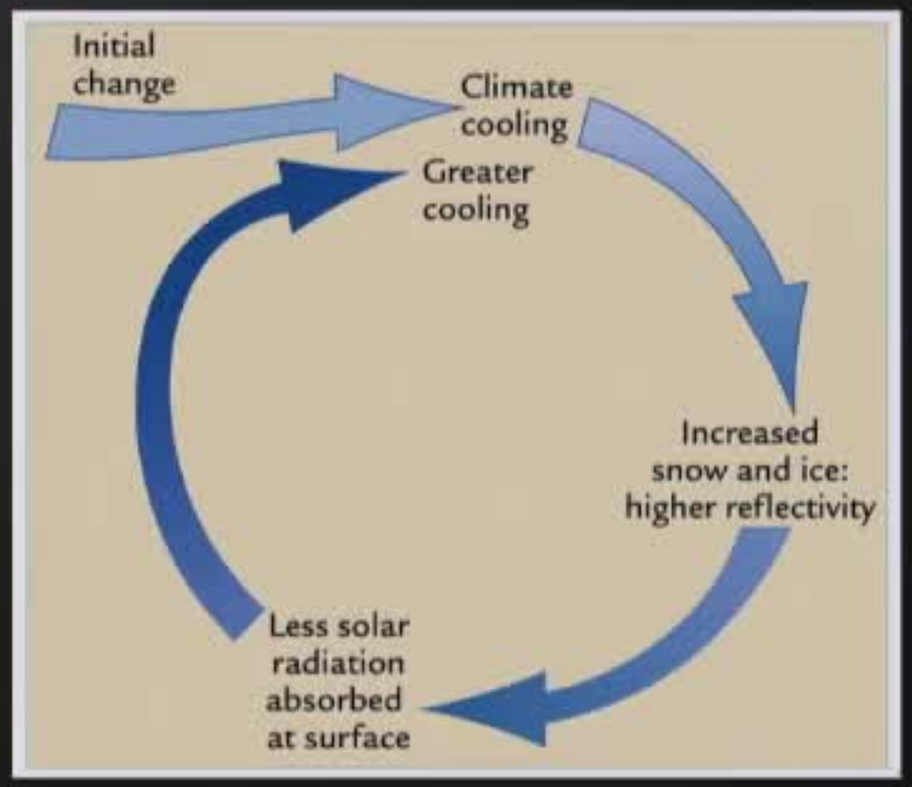
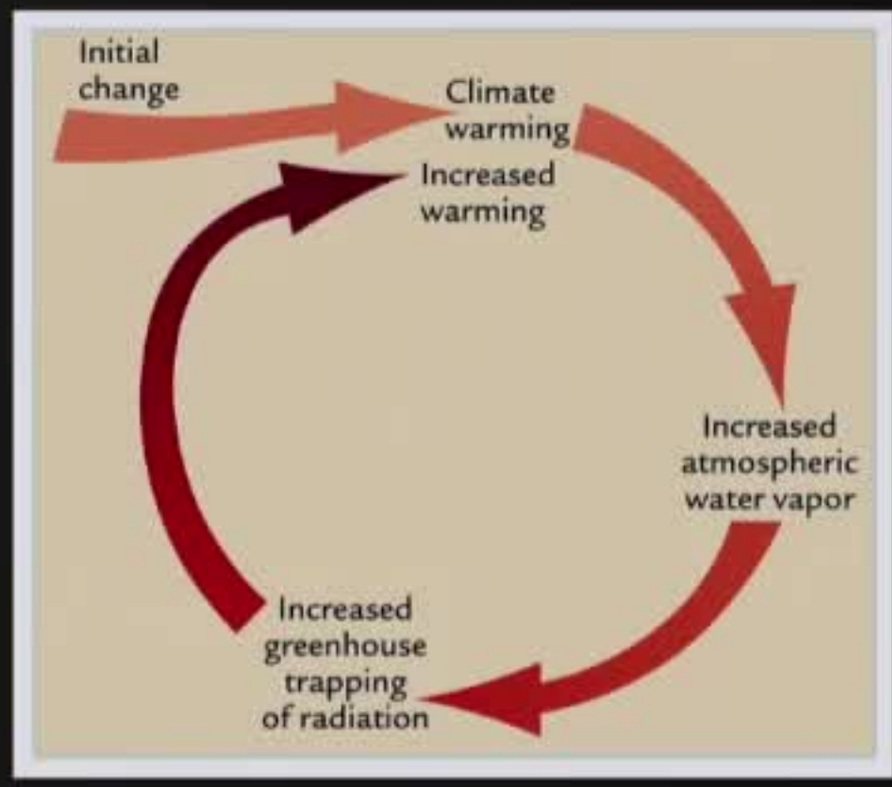
Climate System Feedbacks



ice-albedo feedback



water-vapor feedback

Henk A. Dijkstra
Institute for Marine and Atmospheric research Utrecht &
Center for Complex Systems Studies
Department of Physics, Utrecht University, NL

Frameworks of Climate System Variability

Mitchell (1976)

Background & (broad) peaks

Lovejoy & Schertzer (2013)

Scaling

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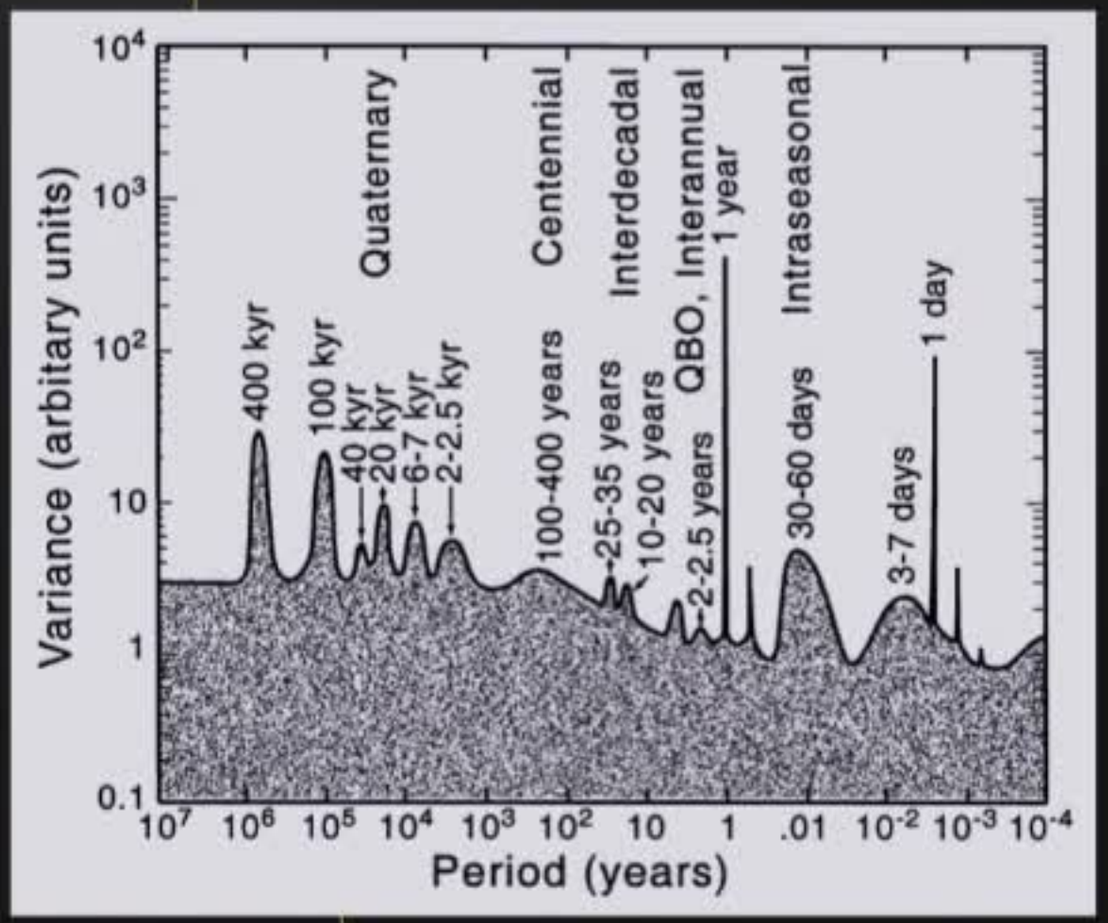

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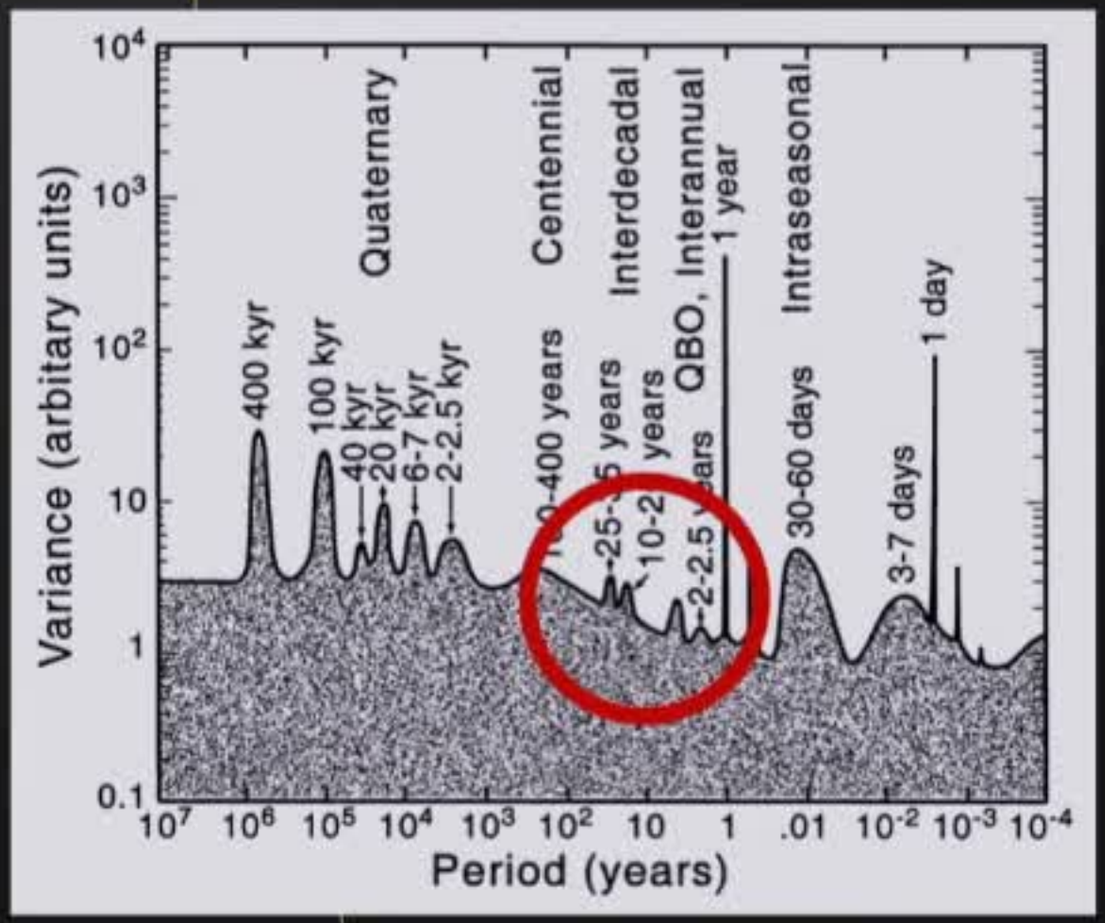

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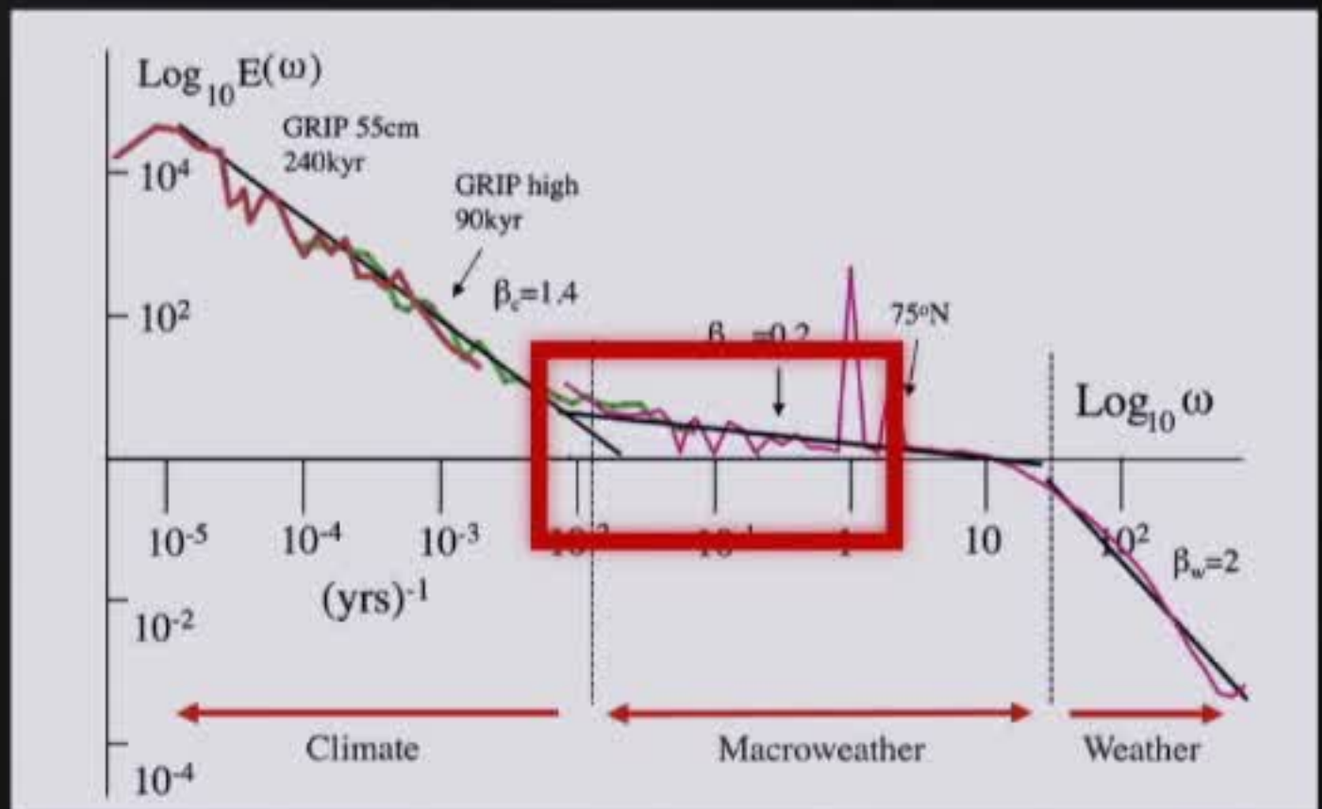

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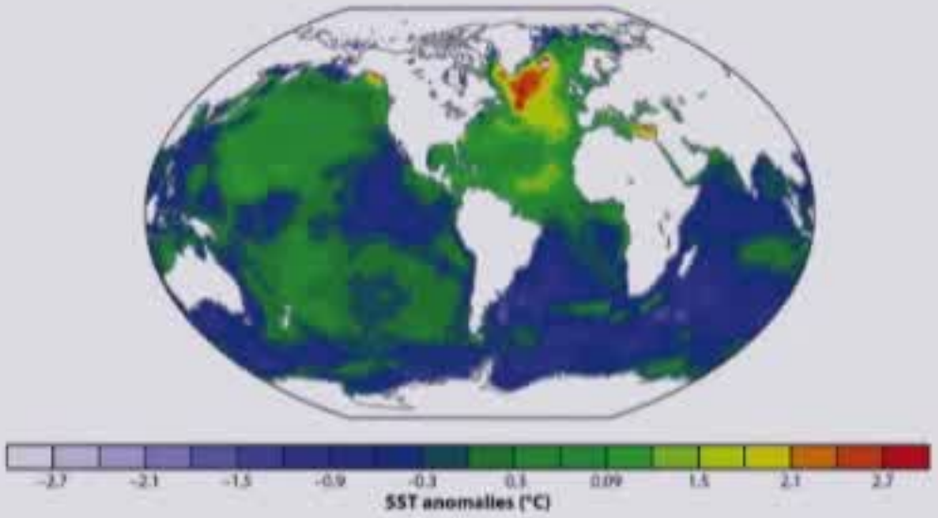
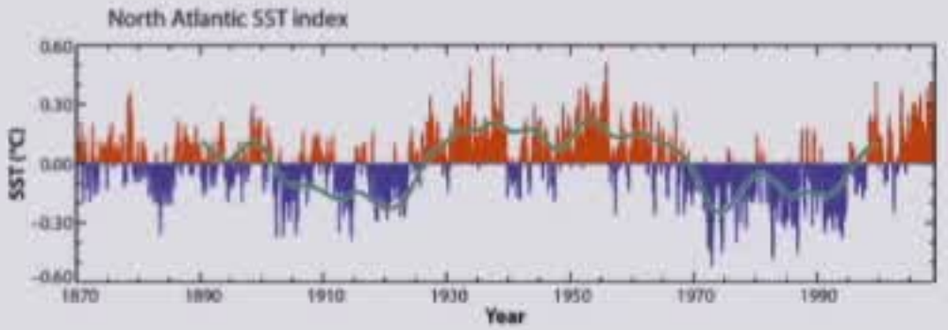
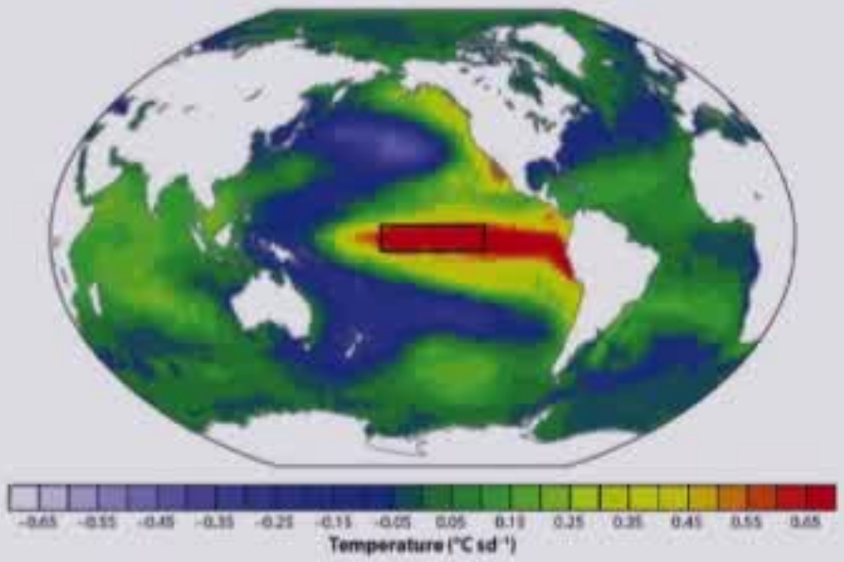
Patterns of SST variability

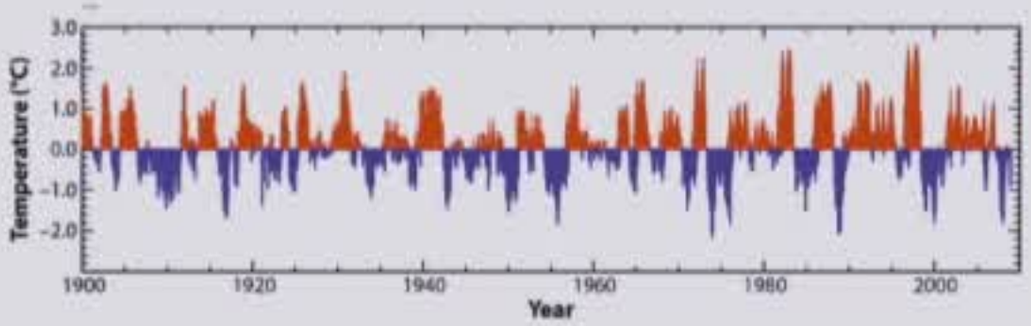
Atlantic Multi-decadal Oscillation (AMO)





