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The Fairmont Orchid Resort
Kohara Coast, Island of Hawaii
November 8 – 11, 2009

Aloha !

GPS Ground Monitoring with Global Collaboration

Crustal fluctuation monitoring with GPS-based control stations' data

Tetsuji Yoshida
CSP-Japan Inc.

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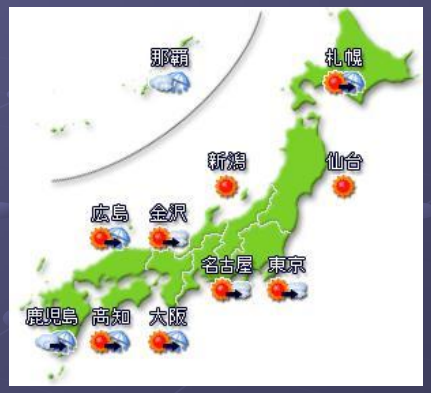
1 . Introduction

- Decades, several earthquakes took place in Japan and Southeast Asia, with serious international damage of Tsunami.

- To decrease damage and loss of life, observations monitoring terrestrial phenomena and R&D to predict earthquakes were promoted by universities and governmental institutions. But to predict strong earthquakes ensuring sufficient time to evacuate for is not yet realized.

- There are legend predictions not verified scientifically. And to predict weather and earthquakes is one of the governmental business. Private prediction delivery is illegal in Japan.

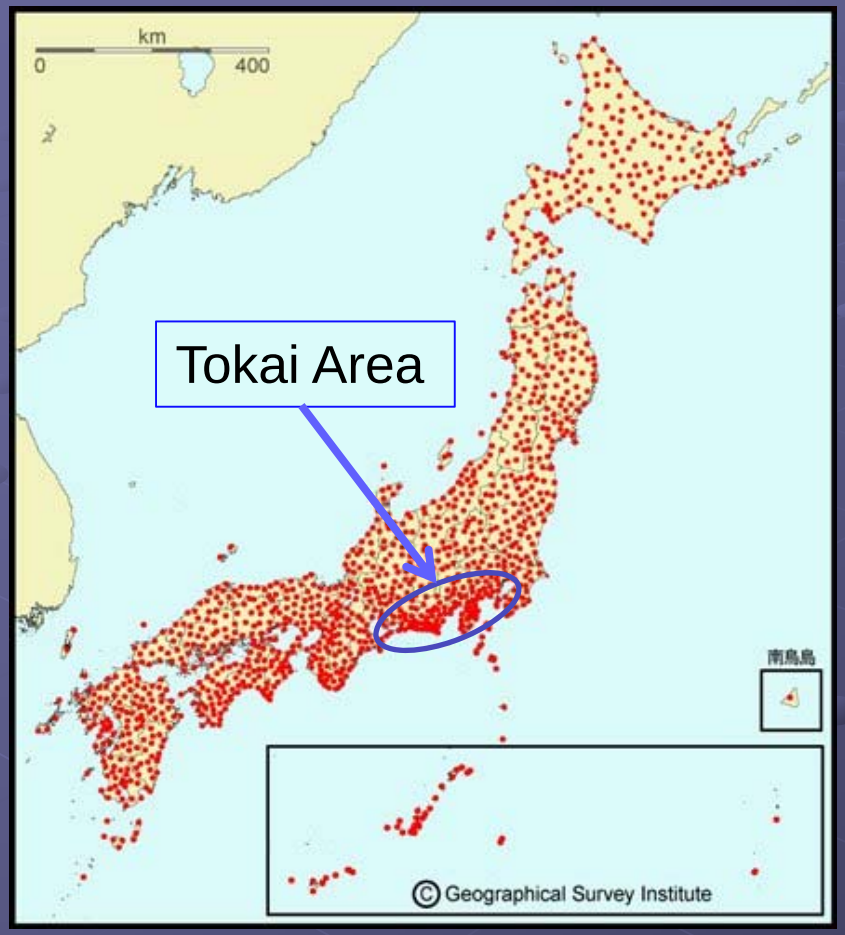


- It is difficult to predict earthquakes, coming up with 3 items “When”, “Where” and “How strong”. Introducing GPS-based control stations data, CSP-Japan started new website “J-Dinosaur” (Japanese) to support the prediction. This service is to supply graphics obtained from the data that shows crustal fluctuation of the land.

２． GPS-based control station

- Geological Survey Institute of Japan has established about 1200 stations, distributed at an interval of about 20 km, to monitor the movement of the land of Japan.
- The data are available through GEONET（GPS Earth Observation Network System）and crustal movement data were accumulated in these years.
- Tokai-area, where the stations are set in dense, is most likely to be hit by strong earthquake in the near future.

GPS-based control stations



Geological Survey Institute

1993 → 2002

Stations are improved and changed in these two decades

1200 GPS-based control stations in Japan

On the peak of Mt. Fuji
（The highest）

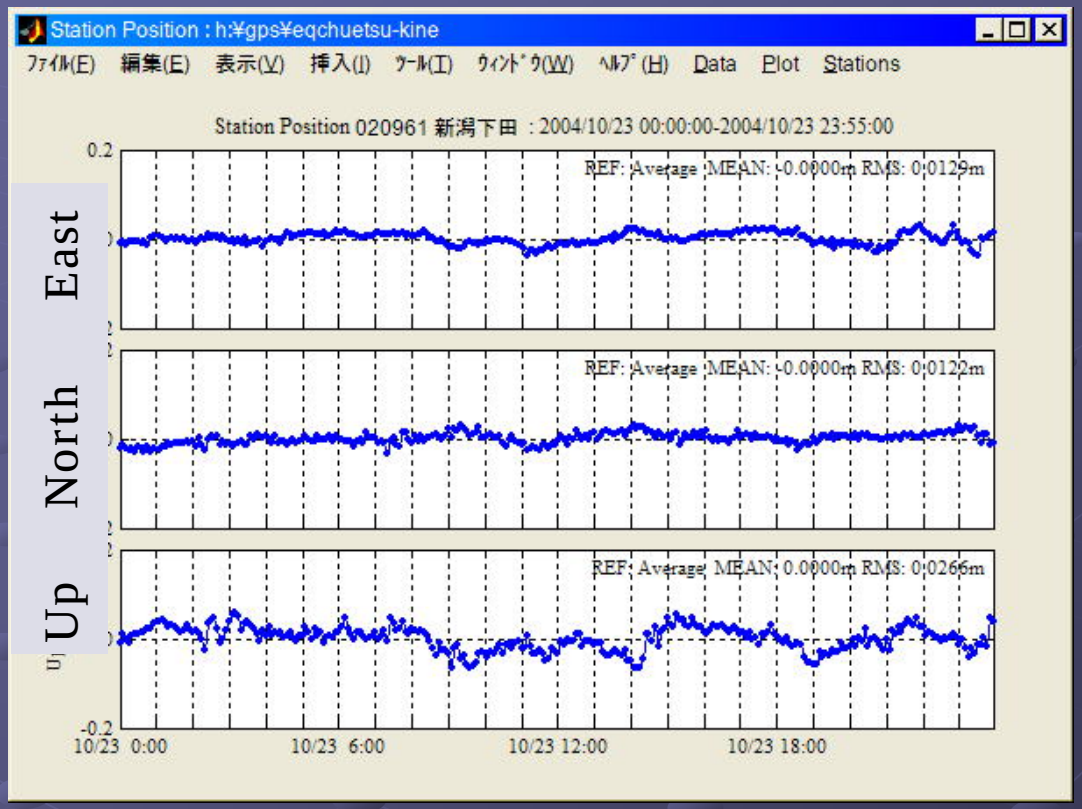
Okinoshima-Island（The southernmost）

Geological Survey Institute

3. Crustal fluctuation monitoring

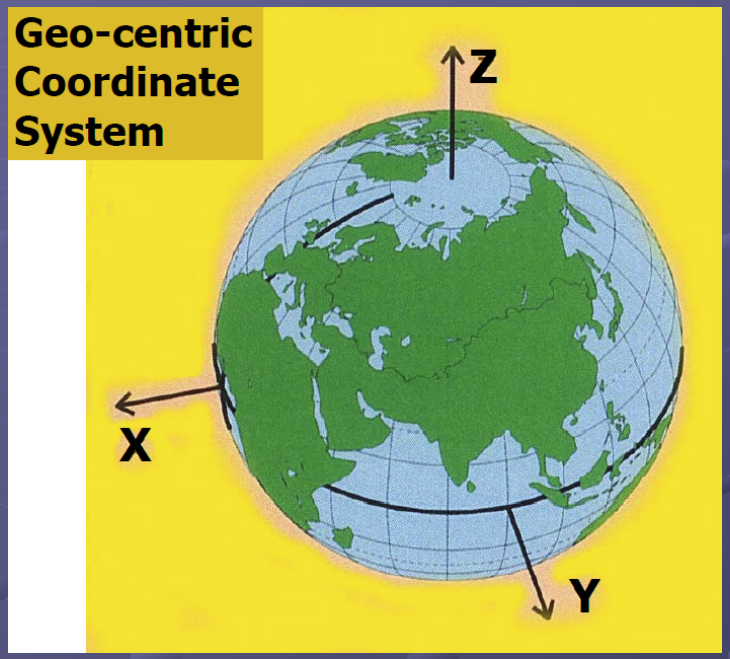
1. Drift visualization
2. Stable crustal movement
3. Monitoring large crustal fluctuation (earthquakes)

3．1　Drift visualization



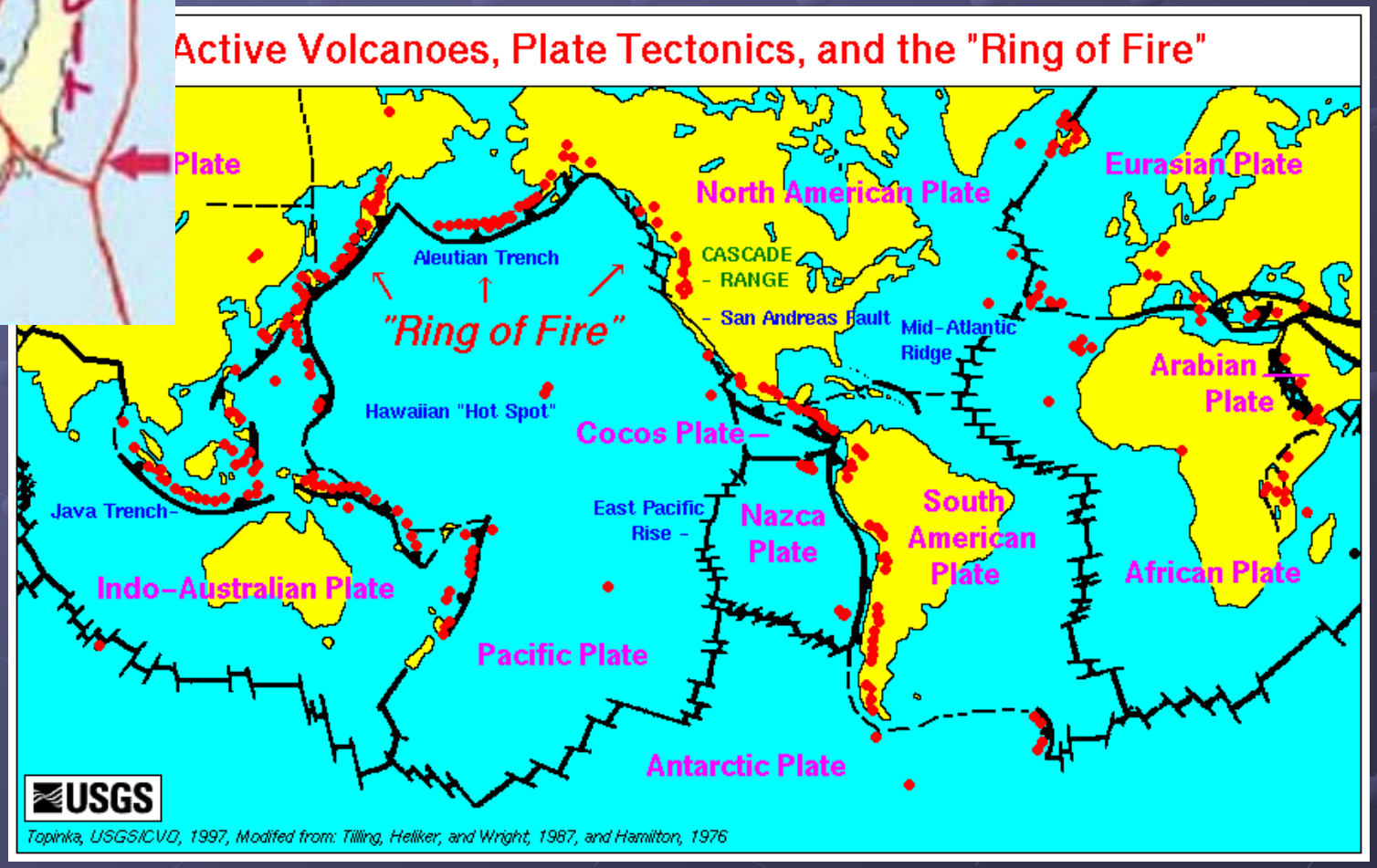
1. The GPS station data is converted to map coordinates (NSEW & Altitude) from global coordinates with calculation error
2. Moisture in the atmosphere makes data noisy, especially on altitude.
3. As the movement of the station is very fine and small, a method minimizing error was applied to this service.

Minimize error on the data processing

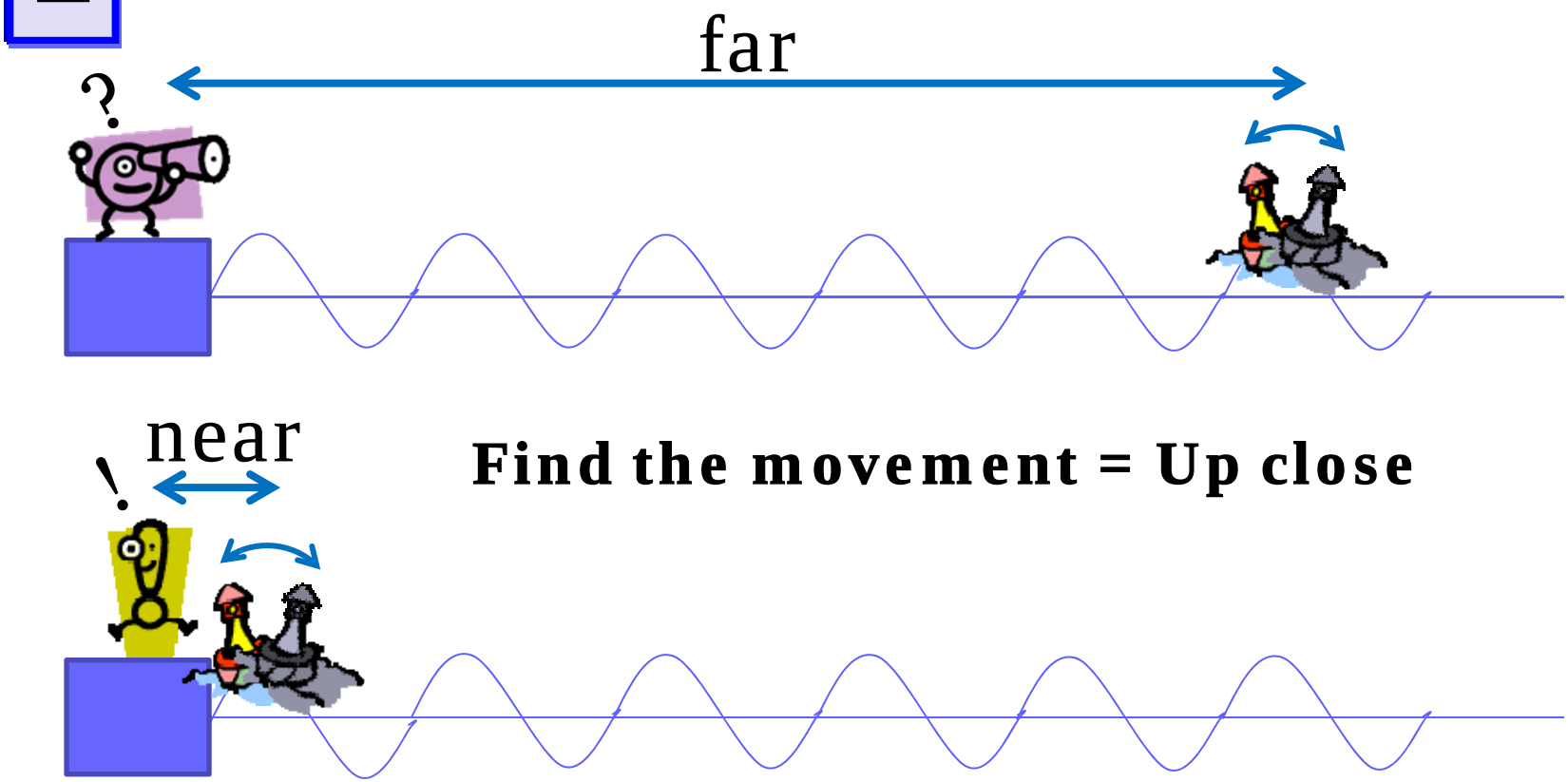


1. Use the raw data (XYZ) from the stations, reducing coordinates conversion error.
2. Use the most recent calibration model on moisture in the atmosphere.
3. Measure the distance between 2 stations.

Plate tectonics



1



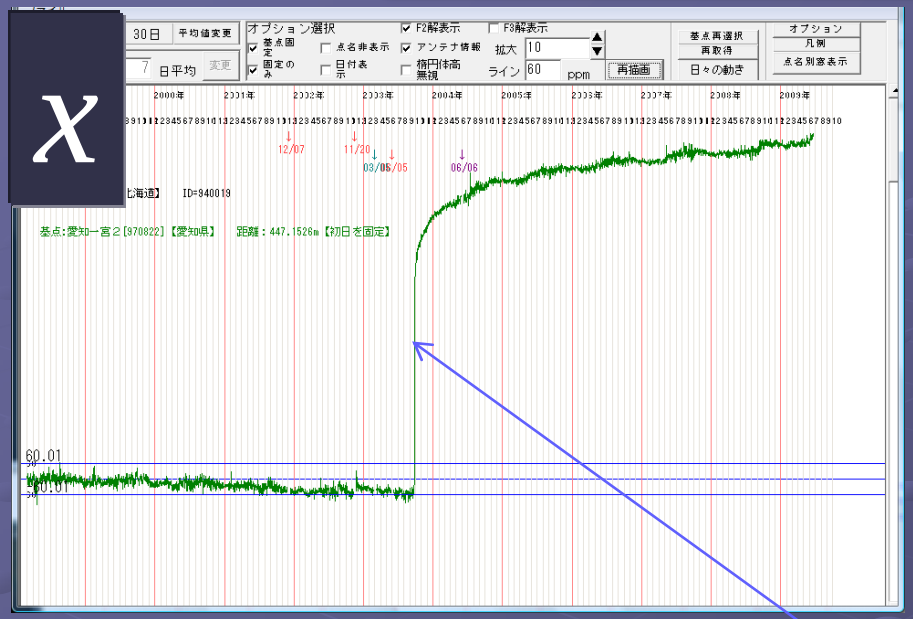
Find the movement = Up close

小さな動きは，近くで見よ!

Drift visualization example

- Tokachi-oki Earthquake in 2003

Drift ratio from the beginning



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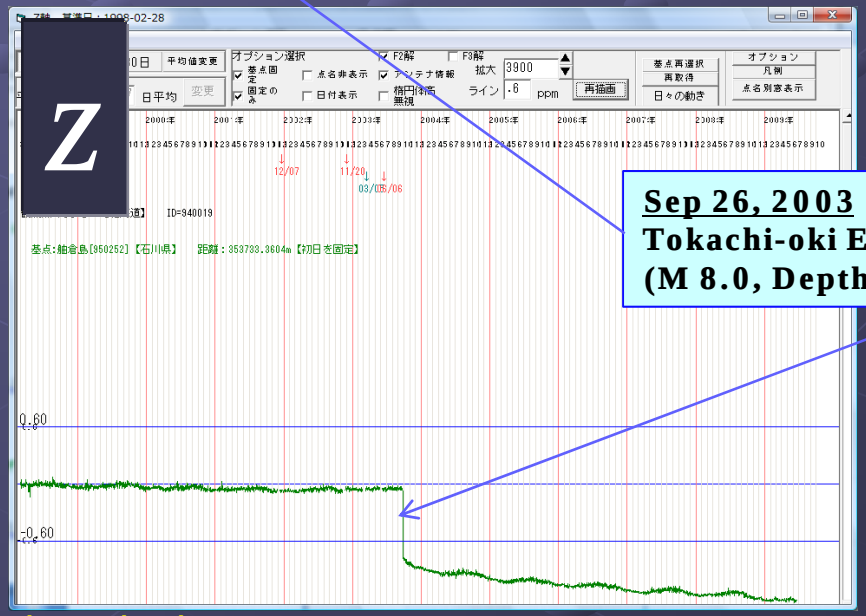


Sep 26, 2003
Tokachi-oki Earthquake in 2003
(M 8.0, Depth 45km)

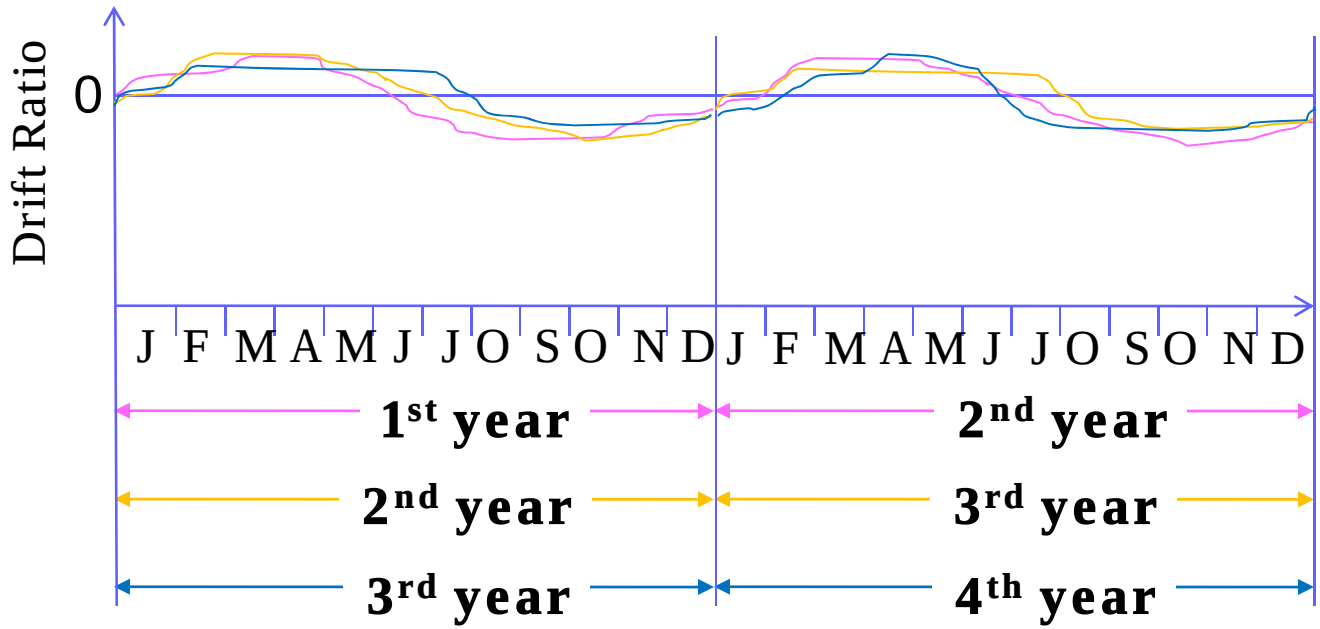
Reference: Tokachi-oki Earthquake in 2003

Drift Ratio Graph in every 2 years

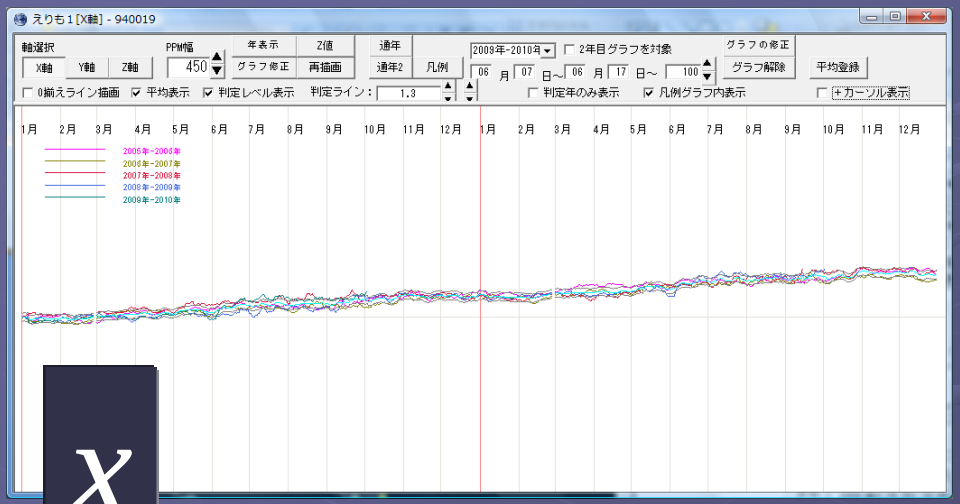
$\Delta x_{min} = |x_o - x_a| \leqq |x_o - x_i| \Rightarrow P_a$

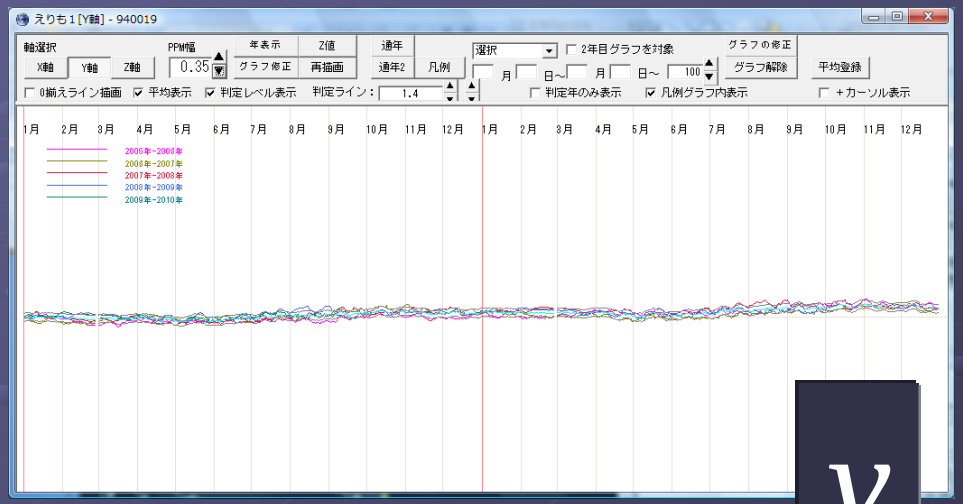
Drift Ratio (x) = $\{ \Delta x_{min}(\text{today}) - \Delta x_{min}(1^{st}\ \text{January}) \} / \Delta x_{min}(1^{st}\ \text{January})$

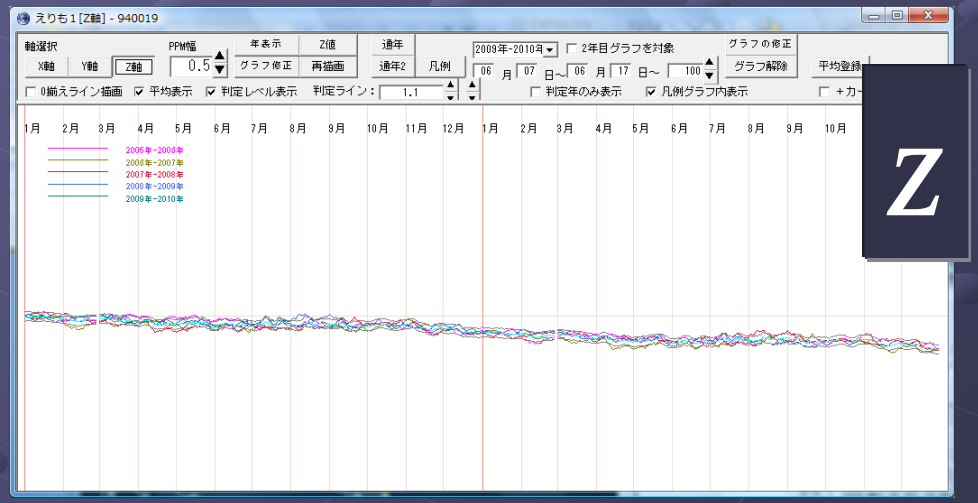
3



3.2 Stable crustal movement



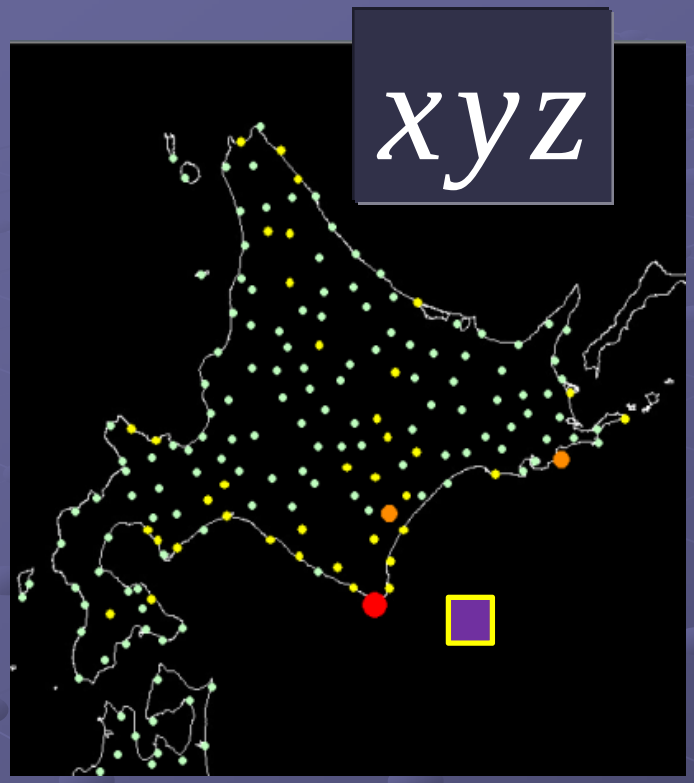


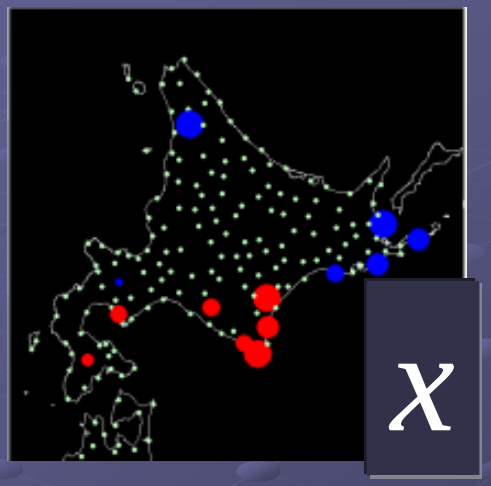


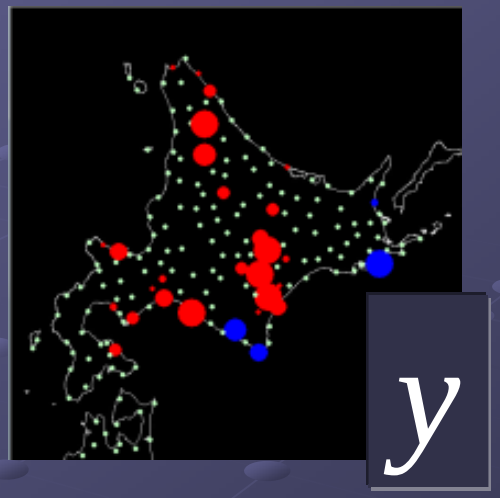
Reference: Tokachi-oki Earthquake in 2003

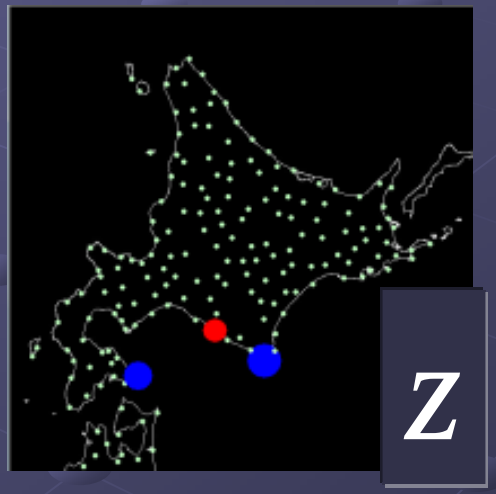
4

Direction and distance moved









Stretched / Shrinked more than 10 days

Stretched / Shrinked less than 10 days

Deviation

- on *xyz*
- on 2 axis
- on 1 axis only

Reference: Tokachi-oki Earthquake in 2003

CSP Japan

Sep 26, 2003_Tokachi-oki Earthquake in 2003

(M 8.0, Epicenter Depth 45km)

3.3 Monitoring large crustal fluctuation (earthquakes)

- Niigata-Chuetsu-oki Earthquake in 2007
- Iwate-Miyagi Nairiku Earthquake in 2008

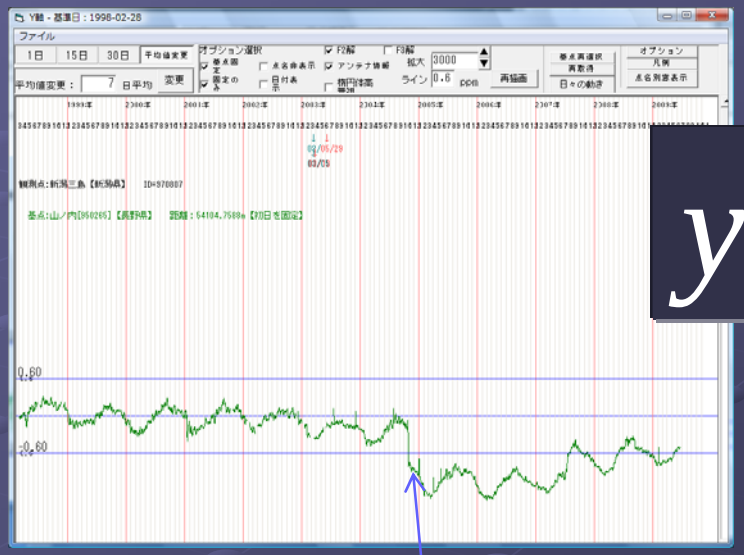
Drift ratio from the beginning

Refernce: Niigata-Chuetsu-oki Earthquake in 2007

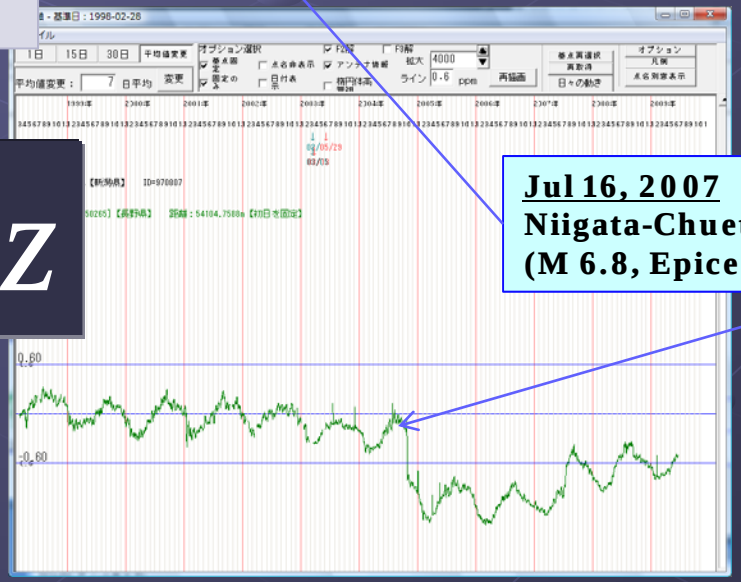
新潟県中越沖地震
2007年7月16日10時13分
（M6.8）

新潟県中越地震
2004年10月23日17時56分
（M6.8）

x



y



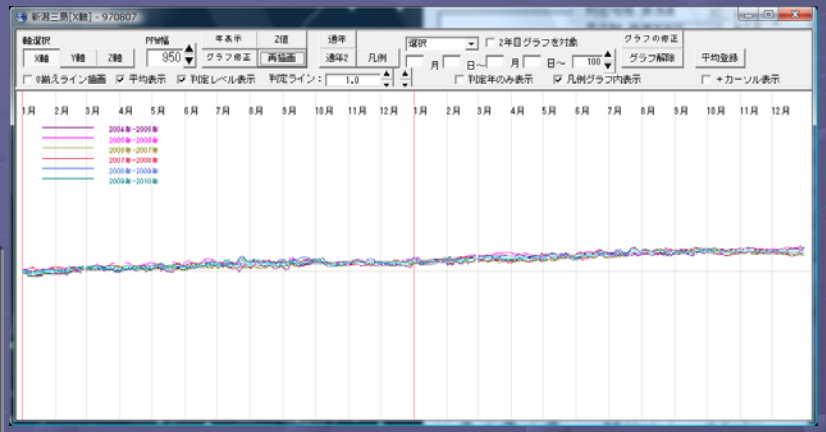
z

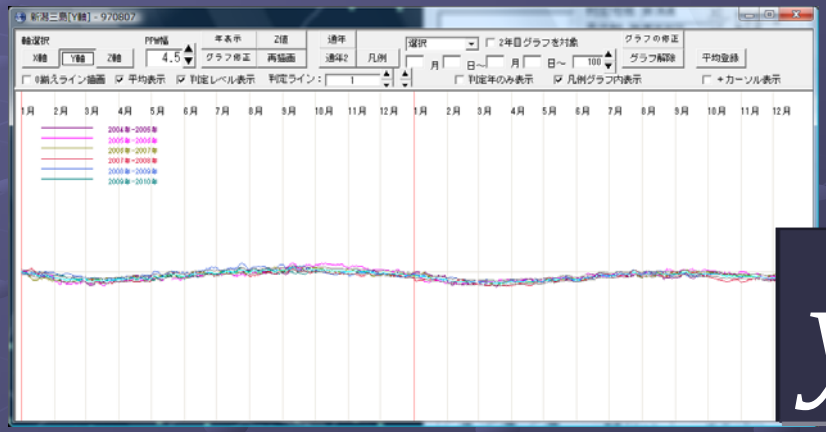
Jul 16, 2007
Niigata-Chuetsu-oki Earthquake in 2007
(M 6.8, Epicenter Depth 17km)

