TOPIC # 10

Introduction to Models:

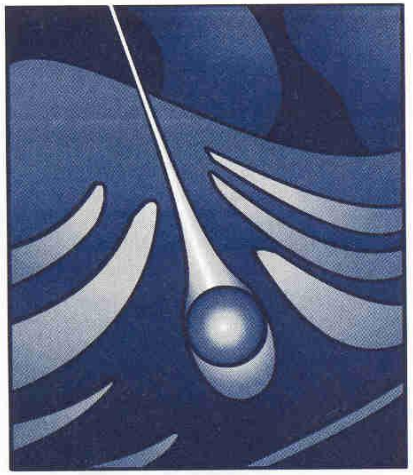
UNDERSTANDING SYSTEMS & FEEDBACKS

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

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.)

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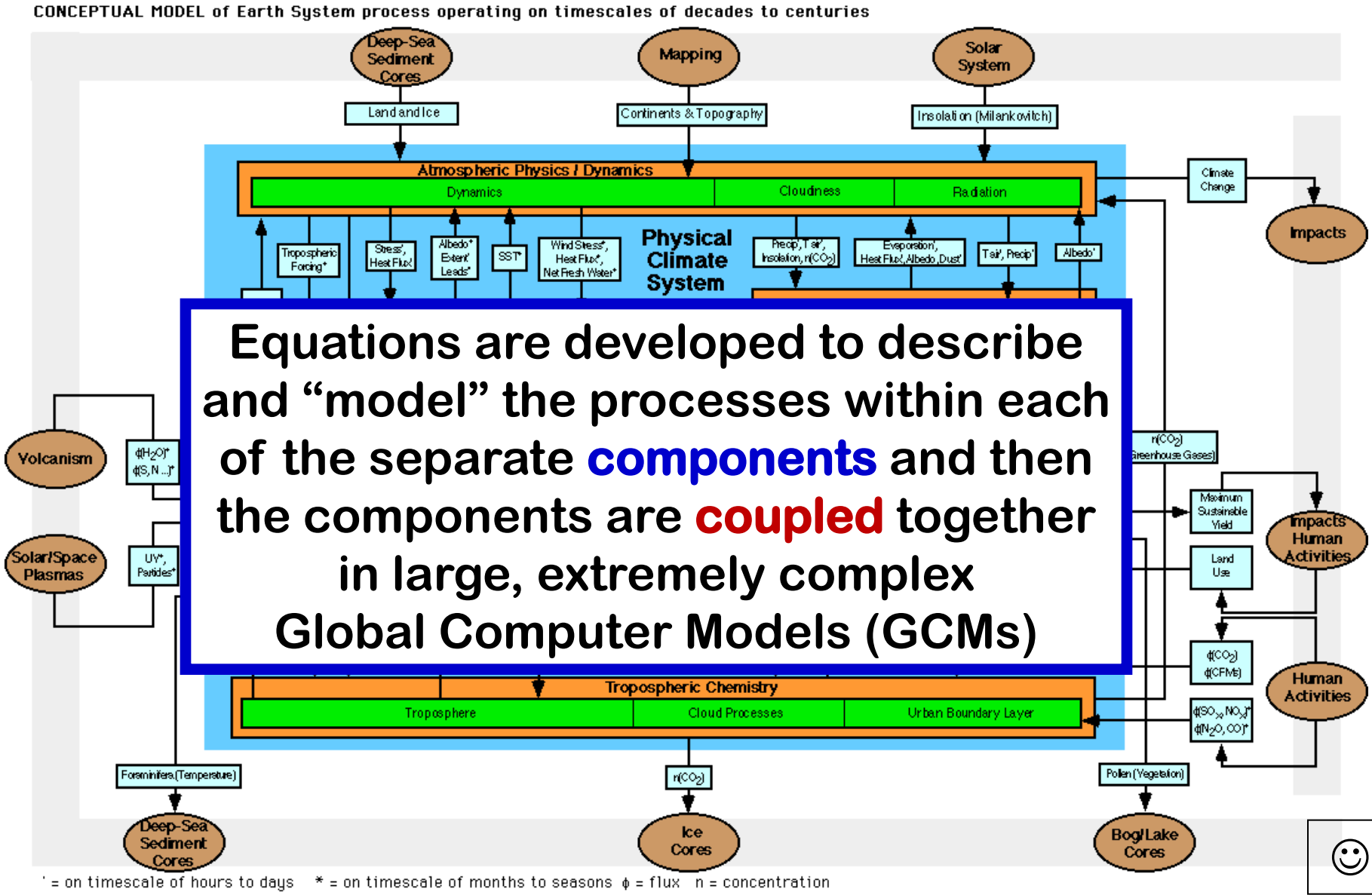
SYSTEM MODEL =

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:



Equations are developed to describe and "model" the processes within each of the separate components and then the components are coupled together in large, extremely complex Global Computer Models (GCMs)

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:

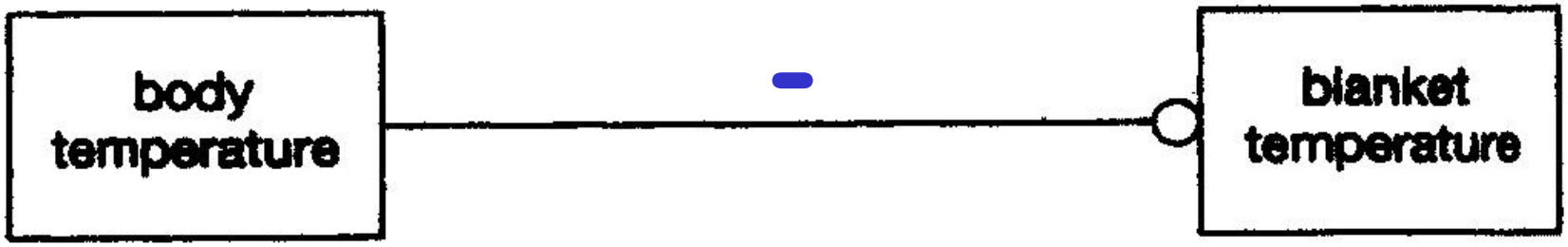
If the electric blanket's temperature INCREASES . . .

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.

