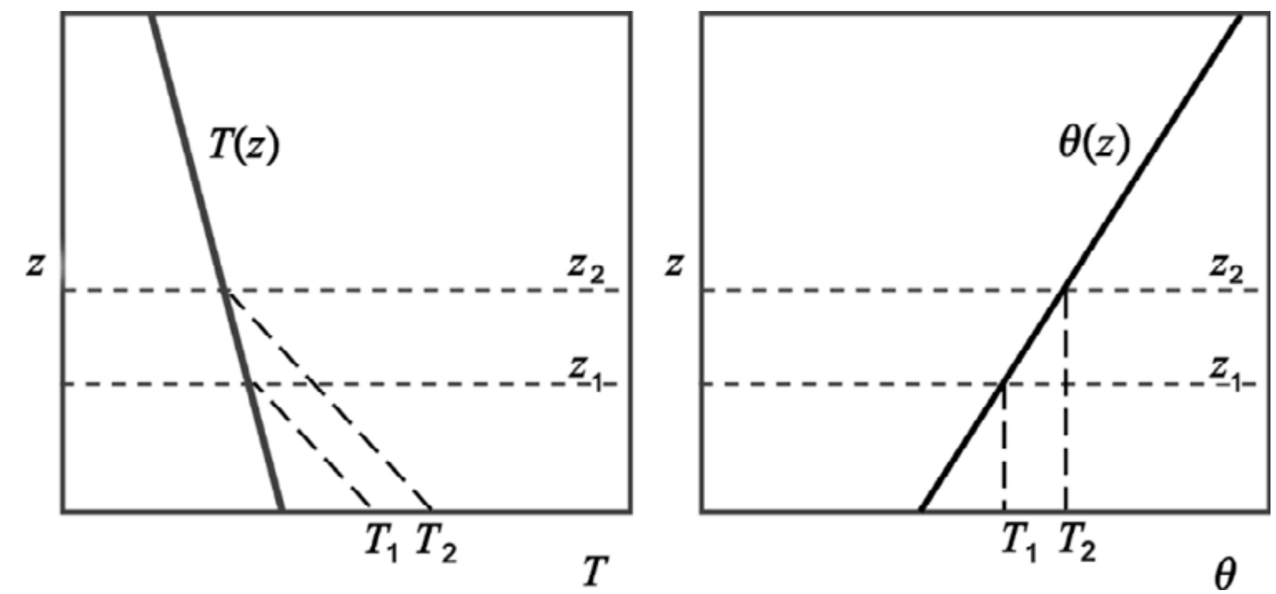
Convection

ATM2106

Last time

- Potential temperature:

$$\theta = T(p)\left(\frac{p_0}{p}\right)^{\kappa}$$



- Specific humidity / situation specific humidity / relative humidity

Today’s topic

- Saturated adiabatic lapse rate
- Equivalent potential temperature
- Convective clouds
- — end of chapter 4 —
- — start of chapter 5 —
- Meridional structure of the atmosphere

1. Saturated adiabatic lapse rate

- Let’s imagine we bring the air parcel up.
- Initially, it will cool down following dry adiabatic lapse rate.
- At saturation, condensation starts to occur.
- There will be a release of latent heat.

$$\delta Q = -Ldq$$

Latent heat change per nit mass of air

Changes in specific humidity

Latent heat of condensation

1. Saturated adiabatic lapse rate

- Then the equation that relates the δp to δT has to be

$$c_p dT = \frac{dp}{\rho} - Ldq$$

- This equation says that if we bring the air parcel up and δp becomes negative, then δT will be also negative.
  - When there is no condensation (dq=0), dp is enough to get dT.
  - With condensation, dq<0 and dT becomes less negative.

