TOPIC # 11

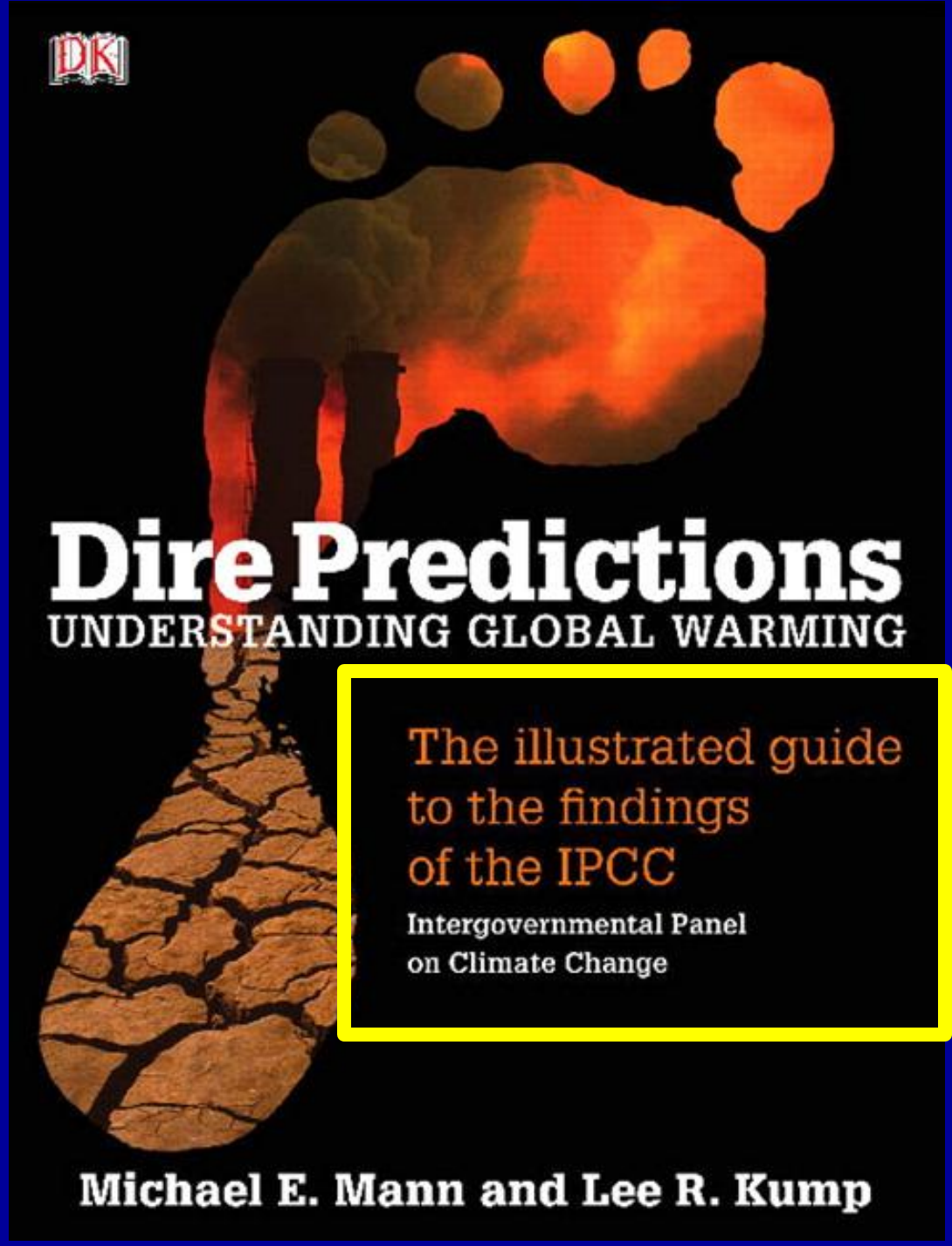
Introduction to Models:

UNDERSTANDING SYSTEMS & FEEDBACKS

Class notes pp 57-61

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

~ John Muir



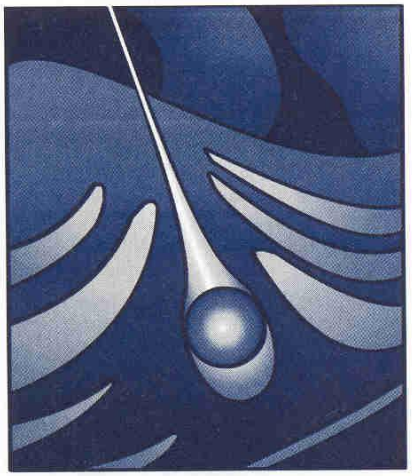
Our best projections of what **the FUTURE CLIMATE** will be like are based on GIANT COMPUTER MODELS – results are given in the **IPCC Report** and summarized in your **DIRE PREDICTIONS** text.

(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.

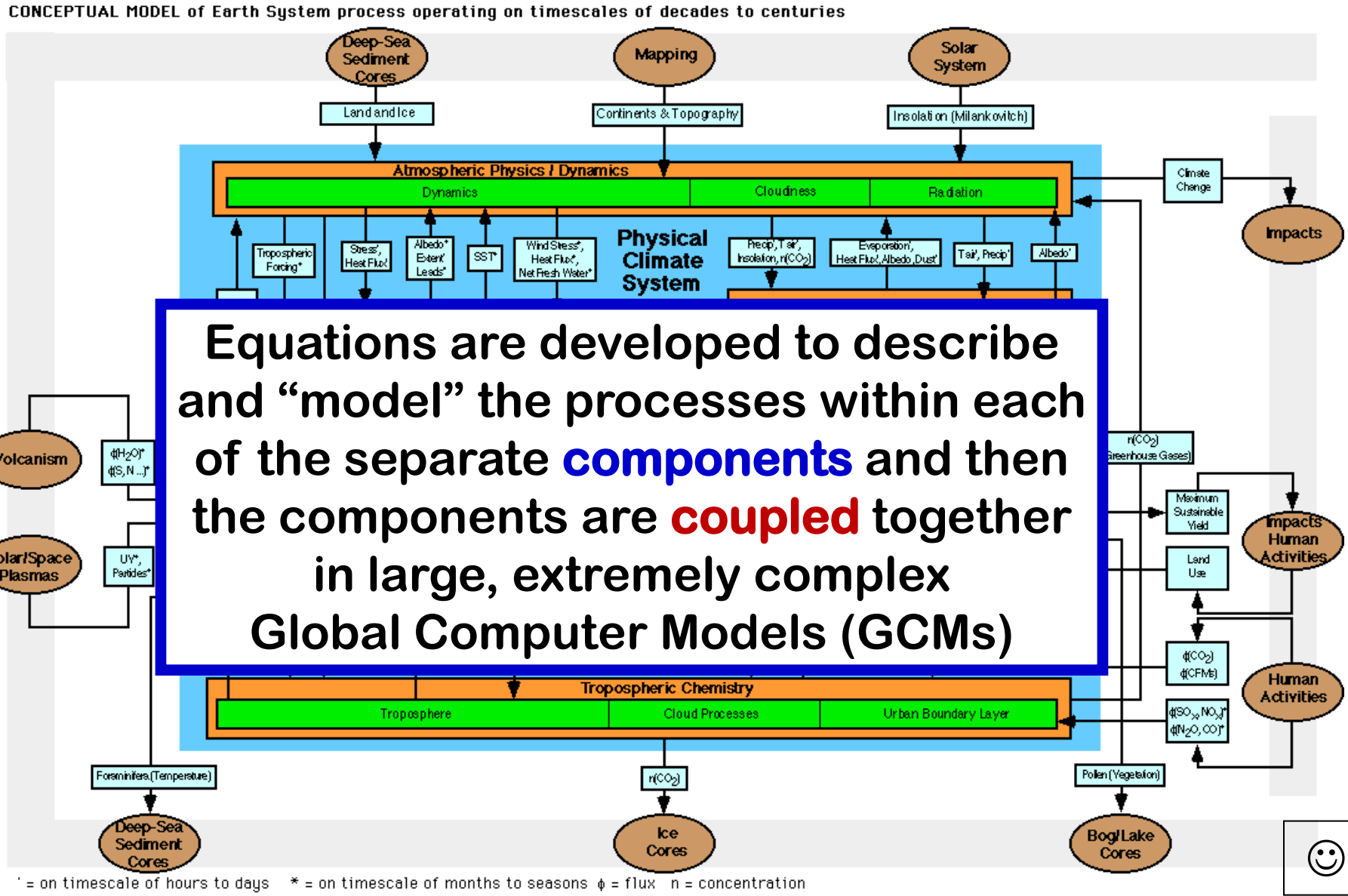
SYSTEM MODEL =

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:

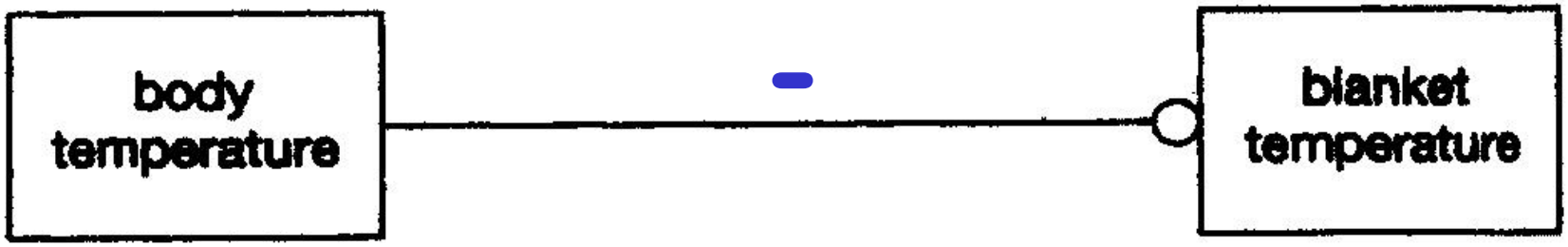
If the electric blanket's temperature INCREASES . . .

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.

