

Chapter 2

Earth's atmosphere (Lectures 4 and 5)

Keywords: Earth's atmosphere; International standard atmosphere; geopotential altitude; stability of atmosphere.

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2.1 Introduction

Airplanes fly in the earth's atmosphere and therefore, it is necessary to know the properties of this atmosphere.

This chapter, deals with the average characteristics of the earth's atmosphere in various regions and the International Standard Atmosphere (ISA) which is used for calculation of airplane performance.

2.2 Earth's atmosphere

The earth's atmosphere is a gaseous blanket around the earth which is divided into the five regions based on certain intrinsic features (see Fig.2.1). These five regions are: (i) Troposphere, (ii) Stratosphere, (iii) Mesosphere, (iv) Ionosphere or Thermosphere and (v) Exosphere. There is no sharp distinction between these regions and each region gradually merges with the neighbouring regions.

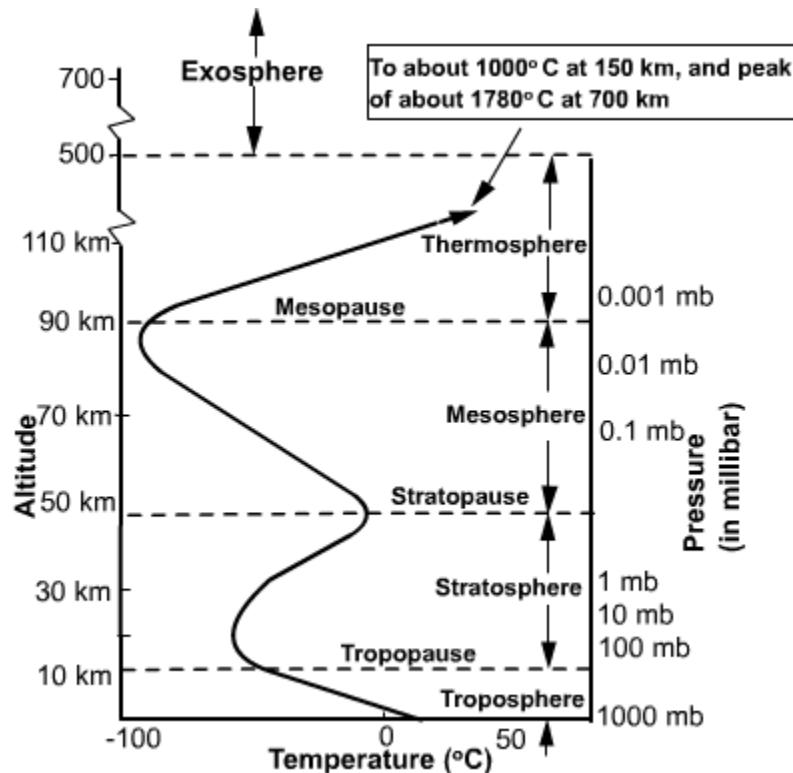


Fig.2.1 Typical variations of temperature and pressure in the earth's atmosphere

2.2.1 The troposphere

This is the region closest to the earth's surface. It is characterized by turbulent conditions of air. The temperature decreases linearly at an approximate rate of 6.5 K / km. The highest point of the troposphere is called tropopause. The height of the tropopause varies from about 9 km at the poles to about 16 km at the equator.

2.2.2 The stratosphere

This extends from the tropopause to about 50 km. High velocity winds may be encountered in this region, but they are not gusty. Temperature remains constant up to about 25 km and then increases. The highest point of the stratosphere is called the stratopause.

2.2.3 The mesosphere

The mesosphere extends from the stratopause to about 80 km. The temperature decreases to about -90°C in this region. In the mesosphere, the

pressure and density of air are very low, but the air still retains its composition as at sea level. The highest point of the mesosphere is called the mesopause.

2.2.4 The ionosphere or thermosphere

This region extends from the mesopause to about 1000 km. It is characterized by the presence of ions and free electrons. The temperature increases to about 0°C at 110 km, to about 1000°C at 150 km and peak of about 1780°C at 700 km (Ref.2.1). Some electrical phenomena like the aurora borealis occur in this region.

2.2.5 The exosphere

This is the outer fringe of the earth's atmosphere. Very few molecules are found in this region. The region gradually merges into the interplanetary space.

2.3 International Standard Atmosphere (ISA)

2.3.1 Need for ISA and agency prescribing it

The properties of earth's atmosphere like pressure, temperature and density vary not only with height above the earth's surface but also with the location on earth, from day to day and even during the day. As mentioned in section 1.9, the performance of an airplane is dependent on the physical properties of the earth's atmosphere. Hence, for the purpose of comparing

(a) the performance of different airplanes and (b) the performance of the same airplane measured in flight tests on different days, a set of values for atmospheric properties have been agreed upon, which represent average conditions prevailing for most of the year, in Europe and North America. Though the agreed values do not represent the actual conditions anywhere at any given time, they are useful as a reference. This set of values called the International Standard Atmosphere (ISA) is prescribed by ICAO (International Civil Aviation Organization). It is defined by the pressure and temperature at mean sea level, and the variation of temperature with altitude up to 32 km (Ref.1.11, chapter 2). With these values being prescribed, it is possible to find the required physical characteristics (pressure, temperature, density etc) at any chosen altitude.

Remark:

The actual performance of an airplane is measured in flight tests under prevailing conditions of temperature, pressure and density. Methods are available to deduce, from the flight test data, the performance of the airplane under ISA conditions. When this procedure is applied to various airplanes and performance presented under ISA conditions, then comparison among different airplanes is possible.

2.3.2 Features of ISA

The main features of the ISA are the standard sea level values and the variation of temperature with altitude. The air is assumed as dry perfect gas.

The standard sea level conditions are as follows:

$$\text{Temperature } (T_0) = 288.15 \text{ K} = 15^\circ\text{C}$$

$$\text{Pressure } (p_0) = 101325 \text{ N/m}^2 = 760 \text{ mm of Hg}$$

Rate of change of temperature:

$$= -6.5 \text{ K/km upto 11 km}$$

$$= 0 \text{ K/km from 11 to 20 km}$$

$$= 1 \text{ K/km from 20 to 32 km}$$

The region of ISA from 0 to 11 km is referred to as troposphere. That between 11 to 20 km is the lower stratosphere and between 20 to 32 km is the middle stratosphere (Ref.1.11, chapter 2).

Note: Using the values of T_0 and p_0 , and the equation of state, $p = \rho RT$, gives the sea level density (ρ_0) as 1.225 kg/m^3 .