

# Topic # 8

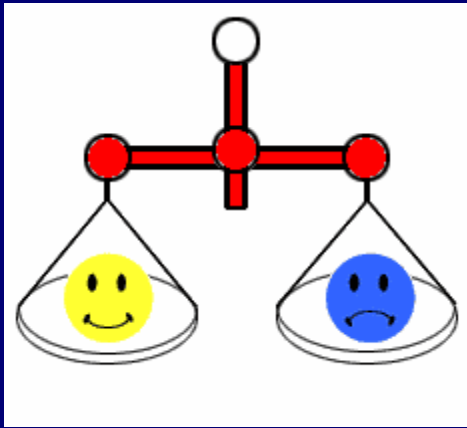
# THE EARTH'S GLOBAL ENERGY BALANCE

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

## Today's Quote:

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

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

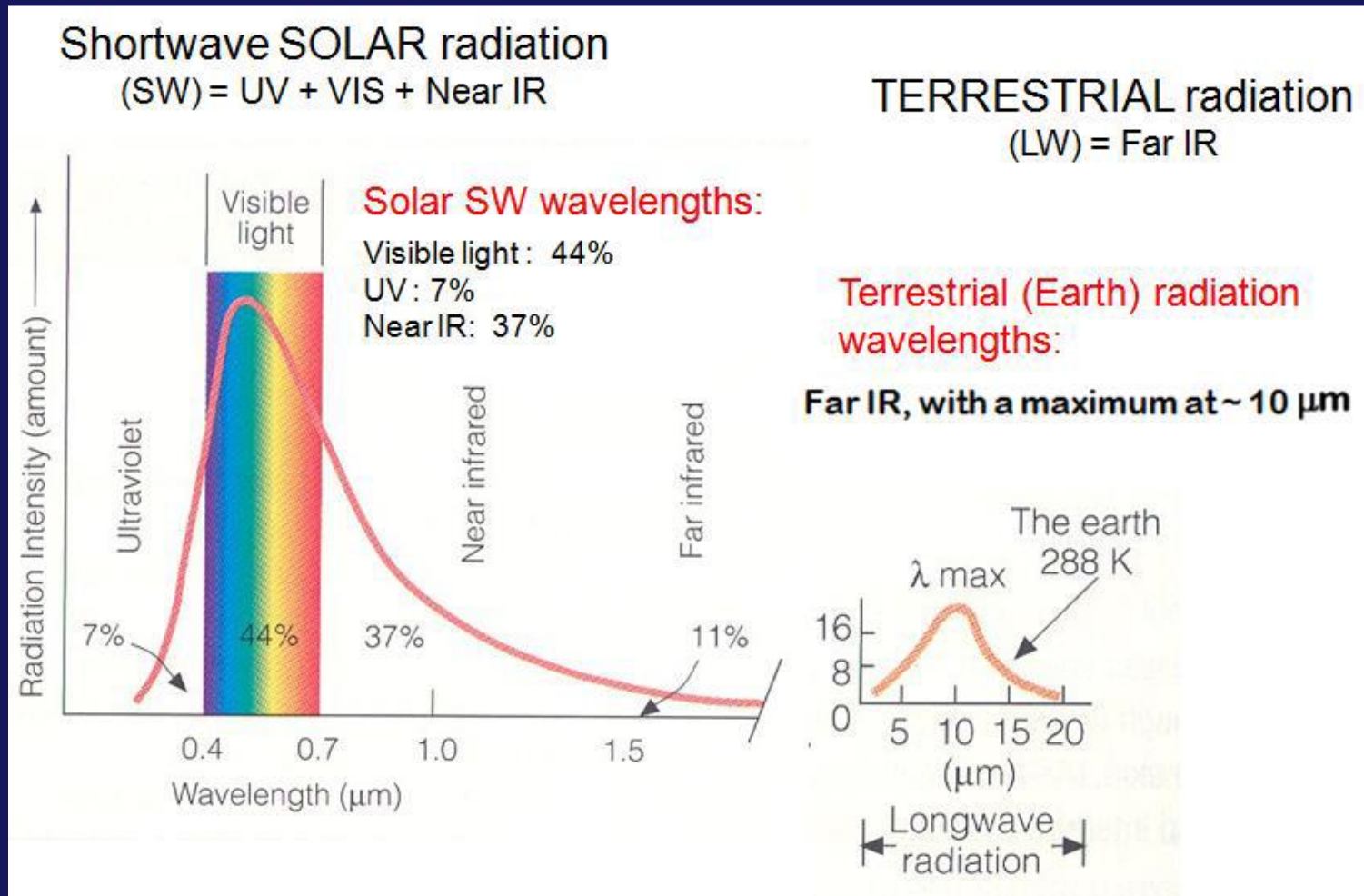


Are my energy expenditures (actions, reactions, thoughts, and feelings) productive or nonproductive?

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

*~ Doc Childre and Howard Martin*

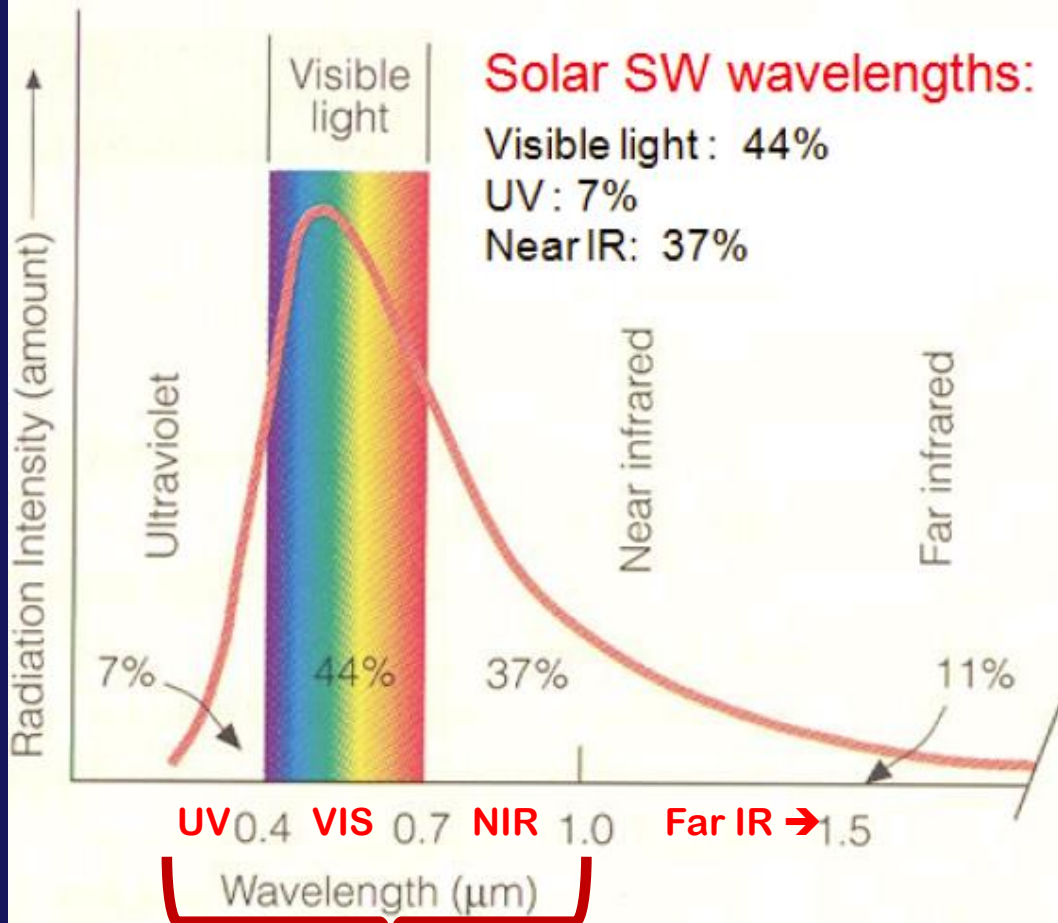
# Review: Do you remember this Figure from Topic # 5 (Radiation Laws)?



# In the Topic #8 Energy Balance topic . . . .

Shortwave SOLAR radiation

(SW) = UV + VIS + Near IR



**SW**

To “simplify”  
we’ll use  
**“SW”**

to indicate the  
**Short  
SOLAR  
wavelengths:**

**SW** = UV + VIS  
primarily

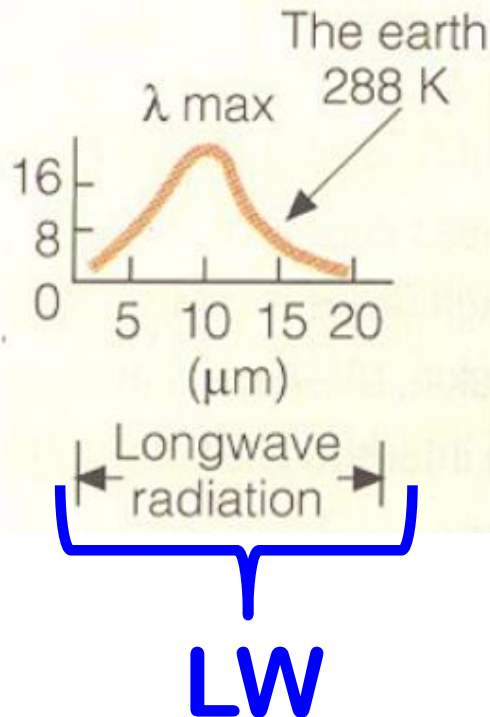
+ NIR (Near IR that  
“reflects” like VIS)

# *In the Topic #8 Energy Balance topic . . . .*

TERRESTRIAL radiation  
(LW) = Far IR

Terrestrial (Earth) radiation  
wavelengths:

Far IR, with a maximum at  $\sim 10 \mu\text{m}$



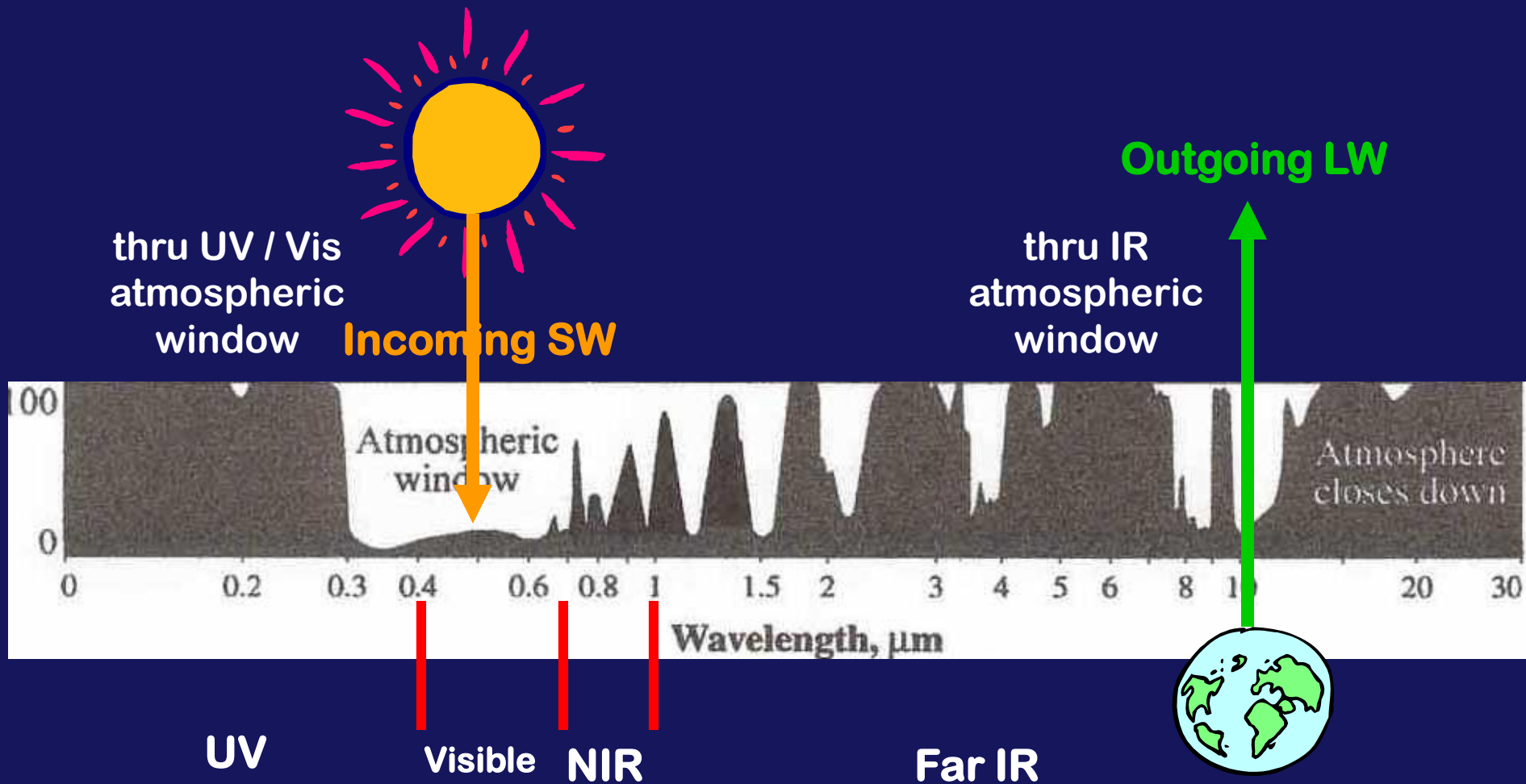
. . . And we'll use  
"LW"  
to indicate the  
Long  
TERRESTRIAL  
Wavelengths

