



COLLÈGE
DE FRANCE
— 1530 —



Paleoceanography: a storybook to understand climate change

Long-term modulation of the glacial mode of the climate system

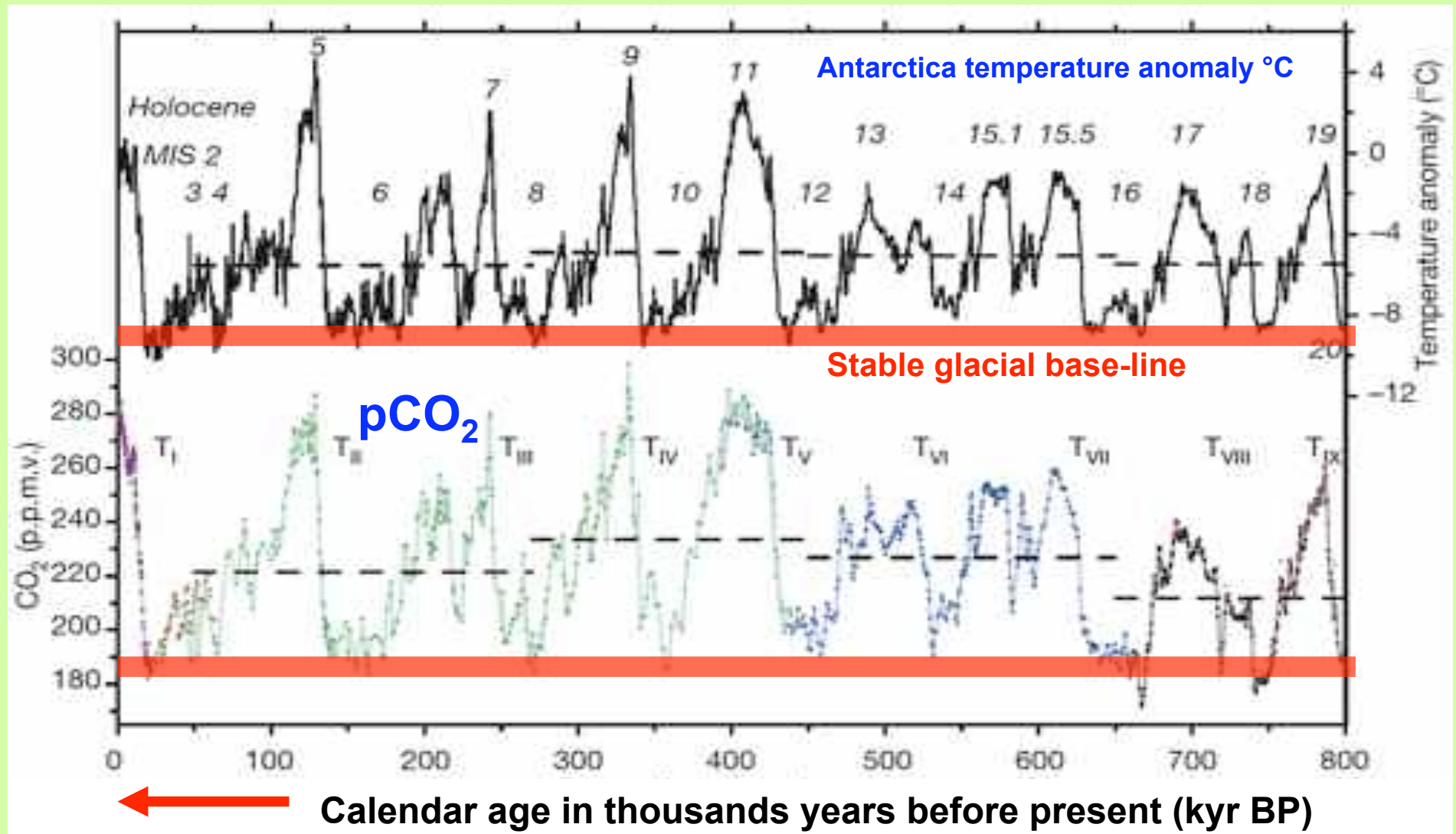
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Oeschger Center 2008-09 visiting scientist

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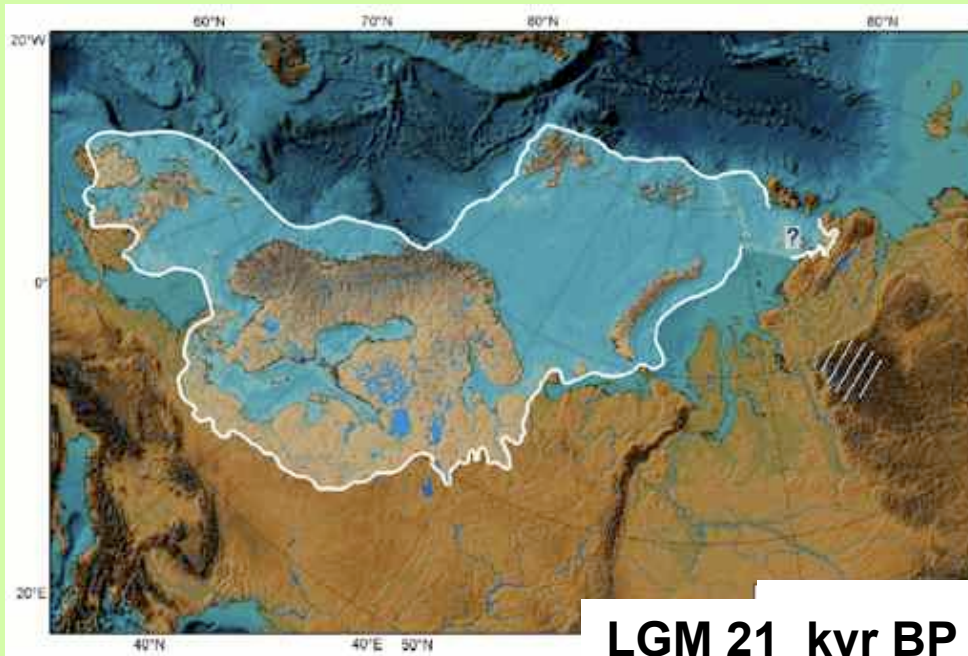
A remarkable match between Antarctica temperature and carbon dioxide content of the atmosphere



