Review of the Greenhouse Effect

EES 2110

Introduction to Climate Change

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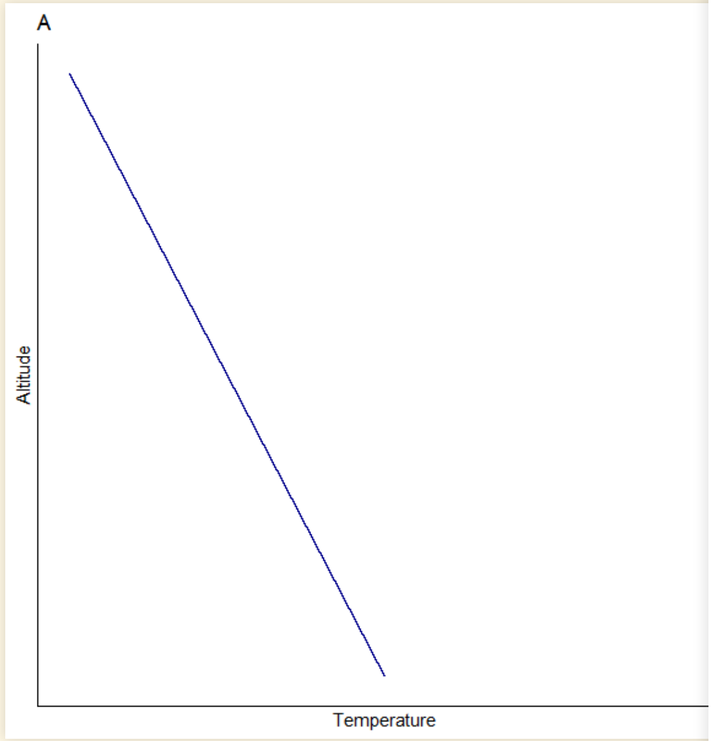
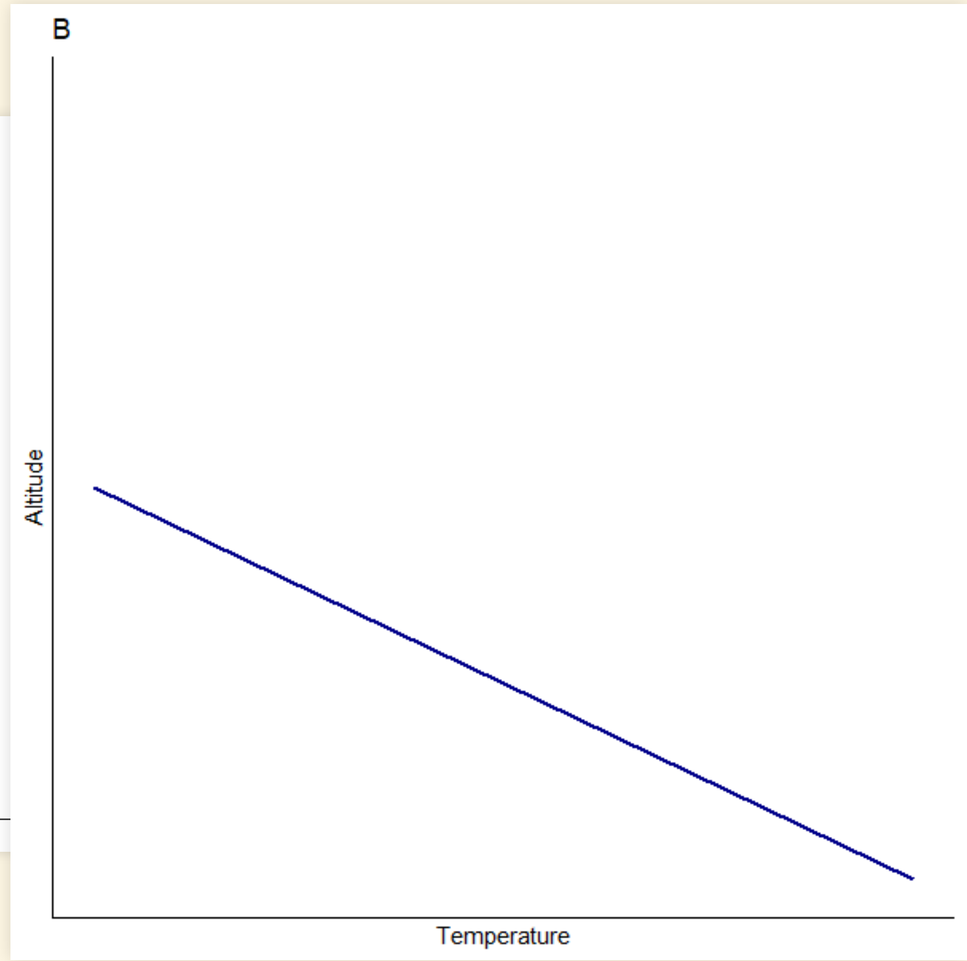
Class #9: Monday, January 30 2023

