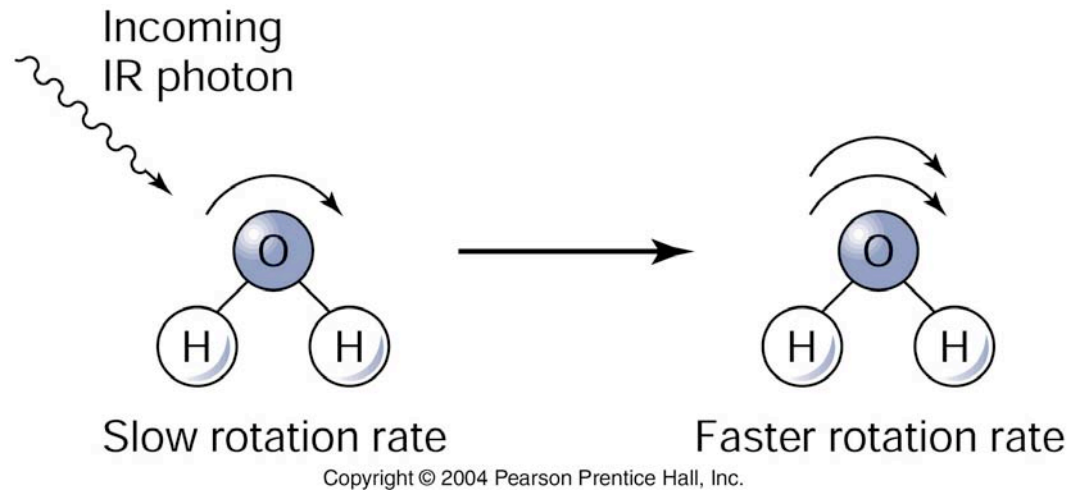


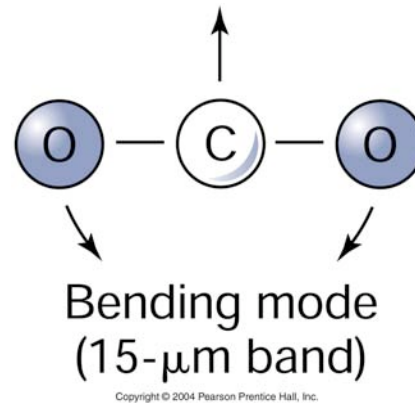
Lecture 14

- Why are some gases greenhouse gases?
- How do clouds affect the climate?
- What are the key climate feedbacks?

Greenhouse gas absorption



(For H₂O absorption in the microwave: the principle of the microwave oven)

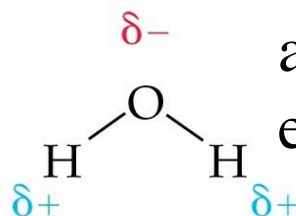
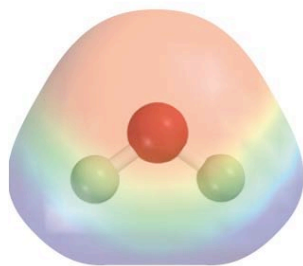
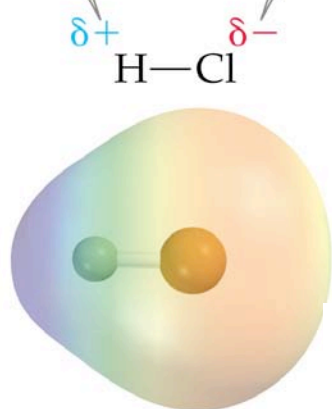


A greenhouse gas needs a “dipole”

Some molecules have a “**dipole**”. An electric dipole is a separation of equal and opposite electric charge over some distance.

This end of the molecule is electron-poor and has a partial positive charge ($\delta+$).

This end of the molecule is electron-rich and has a partial negative charge ($\delta-$).



