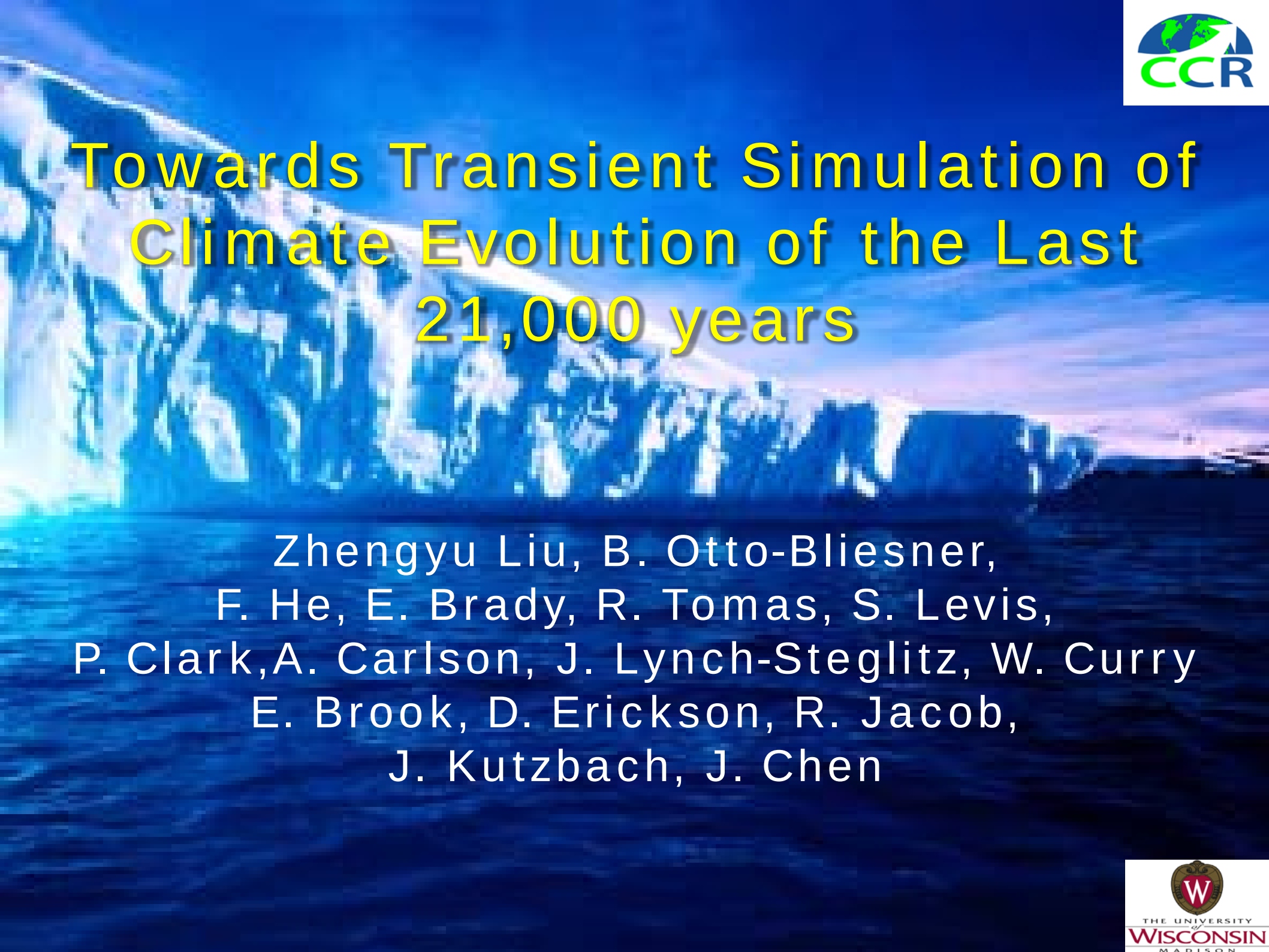


Towards Transient Simulation of Climate Evolution of the Last 21,000 years

Zhengyu Liu, B. Otto-Bliesner,
F. He, E. Brady, R. Tomas, S. Levis,
P. Clark,A. Carlson, J. Lynch-Steglitz, W. Curry
E. Brook, D. Erickson, R. Jacob,
J. Kutzbach, J. Chen

Transient Climate Evolution of Last 21,000 Yrs

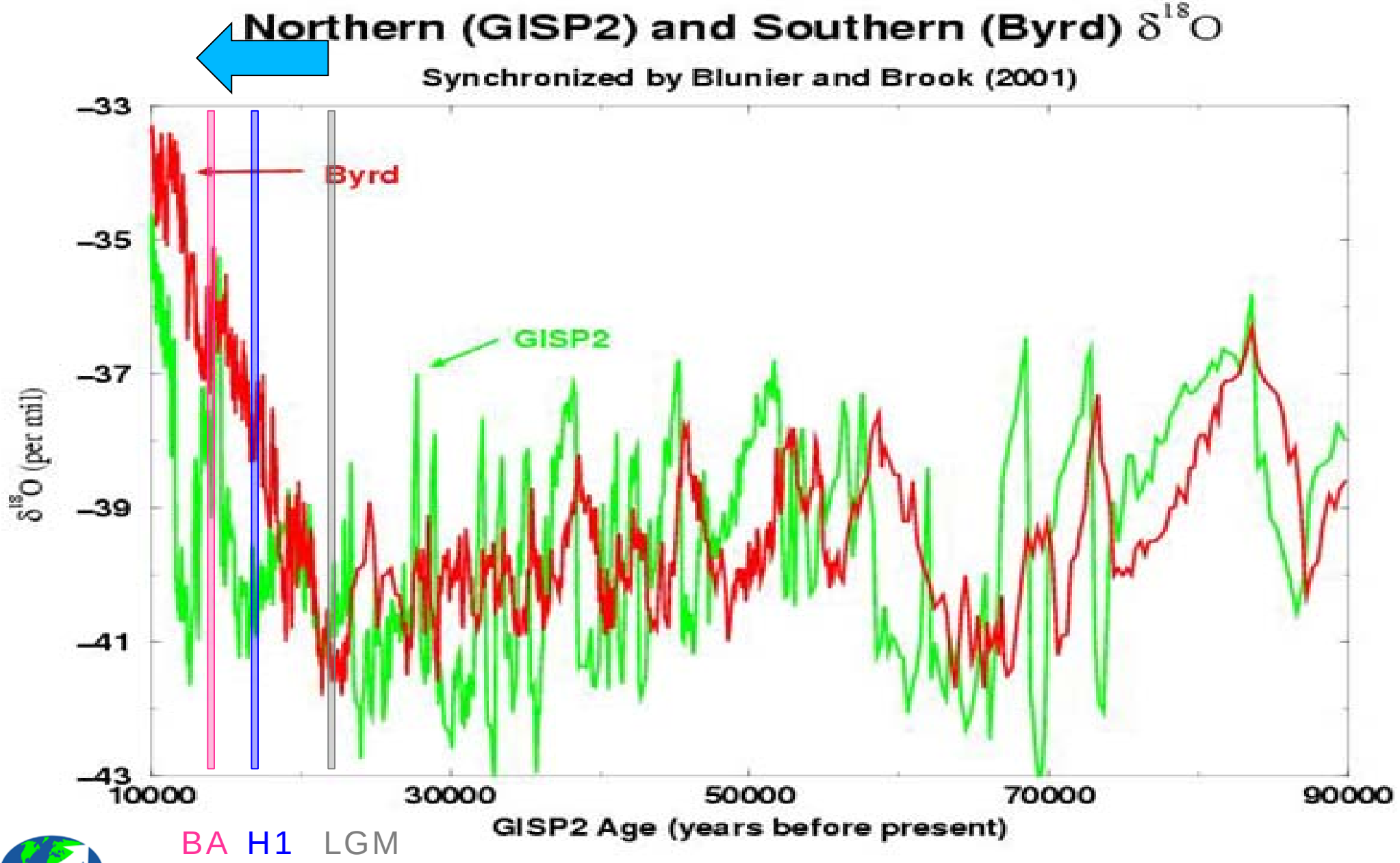
TRACE-21,000

Z. Liu (UW-Madison), B. Otto-Bliesner (NCAR)

Objective

- Validating climate models on large climate changes
- Understand abrupt climate changes
- Model/data comparison on time series

Challenges


Northern (GISP2) and Southern (Byrd) δ18O
Synchronized by Blunier and Brook (2001)
Byrd
GISP2
δ18O (per mil)
−33
−35
−37
−39
−41
−43
10000
30000
50000
70000
90000
GISP2 Age (years before present)
BA
H1
LGM

Model Setup

CCSM3 (T31_gx3v5) + Dyn Veg

- Atmosphere (CAMT31): ~ 3.75º (long) x 3.75º (lat) x 26 level
- Ocean (POP+Sea Ice): 100 (long) x 116 (lat) x 25 level
- Land (CLM+LPJ):
- Forcing: Realistic Orbital, GHGs, Continental Ice Sheet

Meltwater ???

Model/Data

Insolation
CO2

Sea Level

Meltwater Flux

AMOC

Greenland

Antarctic

N. Atl. SST

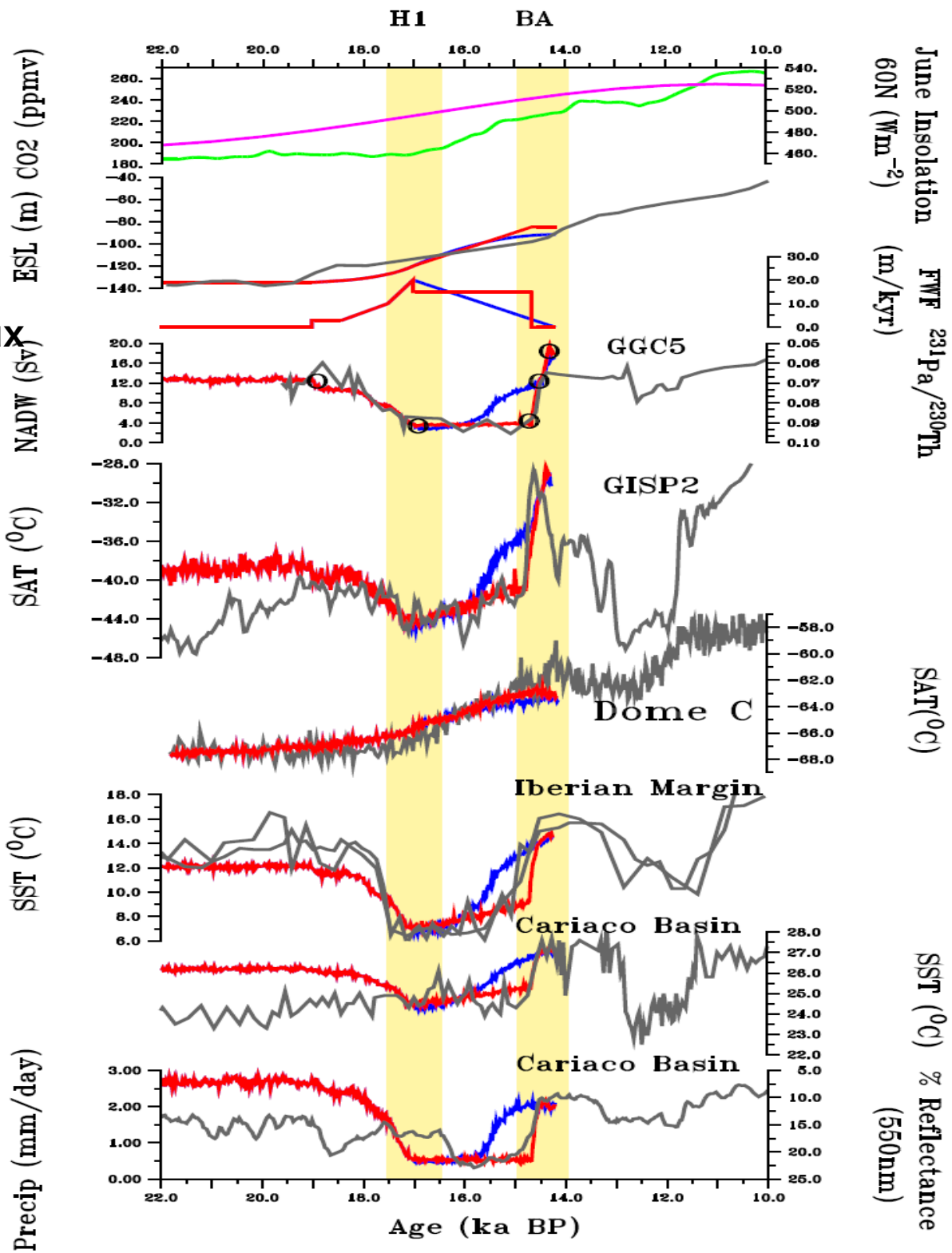
T. Atl. SST

T. Atl. Prep

------- Exp 1

------- Exp 2

------- Data

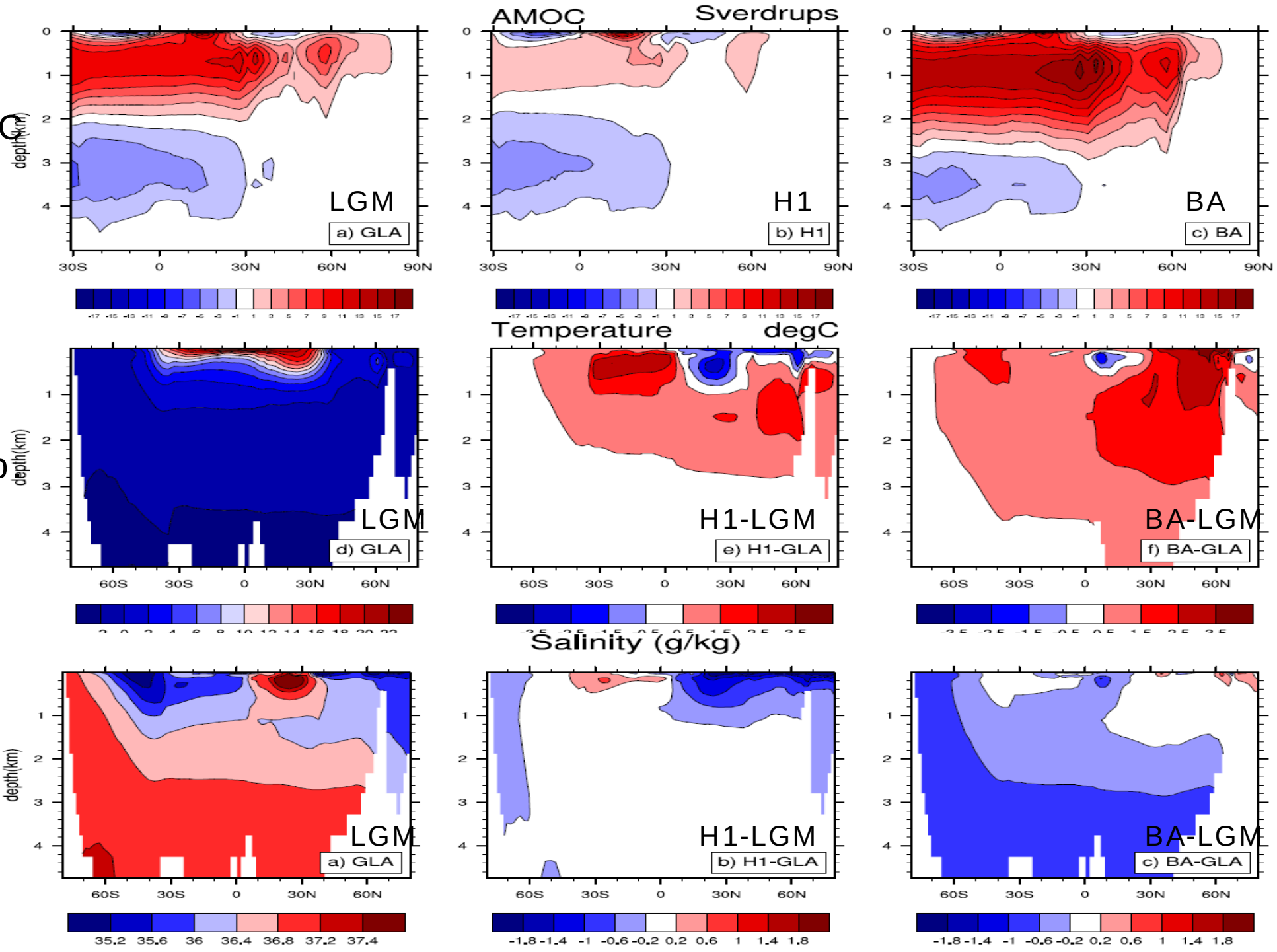


Liu et al., 2009, Science, in press

AMOC

Temp

Sal.



Proxy (Clark et al., 2002)

