TOPIC # 11

Introduction to Models:

UNDERSTANDING SYSTEMS & FEEDBACKS

Class notes pp 55-61

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

~ John Muir

SYMBOLIC NOTATION

- use of a picture or diagram instead of words

- abbreviation, symbol, or acronym instead of spelling out the whole word or concept:

NATS 101-GC

$ % & + - = x or *

IPCC

SYMBOLIC NOTATION (cont)

NUMBERS!!

1, 2, 8 3.8×10^{-4}

Elements and molecules:

H, He, H_2O CO_2

Formulas & Equations

$y = a + bx$ (equation for a straight line)

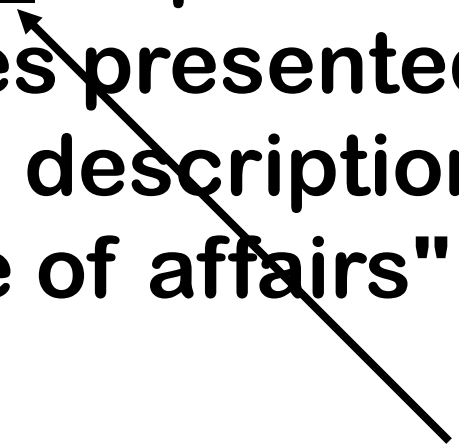
SYMBOLIC NOTATION (cont)
MODELS!

WHAT IS A MODEL?

- a representation of something (usually miniature or not to scale)
- an example for imitation or emulation
- a person or thing that serves as a pattern
- an analogy or analogue of something

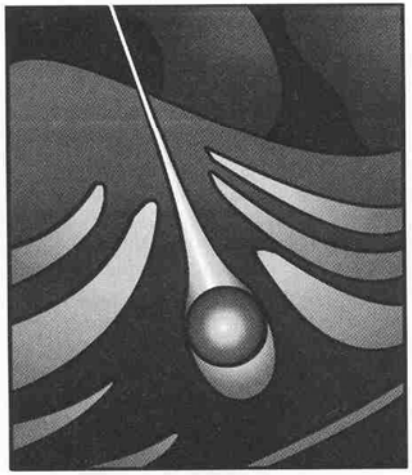
WHAT IS A MODEL?

- "a description or analogy to help visualize something that cannot be directly observed"
- or "a system of postulates, data, and inferences presented as a mathematical description of an entity or state of affairs"



Note the word “system”

CHAPTER 2



Daisyworld: An Introduction to Systems

WHAT IS A SYSTEM?

- **SYSTEM = a set of interacting components**

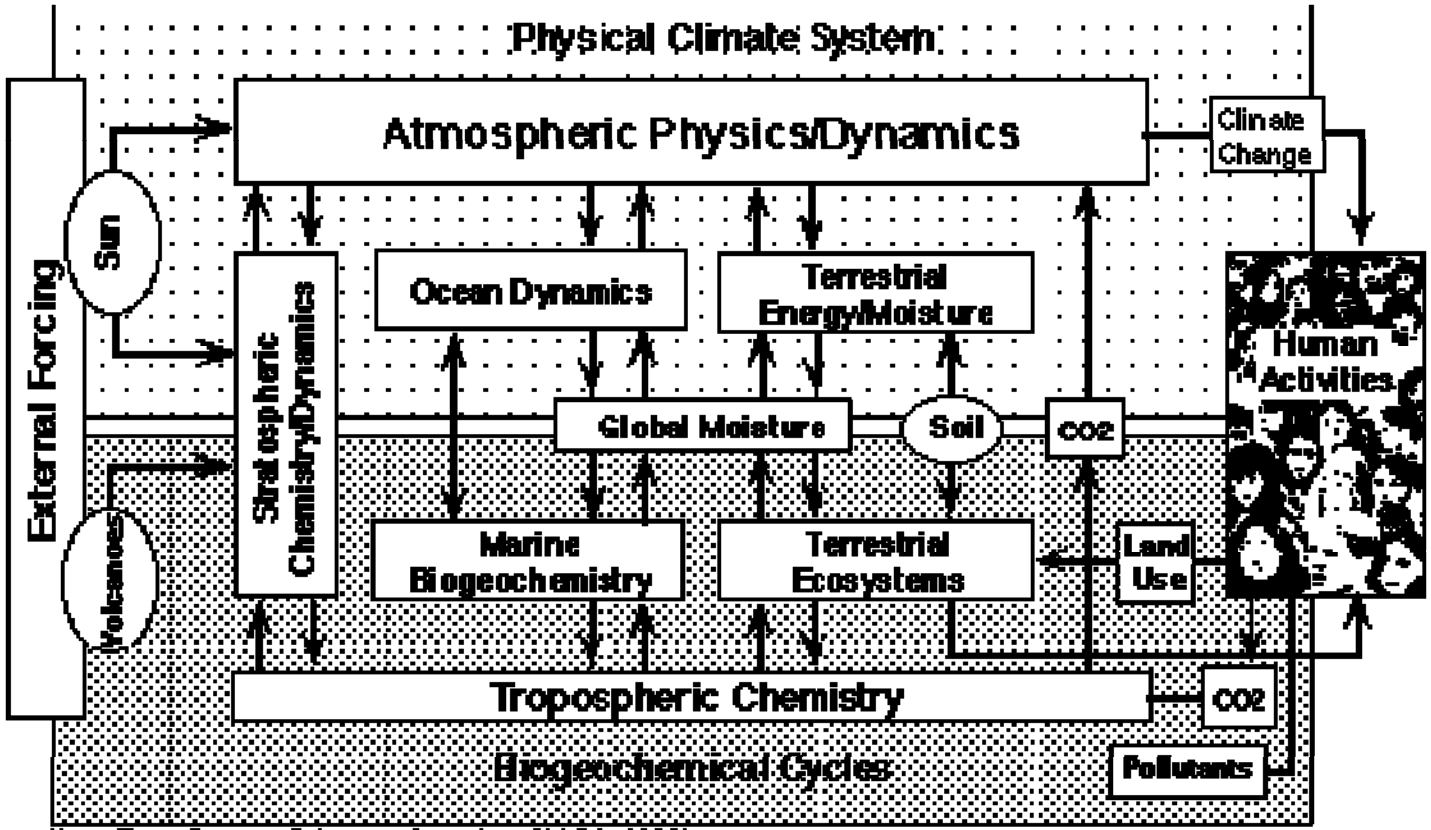
- **SYSTEM MODEL =**

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 =

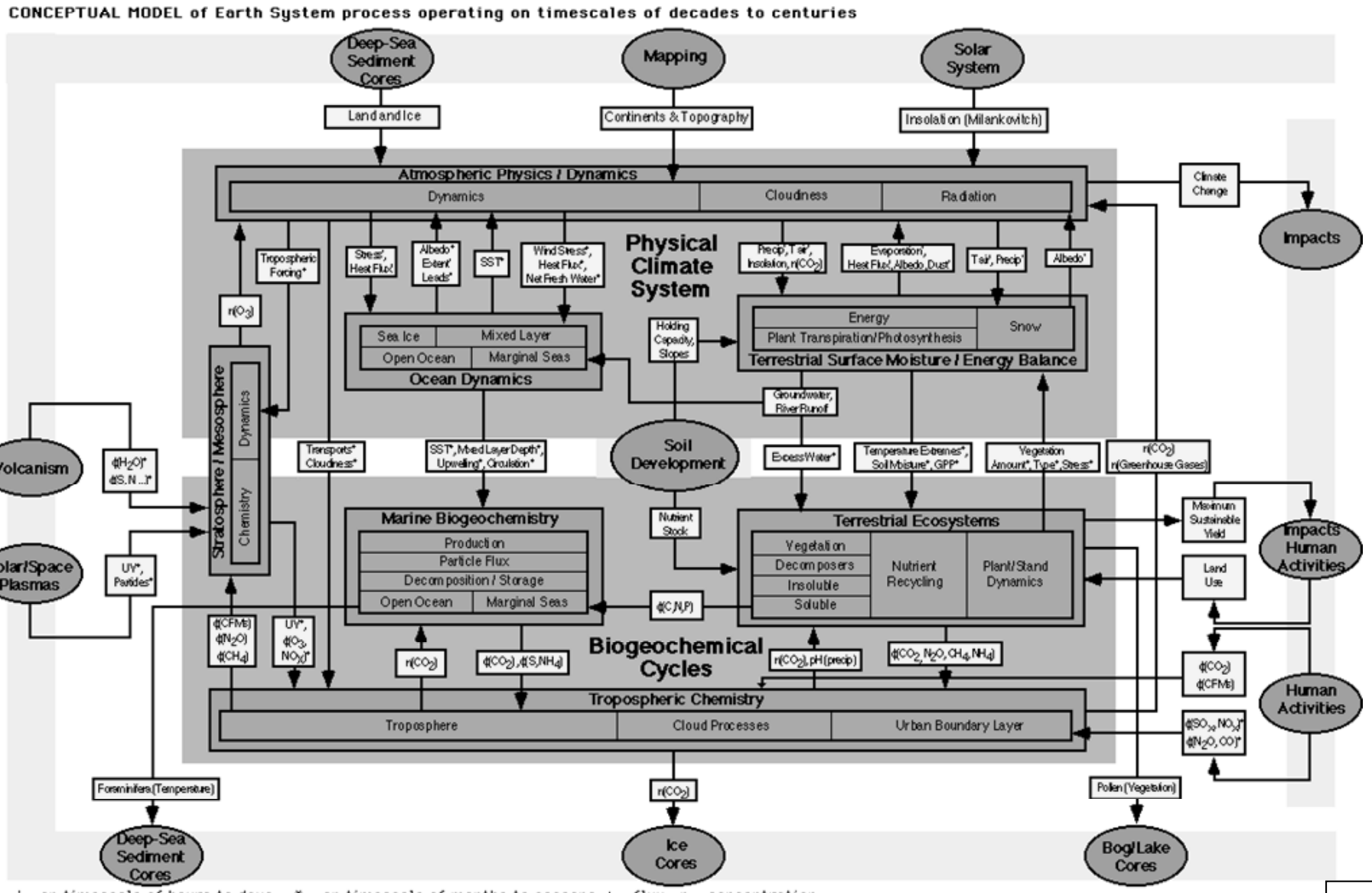
A diagram of a system that uses graphic symbols or icons to represent components in a depiction of how the system works

One example of a system diagram for a model used in global change studies:



(from Earth System Science - Overview, NASA, 1986)

Another more complicated system diagram:



COMPONENT

Component *(def)* =

An individual part of a system. A component may be a reservoir of matter or energy, a system attribute, or a subsystem.

