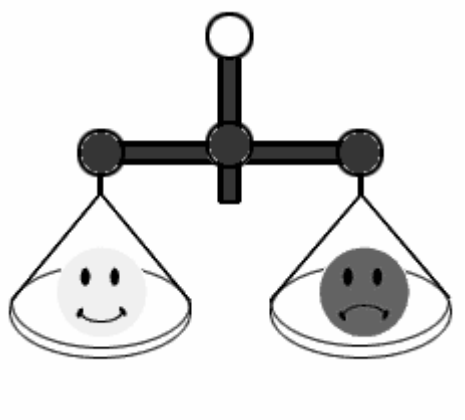
Topic # 10
THE EARTH'S GLOBAL ENERGY BALANCE

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

➔ BOOKMARK pp 51 & 115
in Class Notes now for lecture today

Today's Quote:

A Different Sort of "ENERGY BALANCE":



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

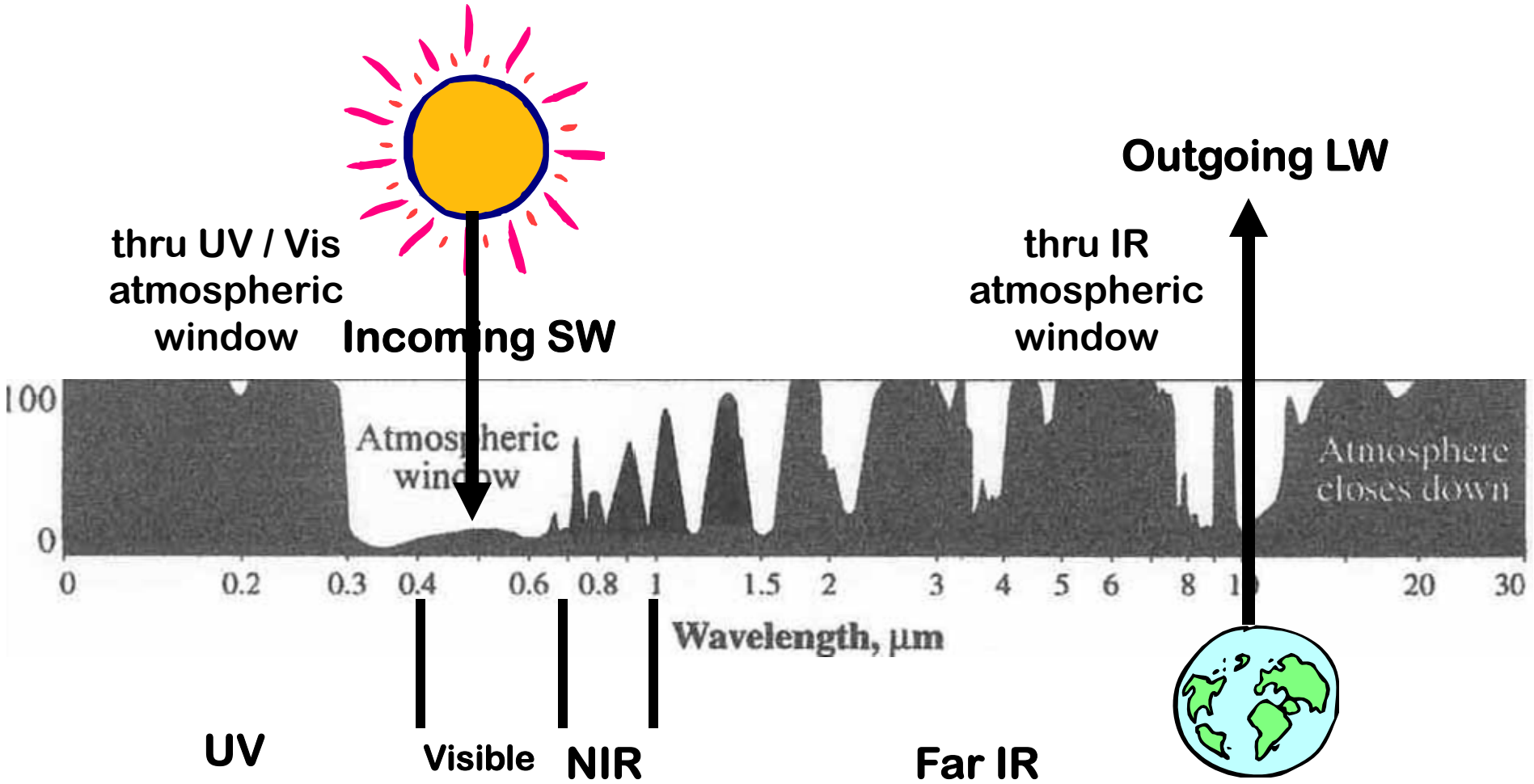
Are my energy expenditures (actions, reactions, thoughts, and feelings) productive or nonproductive?

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

~ Doc Childre and Howard Martin

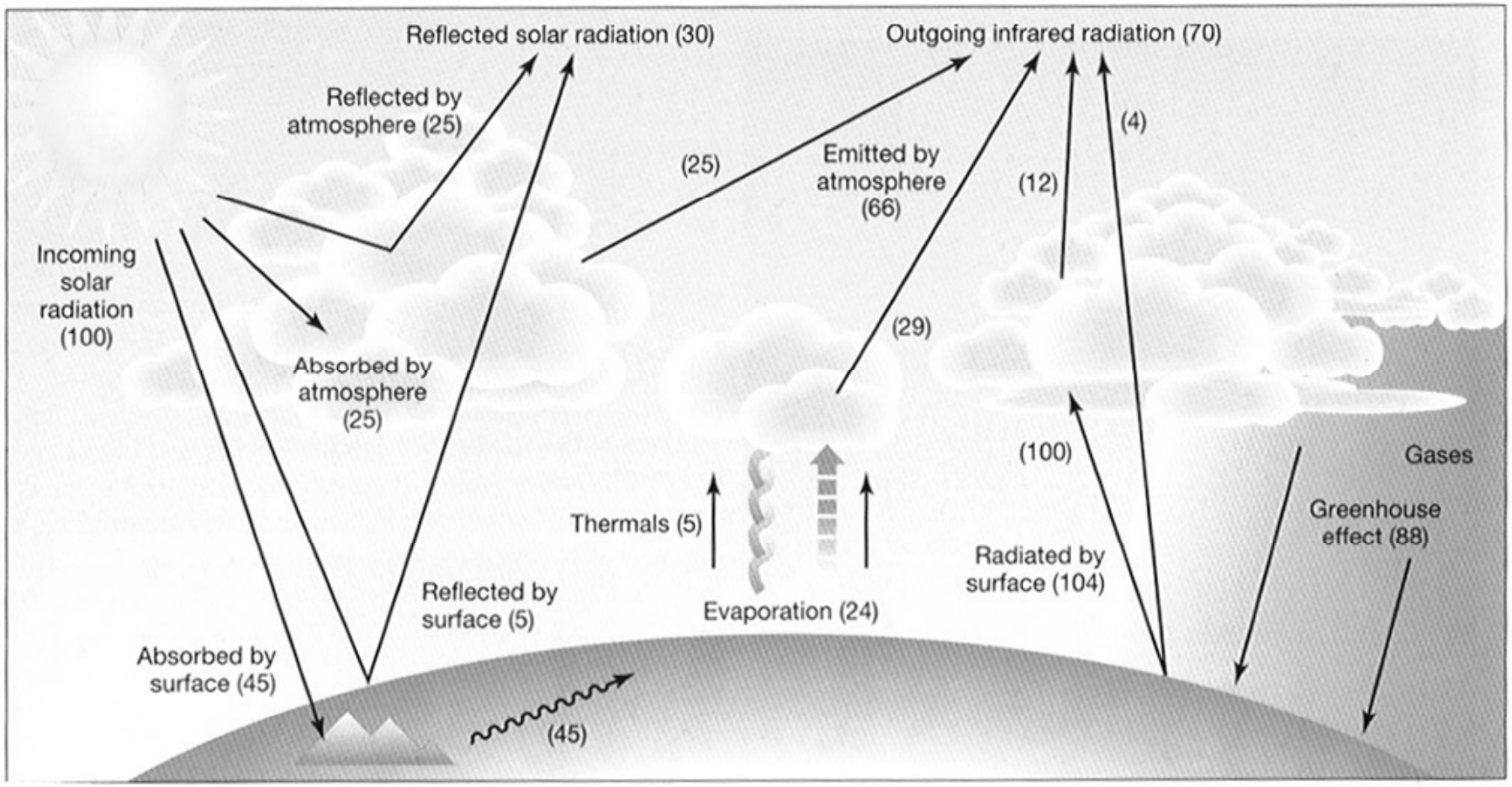
Review: Absorption curve for the "Whole Atmosphere"

OVERALL BALANCE: **Incoming = Outgoing**



Review

Typical Energy Balance Diagram



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

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

Similar to p 51 in Class Notes

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

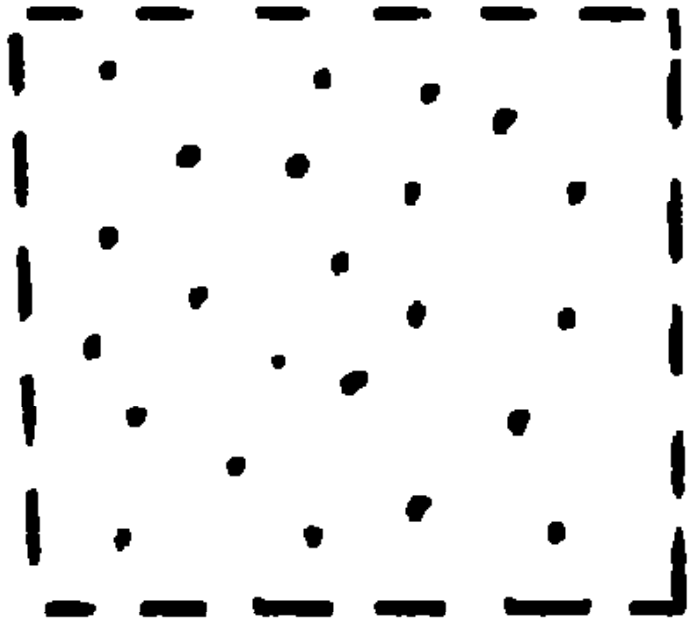
We'll use "cartoon symbols" . . .

“CARTOON” SYMBOLS:

To represent the Earth’s surface:

Go to p 115

“CARTOON” SYMBOLS:



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

“CARTOON” SYMBOLS:

To represent CLOUDS

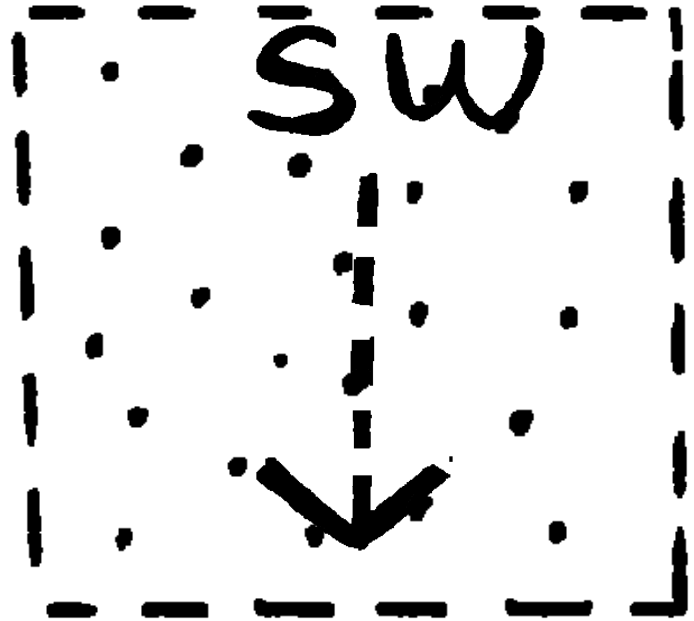
“CARTOON” SYMBOLS:

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

Direct SW radiation easily casts well-defined shadows when blocked

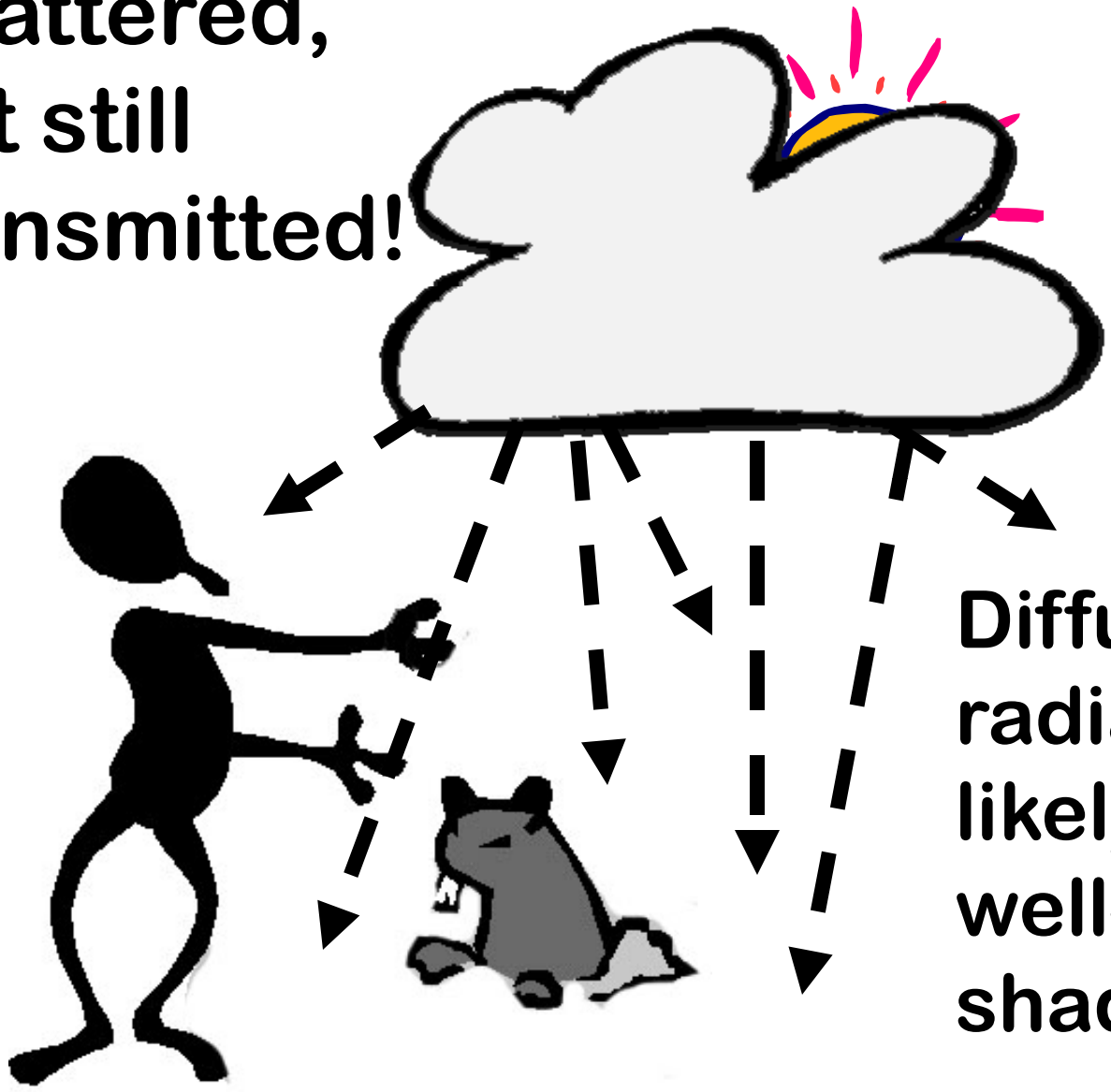
Take notes

“CARTOON” SYMBOLS:



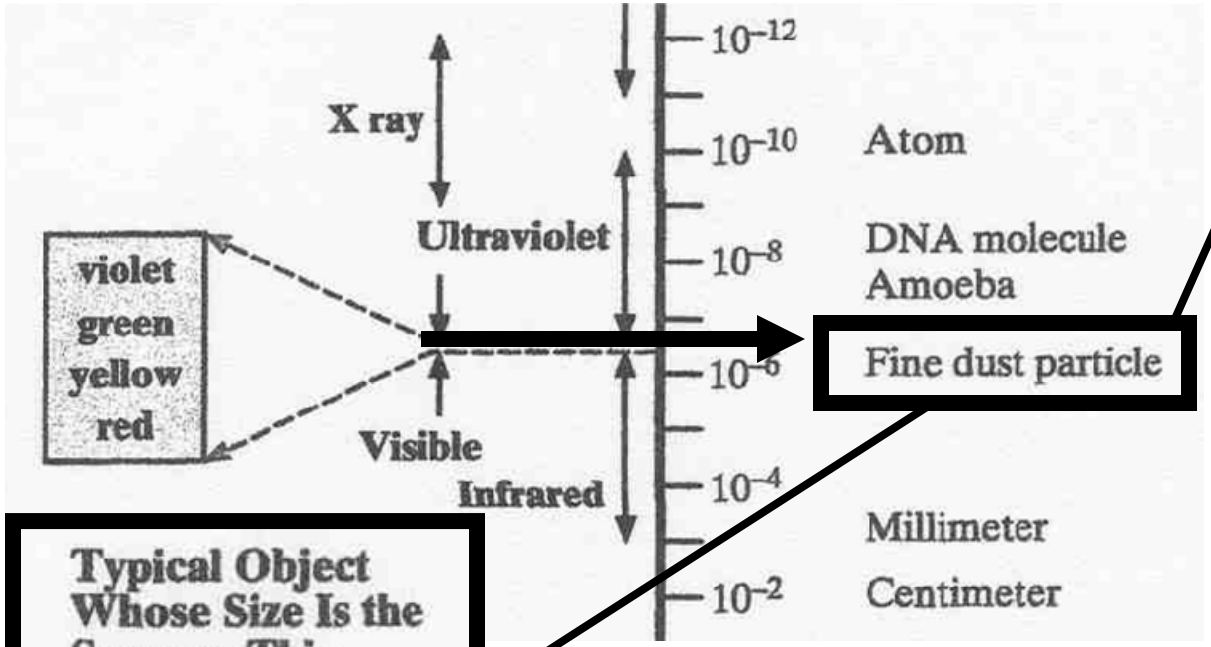
To represent SOLAR (shortwave) radiation coming in as DIFFUSE shortwave radiation, i.e. scattered by gases, clouds, and particles in the atmosphere.

Scattered, but still transmitted!



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

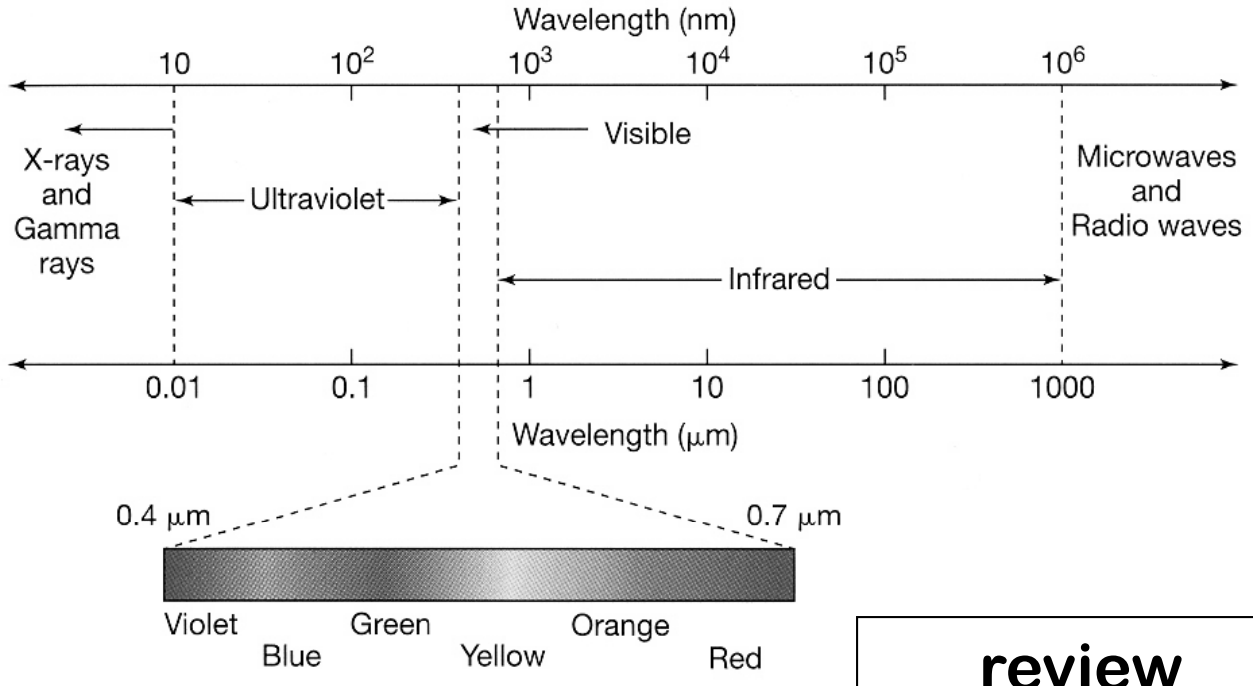
Take notes



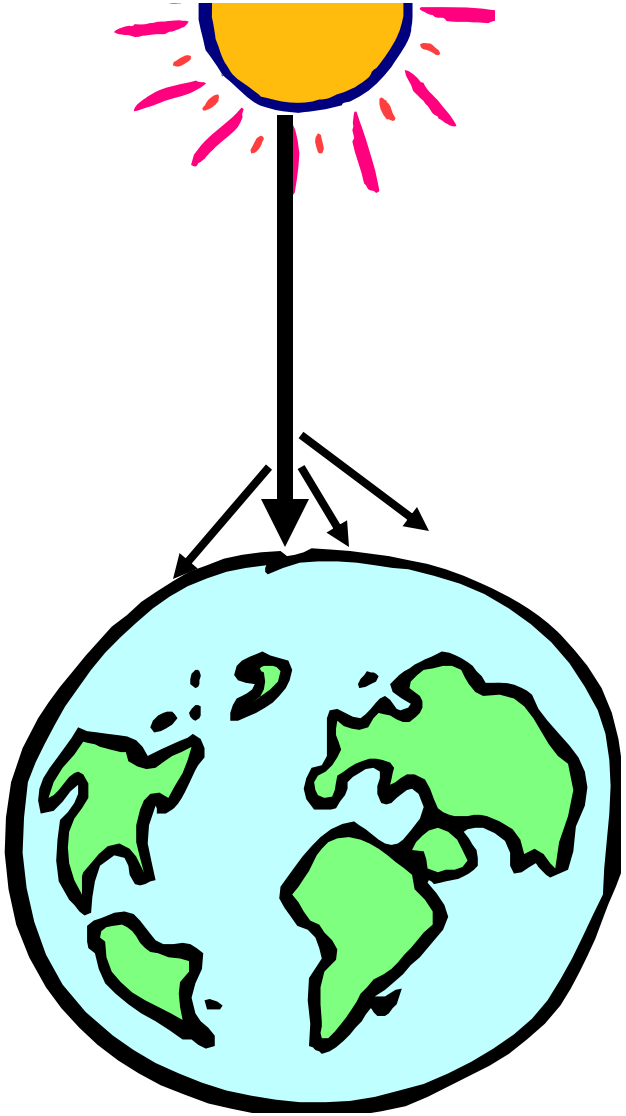
Different sized dust particles, water droplets, aerosols,

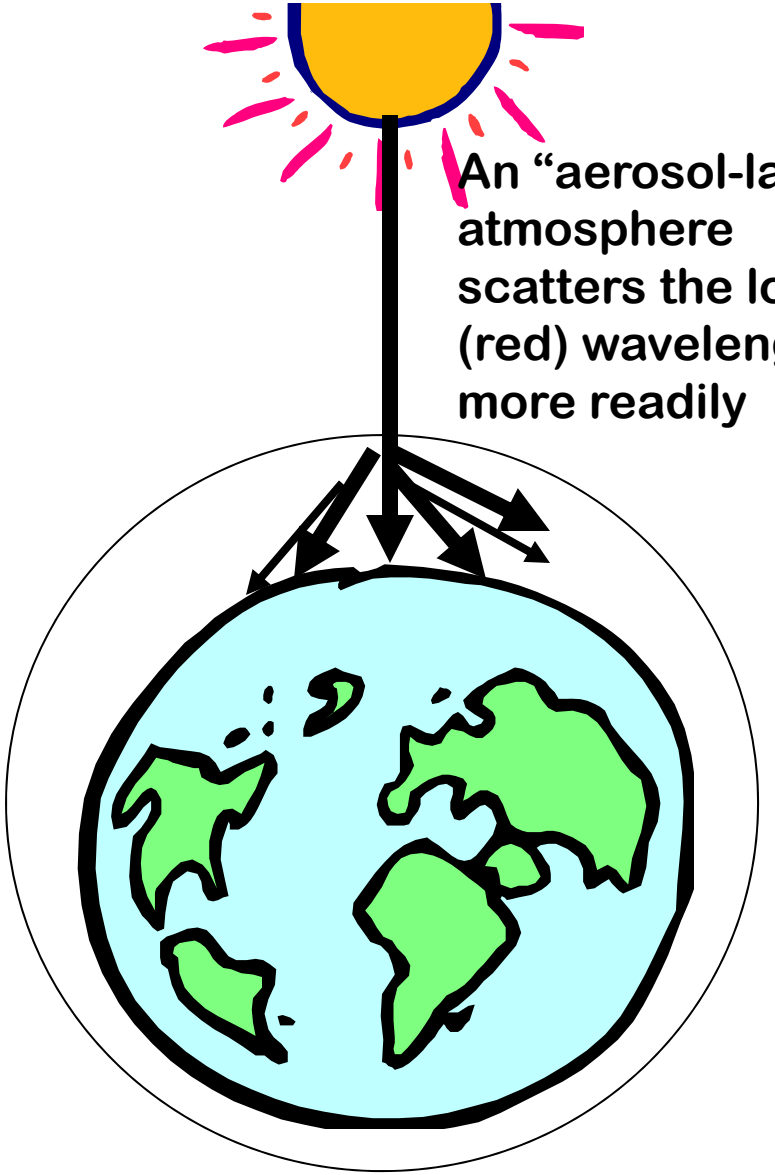
(even gas molecules themselves)

Scattering of visible light



review



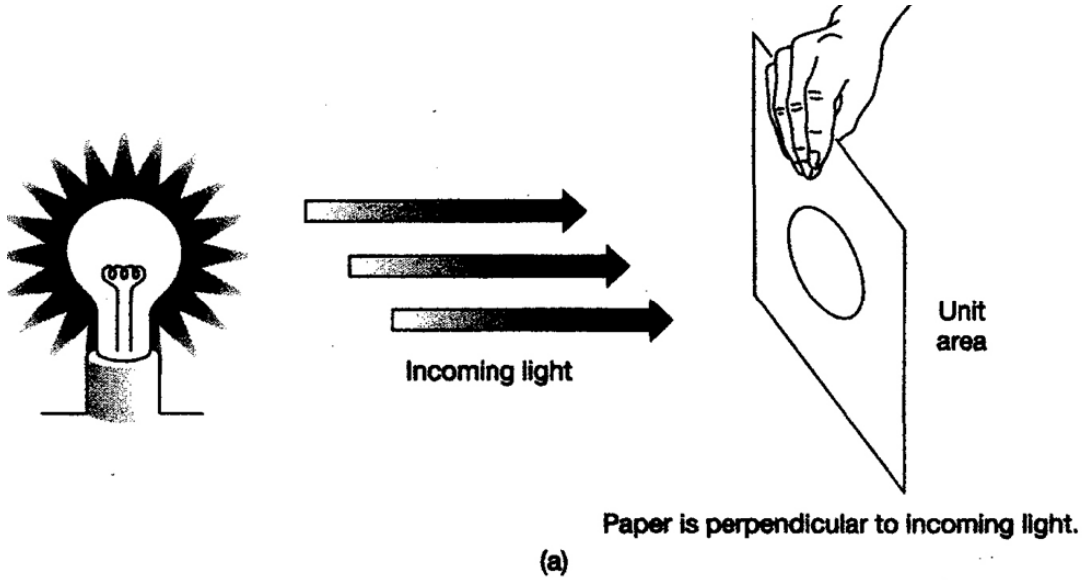


“Clear” atmosphere composed primarily of fine particles, water droplets, gas molecules

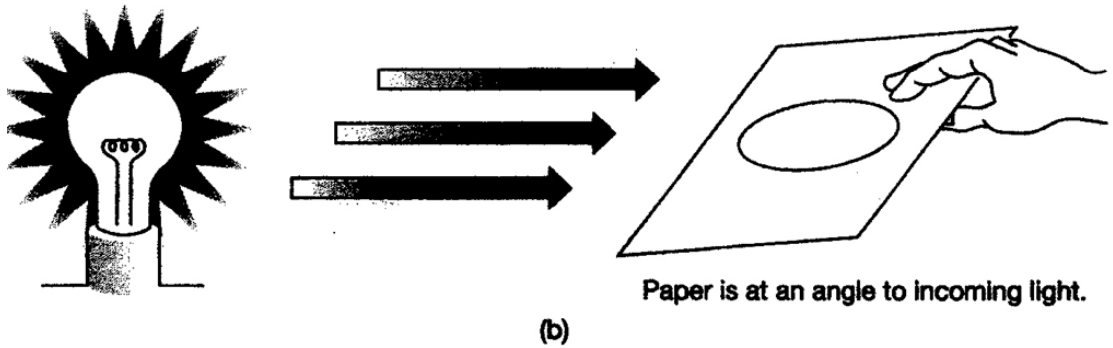
“Dirty” (aerosol-laden) atmosphere composed of fine particles, gases, & H_2O -- PLUS larger dust particles, aerosols, pollution, etc. ☺

