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 O_3 rich air with low humidity from stratosphere rapidly deep into the troposphere. In this study we present O_3 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 O_3 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 O_3 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**).

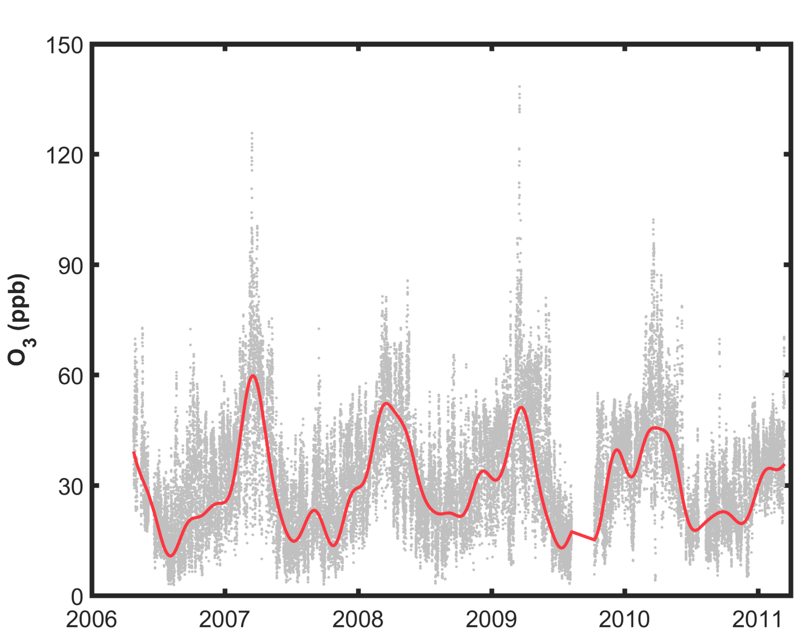

Fig. 1 Five years of O_3 observation at the LABS.

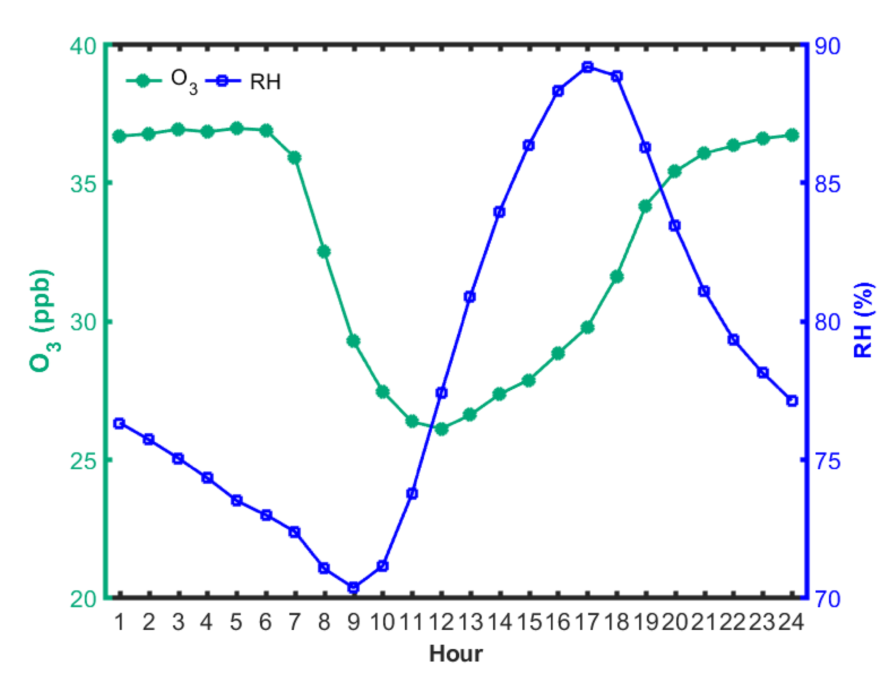

Fig. 2 Diurnal cycle of O_3 and relative humidity (RH) at the LABS.