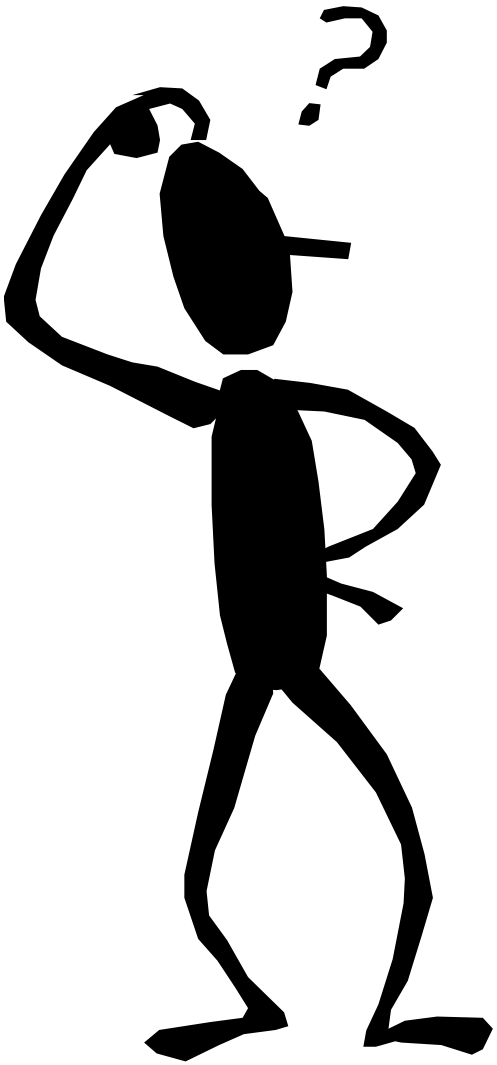
Feedback loops can be positive (+) or negative (-).

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)



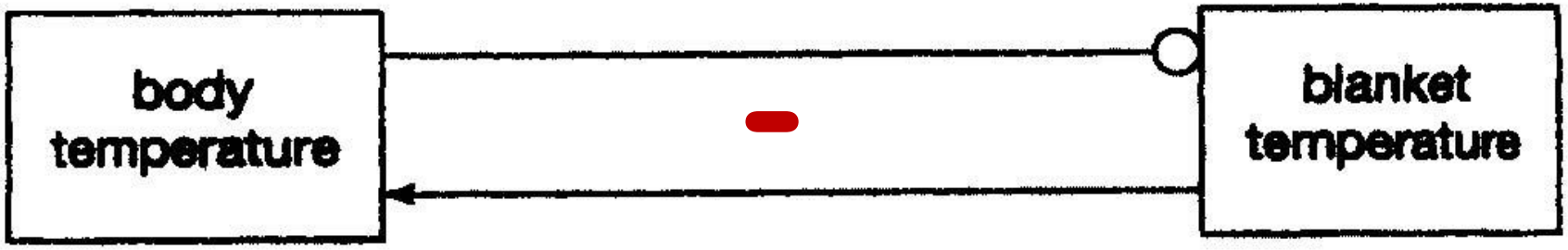
One way to remember the effect that a NEGATIVE feedback loop has is to think of the word "negligible"

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

Q1: What kind of FEEDBACK LOOP IS IT?

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

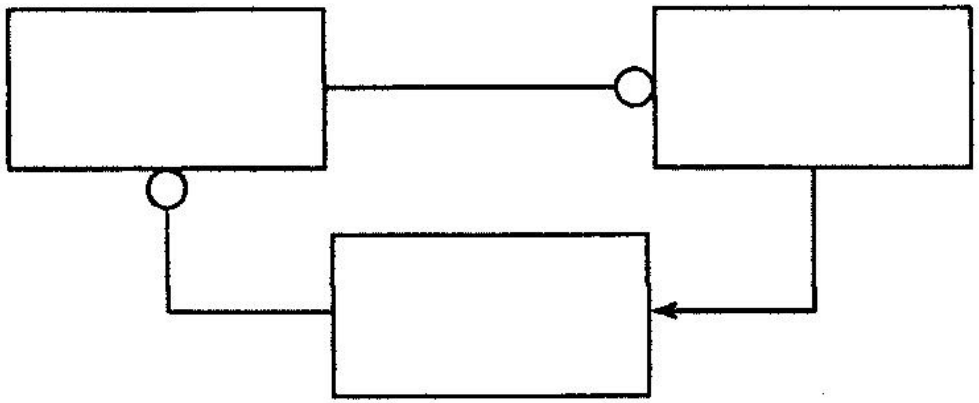


THE "RULE" – how to tell if it's a positive or negative feedback LOOP:

Count the # of number of NEGATIVE COUPLINGS:

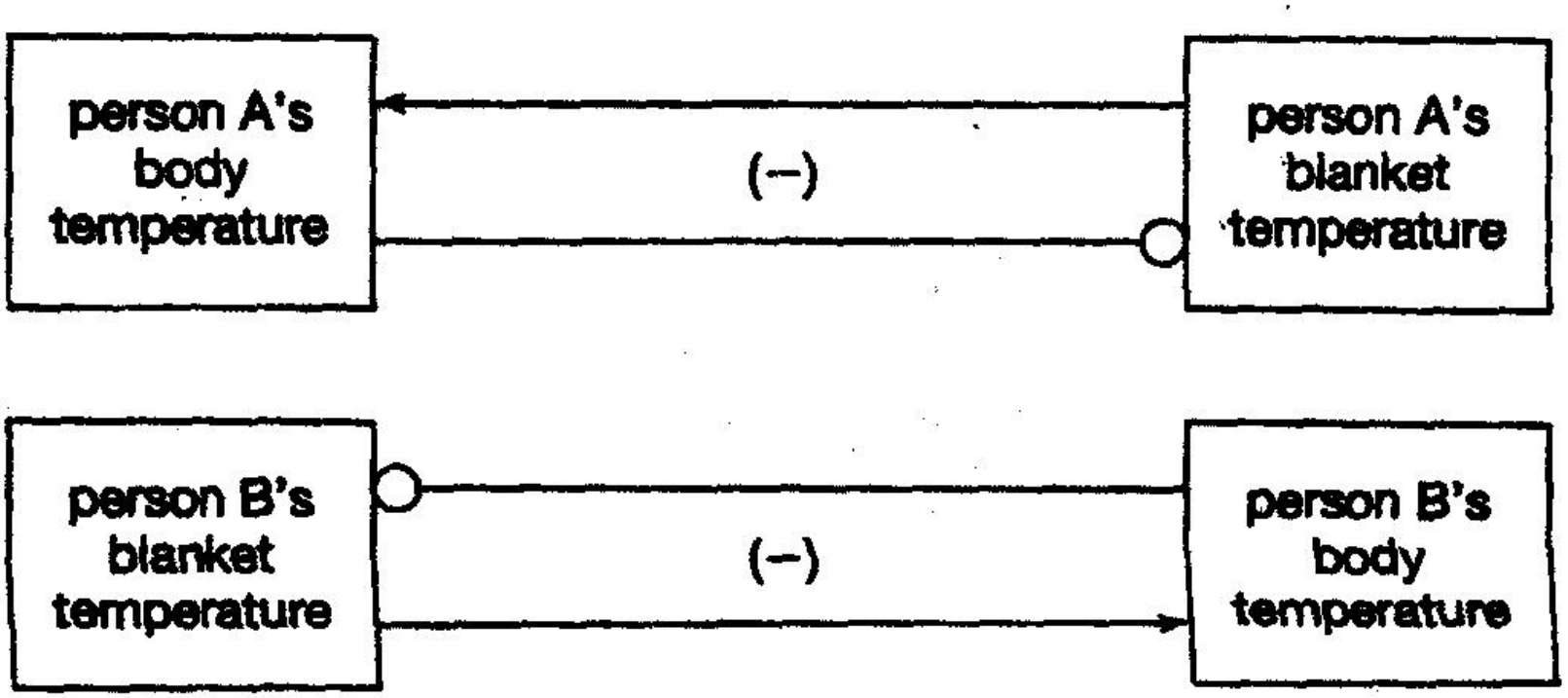
If there is an ODD # of negative Couplings, the loop is NEGATIVE:

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



Everyday life example:

Proper alignment of dual control electric blanket:

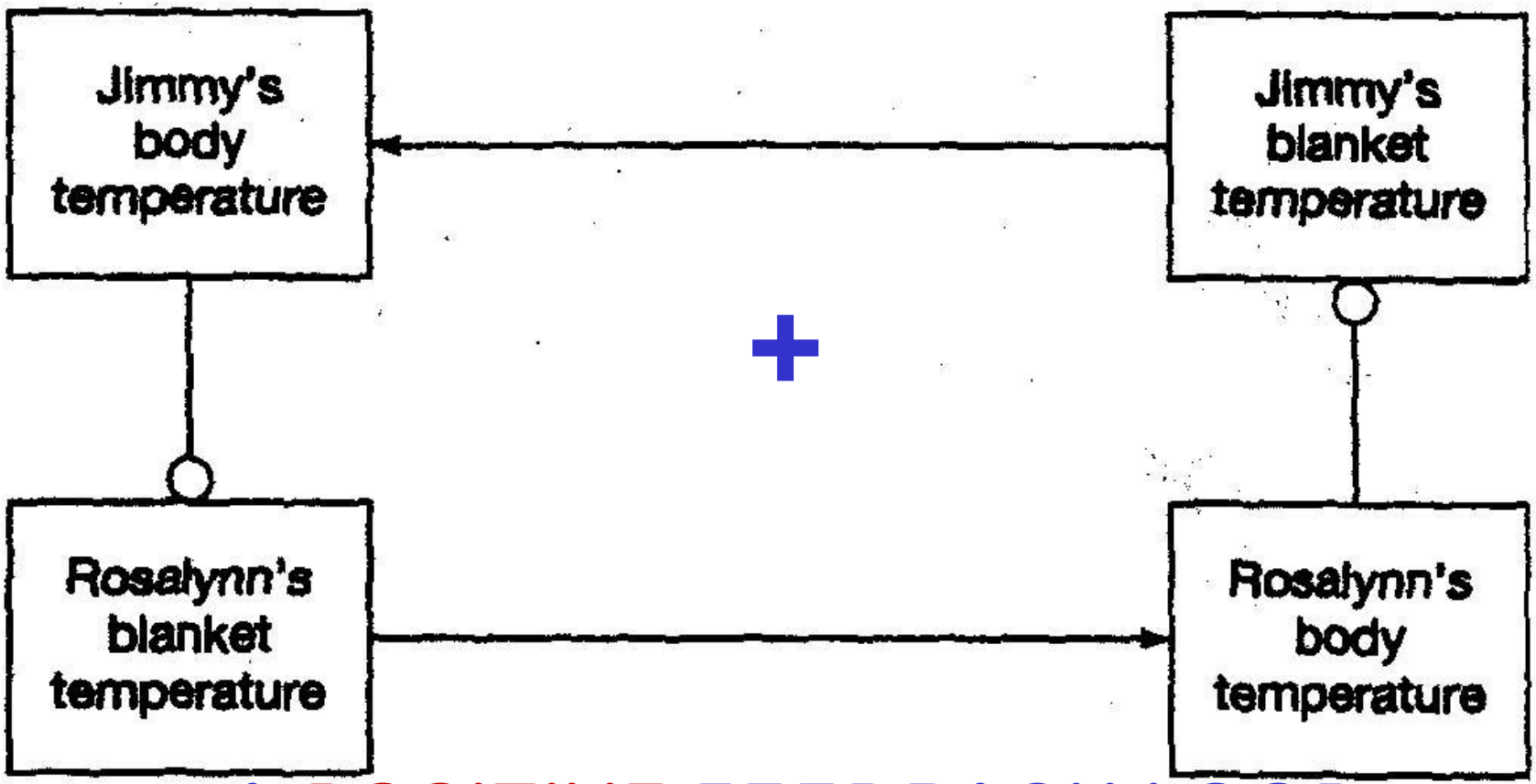


Back to p 58

Improper alignment:

Q2. 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:

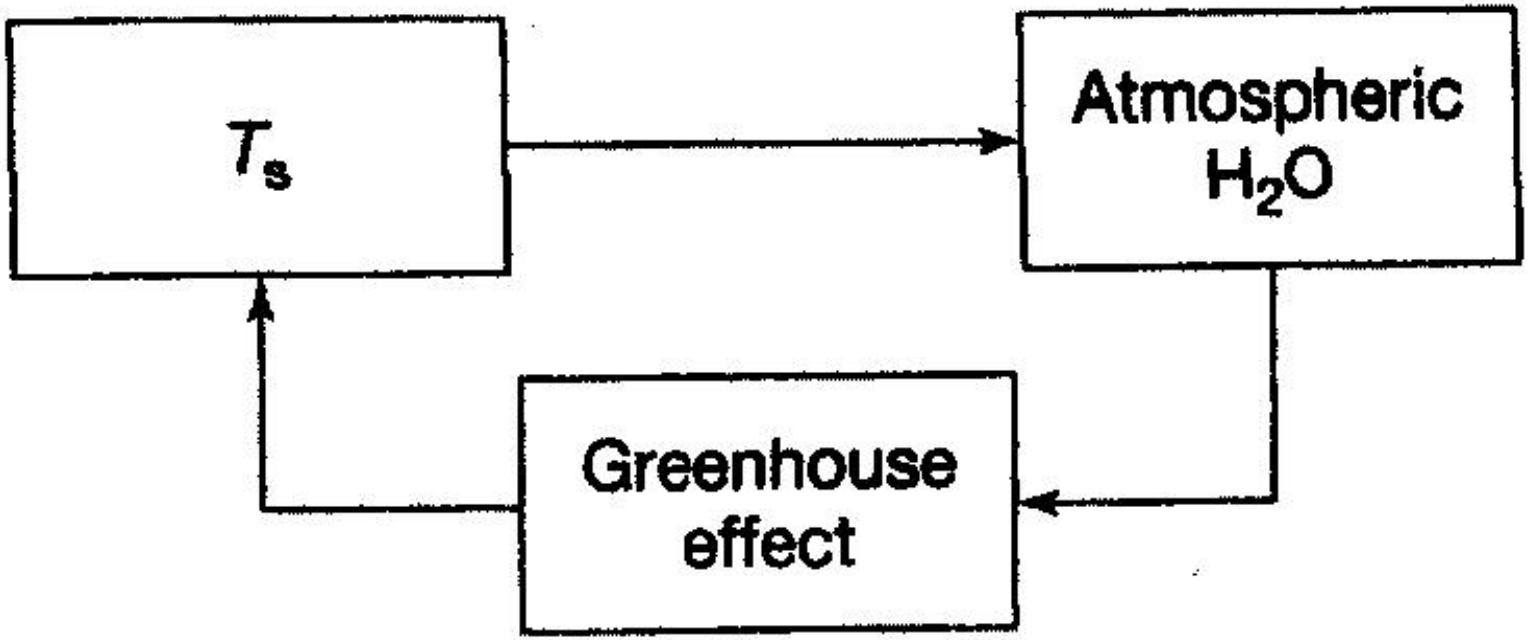
(e.g. increasing carbon dioxide)

. . . 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

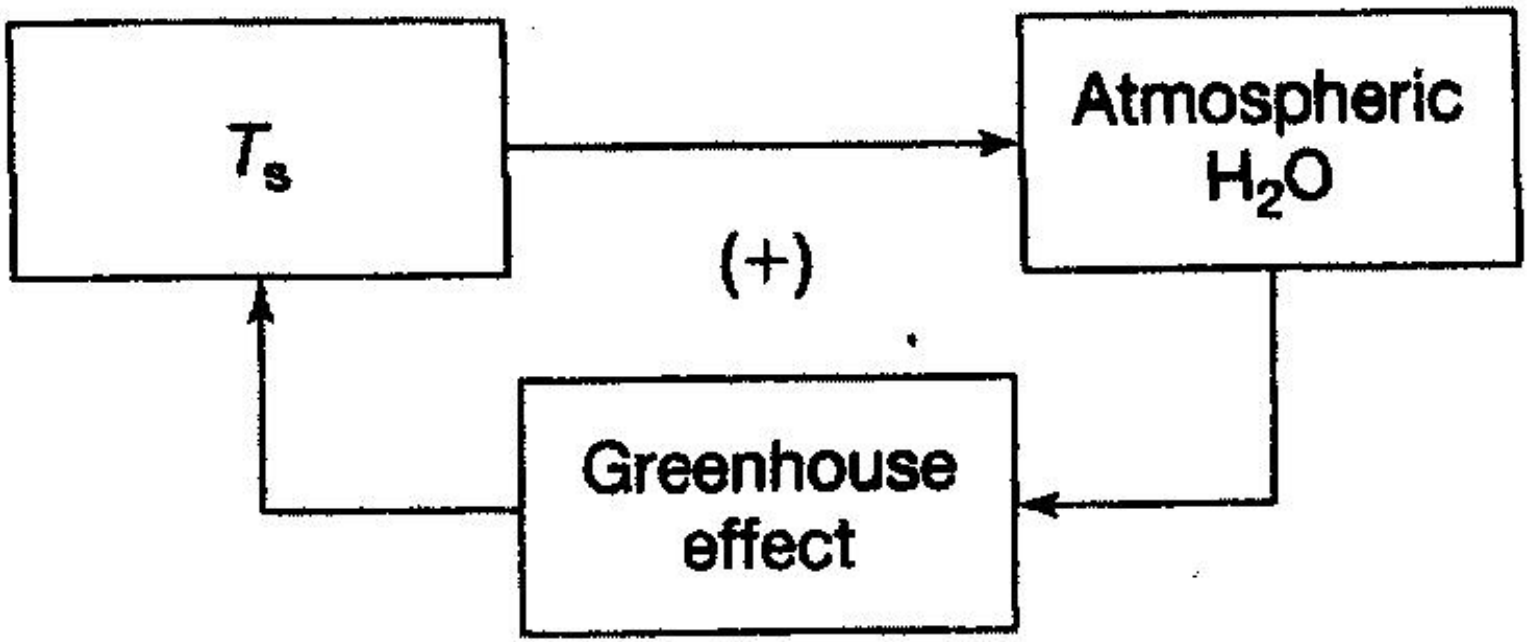
WATER VAPOR Feedback in the Earth-Atmosphere

Q3: What kind of FEEDBACK LOOP IS THIS?

1) Positive + 2) Negative -



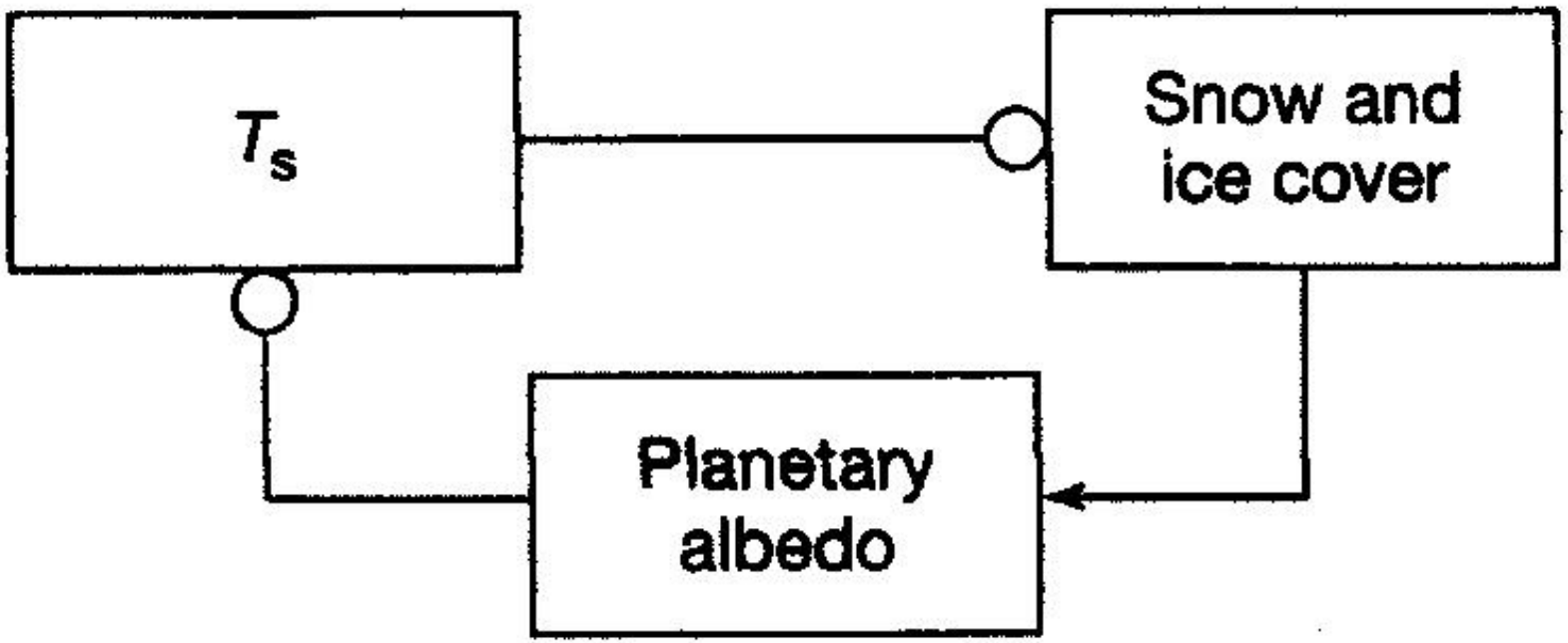
POSITIVE FEEDBACK LOOP
that amplifies the effect!



