I. INTRODUCTION

A. Dynamic Meteorology

The earth's atmosphere can be thought of as a huge body of fluid composed of several gases. In addition, it contains liquids and solids in suspension. This fluid has certain physical properties, called its state, described by the fluid's temperature, density or motion. The most important characteristic of earth's atmosphere is that its physical state varies in space and time. Theses variations involve energy transformations and fluxes. The earth's atmosphere can also be thought of as a huge heat engine in which some of the observed heat energy is converted into a different form of energy, and the unused portion is given up or down through an exhaust. E.g., the atmosphere converts some of the heat energy from the sun into energy of motion and returns a certain amount of energy to space or inside ground. The operation of this heat engine requires differences in energy levels. These differences are due to the sun-earth system and their motions, as well as to characteristics of the earth's surface and the atmosphere itself.

The atmospheric heat engine is a complex engine whose operation is not easy to understand. Some of the reasons for this are:

1) There are complicated interdependencies of the physical parameters which affect the energy distribution.

2) The atmosphere is an open thermodynamic system: it has no material upper boundary and its lower boundary is not uniform either in height or composition.

Dynamic meteorology deals with the fluxes, conversion of thermal and mechanical energy and also with the equilibrium states of the atmosphere. We thought that the motions of the atmosphere, ultimately made possible by conversion of heat energy, can be describe by a set of *conservation laws* founded in general physical principles. These laws are:

1) Conservation of momentum, embodied in Newton's second law of motion, valid in an absolute frame reference. This law is expressed mathematically by the *equation of motion*, and is the fundamental law of dynamic meteorology.

2) Conservation of mass, stating that mass can neither be created nor destroyed. This law is expressed mathematically by the *equation of continuity*.

3) Conservation of thermodynamic energy, embodied in the first law of thermodynamics.

The three conservation laws above give rise to five partial differential equations in six unknowns: three from the equation of motion, and one each from the equation of continuity and the first law of thermodynamics. To these five equations we add a sixth equation, the *equation of state*. Sometimes, an equation of continuity for water substance must also be added. If the rate of heating can be considered as known, these seven equations in seven dependent and four independent variables form a mathematically complete system. Some simplified physical models of the atmosphere can dispense with some of these equations. The seven equations may be called the fundamental equations of fluid dynamics, and dynamic meteorology is the study of atmosphere motions as solutions of these equations and their modified forms. The theory of fluid dynamics can be developed from two points of view:

1) *The microscopic point of view*. Here the molecular structure of the medium is explicitly taken into account. The approach is statistical in nature. The microscopic point of view often affords great insight into the physical behavior of the medium under study.

2) *The macroscopic point of view*. The molecule structure of the medium is not explicitly taken into account; only the bulk properties or gross features of matter are considered. The physical properties of the medium are directly measurable by our instruments.

The molecules of gas (and even of a liquid) are separated by empty regions whose linear dimensions are much larger than those of the molecules themselves. The mass of the material is concentrated in nuclei of the atoms composing the substance and is not uniformly spread through the volume occupied by it. Other fluid properties, such as velocity, also have a highly non-uniform distribution when the fluid is viewed on such a small scale that individual molecules are revealed. Thus, matter is not continuous.

Fluids mechanics is normally concerned only with the bulk properties of the medium. We will assume that the macroscopic behavior of the atmosphere is the same as if it were perfectly continuous structure. Physical quantities such as mass, momentum, temperature, etc. associated with the matter in a given small volume will be regarded as being spread uniformly over that volume instead of, as in strict reality, being concentrated in a small fraction of it (Batchelor, 1967; Riegel, 1999). This is the so called continuum hypothesis. This hypothesis implies that it is possible to attach definite values of fluid properties to a point, and that the values of these properties are continuous functions of position in the fluid, and of time. This will allow establishing equations governing the motions of the fluid which are independent of the nature of the particle structure. The volume in which measurements are made, so-called *sensible volumes*, are assumed to be small enough for the measurements to be a local one, in the sense that changes in the volume do not change the reading of the instrument.

B. Water Substance Thermodynamics

B.1—Theoretical Approaches

The pressure (p), specific volume (α) and absolute temperature (T) of every substance are related by an equation of the form $F(p, \alpha, T) = 0$, which is called the equation of state of the substance. The equation of state of an ideal gas is very simple analytical expression. However, it is usually not possible to write down such a simple analytic expression for $F(p, \alpha, T) = 0$ when dealing with real substance. Nevertheless, the equation of state of a real substance can be represented graphically by a p α T-surface, and a given state of the substance corresponds to a certain point of such a surface. A portion of the p α T-surface for water substance is shown in (**Figure I-1.**). Incidentally, by water substance we shall mean pure water, regardless of its phase. The projections of the p α T-surface into the p T-plane and the p α-plane, respectively, are shown in (**Figure I-2.**) and (**Figure I-3.**).

Water substance phase-changes (**Figure I-4.**) occur spontaneously throughout the troposphere and trigger liquid (or solid) precipitations, clouds and related phenomena like hurricanes and cyclones.

B.2—What Is Thermal Inertia?

Thermal inertia is defined as [SI units]: