Influence of stratospheric intrusions on the lower free tropospheric ozone at Lulin Atmospheric Background Station

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Introduction

Stratospheric intrusion (SI) often brings O₃ rich air with low humidity from stratosphere rapidly deep into the troposphere. In this study we present O₃ data in the free troposphere and selected SI events observed at Lulin Atmospheric Background Station (LABS, 23.47° N, 120.87° E, 2862 m a.s.l.) from April 2006 to March 2011. The LABS is a high-altitude site located in East Asia. During the 5 years of measurement, distinct seasonal variation of O₃ was observed with a springtime maximum and a summertime minimum (Fig. 1). Diurnal cycles were also observed at the LABS, with a maximum around midnight and a minimum during noontime (Fig. 2). The O₃ seasonal cycle was predominately shaped by the long-range transport of biomass burning air masses from Southeast Asia and oceanic influences from the Pacific, respectively (Figs. 3 and 4).

Case studies

The characteristics of selected SI were investigated in association with Modern Era Retrospective Analysis - 2 (MERRA-2) assimilated data provided by NASA/GSFC.

Case 1 (2007/1/9)

The SI occurred in the surrounding area of Taiwan (Fig. 10). In this case (Fig. 11), the O₃ was approximately 18.5 ppb higher than the mean mixing ratio of that month (33.3 ppb). Downward winds in association with increased vorticity can be found in this case (Fig. 12).

Case 2 (2010/2/21)

In this case, the SI occurred in southern China at location of approximately 22° N x 110° E (Fig. 13) and then transferred toward LABS in the western Pacific (Figs. 14-15).

Fast-screening algorithm to identify SI events

An algorithm as addressed in Figs. 5 and 6 is proposed to identify SI events at the LABS. Only the SI events with rapid increasing O₃ and decreasing relative humidity (RH) were targeted in this study (Fig. 7). Most SI events were observed in winter (November - January) (Fig. 8). The O₃ mixing ratio was elevated approximately 11.5 ppb on average during the 64 detected SI events, whereas the mean O₃ mixing ratio was estimated to be 32 ±15.2 ppb.

Fig. 1 Five years of O₃ observation at the LABS.
Fig. 2 Diurnal cycle of O₃ and relative humidity (RH) at the LABS.
Fig. 3 Cluster analysis of 5-days backward trajectories.
Fig. 4 Frequencies of classified trajectories in each month.

Fig. 5 Proposed algorithm to select SI events.
Fig. 6 Calculation of O₃ and RH increasing/decreasing rate with 3-hr moving averages (dash lines).
Fig. 7 Distribution of (a) O₃ increasing rate and (b) RH decreasing rate during an event.
Fig. 8 Seasonal variation and enhanced levels of O₃ by SI at the LABS from April 2006 to March 2011. Numbers of detected events in each month are listed on the top of the figure.

Fig. 10 MERRA-2 (a) O₃ and (b) water vapor (WV) at 700 hPa in East Asia. The marked area indicates the location of the SI.
Fig. 11 Time-series of MERRA-2 vertical profiles and in-situ data at the LABS.
Fig. 12 Latitude-altitude cross-section of MERRA-2 O₃, omega (Ω) and potential vorticity (PV) at longitude of 120.87° E.

Fig. 13 MERRA-2 (a) O₃ and (b) WV at 700 hPa in East Asia. The marked area indicates the location of the SI.
Fig. 14 Time-series of MERRA-2 vertical profiles and in-situ data at the LABS.
Fig. 15 Longitude-altitude cross-section of MERRA-2 O₃, Ω and PV at latitude of 23.47° N.