1. Saturated adiabatic lapse rate

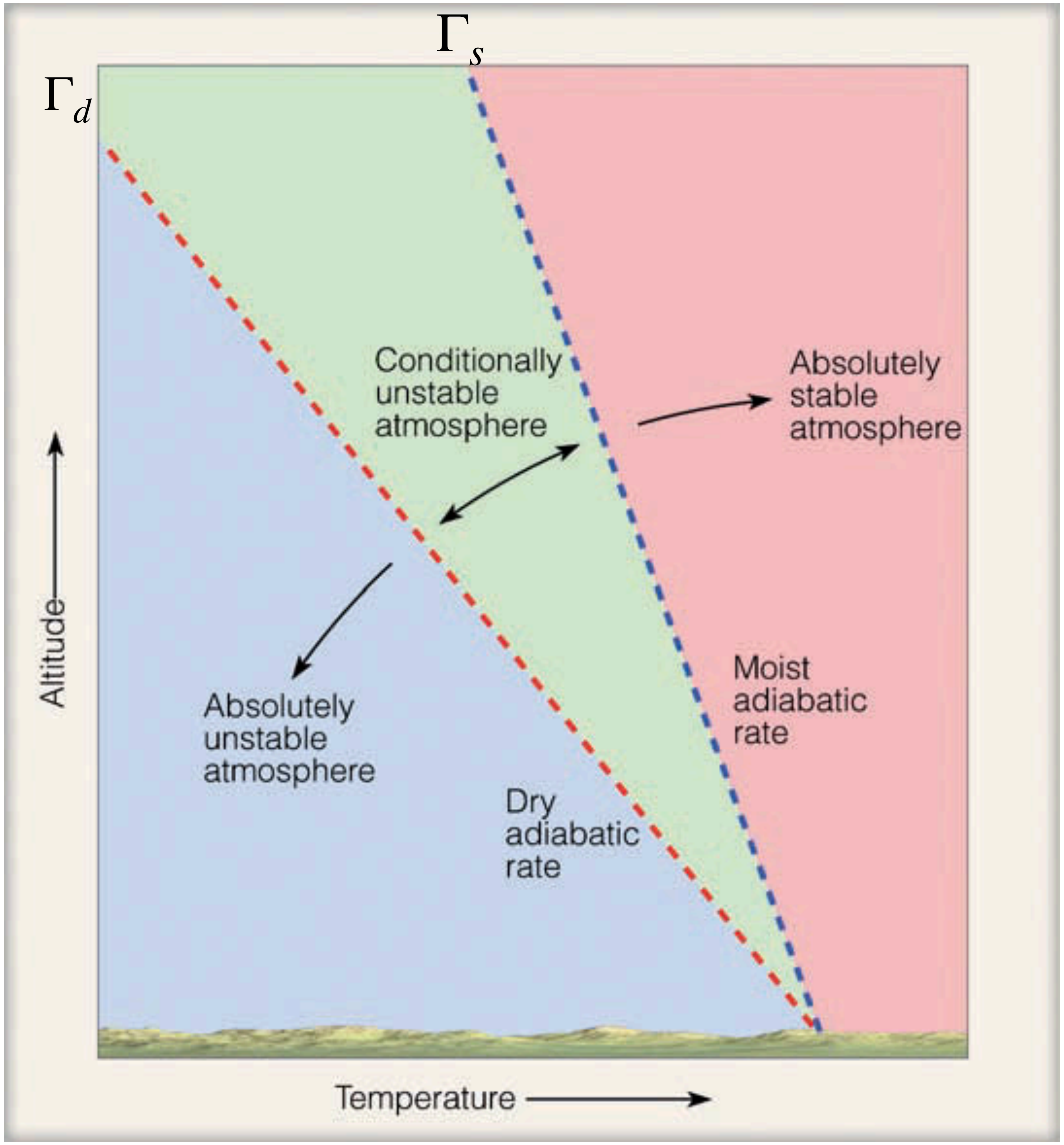
- Using saturation specific humidity and saturated partial pressure of water vapor, one can convert the equation in the previous slide to

$$-\frac{dT}{dz} = \Gamma_s = \Gamma_d \underbrace{\left[\frac{1 + Lq_*/RT}{1 + \beta L q_*/c_p}\right]}_{<1}$$

Saturated adiabatic lapse rate

- $\Gamma_s < \Gamma_d$
- Γ_s Is a function of both p and T, and is $3\ \mathrm{K/km} < \Gamma_s < 10\ \mathrm{K/km}$

Stability, AGAIN!



