SPACE ENVIRONMENT, 2020-2021 **LAB WORK-4**
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1. Purpose of LabWork04:

Understanding the characteristics of magnetic storms and magnetospheric substorms, showing how magnetic indeces are related to those events. Investigating a correlation between those events and sensor data from a spacecraft in solar wind region.

WIND

Event Interval: 2014/01/07 00.00.00.000 - 2014/01/07 23.00.00.000

Magnetic Storms and Magnetospheric Substorms

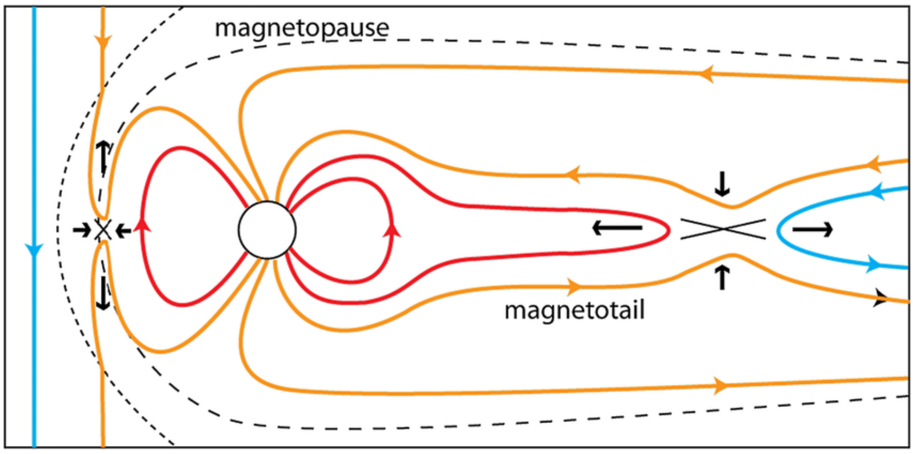

Figure 1: Demonstration of dayside and magnetotail reconnections on XY plane (Eastwood, Nakamura & Turc, 2017, p. 1223)

Magnetic Storms	Magnetospheric Substorms
Magnetic storms occur when there is a magnetic reconnection due to negative IMF B_Z on dayside of Earth.	Magnetospheric substorms occur when there is magnetic reconnection on the magnetotail of Earth.
The Dst (Disturbance Storm Time) index indicates the world wide magnetic stroms level.	The AE (Auroral Electrojet) index indicates the magnetic substorms level of auroral zone. $AE = AU + \|AL\|$
The effects of magnetic storms may be seen globally.	Magnetospheric substorms affect higher latitudes and cause the northern lights.
Magnetic storms may lead to magnetospheric substroms.	Although magnetic substorms may occur because of magnetic storms, those events can also occur due to magnetotail dynamics.

The Kp (Planetarishe Kennziffer) index is measured in midlatitude stations. It shows the latitudes of magnetic disturbances.

2. Stacked Plots :

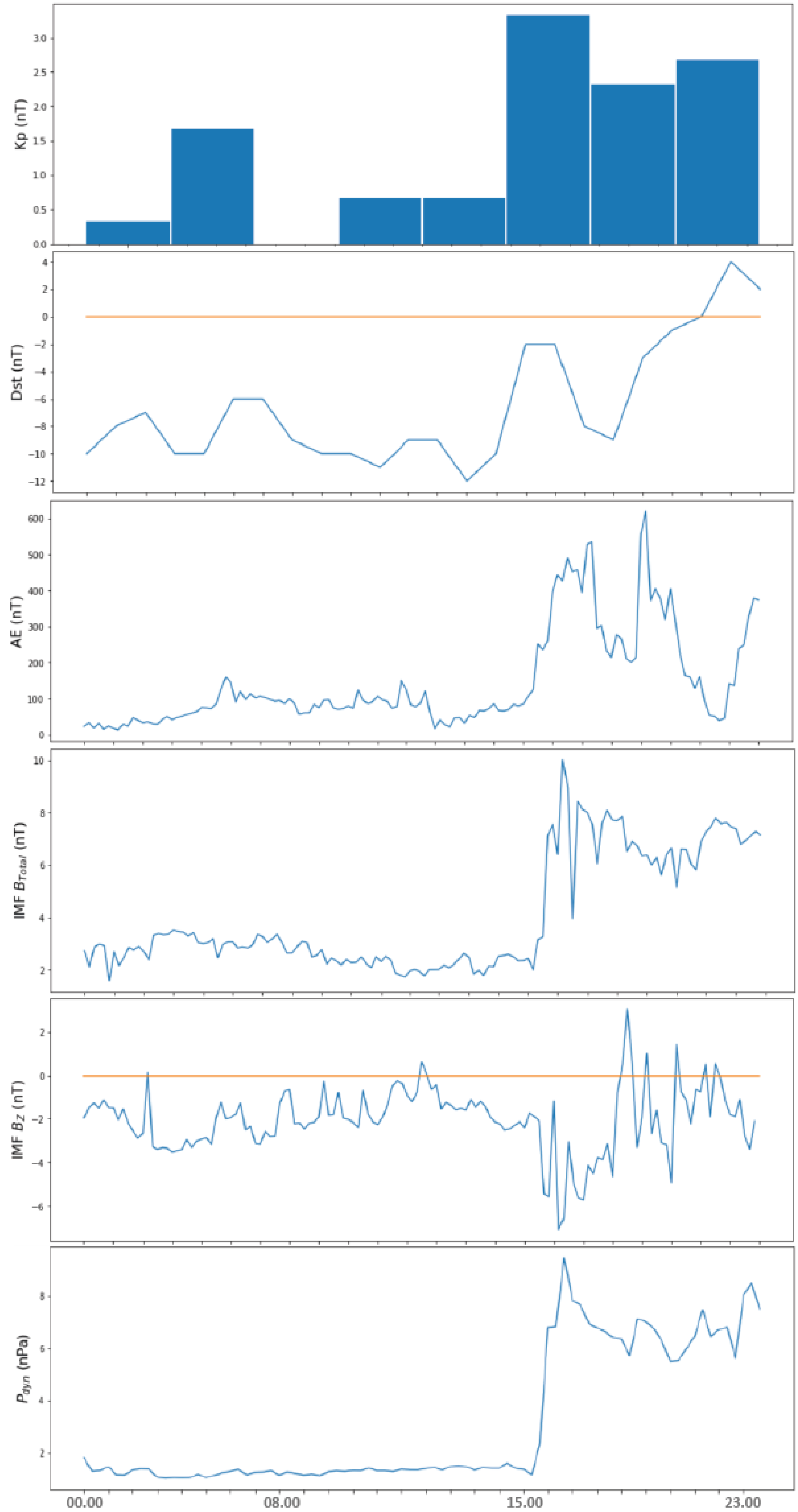

Figure 2: Stacked Time Series Plots of Dst, AE, Kp, IMF B_{tot}, IMF B_z, and P_{dyn}

3. Sudden Commencement (SC) :

Sudden commencement occurs when there is an increasing jump in velocity and density of the solar wind particles. Sollar wind particles push the magnetopause and make it closer to Earth in the dayside of Earth. Since the magnetopause is closer to Earth, the magnetic field in the dayside of the magnetosphere suddenly increases. At one point it dramatically discharges and leads to magnetic storms. It can be seen as an increase in Dst index. On 7 Jan. 2014, there is a quite weak sudden commencement and it increases the Dst index up to 4 nT.

4. Magnetic Storms :

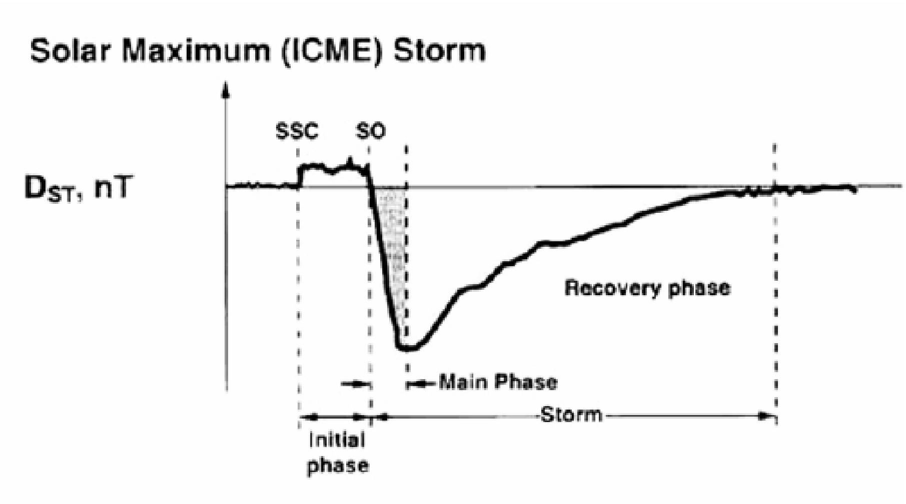

Figure 3: Typical profile of the Dst index during storms (Guarnieri et al., 2006, p. 2)

Magnetic storms occur when there is a dayside magnetic reconnection due to negative IMF B_Z. Negative Dst Indices indicate the magnetic storms. When the Dst indices reach -40 nT and smaller values, the effects of magnetic stroms can be seen globally. The Dst indices that are bigger than -20 nT are considered as quiet time activity. Besides, an increasing jump in P_{dyn} of solar wind may lead to a magnetic storm if IMF B_z becomes negative. On 7 Jan. 2014, the Dst indices are relatively high, and therefore the effects of the magnetic storm are negligible.

5. Magnetospheric Substorms :

Magnetospheric substorms occur when there is a magnetic reconnection in the magnetotail. Magnetic storms and the dynamics of the magnetotail may cause magnetospheric substorms. High AE indices which are meausured at high latitudes are indicator of those substorms. Apart from this, high P_{dyn} of the solar wind particles may cause magnetospheric substorms. On 7 Jan. 2014, according to AE indices from Figure 2, there are 3 magnetosphere substorms at 16:00, 19:00 and 23:00.

6. Kp Index :

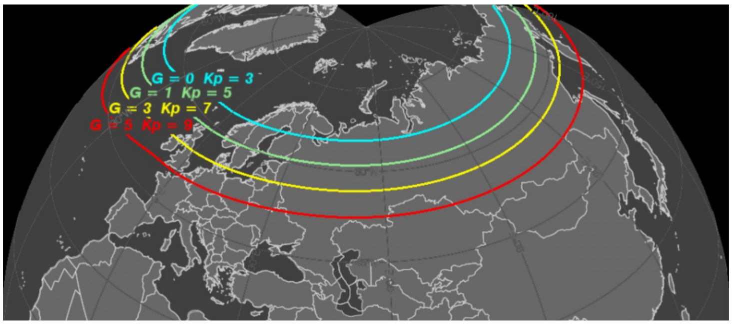

Figure 4: The relation between Kp indices and latitudes (NOAA Space Weather Prediction Center, Boulder CO, USA)

Kp indices that are higher 4 may cause mid-latitudes magnetospheric disturbances also known as the aurora borealis. In Figure 4, the relation between Kp indices and latitudes is shown. On 7 Jan. 2014, according to Kp indices from Figure 2, the maximum Kp index is 3, and thus magnetospheric disturbances are not expected in mid-latitudes.

7. Statistics Table :

	Max	Min
$\|Dst\|$	12.000000	0
AE	644.000000	14.00000
Kp	3.330000	0.00000
IMF $B_Z < 0$	-0.008520	-8.16829
IMF $B_Z \geq 0$	3.054070	0.026908
P_{dyn}	9.593593	0.96398

Table 1: Statistics Table of Dst (nT), AE (nT), Kp (nT), IMF B_Z (nT), P_{dyn} (nPa)

8. Orbit Plot :

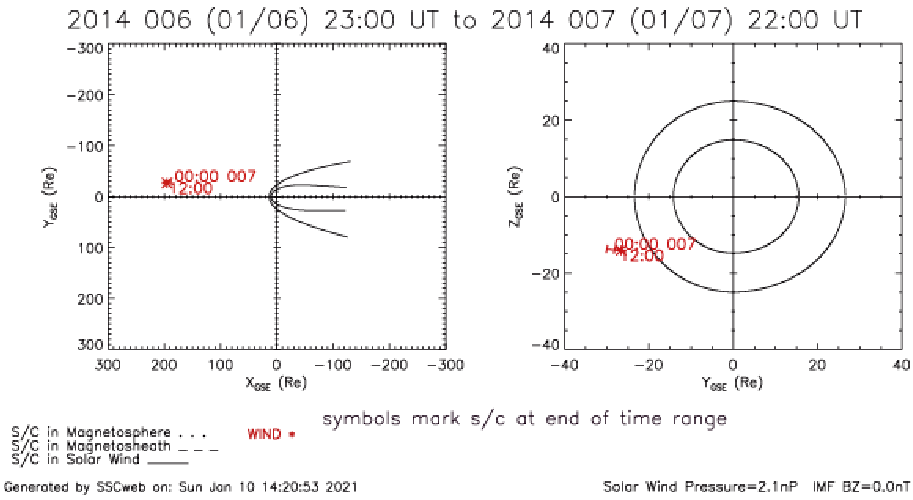

Figure 5: Orbit of WIND Spacecraft during the event

9. Evaluation :

Wind spacecraft is in a halo orbit around the Lagrange point 1 and always directing the Sun. This is why the properties of the solar wind particles can be measured 1 hour before those particles reach Earth. In Figure 2, increase in P_{dyn} caused increase in AE indices, and thus magnetospheric substorms occured. Kp indices shows that magnetospheric disturbances may be seen at high latitudes. In Table 1 and Figure 2, Dst indices are higher than -40 nT and relatively high, therefore there is no magnetic storm in the event date. IMF B_Z and AE indices are inversely proportional.

10. Learning Outcomes :

Summary:
Firstly, the characteristics of magnetic storms and magnetospheric substorms are determined and the difference between them are shown. Time series plots are used to show the correlation between WIND spacecraft data and Dst, Kp and AE indices. Sudden commencement and its magnitude are demonstrated. Dst, AE and Kp indices are defined, the correlation between storms, substorms, their latitudes and those indices are shown. The orbit of WIND spacecraft is shown. The interpretations of the figures and table are fulfilled.
The report is written in LaTeX.
Project Code: `https://github.com/kadirkilicnet/magnetic-storms`

In this Labwork04, I learned the followings:

- The characteristics of the magnetic storms
- The characteristics of the magnetospheric substorms
- The characteristics of the sudden commencement
- The correlation between Dst, AE, Kp indices and magnetics storms and magnetospheric substorms
- The importance of satallites at Lagrange point and using their data to investigate magnetic storms and magnetospheric substorms approximately 1 hour early
- The correlation between Lagrange point satallites' data and geomagnetic storms

References

Eastwood, J.P., Nakamura, R., Turc, L. et al. The Scientific Foundations of Forecasting Magnetospheric Space Weather. Space Sci Rev 212, 1221–1252 (2017).

Guarnieri, F., Tsurutani, B., Gonzalez, Walter, Gonzalez, Alicia, Grande, M., Soraas, Finn, Ech, E.. (2006). ICME and CIR storms with particular emphasis on HILDCAA events.