

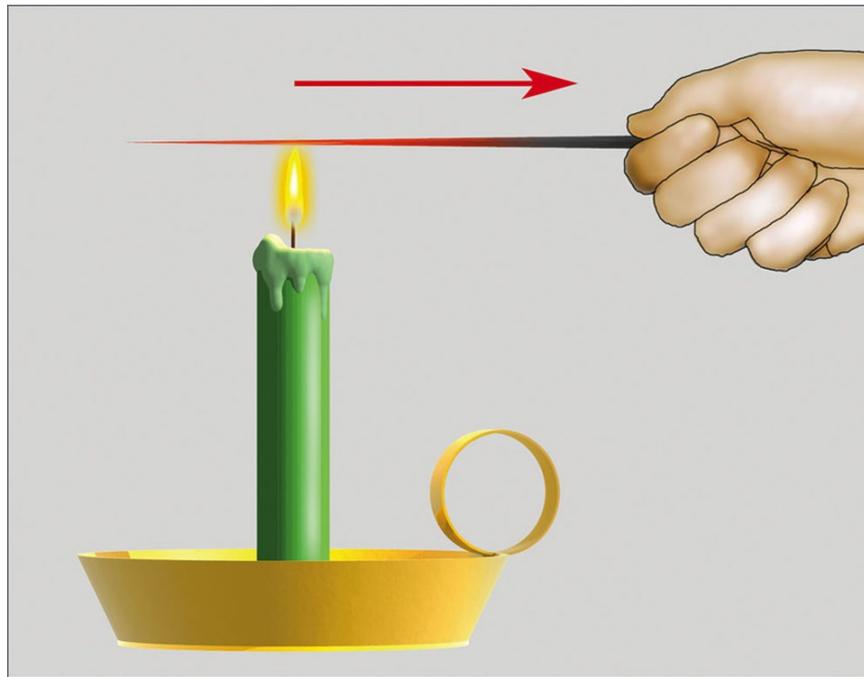
## Heat Transfer: Conduction, Convection and Latent Heat

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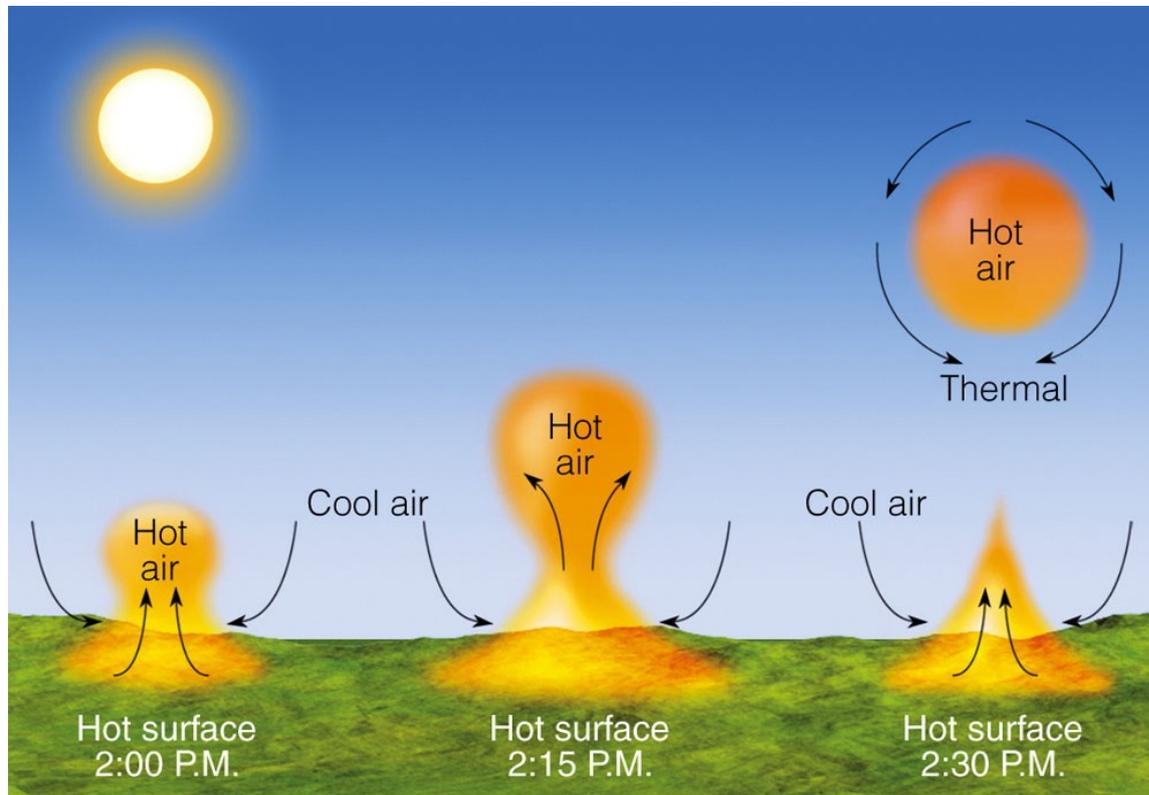
conduction of heat  
along a metal rod

## Heat Transfer: Conduction, Convection and Latent Heat

In addition to radiation, energy can also be transferred in the form of heat. There are three ways this can happen:

- When heat simply diffuses through an object, passing from molecule to molecule, that's called **conduction**
- As it turns out, air is actually very poor at diffusing heat through conduction.....that is, **air is a very poor conductor**
  - (- Equivalently, air is a very good insulator)
- As a result, conduction is really only important right next to the ground.....over the lowest few cm, really

- When heat is moved from place to place due to warm and cold air masses moving around, that's called **convection**



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a rising warm air  
bubble transfers  
heat by convection

- When heat is moved from place to place due to warm and cold air masses moving around, that's called **convection**
- Some terminology:
  - Heat transfer due to **vertical** air motions is always referred to as convection.....but
  - Heat transfer due to **horizontal** air motions is often called **advection** instead
- In the atmosphere, convection / advection is the main way of moving heat from place to place
  - **Convection is much, much more efficient at transferring heat than conduction**

- Depending on the temperature, water in the air can exist in any of three phases: liquid, solid or gas (aka vapor).  
And.....
- Transformations between these phases (referred to as **phase changes**) are accompanied by either the release or the absorption of heat, referred to generally as **latent heating**.  
Why do we care?

- Depending on the temperature, water in the air can exist in any of three phases: liquid, solid or gas (aka vapor).  
And.....
- Transformations between these phases (referred to as **phase changes**) are accompanied by either the release or the absorption of heat, referred to generally as **latent heating**.  
Why do we care?
  - If heat is released, it warms the surrounding air
  - If heat is absorbed, it cools the surrounding air

If water goes  
from....

that's  
called.....

and the effect on the  
surrounding air is.....

vapor to liquid

liquid to solid

vapor to solid

solid to liquid

liquid to vapor

solid to vapor

If water goes  
from....

that's  
called.....

and the effect on the  
surrounding air is.....

vapor to liquid

condensation

liquid to solid

vapor to solid

solid to liquid

liquid to vapor

solid to vapor

If water goes  
from....

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and the effect on the  
surrounding air is.....

vapor to liquid

condensation

liquid to solid

freezing

vapor to solid

solid to liquid

liquid to vapor

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If water goes  
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condensation

liquid to solid

freezing

vapor to solid

deposition

solid to liquid

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deposition

solid to liquid

melting

liquid to vapor

evaporation

solid to vapor

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freezing

vapor to solid

deposition

solid to liquid

melting

liquid to vapor

evaporation

solid to vapor

sublimation

If water goes  
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and the effect on the  
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vapor to liquid

condensation

warming

liquid to solid

freezing

warming

vapor to solid

deposition

warming

solid to liquid

melting

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evaporation

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If water goes  
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vapor to solid

deposition

warming

solid to liquid

melting

cooling

liquid to vapor

evaporation

cooling

solid to vapor

sublimation

cooling

- So water vapor in the atmosphere is thus a hidden form of heat, with the heat realized once condensation (or freezing, or deposition) occurs



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condensation and freezing in clouds releases latent heat to the surroundings, thus warming the air

- Now, over most of the atmosphere, shortwave radiation from the sun passes straight through, without being absorbed
  - Exceptions: UV absorption in the stratosphere (by ozone) and X-ray and gamma-ray absorption in the thermosphere (by  $O_2$ )
- **Question:** If not the sun, then where does the atmosphere get its energy from?

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  - Answer:** Most of the atmosphere's energy comes from from the Earth below

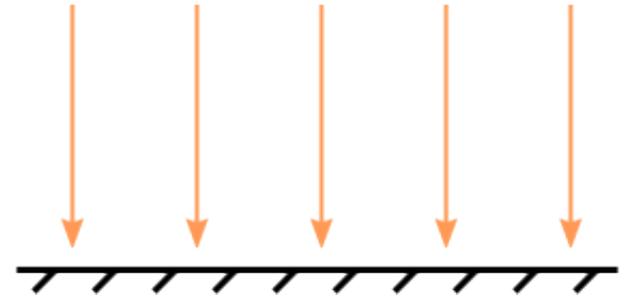
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**Answer:** Most of the atmosphere's energy comes from from the Earth below

(Of course, the Earth gets its energy from the sun, so ultimately it does all come from the sun....just not directly)

