# IGS14/igs14.atx: a new framework for the IGS products

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## Introduction — A

The International GNSS Service (IGS) is about to switch to a new reference frame (IGS14), based on the latest release of the International Terrestrial Reference Frame (ITRF2014; Altamimi et al., 2016), as the basis for its products. An updated set of satellite and ground antenna calibrations (igs14.atx) will become effective at the same time. IGS14 and igs14.atx will then replace the previous IGS08/igs08.atx framework in use since GPS week 1632 (17 April 2011) and thus applied for the second IGS reprocessing campaign (repro2).

The official switch to the IGS14/igs14.atx framework is now expected by the **end of January 2017**.

## What's new in igs14.atx? — B

### Ground antenna calibration updates

Compared to igs08.atx, igs14.atx includes robot calibrations for 17 additional ground antenna types, so that the percentage of stations with absolute calibrations in the IGS network will reach >90% after the switch (Table 1). 19 type-mean robot calibrations were also updated thanks to the availability of calibration results for additional antenna samples.

The impact of the ground antenna calibration updates on IGS station positions was assessed by means of differential PPP solutions. In general, the estimated position offsets are not negligible and can reach up to 6 mm in horizontal and 19 mm in vertical direction.

Latitude-dependent models were additionally derived. They can be used to assess the impact of the ground antenna calibration updates from igs08.atx to igs14.atx on the positions of specific (non-IGS) stations.

| | igs08.atx | igs14.atx |
|---|---|---|
| Absolute calibration | 428 (84.9%) | 457 (90.7%) |
| Converted field calibration | 31 (6.2%) | 11 (2.2%) |
| Uncalibrated radome | 45 (8.9%) | 36 (7.1%) |

*Table 1* Antenna calibration status of the 504 current IGS stations, based on either igs08.atx or igs14.atx

### Satellite antenna calibration updates

Despite the negligible scale difference between ITRF2008 and ITRF2014 (0.02 ppb), the radial components of all GPS and GLONASS satellite antenna phase center offsets ($z$-PCOs) had to be updated in igs14.atx, because of recent modeling changes affecting the scale of the IGS products (Earth radiation pressure, antenna thrust). This was achieved by deriving time series of satellite antenna $z$-PCO estimates, consistent with the ITRF2014 scale, from the daily repro2 and latest operational SINEX solutions of seven IGS analysis centers (ACs). The $z$-PCO time series were then trend-corrected to epoch 2010.0 before computing weighted averages. From igs08.atx to igs14.atx, satellite antenna $z$-PCOs change by −6 cm on average, which induces a net scale change of the IGS terrestrial frame solutions by approximately +0.5 ppb (+3 mm; see Section E).

Satellite-specific $x$- and $y$-PCOs from pre-flight calibrations were additionally introduced in igs14.atx for the GPS Block IIR satellites (Dilssner et al., 2016).

## Focus on the terrestrial scale — E

The **mean scale** of the IGS terrestrial frame solutions is conventionally defined by the adopted satellite antenna $z$-PCOs (e.g., Ray et al., 2013). The $z$-PCO values estimated for igs08.atx allowed to access the ITRF2008 scale. However, due to recent orbit modeling changes, the mean scale of the repro2 and current IGS solutions differs from the ITRF2008 scale by about −0.3 ppb (see bias in Figure 5, top). The igs14.atx $z$-PCO values, in contrast, give access to the ITRF2014 scale at epoch 2010.0 (Figure 5, bottom).

The **long-term scale rate** of the IGS terrestrial frame solutions is determined by the use of *constant* $z$-PCO values and can be compared with the ITRF scale rate (Collilieux and Schmid, 2013). Figure 5 shows, based on the daily repro2 combined solutions, that this "intrinsic GNSS scale rate" differs from the ITRF2008 scale rate by only −0.004 ppb/yr (−0.03 mm/yr), whereas it significantly differs from the ITRF2014 scale rate by +0.026 ppb/yr (+0.17 mm/yr). The difference between the two values perfectly matches the differential scale rate of 0.03 ppb/yr between ITRF2014 and ITRF2008 (Altamimi et al., 2016).

**Non-linear scale differences** between the daily repro2 combined solutions and IGb08/IGS14 are expected from

- the aliasing of non-linear deformations of the station network into the estimated daily scale offsets (→ mostly annual + semi-annual signals),
- imperfections in the adopted satellite antenna $z$-PCO values combined with changes in the observed satellite constellation (Ge et al., 2005).

