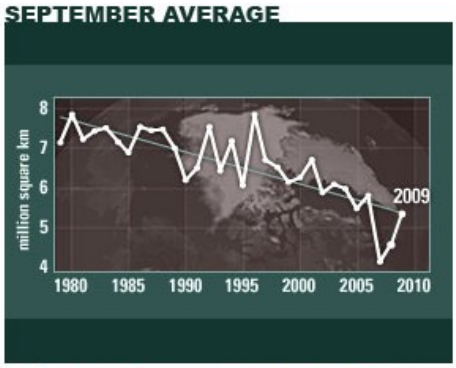
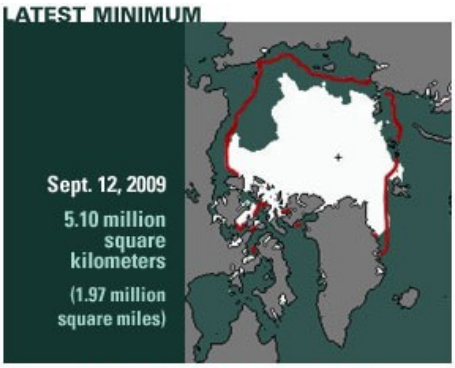
Climate Change

➢ Polar Ice Melts

- **Greenland Ice Sheet melt is rapidly accelerating** (23 mi^3 melted in 1996 vs. 53 mi^3 in 2006)
- Part of this increased rate of melting has to do with the **reflectivity & absorbption feed-back loop**
  → 90% of the sunlight that hits the polar ice is **reflected**; whereas, the ocean **absorbes** 90% of the sunlight
  → thus each mile of ice that melts vanishes faster than the mile that melted before it
- 2007 was the first time in known history in which the polar ice had melted enough to allow passage between Russia & Alaska
- By **2060 all of the polar ice will be melted**



September Arctic sea ice extent from 1979 to 2009 shows a 30-year decline.
Source: NSIDC

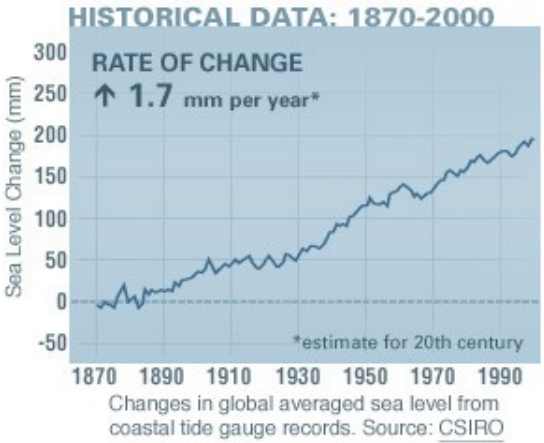


Red line shows the average ice extent for Sept. 12 from 1979 to 2000
Source: NSIDC

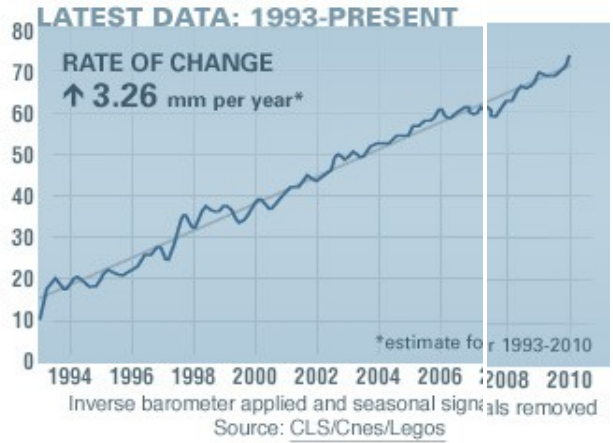
- September Arctic sea ice is now declining at a rate of 11.2 percent per decade, relative to the 1979 to 2000 average
- Arctic sea ice reaches its minimum extent each September.
- The graph on the left charts the average September extent from 1979 to 2009, derived from satellite observations.
- The illustration on the right shows the Arctic sea ice minimum extent for 2009, which was the third-lowest in the satellite record.

➢ Sea Level Rise

- The last time sea level was higher than it is today was ~130,000 years ago, then it was 20 ft higher
- Sea Level Could rise > 3 feet by **2100** → most of **Louisiana's coastline** will be **underwater**
- by **2500** the Gulf-Coast shore-line will likely run through Baton Rouge



Changes in global averaged sea level from coastal tide gauge records. Source: CSIRO

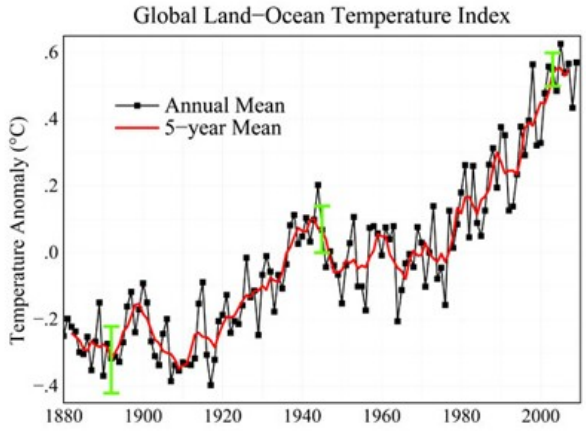


Inverse barometer applied and seasonal signals removed
Source: CLS/Cnes/Legos

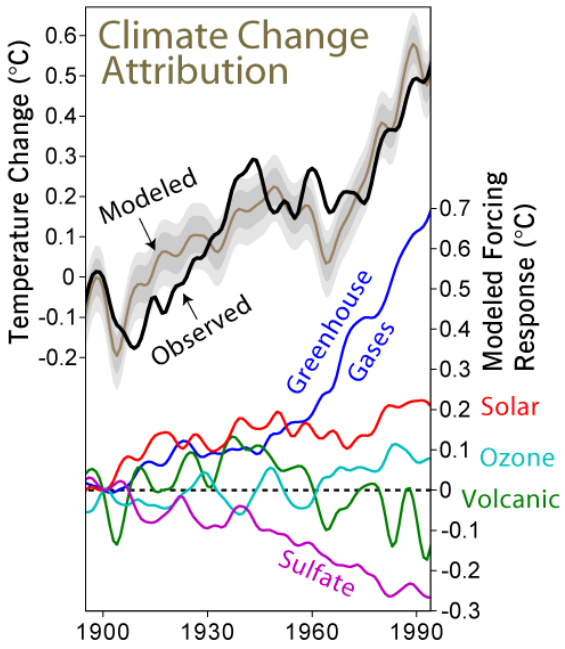
- The chart on the left shows historical sea level data derived from coastal tide gauge records (trend calculated using the linear regression method).
- The chart on the right shows the average sea level since 1993 derived from global satellite measurements, updated here monthly.
- Sea level rise is caused by the thermal expansion of sea water due to climate warming & widespread melting of land ice

