

Skydiver Felix Baumgartner breaks sound barrier in death-defying free-fall

Daredevil jumps from 24 miles up in world's first successful attempt at a supersonic skydive!

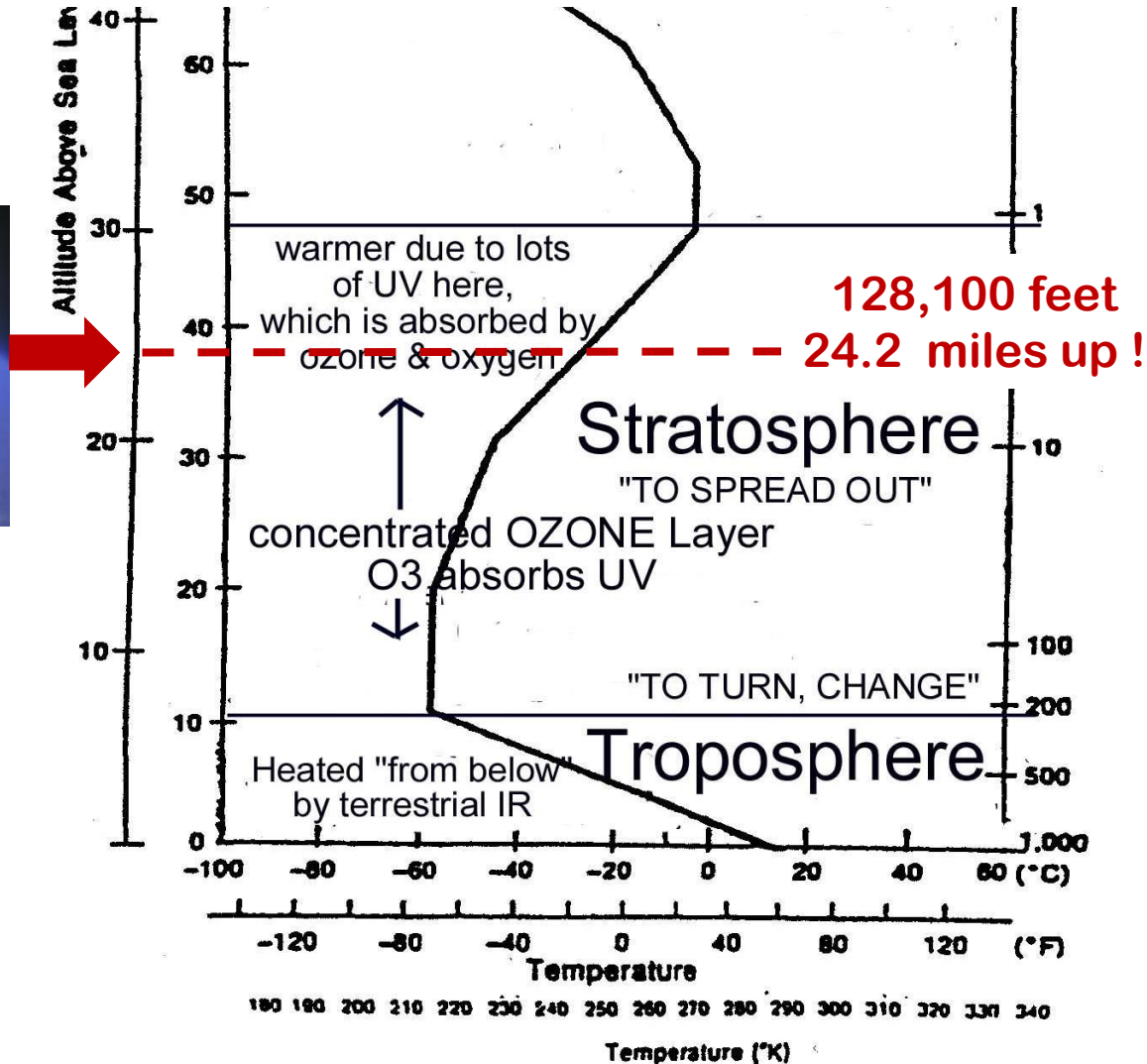
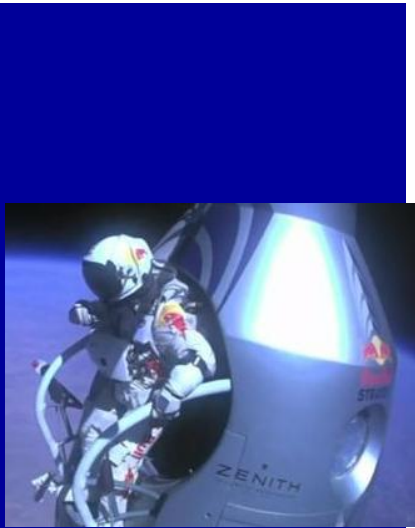


Figure on p 37

Topic # 10
THE EARTH'S GLOBAL
ENERGY BALANCE
PART II

“BOOKMARK” p 53 in Class Notes
but turn to p 122 (in Appendix)
We'll be referring to both sections
in class today

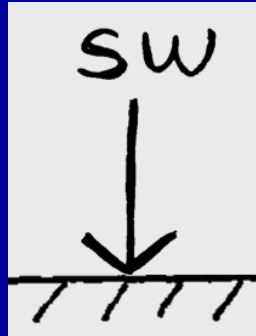
ENERGY PATHWAYS =

(movement of energy in different forms through earth-atmosphere system)

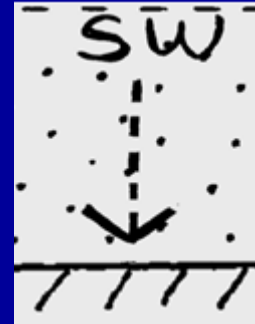
SOLAR RADIATION

UV + Vis

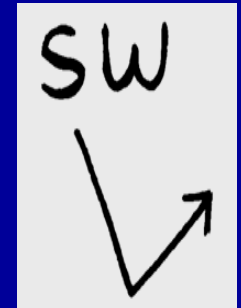
(also near IR)



Incoming Direct Solar



Incoming Diffuse Solar



Outgoing Reflected Solar

TERRESTRIAL RADIATION

(far IR)



Outgoing IR

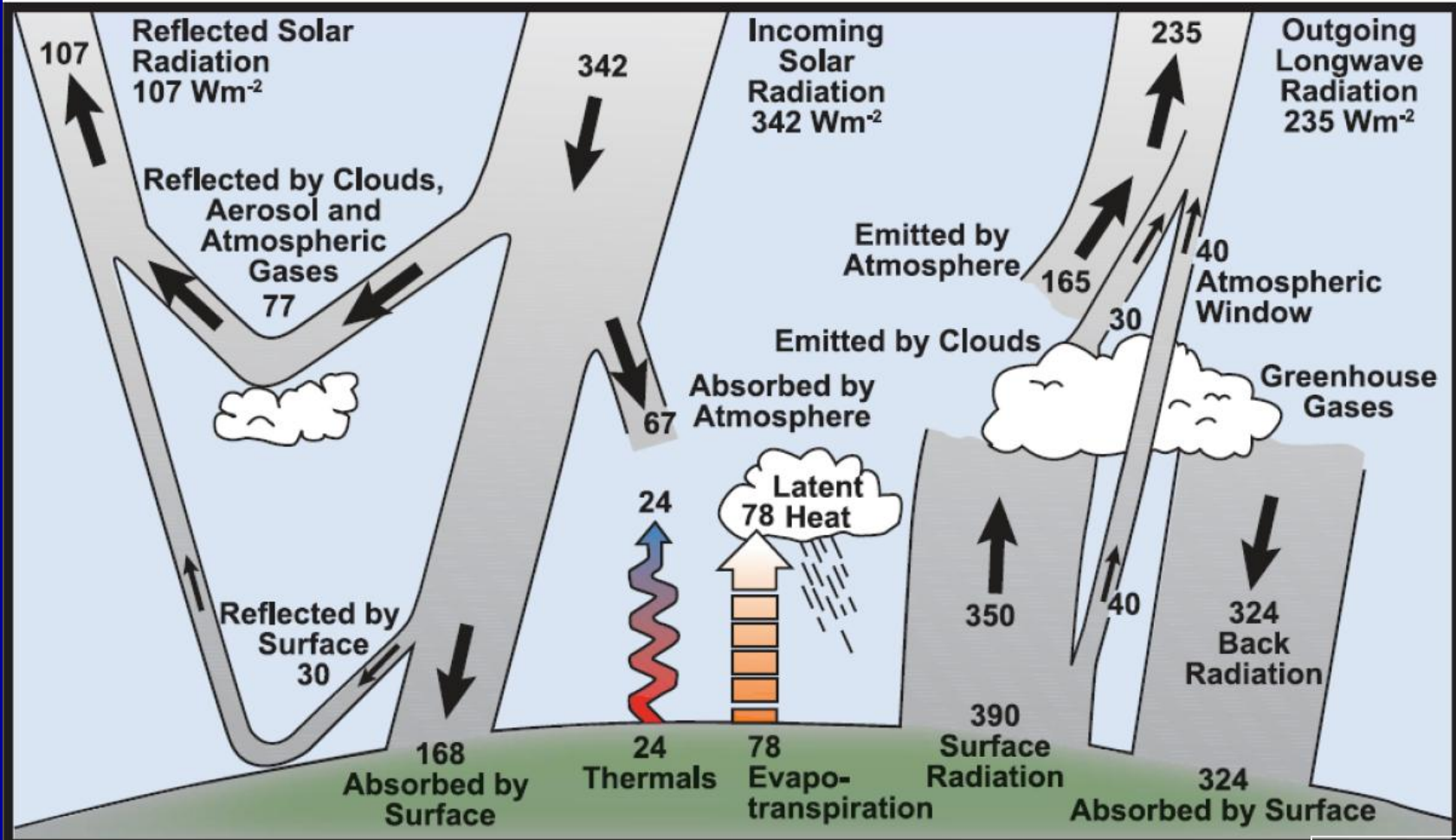


Incoming IR

ENERGY PATHWAYS

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.



PUTTING IT TOGETHER:

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

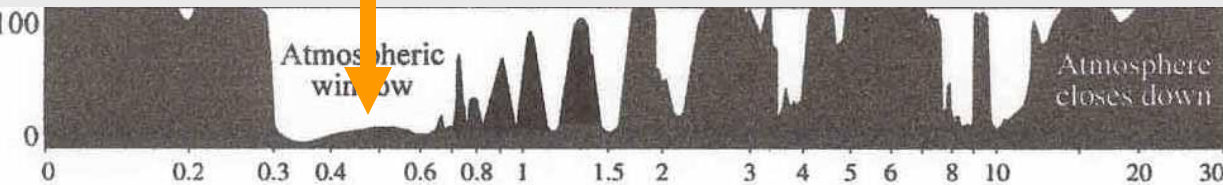
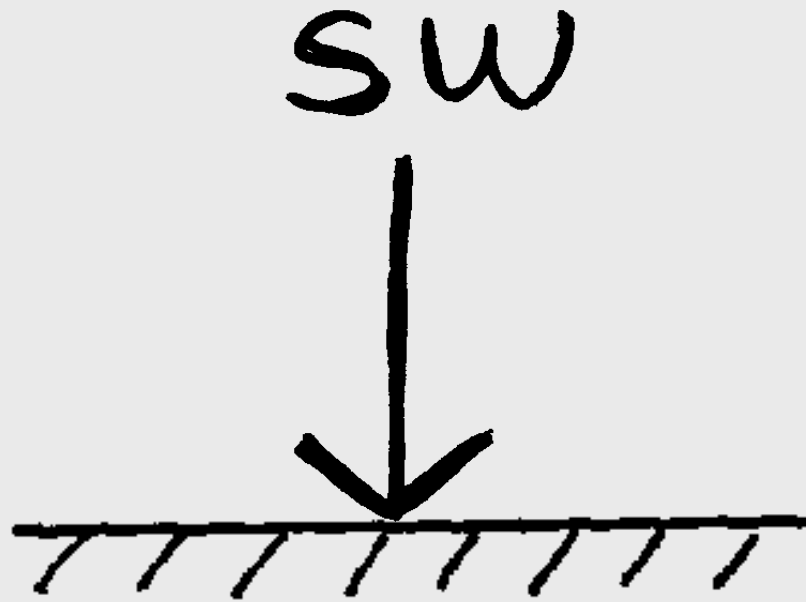
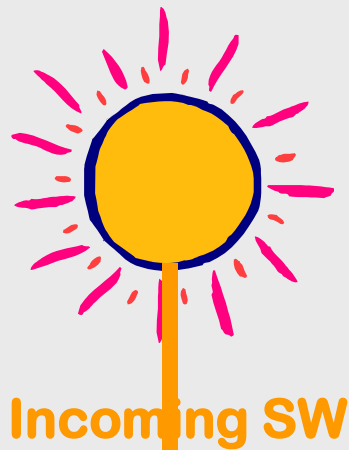
$$R_{NET} = \begin{array}{ccccccc} SW & & SW & & SW & & LW \\ \downarrow & + & \downarrow & - & \swarrow & - & \downarrow \\ R_{NET} = & & & & & & \\ (Q & + & q) & - & a & - & Lu & + & Ld \end{array}$$

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

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



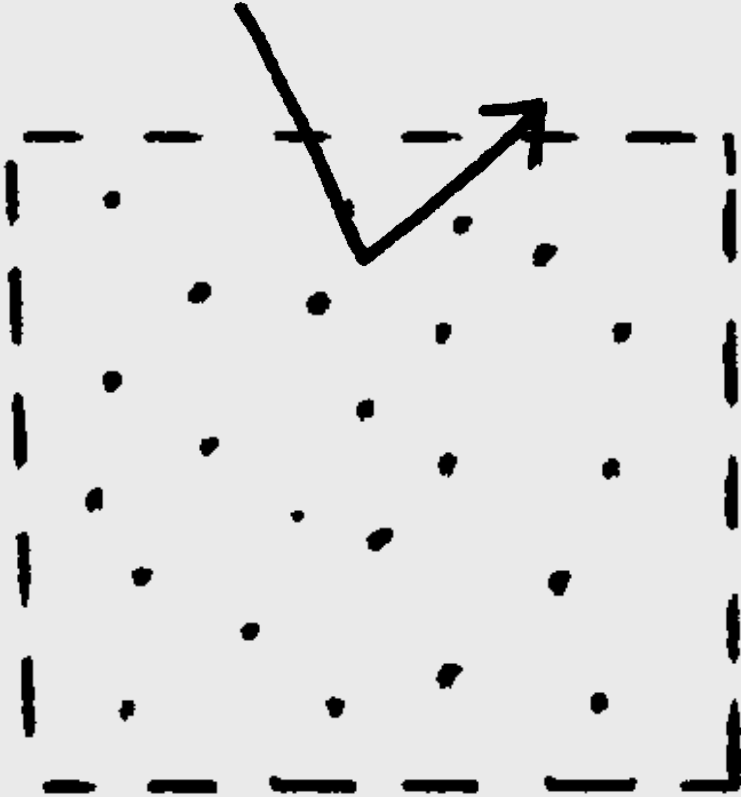
By
Earth's
surface



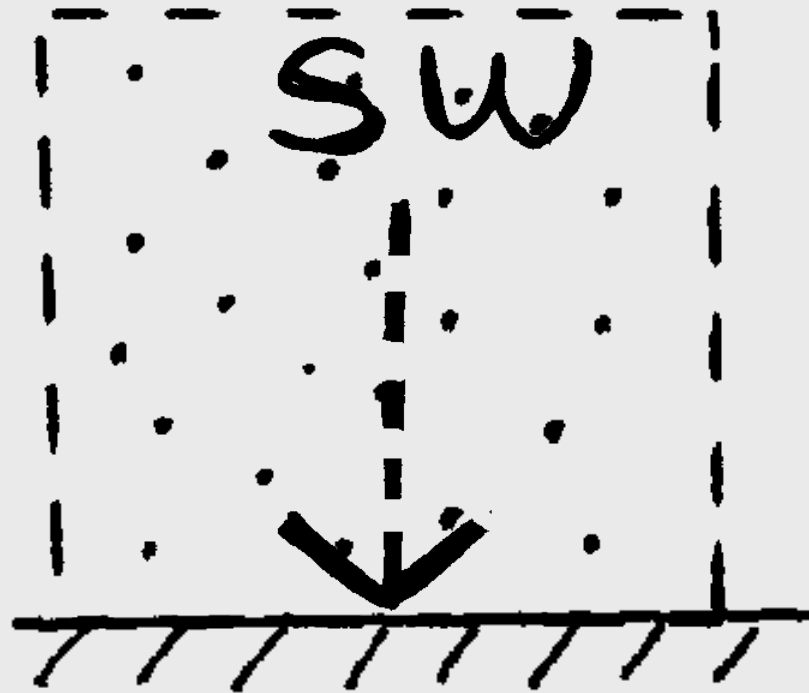
This is determined by
the ALBEDO of the
clouds or surface