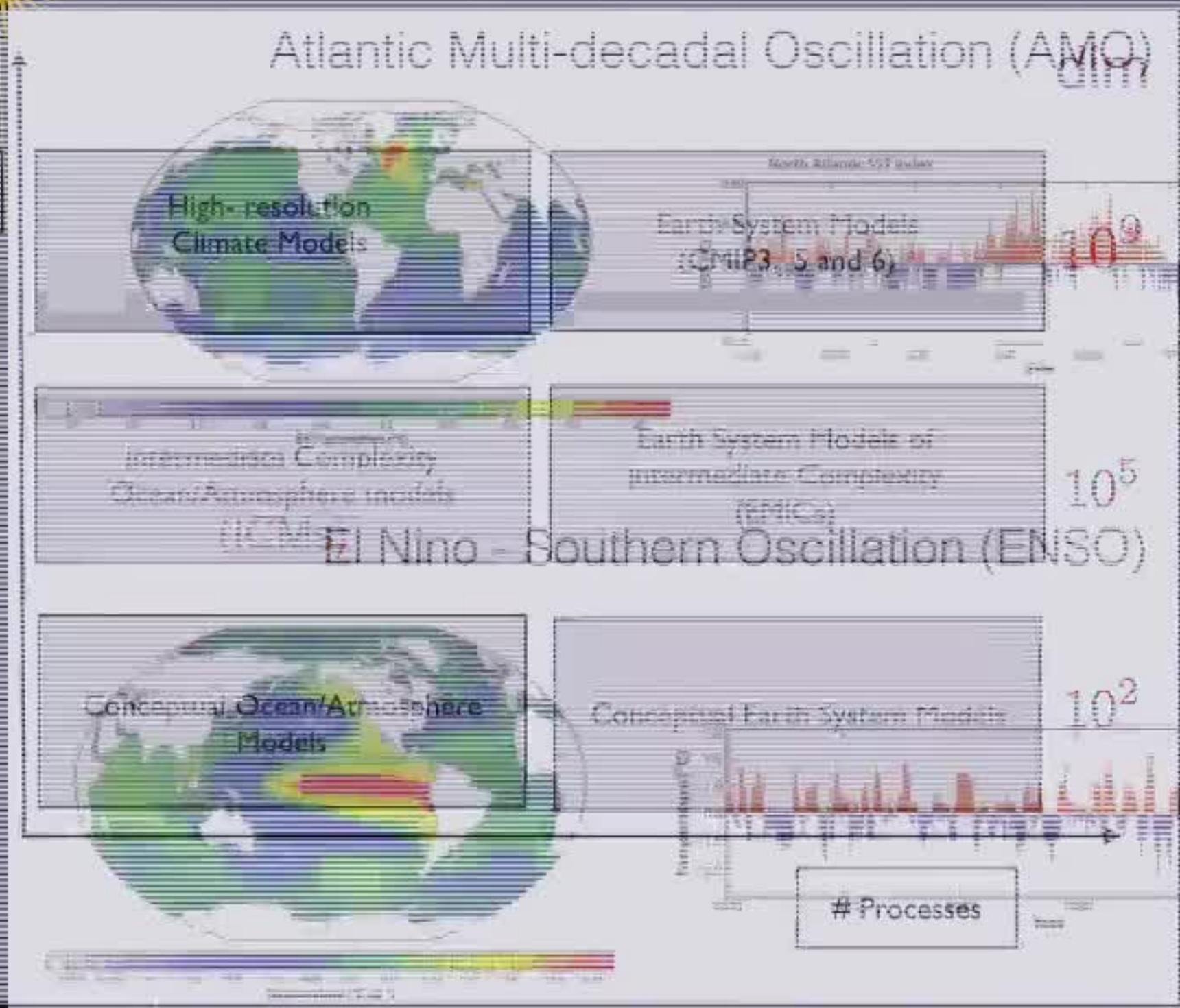
El Nino - Southern Oscillation (ENSO)





Deser et al (2010)

Patterns of Model Variability



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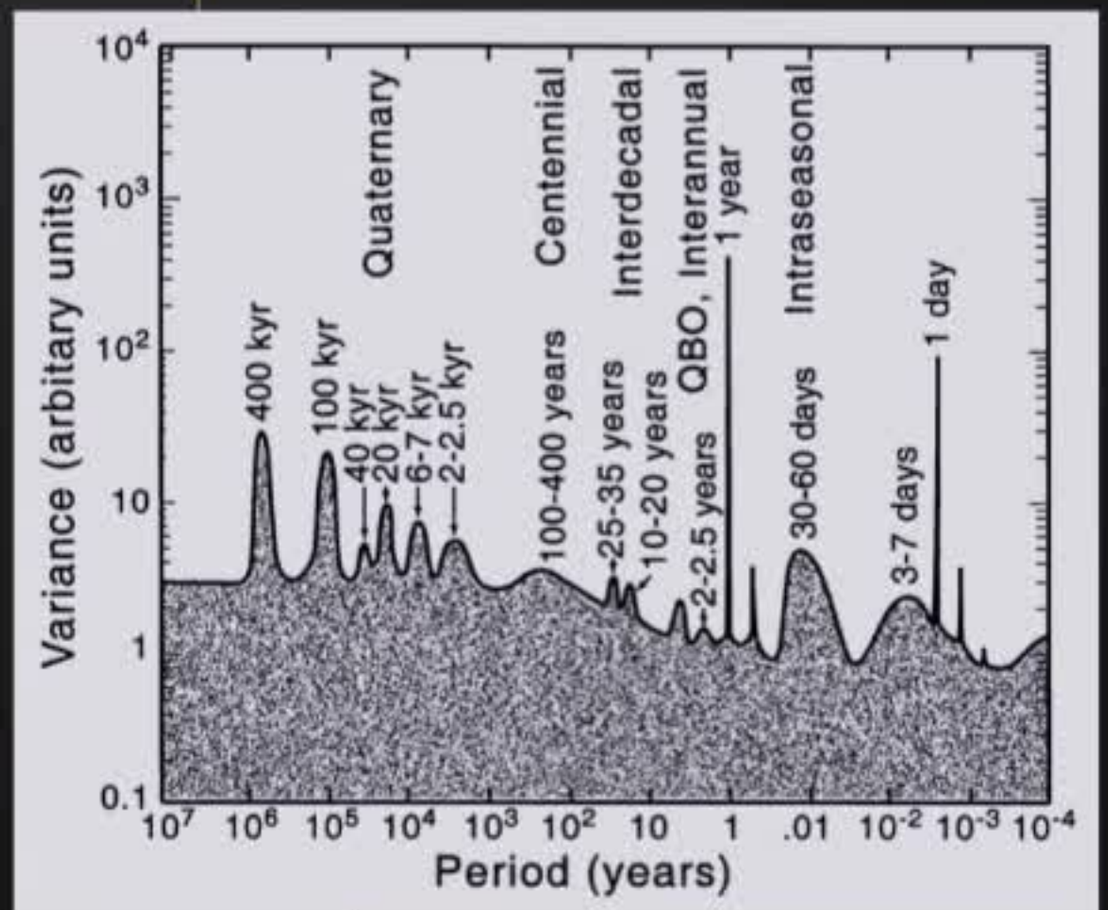

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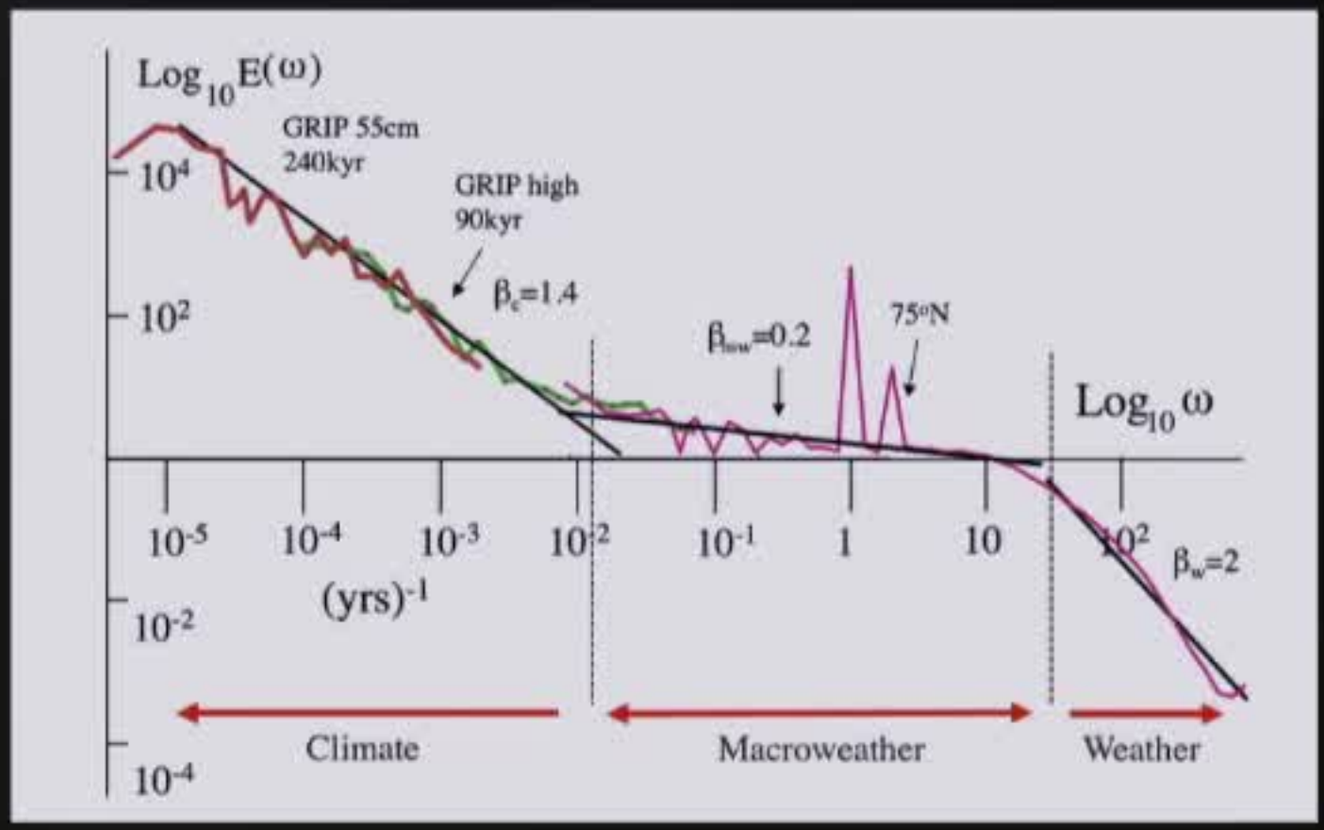

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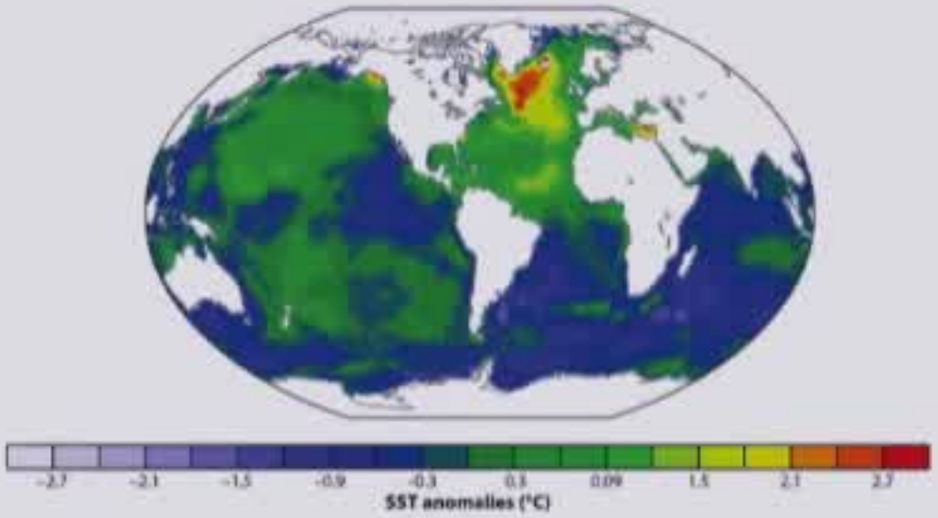

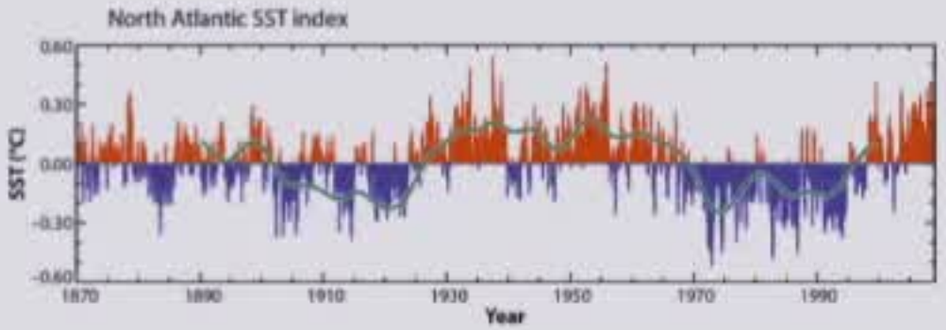

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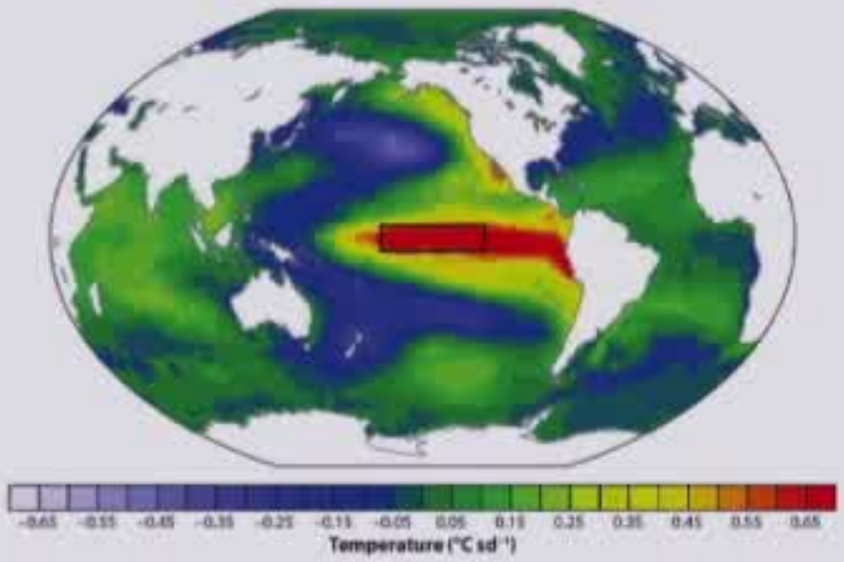

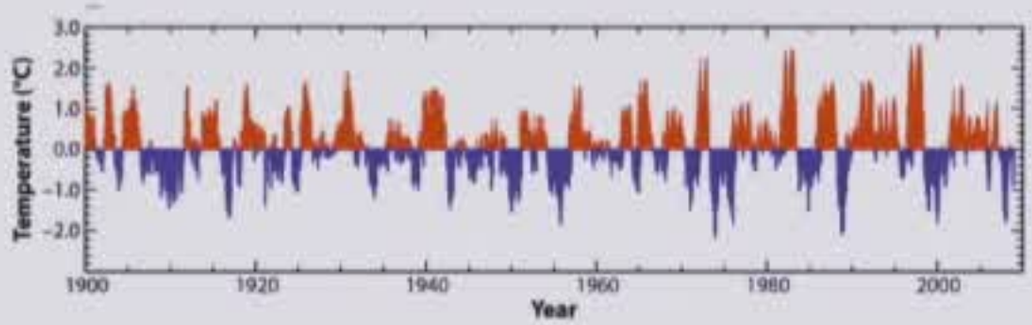

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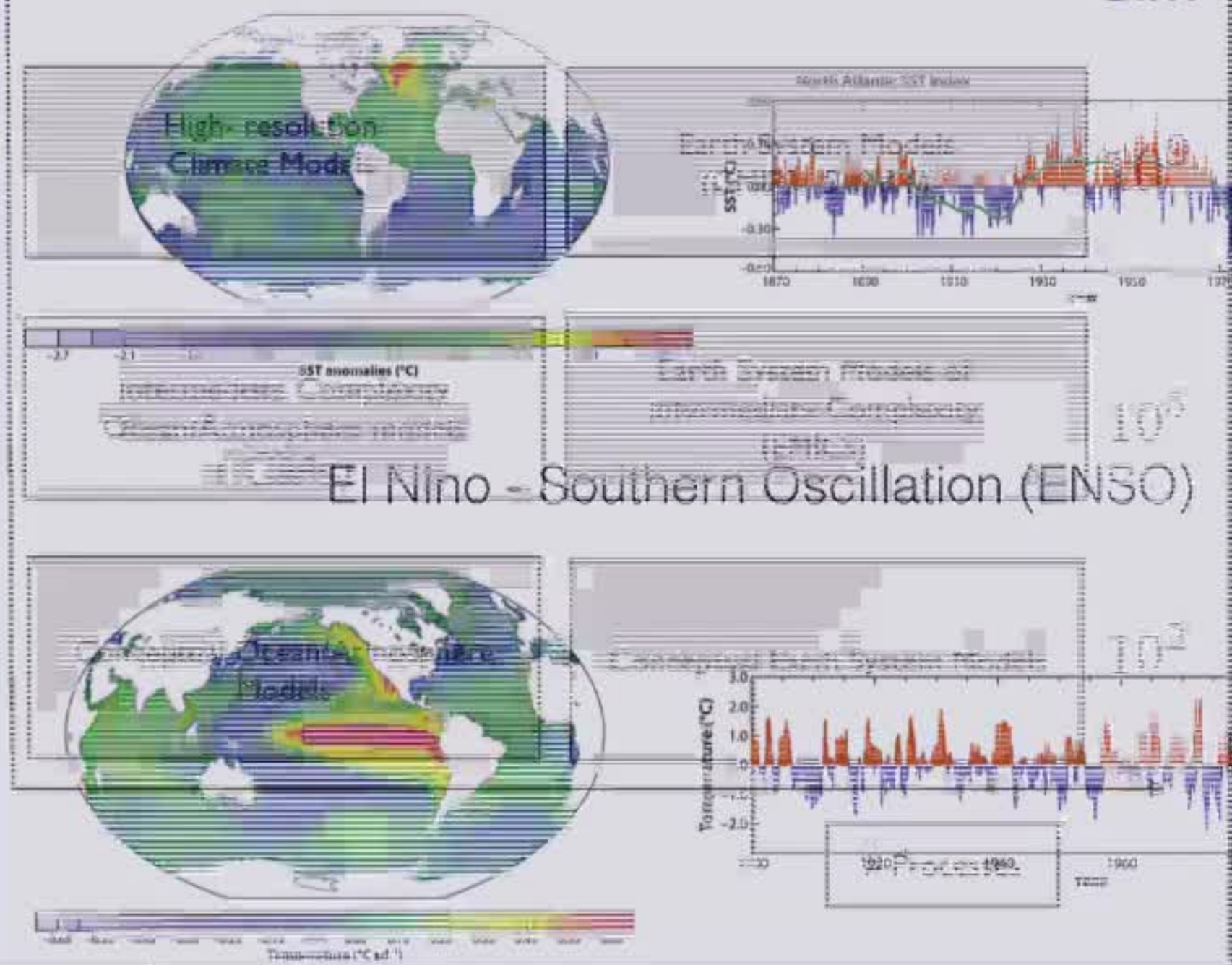

context

spatial

temporal

Dijkstra, Nonlinear Climate Dynamics CUP (2010)

