ICG Working Group D

Reference Frames, Timing and Applications

Realization of semi-dynamic reference frame using multi constellation of GNSS and IGS products in Japan

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GEONET

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Contents

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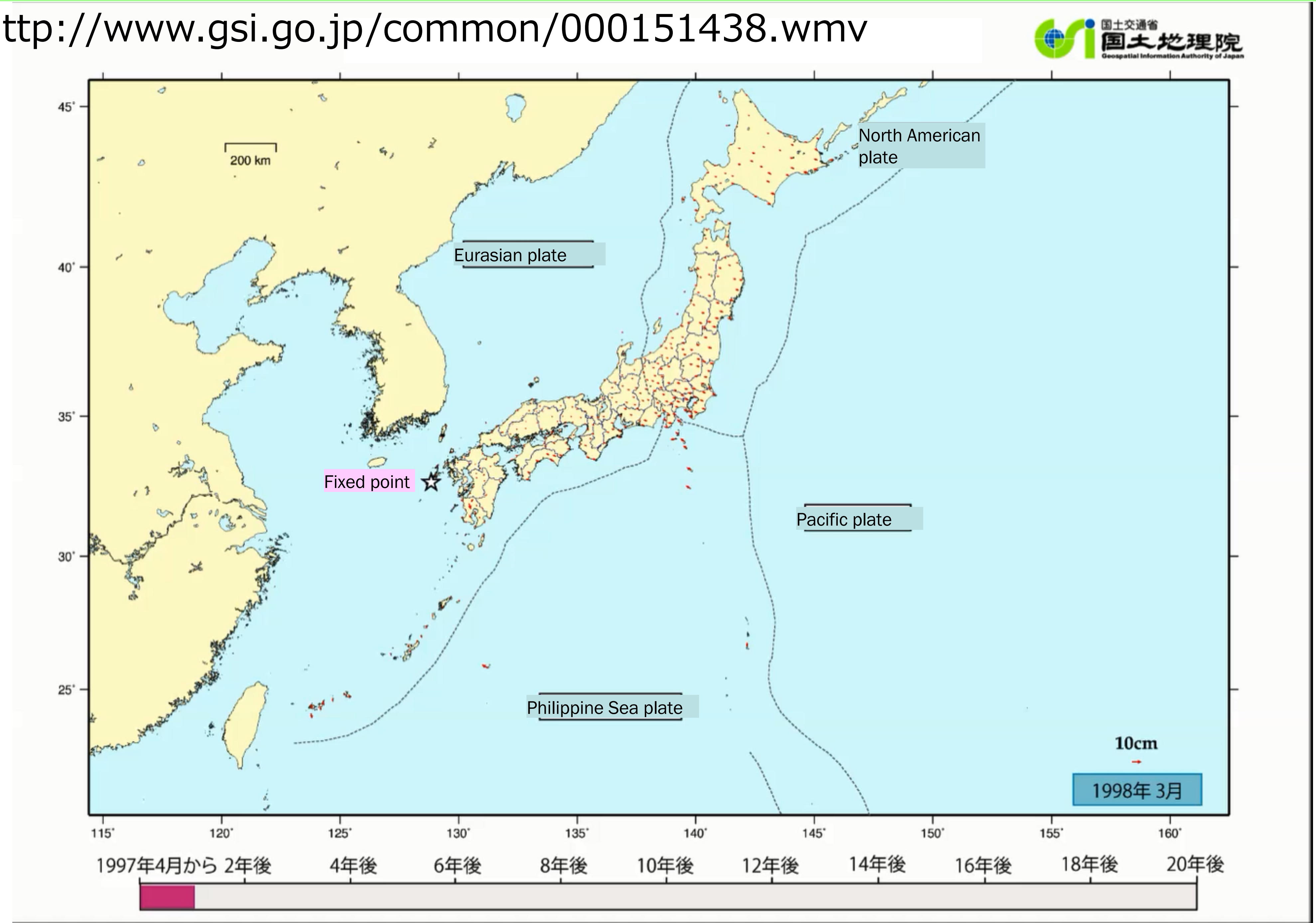
1. Necessity of semi-dynamic correction to relate
   - the current ITRF coordinates obtained from GNSS positioning, and
   - the past ITRF coordinates at the epoch of national datum that existing maps follow
2. Status on the realization of ITRF using GNSS CORS (GEONET) in Japan
   - "F3" (ITRF2005) ⇒ "F4" (ITRF2014)
     - Source of semi-dynamic correction
     - QZSS CLAS also refers

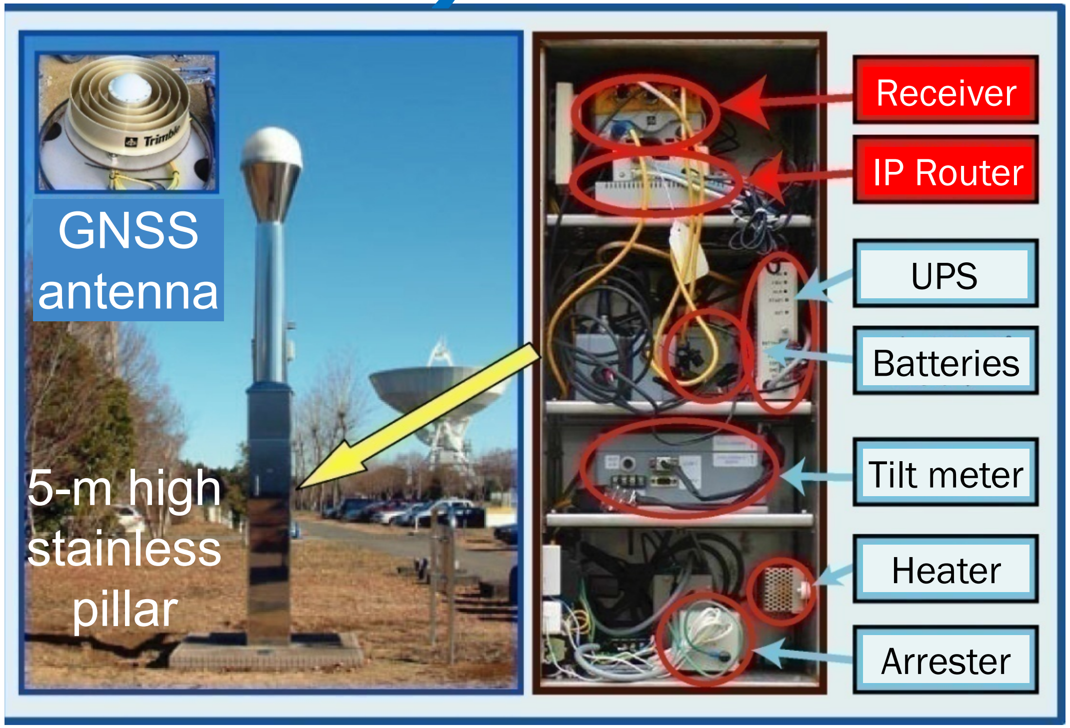
Crustal deformation since 1997

Geospatial Information Authority of Japan (GSI)