Figure 5 shows that the non-linear, non-seasonal scale variations (red) are less scattered when using igs14.atx, especially in recent years. This indicates an improvement of the igs14.atx satellite antenna $z$-PCO values compared to igs08.atx, especially for recently launched satellites.

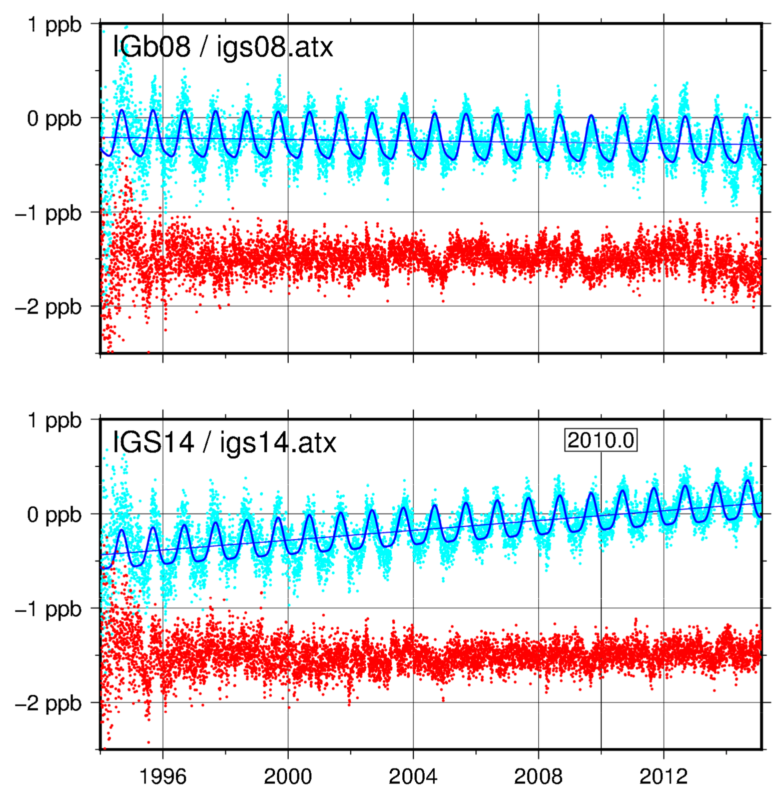


*Figure 5* Cyan: Scale factors between IGb08/IGS14-based daily repro2 solutions and IGb08/IGS14
Blue: linear trend [+ annual and semi-annual signals]
Red: residuals of the fits, shifted by -1.5 ppb

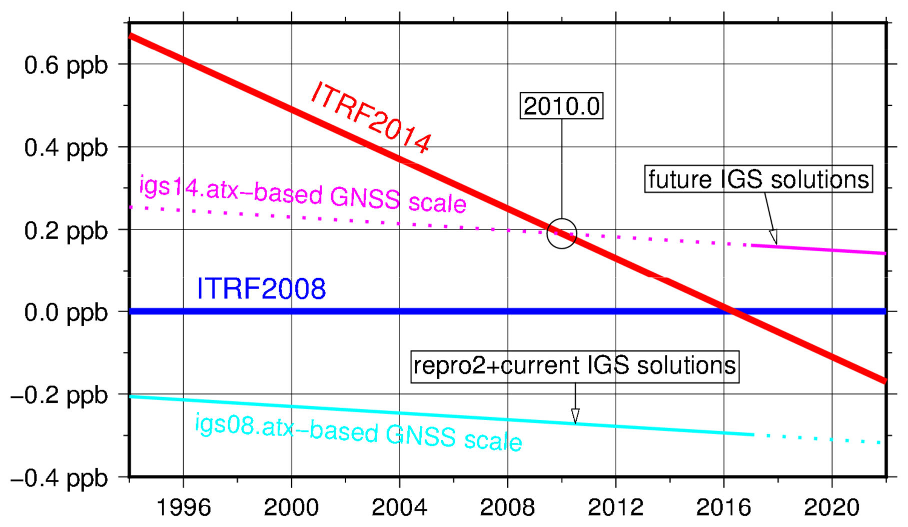


*Figure 6* Schematic representation of the scale and scale rate differences between ITRF2008, ITRF2014 and GNSS solutions based on either igs08.atx or igs14.atx

### Summary

- The 0.03 ppb/yr scale rate difference between ITRF2014 and ITRF2008 clearly shows up when confronting the daily repro2 solutions with both RFs.
- The "intrinsic GNSS scale rate" based on constant $z$-PCO values is closer to the ITRF2008 than to the ITRF2014 scale rate.
- The scale of igs14.atx-based GNSS solutions matches the ITRF2014 scale at epoch 2010.0, but progressively diverges with time.

