ATOC 1060-002
OUR CHANGING ENVIRONMNET

Class 9 (Chapter 3)

Objectives of today's class:

1)Physical causes of greenhouse effect;

2)Effect of clouds on atmosphere radiation budget;

3)Climate feedback, climate modeling;

1. Physical causes of the greenhouse effect

The defining property of a greenhouse gas is its ability to absorb or emit infrared radiation.

a)Quantum mechanics: molecules can rotate only at certain discrete frequencies (just like fans can rotate at certain speeds). Determined by molecule's structure.

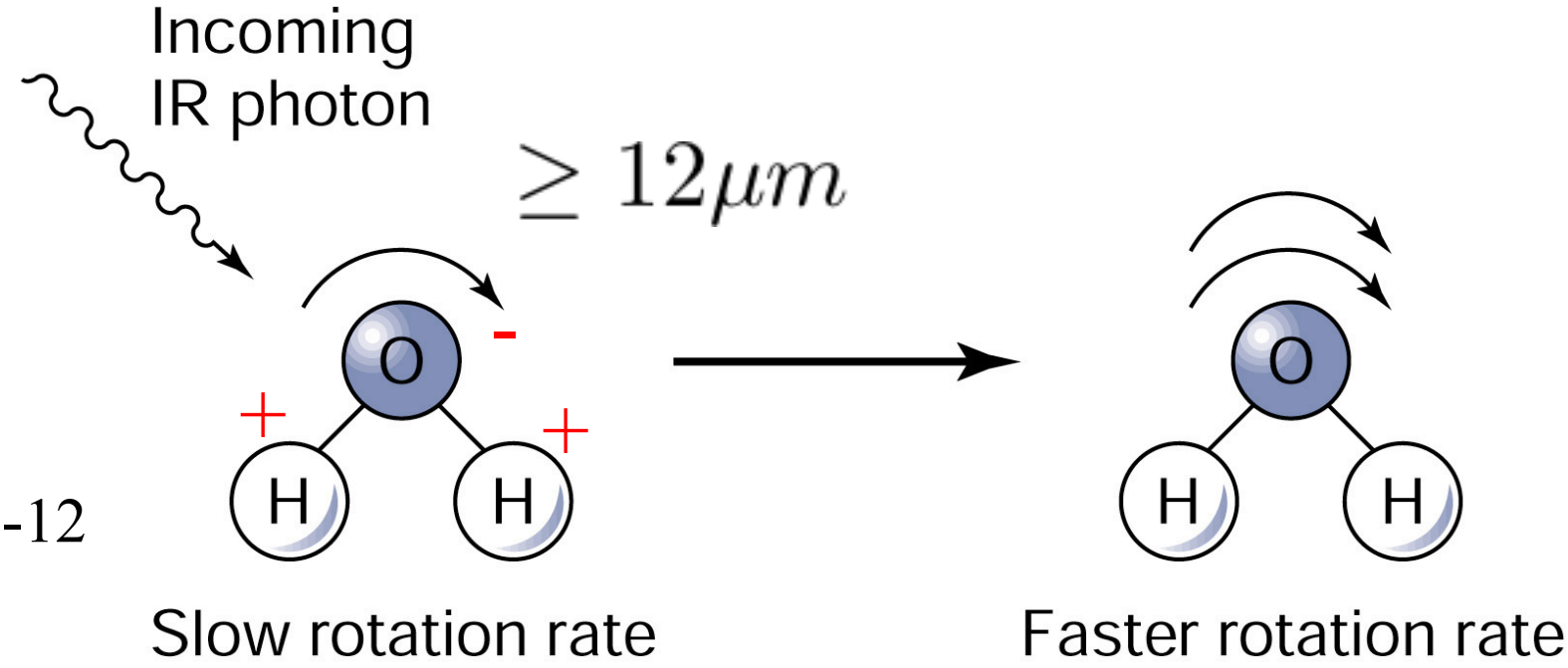


Fig. 3-12

b) Molecules can absorb or emit IR radiation by changing the amplitude with which they vibrate.

