

# Topic # 10

# THE EARTH'S GLOBAL ENERGY BALANCE

Applying the laws, etc. to understand how processes all work together to create global weather & climate!!

Go to p 55 &  
“bookmark” p 129 in Appendix  
in Class Notes  
We'll be referring to both sections  
in class today

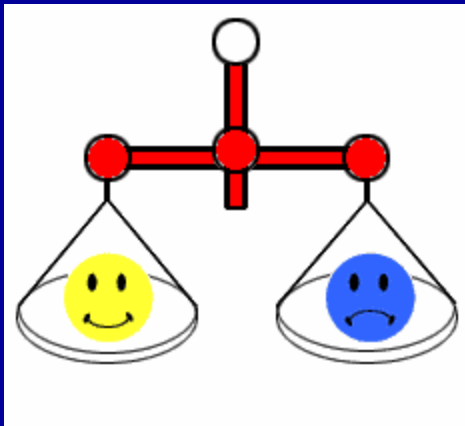
## Today's Quote:

### A Different Sort of "ENERGY BALANCE":

Look at life as an **energy economy game**. Each day, ask yourself,

Are my energy expenditures (actions, reactions, thoughts, and feelings) productive or nonproductive?

During the course of my day, have I accumulated more stress or more peace?

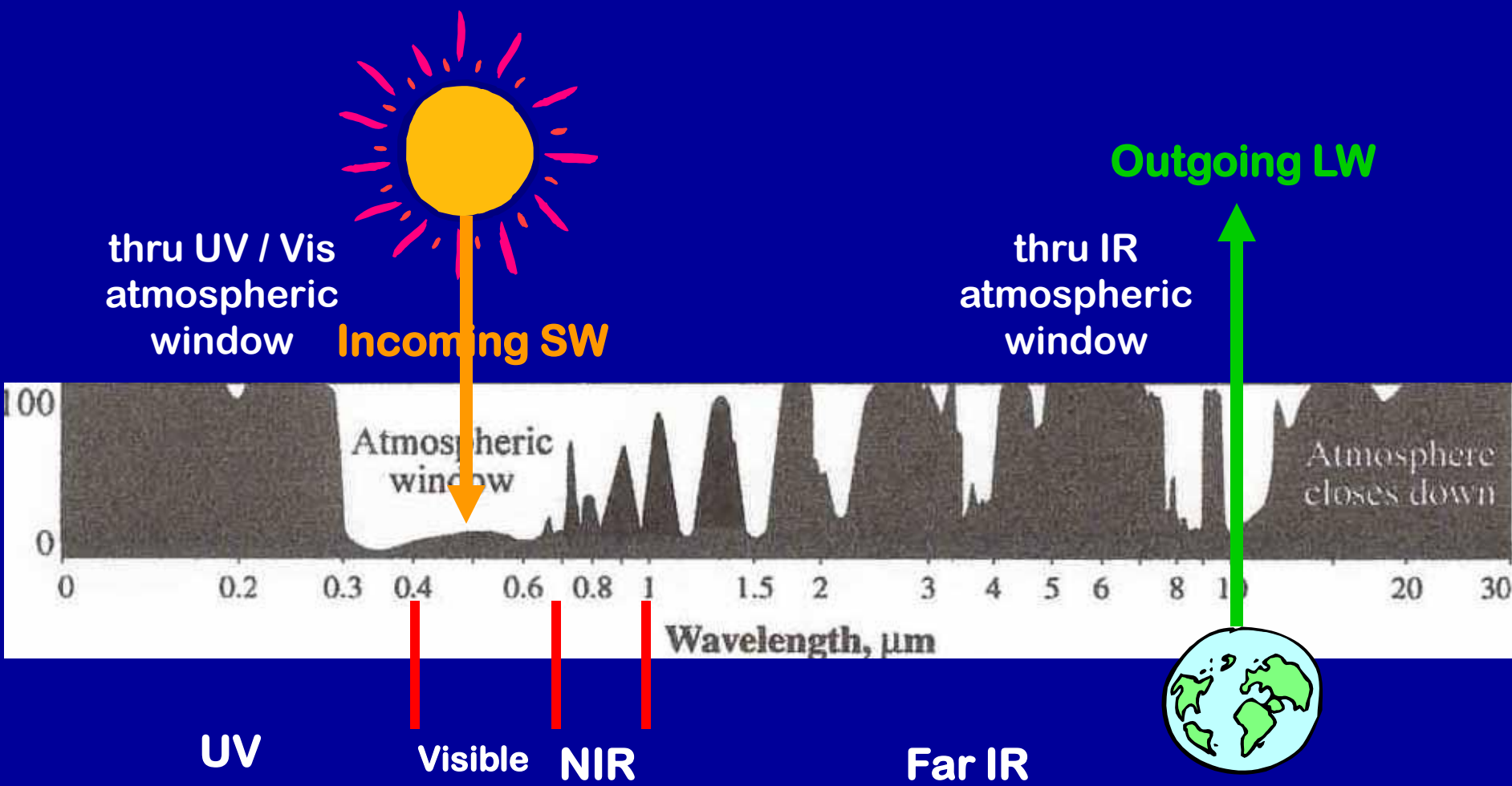


*~ Doc Childre and Howard Martin*

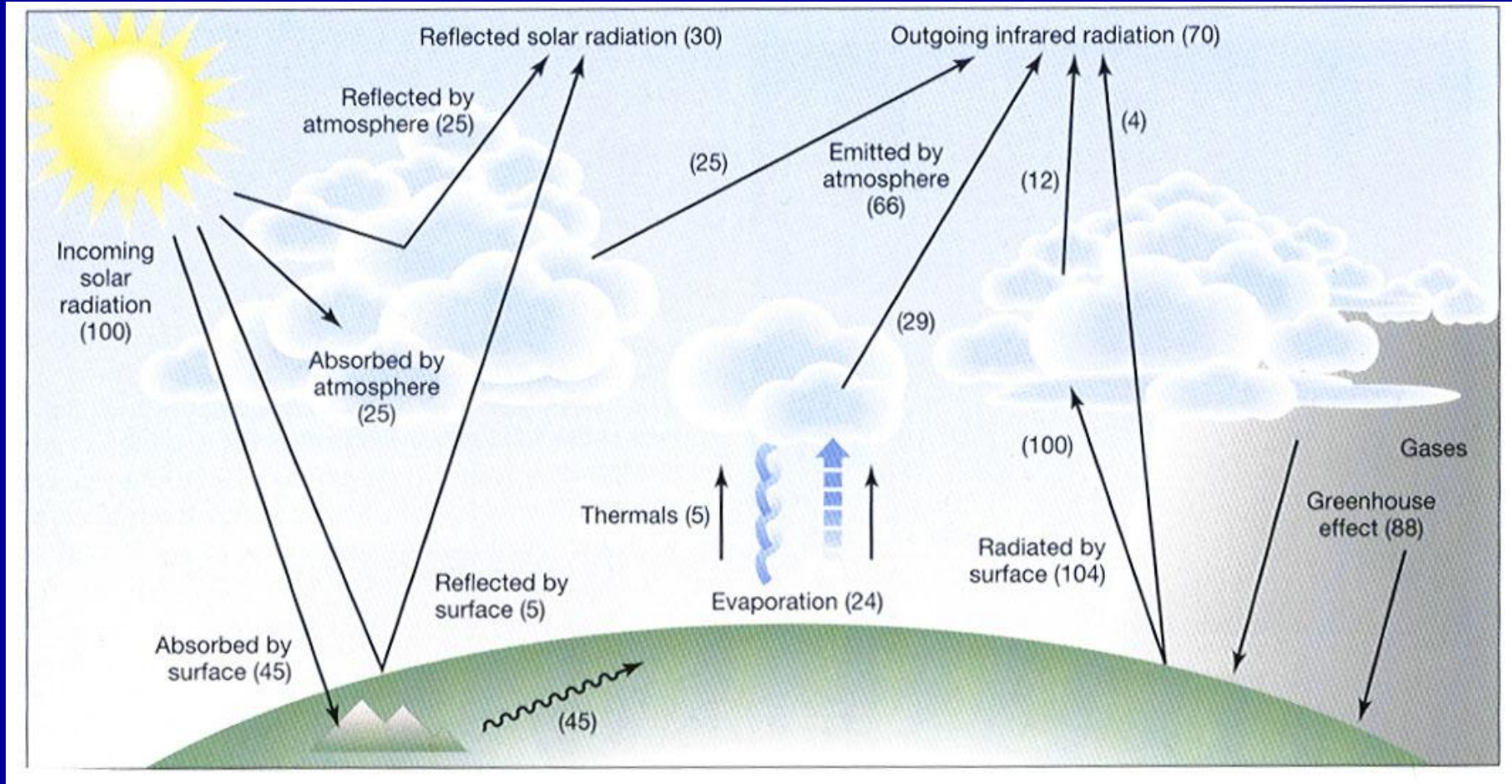
# Review: Absorption curve for the "Whole Atmosphere"

OVERALL  
BALANCE:

$$\text{Incoming} = \text{Outgoing}$$



# Typical Energy Balance Diagram

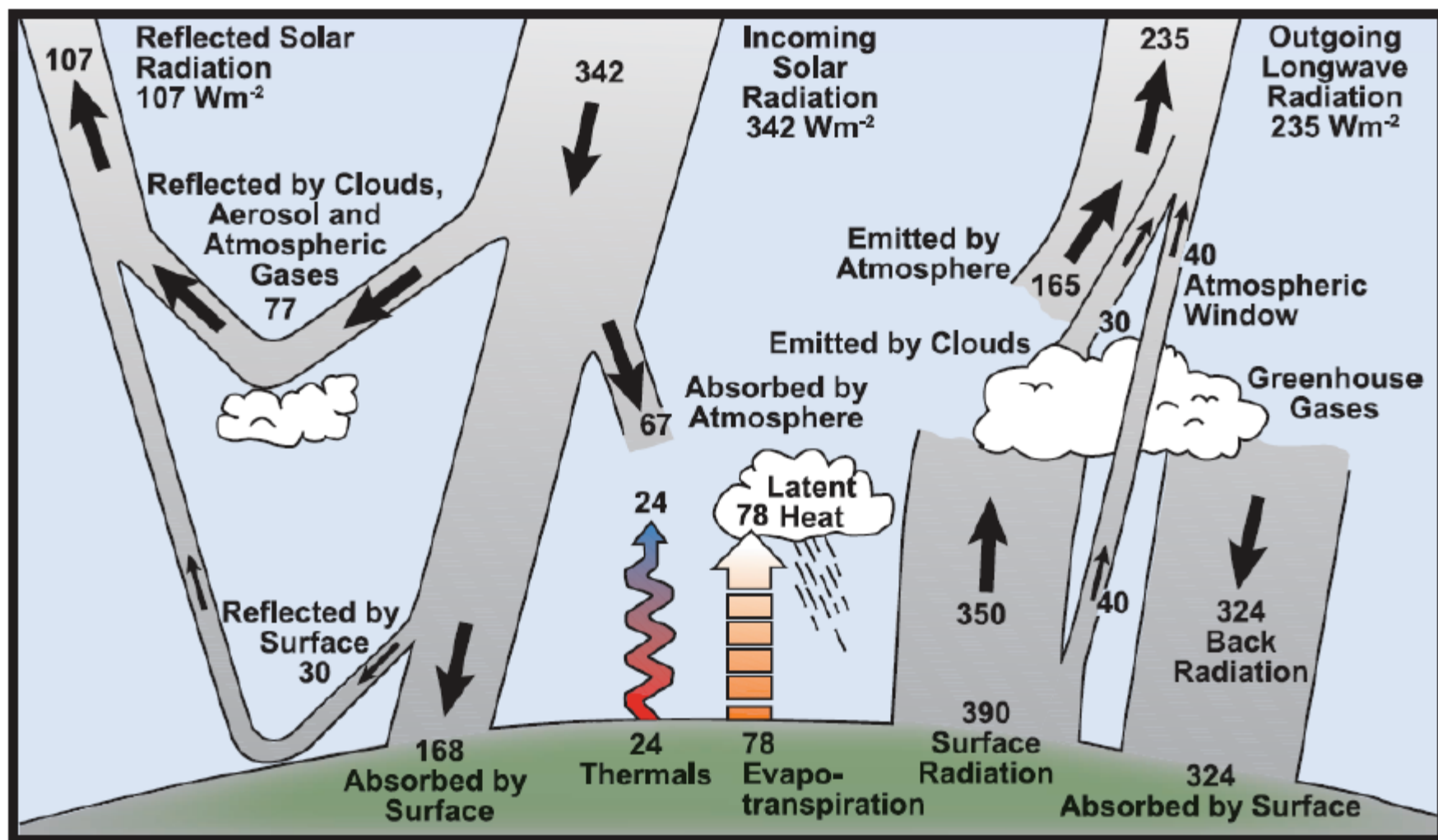


From SGC-E-Text Chapter Fig 3-19

# You've got a similar one on p 55:

## Representation of the Energy Balance & Energy Pathways

*Throughout the whole Earth-Atmosphere system, the energy units balance out, energy is conserved, and the 1st Law of Thermodynamics applies.*



# Energy Balance Equation:

$$R_{\text{net}} = (Q + q) - a - Lu + Ld = H + LE + G$$

(one of several ways this equation can be written)





Up till now we've  
been emphasizing  
Absorption, Emission  
& Transmission →

**BUT Electromagnetic  
Radiation can also be:**

*Electromagnetic Radiation  
can be:*

- **ABSORBED (and EMITTED)**
- **TRANSMITTED**
- **SCATTERED, or**
- **REFLECTED**

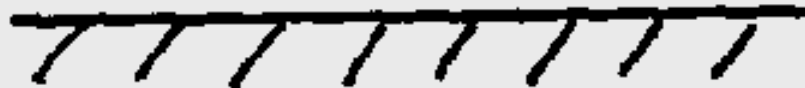
Let's see how it all fits together  
in the various components of  
the **Earth's Energy Balance**

→ We'll use "cartoon symbols" . . .



