We have received two referee reports on our paper and write two separate responses. The 2. referee report is reproduced below and authors responses are written in *italics* after each point. The revised version of the paper shows additions and nontrivial changes in red color. Deletions are not marked. Due to the automatic LaTex formatting, we could not color new references but there are several, as seen when comparing the present and original versions. The revised paper with colors will be made public when we have included changes due to both referee comments in it.

We have some general comments to this referee report. First of all, we find it constructive and with a clear helpful intent, but in our opinion it fails in identifying the scope of our analysis. The starting point in our analysis is a simple model for estimating the "stand-off" distance between the Earth and the magnetopause. The model has no free parameters and supported by a dimensional analysis. The basics of the static model are known. Our question was then to what extent this static model could be generalized to include also dynamic effects? It is very easy to find shortcomings of such simple models, but our question was (as also stated in the paper) to see what it does right. In our conclusion we had and have a list of the shortcomings of the model: its ability to give an account of field aligned currents was mentioned as one. Some elements of such currents can be argued, but a complete description is impossible within this model. We have, however, expanded on the relations to other works, Araki 1994 in particular, this was one of the suggestions of the referee.

Title: Impulse-driven oscillations of the near-Earth's magnetosphere

Author(s): Hiroatsu Sato et al.

MS No.: egusphere-2022-232

[Comments]

There are major questions as listed below.

The ground magnetic variations at high latitudes are described as being caused by magnetopause currents. However, ground magnetic variations at high latitudes are caused by ionospheric Hall currents driven by the electric field created by the dynamo in the outer magnetosphere (e.g., Tanaka et al., 2020 JGR, https:// doi.org/10.1029/2019JA027172). Furthermore, the field-aligned currents generated by the dynamo flow to the global ionosphere via the polar ionosphere, resulting in simultaneous occurrence of the preliminary impulse (PI) and main impulse (MI) of SC at high latitude and equator (Araki, 1994 AGU book). The authors are recommended to discuss their results in the context of the current system between the magnetosphere and ionosphere. The dynamos of the PI and MI have also been reproduced by the global simulations (Slinker et al., 1999 JGR; Fujita et al, 2003 JGR).

Damping of the magnetosphere is attributed to the non-linearity of the equation (4). On the other hand, the FACs flow into the polar ionosphere and further to the global ionosphere, where the energy is consumed by the Pedersen currents (e.g., Kikuchi et al., 2021 EPS). When discussing the damping of the ground magnetic fields, it is advisable to discuss the energy loss in the ionosphere.

Authors response: if eq. (4) is linearized, it still contains a damping, so it is not a nonlinear effect. The damping is caused by the asymmetry in the solar wind pressure: when the magnetopause is approaching (i.e., moving away from the Earth) the magnetopause is doing work on the solar wind, while in the receding phase it is opposite. The two cases are not symmetric since the solar wind ram-pressure depends on the relative velocity between the solar wind and the magnetopause. In the *approaching phase this force is large, while it is smaller in the receding phase. The work done in the two oscillation phases is different. Integrated over an oscillation period 2\pi/\Omega, the oscillations loose net energy to the solar wind so the net result is a damping of the oscillations. The initial transient time interval is different: here the solar wind pulse or shock arrives at an interface at rest, and the oscillations are initiated to reach full amplitude. We have no objections to cite the work by Kikuchi et al (hoping we found the correct reference) but we see no reason why this type of damping should be superior to the one we found.*

The motion of plasma is described as being earthward, but the calculated and observed electric fields presented in the present paper are directed from the dawn to dusk, which drives sunward motion of plasma. Explanation or comments are required for the difference between the compression of the magnetopause and sunward motion of the magnetospheric plasma.

Authors response: we imagine this comment refers to a plotting error in figure 9 as also mentioned later. The error is corrected now. We thank the referee for noting this.

[Others]

Line 116

The Faraday's law is equivalent to E=UxB?

Authors response: That part of the sentence has been deleted.

