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Atmospheric Chemistry and Physics Discussions

Interactive comment on "A new transport mechanism of biomass burning from Indochina as identified by modeling studies" *by* C.-Y. Lin et al.

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Reviewer #2

We greatly appreciate the constructive comments and suggestions from this reviewer and, accordingly, have revised the paper. The detail response as following:

Specific comments:

1-1. the authors must comment on whether the 11 April 2005 event is a unique event or if it has been observed multiple times. The authors should determine if a trough at the lee side of Tibetan Plateau was present and can be linked to the events.

R: The case we simulated in this study had the highest concentration at around 4 km

during our intensive measurement programs in 2004 and 2005 (36 samples in total) but not the only one. In this revision, we further present another 2 cases (6 May 2005, and 20 April, 2005) with significant average ozone peak around 4 km (about 95 ppb, Figure 6a) and the average weather map (Fig. 6b, similar to mean average weather map) deduced from NCEP/NCAR reanalysis dataset (Page 12, L9-L15). Actually, the average weather map is similar to the mean trough in Figure 9a, i.e., the existence of a significant leeside trough over Indochina. On the contrary, there were three cases (1 April, 2005, 14 April, 2005, and 17 April, 2005) with no significant ozone peak around 4 km (Fig. 8a). Figure 8b shows the average of 850 hPa geo-potential height deduced from NCEP reanalysis dataset which shows no leeside trough east of Tibetan Plateau and Indochina mountains (Page 13, L14-L19).

The climatology analysis (Figure 9a) shows the mean trough exist implying the leeside trough occurs frequently. Yet, although the number of active fire detections impacts the downwind tracer peak, the weather system also plays a critical role to the lifting and transport. Without leeside trough and upward warm advection, local convective and turbulent activities are insufficient to lift the pollutants over Indochina, even if a large amount of pollutants are present over there. That's why sometimes we can measure ozone peak but sometimes not. However, the existence of the leeside trough plays to provide the upward motion and hence affect the concentration of the tracer over the downwind area. As stated in the article, there are limited ozone soundings in the previous in Taiwan. Based on our intensive samples, tracer simulation and the clearly dynamic forcing of the mountain over Indochina we hence proposed this mechanism.

1-2. The authors need to discuss previously reported elevated ozone –biomass burning events in the region (Chan et al., 2003a, 2003b, Liu, 1999) and comment on the likelihood their proposed transport mechanism played a role in these events.

R: As mentioned in article in Introduction, we already pointed out the defect of the previous study (Chan et al. 2003a, 2003b, and Liu et al. 1999). They just general mentioned the mechanism similar to the study area around the equator by other researchers (Page 4, L13∼Page 5, L7). However, the lofting mechanism is quite different even the Indochina is the scope of the South East Asia. In this revision, we further discuss if it is possible that the thermal buoyancy forcing from fire plumes to lift pollutants above 3 km, without any other forcing (Page 14, section 6, Discussion).

In addition, the previous studies generally use the trajectory analysis to link the peak ozone occurrence over Hong Kong (Chan et al. 2003a, 2003b, and Liu et al. 1999.). In this study, we have pointed out the traditional trajectory analyses can only describe atmospheric air masses motion (i.e. large-scale circulation) in part as they do not consider important physical processes (e.g. dry and wet depositions) and dynamical process (e.g. small-scale convection and turbulent mixing) (Page5, L16-Page6, L6). Our tracer simulation provides the high resolution and reliable transport mechanism from Indochina to Taiwan.

2-1. The sensitivity study as presented by the authors, does not demonstrate that the absence of a leeside trough is responsible for the lack of tracer over the Taiwan. Details of the sensitivity study are completely insufficient. ….. The authors should provide the results of Hysplit simulations for the sensitivity study (similar to Fig. 2, but 4/10-4/14) and near surface weather charts (similar to Fig 3.)

