Suppression of GLONASS apparent fluctuation with a period of 8 days

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Abstract

Geospatial Information Authority of Japan (GSI) has been operating Continuously Operating Reference Stations (CORS) called GEONET (GNSS Earth Observation Network System), since 1996. We currently operate more than 1,300 stations to cover whole Japan, with an average spacing of about 20km.

We calculate daily coordinates for each GEONET station by using Bernese GNSS software to monitor the crustal deformation in Japan. We are now developing new strategy because we use the old version Bernese (Ver.5.0), and reference frame and other physical models have been obsolete.

In this paper, we focus on the GPS and GLONASS integration. We process GPS and GLONASS data independently to estimate the ambiguities, and then combine the solutions with normal equations. The daily site coordinates from GLONASS data show the apparent fluctuation with the period of 8 days that was not found on the GPS result. This fluctuation is clear in longer baseline, but it is spatially systematic at least for regional network. For example, scale and frame rotation can explain the fluctuation. IGS analysis centers using GLONASS observations reported the same phenomenon that seemed to be caused by the GLONASS constellation geometry (Ray et al., 2013, Rebischung et al., 2016). Although we try to suppress the apparent fluctuation by introducing the Helmert transformation parameters of GLONASS when the normal equation of GPS and GLONASS are combined, it remains in troposphere delay parameters. Thus, eliminating troposphere delay parameters of GLONASS normal equation is applied in addition to above procedure. As a result, the apparent fluctuation is suppressed.

How does the 8-day fluctuation appear in GEONET?

Analysis settings

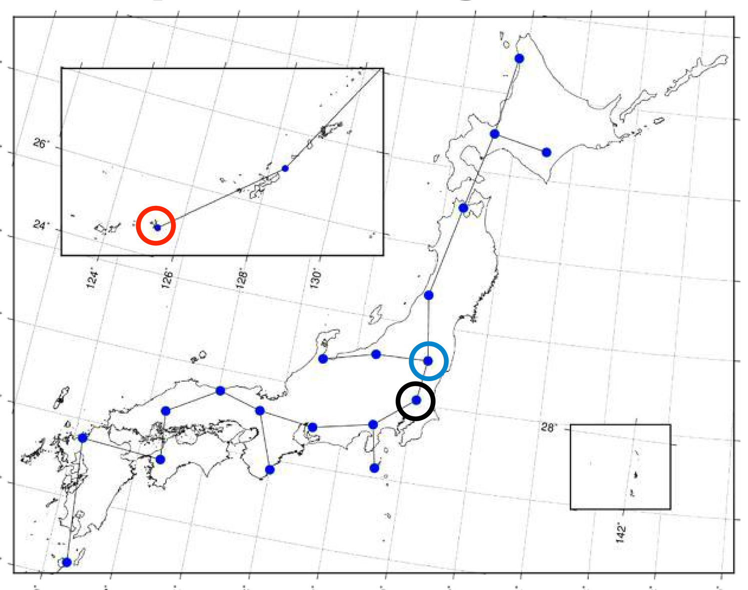

Fig.1. Distribution of stations

- Period: 2014/01/01 ~ 2014/12/31
- Satellite systems:
  Solve GPS and GLONASS independently
- Parameter estimation:
  coordinate, troposphere parameters

○ 2110: Fixed site (Tsukuba-1)
○ 0210: Nearest from 2110
○ 0498: Farthest from 2110

Results

- The daily site coordinates from GLONASS data show the apparent fluctuation with the period of 8 days.
- The 8-day fluctuation is **clear in longer baseline and UD components** (Fig.2).
- The scale of fluctuation **depends on season** (Fig.2, shaded period).
- The fluctuation also **intrudes to troposphere parameters** (Fig.3).

