Buoyancy and Entropy

Specific Volume:
$$\alpha = \frac{1}{\rho}$$

Specific Entropy: s

$$\alpha = \alpha($$
,

$$\left(\delta\alpha\right)_{p} = \left(\frac{\partial\alpha}{\partial s}\right)_{p} \delta s = \left(\frac{\partial T}{\partial p}\right)_{s} \delta s$$

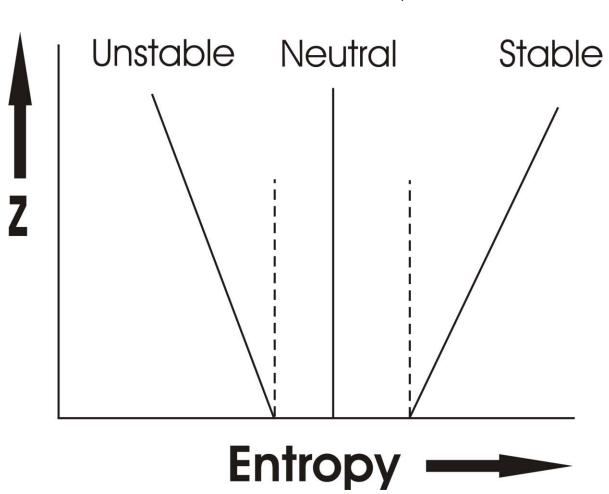
$$B = g \frac{\left(\delta \alpha\right)_{p}}{\alpha} = \frac{g}{\alpha} \left(\frac{\partial T}{\partial p}\right)_{s} \delta s = -\left(\frac{\partial T}{\partial z}\right)_{s} \delta s \equiv \Gamma \delta s$$

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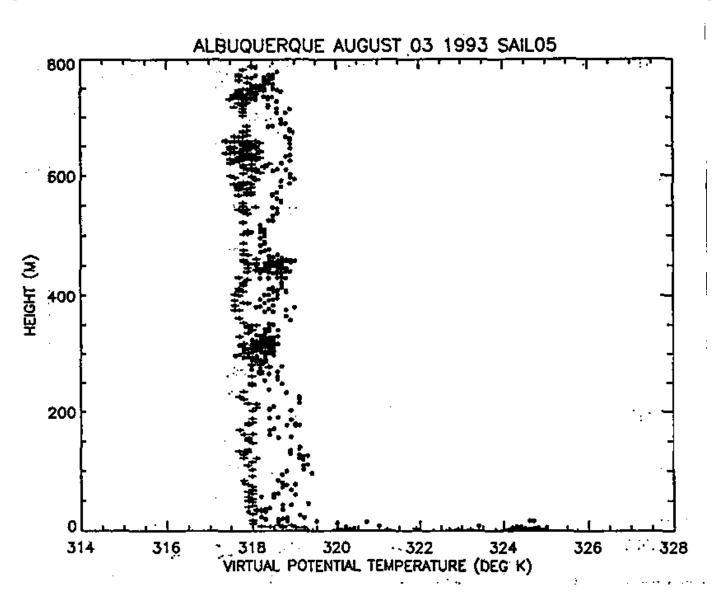
Note: For ideal gas: $\Gamma = \frac{g}{c_p}$

$$\Gamma = \frac{g}{c_p}$$

Earth's atmosphere:
$$\Gamma = {}^{1}K/_{100 m}$$



Model Aircraft Measurements (Renno and Williams, 1995)



Water Variables

Mass concentration of water vapor (specific humidity):

