# Chapter 1 | Introduction

## 1.1 Scope of Micrometeorology

Atmospheric motions are characterized by a variety of scales ranging from the order of a millimeter to as large as the circumference of the earth in the horizontal direction and the entire depth of the atmosphere in the vertical direction. The corresponding time scales range from a tiny fraction of a second to several months or years. These scales of motions are generally classified into three broad categories, namely, micro-, meso-, and macroscales. Sometimes, terms such as local, regional, and global are used to characterize the atmospheric scales and the phenomena associated with them.

Micrometeorology is a branch of meteorology which deals with the atmospheric phenomena and processes at the lower end of the spectrum of atmospheric scales, which are variously characterized as microscale, small-scale, or local-scale processes. The scope of micrometeorology is further limited to only those phenomena which originate in and are dominated by the shallow layer of frictional influence adjoining the earth's surface, commonly known as the atmospheric boundary layer (ABL) or the planetary boundary layer (PBL). Thus, some of the small-scale phenomena, such as convective clouds and tornadoes, are considered outside the scope of micrometeorology, because their dynamics is largely governed by mesoscale and macroscale weather systems.

In particular, micrometeorology deals with the exchanges of heat (energy), mass, and momentum occurring continuously between the atmosphere and the earth's surface, including the subsurface medium. The energy budget at or near the surface on a short-term (say, hourly) basis is an important aspect of the different types of energy exchanges involved in the earth–atmosphere–sun system. Vertical distributions of meteorological variables such as wind, temperature, and humidity, as well as trace gas concentrations and their role in the energy balance near the surface, also come under the scope of micrometeorology. In addition to the short-term averaged values of meteorological variables, more or less random fluctuations of the same in time and space around their respective average values are of considerable interest. The statistics of these so-called turbulent fluctuations are intimately related to the above-mentioned exchange processes and, hence, constitute an integral part of micrometeorology or boundary-layer meteorology.

### *1.1.1 Atmospheric boundary layer*

A boundary layer is defined as the layer of a fluid (liquid or gas) in the immediate vicinity of a material surface in which significant exchange of momentum, heat, or mass takes place between the surface and the fluid. Sharp variations in the properties of the flow, such as velocity, temperature, and mass concentration, also occur in the boundary layer.

The atmospheric boundary layer is formed as a consequence of the interactions between the atmosphere and the underlying surface (land or water) over time scales of a few hours to about 1 day. Over longer periods the earth–atmosphere interactions may span the whole depth of the troposphere, typically 10 km, although the PBL still plays an important part in these interactions. The influence of surface friction, heating, etc., is quickly and efficiently transmitted to the entire PBL through the mechanism of turbulent transfer or mixing. Momentum, heat, and mass can also be transferred downward through the PBL to the surface by the same mechanism. A schematic of the PBL, as the lower part of the troposphere, over an underlying rough surface is given in Figure 1.1. Also depicted in the same figure is the frequently used division of the atmospheric boundary layer into a surface layer and an outer or upper layer. The vertical dimensions (heights) given in Figure 1.1 are more typical of the near-neutral stability observed during strong winds and overcast skies; these are highly variable in both time and space.

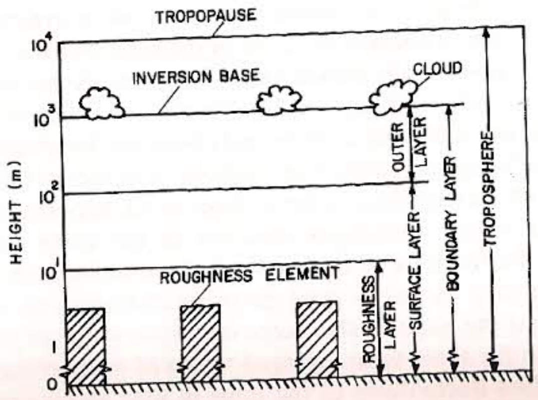


**Figure 1.1** Schematic of the planetary boundary layer as the lower part of the troposphere. [From Arya (1982).]



The atmospheric PBL thickness over land surfaces varies over a wide range (several tens of meters to several kilometers) and depends on the rate of heating or cooling of the surface, strength of winds, the roughness and topographical characteristics of the surface, large-scale vertical motion, horizontal advections of heat and moisture, and other factors. In the air pollution literature the PBL height is commonly referred to as the mixing height or depth, since it represents the depth of the layer through which pollutants released from the near-surface sources are eventually mixed. As a result, the PBL is generally dirtier than the free atmosphere above it. The contrast between the two is usually quite sharp over large cities and can be observed from an aircraft as it leaves or enters the PBL.

In response to the strong diurnal cycle of heating and cooling of land surfaces during fair-weather conditions, the PBL thickness and other boundary layer characteristics also display strong diurnal variations. For example, the PBL height over a dry land surface in summer can vary from less than 100 m in the early morning to several kilometers in the late afternoon.

Following sunrise on a clear day, the continuous heating of the land surface by the sun and the resulting thermal mixing in the PBL cause the PBL depth to increase steadily throughout the day and attain a maximum value of the order of 1 km (range $\simeq$0.2–5 km) in the late afternoon. Later in the evening and throughout the night, on the other hand, the radiative cooling of the ground surface results in the suppression or weakening of turbulent mixing and consequently in the shrinking of the PBL depth to a typical value of the order of only 100 m (range $\simeq$20–500 m). Thus the PBL depth waxes and wanes in response to the diurnal heating and cooling cycle. The winds, temperatures, and other properties of the PBL may also be expected to exhibit strong diurnal variations. Diurnal variations of the PBL height and other meteorological variables are found to be much smaller over large lakes, seas and oceans, because of the small diurnal changes of the water surface temperature due to the large heat capacity of the mixed layer in water.

Other temporal variations of the PBL height and structure often occur as a result of the development and the passage of mesoscale and synoptic systems. Generally, the PBL becomes thinner under the influence of large-scale subsidence (downward motion) and the low-level horizontal divergence associated with a high-pressure system (anticyclone). On the other hand, the PBL can grow to be very deep and merge with towering clouds in disturbed weather conditions that are associated with low-pressure systems (cyclones). It is often difficult to distinguish the PBL top from in-cloud circulations under these conditions; the cloud base is generally used as an arbitrary cutoff for the boundary layer top.

Spatial variations of the PBL depth and structure occur as a result of changes in land use and topography of the underlying surface. Spatial variations of meteorological variables influenced by mesoscale and large-scale systems also