2. Equivalent potential temperature

- As the potential temperature, we want to have a quantity that is conserved in moist processes.

$$c_p dT = \frac{dp}{\rho} - L dq$$

$$\frac{dT}{T} = \frac{R}{c_p}\frac{dp}{p} - \frac{L}{c_p T} dq$$

$$\frac{d\theta}{\theta} = -\frac{L}{c_p T} dq$$

2. Equivalent potential temperature

- If we integrate this partial differential equation from the current state to the state where there is no water vapor (q=0).
- And if we assume that T varies little compared to q so that we can treat T as a constant,

$$\ln\theta - \ln\theta_e = -\frac{Lq}{c_pT}$$

or

$$\theta_e = \theta \exp\left(\frac{Lq}{c_pT}\right)$$

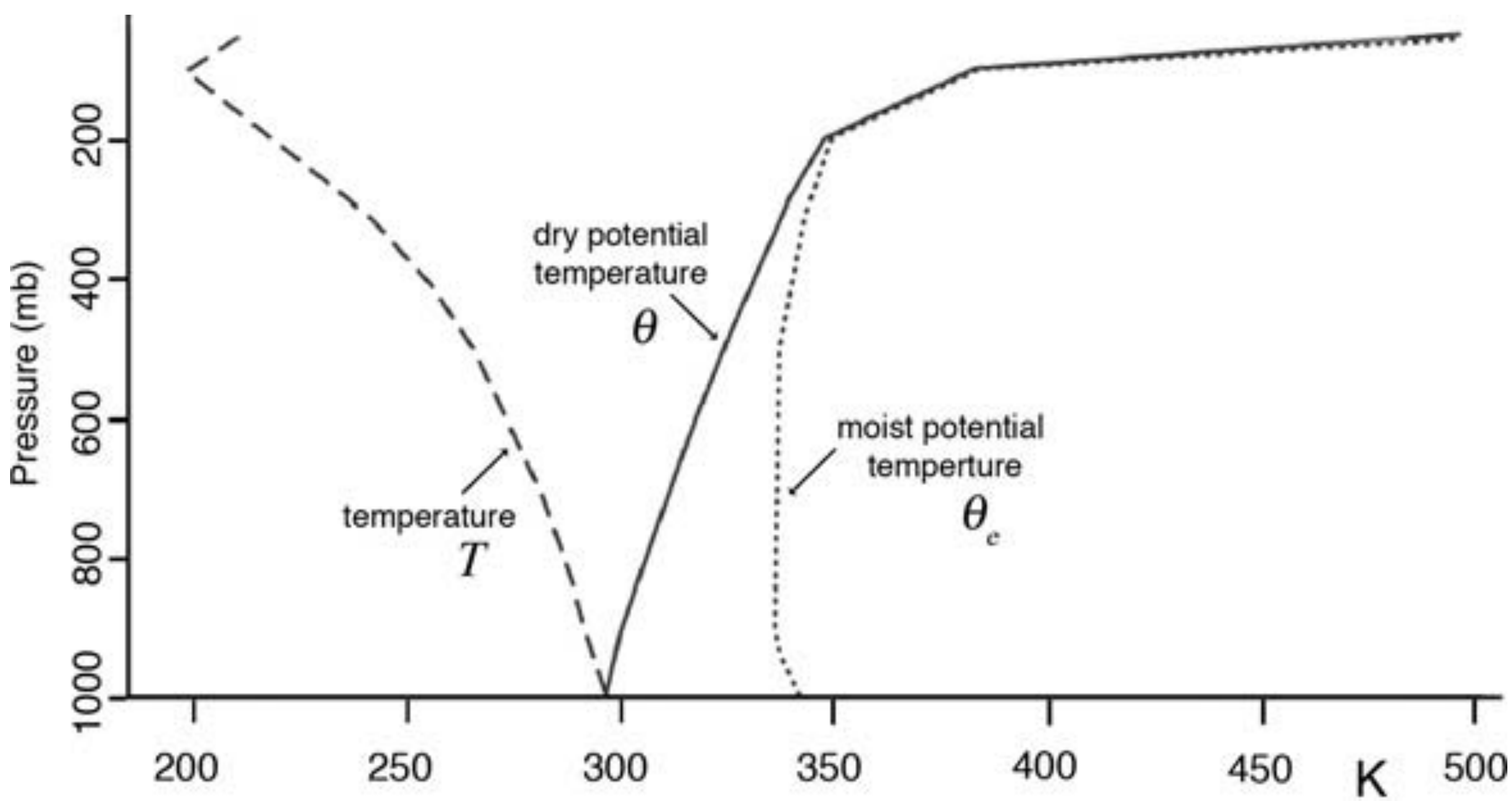
2. Equivalent potential temperature

$$\theta_e = \theta \exp\left(\frac{Lq}{c_p T}\right)$$

- θ_e is conserved when q and T are fixed.
- In dry adiabatic process, $\theta_e = \theta$
- The atmosphere is nearly neutral to the moist convection.