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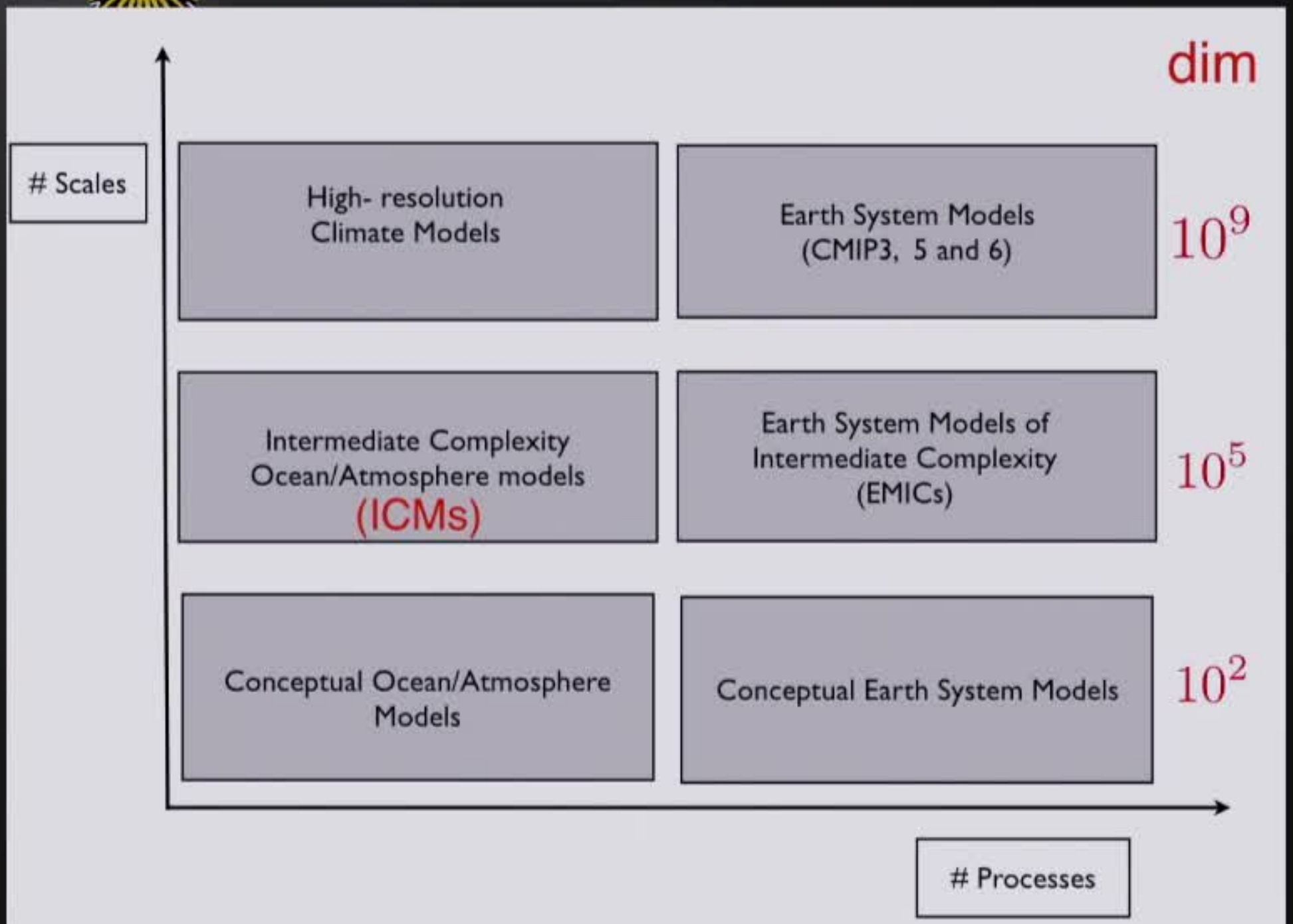
Model Overview



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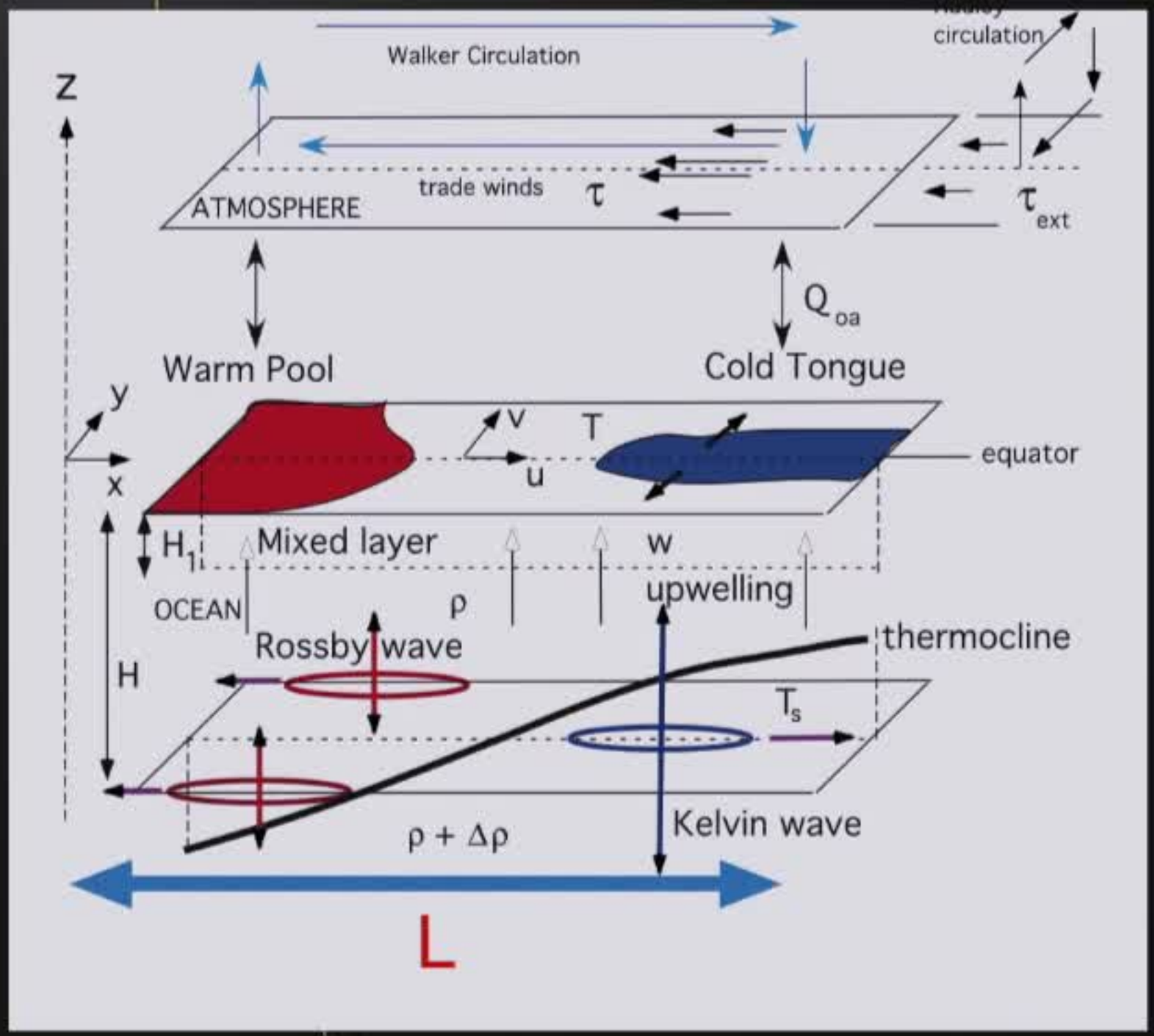
Example ICM:
Zebiak - Cane model of ENSO



shallow water model

mixed layer model

shallow water model

coupling strength:

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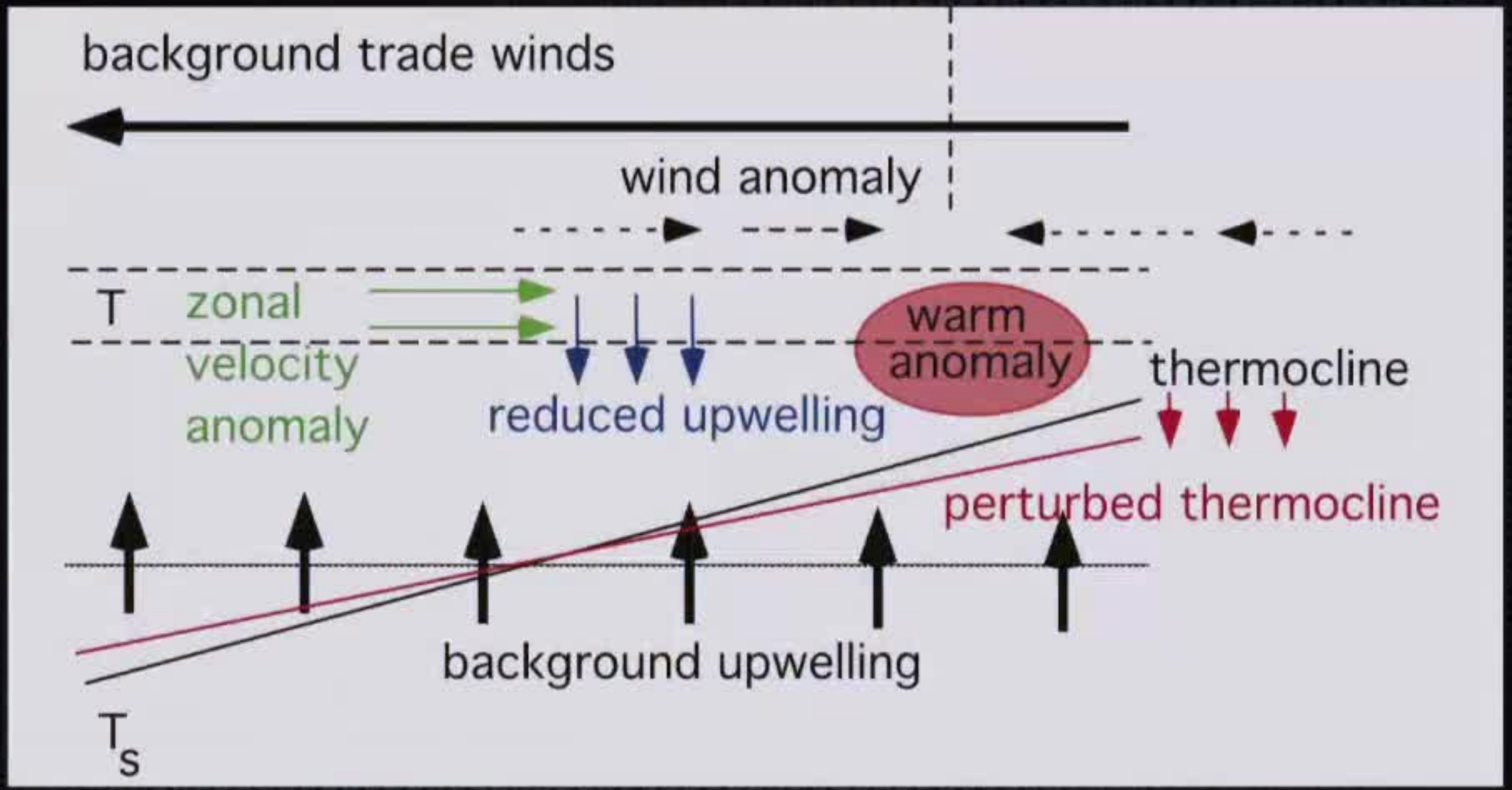
Coupled (Bjerknes') positive feedbacks



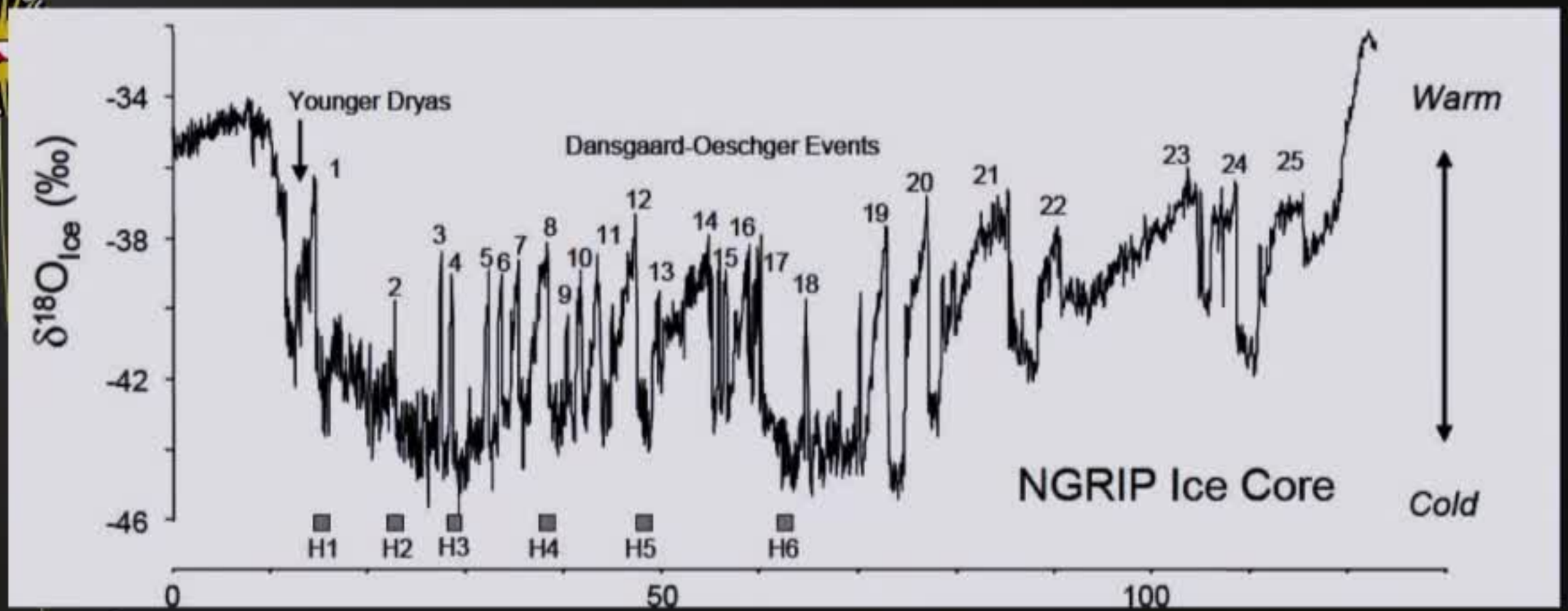
Thermocline feedback

Upwelling feedback

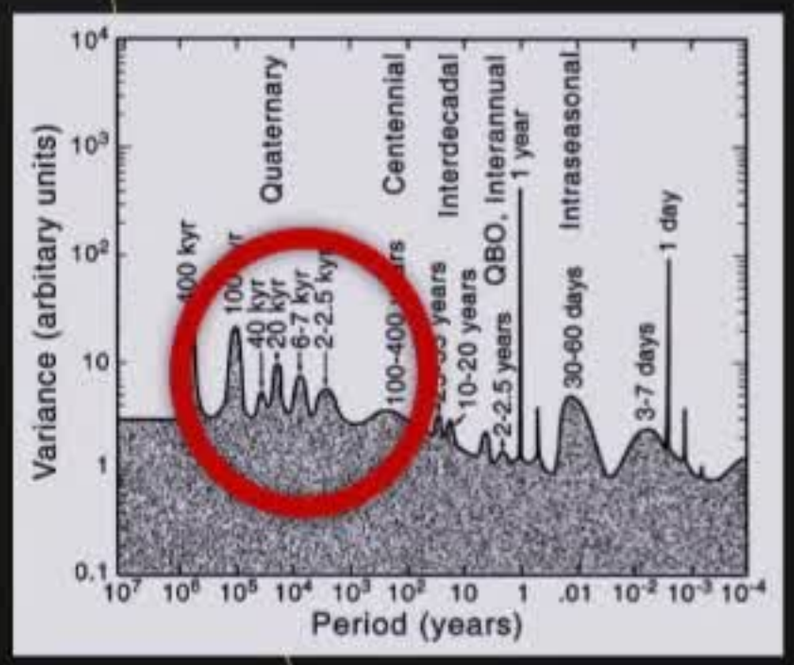
Zonal advection feedback

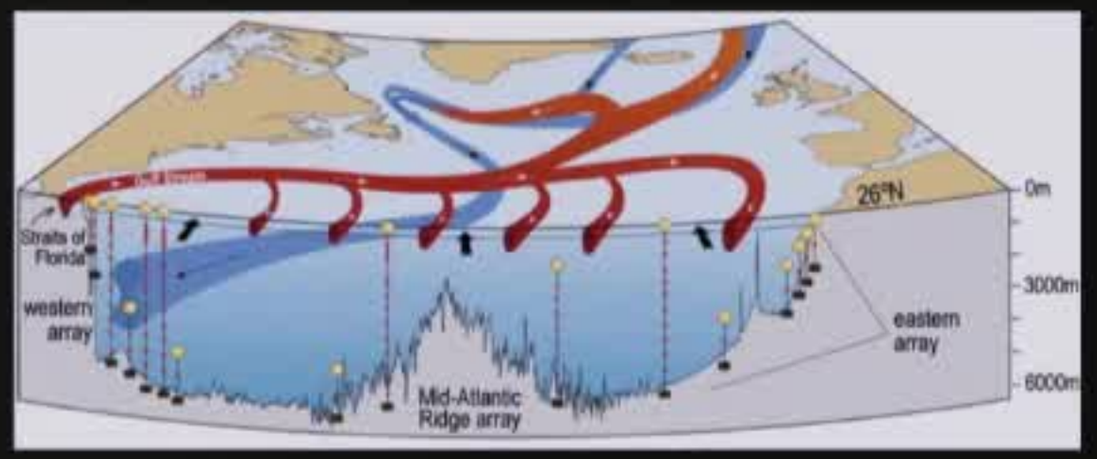
Delayed negative feedback due to equatorial wave propagation

Tipping behavior



time (kyr)

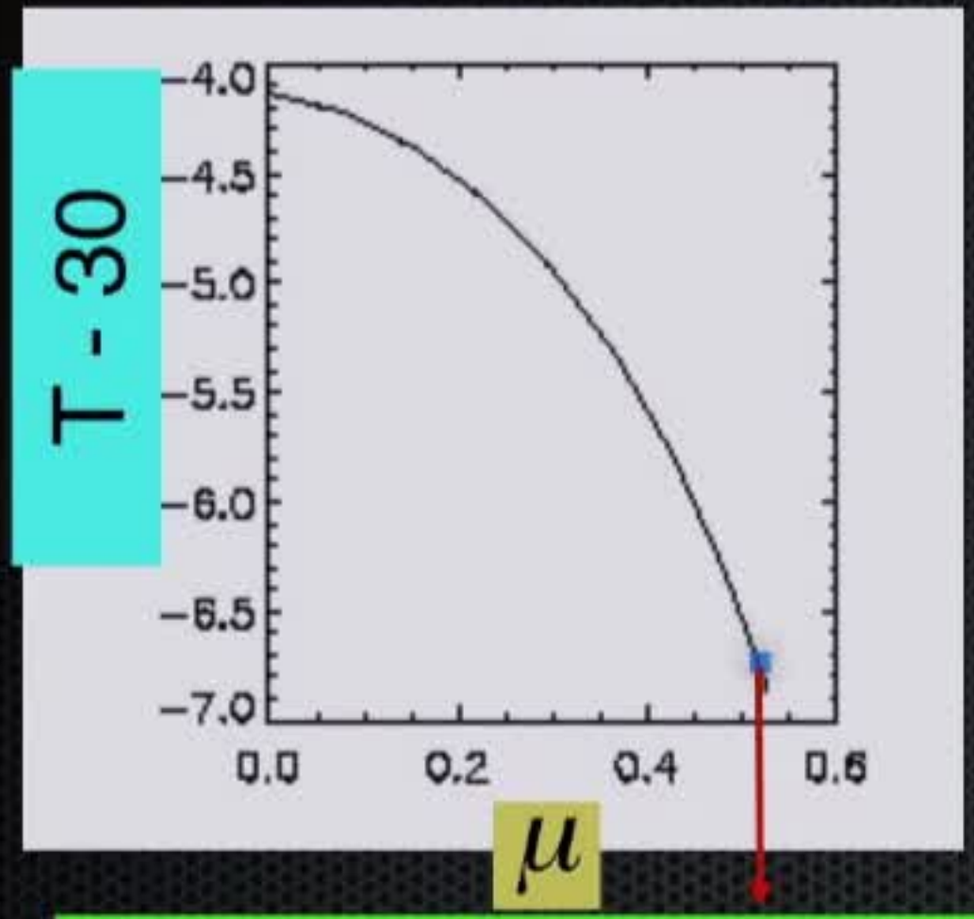




Meridional Overturning Circulation (MOC)

