

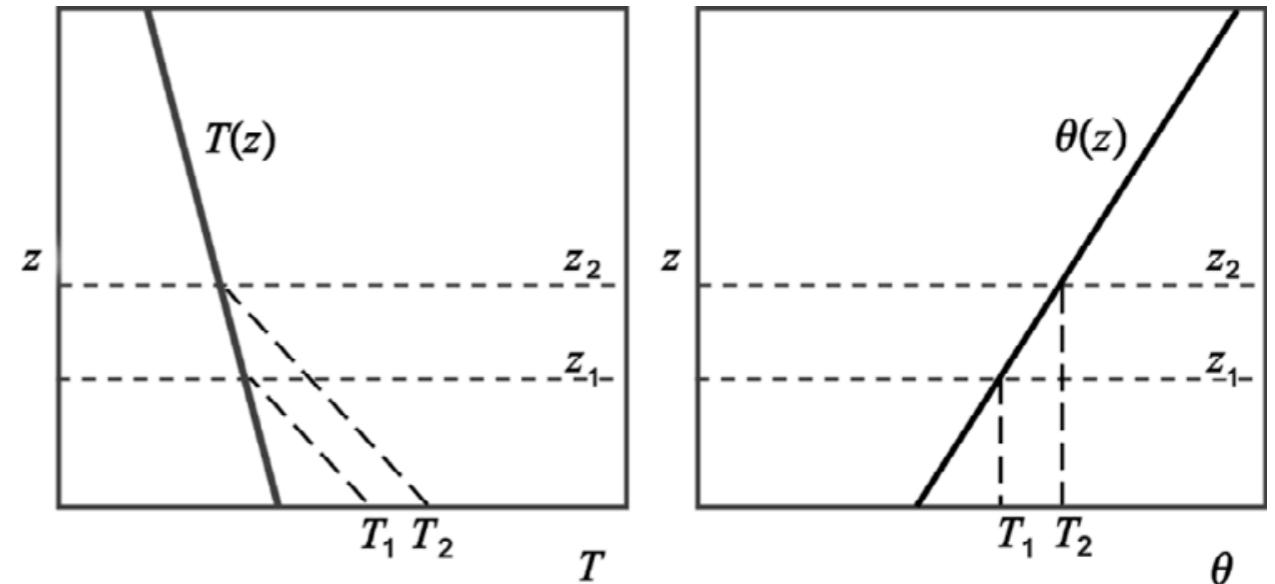
Convection

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

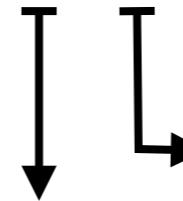
1. Saturated adiabatic lapse rate

- 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 unit 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

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

- 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

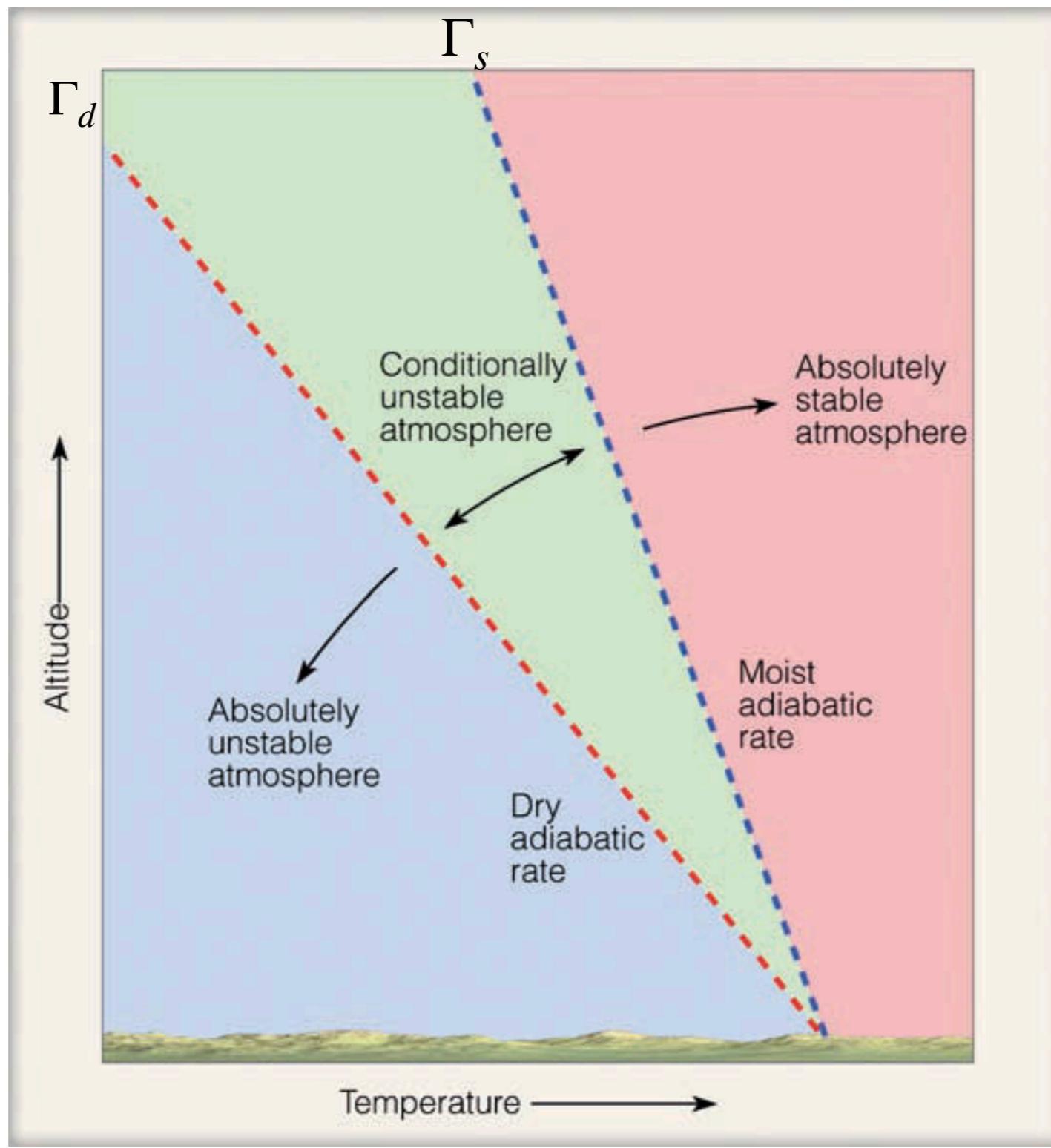
$$-\frac{dT}{dz} = \Gamma_s = \Gamma_d \left[\frac{1 + Lq_*/RT}{1 + \beta Lq_*/c_p} \right]$$