2. Equivalent potential temperature

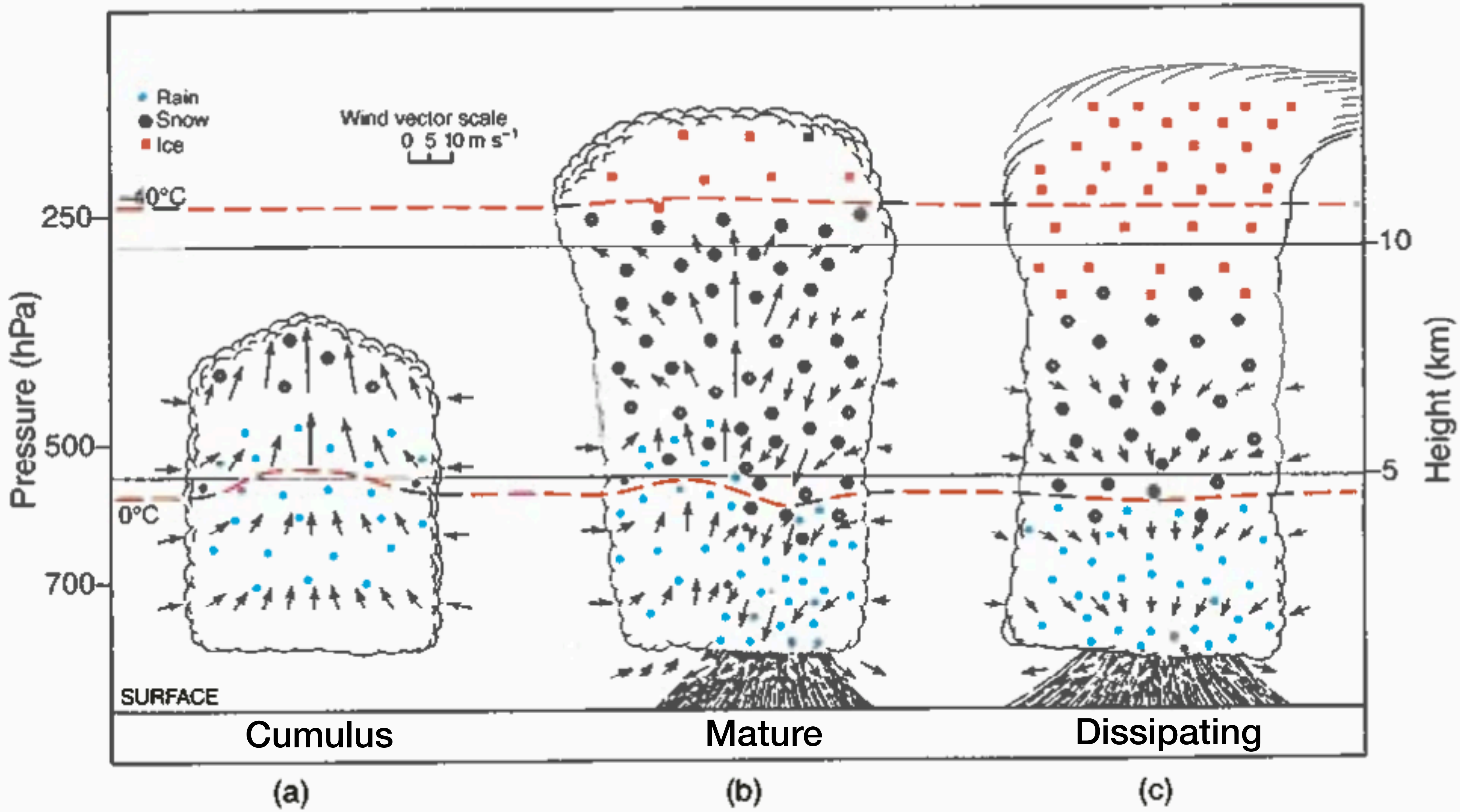
$$\theta_e = \theta \exp\left(\frac{Lq}{c_p T}\right)$$



Mean T, θ and θ_e between 30S and 30N

3. Convective clouds

3. Convective clouds



3. Convective clouds : changing humidity

[Convective drying]

1. Moist air goes up fast and is saturated.
2. Descent of dry air balances the updraft.
3. Net effect on column is drying because of precipitation.

