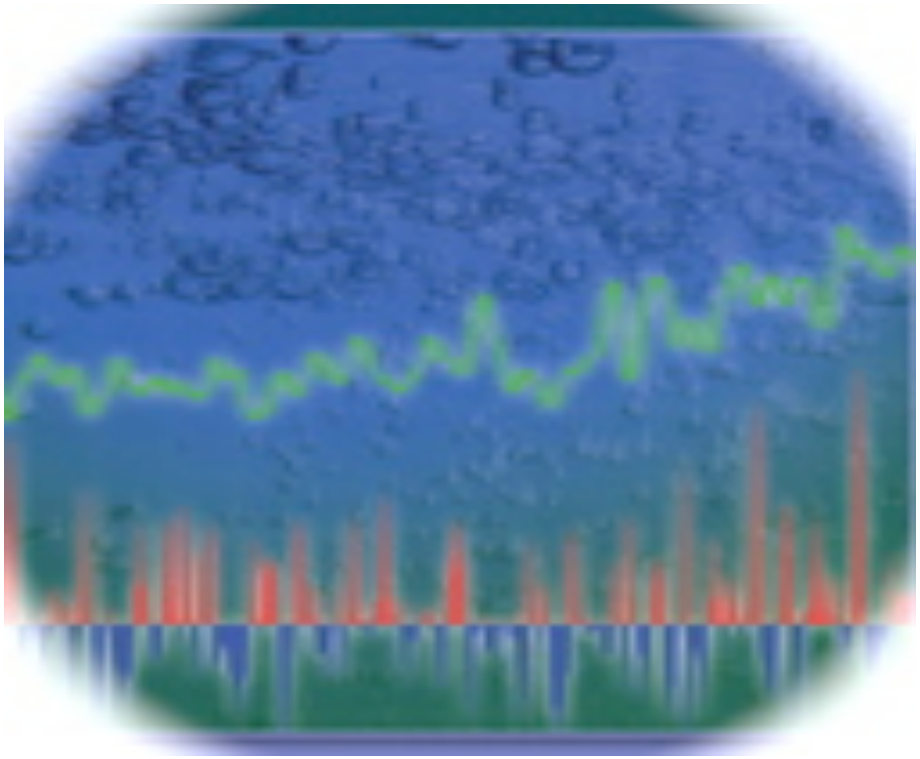
Climate Dynamics: Why Does Climate Vary?



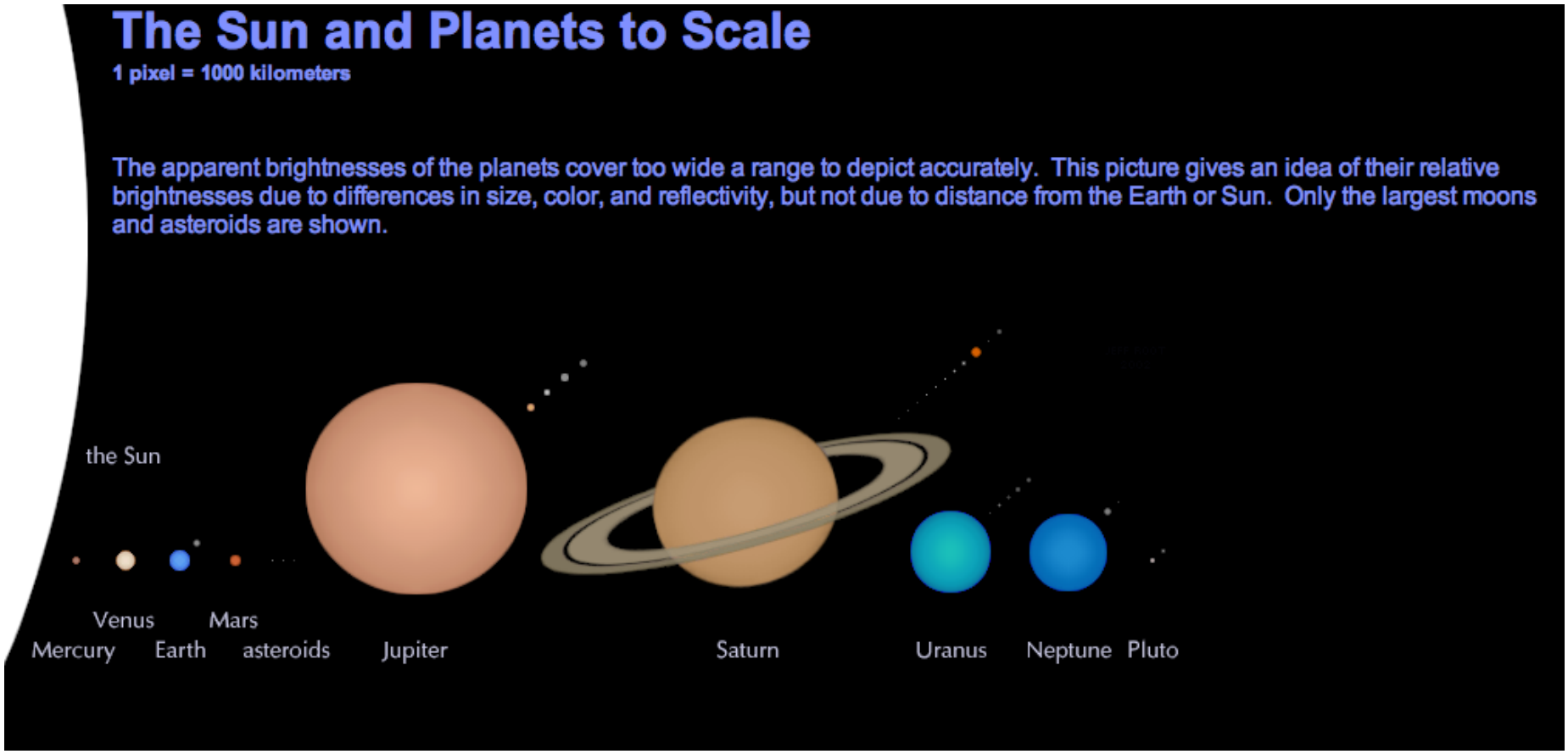
The Medieval Climate Anomaly and the Little Ice Age: Thermolhaline Circulation and the Tropical-Extratropical Interaction

http://www.esrl.noaa.gov/psd/people/dezheng.sun/lectures/ATOC7500.html

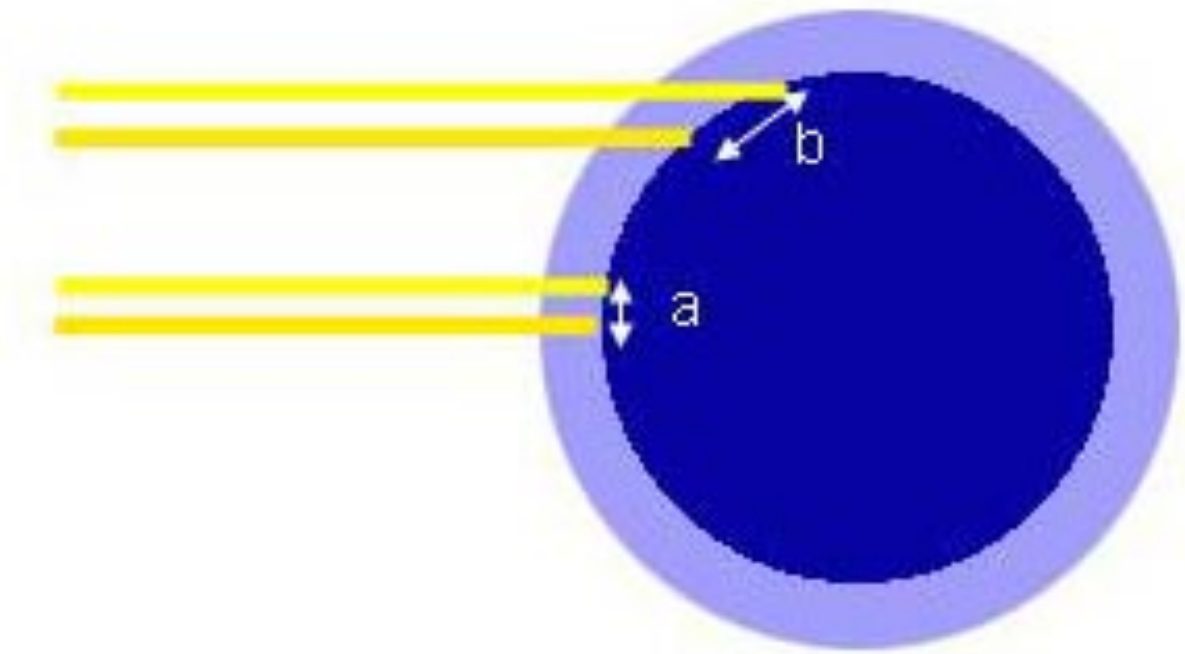
Midterm Exam

Question # 3
Question # 14
Question #15
Question #18
Question # 19
Question # 20

The sizes of the planets and their distances from the Sun



Why does the tropics receive more solar radiation than the extra-tropics?



