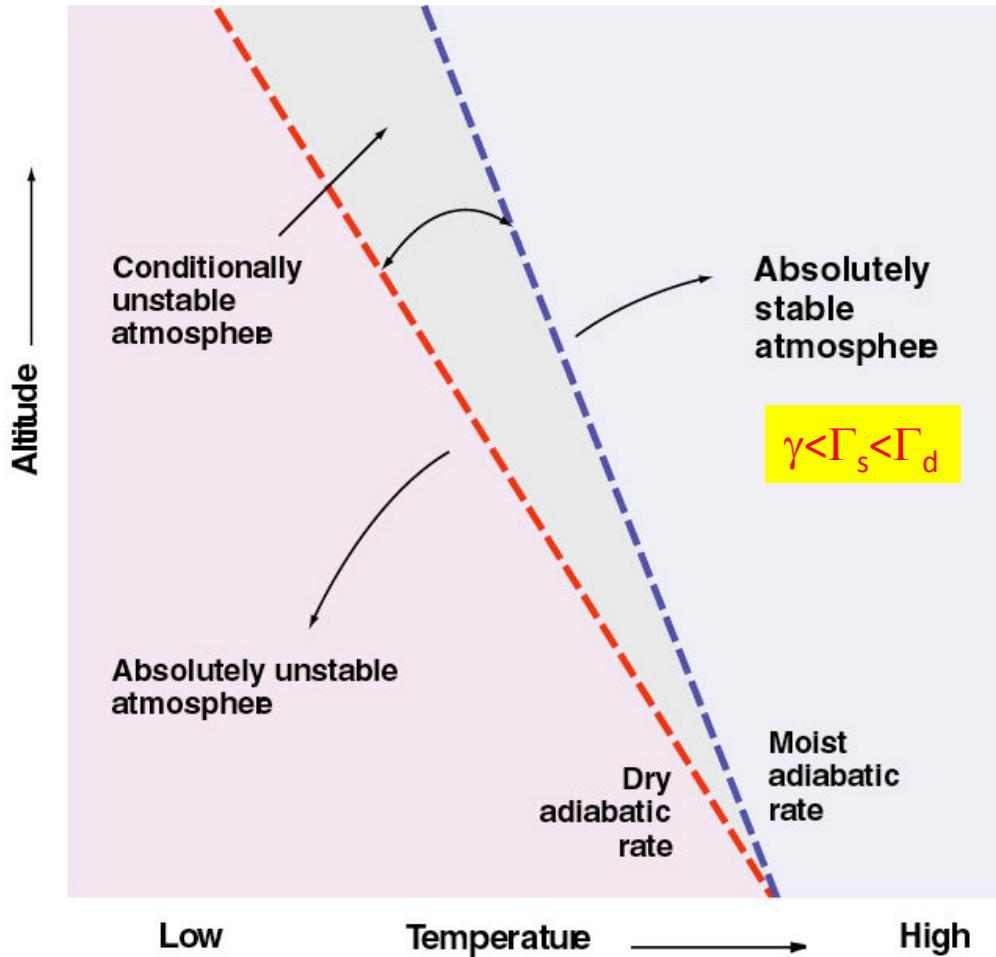


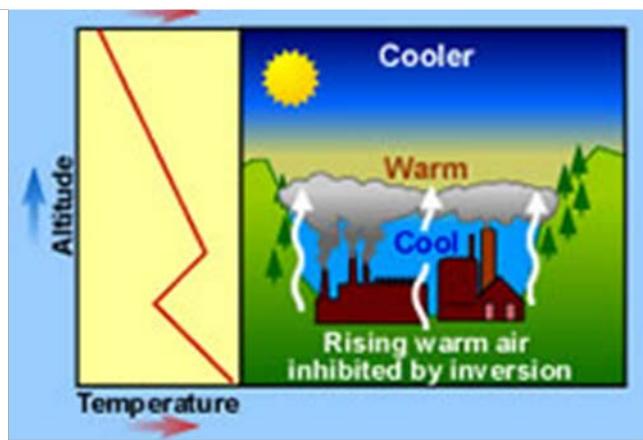
# Unit 7

Atmospheric stability  
Nicole Mölders

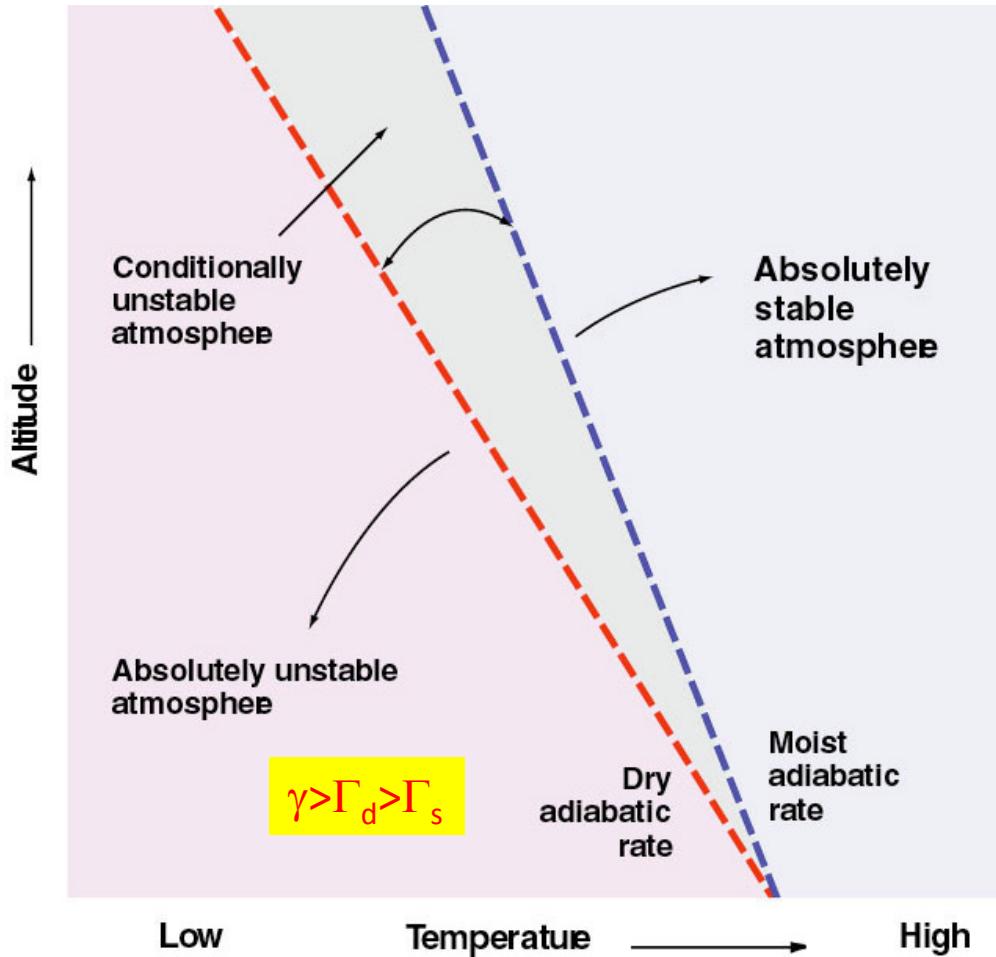
# Absolutely stable: $\gamma < \Gamma_s < \Gamma_d$