Instability of the annual mean state

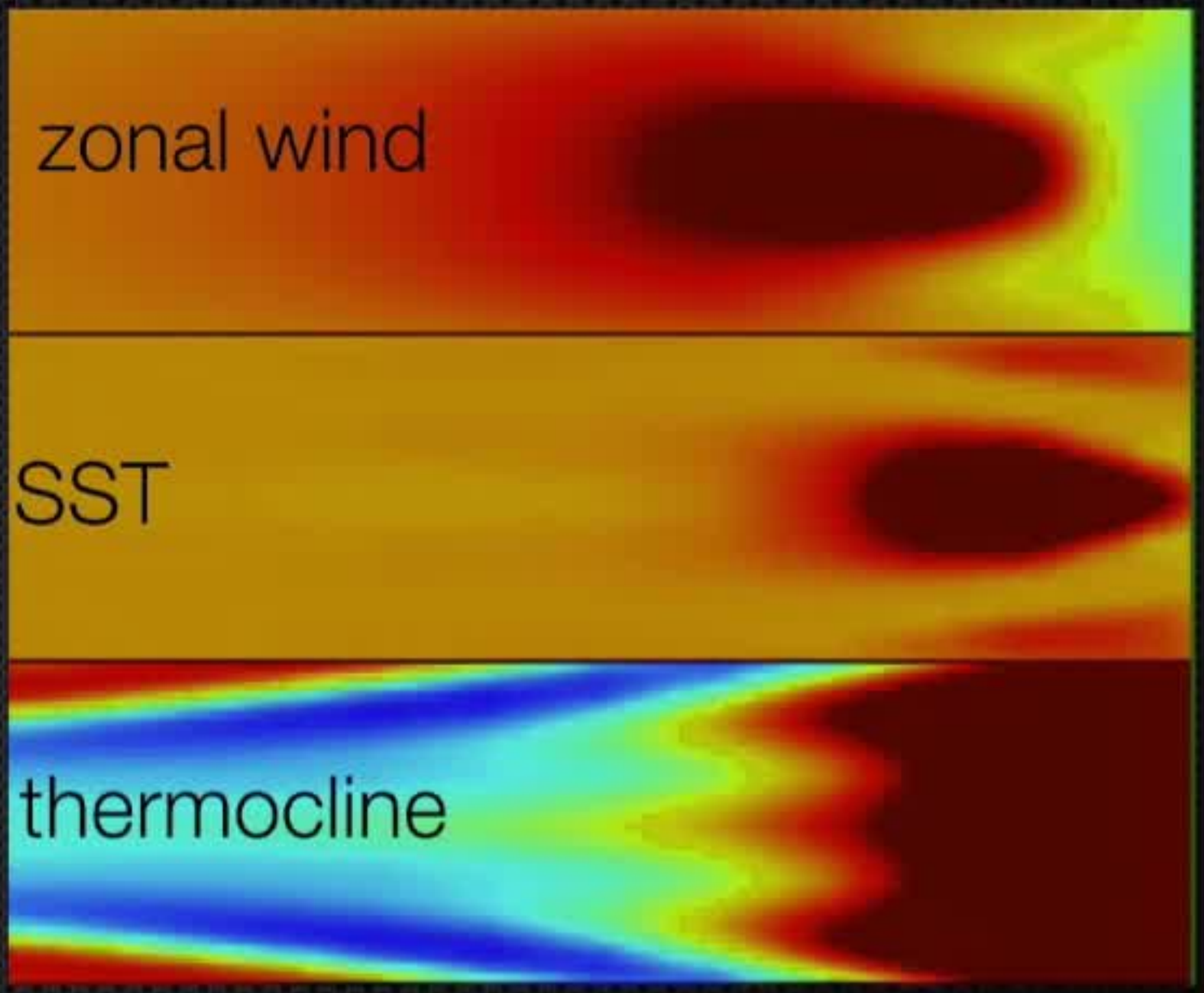
Cold tongue temperature



Hopf bifurcation: ENSO mode

period ~ 4 years

VdVaart et al. JAS, (2000)



ENSO mode patterns

Spatial patterns: background state

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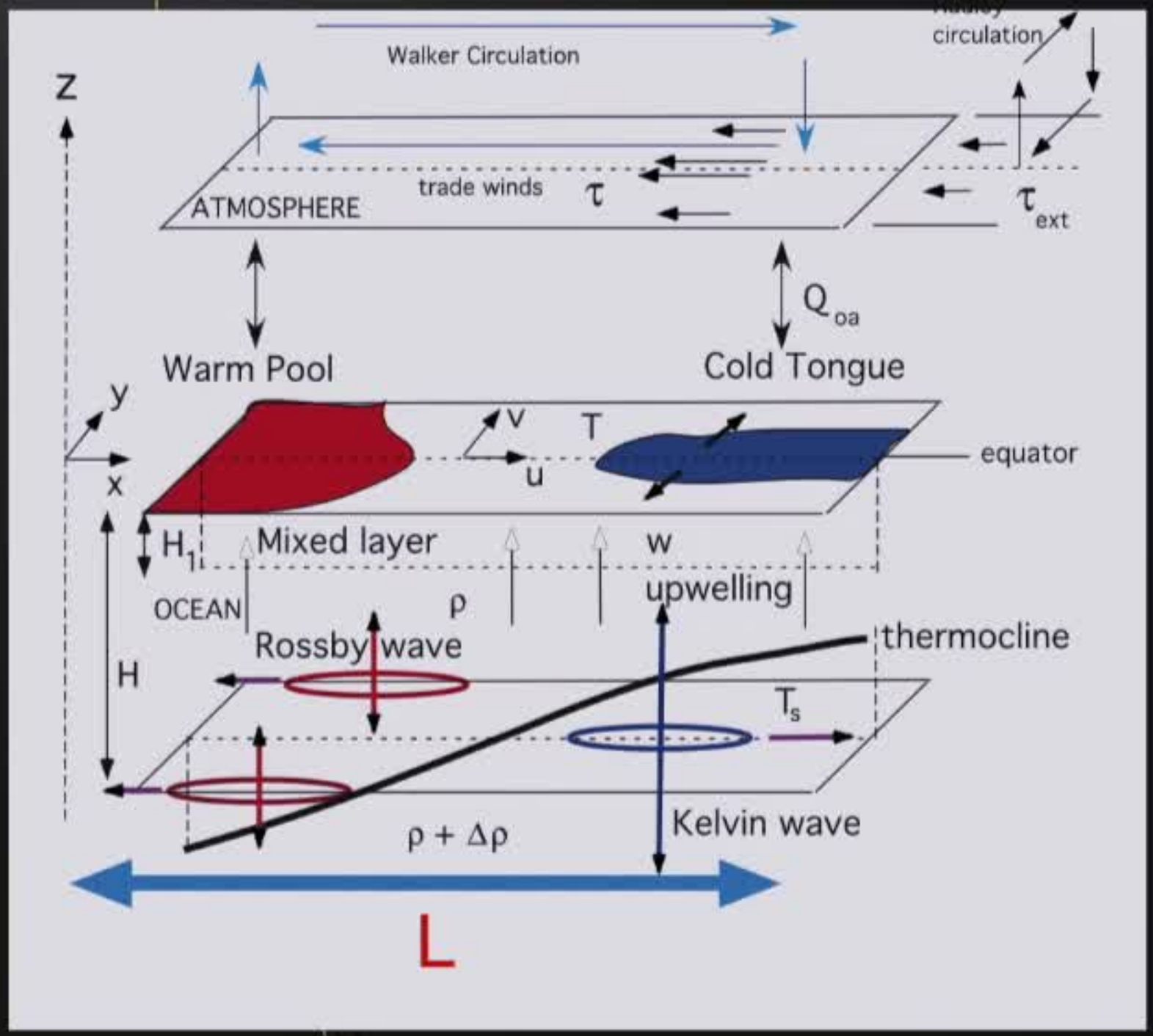

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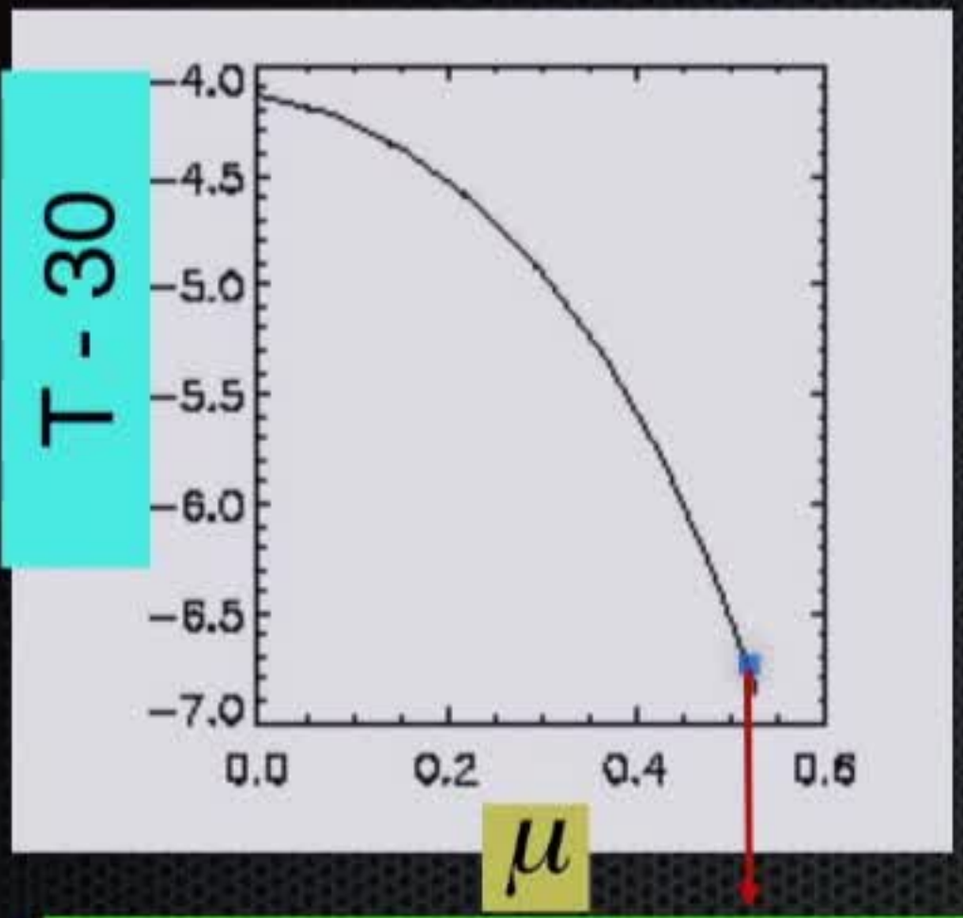

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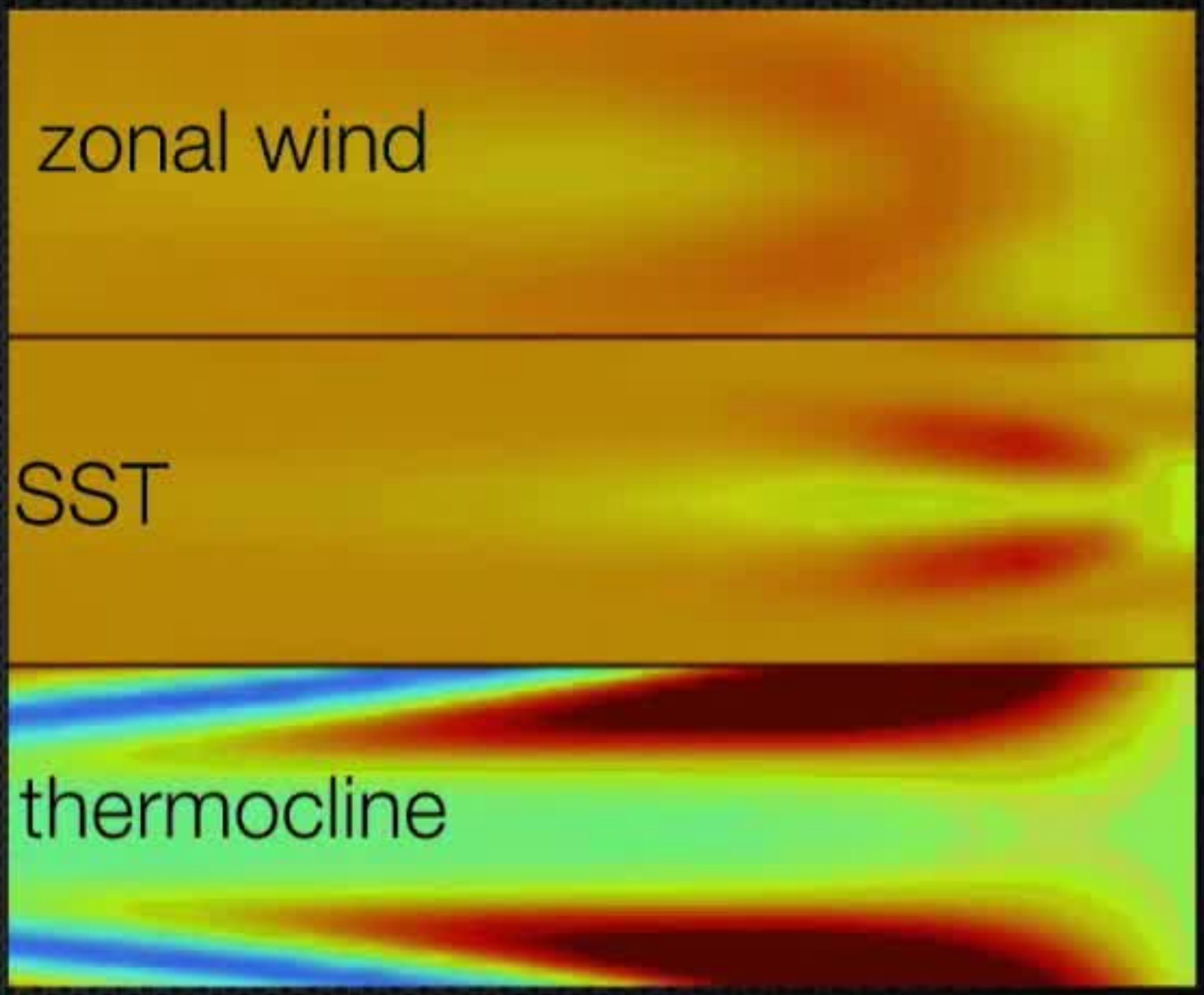

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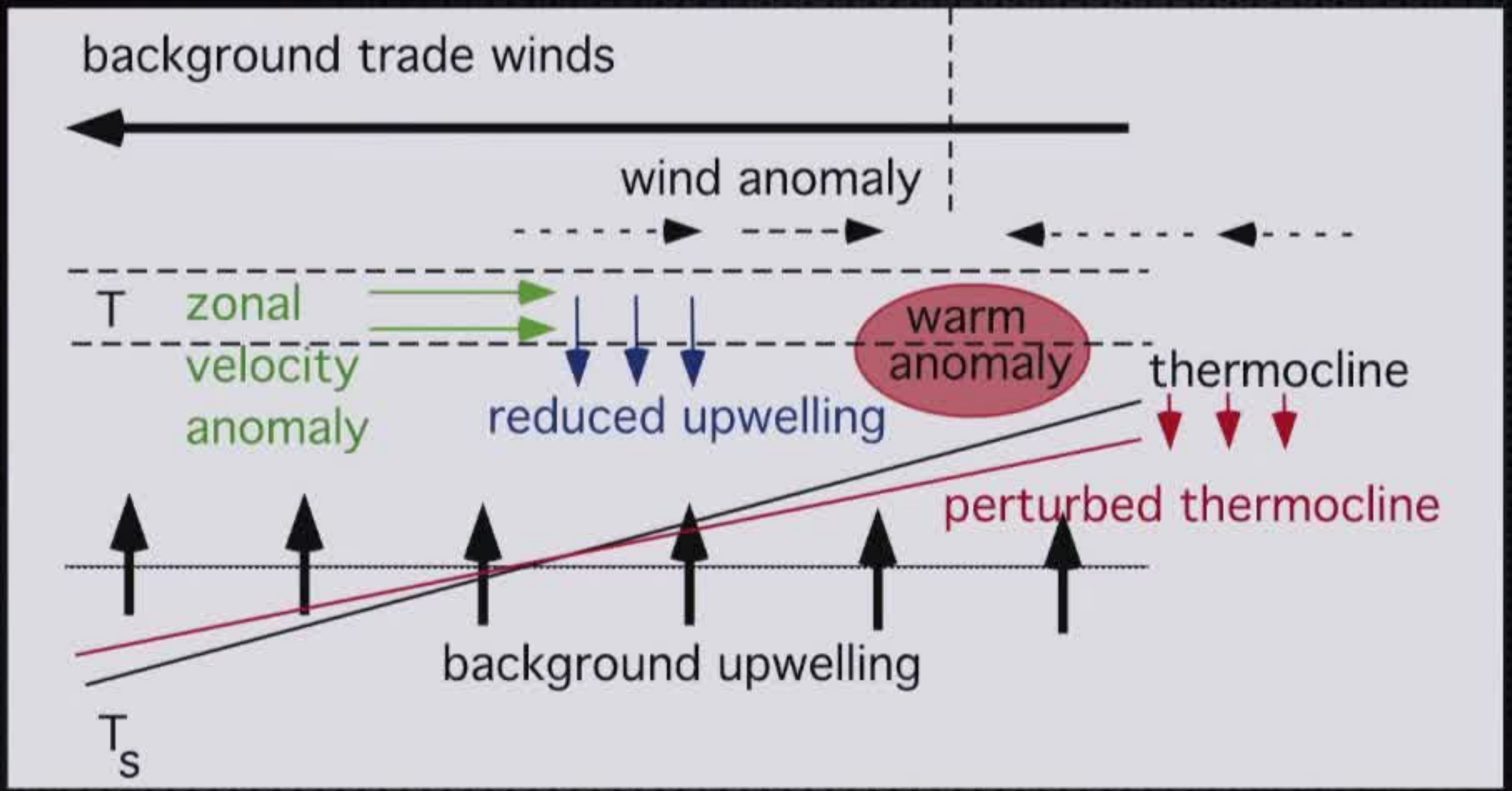

