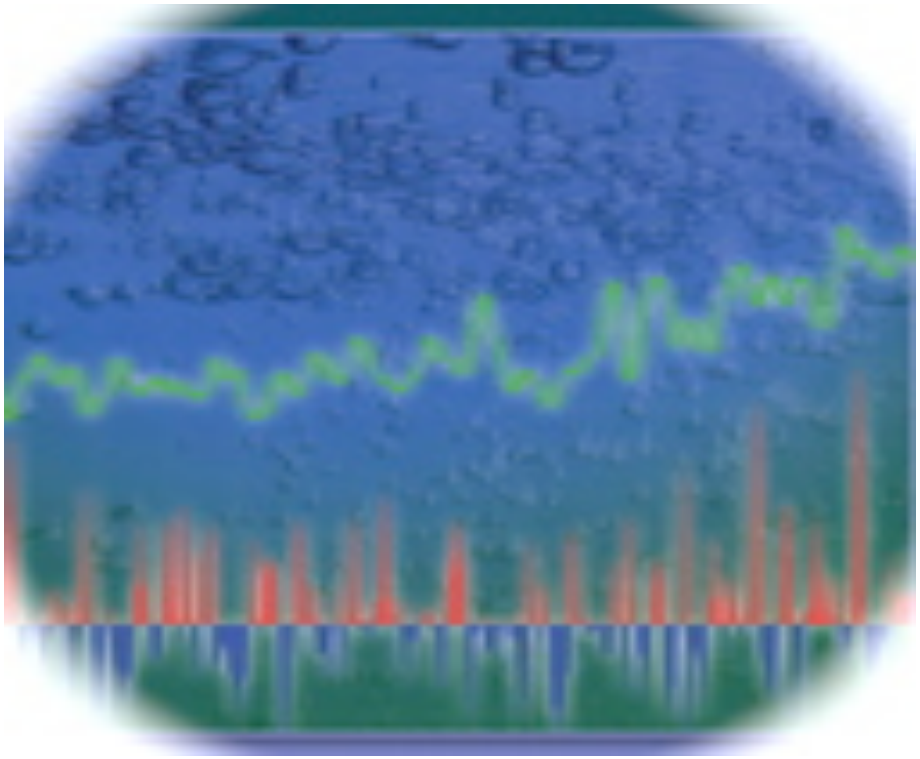
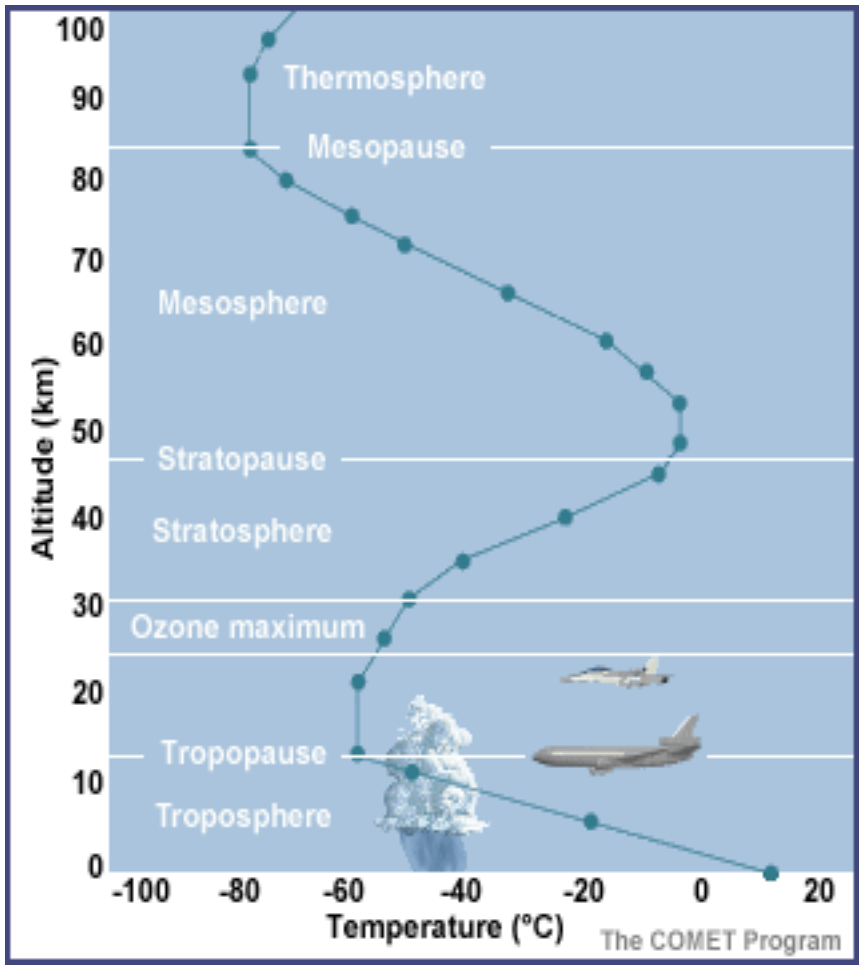
Climate Dynamics: Why Does Climate Vary?

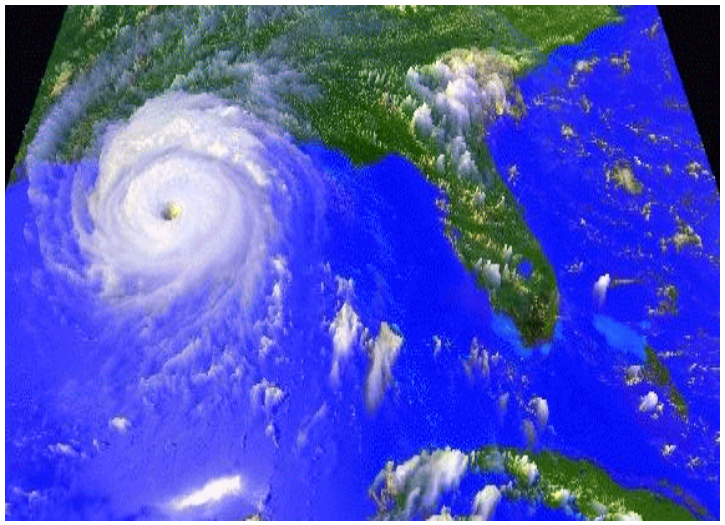


The Madden-Julian Oscillation: Organization of Weather Events Over the Warm Oceans

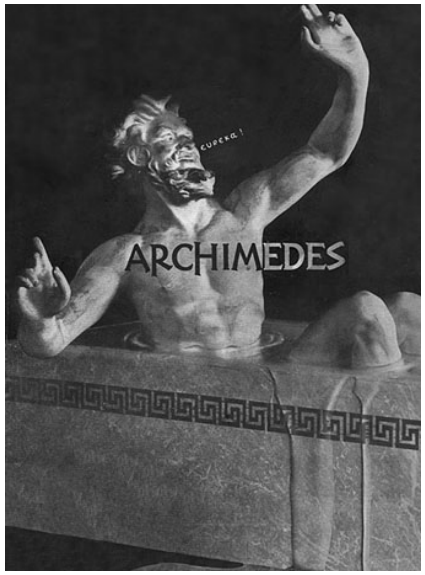
http://www.esrl.noaa.gov/psd/people/dezheng.sun/lectures/ATOC7500.html

The Atmosphere





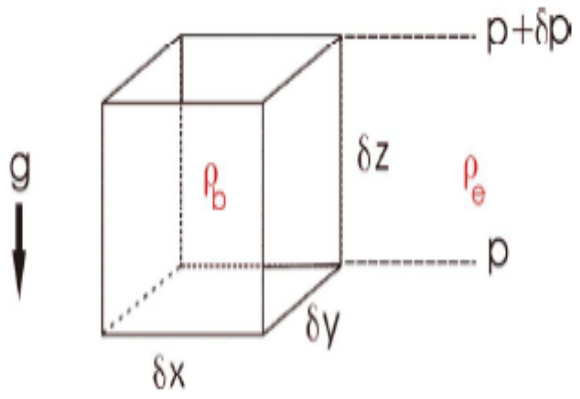
The Discovery of Buoyancy



Archimedes
287-212 BC

Archimedes' principle: a body immersed in a fluid is subject to an upward force (buoyancy) equal in magnitude to the weight of fluid it displaces