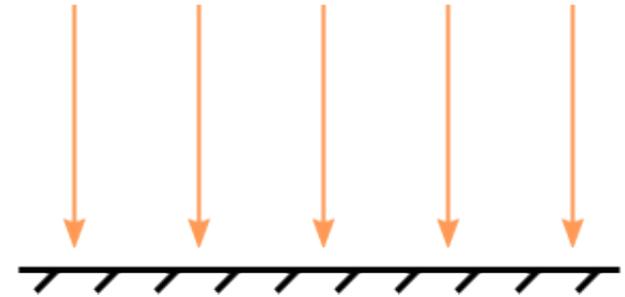
## Warming the Atmosphere from Below

**Step 1:** Shortwave passes through and is absorbed by the ground, causing the ground to warm (radiation)



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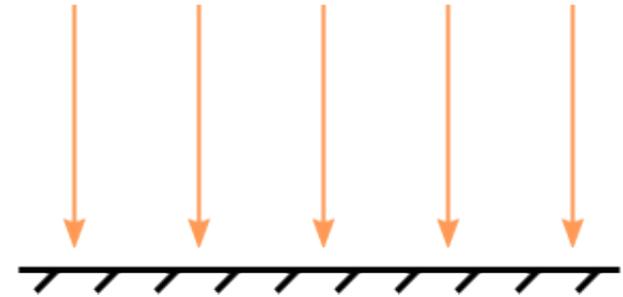


**Step 2:** Air in the lowest few cm is warmed by contact with the ground and moistened by evaporation



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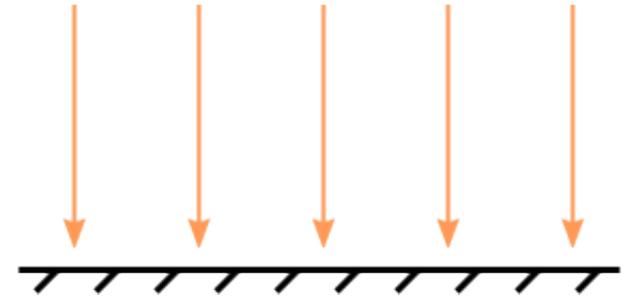


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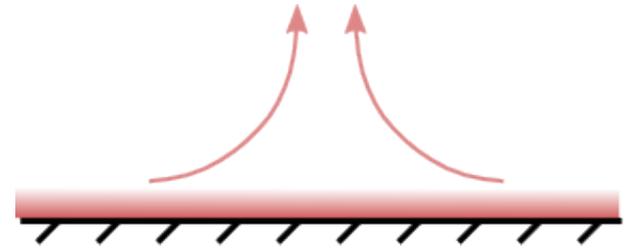


**Step 2:** Air in the lowest few cm is warmed by contact with the ground  
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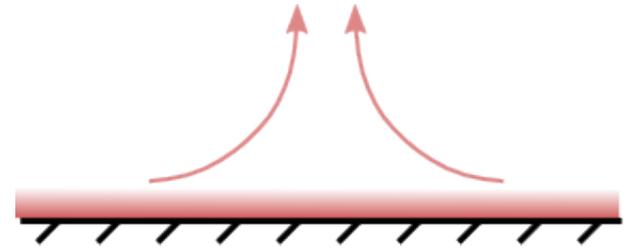
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**Step 3:** Warm air rises, transferring heat upwards



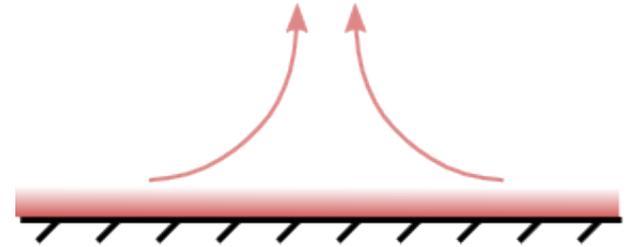
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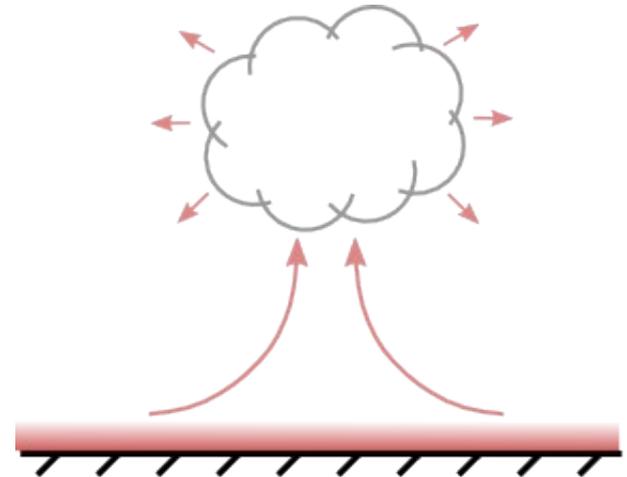