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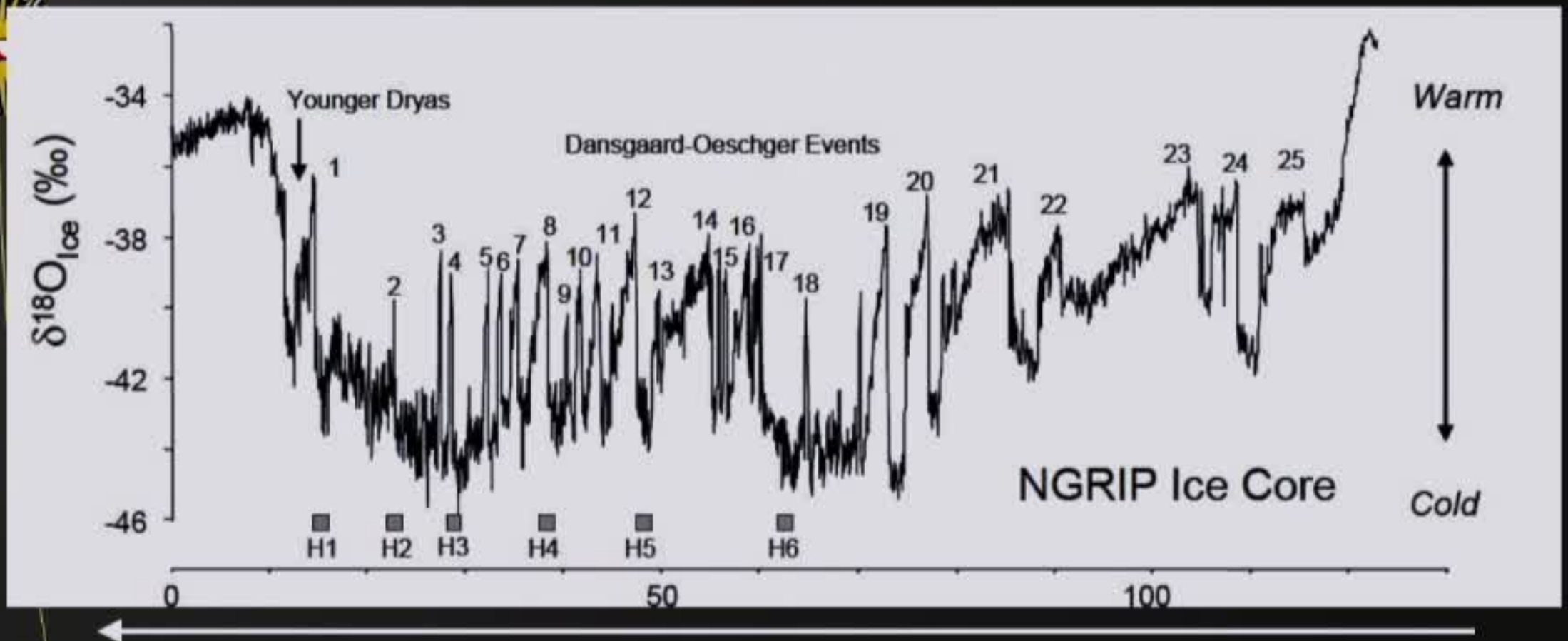
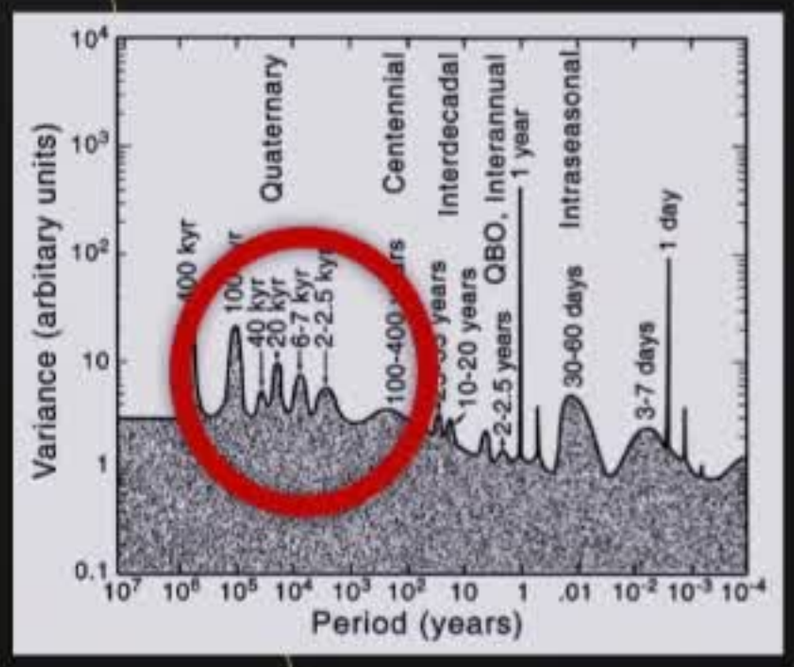
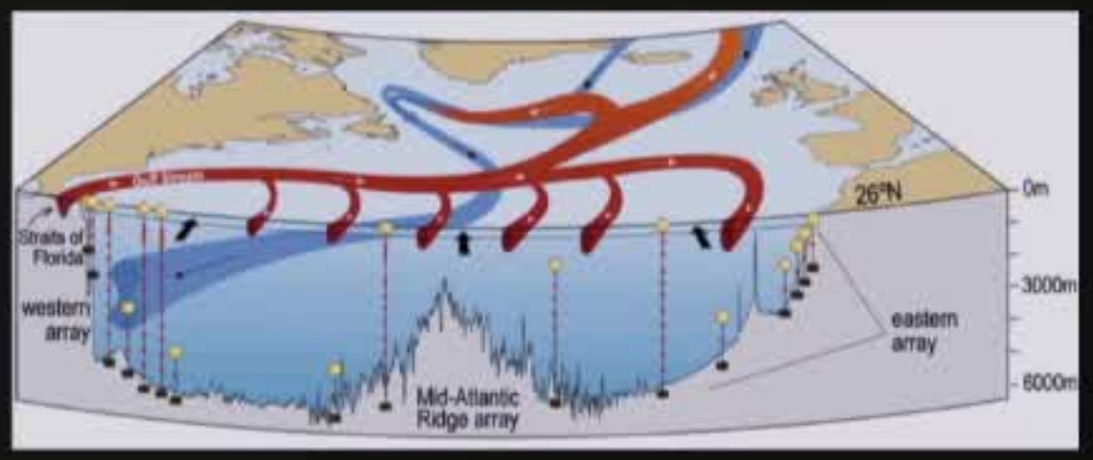
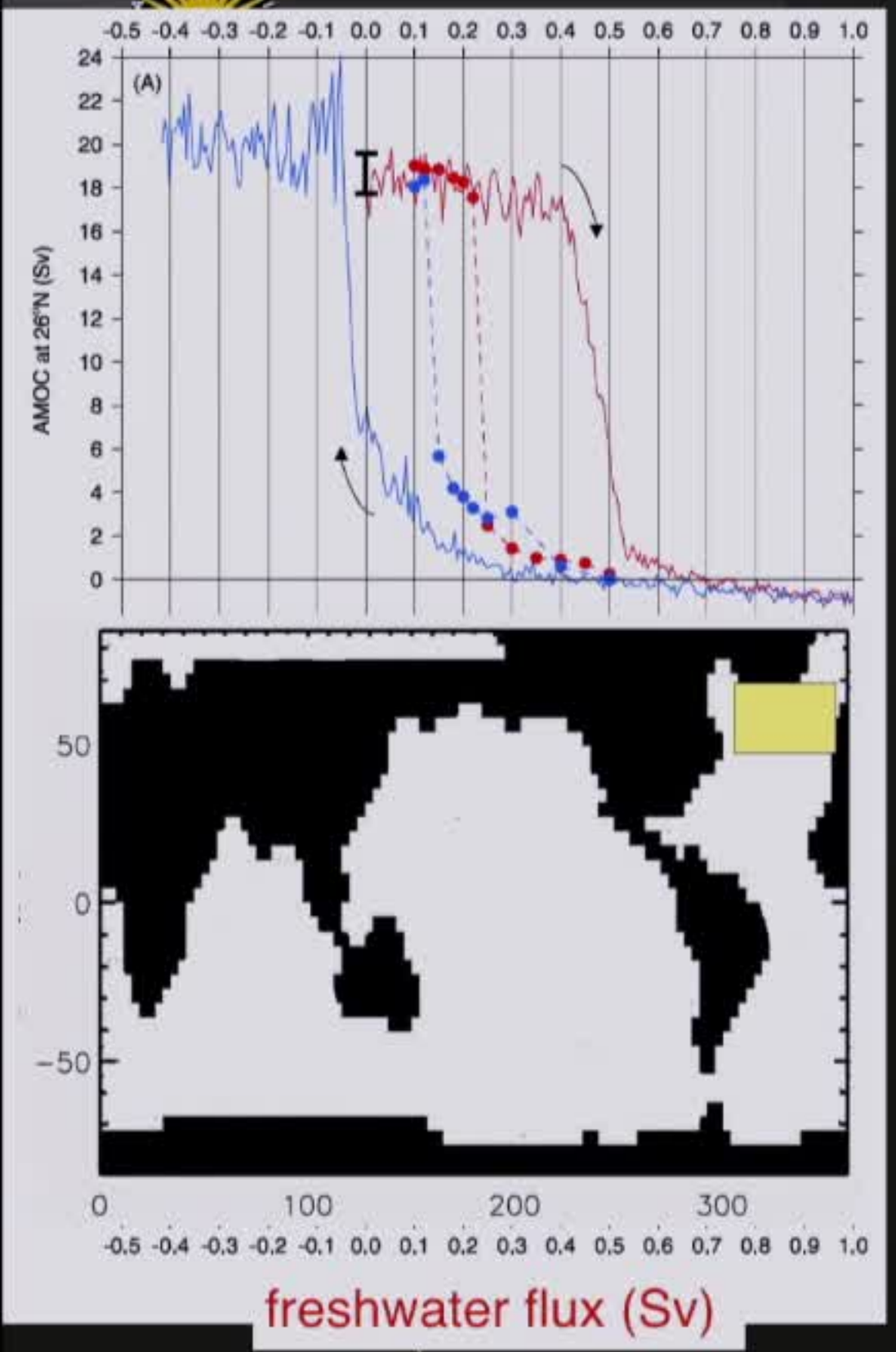


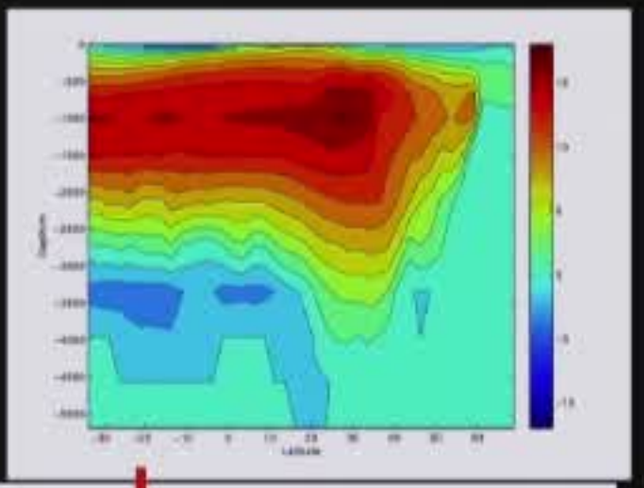


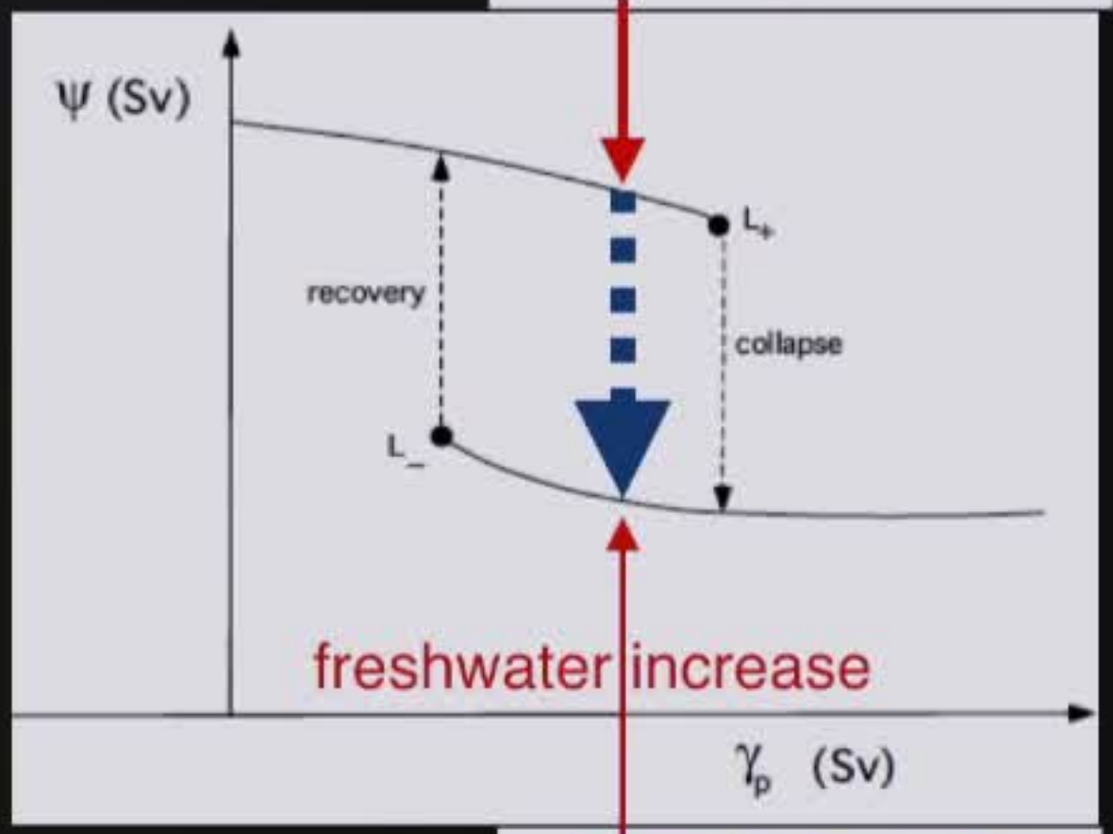


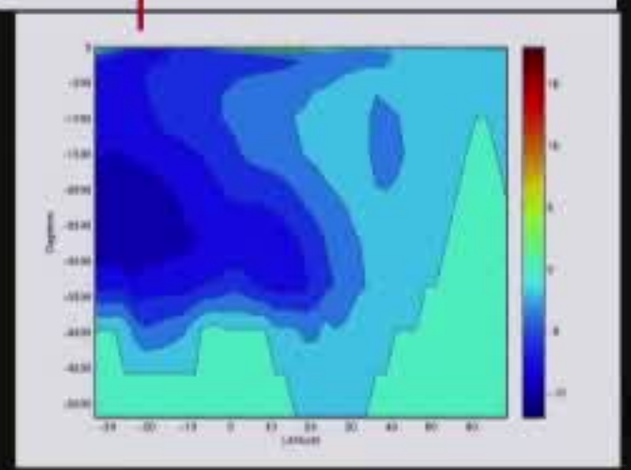
Meridional Overturning Circulation (MOC)

MOC Collapse









Hawkins et al. (2011)

Salt - Advection Feedback

z

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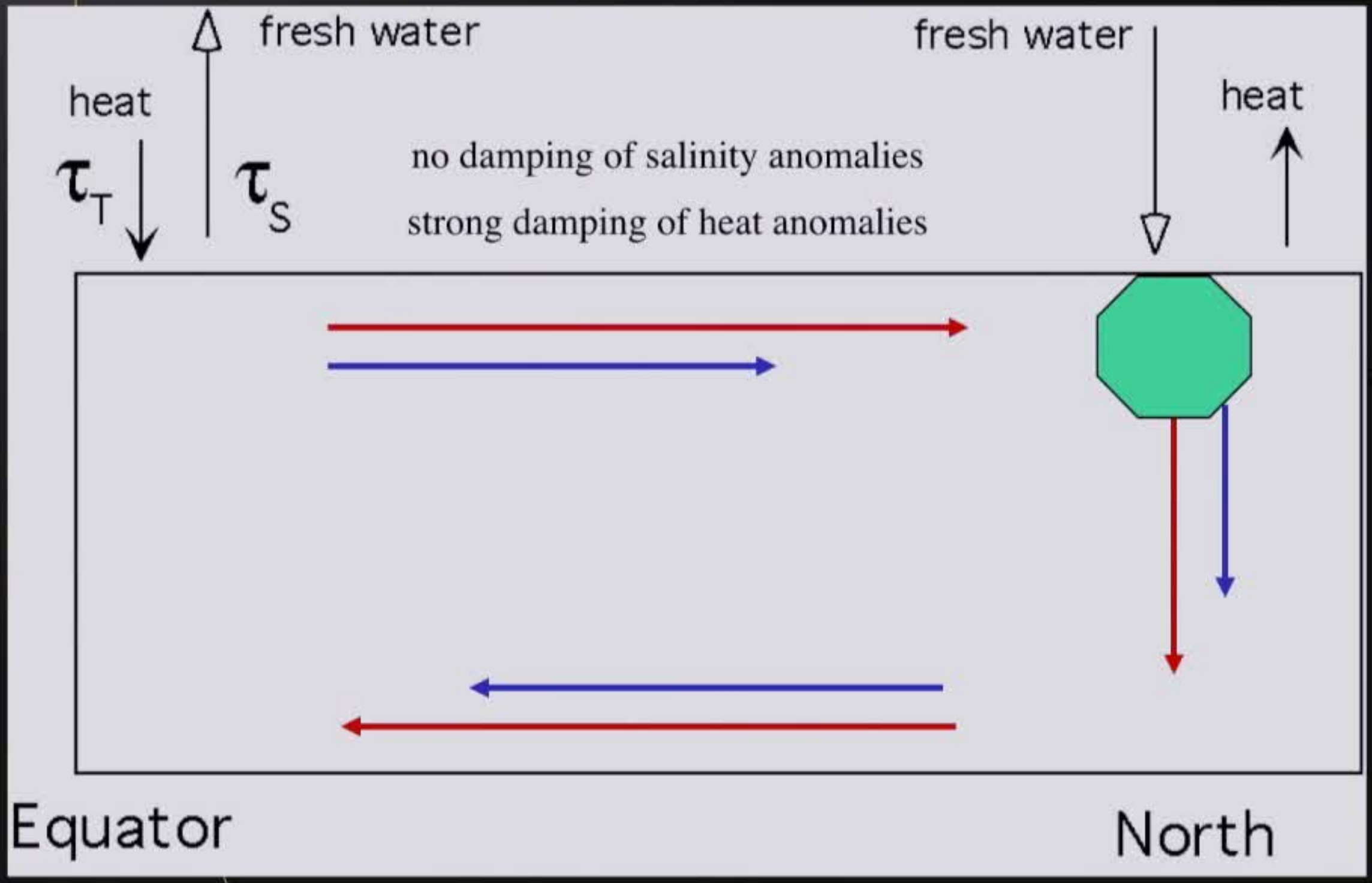

