Holocene climate variability

I. Have seen climate variability on a number of time scales during glacial times
  A. orbital cycles to millennial-scale climate change
    1. D-O events, Bond cycles
  B. others argue that 1-2 kyr (sub-Milankovitch) climate changes occurs throughout the Holocene **Fig. 15.16**
    1. poss. related to changes in freshwater flux to the North Atlantic
    2. exact causes not well understood (if indeed this periodicity is real)
    3. again may be stochastic resonance **resonance fig.**
      a. could explain the "quasi"-periodicity
      b. could also explain why this doesn't show up in all NH climate records
  C. understanding Holocene climate variability over the past thousand years is important to separate out natural climate variability on "short" time scales versus anthropogenic forcing
    1. discussion of recent global warming/climate change

II. Holocene climate variability **Fig. 12-12**
  A. After YD event the relaxation of orbital forcing led to rapid ice melting **Fig. 14-1**
    1. rising summer solar insolation, melting of ice sheets and increase in CO_2 and methane
    2. likely driven by many of the same positive feedbacks that operated during the onset of glacial conditions when opposing changes in N Hemisphere solar insolation occurs
  B. up to ~6 kyr bp led to a gradual warming
    1. Holocene maximum (Holocene climatic optimum)
    2. slightly warmer and wetter than pre-industrial Holocene conditions
  C. after 6 kyr the decrease in summer insolation leads to a general cooling
    1. ends with Little Ice Age
    2. but also interrupted by Medieval warm period
  D. Medieval warm period **back to Fig. 12-12**
    1. increase in temp. that played an important role in the history of Europe
      a. exploration and colonization of Greenland by the Vikings
      b. farm settlements were able to spread further north and to higher elevations
    2. degradation of environmental conditions occurs near the end of the Medieval warm period also compounded by the arrival of the Bubonic plague (1346-1361)
  E. Little Ice Age
    1. episodic cooling from ~1500's to the mid-1800's
    2. has a strong regional focus (climate of the N Atl. And Europe)
    3. growing evidence also suggests other parts of the world experienced similar cooling

III. Causes of Holocene climate variability
  A. from LGM (21 kyr pb) to Holocene climatic optimum orbital forcing (+ assoc. feedbacks) appears to dominate
  B. Early anthropogenic hypothesis **Fig. 15-14**
    1. greenhouse gasses behave differently in the intial stages of this interglacial (vs. others)
    2. human activity has staved off the next glacial early in "modern" history
      a. should be headed into the next glacial by now
    3. very controversial

C. other more short term changes a bit more complicated
1. Medieval warm period, Little Ice Age

D. Periodic or episodic processes
1. internal oscillations driven by fast-response components of the Earth system
a. hysteresis
2. role of stochastic resonance **Fig. 15.2**

E. Episodic factors include changes in solar activity plus volcanic eruptions

IV. Variations in solar flux

A. in addition to very long-term increase in solar flux, solar output also changes on much much shorter time scales
1. on decadal to century time scales changes in solar output are accompanied by changes in sunspots

B. sunspot cycles may be proxies for changes in total solar energy output
1. both the # of sunspots and the lengths of the sunspot cycles appears to be important
2. some correlation between global temps and sunspot cycles **Fig. 15-8**
a. causal relationships still difficult to establish
b. shorter cycle length -> greater solar energy output (?)
3. some relationship between sunspots and Holocene climate variability **mod. Fig.12-12**

C. historical periods of low sunspot activity correlate with colder temperatures
1. clearly does not explain all of the climate variability

V. Frequency of volcanic eruptions

A. From previous lectures we know that volcanic eruptions can impact climate
1. SO_2 injection into the stratosphere and production of sulfate aerosols
2. some historical evidence that eruptions effect climate **Fig. 15-6**
a. these perturbations are also comparable to natural climate variability

B. climate effects associated with volcanic activity can also be only regional and not global
1. are multiple eruptions required?
2. are these events the random events that trigger stochastic resonance

C. Holocene record
1. can use the Greenland ice core records to look for periods of high and low volcanic activity **next mod. 12-12**
2. again some correlations are seen

VI. Over the past 1000 yrs solar activity, volcanic eruptions and orbital variations can "roughly" explain climate variability in an atmospheric energy balance model **Fig. 15.9**

A. model breaks down in recent past (Industrial Revolution)

B. addition of recent greenhouse gas forcing provides a better fit in recent past **Fig. 15-10**

VII. Summary

A. these results provide the basis to begin to examine any anthropogenic forcing in recent climate records

B. will be important to separate out natural vs anthropogenic climate variability