LW = all infrared  
(Far IR)

# Review: Absorption curve for the "Whole Atmosphere"

OVERALL  
BALANCE:

Incoming = Outgoing



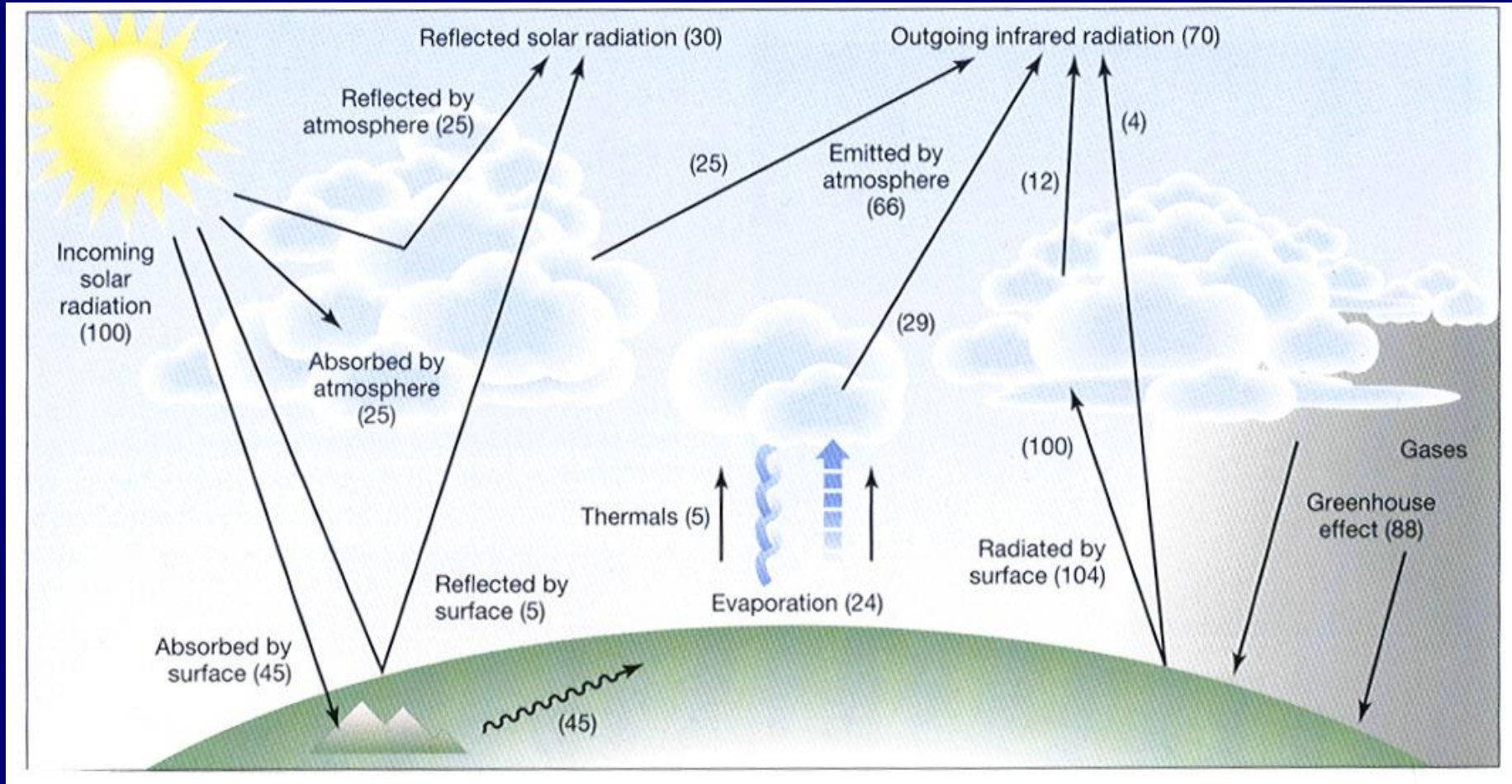
# The Energy Balance Equation:

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

(one of several ways  
this equation can be written)

# Typical Energy Balance Diagram

(how the energy gets distributed into different “pathways”)



From SGC-E-Text Chapter Fig 3-19



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**

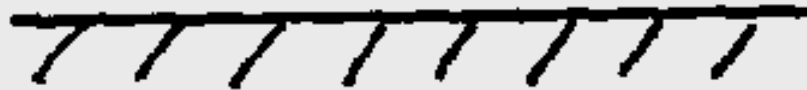
Let's see how it all fits together in the  
various components & pathways of  
the **Earth's Energy Balance**

→ We'll use "cartoon symbols" . . .



# “CARTOON” SYMBOLS:

To represent  
the Earth’s surface:

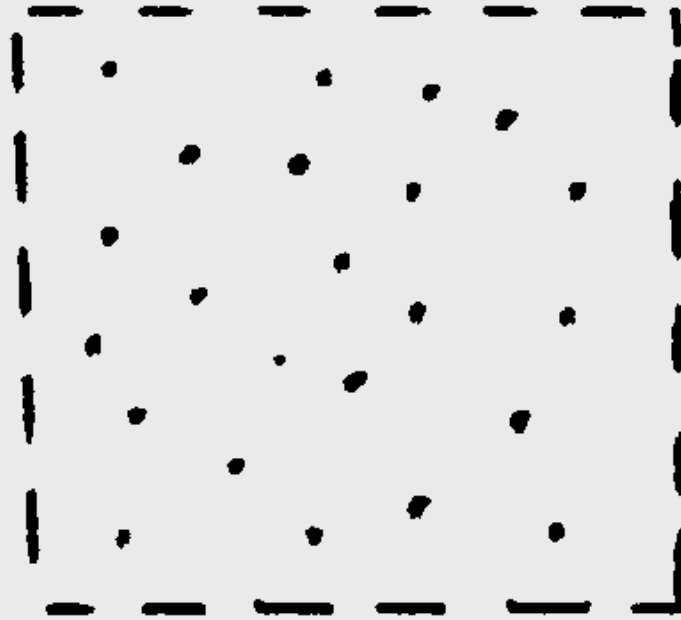


*Note-taking suggested:*



**on blank page 46**

## “CARTOON” SYMBOLS:



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



But, to envision the Earth's atmosphere  
... remember that it is a SPHERE!  
(atmos + sphere)

From  
Greek:  
“vapor”



