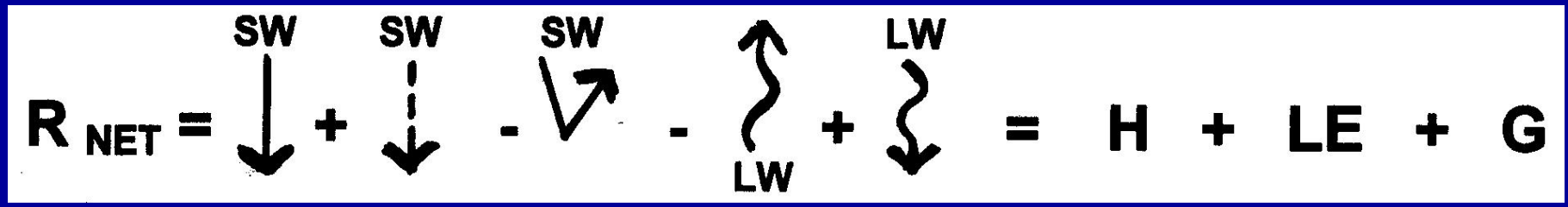
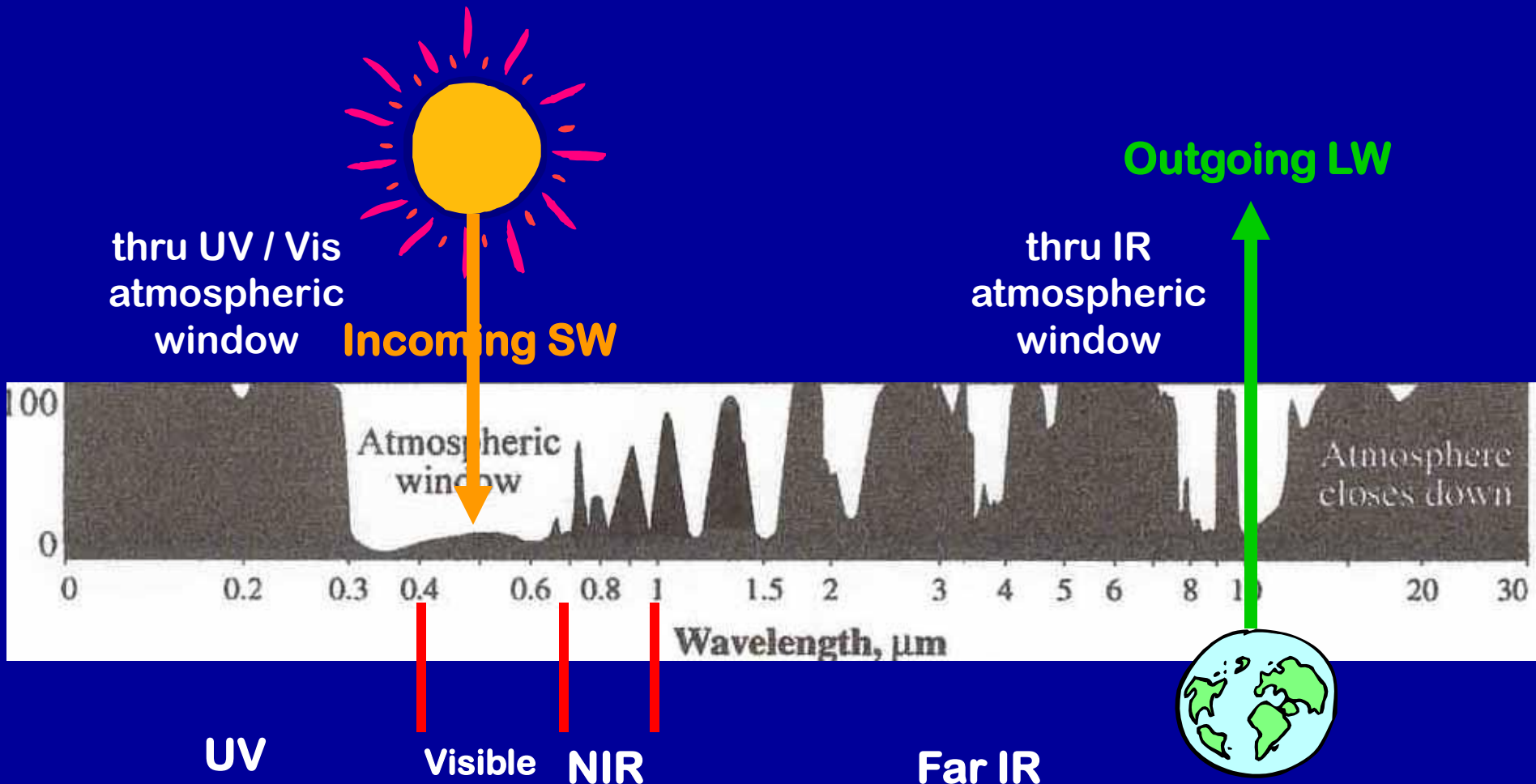
Topic # 10
THE EARTH'S GLOBAL ENERGY BALANCE
Part II

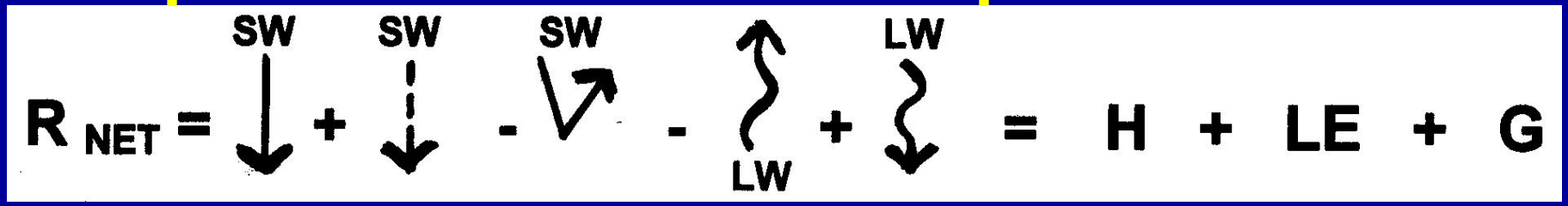


OVERALL BALANCE: Incoming = Outgoing



Review

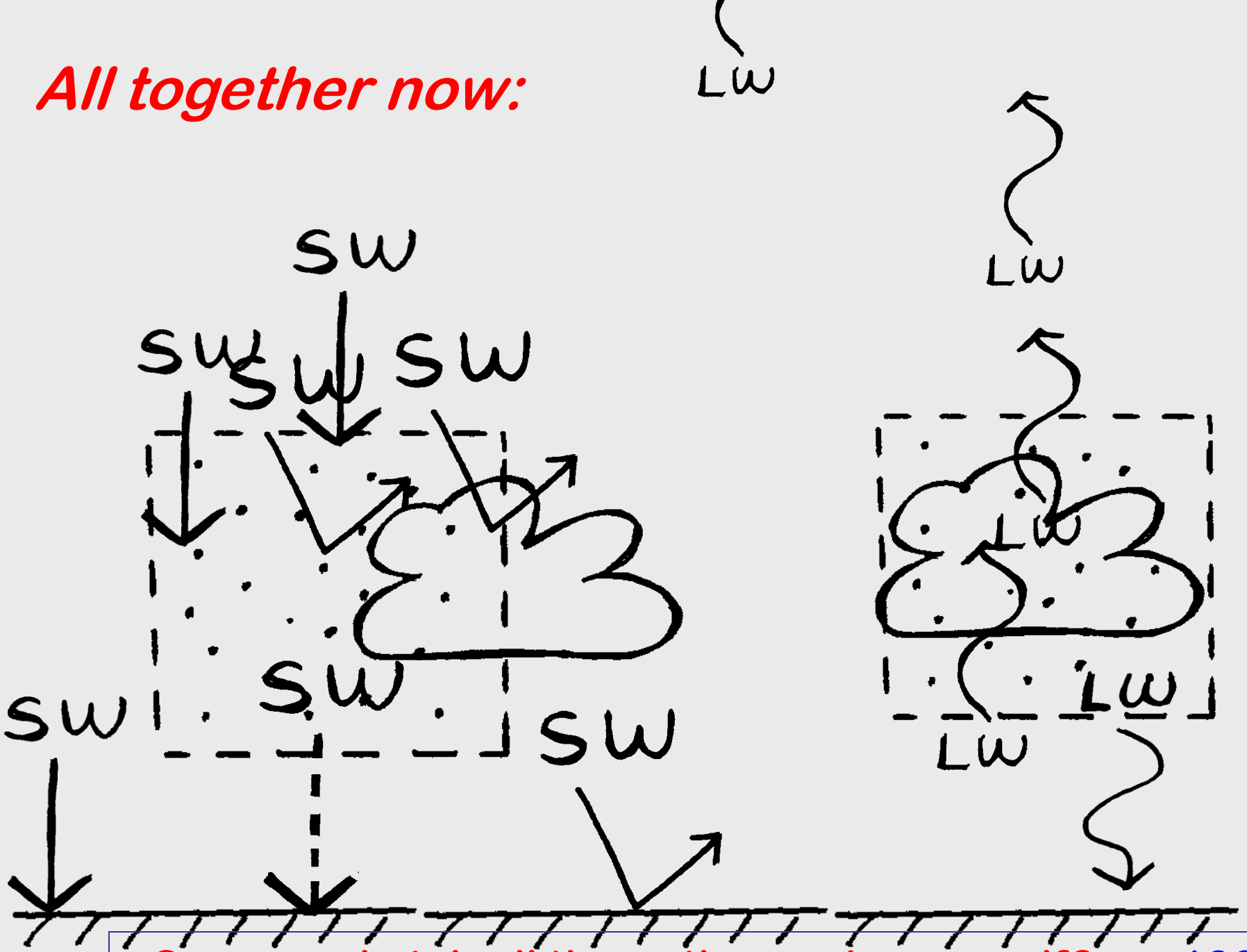
Tuesday's class:



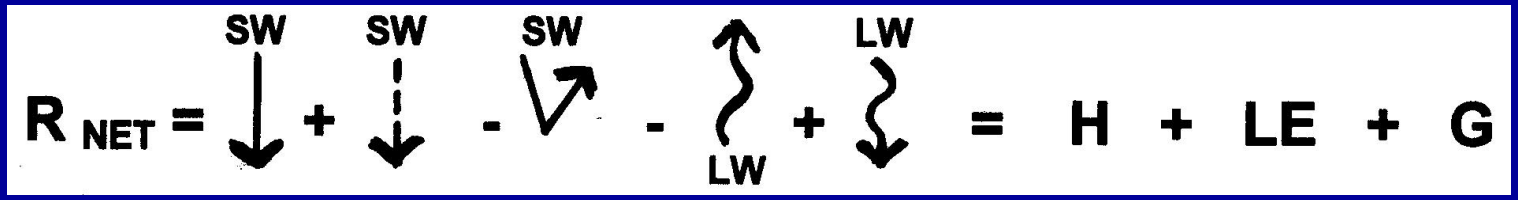
R_{NET} : NET RADIATION

In – Out ≡ R_{NET}

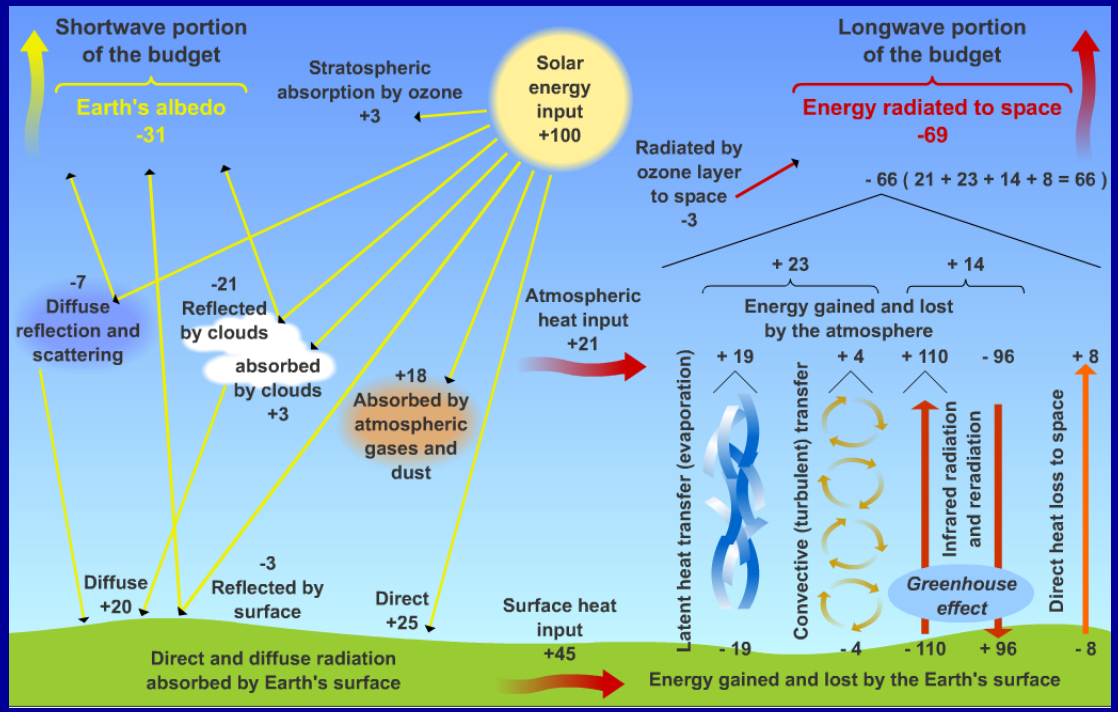
All together now:



