

Present Day Global Cycles – Atmosphere

I. Intro

- A. biogeochem. cycles are the major way that elements which are important to earth processes and life are moved on the earth's sfc.
 - 1. driven by energy input from solar radiation (primary production)
- B. interaction with physical processes also important here - tectonic/rock cycle
- C. oceans and atmos are important conduits for matter and energy movement
 - 1. interplay between phys and biogeochem. processes
 - 2. cycles operate on different time scales **Fig. 5.3**
 - 3. get couplings of short term and long term cycles
- D. elements cycle between reservoirs that operate on very different time scales
 - 1. different cycles also involve positive and negative feedbacks **Fig. 4-14 GBC**
 - 2. determines how systems will respond to perturbations
- E. atmosphere **show CO₂ figure**
 - 1. exchange times between different parts of the atmosphere range from hours to decades
 - a. atmos. serves as an effective and rapid conduit for cycling between oceans and continents
- F. oceans **Fig. 4-14 GBC**
 - 1. mixing between sfc & deep waters – years
 - 2. deep ocean circulation - 100's to 1000's of years
- G. these are all significantly shorter than time scales of geologic/tectonic cycles

II. some general observations

- A. atmosphere exchanges material with biota and oceans rapidly
- B. cycles that include an atmospheric component tend to have more rapid recycling
 - 1. N and C
- C. those without an atmospheric component can be tied up in immobile forms
 - 1. slower recycling because geological processes more important
 - 2. phosphorus

III. Atmosphere

- A. major conduit for transport between oceans and land
 - 1. plays a major role in controlling climate (heat transport)
- B. atmospheric composition has evolved as a result of evolution of life
 - 1. also changing as a result of man's activity
 - 2. atmos tends to be well-mixed - first indicator of global change **show CO₂ figure**
- C. atmosphere is layered **atmos. Fig.**
 - 1. atmos held on earth's sfc by gravity
 - a. pressure decrease with altitude
 - b. lower atmos. (troposphere) contains 80% of the atmos. mass
- D. troposphere
 - 1. well-mixed lower atmosphere
 - 2. heated by long wave radiation (heat) re-radiated from Earth's surface
 - a. temp decreases with altitudes
 - 3. heating also leads to rising of this warm air
 - a. this thermal instability leads to atmospheric circulation

- E. stratosphere
 - 1. region where temp. now increases with altitude
 - 2. absorption of UV light by ozone (top of the stratosphere)
 - a. releases heat
 - 3. limited exchange between troposphere and stratosphere

IV. Atmospheric circulation

- A. driven by uneven solar heating
 - 1. atmospheric and ocean circulation move heat poleward
 - 2. air moves from high pressure to low pressure
 - 3. the poleward motion of warm air and equatorward motion of cold air

Fig. 4.1

Fig. 4-2

Fig. 13.11

- B. Heat is moved two ways
 - 1. sensible heat versus latent heat
 - 2. sensible heat is transported by a body that has a temperature higher than its surroundings
 - a. occurs via conduction, convection, or both
 - 3. latent heat
 - a. associated with the phase changes of water
 - b. evaporation takes up heat, condensation releases heat

V. on a rotating Earth atmospheric circulation is more complex

Fig. 4-3

- A. Hadley cells
 - 1. air that rises at the ITCZ sinks $\sim 30^\circ$
 - 2. Coriolis effect deflects upper flow to the right
 - 3. by 30° the flow has been deflected 90°
 - a. sub-tropical jet stream
 - b. can also think of air as “piling” up here
 - 4. air also cools by radiation to space
 - a. air sinks and then flows north and south
 - 5. again Coriolis effect deflects surface flow

Fig. 4-11

B. Polar front and polar cell

Fig. 4.7

- 1. cold air near the poles increases air density and leads movement of cold air towards the equator
- 2. cold surface flows from the poles and warm air from the Hadley cell converge near 60°

C. This basic circulation is modified by several factors

- 1. presence of land masses
 - a. land heats up and cools more rapidly
 - b. acts on local scales as well as global scale
 - c. modifies the temp. field
 - (i) isopleths in N AM dip south

Fig. 4-17

Fig. 4-18

- 2. seasonality and its effect on atmospheric circulation
 - a. shifts in the polar front and ITCZ (thermal equator)

Fig. 4-15 and 16

- 3. together all of these factors lead to global patterns of temperature and pressure
 - a. see that the cells are not continuous bands around the globe
 - (i) general pattern of H/L pressure bands – esp. in southern hemisphere
 - b. individual cells
 - c. impacted by land-sea contrasts

Fig. 4-19

VI. Atmos. circulation and precipitation patterns

A. movement of air also carries water vapor

1. because evap. and precp. are a function of temp., atmospheric circulation and global temp patterns affect rainfall distribution

B. in general, uplift of air masses induces precipitation

Fig. 4-25

1. horizontal line – cool air mass
2. also a function of increasing water vapor pressure
3. vertical lines
 - a. water moving across the ocean
4. like temp, precip patterns are also affected by distribution of land masses

C. see this in distribution of deserts

show figure

1. descending arms of Hadley cells
2. continental interiors
3. leeward (downwind) of mountains
4. along western coasts of major continents
 - a. related to the occurrence of upwelling and cool off-shore currents

VII. Major gasses in the atmos

show tables

A. N₂ - major component (79%)

1. essentially inert - long atmospheric residence time (~20 my)

B. O₂ (20%)

1. accumulation w/ time as a result of the evolution of photosynthesis
2. complex controls
3. shorter residence time - ~10,000 yrs

C. CO₂

1. trace constituent
2. affected by a variety of processes operating on different time scales
 - a. geologic time scales carbonate-silicate cycle
 - b. dissolution in the oceans (decadal)
 - c. annual cycles of photosynthesis and respiration
3. rel short residence time in atmos. - ~3 yrs
 - a. largely determined by exchange w/oceans
4. also show long term variations
 - a. ice core data - significant changes on glacial-interglacial cycles
5. presence of CO₂ and other greenhouse gasses important
 - a. without them earth's sfc. would be frozen
 - b. if concs. were too high -> runaway greenhouse like Venus
 - c. delicate balance required to maintain life

Fig. 5-3

Fig. 1-9

D. minor gasses in the atmosphere

back to tables

1. a wide range of reduced gasses found in atmosphere at trace levels
 - a. H₂S, H₂, CH₄, N₂O, (CH₃)S
2. Hadean sources of many may have been excess volatiles and abiotic rxns.
 - a. basalt-seawater reactions
3. most now seem to be produced by microbes
 - a. well out of chemical equilibrium
4. conc maintained by a balance between prdn and oxidation or removal in rain

5. concs. of many are also increasing in recent time
 - a. related somehow to man's activities
 - b. not always clear how this works
 6. these N and S gasses plays a major role in global N and S cycling
 - a. oxidation of these gasses mediated by ozone
- E. ozone (O_3)
1. in the stratosphere (upper atmos) it is produced and consumed by the rxn. of UV sunlight with O_2
 - a. important in shielding us from short wave, high energy UV radiation
 - b. destroyed by CFC's
 2. can also be produced in the troposphere (lower atmos)
 - a. photochemical rxns. involving nitrogen oxides and hydrocarbons
 - b. the latter produced by fossil fuel burning
 - (i) photochemical smog
 - c. here it can act as a greenhouse gas
 - d. also a very potent oxidant affects plants and animals
- F. water vapor
1. varies tremendously in the atmosphere
 2. evaporation/ppt. and atmos. circulation
 - a. latent heat of evaporation acts as an important heat transporting mechanism
 3. water vapor is also a very important greenhouse gas
 4. water vapor also acts as a positive feedback on warming