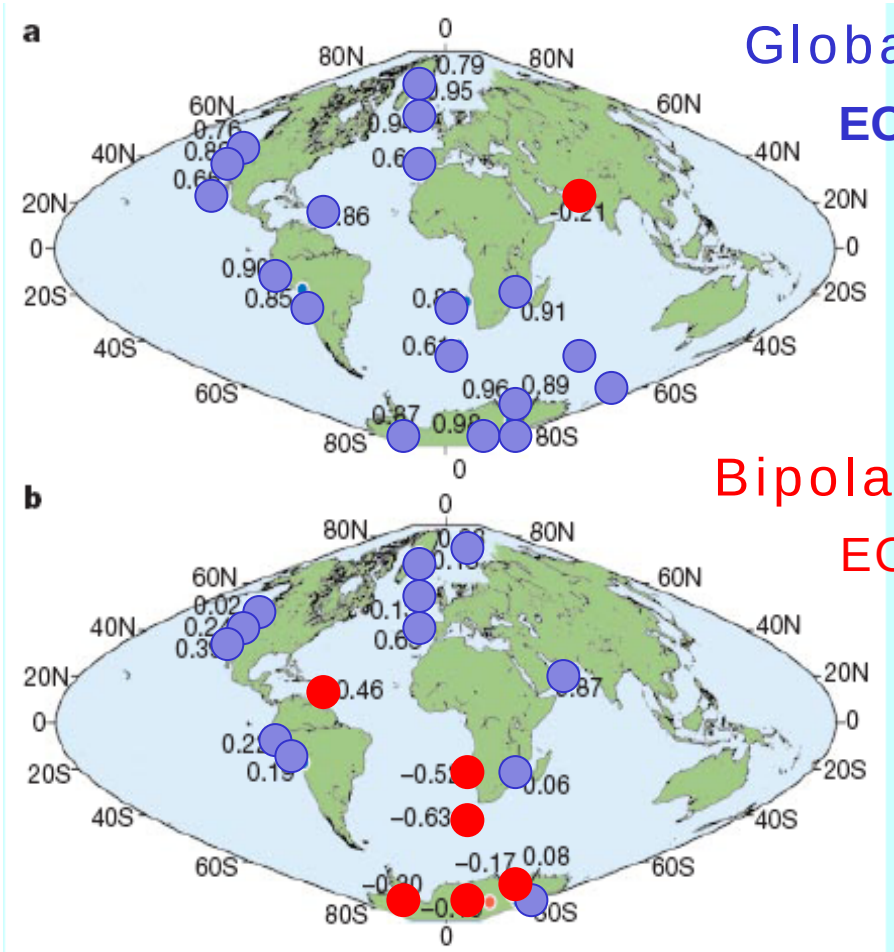
Model

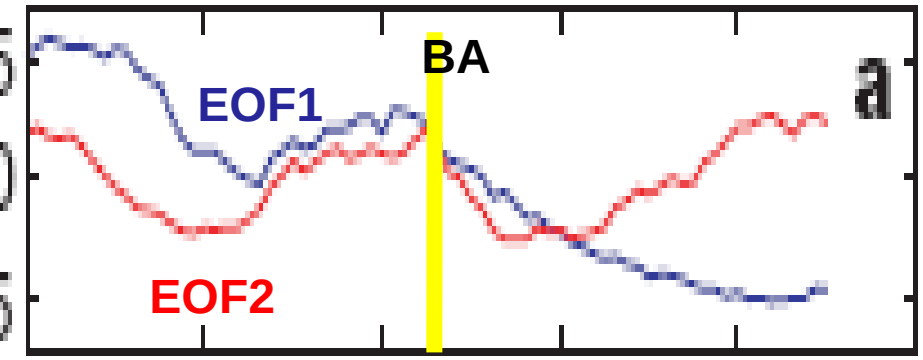
Global mode

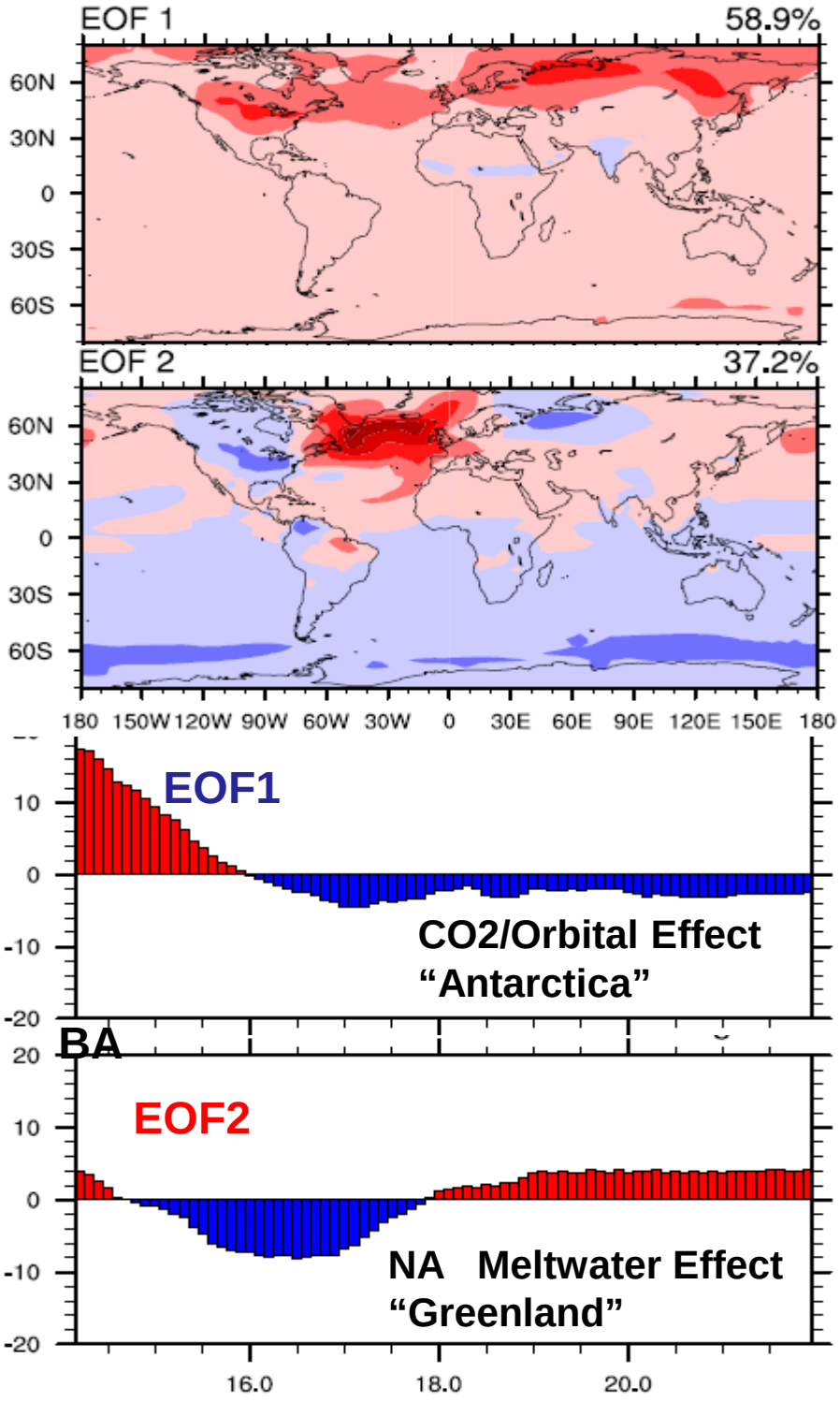
EOF1

Bipolar mode

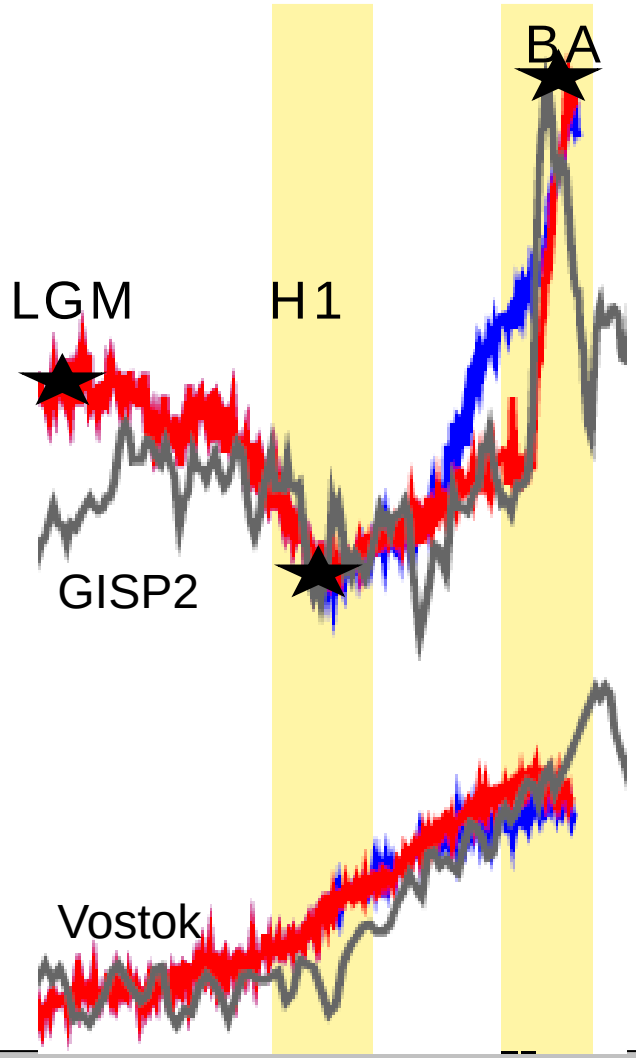
EOF2

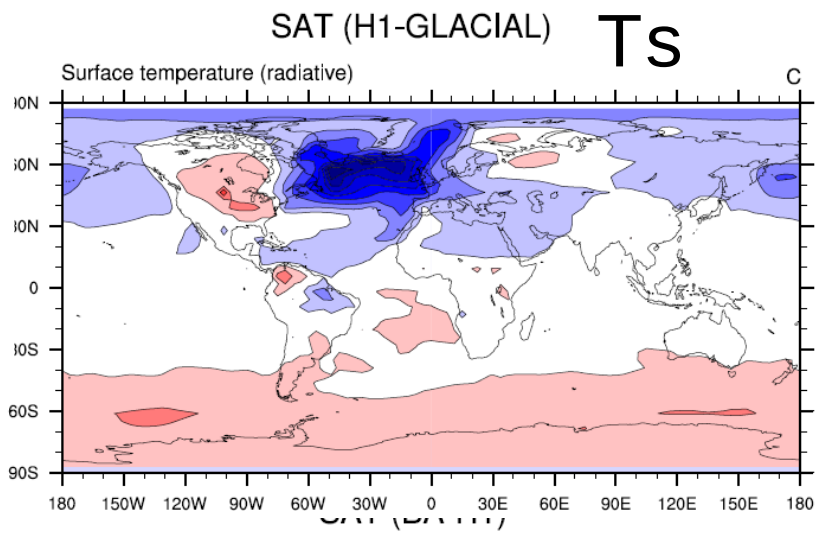




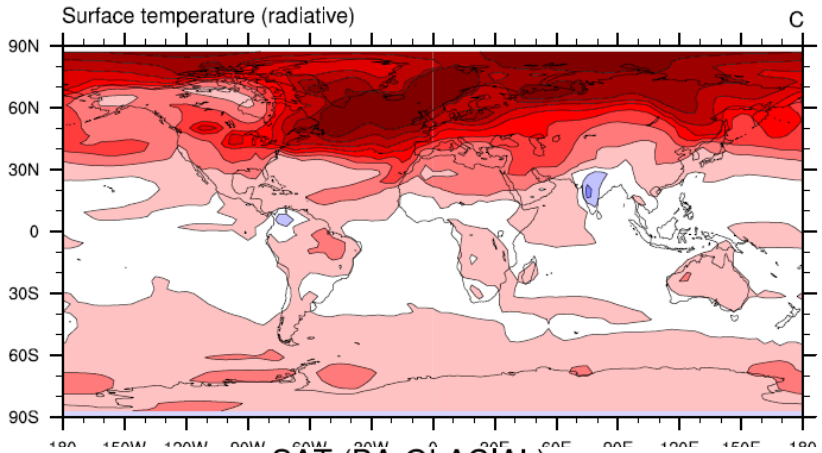


BA: Amplitude