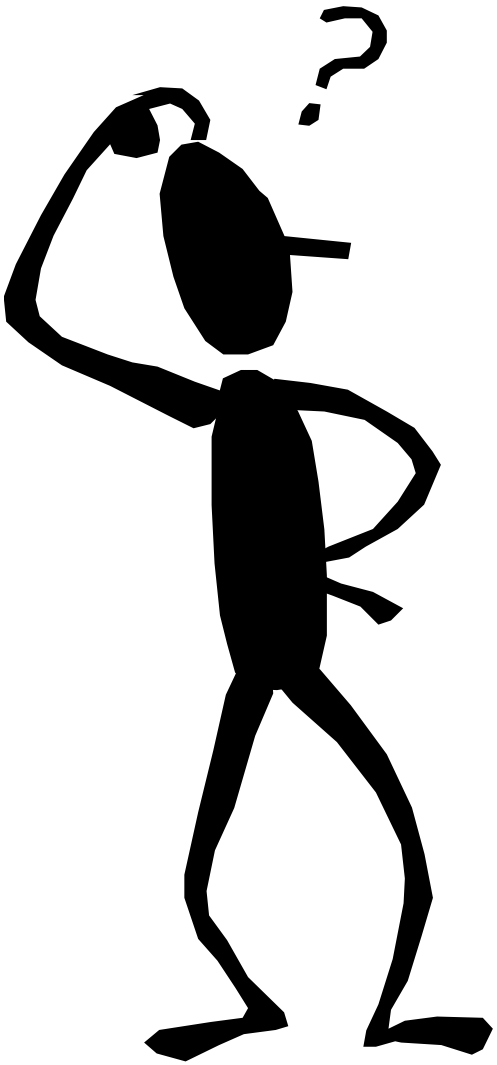
Feedback loops can be positive (+) or negative (-).

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)



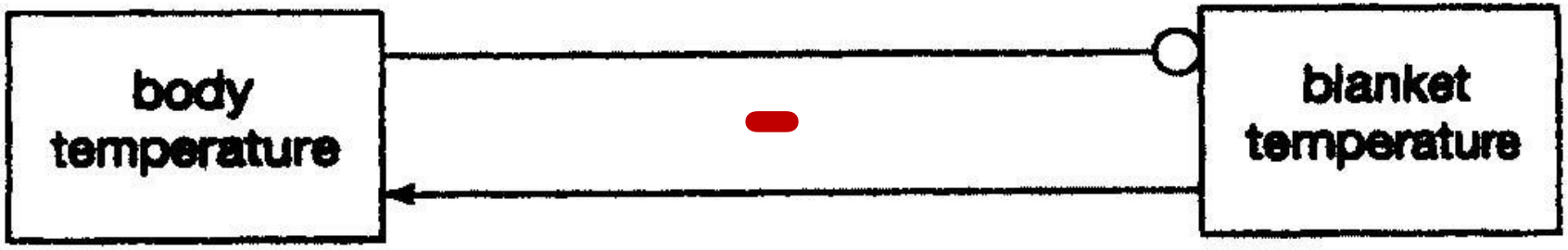
One way to remember the effect that a NEGATIVE feedback loop has is to think of the word "negligible"

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 (-) ???

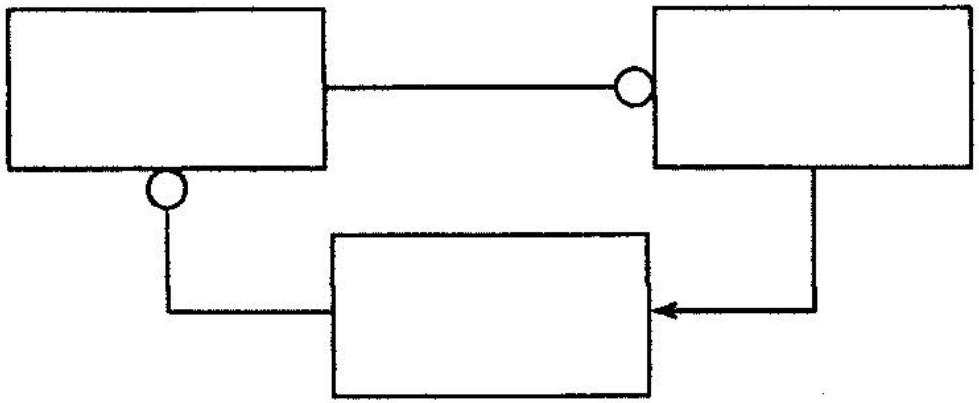


THE "RULE" – how to tell if it's a positive or negative feedback LOOP:

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



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.

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"]

STABLE EQUILIBRIUM STATES:

- are resistant to a range of perturbations

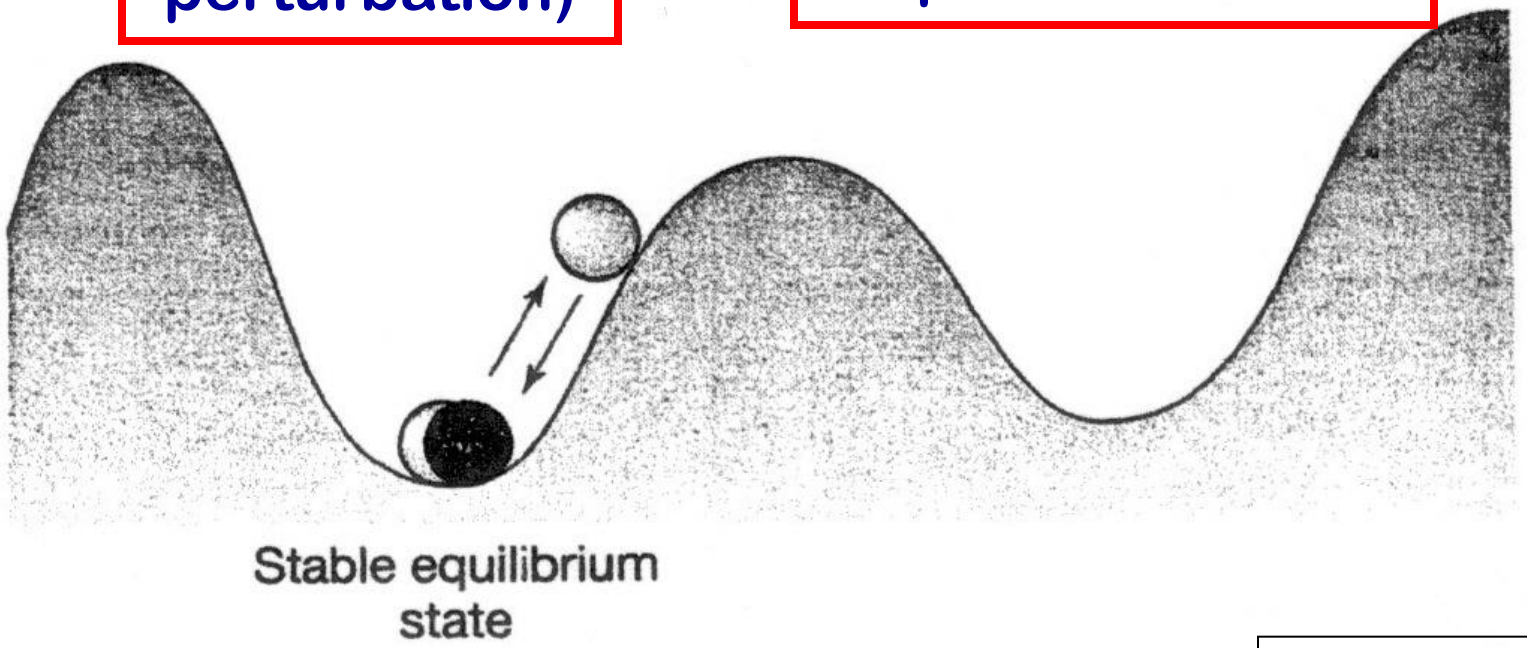
(i.e., system responds to modest perturbations by returning to the stable equilibrium state)

