Transient simulation of AMOC and climate through the last deglaciation in CCSM3

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THE UNIVERSITY of WISCONSIN MADISON

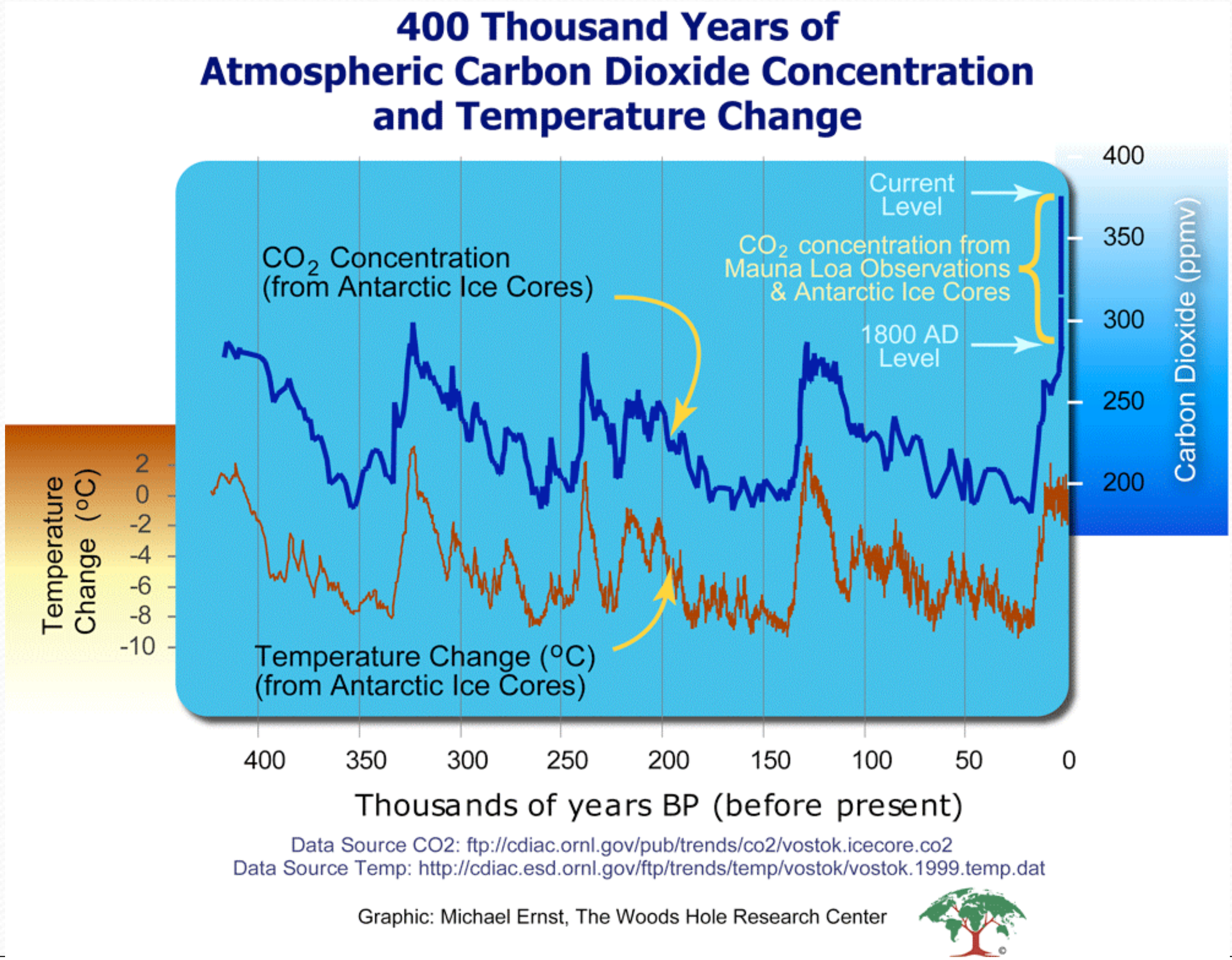
NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Oregon State UNIVERSITY OSU

Objective

- Model validation and development
- Abrupt climate changes
- Earth system climate sensitivity to GHGs