↓

< 1

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

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,

$$\ln \theta - \ln \theta_e = -\frac{Lq}{c_p T}$$

or

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

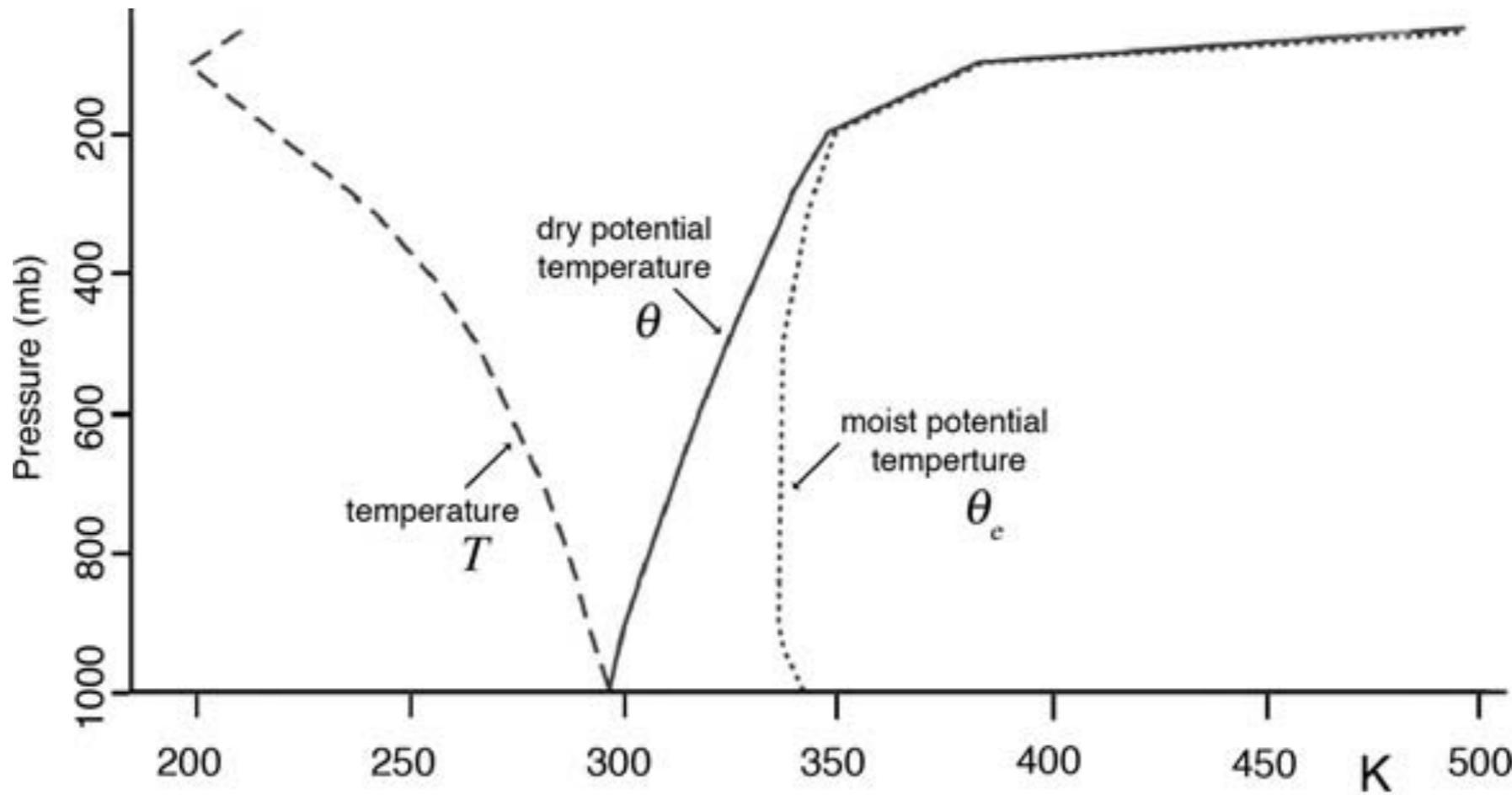
2. Equivalent potential temperature

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

- 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

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

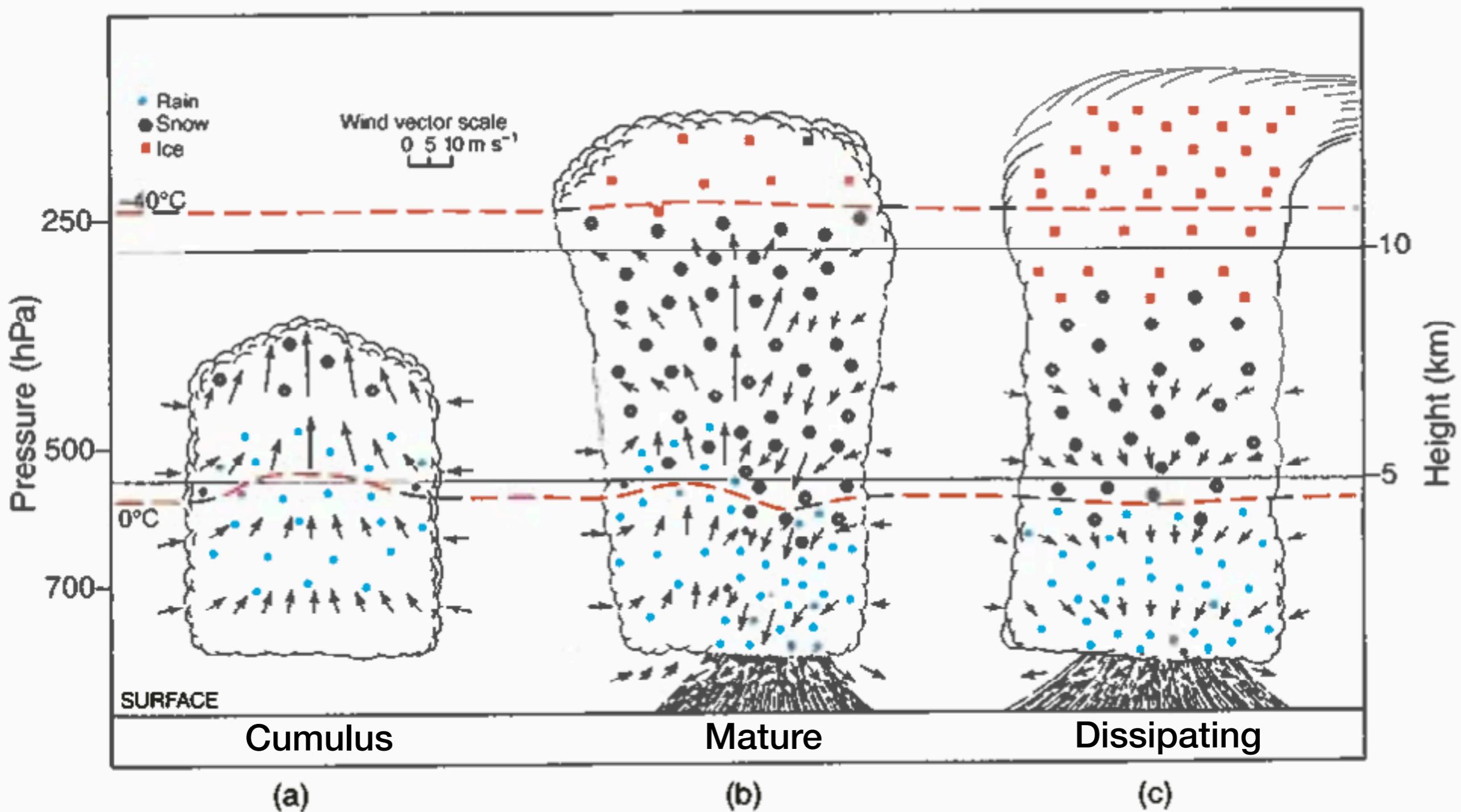


Mean T , θ and θ_e between 30S and 30N

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.

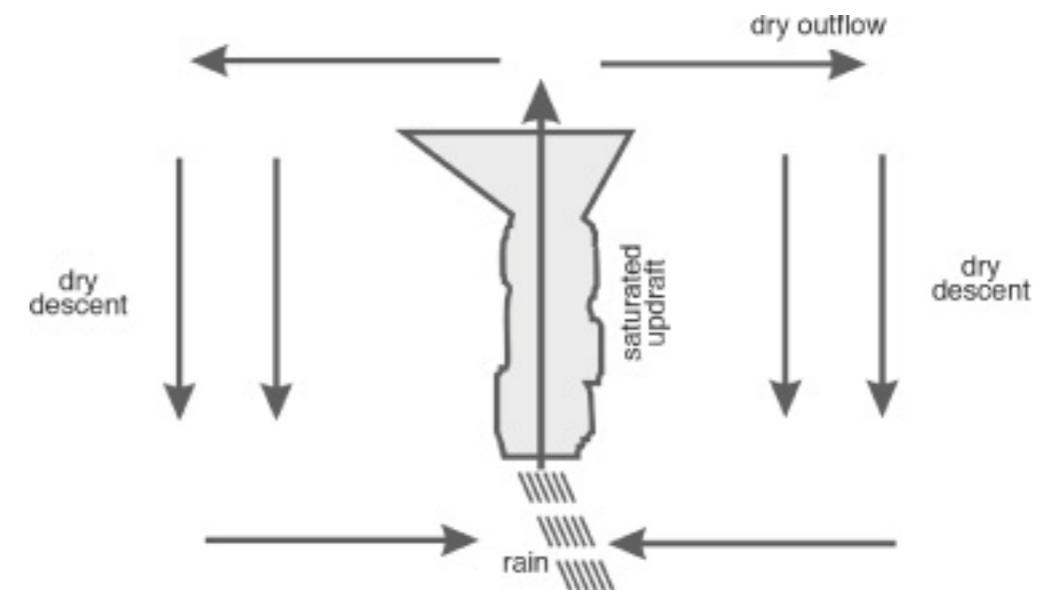


Figure 5.18: Drying due to convection. Within the updraft, air becomes saturated and excess water is rained out. The descending air is very dry. Because the region of ascent is rather narrow and the descent broad, convection acts as a drying agent for the atmosphere as a whole.

