

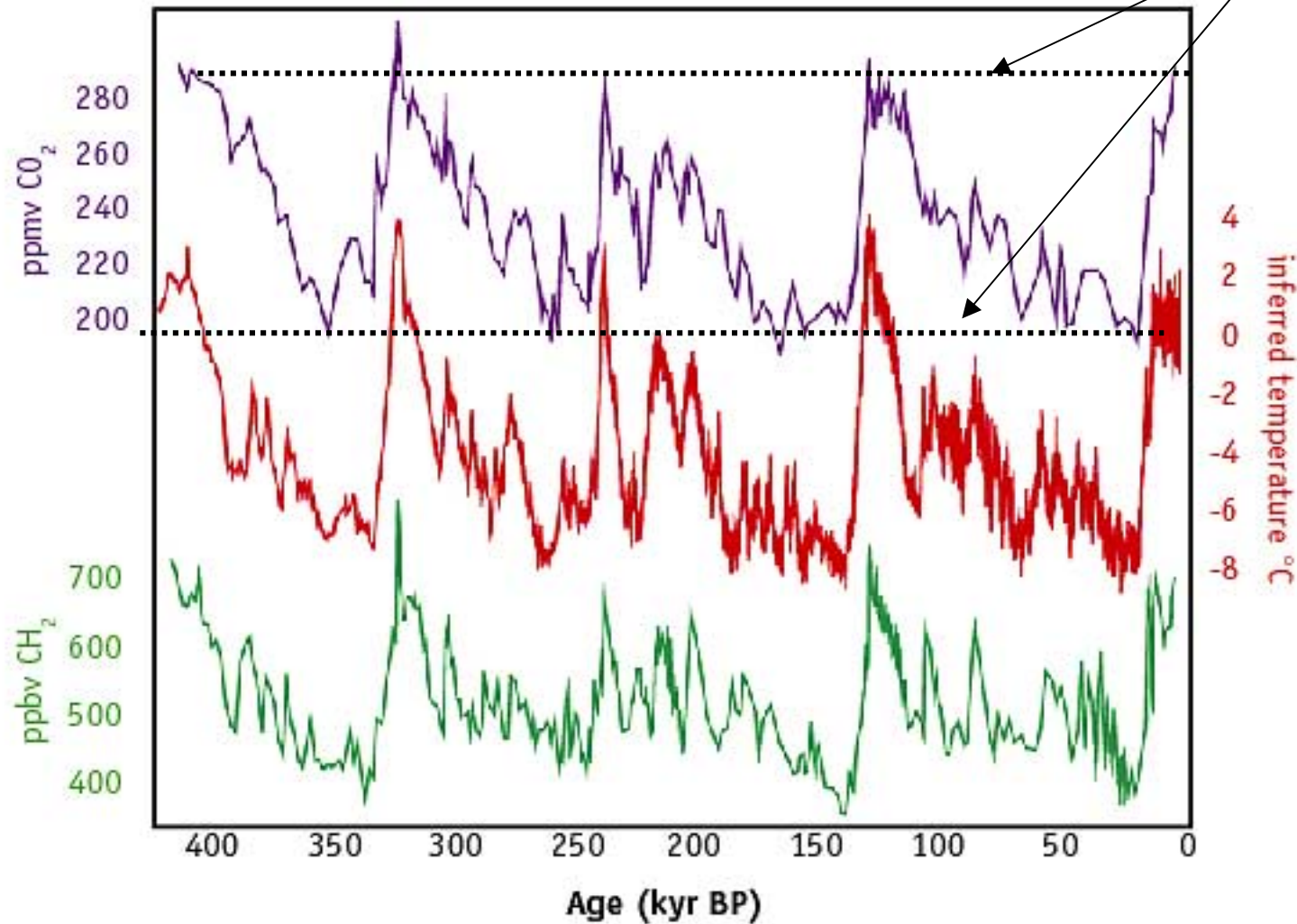


**SAILING INTO A SEA OF EXCITEMENT:
An Earth System Perspective on Marine
Research in the Next Decade**

**Will Steffen
Executive Director, IGBP
Royal Swedish Academy of Sciences
Stockholm**

4 glacial cycles recorded in the Vostok ice core

Set points at ca. 200 & 290 ppm



J.R. Petit et al., *Nature*, **399**, 429–36, 1999.

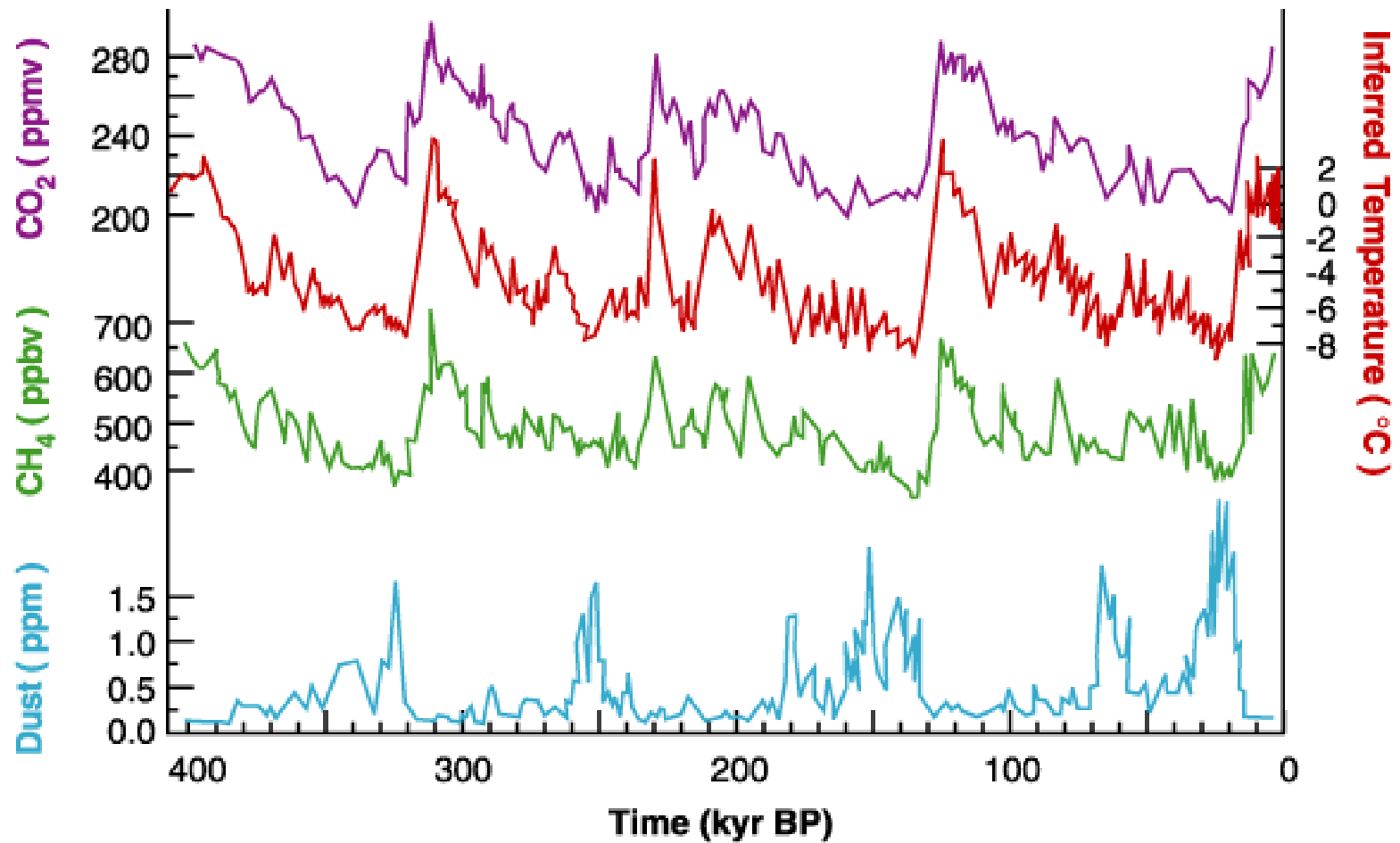
The Vostok Challenge

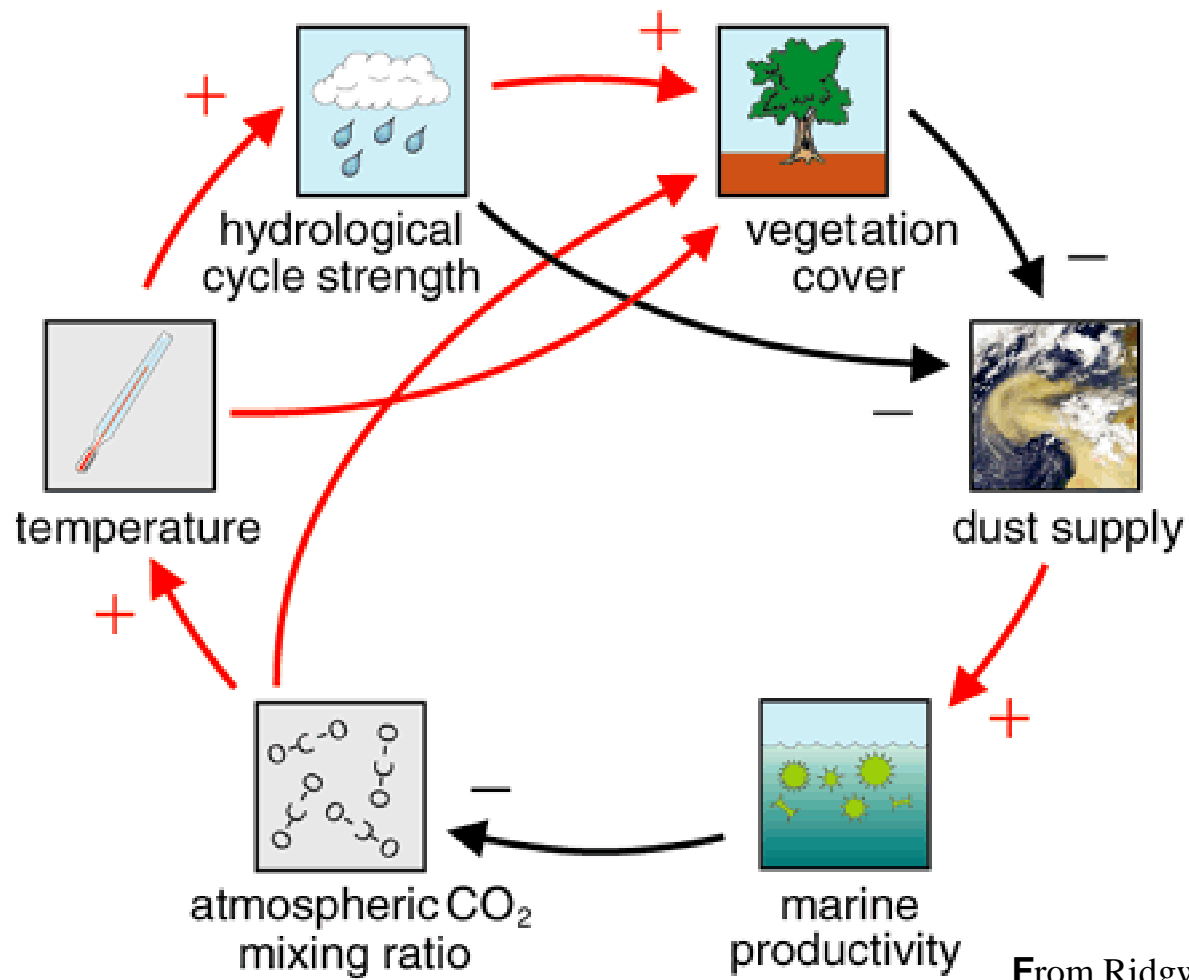
What are the forcings and feedbacks that move the Earth System between glacial and interglacial states?
What are the important marine processes in these forcings and feedbacks?

