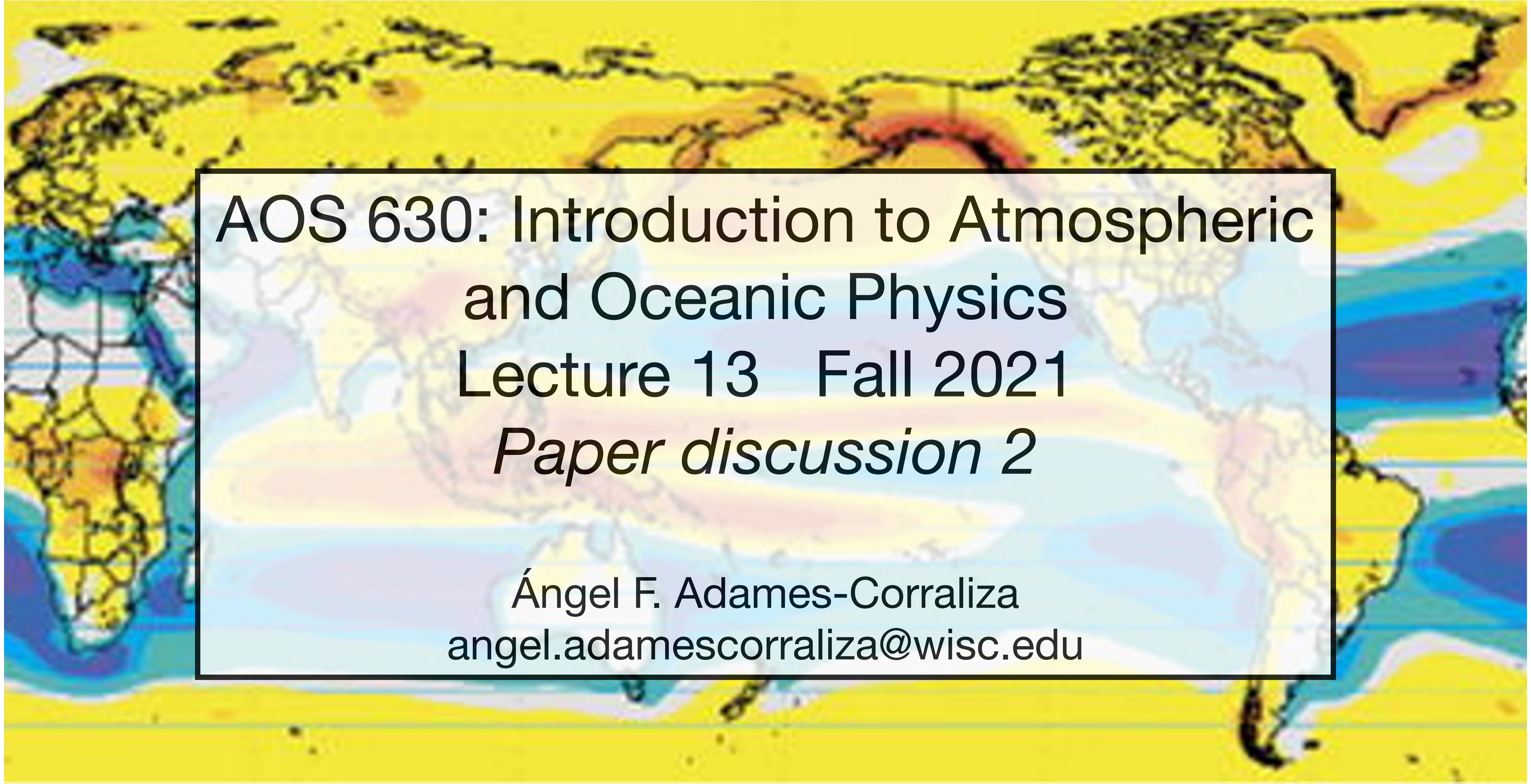

AOS 630: Introduction to Atmospheric and Oceanic Physics

Lecture 13   Fall 2021

Paper discussion 2

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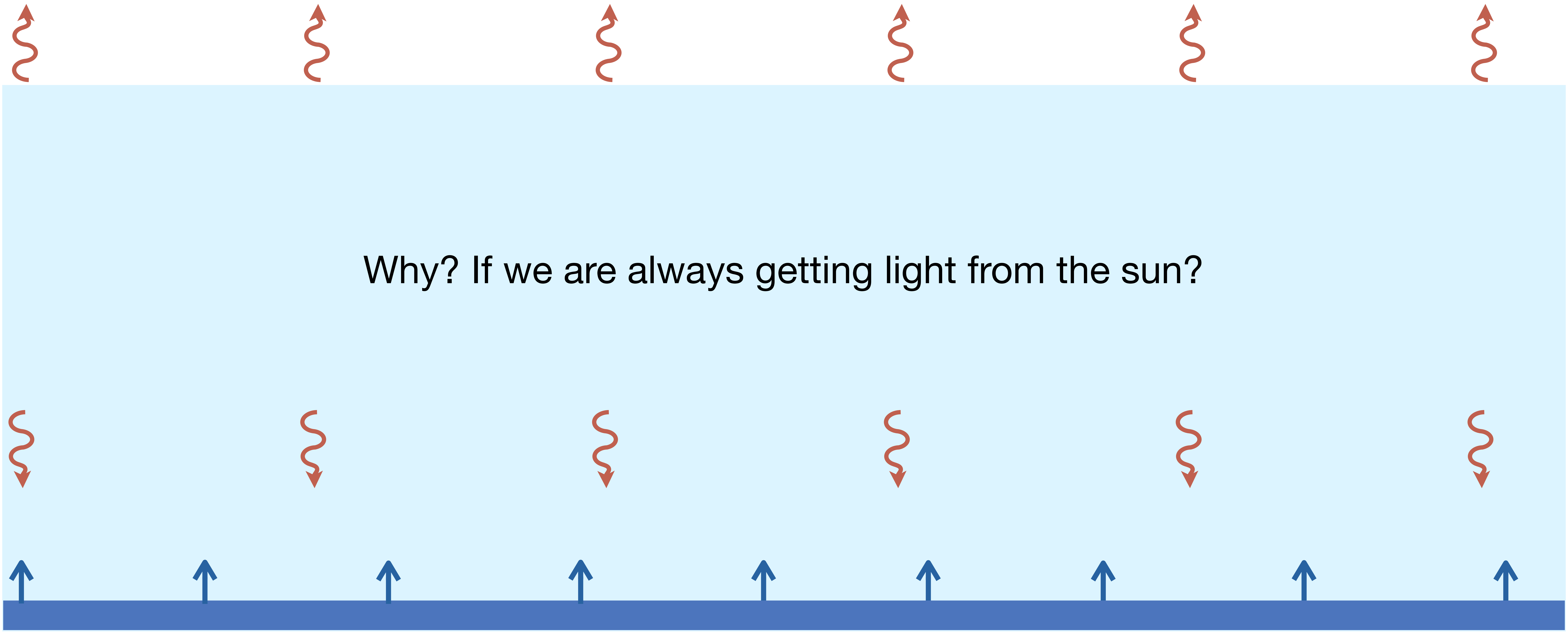
Today in thermo

http://tropic.ssec.wisc.edu/real-time/mtpw2/product.php?color_type=tpw_nrl_colors&prod=global2&timespan=24hrs&anim=html5

https://www.tropicaltidbits.com/analysis/models/?model=gfs&region=wus&pkg=mslp_pwata&runtime=2021102106&fh=-12