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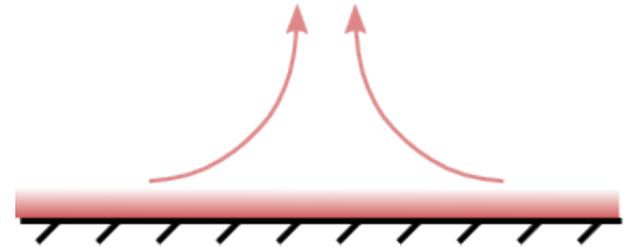


**Step 4:** As air rises it cools, leading to condensation....

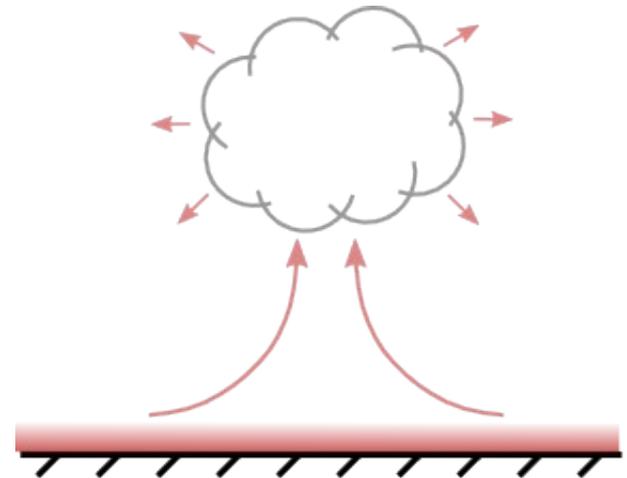


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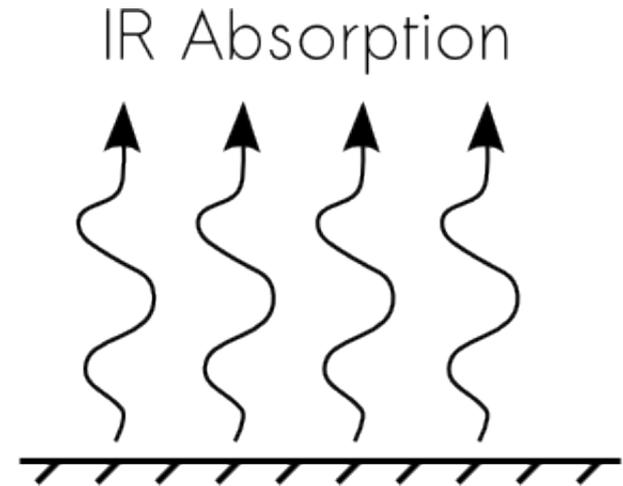


