CHAPTER 1

The Atmosphere

The envelope of air surrounding the earth to great heights is called atmosphere. The atmospheric air is a mixture of gases and contains the particles of liquid, solid (which are suspended in air). These are bound to the earth by the gravitational attraction of the earth. Atmospheric gases obey the ideal gas laws and for practical purposes treated as fluid.

1.1 COMPOSITION OF THE ATMOSPHERE

The composition of the dry atmosphere has:

Constituent	**by volume**	**by wt.**	**Total weight × 10^{17} kg**
Nitrogen (N_2)	78%	75.5%	38.65
Oxygen (O_2)	21%	23.1%	11.84
Argon (A_r)	0.93%	1.29%	0.66

The other minor gases include Neon, Helium, Methane, Krepton, Hydrogen, Xenon, Carbondioxide, Ozone and water vapour. The last three gases are variable both in time and space. This composition of atmospheric gases are practically in the same proportion up to an altitude of about 80-90 km. The non-gaseous constituents are dust, smoke, salt particles from sea spry and water particles, which are all variable.

More than 50% of the mass of atmosphere lies below an altitude of 5.5 km and 98% of mass below 30 km altitude. The lowest one kilometer of atmosphere contains about 10% of the mass of atmosphere. All biological and human activities except aircraft flights are confined to this lowest one kilometer, which is called Planetary Boundary Layer (PBL).

The mass of the atmosphere is about 5.6×10^{18} kg. The mass of the oceans water is about 1.4×10^{21} kg. The density of dry air at surface (msl) is 1.225 kg/m^3 which reduces to 50% (0.6125 kg/m^3) at 6 km altitude, 25% (0.30625 kg/m^3) at 12 km, at 18 km altitude to 10% (0.1225 kg/m^3) and at 30 km altitude to about 0.013 kg/m^3 (about 1%).

On an average at msl nitrogen exerts a pressure of about 760 hPa, oxygen 240 hPa and water vapour about 10 hPa.

Atmospheric mass (gases, liquid and solid particles together) is treated as fluid and it obeys gas laws. The main properties of atmospheric mass are:

(i) Molecular mobility; (ii) capacity for expansion and compression with adiabatic heating or cooling

1.2 ATMOSPHERIC HEAT PROCESS

Heat is a form of energy, which produces sensation of warmth in us.

The degree of hotness of a body is called temperature. Heat flows from one body (at higher temperature) to another body (at lower temperature) till they are at equal temperature. The measurement of temperature is made by thermometers. Heat is transferred in the atmosphere in five ways: (i) conduction, (ii) convection, (iii) radiation (iv) advection and (v) condensation.

Conduction: The transfer of heat energy from hot surface to the adjacent cooler surface without the movement of molecules is called conduction. This process is important in transfer of heat very close the ground surface.

Note: air is a poor constructor of heat.

Convection: The transfer of heat energy with the movement of molecules and applies to fluids (liquids and gases). This process is important in atmosphere.

Radiation: The transfer of energy in the form of electromagnetic waves is called radiation. In this case no medium is required. All objects in the universe radiate as long as its temperature is more than 0 ^{o}K.

Advection: The transfer of heat energy from one area to another, through horizontal wind motion is called advection (i.e., by the movement of air masses).

Condensation: In atmosphere precipitation in the form of rain or snow releases latent heat, which warms the atmosphere.

The important methods of heat transfer from the earth to the\ atmosphere are: (i) convection (ii) Advection, (iii) latent heat of condensation of water vapour (which was transported upwards). Sun is the main source of heat energy for the earth and atmosphere, which is received in the form of radiation (insolation). The sun's rays do not heat the air in the atmosphere but heat the solid and liquid particles suspended in it. Because of this about 85% of the insolation hits the earth's surface, while only about 15% heats the atmospheric (aerosols) particles. The surfaces of the earth, which are heated by the suns' rays, pass heat energy to the air film in contact with the surface by way of conduction. By convection warm air moves up and it is replaced by cooler air. The transfer of heat from the surface of the earth to the atmospheric air takes place by conduction and convection, **but** it is called re-radiation or back radiation. Thus earth acts as the secondary source of heat for the lower atmosphere. In meteorology the incoming solar radiation is called insolation (also shortwave radiation) and the back radiation from the earth to space is called Terrestrial radiation (or long wave radiation or **IR** radiation). The absorption of solar energy at the surface of the earth depends on the angle of incidence of the sun's rays or inclination of the sun and the materials of the earth on which it falls. Different types of surfaces absorb differently on earth and create uneven heating (such as sea water, black soil, sandy soil, green trees etc.) which in turn results in horizontal motion of air. The unequal heating of the surface of the earth is the cause for Cell pattern (Hadley Cell, Ferrel Cell) of atmospheric circulation.

