Simulating Transient Climate Evolution of the Last 21,000 years with CCSM3 (TraCE-21,000): A Progress Report

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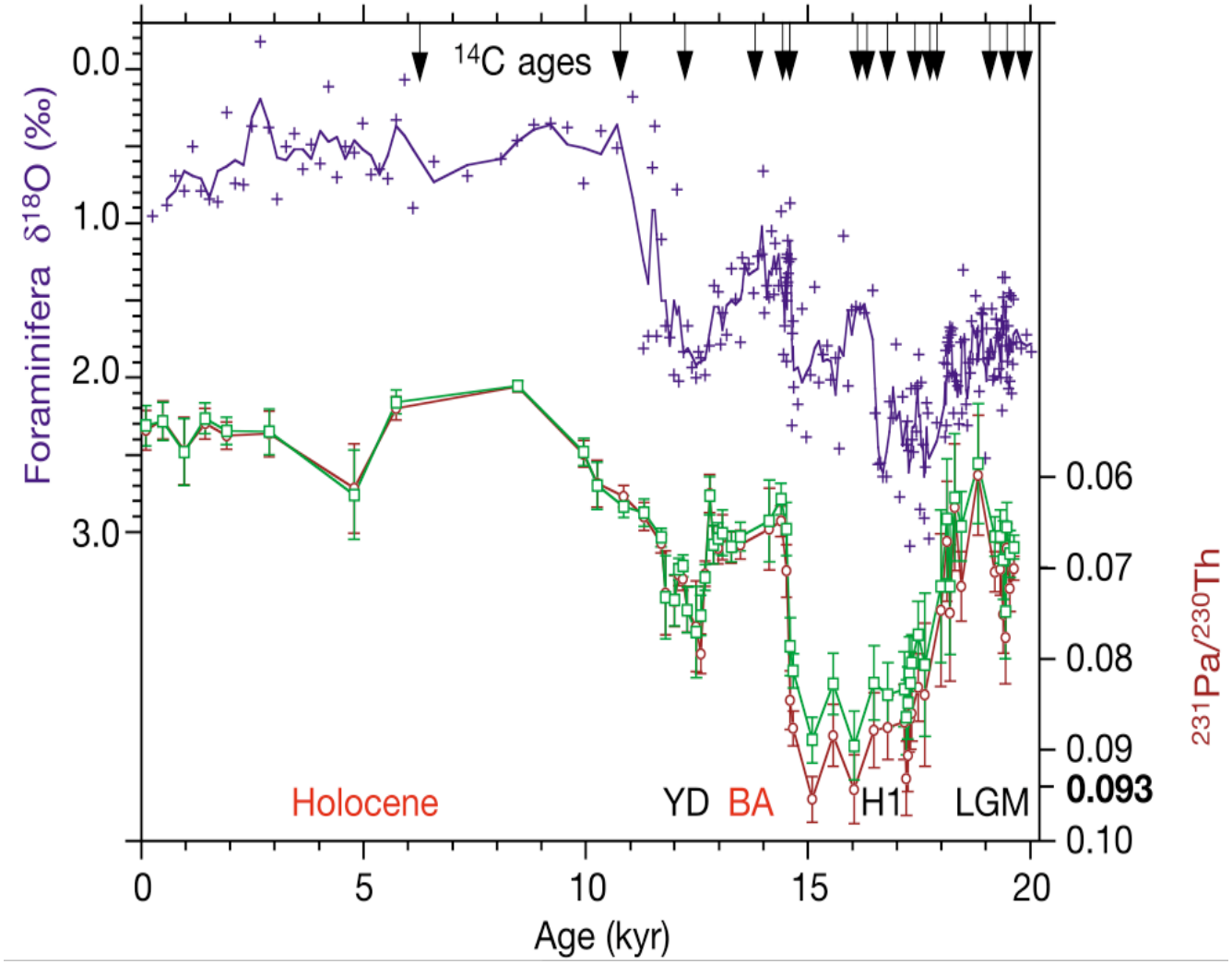
Outline

- The Objective of TraCE-21,000
- The Reconstruction of AMOC and Sea Level Rise since LGM
- Model Configuration and Overall Strategy
- 22ka-15.5ka Progress Report
- The Collapse of AMOC during H1
- The Hysteresis of AMOC in CCSM3
- AMOC Resumption as the Cause of BA Warming
- Conclusion

The Objective of TraCE-21,000

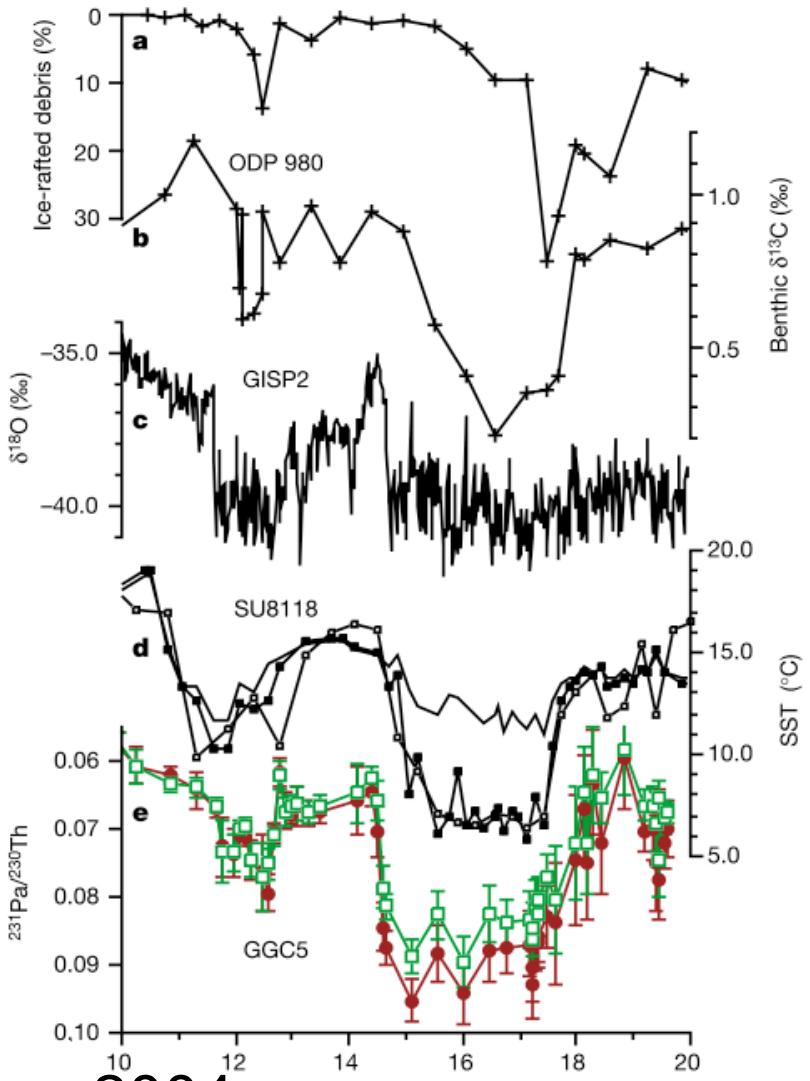
- Provide the synchronously coupled transient ATM-OCN-DV-GCM simulation of the last 21,000 years
- Assess the sensitivity of the climate system to the change of greenhouse gases, notably CO2
- Investigate how the climate system exhibits abrupt changes on decadal-centennial time scales (H1, BA, YD, etc)

AMOC Reconstruction



McManus et al, Nature 2004

AMOC & North Atlantic Climate

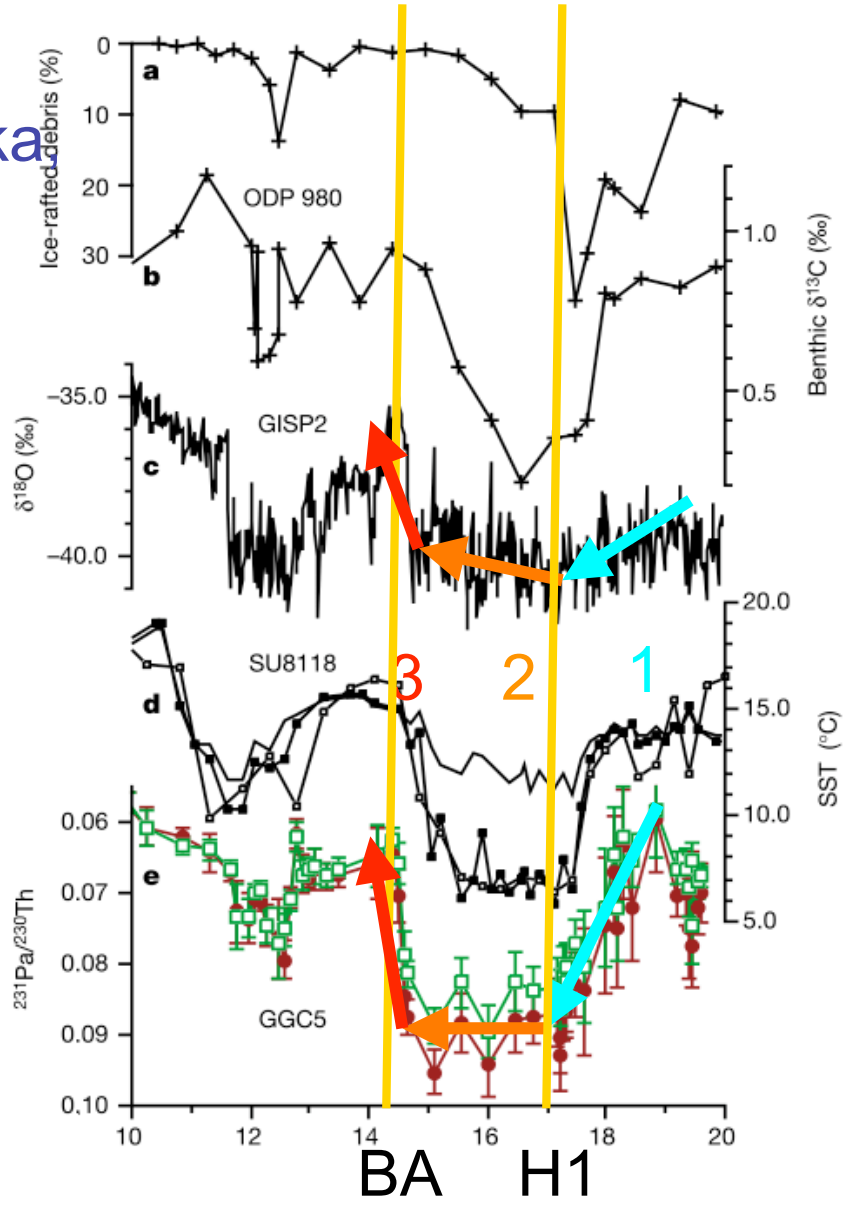


McManus et al., Nature 2004

Three Challenges!

