Response to Reviewers

Point-by-point responses to each comment are given in bold below. Line numbers correspond to the tracked changes version of the manuscript.

Reviewer 1

1. Effects of polar cap absorption. In the introduction, the authors mentioned past studies of the effects of polar cap absorption including their work (Bland et al., 2018). I wonder why this effect is not discussed in the present manuscript.

   In Lines 318-320 the authors said "...75-77 latitude (35% and 24% respectively). Although Grono and Donovan (2020) reported zero occurrence of optical PPA and PA at these latitudes, there are several PPA events..." I am concerned that the HF radar wave absorption at these latitudes is the effect of polar cap absorption.

   The absence of pulsating auroras at 74-77 latitudes was reported not only by Grono and Donovan (2020) but also by old literature by Oguti et al. (1981) (in the Supplement, see their Fig. 4). The authors should discuss the possibility of the effect of polar cap absorption.

   The event list used in this study is the same as from Bland et al., (2019), where solar proton events (i.e. PCA) had been excluded. This has now been clarified on line 193, and again in the discussion (lines 389–394). References to earlier work on the latitude extent of PsA have also been added to the discussion section including Oguti et al (1981), and an earlier paper they cited, Kvifte and Pettersen (1969), who reported PsA observations at 75 degrees magnetic latitude (lines 372–389).

   Kvifte, G. J., & Pettersen, H. (1969). Morphology of the pulsating aurora. Planetary and Space Science, 17(9), 1599-1607.

2. Discussion of longitude span. In Lines 326-330, the authors showed that the probability of simultaneously observing HF radar echo attenuation at longitudinally separated stations is higher at lower latitudes (KER-HAL) than higher latitudes (SPS-ZHO), and concluded that the longitudinal extent of the energetic particle precipitation is wider at lower latitudes. I am concerned that it is just the effect of latitudinal distribution. At lower latitudes, the probabilities of KER-ASC, HAL-ASC, and KER-HAL-ASC sets are 38%, 75%, and 44% respectively. At higher latitudes, the probabilities of SPS-ASC, ZHO-ASC, and SPS-ZHO-ASC sets are 35%, 24%, and 17% respectively. From these values, I consider that the difference of 44% and 17% is mostly due to the latitudinal difference (38%, 75% and 35%, 24%). The author should discuss this latitudinal effect.

   The discussion about the longitude span has been expanded (lines 357-365).

3. The validity of statistical analysis with a limited number of samples. When I checked the major point 2 as shown above, I also noticed that the probability of KER-HALASC set (44%) is higher than KER-ASC pair (38%). I understand that it is due to the different datasets with simultaneous operation of a camera and radar(s), but then I wonder how accurate and reliable the value 44% is. I consider that this issue should be carefully discussed because it affects the interpretation of the latitude dependence of longitudinal extent (major point 2)

   We have added a paragraph to the discussion about the reliability of the statistical results (lines 344–354), and also clarified the limitations in the conclusion (line 434-435).

4. Lines 63-64: "determining whether an atmospheric chemical response will occur" should be rewritten as "determining whether a noticeable atmospheric chemical response will occur". Atmospheric chemical responses always occur.

   Corrected (lines 69 and 72)

5. Lines 95-96: "(180-600 km range), which is the approximate area where the transmitted radiowaves pass through the D-region ionosphere"—In order to say this, the authors should describe the typical elevation angle range of the SuperDARN radio waves.

   This information has been added on lines 102–103

6. Line 138 and Figure 2 caption: "beam 5" – beam 5 direction for each radar is not shown. Probably Figure 1 is an appropriate point of showing beam 5

   The beam 5 orientation for each radar has been added to Figure 1, and the caption updated.

7. Line 196: "backscatter noise measurements" should be rewritten as "background noise level".

   Corrected (line 208)

8. Line 197: "classified as clearly observed/not observed or probably observed/not observed"—the authors should describe the dynamic range and indicate the number of colours in one colour table, to make the manual inspection as objective as possible.

   This information has been added on lines 136–138. See also lines 209–210 where we have clarified the key factor that affects our classification.

9. Line 244 and Figure 4 caption: please describe how the dark grey shading areas were drawn.

   We have added this information on lines 261–262, and in the caption of Figure 4.

10. Lines 245-247: "Since the event onset times are slightly different for each radar, we use the dark grey shading to represent the total area over which attenuation was observed during the event."—It is better to say "The event onset times are slightly different for each radar. To focus on the presence/absence of the events, we use the dark grey shading to represent the total area over which attenuation was observed during the event. "

    Replacement made (lines 264–265)

11. Figures 3 and 7 captions: the style for showing geomagnetic coordinates are different, i.e., (−58°,124°) and (58°S, 124°E). Use the same style.

    The first style (−58°,124°) is now used throughout.

Reviewer 2

1. Figure 3. This bar graph plot is ordered in magnetic longitude. It would be useful to plot the same data in a second panel, but this time ordered in latitude.

   Figure 3 has been updated to include two panels—one sorted by magnetic latitude and the other by magnetic longitude. The actual data in both panels is the same.

2. Figure 7. A similar commment. I would have thought that this plot would best be shown with site latitude on the y-axis, and longitude on the x-axis. As it is the ordering is mostly longitudinal on both axis, apart from DCE, which is an outlier. Thus the plot misses the chance to show a reasonably clear representation of the precipitation region extent, for events centred on Syowa.

   The vertical axis in Figure 7 is now organised by magnetic latitude. We have also reversed the order of radars on the horizontal axis to be west (left) to east (right)

3. Characterising the size of the EEP region during pulsating auroral events is an important step in identifying the contribution of EEP forcing to natural climate variability. However, care should be taken to note that in the event of climate modelling using an actual EEP data stream from a satellite (for example POES) the electron fluxes would be at least partially included [Orsonlini et al., 2018]. Whereas, to properly capture the long-term impact of EEP on natural climate variability, EEP fluxes are typically modelled using geomagnetic indicies [van de Kamp et al., 2016; Matthes et al., 2017]...

   We have clarified in the introduction section that the EEP fluxes are usually described by geomagnetic indices for long-term modelling studies, and that this is unlikely to capture the contribution from pulsating aurora (lines 28–34).

4. ...and the statement on Line 249 "we note that there is no obvious correlation between geomagnetic activity and the size of the EEP impact area" clearly empasises that understanding this form of EEP is important in order for it to be propoerly included in EEP models for long-term impact studies.

   Our observation that the PsA spatial extent does not appear to be correlated with geomagnetic activity has now been put into the context of atmospheric modelling using geomagnetic indices (lines 267-269).

5. Once the EEP region size has been estimated it would be useful to contrast it with the characteristics of substorm precipitation studies (rather than pulsating aurora studies) undertaken previously. Using riometers, Berkey et al. [1974] found that the substorm precipitation region covered a corrected geomagnetic latitude range of 60–74°, with only a small dependence upon Kp. This work was expanded by Cresswell-Moorcock et al. [2013] using POES electron precipitation observations, finding that some substorm precipitation events could extend to much higher latitudes.

   We have added an extra paragraph to the discussion section comparing our results to substorm EEP (lines 395–404)