# Absolutely stable: $\gamma < \Gamma_s < \Gamma_d$



# Absolutely unstable: $\gamma > \Gamma_d > \Gamma_s$

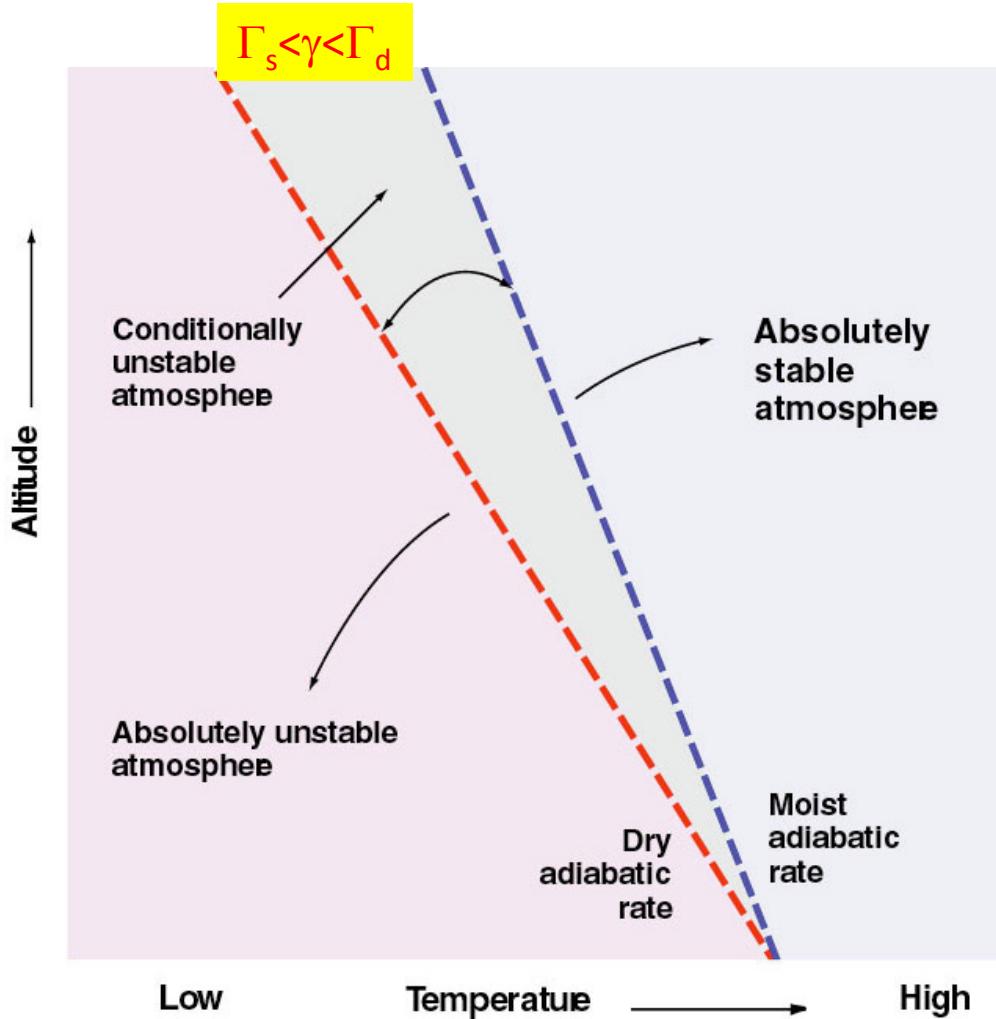


# Absolutely unstable: $\gamma > \Gamma_d > \Gamma_s$



<https://encrypted-tbn2.gstatic.com/images?q=tbn:ANd9GcRLrRQjzBPQc9qJlajH-JN0fWoaVCewGuuERzwtomr6m0mfuSHBNA>

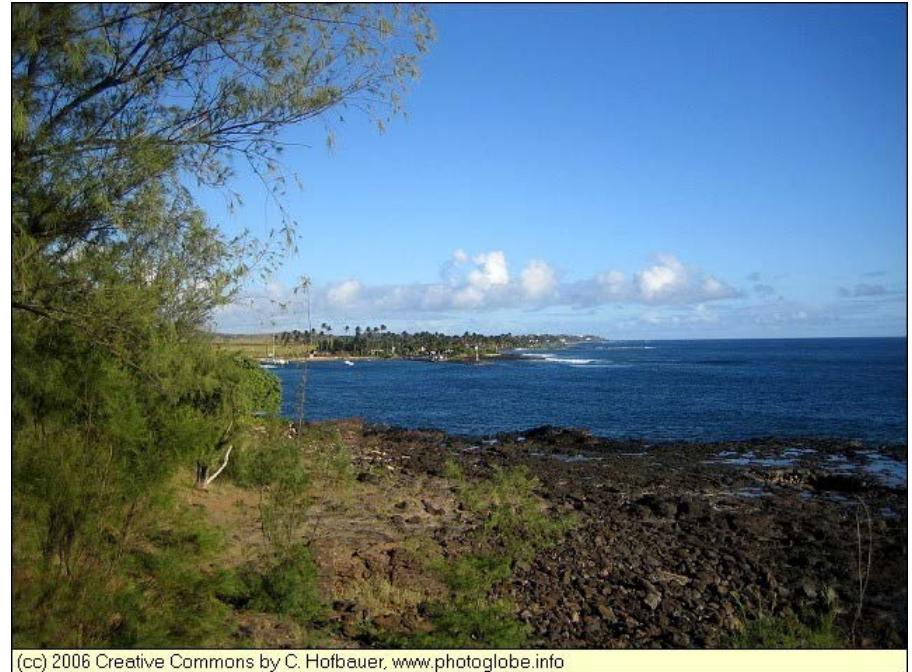
# Conditionally unstable: $\Gamma_s < \gamma < \Gamma_d$