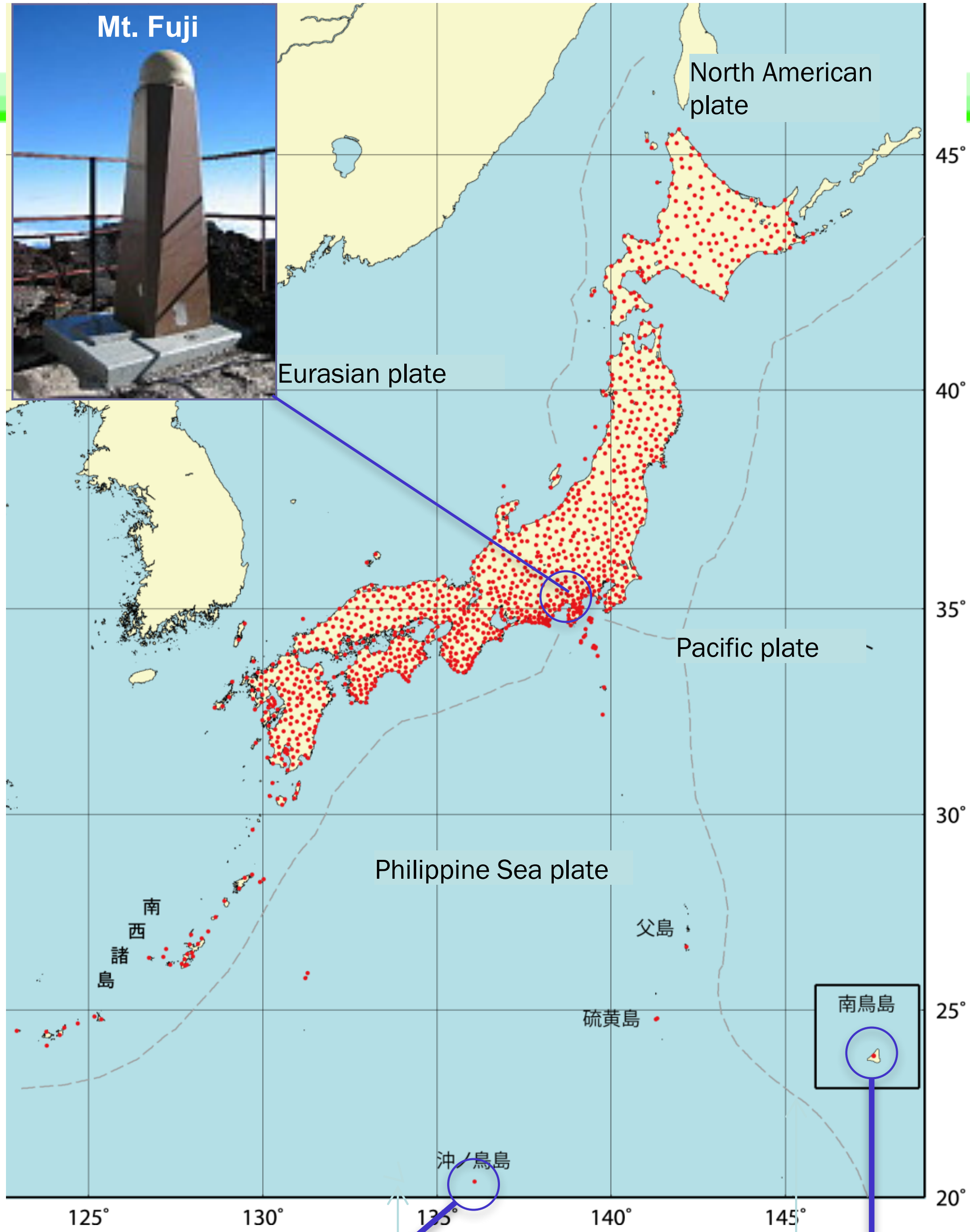
http://www.gsi.go.jp/common/000151438.wmv



GNSS CORS in Japan (GEONET)



Model 93	Model 94	Model 95	Model 02
1993	1994	1995-1997	2002-




Okino Tori island


Minami Tori island

VLBI: from Tsukuba to Ishioka

Geospatial Information Authority of Japan (GSI)

17 km NE of Tsukuba

Tsukuba 32-m VLBI

- Used to be the core station of geodetic reference frame in Japan from 1999 to 2016.

Ishioka 13-m VLBI

- The state-of-the-art telescope conformable to the IVS VGOS specification
- Collocated with GNSS CORS

What is the Problem ?

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- GNSS positioning yields coordinates in WGS84, PZ90.11, GTRF, …
  = current ITRF coordinates
- Existing maps are made by surveys based on the static datum
  = past ITRF coordinates at the epoch of static datum definition

There will be a difference between GNSS positioning and maps, as time goes by, and as GNSS precision increases …

Semi-Dynamic correction

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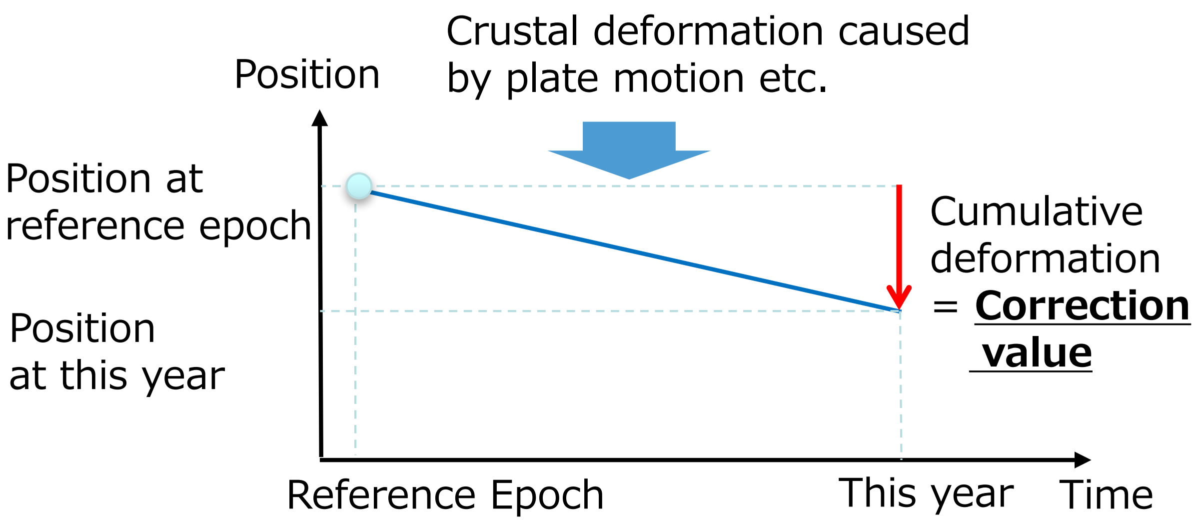
- <u>**Cumulative deformation model from GNSS CORS**</u> **is used to align the current and epoch coordinates**
  - **Model is updated once a year for surveying**
  - **Now proposing to apply semi-dynamic correction for precise positioning, with more frequent model updates**



Due to the 2011 Tohoku EQ, reference epoch is 2011/05/24 in East Japan, and 1997/01/01 for West Japan and Hokkaido

