Variation of ULF and VLF due to Space Weather Conditions

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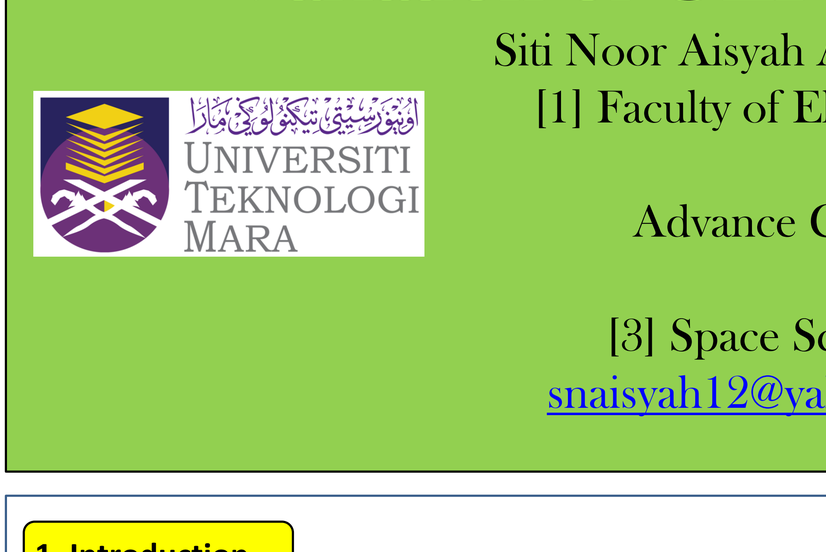
1. Introduction

The process of interaction between space weather conditions and Earth's magnetic field is one of the factors that lead to the variation effect of both ultra-low frequency (ULF) and very low frequency (VLF) waves which can be observed in space and on the ground. These variations are recorded in the frequency range of ULF and VLF with 1.7 - 500 mHz and 3-30 kHz respectively. Therefore, investigations on variations of ULF and VLF due to space weather conditions are important. In our analysis, the recorded ULF and VLF waves were analyzed at different stations with the occurrence of strong geomagnetic storm.



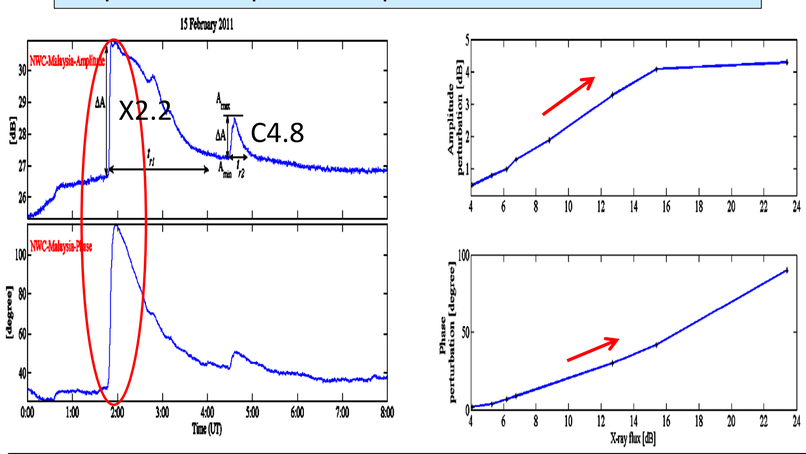
2. Objectives

1. To investigate the possible correlation of ULF and VLF due to space weather conditions.
2. To characterize the ULF and VLF signals due to space weather conditions.

3. Motivations

1. M. Masri et.al, 2013 : VLF Observation of D-region Disturbances Associated with Solar Flares at UKM, Selangor, Malaysia

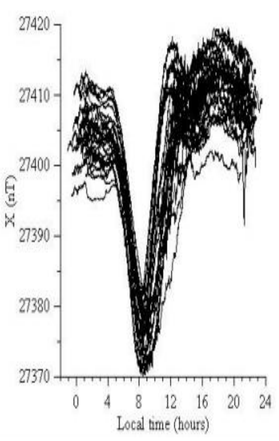
Amplitude and phase VLF perturbations on 15 Feb 2011



- Amplitude and phase perturbation produced by an X2.2 and a C4.8 solar flares occurred on 15 February 2011.
- The solar flare started at 01:44 UT and reached to the maximum at 01:56 UT (local time = UT + 8)
- VLF amplitude and phase signal started to increase a few minutes and reached a fully perturbed level at ~01:58 UT.

2. R. A. Greculeasa et. al, 2013: Sources of Geomagnetic Activity at Mid-Latitudes: Case Study – European Observatories

Geomagnetic field (X-component) for August 2010 at 29 observatories



- One minute averages of the northward geomagnetic component, X, in the time interval 1-10 August 2010, from 29 European geomagnetic observatories were used.
- The magnetospheric ring current and the ionospheric auroral electrojets control the disturbed field observed at mid-latitude observatories except for LYC, SOD, ABK.
- The results for LYC, SOD and ABK indicate the presence of additional effects from currents in the polar cap area.

4. Data Analysis

A) Space Weather Conditions

- Solar wind parameters have been considered which are; (1) solar wind speed, (2) z-direction of IMF, Bz, (3) solar wind input energy and (4) Dst index.
- Solar wind speed and IMF Bz (nT) were obtained from the Space Physics Data Facility (SPDF) based at NASA's Goddard Space Flight Center.
- Dst indices are provided by the World Data Center for Geomagnetism, Kyoto, Japan.
- Solar wind input energy can be calculated using Akasofu epsilon, ε as equation:

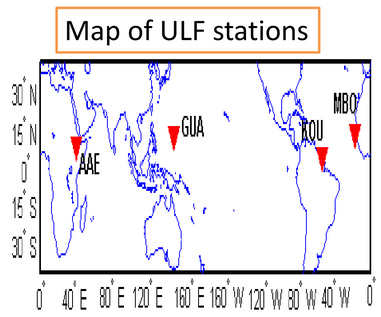
$$\varepsilon = V_{sw} B^2 F(\theta) I_o^2 \quad \text{(Watt or ergs)}$$

- Where Vsw is solar wind speed [km/s], B is total magnetic field [nT], Io is Earth's radius [km] and F(θ) is a function of the angle, θ (By/Bz).

B) ULF Waves

- International Real-time Magnetic Observatory Network (Intermagnet)
- The global network of observatories, monitoring the Earth's magnetic field.
- The analysis of H-component was done at AAE, GUA, KOU, MBO stations.

Map of ULF stations

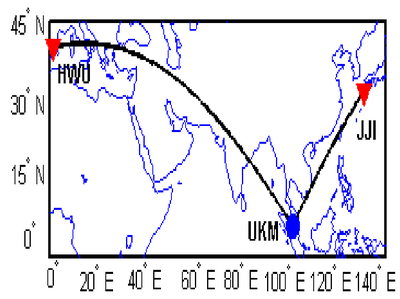


Station Name	Code station	Lat.	Long.
Addis Ababa, Ethiopia	AAE	9.03	38.77
Guam, USA	GUA	13.59	144.87
Kourou, French Guana	KOU	5.21	307.27
Mbour, Senegal	MBO	14.38	343.08

C) VLF Waves

- An Atmospheric Weather Electromagnetic System for Observation Modeling and Education (AWESOME) was constructed and introduced by Stanford University, United States research group installed at the Institute of Space Science in Universiti Kebangsaan Malaysia (UKM), Malaysia (6.3°N, 99.78°E) in 2009.
- This equipment is function to monitor the strength of single frequency radio stations from the transmitter and detect a natural signal.
- The analysis of VLF amplitude was detected a signals from HWU and JJI transmitters at UKM receiver.

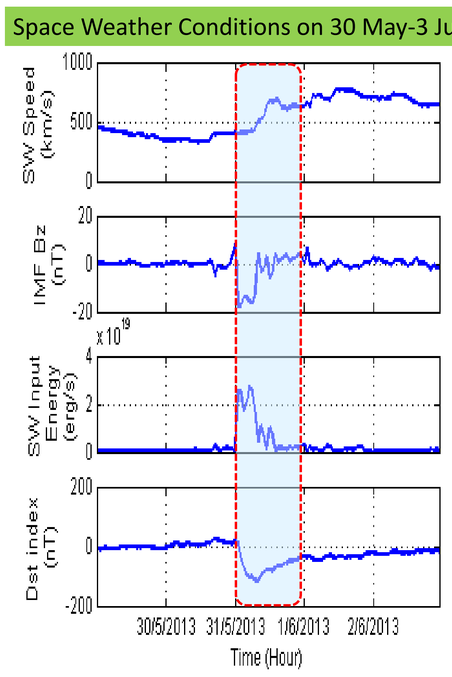
Map of VLF transmitters, HWU and JJI with UKM receiver