Water, H₂O

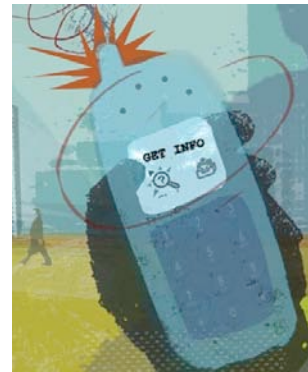
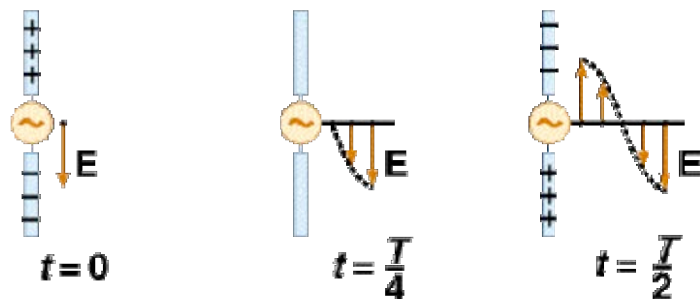
A dipole is caused by unequal sharing of electrons in a chemical bond. This occurs when atoms forming the bond have different ability to attract electrons.

e.g. HCl, H₂O

EM waves and dipoles

Electromagnetic (EM) waves are generated by an oscillatory acceleration of dipole electric charges.

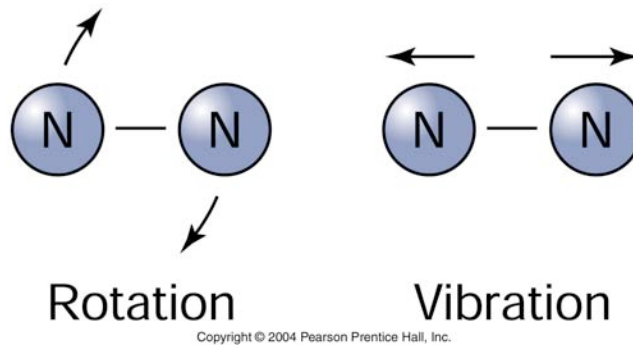
This is how the radio transmitter works in your cellphone.



The converse is true: oscillatory acceleration of electric charge can be generated by absorption of an EM wave. For molecules this only works when a separation of charge is possible.

i.e., EM waves only excite molecules with electric dipoles.

N_2 and O_2 have no dipole, so they are not greenhouse gases



Nitrogen (N_2) is symmetrical AND made of identical atoms.

Even with rotation or vibration, there is no unequal sharing of electrons between one N atom and the other. So N_2 has no dipole, and an EM photon passes by without being absorbed.