What is the role of the ocean in controlling the set points?

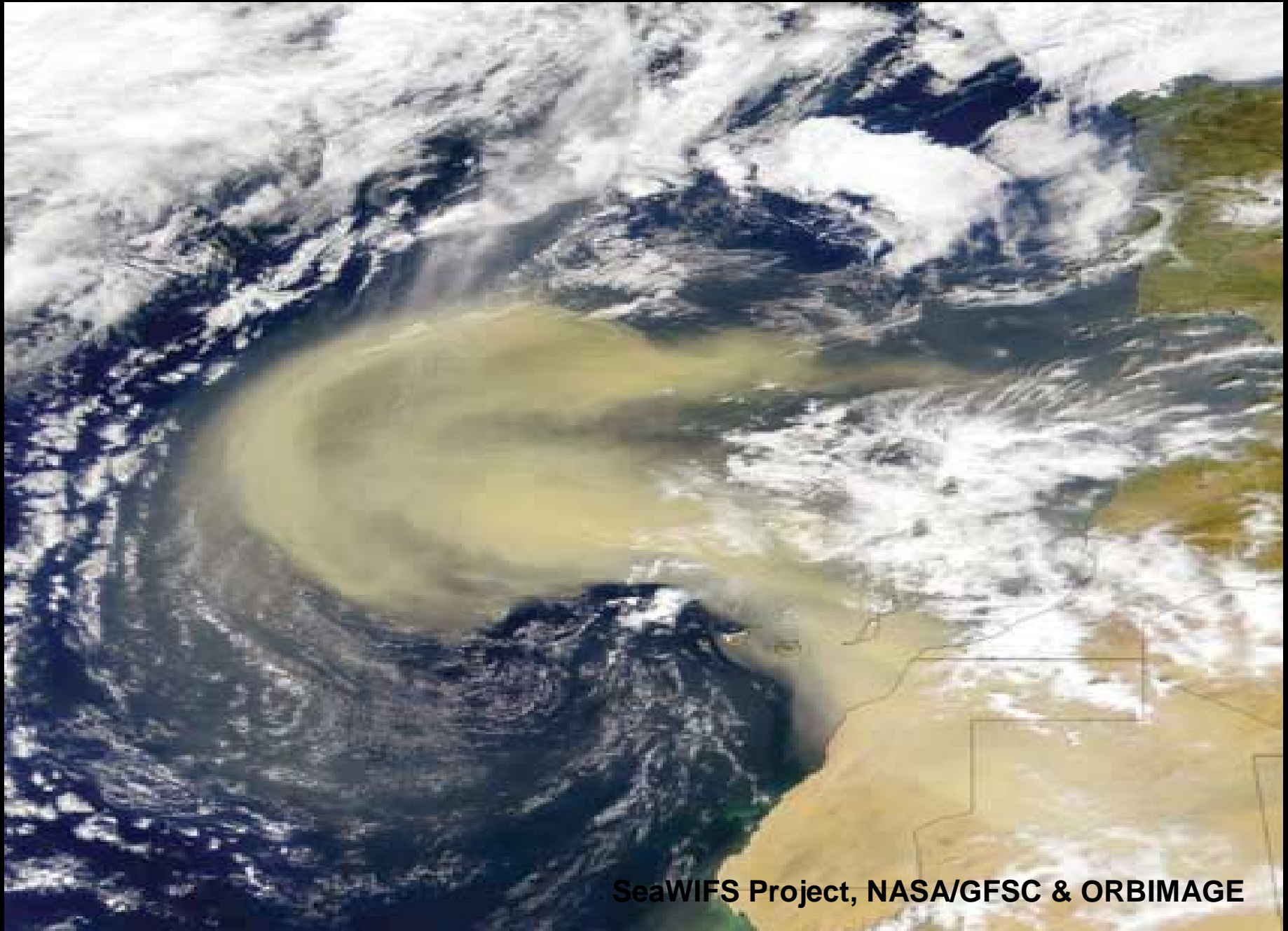
How important is marine biology in the self-regulation of the Earth System as seen in the Vostok record?

J.R. Petit et al., Nature, **399**, 429-436 (1999)

