

# ATOC 1060-002

## OUR CHANGING ENVIRONMENT

### **Class 5: Introduction to Systems (Chapter 2)**

Objectives of today's class:

- a) Systems;
- b) The daisy world climate systems.

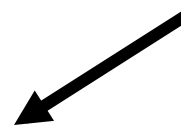
<http://atoc.colorado.edu/~whan/ATOC1060>

# Clicker question 1

# Previous classes

The Earth System: Atmosphere, hydrosphere, biota, and solid earth.

Introduce today



Interact; feedback loops; equilibrium state.

The Earth system approach: deeper insight into interrelationships among physical and biological worlds. Self-regulating?

# The Systems Approach

**System** - components, interact;

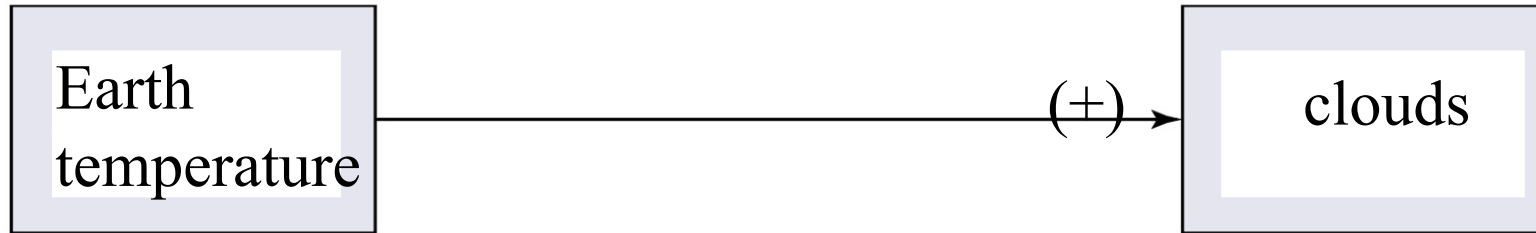
**State:** set of important attributes that characterize the system at a particular time;

**Coupling:** linked, flowing of information from one component to the next.

**Coupling allows** system regulation

# Coupling & feedback loop

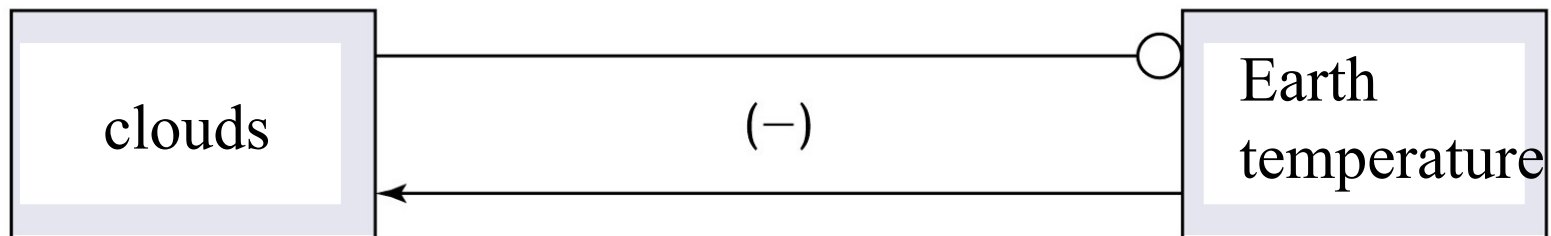
example



(a) Positive coupling



(b) Negative coupling



(c) Feedback loop (negative)

# Negative and positive feedback loops

Negative feedback loop: damp initial disturbances, system stable;