# “CARTOON” SYMBOLS:

To represent  
the Earth’s surface:



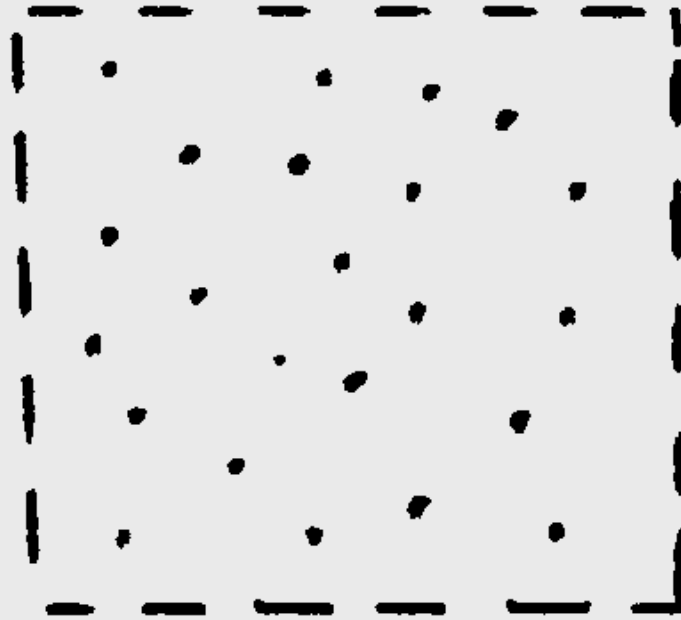
*Note-taking suggested:*



**on blank page 54**



## “CARTOON” SYMBOLS:



To represent the atmosphere –  
composed of both invisible  
gases, aerosols, dust and other  
particulate matter:





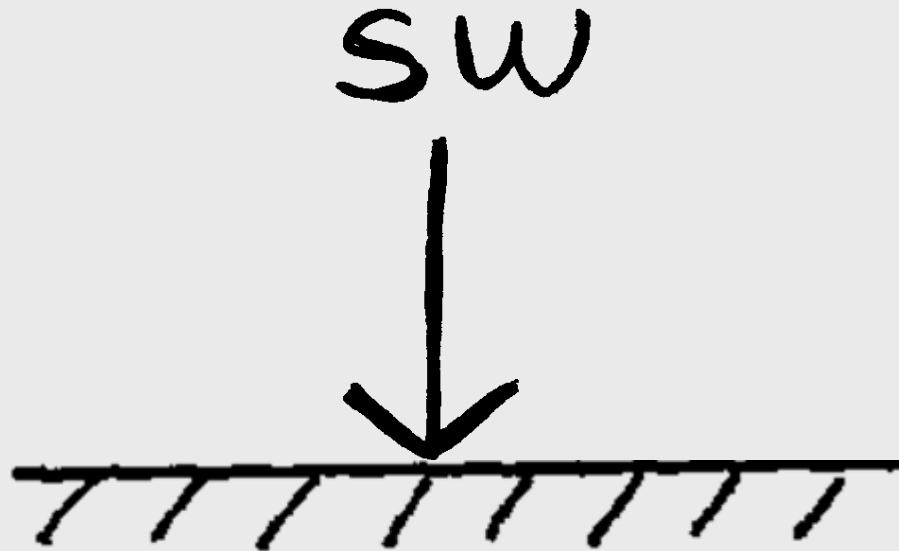
# **“CARTOON” SYMBOLS:**



**To represent CLOUDS**

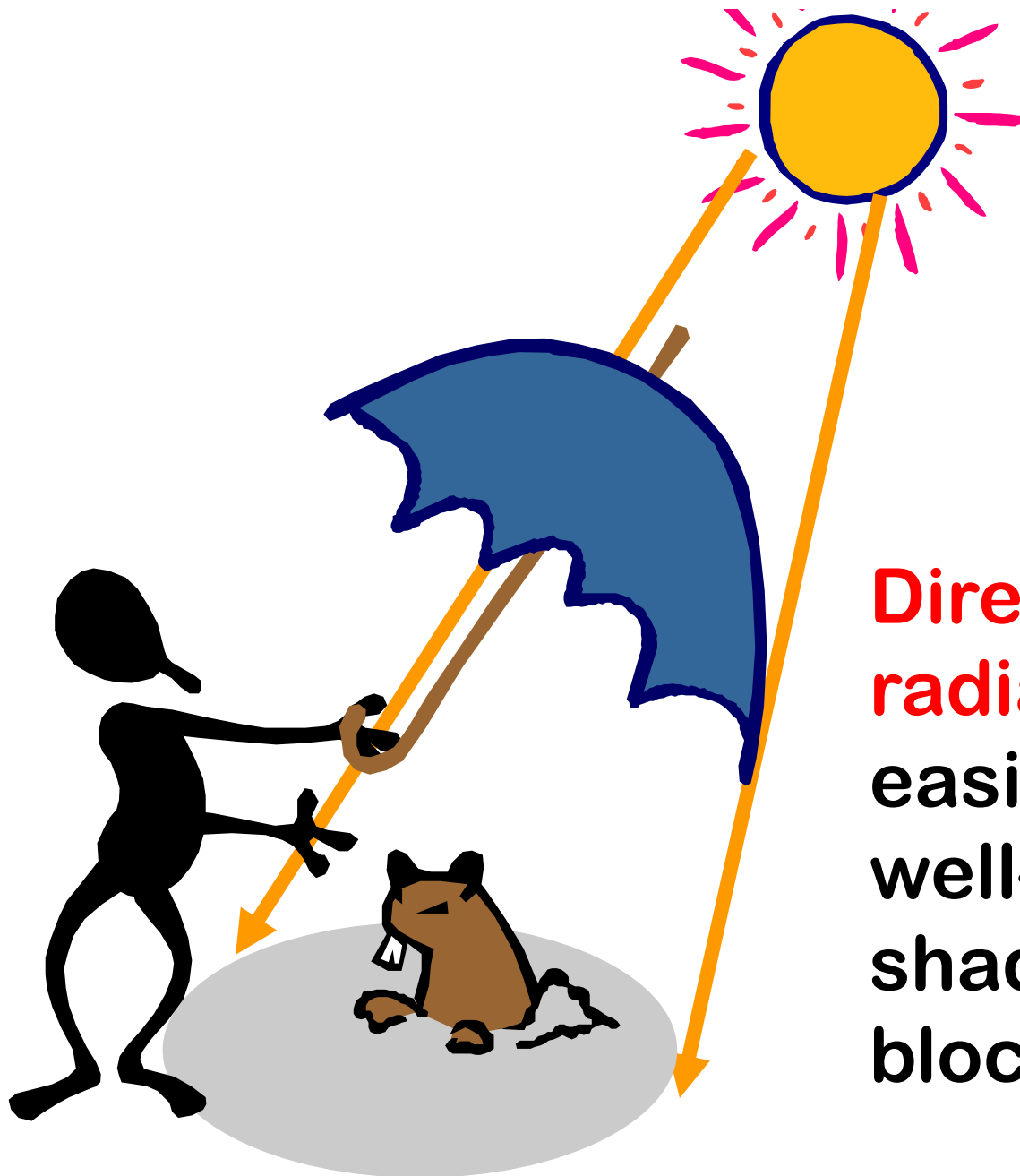


## “CARTOON” SYMBOLS:



To represent SOLAR (shortwave) radiation coming in **DIRECTLY**.  
(aka **Direct shortwave radiation**)

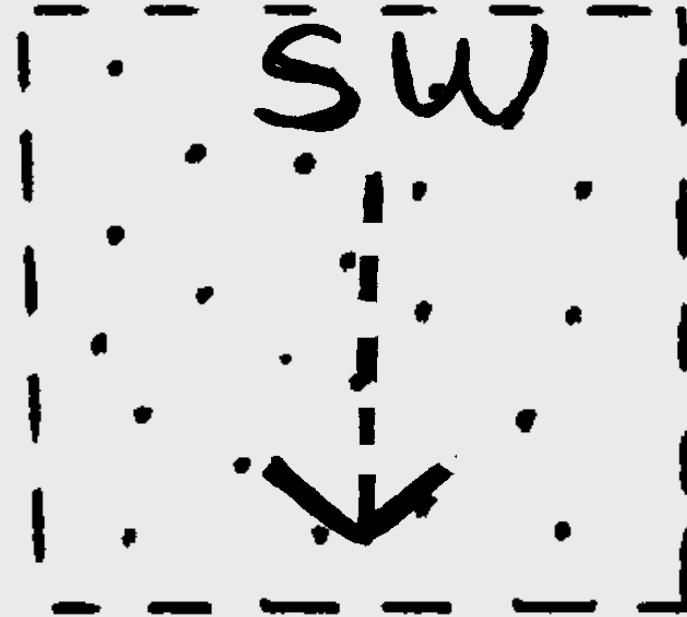




**Direct SW  
radiation**  
easily casts  
well-defined  
shadows when  
blocked



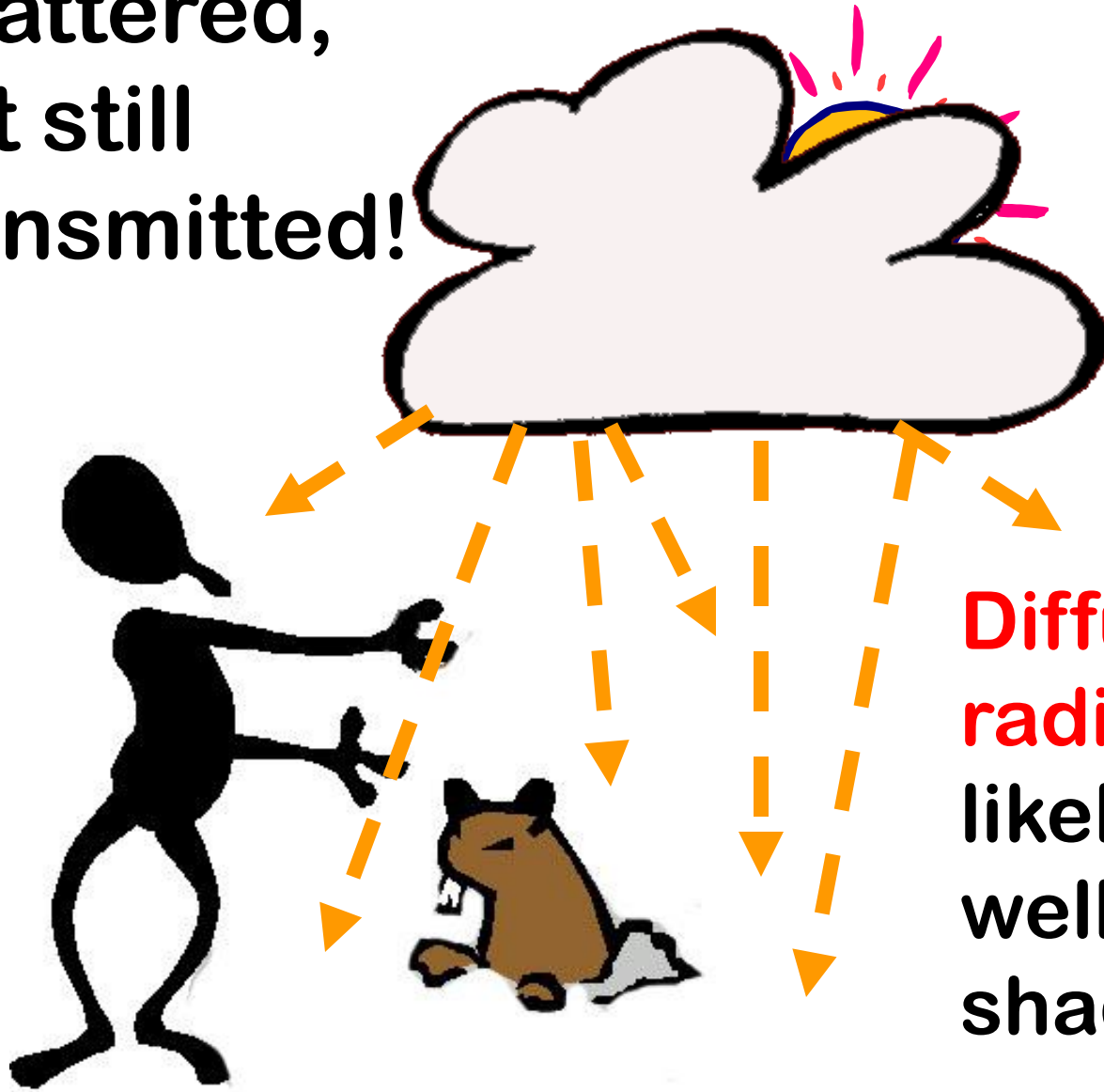
## “CARTOON” SYMBOLS:



To represent SOLAR (shortwave) radiation coming in as **DIFFUSE shortwave radiation**, i.e. scattered by gases, clouds, and particles in the atmosphere.



Scattered,  
but still  
transmitted!



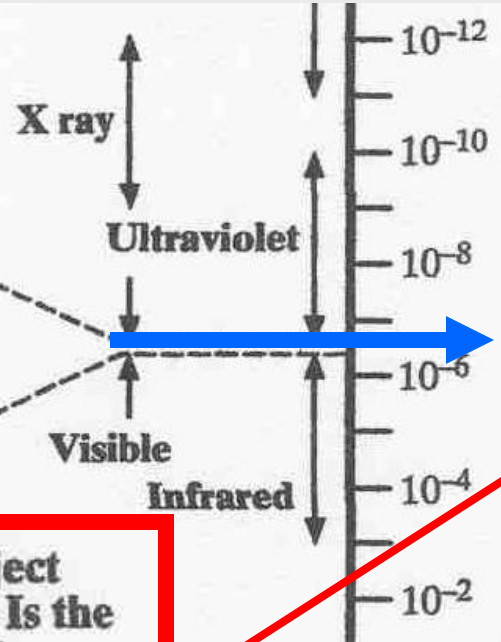
**Diffuse SW  
radiation** is less  
likely to cast a  
well-defined  
shadow!





# What does the scattering?

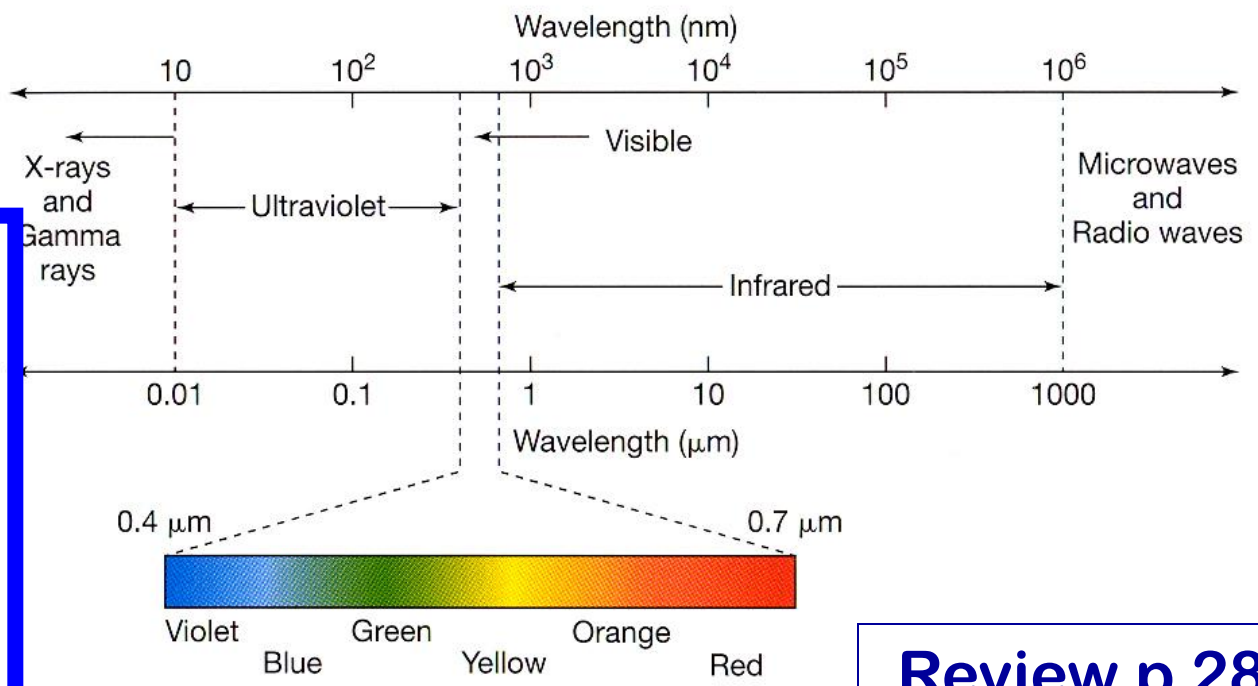
Different sized dust particles, water droplets, aerosols, (even **GAS MOLECULES** themselves!)



- Atom
- DNA molecule
- Amoeba
- Fine dust particle**
- Millimeter
- Centimeter

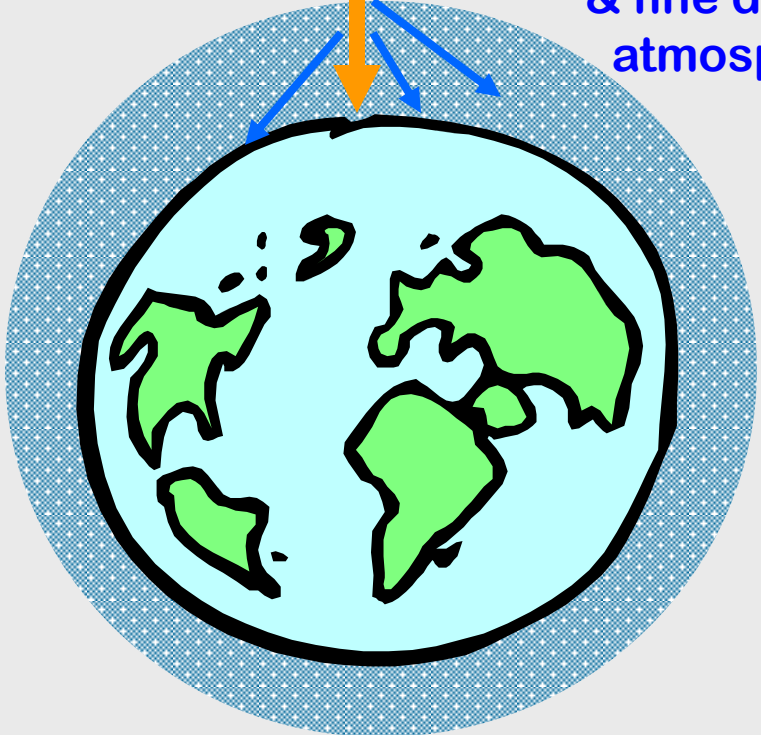
Typical Object Whose Size Is the Same as This Wavelength:

Scattering of visible light wavelengths





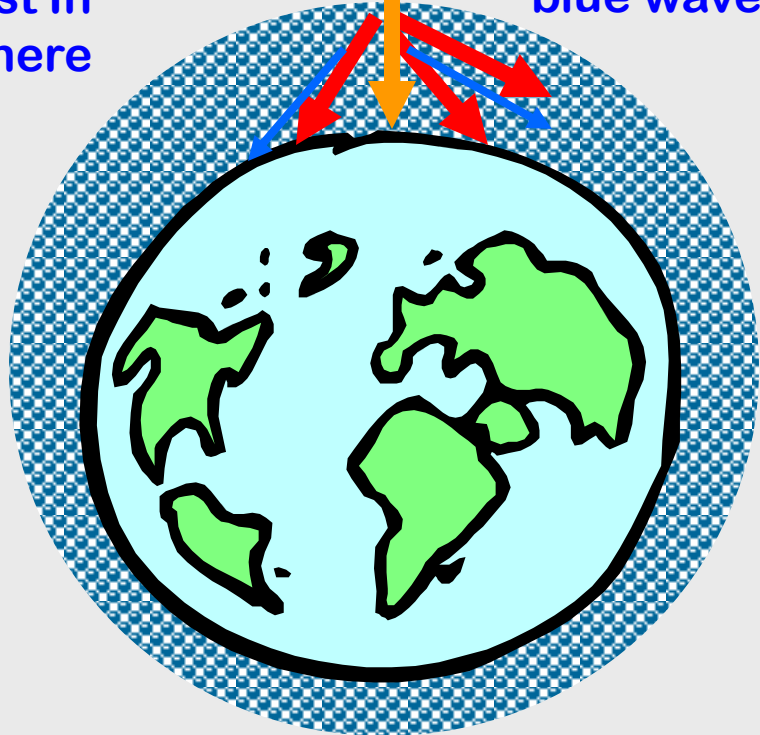
blue wavelengths are scattered easily by gases, water droplets, & fine dust in atmosphere



“Clear” atmosphere composed primarily of fine particles, water droplets, gas molecules



An “aerosol-laden” atmosphere scatters the **LONGER (red) wavelengths** more readily than the shorter blue wavelengths