# Conditionally unstable: $\Gamma_s < \gamma < \Gamma_d$

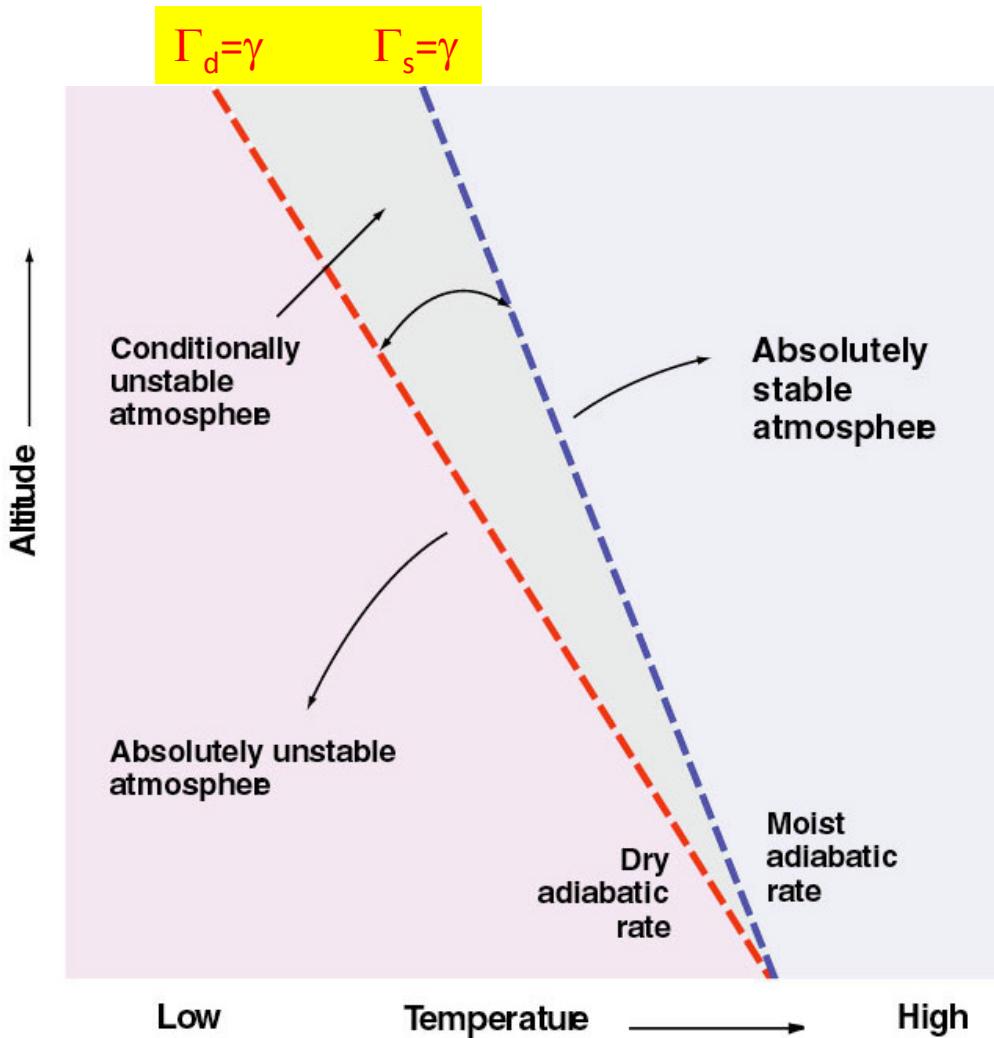