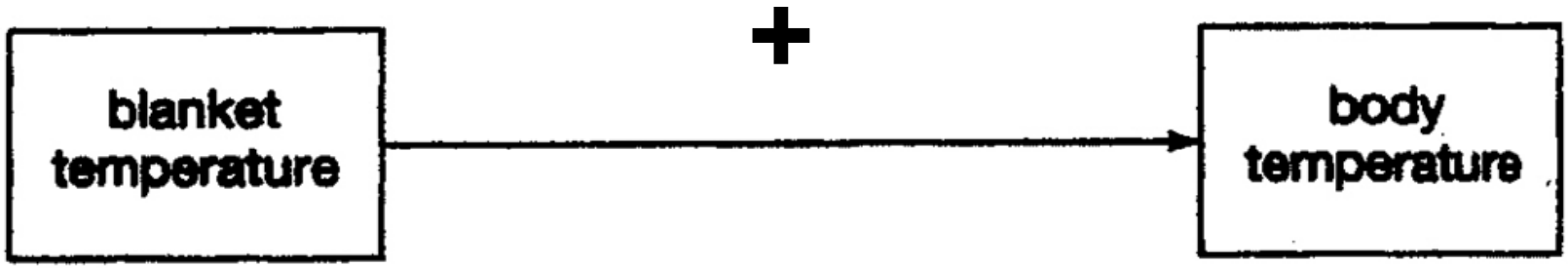
COUPLING

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:



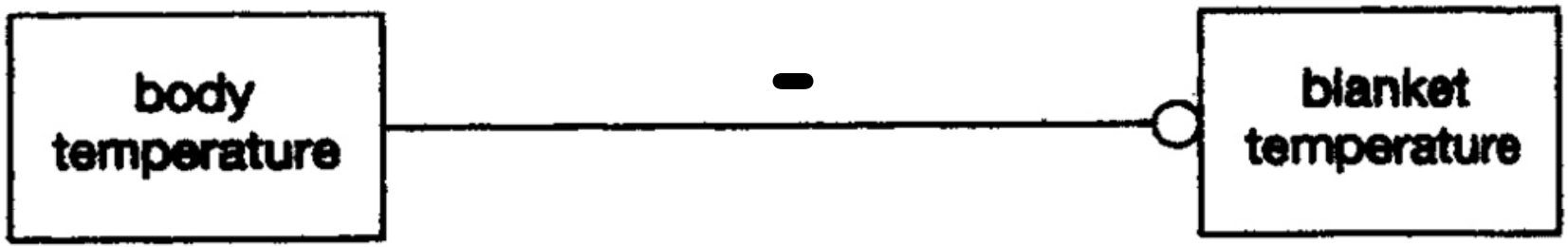
If the electric blanket's temperature INCREASES . . .

The person's body temperature will also INCREASE

Q1: What type of COUPLING IS THIS?

1) Positive + 2) 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

Q2: What type of COUPLING IS THIS?

1) Positive + 2) 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

<u>Feedback mechanism</u> ***(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.

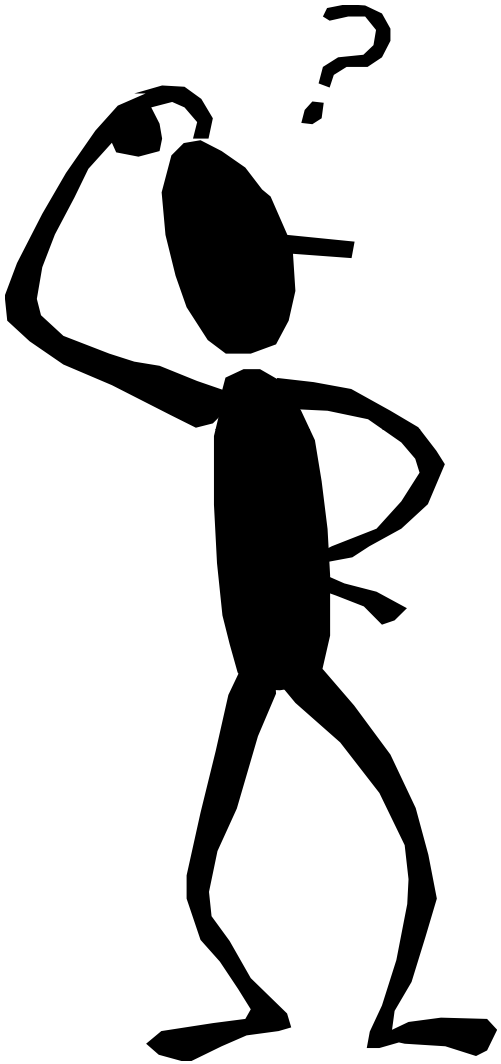
Feedback loops can be positive (+) or negative (-).

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))



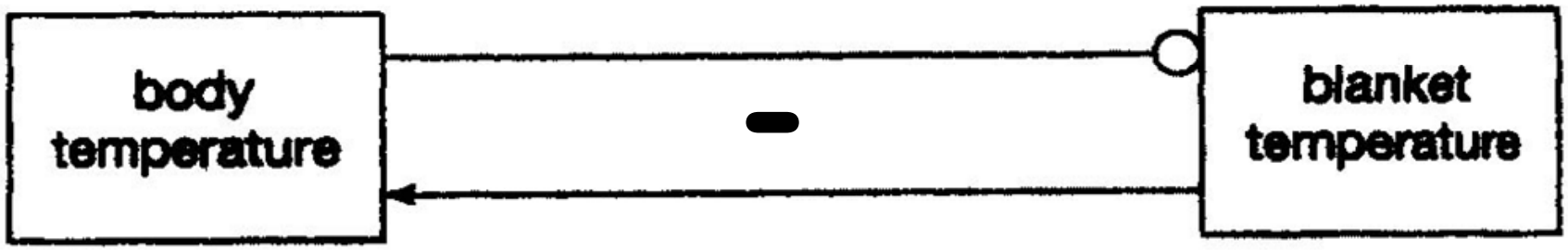
One way to remember the effect that a NEGATIVE feedback loop has is to think of the word "negligible"

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

Q3: What kind of FEEDBACK LOOP IS IT?

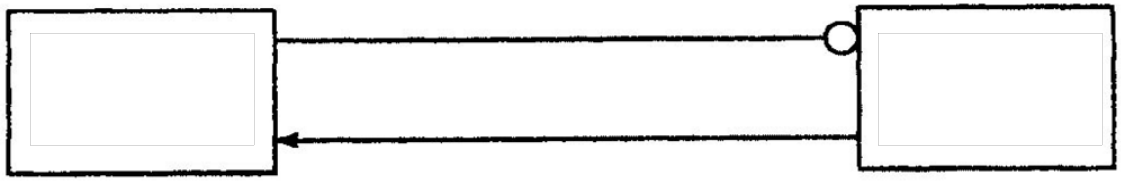
1) Positive (+) 2) Negative (-) ???



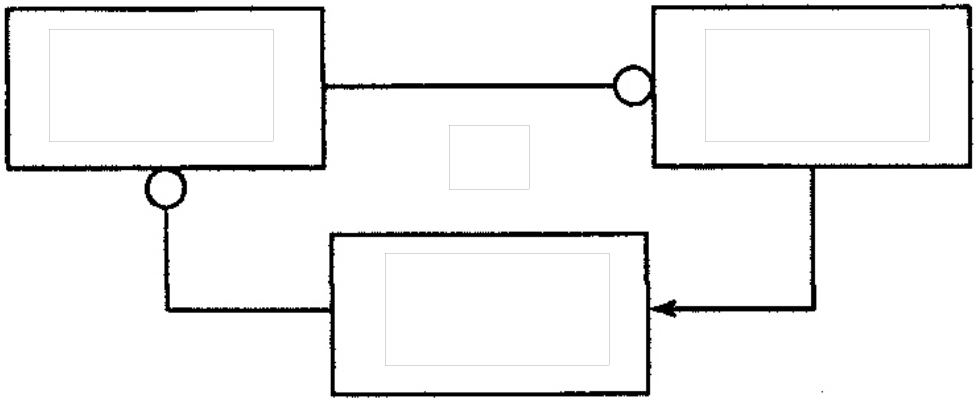
THE "RULE" – how to tell if it's a positive or negative feedback LOOP:

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



One more term:

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.

Take notes

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

- **Negative feedback loops establish STABLE equilibrium states**

  NEGATIVE LOOP ➔ STABLE EQUILIBRIUM

  [recall negative feedback = "self regulating"]

<u>STABLE EQUILIBRIUM STATES</u>:

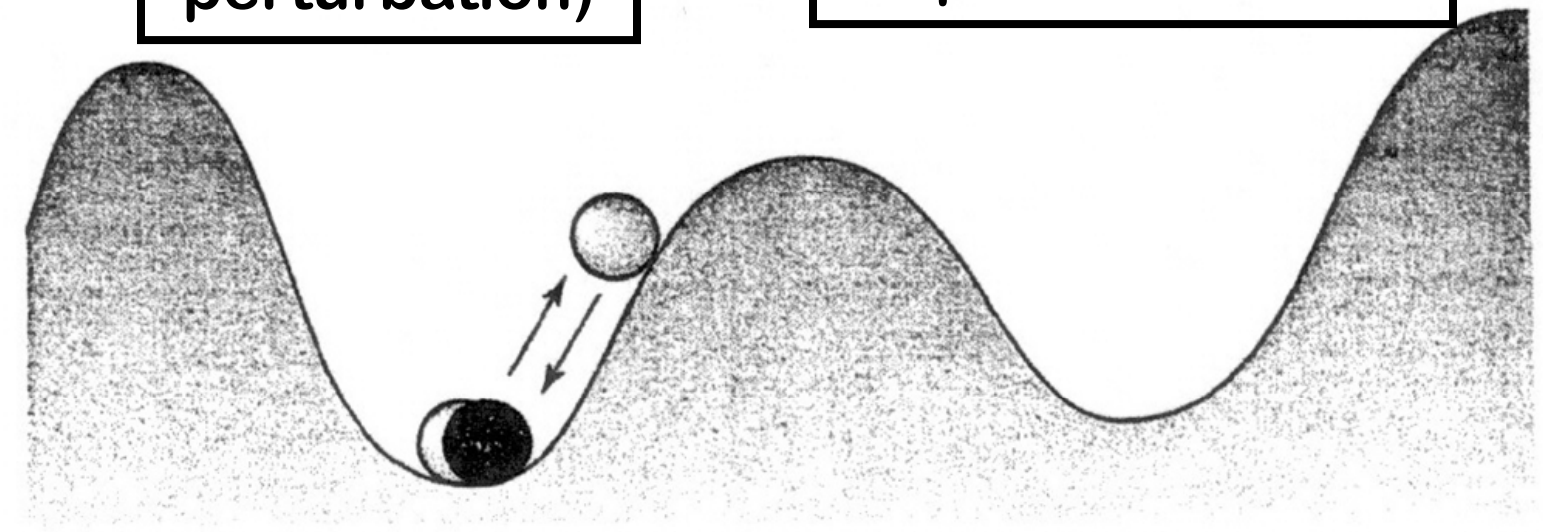
- **are resistant to a range of perturbations**

  (i.e., system responds to modest perturbations by returning to the stable equilibrium state)