C1:
Starting from 19ka AMOC linearly decreases and collapses during H1

C3:
During BA, AMOC recovers but SAT_{GISP} overshoots



C2:
AMOC keeps "off" between H1 and BA, but SAT_{GISP} recovers after H1

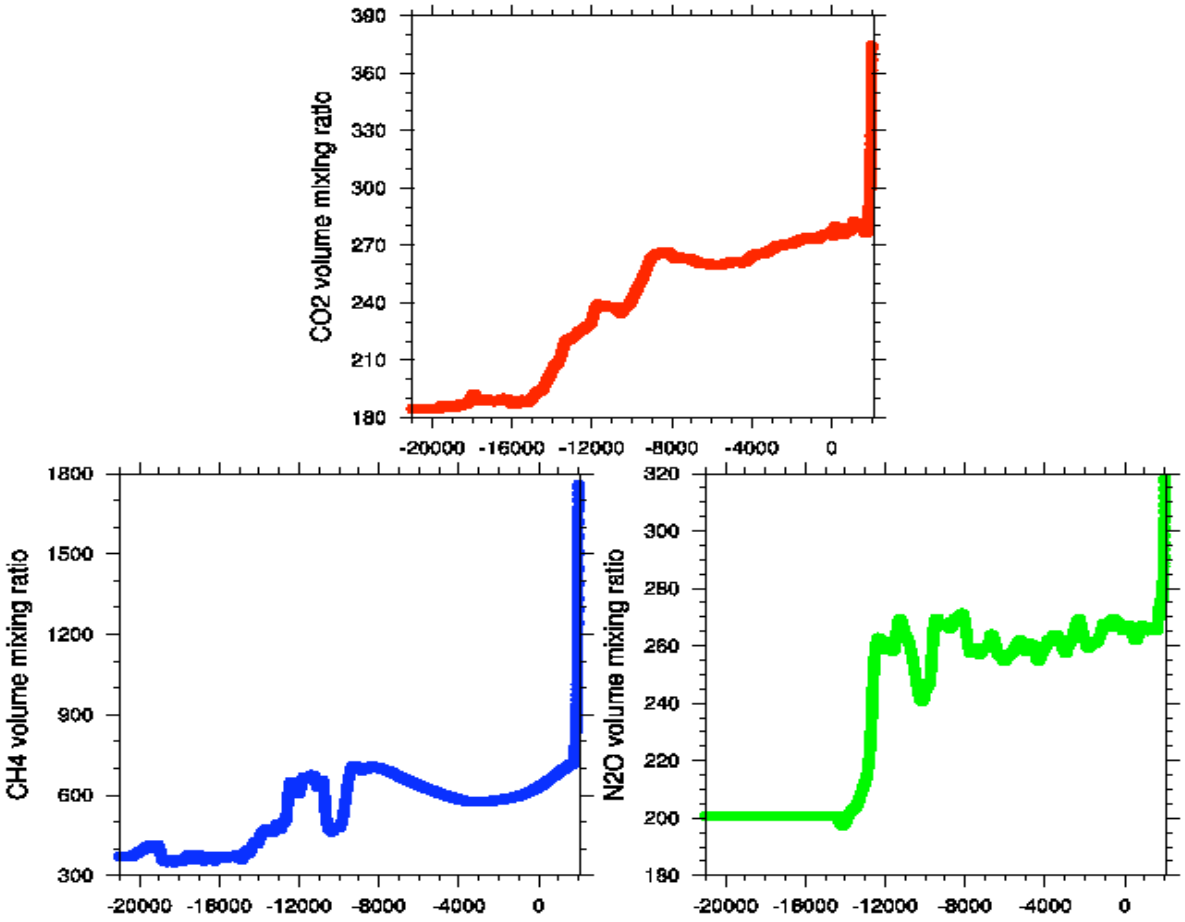
Model Configuration

- Configuration: Fully coupled CCSM3 (T31_gx3v5) + Dynamic Vegetation
- Machine: Phoenix (Cray X1E) at NCCS/ORNL
- Performance: 45 Model Year/Day with 20 minutes CAM timestep for better stability

Overall strategy I

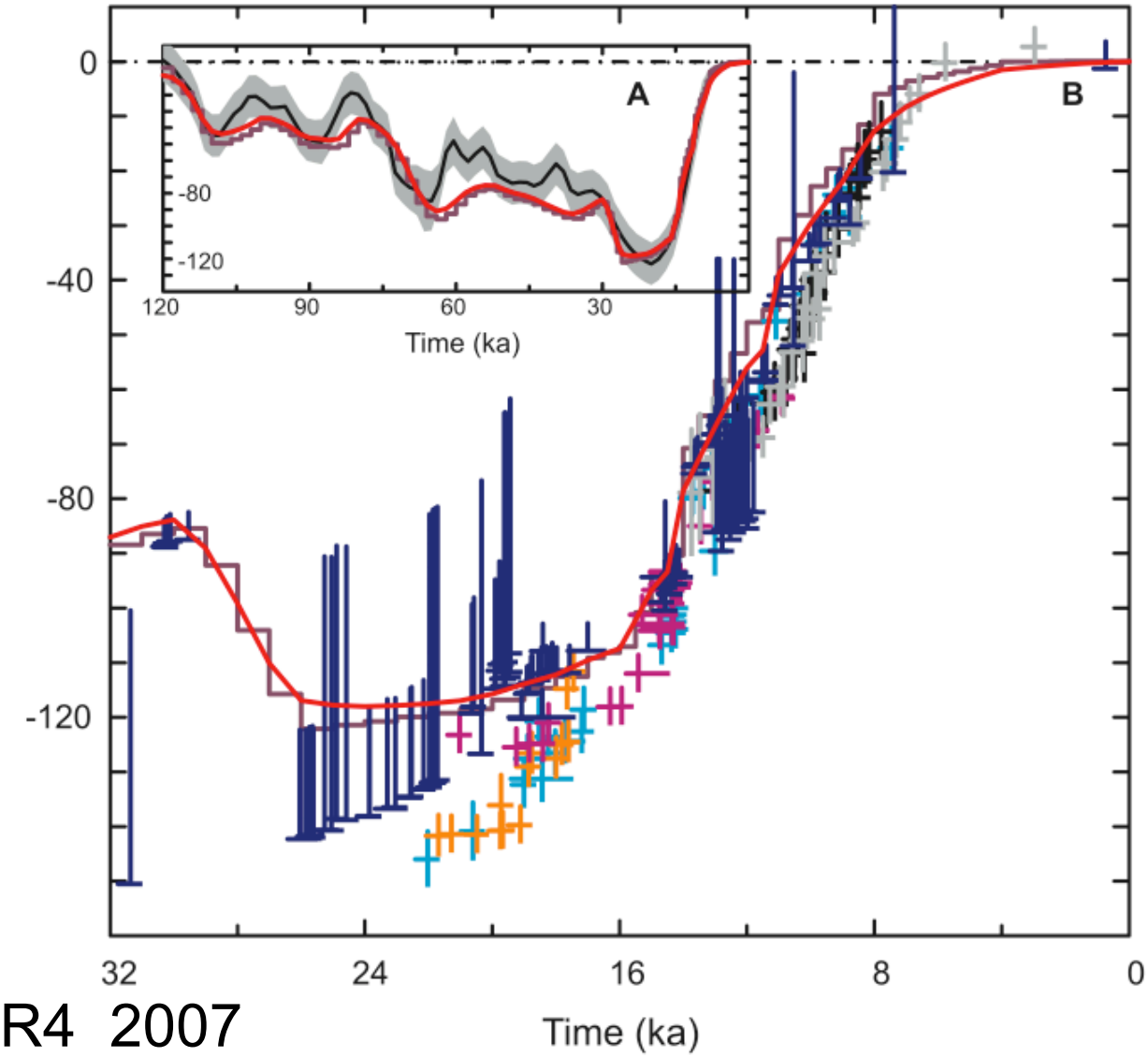
- Use SLR as the constraint to simulate AMOC
- Prescribe GHG (CO2, CH4, N2O), orbital forcing together with continental ice sheet (ICE5G)
- Performed 1,800 year equilibrium run with dynamic vegetation code before the 22 kyr transient simulation (branched off from equilibrium LGM run b30.106 / no dynamic vegetation code)