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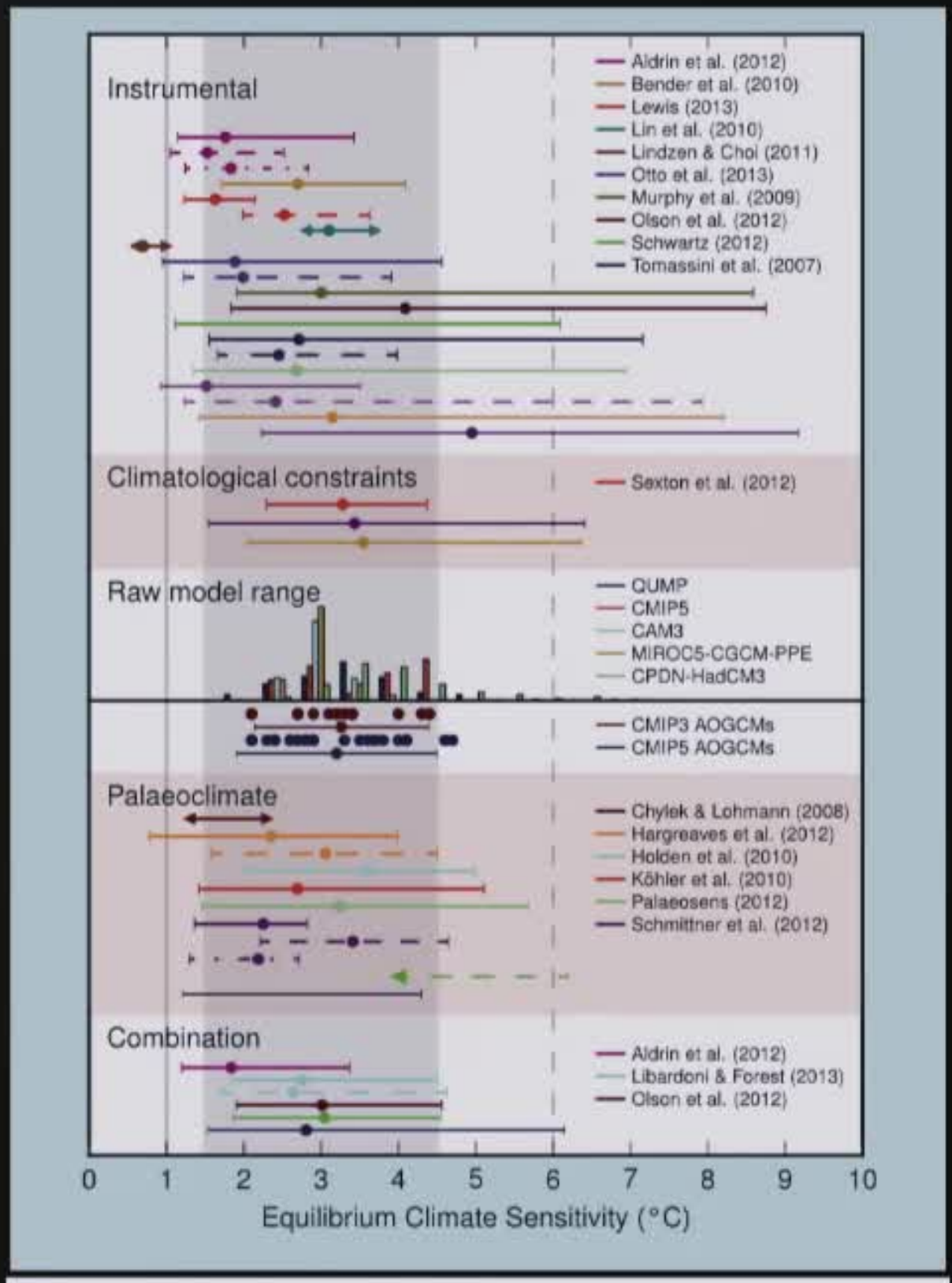
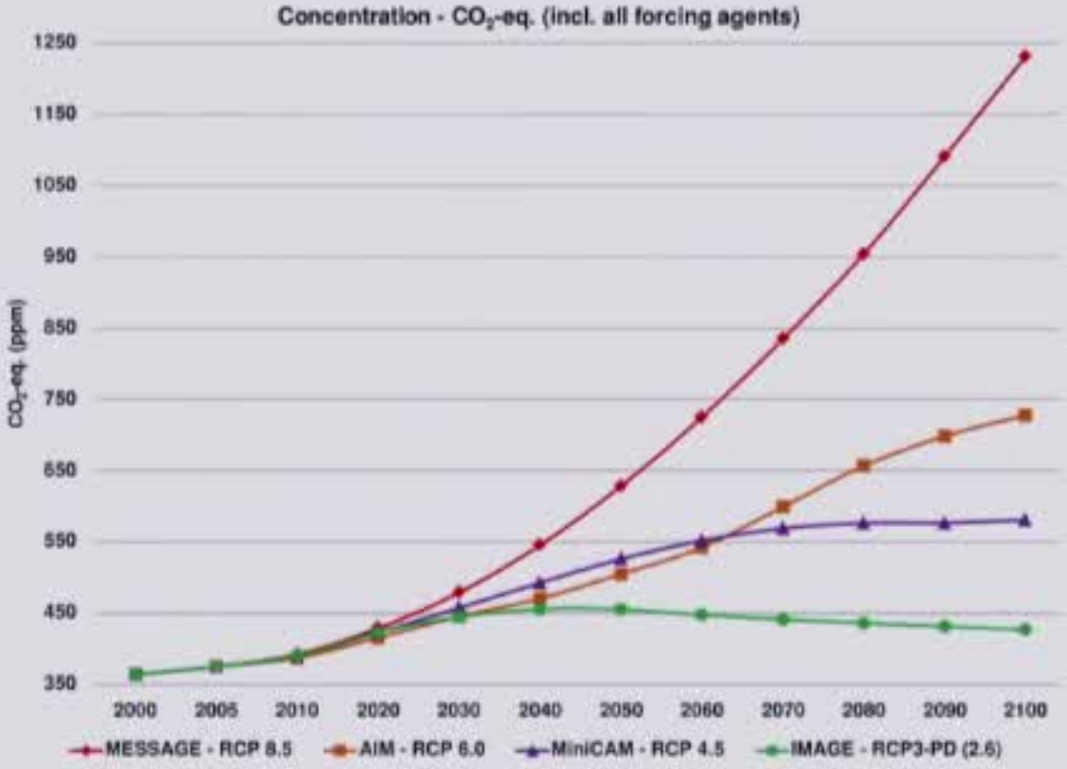


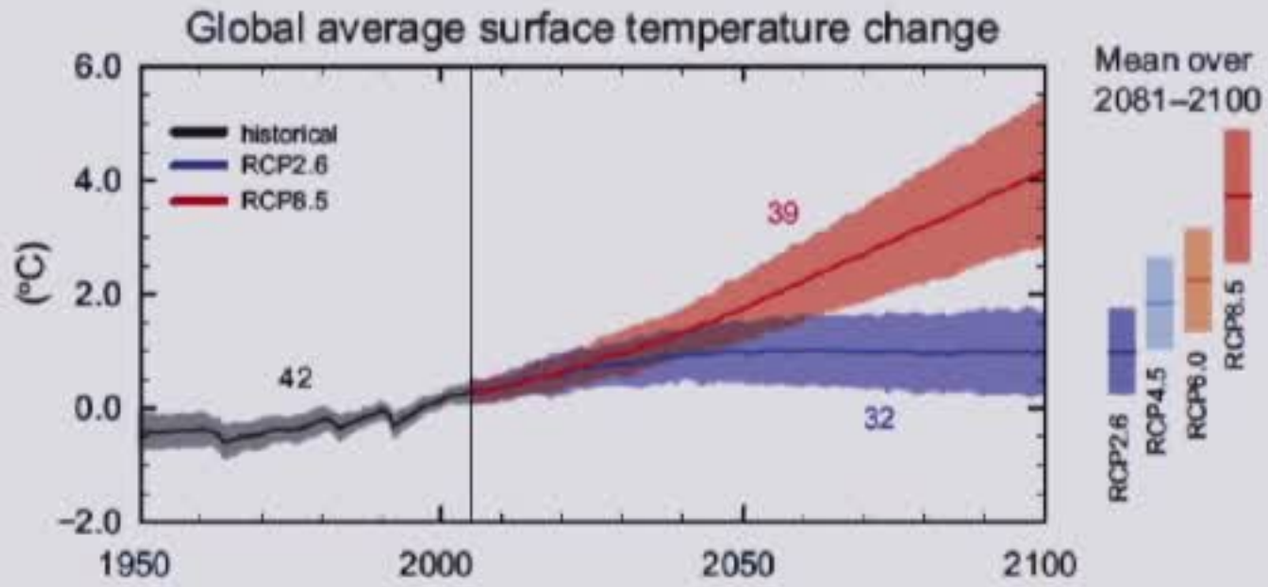
Chapter 12 of IPCC-AR5 (2013)

Future Climate Change (CMIP5)

Forcing



Response



How warm is it going to be in 2100?

Are the changes going to be ‘smooth’ or ‘bumpy’?

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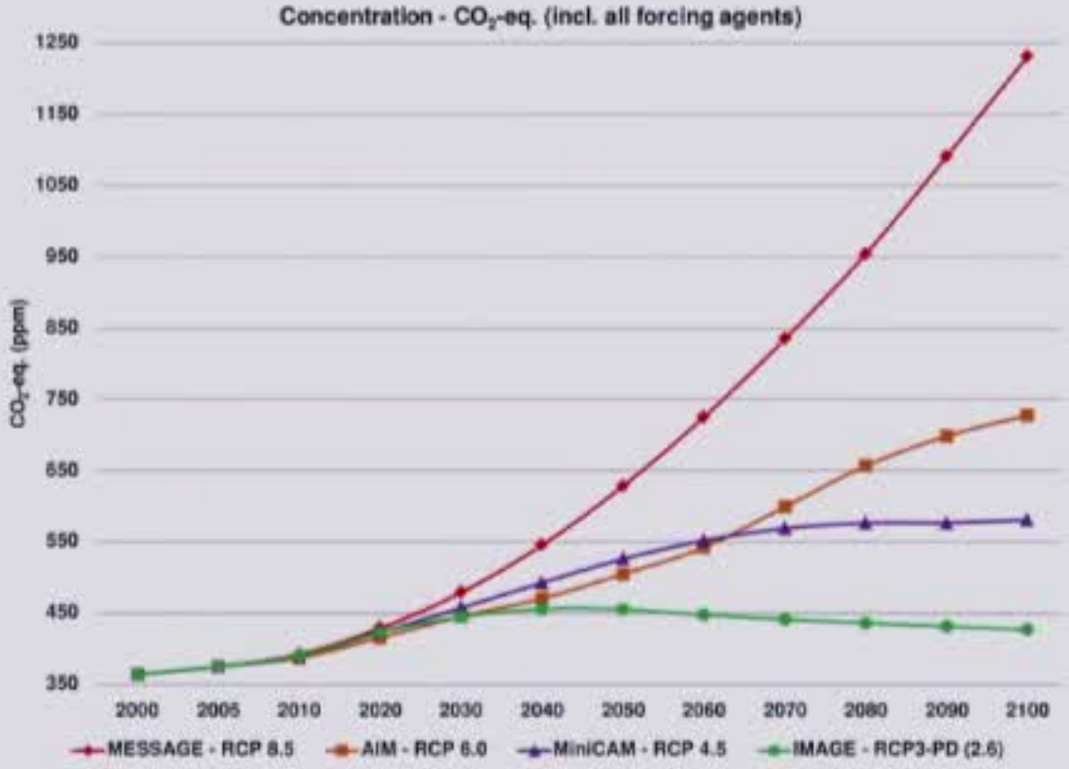

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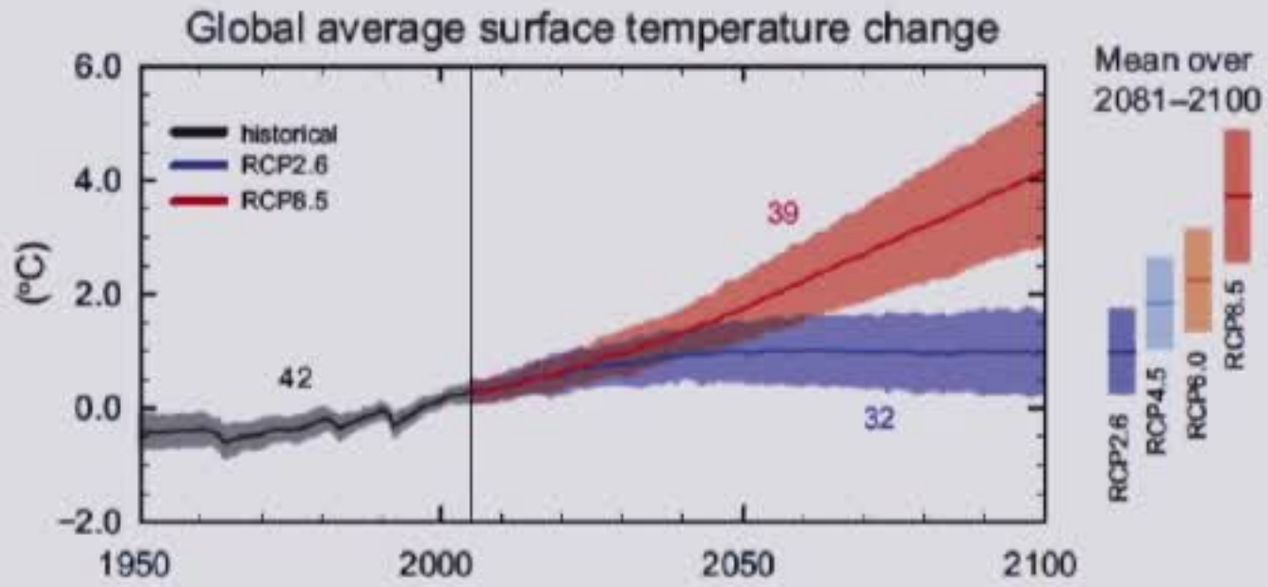

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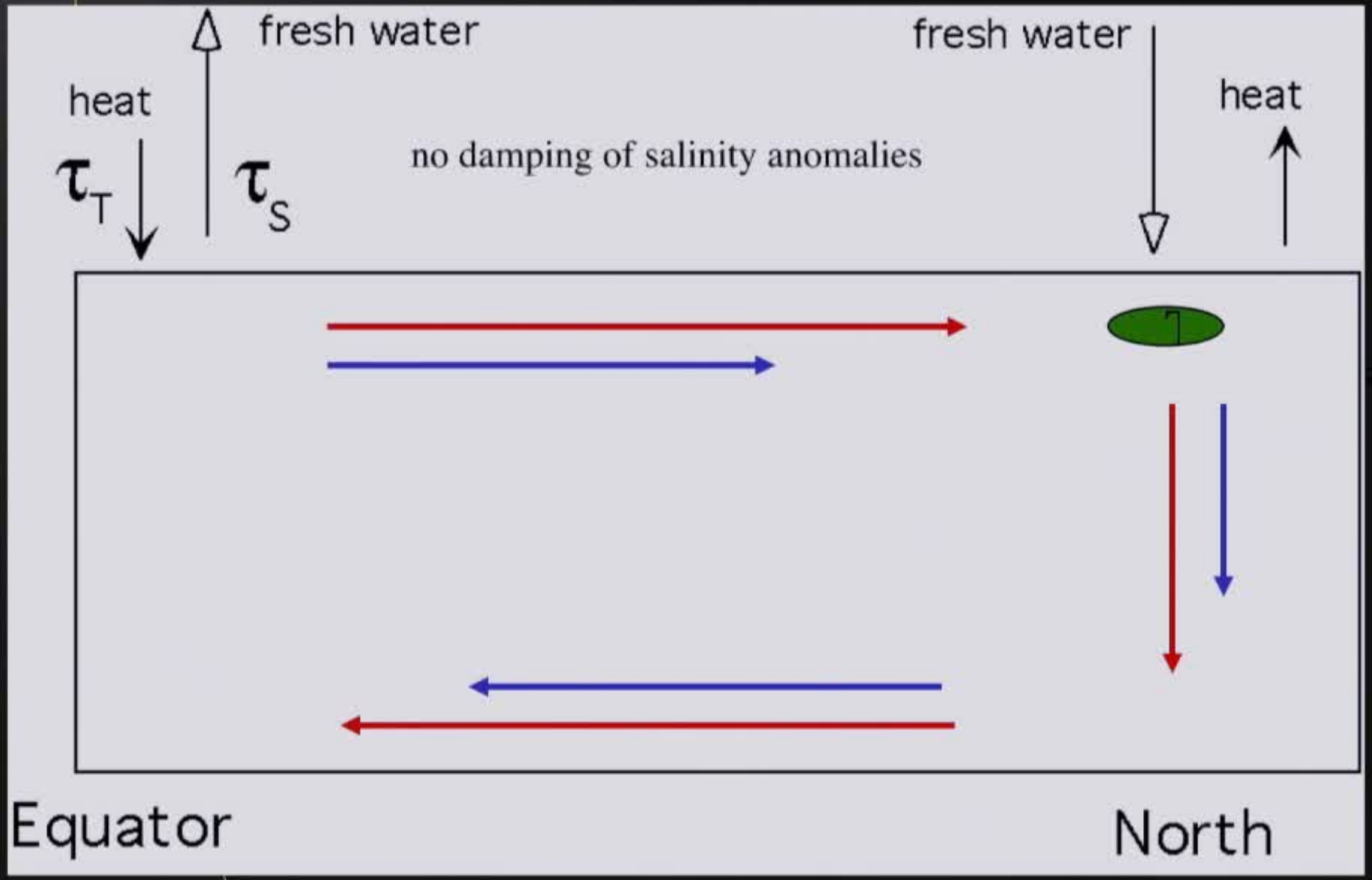

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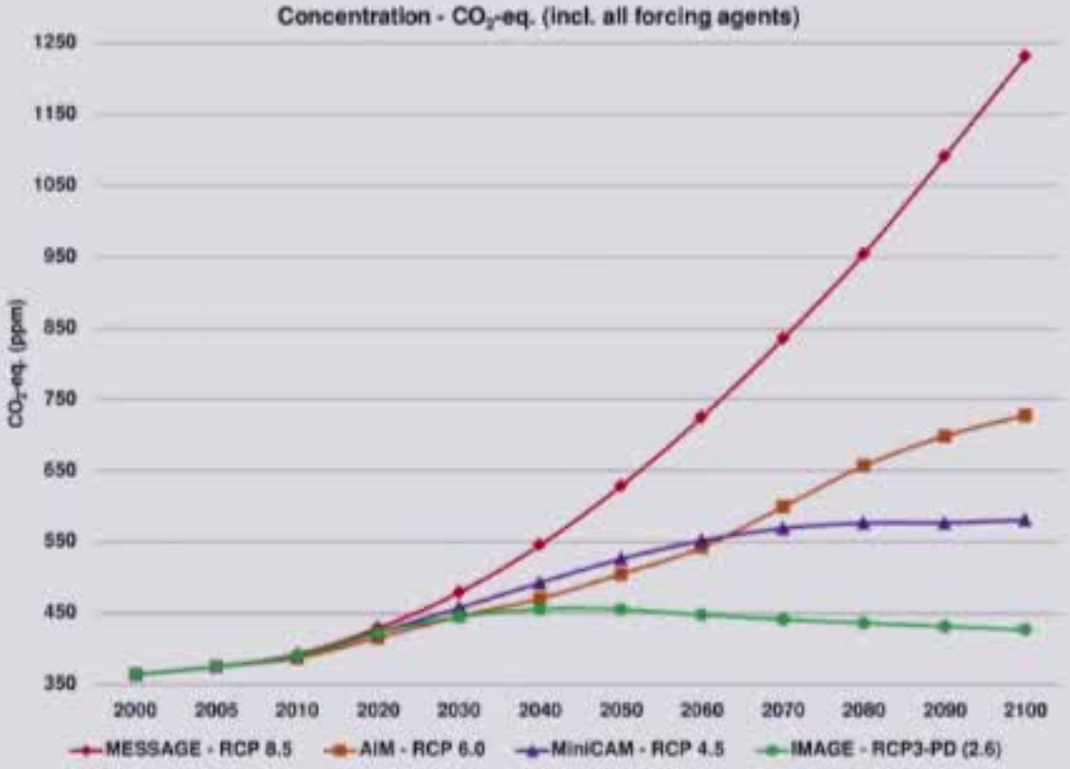

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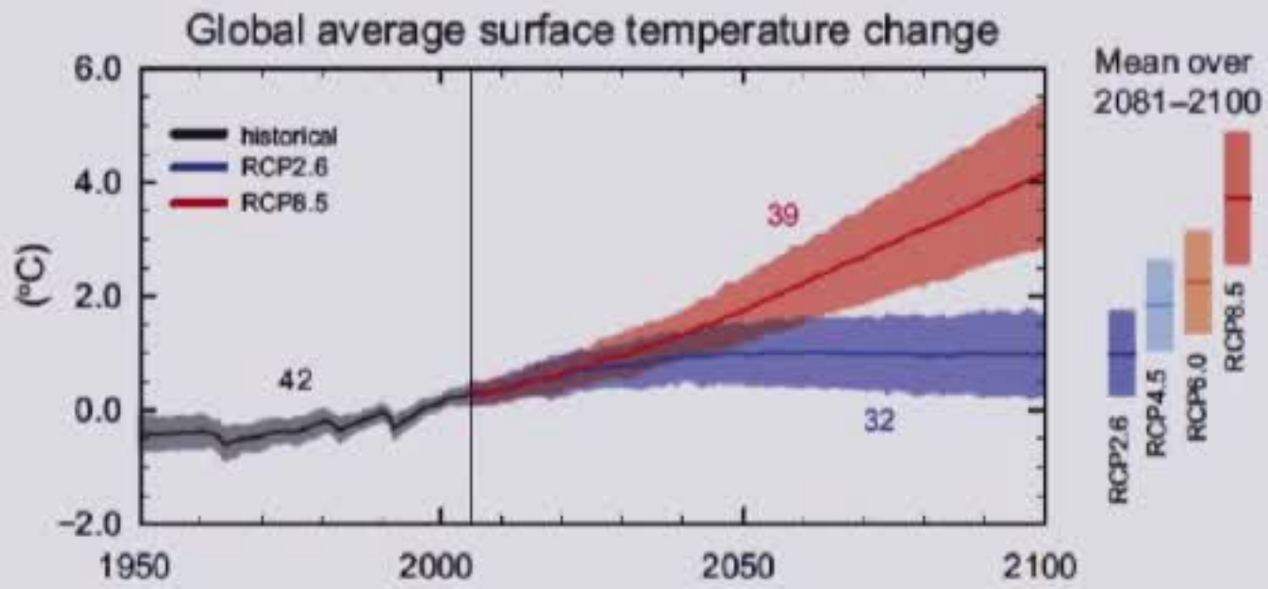

