Impact of stratosphere-to-troposphere exchange on surface ozone in eastern China from the valley between the South Asia High and the Subtropical Pacific High

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Stratosphere-to-troposphere exchange (STE) plays important role in determining chemical composition and radiative species of both the lower stratosphere and the troposphere. Stratospheric ozone intrusion via irreversible stratosphere-to-troposphere transport (STT) is an important source of tropospheric ozone and modifies the tropospheric oxidative capacity. In some cases, deep intrusion of stratospheric ozone reaches the surface and therefore influences the surface air quality. However, stratospheric ozone intrusion is still poorly understood and inadequately quantified. In particular, local intrusion of stratospheric ozone over eastern China, whereas heavy air pollution happens frequently, has been less investigated. To what extent does stratospheric ozone intrusion processes contribute to the surface ozone in eastern China is largely unknown.

Ozone intrusion from the stratosphere to the troposphere over eastern China is investigated using a combination of IAGOS (In-service Aircraft for a Global Observing System) profiles, ERA5 (the fifth generation of ECMWF atmospheric reanalysis) data and ground-based ozone observations in eastern China. Results indicate that, STT happens in all seasons over eastern China, with a maximal frequency during winter. On the other hand, deep intrusion of stratospheric ozone together with strong vertical convection exists during summer time. For example, in July of 2016, three ozone intrusions were evident over eastern China from ERA5 ozone and potential vorticity (PV) distributions and nearby ozone profiles measured by IAGOS. Correspondingly, several ozone concentration peaks are measured at the Station for Observing Regional Processes of the Earth System (SORPES) in Nanjing (118°46' E, 32°03' N) and were largely underestimated by WRF-Chem simulations due to a lacking of proper upper boundary conditions near the tropopause.

Analyses using the ERA5 data indicate that, such stratospheric ozone deep intrusion cases are associated with similar circulation conditions in the upper troposphere: with a cyclonic valley between the South Asian High and the summer Subtropical High. Such a valley accompanied by a downward motion provides a pathway of ozone from the stratosphere to the troposphere. The relative contribution of STE to summer time ground ozone peaks in eastern China is further quantified by a series of WRF-Chem and CAM-Chem simulations. Results show that deep intrusion of stratospheric modulates surface ozone concentrations in eastern China during summer, when ozone values are highest over the year, and therefore contributes to extreme ozone pollution episodes. Our results provide important information for surface air quality prediction and control in eastern China.

Key words: STE, stratospheric ozone intrusion, tropospheric ozone, eastern China, interannual variability