Climate Sensitivity



Climate Evolution of Last Deglaciation

Insolation

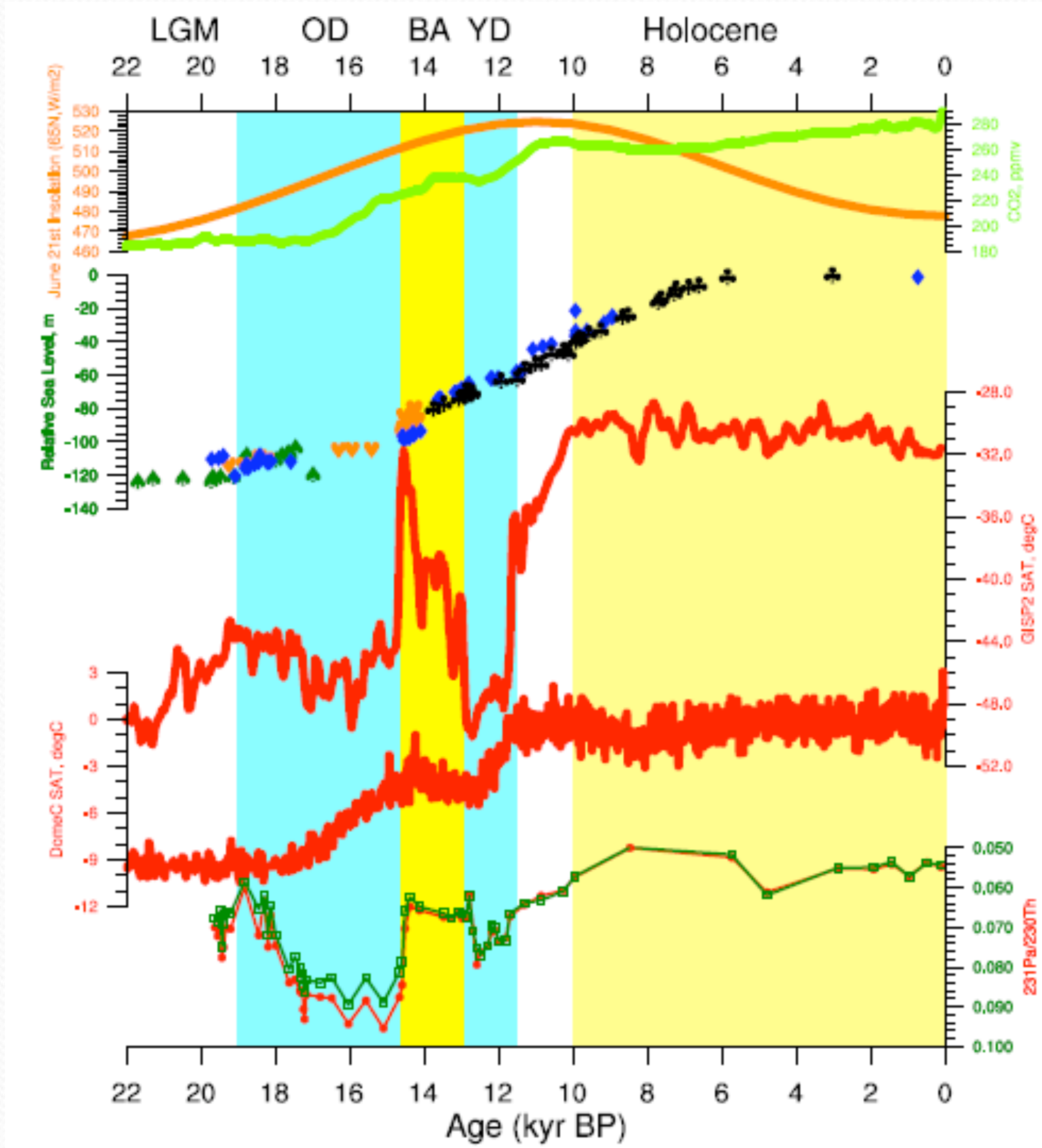
CO_2

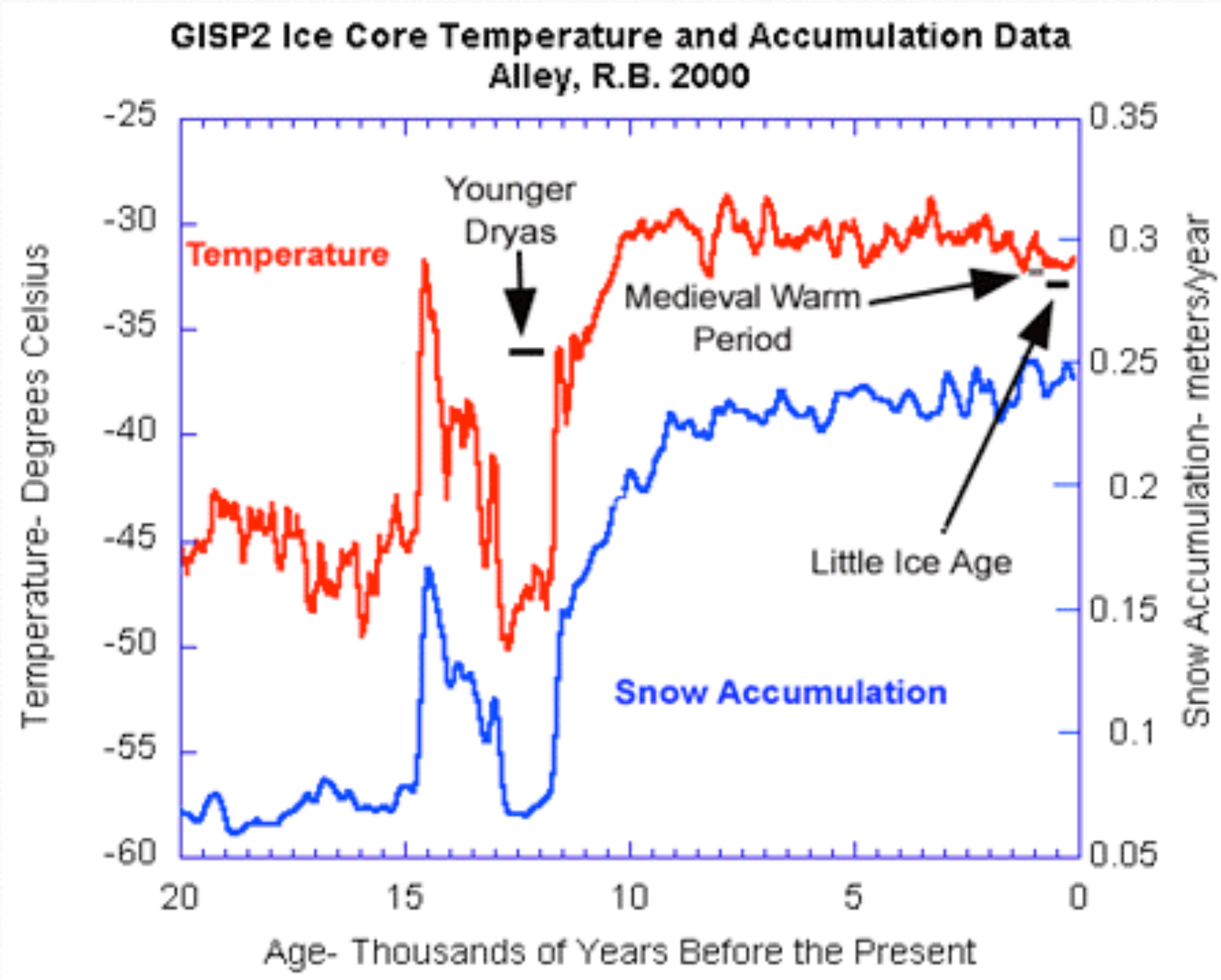
Sea Level

Greenland SAT

Antarctic SAT

AMOC




GISP2 Ice Core Temperature and Accumulation Data
Alley, R.B. 2000
Temperature
Younger
Dryas
Medieval Warm
Period
Little Ice Age
Snow Accumulation
Temperature- Degrees Celsius
Snow Accumulation- meters/year
Age- Thousands of Years Before the Present
-25
-30
-35
-40
-45
-50
-55
-60
0.35
0.3
0.25
0.2
0.15
0.1
0.05
20
15
10
5
0

Climate Evolution of Last Deglaciation

Insolation

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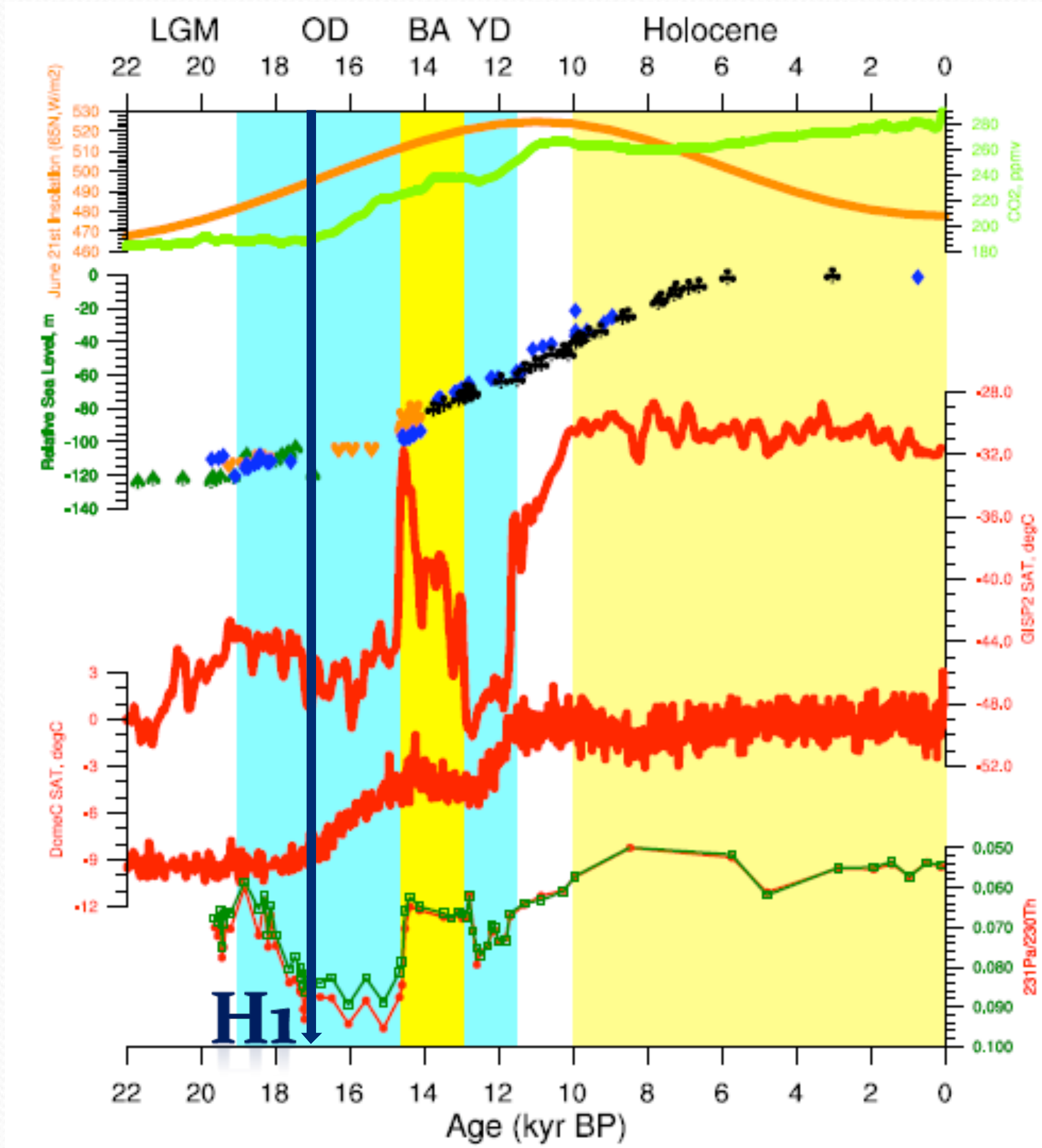
AMOC



INCITE Supercomputing Support

Model: **CCSM3 (T31_gx3v5) + dynamic vegetation**

ATM 3.75(lon) x 3.75(lat) x 26(level)

OCN ~3 (lon/lat) x 25 (level)

Peak performance: 120 model years per day

21,000 years in 6 months

U.S. DEPARTMENT OF ENERGY
INCITE
LEADERSHIP COMPUTING

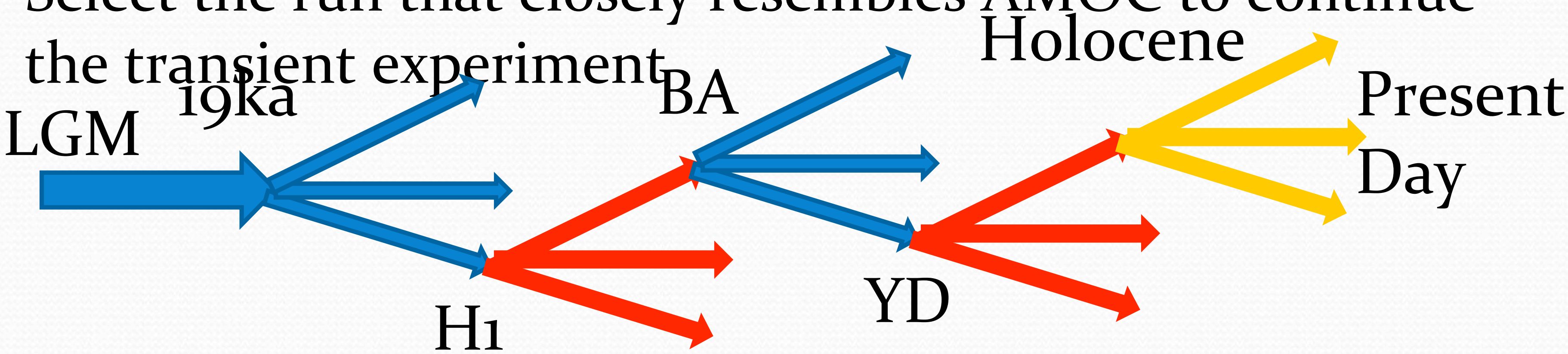
National Center for Computational Sciences

