Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

MIS28-01 Room:313 Time:May 1 09:00-09:15

Amplification of induced current due to complicated resistivity structure in the earth

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Abrupt changes of geomagnetic field can make large induced electric current on the earth, and yield damages to pipelines, cables and other architectures. For understanding the phenomena and future risks, explorations of sub-surface resistivity structure are necessary because the heterogeneous resistivity structure in the crust and mantle amplifies the induced electrical current locally. The hazard prediction based on the homogeneous earth may result in the under-estimation. Here, I introduce possible cases of induced current near the coastal areas, based on two-dimensional (2D) and three-dimensional (3D) earth structure including the sea layer. My study is based on the numerical forward calculation of induced electric field in the earth. The former case comes from 2D forward simulation. In this case, the straightly elongated coastal line is assumed, and various sub-surface and sub-seafloor resistivity structures are imposed. The numerical results suggest that the amplitude of induced current becomes about 6 times larger than the homogeneous earth without the sea layer. The width of affected land zone is about 20 km from the coast line. In the second case, the 3D forward modeling is employed to express the complicated coastal line and bathymetry. As a result, the amplitude goes double at the cape zones. These phenomena come from the boundary charge along the coastal area. I conclude that electrical structure around the coast line (not only below the land, but also below the seafloor) should be focused for the huge induce current.

Keywords: Geomagnetic field, Induced current, Land-Ocean interaction, resistiivty

Japan Geoscience Union Meeting 2014
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MIS28-02 Room:313 Time:May 1 09:15-09:30

A Numerical Simulation of the Geomagnetically Induced Electric Field with the Three-Dimensional Resistivity Model

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The Geomagnetically induced current (GIC) sometimes causes power-line failure in the geomagnetically high-latitude regions like Canada and Sweden. On the other hand, it has been regarded that Japan is free from this danger because it is located in the lower-latitude region. However, this assumption may not be valid when an extremely severe space weather event happens. In addition, as the GIC and the induced electric field are strongly controlled by non-uniform distribution of the Earth's electric resistivity, we need to evaluate these values taking the non-uniform distribution into account. It is noted that there has been no works about it. In this talk, we will present the geomagnetically induced electric field based on the modeled electric resistivity distribution by using a numerical code applicable to the three-dimensional induction problems. As the results, there are large anomalies in the intensity of the electric field in Japan.

Keywords: Geomagnetically Induced Current, SC, resistivity, conductivity, magnetic storm

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MIS28-03 Room:313 Time:May 1 09:30-09:45

Simultaneous inversion of temporal magnetotelluric signal change and conductivity structure using the time domain simula

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Magnetotelluric method is mainly used for estimation of subsurface resistivity structure. However, the time-domain analysis of source field is normally omitted, although its estimation should be included at the cases such as in the high-latitude zones or on the global scale. In previous research, simultaneous inversion is proposed to estimate both magnetotelluric signal and resistivity structure in the earth. Koch and Kuvshinov (2013) proposed inversion algorithm that iteratively estimates magnetotelluric signal and resistivity structure, although this inversion method cannot determine both unknowns in a seamless manner. In this study, we developed simultaneous inversion that can determine both unknowns at the same time. Because magnetotelluric signal is considered non-stationary time series, we try a direct inversion of time-domain electromagnetic field, not in the frequency -domain. It has a chance to give higher accuracy than the frequency domain inversion.

Our new inversion results applied to the synthetic model suggested that we could estimate both magnetotelluric signal and resistivity structure properly even under the condition of noise contamination in the observed data. Moreover, when the time domain and frequency domain inversions are applied to same synthetic time series, the result using time domain inversion has higher resolving capability than result using the frequency domain inversion.

Keywords: Magnetotelluric method, Time domain modelling, Simultaneous inversion

MIS28-04 Room:313 Time:May 1 09:45-10:00

Geoelectric Field at Kakioka, Kanoya, and Memambetsu

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Kakioka Magnetic Observatory, Japan Meteorological Agency (JMA) has continuously observed the geoelectric field at Kakioka, Kanoya, and Memambetsu for decades. I checked the JMA collection of the geoelectric field from a view point of applicability to studies on the geomagnetically induced current (GIC).

Two horizontal components (northward and eastward components) of the geoelectric field are obtained on the geographical coordinates at the three sites by measuring voltage differences between two pairs of electrodes. Details of the measurements such as locations and materials of the electrodes, baseline lengths, sampling intervals, and filtering responses of the systems differ time to time giving fluctuations on data quality.

I picked up a 11-year data segment ranging from Jan 1, 2000 to investigate the characteristics of the geoelectric field obtained by JMA.

It turned out that the geoelectric fields at three sites ware unstable on the long-term basis because the baseline lengths are as short as a few hundred meters and the instability of the electrodes are relatively noticeable. However, the electric field highly correlates with the geomagnetic field at periods from 100 sec to 1 day at any of three sites, suggesting the geoelectric field induced by a change of the geomagnetic field is successfully obtained at least on the short-term basis. Amplitudes of the geoelectric field are different among the sites. For instance, the eastward component of the field is about 10 times larger than the other at Kakioka, while the northward component is larger than the other at Memambetsu.

The MT response was computed at the three sites to evaluate the signal and infer effects of electrical conductivity structures. A robust procedure BIRRP (Chave and Thomson, 2004) was applied to 0.1 sec, 1 sec and 1min values of the geoelectric and geomagnetic fields at large-scale geomagnetic storms in 2003 and 2004 to estimate the MT response at periods shorter than 10000 sec. Since the 0.1 and 1 sec values of the geoelectric and geomagnetic fields are affected by system filters, shortest periods were not able to be included into the response estimation even after corrections of the filters were made. As for that at periods longer than 10000 sec, I verified a procedure to decompose a time series by Fujii and Kanda (2008) so that a noisy data set can be treated. Then, a trend with step-like anomalies and outliers were estimated from a 11-year segment of 1 hour values of the geoelectric field. Then, the MT response was estimated from the geoelectric field with the trend and outliers removed. In the end, the MT response was obtained at periods from several sec to 12 days. If this response is converted into the time domain by convolution, filter coefficients to estimate the geoelectric field from the geomagnetic field will be obtained.

Effects of local small-scale structures on the MT response were checked as a next step. The Zyx at Kakioka shows an unusually high value (~1000 ohm m) even at a period of 10days and the comparison with the C value by Fujii and Schultz (2002) suggests it is about 100 times amplified by the local small-scale structures.

Yanagihara and Yokouchi (1965) explained a biased distribution of the electric field at a short frequency range at Kakioka by heterogeneities of a near surface structure. If these affects even at very long periods, use of the geoelectric field at Kakioka for GIC or induction studies should be done with a certain caution.

The electric field at three sites basically reflects the induction as it is supposed to be, although the measurement system and procedure can be verified so that data of higher quality are obtained.

Keywords: geoelectiric field, induction, geomagnetically induced current, MT response

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MIS28-05 Room:313 Time:May 1 10:00-10:15

Magnetotelluric method and the source field with finite wave number

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Magnetotelluric method is now widely used for mapping the crustal and upper mantle structure in three-dimensions. In magnetotelluric method, we normally assume the source field as a plane wave. However, if the source field has a finite wave length, the impedances (apparent resistivity, and impedance phase) and the geomagnetic transfer functions will be affected. In a simple case with uniform earth where the source field has a wave number is considered. The apparent resistivity inferred from the impedance (ratio of horizontal electric field to the orthogonal horizontal magnetic field), by assuming a plane wave source will be biased downward and impedance phase will be biased upward. Also the geomagnetic transfer function will have phase of pi/4, even without any lateral heterogeneity.

Some magnetotelluric studies at the high latitude and under the magnetic equator will be reviewed.

Keywords: magnetotelluric method, source field

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MIS28-06 Room:313 Time:May 1 10:15-10:30

Electromagnetically coupled system between non-uniformly and anisotropically conducting inner earth and upper atmosphere

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lectromagnetically coupled system between upper atmosphere and inner earth, is discussed. It is well known that upper atmosphere and inner earth system is electromagnetically coupled across very small conducting atmospheric region, which means 'primary' induced electric field produced by the mutual coupling is almost inductive (divergence free). However if the conductivity distribution is inhomogeneous, 'secondary' polarization (curl-free) electric field can be produced at the region of conductivity gradient. In the ionosphere, non-uniform Hall conductivity distribution induces the Hall polarization field, which becomes cause of current concentration and potential deformation by the Cowling effect. Formation of Cowling channel is one of the most important and peculiar nature of weakly ionized system under strongly background magnetic field distribution.

In this presentation, we will introduce basic feature of electrodynamics at the non-uniform and anisotropically conducting ionosphere, and will discuss a possible electromagnetic coupling mechanism when the telluric conductivity distribution is non-uniform and anisotropic.