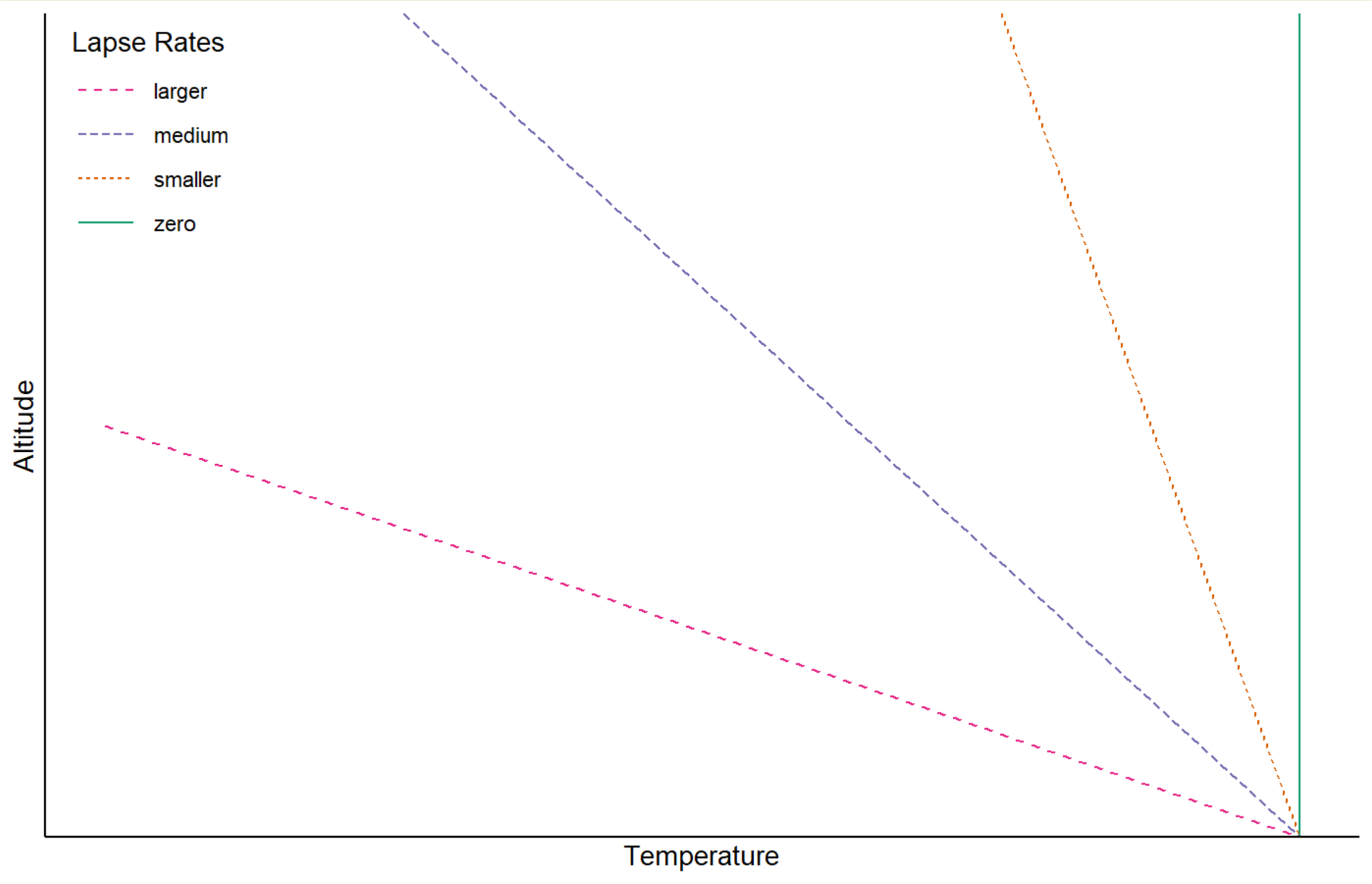
Lapse Rates

Which lapse rate is greater?