Recent field data show that glacial periods were not equal

Example of the Fennoscandian ice sheet

ESF program “Quaternary Environment of the Eurasian North” (QUEEN)



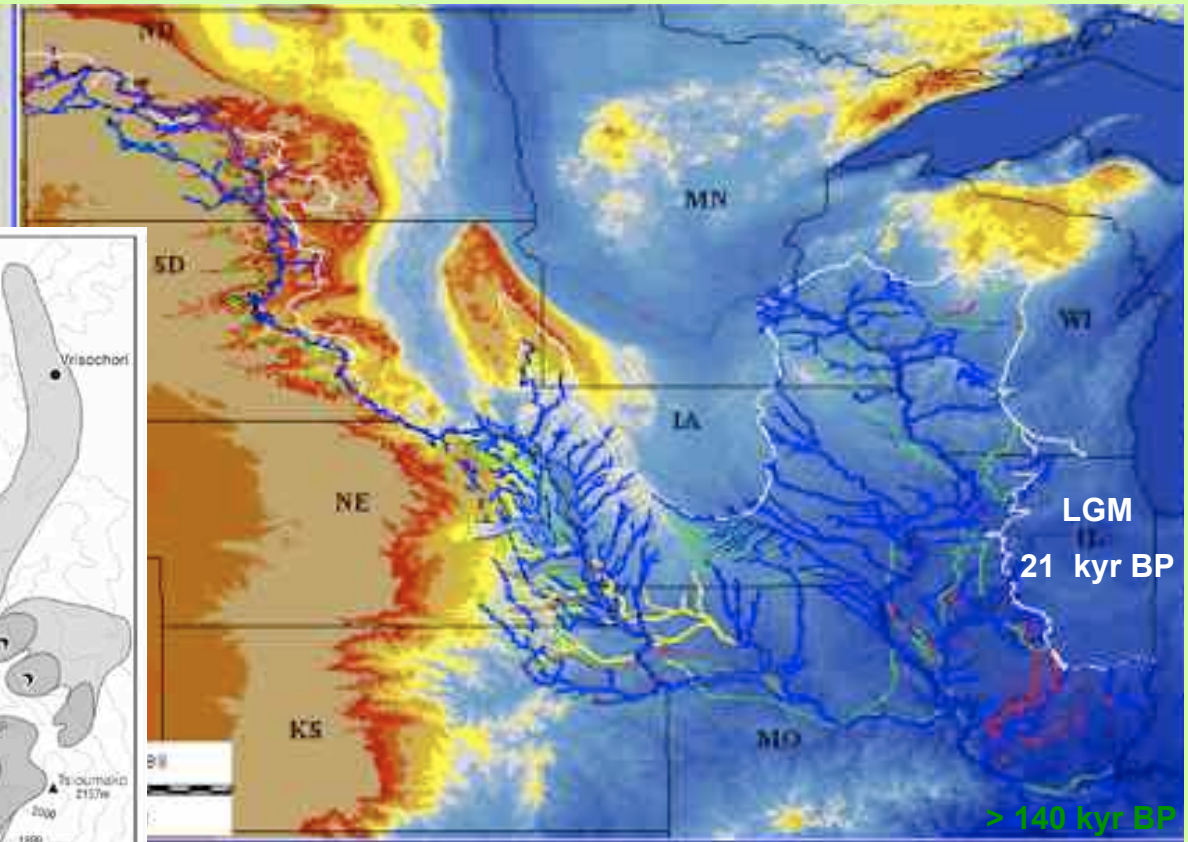
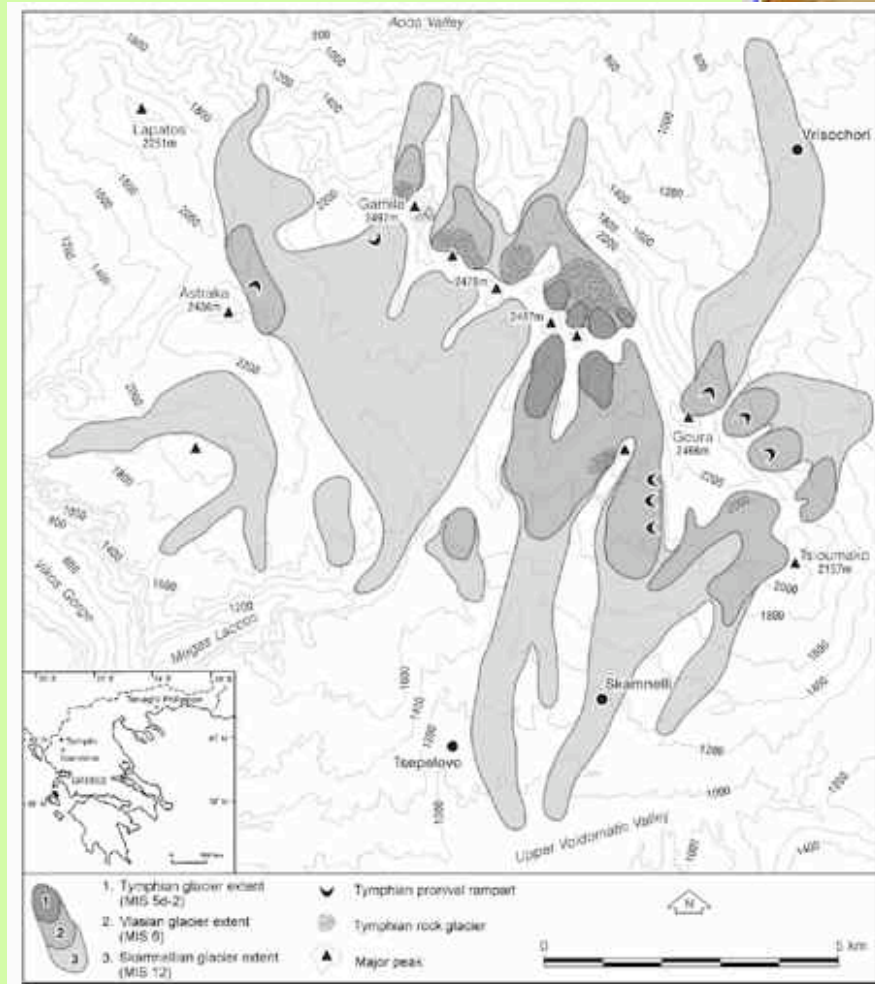
LGM 21 kyr BP



> 140 kyr BP

Svendsen et al. 2004 QSR

Other examples from the Laurentide ice sheet and mountain glaciers in Greece



Map of US terminal moraines

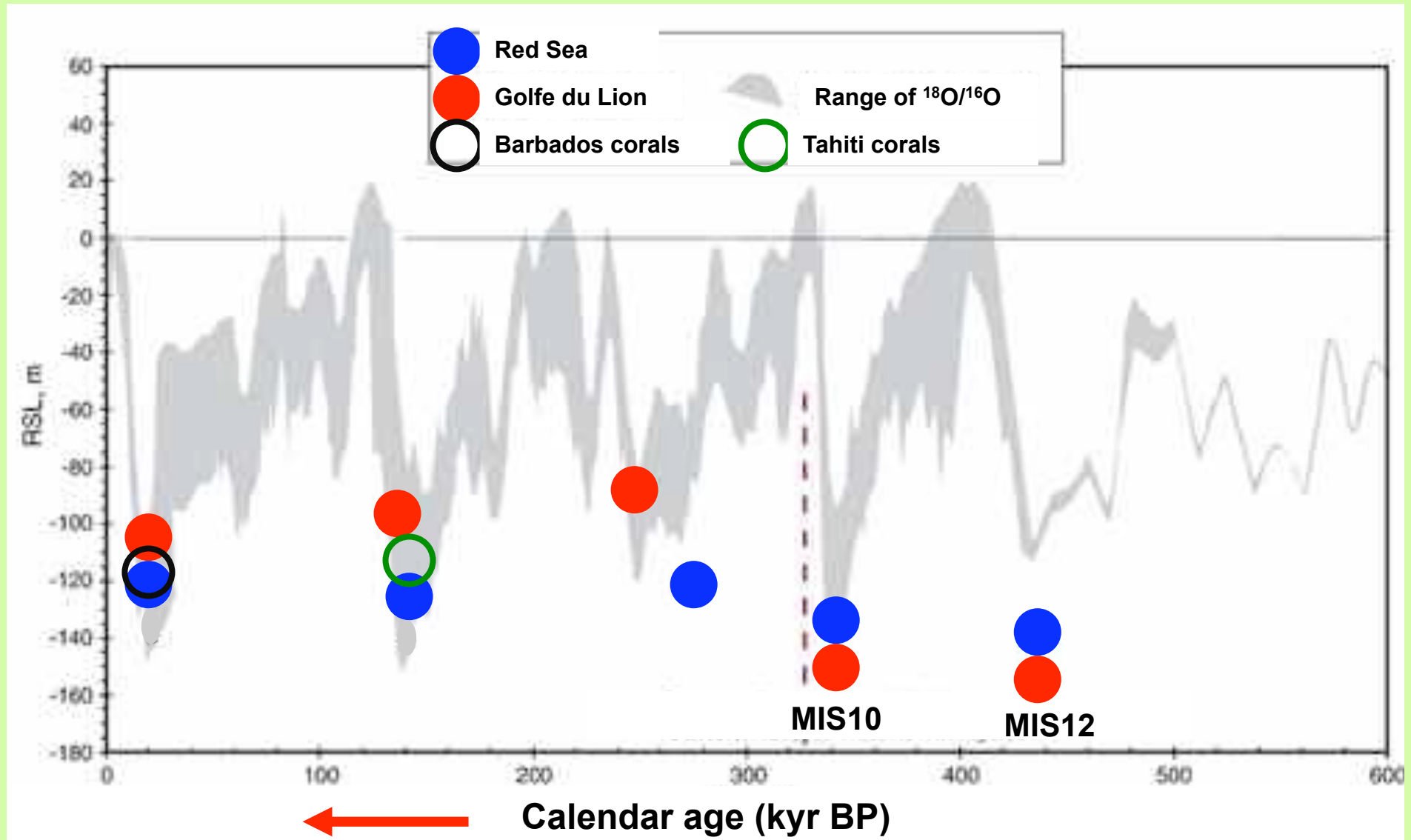
INQUA GAGE 2000

MIS 12 is also the most extreme glacial in long pollen diagrams such as Tenaghi Philippon