Green House Gas Forcing



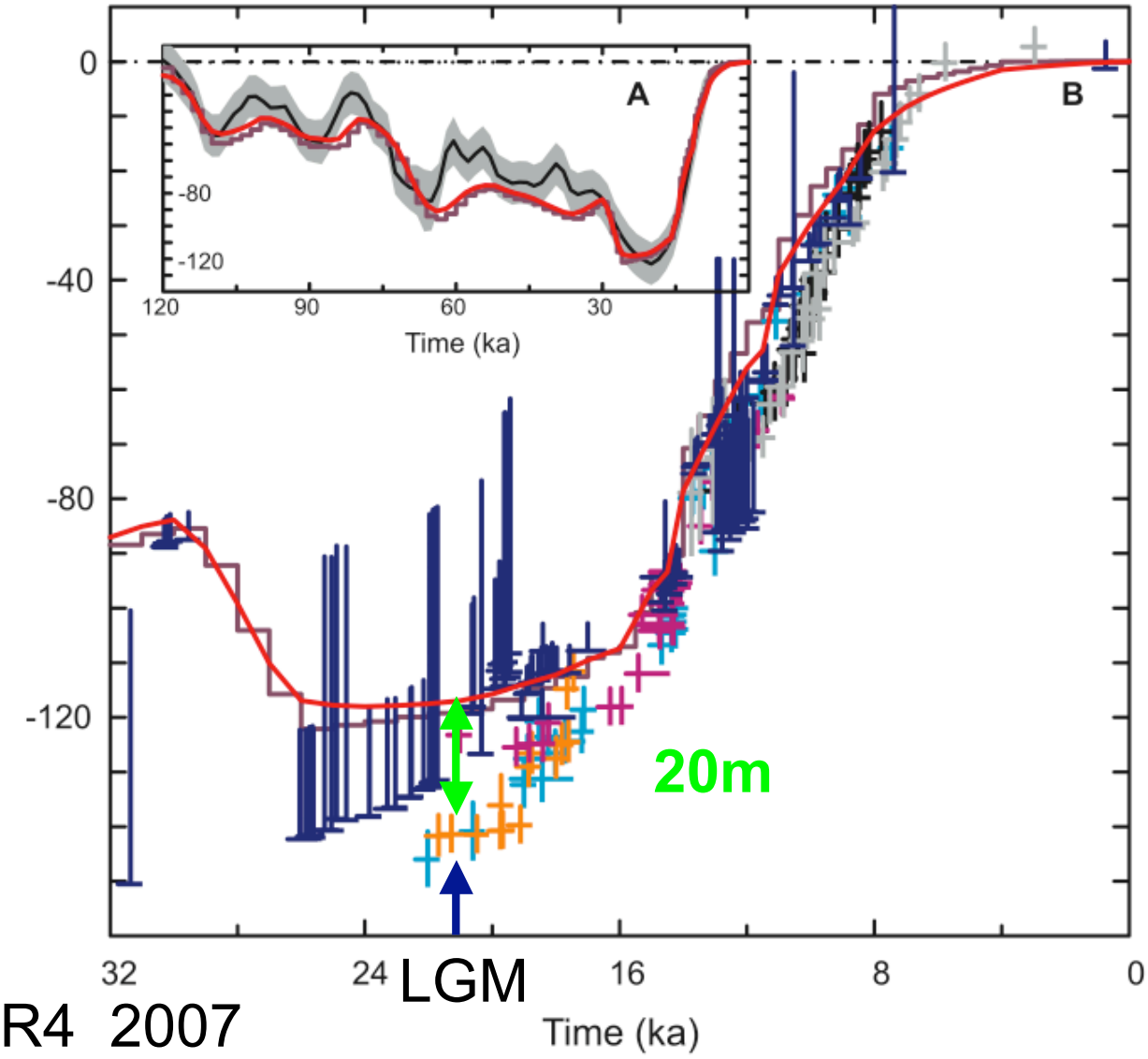
Courtesy of F. Joos

Sea Level Rise



IPCC/AR4 2007

Sea Level Rise



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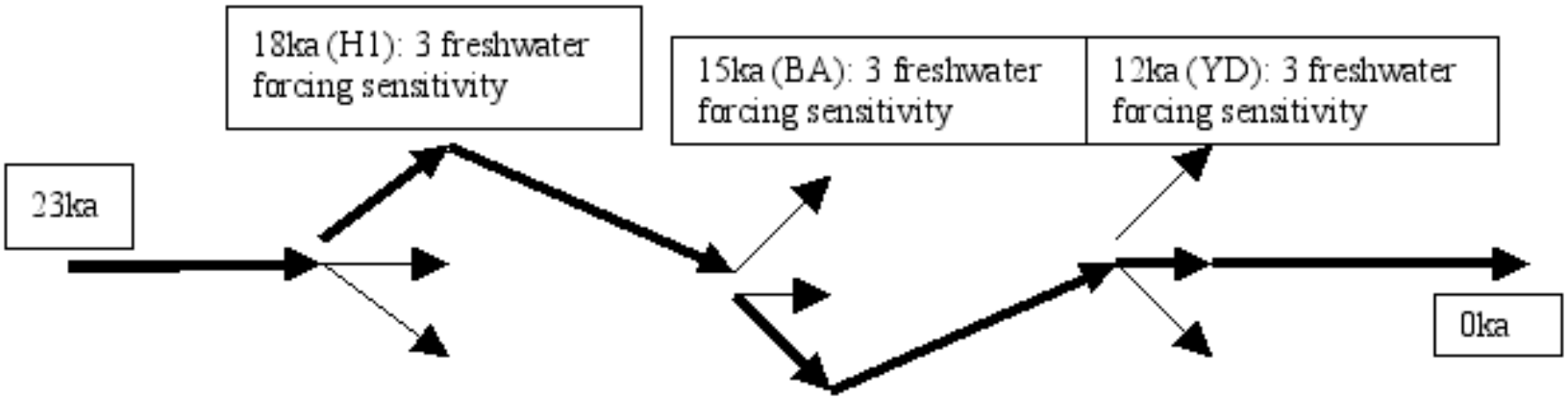
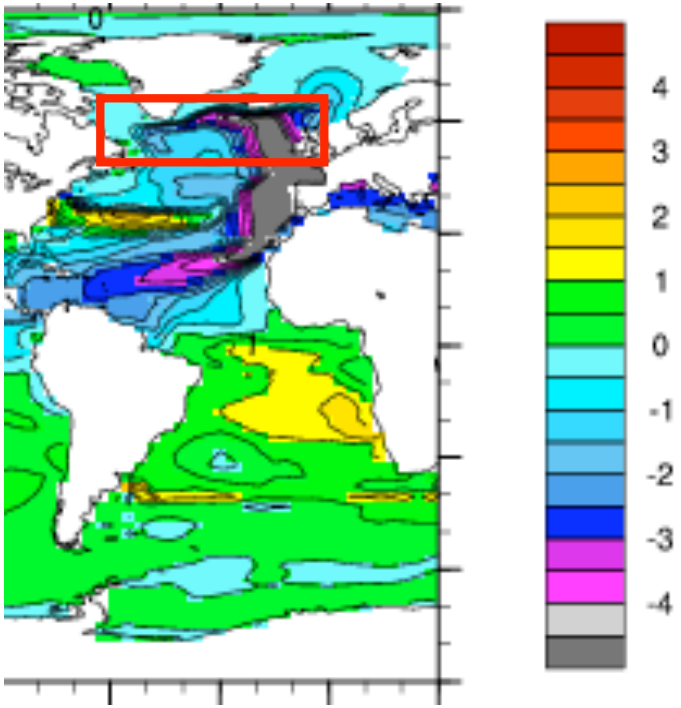
Overall strategy II

- Special considerations for 19ka, H1, BA, YD events
- Several sensitivity runs with same initial condition but different routing/rates of freshwater pulses
- Select the run that closely resembles AMOC to continue the transient experiment



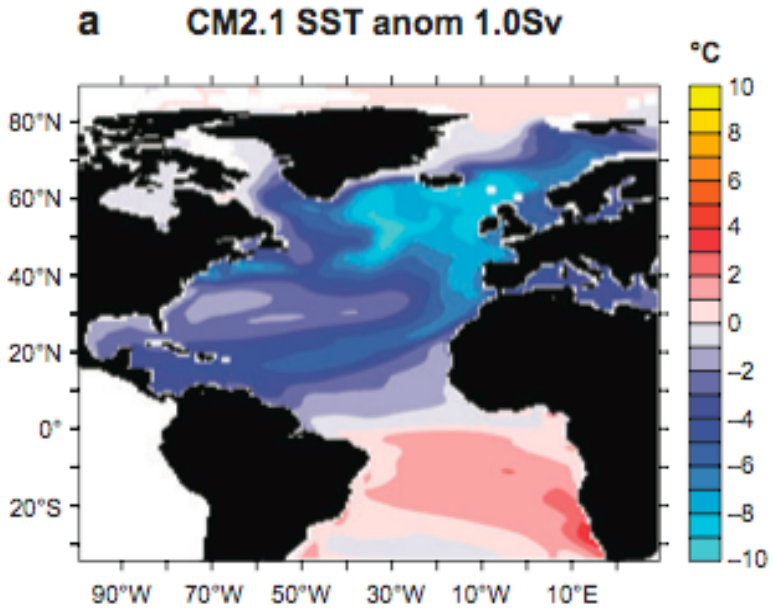
Introduction to the Hosing Experiment

CCSM3



SSTA

GFDL

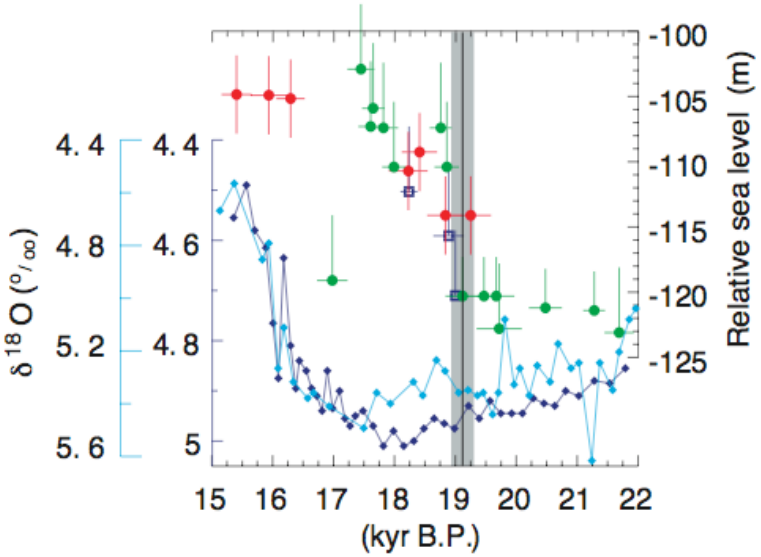


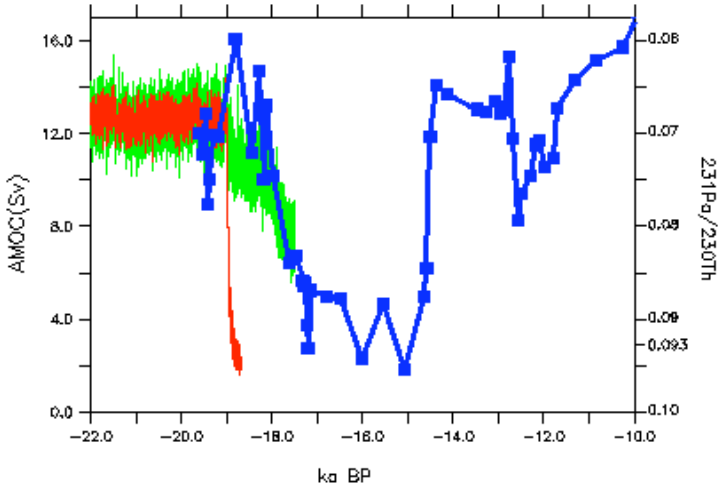
Barreiro et al.
Annu. Rev. Earth Planet. Sci.
2008

