# ATM S 111: Global Warming

## Greenhouse Gases

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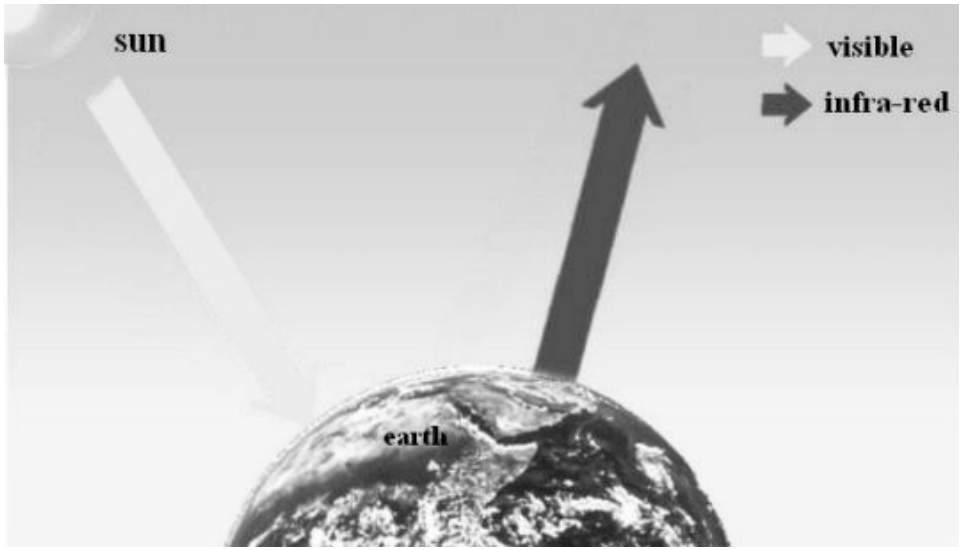
Day 4: June 24 2010

# What are the Major Greenhouse Gases?

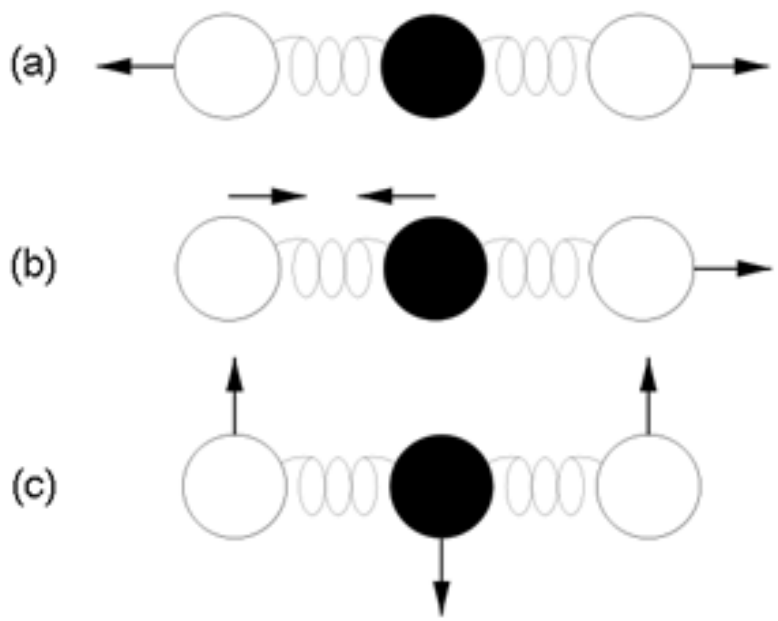
- Our atmosphere is mostly nitrogen ($N_2$, 78%), oxygen ($O_2$, 21%), and argon (Ar, 0.9%)
  - But these are **not** greenhouse gases
- Molecules with 1 atom or 2 of the same atoms aren't greenhouse gases
  - Just like the atmosphere is almost transparent to solar radiation, the primary gases in our atmosphere are transparent to longwave radiation




If our atmosphere was only nitrogen, oxygen, and argon, this picture with no greenhouse effect would be accurate

# Greenhouse Gases

- **Polyatomic** molecules (having three or more atoms) are greenhouse gases
  - **Water vapor** ($H_2O$)
  - **Carbon dioxide** ($CO_2$)
  - **Methane** ($CH_4$)
  - **Nitrous oxide** ($N_2O$)
  - **Ozone** ($O_3$)
  - **Chlorofluorocarbons** (the ozone depleting chemicals which have been banned)




**Fun with quantum mechanics (not on homework or test, but to help you make sense of this material):** A molecule will only absorb radiation if the energy that radiation has (related to its wavelength) is the same as the energy it takes for the molecule to change the way it's moving, vibrating, or rotating. Polyatomic molecules can rotate and vibrate in multiple ways, so they can absorb the right frequencies of longwave radiation.