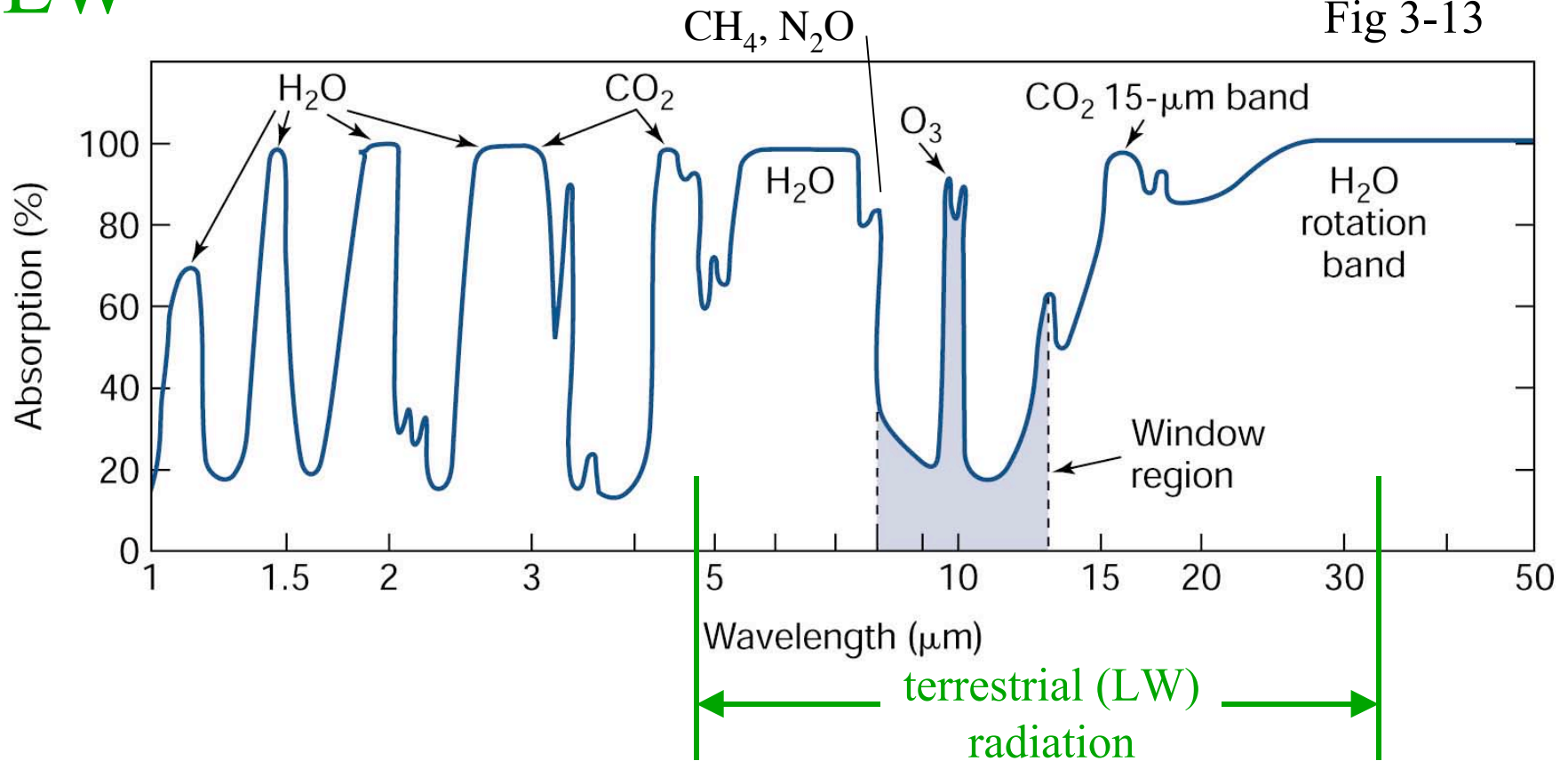
Similarly, for O_2 .