Flow of Semi-Dynamic correction for surveying

Positions of CORS at reference epoch

↓ <u>Add correction value to positions of CORS</u>

Positions at CORS at this year

↓

GNSS positioning of new points

↓

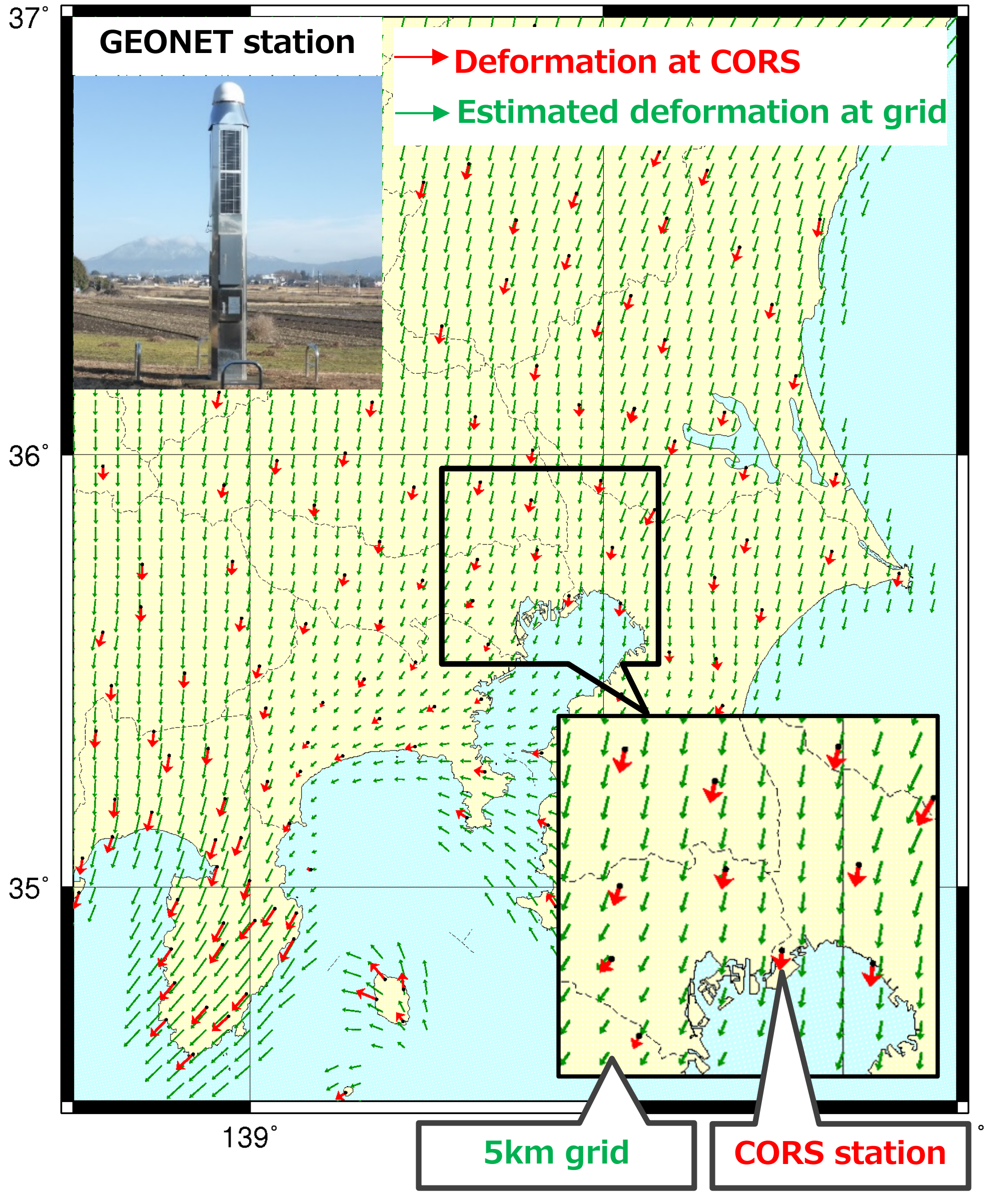
Positions of new points at this year

↓ <u>Remove correction value from positions of new points</u>

Positions of new points at reference epoch

How to model crustal deformation

Geospatial Information Authority of Japan (GSI)



Cumulative crustal deformation is calculated from time series of ITRF coordinates of each CORS (average spacing 20km in Japan).

Deformation is estimated for each 5km grid by interpolating the cumulative deformation at each CORS.

Users can estimate crustal deformation anywhere within the CORS network by interpolating the deformation at nearby grids.

The cumulative crustal deformation model is updated once a year and available on the Internet.

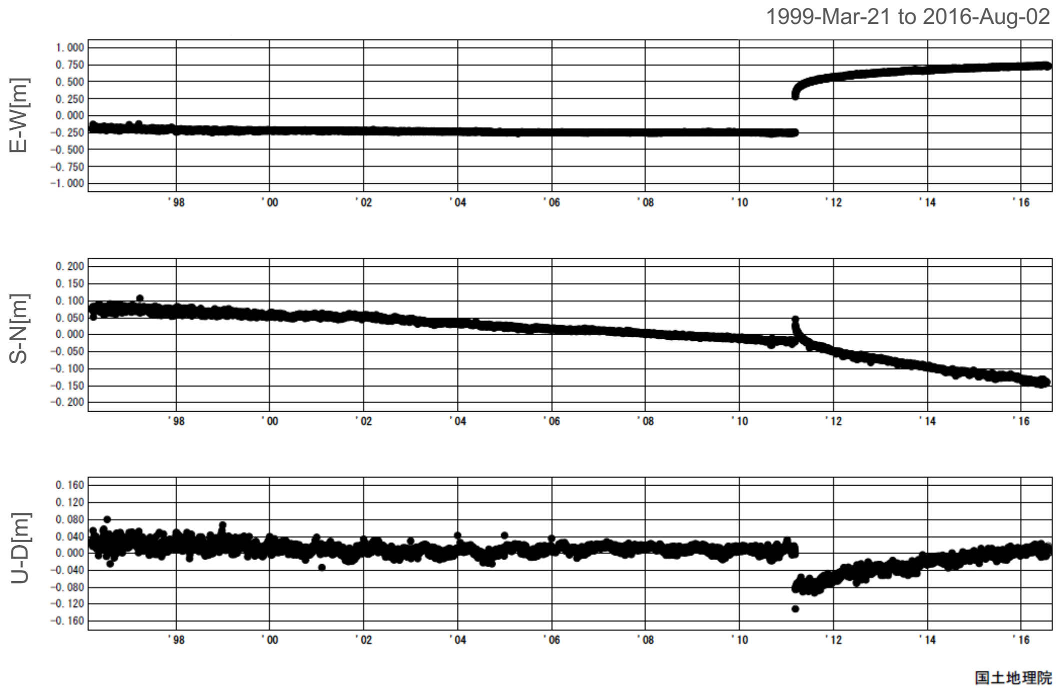
R&D status on the realization of ITRF using GNSS CORS in Japan