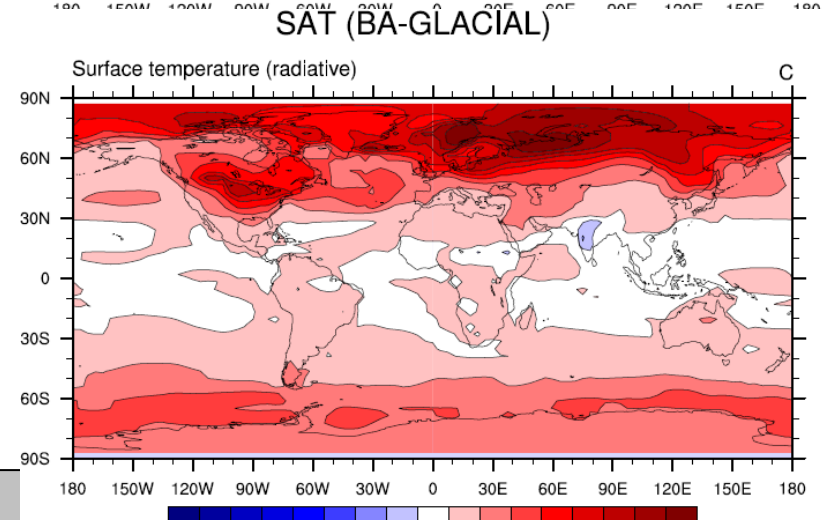




H1 - LGM

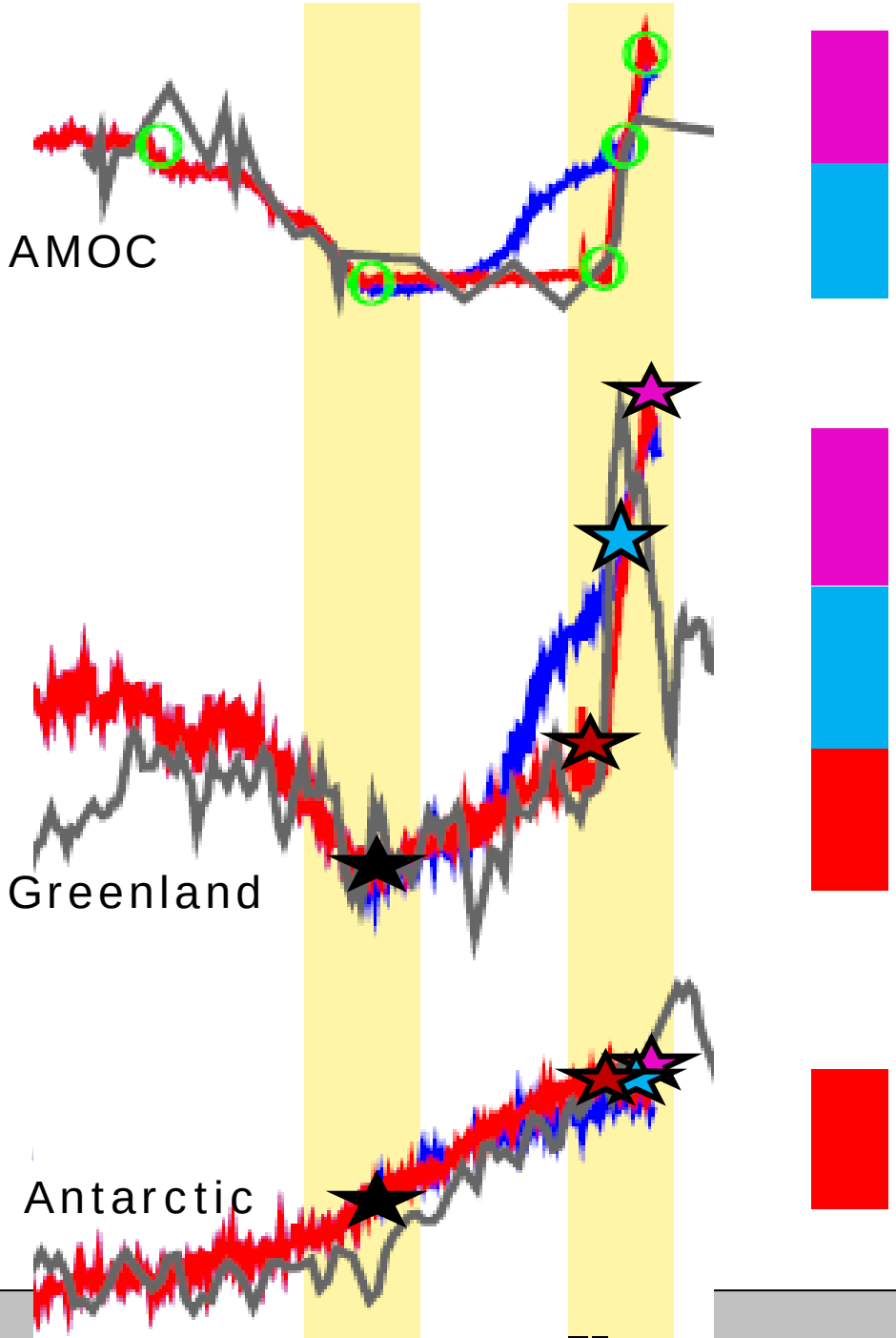


BA - H1

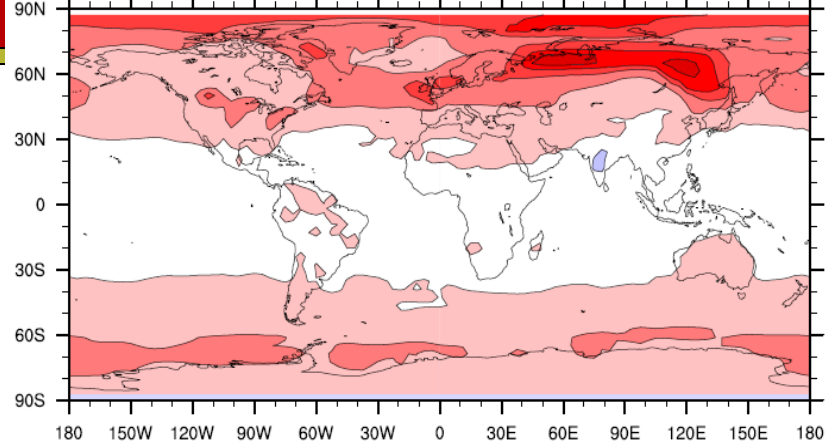


BA - LGM

BA warming

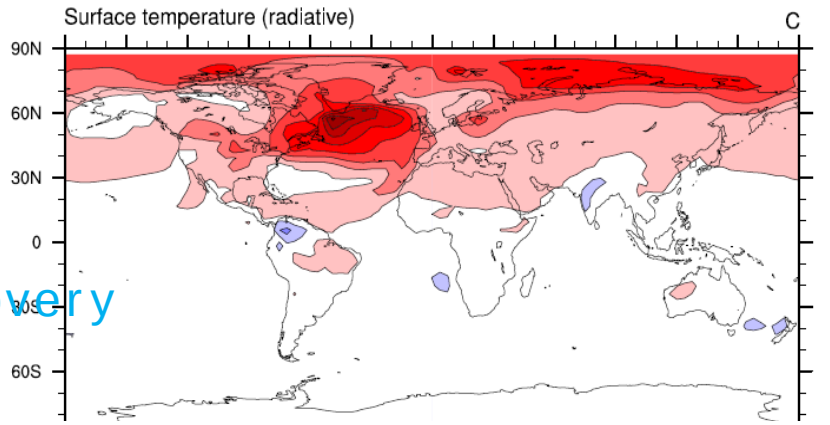


CO2



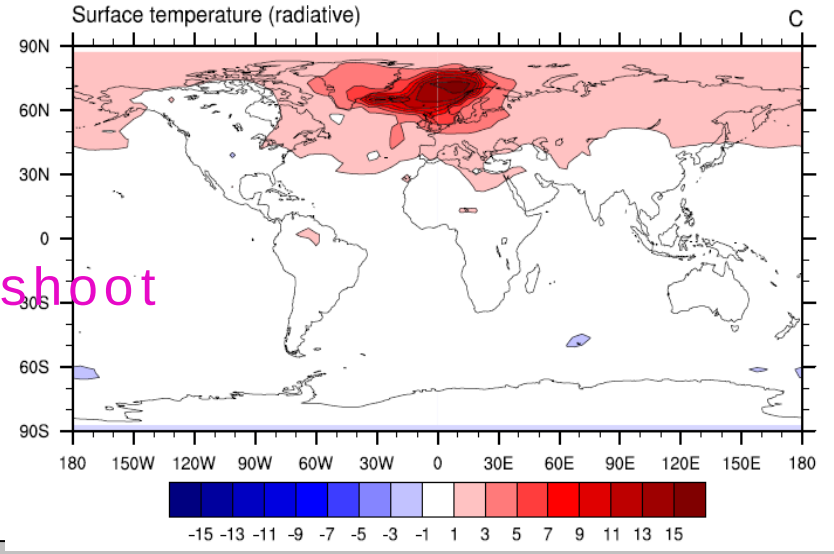
SAT (RECOVERY3-FIXMOC)

Recovery



SAT (BA-RECOVERY3)