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

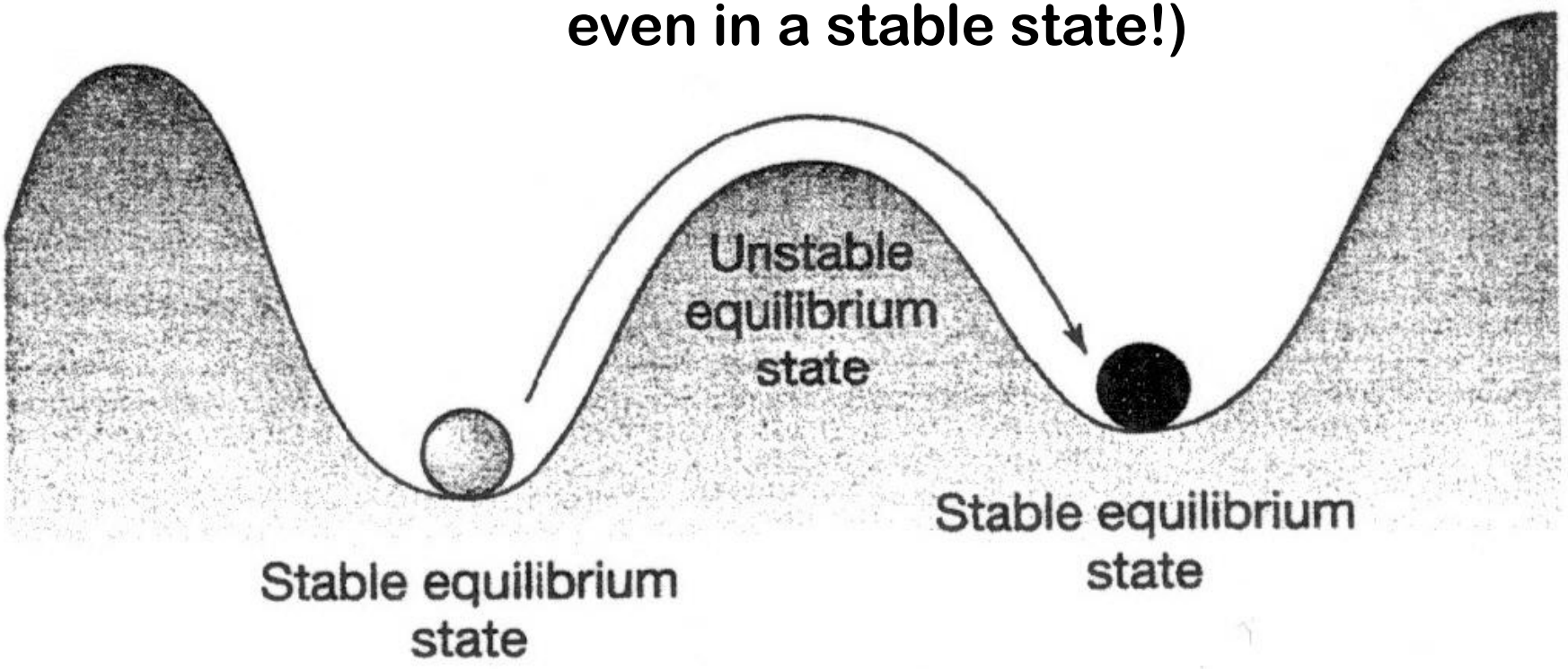


Stable equilibrium state

See this figure on p 58

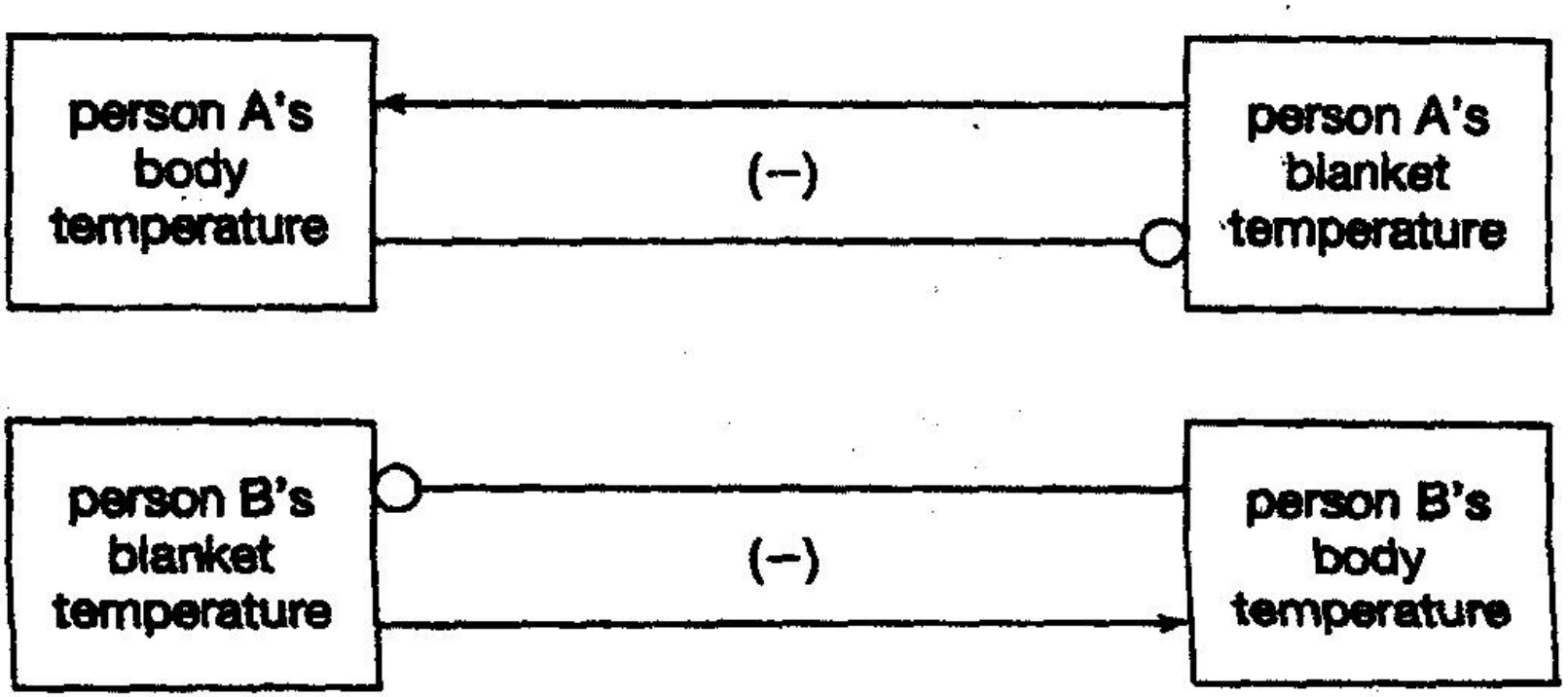
A LARGE or more persistent disturbance (a forcing) can carry the system to a different equilibrium state