Take notes

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

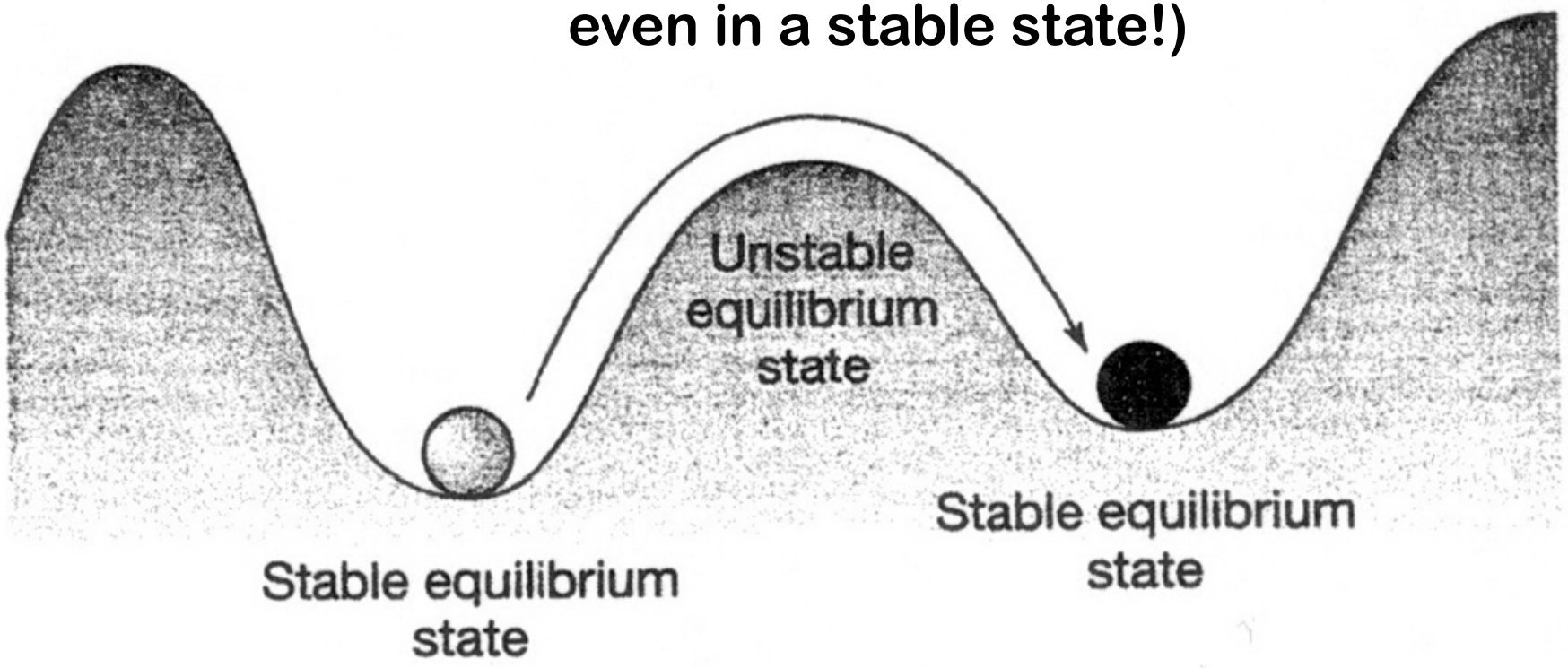


Stable equilibrium state

Take notes
See top figure on p 59

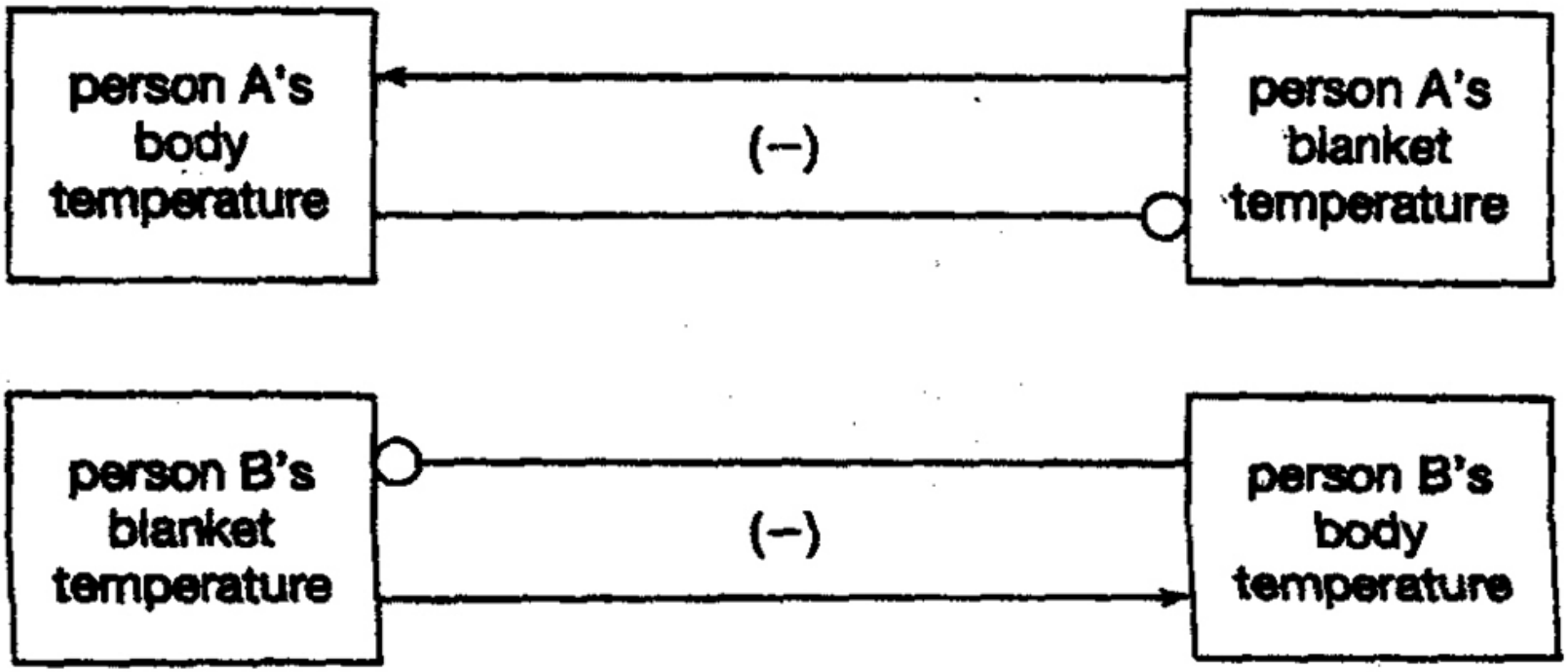
A LARGE or more persistent disturbance (a forcing) can carry the system to a <u>different</u> equilibrium state

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



Everyday life example:

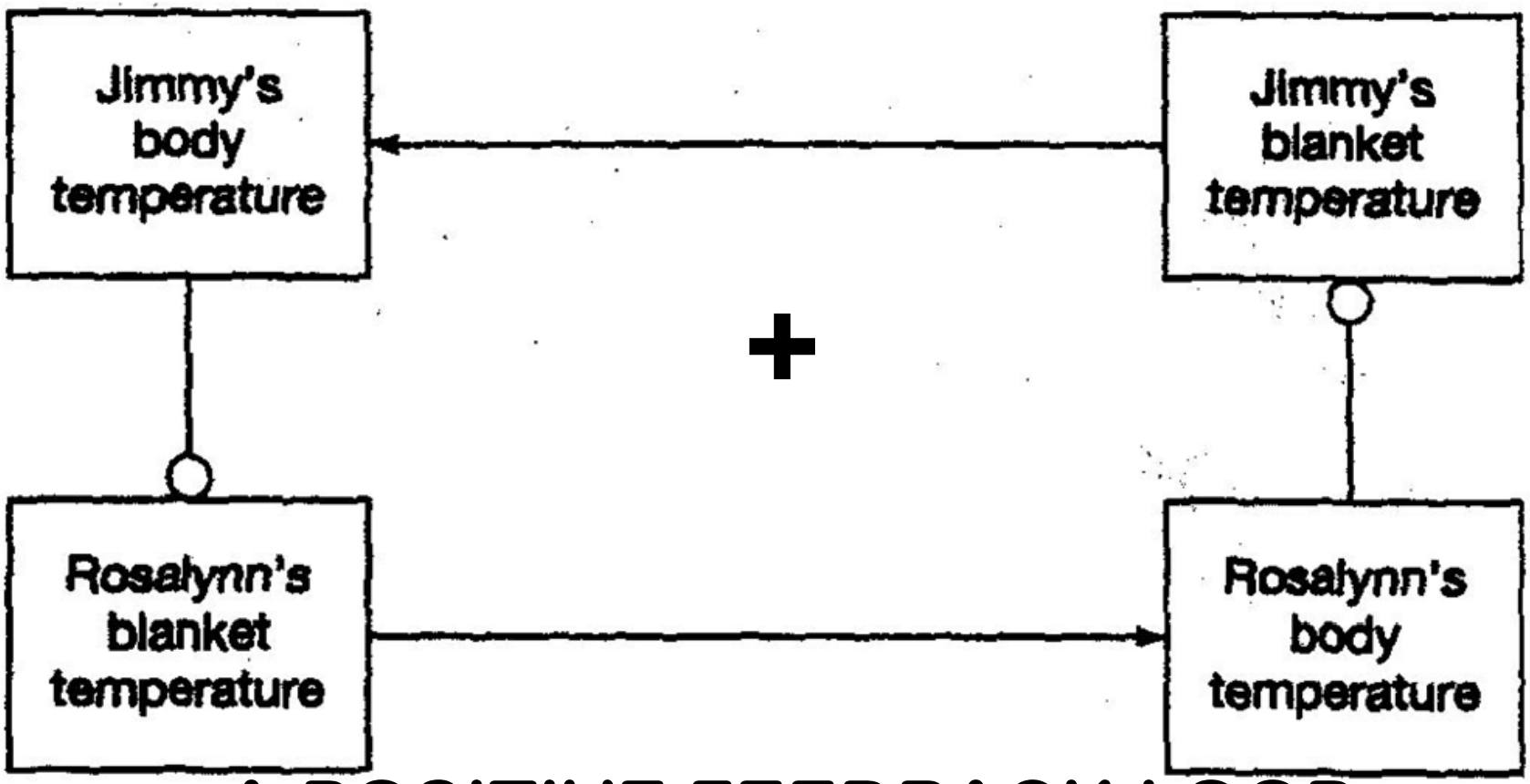
Proper alignment of dual control electric blanket:



Improper alignment:

Q4. What kind of FEEDBACK LOOP IS IT?