Buoyancy



$$Weight: \quad -g\rho_b \delta x \delta y \delta z$$

$$Pressure: \quad p\delta x\delta y - (p+\delta p)\delta x\delta y$$

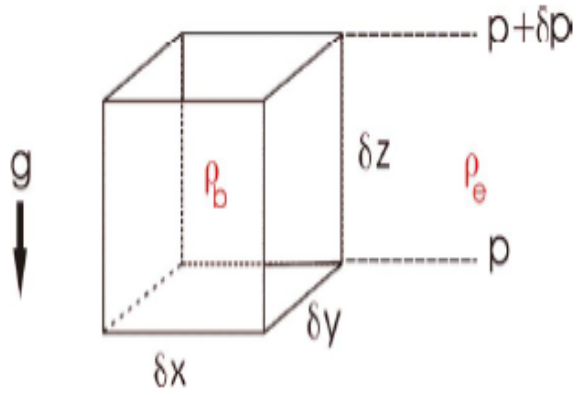
$$F = MA: \quad \rho_b \delta x\delta y\delta z \frac{dw}{dt} = -g\rho_b \delta x\delta y\delta z - \delta p \delta x \delta y$$

$$\frac{dw}{dt} = -g - \alpha_b \frac{\partial p}{\partial z} \qquad but \quad \frac{\partial p}{\partial z} = -\frac{g}{\alpha_e}$$

$$\rightarrow \quad \frac{dw}{dt} = g\frac{\alpha_b - \alpha_e}{\alpha_e} \equiv B$$

$$B = g\frac{\alpha_b - \alpha_e}{\alpha_e} = g\frac{\rho_e - \rho_b}{\rho_e \rho_b} \approx -g\frac{\rho'}{\rho_e}$$

Buoyancy



$$B = g\frac{\alpha_b - \alpha_e}{\alpha_e} = g\frac{\rho_e - \rho_b}{\rho_e \rho_b} \approx -g\frac{\rho'}{\rho_e}$$

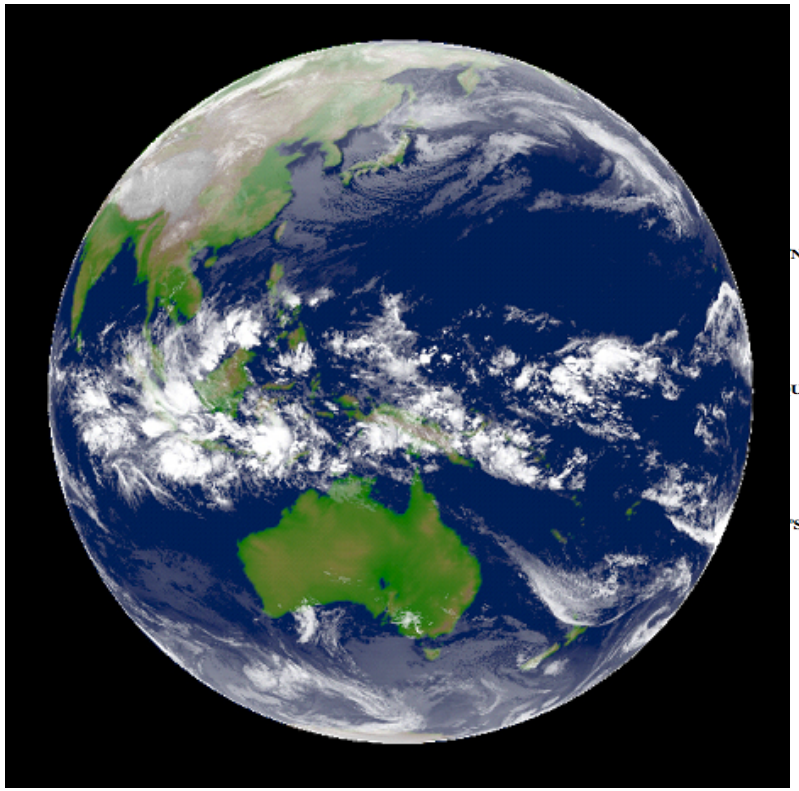
For Air:

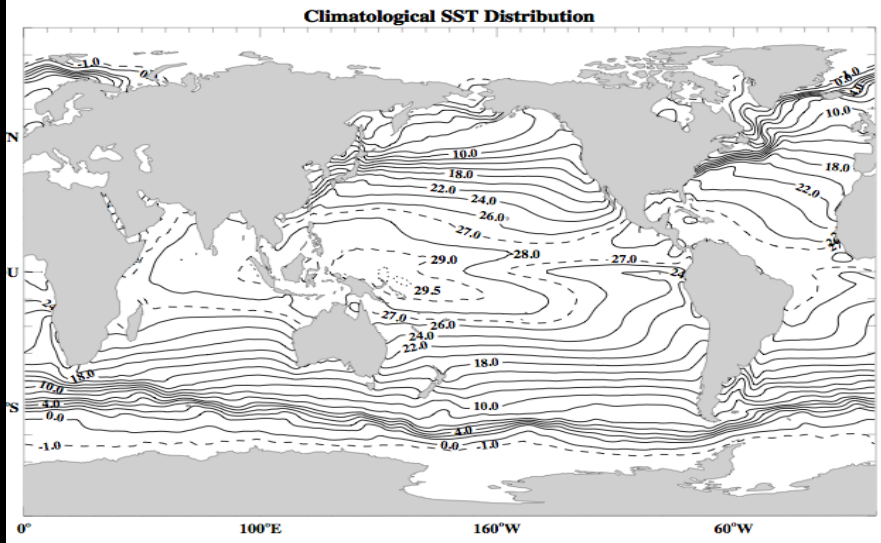
$$B \approx g\frac{T'}{T_e}$$

For Sea Water:

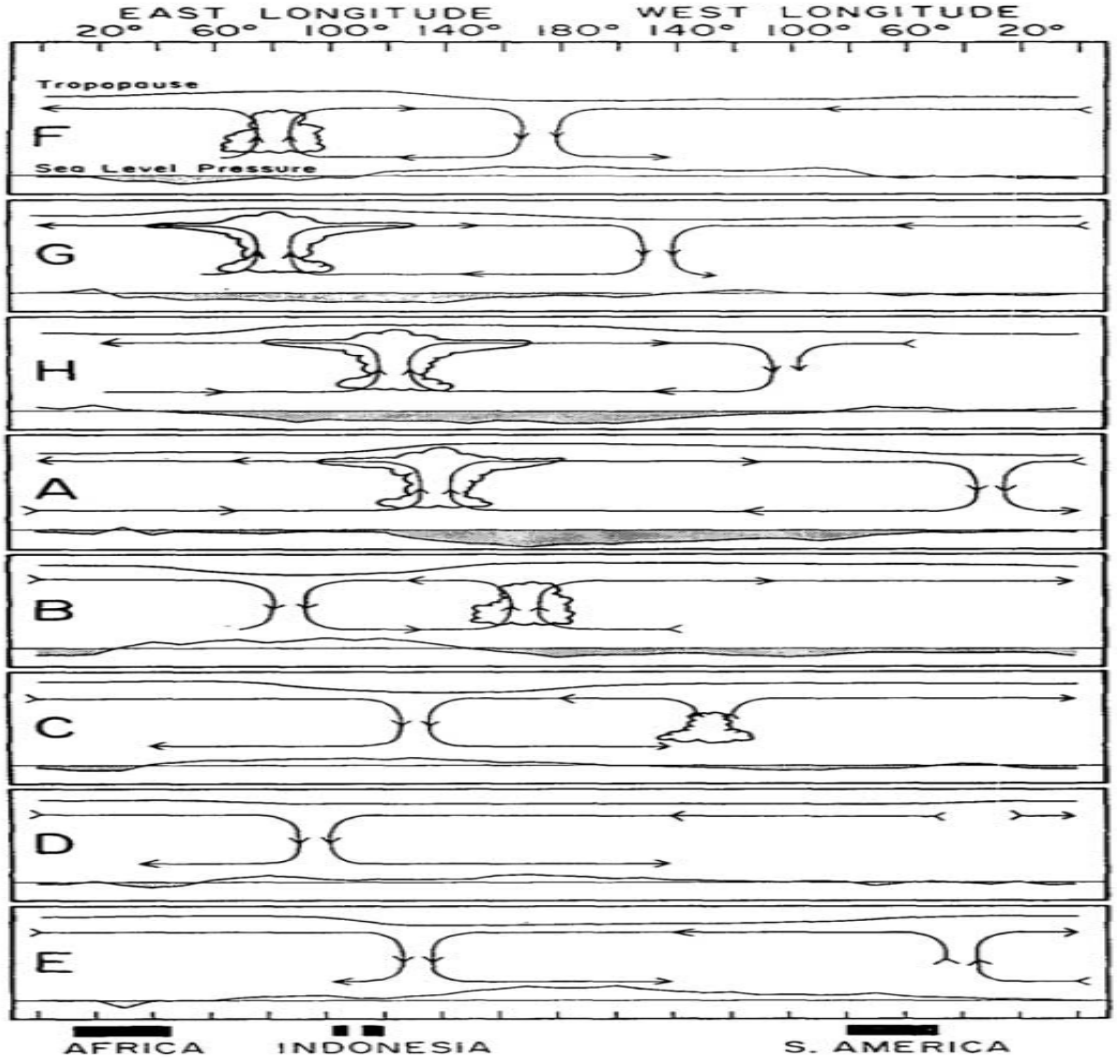
$$B \approx g\left(\frac{1}{\alpha}\right)\left(\frac{\partial \alpha}{\partial T}\right)T' + g\left(\frac{1}{\alpha}\right)\left(\frac{\partial \alpha}{\partial S}\right)S'$$

