

- I. ENSO—El Niño and the Southern Oscillation
  - A. Change in pressure patterns in southern hemisphere
  - B. Trade winds cease, and perhaps blow from west to east (backward)
  - C. Changes location of precipitation across much of southern hemisphere, and elsewhere also
    1. summer monsoon rains of South Asia minimized
    2. drought in Australia and Africa
    3. increased rainfall to west of Andes, reduced to east
- II. Human-caused climate change
  - A. Causes
    1. fire
    2. deforestation
      - a. agriculture
      - b. overgrazing
    3. cities
      - a. urban heat island
      - b. particulates become cloud seeds
    4. carbon dioxide
      - a. important 'greenhouse gas'
        - 1) transparent to incoming solar radiation
        - 2) absorbs and reflects infrared wavelengths emitted by Earth
      - b. sources
        - 1) volcanic gases
        - 2) respiration
        - 3) burning carbon compounds
          - a) fossil fuels
          - b) other methane
          - c) biomass
        - 4) removal of massive vegetation reduces carbon fixation
          - a) deforestation of tropics
          - b) agriculture
      - c. increase from ~275 ppm to ~375 ppm in past 500 years
        - 1) greater than any rise in past 11,000 years, since retreat of last major ice advance, but
        - 2) dramatic rise starting ~ 200 years ago
        - 3) recent increase correlates with rise in use of fossil fuels
        - 4) increase atmospheric CO<sub>2</sub> will increase plant vigor, acting as a negative feedback to CO<sub>2</sub> levels
      - d. ocean can be a sink for CO<sub>2</sub>:
        - 1) dissolved in it
        - 2) dissolution of carbonate minerals also reduces CO<sub>2</sub>:
        - 3) formation of carbonate minerals that sink to bottom also removes CO<sub>2</sub>

- e. atmospheric response
  - 1)  $0.6^{\circ}\text{C}$  increase since 1900—
  - 2) remember ice age changes only about  $5^{\circ}\text{C}$
  - 3) models show polar areas may increase in temperature more than equatorial areas, due to a reduction in sea ice
- 5. other greenhouse gases
  - a. trace gases
    - 1) methane—flood agriculture, ruminants, termites in deforested areas
    - 2) nitrous oxide,
    - 3) CFCs
  - b. Water is important greenhouse gas too

### III. Feedback mechanisms

- A.  $\text{CO}_2$ -water system—
  - 1. positive feedback
    - a. more  $\text{CO}_2$ —higher temperature
    - b. higher temperature—more evaporation
    - c. more water vapor—higher temperature
  - 2. water also has negative feedback
    - a. more water vapor—more cloud cover
    - b. more cloud cover—higher atmospheric albedo
  - 3. models suggest positive feedback is greater than negative feedback
- B. aerosols of sulfur dioxide emitted as pollutants
  - 1. increase albedo directly, and make clouds more reflective
  - 2. act as nuclei for cloud formation
  - 3. a cooling effect on climate

### IV. consequences

- A. temperature change will not be uniform
  - 1. greater in polar areas
  - 2. less in tropics
  - 3. longer growing seasons in high latitudes
- B. changes in amount and distribution of precipitation
  - 1. many areas will increase
    - a. high latitudes year-round, mid-latitudes winter
    - b. —increase flooding potential
  - 2. other areas will decrease
    - a. Colorado River basin
    - b. Temp  $\uparrow 2^{\circ}\text{C}$ , rainfall  $\downarrow 10\%$ , reduce river flow 50%
  - 3. south Asia monsoon rainfall will be more variable
  - 4. increased intensity of tropical cyclone, and perhaps mid-latitude cyclones also

- C. Sea level change
  - 1. melting ice
    - a. melting icebergs do not change the level of sea!
    - b. melting land-bound ice does change sea level
  - 2. higher temperatures causes water to expand—physics
  - 3. 10-25 cm in past 100 years
    - a. trend expected to continue, perhaps accelerate
    - b. perhaps 50 cm in next 100 years
  - 4. gently sloping shorelines have large changes in coastal location
- V. models of climate change have uncertainty due to lack of knowledge of all the variables, and lack of understanding of the feedback of variables
  - A. El Niño increase in water temperature reduces severity of Atlantic tropical cyclones—which will be more important to climate change?
  - B. Release of hydromethane in permafrost areas will increase greenhouse gases
    - 1. rise in temperature will cause ice melting
    - 2. increased sea level will increase deep shelf areas, where hydromethane also forms
  - C. climate change probably cannot be reversed quickly
    - 1. causes can be changed in the short term
    - 2. will take time for environment to respond
- VI. mitigation
  - A. reduce use of fossil fuels
    - 1. fuel efficient vehicles
    - 2. better insulated homes
    - 3. recycling of metals, especially aluminum
  - B. alternative fuels
    - 1. nuclear power
      - a. some operational problems
      - b. advantage is NO release of carbon dioxide
    - 2. renewable energy
      - a. wind power
      - b. solar power
        - 1) direct heat application
        - 2) photovoltaic cells to make electricity
      - c. geothermal power
    - 3. plants
      - a. reduce logging
      - b. plant more trees
      - c. fertilize sea with iron to enhance algae production
        - 1) remove CO<sub>2</sub> by organism function
        - 2) increase cloud cover, increasing albedo