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



Everyday life example:

Proper alignment of dual control electric blanket:



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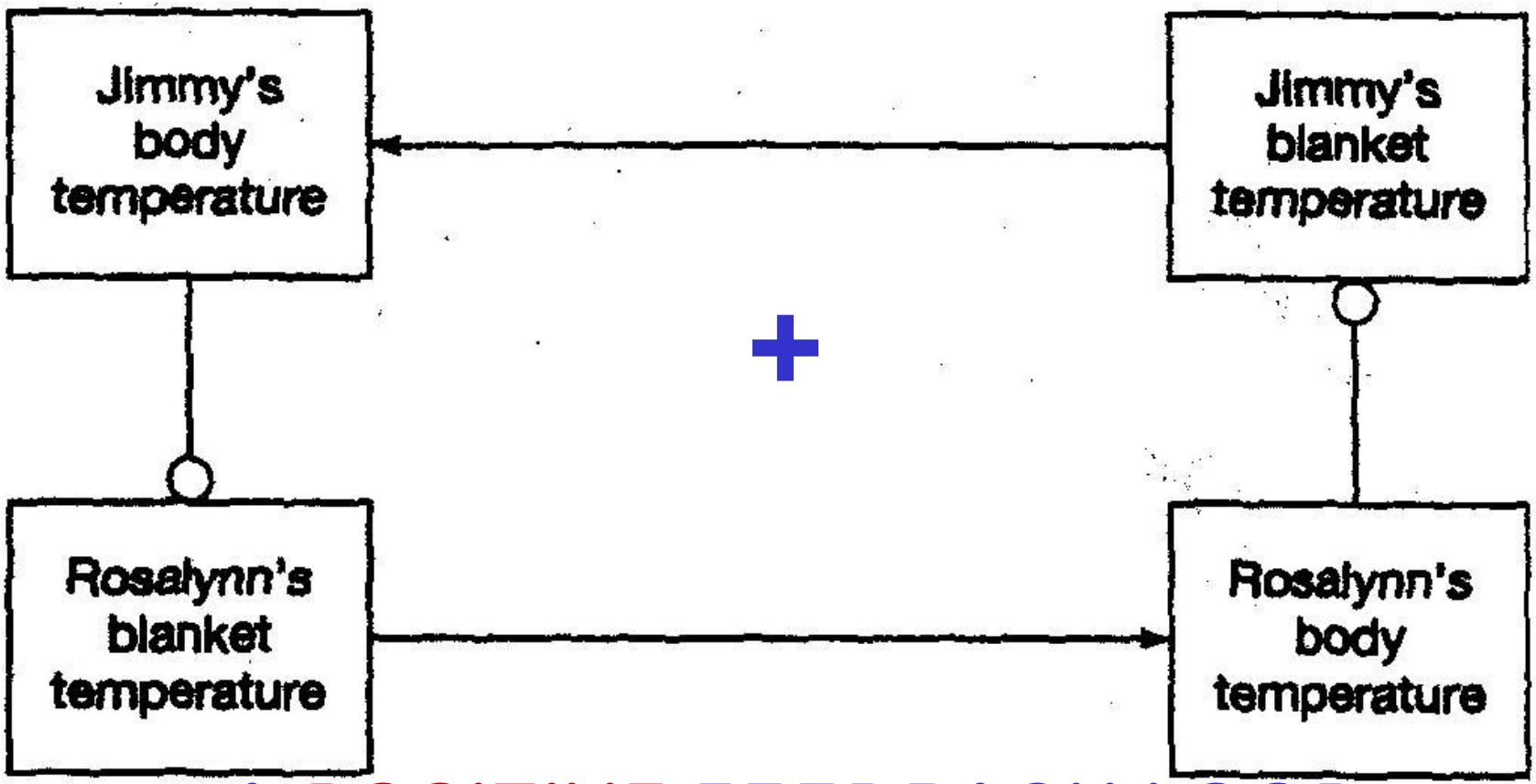
Improper alignment:

Q2. What kind of FEEDBACK LOOP IS IT?

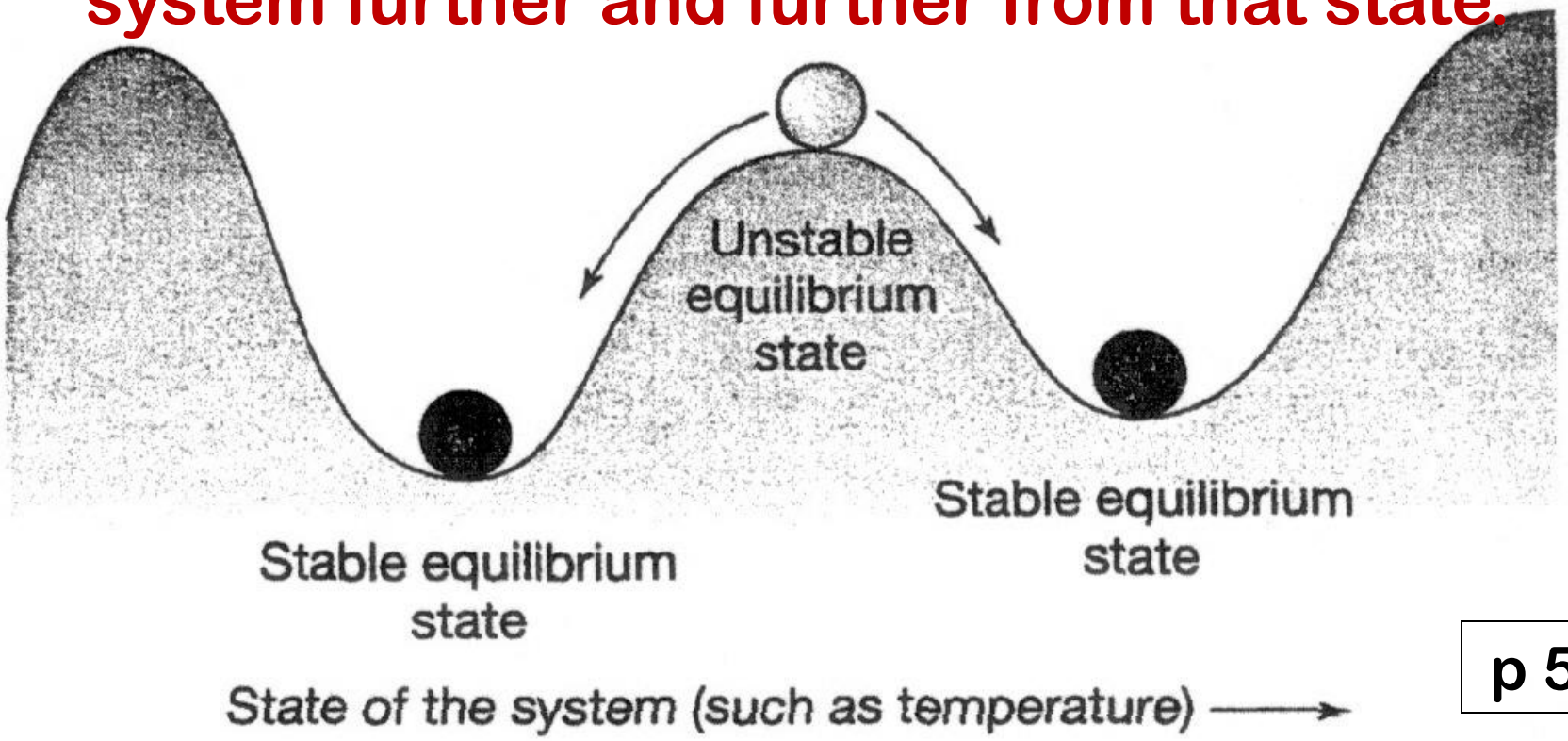
1) Positive + 2) Negative -



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.



RECAP:

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

- **NEGATIVE** feedback loops:
  - establish **STABLE** equilibrium states
  - are **resistant to a range** of perturbations
  - system responds to **modest perturbations** by **returning to the STABLE equilibrium state**

- **POSITIVE FEEDBACK** loops:
  - establish **UNSTABLE** equilibrium states
  - can stay poised in such a state indefinitely
  - BUT, 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:

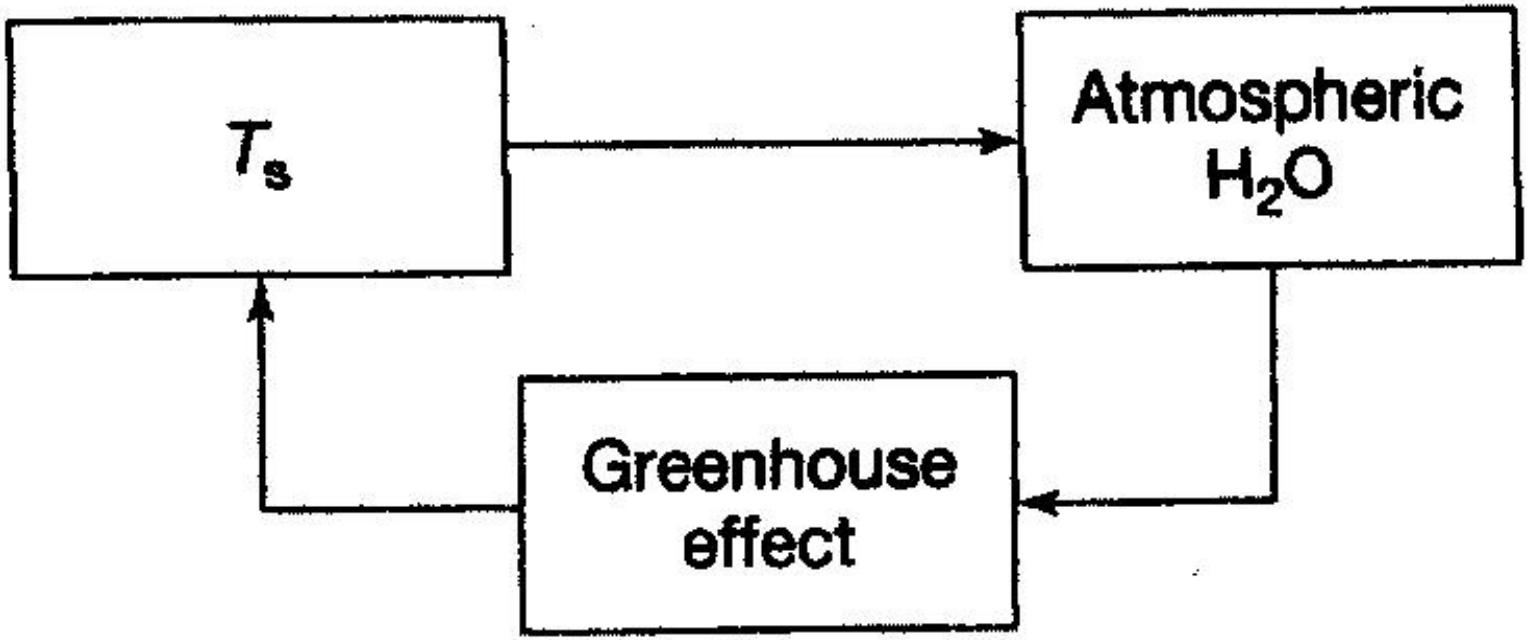
(e.g. increasing carbon dioxide)

