Chemical Degradation

NREM 612

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Chemical Degradation

I. Acid Deposition

A. Types

1. Wet: rain, snow, mist, hail

2. Dry: dust, particulate, aerosols, smog

B. Major cause:

1. $\text{SO}_2$ emissions

   a. Natural sources:

   b. Anthropogenic sources:
C. Effects on Ecosystems:

1. Damage to plants

2. Alteration of soil, H₂O chemistry
   
   i. ↓ in acid neutralization capacity of soil & H₂O

3. Alteration of microbial activity, diversity
II. Salinization

A. Natural causes

1. insufficient rainfall to flush salts from soils

2. fossil deposits?

B. Irrigation-related causes:

1. leakage of $H_2O$ from canals

2. over application of $H_2O$

3. inadequate drainage

4. inadequate application of $H_2O$ to leach away salts
C. Effects on ecosystems

1. High levels of salt
   a. prevent plants from extracting H₂O
   b. ↓ nutrient extraction
   c. stunt growth

D. Problem Areas?
III. Greenhouse Effect (GHE) & Glob Clim

Explanation:

Solar energy passes thru atmo w/ little absorption

Earth’s land & sea surf warmed by radiation, & reradiate energy @ longer $\lambda$s

Some re-radiated energy (~30 %) absorbed by $\text{H}_2\text{O}$ vapor, some by $\text{CO}_2$.

Most trapping takes place in lower atmosphere
Idealized model of the natural greenhouse effect. (IPCC 2007)
Estimate of Earth’s annual and global mean energy balance. Incoming solar radiation absorbed by earth & atmosphere balanced by release of same amount of outgoing longwave radiation.

(IPCC 2007)
A. Basic GHE good

1. w/o GHGs, earth’s avg. temp. ~ 33°C (59°F) colder, based on avg. dist. from sun

2. GHE modulates temps, i.e. less day heating & night cooling

<table>
<thead>
<tr>
<th>Planet</th>
<th>Temp (°C)</th>
<th>CO₂%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mars</td>
<td></td>
<td></td>
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<tr>
<td>Earth</td>
<td></td>
<td></td>
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<tr>
<td>Venus</td>
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</tbody>
</table>
B. Human modif GHE: Change in conc of atmospheric GH gasses that alters climate

1. *What is composition of earth’s atmosphere?*

2. *What are the GH gasses?*

3. *Which GHGs are most potent?*
Estimated lifetime heat-trapping potential of each molecule relative to single molecule of CO$_2$

<table>
<thead>
<tr>
<th>Gas</th>
<th>CO$_2$</th>
<th>CH$_4$</th>
<th>N$_2$O</th>
<th>CFCs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warming Effect</td>
<td>1</td>
<td>25</td>
<td>230</td>
<td>10,000-20,000</td>
</tr>
<tr>
<td>Residence time (yrs)</td>
<td>500</td>
<td>7-10</td>
<td>150</td>
<td>60-400</td>
</tr>
</tbody>
</table>

CH$_4$ sources?

N$_2$O sources?

Natural CO$_2$ sinks:
CARBON DIOXIDE CO₂  
METHANE CH₄  
NITROUS OXIDE N₂O

MOLECULE'S HEAT-ABSORBING ABILITY

GAS'S 20-YEAR GLOBAL WARMING POTENTIAL

26 TIMES THE ABILITY OF CO₂

72 TIMES THE POTENTIAL OF CO₂

216 TIMES THE ABILITY OF CO₂

289 TIMES THE POTENTIAL OF CO₂

(IPCC 2007)
C. Q: w/ fluctuations in climate (i.e. changes in solar radiation [sunspots], Milankovitch Cycles, El Nino, volcanoes, etc.) is Clim Δ real or part of natural variation?

1. **Milankovitch Cycles**: Δs in amount of solar rad. received by earth, drives glaciation
a. **Eccentricity**: (Departure of an ellipse from circularity) earth's orbit varies from nearly circular to mildly elliptical.

i. Major component of these variations occurs on a period of 413,000 yrs. A number of other terms vary between 95,000 & 136,000 years. Results in

![Eccentricity Cycle (100 k.y.)](http://ircamera.as.arizona.edu/NatSci102/NatSci102/images/milankovitch.gif)
b. **Obliquity**: angle of earth's axial tilt varies w/ respect to plane of orbit

i. periodic variations \(~41,000\) **years** to shift between tilt of 22.1° & 24.5° & back

ii. As obliquity ↑, summers (in both hemispheres) receive ↑ radiative flux, winters less.
c. **Precession**: Earth also wobbles like a top. Δ in direction of Earth's axis of rotation relative to fixed stars, w/ ~ **26,000 year** period

(Precession of the Equinoxes)

Northern Hemisphere tilted away from the sun at aphelion.

