S5

SLO 1 - Human induced climate change (anthropogenic causes)

SLO 2- Global radiance balance of climate system

S5 – SLO 1 Human causes

- Climate change can also be caused by **human activities,** such as the burning of fossil fuels and the conversion of land for forestry and agriculture.
- Since the beginning of the Industrial Revolution, these human influences on the climate system have increased substantially. In addition to other environmental impacts, these activities change the land surface and emit various substances to the atmosphere. These in turn can influence both the amount of **incoming energy and the amount of outgoing energy** and can have both warming and cooling effects on the climate. The dominant product of fossil fuel combustion is carbon dioxide, dioxide, a greenhouse gas. The overall effect of human activities since the Industrial Revolution has been a warming effect, driven primarily by emissions of carbon dioxide and enhanced by emissions of other greenhouse gases.
- The build-up of greenhouse gases in the atmosphere has led to an enhancement of the natural greenhouse effect. It is this **human-induced enhancement** of the greenhouse effect that is of concern because ongoing emissions of greenhouse gases have the potential to warm the planet to levels that have never been experienced in the history of human civilization. Such climate change could have far-reaching and/or unpredictable environmental, social, and economic consequences.

- The Industrial Revolution in the 19th century saw the large-scale use of fossil fuels for industrial activities. These industries created jobs and over the years, people moved from rural areas to the cities. This trend is continuing even today.
- More and more land that was covered with vegetation has been cleared to make way for houses. Natural resources are being used extensively for construction, industries, transport, and consumption. Consumerism (our increasing want for material things) things) has increased by leaps and bounds, bounds, creating mountains of waste. Also, our population has increased to an incredible extent.
- All this has contributed to a rise in greenhouse gases in the atmosphere. Fossil fuels such as oil, coal and natural gas supply most of the energy needed to run vehicles, generate electricity for industries, households, etc.
- The **energy sector** is responsible for about ¾ of the carbon dioxide emissions, 1/5 of the methane emissions and a large quantity of nitrous oxide. It also produces nitrogen oxides (NOx) and carbon monoxide (CO) which are not greenhouse gases but do have an influence on the chemical cycles in the atmosphere that produce or destroy greenhouse gases

- **Carbon dioxide** is undoubtedly, the most important greenhouse gas in the atmosphere. Changes in land use pattern, deforestation, land clearing, agriculture, and other activities have all led to a rise in the emission of carbon dioxide.
- **Methane** is another important greenhouse gas in the atmosphere. About ¼ of all methane emissions are said to come from domesticated animals such as dairy cows, goats, pigs, buffaloes, camels, horses, and sheep. These **animals produce** methane during the cud-chewing process. Methane is also released from **rice or paddy fields** that are flooded during the sowing and maturing periods. When soil is covered with water it becomes anaerobic or lacking in oxygen. Under such conditions, methane-producing bacteria and other organisms decompose organic matter in the soil to form methane. Nearly 90% of the paddy-growing area in the world is found in Asia, as rice is the staple food there. China and India, between them, have 80-90% of the world's rice-growing areas.
- Methane is also emitted from **landfills** and other waste dumps. If the waste is put into an incinerator or burnt in the open, carbon dioxide is emitted. Methane is also emitted during the process of oil drilling, coal mining and also from leaking gas pipelines (due to accidents and poor maintenance of sites).
- A large amount of **nitrous oxide** emission has been attributed to fertilizer application. This in turn depends on the type of fertilizer that is used, how and when it is used and the methods of tilling that are followed. Contributions are also made by leguminous plants, such as beans and pulses that add nitrogen to the soil.

How we all contribute every day

All of us in our daily lives contribute our bit to this change in the climate. Give these points a good, serious thought:

1) **Electricity** is the main source of power in urban areas. All our gadgets run on electricity generated mainly from thermal power plants. These thermal power plants are run on fossil fuels (mostly coal) and are responsible for the emission of huge amounts of greenhouse gases and other pollutants.

2) Cars, buses, and trucks are the principal ways by which goods and people are **transported** in most of our cities. These are run mainly on petrol or diesel, both fossil fuels.

3) We generate large quantities of **waste in the form of plastics** that remain in the environment for many years and cause damage.

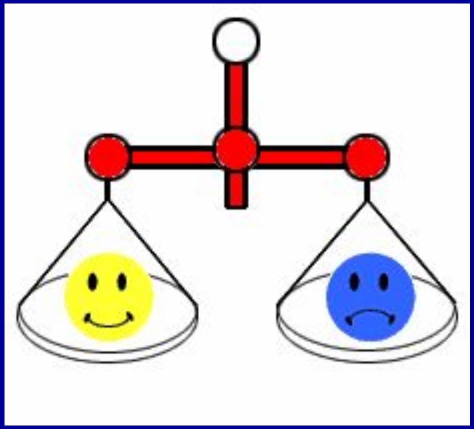
4) We use a huge quantity of paper in our work at schools and in offices. Have we ever thought about the **number of trees** that we use in a day?

5) Timber is used in large quantities for **construction** of houses, which means that large areas of **forest have to be cut down**.

6) A **growing population** has meant more and more mouths to feed. Because the land area available for agriculture is limited (and in fact, is actually shrinking as a result of ecological degradation), high-yielding varieties of crop are being grown to increase the agricultural output from a given area of land. However, such **high-yielding varieties of crops** require large quantities of fertilizers; and more fertilizer means more emissions of nitrous oxide, both from the field into which it is put and the fertilizer industry that makes it. **Pollution also results from the run-off of fertilizer into water bodies**.

Global radiance balance of climate system

Global radiance balance of climate system



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

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

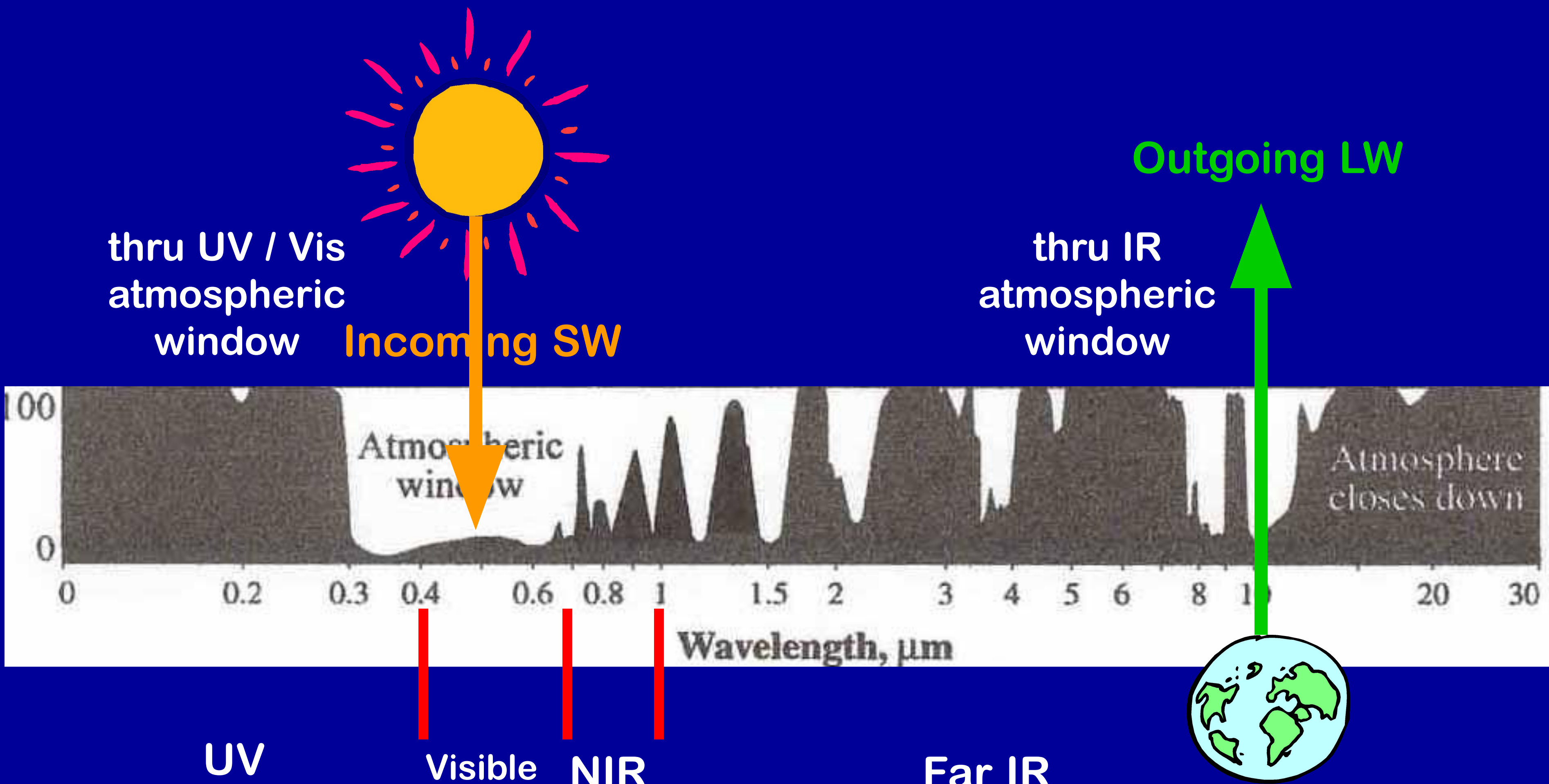
During the course of my day, have I accumulated more stress or more peace?

~ Doc Childre and Howard Martin

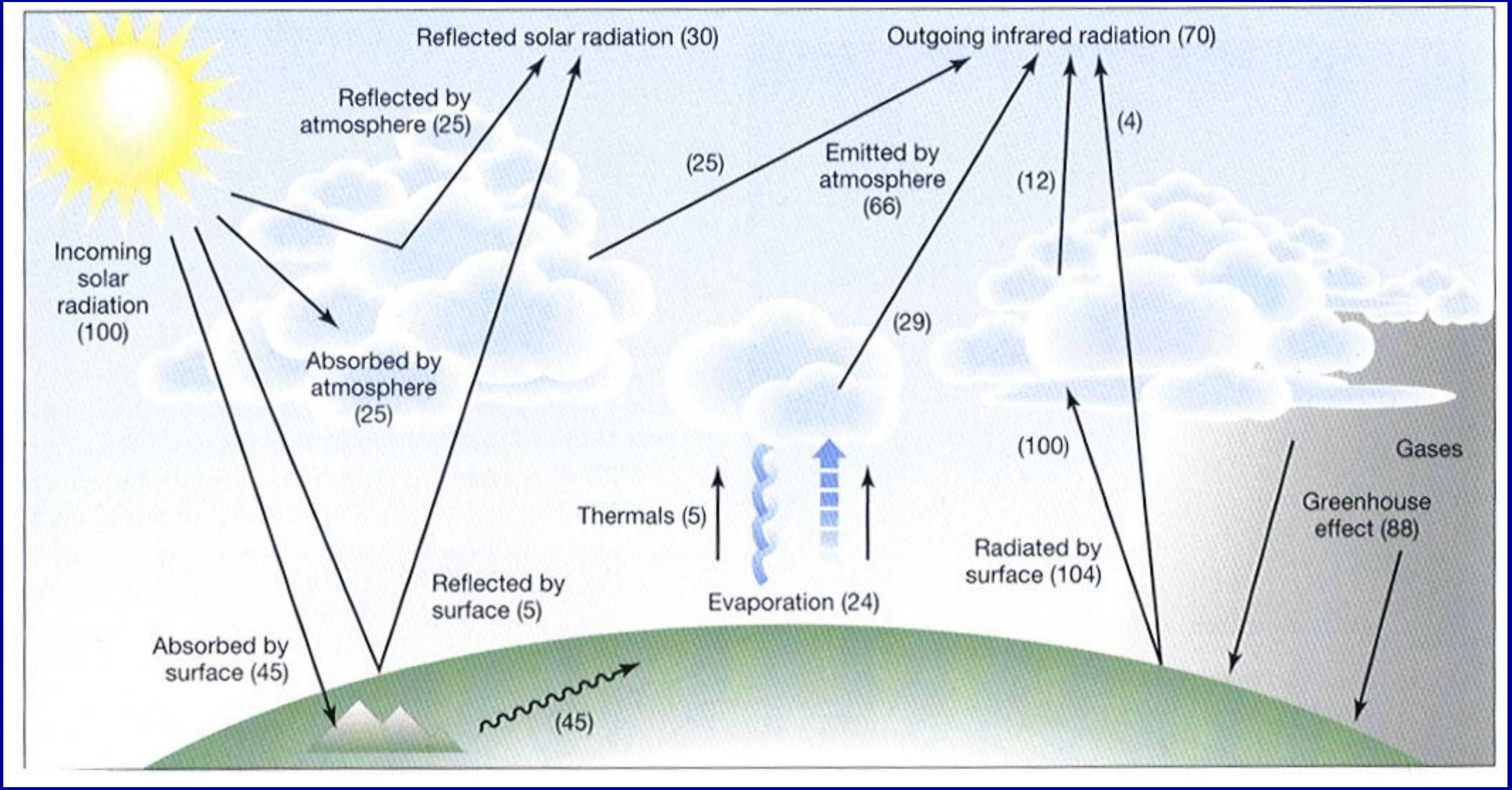
Review: Absorption curve for the "Whole Atmosphere"

