When Saturation Occurs…

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

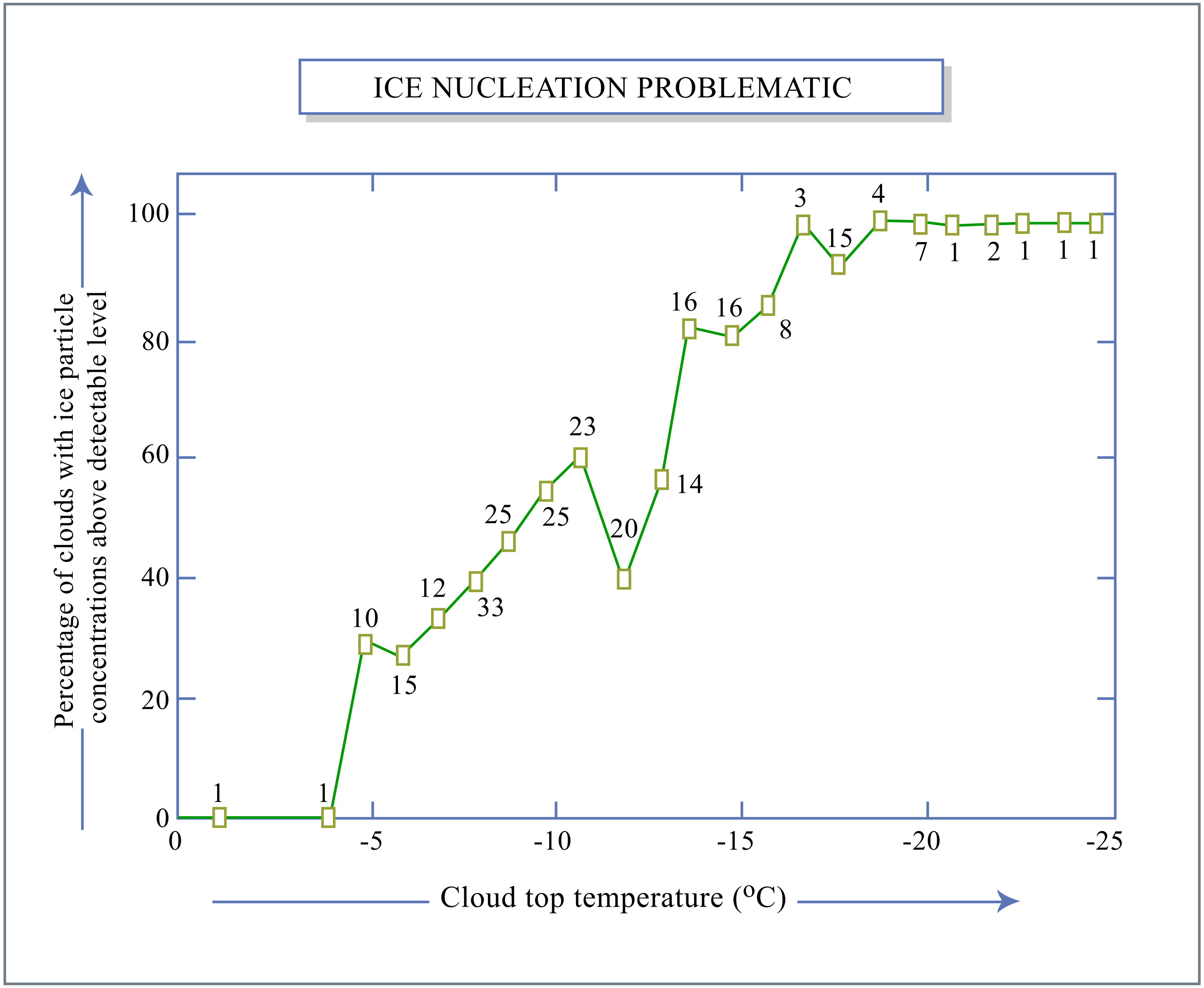


Image by MIT OpenCourseWare.