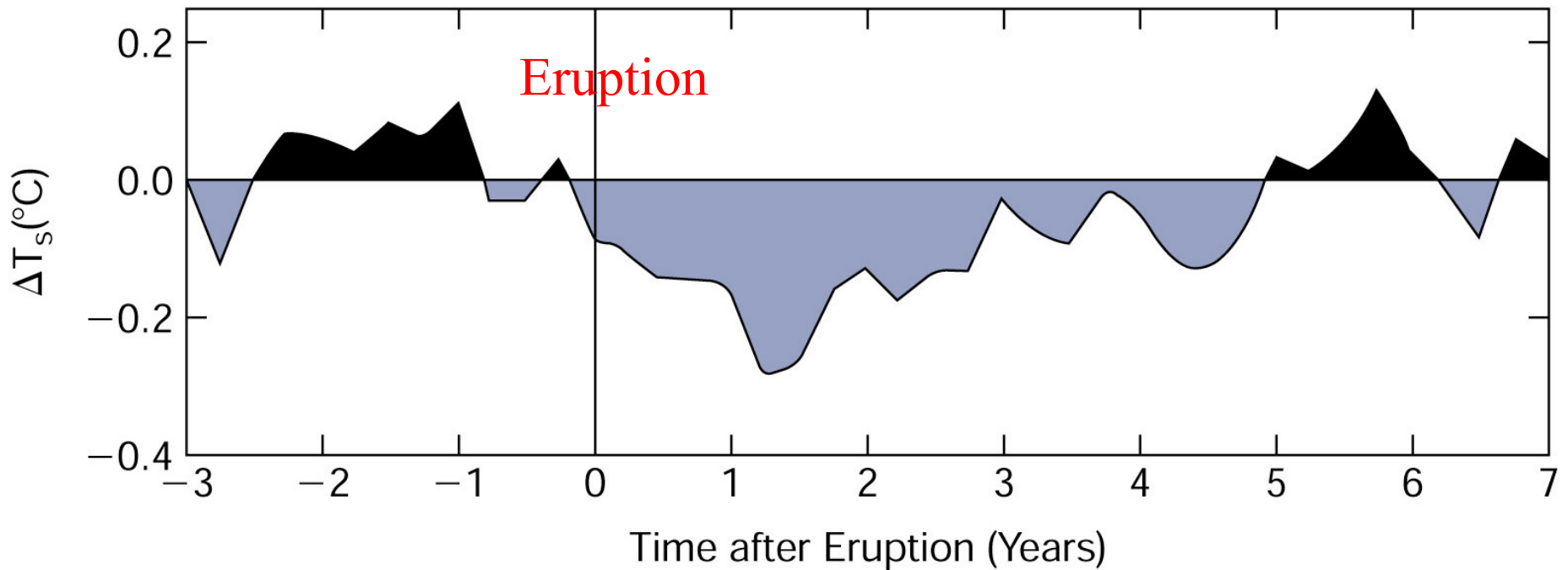
Positive feedback loop: amplify the effects of initial disturbances.

Equilibrium state: Temperature and clouds maintain stable values:  
reach “equilibrium state”

# Perturbation and forcing

The Earth system: complicated;  
Stability, determined mathematically.

$SO_2$  → Sulfate aerosol particles: disturbance



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Fig 2-4 Global T response to 5 largest volcanoes, ~last century

A more persistent disturbance of a system is called a forcing. For example, sunlight ↗  
Gaia hypothesis: the Earth system self regulating.

**Major focus of the course:**

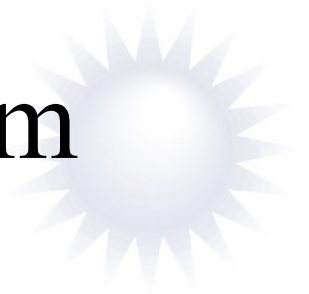
**Understanding how the Earth system responds to forcing.**

Begin with simple hypothetical planet Daisyworld.