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

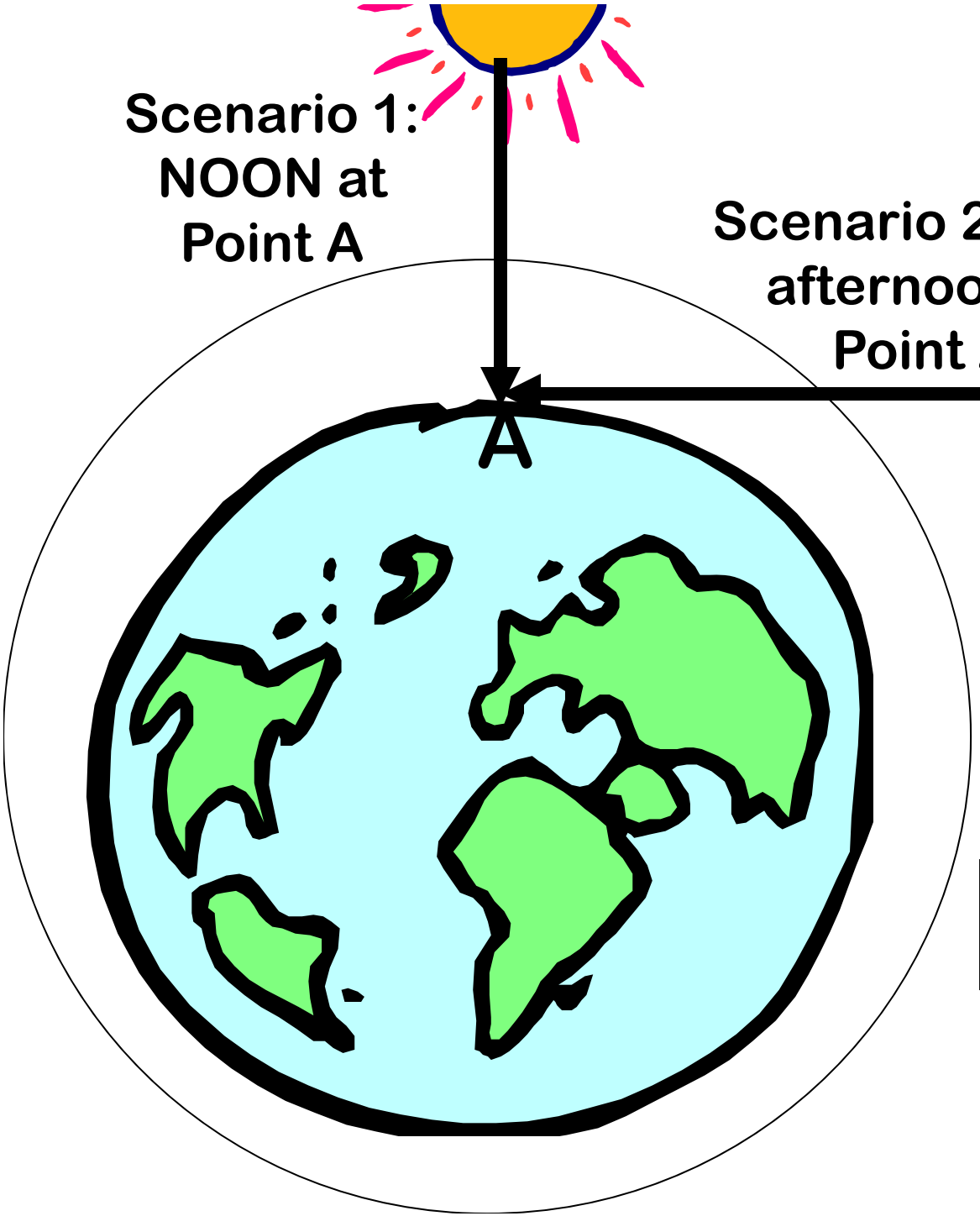
Radiation is concentrated over a small area & hence is more intense when it comes in perpendicular to the surface

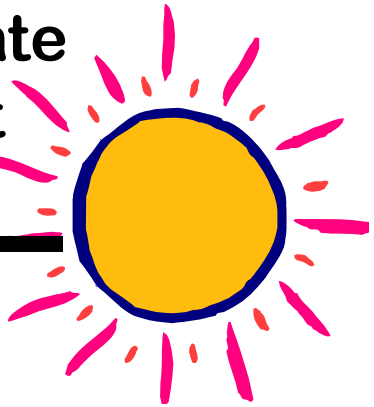


Radiation is spread out over a larger area & hence is less intense <u>per unit area</u> when it comes in at an angle.



From Figure on p 37 in SGC-I, Ch 3





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

1 = Scenario 1

2 = Scenario 2

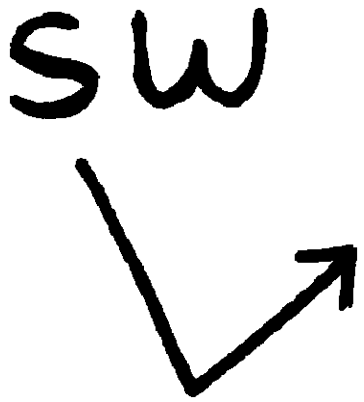
Q2 = WHY is the intensity of the SW radiation at Point A not as strong in the late afternoon as it is at noon?

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

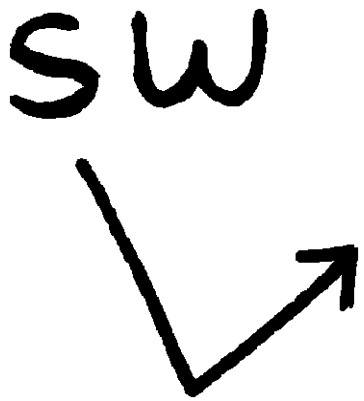
2 = because the SW radiation is coming in at an angle in the late afternoon, and is not directly overhead (perpendicular) like it is at noon.

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

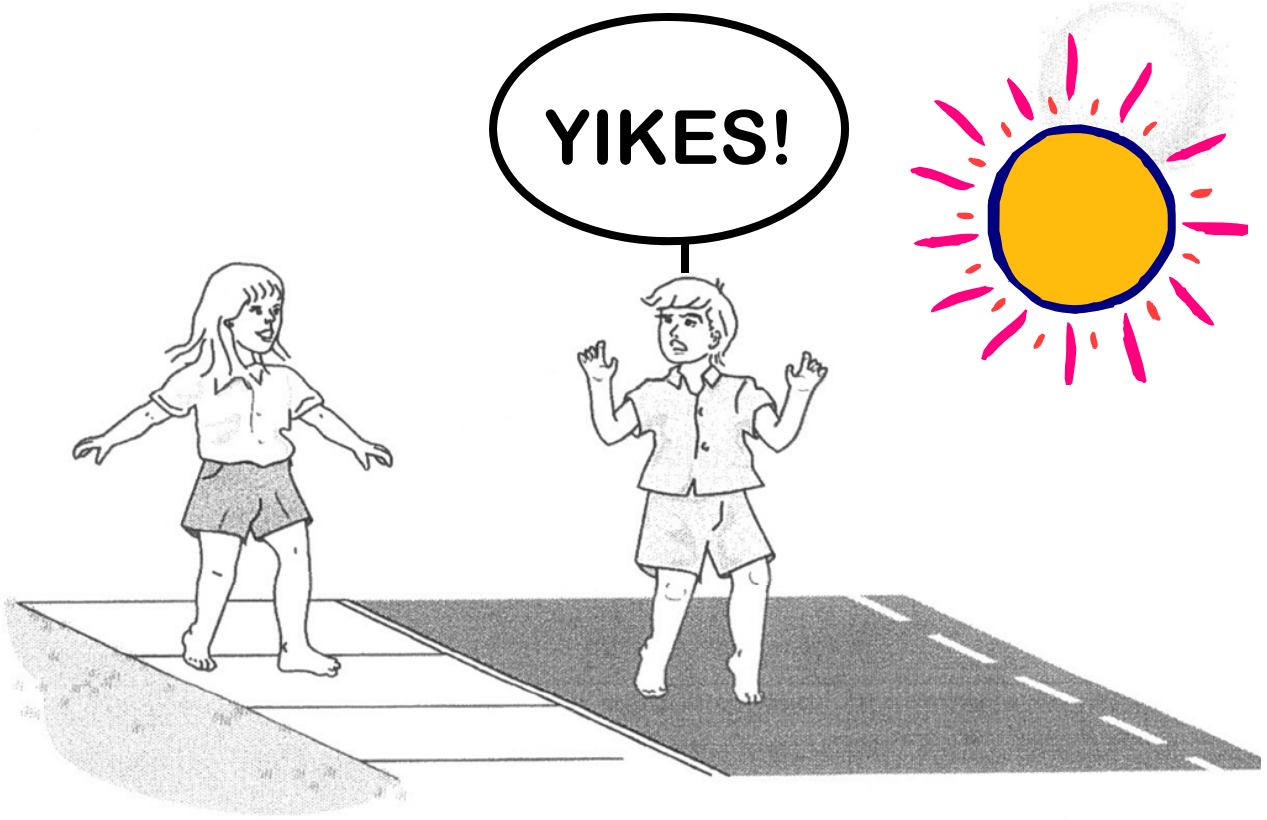
"*symbol*" = a

Represented as:

a decimal from 0 to 1.0 *or*
% from 0 – 100 % (perfect reflectivity)

Hence, amount ABSORBED = (1 – albedo)

← Flip back to p 51



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

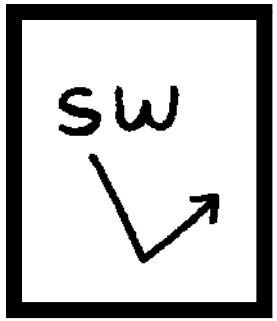
➔ **CLOUDS: 0.44 (high, thin clouds) - 0.90 (low, thick clouds)**

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



Before

After

☺

"CARTOON" SYMBOLS:

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

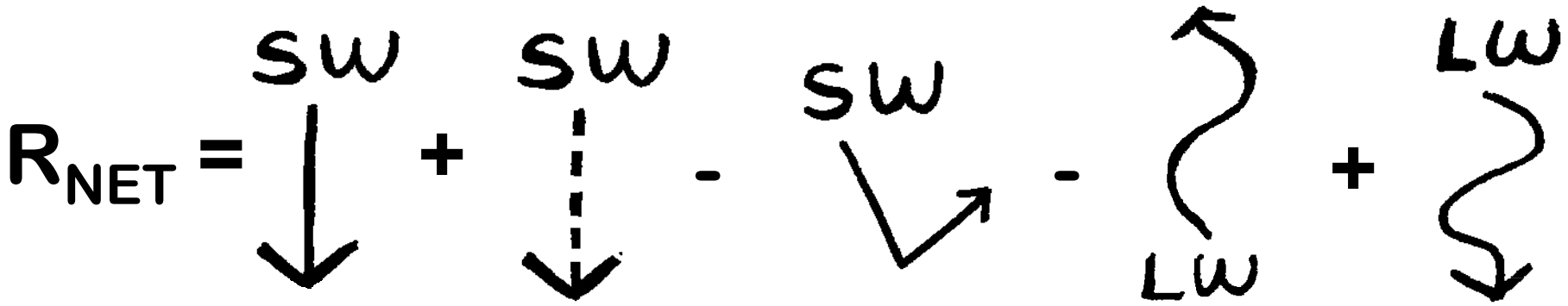
Return to p 115

“CARTOON” SYMBOLS:

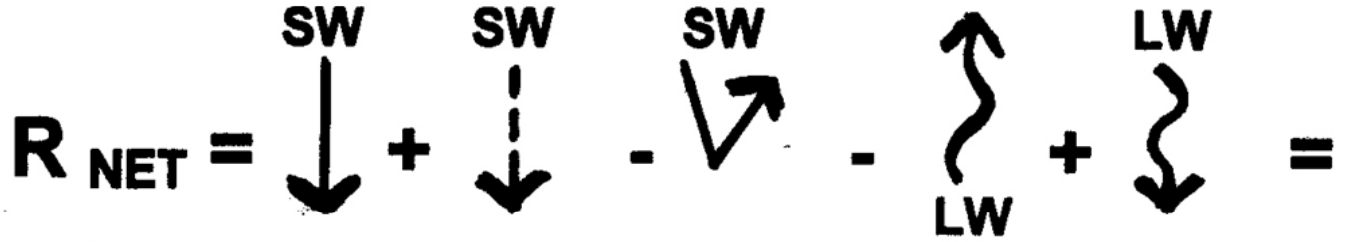
To represent TERRESTRIAL (longwave IR) re-radiation emitted downward by the Earth’s ATMOSPHERE

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 . . .

See top p 51

First, what if . . .

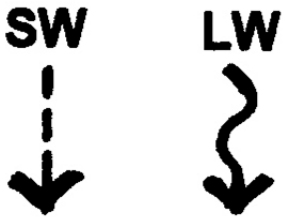
. . . The Earth didn't have an atmosphere, and therefore didn't have a greenhouse effect??

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

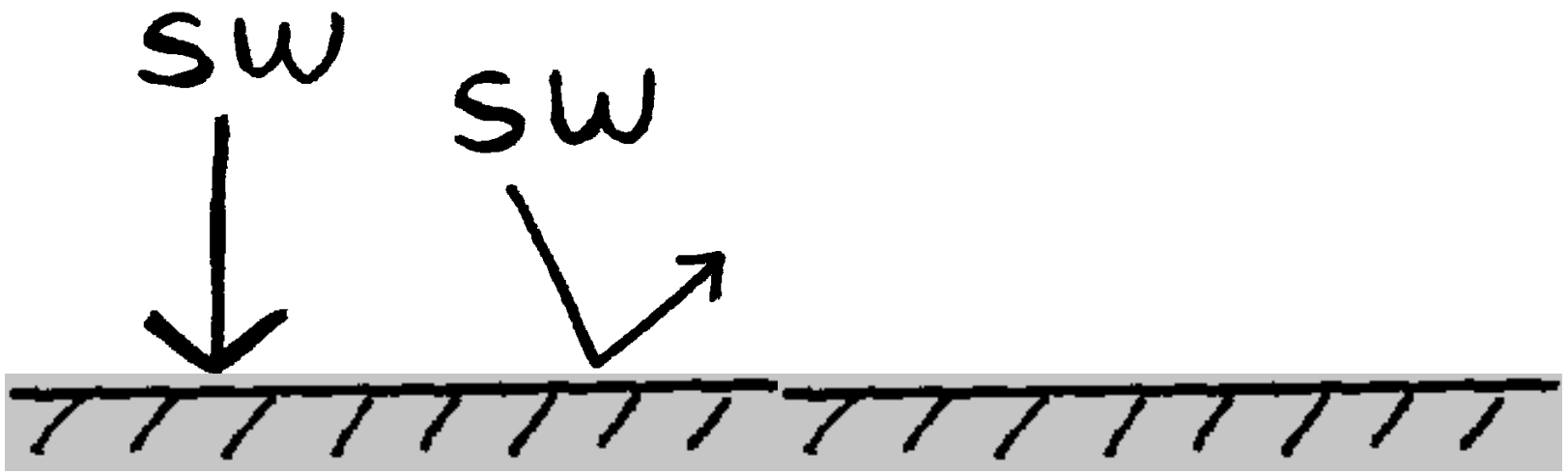
Lw

Which terms are not involved?

No scattering by atmosphere

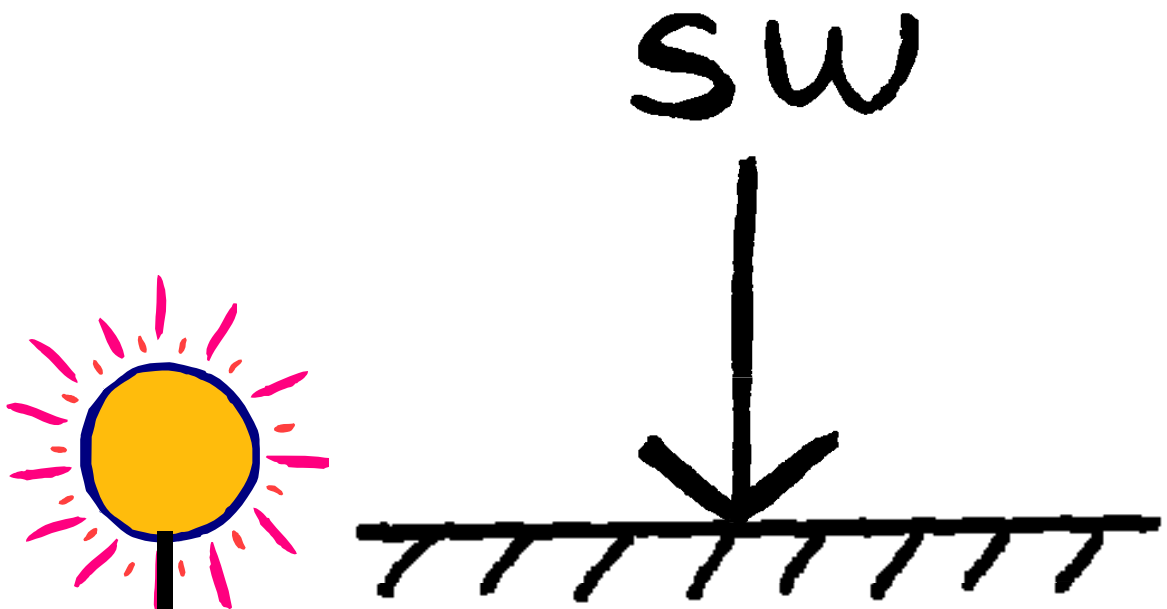


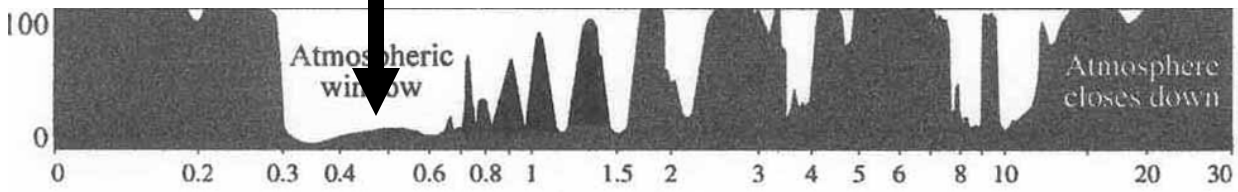
No re-radiation of infrared by GHG's



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:



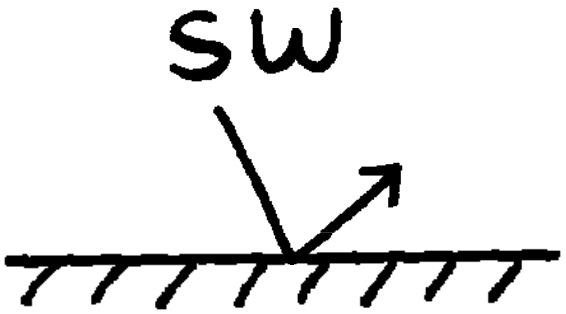


p 116

SW REFLECTED BACK TO SPACE:

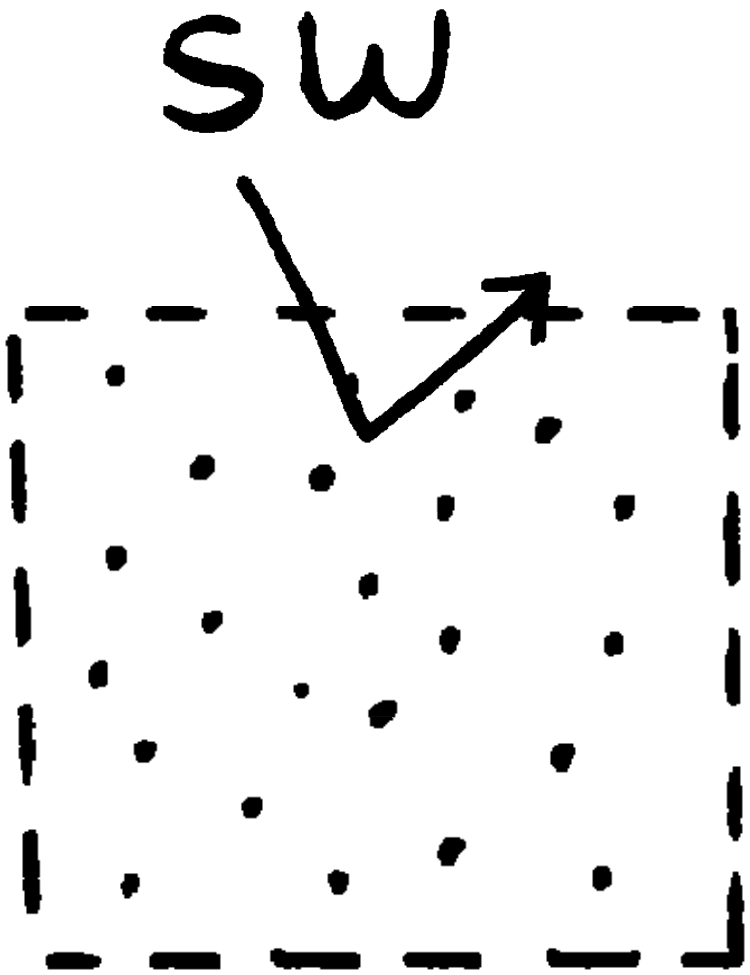
By clouds

By Earth's surface

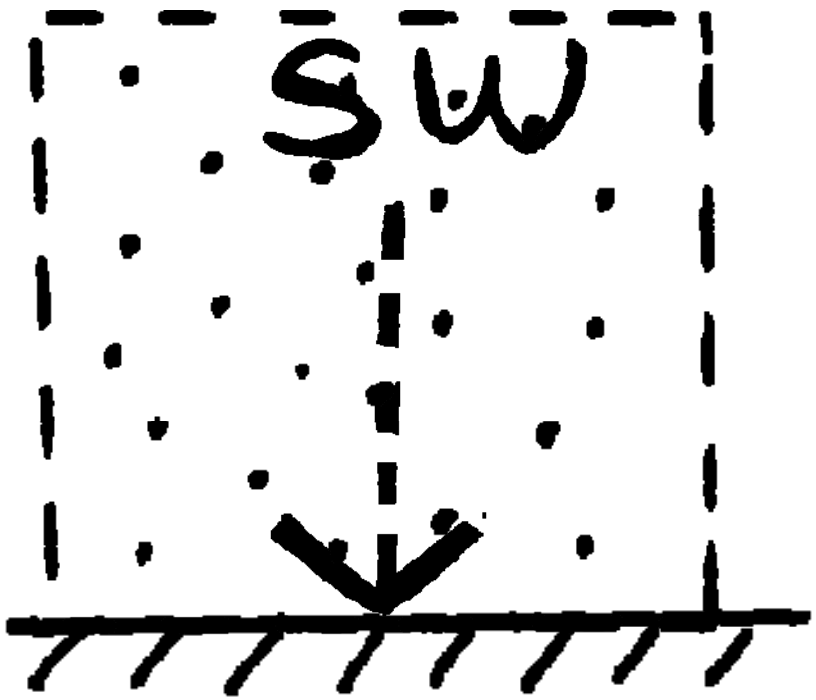


This is determined by the ALBEDO of the clouds or surface

SW SCATTERED BACK TO SPACE BY ATMOSPHERE:

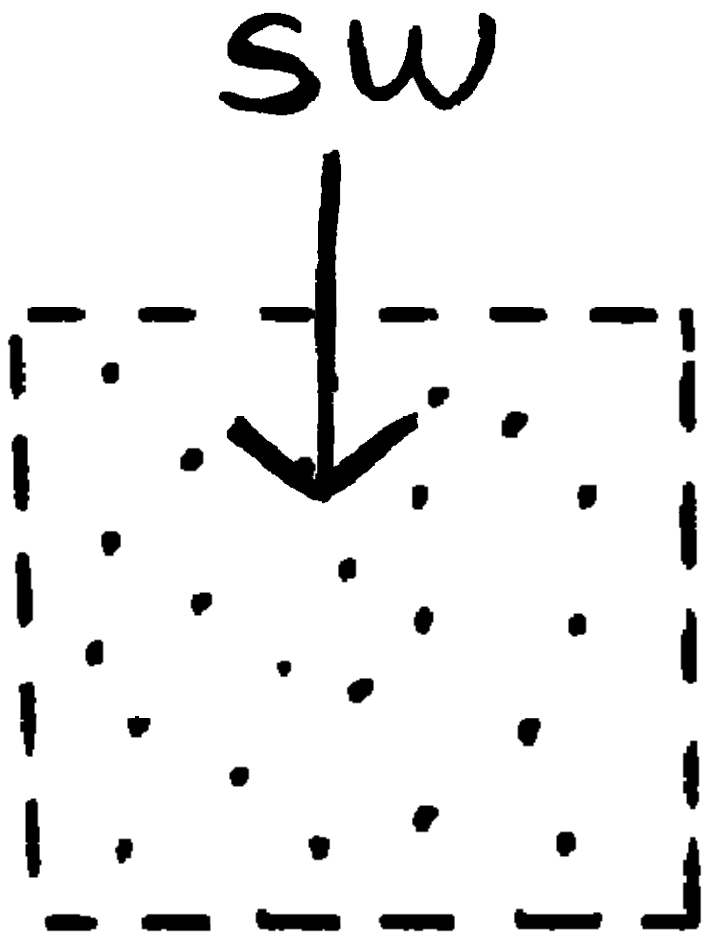


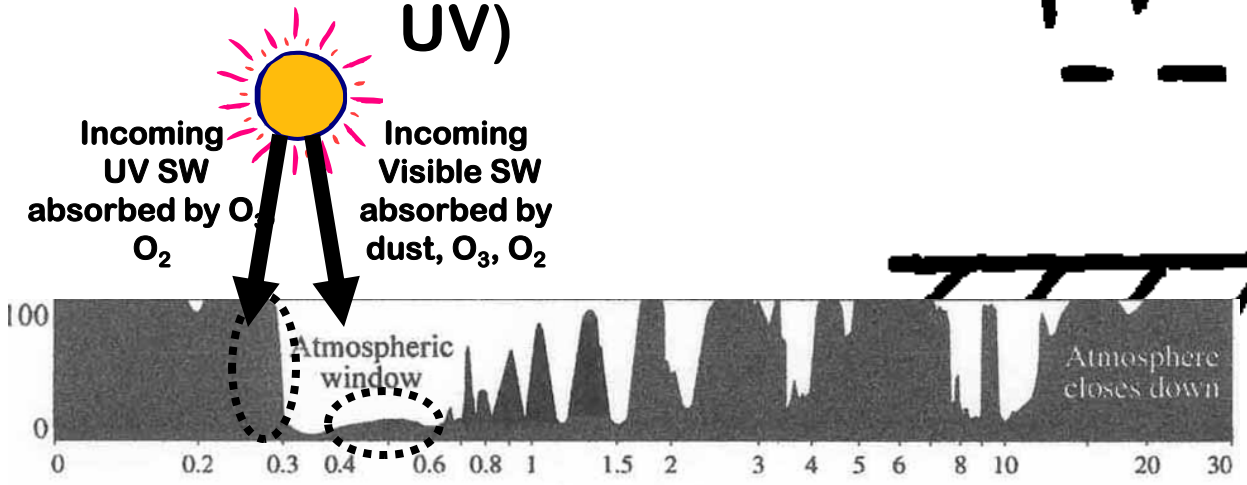
SW SCATTERED DOWN TO EARTH's SURFACE where it is absorbed



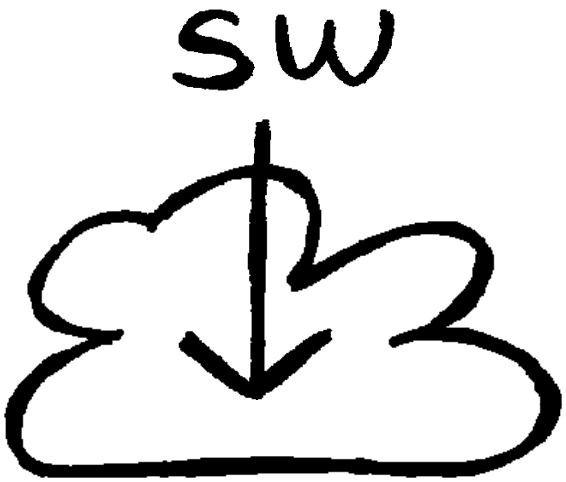
SW ABSORBED IN ATMOSPHERE BY GASES, DUST, etc.

(including Ozone absorbing shortwave UV)

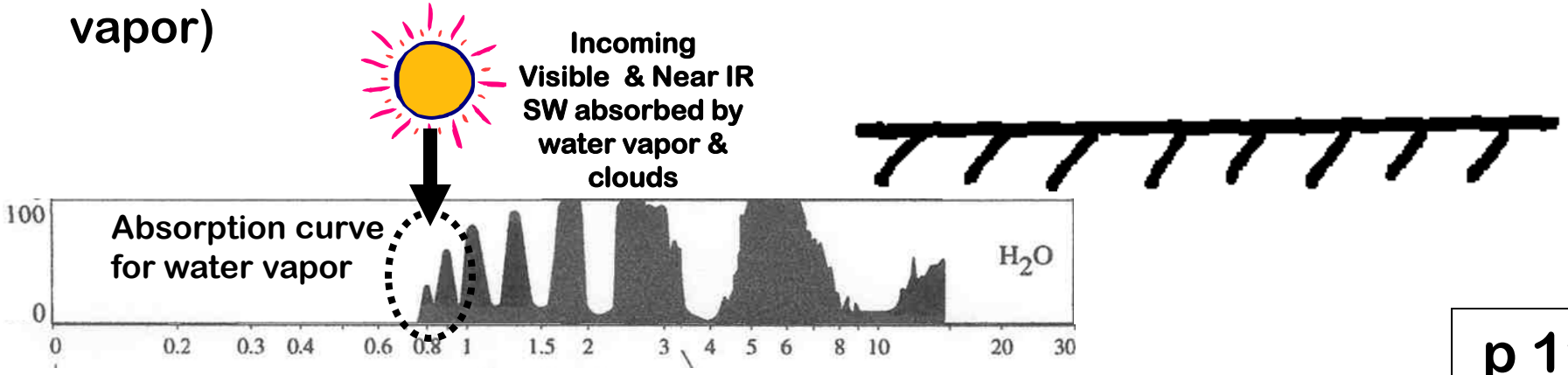




SW ABSORBED In ATMOSPHERE BY CLOUDS & H2O vapor:

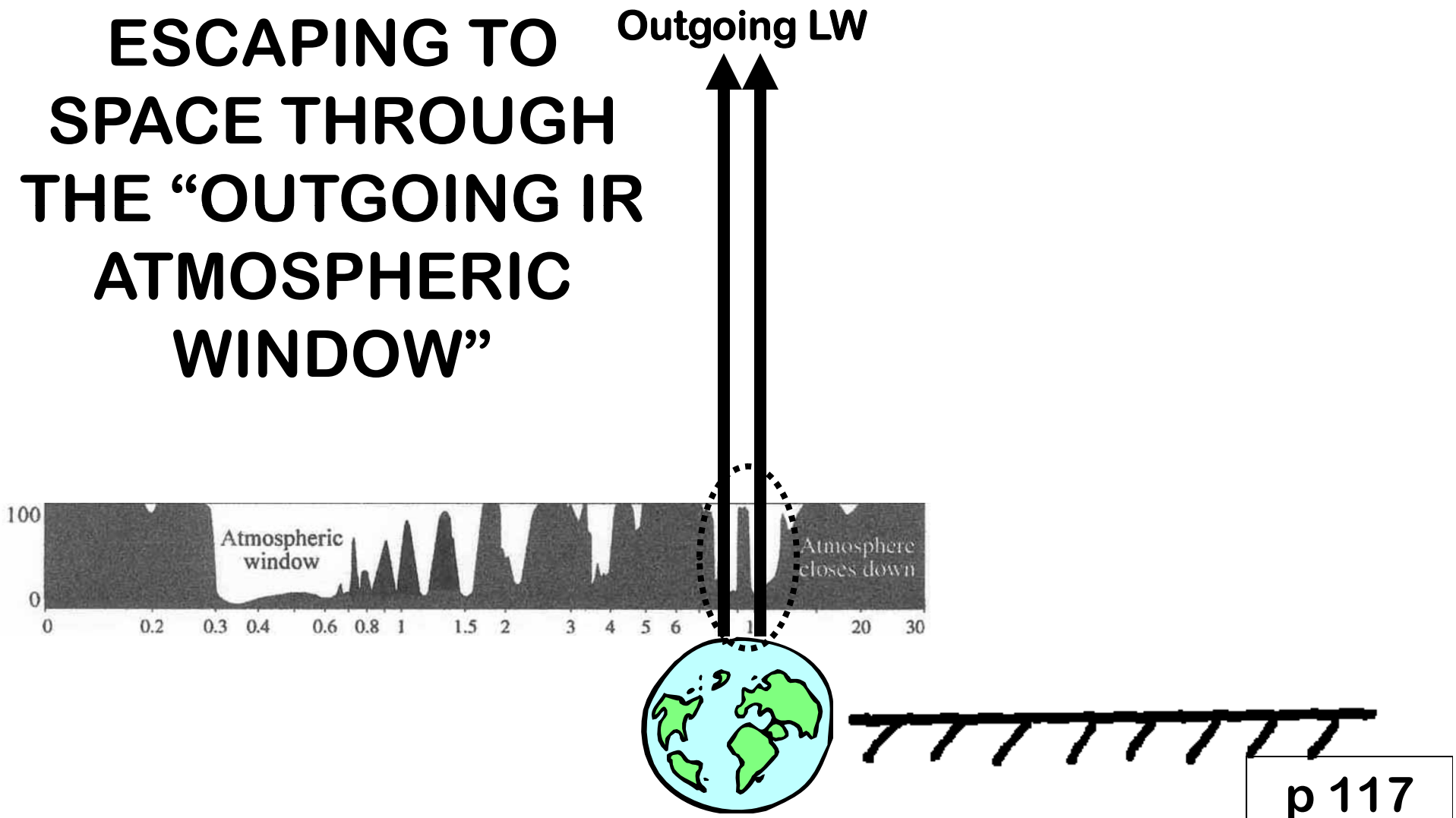


(NOTE: clouds are made up of tiny droplets of water surrounded by lots of water vapor)