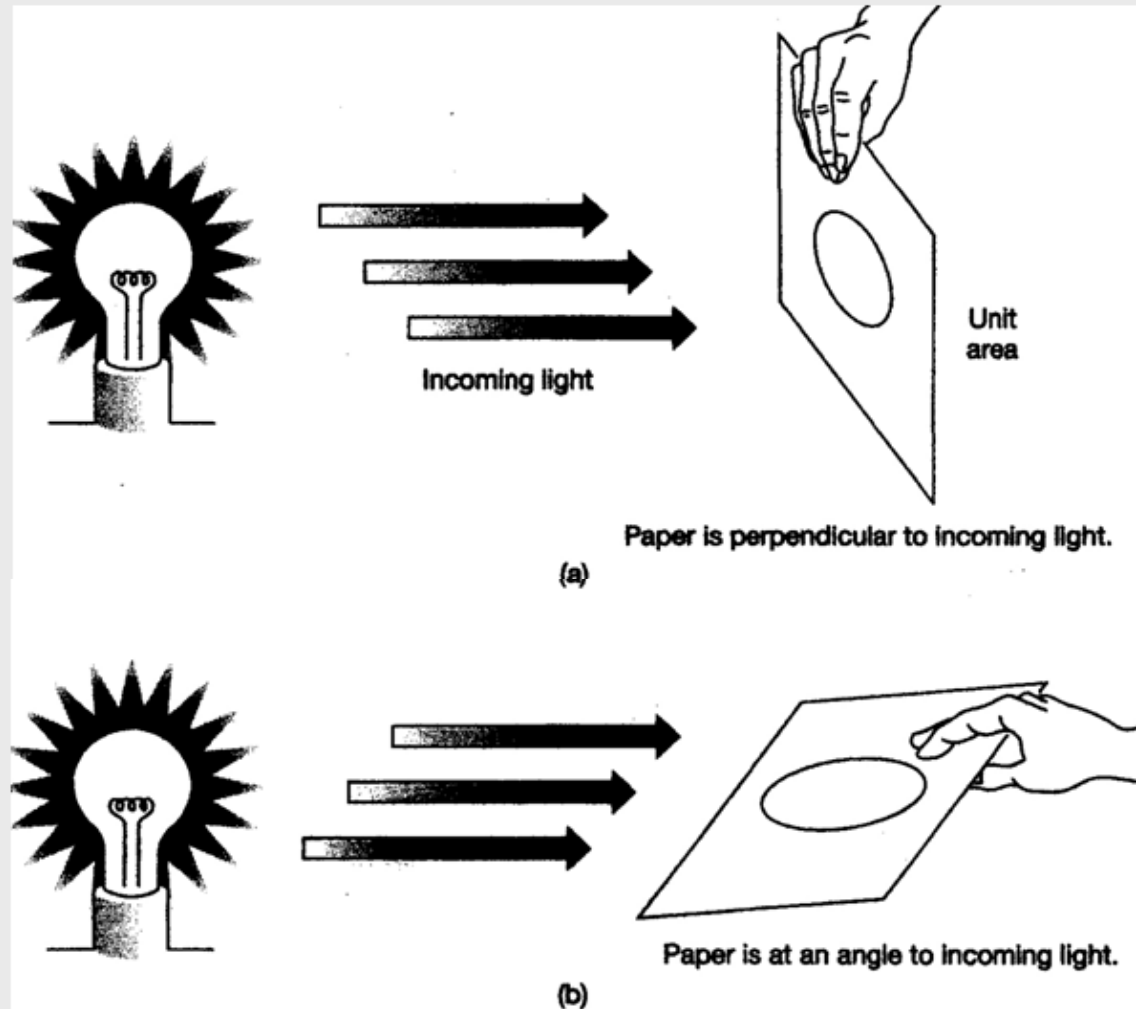
“Dirty” (aerosol-laden) atmosphere composed of fine particles, gases, & H<sub>2</sub>O -- **PLUS larger dust particles, aerosols, pollution, etc.**



**ALSO:** The **angle** at which direct SW radiation is intercepted by a surface makes a difference!!

Radiation is concentrated over a small area & hence is more intense when it comes in perpendicular to the surface

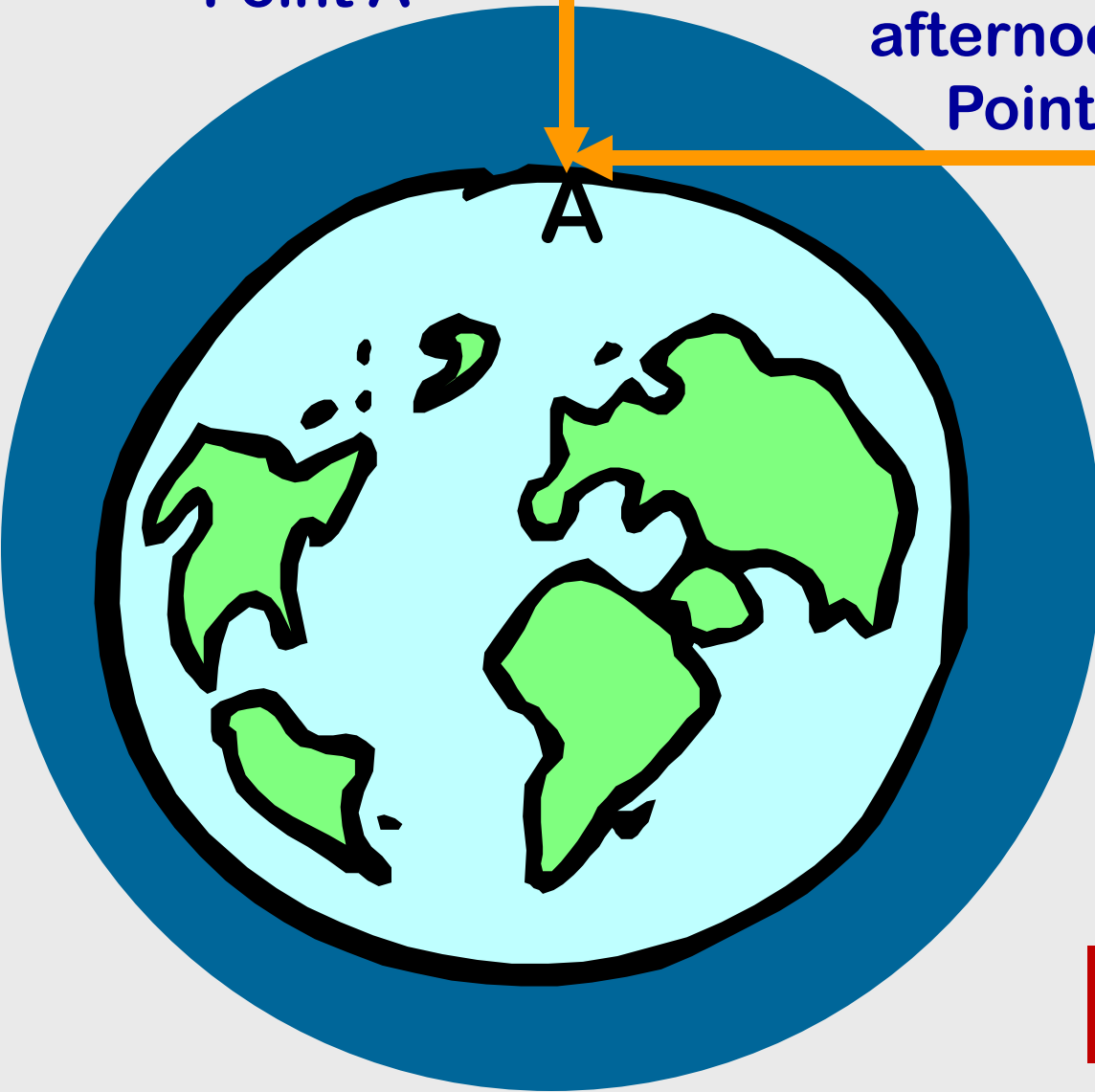
Radiation is spread out over a larger area & hence is less intense per unit area when it comes in at an angle.



From Figure 3-4 in SGC-E-text, Ch 3

Scenario 1:  
NOON at  
Point A

Scenario 2: Late  
afternoon at  
Point A



Q1: which scenario  
will deliver MORE  
INTENSE radiation  
to Point A?

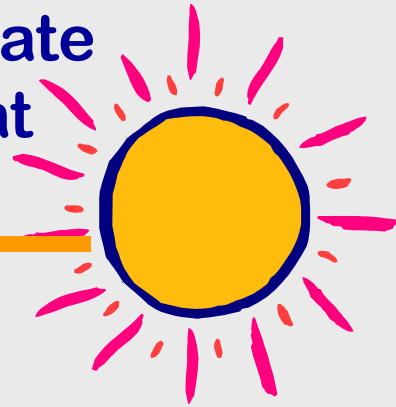
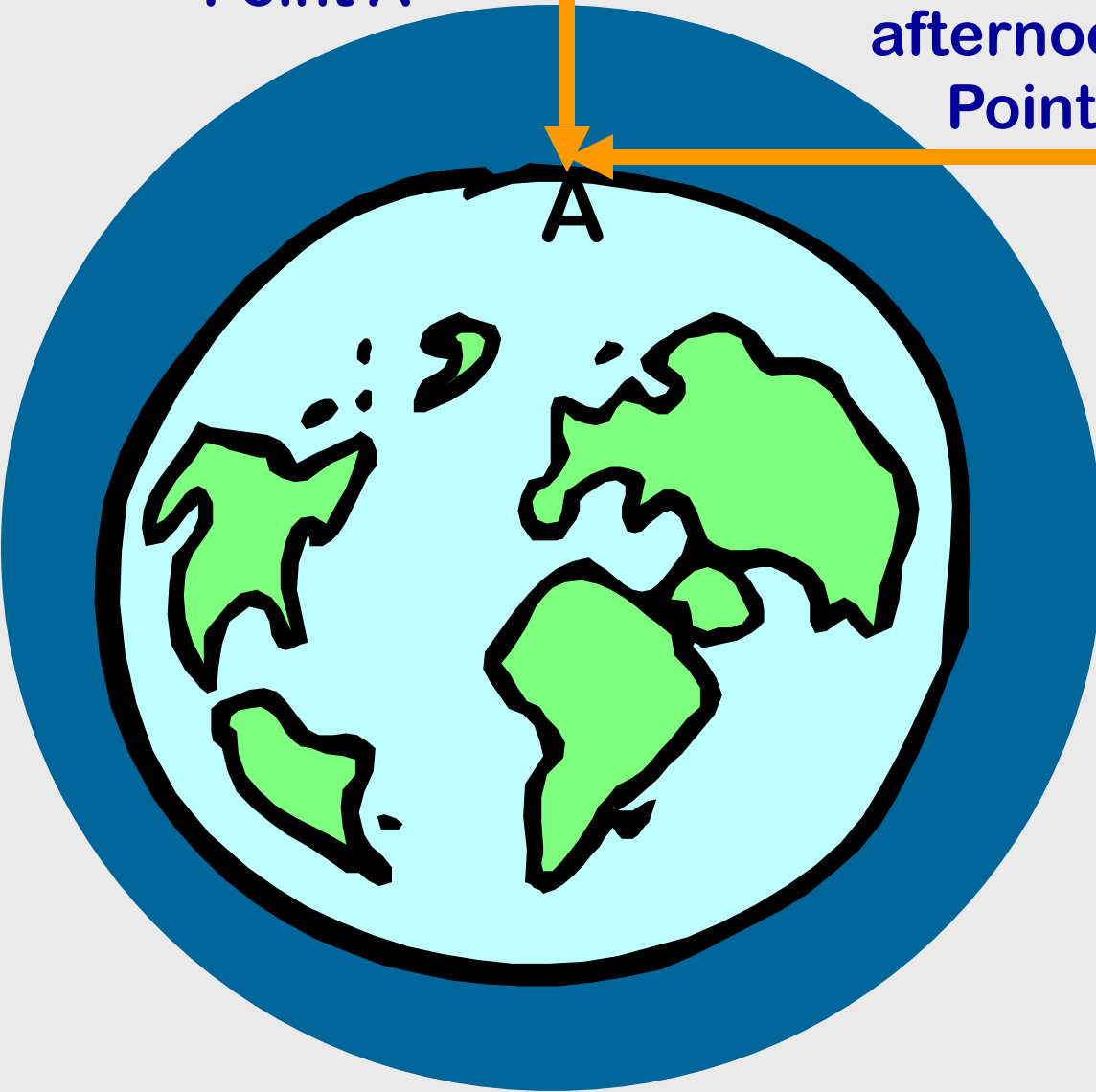
1 = Scenario 1

2 = Scenario 2

**CLICKER Q!**

Scenario 1:  
NOON at  
Point A

Scenario 2: Late  
afternoon at  
Point A



Q1: which scenario  
will deliver MORE  
INTENSE radiation  
to Point A?

1 = Scenario 1

2 = Scenario 2

**Q2- WHY is the intensity of the SW radiation at Point A not as strong in the late afternoon as it is at noon?**

**1 = because as the Sun goes down close to sunset time, it gives off less radiation**

**2 = because the SW radiation is coming in at an angle in the late afternoon, and is not directly overhead (perpendicular) like it is at noon.**

**3 = because the SW radiation is being transmitted through a thicker atmosphere & hence scattered more**

**4 – BOTH #2 and #3 are applicable!**

**Q2- WHY is the intensity of the SW radiation at Point A not as strong in the late afternoon as it is at noon?**

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**4 – BOTH #2 and #3 are applicable!**



## “CARTOON” SYMBOLS:



To represent SOLAR (shortwave) radiation that is **REFLECTED** (or scattered) **BACK TO SPACE** by: atmosphere, clouds, Earth's surface, etc.





