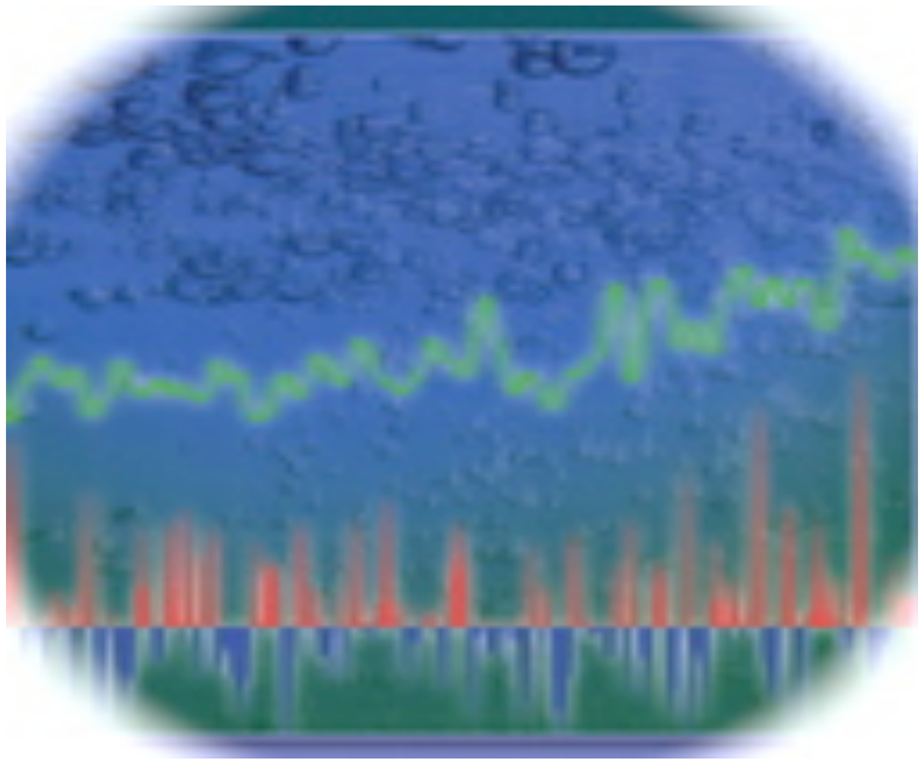
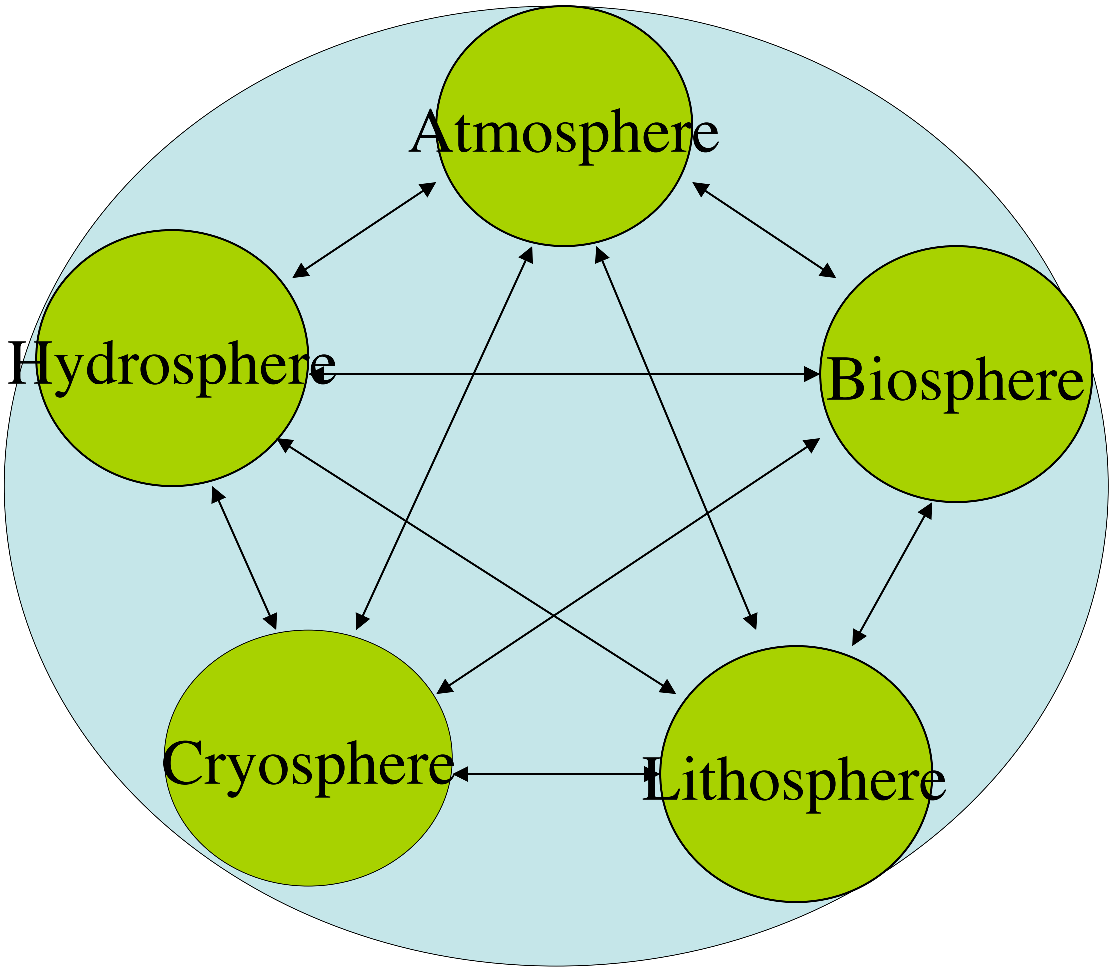
Climate Dynamics: Why Does Climate Vary?



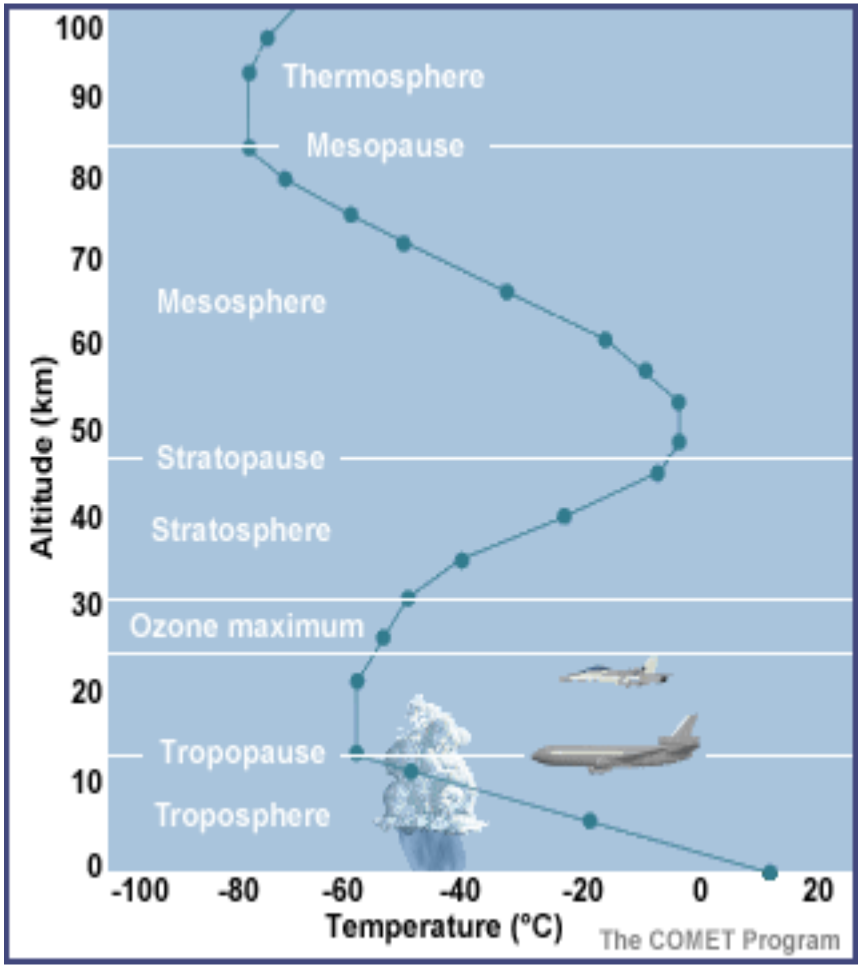
The Climate System: Components, Interactions, Forces, Circulations, and Instabilities