Overview of GEONET analysis strategy

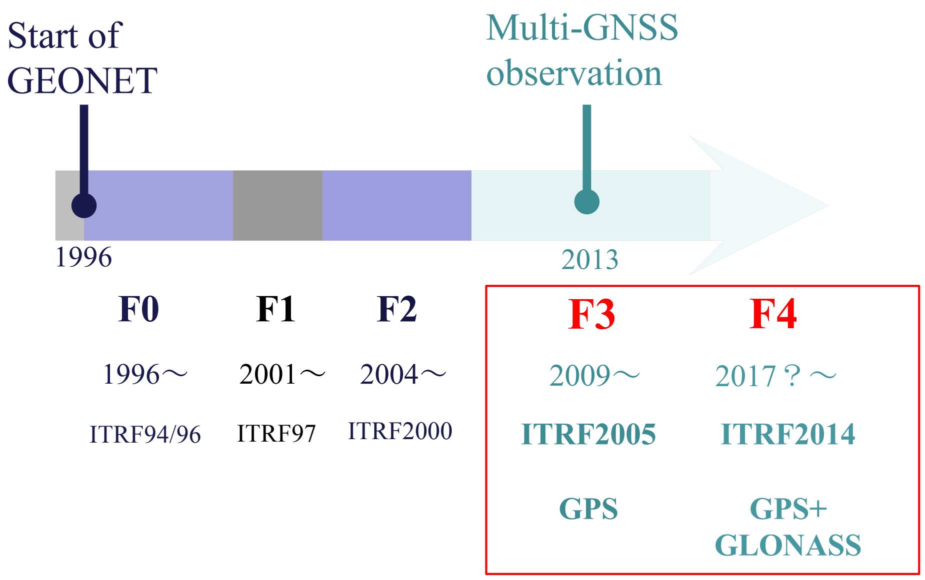
Geospatial Information Authority of Japan (GSI)

GSI calculates daily coordinates of each GEONET station

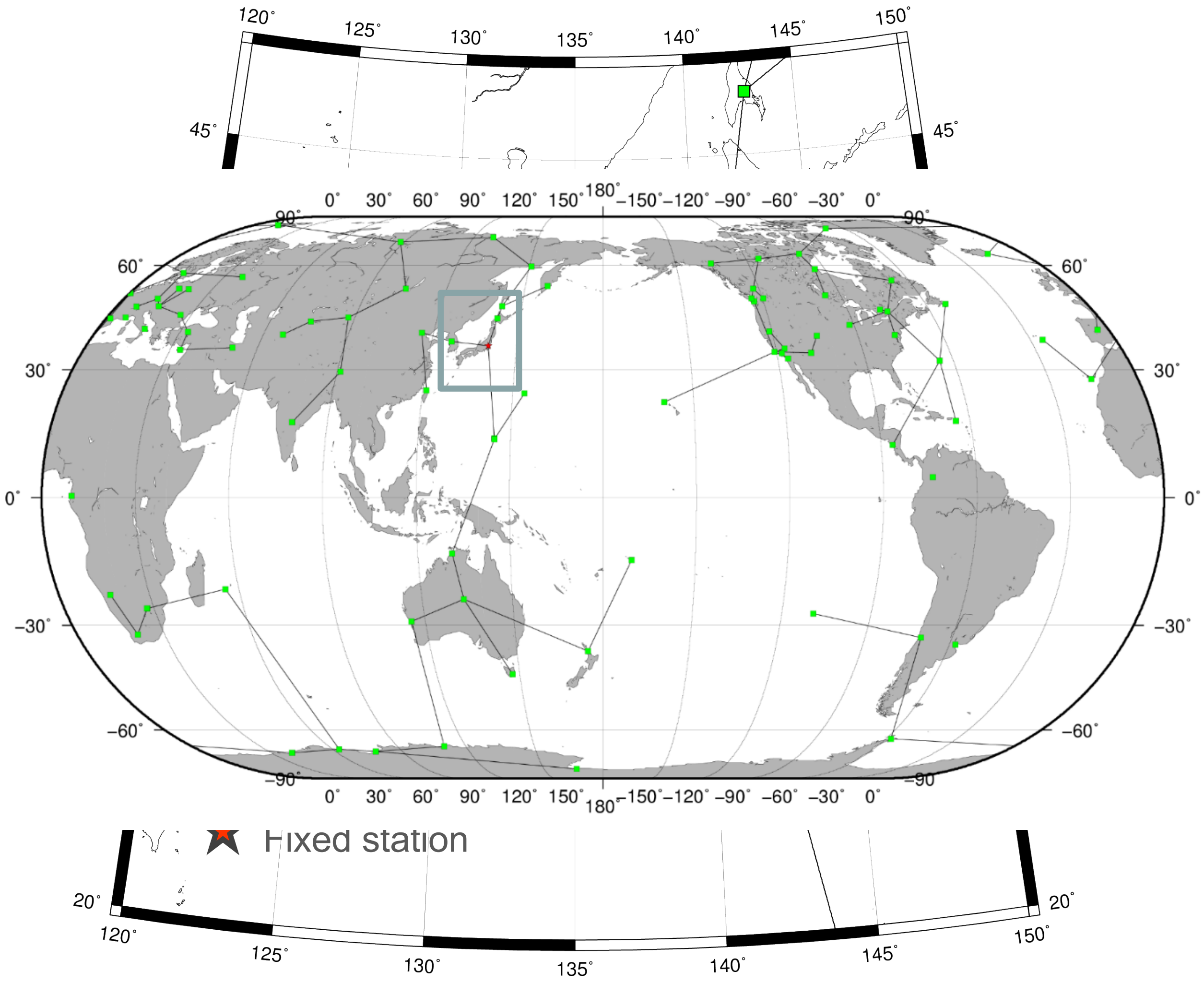
Results of GEONET analysis (daily coordinates at TSUKUBA-1)



We call the way of calculating coordinates of each GEONET station as “analysis strategy”.



