TOPIC # 11

Introduction to Models:

UNDERSTANDING SYSTEMS & FEEDBACKS (cont)

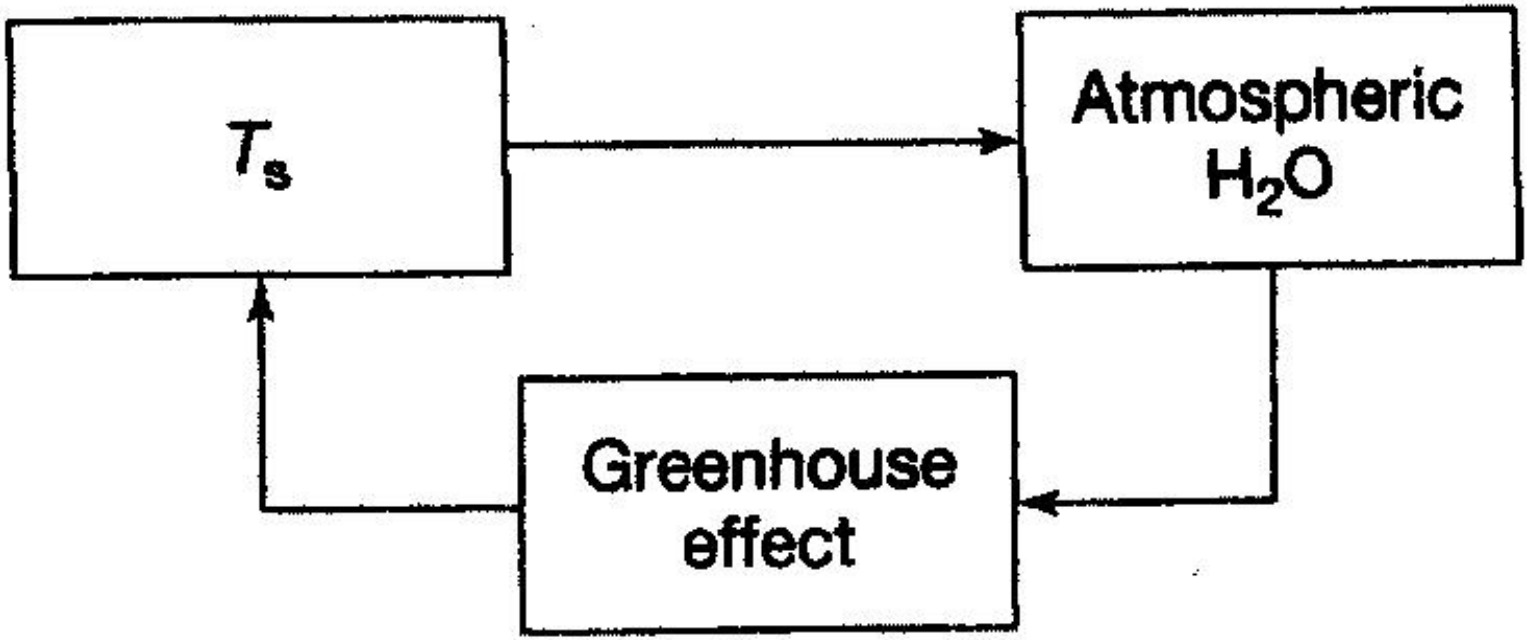
Class notes pp 61 - 65

LINKING TO GLOBAL CHANGE:

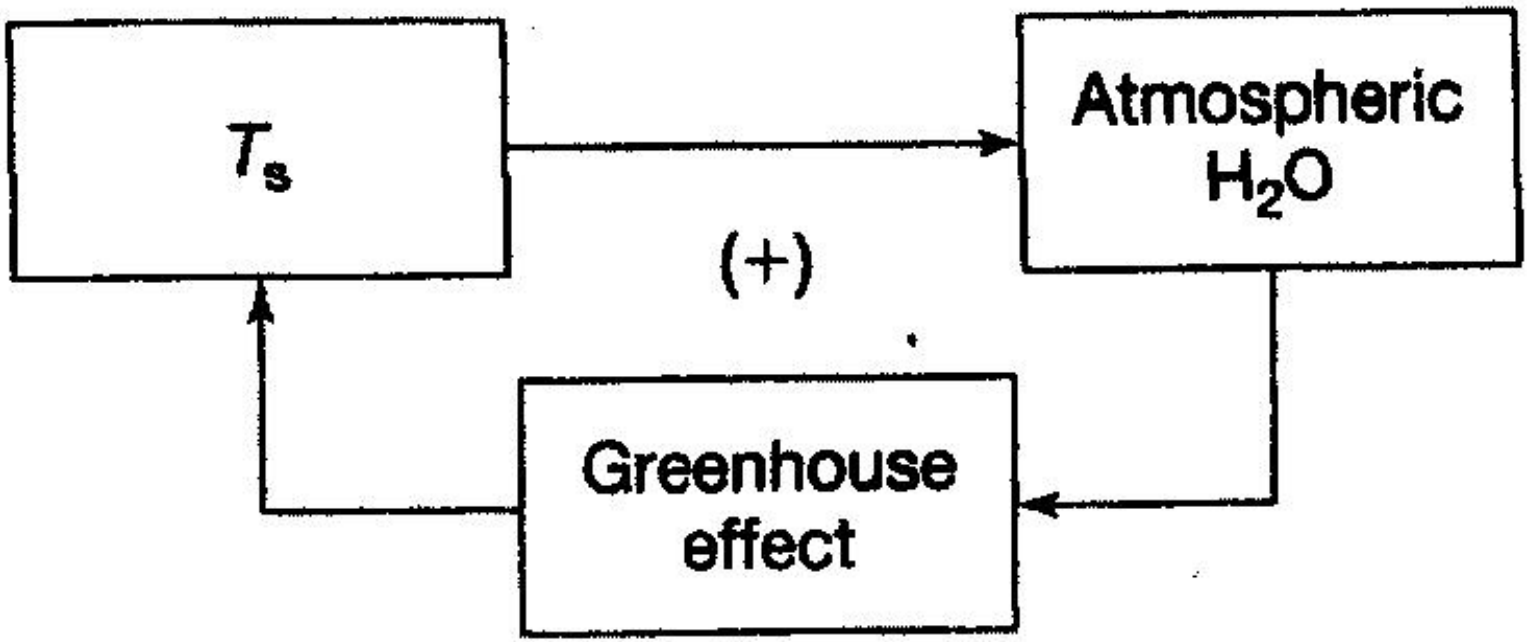
WATER VAPOR Feedback in the Earth-Atmosphere

Q1 -What kind of FEEDBACK LOOP IS THIS?

1) Positive + 2) Negative -



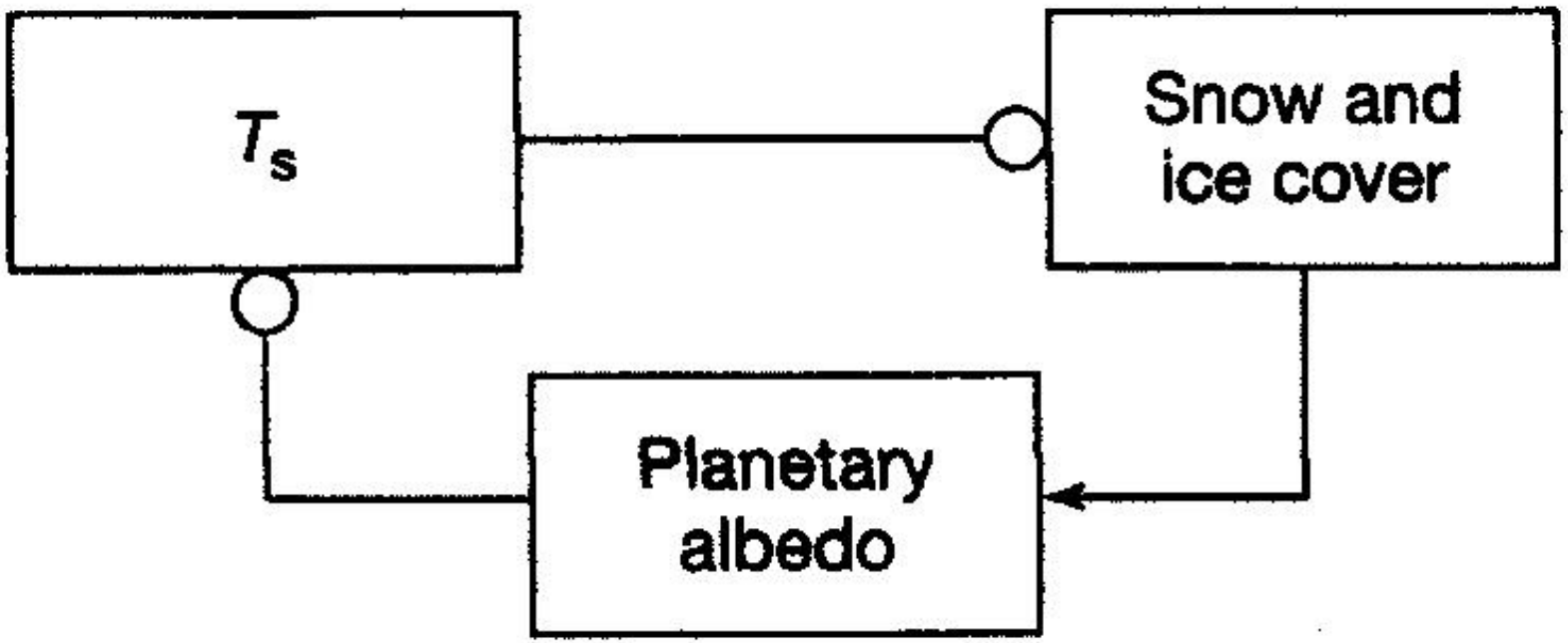
POSITIVE FEEDBACK LOOP
that amplifies the effect!



SNOW AND ICE ALBEDO Feedback

What kind of FEEDBACK LOOP IS THIS?

1) Positive + 2) Negative -



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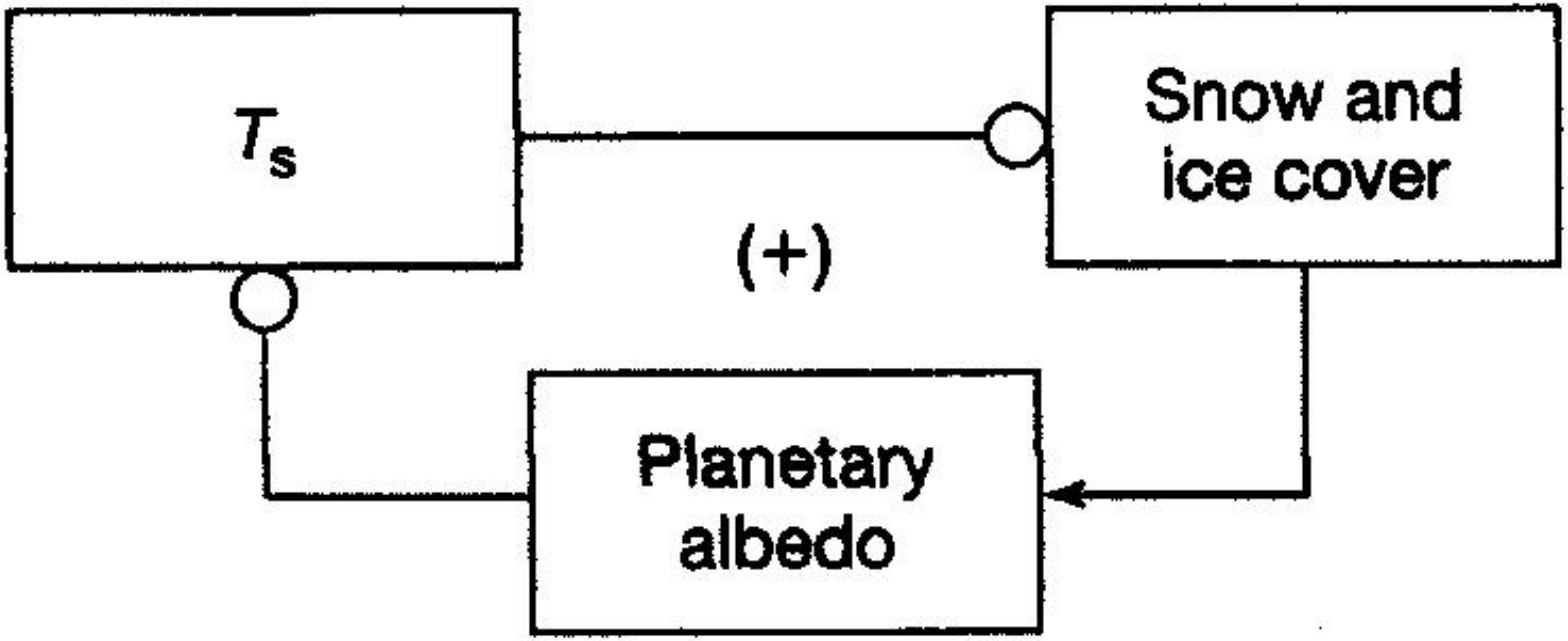
ALSO a POSITIVE FEEDBACK LOOP that amplifies the effect!

but

HOW DOES IT WORK?