*Key term:*

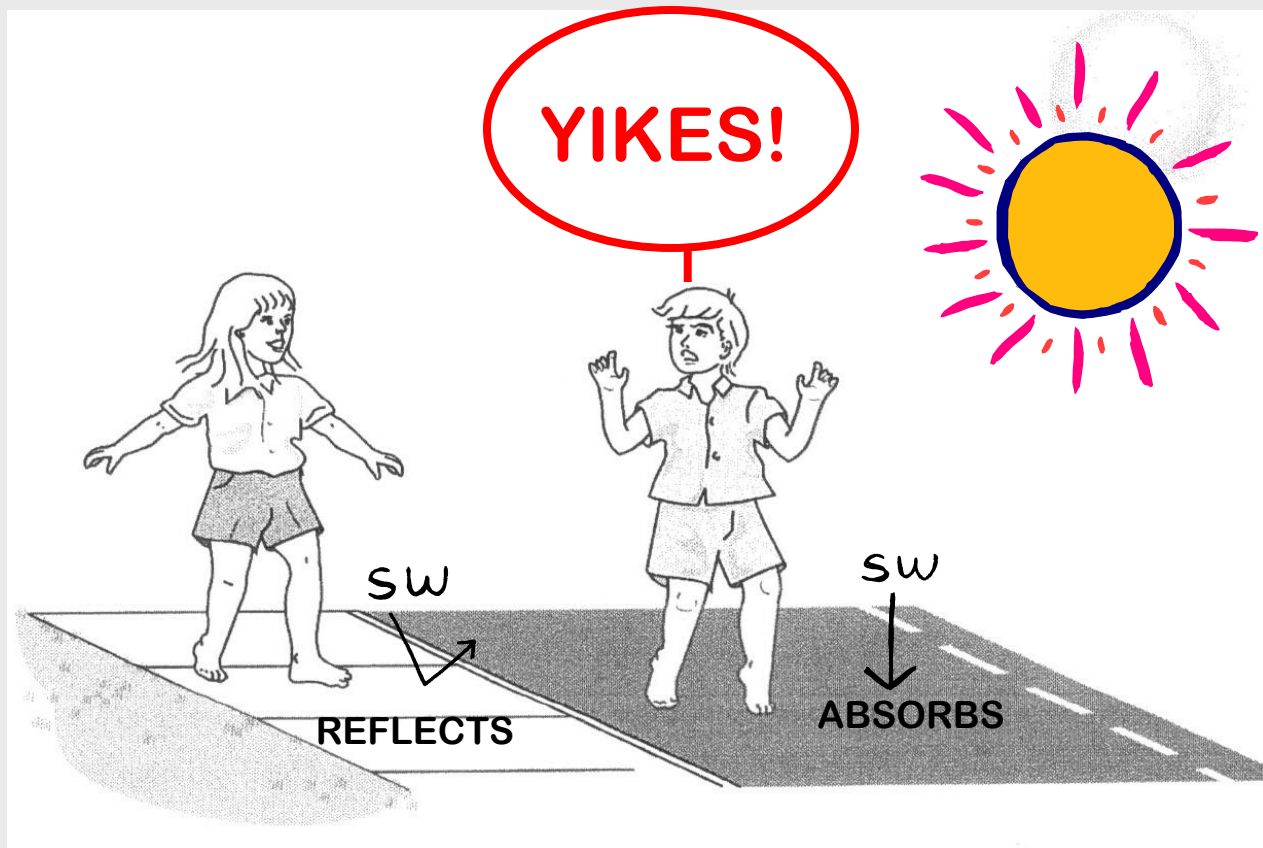
ALBEDO = reflectivity of a surface  
“symbol” = **a**

Represented as:

a decimal from **0 to 1.0** or

**% from 0 – 100 %** (perfect reflectivity)

Hence, amount **ABSORBED** =  $(1 - \text{albedo})$



If a surface's albedo is HIGH, absorption by the surface is LOW  
→ **COOLER** surface

If a surface's albedo is LOW absorption by the surface is HIGH =>  
**HOTTER** surface!

## Albedos of Some Common Surfaces

<i>Type of Surface</i>		<i>Albedo</i>
Sand		0.20–0.30
Grass		0.20–0.25
Forest	<b>Low albedo</b>	0.05–0.10
Water (overhead Sun)		0.03–0.05
Water (Sun near horizon)		0.50–0.80
Fresh snow		0.80–0.85
Thick cloud	<b>High albedo</b>	0.70–0.80

→ **CLOUDS:** 0.44 (high, thin clouds) - 0.90 (low, thick clouds)

**AVERAGE PLANET EARTH = ~ 0.30**

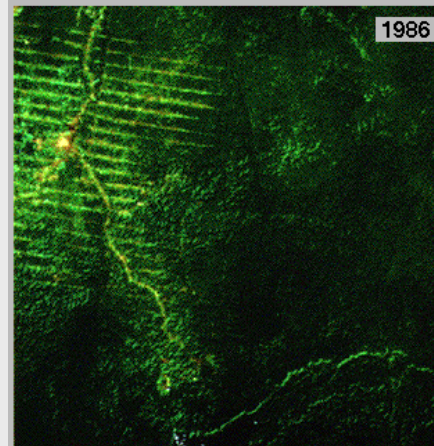
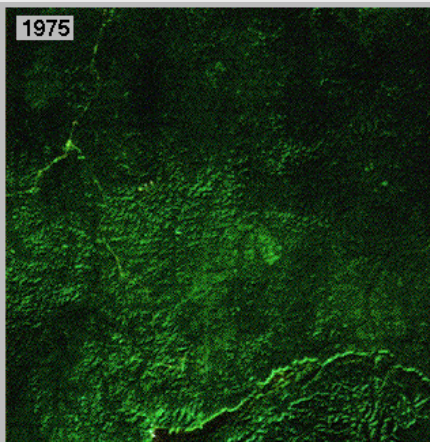
# CLICKERS again!

**Q3: What will happen to incoming SW over the Amazon Rain Forest if parts of it are deforested?**

**1 = more SW will be absorbed**

**2 = less SW will be absorbed**

Before



After

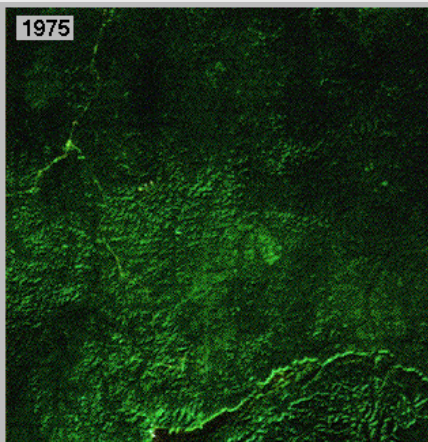
**Q3: What will happen to incoming SW over the Amazon Rain Forest if parts of it are deforested?**

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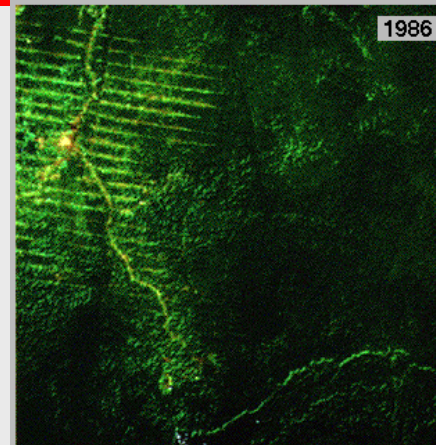
**2 = less SW will be absorbed**



Before



After





## “CARTOON” SYMBOLS:

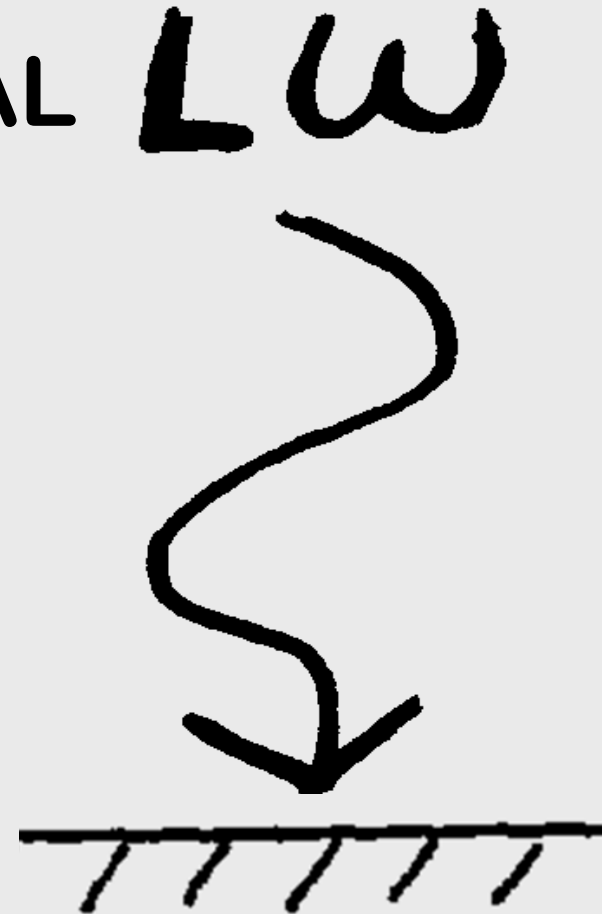
To represent **TERRESTRIAL** (longwave IR) radiation emitted upward by the Earth’s surface or the atmosphere





# “CARTOON” SYMBOLS:

To represent TERRESTRIAL  
(longwave IR) re-radiation  
emitted downward by the  
Earth’s ATMOSPHERE



Now flip to p 129 in  
Appendix →

## PUTTING IT TOGETHER:

Can you place + and – signs where  
they ought to go in the equation?

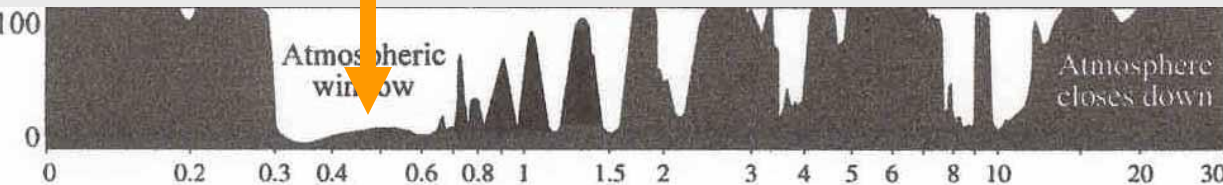
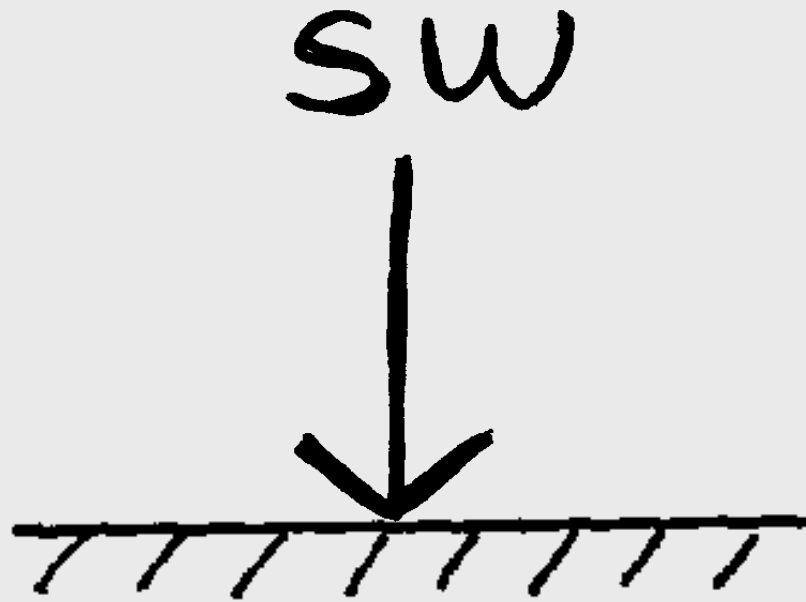
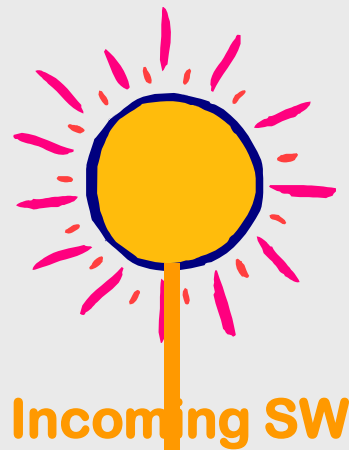
$$R_{\text{NET}} = \begin{array}{ccccccc} \text{SW} & & \text{SW} & & \text{SW} & & \text{LW} \\ \downarrow & + & \downarrow & - & \swarrow & - & \uparrow \\ & & \text{---} & & & & \downarrow \\ & & & & & & \text{LW} \\ R_{\text{NET}} = & (Q & + & q) & - & a & - & Lu & + & Ld \end{array}$$

$$R_{\text{NET}} = \begin{array}{c} \text{SW} \\ \downarrow \\ \text{+} \end{array} \begin{array}{c} \text{SW} \\ \vdots \\ \downarrow \\ \text{+} \end{array} \begin{array}{c} \text{SW} \\ \searrow \\ \text{-} \end{array} \begin{array}{c} \uparrow \\ \text{LW} \\ \text{-} \end{array} \begin{array}{c} \text{LW} \\ \downarrow \\ \text{+} \end{array} =$$

Now we'll look at the energy pathways in a bit more detail by combining the cartoon symbols in various ways . . .