Step of NEW GEONET analysis strategy

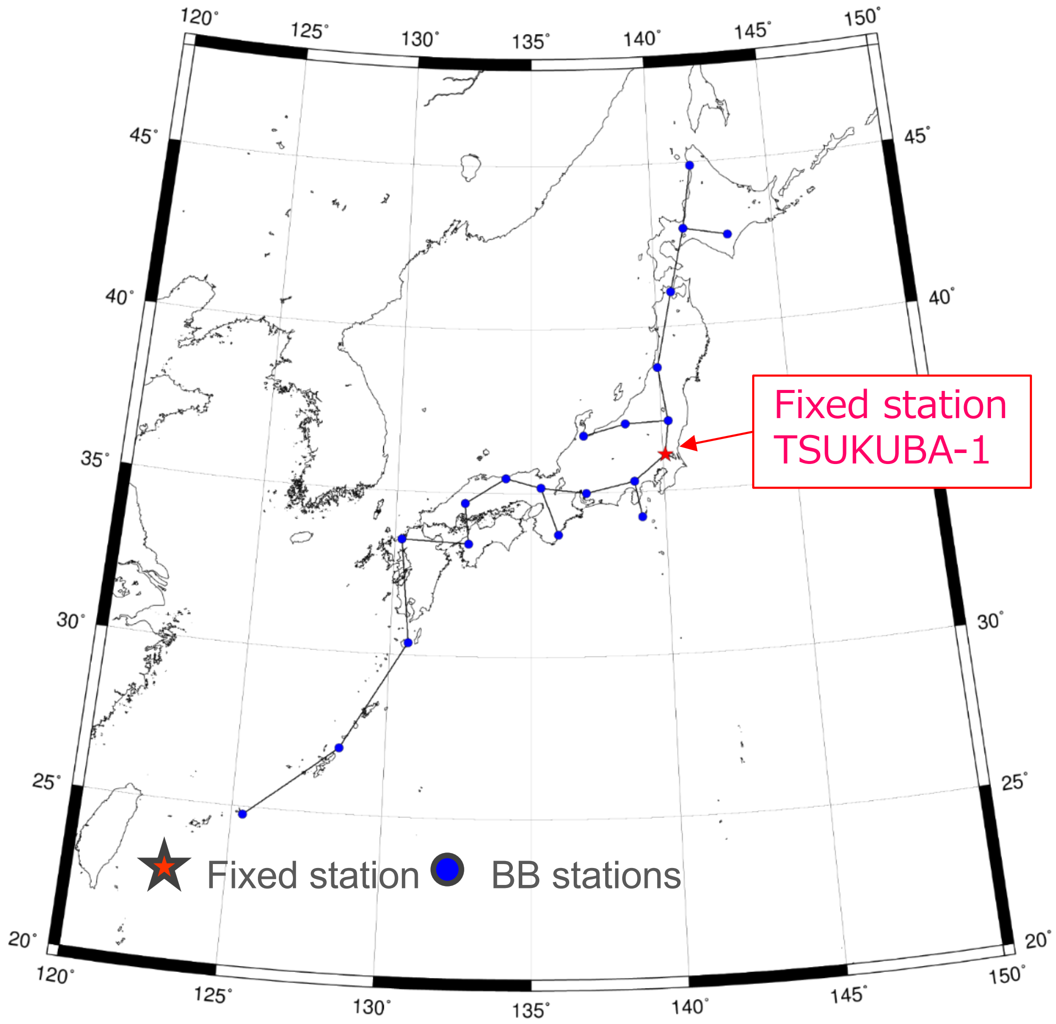


ITRF2014
Bernese software ver.5.2

- Calculate coordinates of one GEONET fixed point with IGS stations. (connected to ITRF)

Step of NEW GEONET analysis strategy

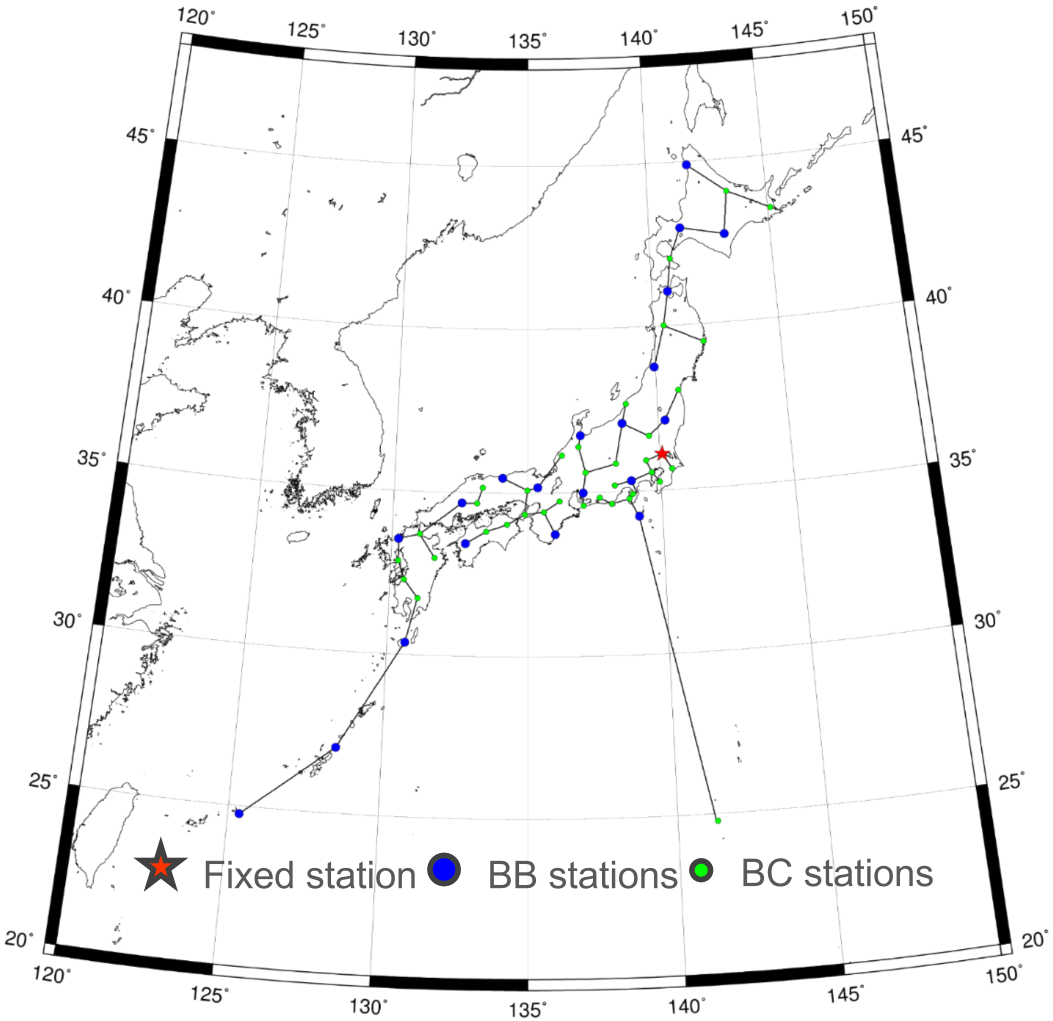
Geospatial Information Authority of Japan (GSI)



ITRF2014
Bernese software ver.5.2

- Calculate coordinates of one GEONET fixed point with IGS stations. (connected to ITRF)
- Select some Backbone (BB) stations in the whole of Japan.
- Calculate the coordinates of each BB station with fixed TSUKUBA-1.

