

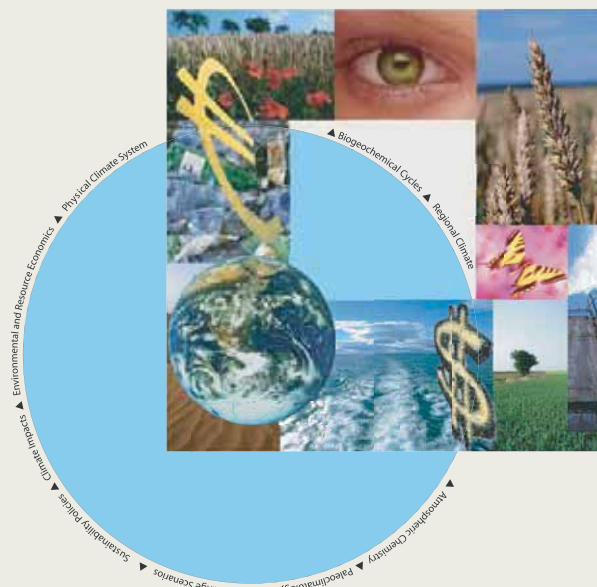


# International Max Planck Research School on EARTH SYSTEM MODELLING

## The impact of african air pollution: A global chemistry climate model study

Adetutu Aghedo

PhD Thesis prepared within the  
International Max Planck Research School on  
Earth System Modelling



---

# Abstract

The problem of air pollution has a long history, which probably dated back to the beginning of human existence. In addition to its local and regional impact, such as its effect on human health, and damage to vegetation including agricultural crops, infrastructure and other historical artefacts, and its reduction of visibility, air pollution is also a global problem because pollutants can be transported far away from their source region, and the ability of photochemical pollutants to influence the radiative balance of the earth, thereby causing climate change.

Air pollution emitted in Africa is from biomass burning, emissions from vegetation and soil, lightning, and anthropogenic emissions. The atmospheric trace species emitted from these sources include  $\text{NO}_x$ , CO, methane ( $\text{CH}_4$ ) and non-methane organic compounds (VOCs). Emissions of these trace species significantly affect tropospheric chemistry and lead to the formation of tropospheric ozone, which is a greenhouse gas with atmospheric radiative forcing of 0.35 (0.25–0.65)  $\text{W/m}^2$  (IPCC AR4, 2007). Africa intricate meteorological patterns and high concentrations of OH radical, makes the continent a region of intense mixing, transport and photochemistry. This thesis therefore investigates the global and regional impact of each of the Africa emission categories, by quantifying the magnitude, the seasonality, the inter-annual variability and assessing the dynamics of transport of primary and secondary air pollutants due to African emissions.

This study employs the 3-D global chemistry climate model ECHAM5-MOZ, which provides a consistent link of the chemistry calculation (MOZART2 tropospheric chemistry) to the parameterisation of the dynamics and the physics of the ECHAM5 model. This thesis presents the first evaluation of the ECHAM5-MOZ model, and it shows that the ECHAM5-MOZ model is both able to simulate the magnitude and the seasonality of ozone and surface CO concentrations worldwide, with a general bias of less than 30 ppbv for ozone. As a contribution of this work to the ECHAM5-MOZ development, the MEGAN biogenic emissions was implemented into the ECHAM5-MOZ model. The global annual emissions estimated by MEGAN are about 488  $\text{Tg(C)}/\text{yr}$  for isoprene, 172  $\text{Tg(C)}/\text{yr}$  for terpenes, 41  $\text{Tg(C)}/\text{yr}$  for CO and 175  $\text{Tg(C)}/\text{yr}$  for other non-terpene VOCs.

The transport of idealized tracers in the ECHAM5 model is rather similar across various model resolutions (T21L19, T42L19, T42L31, T63L31 and T106L31), except that large differences occur when there is a change in the vertical resolution or lifetime of the artificial tracers, or when the model is forced towards ERA40 meteorology. The T42L31 resolution gives very similar results to the other finer horizontal resolutions with the same vertical levels, although the ECHAM5 model climate simulations give better results at higher spatial resolutions (Roeckner et al., 2006). The use of ERA40 data only slightly affect the meridional and vertical transport of tracers at the surface and the tropopause, whereas it increases the inter-hemispheric and vertical transport of tracers in the stratosphere by about 10% – 150% and a factor of 2.5, respectively.

The model studies indicate that the surface ozone concentration may rise by up to 50 ppbv in the burning region of Africa during the biomass burning seasons. Biogenic emissions yield between 5 ppbv and 30 ppbv increase in the near surface ozone concentration over tropical Africa. The impact of lightning on surface ozone is negligible, while anthropogenic emissions yield a maximum of 7 ppbv increase in the annual-mean surface ozone concentration over Nigeria, South Africa and Egypt. The results show that biogenic emissions are the most important African emission source affecting total tropospheric ozone worldwide, due to the combined effect of intense convection on biogenic isoprene and methanol emissions, and their reaction products, which increases the upper troposphere ozone concentrations. The influence of each of the African emissions on the global tropospheric ozone burden (TOB) of 384Tg yields about 9.5 Tg, 19.6 Tg, 9.0 Tg and 4.7 Tg for biomass burning, biogenic, lightning and anthropogenic emissions emitted in Africa respectively. The impact of each of these emission categories on African TOB of 33 Tg is 2.5 Tg, 4.1 Tg, 1.75 Tg and 0.89 Tg respectively, which together represents about 28% of the total TOB calculated over Africa, indicating that more than 70% of the tropospheric ozone produced by each of the African emissions is found outside the continent, thus exerting a noticeable influence on a large part of the tropical troposphere. Apart from the Atlantic and Indian Ocean, Latin America experiences the largest impact of African emissions, followed by Oceania, the Middle East, Southeast and south-central Asia, northern North America (i.e. the United States and Canada), Europe and north-central Asia, for all the emission categories.