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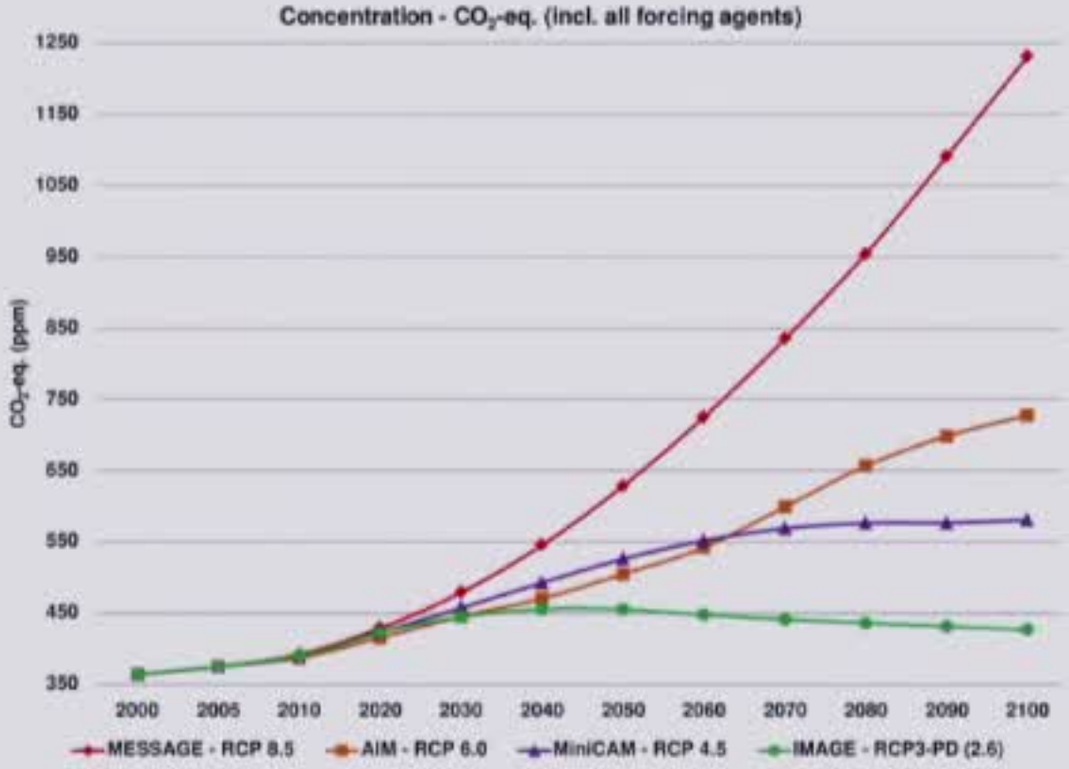

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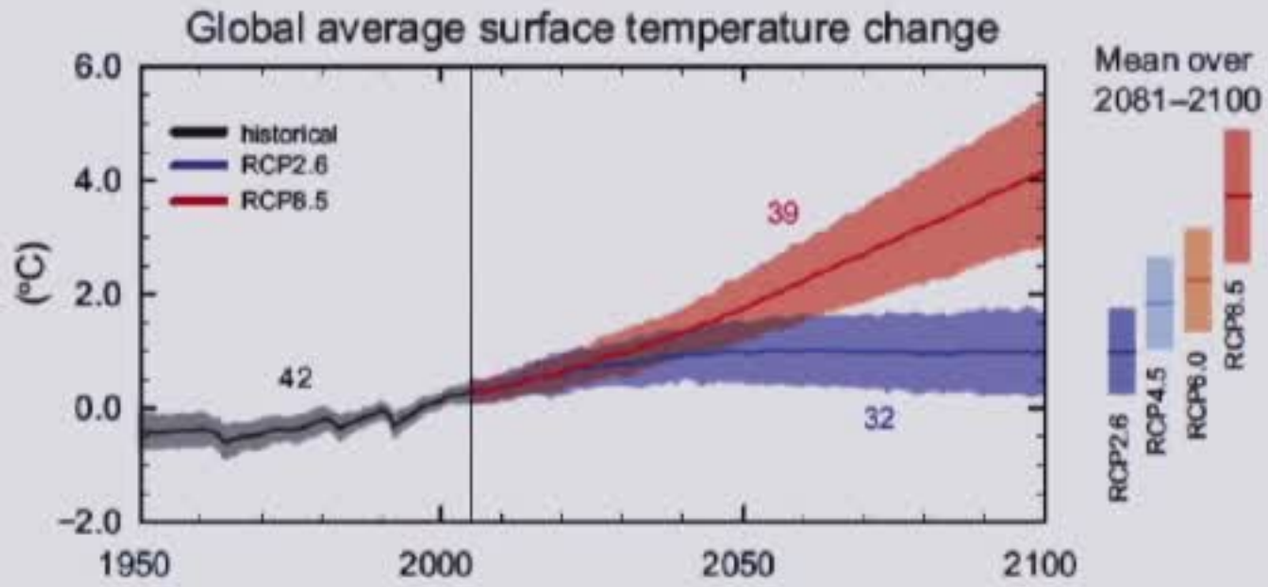

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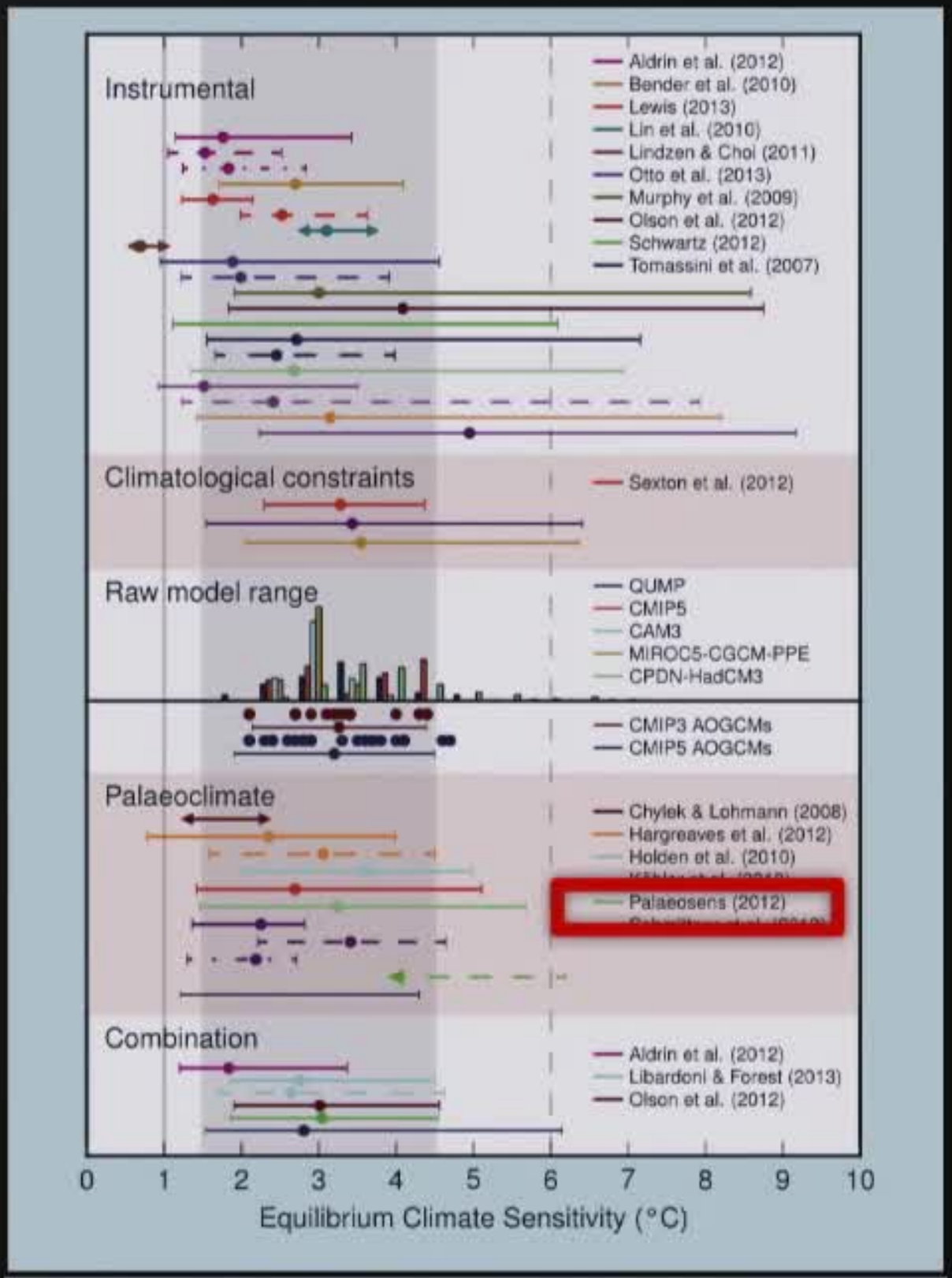
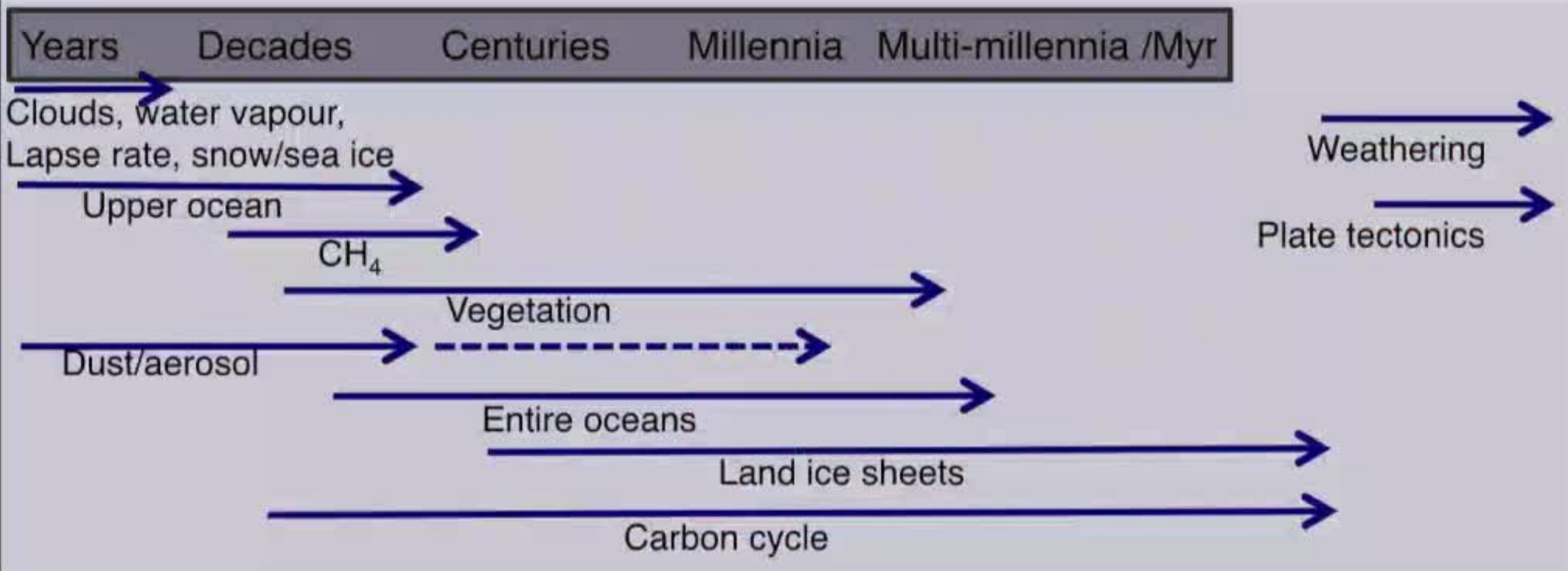


Chapter 12 of IPCC-AR5 (2013)

Feedbacks on different time scales

PALAEOSENS,
Rohling et al., Nature 491 (2012)



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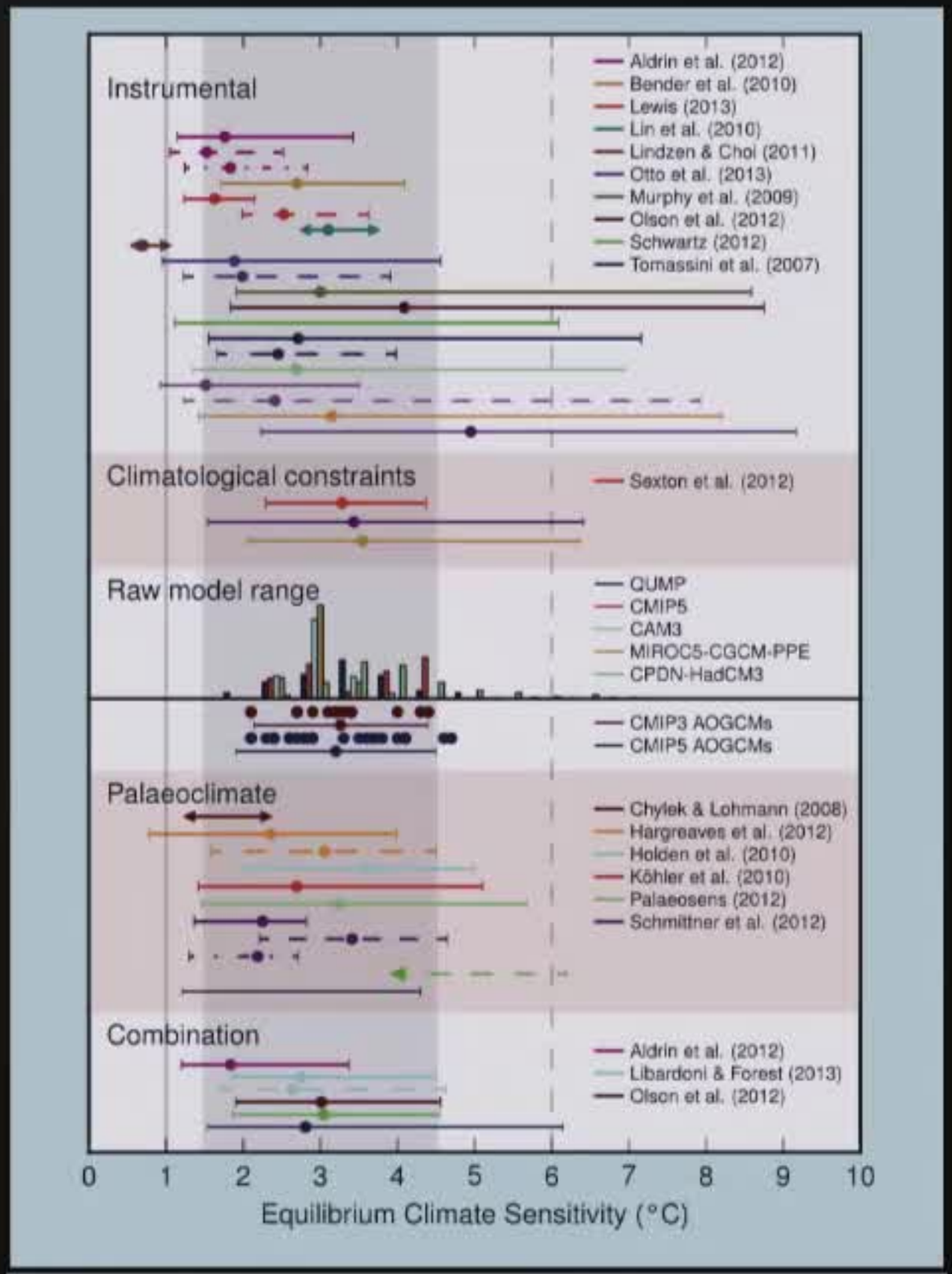

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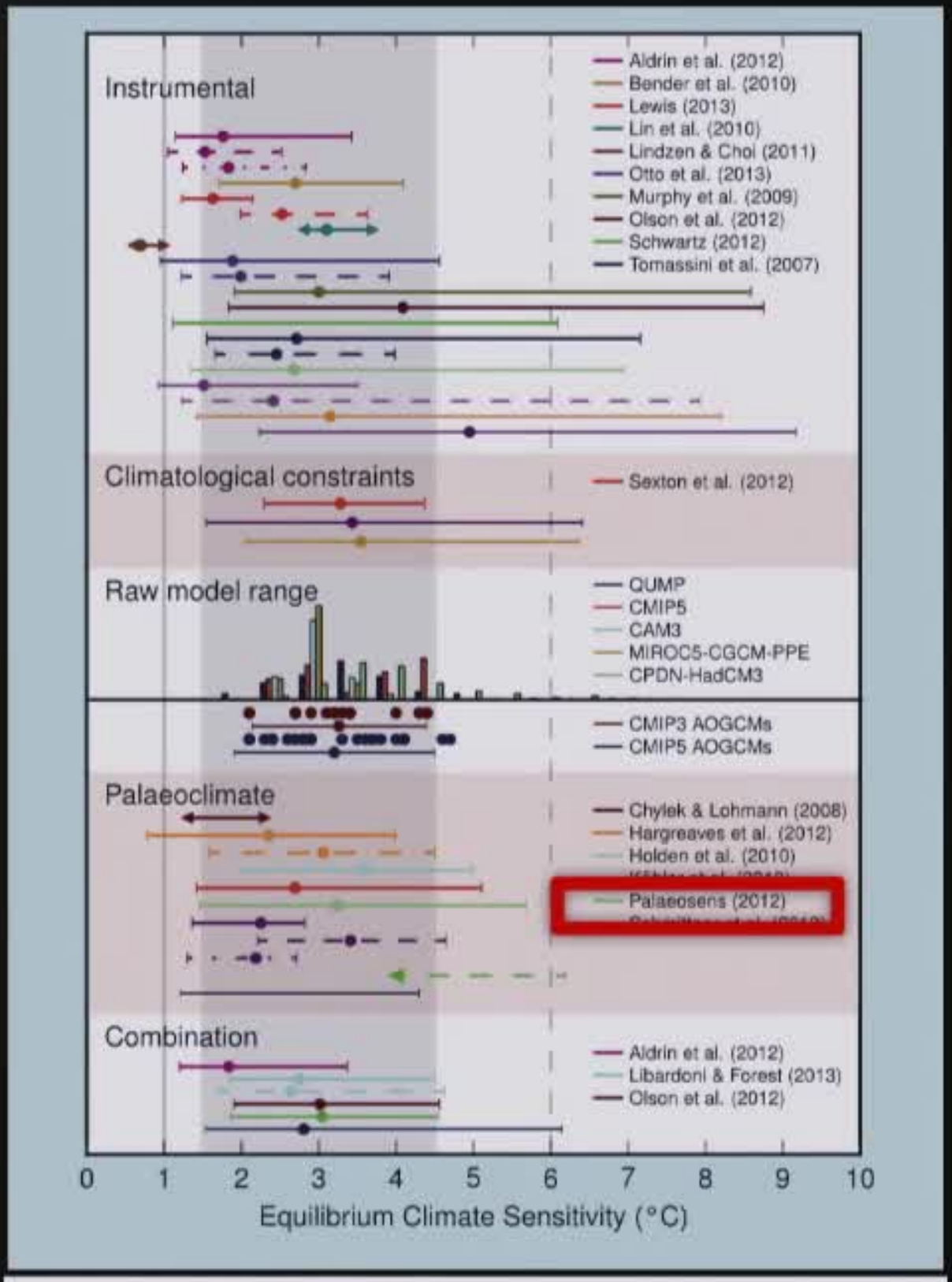

