Evaluating global distribution and interannual variation of stratosphere-troposphere exchange of ozone: impacts of climate variabilities

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The stratosphere-troposphere exchange (STE) of ozone (O_3) can have significant impacts on the interannual variability and long-term trend of global tropospheric ozone and radiation budget. This study investigates global STE of O_3 particularly focusing on the roles of major climate variabilities such as ENSO, PDO, and QBO and climate trend (surface temperature). Using a chemistry coupled climate model, this study estimates temporal variation in the vertical and meridional STE O_3 fluxes during the years of 2000-2016. For the major climate variabilities of ENSO and PDO, associated STE changes are assessed in detail using a composite analysis. The model validation shows that the model well captures the OMI-observed tropospheric column ozone (TCO) abundances (r~0.55), especially around the tropical Pacific (r~0.8). It is shown that in the tropics there is upward O_3 transport to the stratosphere (troposphere to stratosphere transport, TST) while in the extratropics, O_3 transport is downward (stratosphere to troposphere transport, STT), consistent with the Brewer-Dobson circulation in the stratosphere. Although geographical distributions of vertical and meridional STE fluxes are not changed largely by ENSO or PDO, the STE fluxes are significantly amplified by the ENSO events. Horizontal patterns of STE flux anomaly are found to be similar with respect to the El Niño episodes and the PDO warm phases (STT increased by 21% and 10%, respectively, in the northwest Pacific). These anomalies are reversed during the La Niña and PDO cold phases (STT decreased by 16% and 3%, respectively, in northeast Pacific). The anomaly of global net STE O_3 flux is interpreted as several key factors using a multiple-regression analysis. The result shows that the STE anomaly is explained largely by the combination of ONI, PDO, QBO, and global mean surface temperature (R^2~43%). Contributions of ONI and PDO to STE anomaly are estimated to be 22.3% and 23.1%, respectively. This study quantitatively reveals the possible connection between climate condition and STE.

Keywords: Stratosphere-Troposphere Exchange (STE), Ozone, chemistry climate model, chemistry-climate interaction, climate change, Budget of tropospheric ozone

