

Reply to Referee comments on “Polar substorm on 7 December 2015: pre-onset phenomena and features of auroral breakup” by Vladimir V. Safargaleev et al.

(Referee comments are bold, our corrections are italic. Corrections in the text of paper are yellow).

MAJOR COMMENTS

As noted previously by reviewer #2, it is strange to talk about periodic structures and periodic reconnection etc. when there are only 2 instances. I recommend that you reduce talk of periodicity and instead talk about 2 structures separated by ~15 minutes. I have made several detailed comments about this below (see minor comments), but have surely missed several points. Especially in Lines 368-372 you should remind the reader that your "periodicity" is based on 2 instances.

We have reduced talk of periodicity indicated in minor comments as it was recommended and add the following sentence in Lines 371 - 372:

We remind the reader that by 15-min periodicity of a parameter we mean two its changes, following one after the other with an interval of 15 minutes.

L70: I'm not sure if Mishin et al. (2001) discussed "quasi-sinusoidal" IMF Bz variations as a necessary condition for triggering a polar substorm. They did discuss the 2-step sequence of the substorm, but I don't think quasi-sinusoidal variations were discussed. Also, the examples in Mishin et al. (2001) seem to show a large variation in timing, not always ~15 minutes. Could you clarify this?

Yes, examples in Mishin et al. (2001) show a larger variation in timing. We have cited this paper to show that sinusoid-like variations in IMF Bz (i.e. gradual change, at first, to negative and then to positive values) were discussed earlier in the context of substorm initiation. To avoid the misunderstanding we rewrite this part of Introduction as follows (L.69-78):

Russell (2000) suggested that double substorm onsets can be caused by a temporal deflection of northward IMF to southward. In the review by Baker et al. (1996) it was noted a class of substorms that were triggered by positive changes in Bz after it turned to south. Mishin et al. (2001) showed by the superimposed epoch analysis that substorm associated Bz variation is a gradual change at first to negative and then to positive values and looks like a fragment of sinusoid. As a rule, the above fluctuations are easily identified in IMF data due to large amplitude and time scale or inferred by statistics. Recently, Safargaleev et al. (2018) proposed that the polar substorm might be initiated by the less prominent sinusoid-like variation in IMF Bz component with period ~ 15 min detected in the solar wind several tens minutes prior onset. To associate substorm onset with such kind of IMF variations one needs careful estimating of the time delay between the arrival of IMF irregularity to the magnetopause and the beginning of the substorm.

L120-122: As mentioned by reviewer #2, the relation between equivalent current and FAC is approximate. Also Palin et al write "...FAC can sometimes be identified by a quasi- circular clockwise (counterclockwise) equivalent current vortex...". More specifically, in order to associate curl of the equivalent current with FAC, you need to assume that conductance gradients are parallel to the electric field, see e.g. section 2 in Amm (2002) for details. Therefore I'd recommend that you change in line 120 "are manifested by" --> "can often be associated with" and add reference to Amm et al. (2002).

Corrected. L.125-127

L259-260: The vortices are in an area where there are few magnetometers. Uncertainty in the equivalent currents increases in these areas, and in my experience there may be spurious vortex-like structures over oceans, where there are no magnetometers. Therefore I'd suggest you to re-phrase the sentence and say something like "The vortices seen in the equivalent

current are consistent with downward FAC at the poleward side of the coiling structure and upward FAC equatorward of it."

Corrected. L.266-267.

L204: Do you mean that the polar patch caused the shift in the electrojet, or that they just happened to occur at the same time?

The patches and displacement happened to occur at the same time. For this reason, we suppose that the arrival of the reconnected flux tubes, which footprints are detected by EISCAT radar as the patches, to the lobe could be resulted in the lobe expansion. As a sequence, the polar cap expanded and auroral oval shifted toward the lower latitudes together with the electrojet.

