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INVITED PAPERS

GPS NETWORK EXPERIENCE IN JAPAN AND ITS USEFULNESS FOR DISASTER MANAGEMENT

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GPS network experience in Japan and its usefulness in Disaster Management

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1. Introduction

Japan now has the densest nation-wide GPS network in the world. The network named GEONET (GPS Earth Observation Network System), consisting of more than 1220 continuous GPS stations (Figure 1) and data analysis system, has been developed and maintained by Geographical Survey Institute (GSI) of Japan. It has become an indispensable tool for the study of geodetic/geophysical phenomena around Japan where 4 tectonic plates are interacting with each other and cause earthquakes and volcanic activities (Figure 2). In this paper, we first review the development of GEONET and its contributions and achievements, especially in view of the natural disaster management. For Asia-Pacific region, which includes tectonically very active regions in the world and often hit by fatal earthquakes, tsunamis and volcano eruptions, we propose a new project of monitoring crustal deformations in Asia and Pacific aiming for the disaster prevention and mitigation.

2. History of GEONET

GSI's first substantial continuous GPS network was laid in Kanto and Tokai area in 1993-4. 110 stations were constructed to continuously monitor crustal deformations (COSMOS-G2). In 1994 another network with 100 stations was installed to cover the whole Japan (GRAPES: GPS Regional Array for Precise Surveying/Physical Earth Science). Just as the GPAPES began operation a series of big earthquakes hit Japan (Hokkaido-Toho-Oki, 1994, M8.1, Sanriku-Haruka-Oki, 1994, M7.5, Hyogoken-Nanbu (Kobe), 1995, M7.2) and the network proved its abilities and effectiveness by swiftly and precisely detecting the crustal deformations by these earthquakes.

In 1996 two separate systems were integrated with an addition of 400 stations into GEONET. In 1999 GSI set the aim for the fully operational number of stations in GEONET as 1200 (or average spacing of 20- 30km), dense enough for detecting the strain accumulation process across the Japanese islands, following the recommendations of government's Headquarters for Earthquake Research Promotion established after the disastrous Kobe earthquake in 1995. Data distribution via internet has started this year.

In 2003 the number reached 1200 and several improvements on the hardware and software have been achieved. For example, double cylindrical structure of observation pillar to reduce thermal effects, unification of antenna type to reduce multi-path, better analysis strategy to obtain more reliable and accurate solutions, etc.

Here is the overview of GEONET at present.

- Number of stations: 1220+a
- Data via internet: Phase & orbit (RINEX), daily solutions (site coordinates)
- Analysis & solutions:

Routine solutions (weekly, daily and every 3 hours for all stations) by Bernese

Emergency solutions (hourly, limited number of sites)

Real-time solutions (limited number of sites)

Services to private companies: real-time data for RTK-GPS survey

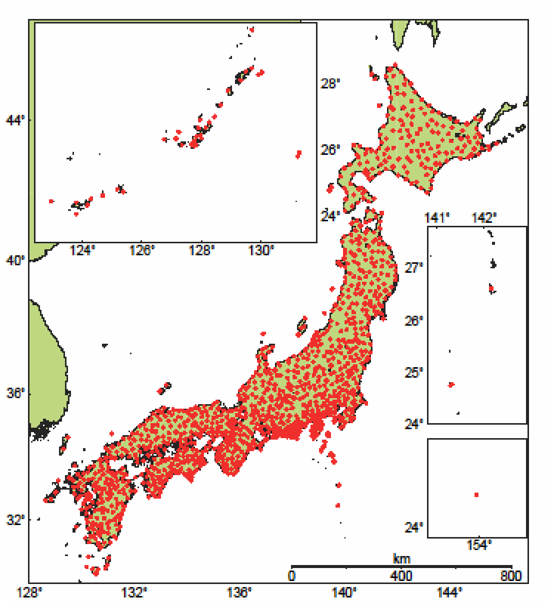

Fig. 1 GEONET sites

Monitoring of crustal activities is done by the GEONET's daily solutions of station coordinates. When an extraordinary data are detected, or a big earthquake or volcanic eruption occurs emergency analysis is performed to get the solutions every 3 hours. These data are used in various disaster related meetings and geophysical model estimation of crustal activities and thus will be reflected in a decision making process to cope with the disaster as well as the scientific researches.