spectral absorption by the atmosphere

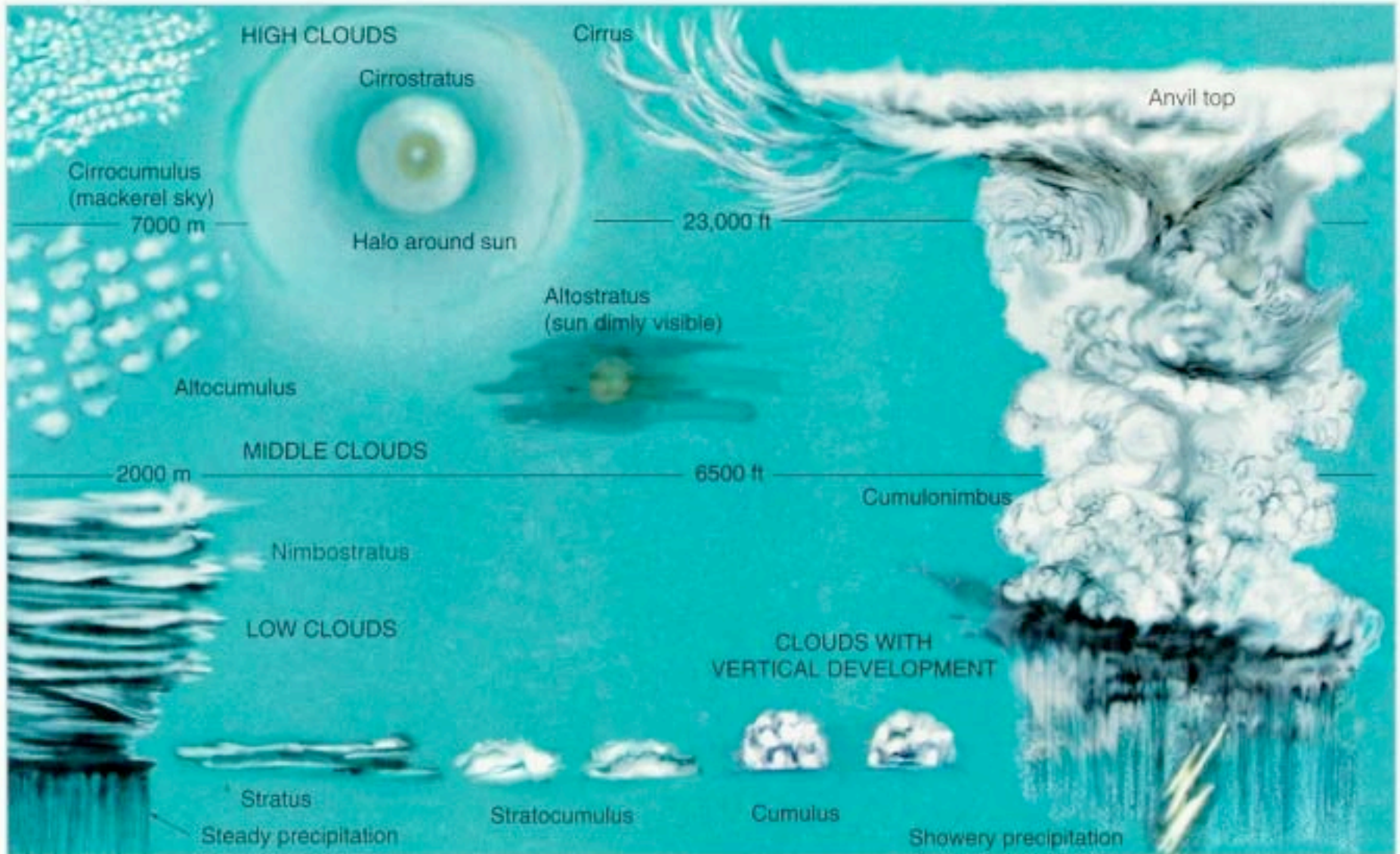
most LW radiation emitted by the surface is absorbed by the atmosphere