Tzedakis et al. 2003 *EPSL*

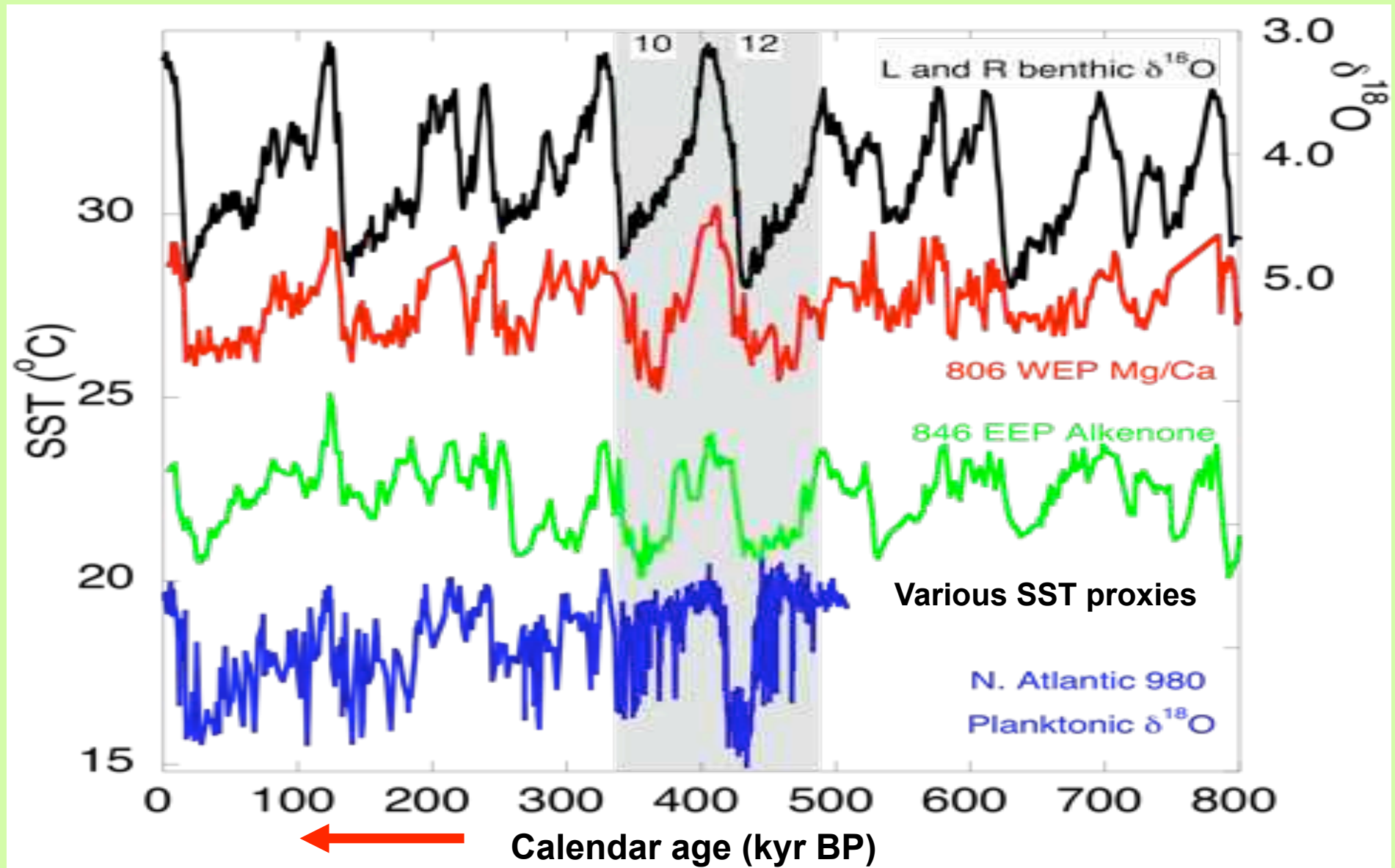
Hughes et al. 2007 *EPSL*

Global sea level based on oceanic $^{18}\text{O}/^{16}\text{O}$
and observed sea level low stands: **MIS 10 & 12 < 150m**



Rabineau et al. 2006 *EPSL* ; Rohling et al. 1998 *Nature*; Bard et al. 1990 *Nature*

