Lecture 18: Earth’s Atmosphere and Deserts

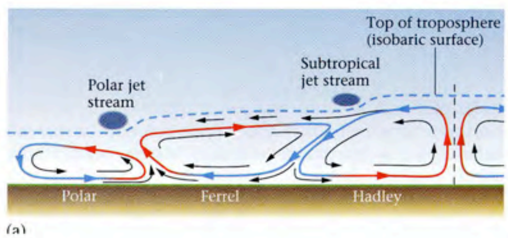
Earth 50; November 3, 2006

Atmospheric Composition:
Three important “Greenhouse Gases” are: Carbon dioxide (CO_2); Methane (CH_4) H_2O (water vapor)

Structure of the Atmosphere: troposphere (surface to ~19 km): Stratosphere (~19 km to 50 km): Mesosphere (50-90 km): Thermosphere (90-120 km)

Atmospheric Circulation
Coriolis Force = the force that causes fluids to be deflected to the right (in the N. hemisphere) and the left in the S. Hemisphere as a result of the Earth’s spin.

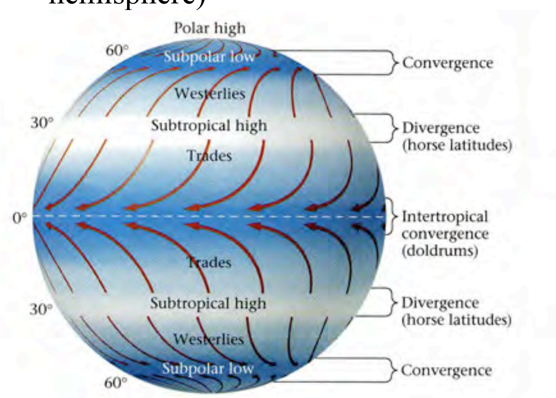
Circulation systems: The Hadley Cell



a. Tradewinds—blow from NE to SW in Northern hemisphere (“easterlies”)

Polar Cell and Ferrel Cell—

b. ‘westerlies” blowing from the southwest to the northeast (in the Northern hemisphere)



Distribution of clouds and rainfall
Distribution of Surface Pressure (Highs and Lows)

Deserts

Processes include: deflation, abrasion, saltation of grains,.
Dune types—a function of wind direction and sand supply

Importance of wind-borne dust

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Atmosphere Composition:
The atmosphere is composed of nitrogen (78%), Oxygen (21%) and Argon (0.9%) as well as trace amounts of other gases and compounds.

Three important trace compounds are:

1. Carbon dioxide (CO_2) currently at 353 ppm (up from about 270 ppm a century ago)
2. Methane (CH_4) at 2 ppm
3. H_2O (water vapor) variable abundance

These trace compounds are important because they are heat trapping gases that absorb solar radiation and add to the heat of the planet; these are therefore some of the most important **"Greenhouse gases"**

Without them, the earth would be about 30°C cooler than it is at present and would be quite frozen over

As it happens both O_2 and Methane are primarily produced by living organisms; hence life has substantially remade (polluted) Earth's atmosphere

The presence of free O_2 also means that there is oxygen around to produce O_3 (ozone) that reflects ultraviolet radiation and make the Earth's surface habitable. Without it, we would all sunburn in a few minutes and surface life would be impossible.

Structure of the Atmosphere
Divided into layers depending upon temperature and structure

1. troposphere (surface to ~19 km):
    a. highest pressure (1 bar at surface) with about 80% of the atmosphere's mass;
    b. temperature falls off quickly to ~-90°C;
    c. temperature falls according to the "lapse rate" of ~6.5°C/km.
    d. most clouds form here; clouds usually form above rising heated air; also rise when water condenses and releases heat (as in thinderheads); descending air, in contrast warms up and clouds disappear. get stratification where air is moving at different speeds or densities
2. Stratosphere (~19 km to 50 km):
    a. temperature warms with increased altitude: from -90°C to -10°C; this heating mostly due to absorption of UV light by ozone;
    b. because stratosphere warms with increased elevation it also becomes less dense and therefore does not mix much with the troposphere;
    c. suspended particulates that enter the stratosphere stay there a long time.
3. Mesosphere (50-90 km): temperature falls with increased altitude from ~-10°C to -90°C

4. Thermosphere (90-120 km) temperature warms to near surface temperatures due to more UV heating

Albedo
~30% of solar radiation received by Earth is reflected back into space; the rest is absorbed to warm the planet.

Most of this reflected light is from "bright areas" like snow fields, grass lands and salt pans; forest and oceans much less reflective and absorb heat. Creates a feedback in which as reflective areas (say snow cover) grows, the landscape cools promoting more snowfall….

Also a latitude effect; because the Earth's surface is curved, the high latitudes receive less solar radiation than low latitudes per km2

Seasons
Earth's spin axis is tilted (currently ~23.5° to the orbital plane) so polar areas receive more sun in summer than in winter.; also accounts for the change in day length between the seasons; more summer sun = longer days.

Atmospheric Circulation
If the Earth was not spinning, heating at the equator would cause hat air to rise, cool in the upper Troposphere, and sink back to the polar surface. However, the Earth does spin, and this spinning motion causes

1. the atmospheric circulation to break up into three belts, and
2. the air to circulate at about 45° to the direction of Earth's rotation (reflecting the combination of motion toward or way form the poles and the rotation due to the rotation of the planet. The Coriolis Force is the force that causes fluids to be deflected to the right (in the N. hemisphere) and the left in the S. Hemisphere as a result of the Earth's spin.

Get three major atmospheric circulation cells:

2. The Hadley Cell—heating at the equator causes air to rise and flow toward the poles in the upper troposphere; As the air cools it sinks and flows back toward the equator it drifts to the west as the Tradewinds (analogy with throwing a ball toward the equator on an east-bound train)
3. Polar cell—differential heating between the equator end of the circulation cell and the pole sets up convection similar to the Hadley cell—winds blow westward at the surface and rise at the equatorward end of the circulation sell
4. Ferrel Cell—formed between the Hadley and Polar cells by drag between them. Rising air at ~60° latitude cools and sinks at 30° latitude,
    a. in this case circulation at the surface is approaching the poles and conservation of momentum forces the winds to speed up and blow towards the east setting up 'westerlies" blowing from the southwest to the northeast (in the Northern hemisphere)

   b. In the southern hemisphere the wsterlies can be very strong between 40-50°S lattude because there are few continents or mountains to get in the way—called the "Roaring Forties"

Distribution of clouds and rainfall

1. Where we have rising air masses (as at the equator between the Hadley cells) warm moist air is cooled as it rises and forms clouds and strong rain [Called the ITCZ or Intertropical Convergence Zone (because the tradewinds come together here)]
2. Where the Hadley cell descends (and the Ferrel Cell too) the air is cool and has already lost most of its moisture—get deserts here
3. Where the Ferrel Cell Rises and the polar cell rises could get storms as well, but the relatively cool air holds less moisture than at the equator so rain is less intense.
4. Jet stream forms at the junction of the Ferrel and Hadley cells and is set up by the temperature contrast between warm are in the Hadley cell and cool air in he Ferrel Cell

Distribution of Surface Pressure (Highs and Lows)

1. get high pressure at the surface where there is descending air masses (as at the junction of the Hadley and Ferrel cells)
2. Get low pressure at the surface where there is rising air (as at the equator and at the junction of the Ferrel Cell and Polar Cell).
3. Distribution of highs and lows reflects distribution of evaporation ((at ~30° latitude in both hemispheres) and maximum precipitation (where there are rising air masses at the equator and ~50-60° latitude.

Deserts

Formed under

1. descending cells (Hadley/Ferrel contact) where cold air masses have lost most of their moisture
2. rain shadows, where moisture has been lost when air is forced to rise and cool over mountains
3. polar environments where there is little moisture because (a) the air is too cold to hold water, and (b) the air is far from the sites of net evaporation at ~30° of latitude.

Processes include:

1. deflation—wind picks up fines and leaves coarse "desert pavement"
2. abrasion—caused by sand blasting, driving sand hard into rocks or outcrops on the surface. Forms ventifacts
3. saltation of grains—bouncing action of grains that are too heavy to be fully suspended in the air.
4. Rounding and frosting of grains—caused by repeated high-energy impacts (since water is not a dense as water get higher energy impacts for small grains that would be the case in water.

Dune types—a function of wind direction and sand supply

1. when sand is limited and wind is constant get Barchan dunes
2. when sand is abundant and wind is consistent, get transverse dunes
3. when sand is abundant but winds are variable—get star dunes (like we saw on the field trip at Algadones Dunes

Importance of wind-borne dust

1. creates rich soils—loess
2. creates much of the "red clay" in the deep sea—remobilized dust from China and the Sahara.