Deep Convection Over Warm Oceans



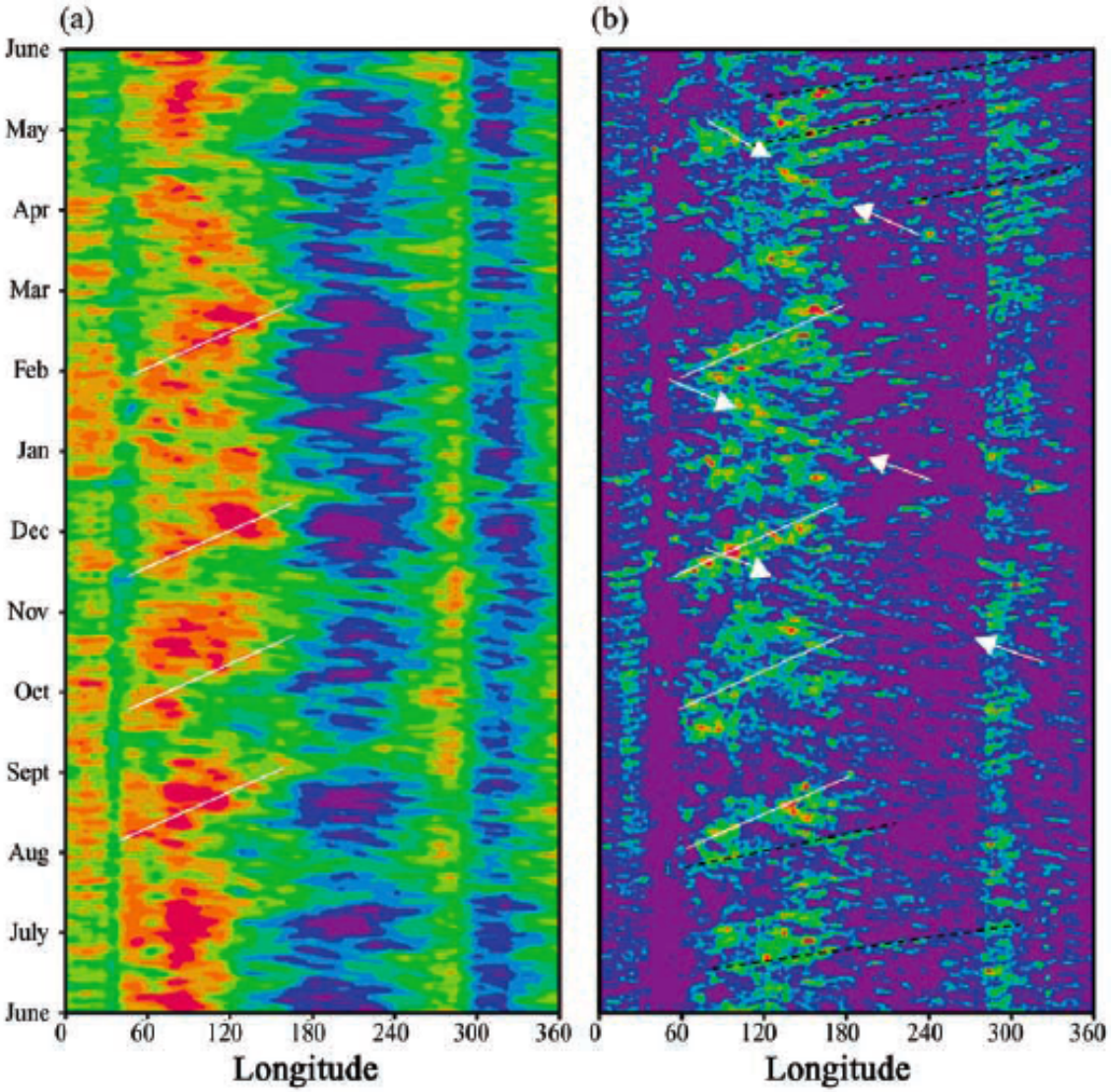


Madden-Julian Oscillation: A Schematic



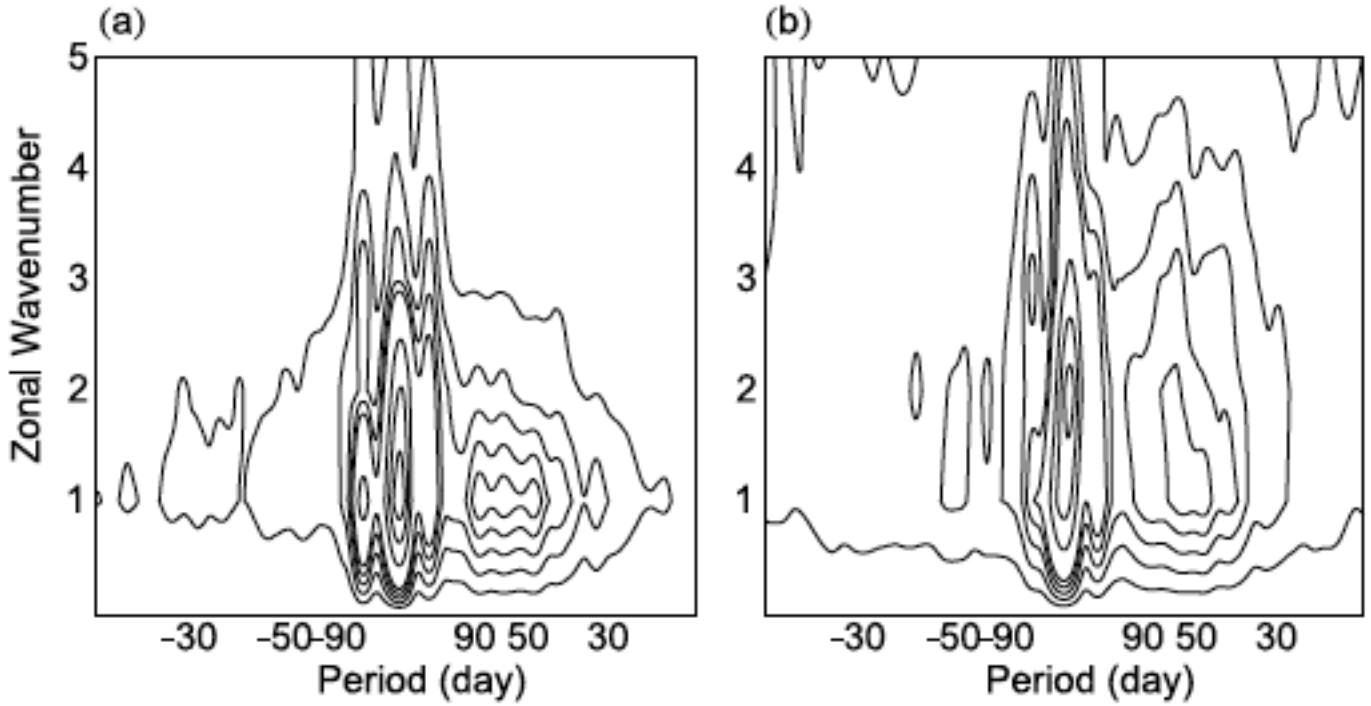
Madden-Julian Oscillation

Winds and Precipitation