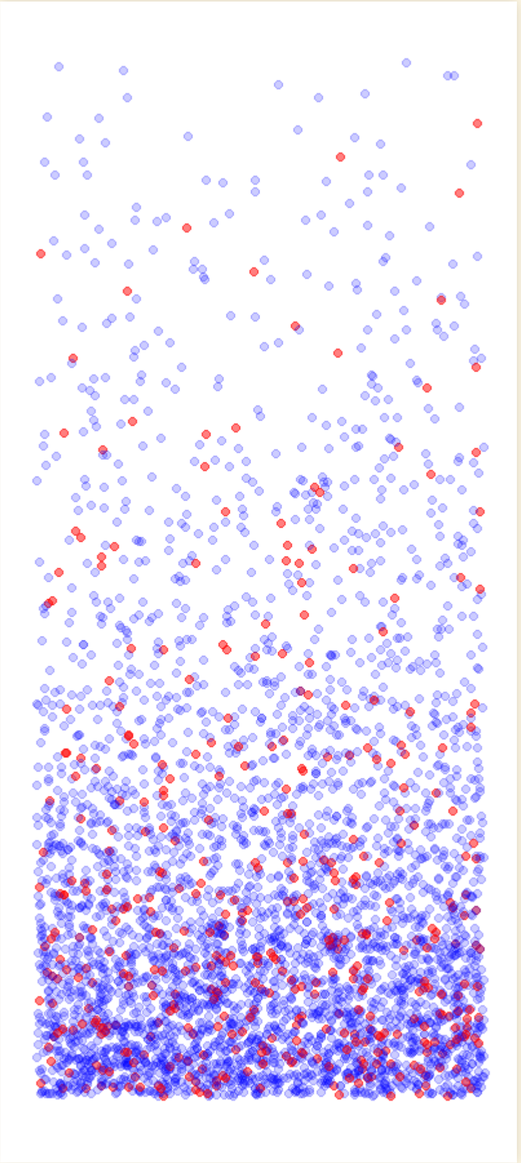
Lapse Rates


Lapse Rates
larger
medium
smaller
zero
Altitude
Temperature

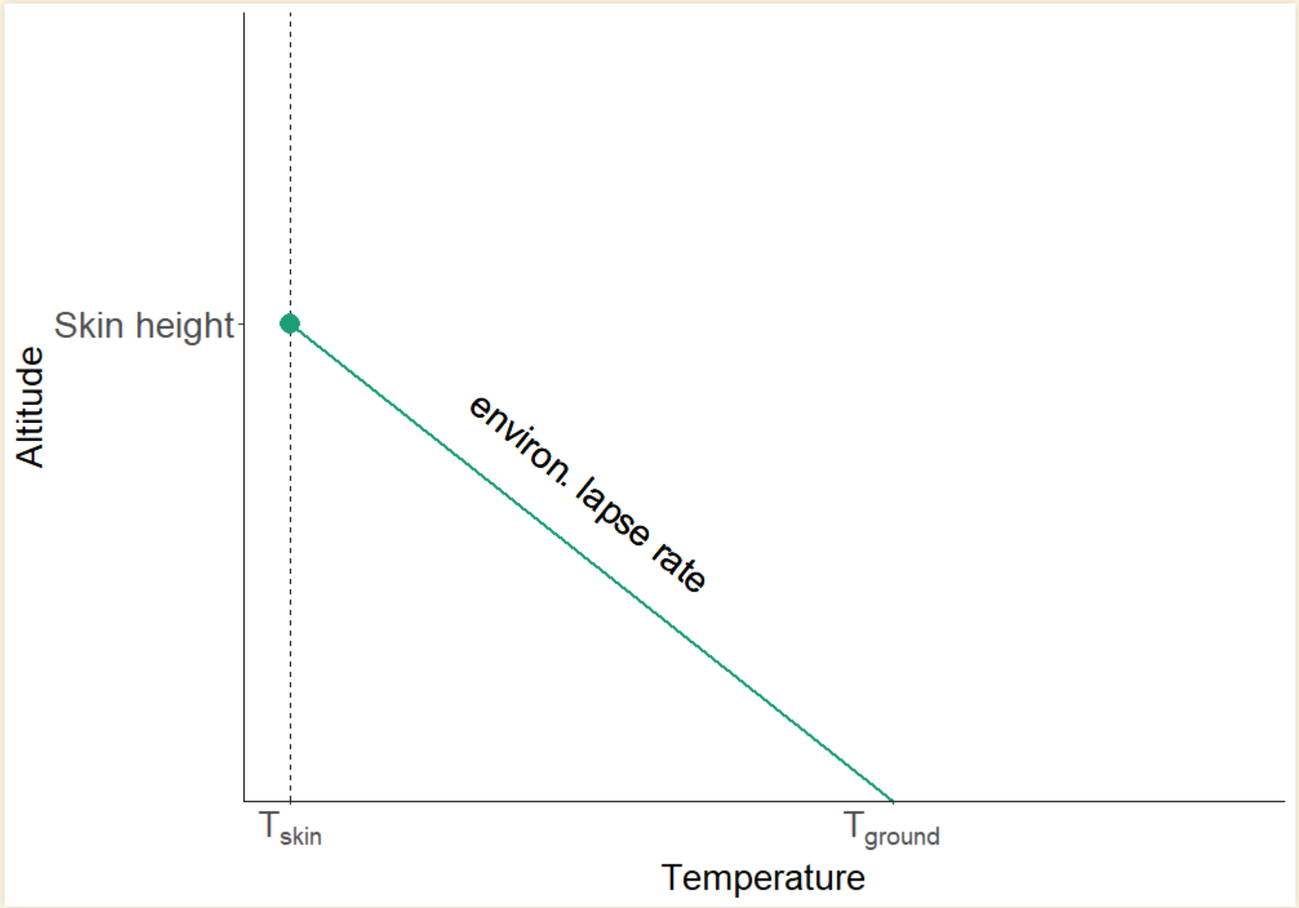
Saturation, Convection, and the Greenhouse Effect

Another Perspective on Band Saturation

- Instead of thinking of saturation as increasing absorption …
- Think of saturation as raising the skin height
  - Skin height = the height at which the atmosphere becomes transparent enough to radiate out to space
    - The height of the top of the atmospheric layer in a layer model
  - The atmosphere becomes opaque at a certain wavelength when there are more than a certain number of molecules per square meter of an absorbing gas overhead.
    - The higher you go, the fewer molecules are overhead and the more are below your feet.
    - The atmosphere gradually becomes more transparent, but we pretend that this happens suddenly at a certain height.
    - Pressure and density fall exponentially as you go higher, so this approximation is reasonable.
- After band saturation sets in, adding more greenhouse gas raises the skin height.