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

SW

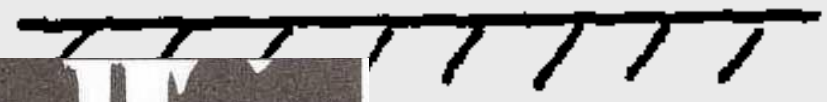
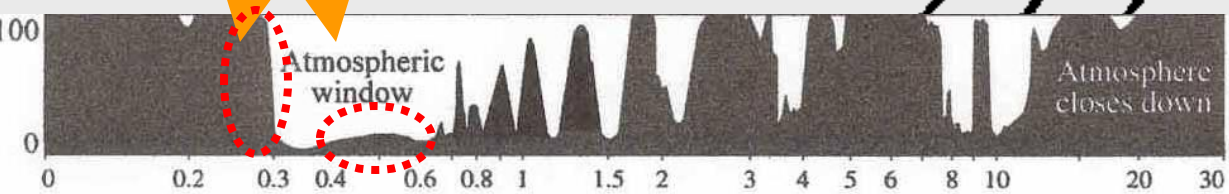
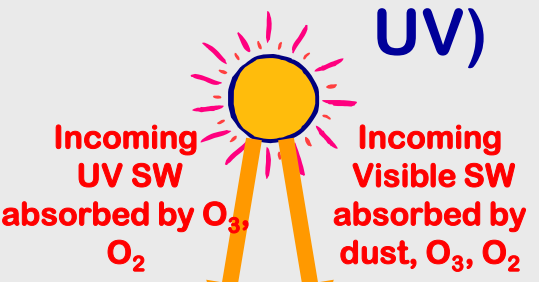
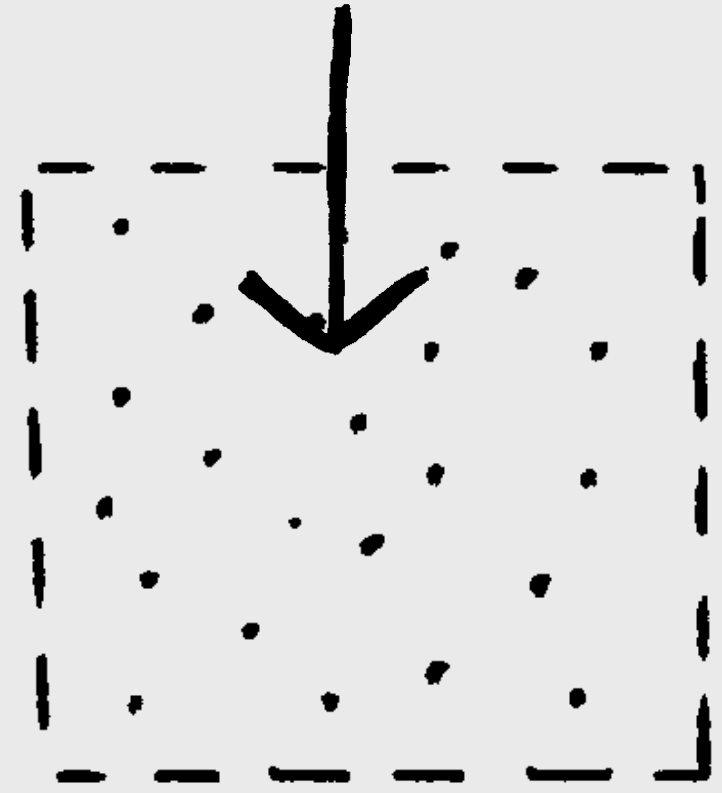


SW SCATTERED DOWN TO EARTH'S SURFACE where it is absorbed

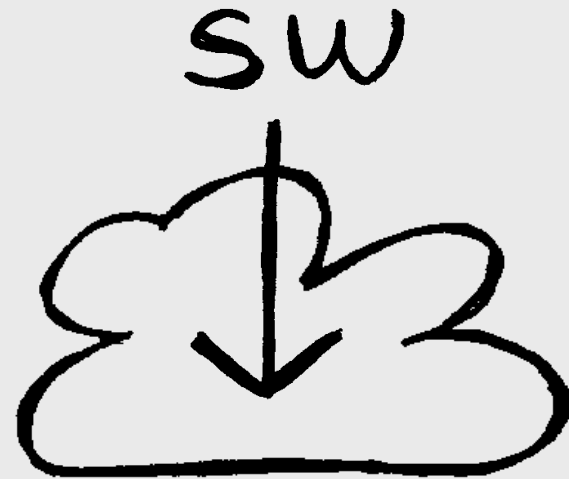


**SW ABSORBED
IN ATMOSPHERE
BY GASES,
DUST, etc.**
(including Ozone
absorbing shortwave
UV)

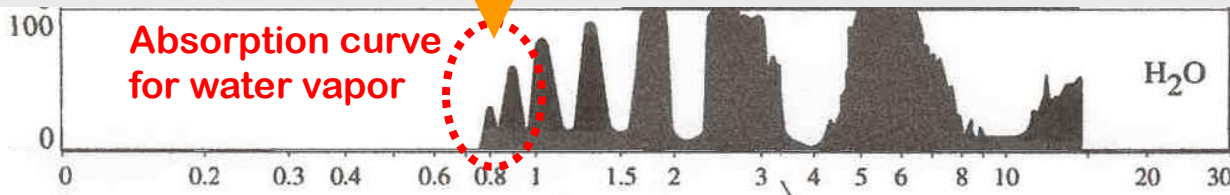
SW



SW ABSORBED In ATMOSPHERE BY CLOUDS & H₂O vapor:



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

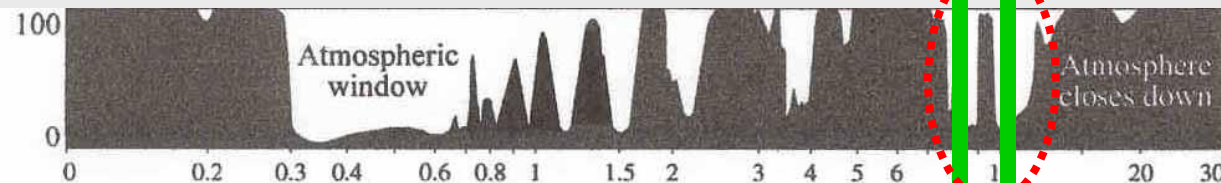


LW (IR) EMITTED
FROM EARTH'S
SURFACE

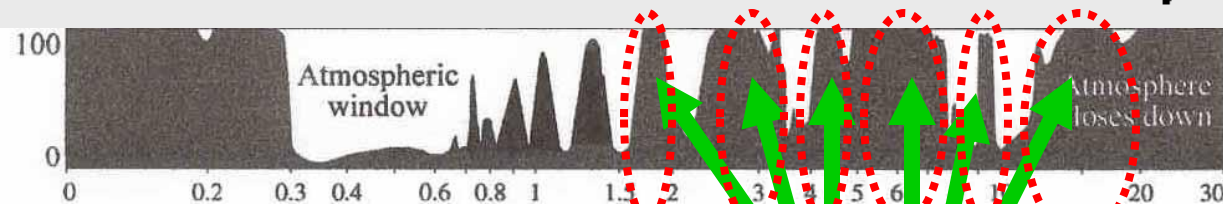
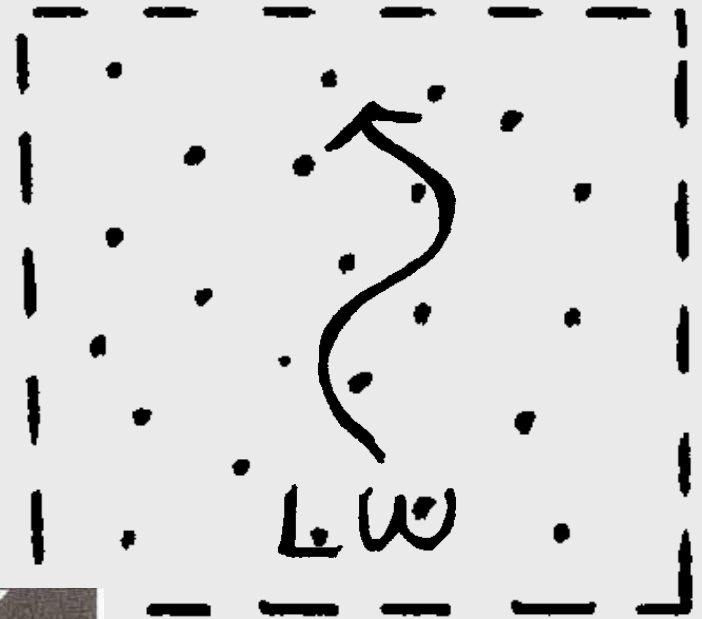
LW