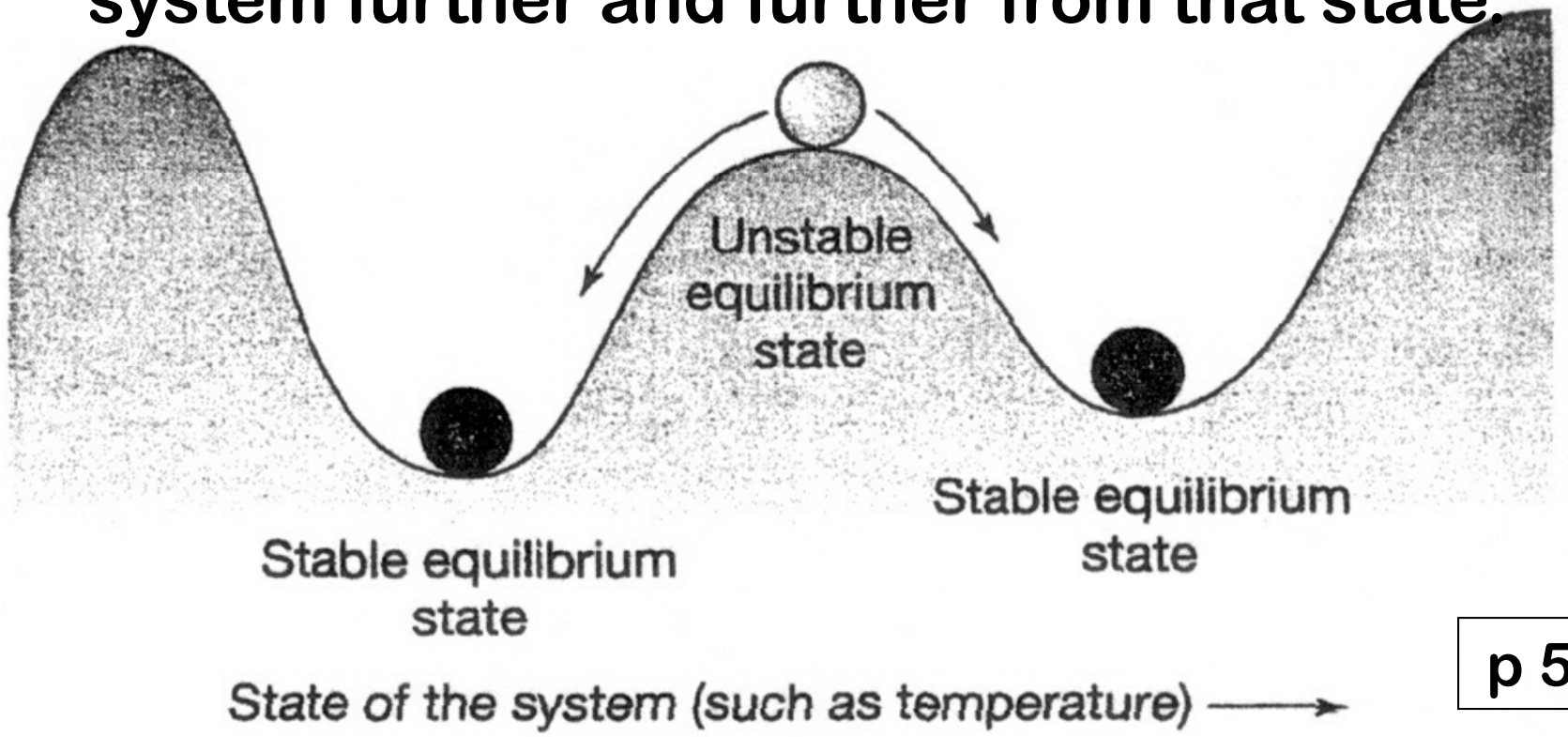
1) Positive + 2) Negative -



A POSITIVE FEEDBACK LOOP that amplifies the effect!

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.



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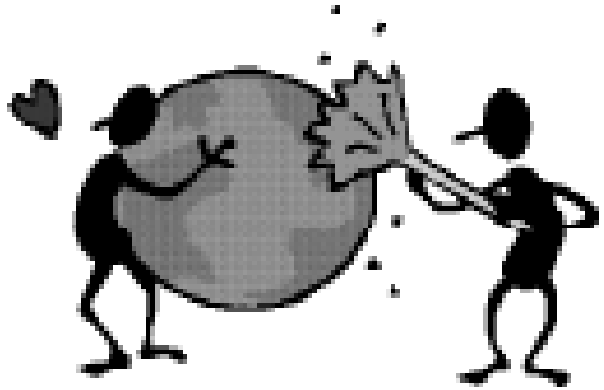
RECAP:

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.**

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:

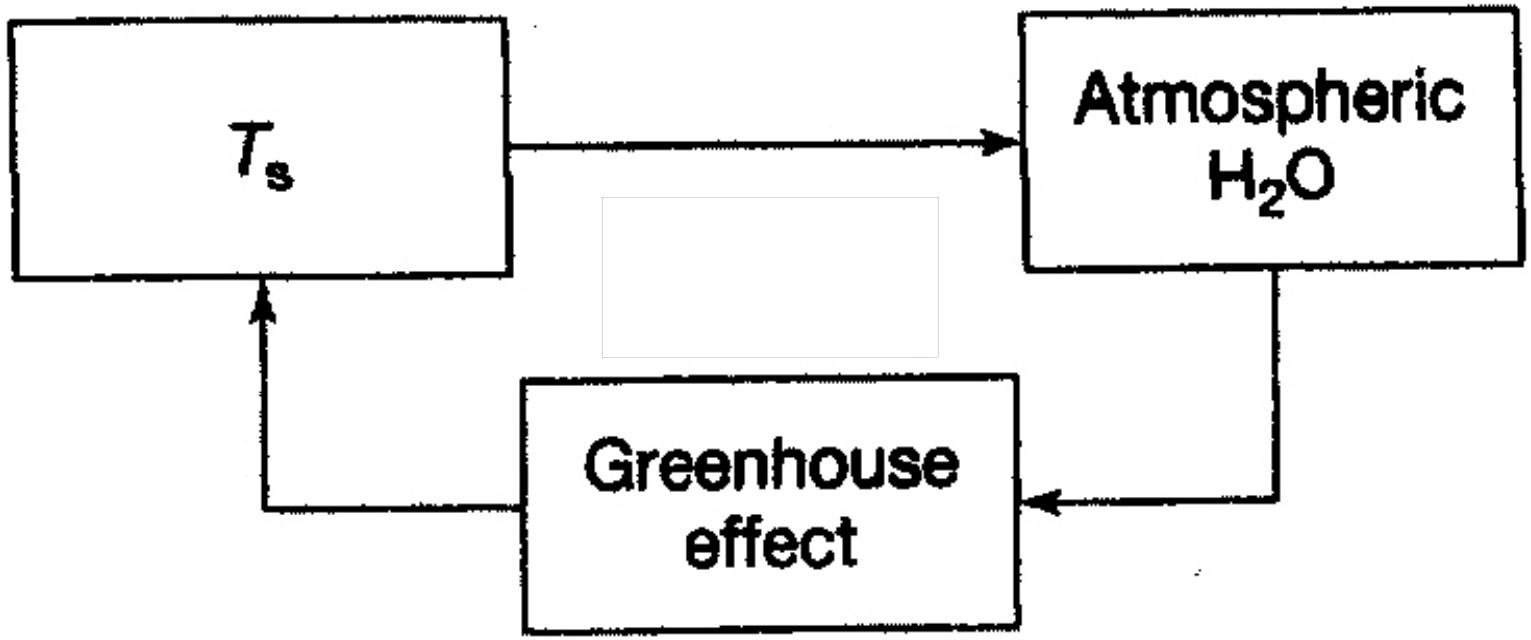
(e.g. increasing carbon dioxide)

. . . 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

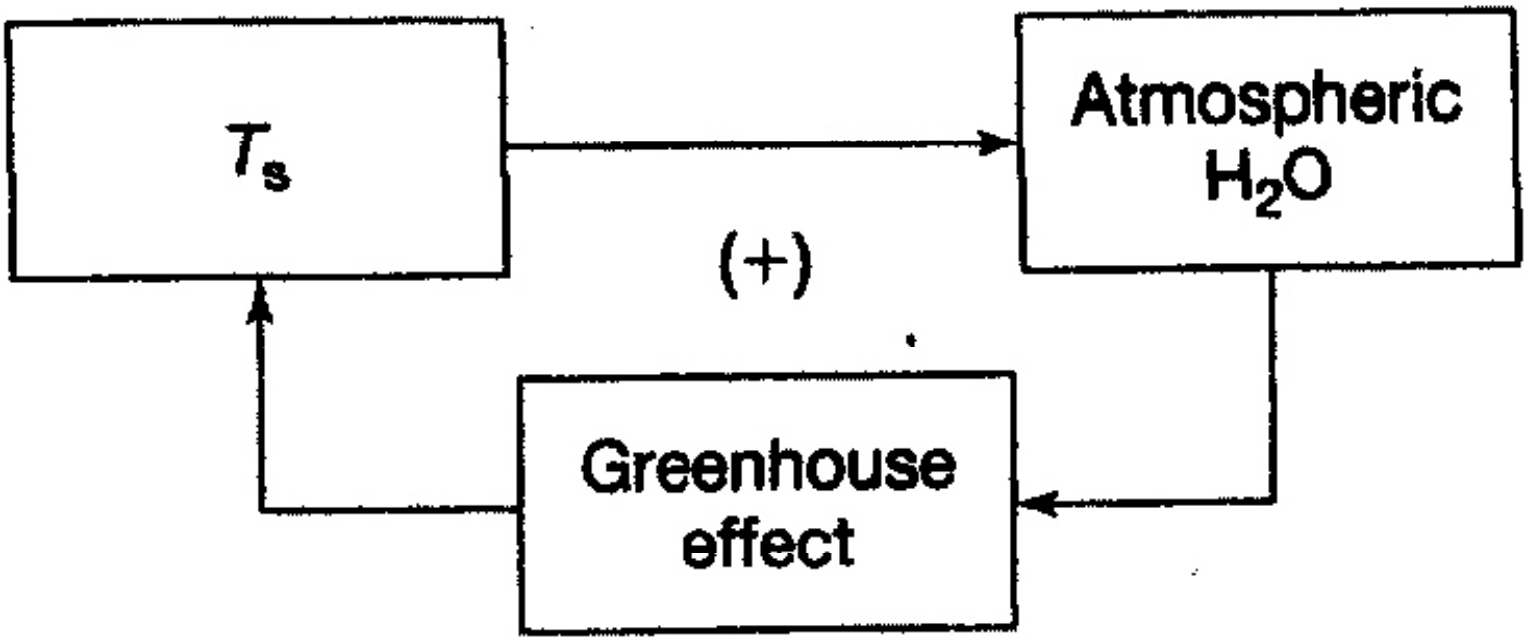
WATER VAPOR Feedback in the Earth-Atmosphere

Q5: What kind of FEEDBACK LOOP IS THIS?