CO_2 molecule can vibrate in 3 ways. This vibration has a frequency that allows the molecule to absorb IR with wavelength $\approx 15\mu m$

This wavelength is near the peak of the Earth's IR radiation, important to Earth's climate!
IMPORTANT greenhouse gas!

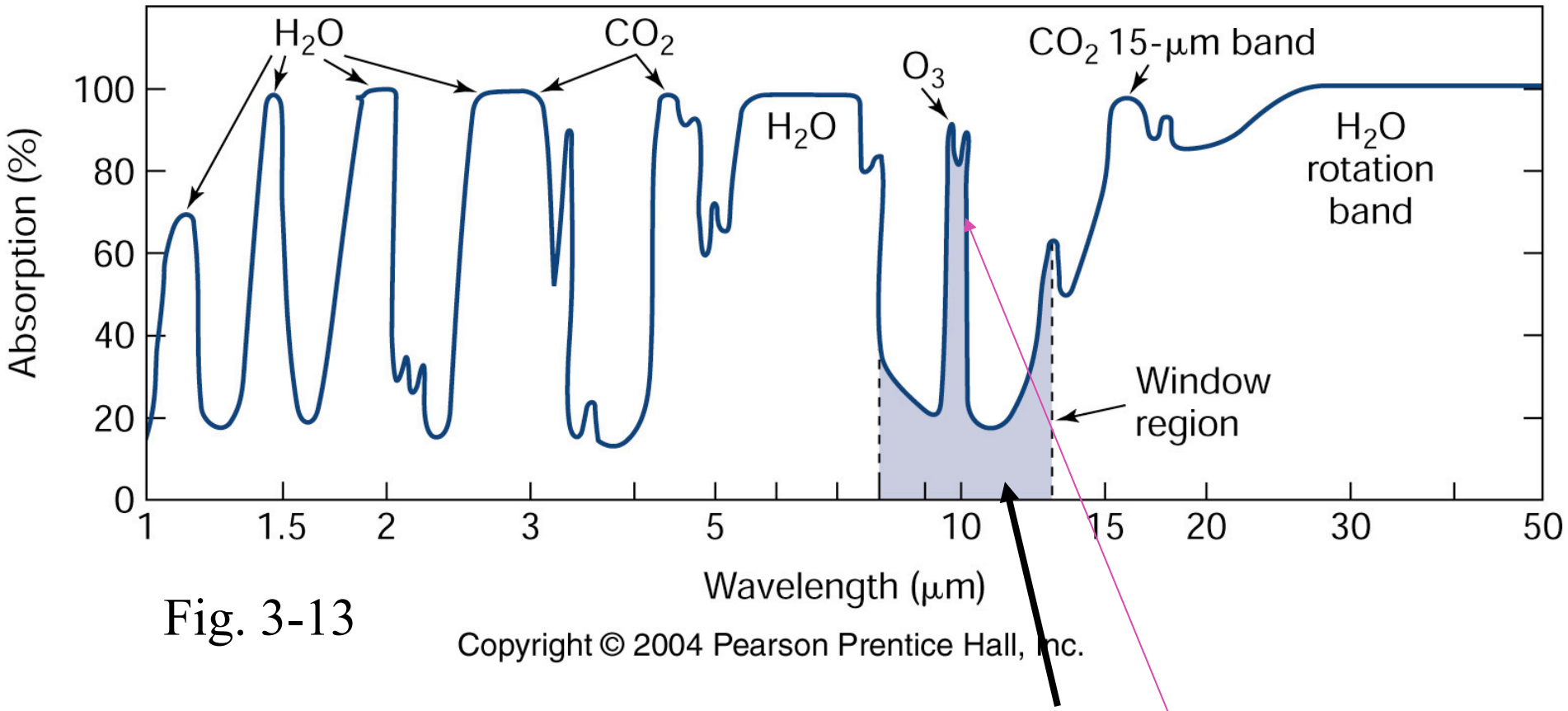
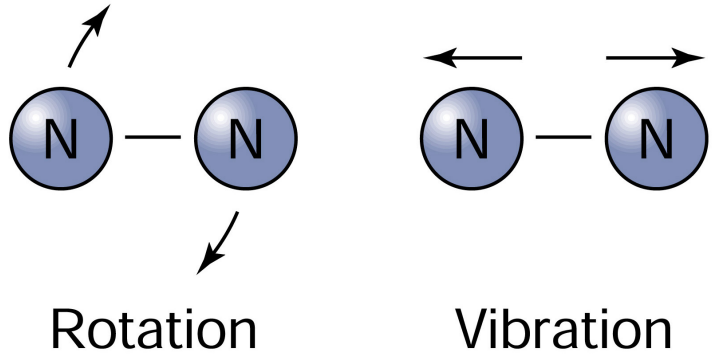


Fig. 3-13

Other greenhouse gases: Freons, O_3

Diatomic (two-atom) molecules: symmetric, no positive/negative charge.

Does not interfere with IR!



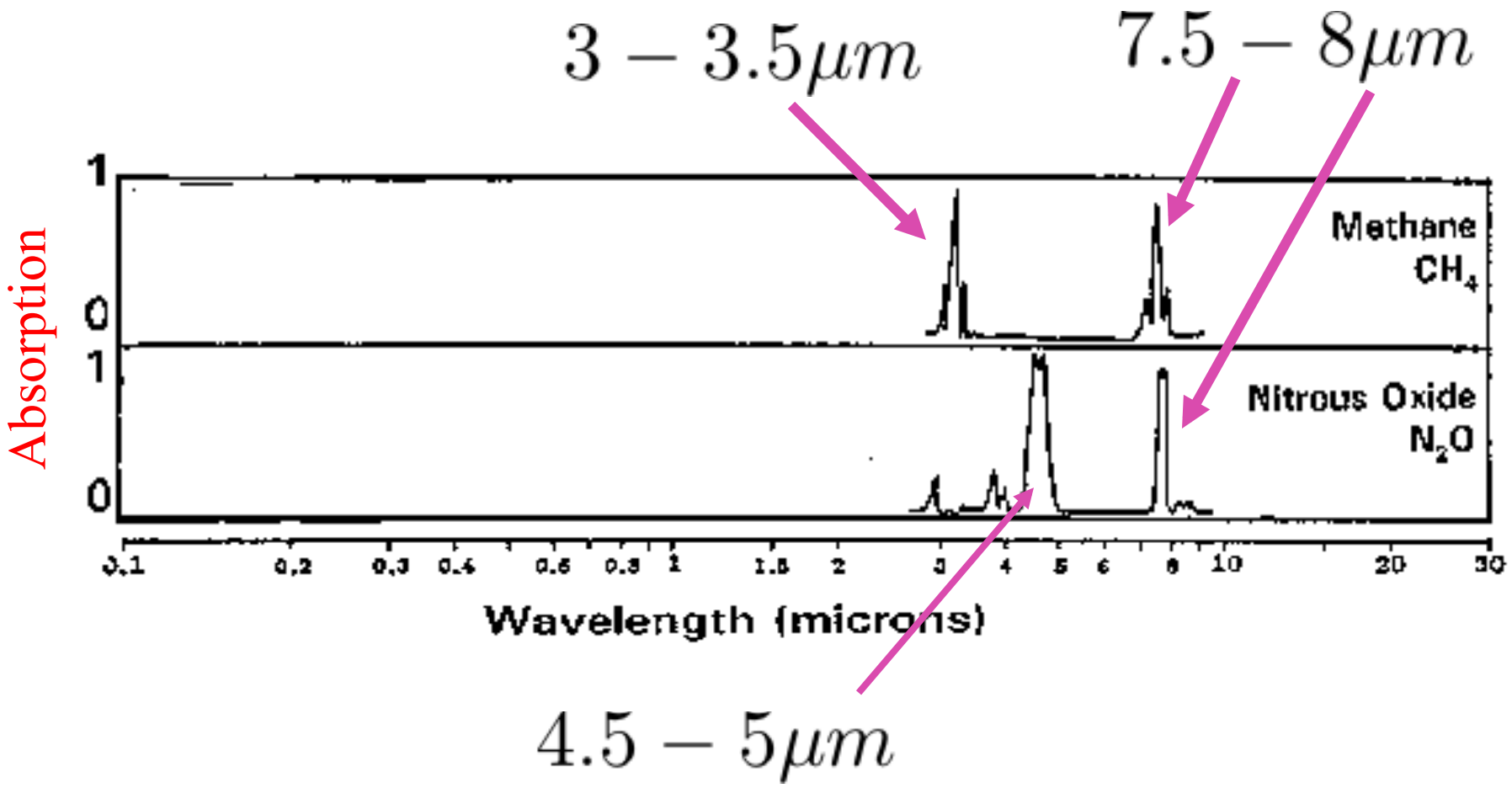

$3 - 3.5\mu m$
$7.5 - 8\mu m$
Absorption
1
0
Methane
CH_4
1
0
Nitrous Oxide
N_2O
0.1
0.2
0.3
0.4
0.5
0.6
1
1.5
2
3
4
5
6
8
10
20
30
Wavelength (microns)
$4.5 - 5\mu m$

Figure a)

Clicker's question 1

Choose the correct statement.

A. CH_4 and N_2O have their maximum absorptions of radiation in the visible light range;

B. Water vapor (H_2O), CO_2 and N_2 are important greenhouse gases;

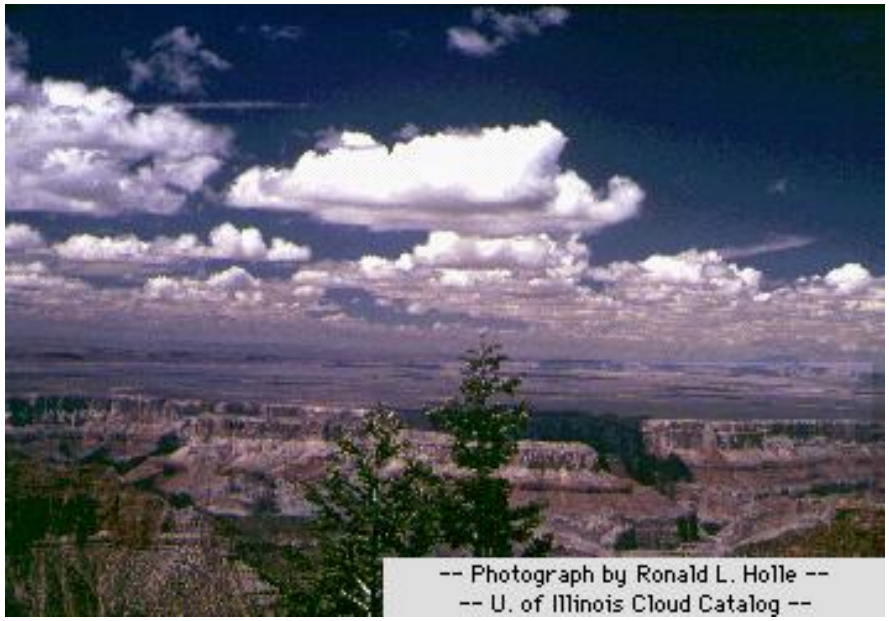
C. CO_2 is an important greenhouse gas because it is a good absorber of the Earth's IR;