Line 124

In Figure 9, the electric field is from the dawn to dusk, which drives sunward motion of plasma in the magnetosphere. If the electric field is induced by the increase in Bz and carried by the compressional MHD wave toward the Earth, the direction of the electric field must be westward, i.e., from the dusk to dawn. How is the dawn-to-dusk electric field generated by the moving magnetopause currents?

Authors response: the referee is right, we made a mistake in figure 9, the arrows should have been with opposite polarity. The error is corrected. Thank you for pointing this out!

Line 147

Draw current vectors on the current lines of the FACs. Previous studies using the global simulations have shown that two kinds of FACs are generated by the compression of the magnetosphere (Slinker et al., 1999 JGR; Fujita et al., 2003 JGR; Tanaka, 2007 SSR), supplying the electric field and currents of the PI and MI of SC. The FAC pair inside the outside pair is also produced by the magnetopause currents?

Authors response: our original argument was based a dissimilarity of the heated and unheated parts of the radiation-belt plasmas. The original text was admittedly schematic and a more detailed calculations show that "our" effect is quite small. It has no meaning to retain discussions of a small effect when the rest of the paper deals with large-scale bulk plasma phenomena, so this particular discussion is now deleted. Instead we introduce a reference (with a short discussion) to Araki's 1994 *results, the polarization current in particular, as advocated by the referee. The figure is completed with an arrow, as suggested.*

Line 149

Please specify the energies of radiation belt particles and of particles that work as a generator of the FAC.

Authors response: this discussion is deleted for reasons mentioned before.

Line 157

Please note that the infinite inner impedance does not allow electric currents to flow, since I=V/(r+R) where r and R are the internal and load resistivities.

Authors response: there seems to be a misunderstanding here. The current generators are circuit elements having an infinite internal resistance. Current generators force a current in the same way as a voltage generator impose a voltage difference. The volage generator has a vanishing internal resistance, but it does not short circuit the current. Given an ideal current generator, the resulting voltage differences are a consequence of the load combined with the forced current. Given an ideal voltage generator, the currents flowing are a consequence of the load and the imposed voltage. In the ideal limit a current generator forces a current into an infinite resistance, giving infinite voltage differences. An ideal voltage generator on the other hand forces a potential between two short-circuited points, giving infinite currents. These extreme cases are remedied by finite internal resistances and the two generators are related by Thevenin's and Norton's theorems. For instance, polarization currents are induced by imposing a cross-field velocity, not by a potential difference.

Line 160

Please note that the FAC is generated by the high-pressure plasma so that the pressure gradient force balances JxB force of the dynamo current J (Tanaka, 2007 SSR).

Authors response: this is so for steady state conditions where we have force balance. The present study deals with transient phenomena.

Lines 160-163

The equations for the current are the same in the warm and cold plasma regions. Please comment on the difference between the nature of the two currents.

Authors response: as mentioned elsewhere, that discussion is now deleted.

Line 209

Ground magnetic disturbances are caused by ionospheric currents, particularly at auroral and subauroral latitudes (e.g., Araki et al., 1997 JGR). At middle and low latitudes, the magnetic fields are caused by magnetopause currents superimposed by weak ionospheric currents. At the dayside equator, the ionospheric Cowling currents work as a major source for the equatorial SC (Araki, 1994 AGU book).

Authors response: in general, we agree with the referee on this, and actually the text contained such statements, but we now gave the point greater emphasis.

Line 235

Figure 17 shows a typical SC in the morning, composed of positive/negative PI and negative/positive MI at lower/higher latitude part of the IMAGE magnetometer array. These magnetic fields are caused by ionospheric Hall currents surrounding the FACs (e.g., Kikuchi et al., 2022 Frontiers, doi: 10.3389/fspas.2022.879314). Note that the onset of PI at higher latitude (NAL, BJN) is simultaneous with those at lower latitude (NUR,,,,), because the ionospheric currents flow at the speed of light to the global ionosphere, including the equator (Kikuchi et al., 2021 EPS, DOI: 10.1186/s40623-020-01350-8). Magnetopause currents cause magnetic fields at low latitude, which is DL according to Araki (1994) model.

