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The transboundary transportation of pollutants from The Zambian Copperbelt

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CHAPTER 4

SUMMARY AND CONCLUSIONS

A summary of the research based on research aims and hypothesis is presented, and the main conclusions drawn. The Mpumalanga Highveld in South Africa, though a major producer of industrial aerosols in the subregion, is not the sole contributor of aerosols traversing southern Africa throughout the year. Other countries in the subregion contribute a substantial amount of biomass burning aerosols during the winter and austral spring burning seasons. The Zambian Copperbelt in particular contributes a large amount of copper processing aerosols throughout the year, and especially so during the spring season owing to large scale recirculation that characterizes the region during this time of the year.

The nature and direction of transportation of aerosols in an area affects the regional concentration, and thus the position and magnitude of radiative forcing related to these aerosols. Aerosols are likely to be transported further during large-scale anticylonic conditions prevalent during the winter period over southern Africa because of a general lack of precipitation during this period. Precipitation during the summer period is likely to lead to the deposition of these aerosols. In late winter and spring, aerosol loading is most likely to comprise of biomass burning products, especially those of non-local origin. During the spring, maximum transportation from the Copperbelt is into South Africa.

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This research is based on a five-year trajectory climatology that has been developed from the Zambian Copperbelt, with Kitwe as the starting point. The underlying premise has been that air reaching South Africa from the region not only comprises industrial sulphur from industrial activities in the South African Highveld, but also from the products of copper processing in the Zambian Copperbelt, and biomass burning products due to the prevalence of savanna fires in the region, especially during the winter and spring burning seasons. Other contributory aerosols are those of aeolian and marine origins.

The findings of the study are summarized as follows:

1. Five point forward trajectory analysis from the Zambian Copperbelt, with Kitwe as the centroid, reveals that the transport plumes from the Copperbelt, are well defined.

2. Air being transported out of South Africa comprises of pollutants not only from the industrialised Highveld and other industralised areas in the country, but from the Zambian Copperbelt and biomass burning in the Southern African subregion as well.

3. Recirculation is a major feature of aerosol transportation of aerosols from the Copperbelt and biomass burning in the southern African subregion. Recirculaiton is a significant transportation mode throughout the years, especially during the spring season where it occurs 56% of the time. It is during this time that meridional flow transports a large amount of pollutants from the Copperbelt and products of biomass burning from the subcontinent. On average, recirculation occurs 32% of the time for the five-year period. The recirculating plume from the Copperbelt is likely to carry

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with it biomass burning products and aeolian dust from the drier parts of the subcontinent, particularly from the western deserts in Botswana and Namibia and the semi-arid regions of Zambia and Zimbabwe, and also from the bare or sparsely covered ground in South Africa.

4. The highest transport plume is easterly for all the pressure levels, and occurs with a frequency of 64% in winter. This second highest is the recirculation plume occurring with a frequency of 56% in the spring. Westerly flow into the Indian Ocean and beyond occurs with a frequency of 10% for the five year period.

5. A smaller plume transports aerosols directly to the north as a northerly flow, and occurs with a frequency of 4% throughout the five-year period. Direct transport from the Copperbelt to the south has a frequency of less than 1%, and joins the plume from the South African Highveld to exit the continent at around 35°S and 20°E. Westerlies dominate in summer (28%) and have the least frequency in winter (1%). These transport air directly over the Indian Ocean to as far north as Australasia.

6. Southeasterly flow is predominantly a winter phenomenon, and occurs with a frequency of 13%.

7. Vertically, easterly transport occurs with a maximum of 65% at the 700hPa level for the five-year period. This coincides with the absolutely stable layer that traps aerosols

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before they are transported within dominant atmospheric plumes. At lower levels of the atmosphere, transport is predominantly recirculation at the 800 and 850hPa levels.

8. Regionally, Angola is the largest recipient of aerosols from the Copperbelt. However, during the spring season, recirculating pollutants from the Copperbelt are likely to join those of biomass burning and aeolian origins from the Southern African subcontinent. This plume enters South Africa via Botswana and Namibia, and exits the continent as The Natal plume between 25-30° S. Air reaching South Africa from the Copperbelt is largely a result of easterly recirculating air masses that move out of Zambia and enter South Africa either via Botswana or Namibia (9.5 and 14.8%). An insignificant plume enters South Africa via Zimbabwe as meridional flow (0.7%). This is likely to join the Cape plume to transport aerosols towards the south Indian Ocean.

9. The trajectory air transport climatology reveals 40% of the transport moves as easterly recirculation from the Copperbelt to exit South Africa on the east coast. 22% of this flows over Botswana and into the Highveld, and exits the country at approximately 25° S, while 18% of the flow is over Namibia and out of South Africa at around 30° S. Such transportation is consistent with the location of the semi-permanent high pressure cell that is the dominant atmospheric circulation feature of the subregion.

10. The largest contribution of industrial aerosols and products of biomass burning from countries in the subregion to South Africa occurs during the spring when recirculation

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occurs 56% of the time. This recirculation plume picks up pollutants generated from the Highveld in South Africa to transport them out of the country and into the Indian Ocean and beyond.

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