D. Both B and C.

E. Both A and C.

2. Effect of clouds on atmosphere radiation budget

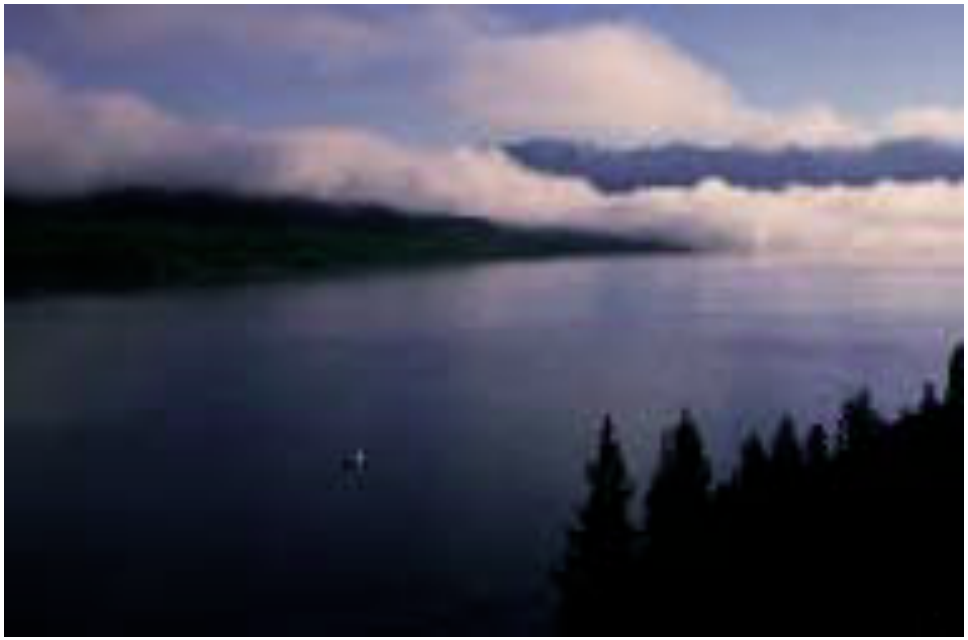
Effects on Earth's radiation budget: difficult to quantify;
because various types of clouds are at various height.



Cumulus: liquid droplet

Cumulonimbus

Reflection dominates



Stratus: liquid water, low

IR absorption dominates

Cirrus: high, ice crystal

Why are cloudy days relatively cool?

Why are cloudy nights relatively warm?

Opposing effects: reflection of solar radiation;
absorption of IR radiation.

Complicated by cloud types.

3. Climate feedbacks on earth

(i) Water vapor feedback:

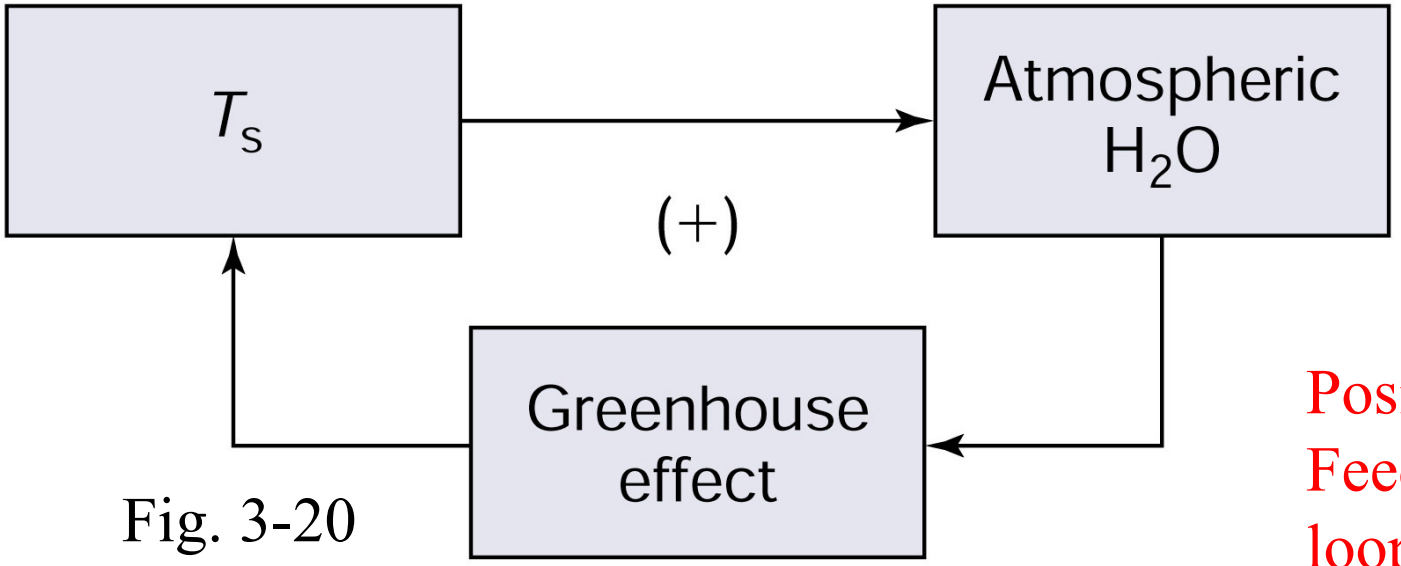


Fig. 3-20

Positive Feedback loop

1-D model calculation: 2.4°C,
double the temperature change comparing to the case without feedback!