➢ Increasing Air Temperatures

The **Earth is Getting Hotter**



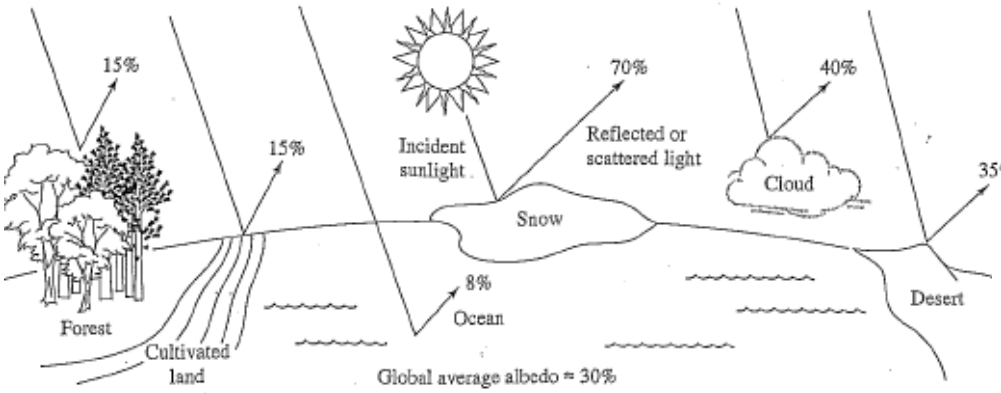
(http://data.giss.nasa.gov/gistemp/graphs)



- This graph illustrates the change in global surface temperature relative to 1951-1980 average temperatures.
- As shown by the red line, long-term trends are more apparent when temperatures are averaged over a five-year period.
- The green error bars represent the uncertainty on measurements. January 2000 to December 2009 was the warmest decade on record. (Source: NASA/GISS)

➢ Heat Balance & Albedo

- There's no net gain or loss of heat at the earth's surface



Surface type	Average albedo
Forest land	10–20%
Agricultural land	10–20%
Deserts	25–40%
Snow cover (above 60° latitude)	60–80%
Oceans (70° latitude and above)	15–20%
Oceans (below 70° latitude)	6–10%
Clouds (average over all types)	35–40%
Over entire surface	~30%

➢ Green House Gases (GHG)

- GHG **absorb** the **heat reflected off earth** instead of letting it escape into space
- GHG allow shortwave radiation from the sun to pass through, but absorb & reflect back the long-wave radiation emitted from the earth's surface, thus trapping it in the atmosphere
- Without the Green House effect, earth would be ~ 60˚F cooler than they are today
- ~50% of the solar energy entering the upper atmosphere is absorbed at the Earth's Surface
- GHG include: **water vapor**, **Carbon dioide (CO_2)**, **Methane (CH_4)**, **Nitrous Oxide (N_2O)**, **Ozone (O_3)**, **Sulfur hexafluoride** (), **hydroflurocarbons** (), **perfluorocorbons** (), etc.
- GHGs & chlorofluorocarbons gang up to destroy the ozone

○ **There are 3 factors that make a particular GHG important:**

1) **amount of gas** in the atmosphere, especially if its concentration is increasing
2) the **relative effectiveness** of a particular gas in **absorbing heat**
3) the **lifetime** of the gas in the atmosphere

○ **EU** proposed that **industrialized** countries slash emissions by **25 - 40% below 1990 levels** by **2020**

○ **GM** claims they'll cut CO_2 emissions in their North America plants by 40% by 2010 from 2000 levels

○ Wetlands impact on GHG

- Wetland soils produce & consume GHG → they play an important role in regulating climate change
- Natural wetlands account for **20-25%** of the **global <u>methane</u> emissions**
- They also are an important source of **Nitrous Oxide**, which in turn causes the **depletion of Ozone**
- **CH_4** & **N_2O** emissions could be **controlled through the Rice Production Management** of

  Mange the following (1) **Flooding to ↓ redox potentials**, (2) amount of **organic matter**, & (3) amount of **fertilizer** use

○ Carbon Dioxide (CO_2)

- CO_2 is the worst GHG
- Deforestation contributes 20% of the CO_2 emissions annually on a worldwide basis
- Warmer oceans carry less CO_2 than cooler oceans

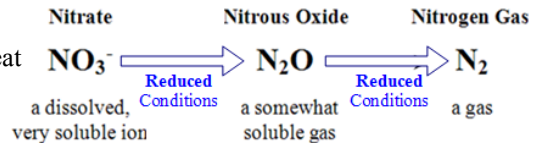
  ~50% of the 80ppm glacial-to-interglacial increase can be explained by the change in the solubility of CO_2

○ Methane (CH_4)

- Methane is the 2nd most important GHG (second to CO_2)
- It has 1/200th the atmospheric concentration of CO_2, but its thermal absorption is more effective
- Methane strongly influences the photochemistry of the atmosphere, accounting for ~15% of the current increase in GHG contribution to global warming
- Methane is an insoluble gas that bubbles to the surface when released to water from strongly reduced sediments
- Under high pressure & very cold conditions in the deed ocean, solid gas hydrates form that trap the methane
- These hydrates are a large potential fuel source (they have 80,000x the amount of natural gas found in conventional reserves)
- Climate change could warm the deep ocean enough to cause these solid hydrates to release the methane ("**methane burp**")
- Total Methane Sources (71% Anthropogenic & 29% Natural Origin) exceed Methane Sinks by 6% → 0.6% ↑
- Rice production is the 4th largest anthropogenic source of methane (b/c its grown in strongly anaerobic flooded fields)

