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Revising the 11-year Solar Cycle Response in Stratospheric Ozone Using an Ensemble of Lasso and Ridge Regression Models

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Solar flux variations associated with the 11-year solar cycle are believed to exert an important climate forcing via changes in stratospheric ozone. However, our understanding of the ozone solar cycle signal (SCS) was significantly revised with the availability of updated SAGE II v7 data. For example, Dhomse et al. (Geophys. Res. Lett., 2016) analysed SAGE II v7 data to show a much smaller upper stratosphere ozone SCS, as well as a more realistic ozone-temperature anti-correlation, that agreed with the relatively short HALOE and AURA-MLS data records. Here, we analyse AURA-MLS satellite data and output from the TOMCAT 3D chemical transport model (CTM) to estimate the ozone SCS for the 2005-2020 period, which covers one of smallest solar cycles (number 24) of the last 100 years. Along with a control simulation, various model simulations with combinations of different dynamical (e.g. ERA5, ERA-Interim, fixed), chemical (e.g. constant ozone depleting substances) and solar flux (NRL, SATIRE, SORCE solar irradiances) forcings are analysed.

Our earlier studies use an Ordinary Least Square (OLS) multivariate regression model to estimate the SCS. However, most of the relevant atmospheric variables are correlated. Hence, to avoid this collinearity problem, we use an ensemble of Lasso and Ridge multivariate regression models and their variants to quantify the SCS in stratospheric ozone. Overall, both MLS and the CTM simulations show a vertical "double-peak"-structured ozone SCS in the tropical stratosphere. However, compared to previous studies, the regression ensemble mean shows a somewhat larger signal in the middle stratosphere and does not show a negative SCS in the lower and upper stratosphere. Our analysis also shows significant inter-hemispheric and seasonal differences in lower stratospheric ozone trends over the 2005-2020 time period (i.e. recent ozone recovery phase). Our CTM simulations also confirm that recent negative ozone trends in the northern hemispheric mid-latitude lower stratosphere (Chipperfield et al., Geophys. Res. Lett., 2018), are primarily caused by changes in the stratospheric circulation.