Stable crustal movement

Refernce: Niigata-Chuetsu-oki Earthquake in 2007

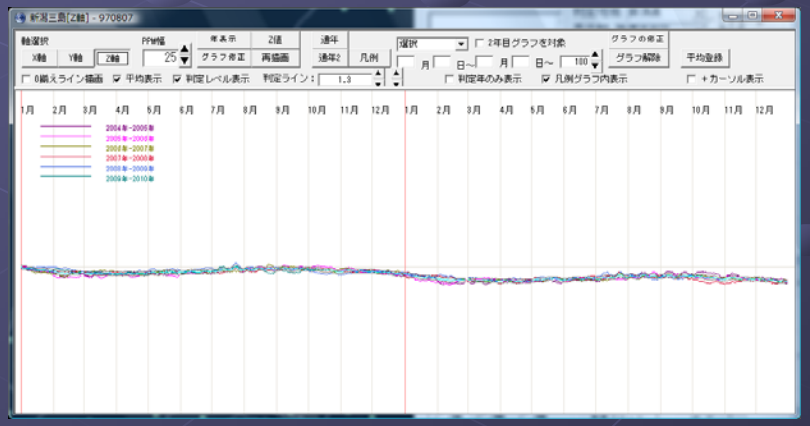
x





y

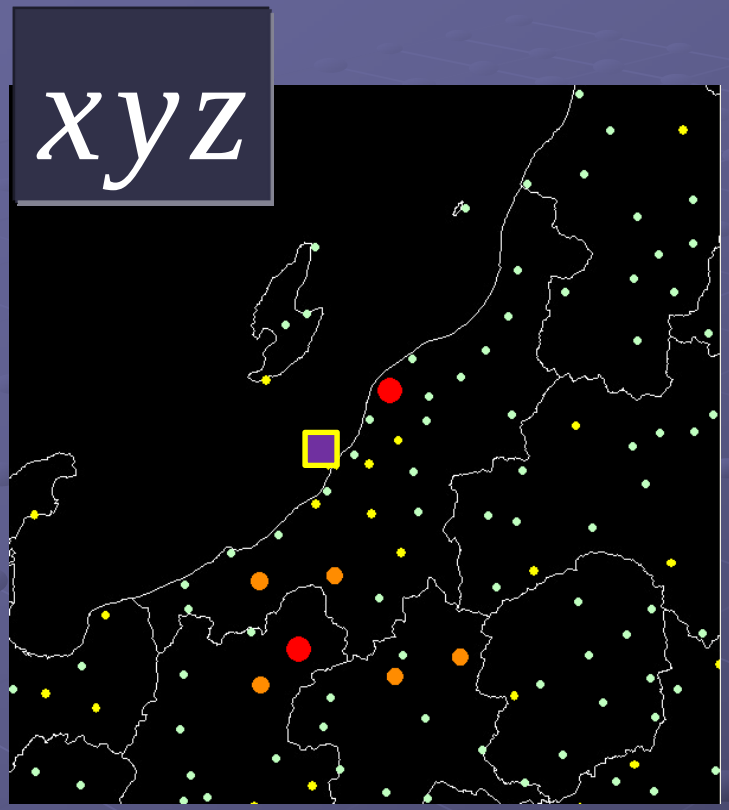
z

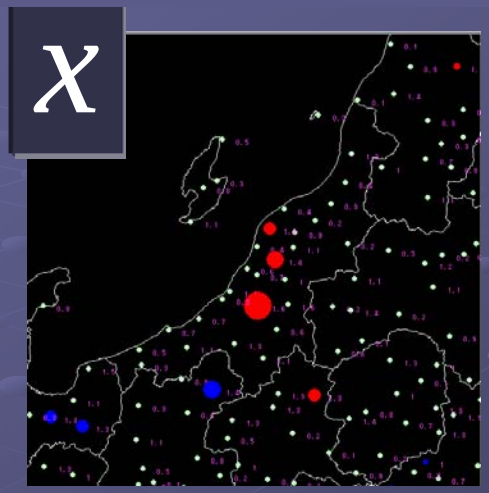


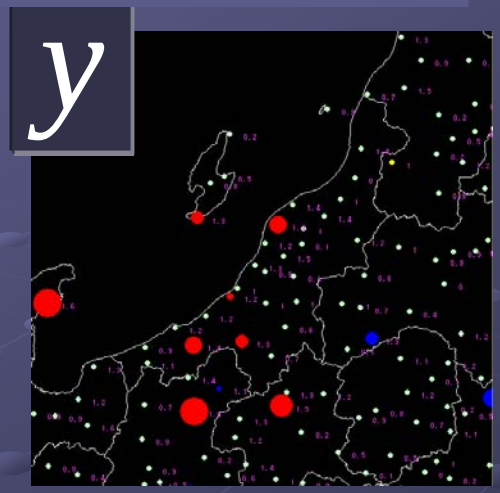
2D

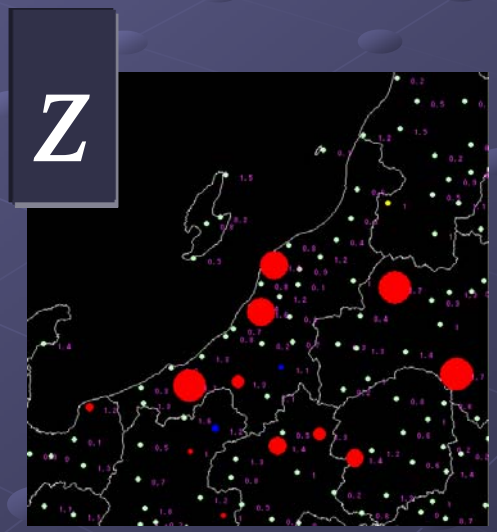
Direction and distance moved

Refernce: Niigata-Chuetsu-oki Earthquake in 2007









Stretched / Shrinked more than 10 days

Stretched / Shrinked less than 10 days

(Jul 14, 2007)

Deviation

- on *xyz*
- on 2 axis
- on 1 axis only

Jul 16, 2007
Niigata-Chuetsu-oki Earthquake in 2007
(M 6.8, Epicenter Depth 17km)

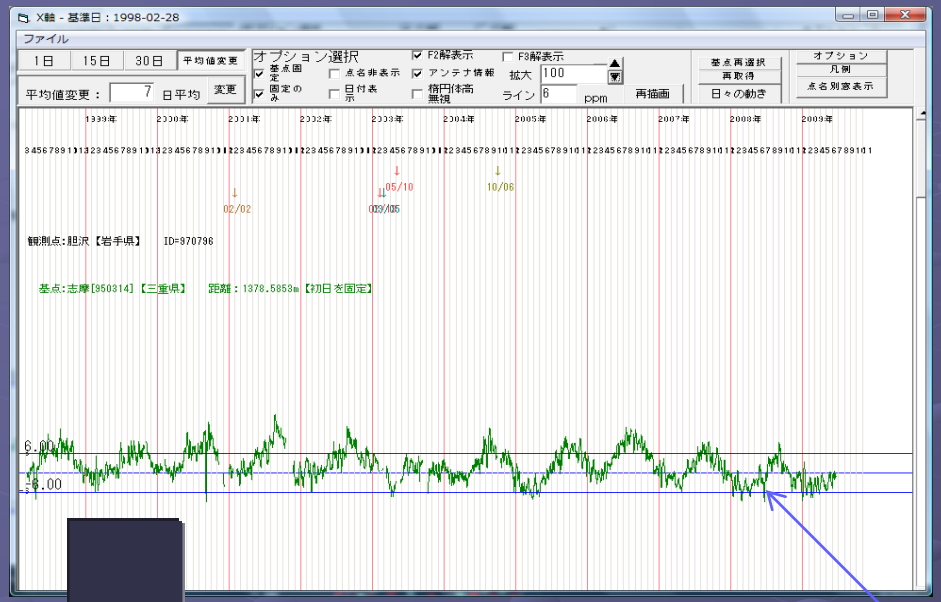
CSP Japan

Jul 16, 2007
Niigata-Chuetsu-oki Earthquake in 2007
(M 6.8, Epicenter Depth 17km)

CSP Japan

Drift ratio from the beginning

Reference: Iwate-Miyagi Nairiku Earthquake in 2008



x

y

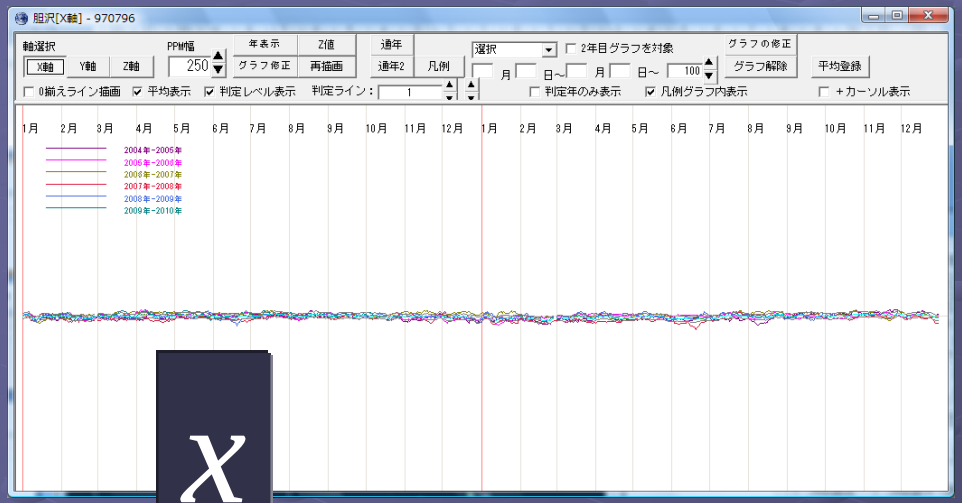
岩手・宮城内陸地震
2008年6月14日午前8時43分

z

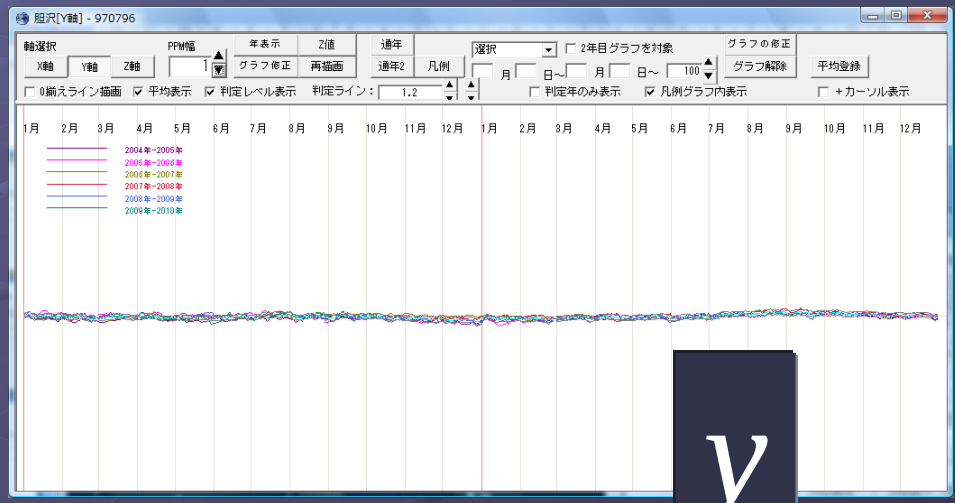
Jun 14, 2008
Iwate-Miyagi Nairiku Earthquake in 2008
(M 7.2, Epicenter Depth 8km)