ESCAPING TO
SPACE THROUGH
THE "OUTGOING IR
ATMOSPHERIC
WINDOW"

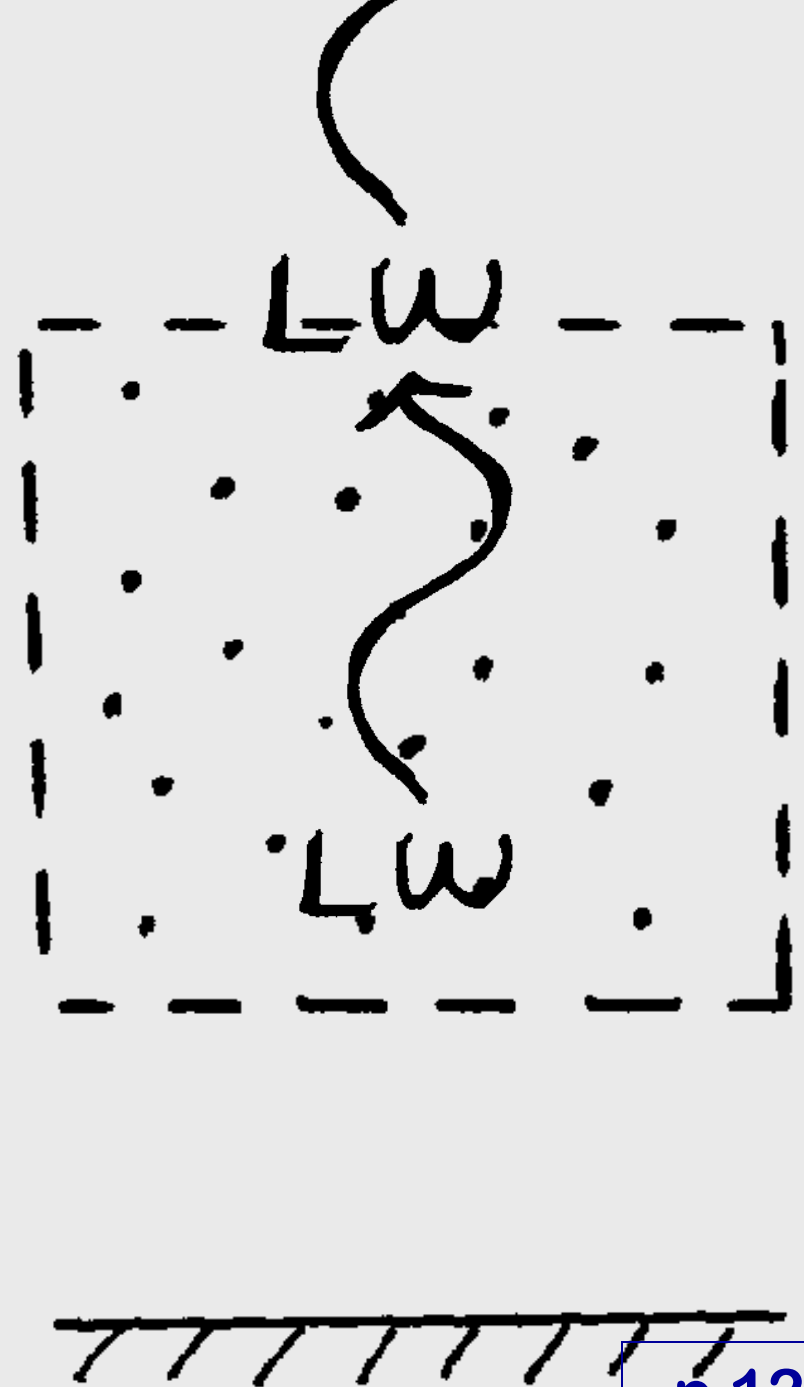
Outgoing LW



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



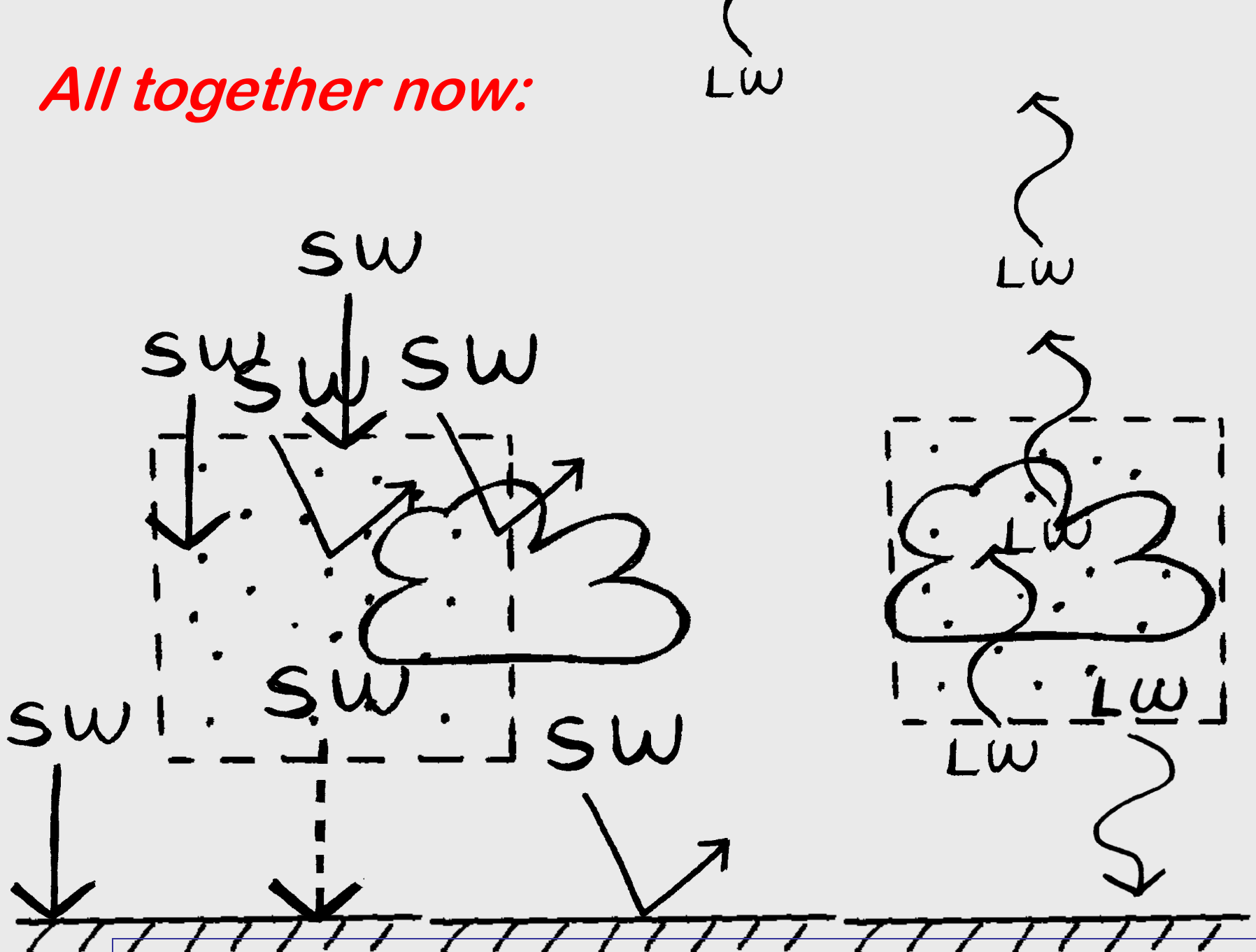
**IR EMITTED
FROM
ATMOSPHERE
ESCAPING TO
SPACE**



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



All together now:

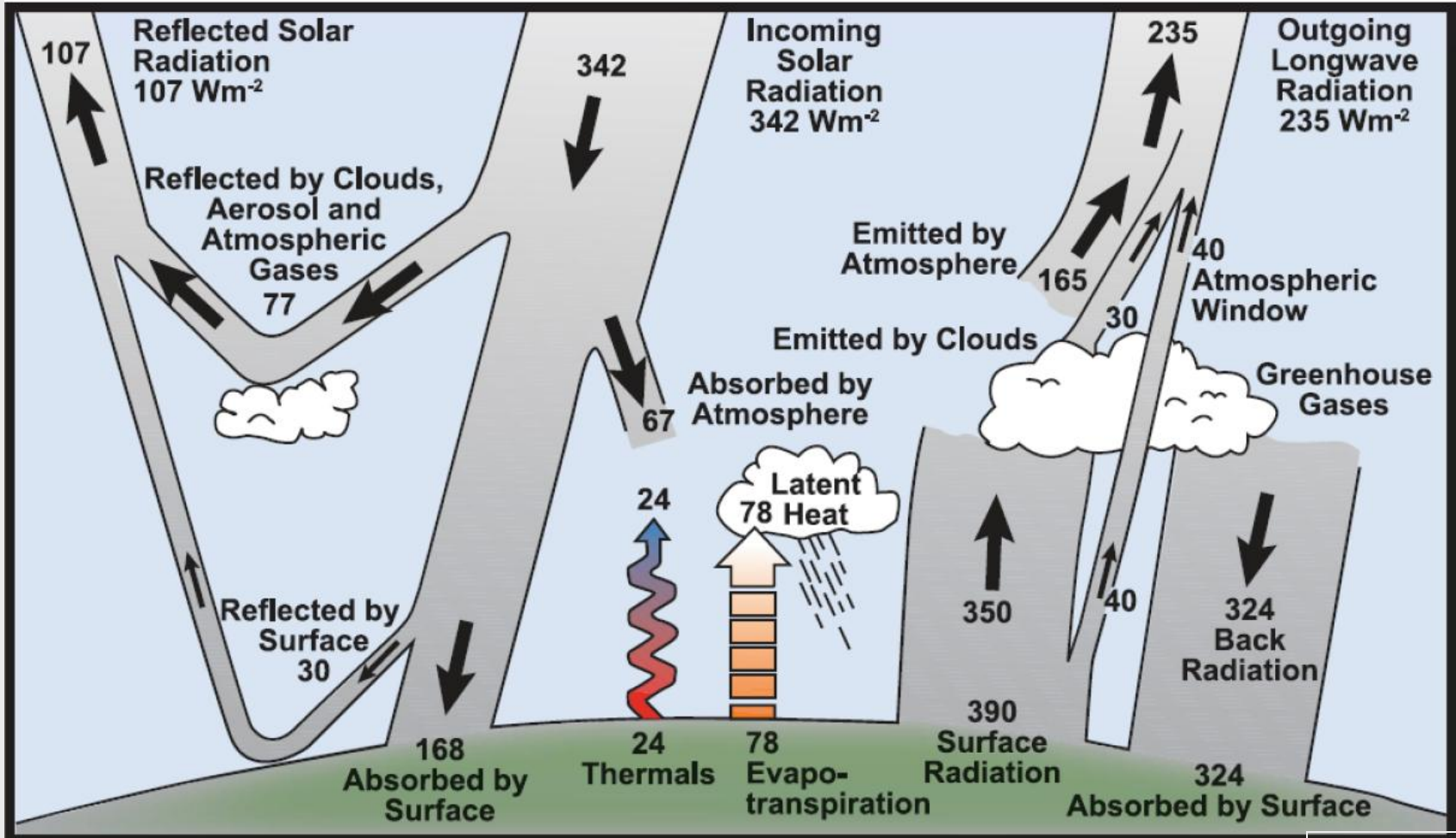


Can you sketch all the pathways in yourself? p 123

ENERGY PATHWAYS

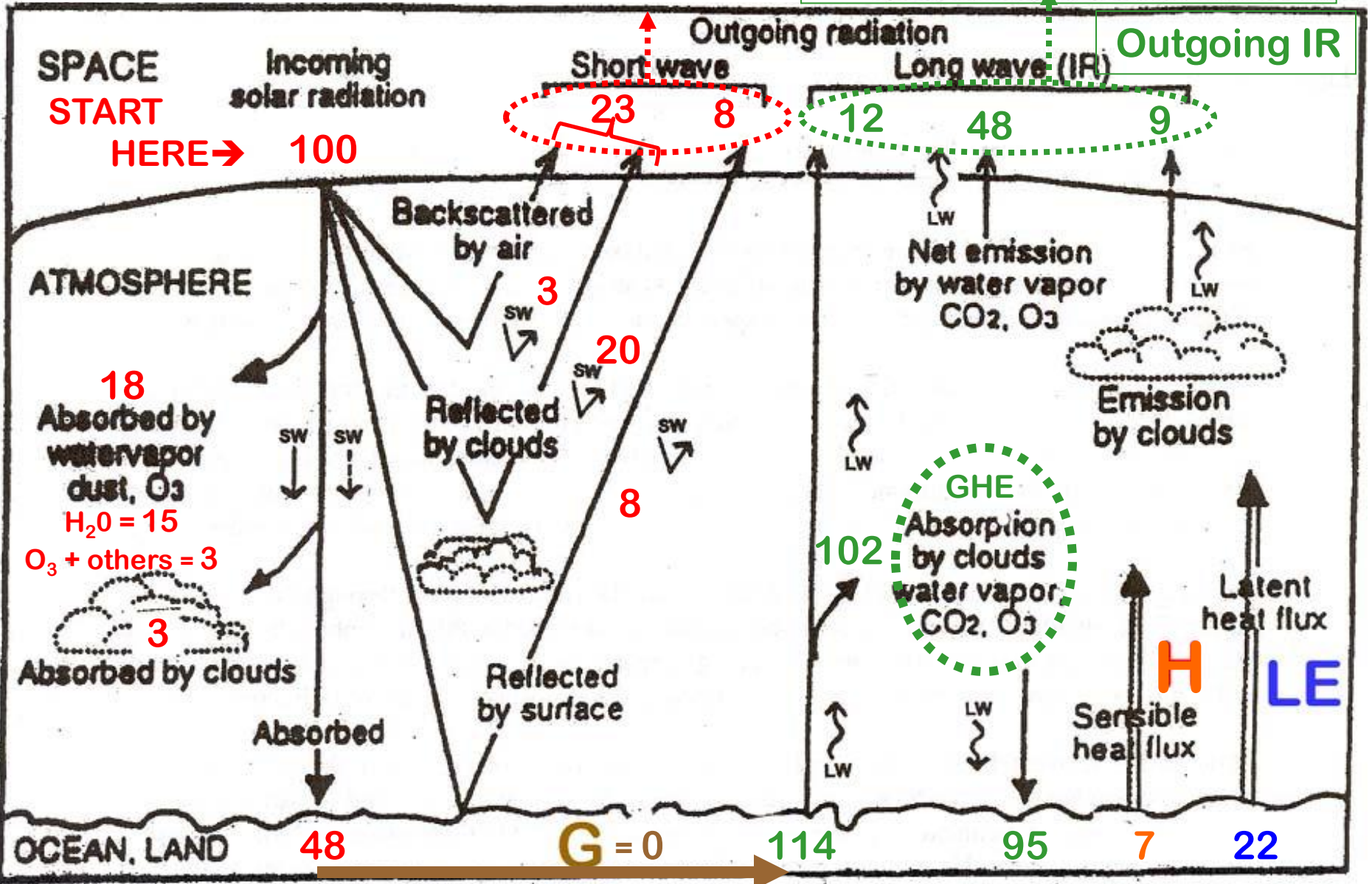
Representation of the Energy Balance & Energy Pathways

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



Earth's new average albedo: $23 + 8 = 31$

$12 + 48 + 9 = 69$



$48 \downarrow - 114 \uparrow + 95 \downarrow = 29 \rightarrow$

$G + H + LE$

$0 + 7 + 22 = 29 = R_{net}$

What if . . .

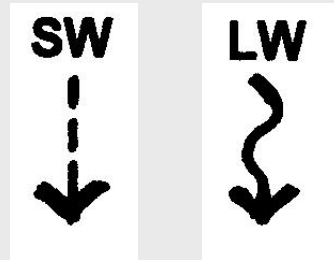
. . . The Earth didn't have an atmosphere containing **greenhouse gases, and therefore did NOT have a **greenhouse effect??****

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


Which terms are not involved?



