CHAPTER 1

INTRODUCTION

The atmosphere of the Earth is a dynamic, evolving system dependent upon its composition. The concentration of various atmospheric species is dependent upon altitude, geographical location, and time of day. These species interact with the incoming sunlight to absorb, scatter, and emit the incoming radiance. Using spectroscopy, concentrations of different species can be determined to discover the composition of the atmosphere. Over a period of time, changes to the composition caused by natural and anthropogenic sources can be used to infer climate change effects. One important species in determining the radiative forcing effect is stratospheric sulfuric aerosol. Aerosols are submicron droplets that scatter incoming irradiance away from earth and assist in the formation of clouds causing a cooling effect to the surface temperature. The source of these aerosols come from the burning of fossil fuels, biomass burning, marine processes and form the background aerosol layer. A large unpredictable perturbation of this layer occurs after large volcanic eruptions that can inject large quantities of sulfur directly into the stratosphere.

Instrumentation has been deployed over the past decades to monitor the atmospheric state from the ground, sky, and in space using many different methods. Some of these instruments have had the capability to measure aerosols however, many of these instruments are no longer operational or are operating well past there expected lifetimes. The evolution of the atmosphere will need to be monitored in the future and new instrumentation is required. Using new technologies the capabilities of future generations can be surpassed and used to monitor the earth with greater efficiency and higher resolution measurements allowing for a more detailed glimpse of the atmosphere and its dynamic processes. Without future techniques to continue the aerosol and other atmospheric species datasets the long term effect of human production and policy cannot be observed to monitor the effects of climate change.

In this work, a proposal for a new passive remote sensing instrument, named the Aerosol Limb Imager (ALI), will be discussed, which images the polarized limb radiance of the atmosphere to determine stratospheric aerosol profiles using a novel filtering technology. ALI measures the atmosphere using two dimensional imaging to acquire cross-track and vertical profiles giving additional measurement resolution and depth. Current limb instruments do not measure the cross-track profile and only the vertical. The addition of the cross track will allow for more localized measurement points which will allow better determination of atmospheric species such as aerosol and how it dynamically interacts with its environment. This instrument, although a prototype for a satellite instrument, will be tested on a stratospheric balloon flight and has been designed for this platform. Slight alterations would be needed to convert the instrument to a satellite platform mission.

In this work, Chapter 2 will outline the background of the atmosphere on which this project is based including an overview of the stratospheric aerosol. The background includes its discovery and discussion about the importance of aerosol in the atmosphere, effect on climate change, sources of aerosol, and microphysical properties. Following that will be an overview of the different techniques used to measure aerosols. This includes techniques used in in-situ measurements like optical particle counters and nephelometers and satellite based methods such as occultation and limb scatter. Then a brief overview of radiative transfer theory will be covered starting with a scalar representation and moving into the more complicated polarized theory needed for this work. Lastly is a brief discussion of the SASKTRAN-HR model used within this work.

Chapter 3 starts with an overview of Acousto-Optics Tunable Filters (AOTF), since this device is at the core of the ALI system. Background and practical application of this device will be covered with focus on the advantages and disadvantages to using this filter in a remote sensing applications. Continuing will be a discussion of the possible optical layouts for ALI and the testing and underling choice for the optical system. With a selected optical layout of the ALI instrument and a finalized design, a discussion of calibration, testing, and creation of the operation software will be presented. Since ALI is a linear polarized instrument, a study was underwent to determine the best polarization to achieve the highest possible aerosol sensitivity, accuracy, and precision possible. Furthermore, the optimal geometry for a limb scatter polarized instrument was also determined in this same study. This was done by probing the solution space and the results of this study will be the focus of Chapter 4. The final discussion section, Chapter 5, is a presentation of the ALI test flight on a stratospheric balloon in Timmins, Ontario. The results from the measurements recorded from the flights are also presented including calibrated images, retrieved aerosol profiles, precision estimates, and particle size estimation. These results are compared to current satellite measurements and a discussion about the quality of the ALI retrievals is underwent.