Can you sketch all the pathways in yourself? p 130



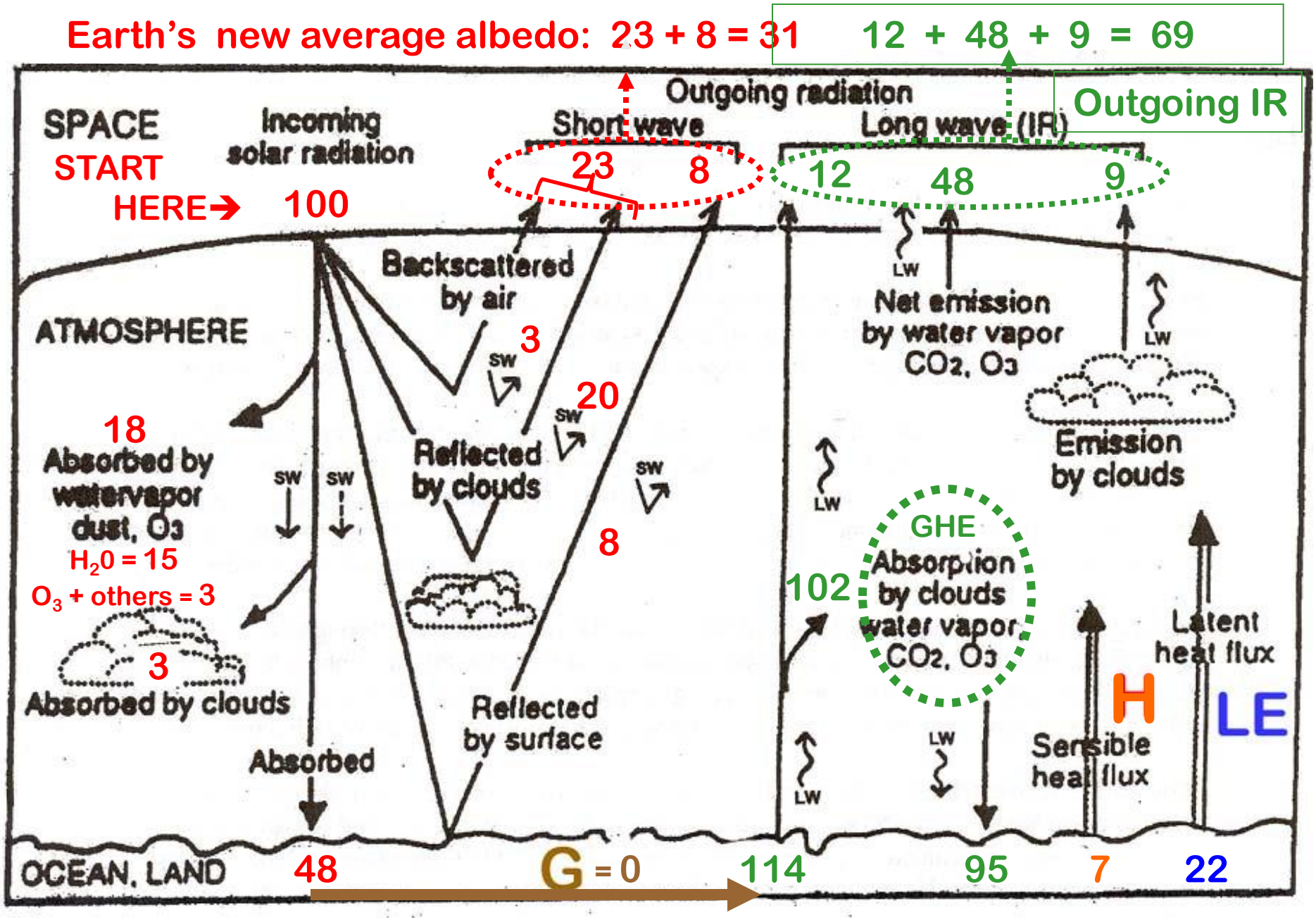
ENCORE:



ENERGY BALANCE ANIMATION:

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

Because climate is changing, the “units” in the above animation have changed slightly and differ from some other figures



G + H + LE

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

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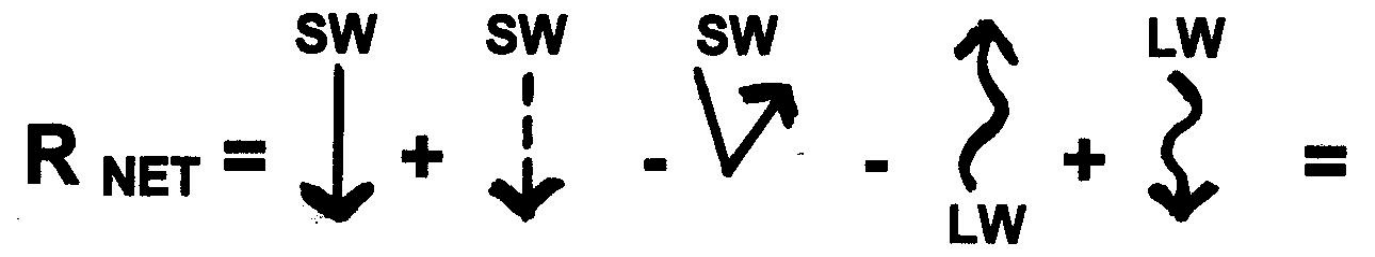
NET RADIATION = In – Out = Whatever is left over

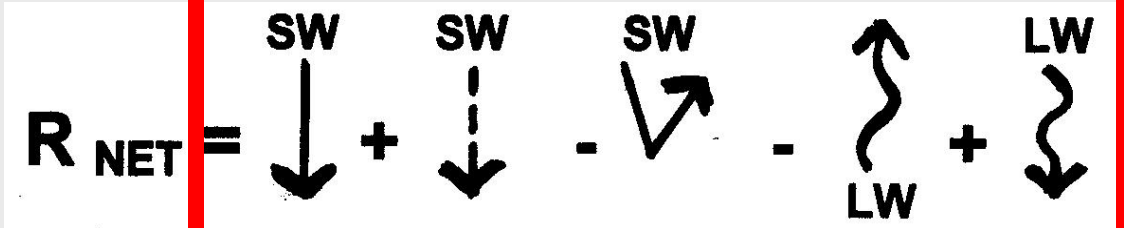


If some energy is "left over," it can be used to DRIVE WEATHER & CLIMATE through HEAT TRANSFER processes or it can STORED by the Earth (in the ground or ocean).

FINAL PART OF TOPIC # 10:

The RIGHT side of the ENERGY BALANCE EQUATION . . .

Left side of equation



= H + LE + G

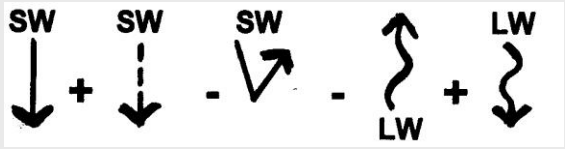
Right side of equation

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

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

p 57 top

Review of: THERMODYNAMICS & HEAT TRANSFER

Radiation: 

Also:

Conduction

Convection

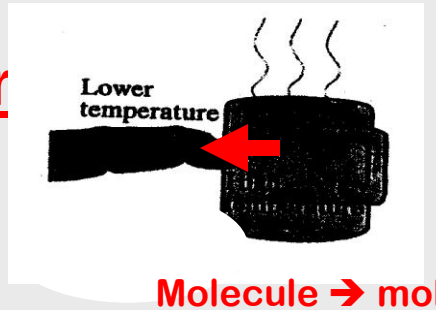
HEAT TRANSFER SUMMARY:

Conduction:

molecule–to-molecule transfer

Most effective in SOLIDS

(earth's surface; soil; the ground)



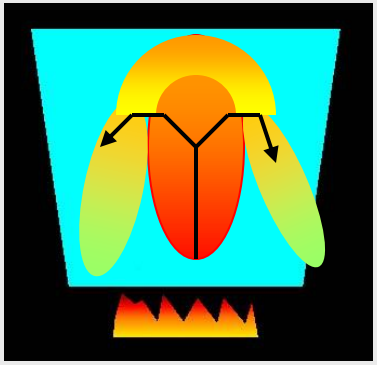
Molecule ➔ molecule vibrations

Convection:

transfer by large-scale movements

Most effective in GASES & LIQUIDS

(atmosphere & oceans)



Radiation:

transfer by ***electromagnetic radiation***

doesn't need MATTER to transfer energy!

(sun ➔ earth, earth ➔ atmosphere,

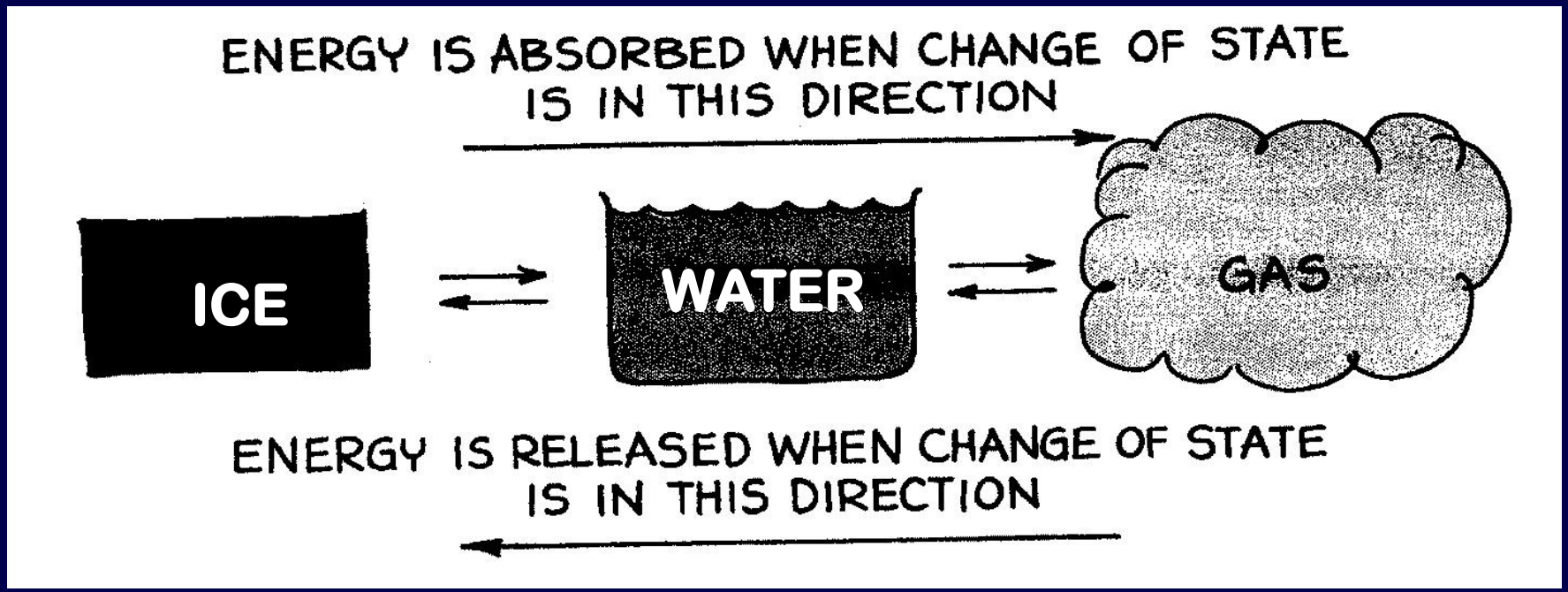
atmosphere ➔earth, earth ➔ space)

PLUS ENERGY TRANSFER DURING PHASE CHANGES: (topic we skipped earlier!)

THERMAL ENERGY & PHASE CHANGES IN H_2O

Energy stored as LATENT ENERGY

(energy is “hidden” & not sensed)



Energy released as SENSIBLE HEAT

(i.e. the warmth can be “sensed”)

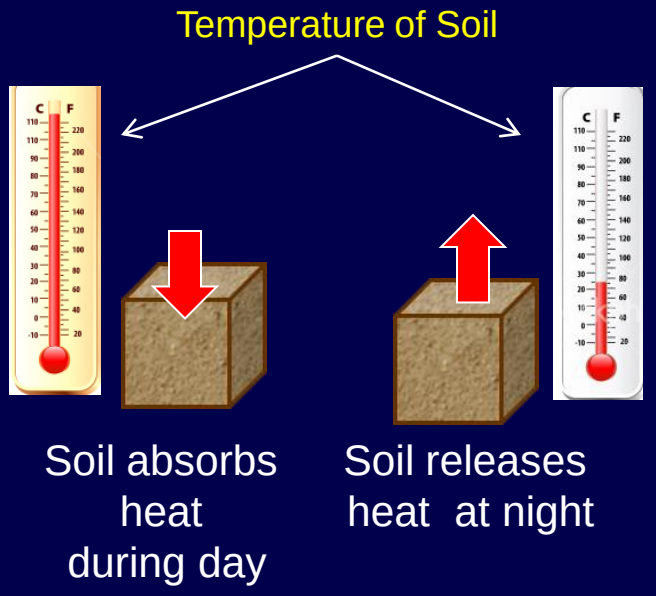
Go back to p 46

DEFINITIONS:

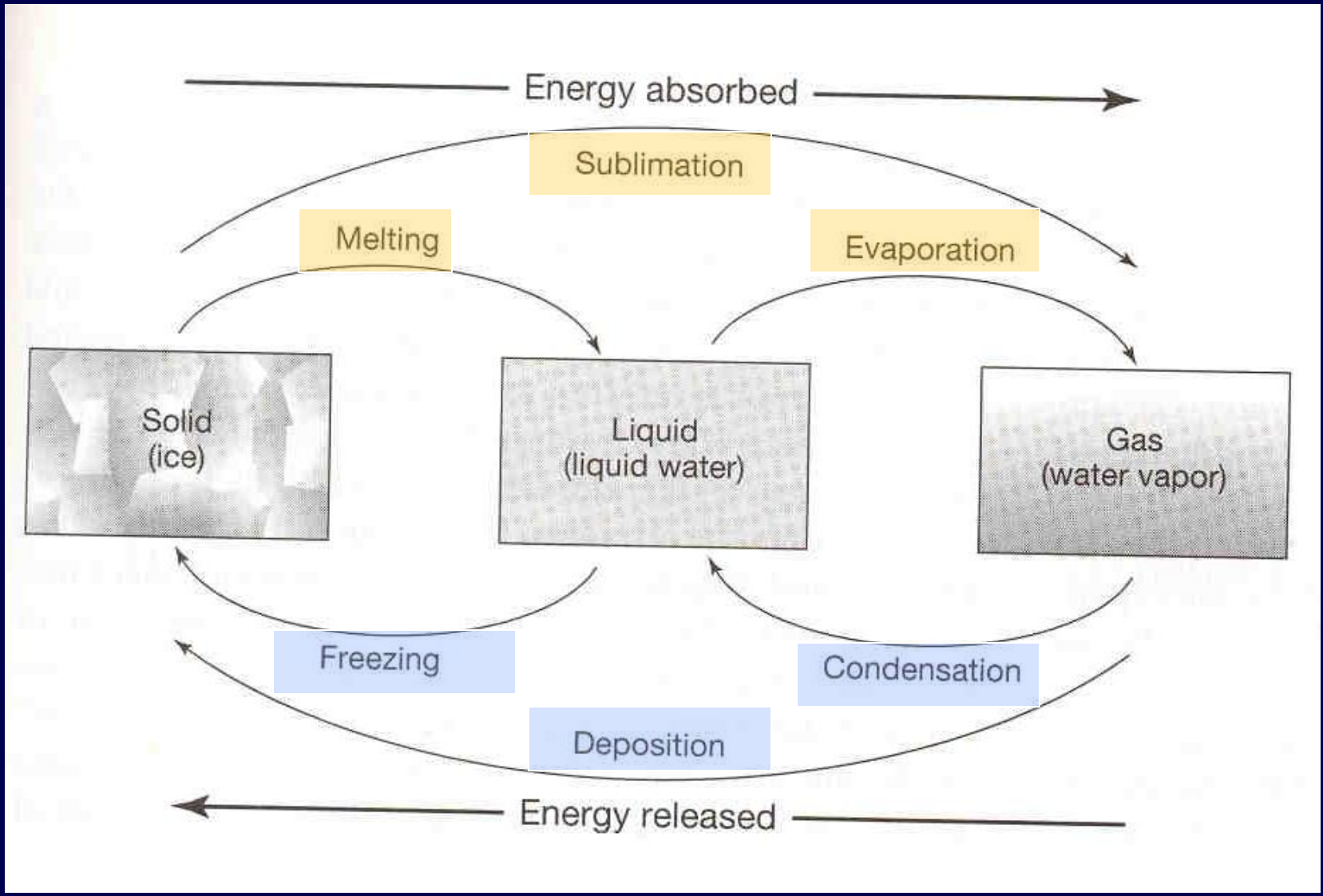
LATENT ENERGY (LE) & SENSIBLE HEAT (H)

LATENT ENERGY (LE) = the amount of energy released or absorbed by a substance during a **change of phase**, such as when water evaporates.

SENSIBLE HEAT (H) = the amount of energy released or absorbed by a substance during a change of temperature (which is not accompanied by a change of state)



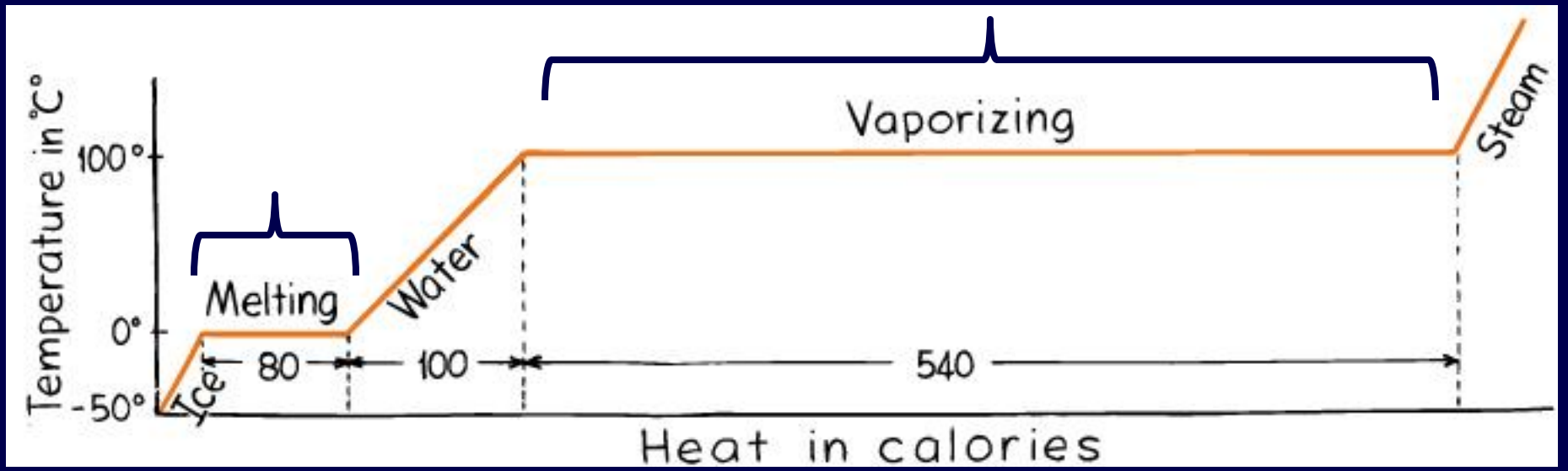
PHASE CHANGES (another view)



This is in your textbook: Fig 4-23 p 77 in SGC E-text

THOUGHT QUESTION:

In this graph, what's happening to the energy in the portions where the graph is <u>horizontal</u>?



HINT: it has to do with

SENSIBLE HEAT (H)

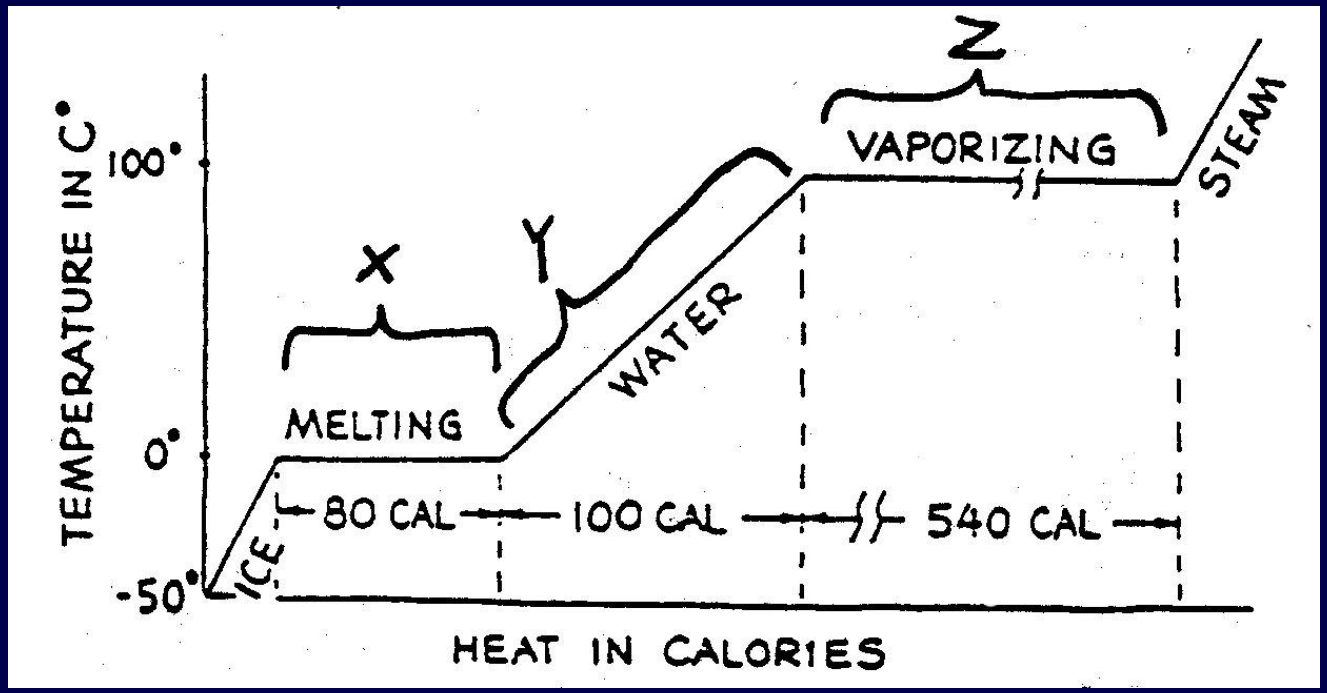
&

LATENT HEAT (LATENT ENERGY) LE

REVIEW / BACKGROUND:

SENSIBLE = the energy can be SENSED (e.g., with a thermometer, by the environment, etc.)

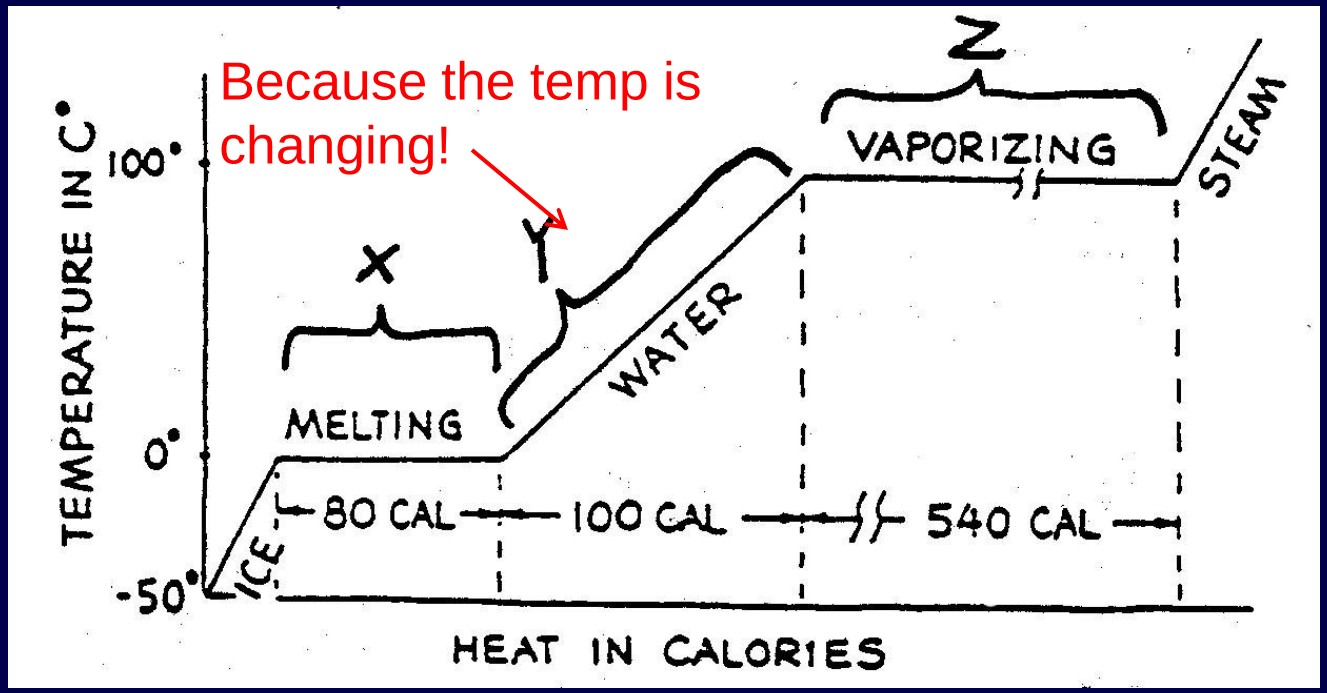
LATENT (means “HIDDEN”) = the energy is there, but it is NOT SENSED by the environment, a thermometer . . . or YOU!



Q1 -- Which segment or segments of the graph represent(s) **SENSIBLE HEAT (H)** ?

1 = X & Z **3 = Y only**

2 = X only **4 = Z only**



Q1 -- Which segment or segments of the graph represent(s) **SENSIBLE HEAT (H)** ?

1 = X & Z

3 = Y only

2 = X only

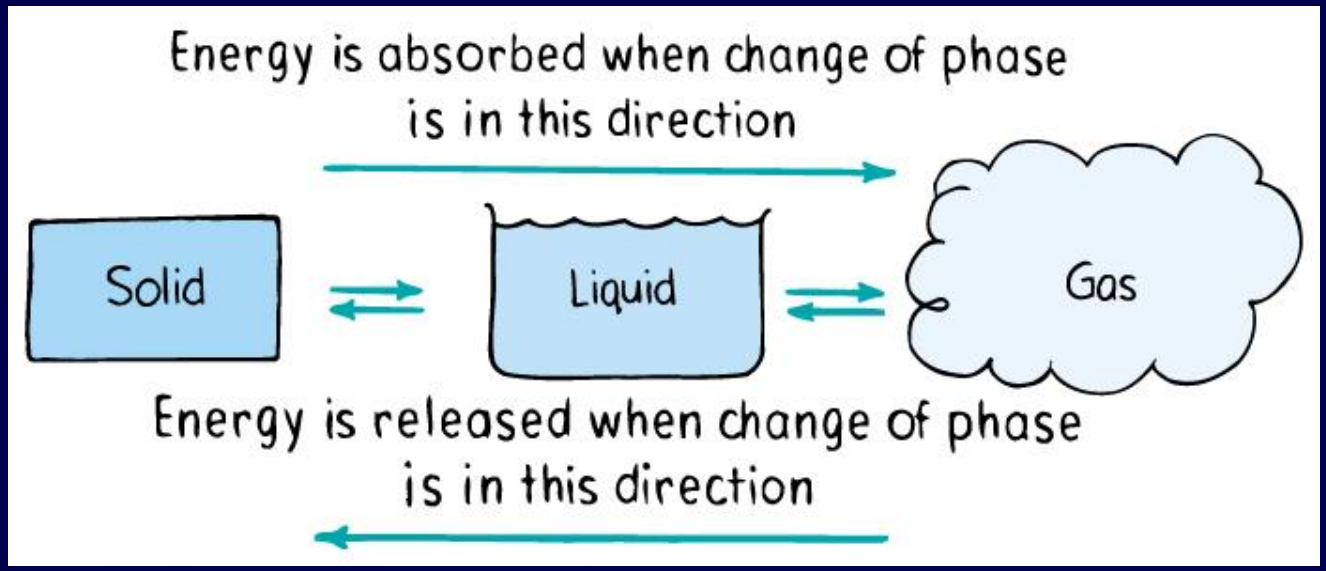
4 = Z only

Q2 - In a phase change from ice to water or water to water vapor, <u>WHAT</u> is absorbing the energy?