Sensitivity Exp I: 19ka Melting Water Event

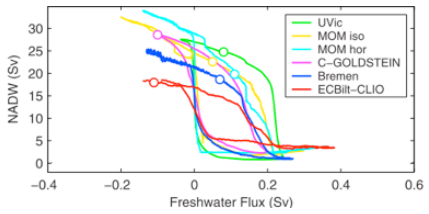
Sea Level Rise:
10~15m/100~500yr

Red: 10m/300yr
Green: 10m/1500yr



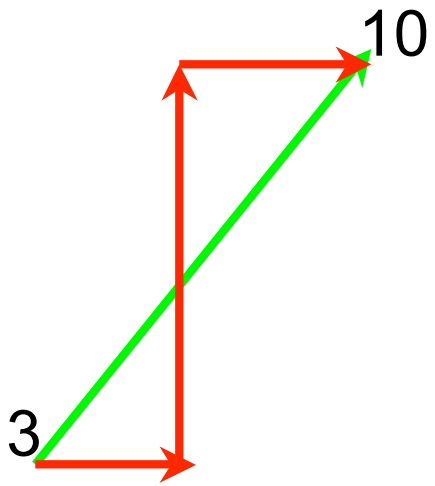


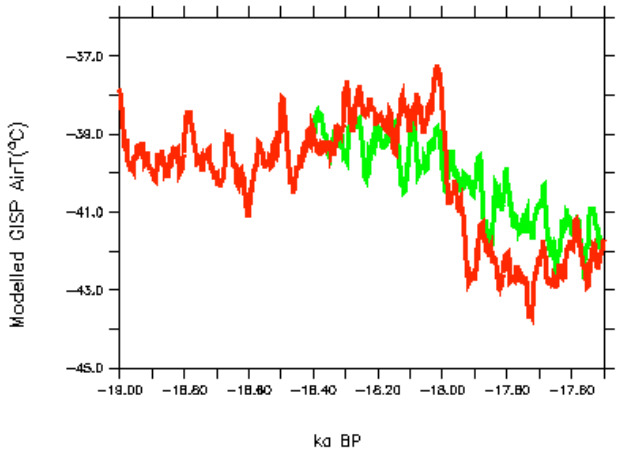
Clark et al., Science 2004



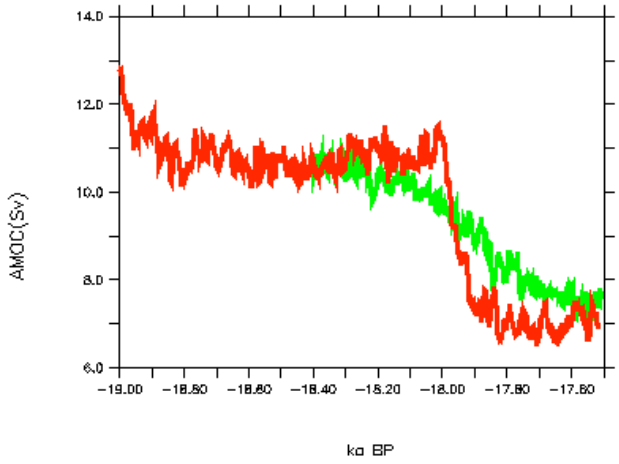
Ramped vs Constant Hosing

Hosing Rate (m/kyr)



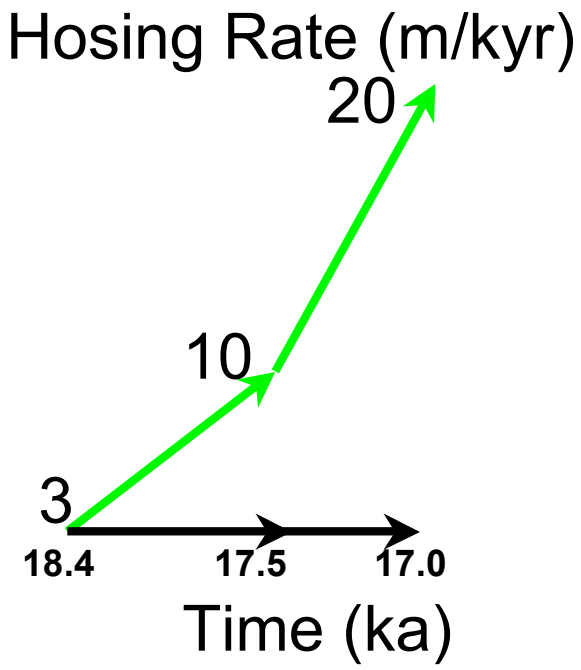


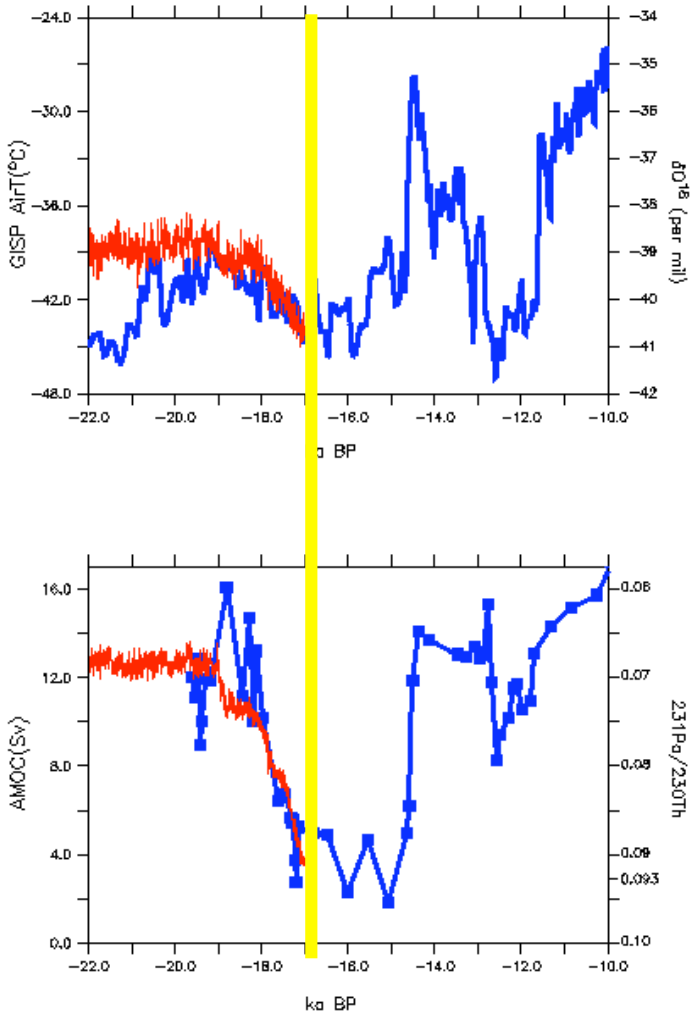
GISP AirT



AMOC

The Collapse of AMOC during H1

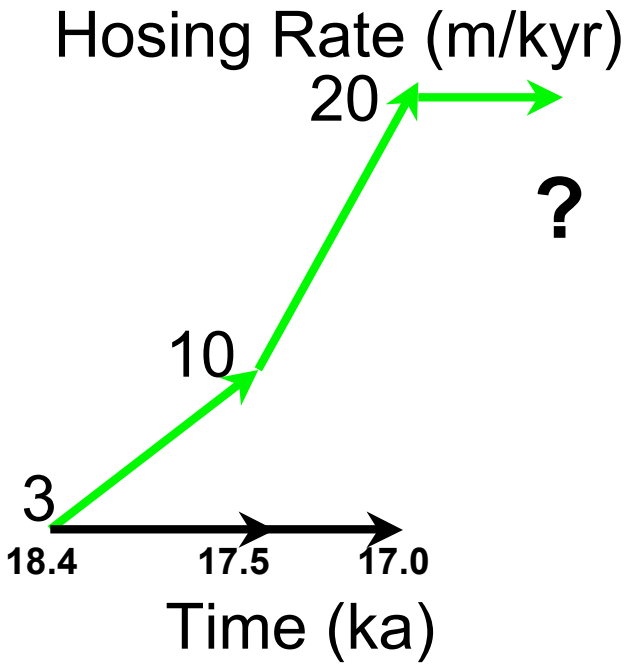


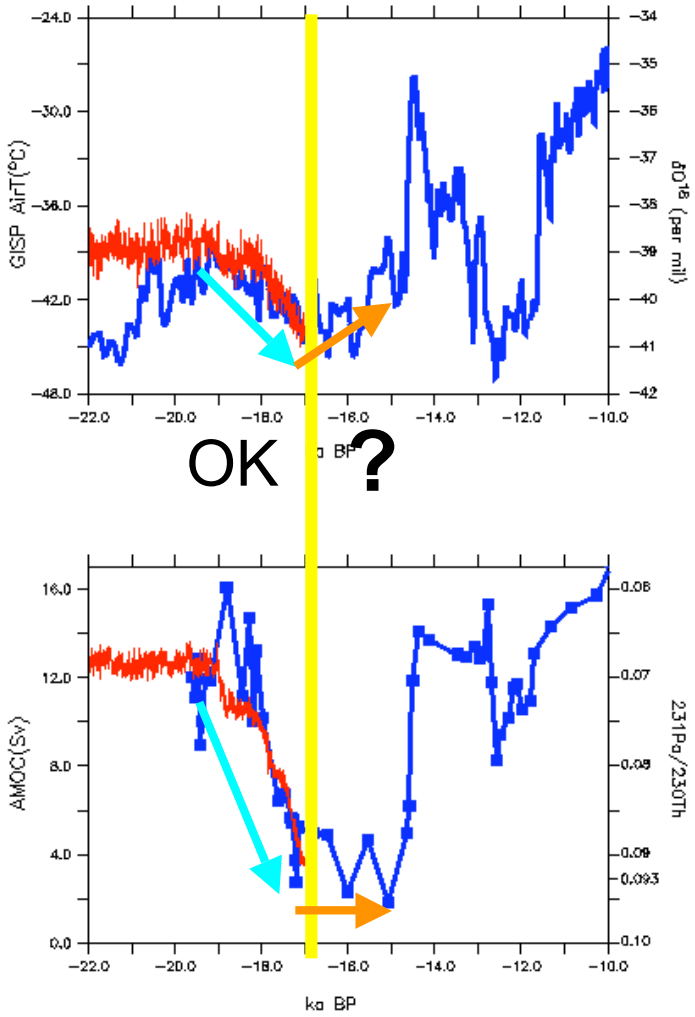


GISP AirT

AMOC

How to keep AMOC “off” before BA for 3000 yrs?