. . . 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

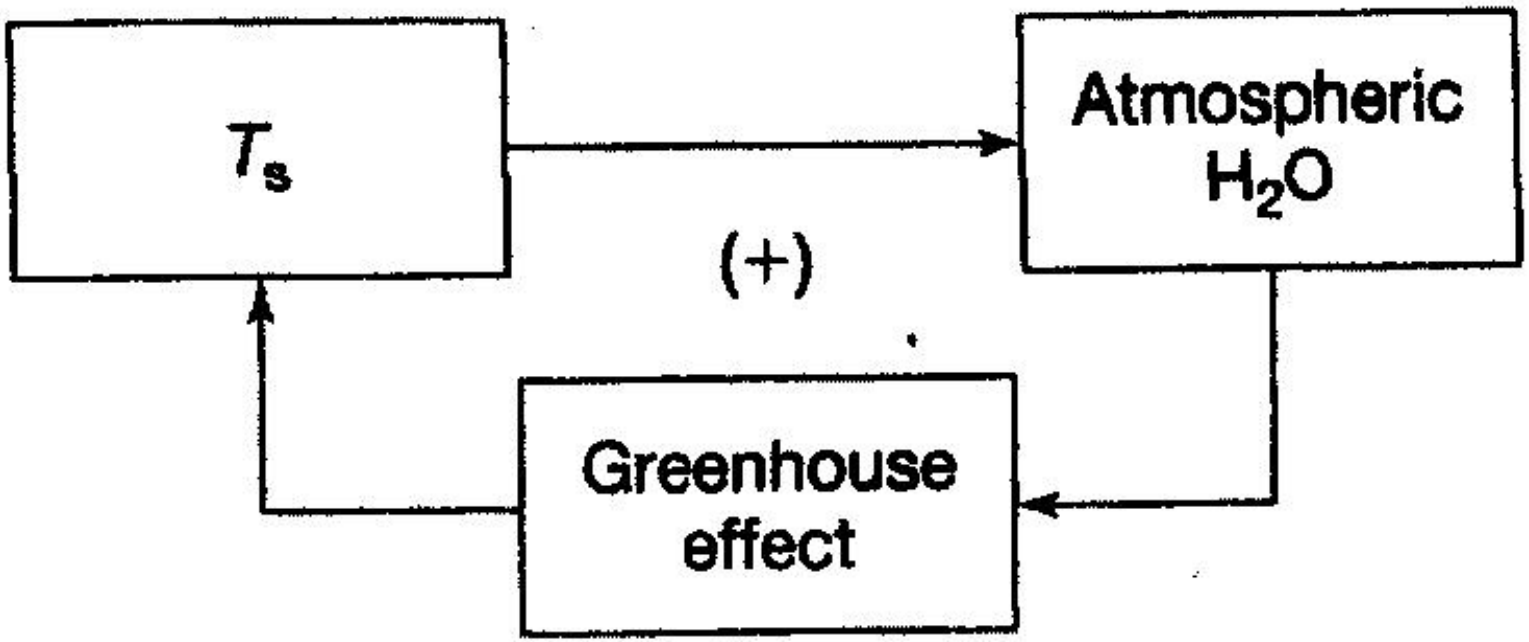
WATER VAPOR Feedback in the Earth-Atmosphere

Q3: What kind of FEEDBACK LOOP IS THIS?

1) Positive + 2) Negative -



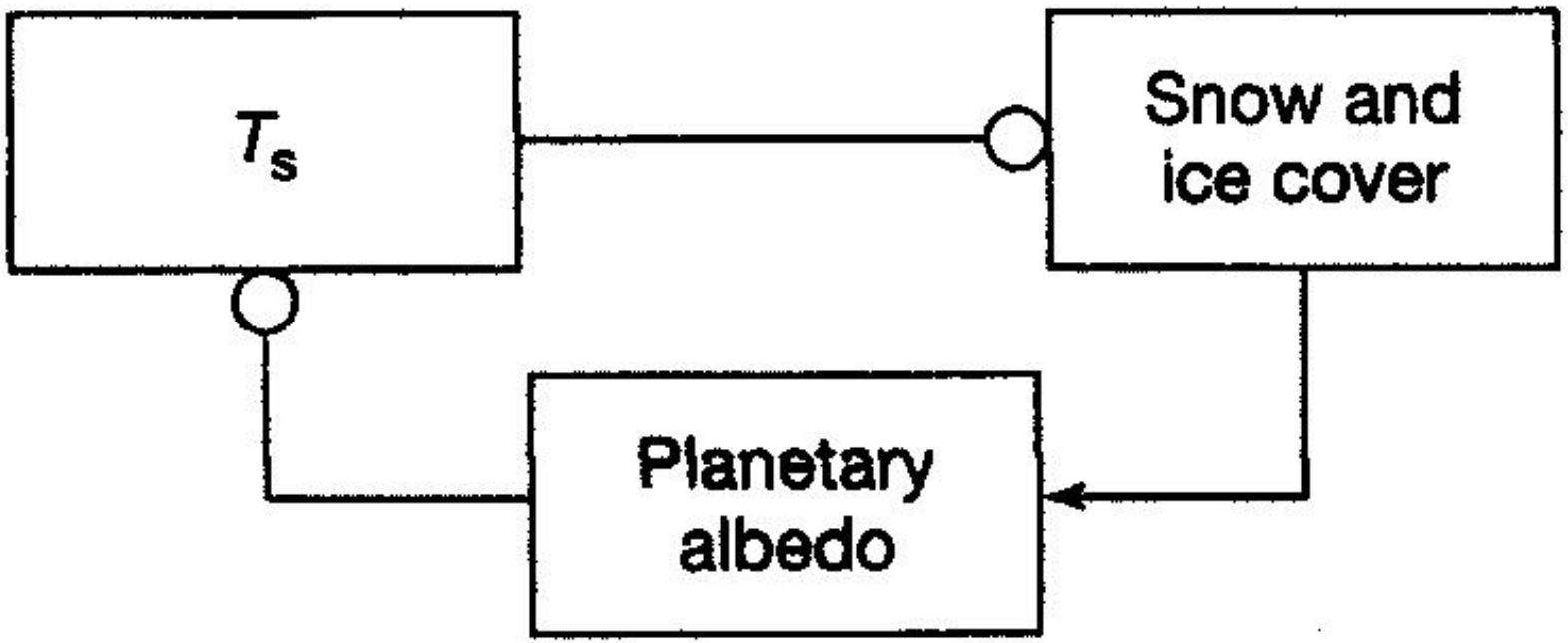
POSITIVE FEEDBACK LOOP
that amplifies the effect!