Overshoot

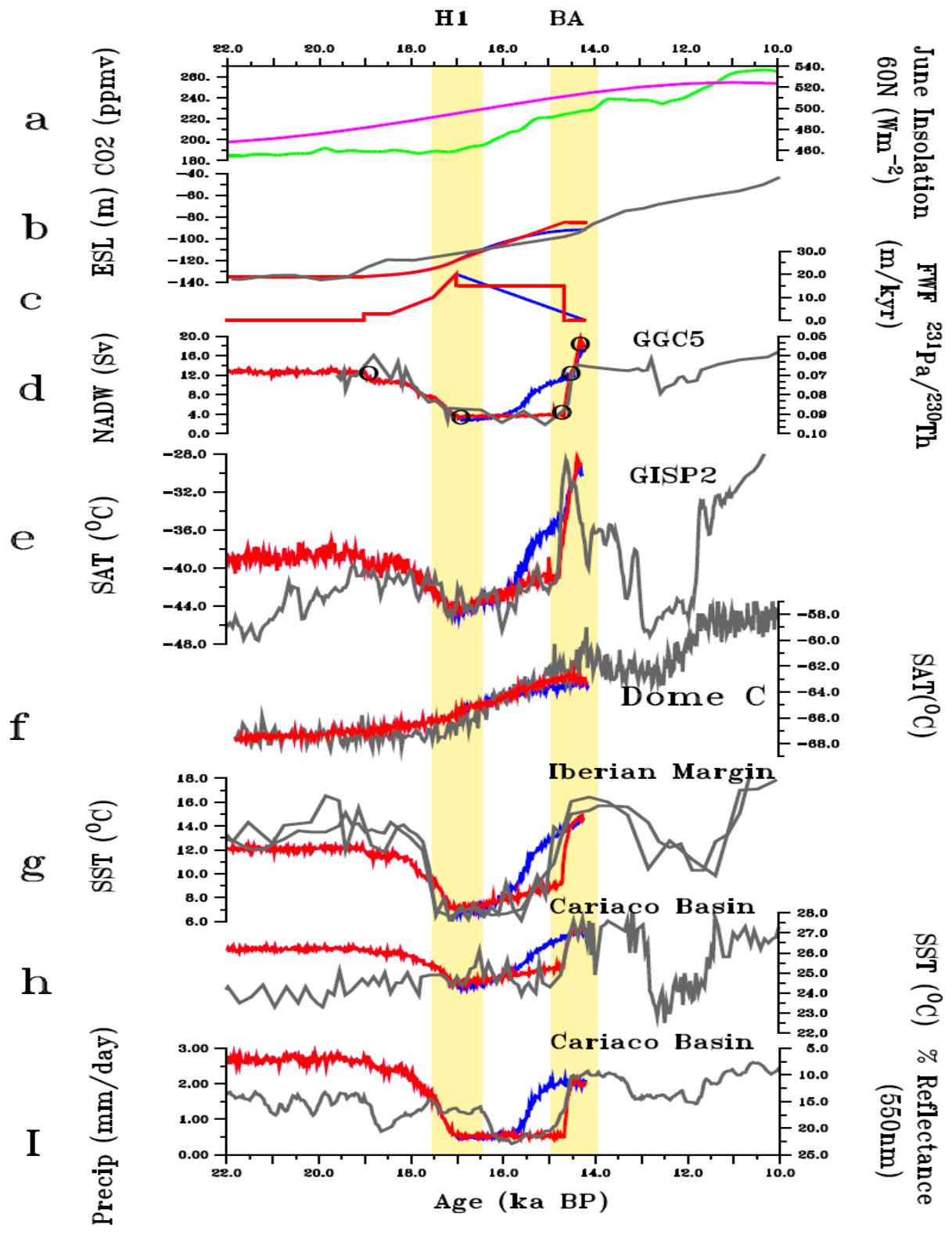


BA: Abruptness

------ Exp. 1

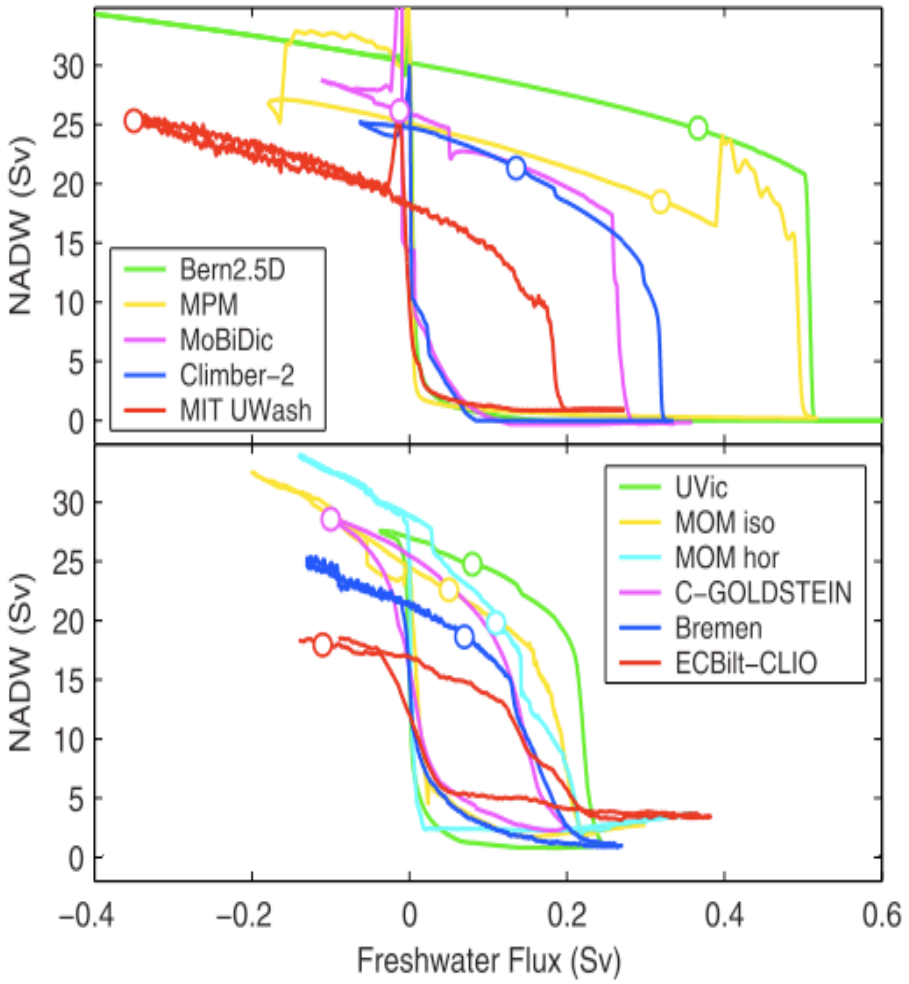
------ Exp. 2

------ Data

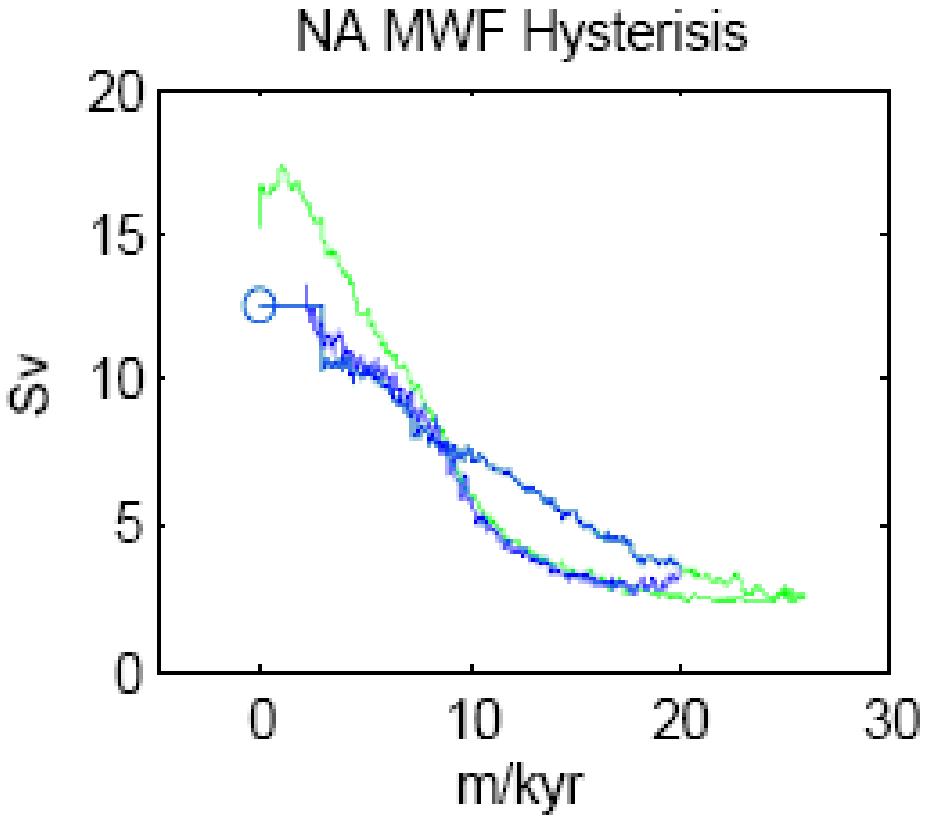


Hysteresis of AMOC

Intermediate models

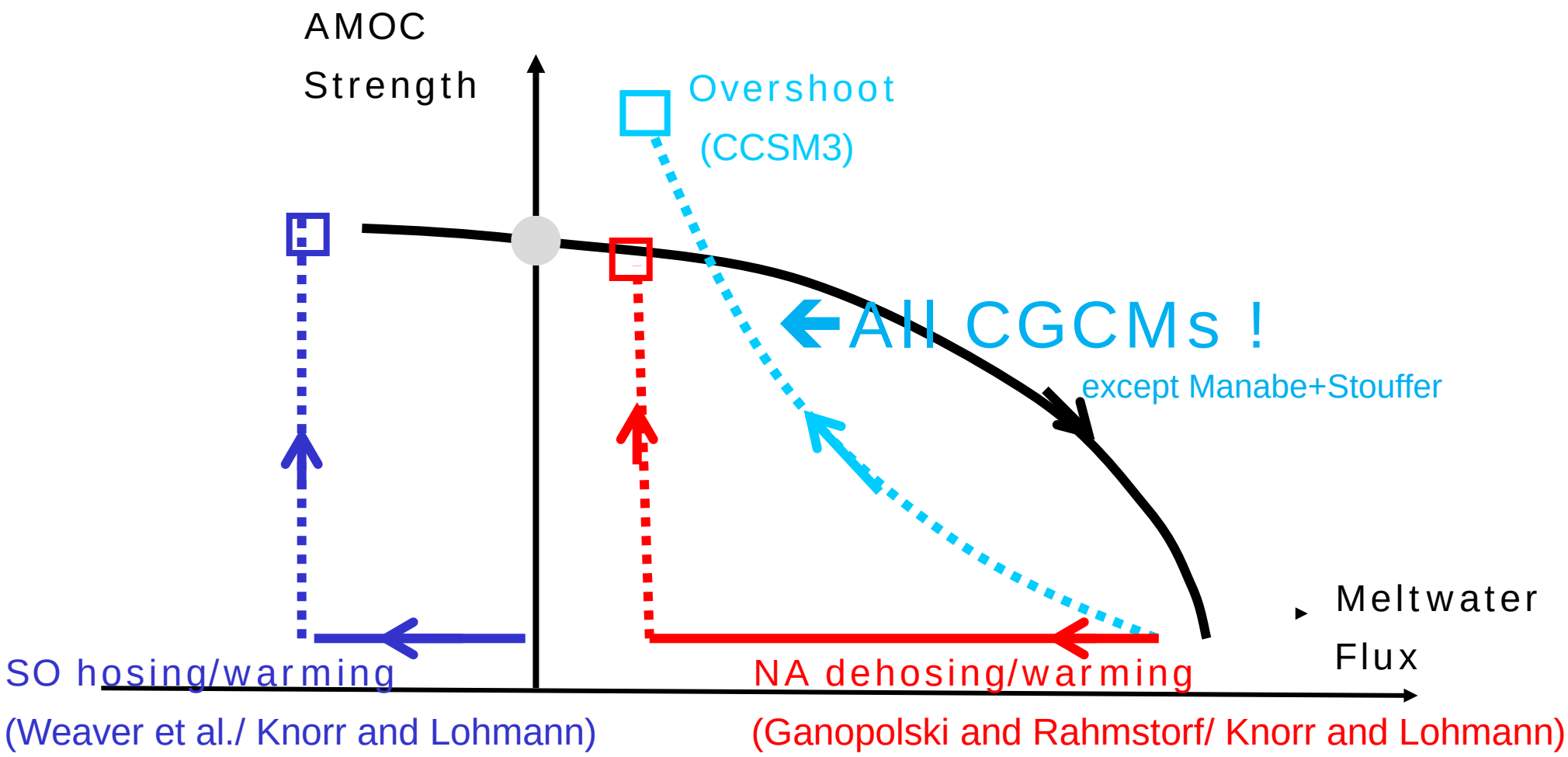


CCSM3



(Rahmstorf et al., GRL 2005)

THC recovery and BA -- An unified view

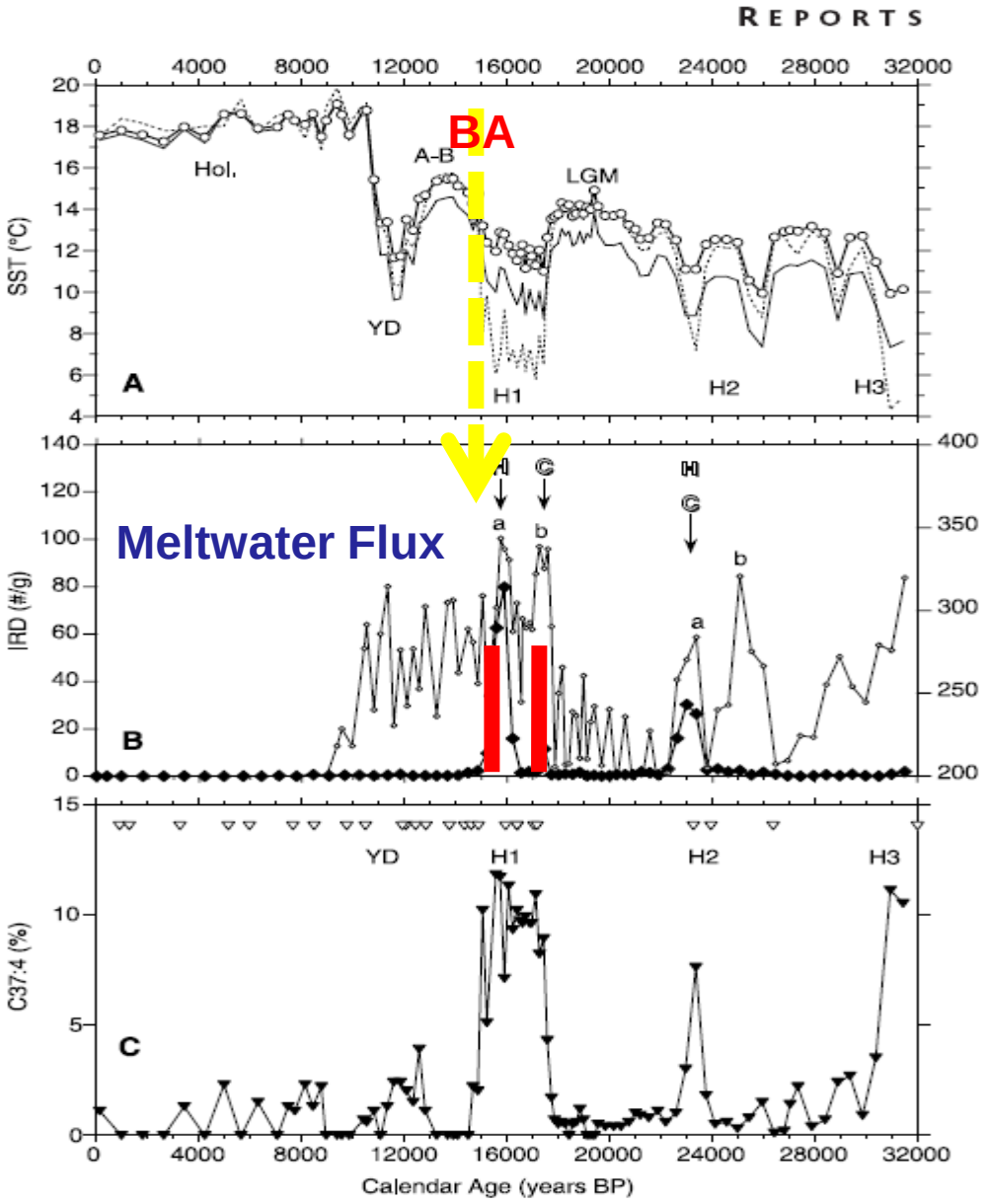