Radiative–convective equilibrium

Our atmosphere is always trying to cool down

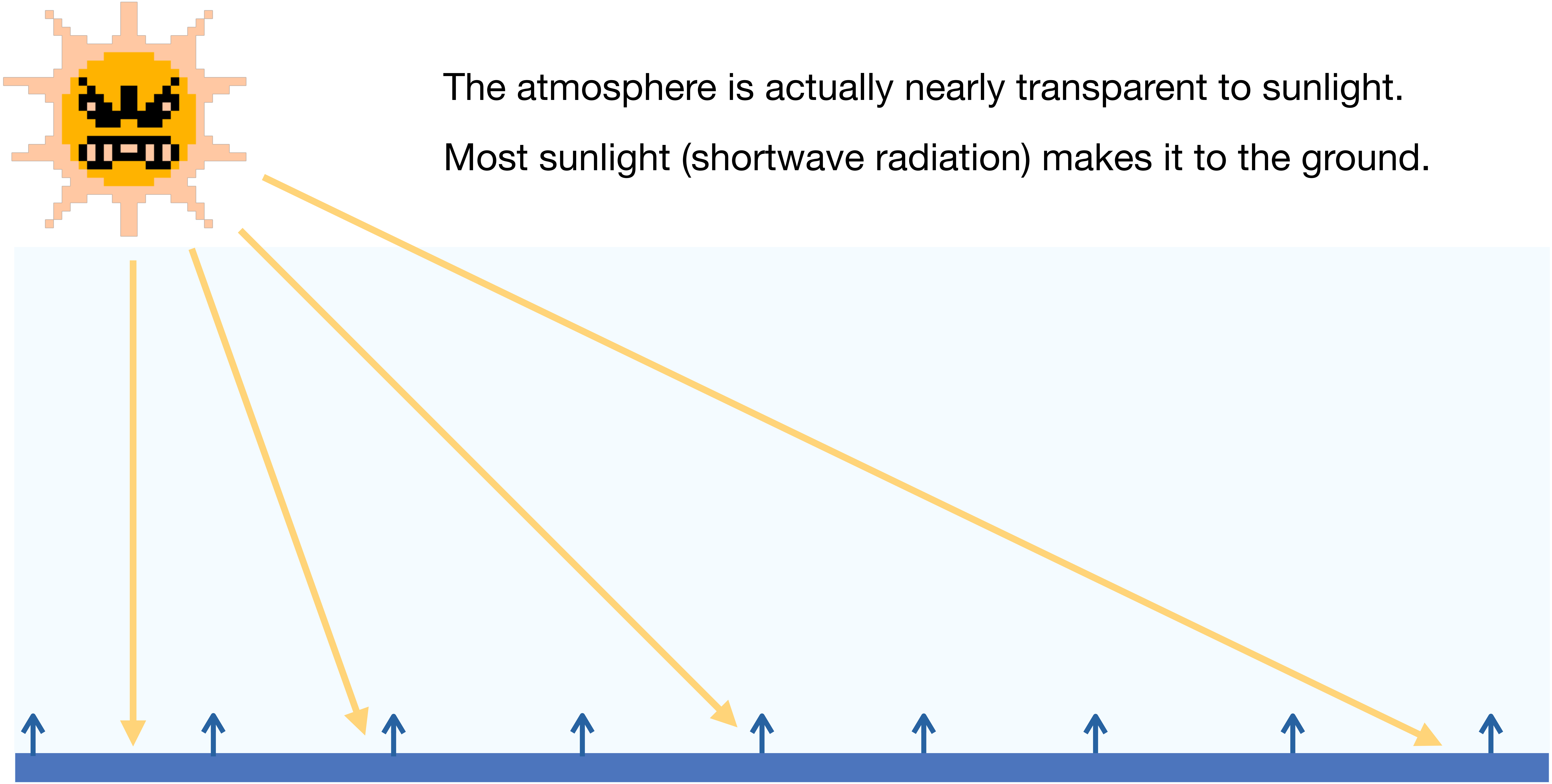


Why? If we are always getting light from the sun?

Radiative–convective equilibrium

The atmosphere is actually nearly transparent to sunlight.

Most sunlight (shortwave radiation) makes it to the ground.