○ Nitrous Oxide (N_2O)

- N_2O is one of the s**tronger** GHGs in terms of its capacity to absorb heat
  - → it's a more effective GHG than CO_2 or CH_4
  - → contributes 4% to the total GHG effect in global warming



- Agriculture causes 50-70% of the anthropogenic emissions of CH_4 & N_2O (Rice production generates a lot of N_2O)

○ Sulfates

- Non-absorbing sulfates directly reflect radiation & increase reflection by clouds → cooling effect
- Sulfates emitted from jet engine exhaust can counteract the warming effect of typical GHGs

➢ Carbon Sequestration

- **Removing Carbon** from the cycle where **organic carbon** is either **combusted as fuels** or **oxidized by microbial activity** (in soils, plants, & sediment-water systems**) rapidly cycles back** to **CO_2**
- There seems to be a **strong correlation** between **changes** in **temperature** & 2 GHG (**CO_2** & **Methane**) going back **150,000** years before present
  - Usually when one goes up, so will the other 2
  - However, in some cases the temperature seems to go up before CO_2
  - This just shows how complex climatic processes are & how they can't be explained any one factor alone
- **Iron fertilization hypothesis**
  - Dump iron into the oceans b/c it's the most limiting nutrient to primary production → it would ↑ algal growth → ↑ CO_2 intake
- By ↑ **soil organic Carbon content** by just 0.01% per yr. we could stop the ↑ in Carbon in the atmosphere
- Trap industrial emitted CO_2 & inject it deep in the earth

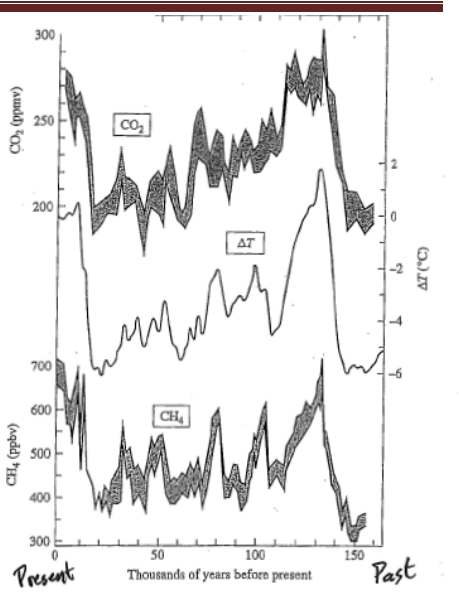
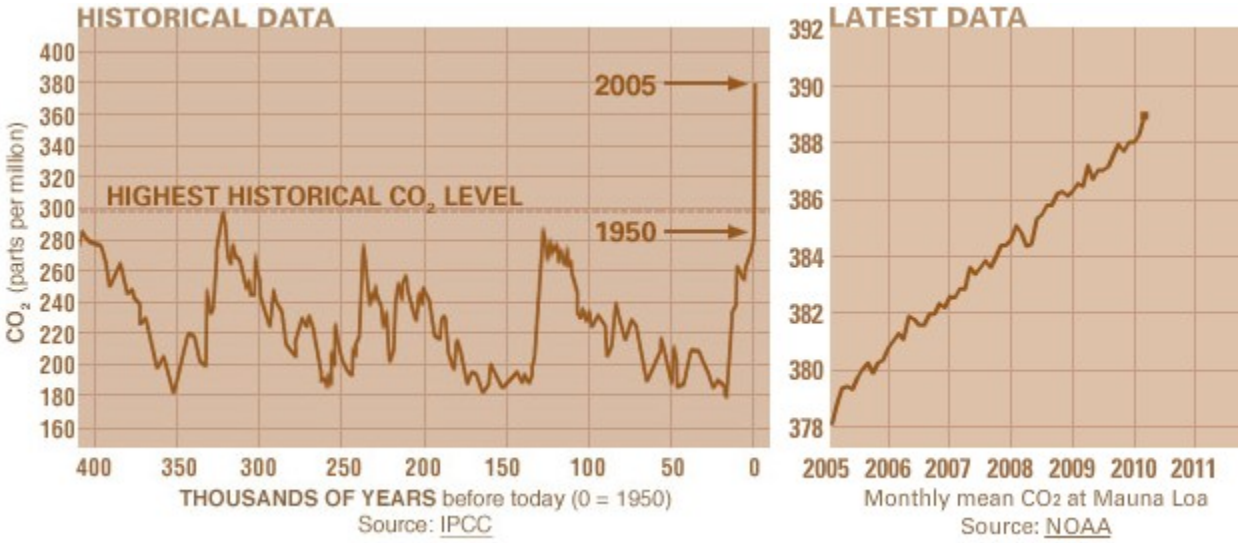
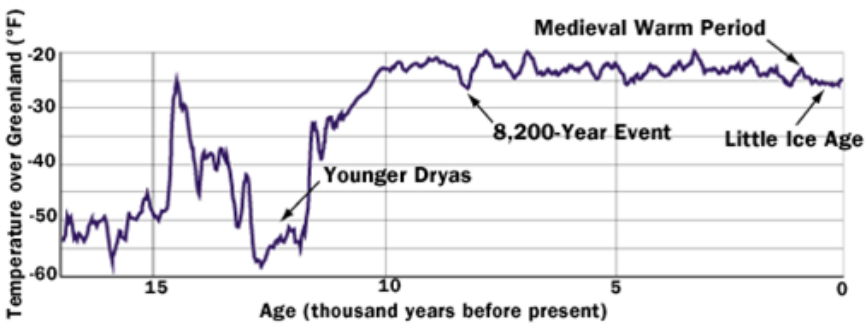
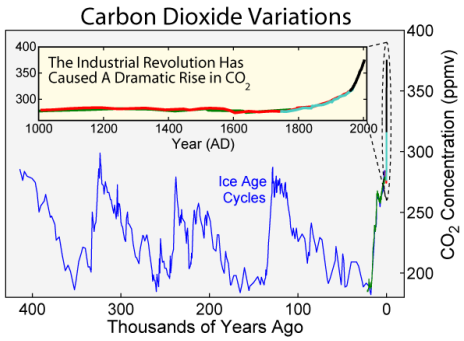


Figure 6.21 Antarctic ice-core records of local atmospheric temperature, and corresponding air concentrations of carbon dioxide and methane for the past 160,000 years. *Source:* J. T. Houghton et al., eds. (1990). *Climate Change: The IPCC Scientific Assessment* (Cambridge, U.K.: Cambridge University Press).