OVERALL BALANCE:

Incoming = Outgoing



Typical Energy Balance Diagram



mesoscale.agron.iastate.edu/agron206/animations/10_AtmoEbal.html

From SGC-I Chapter 3, p 50, Fig 3-19

Energy Balance Equation:

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

(one of several ways this equation can be written)

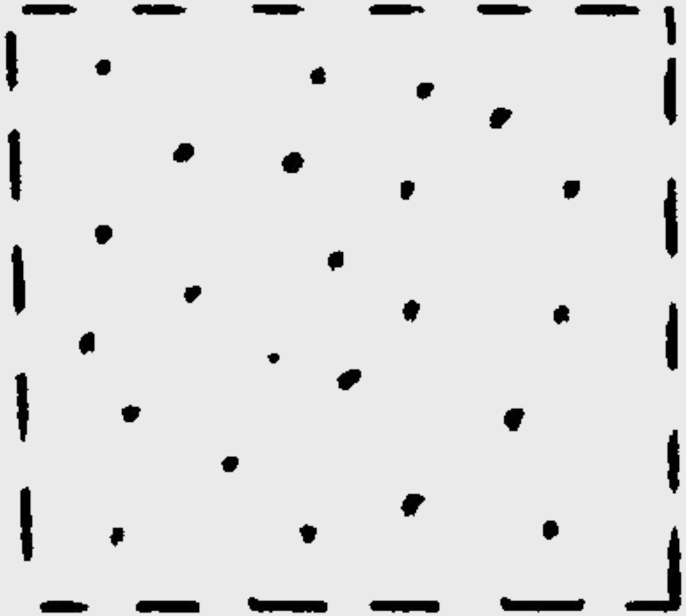
Let’s try to find an easy way to understand and remember all the components of the Earth’s Energy Balance

We’ll use “cartoon symbols” . . .

“CARTOON” SYMBOLS:

To represent the Earth’s surface:

"CARTOON" SYMBOLS:



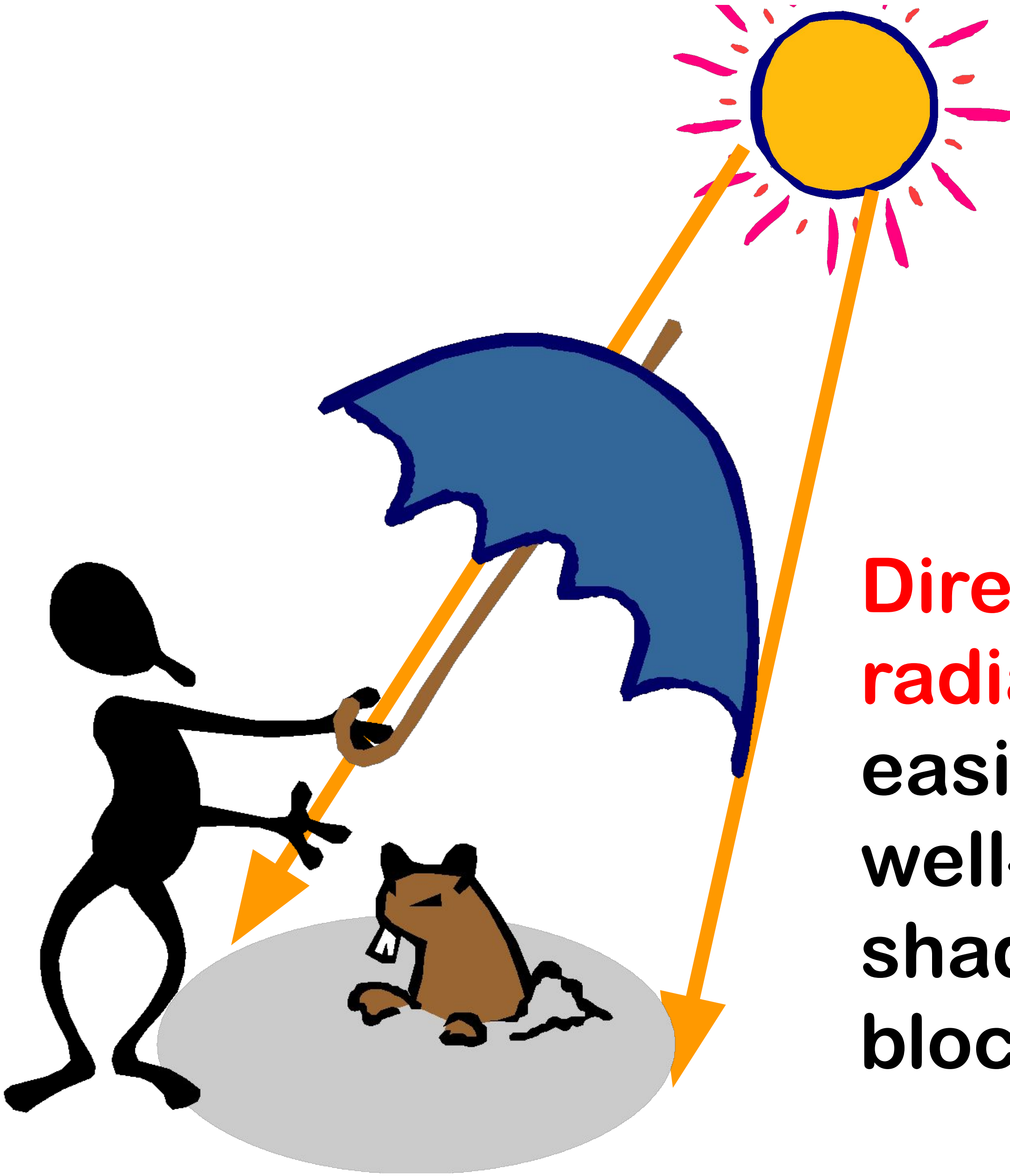
To represent the atmosphere – composed of both invisible gases, aerosols, dust and other particulate matter:

“CARTOON” SYMBOLS:

To represent CLOUDS

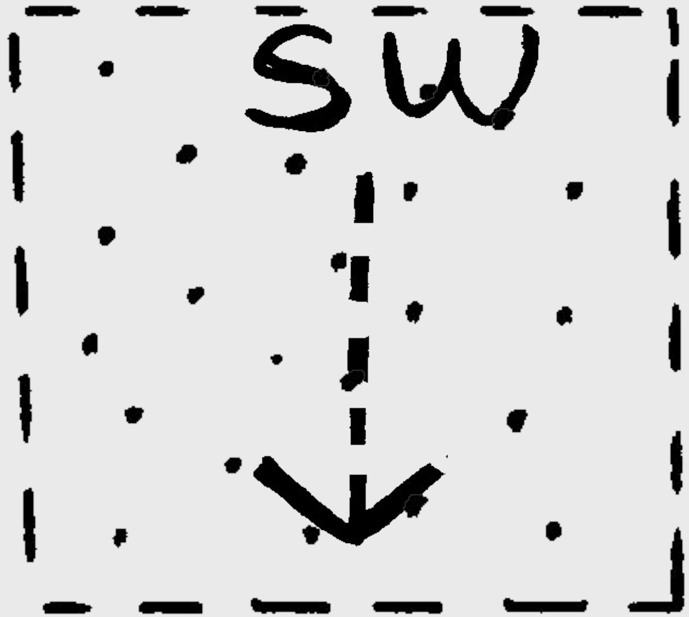
"CARTOON" SYMBOLS:

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



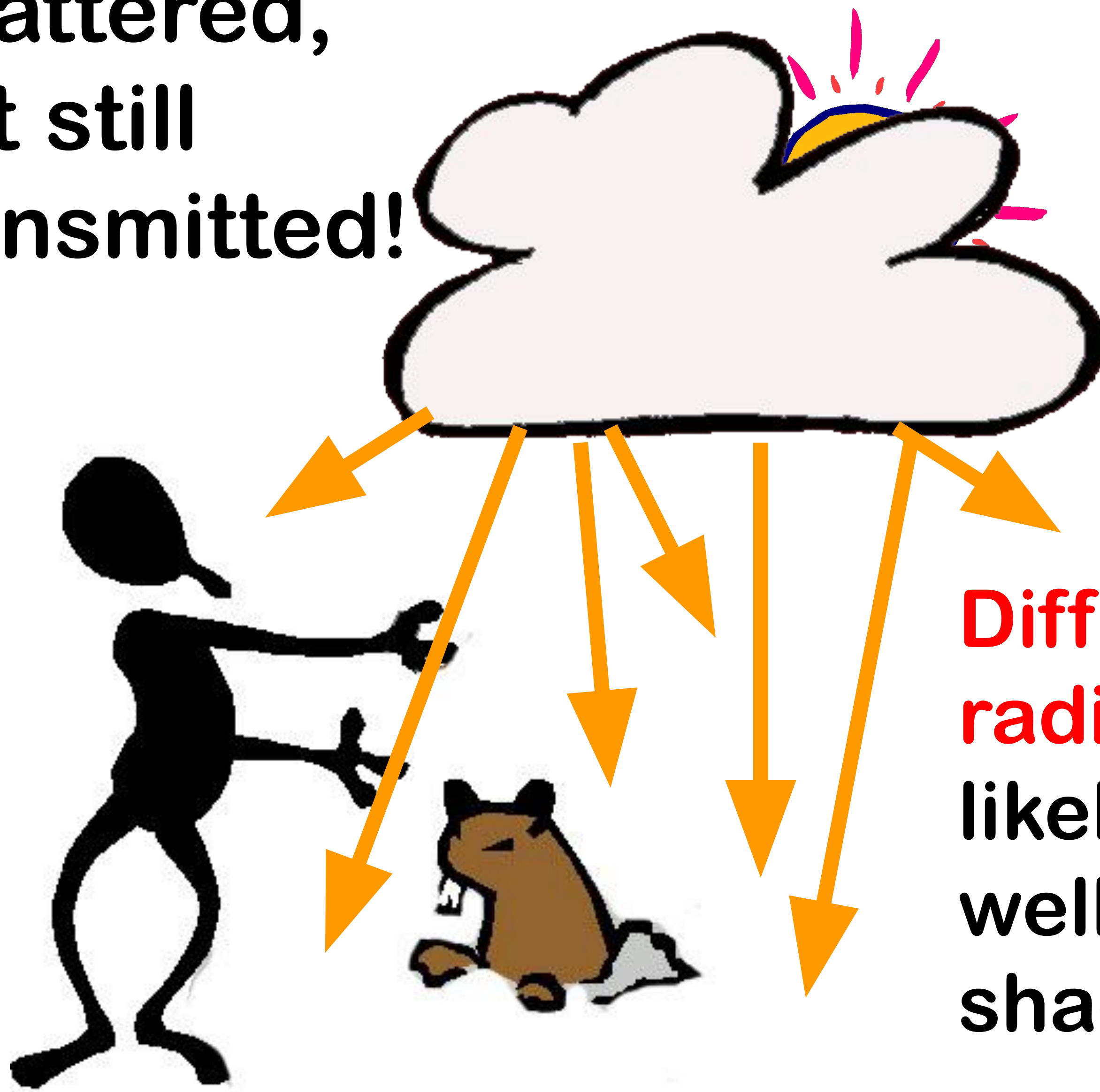
Direct SW radiation easily casts well-defined shadows when blocked

“CARTOON” SYMBOLS:

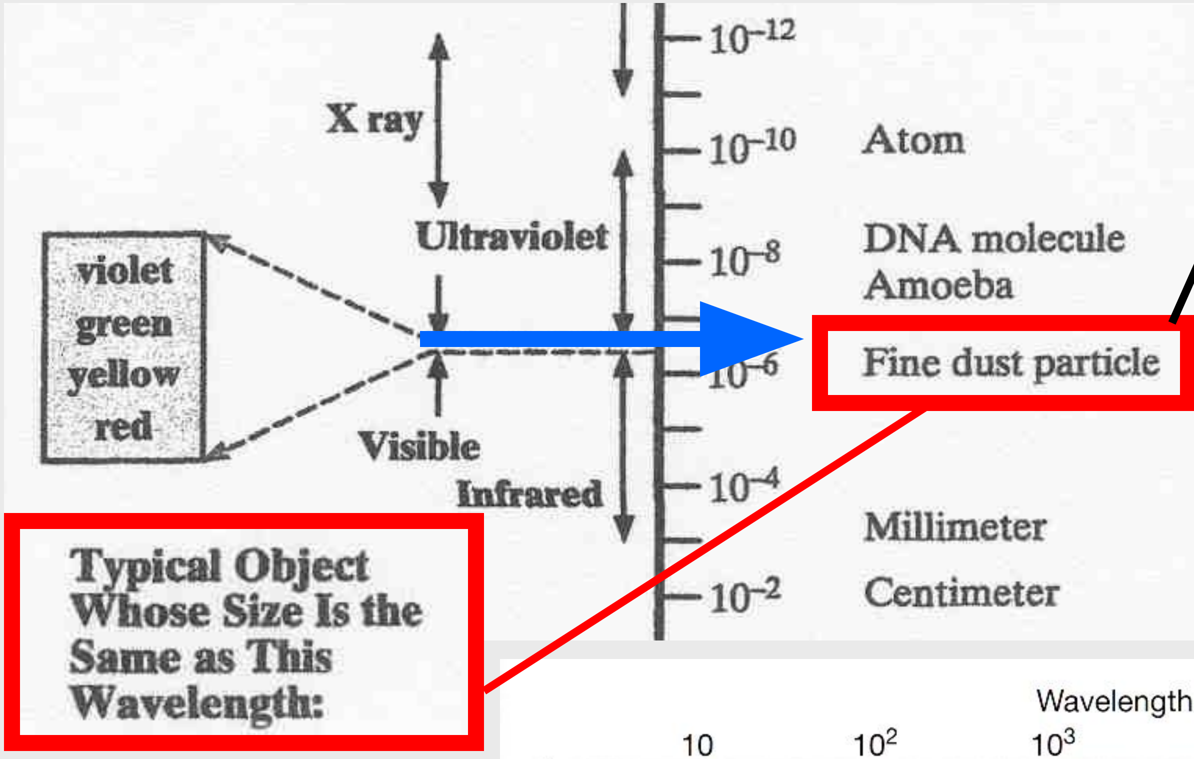


To represent SOLAR (shortwave) radiation coming in as **DIFFUSE shortwave radiation**, i.e. scattered by gases, clouds, and particles in the atmosphere.