Stable crustal movement

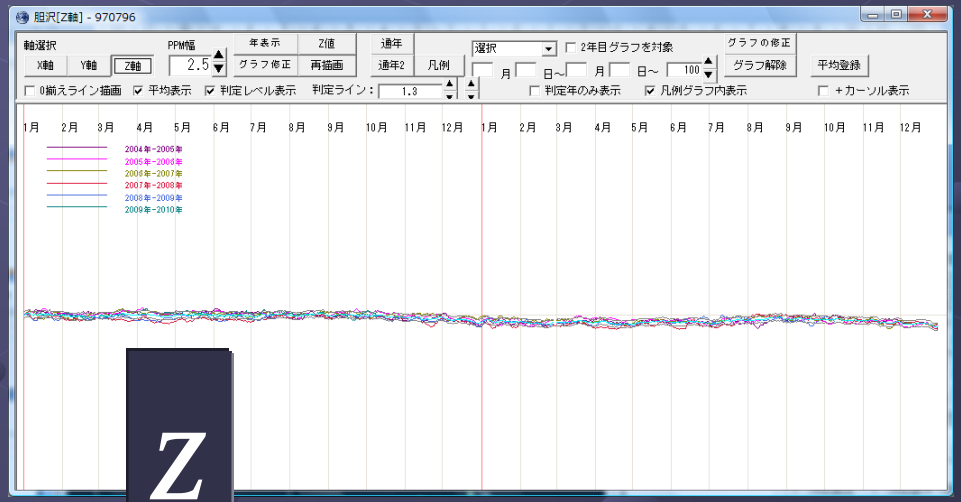
Reference: Iwate-Miyagi Nairiku Earthquake in 2008



x



y

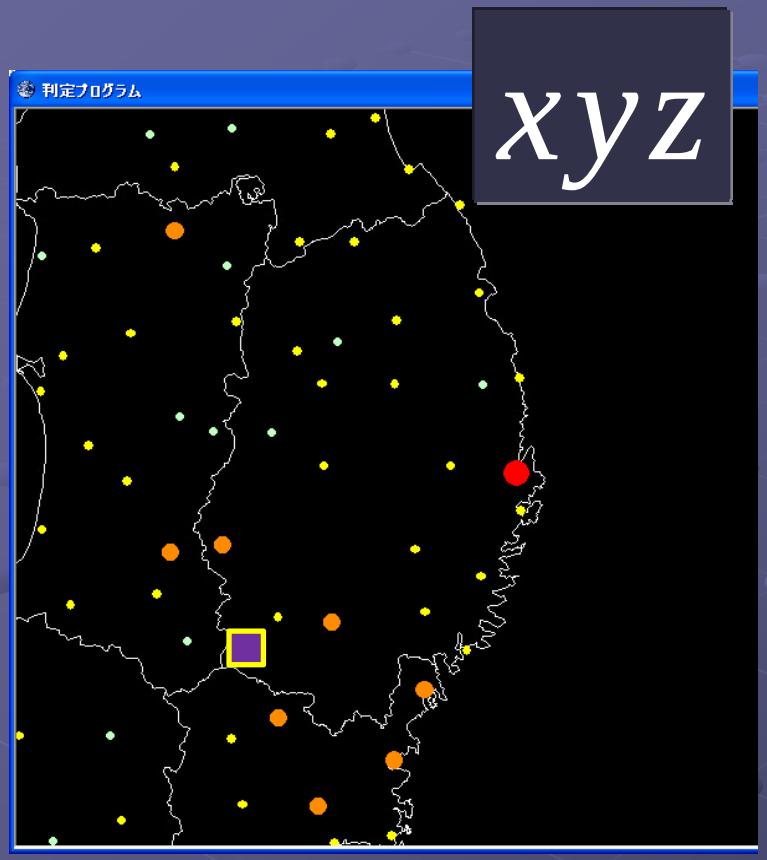


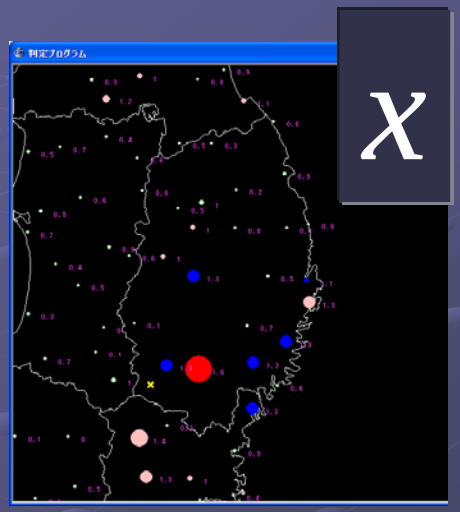
z

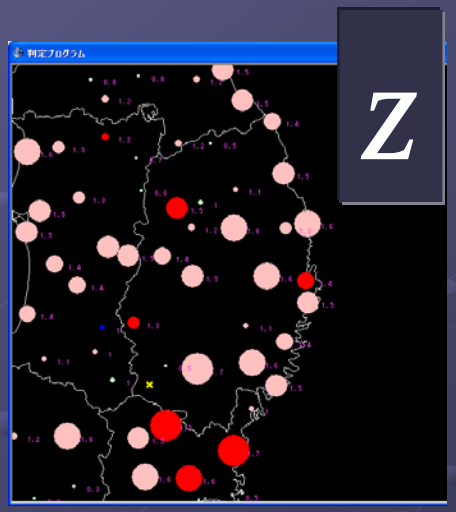
3D

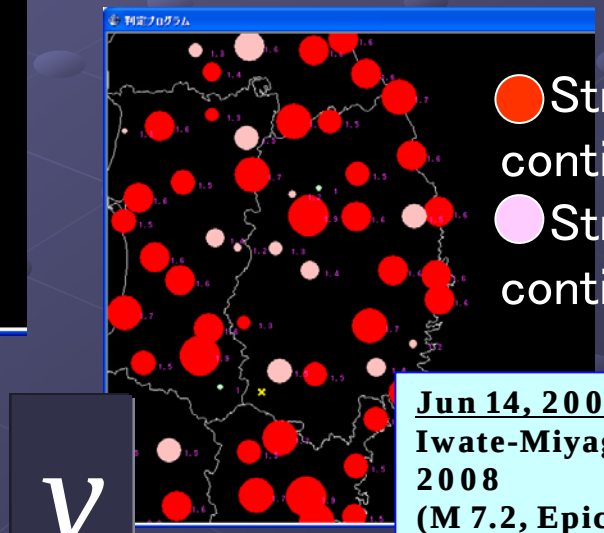
Direction and distance moved

Reference: Iwate-Miyagi Nairiku Earthquake in 2008









Stretched / Shrunk continued more than 10 days

Stretched / Shrunk continued less than 10 days

Jun 11, 2008

Jun 14, 2008

Iwate-Miyagi Nairiku Earthquake in 2008

(M 7.2, Epicenter Depth 8km)

Deviation

- on *xyz*
- on 2 axis
- on 1 axis only

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<u>Jun 14, 2008</u>
Iwate-Miyagi Nairiku Earthquake in 2008
(M 7.2, Epicenter Depth 8km)

4. Developing a website, “J-Dinosaur”

1. World wide crustal movement information service with IGS
   1. Movement (NSWE) of each station are shown directly on the map of the world.

Distribution of the GPS station from the IGS.

2. 3-Dimentional and Real Time Movement visualization
   1. Measure the area change of triangle, composed from 3 stations and sides of the triangle of each 2 stations are calculated, and shown on the 3-D map.

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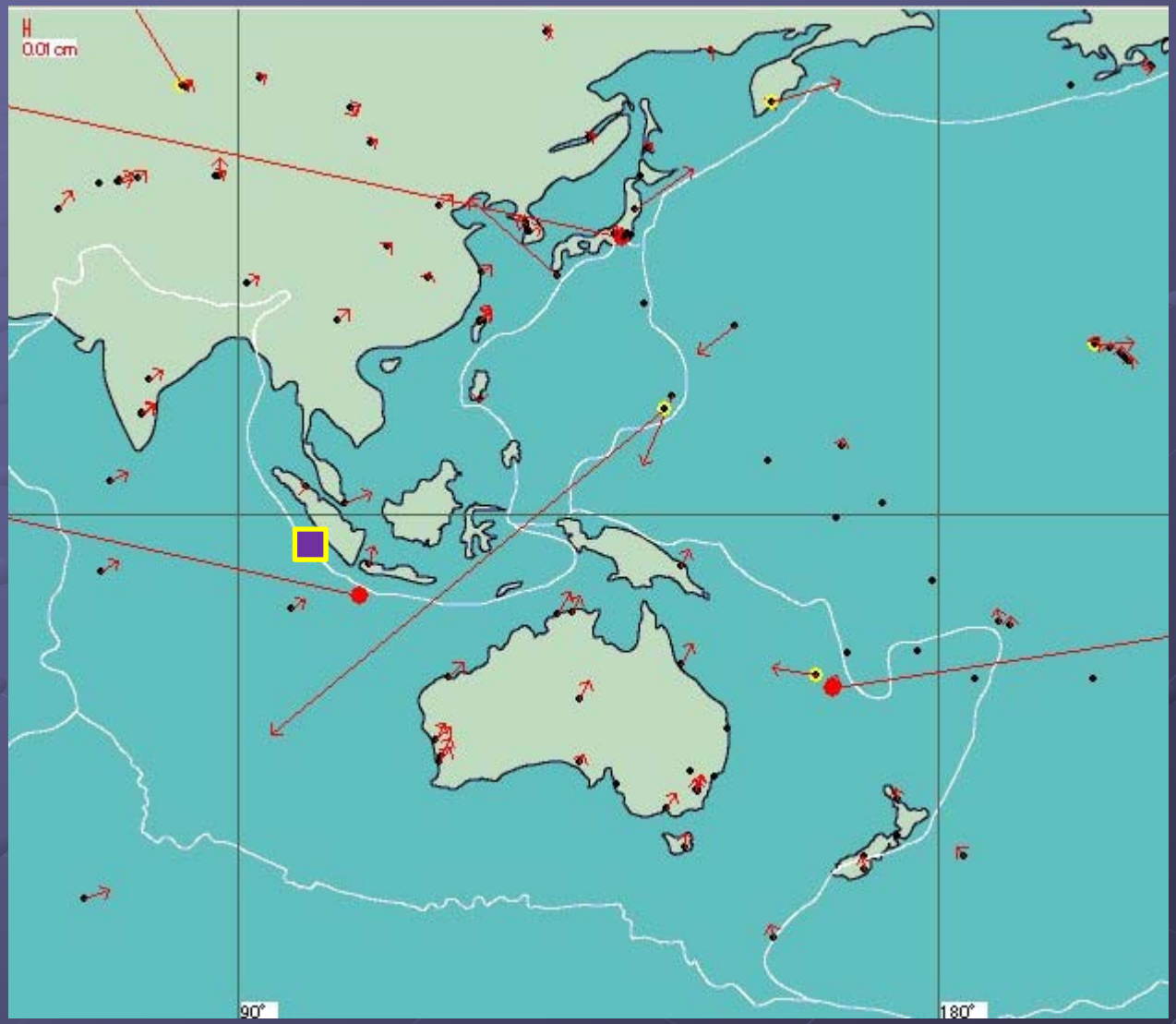
September 2007 Sumatra earthquake
Sep 12, 2007 06:10 M8.5 D30km

