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Ozone database in support of CMIP5 simulations: results and corresponding radiative forcing

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A continuous tropospheric and stratospheric vertically resolved ozone time series, from 1850 to 2099, has been generated to be used as forcing in global climate models that do not include interactive chemistry. A multiple linear regression analysis of SAGE I II satellite observations and polar ozonesonde measurements is used for the stratospheric zonal mean dataset during the well-observed period from 1979 to 2009. In addition to terms describing the mean annual cycle, the regression includes terms representing equivalent effective stratospheric chlorine (EESC) and the 11-year solar cycle variability. The EESC regression fit coefficients, together with pre-1979 EESC values, are used to extrapolate the stratospheric ozone time series backward to 1850. While a similar procedure could be used to extrapolate into the future, coupled chemistry climate model (CCM) simulations indicate that future stratospheric ozone abundances are likely to be significantly affected by climate change, and capturing such effects through a regression model approach is not feasible. Therefore, the stratospheric ozone dataset is extended into the future (merged in 2009) with multi-model mean projections from 13 CCMs that performed a simulation until 2099 under the SRES (Special Report on Emission Scenarios) A1B greenhouse gas scenario and the A1 adjusted halogen scenario in the second round of the Chemistry-Climate Model Validation (CCMVal-2) Activity. The stratospheric zonal mean ozone time series is merged with a three-dimensional tropospheric data set extracted from simulations of the past by two CCMs (CAM3.5 and PUCCINI) and of the future by one CCM (CAM3.5). The future tropospheric ozone time series continues the historical CAM3.5 simulation until 2099 following the four different Representative Concentration Pathways (RCPs). Generally good agreement is found between the historical segment of the ozone database and satellite observations, although it should be noted that total column ozone is overestimated in the southern polar latitudes during spring and tropospheric column ozone is slightly underestimated. Vertical profiles of tropospheric ozone are broadly consistent with ozonesondes and in-situ measurements, with some deviations in regions of biomass burning. The tropospheric ozone radiative forcing (RF) from the 1850s to the 2000s is 0.23 W m-2, lower than previous results. The lower value is mainly due to (i) a smaller increase in biomass burning emissions; (ii) a larger influence of stratospheric ozone depletion on upper tropospheric ozone at high southern latitudes; and possibly (iii) a larger influence of clouds (which act to reduce the net forcing) compared to previous radiative forcing calculations. Over the same period, decreases in stratospheric ozone, mainly at high latitudes, produce a RF of -0.08 W m-2, which is more negative than the central Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) value of -0.05 W m-2, but which is within the stated range of -0.15 to 0.05 W m-2. The more negative value is explained by the fact that the regression model simulates significant ozone depletion prior to 1979, in line with the increase in EESC and as confirmed by CCMs, while the AR4 assumed no change in stratospheric RF prior to 1979. A negative RF of similar magnitude persists into the future, although its location shifts from high latitudes to the tropics. This shift is due to increases in polar stratospheric ozone, but decreases in tropical lower stratospheric ozone, related to a strengthening of the Brewer-Dobson circulation, particularly through the latter half of the 21st century. Differences in trends in tropospheric ozone among the four RCPs are mainly driven by different methane concentrations, resulting in a range of tropospericozone RFs between 0.4 and 0.1 W m-2 by 2100.