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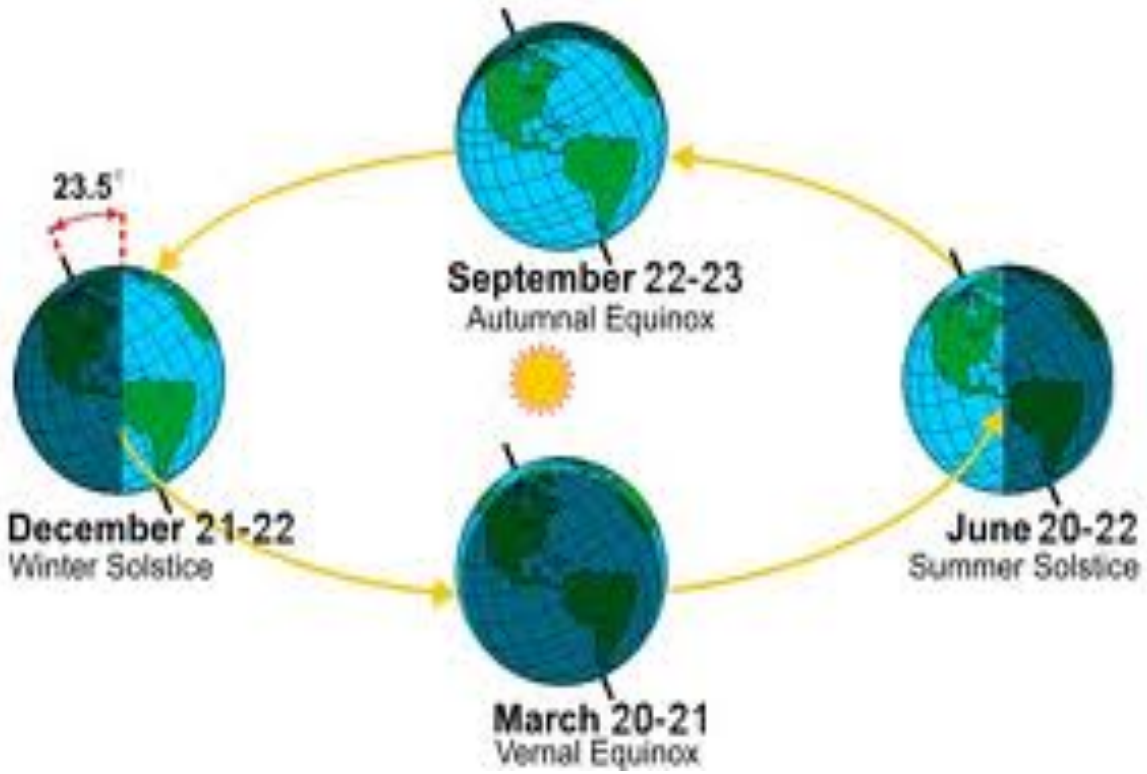
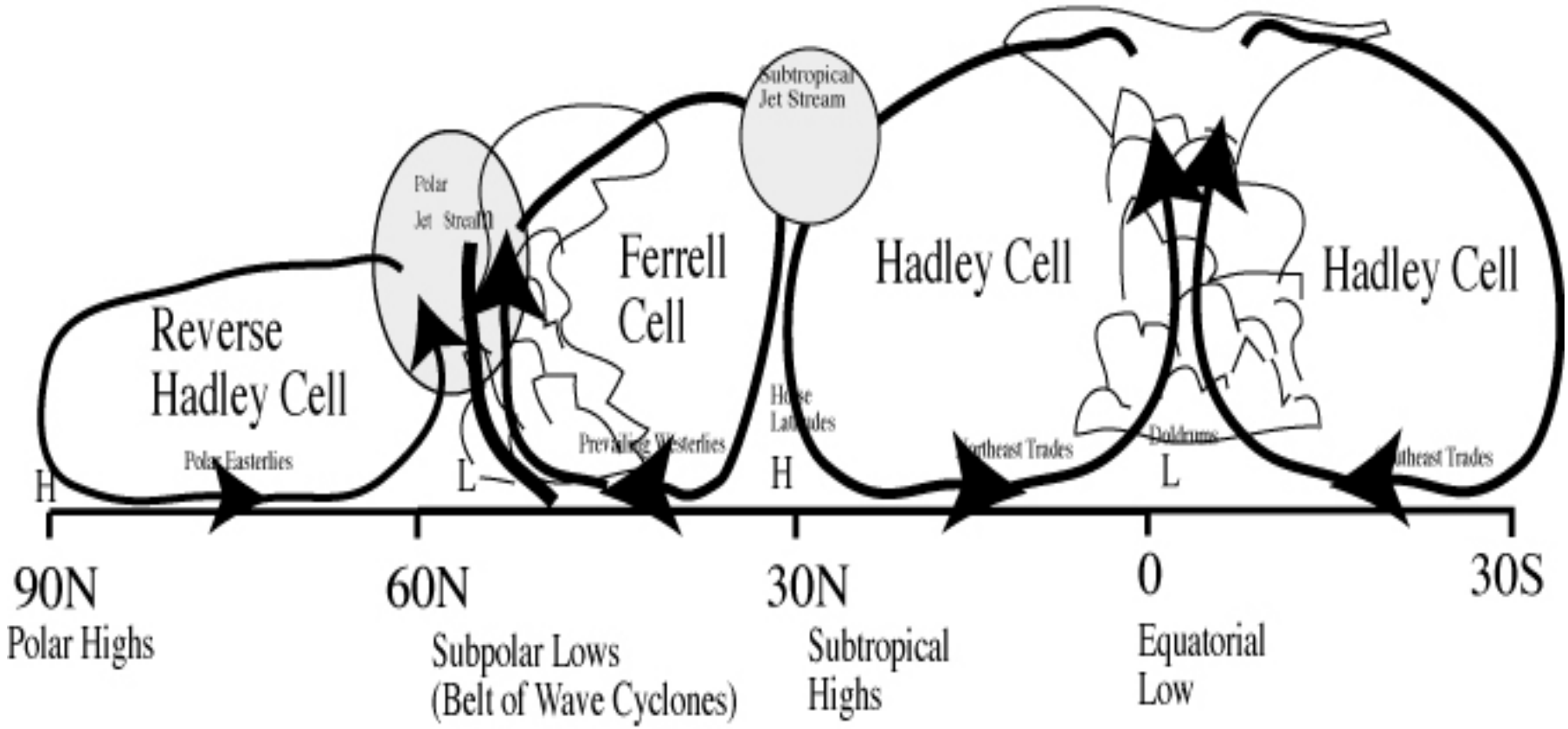
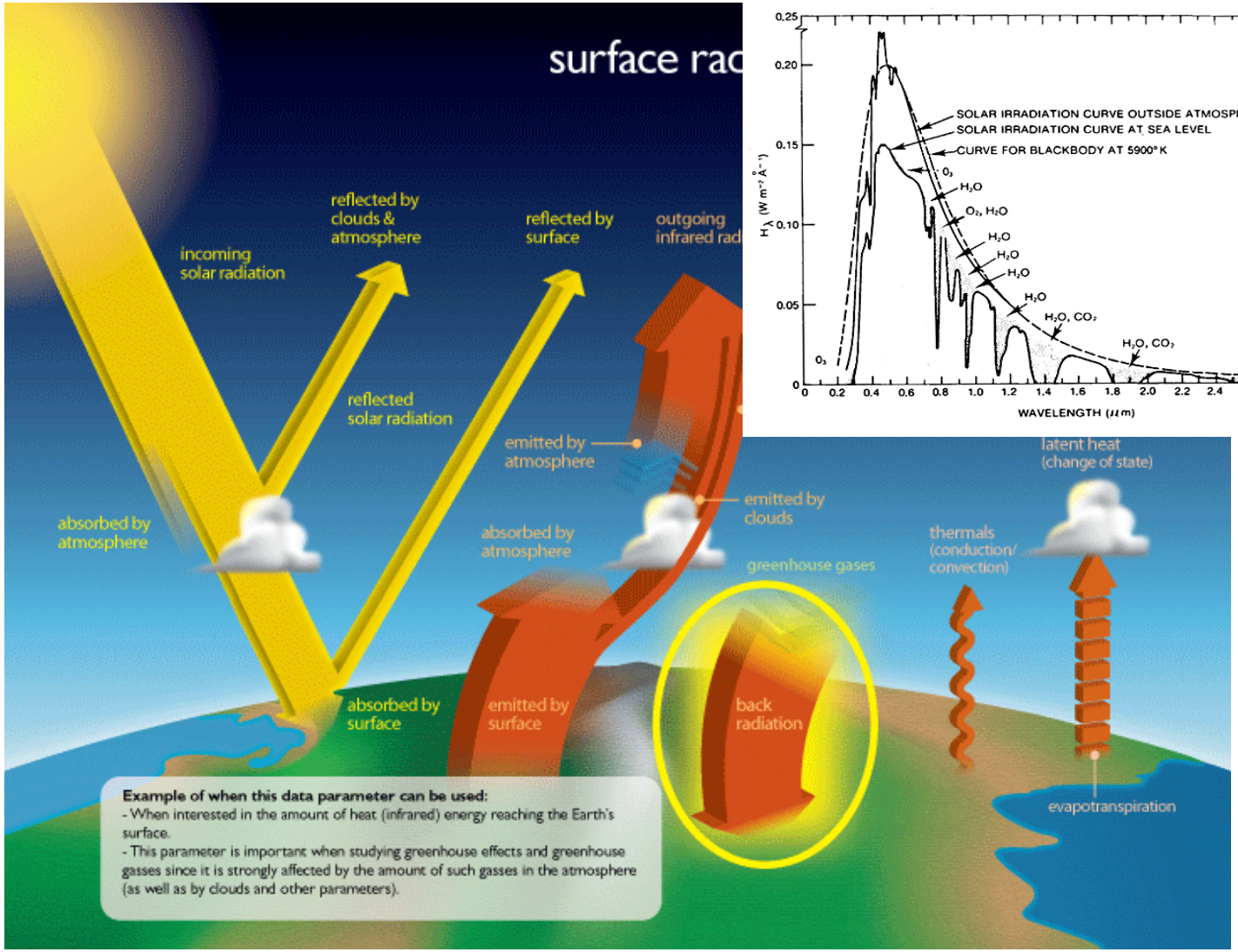


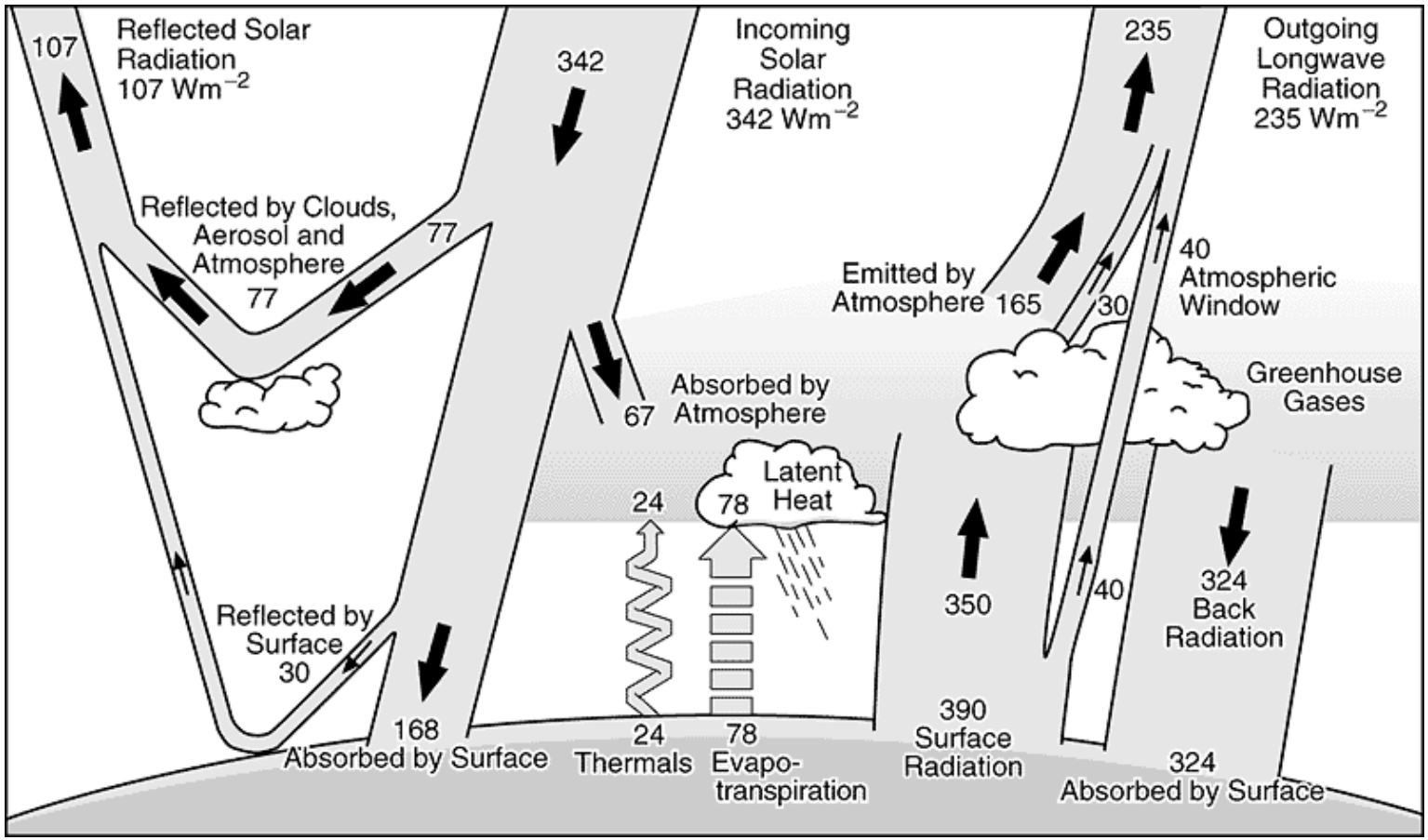
Meridional Differential Heating & General Circulation



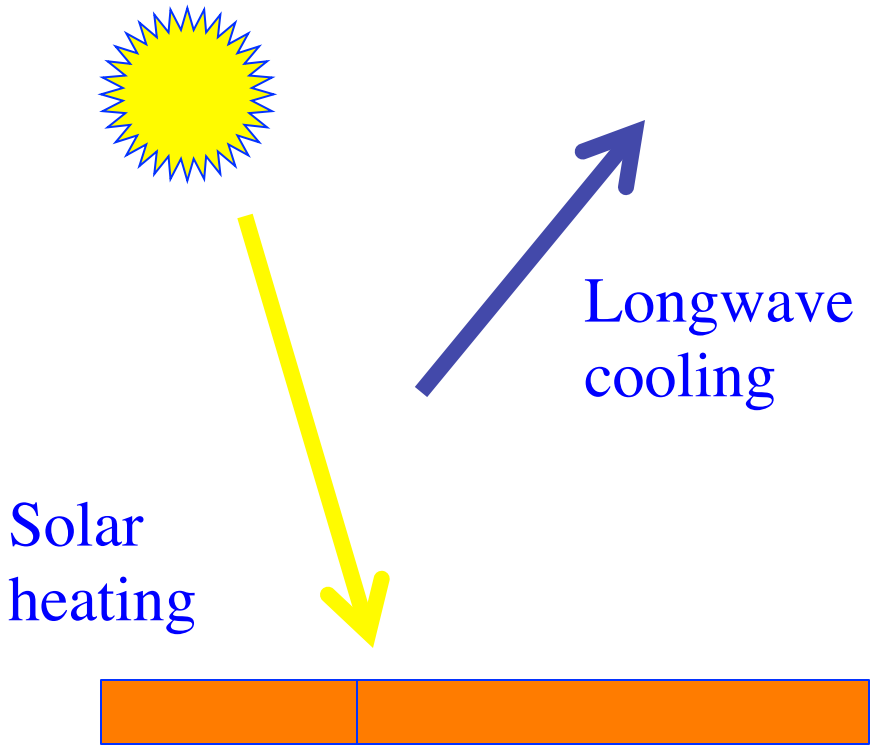
Why during a clear sunny day, the earth's surface is heated up more quickly than the overlying atmosphere?