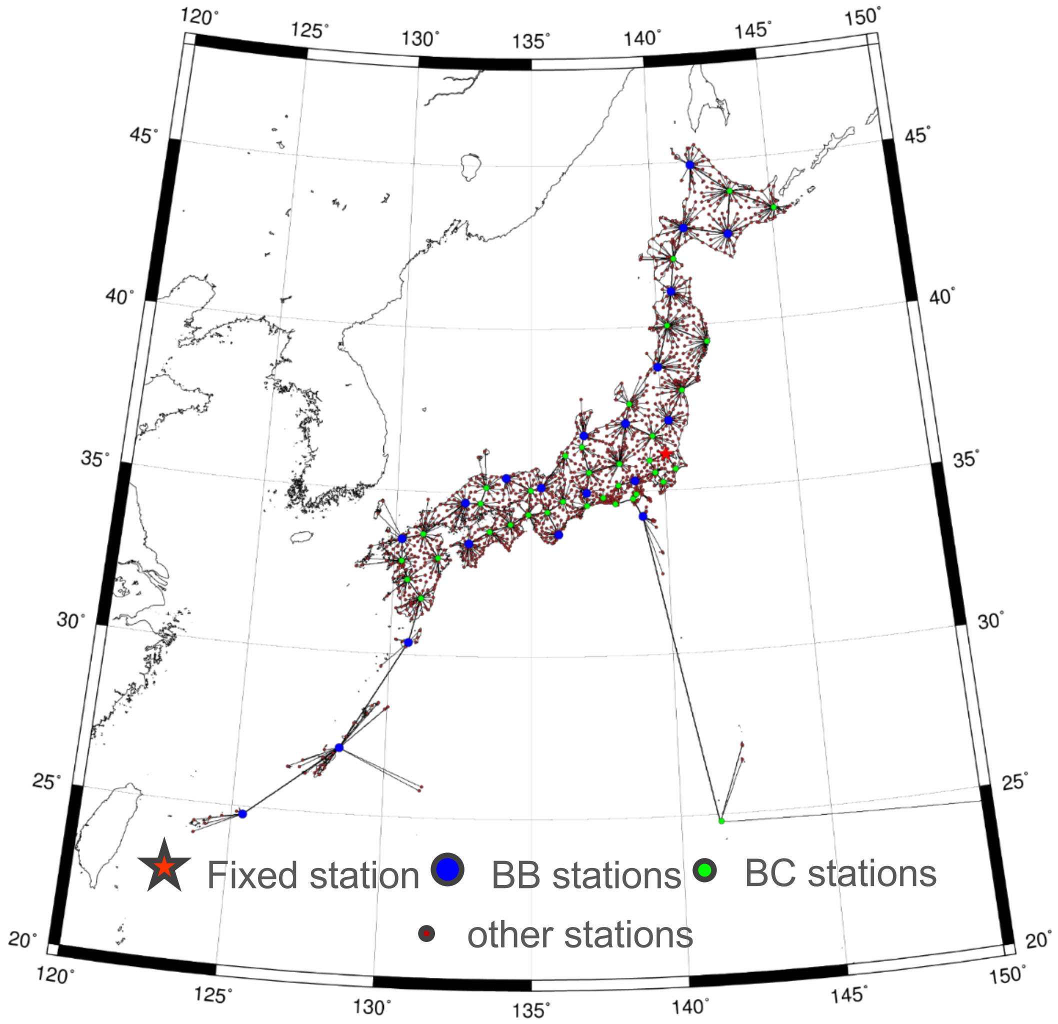
Step of NEW GEONET analysis strategy



ITRF2014
Bernese software ver.5.2

- Calculate coordinates of one GEONET fixed point with IGS stations. (connected to ITRF)
- Select some Backbone (BB) stations in the whole of Japan.
- Calculate the coordinates of each BB station with fixed TSUKUBA-1.
- Select some Basic Cluster (BC) stations in the whole of Japan.
- Calculate the coordinates of each BC station with fixed BB stations.

Step of NEW GEONET analysis strategy



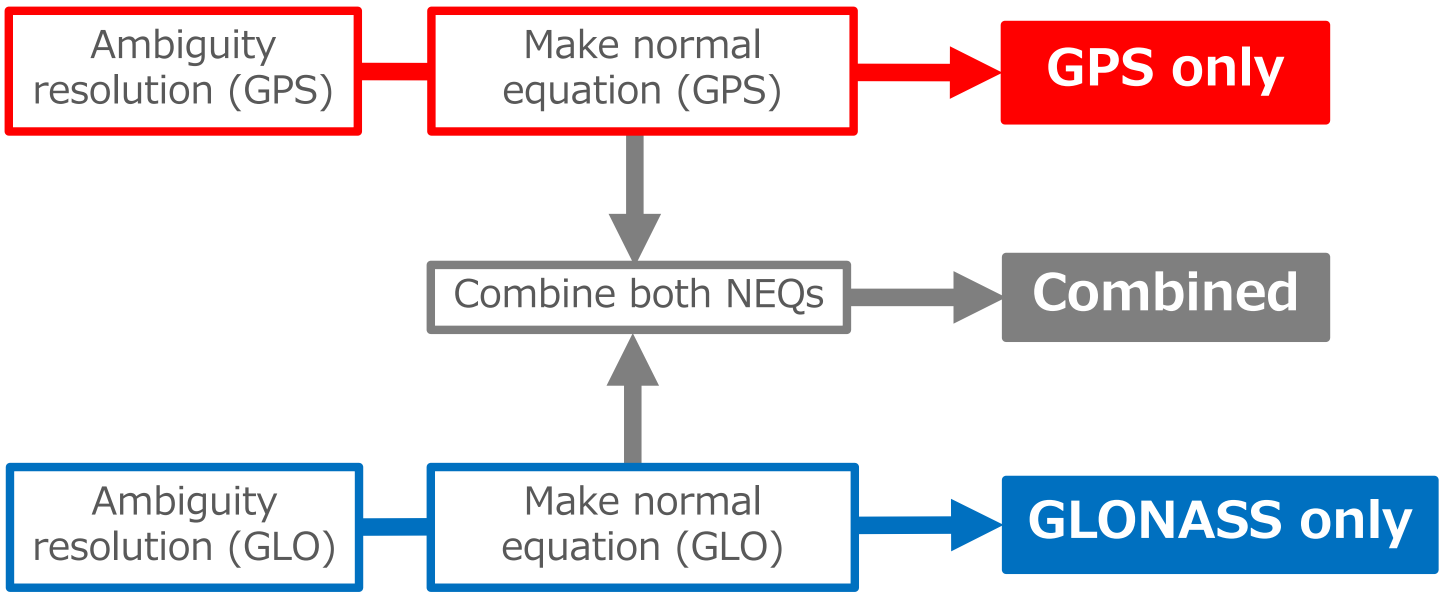
ITRF2014
Bernese software ver.5.2

- Calculate coordinates of one GEONET fixed point with IGS stations. (connected to ITRF)
- Select some Backbone (BB) stations in the whole of Japan.
- Calculate the coordinates of each BB station with fixed TSUKUBA-1.
- Select some Basic Cluster (BC) stations in the whole of Japan.
- Calculate the coordinates of each BC station with fixed BB stations.
- Calculate other stations which connected to BB and BC stations by radial baselines with fixed BB and BC stations.