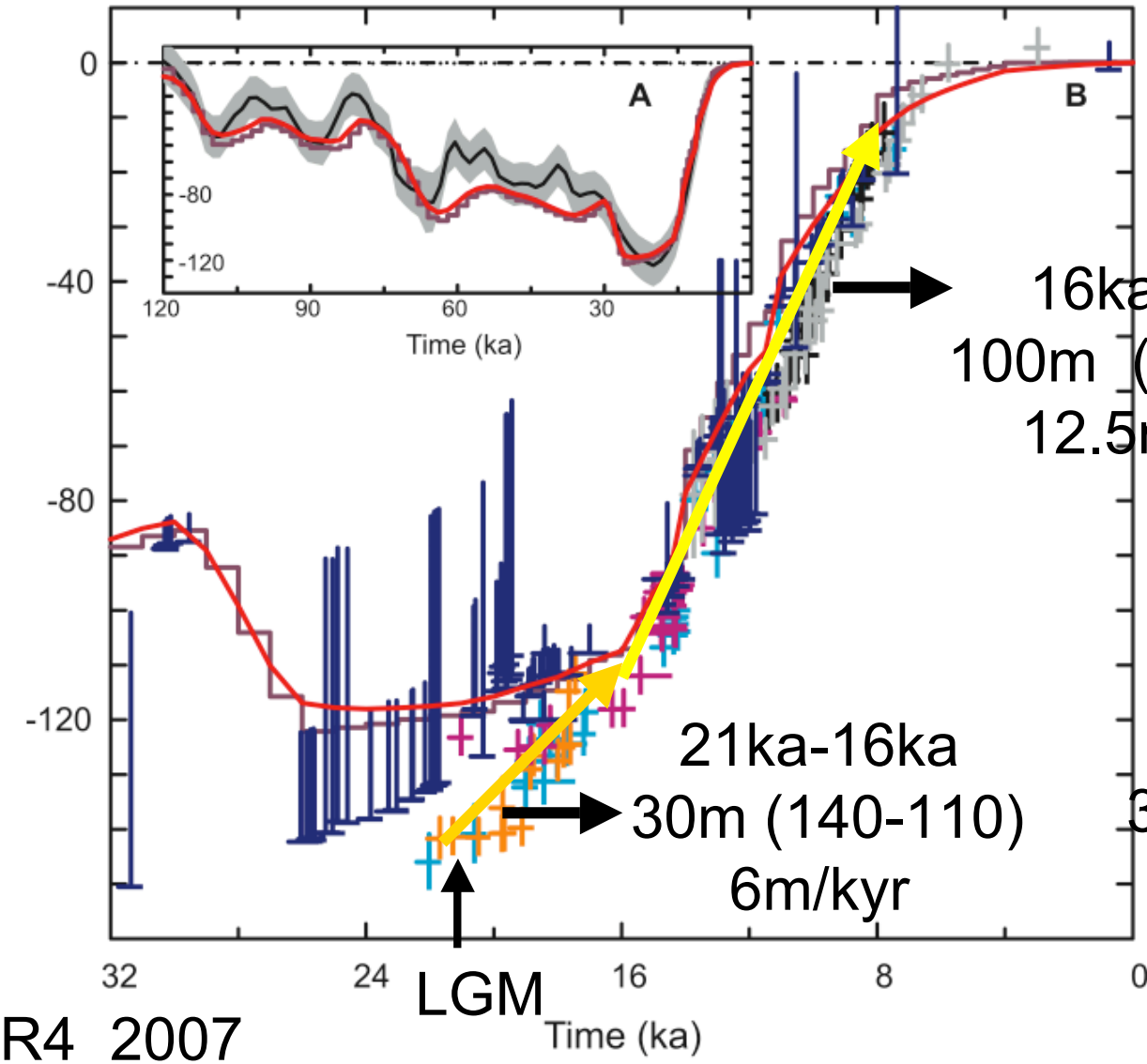




GISP AirT

AMOC

Early Less Sea Level Rise vs Collapsed AMOC



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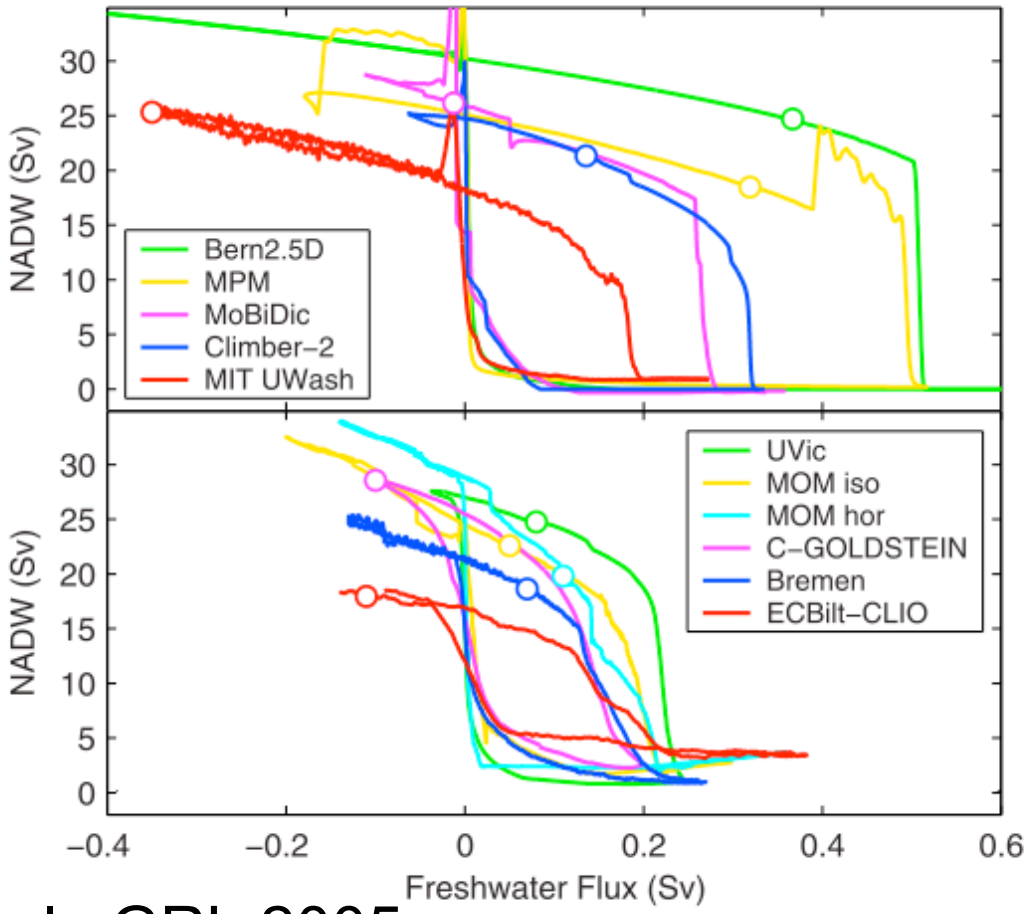
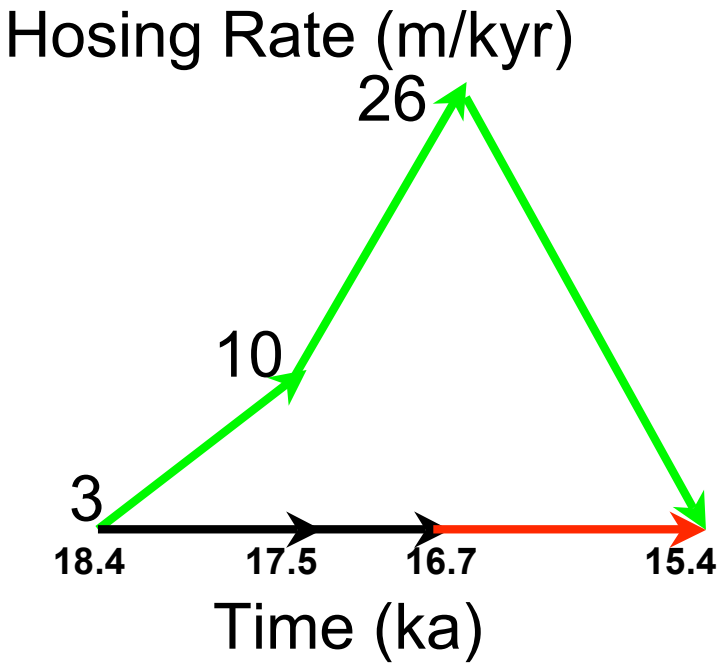
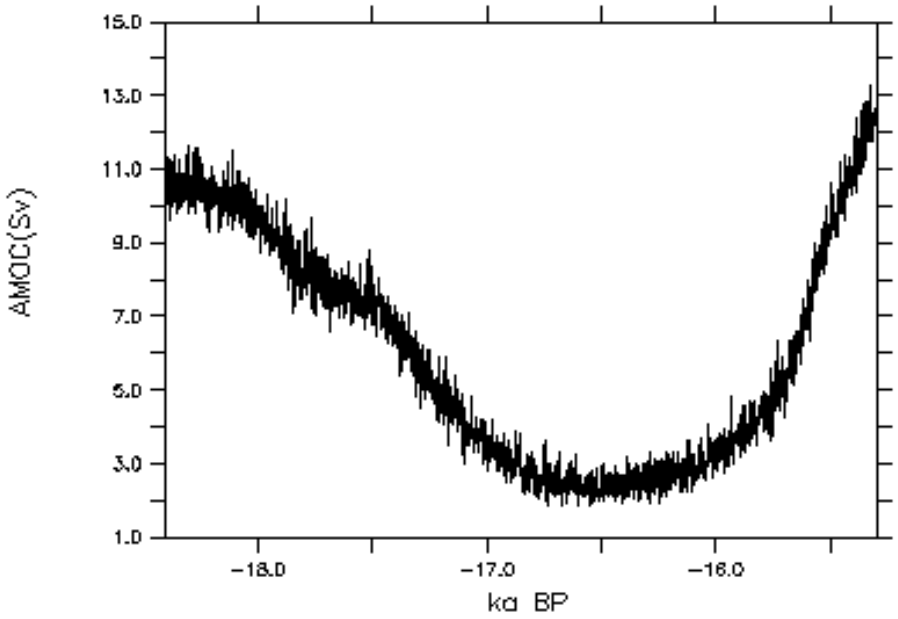
The Hysteresis of AMOC