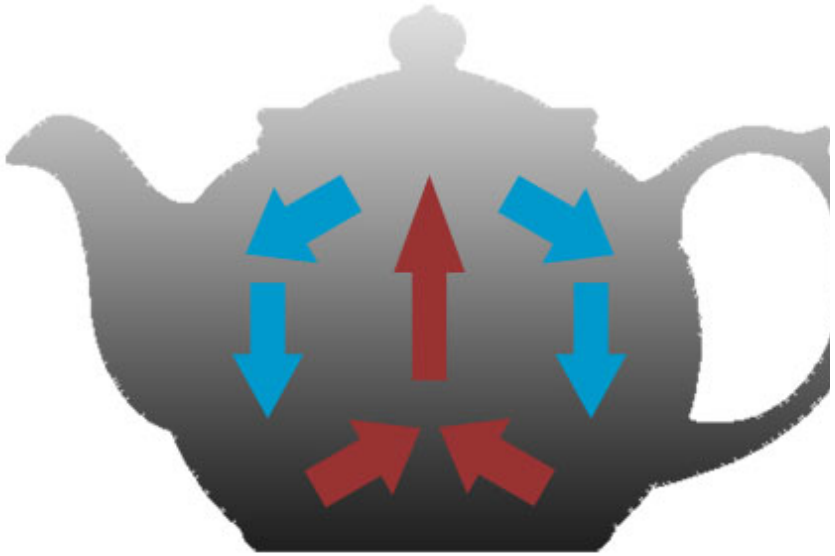


Even climatologically speaking, the Sun effectively "heats" the atmosphere from below

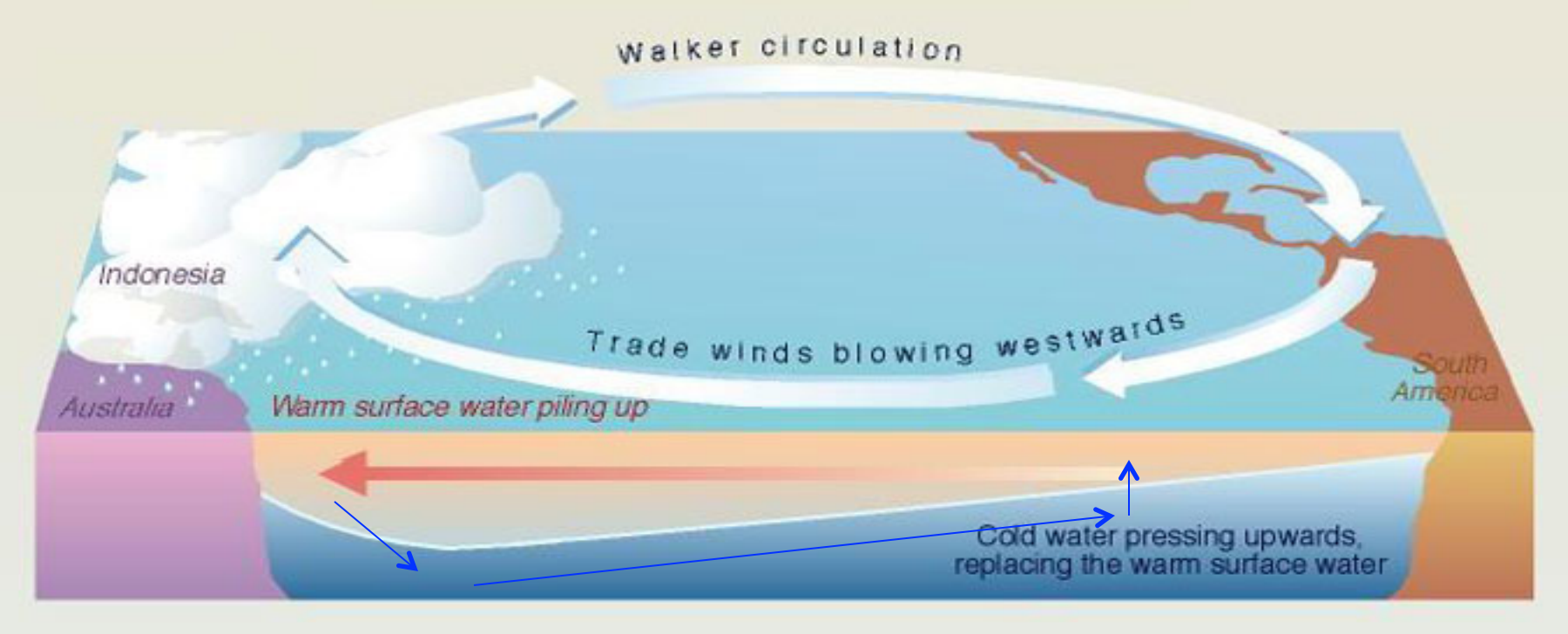


Why does the tropical atmosphere convect?

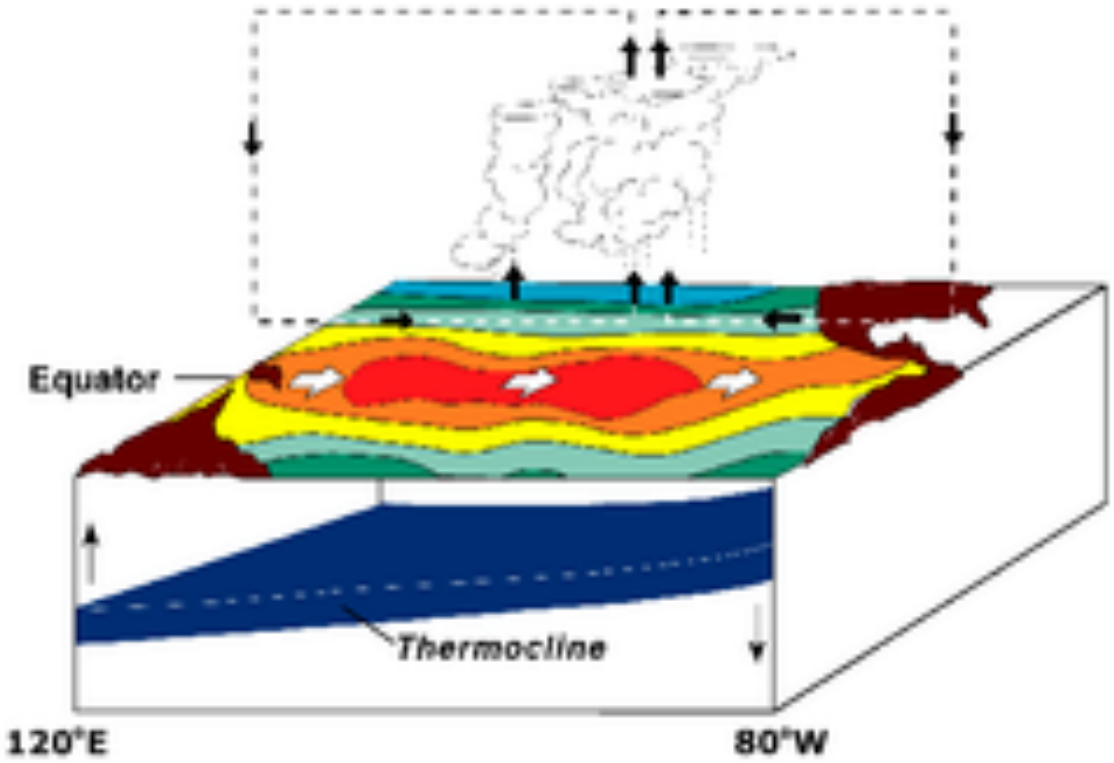




Why Is the East Colder than the West?

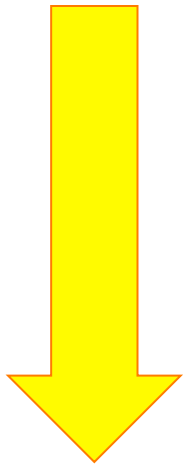


But Zonal SST distribution During El Nino Suggests that The east can be as warm as the west!

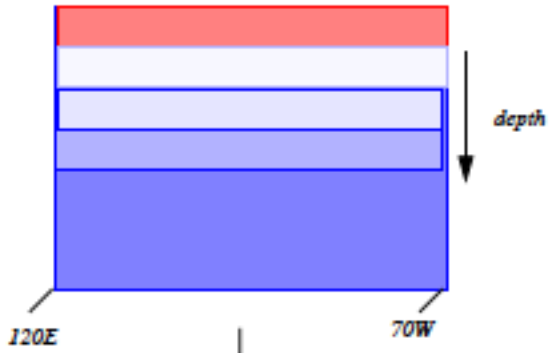


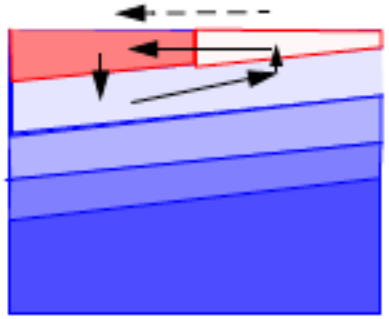
Yes, I can be there momentarily, but I cannot stay there, because it is unstable!

Heating from above



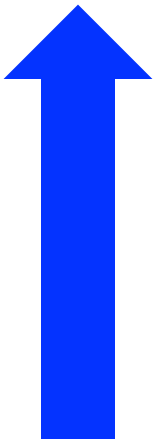
I





II

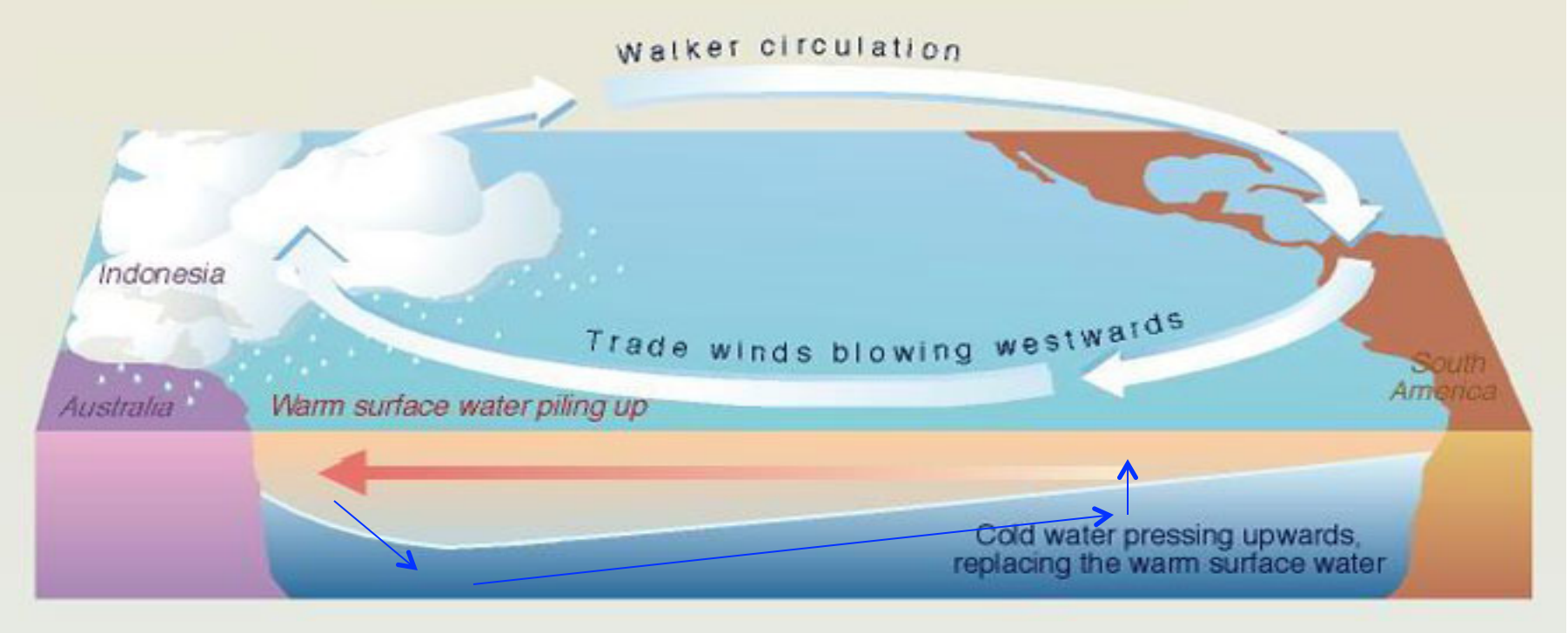
Pitch-fork bifurcation



Cooling from Below

Sun & Liu 1996;
Sun 2000

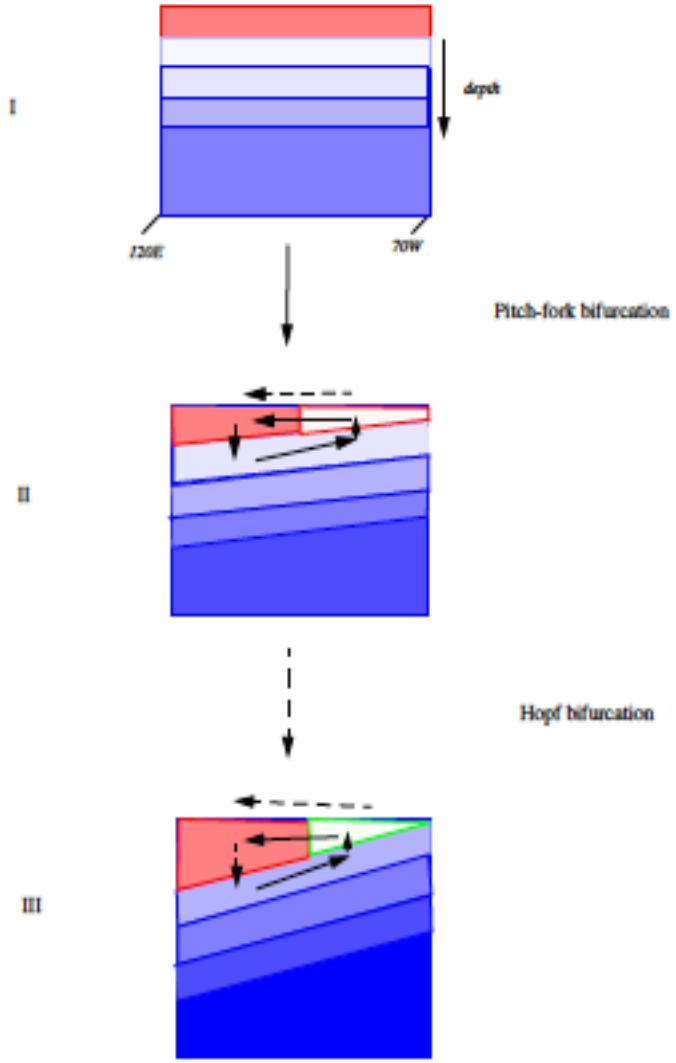
Why can't the warmpool—cold-tongue configuration keep steady?