Climate Forcing (boundary condition)

- Orbital forcing
- GHGs, and other atm trace gases
- Sea level (Bering strait opening etc)
- Ice sheets
- Meltwater forcing (AMOC)

Strategy

- Use AMOC and Greenland temperature (GISP2) as target to experimentally derive meltwater forcing from sea level record
- Special attention paid to abrupt climate events 19ka, H1, BA, MWP1a and YD
- Several sensitivity runs with the same initial condition but different routing/rates of freshwater pulses
- Select the run that closely resembles AMOC to continue the transient experiment

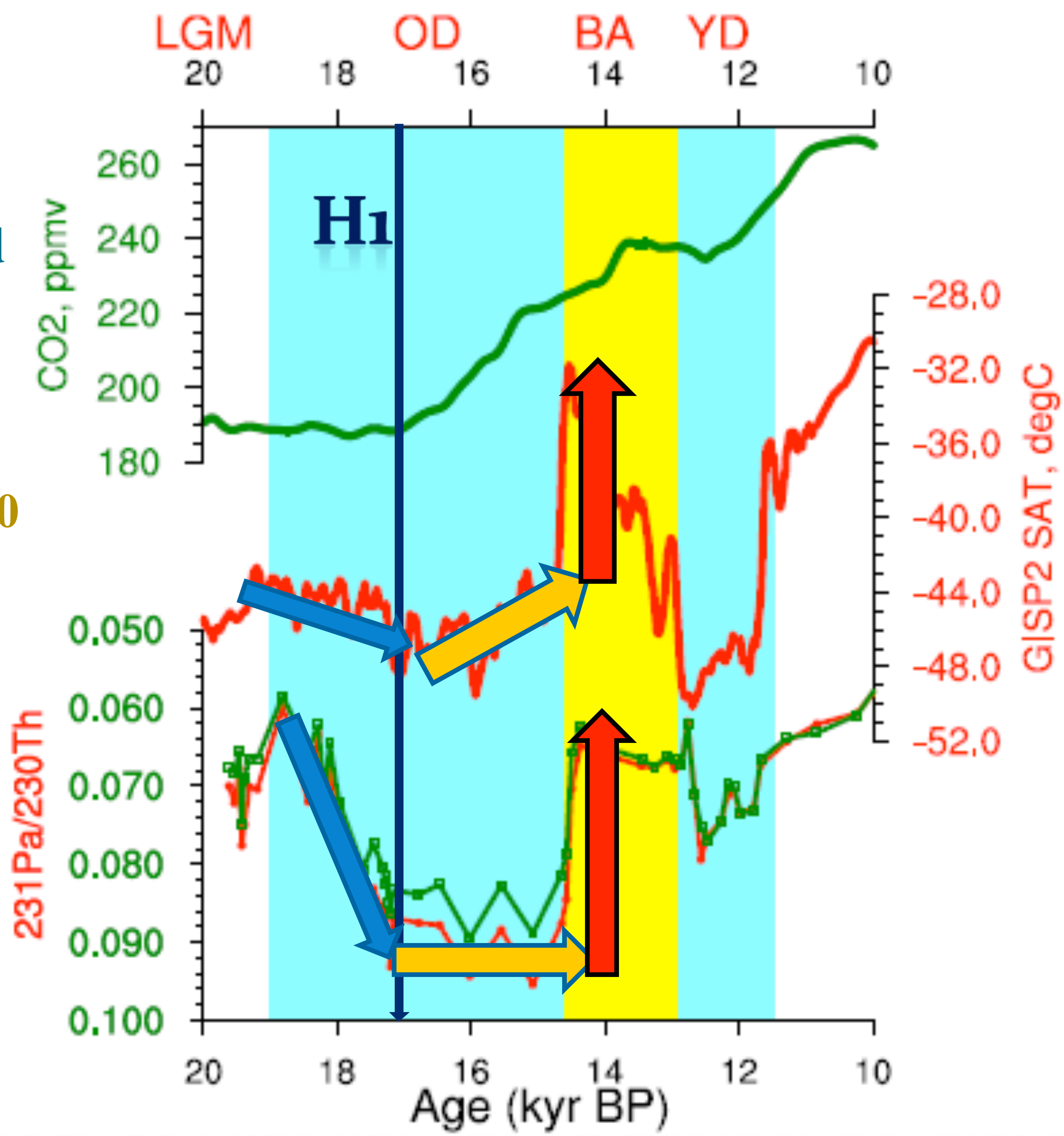


Some Challenges

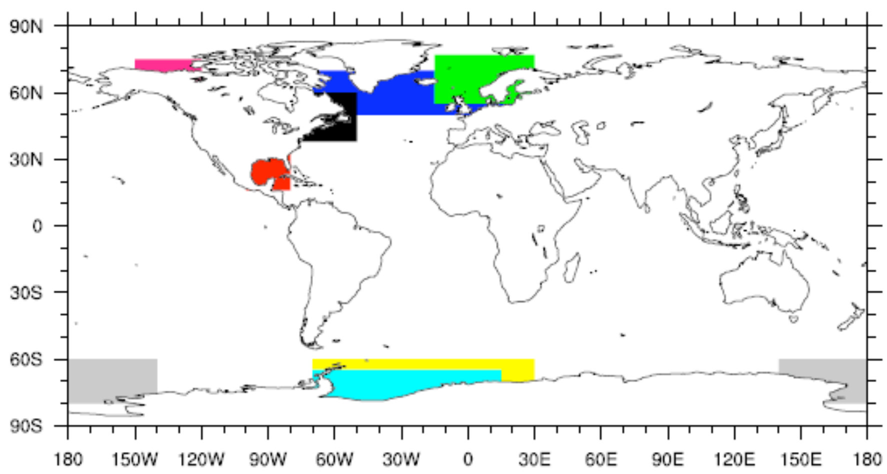
C1: From 19ka, AMOC linearly decreases and collapses at H1. Greenland SAT drops ~3 °C

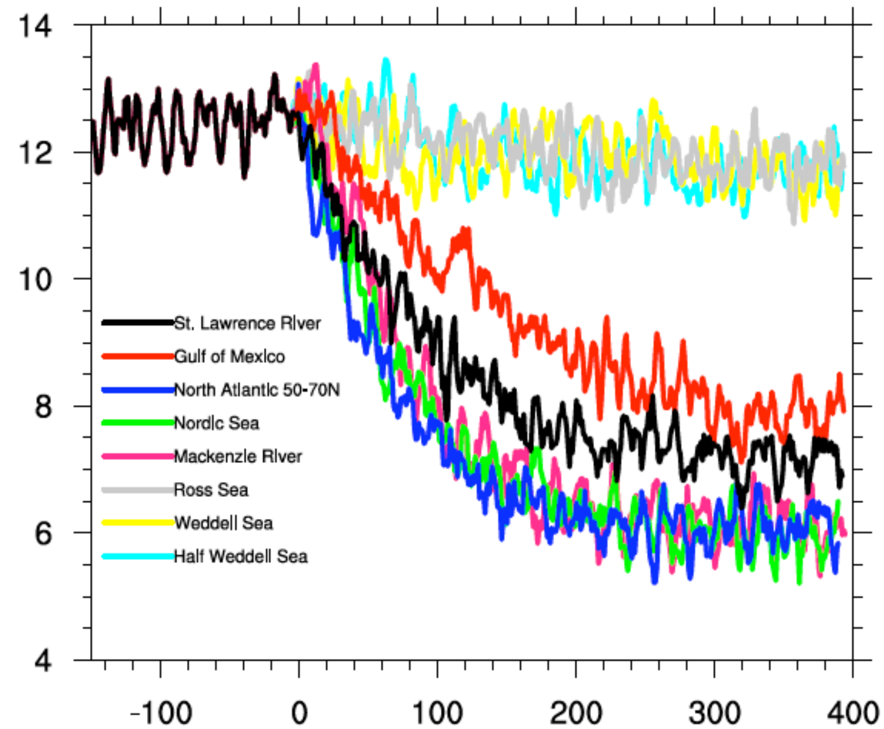
C2:Keep AMOC off for ~2300 years with ~3 °C increase of Greenland SAT

C3:AMOC abruptly recovers with ~13 °C abrupt increase of Greenland SAT



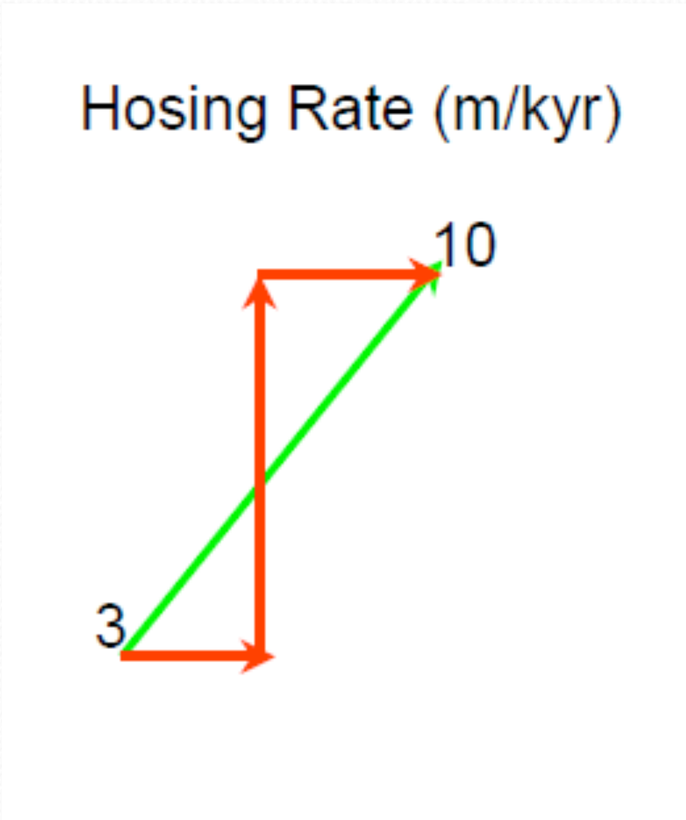
AMOC sensitivity to the location of freshwater forcing

