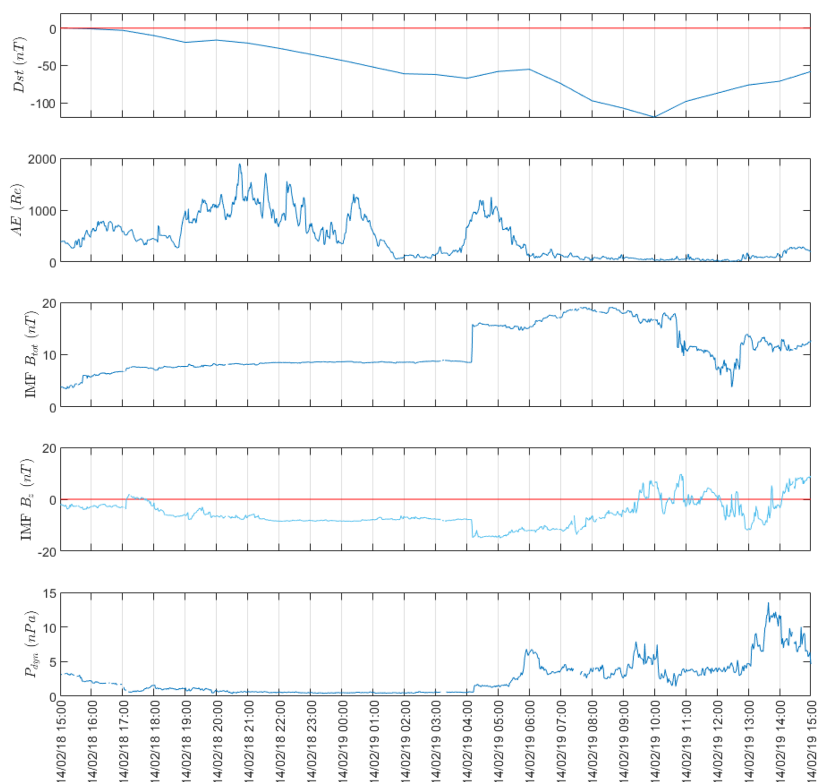
1.1. Purpose of LabWork-4 : In this Lab Work, we will learn about the magnetic storms, magnetospheric substorms, magnetic indices and the consequence of magnetic storms. We will use magnetic index data to decide on the presence of the storms and substorms and correlate them with the solar wind plasma and IMF data from WIND spacecraft at L1 location. As a result of magnetic storms, the variations in the atmospheric neutral density which affect the lifetime of the LEO spacecraft.

1.2. Event Days : Active Day : 2014/02/18 15:00 - 2014/02/19 15:00; Quit Day : 2014/02/14

If solar winds with high energy are southward, they merge with Earth's magnetic field lines running from south pole to north pole and this causes high energy particle transfer to the earth environment. Observable effect of this state on Earth is called a magnetic storm. Magnetic substorms are a much more frequently observed phenomenon, and they are formed as a result of magnetic reconnection of solar winds with magnetotail. Magnetic substorms may or may not be an effect of magnetic storms. In this Labwork, Dst (Disturbance Storm Time) and AE (Auroral Electrojet) indices are used to determine the magnetic activity.

Differences : • Magnetic storm causes magnetic substorms. • Storms are global while subtorms are local phenomenons. • Effect of storms can be observed lower latitude. • Effects of magnetic storms last much longer.

2. Time Series Plots for Active Day



3. Sudden Commencement (SC)

SC is called a sudden increase in magnetic field magnitude and is observed with a sudden northward increase in the Dst index.

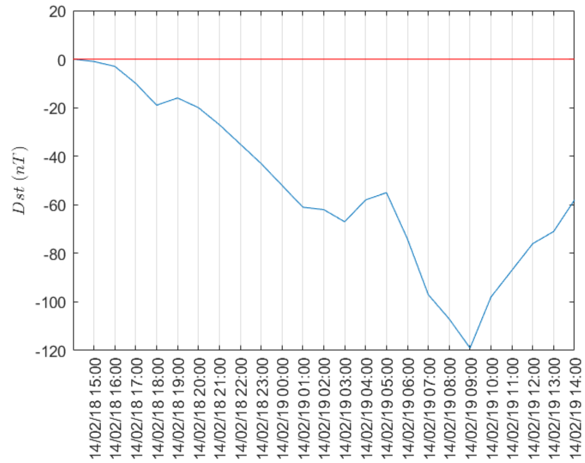


Figure 1: Dst Index for Active Day

In our event day SC was not observed.

4. Dst According to Dst index, storm started at 2014/02/18 at 23:00 ($Dst = -43\ nT$) and it continued throughout the event day.

5. Ae

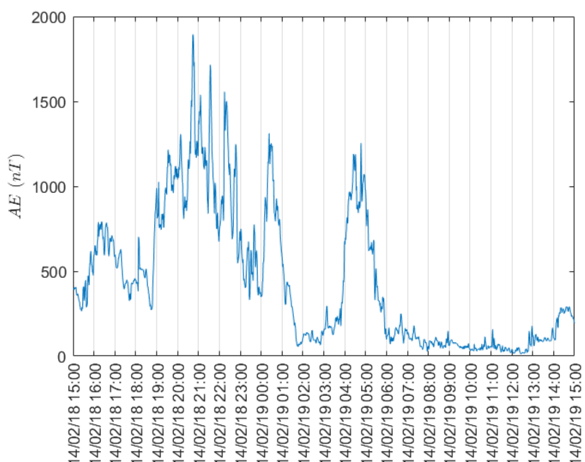
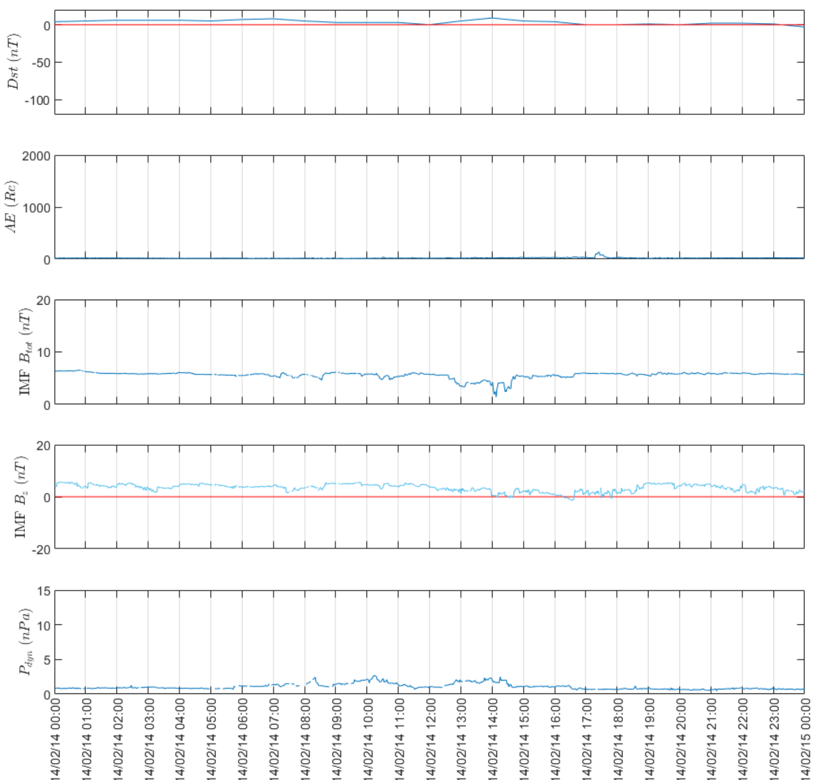


Figure 2: AE Index for Active Day

By looking AE index it can be said that there is a magnetic substorm when $AE > 100\ nT$. Event day contain more than one strong substorms. Even it is hard that when chained magnetic substorms are started there are very strong magnetic substorms between 2014/02/18 19:00 and 2014/02/19 01:00 and between 03:00 and 06:00 a clear substorm can be observed.

6. Time Series Plots for Quiet Day



7. Calculation of Drag Force for Active Day

$$\rho = n.m_{p,oxg}; \quad n = 1 \times 10^{10}\#/cm^3; \quad m_{p,oxg} = 16 \times 1.67 \times 10^{-27}kg; \quad C_d = 2; \quad A = 1m^2$$

$$G = 6.67 \times 10^{-11}m^3kg^{-1}s^{-2}; \quad M_e = 5.972 \times 10^{24}kg; \quad R = R_e + r_o = 6378km + 410km = 6788 \times 10^3m$$

$$V = \sqrt{\frac{G.M_e}{R}} = 7.66km/sec$$

$$F_{drag} = \frac{1}{2}\rho V^2 C_d A = 0.0157N$$

8. Calculation of The Lifetime of the Spacecraft for Active Day

$$k = 1.38 \times 10^{-23}m^2kgs^{-2}K^{-1}; \quad T = 1500K; \quad M_{oxg} = 16amu; \quad g = 10m/s^2; \quad m_{sat.} = 300kg$$

$$m_{oxg} = M_{oxg}.m_p; \quad H = \frac{kT}{m_{oxg}g} = 77470km$$

$$B = \frac{m}{C_D A} = \frac{300}{2.1} = 150kg/m^2$$

$$L = \frac{HB}{2\pi\rho h^2} = \frac{774.7706 \times 10^3 \times 150}{2.\pi.(5 \times 10^{16}.1.6710^{-27}).(678810^3)^2} = 150.2191 rev.$$

9. Conversation

$$1\,rev = 2\pi\,rad; \qquad L = 2.\pi.150.2191\,rad; \qquad w = \frac{V}{R} = \frac{7.66}{6788}\,rad/sec$$

$$L = \frac{2.\pi.150.2191\,rad}{7.66/6788\,rad/sec}/(60.60.24) = 9\,days,\ 16\,hours,\ 19\,minutes$$

10. Calculation of Drag Force for Quiet Day

$$n = 1\times 10^8\,\#/cm^3; \qquad \rho = n.m_{p,oxg}; \qquad V = 7.66km/sec;$$

$$F_{drag} = 0.1568\,mN$$

11. Calculation of The Lifetime of the Spacecraft for Quiet Day

$$T = 500K; \qquad B = 150kg/m^2; \qquad H = 25823km$$

$$L = 5007.3\,rev$$

12. Conversation

$$1\,rev = 2\pi\,rad; \qquad L = 2.\pi.5007.3\,rad; w = \frac{V}{R} = 0.0011\,rad/sec$$

$$L = \frac{2.\pi.5007.3\,rad}{0.0011\,rad/sec}/(60.60.24) = 322\,days,\ 16\,hours,\ 6\,minutes$$

13. Statistics Table

Maximum	Active	Quiet
Dst (nT)	-119	-3
AE (nT)	1894	136
IMF Btot (nT)	19.1	6.55
IMF Bz $\geq$ 0 (nT)	9.65	5.6413
IMF Bz <0 (nT)	-14.61	-1.3631
Pdyn (nPa)	13.58	2.6749

Table 1: Maximums for Active and Quiet Day

Minimum	Active	Quiet
Dst (nT)	0	9
AE (nT)	13	6
IMF Btot (nT)	3.4577	1.40666
IMF Bz $\geq$0 (nT)	0.0278	0.0066
IMF Bz <0 (nT)	-0.0301	-0.0766
Pdyn (nPa)	0.3646	0.4552

Table 2: Minimums for Active and Quiet Days

	Avtive	Quiet
Fdrag (Newton)	0.0157	0.1568 x 10^{-3}
Lifetime (rev)	150.2191	5007.3
Orbital Time (days)	9	322

Table 3: Additional Values for Active and Quiet Day

13. Evaluate/interpret

For event date selected for active day, IMF Bz values are usually below 0, and as it continues to increase in the negative direction Dst graph follows it. When the IMF Bz values are above 0, the Dst graph also moves upwards. AE graph, which does not seem to be directly affected by high fluctuations in other graphs, is often well above 100 nT (mean : 442 nT). By looking only AE and Bz graphics, it can be said that a substorm and sudden increase at magnitude of southward IMF Bz observed at the same time.

For event date selected for quiet day, all graphs are smoother and with smaller magnitudes unlike the active day.

As day went from quiet to active, temperature and drag force increased, oxygen density decreased, and as a result, number of revolution and lifetime of spacecraft are shortened.

8. Learning Outcomes

Summary: After event dates are selected, data of Dst and AE indices are obtained. Then data of magnetic and plasma properties of solar wind are obtained from WIND spacecraft. Stacked plots are drawn. After this part is done, for a spacecraft at an attitude of atmosphere, drag force on spacecraft and it's lifetime are calculated for active and quiet day with given values. Statistic studies are done for both day.

Learning Outcomes: Magnetic storms are highly dependent on direction and magnitude of the z-component of the magnetic fields of the solar winds, and their presence is determined by the Dst index.

Lifetime of spacecraft depends on properties of the upper atmosphere, and these properties change depending on sun-earth interaction.