1 = the surrounding environment

2 = the H_2O molecules

3 = both the environment & the H_2O



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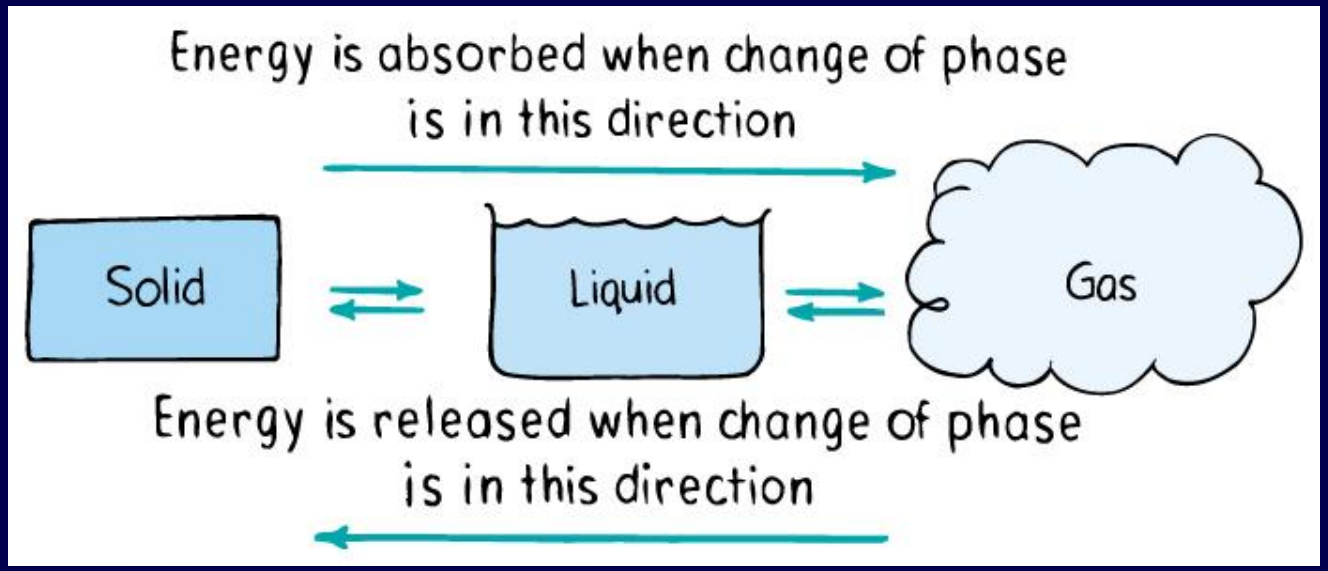
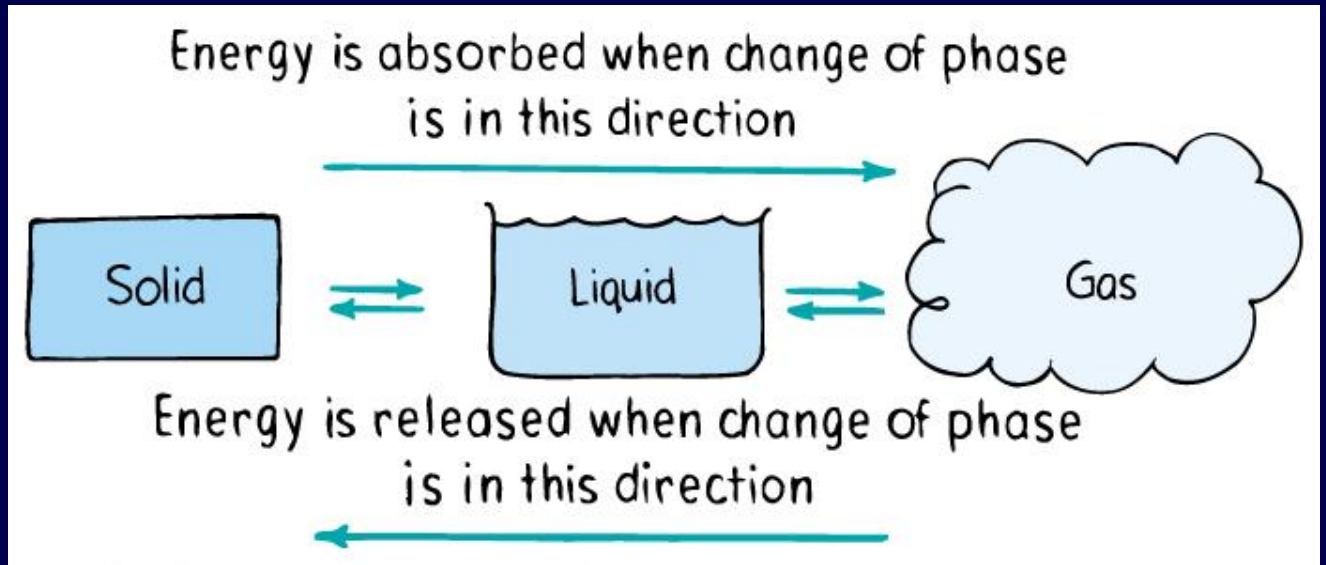


Q3 - In a phase change from water vapor to liquid water or liquid water to ice, TO WHERE is the energy being released?

1 = into the surrounding environment

2 = into the H_2O molecules

3 = into both the environment & the H_2O



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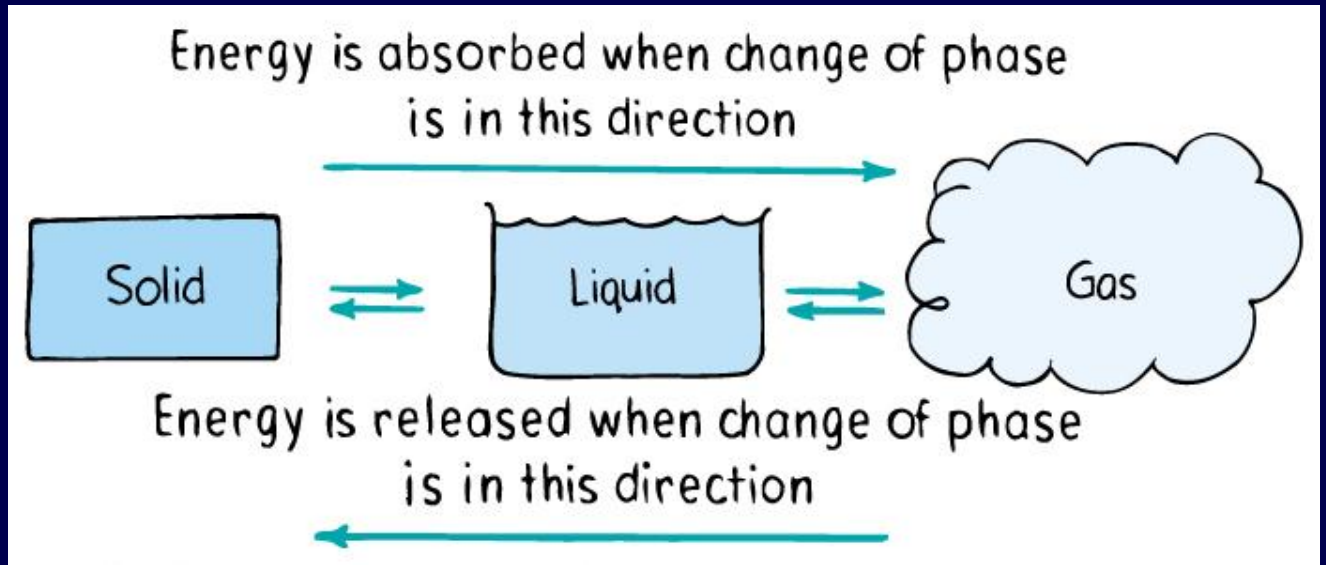
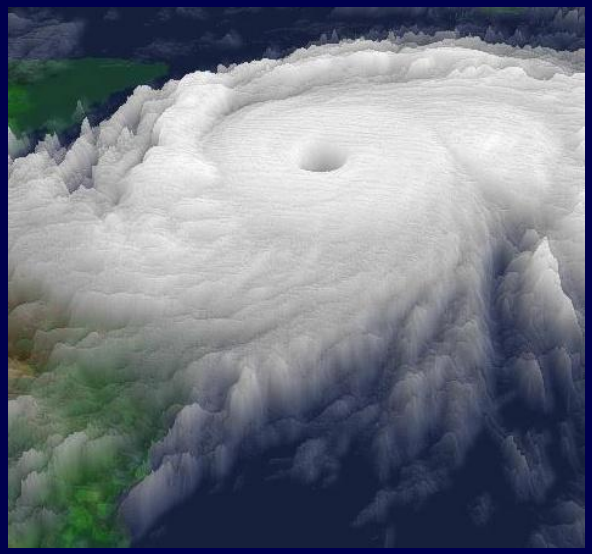
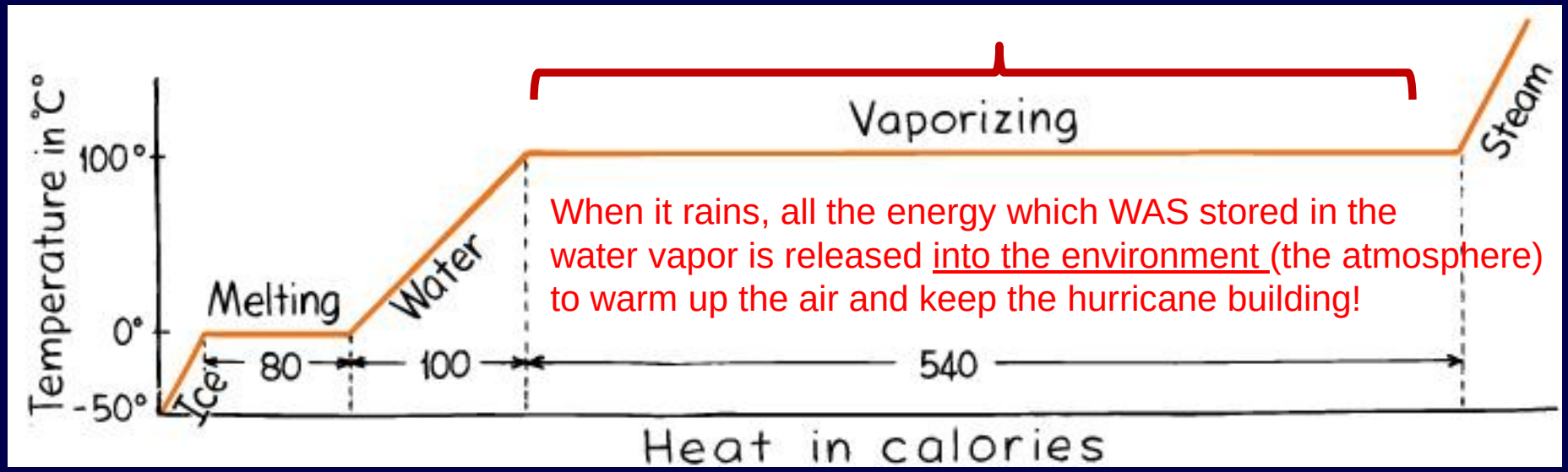


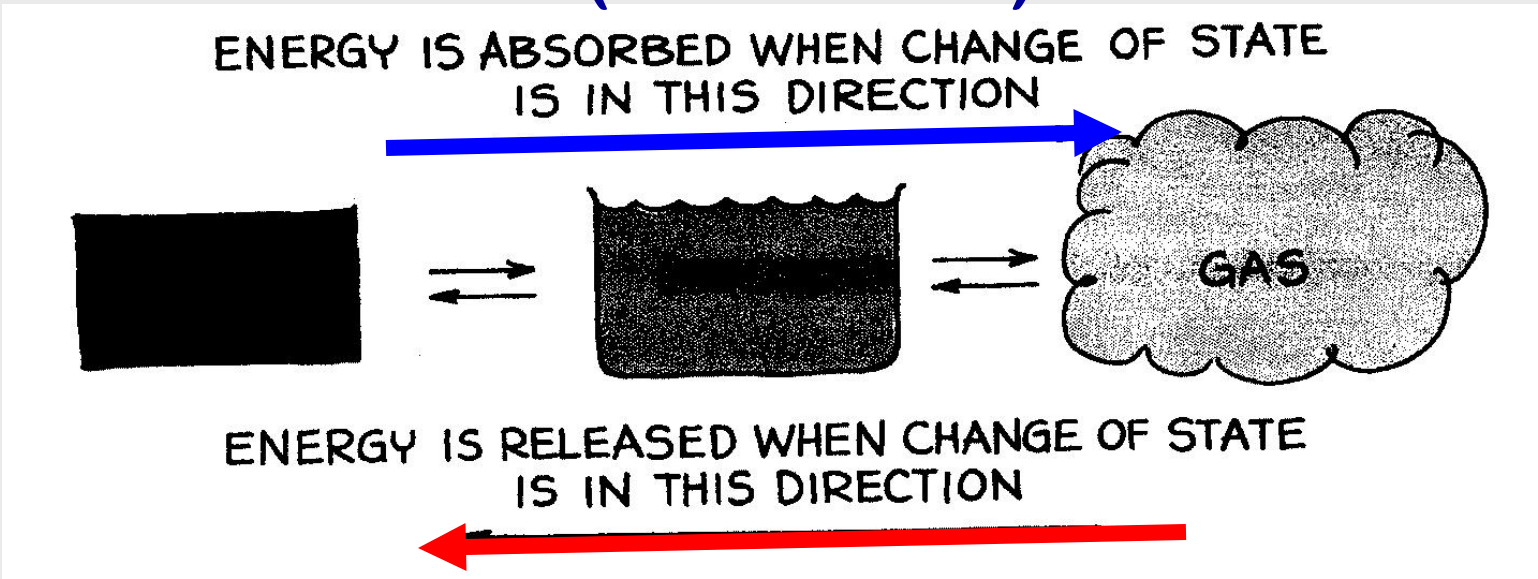
This is what drives tropical storms & HURRICANES!!