Clouds over Fairbanks

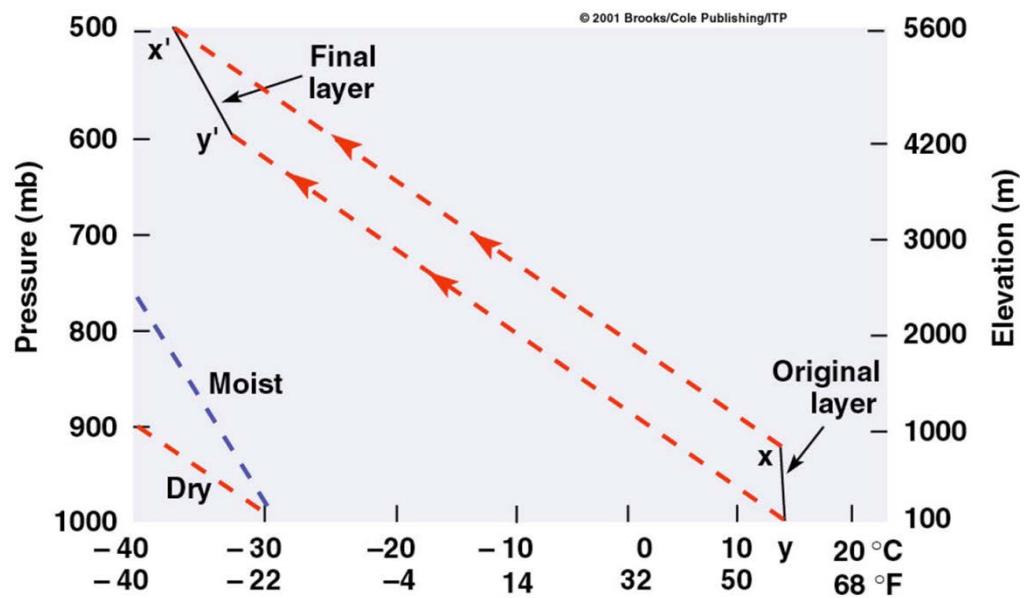
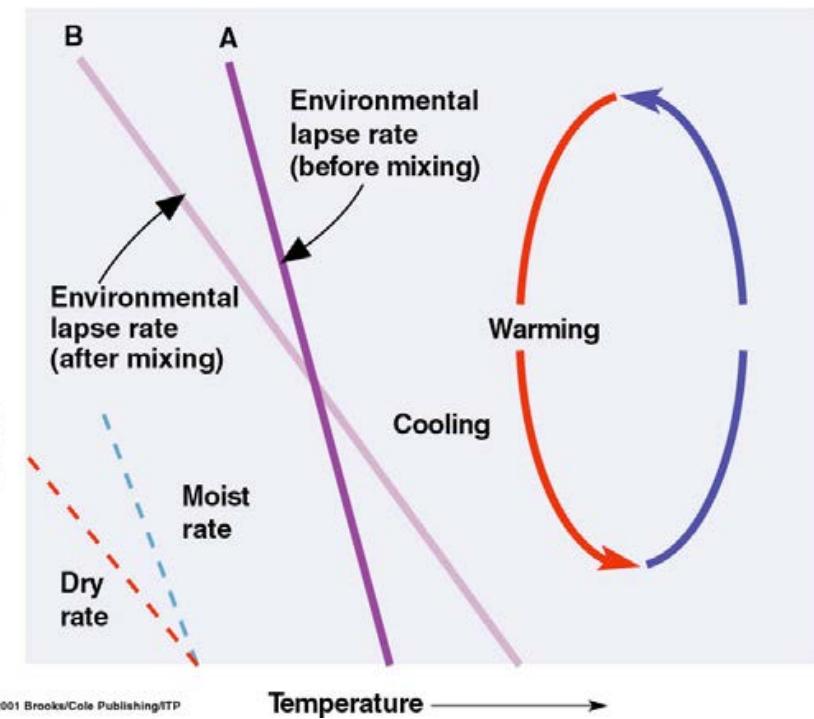