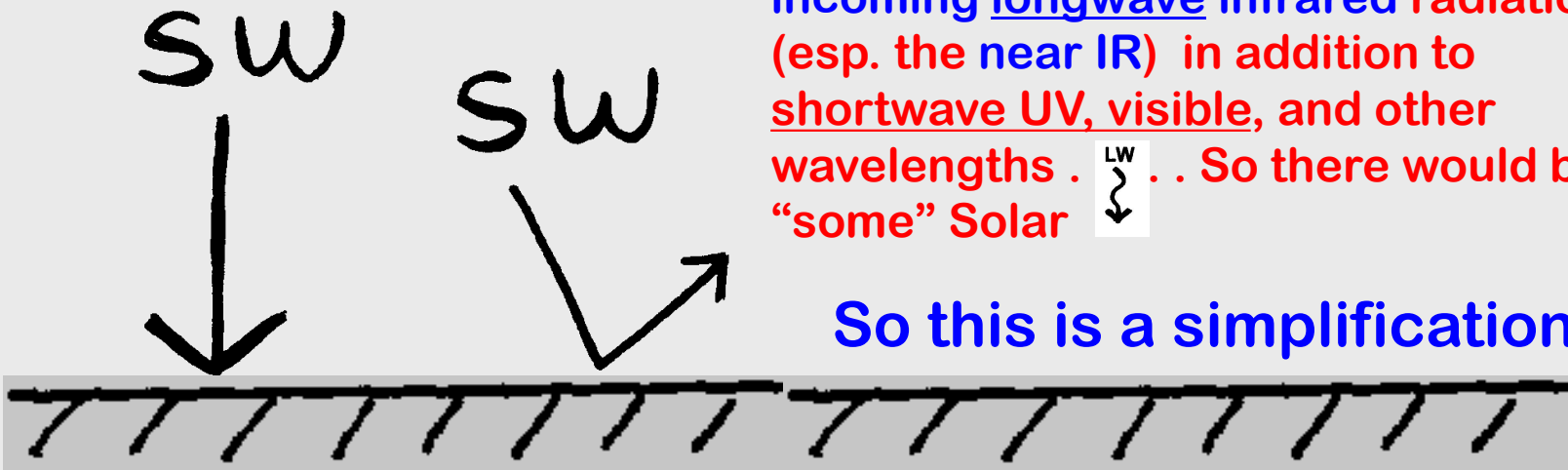
No scattering by atmosphere



No re-radiation of far infrared from the atmosphere because there would be NO GHG's

NOTE: Technically, the SUN does emit incoming longwave infrared radiation (esp. the near IR) in addition to shortwave UV, visible, and other wavelengths . . . So there would be "some" Solar 

So this is a simplification!!!



An Energy Balance Animations

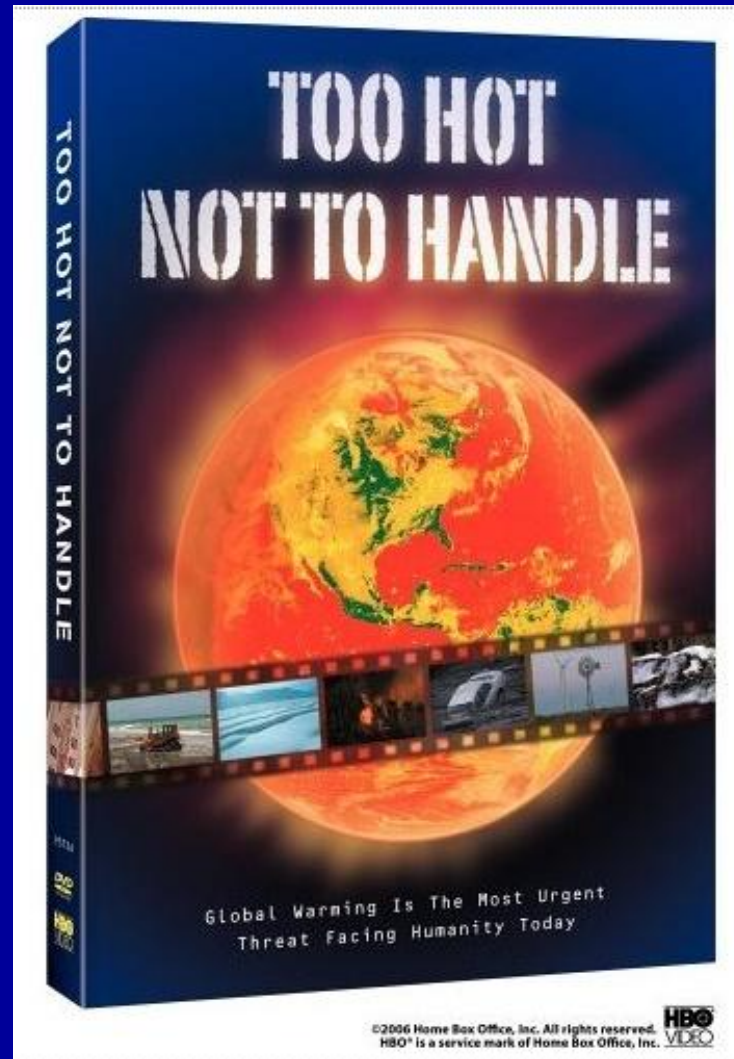
showing energy flow pathways
& “units” of energy that
eventually balance out:

SHORTWAVE & LONGWAVE
ENERGY FLOW & BUDGET:

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

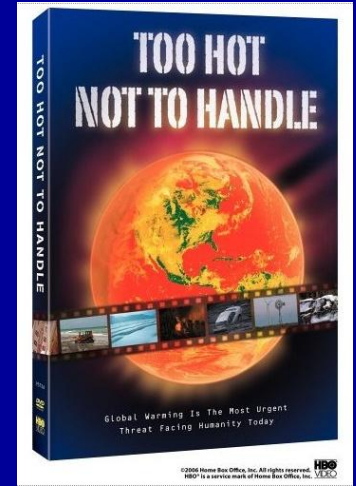


The next segment of

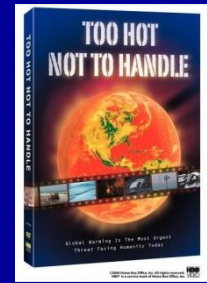


Last segment . . .

- **HEAT WAVES**
(odds change to favor them)
- **INCREASES IN EXTREMES:**
 - **HEAVY RAINS**
→ FLOODING → sanitation problems
→ PUBLIC HEALTH ISSUES--
 - **INCREASING DROUGHT**
 - **SEASONAL CHANGES**



Today's segment . . .



- **DECREASES IN SNOWPACK**
- **WATER STORAGE / INFRASTRUCTURE & WATER SUPPLY PROBLEMS**
- **AGRICULTURE / FRUIT CROPS**
- **FOREST FIRES** (heat + drought + dead trees)
- **SPECIES MIGRATION / EXTINCTIONS**
- **TROPICAL DISEASES** (e.g., West Nile)
- **WEEDS / POLLEN / HEALTH ISSUES**