1) Positive + 2) Negative -



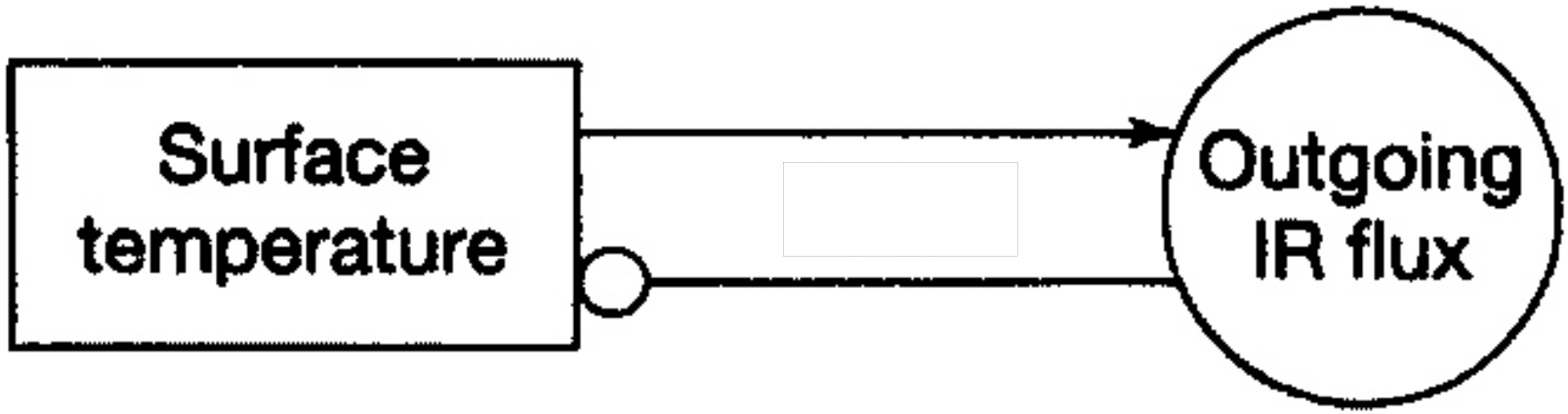
POSITIVE FEEDBACK LOOP
that amplifies the effect!



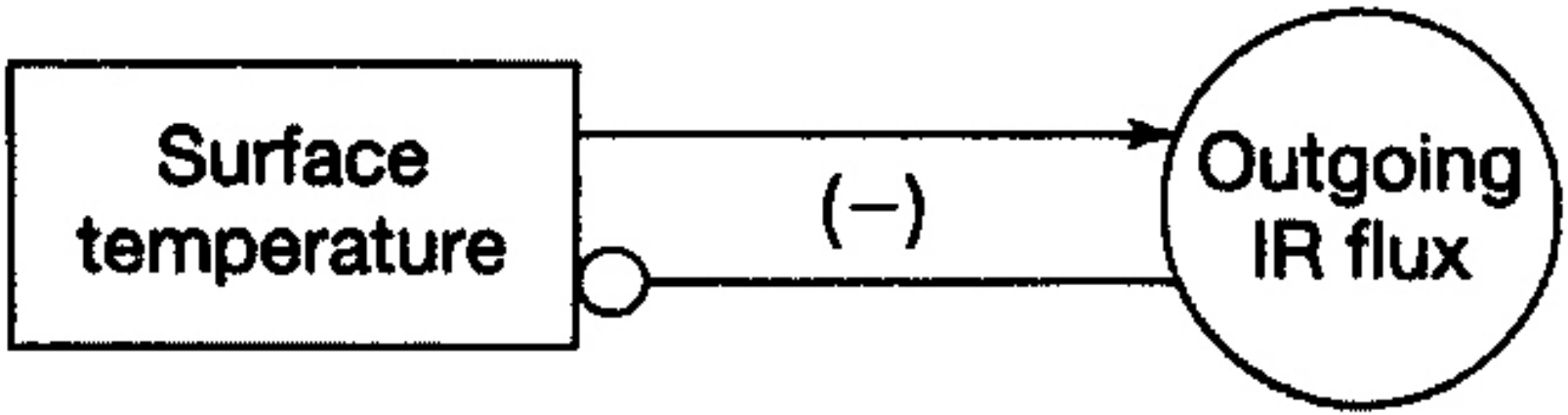
OUTGOING INFRARED ENERGY FLUX / TEMPERATURE Feedback

Q6: What kind of FEEDBACK LOOP IS THIS?

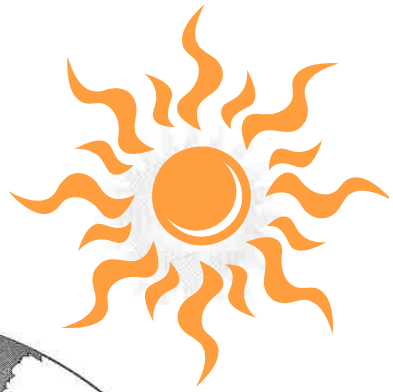
1) Positive + 2) Negative -

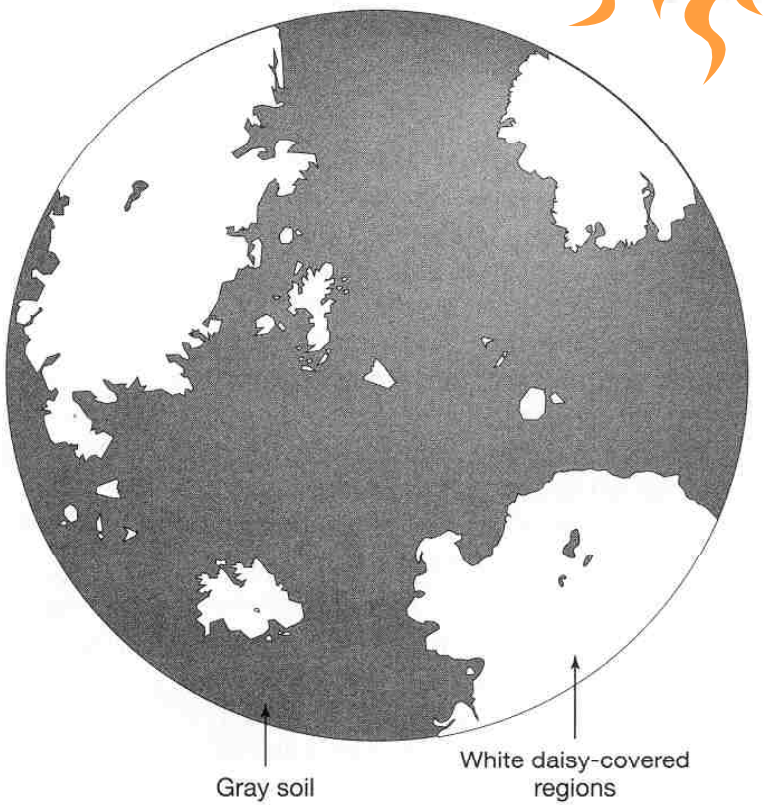


NEGATIVE FEEDBACK LOOP
that is self-regulating!