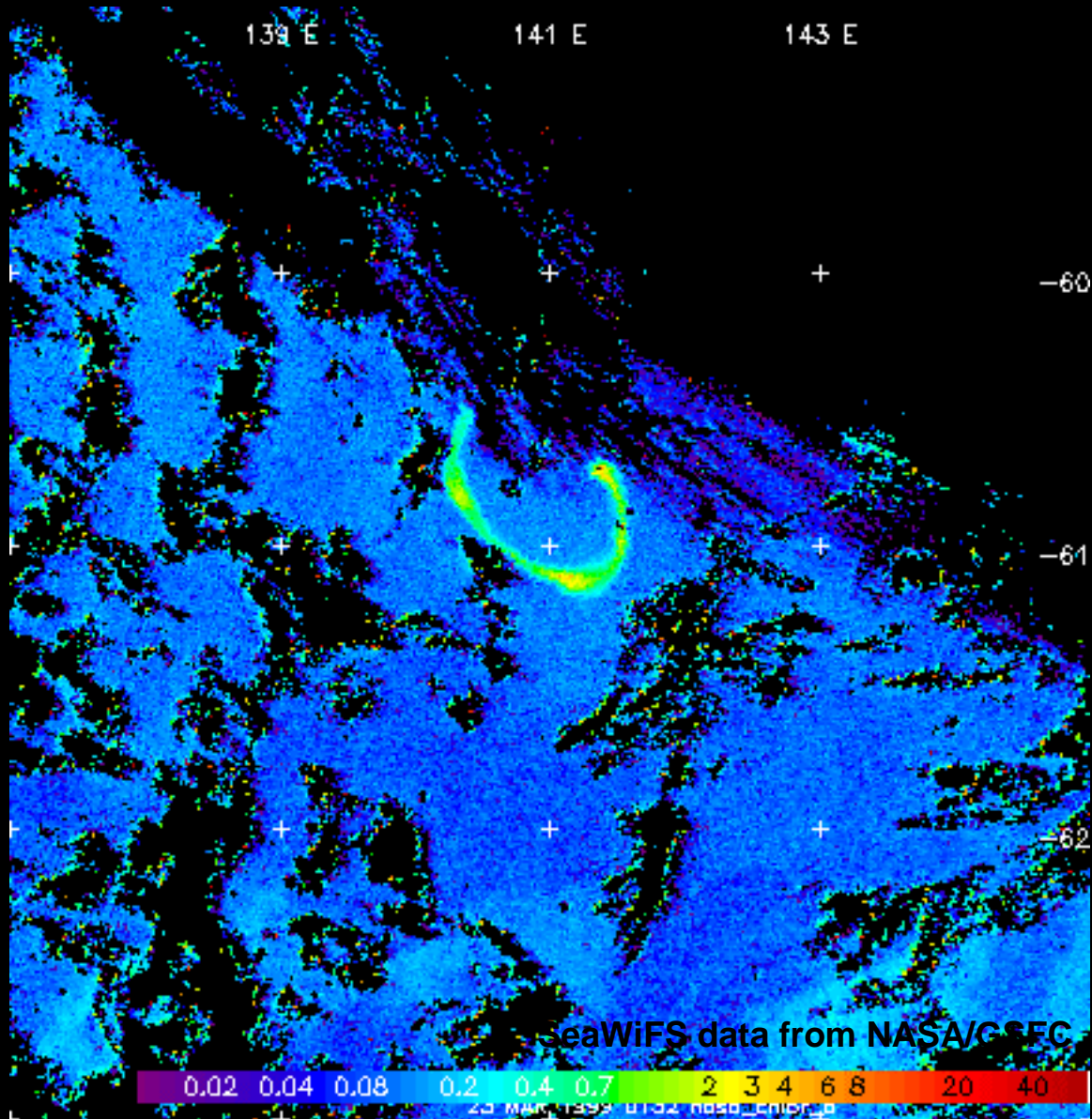


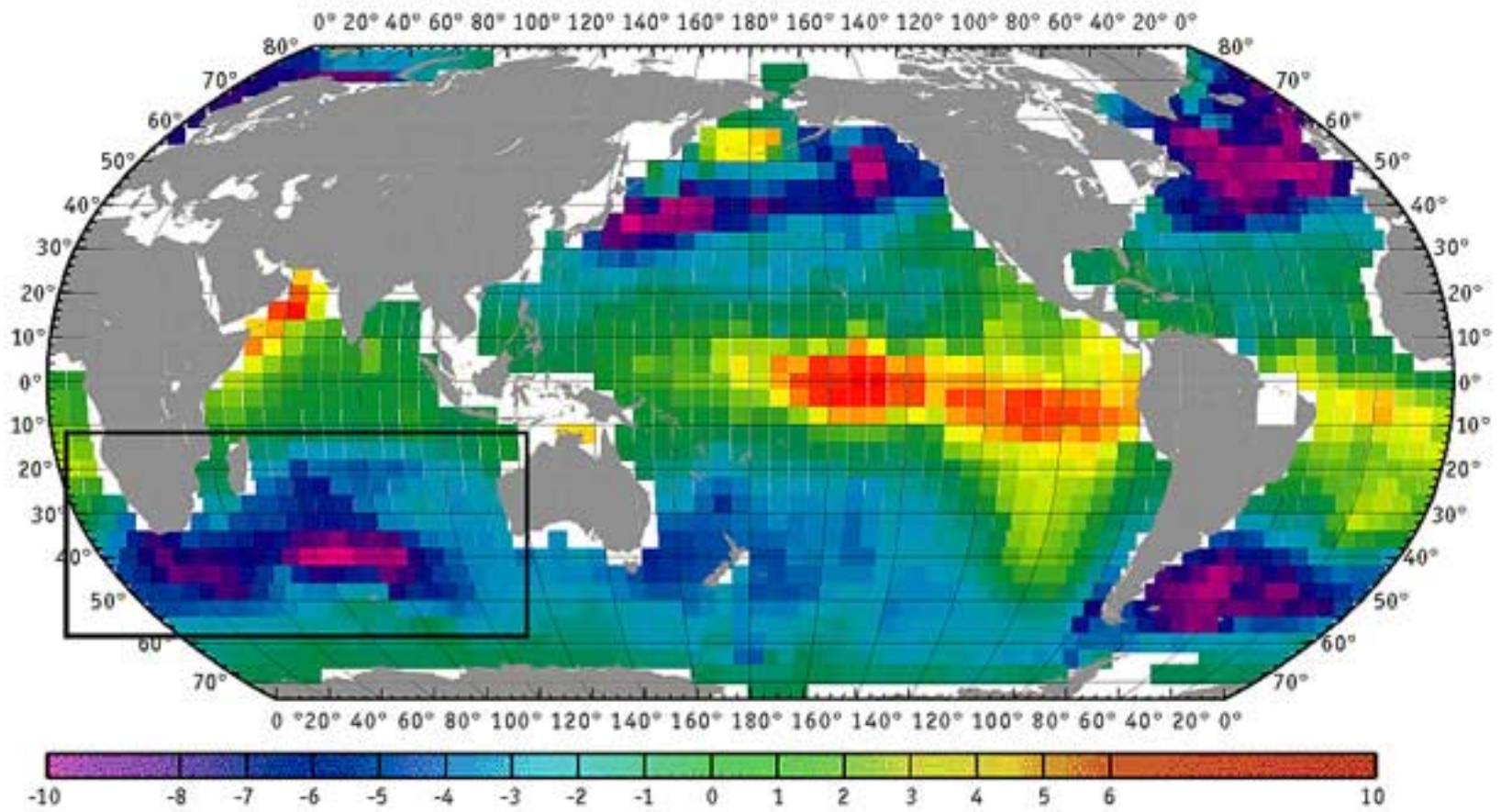


From Ridgwell
2002



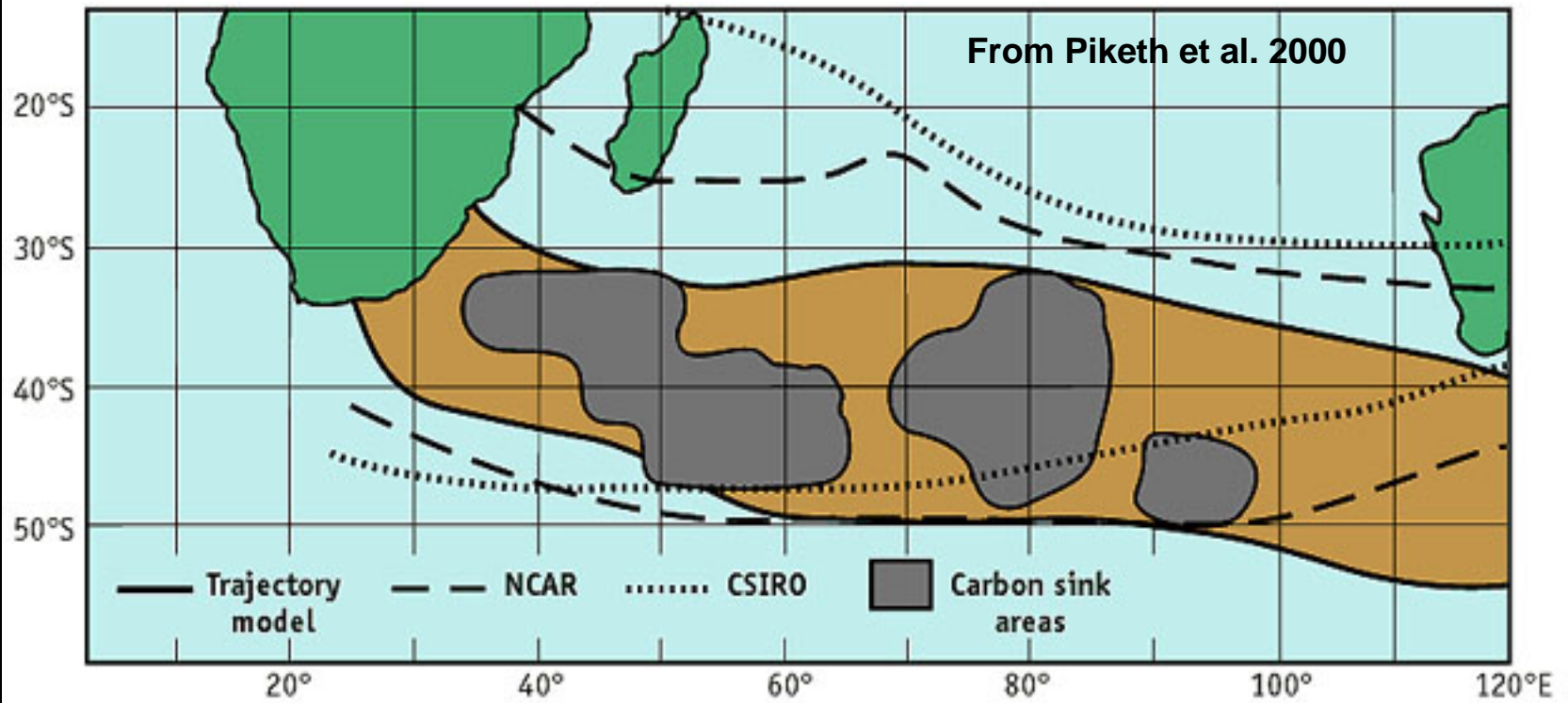
SeaWiFS Project, NASA/GFSC & ORBIMAGE

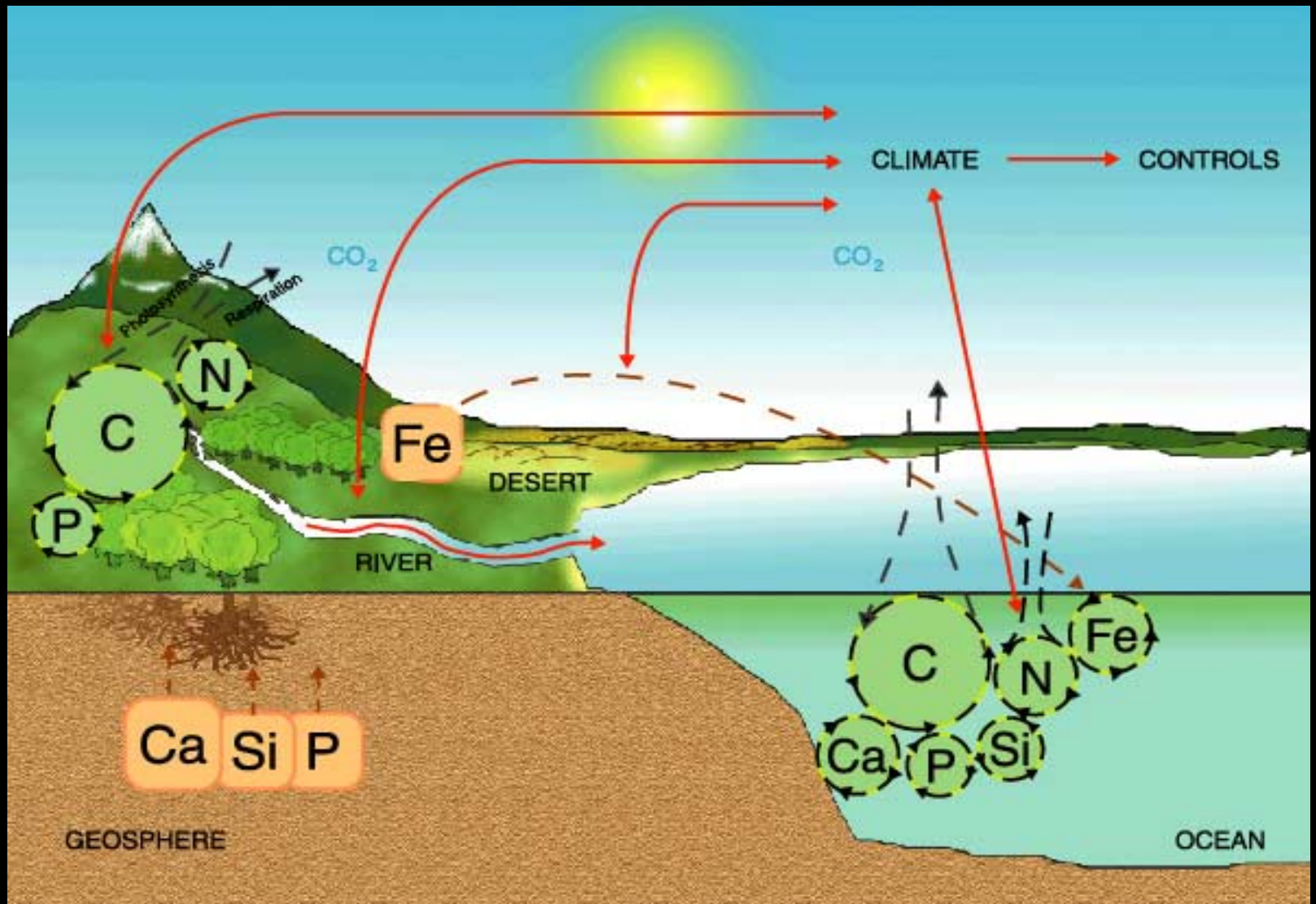




From Takahashi et al. 1997

From Piketh et al. 2000



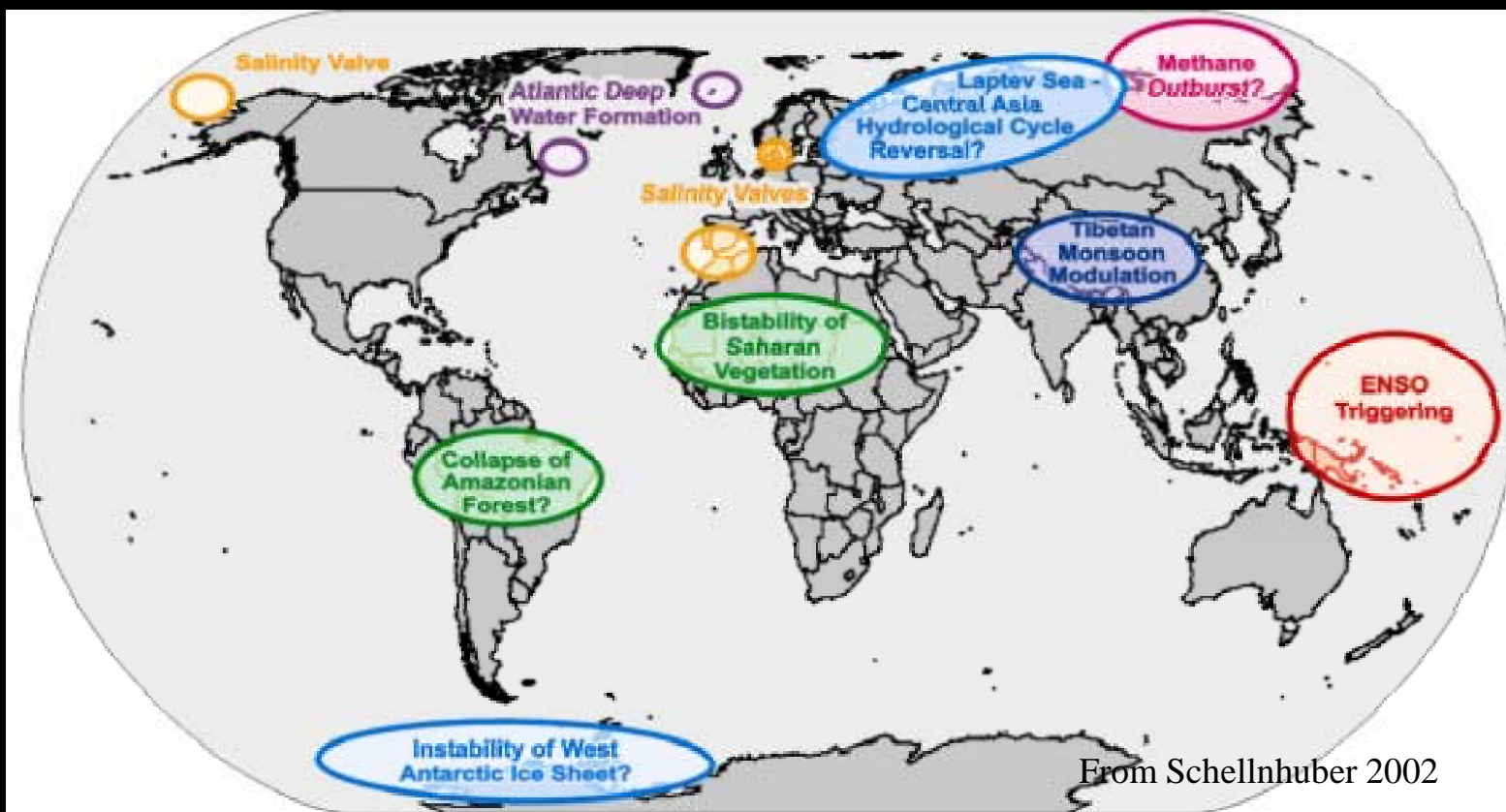


The Role of the Ocean in the Planetary Machinery

How important is marine biology in the functioning of the Earth System?

How important is the complexity of marine ecosystems? Of higher trophic levels in food webs?

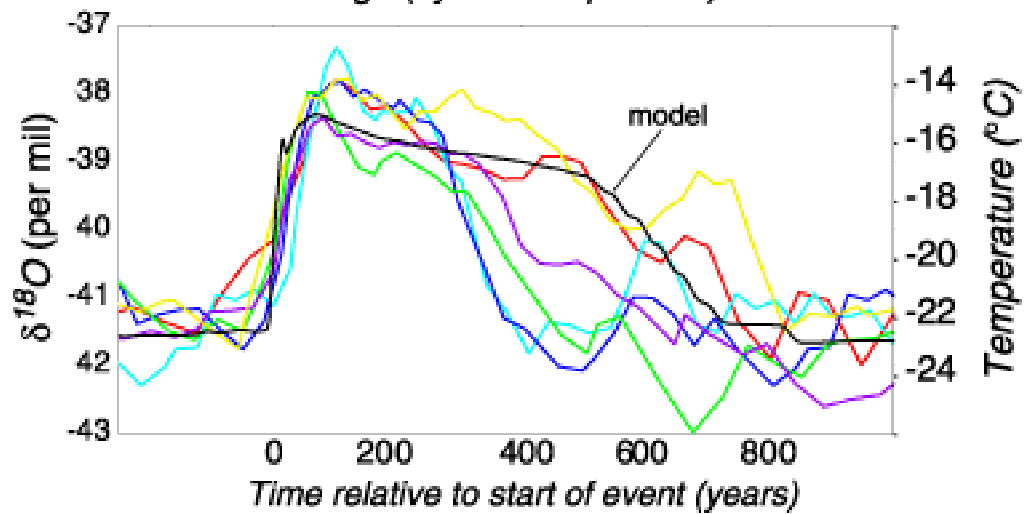
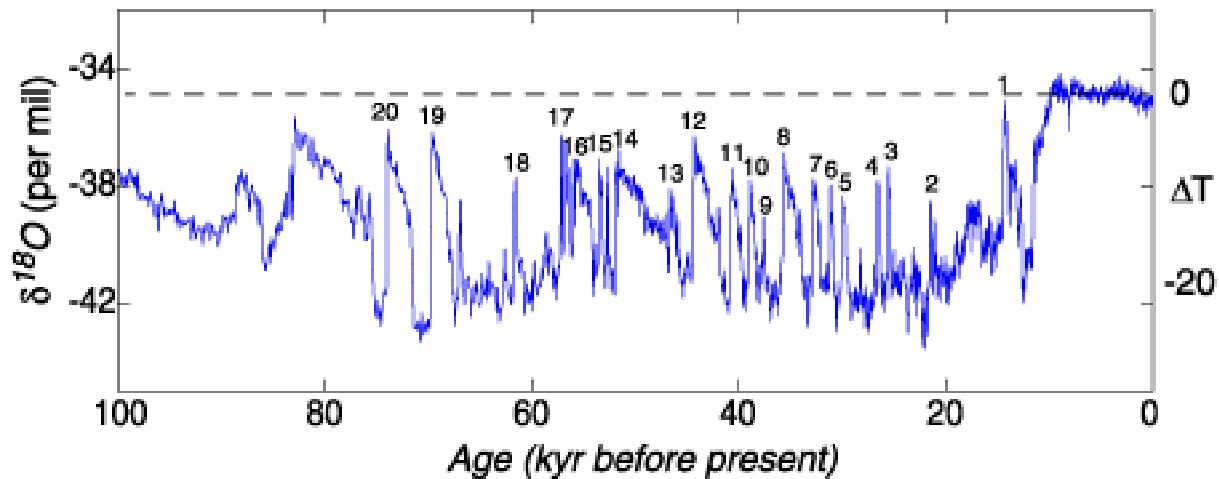
How critical is the linkage between land and ocean in the functioning of the Earth System?



From Schellnhuber 2002

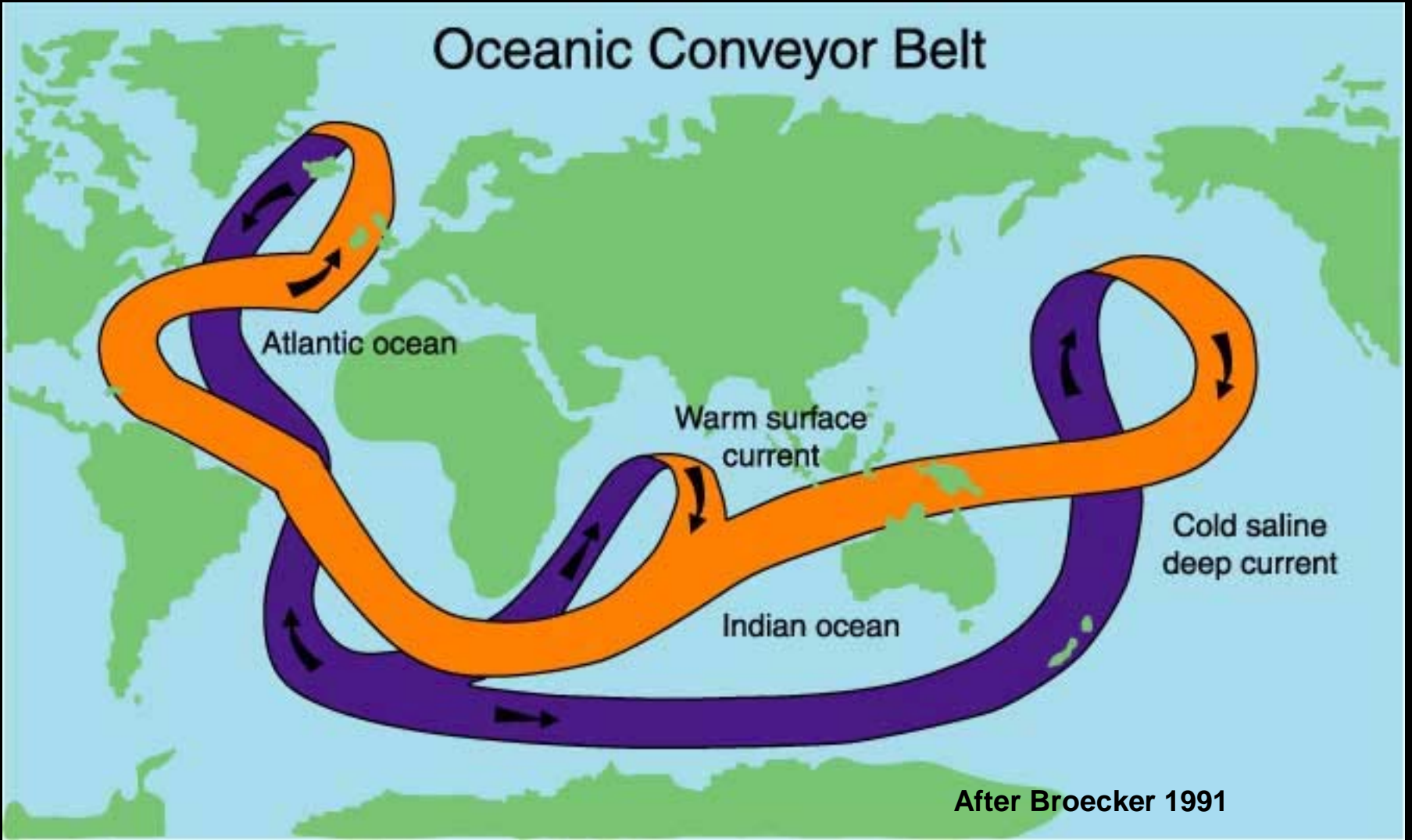
Abrupt Changes?