Radiative-convective equilibrium

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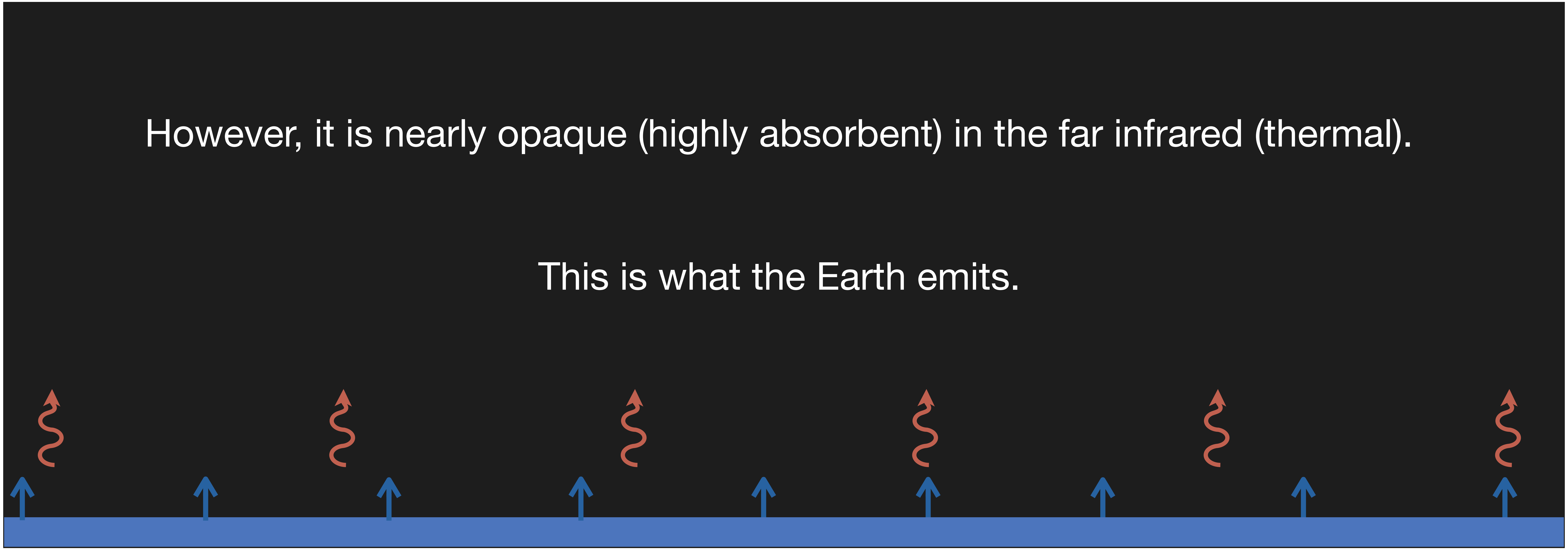
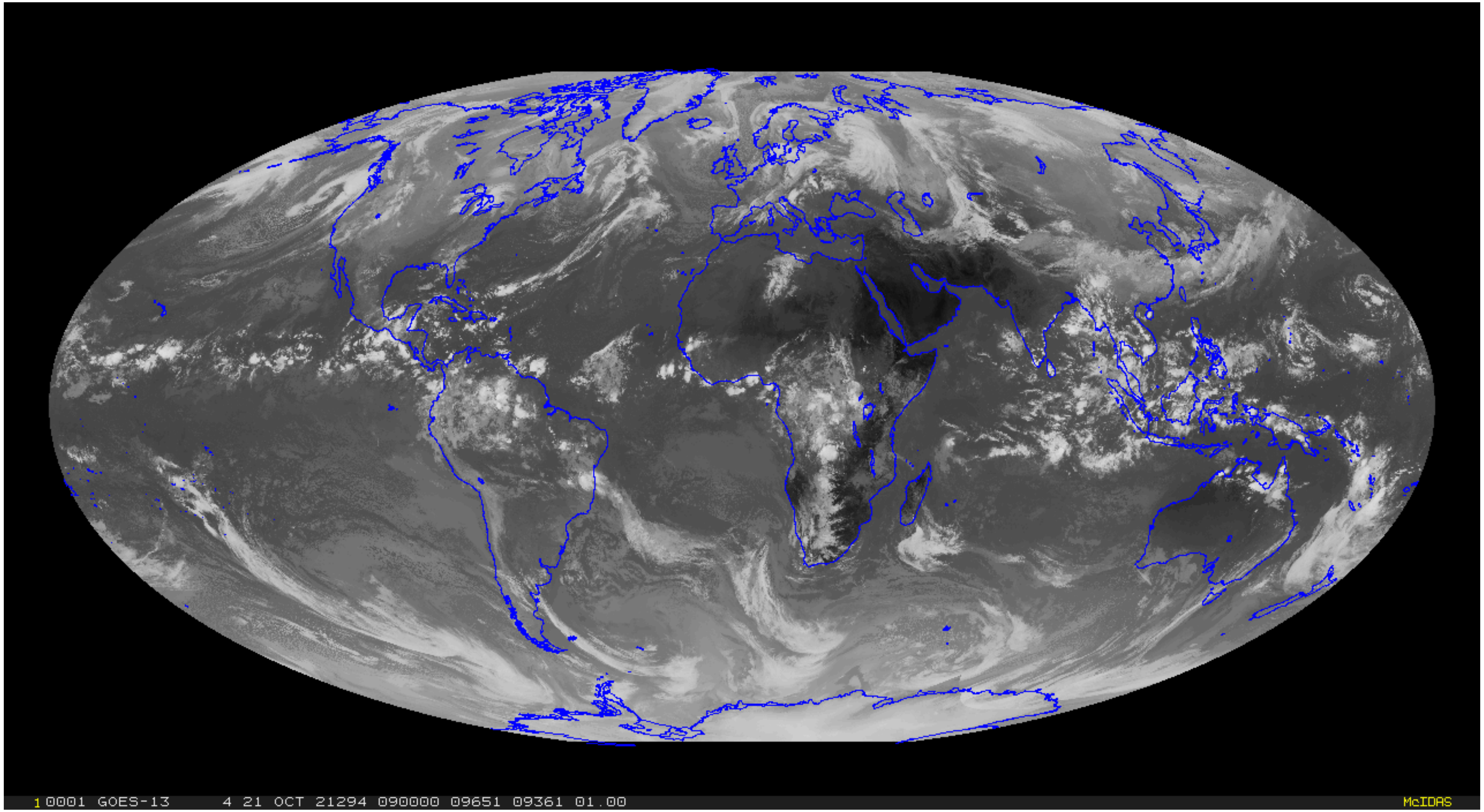


However, it is nearly opaque (highly absorbent) in the far infrared (thermal).

This is what the Earth emits.

Radiative-convective equilibrium

Most of the long wave radiation our satellites observe comes from emissions from the atmosphere, not from the ground