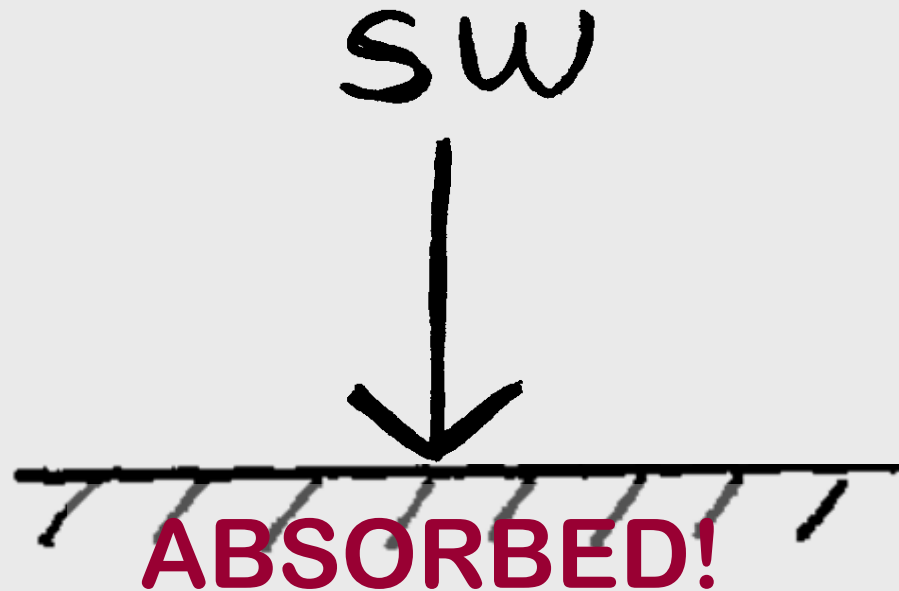
# **“CARTOON” SYMBOLS:**



**To represent CLOUDS**

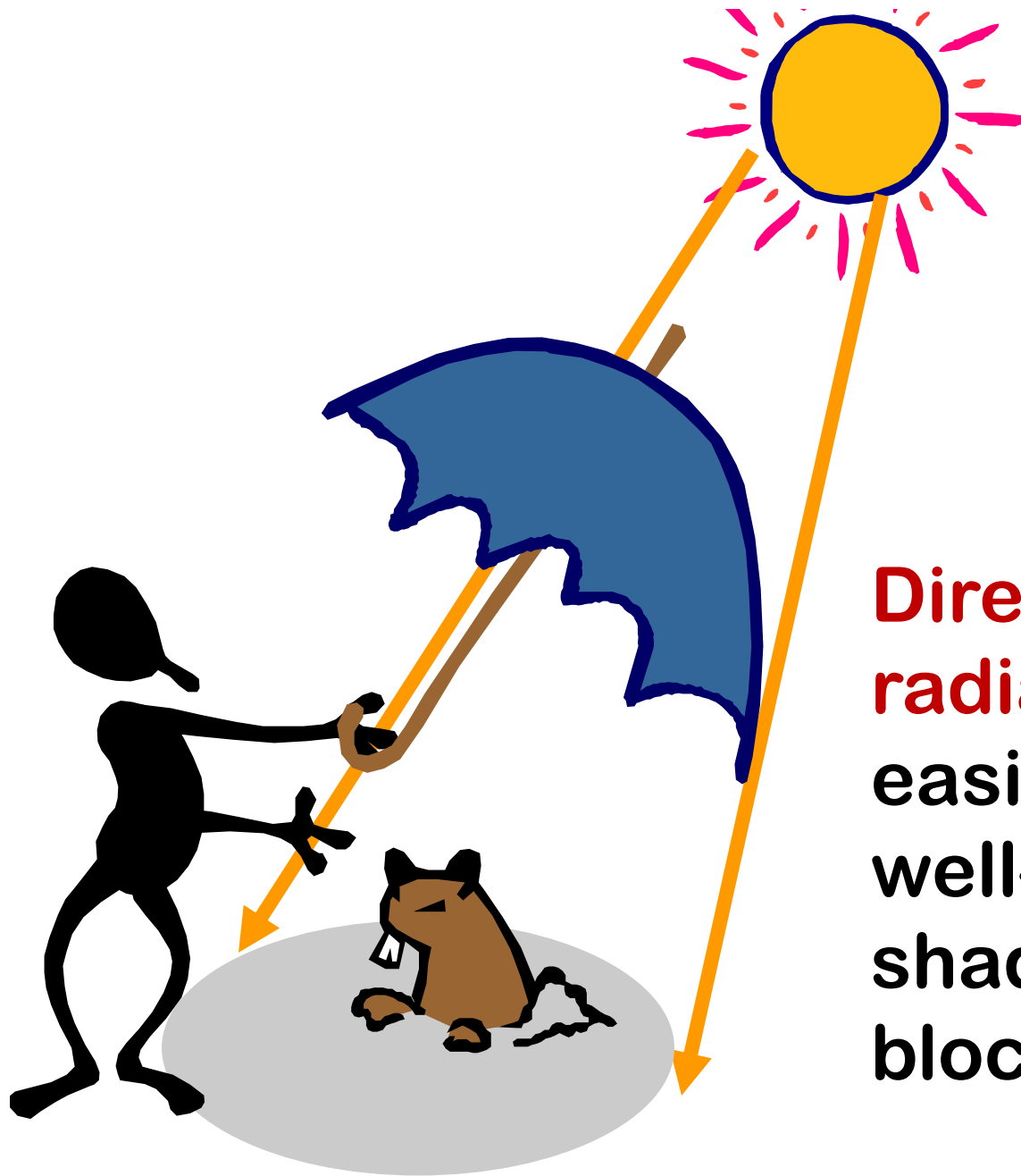


## “CARTOON” SYMBOLS:



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

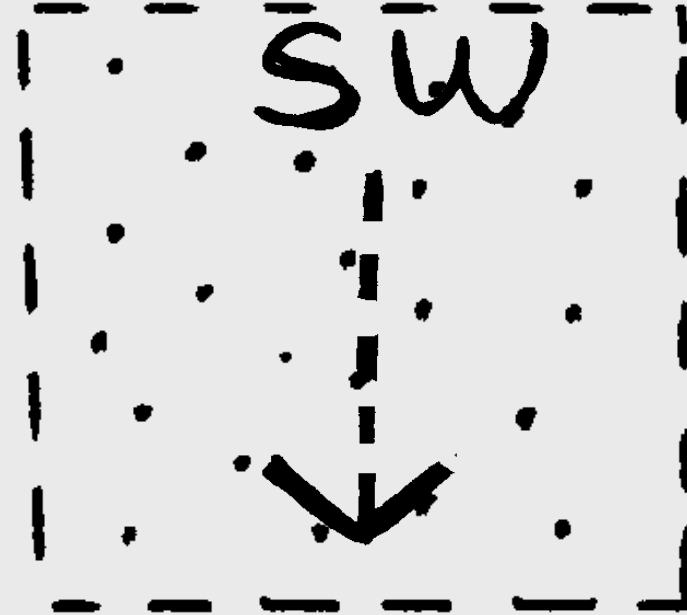




**Direct SW  
radiation**  
easily casts  
well-defined  
shadows when  
blocked



## “CARTOON” SYMBOLS:

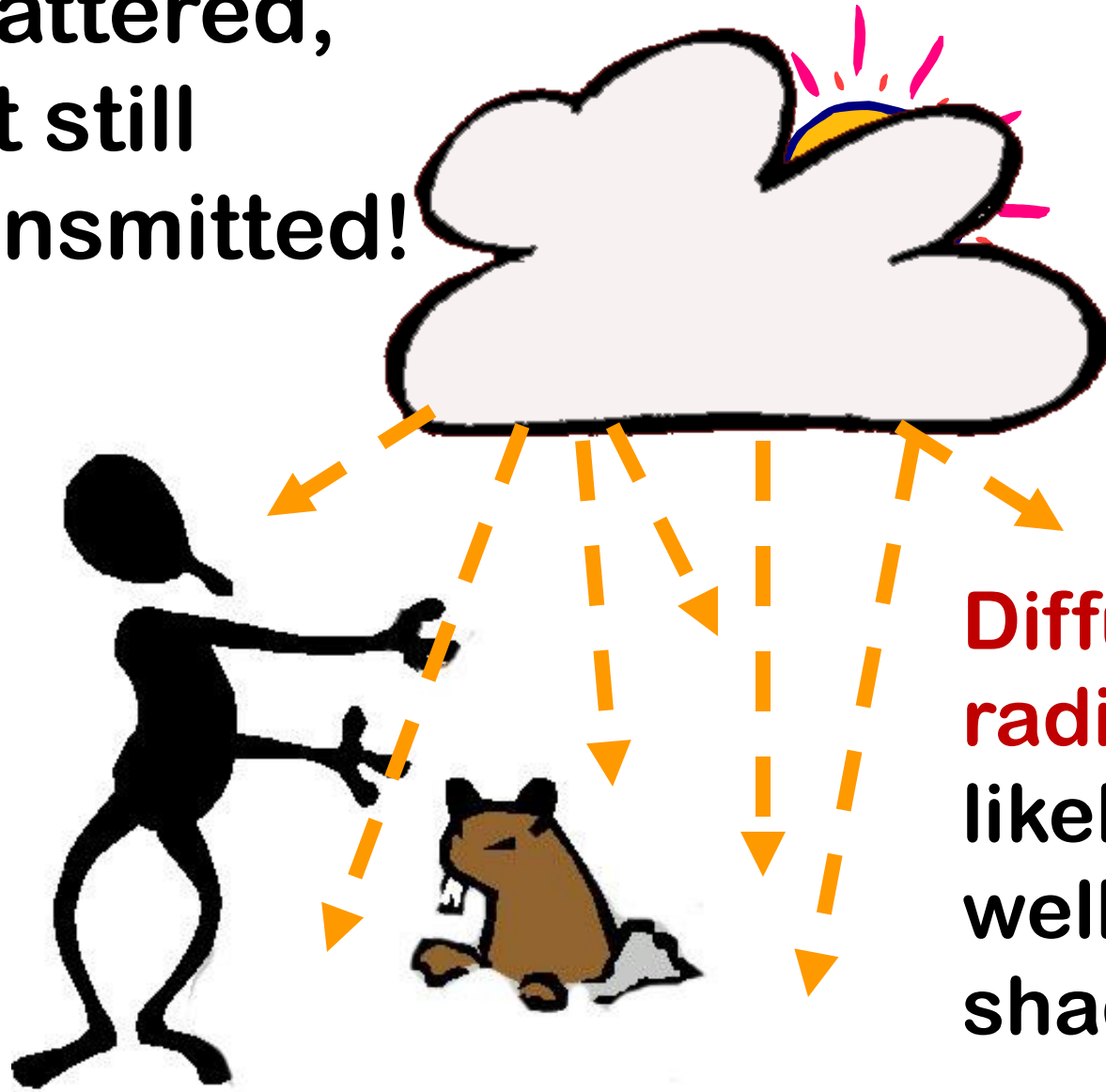


To represent SOLAR (shortwave) radiation coming in as **DIFFUSE shortwave radiation**, i.e. scattered by gases, clouds, and particles in the atmosphere.





Scattered,  
but still  
transmitted!

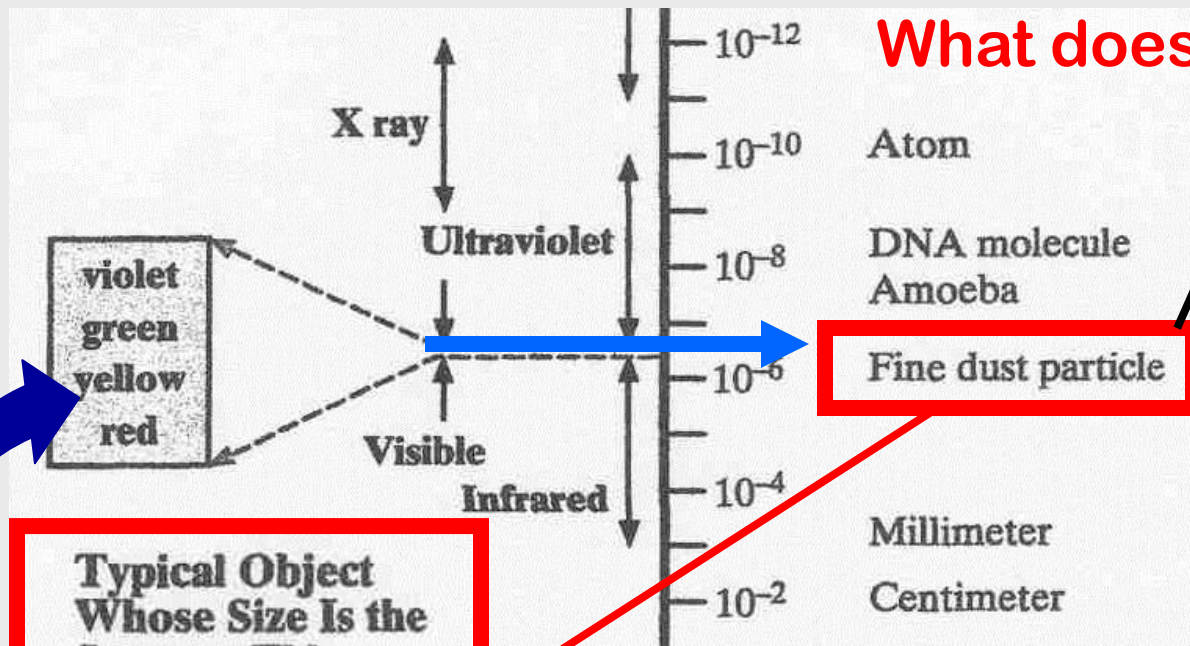


**Diffuse SW  
radiation** is less  
likely to cast a  
well-defined  
shadow!



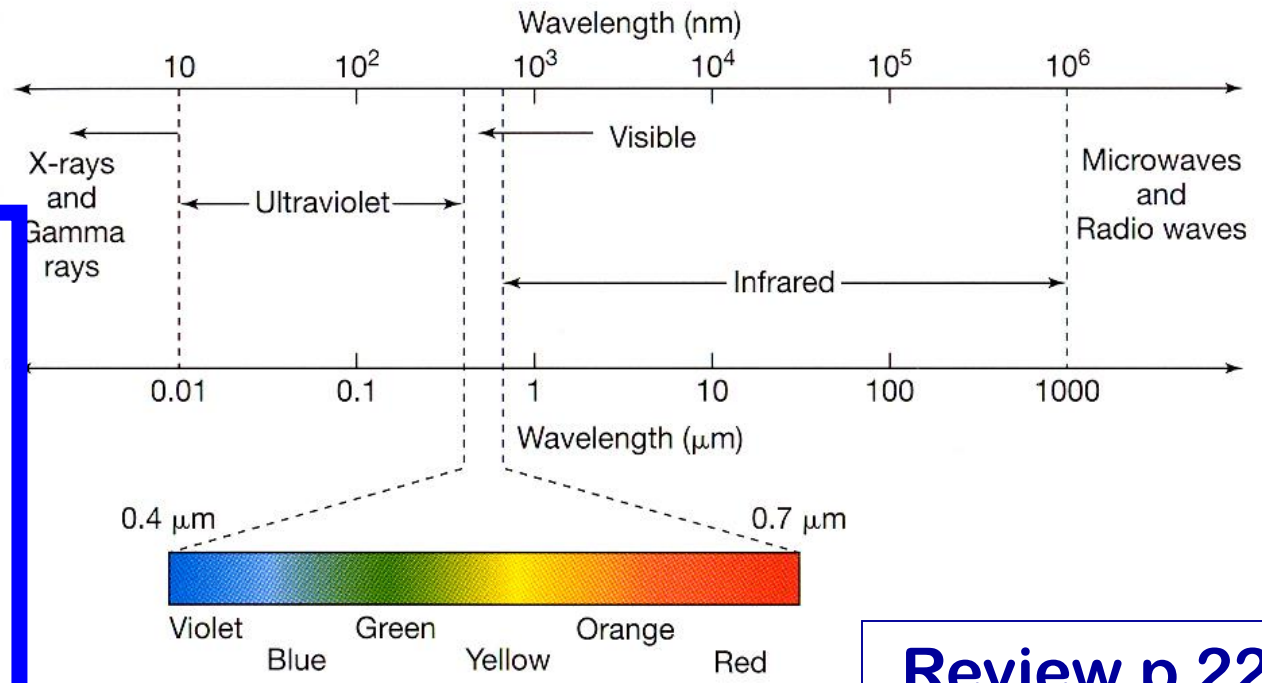
# What does the scattering?