To describe the real  
Earth-Atmosphere  
system, **more detail** is  
needed in our simple  
representation . . . . .  
We'll use our symbols to  
build an **energy balance**  
**“model”**

# SW BEAMED DIRECTLY TO EARTH'S SURFACE WHERE IT IS ABSORBED:



# SW REFLECTED BACK TO SPACE:

By  
clouds



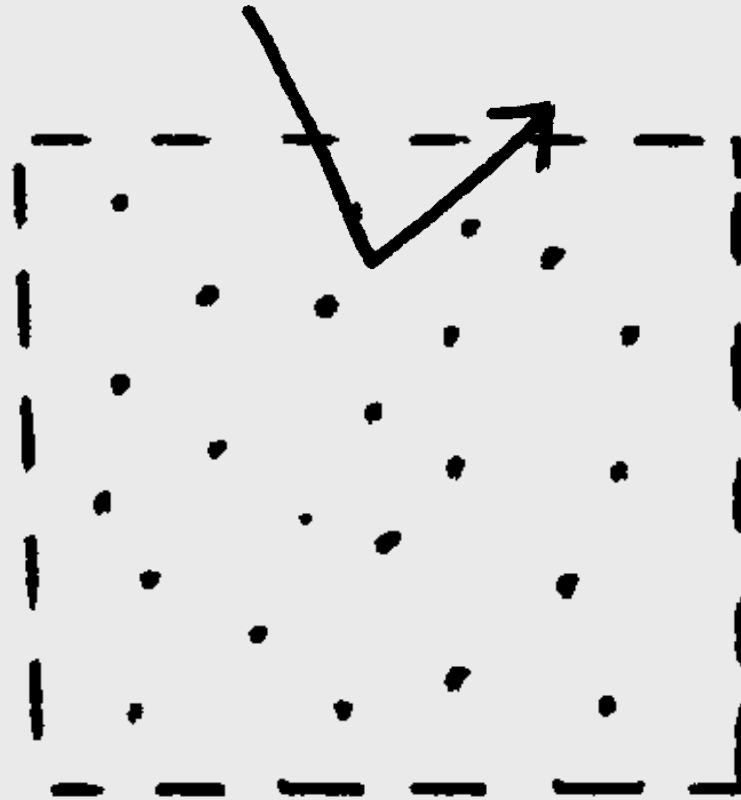
By  
Earth's  
surface



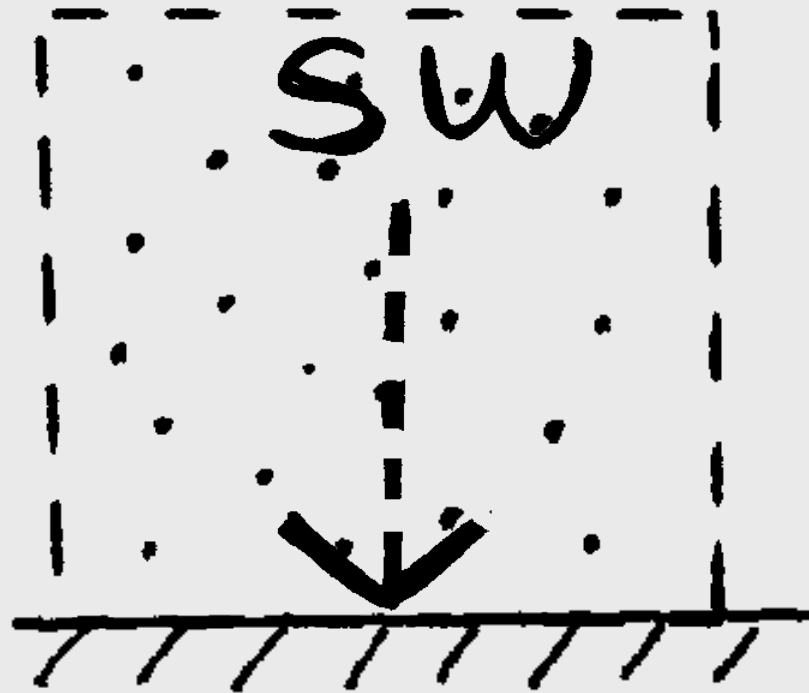
This is determined by  
the ALBEDO of the  
clouds or surface

# SW SCATTERED BACK TO SPACE BY ATMOSPHERE:

SW



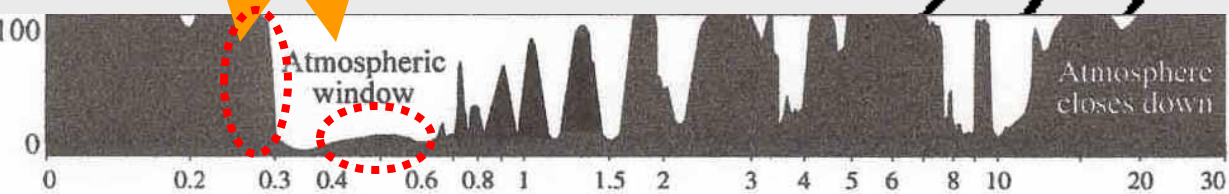
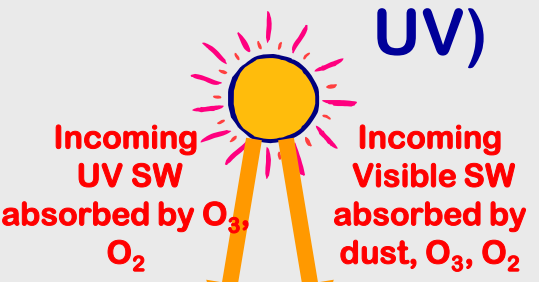
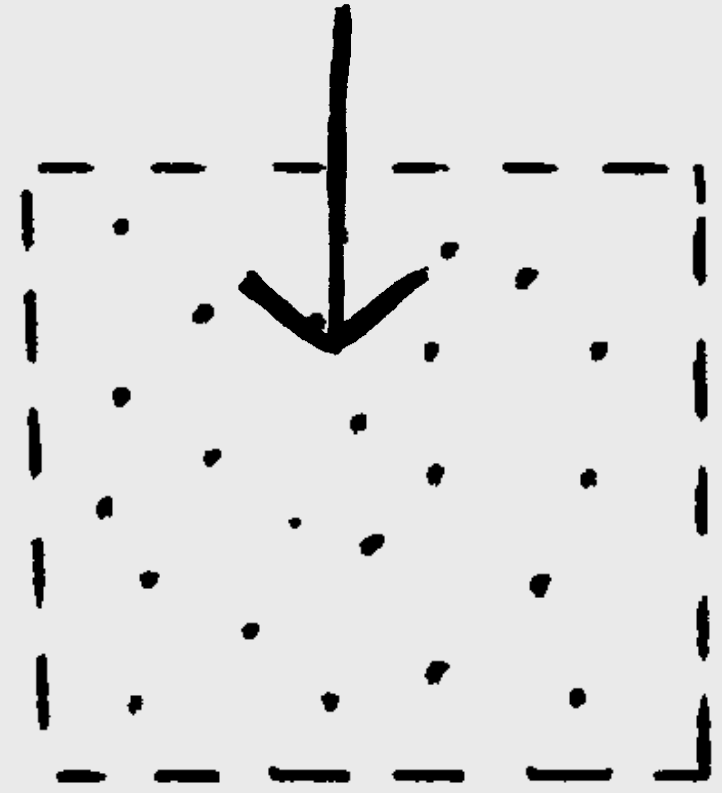
**SW** SCATTERED DOWN TO EARTH'S SURFACE where it is absorbed



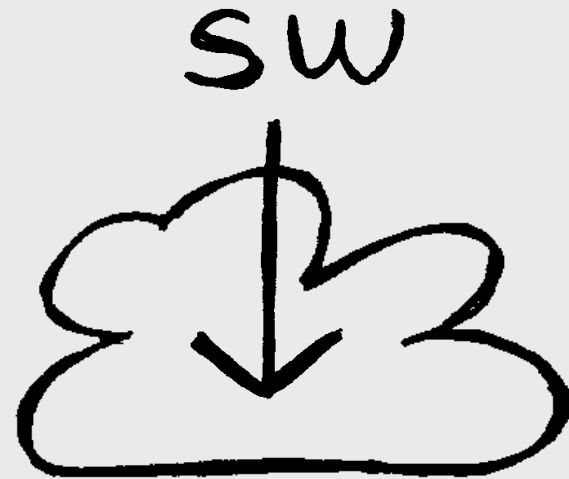


**SW ABSORBED  
IN ATMOSPHERE  
BY GASES,  
DUST, etc.**  
(including Ozone  
absorbing shortwave  
UV)

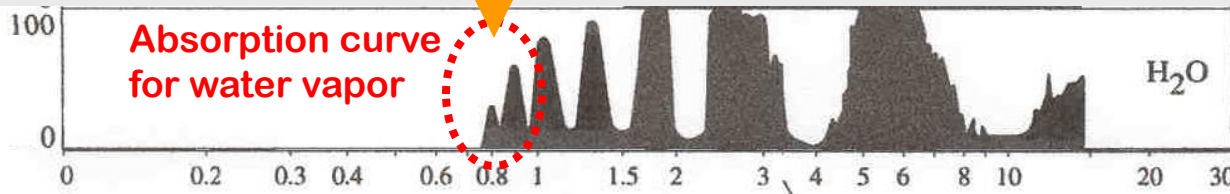
SW



**SW ABSORBED**  
**In ATMOSPHERE**  
**BY CLOUDS &**  
**H2O vapor:**



(NOTE: clouds are made up of tiny droplets of water surrounded by lots of water vapor)