SNOW AND ICE ALBEDO Feedback

Q4: What kind of FEEDBACK LOOP IS THIS?

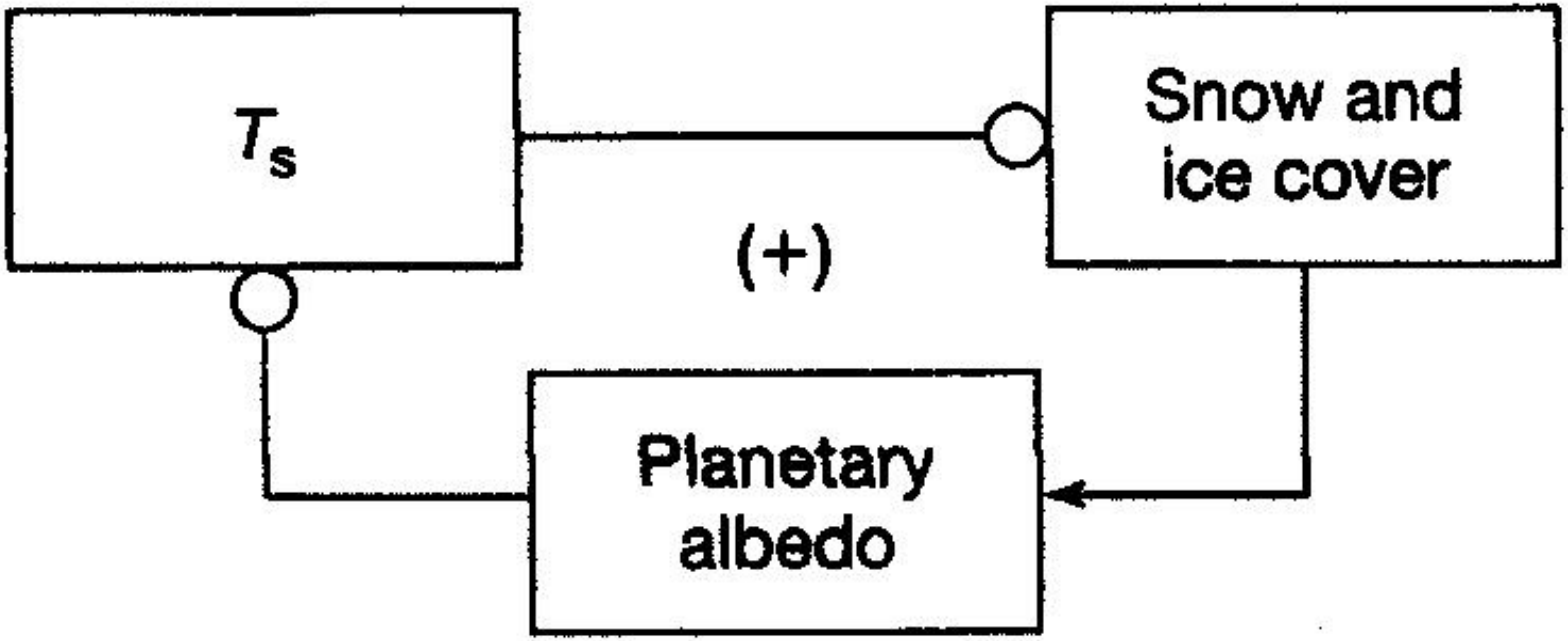
1) Positive + 2) Negative -



ALSO a POSITIVE FEEDBACK LOOP that amplifies the effect!

but

HOW DOES IT WORK?



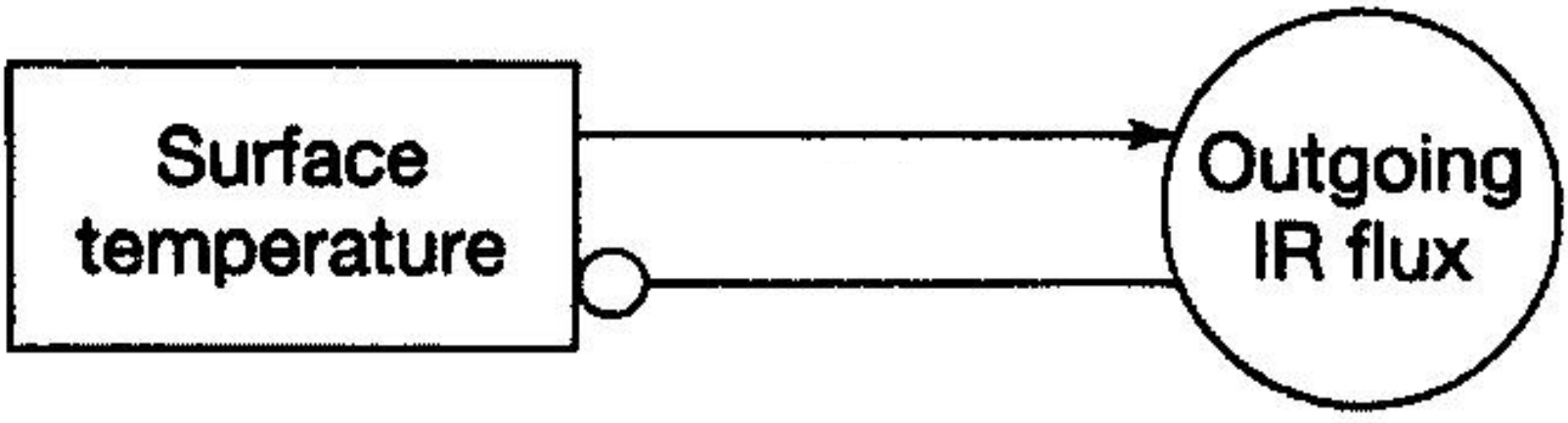
ALBEDO REVIEW →

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

OUTGOING INFRARED ENERGY FLUX / TEMPERATURE Feedback

Q5: What kind of FEEDBACK LOOP IS THIS?