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

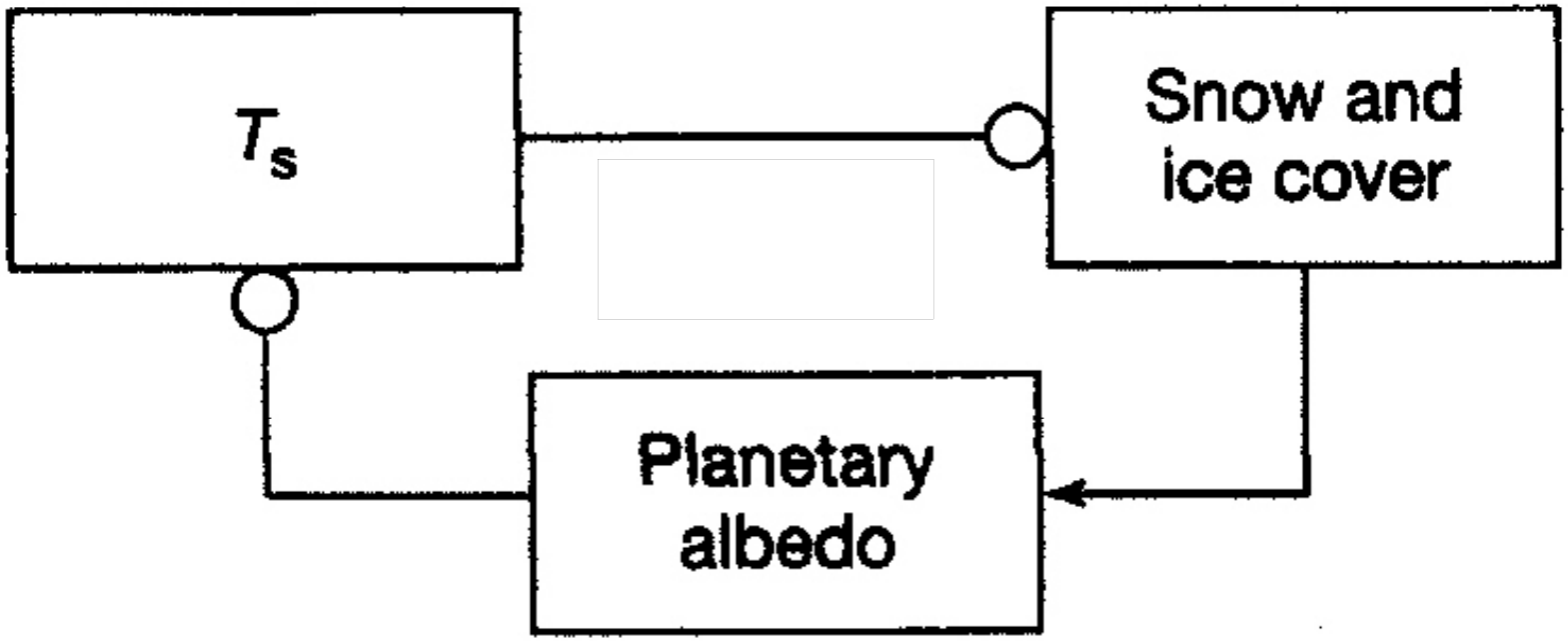




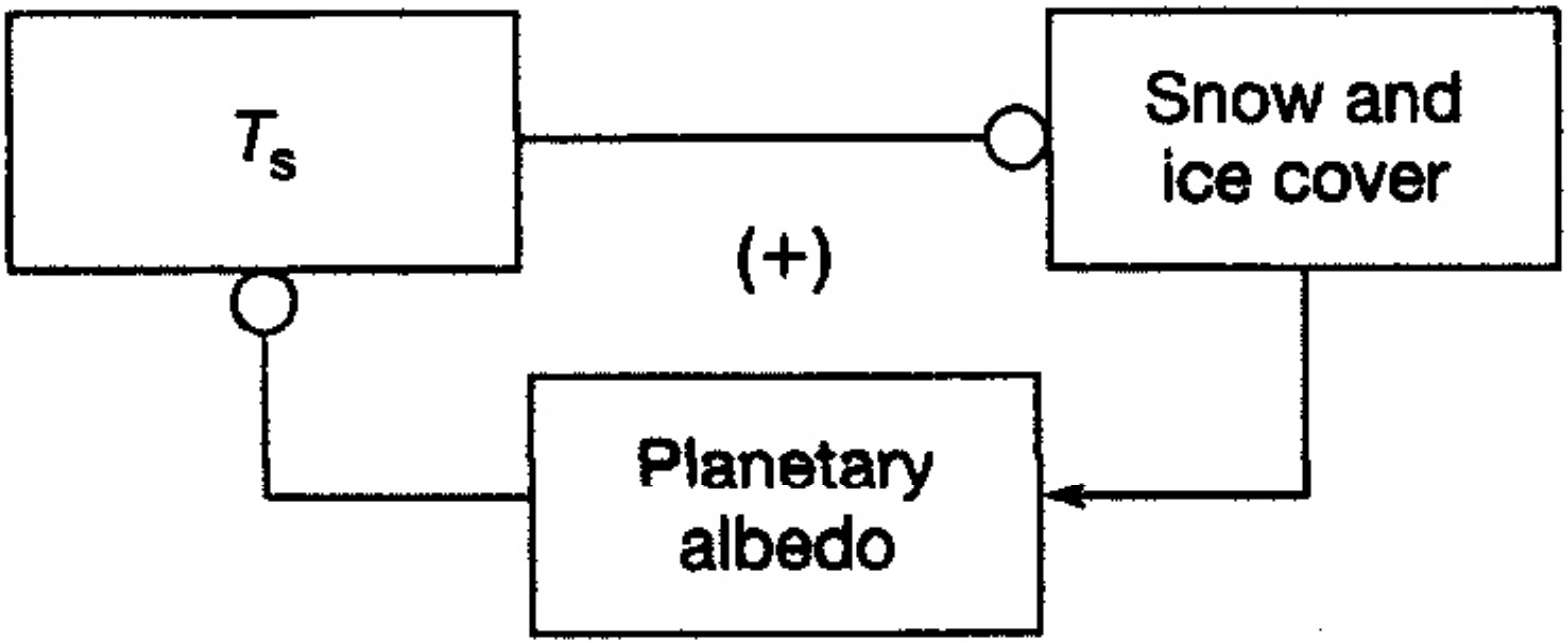
SNOW AND ICE ALBEDO Feedback

Q7: What kind of FEEDBACK LOOP IS THIS?

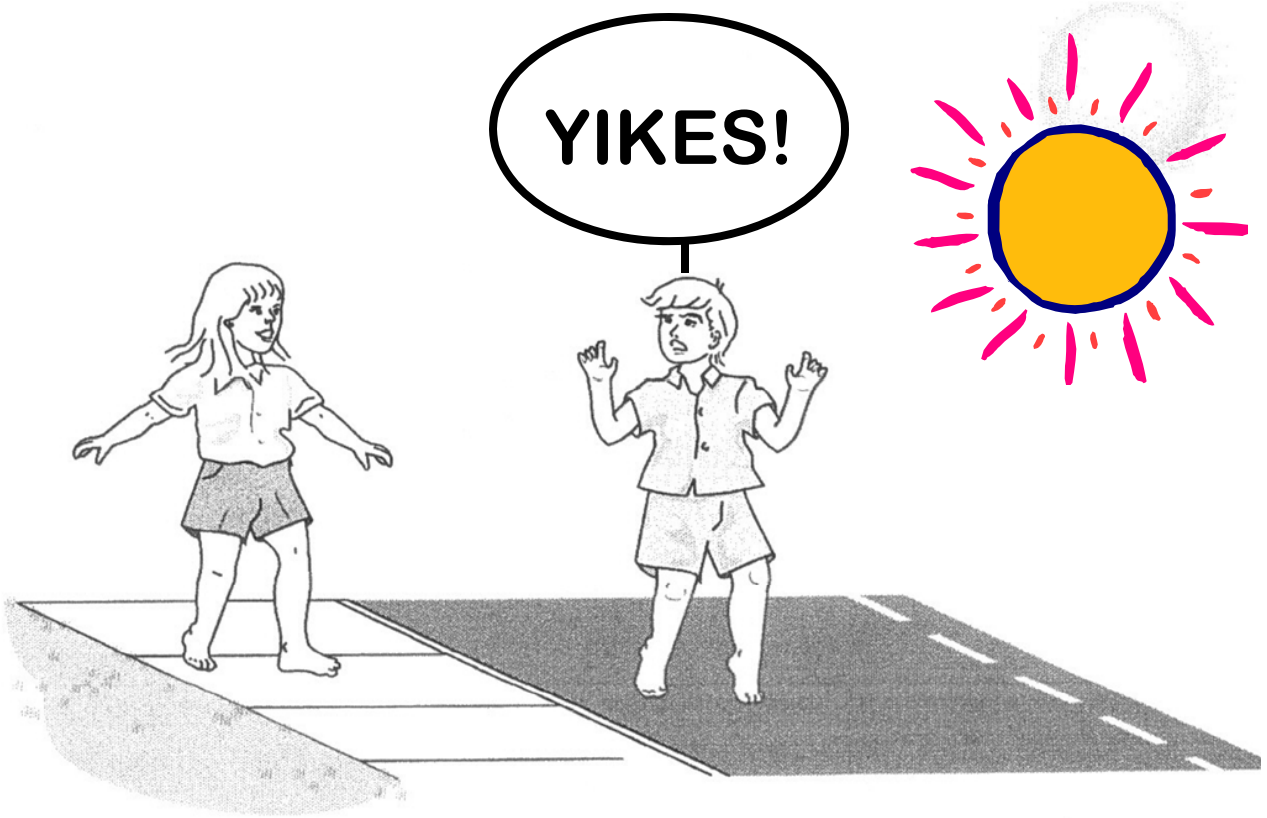
1) Positive + 2) Negative -



ALSO a POSITIVE FEEDBACK LOOP that amplifies the effect!



ALBEDO REVIEW →



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!

Review

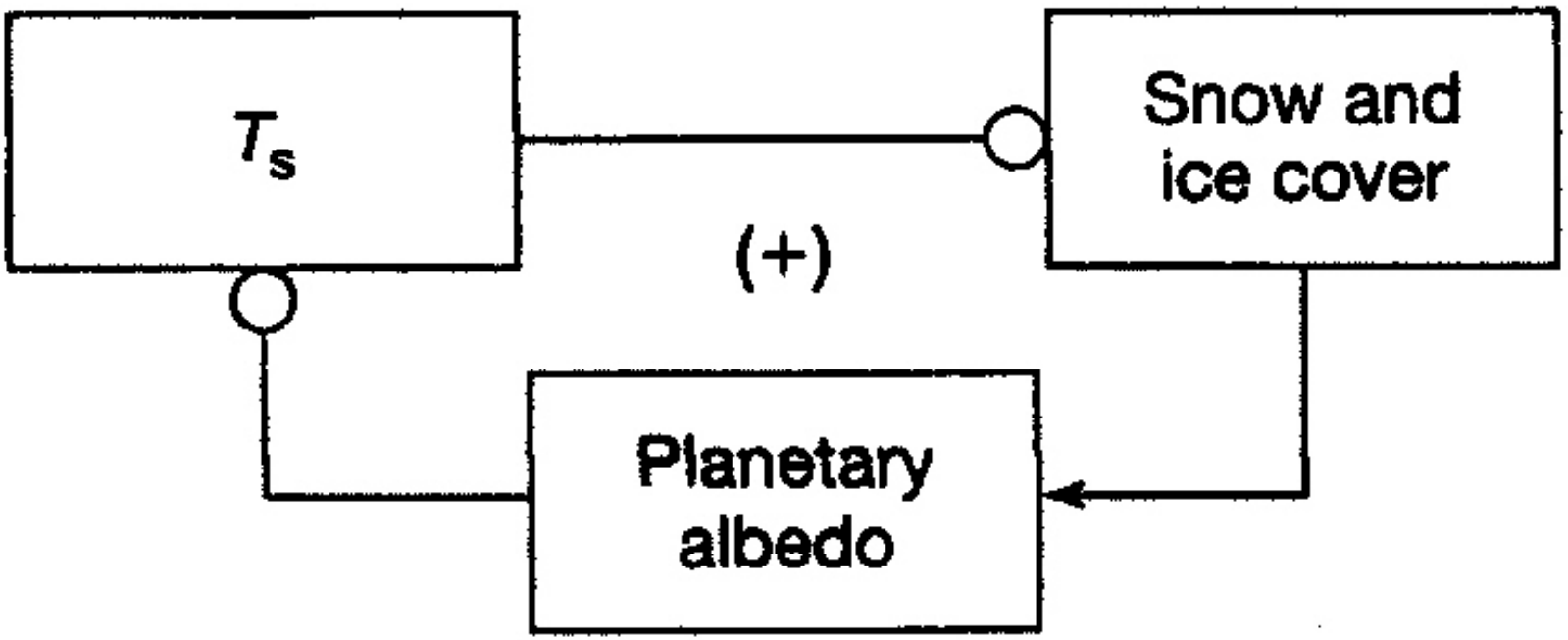
Albedos of Some Common Surfaces	
Type of Surface	***Albedo***
Sand	0.20–0.30
Grass	0.20–0.25
Forest	0.05–0.10
Water (overhead Sun)	0.03–0.05
Water (Sun near horizon)	0.50–0.80
Fresh snow	0.80–0.85
Thick cloud	0.70–0.80

PLANET EARTH = ~ 0.30

“Planetary albedo”

Review

Positive & Self-Amplifying Feedback Loop!



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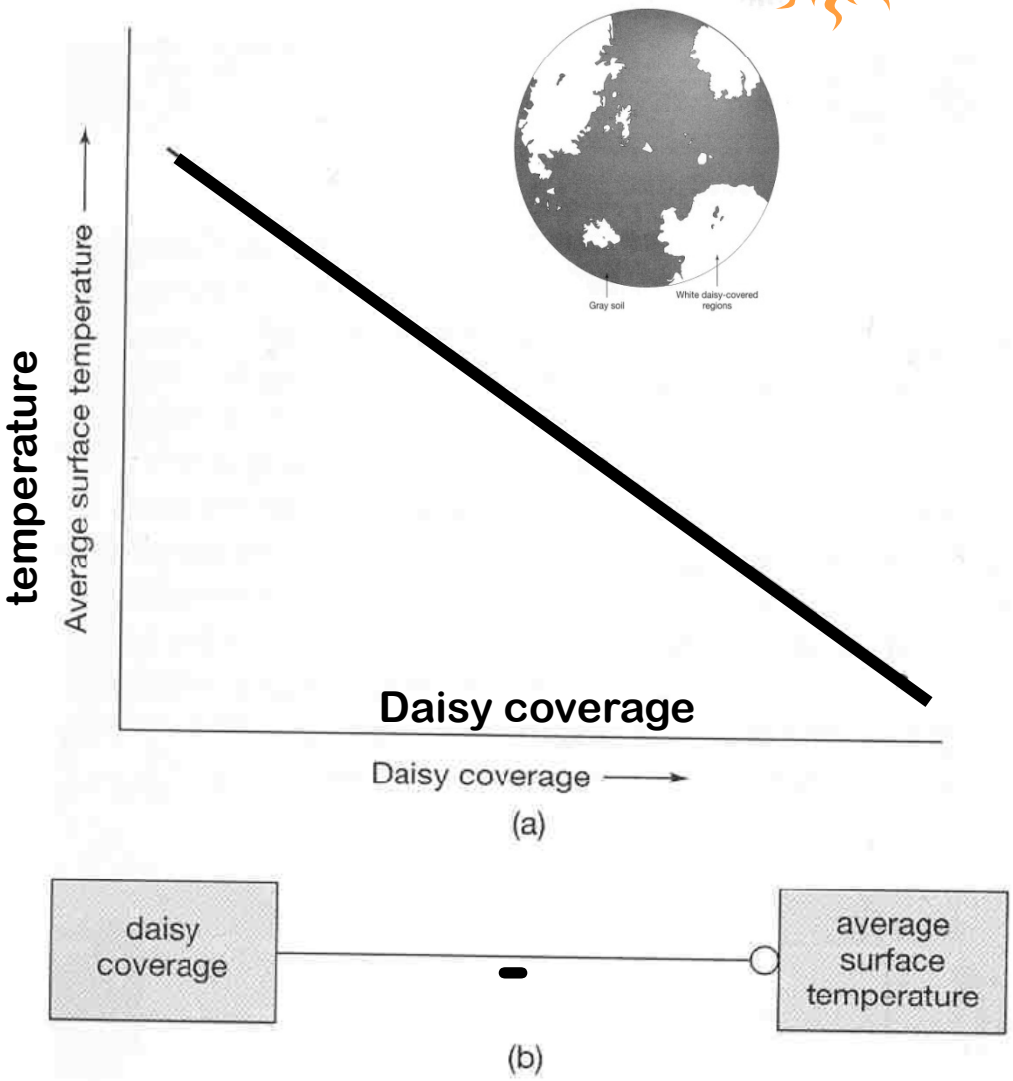
PLANET EARTH = ~ 0.30

