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$_2$O 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, 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 $O_2$. 
most LW radiation emitted by the surface is absorbed by the atmosphere
Clouds and climate: First, cloud types.
High vs. Low Clouds and their climate effect

(a) Low clouds
- Solar: High albedo
- Thermal: High emission
- Low stratus
- Warm and thick

(b) High clouds
- Solar: Low albedo
- Thermal: Low emission
- High cirrus
- Cold and thin

Planetary cooling

Planetary warming
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!

\[ 250^4 = 221 \ \text{W/m}^2 \]

\[ 280^4 = 349 \ \text{W/m}^2 \]

\[ 288^4 = 390 \ \text{W/m}^2 \]

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?
Sunlight

Outdoor Temperature

Time

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