

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, H₂O CO₂

Formulas & Equations

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

SYMBOLIC NOTATION (cont)

MODELS!

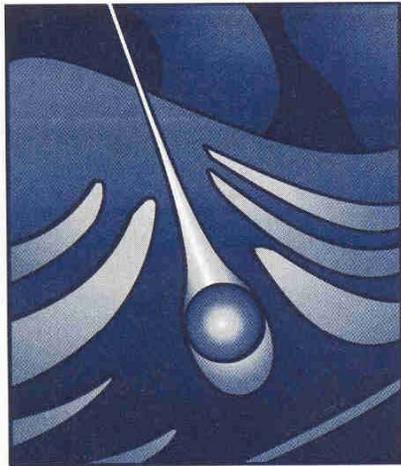
WHAT IS A MODEL?

- 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"



Daisyworld: An Introduction to Systems

WHAT IS A SYSTEM?

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

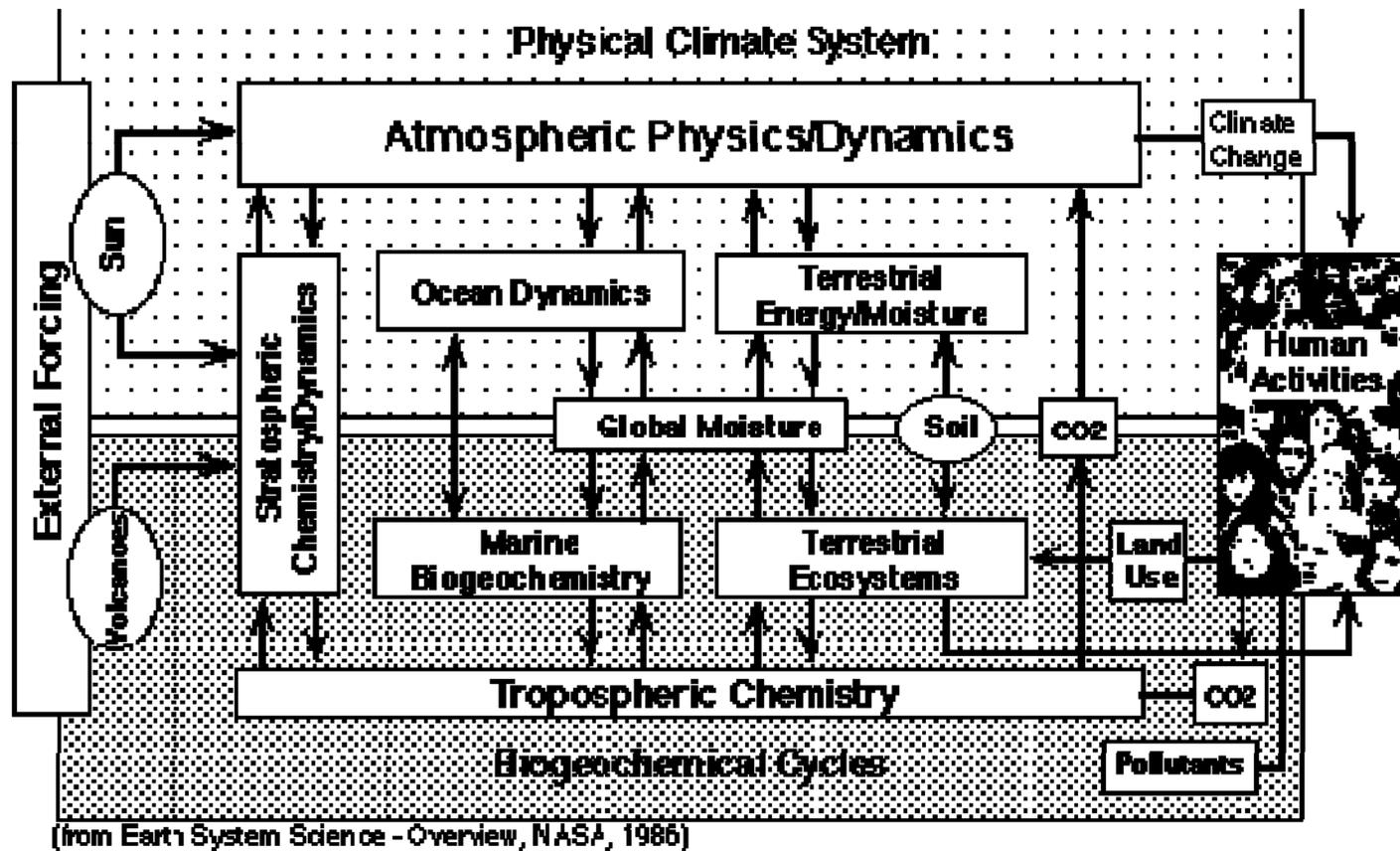
- **SYSTEM MODEL** =

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 =

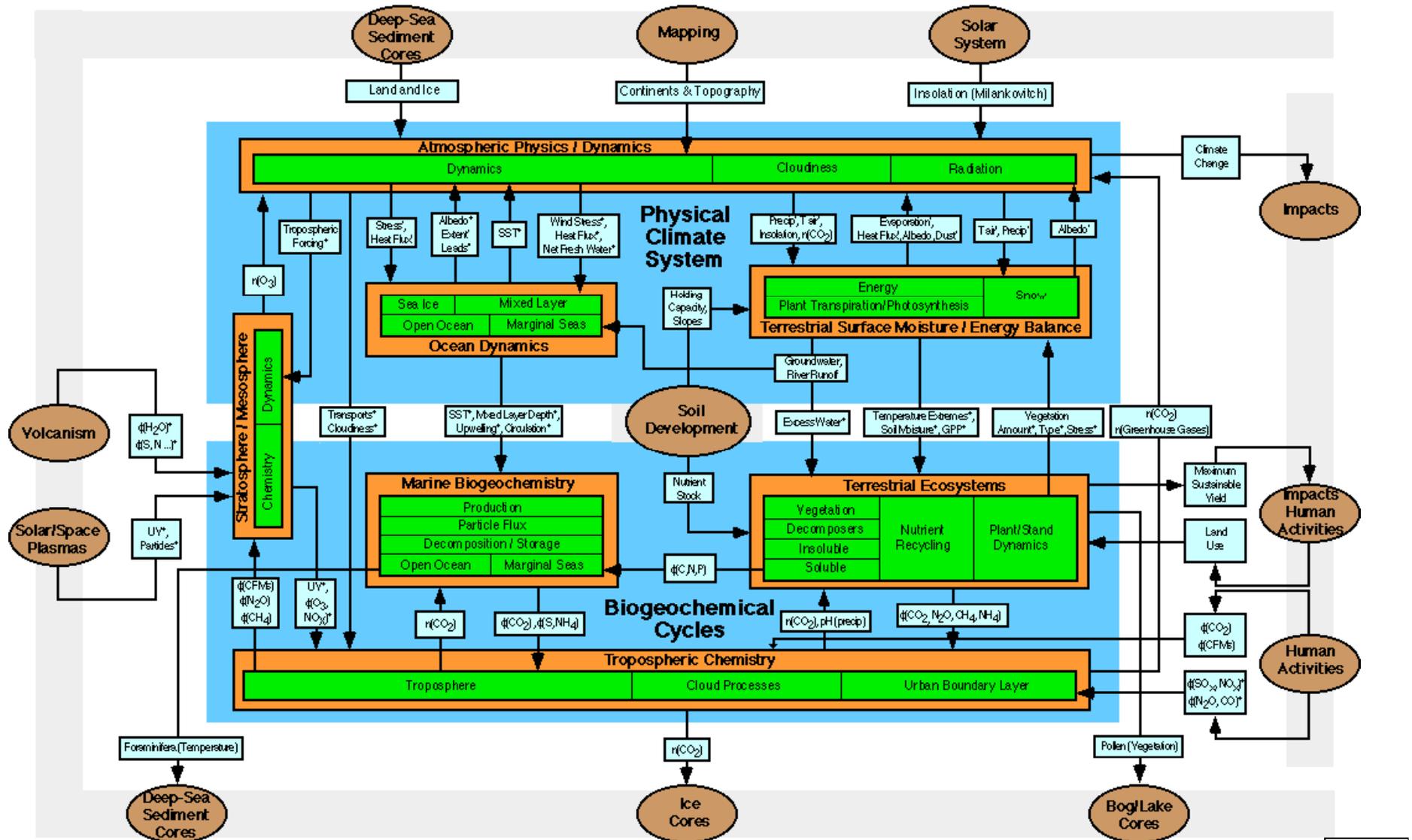
A diagram of a system that uses graphic symbols or icons to represent components in a depiction of how the system works

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



Another more complicated system diagram:

CONCEPTUAL MODEL of Earth System process operating on timescales of decades to centuries



' = on timescale of hours to days * = on timescale of months to seasons ϕ = flux n = concentration



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.

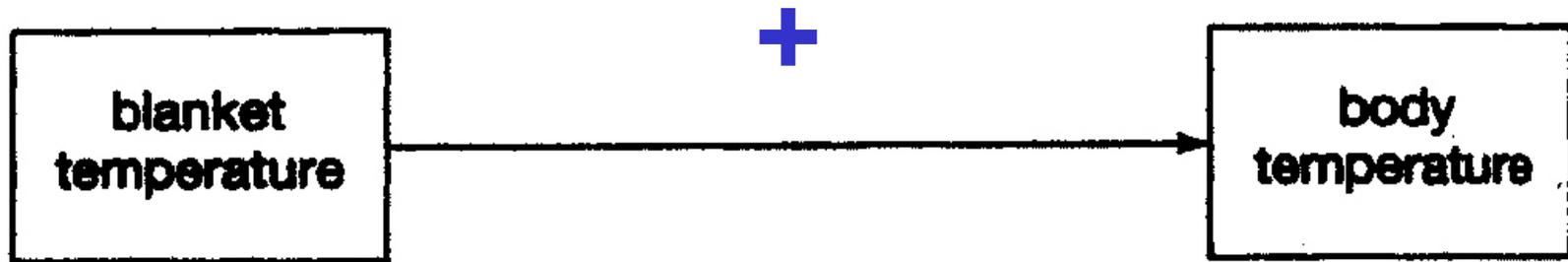
COUPLING

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 . . .**

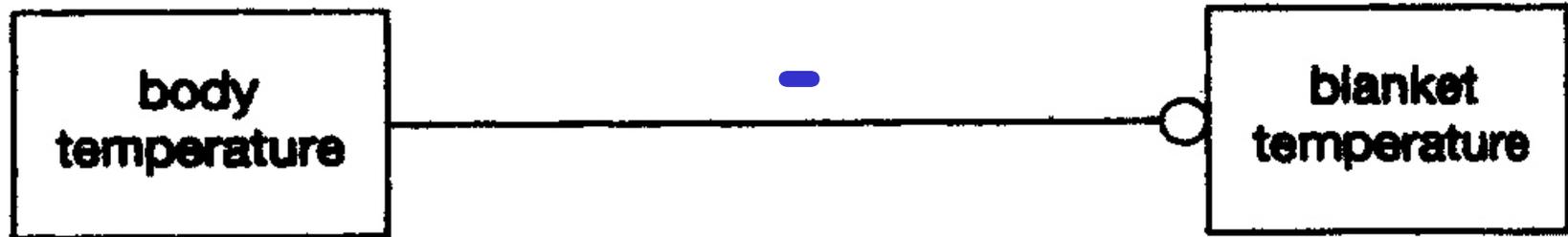
The person's body temperature will also **INCREASE**