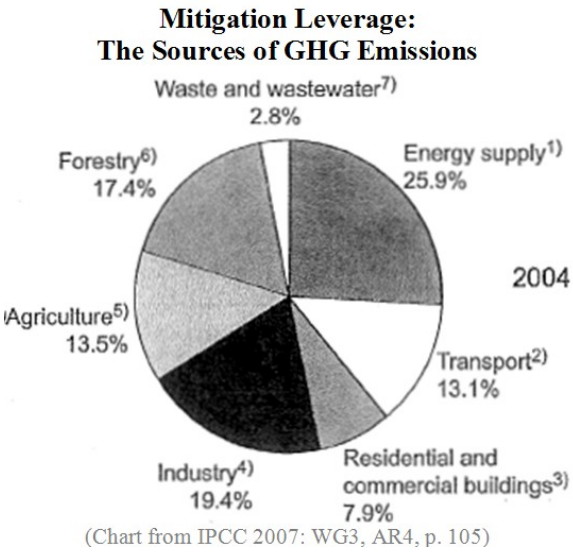
- Carbon dioxide (CO_2) is an important greenhouse gas released through natural processes such as respiration and volcano eruptions and through human activities such as deforestation and burning fossil fuels.
- The chart on the left shows the CO_2 levels in the Earth's atmosphere during the last three glacial cycles, as reconstructed from ice cores.
- The chart on the right shows CO_2 levels in recent years, corrected for average seasonal cycles.





➢ Greenhouse effect

- Trapping of heat in the atmosphere.
- Incoming short-wavelength solar radiation penetrates the atmosphere, but the outgoing longer-wavelength radiation is absorbed by greenhouse gases and reradiated to Earth, causing a rise in surface temperature.
-

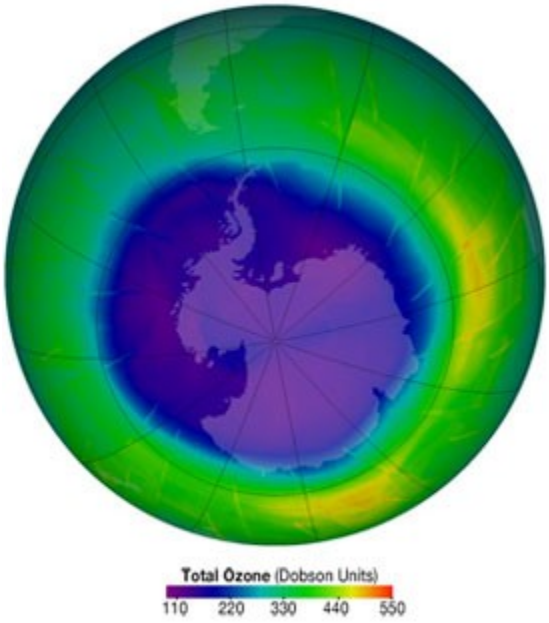


(Chart from IPCC 2007: WG3, AR4, p. 105)

➢ Greenhouse Gases (GHG)

- Gases in Earth's atmosphere that cause the **greenhouse effect**;
- include carbon dioxide, methane, and CFCs.
-

➢ Ozone Hole Data



Total ozone for Sept. 17, 2009

Daily maximum for 2009:
24 million square km (9.3 million square miles)

The "ozone hole" is a severe depletion of the ozone layer high above Antarctica. It is primarily caused by human-produced compounds that release chlorine and bromine gases in the stratosphere. The ozone layer acts to protect life on Earth by blocking harmful ultraviolet rays from the sun.

The image at left is a view of the most recent Antarctic ozone hole, derived from satellite measurements that monitor the ozone layer. The blue and purple colors are where there is the least ozone, and the greens, yellows, and reds are where more ozone is present.

There are signs that ozone depletion is slowing in response to the 1987 Montreal Protocol, which resulted in a significant reduction in global emissions of ozone-depleting chemicals. However, climate change may cause the ozone hole to expand further.

