Lecture(s) 9
Slides from atmosphere-ocean lectures
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ATMOSPHERE AND OCEAN

– finely layered, like a parfait, by fluid density, the
atmosphere's temperature decreases upward
at about 7ºC per km....80% of the mass of the atmosphere
is in the *troposphere*, the lowest 8 to 10 km. and the temperature
decreases 50 to 70ºC from sea level to that altitude
The *stratosphere* above this level is more stratified, more stably layered.
At the ground the pressure is about 10^5 Newton.m^2 or Pascals. This simply
reflects the weight of the air overhead.

In the deep sea the pressure, also the weight per square meter of the water overhead, rises to typically 400 times the atmospheric pressure at sea level
(water is 800 times denser than air at sea level. The upper 2.5m layer of ocean has the same heat capacity as the entire atmosphere above. The average ocean depth is 3800m yet the water in the atmosphere above if condensed would make a layer only 3 cm. deep!)

– solar radiation incoming (minus the simple reflection due to the whiteness..albedo..of clouds, snow and deserts) balances infrared radiation outgoing radiation. Without the atmosphere this balance gives a too-cold Earth (by about 35ºC). With a one-pane-of-glass atmosphere model we have a too-warm Earth since convection in the air also cools the Earth. A distributed greenhouse effect gives a total downward radiation about 3 times the incoming solar radiation.

– But the radiation comes in more strongly in the tropics and exits more strongly near the poles. Heat- and water-flow carries the required energy poleward. the atmosphere is a heat engine, with Hadley convection cells driven by the difference between tropical and polar solar radiation, together with albedo differences and contrasts in evaporation of ocean water between tropics and polar regions.

– Clouds are the miniature heat engines the make the great general circulation go: the sun heats the ocean, the ocean warms the air and also evaporates moisture: both the 'sensible' and 'latent' heat fuels the vigorous overturning of the cloud visible as 'cauliflower' headed cumulus clouds. Where they bump up against the stratosphere they from 'anvil clouds with flat tops.

- the ocean is also a heat engine, augmented by density differences due to the contrasts in salinity produced by evaporation and precipitation. But in addition the atmosphere blows winds on the sea, driving ocean currents through mechanical energy exchange…sort of two gear wheels, the atmosphere and ocean, meshed together and yet also forced by buoyant density differences. Ice and snow..the *cryosphere* are crucial components of the fresh-water cycling of the Earth…and they are disappearing…they affect albedo and ice can insulate the ocean from the atmosphere above. When the ocean surface freezes it rejects cold salty water (brine) which is very dense, while retaining nearly fresh water. Then when it melts in summer this ice makes a layer of quite fresh water at the surface.

- beside the density layering, the dominant feature that shapes the circulation of the atmosphere is the Earth's rotation (through the *Coriolis force*). This force turns the north-south motions into east-west winds, which are the most visible part of the atmospheric circulation. Both the great overturning circulations and the east-west winds are cooperatively ventilating the tropics, warming the polar regions, and controlling rainfall, temperature and winds throughout the world.

- Ocean and atmosphere have many similar circulation features, jet streams (*Science,26 Jan 07)*, cyclones and anticyclones, global overturning circulations. Yet the size of these is 10 times smaller in the ocean, making ocean 'weather' more complex than atmospheric weather.
  - The Earth's spin is a vector sticking out of the North Pole. The strong rotation represents and angular momentum that is 'inherited' by the fluid oceans and atmosphere. A gyroscope illustrates the great strength of this spin: moving the spin axis requires great torque…after all, it involves changing the direction of the velocity, which requires a force.
  - To gauge the strength of the Earth's rotation, consider the 'figure-skater effect' which explains the westerly and easterly winds (the latter are the 'trade winds' in the tropics), weather systems, hurricanes and tornadoes. If air moves a distance L horizontally, it will gain a velocity roughly 10^{-4}L: that is 100 m/sec for L = 1000 km. The air pressure provides a dominant force that balances this Coriolis force.