Relationship between storm time disturbance and mass density on short time scales

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1 Prior work

[Takahashi et al., 2010] state that spikes in the Disturbance Storm Time (D_{ST}) index coincide with with significant changes in equatorial mass density. They look at five specific storms over a 20 day period with evidence that two had density spikes after the D_{ST} drop, two had density spikes before the drop, and one showed no effect. They then show an epoch analysis where mass density is seen to spike the day of a mass density drop, using a daily average of 30 minute mass density and one hour D_{ST} measurements.

The prior paper, [Takahashi et al., 2006], show how trends in storm dependence on mass/density only appear in longer timescales. Looking at Kp vs mass (amu) between a field shell line of 6 and 7 R_E, a trend shows up in the 1.5 day averages that doesn't appear in the 3 hour averages.

[Lavraud et al., 2006] show that storms preceded by a northward interplanetary magnetic field (IMF) tend to have higher plasma density than those preceded by a southward IMF, and suggest an increased geoeffectiveness from a northward IMF and dense plasma sheet.

[Tsurutani and Gonzalez, 1997] show how the density of a corotating interaction region (CIR) shows strong preconditioning for a drop in D_{ST} and spike in magnetic field intensity. Assuming a reasonable amount of coupling between that region's density and the plasmaspheric density, this result could be relatable to others focusing on the plasmasphere.

[Denton et al., 2006] show how D_{ST} affects the distribution of plasma density along different magnetic latitudes, and specifically along the same field lines as looked at in later papers (6-8R_E).

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2 Our work

Our work takes the datasets from [Denton, 2007] and [Kondrashov et al., 2014], uses a mean interpolation to take the mass density parameter from a highly non-uniform 15 minute grid of the former to the contiguous one hour grid of the latter, and looks for storms based on the definition of storm periods provided by [Takahashi et al., 2010], namely when $D_{ST} < -50nT$. The former has a time coverage of 1980-1991, but covered by different satellites in different years (sometimes with overlap), and the latter data set covers 1972-2013. By then looking at an hourly average of variables from 24 hours before storm onset to 48 hours after, short timescale trends can be discerned.

In this paper we try to test the relationship of short timescale effects on mass density from D_{ST}, $F_{10.7}$, and B_Z, in comparison to the long time scales presented in [Takahashi et al., 2010, 2006], as well as looking at other preconditioning factors by analysis of hourly data within a day surrounding storm onsets. We will briefly compare our results to other published results to verify our methods and handling of data. We also hope that by looking at all possible storms under less stringent qualifications, instead of hand selected storms with specific selection criteria, our results will be more generalizable and less prone to bias.

2.1 DST Storm

Two storm indicators are looked at in this study. The first is looking for a drop in DST below the threshhold of $-50nT$ specified in [Takahashi et al., 2010], dubbed the "onset", and then considering the timeframe a storm until D_{ST} passes back above the $-50nT$ threshold. This method finds 669 such periods between May 1983 and August 1991 with an average duration of 9 hours and a median duration of 3 hours. A subset of longer duration storms will be looked at later. Figure 1 shows the average values of B_Z, V_{SW}, D_{ST}, $F_{10.7}$, and Mass Density for a period of 24 hours before and 48 hours after a storm onset, as well as a plot of mass density with the found storm times highlighted.

This figure shows a definite spike in the Z component of the magnetic field, as well as the defined drop in DST, but no obvious change in mass density at an hourly timescale. This points to an issue with only looking at long-timescale trends between density and D_{ST}, and allows for the possibility that other factors are influencing the long term correlation since there's no obvious connection on a short timescale. One possibility is that, as suggested in [Takahashi et al., 2010], $F_{10.7}$ plays a significant role in driving long term density values which biases the long term correlation of density and D_{ST}.

2.2 Mass Density Storm

Figure 2 shows this same algorithm, but looking for a rise in mass density over a value of $40g/cm^3$. This results in 130 storms with a mean duration of 32 hours and a median duration of 17 hours, marked in red on the left figure.

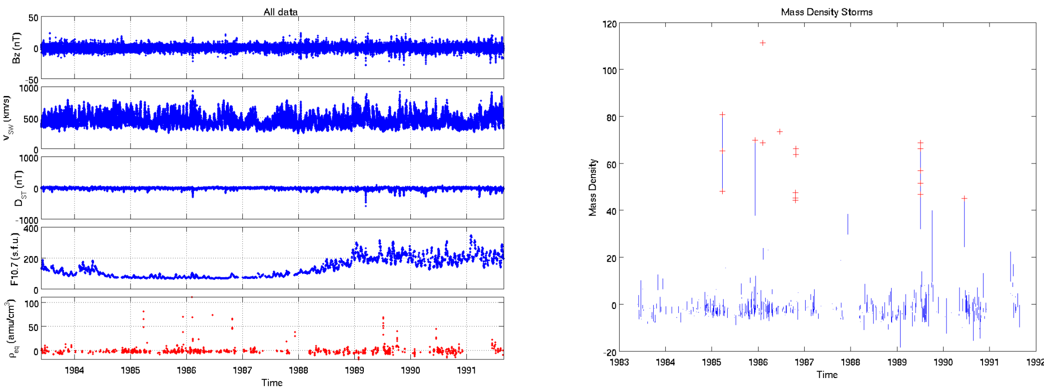

Figure 1: All used data (left) and selected storm times highlighted (right)

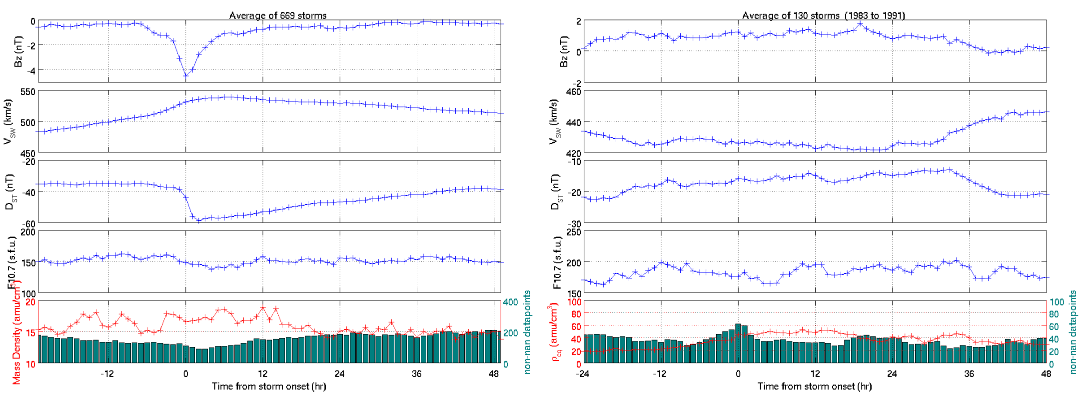

Figure 2: $D_{ST} < -40nT$ onset, Mass Density $> 40amu/cm^3$

This shows that when using all data for mass density derived storms, almost no significant changes can be seen around storm onset.

3 More specific storms

It's hypothesized that progressively picking more specific storm criteria will allow for the possibility of more significant results, at the expense of more bias in the selection process and potentially less overall usefulness of the results. That said, the predictability of extreme storms is of definite interest, so an attempt has been made to find some reproducible method of prediction. Looking at storms that last longer than 12 hours and storms with an onset threshhold greater than $70g/cm^3$ results in the left and right sides of Figure 3 respectively.

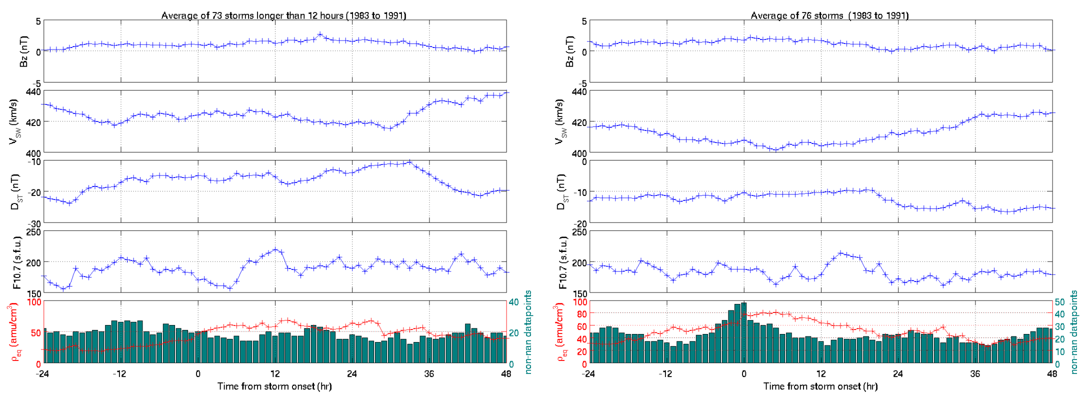

Figure 3: Duration > 12 hours, Mass Density > $70amu/cm^3$

Neither of these seem to indicate anything too significant, so looking at D_{ST} storms instead to look for something that causes a significant change in Mass Density results in Figure 4. This shows that by either looking only at D_{ST} storms that last longer than an hour (left) or at storms where the onset condition is $D_{ST} < -80nT$, a spike in mass density is seen, but also a definite lack of data availability to the point where that spike may be coming from less than five of the total 143 storms.

Unforunately there are no storms in this time frame that are longer than 12 hours with D_{ST} minima lower than $-80nT$ that have existing mass density data around onset, so an analysis of this particular relationship can't be made.

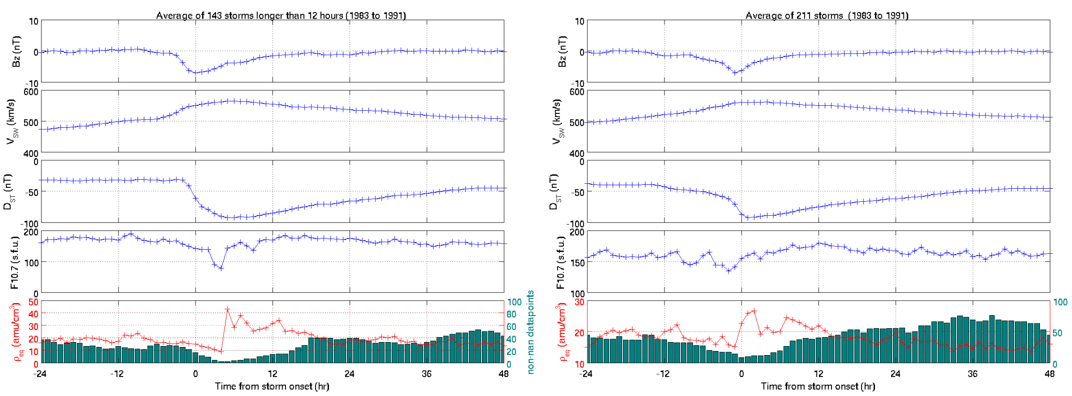

Figure 4: D_{ST} Storms > 12 hours, $D_{ST} < -80nT$

References

K. Takahashi, R. E. Denton, and H. J. Singer. Solar cycle variation of geosynchronous plasma mass density derived from the frequency of standing Alfvén waves. *Journal of Geophysical Research (Space Physics)*, 115:A07207, July 2010. doi:10.1029/2009JA015243.

K. Takahashi, R. E. Denton, R. R. Anderson, and W. J. Hughes. Mass density inferred from toroidal wave frequencies and its comparison to electron density. *Journal of Geophysical Research (Space Physics)*, 111:A01201, January 2006. doi:10.1029/2005JA011286.

B. Lavraud, M. F. Thomsen, J. E. Borovsky, M. H. Denton, and T. I. Pulkkinen. Magnetosphere preconditioning under northward IMF: Evidence from the study of coronal mass ejection and corotating interaction region geoeffectiveness. *Journal of Geophysical Research (Space Physics)*, 111: A09208, September 2006. doi:10.1029/2005JA011566.

B. T. Tsurutani and W. D. Gonzalez. The Interplanetary causes of magnetic storms: A review. *Washington DC American Geophysical Union Geophysical Monograph Series*, 98:77–89, 1997. doi:10.1029/GM098p0077.

R. E. Denton, K. Takahashi, I. A. Galkin, P. A. Nsumei, X. Huang, B. W. Reinisch, R. R. Anderson, M. K. Sleeper, and W. J. Hughes. Distribution of density along magnetospheric field lines. *Journal of Geophysical Research (Space Physics)*, 111:A04213, April 2006. doi:10.1029/2005JA011414.

R. Denton. Database of Input Parameters for Tsyganenko Magnetic Field Modles, 2007. URL `http://www.dartmouth.edu/~rdenton/magpar/index.html`. Retrieved 2013-10-28.

D. Kondrashov, R. Denton, Y. Y. Shprits, and H. J. Singer. Reconstruction of gaps in the past history of solar wind parameters. *Geophysical Research Letters*, 41:2702–2707, April 2014. doi:10.1002/2014GL059741.