We would like to thank the referee for the thoughtful and insightful comments. We have addressed all of the comments. Our responses are as following in blue.

Title: Climatological perspectives of air transport from atmospheric boundary layer to tropopause layer over Asian monsoon regions during boreal summer inferred from Lagrangian approach (MS No: acp-2011-962)

Comments by Anonymous Referee #3

Reviewer #3 (Comments): This manuscript gives a detailed description of air transportation into the ASM tropopause layer from the boundary layer from a large amount of trajectory model running. These results will enhance our understanding of how the atmospheric species and pollution in the lower level is transported into the global stratosphere from the ASM region. I recommend the publication of this manuscript in ACP journal. However, I would like to provide some concerns in the following.

In the part of 2.2 Methodology, could you give more information, such as:

(1) Is the FLEXPART model run forward, not backward? Regionally or globally? (2) How is the total atmospheric mass (7.0×10^{11} kg) estimated?

Reply: The FLEXPART model is run forward and a limited domain is chosen in this work. Each particle receives the same mass, altogether accounting for the total atmospheric mass over Asian monsoon region. Please kindly find the details related to these two questions in point (5) below.

(3) How to deal with the particles that come into the tropopause layer over ASM region but from PBL somewhere outside of ASM region? How to estimate their contribution? (4) And how deal with the particles that depart from PBL in the ASM region but come into the tropopause layer outside of the ASM region?

Reply: The main subject of this work is concentrated on the atmospheric composition in stratosphere over Asian monsoon region. In this work, we only considered the TST-trajectories (air parcels) depart from PBL in the ASM region and then arrived at the tropopause over Asian monsoon region. Additionally, as the Asian monsoon region cover a vast region, we thought that the air parcels outside of ASM region fulfill this criterion could make a significant contribution to these transport. Thus the particles those departed from PBL in the ASM region but come into the tropopause layer outside of the ASM region are beyond the scope of the current manuscript.

(5) How are these 2.2 million particles distributed horizontally and vertically? Does each particle have the same mass?

Reply: In order to identify each particle trajectory, the whole column atmosphere over the

ASM region (40 °E–160 °E; -10 °N–60 °N) is divided homogeneously into 2.2 millions particles at the beginning of modeling. The atmosphere is "filled" homogeneously with parcels, each representing an equal mass (roughly equal to 7.0×10^{11} kg) of the total atmospheric mass in the atmosphere according to the distribution of atmospheric density.

(6) Since FLEXPART model is Lagrangian one, how often do you start the initial particles, daily, weekly, or other? And how long do you trace these particles each turn?

Reply: Once the initialization of each modeling, the time period of integration for each summer modeling lasted for107 days, ranging from 00UTC, 15 May to 00UTC, 31 Aug. The analyses are based on the model output from 1, Jun to 31, Aug (JJA), as claimed in the paper. The time steps for the FLEXPART model integration is 600s. In this modeling, at the outflowing boundaries particles are terminated. So the tracking for every TST-trajectories (air parcels) lasted for a quite long time, depending on the time of boundary-crossing of Asian monsoon region (40 °E–160 °E; -10 °N–60 °N).

(7) Since NCEP/GFS has no vertical velocity above 100 hPa, how to deal with the vertical wind there?

Reply: In this work, we focus on the transport processes from the atmosphere boundary to the altitude of tropopause. Since most tropopause is below 100 hPa, we didn't think the vertical velocity above 100 hPa could not exert a significant effect on the results presented in the manuscript.

(8) How to count the TST-trajectories? Do you care the region where the trajectory enters the tropopause layer, in the ASM anticyclone, middle latitude, or even the tropics?

Reply: The TST-trajectories are selected and defined as those parcels departed from the atmospheric boundary layer and then undergo tropopause-crossing during the period from 1, Jun to 31, Aug (JJA) days forward tracking. Additionally, we apply a residence time criterion to the trajectory. The air parcel lasts for at least 24 h in the troposphere after the tropopause-crossing. We counted all the air parcels as the number of TST-trajectories.

We took the Asian monsoon region (40 °E–160 °E; -10 °N–60 °N) as a whole in this study without a consideration for different regions.

(9) How to determine the PBL, especially in the plateau regions? (10) How to define the tropopause height?

Reply: These two questions are similar to the comments by another reviewer. (1)The PBL heights are calculated according to Vogelezang and Holtslag (1996) using the critical Richardson number concept. The PBL height is set to the height of the first model level for which the Richardson number exceeds the critical value of 0.25. (2) As to the tropopause definition, the dynamical tropopause is used in middle and high latitude, while thermal one in tropical region. In subtropics, linear interpolation method is adopted to get the hybrid tropopause. The dynamical tropopause refers to the potential vortices

surface of 2 PVU (1 PVU=1.0×10^{-6} m^2 s^{-1} K kg^{-1}), and the thermal tropopause follows the definition of WMO (the height apart from ground more than 500 hPa, and with temperature lapse rate less than or equal to 2℃/km. More details could be found in Technical note by Stohl A et al. (2005).

Descriptions related to the questions above have been added accordingly in update paper.

References:

Vogelezang, D. H. P. and Holtslag, A. A. M.: Evaluation and model impacts of alternative boundary-layer height formulations, Bound.-Layer Met.,1996, 81, 245–269, 1996.

Hoinka K P. The tropopause: Discovery, definition and demarcation, Meteorol. Z., 1997, 6, 281~303.

Stohl A., Forster C., Frank A., Seibert P., Wotawa G. Technical note: The Lagrangian particle dispersion model FLEXPART version 6.2. Atmospheric Chemistry and Physics. 2005, 5:2461-2474.