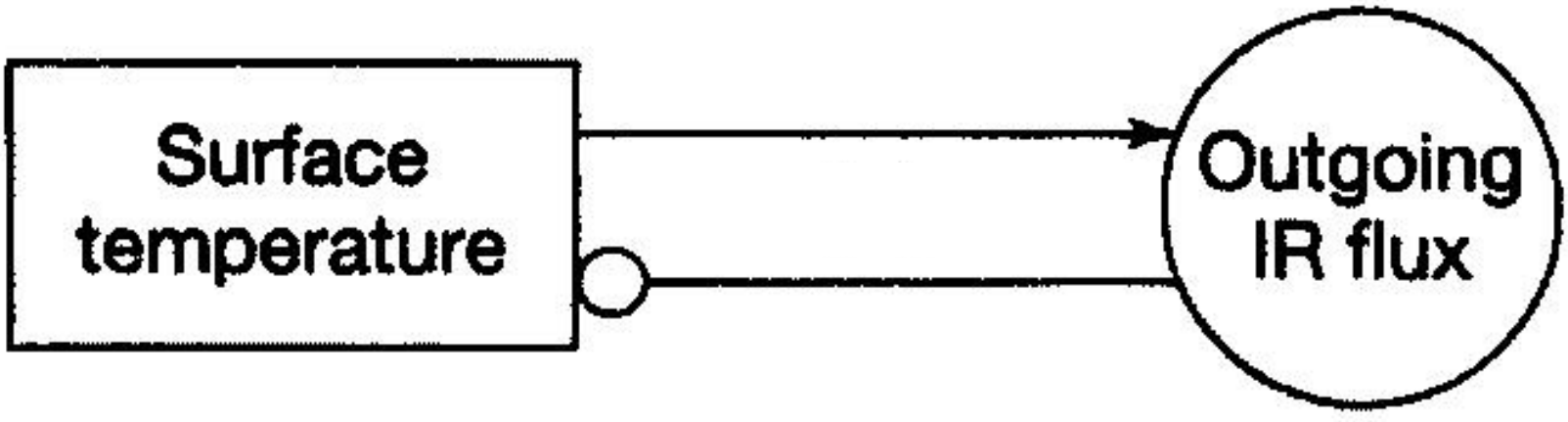
ALBEDO REVIEW →

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

OUTGOING INFRARED ENERGY FLUX / TEMPERATURE Feedback

Q2: What kind of FEEDBACK LOOP IS THIS?

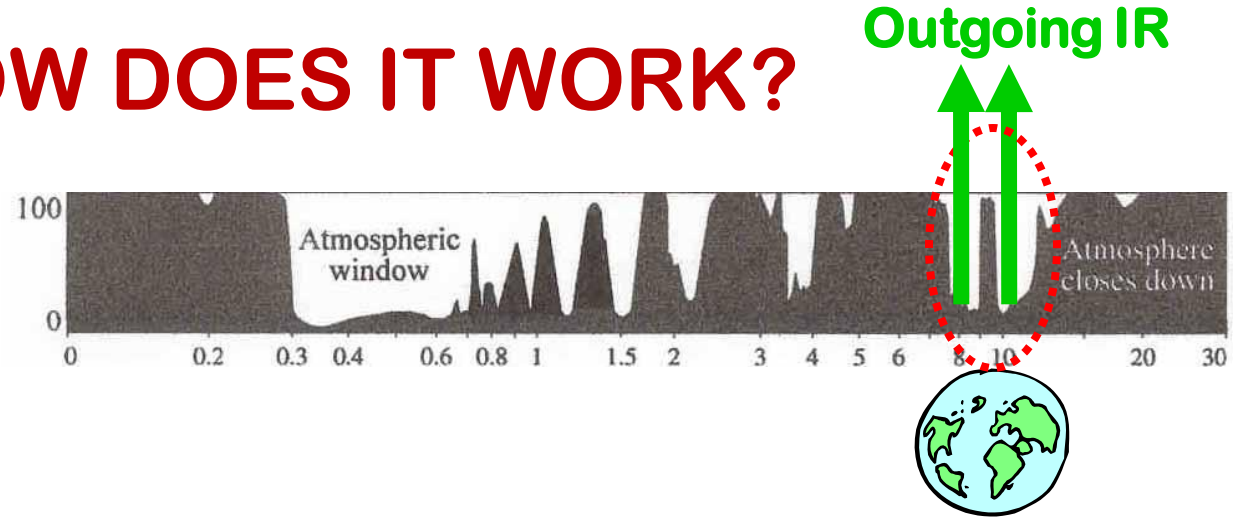
1) Positive + 2) Negative -

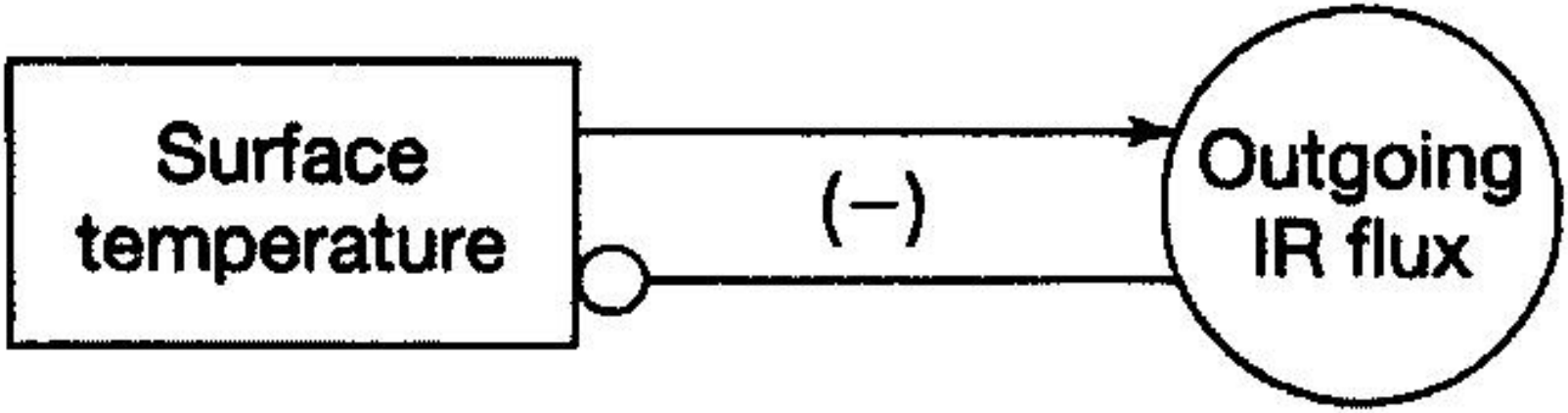


NEGATIVE FEEDBACK LOOP

that is self-regulating!

HOW DOES IT WORK?





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

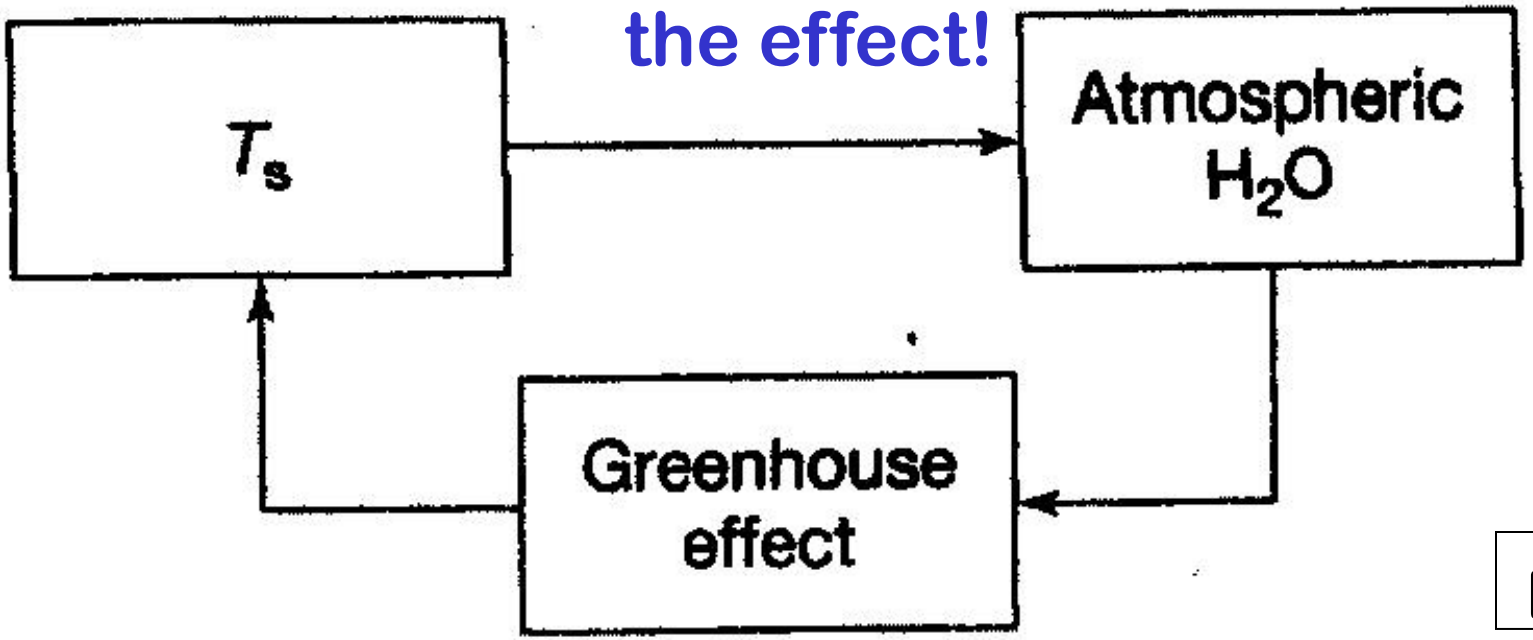
Review:

WATER VAPOR Feedback in the Earth-Atmosphere

What kind of FEEDBACK LOOP IS THIS?

Positive + OR Negative -

POSITIVE FEEDBACK LOOP that amplifies the effect!