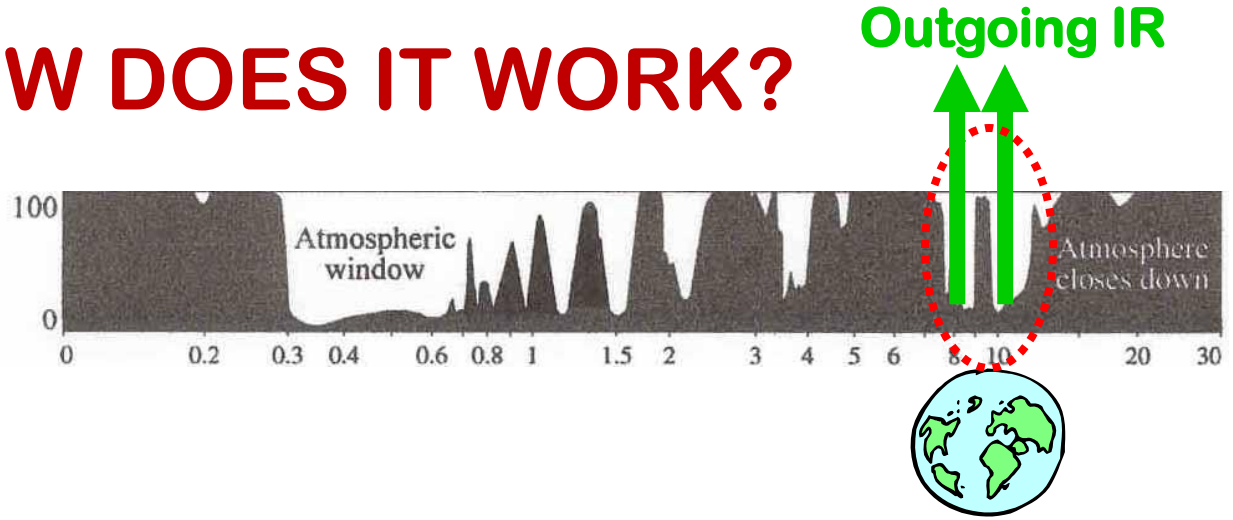
1) Positive + 2) Negative -

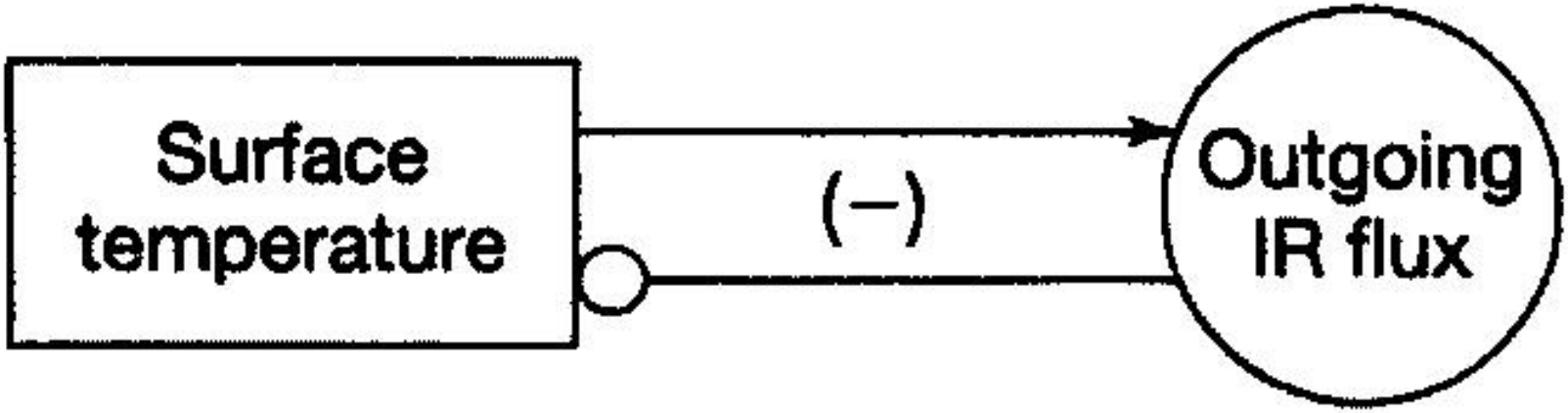


NEGATIVE FEEDBACK LOOP

that is self-regulating!

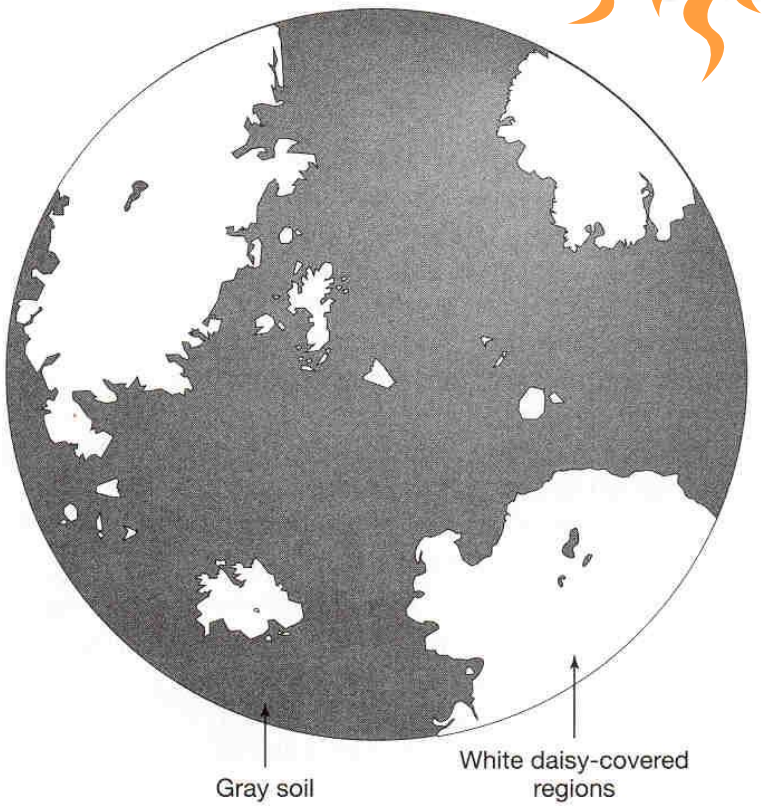
HOW DOES IT WORK?





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

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



TO BE CONTINUED . . . . .