# GPS Earth Observation Network System (GEONET)

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1. Introduction of the Geographical Survey Institute (GSI)
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# Introduction of Geographical Survey Institute (GSI) (1/2)

GSI conducts national surveying and mapping activities

- A special organization of Ministry of Land, Infrastructure, Transport and Tourism
- About 770 stuff
- Head office at Tsukuba
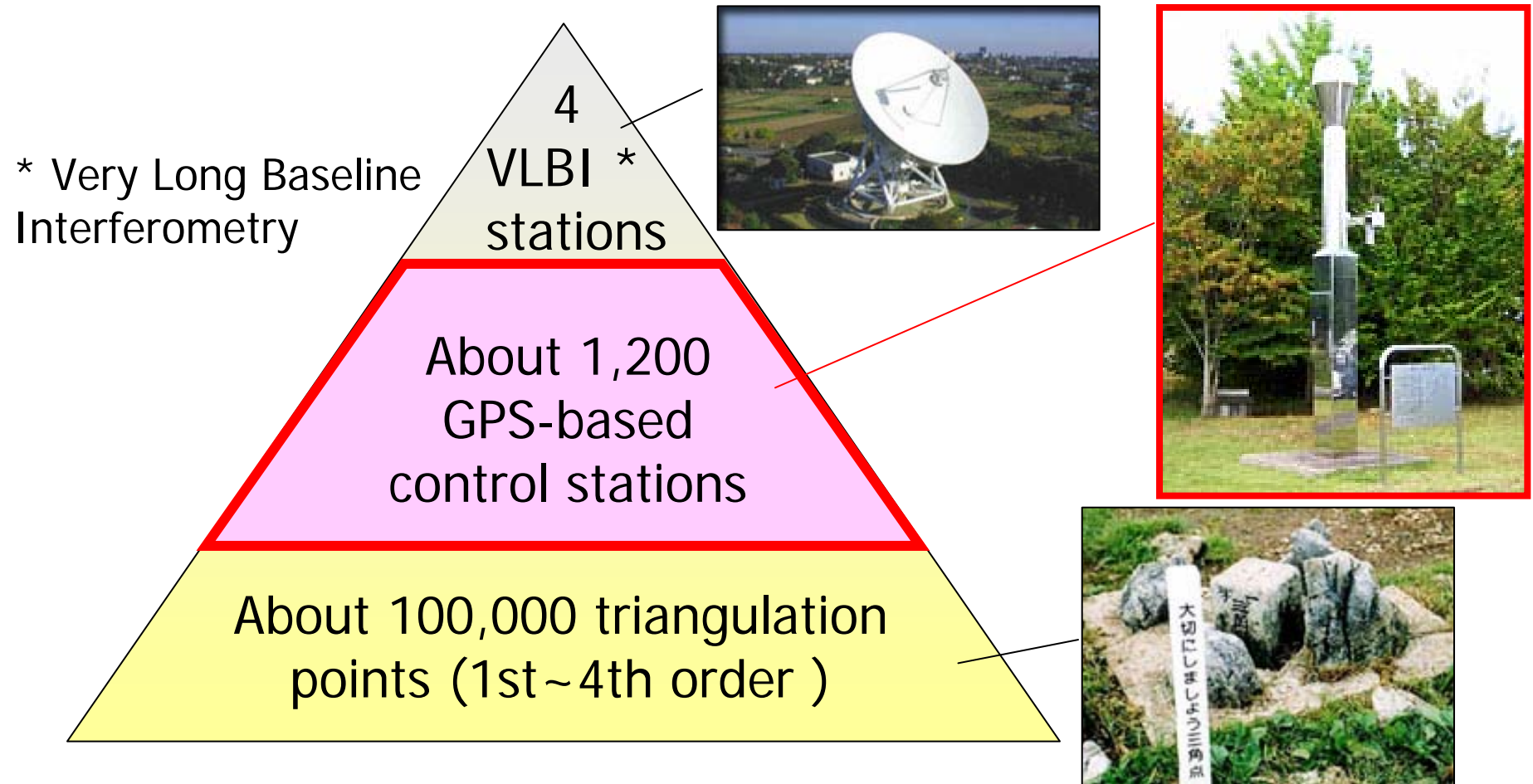
# Introduction of GSI (2/2) : Mission

- Development of Fundamental Geospatial Information of Land
  - ~ Land Survey and Representation by Map~
    - National control points, basic maps etc.
- Grasp the National Land Conditions to Contribute to Disaster Prevention
  - Monitoring crustal movement and analyzing the danger of disaster etc.
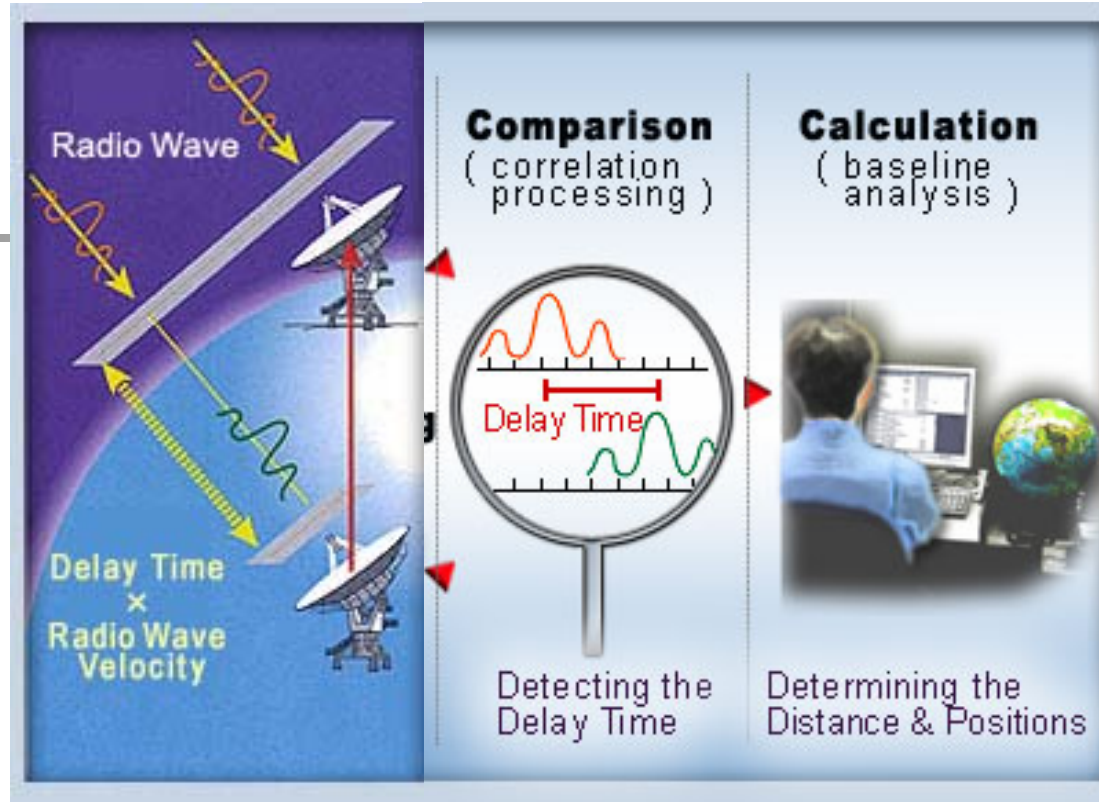- Promoting the Further Development and Intensive Utilization of Geospatial Information

# National reference framework of Japan (Horizontal)

## System of control points



* Very Long Baseline Interferometry

4 VLBI * stations

About 1,200 GPS-based control stations

About 100,000 triangulation points (1st~4th order )
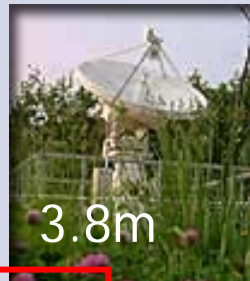
# Very Long Baseline Interferometry (VLBI)

- Advanced space geodetic technique
- Can measure distance of thousands of kilometers with an accuracy of few millimeters
- Determine the Japan's geographical position on a global basis
- The position of other Japanese national control points are based on the position of VLBI stations



Radio Wave

Delay Time × Radio Wave Velocity

**Comparison** ( correlation processing )

Delay Time

Detecting the Delay Time

**Calculation** ( baseline analysis )

Determining the Distance & Positions

- Two or more antennas receive radio wave from astronomical objects as far as several billion light years away simultaneously
- By detecting the delay time, relative position of antennas are determined

# Four VLBI stations and the places where VLBI observations were conducted by transportable antenna



fixed station
transportable station
correlator

3.8m

Shintotsukawa

Suwon (Korea)

Tonami

Mizusawa

Tsukuba

32m

Kanozan

Sagara

Miyazaki    Kainan

Aira

Chichijima

10m

10m

# GPS (Global Positioning System)

- Operated by USA
- 31 satellites in six orbital planes (as of June 2007)
  - Altitude: about 20,000 km
  - Orbital inclination: 55 degrees
  - Orbital periods: about 11 hr. 58 min. (half a sidereal day)
- Satellites transmit signals
  - Satellite clock reading, orbital information, etc.
  - Two carrier frequencies: L1(1575.42 MHz), L2(1227.6 MHz)
- Receiving the signal, position is calculated
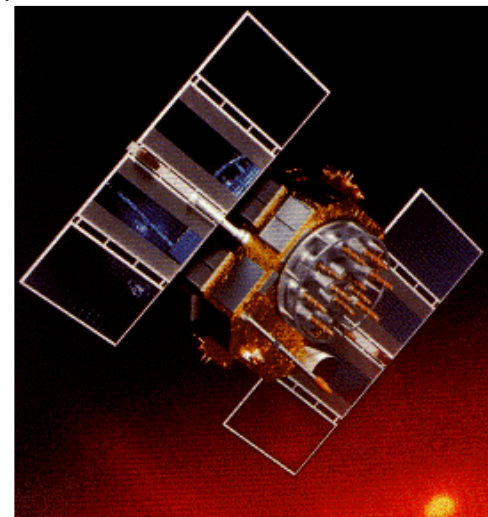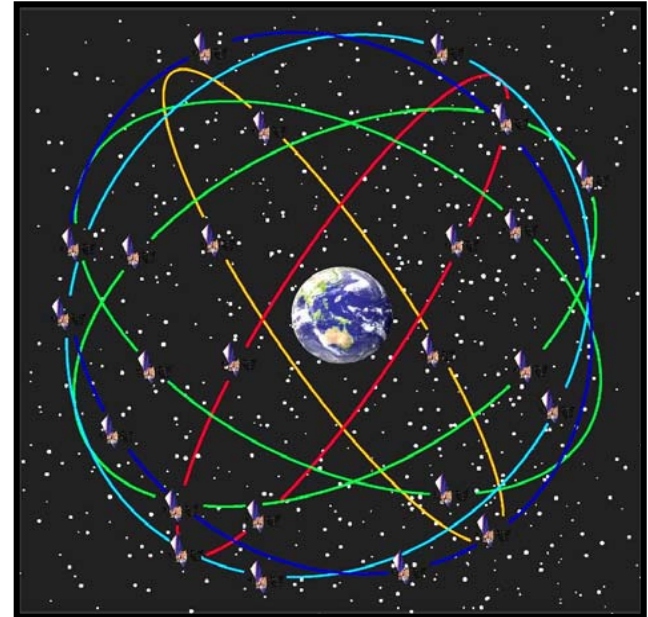
# Point positioning

Position of GPS antenna is obtained in real time

- Need one GPS receiver
- Receiving signal from four or more satellites
- Use information transmitted from satellite

Accuracy: about 10m
Main application: Navigation

Receiver

# Static relative positioning

Obtain **relative position** of GPS antennas
(baseline vector)

- Need two or more GPS receivers observing same four or more satellites simultaneously
- Observation time: Long (e.g. one hour)
- Post-processing
- Use phase difference of the carrier phase

Accuracy: about  5mm+1**ppm*D**

(D: baseline length)

Main application: Surveying

Receiver 1                Receiver 2

# GPS surveying by static relative positioning



GSI

Data

Receiver 1

Receiver 2

dX, dY, dZ

Lat., Long., H

Control point (e.g. triangular point)
(Coordinate: known)