SNOW AND ICE ALBEDO Feedback

Q4: What kind of FEEDBACK LOOP IS THIS?

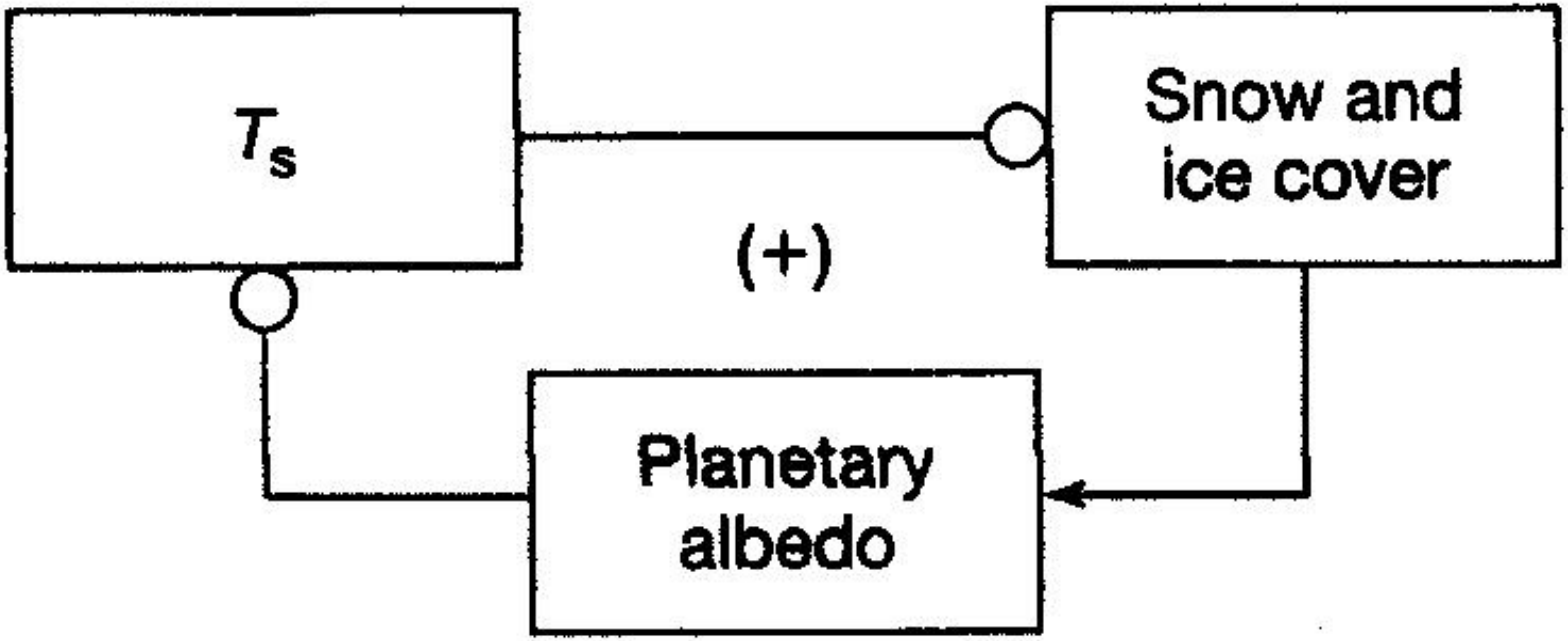
1) Positive + 2) Negative -



ALSO a POSITIVE FEEDBACK LOOP that amplifies the effect!

but

HOW DOES IT WORK?



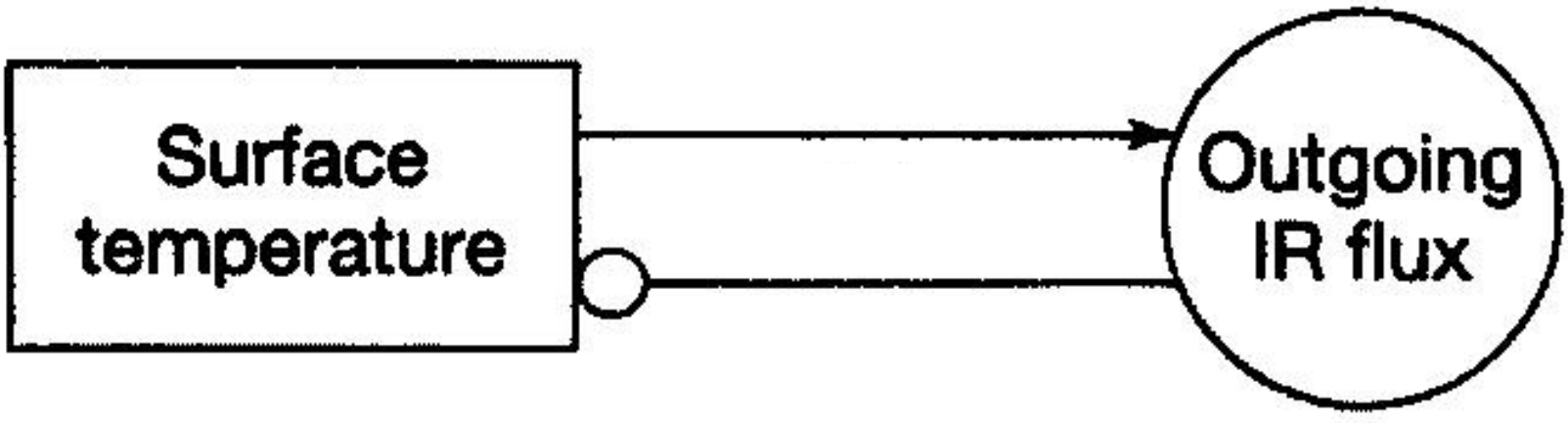
ALBEDO REVIEW →

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

OUTGOING INFRARED ENERGY FLUX / TEMPERATURE Feedback

Q5: What kind of FEEDBACK LOOP IS THIS?

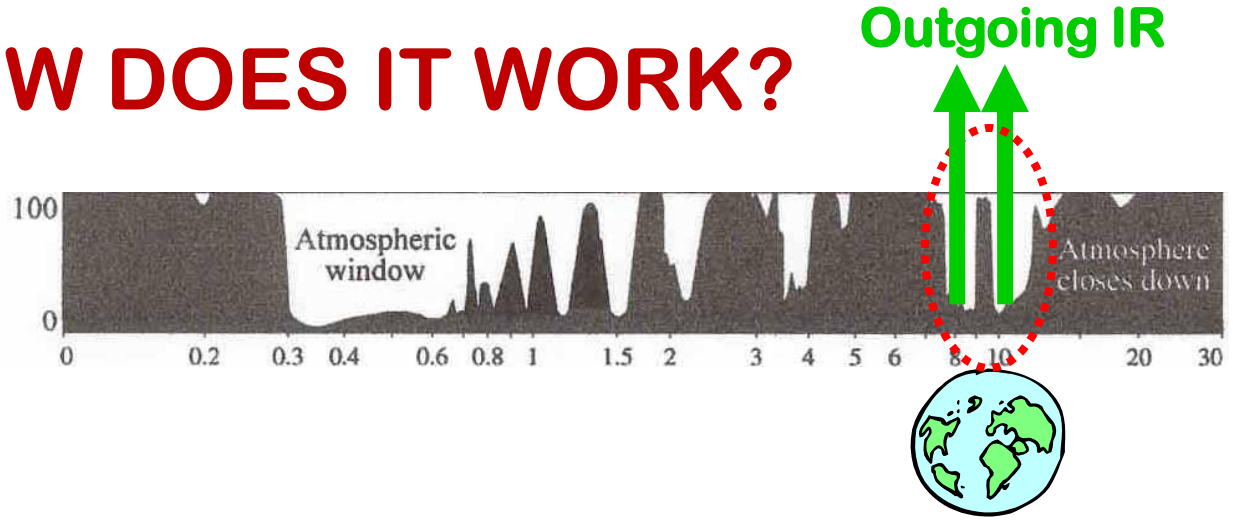
1) Positive + 2) Negative -

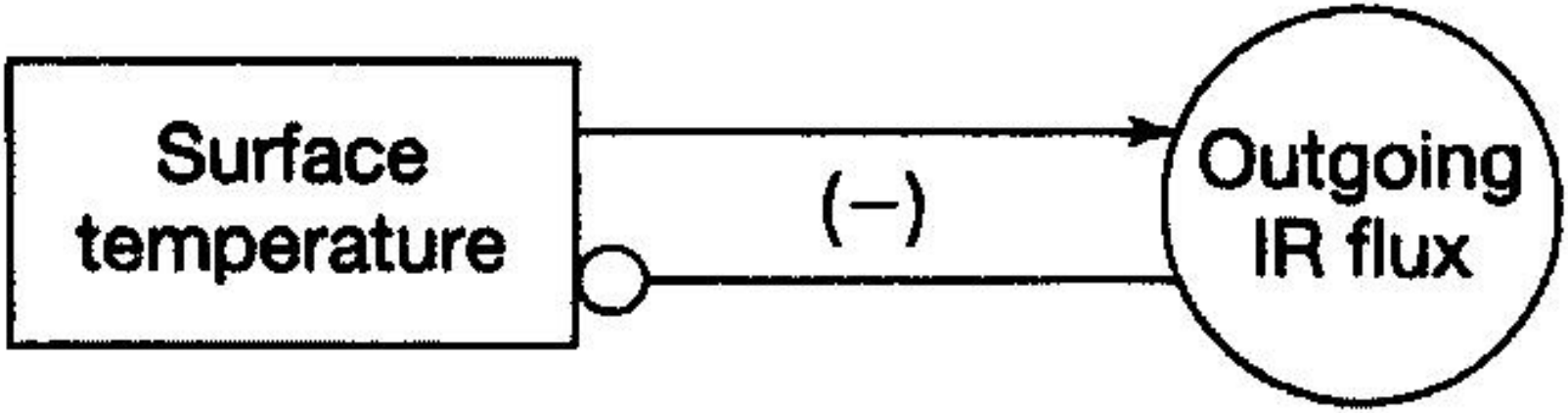


NEGATIVE FEEDBACK LOOP

that is self-regulating!