HEAT TRANSFER & STORAGE DURING PHASE CHANGES: LE & H

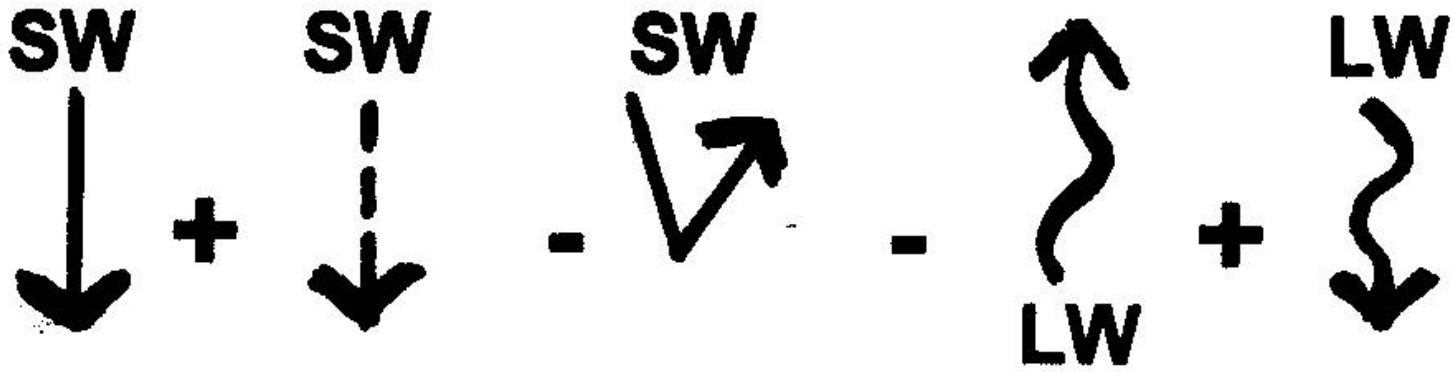
LE = LATENT (hidden) ENERGY (LE stored)



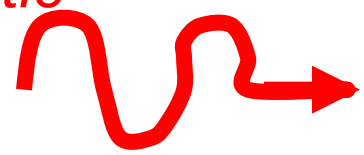
(LE released, hence it can be sensed as H)

H = SENSED (via thermometer) ENERGY

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:

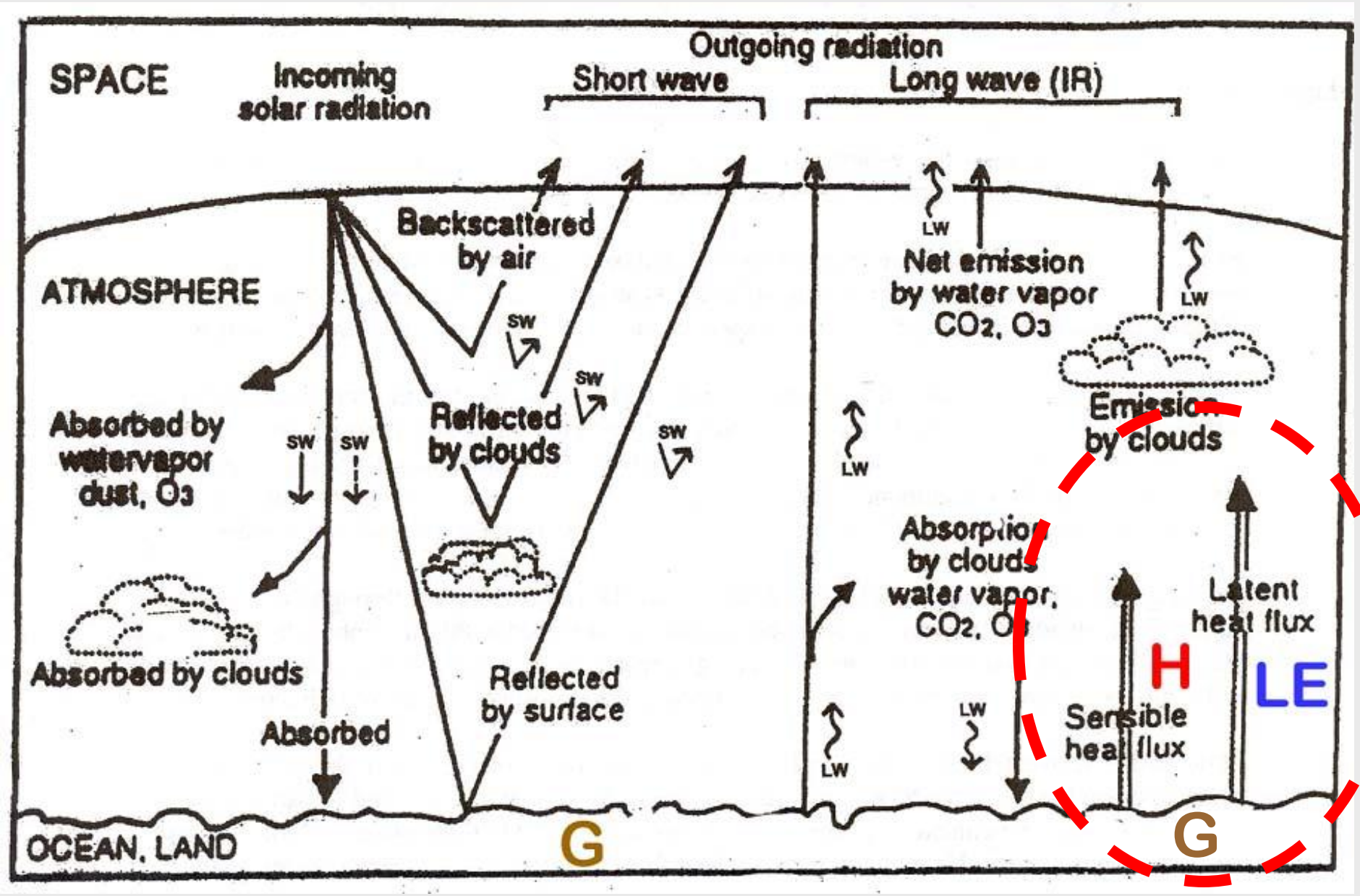
$$H + LE + G$$

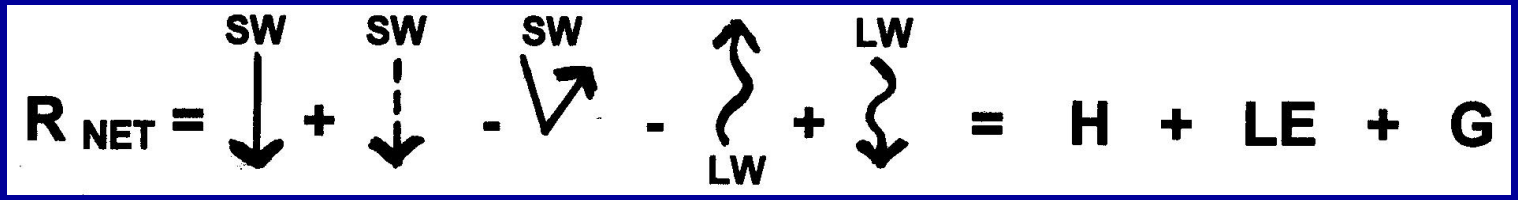
WHAT IS G???

G = GROUND STORAGE

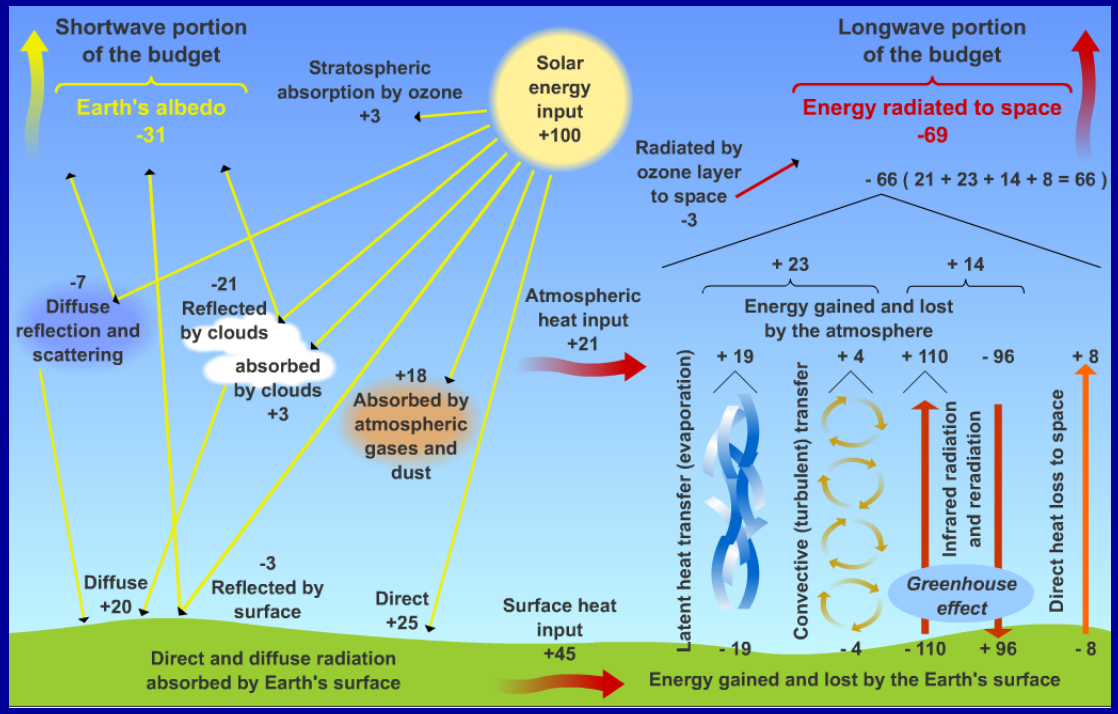
ENERGY CONDUCTED into soil or CONVECTED & CONDUCTED into water (e.g. ocean) and temporarily STORED THERE

Tends to "zero out" over an annual cycle or several years


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



ENCORE:

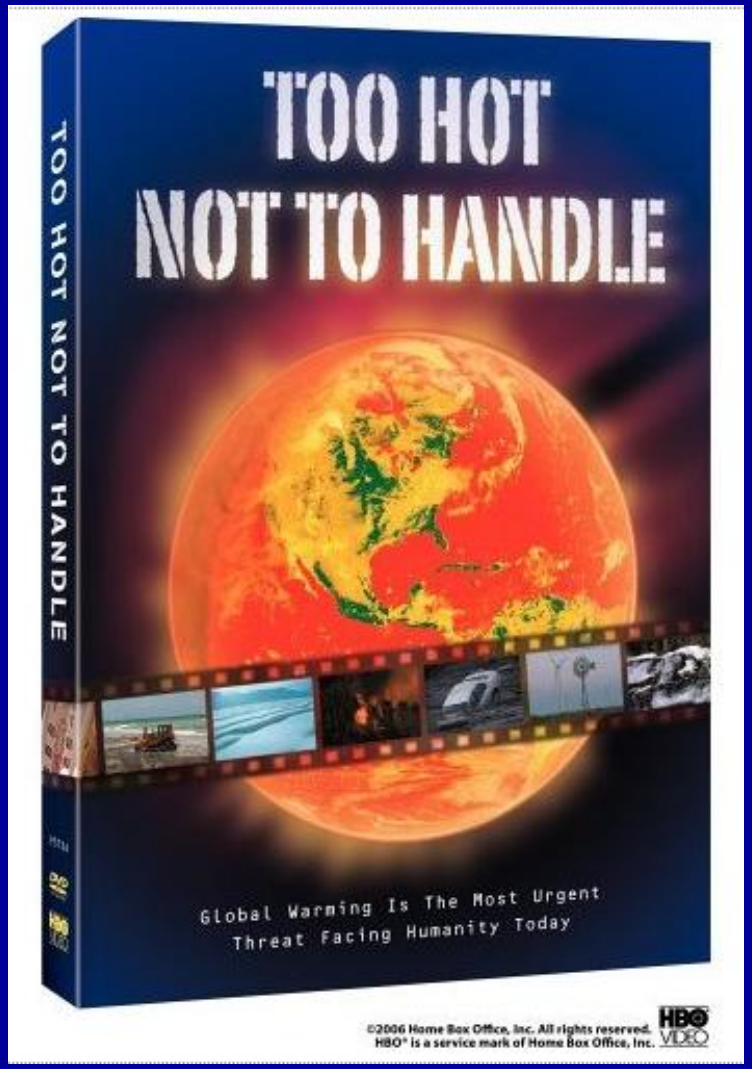


ENERGY BALANCE ANIMATION:

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

Because climate is changing, the “units” in the above animation have changed slightly and differ from some other figures

A new film for our "SUSTAINABILITY SEGMENT"



HBO Documentary FIlm (2006)

http://uanews.org/photos/solar-oven-throwdown-heats-ua-mall

Greenhouse gas emissions from power plants declined from 2011 to 2012, EPA says

By Lenny Bernstein, Published: October 23 E-mail the writer

Greenhouse gas emissions from power plants and other industrial facilities declined by 4.5 percent from 2011 to 2012 as utilities continued to switch from coal to natural gas to generate electricity and produced slightly less power overall, the Environmental Protection Agency reported Wednesday.