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



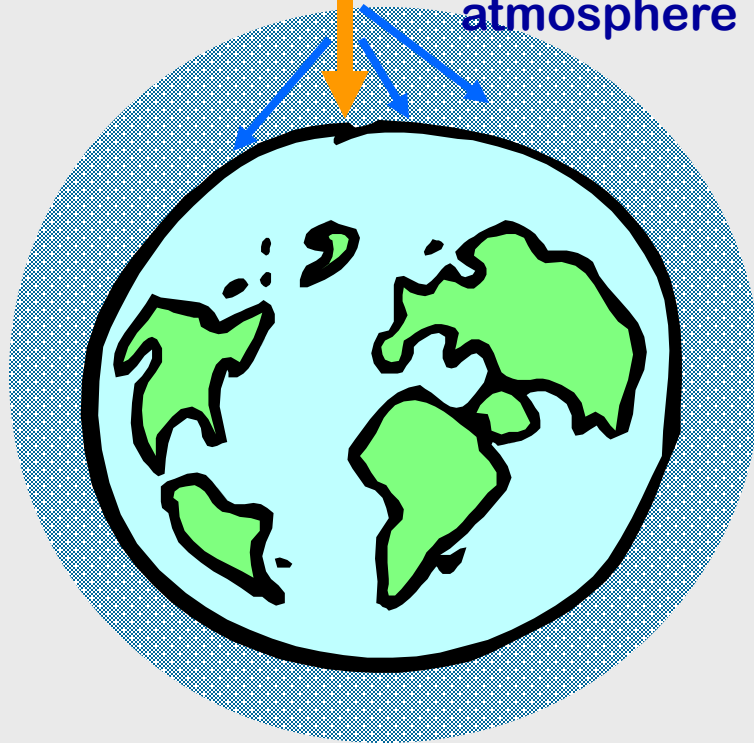
Typical Object Whose Size Is the Same as This Wavelength:

Scattering of visible light wavelengths





**SHORTER**  
 (blue) wavelengths are scattered easily by gases, water droplets, & fine dust particles in atmosphere

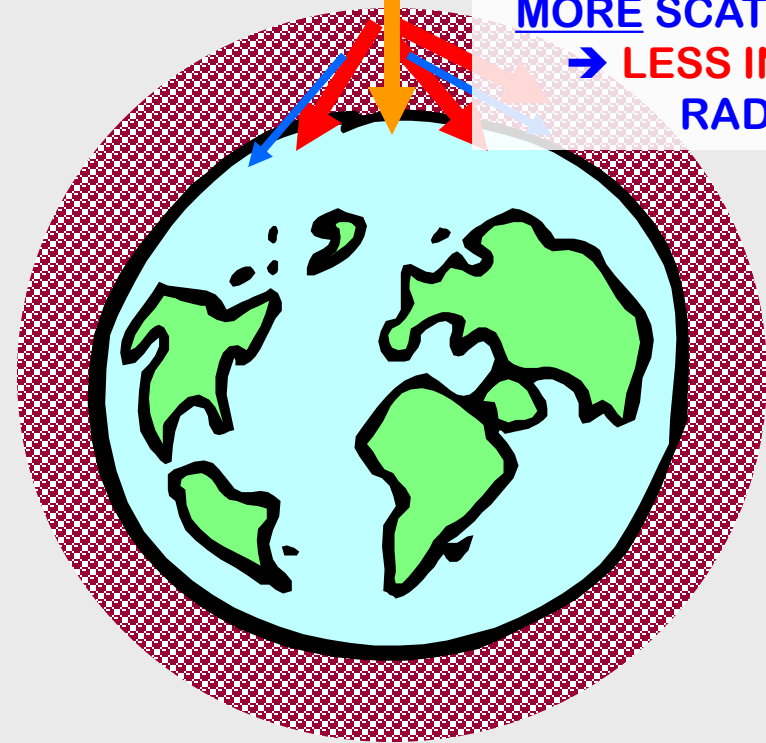


“Clear” atmosphere composed primarily of **fine particles**, **H<sub>2</sub>O droplets**, gas molecules



“Aerosol-filled” atmosphere scatters the **LONGER** (red) wavelengths plus the shorter blue wavelengths

**MORE SCATTERING**  
 → **LESS INTENSE RADIATION!**

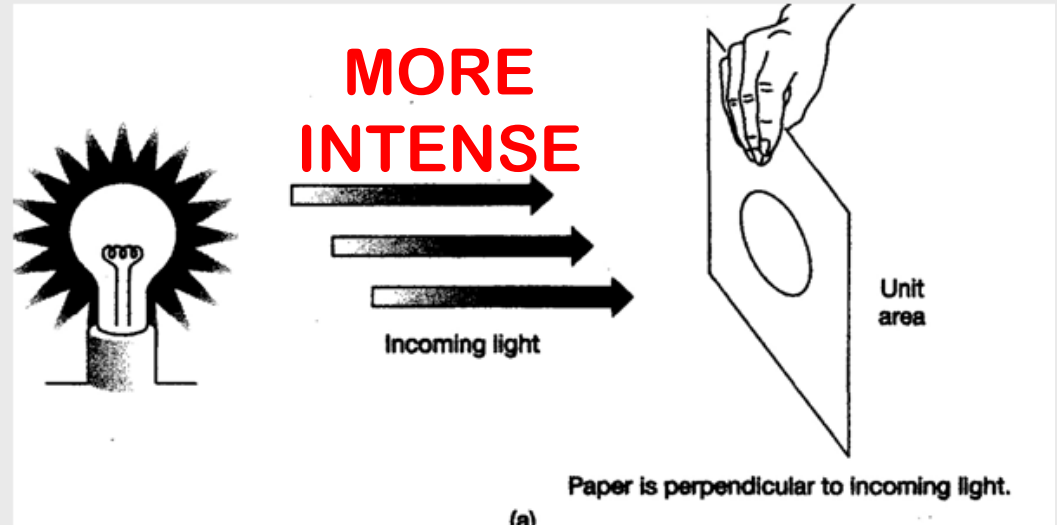


“Dirty” (aerosol-laden) atmosphere composed of **fine particles**, **gases**, & **H<sub>2</sub>O** -- **PLUS larger dust particles**, **aerosols**, **pollution**, etc.

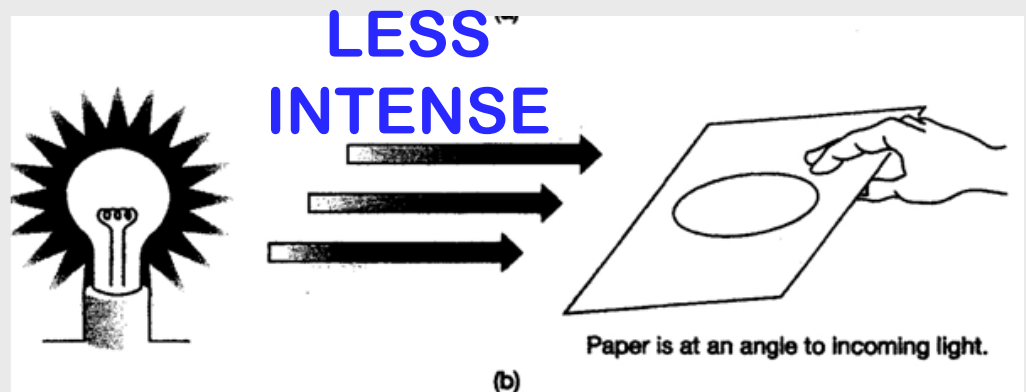


**ALSO:** The **angle** at which direct SW radiation is intercepted by a surface makes a difference in the **INTENSITY** **OF THE RADIATION!!**

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



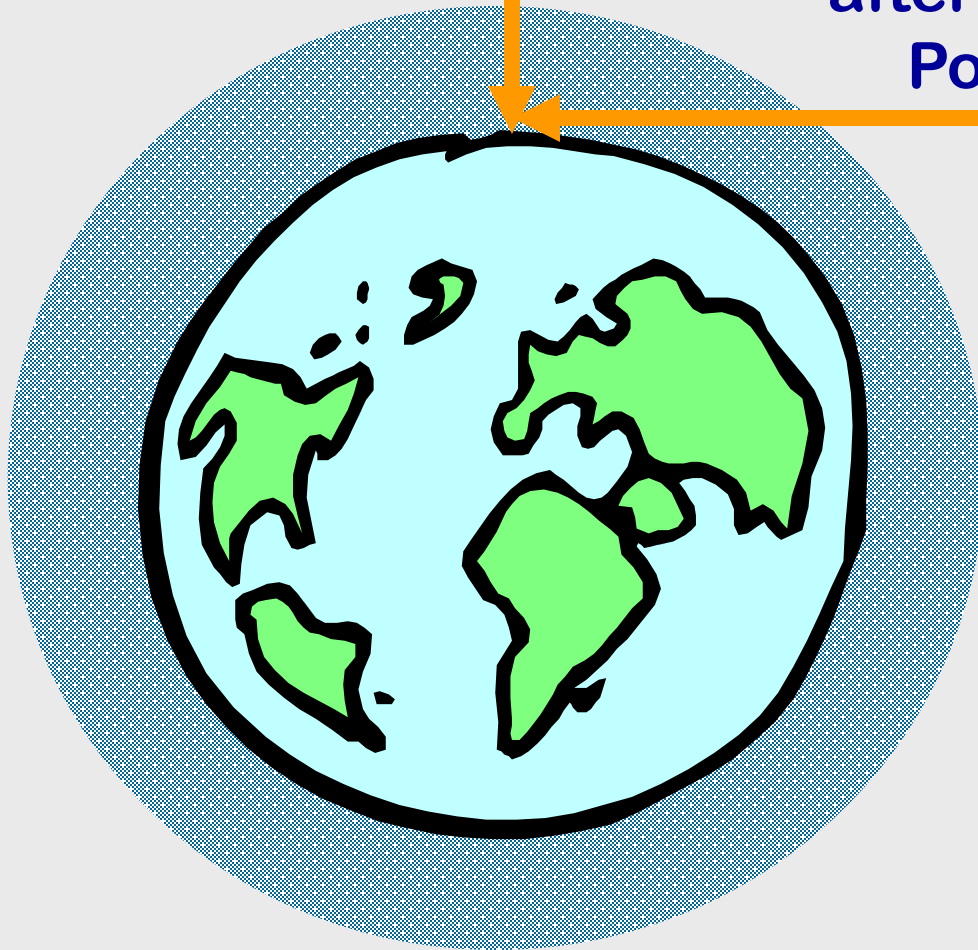
Radiation is spread out over a larger area & hence is less intense per unit area when it comes in at an angle.



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

Scenario 1:  
NOON at  
Point A

Scenario 2: Late  
afternoon at  
Point A



**DISCUSS:**

Which scenario will  
deliver **MORE**  
**INTENSE** radiation to  
Point A?

**1 = Scenario 1**

**2 = Scenario 2**

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

**CLICKER Q!**

**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!**

# 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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## “CARTOON” SYMBOLS:

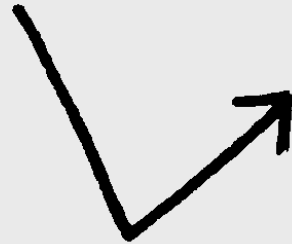


To represent SOLAR (shortwave) radiation that is **REFLECTED** (or scattered) **BACK TO SPACE** by: atmosphere, clouds, Earth's surface, etc.





SW



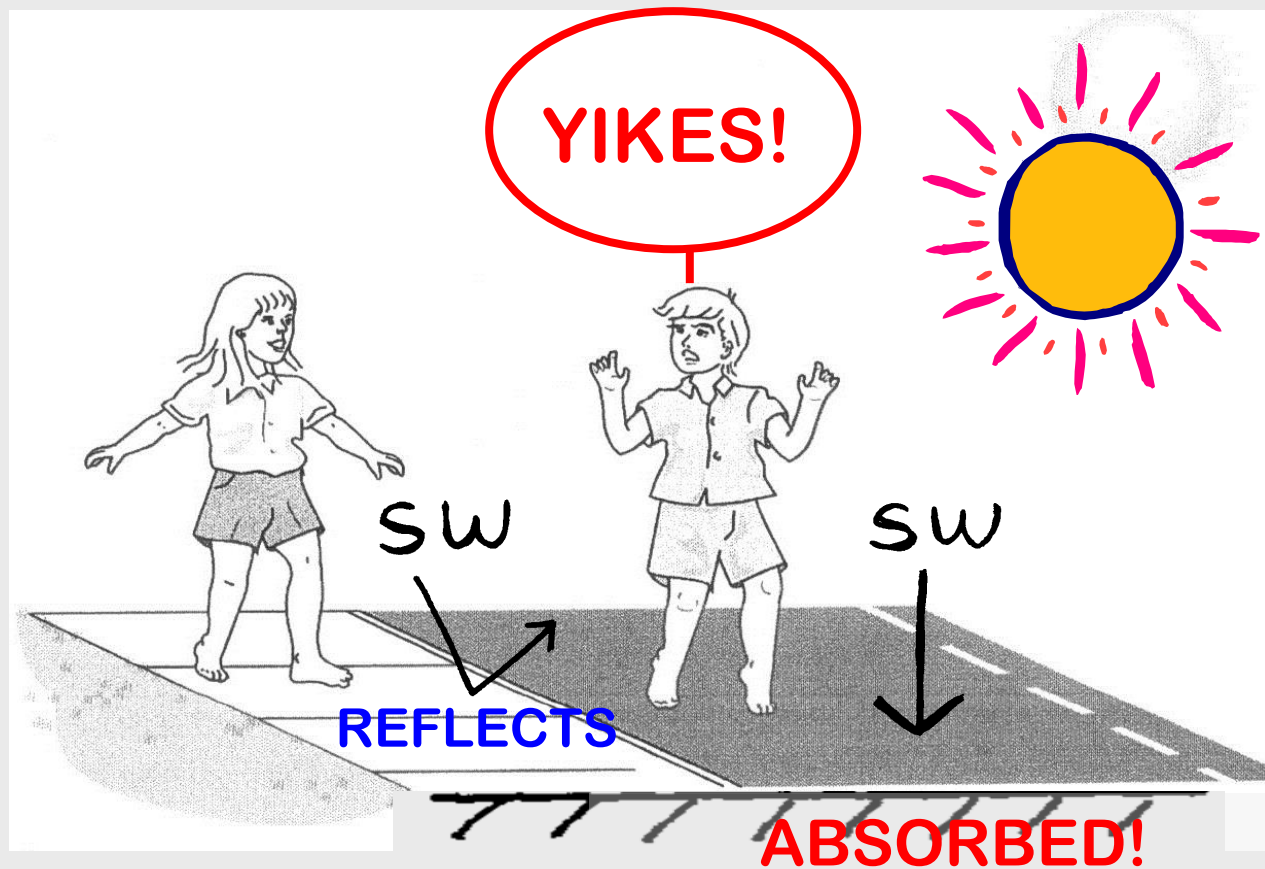
*Key term:*

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

ALBEDO of **1.0** = **100% REFLECTION**  
(perfect reflectivity)

