Characteristics of the Geomagnetic Field Fluctuations at Jeju Island, Offshore Korea during the periods 2001 and 2002

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Introduction

The earth' s magnetic field is generally developed from three main parts: the Earth' s interior (outer core), Earth' s lithosphere, and Earth' s exterior (solar winds). The largest part is however generated from the Earth' s outer core, usually called the main field. Solar winds play an essential role in charging the ionoshperic and magnetospheric with the electric currents.

The intensity of the Earth' s magnetic field is in reality quite irregular and slowly varies at different rates according to the position at the Earth' s surface (**Filipski & Abdullah, 2006**).

The Earth's magnetic field varies over it's surface from time to time at a fixed place through one day called daily or diurnal variation. These changes are mainly due to variations in solar flare activity in the ionosphere and magentosphere. Monitoring and analysis of the daily variation of the earth's magnetic field is of great importance to exploration geophysical surveys, radio communications, navigation systems, and spcae weather. These daily variations are larger in summer than in winter.

Magnetic flux density on the surface of the Earth typically varies between about 18μT to 70μT, depending on location. The flux density at any fixed location on the Earth' s surface also varies with time due to diurnal effects, which include influence from the Sun, and movement of the Earth' s molten interior. The Sun' s influence on the magnetosphere is apparent at the Earth' s surface as a low frequency variation that can have high amplitude. Different levels of solar activity can result in changes of several hundred nT in the course of a few hours (**SeaSPY, 2002**).

The magnetic fields of the Earth and the Sun are constantly changing and interacting, causing variations in the magnetic flux density at the Earth' s surface.

High magnetic variation (e.g. storms) on the earth is mainly owing to the solar winds which contains a large amount of kinetic and electrical energy. This energy is transferred to the magnetosphere and ionosphere creating different levels of the geomagnetic activities like storms, substorms and aurora.

It has been shown that solar wind speed correlates well with geomagnetic activity at time scales longer than about one month (**Gosling et al., 1976; Crooker et al., 1977**).

The level of the geomagnetic activity is measured using different activity indices, most of which are based on ground-based magnetometer recordings. These recordings can be used, e.g., to study the longer trends in the solar activity (e.g., **Russell, 1975**).

The Dst index is widely used to define the occurrence, duration and magnitude of a storm. Prior to the storm, Dst varies about some level around 0 nT. The start of the storm is identified by a rapid drop in Dst over several hours. It reaches a minimum and then recovers more slowly to pre-storm levels. The minimum Dst value reached is often used to classify the strength of a magnetic storm.

Storms, are initiated when enhanced energy transfer from the solar winds into the magnetosphere leads into intensification of ring currents, which can be monitored with the Dst index. **Gonzales et al. (1994)** had defined the occurrence of storm as an interval of time when a sufficiently intense and long-lasting interplanetary convection electric field leads, through a substantial energization in the magnetosphere-ionosphere system, to an intensified ring current strong enough to exceed some key threshold of the quantifying storm time Dst index.

Abrupt variation like geomagnetic storms can cause a large damage to the control of precise electronic devices, etc. in the modern societies based on technology.

As the Earth' s magnetic field is constantly changing with time it is necessary to study its characteristics to detect the quiet zones (i.e. magnetically stable periods) to provide a suitable base line for the diurnal correction of the marine magnetic survey of the Korean seas.

Jeju island station is deployed to monitor variations in the Earth' s field for the purpose of diurnal correction required for the magnetic exploration in the Korean seas. The operating system of Jeju Island station is composed of a Geometrics G-856 magnetometer of 0.1 resolution and 12500 reading memory. The sampling rate of the instrument used in this station is 5 minutes. The G-856 magnetometer (**Fig. 1**) was operated continuously throughout the survey production of 2001 and 2002 as a ground station to provide digitally-recorded observations for the diurnal correction of the marine magnetic survey of the Korean seas.

The objective of this paper is to identify the quiet zones that can be based upon when the data of the marine magnetic survey of the Korean seas undergo for diurnal correction.

Experimental results and Data analysis

The Earth' s magnetic field at Jeju Island station over a period of two years is approximately analogous whereas it ranges from 48448 to 48652 nT in 2001 and from 48455 to 48666 nT in 2002. The regional field of long wavelengths was removed from the original data using the IGRF model 2005 developed by the National Oceanic and Atmospheric Administration (NOAA).

Examination of the variations of the lengths of days shows that several jerks in the geomagnetic field are existing at Jeju Island station over a time period of 140 days in 2001 and 55 days in 2002 (**Fig. 2**).

The daily variations of 2001 (**Fig. 3**) reflect remarkable high amplitudes at ~5000 min (April 7), ~9500−12000 min (April 10, 11 & 12), and ~18500 (April 16) of −128 nT, −285 nT, −105 nT, respectively. Similarly, the variations in 2002 (**Fig. 3**) express high amplitudes at ~ 19700 (April 17) and ~68700−69900 (May 21 & 22) of −118 nT and −168 nT respectively.