Combination of GPS and GLONASS

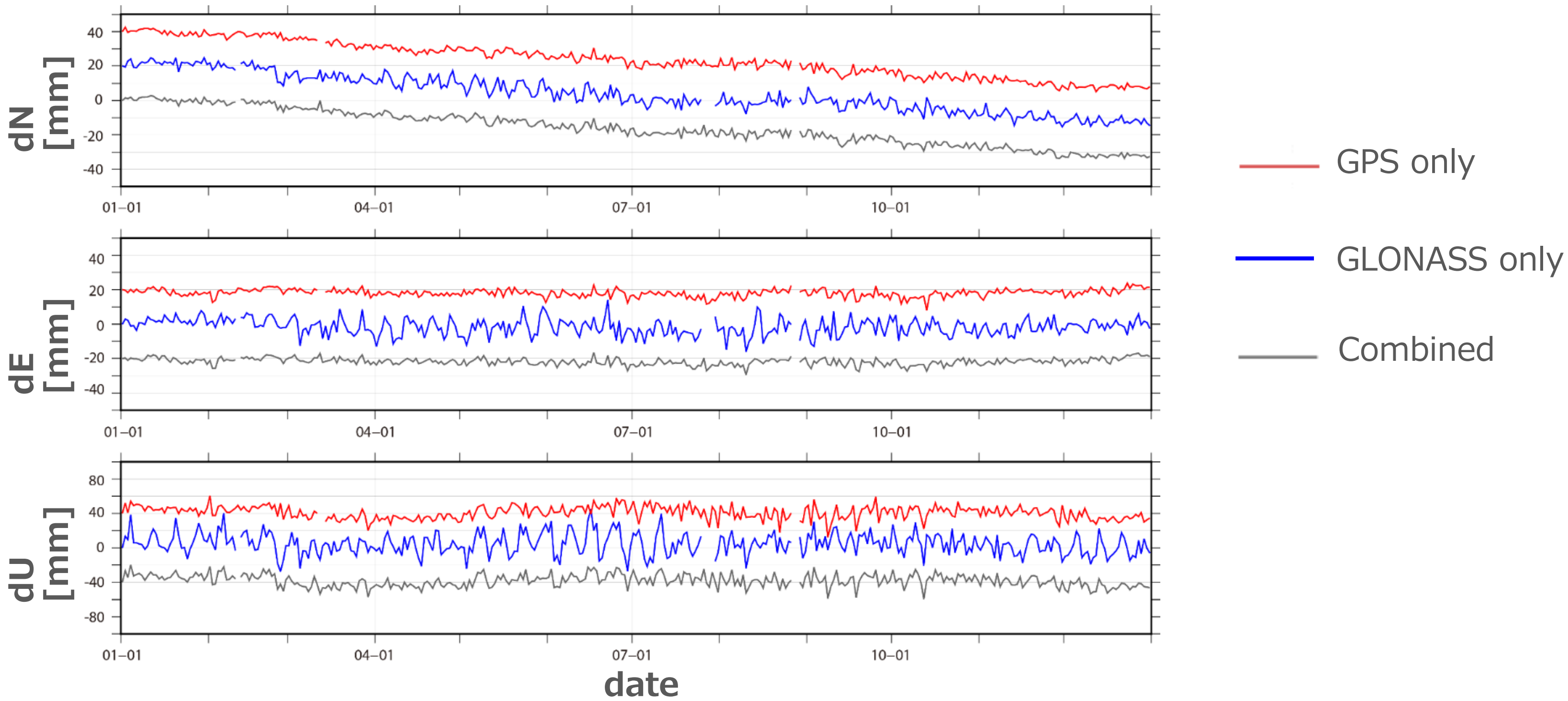
Solve GPS and GLONASS independently

coordinates and tropospheric delay



Initial Result of combination

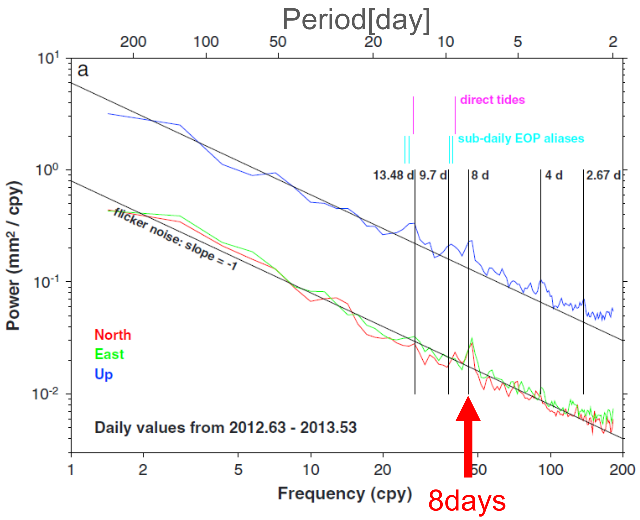
Time series of Baseline components at farthest station from fixed station for a year



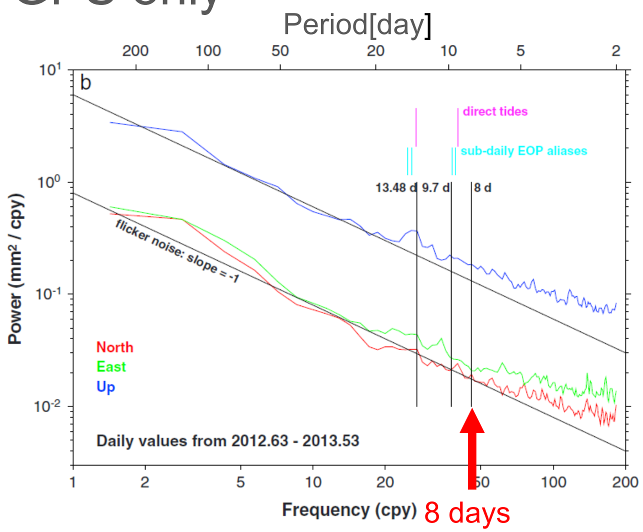
The periodic noise in GLONASS only solution also affects the combined solution

Problem of combination

GPS + GLONASS



GPS only

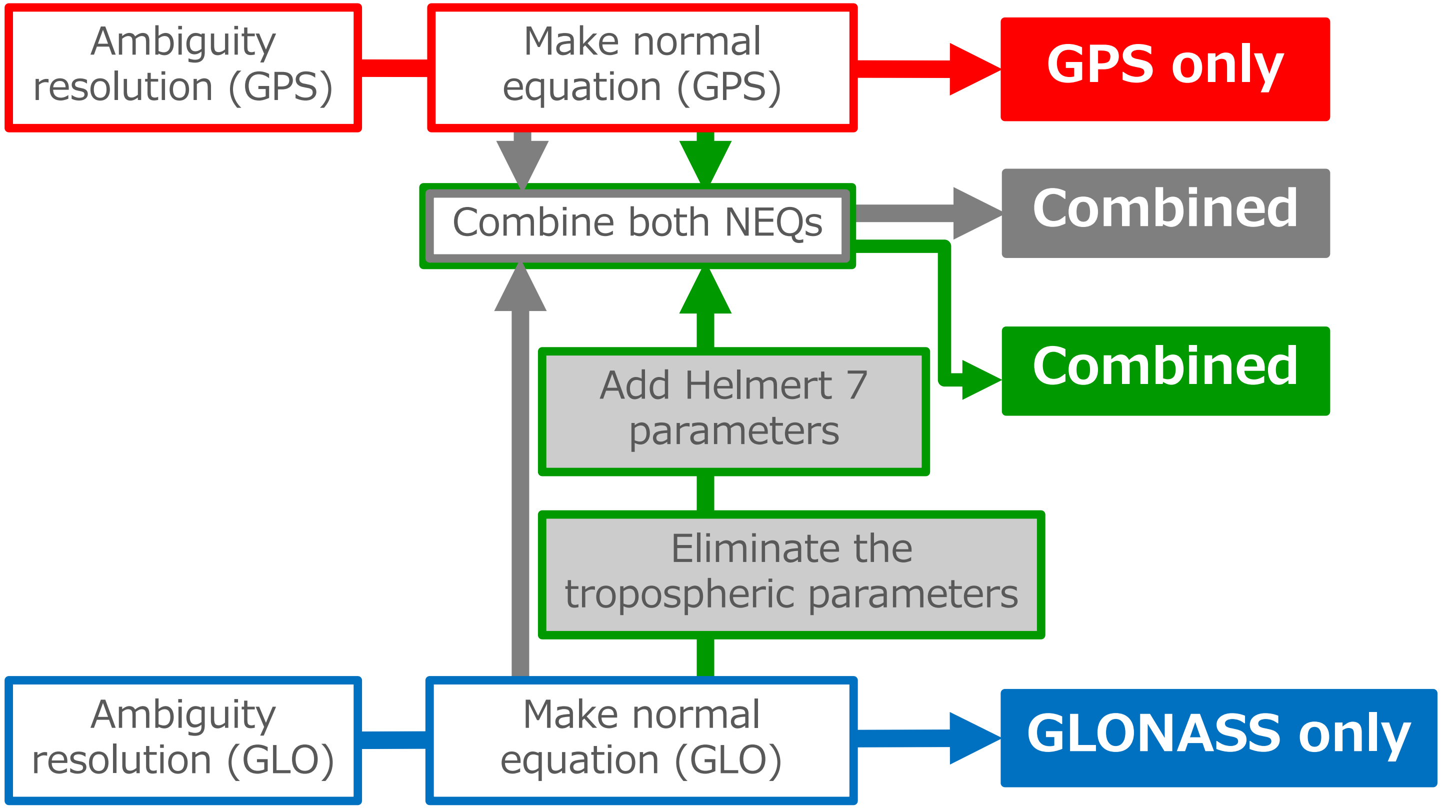


Modified after Ray et al. (2013, GRL)

Periodic noise (~8 days) is clear for GPS+GLONASS.