# Water Vapor

- Gas form of water
  - AKA humidity
  - Not visible. If you can see it, it's in liquid or gas phase. The steam coming out of your kettle is tiny liquid water droplets, which quickly evaporate.
- The number one greenhouse gas!
  - Powerful because there's **a lot** of it
- Not controlled by humans
  - Water vapor concentrations are controlled by natural cycles of evaporation and precipitation
  - Observed to be increasing with global warming

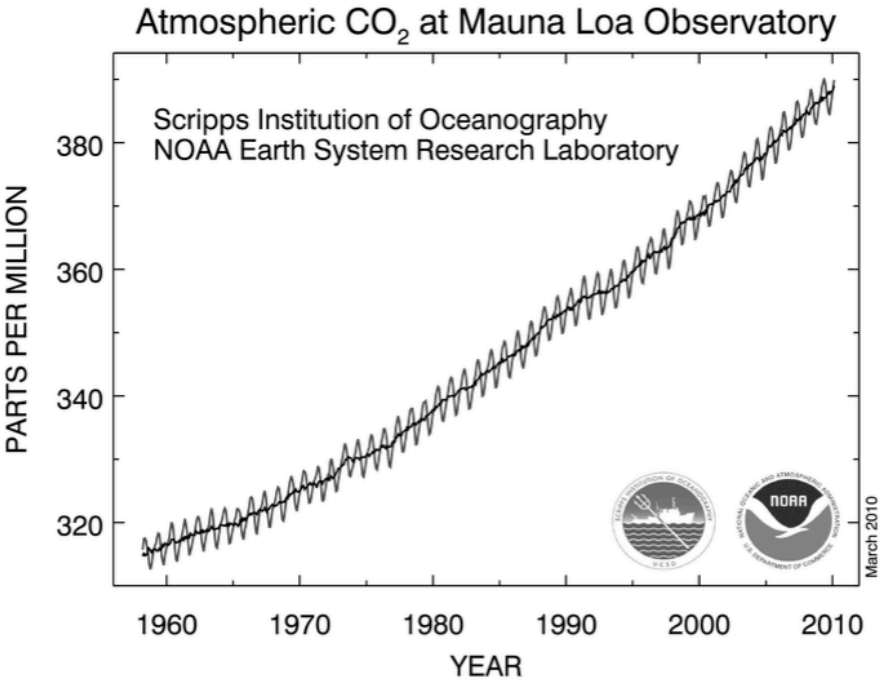
# Carbon Dioxide

- $CO_2$
  - It's what we breathe out, what plants breathe in
- The primary contributor to the anthropogenic (human-caused) greenhouse effect
- Increases primarily due to

  fossil fuel burning (80%)

  and biomass burning (e.g.,

  forest fires; 20%)
  - Preindustrial value: 280 ppm
  - Current value: 386 ppm



# Carbon Dioxide

- $CO_2$ will also be the main problem in the future
- It's extremely **long-lived** in the atmosphere
  - 50% of what we emit quickly gets taken up by the ocean or land
    - We'll discuss this more later
  - Most of the rest sticks around for over **100 years**
  - Some of what we emit will still be in the atmosphere over **1000 years** from now!

# Methane

- $CH_4$
  - Natural gas like in stoves/heating systems
- Much more potent on a per molecule basis than $CO_2$
  - Only 1.7 ppm though – much smaller concentration than $CO_2$
- Natural sources from marshes (swamp gas) and other wetlands
- Increases anthropogenically due

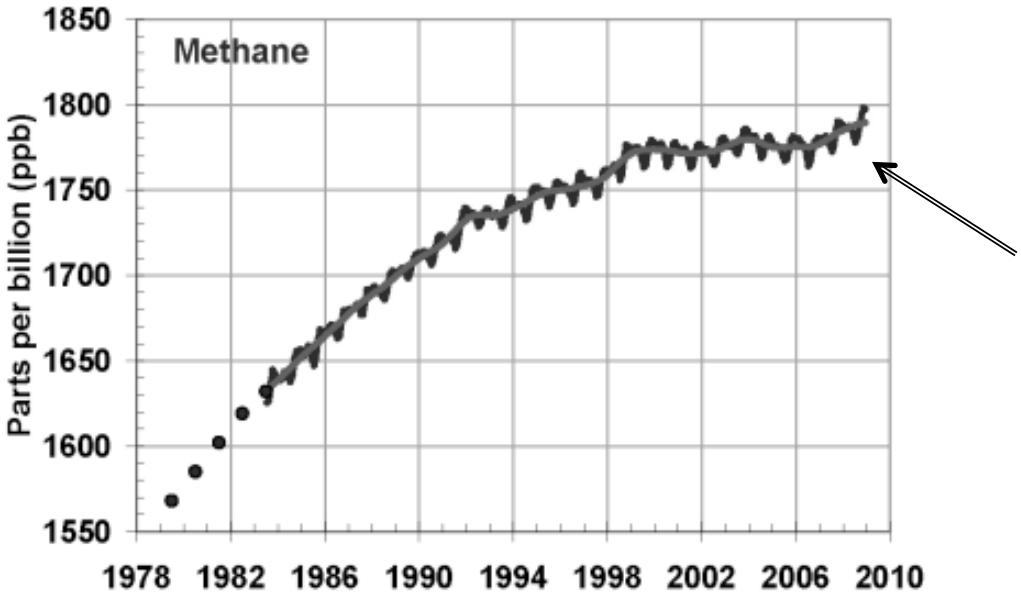
to farm animals (cow burps),

landfills,  natural gas leakage, rice

farming

# Methane

- The lifetime of $CH_4$ is significantly shorter than carbon dioxide
  - Breaks down in the atmosphere in chemical reactions
  - Lifetime of methane is only 8 years

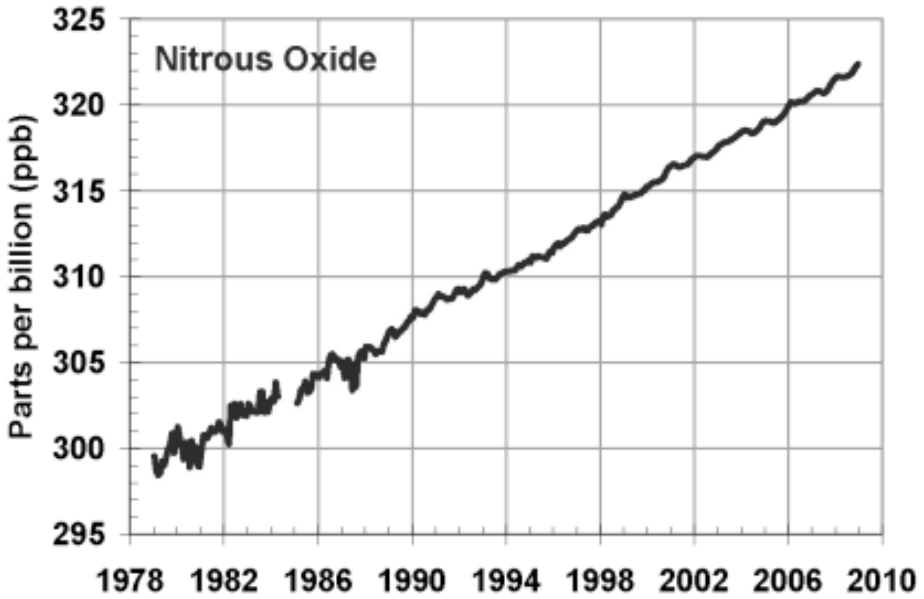



Methane concentrations have been leveling off in recent years, possibly due to drought in wetlands at high latitudes