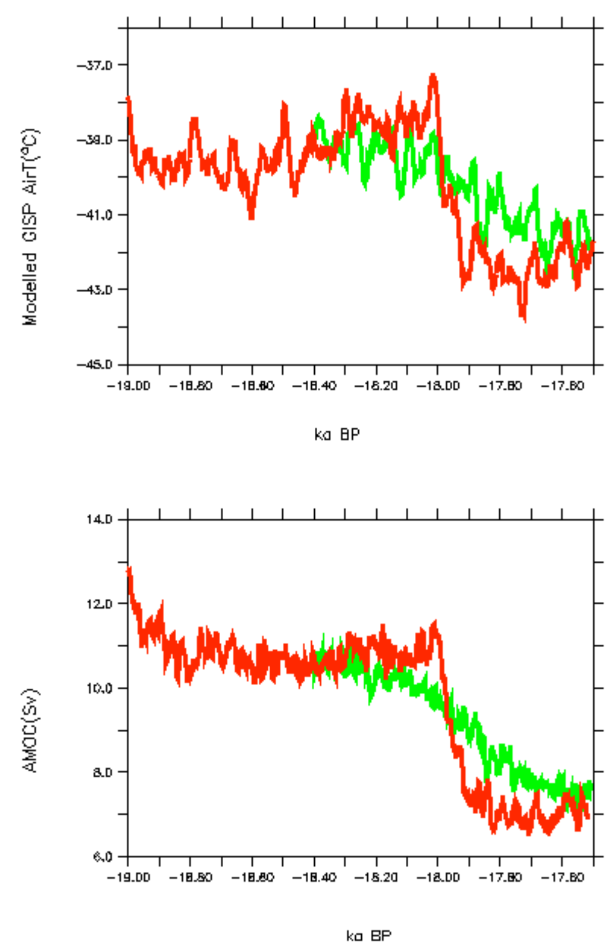




AMOC response to 0.1 Sv freshwater forcing in eight regions at LGM condition

Ramped v.s. Constant forcing

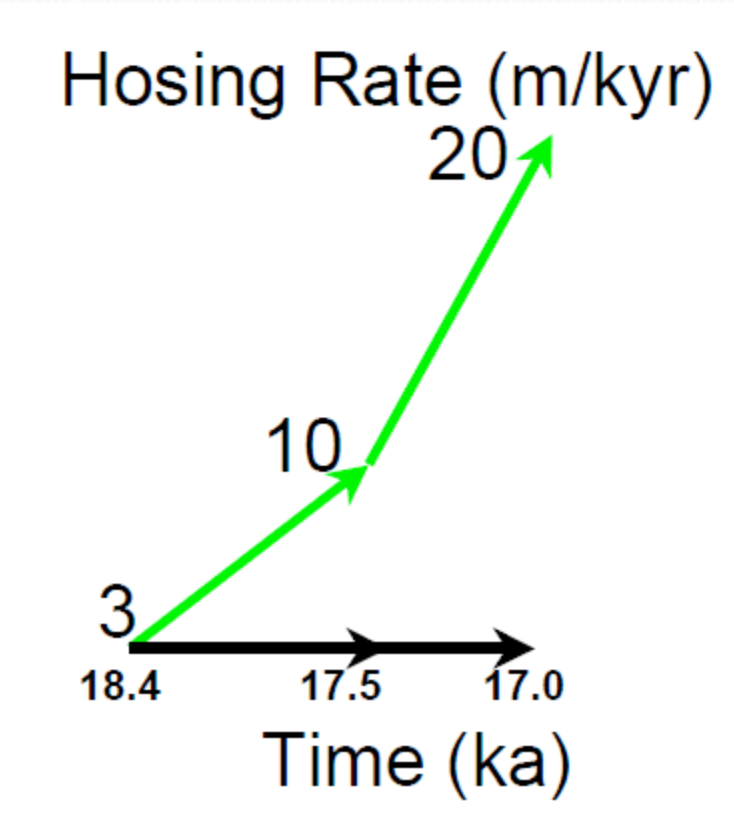


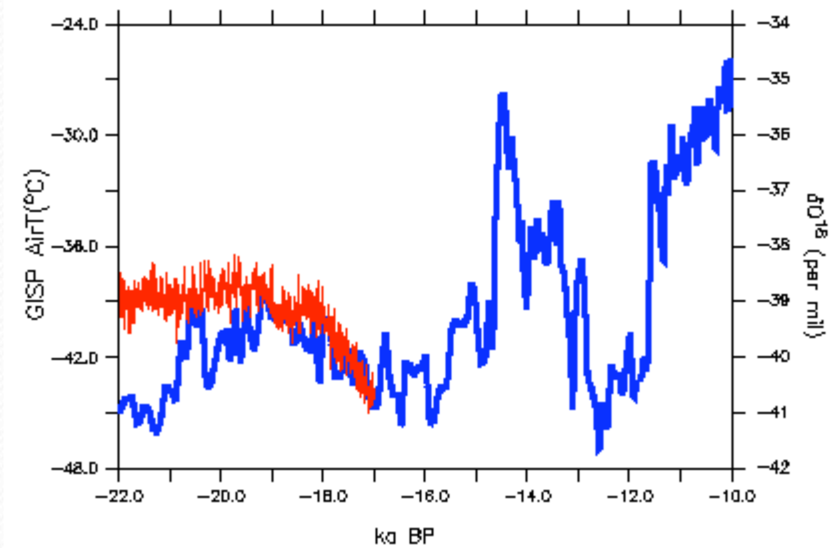


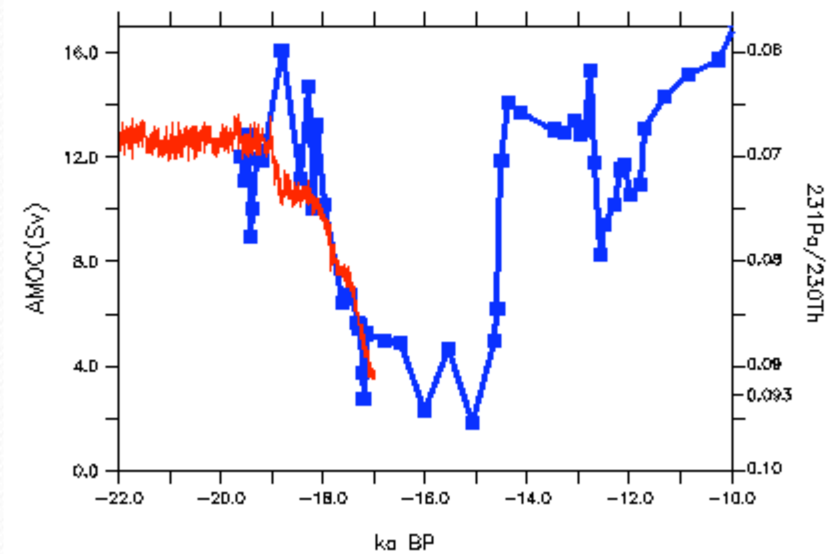
Greenland temperature

AMOC

Heinrich Event I



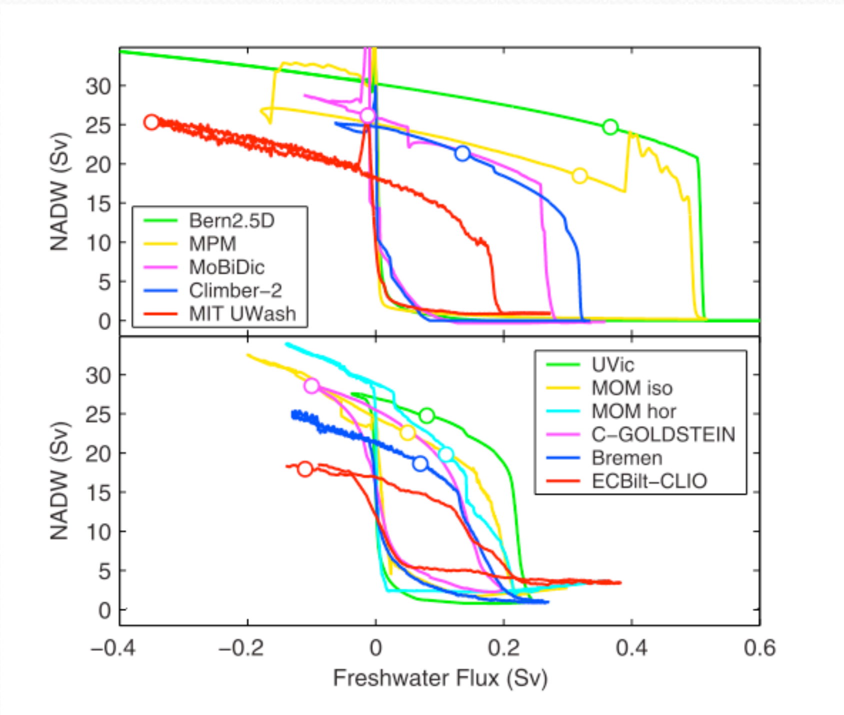




How to keep AMOC off for ~2300 years?

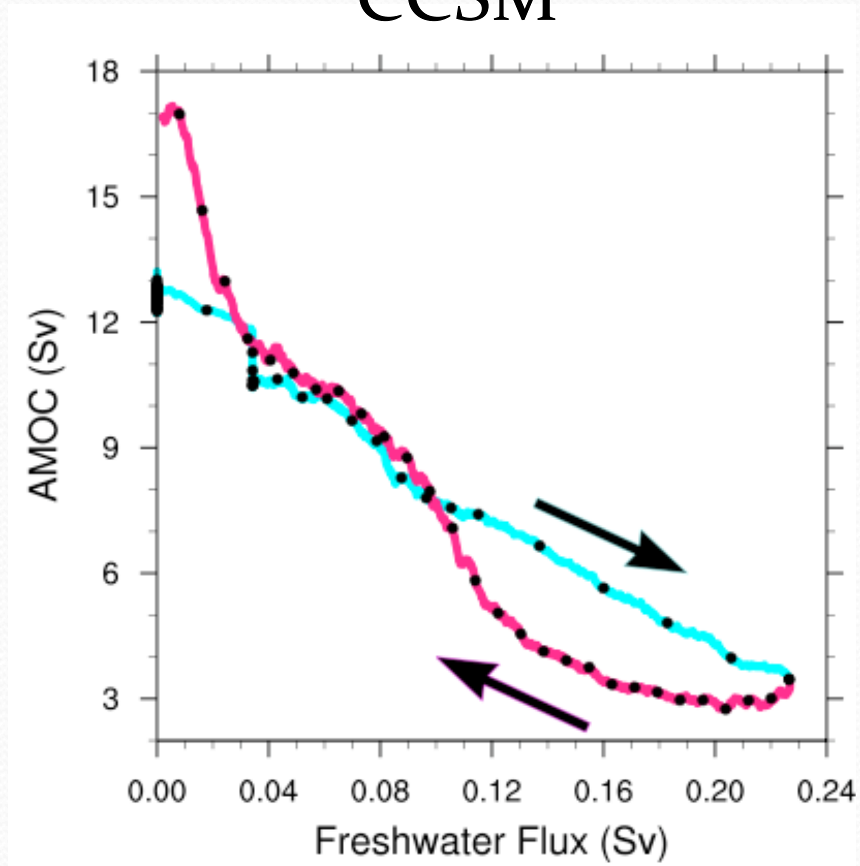
Depends on hysteresis of AMOC in CCSM

EMIC



Rahmstorf *et al.*,2005

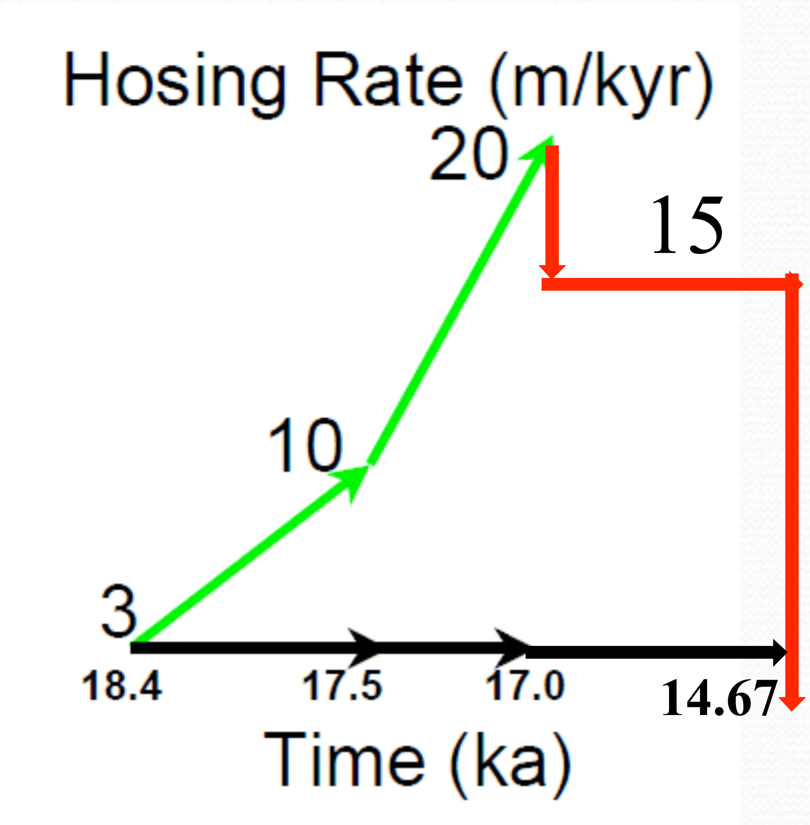
CCSM

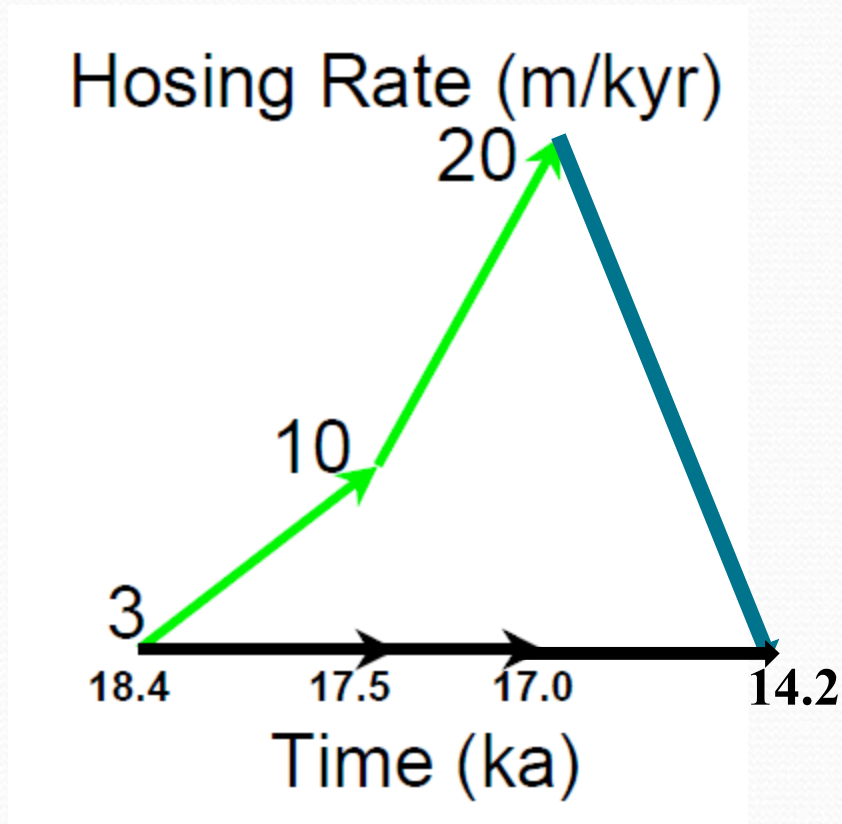


Liu *et al.*, 2009

How to keep AMOC off for ~2300 years?

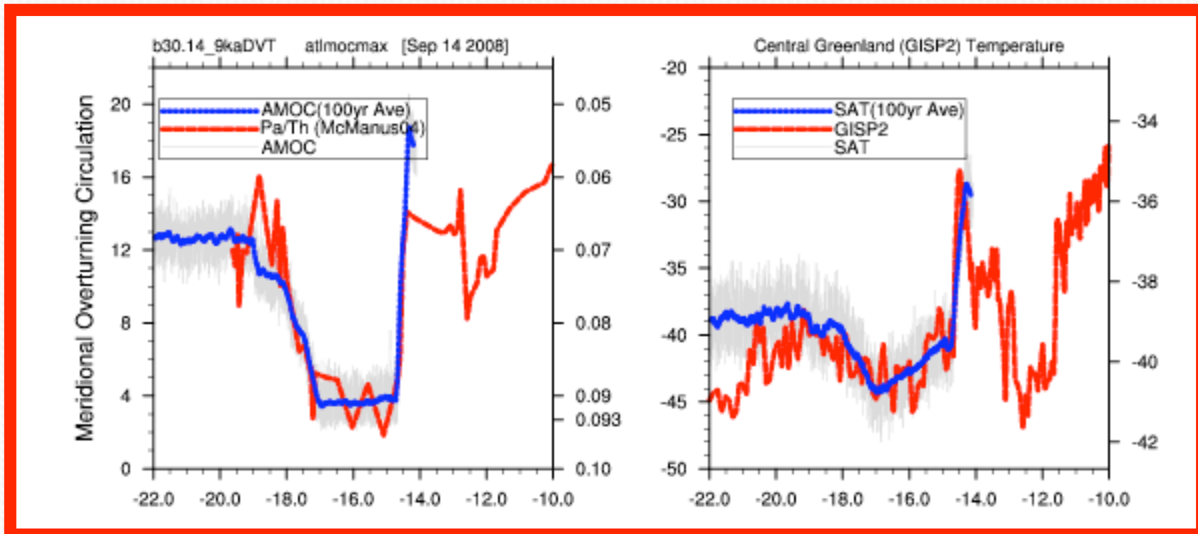
Abrupt Cessation v.s. Linear Ramping



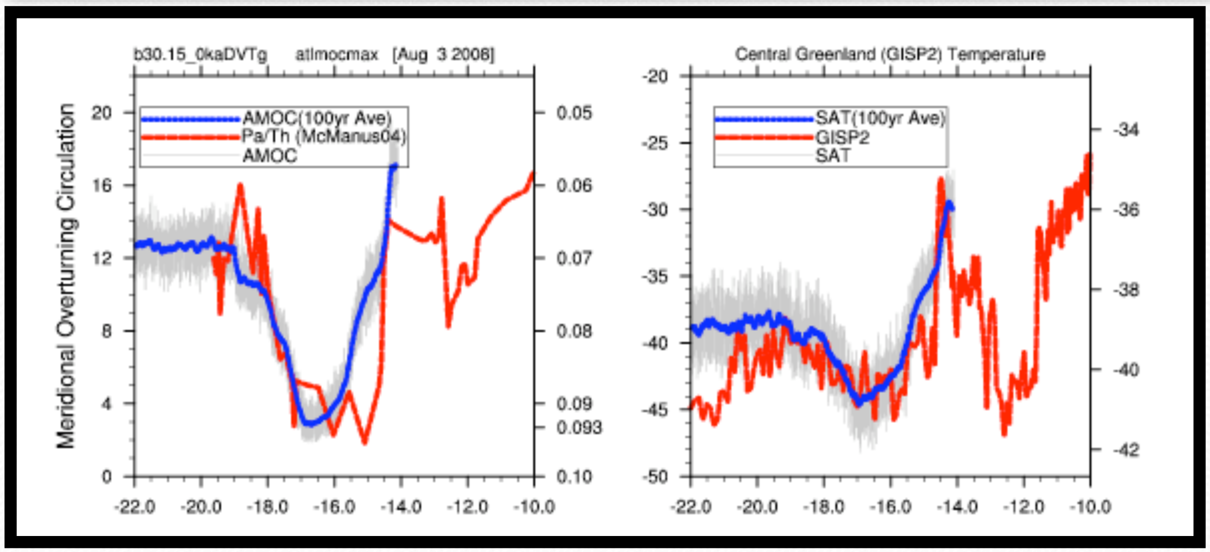


How to keep AMOC off for ~2300 years?