3. Major achievements and insights obtained by GEONET

Using the GEONET data spanning several years, we can get a detailed map of deformation along the Japanese islands and thus know where the strain-buildup is happening. (ex. see Sagiya et al., 2000)

When a big earthquake occurs, GEONET detects the coseismic movements of the stations in a few hours and fault model is estimated based on the displacement data. In case of large-scale interplate earthquakes which occur periodically on the boundary of a subducting oceanic plate under a continental plate, there is a crustal deformation going on after the event around the source region. That post-seismic deformation continues for months to even years. When this post-seismic deformation ends, the region enters into the steady state of crustal deformation along the plate boundaries to store the energy for the next earthquake. GEONET has revealed to us a great deal of knowledge about this interplate earthquake cycle. We can estimate the plate-coupling, the degree of which indicates the storing of earthquake energy on the boundary from the annual rate of deformation and come to know that a sudden big slip at the event (co-seismic movement) and a slow slip after the event (post-seismic movement) are happening at different places. Risk evaluation is possible by monitoring the crustal activity along the plate boundaries with GEONET and identifying which segment of the boundary will be slipped big in the next earthquake and at which stage of the cycle it is on. A case of Tokachi-oki earthquake (M8.0, 2003) is illustrated in Figures 3 and 4.

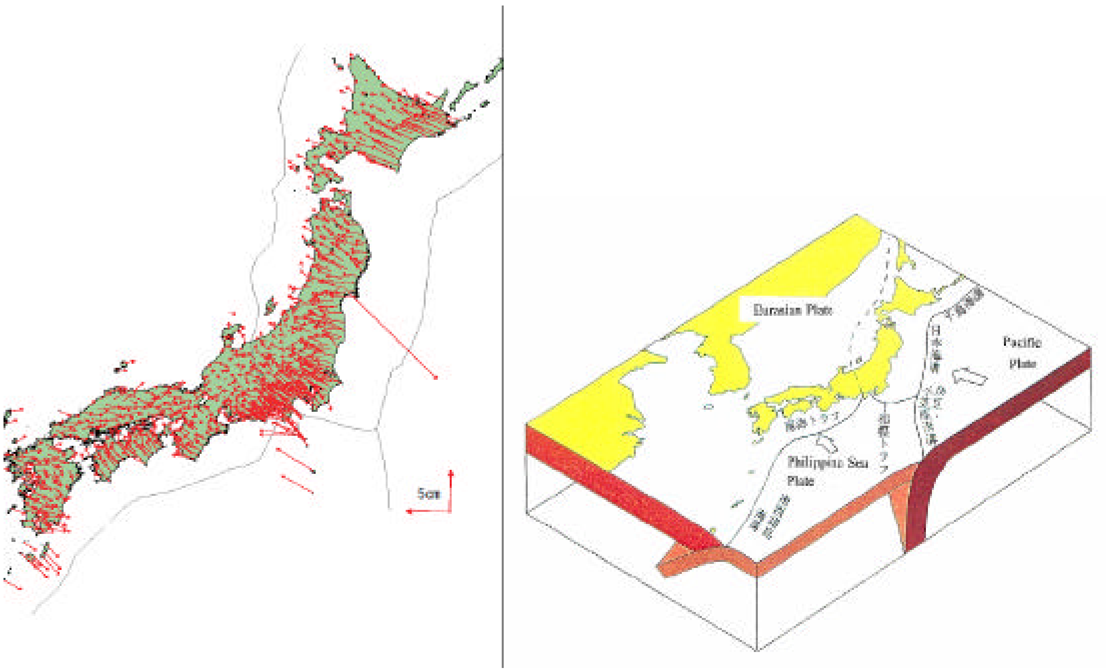

Fig.2 Movement of GEONET sites in 2002-2004 (left) and tectonic plates around Japan (right)