$$q = \frac{M_{H_2O}}{M_{air}}$$

Vapor pressure (partial pressure of water vapor): e

Saturation vapor pressure: e*

C-C:
$$e^* = 6.112 \, hPa \, e^{\frac{17.67(T-273)}{T+30}}$$

Relative Humidity:
$$H \equiv \frac{e}{e^*}$$

The Saturation Specific Humidity

$$p = \rho \frac{R * T}{\bar{m}}$$

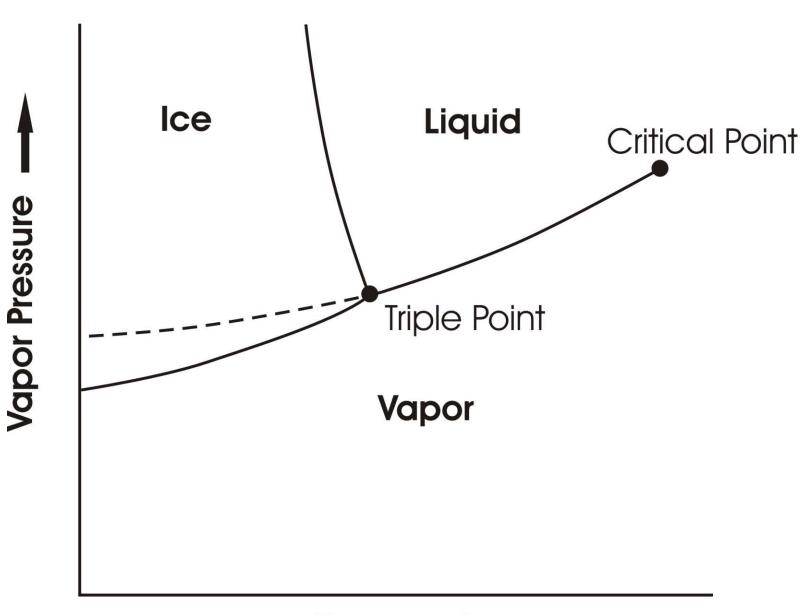
Ideal Gas Law:

$$e = \rho_{v} \frac{R * T}{m_{v}}$$

$$q = \frac{\rho_{v}}{\rho} = \frac{m_{v}}{\overline{m}} \frac{e}{p}$$

$$q^* = \frac{m_v}{\bar{m}} \frac{e^*}{p}$$

Phase Equilibria



Temperature -

Bringing Air to Saturation:

$$e = qp \left(\frac{\overline{m}}{m_v} \right)$$

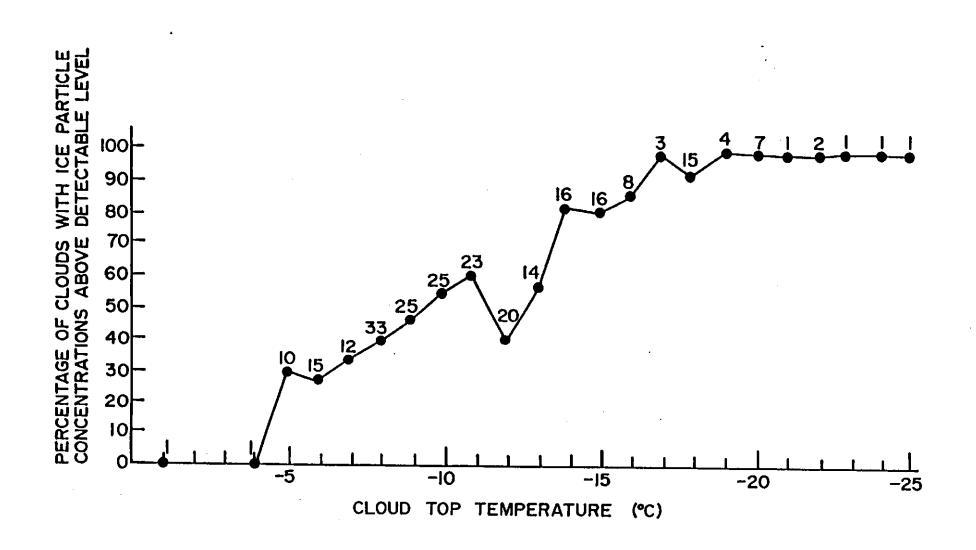
$$e^* = e^* (T)$$

- 1. Increase q
- 2. Decrease e* (T)

When Saturation Occurs...

- Heterogeneous Nucleation
- Supersaturations very small in atmosphere
- Drop size distribution sensitive to size distribution of cloud condensation nuclei

Ice Nucleation Problematic



Precipitation Formation:

- Stochastic coalescence (sensitive to drop size distributions)
- Bergeron-Findeisen Process
- Strongly nonlinear function of cloud water concentration
- Time scale of precipitation formation ~10-30 minutes

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12.103 Science and Policy of Natural Hazards Spring 2010

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