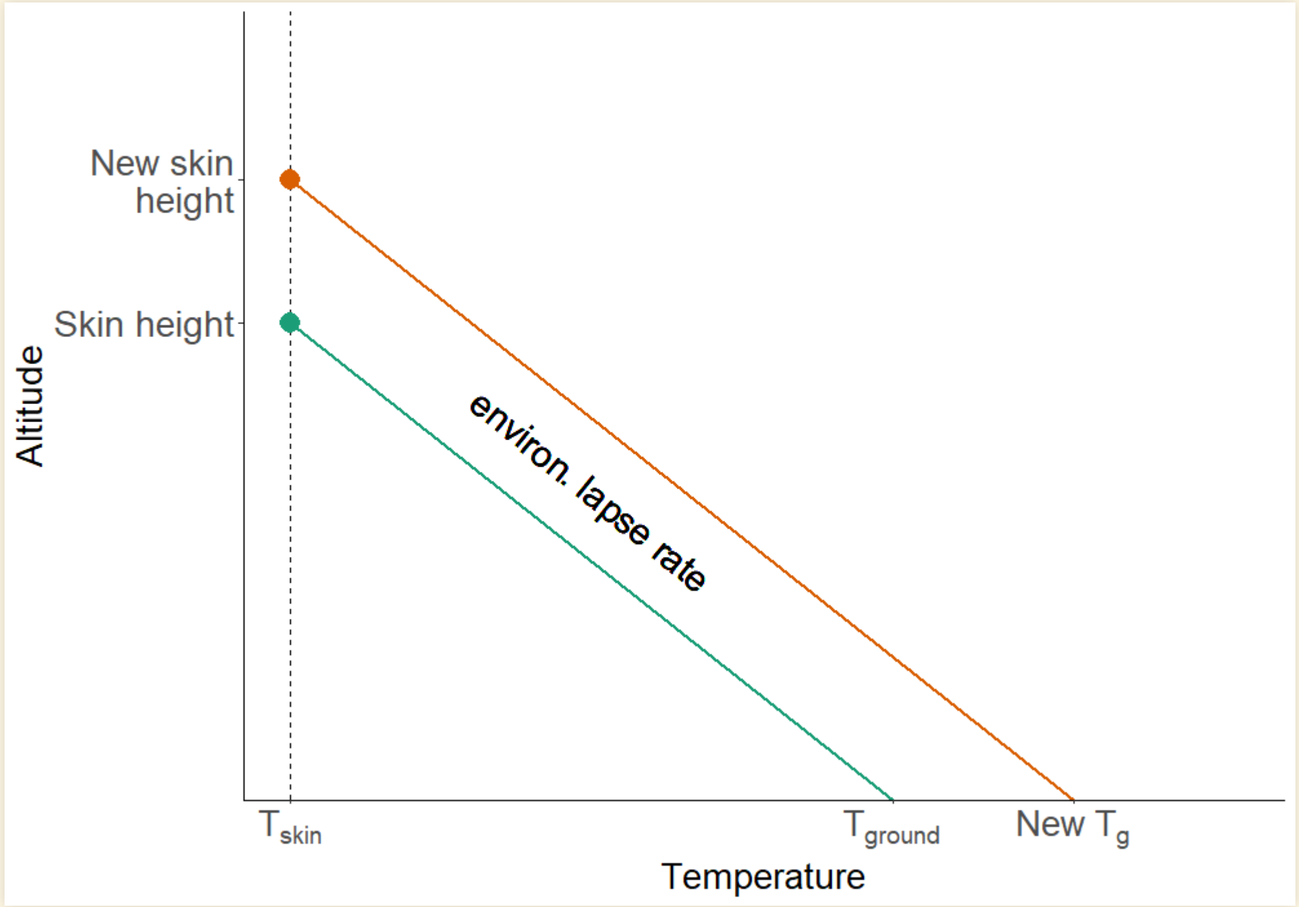


Greenhouse effect



- Skin temp: $T_{\text{skin}} = T_{\text{bare rock}} = 254$ K.
- Ground temp: $T_{\text{ground}} = T_{\text{skin}} + h_{\text{skin}} \times \text{ELR}$
  - ELR = Environmental Lapse Rate