Unknown point
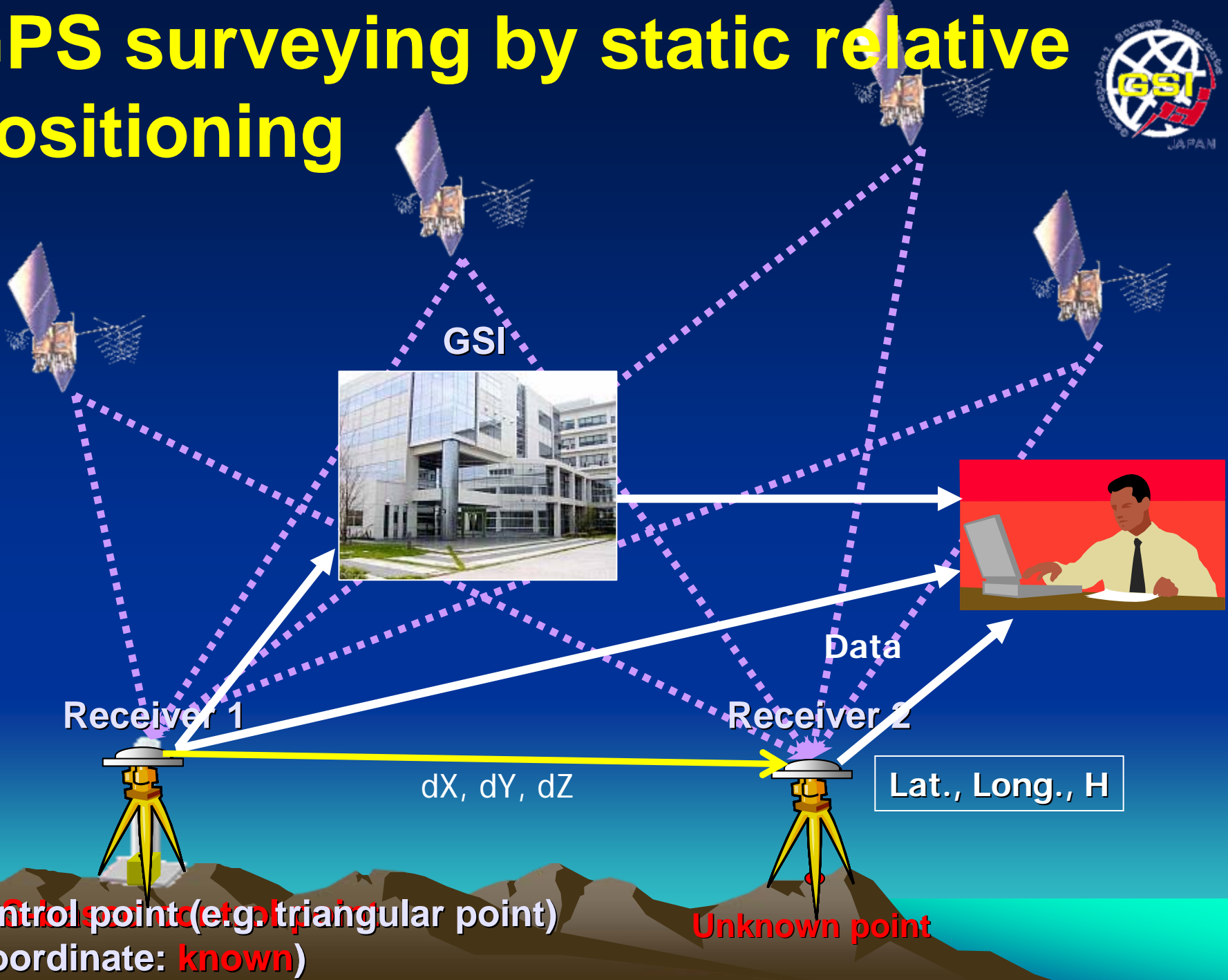
# Major Error sources

**Orbital error of satellite**
Use precise orbit, if necessary

**Poor satellite geometry**
Reduced by long observation time

**Ionospheric refraction**
Use dual frequency data

ionosphere

troposphere **Tropospheric refraction**
Modeled and estimating parameters

**Multiple refractions of the signal ("Multipath")**
Selecting site carefully
Antenna design

GSI JAPAN
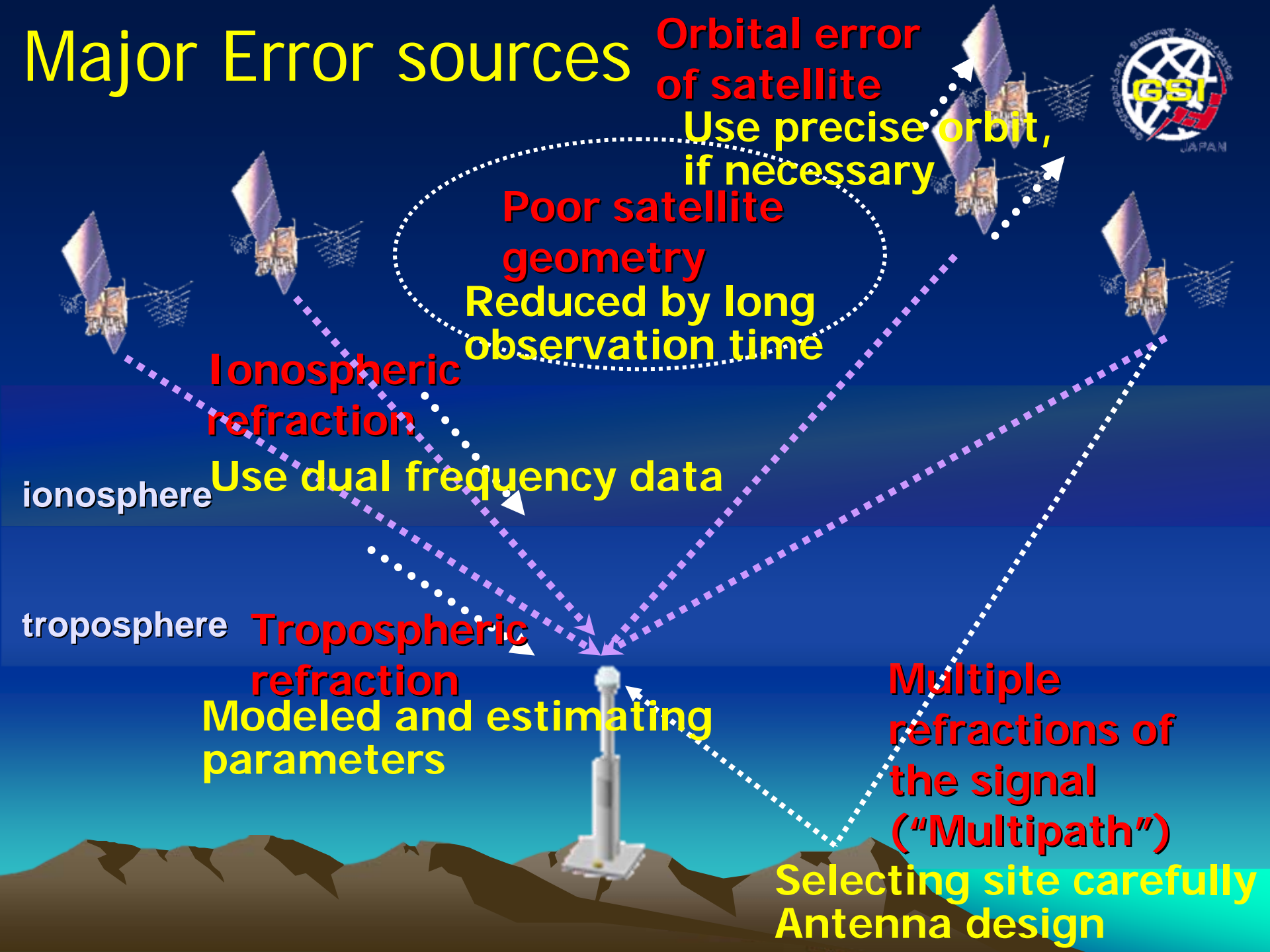
# GPS Earth Observation Network (GEONET): Purposes and Duties

- Reference for Surveys
  - GPS-based control stations are national control points.
  - Observation data is provided by internet
- Monitoring Crustal Movement
  - Positions of GPS-based control stations are calculated every day.
- Information Infrastructure for Positions
  - Real-time (1 Hz) data are provided in real-time via private companies.