Scattered, but still transmitted!



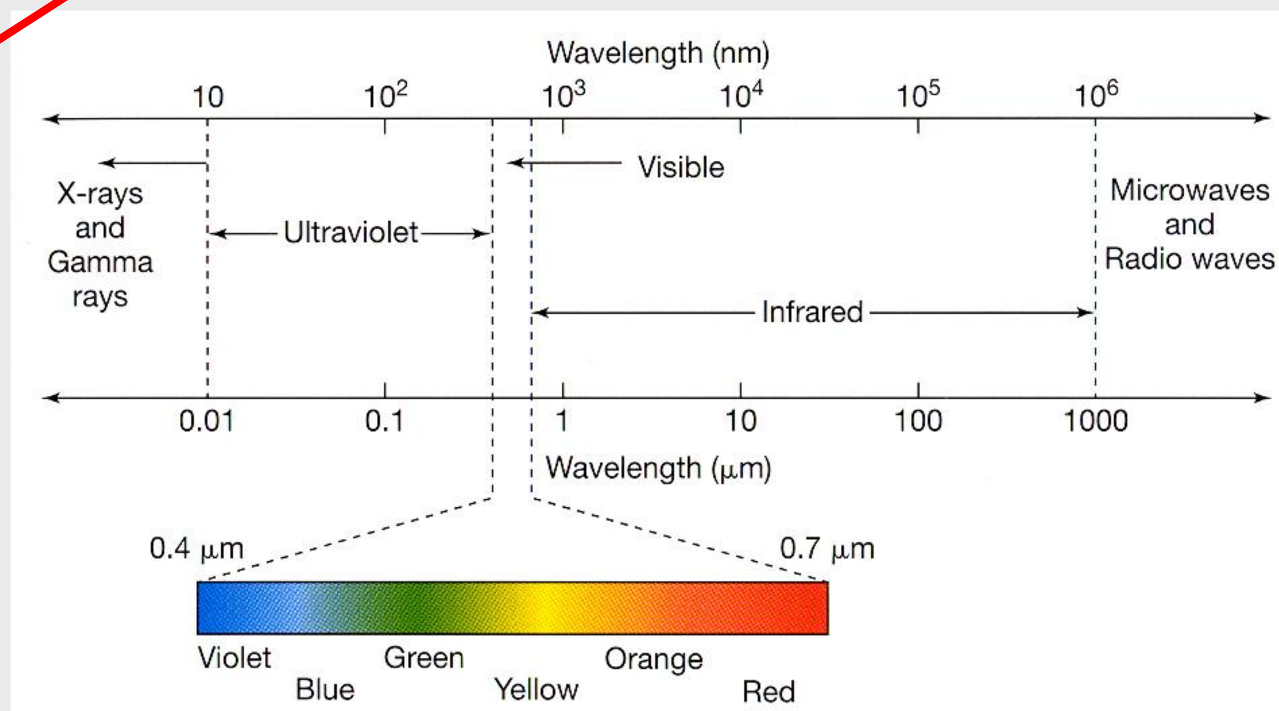
Diffuse SW radiation is less likely to cast a well-defined shadow!

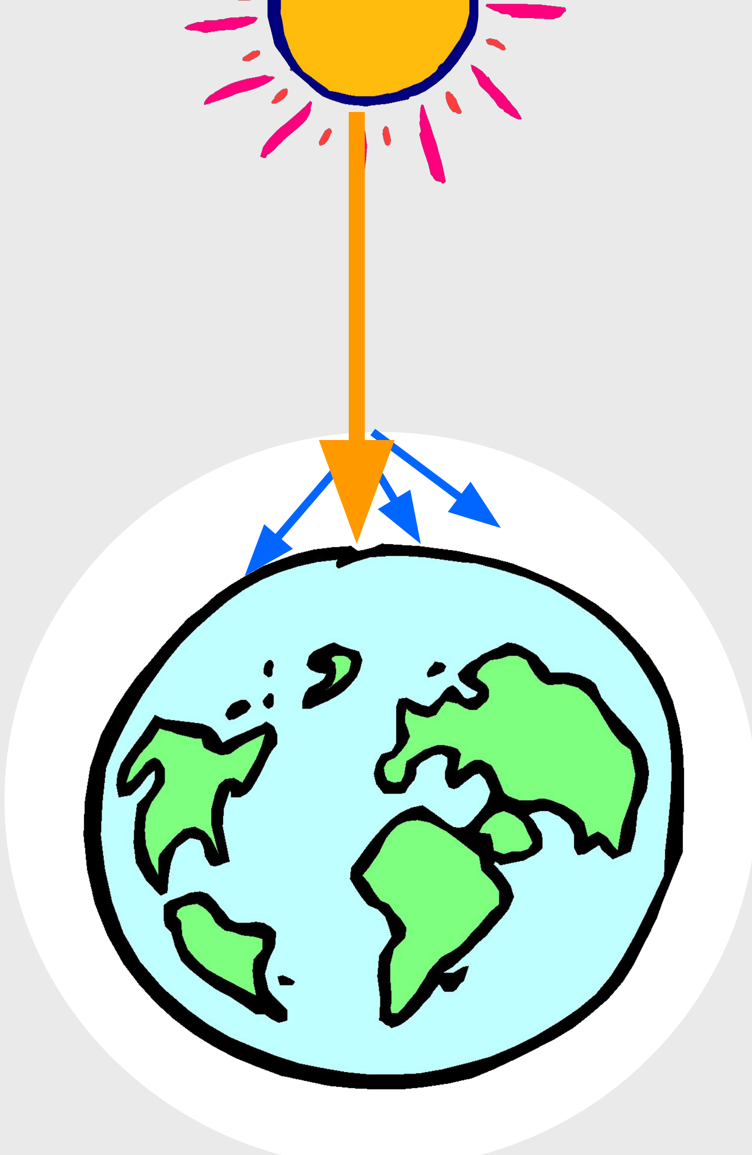


Different sized dust particles, water droplets, aerosols,

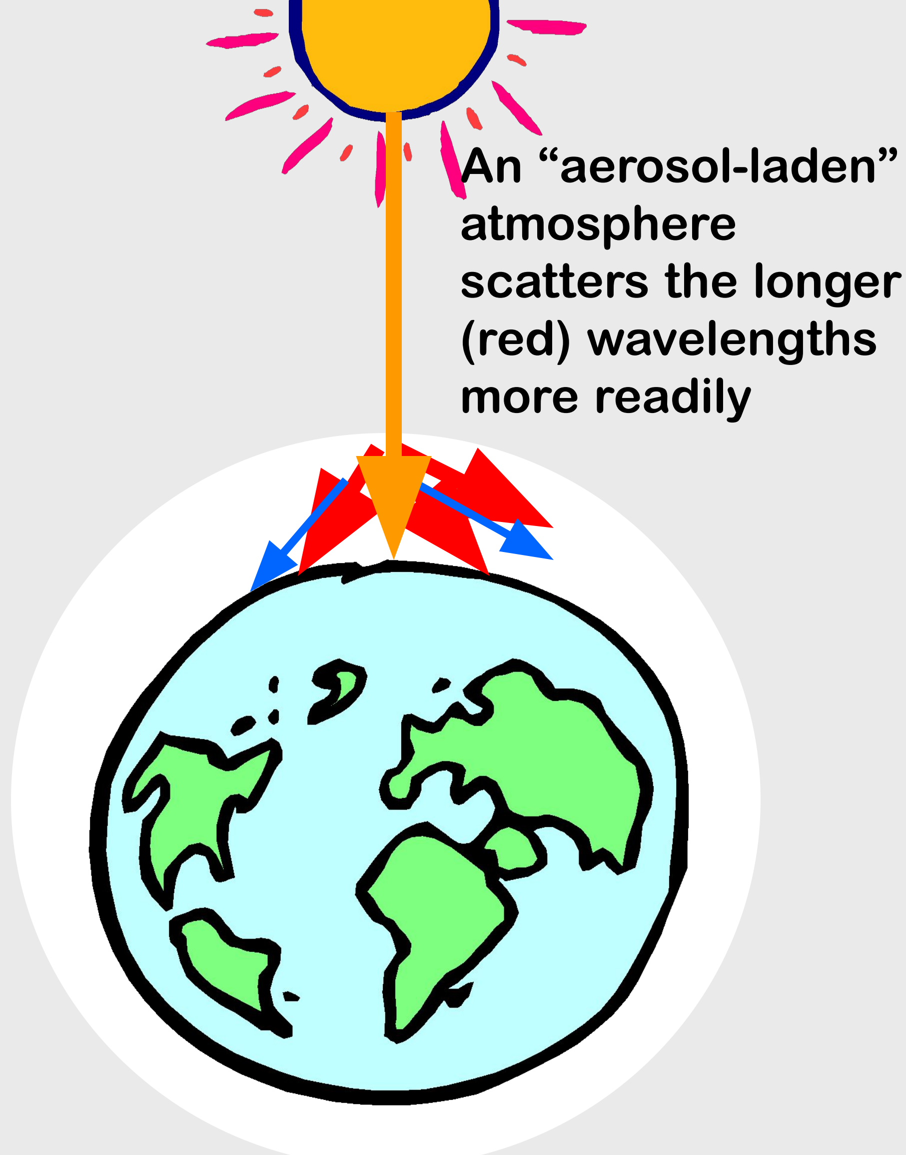
(even gas molecules themselves)

Scattering of visible light





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

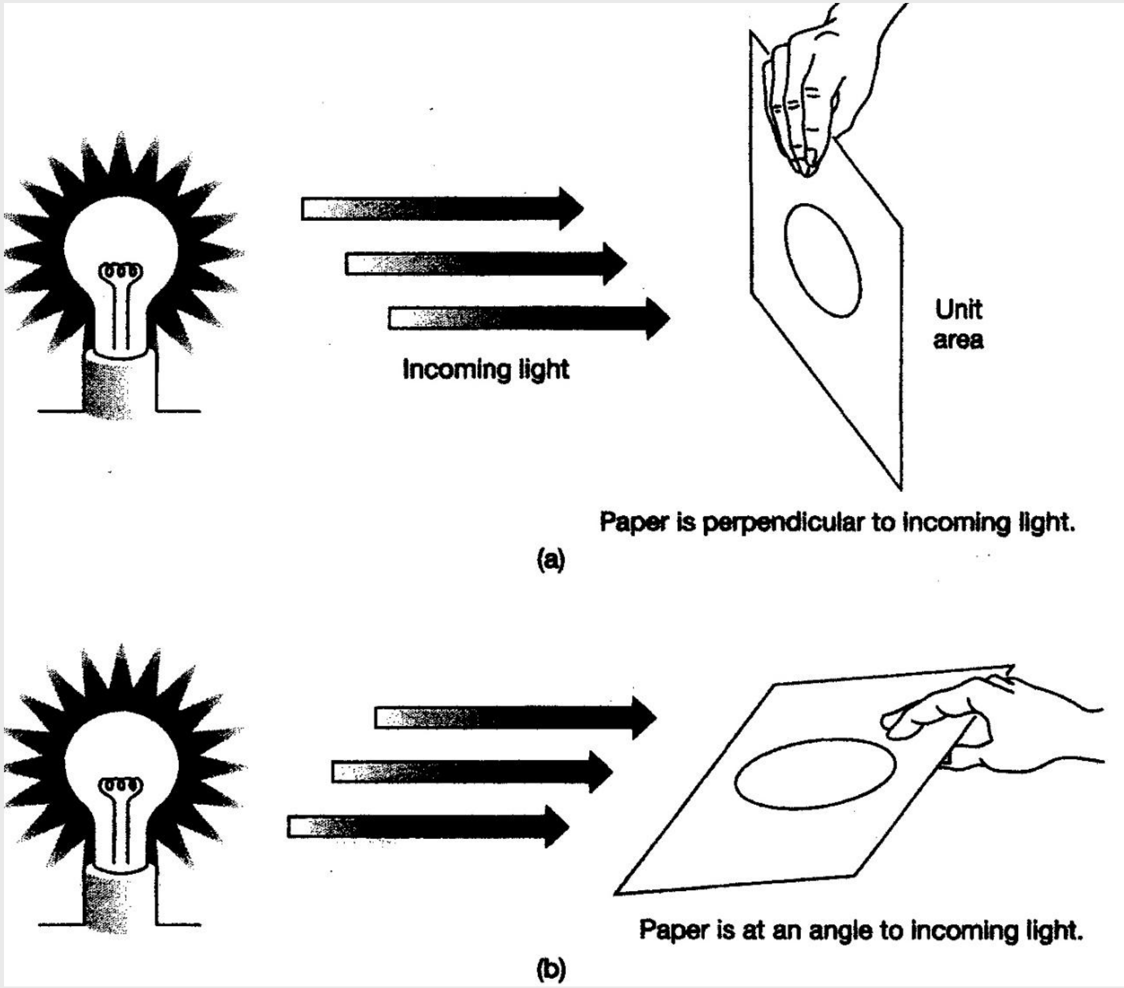


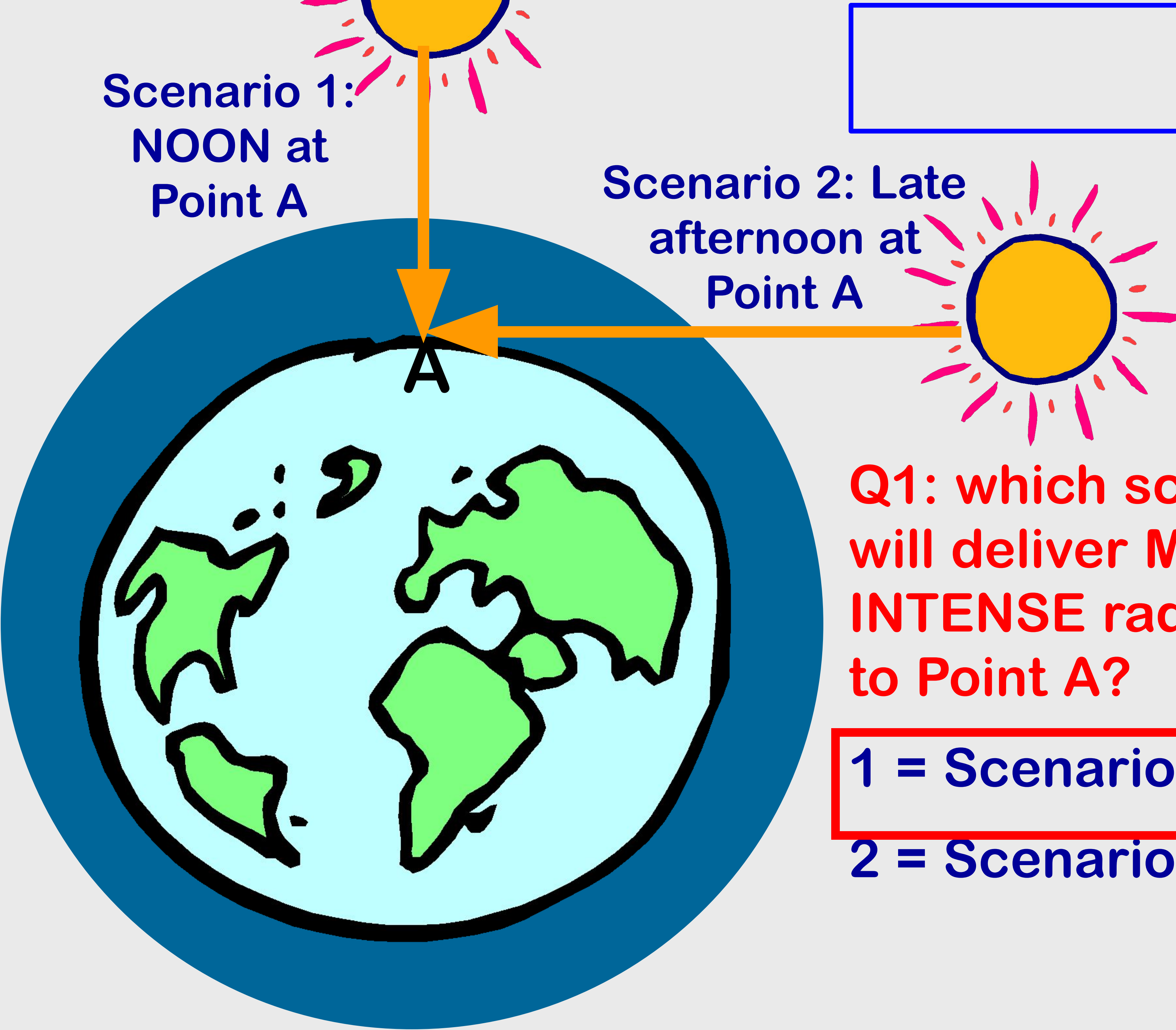
"Dirty" (aerosol-laden) atmosphere composed of fine particles, gases, & H_2O -- **PLUS larger dust particles, aerosols, pollution, etc.**

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.





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

BOTH #2 & #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.

New term:

<u>ALBEDO</u> = reflectivity of a surface

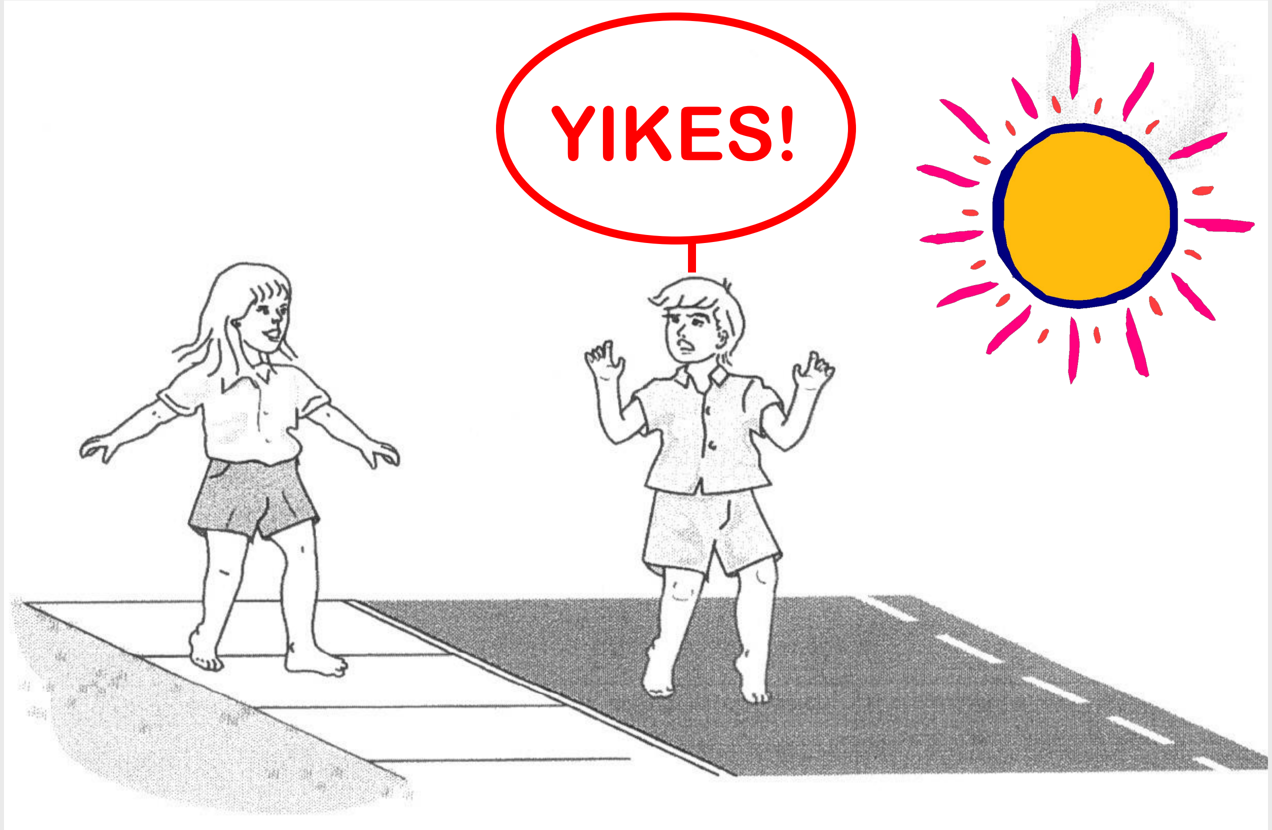
"*symbol*" = a

Represented as:

a decimal from 0 to 1.0 ***or***

% from 0 – 100 % (perfect reflectivity)

Hence, amount ABSORBED = (1 – 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	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	0.70–0.80

Low albedo

High albedo

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

AVERAGE PLANET EARTH = ~ 0.30

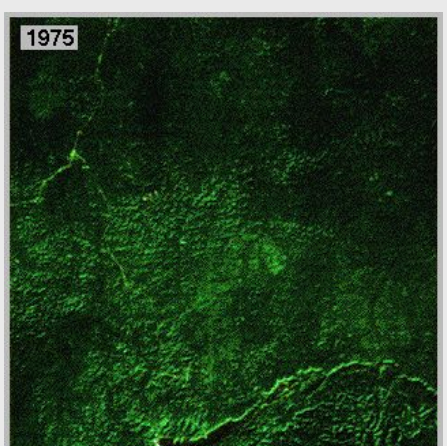
Q3: What will happen to incoming SW over the Amazon Rain Forest if parts of it are deforested?

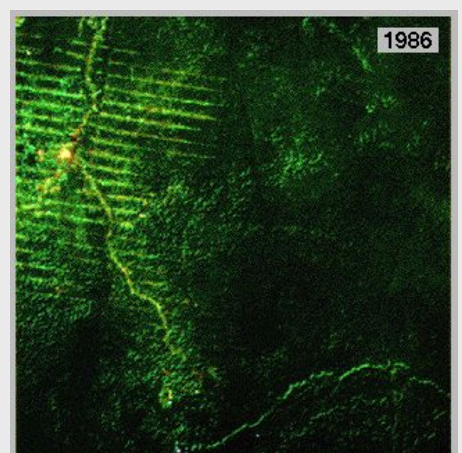
1 = more SW will be absorbed

2 = less SW will be absorbed

sw

Before





After

“CARTOON” SYMBOLS:

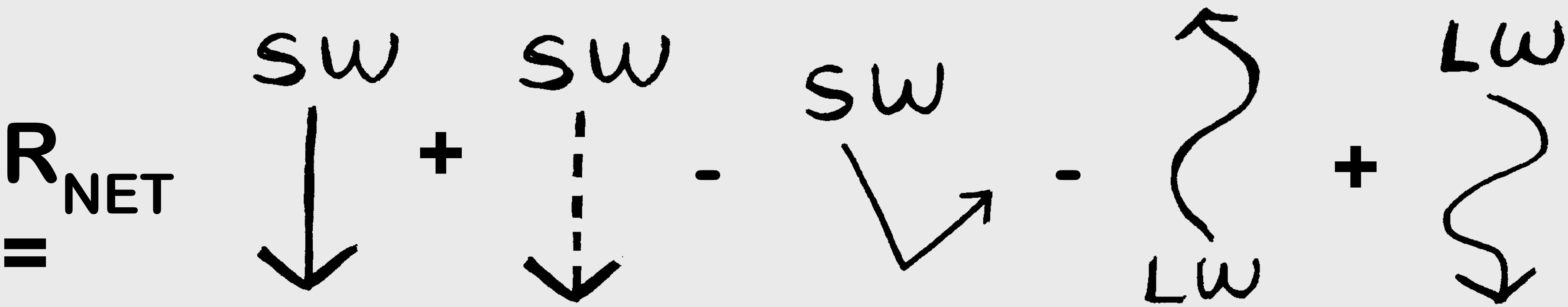
To represent TERRESTRIAL (longwave IR) radiation emitted upward by the Earth’s surface or the atmosphere

“CARTOON” SYMBOLS:

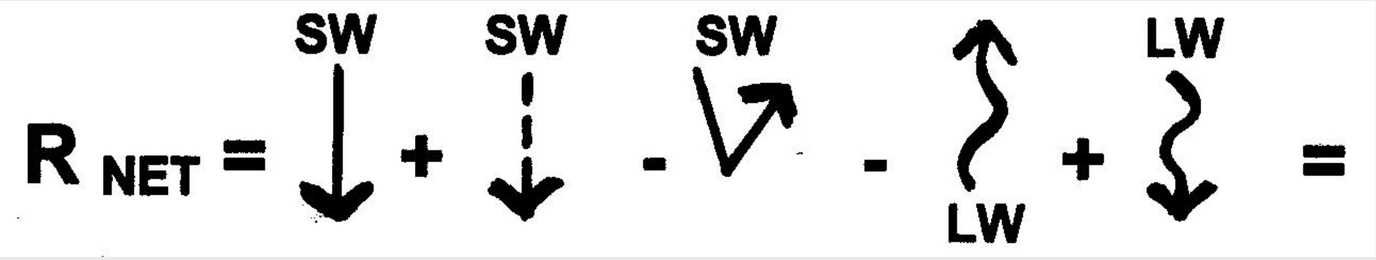
To represent TERRESTRIAL (longwave IR) re-radiation emitted downward by the Earth’s ATMOSPHERE

PUTTING IT TOGETHER:

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



$$R_{NET} = (Q + q) - a - Lu + Ld$$



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

First, what if . . .