Source: NASA

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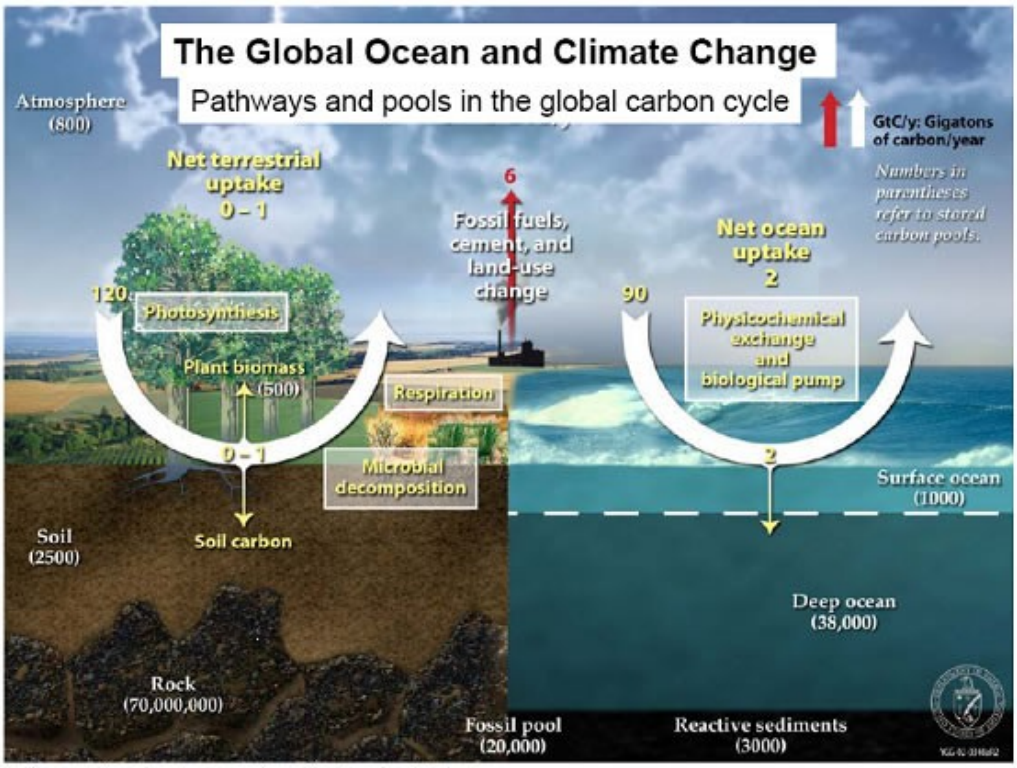
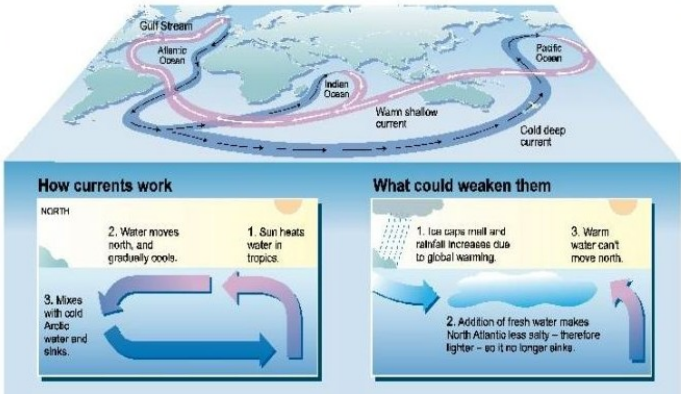


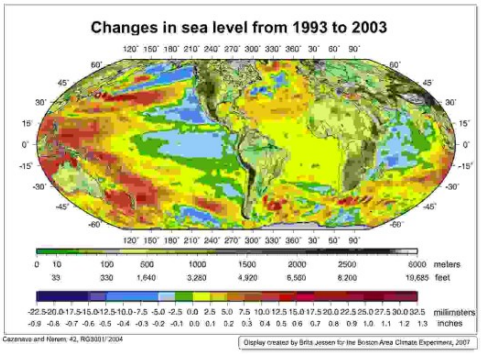
http://genomicsgtl.energy.gov/benefits/simple.shtml

Threat to the ocean currents

The Gulf Stream, which warms Western Europe, is part of a network of ocean currents driven by warm tropical water. Some scientists fear global warming will weaken these currents, causing the tropics to overheat and northern continents to become even cooler.



From 1993-2003, average global sea level rose about 3 mm per year. By the end of the century, the sea level is projected to rise 0.2 - 0.6 m (0.6 - 1.8 feet), although this estimate does not fully take into account carbon-cycle feedbacks or changes in recent ice sheet melting.

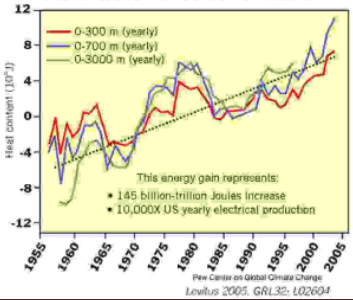


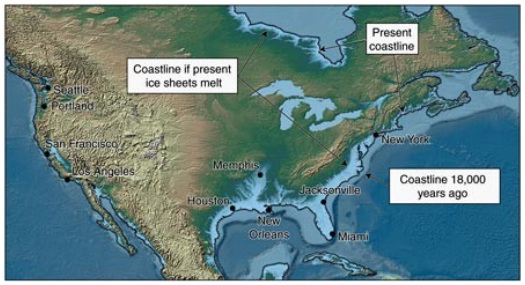
Effects on the Oceans

Carbon dioxide emissions and warming will cause:

- **Sea level rise**
- **Ocean acidification**
- **Decreasing salinity**
- **Increasing storm intensity**
- **Loss of artic sea ice**

The oceans have absorbed heat and warmed since 1961. The graph below shows ocean heat content over time.





