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Geodetic Reference Frame of Japan as basic infrastructure enabling us precise GNSS positioning

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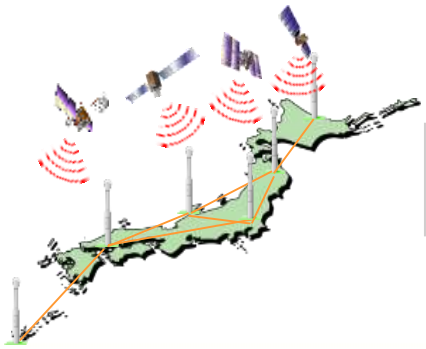
Advance of GNSS positioning services and growing users

- Geospatial Information Authority of Japan (GSI) operates nationwide GNSS CORS network (GEONET). GEONET enables us to provide real-time precise GNSS positioning services.
- Users of Precise GNSS positioning is growing in many emerging fields, such as smart construction, autonomous vehicle operation, smart agriculture, UAV operation and etc.
- In order to establish geodetic reference frame as basic infrastructure enabling us precise GNSS positioning, we are planning to improve geodetic reference frame of Japan.



Geodetic reference frame of Japan and its issue

- In order to fully utilize advancing GNSS positioning, it is essential to ensure consistency between GNSS positioning and existing geospatial information.
- Almost all of geospatial information in Japan including topography maps are created based on national geodetic reference frame of Japan (JGD2011).
- JGD2011 is fixed to positions of reference epoch (1997/1/1 in western part and 2011/5/24 in eastern part) in order to keep consistency of positions between these geospatial information.
- This means the positions of almost all of geospatial information are also fixed to reference epoch and do not change time by time.

Geodetic reference frame of Japan and its issue

- Positions of JGD2011 are fixed to those of the reference epoch. This means positions of almost all geospatial information in Japan are also fixed and do not change time by time.
- On the other hand, GNSS positioning provides a position at observation epoch. They are changing time by time.
- Japanese islands are continuously deforming because of crustal deformation caused by plate motions.
- This means positions of JGD2011 and GNSS positioning are different and the inconsistency is gradually increasing time by time.

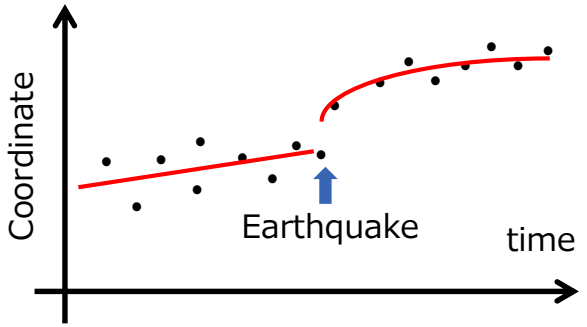
Martin et al. (2012)

Solution to ensure consistency

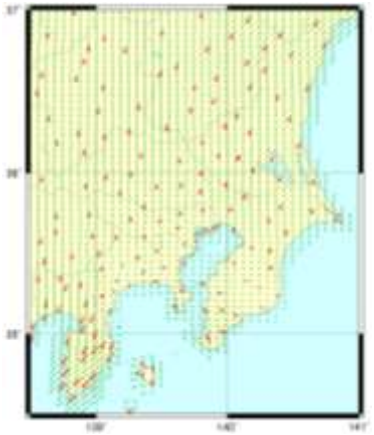
- In order to fully utilize advancing GNSS positioning, it is essential to ensure consistency between GNSS positioning and existing geospatial information.
- We are planning to develop correction system to connect positions of GNSS positioning and geodetic reference frame (existing geospatial information).
- In order to realize such system, it is necessary to develop models of both secular and coseismic crustal deformation.
- We are also seeking a possibility to introduce time-dependent 4D geodetic reference frame which can express positions of any epoch users need by utilizing the crustal deformation model.

Model development of secular crustal deformation

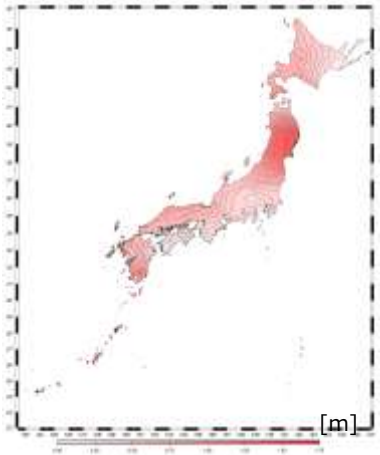
- The first step is fitting coordinate time series of each GEONET station to functions such as linear or exponential etc., and determine most probable value of each day.
- The second step is to spatially interpolate the most probable values and generate deformation field of each day.