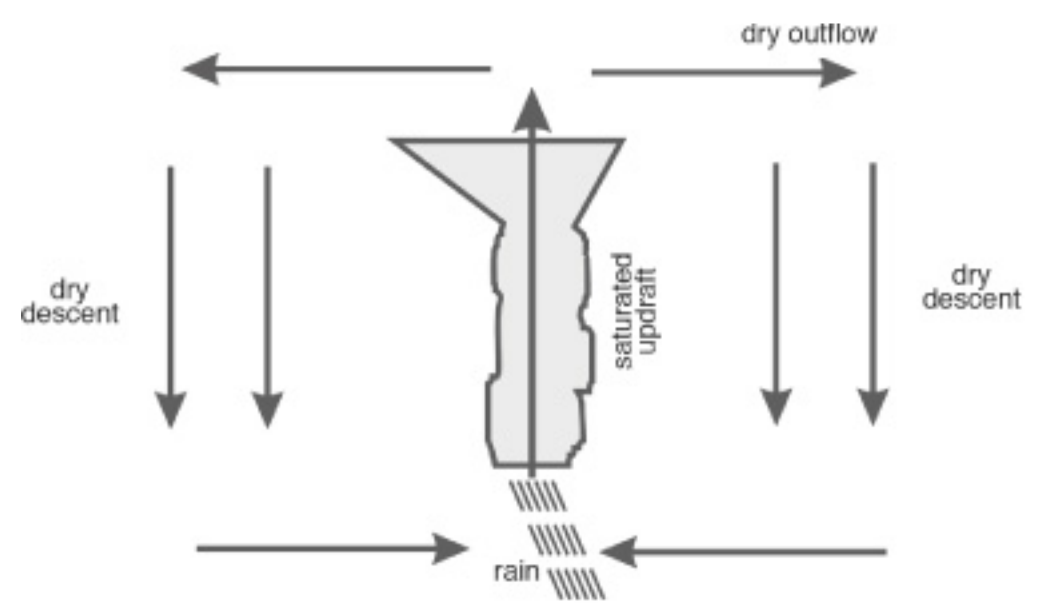


Figure 5.18: Drying due to convection. Within the updraft, air becomes saturated and excess water is rained out. The descending air is very dry. Because the region of ascent is rather narrow and the descent broad, convection acts as a drying agent for the atmosphere as a whole.

3. Convective clouds : changing radiation

[Convective drying]

1. Outgoing longwave radiation follows Stefan-Boltzmann Law.
2. Tall cloud is colder than the earth's surface.
3. Less outgoing longwave radiation by convective clouds

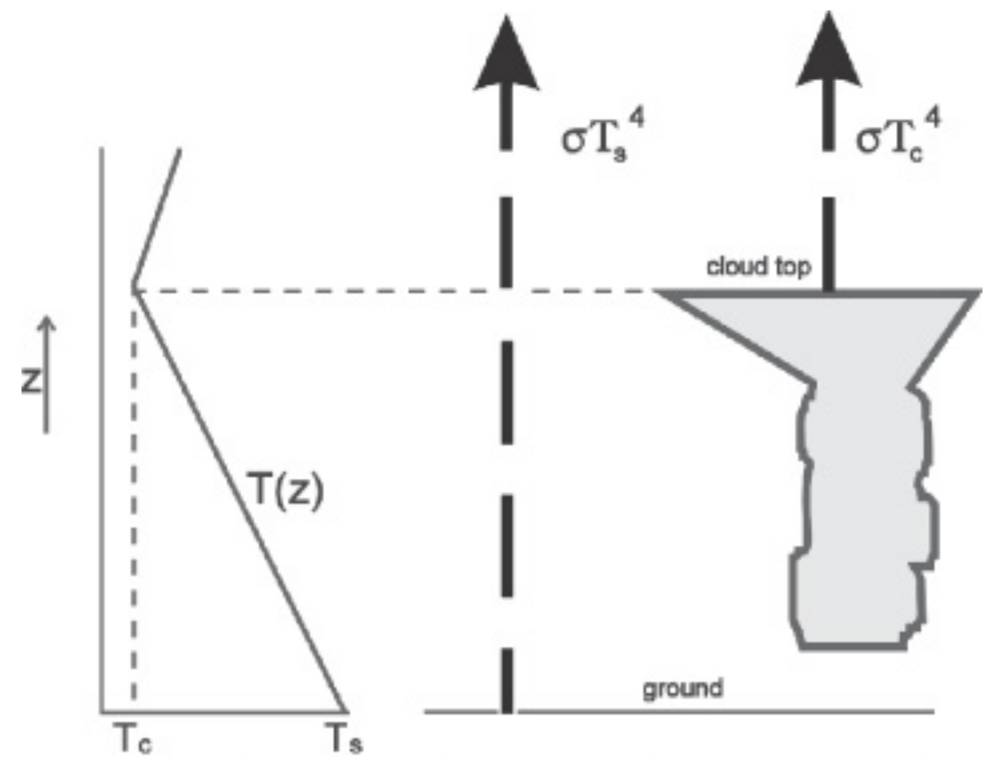
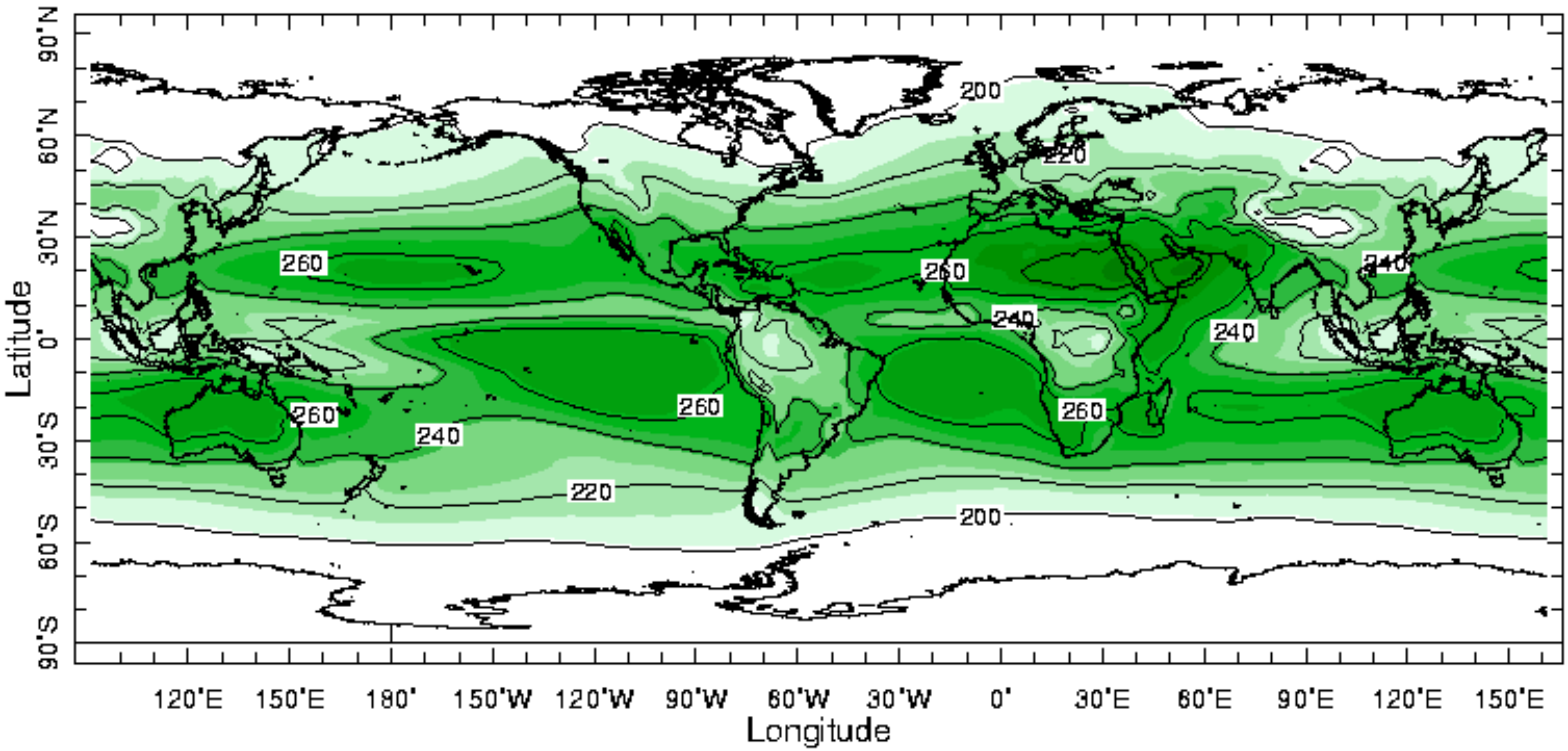


Figure 4.27: Schematic of IR radiation from the ground (at temperature T_s = 300 K in the tropics) and from the tops of deep convective clouds (at temperature T_c = 220 K).

