Dense Seismic and GPS Observation around the Nagaoka Plain Western Margin Fault Zone

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SUMMARY
A new dense seismic and GPS observation network called AN-net has started from November, 2010 in order to investigate the seismic activity of the Nagaoka plain western margin fault zone located in the central part of Niigata Prefecture, Japan. The 2011 Tohoku earthquake (Mw9.0) occurred on March 11. The area of AN-net was elongated in the direction of east-and-west (about 5ppm in strain) by main shock, which deformation is a reverse sense in comparison with the previous transformation pattern. On the other hand, seismic activity after the earthquake decreased about 30%. It can be said that the influence on seismic activity due to the earthquake was comparatively weak although large crustal deformation occurred.

Keywords: Seismic observation, GPS observation, Active fault zone

1. INTRODUCTION

In recent years, large earthquakes such as 2004 Niigata Chuetsu Earthquake, 2007 Niigata Chuetsu-oki Earthquake occurred in the high strain rate zone at eastern margin of Japan Sea, and a great deal of interest is being expressed not only by specialists, but also by the general public, in subjects such as the relationship between active tectonics and earthquake faults, source mechanisms, and ground amplification characteristics. Although a range of investigations have already focused on the western margin of the fault zone of the Nagaoka plain, located in the high strain rate zone at eastern margin of Japan Sea, its activity characteristics, including the possibility of a link with fault activity, have not necessarily been explicated. Accordingly, the Association for the Development of Earthquake Prediction (ADEP), determined to newly construct a dense seismic and GPS observation network called AN-net in the region in question, as a part of its investigation and research into seismic activity in the Nagaoka-seien-fault zone. Construction of AN-net started around in March, 2009, and AN-net has begun operation in November, 2011.
The 2011 Tohoku earthquake (Mw9.0) occurred on March 11, 2011 about four months after the seismic observation started [Hirose *et al* (2011)]. By the occurrence of this earthquake and subsequent after slip, it had the large effect in crustal deformation in the surrounding area of observation network. Therefore, it is very interesting whether the seismic activity around this area is subject to what kind of influence, when we investigate the mechanism of the occurrence of earthquake.
In this paper, we introduce the outline of observation network first. Next, we describe about the influence of the 2011 Tohoku earthquake having done to crustal deformation and seismic activity based on observational data.

2. OUTLINE OF OBSERVATION

2.1 Seismic observation

The observation network consists of 40 stations deployed in a pattern that surrounds the region. 9 of

the 40 stations were constructed in 2009 and the other 31 were constructed in 2010 (see Figure 1). The space interval between each station is about 3~10 km. To investigate the relationship between tectonics, faults and seismic activity in the region, continuous GPS observation stations were also installed at 20 of the 40 stations. At each seismic observation station, in order to respond to activity ranging from microearthquakes to large earthquakes, 3-component velocity type seismometers (Lennartz electronic, LE-3D) and servo type accelerometer (Japan Aviation Electronics Industry, JA-40GA) are combined to create a new high dynamic range broadband borehole seismograph. To achieve stable high sensitivity seismic observation and to avoid surface ground noise, seismograph was installed at the bottom of a borehole roughly 100 m in depth. An accelerometer was also installed near ground surface (see Figure 2).
The data logger carries out the AD translation of the signal from seismograph, stores data in the form synchronized with exact time information, and is carrying out UDP/IP protocol transmission in WIN format to the network simultaneously. The A/D converter currently used by the data logger is a 24bit ΔΣ system, and records 100Hz sampling data. An effective dynamic range is about 130 dB, when a self-noise etc. is taken into consideration. The data logger is backed up with the battery power supply of capacity 22Ah, and when commercial power fails for power, observation can be continued over about 20 hours. Moreover, the continuation record for about two months is possible on CF card (capacity of 8 GB) built in the data logger. After commercial power and a telephone line are recovered, the data saved on CF card is collected using FTP.
The data from the seismic observation network is transmitted to the data centre in our office in 1 second packets, and is combined with data from pre-existing seismic networks operated by various institutions, and subjected to carrying out a series of data processing such as event detection, determination of hypocenter, seismic intensity and focal mechanism.