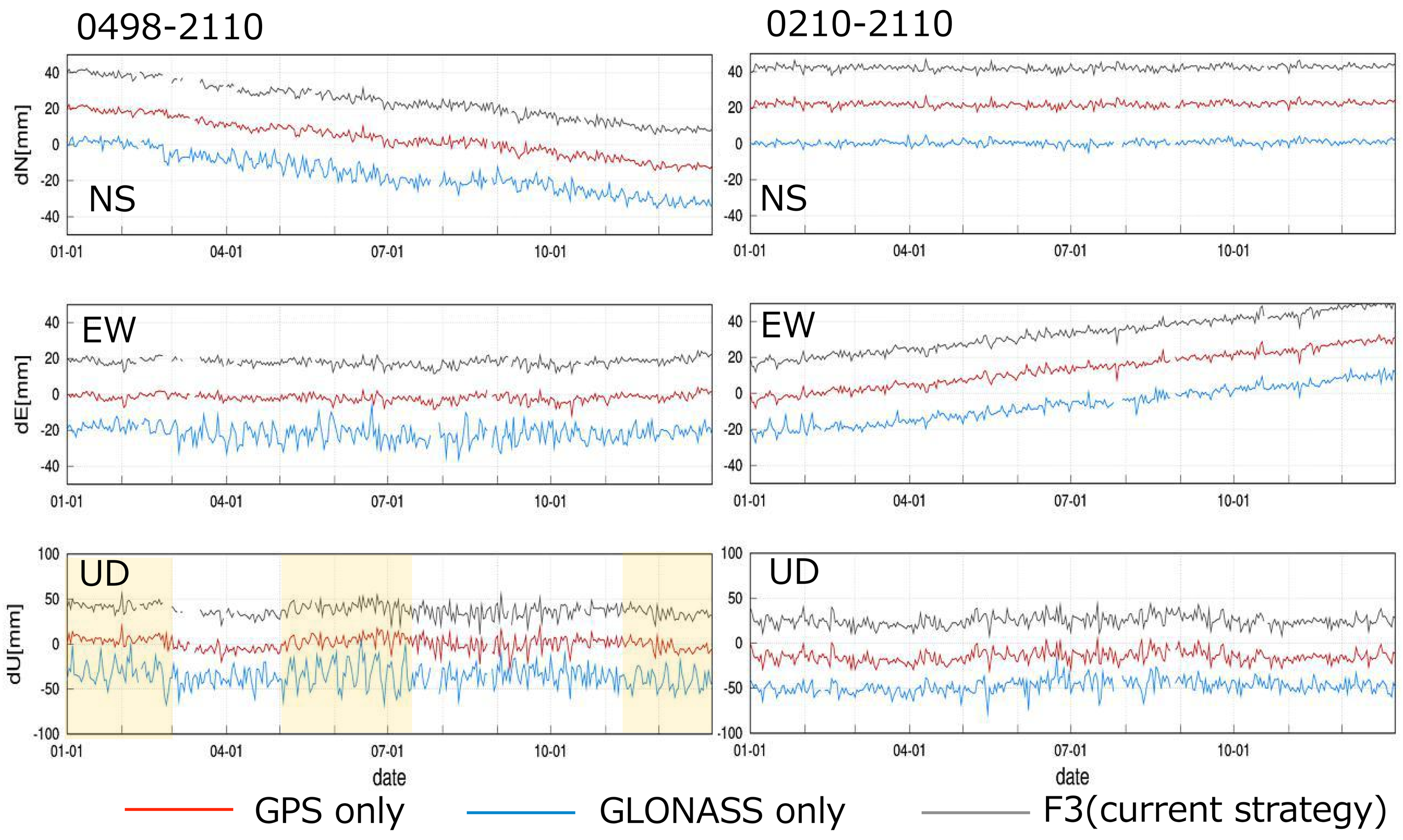

Fig.2. Time-series of baseline components

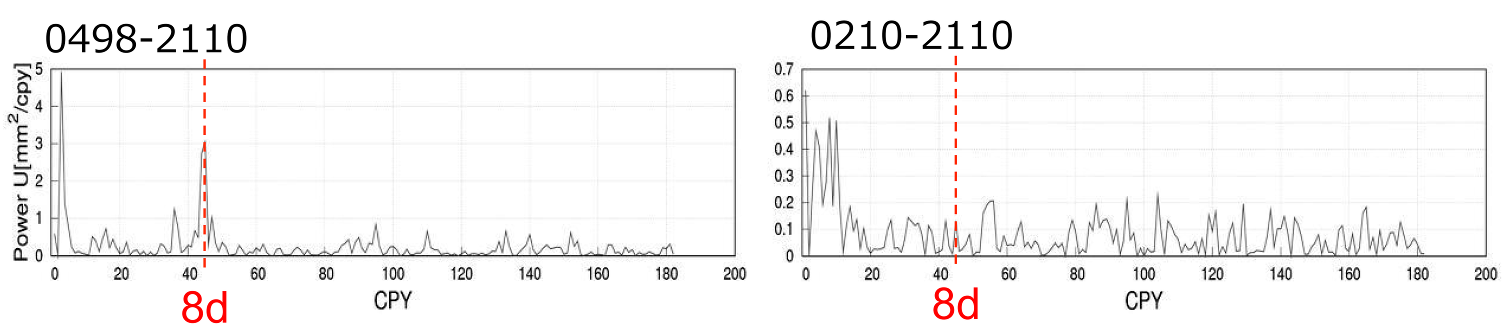

Fig.3. Power spectrum of troposphere parameters
(difference between GPS and GLONASS)

Can Helmert 7 parameters explain the 8-day fluctuation?

Analysis settings

Make time series of coordinate estimated by GLONASS only
→ Remove linear trend
→ Shift origin to 2110
→ Make following observation equation
→ Estimate Helmert 7 parameters day-by-day.

Design Matrix · Helmert 7 parm. · Observables

$$\begin{bmatrix} 1 & 0 & 0 & x_1 & 0 & z_1 & -y_1 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & 0 & 0 & x_n & 0 & z_n & -y_n \\ 0 & 1 & 0 & y_1 & -z_1 & 0 & x_1 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 1 & 0 & y_n & -z_n & 0 & x_n \\ 0 & 0 & 1 & z_1 & y_1 & -x_1 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 1 & z_n & y_n & -x_n & 0 \end{bmatrix} \begin{bmatrix} T_x \\ T_y \\ T_z \\ Sc \\ R_x \\ R_y \\ R_z \end{bmatrix} = \begin{bmatrix} \Delta x_1 \\ \vdots \\ \Delta x_n \\ \Delta y_1 \\ \vdots \\ \Delta y_n \\ \Delta z_1 \\ \vdots \\ \Delta z_n \end{bmatrix}$$

T_x, T_y, T_z: Translation; Sc: Scale; R_x, R_y, R_z: Rotation

(x_i, y_i, z_i); Mean component of coordinate

$(\Delta x_i, \Delta y_i, \Delta z_i)$; Fluctuation component of coordinate

Results

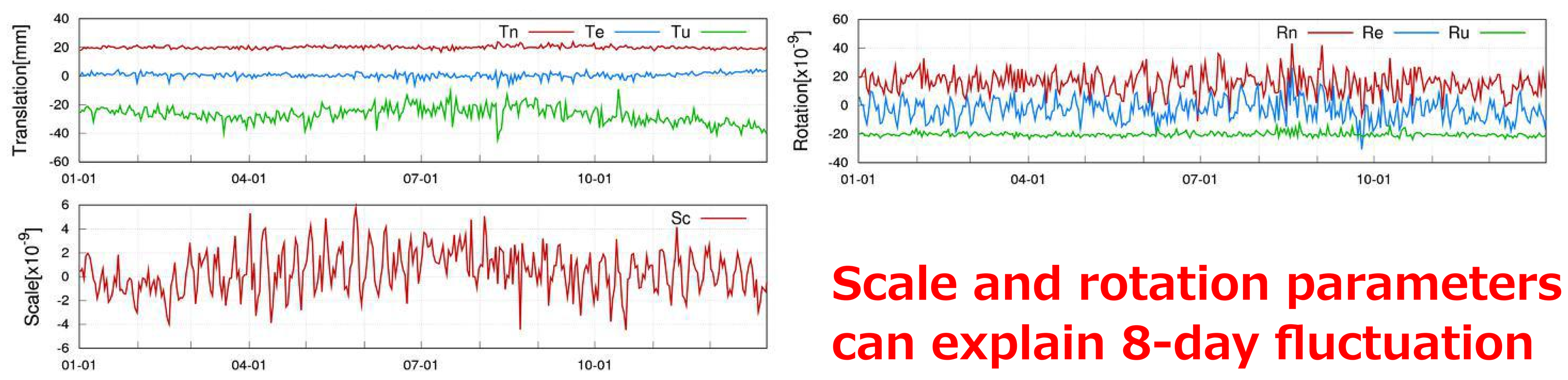

Fig.4. Time series of estimated 7 parameters

Scale and rotation parameters can explain 8-day fluctuation

Introducing 3 reduction methods

Flow diagram of reduction method

- We developed 3 method, i.e. **Combined**, **Combined with GLO TRP**, and **Combined without GLO TRP**, to reduce fluctuation.