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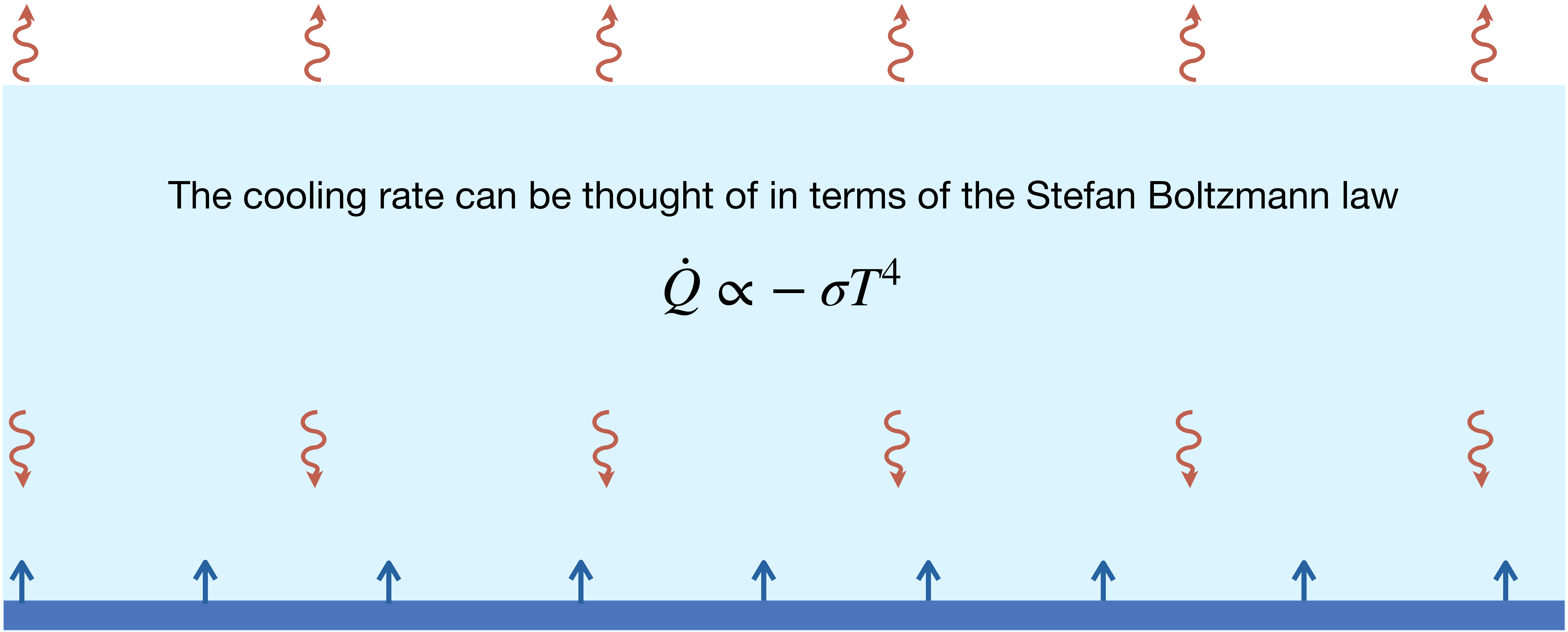
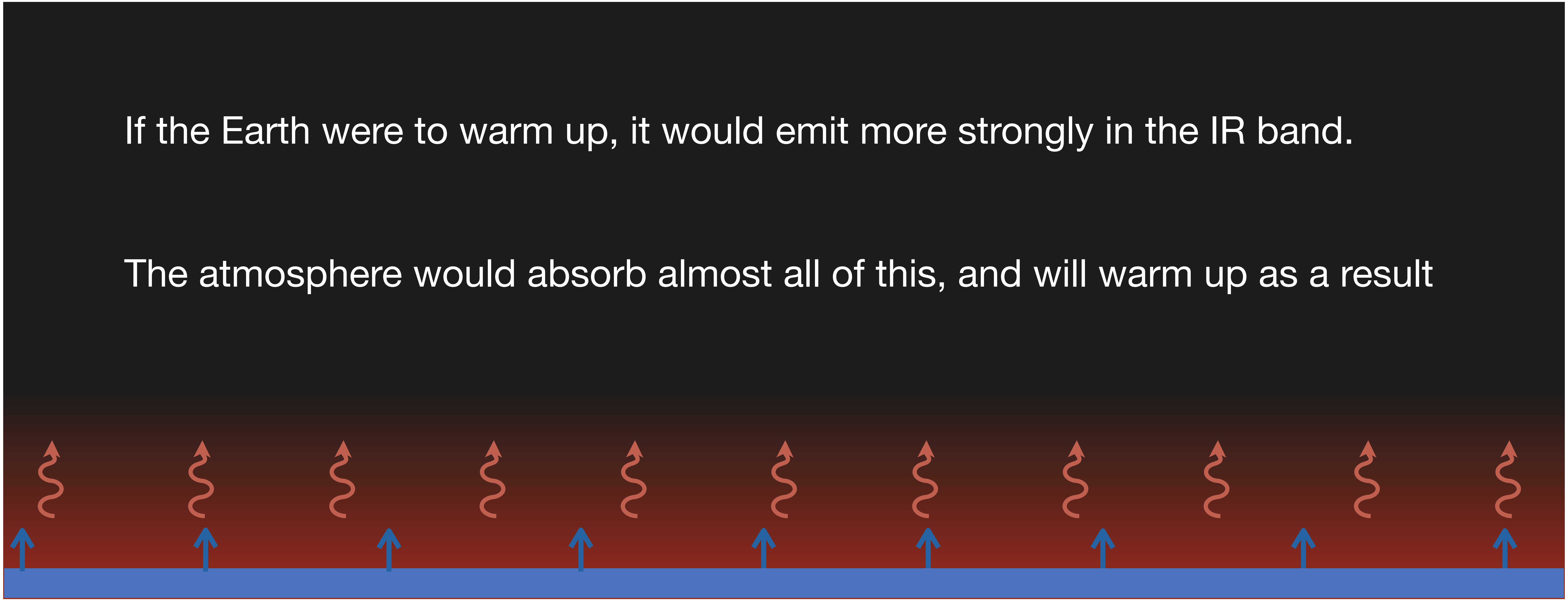


The cooling rate can be thought of in terms of the Stefan Boltzmann law

$$\dot{Q} \propto -\sigma T^4$$

Radiative–convective equilibrium

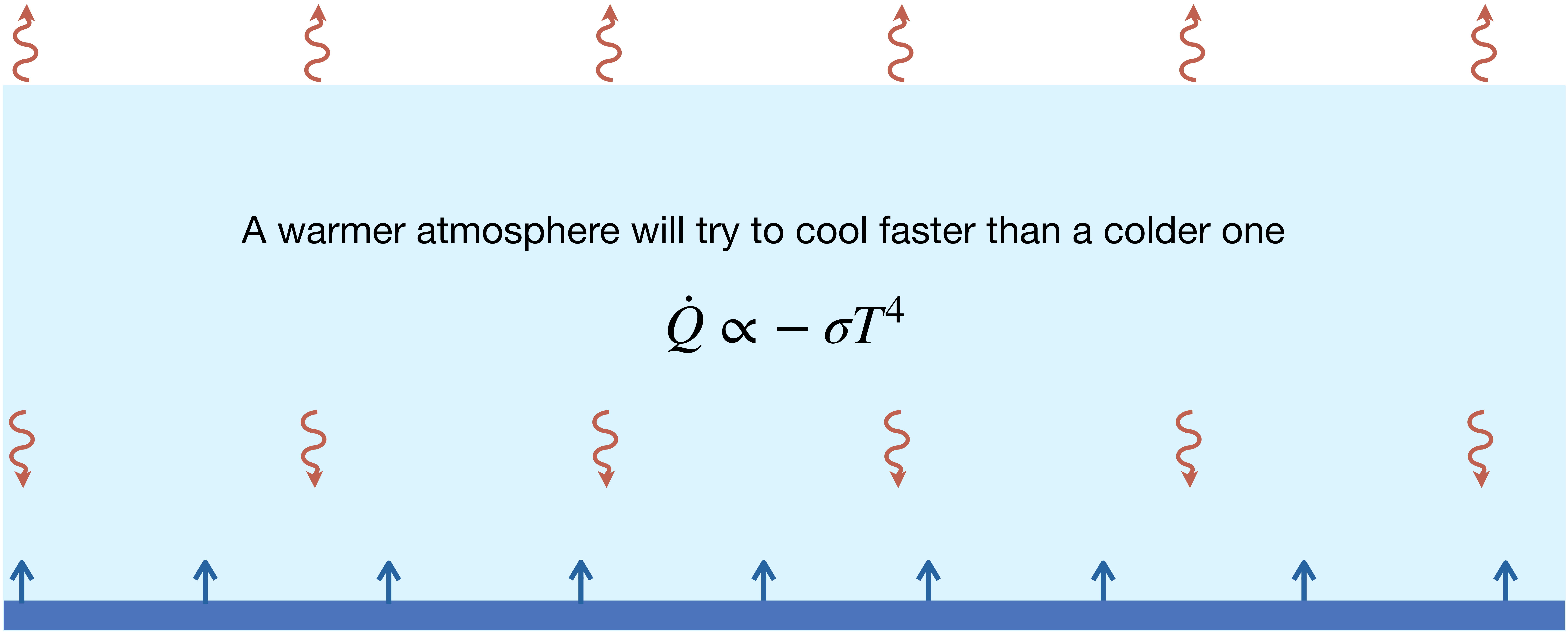
Our atmosphere is always trying to cool down



