Influences of QBO and solar cycle on the Arctic ozone

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The quasi-biennial oscillation (QBO) and the solar 11-year cycle are known to cause year-to-year variability of the Northern Hemisphere (NH) polar vortex (e.g., Holton and Tan, 1980; Labitzke and van Loon, 1988). Yamashita et al. (2015) indicated that the polar vortex is strong in early winter and weak in late winter for the westerly phase of the QBO (QBO-W) and solar maximum (S_{max}) years. In contrast, the polar vortex is strong from early to late winter for the QBO-W and solar minimum (S_{min}) (QBO-W/S_{min}) years, implying the small Arctic ozone in late winter. Li and Tung (2009) found that the observed Arctic total ozone in March is the smallest in magnitude for the QBO-W/S_{min} years.
In this study, the influences of QBO-W/S_{min} on the Arctic ozone in late winter are analyzed from outputs of a chemistry climate model (CCM) in which the meteorological fields of the model are nudged toward the observational data for 1979-2011. The strong polar vortex relative to the climatology is shown in February-March during QBO-W/S_{min}. The minimum of Arctic total ozone is simulated during the QBO-W/S_{min} condition in February-March, in agreement with the satellite observations. We also analyze the total ozone derived from passive ozone tracer that is simply advected without any chemical change. The results of the passive ozone tracer show the similar results of the original total ozone, suggesting the prominence of transport change of ozone for the minimum total ozone under the QBO-W/S_{min} condition in February-March. The further analysis of the vertical structure suggests that while the minimum of Arctic total ozone is mainly explained by the transport change of ozone around 100-200 hPa, the enhancement of chemical destruction of ozone due to the low temperature within the polar vortex observed around 20-50 hPa under the QBO-W/S_{min} condition is partly related to the local ozone depletion around 20-50 hPa.

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