Keywords: ionospheric current, telluric current, electromagnetically coupled system

MIS28-07 Room:313 Time:May 1 10:30-10:45

The distribution of the internal geomagnetic field during a magnetic storm

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We calculated the Gauss coefficients of magnetic potential and estimated the current in the earth during a magnetic storm.

There are two kinds of magnetic storms. One is sudden. The other is synchronized to the sun's rotation period. How does the earth react to such a strong disturbance of external magnetic field?

We quantitatively estimated the induced current in the earth which had reacted to the large change of magnetic field like a strong magnetic storm, using a spherical harmonic expansion and a three dimensional forward calculation code. With a spherical harmonic expansion, we used geomagnetic data of the surface of the earth and calculated the internal and external geomagnetic field. With a three dimensional forward calculation code, we used the time variation of the external Gauss coefficients calculated by the spherical harmonic expansion and visualized and quantified the induced current in the earth during a magnetic storm.

We expect that we estimate the electric conductivity of the earth with the internal Gauss coefficient to the external Gauss coefficients ratio as a development of this study.

Keywords: induced current, magnetic storm

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MIS28-08 Room:313 Time:May 1 11:00-11:15

Why did the Carrington storm recover very rapidly?

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[1]Solar-Terrestrial Environment Laboratory, Nagoya University, [2]Research Institute for Sustainable Humanosphere, Kyoto University, [3]National Institute of Polar Research

Intense geomagnetic storms are accompanied by rapid recovery, as represented by a quick increase of the Dst index after its minimum. As far as the geomagnetic storms that we have observed since the early 20th century, the more intense storms experienced the more rapid recovery. The Carrington event on 2 September 1859 also experienced an extremely rapid recovery (>1000 nT/h at Bombay, India; >300 nT/h with 1-hour average data). At least three major processes that occur in the Earth's inner magnetosphere are proposed to explain such rapid recovery: (1) the neutralization of energetic O^{+} ions through charge exchange, (2) flow-out of energetic ions to the interplanetary field, and (3) loss of energetic ions into the atmosphere through pitch-angle scattering due to interactions with electromagnetic ion cyclotron (EMIC) waves. In addition, a sudden increase in the solar wind dynamic pressure around the storm maximum could cause a quicker recovery.

In this talk, we focus on intense magnetic storms with the Dst minimum smaller than -200 nT for which solar wind data are available. We first examine whether the rapid recovery can be explained by an ion flow-out effect associated with sudden changes of solar wind density, by modifying the empirical Burton's equation. We also estimate the amount of energetic O^{+} ions, the spatial extent of EMIC wave active regions, and the increase rate of the solar wind dynamic pressure that could be required to reproduce the storm rapid recovery. In addition, we discuss how quickly the geomagnetic field could change during the recovery of an extremely intense storm such as the Carrington event.

Keywords: The Carrington event, Geomagnetically induced currents (GICs), Ring current, Magnetopause current, Interplanetary shocks, Coronal mass ejections (CMEs)

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MIS28-09 Room:313 Time:May 1 11:15-11:30

Consideration of geomagnetically induced currents — a case of geomagnetic sudden commencement(SC)

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Siscoe et al.(1968) assumed a relationship between the SC amplitude, dH, and solar wind dynamic pressure, Pd, as dH = fgk d(Pd)∗∗0.5 and experimentally determined the proportional constant, k. Here f is a constant associated with the solar wind-magnetosphere interaction and g shows effects of currents induced in the Earth. This constant g has been traditionally taken as 1.5 without detailed check of its meaning for a long time. Here we make a physical consideration on it based upon the present SC model.

The disturbance field of SC, Dsc, is expressed as Dsc = DL + DPpi + DPmi.

Here, DL is caused by the magnetopause current (MC) enhanced during sudden compression of the magnetosphere and dominant in low latitudes on the ground. DP is produced by field-aligned currents (FAC) and FAC- produced ionospheric currents (IC) and larger in the higher latitude region.

The DP shows a two pulse structure where the first pulse is called pi (preliminary impulse) and the following pulse is denoted as mi (main impulse). Thus we have to assume 3 current sources in the consideration of induction effects of SC.

The magnetopause current, MC induces currents both in the ionosphere and Earth. As the induced ionospheric current reduces the amplitude of SC on the ground while the earth currents enhance it, induction current effects will be small for the DL field. Ionospheric currents causing the DP field induces currents only in the Earth which enhances the DP field on the ground.

The LT variation of SC amplitude shows the maximum in the D-component and minimum in the H-component around 8h LT in low and middle latitudes. On the other hand, calculation of a global distribution of ionospheric currents produced by a pair of FACs shows that the current direction is in north-south near 8h LT. This means that the H-component amplitude of SC observed near 8h LT consists of only the DL field which is less affected by induction effects..

Keywords: sudden commencement, induced current, ionospheric current,, magnetopause current, DL/DP-field

MIS28-10 Room:313 Time:May 1 11:30-11:45

Quasi-periodic DP2 fluctuations in the geomagnetically induced currents

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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 at mid latitudes [e.g., Watari et al., Space Weather 2009]. Braendlein et al., JGR 2012] reported that the GIC has diurnal and seasonal variations, and suggested that the GIC could be a return current of the ionospheric currents via the wave front of the TM0 mode waves in the Earth-ionosphere waveguide [Kikuchi and Araki, JATP 1979]. We analyzed the quasi-periodic fluctuations in the GIC recorded in Hokkaido on December 14 2006, which accompany the DP2 fluctuations in the equatorial electrojet (EEJ) and D-component magnetic field at midlatitudes. We found that the GIC is well correlated with the EEJ as well as the madlatitude D-components. We suggest that the midlatitude GIC is a part of the magnetosphere-ionosphere-ground (MIG) circuit currents [Kikuchi, JGR 2014], and therefore, the GIC is the return current of the ionospheric currents via the wave front of the TM0 mode waves.

Keywords: midlatitude geomagnetically induced current, midlatitude D-component magnetic field, equatorial electrojet, TM0 Earth-ionosphere waveguide mode

MIS28-11 Room:313 Time:May 1 11:45-12:00

Statistical properties of superflares on solar-type stars

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Solar-flares are energetic explosions in the solar atmosphere. The energy released by a solar flare is typically of the order of 10^{29} - 10^{32} erg. Recent high-precision photometry from space shows that "superflares", which are 10-10000 times more energetic

than the largest solar-flares, occur on Sun-like stars (slowly rotating G-type main sequence stars).

We present recent results on superflares on solar-type stars using the high time-resolution data. We search for superflares from the short-cadence data (time resolution: 1 min) of about 1300 solar-type stars observed with the Kepler space telescope and found about 150 superflares on 20 stars. The energy of detected flares ranges from 10^{33} to 10^{35} erg, which is equivalent to that of X100 - X10000 class solar flares. These superflare data, combined with the previous results from the low time-resolution data (1547 superflares on 279 solar-type stars), indicate that the occurrence frequency distribution of superflares can be fitted in the energy range $>10^{33}$ erg by a simple power-law function with the index of about -2. Moreover, the frequency distribution of superflares on Sun-like stars and that of solar flares are roughly on the same power-law line. The average occurrence frequency of superflares with energy of 10^{33} erg (X100 class) is about once in 100 years and that of superflares with energy of 10^{34} erg (X1000 class) is about once in 1000 years. The duration of superflares depends on the total energy released by superflares. Larger flares tend to have longer duration time. The duration of superflares is proportional to the 1/3 power of the flare energy. This correlation between energy and duration of superflares on solar-type stars is similar to that of solar flares. These results suggest that statistical properties of superflares on solar-type stars is basically the same as thoes of solar flares.

Keywords: superflare, solar flare

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MIS28-12 Room:313 Time:May 1 12:00-12:15

Extreme value statistics analysis of the auroral electrojet indices

NAKAMURA, Masao[1*] ; YONEDA, Asato[1] ; TSUBOUCHI, Ken[2]

[1]Osaka Prefecture University, [2]Tokyo Institute of Technology

The worst space environment phenomena have a possibility of damaging electric transmission grids due to large induced currents on the earth and causing satellite anomalies due to increased high energy plasma on satellite orbits. Therefore a statistical study of the worst substorm events is important. For the study, we utilize extreme value statistics, which focus on the statistical behavior in the tail of a distribution. We analyze the one-minute values of the auroral indices (AE, AU, AL) in 1996-2012. These indices are derived from geomagnetic variations in the horizontal component observed at twelve observatories along the auroral zone in the northern hemisphere. The AU and AL indices are the uppermost and lowermost envelopes of the superposed horizontal component perturbations, and are thought to represent the maximum eastward and westward electrojet currents over the auroral zone, respectively. The AE index is defined by the separation between the upper and lower envelopes (AE=AU-AL) and commonly used as an index of the aurora activity. As a result of the analysis, we can estimate the upper limit of AU and the lower limit of AL, which suggests the maximum strengths of the eastward and westward electrojet currents. However, it is found that the AE index is not suitable for the extreme value statistics analysis, because it is a combined index. The largest values of AE are not generated by a single process and do not show a simple extreme value distribution.

Keywords: Auroral electrojet index, Extreme value statistics

MIS28-13 Room:313 Time:May 1 12:15-12:30

Statistical estimations of geomagnetic disturbances at Kakioka, Memambetsu and Kanoya

MINAMOTO, Yasuhiro[1*] ; FUJITA, Shigeru[2] ; OOGI, Junpei[1] ; HARA, Masahiro[1]

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We investigated scale of geomagnetic disturbances which can cause extremely large geomagnetically induced current with record of geomagnetic phenomena by The Japan Meteorological Agency with statistical analyses. In this presentation, we will show the following items,

1. an estimation of the scale of millennium magnetic storm calculated from 1932 cases of observations at Kakioka magnetic observatory.

2. estimations of the scale of millennium storm sudden commencements and sudden impulses calculated from 2848, 2408 and 2257 cases of observations at Kakioka, Memambetsu and Kanoya respectively.

3. probable geomagnetic disturbances suggested from one-minutes data of geomagnetic field at Kakioka, Memambetsu and Kanoya over about thirty years.

Keywords: magnetic storm, sudden impulse, storm sudden commencement, statistics, magnetic observatory

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MIS28-P01 Room:Poster Time:May 1 18:15-19:30

Analysis of geomagnetically induced current measured in Japan

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It is known that there is a possibility of failure of power grids caused by geomagnetically induced currents associated with intense geomagnetic storms. It is believed that effect of GIC is small in Japan because Japan locates low geomagnetic latitude comparing with its geographical latitude. Damage of transformer is reported from the Republic of South Africa associated with the October, 2003 storm. The Republic of South Africa locates in similar geomagnetic latitude with that of Japan. We made GIC measurements of a transformer of the Memanbetsu substation between 2005 and 2007. Those data are compared with geoelectric data observed by the Memanbetsu geomagnetic observatory of Japan Meteorological Agency. We estimated GICs associated with past intense geomagnetic storms using the geoelectric field data based on the result of the comparison. The result of our analysis will be reported.

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

MIS28-P02 Room:Poster Time:May 1 18:15-19:30

Global MHD simulation of the magnetospheric response to large and sudden enhancement of the solar wind dynamic pressure

KUBOTA, Yasubumi[1*] ; KATAOKA, Ryuho[2] ; DEN, Mitsue[1] ; TANAKA, Takashi[3] ; NAGATSUMA, Tsutomu[1] ; FUJITA, Shigeru[4]

[1]NICT, [2]NIPR, [3]Kyushu University, [4]Meteorological College

A large and sudden enhancement of the dynamic pressure in the solar wind generates a geomagnetic sudden commencement (SC). The magnetic field variation of SC at auroral latitudes shows a bipolar change which consists of preliminary impulse (PI) and main impulse (MI). Fujita et al. [2003a, 2003b] reproduced the PI/MI magnetic field variation using a magnetosphere-ionosphere coupling simulation and clarified the fundamental mechanisms. Interestingly, Araki et al. [1997] reported an anomalously large-amplitude SC of more than 200 nT with an unusually spiky waveform at low latitude, which occurred when the magnetopause was pushed inside geostationary orbit. Such a super SC is the target of this study. We investigate the large-amplitude SC at auroral latitudes when a large solar wind dynamic pressure impinges on the magnetosphere using a newly developed magnetosphere-ionosphere coupling simulation which has advanced robustness. We simulate two SC events of dynamic pressure enhancement of 16 times larger than the standard value, caused by the density enhancement and velocity enhancement, respectively. As an initial result of the comparison with the SC events, it is found that magnetic field variation of PI/MI is larger and sharper in the case of velocity rise than the case of density rise. It is therefore suggested that high-speed solar wind may be needed to create large and sharp SC. It is also found that a magnetic field variation similar to so-called Psc appears after PI/MI only in the case of velocity rise. When the high-speed solar wind impinges on magnetosphere, vortices are repeatedly formed at the equatorial magnetopause, probably due to the K-H instability. It seems that the high pressure of the vortices play an essential role as a current generator to drive the field-aligned currents and the magnetic field oscillation. In this presentation, we discuss the mechanisms of super SC in more detail, combining the other interesting simulation results.