# Nitrous Oxide

- $N_2O$ – Laughing gas
- Also more 310 times more potent a greenhouse gas than $CO_2$ on a per molecule basis
- Comes from agriculture, chemical industry, deforestation
- Small concentrations of

  only 0.3 ppm

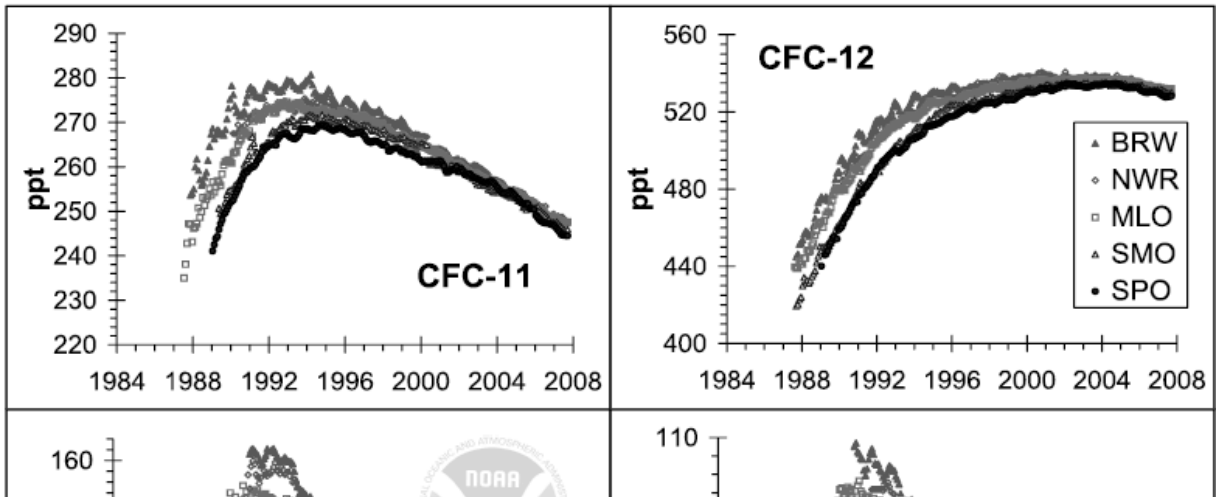


# Ozone

- Ozone or $O_3$ occurs in two places in the atmosphere
  - In the **ozone layer** very high up
    - This is “good ozone” which protects us from ultraviolet radiation & skin cancer
    - Remember **ozone depletion is not global warming!**
  - Near the surface where it is caused by air pollution: “bad ozone”
- Ozone is a greenhouse gas, and is more potent on a per molecule basis than $CO_2$. But it is very short lived and in much lower abundance.

