

地震先行現象の統計的有効性に関する一考察 神津島の先行的地電位差変化の研究を例として

Examination of statistical significance of earthquake-related precursory phenomena -Izu Islands Koizu case, as an example

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2012年、我々は“神津島で観測された地震に先行する地電位差異常”という論文を全米科学アカデミー紀要に発表した(著者:織原義明、鴨川仁、長尾年恭、上田誠也)。この論文は地上観測において、世界で初めて地震に先行する地電流異常というものが、統計的に圧倒的に有意である事を示し、先行現象の実在性を示した論文と位置づけている。しかしながら、これだけの有意性を示しても懐疑的な研究者は多く存在する。一例として、地震学で有名なETASモデルを用いると、ある場合には、ランダム予測より100倍以上効果的な予測が地震活動の推移からだけでも可能であると主張している。それゆえ、これらの議論(疑問)に打ち勝つためにも、先行現象を用いた予測がどの程度ランダム予測より有効なのかを示していく必要がある。このためのキーワードが“確率利得(probability gain)”である。本来は先行現象を利用した予測とこの確率利得の議論はなじまないものであるが、越えなければならないステップである事も確かである。講演ではまず先行現象の研究者が最低限示さなければならない統計的な扱いを提案し、確率利得についても考えていきたい。

キーワード: 地震先行現象, 前兆, 統計

Keywords: precursor, statistics

点熱源に起因する熱電効果による電磁場変動の評価
An estimation of electromagnetic field variations due to the thermoelectric effect accompanying a point heat source gene

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Thermoelectric effect which couples both the temperature gradient and the electric field to both the heat flow and the electric current density can cause, in principle, coseismic electromagnetic field variations due to fault motions with frictions. The present study attempts to estimate the field variations.

Assuming a point heat source with spherical symmetry which is regarded to be generated by a point dislocation with friction in a homogeneous whole space, the equation of the temperature is separated. The magnetic field variation is not excited.

Expanding the self-consistent system of the equations with spherical symmetry, the temperature satisfies a non-linear diffusion equation, for the coupling between the heat flow and the electric field depends on the temperature.

By a kinematic approach which considers the contribution of the temperature gradient to the electric current density and neglects the contribution of the electric field to the heat flow, the resultant electric field and the temperature variations with respect to time both show increase, maximum and decay. However, order estimations with realistic quantities of physical properties suggest that the arrival time of the maximum amplitude at kilometers away from the heat source amounts to years. The maximum amplitude of the electric field does not exceed the observable level in realistic situations.

Numerical simulation of co-seismic electromagnetic signals in porous media Numerical simulation of co-seismic electromagnetic signals in porous media

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Field observations indicated the existence of the electromagnetic signals accompanying with natural earthquakes. Such co-seismic electromagnetic signals may provide some useful information of earthquake process. So it is becoming an interesting topic in geophysical community. Unfortunately, the generation mechanisms of co-seismic electromagnetic signals are not well understood at the current stage. In this study, we simulate numerically the co-seismic electromagnetic signals in layered porous media by using the generalized reflection and transmission coefficients method. We focus on the characteristics of electromagnetic signals generated by a double couple point source or a finite fault source in different models. The effects of source time function type and center frequency have been investigated. The numerical results show that the co-seismic electromagnetic signals depend on the model structures and the rupture sources. The simulation results also indicate that seismic waves and electromagnetic signals have good correlations in both the waveform and the dominant frequency.

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キーワード: Seismo-electromagnetic signals, Finite fault, Source time function

Keywords: Seismo-electromagnetic signals, Finite fault, Source time function

Locating earthquakes using magnetic data via the magnetic transfer function in Taiwan Locating earthquakes using magnetic data via the magnetic transfer function in Taiwan

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Magnetic data have been widely utilized to survey direction of high-conductivity materials via the magnetic transfer function. Many studies have reported that conductivity of rocks close to epicenters is increased before earthquakes due to stress accumulation. Here, magnetic data are utilized to investigate location in which conductivity is enhanced during earthquakes in Taiwan. Analytical results show that anomaly increased conductivity appears about 30 days prior to M5 earthquakes in Taiwan. Directions determined through the anomalous increased conductivity via the magnetic transfer function well agree with earthquake azimuths to one magnetic station when effects of tectonic structure and sea water on magnetic data are mitigated. Earthquake epicenters can be further determined by using an intersection of anomalous directions determined by two or more magnetic stations. Meanwhile, depths of forthcoming earthquakes can be roughly estimated when the skin effect is conducted into the magnetic transfer function.