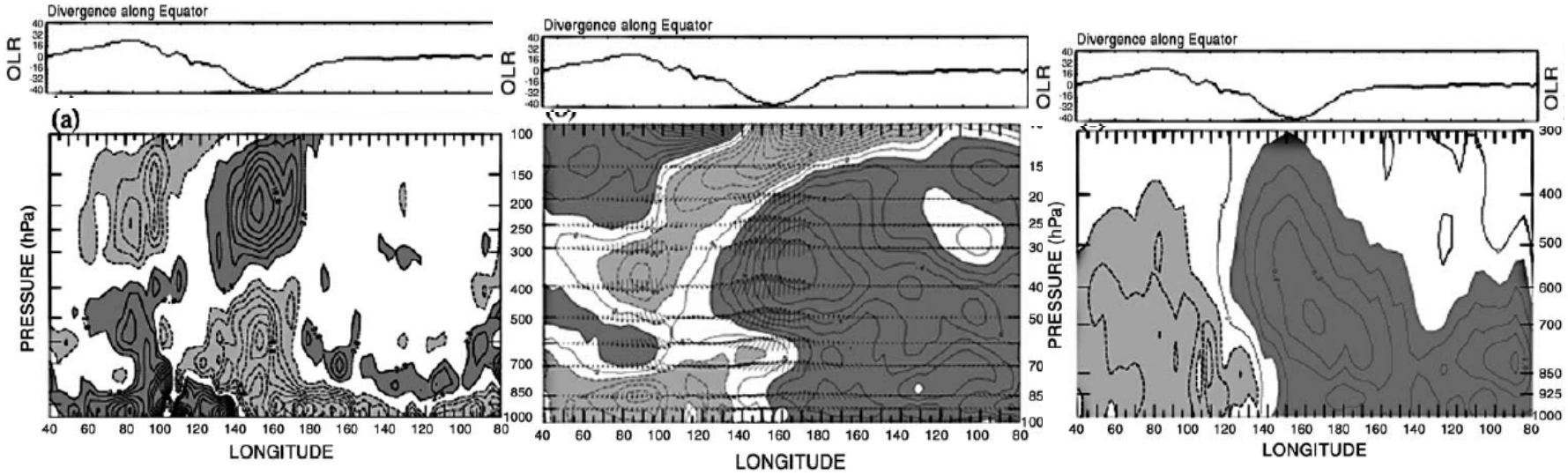
Madden-Julian Oscillation

Wave number and Frequency



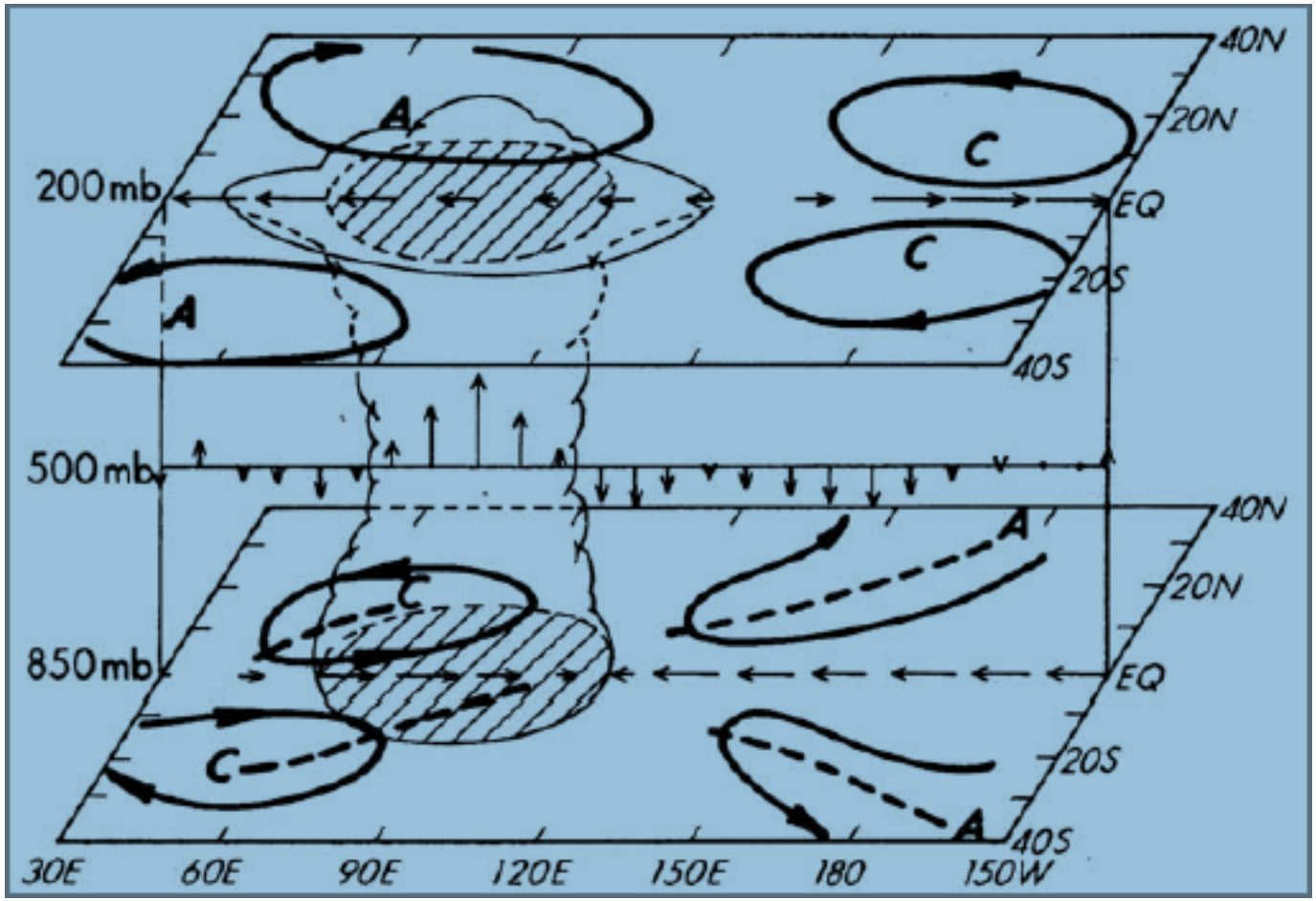
Madden-Julian Oscillation

Vertical Structure

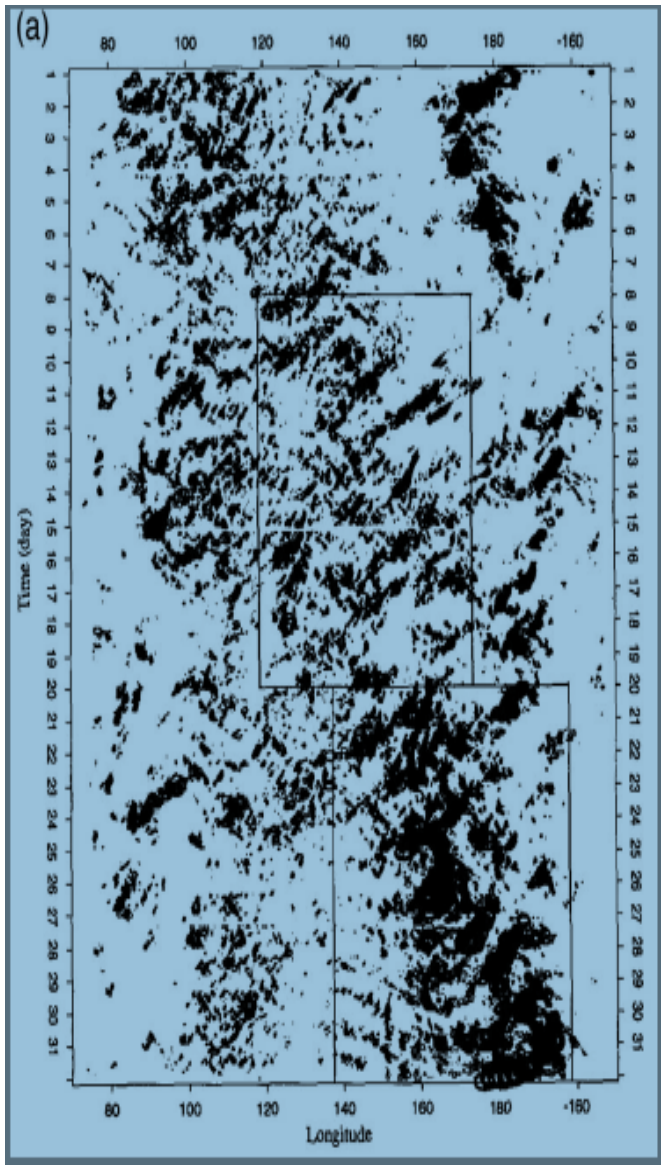