Northern hemisphere tilted toward the sun at aphelion.

(http://ircamera.as.arizona.edu/NatSci102/NatSci102/images/milankovitch.gif)
Milankovitch Cycles

(www.wikipedia.com)
D. Trace gases trapped in air bubbles from ice cores (Greenland, Antarctica) → 650,000 yrs, CO$_2$ ranges 180-300 ppm

1. CO$_2$↑ from pre-industrial 280 ppm to 379 ppm by 2005

   a. CO$_2$ sources?

A scientist removes a glacial ice core stored in a freezer. (Keller & Botkin 2008)
Vostok ice-core temperature and CO$_2$ from Oak Ridge National Laboratory. Sea level from NASA/GISS.
Atmospheric concentrations of CO₂, CH₄, N₂O over last 10,000 years (large panels) & since 1750 (inset panels). Atmospheric samples = red lines, ice core data = different colors for different studies. Radiative forcing shown on right hand axes.

(IPCC 2007)
Global Trends in Major Greenhouse Gases to 1/2003

Global trends in major long-lived greenhouse gases through the year 2002. These five gases account for about 97% of the direct climate forcing by long-lived greenhouse gas increases since 1750. The remaining 3% is contributed by an assortment of 10 minor halogen gases, mainly HCFC-22, CFC-113 and CCl₄.

(www.wikipedia.com)
3. Earth surface temps ↑

4. Many glaciers retreating to smallest area in historic record

5. Polar ice caps shrinking

E. Varied evidence suggests unprecedented climate ∆
F. **Climate Δ & Degr** (IPCC 2007)

1. Global climatic Δs:

   a. Warming expected to be greatest over land & high N latitude

   b. Very likely (90%) that heat waves, heavy precip events become more frequent

   c. Likely (60%) that tropical cyclones become more intense

   d. Retreating ice sheets, glaciers; earlier spring snowmelt; larger more freq fires
Global average radiative forcing (RF) estimates for important agents & mechanisms, with spatial scale, & assessed level of scientific understanding (LOSU).
2. HI Climatic $\Delta s$ (Giambelluca et al. 2008):

   a. All stations: +0.163 °C dec$^{-1}$

   b. <31 m elev: +0.087 °C per dec$^{-1}$

   c. 1,100-3,400 m: +0.268 °C per dec$^{-1}$
Recent Temp. Changes in Hawaii

(Giambelluca et al. 2008)
3. Impacts on Oceans

a. Sea level (SL) rise

   i. Global avg. SL rose 1.8 mm yr\(^{-1}\) from 1961-03 (IPCC 2007)

   ii. Predicted rise: 0.18-0.59 m by 2099

   iii. Effects:

b. SL rise trouble areas?
People & wetlands at risk from a 44-cm rise in sea level by 2080s assuming coastal flood protection remains as it is today.

(Keller & Botkin 2008)
c. Dissolving CO₂ in seawater increases H⁺ conc. in ocean, ↓ ocean pH.
   i. ↓ 0.1 units since IR, predicted ↓ 0.1-0.5 by 2100
   ii. neg effects on corals, diatoms
4. Impacts on plants

a. N latitudes: ↑ temp & grow season, modest CO₂ fertilizer effect
   i. C3 favored
   ii. Ag. land shifts from Midwest to < fertile Canad. Shield

b. Trops/Subtrops: hurt by ↑ temp & drought
   i. globally about 20% of ag. land would be lost (Bush 2003)
   ii.

c. ↑ Temp & drought may favor invasives
5. Impacts on soils

a. ↑ microbial activity, ↑ decomp. of SOM, ↑ release of CO$_2$, ↑ acidity

b. Warming of peatlands, melting of permafrost → release of CO$_2$, CH$_4$

(Kunzig 2008)
6. Impacts on animals
   a. species Δ geographic ranges
      i. general movement ?
   b. Δs in migratory & breeding cycles

E. Other chem. degr. problems
   1. NO₃-N induced hypoxia:
   2. P enrichment: