Comparison of air pollution hotspots in the Highveld using airborne data

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ABSTRACT

The Highveld region is the economic heart of South Africa with a large number of different industries. As a result it has grown to be one of the most populated and developed regions in South Africa. It developed as an industrial region of South Africa because of its abundant mineral resources. The dense concentration of industrial, domestic and transport sources of air pollution have led to degraded air quality over the region. In this study the air pollution hotspots over the Highveld are compared by utilizing the airborne data of SO_2, NO_X, O_3 and aerosols. The South African Weather Service (SAWS) Aerocommander 690A (ZS- JRA) research aircraft was used as an airborne platform to monitor air pollution hotspots over the Highveld. The aircraft is equipped with trace gas analysers and aerosols spectrometer probes. The flight patterns involved vertical profiles that reached approximately 3000 masl. Plume penetrations were conducted to characterize emission from specific sources and mapping to determine the extent of the spatial distribution of pollutants. The seasonal variations of air pollution in these hotspots are also compared. The airborne data is also compared to data from ground based monitoring stations. O_3 concentrations were found to be fairly comparable over the Highveld air pollution hotspots in each season monitored. The inconsistency in the time and the meteorological conditions prevailing when the sites were monitored complicated the comparison of the relative loading of the other air pollutants over the hotspots. However the Vaal Triangle area was found to have high SO_2 and $PM_{2.5}$ aerosols concentrations in comparison to the other sites in all the seasonal case studies. Witbank was an exception to this, it was found to have high $PM_{2.5}$ aerosols loading in comparison to the Vaal Triangle during the spring case study. The airborne and ground based data were found to be reasonably comparable especially O_3 data.

I declare that this thesis is my own unaided work. It is being submitted for the degree of Masters 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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Xolile Gerald Ncipha

……………… day of ………………………….. 2011

This thesis is dedicated to my Entire Family

especially my daughter

Xoliswa Tshiamo Ncipha

PREFACE

The Highveld region of South Africa is the economic power-house of the country. The region is rich in natural resources and over the years it has developed to be an important agricultural and industrial region. Abundance of mineral resources over the Highveld led to diverse industrial activities to be concentrated over this region. About 75% of industrial infrastructure of South Africa is based in the Highveld (Wells, 1996; Freiman and Piketh, 2003). This attracted scores of people from different areas of South Africa to this region, and led to the development of extensive urban areas with high population density (Gauteng Department of Agriculture, Conservation and Environment (GDACE), 2004).

Over the years the social and economic activities in this region have been increasingly exerting pressure on the environment, especially the atmosphere. Growth in industrial activity has been coupled with increased emissions of air pollutants, especially the oxides of nitrogen and sulphur. These oxides can be dry-deposited or wet-deposited to the surface as acid rain. Emissions from domestic fossil fuel burning from low income households have also increased with population. The rise in use of private and public transport (minibus taxis) has also contributed to the degrading air quality. The degraded air quality has a negative health impact on the population, vegetation and it also influences the climate of this region (North West Department of Agriculture, Conservation and Environment (NWDACE), 2002; Mpumalanga Department of Agriculture, Conservation and Environment (MDACE), 2003; GDACE, 2004).

There are limited ambient air quality data available despite air quality problems over this region. The geographical coverage of air quality data is poor. This is caused by a lack of coordination of air quality monitoring activities and cooperation between stakeholders. Air quality monitoring is performed by several separate organisations. In addition, the existing data is not readily shared amongst organisations involved in the monitoring. This makes it difficult to obtain a complete spatial picture of ambient air quality in this region and to compare air pollution levels between different sites over the Highveld region (MDACE, 2003).

This study was part of a national project which aimed at establishing baseline ambient conditions for greenhouse gases and criteria and hazardous air pollutants over air pollution hotspots in South Africa using a research aircraft. The advantage of aircraft measurements is that they offer accurate 3-D data over a large area in fine spatial resolution (National Aeronautics and Space Administration (NASA), 1994. Because this type of measurement platform is mobile, it enables the monitoring of many sites, making it possible to compare them. The aim of this study is to compare air pollution hotspots over the Highveld, utilizing the airborne data of sulphur dioxide (SO_2), nitrogen oxides ($NO_X = NO + NO_2$), ozone (O_3) and aerosols with a diameter less than or equal to 2.5 µm ($PM_{2.5}$). The air pollution hotspots regions investigated are Witbank, Secunda, Rustenburg and the Vaal Triangle. They consist of industrialised sites surrounded by urban and rural settlements. The specific objectives of this study are to:

1. Compare the air pollution hotspots over the Highveld by identifying the differences and or similarities in O_3, NO_X, SO_2, and $PM_{2.5}$ concentrations.
2. Compare the seasonal variations of O_3, NO_X, SO_2, and $PM_{2.5}$ concentrations over the air pollution hotspots.
3. Investigate the relationship between airborne and ground based air pollution data.