Fitting GEONET time series to functions



Spatial interpolation of most probable values of a day



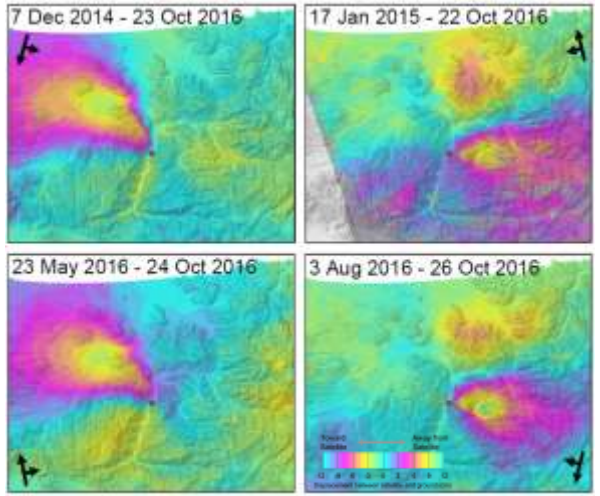
Accumulated horizontal deformation filed from reference epoch to 2017

Model development of coseismic crustal deformation

- Coseismic crustal deformation field can be created from coseismic displacement detected at GEONET stations and coseismic displacement distribution detected by 3D InSAR.

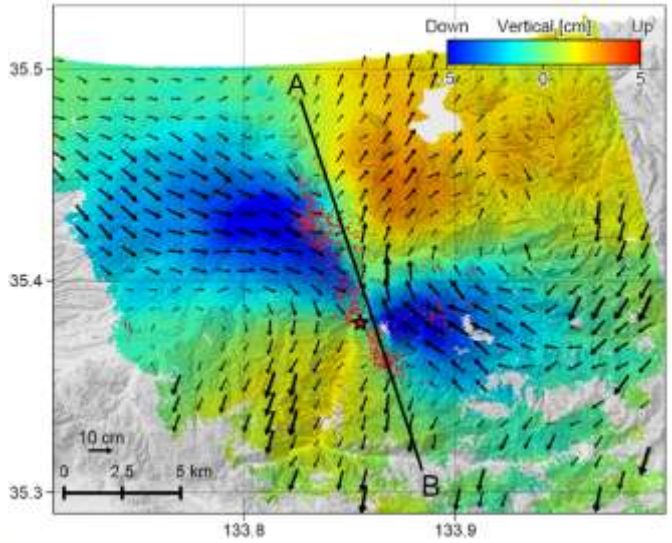
Coseismic displacement vector map

Interferograms



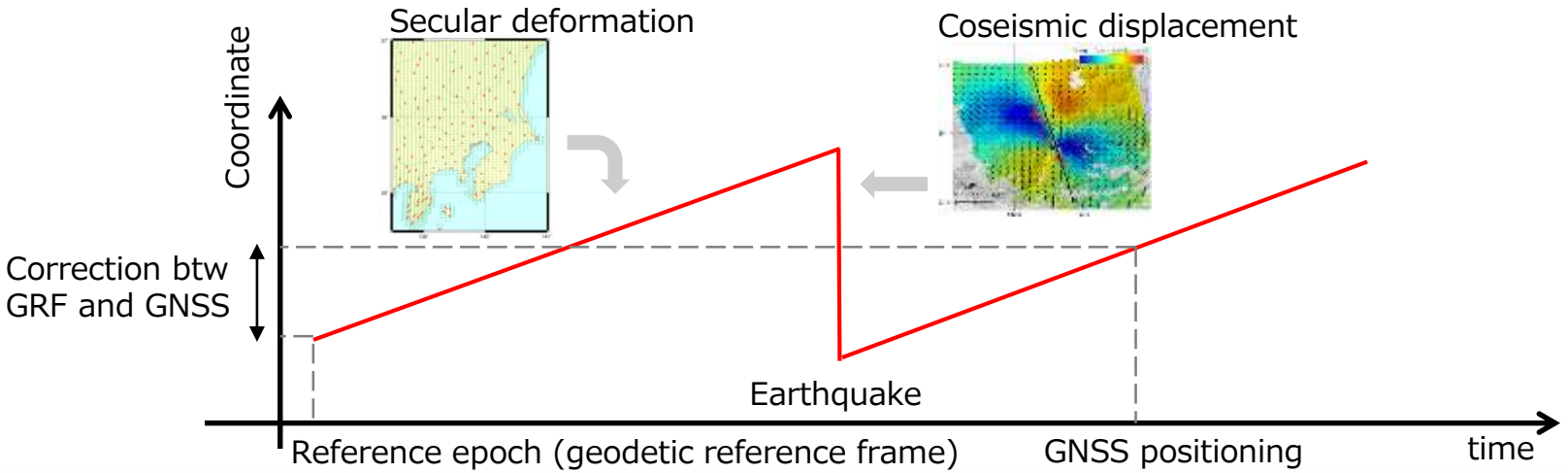
Analysis by GSI from ALOS-2 raw data of JAXA