# GEONET: Components

- **GPS-based control stations**
  - 1233 stations nationwide
  - Observing GPS signals continuously
- **Analysis system** at GSI (Tsukuba).
  - Data Storage and providing
  - Calculate positions of GPS-based control stations regularly

# Distribution Map of GPS-based Control Stations



- **1233** stations throughout Japan
- Average spacing: about **20 km**
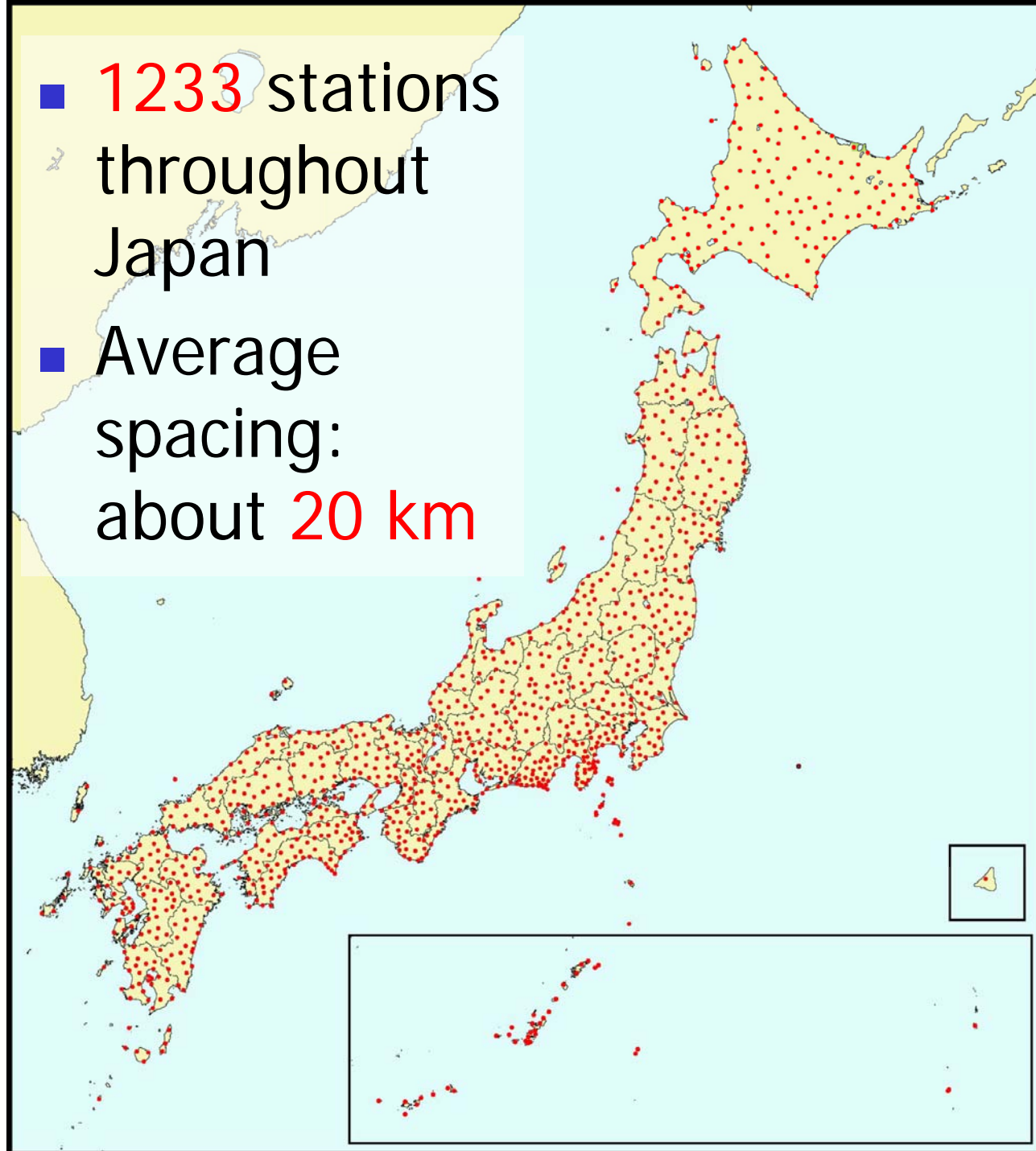
# GPS-based Control Station

Continuously observing signals from the GPS satellites

GPS Antenna

**Trimble**
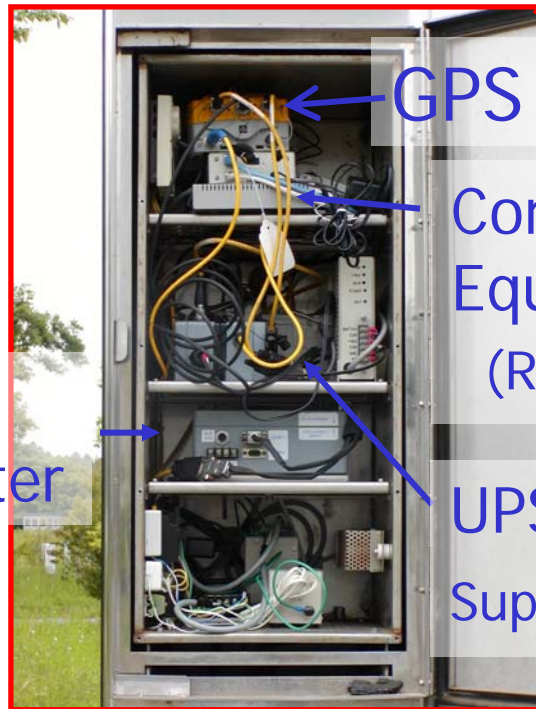
GPS Receiver

Communication Equipment
(Router, Protocol Converter)