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

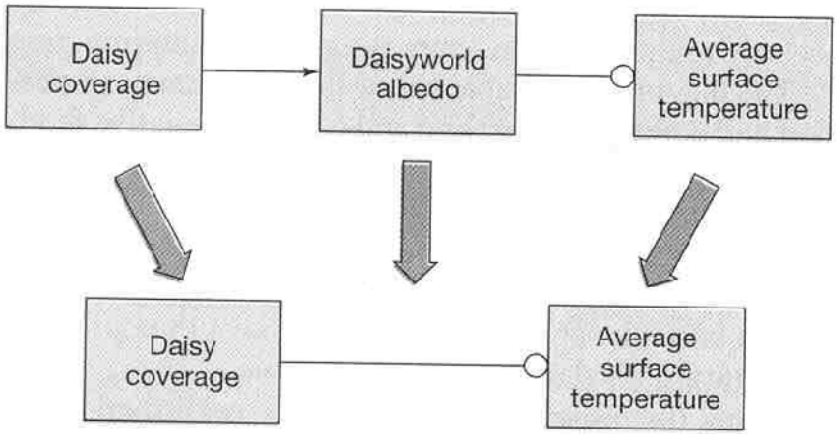
Review

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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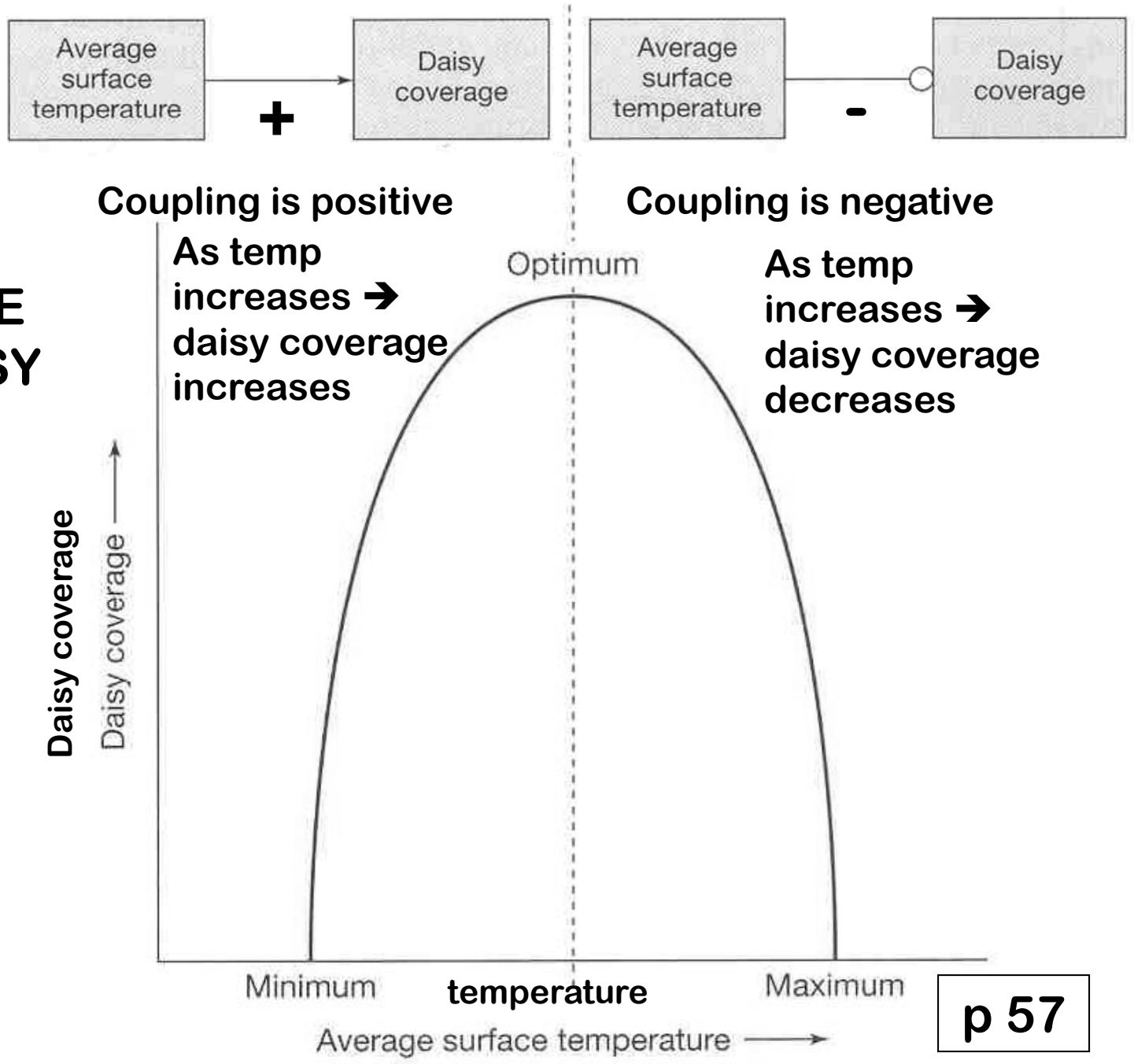
HOW TEMPERATURE AFFECTS DAISY COVERAGE:



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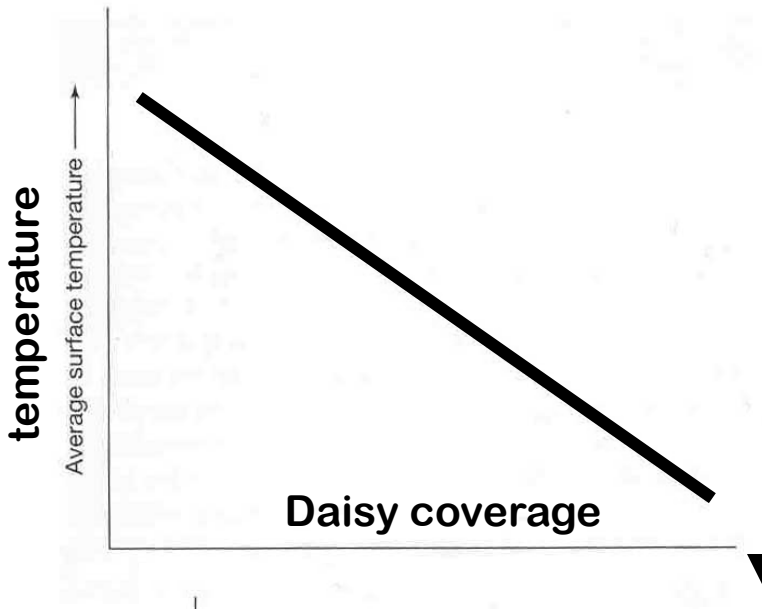
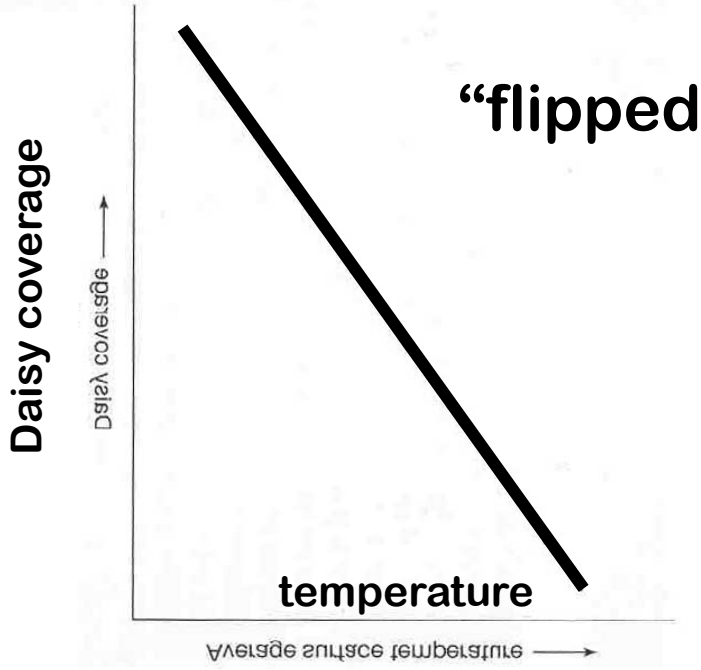
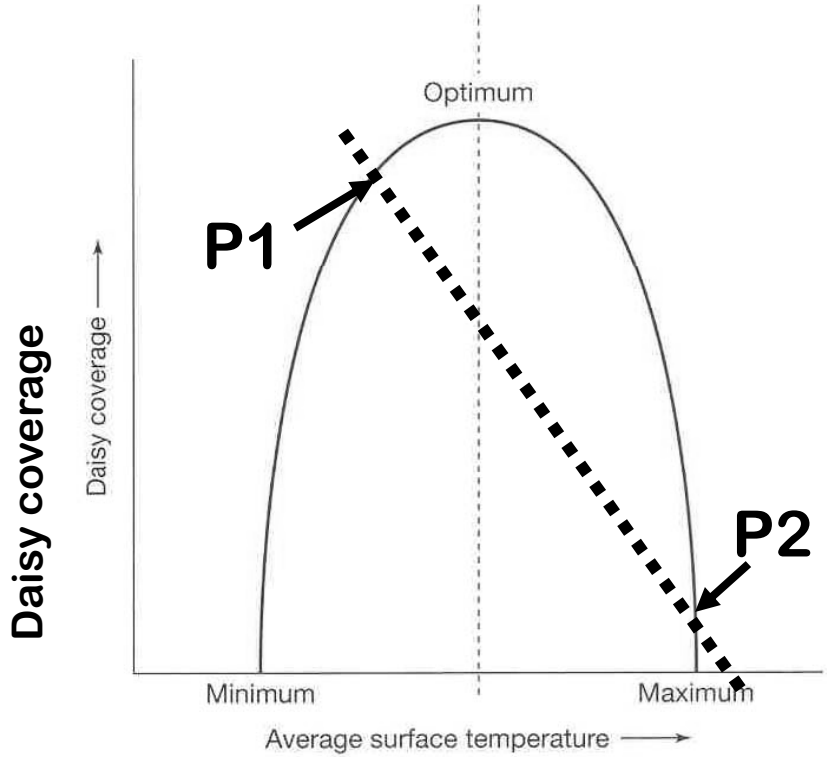
PUTTING THE TWO GRAPHS TOGETHER!



