Response to the Reviewer #1

Dear Editor and Reviewers:

Many thanks for your careful reading and good comments for our manuscript entitled " Statistical Study and Corresponding Evolution of Plasmaspheric Plumes under Different Levels of Geomagnetic Storms". These valuable suggestions are really beneficial to our present research. We've carefully considered these suggestions and implemented the necessary changes, which we hope will adequately address the reviewers' concerns. The following are our primary replies to the reviewer's comments and the corresponding corrections.

<u>Responses to the Reviewer 1:</u>

Comments from Reviewer 1:

The preprint is dealing with plasmaspheric plumes in the Earth's magnetosphere and their occurrence rate dependence to geomagnetic storms intensity. The study is based on observations and simulations. The study is based on Van Allen Probe A observations of plasmaspheric plumes. Results are compared in detailed to the output of a previous study (Lee et al., 2016) that focused on the observations of plumes close to the magnetopause. Simulations of plume evolution are presented for two geomagnetic storms of different intensities to explain the different results between the present study and Lee et al. study. The overall impression of the study is positive: the paper is well-organized, the reasoning is logical, figures support the interpretation, and considering simulations to explain observations make the conclusion stronger.

Specific comments:

1. Only VAP-A observations are used (and not VAP-B), which make sense for the occurrence rate calculations. It is therefore surprising that only VAP-B orbit is overplotted on the simulation output with the indication "the black curves indicate the observed plasmaspheric plume" (Figure 5 and Figure 7). Why is that plume observation made by VAP-B? one could expect observations from VAP-A or, even better from both probes.

<u>Answer:</u> Thank you very much for your suggestion. As you kindly suggest, only VAP-B orbit is overplotted on the simulation output. The simulation output largely depends on the initial configuration of plasmasphere. The initial shape and density of real plasmasphere are very complicated, and there is obvious asymmetry of Earth's plasmasphere. However, the real initial configuration of plasmasphere is hard to obtain, thus only an empirical plasmaspheric model is adopted in the simulations. The output implies that there is larger deviation between the plume MLT observed by VAP-A and that provided by simulation. On the other hand, the deviation between the plume MLT observed by VAP-B and that provided by simulation is smaller. For those reasons, we only depict the orbit of VAP-B in the study.

However, the simulation in the study provides an alternative mechanism to interpret the evolution trend and occurrence rates of observable plasmaspheric plumes in different L shells.

In order to make it clearer, the sentences have been added as follows:

On lines 192-193:

'However, the real plasmasphere is hard to obtain, thus only an empirical plasmaspheric model is adopted in the simulations.'

On lines 160-164:

'It should be pointed out that the shape of the real plasmasphere is complicated. As it is difficult to obtain the absolutely accurate shape of a real plasmasphere, a typical plasmaspheric model is used as the initial distribution of electron density in the current study. Although there may be some deviations between the simulated plume and the real plume, the simulation can still reflect the trends of density variation.'

2. The main finding of the study is that the occurrence rate of plumes at lower l-shell is higher during large geomagnetic storms and higher at large l-shell during low geomagnetic storms. As shown in your simulations a given plume plume is larger close to the plasmapause (at low-shell) that farther from the plasmapause (at larger L-shell). The plume criteria detection is however the same for every L-shells. How can this affect the occurrence rate estimation, and hence the conclusion?

Answer: Thank you very much for your suggestion. As the reviewer kindly suggest, the criteria detection is the same for every L-shells, this may affect the estimation of occurrence rate. In fact, in previous studies, the researchers generally using the same criteria to identify the observable plume in different L shells, such as Lee et al., (2015), Zhang et al., (2019).

The plasmaspheric plume is structure detached plasma region which connect to main body of the plasmasphere. A key point of the study is to explain the proportion of observable plasmaspheric plume in different L shells associated with geomagnetic activity on account of traditional criteria.

In order to explain better, the sentences have been revised as follows:

On lines 256-258:

'The researchers generally using the same criteria to identify the observable plume in different L shells, such as Lee et al., (2015), Zhang et al., (2019). A key point of the study is to explain the proportion of observable plasmaspheric plume in different L-shells associated with geomagnetic activity.'