Now the asymmetric state also becomes unstable!

Being "homeless" now, the system "travels" around these two equilibrium states, resulting an oscillating behavior.

Heating from above



Cooling from Below

Sun 1997; Sun 2000

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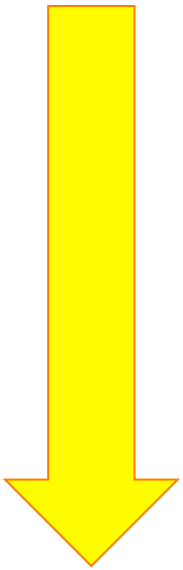
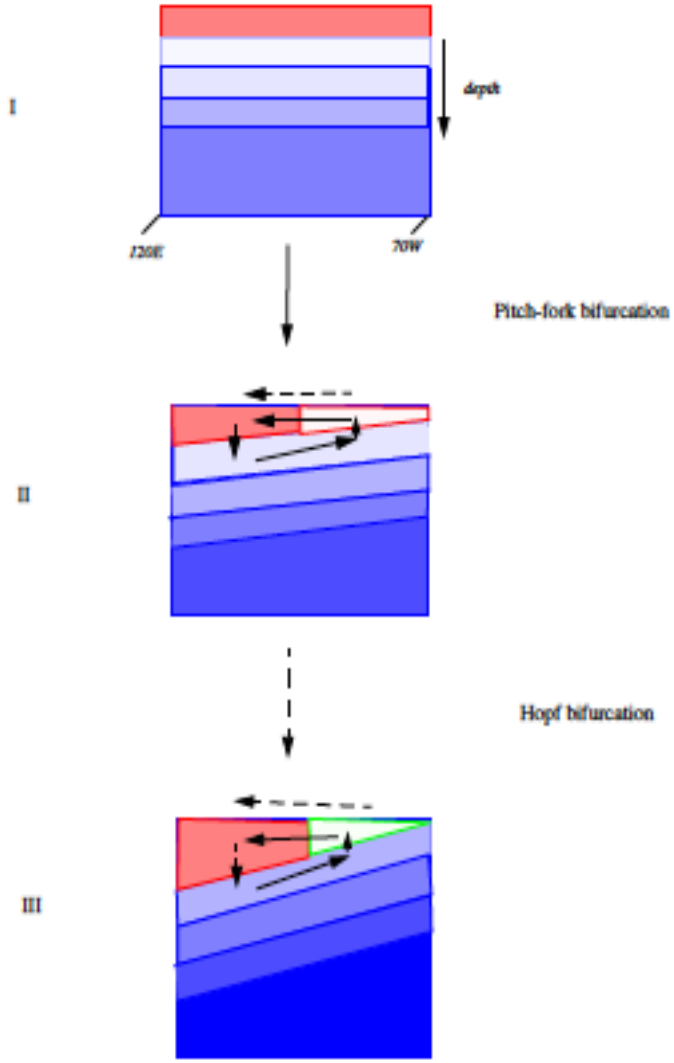
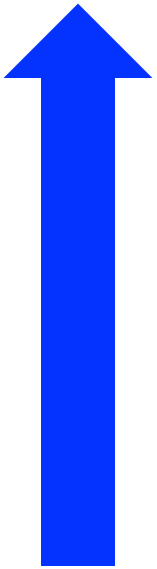


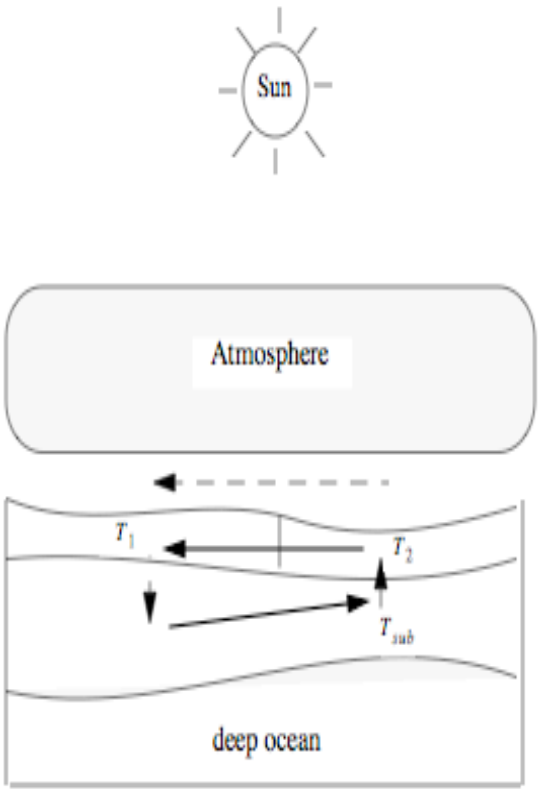




Cooling from Below

Sun 1997; Sun 2000

A Box Model for the ENSO System



West East

$$\frac{dT_1}{dt} = c(T_e - T_1) + sq(T_2 - T_1)$$

$$\frac{dT_2}{dt} = c(T_e - T_2) + q(T_{sub} - T_2)$$

$$q = \frac{\alpha}{a}(T_1 - T_2)$$

$$T_{sub} = \Phi(-H_1 + h_2')$$

$$\Phi(z) = T_e - \frac{T_e - T_b}{2}(1 - \tanh(\frac{z + z_0}{H^*}))$$

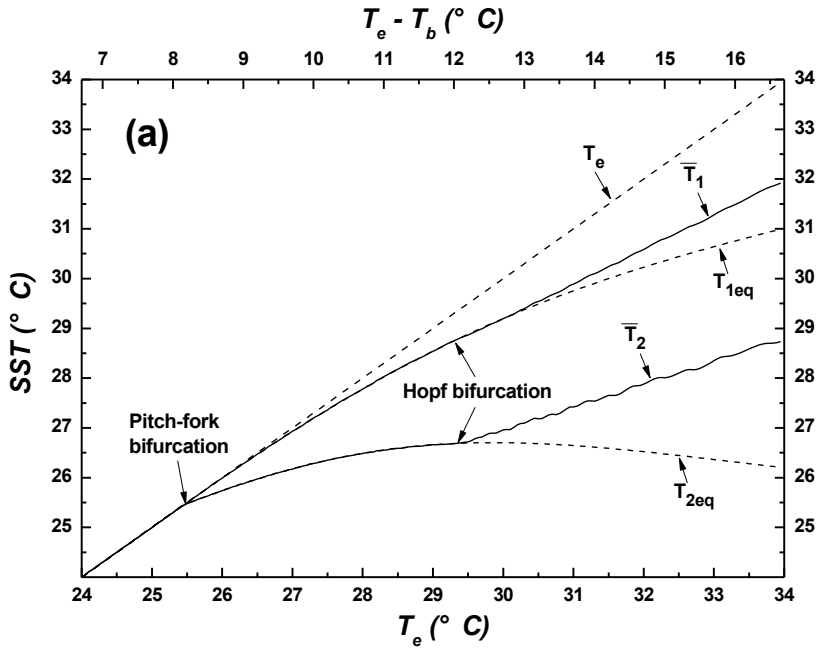
$$h_2' - h_1' = -\frac{H_1}{H_2} H \frac{\alpha}{b^2}(T_1 - T_2)$$

$$\frac{1}{r}\frac{dh_1'}{dt} = -h_1' + \frac{H_1}{2H_2} H \frac{\alpha}{b^2}(T_1 - T_2)$$

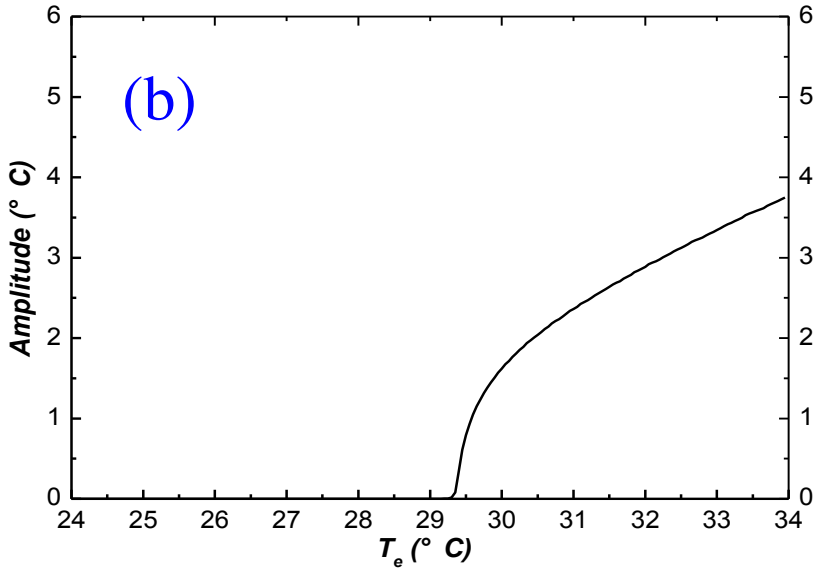
Sun and Liu 1996, Jin 1996, Sun 1997,

Tropical Pacific Climate as a Function of T_e.