Greenhouse gas emissions from these sources have declined by 10 percent in the two years since the EPA began compiling the data in 2010.

http://www.washingtonpost.com/national/health-science/greenhouse-gas-emissions-from-power-plants-declined-from-2011-to-2012-epa-says/2013/10/23/4d8715a0-3c18-11e3-a94f-b58017bfee6c_story.html

TOPIC # 11

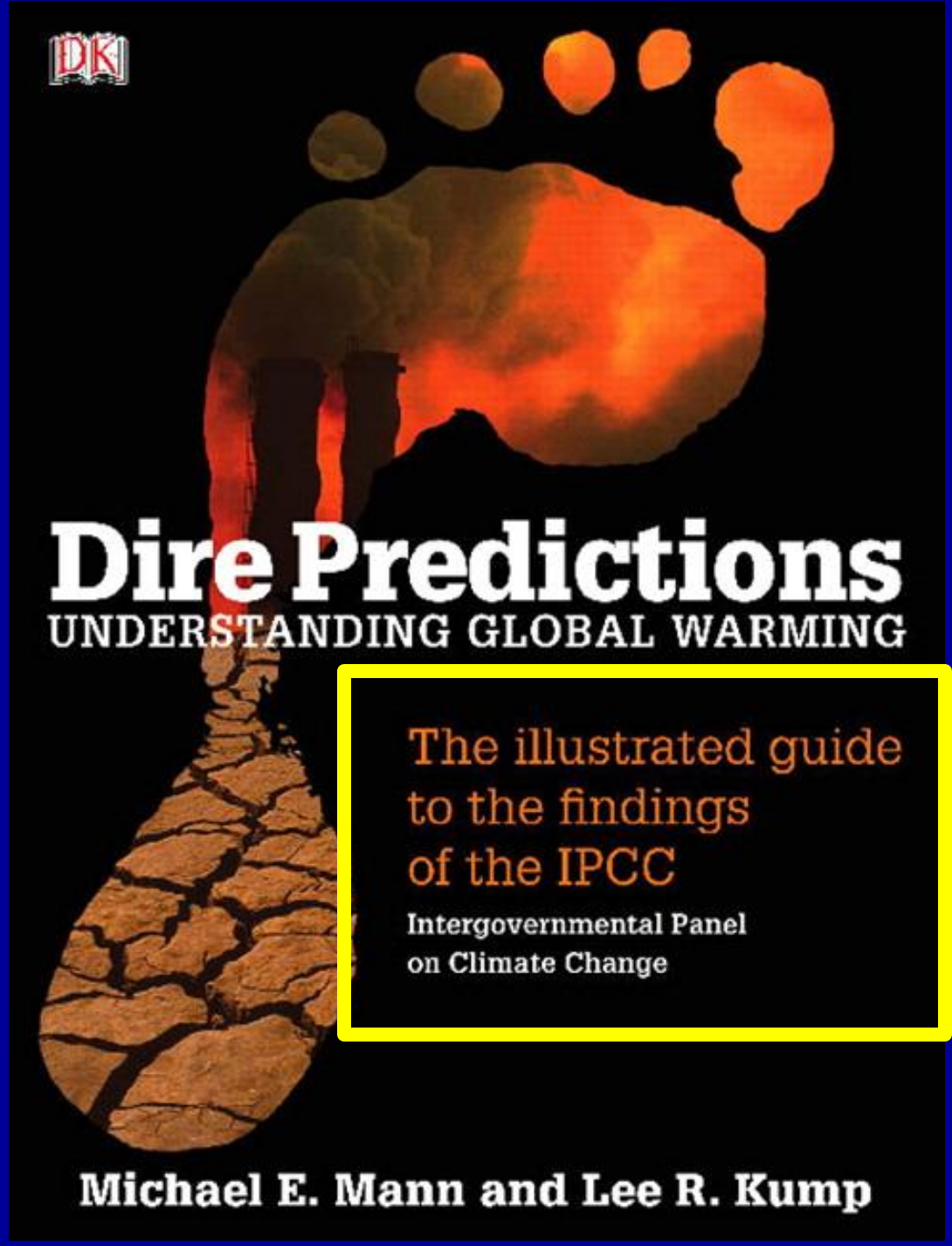
Introduction to Models:

UNDERSTANDING SYSTEMS & FEEDBACKS

Class notes pp 61 - 65

“When one tugs at a single thing in nature, one finds it attached to the rest of the world.”

~ John Muir



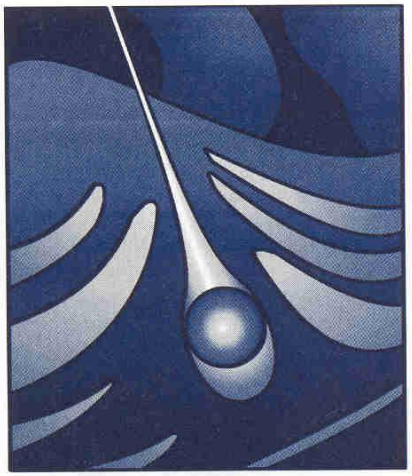
Our best projections of what **the FUTURE CLIMATE** will be like are based on **GIANT COMPUTER MODELS** – results are given in the **IPCC Report** and summarized in your **DIRE PREDICTIONS** text.

(More on these projections later)

THIS CHAPTER INTRODUCES YOU TO

"THNKING LIKE"
The IPCC COMPUTER MODELS WORK

CHAPTER 2



Daisyworld: An Introduction to Systems

WHAT IS A SYSTEM?

SYSTEM = a set of interacting components

COMPONENT *(def)* = An individual part of a system.

A component may be a reservoir of matter or energy, or some other aspect of the system, a "system attribute" or a subsystem:

e.g. the atmosphere, the energy in the atmosphere as measured by temperature, or the amount of CO_2 in the atmosphere, etc.

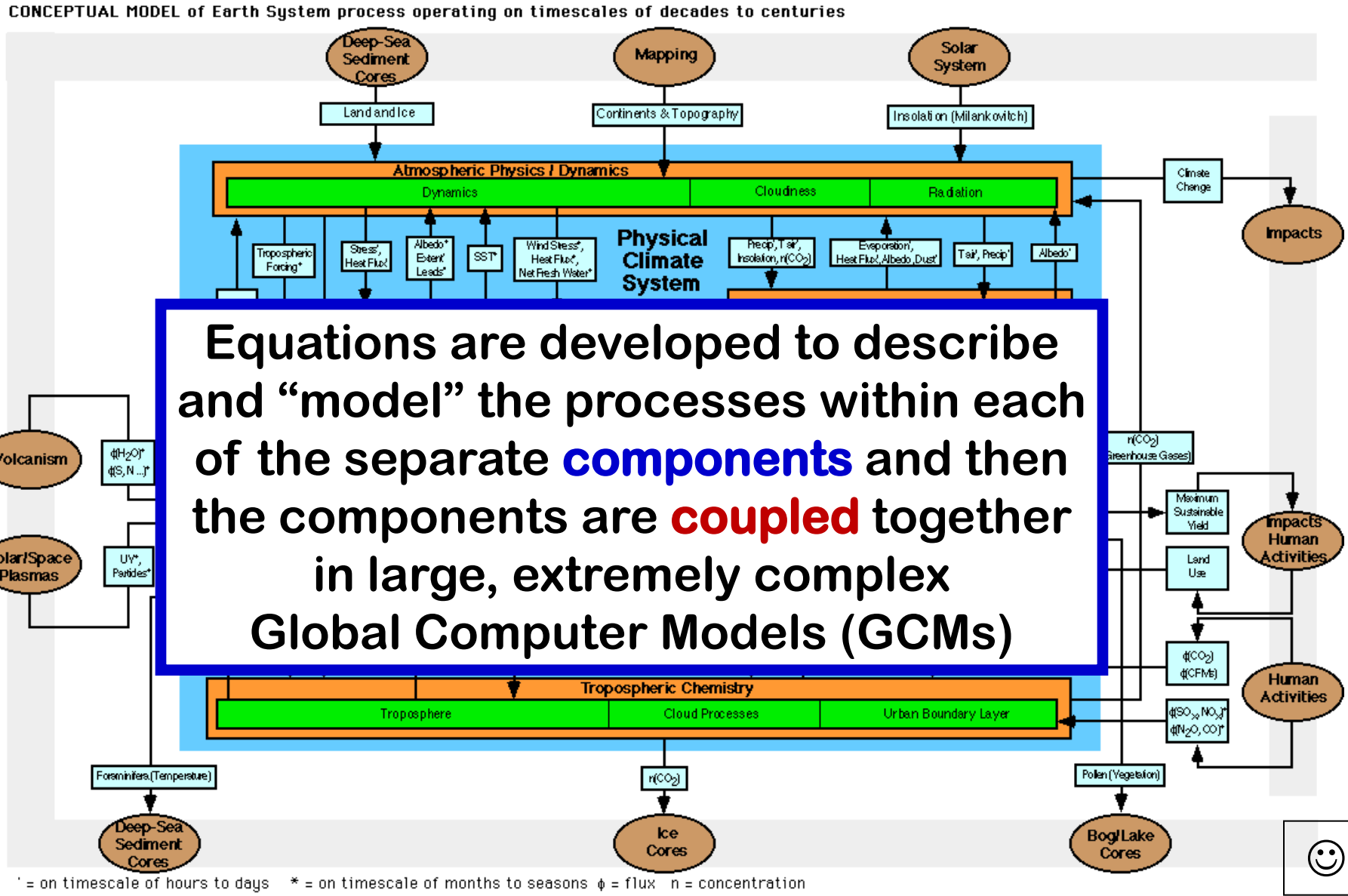
SYSTEM MODEL =

a set of assumptions, rules, data and inferences that define the interactions AMONG the components of a system and the significant interactions between the system and the "universe" outside the system

SYSTEM DIAGRAM =

A diagram of a system that uses graphic symbols or icons to represent components in a depiction of how the system works

A complicated "system diagram" of the Earth-Atmosphere System:



Coupling *(def):*

The links between any two components of a system.

Couplings can be positive (+) or negative (-)

A coupling between an electric blanket temperature component and a body temperature component:

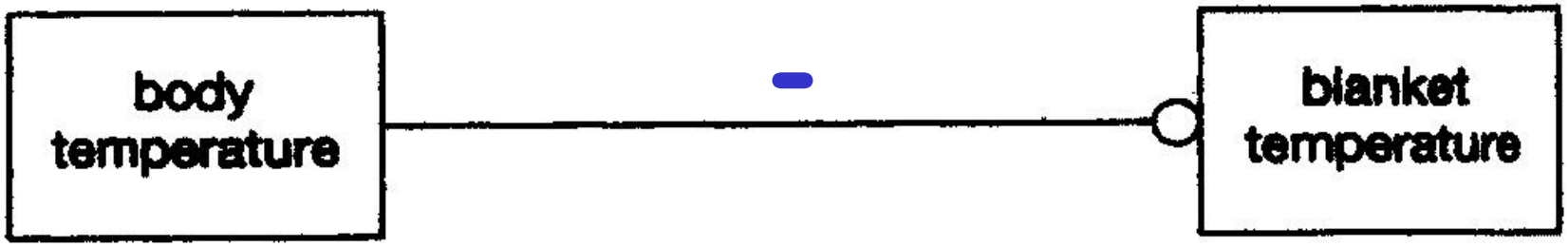
If the electric blanket's temperature INCREASES . . .

The person's body temperature will also INCREASE

What type of COUPLING IS THIS?

Positive + OR Negative - ???

A coupling between a person's body temperature and an electric blanket's temperature



If the person's body temperature INCREASES and he gets too hot . . .

The electric blanket's temperature control will be turned down and the blanket temperature will DECREASE

What type of COUPLING IS THIS?

Positive + OR Negative - ????

THE "RULE" – how to tell if it's a positive or negative coupling:

Positive couplings have a **solid "arrow"** with a normal arrowhead pointing in the direction of the coupling:

Negative couplings have an **"open circle"** arrowhead pointing in the direction of the coupling:

FEEDBACKS

Feedback mechanism *(def):*

a sequence of interactions in which the final interaction influences the original one.

Feedbacks occur in loops ➔

Feedback Loop *(def)* =

A linkage of two or more system components that forms a ROUND-TRIP flow of information.

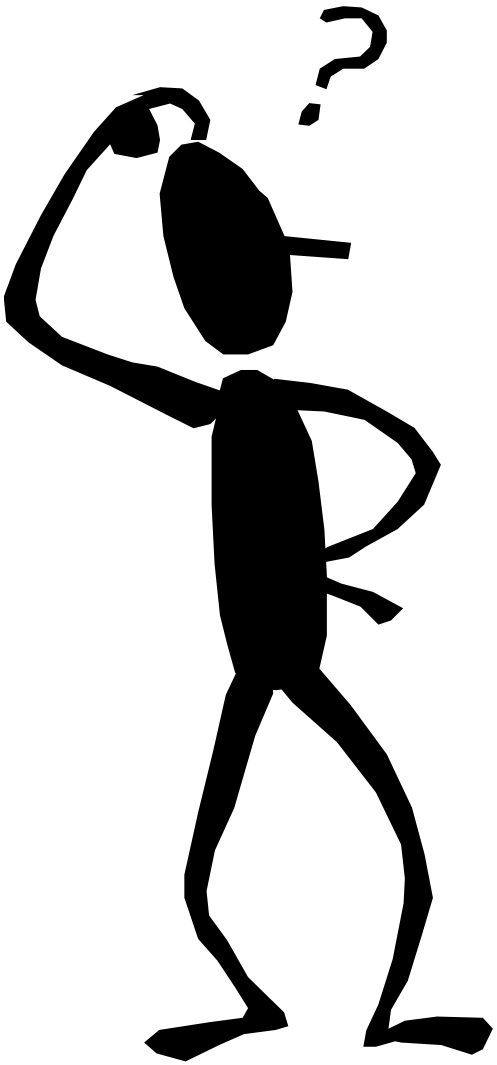
Feedback loops can be positive (+) or negative (-).