ALBEDO of **0.0** = **NO REFLECTION**  
(perfect absorption)

To figure out amount of SW **ABSORBED** =  
(1 – 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

*Type of Surface*

*Albedo*

Sand

0.20–0.30

Grass

0.20–0.25

Forest

**Low albedo**

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

**High albedo**

0.70–0.80

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

**AVERAGE PLANET EARTH = ~ 0.30**

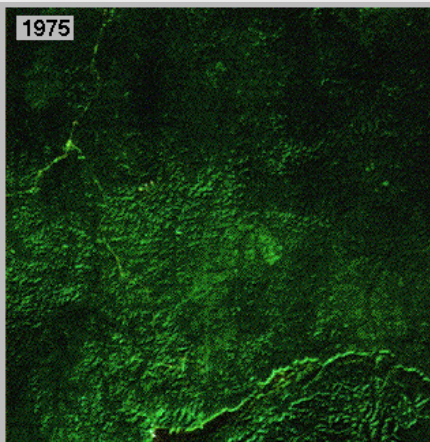
## CLICKER Q!

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

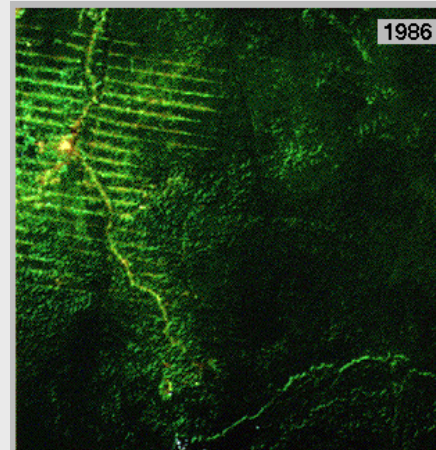
1 = more SW will be absorbed

2 = less SW will be absorbed

Before



After



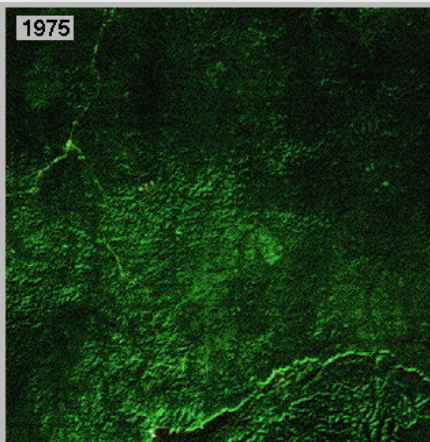
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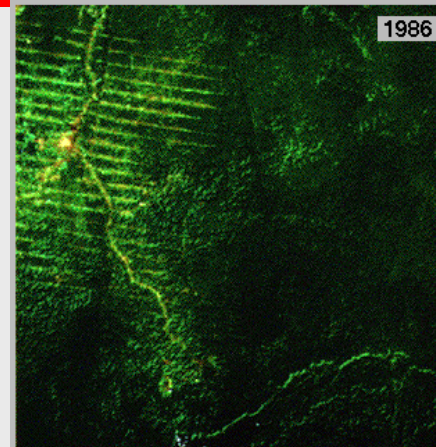
2 = less SW will be absorbed



Before



After



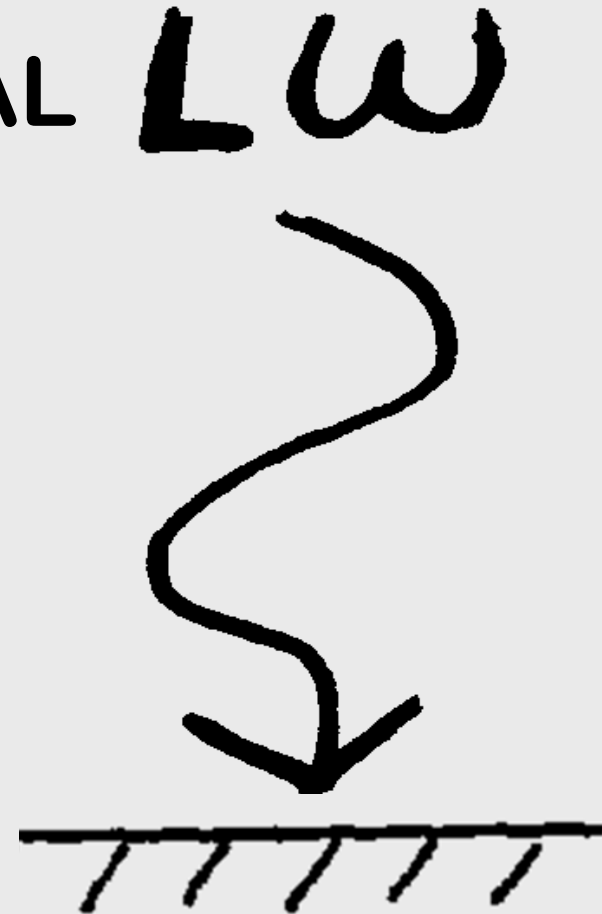
## “CARTOON” SYMBOLS:

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 107 in  
Appendix →**



# PUTTING IT ALL TOGETHER:

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

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

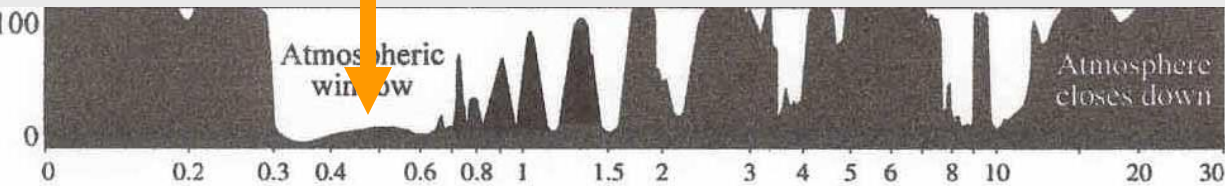
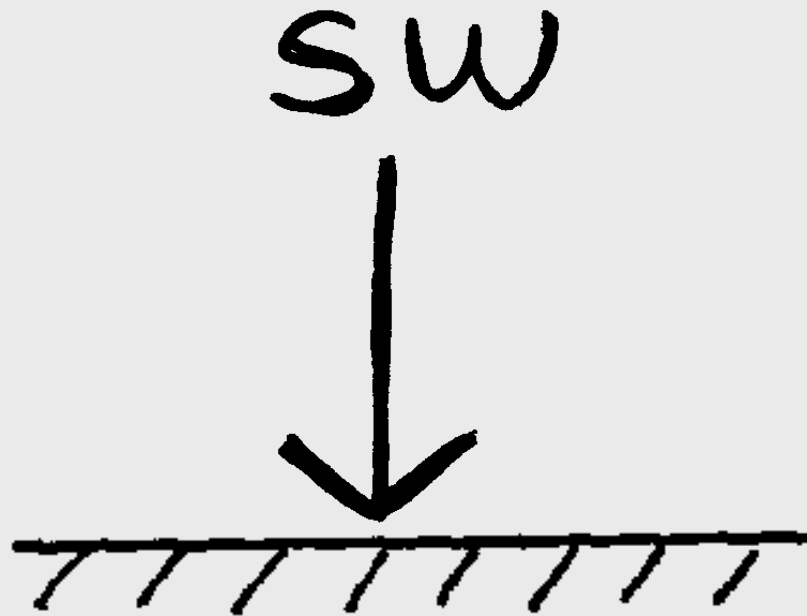
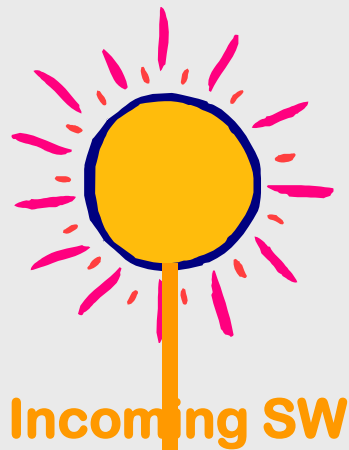
$$R_{\text{NET}} = \begin{array}{c} \text{SW} \\ \downarrow \\ \text{+} \\ \begin{array}{c} \text{SW} \\ \vdots \\ \downarrow \end{array} \\ \text{-} \\ \begin{array}{c} \text{SW} \\ \searrow \end{array} \\ \text{-} \\ \begin{array}{c} \uparrow \\ \text{LW} \end{array} \\ \text{+} \\ \begin{array}{c}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

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:

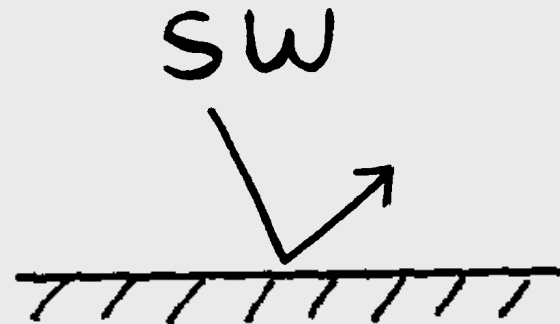


# SW REFLECTED BACK TO SPACE:

By  
clouds



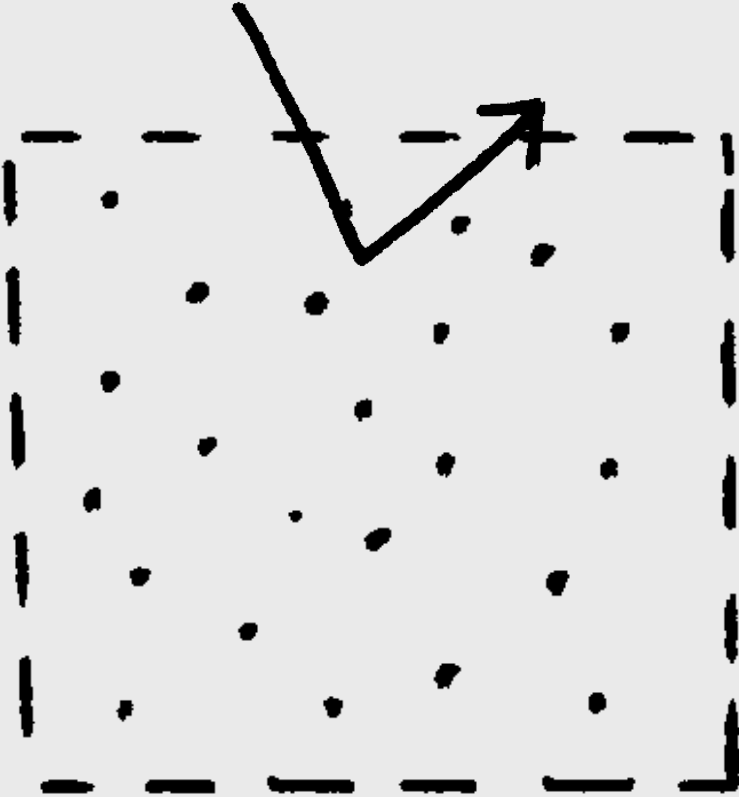
By  
Earth's  
surface



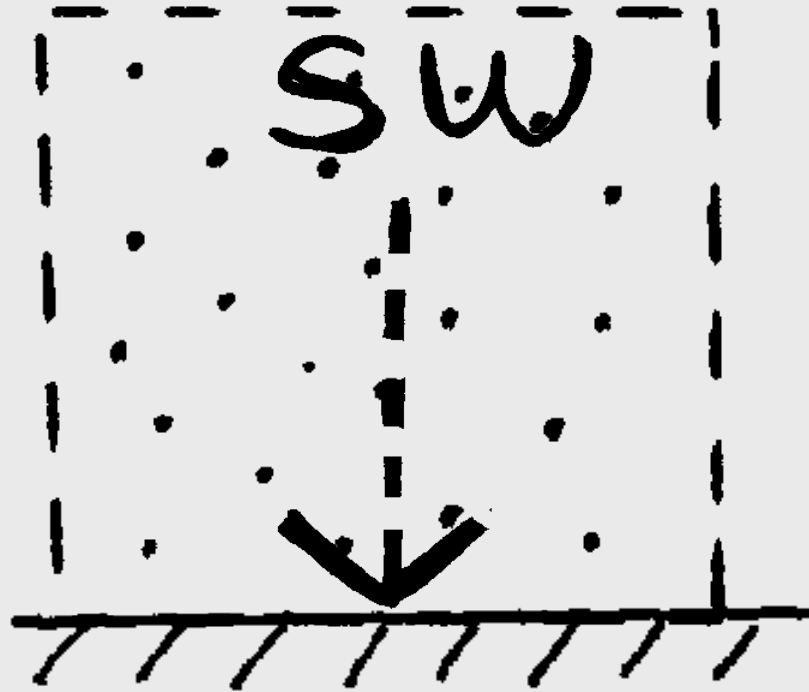
This is determined by  
the ALBEDO of the  
clouds or surface