## IGS14 and IGS14 core network design — C

IGS14 is basically an extract of 252 well-suited reference frame stations (i.e., with long and stable position time series) from ITRF2014 (Figure 1). However, to make the IGS14 station coordinates consistent with the new igs14.atx ground antenna calibrations, position offsets due to the switch from igs08.atx to igs14.atx were derived for all IGS14 stations affected by ground antenna calibration updates and applied to the ITRF2014 coordinates.

A well-distributed IGS14 *core* network was additionally designed for the purpose of aligning global GNSS solutions. It is composed of 51 clusters of stations (i.e., 51 primary stations, each with possible substitutes) selected to ensure a homogeneous global distribution (Figure 2) and the best possible temporal stability of the core network (Figure 3, bottom right).

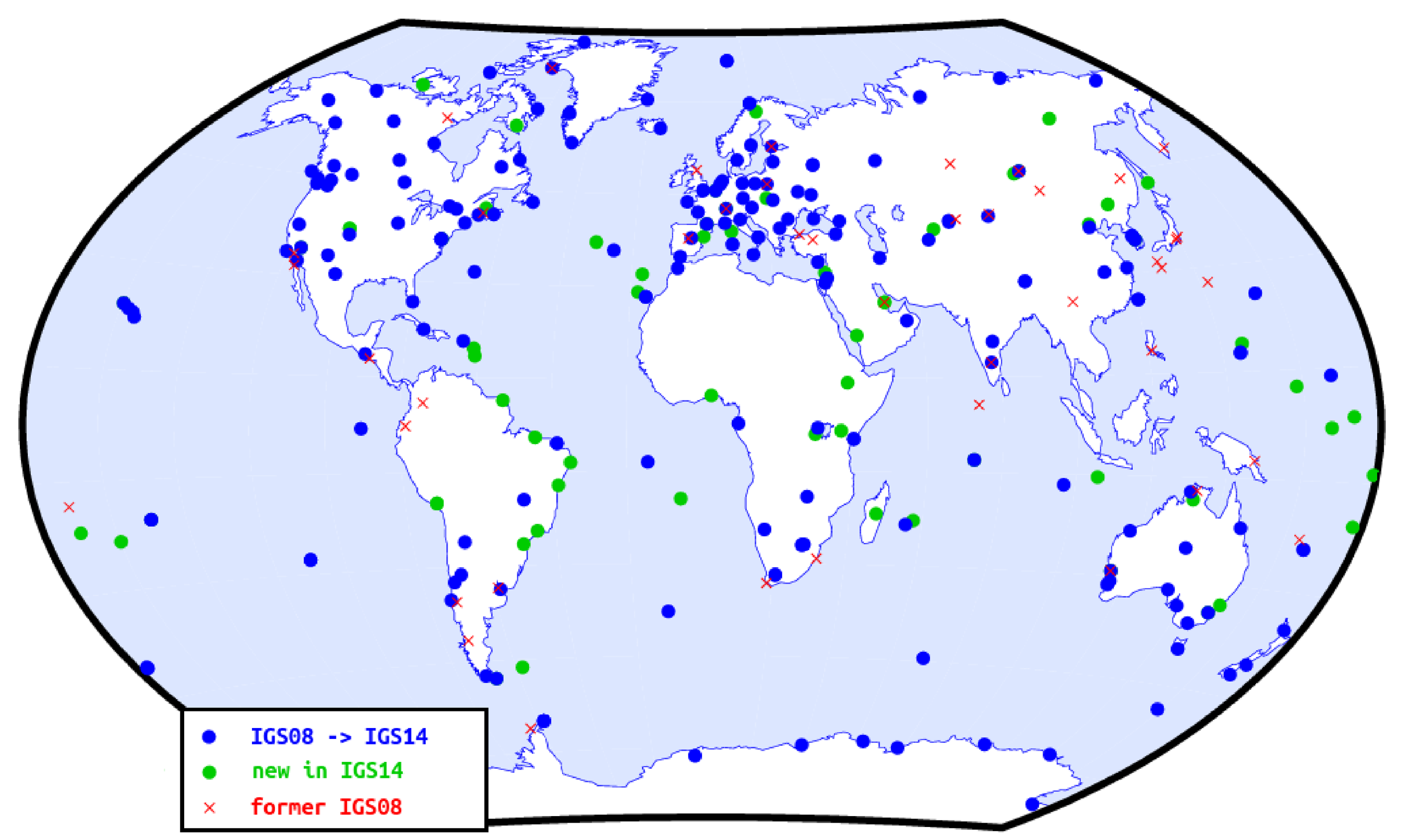


*Figure 1* Distribution of the IGS14 and the former IGS08 RF stations

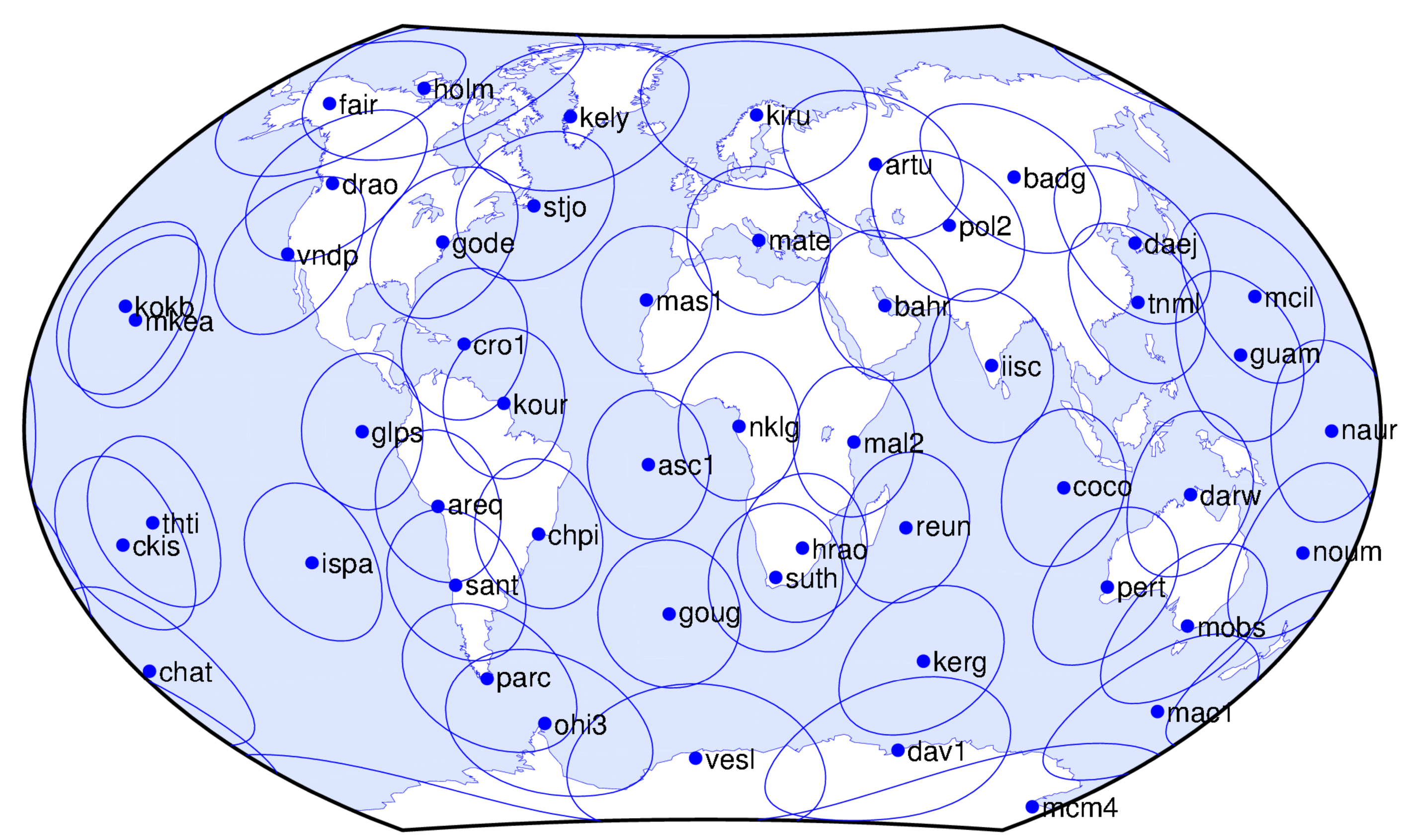


*Figure 2* Distribution of the 51 primary stations of the IGS14 core network

## Impact on GNSS-derived geodetic parameters — D

In order to assess the impact of the switch from IGb08/igs08.atx to IGS14/igs14.atx on GNSS-derived geodetic parameters, the daily repro2 AC solutions were re-combined with two changes compared to the official daily repro2 SINEX combinations (Rebischung et al., 2016):