Trade wind clouds over Hawaii

**Neutral:**  $\gamma = \Gamma_d$  or  $\gamma = \Gamma_s$



# Stability can change by mixing or lifting



# $\theta$ and entropy – revisit under the aspect of stability

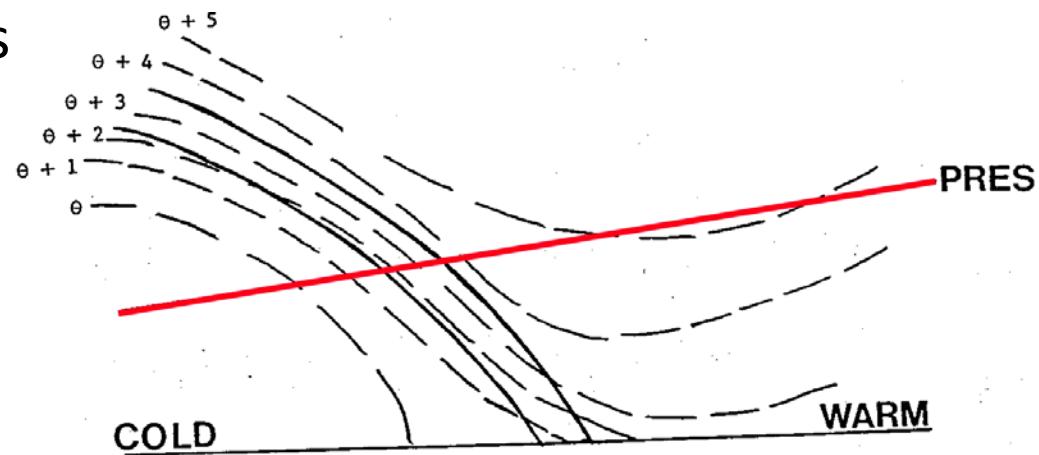
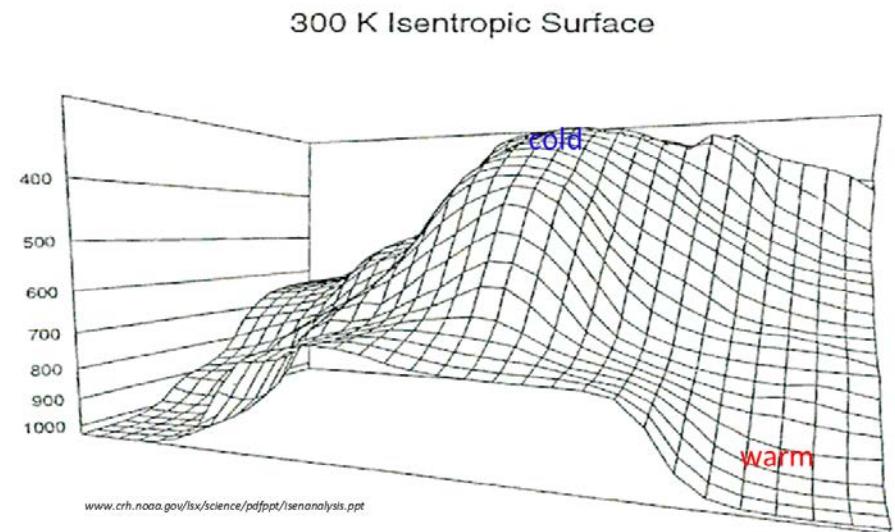
$$\theta = T (1000/P)^\kappa \text{ with } \kappa = R_d / C_p$$

$$S = C_p \ln \theta + \text{const}$$

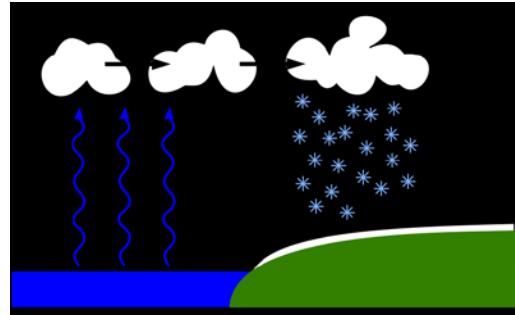
$$d\theta/dz = (\theta/T) [\Gamma_d - \gamma]$$