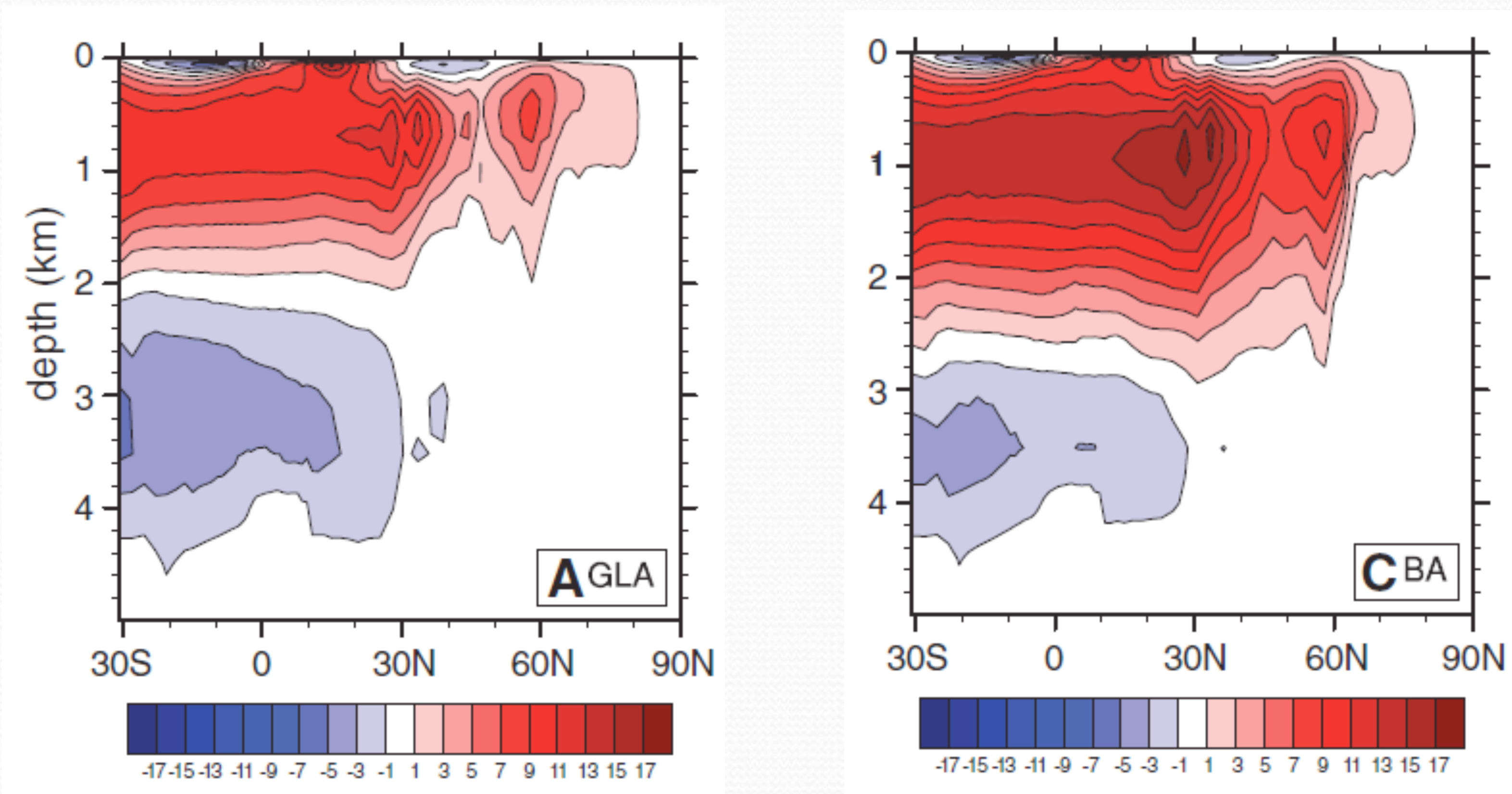
Abrupt Cessation



Linear Ramping



AMOC Overshoot in CCSM3

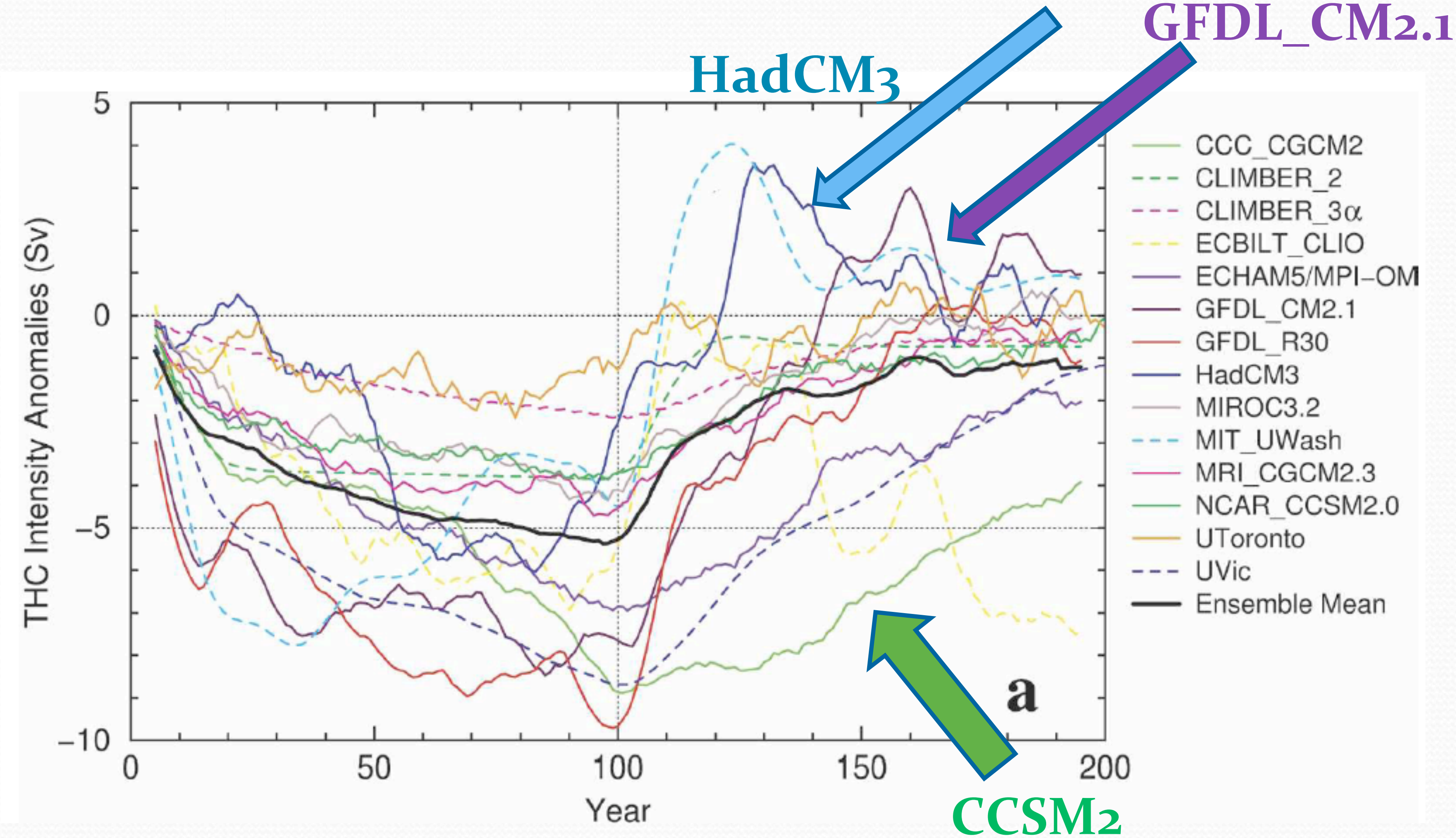


LGM

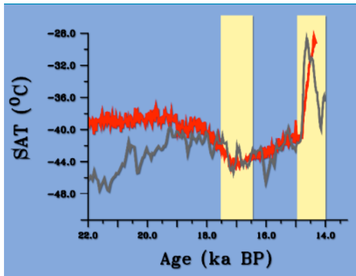
BA

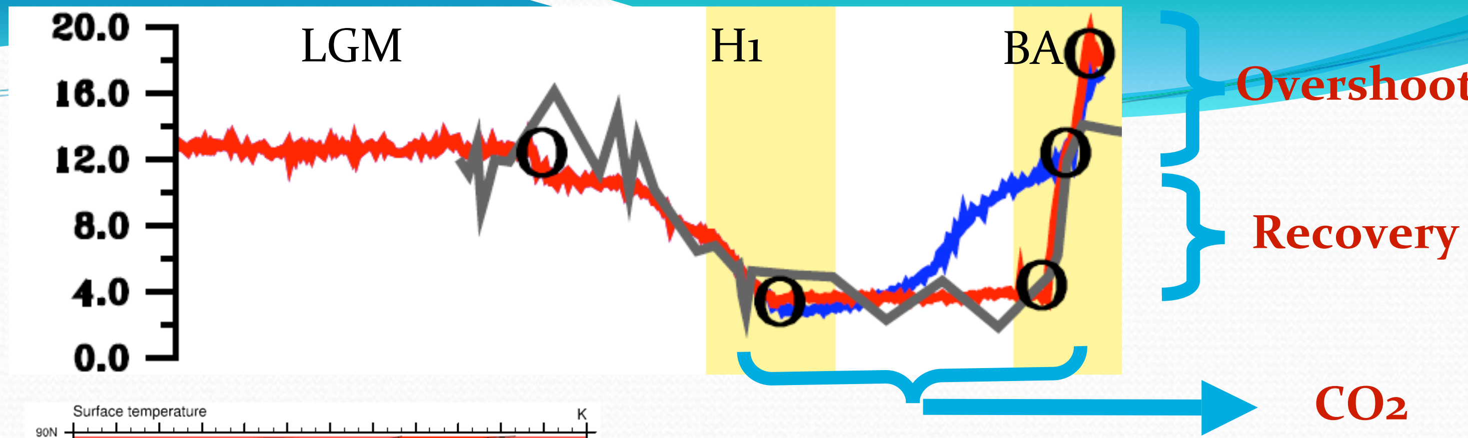
Liu *et al.*, 2009

AMOC Overshoot in CMIP



Stouffer *et.al.* 2006

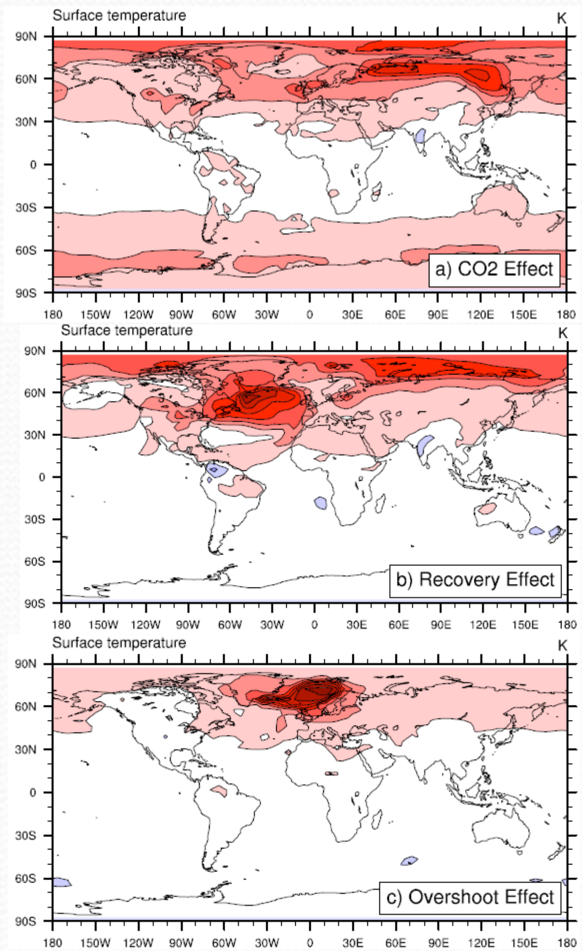




A New Mechanism

For

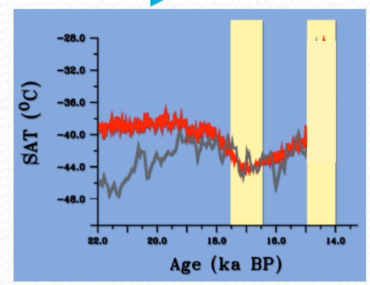
BA Warming

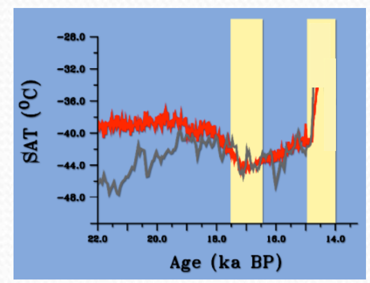


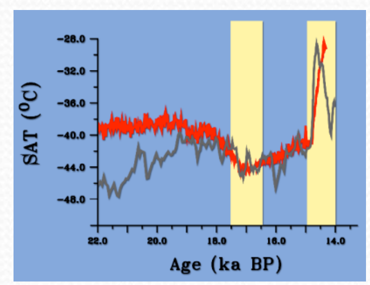
40ppmv CO2 Rise

AMOC Recovery

AMOC Overshoot







Liu *et al.*, 2009

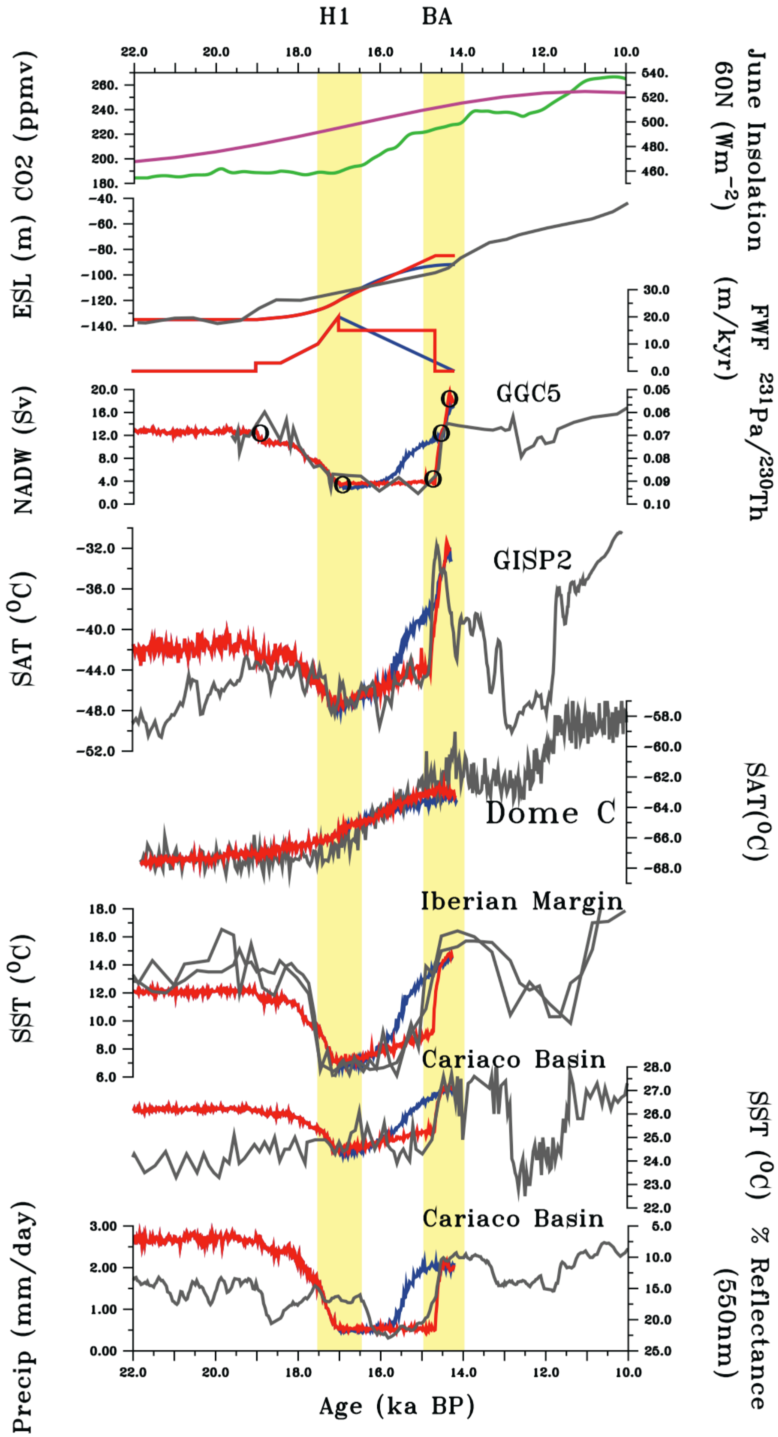
Climate Sensitivity &

Abrupt Climate Change

Model : Red/blue

Proxy data: Gray

Liu *et al.*, 2009



Insolation
CO2

Sea Level

Freshwater forcing

AMOC

Greenland temperature

Antarctic temperature

Subtropical SST

