The 2011 Great East Japan Earthquake and Tsunami
- What we did and what we learned -

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Outline

1. Great East Japan Earthquake in 2011
2. Immediate Response
3. Recovery/Reconstruction
4. Improved Preparedness
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Great East Japan Earthquake in 2011
Disaster caused by the Great East Japan Earthquake on 11 March 2011

• Earthquake:
  – Mw: 9.0 (Epicenter: 70km east of Sendai)
  – Co-seismic crustal deformation (max):
    5.3m (horizontal), -1.2m (vertical)

• Tsunami:
  – Highest elevation reached: 43m
  – Inundated areas: 561 square km
    (approx. 10 times the Manhattan Island in New York)

• Nuclear meltdown:
  – 3 reactors in Fukushima
Disaster caused by the Great East Japan Earthquake on 11 March 2011

• Casualties (as of 10 March 2016)
  – Death: 15,894 (>90% by Tsunami)
  – Missing: 2,561
  – Injured: 6,152

• Liquefaction (as of 27 September 2011)
  – Damaged houses: 26,914

• Economy
  – Estimated economic loss: > 200B US$
Immediate Response
What we did after the Earthquake

• Detection of co-seismic crustal deformation using CORS network
• Aerial survey (Aerial photos + Ortho images)
• Photo interpretation (Inundated areas)
• :
Co-seismic Crustal Deformation

CORS Network in Japan
1,300 stations
(Ave. 20km interval)

Geospatial Information Authority of Japan (GSI)
Co-seismic Crustal Deformation

**Horizontal**
- Oshika: 5.3m
- Tokyo: 0.2m

**Vertical**
- Oshika: 1.2m
Aerial Survey

Seven airplanes were mobilized, based on an MOU with private companies, to take aerial photos covering approx. 7,000 square km starting from the next day.
Aerial Survey

Taken in 2008

Tsunami
Photo Interpretation (Inundated Areas)
Recovery/Reconstruction
Resurveying of Control Points

• The deformation caused by the earthquake was too large to start surveying for reconstruction without revising the control points coordinates.

• Two questions:
  – When should the resurveying be conducted?
    • Large post-seismic deformation required a careful analysis to find the right time for revising the datum.
  – Which control points’ coordinates are to be revised?
    • The extent of deformed areas were to be identified before surveying.
When the revision should be conducted?

Logarithmic function is adopted to estimate the future trend of post-seismic deformation by using CORS data.

\[ y(t) = c + a \ln \left( 1 + \frac{t}{\tau_{\log}} \right) \]

(c, a: constant, \( \tau_{\log} \): constant(time), t: time)

The end of May was set as the date for fixing the coordinates given that the deformation trend is estimated to become moderate after that.
Areal Extent of New Datum

The area where estimated strain was over 2ppm was identified for revision.

Strain map estimated from the fault model
Coordinate Differences

Coordinate differences between old and new datums derived from CORS.
Areas Excluded from Applying Transformations with Parameters

- Large aftershocks made some areas unsuitable for applying coordinate transformations with parameters.
- InSAR analysis was employed to quickly identify the extent of the areas that should be excluded from the coordinate transformations.

Local co-seismic displacements by aftershocks
Correction Parameters for control points

Horizontal Coordinates of triangulation control points

Revision completed in less than seven months after the earthquake.

Elevation of benchmarks
Improved Preparedness
Digital Archives of Maps and Photos

Geospatial Information Authority of Japan (GSI)
The revised map is made available on the web on the same day the road is made available to the public.
Number of Municipalities Conducting Cadastral Survey

- The data of end of 2014 and end of 2015 are estimated values.

* The Tohoku Earthquake on 11 March 2011

Year


721 723 728 721 753 757 768 792

* Geospatial Information Authority of Japan (GSI)
Completed Cadastre Facilitates Reconstruction

**Coastal Areas**

**Benefits of Cadastral Survey**

*With* pre-existing cadastral data

- $12 \text{ M, 0.7 year}$
- Saved: $10 \text{ M, 0.5-1 year}$

*Without* pre-existing cadastral data

- $22 \text{ M, 1-1.5 year (estimated)}$

The cost for relocation was reduced by $10 \text{ M}$ and the time cut by 0.5-1 year.

**Inland Areas of Higher Elevation**

Relocation
Real-time Analysis of CORS Network for More Accurate Tsunami Warning

• Initial tsunami warning (up to 6m in wave height) issued by the Meteorological Agency was too low due to the saturated seismic wave data by seismometers.
  • Real height was up to 15m.
  • Highest elevation reached by tsunami was 43m.

• Real-time analysis of CORS network to estimate the magnitude of large earthquakes can estimate tsunami wave height without saturation in a few minutes.
Real-time CORS Analysis of Kumamoto Earthquakes

TIME (h:m)

DEFORMATION IN METERS

EAST-WEST

~ 0.70m

NORTH-SOUTH

~ 0.75m

VERTICAL

1 Minute

TIME (h:m)
Real-time CORS Analysis of Kumamoto Earthquakes

~ 0.40m
~ 0.80m
~ 1.0m
Kumamoto Earthquakes
(14-16 April 2016)
CORS Data Analysis/Modeling and ALOS-2 InSAR Analysis
InSAR (ALOS-2) Analysis in 2.5 Dimensions

- InSAR data from two different directions were used to estimate near vertical deformation.
- The result was compatible with GNSS survey on the ground.
Summary (What we learned)
Summary: What We Learned

• CORS network has crucial roles in:
  – Assessing the magnitude and extent of co-seismic and post-seismic deformation for efficient resurveying and modeling of the earthquake, particularly when combined with InSAR analyses.
  – Providing accurate control for aerial surveys.
  – Estimating the magnitude of large earthquakes and tsunami wave height near real-time.
Summary: What We Learned

• Cooperation with private aerial survey companies provides emergency aerial survey activities in large-scale disasters.

• Digital archives of past aerial photos and maps help quickly assess the magnitude and extent of disaster damage.

• Maps need to be updated, particularly for transport information, to facilitate emergency responses.

• Completed cadastre helps streamline post-disaster reconstruction processes.
Thank you.