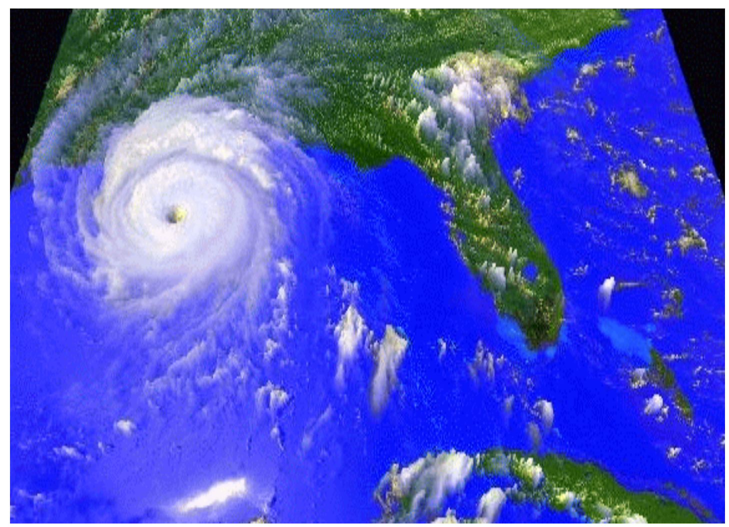
http://www.esrl.noaa.gov/psd/people/dezheng.sun/lectures/ATOC7500.html