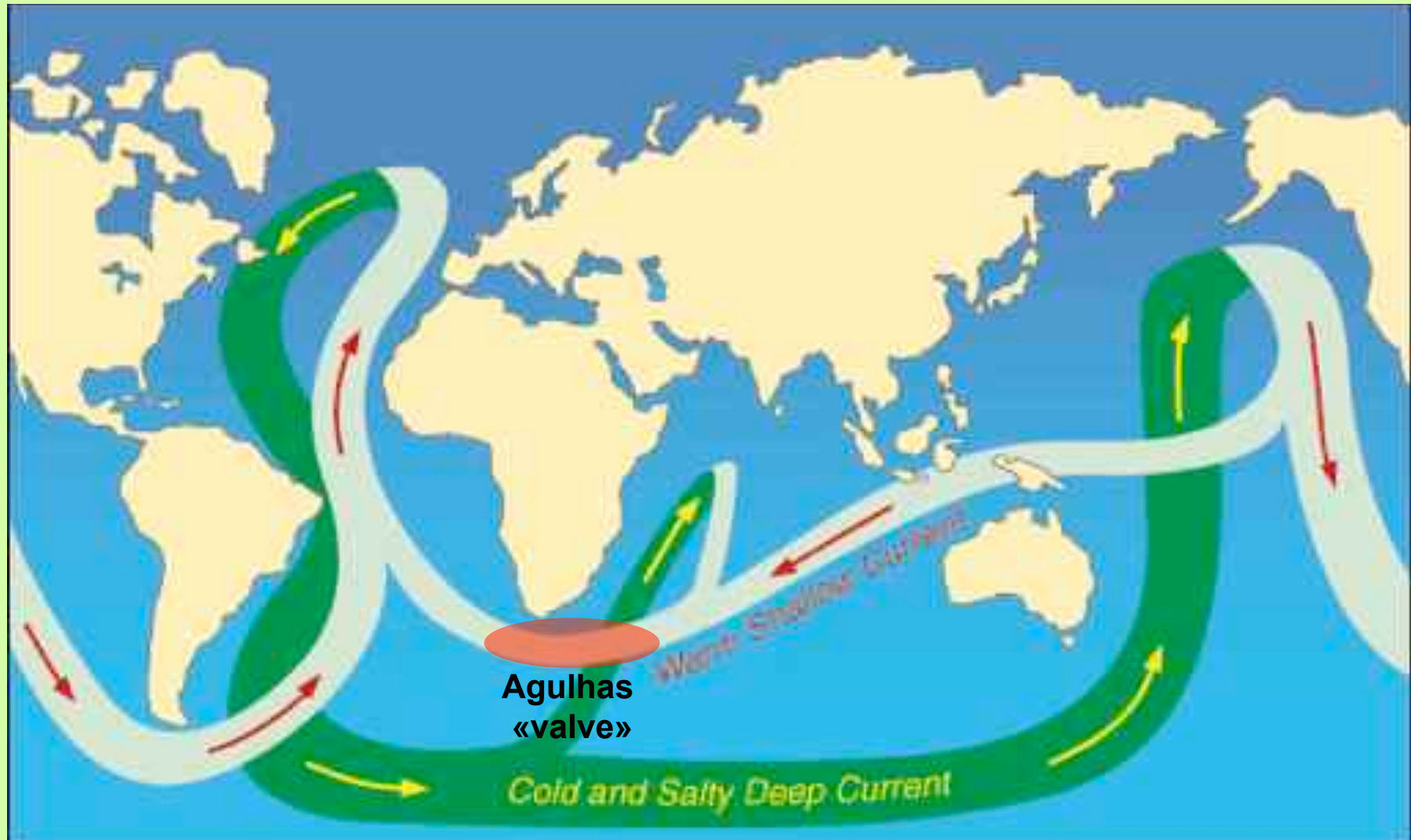
Other climate records confirm the singularity of MIS 10 & 12



Lisiecki & Raymo 2005 *Paleoceanol.*; Medina-Elizalde & Lea 2005 *Science*; Liu & Herbert 