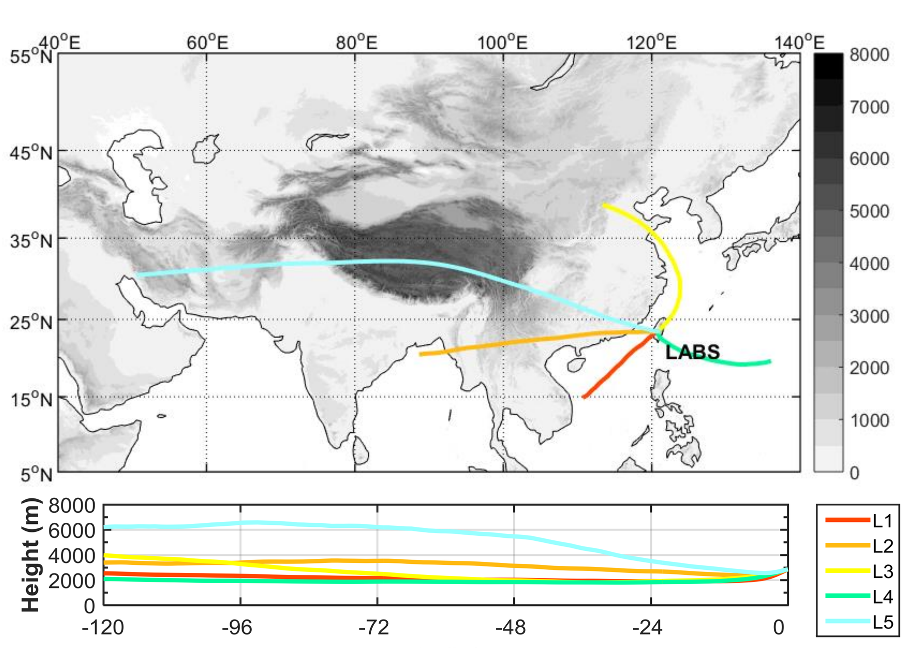

Fig. 3 Cluster analysis of 5-days backward trajectories.

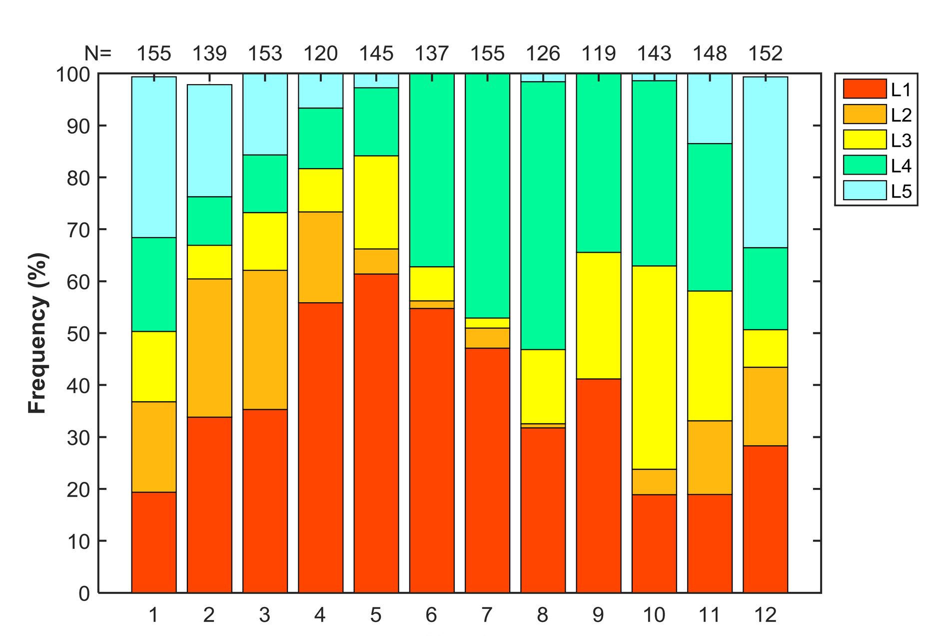

Fig. 4 Frequencies of classified trajectories in each month.