The Climate System



The Atmosphere





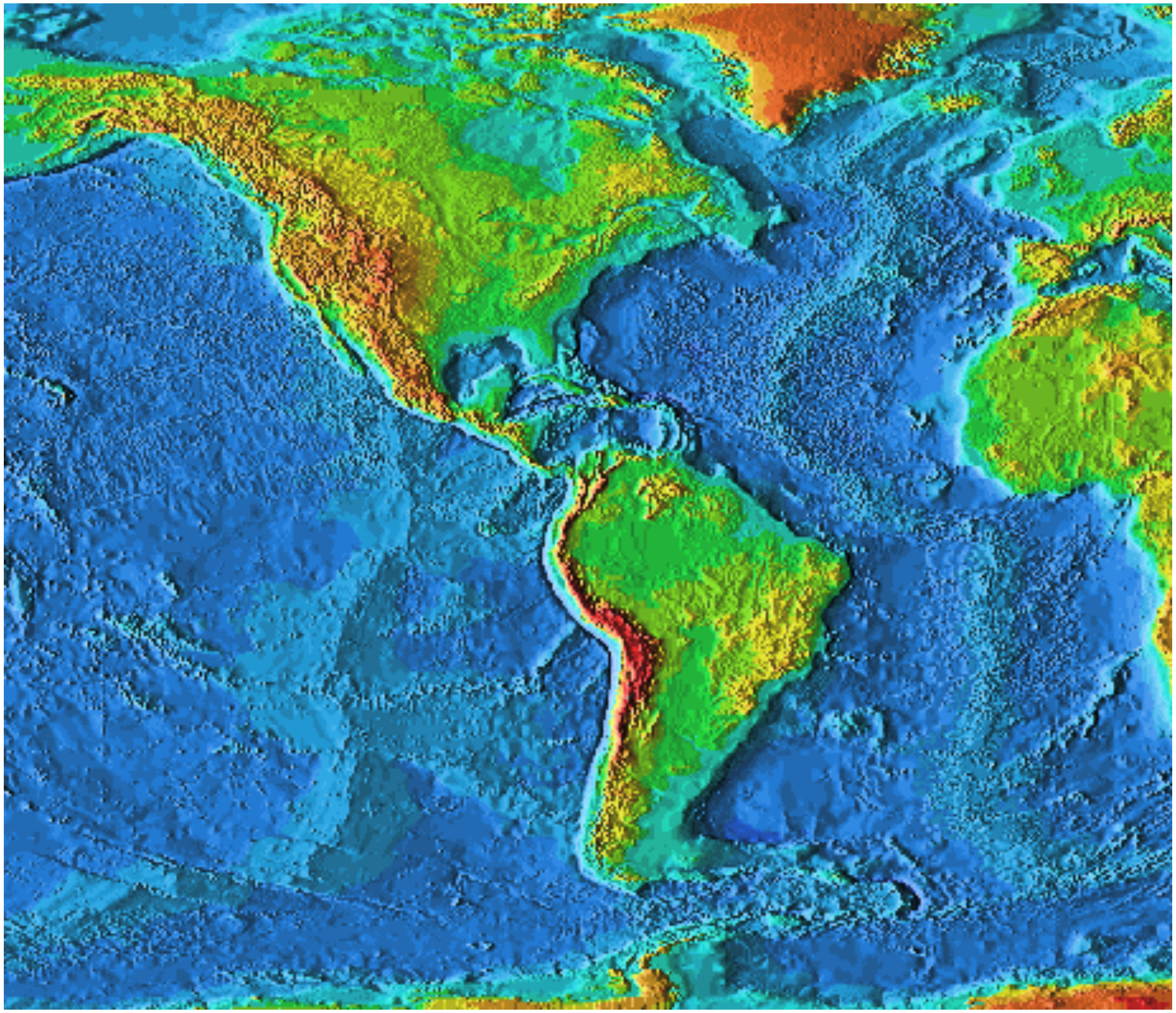
The Hydrosphere

The Cryosphere

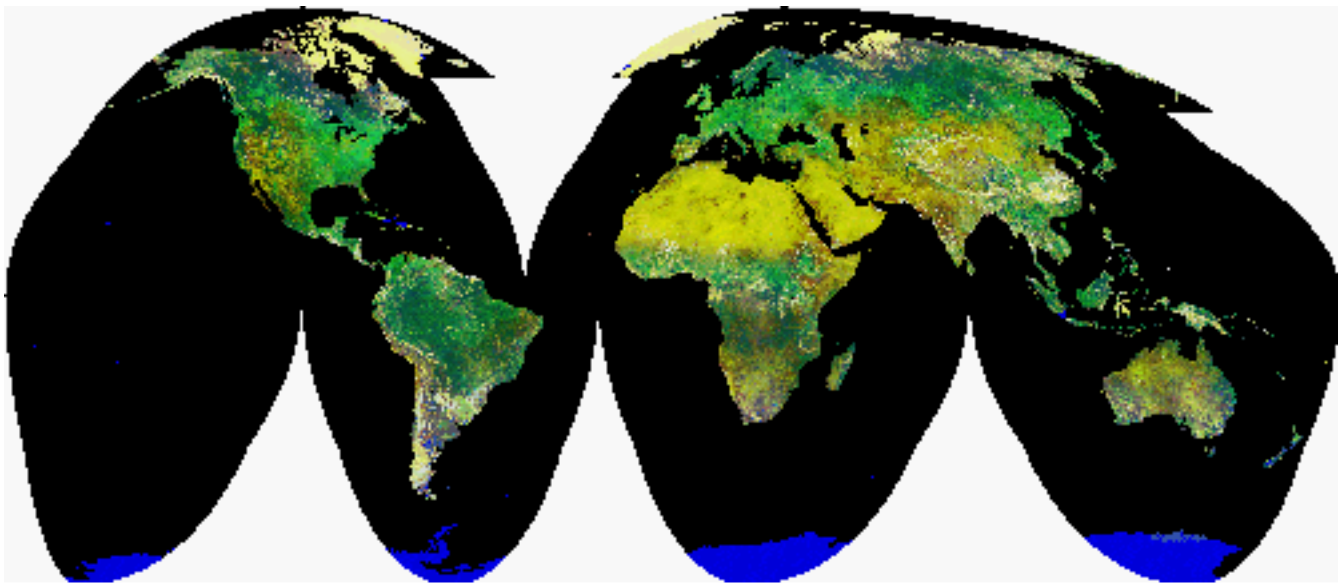
Land Ice

Sea Ice

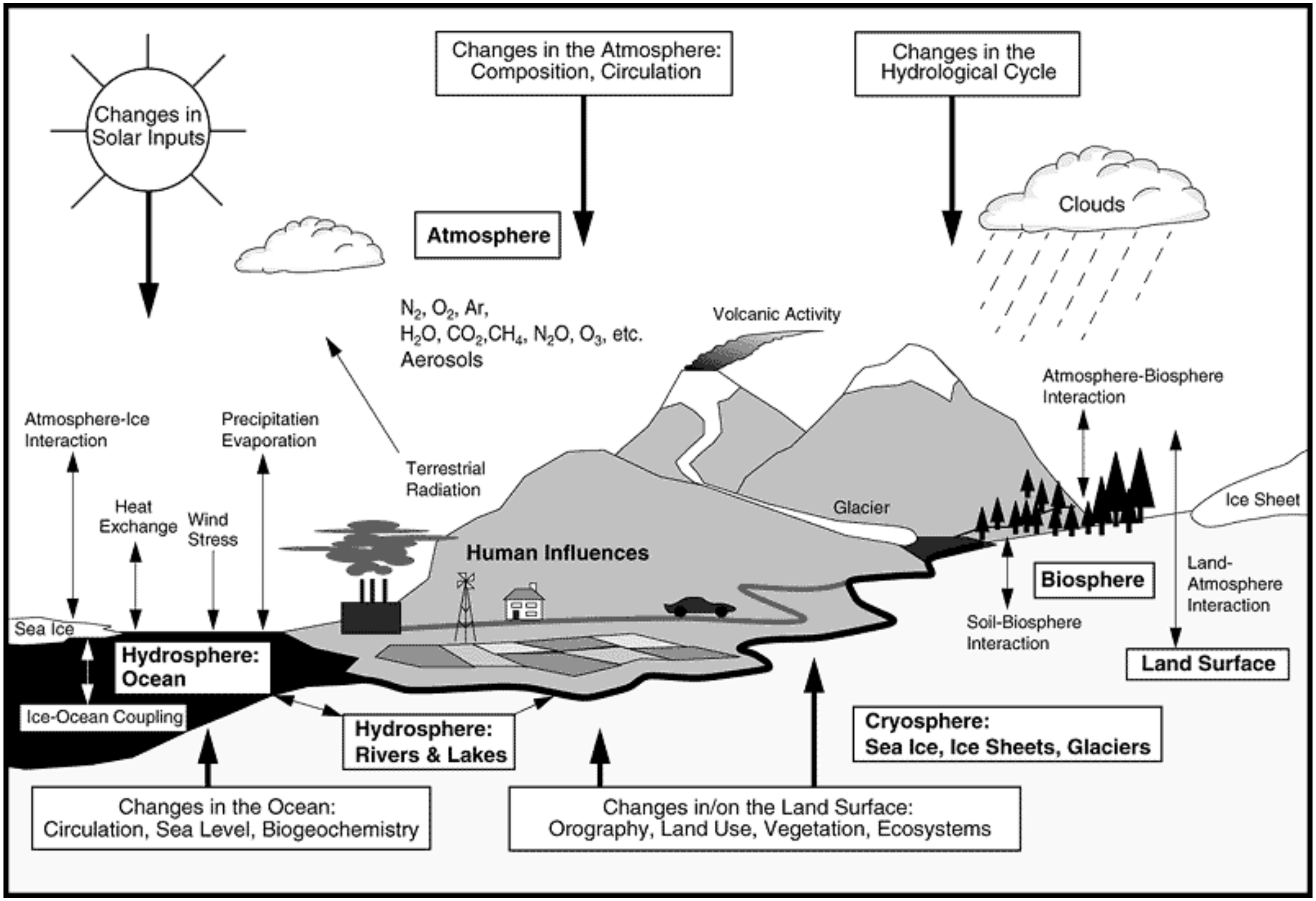
The Lithosphere



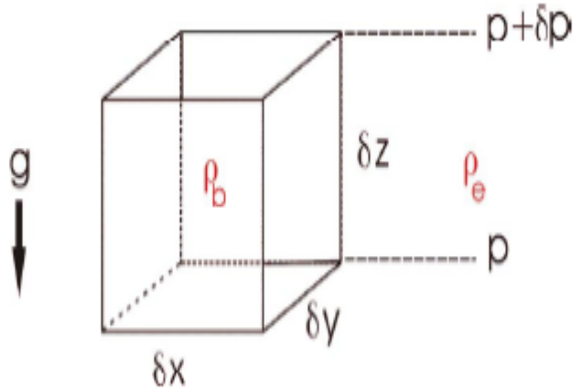
The Biosphere



The Interactions



Buoyancy



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

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

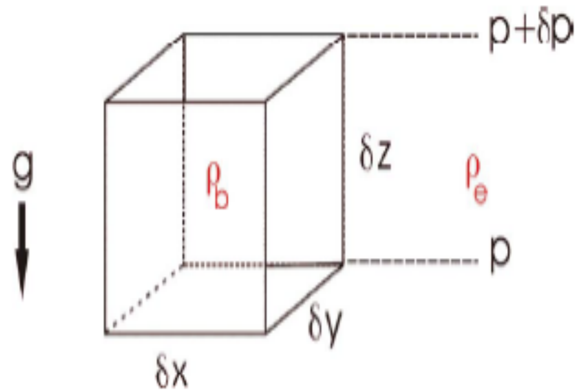
$$F = MA: \quad \rho_b \delta x \delta y \delta z \frac{dw}{dt} = -g\rho_b \delta x \delta y \delta z - \delta p \delta x \delta y$$

