**Development of a weather forecasting model in order to improve weather forecasts and build a weather-ready and food secure Zambia.**

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## Introduction

Timely and accurate weather forecasts, as well as early warning, can impact the choices of crops and seed varieties famers must grow and therefore minimize impacts of shortened rainy seasons and reduced rainfall activities as farmers would select more drought resistant and early maturing varieties of crops. Over the recent past, numerical weather prediction, application of statistics to model output, and advanced satellite and radar technology have contributed to much improved forecasts of all kinds.

Weather forecasts are becoming more detailed, more accurate and are extending further out in time - providing the information needed to make sound decisions to protect life and property. Technological advances, such as apps, are making weather information more accessible and immediately alerting those in harm's way.

However, Zambia in general and the Zambia meteorological department in particular still lags considerably behind several major weather centers abroad when it comes to the accuracy of its main weather forecasting models. The major factors affecting the accuracy and extent of weather forecasting in Zambia include:

- Significant lack of ground-based meteorological observation stations. The Zambian forecaster's ability to analyze weather systems has over the years been limited by the availability of surface observations from weather stations. There are huge data gaps. Weather forecasting is dependent on accurate observations of the atmosphere surrounding the whole planet. That and limited access to accurate satellite and radar surface level data from over the world's oceans and polar regions limits the reliability of climate and weather predictions.

- Lack of supercomputing capacity. One of the biggest contributors to improved weather forecasts is the increase in supercomputing power. Modern meteorology is underpinned by satellites, providing real-time situational awareness, such as the position of a tropical cyclone. Such data is fed into the models in a process known as data assimilation hence improving the models. As more data becomes available, techniques for data assimilation must also be updated. All this required improved supercomputing capacity.

- Further and more importantly, Zambia lacks numerical prediction skills. This is compounded by the general absence of active and continuous cutting age research in weather and climate through which numerical prediction skills can be developed and improved. Continuous and active research in this field should lead to significant advances in basic understanding of weather dynamics and physics over the region and globally and the growth of human capital skilled in numerical weather prediction thereby putting weather forecasting on a solid scientific foundation. As more frequent, observations become available, the role of the forecaster is expected to evolve through improved numerical prediction skills. As researchers study the mysteries of our weather and climate - so, too, will the forecasts improve.

**Project description**

The aim of the project is to develop a detailed numerical weather prediction model that will be able to provide reliable weather forecasting of the weather in Zambia. The forecast model will solve fundamental equations of fluid dynamics and heat transfer to compute the evolution of the atmosphere with time. The basic formulae for doing this is based on Newtonian physics and the application of this knowledge to weather prediction is made possible by the advent and growth of computing power. It is therefore hoped that the recently established powerful supercomputing facility within the country at ZAMREN will play a key role in the project. This project also takes advantage of the improved quantity and quality of observations world over. Therefore, a crowning achievement of collaboration such as this and collaboration across many scientific and technological fields will be access to more data more so satellite data which include temperature, humidity, surface pressure and wind - collected from a variety of sources. Such data will provide vital information about what's actually happening at the start of the forecast period and will be used as the major initial input into weather model in order to yield an understandable, reliable and actionable weather forecast system. A key benefit will be the ability to observe thunderstorm formation. Other benefits will be seen in the detection of tropical cyclone genesis. Other benefits of the project will include development of specialized skills in ICT, big data as well as data science for the students involved that can be applied in various other sectors there by leading to profound economic advantages.

**Project Development**

The project will be divided into three (MSc level project)

1. Particle tracking

   This will involve development of a mathematical modelling project that will employ the mathematics of particle trajectories. The main objective of the project is to develop the infrastructure needed to track a number of particles in a flow field where the velocity is prescribed for all time and space.

   This infrastructure is useful for various applications which include the tracking of pollution. The project will involve the use of wind velocity data from atmospheric prediction websites. Therefore the results of the project will have a direct application to atmospheric predictions and applications as the basic infrastructure for processing of wind velocity data will be developed in the process. Some specific stages of the project will involve developing routines for processing of various datasets which generally come in different formats. The project will also require developing of interpolation routines as the data sets may be sparse and require interpolation.

2. Evolution of flow field with particle tracking using the vortex methods

   Where the vorticity is represented by particles whose position and circulation are known, these vorticity blobs are advected by the flow and can be tracked. The main aspect of the project will take advantage of the fact that in 2D problems the vorticity carried by the particle is conserved and remains constant so that the only update needed is for the position of the particle. The project work will therefore involve the programming of a simple formula to compute the flow field induced by the vortex blobs. One can then model the evolution of an entire flow field with particle tracking only. The model will be parallelized to speed it up.

3. **Passive Tracer Advection**
   The purpose of this project will be to write a parallel 2D tracer advection code using a finite volume method. The tracer is passive (in that it does not affect the flow field) and can represent temperature, humidity, or a pollutant concentration. This is the Eulerian counterpart to the Lagrangian particle tracking scheme.