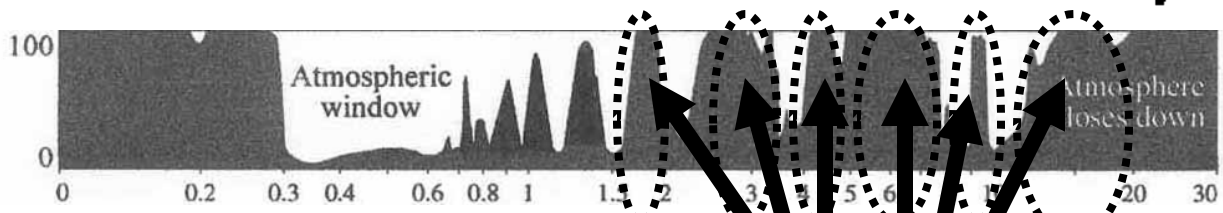


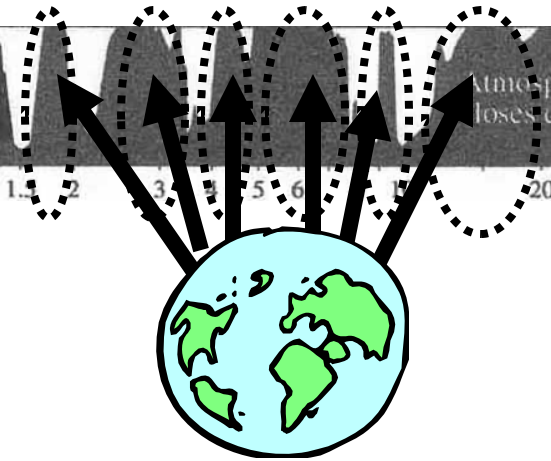
LW (IR) EMITTED FROM EARTH'S SURFACE ESCAPING TO SPACE THROUGH THE "OUTGOING IR ATMOSPHERIC WINDOW"

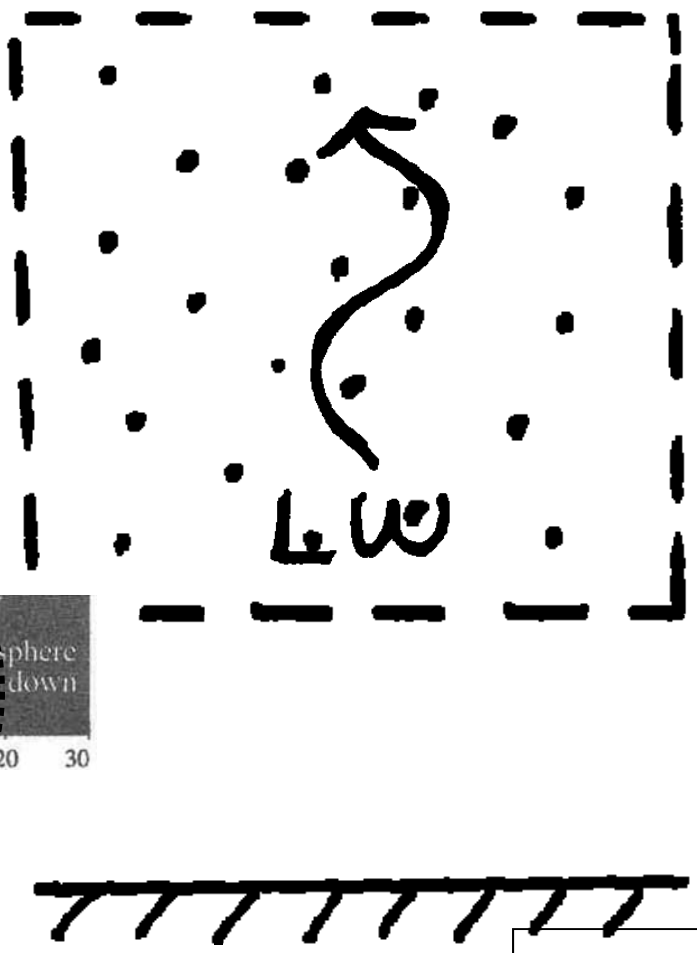
LW



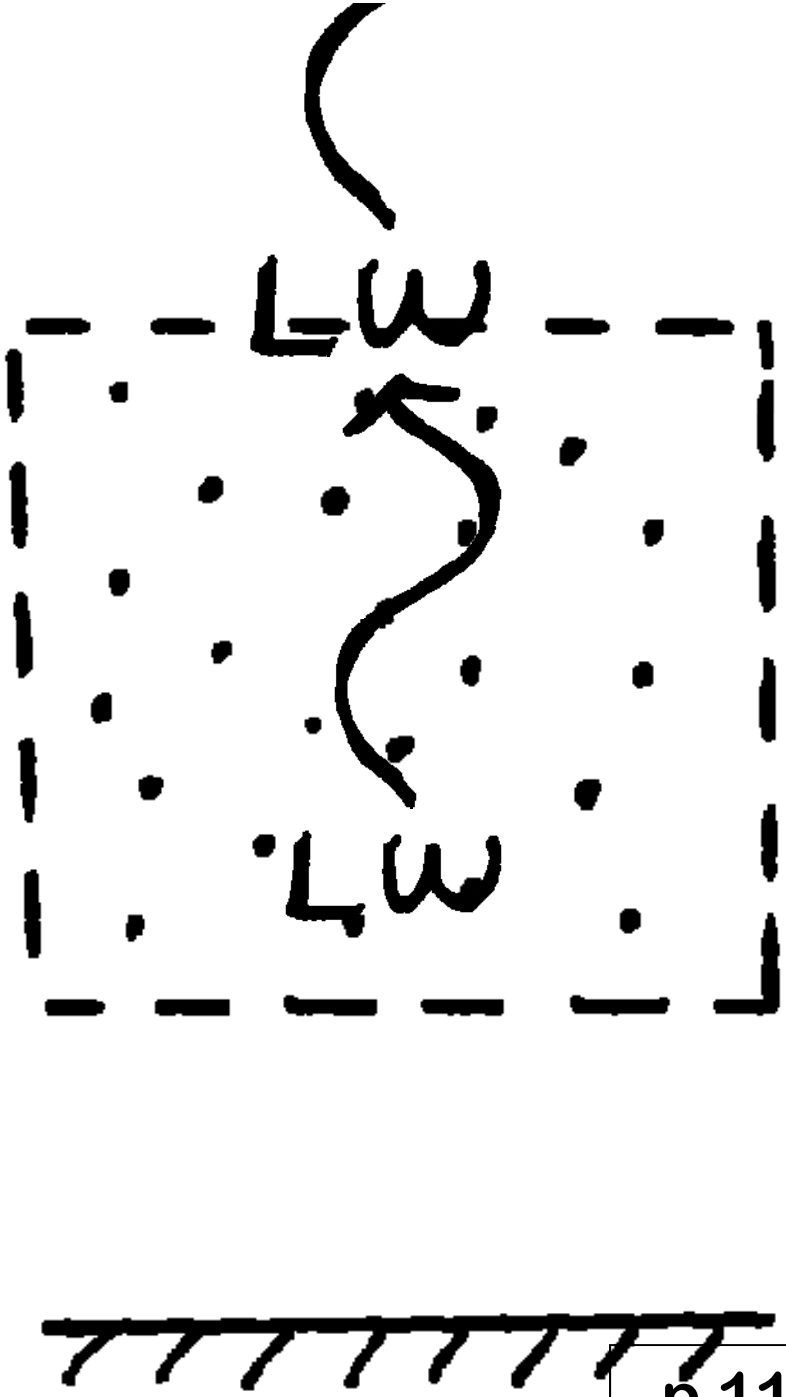
IR EMITTED FROM EARTH'S SURFACE BUT ABSORBED IN THE ATMOSPHERE BY GREENHOUSE GASES (H_2O,CO_2, CH_4, ETC.)





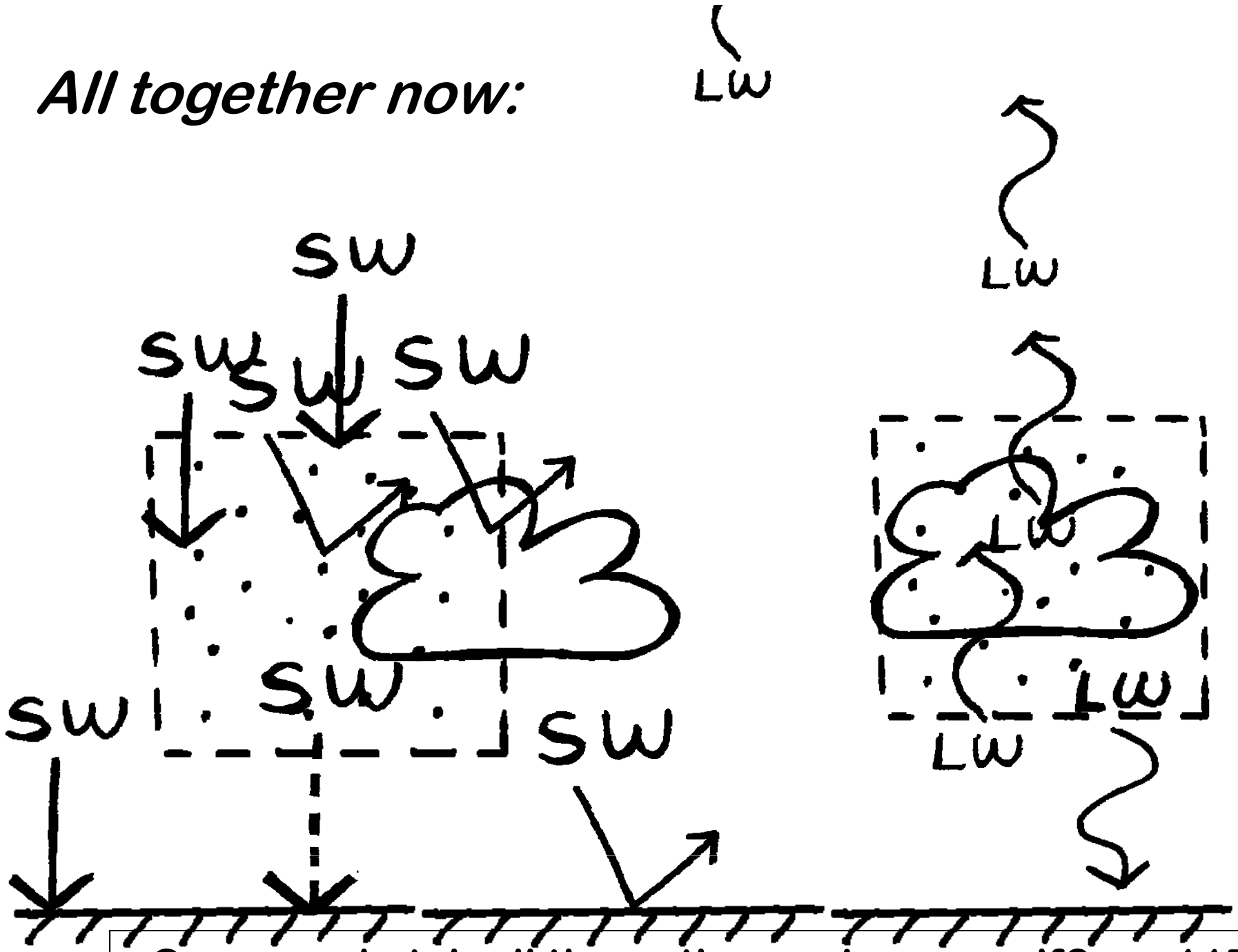


IR EMITTED FROM ATMOSPHERE ESCAPING TO SPACE



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

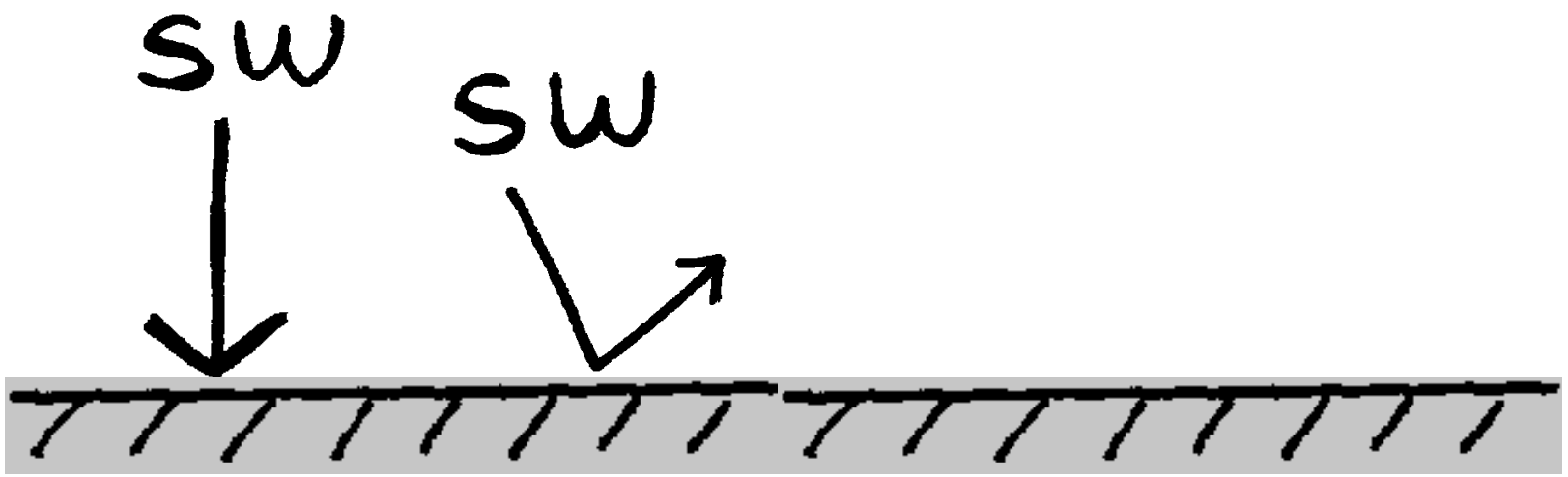
All together now:



Can you sketch all the pathways in yourself? p 117

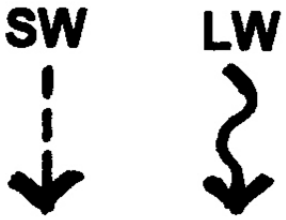
LW

Compare with simpler model of energy balance with NO atmosphere:



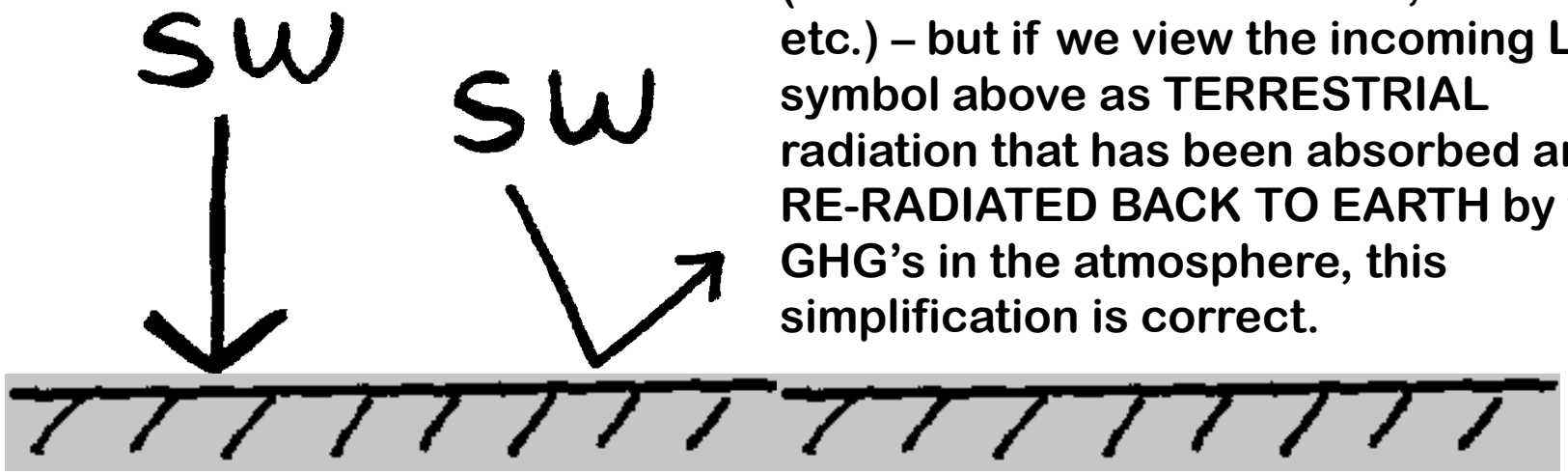
Which terms are not involved?

No scattering by atmosphere



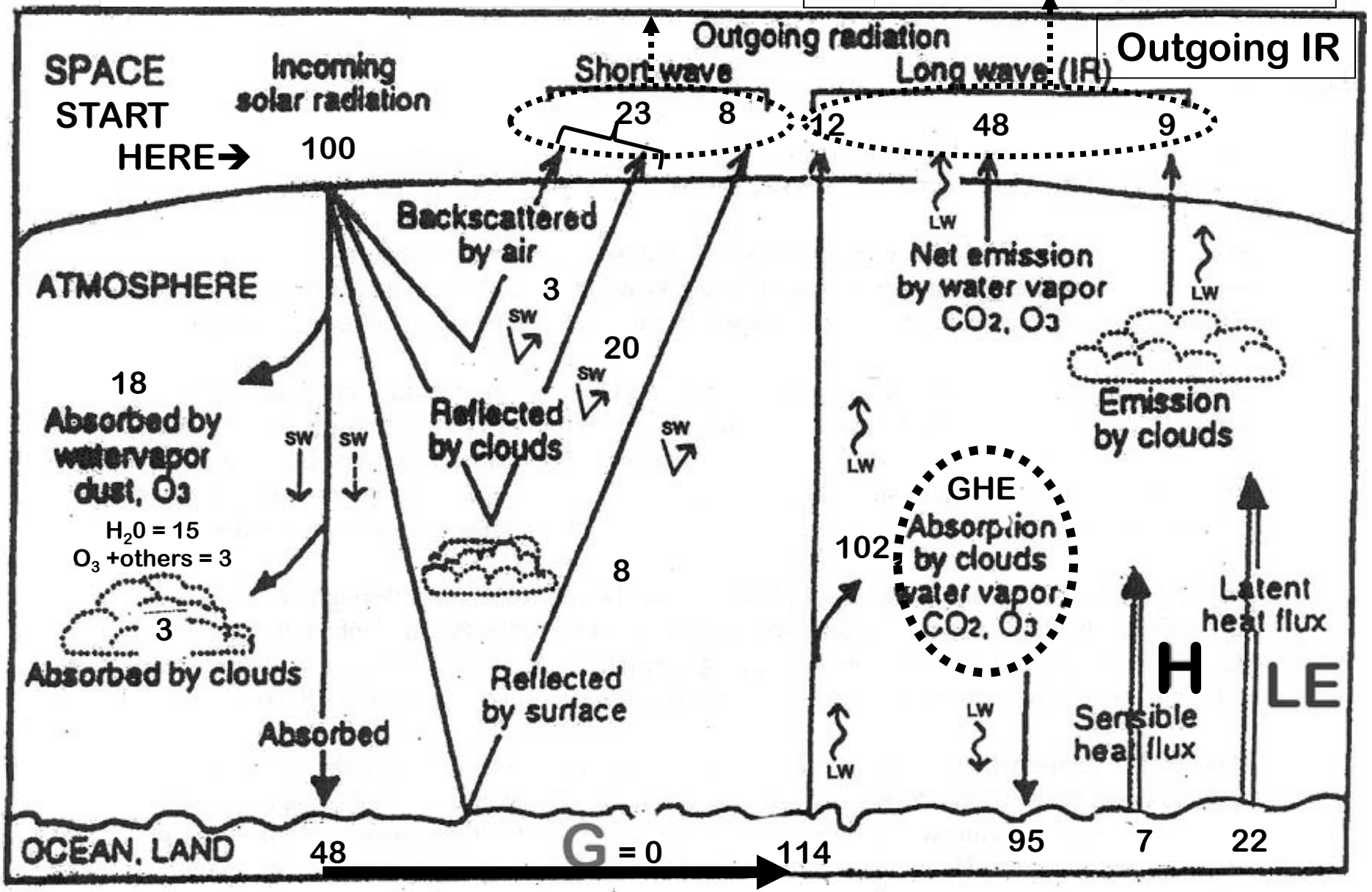
No re-radiation of infrared by GHG's

NOTE: Technically, the SUN <u>does</u> give off incoming <u>longwave</u> 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.



Earth's average albedo: 23 + 8 = 31

12 + 48 + 9 = 69



48 ↓ - 114 ↑ + 95 ↓ = 29 → G + H + LE = 0 + 7 + 22 = 29 = R_{net}

Back to p 52

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

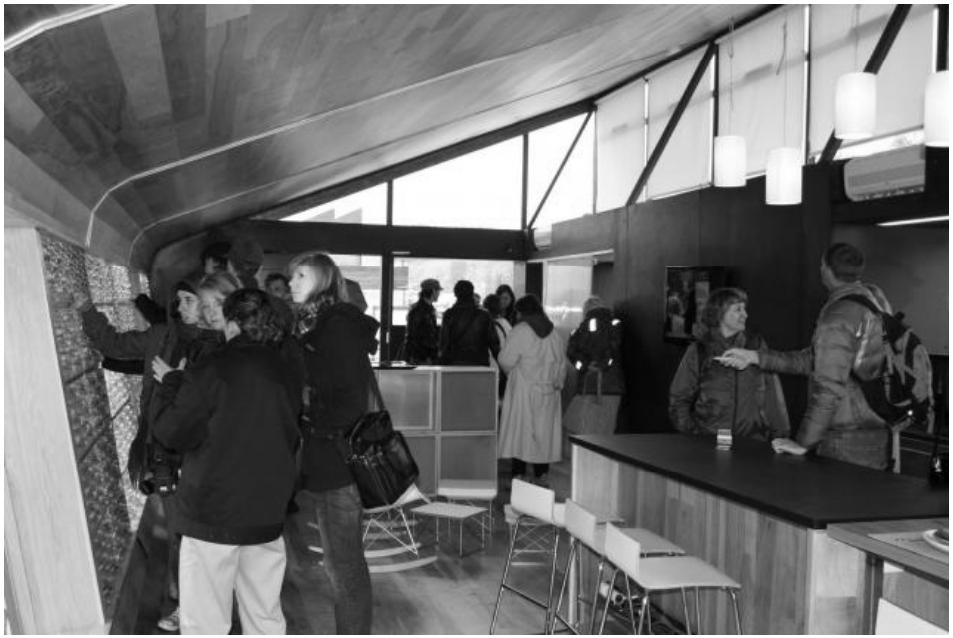
SHORTWAVE & LONGWAVE ENERGY FLOW & BUDGET:
http://mesoscale.agron.iastate.edu/agron206/animations/10_AtmoEbal.html

Time for SUSTAINABILITY SEGMENT #1!

Solar Popcorn Popper!

U.S. DEPARTMENT OF ENERGY
SOLAR DECATHLON

a competition to design, build, and operate the most attractive and energy-efficient solar-powered house

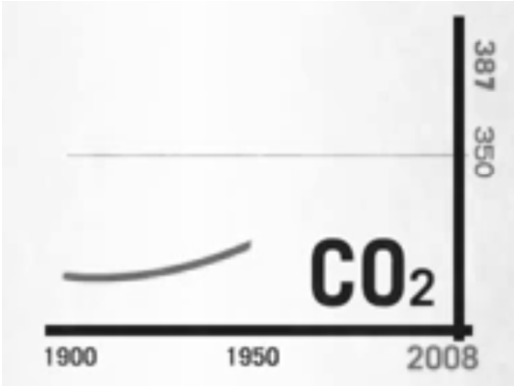


UA's Entry!

http://www.solardecathlon.org/

http://uanews.org/node/28039

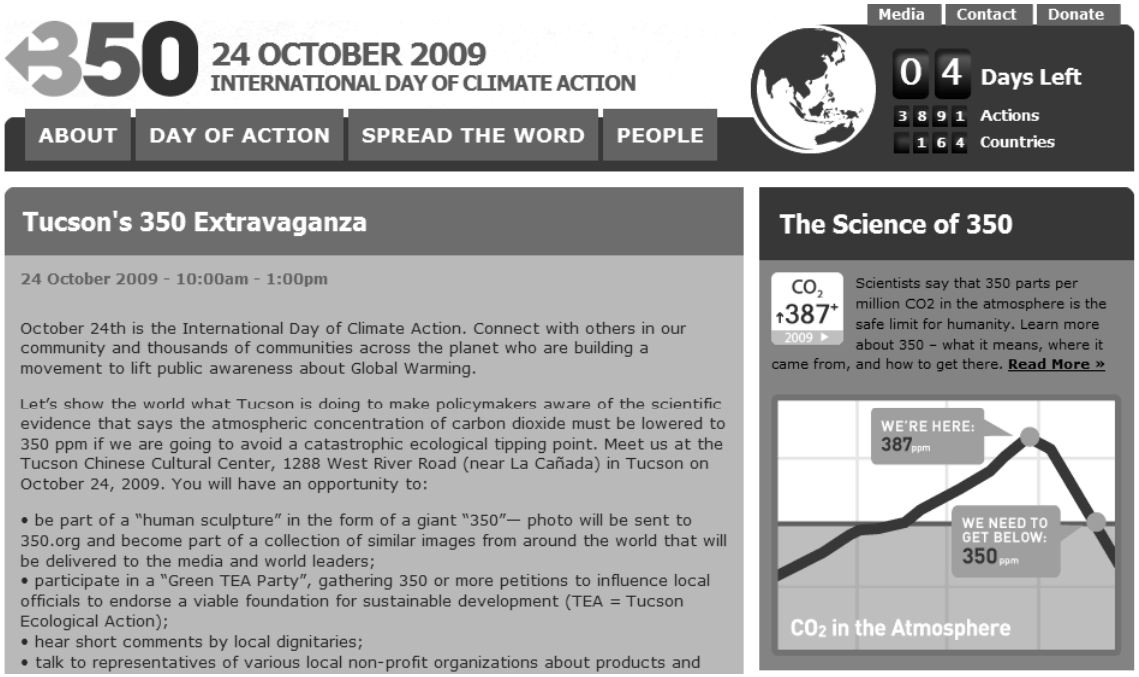
Remember 350.org?



International Day of Climate Action Video:

http://www.youtube.com/v/dqof641pWys;autoplay=1

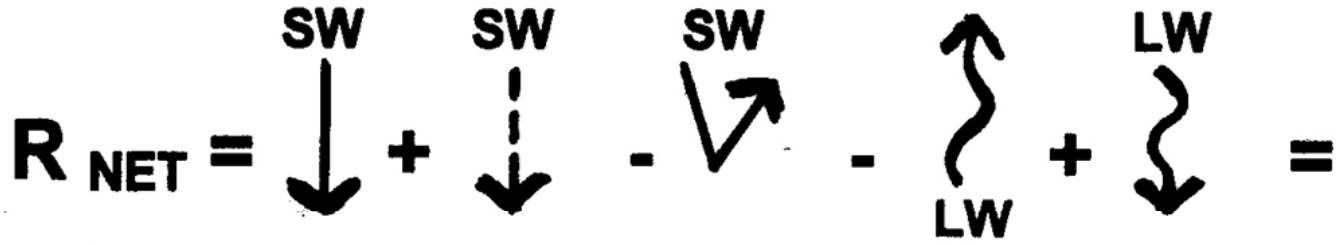
TUCSON'S 350 Extravaganza



http://www.350.org/node/6874

BACK TO THE BALANCE!

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).

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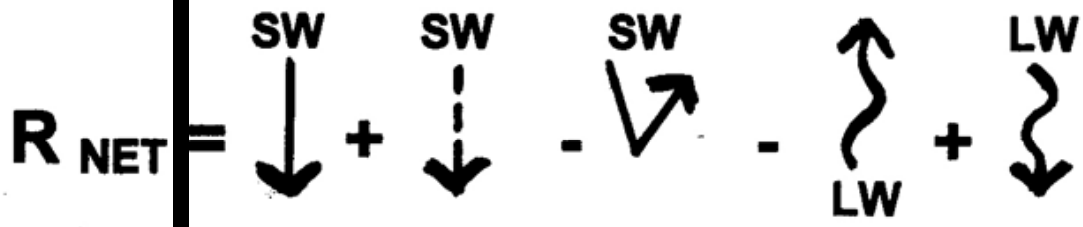
FINAL PART OF TOPIC #10:

The RIGHT side of the ENERGY BALANCE EQUATION . . .

Left side of equation



= 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).

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

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Review of: THERMODYNAMICS & HEAT TRANSFER

Conduction = passage of thermal energy through a body **without large-scale movement** of matter within the body. Most effective in SOLIDS.

Convection = passage of thermal energy through a fluid (liquid or gas) **by means of large-scale movements** of material within the fluid, as in a convection cell. Most effective in GASES & LIQUIDS.