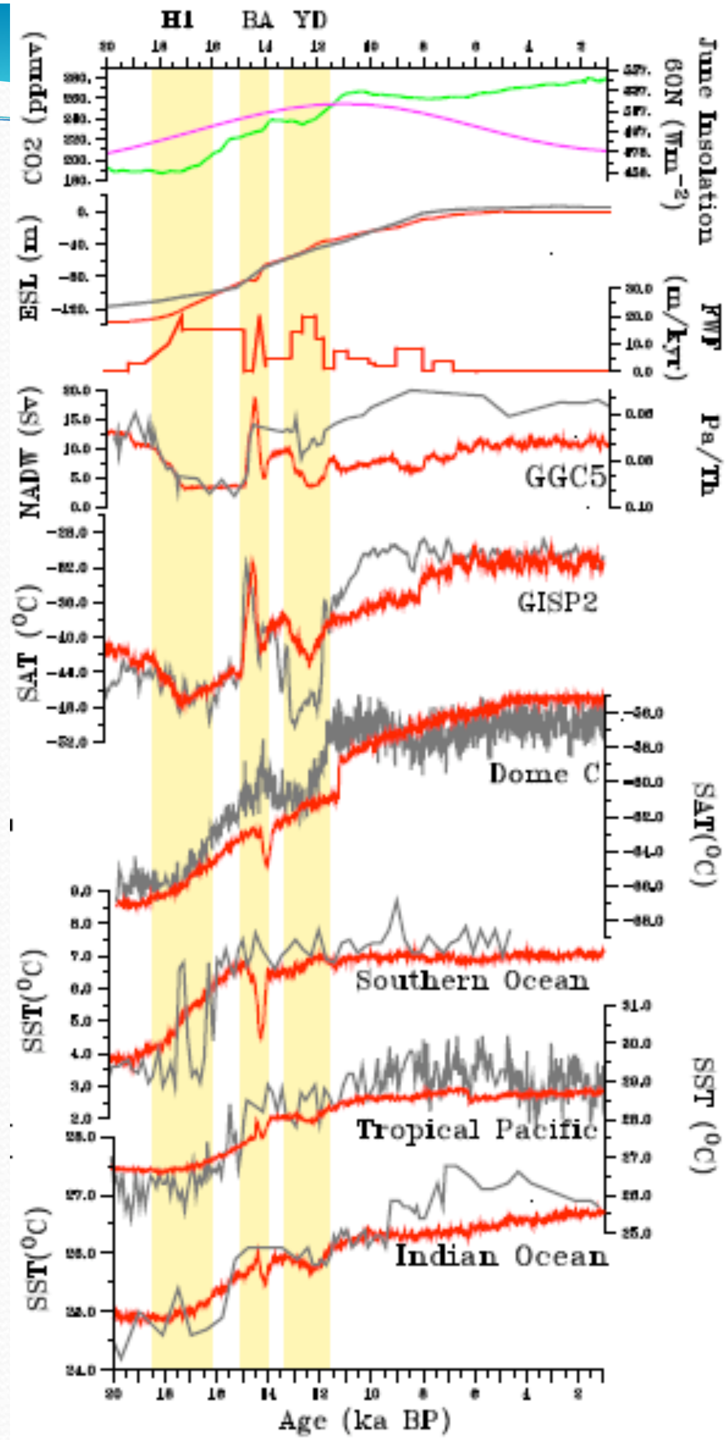
Tropical SST

Tropical precipitation

Climate Sensitivity &

Abrupt Climate Change

Since LGM



Insolation
CO_2

Sea Level

Freshwater forcing

AMOC

Greenland temperature

Antarctic temperature

Southern Ocean SST

Tropical Pacific SST

Indian Ocean SST

Model : Red/blue
Proxy data: Gray

He *et al., in prep*

Conclusion

- **CCSM3 reproduces several major features of the deglacial climate evolution**

  Suggests there is a good agreement in climate sensitivity between the model and observations

- **Abrupt BA warming mechanism**

  Transient CO2 forcing (precondition)

  AMOC recovery from Heinrich Event 1

  AMOC overshoot.

- **CCSM3 doesn't exhibit substantial hysteresis**

  Accurate reconstructions of the rate of melting water are needed to clarify whether the hysteresis is a fundamental feature of the real-world AMOC