Clicker's question 2

An increased the Earth's surface temperature will

A. increase water vapor in the atmosphere, which will further increase the Earth's surface temperature;

B. decrease water vapor in the atmosphere, which will further increase the Earth's surface temperature;

C. increase water vapor in the atmosphere, which will decrease the Earth's surface temperature;

D. decrease water vapor in the atmosphere, which will decrease the Earth's surface temperature

(ii) Snow and ice albedo feedback

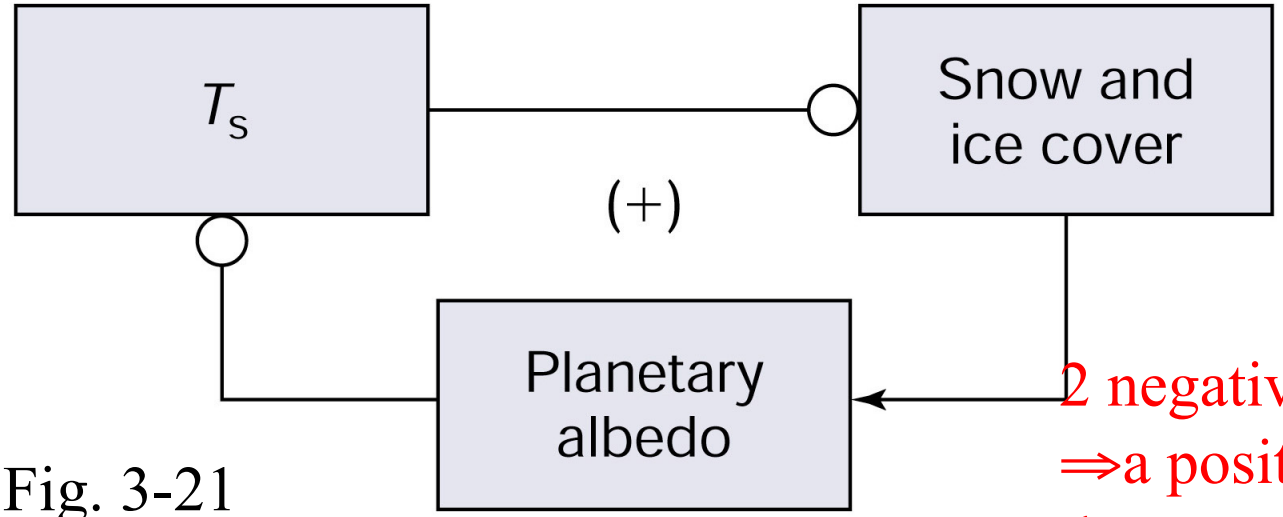


Fig. 3-21

2 negative couplings
⇒a positive feedback loop

TABLE 2-1

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

(iii) IR flux/temperature feedback

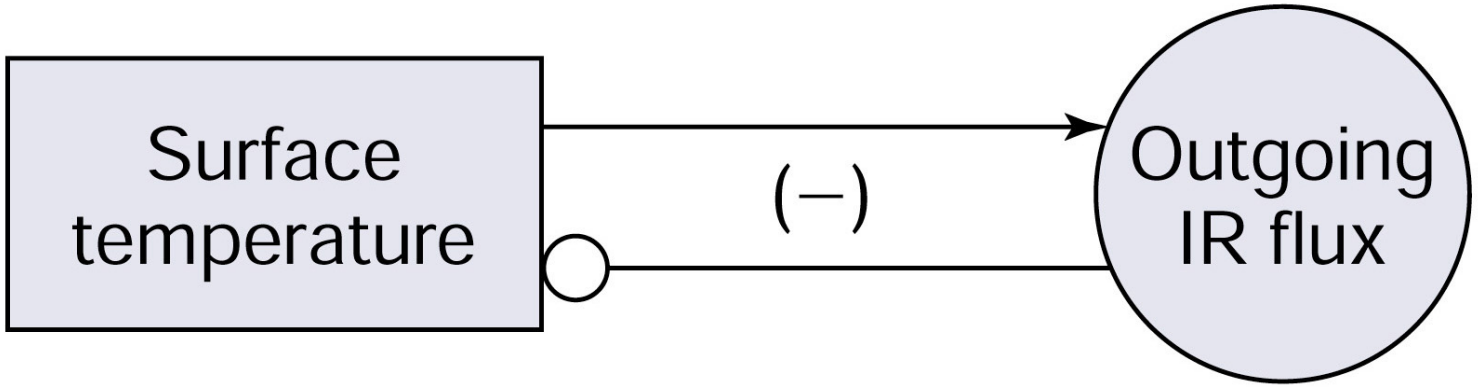


Fig. 3-22

Another: Gaia hypothesis.

Negative feedback loop!

(iv) Uncertain feedback caused by clouds

Clouds: reflection & IR absorption;
various cloud types, structures.

=> Large uncertainties in global warming

Clicker's question 3

How does snow&ice cover **feedback** to an increased Earth temperature?

A. Further increases the Earth's temperature due to reduced snow&ice cover;

B. Decreases the Earth's temperature due to reduced snow&ice cover;

C. Does not produce feedback;

D. Increases the Earth's temperature due to increased snow&ice cover.

Climate modeling

How can we utilize our knowledge of Earth's current energy budget to predict what Earth's surface temperature might have been in the past, or how it might vary in the future?

Climate system - complex - computer model.

In the model, all processes (clouds, greenhouse gases) are included. Global atmospheric general circulation model (AGCM):

$\Rightarrow$Atmospheric winds, moisture transport, energy balance, all weather phenomena.

Ocean general circulation model (OGCM):
⇒currents, heat transports, etc

Land surface model: land processes

Feedbacks: coupling among components

Global coupled climate model (3-dimensional)=>
predict climate variability; central role
in climate policy making today.

