GPS Earth Observation Network System (GEONET)

Hiroyuki NAKAGAWA
Assistant Director for Earthquake Investigation,
Geodetic Observation Center,
Geographical Survey Institute
Contents

1. Introduction of the Geographical Survey Institute (GSI)
2. National reference framework of Japan
3. GPS and positioning using GPS
4. GEONET: GPS Earth Observation Network
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

- About 1,200 GPS-based control stations
- About 100,000 triangulation points (1st~4th order)
- 4 VLBI stations

* Very Long Baseline Interferometry
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

- 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.
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
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 \( 5 \text{mm} + 1 \text{ppm} \times D \)
(D: baseline length)

**Main application**: Surveying
GPS surveying by static relative positioning

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

Unknown point

Lat., Long., H

dX, dY, dZ

Data

Receiver 1

Receiver 2

GSI
Major Error sources

- Poor satellite geometry
- Orbital error of satellite
- Reduced by long observation time
- Use precise orbit, if necessary
- Use dual frequency data

Ionospheric refraction
- Modeled and estimating parameters
- Ionosphere

Tropospheric refraction
- Selecting site carefully
- Antenna design
- Multiple refractions of the signal ("Multipath")
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

- About 5m high
- Made of stainless steel

GPS Antenna

GPS Receiver

Communication Equipment (Router, Protocol Converter)

UPS (Uninterruptible Power Supply) & Battery

Tilt meter
System components and Data flow of GEONET

- GPS-based Control Stations
- Communication Operating Unit
- Administration System
- Data Analysis Unit
- Display Unit
- Data Providing Server
- Real-time Communication Operating Unit
- Data Storage Server
- BuckUp Data Storage Server

* Observation Data Flow
* Analysis Result
* Command
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
- Real-time Communication Operating Unit
- Data Storage Server
- Backup Data Storage Server
- Data Providing Server
- Administration System
- Data Analysis Unit
- Display Unit

* Observation Data Flow
* Analysis Result
* Command
Comparison three types of Routine Analysis

<table>
<thead>
<tr>
<th></th>
<th>F2</th>
<th>R2</th>
<th>Q2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data used</strong></td>
<td>24 hours</td>
<td>24 hours</td>
<td>6 hours</td>
</tr>
<tr>
<td><strong>orbit</strong></td>
<td>IGS final orbit</td>
<td>IGS ultra-rapid orbit</td>
<td>IGS ultra-rapid orbit</td>
</tr>
<tr>
<td><strong>Schedule</strong></td>
<td>Collectively, on Sunday</td>
<td>Everyday at UTC1:30</td>
<td>Every 3 hours</td>
</tr>
</tbody>
</table>

- **Promptness**: Slow to Quick
- **Accuracy**: High to Low

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

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

- Time series of baseline length change
  - Mar. 31 13:10 Eruption
  - 3cm
  - 1cm
  - 1 Day

Mar. 27: Time series graph
  - 24-hour analysis
  - 6-hour analysis
Thank you