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

Feedback mechanism *(def):*

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

Feedbacks occur in loops →

Feedback Loop (def) =

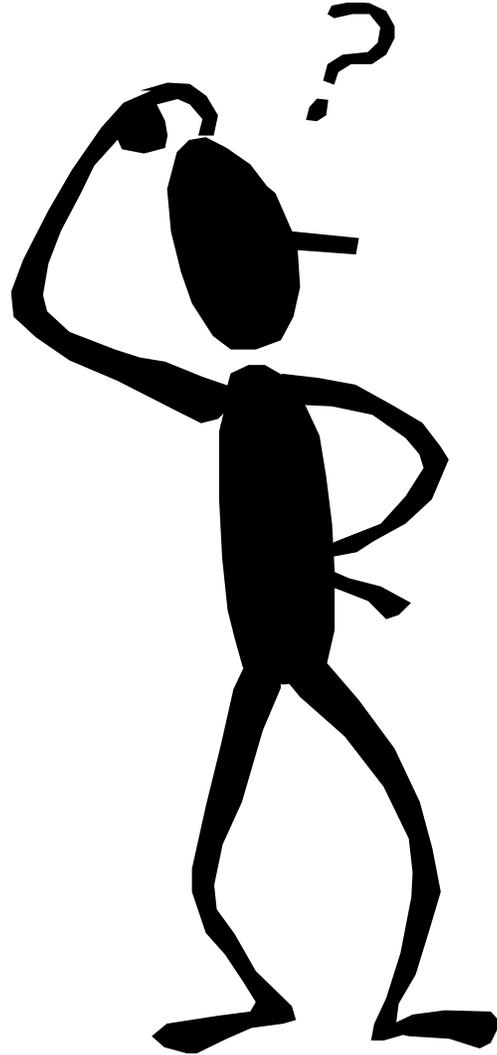
A linkage of two or more system components that forms a ROUND-TRIP flow of information.

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"

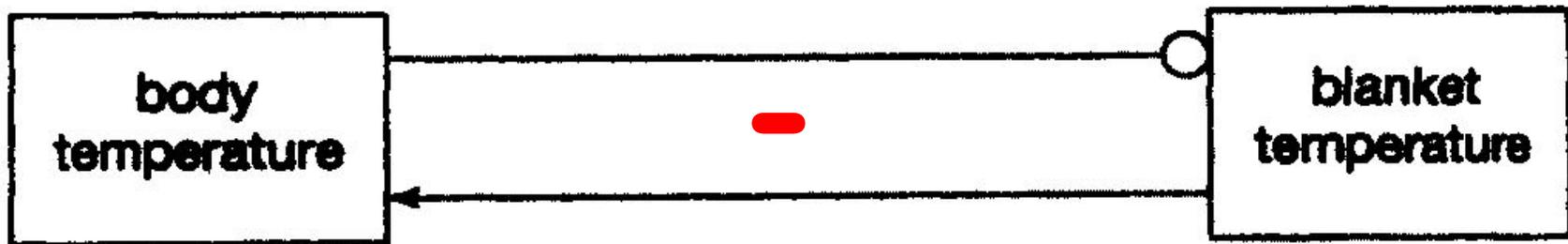
i.e., a perturbation or disturbance in a system characterized by a **negative feedback loop** will be able to adjust to the perturbation and ultimately the effect on the system will be negligible

FEEDBACK LOOP

Q3: What kind of FEEDBACK LOOP IS IT?

1) Positive (+)

2) Negative (-) ???



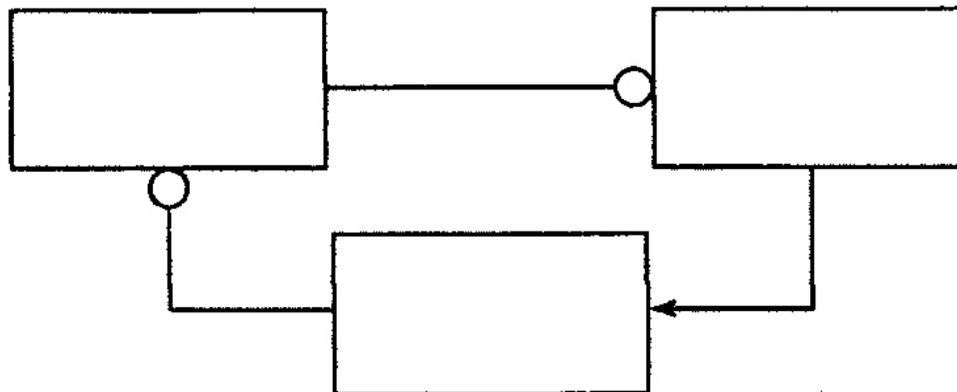
THE “RULE” – how to tell if it’s a positive or negative feedback LOOP:

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”]

STABLE EQUILIBRIUM STATES:

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

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

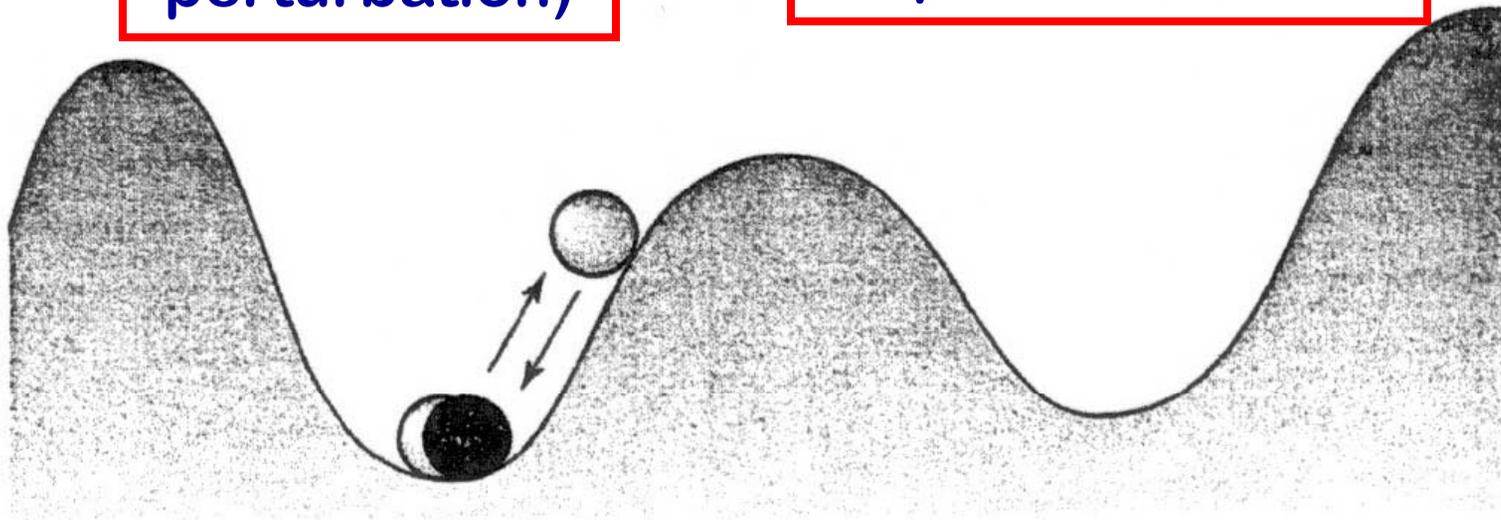
Take notes

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

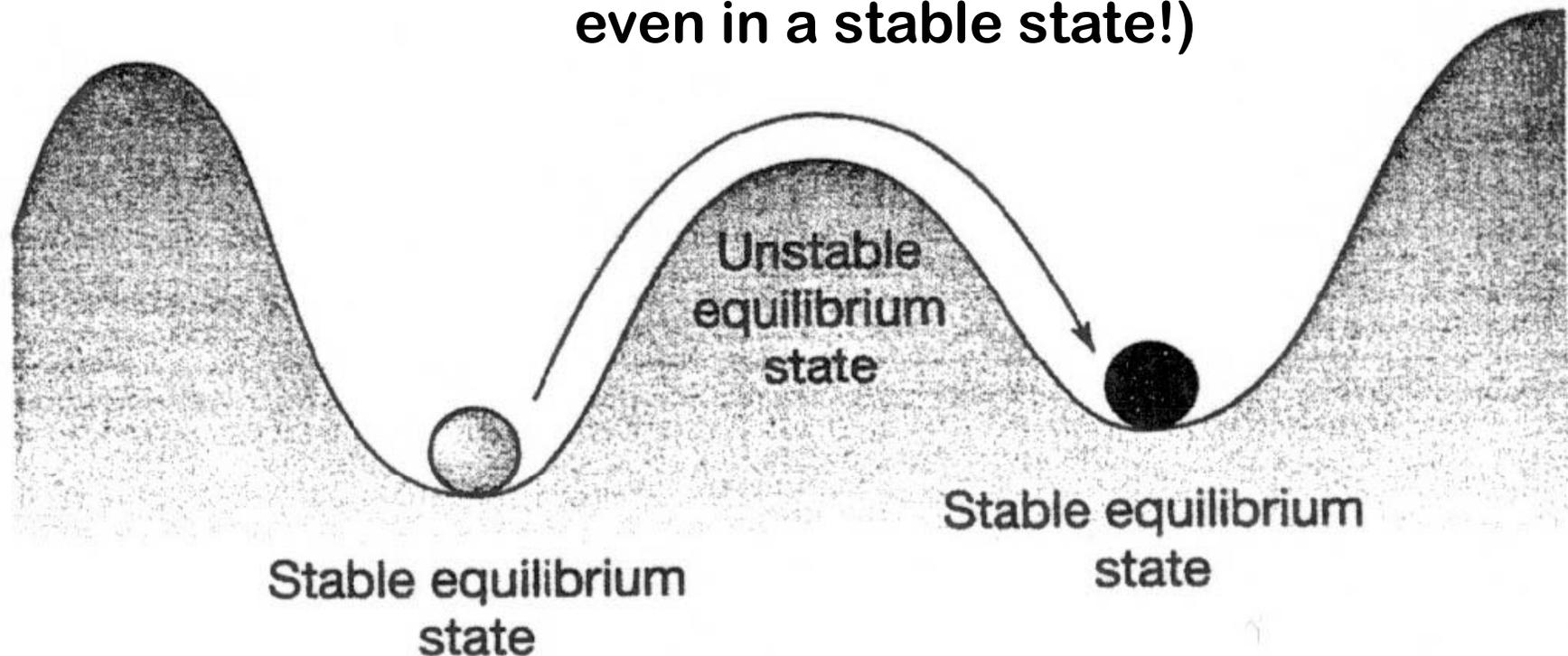


Stable equilibrium
state

Take notes
See top figure
on p 59

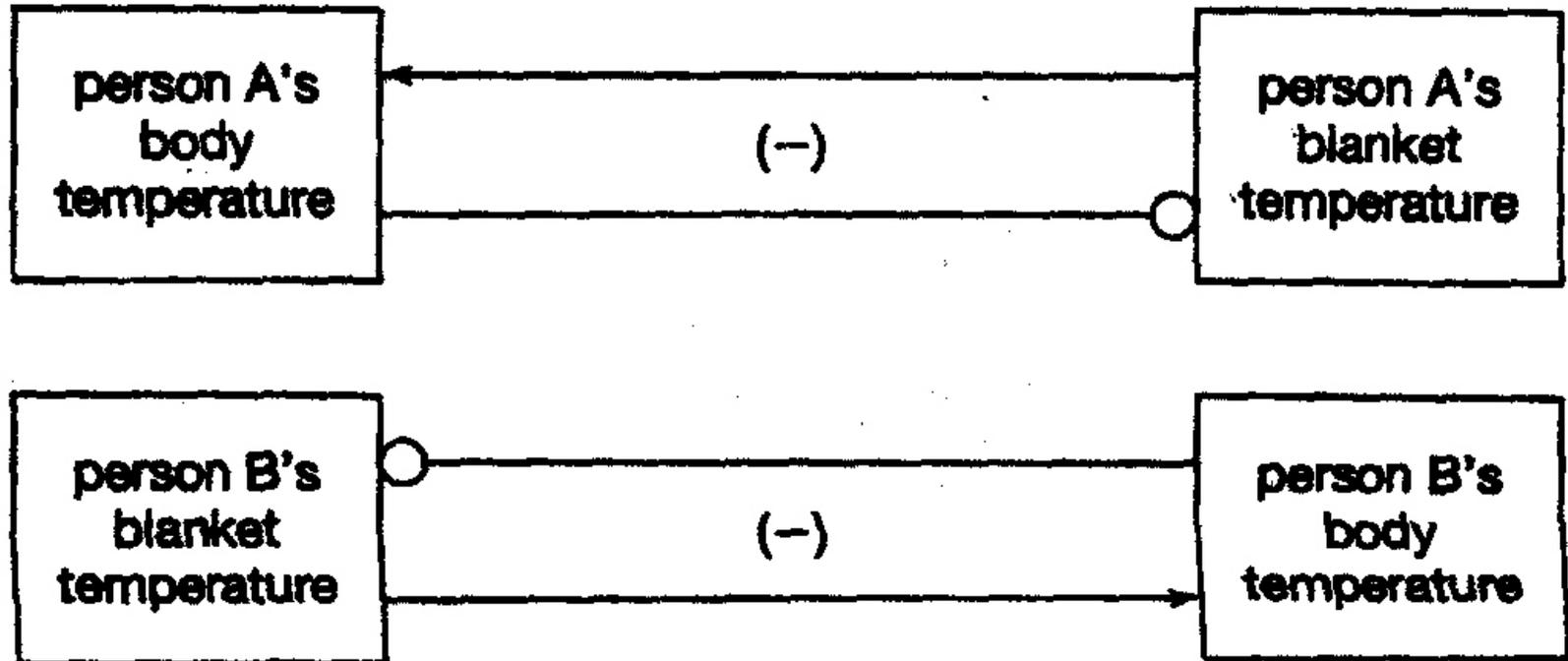
A **LARGE or more persistent** disturbance
(a forcing) can carry the system to a
different equilibrium state

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



Everyday life example:

Proper alignment of dual control electric blanket:

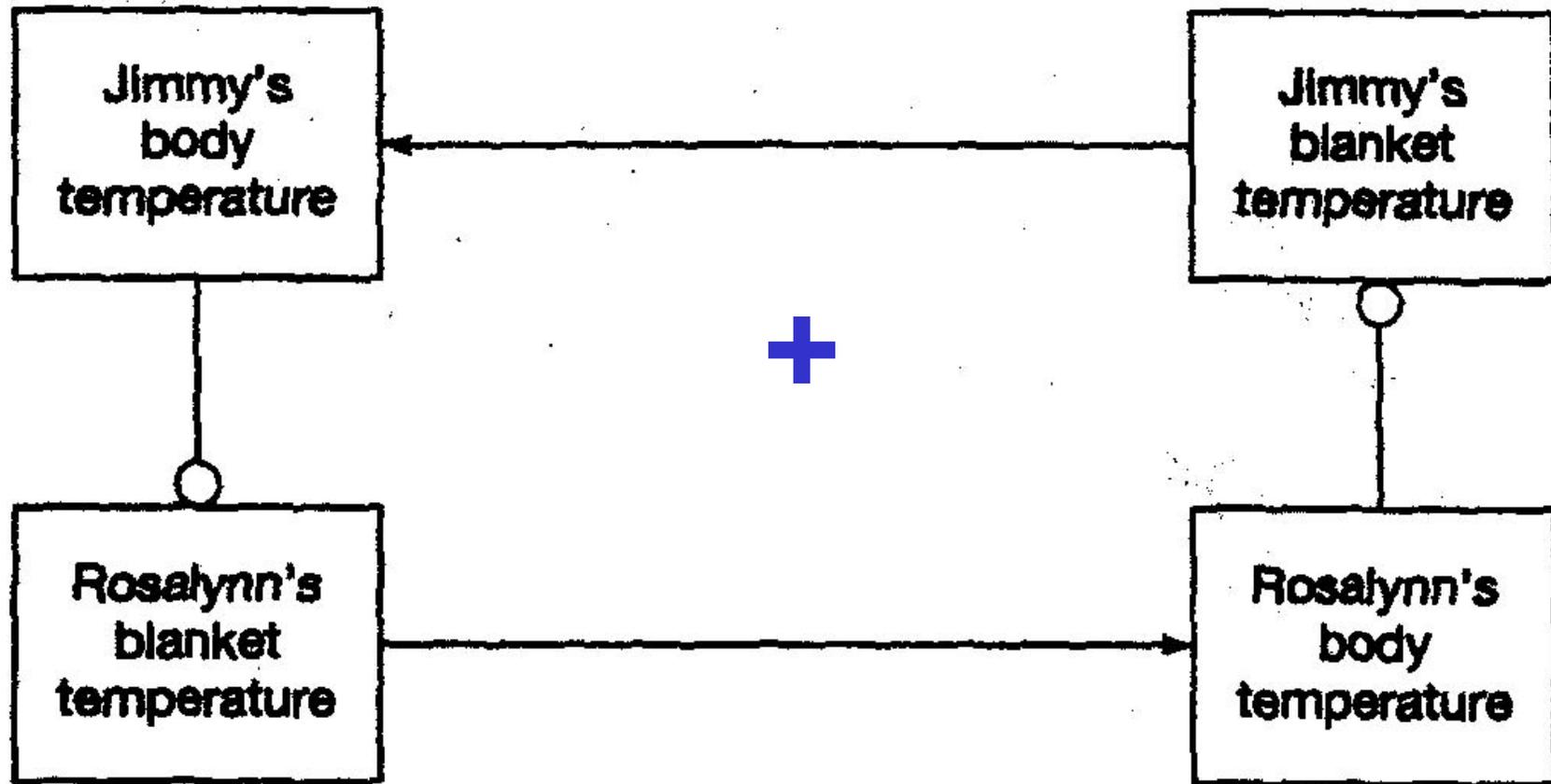


Improper alignment:

Q4. What kind of FEEDBACK LOOP IS IT?

