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Interactive comment on "Local time extent of magnetopause reconnection X-lines using space–ground coordination" *by* Ying Zou et al.

Anonymous Referee #1

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Local time extent of magnetopause reconnection X-lines using space-ground coordination

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The authors discuss conjugate observations of two THEMIS satellites crossing the magnetopause in short succession, with ground based radar observations to determine the lengths of a dayside reconnection line at the magnetopause. The methodology seems to be interesting and the paper is well written with a very good introduction to the general problem. However I have some issues with the current data analysis and the event selection that are significant enough to not recommend publication at this time.

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Discussion paper

General Point: As the authors admit, their determined length of the X-line will be limited to the longitudinal coverage of the radars. This unavoidable limitation will always significantly influence their conclusion about the length of the "actual" X-line, which could be considerably longer, and will prevent them from ever finding a global answer. That will seriously limit the usefulness of the methodology, thought generally its an interesting approach.

About the introduction: There are several significant publications using IMAGE/FUV observations. This mission had the ability to observe emissions from precipitating (cusp) ions over the entire polar region at once and was therefore not limited like the radar coverage in the present manuscript. Studies using these data have shown evidence that during southward IMF conditions the entire dayside is open leading to very long dayside reconnection lines. So, based on these results the length of the X-line is not the driving question. In additions, decades of cusp observations in all local time sectors show precipitating ions. X-lines in general seem to be very long.

Cusp observations have shown that a substantial part of reconnection is dominated by pulsed reconnection [Lockwood et al.,. . ...]. The question is therefore – is the long X-line pulsing as "One" or are individual longitudinal sections have their own pulsation frequency? That should lead to scenarios presented in this manuscript, sections of X-lines that are active next to sections of X-lines temporarily inactive. This is how I would interpret the observations in the manuscript. Therefore the conclusion would not be about the length of the X-line since that would be masked by the temporal nature of the reconnection process, which might lead to misleading results.

In any case, I was surprised that there was no reference to this rather ground breaking IMAGE observations anywhere. These observations [e.g., Fuselier et al., 2002] should be added in the introduction and properly described.

Specific Points:

Line 188: the D-shaped distribution do not persist into the ionosphere due to the conservation of the first adiabatic invariant. The D shape changes into a Crescent shape as soon as the ambient B field increases, which it definitely will in the cusps. This has been observed in the cusp regions for decades. This effect is so pronounced that it can be even used directly at the magnetopause. The "bending over" of the D-shape distribution observed during magnetopause crossings has been used in a recent study by Broll et al. (2017) (JGR) to determine the distance to the X-line from the MMS satellites and infer the Xline location.

Cusp Steps have nothing to do with D-shape distributions. Cusp steps are the result of changes in the reconnection rate at the magnetopause or caused by spatially separated X-lines. Cusp-steps have been discussed in great detail by Lockwood and Smith in the 90ties as manifestation of pulsed reconnection leading to the pulsed reconnection model and by e.g., Onsager et al [1995] or Trattner et al. [2002] as spatially separated X-lines.

The authors use patchy reconnection also in the case of spatially separated X-line or partial X-lines. This will be a source of confusion for colleagues not too familiar with the subject. Patchy reconnection usually describes pulsed reconnection – temporal changes in reconnection. While the authors do a reasonable good job in trying to keep the temporal and spatial regimes apart I would recommend to revisit that issue throughout the paper.

Figure 2: The symbol for Th-D is completely invisible – if it wasn't for Figure 4 I would not have realized that there are indeed two separate magnetic foot points in that plot. Chose a different more prominent color.

Figure 2: it is mentioned in line 209 – the satellite foot points should map close to the radars FOV. I would recommend that the authors look for events where the satellite foot points are actually in the FOV of the radars to make absolutely sure that these observations are linked. Throughout the paper but especially in Figure 2 I do not have the impression that this is the case which makes the data analysis rather questionable.

Therefore I fail to see how the observed D-shape distributions at the magnetopause are connected with particular flow channels which is the essential part of the study.

The authors also mark the cusp foot point in the radar images. Discussing again the events in figure 2, Th-D clearly saw an ion jet. It therefore observed reconnection at the magnetopause and was on a newly opened field line. The D shape distribution, while looking a bid crooked compared to the other D-shape distributions in the manuscript, travels along the magnetic field. The magnetic field, at that time the distribution was observed, was still northward. Therefore the satellite was in the LLBL and the ions move toward the northern cusp where the radar observations observe flow channels. All open magnetopause field lines map into the cusps. So the Th-D magnetic foot point, were the D-distribution was observed, should be in that region marked as cusp in figure 2d. It is not, its not even in the FOV for the radar.

Line 338: One of the open questions in magnetic reconnection is still how the reconnection rate develops along the length of the X-lines. Since decades of research showed that pulsed reconnection is a rather significant process, it is conceivable that individual sections along a “long” X-line pulse at different frequencies. I therefore would expect that it is very likely that magnetopause crossings by multiple satellites show active and temporarily inactive sections along an X-line. This is not prove that a dayside X-line is short. The interpretation of the authors that this event is a spatially restricted X-line based on flow channels at very different latitudes is not convincing, especially since the satellite observations are outside the flow channels for which observations exist.

I also want to stress that in the pulsed reconnection model, field lines that were opened before reconnection briefly stopped, are convecting and provide a continuous transfer of magnetosheath plasma into the magnetosphere. That should certainly influence your radar observations. It is unlikely that the ionosphere would respond that quickly to short changes in the reconnection rate. The magnetosphere is generally rather slow in its response to outside changes. That will make linking ionospheric flow channels to magnetopause observations rather challenging.

Radar observations of ionospheric convection, direction and velocities, are often used to estimate global convection pattern in the polar ionosphere using various models. These “convection cells” could be overlayed in the radar plots to make a connection between the satellite magnetic foot points outside the radar FOV and the radar data. Depending on how these global convection cells look like they might provide a more convincing picture that these observations are actually linked.

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