Oceans Processes

I. Oceans **ocean picture**
  A. cover over 75% of the Earth's sfc.
  B. cycling in the ocean important for several elements
    1. couples relatively "rapid" atmos. & oceanic cycles w/ long term tectonic cycles
    2. these cycles ultimately involve burial in marine sediments
  C. plays an important role in regulating atmos CO_2
  D. important in heat transport

II. can think of the ocean as 2 boxes **Fig. 8.9**
  A. thin (~50-100 m) sfc. mixed layer
    1. sunlight penetrates
    2. net primary prod./photosynthesis here drives many oceanic biogeochem. cycles
    3. OM produced here sinks into deep ocean where it is remineralized
    4. important in surface heat transport
  B. deep ocean
    1. most of the volume of the ocean (>90%)
    2. isolated from the sfc for ~500-1000 yr
      a. average mixing time of bottom waters
    3. important in terms of understanding the role of the oceans in the uptake of atmos. CO_2
  C. processes within each "box" as well as between boxes are important
  D. these ocean zones are defined by density differences **Fig. 5-6**

III. Surface currents
  A. at a first order level controlled by wind pattern **Fig. 5-1**
    1. friction between ocean and atmos.
  B. More complex real-world circulations **Fig. 5-2**
    1. several factors are important including the position of continents
  C. Ekman transport **Fig. 5-3**
    1. controlled by friction between surface ocean and atmos. and the Coriolis effect
    2. pushes water to the center of the gyre
    3. leads to regions of water convergence and divergence **Fig. 5-4**
      a. divergence leads to upwelling – more later
  D. geostrophic flow
    1. due to the interaction between the pressure gradient associated with Ekman transport/convergence and Coriolis effect
  E. leads to the broad general subtropical gyres **back to 5-2**
    1. vorticity effects also lead to further asymmetry in the current flow
    2. western boundary currents (Gulf Stream, Kuroshio current) tend to be fast-flowing and more narrow
    3. eastern boundary currents are slower and more diffuse

IV. Within the deep ocean, circulation processes are also important
  A. ocean conveyor belt **Fig. 5-12**
    1. bottom water primarily forms in N Atl and flows thru the deep ocean

2. forms by the cooling and sinking of sfc water (warm Gulf Stream)
3. releases heat in the process
   a. plays a major role in the global and local heat and water budget
   b. works in conjunction with atmos processes to moves heat globally
4. plays an important role in regulating climate
   a. important in glacial-interglacial cycles
5. moves salt and nutrients thru the deep ocean
6. flows along constant density lines **Fig. 5-10 w/radiocarbon overlay**
   a. see evidence of thermohaline circulation with radiocarbon results

V. Material transport/elemental cycling in the oceans **Fig. 8-9**
  A. primary production produces biogenic material
    1. organic matter **Redfield ratio slide**
       a. nutrients (N and P) also "fixed" into this organic matter
    2. biogenic opal (silica) and calcite
       a. hard parts of organisms
    3. processes strip nutrients out of the surface waters
       a. concs are quite low in the surface ocean **box fig. 8-1**
  B. living OM eventually dies - detritus
  C. part. material transported from sfc. to deep **back to Fig. 8-9**
    1. often referred to as the biological pump
    2. leads to transport of materials from sfc. to deep ocean
  D. dissolution/remineralization of these particles occurs in the deep oceans
    1. OM remineralization and dissolution of inorganic biogenic material
  E. particles continually sink into BW as it moves along the deep ocean **Broecker figure**
  F. bottom waters continually "pick up" the end products of these rxns **Fig. 8-11**
    1. bottom waters become a repository for the soluble remineralization end-products
    2. oxygen is also consumed
  G. bottom water nutrients concs increase in several ways **animated nitrate profile**
    1. vertical and horizontal factors
    2. vertical - concs increase with depth (esp. upper 1000 m) as a result of wc remineralization
       a. vertical mixing
    3. horizontal - nutrients accumulate along flow path of bottom waters
    4. as OM is remineralized in the water column inorganic nutrients accumulate in the bottom waters
       a. nitrate, phosphate, silicate and carbonate accumulate
       b. oxygen decreases
    5. carbonate/CO_2 accumulation occurs from both OM remineralization and calcite dissolution
       a. leads to BW that is super-sat'd wrt CO_2 **show pCO_2 depth profile**
       b. more later

VI. Upwelling
  A. returns water and dissolved materials to the sfc.
  B. completes oceanic cycles **next Fig. 8-9**

C. bring cold, nutrient-rich waters from below the thermocline back up to the surface
   1. see upwelling in maps of surface temperature and nutrients for the oceans **sfc. T map**
   2. causes enhanced productivity in the upwelling region.

