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The chemistry climate model results to the solar cycle and volcanic aerosol during 1980-2000

Yousuke Yamashita[1]; Kei Sakamoto[2]; Hideharu Akiyoshi[2]; Masaaki Takahashi[1]; Tatsuya Nagashima[2]; Libo Zhou[3]

[1] CCSR, Univ. of Tokyo; [2] NIES; [3] IAP, CAS

Decadal variation in the upper stratospheric ozone and temperature over the equator caused by solar cycle has been reported using satellite observation, reanalysis data and model experiments (e.g. Hood et al., 1993; Scaife, 2000; Crooks and Gray, 2005; Soukharev and Hood, 2006; Austin et al., 2008). These studies indicate that a density of ozone / temperature is strong / warm in solar maximum, which is weak / cold in solar minimum. In lower stratosphere at 100-40 hPa, similar variation of ozone and temperature is seen. But in the lower stratosphere the decadal variation associated with the solar cycle is affected by aliasing of volcanic eruption, quasi-biennial oscillation (QBO) and sea-surface temperature (SST) variation, thus accurate separation of these effects with multiple regression analysis is difficult in the short time period data (e.g. Lee and Smith, 2003). In particular, two major volcanic eruptions occurred within a decadal interval (El Chichon in 1982 and Mount Pinatubo in 1991) for 1980-2000, thus the effect of the volcanic eruption was detected as solar cycle component. Then, it is useful to perform sensitivity experiments by numerical model to isolate these effects. In this study, we use sensitivity experiments of a three-dimensional Chemistry Climate Model (CCM) to isolate the solar cycle variation from the volcanic and other variations.

In this study, we use the CCM developed in the Center for Climate System Research (CCSR)/National Institute for Environmental Studies (NIES). The CCSR/NIES CCM runs are performed over the period of 1980-2000 with observational distributions of the decadal solar cycle, QBO, volcanic aerosol and SST (CCMVal-REF1). The CCM has T42 horizontal resolution and 34 vertical layers (top of the model is about 80 km). The sensitivity experiments are performed without these effects respectively to analyze the individual effects to the solar cycle component.

The solar cycle component of the multiple regression analysis to the REF1 scenario of the CCM output clearly shows two vertical maxima over the equatorial 5 hPa and 80 hPa. Sensitivity runs show that the upper signal was due to the solar cycle forcing. The results are consistent to the previous studies. The lower signal was explained mainly by the volcanic forcing. A contribution of the interannual variability in SST was about 10 % of the lower signal, and a contribution of the solar cycle forcing was also 10%. The effect of the QBO is small. Austin et al. (2008) indicated that the lower maximum is weak when the analysis period is 1960-2000. A tentative analysis of the solar regression coefficients using CCMVal2 output for 1960-2006 shows weaker signal at 80 hPa. Longer analysis can reduce the aliasing of the volcanic forcing.

Thus, the multiple regression analysis may have produced an artificial solar cycle component at 80 hPa, whereas the maximum at 5 hPa was the real solar signal for 1980-2000.