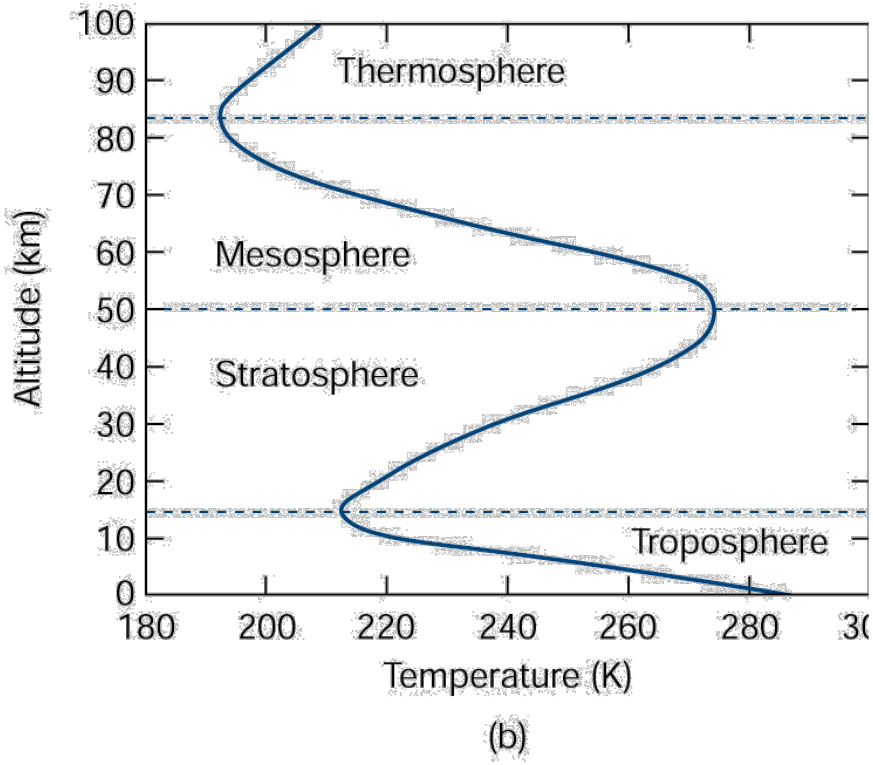
Simple, 1-dimensional (1-D) models

Radiative-convective model: average incoming solar & outgoing IR over entire Earth's surface; vertically, atmospheric structure is considered:

1-D: in altitude (vertical);

Each layer: energy layers absorption, emission, convection & latent heat in troposphere.

[a]Successfully predict: 33°C Temperature Change due to greenhouse effects!



1-D model: double CO_2 (300ppm to 600ppm) => global warming effect.
Prediction: 1.2°C temperature increase. DID NOT consider feedbacks in the system.

Climate Feedbacks

Extremely important! Amplify or moderate radiative effect of changes in greenhouse gas concentrations. [This is why we discuss the Daisyworld climate system feedback=> demonstrate how feedback works.]

Clicker's question 4

The 1-D climate models:

A. Consider the Radiative-convective effect;

B. Consider the vertical structure of the Earth's atmosphere;

C. Consider the horizontal structure of the Earth's atmosphere;

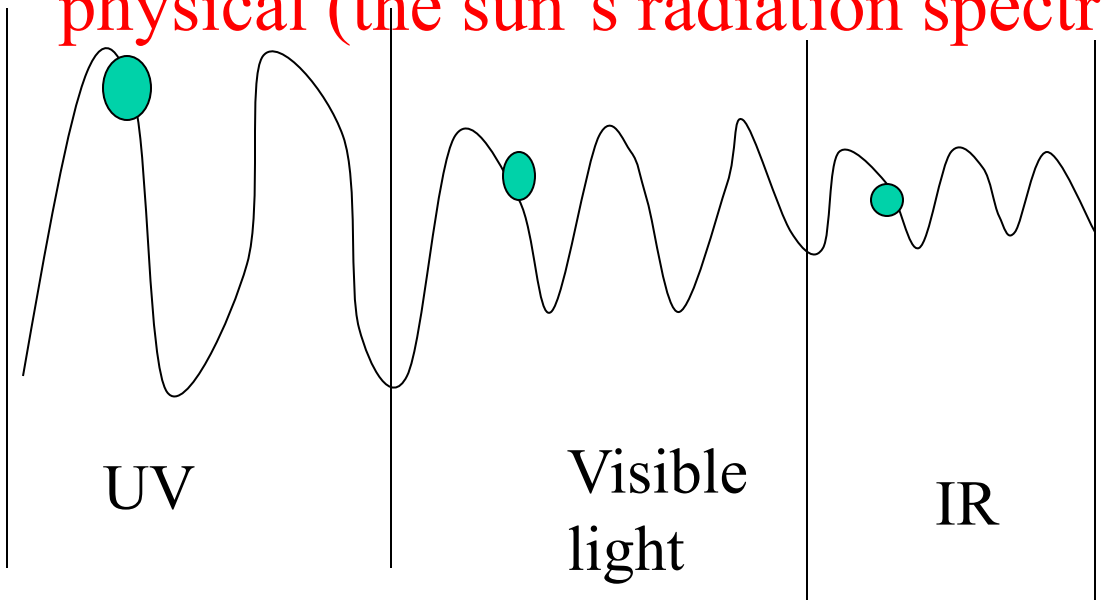
D. All of the above.

E. Both A and B.

Clarification: 1 photon of energy versus total

The numbers below are just for illustration and not physical (the sun's radiation spectrum)

1 photon:



1 photon			
Energy (E) :	4	2	1
No. of photons:	1	10	6
Total E:	4	20	6

Largest!