Chapter 1. Introduction

What is physical mechanics?

It is a branch of physics concerned with the motion or change in motion or position of physical objects (can include air parcels).

When we study physical phenomena, we first make observations. Then, we apply known physical laws, most typically in a mathematical model which is sometimes turned into a computer program. We then compare the behavior of this model with observations to determine its validity. This is exactly what the Numerical Weather Prediction (NWP) is!

In NWP, we first try to describe the atmosphere, which is mainly made up of dry air and water (in vapor, liquid and ice forms), using mathematical equations. The equations are based on physical laws such as the mass conservation, momentum conservation (a form of the second Newton's law) and energy conservation. Equations describe the time evaluation of the atmosphere starting from an initial state. To obtain the solution to the equations at a future time (the prediction), we need to first know the current state. So we need to make observations. These observations are processed, by computers, into a form that fully describe the current state of the atmosphere, the equations are then solved numerically to obtain a predicted state of the future atmosphere – that is the product of NWP!

To do all that, we first have to have the following in our scientific tool kit:

1. Knowledge of physics
2. Skills in mathematics
3. Knowledge of how to formulate and solve the problems
4. Understanding of the physical phenomena we are studying.

In this course, we will seek to fill this tool kit as a preparation for the rest of your studies in meteorology.

Three Branches of Mechanics

Kinematics –	The description or geometry of the motion of (material) bodies – can be air.
Dynamics –	The physical cause of the motion, which usually involves force.
Statics –	Deals with the study of forces acting on bodies at rest or with no apparent motion.

Physical examples:

Kinematics – the rotational flow within a tornado – a vortex flow, we will look later at vorticity ($\nabla\times\vec{V}$) as a way for quantifying this rotation.

Dynamics – the acceleration of air from high to low pressure in geostrophic (large) scale weather systems.

Statics – the balance in the atmosphere between the weight of the air and the tendency for the air to rise as a result the fact that pressure decreases with height. This is called hydrostatic balance.

Physical mechanics can be rather dry. So, we will fold in as much meteorology as we can. Looking at the list of topics to be dealt with in this course, we can come up with the following matches:

Gravitation – Geopotential height; all aspects of meteorology including, most noticeably, the vertical equation of motion…. Storm updrafts and downdrafts!

1-D Motion – 1-D cloud models, climate and boundary layer models, the models that describe features that change mostly in one direction.

Oscillatory Motion – Gravity waves, clean-air turbulence, parcel stability theory.

2-D / 3-D Motion – All aspects of wx systems; Air parcel trajectories; storm dynamics; angular momentum – tornadoes and hurricanes.

Moving Coordinate System – Coriolis force and all aspects of wx on a spherical planet!

Energy – Basic conservation laws of mass, momentum and energy – they are the foundation to studying the atmosphere.

Problem Solving – After we review some basics, we will spend some time learning how to solve problems. This is one of the major weakness of students in meteorology (on average), compared to, for example, physics. Now is the time to learn!! If you don't, you may have considerable trouble from now on!