**Step 4:** As air rises it cools, leading to condensation, which brings **latent heat** release

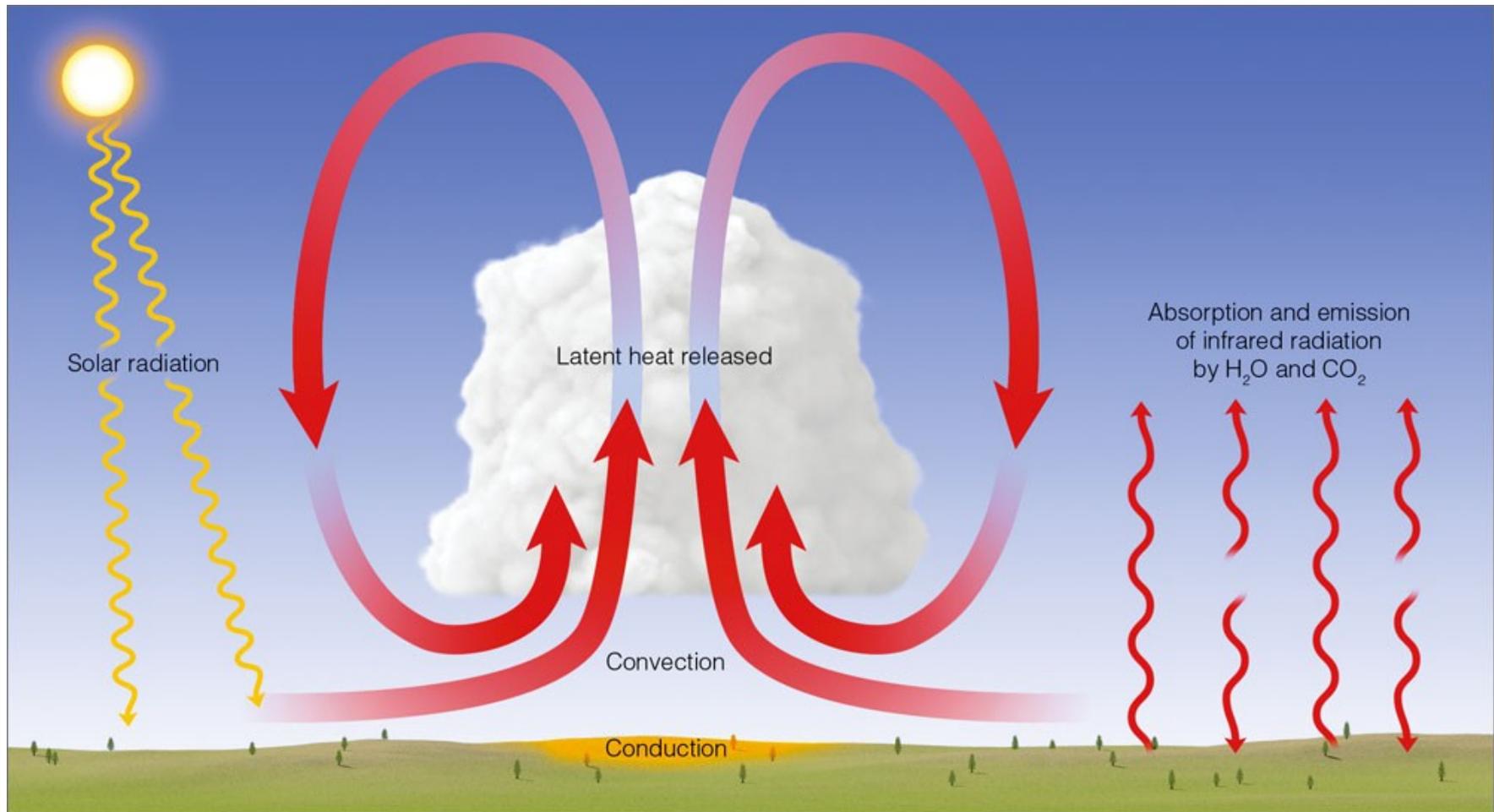


## Warming the Atmosphere from Below

Of course, we also have absorption of radiation..... it's just IR from the Earth instead of shortwave from the sun.



# Warming the Atmosphere from Below



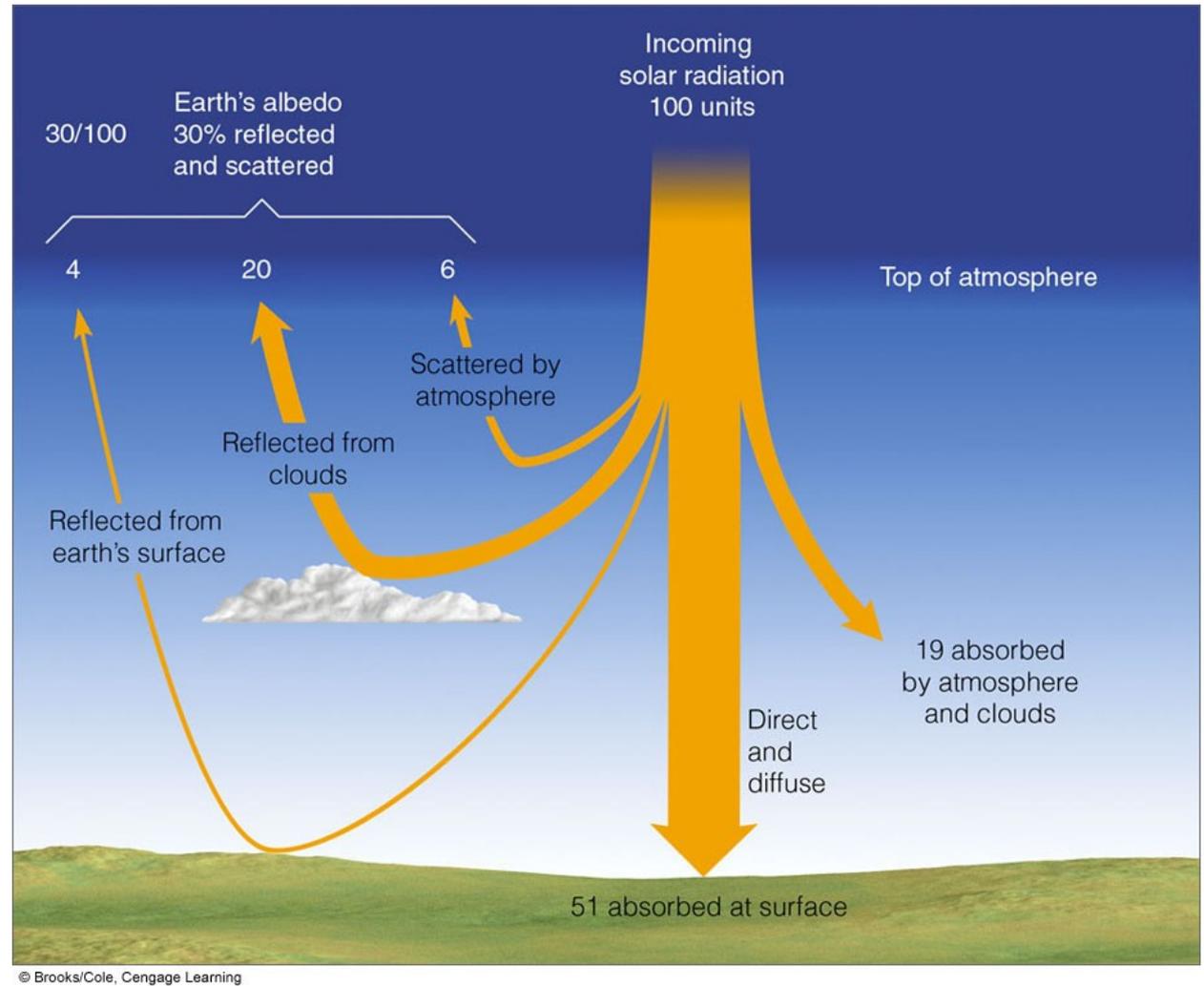
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Putting it together: Warming from below