1) Positive +

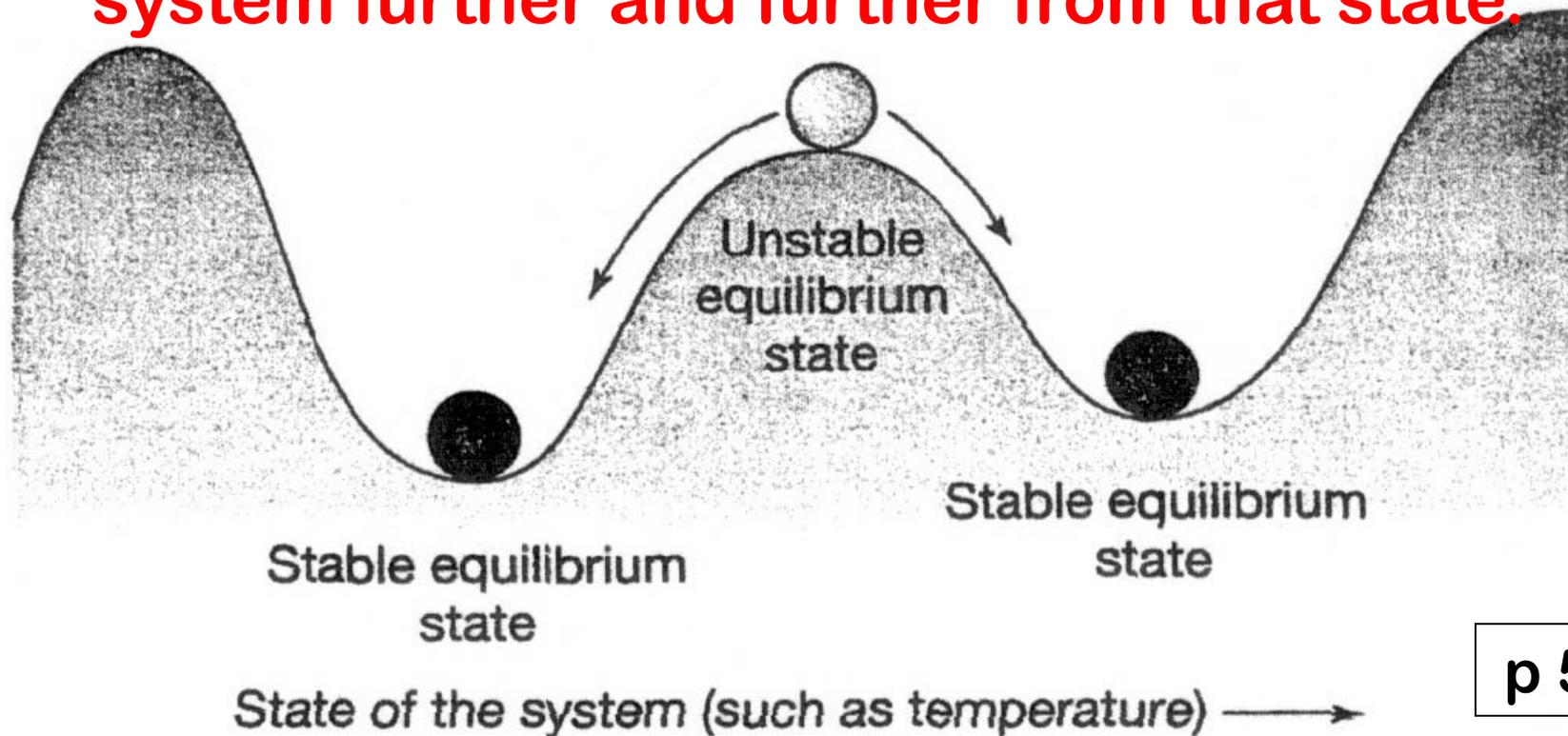
2) Negative -



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.



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)

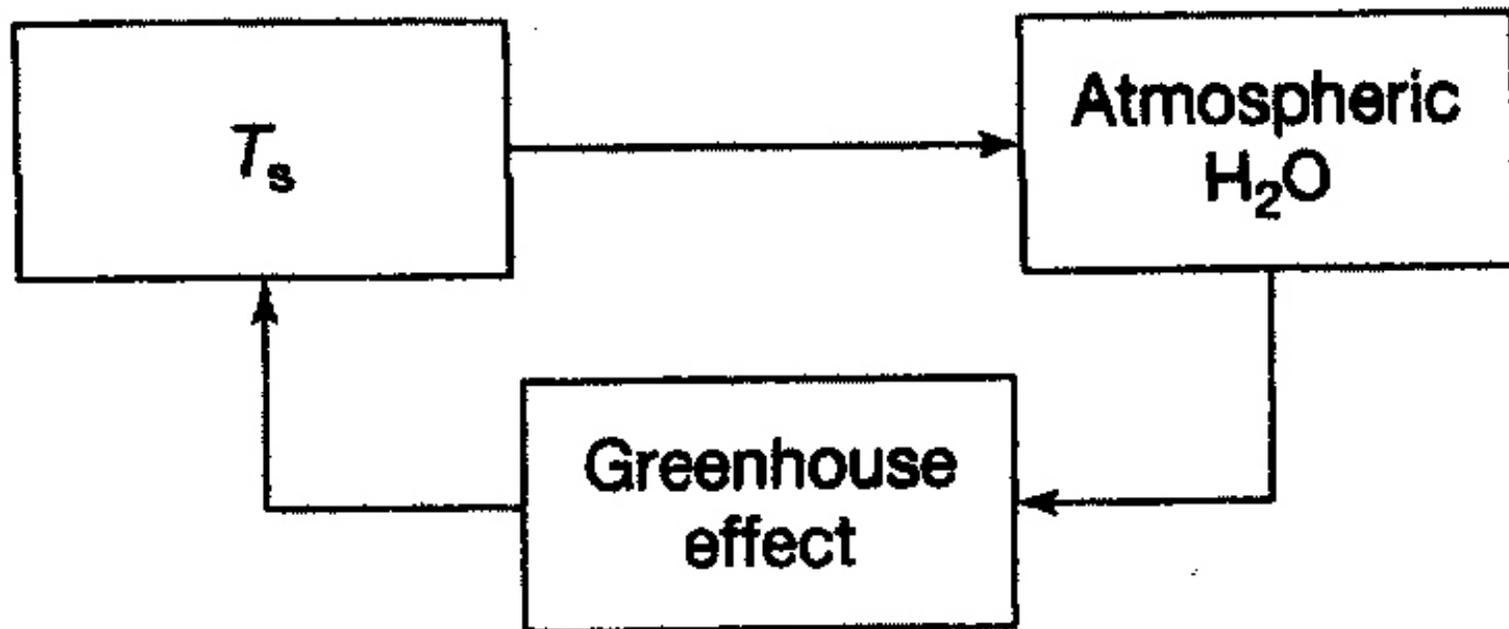
. . . and whether or not the Earth can **adjust** to these and have **a stable equilibrium state**, or be thrown into **an unstable state** due to **positive feedback loops**

WATER VAPOR Feedback in the Earth-Atmosphere

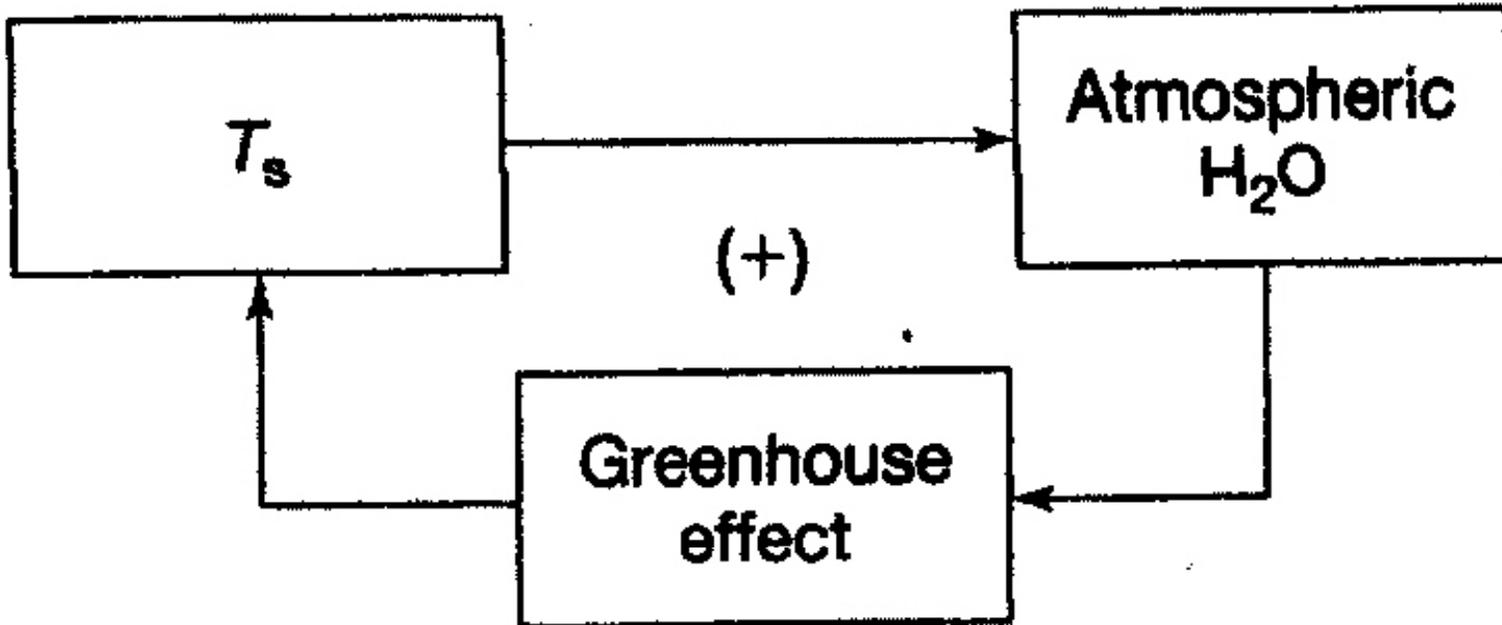
Q5: What kind of FEEDBACK LOOP IS THIS?

1) Positive +

2) Negative -



POSITIVE FEEDBACK LOOP
that **amplifies** the effect!