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

Stability

No simple criterion based on entropy:

$$s_d = c_p \ln\left(\frac{T}{T_0}\right) - R_d \ln\left(\frac{p}{p_0}\right)$$

$$\alpha = \alpha\left(s_d, p\right)$$

$$s = c_p \ln\left(\frac{T}{T_0}\right) - R_d \ln\left(\frac{p}{p_0}\right) + L_v \frac{q}{T} - qR_v \ln\left(\mathcal{H}\right)$$

$$\alpha = \alpha\left(s, p, q_t\right)$$

Virtual Temperature and Density Temperature

Assume all condensed water falls at terminal velocity

$$\alpha = \frac{V_a + V_c}{M_d + M_v + M_c}$$

$$pV = nR^*T$$

$$V_a = \frac{R^*T}{p}\left(\frac{M_d}{m_d} + \frac{M_v}{m_v}\right),$$

$$\overline{m_d} \equiv \frac{1}{\frac{1}{M_d} \sum_i \frac{M_i}{m_i}}$$

$$\rightarrow \quad V_a = \frac{R_d T}{p}\left(M_d + M_v / \varepsilon \right),$$

where $$\varepsilon \equiv m_v / \overline{m}_d \cong 0.622$$

$$R_d \equiv R^* / \overline{m}_d$$

$$\alpha = \frac{V_a + V_c}{M_d + M_v + M_c} = \frac{R_d T}{p}\left(1 - q_t + {q}/{\varepsilon}\right)\left(1 + \frac{q_c}{1 - q_c}\frac{\rho_a}{\rho_c}\right)$$

$$\cong \frac{R_d T}{p}\left(1 - q_t + {q}/{\varepsilon}\right)$$

$$q_t \equiv \frac{M_v + M_c}{M}, \qquad q \equiv \frac{M_v}{M}$$

Density temperature:

$$T_\rho \equiv T\left(1 - q_t + {q}/{\varepsilon}\right)$$

$$\alpha = \frac{R_d T_\rho}{p}$$

Trick:

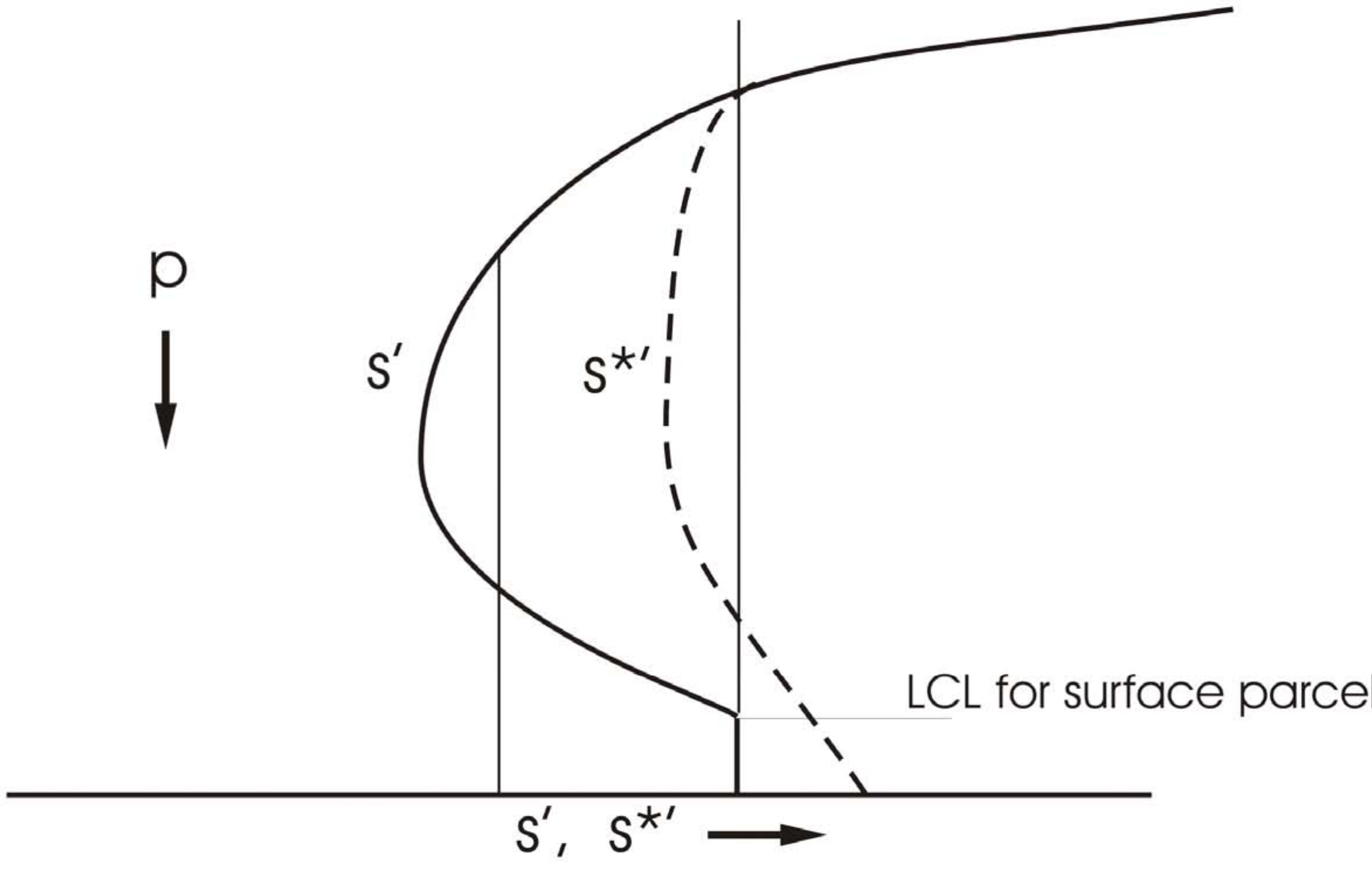
Define a *saturation entropy, s** :