Coseismic displacement field



Time dependent (4D) crustal deformation model

- By combining models of secular crustal deformation and coseismic displacement, we can generate 4D crustal deformation model which provides positions of anywhere at any time.
- The 4D model can be base of next generation correction system which connects geodetic reference frame and GNSS positioning .



Issue on vertical datum of Japan

- Vertical datum of Japan has been realized and maintained with nationwide geodetic leveling.
- However, geodetic leveling covering the whole territory takes long time and huge cost.
- Prompt revision of datum is strongly required for prompt rehabilitation and reconstruction especially after large earthquakes, but leveling takes at least several months.
- Orthmetric height determination with GNSS and geoid have a capability to enables us more prompt revision, but current gravity geoid model of Japan is not enough accurate to substitute for geodetic leveling.
- One solution is hybrid geoid model created from gravity geoid and GNSS/leveling, but the accuracy degrades time by time because of continuous crustal deformation.

Development of precise gravity geoid of Japan

- Another issue is realization of geopotential vertical datum which enable us determine accurate orthmetric heights directly by GNSS positioning.
- Precise gravity geoid model is essential for realizing geopotential vertical datum.
- Dense and fresh gravity data covering the whole territory is essential for the development of precise gravity geoid model.

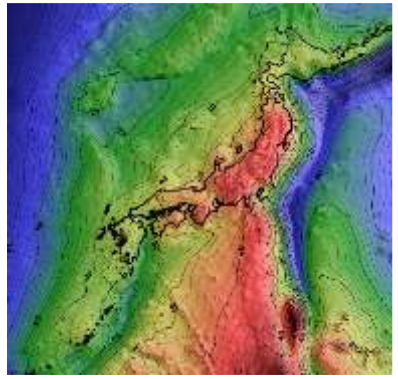
- We will purchase an airborne gravimeter in 2018.
- We are also seeking a possibility to conduct airborne gravity measurements covering the whole territory, develop precise gravity geoid model of Japan and shift to geopotential vertical datum.

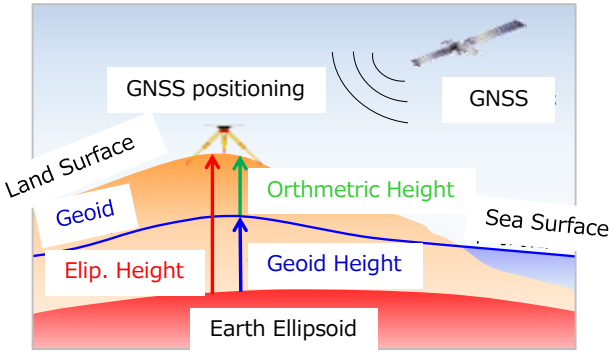
Future Plan of Development

2018: Purchase of reliable airborne gravimeter
2019-2022: Airborne gravity measurements & development of beta version of geoid models
2023: Development of national gravity geoid model
2024: Evaluation and Publication of the new geoid model
Shift to next generation geopotential vertical datum

Purchase airborne gravimeter

Airborne gravity measurement


Development of gravity geoid model



Geopotential Vertical datum

Summary

- We are planning to improve geodetic reference frame of Japan in order to provide basic infrastructure for more accurate GNSS positioning.
- We are planning to develop correction system which connects geodetic reference frame (existing geospatial information) and GNSS positioning.
- First step of the development is modeling of secular and coseismic crustal deformation of Japan.
- The secular model is planed to be developed by utilizing coordinate time series of GNSS CORS network of Japan (GEONET).
- The coseismic model is planned to be developed by GEONET and 3D InSAR.
- We are also planning to develop precise gravity geoid model of Japan, and seeking a possibility to shift to geopotential vertical datum.
- We will purchase an airborne gravimeter in 2018.
- We also plan to conduct 4 years airborne gravity measurement project covering Japan.