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 O_3 and decreasing relative humidity (RH) were targeted in this study (**Fig. 7**). Most SI events were observed in winter (November - January) (**Fig. 8**). The O_3 mixing ratio was elevated approximately 11.5 ppb on average during the 64 detected SI events, whereas the mean O_3 mixing ratio was estimated to be 32.8±15.2 ppb.

1. RH < 30%
2. $[O_3]$ > 1.1 x monthly $[O_3]$ avg.
3. [CO] < 25th [CO] of individual month
4. $\Delta[O_3]/\Delta t$ > 1.5 ppb/hr **(> 75%)**
5. $\Delta RH/\Delta t$ < -6%/hr **(< 50%)**

Fig. 5 Proposed algorithm to select SI events.

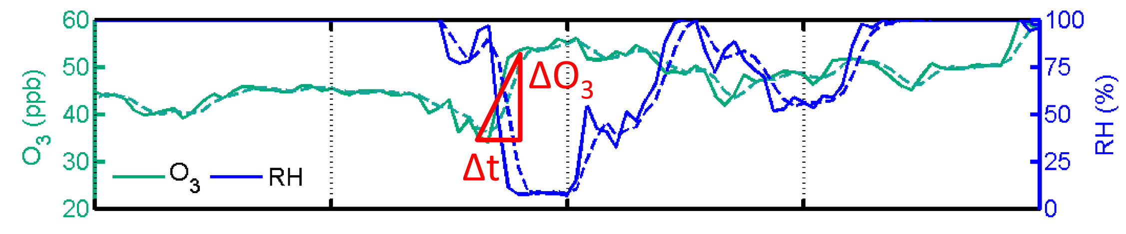

Fig. 6 Calculation of O_3 and RH increasing/decreasing rate with 3-hr moving averages (dash lines).

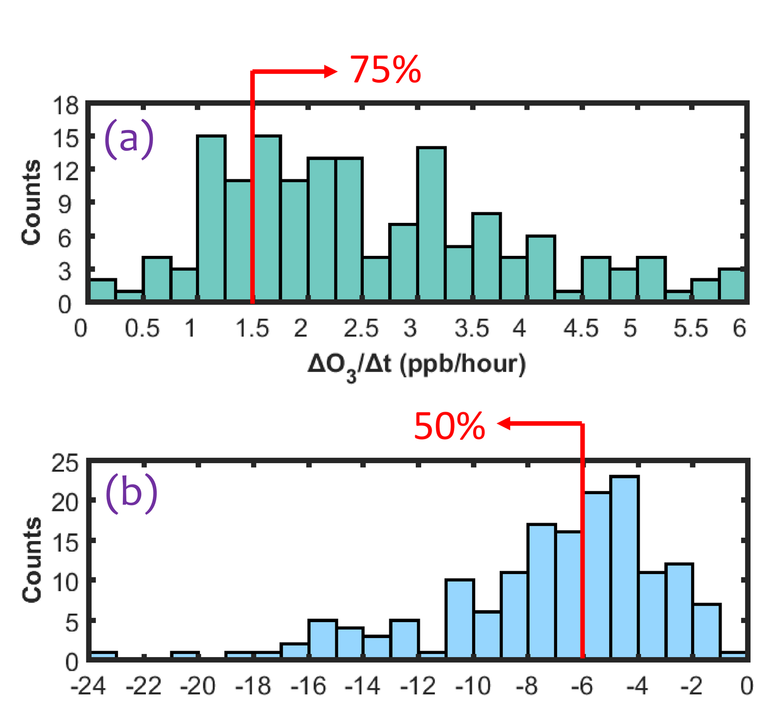

Fig. 7 Distribution of (a) O_3 increasing rate and (b) RH decreasing rate during a event.

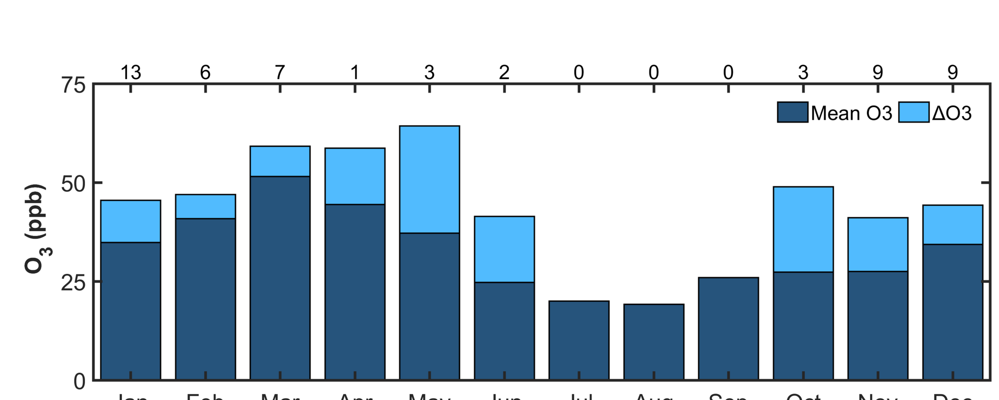

Fig. 8 Seasonal variation and enhanced levels of O_3 by SI at the LABS from April 2006 to March 2011. Numbers of detected events in each month are listed on the top of the figure.

Case studies

The characteristics of selected SI were investigated in associated 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 O_3 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**).

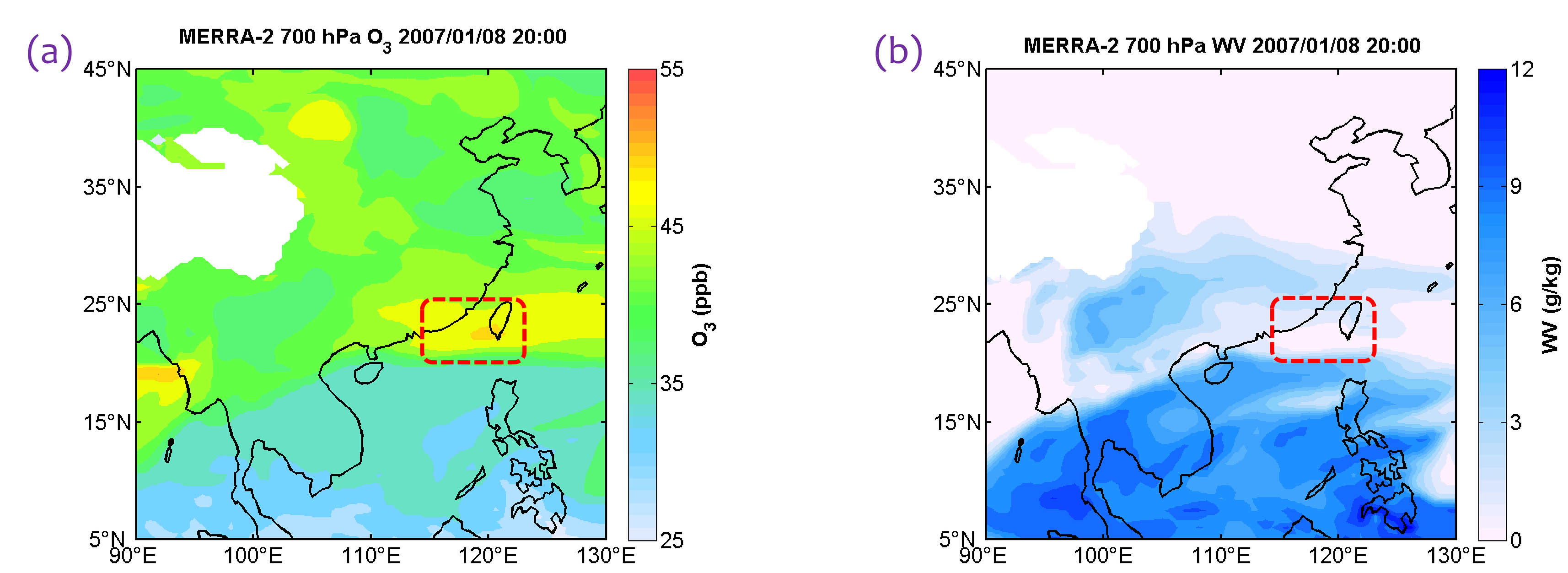

Fig. 10 MERRA-2 (a) O_3 and (b) water vapor (WV) at 700 hPa in East Asia. The marked area indicates the location of the SI.

