

## 1. Modern Man, climate, and Earth's demise in general

- a. Population increase has been astronomical in past few centuries
- b. Man uses incredible amount of natural resources and requires a lot of energy
- c. CO<sub>2</sub> concentration has increased from less than 300 ppm to nearly 400 ppm in the last 150 years
- d. Rate of CO<sub>2</sub> increase was faster from 2000-2010 than any time in history, i.e., Man does not seem to be interested in curbing emissions
- e. CO<sub>2</sub> emissions from coal have increased greatly in the last few years with most from China and India.
- f. Deforestation adds CO<sub>2</sub> to the atmosphere. Vegetation that is cut and burned adds CO<sub>2</sub>. CO<sub>2</sub> re-enters the forest if it is allowed to grow back completely, but this rarely happens.
- g. CO<sub>2</sub>, N<sub>2</sub>O (nitrous oxide) and CH<sub>4</sub> (methane) are the primary greenhouse gases emitted by Man's activities
- h. Gas, particles and surfaces that reflect light (increase albedo) lead to temperature decreases such as S gases, soot, and bare land surfaces.
- i. Natural phenomena such as changes in solar output (insolation) affect global temperature too, but in last 40-50 years, Man's effect has greatly overridden these effects.
- j. Solar energy hitting Earth varies on a ~11 year cycle and can be seen a changes in Sun spots.
  - i. Sun spots have been recorded for millennia.
- k. Examples of Man's screw-ups
  - i. Man uses over 1/3 of all accessible fresh water
  - ii. 75% of N enter water bodies is from Man's activities
  - iii. over 50% of all S in atmosphere is from Man
  - iv. pesticide and other organic pollutants , as well as inorganic (metals) occur at high levels even in the most remote regions of Earth
    1. some of these compounds cause aquatic animals to change gender

- v. extinction rates are far higher than any other time in Earth's history
  - vi. Ozone pollution on the continents has increased greatly
  - vii. Increased atmospheric CO<sub>2</sub> has led to increased CO<sub>2</sub> in surface ocean water, which has significantly lowered pH
  - viii. Fish stocks in the sea have dwindled including the deep sea and are moving north
1. Recent climate change from CO<sub>2</sub> and CH<sub>4</sub> increases
    - i. Caused rapid warming of Earth
    - ii. More violent storms
    - iii. Droughts increased in dry areas
    - iv. Sea level rising rapidly
    - v. Species distributions have changed (moving toward poles on land and in sea)

## **2. Garrels and Lerman's Global Biogeochemical Model**

- a. Reservoirs (pools) representing Earth's crustal components, atmosphere, ocean, and biosphere (organic matter)
- b. Chem of atmosphere and ocean assume to not change
- c. If any other pool changes, then others must change too
- d. If biosphere increases, like what happened during the carboniferous periods that created oil and coal, then a set of connected changes must occur leading to changes in the crustal components.

## **3. Early Earth**

- a. How old is Earth and how do we know?
- b. What was early Earth like?
  - i. Sun was cooler; bombarded by objects; molten at first, but cooled enough for oceans to form
  - ii. Life may have appeared several times, but destroyed by meteors

## **4. Thoughts on early life**

- a. Misconceptions from Darwin's warm little pond to the use of the fossil record
  - i. Early thoughts that life took billions of years to appear (time for macrofossils to appear), ocean contained billions of years of concentrated food that fed early life, autotrophy evolved when food ran out
- b. Advent of molecular chronometers
  - i. RNA molecule ideal since cannot evolve rapidly
  - ii. SSU RNAs sequenced and led to 3 domains of life
    - 1. Organisms near root are thermophiles suggesting life evolved in hot places
    - 2. Early life was often autotrophic
  - iii. Recently found fossils and organic chem of old rocks indicate that life was rampant on Earth ~4 billion years (BY) ago
    - 1. Stromatolites were abundant and resemble modern cyanobacterial mats
    - 2. Stable C isotopes ( $^{13}\text{C}/^{12}\text{C}$  ratios) indicate photosynthesis was widespread >3.5 BY ago. Plants fractionate C isotopes (preferentially take up more of the 12 compared to the 13 isotope)
- c. Sun was 25% cooler 4 BY, but thought that greenhouse gases were more concentrated and kept Earth warm
  - i. As sun warmed, life removed these gases, especially  $\text{CO}_2$ , which kept temp stable
    - 1.  $\text{CO}_2$  uptake by autotrophy followed by decomposition led to increased  $\text{CO}_2$  near rocks, which produced carbonic acid that weathered rocks and produced bicarbonate that accumulated in ocean. This led to decrease in atmospheric  $\text{CO}_2$  over time.
    - 2. If life had not evolved early, this weathering would not have been rapid enough to keep up with the sun's warming and Earth would have a fate like Venus (run away greenhouse)
  - ii. Idea that  $\text{CO}_2$  has declined to low level and Sun is still warming, so eventually  $\text{CO}_2$  will be too low to sustain photosynthesis and life will cease (200 million years from now)
  - iii. Therefore, life may have started early in Earth History, but Man arrived with only a 5% window of time left.

## 5. Role of Sun in climate over time

- a. Eccentricity, obliquity and precession affect heating and cooling cycles and these are seen clearly in past climate and atmospheric gases
  - i. Eccentricity leads to ~100,000 year glacial-interglacial cycle
  - ii. Warming leads to increased CO<sub>2</sub> and CH<sub>4</sub> that exacerbates further warming
- b. We may postpone the next glaciation.

## 6. Early man and climate

- a. For about 5000 years appears that Man has increased CO<sub>2</sub> and CH<sub>4</sub> above levels expected from solar cycles
  - i. CO<sub>2</sub> from deforestation, CH<sub>4</sub> from rice agriculture
  - ii. Decreases in these gases from disease and mass losses of human life
    - 1. CO<sub>2</sub> decreases due to regrowth of previously deforested land
  - iii. Higher greenhouse gases may have delayed onset of glacial advance
- b. It has been proposed that the Younger Dryas period (12,000-14,000 years ago) was due to extinction of large mammals due to Man's activity, and the loss of CH<sub>4</sub> production by these mammals
- c. Wars and mass disease over history affected CO<sub>2</sub> concentrations. Human death led to less agriculture. When fields regrow forests, CO<sub>2</sub> is removed and temp of Earth decreases.