A ***positive feedback*** is an interaction that amplifies the response of the system in which it is incorporated

(self-enhancing; amplifying).

A ***negative feedback*** is an interaction that **reduces** or **dampens** the response of the system in which it is incorporated

(**self-regulating**; diminishes the effect of perturbations)



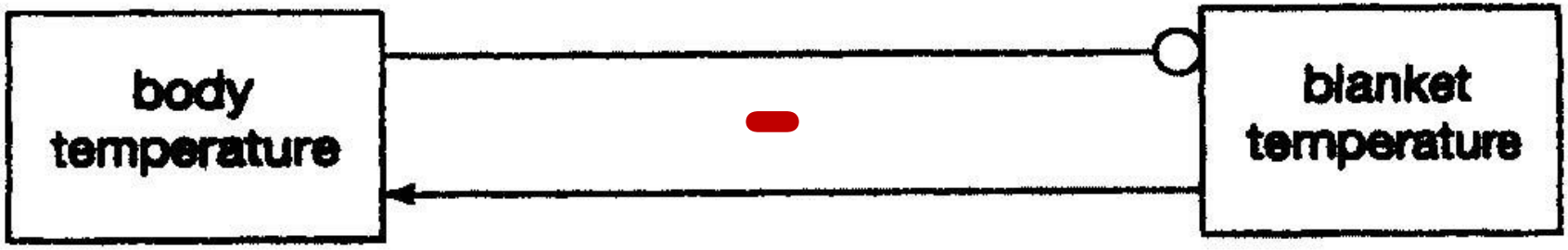
One way to remember the effect that a NEGATIVE feedback loop has is to think of the word "negligible"

i.e., a perturbation or disturbance in a system characterized by a negative feedback loop will be able to adjust to the perturbation and ultimately the effect on the system will be negligible

FEEDBACK LOOP

What kind of FEEDBACK LOOP IS IT?

1) Positive (+) 2) Negative (-) ???

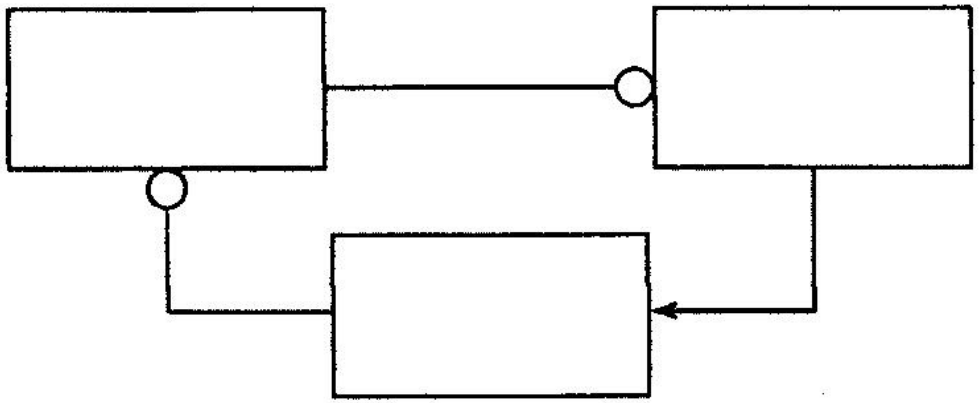


THE "RULE" – how to tell if it's a positive or negative feedback LOOP:

Count the # of number of NEGATIVE COUPLINGS:

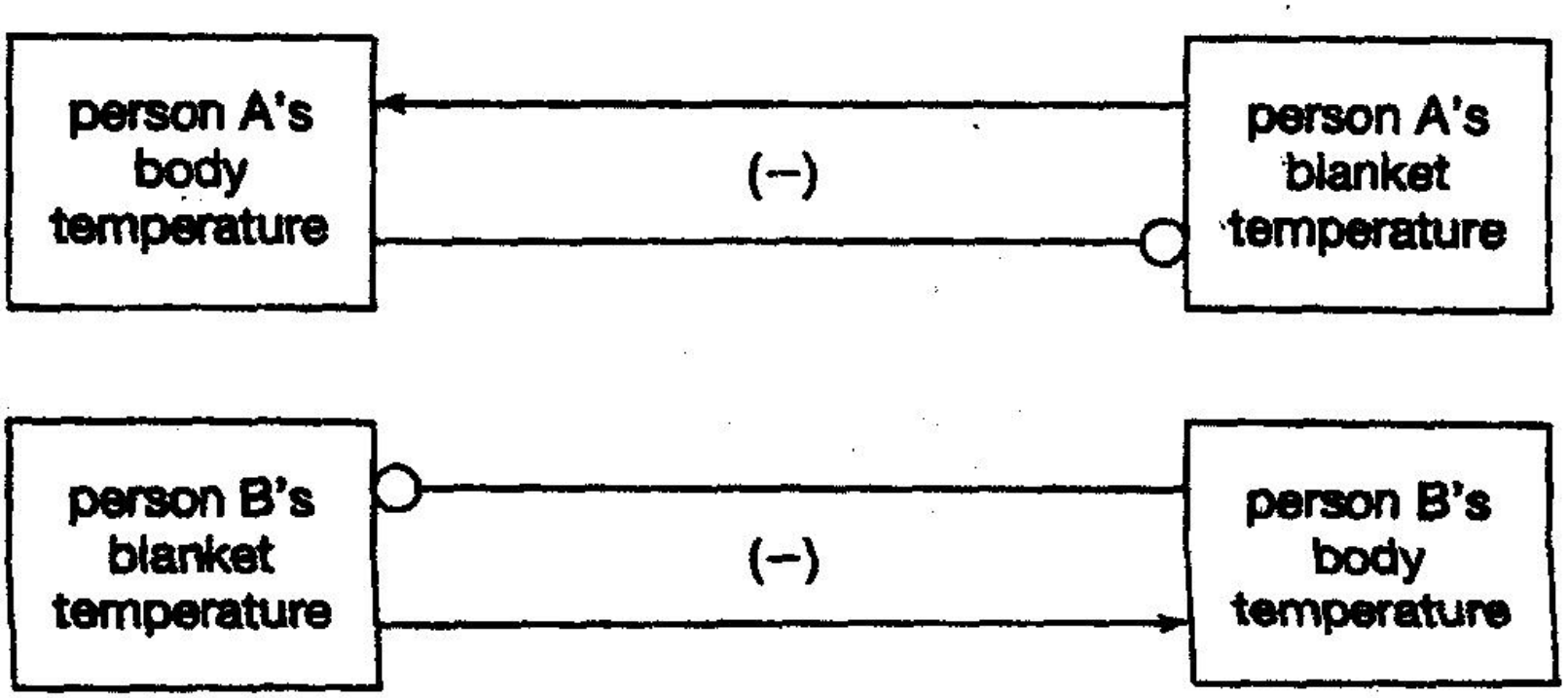
If there is an ODD # of negative Couplings, the loop is NEGATIVE:

If there is an EVEN # of negative couplings, the loop is POSITIVE



Everyday life example:

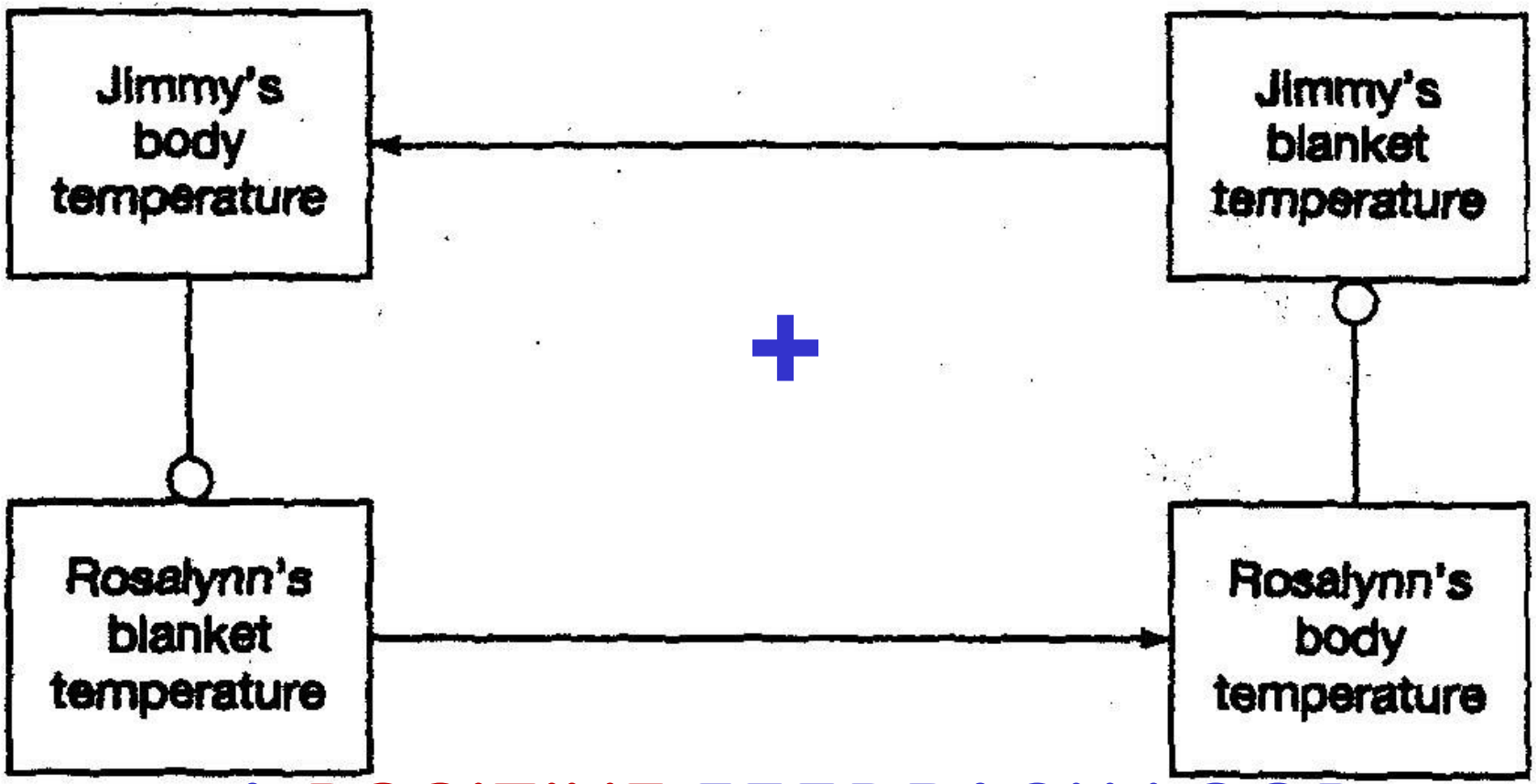
Proper alignment of dual control electric blanket:



Improper alignment:

What kind of FEEDBACK LOOP IS IT?

1) Positive + 2) Negative -



A POSITIVE FEEDBACK LOOP that amplifies the effect!

QUICK SUMMARY:

- **NEGATIVE** feedback loops:
  - are **resistant to a range** of disturbances
    (small changes have a "negligible" effect)
  - system can return to it's beginning state
  -- STABLE equilibrium state

+ **POSITIVE** feedback loops:

  - **amplify the effects of disturbances**
    (small changes can "amplify" the response)
  - system can become UNSTABLE and
    be taken to a new, amplified state

LINKING TO GLOBAL CHANGE:

In Global Change science we are concerned about disturbances that both humans and natural factors can produce in the Earth system:

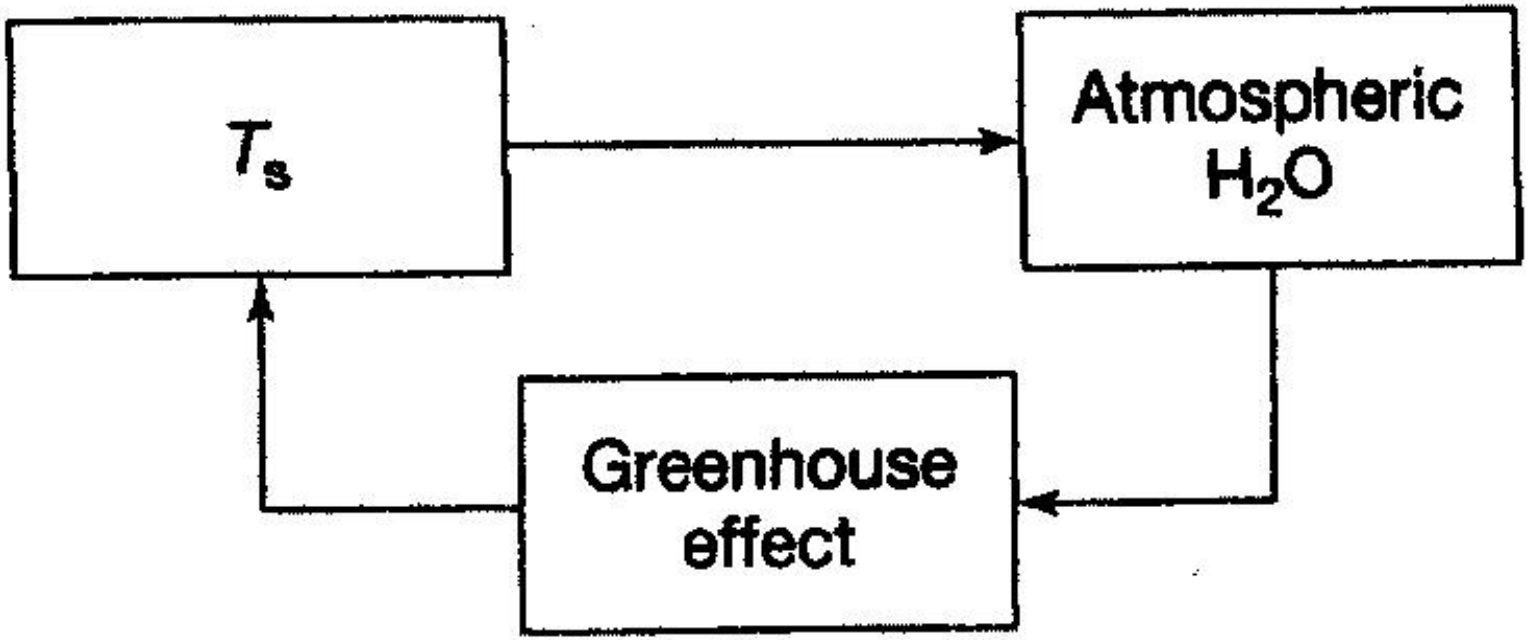
(e.g. increasing carbon dioxide)

