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Long-term Trends and Response to Solar Cycle of Carbon Dioxide in the Mesosphere and Lower Thermosphere

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CO_2 has a substantial cooling effect by infrared emission in the upper atmosphere with respect to the warming effect in the lower atmosphere. The definitive knowledge about CO_2 secular change is important to the determination of dynamics and energy budget of the upper atmosphere and the evaluation of near-space environment for low-orbit satellites.

We investigated the long-term trends and response to 11-year solar cycle (SC) of carbon dioxide (CO_2) volume mixing ratio (VMR) in the mesosphere and lower thermosphere completely. The global trend, response to SC and their seasonal dependence were obtained simultaneously by fitting global averaged CO_2 VMR time series from the Sounding of the Atmosphere using Broadband Emission Radiometry onboard the Thermosphere Ionosphere Mesosphere Energetics Dynamics (TIMED/SABER) to a multiple linear regression function which includes the terms of seasonal variations, quasi-biannual oscillation (QBO), El Niño-Southern Oscillation (ENSO), solar cycle and long-term trend. As SABER sampling has nearly homogeneous spatial coverage and continuous temporal extent between latitude 54S and 54N, we also derived CO_2 VMR trends and its response to SC in the latitudinal bands of this range.

We find that CO_2 VMR global annual mean trend remains 5-5.5% per decade in the altitude range of 65-110 km. CO_2 VMR trend shows salient seasonal dependence above 85 km with the maximum value of $\sim$7.0% per decade around the equinoxes and the minimum value of $\sim$2.5% per decade during the Northern Hemisphere summertime, while little seasonal dependence is shown below 85 km. The seasonal dependence of CO_2 VMR trend may indicate that there is a year-to-year changing in general circulation or seasonal variations of gravity wave activity. Besides, a nearly uniform latitudinal distribution of CO_2 VMR trend with an insignificant inter-hemispheric symmetry is found. On the other hand, the negative response to SC of CO_2 VMR occurs between 85 km and 105 km with the value of $\geq$-1.8% per 100sfu, while a positive response is presented between 65 km and 75 km with the value of $\leq$0.6% per 100sfu. Extra dynamical feedbacks or other decadal variations are needed to explain the positive response. The negative response to SC is only significant around the equinoxes and the positive response to SC is significant from June to October. There is an asymmetric distribution for the negative response between Northern Hemisphere and Southern Hemisphere.