LW

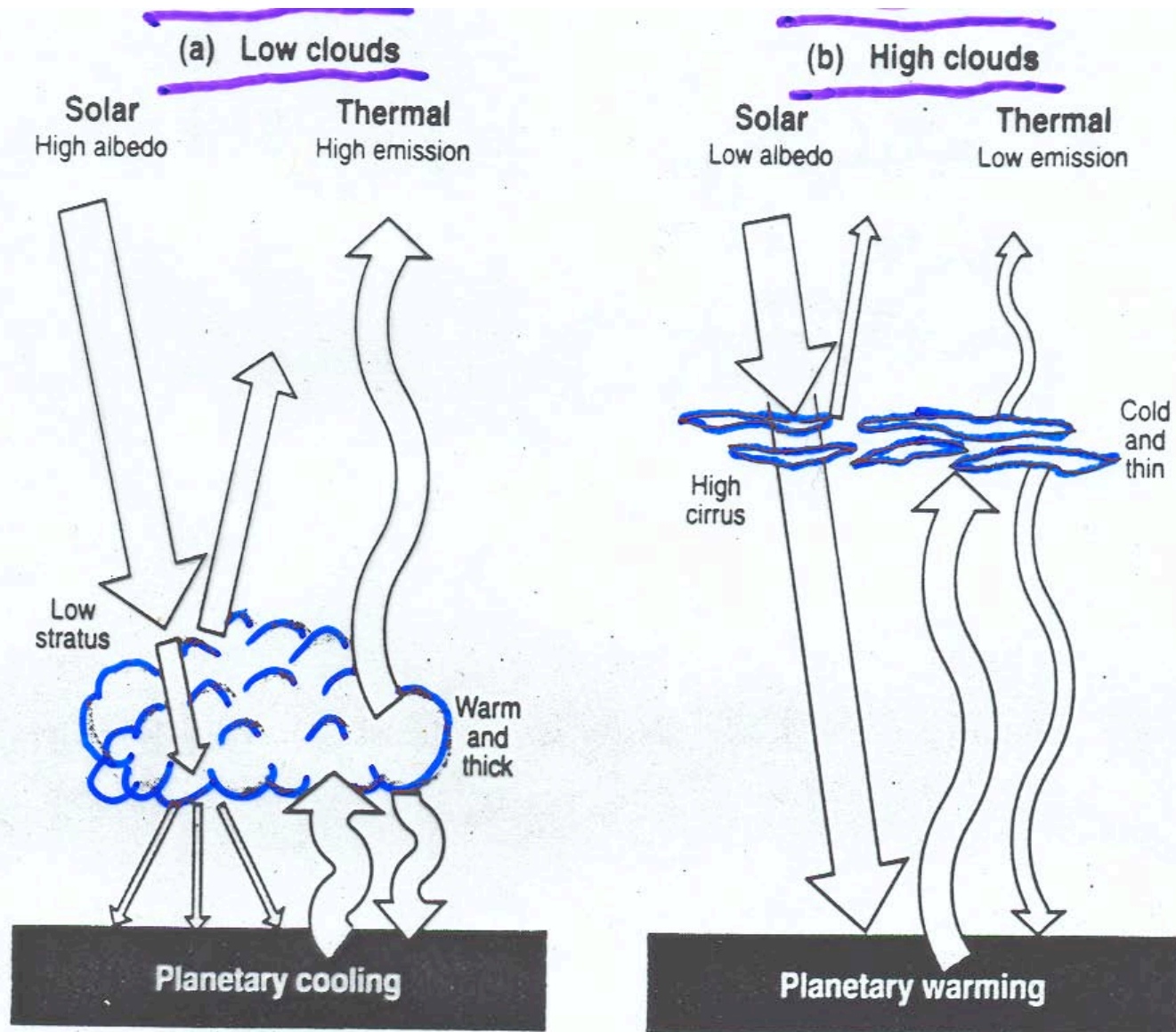
Fig 3-13



Clouds and climate: First, cloud types.



High vs. Low Clouds and their climate effect



Multiple roles of clouds in the energy budget

SW: Clouds are the major player in the Earth's albedo

LW: Clouds are a major player in heat-trapping (greenhouse effect)

high clouds:

modest albedo (small SW effect)

lots of "heat-trapping"

complete IR absorption

cold, so have low IR emission (T^4)

low clouds:

high albedo (big SW effect)

modest "heat-trapping"

complete IR absorption

almost as warm as the surface, so emit almost
as much IR upwards

High-low clouds: Bad textbook figure!