. . . and whether or not the Earth can adjust to these and have a stable equilibrium state, or be thrown into an unstable state due to positive feedback loops

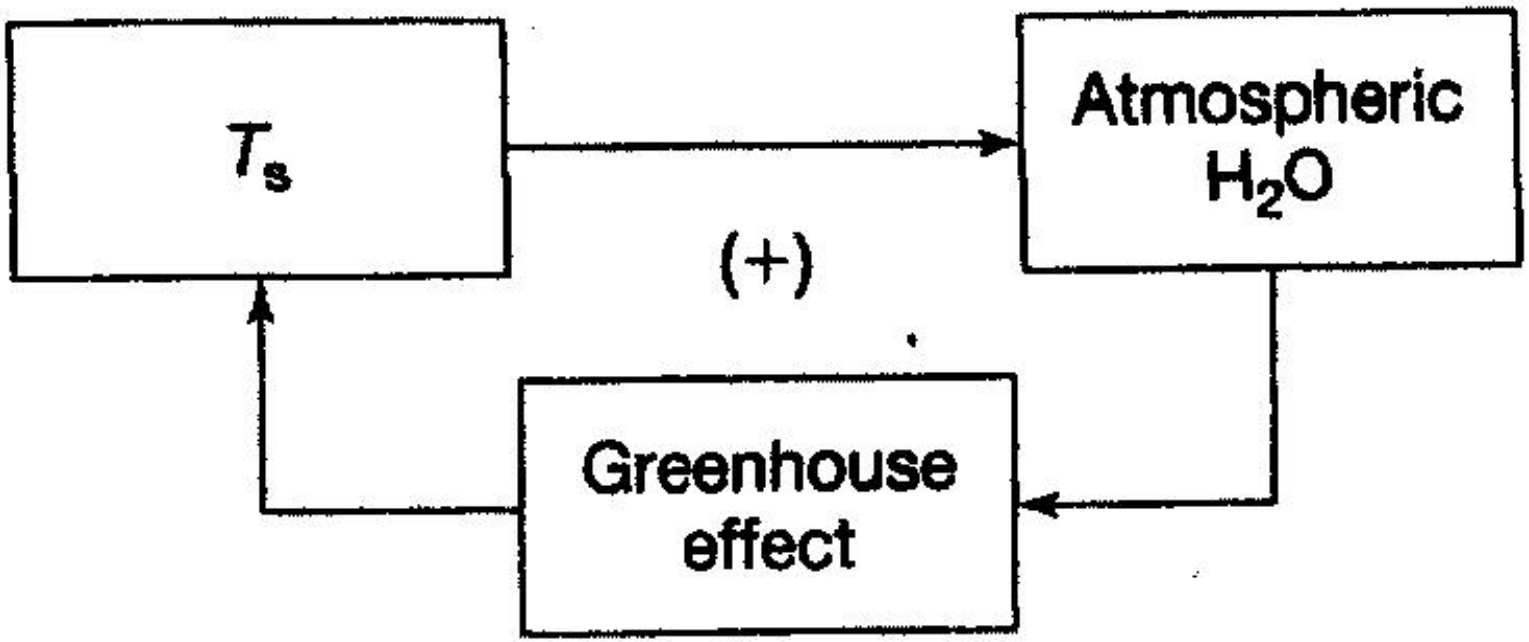
WATER VAPOR Feedback in the Earth-Atmosphere

Q4: What kind of FEEDBACK LOOP IS THIS?

1) Positive + 2) Negative -



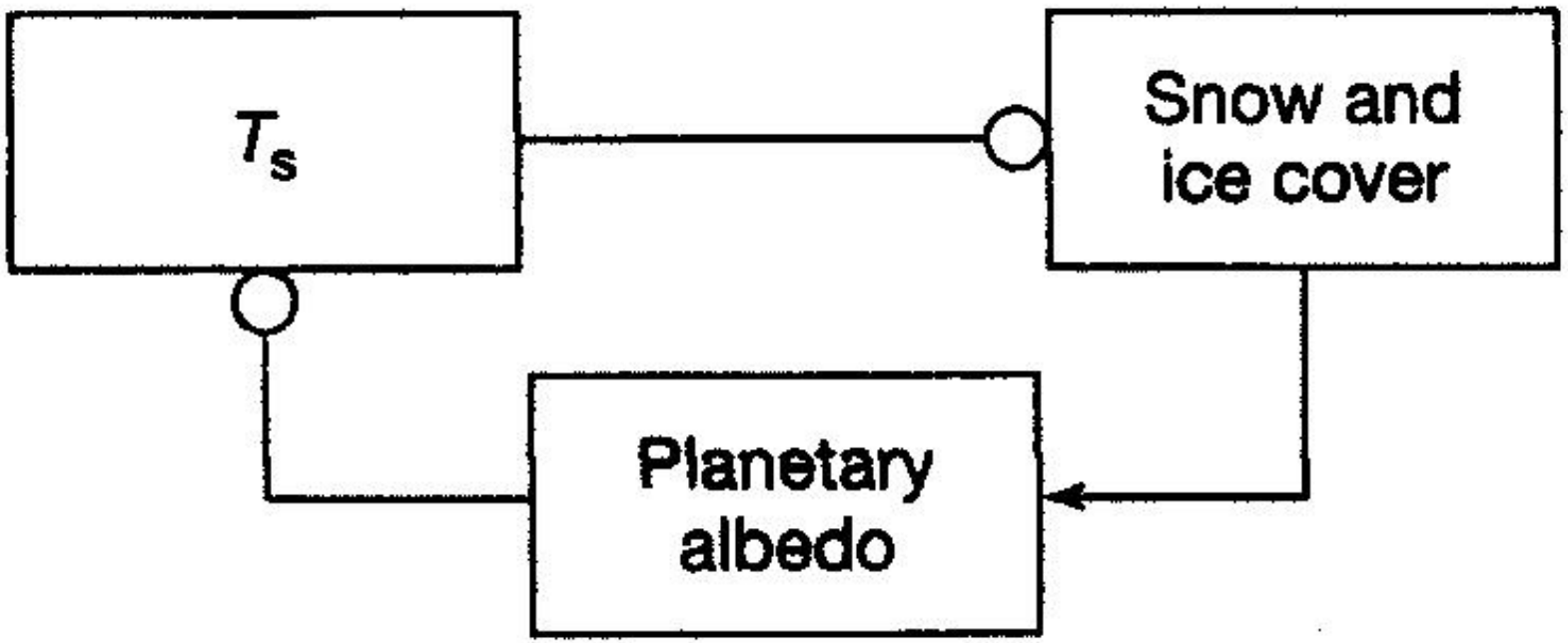
POSITIVE FEEDBACK LOOP
that amplifies the effect!



SNOW AND ICE ALBEDO Feedback

Q5: What kind of FEEDBACK LOOP IS THIS?

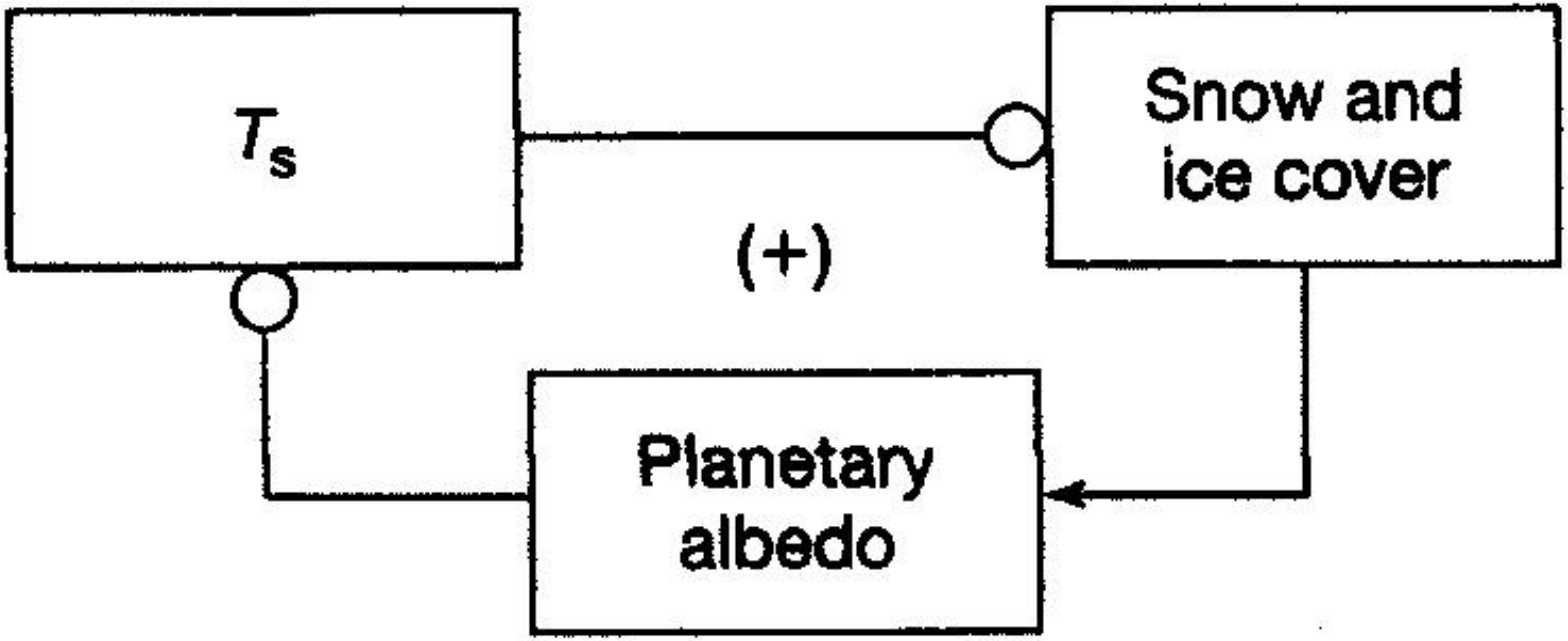
1) Positive + 2) Negative -



ALSO a POSITIVE FEEDBACK LOOP that amplifies the effect!

but

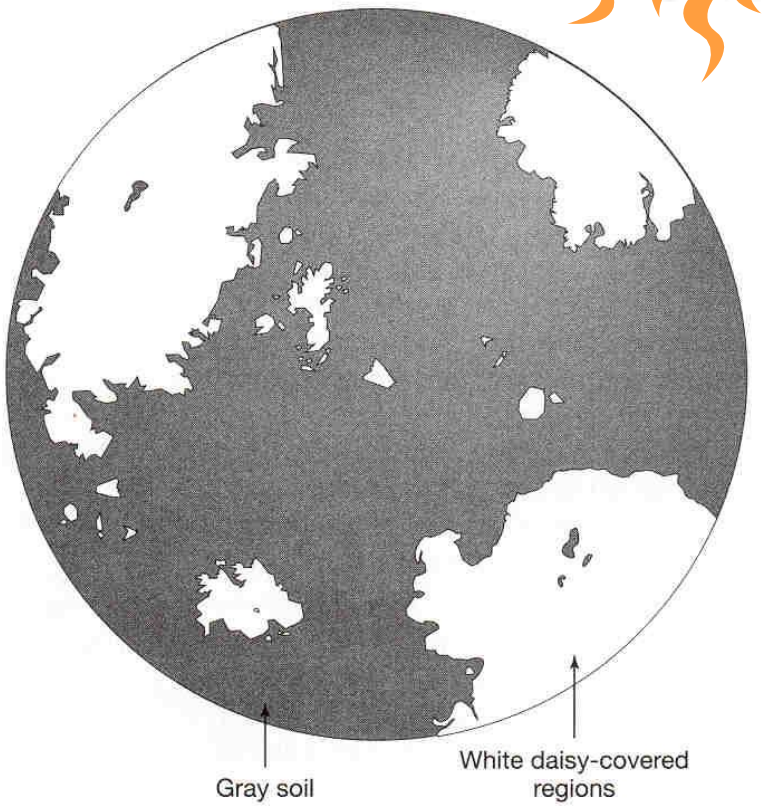
HOW DOES IT WORK?



ALBEDO REVIEW →

Fresh Snow & Ice = very high albedo (0.80 - 0.85)

We'll talk about the Daisyworld Climate System later . . .



TO BE CONTINUED . . . . .

Have a great weekend!

GO CATS!

GO STUDENTS!