R: For this comments, it is due to some figures are not presented in our original manuscript. In this revision we included the figures of weather map, trajectory analysis, ozone profile in northern Taiwan and the simulated horizontal distribution of tracer concentration at level 650 hPa for a non-ozone event (Figure 7a-d). This study indicated that no significant tracer occurred in northern Taiwan even we give the same active fire points as the control run. Indeed, this case is with a very weak trough and no elevated ozone was observed over northern Taiwan. (Page 12, L17-Page 13, L13)

2-2 Can the authors identify a period with trajectories similar to these in Fig 2c. but in the absence of a lee side trough and without elevated ozone over the northern Taiwan site ?

R: We do see the cases with the similar trajectory paths but without elevated ozone over northern Taiwan and lack of significant leeside trough (Figure 7a-d). As response to question#1-1, there were 3 cases belong to this type and we already showed the average ozone profile and the average of 850 hPa geo-potential height in Figure 8a-b. (Page 13, L14-Page 14, L1)

3-1. The authors must describe the MODIS data they are using. Is it Terra only (MOD14) or is Aqua also used (MYD14) ? What MODIS collection was used ? Where was the data obtained ? Was it acquired from the Land Processes Distributed Active Archive Center (LPDAAC), or was it from another sources, e.g. University of Maryland ? The MODIS active fire product should be identified and described (Terra only, Terra & Aqua, Collection 4 or Collection 5 etc) and referenced (Giglio et al. 2003)

R: The MODIS data we used in this study is the Collection4, MOD14 (i.e. Terra only) with 1 km resolution and the data obtained from LP DAAC (Land Processes Distributed Active Archive Center)(https://lpdaac.usgs.gov/lpdaac/products/modis_products_table/thermal_anomalies_fire/5_min_l2_swath_1km/v5/terra). (Page 6, L15-17) We further cited the papers what reviewer recommended (Page 3, L15-16).

3-2. The authors should use " active fire" detections and not simply "fires.

R: Text has been amended in this revision (Page 2, L4; Page 4, L3; Page 7, L1; Page17, L5 , Page 25, L3, L5 and L10)

3-3 Biomass burning in SE Asia in the introduction, the authors should include relevant references for remote sending based biomass burning estimated that include SE Asia-van der werf et al. (2006), Giglio et al. 2006a and 2006b.

R: We already included those references papers in this revision (Page 3, L15-16)

3-4. The authors need to address the possibility that thermal buoyancy of fires plumes is responsible for the lofting of emissions to above 3km. Survey the literature to obtain estimates for a range of fuel load, fuel consumptions and burned area of typical fires in the region. Then estimate the range of initial buoyancy flux and estimate plume raise height using the Briggs equation.

R: In this revision, we further discussed the possibility that thermal buoyancy of active fire plumes for the lofting of emission in Discussion section (page 14-Page 15, L9)

With this regarding, the Briggs equations (Arya 1999) are employed to estimate the plume rise heights. The Briggs plume rise in stable or neutral conditions as following: ∆H=1.6Fb1/3(u)-1Xf2/3 ……………………………………………………………(1) where, Fb denotes the buoyancy flux parameter (m4s-3); u is wind speed at actual stack height (m/s); Xf is downwind distance from plume source to point of maximum plume rise (m). Fb= gd2Vs(Ts-Ta)/4Ts (g: Acceleration due to gravity, Vs: Stack exit velocity, d: Exit gas diameter, Ts: Stack gas exit temperature, Ta: Ambient air temperature)

Here, we assume Vs=10 m/s, Ts=1000 K, Ta=298, d=2 m, then Fb=34 (m4s-3), we assume Fb could reach as high as 1000 m4s-3 , and Xf=1000 m, then the plume rise high ∆H would be only 160 m (from equation (1)). Yet, the biomass burning should be area source and will not apply to the wild fire. Based on the above equation, we estimate the plume rise height should be only few hundred meters under the stable and neutral conditions. Further, Nopmongcol U. (http://www.crwr.utexas.edu/gis/gishydro03/Classroom/trmproj/Nopmongcol/report.htm) studied the plume rise for forest fires during Texas Air Quality Study period by using ArcGIS modeling tool. He analyzed three wild fire events and showed similar trend of plume rise with low height at night time and peak during the late afternoon. The maximum plume rise height is in range of 800-1300 m in his study. Therefore, even though the highest topographic height is nearly 1000 m (cross section topographic in Fig. 5b) over Indochina, additional forcing is needed for a large amount of biomass burning products to be lifted to above 3 km. Therefore, we believe the leeside trough east of the Tibetan Plateau and Indochina mountains is one of the major contributors, at least, for uplifting the biomass burning products from Indochina into the westerlies.

