

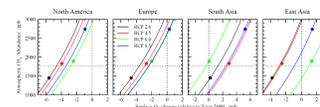
Research Highlight

Increases in anthropogenic emissions of ozone precursors are believed to make a substantial contribution to the rising levels of surface ozone (O₃) observed at many long-term measurement stations over past decades. As a strong oxidant detrimental to human health and damaging to plant growth and crop yields, surface O₃ contributes to poor air quality and to economic and environmental damage. Understanding the reasons for its growth presents a considerable challenge, as the balance of natural and anthropogenic, regional and global changes contributing to its growth varies greatly over the globe and remains poorly characterized. It remains unclear how regional emission controls aimed at reducing surface O₃ may be offset by global “background” O₃ increases, by changes in the abundance of longer-lived O₃ precursors such as methane (CH₄), or by changes in chemical processing or transport driven by future shifts in climate. This study explores the contribution of changes in anthropogenic O₃ precursor emissions to changes in the regional and global abundance of surface O₃. It describes a simple approach to quantify surface O₃ changes based on regional precursor emission changes derived from global chemical transport model simulations from a recent model intercomparison. This is applied to past and future emission scenarios to explore the range of surface O₃ responses expected over different parts of the world and to provide a source attribution for these changes.

Under the Convention on Long-range Transboundary Air Pollution (LRTAP), the task force on Hemispheric Transport of Air Pollution (HTAP) was established to develop a fuller understanding of the transport of a range of key air pollutants over intercontinental scales. A series of multi-model intercomparison experiments was coordinated by HTAP to provide a consistent quantification of intercontinental source-receptor relationships between major industrialised regions. Among those models was the Lawrence Livermore National Laboratory's IMPACT model (Dan Bergmann, supported at that time by DOE's ASP program). All global and regional models of atmospheric chemistry and transport were run with 2001 meteorological conditions and with best estimates of natural and anthropogenic emissions and a specified atmospheric abundance of CH₄ (1760 ppb), and these provided monthly mean distributions of O₃ and aerosol and their precursors for the year. A simulation with 20% reduced atmospheric concentrations of CH₄ was performed to determine the impacts of CH₄ abundance on O₃ in each model, and this was followed by a further series of runs with 20% reductions in annual anthropogenic emissions of the main O₃ precursors, nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compounds (VOCs), individually and together, over each of the four main continental scale regions of interest in turn. For the present study, an additional set of four runs were defined with 20% global emission reductions for each precursor so that the effects of emission changes outside the four HTAP regions, the Rest-of-World response, can be considered.

In this study we use model results from the HTAP intercomparisons to quantify the impact of a realistic range of changes in anthropogenic precursor emissions on surface O₃ on a global, regional, and sub-regional basis. The approach involves scaling surface O₃ responses derived from 20% emission reductions by the fractional emission change for a given emission scenario over each region for each precursor.

This study describes a simple parameterization for estimating regional surface O₃ changes based on changes in regional anthropogenic emissions of NO_x, CO, and VOCs and in global CH₄ abundance using results from 14 independent global chemical transport models that contributed results to the HTAP model intercomparison. The approach successfully reproduces regional O₃ changes through the year compared with full model simulations from a range of different



Sensitivity of regional surface O₃ in 2050 to the atmospheric CH₄ abundance under each of the RCP scenarios. Circles mark the ensemble mean surface O₃ response under each scenario, and curves show how this would change under different levels of CH₄. Dashed lines mark CH₄ and surface O₃ for year 2000.

models under conditions where precursor emissions do not deviate too greatly (typically $\pm 60\%$) from those of the present day. While not replacing the need for full model simulations, the approach allows the effects of different emission scenarios to be explored and thus allows identification of scenarios of particular interest for further study. The study reveals the increasing importance of limiting atmospheric methane growth as emissions of other precursors are controlled, but highlights differences in modeled ozone responses to methane changes of as much as a factor of two, indicating that this remains a major uncertainty in current models.

Reference(s)

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Aerosol Life Cycle