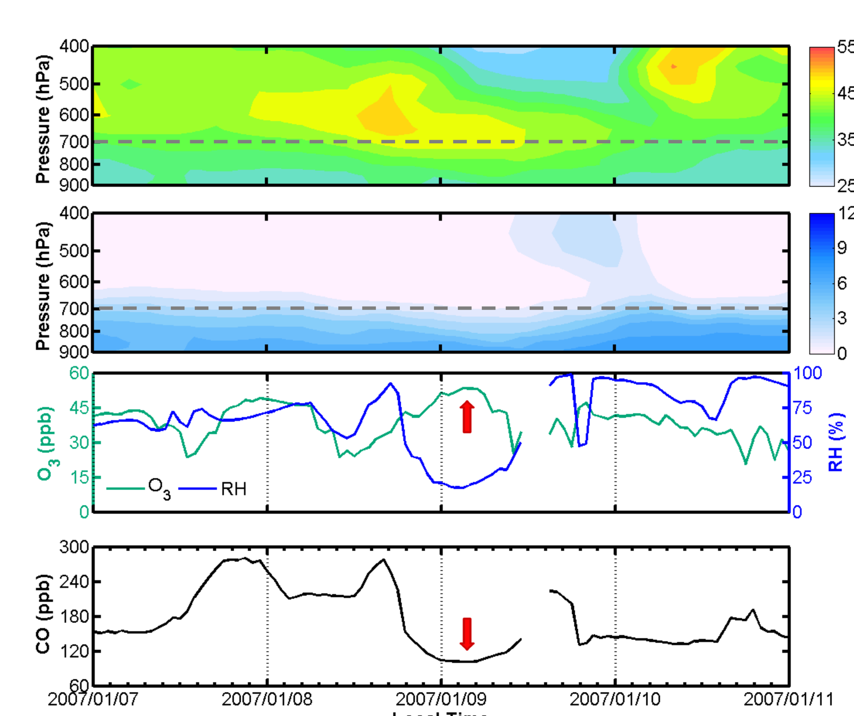

Fig. 11 Time-series of MERRA-2 vertical profiles and in-situ data at the LABS.