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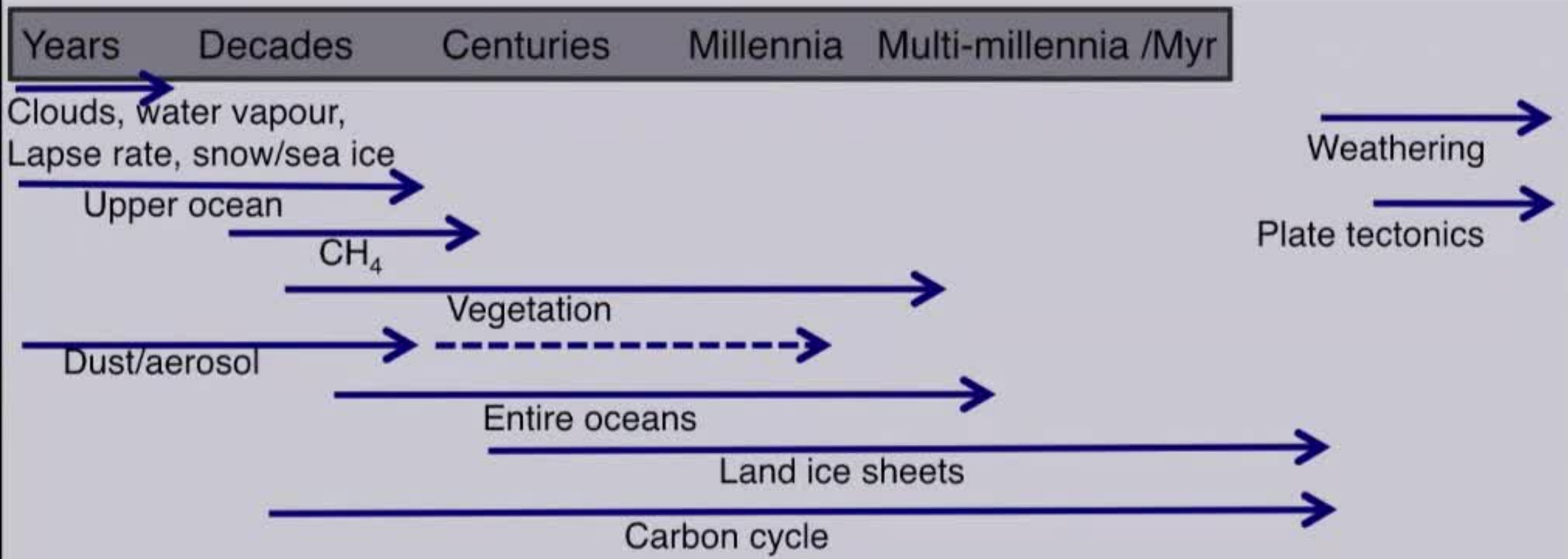

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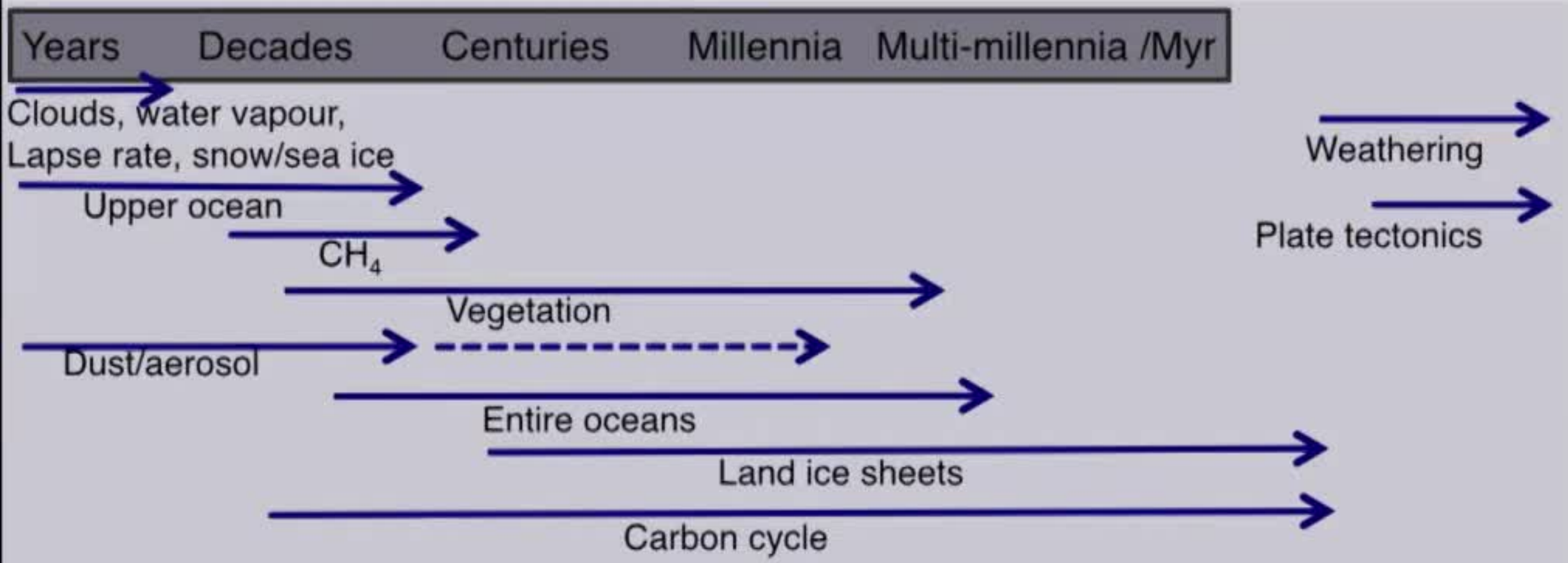
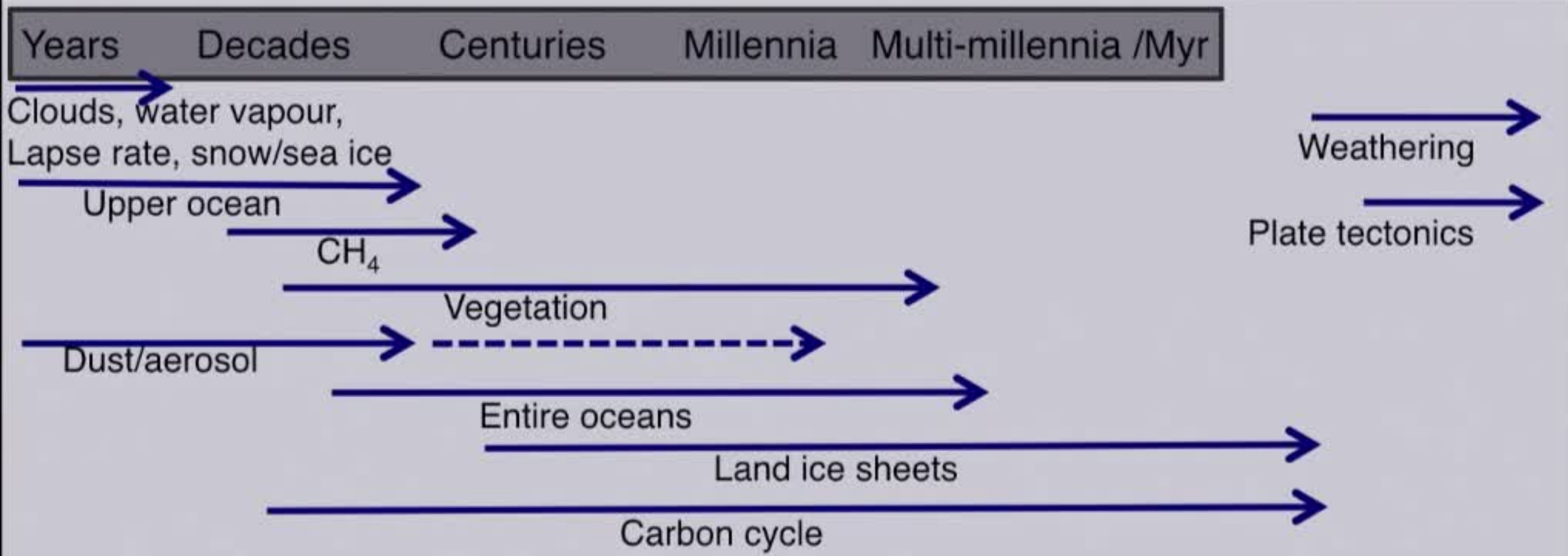
PALAEOSENS,
Rohling et al., Nature 491 (2012)



Feedbacks on different time scales

PALAEOSENS,
Rohling et al., Nature 491 (2012)



Feedbacks on different time scales

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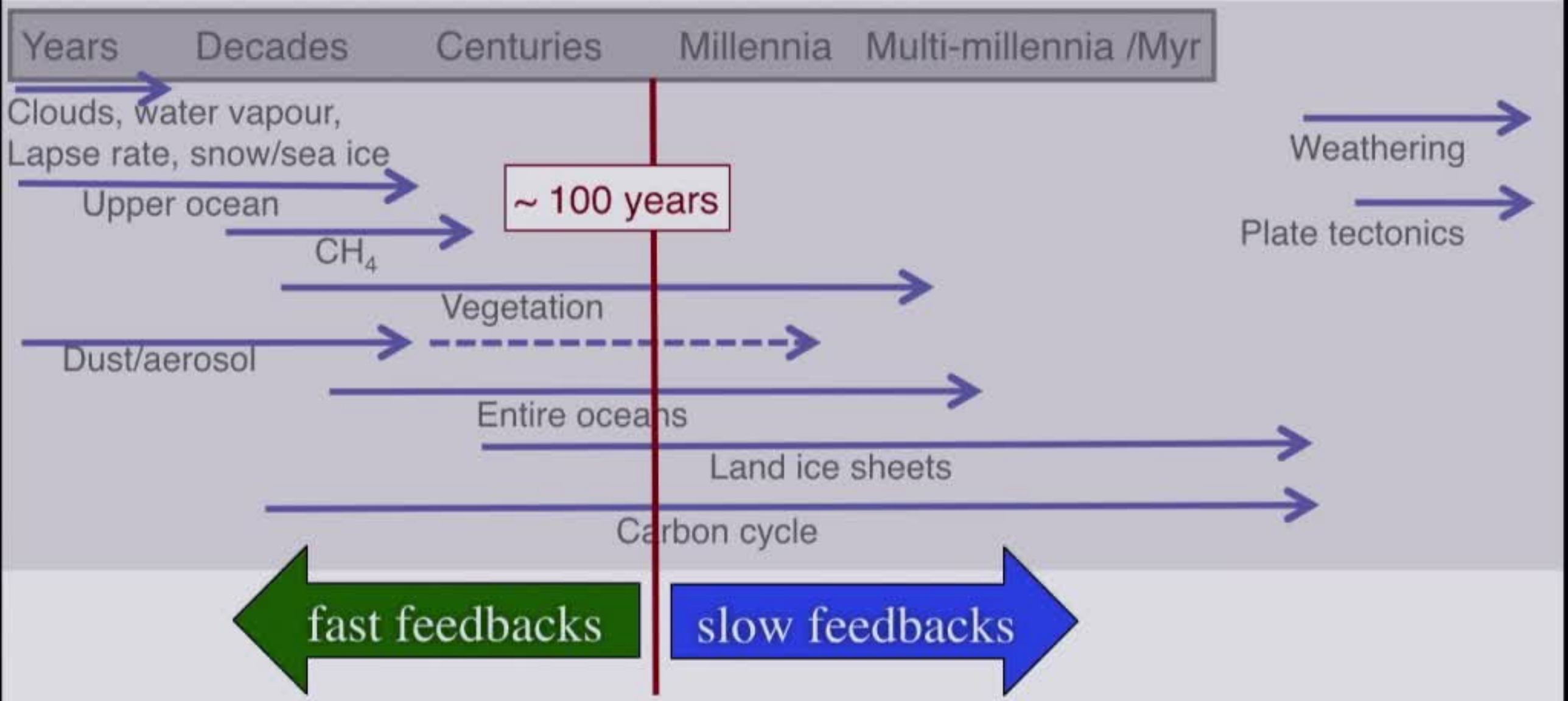

Feedbacks on different time scales

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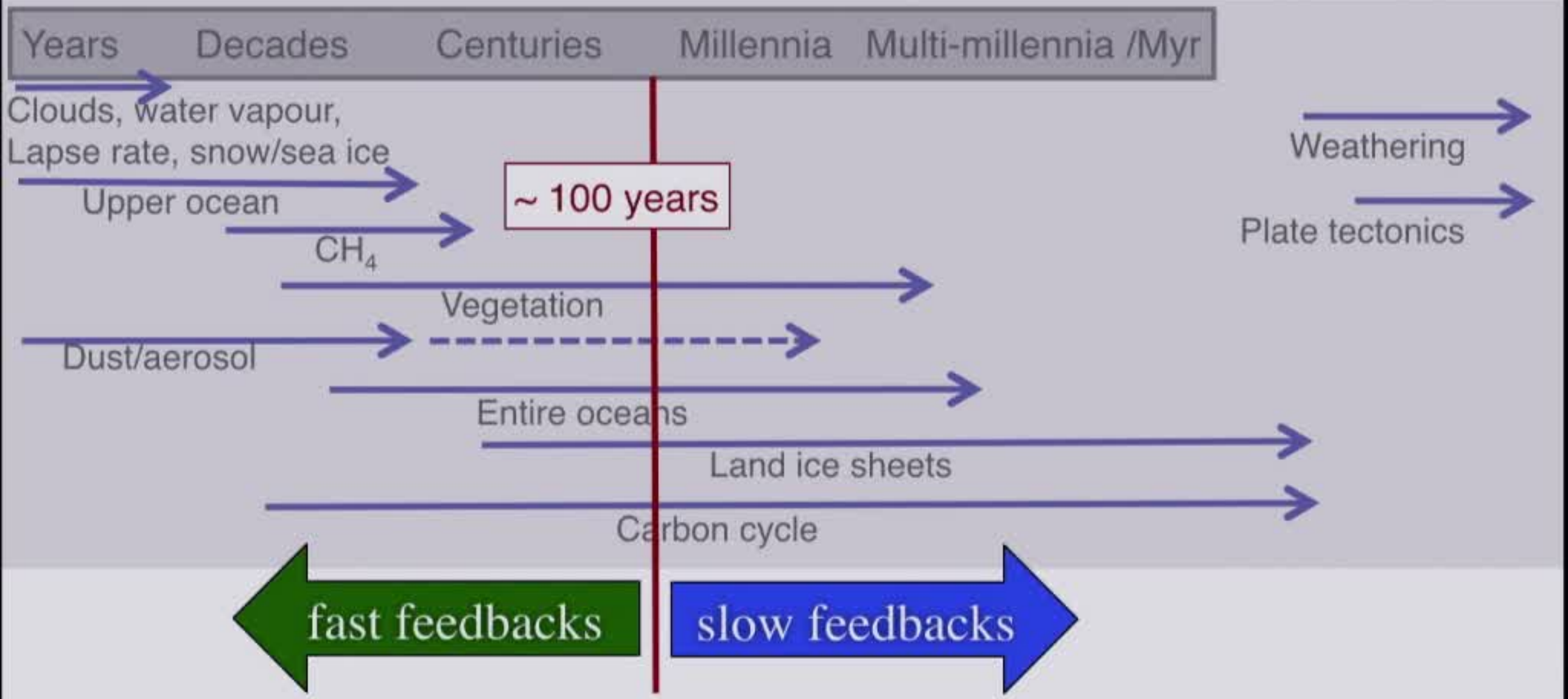


Earth system sensitivity

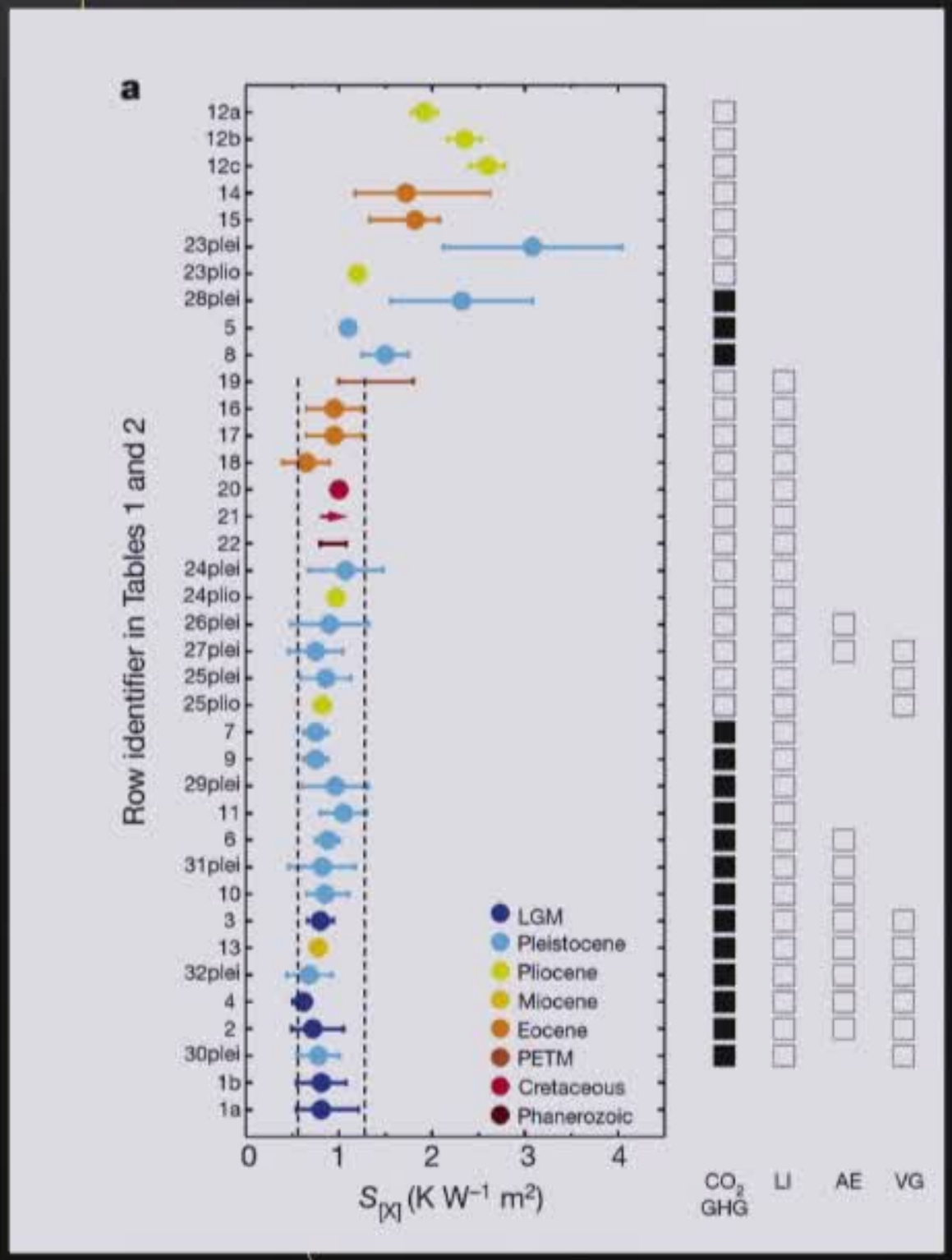
$$S^p = S_{[CO_2]} = \frac{\Delta T}{\Delta R_{[CO_2]}}$$

Correct for slow feedbacks, e.g.

$$S_{[CO_2,LI]} = \frac{\Delta T}{\Delta R_{[CO_2]} + \Delta R_{[LI]}}$$

Equilibrium sensitivity S^a: corrected for all slow feedbacks

Estimates of equilibrium climate sensitivity over geological time



Range of S^a from proxy data corresponds to those from instrumental data over a large interval of geological time once S^p is corrected for the slow feedbacks