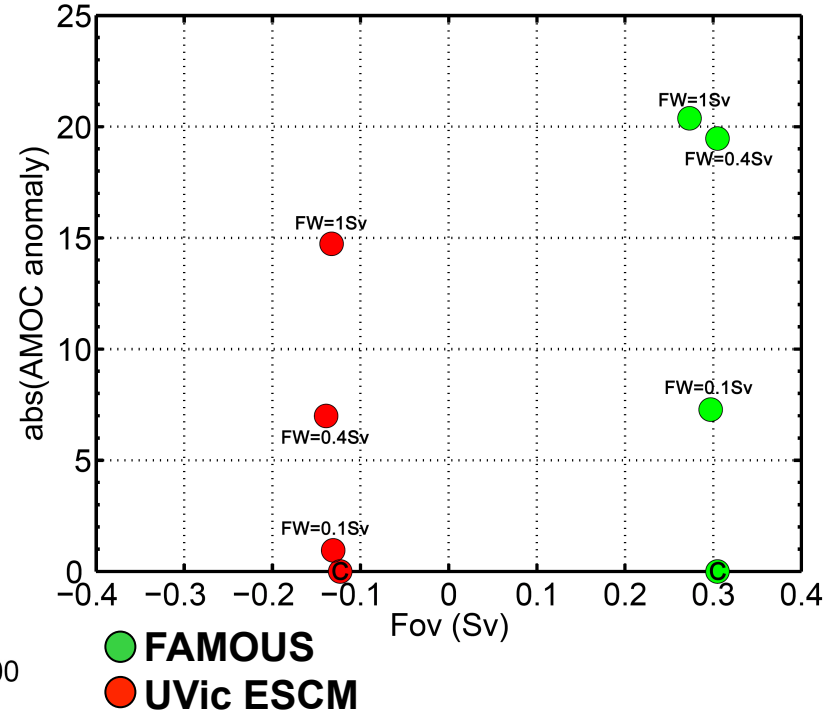
The AMOC strength and temperature over Greenland vary in response to freshwater hosing at 0.1 Sv.

AMOC response to freshwater hosing in different climate condition



AMOC models stability analysis





Fov is the freshwater flux by the MOC into the Atlantic through 30º-32ºS and it provides information if the MOC is in monostable (Fov>0) or bistable region (Fov>0).

Summary

Simulations of Heinrich events using freshwater hosing in all models produce:

- various AMOC responses and its different sensitivities to background climate state,
- magnitude of AMOC and temperature changes are also sensitive to background climate state, but the pattern of these changes are similar.

Future plan overview

→*to do regional analysis to compare with proxy data.*

→*to improve understanding different climate responses to fresh-water hosing in distinctive background climates in each model.*

→*to test AMOC stability properties behaviour in each model and understand potential driver of the ocean circulation change.*