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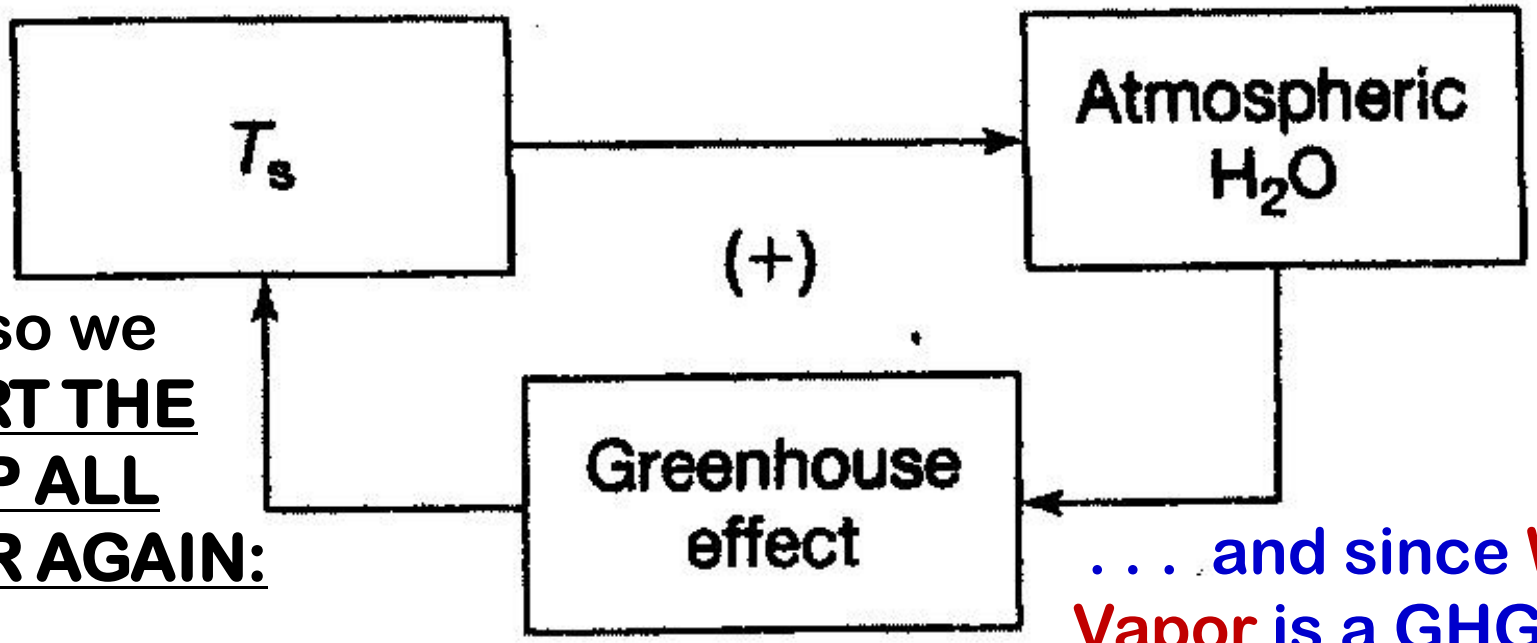
START HERE:

If the temperature of the Earth's surface (Ts) DECREASES ↓. . . .

. . . the colder temperatures will reduce evaporation, which will result in a DECREASE ↓ in the amount of Water Vapor in the atmosphere . . . . .



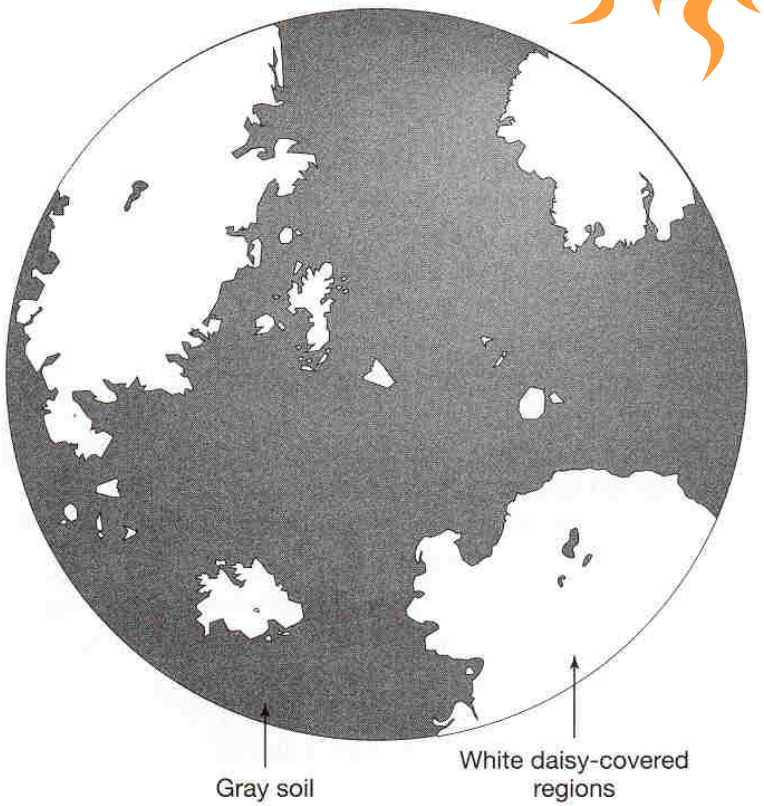
And so we **START THE LOOP ALL OVER AGAIN:**

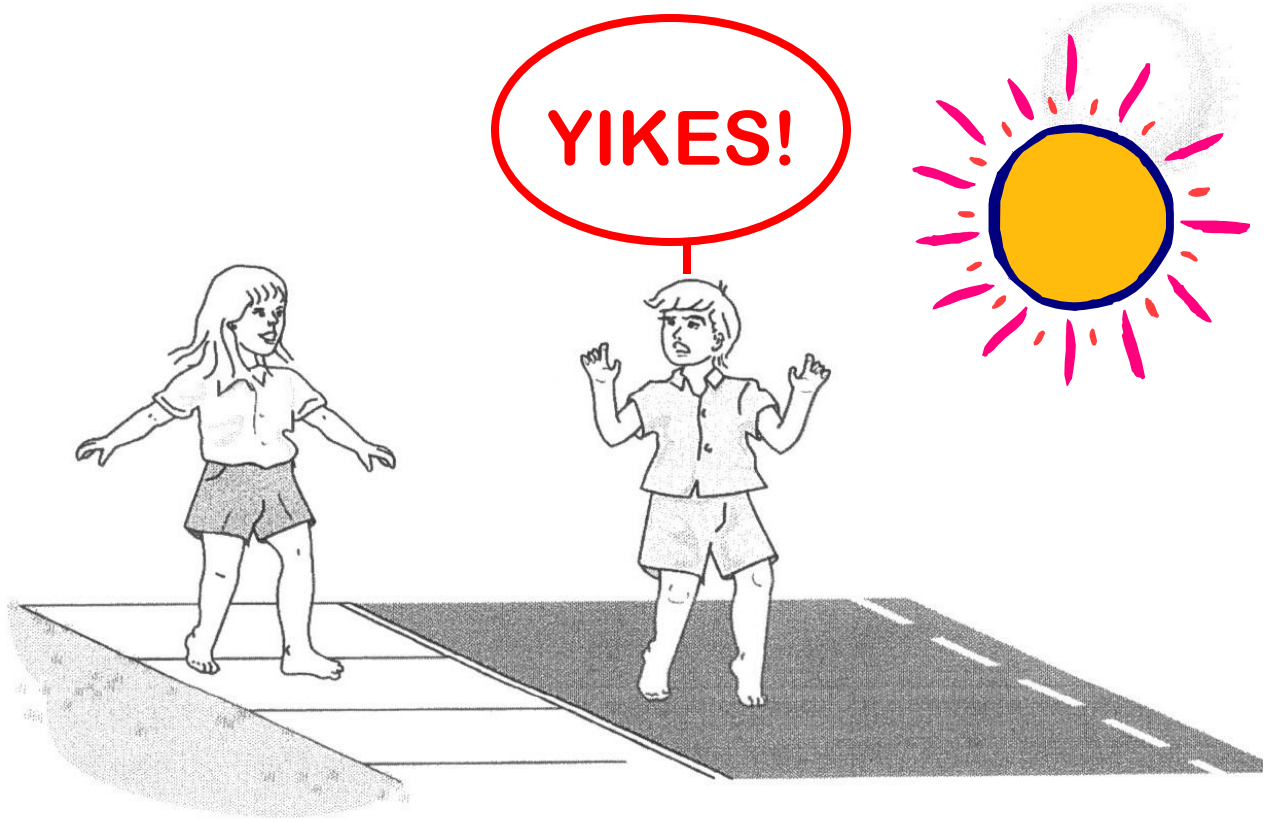
. . . and since Water Vapor is a GHG, the Greenhouse Effect will then DECREASE ↓ . . . .

. . . and with a weaker GHE, the temperature (Ts) will DECREASE further ↓

AMPLYFYING the initial perturbation!!

Ok, so what's this Daisyworld Climate System all about and why should I care??????





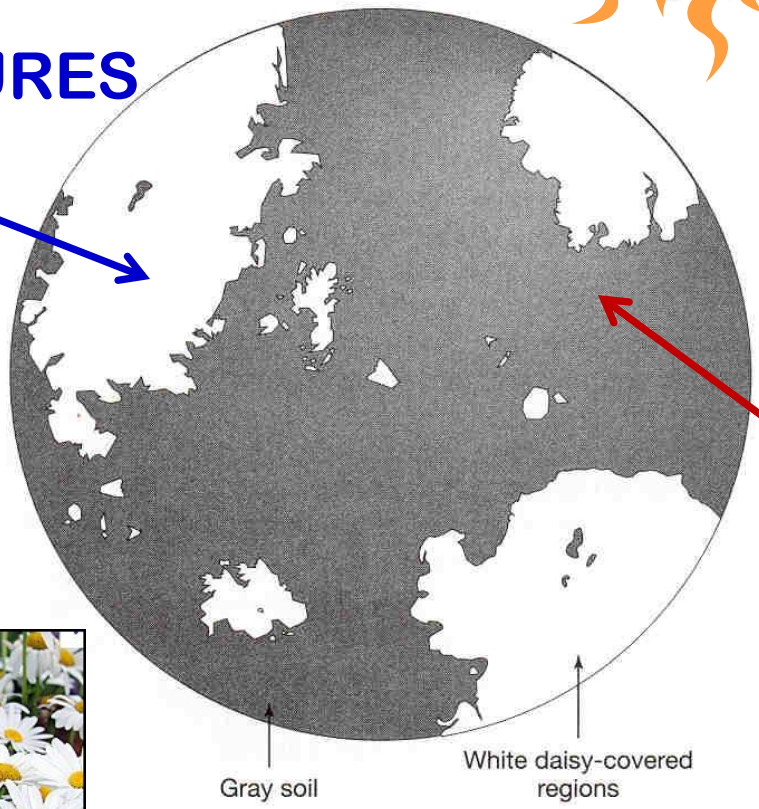
HIGH ALBEDO **LOW ALBEDO**

Review

HIGH albedo,
HIGH reflectivity,
& LOW absorption
➔ COOL TEMPERATURES

FEW or NO DAISIES

Lots of WHITE DAISIES

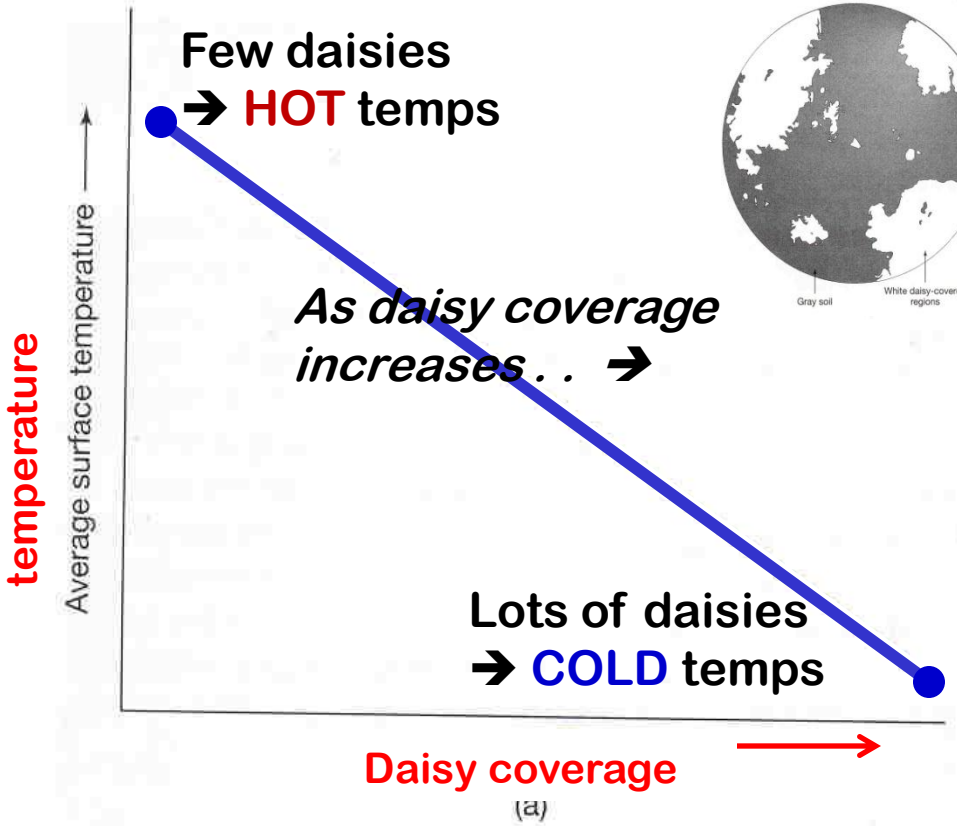


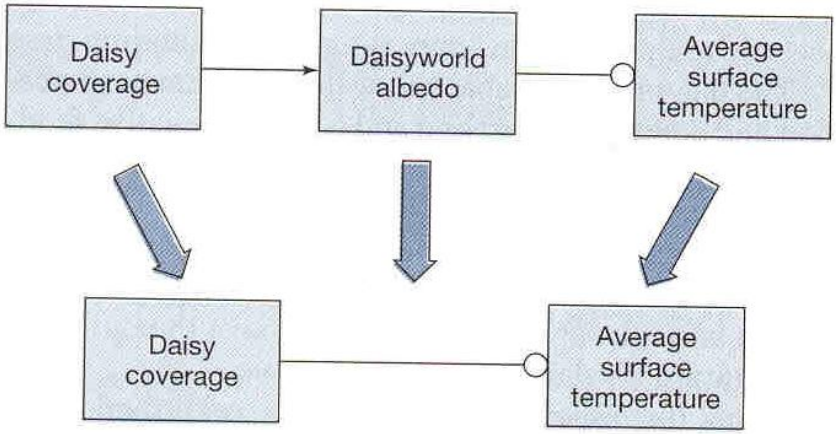
LOW albedo,
LOW reflectivity,
& HIGH absorption
➔ HOT TEMPERATURES

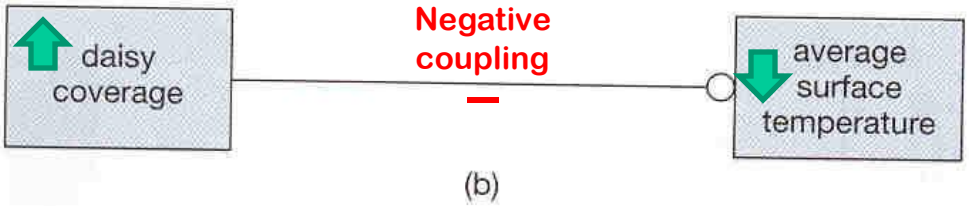
HOW DAISY COVERAGE AFFECTS TEMPERATURE:

An increase in daisy coverage ➔ a decrease in surface temperature

WHY? because more sunlight is reflected back (albedo increases) ➔ less sunlight is absorbed ➔ cooler temps







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Defined:

EQUILIBRIUM STATE

= a state in which a system is in equilibrium

stated another way:

= the state in which the system will remain unless something disturbs it.)

An equilibrium state can be:

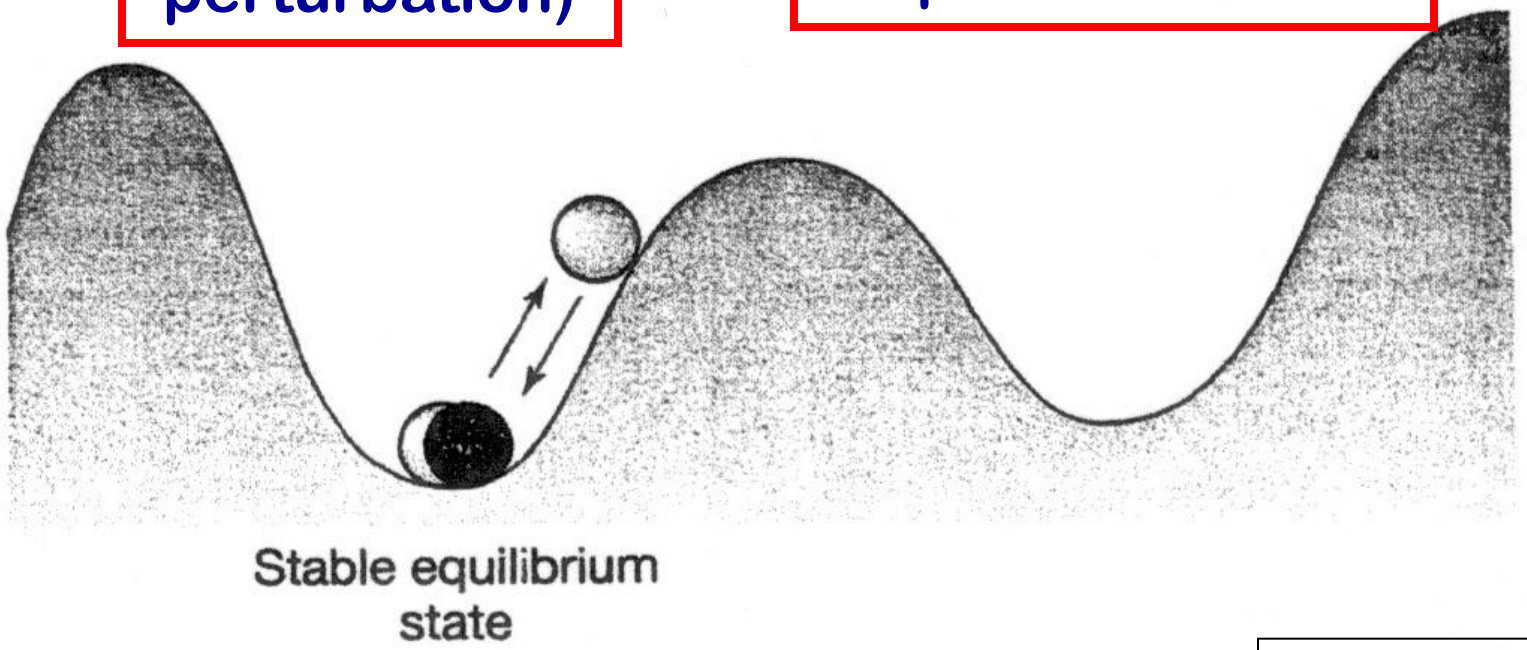
stable or unstable.

A negative feedback loop
(can also be described as)
a STABLE EQUILIBRIUM STATE :

A modest disturbance (short-term perturbation)

→

response that tends to return the system to its equilibrium state

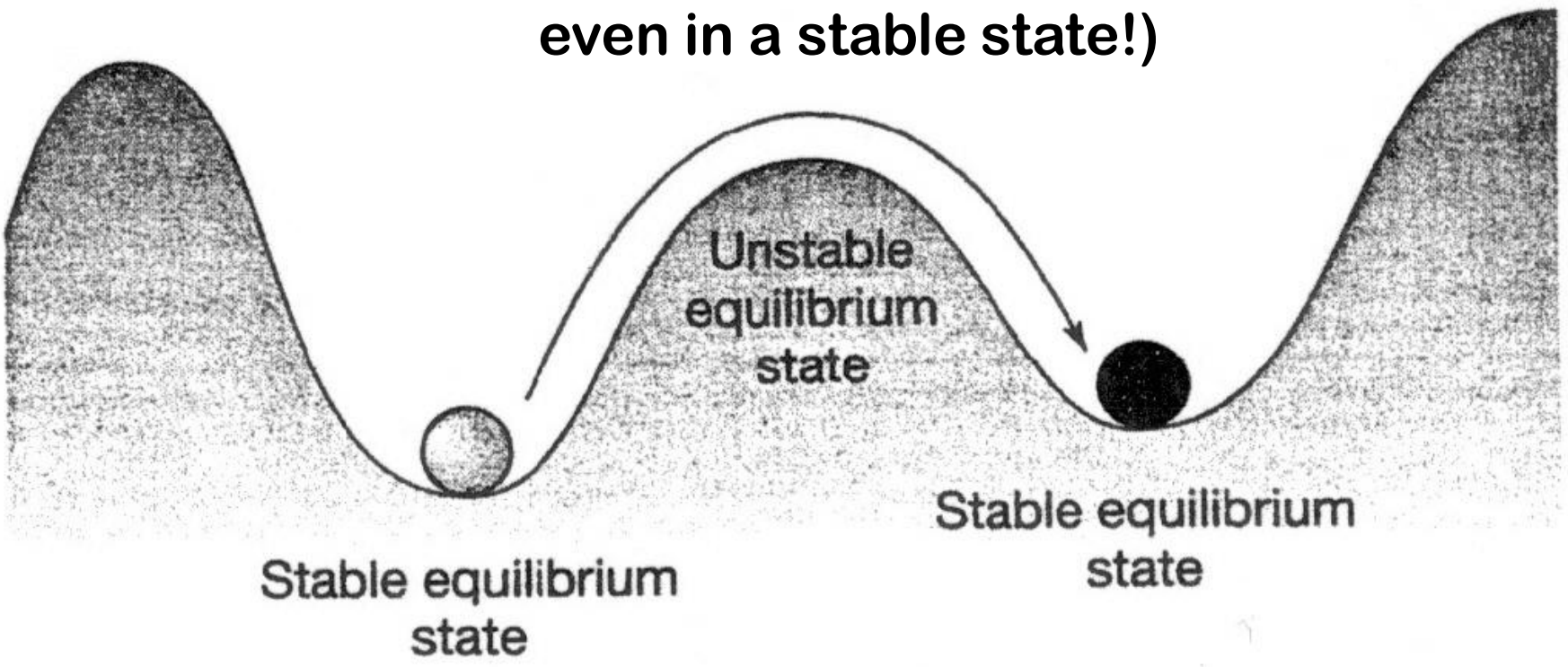


Stable equilibrium state

See this figure on p 63

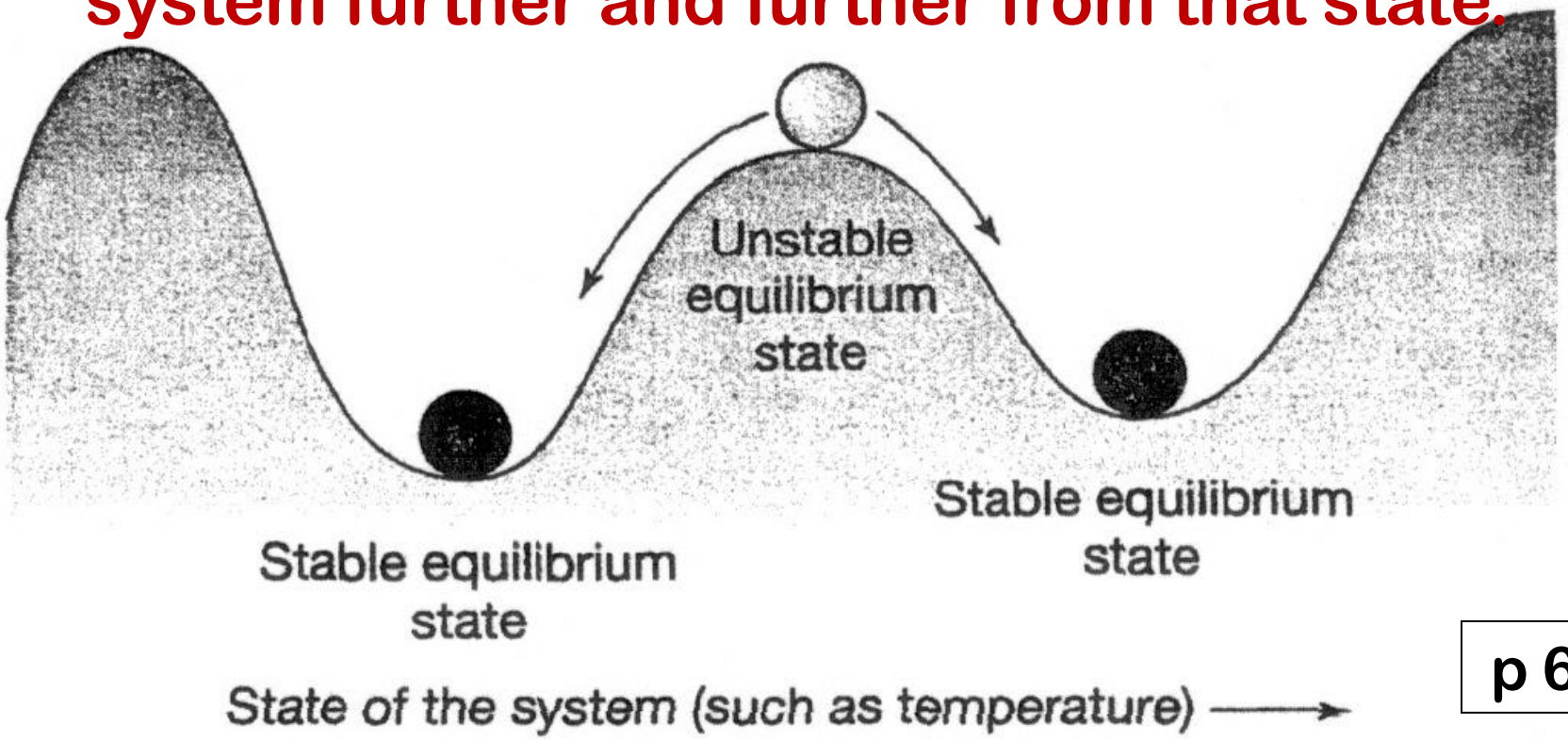
A LARGE OR MORE PERSISTENT DISTURBANCE (a forcing) can carry the system to a different STABLE equilibrium state

(so there area some limits to stability, even in a stable state!)