Records from the past have shown us that the Earth System is capable of abrupt changes that could devastate modern civilisations. For example, the mean temperature in the North Atlantic region has changed by 10 deg C in a decade. Could such changes happen again? Could global change act as a trigger for such changes? Are human pressures on the Earth System pushing the System towards or away from these changes?

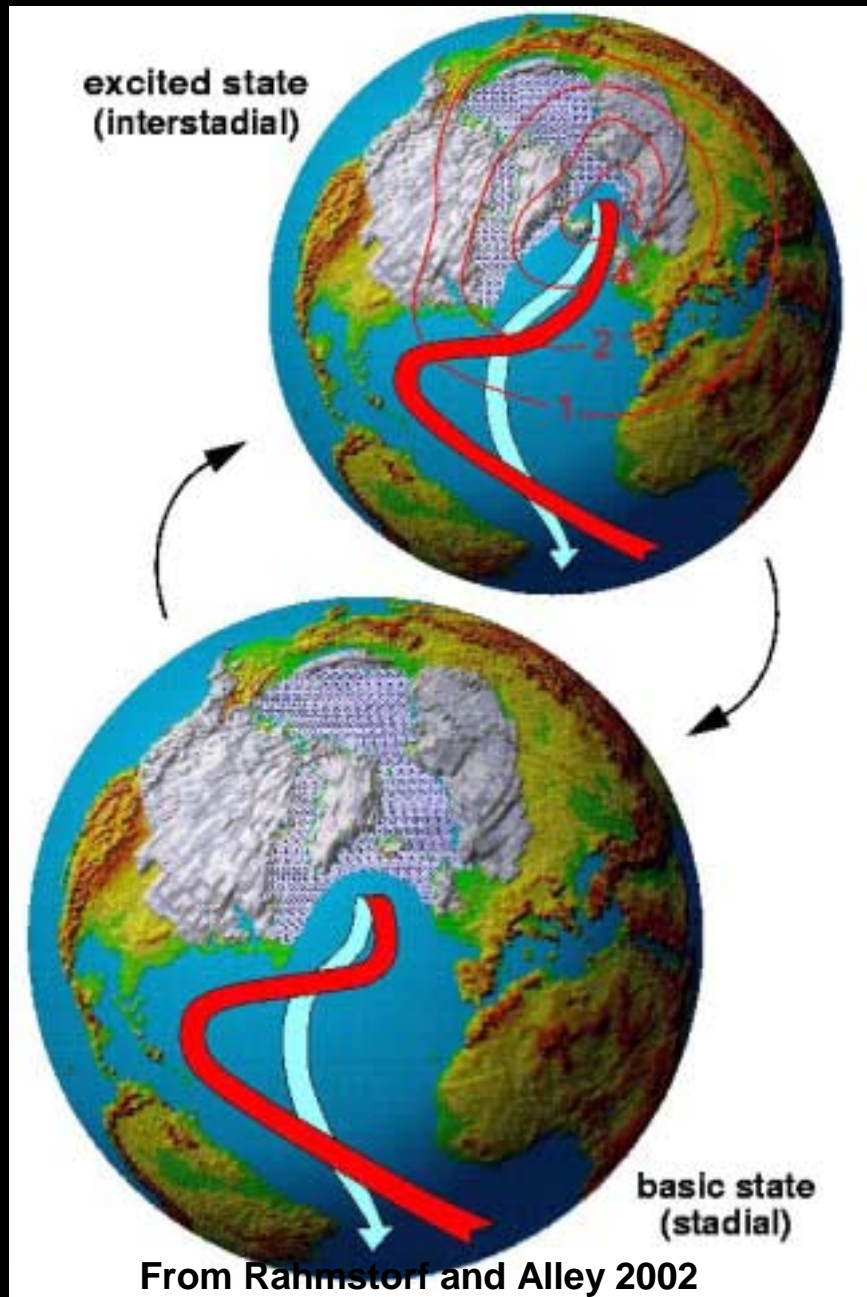


From Rahmstorf and Alley 2002

Oceanic Conveyor Belt

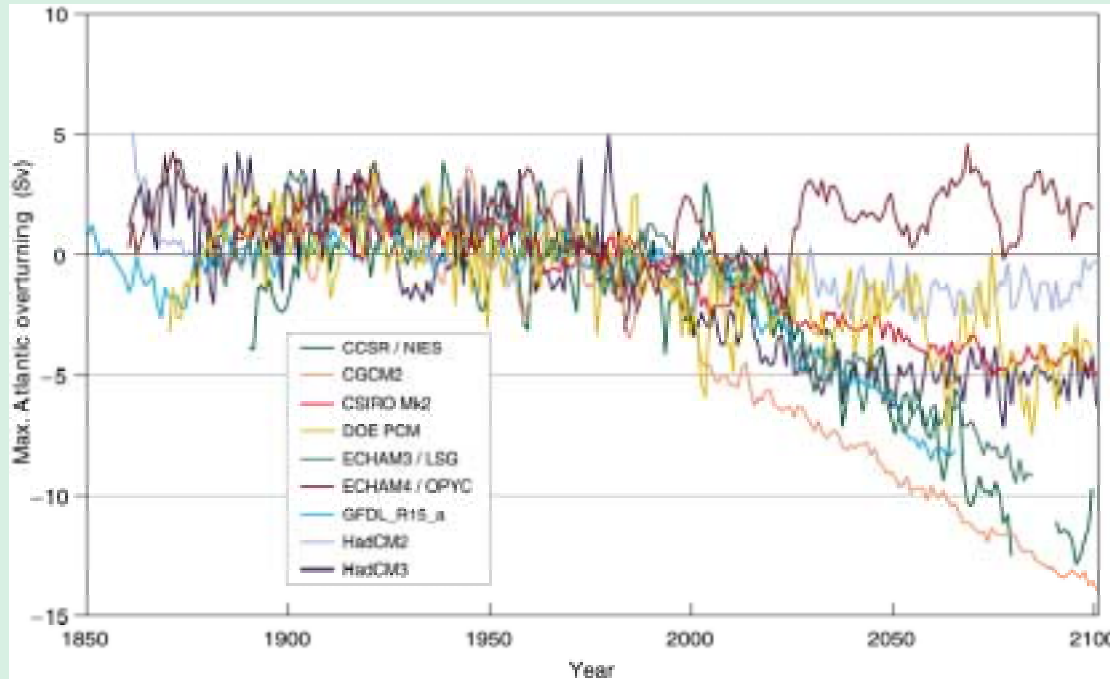


After Broecker 1991



From Rahmstorf and Alley 2002

Change in the strength of the North Atlantic meridional overturning circulation (svds) in a number of simulations with increases in greenhouse gases