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

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

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

Buoyancy

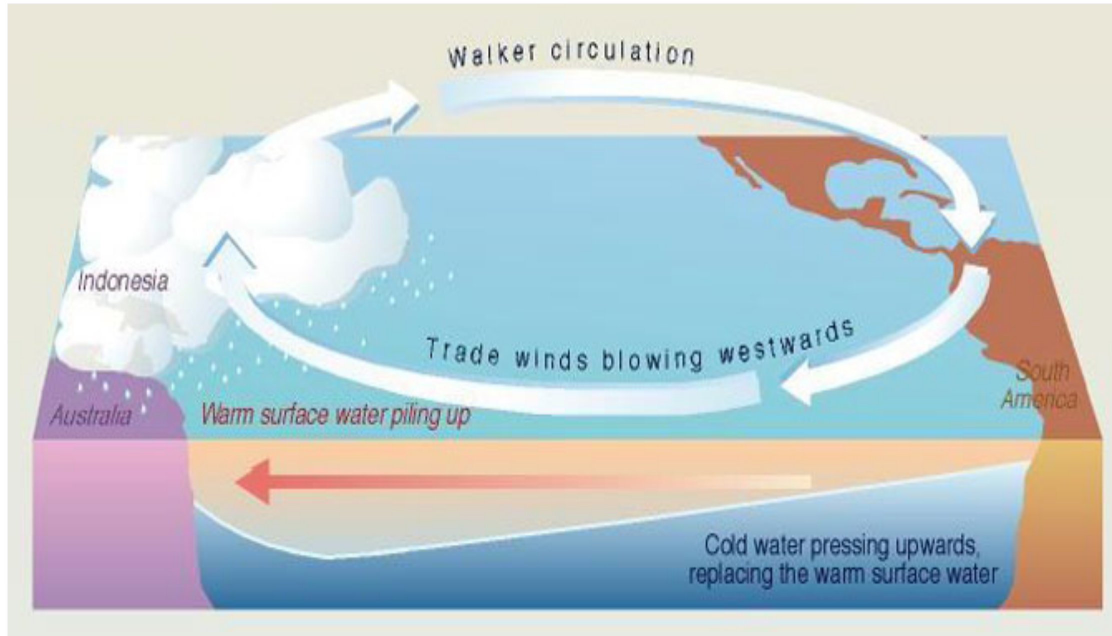


$$B = g\,\tfrac{\alpha_b - \alpha_e}{\alpha_e} = g\,\frac{\rho_e - \rho_b}{\rho_e \rho_b} \approx -g\,\frac{\rho'}{\rho_e}$$

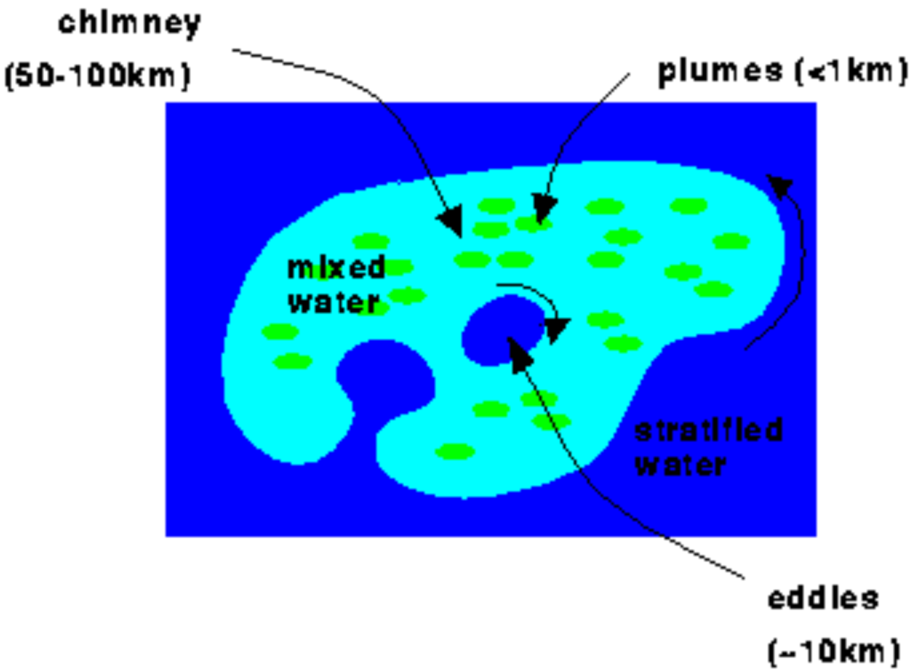
For Air: $$B \approx g\,\frac{T'}{T_e}$$

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

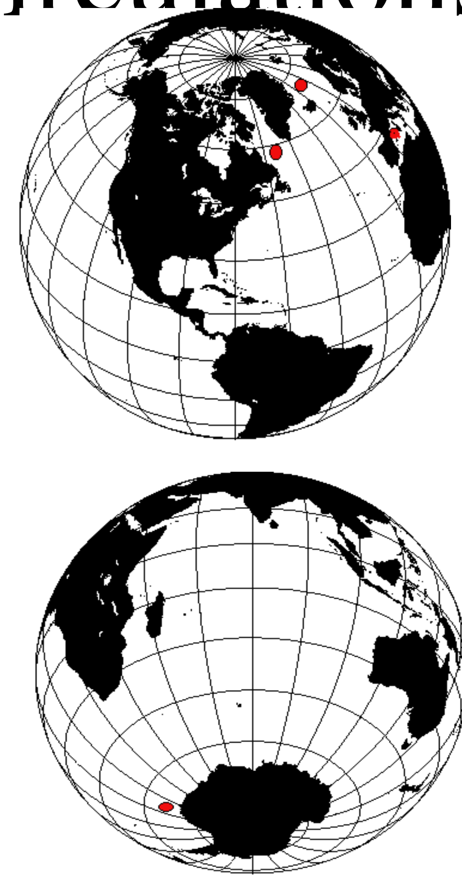
Buoyancy Driven Circulations



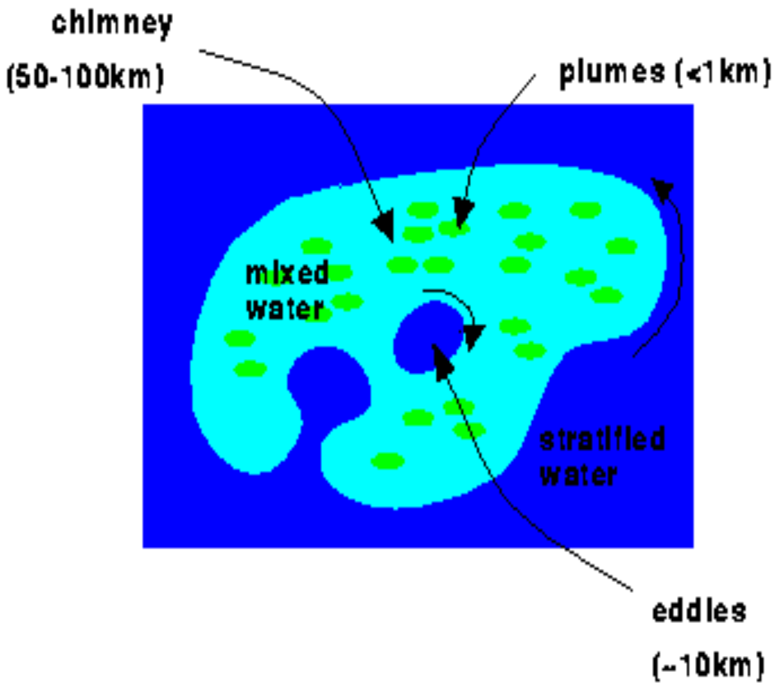
Buoyancy Driven Circulations



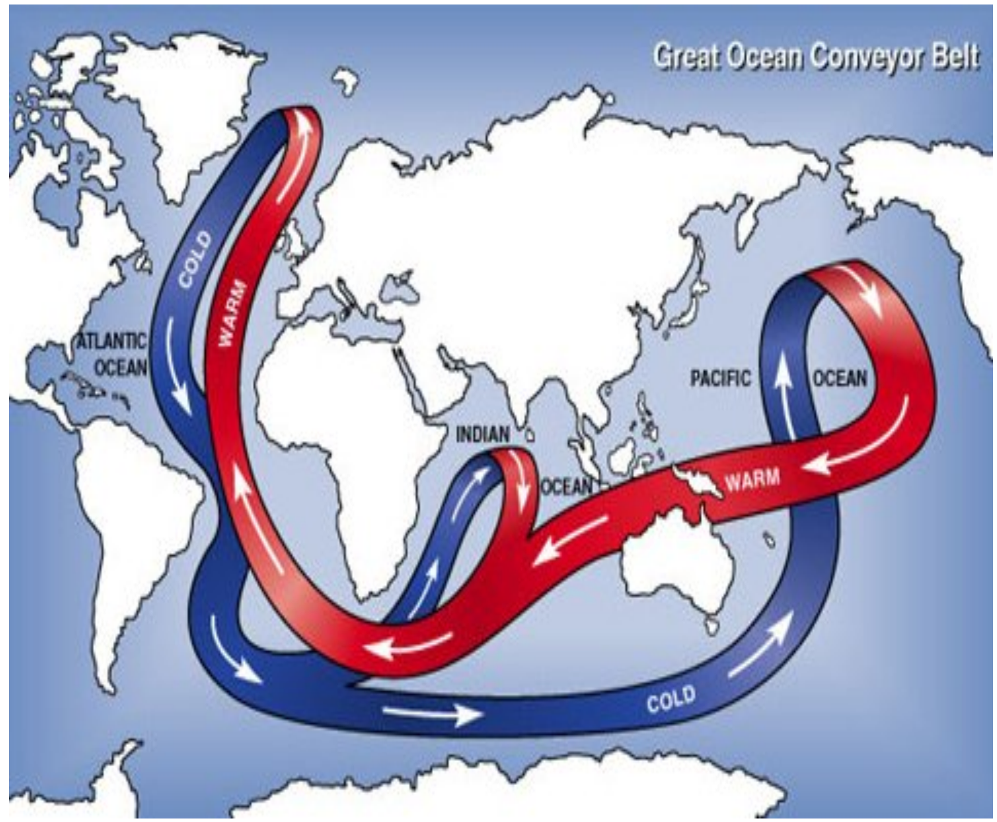
Plan view of a deep convection chimney



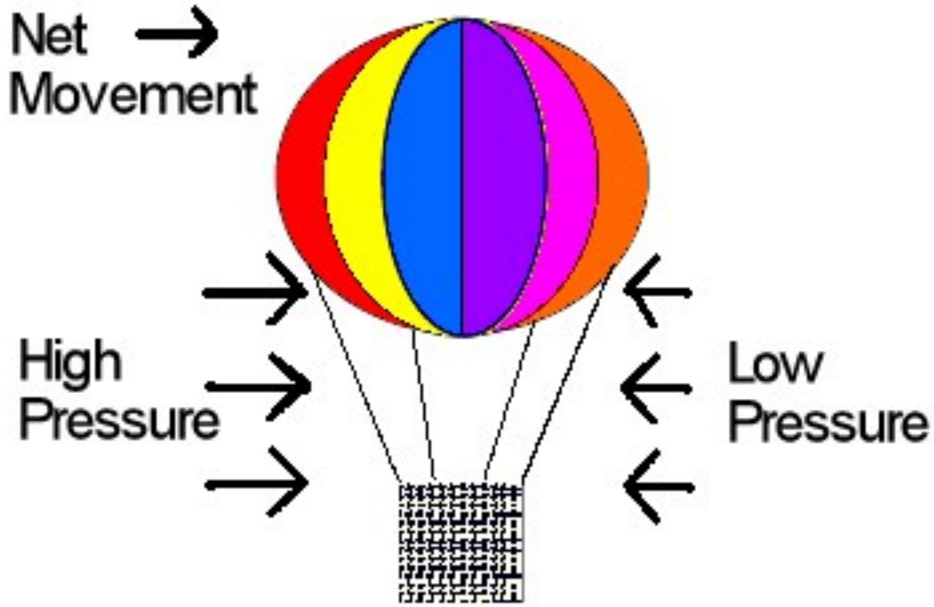
Buoyancy Driven Circulations

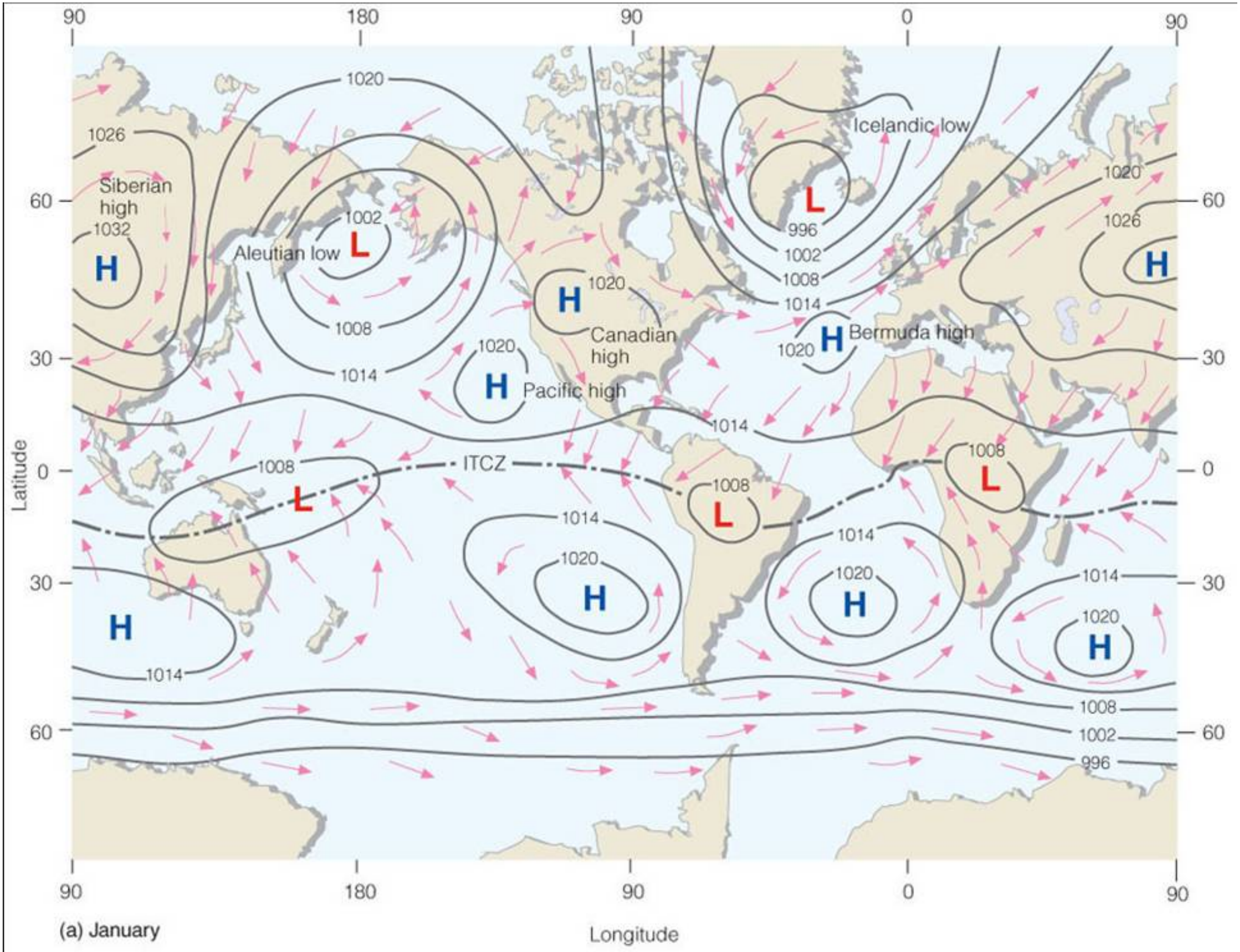


Plan view of a deep convection chimney



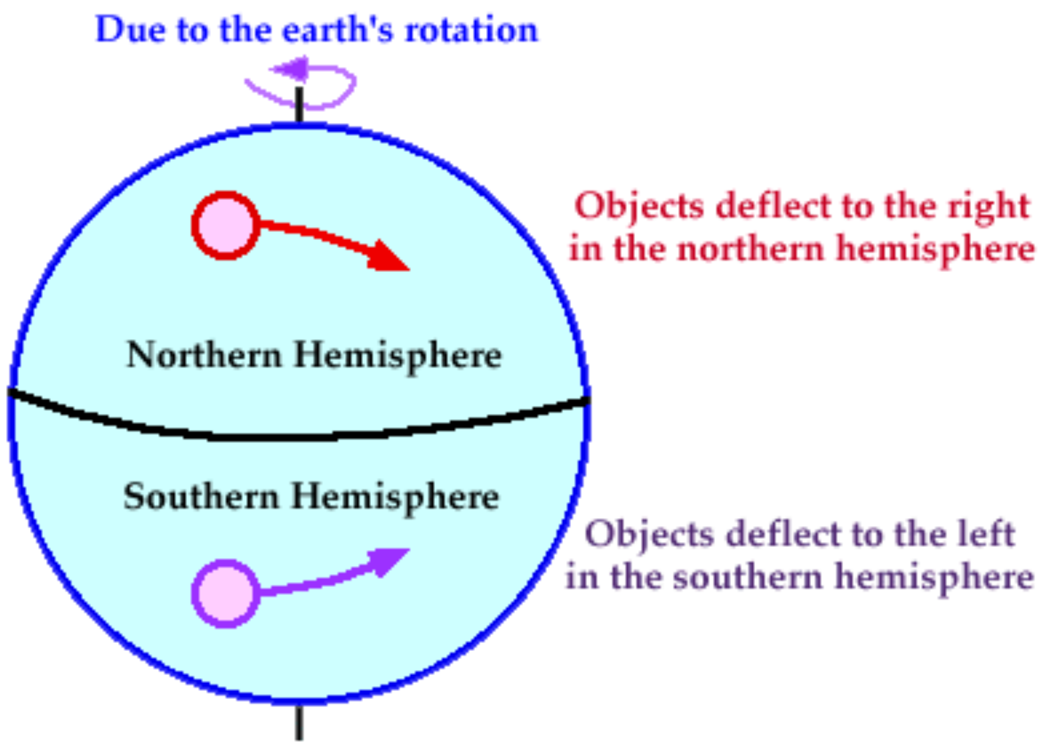
Horizontal Pressure Gradients



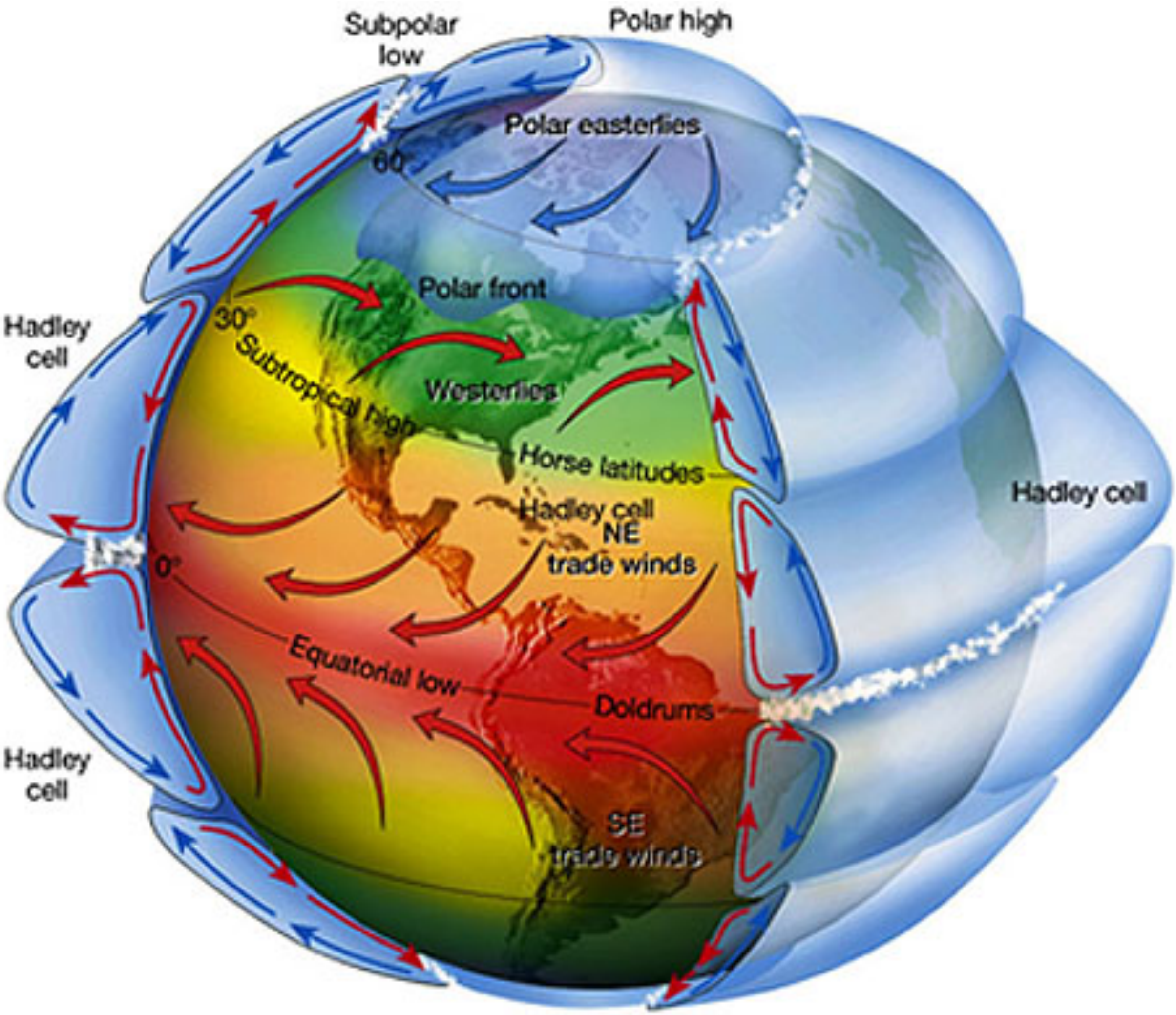


Siberian high
Aleutian low
Icelandic low
Canadian high
Pacific high
Bermuda high
ITCZ
Latitude
Longitude
(a) January