0W

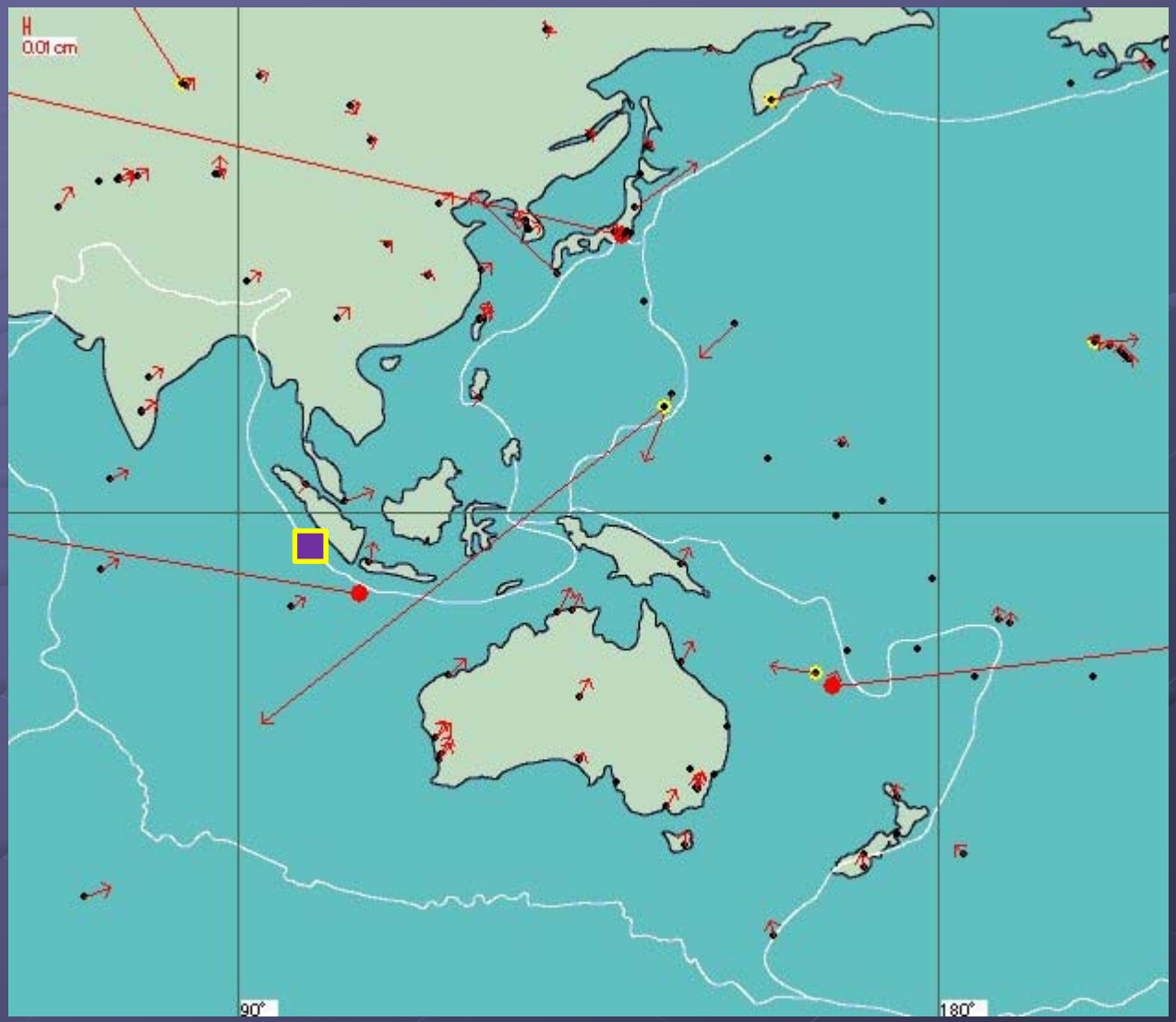


2007/07/01-2007/09/16 **including Sep 12**

CSP Japan

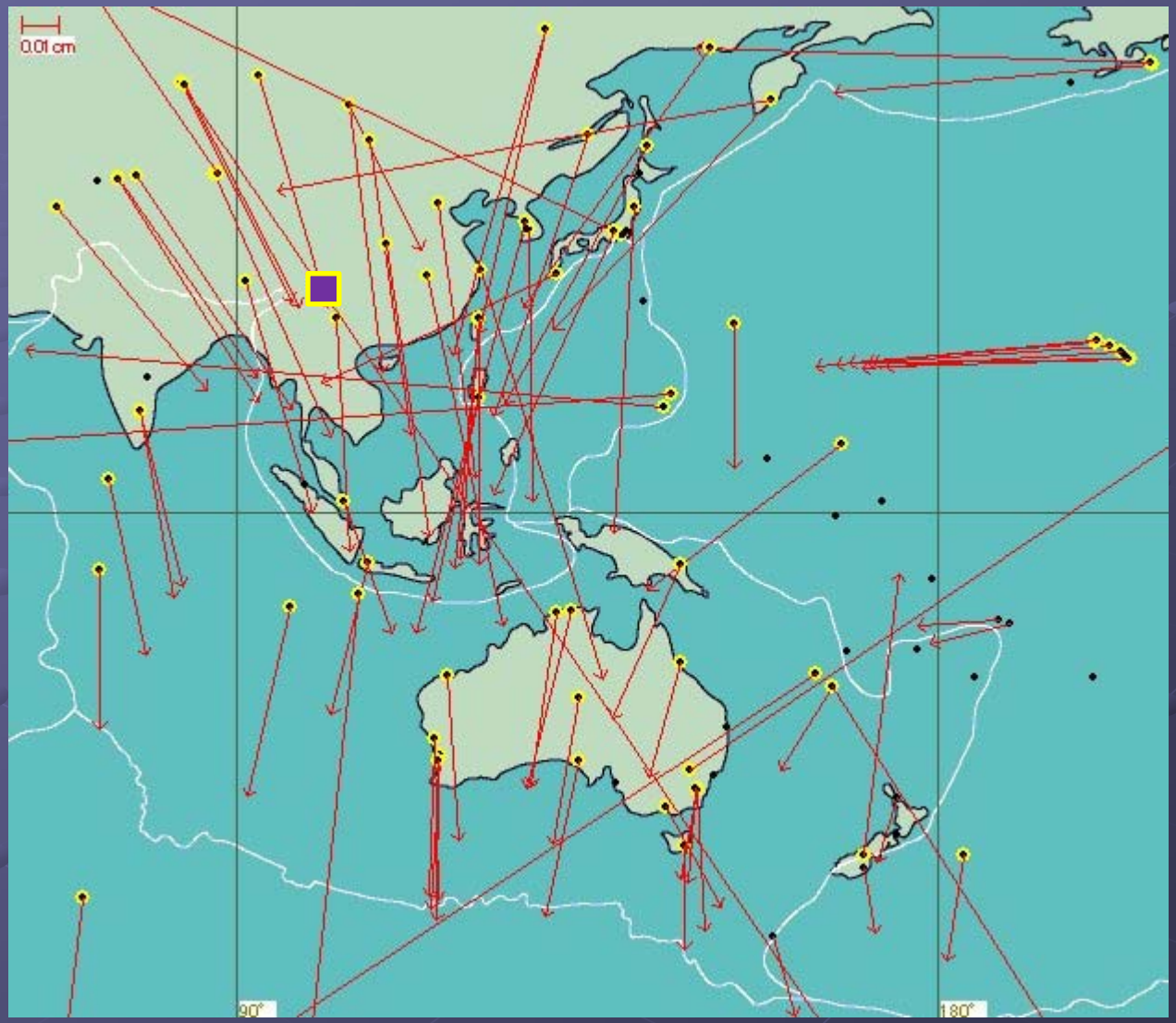
September 2007 Sumatra earthquake
Sep 12, 2007 06:10 M8.5 D30km