Authors response: we have no objections to referencing the work of Araki (1994) and added this together with a short discussion. The bipolar signal seen in our Fig. 17 at auroral latitudes corresponds to the DP-type perturbations described by Araki (1994). The interpretation of this signature given in there (auroral zone, morning local time) is in terms of an M-I-coupling illustrated in Fig. 12 in that work. The signatures shown in the present work at Svalbard latitudes are explained in terms of lobe-cell polar cap convection with an associated Hall-current.

In the discussion of the Araki-model of M-I current system in relation to our manuscript we might add the following. This is related to the bipolar DP-type perturbation (at auroral latitudes). (DL is Arakis term for perturbations in the equatorial region). In the M-I system of Araki (his Fig. 12) the auroral ionosphere is coupled (via FACs) to his Jp-current in the magnetosphere (directed dusk to dawn), which is located well inside the magnetopause. Jp is a polarization current (giving rise to FAC-system). Our figure 2 gives the dawn-dusk directed Chapman-Ferraro current (which is moving inward during the external pressure enhancement

We point out that Araki (1994) splits the the SC magnetic perturbation in two components (called DP and DL), corresponding to two different sources (as described in his Figs. 11 and 12): i) the CF-current (as illustrated in our Fig. 2), giving rise to Arakis DL-type, similar to that shown in our Fig. 1, and ii) the polarization current of the Araki-model (Jp) with associated FAC-currents and currents in the auroral ionosphere, accounting for the DP-type perturbation (illustrated by the bipolar signature in our Fig.17). In addition, we observe at the highest latitudes (at Svalbard stations in Figure 17) a perturbation that may be attributed to lobe cell convection (and associated Hall currents) under the prevailing strongly northward IMF conditions.

Line 248

Which part of the data is believed to have been caused by FAC?

Authors response: as mentioned, the part referring to the polar regions.

Line 253

The electric fields measured by the satellites are from the dawn to dusk (Fig. 21), same as in the model calculation (Fig.9). The ExB drift velocity is sunward, which is opposite to the earthward motion of the magnetopause. The electric field observed in the ionosphere at middle latitude is also directed from the dawn to dusk, which lifts up the dayside ionosphere (Kikuchi et al., 2016 JGR, doi:10.1002/2015JA022166).

Authors response: as mentioned elsewhere, we had a plotting error in our original figure 9. The y-component of Electric field components shown from the van Allen probes is in the opposite direction. The model electric field is obtained for electromagnetic variations in vacuum, while the satellites are in the radiation belts so our comparison is in reality misplaced if it is applied in detail, but we still find the oscillation period detected by the satellites interesting since it agrees with the model predictions. Our main interest on the electric field signal is found in its use as a reference "time-marker" for estimating the time delay for the arrival of the energetic particles.