Questions

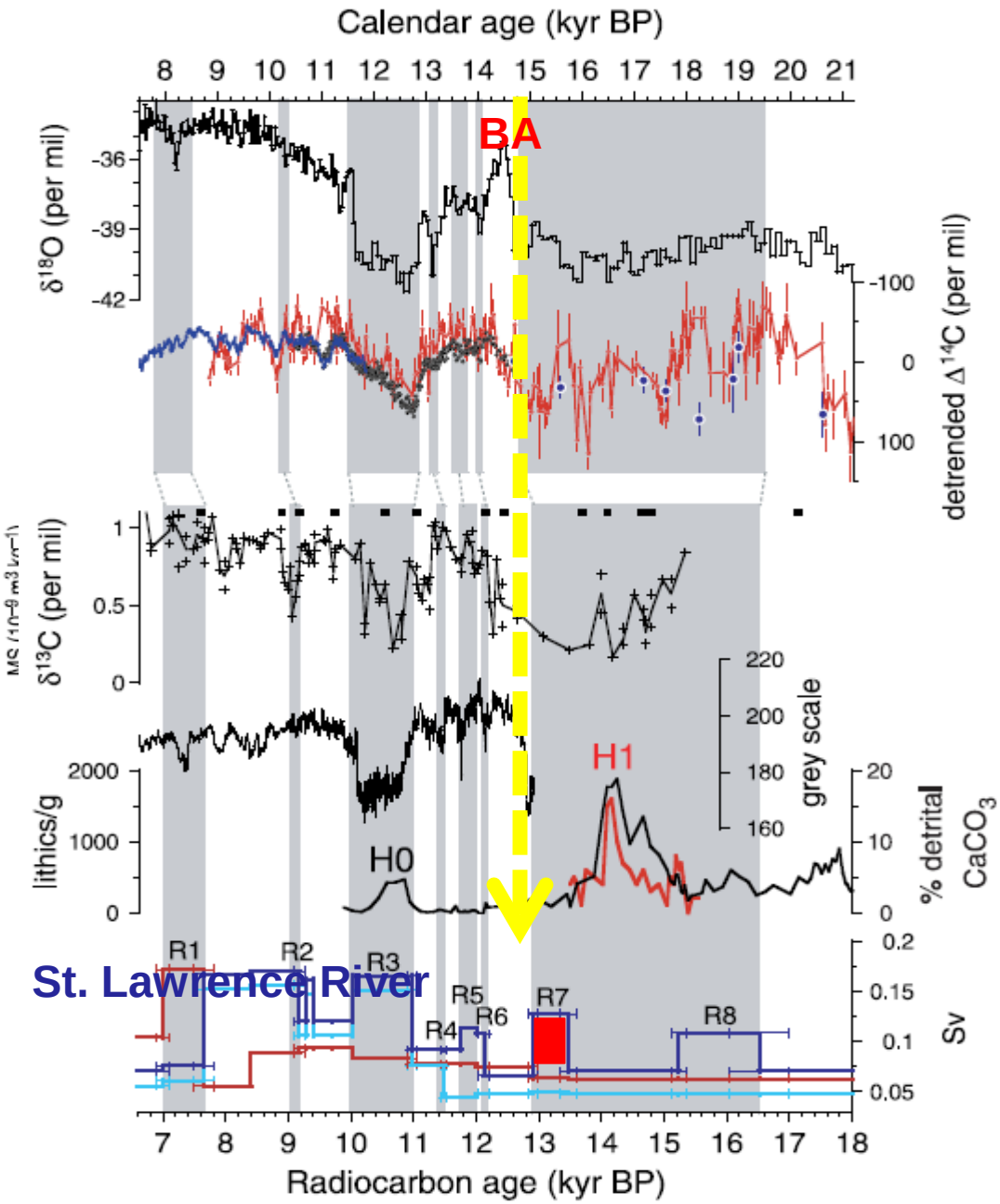
- Why intermediate models tend to have AMOC hysteresis while CGCMs not?
  - Which i*s* more correct, intemediate models or CGCMs?
  - Does the real world AMOC has hysteresis?
    Need the reconstructioin of meltwater history prior to BA
  - Is the NA abrupt change originated from the AO system, or ice sheet dynamics?