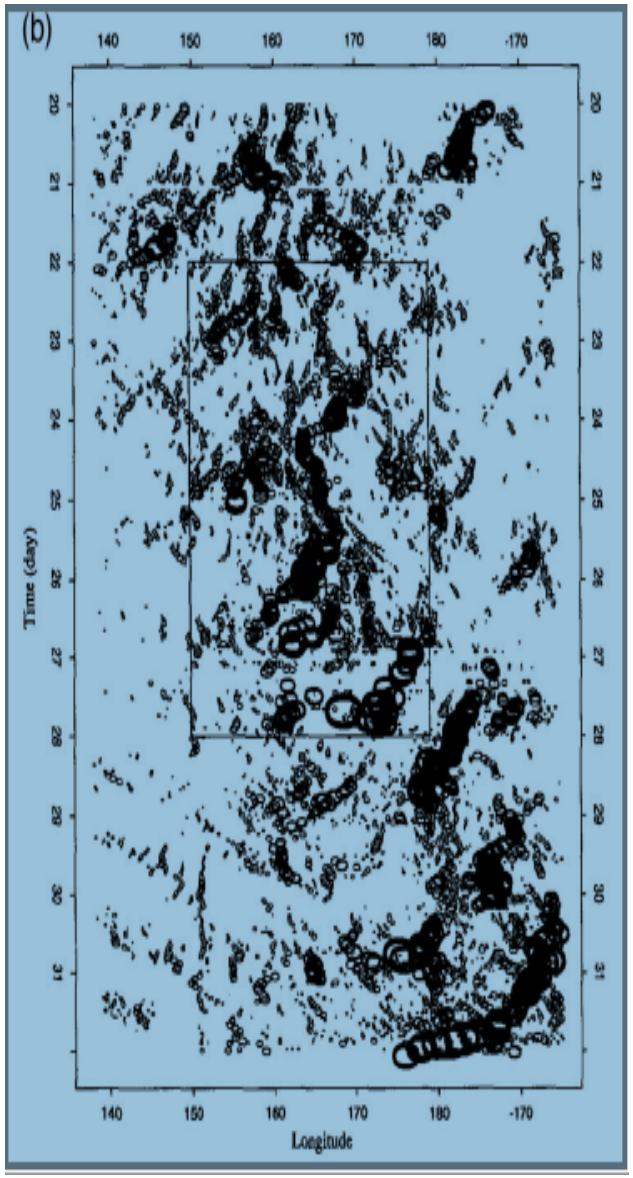
Madden-Julian Oscillation

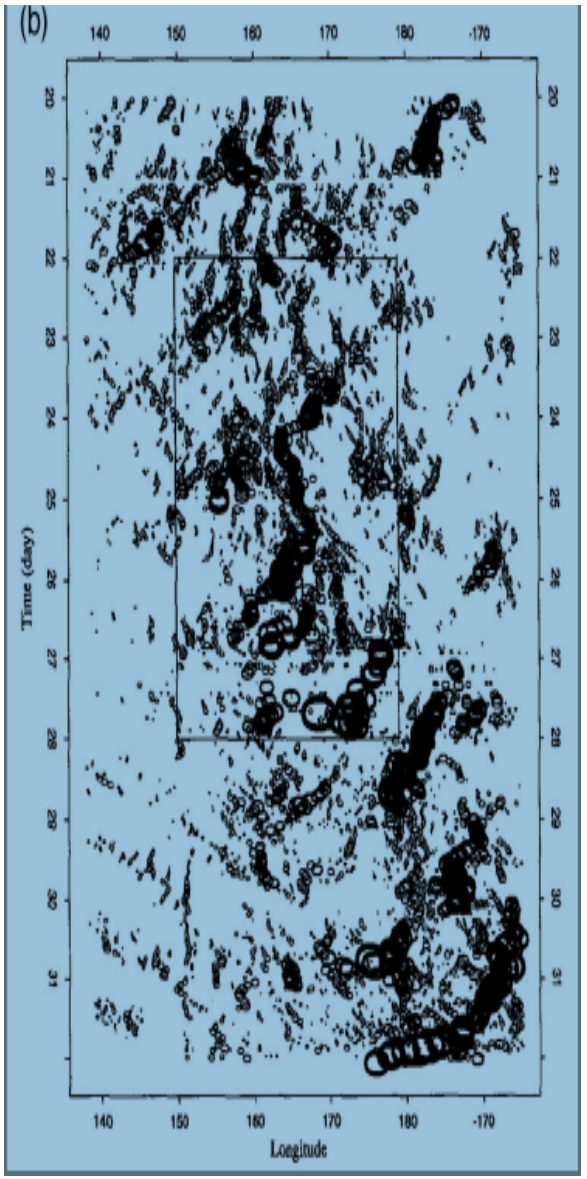
A Three-D Schematic View



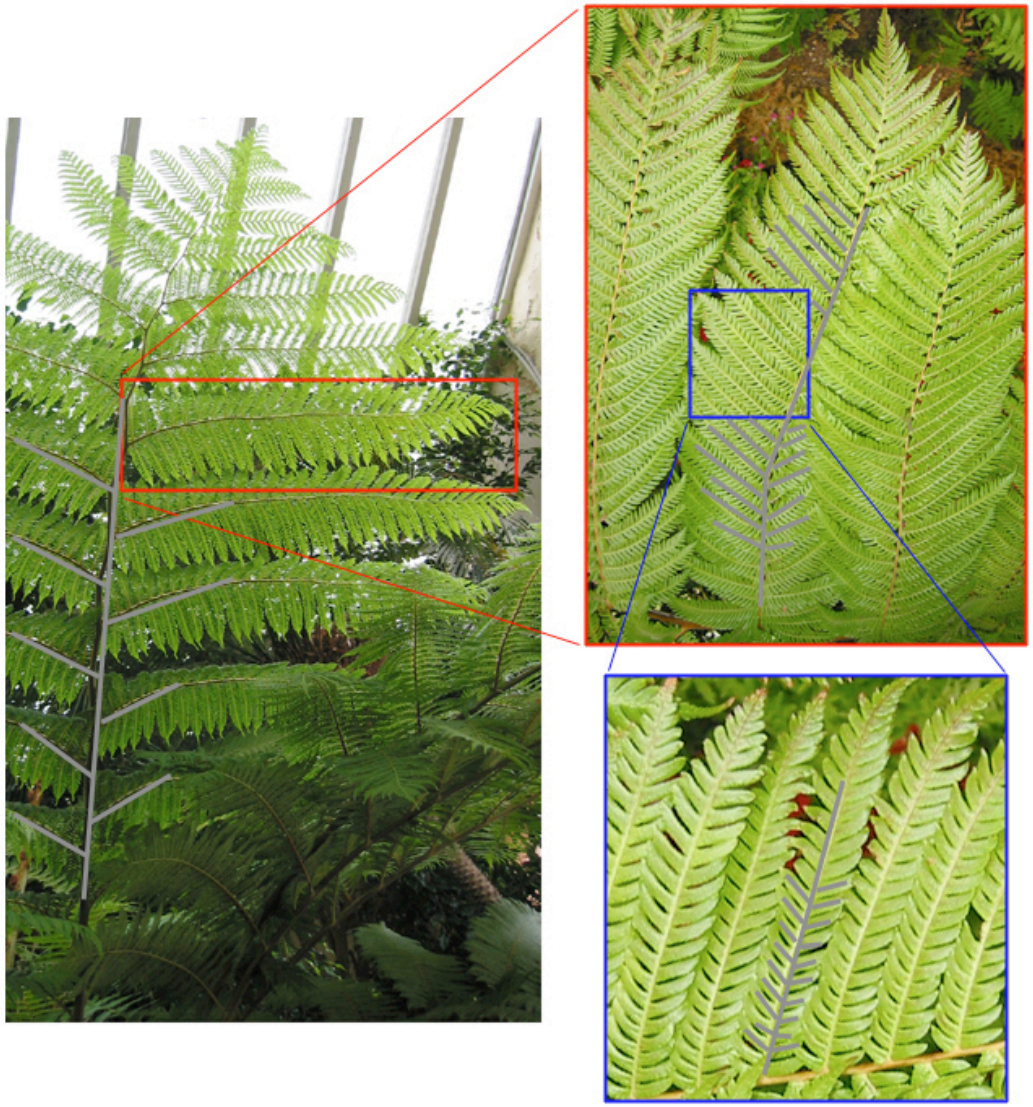
MJO: Multi-scales and Self-similarity