# Clicker's question 2

# The Daisyworld Climate System

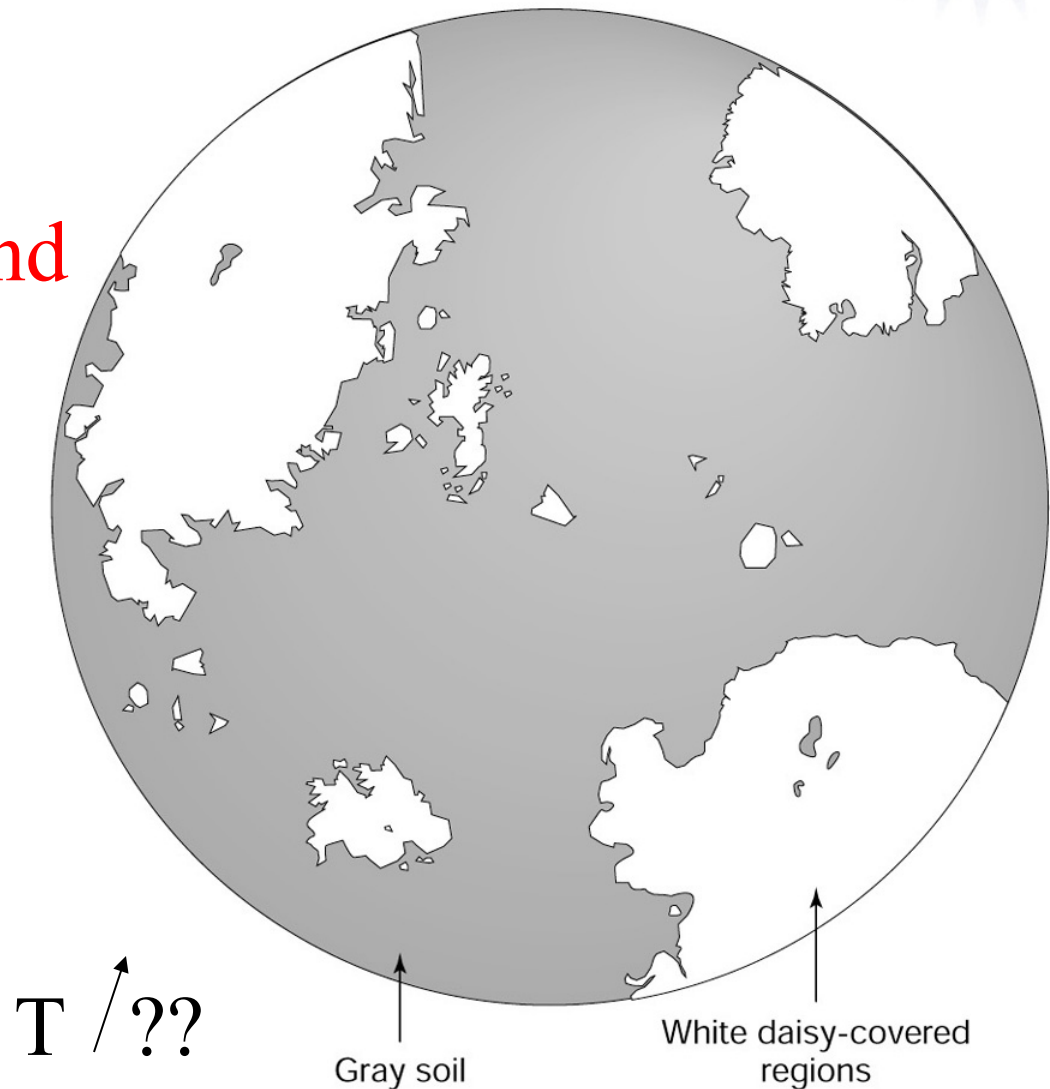


Only life:  
pure white daisies.  
Growth  $\Rightarrow$  T around

Atmosphere:  
no clouds, no  
greenhouse  
gases.

Assume sunlight  
quickly

Fig 2-5



# Couplings in the daisyworld climate system

Response of surface temperature to changes in Daisy coverage. **Albedo: reflectivity. A decimal fraction of the total incoming energy reflected from the surface.**