**SW SCATTERED BACK TO SPACE  
BY ATMOSPHERE:**

SW

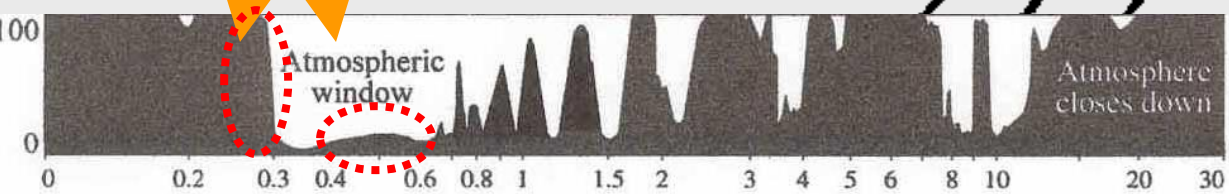
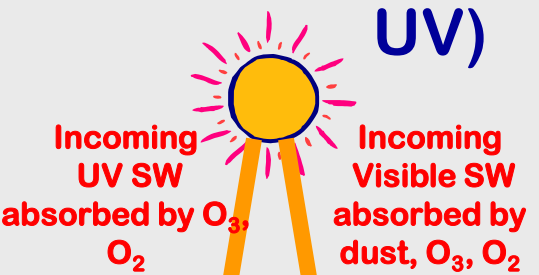
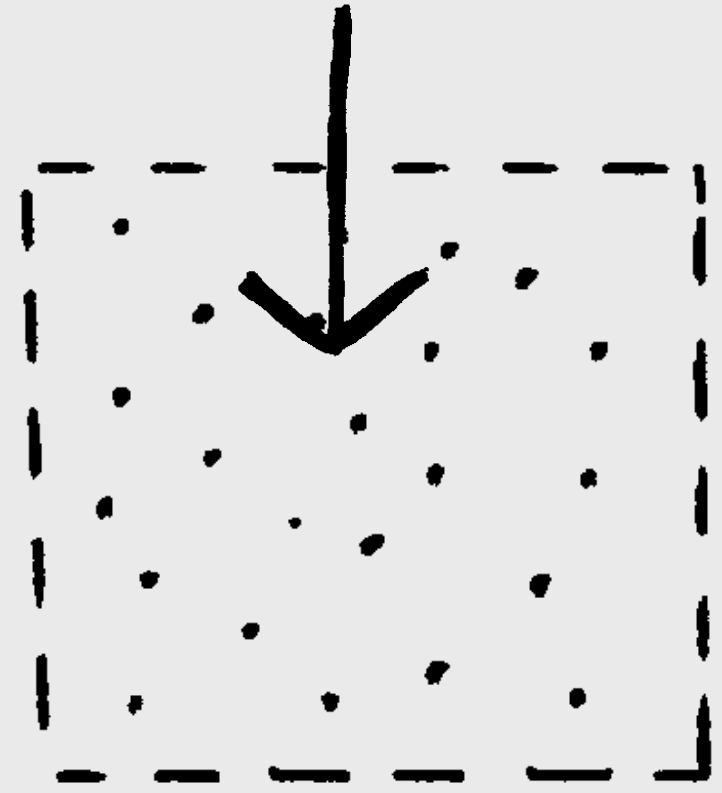


**SW** SCATTERED DOWN TO EARTH'S  
SURFACE where it is absorbed



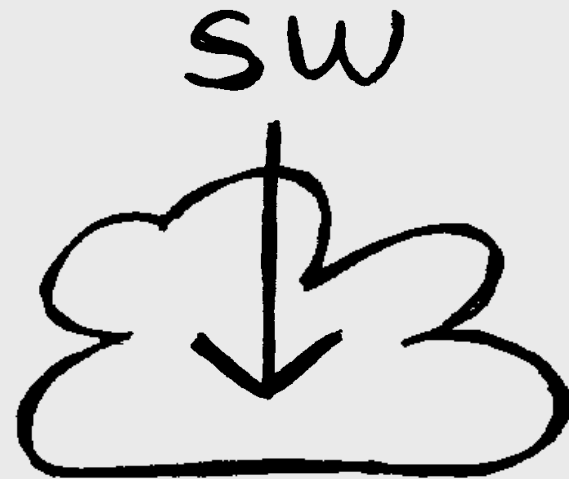
**SW ABSORBED  
IN ATMOSPHERE  
BY GASES,  
DUST, etc.**  
(including Ozone  
absorbing shortwave  
UV)

SW

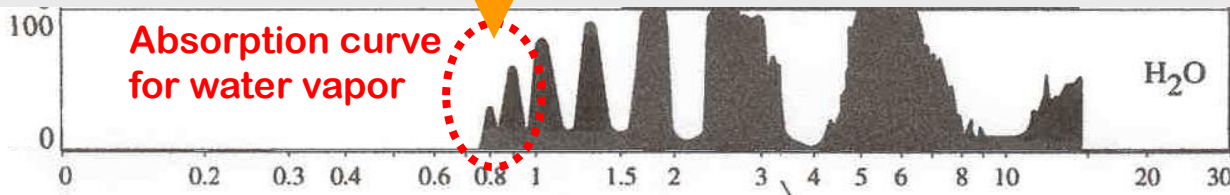




**SW ABSORBED  
In ATMOSPHERE  
BY CLOUDS &  
H2O vapor:**



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

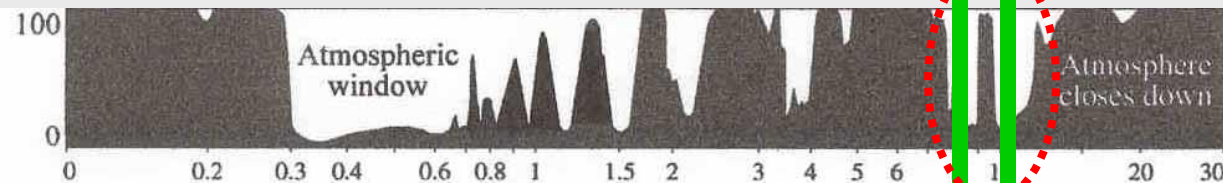


LW (IR) EMITTED  
FROM EARTH'S  
SURFACE

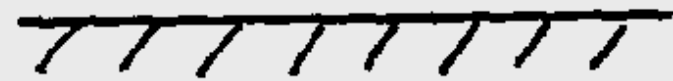
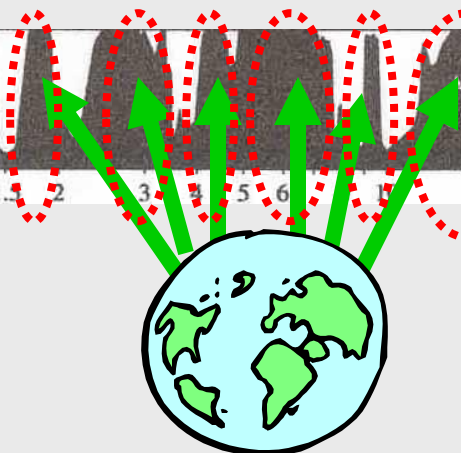
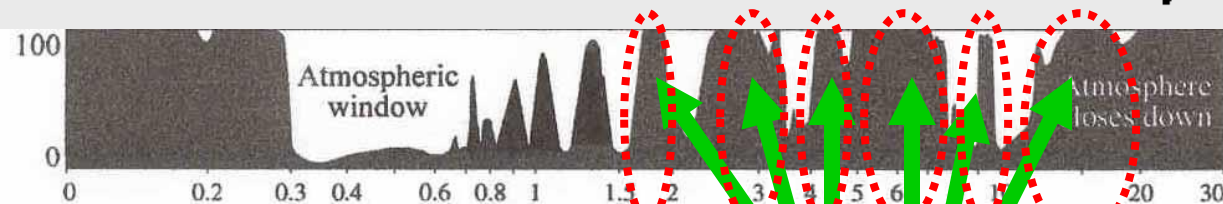
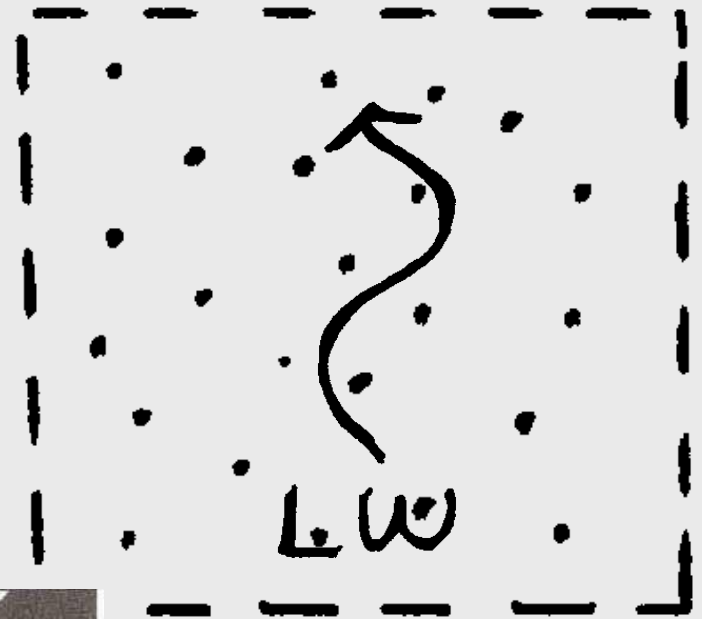
LW

ESCAPING TO  
SPACE THROUGH  
THE "OUTGOING IR  
ATMOSPHERIC  
WINDOW"