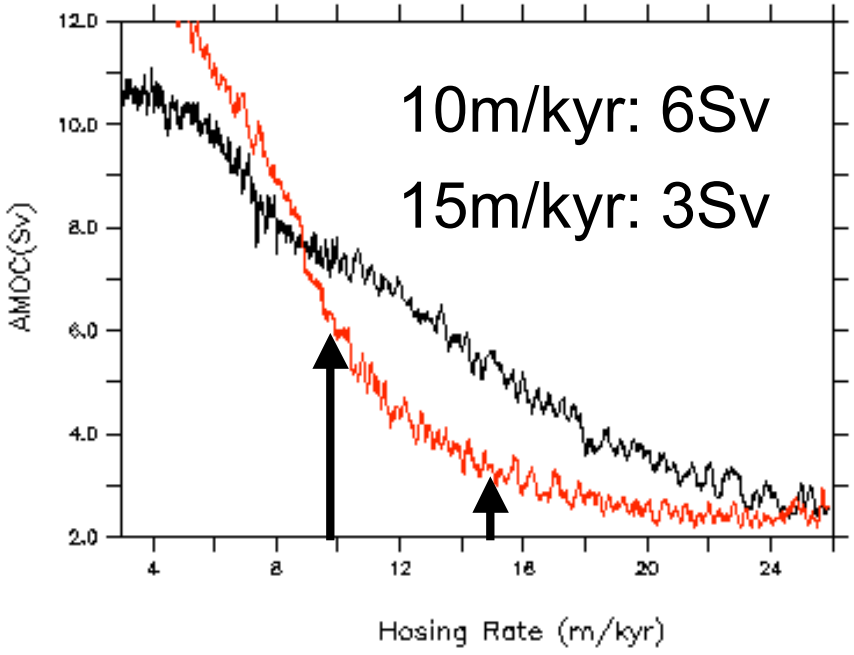


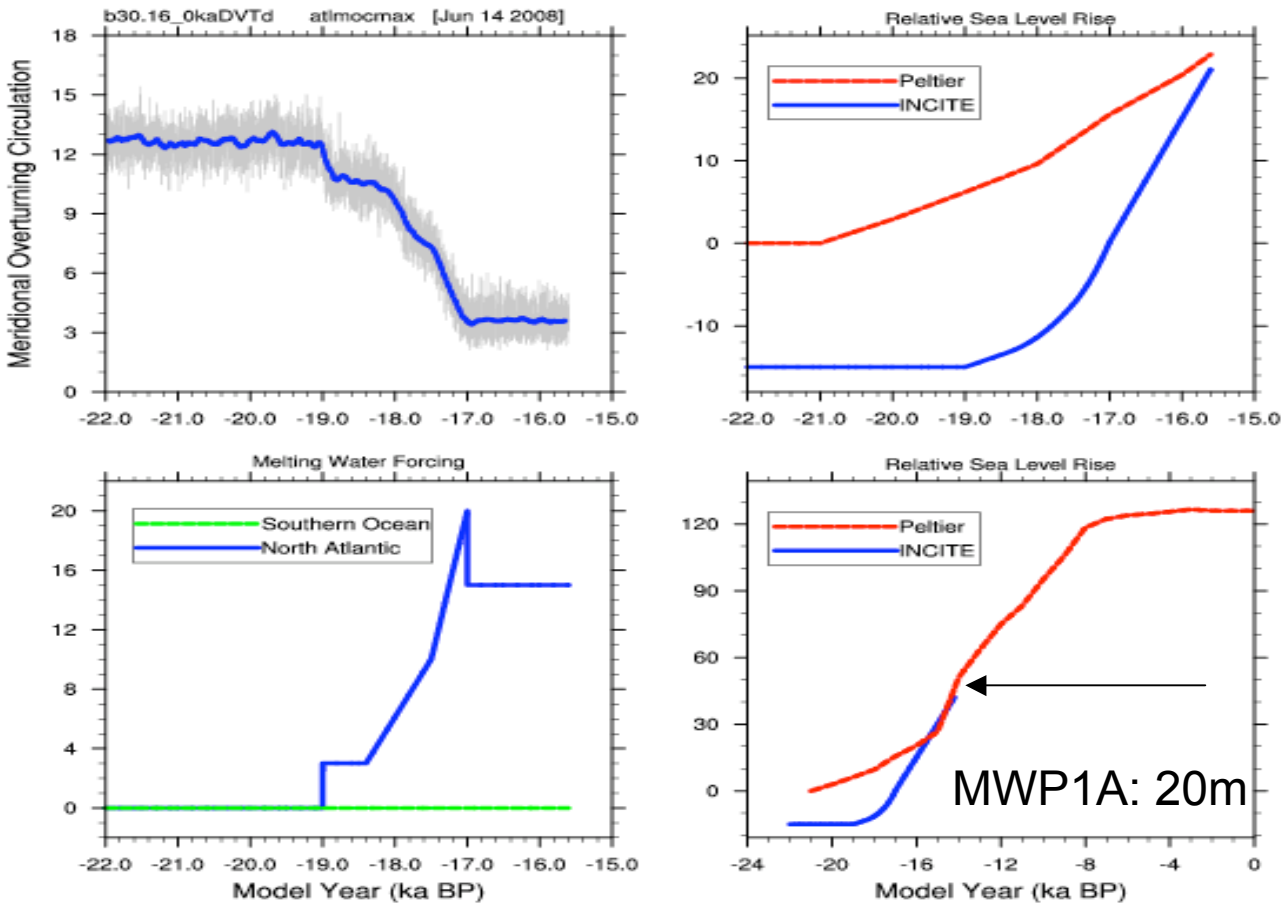
Rahmstorf et al., GRL 2005

AMOC Hysteresis in CCSM3 (After H1)





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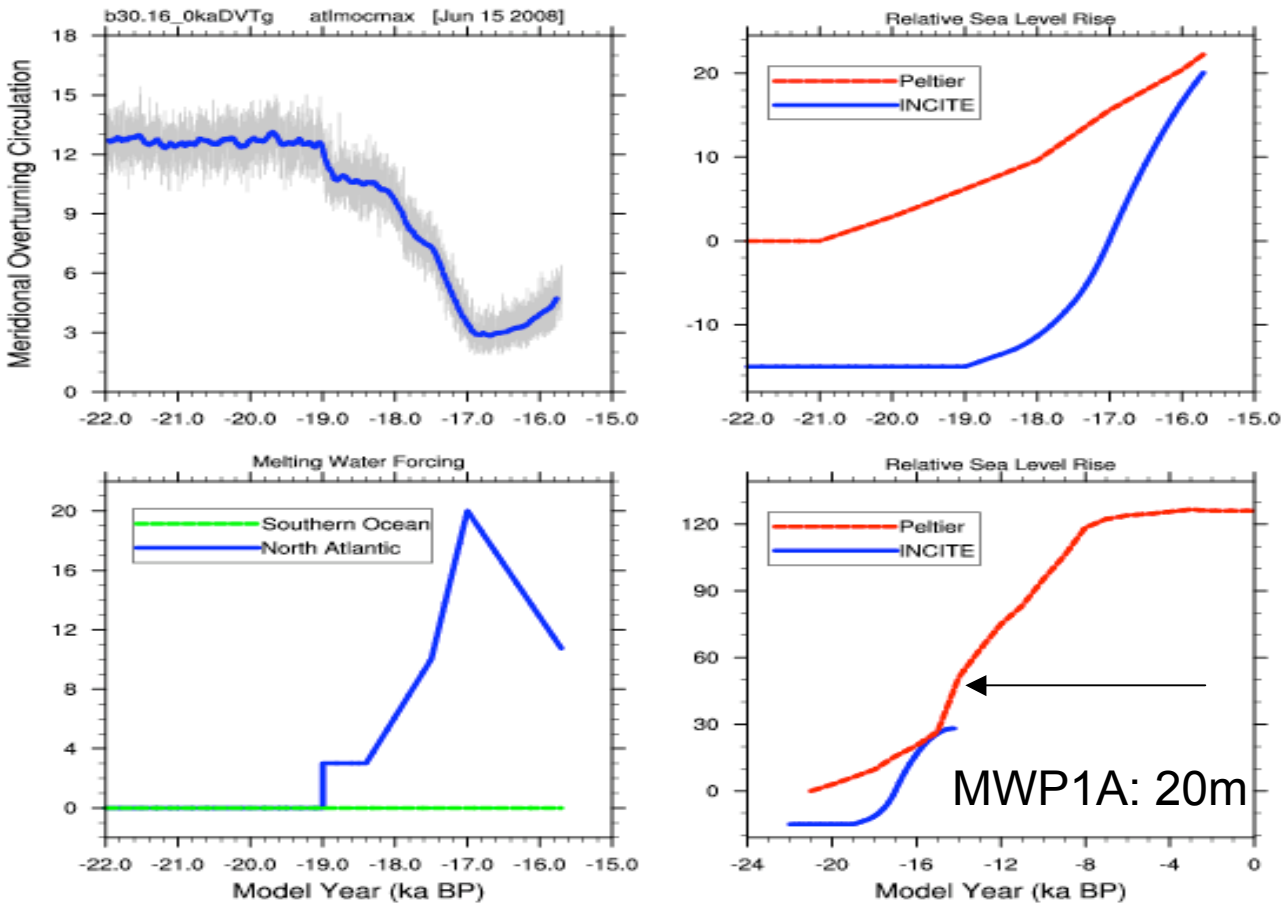
Meridional Overturning Circulation
18
15
12
9
6
3
0
-22.0 -21.0 -20.0 -19.0 -18.0 -17.0 -16.0 -15.0
Relative Sea Level Rise
Peltier
INCITE
20
10
0
-10
-22.0 -21.0 -20.0 -19.0 -18.0 -17.0 -16.0 -15.0
Melting Water Forcing
Southern Ocean
North Atlantic
20
16
12
8
4
0
-22.0 -21.0 -20.0 -19.0 -18.0 -17.0 -16.0 -15.0
Model Year (ka BP)
Relative Sea Level Rise
Peltier
INCITE
120
90
60
30
0
-24 -20 -16 -12 -8 -4 0
Model Year (ka BP)
MWP1A: 20m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Meridional Overturning Circulation
18
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-22.0 -21.0 -20.0 -19.0 -18.0 -17.0 -16.0 -15.0
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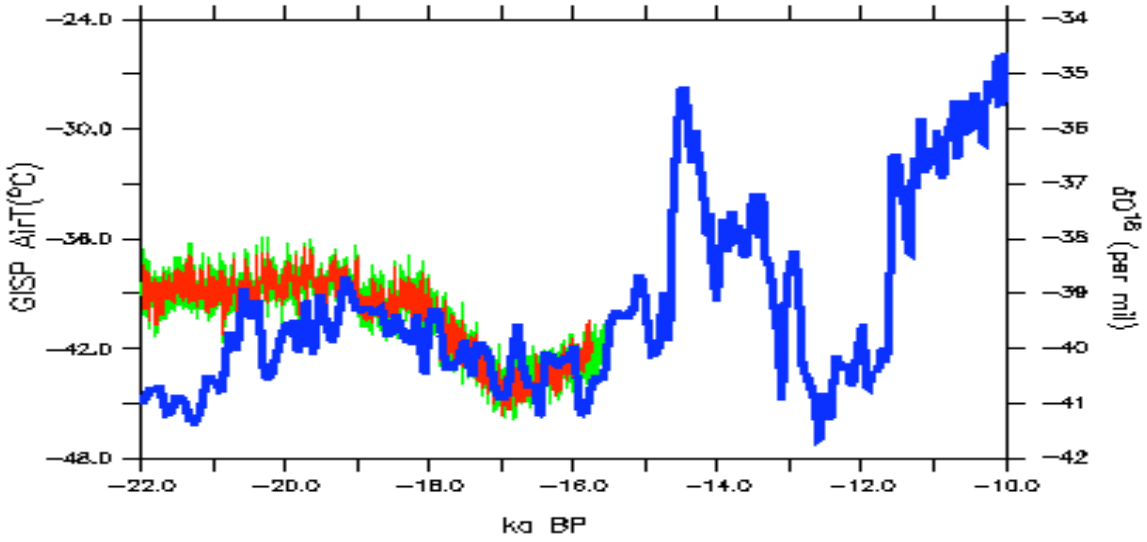
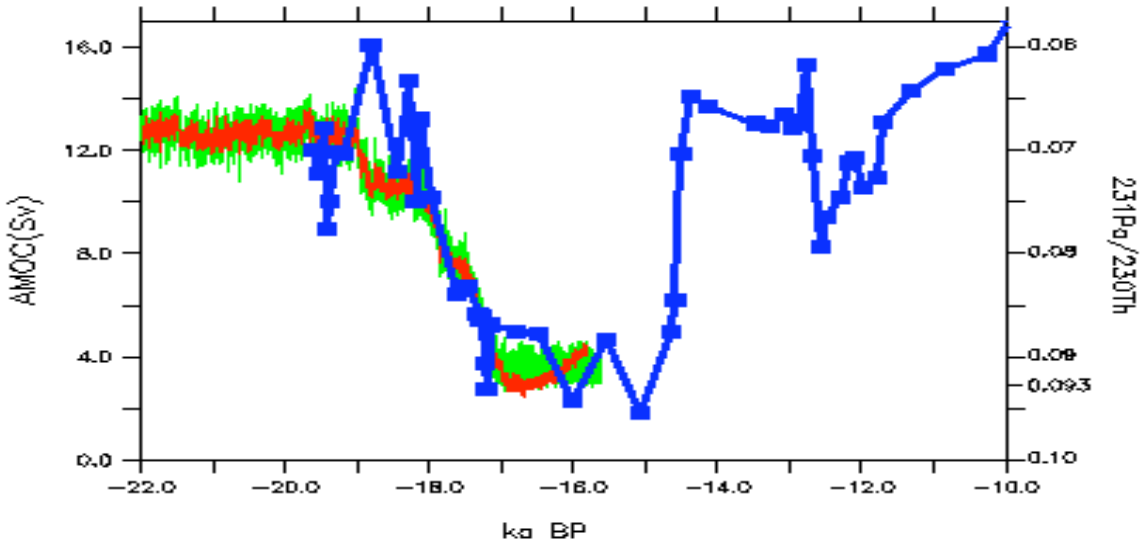
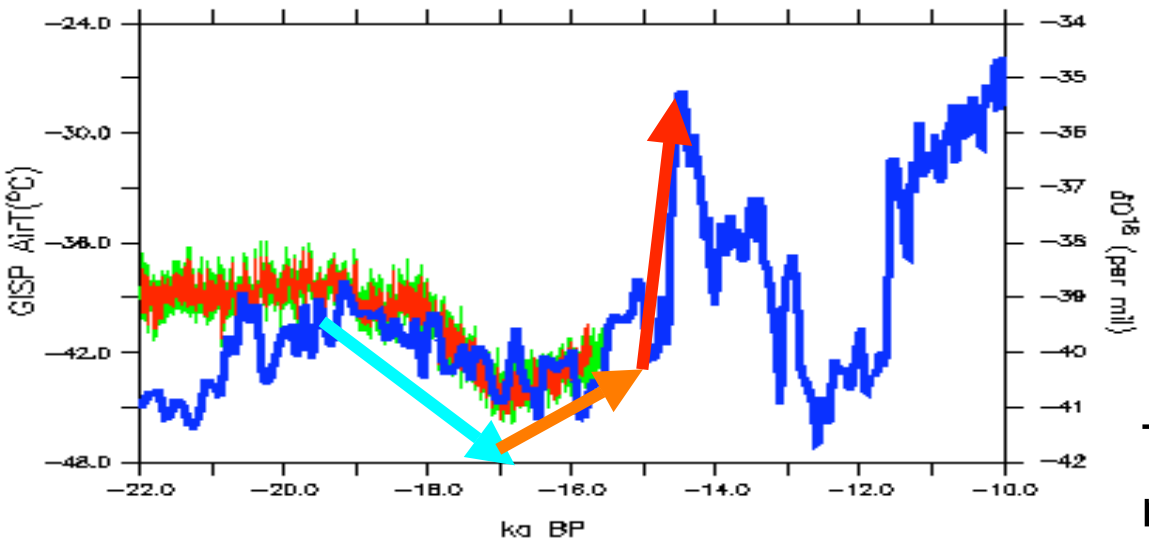
MWP1A: 20m