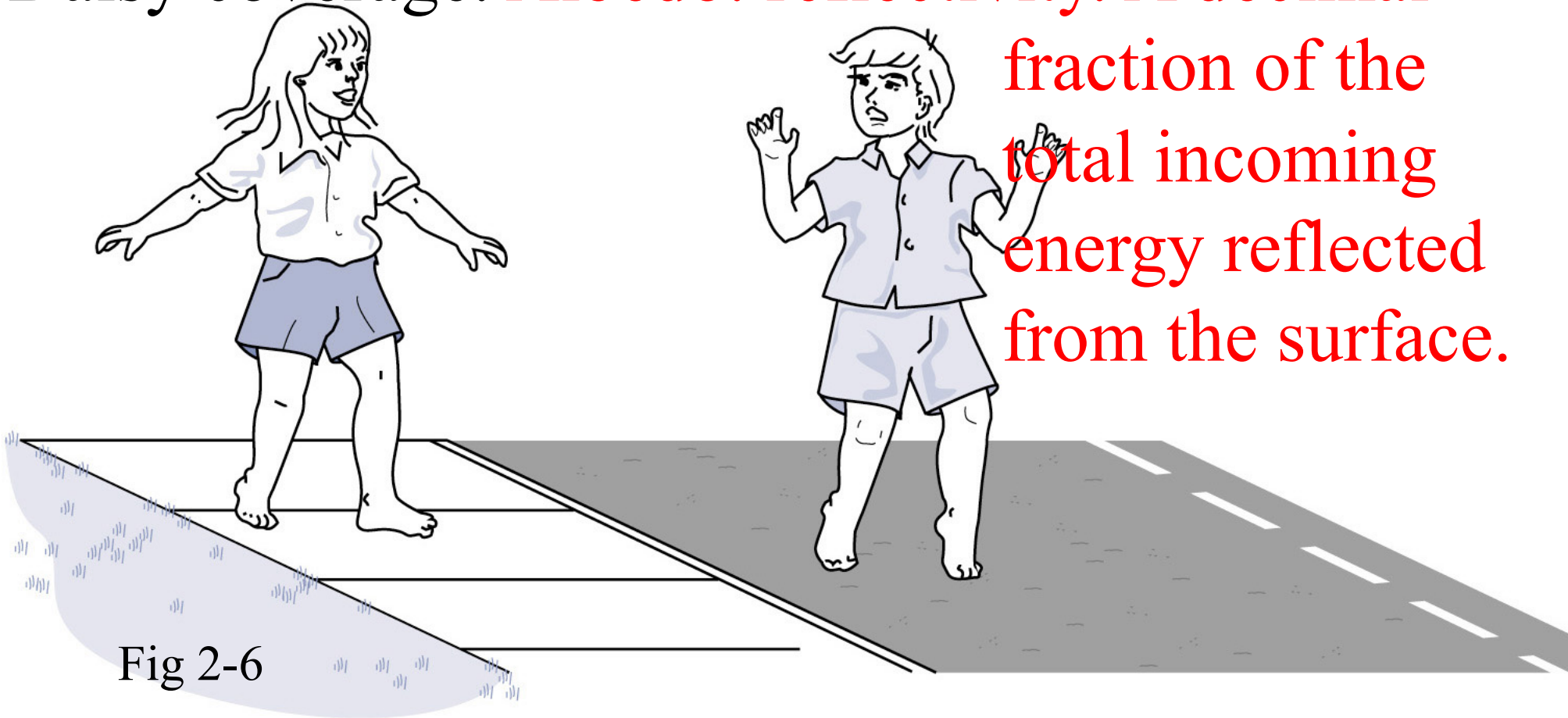


Fig 2-6

# Feedback of albedo: white daisies > soil

**TABLE 2-1**

<b>Albedos of Some Common Surfaces</b>	
<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 (thick Ice)	0.80–0.85
Thick cloud	0.70–0.80

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Table 2-1

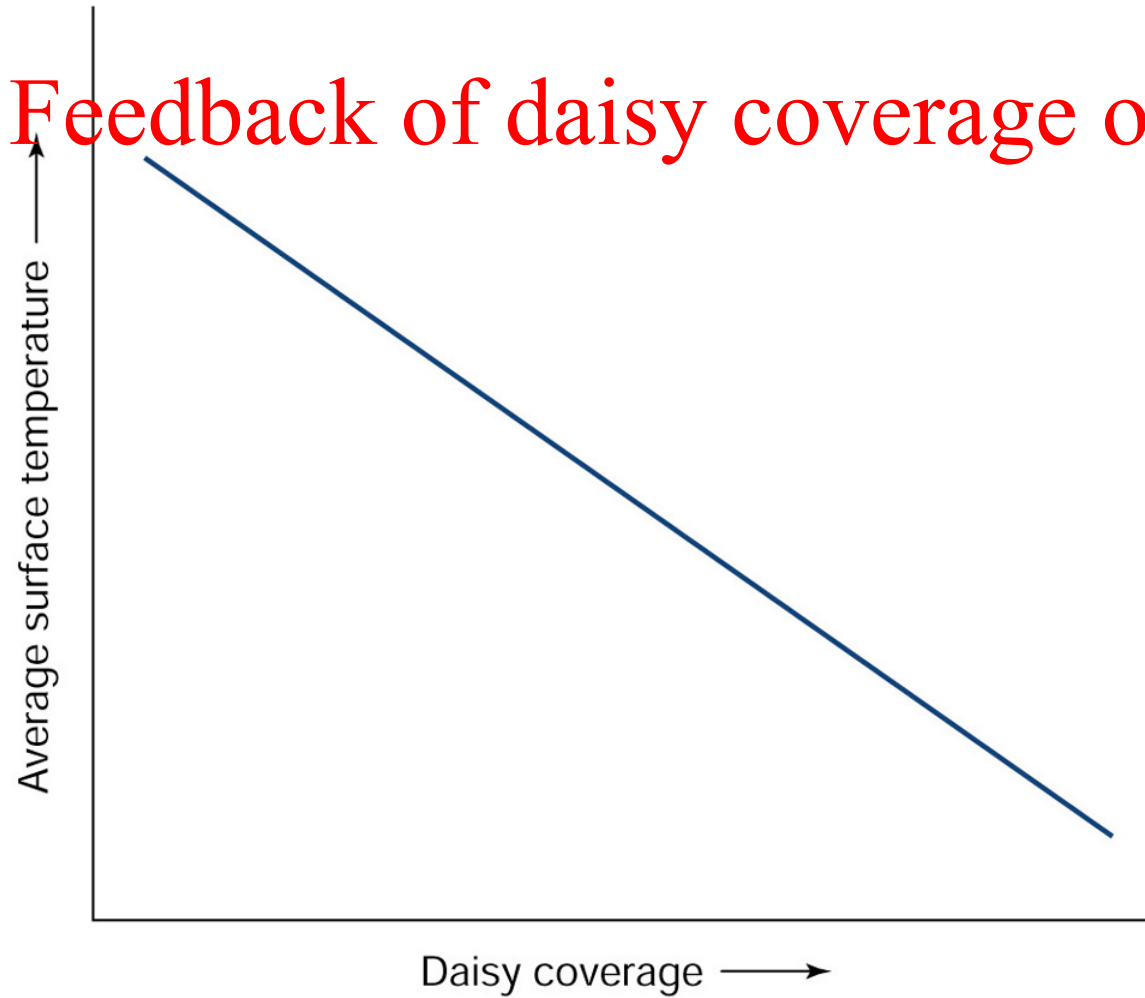
# Clicker's question 3

# Two components daisyworld climate system

1. Area of daisy coverage;
2. Average surface temperature of the planet.

Daisy feedback: decreases  $T$ .

# Feedback of daisy coverage on T



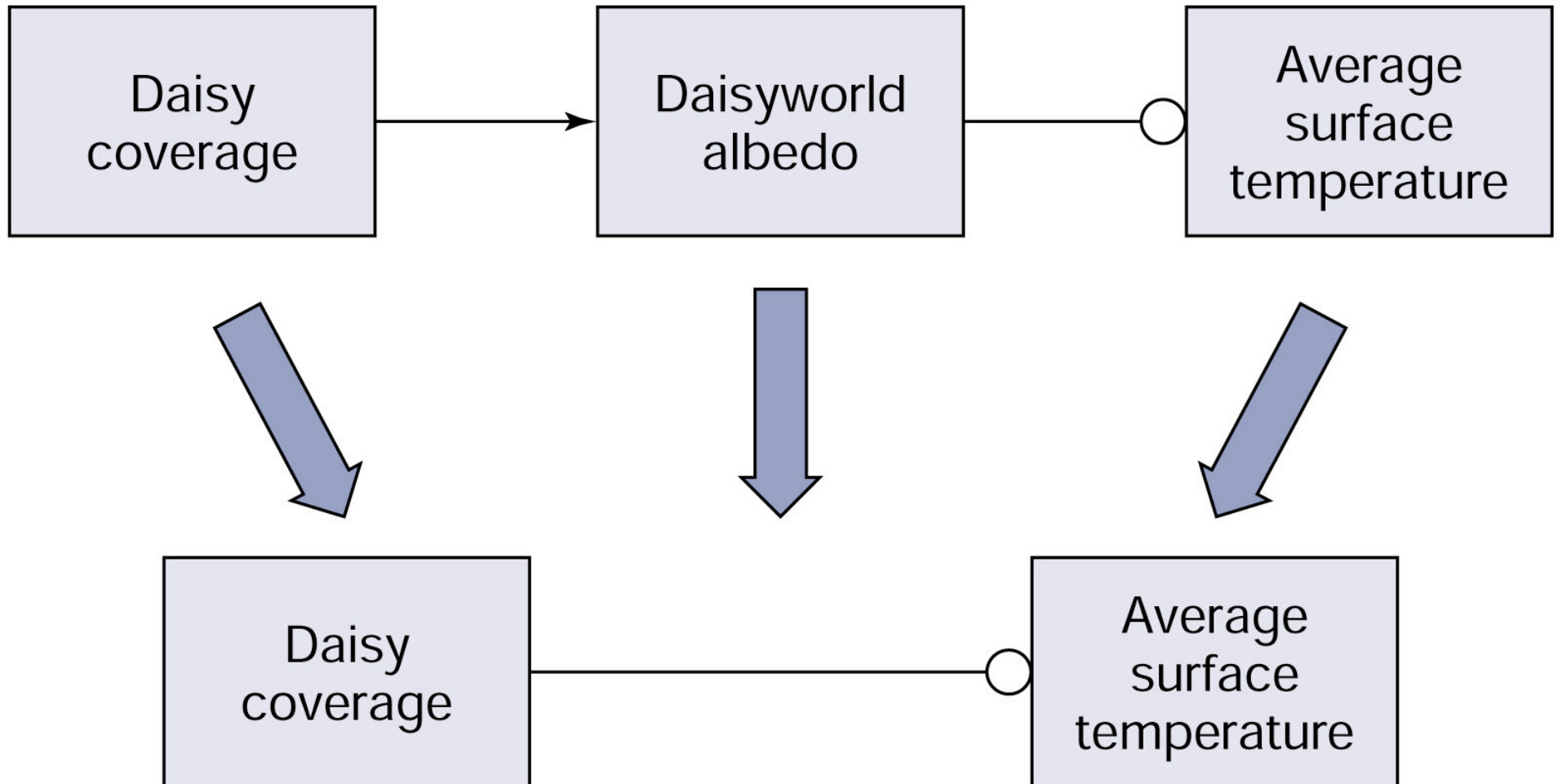
(a)