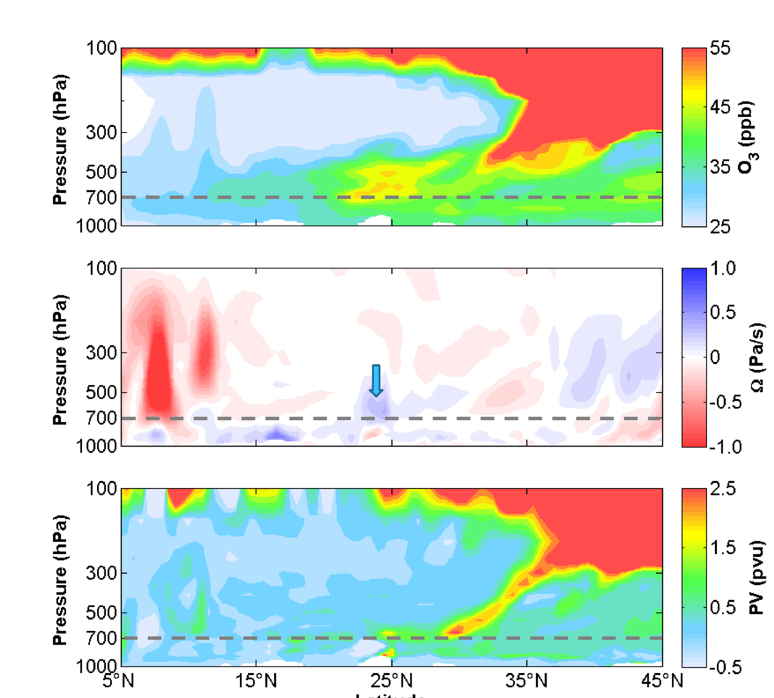

Fig. 12 Latitude-altitude cross-section of MERRA-2 O_3, omega (Ω) and potential vorticity (PV) at longitude of 120.87˚E.

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 was transported toward LABS in the western Pacific (**Figs. 14-15**).

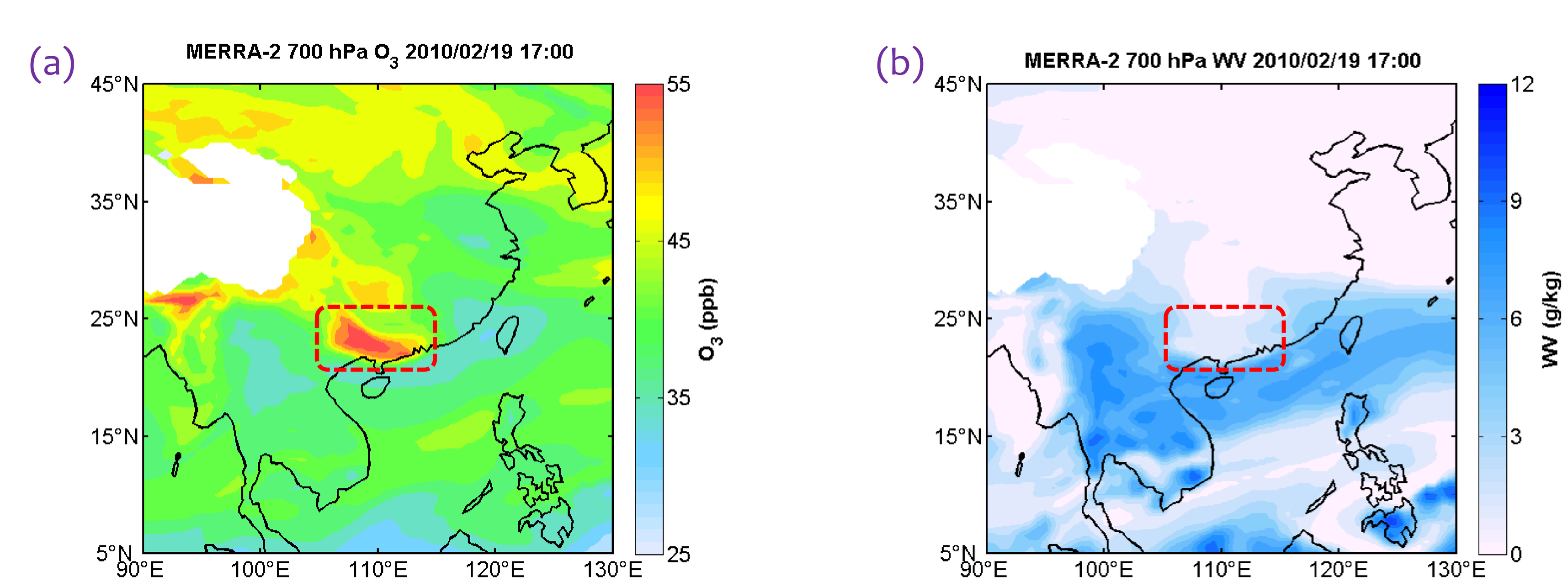

Fig. 13 MERRA-2 (a) O_3 and (b) WV at 700 hPa in East Asia. The marked area indicates the location of the SI.