"flipped axes"





Daisy coverage

temperature

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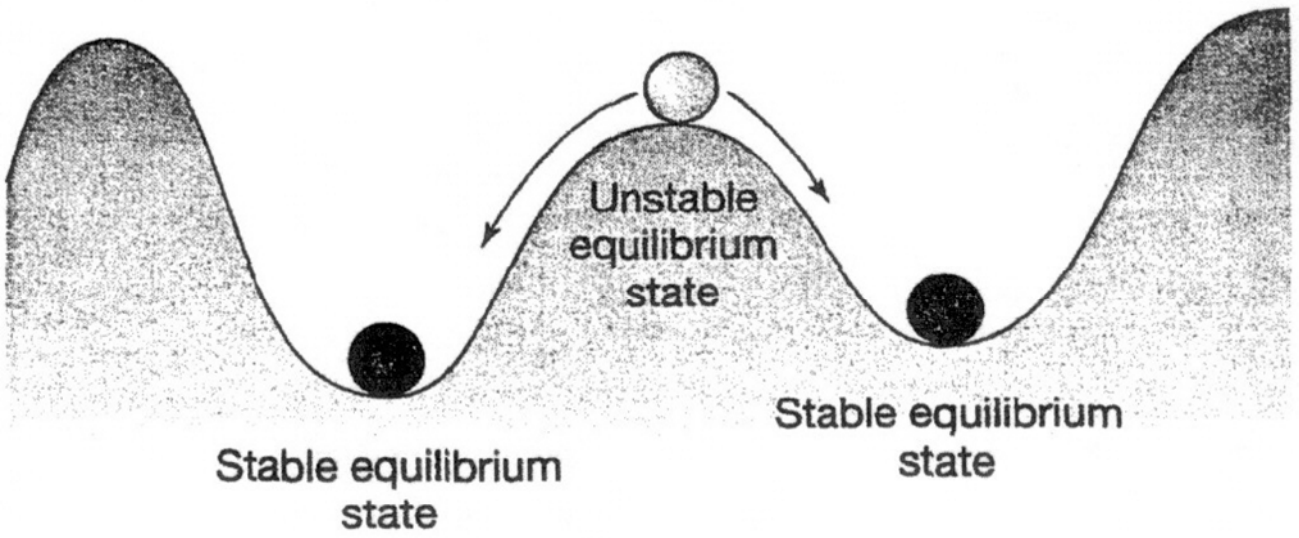
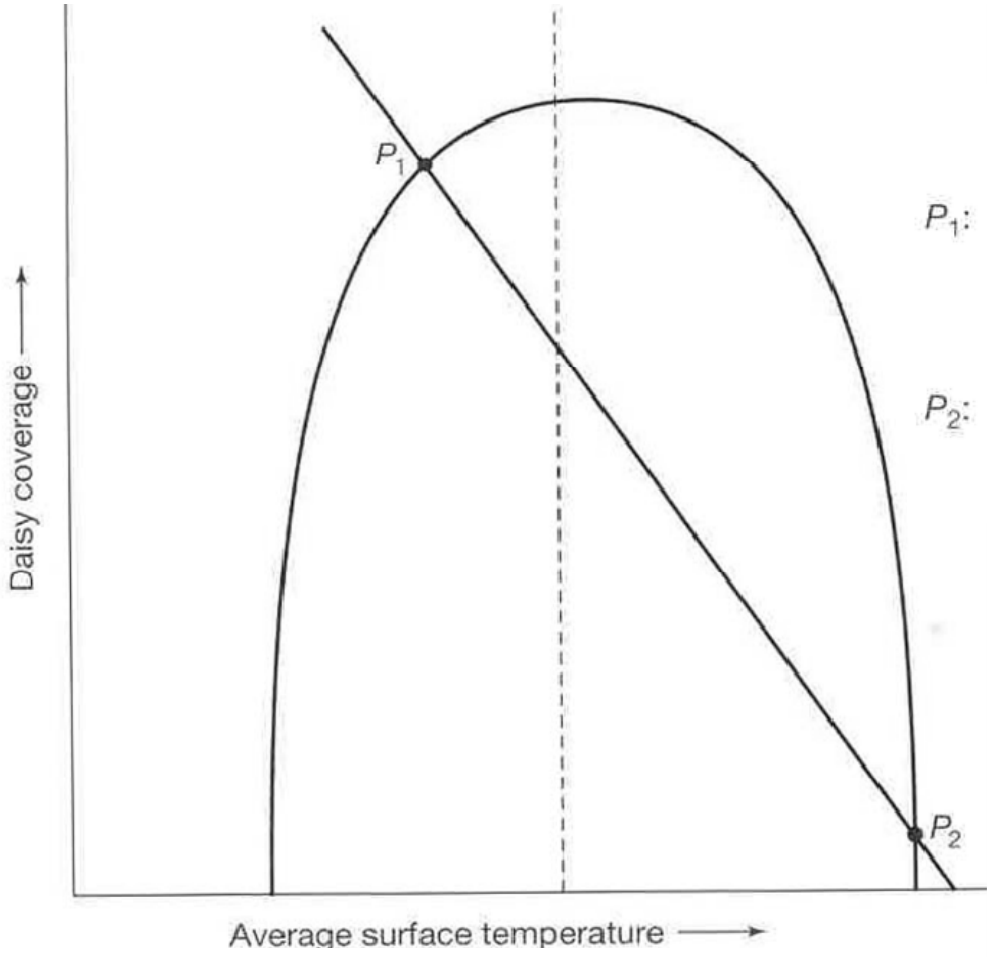
P1 and P2 are:

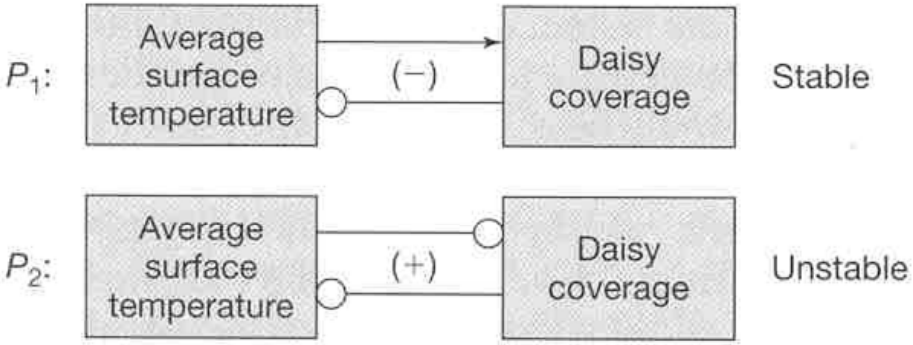
EQUILIBRIUM STATES

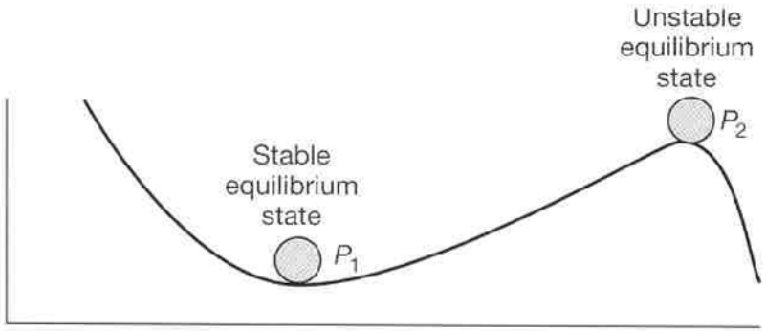
= a state in which a system is in equilibrium, that is, the state in which the system will remain UNLESS something disturbs it.

An equilibrium state can be stable or unstable.









P1 & P2 are each "EQUILIBRIUM" states, but one is in a more precarious state (unstable) than the other . . . .

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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.**

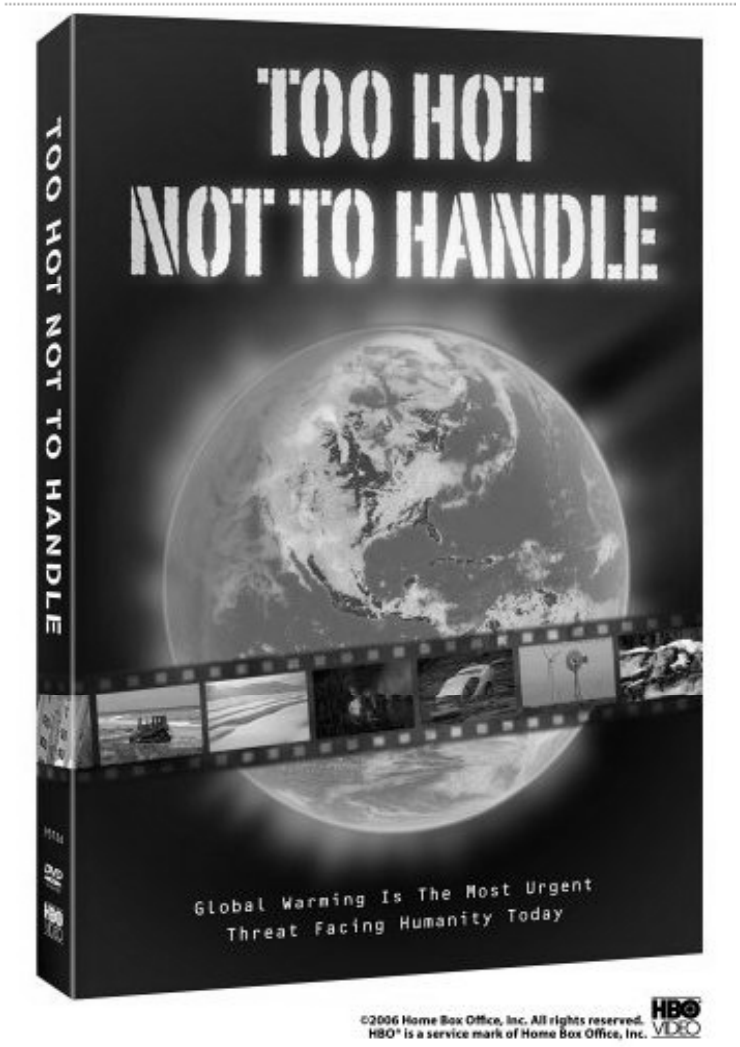
The last part of Chapter 2 illustrates that:

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.

MOVIE TIME!!



HBO
DOCUMENTARY

http://www.hbo.com/docs/programs/toohot/synopsis.html

HAVE A GREAT WEEKEND!

GO CATS!