CHAPTER I

INTRODUCTION

1.1 STATEMENT OF THE PROBLEM

The Planetary Boundary Layer (PBL) is the part of the troposphere that is directly influenced by the presence of Earth's surface. The PBL is recognised as an important layer that connects the upper free atmosphere with Earth's surface. It responds to the surface forcings with a time scale of about 1 hour or less (Stull, 1988). These forcings include frictional drag, evaporation, transpiration, heat, and pollutant emissions. On warm sunny days, with strong heating of the surface, dry and humid warm convective thermal plumes play a dominant role in the development of the PBL (Nagar *et al.*, 2001). Under such conditions the PBL is referred to as the "Convective Boundary Layer" (CBL).

The estimation of the height of the Atmospheric Boundary Layer (ABL) and the turbulent fluxes for the whole boundary layer is necessary for a variety of practical applications. The time evolution of the ABL height is important for the vertical distribution of energy, water vapour and momentum, and cloud formation, whereas the vertical profile of fluxes is necessary for estimations of the divergence of vertical fluxes and/or fluxes at the base of thermal inversion (Garratt, 1993).

Air quality assessments at the local or regional scale are required for a variety of purposes, e.g., emission control, air quality forecasts and implementation of legislation, and can be performed using different types of models. Key inputs to those models are the meteorological data required to compute the transport, dispersion, and removal of pollutants. The dispersion of pollutants depends primarily on atmospheric turbulence, but turbulence measurements *per se* are not routinely performed by meteorological services. Thus, dispersion characteristics are inferred either from basic meteorological parameters such as wind, temperature and radiation using parameterisation schemes, or from the output of numerical models. The height or mixing-layer height (h) of the Convective Boundary Layer (CBL) is a key parameter for air pollution models. It determines the volume of atmosphere available for the dispersion of pollutants, and is a component in many predictive and diagnostic methods and models used to assess pollutant concentration. It is also an important parameter in atmospheric flow models. The mixing height is not measured by standard meteorological practices, and, furthermore, its definition and estimation are not straightforward and it often remains an unspecified parameter (Seibert *et al.*, 2000).

Substances emitted into the ABL are gradually dispersed horizontally and vertically through the action of turbulence, and finally become completely mixed over this layer if sufficient time is given and if there are no significant sinks. Therefore, it has become customary in air pollution meteorology to use the term "mixed layer" or "mixing layer". Obviously, the mixing layer coincides with the ABL if the latter is defined as the turbulent domain of the atmosphere adjacent to the ground.

Most current air pollution models were developed for mid-latitude conditions and as such the empirical estimates of the parameters used were based on observations taken in the mid-latitude boundary layer, which in many respects is physically different from the tropical boundary layer. In the tropics, the Coriolis parameter, f, is small or zero; in addition, the moisture in the air plays a more important role in the control of stability and the surface energy balance than is the case for the mid-latitude situation (Abu Samah, 1997).

Air pollution models, such as the OMLMULTI or the ADMS, have been developed for mid-latitude conditions and hence need some modifications to properly simulate the properties of the tropical atmospheric boundary layer (TABL), especially the meteorological pre-processors of these models. Therefore, detailed observations of the tropical atmospheric boundary layer to verify these estimates are also required. As a response to these needs, this study addresses some of the problems of modelling the evolution of mixing height in the tropics.

1.2 OBJECTIVES

The general objective of this study is to improve the ways in which the meteorological data are used in air pollution calculations. In particular, because the CBL is an active link between the surface and the free atmosphere, the processes that control the development of this layer in the tropics need to be better understood and accurately represented in the air pollution dispersion models.

Due to the lack of detailed observations of the tropical atmospheric boundary layer, the TBLEs (Tropical Boundary Layer Experiments) were conceived to collect

data on the evolution of the tropical ABL. Two regimes were considered: namely, evolution under unstable (daytime) and stable (night-time) conditions. To take into consideration the possible effect of the monsoon, the experiments took place during the North-East and South-West monsoon seasons. The collected data will enable a clear understanding of the evolution and development of the ABL in the tropics; under different meteorological conditions.

This study contributes to micrometeorological research by increasing knowledge and understanding concerning the development of the ABL over a tropical area under different meteorological conditions. This is achieved through the determination of its observational aspects and the use of numerical models to analyse the main growth mechanisms of the layer.

1.3 ORGANIZATION OF THE THESIS

Chapter II of this thesis describes the structure of the atmospheric boundary layer and the transfer of properties in the ABL. In addition, the evolution of the two basic ABL regimes, namely the convective and stable boundary layers, is presented. In Chapter III, the methods of mixing height determination including the two basic methods for the practical determination of the MH are discussed. The different methods used in the literature are reviewed. Presented in Chapter IV are the main characteristics of ABL and its development over tropical areas; the data collection procedures and instrumentation used in the measurements; the experimental location and climatology of the experimental site; and the main observations of the TBLEs. The partitioning of the available radiation energy at the surface into the main surface turbulent fluxes in the tropics is described in Chapter V. The estimation of these fluxes is also

discussed. In Chapter VI, a numerical model for the growth of the daytime boundary layer in the tropics was developed and compared to the observations made during the TBLEs. Model sensitivity analyses for different physical mechanisms and characteristics are performed and discussed in Chapter VII. The development of model performance in simulating the convective boundary layer over a tropical area is also included. Finally, Chapter VIII concludes the thesis with a summary of important accomplishments and concepts and suggestions for future research avenues.