MIS29-01 Room:101A Time:May 22 09:00-09:15

Anomalous large amplitude geomagnetic sudden commencement (SC)

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The CRRES satellite detected instantaneous formation of the inner radiation belt near the equator in L=2.6Re and 2.5h local time at 0341 UT, March 24, 1991 [Blake et al., 1992]. At this time ground geomagnetic observatories globally observed an SC preceded by a large amplitude pulse of short duration [Araki et al., 1997]. The H-component amplitude and duration of the pulse was measured as 202 nT and 1 min, respectively by 1 sec values at Kakioka observatory. The 1 min values of routine geomagnetic observations can not record such a rapid variation accurately. Since the SC amplitude at Kakioka is usually less than 50 nT and the rise time is mostly 3-4 min, the amplitude of this pulse is anomalously large and the duration is anomalously short. A computer simulation by Liu et al. [1993] shows that an electromagnetic pulse due to the magnetospheric compression accelerated magnetospheric partcles to form the inner radiation belt. The data of EXOS-D (Akebono) satellite indicates that this radiation belt lasted more than one year [Yukimatsu et al, 1996]. Although it is interesting to see the corresponding solar wind variations, there is no data of the solar wind.

Being stimulated by this SC, we checked the SSC list publicized by Kakioka observatory since 1924.
It shows that the 1991 SC mentioned above is the second largest. The largest SC occurred on March 24, 1940. Referring to the SC list by Mayaud [1973] this seems to be the largest since 1868. If we include SI (Sudden Impulse) for which Kakioka observatory publicizes the list separately, the 1991 SC is the third largest. The second largest is an SI (220nT) occurred on November 13, 1960.

The currents induced in the earth depend upon the time variation rate of the SC. It is known that the SC amplitude correlates positively with its time variation rate [Araki et al., 2004] and so larger SCs induce stronger induction currents. Usually a linear relationship is assumed between the SC amplitude dH and jump in the square root of Pd, d(Pd**0.5) as dH=A*d(Pd**0.5) and A is experimentally estimated as about 15 nT/[Pd(nPa)]**0.5. If this A is used for SC with 200nT amplitude, Pd should be increased from 2nPa (quiet time value) to 210 nPa , but the non-linear effect will require a larger Pd.

In the estimation of A the induction effect is usually assumed to be 1.5 (i.e. SC is amplified 1.5 times on the earth). For more accurate considerations of SC, however, the induction effect should be estimated taking the time variation rate of each SC into account.

Prof. Rikitake said ; Although researchers of the upper atmosphere use observed amplitude of SCs, it is important to consider the effects of induction currents.

Keywords: geomagnetic sudden commencement(SC), historically largest SC, radiation belt, particle acceleration, induced earth current

Japan Geoscience Union Meeting 2013
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MIS29-02 Room:101A Time:May 22 09:15-09:30

Introduction of Network-MT method - toward elucidating nation-wide deep electrical conductivity structure -

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To determine a nation-wide 3-D deep electrical conductivity structure e.g. of several hundreds times several hundreds km² scale, electric field had better be measured with a typical dipole length of 10km or more. In order to estimate spatial variation of the structure in this scale, all the electrodes ideally mutually connected by the observation network. Then, referring to the pioneering works in employing telephone lines for electric dipoles (e.g., Mori, 1985, 1987), Uyeshima et al. (2001) developed an observation technique named Network- MT method. In this method, the telephone line network is fully used to determine horizontal distribution of voltage differences with long electrode spacings. The dipoles in the method are telephone lines connected to electrodes, which are either earths installed for telecommunications facilities by the telephone company, or electrodes purpose built for the experiment. Dipole lengths range from ten to several tens of kilometers. As a reference magnetic field, magnetic records obtained by three component magnetometers at geomagnetic observatories or at purpose built stations are used. Data loggers are often installed at the central telephone station. If we deploy long dipoles, the S/N ratio of electrical records will be enhanced. This enhancement will enable us to extend the experiment both in space and frequency domain (especially toward the lower frequency range). We also obtain responses relatively free from the static effect.