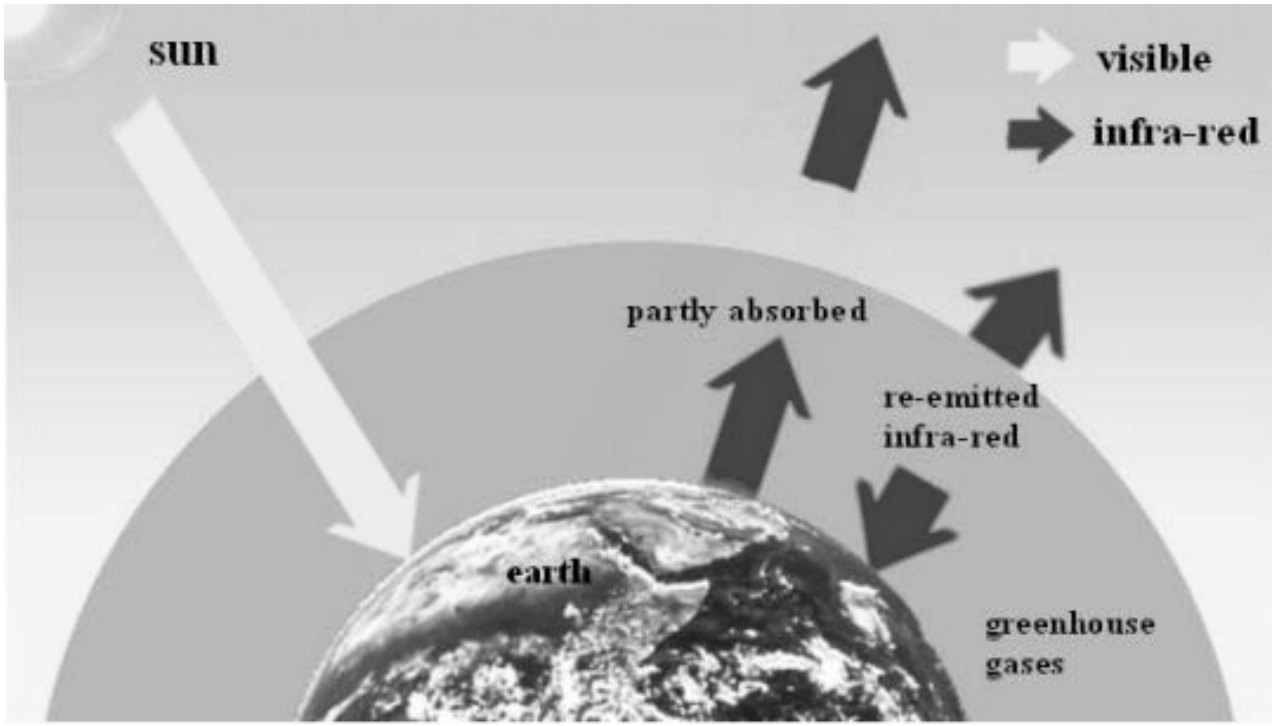
# CFCs

- CFCs or chlorofluorocarbons are the **ozone depleting** chemicals
  - Have been almost entirely phased out
- CFCs are strong greenhouse gases
  - Their reduction likely prevented significant global warming in addition to saving the ozone layer!
- Some replacements for CFCs (called **HFCs**) are strong greenhouse gases though



# The Unnatural Greenhouse Effect

- Increasing levels of $CO_2$ and other greenhouse gases leads to a stronger greenhouse effect
  - With more greenhouse gases, it becomes harder for outgoing radiation to escape to space



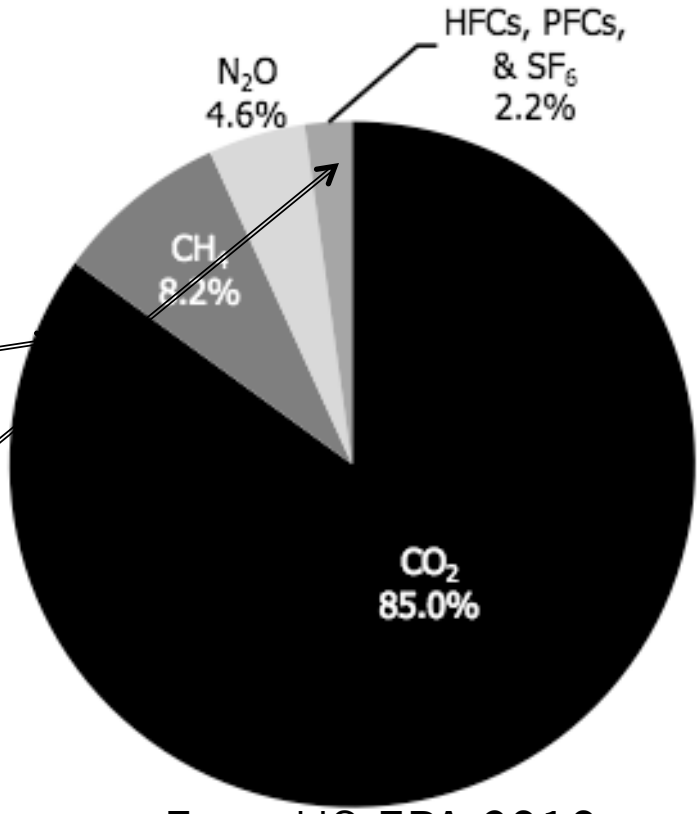

It's like this picture from before, but more.

More radiation trapped before it gets out to space.

Longwave radiation is emitted from a higher (and colder) level on average.

# The Anthropogenic Greenhouse Effect

- Contributors to the "anthropogenic" greenhouse effect
  - Numbers for the US based on current (2008) emissions




$CO_2$ is the big problem in the US currently.

Note how much lower the CFCs are than on the previous slide. This is b/c we basically don't emit CFCs any more.

From US EPA 2010 report (draft)

# Summary

- The Earth is heated by the Sun
  - This is **shortwave radiation**
  - **Albedo**: key factor that determines how much radiation is absorbed vs reflected
- Earth loses energy due to **longwave radiation**
  - The greenhouse effect causes less heat loss due to longwave radiation
- Greenhouse gases:
  - Number one is water vapor
  - Number two is $CO_2$
  - Global warming potential: key concept