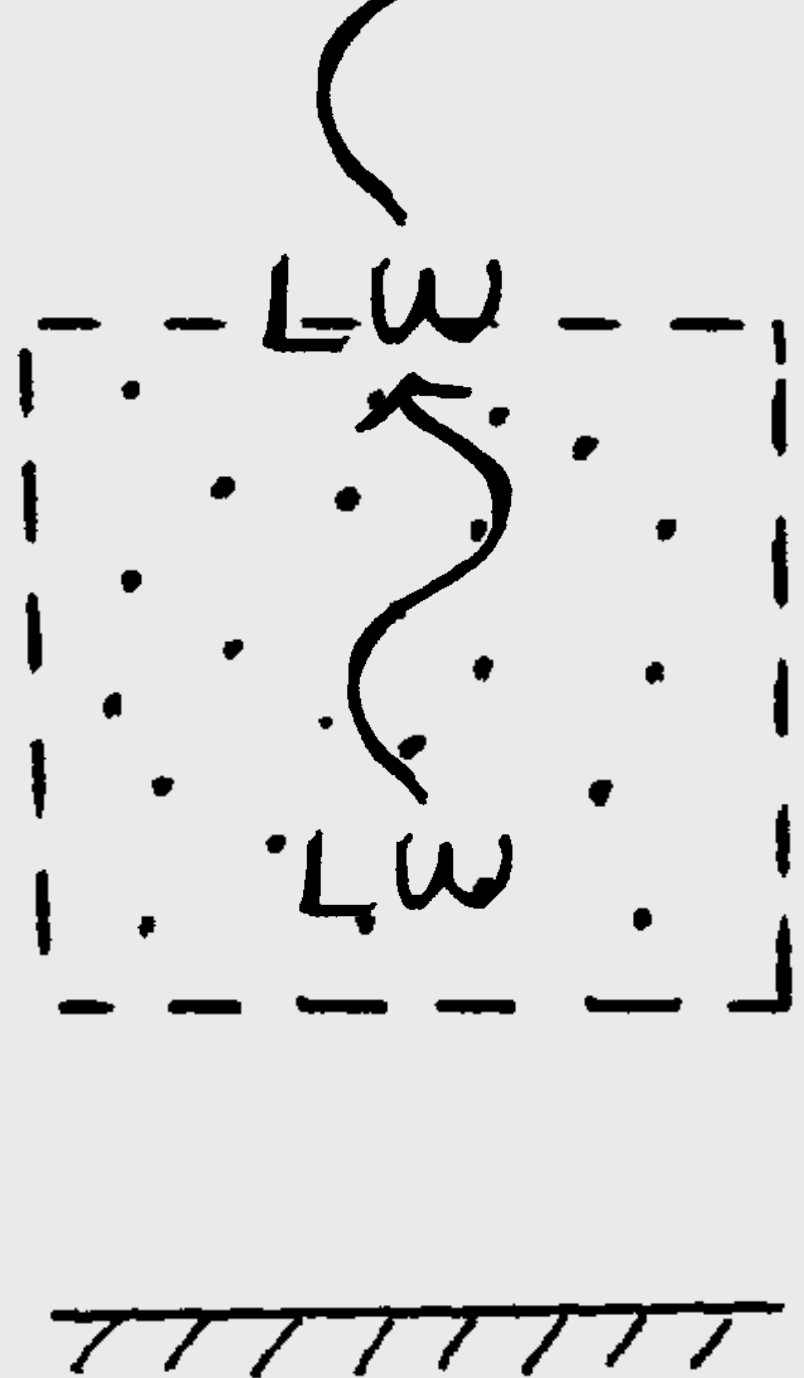
Outgoing LW



**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.)**



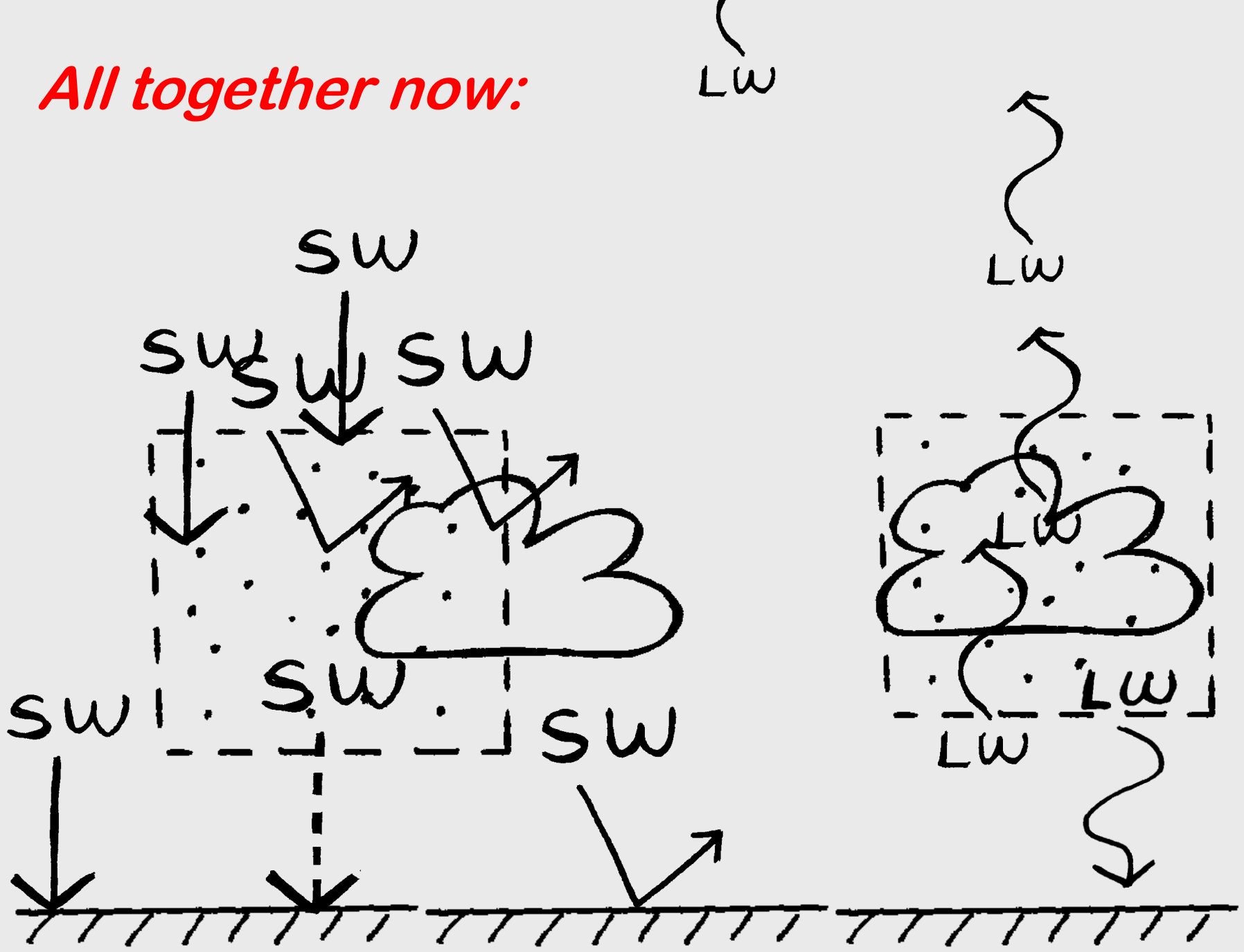
**IR EMITTED  
FROM  
ATMOSPHERE  
ESCAPING TO  
SPACE**



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



*All together now:*



**What if . . .**

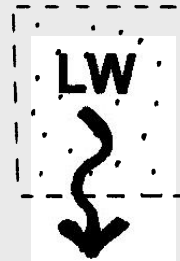
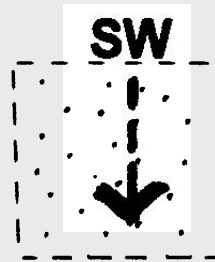
**. . . The Earth didn't have an atmosphere, and therefore didn't have a **greenhouse effect**??**

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

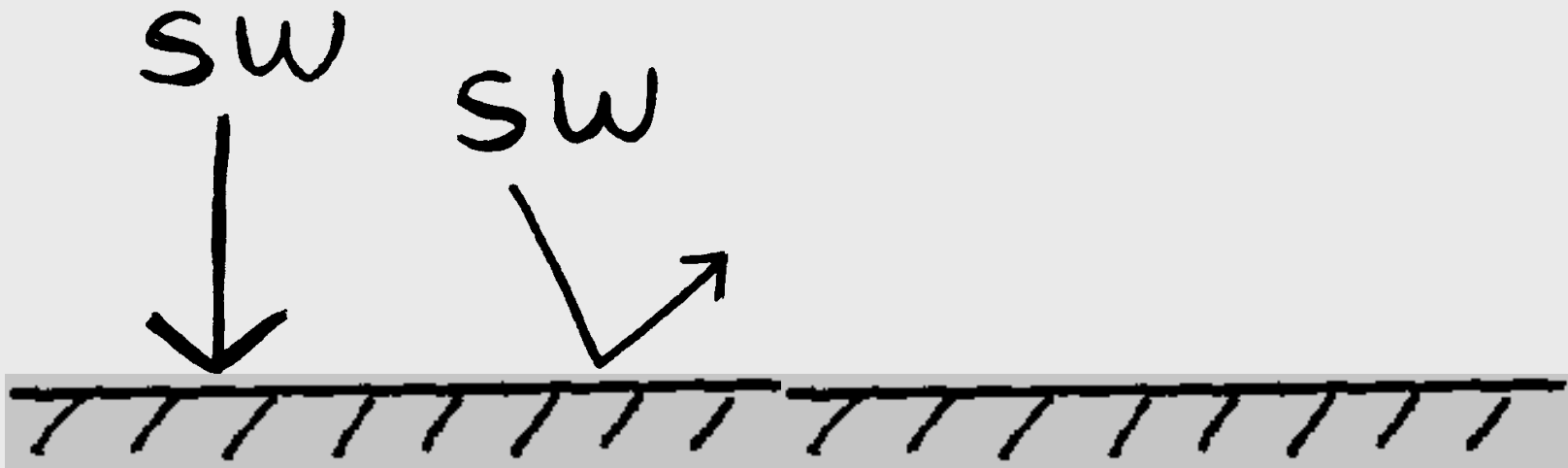
LW

# Which terms are not involved?

No scattering of SW by atmosphere

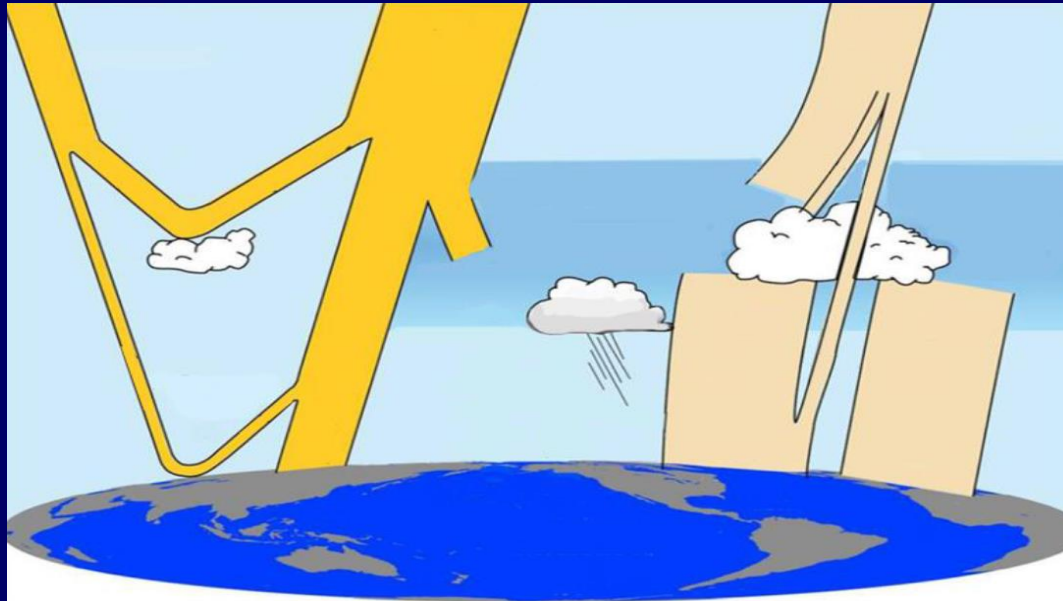


No downward re-radiation of LW / IR from the atmosphere because there would be **NO GHG's**