Station Name	Code station	Lat.	Long.	Frequency (kH)
Rosnay, France	HWU	40.7	1.25	1.83
Ebino, Japan	JJI	32.04	130.81	22.2

1 Space Weather Conditions

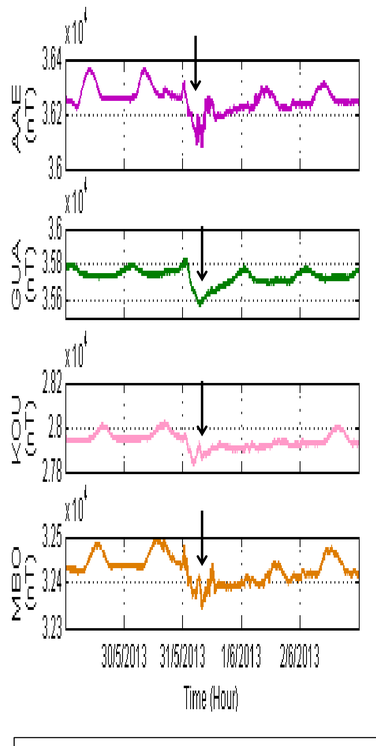
Space Weather Conditions on 30 May-3 June 2013



- Solar wind input energy is increased when IMF Bz turns southward
- The amount of SW input energy (2.5x10^19 erg/s) is increasing followed by Dst index (minimum -119 nT) where the strong geomagnetic storm is occurred on 1 June 2013.
- This is categorized as disturbed period.

2 ULF Variations

H-component on 30 May-3 June 2013 at AAE, GUA, KOU and MBO



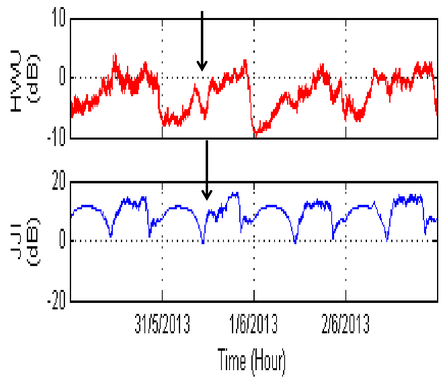
Correlation Coefficient

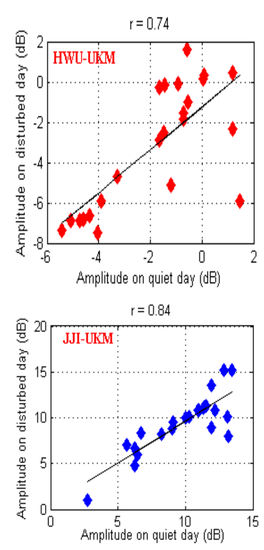
H-component	Quiet Period	Disturb Period
AAE	0.81	-0.41
GUA	0.8	0.57
KOU	0.9	0.35
MBO	0.87	-0.02

- H-components is fluctuated during strong geomagnetic storm.
- H-components are less correlated during disturb period compared to the quiet period.

3 VLF Variations

Amplitude Variations on 31 May-3 June 2013 from HWU and JJI transmitter.





Correlation Coefficient

Amplitude VLF	Quiet Period	Disturb Period
HWU	0.79	0.74
JJI	0.97	0.84

- Small different variations occurred during disturbed period from HWU and JJI transmitter stations.
- Amplitude of VLF are less correlated during disturbed period at both transmitter stations.

Conclusion

- The analysis shows significant between space weather conditions and both ULF and VLF variations, where the increasing of Solar Wind Speed correspond to the variations of ULF and VLF.
- The higher range of geomagnetic storm can cause a very significant increased of H-component and VLF amplitude variations.
- An activity from Sun traveling to the surrounding area in space and then penetrates to the Earth due to reconnection process however will affecting the ground base system.

Acknowledgment

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