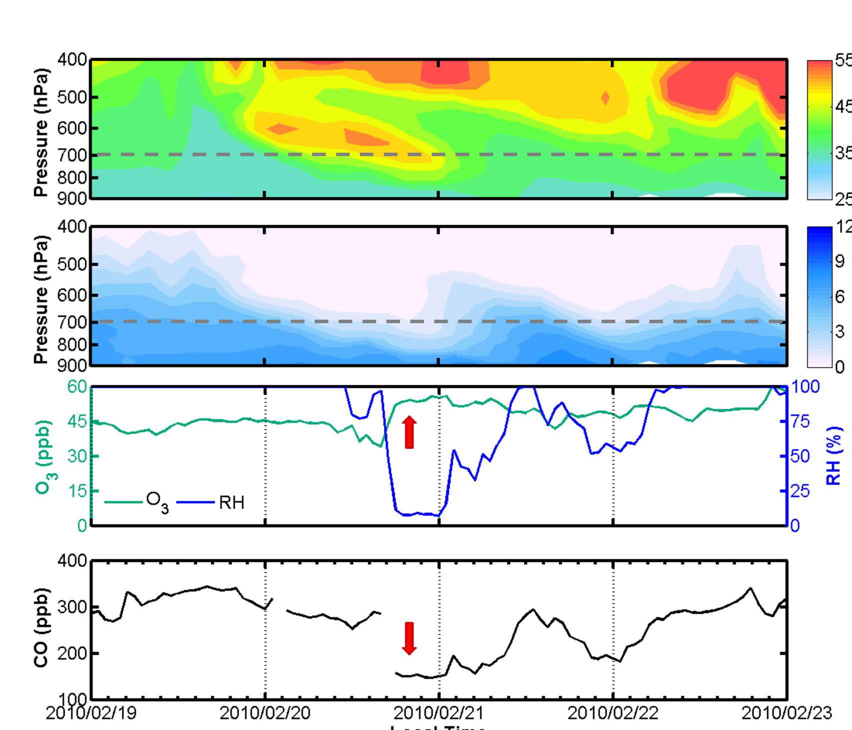

Fig. 14 Time-series of MERRA-2 vertical profiles and in-situ data at the LABS.

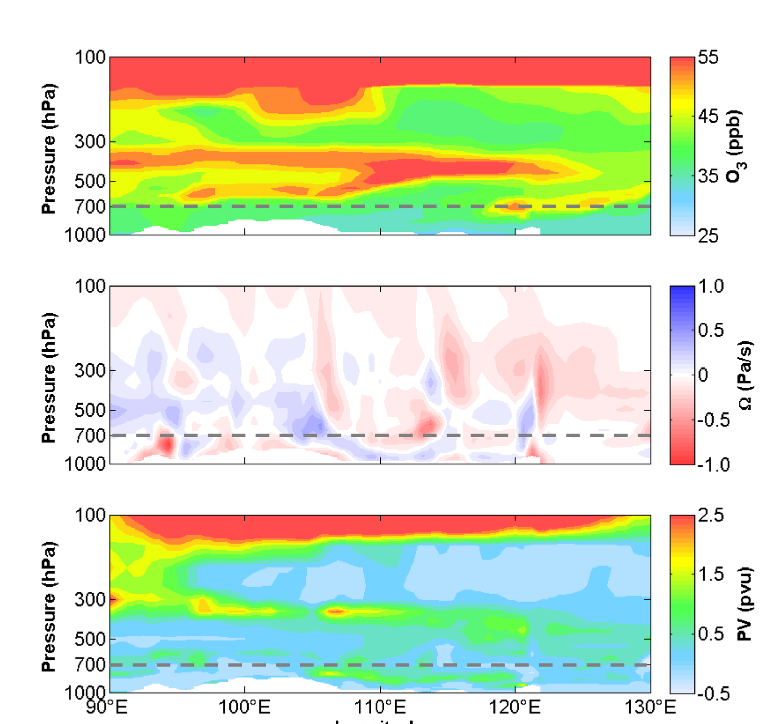

Fig. 15 Longitude-altitude cross-section of MERRA-2 O_3, Ω and PV at latitude of 23.47˚N.