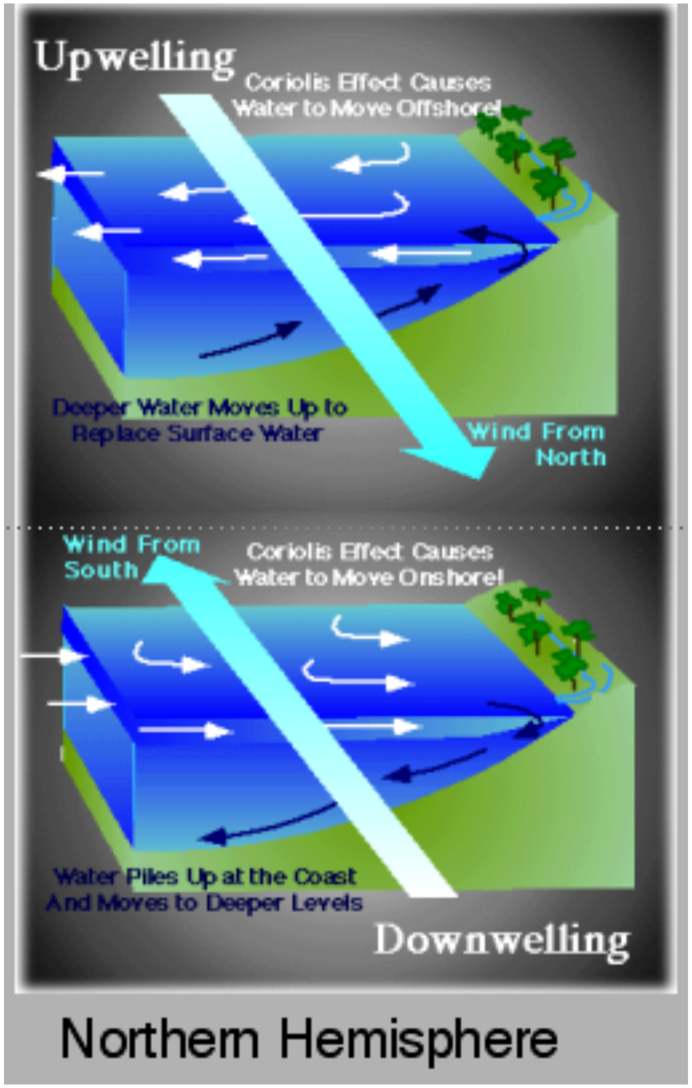
The Coriolis Force

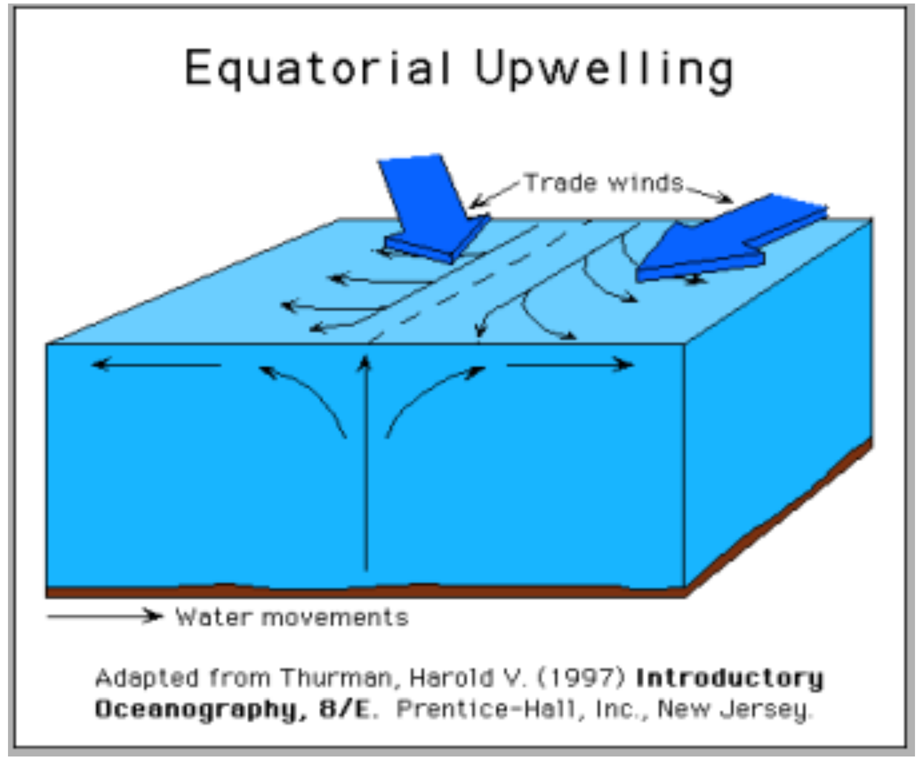


The Coriolis Force



The Coriolis Force

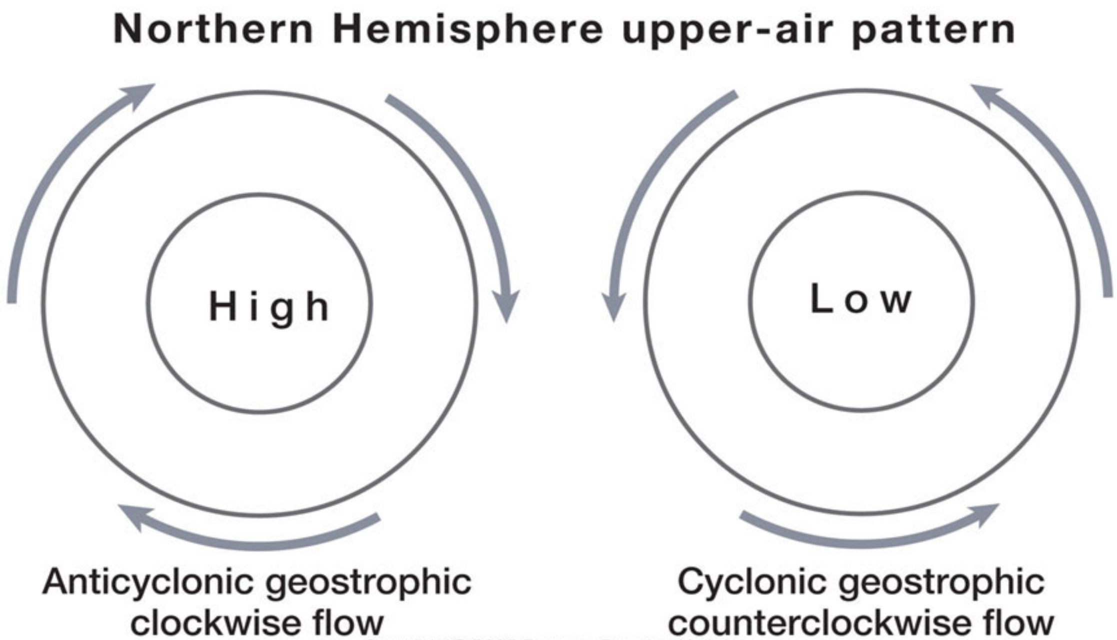




The Geostrophic Balance

$$f \cdot v = \frac{1}{\rho}\frac{\partial P}{\partial x}$$

$$f \cdot u = -\frac{1}{\rho}\frac{\partial P}{\partial y}$$



Frictions/Drags

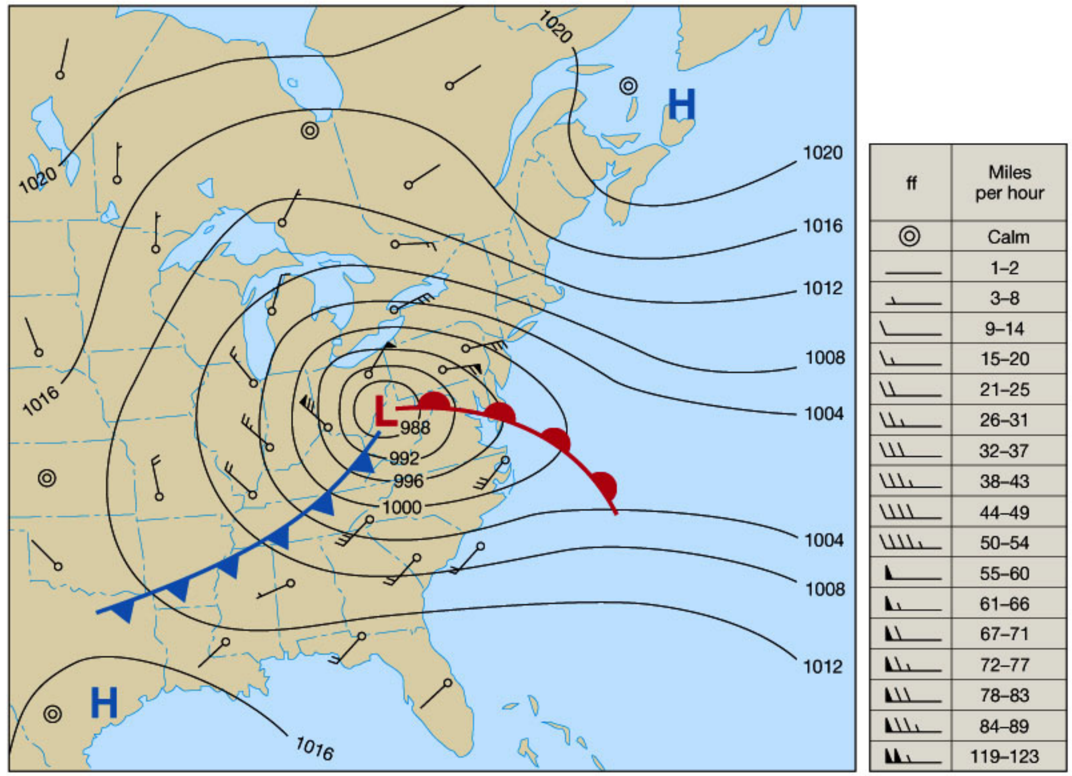
 

Frictions/Drags

$$-fv = -\frac{1}{\rho_o}\frac{\partial p}{\partial x} + K_m \frac{\partial^2 u}{\partial z^2},$$

$$fu = -\frac{1}{\rho_o}\frac{\partial p}{\partial y} + K_m \frac{\partial^2 v}{\partial z^2},$$

$$0 = -\frac{1}{\rho_o}\frac{\partial p}{\partial z},$$

