

Attribution of regional radiative forcing due to tropospheric ozone: A step towards climate credit for reductions in emissions of ozone precursors

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Abstract:

The global distribution of O₃ depends on the emissions of its precursors, in addition to chemistry and transport. The radiative forcing of tropospheric ozone (O₃) can be expressed as a sum of regional forcings arising from emissions of precursors from different countries. Studies have shown that O₃ concentrations have increased significantly since pre-industrial times resulting in a radiative forcing similar to that due to the increase in CH₄ concentration. However, no binding targets have been set for tropospheric O₃ primarily because of the uncertainties in estimating the contribution of regional emissions of O₃ precursors to global O₃ distribution and the resulting climate forcing. In this study, we quantitatively estimate the reduction in radiative forcing from tropospheric O₃ attainable through potentially feasible reduction in the emissions of O₃ precursors (NO_x, CO, and NMHCs). We simulate, using the global chemistry transport model, MOZART-2, the change in global O₃ distribution resulting from a 10% reduction from 1990 emission levels in surface anthropogenic emissions of NO_x alone from nine geographic regions (Africa, Australia, East Asia, Europe, the Former Soviet Union, the India subcontinent, North America, South America, and Southeast Asia), and also from a combined 10% reduction in anthropogenic emissions of NO_x, CO, and NMHCs from three of these regions. The resulting changes in O₃ and CH₄ concentrations are used to estimate the change in global radiative forcing on climate resulting from the regional

emissions reductions. Our results show that O₃ production and resulting distribution depend strongly on the geographical location of emissions of its precursors. The sensitivity of O₃ changes to NO_x emission reductions range from about 5 Tg O₃/ Tg N yr⁻¹ for Southeast Asia to 0.2 Tg O₃/ Tg N yr⁻¹ for Europe. For reductions of NO_x emissions alone, radiative forcing changes due to O₃ per unit of NO_x reduction are highest for emission reductions from tropical regions (Southeast Asia, South America, and the Indian subcontinent) and smallest for emission reductions from mid- and high latitude regions (Europe, the Former Soviet Union and North America). Changes in CH₄ and O₃ concentrations resulting from NO_x emission reductions produce radiative forcing changes that largely offset each other leaving a small residual forcing that is positive for all regions except Southeast Asia and the Indian subcontinent. In contrast, for combined reductions of anthropogenic emissions of NO_x, CO, and NMHCs, changes in O₃ and CH₄ concentrations result in a net reduction in the radiative forcing for all regions we considered here, suggesting an overall cooling. Our key finding is that in order to reduce radiative forcing resulting from emission of tropospheric O₃ precursors, it is necessary to consider simultaneous reductions of CO, NMHCs, and NO_x; NO_x emission reductions alone are not sufficient to guarantee a reduction in radiative forcing when the full effect of changes in O₃ and CH₄ concentrations are taken into account.