Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)


SSS25-01 Room:301B Time:May 20 15:30-15:45

# Precursor observed by movements of aero-ionization measurement prior to the pacific coast of tohoku earthquake in 2011

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1. Introduction

Earthquake predictions that predict when, where, how much of an earthquake will happen, is one of the most important theme in Japan. In this study, we aim at correct information of earthquake predictions by means of measurements for aero-ionization in many measurement points. Before the 3.11 earthquake, in our network of measurement an unusual behavior appeared. This study reported the unusual behavior in detail.

2. Experimental method

The experimental apparatus is based on Gerdien-condensor method, was developed by COMSYSTEM Co.Ltd. The apparatus has been setting up in a campus of Kanagawa Institute of Technology(KAIT), and aero-ionization value have been measured in 24 hours. The data of ionization was sent to the headquarters of e-PISCO and was opened in a website. In KAIT we have measured aero-ionization since ten years ago, predictions of earthquake have been informed locally. The target earthquakes of predictions were sensible earthquakes in Kanagawa Pref. or over the magnitude 5.0.

3. Results and discussions

This study reports the unusual behaviors of aero-ionization measurements in some experimental points in December 2010 before the 3.11 earthquake. Especially the unusual behavior appeared at Matsumoto measurements point in Nagano Pref., which is located over 500 km from the epicenter. The unusual behavior is wondered that the experimental apparatus is in trouble.

In our experience, for one large earthquake(M=7.0) cause less than 5 times of unusual behavior for aero-ionization, based on this experience we succeed in predictions for the day of Chuetsu earthquake in 2004 and of Iwate-Miyagi earthquake in 2008 and so on. On the contrary, for the 3.11 earthquake both behavior and period of aero-ionization have the new case, and we cannot predict the earthquake.

4. Conclusions

Now, for correct information of earthquake predictions, many method have been challenged. The method of aero-ionization observation is one of them. Because all of them have some demerits each other, in the present a better way is combination of some methods. Although for the prediction of earthquakes, many discussions occurred academically, many challenges should be executed by means of various methods.

Keywords: prediction of earthquake, precursor, aero-ionization, the pacific coast of tohoku eartquake in 2011

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SSS25-02 Room:301B Time:May 20 15:45-16:00

# Precursory and after-effect anomalous groundwater changes associated with the 2011 giant Tohoku earthquake of M9.0

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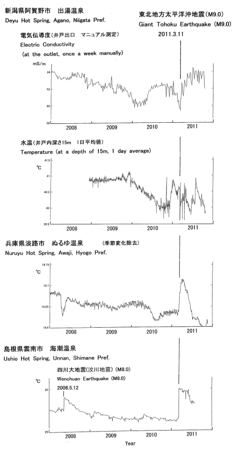
Clear precursory changes for the 2011 off the Pacific coast of Tohoku Earthquakethe of M9.0 was recorded in electric conductivity and temperature of groundwater, representing the changes on ion concentration and water temperature induced by the intrusion of water from deep underground, which is responsible to the crustal stress conditions. The observing point, Deyu Hot Spring, Agano City, Niigata Prefecture, is located 200km west of the end of the seismic fault of the earthqake. Since April, 2001, Mr. Sadao Kawakami has been manually measuring temperature and electric conductivity of groundwater at the hot spring. The measurement is conducted at an interval of one week for the water pumped up from the well. Furthermore, we have temperature data recorded automatically since December 7, 2008. Around the end of 2009 the conductivity started to decrease with clearly decreasing temperature, indicating stress relaxation underground. Then the conductivity tended to increase in May, 2010, and the temperature similarly turned to increase in December, the same year. The resultantl precursory time is one year and several months. The conductivity data from this observation station had recorded precursors before the 2004 Niigata Chuetsu Earthquake of M6.8 and the 2007 Niigata Chuetsu-oki Earthquake of M6.8. Clear after-effect groundwater temperature rises were recorded at Nuruyu Hot Spring, Awaji City, Hyogo Pref., and Ushio Hot Spring, Unnan City, Shimane Pref. The rise time and hight are 20 days and 70m degree in centigrade at Nuruyu, and 10 hours and several hours and 3.5 degree at Ushio, respectively.

Keywords: groundwater, ground water temperature, electric conductivity, earthquake prediction, precursor, after-effect



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SSS25-03 Room:301B Time:May 20 16:00-16:15

# Re-examination of seismic quiescence prior to the 2011 Tohoku earthquake

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We have presented the seismic quiescence to be detected prior to the 2011 Tohoku earthquake in the last SSJ meeting (Yoshikawa,2011). We examined two cases of the periods, considering the difference of the detectability of seismic activity. According to this, the seismic quiescence appeared since 2001 around the San-Riku coastal area, the major length of three to four hundred km, in the period from October 1997 to February 2011 with the threshold of M3.0 (Case-A). And it appeared since 1996 in the wider area than the above case with the major length 500 km, in the period from January 1984 to February 2011 with the threshold of M4.0 (Case-B). Against this result, it was pointed out that the appearance should be influenced by de-clustering and the seismic activity in the reference period. And as stated above, the difference of the quiescence area and the period between the two cases suggests dependences of the parameters used for the analysis of the quiescence. In this study we present the results of re-examination, considering the problems.

As a method for detection of seismic quiescence we chose the method developed by Aketagawa and Ito (2008) and Hayashimoto and Aketagawa (2010) in order to find the areas of activation and quiescence of seismicity (hereafter, it may be called 'e-Map'). We can obtain the seismicity map depending on the seismic density of each region by this method. We investigated the influences of the threshold of magnitude, the radius of the test circle in survey area, the reference period, the survey period, etc. and found that the appearance form of quiescence area can be remarkably changed by choice of the above parameters, although a scaling law between the quiescence area and the magnitude of the earthquakes accompanied by seismic quiescence was clear.

As the results of the study, we did not find large differences both in the area and commencement of quiescence prior to the 2011 Tohoku earthquake caused by de-clustering. And we found that since the seismic activity in the coastal area of the San-Riku became high from 1989 to 1995, it makes the appearance of quiescence earlier, if the reference period includes that active period. Then as we set the reference period in the period from 1984 to 1988 for Case-B, the appearance of quiescence delayed to 2001, as in Case-A.

Keywords: seismic activity, quiescence, Tohoku earthquake

SSS25-04 Room:301B Time:May 20 16:15-16:30

# Groundwater level changes associated with aftershocks following the 2011 M7 earthquake occurred in Iwaki City, Japan

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The great Tohoku-oki earthquake induced a normal fault-type M7 earthquake beneath the western part of Iwaki City on April 11, 2011. A NNW-SSE trending surface rupture longer than ten kilometers emerged with west side throw as large as 2 m. It is an opportunity to observe ground water level (GWL) changes associated with many aftershocks within a short observation period. The observation at a short epicentral distance also is advantageous to detecting precursory changes. Borrowing two deep boreholes in the aftershock area, I conducted GWL observation during 50 days since April 21. Borehole SMK is located 4.3 km southeast from the southern tip of the surface rupture, and borehole HLN is 6.2 km east from SMK. The precision of water-level gauges used is 1 mm, and the data were acquired minutely. The GWL changes related to 23 inland shallow aftershocks and 4 deeper earthquakes off Iwaki City were recorded.

1) GWL rose about 4 m at SMK, while about 5 m dropped at HLN. These changes are approximated well by exponential functions of time whose origins are set at April 11. They indicate that the GWL at SMK (HLN) dropped (rose) about 8 m (10 m) just after the earthquake and rose (dropped) thereafter at a relaxation time of 47.6 days (29.4 days).

2) The effects of the earth tide and barometric pressure to GWL were corrected by using BAYTAP-G. Comparing the output components attributed to the earth tide with the corresponding volumetric strain calculated by GOTIC-2, 1 mm GWL change at SMK and HLN are estimated to be equivalent to the volumetric strain of 0.30 and 0.24 nano-strain, respectively.

3) After defining the normalized earthquake magnitude $M*$ as $M* = M - Mc$ and the lower limit magnitude Mc below which earthquakes are not detected as GWL changes as Mc = 2.4logr ? 1.0, 156 earthquakes which fulfill the condition $M*>1$ were selected from JMA database. The parameter r denotes the epicentral distance (in km). The occurrence of the earthquakes with larger $M*$ are synchronous with step-like GWL changes which are found in the trend-component output from BYTAP-G. Obviously the lager $M*$, the higher step. Through such procedure 27 and 10 earthquakes-related GWL changes were identified in the data from SMK and HLN, respectively. The maximum change attains 52 mm.

4) Mc is expressed conclusively as Mc = 2.48logr ? 1.00 for the data from SMK. The relation between the observed GWL changes w (mm) and $M*$ are approximated as $M*$ = 0.704logw ? 0.198, being consistent with a theoretical consideration.

5) Focal mechanism solutions of the 24 earthquakes among the 27 earthquakes are opened on the websites of JMA or NIED. Using the source parameters and MICAP-G, static volumetric strain changes at SMK and HLN were calculated. They were converted to GWL changes and compared with the observed values. As a result, they are consistent each other for 15 earthquakes (63 %). When the epicentral positions are allowed to move slightly within their determination errors, the theoretical GWL changes can be consistent with the observed values for the additional 7 earthquakes (29 %). With regard to the data for 92 % of the earthquakes, the ratios of volumetric strain to GWL change are averaged to 0.38 nano-strain/mm for the data from SMK, being consistent with the volumetric strain equivalent to water level change (0.30 nano-strain/mm). These results strongly suggest that the main cause of the GWL changes is the static volumetric strain changes. The GWL changes related to other two earthquakes may be due to ground shaking.

6) It is not rare that small (<several mm) GWL changes preceded a few hours before earthquakes (11 among 37 observations). These preseismic changes may be attributed to the incomplete correction of the effects of the earth tide, but the preliminary examination rejected this possibility. Evidences which indicate the preseismic changes as precursors have not been obtained so far.

Keywords: groundwater level, Iwaki earthquake, aftershocks, volumetric strain, precursor

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# Characteristics of Date, Time and Lunar Phase of Giant Earthquakes for Each Subduction Zone

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There are several studies which suggest that the tidal force affects earthquake occurrence. The studies focus on earthquake precursory of Sumatra (Tanaka, 2010), non-volcanic tremor resulting from slow slip events (Nakata et al., 2008) etc. If predictions on date, lunar phase and time of giant earthquake occurrences can be narrowed for every subduction zone, it would be very effective to reduce earthquake damages. Only the giant main shock, mainly $M_w$ 8+ earthquakes between 1900 and 2011, were investigated for each subduction zone in this study. UTC is used hereafter.

In Kuril Islands, six of the seven earthquakes occurred during Aug. 11 and Nov. 15 on lunar phase between 24.2 and 1.6 days. Earthquakes of Hokkaido in Japan near Kuril Islands occurred in a similar manner. In Tonga, four of the five earthquakes occurred during Apr. 30 to June 26. All events occurred on lunar phase between 0.8 and 6.2 days and between 5:07 and 15:26. In Chile, no clear date dependency is observed. However, four of the seven earthquakes occurred around the new moon (lunar phase between 22.1 and 1.8 days) and two occurred just before the full moon (lunar phase between 12.0 and 13.6 days). All events occurred during 16:07 to 6:34. In Peru, no clear date dependency is observed. However, three of the seven earthquakes occurred around the new moon (lunar phase between 2.2 and 3.5 days) and the rest four occurred around the full moon (lunar phase between 12.6 and 18.8 days). All events occurred during 12:08 and 23:40. In Japan, three of the six giant earthquakes occurred around the lunar phase of 6 days and the rest three occurred around the lunar phase of 20 days. Five of the six earthquakes occurred during Mar. 2 to June 15. No clear dependency was observed for earthquakes in Southeast Asia.

$M_{JMA}$ 6+ earthquakes in Japan were investigated since there are not enough $M_w$ 8+ earthquakes. No clear dependency between the earthquake occurrence and lunar phase was observed. However, in the case of $M_{JMA}$ 7+ earthquake occurrence is high on lunar phase between 6 and 12 days and between 20 and 22 days. All land earthquakes occurred on lunar phase between 4 and 14 days and between 20 and 22 days.

Investigating the areas (Hokkaido, Pacific Ocean side between Aomori and Chiba, Kansai, Kyushu and Okinawa islands), the earthquakes in Hokkaido were similar to the ones in Kuril Islands. Giant earthquakes occurred on lunar phase between 20 and 0 days. Most earthquakes in Pacific Ocean along Aomori to Chiba occurred on lunar phase of about 6, 12 and 22 days. The most earthquakes in western part of Japan were on lunar phase between 9 and 21 days. Not many giant earthquakes in this area.

Investigating the seasons, most earthquakes in February to April occurred on lunar phase between 4 and 15 days. Earthquakes which occurred in May to July occurred on lunar phase between 10 and 20 days. Most giant earthquakes in August to January occurred on lunar phase between 20 and 0 days. Occurrence of the giant earthquakes was higher during winter to spring than summer to fall.

If a dangerous time zone is narrowed for each subduction zone in future, the validity will be examined based on change in the stress state of the subduction zone by tidal force. Investigation on the stress state of the whole subduction zone rather than statistical analysis for small earthquakes will be carried out since the prediction of giant main shocks is much more important than that of predict small earthquakes.

Keywords: giant earthquake, lunar phase, tidal force, subduction zone, plate

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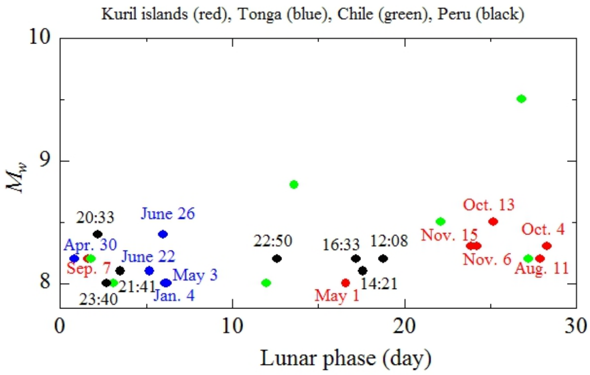

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SSS25-06 Room:301B Time:May 20 16:45-17:00

# Long-term probability forecast of the regional seismicity that was induced by the M9 Tohoku-Oki earthquake

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Seismicity of the eastern Japan has become active, induced by the M9 Tohoku-Oki earthquake of 11 March 2011. Since November 2009, Japan Testing Center of the CSEP has been evaluating some probabilistic forecasts of seismic activity in and around the Japanese islands, including the Kanto region and inland areas. However, it now accepts re-submissions of the probability forecasts due to the influence of this M9 mega-earthquake. Originally, these were relatively short-term forecasts that assumes the space-time probability forecasts. However, recently, long- and mid-term forecast of probability of large earthquakes in the Tokyo metropolitan area has been attracting wide attention.

In this report, I will consider such a forecasting method for each region of Japan. If the region does not contain the M9 earthquake in it, I predict the seismicity rate by the superposed model of the ETAS model and the Omori-Utsu formula. Here, the ETAS model represents the triggered earthquake chains within the region, and the Omori-Utsu formula represents the induced seismic activity by the M9 earthquake. This superposed model fit well to data for period up until now. Hence, I will use this to forecast of seismic activity of the region in the future.

A sequence of earthquake magnitudes may be generated by use of the Gutenberg-Richter's law. However, this is not quite suitable for an unbiased prediction of frequency of large earthquakes because the b-value can be different depending on the threshold magnitude. Alternatively, I will simulate them by bootstrap re-sampling based on the magnitude data of the earthquakes in that region of the Utsu catalog (1885-1925) and the JMA catalog before and after the unification (November 1997). Here, the re-sampling weights considering the detection rate and duration of each catalog.

After obtained the magnitude series of earthquakes, I simulate the seismic activity using the superposed model of the ETAS and Omori-Utsu formula. Repeating this procedure, we estimate long-term probability of occurrence of large earthquakes. In this report, we will see probabilities of large earthquakes during the passage of up to 30 years period in South Kanto metropolitan area, the Tohoku inland region and the Itoigawa-Shizuoka Tectonic zone

Keywords: long-term probability forecast, ETAS model, Omori-Utsu formula, Bootstrap resampling