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Interactive comment on "Dynamics Geomagnetic Storm on 7–10 September 2015 as Observed by TWINS and Simulated by CIMI" *by* Joseph D. Perez et al.

Anonymous Referee #2

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This manuscript shows comparisons between models and observations of the pressure peaks in the inner magnetosphere during a storm event. The comparison reveals both consistency and significant differences between the observations and model predictions. The authors discussed the possible cause of the difference (i.e., the missing transient structures in the simulation). The results of this manuscript are important for future improvement of models. However, there a few points that I would suggest the

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authors to address before I recommend the manuscript for publication:

- Line 276: varies -> vary

Done. Thanks.

- Line 399-400: The authors start the sentence with both electric and magnetic shield-

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ing but only explain magnetic shielding (gradient curvature drifts) in the later half of the sentence. The electric shielding is caused by the closure of region 2 current through the ionosphere, which creates a Peterson current, and thus electric field at lower latitudes than the region 2 current. This electric field, when mapped to the inner magnetosphere, cancels the original cross-tail electric field, so particles cannot ExB drift closer to Earth (see, e.g., Jaggi and Wolf, 1973). The electric shielding is more effective for low-energy particles. I do not think it is very important for the energy range which the authors are interested in.

Referee #1 made it clear to us that our use of the term magnetic shielding was not precise. The term has another meaning. So we have eliminated the term and replaced it with "spatially-localized, short-duration injections".

Again in response to comments by Referee #1, this paragraph has been significantly revised as follows: (We have added a reference to Jaggi and Wolf (1973) as suggested by Referee 2.)

Injections from the plasma sheet are thought to be the primary source of ring current protons in the inner magnetosphere, i.e., those that are observed by TWINS. Electric and magnetic fields determine the ultimate path of the injected ions, i.e., whether they reach locations close enough to the Earth where the magnetic gradient and curvature drifts are strong enough to exceed the electric drift forming the ring *current or whether they drift out to the magnetopause. The locations of the partial pressure peaks from the CIMI/RCM and the CIMI/Weimer 2K simulations and the TWINS observations during the 4-day period, 07-10 September 2015, show that the peaks are usually in the dusk/midnight sector. (See Figure 2b) This phenomenon is consistent with analysis of data at geosynchronous orbit (Birn et al., 1997). Nevertheless the TWINS observations show partial pressure peaks that are often at larger radii than the CIMI simulations, even when they are in the dusk/midnight sector (See Figure 2a.). The fact that the CIMI/Weimer peaks are generally closer to dusk than the CIMI/RCM. (See Figure 2b.) is consistent with simulations reported by Fok, et al. (2003). The TWINS MLT locations are closer to midnight and in the midnight /dawn sector more frequently than the CIMI results. This suggests that there are often enhanced electric shielding and effects from localized and short time injections that are not present in the CIMI simulations. To understand how the electric shielding works to affect the paths of the injected* *particles, we note that the convection electric field from the solar wind is mapped into the magnetosphere along open field lines into the polar ionosphere. It is then shielded from penetrating to lower latitudes and therefore further into the inner magnetosphere by the Birkeland region 2 currents driven by pressure gradients in the ring current. See for example Jaggi and Wolf (1973). During geomagnetic storms when there is a sharp turn in the z-component of the interplanetary magnetic field (IMF) from negative to positive (See row 2 of Figure 1.), the accompanying electric field in the ionosphere associated with the Region 2 currents can produce what is referred to as over-shielding. There are also neutral disturbance dynamo electric fields in the ionosphere that affect electric shielding. Localized and short time injections may contribute to the complexity of these effects.*

As to the energy dependence of the effect of the electric field, it is true that for low energies where the magnetic drifts are small, the electric field is dominant. But it has been shown by Fok et al (2003) that a self-consistent electric field in place of the Weimer electric field model moves the simulated peak of ions observed by IMAGE/HENA from the dusk side of midnight to the dawn side where it is observed. Thus it is clear that it does have an effect on the pressure in the energy we measure and simulate

- Line 455, and Line 547-548: 'parallel pitch angle anisotropy … first adiabatic invariant as they enter the inner magnetosphere': The conservation of first adiabatic invariant says that when a particle moves to a stronger magnetic field, it will have more perpendicular energy. Thus, the perpendicular anisotropy should increase instead of the parallel.

The Referee is correct. That was a mis-statement. That has been replaced by the following:

. *As they are accelerated while conserving the first adiabatic invariant to enter the region observed by TWINS, i.e. an outer radius of 8 R_E, their pitch angle distributions become parallel because the energy increase exceeds what can be absorbed in the perpendicular pitch angles while still conserving the first adiabatic invariant. One mechanism for reducing the parallel anisotropy is wave-particle interactions which are not included in the CIMI simulations..*

The key point is that the particles are increasing their energy as they enter from the tail. This is illustrated in Figure 10.

- Line 512-Line 527: This paragraph makes a strange comparison. To find the origin of the multiple pressure peaks, the authors uses particle tracing in the model, which does not have the multiple pressure peaks. As the authors said, the reason why the model cannot reproduce the observed multiple peaks is that there may be transient, small-scale structures that do not show up in the model. These structures can change the particle trajectory significantly. Therefore, the trajectories shown in the manuscript does not bear much useful information in explaining the multiple pressure peaks.

The Referee is correct in saying that the model fields that we use for the particle tracing is not one that necessarily produced the multiple peaks. The idea is that it might have if the input across the outer boundary at 10 RE in CIMI simulations had included non-isotropic, spatially localized and short-time dependent injections.

Line 537-538: '… indication of enhanced electric and magnetic shielding in the observations': How can you which of these two is effective from observation? As I commented above, the electric shielding may be not very effective for the energy range considered by the authors.

As stated above we think it is clearer to speak of "enhanced electric shielding and/or spatially-localized, short-duration injections". The Referee is correct that the relative importance of the two effects cannot be determined from observations of the type we show here. That is why we are trying to compare observations with simulations.

As for the energy dependence of the electric shielding, the fact that it is important for more than just low energies has been demonstrated by Fok et al (2003).

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Figure 2a: Which MLT is this panel showing? Figure 2b: Which radial distance is this panel showing?

It is showing the location, radial distance and MLT, of the main peak. The one marked by the star in the figures. We will add a statement to that effect.

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