3. Convective clouds : changing radiation

Time-mean outgoing longwave radiation (W/m²)

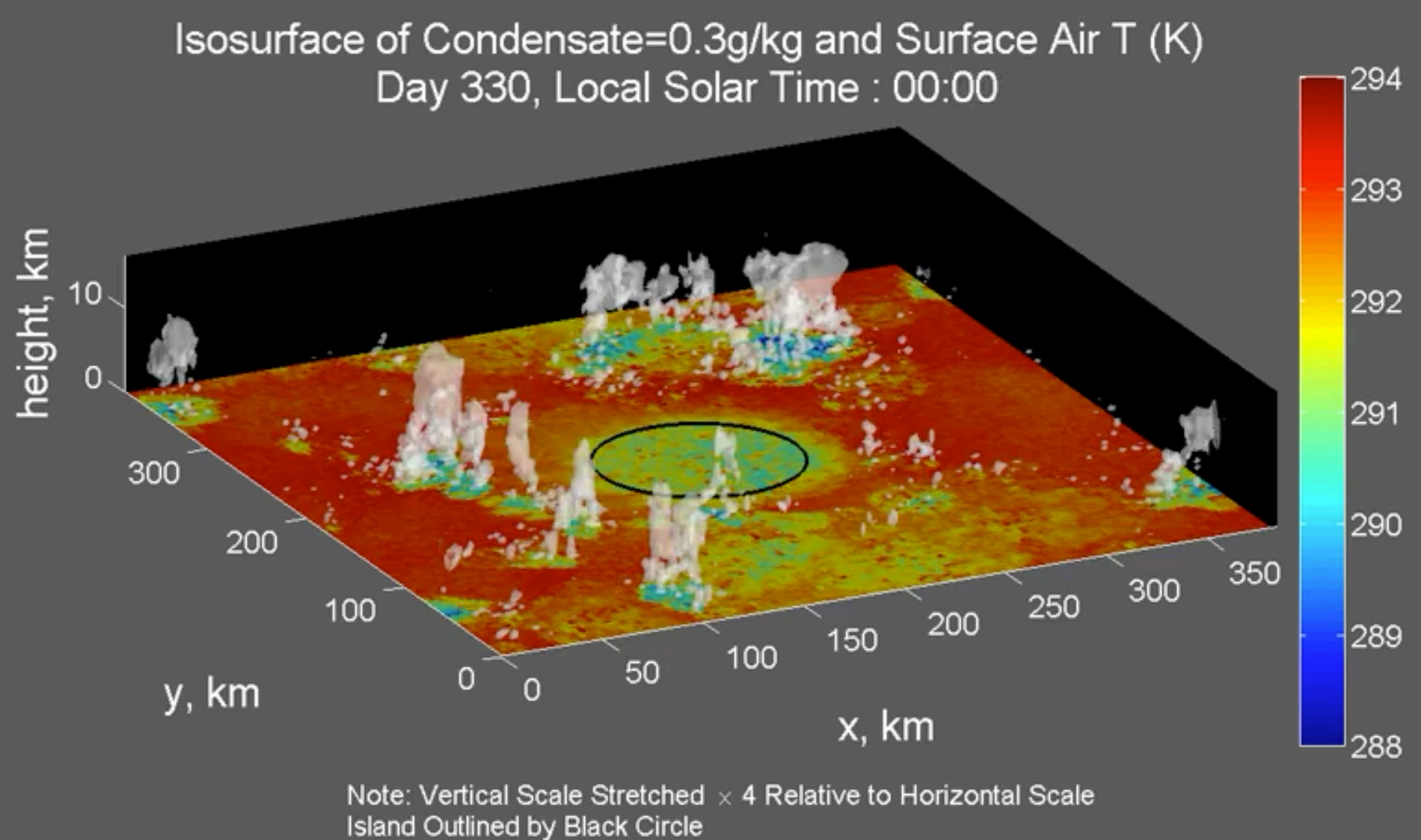


3. Convective clouds

[When does convection occurs?]

- Tropics
- Afternoon convection over land in summer
- At night over ocean (radiative cooling of atmosphere)
- Passage of cold fronts in midlatitude weather systems

3. Convective clouds



A movie from http://web.mit.edu/~twcronin/www/movies.html