- Satellite PCOs were fixed to their **igs14.atx** values in the input AC solutions.
- The combined solutions were aligned to the **IGS14** core network. (Note that non-corrected ITRF2014 coordinates were used as reference coordinates for the IGS14 core stations, since the AC repro2 solutions are consistent with the igs08.atx ground antenna calibrations.)

Figure 3 shows the WRMS of the alignment of each daily combined solution to either the IGb08 or IGS14 core network. A notable improvement is obtained with IGS14 after 2010, when IGb08 coordinates are extrapolated.

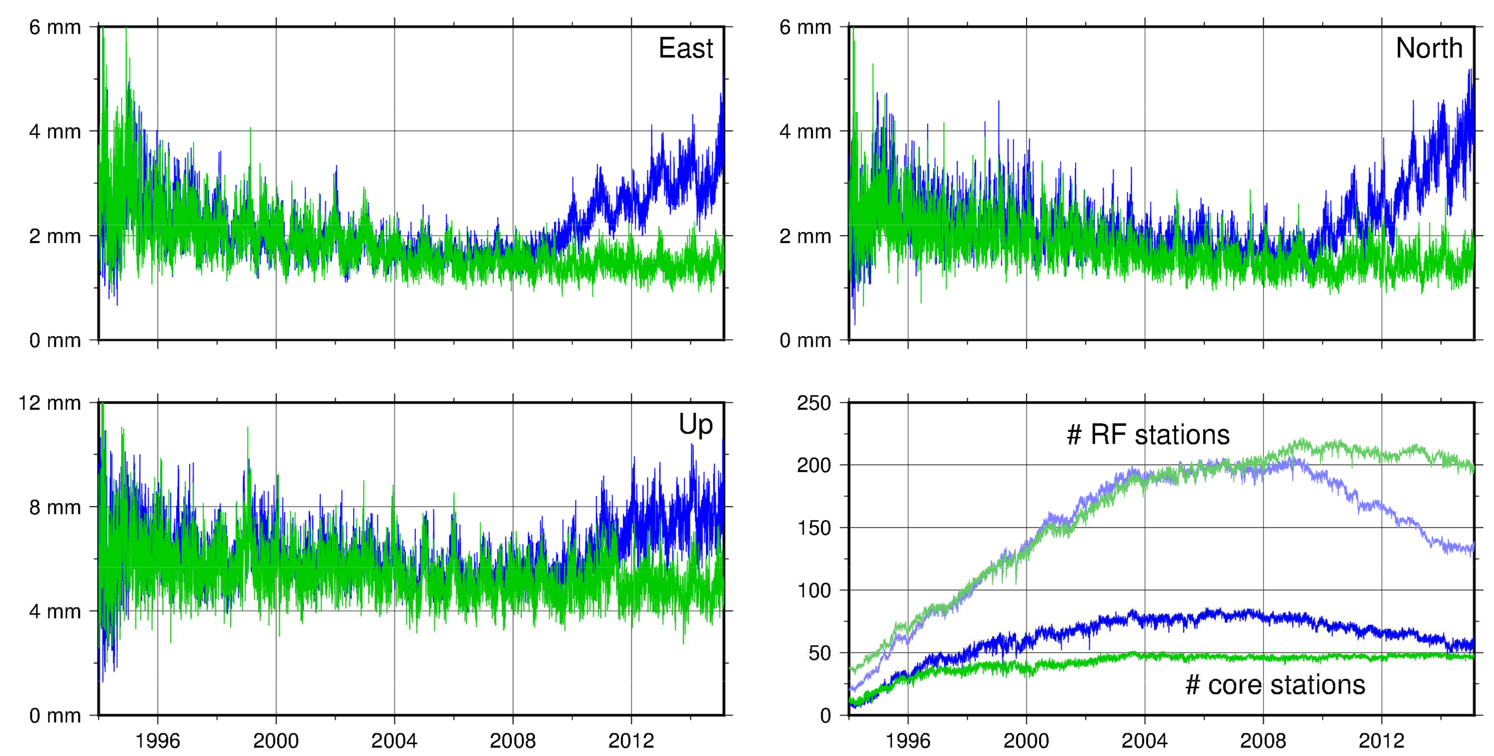


*Figure 3* Top and bottom left: WRMS of the residuals of 7-parameter similarity transformations between the repro2 daily combined SINEX solutions and (a) the IGb08 core network, (b) the IGS14 core network
Bottom right: Number of available IGb08/IGS14 [core] stations in the repro2 daily combined SINEX solutions

