Answer to Referee Comments RC1: Advancing geodynamic research in Antarctica: Reprocessing GNSS data to infer consistent coordinate time series (GIANT-REGAIN), essd-2024-355

January 29, 2025

We thank Alvaro Santamaría-Gómez and the anonymous reviewer for the very helpful and constructive comments, which helped to improve the manuscript, as well as the data set. In the following, we discuss the reviewers comments, elaborate on our initial responses and describe the extent to which the manuscript or dataset has been edited. We structured the RC comments identical to our initial response. The referee comment is given in italic, followed by the author's response in green. We then indicate the updated text passage and changes in the manuscript.

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1 Responds to RC1

RC 1.1: *The four input solutions represent different realizations of the IGb14 frame and it is natural that the authors decided to harmonize the frame differences. Some of the input solutions were globally aligned to the IGb14 frame while others were aligned using a regional subset of the IGb14 frame. A regional frame alignment is a very effective way to remove common-mode noise from the daily position time series, and conversely, a global frame alignment is effective in introducing frame noise into the daily position time series. In addition, the quality of the frame alignment could change over time differently among the solutions, especially for those based on sparse regional subsets. The frame noise in the input solutions can be minimized by applying a new regional daily frame alignment to all the solutions, so that all the aligned series have a consistent level of frame noise before their combination. However, the authors decided to remove the long-term alignment bias only, instead of removing an alignment bias on a daily basis (the frame jitter) that would account for both the frame bias and the frame noise altogether.*

Of course, the reviewer is right in the sense, that by using the selected IGS sites with their IGb14 frame solution the long-term alignment bias is considered. However, we think that by using daily Helmert parameters to align the individual solutions (cf. preprint line 305) the frame jitter is reduced at least to a certain extent. As you remarked, an internal regional frame alignment would further reduce the frame jitter. This will be an issue to be followed in a subsequent re-processing. Please also see our answer further below.

RC 1.2: *Related to the previous point, the authors decided to align the position series to the IGb14 frame instead of the latest IGS20 frame. Since the objective is to provide a self-consistent and complete dataset of the highest quality in terms of series noise, the choice of the frame is mostly irrelevant for the correct combination of the position series. Mostly irrelevant, but maybe not totally, because the reported position discontinuities for many reference stations in Antarctica are not the same in these two reference frames (see for instance the changes in DUM1, MAW1 or DAV1).*

For highest consistency to the ITRF it is of course correct to adopt the latest version of the ITRF (currently ITRF2020 or IGb20). At the time of the initial processing of the individual AC solutions the ITRF2020 (resp.

IGS20) was not available. In a next reprocessing we will use the IGS20/IGb20 (or whichever version will be the most recent one). We added a sentence to the manuscript to clarify our choice of the version of the ITRF.

edited lines: 204 - 207

The individual analysis methods of the ACs differ in the analysis software, the processing strategies (e.g. double differencing or zero differencing), auxiliary products, and the strategies to realise the terrestrial reference frame~~. All ACs based their analysis on~~ , while all ACs adopted the same version of the ITRF to ensure consistency. At the time of the initial processing, the latest version, the ITRF2020 (Altamimi et al., 2023) was not available. Therefore, all ACs realised the IGb14 reference frame, the GNSS-only realisation of the ITRF2014 (Altamimi et al., 2016), and adopted the associated absolute antenna corrections for satellite and ground antennas provided by the IGS (igs14.atx).

RC 1.3: *Although this may have an impact on the terrestrial frame that was realized by the combined series, it might be possible that the use of a small set of stations has even a larger impact than the choice of one of these two reference frames. In this regard, a daily frame that is obtained from the combination of the four solutions themselves, without any external reference, could improve the regional frame alignment (and reduction of the frame noise) by including the maximum number of sites, including those that may not be included in the IGb14. Even the temporal sites could possibly contribute, though this may introduce a seasonal frame noise signature in the series with a frame systematically better in summer. In addition, a self-consistent combined frame would account for systematic coordinate variations that are not considered in the secular IGb14 frame, such as the periodic variations and the impact of ice inside some of the antennas of the network, among other effects. Once the frame noise is minimized and the series are combined, they could be translated to the IGb14 or the IGS20 using a selected subset of reference stations, as the authors did.*

We are grateful for the helpful suggestion. We will definitely consider your suggested two-step approach for a future re-processing. We believe that the "internal" alignment of the individual solutions could be enhanced by considering an increased number of sites or even all possible sites, as you suggested. In any case, it is a comment which we regard very much valuable for consideration in a next reprocessing.

RC 1.4: *Related to the previous point, it may be useful for the non-specialist reader adding a paragraph to inform that the frame of the combined dataset may not be free of secular biases and that caution must be taken when using the combined series (and their velocities) in an absolute sense. This is particularly relevant in Antarctica because, in addition to the difficulty of realizing a frame in a continent with sparse geodetic infrastructure, the stability of the origin of the global reference frame along the polar axis is affected by relatively large uncertainties. For instance, the translation drift between IGb14 and IGS20 is 0.2 mm/yr along the polar axis, i.e., a direct bias of the vertical velocities in Antarctica. The actual uncertainty is likely larger than this bias*

We included a short paragraph in the results section of the manuscript to emphasize on the limitations of the combined solutions w.r.t. geodynamical interpretation (esp. on secular time scales). We address your first point that the different versions of the ITRF (here ITRF2014 and ITRF2020) show a secular bias, especially in translation of the Z-axis, which maps to the uncertainties of derived local vertical velocities in the polar regions. The second point considers the strategy how the TRF is realized in this specific solution: alignment to a selection of regionally distributed reference sites vs global alignment. This can introduce an additional (secular) bias as shown by Legrand et al. (2010) for sites in Fennoscandia.