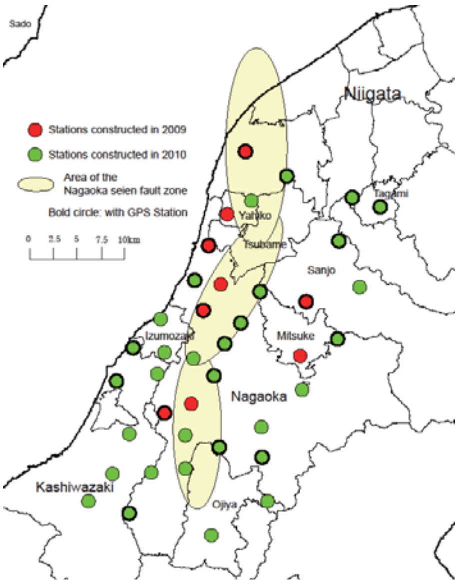

Figure 1. Distribution of the AN-net stations

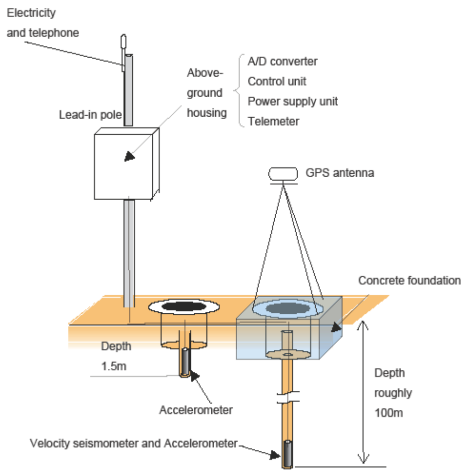

Figure 2. Configuration of the AN-net station

2.2 GPS observation

The GPS continuation observation was carried out among 40 seismic stations at 20, and has been arranged at intervals of about 5 km centering on the Nagaoka plain (see Figure 1). GPS receiver NetR5 made from Trimble and a Zephyr Geodetic antenna were installed in each station. The GPS receiver is connected to the IP network as well as earthquake data, and the GPS data of each observation station is sent to Nagoya University, then, combined with the data from the surrounding GEONET (GPS Earth Observation Network System; Geospatial Information Authority of Japan) stations.

3. CRUSTAL DEFORMATION AND SEISMIC ACTIVITY

3.1 Crustal deformation

An example of coordinate change of GPS station obtained as a result of precision re-analysis is shown in Figure 3. This result was computed on the basis of the electronic reference point 940052 in Nyuzen-cho, Toyama prefecture. It is sure that the displacement to east of about 30-40 cm arose in connection with the 2011 Tohoku earthquake, and the displacement to east of about 10-20 cm arose between about nine months and a half after the earthquake further in all the stations. Change of a north-south component is to south of displacement of about 10 cm, and significant displacement is not accepted about up-and-down change.

Figure 4(a) shows the principal strain axes distribution before the occurrence of the 2011 Tohoku earthquake based on the data of GEONET of the Geographical Survey Institute. In near the Nagaoka plain, east-and-west shortening modification is remarkable, and the shortening modification of 0.2-0.3 ppm per year had arisen.

On the other hand, the principal strain axes distribution accompanying the earthquake is shown in Figure 4(b). Although the strain distribution is greatly disturbed in the southern part of the domain due to the earthquake (M6.7) which occurred in the prefectural border between Niigata and Nagano on March 12, it turns out that big extension modification of the direction of east and west occurred uniformly over the whole domain. The modification in case of the earthquake shows the dynamics response of this fault zone to momentary compulsive displacement. That is, when it is regarded as an elastic body, this area shows a uniform change and cannot recognize a fault zone. Moreover, in the after slip, although the remarkable growth of the direction of east and west is seen over the whole region as well as the time of the earthquake, the large domain of growth has a significant spread and cannot consider the motion relevant to movement of the fault zone.

The extension distortion in case of the 2011 Tohoku earthquake is about 5 ppm. For recovering the distortion change in case of an earthquake, it requires tens of years of time at the distortion rate before the earthquake. Although after slip of the earthquake continues till when or it will be unknown from now on, even after being completed by it, by the time shortening modification of this area returns to the original state, it will be thought that considerable time will be required.

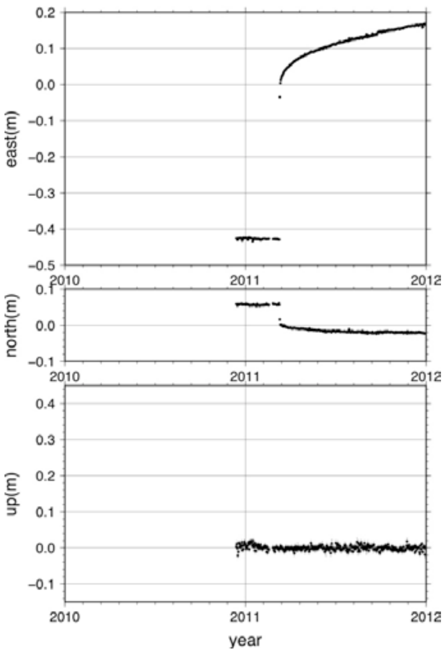

Figure 3. An example of coordinate change of GPS station (NMOK)

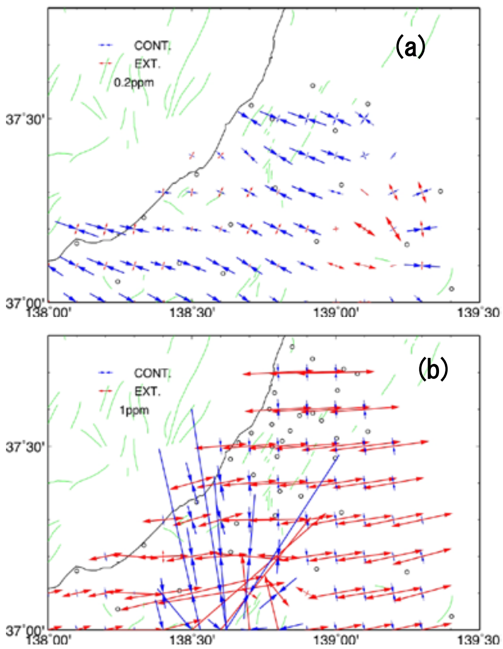

Figure 4. Principal strain axes distribution
(a): before the earthquake (2009/01-2011/01, GEONET)
(b): on the earthquake (AN-net and GEONET)

3.2 Seismic activity

In AN-net and its surrounding area, large crustal deformation occurred due to the 2011 Tohoku earthquake.Since the shortening distortion before the earthquake was cancelled by this change, reducing the seismic activity of this area sharply is expected. Based on the JMA (Japan Meteorological Agency) unified seismic catalog and the AN-net catalog about hypocenters, the change of seismic activity was investigated.

3.2.1 JMA unified catalog

Figure 5 shows the hypocenter distribution of and the M-T (Magnitude-Time) diagram for about one year before and after the 2011 Tohoku earthquake. If these two focus distribution maps are compared, in one year after the earthquake, it is clear that the earthquake decreased greatly. The number of earthquake occurrences is decreasing sharply from 1437 to 450. This reduction is remarkable, though in for one year before the main shock two swarm earthquakes have occurred at the easternmost end and the southwest end of a domain on May 9 and October 3 and there are slightly many earthquakes by that influence compared with an ordinary year. However, according to the M-T diagram, while the minimum of M is in about zero level in general before the earthquake, after the earthquake, it turns out that the minimum of M is going up to about 0.3~0.5. Moreover, the rise of this lower limit has started around December, 2010 not only after the earthquake but three months ago.
Then, the accumulation curves of the monthly frequency of the magnitude in the JMA unified catalog are shown in Figure 6. Here, black solid lines are curves from January, 2010 to November, 2010, and red solid lines are curves from December, 2010 to February, 2012. In the range in which magnitude is smaller than the 1.5, the red curves are distributed above black curves, and the figure shows that there are few earthquakes of magnitude smaller than this magnitude. JMA unified catalogue is conjectured that a change of a reading standard is made from the time three months before the 2011 Tohoku earthquake. Therefore, it cannot be judged that the seismic activity after the main shock fell sharply immediately from this data.

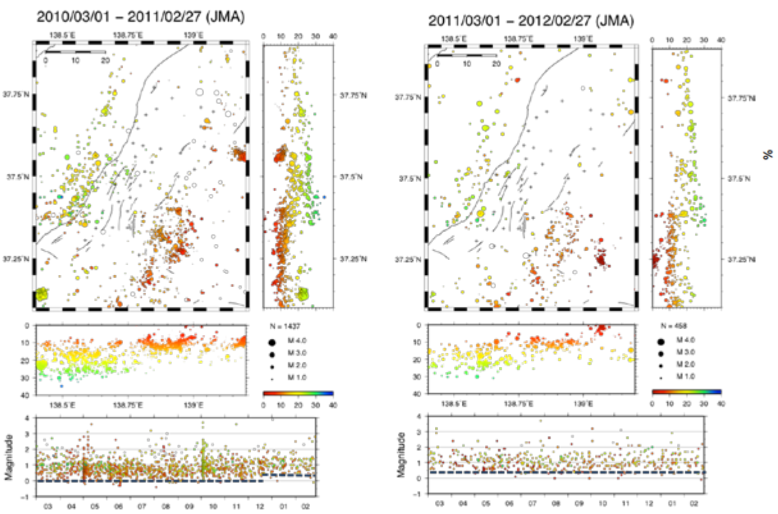

Figure 5. Hypocenter distributions of JMA catalog before (left side) and after (right side) the 2011 Tohoku earthquake in term of about one year

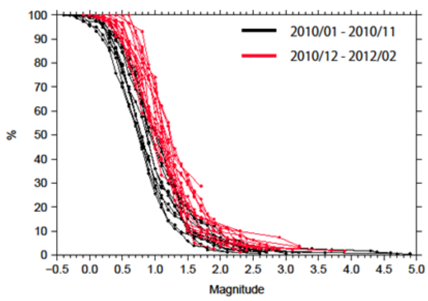

Figure 6. Accumulation curves of the monthly frequency of magnitude in JMA catalog

3.2.2 AN-net catalog

The data based on An-net is obtained from November 1, 2010, four months ago from the 2011 Tohoku earthquake. So, the hypocenter distribution and the M-T diagram in every four months from November, 2010 to February, 2012 are shown on (a), (b), (c), (d) in figure 7, respectively. From these figure, it is thought in this domain that the seismic activity after the main shock may have decreased by about 30% compared with the activity before the main shock. Although aftershock activities of the Niigata Chuetsu earthquake and the Niigata Chuetsu-oki earthquake were remarkable before the main shock shown in (a), in (b) after a main shock, these activities became weaker. It seems that it is not recovered by the activity before the main shock in subsequent (c) and (d) although activity tends to return a little.

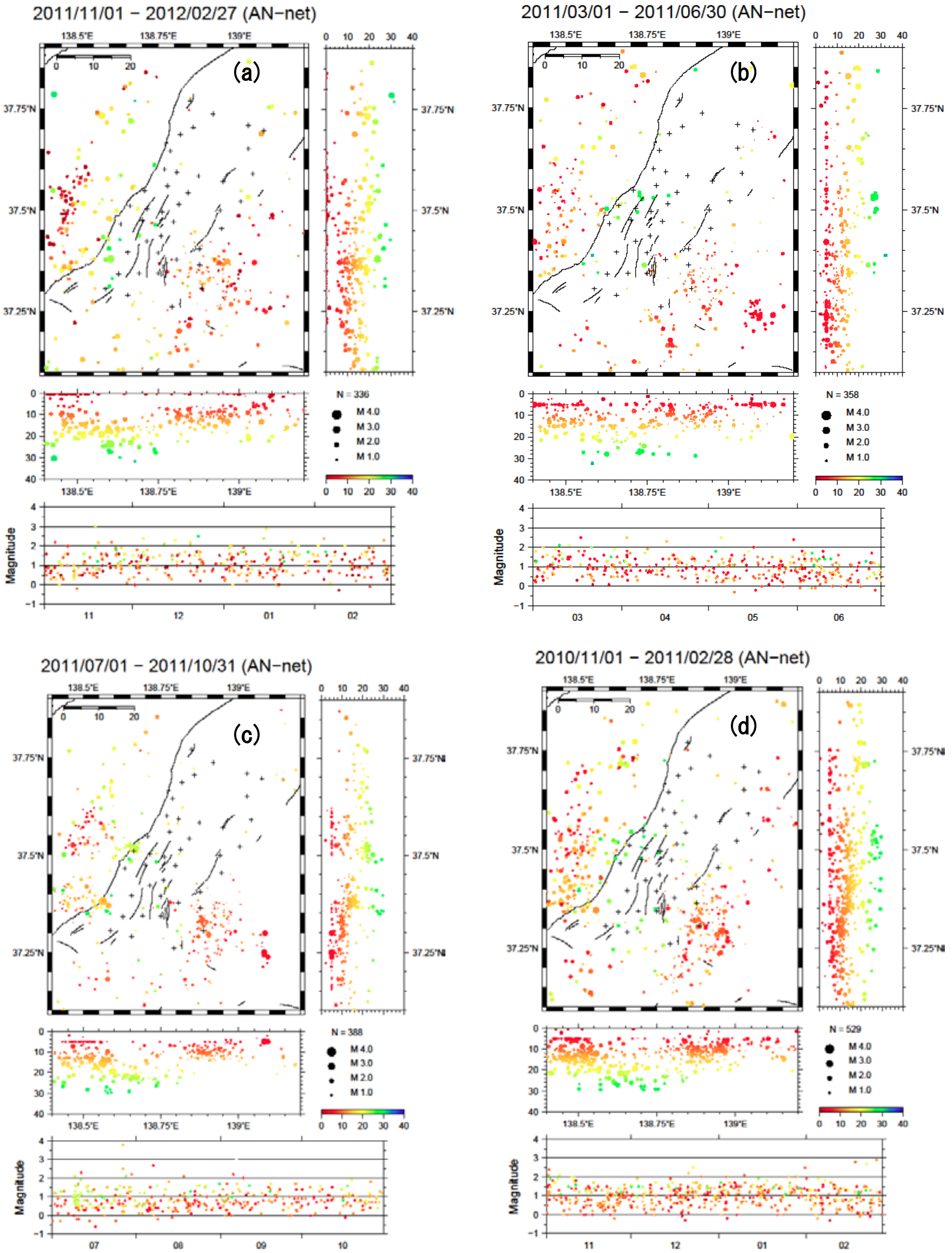

Figure 7. Hypocenter distribution and the M-T diagram of AN-net catalog in every four months from November, 2010 to February, 2012

Transition of the monthly number of earthquakes of AN-net and JMA is shown in Figure 8. Although the number of monthly earthquakes of AN-net and JMA has a 2 or so-time difference, it is parallel-like as a whole, and if four months before the main shock are averaged also in the case of JMA data, it can also be considered that the fall of activity after the main shock is about 30%. According to the data of AN-net, the number of monthly earthquakes in August or September and afterwards is about 80 on the average, and the consequence of the huge earthquake having done to the area concerned seems to be settled gradually. However, since it is data for about one year, it is still required to watch carefully and to continue to go.

In addition, in such examination, it is indispensable that the quality of the data in an examination period is kept constant. Figure 9 shows the accumulation curve of the monthly frequency of the magnitude in AN-ne data. The curves for four months before the main shock and one year after the main shock are almost the same, and it turns out that it is satisfactory in the quality of data.

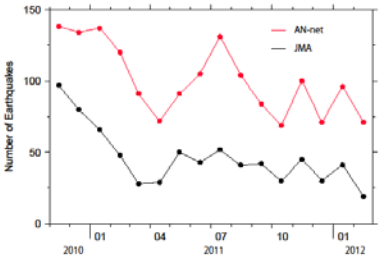

Figure 8. Transition of the monthly number of earthquakes in AN-net catalog and JMA catalog