After the telluric voltage difference records are obtained, response functions in the frequency domain between each voltage difference and 2 component horizontal magnetic fields are estimated. Period range is from several s to 10⁵⁻⁶ s. If all the electrode points are connected by the observation network, virtual voltage difference between any pairs of electrodes can be estimated by linear combination of the response functions for real (or measured) dipoles. In this way, after selecting three electrode points in the observation area, voltage differences along two sides of the triangle made by the selected electrode points can be estimated, and then, average 2 component electric fields in the triangle, when a unit magnetic variation occurs in the x- or y-direction at the reference site, can be estimated by linear combination of the response functions. Thus the average impedance tensor for the triangle can be estimated and will be inverted to yield the electrical conductivity structure. At the same time, the response functions or the impedance tensors can be used to evaluate spatial distribution of GIC at large geomagnetic storms.

In order to obtain regional 2-D or 3-D structures from the Network-MT data, several methods were developed. One way is to first compose averaged impedance tensors for triangles made by three electrode points, as mentioned above, and then, conventional inversion schemes are applied to those impedance tensors (Yamaguchi et al., 1999; Shiozaki et al., 1999; Satoh et al., 2001). In Uyeshima et al. (2001, 2002), the response functions between respective voltage difference and magnetic field are directly reproduced in the 2-D or 3-D forward calculations. This method is adopted in a subsequent 3-D inversion scheme by Siripunvaraporn et al. (2004), which is based on a 2-D and 3-D data space Occam's inversions designed for inverting conventional MT datasets (Siripunvaraporn and Egbert, 2000; Siripunvaraporn et al., 2005). Recently, a new 2-D inversion technique for combining conventional and Network MT response functions was developed (Usui, 2010). The technique will be extended for the 3-D problem.

Keywords: Network-MT method, nation wide deep electrical conductivity structure, spatial distribution of induced currents

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MIS29-03 Room:101A Time:May 22 09:30-09:45

Mid latitude GIC as the ground surface currents carried by the TM0 mode waves in the Earth-ionosphere waveguide

Takashi Kikuchi[1*], Shinichi Watari[2], Kumiko Hashimoto[3]

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The geomagnetically induced current (GIC) has been attributed to the time change in the Bx component of the ground magnetic field. However, the GIC was found to be well correlated with By component [e.g., Watari et al., Space Weather 2009]. Recently, it was reported that the GIC has diurnal and seasonal variations, which suggests that the GIC could be a return current of the ionospheric currents since the ionospheric conductivity is affected by the solar radiation [Braendlein et al., JGR 2012]. To explain the close relationship between the GIC and ionospheric currents, the authors used the Earth-ionosphere waveguide model proposed by Kikuchi et al. [Nature 1978]. In this model, the TM0 mode wave propagates at the speed of light with accompanying the ionospheric and ground surface currents connected by the displacement currents flowing on the wave front. In the present talk, we review the Earth-ionosphere waveguide model and explains the close relationship by applying the Earth-ionosphere waveguide model.

Keywords: Geomagnetically induced current, Earth-ionosphere waveguide, ionospheric current, polar-equatorial propagation

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MIS29-04 Room:101A Time:May 22 09:45-10:00

Three-dimensional analysis technique for marine magnetotelluric method

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Magnetotelluric (MT) sounding is a powerful geophysical method to explore electrical conductivity structure in the Earth's interior. The electrical conductivity of Earth material is known to be strongly dependent on physical conditions such as temperature, water content, and degree of partial melting which control their mechanical properties. Especially in oceanic areas, therefore, a number of efforts have been made to obtain accurate images of the electrical conductivity distribution in the upper mantle since the pioneering work by Filloux's (1973).

However, topographic effect makes difficult to obtain accurate electrical conductivity images. The electric and magnetic (EM) fields observed on the seafloor are generally distorted by rugged seafloor topography. The effect of seafloor topography is more significant than that of land topography (e.g., Nam et al., 2008) because seawater, which has extremely high conductivity, produces strong conductivity contrast at the seafloor (Schwalenberg and Edwards, 2004).

In recent years, several works have attempted to solve the problem of topographic effects on the seafloor MT data. Baba and Seama (2002) proposed a three-dimensional (3-D) forward modeling called FS3D which can incorporate precise 3-D topography over arbitrary subsurface structure. Tada et al. (2012) introduced a practical 3-D inversion scheme called WSINV3DMT with approximate treatment of topography (ATT) which expresses conductivity using volumetric averaging in order to describe seafloor, which treats large-scale topographic effect. Furthermore, Baba et al. (submitted) combined the FS3D method with the WSINV3DMT with ATT in order to treat both small-scale and large-scale topographic effects. These techniques allow us to estimate detailed 3-D electrical conductivity structures beneath the seafloor. Now we can perform 3-D inversion analysis for a data set of seafloor EM survey in the Philippine Sea and in the western edge of the Pacific Ocean in order to reveal upper mantle electrical conductivity distribution.

Keywords: Marine magnetotelluric method, Topographic effect, Three-dimensional, Forward modeling, Inversion analysis

MIS29-05 Room:101A Time:May 22 10:00-10:15

Development of measurement equipment for effects of GIC(Geomagnetically-Induced Currents)

OOSATO, Kenichi[1], NAKATANI, Hideyuki[2], YAMAMOTO, Yasuhiro[2], Sadayuki Ishikura[2*], TAMAKI, Hajime[2]

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We developed the GIC which could measure the geomagnetically-induced currents to occur to an electric power system by influence of the magnetic storm. This device can grasp the influence of the electric power system by the magnetic storm for stable supply and use of the electricity in real time. In addition, this device resembled a base at the record unit of a record device for unit type electricity that I developed in 2007 that I cost-cut it in what I developed and was able to realize high reliability.

Keywords: Geomagnetically induced currentsunit, Measurement, Electric power

MIS29-06 Room:101A Time:May 22 10:15-10:30

A general introduction of magnetotellurics and of electrical conductivity distribution beneath Japan for the GIC study

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Electrical conductivity distribution in the earth is one of the most fundamental parameter to estimate geomagnetic induced current (GIC). The electrical conductivity distribution deeper than a few km depth is usually inferred by using magnetotellurics. In this presentation, I introduce the magnetotelluric principle and a general view of the conductivity model in the crust and uppermost mantle beneath the Japan Island Arc for the GIC researchers.

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

MIS29-07 Room:101A Time:May 22 11:00-11:15

Toward Construction of iES Database (Database for Information on Electromagnetic Surveys) for Conductivity Structure ben

Naoto Oshiman[1*], Satoru Yamaguchi[2], Makoto Uyeshima[3], Tada-nori Goto[4], Hiroaki TOH[5], Ryokei Yoshimura[1], Hideki Murakami[6], Yasuo Ogawa[7], Takeshi Hashimoto[8], Shinichi Takakura[9]

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The Japan Arc, where many large earthquakes and volcanic eruptions have occurred, is formed by the Philippine Sea and Pacific plates subducting beneath the Eurasian and North American plates. Moreover, these two different aged plates are subducting with overlapped geometry in the central part of Japan. Therefore, subsurface structure beneath the Japan Arc up to deeper part is highly three-dimensional. Recently, three-dimensional seismic velocity structure models beneath the Japan Arc have been presented, and displacement fields are monitored in real time with the Japanese Archipelago scale using very high density GPS observation network (GEONET). Electrical conductivity provides us very important physical quantity suggesting condition beneath the Japan Arc, which is independent from density, seismic velocity, etc. Therefore, construction of a three-dimensional conductivity model beneath the whole Japan Arc is very important issue in geosciences, because conductivity models give constraint to the thermal structure and/or fluid distribution in the crust and mantle of the earth. In order to achieve the scientific goal, we made a research plan composed of the following three phases;

Phase I: We collect all information on electromagnetic surveys, which were carried out in and around Japan, among scientific community in Japan to form the iES Database (Database for Information on Electromagnetic Surveys). Then, we will chose suitable data sets among the iES Database to construct the database of observed electromagnetic data at 50km interval mesh covering the whole Japan Arc (50km Interval Mesh Database), which will be used for construction of 3D conductivity structure model beneath the Japan Arc at the final phase (Phase III).

Phase II: In addition to the data set chosen from the iES Database in Phase I, new observations will be made to infill gap regions over the Japan Arc to obtain full set of data covering the whole Japan Arc.

Phase III: A three-dimensional conductivity model beneath the Japan Arc will be inverted based on data set in the 50km Interval Mesh Database.

The overall research plan from Phase I to Phase III above is called JEMINI (Japan Electro-Magnetic Imaging with Network observation In-depth) project. In our presentation, we will introduce the details of Phase I in the JEMINI project, especially about the iES Database, which is the main component in Phase I.

Keywords: resistivity structure, conductivity structure, geo-electromagnetic survey, database

Japan Geoscience Union Meeting 2013
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MIS29-08 Room:101A Time:May 22 11:15-11:30

Superflares on solar-type stars

Hiroyuki Maehara[1*], Takuya Shibayama[2], Yuta Notsu[2], Shota Notsu[2], Takashi Nagao[2], Satoshi Honda[3], Daisaku Nogami[2], Kazunari Shibata[2]

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We will present our recent research on superflares on solar-type stars (G-type main sequence stars).

Superflares are eruptive events mainly seen in rapidly-rotating stars like young stars and close binary stars, and have a total energy of 10^{33}-10^{38} ergs, 10-10^{6} times larger than that of the largest solar-flares observed so far.

We searched for superflares from the data of 90,000 solar-type stars observed by the Kepler space telescope between 2009 April and 2010 August. We found more than 1,500 superflares on 279 solar-type stars, including 60 superflares on 25 Sun-like stars (solar-type stars with a rotation period longer than 10 days and with the surface temperature of 5600-6000 K). Most of these stars show quasi-periodic light variations with the amplitude of 0.1-10% which suggest the existence of large starspots on rotating stars.

The energy-frequency distribution of superflares are similar to that of solar-flares and can be fitted by a power-law function with the index of -1.6 - -2.0 in the energy range between 10^{34} and 10^{36} erg.

Although the flare occurrence frequency decreases as the rotation period increases, the maximum energy of superflares does not depend on the rotation period of stars. These results suggest that superflares can occur on the slowly rotating stars like our Sun.

The average occurrence frequency of superflares which release 10^{35} erg of energy (1,000 times larger than that of the largest solar-flares) on Sun-like stars is estimated to be once in a few thousand years.

Keywords: solar flares, superflares, extreme space weather events

MIS29-09 Room:101A Time:May 22 11:30-11:45

Concentration of magnetotelluric current caused by local 3-D resistivity heterogeneities

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Geomagnetic variation originated from solar activities induces telluric current in the earth. The telluric current largely depends on the resistivity heterogeneity. Recent progression on magnetotelluric method enabled us to model 3-D resistivity distribution and revealed complicated resistivity structure of subsurface. In this presentation, I introduce the phenomena that complex conductive body composed from seawater and sediment induces local concentration of telluric current (e.g. Ichihara and Mogi, 2009). These phenomena are reported especially in Japan such as northeastern Hokkaido (Ichihara et al., in rev) and Kitakami area.

Keywords: magnetotelluric, current channeling, out-of-quadrant-phase, 3-D resistivity structure

Japan Geoscience Union Meeting 2013
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MIS29-10 Room:101A Time:May 22 11:45-12:00

On GIC associated with past intense geomagnetic storms

Shinichi Watari[1*], Takashi Watanabe[1]

[1]NICT

Geomagnetically Induced Current (GIC) of the electric power grid was measured in Memanbetsu, Hokkaido between 2005 and 2007 by cooperation with the Hokkaido Electric Power Co., Inc. However, few intense geomagnetic storms occurred in this period because of low solar activity near minimum. It is usually difficult to obtain GIC data at the moment of past intense geomagnetic storms. It is known that the maximum value of GIC is given with the value of electric field along the power line divided by power line resistance per unit length considering a single power line. Geoelectric data by earth current measurement in Memanbetsu, Kakioka, and Kanoya are provided from the Kakioka Geomagnetic Observatory of Japanese Meteorological Agency (JMA). Using those data, we estimate GICs at the moment of past intense geomagnetic storms such as the March 1989 storm associated with the electric power blackout in Canada and the October 2003 storm associated with the blackout in southern Sweden. The result of our analysis will be presented.

Keywords: Geomagnetically Induced Current (GIC), geomagnetic storm, earth current, power grids, space weather

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MIS29-11 Room:101A Time:May 22 12:00-12:15

Inhomogeneity of the shallow resistivity structure inferred from EM surveys and resistivity logging data in Kanto Plain

Shinichi Takakura[1*]

[1]Geological Survey of Japan, AIST

It is worried that huge geomagnetically induced currents (GICs) associated with sudden changes of the geomagnetic field affect society's infrastructures such as a power line and a communication network. Although the damage caused by GIC mainly happens in the area of higher geomagnetic latitudes, they may occur also in Japan if the greatest geomagnetism sudden change takes place. For the prediction of GIC, it is effective to carry out the simulation of the induced electric field on the surface of the Earth and GIC by using 3D resistivity structure (conductivity distribution of the Earth). Resistivity structures of many areas except urban areas have been clarified by electromagnetic (EM) methods for scientific research and resource investigation. In the city plains where the damage caused by GIC will concentrate, however, the resistivity structures are not clarified because the application of the EM methods is difficult due to a severe electromagnetic noise. Earth crust is generally heterogeneous as compared with a mantle. Especially the resistivity structure above a pre-Tertiary basement has high heterogeneity because various geologic formations from which solid state, water content, and salinity differ are distributed intricately. This suggests that GIC flows intricately there. Since the density of the electric current induced by the magnetic field variation is the largest near surface of the earth, it is important for prediction of GIC to know the sallow resistivity structure. So, I tried to estimate the resistivity structure of the thick Neogene and Quaternary sedimentary layers in Kanto Plain where population is concentrating most in Japan. In this research, the some results of EM surveys were used to estimate the resistivity structure in the circumference of urban areas. The resistivity logging of the wells excavated by investigation of urban disaster prevention or engineering works were referred to estimate the resistivity structure of the urban areas where no EM surveys were carried out.

Keywords: geomagnetically induced currents (GIC), sudden changes of the geomagnetic field, Kanto Plain, electromagnetic (EM) method, resistivity logging, shallow resistivity structure

Japan Geoscience Union Meeting 2013
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MIS29-12 Room:101A Time:May 22 12:15-12:30

Super magnetic storms and geomagnetically induced currents in Japan

Ryuho Kataoka[1*]

[1]Tokyo Tech

Geomagnetically induced currents (GIC) flowing in ground-based conductor systems during large geomagnetic storms are one of the most important space weather phenomena that affect our ground-based infrastructures. Former research showed that GIC activity in subauroral latitudes depends on the storm phase and on the interplanetary drivers, such as coronal mass ejections (CMEs) and corotating interacting regions (CIRs). Despite of the differences between CME and CIR storms, the relationship between GIC and the time derivative of the horizontal ground magnetic field is always the same. However, Japan is located at lower latitude, and because of its distinctive ground conductivity structure, it is not obvious how large GICs flow in Japan during super storms. Further, ionospheric current system itself of super storms is not obvious. I will discuss the methodology how to study the GICs in Japan during super storms using our limited observations.

Keywords: magnetic storms, geomagnetically induced currents, ground conductivity