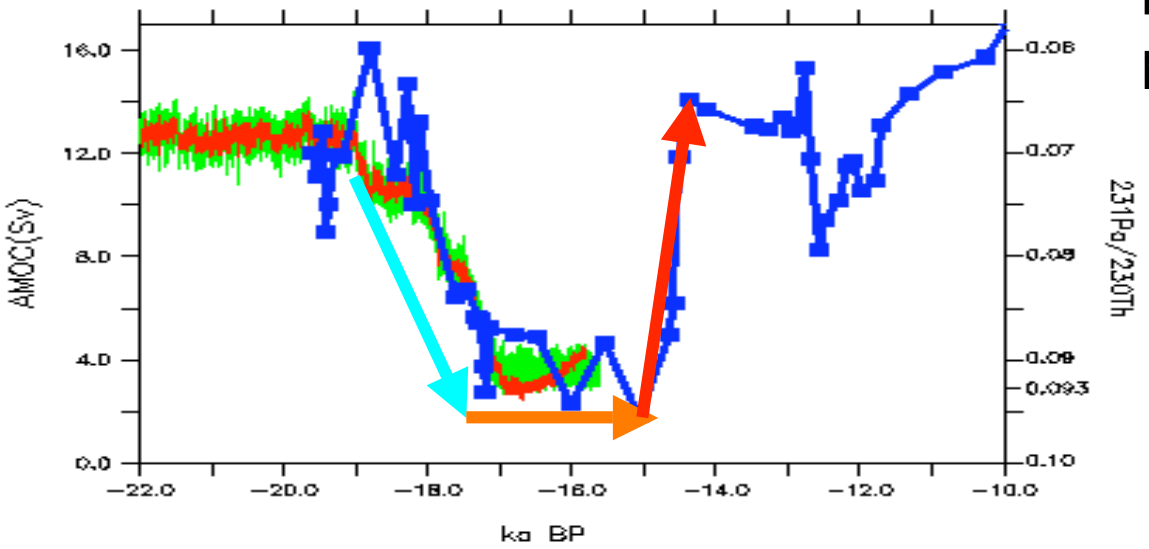


Progress Report

(22ka-15.5ka)



OK OK ?



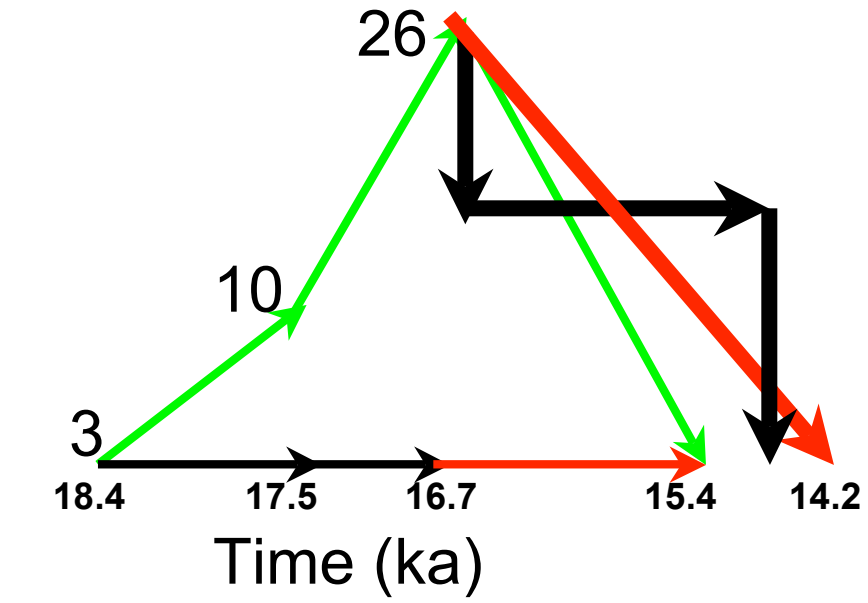
Progress Report

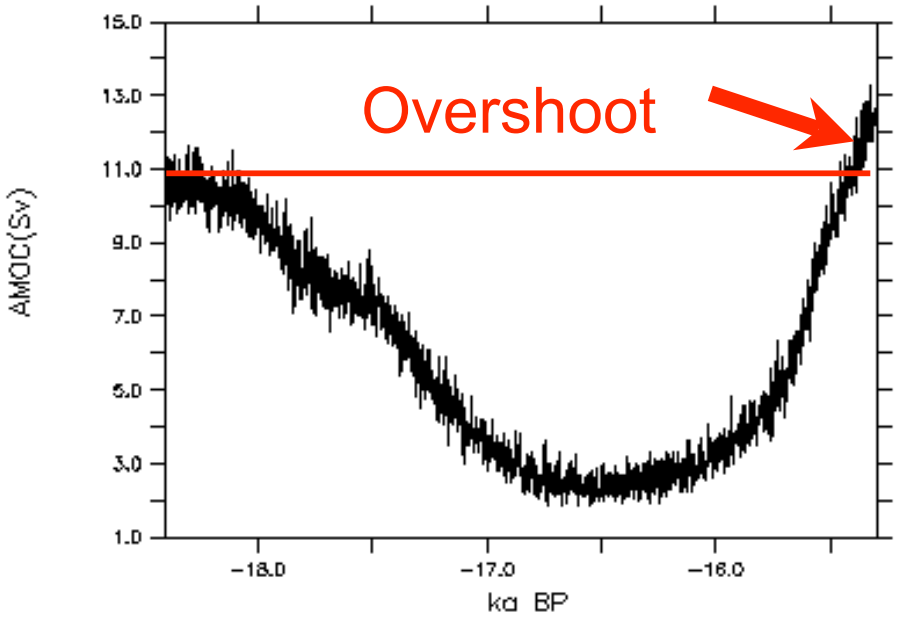
(22ka-15.5ka)

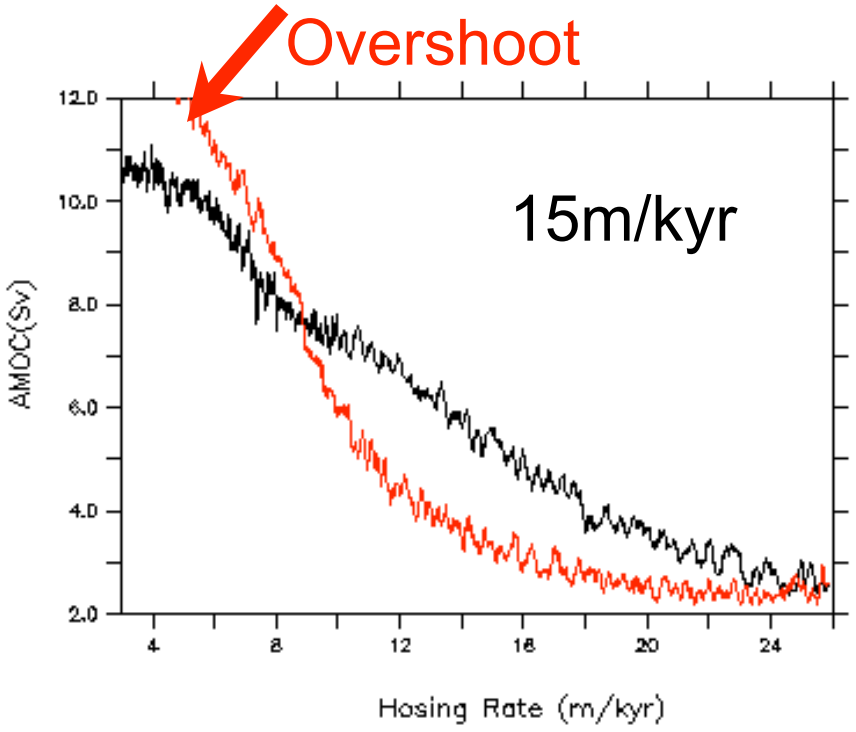
The increase of SAT might be due to either CO2 increase or rebounding after it was pushed down during H1