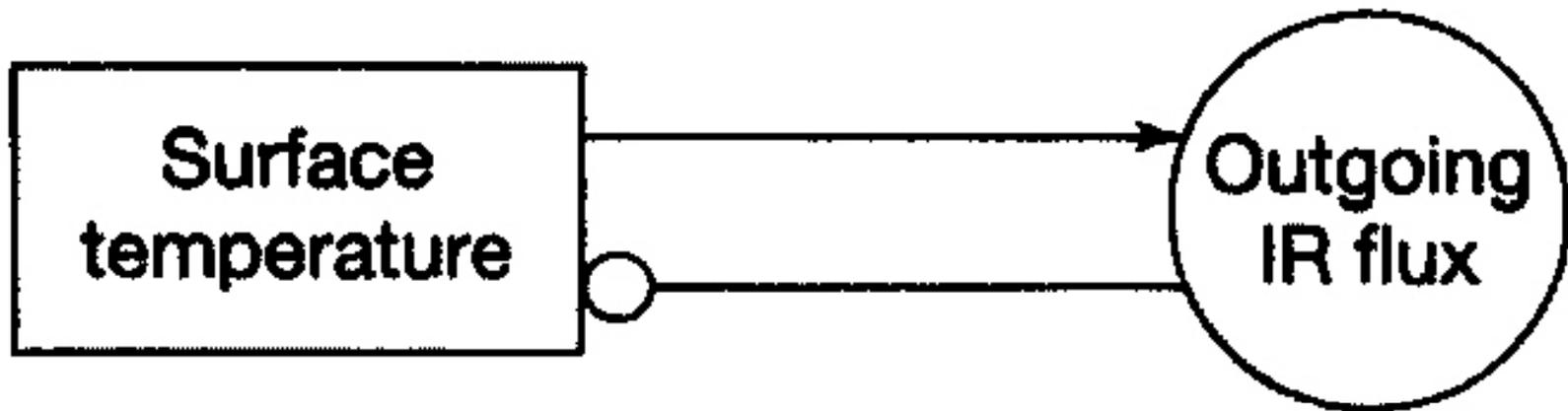


OUTGOING INFRARED ENERGY FLUX / TEMPERATURE Feedback

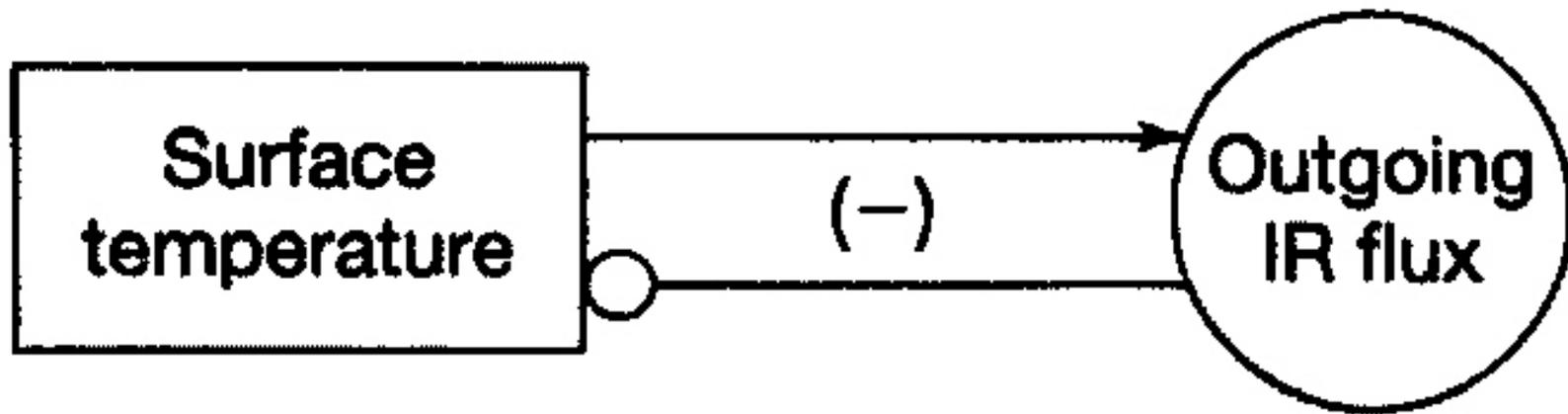
Q6: What kind of FEEDBACK LOOP IS THIS?

1) Positive +

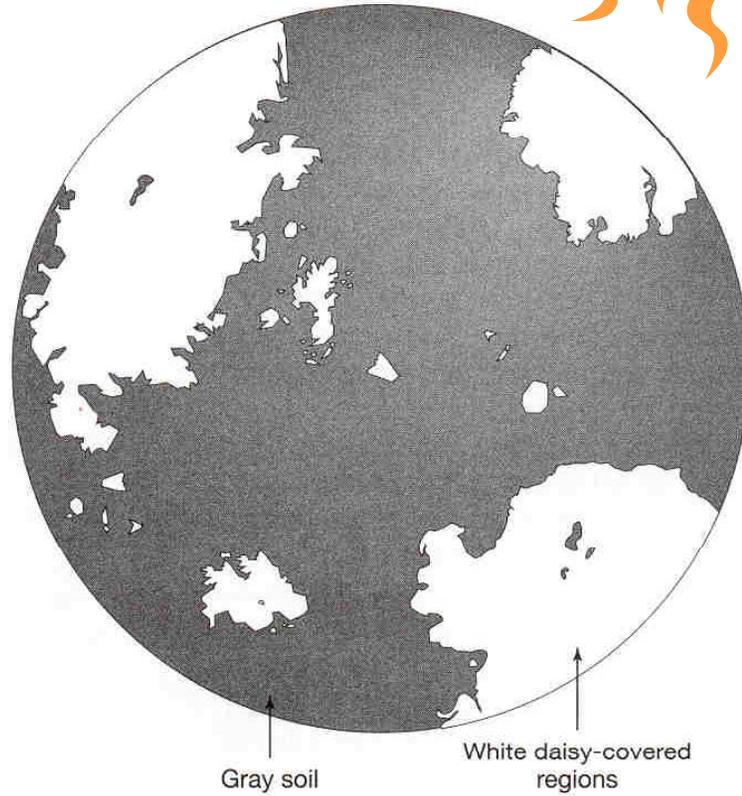
2) Negative -



NEGATIVE FEEDBACK LOOP
that is self-regulating!



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

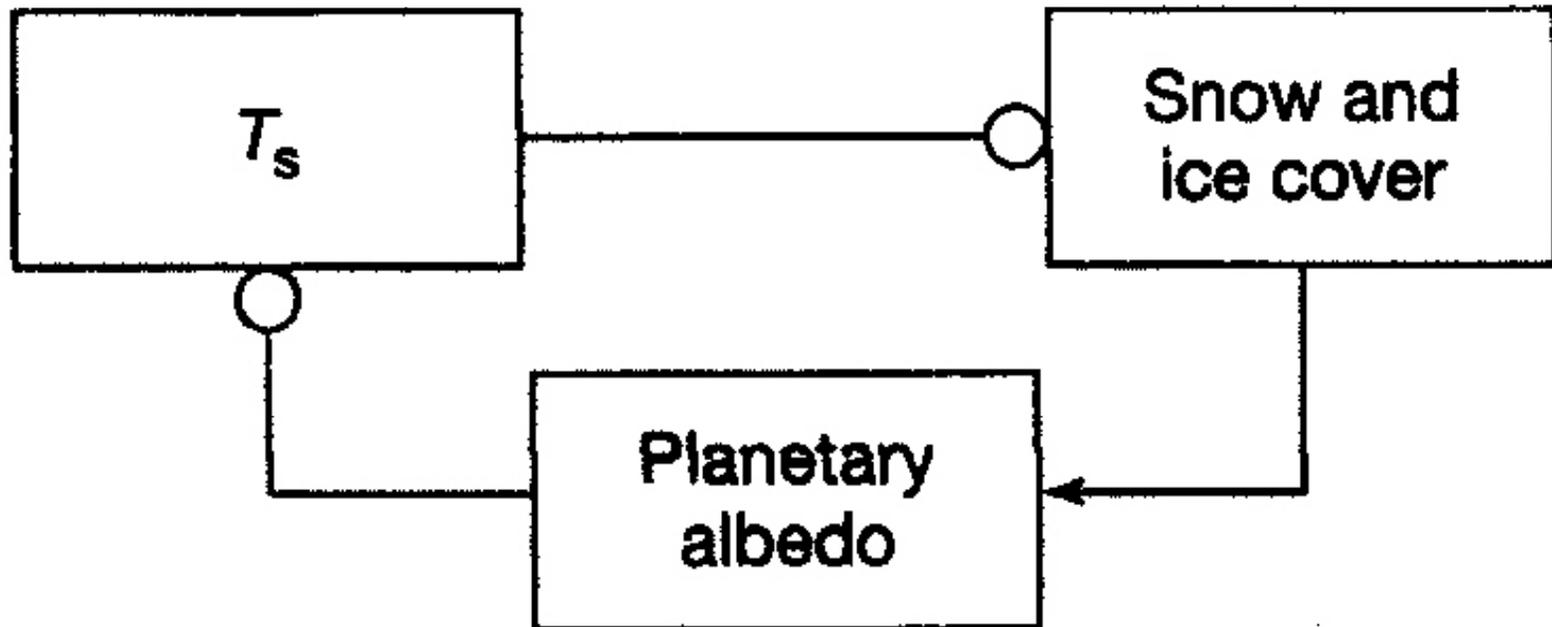


SNOW AND ICE ALBEDO Feedback

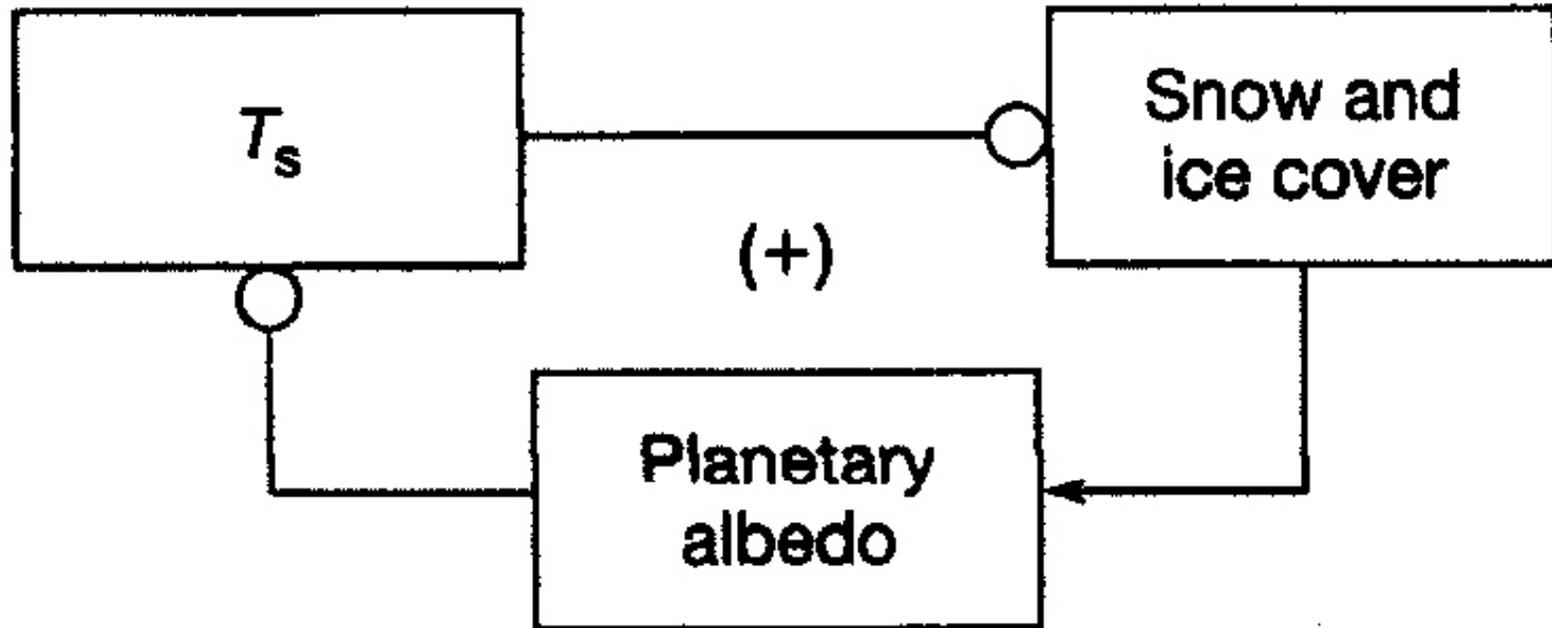
Q7: What kind of FEEDBACK LOOP IS THIS?