キーワード: Seismo-electromagnetic anomaly, Magnetic transfer function

Keywords: Seismo-electromagnetic anomaly, Magnetic transfer function

地中電磁波パルスの観測による地震発生予測の研究へ Study for earthquake prediction by detections of electromagnetic pulses in the earth

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地殻活動における力学的エネルギーの散逸過程で発生する電磁波に関して、数 kHz 成分については、地中媒質の電気伝導度の大きさのためにその地中内伝搬途中でエネルギーが減衰してしまい、殆ど検出できなかった。しかし、観測周波数を 25 Hz 以下にした結果、地震に同期して電磁波パルスの低周波成分を検出できる事が判った。

京都産業大学構内のボアホール内での観測では、2011 年 12 月 20 日から 2013 年 1 月 25 日までの間に、そのボアホールを中心に半径が 40km の内側で発生したマグニチュード 2 以上の地震は 13 件あった。その内、10 件については全てで電磁波パルスを検出している。電磁波パルスの伝搬距離の限度が 40 km のように思われるが、地形的要因が関与している可能性が大きい。発生した地震が電磁波観測点の周囲に一樣に分布していないので、明確には言えないが、電磁波観測点に対して、水分を含んだ場所の反対側の地下で発生した地震においては電磁波パルスが検出できない状況を示している。これらはやはり電磁波検出点に至る電磁波伝搬路での電気伝導度が大きすぎたためと思われる。

一方において、電磁波パルスの観測データを見ていると、それらは地震波の到来により電磁波観測点近傍の岩盤内で励起されたのではないかと思われるデータがある。即ち、電磁波観測点においての震度が 1 程度であれば電磁波パルスが容易に励起される可能性がある。これは電磁波パルスがこの程度の圧力印加での圧電現象で十分に励起されうる事を示している。

以上のような状況を考えると、ある地点での電磁波観測では、

1. 地震発生地点で励起された波形
2. 地震波の伝搬路に沿って励起された電磁波パルス波形の合成波
3. 電磁波観測点近傍で地震波の波頭で励起される電磁波パルス波形、
が合成された波形として現れる可能性がある。

今後、地震発生予測の研究としては、地震発生に至らない弱い応力印加時での電磁波パルスの検出が重要である。それを実現する方法は、地中電磁波パルス観測としては電気伝導度の小さい更に深い地層（深さ約 1km）までセンサー位置を下げる事であり、それにより上記の波形を得る事ができ、様々な情報を含んだ極めて有意なデータが得られるものと思われる。

何れにしても観測では信号処理に影響が少なくなるように、やはり雷放電や人工雑音の少ない地下深い環境が必要であり、そのような場所のできる限り感度の良いセンサーを使用する必要がある。

キーワード: 地中電磁波パルス, ボアホール内での検出, 地震関連電磁波, 地震発生予測

Keywords: electromagnetic pulses in the earth, detections in boreholes, relation with earthquakes, earthquake prediction

Comparative study of ULF depression and ELF radiation associated with seismic activity Comparative study of ULF depression and ELF radiation associated with seismic activity

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Magnetic anomalies in the ULF and ELF ranges in association with major seismic activities are investigated. Previously depression of the magnetic intensity in the ULF range and the radiation in the ELF range were separately studied for different seismic events. In this paper we report first time the comparison of the results between the ULF and ELF anomalies based on the several common seismic events occurred in the vicinity of Japan. The ULF magnetic depressions are observed by two fluxgate magnetometers in Hokkaido and Kyushu while ELF radiations are identified by two induction type magnetometers in Hokkaido and central Japan. Initial result indicates that both ELF and ULF anomalies are observed nearly simultaneously with local seismic events.

INTEGRATED STUDIES OF EARTHQUAKE PRECURSORS IN INDONESIA INTEGRATED STUDIES OF EARTHQUAKE PRECURSORS IN INDONESIA

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Integrated studies of earthquake precursors have been done by the research and development center of BMKG since 2010. Studies of earthquake precursors carried out in stages and sustainable that is focused on geophysical, geo-atmospheric and geochemical parameter. This studies are to develop test methods that have been developed with field data in Pelabuhan Ratu, West Java. The target for third year is to studies of vp/vs ratio, magnetic, impedance of EM wave, temperature, humidity and radon concentration as well as verify the predictability of earthquake precursors based on information that has been done.

Research focused on identifying the physical parameters of the character as an earthquake anomaly precursor in the Pelabuhan Ratu, West Java, Indonesia along 2012. The analysis of vp/vs ratio using earthquake catalog and phase report sheet from BMKG. Electromagnetic parameter data used is the magnetotelluric data that observed at geophysical observatories of Pelabuhan Ratu which was collaboration with Chiba University (Japan). Observation data of the radon gas concentration, air temperature and humidity in the soil obtained from RAD7 that installed with sensor of soil gas probe is planted in the ground as deep as 1.2 meters. And surface temperature data is the maximum temperature (Tmax) and minimum temperature (Tmin) were recorded using a mercury thermometer.

Based on the analysis of vp/vs ratio, the accumulation of stress in rocks began to be detected around 1-3 months before the earthquake occurred. Results of electromagnetic parameters analysis using polarization of magnetic data and impedance of EM wave obtained precursor anomaly approximately 14-56 days before the earthquake occurred, so these parameters are included in short-term precursors are likely due to the electrokinetic and microcrack before the accumulation of energy released as earthquakes. Parameters of temperature and humidity as well as radon gas precursor patterns detected about 9-30 days before the earthquake happened so that the parameters are included in short-term precursors. Radon gas and temperature anomalies associated with the deformation in the region of observation before the earthquake occurred.

Keywords: EARTHQUAKE PRECURSORS, INTEGRATED STUDIES, INDONESIA

Investigation of ULF seismo-magnetic phenomena in Kanto, Japan during 2000-2010 Investigation of ULF seismo-magnetic phenomena in Kanto, Japan during 2000-2010

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In this study we have conducted an investigation of ULF seismo-magnetic phenomena in Izu and Boso Peninsulas, Japan, based on the data observed from 2000-2010.

First, case studies of major events have been applied. Energy of ULF geomagnetic signals at the frequency around 0.01 Hz has been investigated by wavelet transform analysis. In order to minimize the influences of artificial noises, only the midnight time data (LT 1:00 ~ 4:00) have been utilized. To identify anomalous changes from ionospheric disturbances, the standard station Memabutsu has been chosen as a reference station. (1) Case studies of the 2000 Izu Islands earthquake swarm have indicated that there are unusual geomagnetic energy enhancements in vertical component before and during the earthquake swarm. (2) Case studies of the 2005 Boso M 6.1 earthquake have also shown clear geomagnetic energy enhancements in vertical component before the earthquake. (3) Case studies of the 2002 and 2007 slow slip events have demonstrated that there are geomagnetic energy enhancements in both vertical and horizontal components during the slip events.

Then, to verify and clarify the relation between ULF geomagnetic anomalies and seismicity, statistical studies by superposed epoch analysis (SEA) have been carried out. The results have indicated that before a sizeable earthquake there are clearly higher probabilities of ULF anomalies than after the earthquake: for Seikoshi (SKS) station in Izu, about 20~30 days before, one week and few days before, and one day after the event statistical results of daily counts are significant; for Kiyosumi (KYS) station in Boso around two weeks before, few days before, and one day after the event.