A positive feedback loop can also be described as an UNSTABLE EQUILIBRIUM STATE :

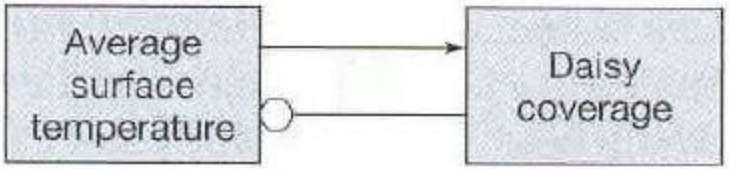
the slightest disturbance from a comfortable state may lead to system adjustments that carry the system further and further from that state.



Lesson 1 of the Daisyworld example:

As the temperature increases, Daisyworld can adapt at first:
as the daisies increase, their high albedo reflects back the sunlight and regulates the temperature

➔ cooling things off and slowing down the temperature increase.



- This is a _____ feedback loop
  negative & self-regulating
  positive & self-amplifying

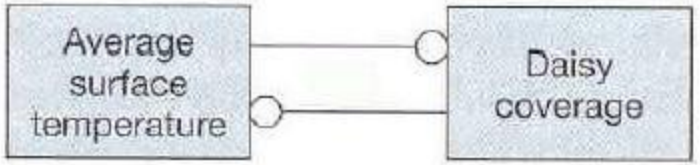
- In the example above, the Daisyworld system
  [IS / IS NOT] in equilibrium.

Lesson 2 of the Daisyworld example . . . as time goes on:

However, if **increased warming** occurs and the **temperature** increases to a point where it **warms too much for the daisies** then the **daisies will start to die off.**

➔As the daises die off, the albedo will decrease, more sunlight will be absorbed instead of reflected back, and the temperature will get even hotter ➔ dead daisies.

- This is a _____ feedback loop
  - negative & self-regulating
  - positive & self-amplifying



- In this example, the Daisyworld system [IS / IS NOT] in equilibrium

MAIN LESSON OF DAISYWORLD!

If certain thresholds are crossed:

NEGATIVE FEEDBACK loops that
normally regulate temperature

Can be replaced by POSITIVE FEEDBACK loops
that amplify temperature!

THOUGHT QUESTION:

Could this happen on OUR PLANET EARTH??
Why or Why not?

RECAP/ SUMMARY

The presence of FEEDBACK LOOPS leads to the establishment of EQUILIBRIUM STATES

- **Negative feedback loops** establish **STABLE** equilibrium states that are resistant to a range of perturbations; the system responds to modest perturbations by returning to the stable equilibrium state

- **Positive feedback loops** establish **UNSTABLE** equilibrium states. A system that is poised in such a state will remain there indefinitely. However, the slightest disturbance carries the system to a new state.

The last part of Chapter 2 illustrates that:

FEEDBACK FACTORS that are negative provide a "buffer" from FORCINGS – they allow the daisies to survive LONGER after a climate change (e.g., an increase in solar luminosity) than they could have survived if NO feedback processes were in operation.

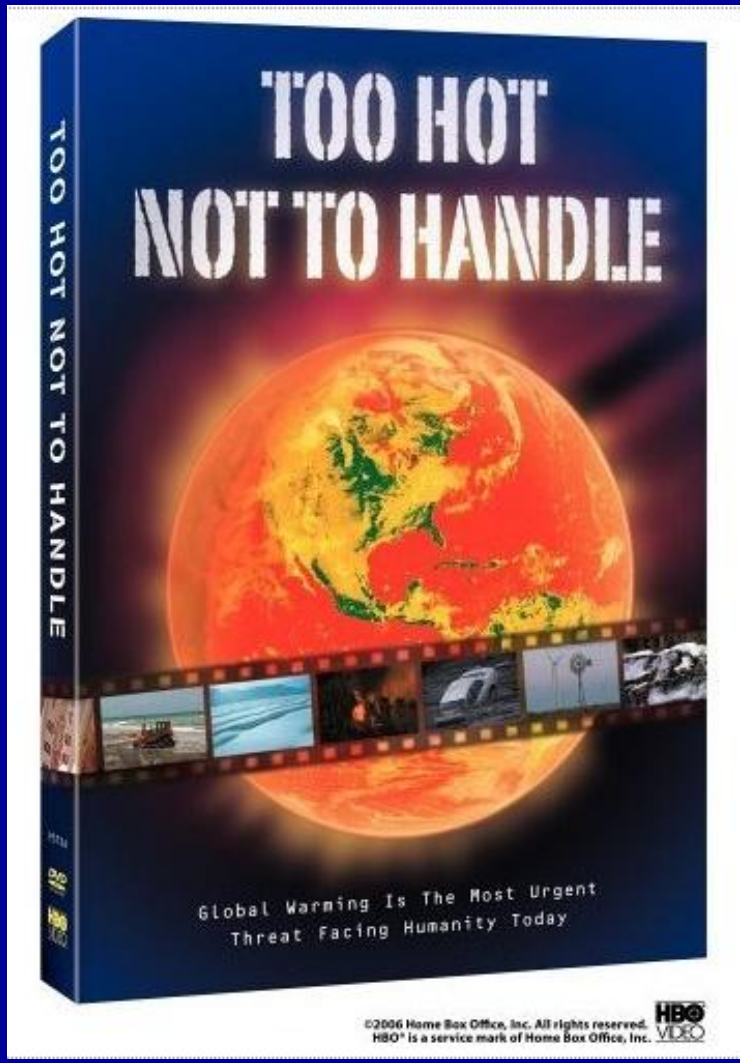
We will learn that this is EXACTLY what is happening on EARTH under many circumstances.

What we are worried about are the circumstances when feedback factors that are POSITIVE under a climatic FORCING.

Watch this short segment of the video carefully.

Can you recognize the FEEDBACK LOOP ???

(HINT: it is one of the loops shown on p 65 in Class Notes)



Q3: WHICH LOOP WAS ILLUSTRATED IN THIS FILM SEGMENT?

1) Water vapor feedback loop

2) Snow/ice albedo feedback loop

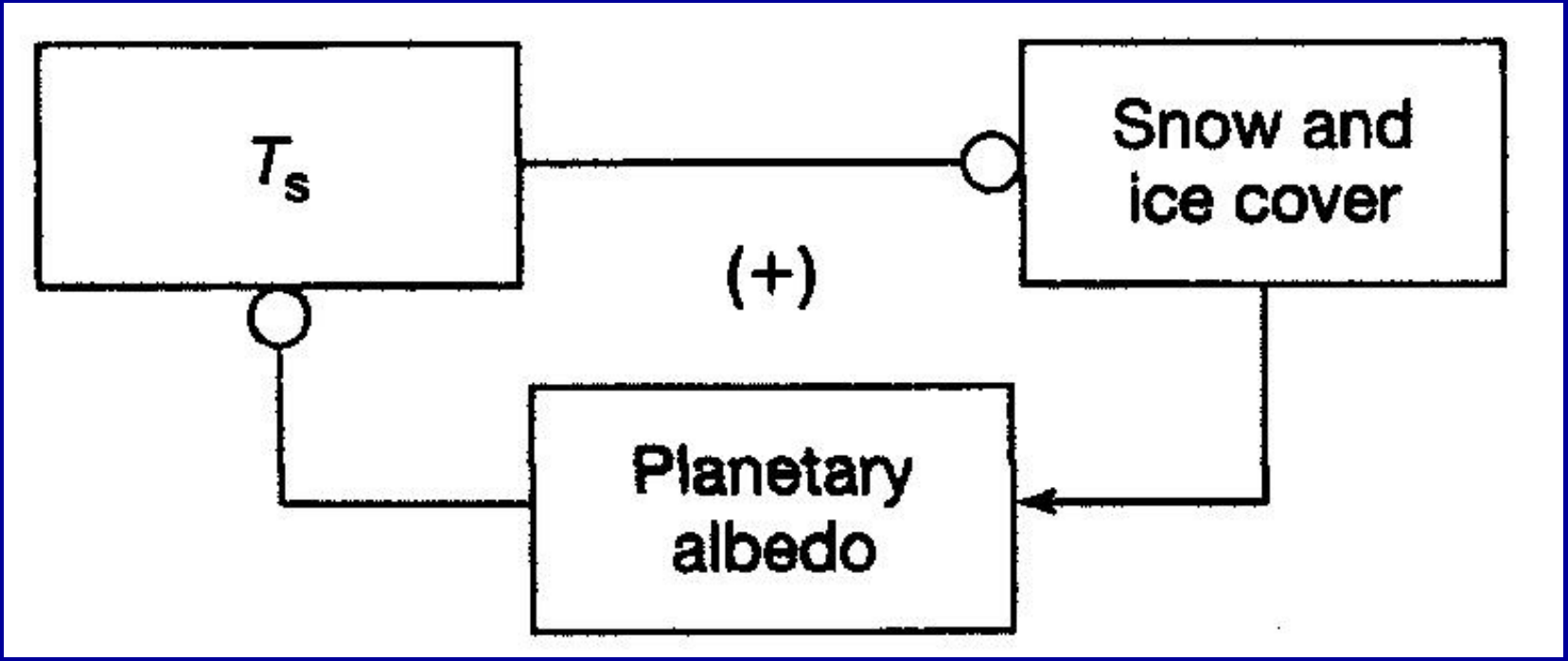
3) Outgoing IR / Temperature Feedback Loop

4) Daisyworld

5) None of the Above

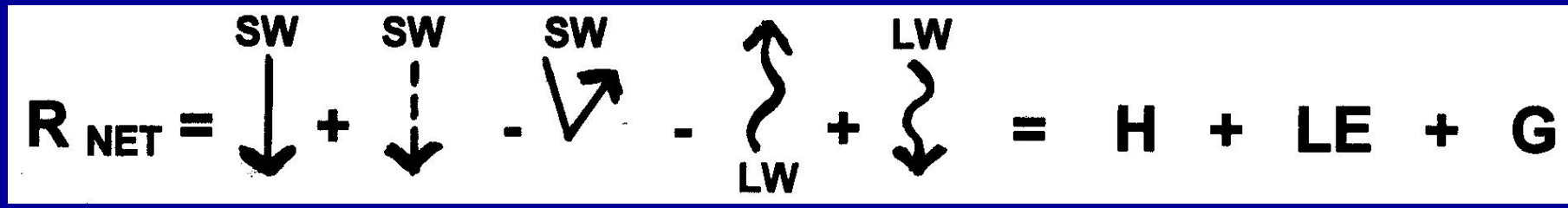
ANSWER!

SNOW AND ICE ALBEDO Feedback



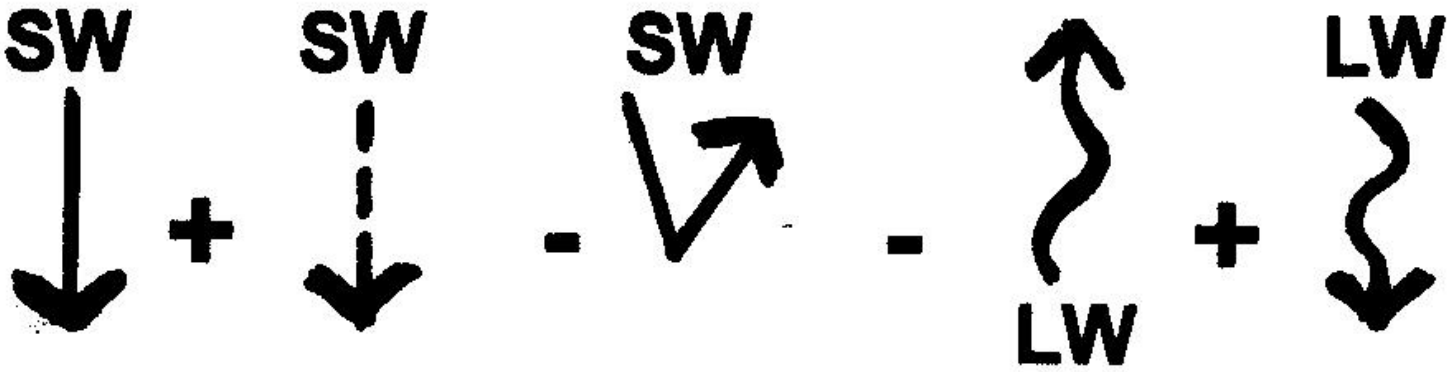
Back to . . .
THE EARTH'S GLOBAL ENERGY BALANCE . . .

The <u>COMPLETE</u> EQUATION!

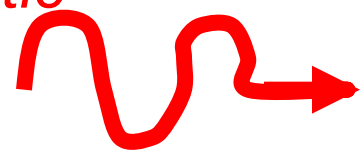


Flip back p 55 top

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

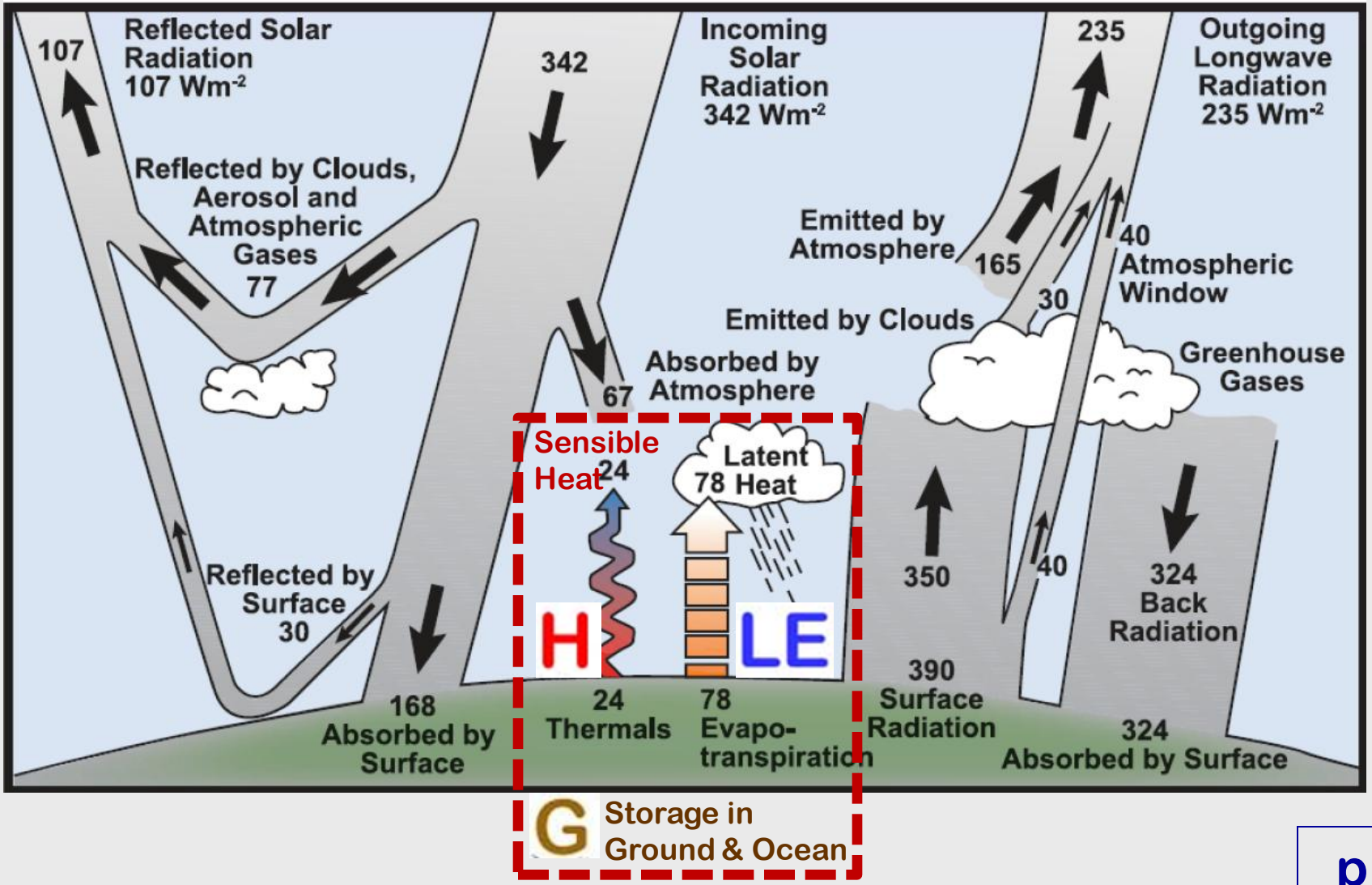
ENERGY CONDUCTED into soil or CONVECTED & CONDUCTED into water (e.g. ocean) and temporarily STORED THERE

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

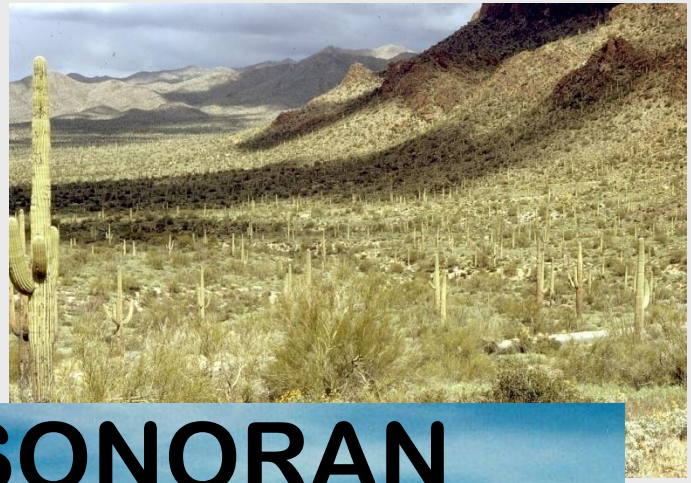
ENERGY PATHWAYS

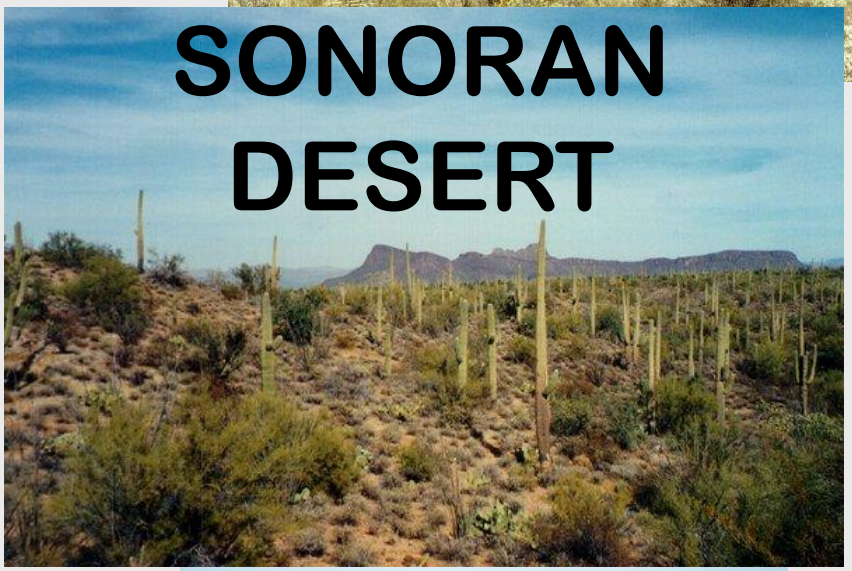
Representation of the Energy Balance & Energy Pathways

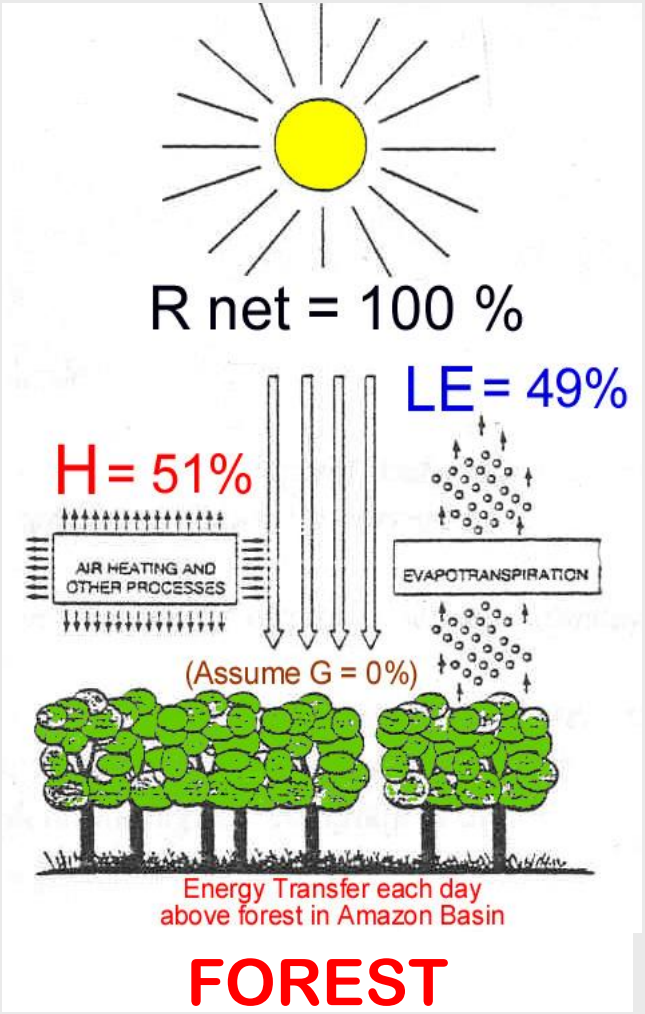
Throughout the whole Earth-Atmosphere system, the energy units balance out, energy is conserved, and the 1st Law of Thermodynamics applies.




AMAZON RAIN
FOREST

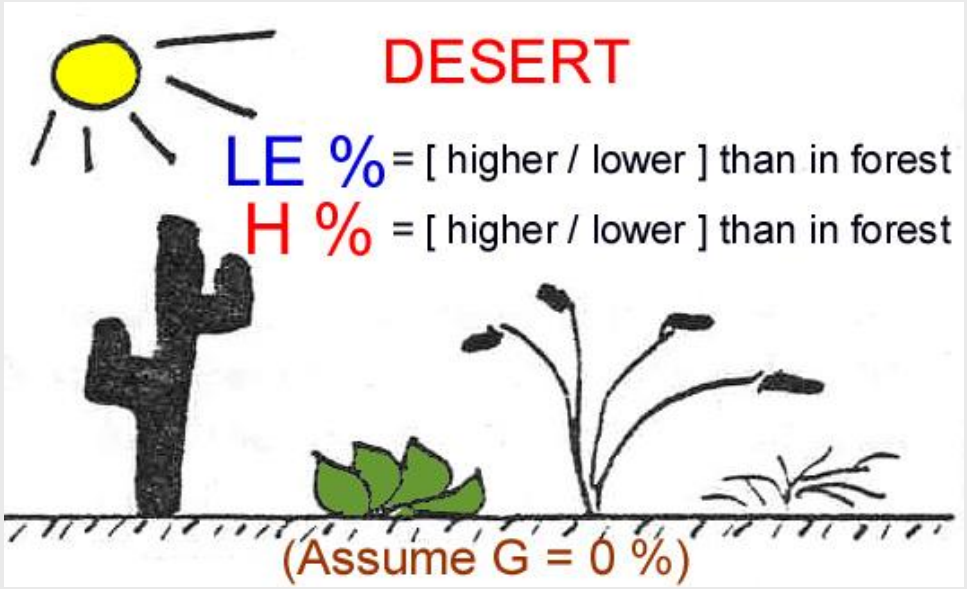



SONORAN
DESERT



FOREST

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



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

1 = HIGHER in the desert

2 = LOWER in the desert

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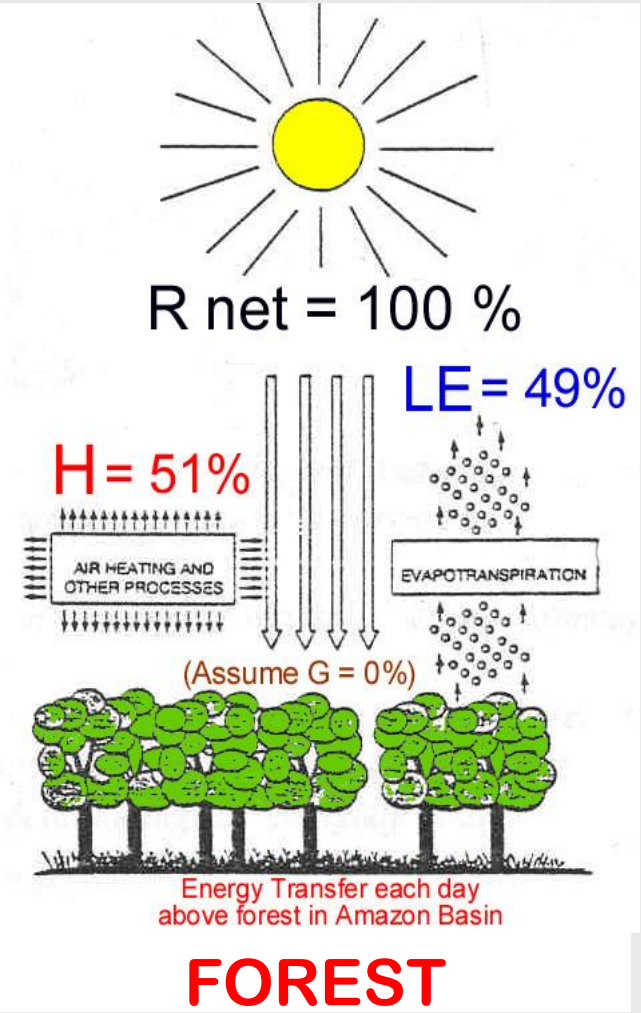