D. this process is important in terms of balancing the flow of nutrients in the oceans.
   1. critical for sustaining surface ocean productivity
      a. internal cycling of nutrients more important than external sources
   2. upwelling also brings waters supersaturated with CO_2
      a. important in terms of the oceanic carbon cycle
      b. upwelling regions act as a source of CO_2 to the atm

E. upwelling is caused by both wind action and surface current flow
   1. tend to be coastal features
   2. see upwelling along both coasts but for different reason

F. surface current driven upwelling
   1. interaction of surface currents and shallow topography
   2. western boundary currents such as Gulf Stream

G. wind driven upwelling **upwelling pixs**
   1. winds blow water offshore and it is replaced by deeper water
   2. western boundaries of continents/eastern boundary currents
      a. California, Peru, Canary (off. N. Africa) and Benguela (off S. Africa) current
   3. upwelling in Arabian Sea is seasonal **Arabian Sea pixs**
      a. shift on wind direction seasonally

H. also see upwelling in the central Pacific along the equator, in the seas around the Antarctic
   1. equatorial divergence **equat. divergence cartoon**
   2. trade winds push water away from the equator
   3. divergence zone between the 2 sub-tropical gyres
   4. upwelling in the S Ocean when NADW runs into the Antarctic continent

VII. Primary production in oceans important in controlling atmos CO_2 and O_2 **Fig. 8-9**

A. > 99% of OM matter produced in sfc. oceans recycled in oceans or sfc. seds
   1. only a small amt. is permanently buried

B. important because this burial of reduced carbon leaves behind O_2 in the atmosphere

C. another way atmos CO_2 is controlled on time scales shorter than carbonate/silicate cycle
   1. more later

VIII. Significance of 2 box model in terms of elemental cycling

A. 2 box model implies that there is elemental cycling between surface and deep ocean
   1. particularly important for “limiting” nutrient elements

B. rapid recycling does not necessarily imply a short whole ocean residence
   1. lots of exchange between different reservoirs
   2. residence time in each “box is short
   3. residence time in “larger” box is much longer

C. P cycle **P cycle fig w/ residence times**
   1. small river inputs balanced by burial in sediments
   2. “rapid” cycling between sfc and deep ocean
   3. each phosphate goes thru several sfc -> deep -> sfc cycles before being eventually lost to sediments

~~IX. El Nino- oceanographic/meteorological event which causes upwelling to temporarily cease off of Peru~~

~~A. leads to low nutrients and warmer surface waters.~~

~~B. now known as ENSO - El Nino Southern Oscillation~~

~~C. recognized to be a ocean/atmos. interaction phenom.~~

~~1. related to changes in the equatorial atmos/ocean circulation in the Pacific~~

~~**a. Show Fig. 15-12 and 13**~~

~~2. E-W atmos ciculation at the equator in addtion to N-S Hadley ciculation~~

~~3. positive feedback amplifies the standard circulation – **Fig. 15-14**~~

~~D. if something breaks down this feedback then positive feedback drives it in the opposite direction – **Fig. 15-13b and Fig. 15-12 & 16**~~

~~**1.** see evidence of these changes in SOI – **show SOI figure and Fig. 15-17**~~

~~E. change in atmos circ at the equator impacts other aspects of global climate~~

~~**1. Fig. 15-18**~~

~~2. effects are often variable (both spatially and temporally)~~

~~F. will global warming affect ENSO pattern?~~

~~1. if depth of the thermocline in the equatorial ocean were to increase too much would induce prolonged ENSO conditions~~