(b)

Fig 2-7a

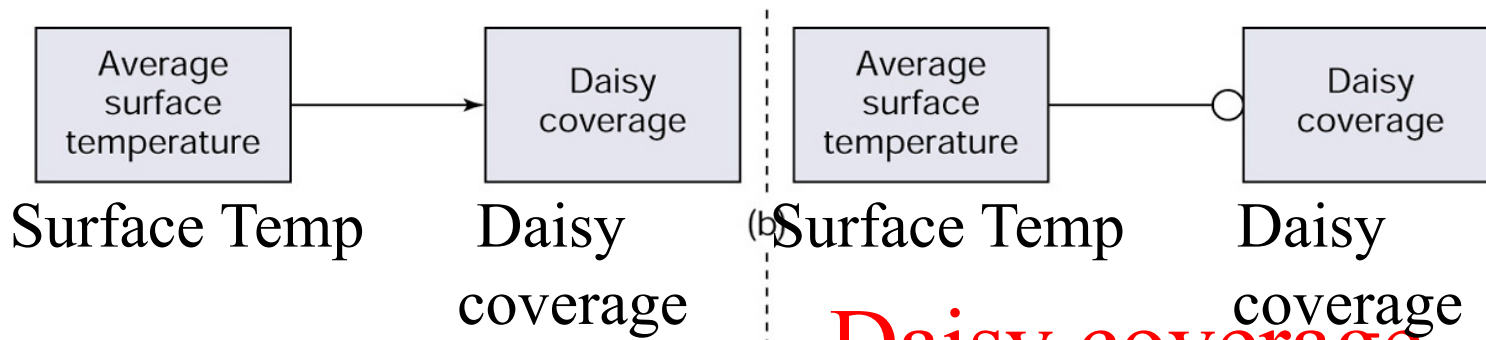
# Explicitly add albedo effect



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Fig 2-8