AMOC Overshoot in CCSM3

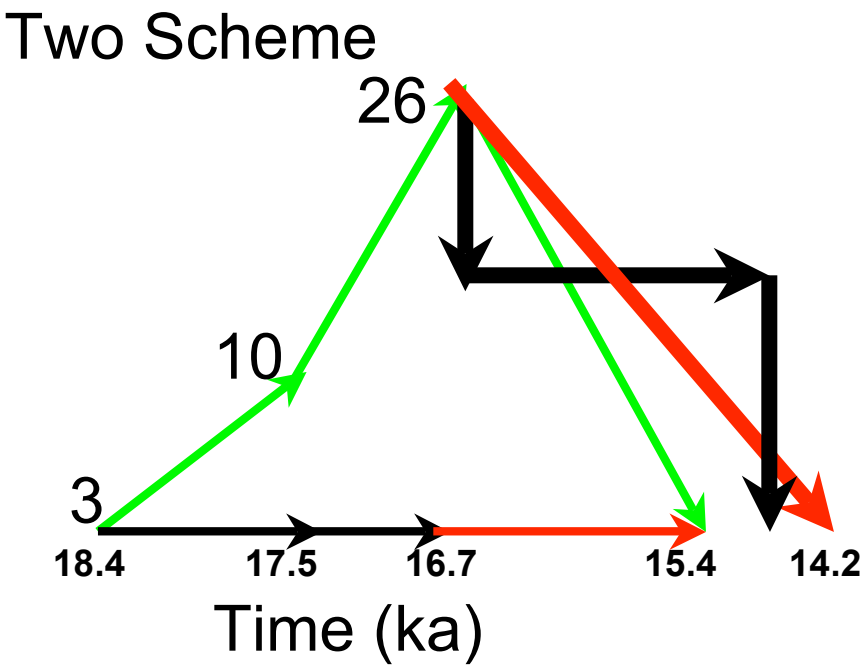
Two Schemes

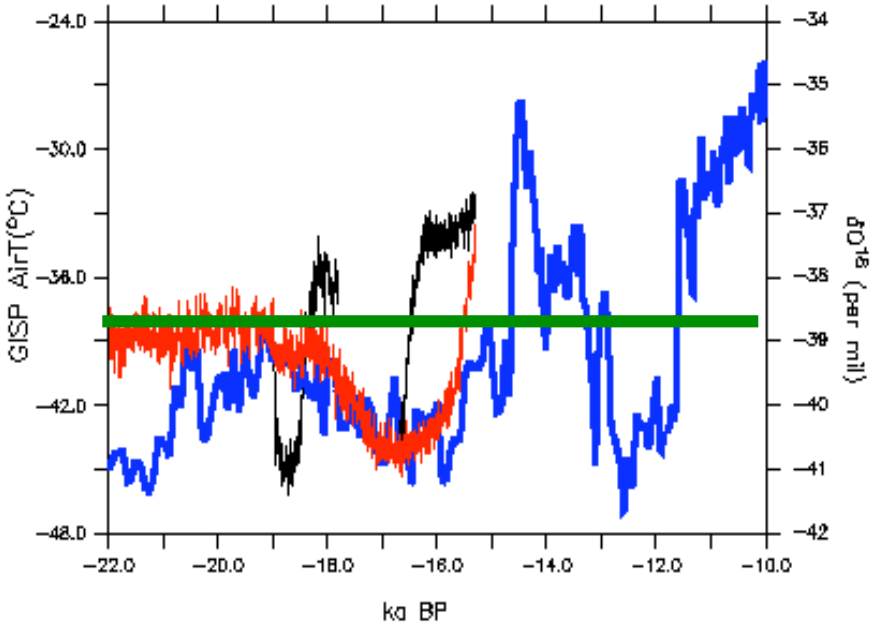


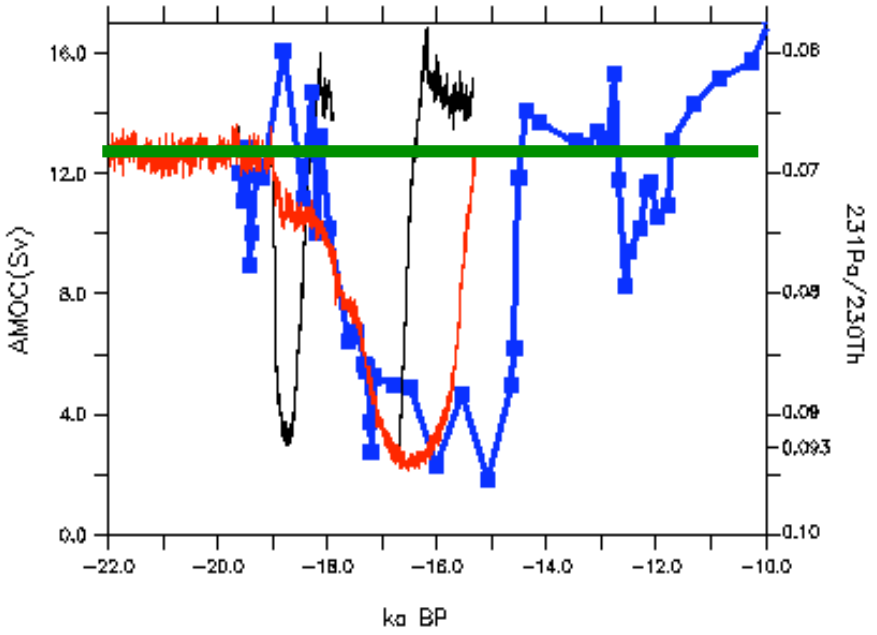




AMOC/SAT$_{GISP}$ Overshoot







PROXY

AMOC

North

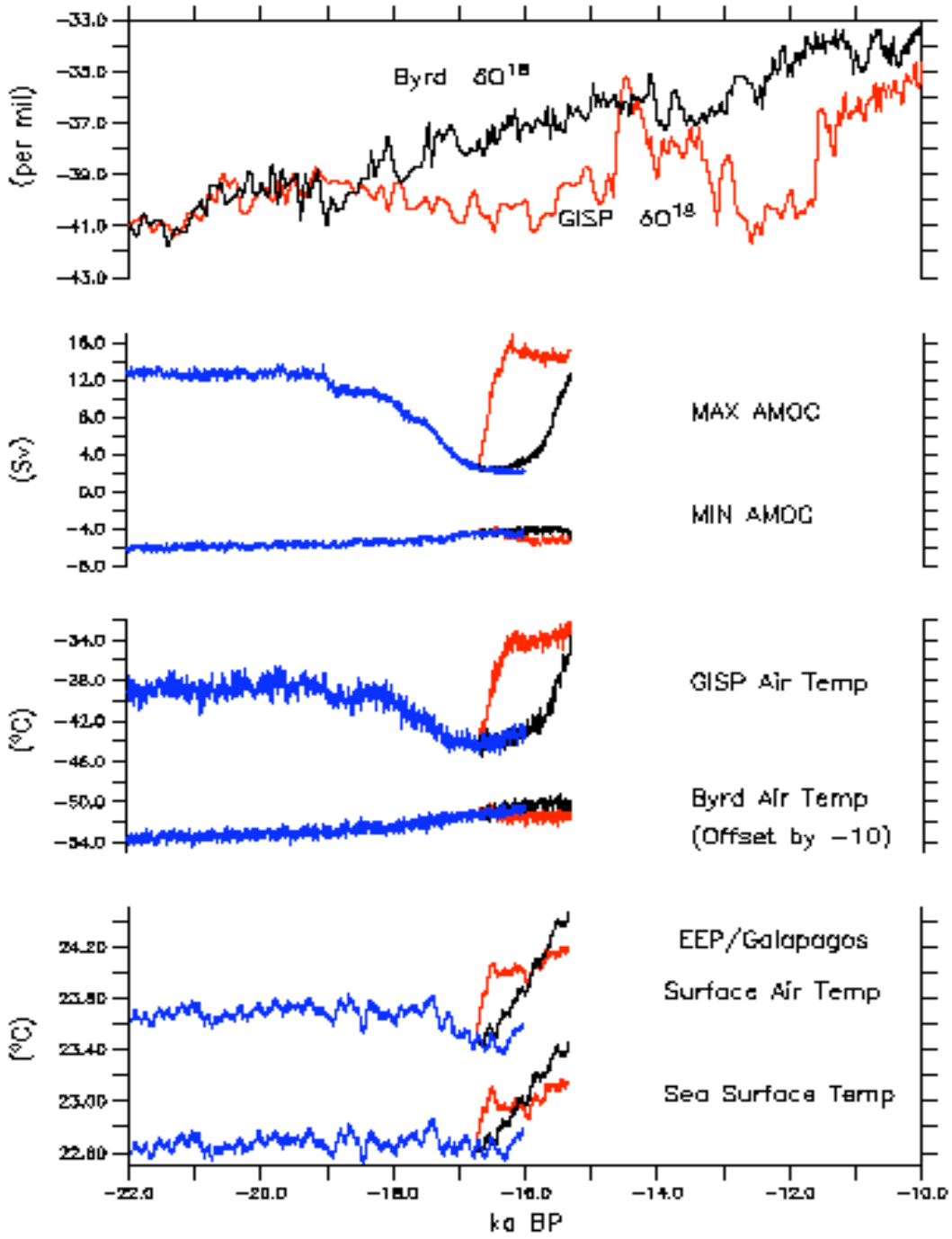
South

SAT

North

South

SST Equator



North

vs

South

Conclusion

- Low resolution CCSM3 could exhibit abrupt changes on decadal-centennial time scales under water hosing scenarios.

- The time scales of the abrupt changes of AMOC (H1, BA) during the last deglaciation could be correctly simulated using certain water hosing scheme.

- The variability of AMOC could produce the signature of the oldest dryers and BA warming in GISP2 ice core record.