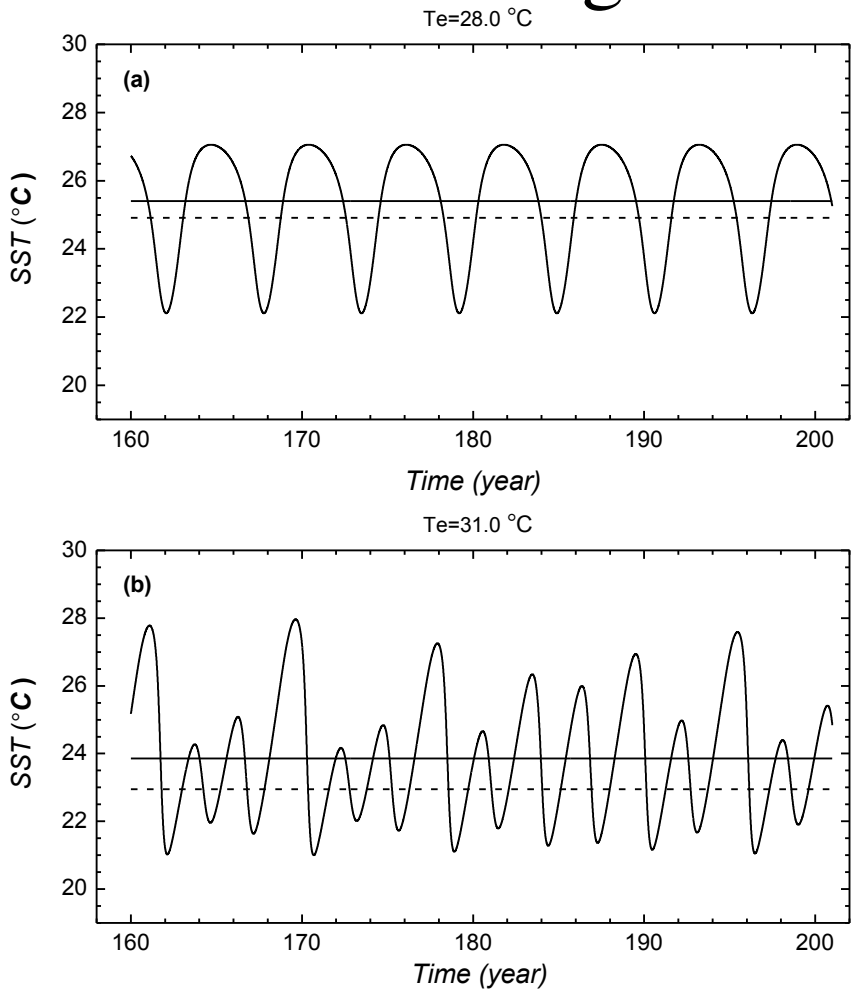
Equilibrium and Time-Mean SST



Amplitude of ENSO

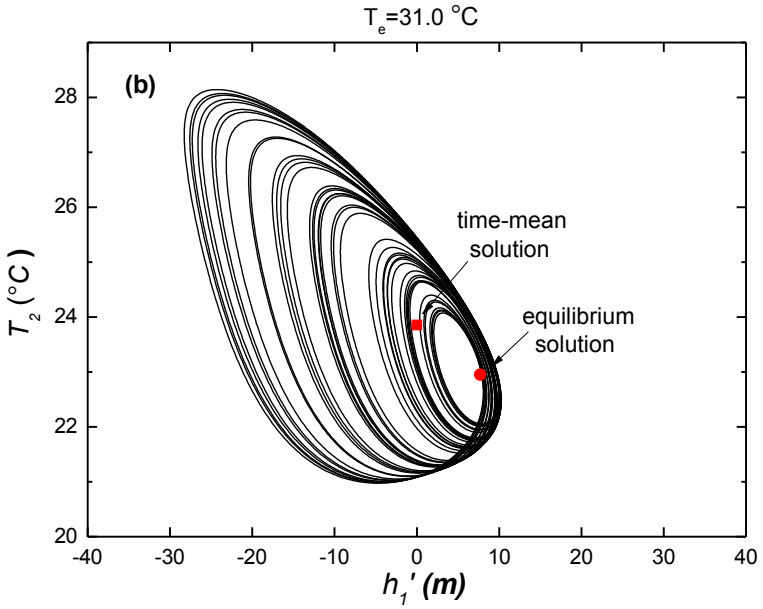


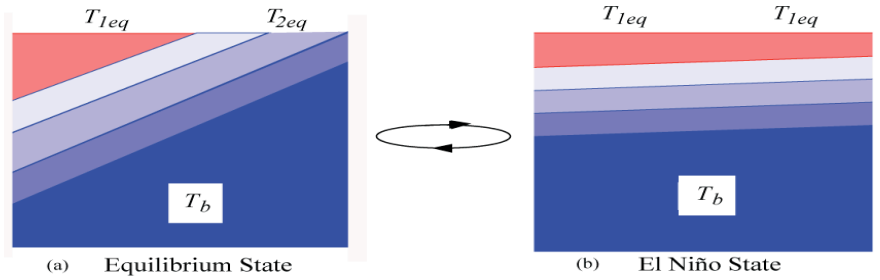
Oscillations in the Model different regimes

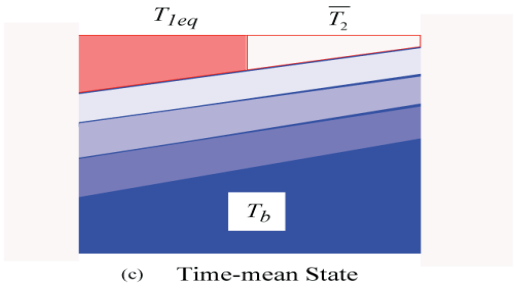


Liang,J., Xiu-Qun Yang, and De-Zheng Sun, 2011: The effect of ENSO events on the Tropical Pacific Mean Climate: Insights from an Analytical Model. J. Climate, 25, 7590-7606.

A New Way to Look at El Nino

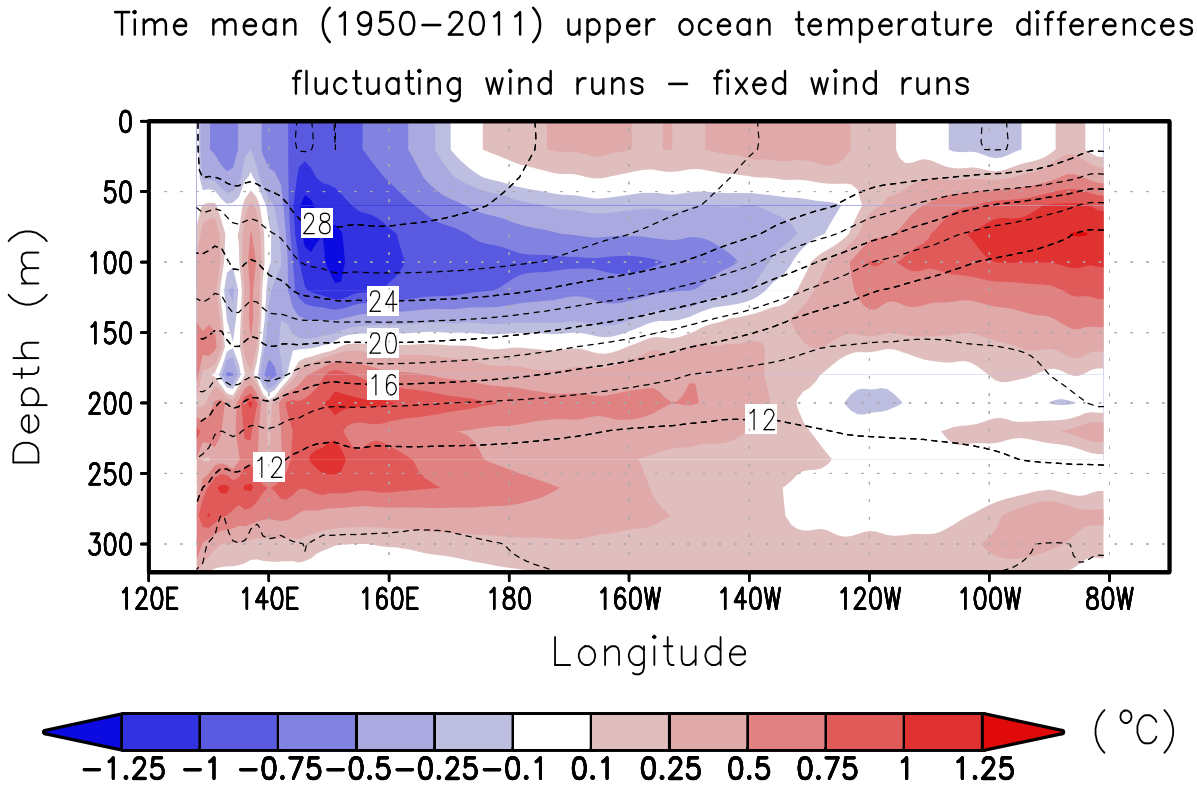






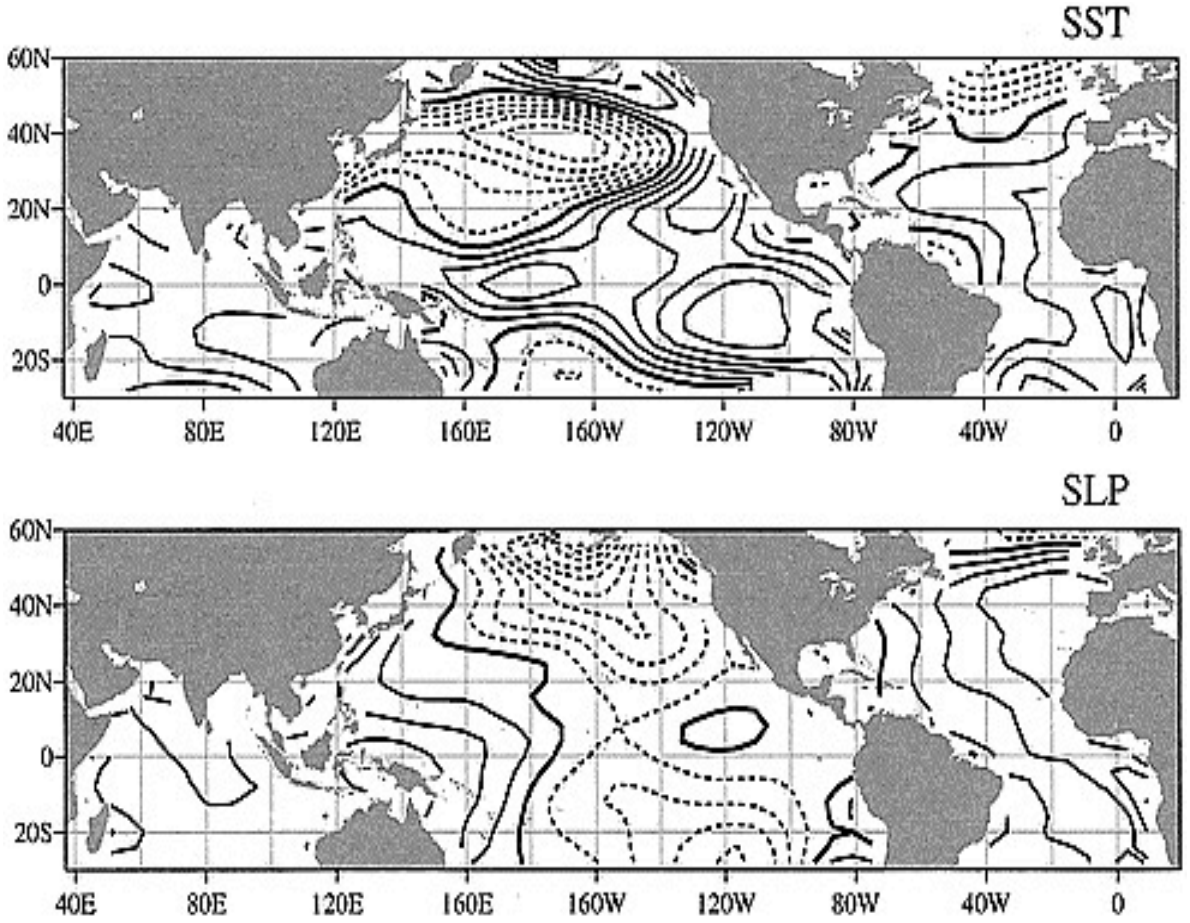
What Does ENSO Events Try to Counteract?

Upper T Difference Between Experiments with/without ENSO

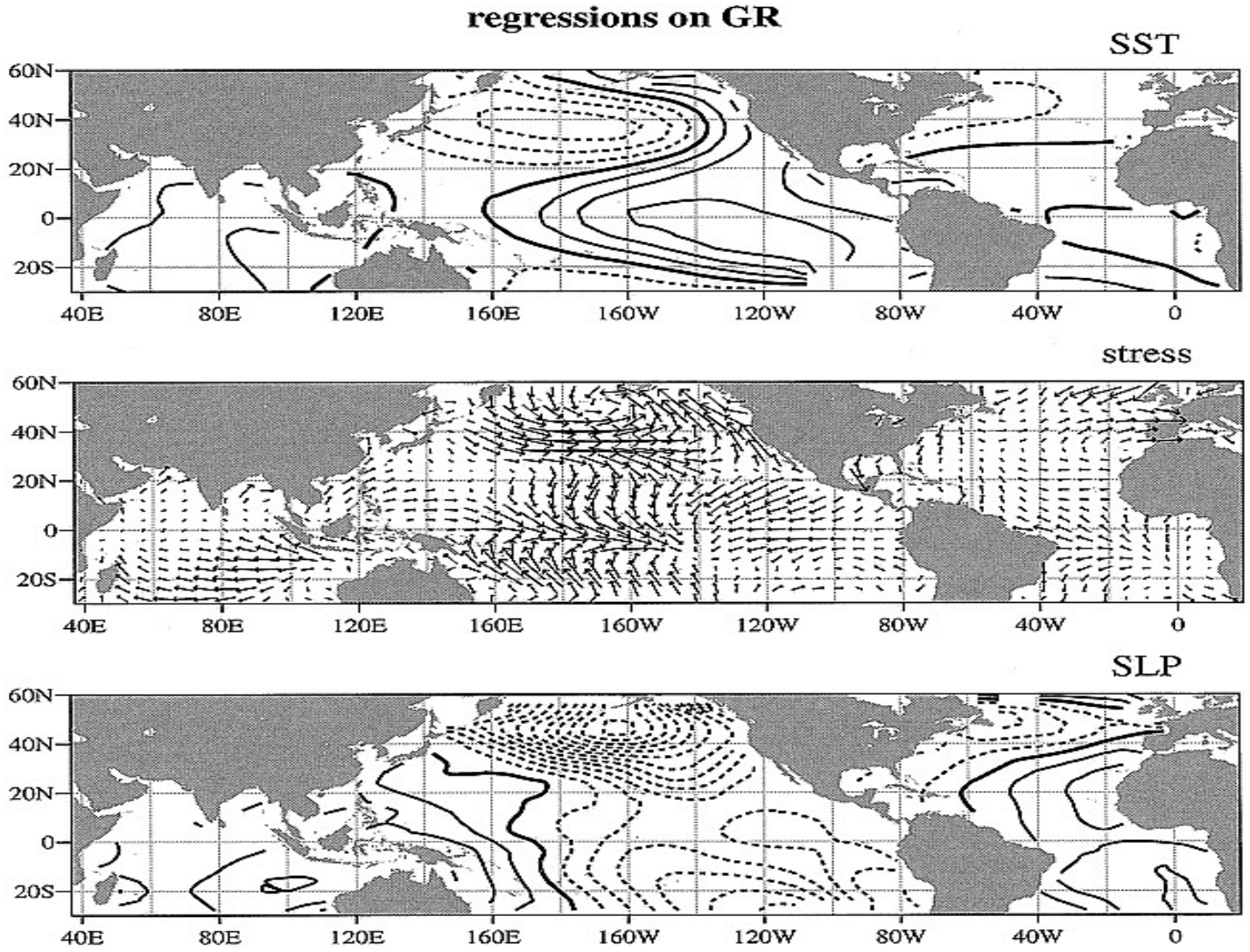


Sun, D.-Z., T. Zhang, Y. Sun, and Y. Yu, 2012: Rectification of El Nino-Southern Oscillation into Climate Anomalies of Decadal and Longer Time-scales. J. Climate, Submitted