Tilt meter

UPS( Uninterruptible Power Supply ) & Battery

- About 5m high
- made of stainless steel

# System components and Data flow of GEONET
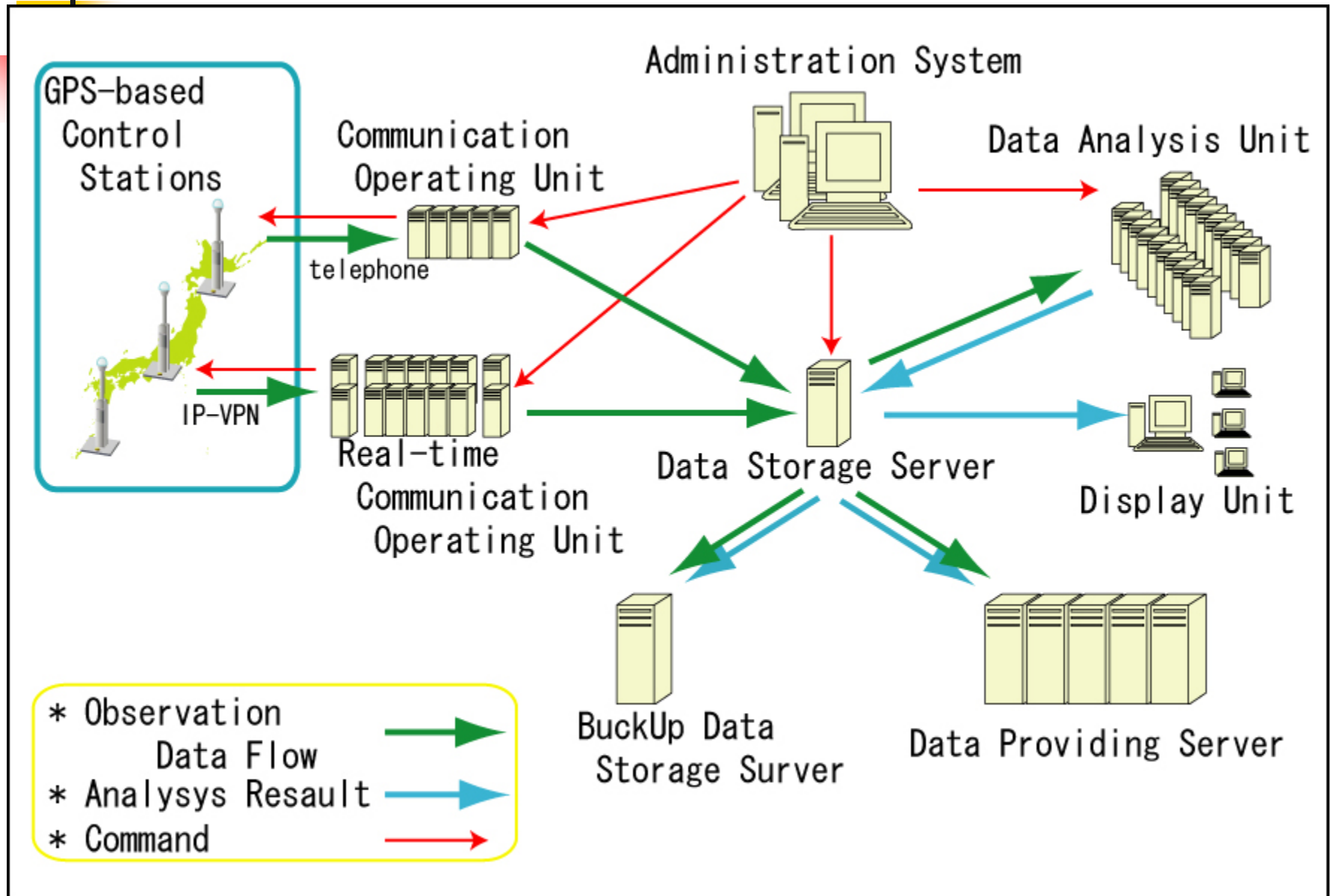
# Providing GEONET data to the public



- **Observation data and related information**
- **Provided from GSI web site**
- **Utilized for**
  - Surveying
  - Earth science research

  Etc.

# System components and Data flow of GEONET

GPS-based Control Stations

Communication Operating Unit

telephone

IP-VPN

Real-time Communication Operating Unit

Administration System

Data Analysis Unit

Data Storage Server

Display Unit

BuckUp Data Storage Surver

Data Providing Server

* Observation Data Flow
* Analysys Resault
* Command

# Comparison three types of Routine Analysis

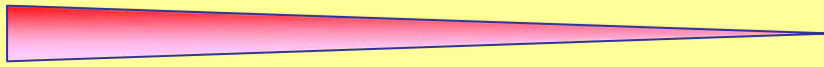|  | F2 (Final Analysis) | R2 (Rapid Analysis) | Q2 (Quick Analysis) |
|---|---|---|---|
| Data used | 24 hours | 24 hours | 6 hours |
| orbit | IGS final orbit | IGS ultra-rapid orbit | IGS ultra-rapid orbit |
| Schedule | Collectively, on Sunday | Everyday at UTC1:30 | Every 3 hours |