$\Rightarrow$  3 types of stability

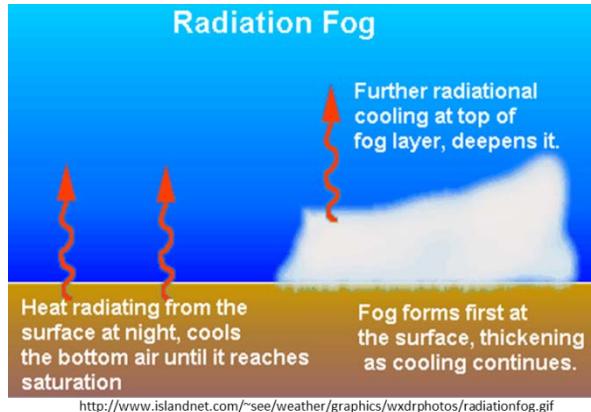
- **stable**:  $\gamma < \Gamma_d$ ,  $\theta$  increases with height
- **neutral**:  $\gamma = \Gamma_d$ ,  $\theta$  is constant with height
- **unstable**:  $\gamma > \Gamma_d$ ,  $\theta$  decreases with height



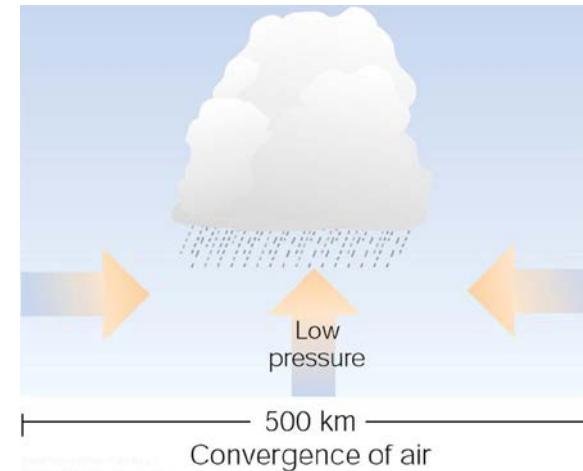
# Enhancement of instability by surface heating, horizontal heterogeneity, lifting, or radiative cooling



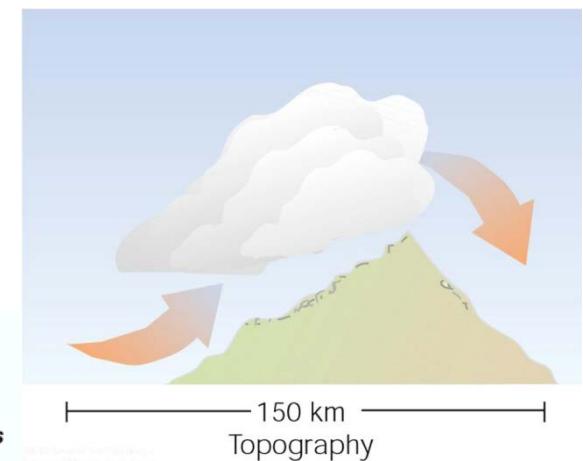
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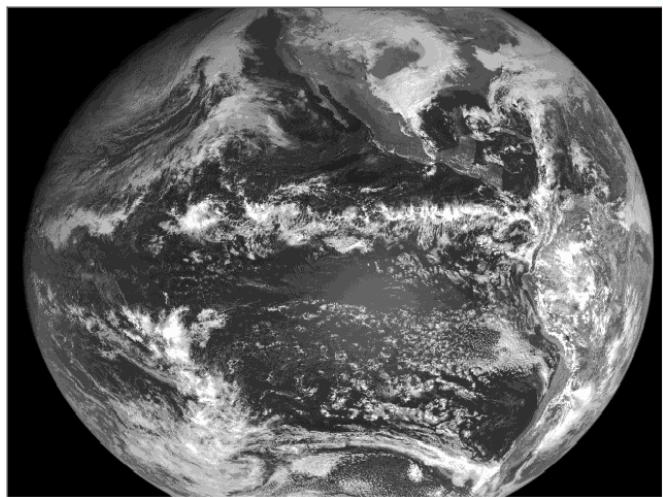
<http://www.islandnet.com/~see/weather/graphics/wxdrphotos/radiationfog.gif>



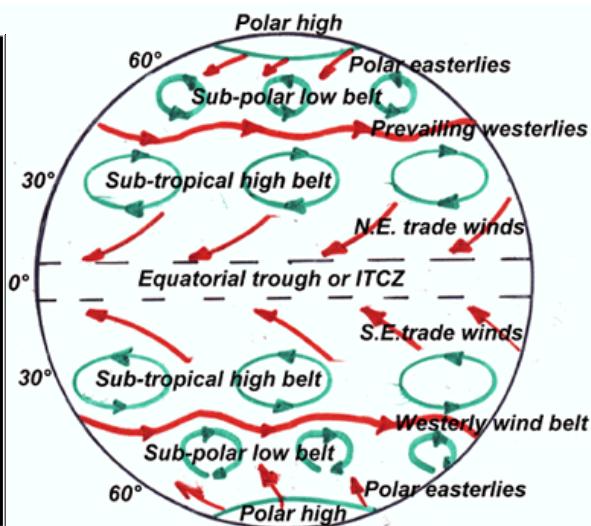
[http://atm.ucdavis.edu/~grotjahn/course/atm10/pdfs/fnl\\_Lect\\_05.pdf](http://atm.ucdavis.edu/~grotjahn/course/atm10/pdfs/fnl_Lect_05.pdf)



