PREFACE

This thesis titled ”Exploration of Characteristics Governing Dynamics of Whirlwinds: Applications to Atmospheric Vortices” is not merely a collection of chapters but a consequence of my devoted efforts to learn atmospheric dynamics for over a half decade. This is in true sense a manifestation of my fantasy to be a young affiliate of such a scientific community.

In terms of chapters, it has been partitioned into seven lessons. However, I do not claim them to be free from overlaps. At least the common theme is that they all deal with vortices and all vortices are atmospheric. **Chapter 1** of the thesis has been planned to be introductory in nature to give an overview of atmospheric vortices involving their anatomy, flow patterns, the regions they occur in and also regional nomenclature. They have also been illustrated with photographs. A recap of some related concepts in brief has also been presented.

Chapter 2 is an important part of the thesis that introduces the foundation and chronological development and the scientific journey of the investigation. A detailed literature, related to analytical, laboratory and simulation models together with the different forms and also the different aspects of investigation has been presented.

Chapter 3 models an ideal whirlwind mathematically, which characterizes this geo-physical phenomenon and eventually helps us decipher the in-built dynamics. A dense cylindrical aerial mass is taken into consideration surrounding a rarer aerial region in order to keep a radial favorable gradient of pressure to sustain a rotational motion. It has been concluded that the whirlwind will survive as long as the low pressure region exits. The vertical pressure gradient also plays an equally important role. Since it is not connected to any cloud and the axial velocity is in the vertically upward direction, the momentary vertical gradient of pressure is required for its growth and survival. This has applied to discuss dynamics of a mature whirlwind.

In **Chapter 4**, a more general model of whirlwind has been modelled. A possible solution is attained with the consideration that the radial velocity is a function exclusively of the radial coordinate, which is later derived as inversely proportional to the radial distance. It is observed for a particular combination of density, viscosity and the inflow parameter of the radial velocity that pressure rises at once in a small neighbourhood of the inflow parameter equaling twice the kinematic viscosity, otherwise it follows a particular pattern. We speculate this extraordinary situation as the genesis of whirlwind when the inflow parameter is twice the kinematic viscosity. The expression of pressure has no discontinuity however in that situation.

In **Chapter 5**, attempts have been made to provide non-steady generalization to some of the existing solutions for azimuthal velocity of vortex motion representing different rotational motions occurring in the nature. It is concluded from the unsteady model extended from the Rankine combined model is that for time approaching infinity, the core radius vanishes for inviscid flows. However, the unsteady viscous flow model, extended from the Burgers-Rott model, reveals that, for time approaching infinity, the core radius becomes infinitely large for zero axial pressure gradient but stabilises when the axial pressure gradient is non-zero. Thus, it is concluded that a vortex survives with time only when the flow is viscous and the axial pressure gradient is non-zero.

Chapter 6 investigates the dynamics of tornadoes by considering that the real inflow radial velocity depends on both the radial and vertical coordinates. The formulation is based on the model for the radial velocity which has been deduced from an experimentally verified model of azimuthal velocity. An analytical model for steady, incompressible and viscous fluids is attempted for exact solutions in dimensionless form. It is observed that the magnitude of the radial velocity increases to the maximum at the core but reverses the trend beyond and vanishes as it reaches the centre line. The magnitude reduces linearly with axial distance as per the supposition. At the core, the larger the Reynolds number, the lower is the velocity for moderate Reynolds numbers. Insignificant impact is observed for very large Reynolds number. However, inside and outside the core, the trends are reversed. Radial pressure distributions for different axial positions are similar to theoretical, numerical and experimental observations. As we move outwards from the axis, pressure increases. Difference between the pressures at the axis and that in outward regions increases with height. Pressure falls with rising Reynolds number uniformly for all radial distances. This is an indication that quantitative difference in pressure is large between viscous and inviscid flows.

In **Chapter 7** is presented an analytical model of hurricane. Due to the nonlinearity and the complexity of the equations governing hurricane, it becomes quite difficult to understand the complete dynamics of hurricane. In most of the earlier models, researchers considered inviscid flow for studying different properties of whirlwinds. Kieu and Zhang (2009) investigated intensification of tropical cyclones by considering a simplified linearized viscous flow and concluded that doubly exponential terms in the azimuthal velocity formula was responsible for it. Unlike a linear simplified form, it is investigated for time dependent viscous flow of general kind. An exact solution is obtained in dimensionless form by applying the method of characteristics and by considering the vertical motion with exponential growth in the core region and no vertical flow outside it. The analytical expressions for the velocities reveal that in the core region of hurricanes possessing general viscous rotation, the rotational flow grows at doubly exponential rate.

The thesis concludes with overall conclusions and further scope of investigation appended to it.