3. The two simulated events correspond to geomagnetic storm of still relatively moderate intensity. Is there any reason for not choosing a Dst<-100nT storm for the second event?

Answer: Thank you very much for your suggestion. Through the statistical analysis based on the observation of Van Allen Probe, we find that the number of plume events corresponding to Dst<-100 nT is very few. Only 2 observable plasmaspheric plume events is located in this Dst range (the total number of plasmaspheric plume is 422). In order to reflect the universality of evolutionary process the extreme cases while Dst<-100nT is not choosed for the second event.

4. L45: for EMIC the situation is a bit more complicated: EMIC are not preferentially observed in the high-density plumes (Usanova) excepted maybe for triggered emission (Grison)

Answer: Thank you very much for your reminder. In order to make it clearer, the sentence has been revised as follows:

On lines 45-49:

'The structureless hiss waves often arise in high-density plasmaspheric plumes (Meredith et al., 2004; Yuan et al., 2012; Zhang et al., 2018, 2019). Furthermore, although electromagnetic ion cyclotron (EMIC) waves are not preferentially observed in the high-density plumes (Usanova et al., 2013; Grison et al., 2018), the plume maybe related to the excitation of EMIC waves (Grison et al., 2018; Yu et al., 2016; Yuan et al., 2010).'

5. L146: Is there any discontinuity in the density or the Sheeley model states a density of 5 at L=7?

Answer: Thank you very much for your suggestion. Sheeley model is only valid for the region within L≤7. In the trough model from Sheeley et al. (2001), the density is ~5 cm^{-3}. To clearly exhibit the position of plasmapause for the simulation. Here, the electron densities outside the plasmapause are assumed to be 5 cm^{-3}, the electron density while L ≤ 7 is provided by the Sheeley plasmaspheric model. In this way, a relatively high density gradient (the position of plasmapasue) can be setted around L~7. In fact, the result of simulation is similar while the density is set to any value less than 5 cm^{-3} in the region with L>7.

In order to make it clearer, the sentences have been revised as follows:

On lines 151-156:

'To obtain the initial electron density distribution in the plasmasphere during the quiet geomagnetic period, the electron density in the plasmasphere as a function of the L-shell provided by the Sheeley et al. (2001) model is used (for L-shell ≤ 7). In order to clearly exhibit the position near the plasmapause, the initial electron density is assumed to be the same at different MLTs. In addition, to simplify the calculation of the model, the electron densities outside the plasmapause are all assumed to be 5 cm^{-3}. In this way, a relatively high density gradient is assumed around L~7.'

6. Figure 4.c: It would be good to extend the time range to the stop time of the simulation (figure 5)

Answer: Thank you very much for your suggestion. In the rewvised manuscript, the end time of Figure 4 is set at 00:00 UT on 16 Feb 2013.

7. Technical corrections:

L25: A torus

Answer: Thank you very much for your suggestion, the error has been revised in the new version of manuscript.

L30: plasmaspheric particles: the convection given by the formula is sign-charge dependent

Answer: The directions of both gradient and curvature drifts depends on the sign-charge. On the other hand, the drift motion is independent of the sign charge. The velocity of E×B drift is: $\frac{\boldsymbol{E}\times\boldsymbol{B}}{B^2}$

L72: deleted artificially: "discarded" might sound better

Answer: Thank you very much for your suggestion. The sentence has been revised as follow: '...these spurious events are discarded...'

L94: define the "non storm" period

Answer: Thank you very much for your suggestion. In order to make it clearer, the sentence has been revised as follows:

‘The period except strom time interval (including initial, main and recovery phases) is defined as nonstorm.’

L101: dusk side: looking at the figure, you could even give a precise range 15-21MLT

Answer: Thank you very much for your suggestion. The sentence has been revised as follow:

On lines 107-108:

‘it seems that the plasmaspheric plume events observed in the recovery phase (174) occupy the largest proportion, and the plasmaspheric plumes in the recovery phase are mainly located on the dusk side (from MLT~15 to MLT~21).’