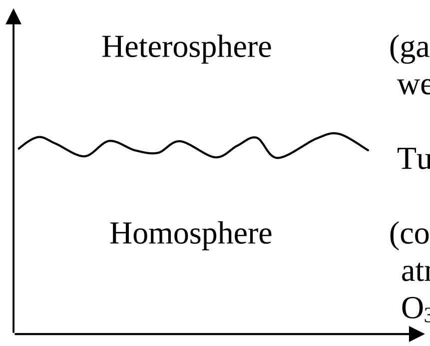
Composition and structure

Composition of the atmospheric:

The mixture of gasses composing the earth's atmosphere. The composition of the atmosphere (with the exceptions of water vapor, ozone, and other minor variable components) remains essentially unchanged up to a height of about 80 km. This region is called the homosphere. Above 80 km, the atmospheric gasses tend to separate according to molecular weight (the heterosphere)



- Show composition of the atmosphere near the earth's surface. (Tab. 1) (Table 1.1, Ahrens)
- Show the variation of CO_2 concentration with time. (Fig. 3) (Fig. 1.4 Ahrens)

Note that carbon dioxide exhibits both a long-term trend and a small seasonal variation.

The trend of about 1.5 ppm increase per year is primarily due to the burning of fossil fuels, roughly 50% of the CO_2 put into the atmosphere remaining there. The rest is absorbed by the oceans and to some extent incorporated into increased biomass, both terrestrial and oceanic. The seasonal variation is due to the cycle of CO_2 uptake by photosynthesis of green plants during the growing season, and the net release of CO_2 by respiration during the subsequent process of decay. The seasonal cycle is larger in the N-hemisphere than in the S-hemisphere.

"Variable" constituents of the atmosphere

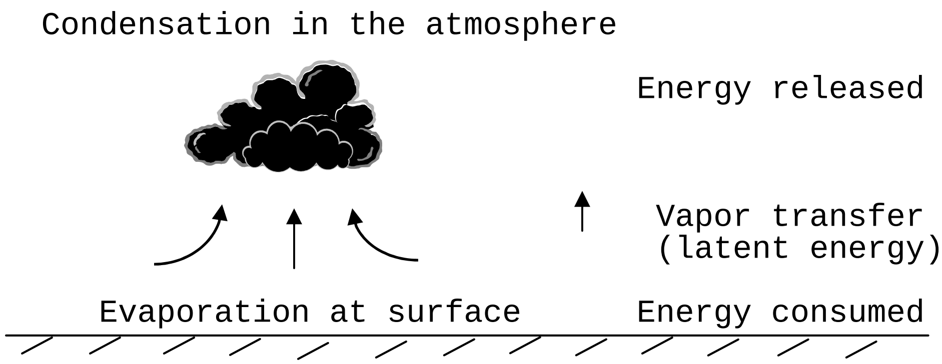
There are numerous trace gasses in the atmosphere that fluctuate in concentration, some of which are considered to be pollutants. The important variable constituents are water vapor, ozone, sulfur dioxide, ammonia, carbon monoxide, with the first two being by far the most important meteorologically.

Water vapor

Constitutes from practically zero to as much as 4% of the atmosphere near the surface in humid tropical regions. It is highly variable in both time and space. The amount of water vapor present in the atmosphere is strongly dependent upon temperature and proximity to a source of evaporation. Hence, water vapor content changes with latitude, season, height above the surface, surface type (vegetation, bare soil, water) and with surface moisture content. There is very little water vapor above altitudes of about 10 km.

Water vapor assures great importance in the atmosphere because:

1) Water vapor condenses in the atmosphere to form clouds and rain or other forms of precipitation (part of the hydrologic cycle).
2) Water vapor is a strong absorber of long wave (terrestrial or infrared) radiation, and is thus a component of the "greenhouse effect".
3) The processes of evaporation (at the surface) and condensation (cloud formation) consume and release (respectively) large amounts of thermal energy and thus play an important role in the energy balance of the earth-atmosphere system. This can result in the effective transfer of energy 100's to 1000's of km from an evaporating area, from where water vapor is added to the atmosphere (consuming energy locally)to where the condensation of this moisture takes place, adding energy to the atmosphere.



Vertical structure of the atmosphere:

There is a natural division of the atmosphere into four height intervals according to the way in which temperature changes with height.

- Show layers of the atmosphere. (Fig. 4)(Fig. 1.9 Ahrens)

Ionosphere: The peak electron density is at about 300 km.

Meteorologically, the most important region of the atmosphere is the troposphere (the lowest 12 km or so) because this layer contains nearly all of the water vapor available for condensation and because this layer is not restricted by strong thermal stratification, as is the stratosphere. The tropopause is the upper boundary of the troposphere.