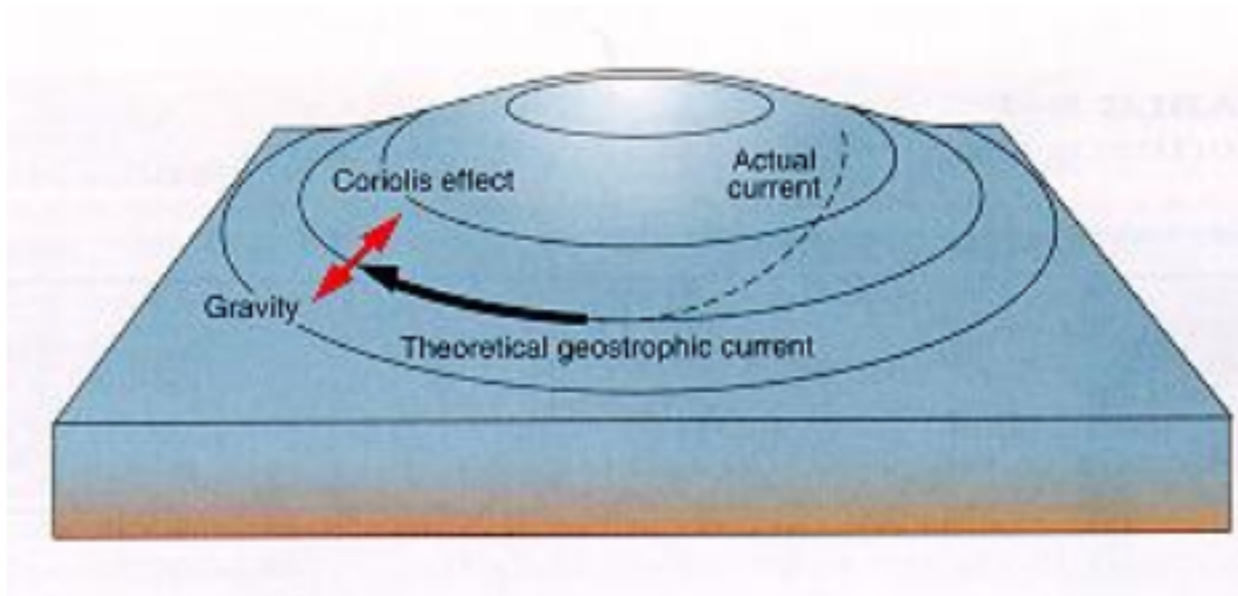


Frictions/Drags

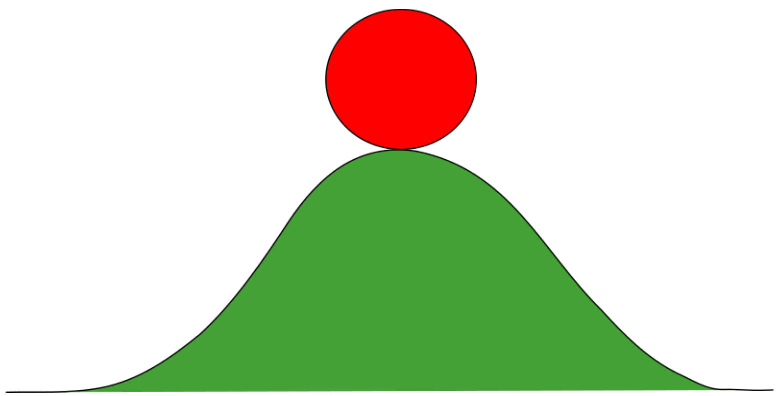
$$-fv = -\frac{1}{\rho_o}\frac{\partial p}{\partial x} + K_m \frac{\partial^2 u}{\partial z^2},$$

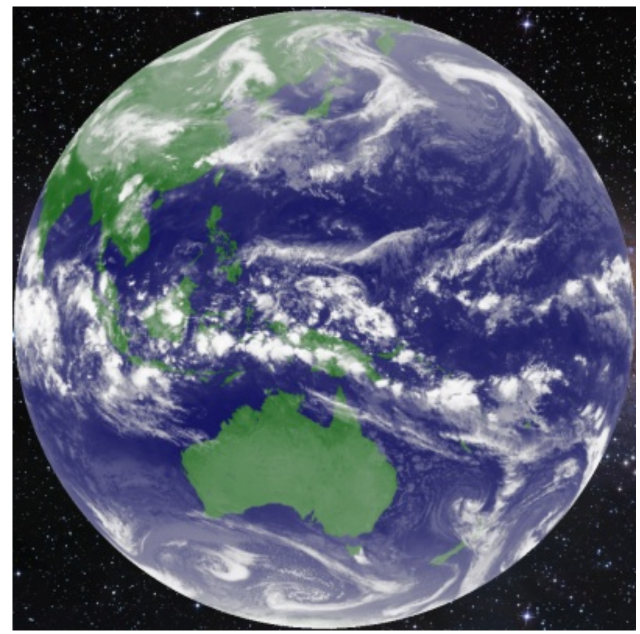
$$fu = -\frac{1}{\rho_o}\frac{\partial p}{\partial y} + K_m \frac{\partial^2 v}{\partial z^2},$$

$$0 = -\frac{1}{\rho_o}\frac{\partial p}{\partial z},$$



Instability





Recommended readings For The Next Lecture

Chapter 3 of Wallace and Hobbs

Chapter 4 of Emanuel

Section 1-2 in Zhang, C. (2005), Madden-Julian Oscillation, Rev. Geophys., 43, RG2003, doi: 10.1029/2004RG000158.