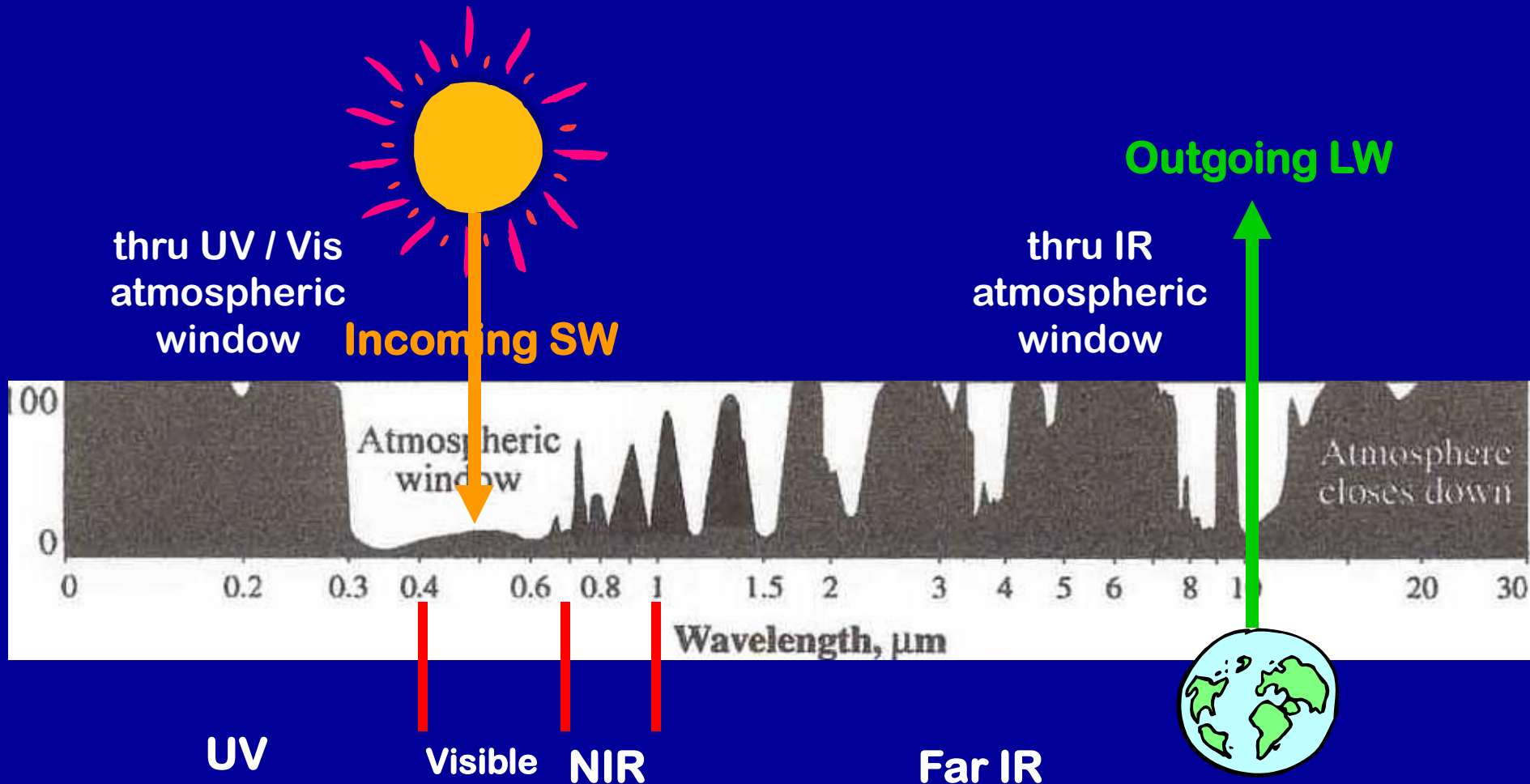
Back to . . . THE EARTH'S GLOBAL ENERGY BALANCE . . .

The COMPLETE EQUATION!

$$R_{\text{NET}} = \begin{array}{c} \text{SW} \\ \downarrow \end{array} + \begin{array}{c} \text{SW} \\ \vdots \\ \downarrow \end{array} - \begin{array}{c} \text{SW} \\ \nearrow \end{array} - \begin{array}{c} \uparrow \\ \text{LW} \end{array} + \begin{array}{c} \text{LW} \\ \downarrow \end{array} = H + LE + G$$

OVERALL
BALANCE:

Incoming = Outgoing



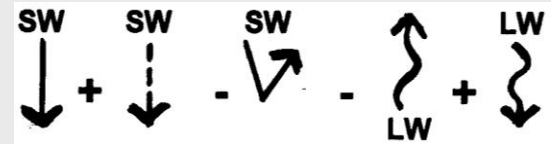
The diagram illustrates the components of net radiation. It shows five arrows representing different radiation fluxes: a solid arrow pointing down labeled 'SW', a dashed arrow pointing down labeled 'SW', a solid arrow pointing up and to the right labeled 'SW', a wavy arrow pointing up labeled 'LW', and a wavy arrow pointing down labeled 'LW'. These are arranged in a sequence: SW down, +, SW down (dashed), -, SW up (diagonal), -, LW up (wavy), +, LW down (wavy). To the right of this sequence is the equation $= R_{NET}$.

R_{NET} = “NET RADIATION”

$$\text{In} - \text{Out} = R_{NET}$$

Review of: THERMODYNAMICS & HEAT TRANSFER

Radiation:

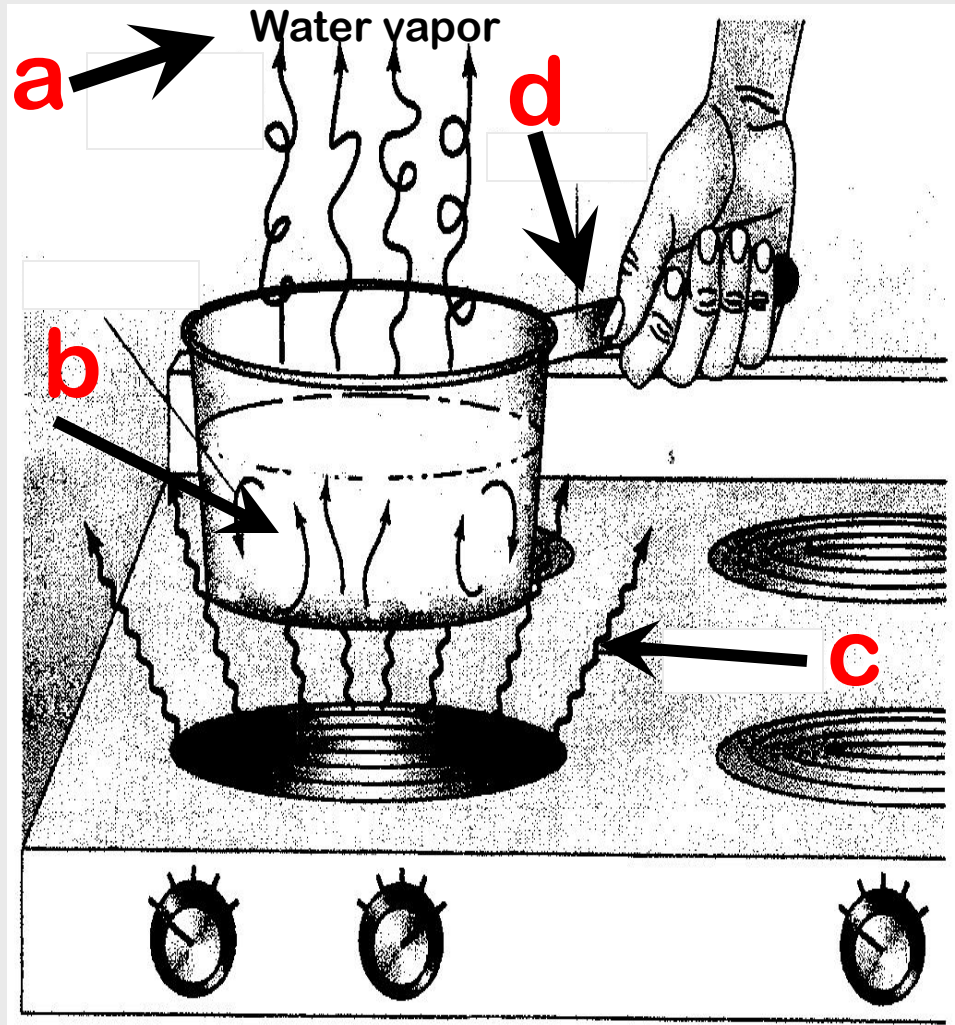


Also:

Conduction

Convection

ENERGY TRANSFER PROCESSES, including a PHASE CHANGE!



Which
involve **LE** &
which involve **H**?

Fill in the blanks:

a. Latent heat **LE**

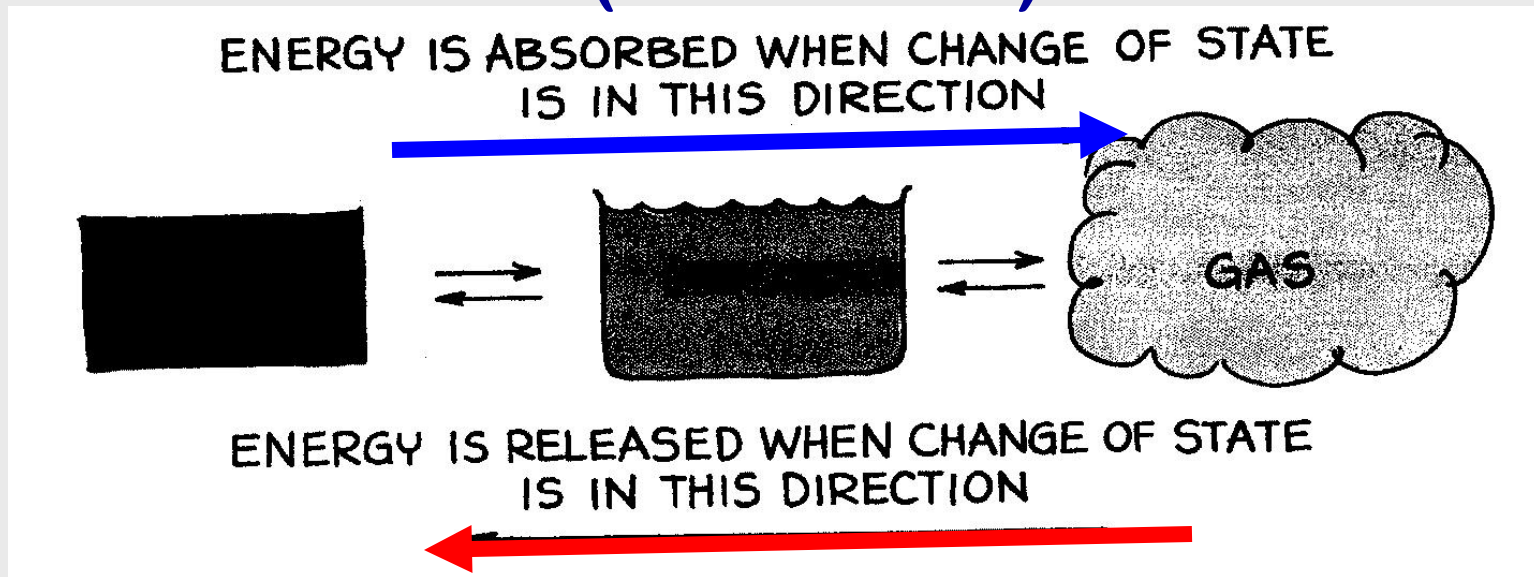
d. Conduction **H**

b. Convection **H**

c. Radiation **No
H or LE**

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

NET RADIATION = In – Out =

Whatever
is left
over

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

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).

The RIGHT side of the
ENERGY BALANCE
EQUATION . . .

Left side of equation

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

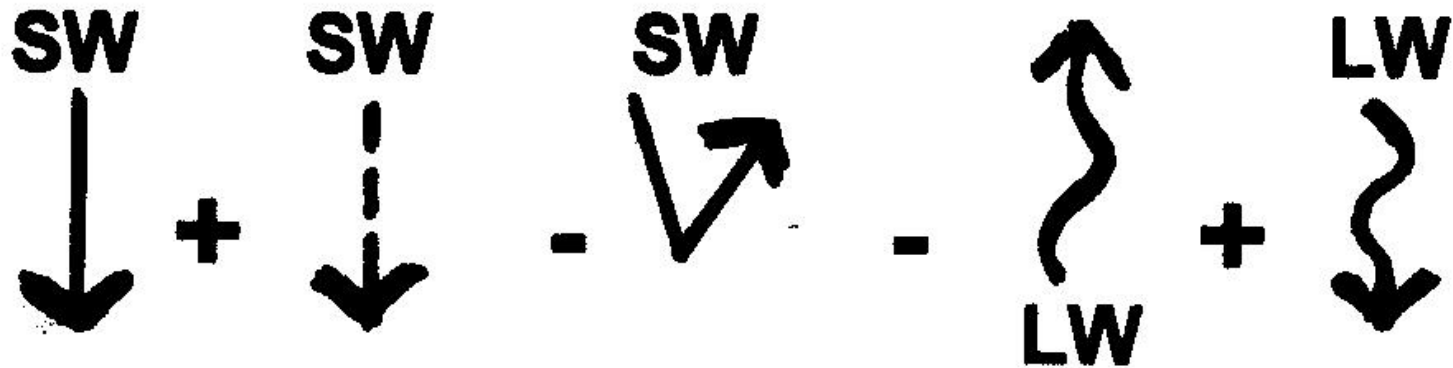
$$= H + LE + G$$

Right side of equation

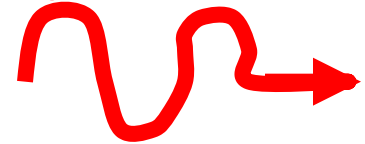
R net = "net" left over energy can be used to **DRIVE WEATHER & CLIMATE** through **HEAT TRANSFER** processes or it can **STORED** by the Earth (in the ground or ocean).

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

Link to the Left Side of Equation:



Radiation = the transfer of energy 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.)

Link to the Right Side of Equation:

H + LE + G

WHAT IS G???

G = GROUND STORAGE

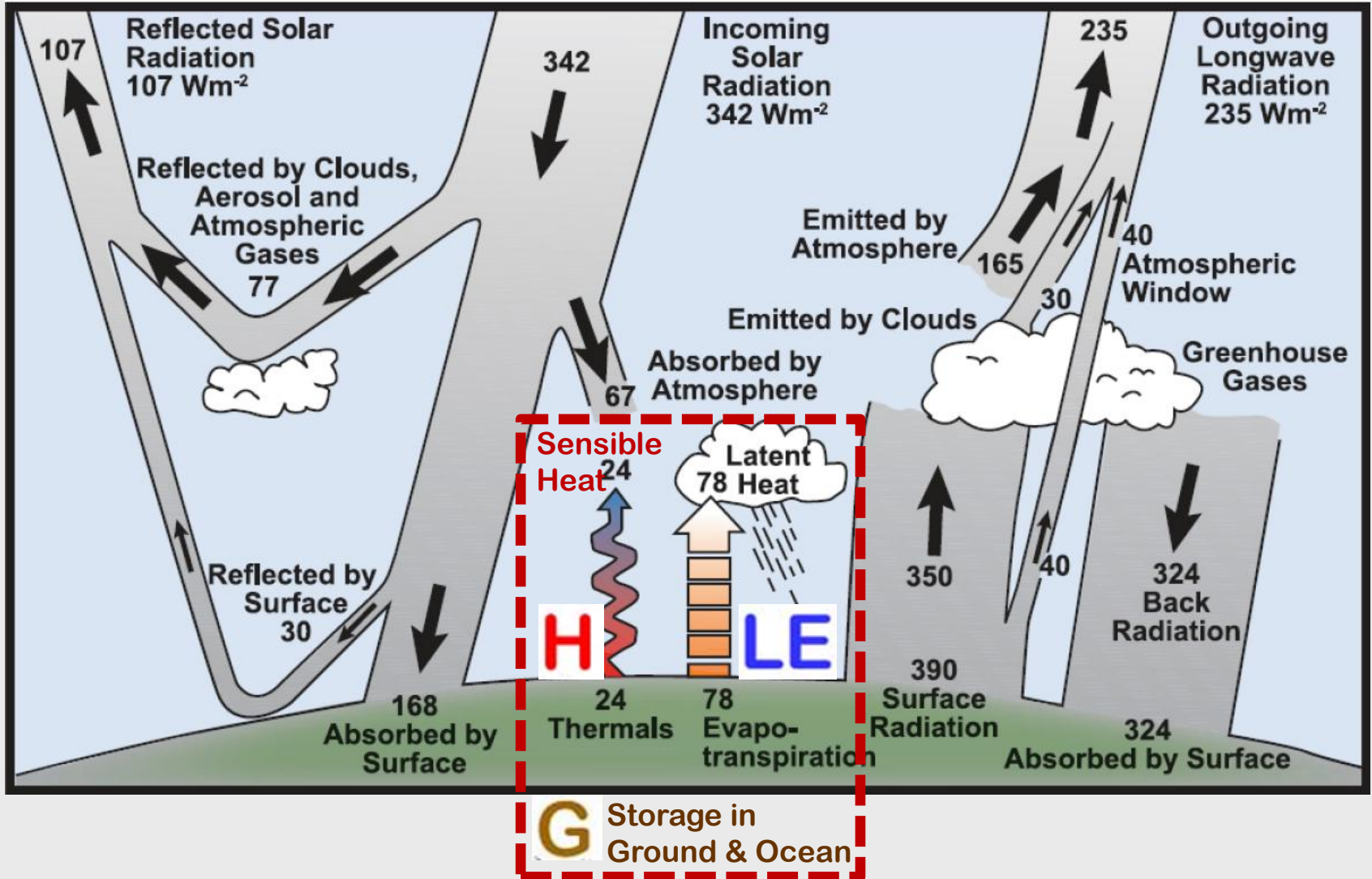
**ENERGY CONDUCTED into soil or
CONVECTED & CONDUCTED into
water (e.g. ocean) and temporarily
STORED THERE**

**Tends to “zero out” over an annual cycle
or several years**

ENERGY PATHWAYS

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.



See you on Wednesday!

Don't forget RQ-5!

Due 30 Minutes

before class!