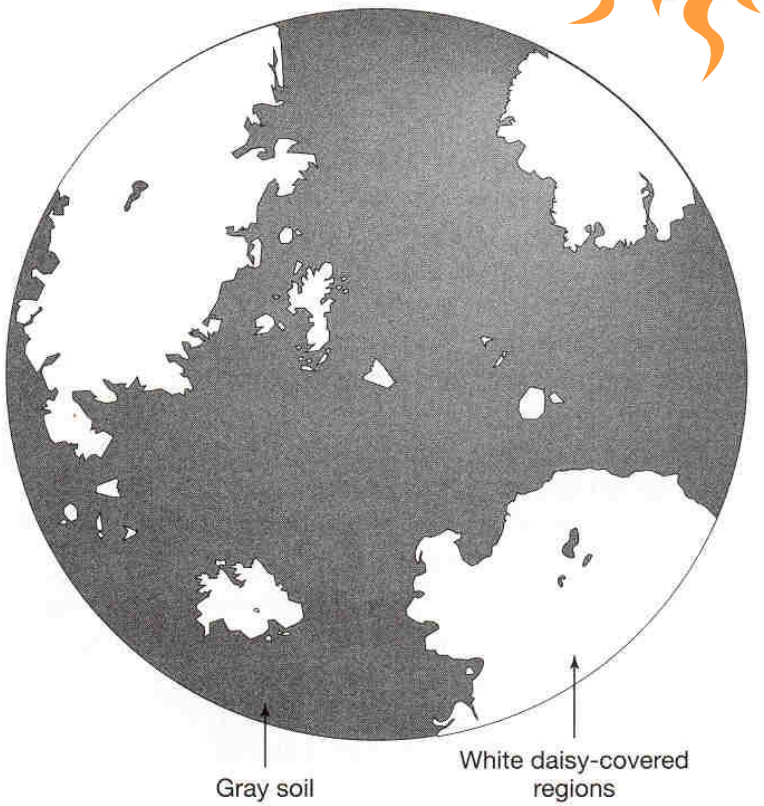
HOW DOES IT WORK?





This is how the **EARTH cools itself!**

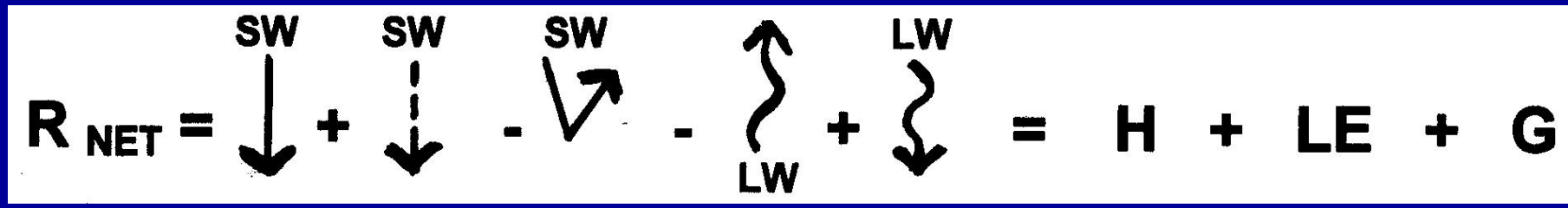
We'll talk about the Daisyworld Climate System later . . .



TO BE CONTINUED . . . . .

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

The COMPLETE EQUATION!



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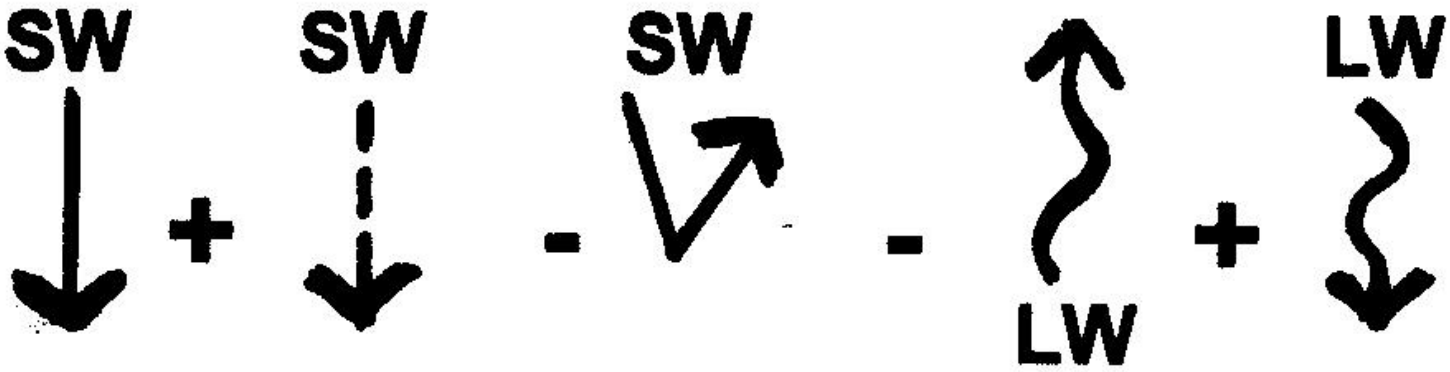
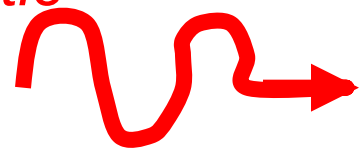
Left Side of Energy Balance Equation:



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



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

Right Side of Energy Balance 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:

WHAT IS G???

G = GROUND STORAGE

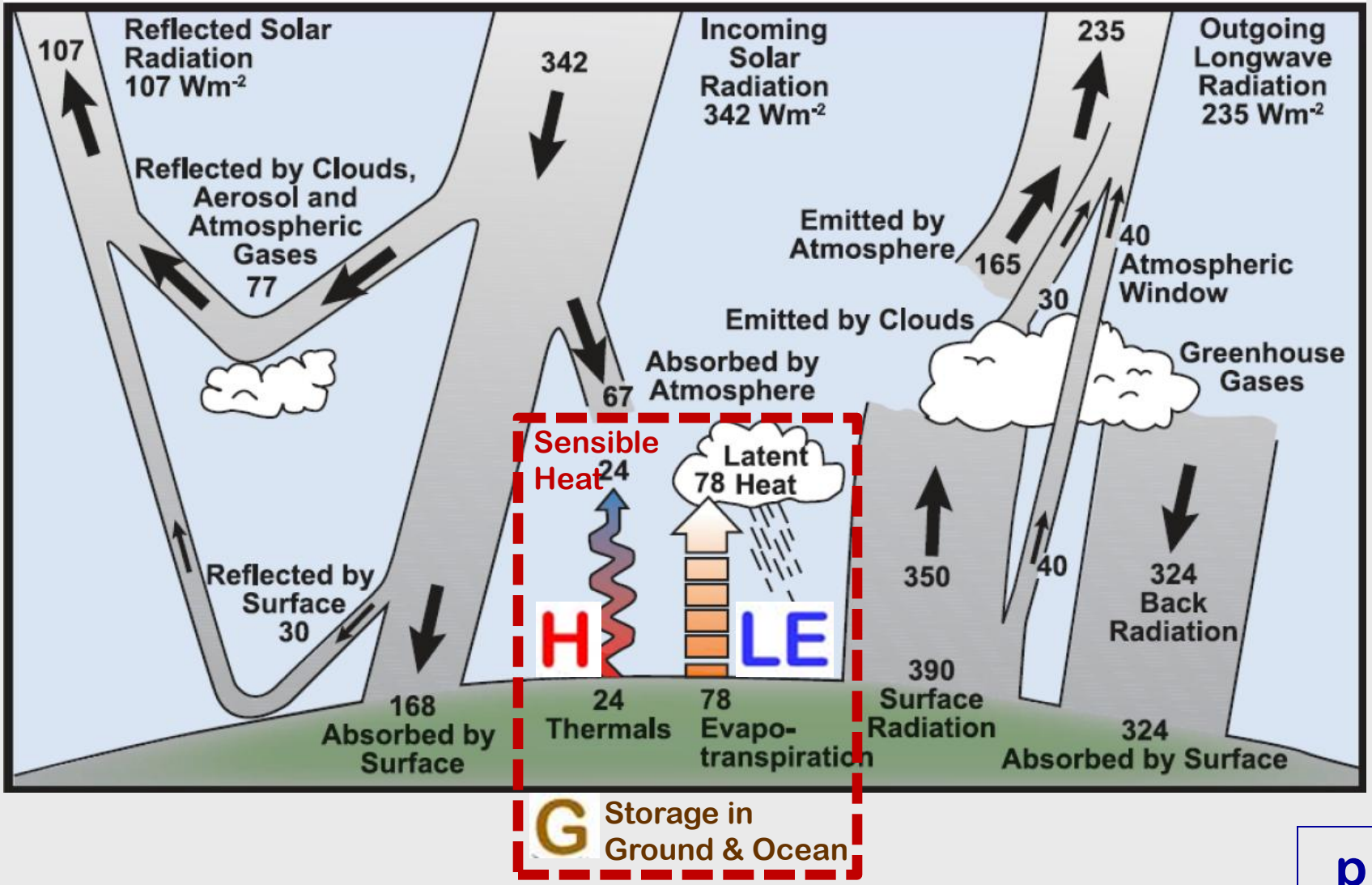
ENERGY CONDUCTED into soil or CONVECTED & CONDUCTED into water (e.g. ocean) and temporarily STORED THERE

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

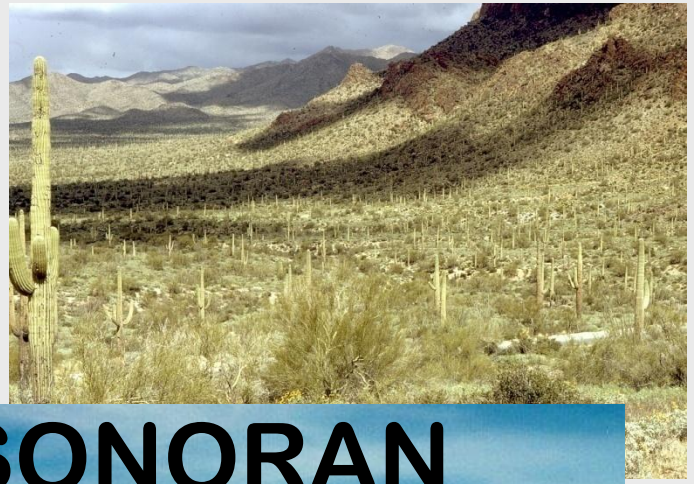
ENERGY PATHWAYS

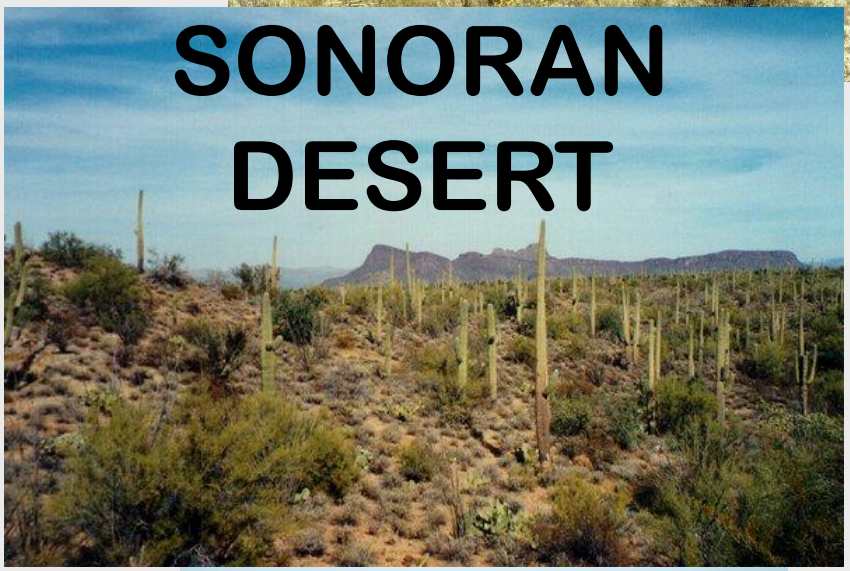
Representation of the Energy Balance & Energy Pathways