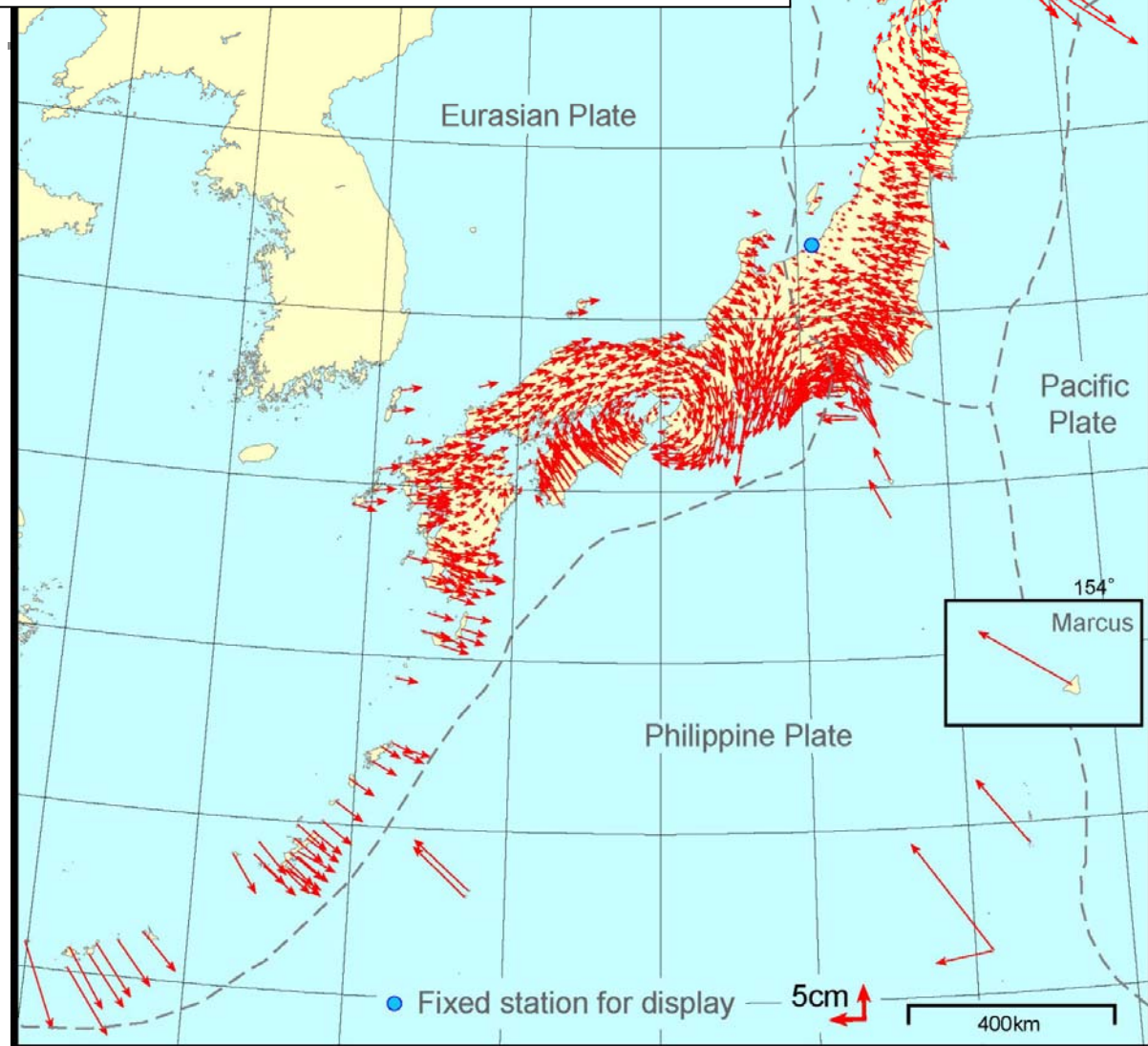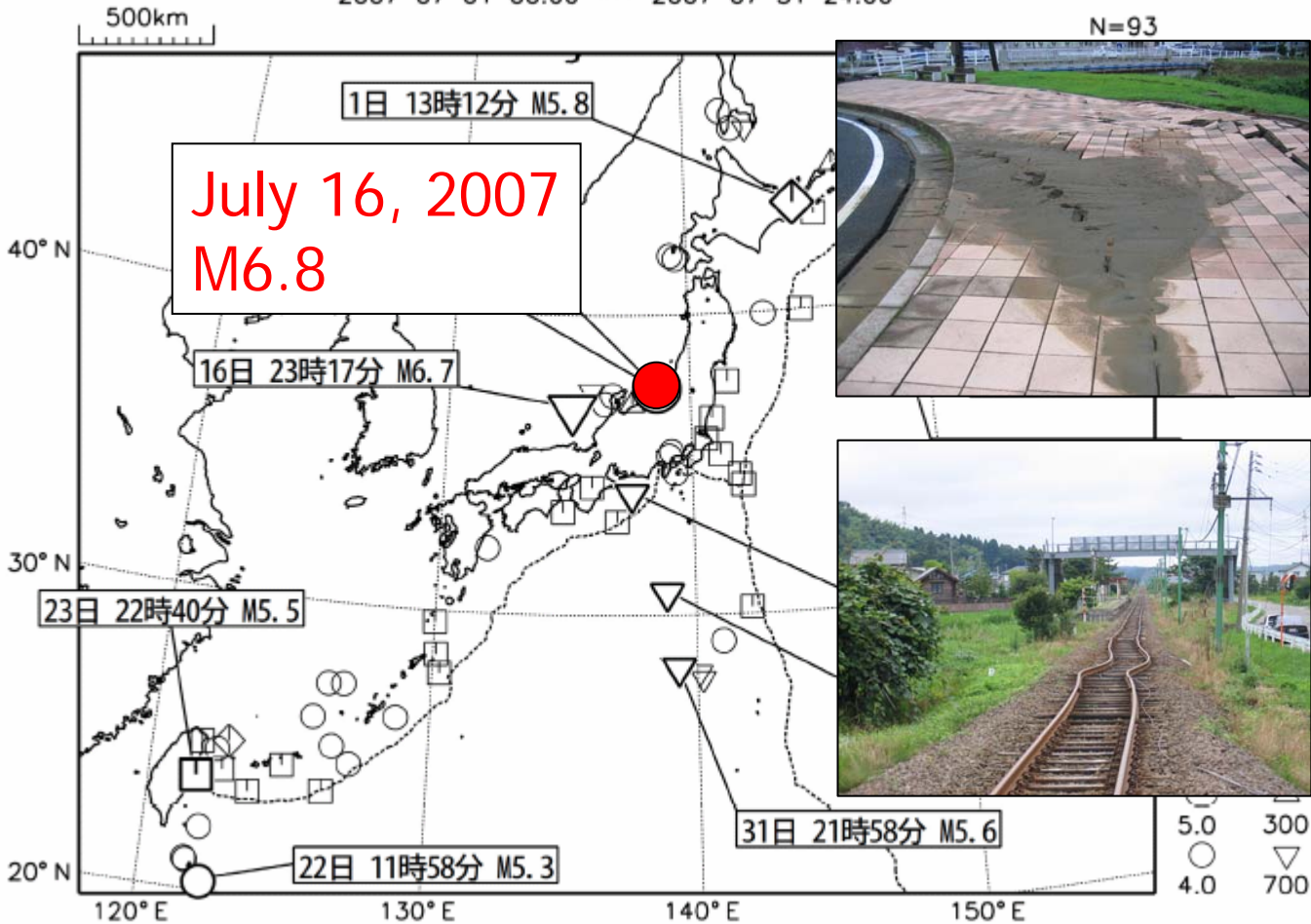| Promptness | **Slow** ➤ **Quick** |
|---|---|