Line 259

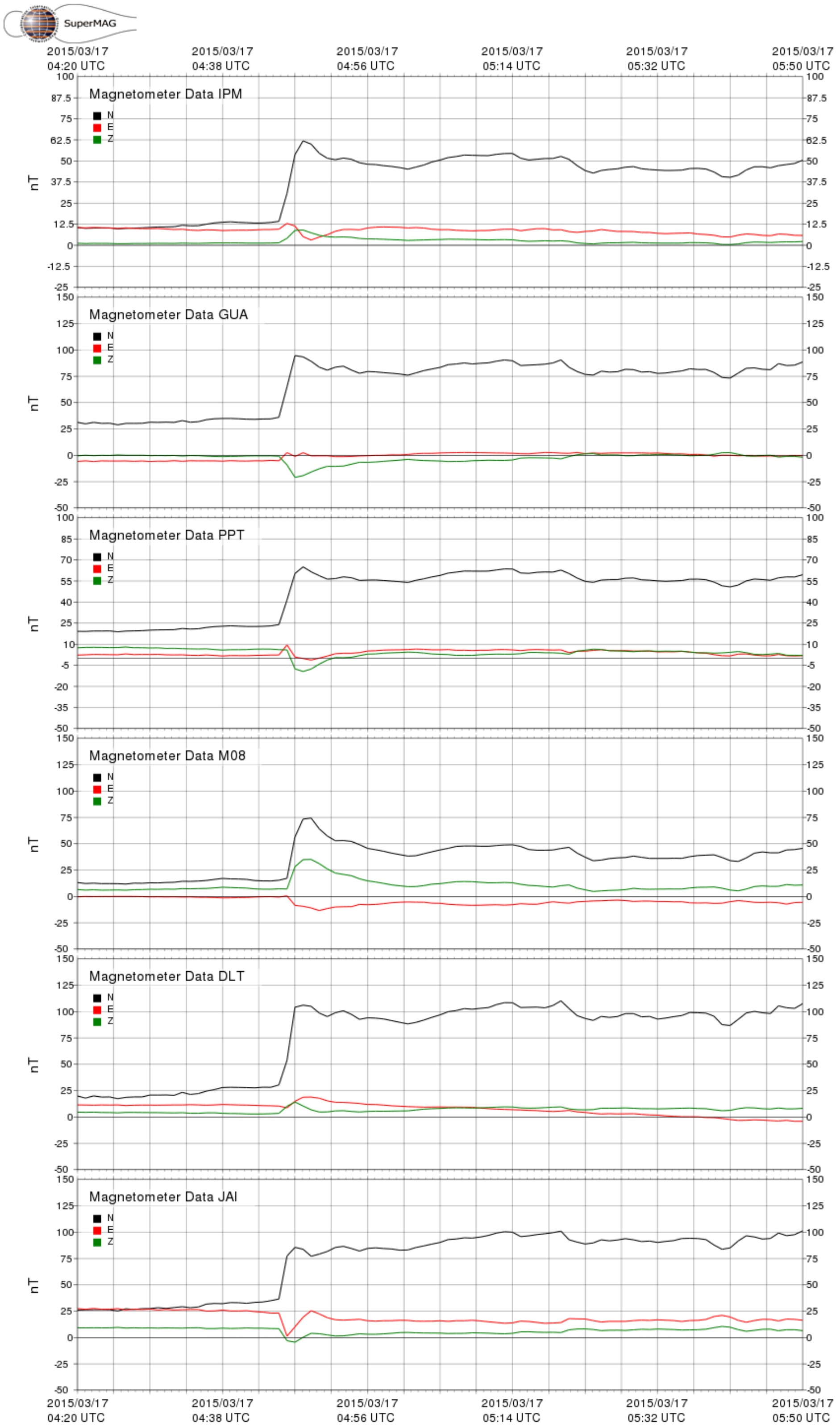
RBSP spacecrafts are located deep inside the magnetosphere, not close to the magnetopause. The location of spacecrafts should be explicitly mentioned in the discussion.

Authors response: the spacecraft position was given explicitly in a separate figure.

Line 300

Phase relationships among the ground magnetic variations should be mentioned. If the magnetic variations are caused solely by the magnetopause currents, we would see coherent variations in multiple locations.

Authors response: our figures 14 and 18 showing time variations for GUA, DLT and M08 stations were inserted for this reason, they show precisely as the referee argues, synchronous variations at widely separated locations. The available journal space does not allow detailed documentation, but we insert below as an illustration for one of our events using stations uniformly scattered over the globe in a band along equator. Note that damped oscillations following the arrival of the shock are noticeable in most signals.


SuperMAG
2015/03/17 04:20 UTC
2015/03/17 04:38 UTC
2015/03/17 04:56 UTC
2015/03/17 05:14 UTC
2015/03/17 05:32 UTC
2015/03/17 05:50 UTC
Magnetometer Data IPM
N
E
Z
nT
100
87.5
75
62.5
50
37.5
25
12.5
0
-12.5
-25
Magnetometer Data GUA
150
125
100
75
50
25
0
-25
-50
Magnetometer Data PPT
100
85
70
55
40
25
10
-5
-20
-35
-50
Magnetometer Data M08
Magnetometer Data DLT
Magnetometer Data JAI