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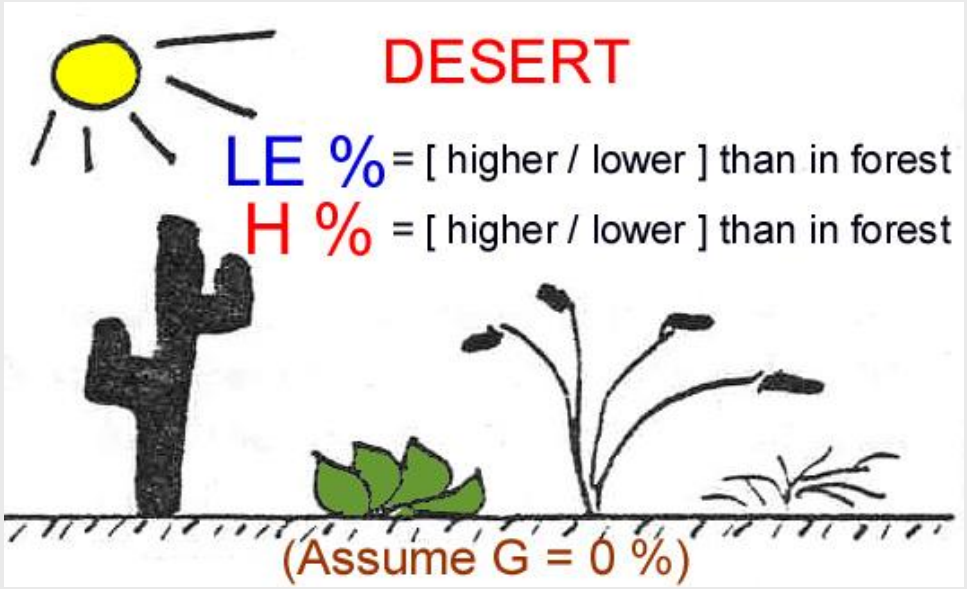

Compared to the Amazon Rain Forest the % of R_{NET} in LE will be . .

1 = HIGHER in the desert

2 = LOWER in the desert

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

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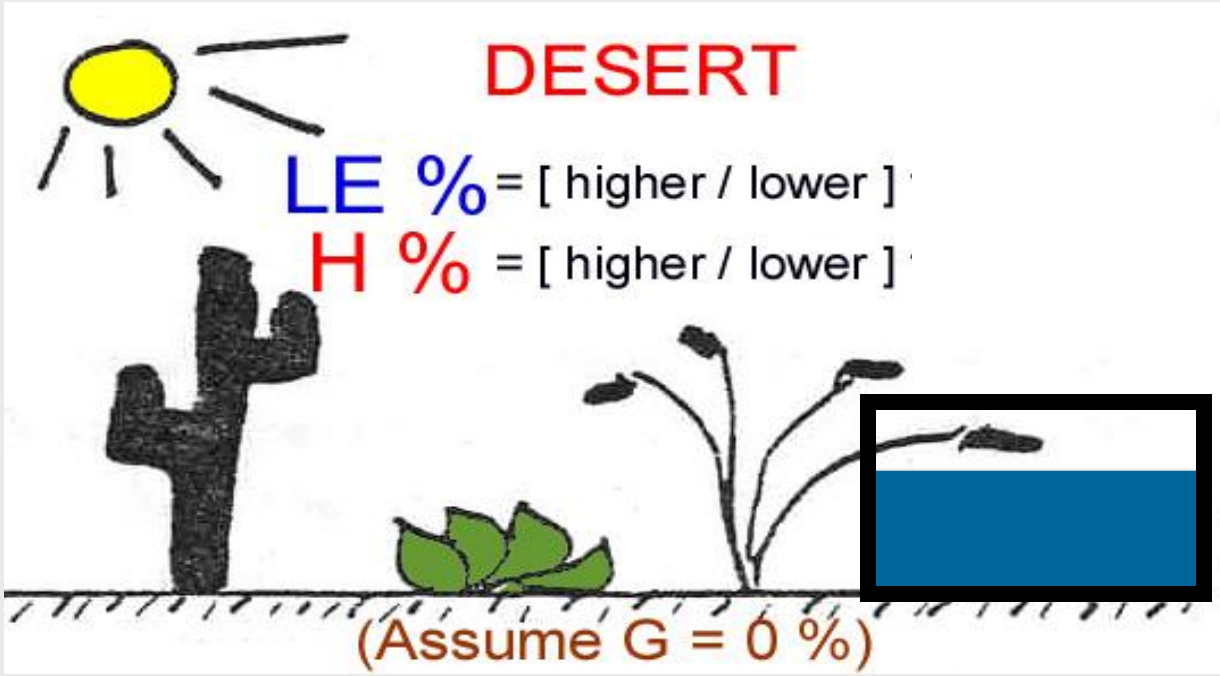
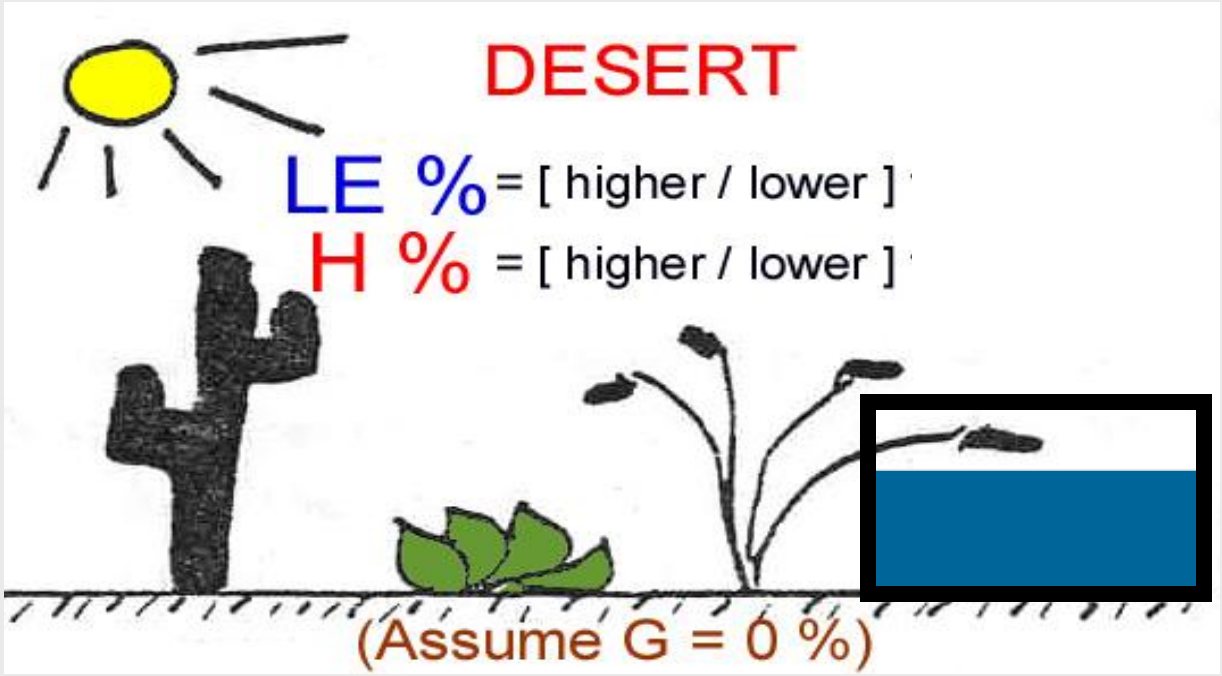


How would the % of LE in the Desert change?

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?



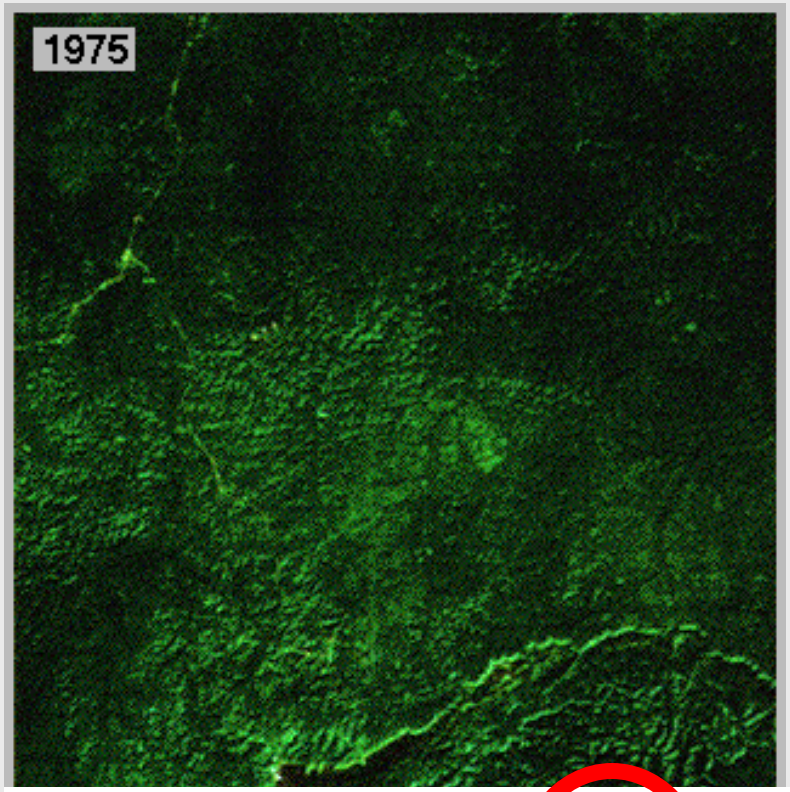
How would the % of LE in the Desert change?

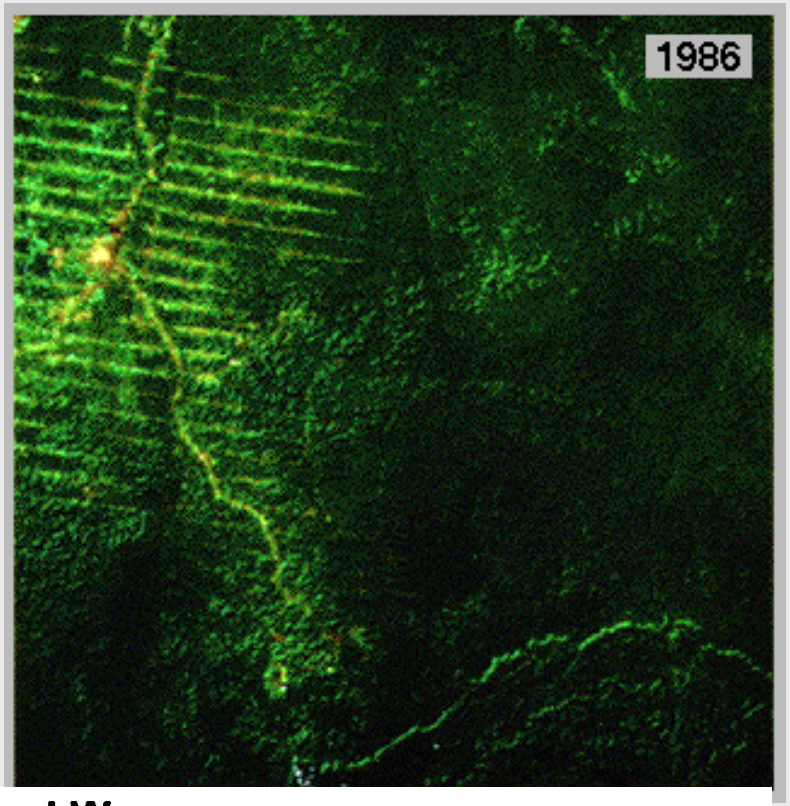
Compared to natural desert with no CAP canals, the % or R_{NET} in LE will be . . .