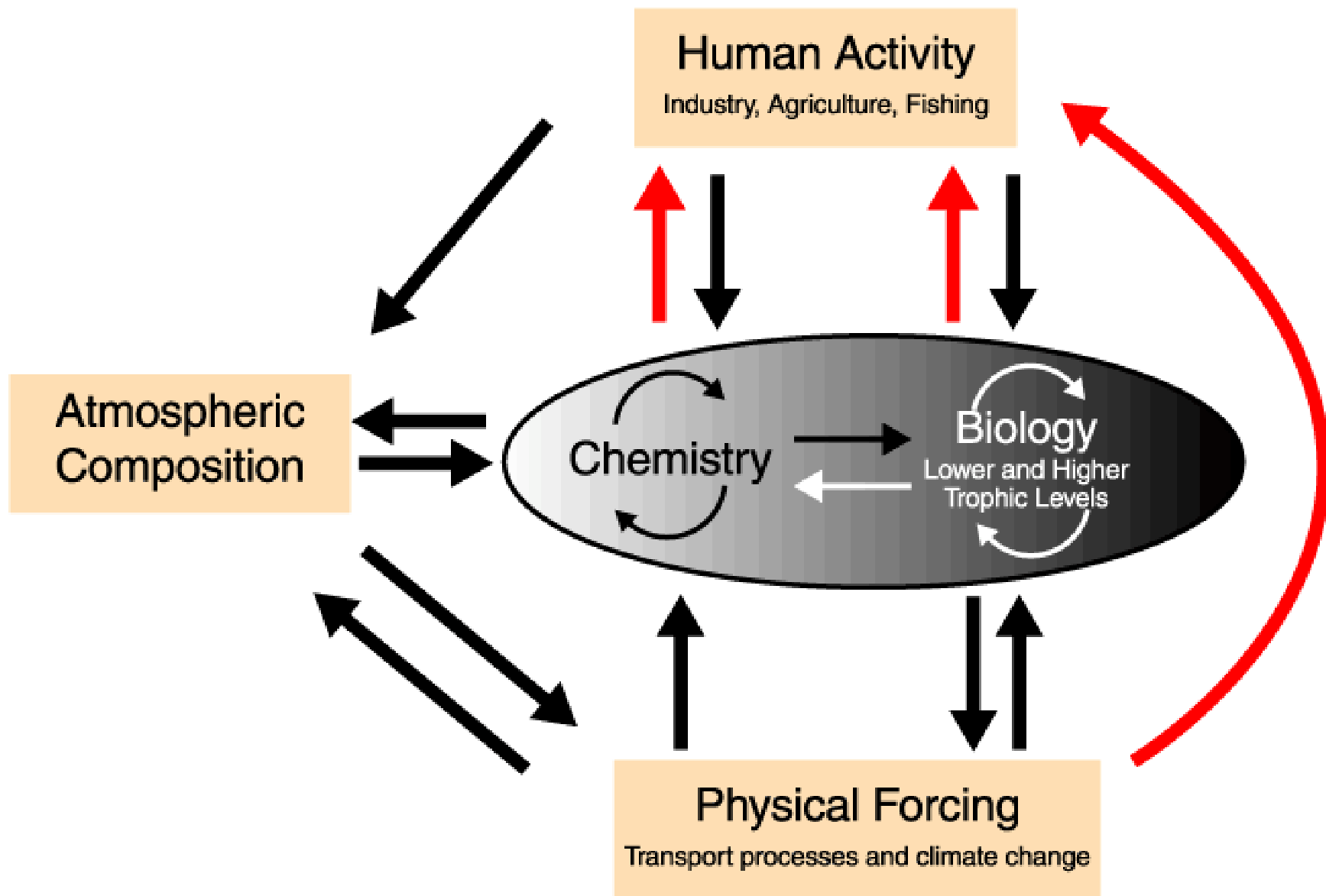


Source: Cubasch et al. 2001

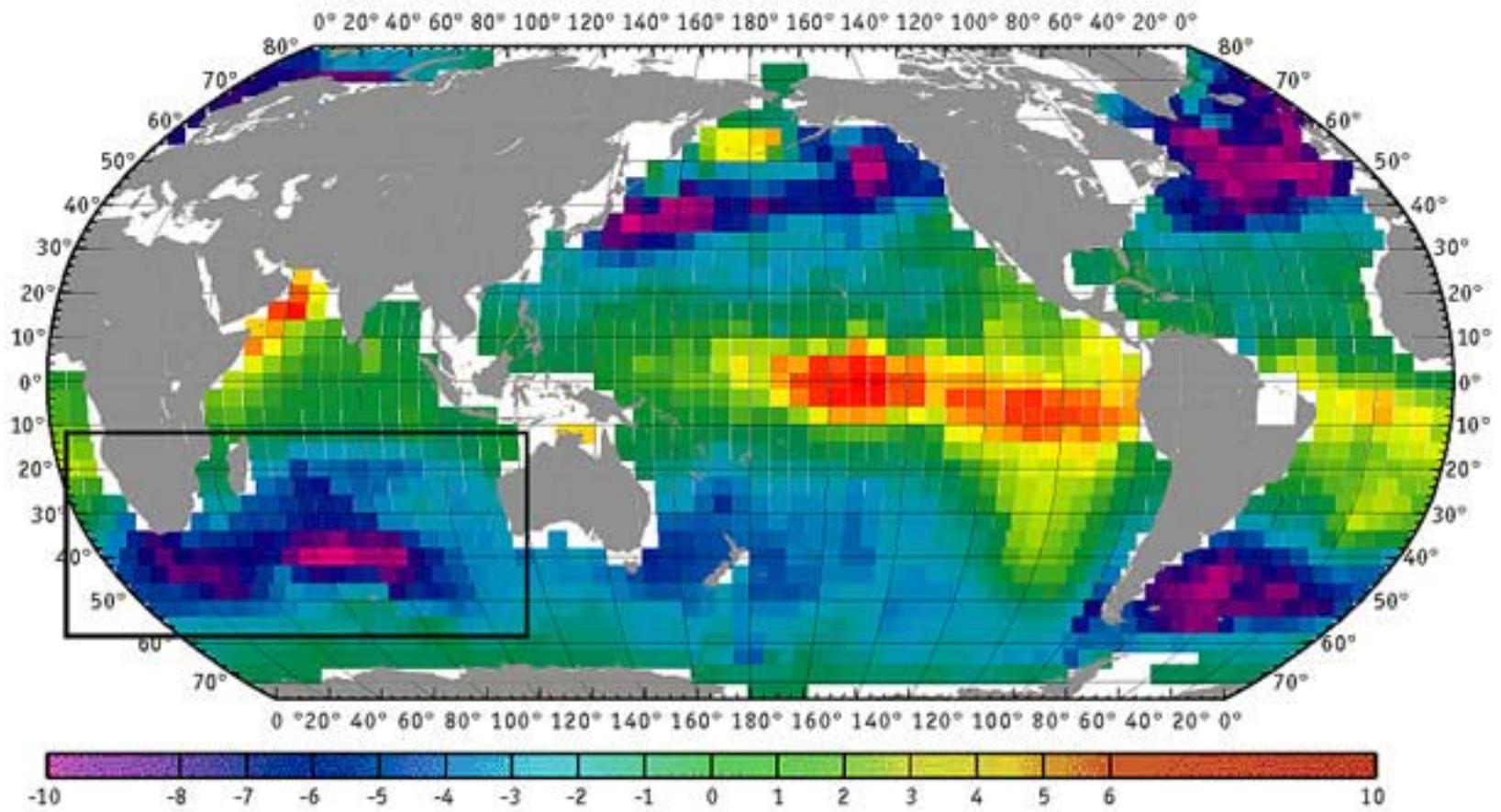
Atlantic Thermohaline Circulation:

Abrupt Changes: Future Surprises?

- the Atlantic THC can have multiple equilibria which implies thresholds
- reorganisations of the THC can be triggered by changes in the surface heat and freshwater fluxes
- most models indicate a weakening of the THC in the next 100 years. This implies an approach towards possible thresholds
- crossing of thresholds and associated irreversible changes of ocean circulation *cannot be excluded* within the range of projected climate changes of the next century.



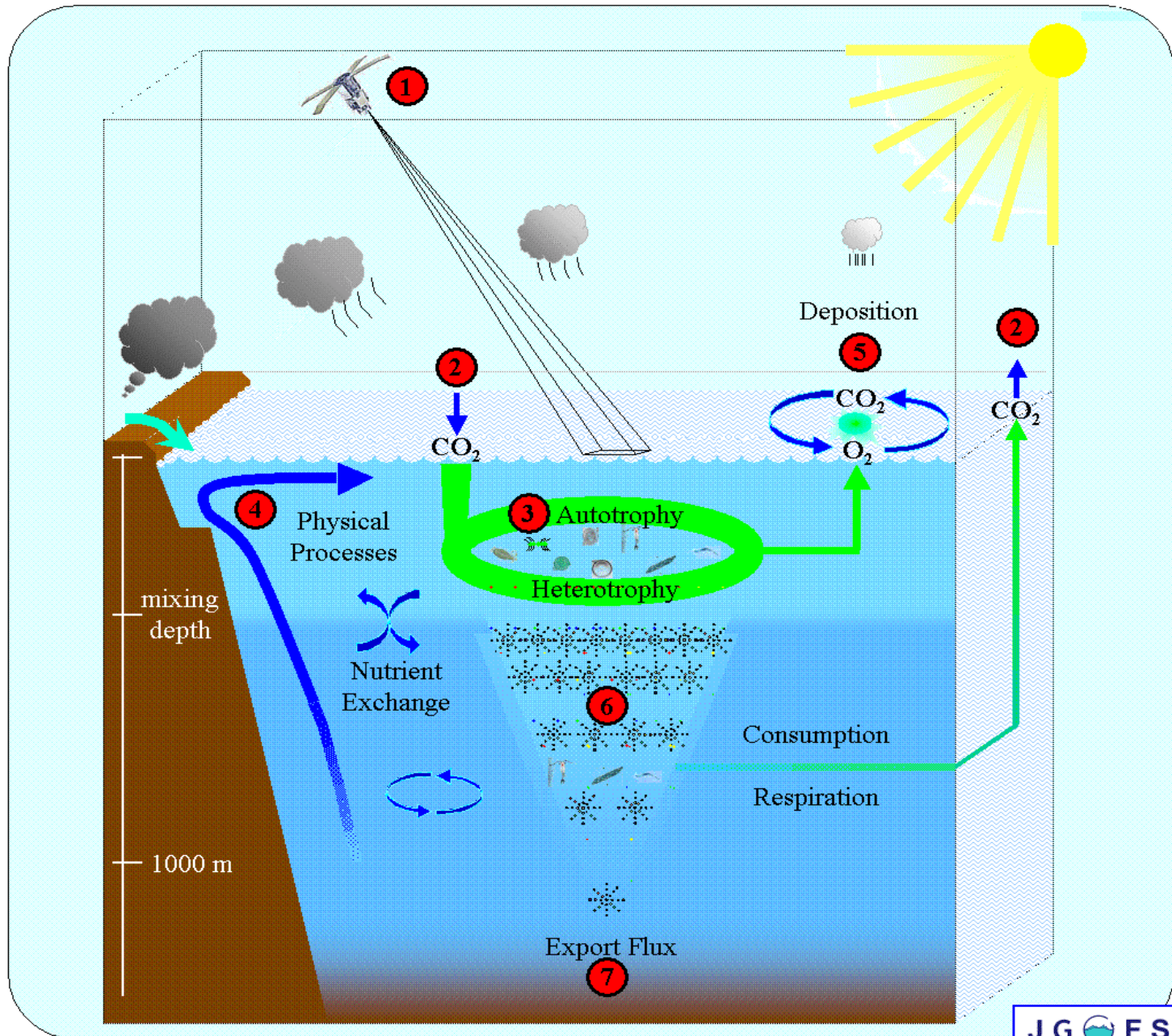
Source: K. Lochte, IGBP/SCOR Ocean Futures Document

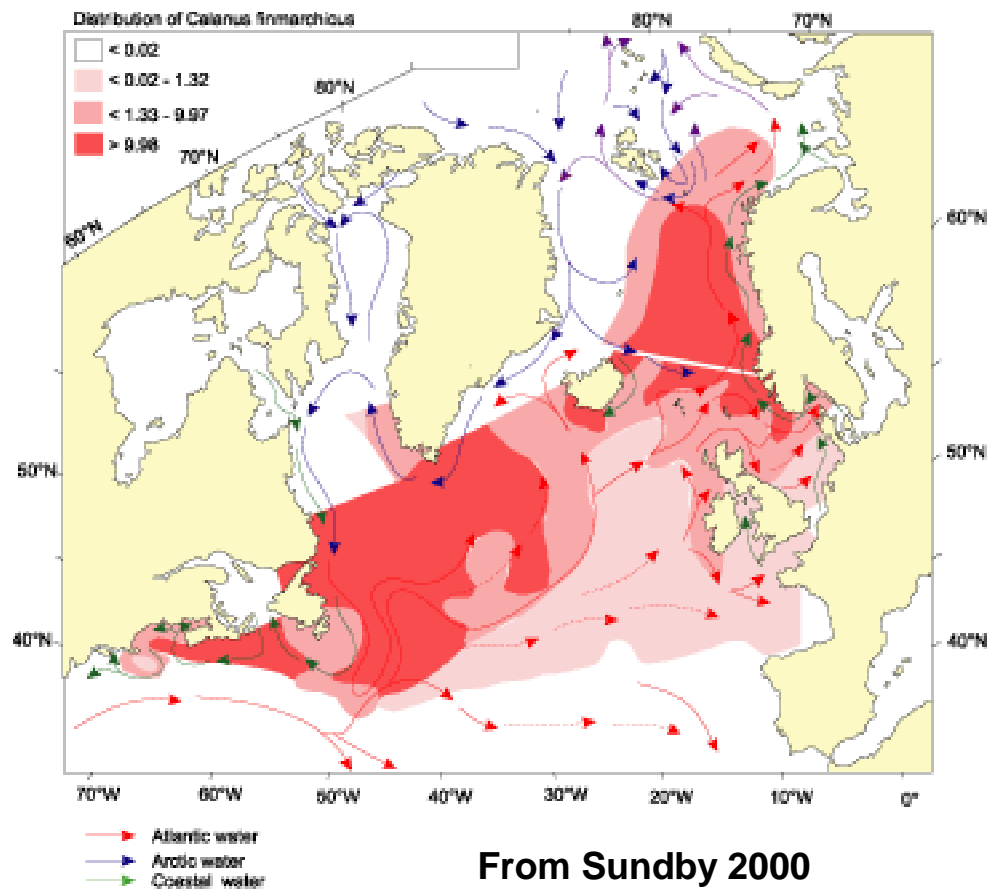


Net Flux (10¹² grams C y⁻¹ in each 4° x 5° area)

