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Modelled surface ozone over southern Africa during the Cross Border Air Pollution Impact Assessment Project

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Abstract

Monitoring of surface ozone over southern Africa has shown that ambient concentrations often exceed a threshold of 40 ppb at which damage to vegetation by ozone could be expected. The Cross Border Air Pollution Assessment Project (CAPIA) was therefore established to assess the potential impacts of ozone on maize, a staple food crop, in five southern African countries. Measured surface ozone data are scare in the region so it was necessary to complement the monitoring with regional-scale photochemical modelling to achieve the objective. The Pennsylvania State and NCAR Mesoscale Model (MM5) is used to produce gridded meteorological data for 5 days in each month of the maize growing season, October to April, as input to the photochemical model, CAMx. Gridded anthropogenic emissions from industry, transport and domestic burning and gridded biogenic emissions from soils and vegetation are input to CAMx. The model estimations indicate large areas on the sub-continent where surface ozone concentrations exceed 40 ppb for up to 10 h per day. Maximum concentrations may exceed 80 ppb, particularly in the winter when mean ozone concentrations are higher. The areas where the 40 ppb threshold is exceeded coincide with maize growing areas in South Africa and Zimbabwe. It appears that neither anthropogenic emissions nor biogenic emissions are dominant in the production of surface ozone over southern Africa. Rather the formation of surface ozone over the region is attributed to the combined contribution of precursors from anthropogenic and biogenic origin.

Keywords: Photochemical modelling; CAMx; MM5; CAPIA; Botswana; South Africa; Mozambique; Zambia; Zimbabwe; Maize; Anthropogenic emissions; Biogenic emissions

1. Introduction

Southern Africa is a region of abundant sunshine, significant sources of ozone precursors and a dominant anticyclonic climatology that suppresses vertical mixing and favours the accumulation of pollutants. These conditions are favourable to the formation of ozone and suggest that ozone concentrations over southern Africa may be relatively high. Ozone is an important constituent in tropospheric chemistry (Jenkins and Clemitshaw, 2000). It is also associated with impacts to human health (Lippman, 1989), vegetation (Emberson et al., 2001; van Tienhoven and Scholes, 2003) and materials (Lee et al., 1996). Even so, measurements of

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ozone in the lower troposphere and at ground level are limited to a few campaign studies and at a limited number of monitoring sites in southern Africa.

In South Africa, surface ozone measurements have been made at Cape Point (Fig. 1) at the Global Atmosphere Watch (GAW) site since 1983 (Brunke and Scheel, 1998). Background concentrations typically vary between 15 ppb in summer and 30 ppb in winter with an annual average of approximately 22 ppb. Surface ozone is also monitored at a number of sites in the industrialised northeastern parts of the country (Annegarn et al., 1996) and monitoring is on going at Maun in Botswana where concentrations of 90 ppb and higher are not uncommon (Zunckel et al., 2004). During the period 1991–1993 a network of 20 monitoring stations was in operation in the eastern highlands of Zimbabwe (Jonnalagadda et al., 2001), where the mean annual surface ozone concentrations ranged between 37 and 49 ppb. Meixner and Helas (1994) measured ozone at Victoria Falls, Zimbabwe during the 1992 Southern Africa Fire Atmosphere Research Initiative (SAFARI-92) campaign. Surface ozone concentrations near the surface measured using tethersonde soundings during SAFARI-92 ranged between 40 and 70 ppb at Etosha, Namibia and 30–50 ppb over Irene, South Africa (Diab et al., 1996a,b). Surface ozone is also monitored at five stations as a component of the IGAC (International Global Atmosphere Chemistry) DEBITS (Deposition of Biogeochemically Important Trace Species) programme at background stations in Namibia and in South Africa and on the industrialised Mpumalanga highveld in South Africa (Zunckel et al., 2004). Kirkman et al. (2000) present an overview of measured ozone in the lower troposphere over southern Africa.