1) Positive +

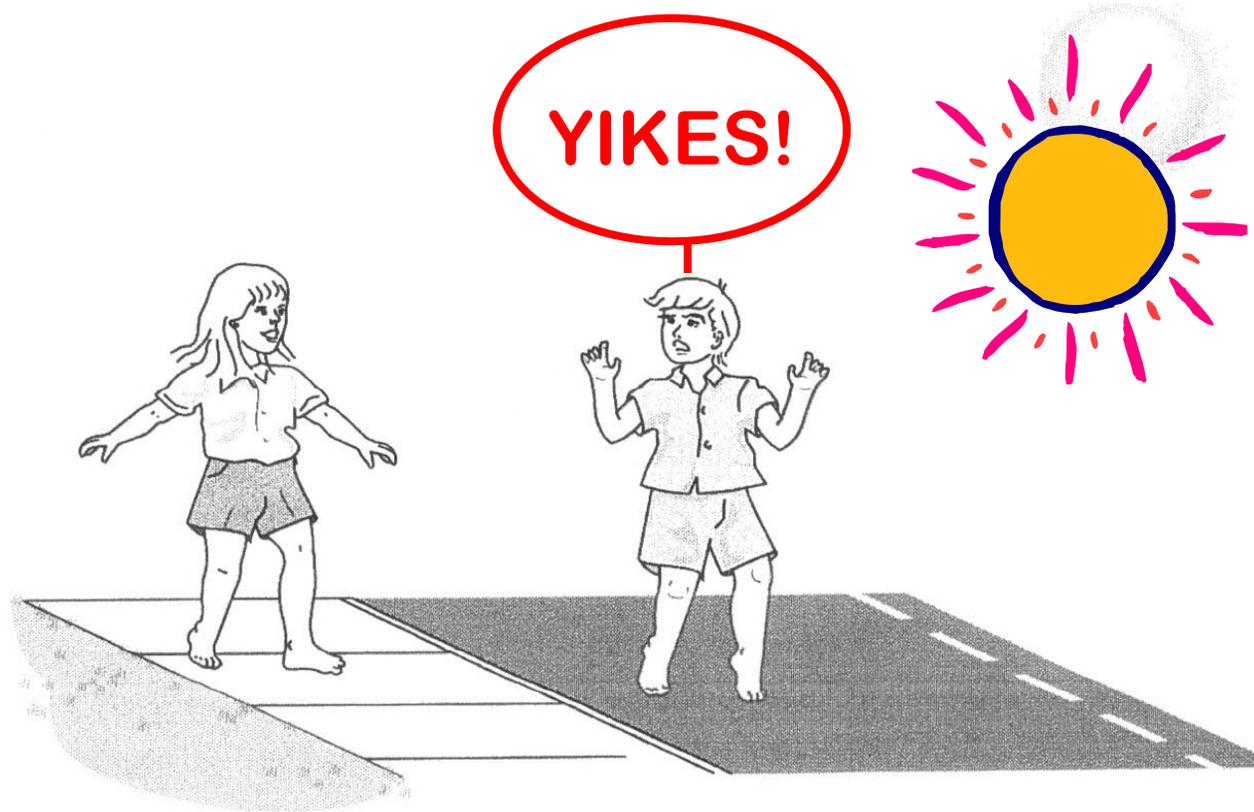
2) Negative -



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

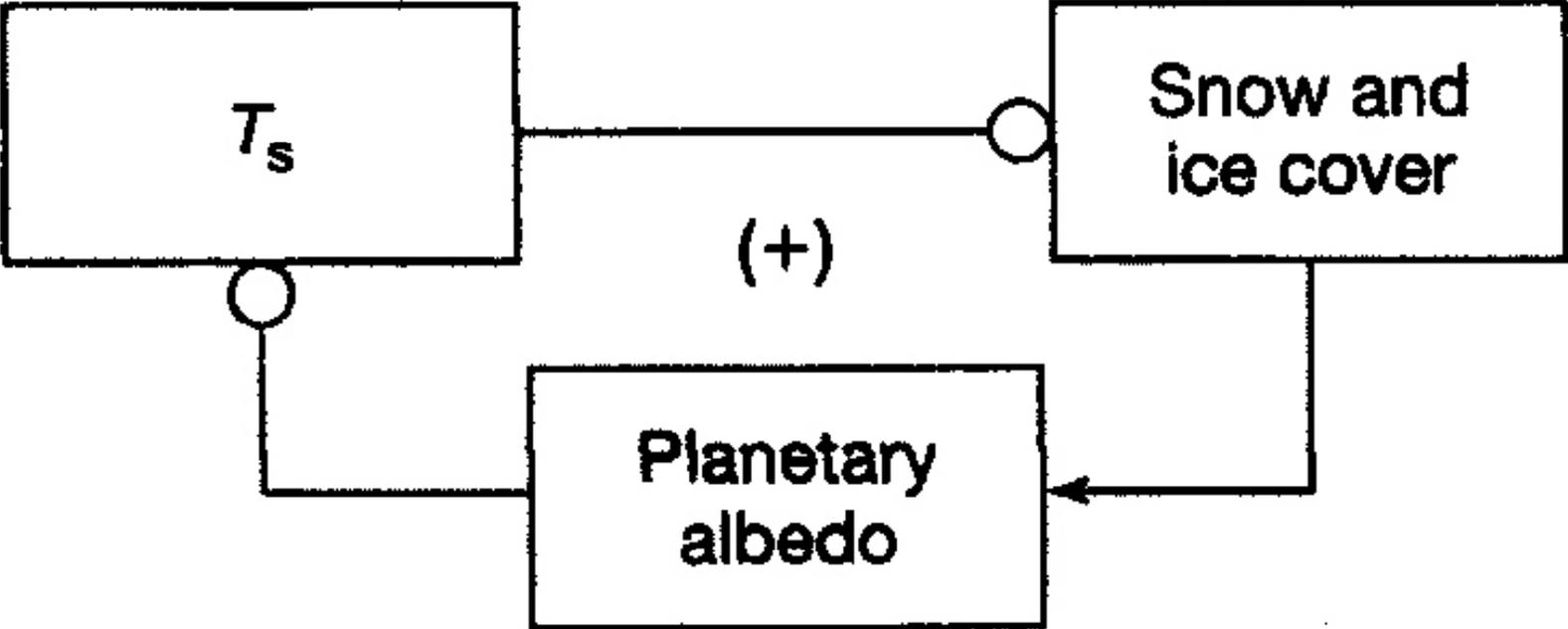
Albedos of Some Common Surfaces

<i>Type of Surface</i>	<i>Albedo</i>
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



Albedos of Some Common Surfaces

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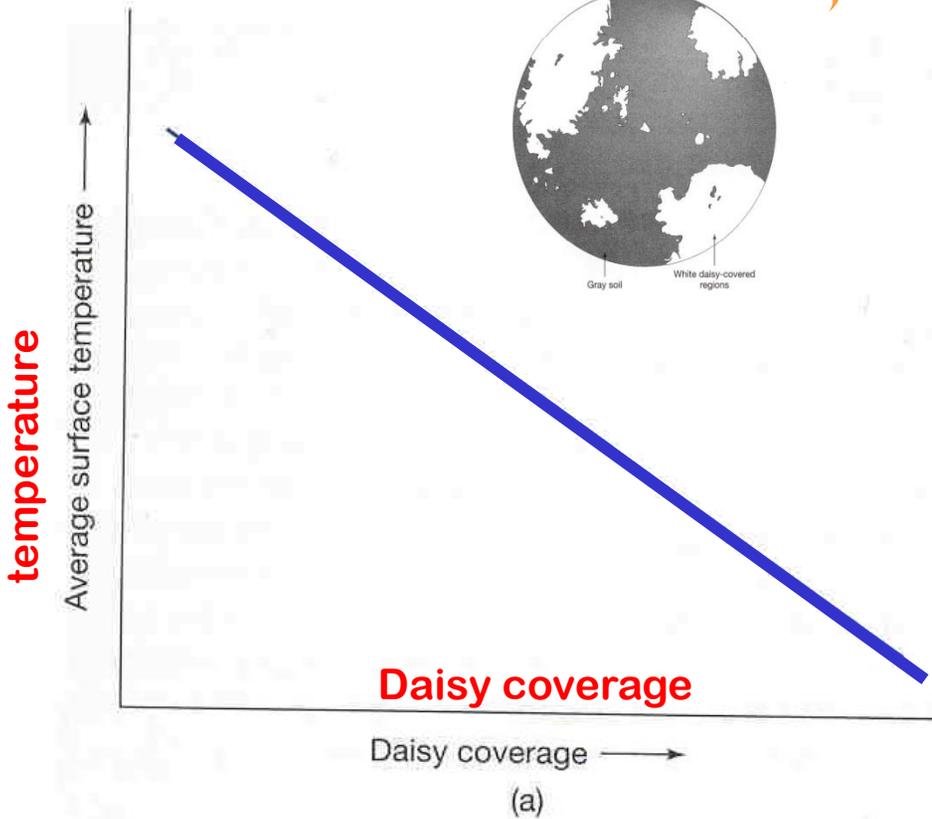
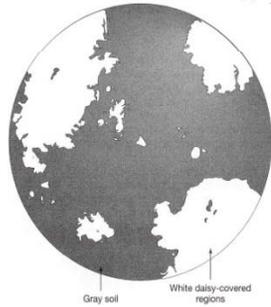
PLANET EARTH = ~ 0.30

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

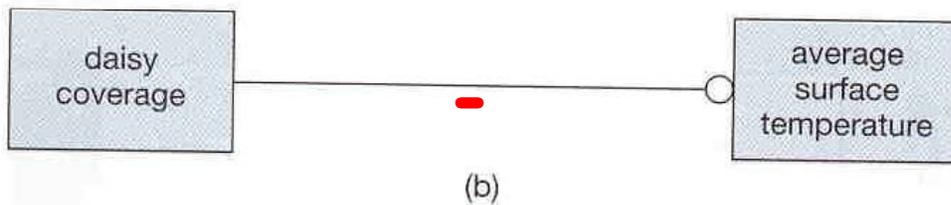
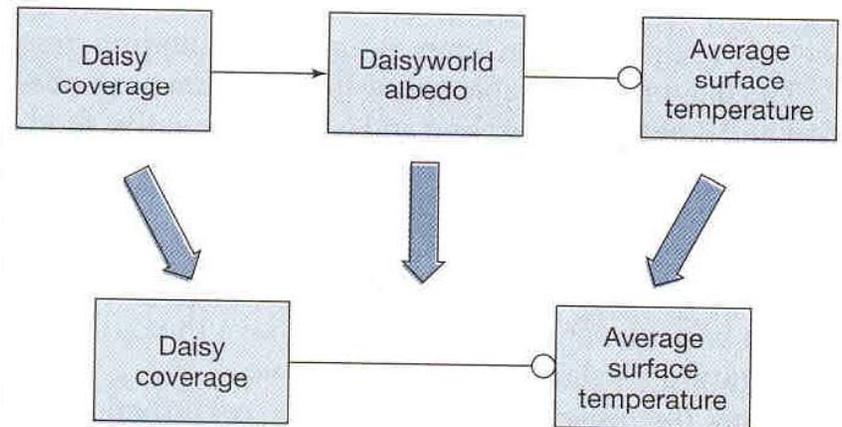
Review

