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

Atmosphere

Hydrosphere

Cryosphere

Biosphere

Lithosphere
The Atmosphere
The Hydrosphere
The Cryosphere

Land Ice

Sea Ice
The Lithosphere
The Biosphere
The Interactions
Buoyancy

\[ \text{Weight: } -g \rho_b \delta x \delta y \delta z \]

\[ \text{Pressure: } p \delta x \delta y -(p+\delta p) \delta x \delta y \]

\[ F = MA: \quad \rho_b \delta x \delta y \delta z \frac{d\omega}{dt} = -g \rho_b \delta x \delta y \delta z - \delta p \delta x \delta y \]

\[ \frac{d\omega}{dt} = -g - \alpha_b \frac{\partial p}{\partial z} \quad \text{but} \quad \frac{\partial p}{\partial z} = -\frac{g}{\alpha_e} \]

\[ \rightarrow \quad \frac{d\omega}{dt} = g \frac{\alpha_b - \alpha_e}{\alpha_e} = B \]

\[ B = g \frac{\alpha_b - \alpha_e}{\alpha_e} = g \frac{\rho_e - \rho_b}{\rho_e \rho_b} \approx -g \frac{\rho'}{\rho_e} \]
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:
\[ B \approx g \left( \frac{1}{\alpha} \right) \left( \frac{\partial \alpha}{\partial T} \right) T' + g \left( \frac{1}{\alpha} \right) \left( \frac{\partial \alpha}{\partial S} \right) S' \]
Buoyancy Driven Circulations
Buoyancy Driven Circulations

Plan view of a deep convection chimney
Buoyancy Driven Circulations

Plan view of a deep convection chimney

- chimney (50-100 km)
- plumes (<1 km)
- mixed water
- stratified water
- eddies (~10 km)
Horizontal Pressure Gradients
The Coriolis Force

Due to the earth's rotation

Objects deflect to the right in the northern hemisphere

Northern Hemisphere

Objects deflect to the left in the southern hemisphere

Southern Hemisphere
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

\[-f v = - \frac{1}{\rho_o} \frac{\partial p}{\partial x} + K_m \frac{\partial^2 u}{\partial z^2},\]

\[f u = - \frac{1}{\rho_o} \frac{\partial p}{\partial y} + K_m \frac{\partial^2 v}{\partial z^2},\]

\[0 = - \frac{1}{\rho_o} \frac{\partial p}{\partial z},\]
Instability
Recommended readings For The Next Lecture

Chapter 3 of Wallace and Hobbs

Chapter 4 of Emanuel