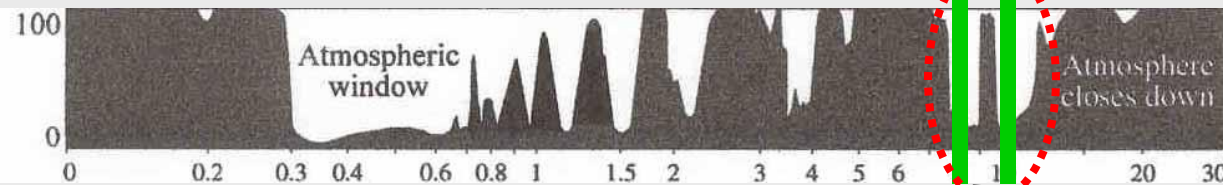


LW (IR) EMITTED  
FROM EARTH'S  
SURFACE

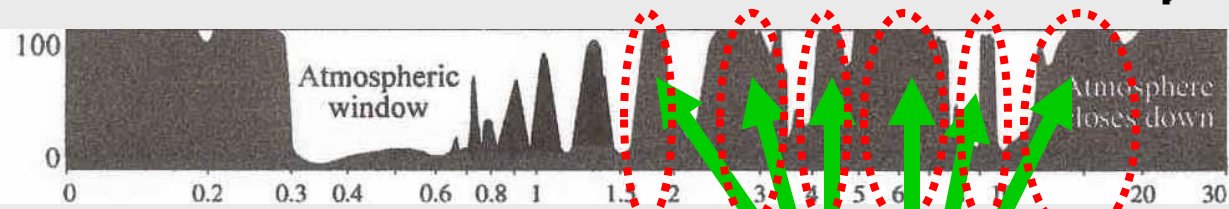
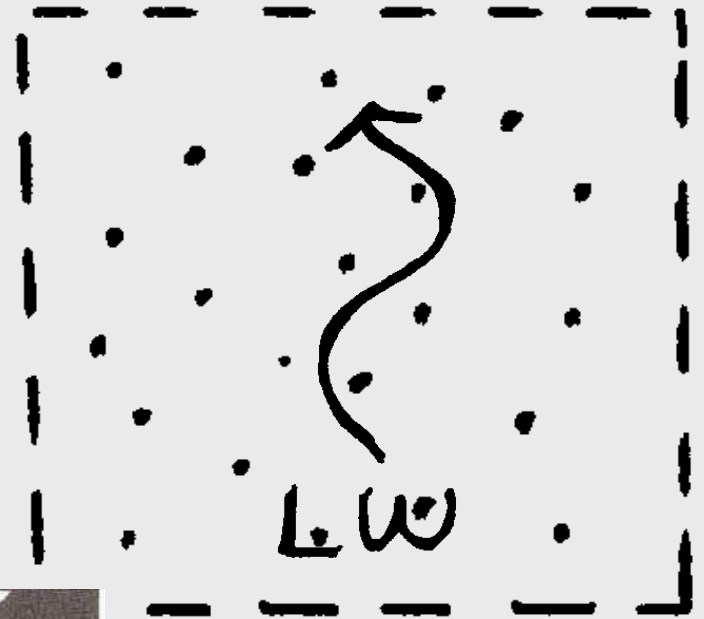
LW

ESCAPING TO  
SPACE THROUGH  
THE "OUTGOING IR  
ATMOSPHERIC  
WINDOW"

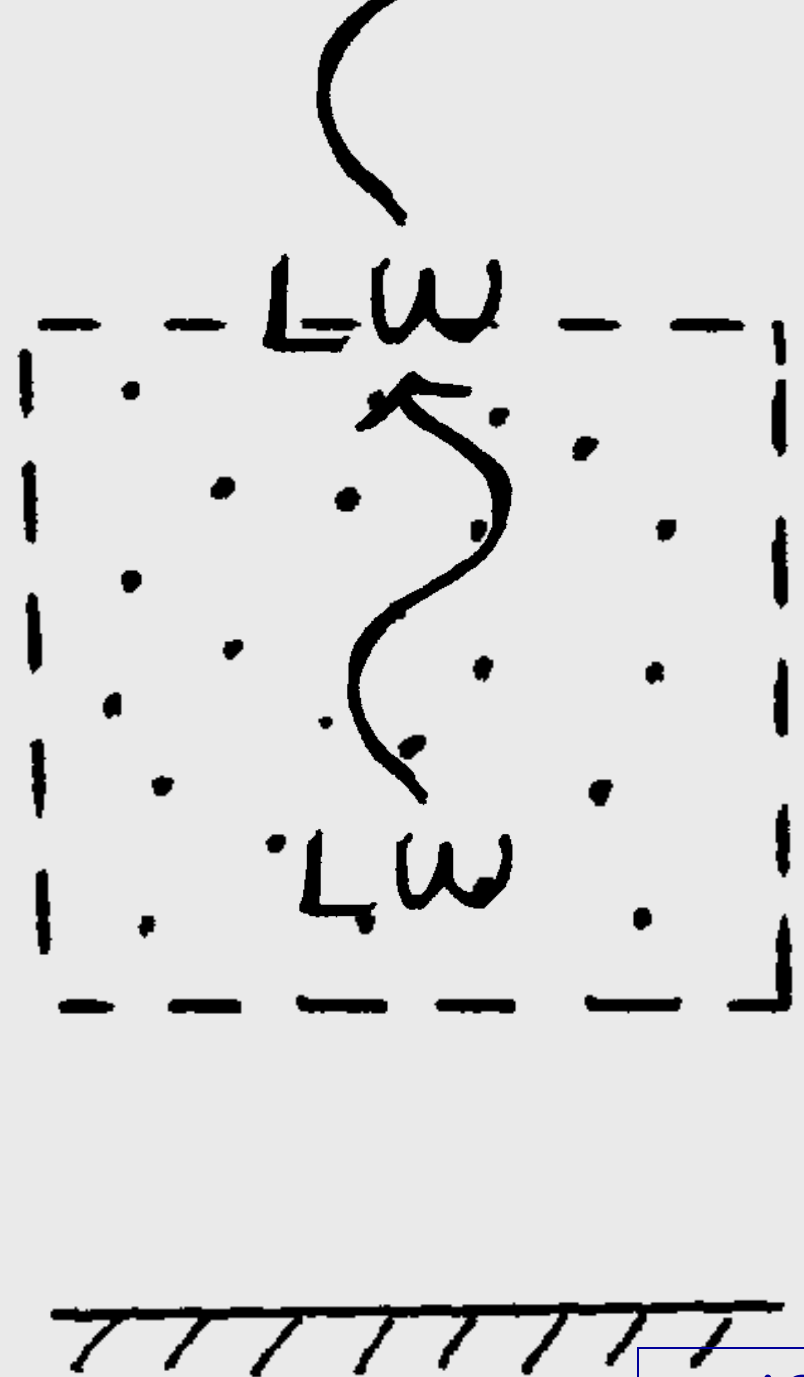
Outgoing LW



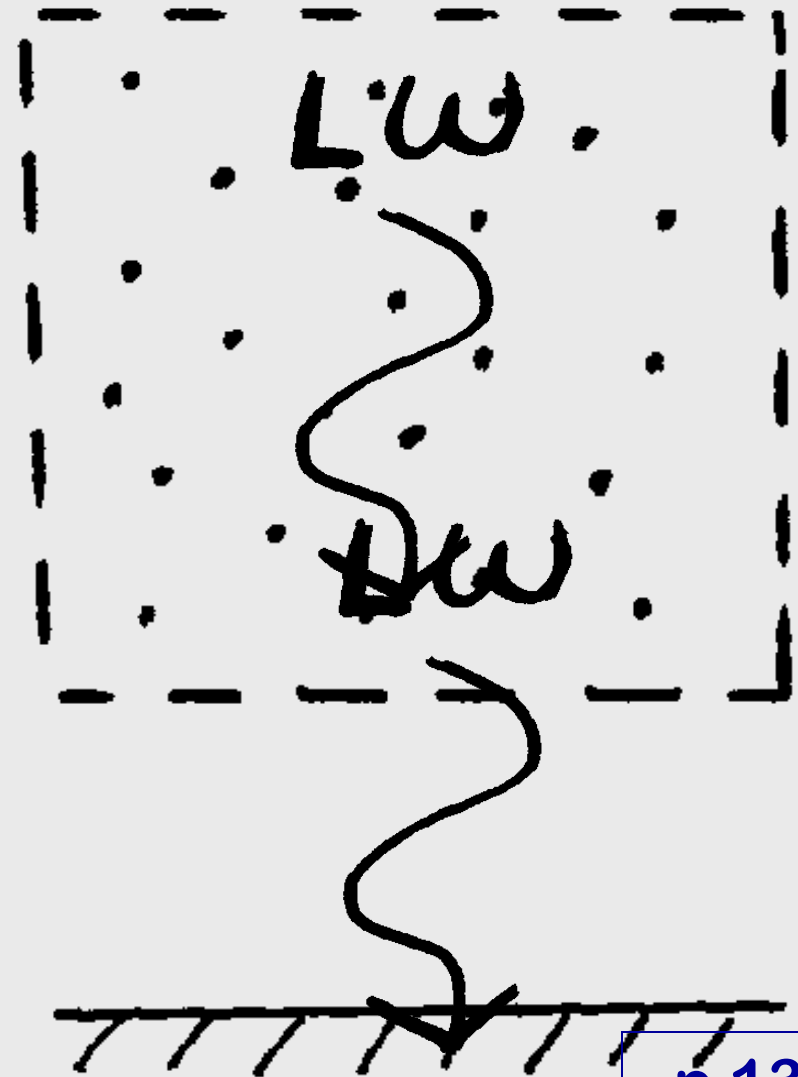
**IR EMITTED FROM  
EARTH'S SURFACE  
BUT ABSORBED IN  
THE ATMOSPHERE  
BY GREENHOUSE  
GASES (H<sub>2</sub>O, CO<sub>2</sub>,  
CH<sub>4</sub>, ETC.)**



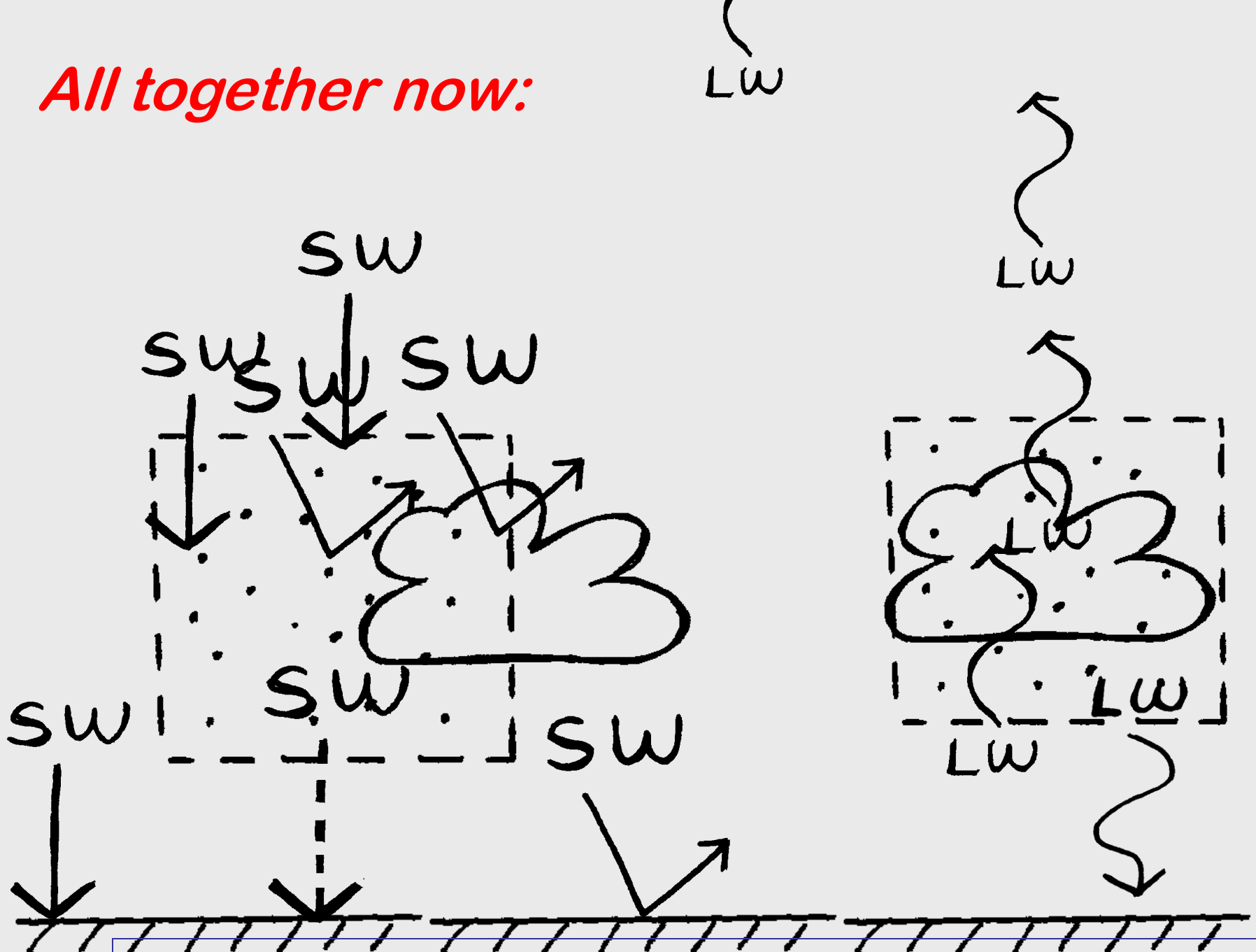
**IR EMITTED  
FROM  
ATMOSPHERE  
ESCAPING TO  
SPACE**