1 = HIGHER with CAP canals

2 = LOWER with CAP canals

How does DEFORESTATION change the local energy balance???





$$R_{NET} = \downarrow_{SW} + \downarrow_{SW} - \nearrow_{SW} - \updownarrow_{LW} + \sim_{LW} = H + LE + G$$

Less

More → cooler temperatures?

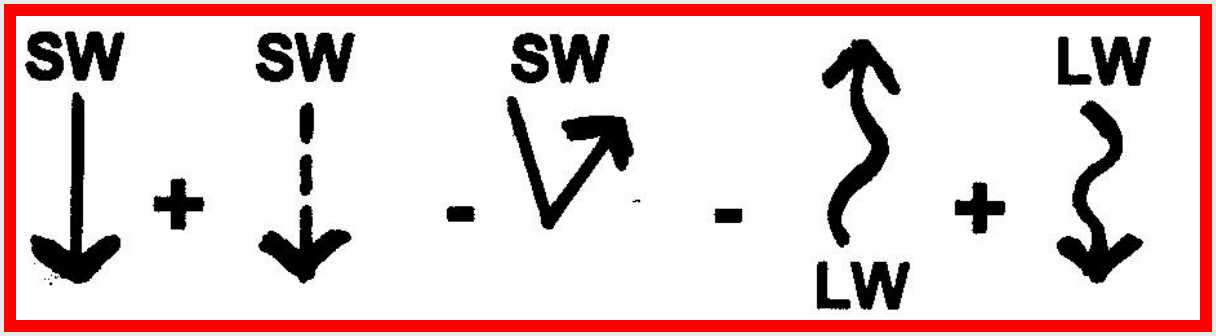
More → warmer temperatures?

G-5 ASSIGNMENT (10 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

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G-5 ASSIGNMENT (10 pts)

Applying the Energy Balance Terms

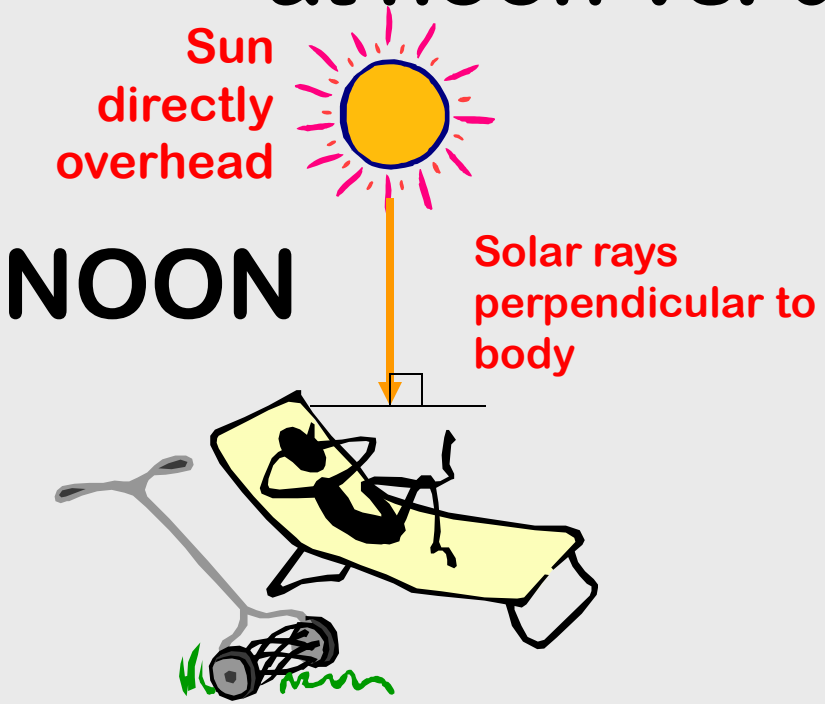
Don't forget to SIGN IN
on the G-5 FORM and on the slips
of paper for the item #s you worked
on and wrote up!

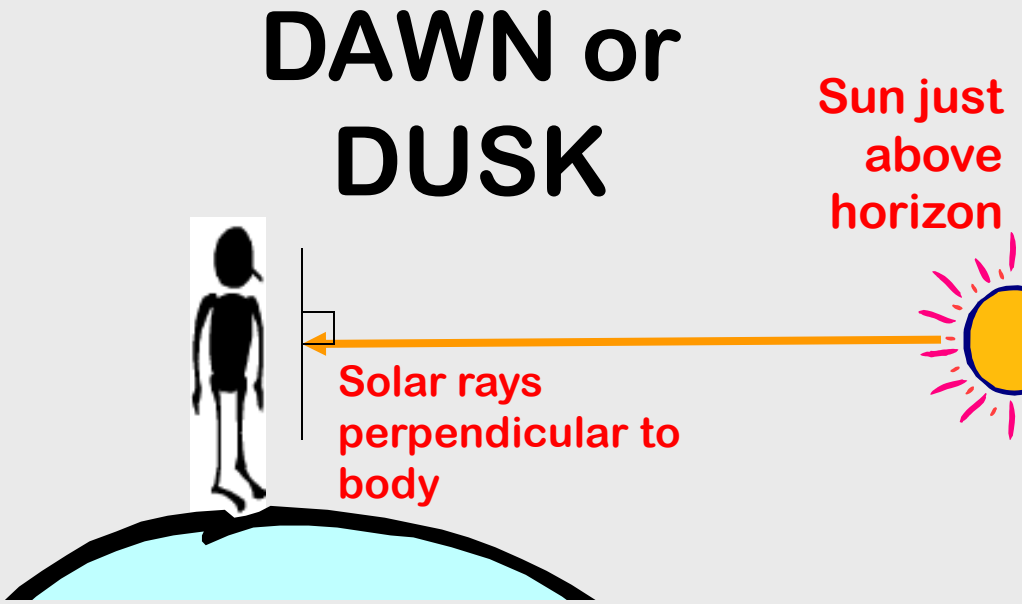
1. blue skies

2. Sunglasses while skiing

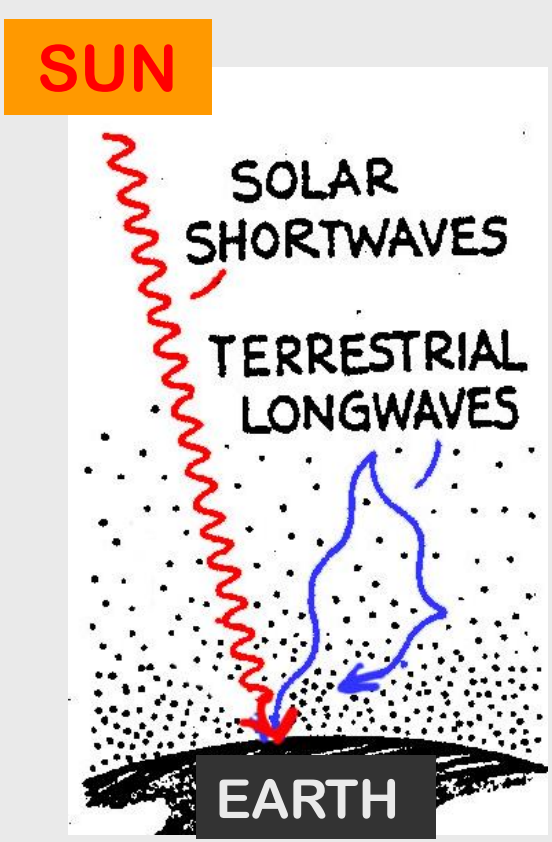
3. Bright even though cloudy

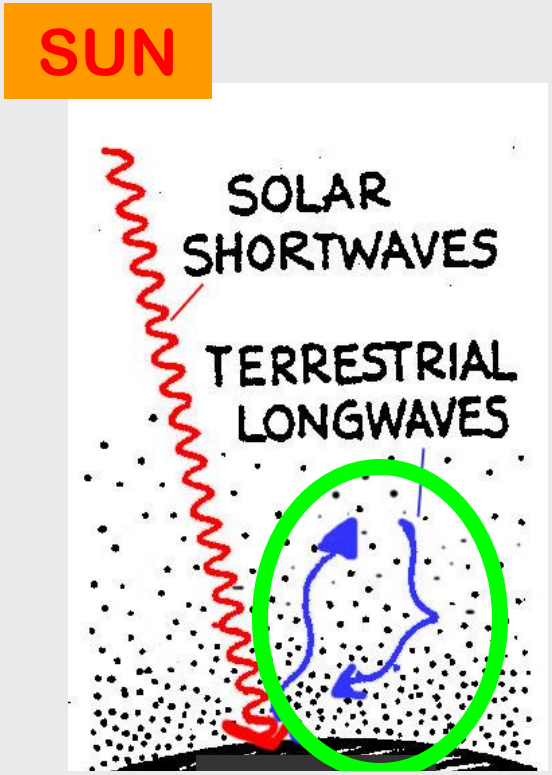
4. More intense solar radiation (tan /skin damage, etc.) at noon vs. dawn or dusk



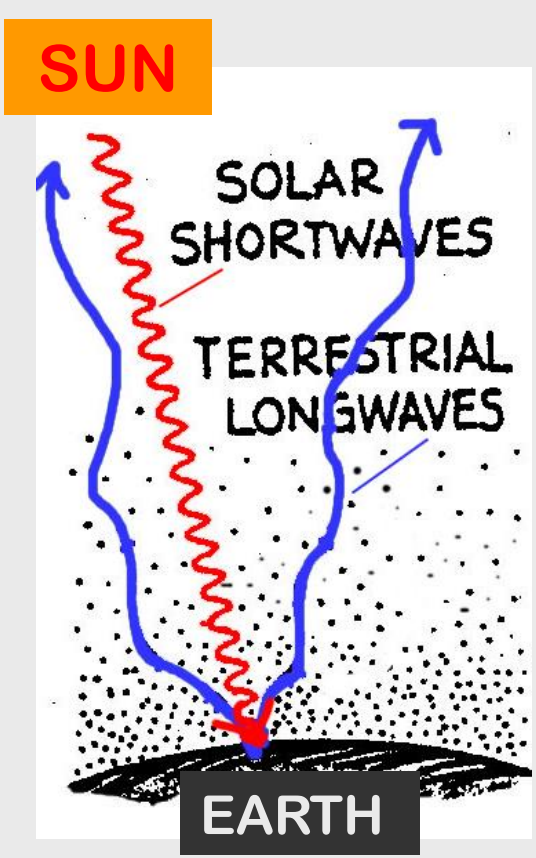


6. illustrate the GREENHOUSE EFFECT:





Greenhouse effect



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

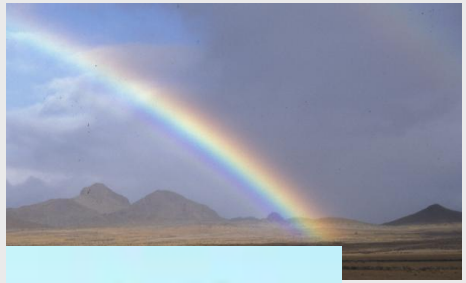
6. Red sunsets

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-5 ASSIGNMENT (10 pts) (cont.)

Applying the Energy Balance Terms

Don't forget to SIGN IN
on the G-5 FORM and on the slips
of paper for the item #s you worked
on and wrote up!

CAREFULLY GET ALL THOSE
SLIPS OF PAPERS
BACK INTO YOUR ENVELOPE
for GRADING!!