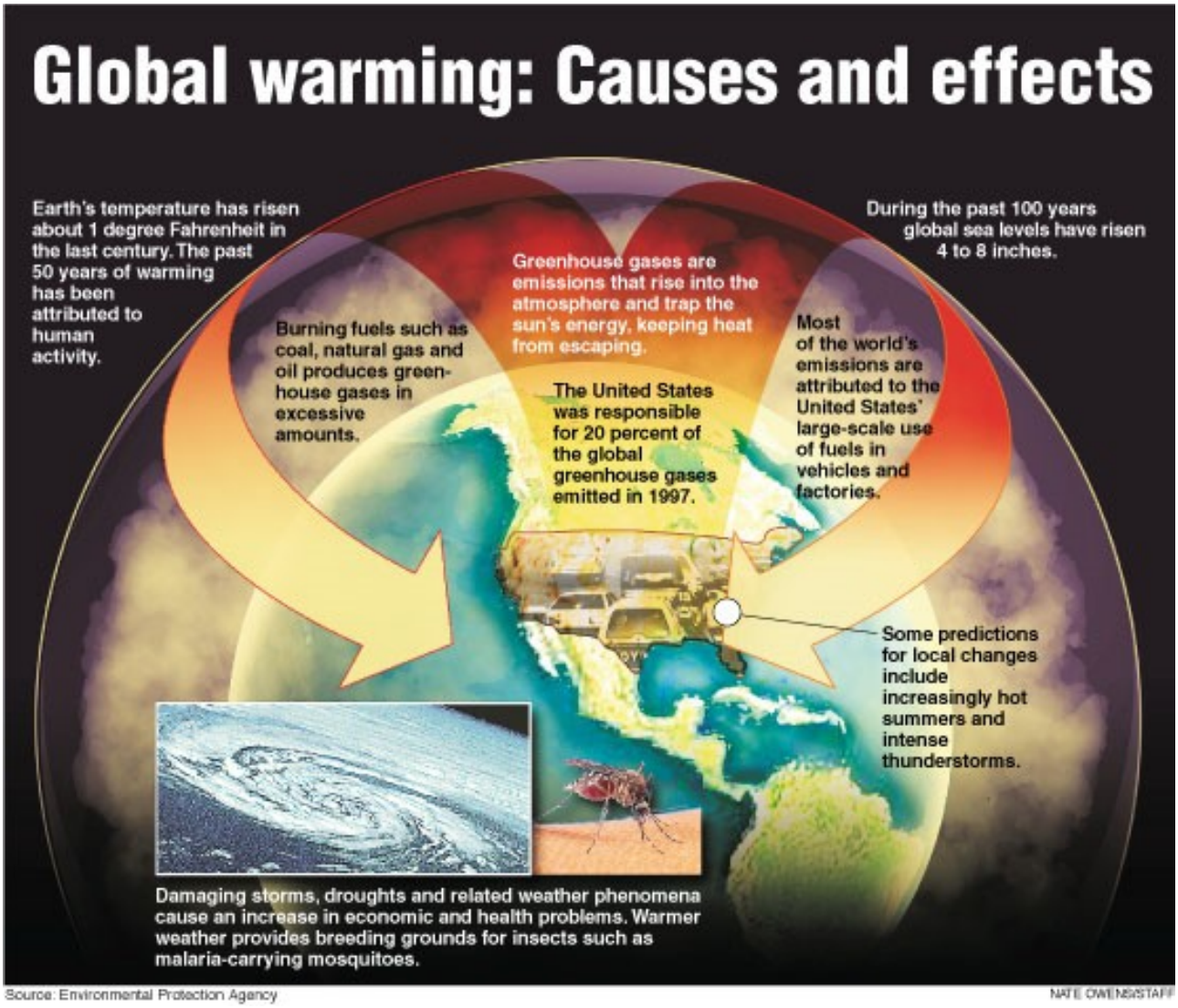
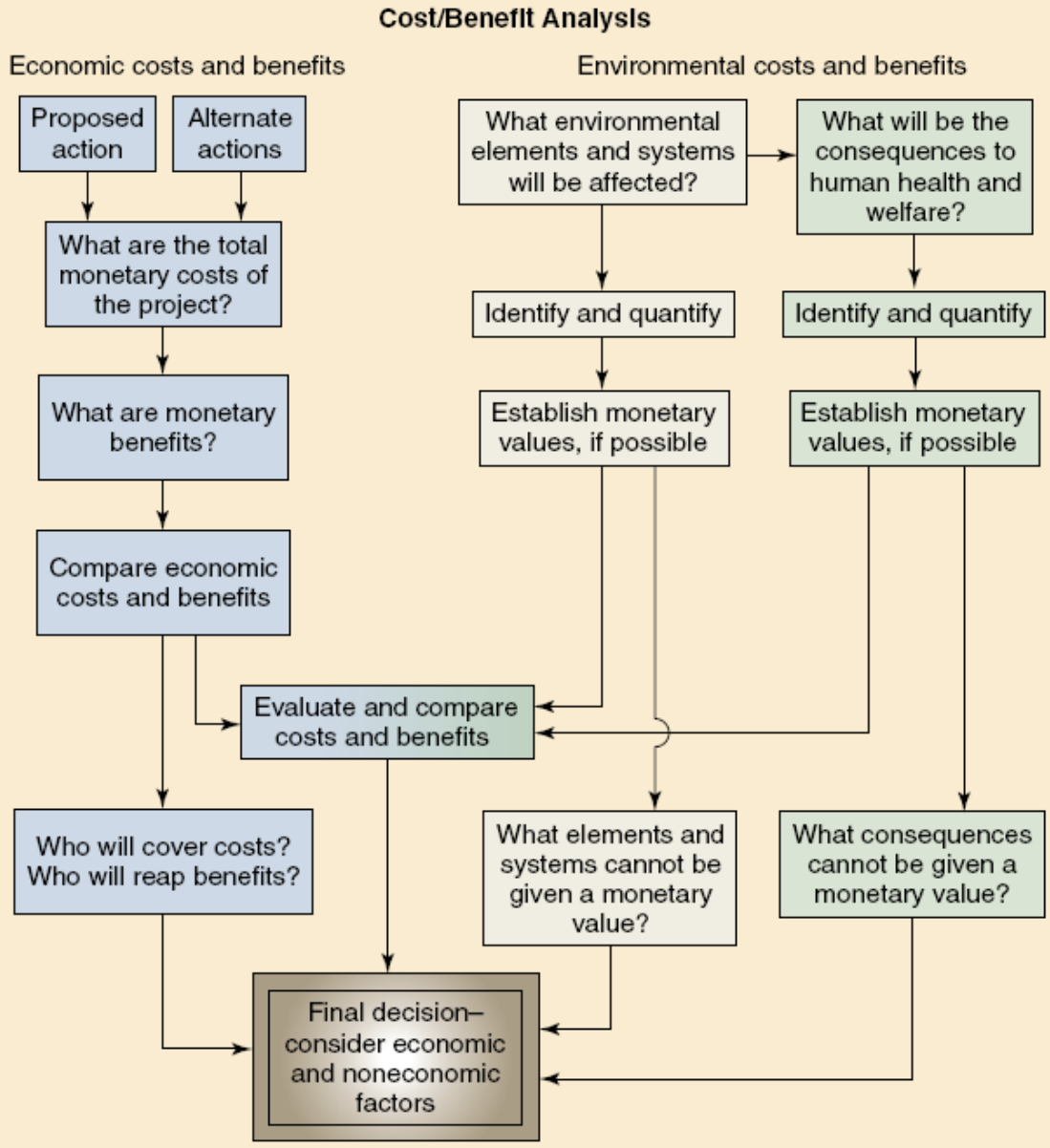
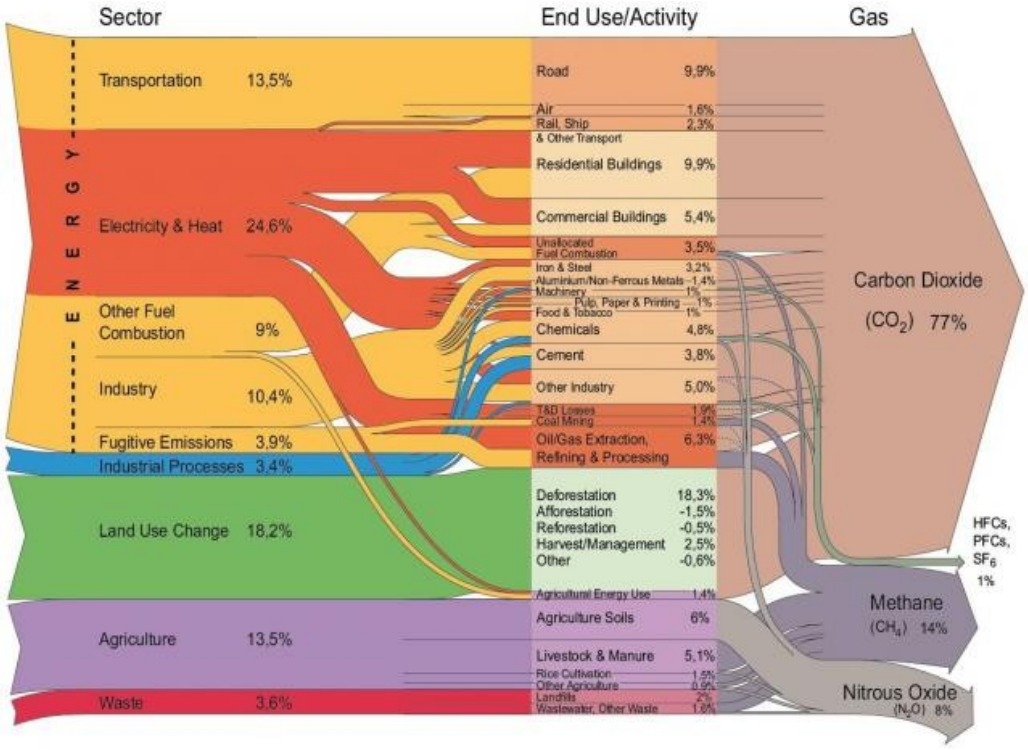