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

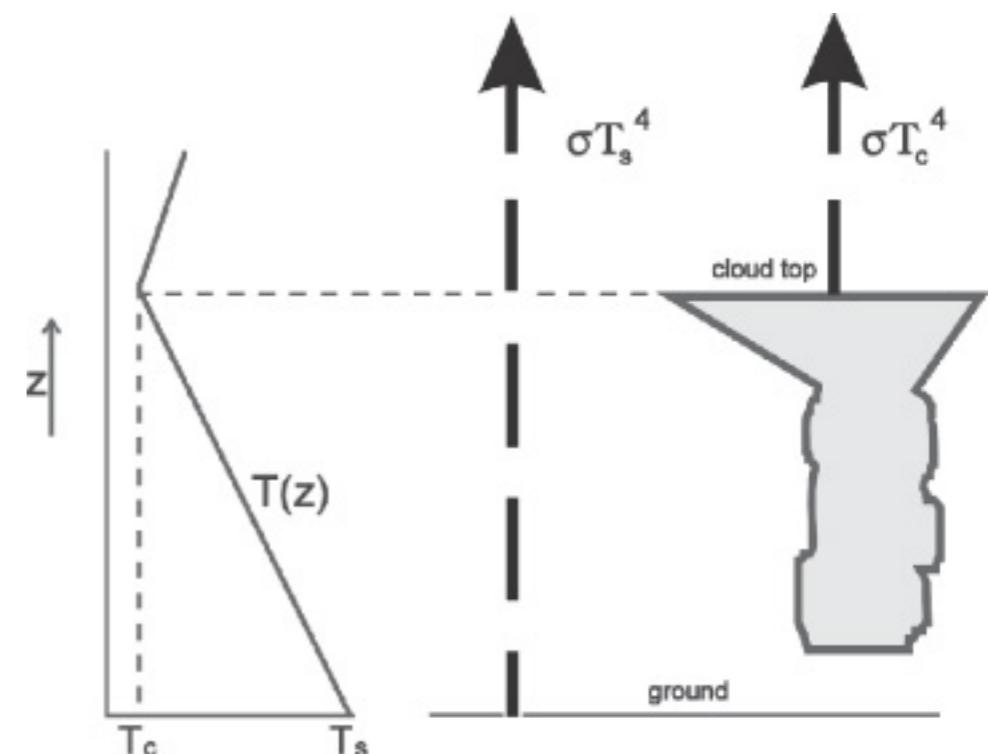
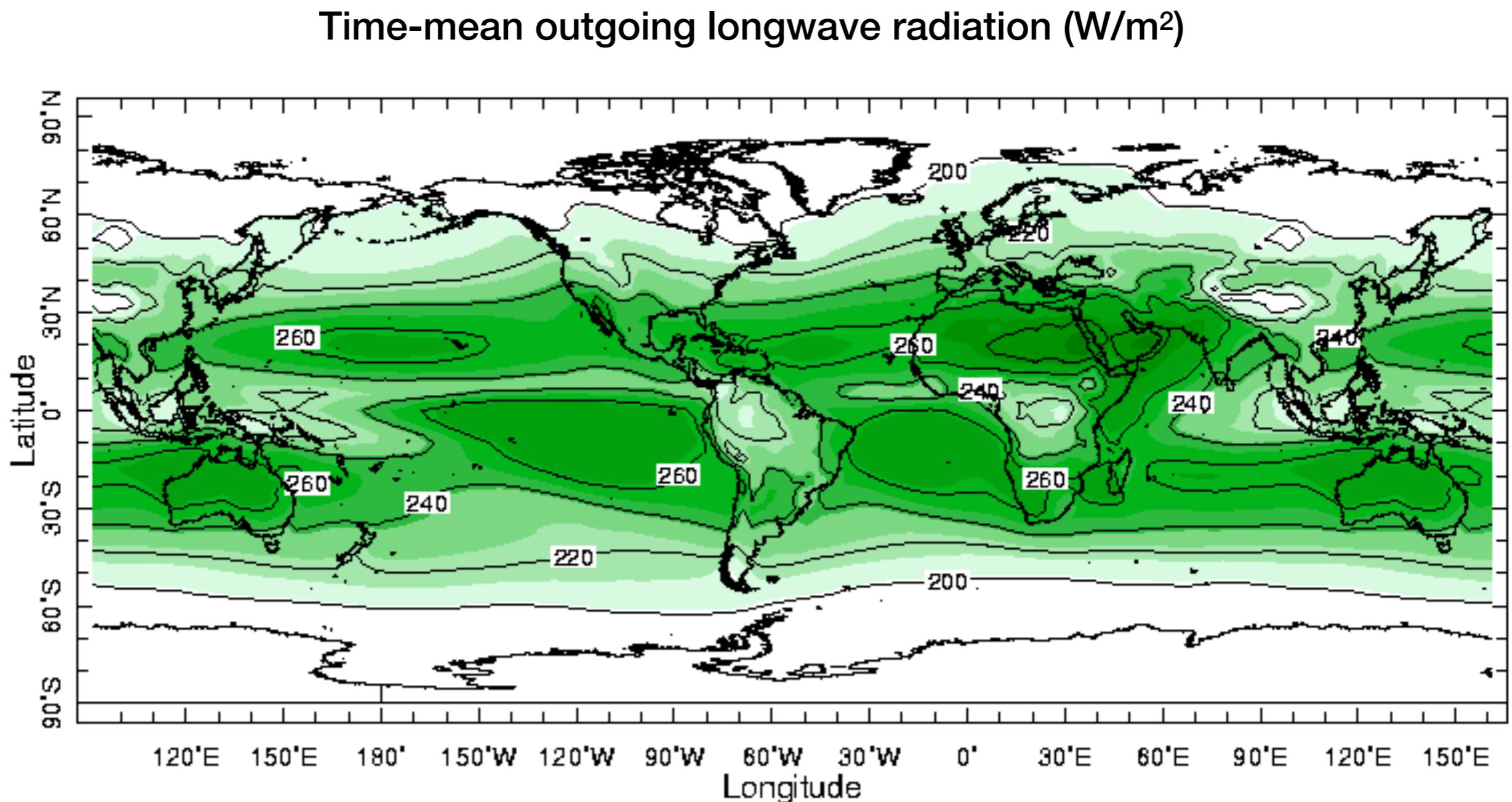


Figure 4.27: Schematic of IR radiation from the ground (at temperature $T_s = 300$ K in the tropics) and from the tops of deep convective clouds (at temperature $T_c = 220$ K).

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3. Convective clouds : changing radiation

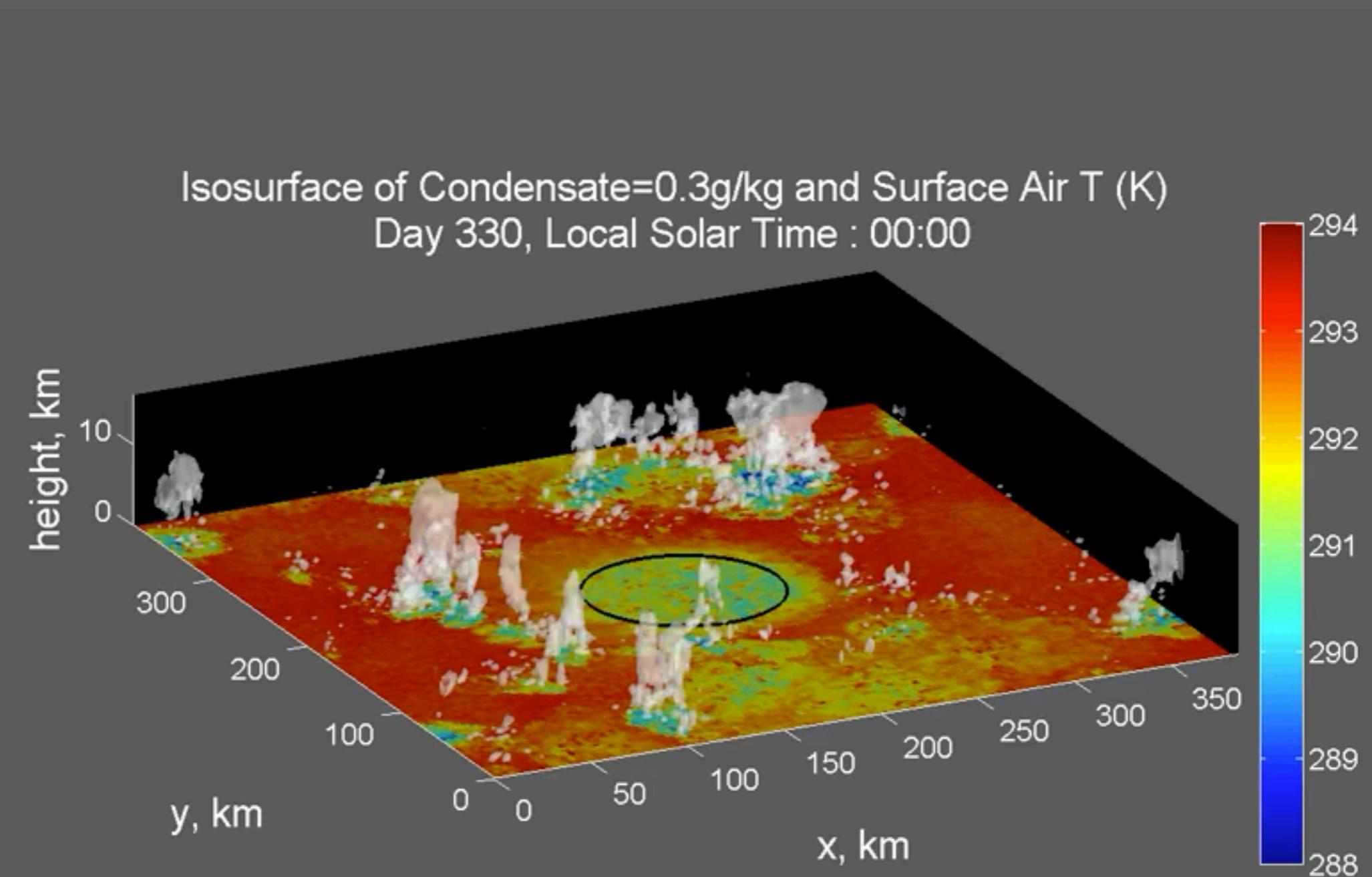


3. Convective clouds

[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

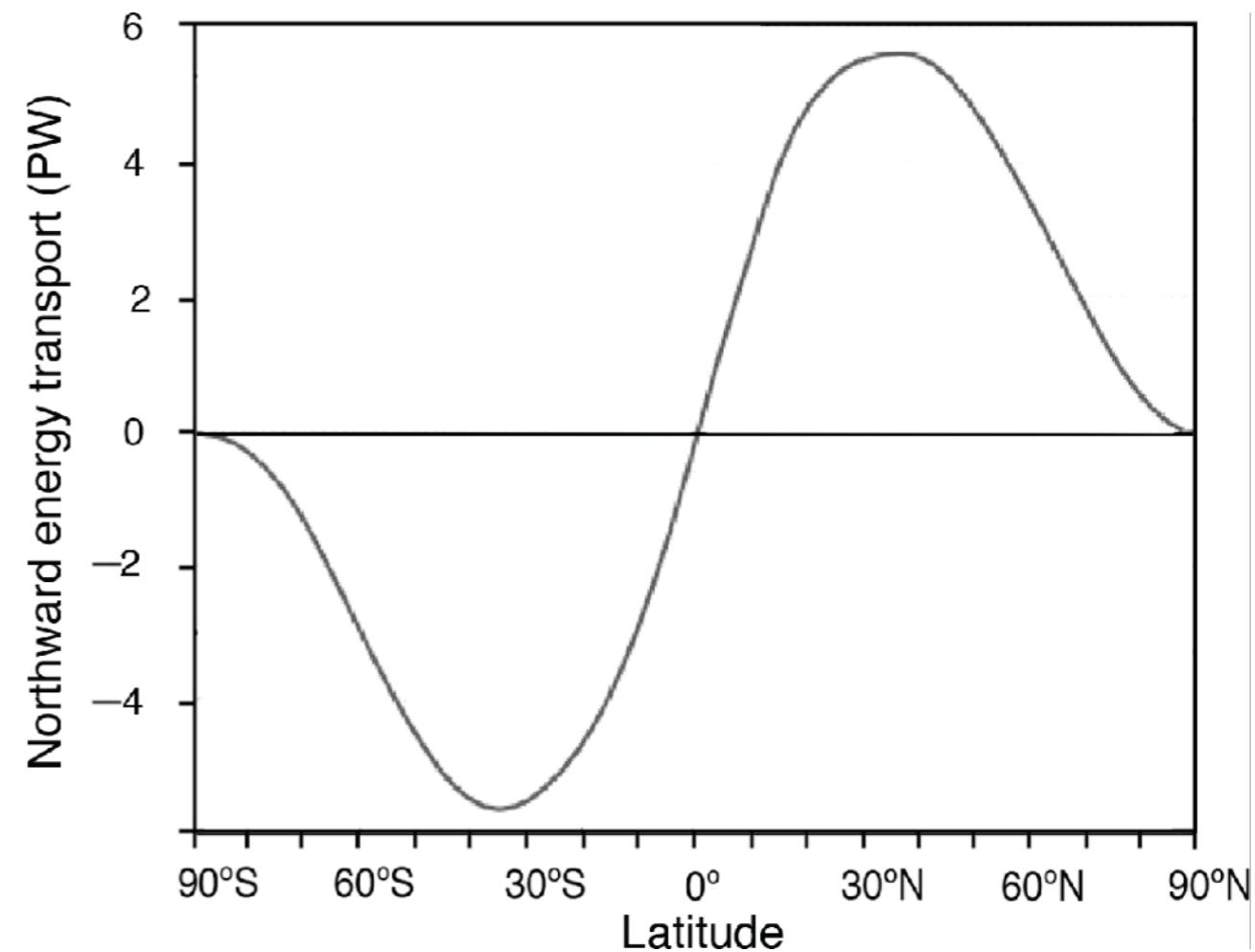
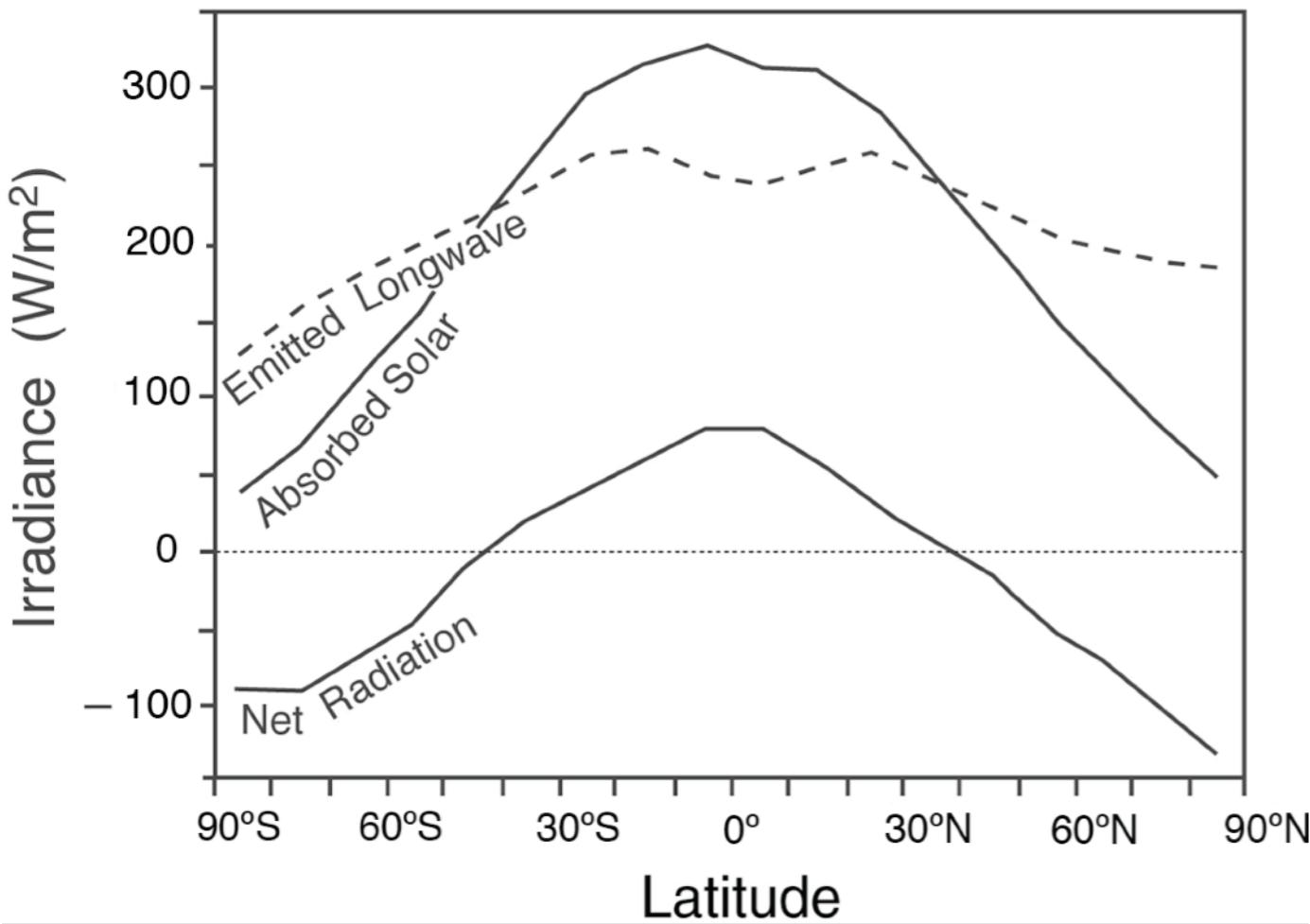


Note: Vertical Scale Stretched $\times 4$ Relative to Horizontal Scale
Island Outlined by Black Circle



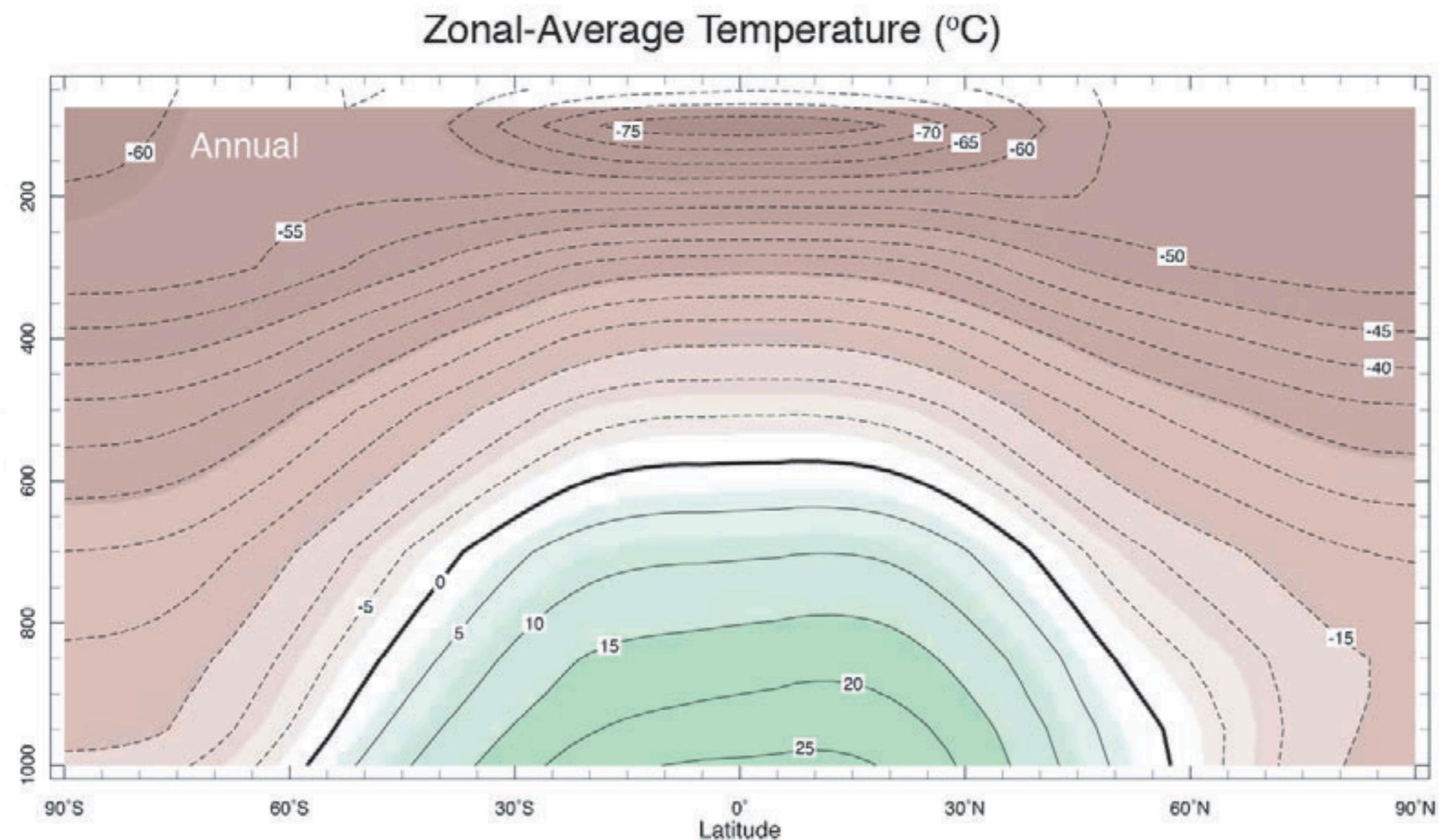
Chapter 5. Meridional structure of the atmosphere

1. Radiative imbalance

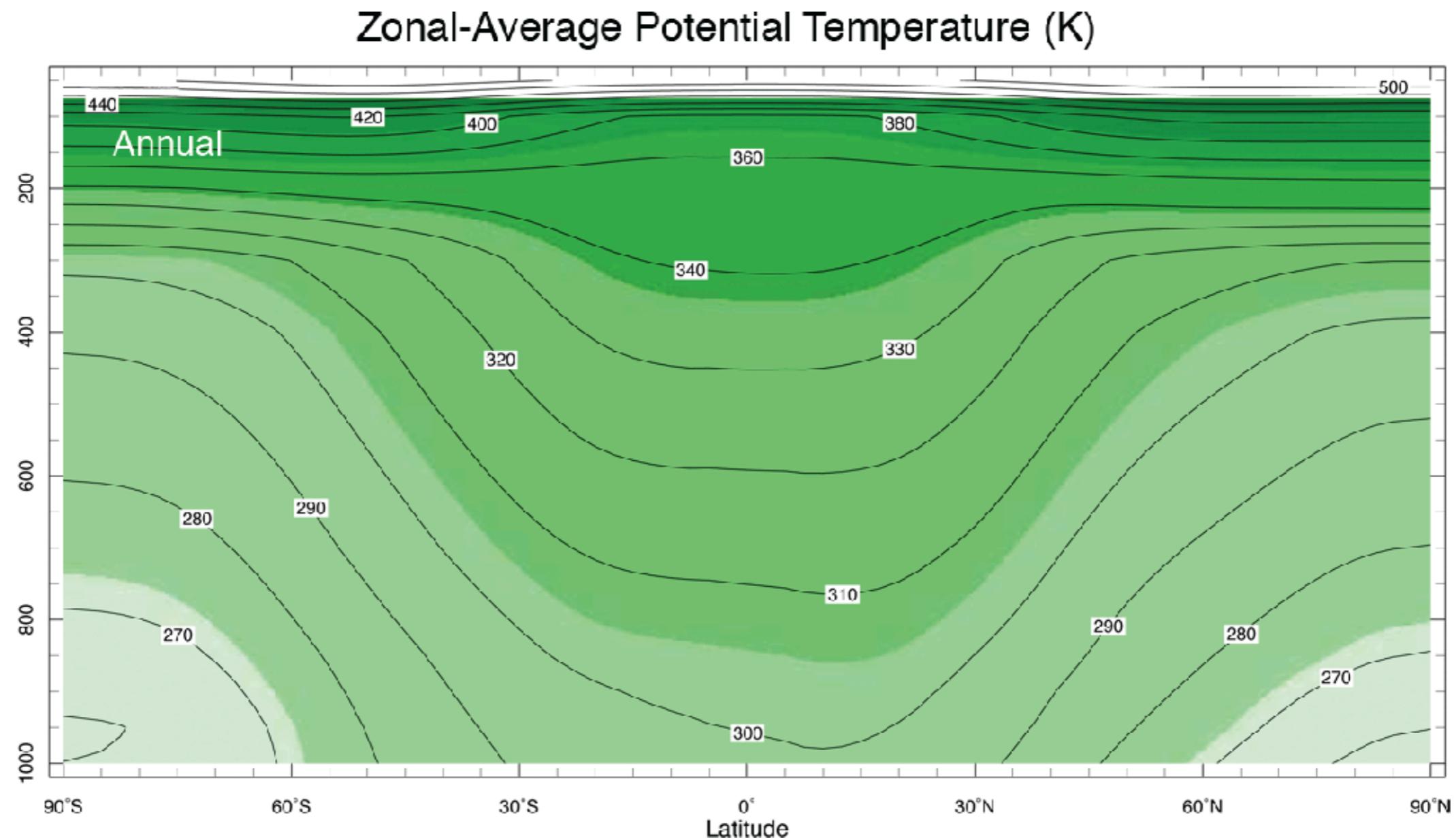


2. Temperature

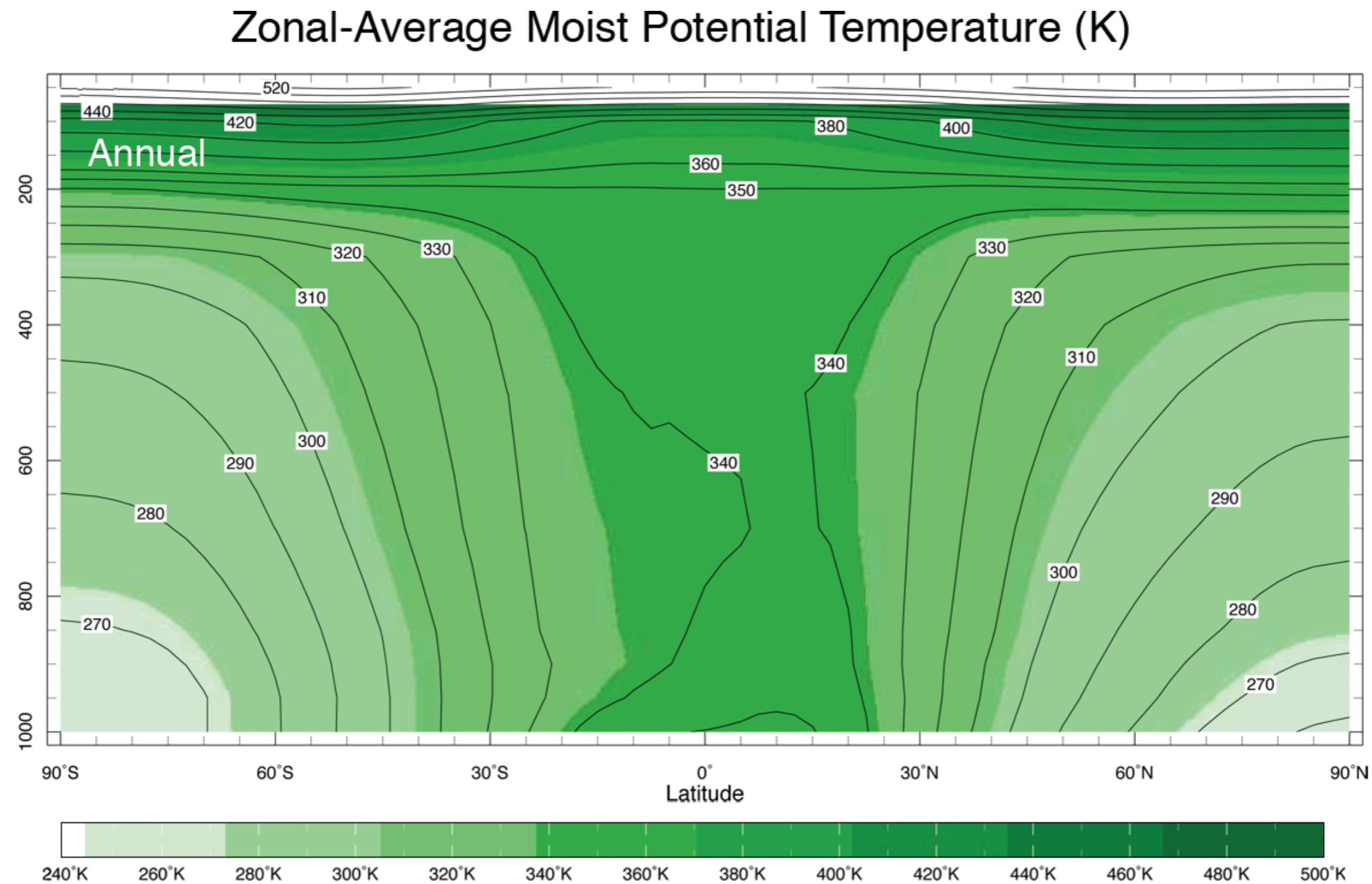
- See how the radiative imbalance shapes T



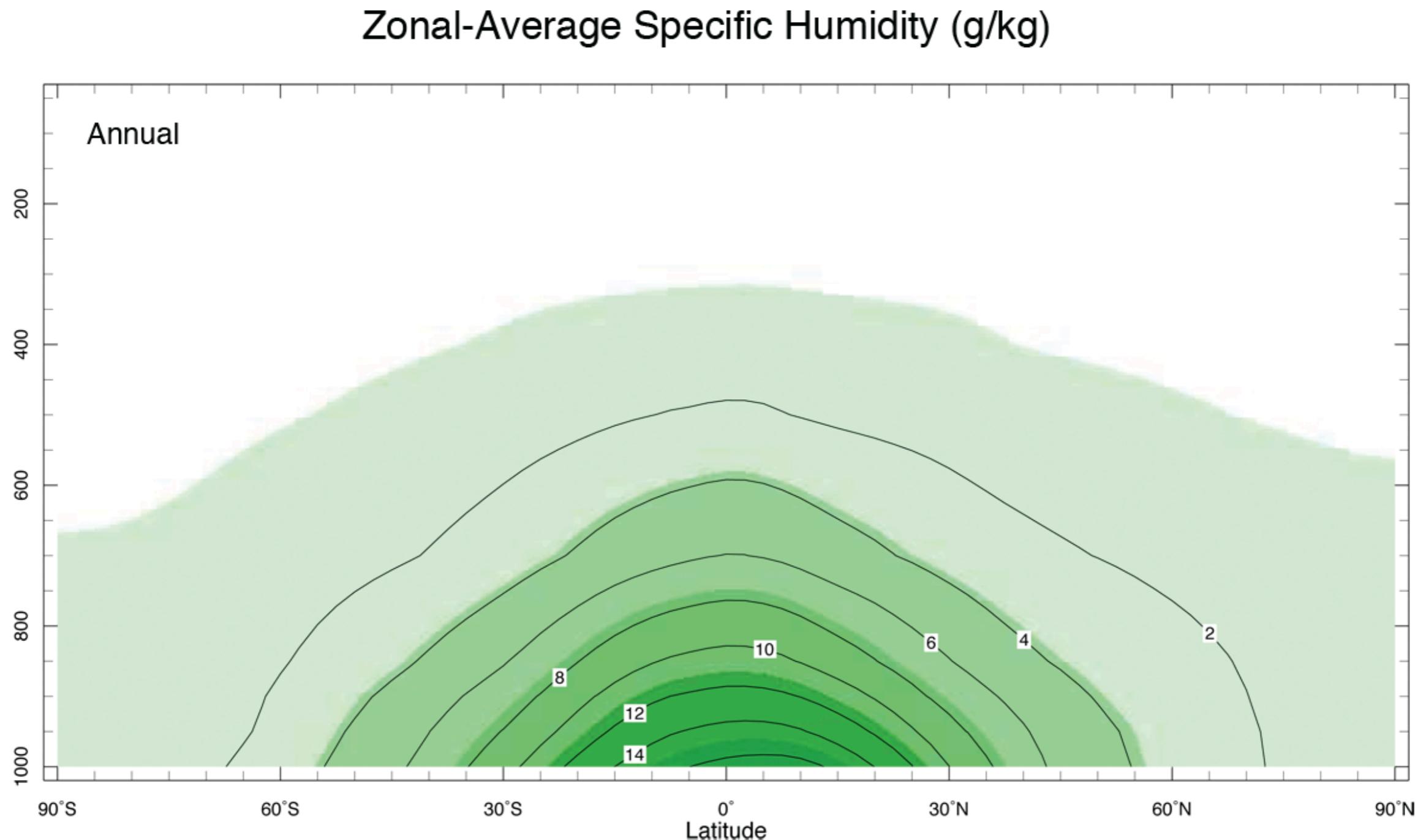
2. Temperature: potential temperature



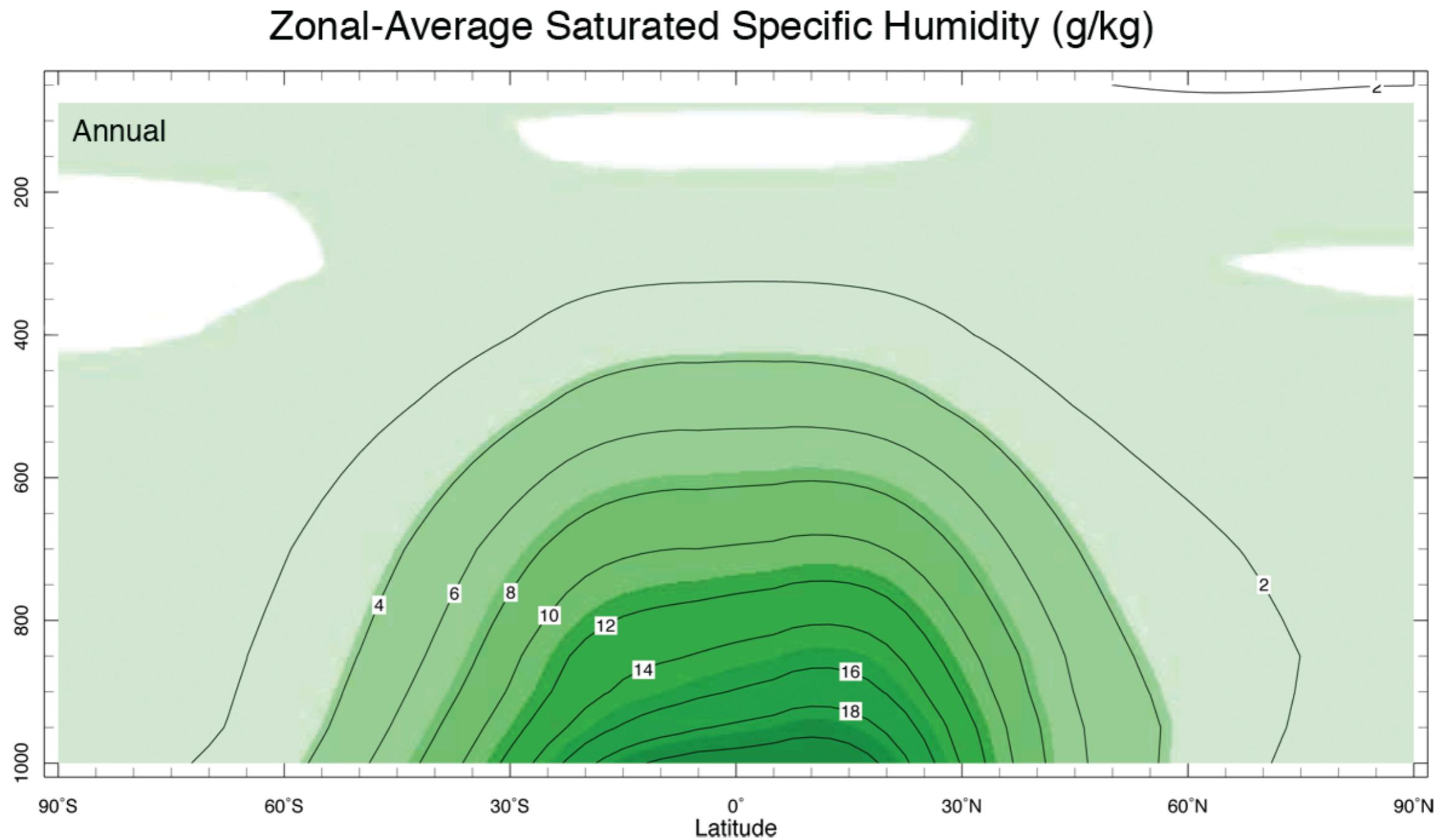
2. Temperature: equivalent potential temperature



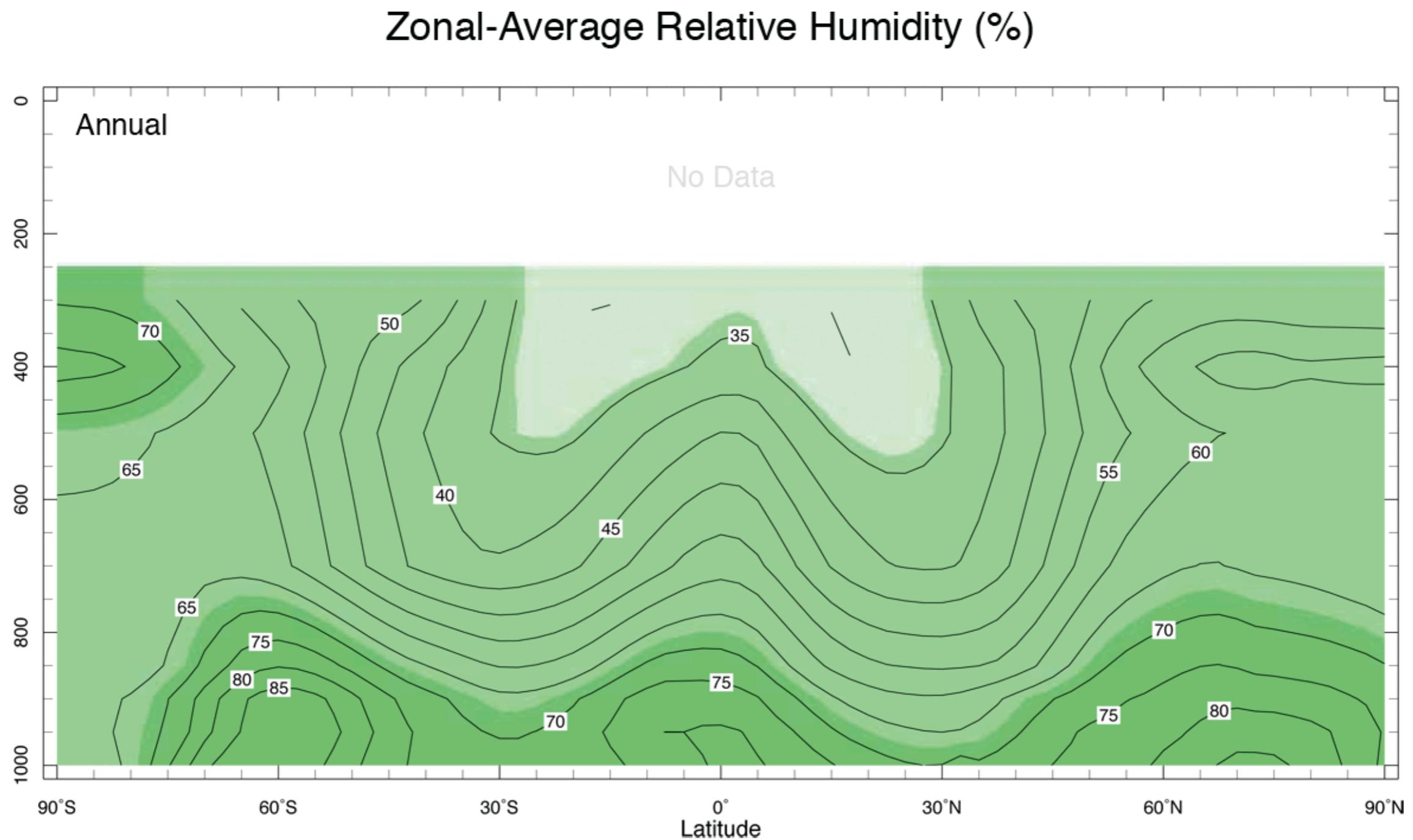
3. Humidity: specific humidity



3. Humidity: saturated specific humidity



3. Humidity: saturated specific humidity



4. Pressure / geopotential height

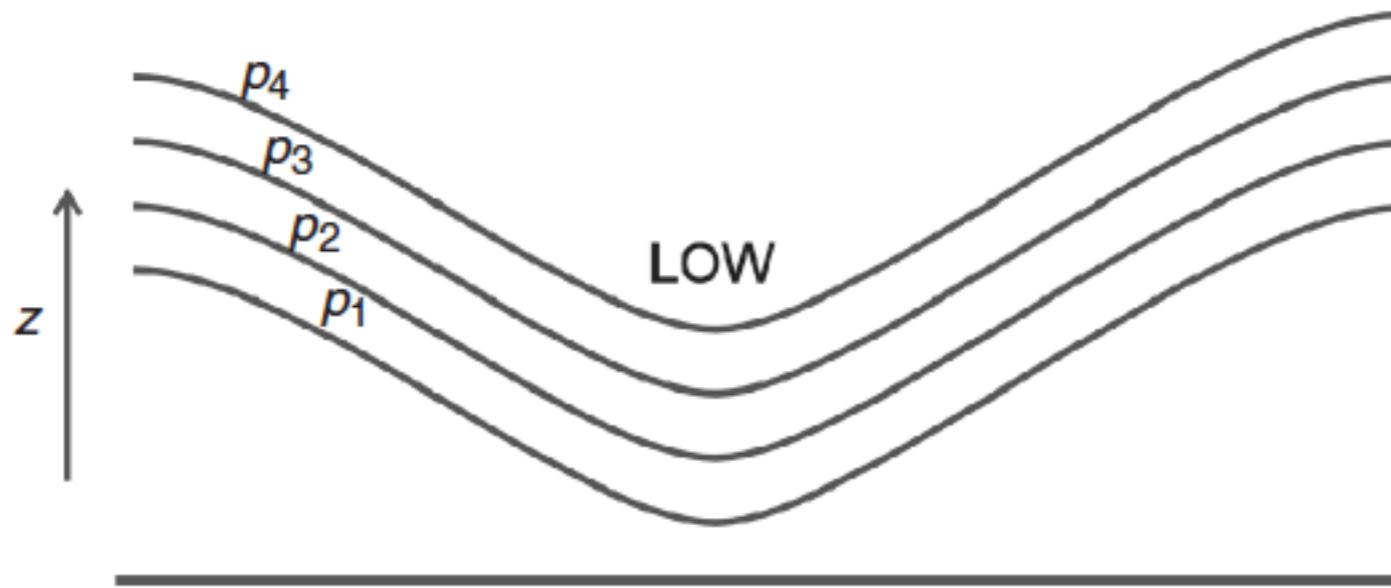
- From a hydrostatic balance and perfect gas law,

$$\frac{\partial z}{\partial p} = - \frac{RT}{gp}$$

$$z(p) = R \int_p^{p_s} \frac{T}{g} \frac{dp}{p}$$

- $z(p)$ is called ***geopotential height***.
- If we assume that T and g does not vary a lot with p , geopotential height is higher when T increases.

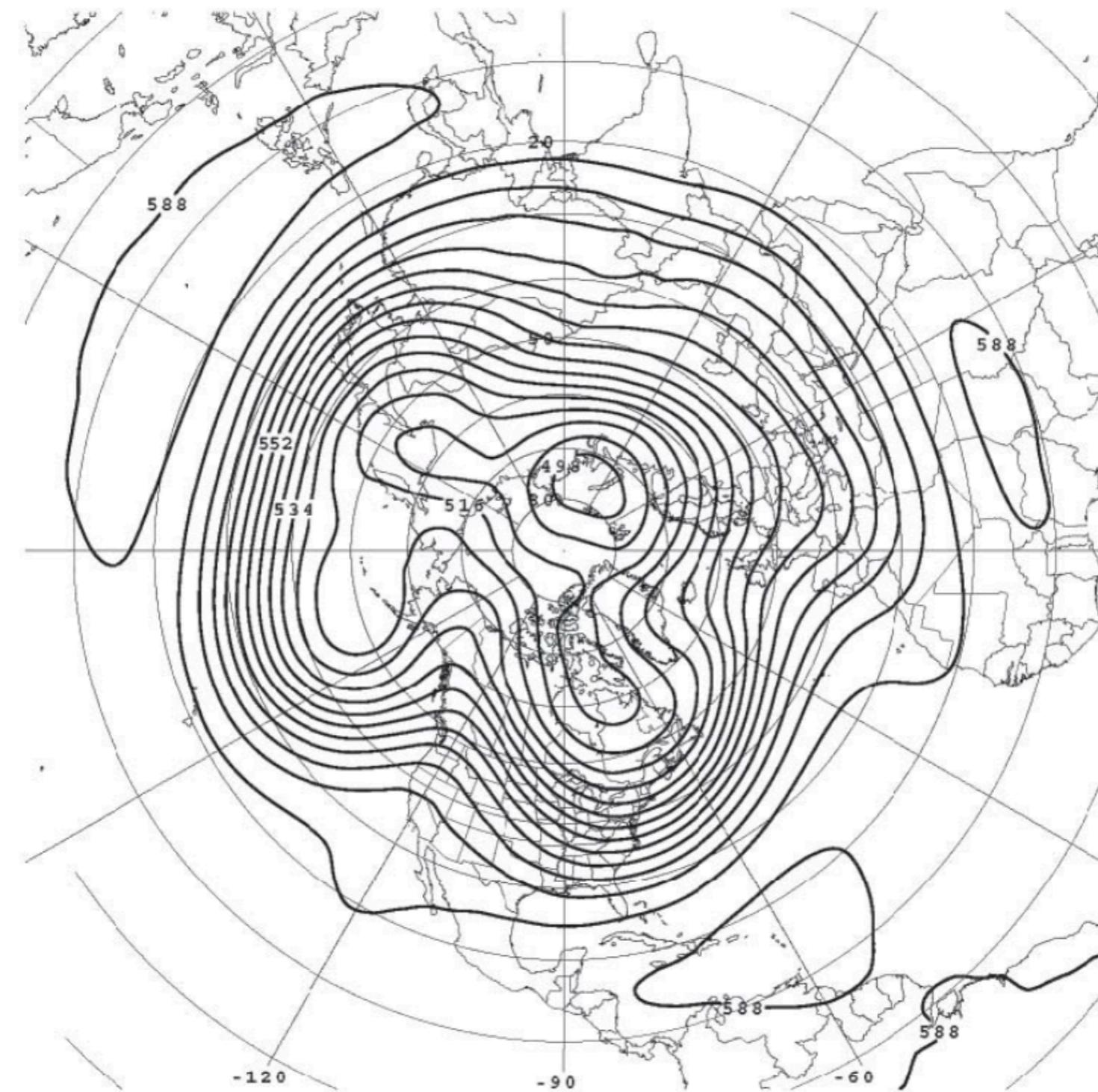
4. Pressure / geopotential height



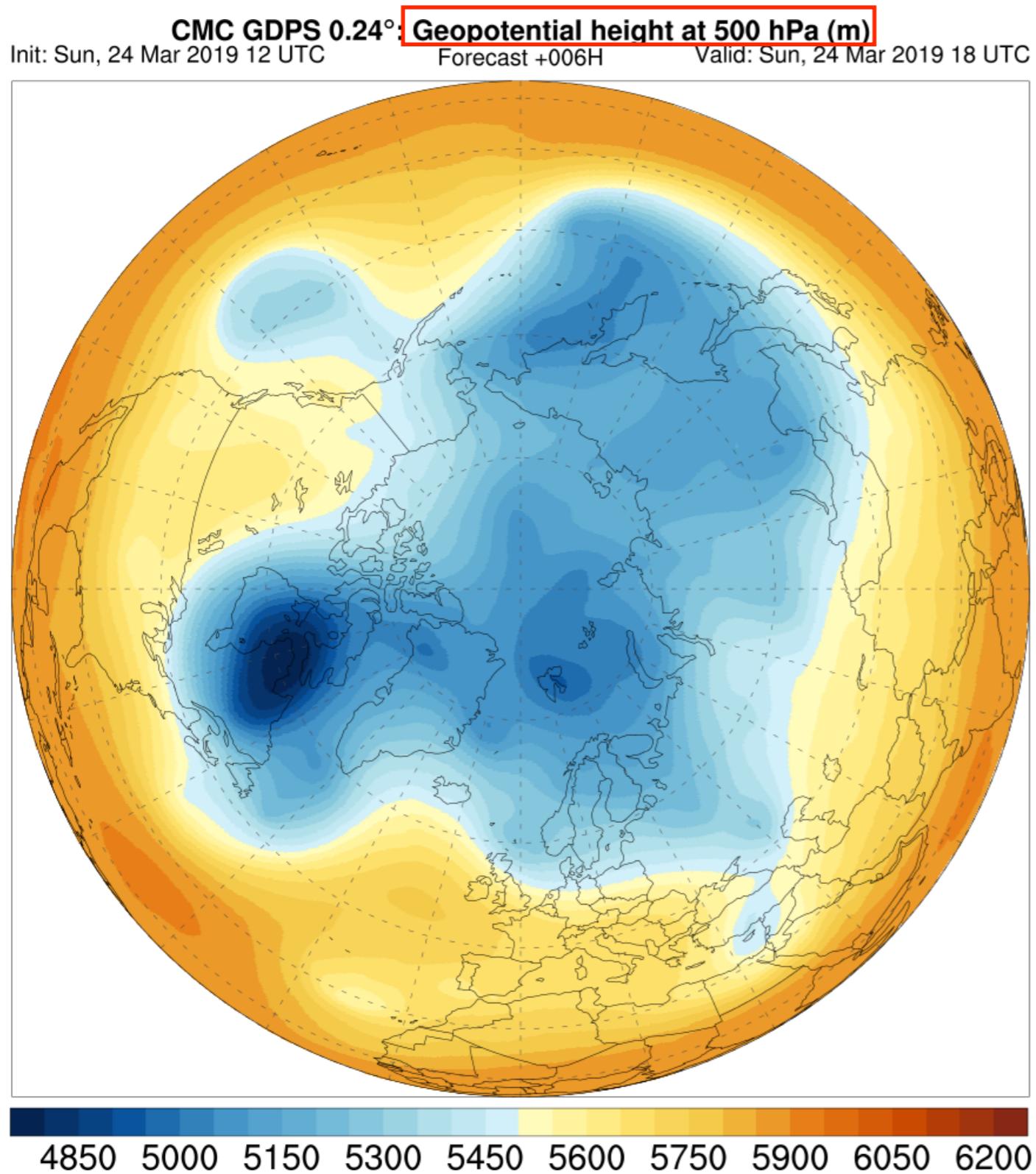
- Geopotential height is lower at the low pressure system.
- Or the high pressure system corresponds to the high geopotential height.
- T tends to be low in the region of low geopotential height.

4. Pressure / geopotential height

The mean height of the 500 mbar surface in January , 2003



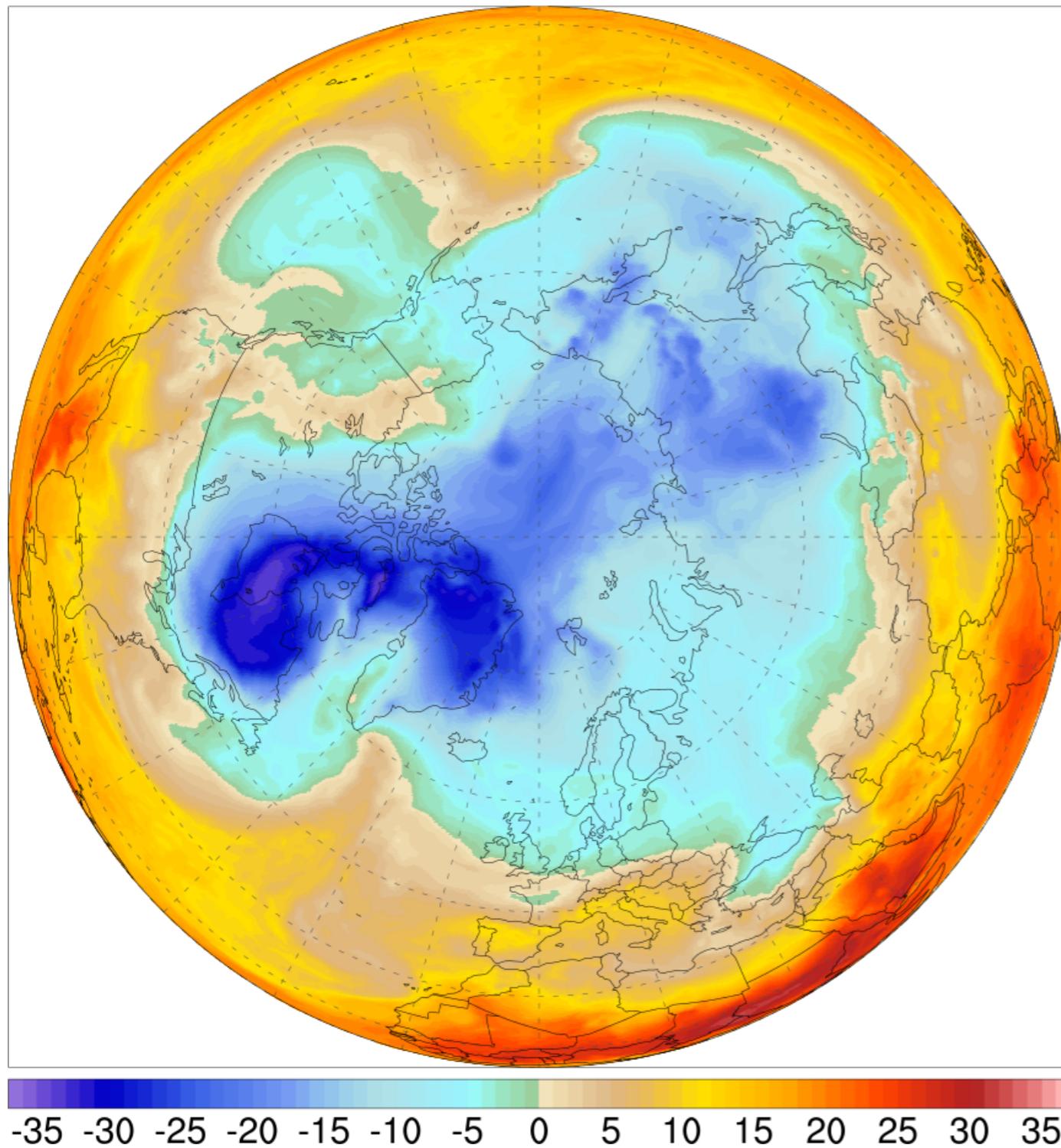
4. Pressure / geopotential height



From <http://www.genuineweather.com/?model=CMC-GDPS&run=12&zone=ART&type=G500&forecast=138>

4. Pressure / geopotential height

CMC GDPS 0.24°: Temperature at 850 hPa (°C)
Init: Sun, 24 Mar 2019 12 UTC Forecast +006H Valid: Sun, 24 Mar 2019 18 UTC



T at 850 hPa

From <http://www.genuineweather.com/?model=CMC-GDPS&zone=ART&type=T850>

4. Pressure / geopotential height