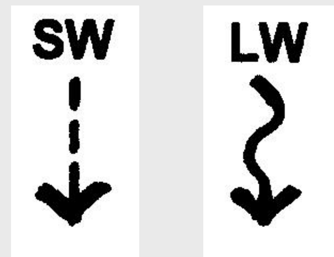
. . . The Earth didn't have an atmosphere, and therefore didn't have a greenhouse effect??

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

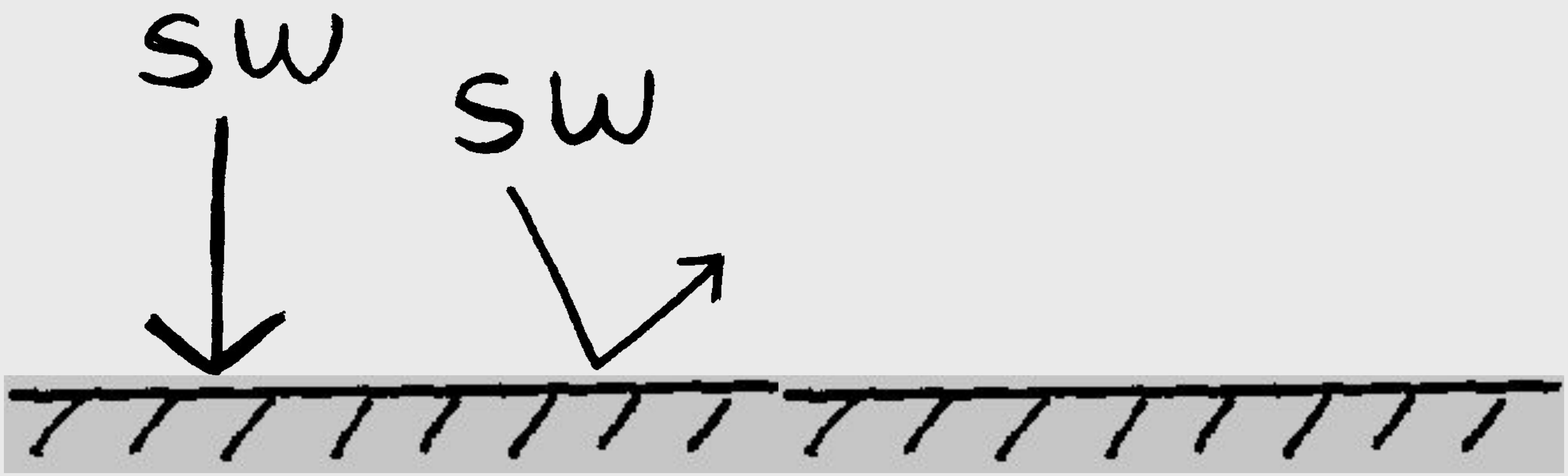
LW

Which terms are not involved?

No scattering by atmosphere

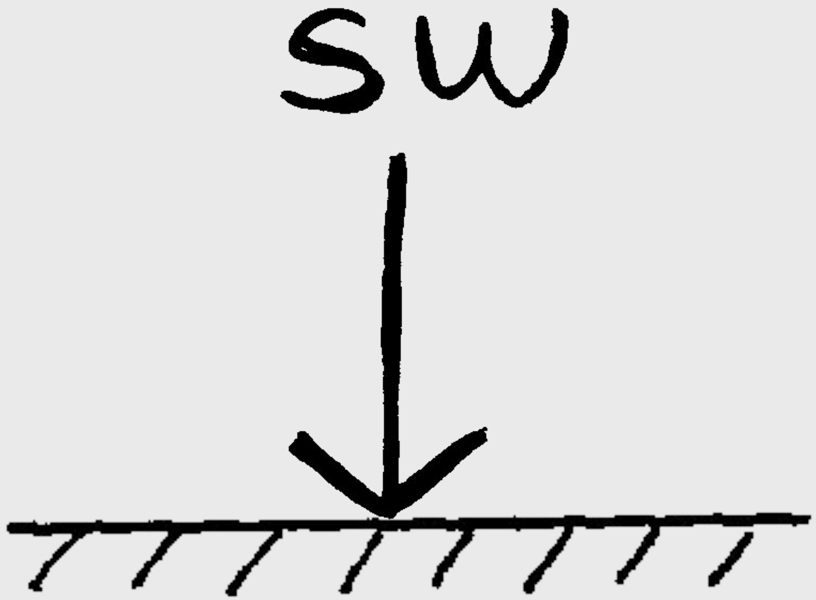


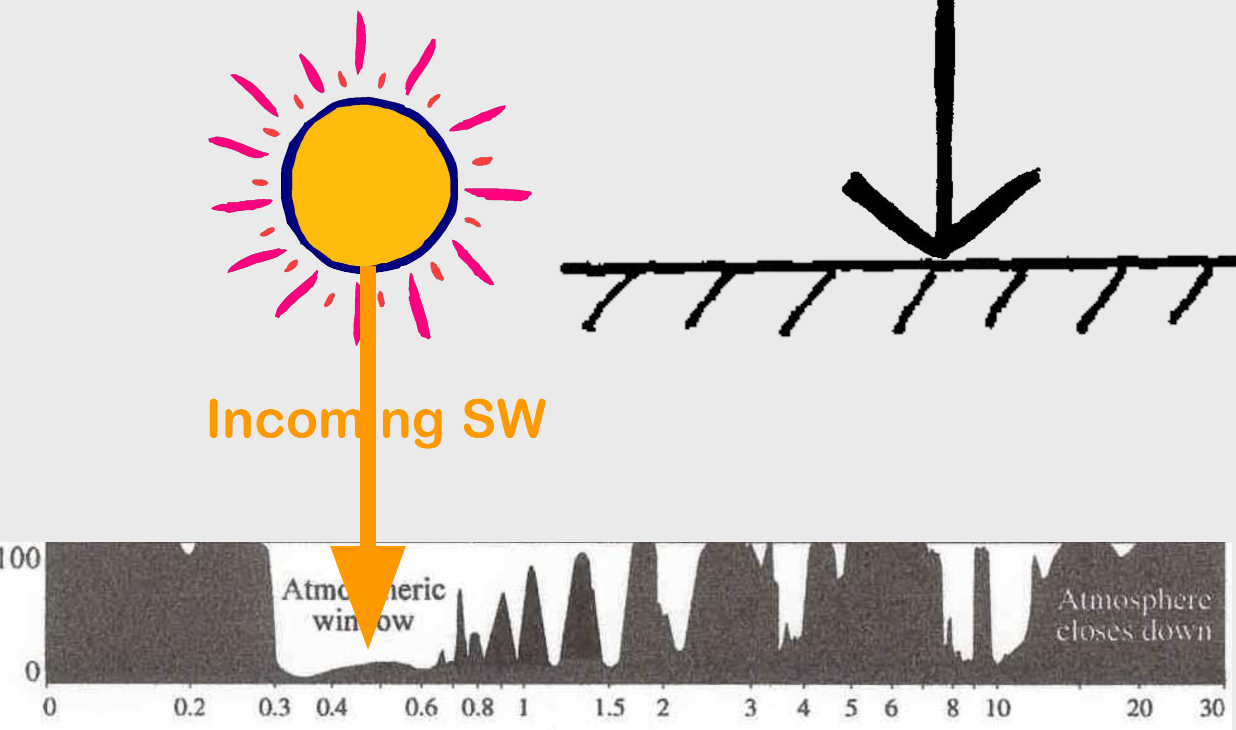
No re-radiation of infrared by GHG's



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:

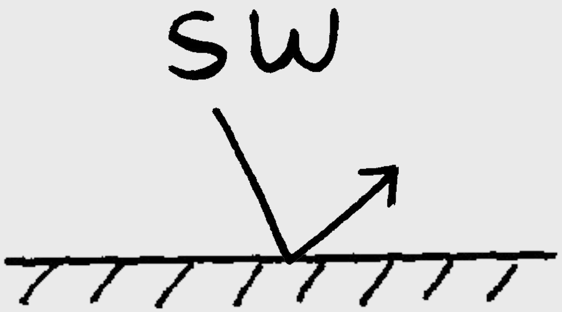




SW REFLECTED BACK TO SPACE:

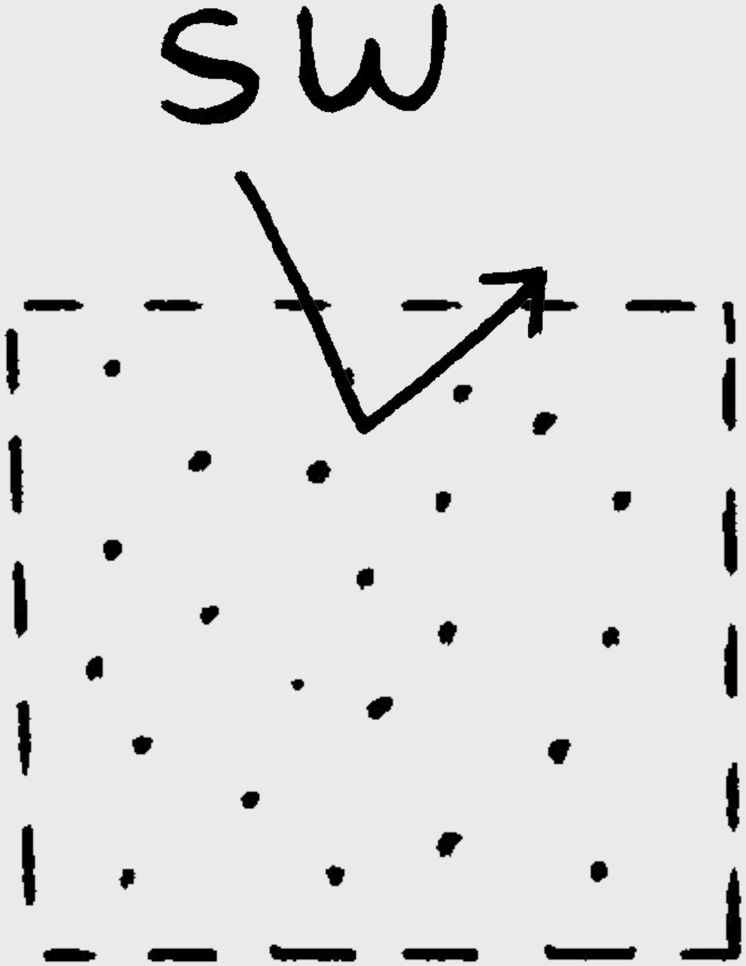
By clouds

By Earth's surface

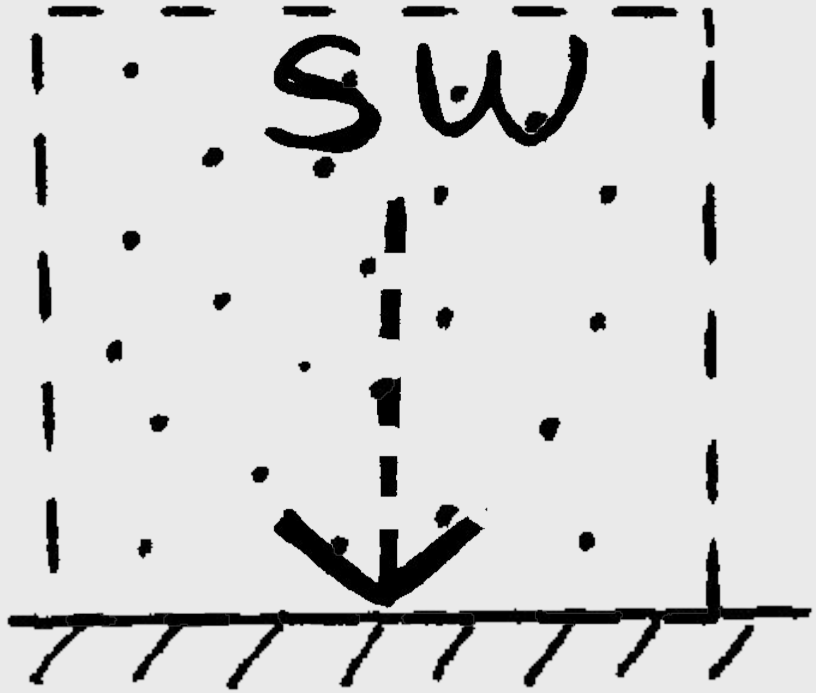


This is determined by the ALBEDO of the clouds or surface

SW SCATTERED BACK TO SPACE BY ATMOSPHERE:

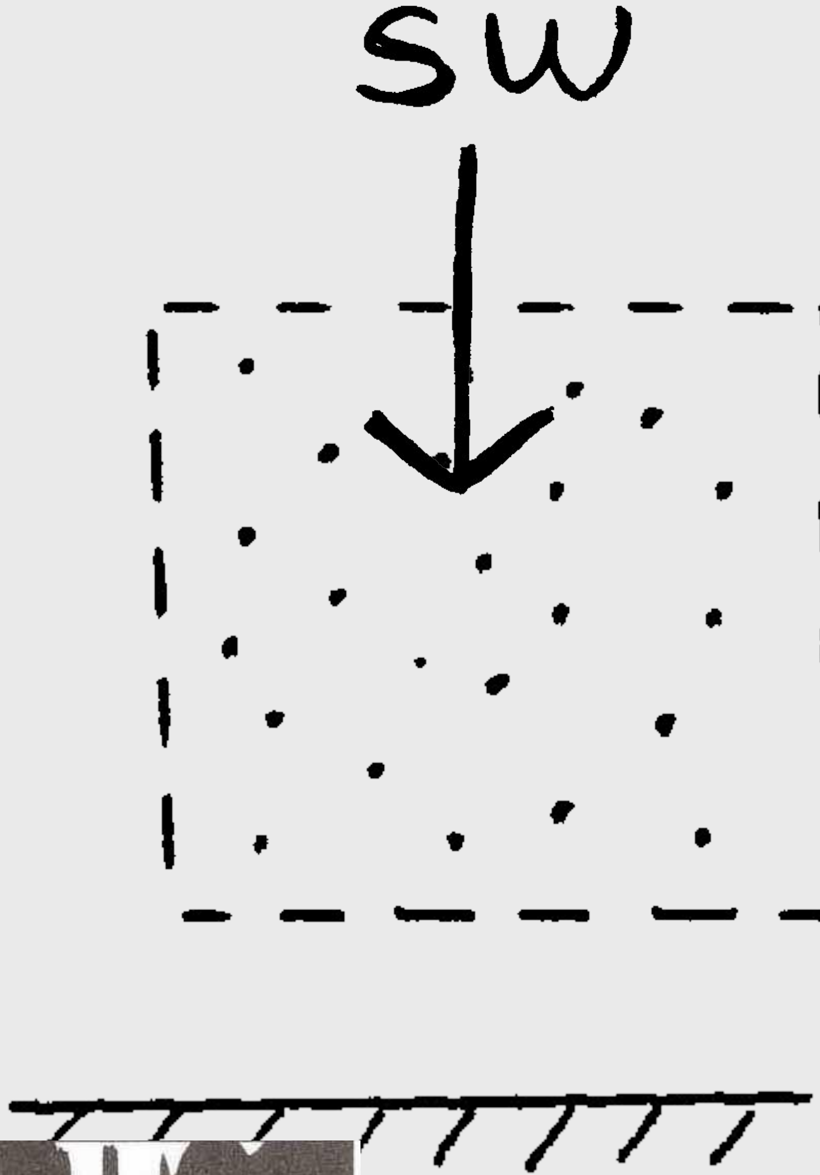


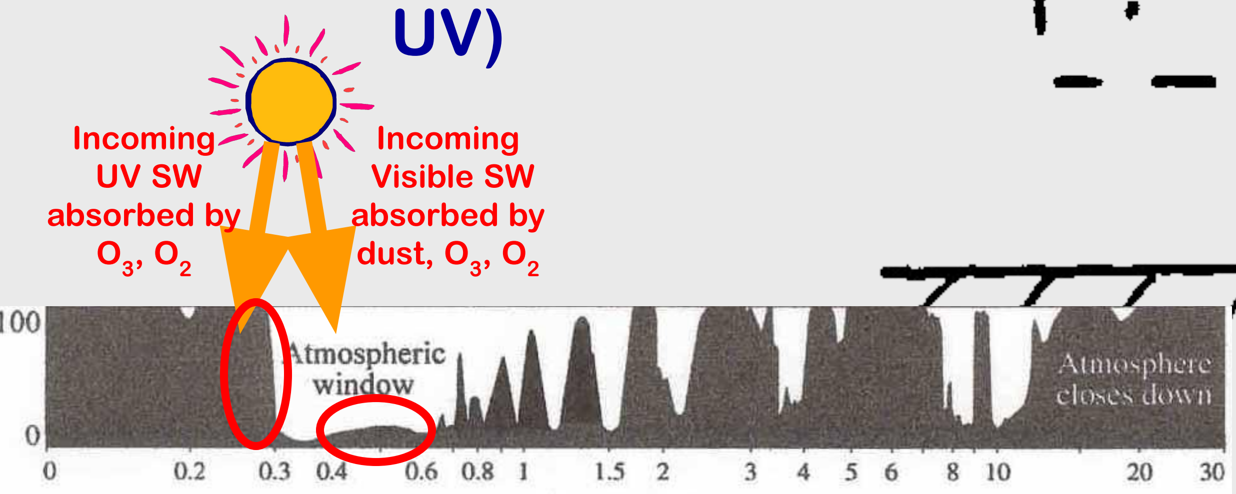
SW SCATTERED DOWN TO EARTH's SURFACE where it is absorbed



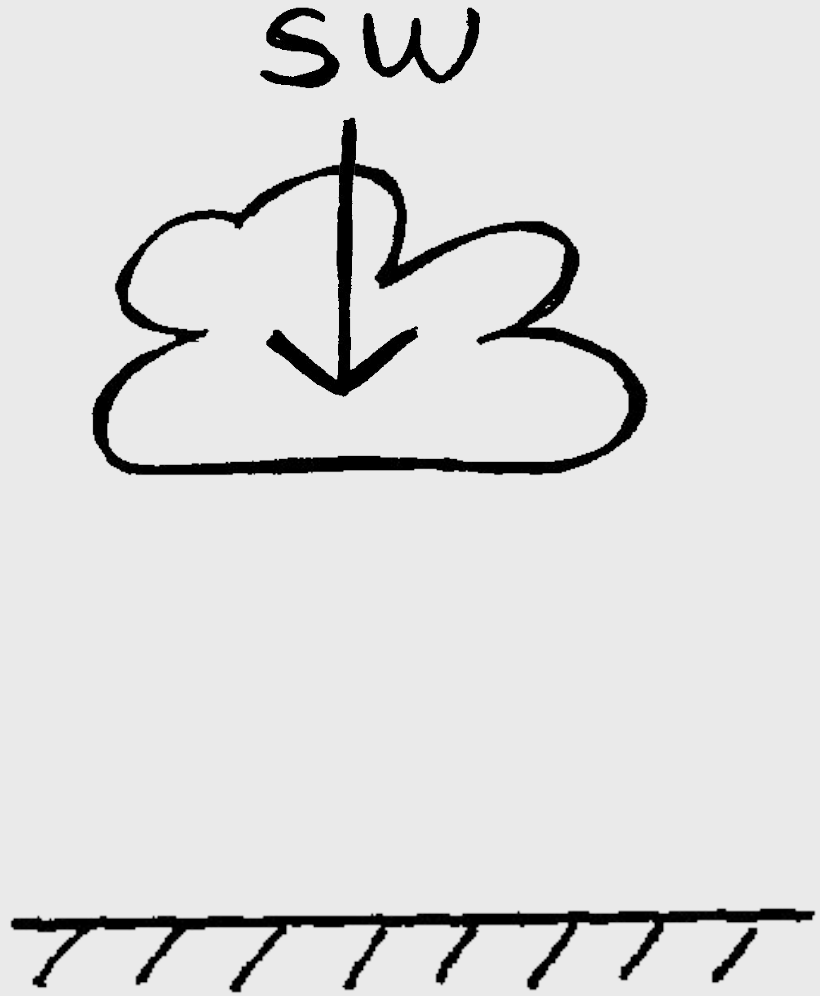
SW ABSORBED IN ATMOSPHERE BY GASES, DUST, etc.

(including Ozone absorbing shortwave UV)



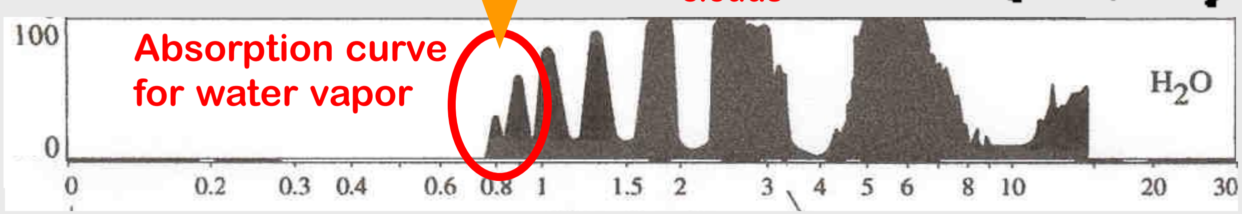


SW ABSORBED In ATMOSPHERE BY CLOUDS & H2O vapor:



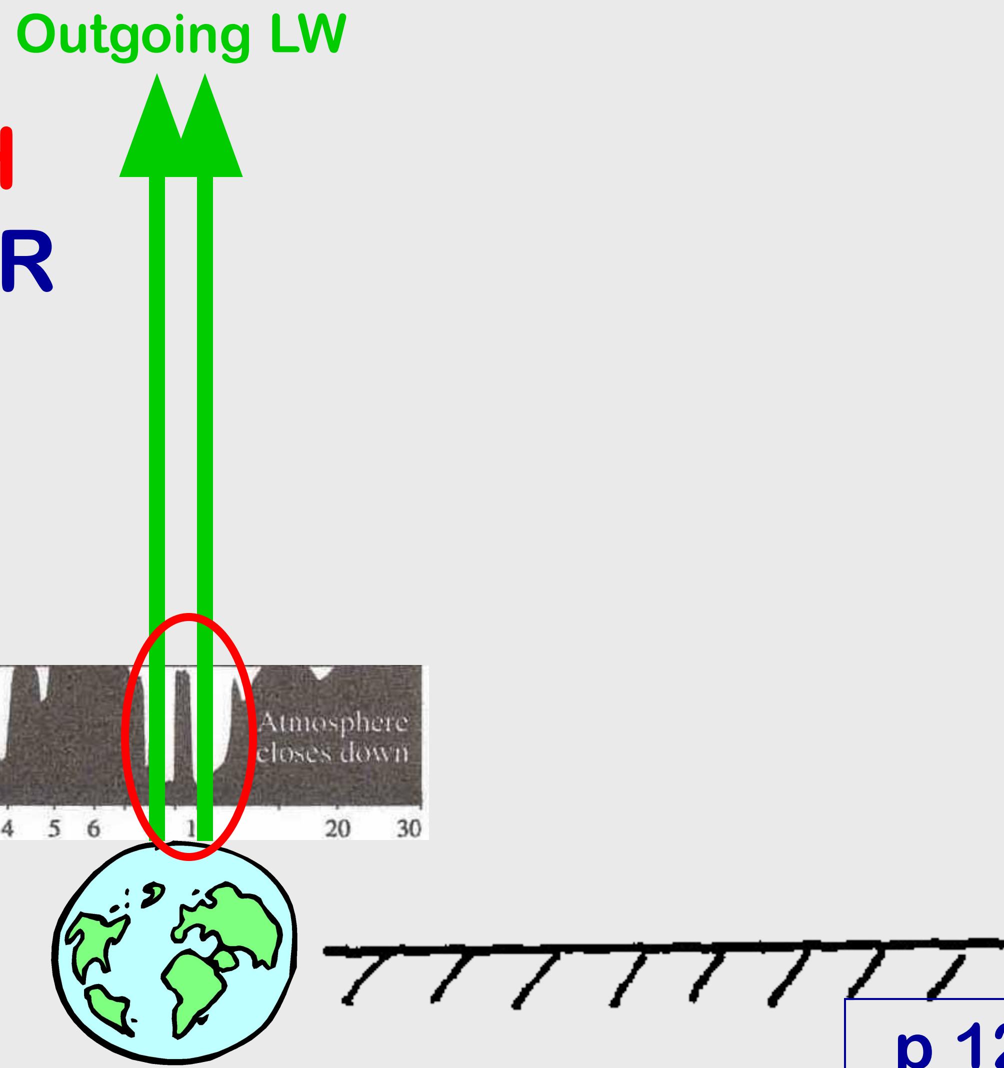
(NOTE: clouds are made up of tiny droplets of water surrounded by lots of water vapor)

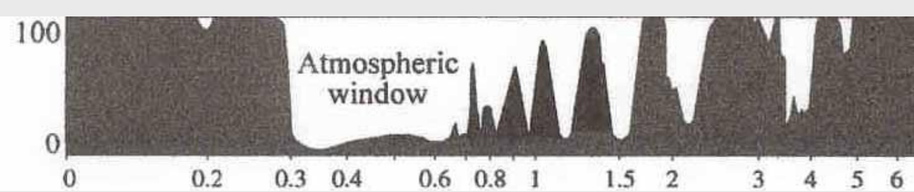
Incoming Visible & Near IR SW absorbed by water vapor & clouds