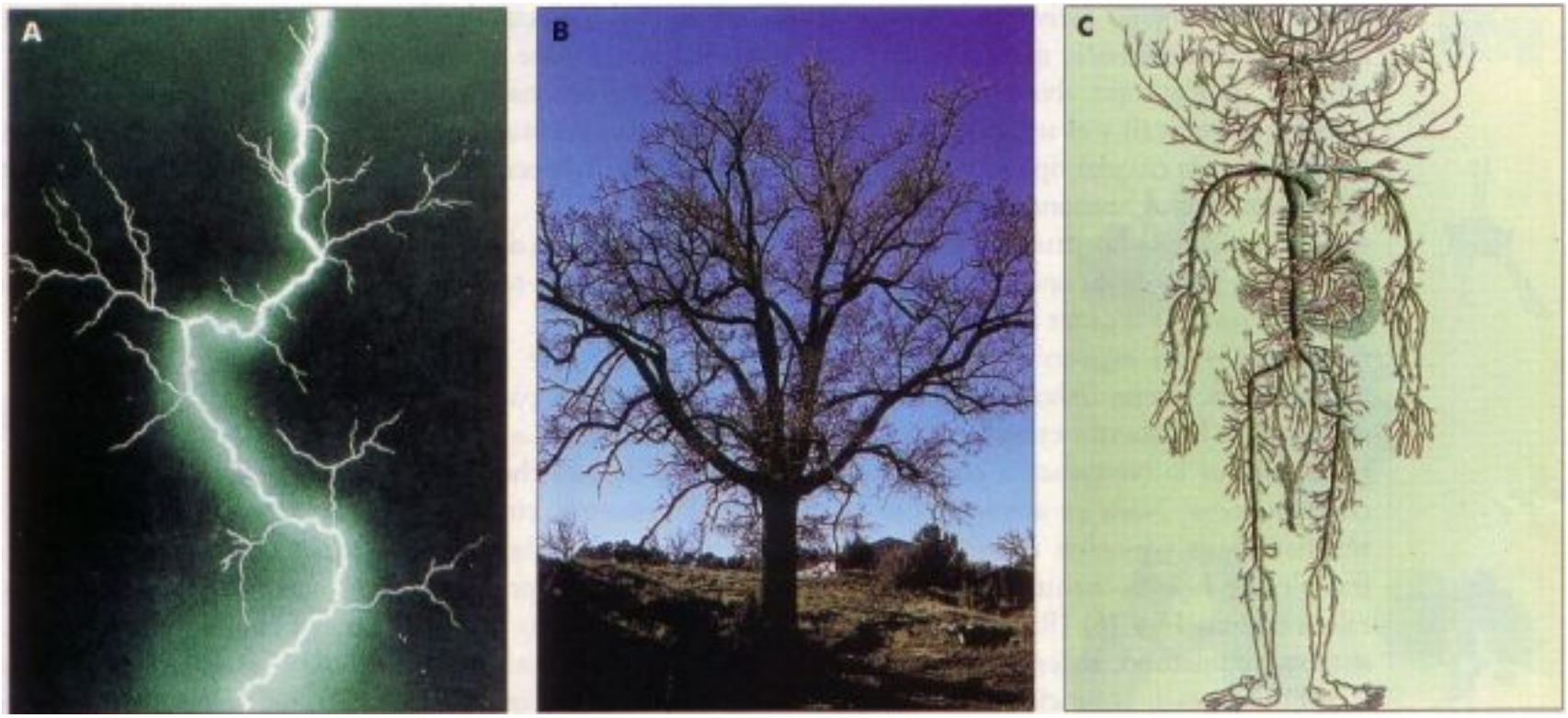




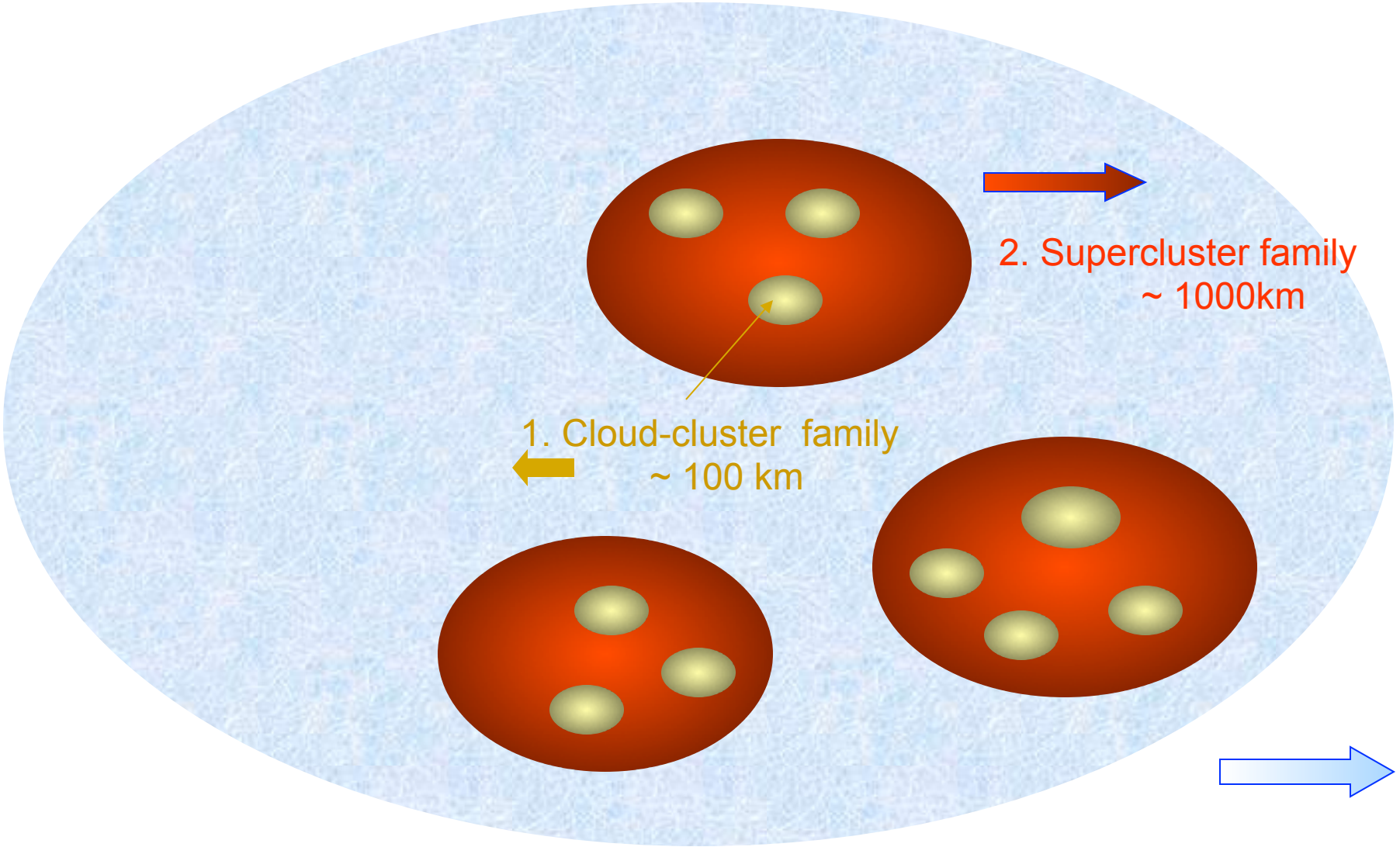
Self Similarity: Some Other Examples in Nature



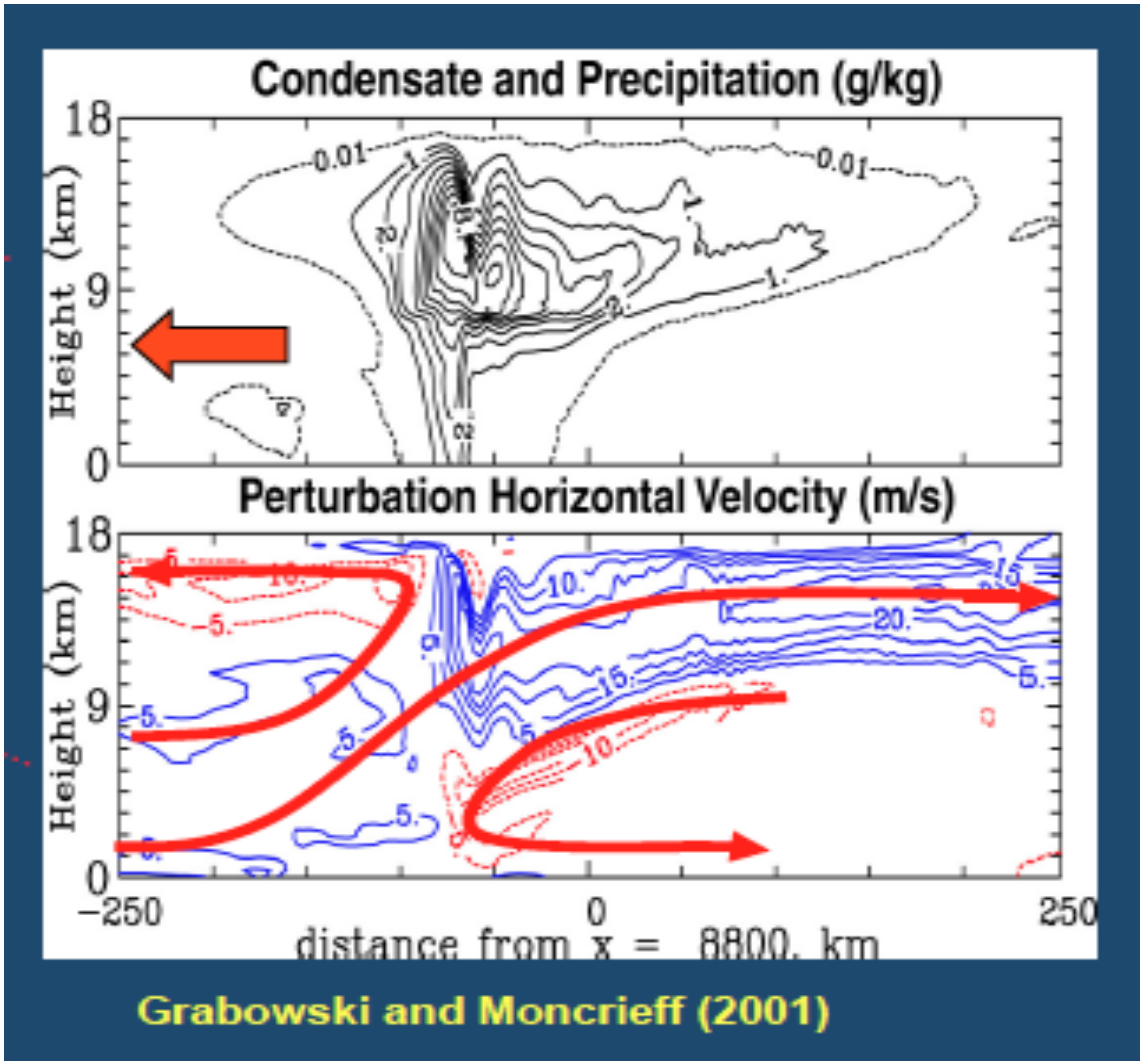
Self Similarity: Some Other Examples in Nature



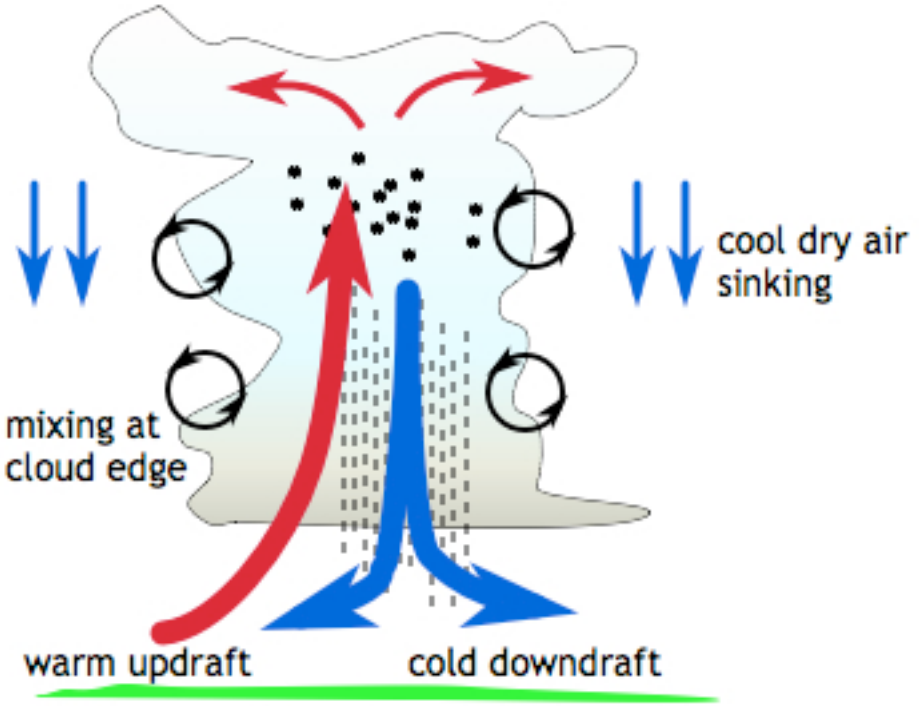
The MJO: hierarchical convective organization



