Evaluation of radiative forcing due to the 11-year solar cycle with a chemistry-climate model

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Different from the uniformly mixed greenhouse gases such as CO2 and CH4, ozone is non-uniformly contained in the middle atmosphere with a sharp peak at 10 hPa. Thus the stratospheric adjustment is indispensable for the evaluation of the radiative forcing associated with ozone change. The 11-year solar cycle induces ozone variations in the upper stratosphere through the incoming irradiance change as well as the radiative heating variations. Hence, models capable of processing the stratospheric adjustment are required for accurate estimation of the radiative forcing due to the 11-year solar cycle. In this study, three models are used to evaluate the radiative forcing due to the 11-year solar cycle and compared their radiative forcings. They are fixed dynamical heating model (FDHM), general circulation model (GCM), and chemistry-climate model (CCM) of the Meteorological Research Institute. CCM predicts 3-dimensional fields of the abundances of chemical species including ozone and dynamical quantities in response to the solar irradiance variations based on 11-year sun spot number cycle. GCM calculates only the 3-dimensional fields of dynamical quantities using the prescribed ozone changes predicted with CCM. FDHM calculates only the zonal-mean temperature response using an assumption of the dynamical heating being fixed irrespective of solar condition and the prescribed ozone changes predicted with CCM. It is found that the radiative forcing is almost zero in the poleward of 30 degrees due to the cancellation by the longwave radiation and that the forcing amounts to about 90% of the solar flux variations at the top of the atmosphere in the equatorward of 30 degrees.