

Radiative effects of ozone enhancements from anthropogenic and lightning-NO emissions

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Coarse global climate models estimate the radiative forcing of tropospheric ozone obtained by comparing present-day and preindustrial levels to be between 0.3 and 0.5 W/m² with mean surface warming of 0.4 K. Applying the climate penalty factor of 2.2 ppbv/K to this surface warming yields a 0.9 ppbv increase in surface ozone. The instantaneous radiative forcing is estimated 20% larger. Our results from simulations with a global chemical transport model and an offline radiative transfer model show that the net downward radiative flux at the tropopause due to ozone produced from lightning-NO emissions can greatly exceed the instantaneous radiative forcing of ozone produced from anthropogenic emission, especially downwind of lightning activity. This is because of stronger radiative forcing efficiency of an upper tropospheric perturbation. To simulate variations of ozone over North America, a region with large summertime flash rate, we use the Weather Research and Forecasting (WRF) model with online coupled chemistry and meteorology (WRF-Chem). In the first part of our study, we estimate the contribution from anthropogenic and lightning-NO emissions to the ozone column on regional scales (10-40 km). The anthropogenic and lightning enhancements are determined from the model simulations with respective emission sources turned off. We conduct an ensemble of WRF-Chem simulations each driven by a different meteorological reanalysis (NASA's MERRA, ECMWF's ERA-Interim, NCEP's NARR and NCEP's FNL). To represent the episodic intercontinental transport of pollution, we investigate the impact of using different chemical boundary and initial conditions from two global Chemical Transport models (NASA's GMI and NCAR's MOZART). The WRF-Chem output is compared to ozonesonde, satellite (OMI, TES) and ground-based observations. In the second part, we quantify the chemistry-radiation feedback of tropospheric ozone on regional scales by allowing two-way interaction between the chemistry and radiation. Heating rates responding to ozone variations calculated by photochemistry can improve the predictive capability of the regional air quality models. The upper tropospheric variations due to lightning NO_x are expected to be more important than variations due to anthropogenic emissions. The impact of lightning-NO emissions on ozone determined in this work is a step towards finding the contribution from lightning NO_x to policy relevant background ozone. We demonstrate the challenges of estimating the radiative contribution of ozone produced from lightning NO_x.