Finally, to find out the detailed waveform of anomalous magnetic signals, waveform analysis has been performed. The results show that there are mainly two kinds of seismo-magnetic signature. (1) Noise-like signals: Compared with the background, the signals exhibit small increases of amplitudes at a wide frequency range. (2) Transient/quasi-rectangular signals: the signals have transient/quasi-rectangular waveforms with amplitudes of several nT (~ nT). The noise-like signals usually persist for several days or even a few weeks, and are mainly associated with large earthquakes; the transient/quasi-rectangular signals have durations of few seconds to few ten seconds, and are registered mainly during slow slip events.

Based on the results obtained above, we conclude that: (1) there is a correlation between ULF geomagnetic anomalies and local sizeable earthquakes in Izu and Boso Peninsulas, Japan, and the common period of significant results is few days before and one day after a sizeable earthquake; (2) there are mainly two kinds of seismo-magnetic signature registered in Izu and Boso Peninsulas: noise-like signals and transient/quasi-rectangular signals. The mechanisms of the anomalous geomagnetic signals are still unclear and need further studies.

キーワード: ULF seismo-magnetic phenomena, earthquake, wavelet transform analysis, statistical study, geomagnetic field, superposed epoch analysis (SEA)

Keywords: ULF seismo-magnetic phenomena, earthquake, wavelet transform analysis, statistical study, geomagnetic field, superposed epoch analysis (SEA)

地震前の電離圏プラズマ密度上昇は前兆現象？ Is an ionospheric electron enhancement preceding the earthquakes a precursor?

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Heki [2011] reported that the TEC gradually enhanced from 40 minutes before the 2011 M9.0 off the Pacific coast of Tohoku earthquake (Tohoku EQ) to the time when the co-seismic acoustic wave reached the ionosphere and the TEC immediately recovered at the normal state. This paper shows an alternative interpretation of total electron content (TEC) variation in the ionosphere associated with the Tohoku EQ. Our interpretation is that a tsunamigenic ionospheric hole, a wide depletion of the TEC, occurred after the co-seismic acoustic wave reached the ionosphere and gradually recovered at the normal state with several tens of minutes [Kakinami et al., 2012]. The difference between Heki [2011] and Kakinami et al. [2012] is attributed to the reference curves of the TEC to extract the ionospheric variations. The former is given by the least-squares fitting curve of the EQ day data excluding an expected precursor period, while the latter is given by the data of the similar orbit of global positioning system (GPS) satellite on another day. The results strongly suggest that variation of slant TEC is explained by the depletion of TEC due to tsunami rather than the precursory enhancement.

キーワード: 地震電磁気, 地震前兆現象, 電離圏擾乱, 電離健全電子数, 東北地震
Keywords: Seismo Electromagnetics, precursor, ionospheric disturbance, total electron content, Tohoku earthquake

Seismo-ionospheric precursors of the total electron content associated with M_{6.0} earthquakes in Japan

Seismo-ionospheric precursors of the total electron content associated with M_{6.0} earthquakes in Japan

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This paper reports statistical results of seismo-ionospheric precursors (SIPs) of the total electron content (TEC) in the global ionosphere map (GIM) associated with 132 earthquakes with magnitude 6 and/or greater in Japan during 1 May 1998 ? 10 March 2011. To detect SIP, a quartile-based (i.e. median-based) process is performed. The earthquakes without being led by magnetic storms are further isolated and investigated to confirm the SIP existence. Results show that the SIP mainly is the TEC significantly increase in the afternoon period 1-5 days before the earthquakes in Japan. Finally, the SIP of the GPS TEC associated with the 11 March 2011 M_{9.0} Tohoku earthquake is presented and discussed.

キーワード: seismo-ionospheric precursors, GPS, total electron content, M_{9.0} Tohoku earthquake

Keywords: seismo-ionospheric precursors, GPS, total electron content, M_{9.0} Tohoku earthquake

地震に先行する電離圏擾乱の3次元構造解析 Three-dimensional structure analysis of ionospheric anomalies associated with large earth-quake