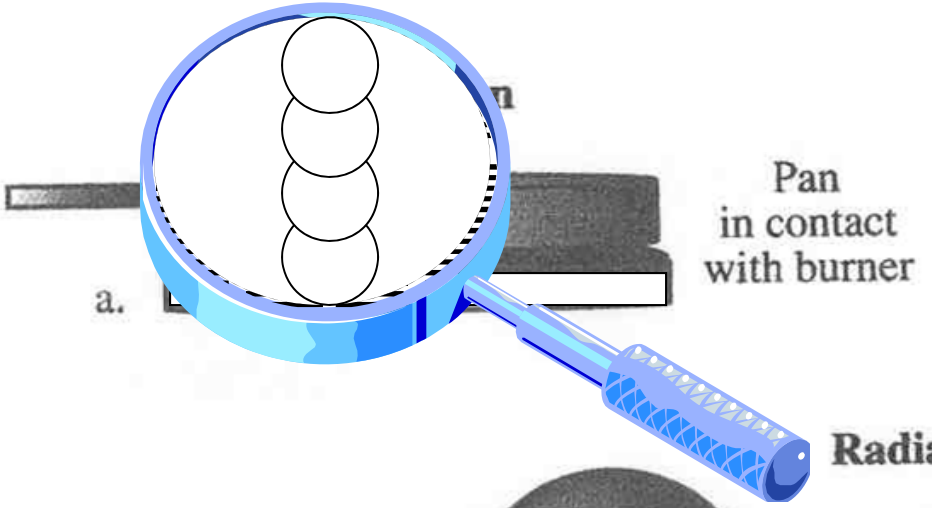
Radiation = the transfer of thermal energy by ***electromagnetic radiation*****.** The only one of the three mechanisms of heat transfer that does not require atoms or molecules to facilitate the transfer process, i.e., **does not even need MATTER as a medium to transfer energy!**

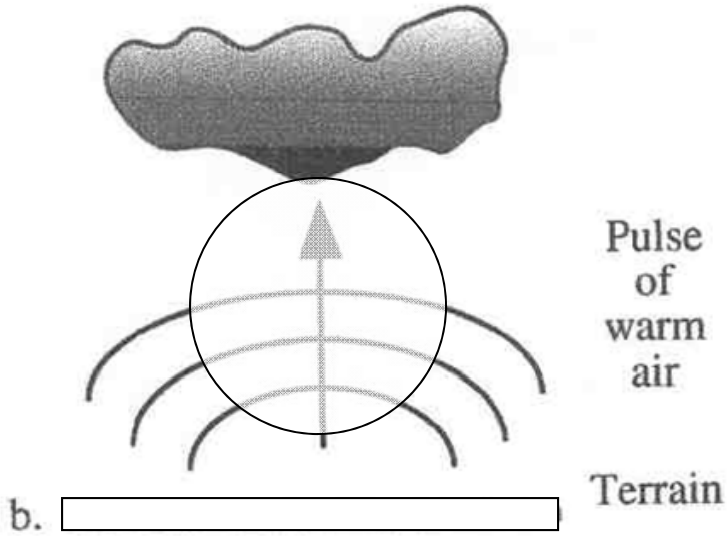
CONVECTION

Mass of warm air or liquid heats, expands, rises

CONDUCTION

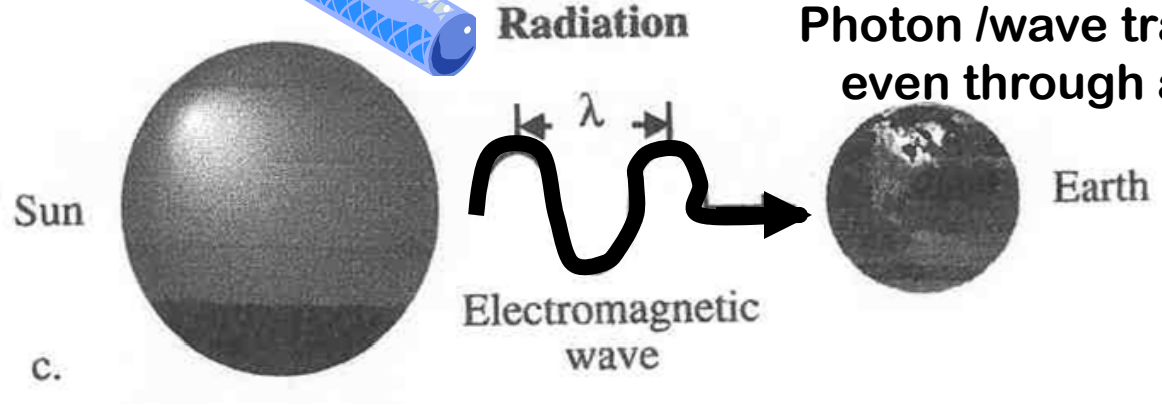
Jiggling molecule ➔ jiggling molecule
transfer of heat
(kinetic energy at molecular scale)





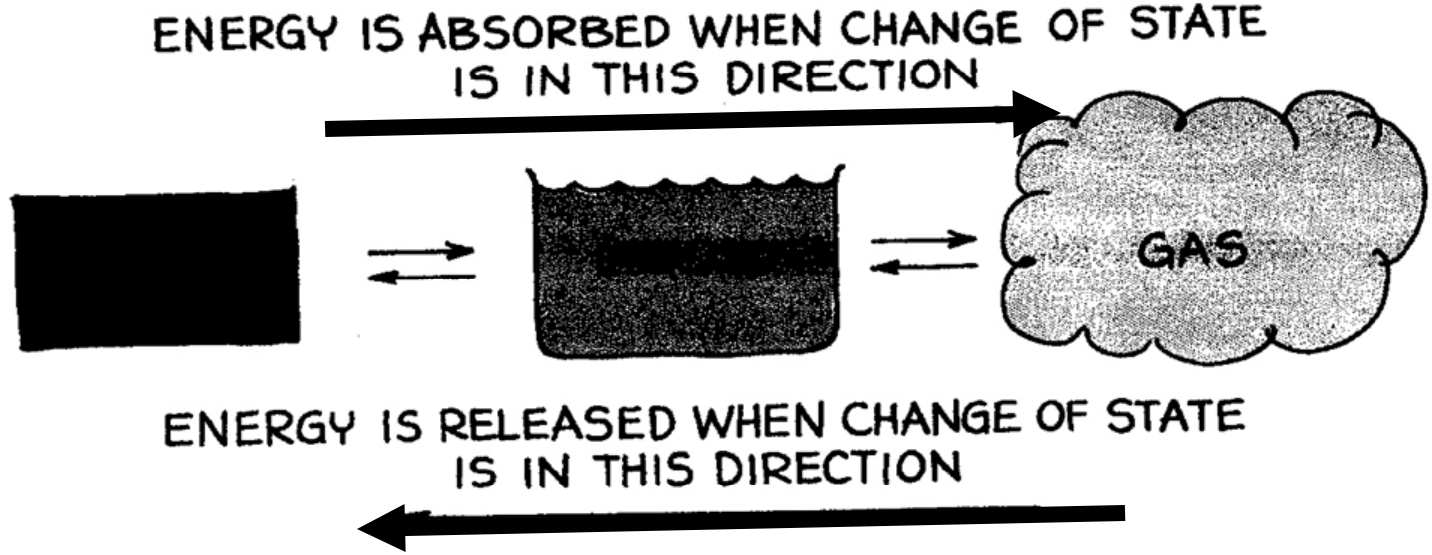
RADIATION

Photon /wave transport:
even through a void!



HEAT TRANSFER & STORAGE DURING PHASE CHANGES: LE & H

LE = LATENT (hidden) ENERGY
(LE stored)

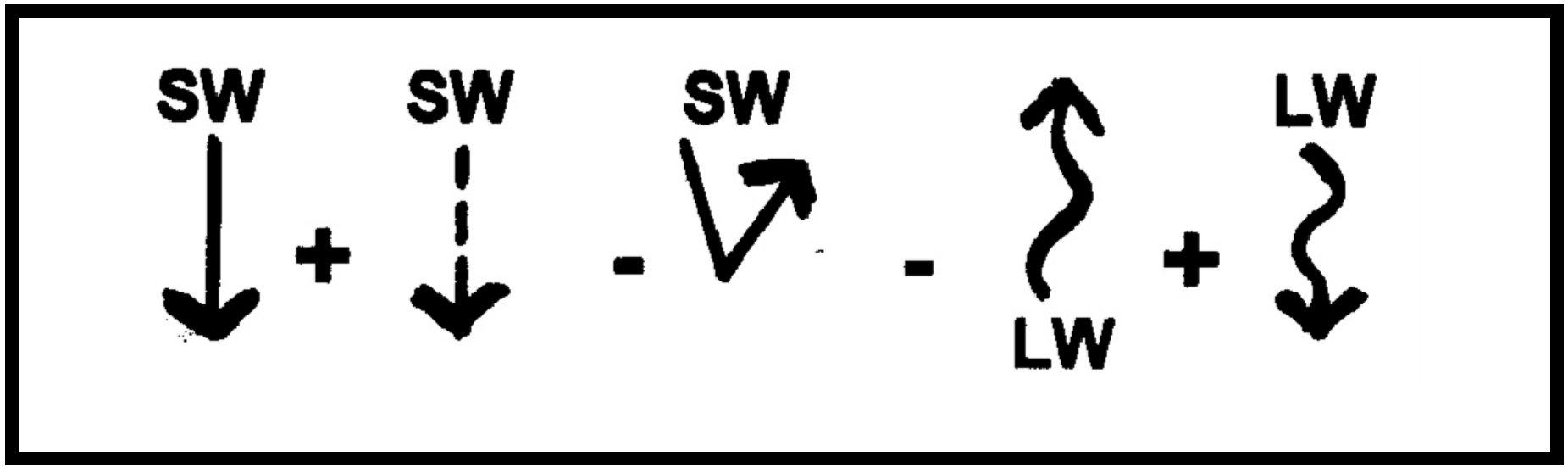


(LE released, hence it can be sensed as H)

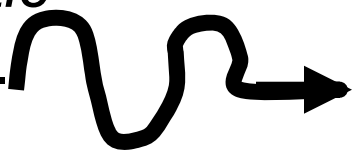
H = SENSED (via thermometer) ENERGY

Review p 53

Link to the Left Side of Equation:



Radiation = the transfer of heat by *electromagnetic radiation*.

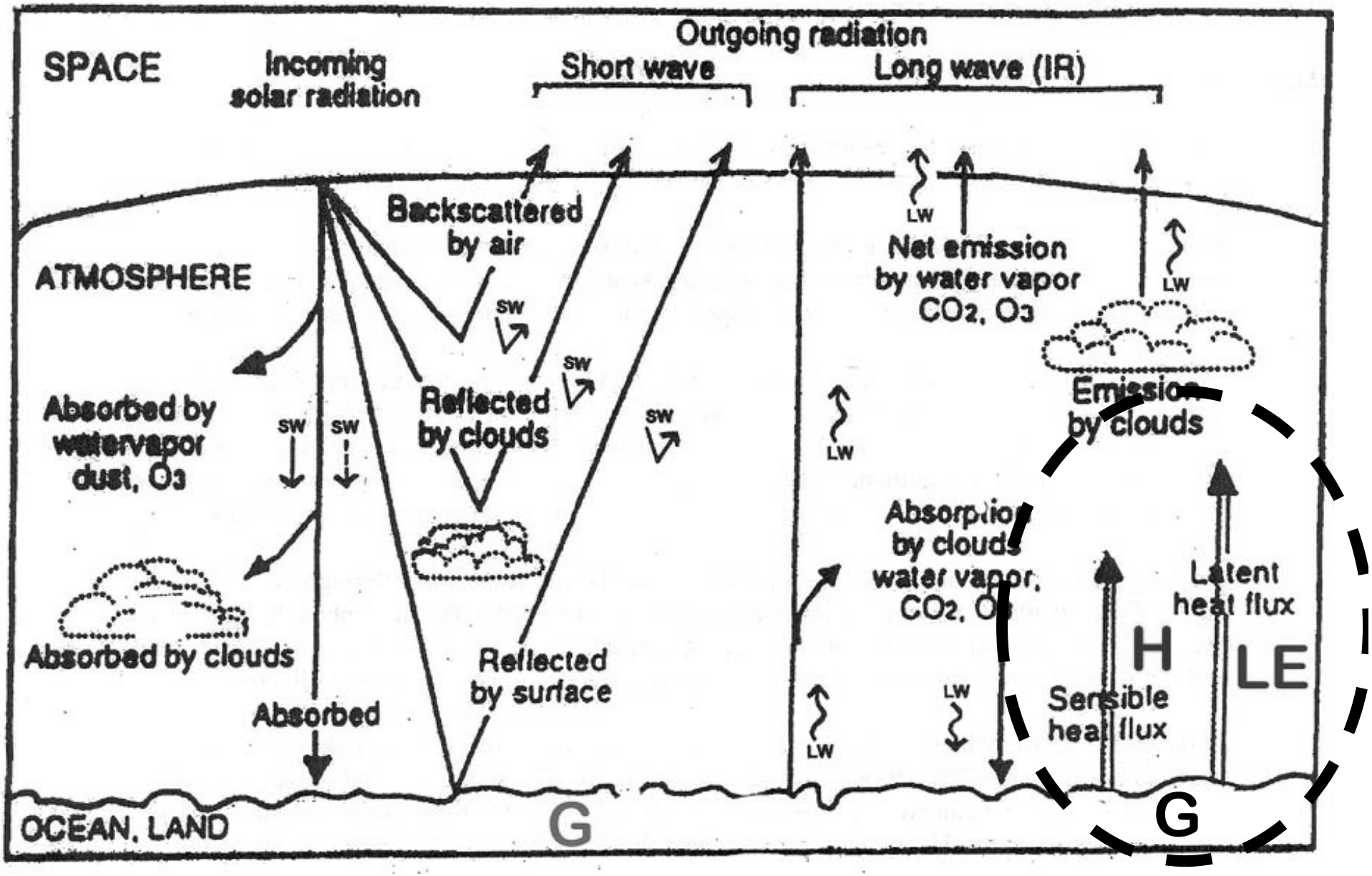


It doesn't need MATTER to transfer energy!
(sun ➔ earth, earth ➔ atmosphere, atmosphere ➔earth, earth ➔ space)

Link to the Right Side of Equation:

$$H + LE + G$$

Conduction & convection
plus energy stored & released
during phase changes (latent
energy => sensible heat, etc.)


SPACE
Incoming solar radiation
Outgoing radiation
Short wave
Long wave (IR)
ATMOSPHERE
Backscattered by air
Absorbed by watervapor dust, O3
Reflected by clouds
Absorbed by clouds
Reflected by surface
Absorbed
Net emission by water vapor CO2, O3
Emission by clouds
Absorption by clouds water vapor, CO2, O3
Latent heat flux
Sensible heat flux
H
LE
G
OCEAN, LAND
SW
LW

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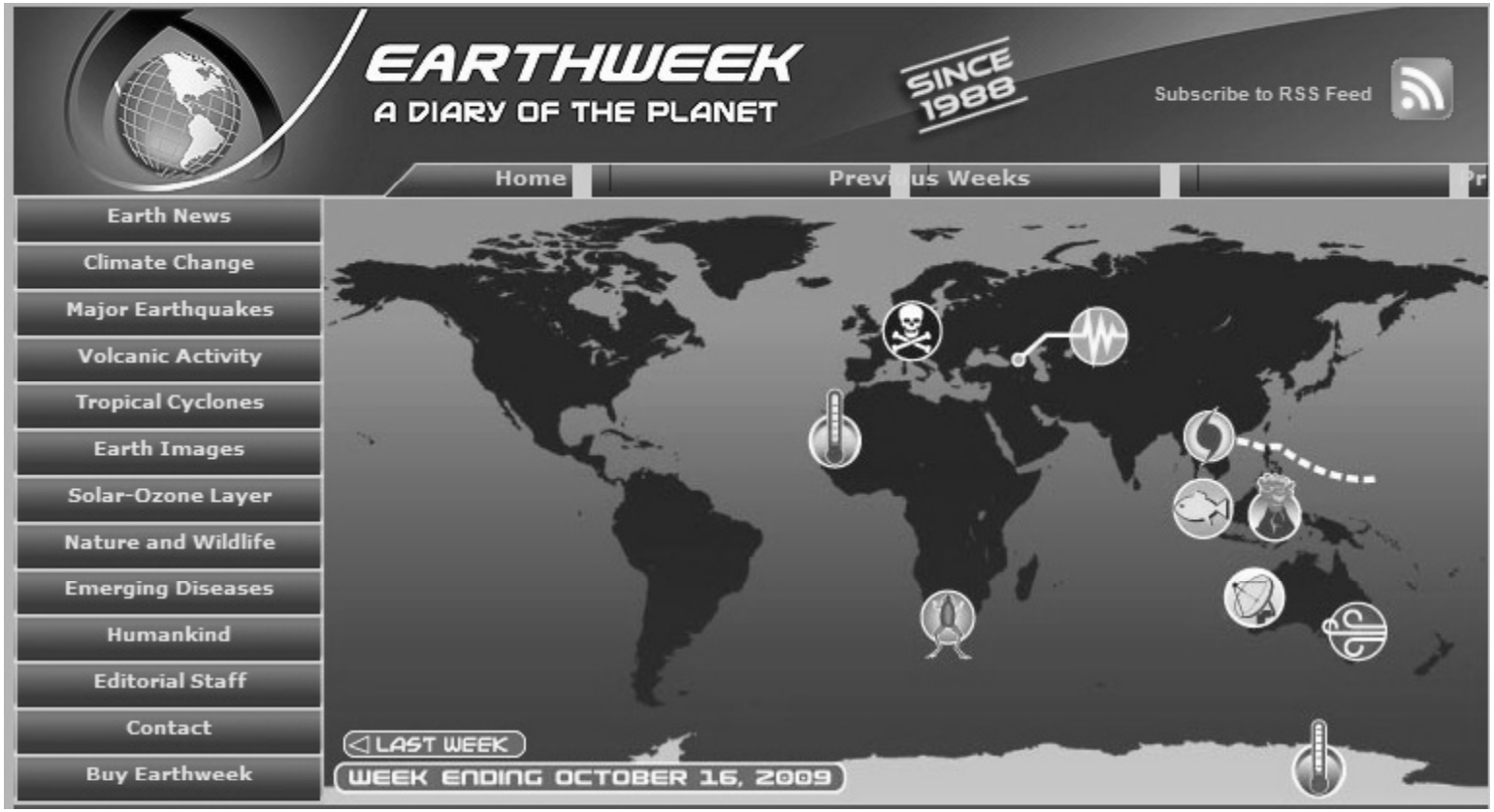
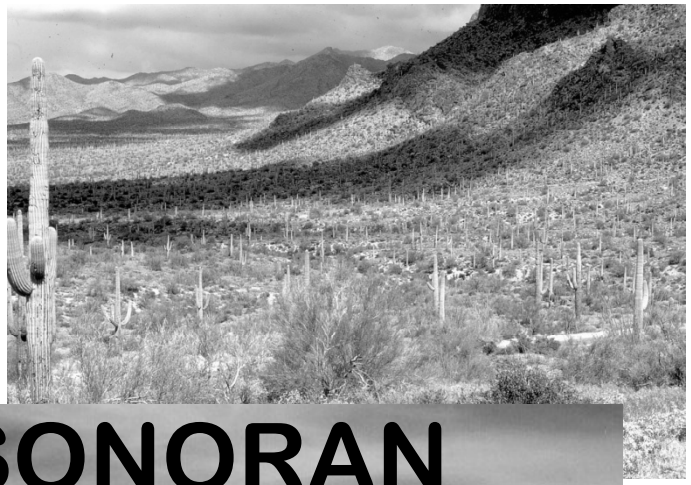
SOME APPLICATIONS OF THE ENERGY BALANCE IN DIFFERENT PARTS OF THE GLOBE:

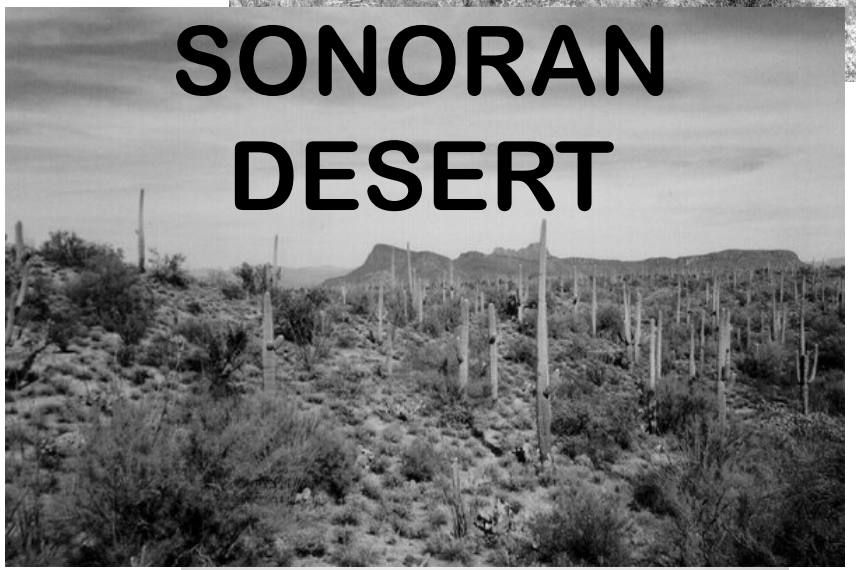


http://www.earthweek.com/

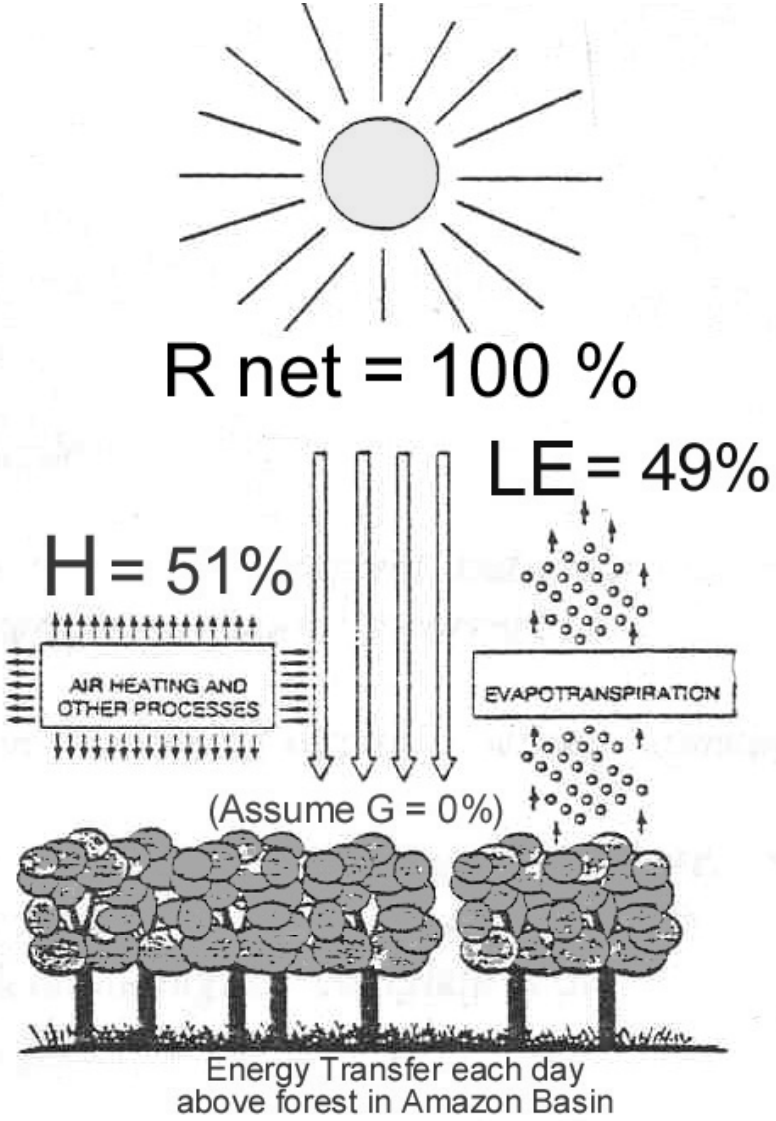
☺


AMAZON RAIN
FOREST



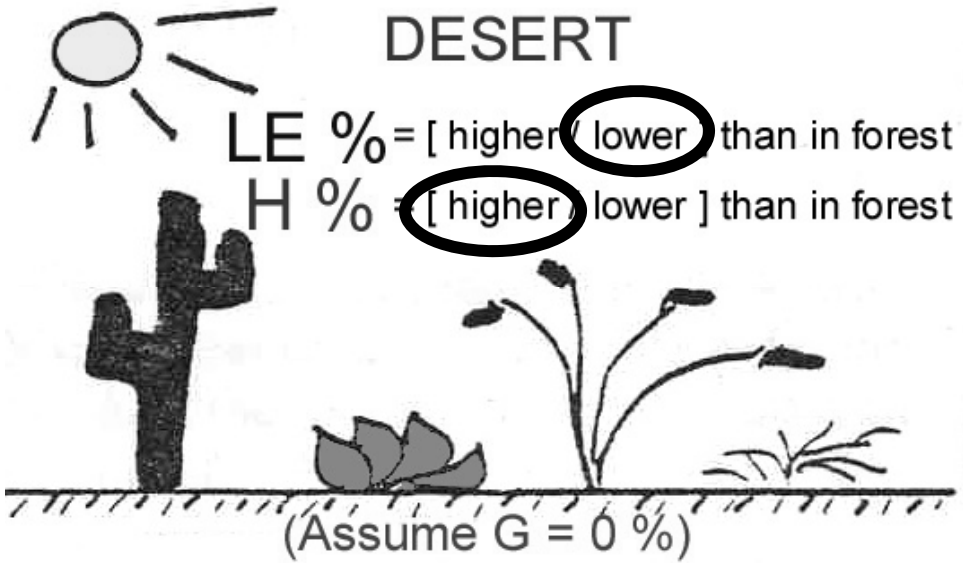

SONORAN
DESERT

☺



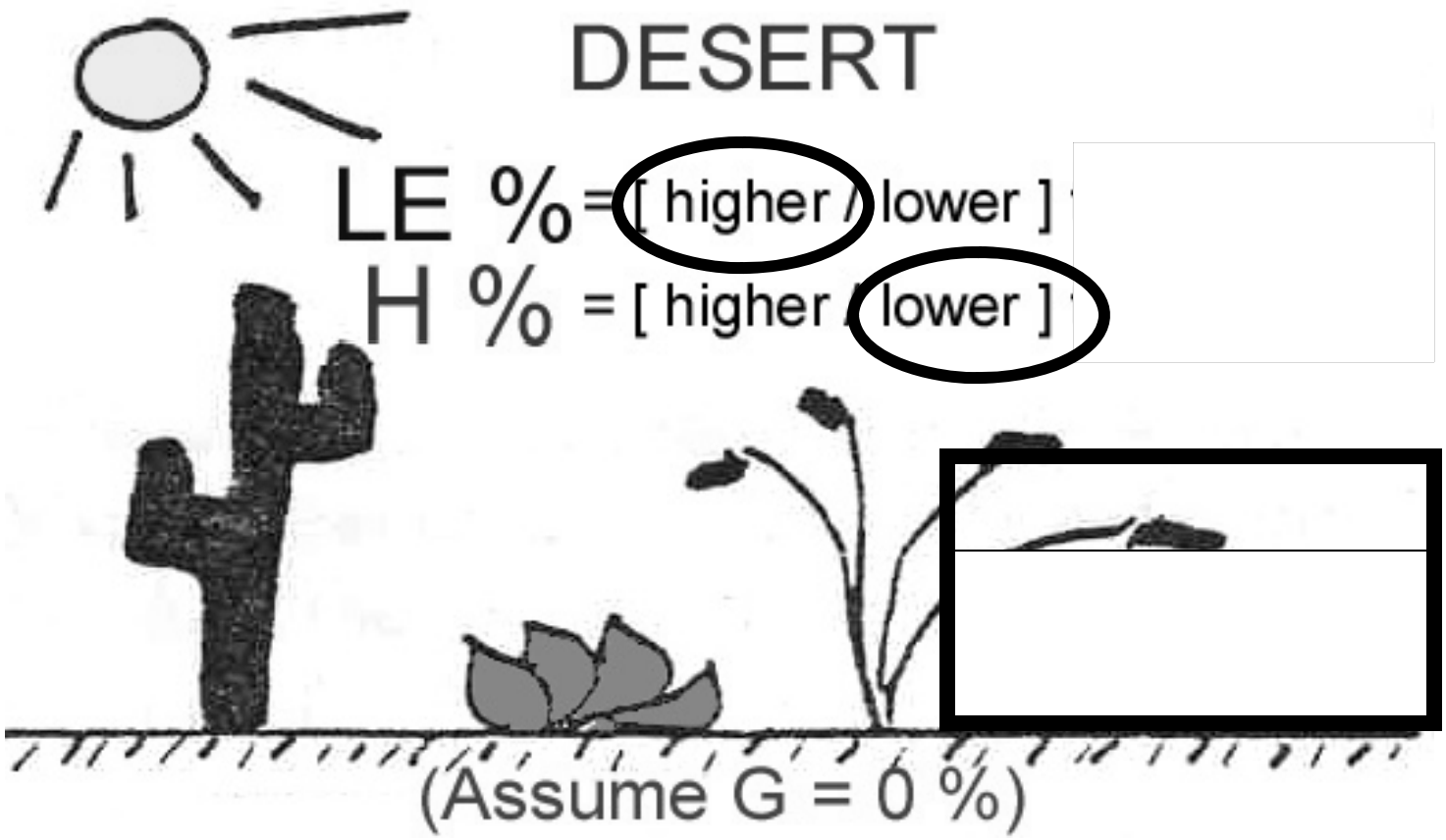
FOREST

Will the % of net radiation in LE form be HIGHER or LOWER in the Desert, when compared to a Rainforest?



What if humans put in canals (CAP), lakes, & artificial water bodies in a desert?

Central Arizona Project (CAP) Canal

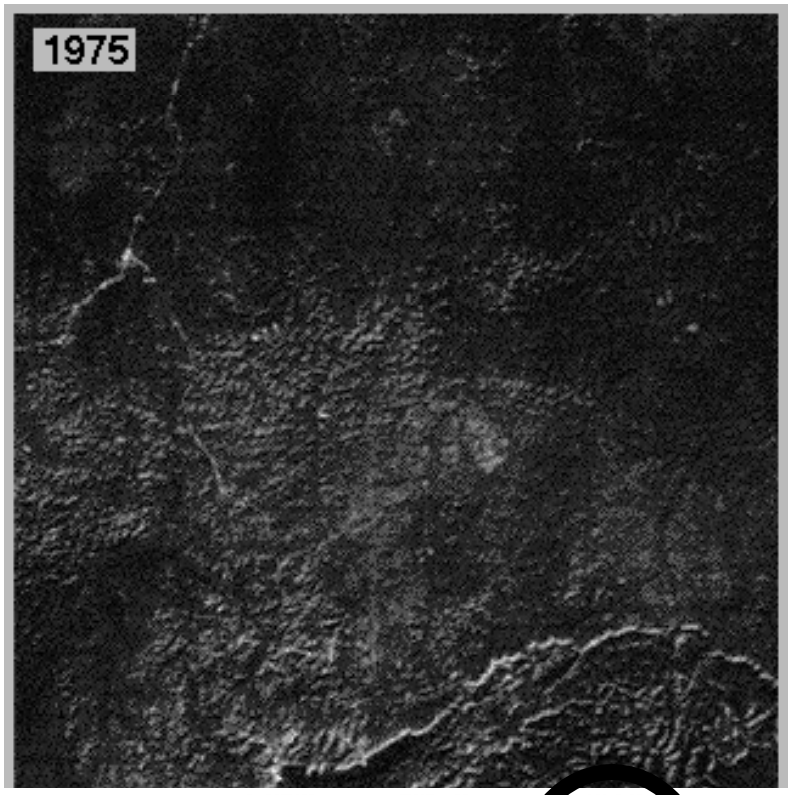


What if humans put in canals (CAP), lakes, & artificial water bodies in a desert?

How would the % of LE in the Desert change?

☺

How does DEFORESTATION change the local energy balance???



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

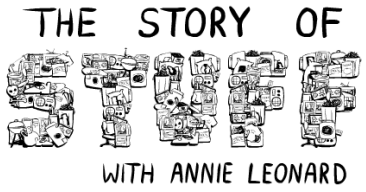
Less

More → cooler temperatures?

More → warmer temperatures?

SUSTAINABILITY SEGMENT #2!

http://www.storyofstuff.com/



Disclaimer: Draw your own opinion – you are free to agree or disagree with it – It's meant to get you thinking!

After class visit the "Stuff" webpage to watch it again if you like and also find :

- **A Fact Sheet**
- **Glossary**
- **Annotated Script with footnotes**
- **plus more . . . .**

http://www.storyofstuff.com/

ABOUT THE AUTHOR:

Annie Leonard is an expert in international sustainability and environmental health issues.

She is an American scholar on international trade, development, international sustainability and environmental health issues, with more than 20 years of experience investigating factories and dumps around the world.

Use the index card to write out your reaction to the film – and get a bonus point for attending class today!

We'll discuss it afterwards . . .

Keep the discussion going . . . .

See you in class on THURSDAY!

Don't FORGET RQ-5!!