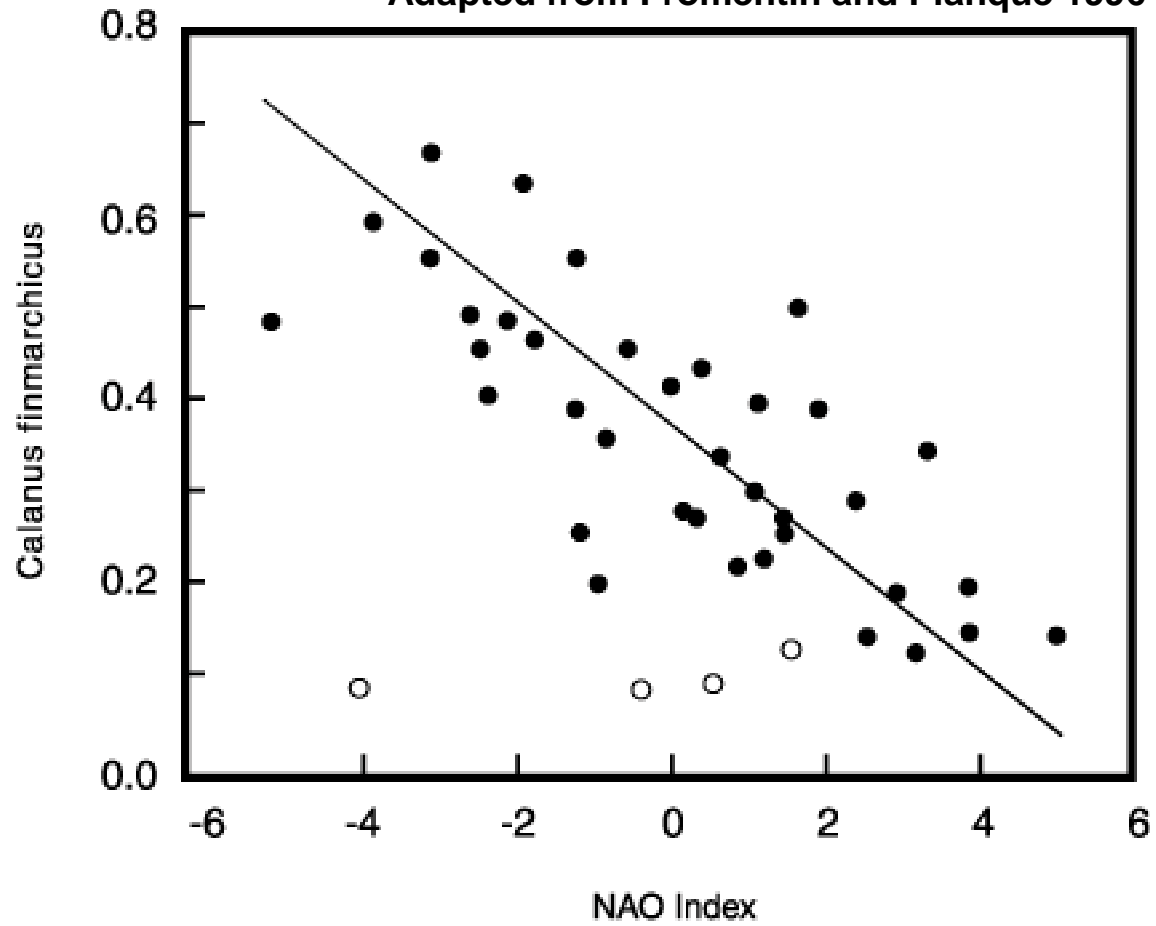
From Takahashi et al. 1997

Biological Carbon Pump in the Oceans





Adapted from Fromentin and Planque 1996



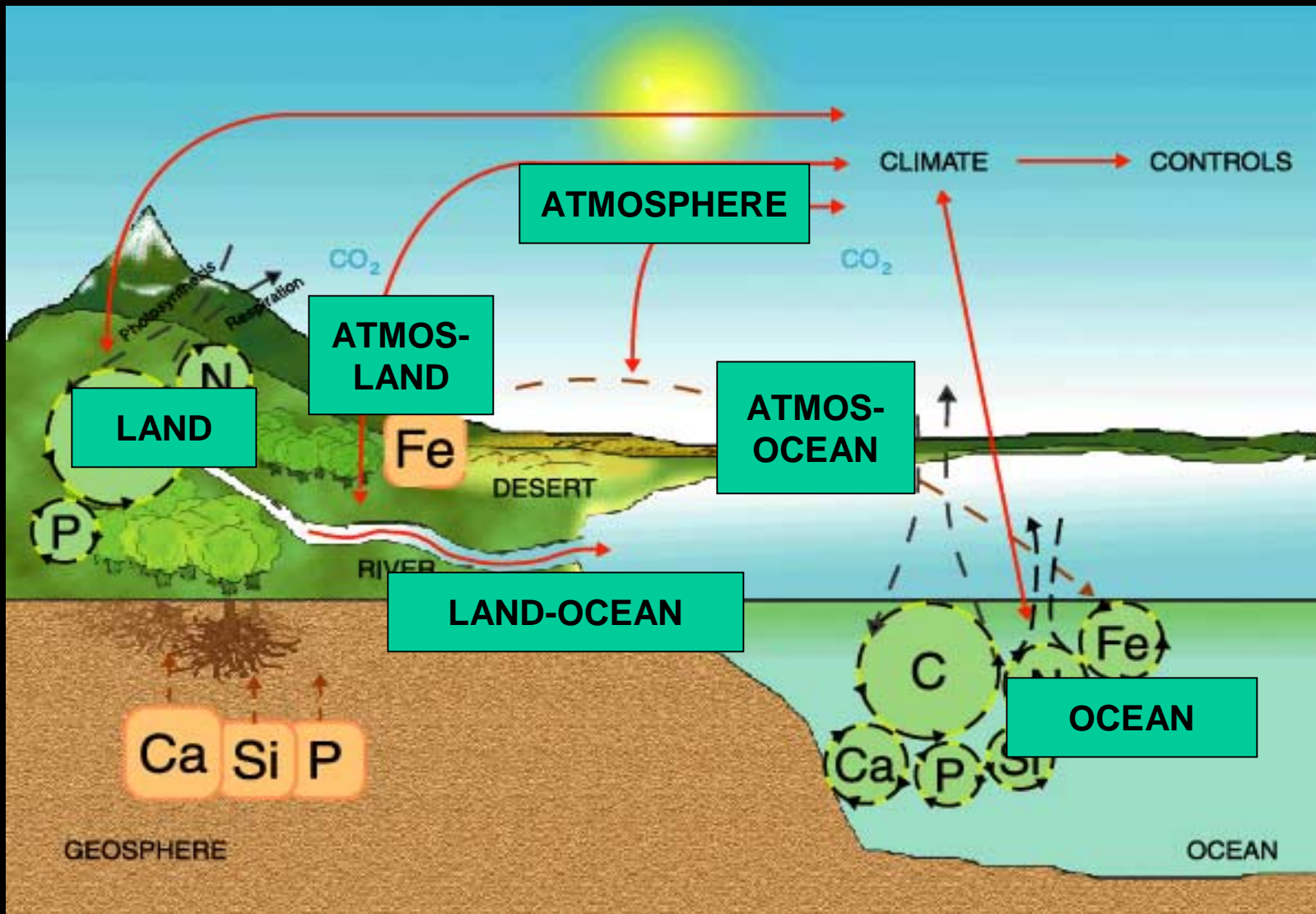
Ocean Dynamics, Thresholds, Regime Shifts and Abrupt Changes