The objective of the Cross Border Air Pollution Impact Assessment Project (CAPIA) is to assess the possible impact of ozone on maize in five countries in southern Africa, namely Botswana, Mozambique, South Africa, Zimbabwe and Zambia (Fig. 1). The monitoring data are however too sparse in the region and do not immediately correspond to the areas where maize is grown (Zunckel et al., 2004; van Tienhoven et al., submitted for publication). It is necessary therefore to apply a photochemical transport model to estimate surface ozone concentrations over the region.

Maize is most susceptible to damage by ozone during the flowering season (van Tienhoven et al., submitted for publication), which varies temporally across the region with climate and with maize variety. In the Cross Border Air Pollution Impact Assessment Project (CAPIA, 2002), van Tienhoven et al. (submitted for publication) assessed the potential risk of damage to

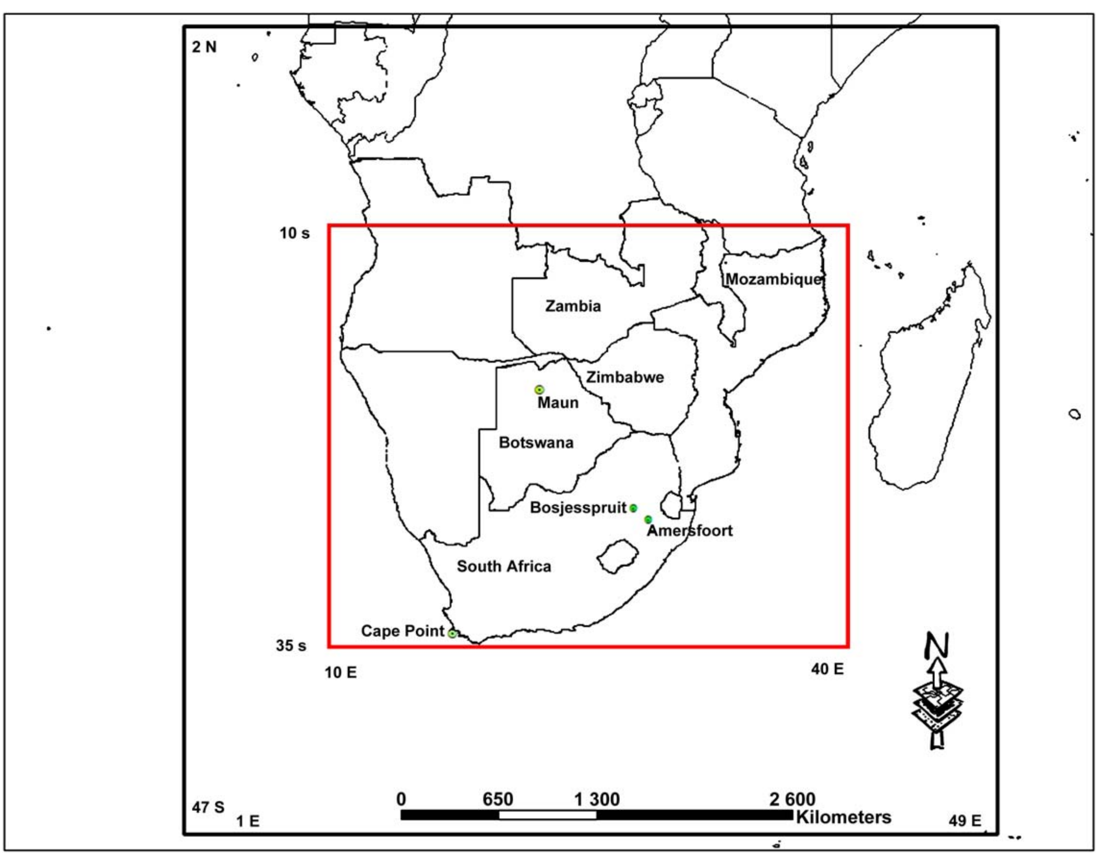

Fig. 1. The CAPIA study area indicating the participating countries and the extent of the larger and nested modelling domains.