$$s^* \equiv s\left(T, p, q^*\right)$$

$$\alpha = \alpha\left(s^*, p, q_t\right)$$

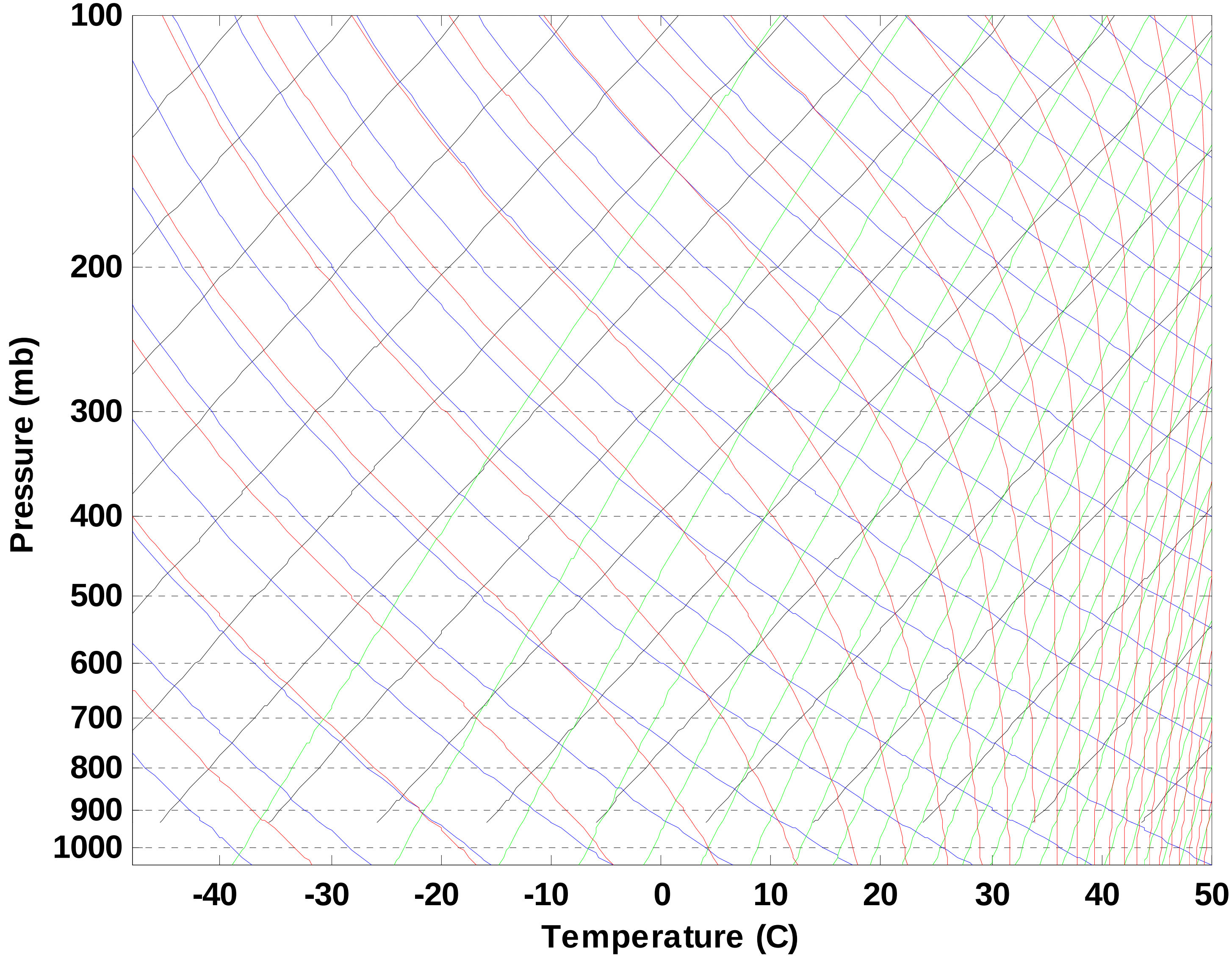
We can add an arbitrary function of q_t to s^* such that