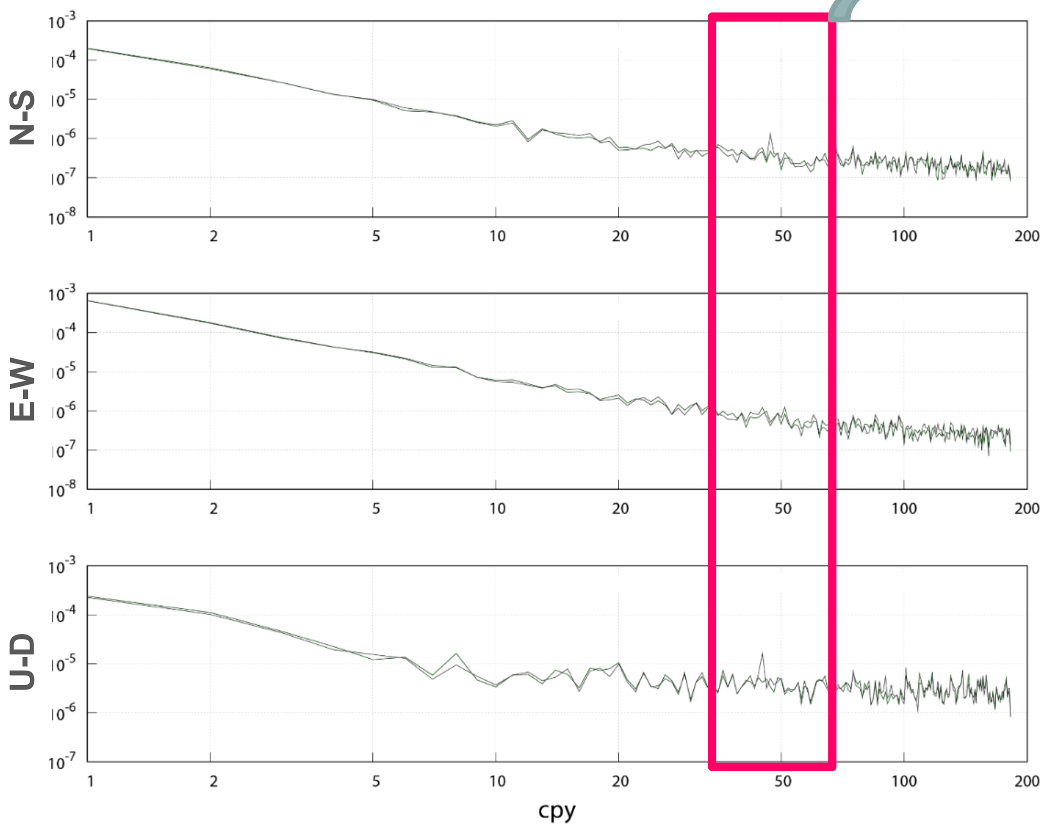
The geometry of GLONASS constellation may contribute to the periodic noise (Ray et al., 2013).

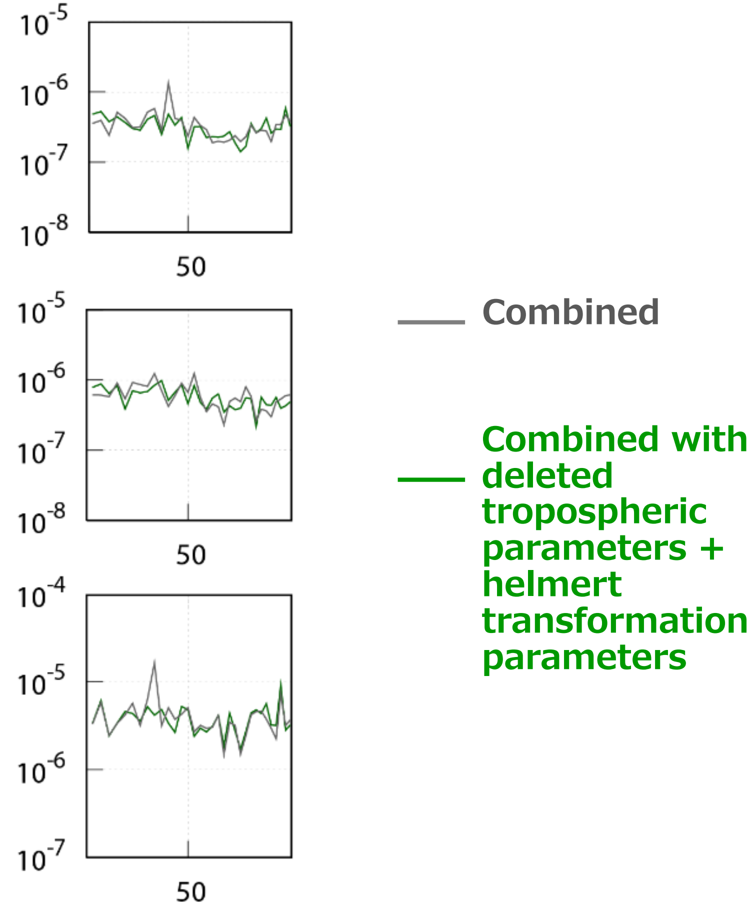
Improved combination of GPS and GLONASS



Periodic noise removed

Power spectrum of time-series of baseline
Stuck all GEONET stations.





Evaluation of accuracy

RMS error of time series of GEONET station

	NS[mm]	EW[mm]	UD[mm]	
GPS	1.52	1.60	6.24	
GLONASS	1.81	3.03	8.04	
Combined	1.44	1.54	5.65	<- contain periodic noise
Combined without GLONASS tropospheric parameter	1.45	1.58	5.71	<- does not contain periodic noise

Combined solution does not contain periodic noise.
But, RMS error is not the best.

For short-term crustal deformation monitoring,
we consider that removing periodic noise is better.

Conclusions

- Necessity of semi-dynamic correction to relate precise GNSS positioning and existing maps
- GSI is developing a new analysis strategy of GEONET("F4”)
  - ITRF2014, GPS+GLONASS

⇒ Realization of semi-dynamic reference frame using multi constellation of GNSS and IGS products in Japan

- Thank you for providing the state of the art GNSS services and IGS products, which enable the realization of “Geospatial Information Society”

How to get GEONET Data

Geospatial Information Authority of Japan (GSI)

- RINEX 30 sec, daily solutions F3, R3 (cc-by)
  - GSI web page http://terras.gsi.go.jp
  - To access from non-jp domain, see http://datahouse1.gsi.go.jp/terras/terras_english.html
  - Old RINEX before April 2010 (marginal cost)
    ⇒ Contact data@geo.or.jp
    (Japan Association of Surveyors)
- RINEX/BINEX 1 sec at events (marginal cost, cc-by)
  ⇒ See http://www.jsurvey.jp/eng-data_rinex-1sec.htm, Contact data@geo.or.jp
- Real-time stream 1 sec (commercial)
  ⇒ Contact Network RTK providers
  https://www.jenoba.jp/support/contact/
  https://www.gpsdata.co.jp/contact_us/
  https://www.terasat.co.jp/contact.html