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Comment on angeo-2021-4

Anonymous Referee #1

Referee comment on "A Survey on High-energy Protons Response to Geomagnetic Storm in the Inner Radiation Belt" by Zhaohai He et al., Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2021-4-RC1, 2021

This paper claims to show that adiabatic effects dominate the changes in proton fluxes in the outer part of the proton radiation belts (sometimes referred to as the inner zone).

A first (more minor point compared to my latter concerns) is that much of the cited literature concerns changes in the proton betls that are more long-lasting. For example, losses due to field line curvature scattering are true losses as opposed to temporary (adiabatic) changes. This paper does not contradict those other studies. It has a different objective.

The major problems with this paper are that (a) the methodology is not presented with enough detail to understand how the authors actually analyzed the data and (b) the methodology itself appears responsible for the results that are presented.

Specifically, the authors present formulas that they claim quantify the changes in flux due to adibatict processes that preserve mu and L. Those are listed in equations 1-4 which represent the flux during the storm (subscript m) as a function of flux prior to the storm (subscript p). The two are related by three variables: Energy, L-shell, and Magnetic field strength. The variables during and prior to the storm are represented by _p and _m.

The first problem is that the equations that relate E_m to E_p and L_m to L_p are not given so the quantities in figure 3 cannot be verified.

The second problem is that figure 3 plots E_p, L_p, and j_p as a function of time for fixed values of L_m and E_m. Surely it should be the other way around. For a given pre-storm condition (_p) the quantities during the storm (_m) are a function of time. It is not at all helpful to present it in terms of the "pre-storm" conditions vary as a function of time during the storm.

The third, and biggest, problem is that the relationship between all of the variables (e.g. L_p to L_m, E_p to E_M) are all a function of B_p/B_m. Since B == B_dip +dB and dB = -symH (for symH<0) then all of the pre-storm and storm-time variables are related to one another as a function of dB == -symH. This can be seen very cleaerly in figure 3 where all predicted variables follow every bump and wiggle of symH.

For true calculations of adiabatic effects the radial gradients of PSD are critical (as is the second invariant which is ignored here). For example, a flat radial gradient produces no change in flux when B changes. This analysis simply samples the ***fluxes*** (j_p) at different values of L and E that are related to an arbitrarily-chosen value of L_m and E_m where the relationship is ***defined*** by symH. It is a totology to conclude that adiabatic changes (defined by dB == -symH) "explain" the flux variations.

The brief discussion of phase space density in section 3.3 does not contain enough information to know what the authors have done or what is being plotted in figure 6. Is the PSD at fixed third invariant (L*)? If so, what L*? It is currently impossibe to know if the PSD results support the preceding conclusions or not.