1.3 THE VERTICAL STRUCTURE OF THE ATMOSPHERE BASED ON TEMPERATURE

In 1962, world meteorological organization (WMO) decided to divide the atmosphere into four regions (strata) based on temperature change with altitude. They are:

(i) Troposphere, (ii) Stratosphere, (iii) Mesosphere, (iv) Thermosphere. The salient features of these layers are given below.

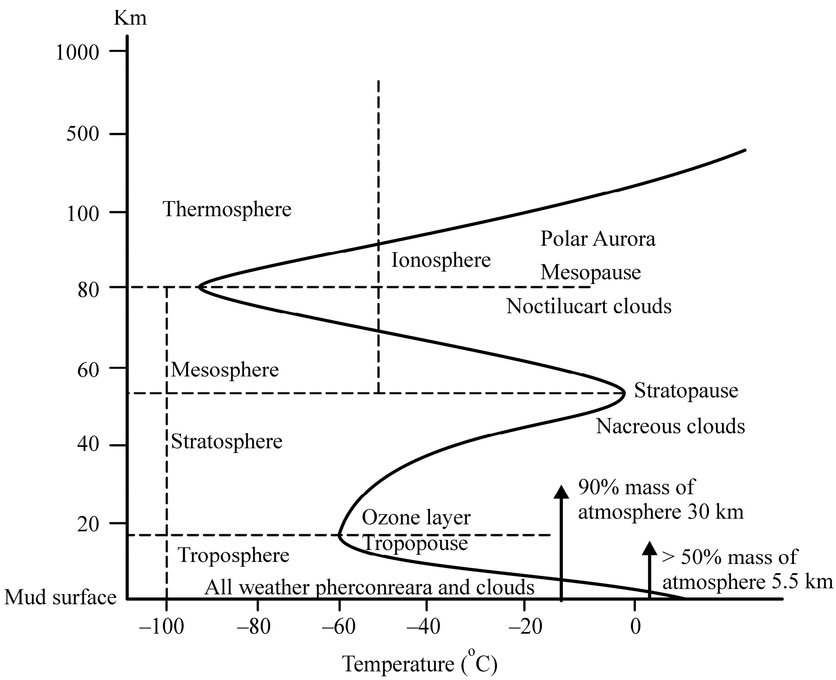

Fig. 1.1 Structure of the atmosphere.

Troposphere: The lowest layer of the atmosphere adjacent to the earth's surface is called troposphere. The altitude of this layer is about 16-18 Km in the equatorial regions (temperature at the top – 75 °C), about 11 Km in middle latitude (lat 30^o), (temperature at the top –60 ^{o}C) and about 8 km at the poles (with temperature at top – 50 ^{o}C).

All weather systems, clouds practically confined to this layer. In this layer (mostly) temperature decreases with increasing height. The troposphere contains about 75% of the mass of the atmosphere and virtually all water vapour of the atmosphere. The average lapse rate (rate of change of temperature with height) is about 6.5 ^{o}C/km. The upper boundary of the troposphere is called tropopause, pause means break.

Tropopause

Definition: The tropopause is the lowest level at which the lapse rate (of temperature) decreases to less than or equal to 2 ^{o}C/km at least for a layer of 2 km and above does not exceed this.

Tropopause is not a continuous surface. In middle latitudes two tropopauses are found. Lower one with tropical characteristics and the other with extra tropical characteristics. In between these two tropopauses lies the subtropical jet stream (around lat 30^o). There is a sharp rise in temperature above tropical tropopause but in subtropical tropopause there is slight fall.

Troposphere is warmed up by the underlying earth surface and hence instability exists.

Stratosphere

The layer above tropopause is called stratosphere, which extends up to an altitude of 50 km, where its temperature is above 0 ^{o}C. There is an isothermal layer (lapse rate zero) above tropopause up to 20 km altitude and thereafter temperature rises (inversion) generally up to about 32 km altitude and thence rises rapidly and equals to the earth's surface temperature (positive) at its top.

This layer has large concentration of ozone between altitudes 18-35 km (60000-115000 ft) with a maximum density at about 25 km (80000 ft). The increase of temperature in stratosphere is attributed to the presence of ozone, which is a green house gas. Ozone absorbs harmful solar UV-radiation (ultra-violet radiation) in the wavelengths 220 nm to 290 nm (1 nm = 10^{-9} m). UV-radiation induces skin cancer, damages eye and suppresses immune system in human beings. It effects the productivity of aquatic and terrestrial ecosystem. 1% decline in ozone concentration in stratosphere may result in 3% increase in the incidence of skin cancer among humans. Ozone layer absorbs about 2% of insolation (incoming solar radiation).

Stratosphere is stable, because it has cold temperature at its base and warm temperature at the top.

In equatorial region of stratosphere biennial wind oscillations are observed.

The boundary surface which separates stratosphere from Mesosphere is called stratopause (where temperature is about 0^{o} C).

Mesosphere

The layer above stratopause is called Mesosphere, which extends up to 80 km altitude. In this layer temperature falls above stratopause and attains the lowest temperature about – 95 ^{o}C at 80 km altitude. Noctilucent clouds belong to Mesosphere, which are observed in higher latitudes during summer. The top of Mesosphere layer is called Mesopause.

Troposphere, Stratosphere and Mesosphere together is called **Homosphere** because the ratio of the constituents of the air in this layer (region) is practically constant (except ozone, carbon-dioxide, and water vapour which are variable).

Thermosphere

The region above Mesopause is called thermosphere which extends to great height (700-1000 km altitude). Thermosphere is also called hetrosphere because the composition of the ratio of constituent gases is heterogeneous. The main gases stratify according to their molecular weights. The temperature rises above Mesopause to about 1000 to 1200 ^{o}C at about 400 km altitude and the density of air falls to 3×10^{-12} kg/m^3 (very thin density) and pressure 10^{-8} mm of mercury.

The lowest layer contains oxygen and Nitrogen molecules (up to 500 km) and thereafter hydrogen (up to 1000 km). There is no boundary to the thermosphere. The upper part of the thermosphere merges with the interplanetary gas with temperature about 2000 ^{o}K which is called Exosphere. The thermospheric gases are found to be mostly in atomic state due to photo-dissociation by the insolation.

Ionosphere

The lower thermosphere and upper Mesosphere contains gases mostly in ionized state and hence it is called Ionosphere. The characteristic property of these ionized gases is that it reflects radio waves, which helps in long wave radio communication. Ionosphere is divided into D-region (50-90 km altitude), E-region (also called Kenelly Heaviside layer) 90-140 km altitude and F-region 140-500 km attitude. F-region is further divided into F_1 region 140-250 km altitude (also called Appleton layer) and F_2 region 250-500 km altitude.

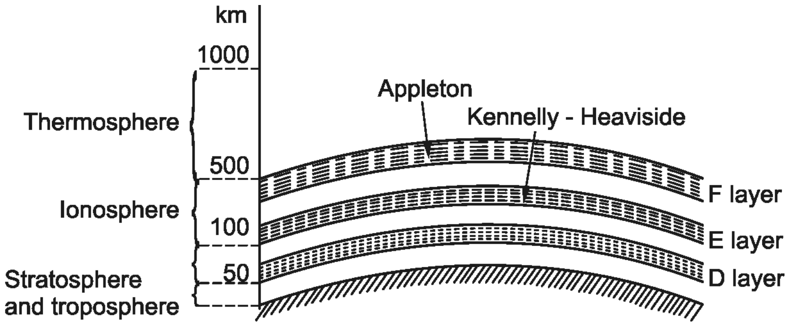

Fig. 1.2 Ionosphere layers.

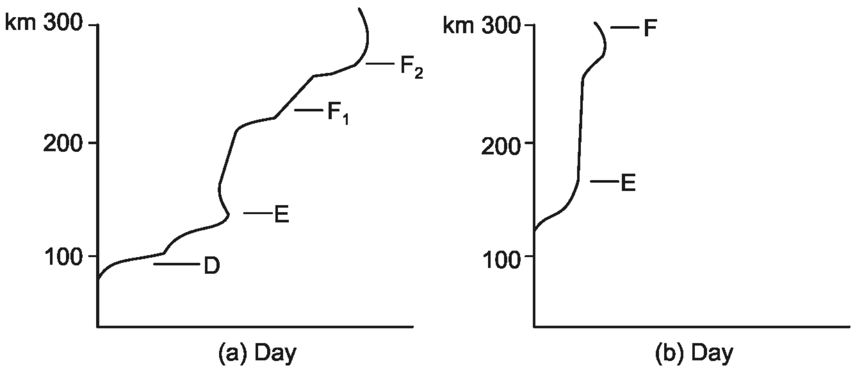

Fig. 1.3 Ionosphere diurnal effects.

D-region (50-90 km altitude) reflects low frequency radio waves but absorbs medium and high frequency radio waves. This region disappears during nights (in the absence of solar radiation). In this region air density is more than electron density.

E-region (90-140 km altitude) strongly reflects medium and high frequency radio waves. This region weakens during might, but does not disappear. However during polar nights, E-region disappears. In this region electron density is ($10^5/cm^3$) and air density is less.

F_1-region (140-250 km altitude) is important for the fact that it propagates medium and high frequency radio waves.

F_2-region (250-500 km altitude) is important for long distance radio communication. When the sun is low and during night, F_1-region merges with F_2-region.

In F-region electron density is high ($10^6/cm^3$) and air density is low.

SHORT TYPE QUESTIONS

1. Write the compositions of the atmosphere.
2. Write briefly the various heat processes of atmosphere.
3. Write briefly about lowest layer of atmosphere
4. Write about stratosphere

ESSAY TYPE QUESTIONS

1. Write briefly about the four vertical strata of atmosphere as per WMO.