If the Earth were to warm up, it would emit more strongly in the IR band.

The atmosphere would absorb almost all of this, and will warm up as a result

Radiative–convective equilibrium



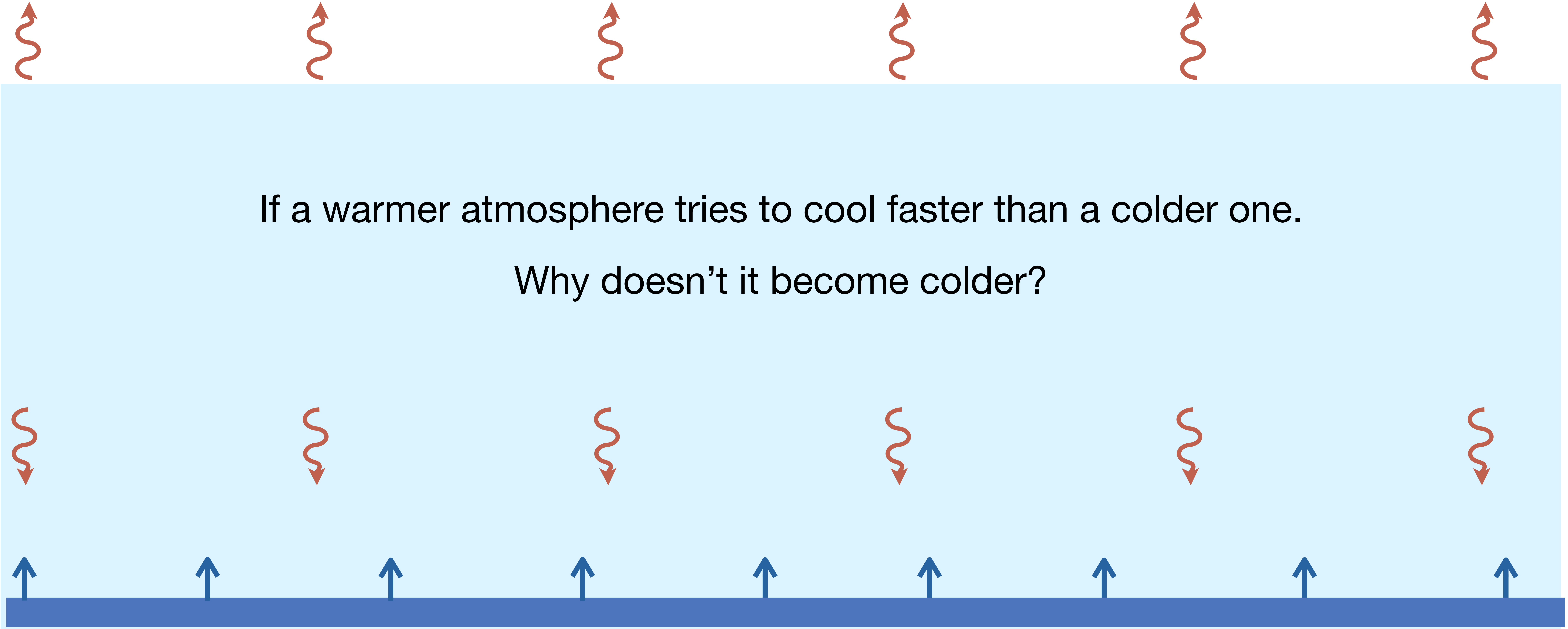
A warmer atmosphere will try to cool faster than a colder one

$$\dot{Q} \propto -\sigma T^4$$

Radiative–convective equilibrium

Think about how quickly a hot cup of coffee cools down compared to something that is closer to room temperature