Global warming: Causes and effects
Earth's temperature has risen about 1 degree Fahrenheit in the last century. The past 50 years of warming has been attributed to human activity.
During the past 100 years global sea levels have risen 4 to 8 inches.
Greenhouse gases are emissions that rise into the atmosphere and trap the sun's energy, keeping heat from escaping.
Burning fuels such as coal, natural gas and oil produces greenhouse gases in excessive amounts.
The United States was responsible for 20 percent of the global greenhouse gases emitted in 1997.
Most of the world's emissions are attributed to the United States' large-scale use of fuels in vehicles and factories.
Some predictions for local changes include increasingly hot summers and intense thunderstorms.
Damaging storms, droughts and related weather phenomena cause an increase in economic and health problems. Warmer weather provides breeding grounds for insects such as malaria-carrying mosquitoes.
Source: Environmental Protection Agency
NATE OWENS/STAFF

Table 3.2 Costs and Benefits of Improving Air Quality

Costs	Benefits
Installation and maintenance of new technology	Reduced deaths and disease
1. Scrubbers on smokestacks	Fewer respiratory problems
2. Automobile emissions control	Reduced plant and animal damage
Redesign of industries and machines	Lower cleaning costs for industry and public
Additional energy costs to industry and public	More clear, sunny days; better visibility
Retraining of employees to use new technology	Less eye irritation
Costs associated with monitoring and enforcement	Fewer odor problems

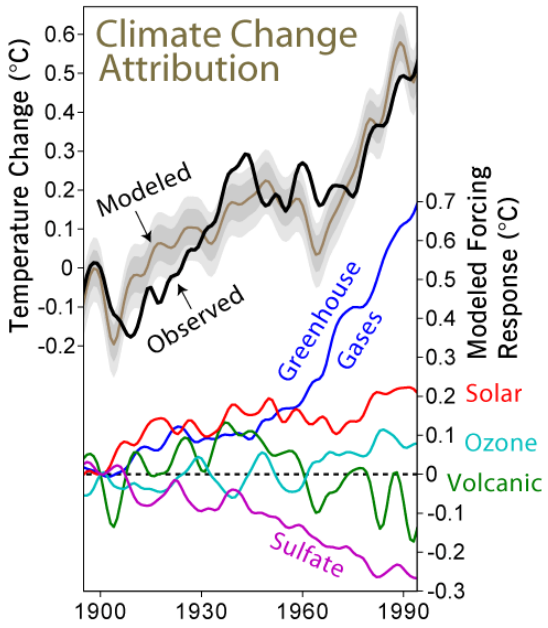


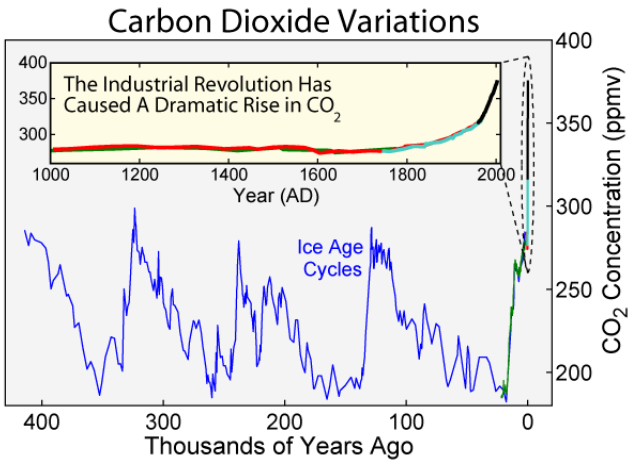
World Greenhouse gas emissions by sector

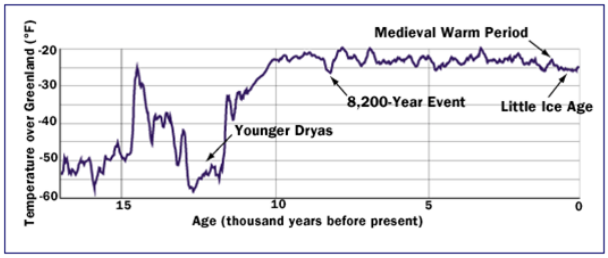


All data is for 2000. All calculations are based on CO_2 equivalents, using 100-year global warming potentials from the IPCC (1996), based on a total global estimate of 41 755 $MtCO_2$ equivalent. Land use change includes both emissions and absorptions. Dotted lines represent flows of less than 0.1% percent of total GHG emissions.