2004 *Nature*; McManus et al. 1999 *Science*

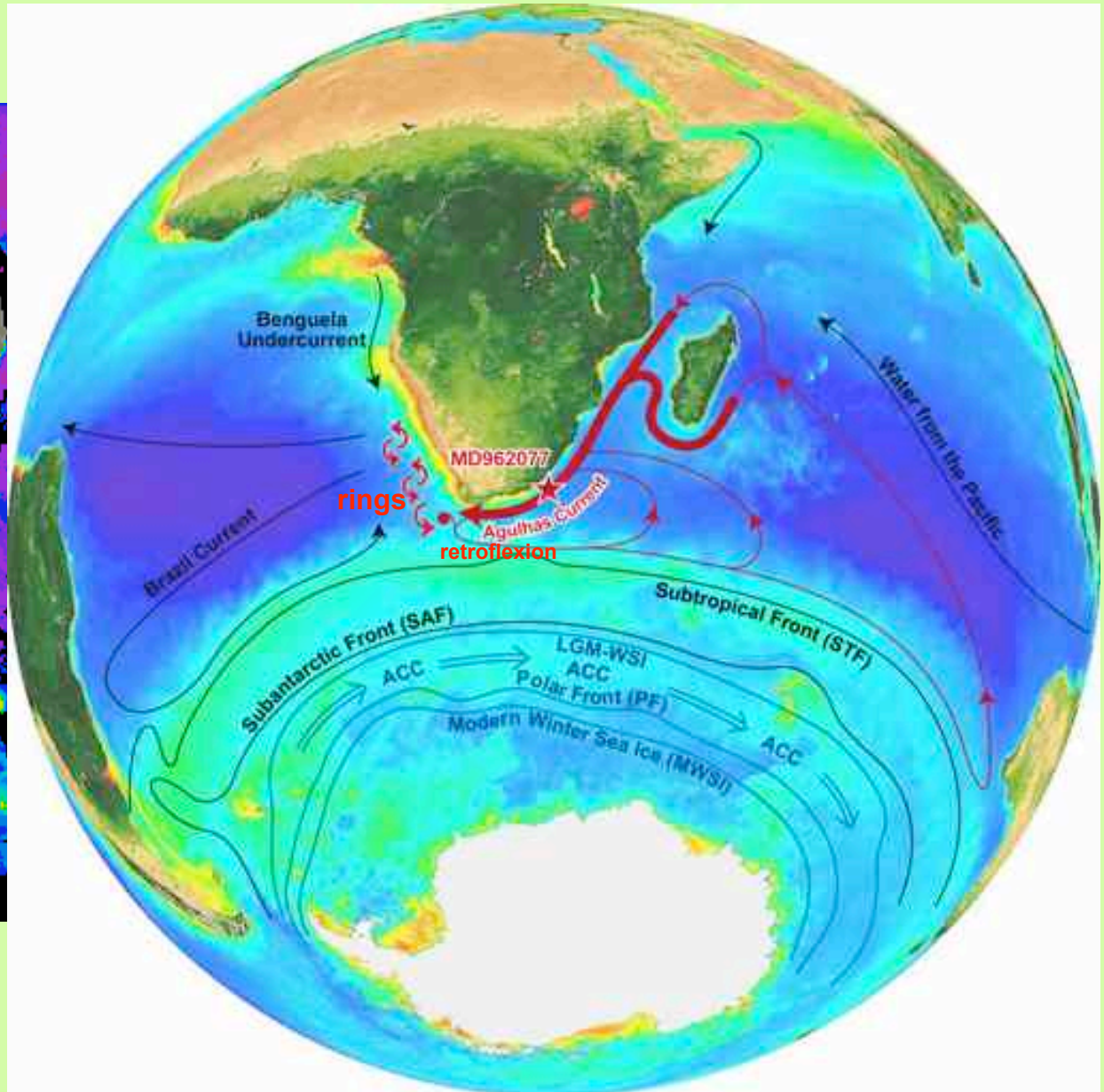
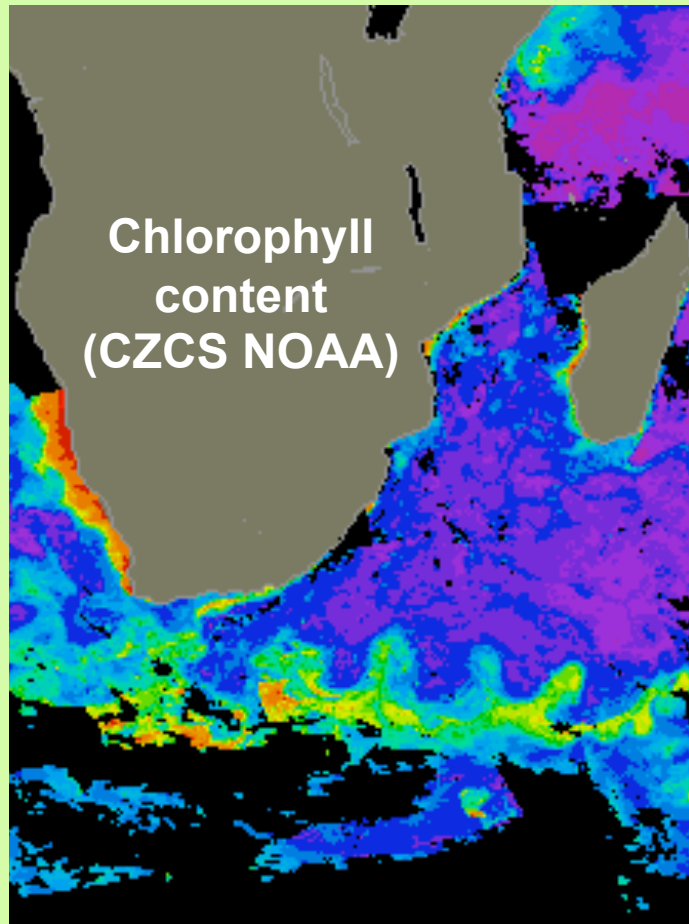
Could the ocean be the cause of these major non-linearities ?

Numerous threshold effects in the global conveyor

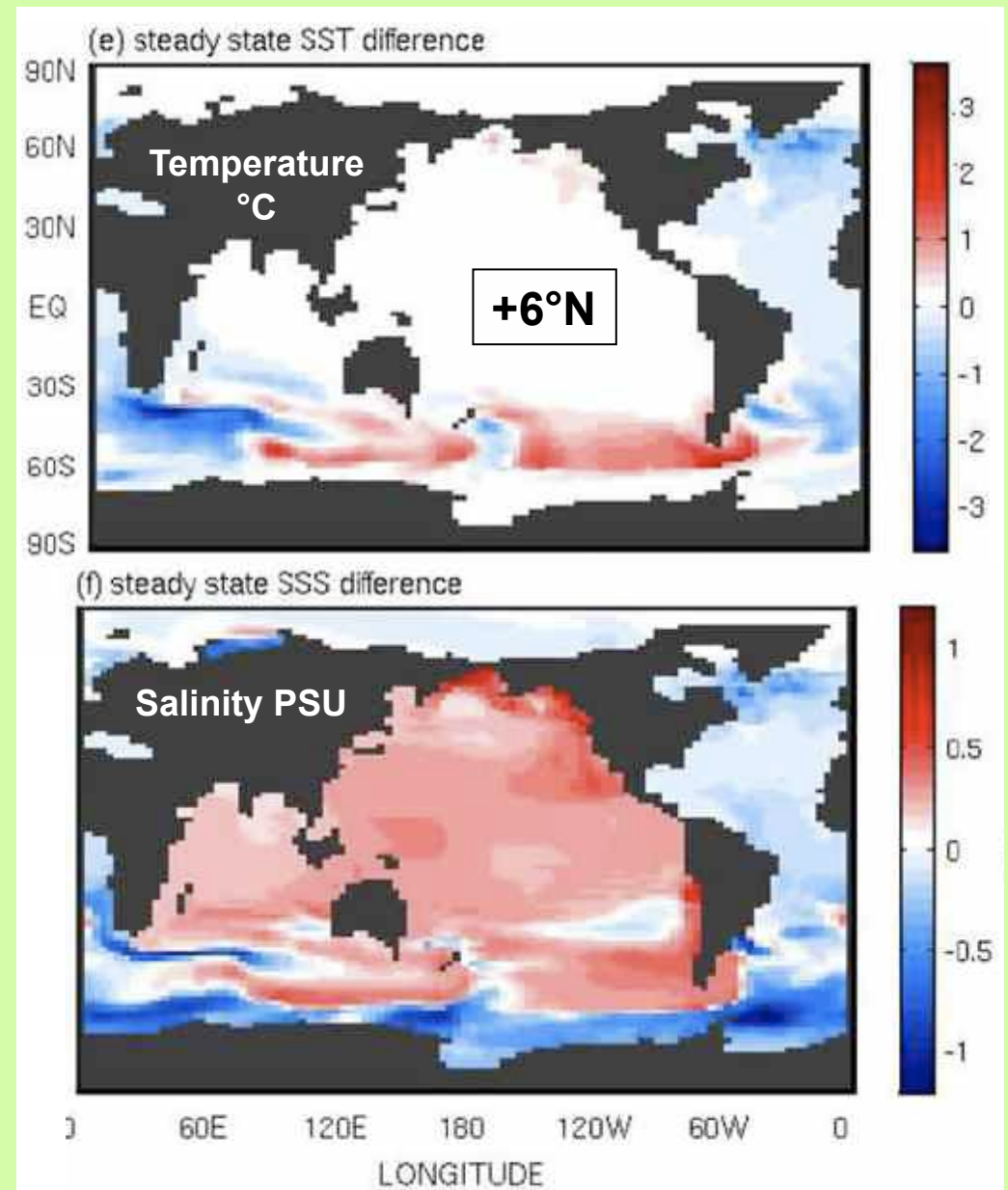
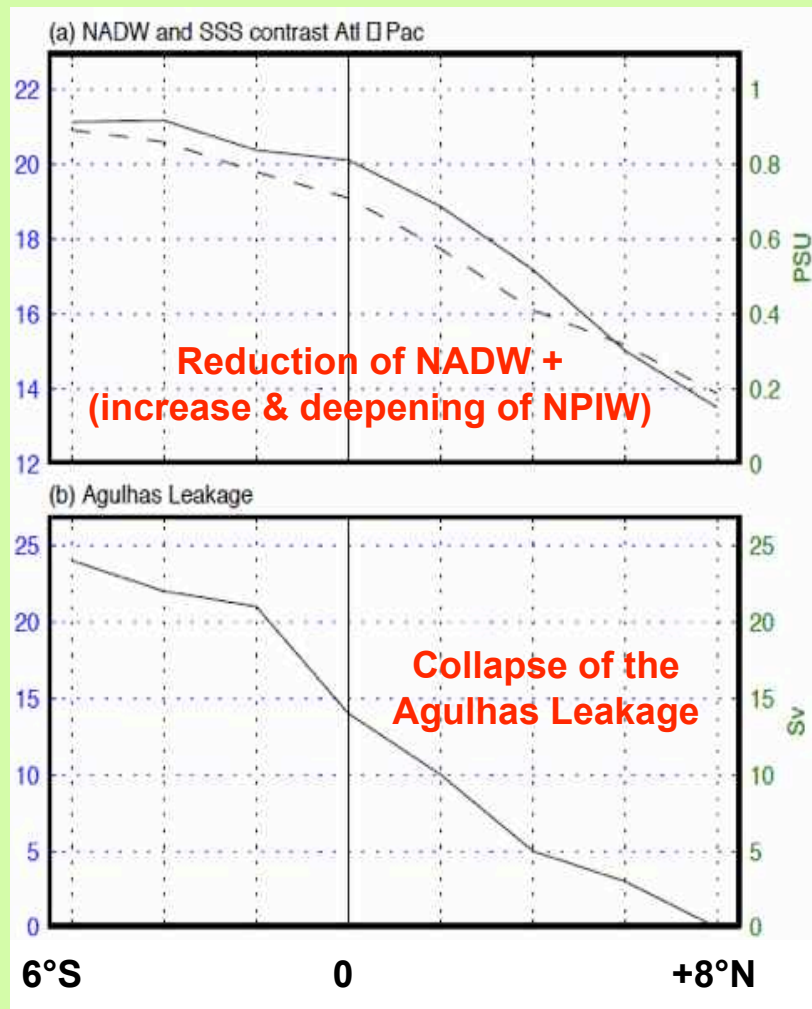


Horribly simplified from Gordon et al. 1986 *JGR*, Broecker 1991 *Oceanography*, Ganachaud & Wunsch 2000 *Nature*

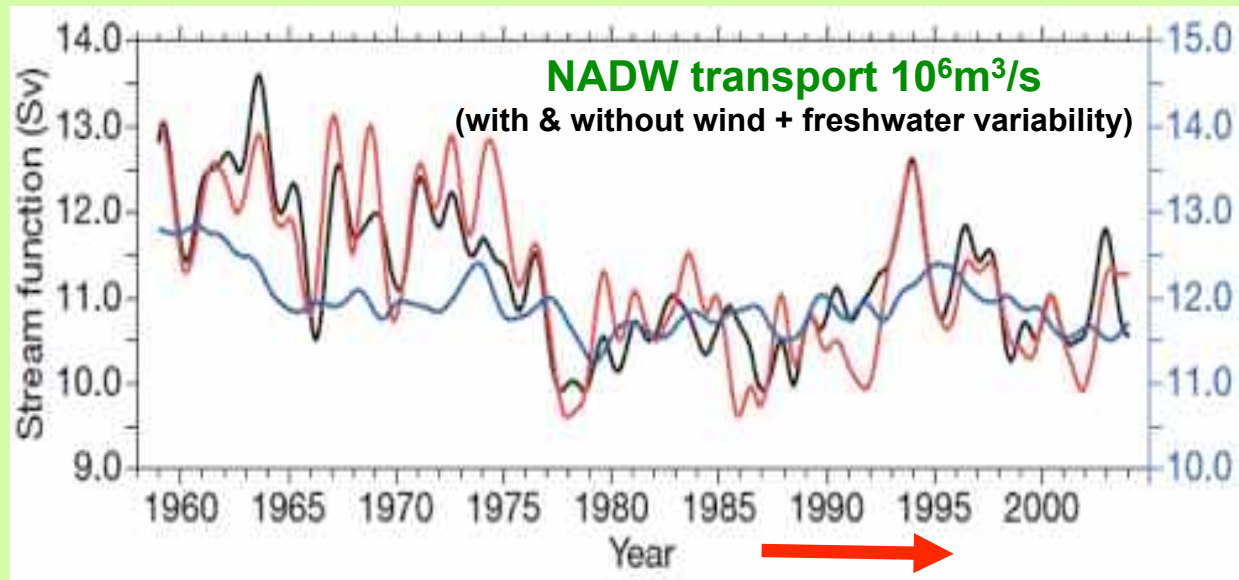
The Agulhas current system is a **salt & heat “valve”** between the Indian and Atlantic Oceans