**Daisy coverage**  
**Responding to T changes**

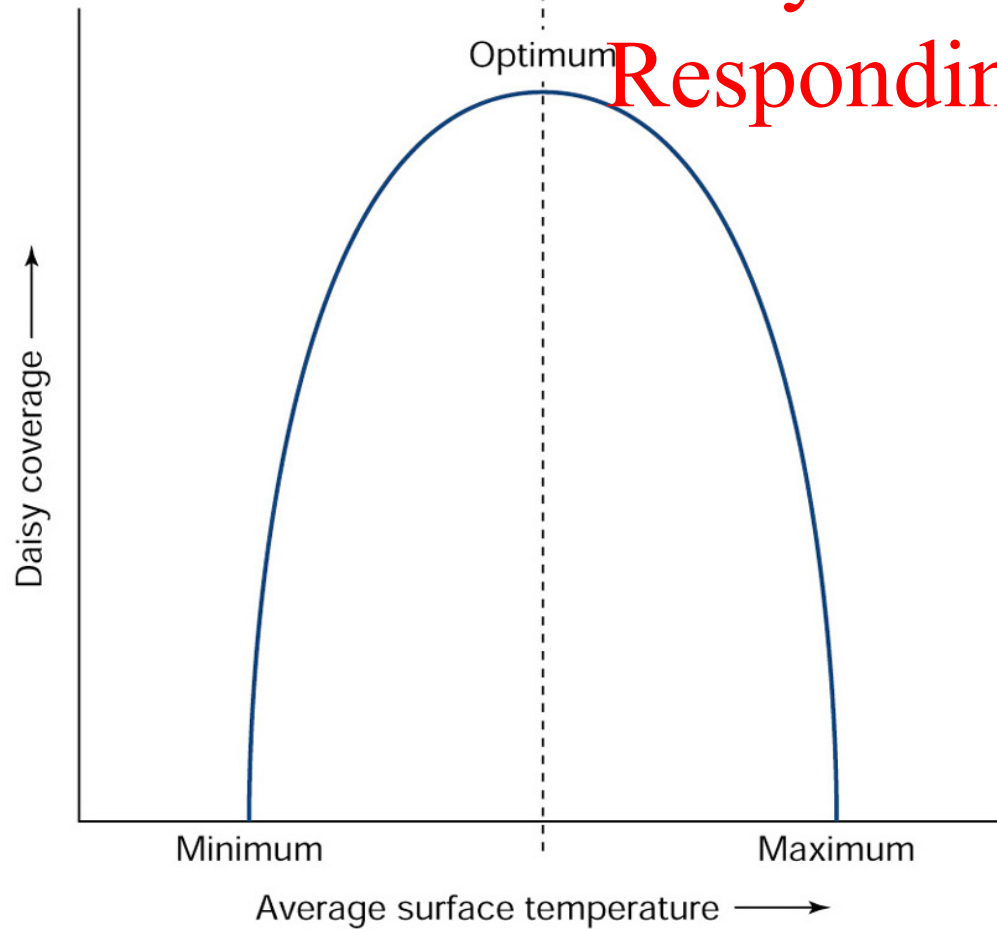
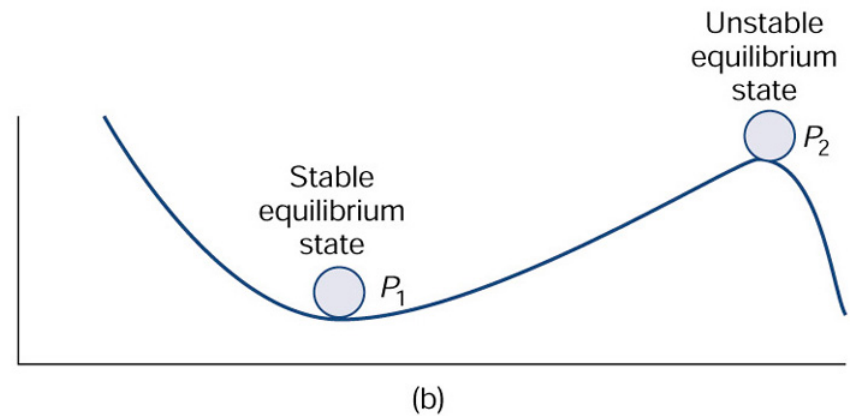
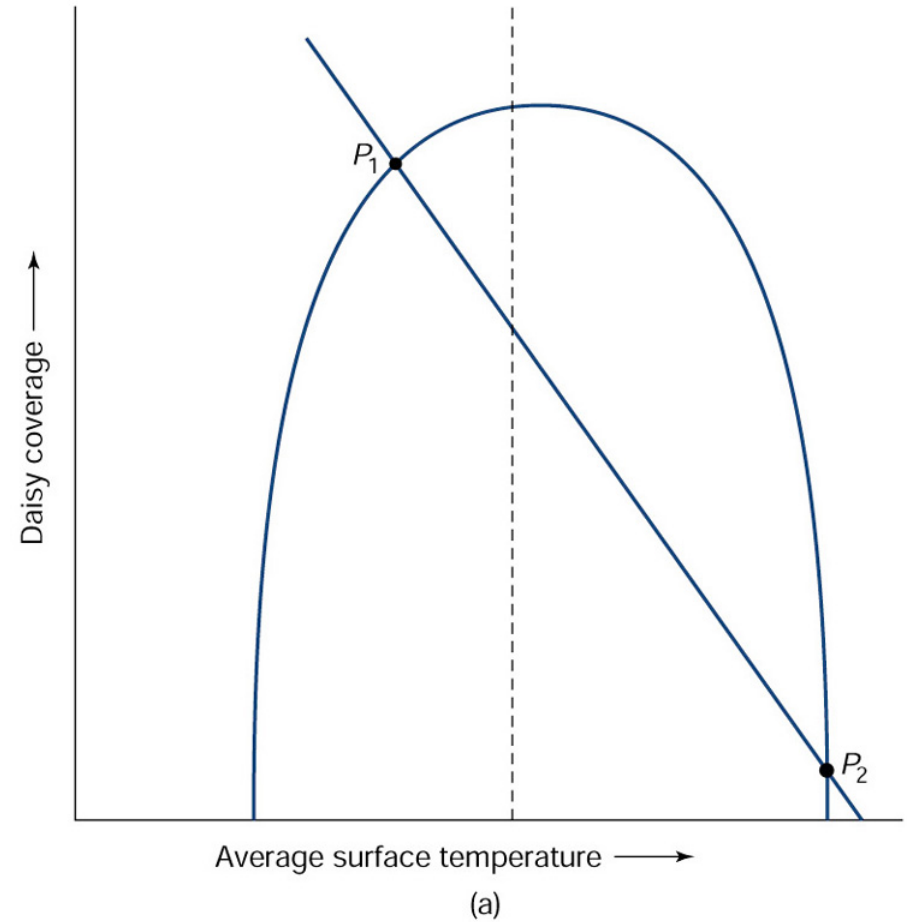