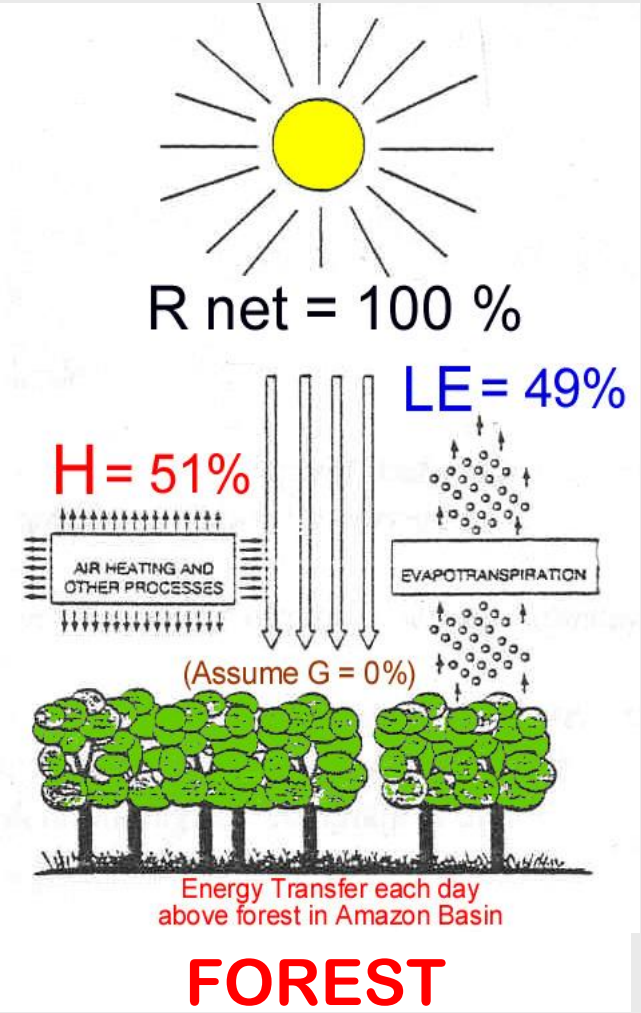
Throughout the whole Earth-Atmosphere system, the energy units balance out, energy is conserved, and the 1st Law of Thermodynamics applies.



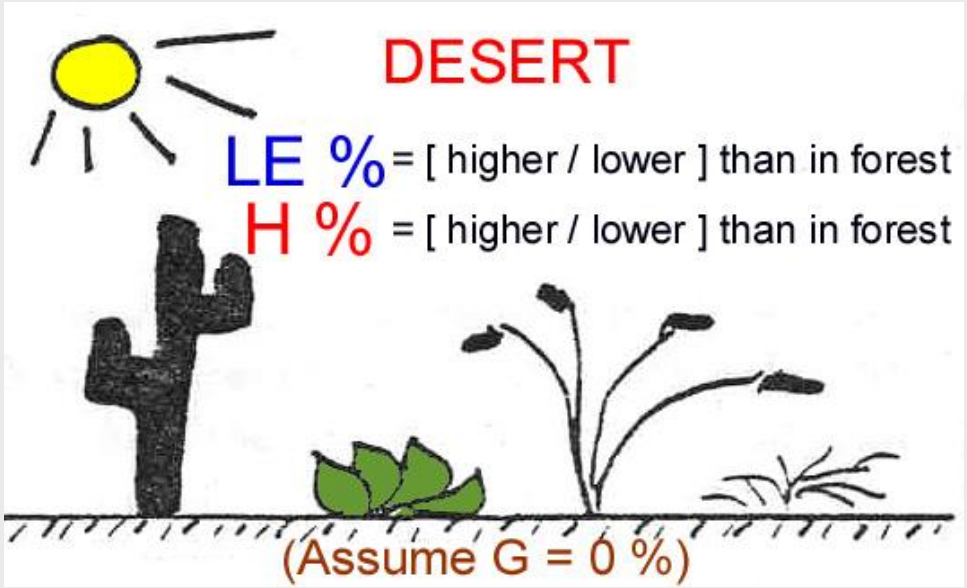
CLICKER Q Channel 32 . . .







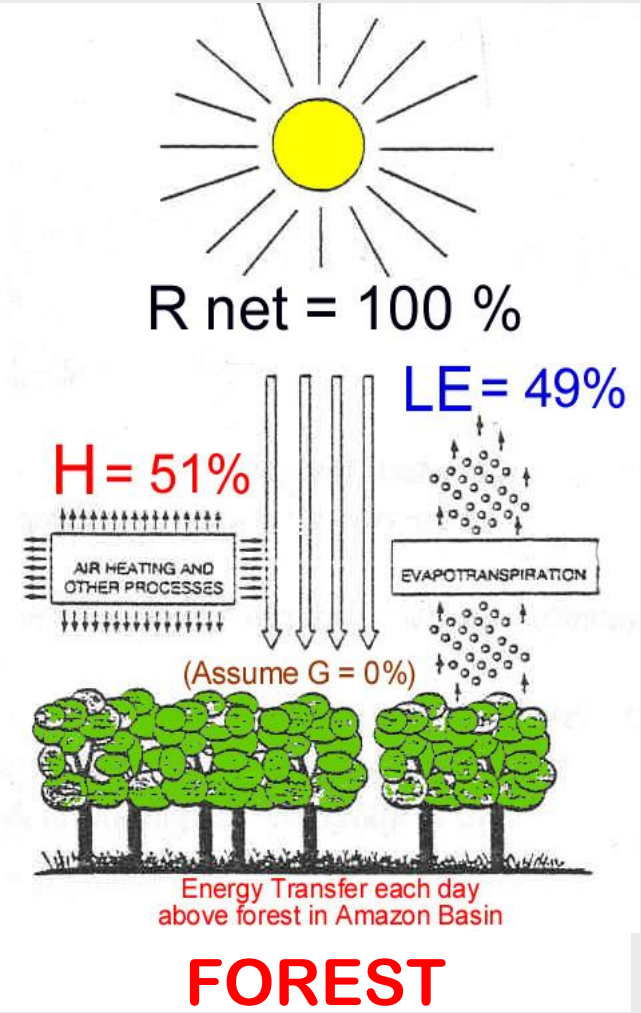
Q-6 Will the % of net radiation in LE form be HIGHER or LOWER in the Desert, when compared to a Rainforest?



Compared to the Amazon Rain Forest the % of R_{NET} in LE will be . .

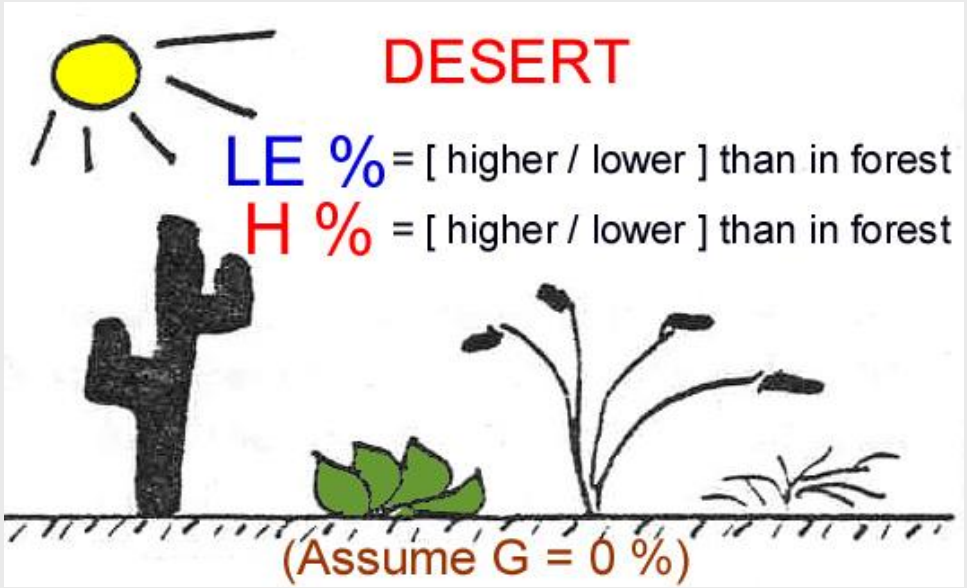
1 = HIGHER in the desert

2 = LOWER in the desert



FOREST

Q-6 Will the % of net radiation in LE form be HIGHER or LOWER in the Desert, when compared to a Rainforest?