Source: World Resources Institute, Climate Analysis Indicator Tool (CAIT), Navigating the Numbers: Greenhouse Gas Data and International Climate Policy, December 2005; Intergovernmental Panel on Climate Change, 1996 (data for 2000).







3. The single biggest threat of human-released CO_2 entering the world ocean is probably

a) alteration of habitats through ocean warming

b) poisoning of organisms that are not able to tolerate CO_2

c) ocean acidification

d) disruption of food webs by ocean warming

e) all of the above

Carbon Dioxide and the World Ocean

- The atmospheric gas, carbon dioxide (CO_2), plays a special role in the world ocean system.
- CO_2 is essential for photosynthesis, so phytoplankton, seaweeds, and corals (which contain symbiotic algae) depend on it.
- CO_2 also controls the pH, or acidity of seawater.
- CO, a greenhouse gas, moderates atmospheric temperatures, and , therefore, the temperature of the world ocean.

CO_2 in the world ocean is important!

- The world ocean contains more carbon dioxide than the atmosphere, so that small changes in oceanic concentrations can have large effects on atmospheric concentrations.
- The concentration of carbon dioxide in the world ocean depends on rates of oceanic photosynthesis (which remove CO2 from seawater), rates of respiration (which release CO2), and rates of sedimentation and burial of organic matter (which contains carbon).
- A major and urgent goal of oceanographers is to understand processes that regulate carbon in the world ocean; simply put, to understand the global oceanic carbon cycle.
- Most of what we study in this course relates to the global oceanic carbon cycle and the geological, physical, chemical, and biological processes that affect it.

Humans are altering the CO_2 balance...

- Some 525 billion tons of human-produced carbon dioxide have been introduced into the world ocean in the past 200 years. That's half of all the carbon dioxide emitted by the burning of fossil fuels since the Industrial Revolution.
- This CO_2 has measurably altered the chemistry of the world ocean.

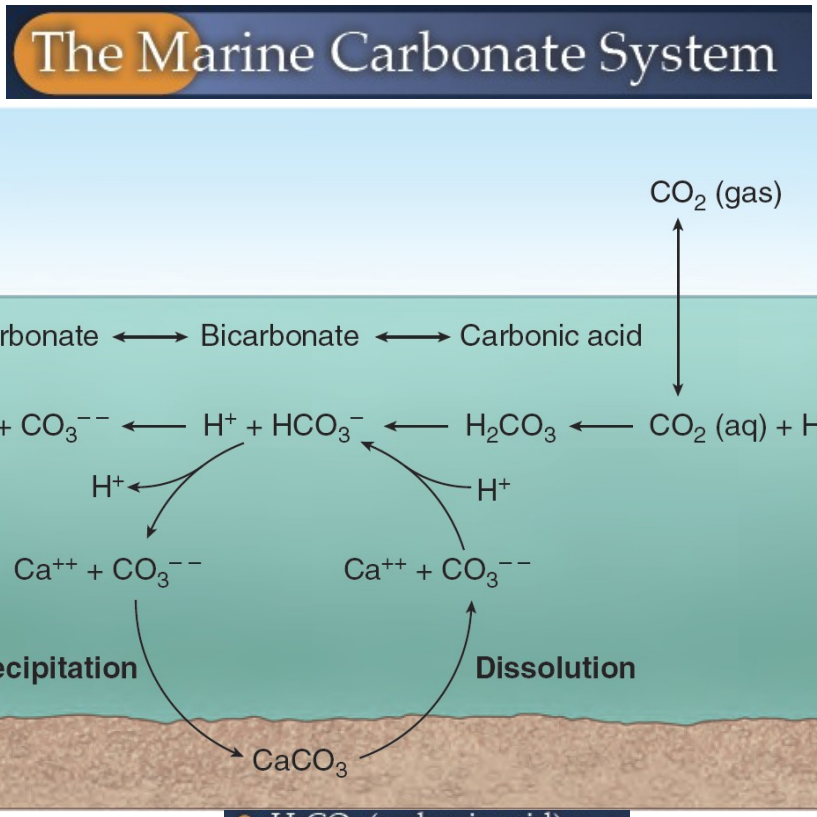
Impacts of Anthropogenic CO_2

- More CO2, more carbonic acid.
- More carbonic acid, more H+ ions.
- More H+ ions, lower pH and a more acidic ocean. This phenomenon is called *ocean acidification*.
- Many marine organisms, including corals and those who form shells, are sensitive to pH.
- Increasing ocean acidity threatens to disrupt food webs where carbonate-dependent organisms are important.

A multi-chambered foraminifera, whose carbonate skeleton may be threatened by ocean acidification. Foraminifera are important members of the microbial food web.

Crabs, clams, oysters, mussels, and a number of other invertebrates and vertebrates whose physiology depends on carbonate chemistry could be affected.

Both hard and soft corals use calcium carbonate in their skeletons. Disruption of coral reefs ecosystems by ocean acidification could have far-reaching ecological and economic impacts.



- $H_2O + CO_2$ <--> H_2CO_3 (carbonic acid)
- In words, carbon dioxide gas dissolves in water and becomes carbonic acid.
- The reaction is pH-dependent (meaning it is affected by pH) and reversible.

- H_2CO_3 (carbonic acid) <--> $H^+ + HCO_3^-$ (bicarbonate)
- In words, carbonic acid dissociates (comes apart) into one hydrogen ion and bicarbonate
- The reaction is pH-dependent (meaning it is affected by pH) and reversible

- HCO_3^- (bicarbonate) <--> $2H^+ + CO_3^{2-}$ (carbonate)
- In words, bicarbonate dissociates (comes apart) into a two hydrogen ions and carbonate.
- The reaction is pH-dependent (meaning it is affected by pH) and reversible.