Radiative–convective equilibrium

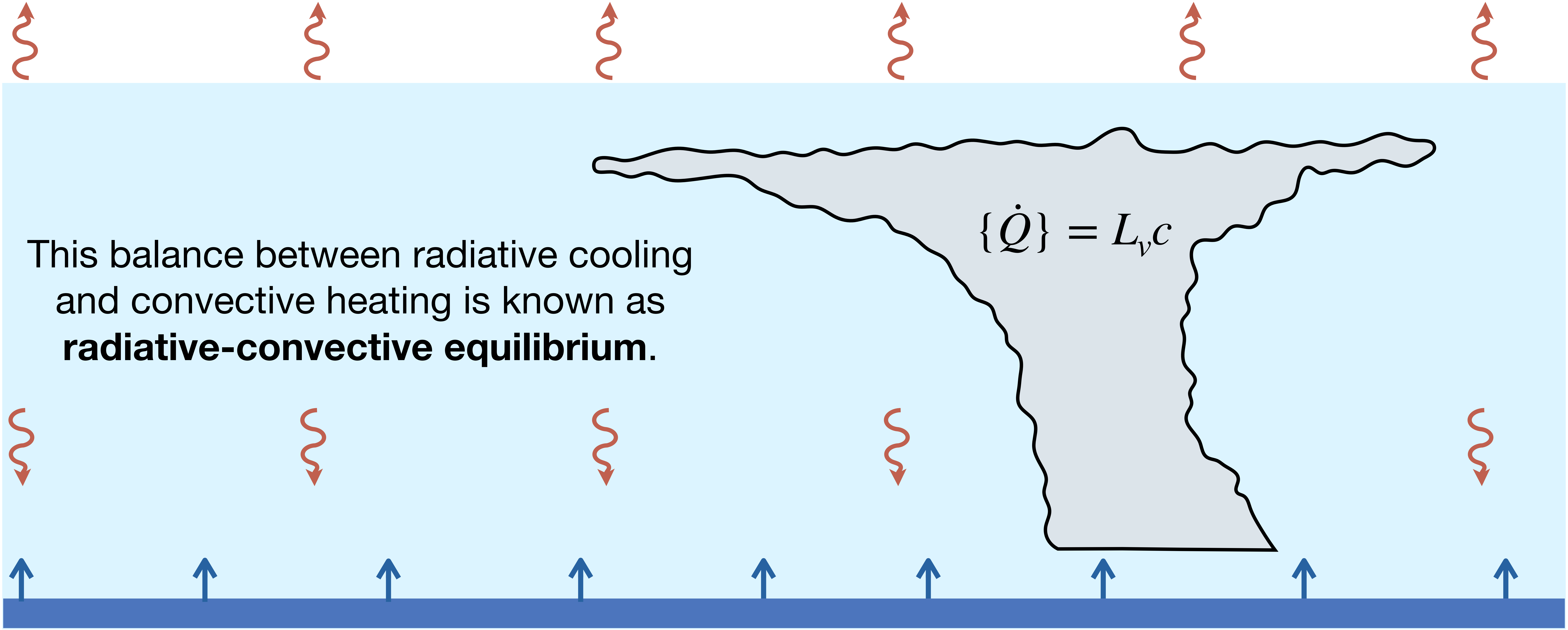


If a warmer atmosphere tries to cool faster than a colder one.

Why doesn’t it become colder?

Radiative–convective equilibrium

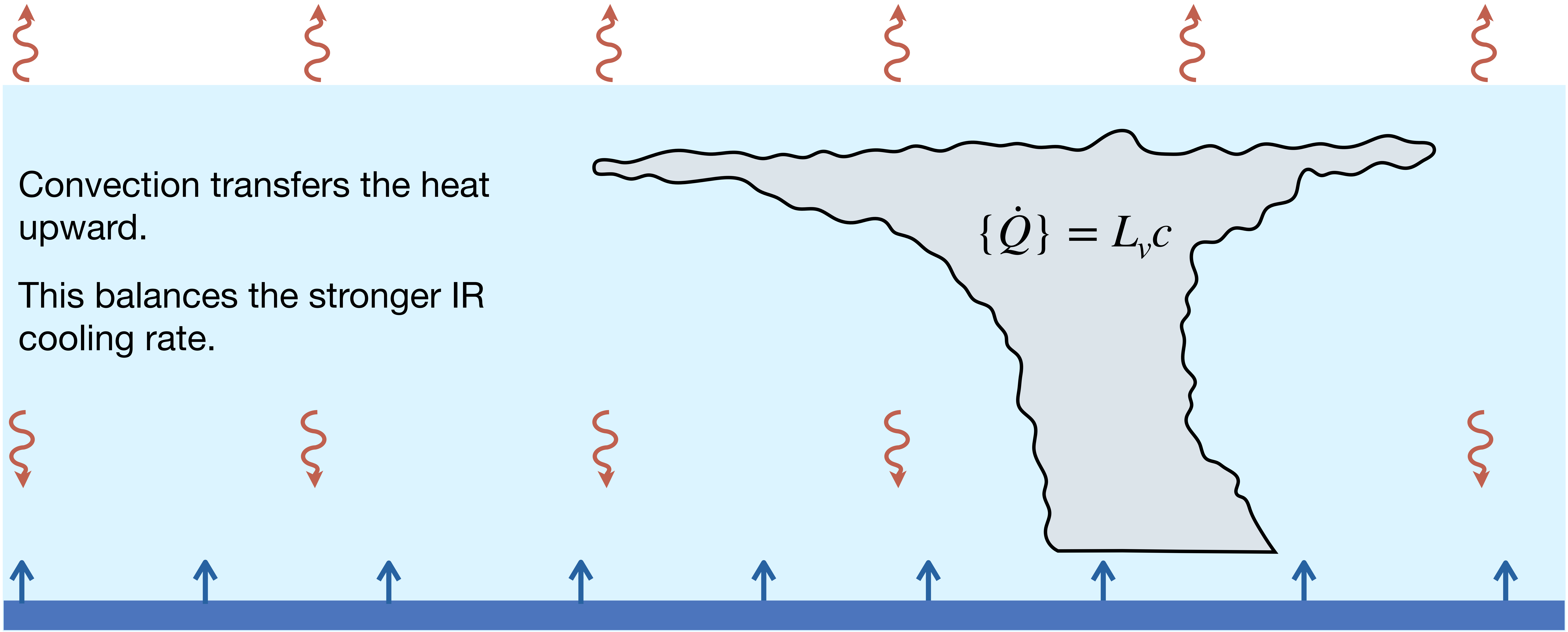
The answer: Atmospheric convection is always transferring heat from the surface into the atmosphere in the form of latent heat release.



This balance between radiative cooling and convective heating is known as **radiative-convective equilibrium**.

Radiative–convective equilibrium

In a hotter climate, the surface is hotter and hence it fluxes more energy in the form of water vapor and enthalpy (sensible heat).



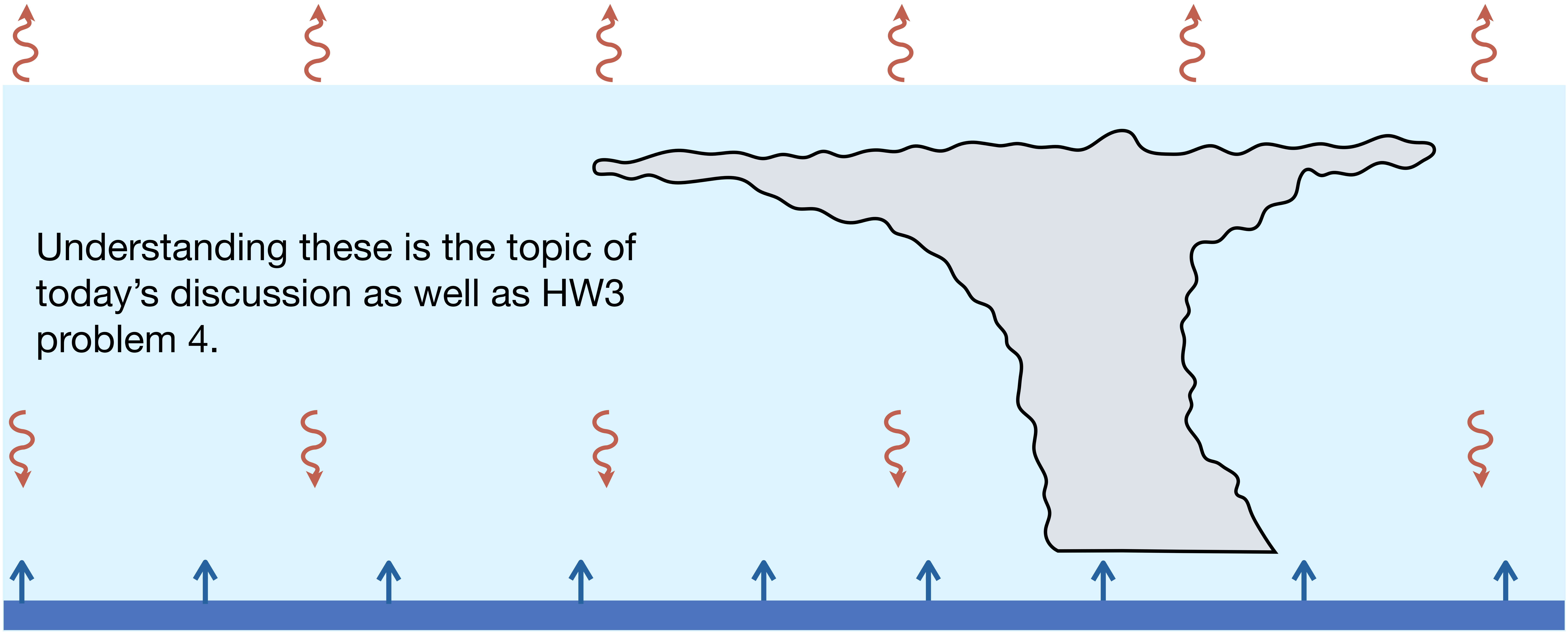
Convection transfers the heat upward.