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

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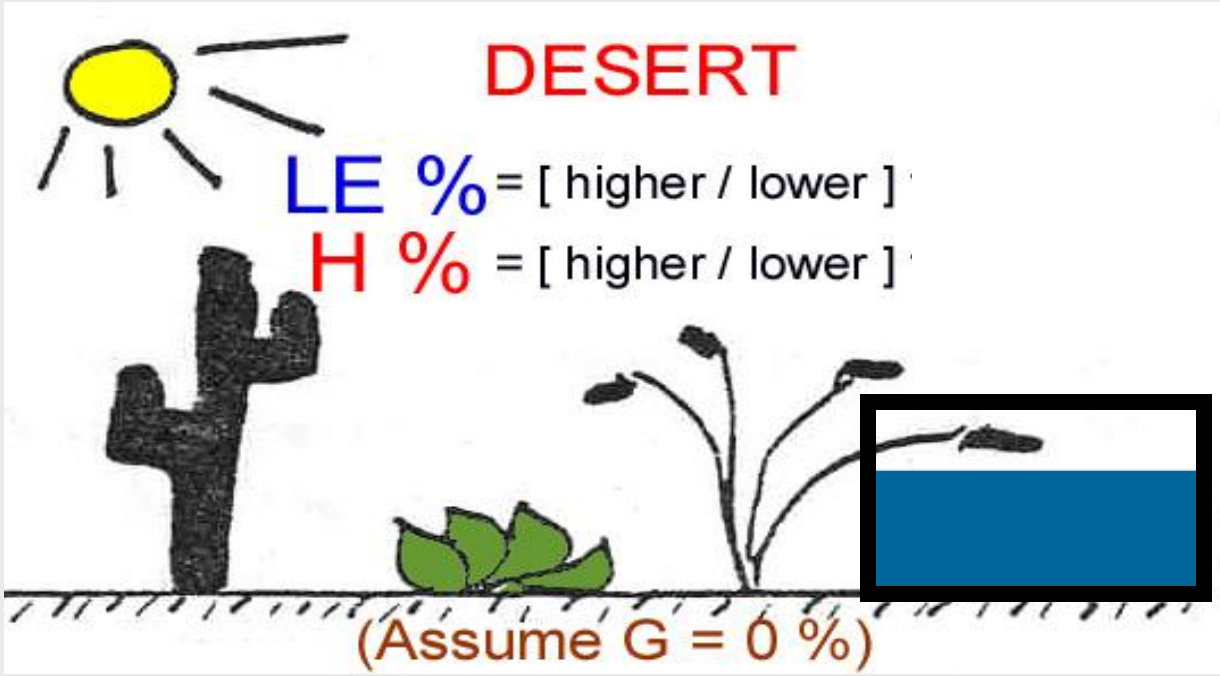
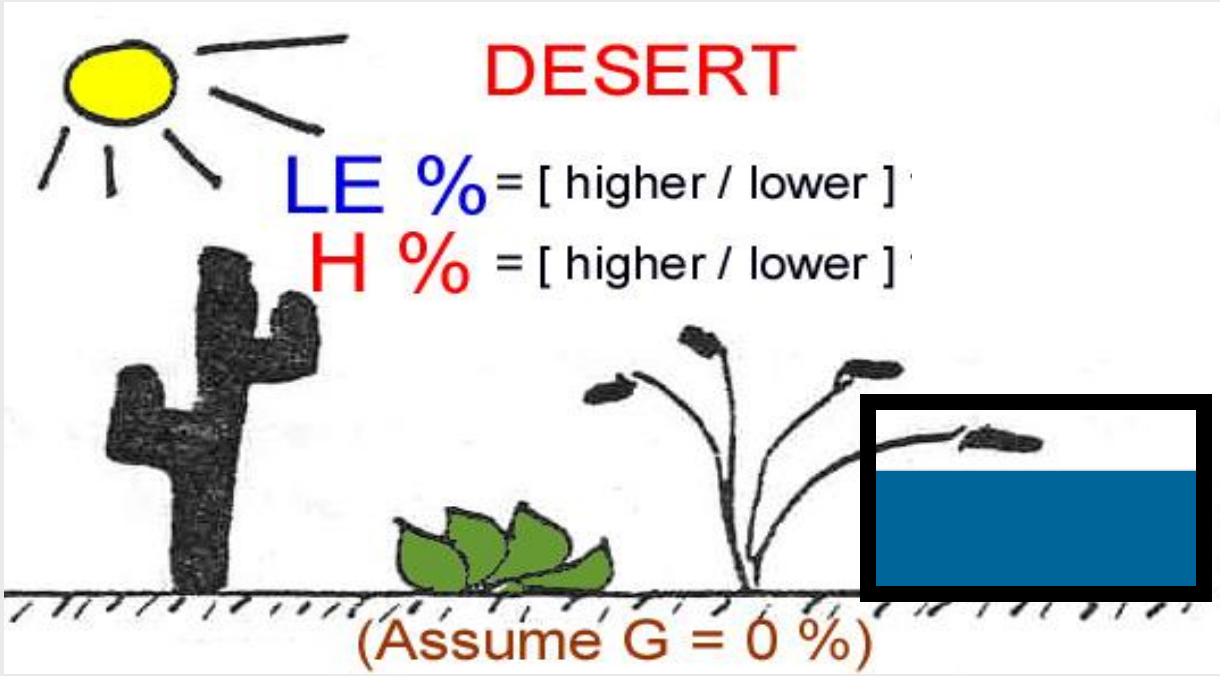


Q7 -How would the % of LE in the Desert change?

Compared to natural desert with no CAP canals, the % or R_{NET} in LE will be . . .

1 = HIGHER with CAP canals
2 = LOWER with CAP canals

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



Q7 -How would the % of LE in the Desert change?

Compared to natural desert with no CAP canals, the % or R_{NET} in LE will be . . .

1 = HIGHER with CAP canals

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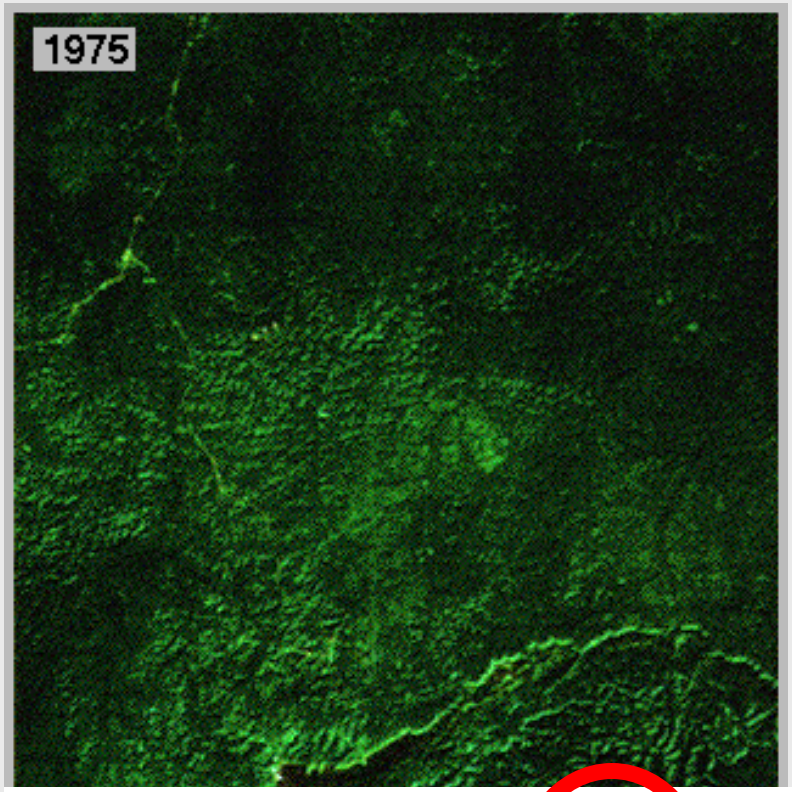
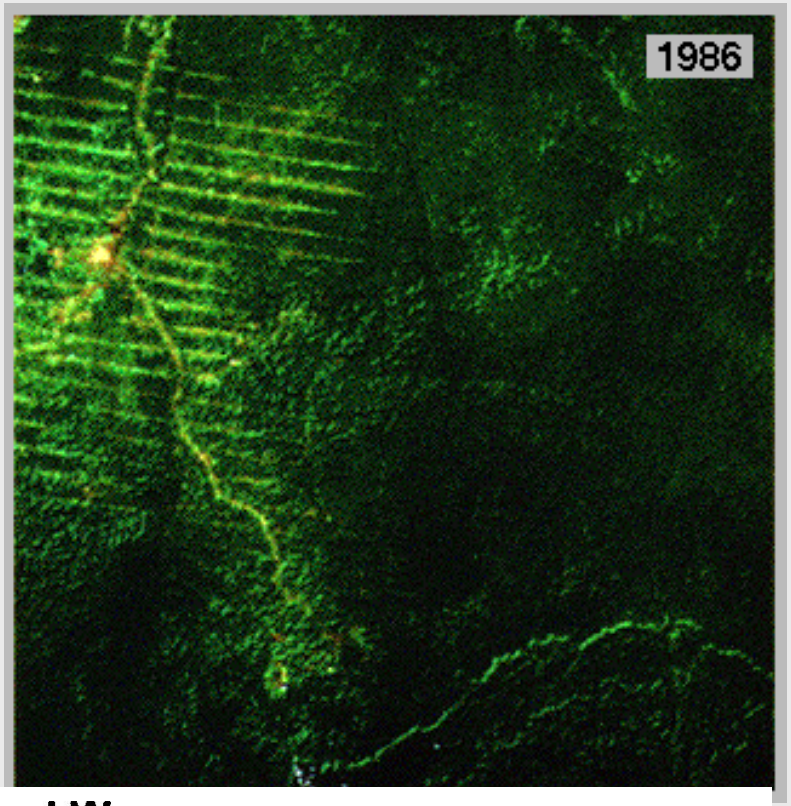
How does DEFORESTATION change the local energy balance???





R_{NET} = SW ↓ + SW ↓ − SW ↗ − LW ↕ + LW ↯ = H + LE + G

Less

More → cooler temperatures?

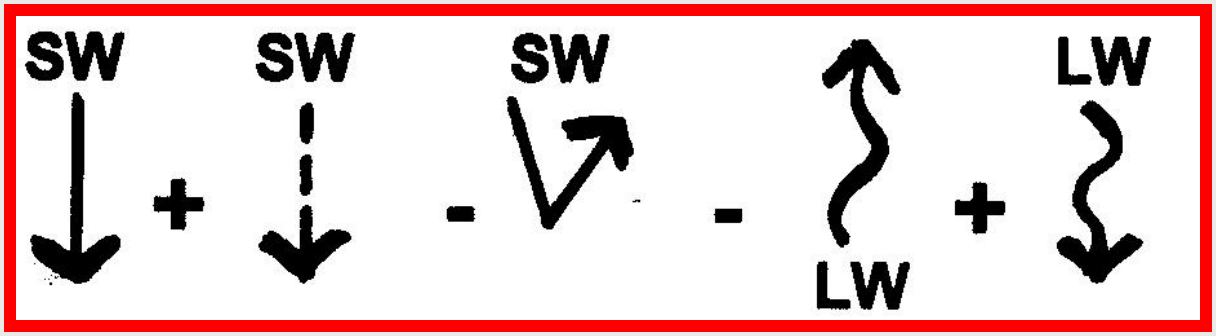
More → warmer temperatures?