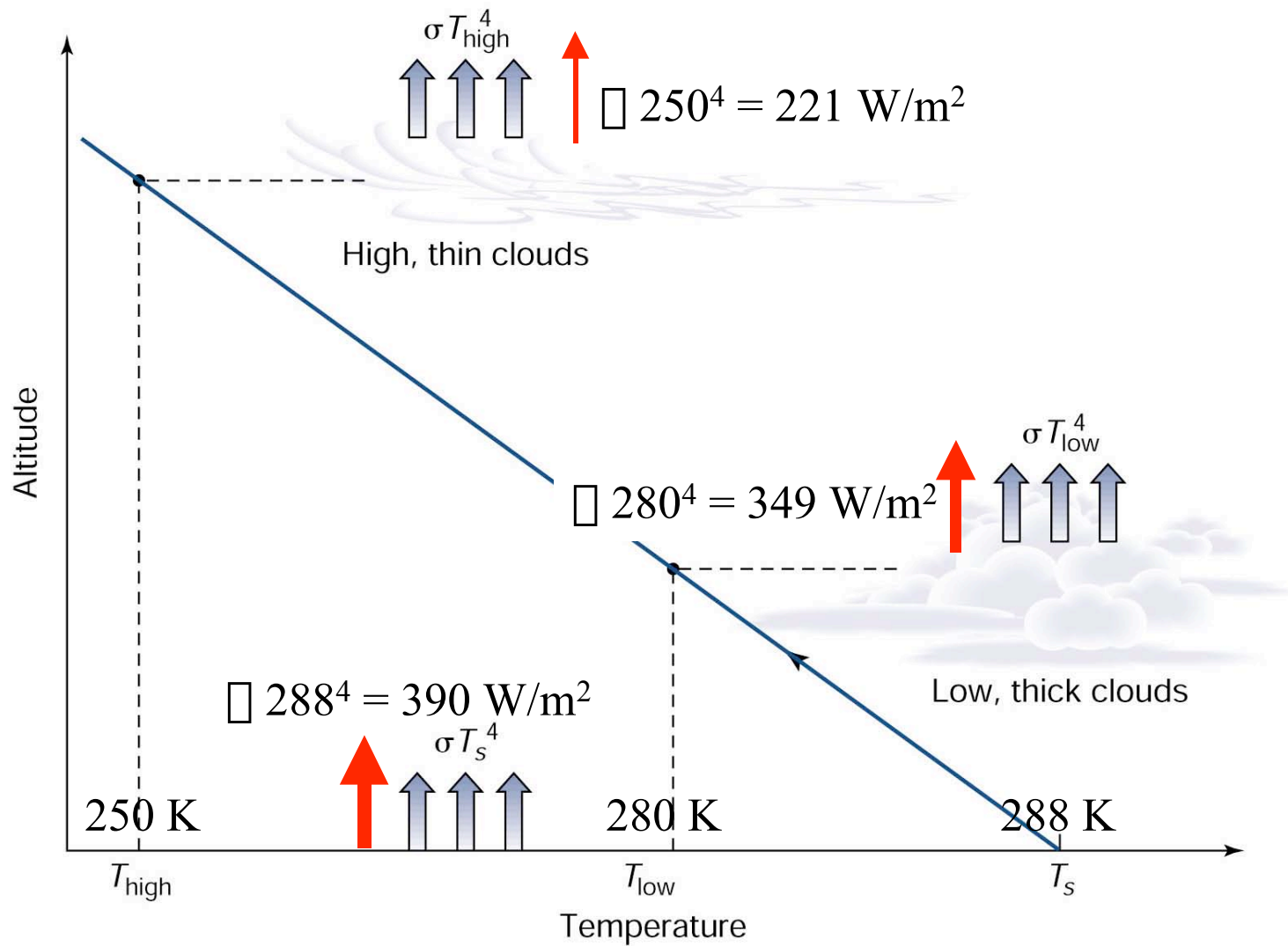


Fig 3-18

Three key feedbacks

1. POSITIVE FEEDBACK FROM WATER VAPOR

If T increases because of an increase in greenhouse warming from CO_2 (for example), the atmosphere will hold more water vapor. Because water vapor is a greenhouse gas, the temperature increases further than expected just from the addition of CO_2 .

This is a positive feedback. Essentially **water vapor feedback doubles the greenhouse effect expected** from the addition of a gas like CO_2 .