IR EMITTED  
FROM  
ATMOSPHERE  
AND RADIATED  
BACK TO  
SURFACE  
WHERE IT IS  
ABSORBED



*All together now:*



Can you sketch all the pathways in yourself? p 130

**What if . . .**

**. . . The Earth didn't have an atmosphere, and therefore didn't have a **greenhouse effect**??**

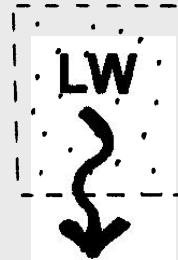
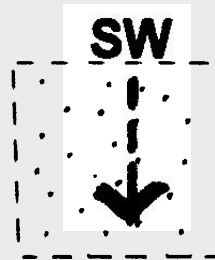
**What would the energy pathways in the Earth-Sun system look like?**



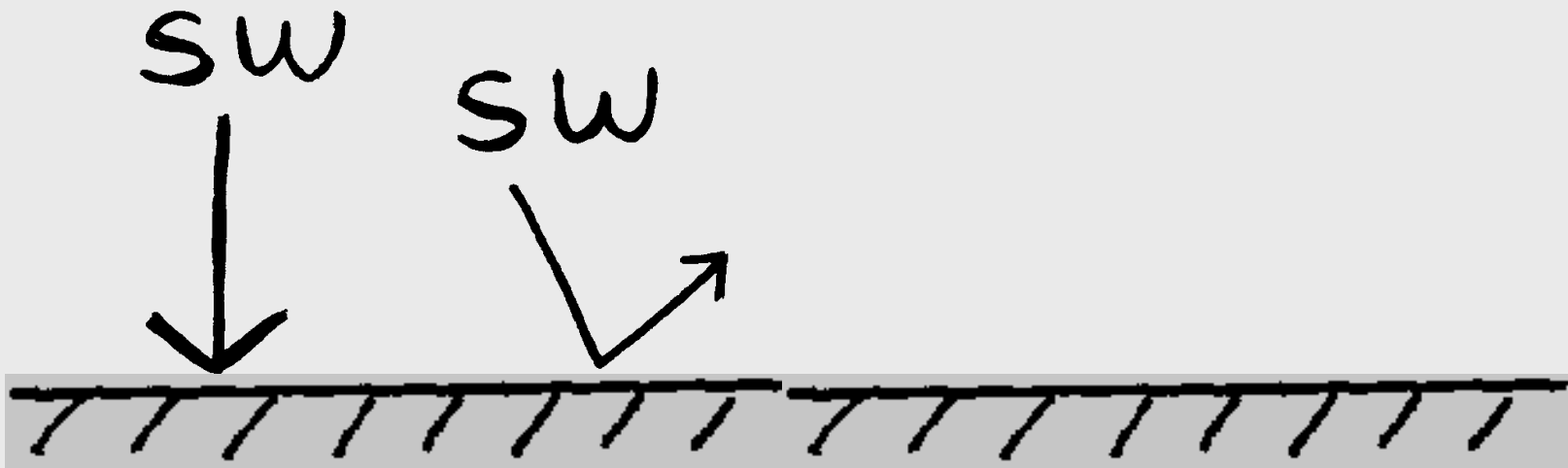
LW

# Which terms are not involved?

No scattering of SW by atmosphere

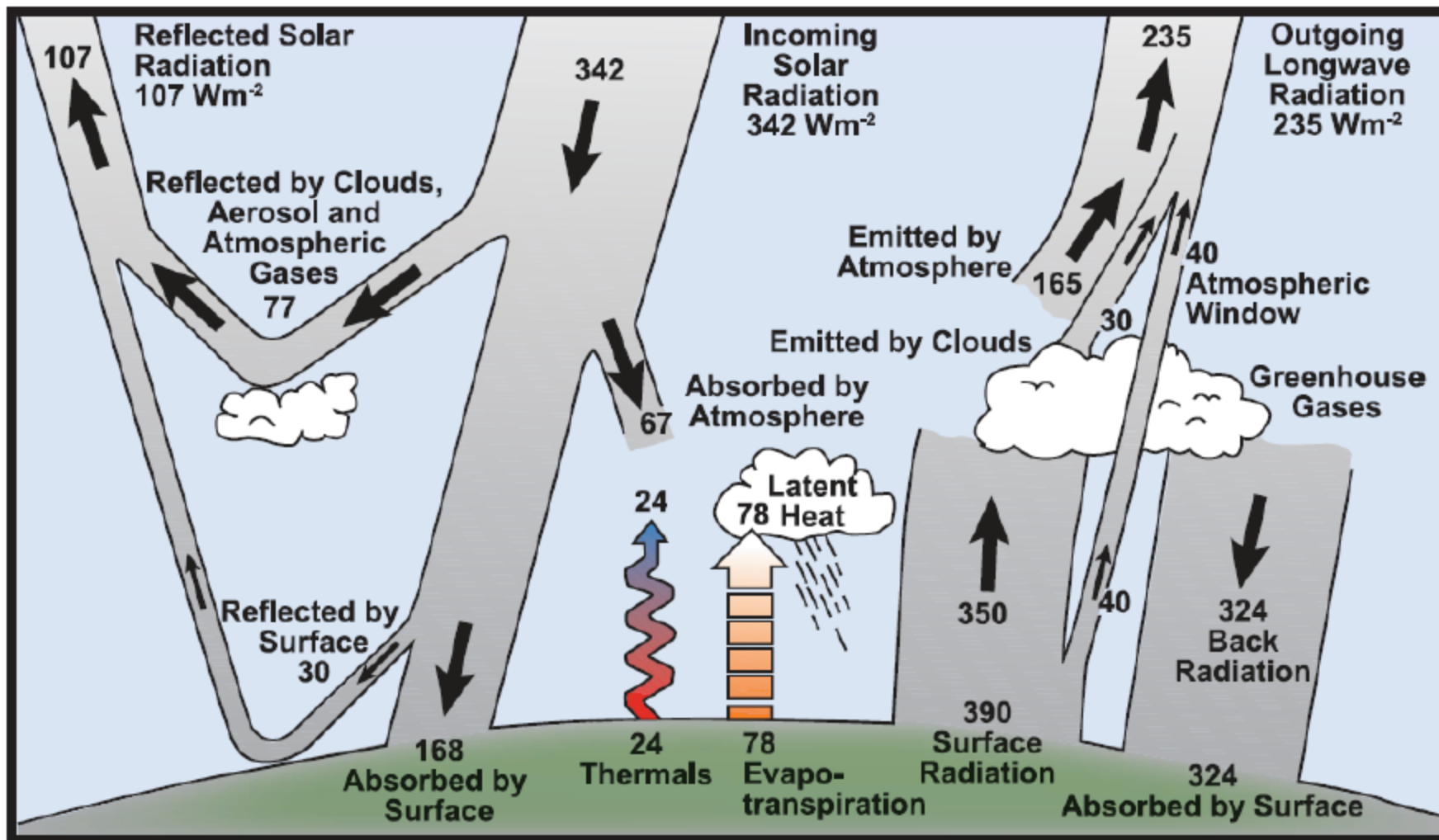


No downward re-radiation of LW / IR from the atmosphere because there would be **NO GHG's**

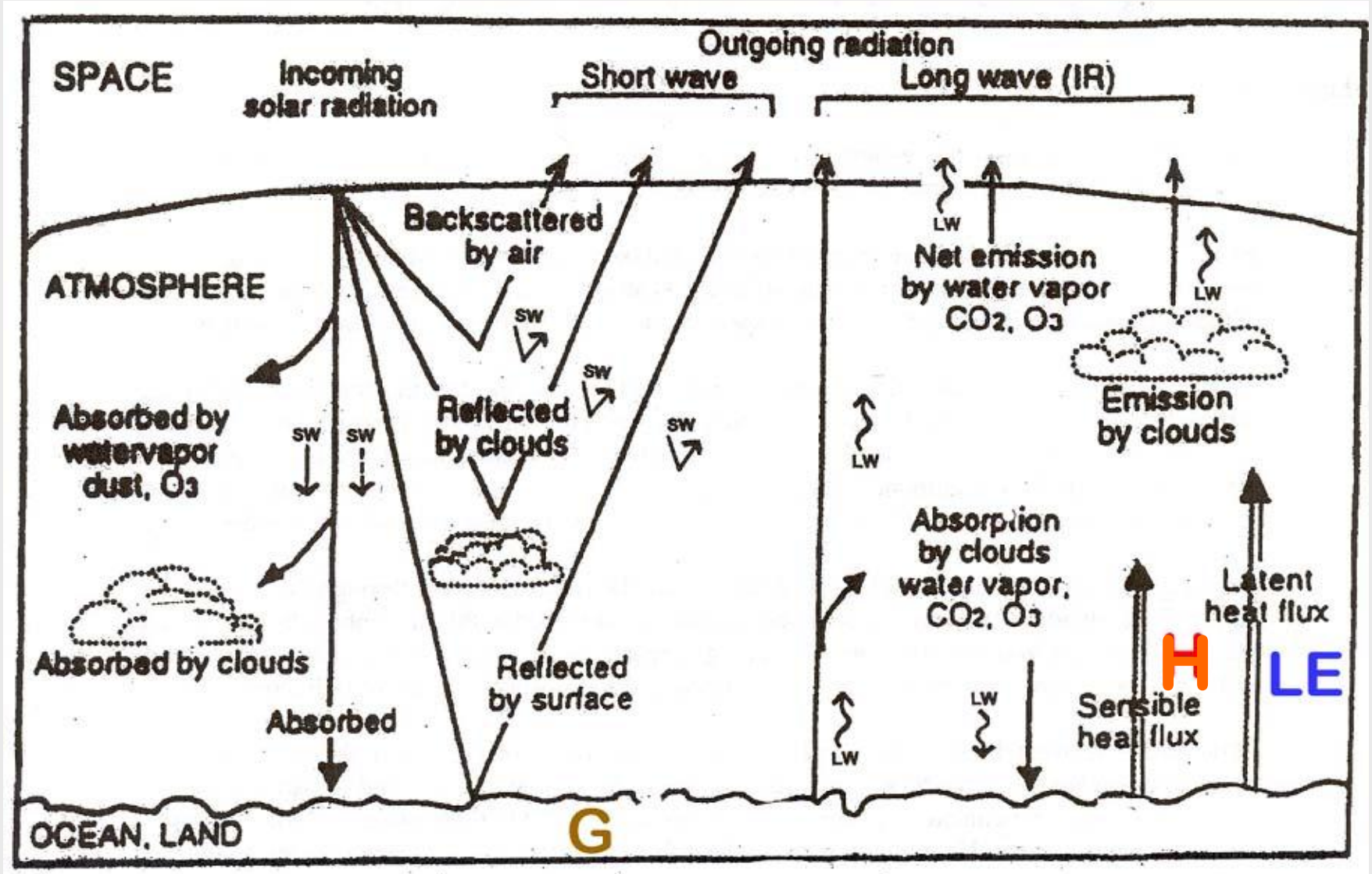


# Representation of the Energy Balance & Energy Pathways

Throughout the whole Earth-Atmosphere system, the energy units balance out, energy is conserved, and the 1st Law of Thermodynamics applies.



# Look for the cartoon symbols:



on Thursday we'll tie it all together! p 56

**And now . . . time to finish up:**

**G-4 DOING SCIENCE with TREE-RINGS:  
With Bristlecone Pines**





REMINDER:

- **Linking-to-Life Part B Film & Video Reviews**  
**are due TONIGHT by 11:59 pm!!**

**RQ 5 is DUE THURSDAY**

**Oct 24<sup>th</sup>**

**30 minutes before class**

**PLEASE RE-ARRANGE YOUR  
CHAIRS BEFORE YOU LEAVE!**