G-4 ASSIGNMENT (5 pts)

Applying the Energy Balance Terms

Your task is to decide which **component** or **components working together** ***are most directly related to*** or ***responsible for*** the observed phenomenon.

1 – #12 : Left side of equation



13 - #15: Right side of equation

H + LE + G

p 56

G-4 ASSIGNMENT (5 pts)

Applying the Energy Balance Terms

While you should work in pairs and discuss with each other, **each member of the group must take the lead in answering at least TWO of the items below in his or her own handwriting. Members present should sign below and indicate which 2 or 3 items they filled in as in the example:**

Stella Student (#2, #10, & #12) _____

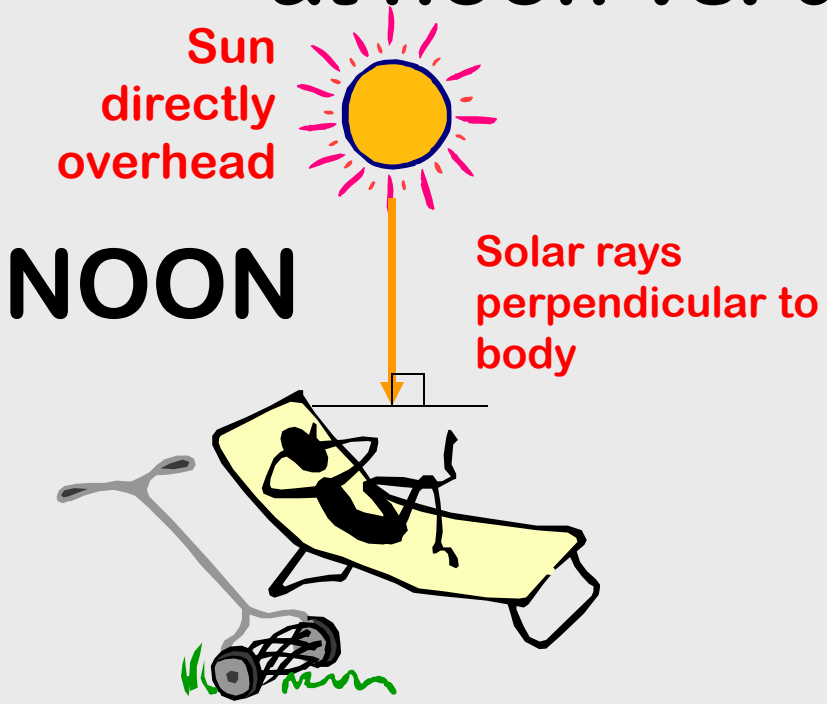
Don't forget to SIGN IN with the #'s you wrote up!

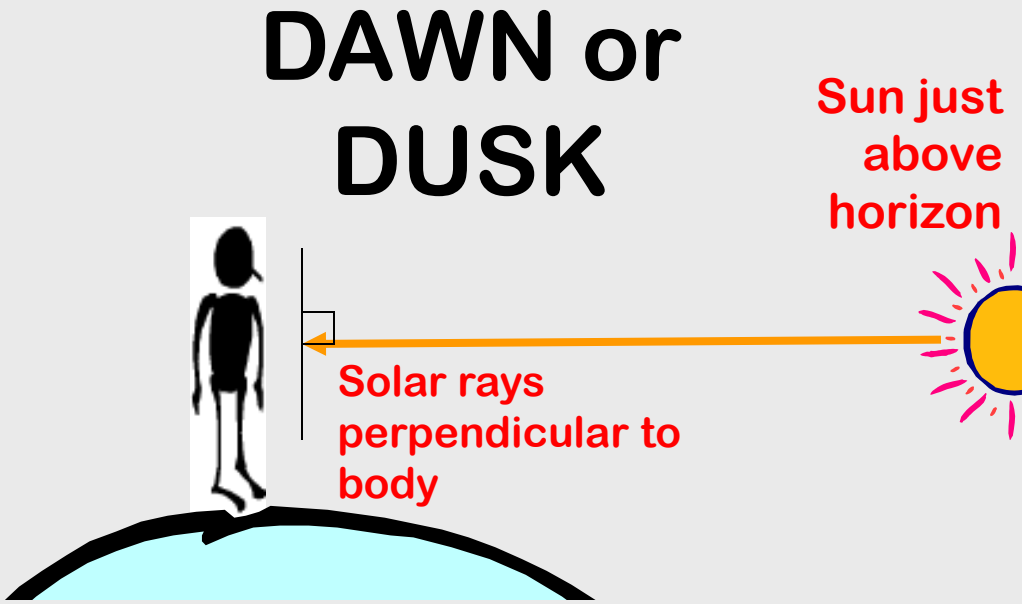
1. blue skies

2. Sunglasses while skiing

3. Bright even though cloudy

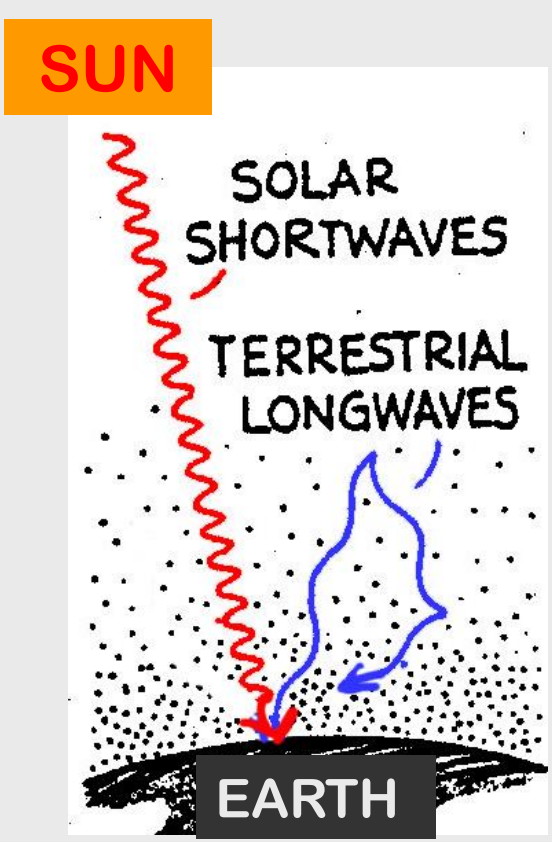
4. More intense solar radiation (tan /skin damage, etc.) at noon vs. dawn or dusk

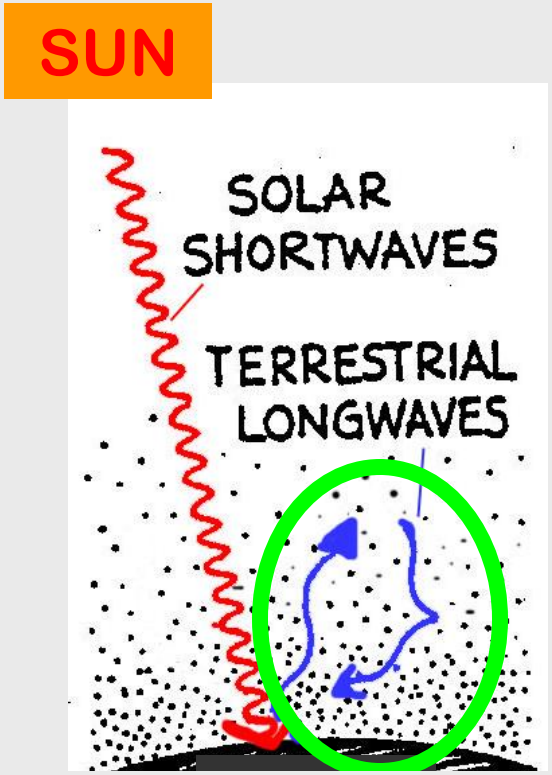




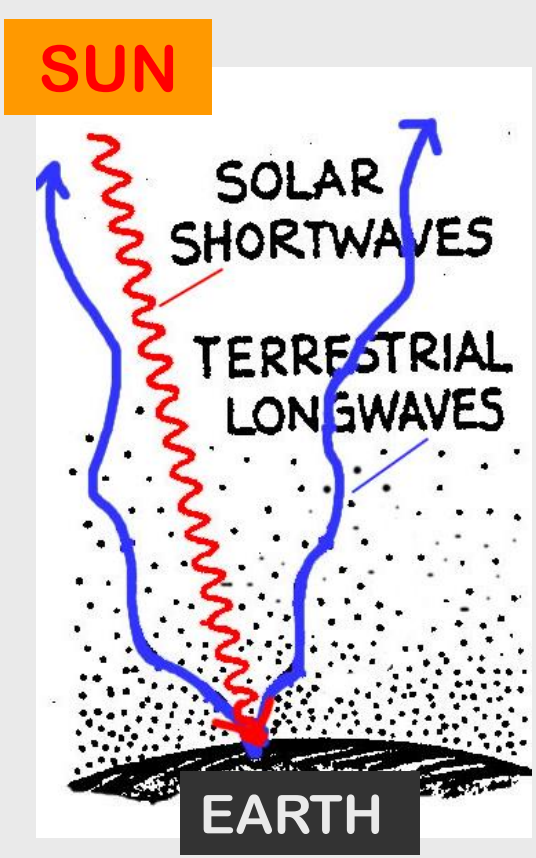
5. The Greenhouse Effect →

To illustrate the GREENHOUSE EFFECT:





Greenhouse effect



B is better than the others . . . But only the circled part represents the GH Effect!! . . .

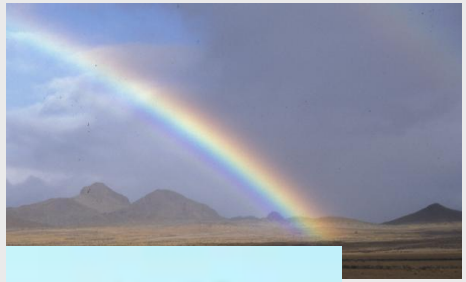
6. Red sunsets

7. Infrared cameras / “night vision”

8. “Tennis whites” tradition

9. Shadow on sunny day

10. Rainbow



11. Black streaks

12. Parking on blacktop

13. Hot air balloon

14. Pigs cooling off in the mud

15. Evaporative coolers work best in the desert

TIME TO WRAP UP FOR TODAY!

G-4 ASSIGNMENT (5 pts) (cont.)

Applying the Energy Balance Terms

While you should work in pairs and discuss with each other, **each member of the group must take the lead in answering at least TWO of the items below in his or her own handwriting. Members present should sign below and indicate which 2 or 3 items they filled in as in the example:**

Stella Student (#2, #10, & #12) _____

Don't forget to SIGN IN with the #'s you wrote up!

See you on Friday!