Meltwater History?

Bard et al., 2000, Science



Clark et al., 2001, Science



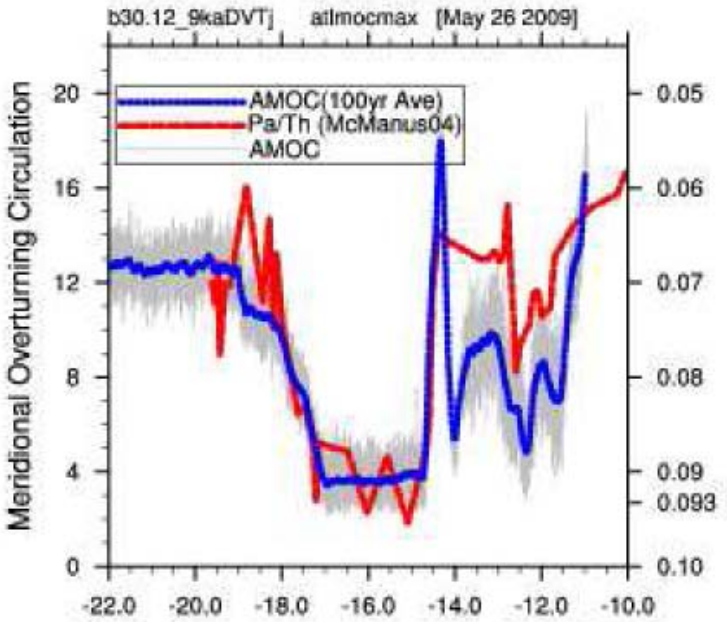
Summary

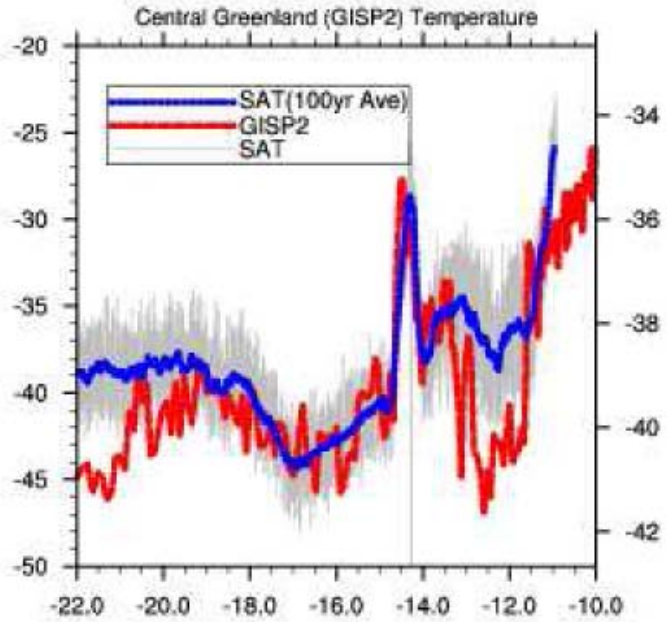
- Deglaciation Climate Evolution
  CCSM3 is able to simulate major features of deglaciation climate evolution as in proxy records, under realistic CO2, orbital forcings, and reasonable meltwater forcings. Global temperature evolution is dominated by the CO2/orbital forcing for the global mode, and meltwater forcing for the bipolar seesaw mode.

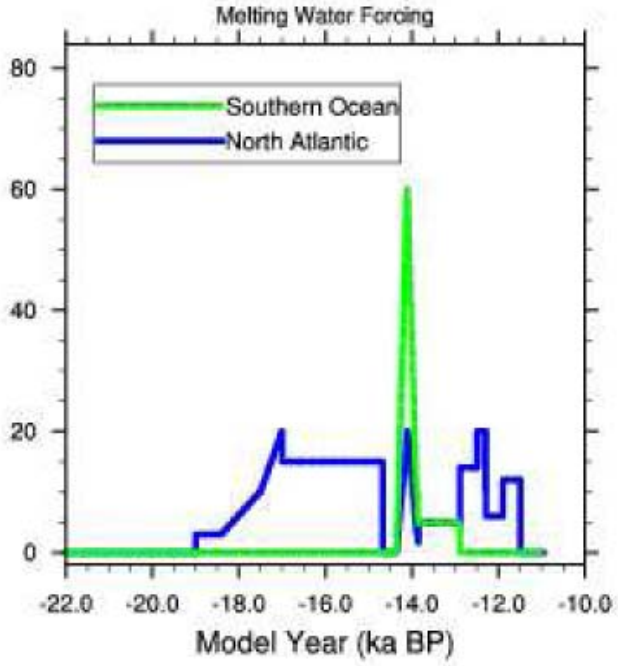
- BA warming magnitude!!
  CCSM3 reproduces the magnitude of the BA warming, suggesting good climate sensitivity of CCSM3. The BA warming is found to be caused by: the CO2 warming effect, the AMOC recovery and the AMOC overshoot.

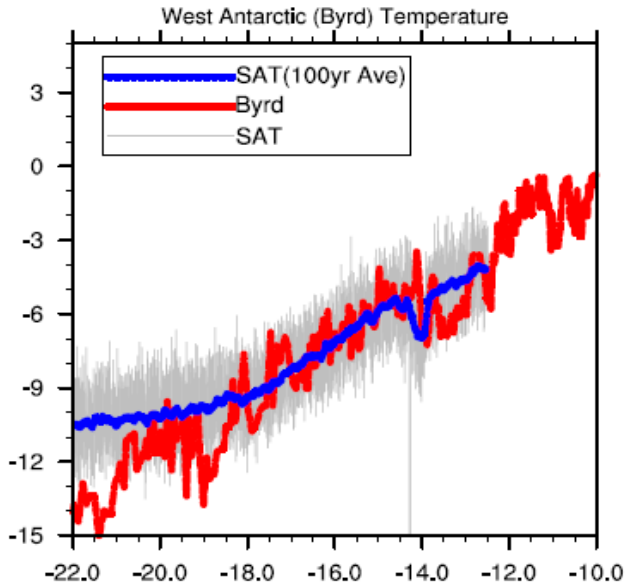
- BA warming abruptness??
  It remains uncertain if CCSM3, and, more generally, current generation of GCMs, are able to simulate the abruptness of the BA warming. The key observation reqruied is the detailed meltwater history prior to BA.

Challenges Ahead !





