# Global Warming

**Observations:**

1. Global temperature has been gradually rising in recent years
   - Problem of interpretation: long-term fluctuations-geophysical evidence and fossil remains
   - Correlation of rising temperature with concentration of "greenhouse" gases
2. Faster growing vegetation
   - Tundra growth extending further north
   - Vegetation growing at higher elevations
3. Glacier melting
   - Significant shrinkage of ice fields in Asia, South America and Africa
   - Last century hottest in 1000 years in Himalayas: ice core samples
   - Ice cap at North pole melted for first time in recorded history this year: 1.5 Km in diameter ice-free patch: Six years ago ice was 3 meters thick.
4. Increase in concentration of "greenhouse gases" like $CO_2$

**What determines global temperature? Energy budget of earth:**

1. Radiation in: $54.4 \times 10^{20}$ KJ/Yr
   - About 70% absorbed by surface
     - 46% by Earth's surface and 24% by atmosphere
   - About 30% reflected back to space: light scattering by clouds and particulates
2. Energy losses:
   - Latent heat for evaporation: heat used to change state of matter
   - Sensible heat: updrafts
   - Black-body radiation: Infra-red (IR) emission and absorption
     - $62.7 \times 10^{20}$ KJ/Yr emitted from earth (More than input!): Corresponds to equilibrated earth temperature of $T = 288$ K.
     - Net loss of $8.8 \times 10^{20}$ KJ/Yr

- Resolution: Greenhouse gases trap heat and make planet habitable.

**Question:** Can increased human consumption of fossil fuels affect temperature?

- Assuming steady increase in rate of consumption at rate of 2.8% per year, it would take 285 years to raise the earth's temperature 1 degree!
- Must be indirect heating: increased trapping of heat through greenhouse gases
- How does this occur?

## Greenhouse effect: IR absorption

- Energy absorbed and emitted by molecules in IR range of spectrum ($1000 - 20,000$ nm)
- Radiation causes vibrational and rotational transitions in molecules: largely $CO_2$ and $H_2O$.
  - Radiation is electromagnetic: interacts with electromagnetic field of moving charges of molecule.
  - IR *active* molecules: molecules with vibrations which change the electronic charge distribution in an asymmetric fashion (change of dipole)
    - Neglible IR absorption from homo-nuclear diatomics like $O_2$
    - Common IR active heteronuclear molecules: $NO$, $H_2O$, $CH_4$, halocarbons like $CH_3Cl$.
- Light absorption occurs at specific $\lambda$ excite vibrations and rotations: $\lambda$ typically larger for heavier atoms.
- After absorption, energy can be released by
  - Collisions: kinetic energy of gas molecules in atmosphere (temperature)
  - Radiative emissions: re-absorption of energy possible
- *Atmospheric window:* region of spectrum where there are few IR-active molecules of natural source which absorb in range $8000 - 12000$ nm
  - CFC's, methane and $N_2O$ important for global warming even though concentrations are $100,000$ times smaller than other IR-active molecules.
    - Absorb in atmospheric window: 1 molecule has a large effect in trapping radiation that otherwise would have escaped

    * Long-lived in troposphere: photolyzed in stratosphere (ozone depletion problem)
    * $CH_4$ less long-lived due to $OH$ chemistry.

# Trends and Controls

- Increasing concentrations of greenhouse gases
  - CFC effects present from refrigerants-lifetime $\sim$ 100 years
  - $N_2O$ from microbial denitrification of fertilizers
  - $CH_4$ from wetlands, termites and cows
  - $CO_2$ from burning fossil fuels and reduction of sink via deforestation
- Greenhouse gas and emissions controls:
  - Conference in Toronto, 1988: Meteorological branch of UN Environmental program-discussed present problem and models predicting 4 Celsius rise in temperature over the next 40 years leading to a rise in sea-level of 140 cm.
  - Conference in Rio, 1992: 100 nations attended. Goal was to fix $CO_2$ production at 1990 levels by the year 2000
  - Kyoto, 1997: Nations agree to cut greenhouse gas emissions to 6% below level of 1990. Canada signs deal, but 1998 levels are 13% above 1990 and only 58 companies report emissions. Among these, 16 companies increased emissions while only 10 actually reduced emissions to required level. Largest producer in Canada, Ontario Hydro, produced 31 million tonnes of $CO_2$, a 36% increase over the previous year.
  - The Hague, November, 2000: Climate change conference to assess greenhouse gas emissions and enforce controls. United States, the largest producer of $CO_2$, at odds with European Union over:
    * Credits for "sinks" of $CO_2$. U.S. wants less stringent requirements on industry due to land and forestry management. European Union objects that real task is to cut emissions.
    * No agreement on a policy on how deal with countries that don't adhere to policies.

# Outlook

Intergovernmental panel on climate change: IPCC

- Publishes scientific reports on greenhouse gases
- Modeling of climate changes

**Projections:**

1. Coal intensive energy supply, depletion of forests with little control on $CH_4$, $N_2O$, CFC emissions $\Longrightarrow$ 4 degrees C rise by year 2100
2. Move to renewable energy sources, hydroelectric, solar, wind and nuclear power: Phase out CFCs and undertake reforestation projects $\Longrightarrow$ 2 degrees rise by year 2100.

**What to do:**

1. Plant a tree.
2. Alternative energy sources
3. Cleaner fuels: reduce coal consumption and impose carbon tax on fuels
4. Removal of $CO_2$: collect $CO_2$ and transform it into harmless product
   - Carbon silicates from sea shells: cheap and abundant

     $$2CO_2 + H_2O + CaSiO_3 \longrightarrow SiO_2 + Ca\left(HCO_3\right)_2$$

     - Dump calcium bicarbonate in ocean
   - Dry ice stored in insulated containers: shot into sun?

**Consequences of global warming:**

- Shrinking polar caps $\Longrightarrow$ decreased albedo so more absorption of radiation
- Less pronounced seasons and other *unpredictable* climate changes
  - More precipitation in some region: desertification in others lead to agricultural problems and their consequences