## Now for the details: The input energy stream

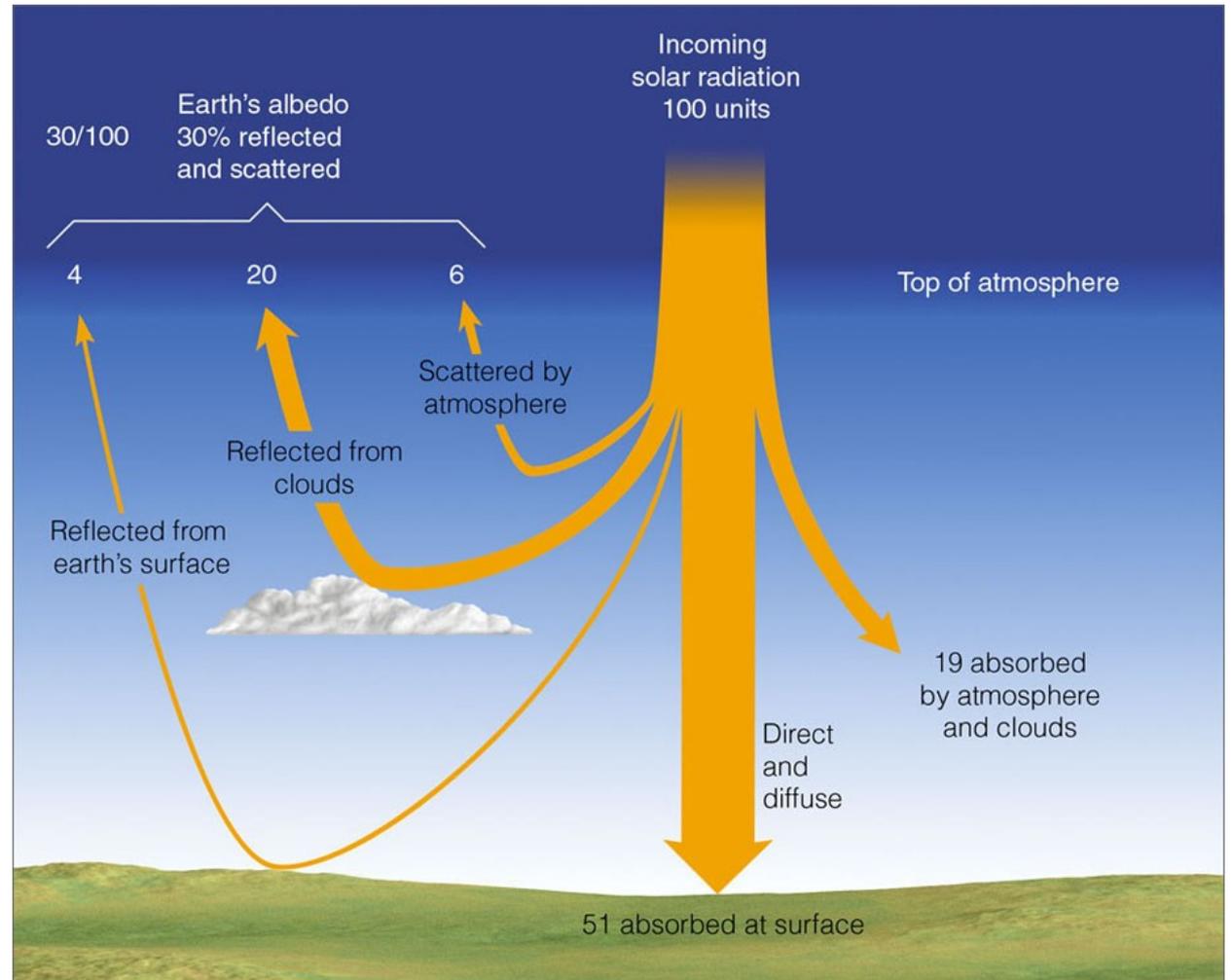
Of the solar energy reaching the Earth.....