This dissertation is divided into five chapters. Chapter 1 provides the background information related to land use and land cover of the study sites, as well as the air quality problems over the Highveld. In addition the characteristics of monitored air pollutants and their effect on health, the environment and the impact of meteorology on air quality levels are described. Chapter 2 describes data collection and analysis methodologies. Chapter 3 presents the results and interpretation of the quartile analysis of air pollution data over the study sites, taking meteorological conditions into account. Chapter 4 presents the results of direct comparisons between airborne and ground based air quality data. Chapter 5 presents the summary and conclusions of the study.

This research is a part of a national project entitled: 'Airborne Monitoring of Greenhouse Gases and other Air Pollutants over South Africa'. The project was funded by the Department of Environmental Affairs and Tourism (DEAT). Components of this project were presented to DEAT during a series of meetings and the final report of the project was presented to DEAT and other South African air quality stakeholders at the project feedback workshop. The South African Weather Service (SAWS) provided its research aircraft, personnel and scientific instrumentation to the project. The Climatology Research Group (CRG) from Wits University supported the project by providing its personnel and scientific instrumentation. The meteorological data used in this study was provided by SAWS. I would like to express my gratitude to SAWS for funding my studies, Mrs. Wendy Job from the Department of Geography, Archaeology and Environmental Studies, Cartography Unit, Wits University for redrawing the synoptic charts, Prof. Stuart Piketh and Dr. Deon Terblanche are thanked for supervising this study.

List of abbreviations

μm - micrometre

ACE - Atmosphere, Climate and Environment

AFIS - Advanced Fire Information System

AQA - National Environment: Air Quality Act

BPDM - Bojanala Platinum District Municipality

CCN - Cloud Condensation Nuclei

VOC - Volatile organic compounds

COL - Cut off low

CRG - Climatology Research Group

DCEPA - Department of the California Environmental Protection Agency

DEAT - Department of Environmental Affairs and Tourism

DMS - Dimethylsulphide

FSSP - Forward Scattering Spectrometer Probe

GDACE - Gauteng Department of Agriculture, Conservation and Environment

GPS - Global Positioning System

IPCC - Intergovernmental Panel on Climate Change

magl - Meters Above Ground Level

masl – Meters above Sea Level

MATCH - Model of Atmospheric Transport and Chemistry

Max - Maximum

MDACE - Mpumalanga Department of Agriculture, Conservation and Environment

MDALA - Mpumalanga Department of Agriculture and Land Administration

Min - Minimum

NASA - National Aeronautics and Space Administration

NWDACE - North West Department of Agriculture, Conservation and Environment

NWPTB - North West Parks and Tourism Board

PCASP - Passive Cavity Aerosol Spectrometer Probe

PMS - Particle Measuring Systems

$PM_{2.5}$ - Particulate Matter with a diameter less than or equal to 2.5 microns

ppb - parts per billion

PPT - Pro – Poor Tourism

QEPA - Queensland Environmental Protection Agency

RAPCA - Regional Air Pollution Control Agency

SAFARI - Fire-Atmosphere Research Initiative

SAAQIS – South African Air Quality Information System

SAST - South African Standard Time

SASOL - South African Coal and Oil

SAVE – Save the Vaal Environment

SAWS - South African Weather Service

SHADOZ - Southern Hemisphere Additional Ozonesondes

StdDev% - Relative Standard Deviation

USEPA - United States Environmental Protection Agency

USNLM - United States National Library of Medicine

UV - Ultraviolet

VAEE - Victorian Association for Environmental Education

VTI - Vaal Triangle Info

WDNR - Wisconsin Department of Natural Resources

WMO - World Meteorological Organisation

WWF - World Wildlife Fund

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