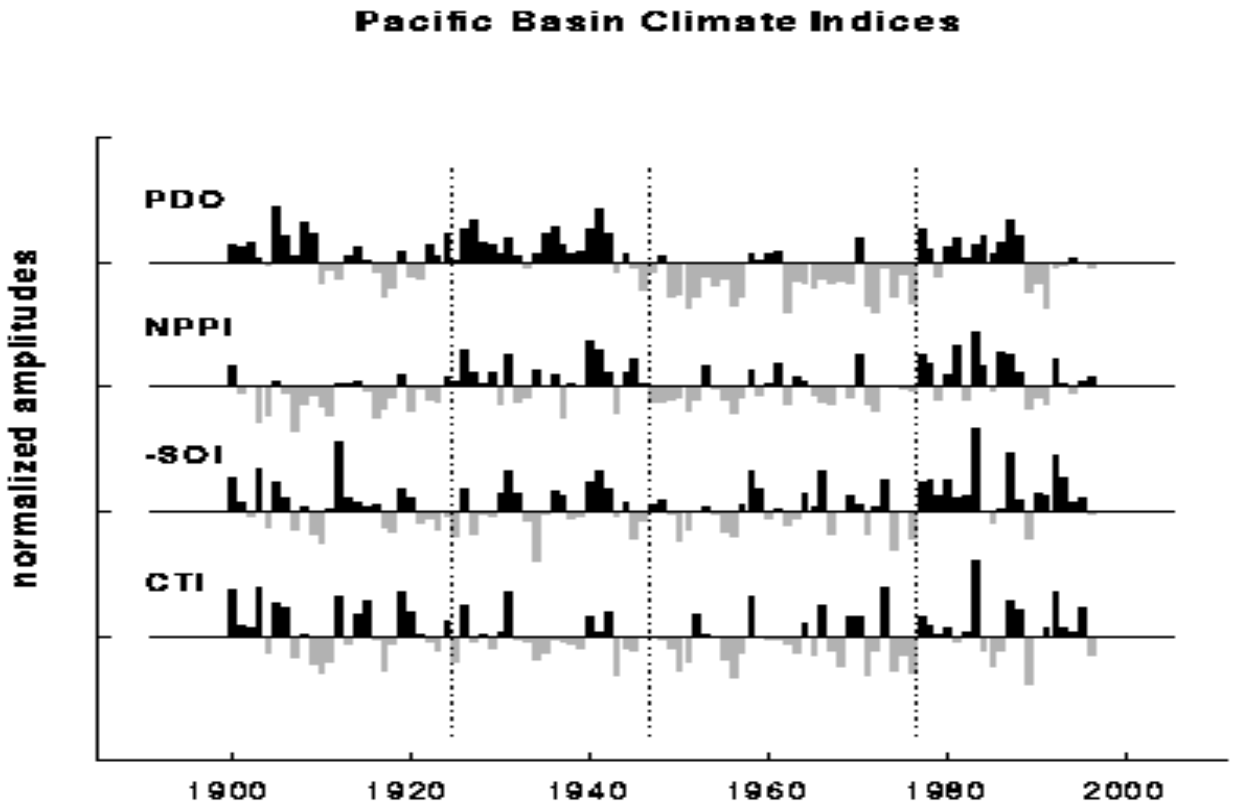
The 1976 Regime Shift
Epoch 1977–93 minus epoch 1950–76



PDO: Spatial Patterns

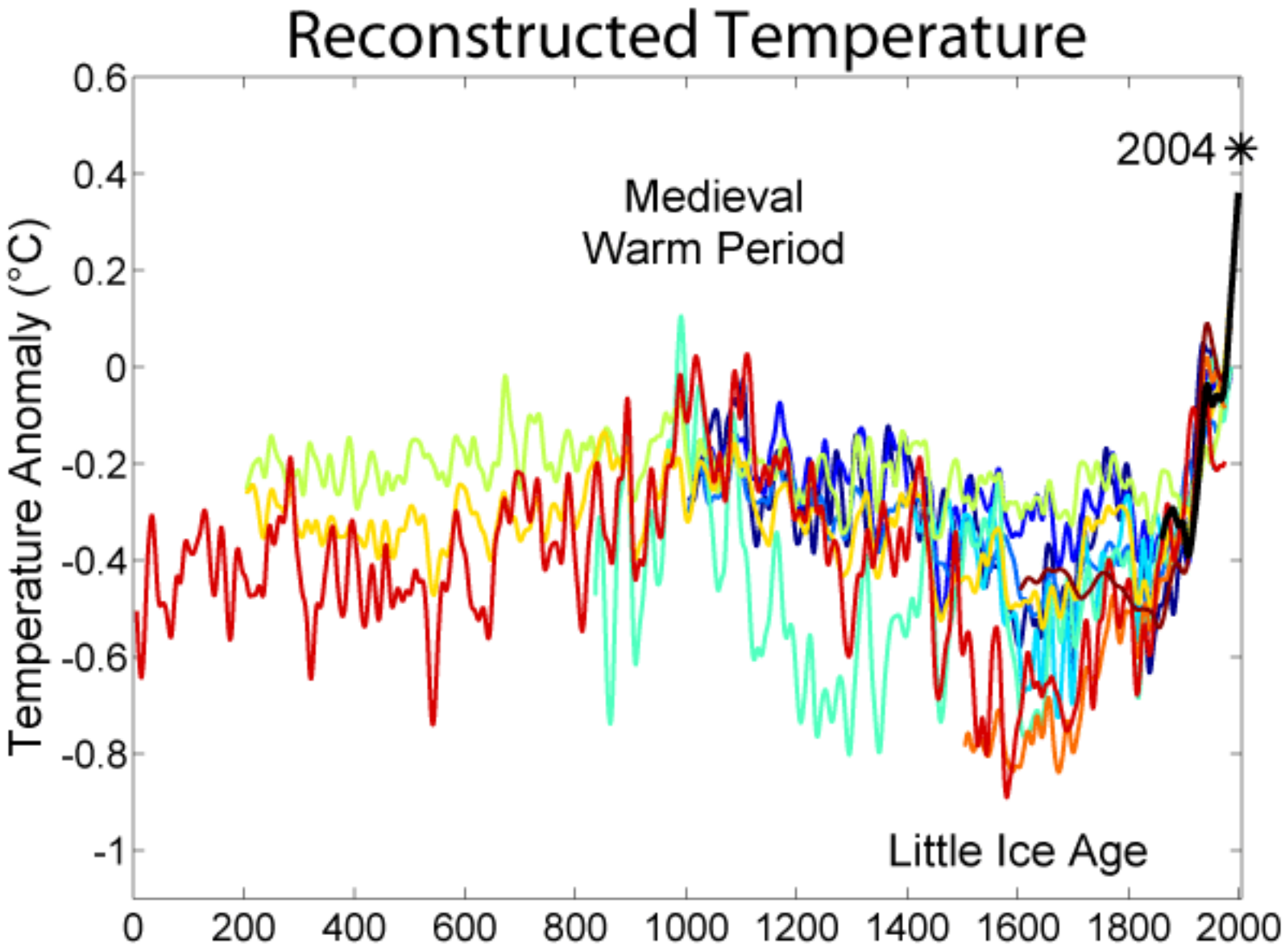


Zhang, Wallace, & Battisti, 1997, J Climate, 10, 1004-1020

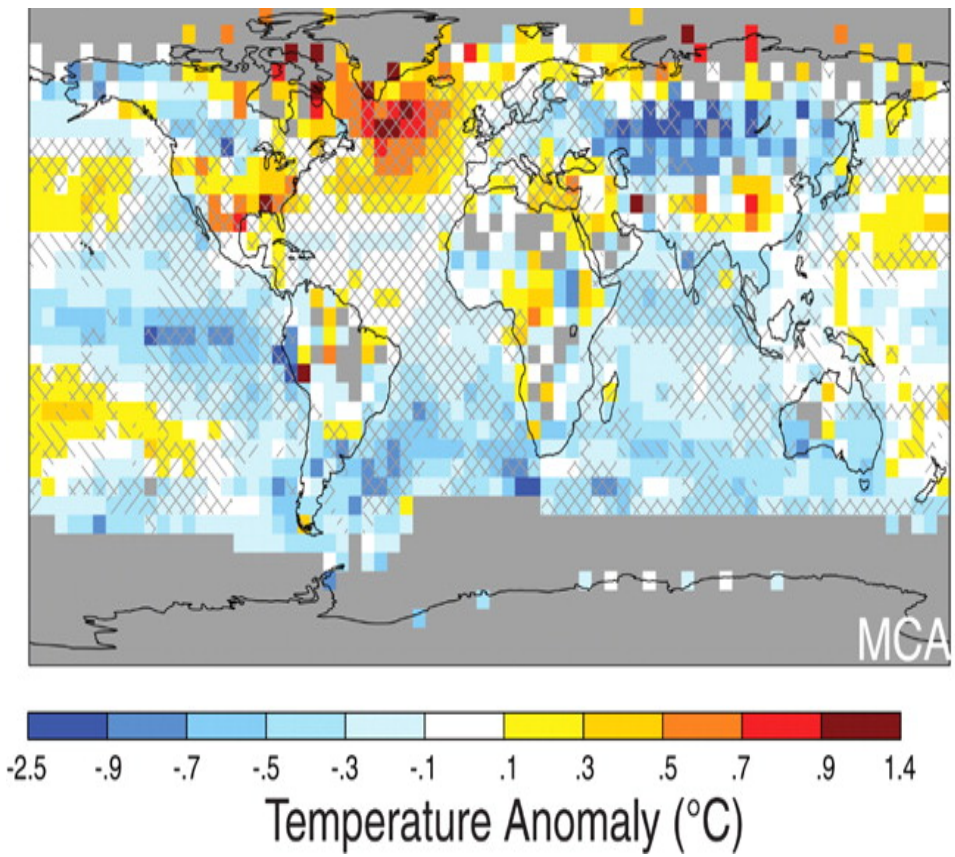


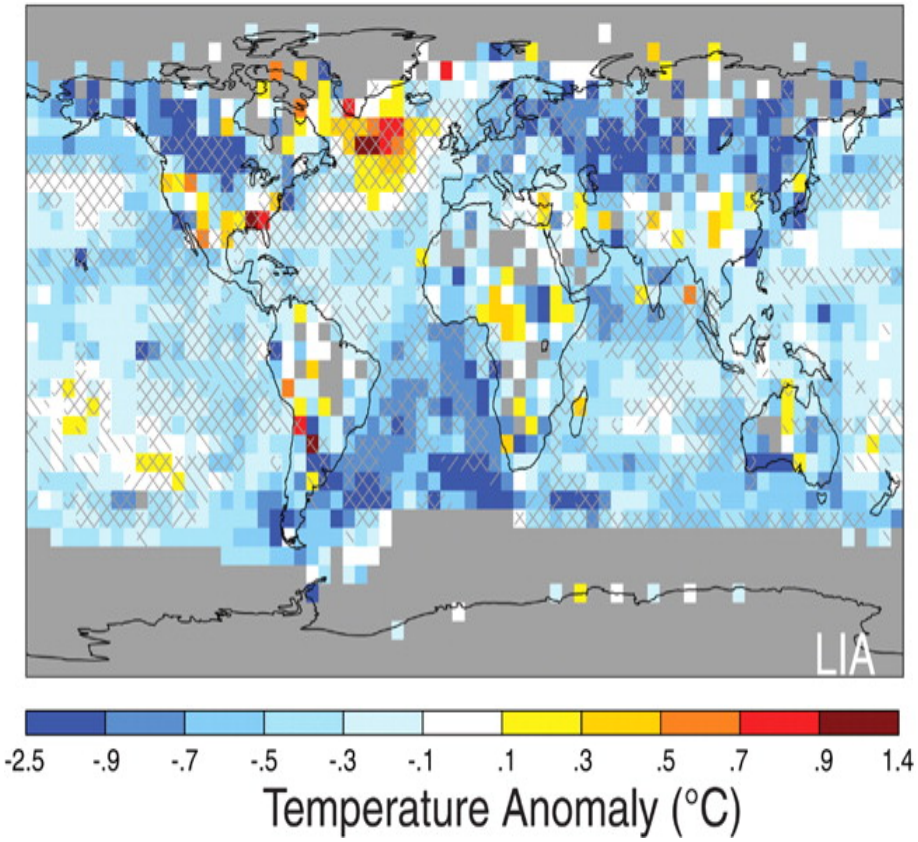
The NPPI (North Pacific SLP), SOI (Southern Oscillation Index, and CTI (Cold-tongue Index) are correlated with the PDO (Mantua et al. 1997, BAMS, 78, 1069-1079)

