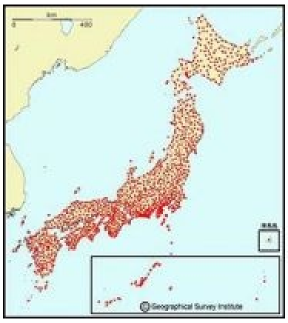
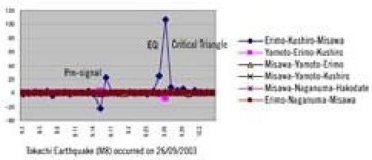
CHALLENGES IN A DIFFICULT SCIENCE

Earthquake Prediction: New Findings



Prediction of earthquakes using GPS analysis remains an unresolved but important problem. Pre-signals -changes in area measured by triangular networks of GPS receivers- were examined for many large earthquakes in Japan and in other Asian regions. We discovered that although the occurrence and location of an earthquake can be predicted, more research is required before the time of an earthquake can be precisely forecast.



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The prediction of earthquakes is one of science's most difficult problems. Japan (Figure 1) is an earthquake-prone country; 162 earthquakes of magnitude ML> 6 on the Richter scale occurred here between January 2000 and December 2007. Much research on earthquake prediction has therefore been carried out, but without complete success. We here update you on research progress since our last article that appeared in GIM International in October 2003 under the headline 'Earthquake Prediction Using GPS. A New Method Based on GPS Network Triangles'.

Background

The method of GPS network triangles was developed by the authors around 2000. The Geographic Survey Institute (GSI) constructed 5-m high towers with GPS antennae for monitoring crustal movement. There are about 1,200 GSI GPS stations (so-called electronic control points) located throughout Japan. Data collected by these antennae is available to the public through the internet. Figure 2 depicts a GSI GPS station and Figure 3 shows the distribution of GSI GPS stations.

The selection of GPS stations for use in triangular network prediction is based on a rather coarse interval (20-50km), as it is important that the triangle spans more than one tectonic plate. Triangles are formed with all possible combinations of selected GPS stations, regardless of distance. From the validation research, 6,590 triangles in Japan were selected. The area spanned by these triangles was checked daily for changes exceeding a certain threshold. The above-mentioned 162 large earthquakes demonstrated pre-signals during the period one to ninety days before each earthquake, depending on its type. This proved that we could predict the occurrence and location of the earthquake, but not its time.

Although the only GPS station networks overseas are those provided by the International GPS Service (IGS), our method also showed pre-signals of large earthquakes from very coarse networks located near the epicentre. Evidence of these large earthquakes is discussed below.

Validation

Every earthquake which occurred after the construction of the GSI GPS stations has been investigated for the presence of pre-signals. The large earthquakes listed in Table 1 (below), which caused serious damage to infrastructure, were thoroughly checked. Pre-signals were detected not only by small triangles near the epicentre, but also by very large triangles which spanned different plates several thousands of kilometres apart.

The Tokachi offshore earthquake was the largest during the study period, with a magnitude of 8.0 on the Richter scale (ML 8.0); although oil tanks were destroyed, there were luckily no casualties. Figure 4 depicts a typical pre-signal detected by a triangle one week before the occurrence, located near the epicentre. Pre-signals were detected 29, 23, fifteen, thirteen, twelve and one day(s) before the Miyagi offshore earthquake (of type 'inner plate'). The strongest pre-signals were found 23 days before the earthquake in 1,944 triangles, while pre-signals were found one day before the earthquake in 178 triangles. The epicentre is marked by a cross; red and blue lines show triangles including and excluding the epicentre. The Noto Peninsula earthquake demonstrated different behaviour to the Miyagi offshore earthquake. Except for one day before, pre-signals were detected in triangles both including and excluding the epicentre.

Sumatra Tsunami

There were 300,000 victims of the Asian tsunami that took place on 26th December 2004, triggered by the Su-matra offshore earthquake (ML 9.0). We selected ten IGS GPS stations around the epicentre, as listed in Table 2 (below).

We checked all possible combinations of triangles formed by these IGS GPS stations, investigating whether daily change in triangle area exceeded some threshold (0.05ppm). There was a drastic daily change of -1.2ppm in the YZ plane of the triangle of ntus-kunm-lhas (Table 2) from 18th December 2004, eight days before the earthquake. There was also a large change of -0.04, 0.05 and -0.05ppm in the XZ plane in the triangle of bako-ntus-lhas on the 21st, 22nd and 23rd December 2004, three to five days before the earth-quake. Although the distance between ntus (Singapore) near the epicentre and lhas (Lhasa) or kunm (Kunmin) is large, pre-signals were detected, highlighting the complexity of the crustal movement. These results imply that it should be possible to detect an early warning of such a huge earthquake.

Sichuan Earthquake

The Sichuan earthquake occurred in Sichuan Province in China on 12th May 2008 (see earlier features 'The Sichuan Earthquake 1 to 3' in GIM International October to December 2008). As well as claiming around 60,000 victims, the earthquake destroyed a huge number of buildings and roads. There are only four IGS GPS stations available around the epicentre: Wuhan (WN), Xian (XN), Kunmin (KN) and Lhasa (LS). The XZ plane of the triangle connecting Lhasa, Xian and Wuhan showed three-sigma abnormalities on 6th May 2008, six days before the earthquake. This triangle includes the epicentre of the Sichuan earthquake. Although this triangle is so large (the longest side exceeds 2,000km), advance warning of an earthquake is still valuable.

Concluding Remarks

Many earthquakes of magnitude ML >6 have been examined using data from GSI GPS stations (Japan) and a limited number of IGS GPS stations (outside Japan). The GPS data detected pre-signals before every earthquake. We have demonstrated that it is possible to predict the occurrence and location of the epicentre; however, predicting the exact time of the occurrence requires more research. Currently data predict that an earthquake will occur within one to ninety days of pre-signal detection.

Acknowledgement

Thanks to Tokyo Electric Power Service Company for funding the validation research.

Table 1. Sample of large earthquakes investigated for pre-signals.

Earthquake	Magnitude	Date	Plate
Miyagi offshore	7.1	26 May 2003	North American
Tokachi offshore	8.0	26 September 2003	North American
Niigata-Chuetsu	6.8	23 October 2004	North American
West Fukuoka offshore	7.0	20 March 2005	Eurasian
Noto Peninsula offshore	6.9	25 March 2007	Eurasian

Table 2. IGS GPS stations around epicentre of the Sumatra offshore earthquake.

IGP GPS	Location	Longitude	Latitude
bako	Cibinong, Indonesia	106.8500 E	6.4910 S
ban2	Bangalore, India	77.5116 E	13.0343 N
coco	Cocos Island, Australia	96.8339 E	12.1883 S
dgar	Diego Garcia Island, UK territory	72.3702 E	7.2696 S
hyde	Hyderabad, India	78.5509 E	17.4172 N
iisc	Bangalore, India	77.5704 E	13.0211 N
kunm	Kunming, China	102.7972 E	25.0295 N
lhas	Lhasa, China	91.1040 E	29.6573 N
mald	Maldives	73.5263 E	4.1886 N
ntus	Singapore	103.6799 E	1.3458 N

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