$$\alpha \cong \alpha\left(s^{*\prime}, p\right)$$



p
s′
s*′
LCL for surface parcel
s′, s*′

Stability Assessment using Tephigrams:

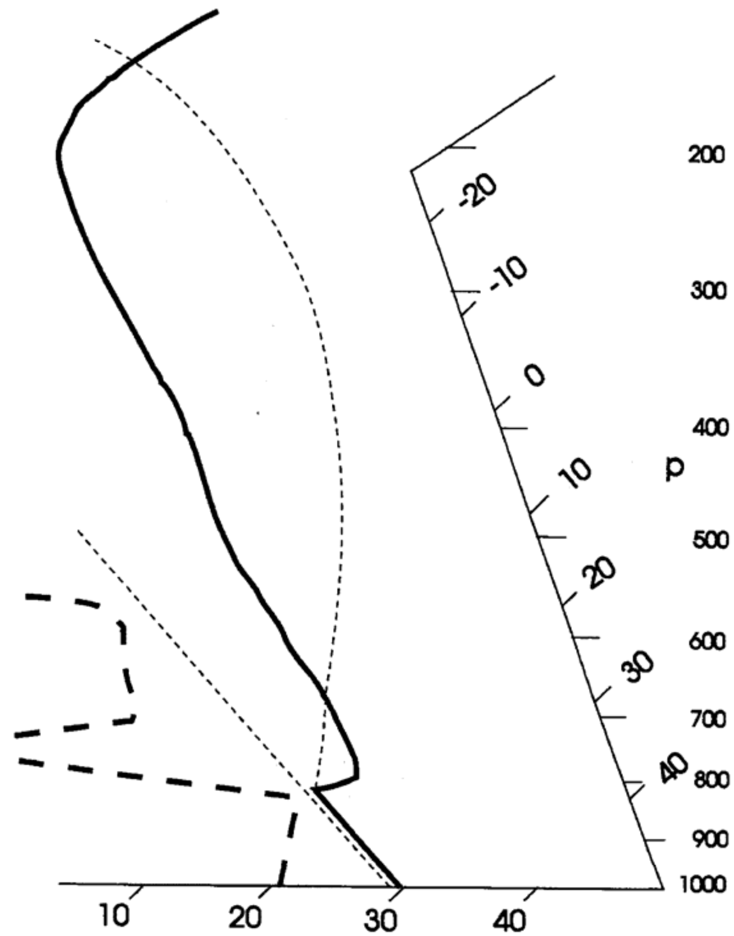


Stability Assessment using Tephigrams:

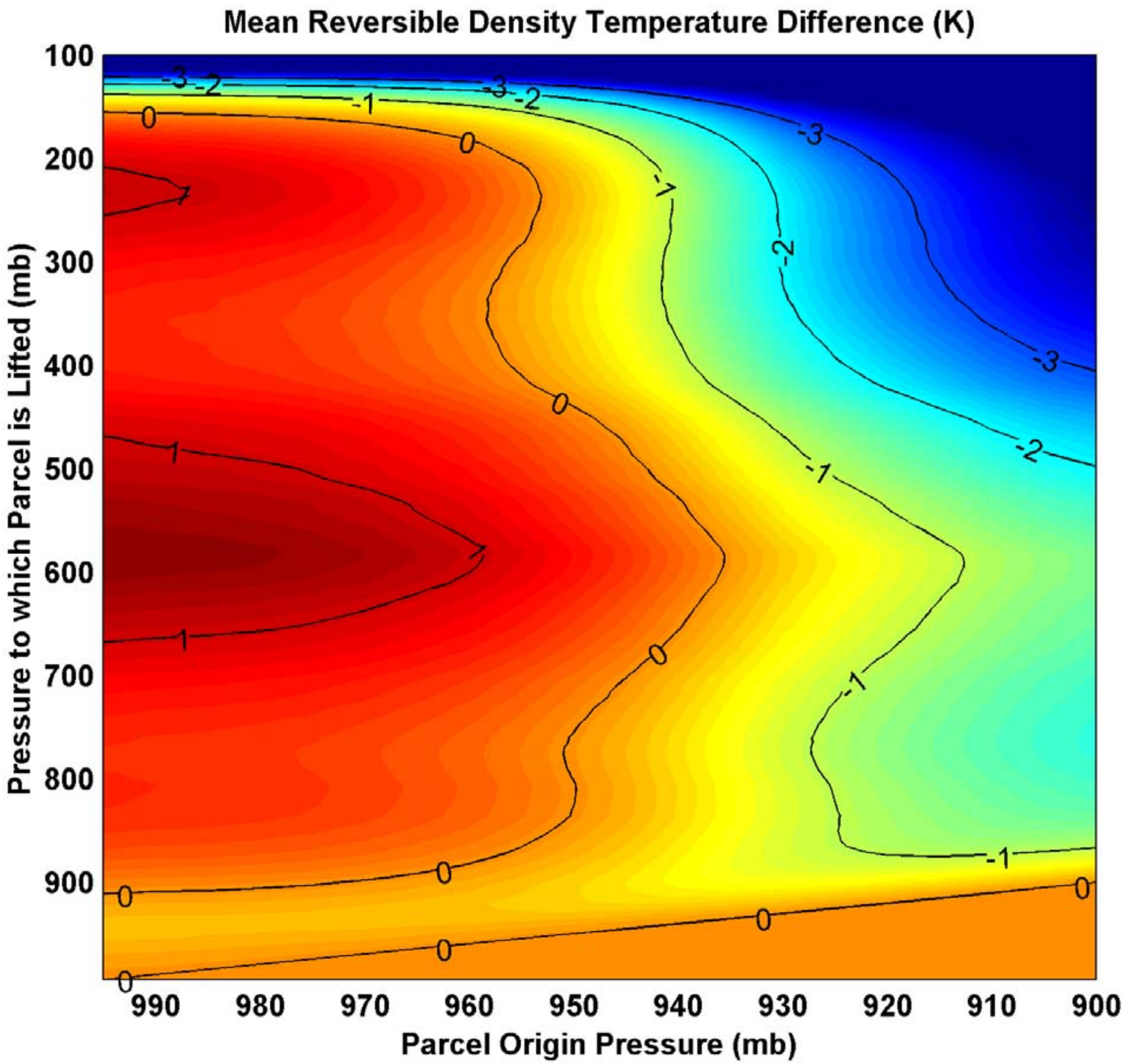
Convective Available Potential Energy (CAPE):

$$CAPE_i \equiv \int_{p_n}^{p_i} \left(\alpha_p - \alpha_e\right) dp$$

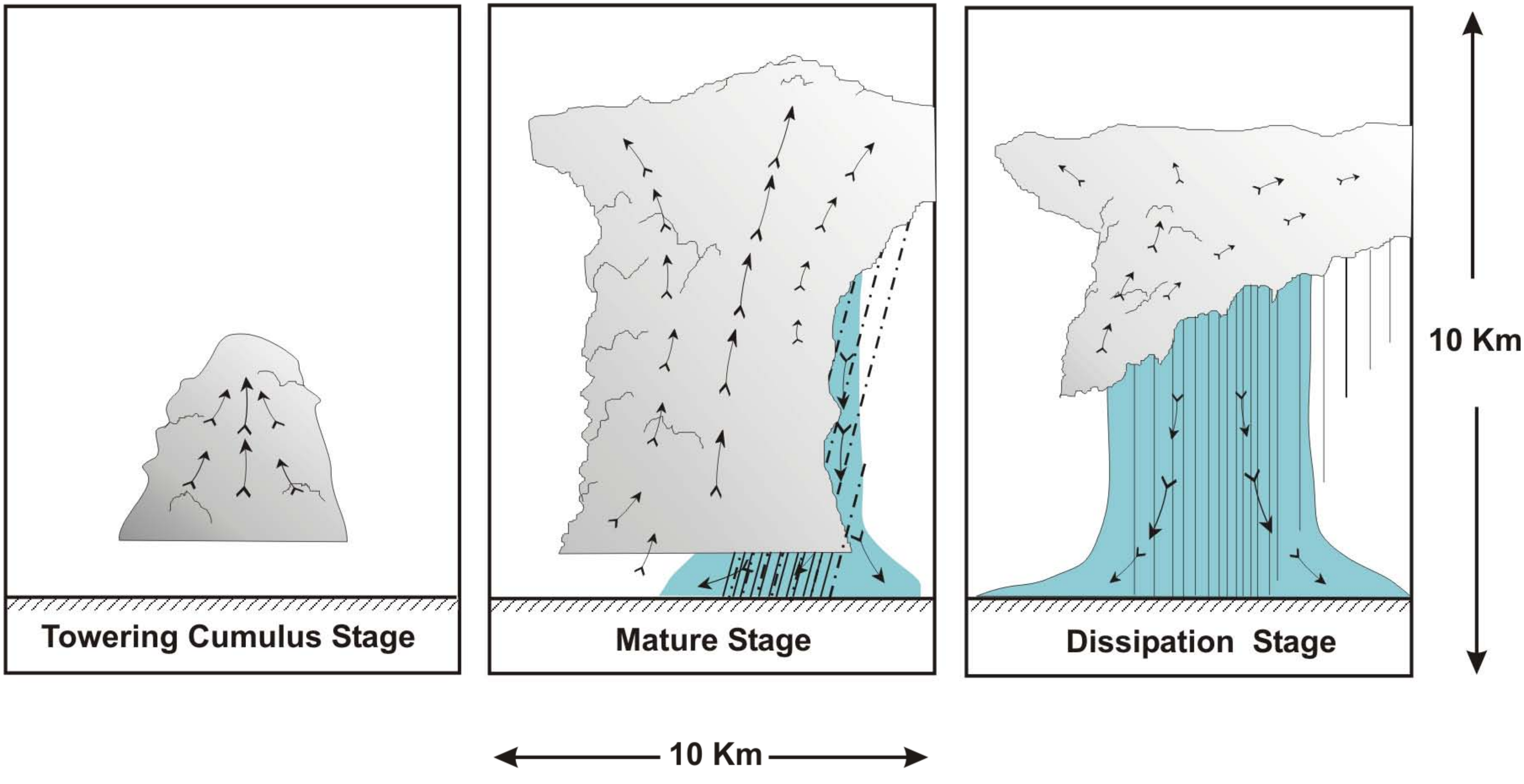
$$= \int_{p}^{p_i} R_d \left(T_{\rho_p} - T_{\rho_e}\right) d\ln\left(p\right)$$



Other Stability Diagrams:



“Air-Mass” Showers:



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