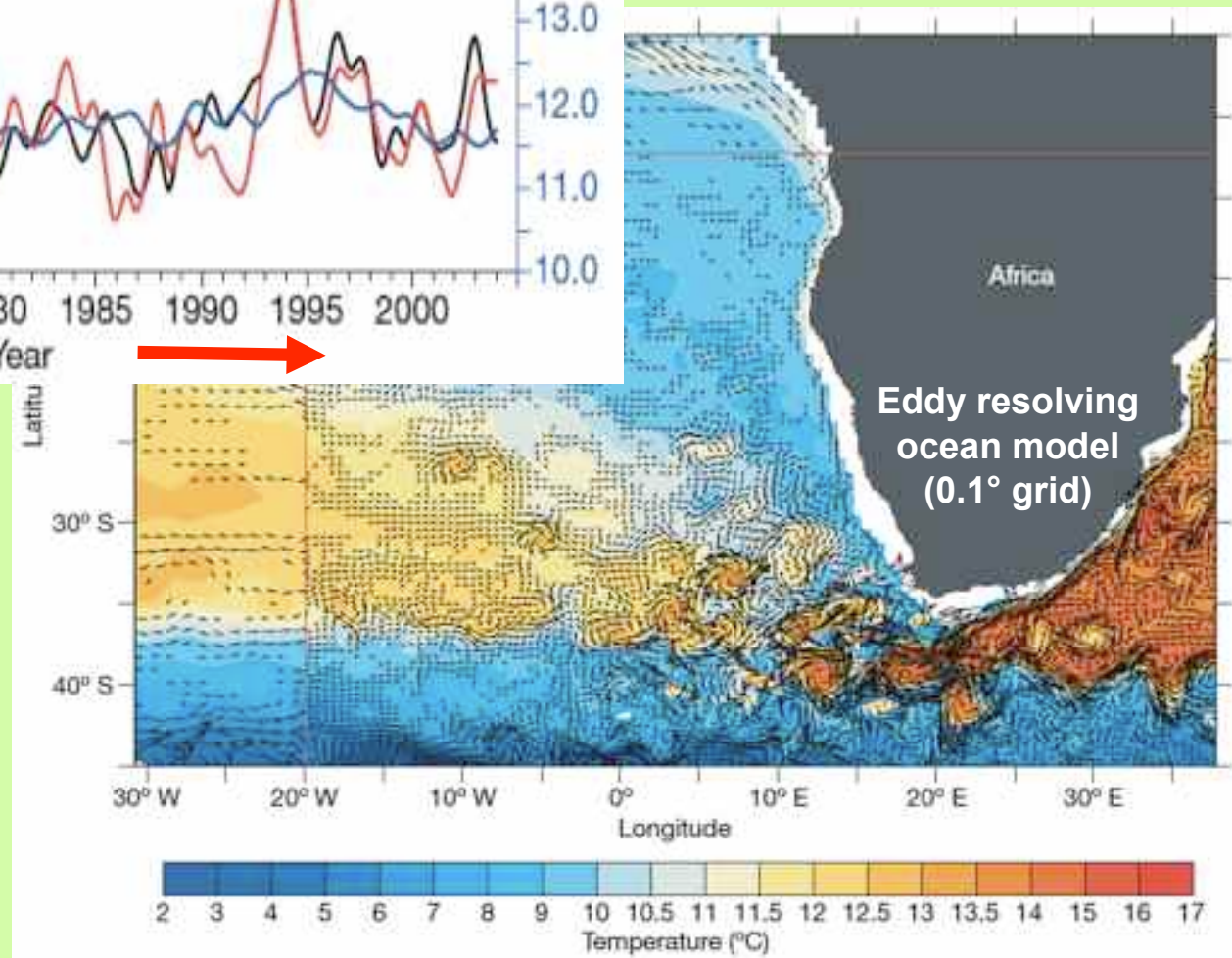
Impact of a latitudinal shift of south westerly winds in a climate model



The Agulhas leakage is also crucial to predict the decadal variability of the meridional overturning circulation



Biastoch et al. 2008 *Nature*



Concluding remarks

- Not all glacial periods are equal to the last glacial maximum (MIS 2),
- The Subtropical Front (STF) migrates to the most northerly position during the most extreme glacial periods (MIS 10 and 12) closing the Agulhas leakage of salt & heat to the Atlantic,
- Migrations of the STF were associated to northward shifts of south westerlies; both effects inducing a strong feedback on Atlantic & Pacific deep circulations,
- The long term trend suggests a link with the eccentricity 400 kyr cycle. A possible cause is cooling at low latitudes, reducing the Hadley cell and shifting winds at higher latitudes,
- This long term cycle is somehow decoupled from climate in Antarctica (isolation effect of expanded sea ice and Antarctic Circumpolar Current surrounding Antarctica ?) and from atmospheric $p\text{CO}_2$ (compensated by other changes in the carbon cycle ?),
- The Agulhas “valve” effect on the ocean circulation is at work today and may vary in the future as a response to poleward shift of westerlies.