Global warming

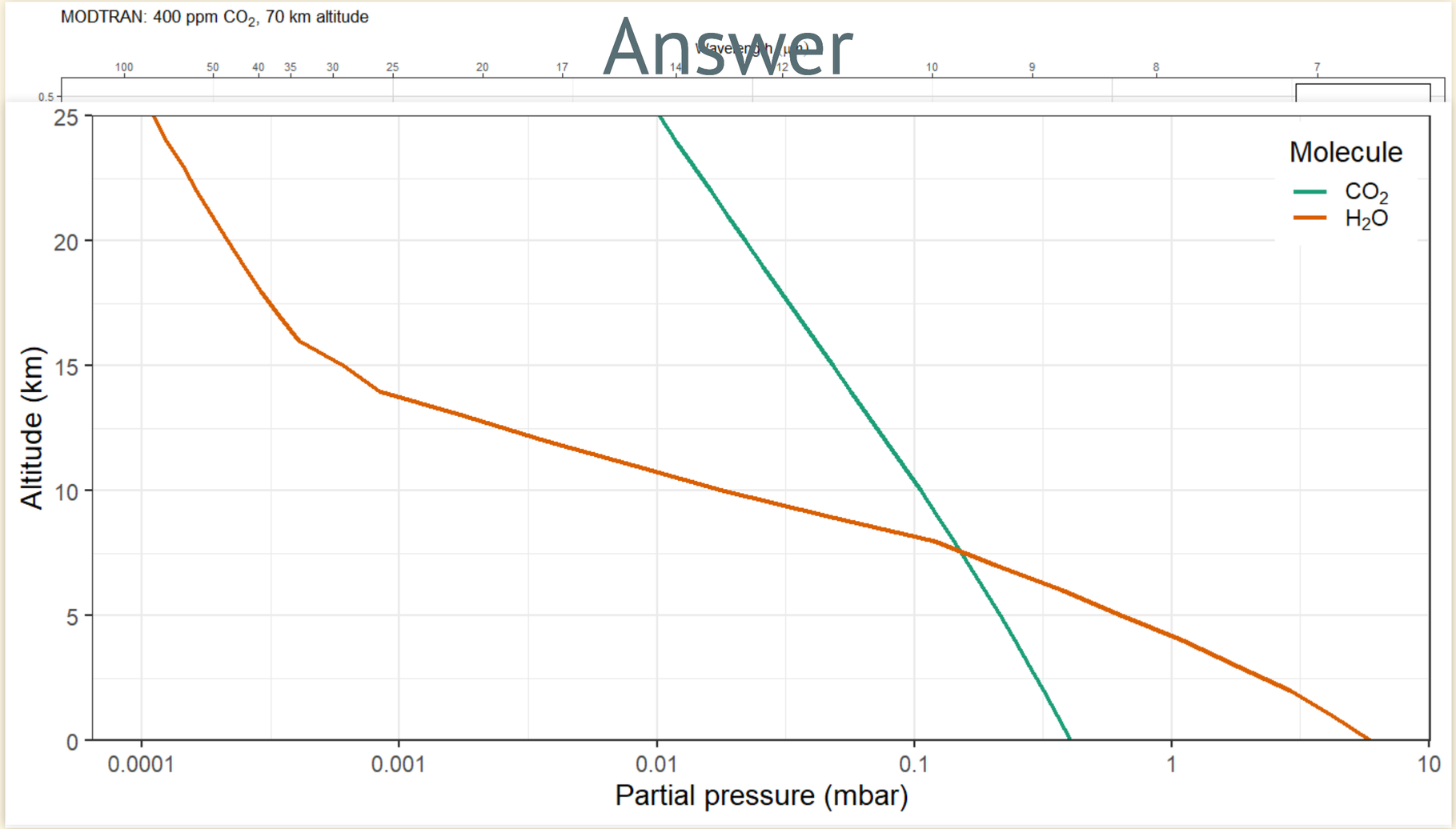


- Greater $CO_2 \longrightarrow$ greater skin height.
- Warming: $\Delta T_{\text{ground}} = \Delta h_{\text{skin}} \times$ **env. lapse**

Question

- Water vapor absorption is saturated, like CO_2.
  - Why does water vapor emit at warmer temperatures than CO_2?

Answer



- Near the ground, there is much more water vapor (15 times more)
- Above about 7 km, there is much more CO_2 (100 times more at 20 km)
  - Water vapor concentrations become small enough to be transparent to space at a much lower altitude than CO_2

Review of the Greenhouse Effect

Review of the Greenhouse Effect

1. **Start with bare-rock temperature**
   - This becomes skin temperature
2. **Add simple layer atmosphere:**
   - Completely black to longwave radiation
   - Top of atmosphere: skin temperature (same as bare-rock)
   - Atmosphere insulates surface $\Rightarrow$ surface heats up
   - More layers $\Rightarrow$ bigger greenhouse effect
3. **Realistic longwave absorption:**
   - Atmosphere is not black
   - Absorption depends on wavelength
4. **Radiative-Convective equilibrium:**
   - Pure radiative equilibrium would have *huge* environmental lapse rate
     - 16 K/km
   - Big lapse rate is unstable $\Rightarrow$ convection
     - ELR (16 K/km) > ALR (6–10 K/km)
     - Convection mixes hot & cold air $\Rightarrow$ reduces environmental lapse until it becomes stable
     - Reduces greenhouse effect
   - **Alternate perspective:**
     - Think of greenhouse effect in terms of raising the skin height instead of blocking heat flow.
     - T_{skin} is always T~bare rock~
     - $T_{ground} = T_{skin} + h_{skin} \times$ Environmental Lapse Rate

Questions & Discussion of Greenhouse Effect

Atmospheric Radiation Spectrum