Analysis of relatively low ozone in Arctic spring during the QBO-westerly and solar-minimum years

*Yousuke Yamashita[1,2], Hideharu Akiyoshi[2], Masaaki Takahashi[2]

1. Japan Agency for Marine-Earth Science and Technology, 2. National Institute for Environmental Studies

The equatorial quasi-biennial oscillation (QBO) and the 11-year solar cycle are known to cause year-to-year variability of the Northern Hemisphere (NH) polar vortex (e.g. Holton and Tan, 1980; Labitzke, 1987). Labitzke (1987) and several studies following her work have been used the four categories of the QBO and 11-year solar cycle, according to the westerly/easterly phase of the QBO (QBO-W/QBO-E) and the maximum/minimum phase of the 11-year solar cycle (S_{max}/ S_{min}). Camp and Tung (2007) suggested that the NH polar vortex is the most stable and the least perturbed state in late winter during the QBO-W/S_{min} years relative to the other three groups (QBO-W/S_{max}, QBO-E/S_{max}, and QBO-E/S_{min}), in agreement with the work of Labitzke and van Loon (1988). Their findings are in agreement with the smallest magnitude of the Arctic total ozone in QBO-W/S_{min} years among the four categories (Li and Tung 2014), because the ozone depletion is enhanced in the stable and cold polar vortex associated with an increase in chemical destruction through heterogeneous reactions on the Polar Stratospheric Clouds (PSCs). Since the Arctic ozone amount is related to the ozone transport as well as the chemical ozone destruction, the estimation of their influences is still challenging issue for understanding the small amount of the Arctic total ozone in March.

In this study, we analyze the Arctic ozone amount using TOMS/OMI observations, ERA-interim reanalysis data, and the outputs of a chemistry climate model (CCM) with REF-C1SD hindcast simulation, in which the model’s zonal/meridional wind and temperature are nudged toward those of the ERA-interim reanalysis data with a 6-hour interval. The anomaly from the average for all the years of 1979–2011 in the Arctic total ozone amount is calculated for QBO-W/S_{min} group in late winter. We estimate the amounts of ozone transport and chemical ozone destruction and their effects on the derived Arctic ozone anomaly for the QBO-W/S_{min} group with CCM outputs.

Result of the composite mean for QBO-W/S_{min} years shows negative anomaly (relatively small amount) of total ozone in February–March compared to the 1979–2011 average from the CCM output, in agreement with the satellite observation, reanalysis data. To distinguish the effect of chemical ozone destruction from that of ozone transport for the total ozone anomaly in February–March, we analyze the total ozone anomaly of the passive ozone tracer without any chemical change in the CCM. The negative anomalies of the passive ozone tracer have a similar distribution to that of chemically reactive ozone with similar magnitude, suggesting that the negative anomalies of total ozone are mainly caused by ozone transport.

The outputs of CCM are also analyzed for vertical profile of ozone concentration, which indicates negative anomaly of the Arctic ozone in the upper troposphere and the lower stratosphere for the QBO-W/S_{min} condition, the maximum anomaly of ozone partial column is located around 50–70 hPa. The partial column of the passive ozone tracer at these levels also shows negative anomalies, whilst their magnitudes are small, especially at 50 hPa in March. These results suggest the significant influence of ozone transport on the negative ozone anomaly in February–March, whilst the influence of chemistry is partially large at 50 hPa in March.

Keywords: stratospheric ozone, Northern Hemisphere polar vortex, chemistry climate mode