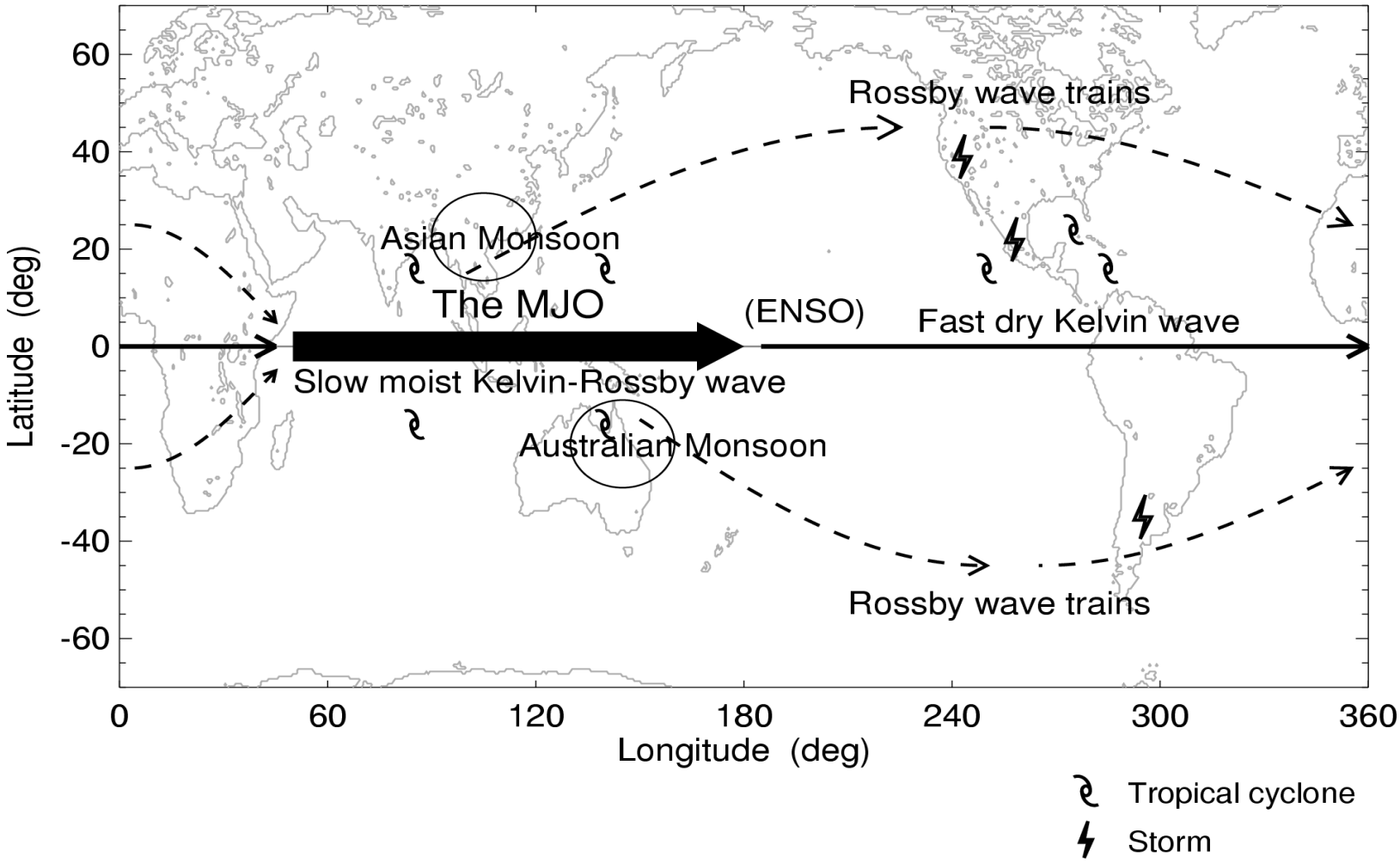
Mesoscale Convective System



Cumulus

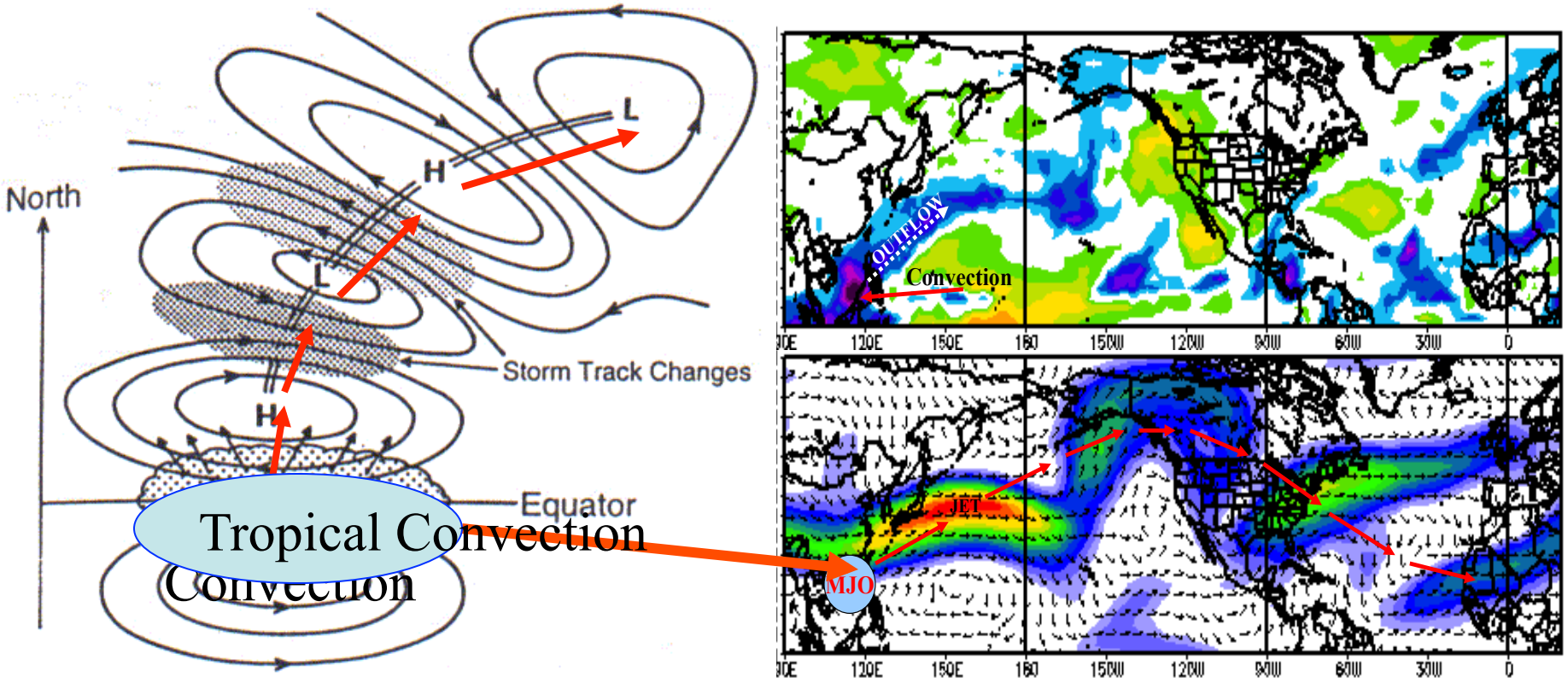

cool dry air
sinking
mixing at
cloud edge
warm updraft
cold downdraft

MJO: Global Climatic Impact

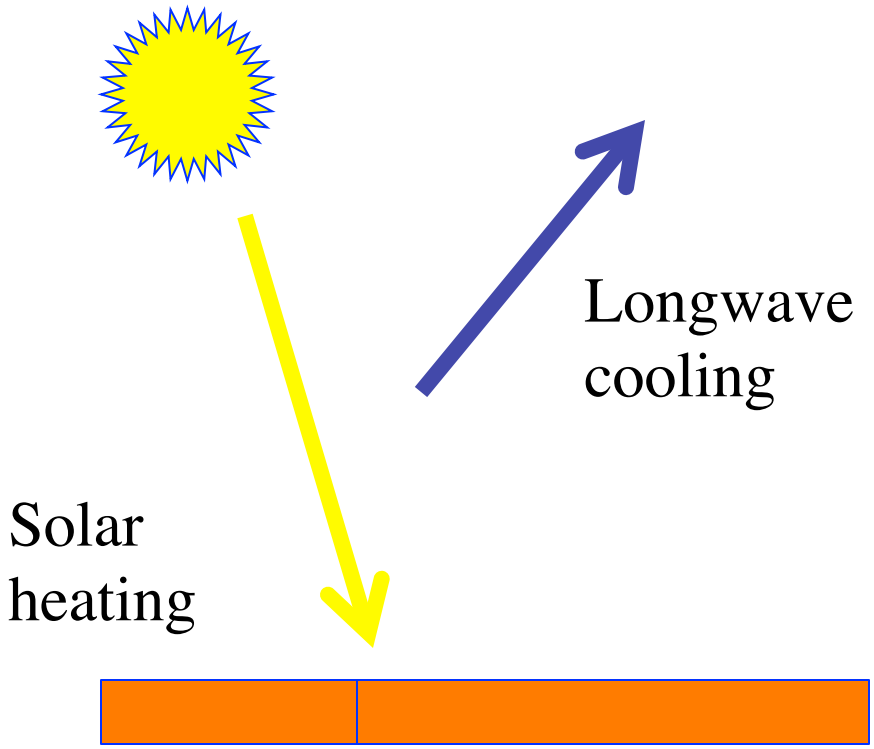


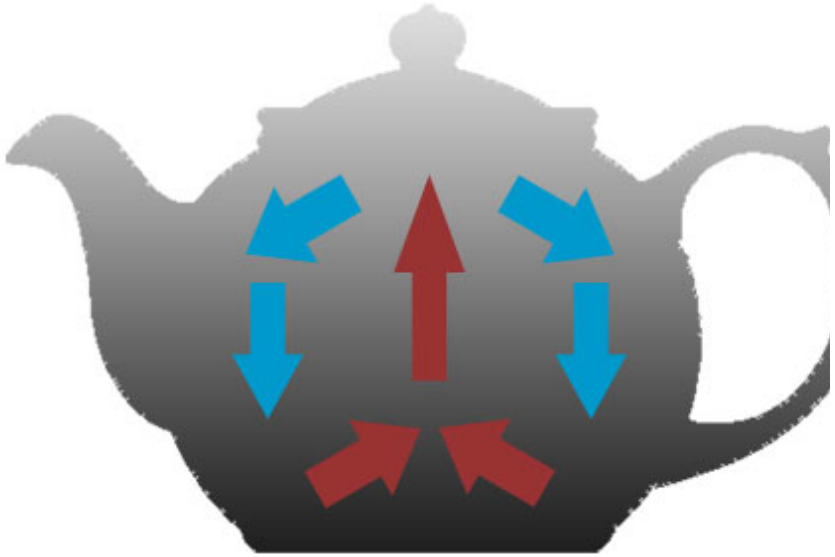
Courtesy of Jialin Lin (NOAA CDC, private communication)

Northward Propagating Rossby-Wave Train

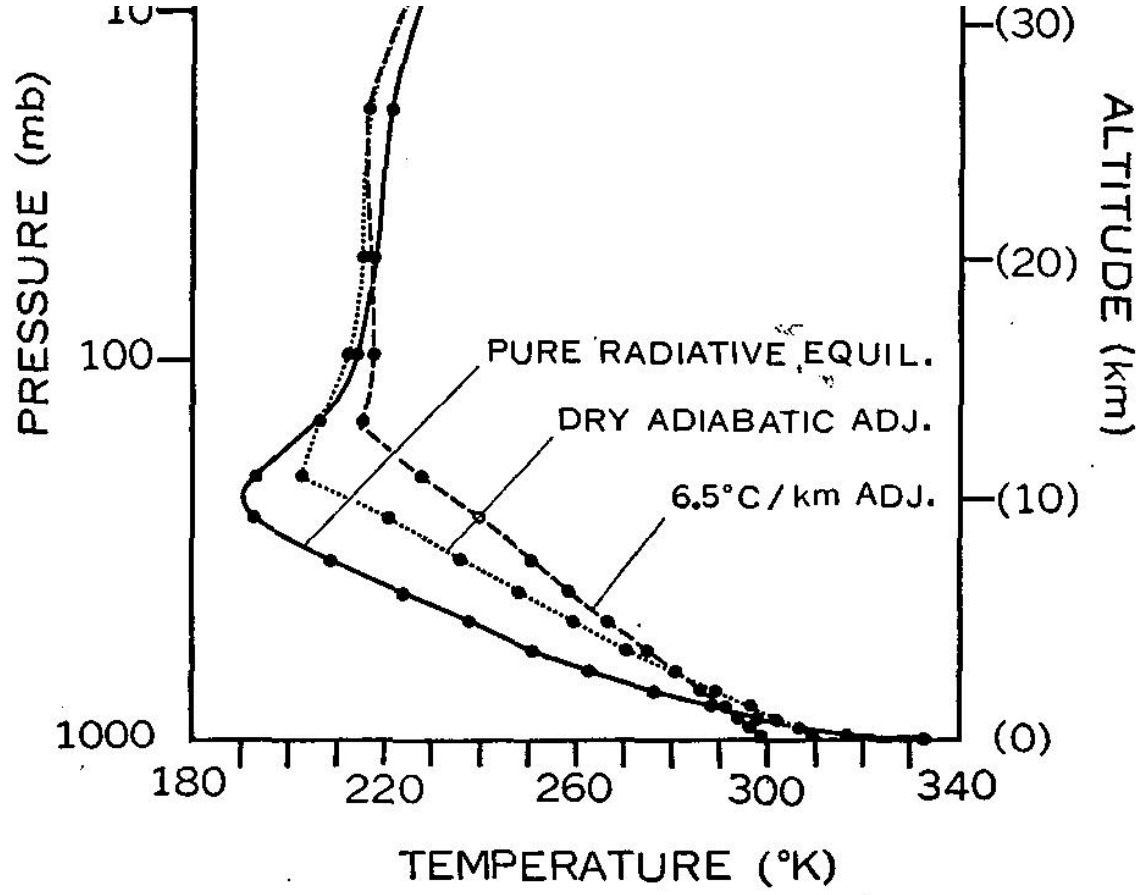


Why does the tropical atmosphere convect?





Radiative Equilibrium /Radiaitve-Convective Equilibrium



Recommended Readings For The Next Lecture

Section 3 in Zhang, C. (2005), Madden-Julian Oscillation, Rev. Geophys., 43, RG2003, doi: 10.1029/2004RG000158.

Chapter 9 of Emanuel

Chapter 11 (section 1—7) of Gill