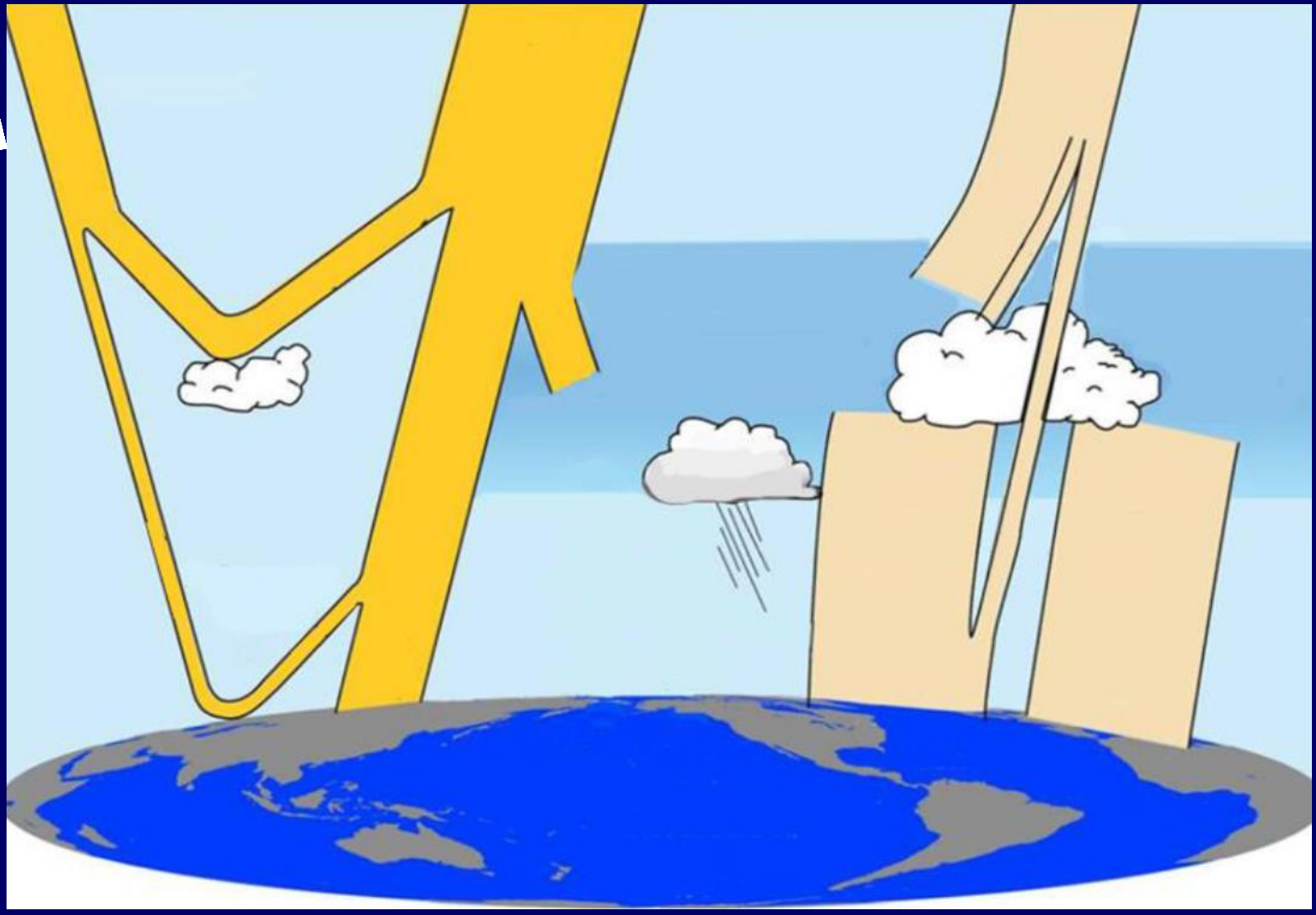
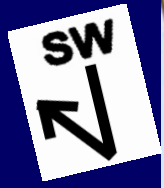
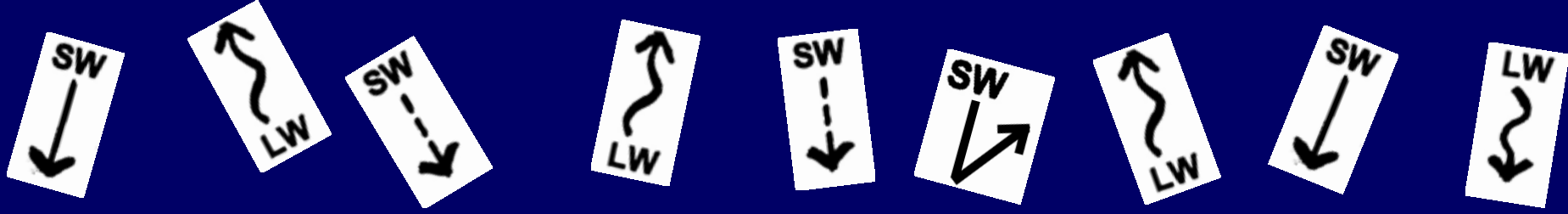




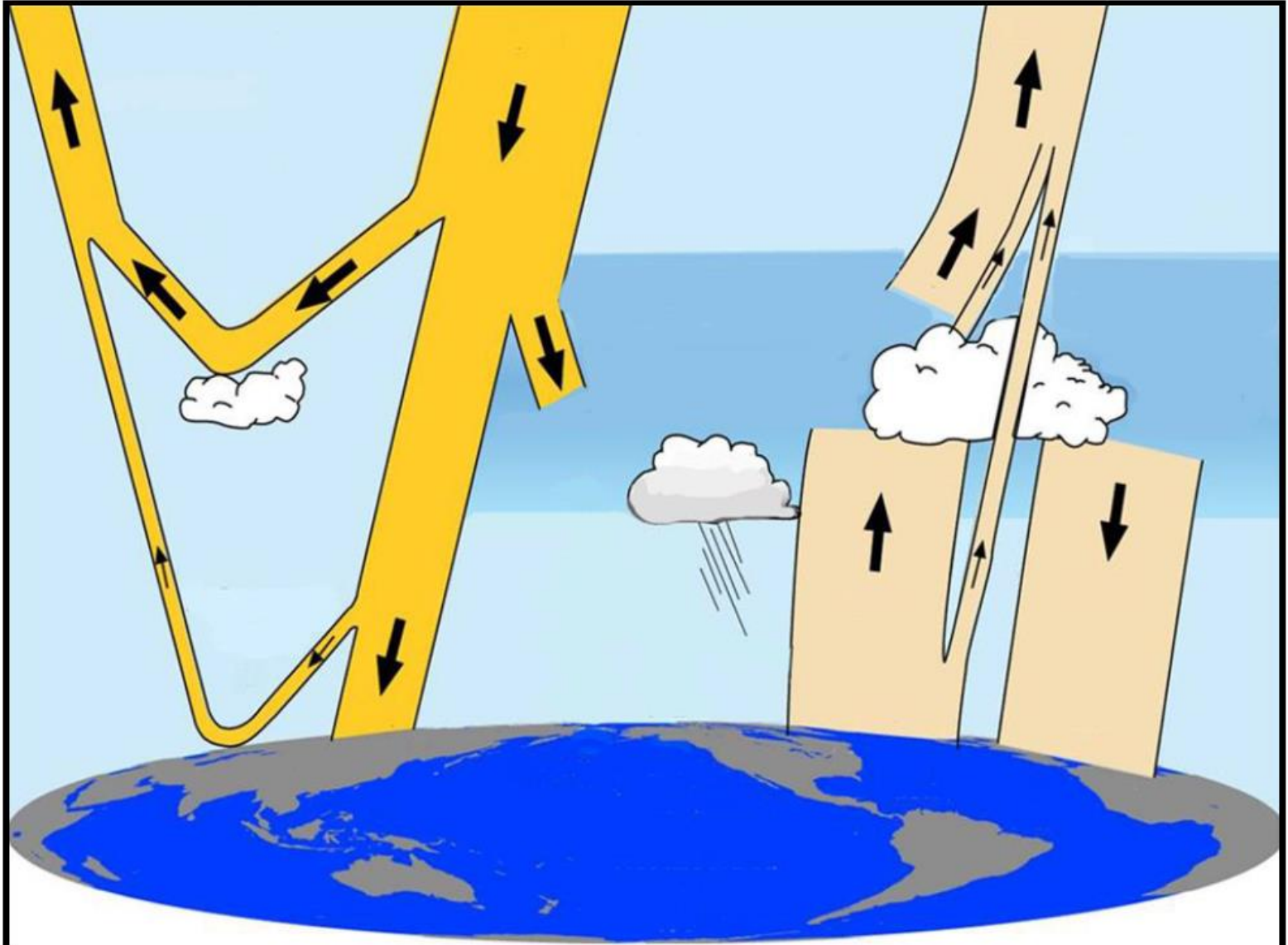
# HANDS ON WITH THE SYMBOLS!



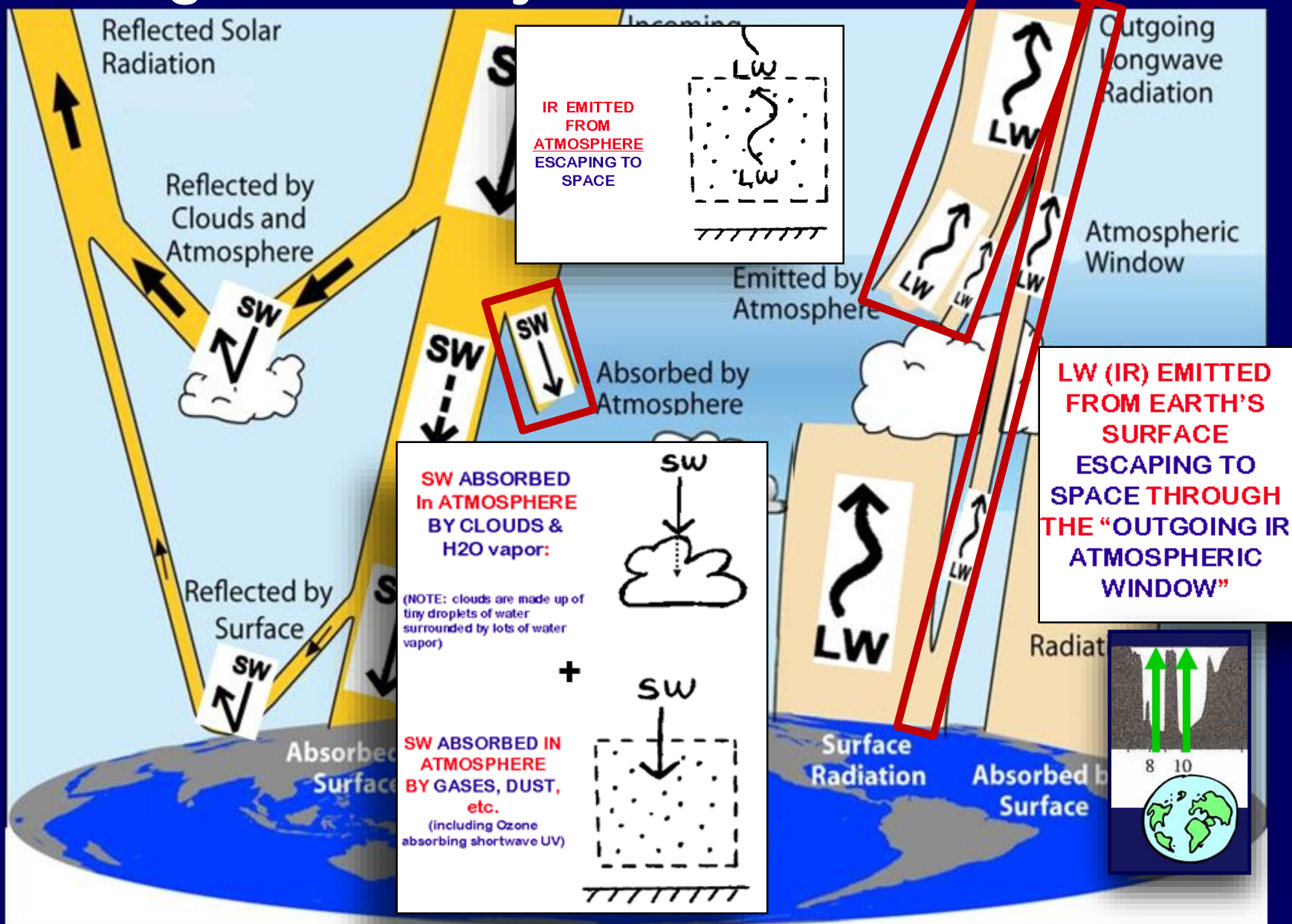
Can you label the **PATHWAYS**  
on this diagram with the  
**CORRECT SYMBOL** ?



**You've got a similar one  
(without labels) on p 45:**



# Naming the Pathways . . . .



Link back to Appendix pp 121-122

*Here's the equation  
you learned today:*

$$R_{NET} = \begin{array}{ccccccc} & SW & & SW & & SW & & & & LW \\ & \downarrow & & \downarrow & & \nearrow & & & \uparrow & & \downarrow \\ R_{NET} = & + & & - & & - & & + & & & \end{array}$$

**$R_{NET}$  = “NET RADIATION”**

**$R_{NET}$  = What goes IN – What goes OUT**

*To be continued next week after the Midterm . . .*

# Two Energy Balance Animations

showing energy flow pathways  
& “units” of energy that  
eventually balance out:

GLOBAL ENERGY BALANCE & PATHWAYS:

<http://earthguide.ucsd.edu/earthguide/diagrams/energybalance/index.html>

SHORTWAVE & LONGWAVE ENERGY FLOW & BUDGET:

[http://mesoscale.agron.iastate.edu/agron206/animations/10\\_AtmoEbal.html](http://mesoscale.agron.iastate.edu/agron206/animations/10_AtmoEbal.html)

