Outstanding seasonality of the lower tropospheric ozone over central China observed by Ozone Monitoring Instrument (OMI)

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Recent study by Cooper et al. (2016) reviewed global ozone (O_3) measurements, and showed a significant positive trend of the surface O_3 over East Asia after 1990' s. However, as the number of ground-based stations in East Asia is limited, a whole picture of the spatial distribution and its interannual variability of the boundary layer O_3 over East Asia is not yet well captured by observations. On the other hand, recent technological advances have made it possible to observe atmospheric concentrations of O_3 from space. However, almost 90 % of O_3 is available in the stratosphere while the amount of O_3 in the boundary layer is usually only several percentage of the total amount. Therefore, the vertical discrimination of O_3 in the lower troposphere is a big challenge in satellite-borne measurements. In spite of the difficulty, substantial progress has been made on this problem. Liu et al. (2010) successfully derived the ozone profiles from the surface up to 60 km into 24 layers using the ultraviolet spectra observed by Ozone Monitoring Instrument (OMI). The lowermost layer corresponds to a layer from 0 km to about 2.5~3 km above the surface. Hayashida et al. (2015) examined the 24th layer of their products and assured the reliability of the O_3 in the lower troposphere under enhanced O_3 conditions. They reported O_3 enhancement observed in Central and Eastern China (CEC), with Shandong as its center, and most notable in June in any given year.
In this study, to reveal spatial and temporal variation of ozone distribution over CEC, we applied cluster analysis to the OMI O_3 data over the regions. We focus the anomaly of ozone (DO_3), which is defined as the difference from the a priori values ($DO_3 = O_3$[retrieval] $-O_3$[a priori]). This analysis is effective to follow O_3 enhancement under polluted condition, because our focus is the temporal O_3 enhancement from the background level, i.e. climatological values. The DO_3 values can be interpreted as an indicator of the ozone enhancement from the background level.
Before cluster analysis, we applied the screening as described in Hayashida et al. (2017) for all OMI retrievals during the period from October 2004 through December 2013 to remove any doubtful data that might be affected by the UT/LS ozone variability.
We divided all of the grids in the range of 25°- 40°N, and 100°-135°E into some clusters according to the similarity of the seasonal variation of DO_3 at the 24th layer. The function used for the analysis is based on the complete linkage method for hierarchical clustering implemented in the statistical tool R (R Core Team, 2012). The number of the cluster was given from 4 to 11. By this analysis, we can distinguish the areas where DO_3 has outstanding seasonality over the North China Plain and Sichuan basin (named as Cluster 1). The Cluster 1 corresponds to the areas of high NO_2 concentration observed by satellite sensors. The values of DO_3 as well as O_3 in Cluster 1 show high in summer (in June in particular) and low in winter. We compared those clustered areas with the model simulations by Meteorological Research Institute –Chemistry Climate Model (MRI-CCM2) (Deushi and Shibata, 2011). The Cluster 1 corresponds to the areas of high chemical production rate in June in the model simulation. We also compared the results of cluster analysis with meteorological data. Along the coastal area, DO_3 tends to drop to negative values (less than climatology) temporarily in August, which can be interpreted as the inflow of oceanic clean air into the inland area.

References

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