This balances the stronger IR cooling rate.

$$\{\dot{Q}\} = L_v c$$

Radiative–convective equilibrium

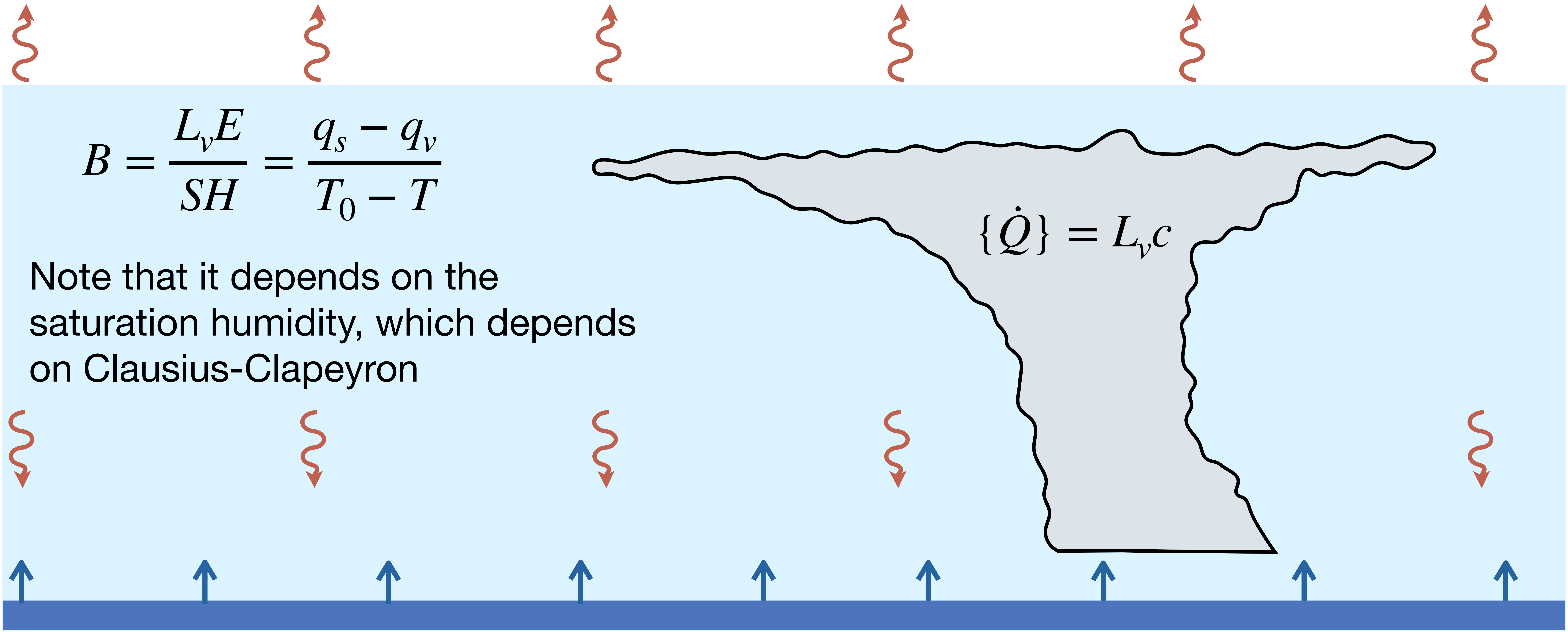
The need of the global-mean atmosphere to be in radiative-convective equilibrium plus the fact that many variables follow the Clausius-Clapeyron equation will lead to constraints in our hydrologic cycle and its response to climate change.



Understanding these is the topic of today's discussion as well as HW3 problem 4.

The Bowen Ratio

We can understand the relative contribution of the latent heat flux (LvE) and sensible heat flux (SH) to convection using the Bowen ratio



$$B = \frac{L_v E}{SH} = \frac{q_s - q_v}{T_0 - T}$$

Note that it depends on the saturation humidity, which depends on Clausius-Clapeyron

$$\{\dot{Q}\} = L_v c$$

Questions to discuss:

1. At what rate (% K^{-1}) would variables that follow the Clausius-Clapeyron equation increase?

2. What does Fig. 2 show us?

3. Why does precipitation increase at a different rate than water vapor?

4. What does Fig. 5 show us? At what rate (% K^{-1}) does the moisture transport increase?

5. What does Fig. 7 Show us?

6. What is the implication of Fig. 8?

7. To what extent is the hydrological cycle's response to climate change constrained by the Clausius-Clapeyron equation?

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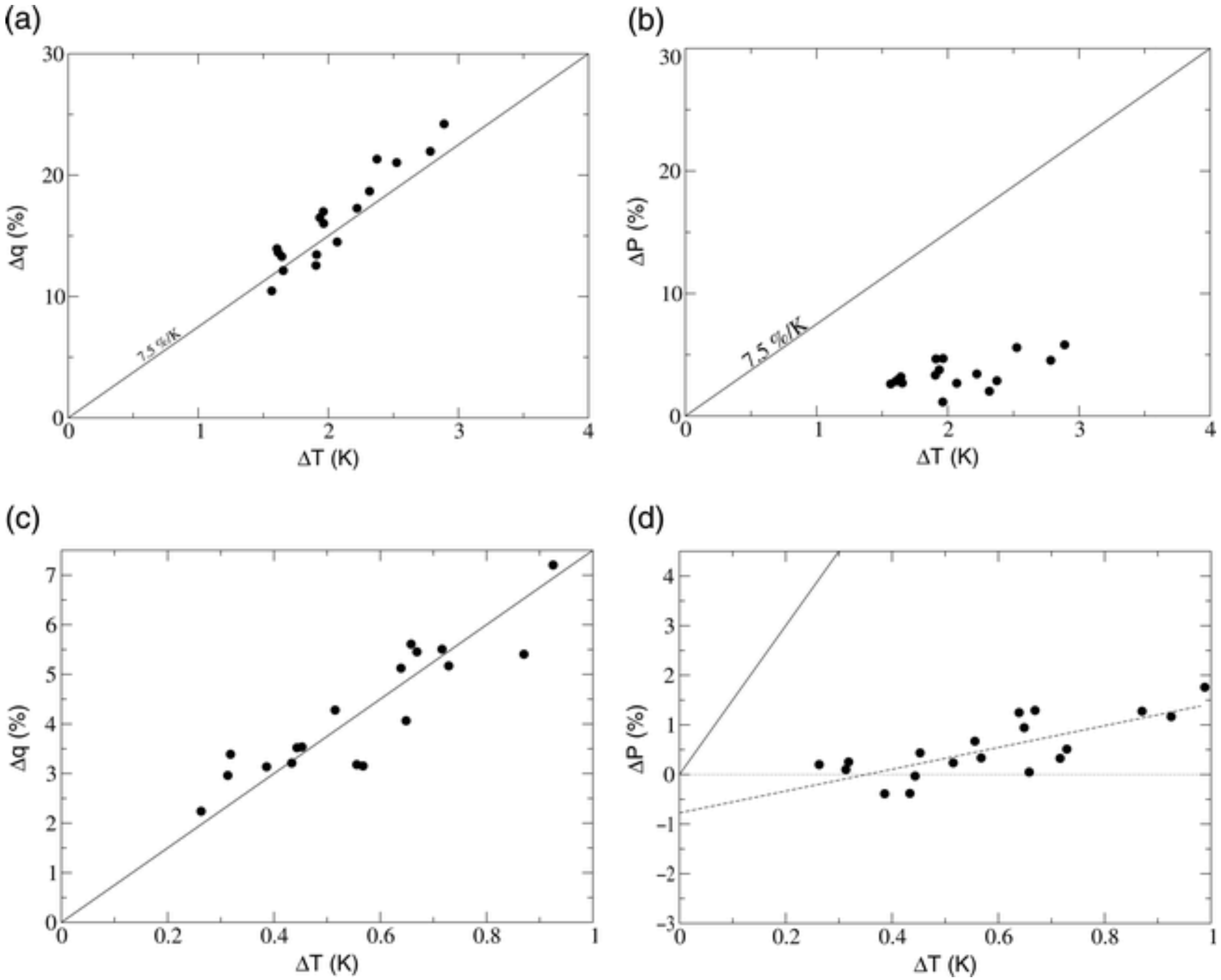

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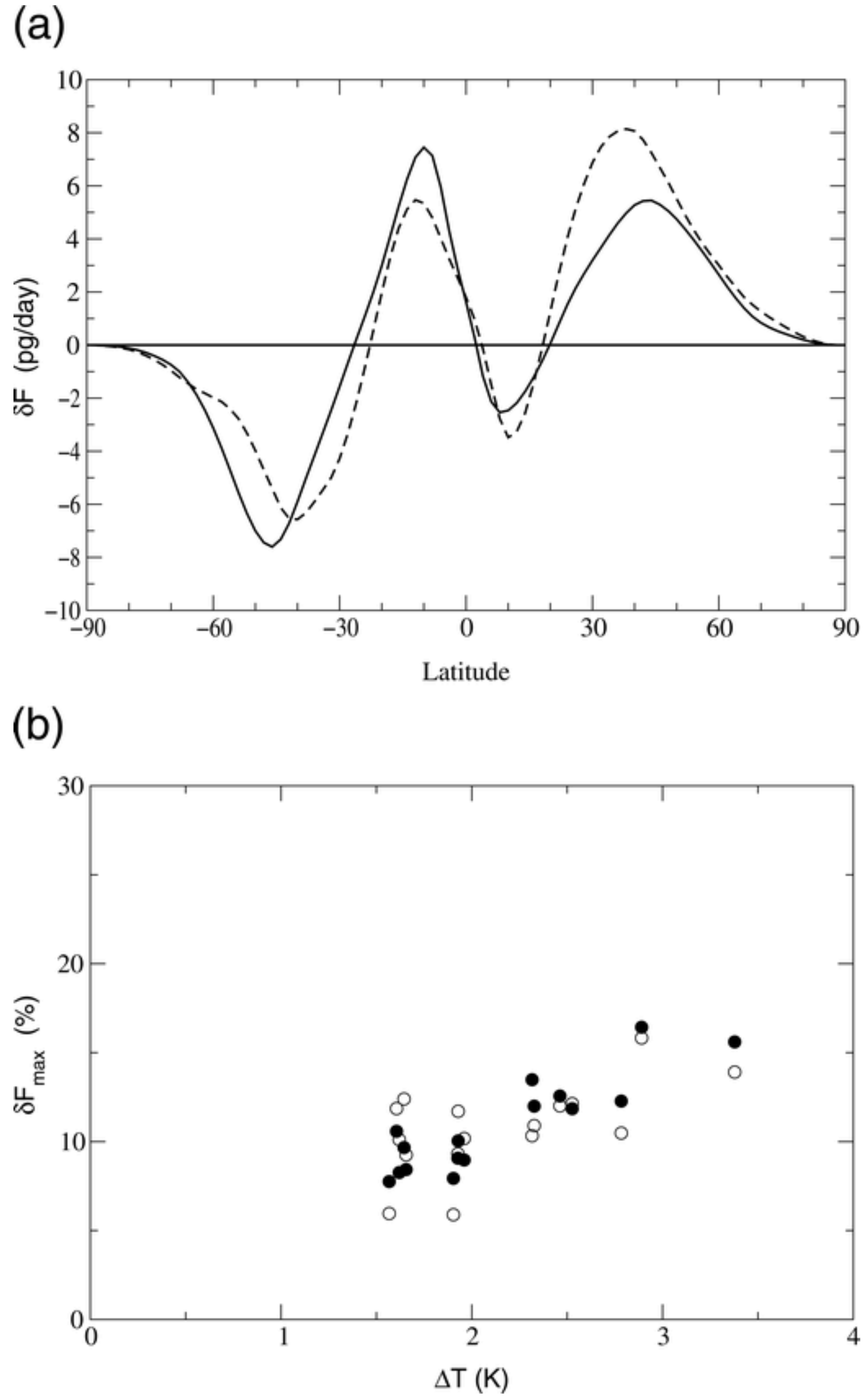

5. What does Fig. 7 Show us?

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7. To what extent is the hydrological cycle’s response to climate change constrained by the Clausius-Clapeyron equation?