Study of Geomagnetic Field Response to Solar Wind Forcing

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Introduction

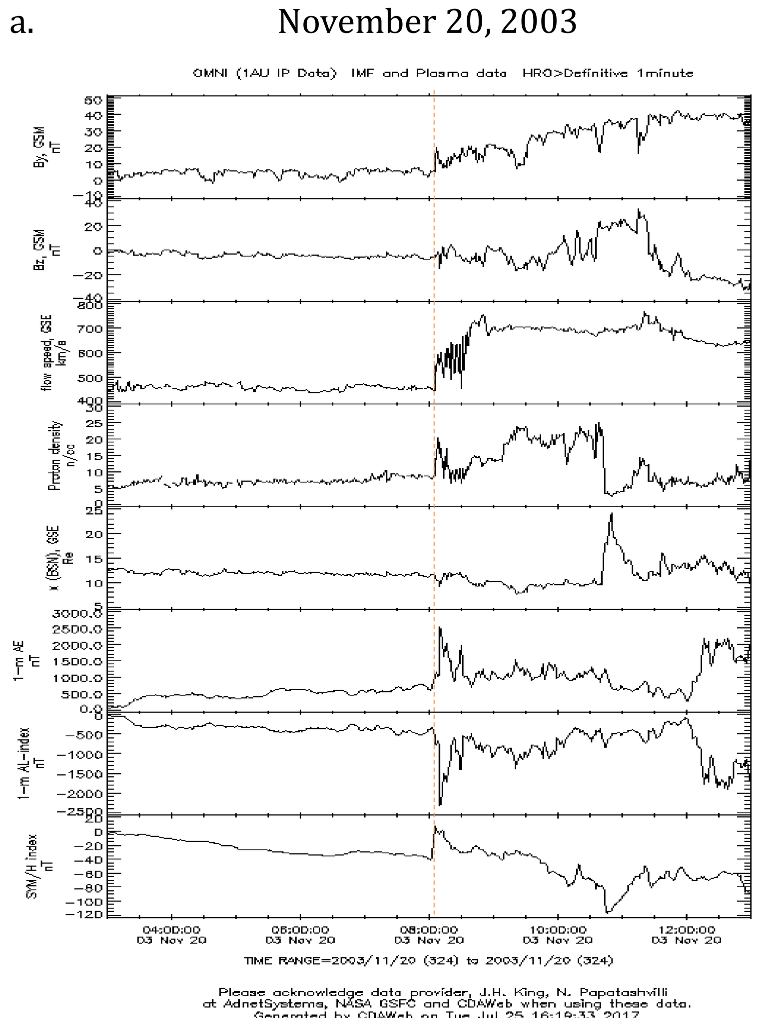
The solar wind is an integral component of space weather that has a huge impact on the near-Earth space conditions, which can in turn adversely impact technological infrastructure. By analyzing solar wind data, we can investigate the response of the Earth's magnetic field to changes in solar wind conditions, such as dynamic pressure, speed, and interplanetary magnetic fields (IMF). When a coronal mass ejection (CME) hits the Earth's magnetosphere, it compresses the dayside magnetosphere, which leads to Sudden Storm Commencement (SSC) seen in Dst or SYM-H index. Dst and SYM-H index are a measure of geomagnetic storm intensity that represents the magnetic field perturbations in the equatorial region originating from ring current. In this study, we focused on SSC intervals with sudden density increase, Δdensity, greater than 10 n/cc from 2000 to 2015 using data obtained from the NASA CDAWEB service. A total of 1,049 events were picked for this project. Then using INTERMAGNET service, corresponding horizontal component of magnetic field data were collected from several stations located in equatorial region, mid-latitude region, high-latitude region on the day-side and night-side of Earth. Using MATLAB, we calculated the rate of change of magnetic fields (dB/dt) for each station and each event. We found that in most cases, the sudden increase in proton density is associated with large changes in magnetic fields, dB/dt. The largest magnetic field changes were observed on the day-side than night-side at high latitudes. Interestingly, some exceptions were found such that greater dB/dt was found on night-side than day-side during some events, particularly at high latitudes. We suspect these are driven by magnetospheric substorms, which are manifested by an explosive release of energy in the local midnight sector. The next step will be creating the statistical form to see the correlation between proton density changes and magnetic field changes.

Methods

1.The interplanetary solar wind data was obtained from Coordinated Data Analysis Web (cdaweb.sci.gsfc.nasa.gov); the satellite ACE was used. High-resolution 1 min solar wind data were retrieved and analyzed. The data composes of IMF B_y and B_z, plasma flow speed (V), proton density (Np), Bow Shock Nose location X(BSN_x) , AE, AL, and SYM-H. The time interval was picked centered around the SSC.

2. The geomagnetic field data was obtained from the Real-Time Magnetic Observatory Network [INTERMAGNET] database (www.intermagnet.org). For each event, we picked geomagnetic data at three different latitudes on the day-side and night-side. We analyzed the rate of change of horizontal magnetic (B_x) component with MATLAB.

a. November 20, 2003



b. June 22, 2015

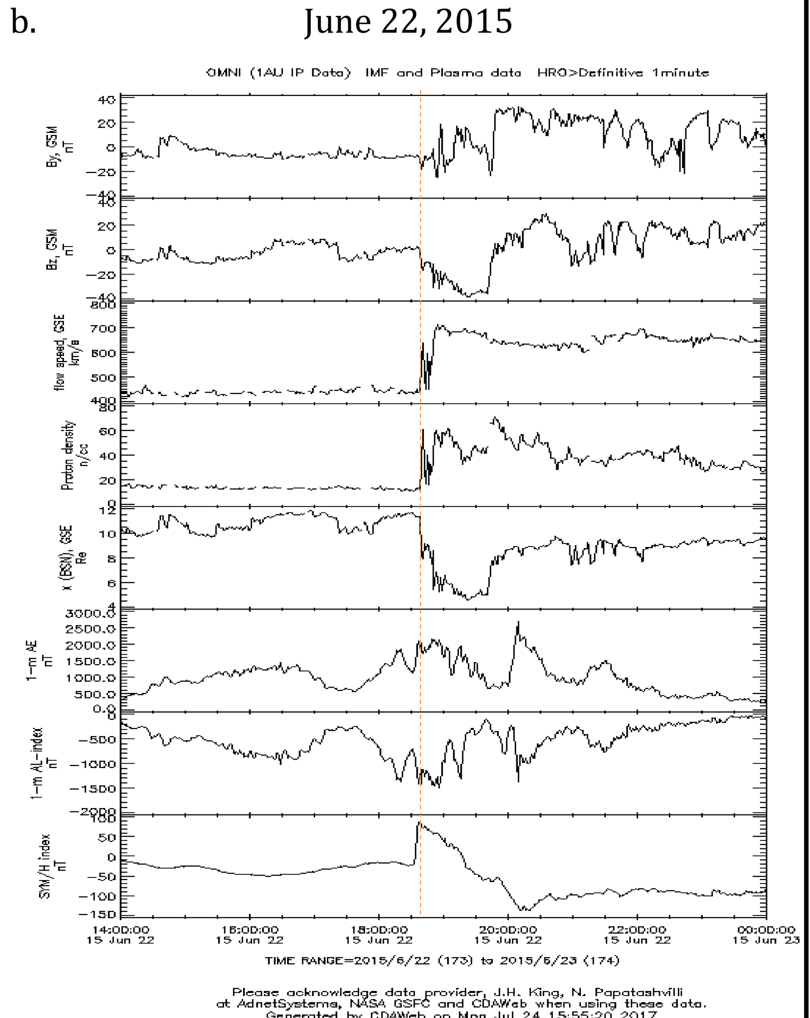
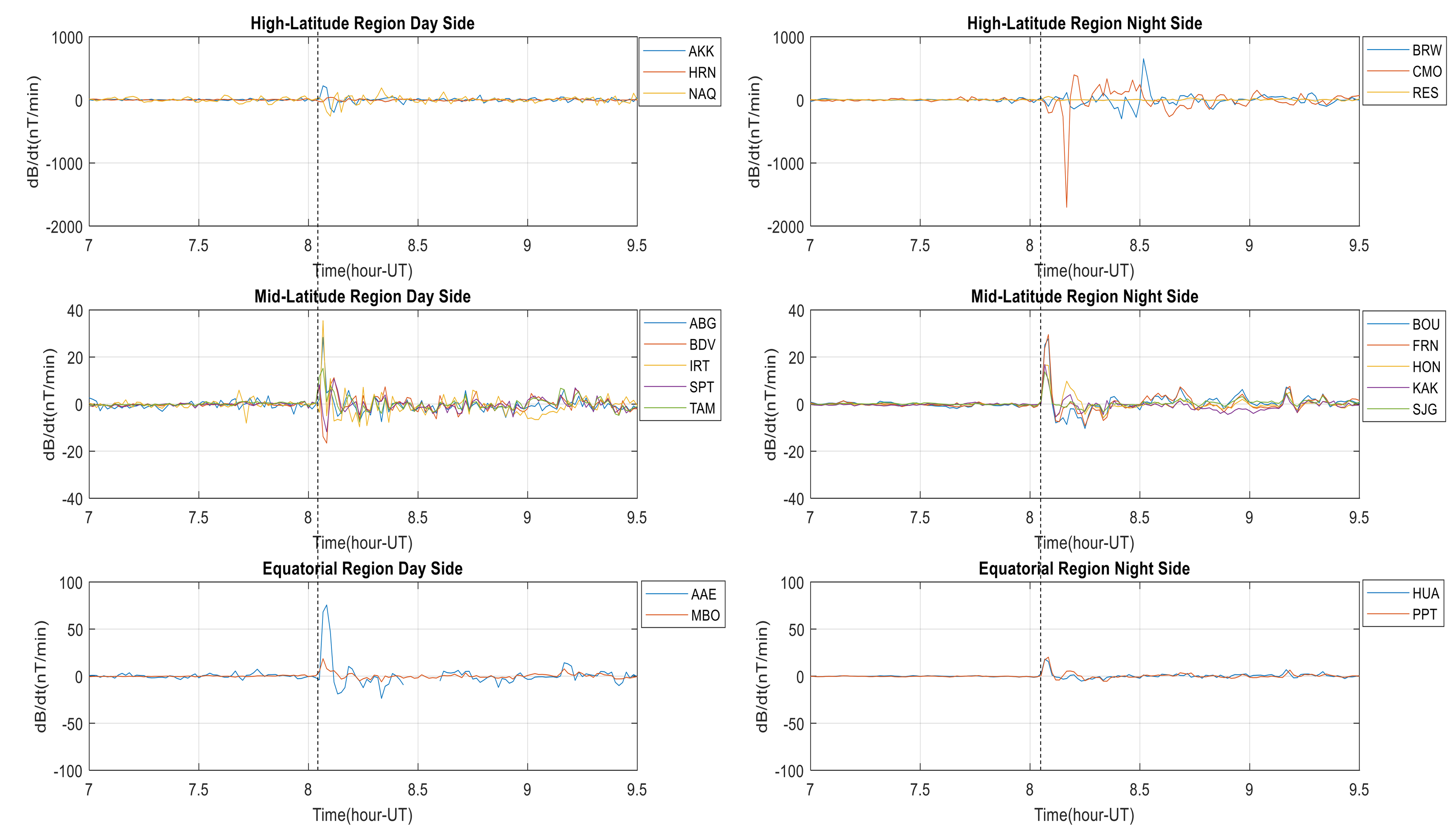


Figure 1: Solar wind data from CDAWeb

a. November 20, 2003



b. June 22, 2015

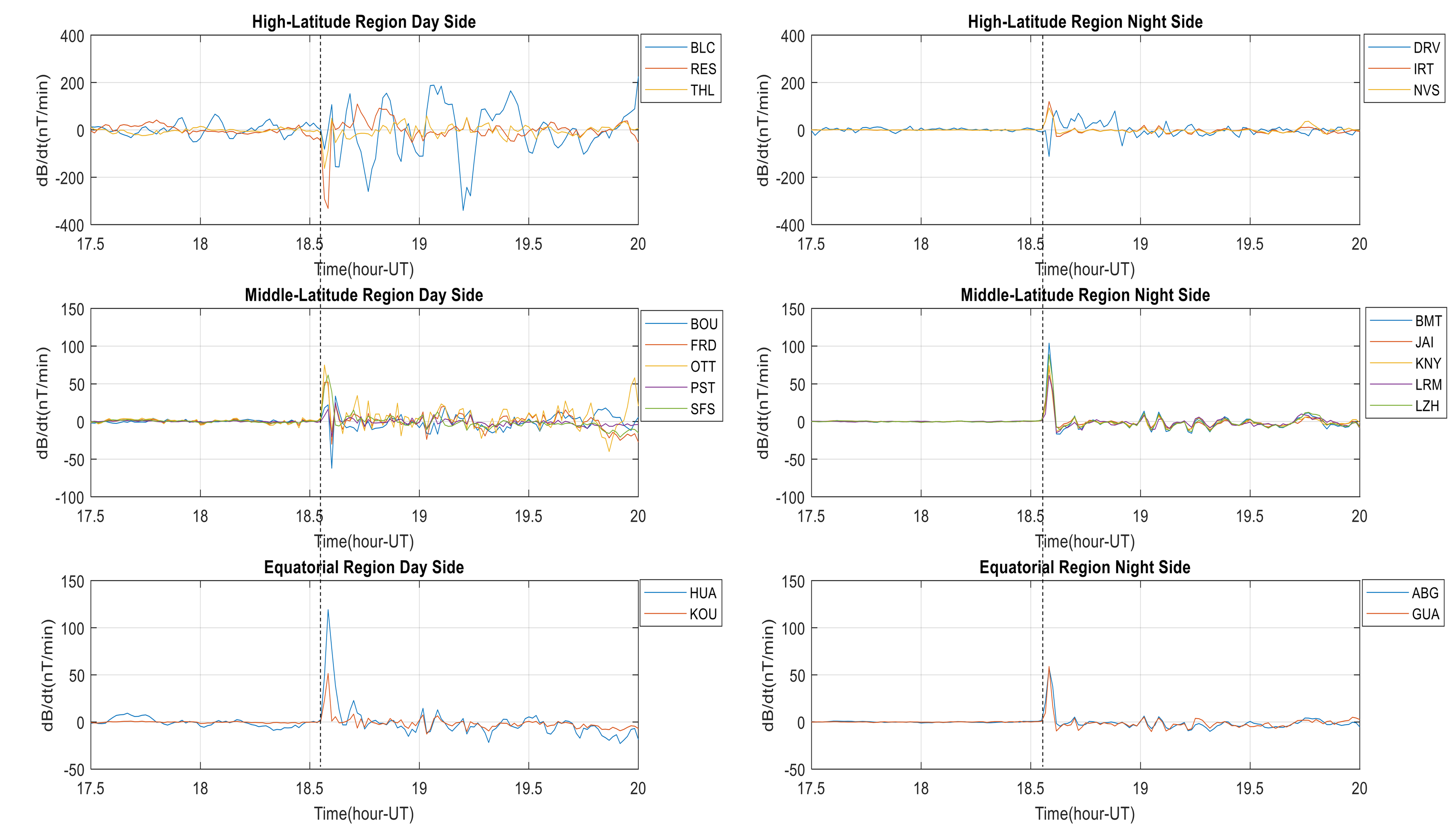


Figure 2: Geomagnetic Field Data from INTERMAGNET

Figure 1a and Figure 1b are corresponding to Figure 2a and Figure 2b respectively.

Day side vs. Night side at High Latitudes

Year	Num. of Events	Day side	%Dayside	Night side	%Nightside
2000	72	47	65.28	25	34.72
2001	21	7	33.33	14	66.67
2002	27	15	55.56	12	44.44
2003	13	9	69.23	4	30.77
2004	26	12	46.15	14	53.85
2005	70	47	67.14	23	32.86
2006	33	19	57.58	14	42.42
2007	21	16	76.19	5	23.81

Year	Num. of Events	Day side	%Dayside	Night side	%Nightside
2008	12	5	41.67	7	58.33
2009	21	9	42.86	12	57.14
2010	26	13	50.00	13	50.00
2011	37	18	48.65	19	51.35
2012	29	17	58.62	12	41.38
2013	27	15	55.56	12	44.44
2014	23	17	73.91	6	26.09
2015	30	19	63.33	11	36.67

Table 1: The number of events of dB/dt increases with SSC

Results & Discussion

- Our observations for the 20 November 2003 storm show sudden proton density increase at 08:03 UT until 08:08 UT. The SSC during the interval is 45 nT. During the same period the surface magnetic field dB/dt has large increase.
- We expected greater dB/dt on day-side than that on night side since solar radiation leads to greater conductivity on dayside. However, CMO station (College, Alaska), which is located at high latitude on night side during that time, shows much greater dB/dt than those from other stations.
- The AE and AL indices show sharp changes from 08:09 UT to 08:10 UT, where AE changed from 1070 nT to 2526 nT, and AL changed from -796 nT to -2328 nT. Therefore, we suspect that there was substorm activity on the night side of Earth.
- For the event on June 22 2015 storm, a strong SYM-H increase during the SSC is seen with changes from minimum -22 nT to maximum 88 nT. The resulting dB/dt changes.
- The large changes in dB/dt are seen on the day-side sector at all latitudes with very enhanced dB/dt values at the equator as compared to the storm on November 20, 2003.
- Comparing Figure 2a and Figure 2b we see that the night side response partner is similar but there is no substorm on June 22, 2015, as AE and AL were quiet and no sudden changes.
- Table 1 showed the number of the events that happened in each year. We compared the day side and night side of each event to see which side had bigger changes in magnetic field. Mostly the day side had bigger magnetic field changes than those on night side, but we also observed that some years had bigger magnetic field changes on night side.
- The next step is to perform a statistical analysis of our data by comparing solar wind parameters and ground dB/dt changes.

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