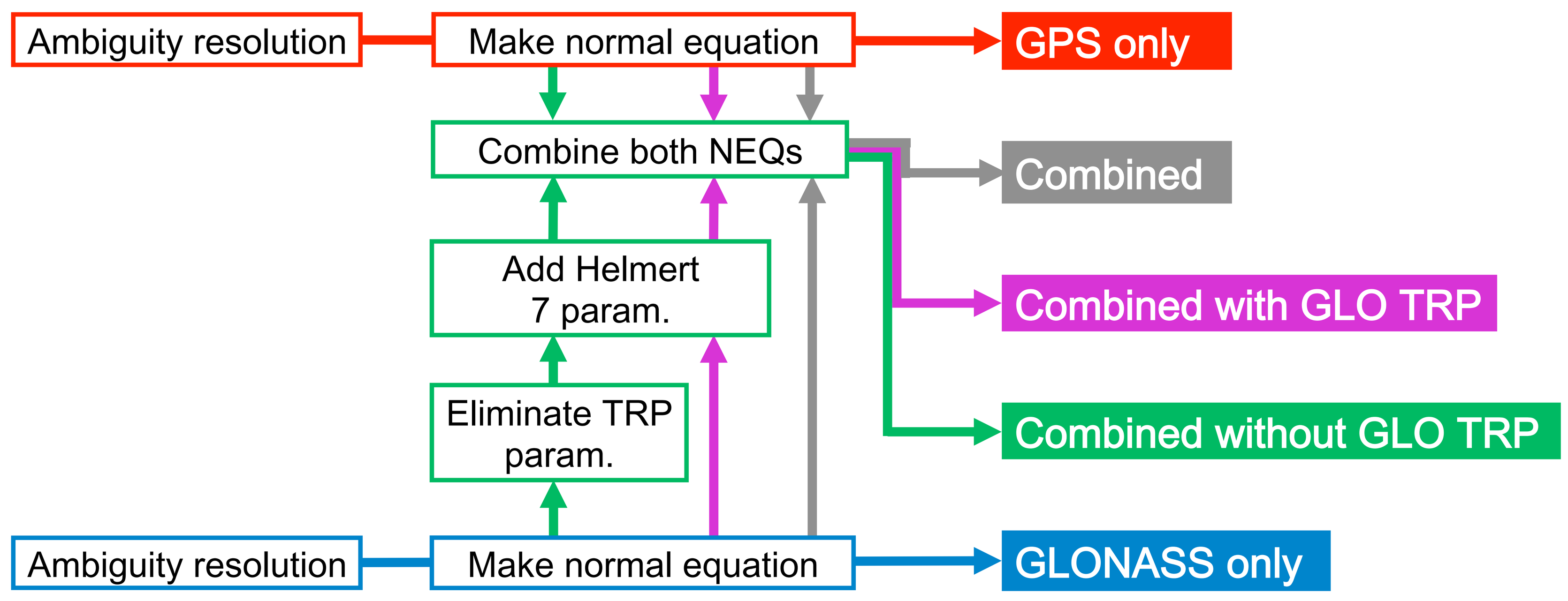

Fig.5. The flow diagram to reduce the 8-day fluctuation

Results

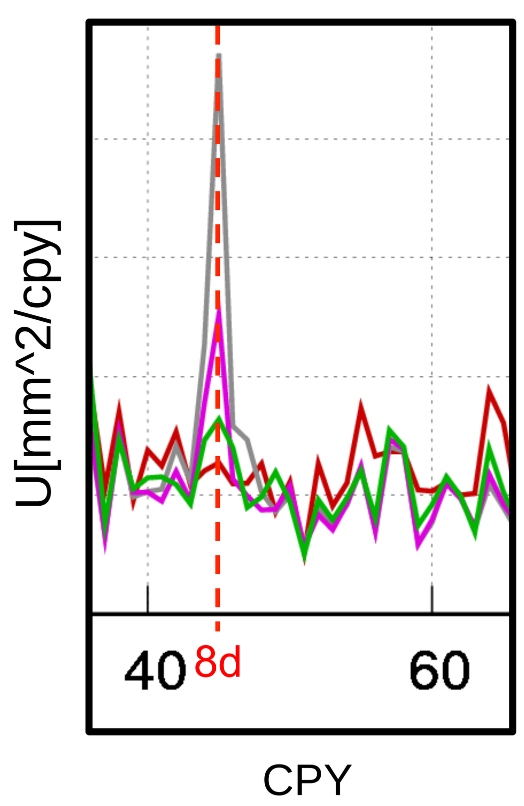

Fig.6. Power spectrum of baseline components

Table 1. RMSE of coordinate from regression curve*

	NS	EW	UD
GPS	1.52	1.60	6.24
GLO	1.81	3.03	8.04
Combined	1.44	1.54	5.65
Combined with GLO TRP	1.43	1.53	5.61
Combined without GLO TRP	1.45	1.58	5.71

*Regression curve is estimated for each site as follows

$$Y_i = A_0 + A_1 t + C_1 \cos\left(\frac{2\pi}{365} t + \alpha_1\right) + C_2 \cos\left(\frac{2\pi}{365} 2t + \alpha_2\right)$$

- The 8-day fluctuation was successfully reduced by **Combined without GLO TRP** scheme (Fig.6).
- The most accurate method is **Combined with GLO TRP**, not **Combined without GLO TRP** (Table 1)

→Although the 8-day fluctuation is suppressed by **Combined without GLO TRP scheme**, the longer fluctuation, i.e. 3-8 cpy (45-120 day) appear significantly.