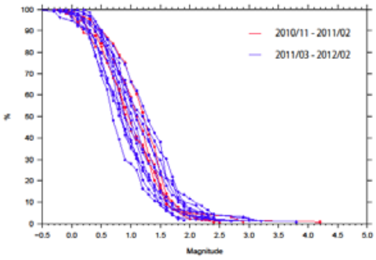

Figure 9. Accumulation curves of the monthly frequency of magnitude in AN-net catalog

4. CONCLUSION

It is as follows if the above examination result is summarized.

(1) The dense seismic and GPS observation stations (AN-net) were installed around the western margin of the fault zone of the Nagaoka plain, located in the high strain rate zone at eastern margin of Japan Sea on November, 2010. The 2011 Tohoku earthquake (Mw9.0) occurred on March 11 about 4 month after construction of AN-net.

(2) From the GPS data, It is sure that the displacement to east of about 30-40 cm arose in connection with the 2011 Tohoku earthquake, and the displacement to east of about 10-20 cm arose between about nine months and a half after the earthquake further in all the stations. The extension distortion in case of the earthquake is about 5 ppm. For recovering the distortion change in case of an earthquake, it requires tens of years of time at the distortion rate before this earthquake.

(3) In examination using JMA catalog, the seismic activity in an examination domain fell dramatically after the 2011 Tohoku earthquake. However, JMA unified catalogue is conjectured that a change of a reading standard is made from the time three months before the earthquake.

(4) According to the hypocenter distribution and the M-T diagram in every four months from November, 2010 to February, 2012 by using AN-net catalog and the transition of the monthly number of earthquakes, it is thought that the seismic activity after the 2011 Tohoku earthquake may have decreased by about 30% compared with the activity before the earthquake. Thus, compared with large crustal deformation, the change of seismic activity is considered to be comparatively slight.

AKCNOWLEDGEMENT

AN-net is installed by the fund of the Tokyo Electric Power Co., Inc. In selection of each observation station, cooperation of the staffs of the Tokyo Electric Power Co., Inc., the staffs of local self-governing bodies, and local residents were indispensable. Moreover, we have gotten much cooperation of companies of seismograph and data logger in construction of AN-net. Profound gratitude is expressed to these persons concerned. All figures were drawn with the Generic Mapping Tools (GMT) developed by Wessel and Smith (1998).

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