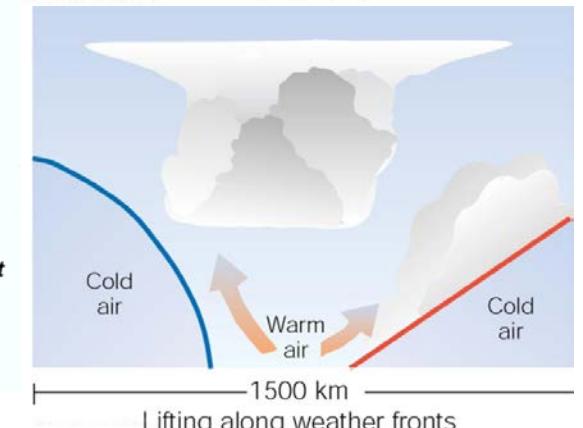
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<http://www.eso.org/gen-fac/pubs/astclim/espas/world/Climate/ITCZ/ITCZ-esrg.gif>



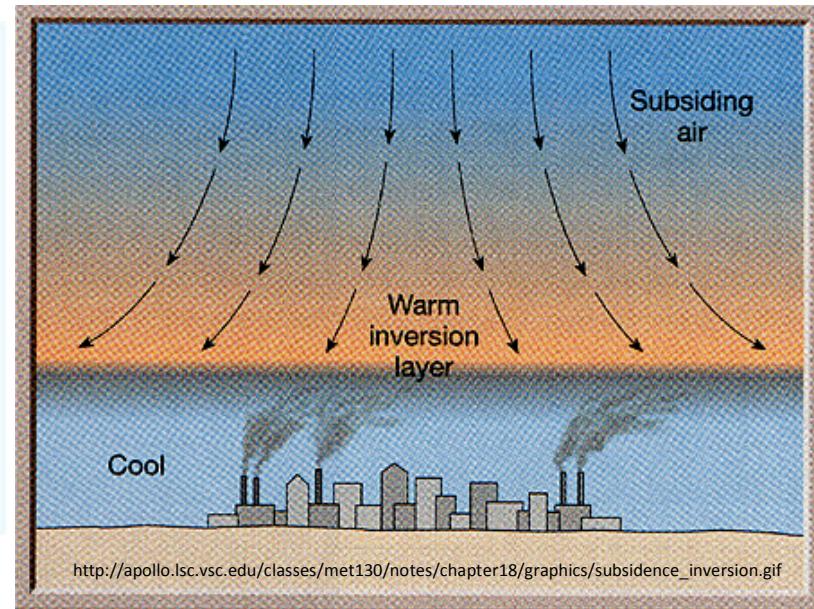
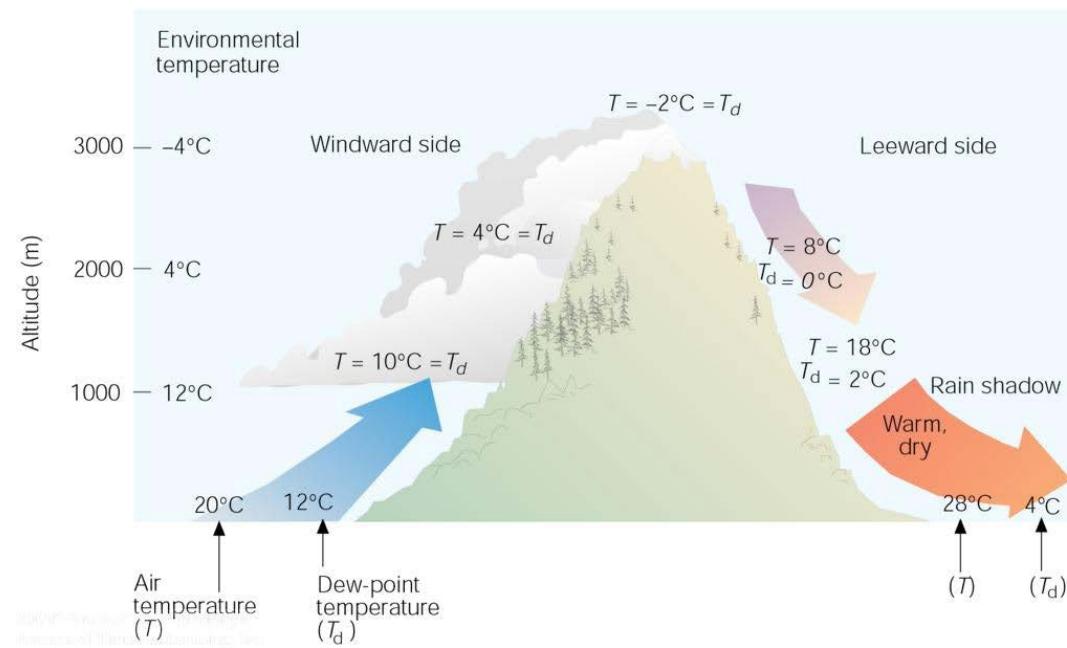
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[http://atm.ucdavis.edu/~grotjahn/course/atm10/pdfs/fnl\\_Lect\\_05.pdf](http://atm.ucdavis.edu/~grotjahn/course/atm10/pdfs/fnl_Lect_05.pdf)