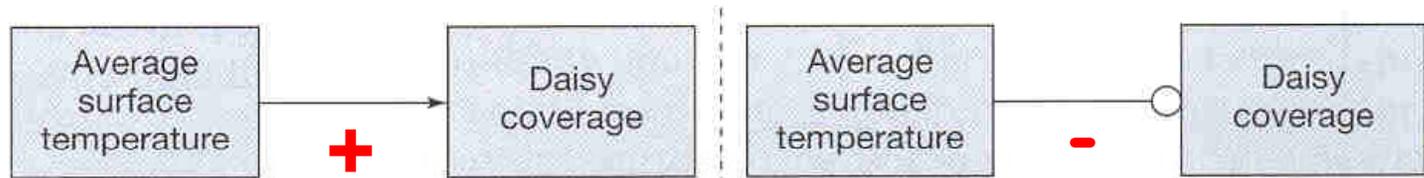
HOW DAISY COVERAGE AFFECTS TEMPERATURE:

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





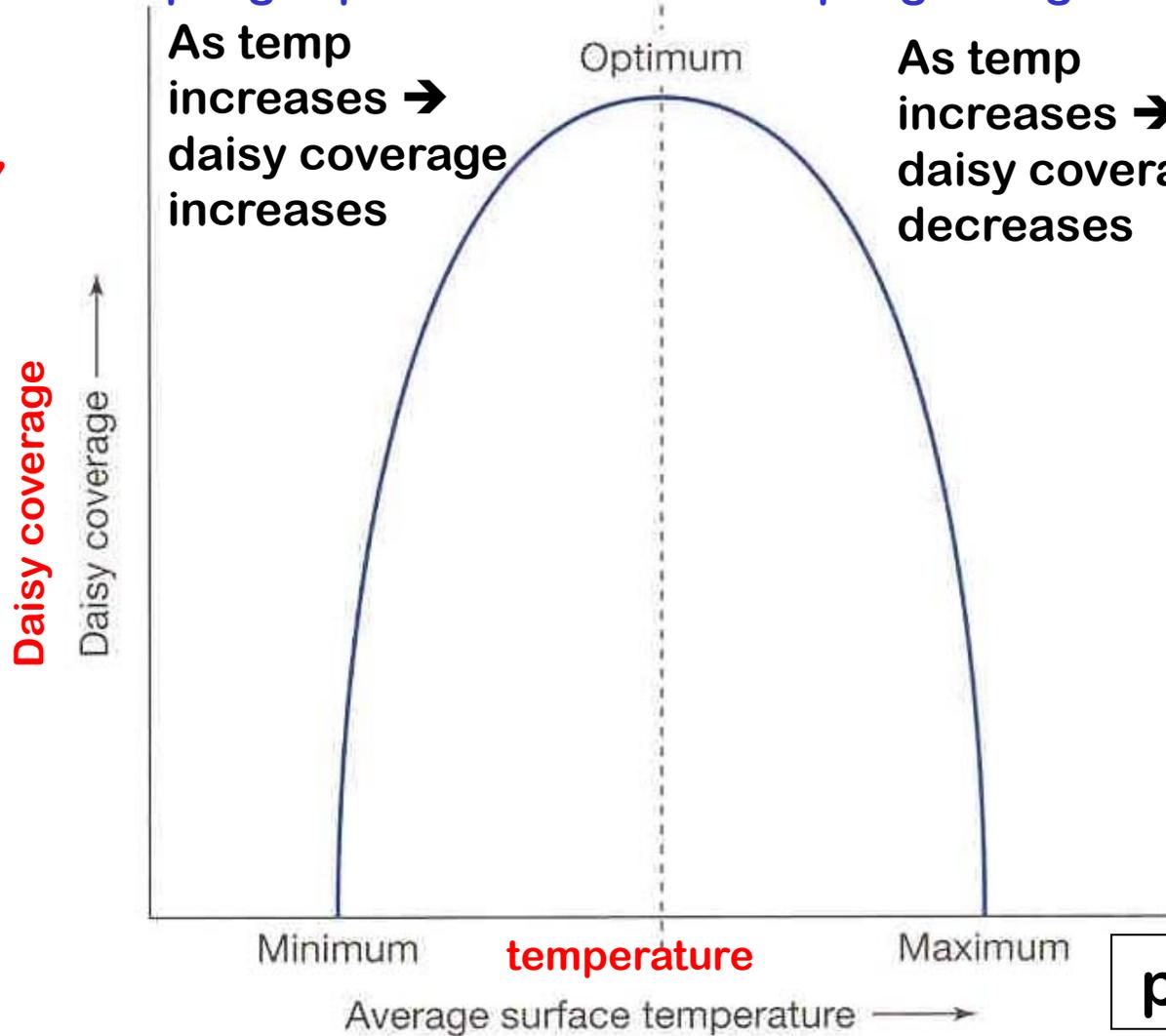
HOW TEMPERATURE AFFECTS DAISY COVERAGE:

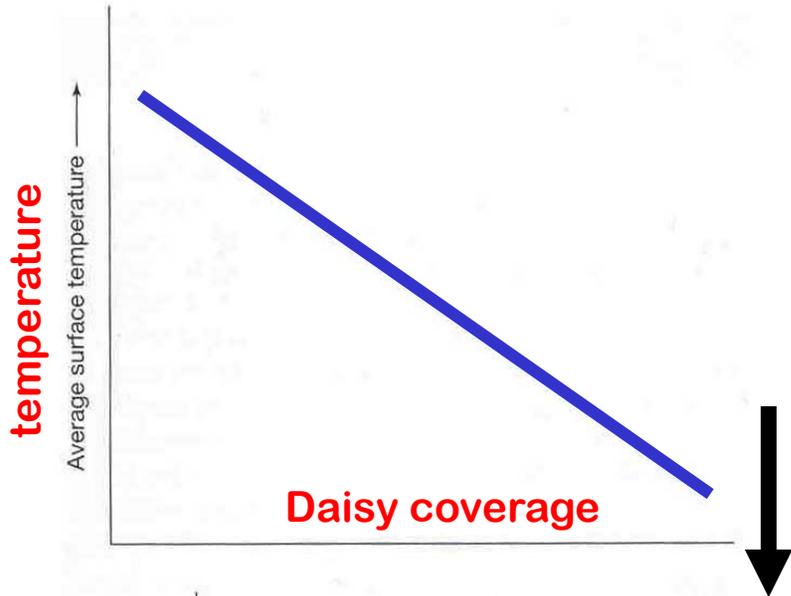
Coupling is positive

As temp increases \rightarrow daisy coverage increases

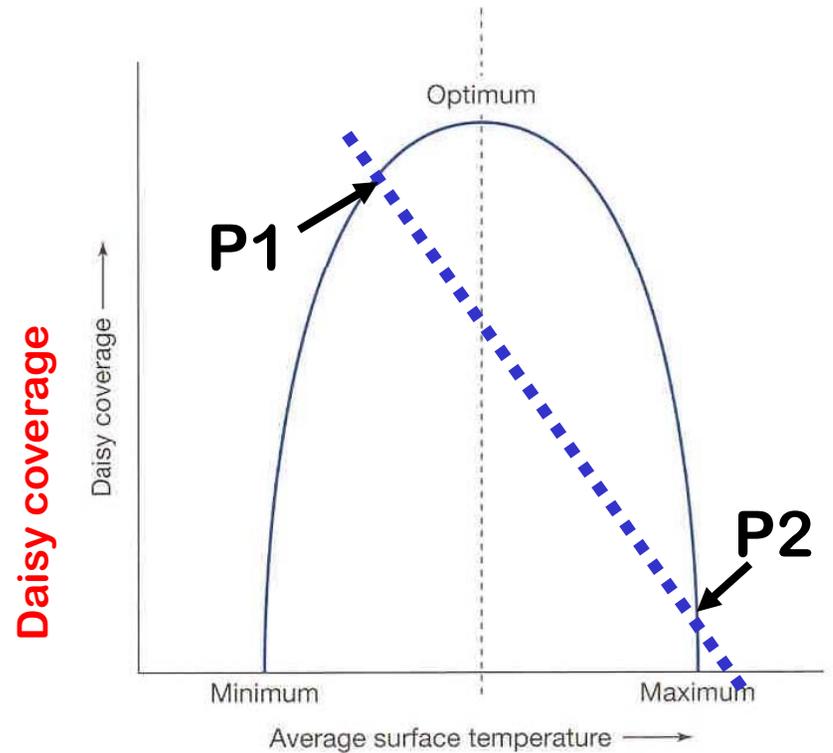
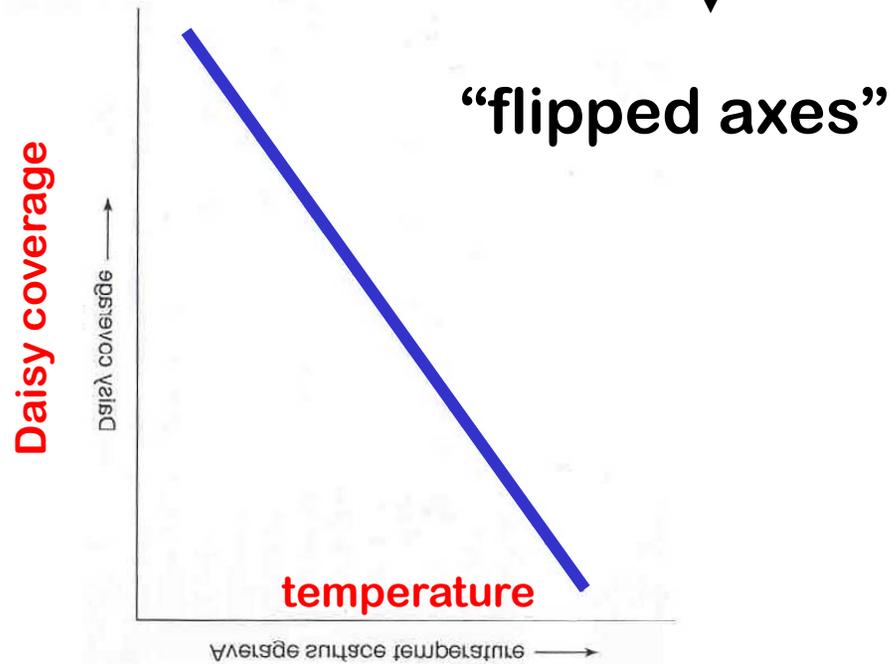
Coupling is negative

As temp increases \rightarrow daisy coverage decreases





PUTTING THE TWO GRAPHS TOGETHER!