Technical corrections:

1. P13156 L4: and P13164, L24, The uses of “fires” is not strictly correct suggest” active fire detections:

R: Text has been amended in this revision (Page 2, L4; Page 4, L3; Page 7, L1; Page17, L5 , Page 25, L3, L5 and L10) .

2. L24-27 P13157, L1-3: Needs additional references (van der wrf et al. (2006), Giglio et al. 2006a, 2006b)

R: The references have been added in the article (Page 3, L15-16)

3. P 13158, L19-20: P 1360, L10-13, what version of WRF/Chem was used ? please specify, Did the authors develop and use their own tracer module or did they use a tracer available with WRF/Chem.

R: The version of WRF/Chem used in this study is version 3.0.. We develop and use our own tracer module in WRF/Chem. (Page8, L12-15)

4. P13160: Please describe WRF/Chem simulation. How many vertical levels, where the vertical levels “stretched”, what is the height of the lowest model layer

R: In this study, the horizontal resolution for our simulations was 27 km and the grid box has 200 $\times$ 200 points in the east-west and south-north directions, respectively. There are 35 levels (The σ levels are: 1.000, 0.998, 0.994, 0.990, 0.985, 0.980, 0.970, 0.960, 0.945, 0.930, 0.910, 0.900, 0.890, 0.870,0.850, 0.820, 0.790, 0.760, 0.720, 0.690, 0.660,0.630, 0.600, 0.550, 0.500, 0.450, 0.400, 0.350,0.300, 0.250, 0.200, 0.150, 0.100, 0.050, 0.000.) in the vertical and the lowest level is about 20 m above the surface. (Page 9, L1-L9)

5. P13161, L8010. It is not unreasonable that the fire plume could reach 1-2 km agl in height. This should be discussed.

R: The backward trajectory analysis only can show where the air masses come from. It does not have the capability to indicate the fire plume can rise and exactly reach northern Taiwan. That's the reason why we use the tracer module in WRF/Chem modeling system to study the transport.

6. P13163, L11, Should read " Fig 5g"

R: Text has been amended.

7. P13164 L16: 'profound' is a poor choice of adjectives.

R: Text has been amended. (Page 16, L17)

8. P13165, L2-4:'The sensitivity study suggest what we proposed……Please see specific comment #2 above.

R: Text has been amended and response in Specific comment #2-1.

9. P12165, L5-7: The authors have not demonstrated that thermal buoyancy of fire plumes is not adequate to loft emissions above 3km. Please see specific comment#3c

R: Text has been amended and response in Specific comment #3-4.

10. P13167, L13: Reference Liu et al. 2003. title should read' Asian pollution' not 'Asian combustion...'.

R: Text has been amended. (Page 23, L1-3).

11. Figure 1 and Figure 2, The caption should read 'Active fire detections' not fires.

R: Text has been amended. (Page 25, L3, L5 and L10)

12. Figure 3 Site source of analysis in the caption.

R: Text has been amended. (Page 25, L14)

13. Figure 4 Include the vertical levels of these figures. Is the a pressure level or model level ? what level is it .

R: Those figures for the vertical are all pressure level at 650 hPa. (Page 25, L17)

14. Figure 6c& 6d y-axis label is needed.

R: The label in y-axis has been amended in Fig. 9 c-d

15. Several instances of poor or awkward grammar are present: P13156, L10-12 P13157, L8-11 P13158, L9-11 P13158, L24 P13162, P15-17 P13164, L17-19, P13156, L14-15.

R: Text has been amended. (Page 2, L10-12; Page4, L3-L5; Page 5, L11-14 ; Page16,L18-19 and Page 17 L1)

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