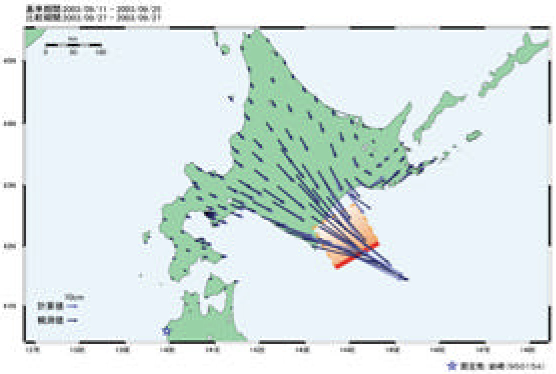

Fig.3 Tokachi-Oki earthquake (Sep.26, 2003): co-seismic crustal deformation by GEONET (rectangular area is the estimated fault region)

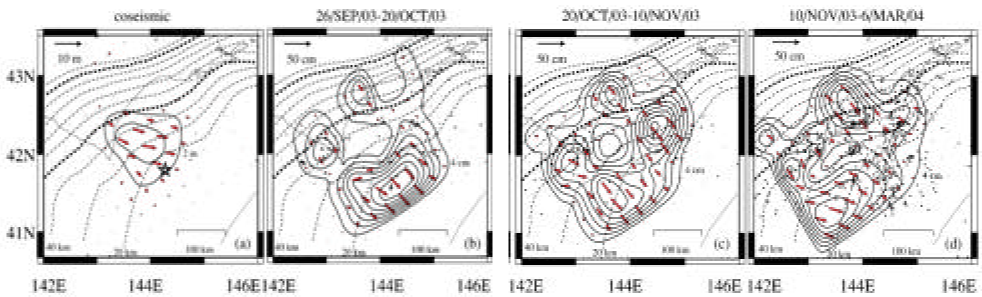

Fig. 4 (from left to right) Distributions of slip vectors at and after the event (Ozawa et al., 2004)

4. Monitoring of Asia-Pacific crustal deformation

Asia-Pacific contains the most active regions in the world. Along Pacific Rim and south of Sumatra and Java islands to and New-Guinea Island and north of India to Himalaya Mountains, many earthquakes, some of them fatal, occur with volcanic activities. Just recall the recent fatal earthquakes and tsunamis. Figure 5 shows the distribution of big earthquakes since 1973.

In PCGIAP's geodetic activity, WG1 has been carrying out annual campaign observation, APRGP (Asia and Pacific Regional Geodetic Project), by space geodetic techniques (GPS, VLBI, SLR, DORIS) for the past 9 years. Its primary objectives are establishment and enhancement of a regional geodetic infrastructure through annual cooperative campaigns, development of transformation parameters for spatial data and geodetic technology transfer to Pacific islands nations. As a result we now have a densified ITRF frame in the region with position and velocity of each geodetic station (Figure 6, Dawson et al., 2004).

To cope with the natural disasters from the geodetic point of view, we regard Japan's GEONET as a model system for the monitoring of crustal deformation and estimating of the risk. By continuously monitoring the positional variations of observation sites for a period of time, we could obtain the tectonic characteristics of the region andand prepare for next fatal disasters. Although thousands of GPS site will not be possible to build for the whole region, the present network will serve as a backbone of the new system. By increasing continuous GPS and employing other advanced techniques like SAR (Synthetic Aperture Radar) and high data-rate communication network, we think we can manage to build an effective system for Asia and Pacific.