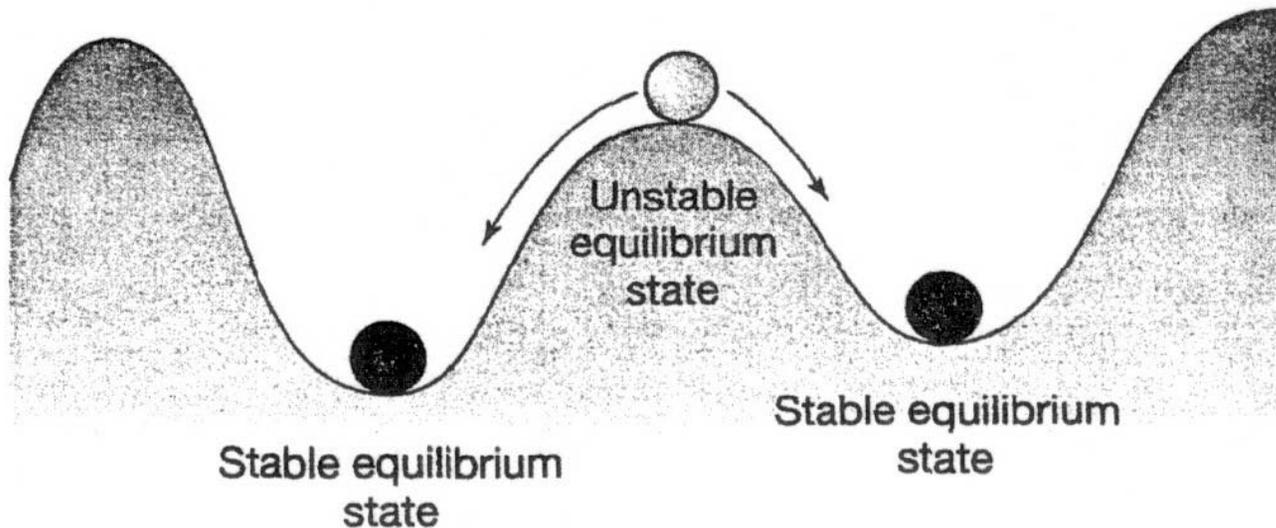
temperature

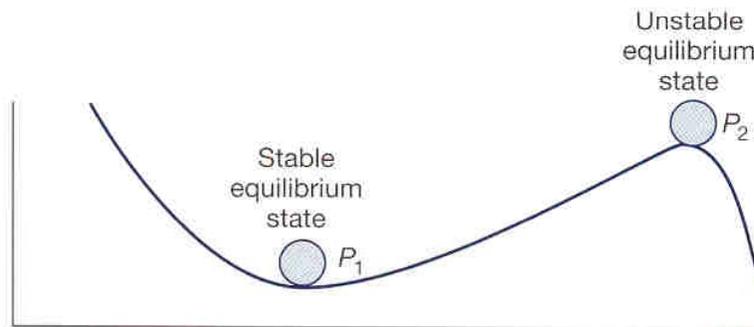
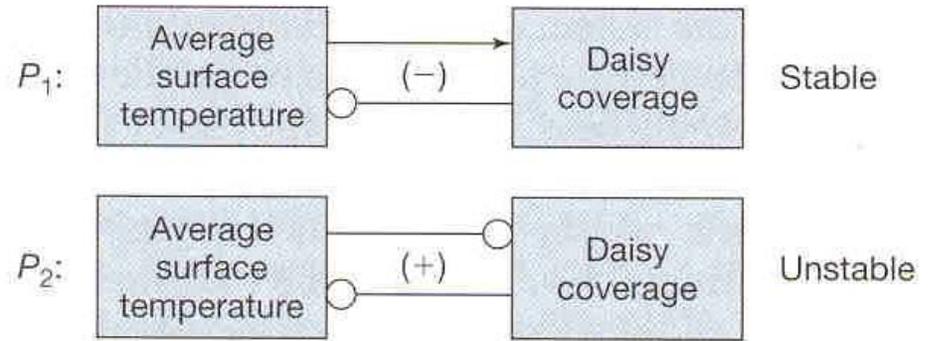
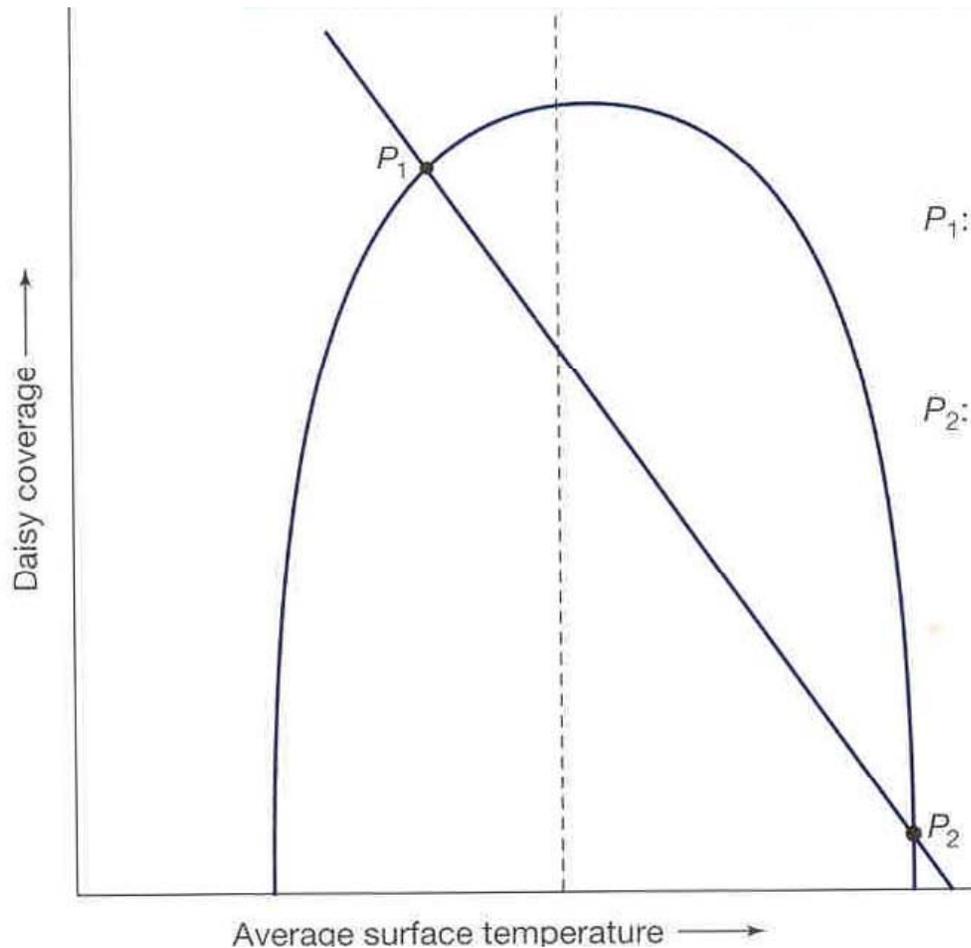
P1 and P2 are:

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**.





P_1 & P_2 are each “EQUILIBRIUM” states, but one is in a more precarious state (unstable) than the other

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:

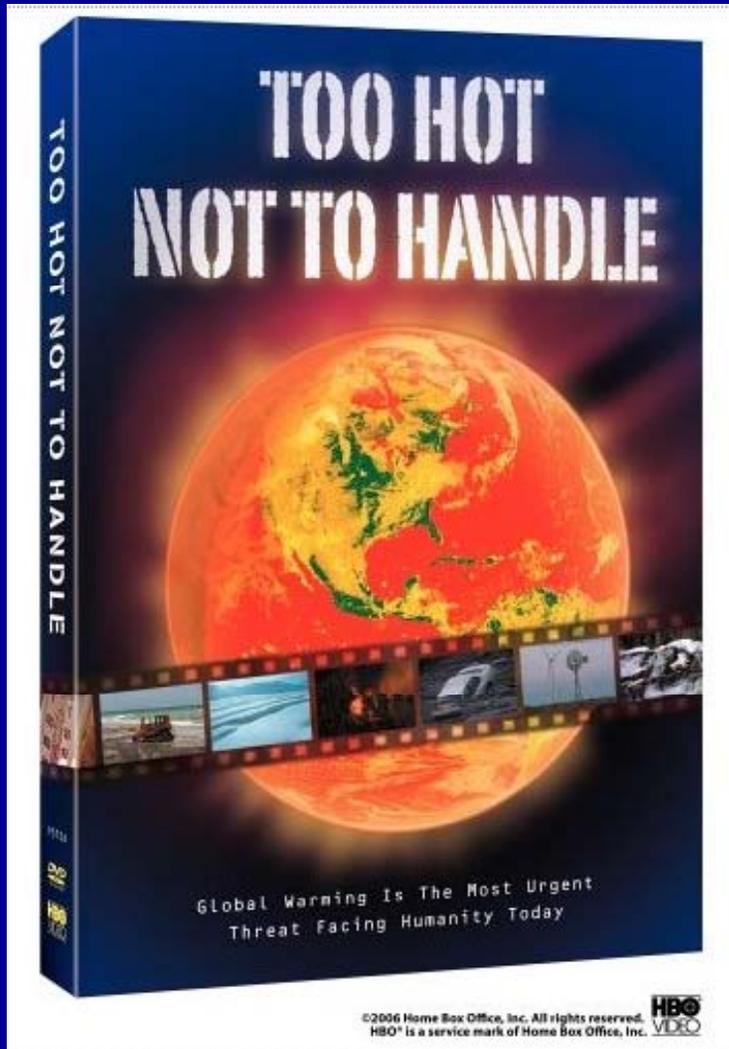
FEEDBACK FACTORS that are negative provide a “buffer” from **FORCINGS** – they allow the daisies to survive **LONGER** after a climate change (e.g., an increase in solar luminosity) than they could have survived if **NO** feedback processes were in operation.

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!