The fluctuated data of 2001 and 2002 (**Fig. 3**) were examined using different statistical programs to pick up the abnormal geomagnetic activity and distinguish between the quiet and unquiet zones. Examination of the magnetic observations indicate that geomagnetic pulsations may be divided into two broad classes, those of a regular and mainly continuous character and those with an irregular pattern (e.g. storm). Like longer period disturbances, the magnetic storms are mostly of solar origin, in contrast to the Earth' s main field and secular variation, which are of internal origin.

Classification of the storms were mainly based on the disturbance time Dst index (**Table 1**), where the magnetic storm can be defined when the field variation start with a rapid increase/decrease within a couple of hours/days, followed by a decrease/increase continuing for a couple of hours/days and later by a slow recovery to normal conditions in a day or two. These different stages of the magnetic storm are now called as initial, main and recovery phases.

Tables 2 and **3** outline the results of the characteristics of the geomagnetic field fluctuation at Jeju Island station in 2001 and 2002 in terms of the magnetic storms occurred within these periods.

Table 1. The thresholds and driving parameters of Dst index

Storm strength	Dst [nT]	Estimated Time [h]
strong	−100	3
Moderate	−50	2
Weak (typical substorm!)	−30	1

Data Transformation

We transformed the mean data from the time domain to frequency domain using the fast Fourier transform (FFT) to identify the individual power spectra from 55 days values with a step size of 1 day at which the geomagnetic activities occurred. The resulting average power spectra of 2001 (**Fig. 7a**) show a steep decay from high to low powers at frequency range 0.06 – 0.075 mHz, 0.185−0.237 mHz, and from moderate to low powers at frequency range 0.298−0.312 mHz.

Likewise, The resulting average power spectra of 2002 (**Fig. 7b**) show a steep decay from high to moderate powers at frequency range 0.03 – 0.06 mHz, and from moderate to low powers at frequency range 0.125−0.14 mHz, and 0.45−0.47 mHz.

In addition, we applied the FFT for some examples of different storms in 2001 and 2002 (**Figs. 8 & 9**) whereas we can investigate the frequency range at which these storms occurred. It is observed in general that the storms of high amplitude occurred at low frequencies while those of low amplitudes are occurred at high frequencies.

In 2001, three selected examples of strong, moderate and weak storms (**Fig. 8**) are presented with an average amplitudes of −285 nT (April 10 & 11: **Fig. 8a**), −52 nT (April 21−22: **Fig. 8b**), and −34 (April 20: **Fig. 8c**), respectively. The FFT of these storms (**Fig. 8**) indicates that the strong storm with high powers of ~ 67.4 nT^2 is occurred at a low frequency range (0.002−0.03 mHz), while the moderate storm with moderate powers ~ 13.1 nT^2 is took place at a moderate frequency range (0.003−0.038 mHz), and the weak storm with low powers of ~ −5.56 nT^2 is occurred at a high frequency range (0.006−0.087mHz).

Similarly, in 2002, three chosen examples of strong, moderate and weak storms (**Fig. 9**) are presented with an average amplitudes of −170 nT (May 21−22: **Fig. 9a**), −67 nT (April 17: **Fig. 9b**), and −34 (May 10: **Fig. 9c**), respectively. The FFT of these storms (**Fig. 9**) indicates that the strong storm with high powers of ~ 56.9 nT^2 is developed at a low frequency range (0.003−0.075 mHz), while the moderate storm with moderate powers ~ 55 nT^2 is enhanced at a moderate frequency range (0.003−0.044 mHz), and the weak storm with low powers of ~ −7.4 nT^2 is occurred at a high frequency range (0.006−0.063 mHz).

Conclusions

Investigating the geomagnetic activity in 2001 and 2002 concludes some important points:

1−Geomagnetic field at Jeju Island station was expressing almost an approximated value in both years where it was ~48550 nT in 2001 and ~ 48560 nT in 2002.

2−The measured field in 2001 and 2002 was not stable and generally fluctuated over some periods extending from few minutes to a couple of days.

3−Diurnal variations represent the core of the occurred geomagnetic fluctuations.

4−Geomagnetic fluctuations in 2001 is higher in number than 2002, while they show 44 events occurred in 2001 against 38 events in 2002.

5−The recoded events in 2001 are classified to 4 strong storms, 20 moderate storms and 20 weak storms, while they are classified into 2 strong storms in 2002, 18 moderate storms and 18 weak storms.

6−The highest magnetic magnitude is recoded in 2001 with an average amplitude of −285 nT, while highest average amplitude in 2002 is −170 nT.

7−The occurred magnetic storms in 2001 and 2002 are believed to be caused by electric currents induced in the Earth from an external source in the ionosphere. These electric currents in the ionosphere are in turn driven by solar activity.

8−It is very necessary to account for the diurnal variation when the one go for the interpretation the acquired data of the marine magnetic survey of the Korean seas, especially when the survey takes several weeks to be completed.

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