# Stability enhancement by cooling from below, subsidence, cold air advection

Föhn - Chinook



From: [http://atm.ucdavis.edu/~grotjahn/course/atm10/pdfs/fnl\\_Lect\\_05.pdf](http://atm.ucdavis.edu/~grotjahn/course/atm10/pdfs/fnl_Lect_05.pdf)

# Quantifying the vertical motion of an air parcel

$$\rho' \frac{d^2 z}{dt^2} = -\rho' g - \frac{dp'}{dz} \text{ or } \frac{d^2 z}{dt^2} = -g - \alpha' \frac{dp'}{dz}$$

$$p = \rho R_d T = \rho' R_d T' = p'$$

$$\frac{d^2 z}{dt^2} = g \left( \frac{T' - T}{T} \right) = g \left( \frac{\rho - \rho'}{\rho'} \right)$$

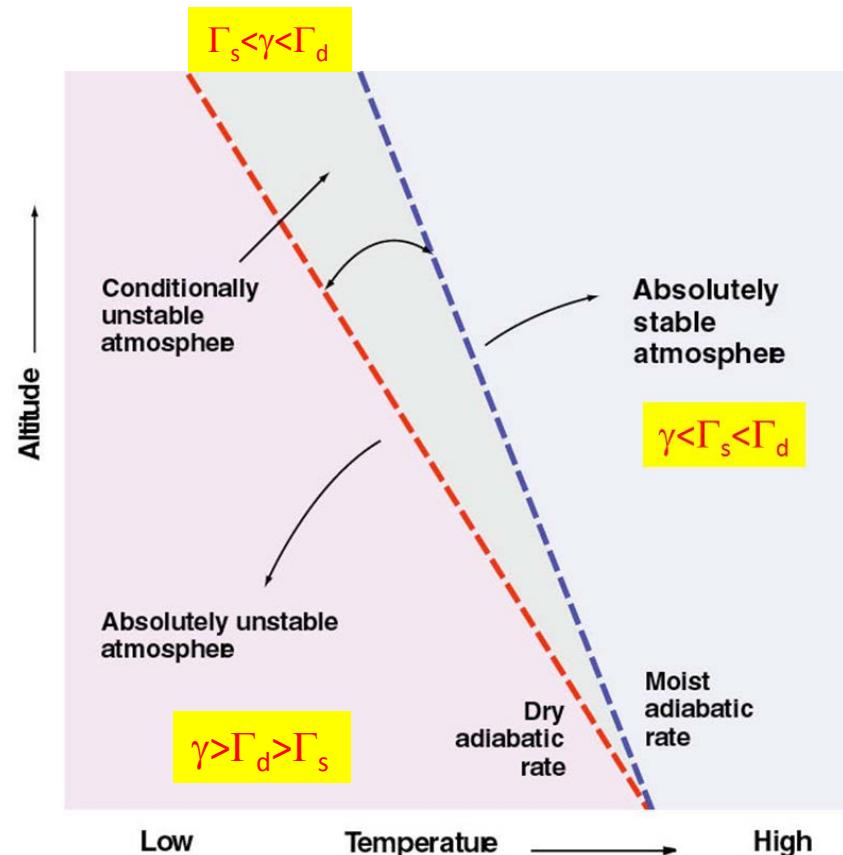
$$T = T_0 + \frac{dT}{dz} z + 0.5 \frac{d^2 T}{dz^2} z^2 + \dots$$

$$\frac{d^2(\delta z)}{dt^2} = -\frac{g}{T} (\gamma - \gamma') \delta z$$

$$\frac{d^2(\delta z)}{dt^2} + N^2(\delta z) = 0$$

$$N^2 = \frac{g}{T} (\gamma - \gamma') = \frac{g}{T} \left( \frac{dT}{dz} + \frac{g}{c_p} \right)$$

$$N^2 = \frac{g}{\Theta} \frac{d\Theta}{dz}$$



# Stability and buoyancy

$$\frac{dw}{dt} = \frac{g}{T_v} (T_{v,p} - T_v)$$

$$dz \frac{dw}{dt} = \frac{dz}{dt} dw = w dw = \frac{d}{dt} \frac{w^2}{2} = \frac{g}{T_v} (T_{v,p} - T_v) dz$$

$$dz = -\frac{1}{\rho g} dp = -\frac{R_d T_v}{g} \frac{dp}{p}$$

$$\frac{d}{dz} \left( \frac{w^2}{2} \right) = -R_d (T_{v,p} - T_v) d(\ln p)$$

$$w_{LFC}^2 - w_{OL}^2 = -2R_d \int_{p_{OL}}^{p_{LFC}} (T_{v,p} - T_v) d(\ln p)$$

$$CIN = R_d \int_{p_{LFC}}^{p_{OL}} (T_{v,p} - T_v) d(\ln p) \leq 0$$

$$w_{LFC}^2 = w_{OL}^2 + 2CIN \geq 0$$

$$w_{OL} = +\sqrt{-2CIN}$$

$$CAPE = g \int_{LFC}^{z_{CT}} \frac{\theta(z) - \bar{\theta}(z)}{\bar{\theta}(z)} dz$$