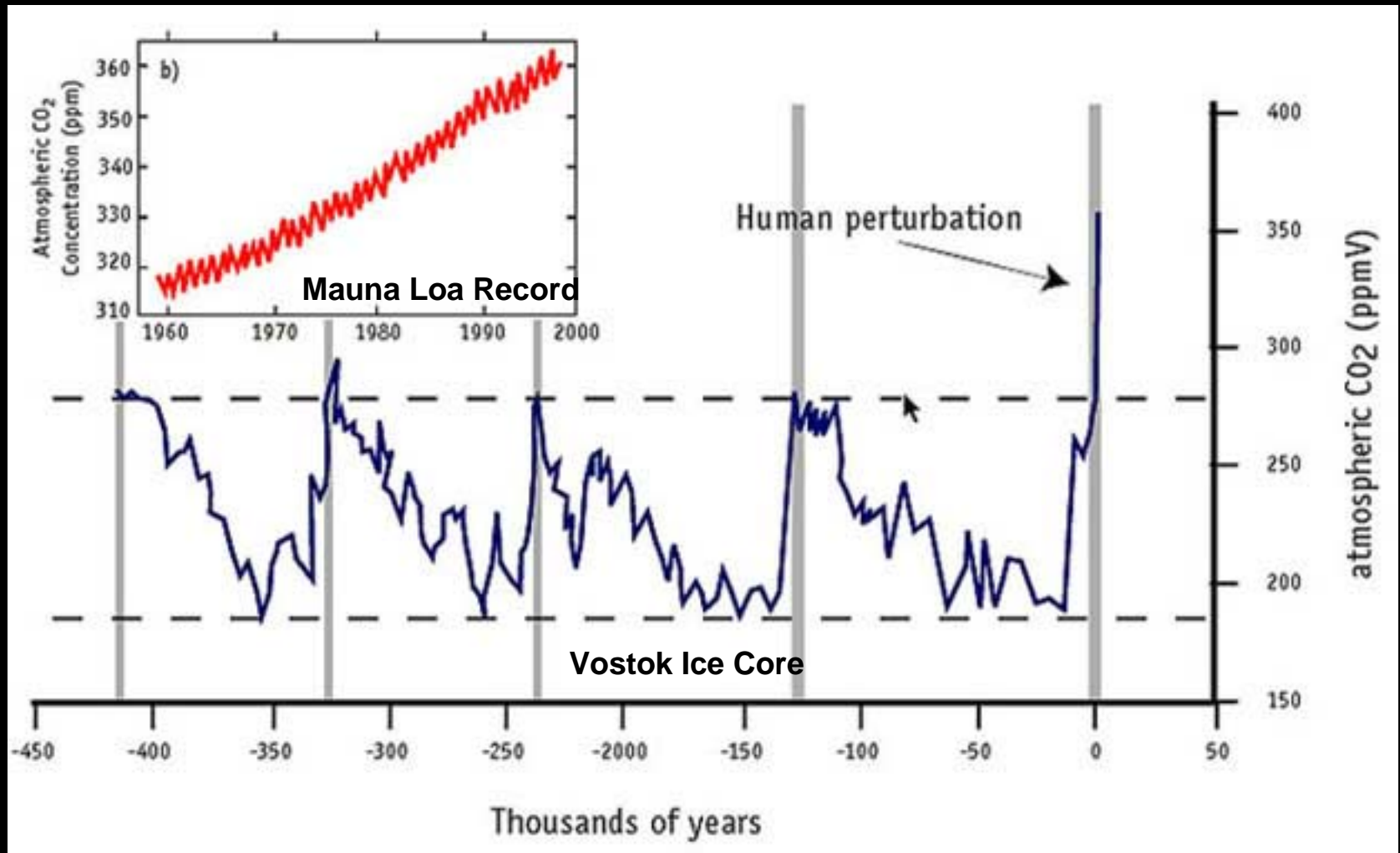
What are the critical thresholds and switches in the ocean?

How are abrupt changes and regime shifts in one aspect of Ocean dynamics processed through the entire physical-Chemical-biological system?

What are the best techniques for analysing and predicting Abrupt changes and regime shifts?

Adapted from the GAIM 'Earth System Questions'







1100
IPCC 2000
Scenarios
for 2100 AD

3700

450

Today

1600

ppbv CH₄

1200

800

400

Vostok Ice Core

ppmv CO₂

360

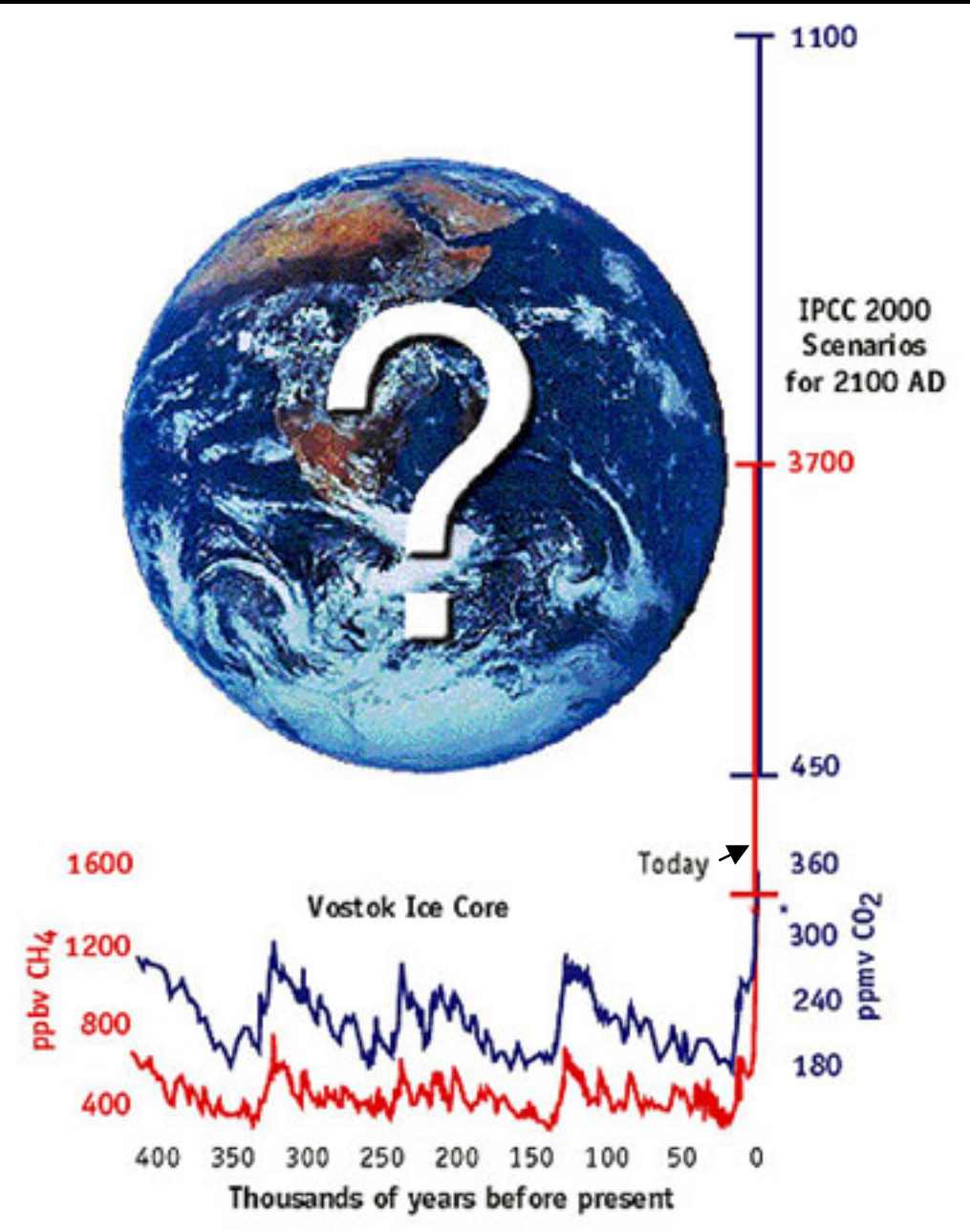
300

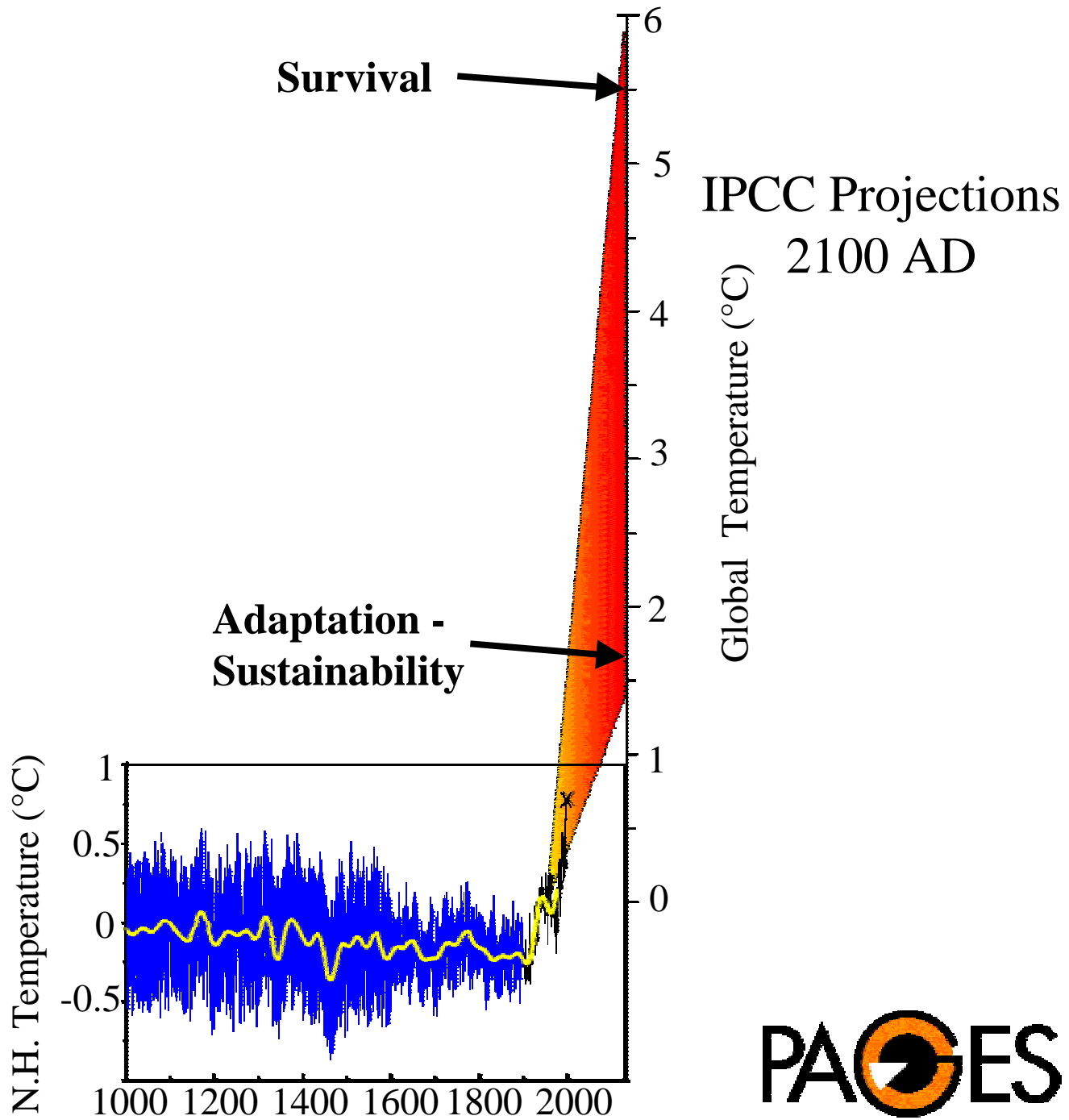
240

180

400 350 300 250 200 150 100 50 0

Thousands of years before present





Ocean Dynamics and Global Change in the 21st Century

What and where are the vital aspects/components of marine biology and chemistry in terms of Earth System functioning?

What and where are the switch-points that can be triggered by direct human actions?

Will the ocean act as a brake on or an accelerator of global change in the 21st century?