In the stratosphere, warm air overlies cold, dense air and the layer is very stable, stratified and resists mixing. Vertical motions are strongly inhibited and there is little in the way of weather phenomena.

Temperatures are relatively high in the upper stratosphere and lower mesosphere because of strong absorption of ultraviolet radiation from the sun by O_2 and O_3, ozone being formed by the photodissociation of molecular oxygen followed by recombination in the form of molecular ozone (more later in our discussion of solar radiation).

In the thermosphere, temperatures increase again with distance from the surface up to about 400 km.

US standard atmosphere:

is a hypothetical vertical distribution of atmosphere temperature, pressure and density corresponding to the average state of the real atmosphere. Such an “atmosphere” is adopted as the basis for the calibration of altimeters, the evaluation of aircraft performance etc.

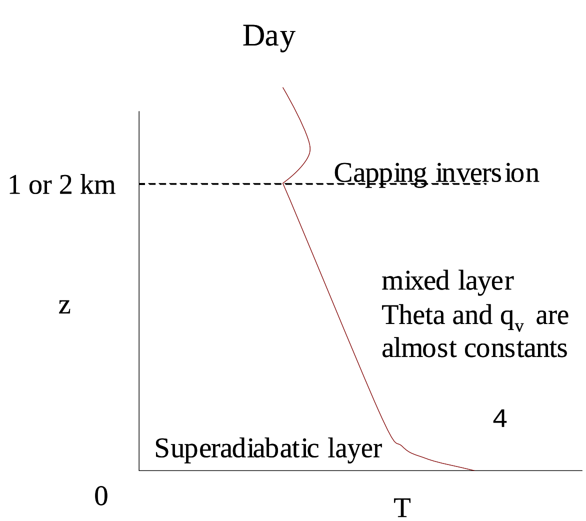
Lapse rate:

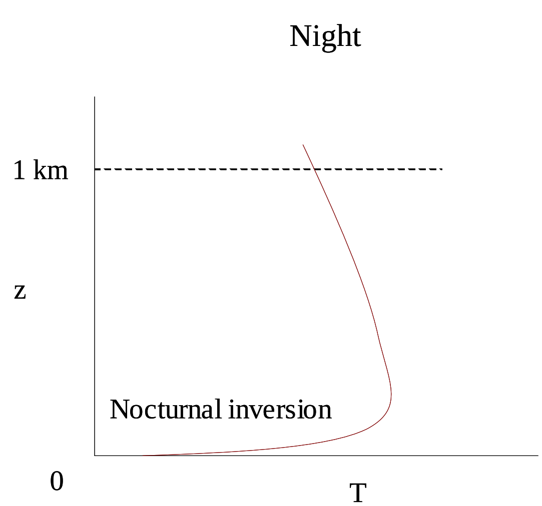
Thermal stratification is very important because of its influence in enhancing or suppressing vertical mixing in the atmosphere in “unstable” and “stable” layers, respectively. We use the term “lapse rate” to describe the rate at which temperature decreases with height. Thus

$$\gamma = -\frac{dT}{dz} \qquad {}^{o}C/km$$

In the case of an inversion (temperature increasing with height dT/dz > 0) the atmosphere is stable and resists mixing, air pollution episodes are possible. As we will see later, however, the degree of instability in a layer in which dT/dz < 0 is very dependent on whether or not the atmospheric layer is at the saturation point and clouds are forming. A cloudy atmosphere is more likely to be unstable.

The stability of the lowest layers of the atmosphere is very dependent on diurnal heating and cooling. Typically, in the daytime with solar heating, a convective “boundary layer” is formed 1 or 2 km thick in which pollutants and other constituents are well mixed, while, at night, cooling of the ground cause a nocturnal inversion which makes the lower atmosphere calm. Temperature profiles are expected of the following forms:





Radiation processes in the atmosphere (Intro)

The atmosphere is a large heat engine which is driven by the imbalance between the absorption of solar radiation and earth's emission of longwave radiation at different latitudes. This is shown in the figure (Fig.5) of the variation with latitude of average incoming and outgoing radiation (annual average).

- Show radiation energy flux vs. latitude. (Fig.5)

The differential heating, net warming by excess solar radiation absorbed at low latitudes and net cooling because of the larger longwave radiation loss to space at high latitudes, is the driving force for atmospheric motions. Atmospheric circulations (and to a lesser extent oceanic currents) redistribute heat about the globe and result in a net transfer of thermal energy poleward, such that a thermal balance is achieved at each latitude (the tropics do not continually heat up, nor the pole regions continually cool down).

Longwave radiation is also called "terrestrial" radiation, and solar radiation is also referred to as "shortwave". The difference between the two radiative streams is large in terms of spectral quality (wavelength), and their spectra, effectively, do not overlap, as we will see shortly.