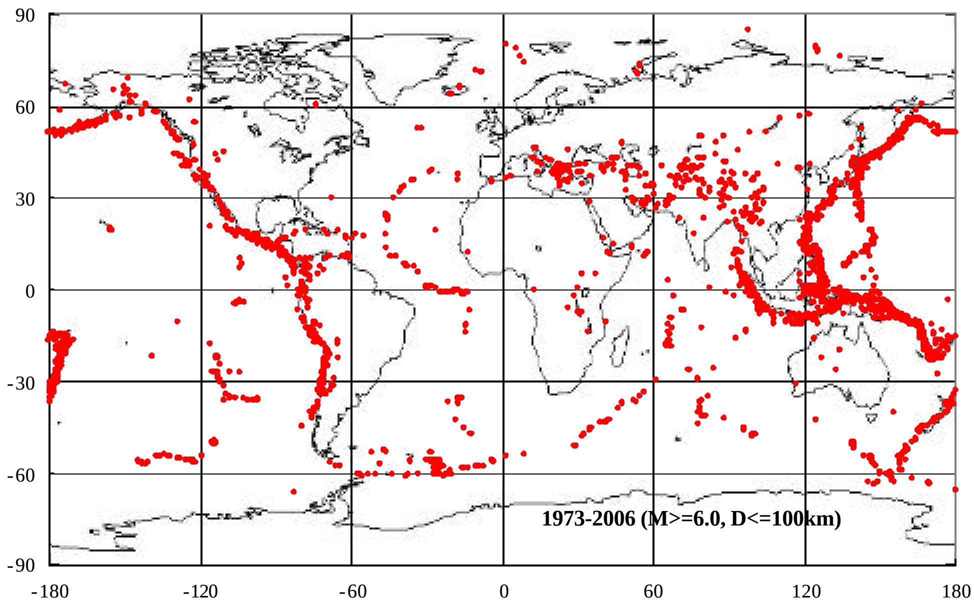

Fig. 5 Distributions of earthquakes, 1973-2006, M>=6.0, Depth<100km

Strengthening the GPS network will be done by increasing the continuous sites around the high-risk regions. Employment of SAR technique will be very effective to obtain a deformation map of wider, large areas for regular monitoring as well as emergency assessment of a disaster. Setting-up of data and analysis center responsible for collecting and distributing data, solutions and risk calculation is indispensable.

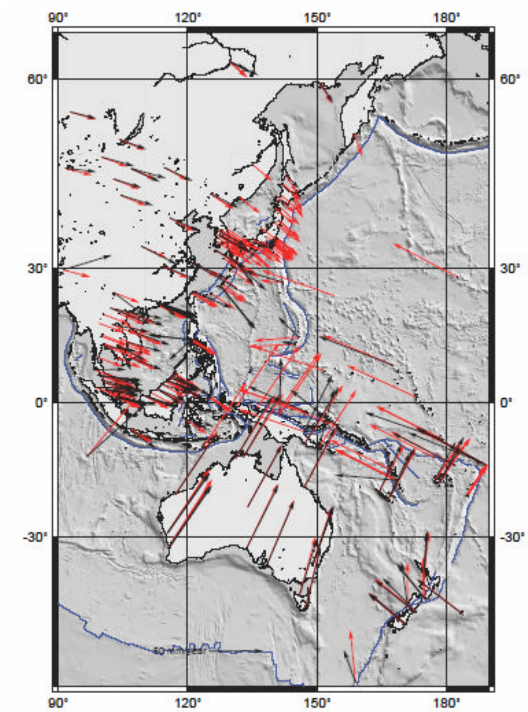

Fig. 6 GPS velocity field by APRGP (black: observation, red: NUVEL-1 NNR model)

5. A new p roposal and future outlook

In 2006, GSI has launched a new project: monitoring crustal deformation in Asia and the Pacific. As a member of PCGIAP and a national surveying and mapping organization, GSI acknowledges the needs to contribute to the region though geodetic activities, recognizing the lessons learned from the recent Indian Ocean tsunami and considering the region's proneness to the natural disasters.

GSI hopes this to be expanded as an international cooperative project: observations of crustal deformations by advanced geodetic techniques, exchange of knowledge and relevant data, transfer of technology and know-how on the prevention and mitigation of natural disasters in the region. It is going to be a new proposal in the PCGIAP geodetic work which will be a development and an extension of continuing space geodetic observations (APRGP) and a contribution of NMO's (National Mapping Organizations) to disaster prevention/mitigation.

If we look at what's going on in the world, 10 year implementation plan for GEOSS (Global Earth Observation System of Systems) is underway now and a number of endeavors are being launched simultaneously in various fields. GEOSS 10-year plan was agreed at the Third Observation Summit in 2005 by 61 countries to revolutionize the understanding of the earth to benefit humanity as well as the environment. Our project shares the objectives with GEOSS and be contributing to this big picture by obtaining data and knowledge about the geophysical phenomena in the region.

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