Fig. 2-9

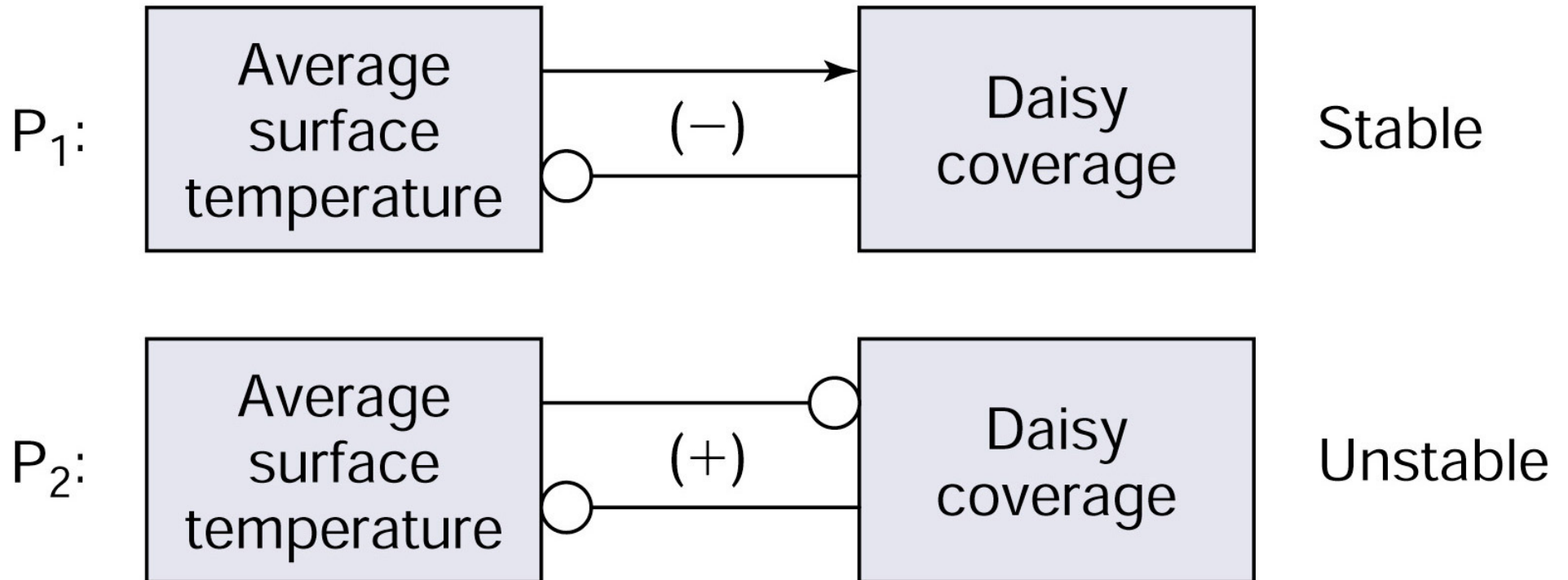
(a)

# Equilibrium state in Daisyworld.

P1 and P2 are the two equilibrium states of the system



# Stable & unstable states



# Clicker question 4