The following comment is added in the text:

Appearance of the polar patch in radar data and the equatorward shift of westward electrojet (Fig.2b) happened to occur at the same time. Assuming the patch to be the footprint of one of the reconnected flux tubes, we suppose that the jet displacements could be a sequence of expansion of magnetospheric lobe caused by reconnected flux tubes, arriving from the dayside. (L209-212)

L386-390: Is there a peak in the power spectra around 15 minutes, or did you just select the 0.8-1.7 mHz band based on earlier observations of structures separated by ~15 minutes? If the latter is true, then it would be good to check the power spectra. Looking at the magnetograms in Fig2 it seems that there could be stuff also at shorter periods.

Yes, there is a peak in power spectrum at ~0.001 Hz (15 min) in variations at BJJ station where the maximum of negative bay is achieved. We have demonstrated this by a new figure 9a and corresponding comments in the text (L393-398) :

To find 15 minute variations using FFT, one need to analyse a long interval (not less than one hour) which include many different variations before and after onset. So, the power spectrum is an integral characteristic of the interval. From this point of view, the procedure of filtering that we used looks preferable.

MINOR COMMENTS

L11: Repetition period --> time interval

Corrected

L31: PBIs is --> PBIs are & trigger --> triggers

In the text "is" refers to "some kind". We are not sure that correction is needed.

L46: Pulkinen --> Pulkkinen

Corrected

L71: by the --> by a

Corrected

L86: Heikila --> Heikkila

Corrected

L94: onset so that such --> onset, so such

Corrected

L108: 15 min oscillations --> 2 structures separated by 15 min

Corrected

L143: event was --> event took place & No a --> No

Corrected

L185: As it was mentioned --> As mentioned

Corrected

L193: So that, the increase --> This increase

Corrected

section 3.2: Check references to panels in Fig 4, some of them may refer to the old version.

Corrected

L201: that gives --> estimated from

Corrected

L216: which --> whose

Corrected

L239: repetition of variation --> interval between the two negative bays

Corrected

L276-284: I had to read this couple times to get the point. I recommend you re-write it, for example: "The bottom panel in Fig.8b shows variation in the H magnetic field component at the low-latitude stations Alibag (ABG, 18.5°N, 72.9°E; geomagnetic latitude 11.65°N) located near midnight and at the dayside station San Juan (SJG, 18.1°N, 293.8°E; geomagnetic latitude 28.79°N). The increase of H-component at low latitudes in all MLT sectors is traditionally connected with the enhancement of solar wind dynamic pressure, while decrease or disruption of the cross-tail magnetospheric current contributes to the Dst variation mainly on the nightside (Maltsev et al. 1996; Huang et al. 2004). Thus the very different magnetic field behaviour seen at ABG and SJG support current disruption of the cross-tail current."

Corrected as referee recommended

L304: of the same periodicity --> with the same time separation

Corrected

L306: 15-minutes periodicity --> 15-minute separation.

Corrected

L330: at latitudes --> at magnetic latitudes

Corrected

L363: 15-min periodicity --> 15-min time separation

Corrected

L372: period --> interval

In the context, the term "period" refers to classification of geomagnetic pulsation. We think that correction is not needed.

L387: 0.8 - 1.7

Corrected

L401: periodic --> two

Corrected

L417 and elsewhere: use consistently either arcX or arc X

Corrected

L453: repetition period --> time separation

Corrected

L454: periodic reconnection --> two bursts of reconnection

Corrected

L457: periodic erosion --> repeated erosion

Corrected

L466: In accordance with --> According to

Corrected

L467: turned out to be sensitive to the --> detected

Corrected

L469 satellite --> satellite's

Corrected

Fig2: Numbers in the panel showing AE index are too small. Similarly the white text in the high resolution SOD and BAB keograms is difficult to see.

Corrected

Fig 3b: Is the colorbar supposed to have another set of numbers on the left side, or why there is text "electrons" and "ions" in blue and red and numbers only in red?

Corrected

Fig 5 caption: arives --> arriving

Corrected

Fig 8 caption: SGN --> SJG

Corrected