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The transboundary transportation of pollutants from The Zambian Copperbelt

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I declare that this research report is my own unaided work. It is being submitted for the degree of Master of Science in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

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Simangele Dlamini

…….day of ……2005

This research report is dedicated to my Entire Family

and my two Daughters

Nomvelo and Nandipha Dlamini

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ABSTRACT

The transportation of aerosols and trace gas material from industrial activities and biomass burning in southern Africa has received widespread attention from scientists over the past decade. Dominant circulation patterns in the sub-region facilitate the southward transportation of sulphur pollutants from the pyromerturllugical processing of copper in Zambia and the Democratic Republic of Congo (DRC), and products of biomass burning from countries in the sub-region in general. This research focuses on the contribution of industrial pollutants from the Zambian Copperbelt and products of biomass burning in the sub-region to total aerosol loading over South Africa.

The seasonality of air transport over the region in general, and South Africa in particular, is determined from different transport fields and their frequency of occurrence. Data supplied by the European Center for Medium Range Weather Forecasting (ECMWF) has been used to run trajectories for the summer, autumn, winter and spring seasons for southern Africa for the years 1990-1994. Forward trajectories have been calculated for the 850, 800, 750 and 700hPa geopotential heights, from Kitwe (12.9° S, 28.2° E, 1262m above mean sea level), at 2.5° resolution. The wall programme has been used as a tool for analysis. Trajectories show widespread recirculation over the subcontinent, resulting in a net transportation of sulphate aerosols from the Zambian Copperbelt. Biomass burning products are likely to join this plume, especially during the late winter and spring seasons. During the summer, air transport is mainly to the west, via Angola and the Democratic Republic of Congo, off the eastern Atlantic towards southern America.

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PREFACE

Air pollution is not restricted by political boundaries, and as such, the development of regional air quality management strategies requires knowledge of the transboundary transport of pollutants. Such knowledge is also of significance if we are to adequately estimate the climate forcing of air pollutants.

Anthropogenic aerosols from industrial activities and biomass burning are transported in a recirculation gyre over the southern African subcontinent more than was originally expected. The Southern Tropical Atlantic Region Experiment (STARE, 1992) and the Southern African Fire Research Initiative (SAFARI 2000) have given more insight into this circulation through intensive field campaigns. A decade of experiments on fire and industrial emissions into the atmosphere has shown that aerosols are having a significant effect on climate at regional scales.

Aerosol particles affect the microphysical properties of clouds. The concentration of small sized particles in the atmosphere potentially diminishes rain from clouds. Sulphur dioxide from industrial activities is transformed through oxidation in the atmosphere into particulate sulphate, which is formed initially in the nucleation mode (smaller that 1micron). These particles quickly grow through coalescence to the size range of 0.4-0.6 microns (the accumulation mode), and at these sizes they tend to trigger convective activity when ingested into clouds at higher altitudes.

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Recently, there has been a growing interest in atmospheric recirculation in the southern African sub-region due to the recognition of the occurrence of absolutely stable layers that allow for the accumulation of aerosols in the lower atmosphere, especially during the non-rain season. This anticyclonic mode results in transport to the west over the Atlantic Ocean via a semi-stationary easterly wave over the western part of the sub-continent. To the south, disturbances within the westerlies enhance transport which exits the continent to the east into the Indian Ocean via a larger plume that transports aerosols to as far east as Australasia (Garstang *et al*, 1995). This research seeks to estimate the contribution of these aerosols, especially those from the Copperbelt in Zambia, to those already generated by the industrialized Highveld in South Africa.

To estimate the contribution of industrial aerosol origins from the northern part of the subcontinent, forward trajectories have been run from the Zambian Copperbelt, more specifically Kitwe (12.9°S, 28.2°E, 1262m amsl). The total number of trajectories is classified seasonally according to frequency of occurrence for the 850, 800, 750 and 700 hPa geopotential heights.

This dissertation is divided into four Chapters. **Chapter 1** provides the necessary background to the study. The nature of the transportation of aerosols and trace gases from the Zambian Copperbelt towards South Africa, and the influence of the absolutely stable layers is discussed. The research hypotheses to be tested are also stated. The Chapter considers in detail the literature related to trace gas and aerosol transportation and the modeling of trajectories. **Chapter 2** describes data collection and analytical methods

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used. **Chapter 3** presents the results of the trajectory analysis and the syntheses of the transboundary nature of aerosol transportation from the Zambian Copperbelt. In **Chapter 4**, the key results are summarized and conclusions presented.

This research forms part of the pool of research for the SAFARI 2000 initiative. Parts of the research have been presented to ESKOM as part of their yearly reports. Trajectory modeling has been carried out at the Climatology Research Group, University of the Witwatersrand under the guidance of Dr. Tal Freiman. I am grateful to Dr. Stuart Piketh for his supervision, and invaluable support and encouragement during my research. I thank the CRG for providing a Grant Holder Bursary in conjunction with the National Research Foundation. (NRF). I also thank the NRF for granting me a Scarce Skills Scholarship, which I used to further my research. The University of the Witwatersrand is acknowledged for providing additional funding through granting me with the University Senate scholarship, which I used during the initial stages of my research.

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LIST OF ABBREVIATIONS

AERONET	Aerosol Robotic Network
amsl	above mean sea level
ARREX	Aerosol Recirculation and Rainfall Experiment
BATTEX	Ben Macdui High Altitude Trace Gas and Aerosol Experiment
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DRC	Democratic Republic of the Congo
ECMWF	European Center for Medium Range Weather Forecasting
ESKOM	Electricity Supply Commission
GCM	General Circulation Model
GISS	Goddard Institute for Space Science
hPa	hecto-Pascal
ITCZ	The Intertropical Convergence Zone
IPCC	Inter-governmental Panel on Climate Change
MPI	Marx Plank Institute
NCAR	National Center for Atmospheric Research
ppb	parts per billion
SAFARI 92	Southern African Fire-Atmosphere Research Initiative (1992)
SAFARI 2000	Southern African Fire-Atmosphere Research Initiative (2000)
TRACE-A	Transport and Atmospheric Chemistry near the Equator-Atlantic
STARE	Southern Tropical Atlantic Regional Experiment

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