| Accuracy | **High** ➤ **Low** |
|---|---|

# Example: Displacement Vector Map of Japan (Oct.,2003-Oct., 2004)

- Plate motion
  - Compression with Pacific plate and Philippine plate
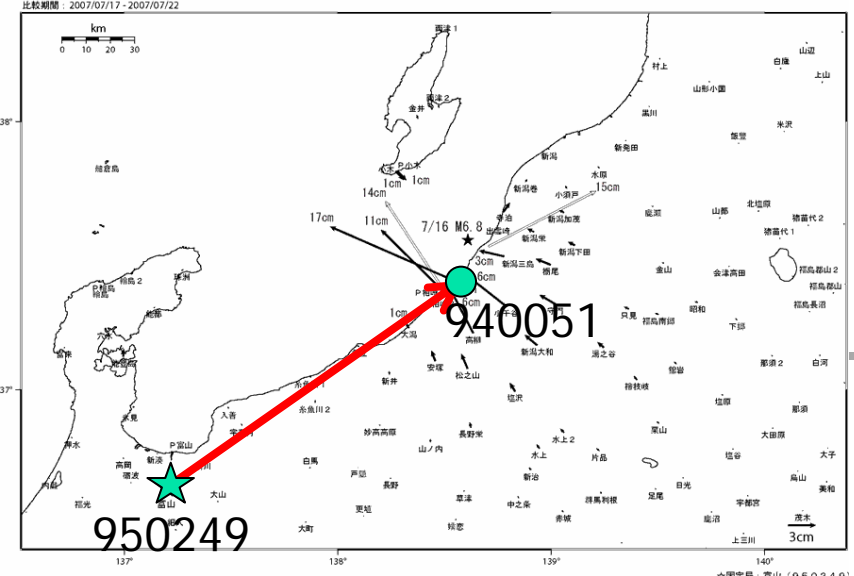- Local events
  - Earthquakes
  - Volcanic activities



North American Plate

Eurasian Plate

Pacific Plate

Philippine Plate

154°

Marcus

- Fixed station for display   5cm

400km

# Example: Niigataken Chuetsu-oki Earthquake



July 16, 2007
M6.8

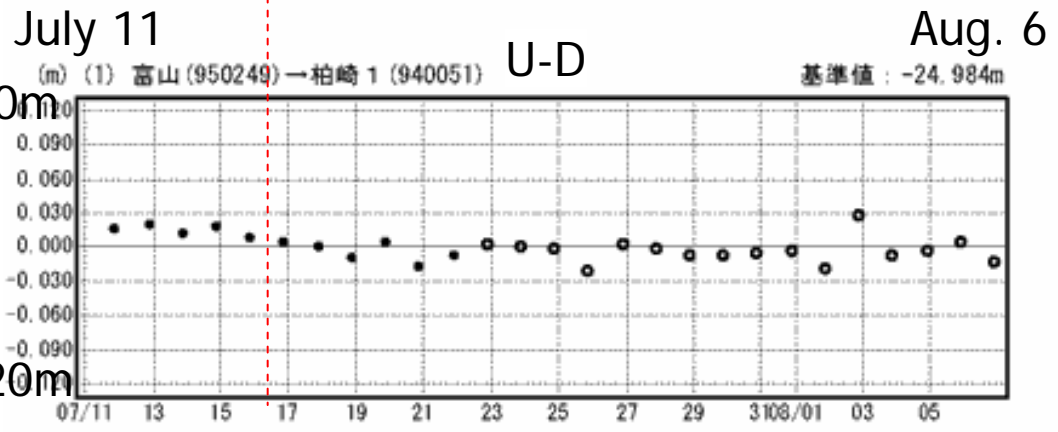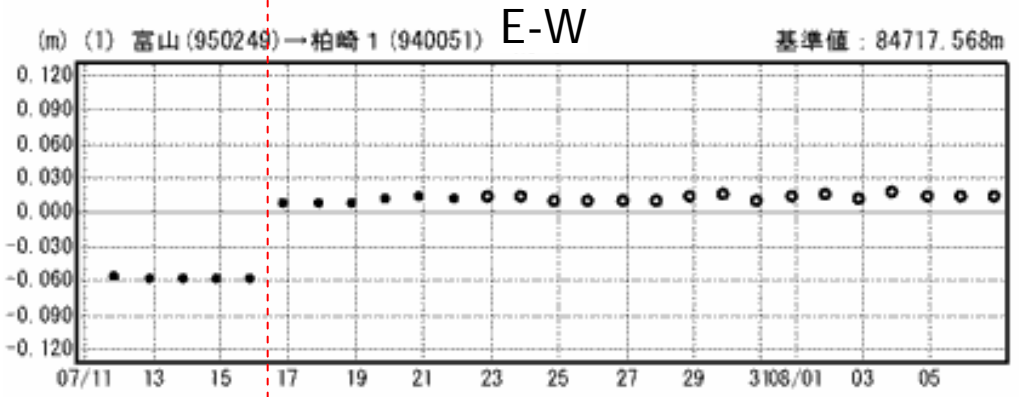(Base map is from Web page of the Headquarters for Earthquake Research Promotion)

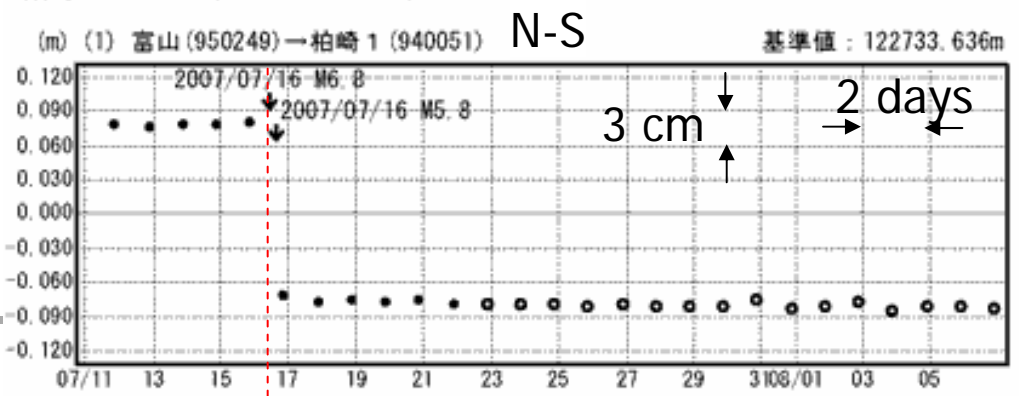# Example: Crustal movement of 2007 Niigataken Chuetsu-oki Earthquake



Reference: 2007/07/10-2007/7/15
Compareed: 2007/07/17-2007/7/22

14cm
17cm
11cm
Epicenter
7/16 M 8
15cm
3cm
6cm
6cm
1cm
1cm 1cm

3cm

期間 : 2007/07/11～2007/08/06  JST

(m) (1) 富山 (950249)→柏崎 1 (940051)  **N-S**  基準値 : 122733.636m

2007/07/16 M6.8
2007/07/16 M5.8

3 cm    2 days

(m) (1) 富山 (950249)→柏崎 1 (940051)  **E-W**  基準値 : 84717.568m

## Time series of baseline vector components

- Station 950249 to 940051
- From Jul.11 to Aug. 6, 2007
- N-S, E-W and U-D components

July 11

Aug. 6

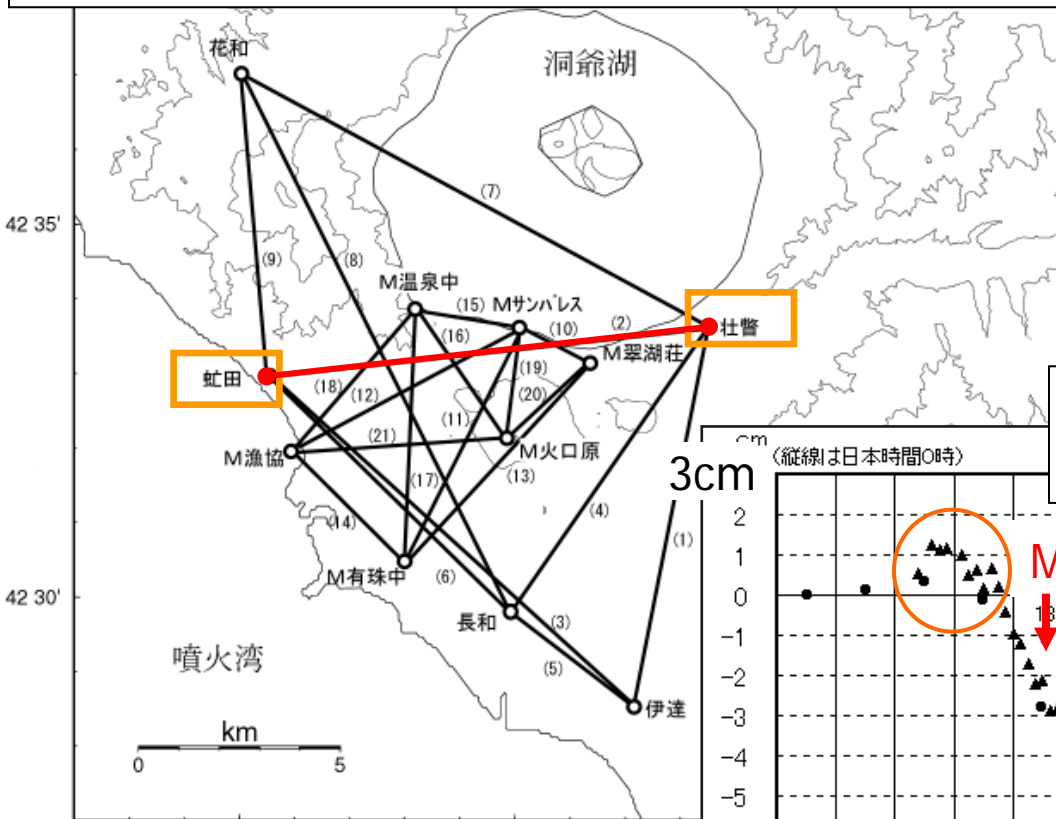(m) (1) 富山 (950249)→柏崎 1 (940051)  **U-D**  基準値 : −24.984m

0.120m

-0.120m

○ ---[R2:速報解]   ● ---[F2:最終解]

950249

940051

7/16 M6.8

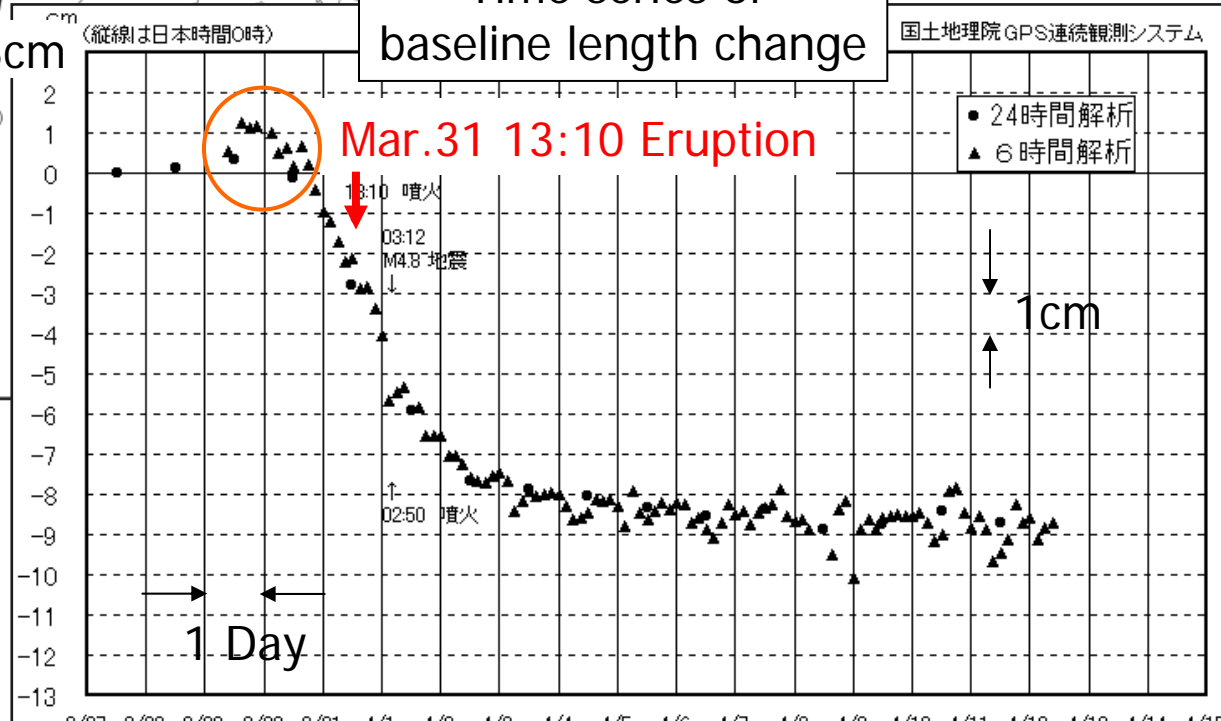※「柏崎2」「出雲崎」（白抜き矢印）は傾斜による変位を補正しています。
「出雲崎」の変動量には地盤の局所的な変形による影響が含まれている
可能性があります。

# Example: Crustal displacement associated with volcanic eruption (Mt. Usu. March 31, 2001)



Time series of baseline length change

3cm

Mar.31 13:10 Eruption

1cm

1 Day

Mar. 27

# Thank you