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The distribution of aerosol and trace gases in the lower troposphere over South Africa

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Abstract

Numerous studies on the sources, transport and fates of criteria air pollutants and greenhouse gases have been done in southern Africa. However, debate on the priority pollutants and areas of concern continue despite a growing national air quality monitoring network. This study attempts a novel approach to characterise sources and ambient air quality over major industrial and urban areas using a single suite of instrumentation to provide information to improve management of air quality. Over 200 hours of data were collected from an airborne platform. Another 5 ground-based campaigns characterised sources and areas out of reach of the aircraft.

The central aim of this study is to prioritise sources and areas of concern with regards to air quality management, using a mobile platform. This complements other modelling and spatial assessments and provides in situ validation for many contemporary debates. The specific aims were to characterise major anthropogenic sources; estimate the state of air quality; investigate the vertical distribution of pollutants; and prioritise sources and areas of concern for effective air quality management in South Africa.

The research has delivered many original contributions to the body of knowledge of air quality over South Africa. These findings can be divided into spatial and temporal relationships between sources and receptors, characterising source contributions and understanding the contribution of atmospheric emissions. High resolution measurements show that spatial scales of prominent atmospheric plumes are much smaller than current remote sensing estimates. In situ measurements further confirm that coal-fired power stations and petrochemical facilities have well defined plumes with high concentrations of criteria pollutants, most notably SO_2 and NO_x. Residential solid fuel burning in low-income communities have a disproportionately large impact on the exposure to particulate matter (evening plumes exceeding 800 µg/m^3 of $PM_{2.5}$ measured at 5 min intervals). Relatively high levels of NO_x (peak values exceeding 500 ppb NO and 300 ppb NO_2 measured at 5 min intervals) close to busy highways, on the same order of magnitude as in-plume concentrations of large industrial facilities, highlights the importance of mobile sources.

In situ measurements confirm high levels of criteria air pollutants over the Vaal priority area, the Highveld priority area and to a lesser extent the Bojanala priority area, especially levels SO_2 and NO_x. These areas with a large number of atmospheric emissions do however seem smaller than those estimated using satellite remote sensing. Relatively high levels of NO_x, SO_2 and PM were measured over Durban, which is not currently being managed as a priority area. This

underscores the difficulty of accurately assessing environments with diverse, clustered sources and complex meteorology through modelling studies and satellite based remote sensing.

The current conceptual model of absolute stable layers is biased because of limited data availability where a limited number of levels are reported. At least 60 levels should be reported in soundings to study absolutely stable layers. The inclusion of the standard reporting levels, (850 hPa, 700 hPa, 500 hPa and 300 hPa), further biases the detection of atmospheric stable layers. The number of observed persistent levels change in number and character when these are omitted from the analysis. Numerous vertical profiles further show that the thermodynamic model of stability as the main driver of stratification is oversimplified, especially close to source regions where different pollutants are observed to peak at different levels unrelated to absolutely stable layers. This suggests that the original buoyancy which is governed by the release temperature, exit velocity and height are important drivers for the stratification of pollutants.

The overall conclusion is made that a small team with a set of regular instrumentation can prioritise pollutants and areas of concern on a national scale. This method could be valuable for countries with limited resources and infrastructures and could be used in combination with modelling and satellite based remote sensing to assess priorities. The ability to obtain in situ data of a large number of variables over vast areas in a short time may offsets the caveats associated with mobile measurements and a limited sample volume.