Trends in ozone concentration caused by emissions from fossil fuel combustion and natural sources

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Introduction
Ozone changes have significant impact on climate
Enhanced NOx emissions lead to an enhanced tropospheric ozone production
Spatial distribution of NOx emissions and therewith ozone vertical profiles of several ozone sources differ
Ozone production depends on location of emission

Ozone Production
Ozone production efficiency (OPE) is dependent on altitude and location of emission:
NOx emissions in higher altitudes produce more ozone than in lower altitudes due to enhanced solar radiation (e.g. lightning)
OPE in remote regions is higher than in polluted regions (e.g. soils)
Ozone changes similar to NOx emission changes

Climate-Chemistry Model E39/C
• Ensemble simulation from 1960 to 2020.
• External forcings: sea-surface temperatures, greenhouse gases, emissions, QBO, volcanoes, solar cycle, and CFCs.
• Road traffic NOx emissions:
  Increased proportionally with industry until 2004. Since 2004 the increase of road traffic emissions is proportional to industrial emissions only in developing regions and decrease elsewhere.

Evolution of Ozone Radiative Forcing
• Ensemble climate-chemistry simulation performed for 1960 to 2020.
• Ozone Production Efficiency and RF efficiency depends on emission altitude and location:
  Large for lightning / Small for industry
  RF changes are slightly decreasing due to:
  a changing atmospheric composition (beside aircraft)
  RF saturation

References
Dameris et al., Long-term changes and variability in a transient simulation – ACP, 2005
Dahlmann et al., Attribution of ozone radiative forcing trends to individual NOx sources, ACF, 2008
Grewe, V., Technical Note: A diagnostic for ozone contributions, ACF 4, 2008

Summary
• Ensemble climate-chemistry model simulation performed for 1960 to 2020.
• Ozone Production Efficiency and RF efficiency depends on emission altitude and location:
  Large for lightning / Small for industry
• Trends in RF from various NOx sources are controlled by their emissions
• RF changes are slightly decreasing due to:
  a changing atmospheric composition (beside aircraft)
  RF saturation

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Evolution of Ozone Radiative Forcing
Temperature correlation between RF und ozone column is rather close for each component
High RF efficiency: lightning
Intermediate RF efficiency: air traffic, soils and biomass burning
Low RF efficiency: ships, road traffic and industry