1W



2007/07/01-2007/09/23

2008 Sichuan Earthquake
May 12, 2008 15:28 M7.9 D:19



OW

2008/02/17-
2008/05/18

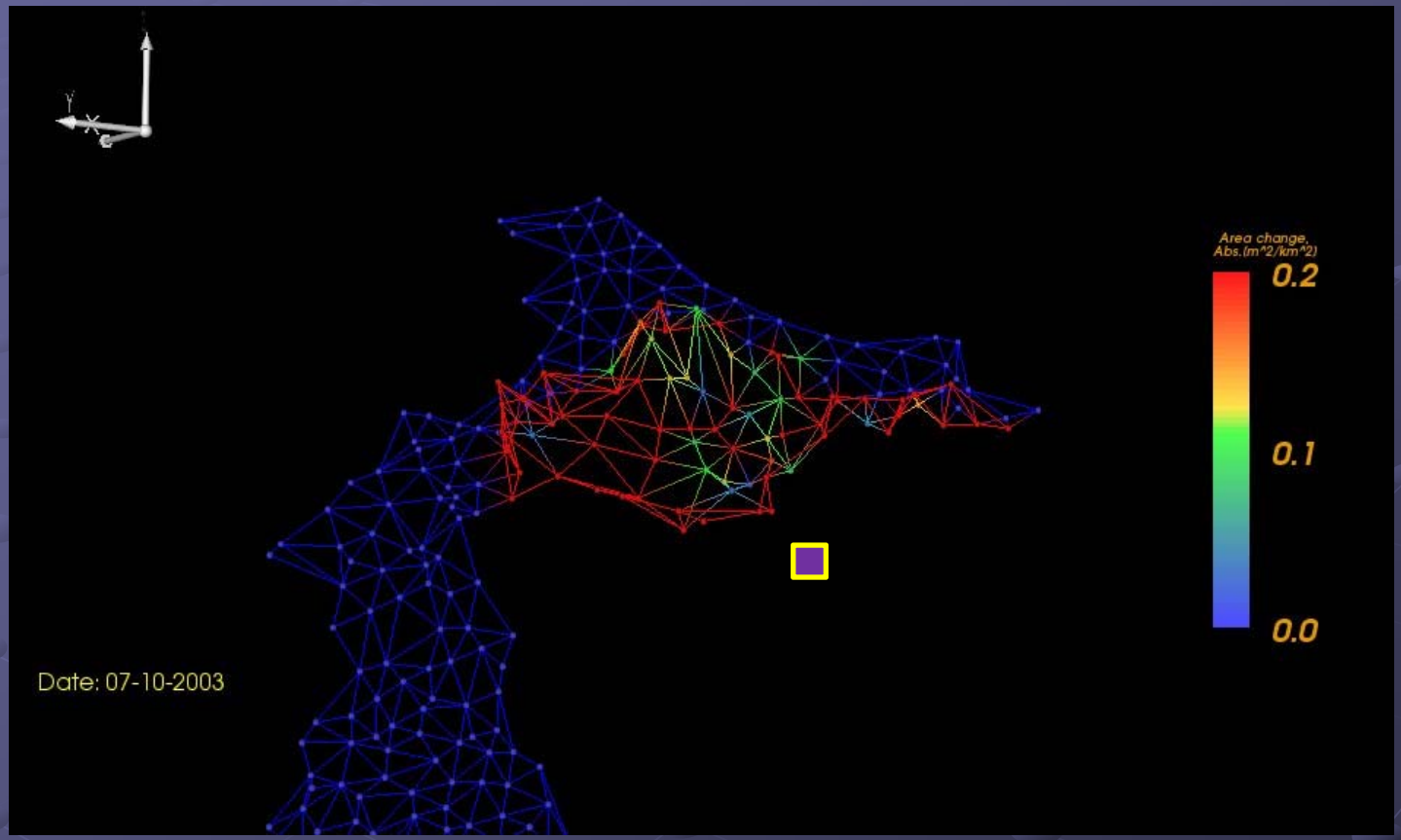
including May 12

3-Dimentional and Real Time Movement visualization

<u>Sep 26, 2003</u>
Tokachi-oki Earthquake in 2003
(M 8.0, Depth 45km)

Tokachi-oki Earthquake in 2003
Sep 26, 2003

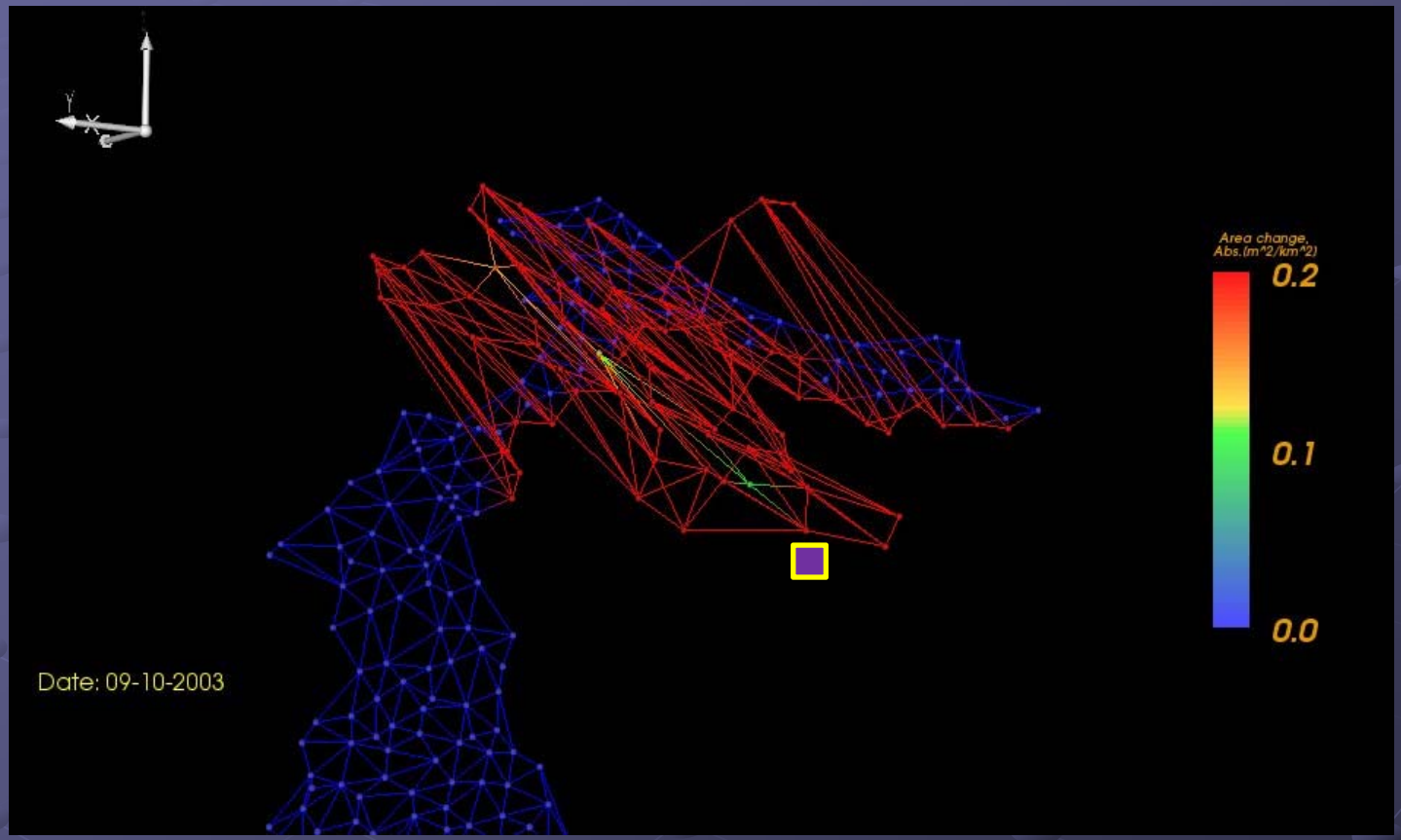
1H



2003/09/26 00:00～06:00 04:50

Tokachi-oki Earthquake in 2003
Sep 26, 2003

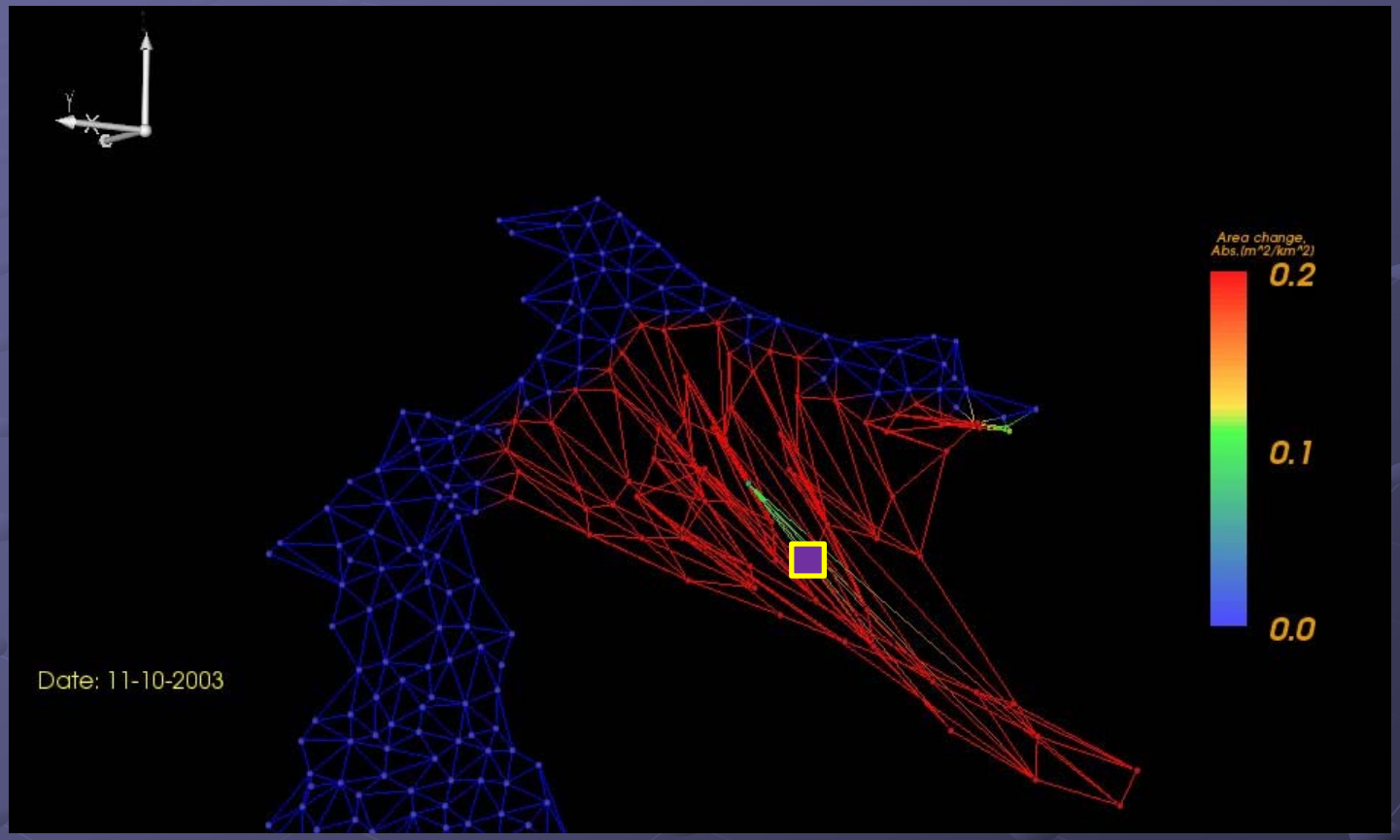
7H



2003/09/26　06:00～12:00

Tokachi-oki Earthquake in 2003
Sep 26, 2003

13H



2003/09/26　12:00～18:00

Conclusion

GPS ground monitoring with global collaboration

- The crustal monitoring using GPS-based control stations` data have shown crustal fluctuation before and after of the strong earthquakes in Japan.

- The monitoring has no physical/statistical models nor hypothesis, boundary conditions etc. The method is simple, and reliable eliminating errors and process by human work as much as possible.

- The monitoring service does not intend to predict or foreseen the future earthquakes, but to supply data or reports continuously on the website "J-Dinosaur". These information may be useful for the people or the organization who want to be free from serious disasters.

- Collaborating with domestic and international partners, CSP-Japan would coordinate joint programs expanding the crustal monitoring, to realize the future society less disasters and damage caused by the future strong earthquakes.

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Mahalo

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