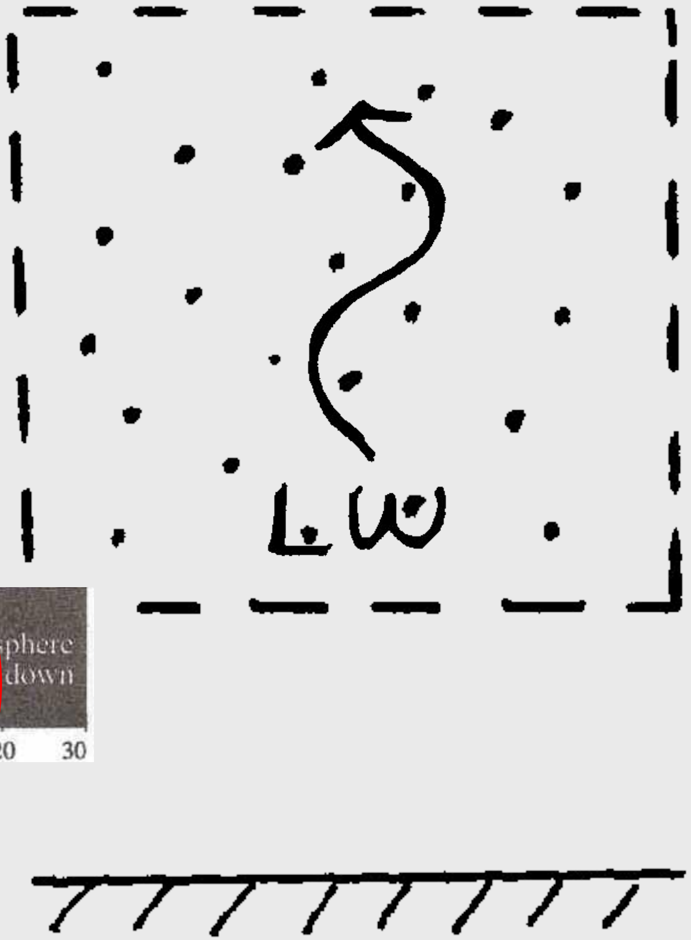
LW

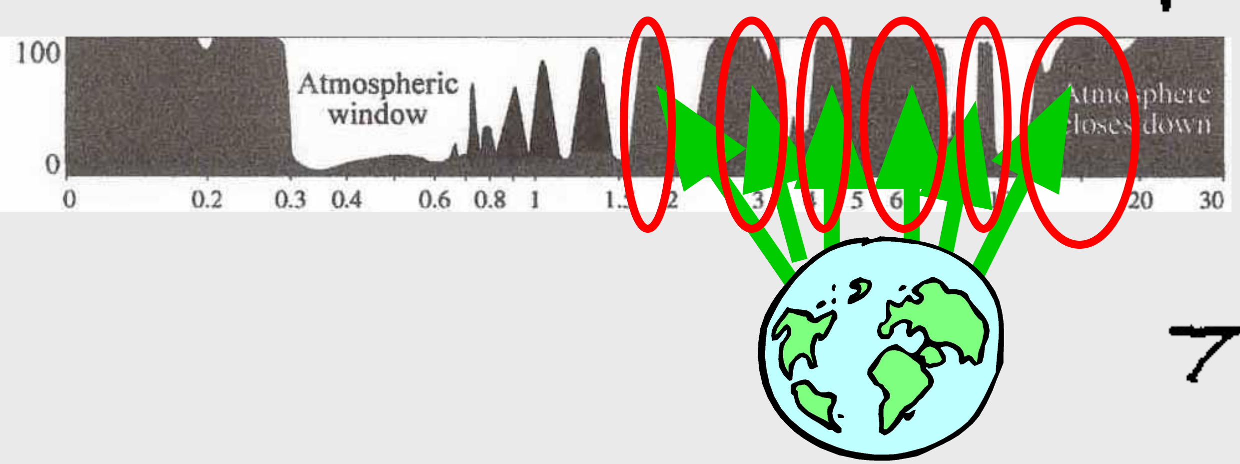
LW (IR) EMITTED FROM EARTH'S SURFACE ESCAPING TO SPACE THROUGH THE "OUTGOING IR ATMOSPHERIC WINDOW"



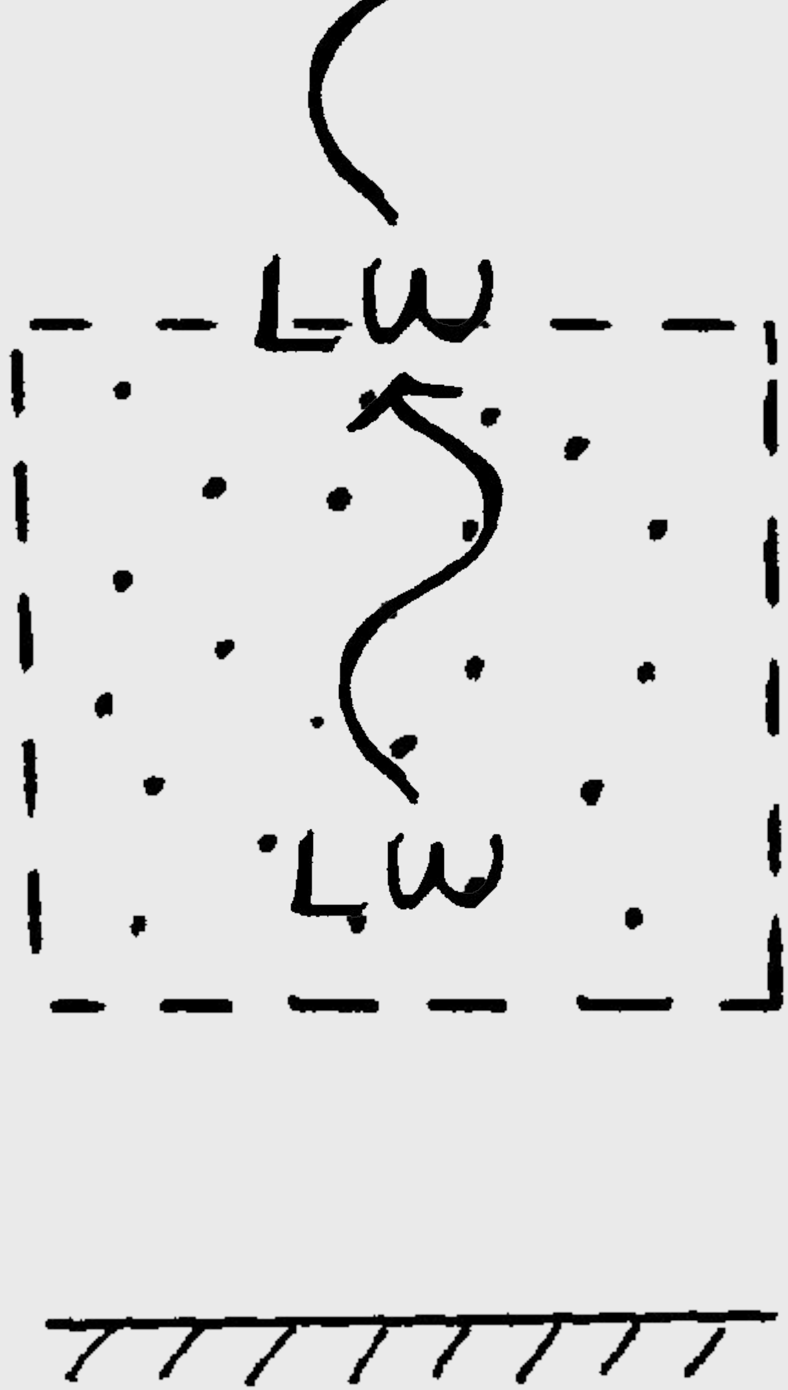


IR EMITTED FROM EARTH'S SURFACE BUT ABSORBED IN THE ATMOSPHERE BY GREENHOUSE GASES (H_2O, CO_2, CH_4, ETC.)



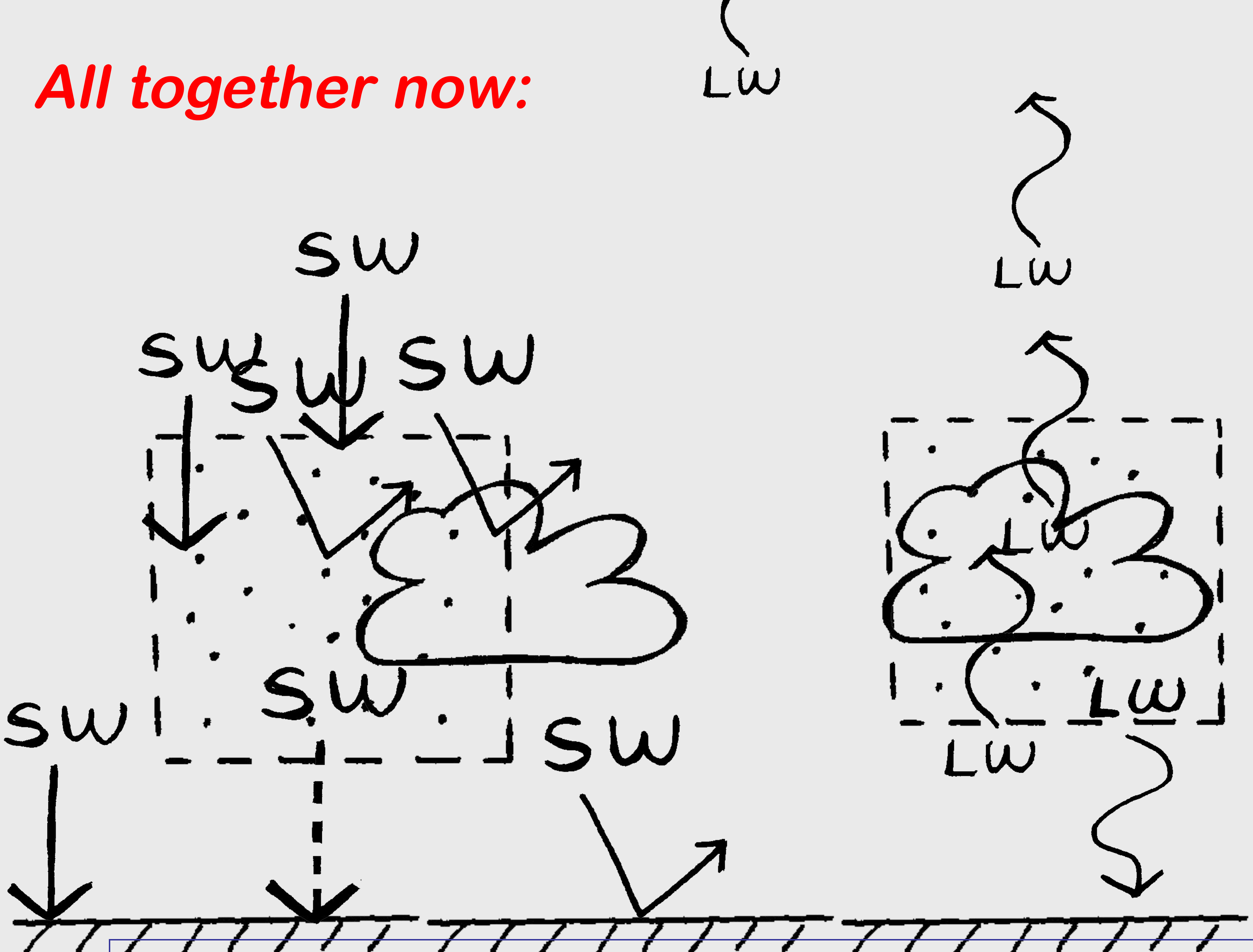


IR EMITTED FROM ATMOSPHERE ESCAPING TO SPACE



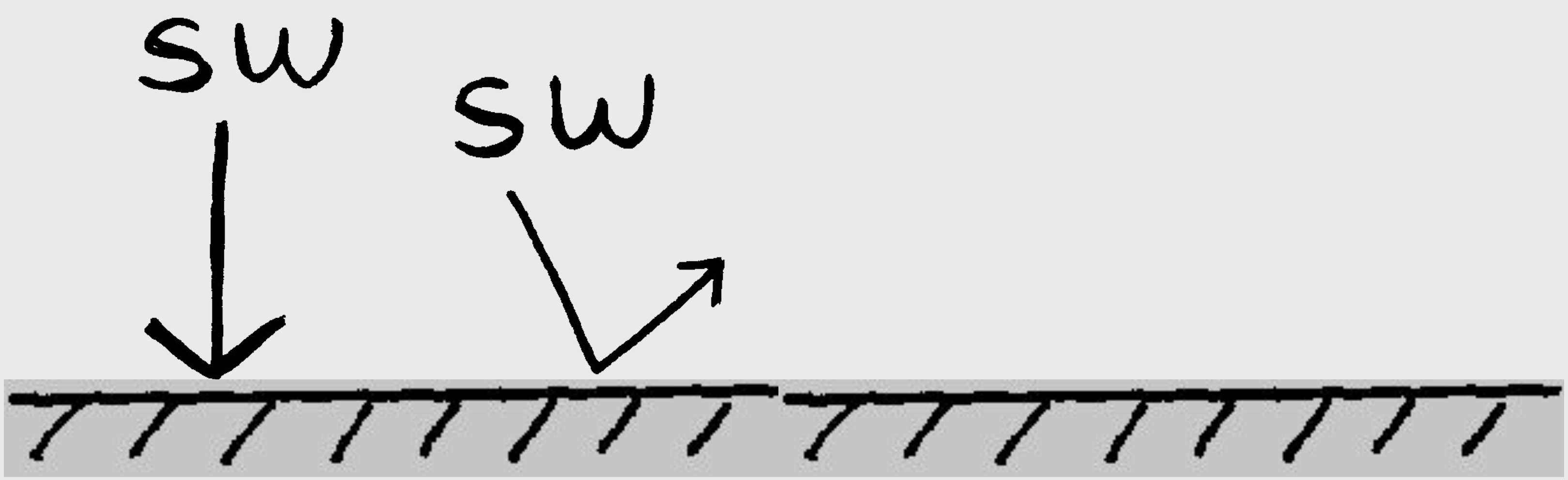
IR EMITTED FROM ATMOSPHERE AND RADIATED BACK TO SURFACE WHERE IT IS ABSORBED

All together now:



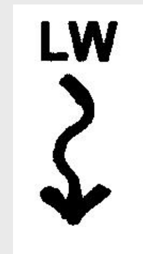
Can you sketch all the pathways in yourself? p 124

Compare with simpler model of energy balance with NO atmosphere:



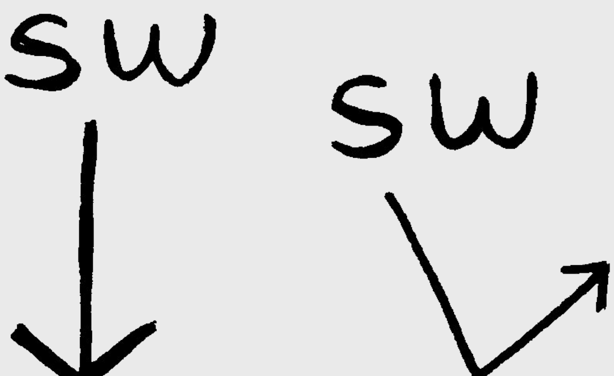
Which terms are not involved?

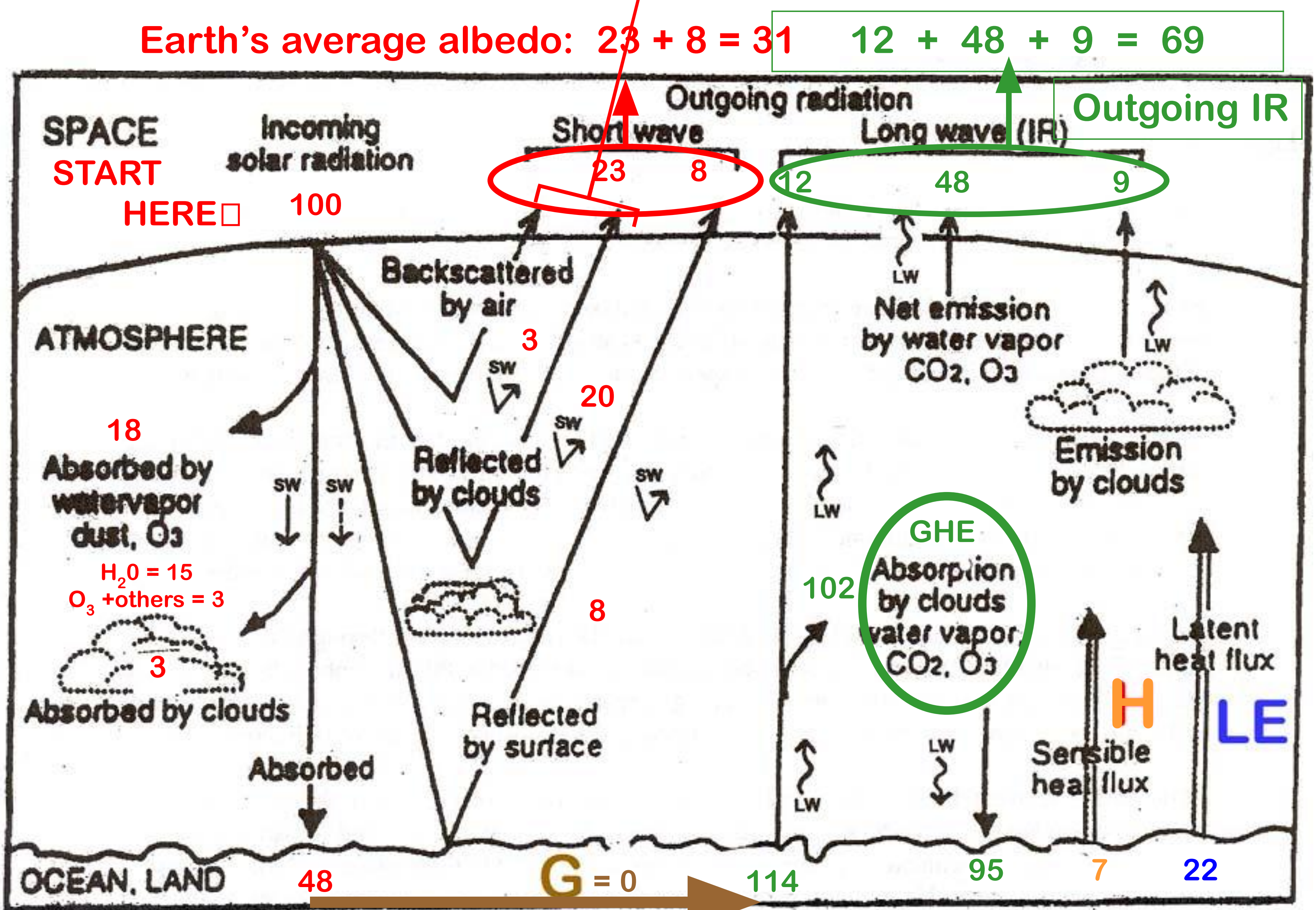
No scattering by atmosphere



No re-radiation of infrared by GHG's

NOTE: Technically, the SUN does give off incoming longwave infrared radiation (in addition to shortwave UV, visible, etc.) – but if we view the incoming LW symbol above as TERRESTRIAL radiation that has been absorbed and RE-RADIATED BACK TO EARTH by the GHG's in the atmosphere, this simplification is correct.





G + H + LE

48 □ - 114 □ + 95 □ = 29 □ 0 + 7 + 22 = 29 =

Two Energy Balance Animations

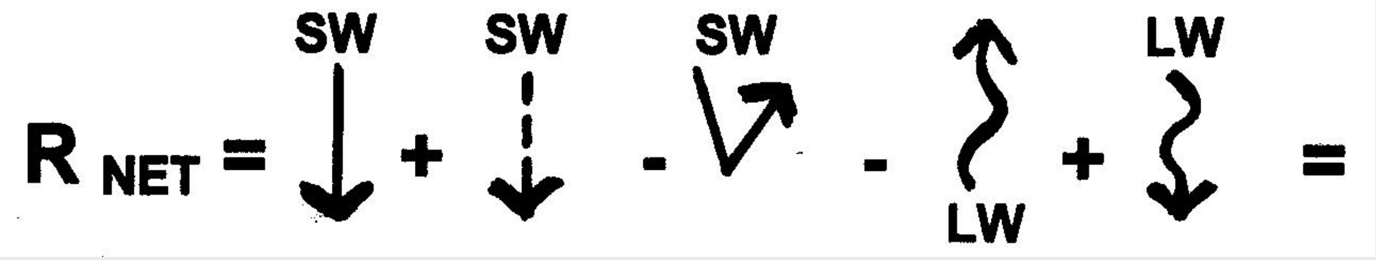
showing energy flow pathways
& "units" of energy that
eventually balance out:

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

NET RADIATION = In – Out = Whatever is left over



If some energy is “left over,” it can be used to DRIVE WEATHER & CLIMATE through HEAT TRANSFER processes or it can STORED by the Earth (in the ground or ocean).

FINAL PART OF TOPIC #10:

The <u>RIGHT</u> side of the ENERGY BALANCE EQUATION . . .

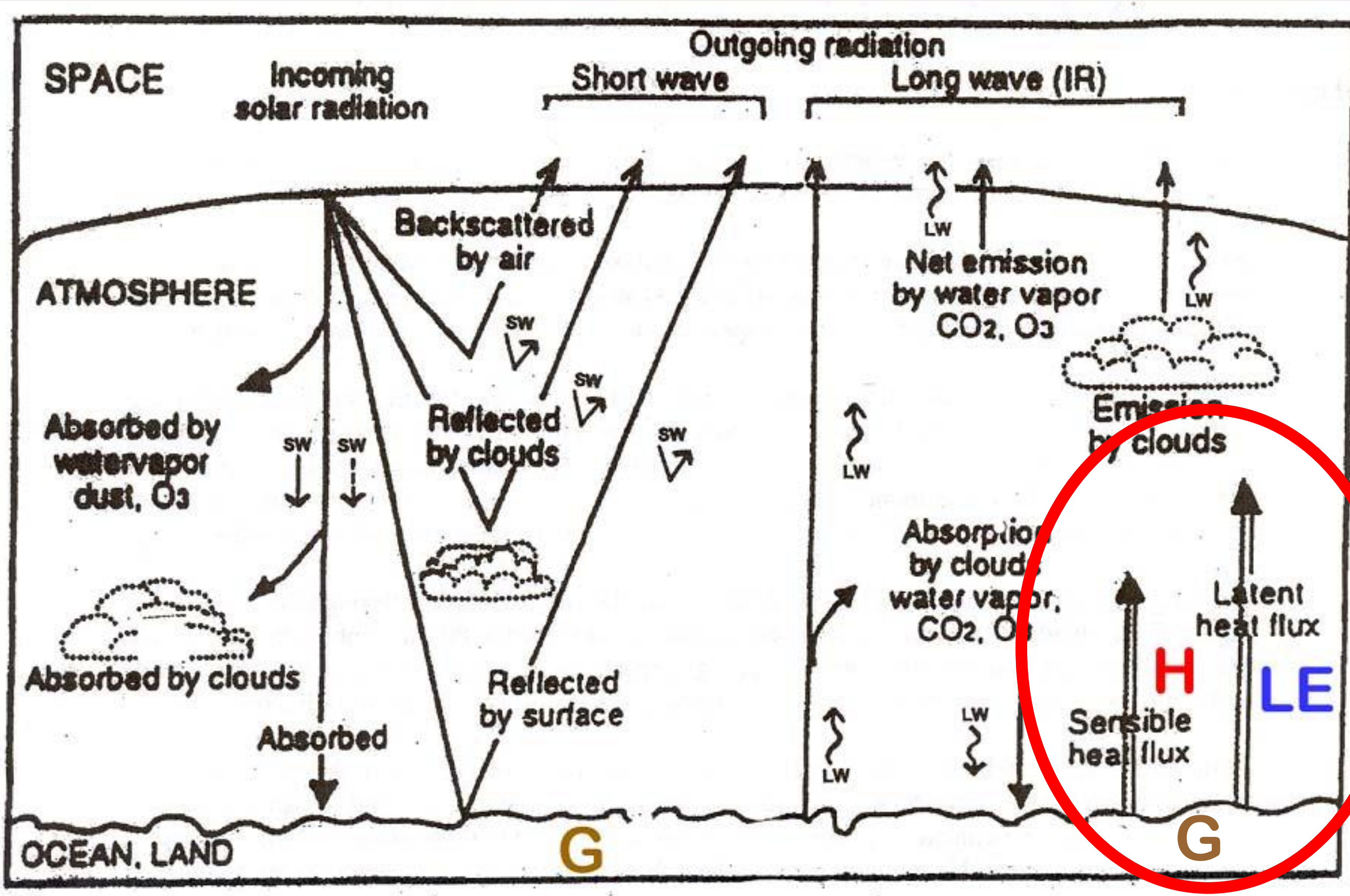
Left side of equation

$$R_{NET} = SW\downarrow + SW\downarrow - SW\nearrow - LW\uparrow + LW\downarrow = H + LE + G$$

Right side of equation

R net = "net" left over energy can be used to **DRIVE WEATHER & CLIMATE** through **<u>HEAT TRANSFER</u>** processes or it can **STORED** by the Earth (in the ground or ocean).

$$R_{NET} = H + LE + G$$



SPACE
Incoming solar radiation
Outgoing radiation
Short wave
Long wave (IR)
Backscattered by air
ATMOSPHERE
SW
LW
Net emission by water vapor CO_2, O_3
Absorbed by watervapor dust, O_3
Reflected by clouds
Emission by clouds
Absorption by clouds water vapor, CO_2, O_3
Latent heat flux
Absorbed by clouds
Absorbed
Reflected by surface
H
LE
Sensible heat flux
OCEAN, LAND
G
G