Figure 4 shows the apparent geocenter and pole coordinate differences between both sets of daily combined solutions (IGS14 vs. IGS08; blue) together with differential translations and rotations between the two sets (red).

- The **pole coordinate** differences $\delta x_p$, $\delta y_p$ perfectly match the differential rotations, indicating that they are entirely due to the RF change (i.e., ITRF datum change + update of the individual ITRF station coordinates).
- The **pole rate and LOD** differences (not shown) are insignificant (WRMS of 6 µas/d and 0.3 µs/d, respectively).
- The **apparent geocenter** coordinate differences $\delta X_{GC}$, $\delta Y_{GC}$, $\delta Z_{GC}$ can also mostly be explained by the RF change. A small additional periodic effect is visible for the $Z$-component, presumably due to the update of the satellite antenna $z$-PCOs. However, the differences are small compared to the general variability of the apparent geocenter time series.
- The impact on the **terrestrial scale** is discussed in Section E.

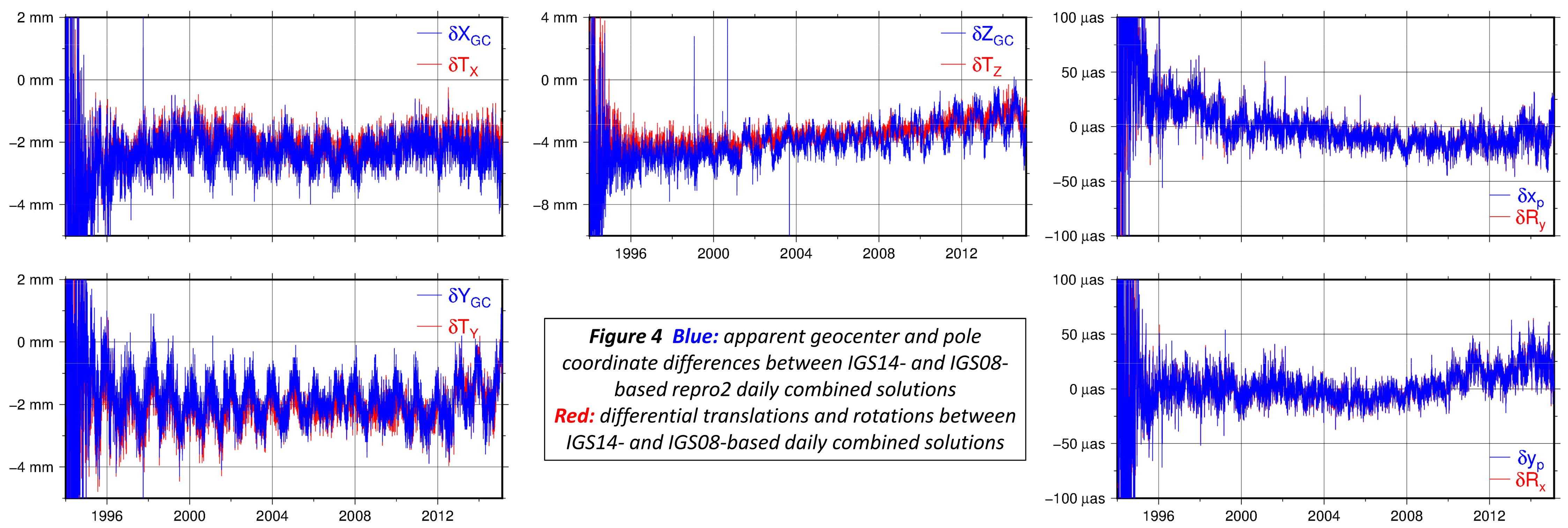


*Figure 4* Blue: apparent geocenter and pole coordinate differences between IGS14- and IGS08-based repro2 daily combined solutions
Red: differential translations and rotations between IGS14- and IGS08-based daily combined solutions

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