The MCA (MWP) & LIA



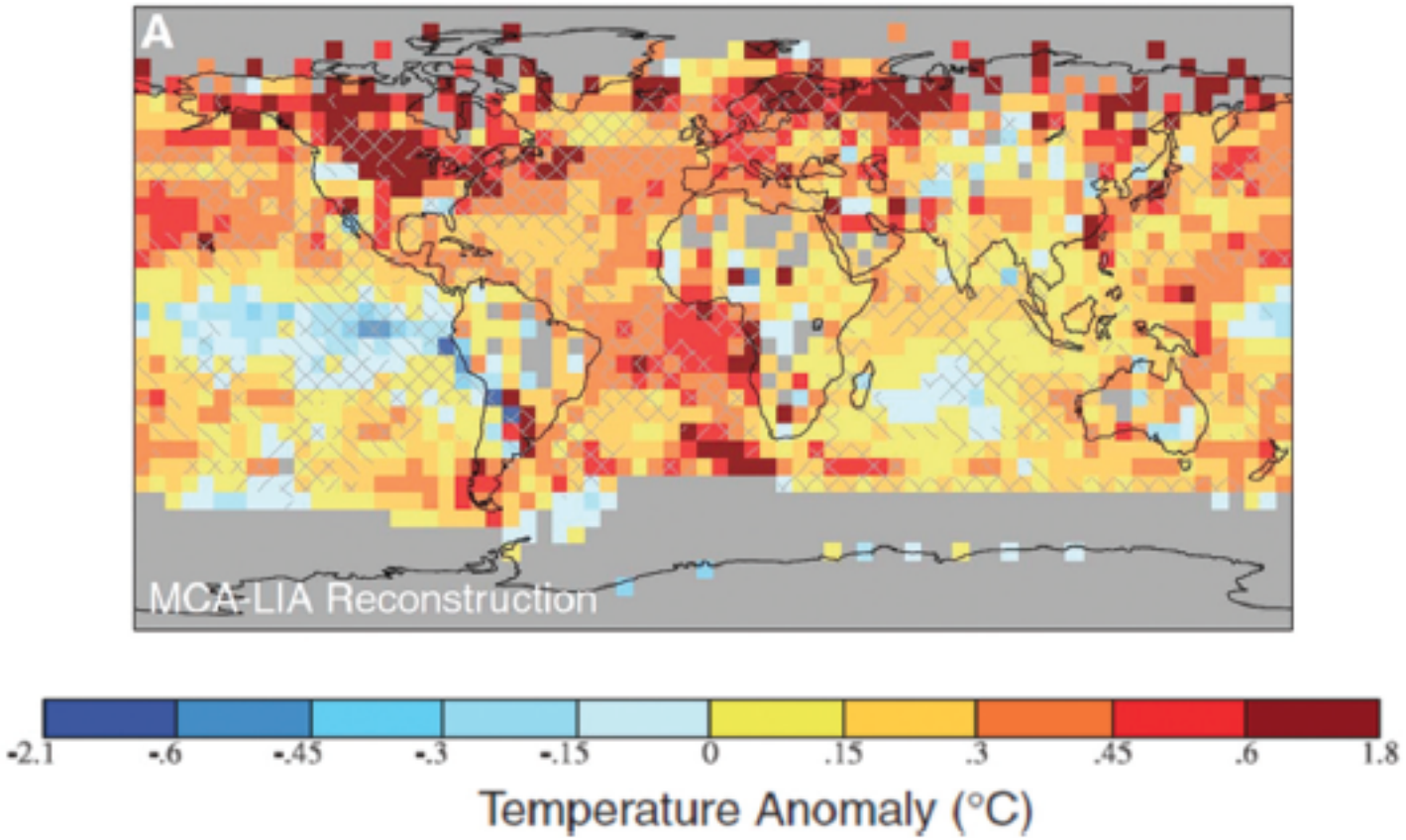
Temperature Anomalies of MCA (950-1250) & LIA (1400-1700) Relative to 1961-1990





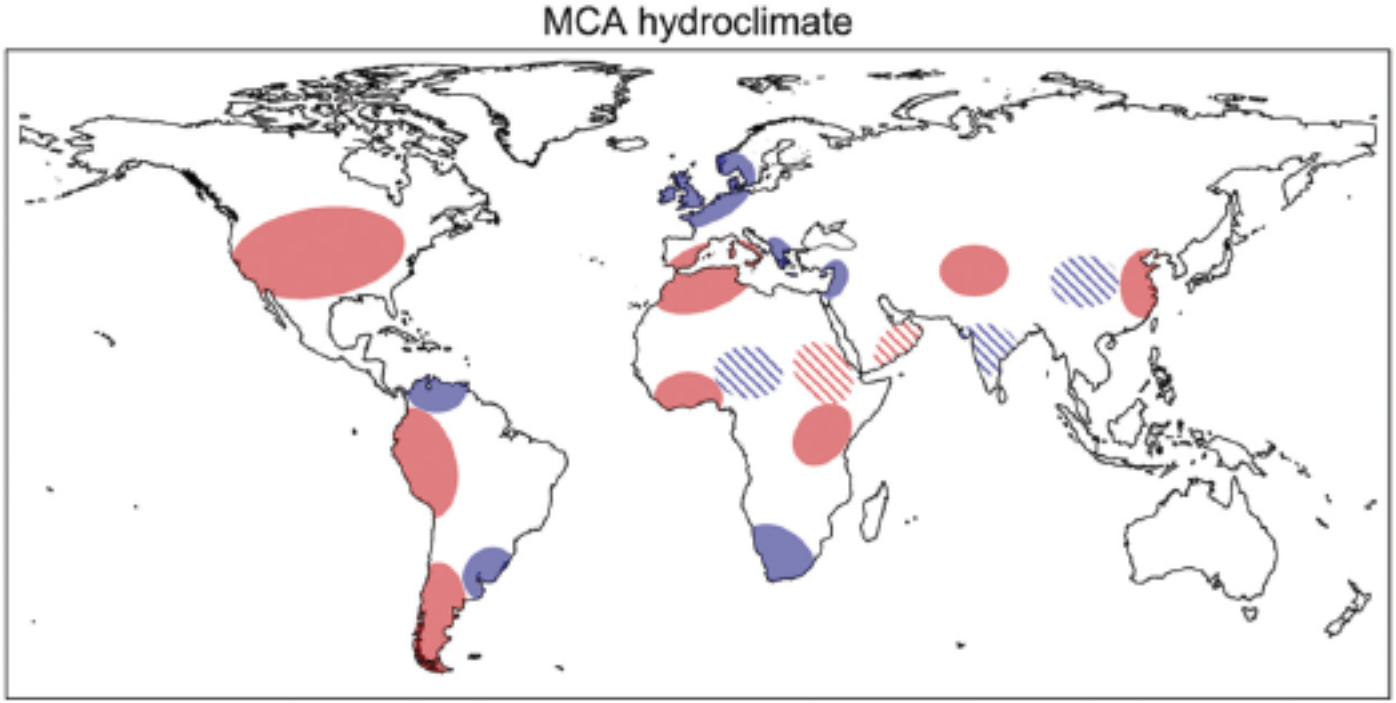
Mann et al. 2009

Temperature Difference Between MCA and LIA



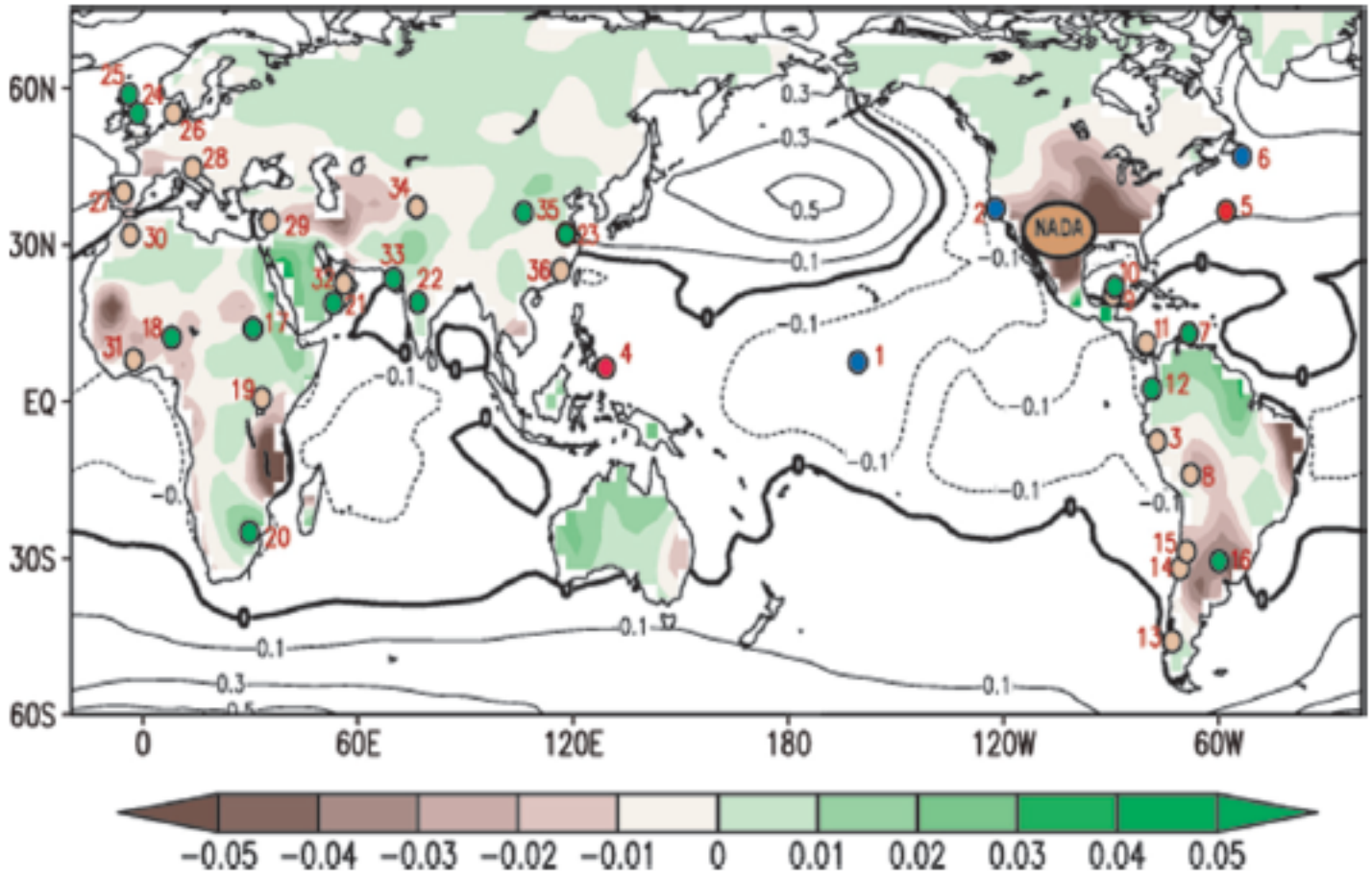
Trenberth (1990)

MCA Hydro-climate

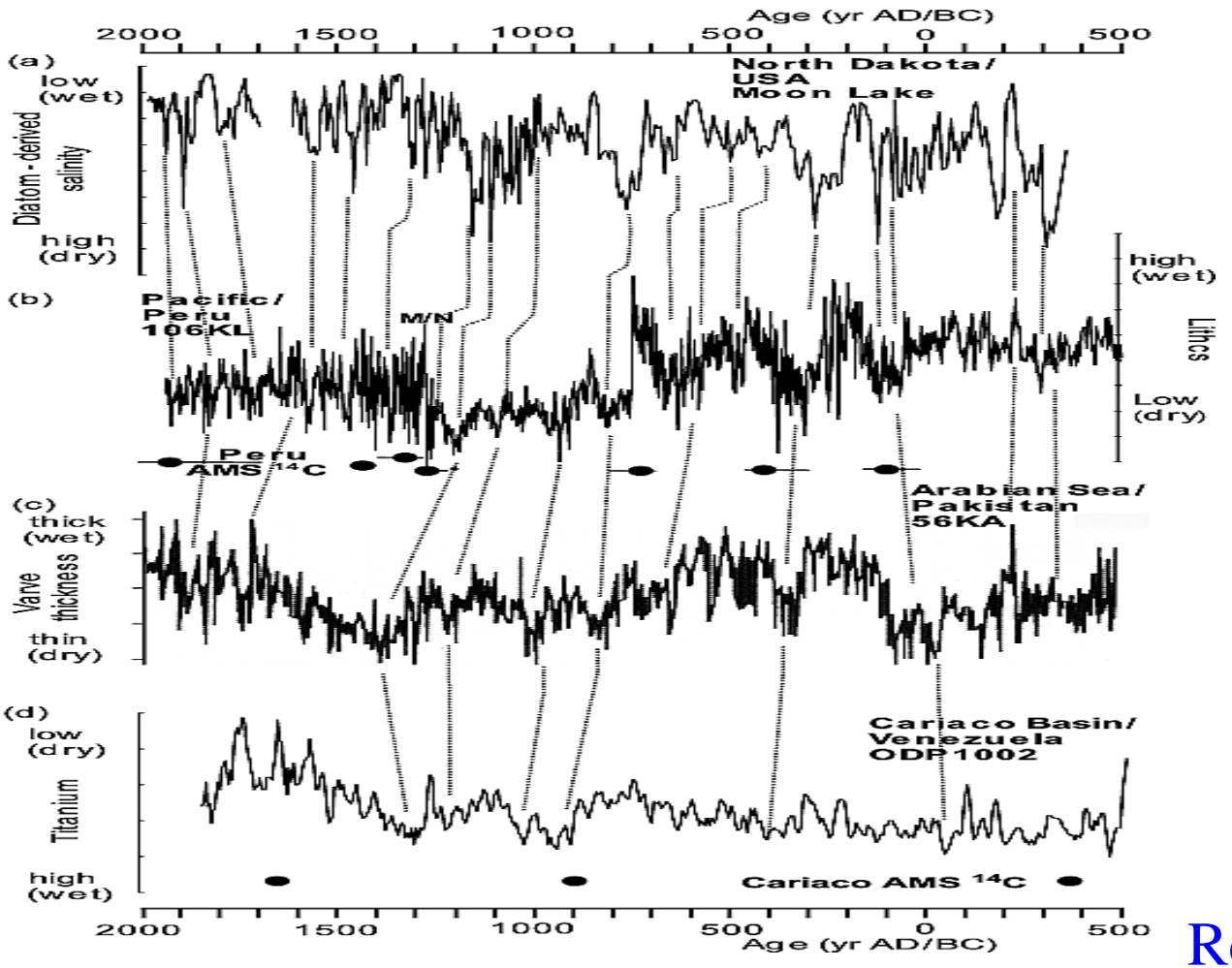


Coral Reconstructed MCA SST

And Model Simulated Hydro-Climate

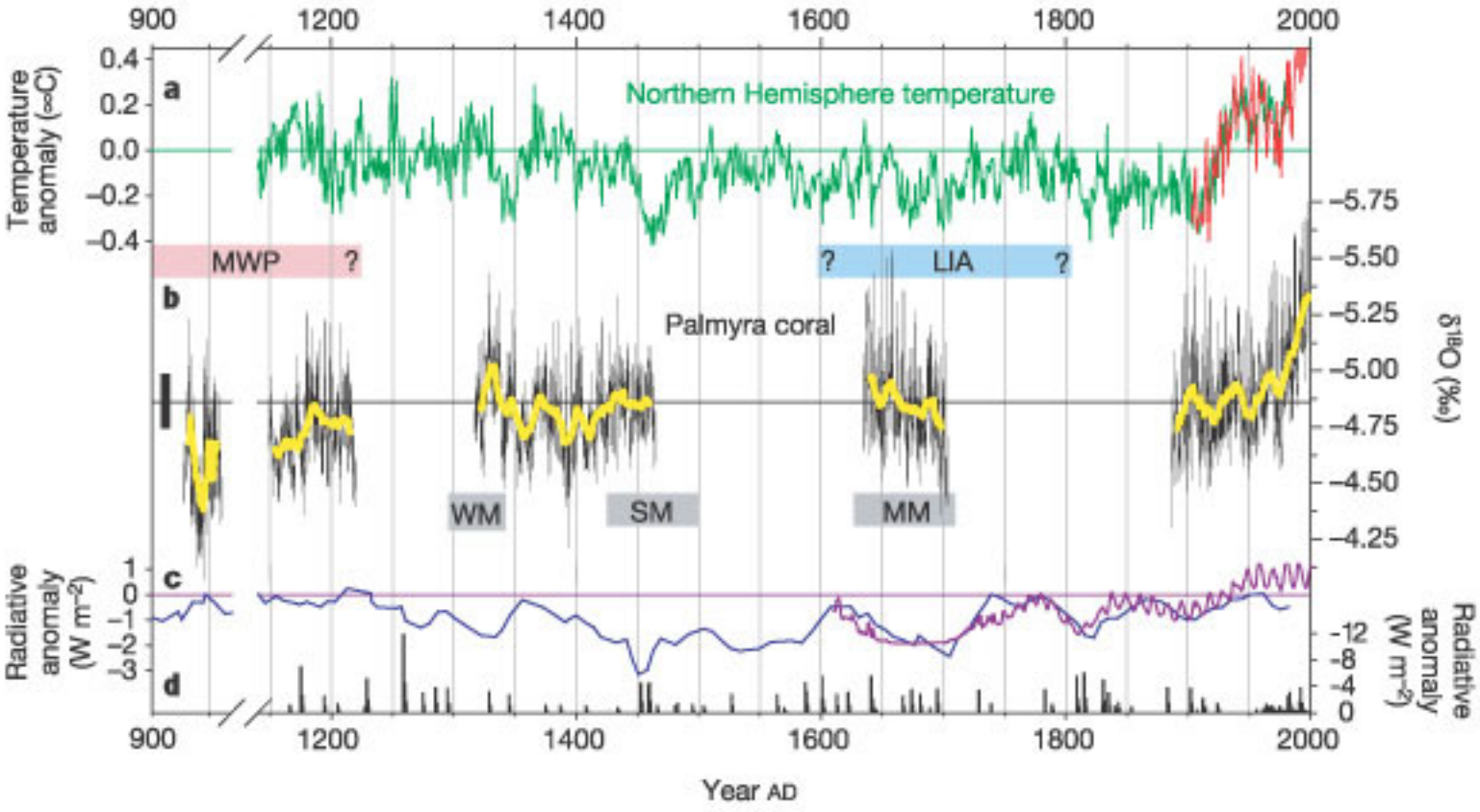


ENSO is Weak During MCA?



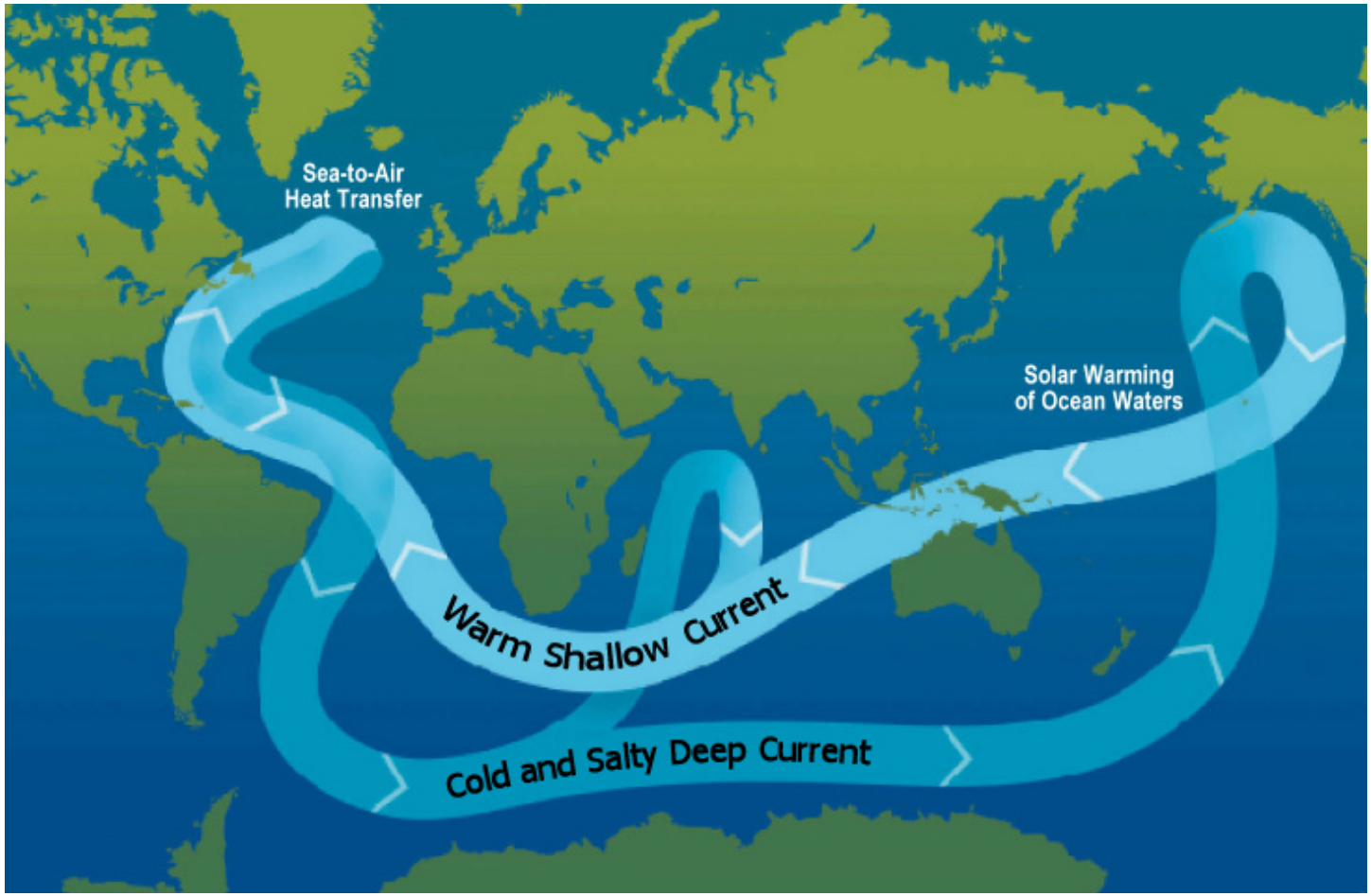
Rein et al. 2004

ENSO During MCA, LIA, and Present

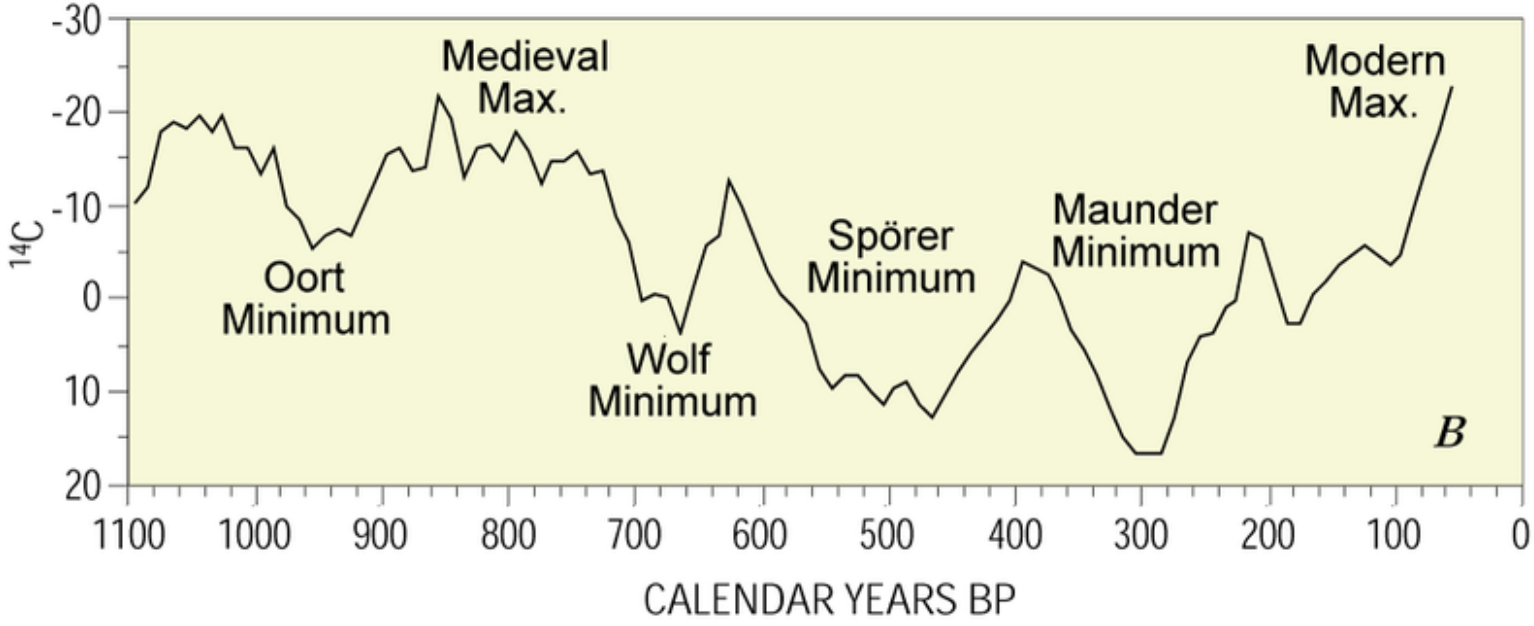


Cobb et al. 2003

Mechanisms
Themohaline Circulation Variability



Mechanisms
Variability in Sunspot Activity



Mechanisms
Variability in Volcanic Activity

Recommended Reading For the Next Lecture

- **Section 1 and 2 in Climate Change 2007: Synthesis Report**
- **Summary for Policymakers in Climate Change 2007: Working Group I: The Physical Science Basis**

Introduction
Human and Natural Drivers of Climate Change
Direct Observations of Recent Climate Change
A Palaeoclimatic Perspective
Understanding and Attributing Climate Change
Projections of Future Changes in Climate

Homework

Submit ONE science question you have about the recent global warming with a brief explanation (<1500 words) how you have come up with this question and why you think it is a potentially important question.