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近年、地震に先行する電離圏異常が多くの研究者により報告されている。特に電離圏総電子数 (Total Electron Content; TEC) の異常については、事例解析のみならず統計解析の結果からもその存在が証明されつつある。しかしながら、その物理機構についてはほとんど明らかにされていない。また、これまでに行われた研究の多くは特定の高度または TEC のような積分量を用いたものであり、電離圏電子密度分布の3次元構造を明らかにした例はほとんど存在しない。地震に先行する電離圏異常の物理機構解明において、電離圏の3次元構造とその時間変化を把握することは極めて重要であると考えられる。

2011年3月11日に発生した東北地方太平洋沖地震 (Mw9.0) に先行すると考えられる電離圏異常について、ニューラルネットワークを用いた3次元電離圏トモグラフィーを適用したところ、地震の3日前の午前より下部電離圏に電子密度の高い領域が現れ、時間とともに磁力線に沿って高高度へ発達する様子が確認された。その発達速度は磁力線に沿って70[m/s]程度であった。さらに、検出された一連の現象は少なくとも6時間以上継続しており、地震に先行して地上から何らかのエネルギーの供給が生じていた可能性が考えられる。講演では、2011年東北地方太平洋沖地震を中心として日本周辺で発生した地震に先行する電離圏異常の3次元構造および時間変化について詳細に報告するとともに、異常の発生メカニズムについて議論する。

キーワード: 地震先行電離圏異常, 電離圏トモグラフィー, GPS

Keywords: Pre-seismic ionospheric anomaly, Ionospheric tomography, GPS

Multi-parameter observations of pre-earthquake atmospheric signals and their validation.
The LAIC concept.
Multi-parameter observations of pre-earthquake atmospheric signals and their validation.
The LAIC concept.

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We are carrying out a scientific framework involving multi-sensor observations in our investigation of phenomena preceding major earthquakes. The recent catastrophic earthquake in Japan in March 2011 has provided a renewed interest in the important question of the existence of precursory signals preceding strong earthquakes and their physical validation. We describe a possible physical link between atmospheric observations with earthquake precursors using the latest Lithosphere-Atmosphere-Ionosphere Coupling model, the physical concept that we are validating. LAIC model explains the synergy of different ground surface, atmosphere and ionosphere processes and anomalous variations, which are usually named as short-term earthquake precursors.

We demonstrate our approach based on integration and analysis of several atmospheric and environmental parameters that were found associated with earthquakes. The newly developed approach named as Interdisciplinary Space ? Terrestrial Framework (ISTF) permits to identify the precursory phenomena in seismically active areas. The observations included in ISTF are: thermal infrared radiation, radon/ ion activities; air temperature and humidity and a concentration of electrons in the ionosphere. We present our findings of the retrospective thermal radiation precursory detection for more than 100 earthquakes ($M > 6$) occurring in 2004-2011 over Taiwan and Japan including the latest M9.0 great Tohoku earthquakes of March 11, 2011. The cause-effect relationship between different types of precursors united by physical basis of the LAIC model is the main advantage of the presented ISTF approach

キーワード: LAIC, earthquake, earthquake precursor, thermal anomaly, GPS/TEC
Keywords: LAIC, earthquake, earthquake precursor, thermal anomaly, GPS/TEC

次期「地震予知研究計画」における電磁気全国連携課題の提案 Proposal for the coordination program of next "earthquake prediction research" based on the electromagnetic methods

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2009年度より5ヶ年計画で開始された大学の「地震及び火山噴火予知のための観測研究計画」は2011年の東北地方太平洋沖地震の発生により、その計画の大幅な見直しが外部評価委員等から求められ、現在次期5ヶ年計画をどうするかについての協議が行われている。我々は地震予知研究の本命は短期・直前予知以外にはないと主張を従来から行ってきたが、電磁気学的手法による短期・直前予知研究を実施している予知協議会メンバーは残念ながら北海道大学と東海大学だけという状況である。次期計画では、連携研究者として多くの大学からの研究者をより積極的に包含する形で統一した課題を提案していくことを考えている。それにはSEMSグループが一体となって目標に向けて行動していく事が必要となる。講演では、現在の大学の地震予知研究の現状、次期計画で我々が提案すべきプロジェクトのたたき台となる情報を提供したい。

キーワード: 地震予知, 電磁気学

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