- Roughly **30%** is scattered or reflected back to space
- Another **19%** is absorbed directly by the atmosphere (think ozone,  $O_2$ , etc.)

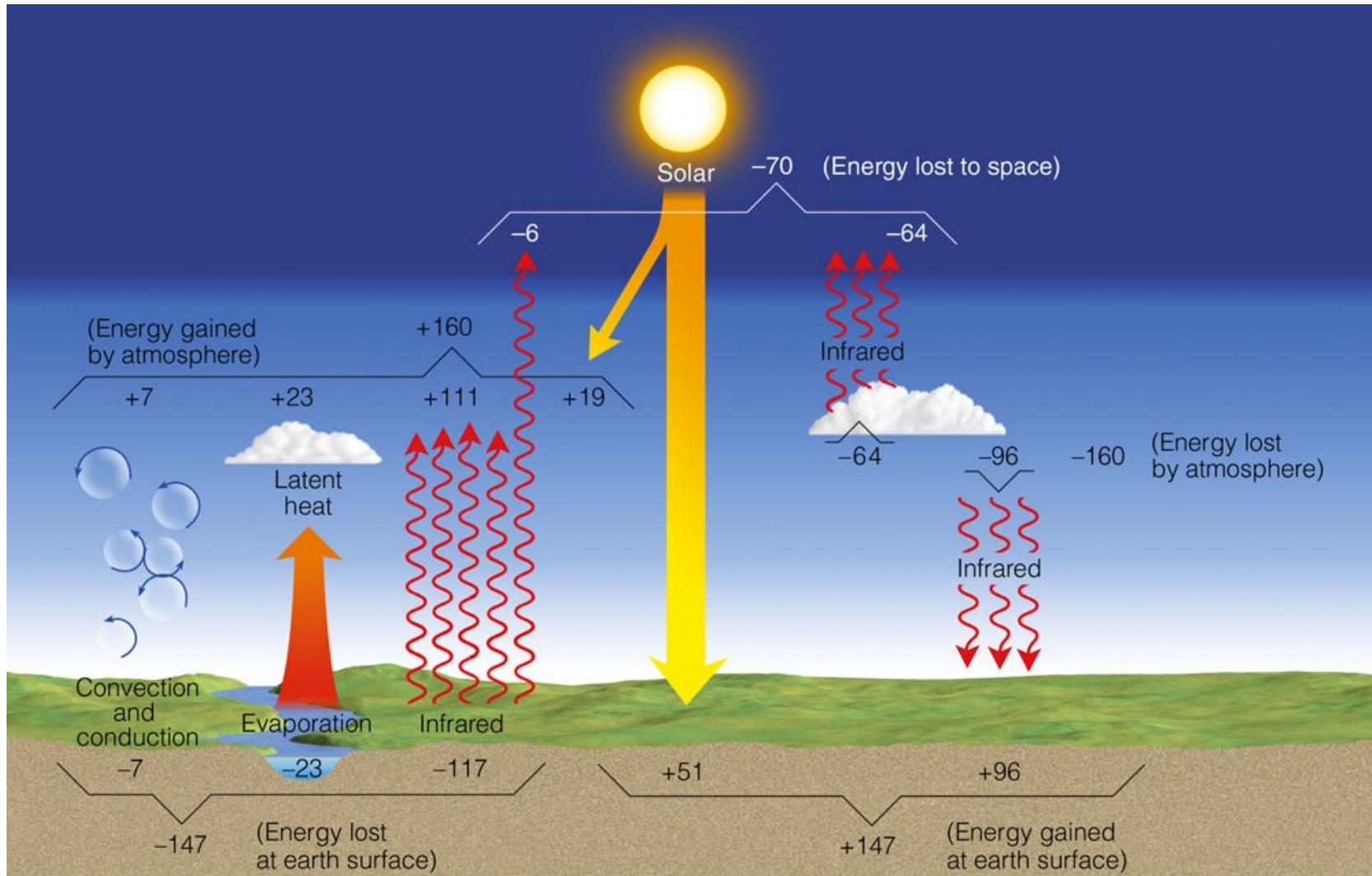


## Now for the details: The input energy stream

**Net result:** Roughly **51%** of the incoming solar radiation gets absorbed by the Earth's surface.



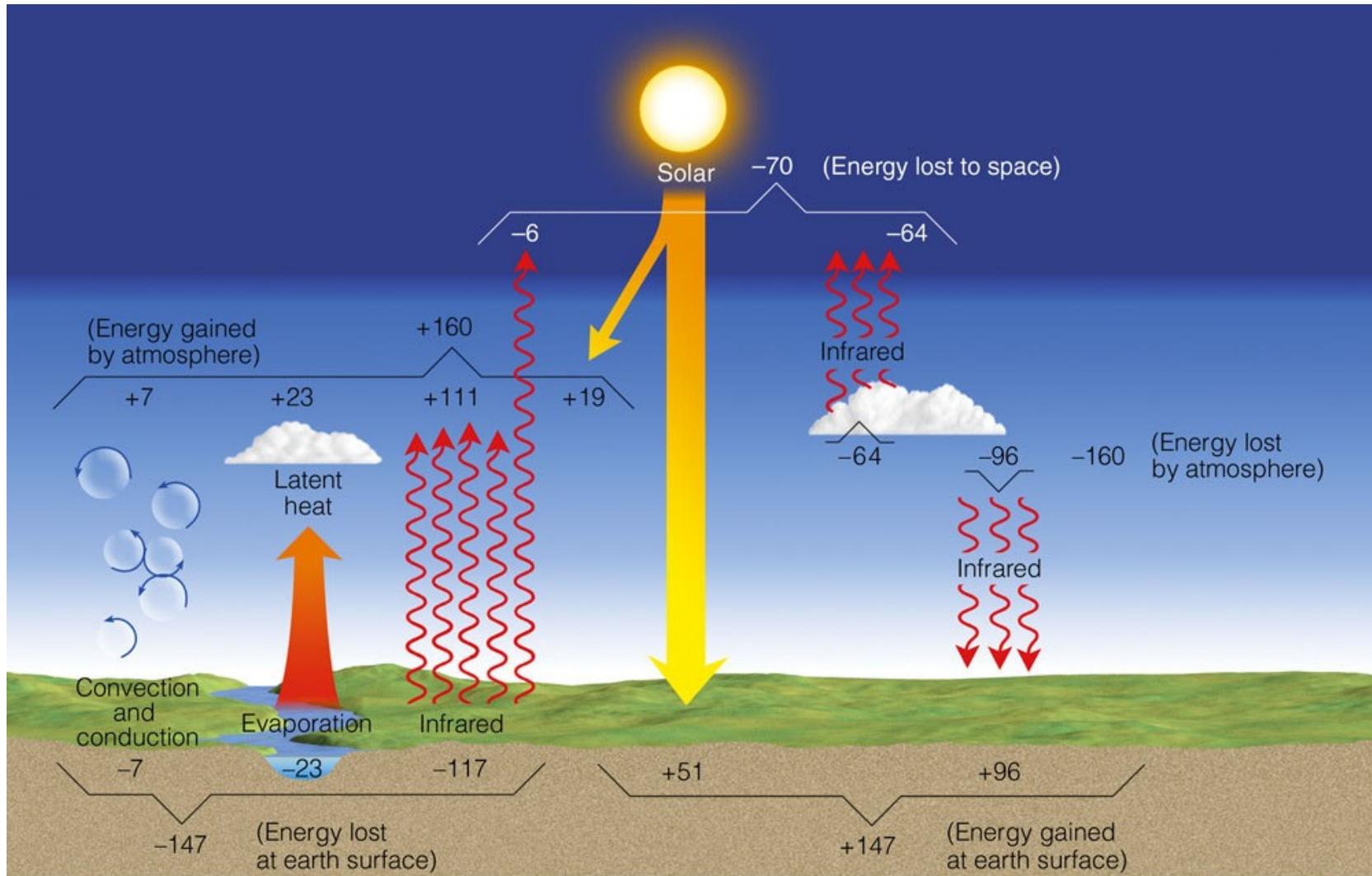
# Now for the details: The total energy budget



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That 51% absorbed by the ground then gets distributed throughout the atmosphere.....

## Now for the details: The total energy budget



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.....which can be pretty complex. But it's the same processes we've already discussed: radiation, conduction, convection and latent heat.