2. POSITIVE FEEDBACK FROM ICE-ALBEDO

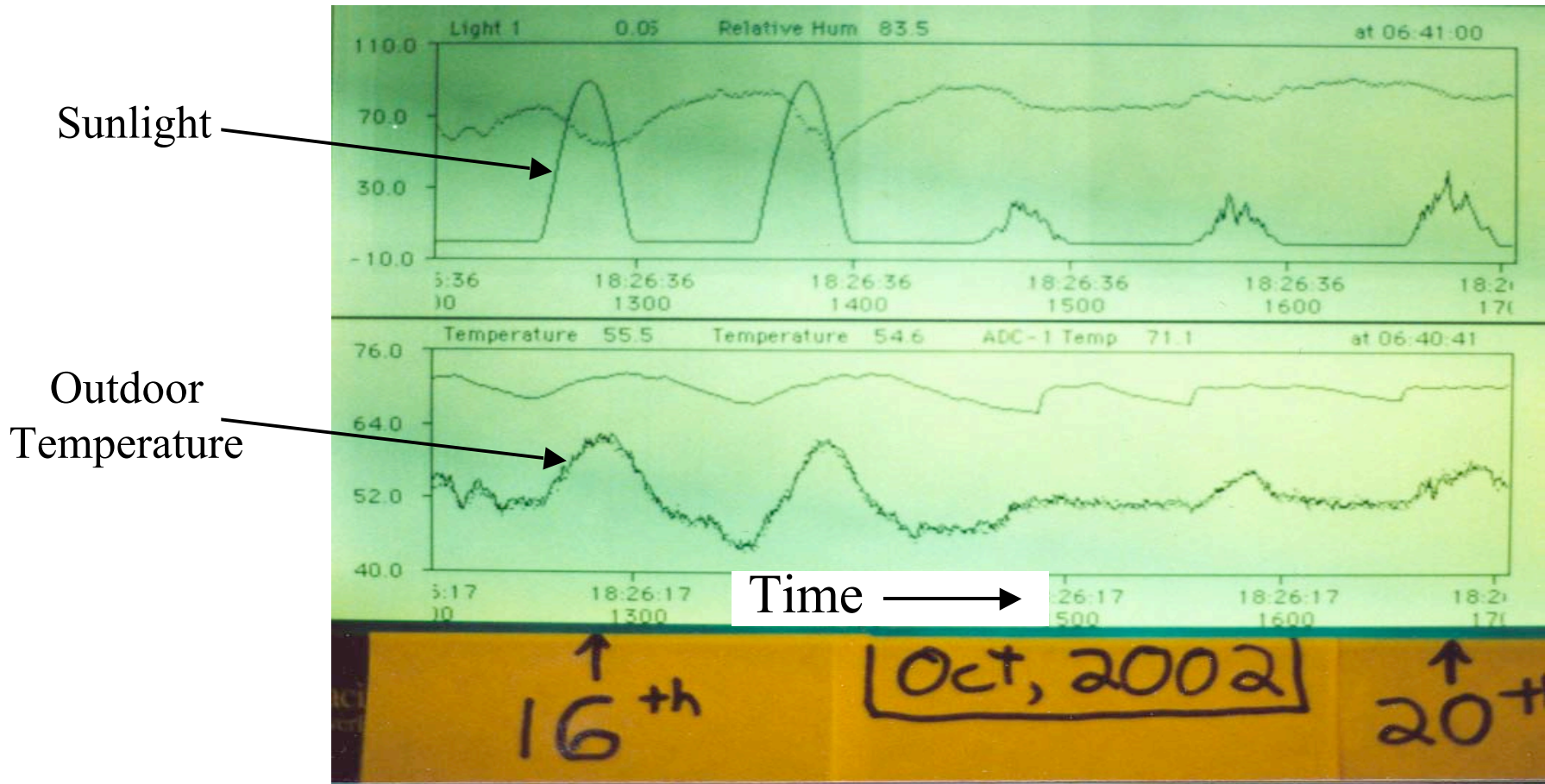
Snow and ice increase the planetary albedo, which reflects more sunlight to space, causing a decrease in surface temperature, and more snow and ice to form, etc.

3. NEGATIVE FEEDBACK FROM OUT-GOING RADIATION

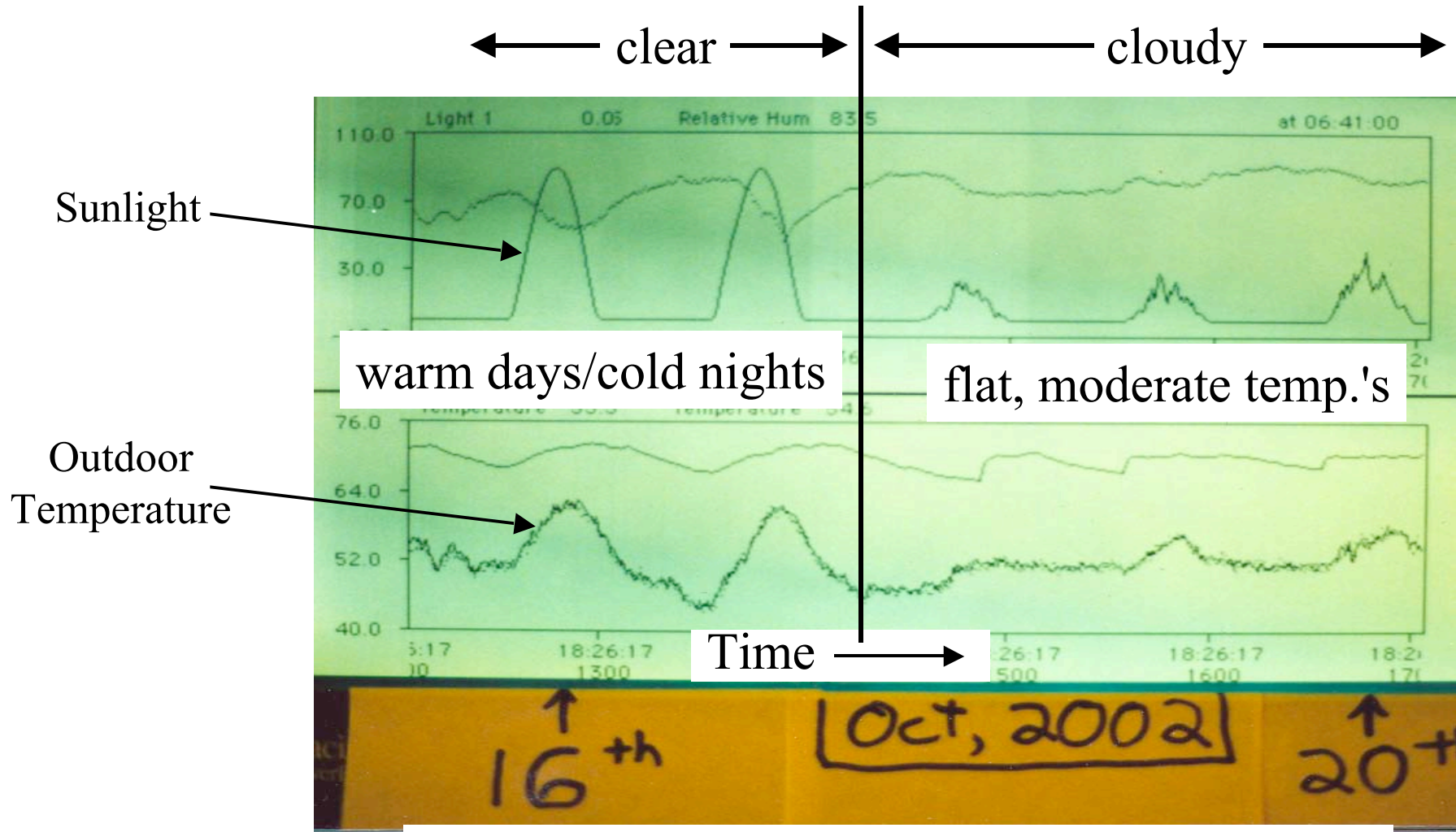
The most basic negative feedback is the interaction between surface temperature and the outgoing infrared flux, F_{IR} . As T_s increases, F_{IR} increases. Earth cools itself by emitting infrared radiation; thus, as F_{IR} increases, T_s decreases. This creates a negative feedback loop that helps the Earth's climate remain stable on short timescales.

Home Weather record - 1

Where on these plots do you see the SW effect of clouds?
Where do you see the LW effect of clouds?



Home Weather record - 2



SW effect: prevents sunlight from reaching the surface,
thus prevents warming during the day

LW effect: traps surface emissions of IR radiation,
thus prevents cooling during the night