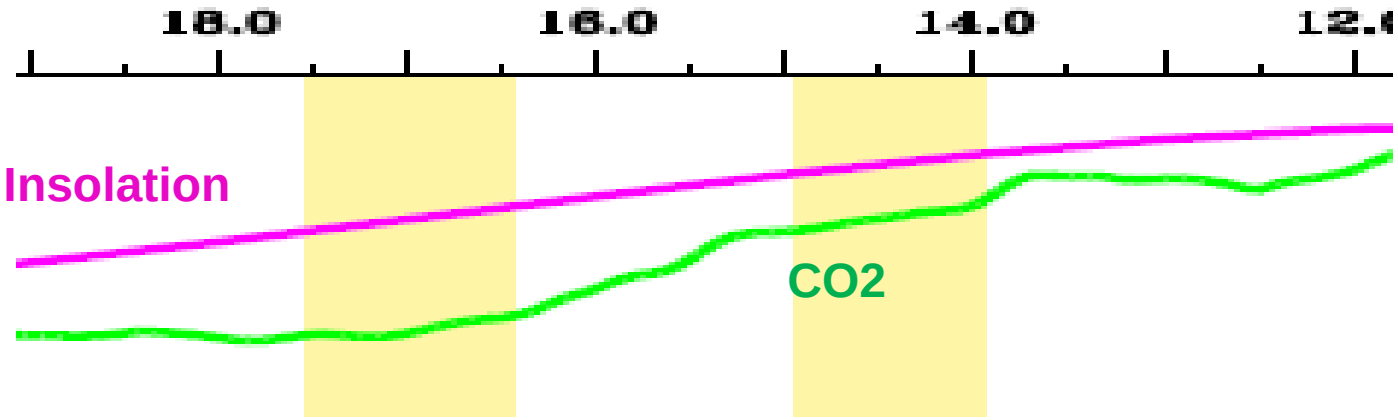


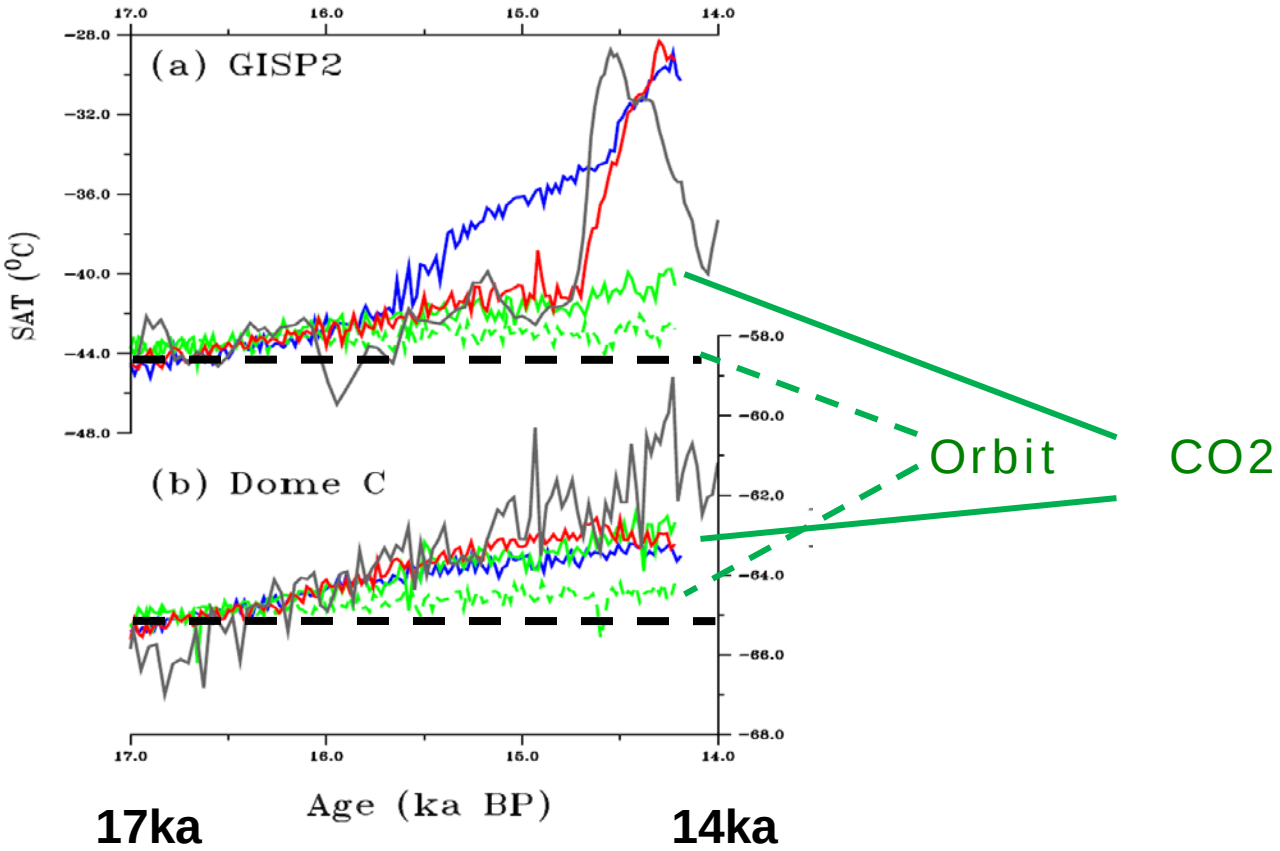


YD?

ACR?

CO2 vs Orbital Forcing





AMOC recovery in CMIP

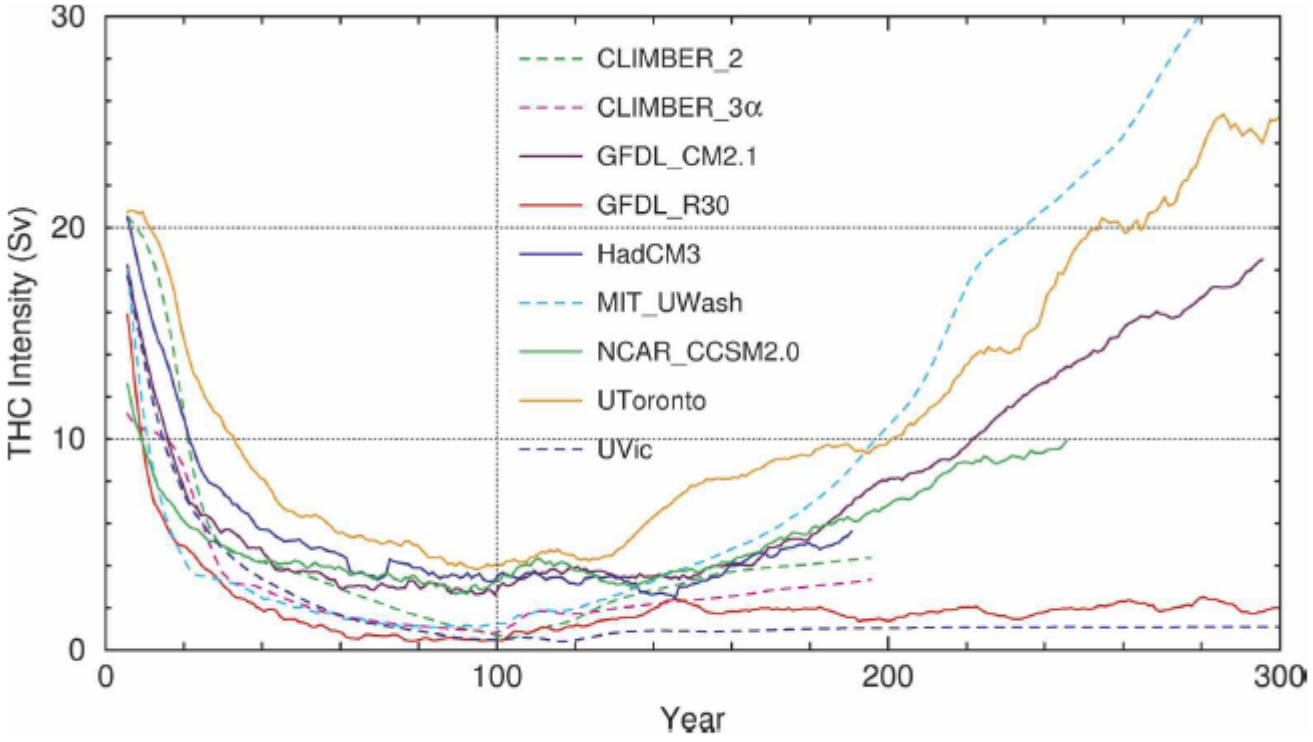


FIG. 13. Time series of the THC intensity evolution in the 1.0-Sv water-hosing experiments.

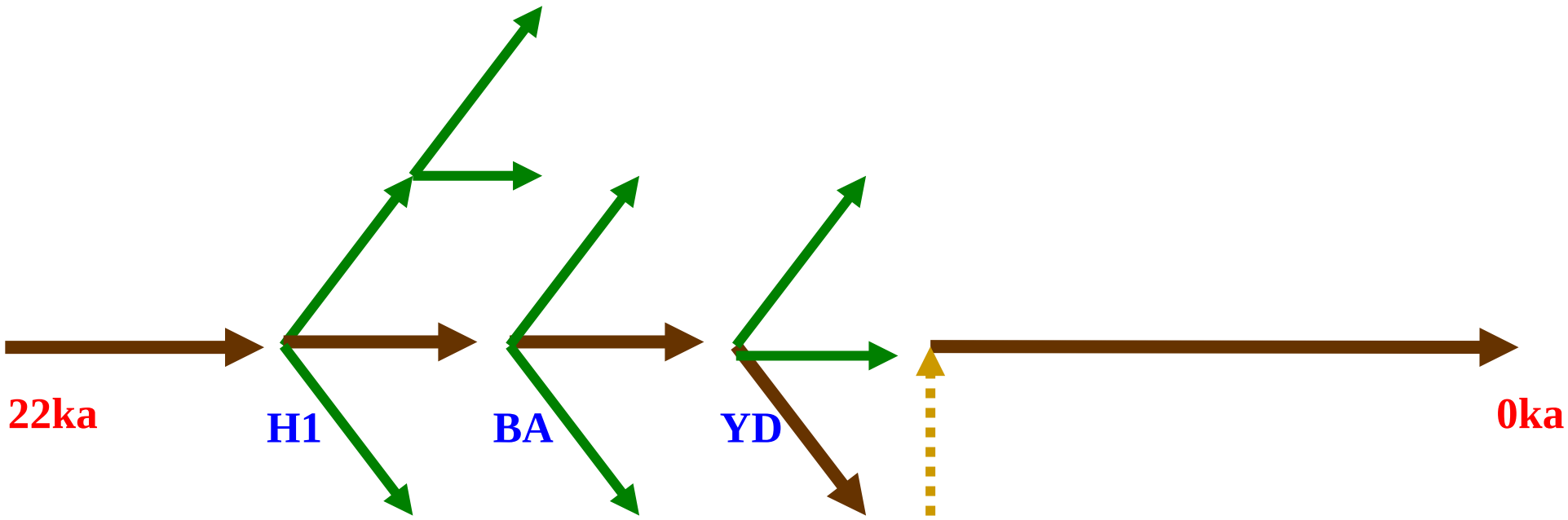
---------- Intermediate model

———————— CGCM

Stouffer et al., 2006, JC

Meltwater Forcing Strategy

------A “Pine Tree”



Convection/Sea Ice/Heat Flux