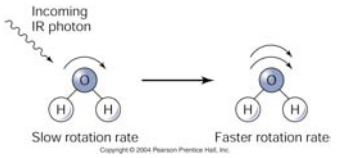
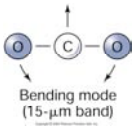
Lecture 14

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

Greenhouse gas absorption

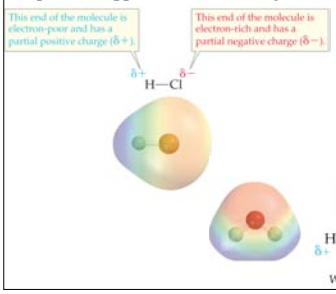


(For H_2O absorption in the microwave: the principle of the microwave oven)



A greenhouse gas needs a "dipole"

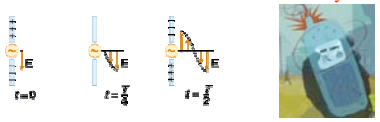
Some molecules have a "dipole". An electric dipole is a separation of equal and opposite electric charge over some distance.



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, H_2O

EM waves and dipoles

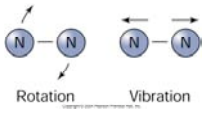
Electromagnetic (EM) waves are generated by an oscillatory acceleration of dipole electric charges.
This is how the radio transmitter works in your cellphone.



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.

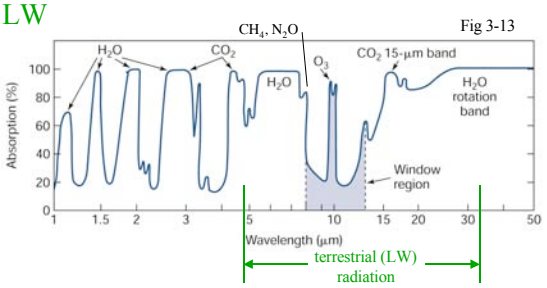
Similarly, for O_2.

spectral absorption by the atmosphere

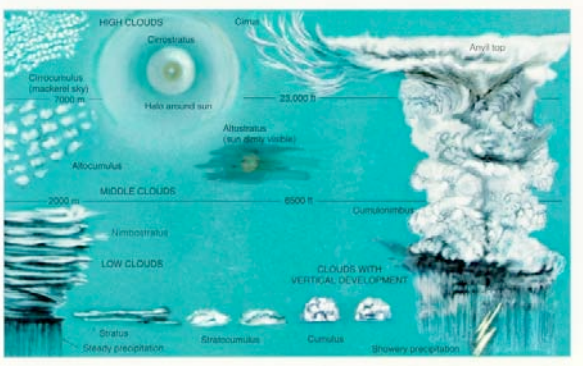
most LW radiation emitted by the surface is absorbed by the atmosphere

LW

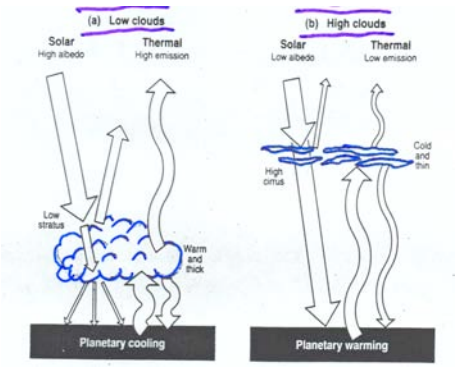
Fig 3-13



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!

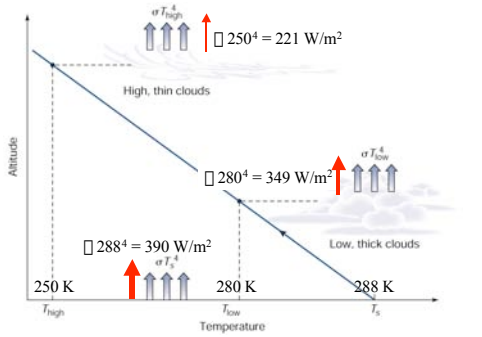


Fig 3-18

Three key feedbacks

1. POSITIVE FEEDBACK FROM WATER VAPOR

If T increases because of an increase in greenhouse warming from CO2 (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 CO2. This is a positive feedback. Essentially water vapor feedback doubles the greenhouse effect expected from the addition of a gas like CO2.

2. POSITIVE FEEDBACK FROM ICE-ALBEDO

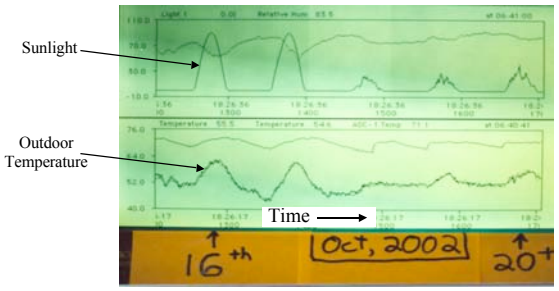
Snow and ice increase the planetary albedo, which reflects more sunlight to space, causing a decrease in surface temperature, and more snow and ice to form, etc.

3. NEGATIVE FEEDBACK FROM OUT-GOING RADIATION

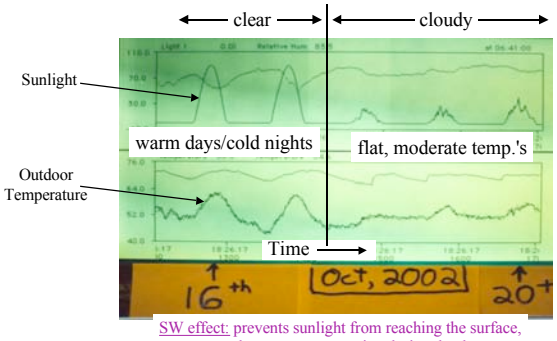
The most basic negative feedback is the interaction between surface temperature and the outgoing infrared flux, F_{IR}. As T_s increases, F_{IR} increases. Earth cools itself by emitting infrared radiation; thus, as F_{IR} increases, T_s decreases. This creates a negative feedback loop that helps the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