edited lines: 431 - 436

We realised the terrestrial reference frame IGb14 using a regional selection of reference sites for the individual AC solutions (see section 3.1). As shown by Legrand et al. (2010), using a sparse set of regionally distributed reference sites can introduce a (secular) bias in the coordinate solutions. This adds to the uncertainty of the reference frame itself which shows a secular bias of $0.2\,\mathrm{mm\,yr^{-1}}$ in the polar axis when comparing ITRF2014 to ITRF2020 (Altamimi et al., 2023). Uncertainties in the reference frame realization, especially in the Z-axis, map onto the uncertainty in the local vertical coordinate component of sites in the polar regions and must be taken into account when using them for geodynamic studies (e.g. GIA).

***RC 1.5**: On a similar point related to the noise in the position series, the NEWC group is the only one that applied non-tidal atmospheric loading corrections (probably at the observation level?). The impact of NTAL in Antarctica is not negligible with detrended and deseasoned variability (RMS) in the range of 2-4 mm in the vertical component, mostly depending on the distance to the coast. It may be appropriate to apply this correction to the series from the other groups in order to have a more consistent dataset before the combination, especially since the weight of each solution was obtained from level of noise in each series.*

We decided to address this issue already in the current data set in order to minimise the inconsistencies between the individual solutions as far as possible. We, therefore, recomputed our data set. To make the NEWC solutions consistent with the other AC solutions, we restore the NTAL induced deformation time series in the NEWC coordinate time series (on time series level). We then recalculate the combined coordinate time series. The combined coordinate time series is then reduced by NTAL to form our final product of coordinate time series. Due to the update of the NEWC coordinate time series and, thus, the combined solution, we updated all related figures and tables, namely Fig. 3 - 5, 7, 9, 10 and Tab. 1. The dataset of coordinate time series Buchta et al. (2024) was updated in the PANAGEA repository. We list the specific passages of the edited manuscript below.

We added the description of the NTAL calculation in description of the NEWC processing, as well as the updated processing of the NEWC solution in section 3.1.

edited lines: 273 - 277

We considered the effects of ocean tide loading by using the FES2014 model (Lyard et al., 2021)~~as well as non-tidal~~. Non-tidal atmospheric pressure loading ~~deformation (Tregoning and Watson, 2009).~~ (NTAL) deformation was considered on the observational level (Tregoning and Watson, 2009). We determined the deformation from VMF1 grids of the atmospheric pressure by convolution in the spatial domain using Green's functions in the CM frame. In order to ensure consistency with the solutions of the other ACs, the mean daily NTAL deformation was restored to the final coordinate time series.

The updated NEWC solution shows very similar results in the analysis of the estimated Helmert parameters in section 3.2.1. The derived rates of Helmert parameters in Fig. 3a, as well as the maps in Fig. 3b were updated. As expected, we see no substantial differences to the previous results on the secular time scales investigated here.

edited line: 306

The OSU and NEWC processings exhibit a similar pattern, dominated by the rate of translation in Z, resulting in a maximum magnitude of ~~$0.17\,\mathrm{mm\,yr^{-1}}$~~ $0.15\,\mathrm{mm\,yr^{-1}}$ (NEWC) and $0.33\,\mathrm{mm\,yr^{-1}}$ (OSU) of local subsidence.

Restoring the NTAL effect in the NEWC coordinate time series leads, as you correctly mentioned, to an increased residual RMS. The RMS was calculated for the selection 29 of stable sites. The median residual RMS is summarized in Tab. 1. We find an increase from $1.2\,\mathrm{mm}$ to $1.4\,\mathrm{mm}$ and $4.5\,\mathrm{mm}$ to $5.6\,\mathrm{mm}$ for north and up, respectively, compared to our previous assessment. The RMS of the east component is not effected. The increased noise is also reflected in the Lomb-Scargle PSDs in Fig. 7.

edited line: 399

The NEWC solution shows the lowest RMS for the lateral components with a median RMS of ~~1.2~~ 1.4 and $1.2\,\mathrm{mm}$ for north and east, respectively.

The re-calcuation of the combined coordinate time series lead to a slightly noisier solution, due to the noisier NEWC solution. We find an increase of the median residual RMS (Tab.1) in the north and up coordinate component from $1.3\,\mathrm{mm}$ to $1.5\,\mathrm{mm}$ and $4.0\,\mathrm{mm}$ to $4.5\,\mathrm{mm}$, respectively. The residual RMS of the up component of the combined solution is now $0.5\,\mathrm{mm}$ larger than the "best" performing individual solution OSU.

edited line: 401 - 404

The RMS values of the combined time series resemble the lowest RMS of the best-performing individual solutions ~~, with 0.1, $-0.1$and~~ for the lateral components with -0.1, $-0.1\,\mathrm{mm}$ for north ~~, east and vertical~~ and east respectively, compared to the best performing individual solution. The RMS for the vertical component is found to be $0.4\,\mathrm{mm}$ larger than that of the OSU solution.

We decided to to reduce the combined coordinate time series by the effect of NTAL, using the daily mean NTAL time series outlined in the NEWC processing.

edited lines: 374 - 375

In a final step, we reduce the combined coordinate time series by the effect of the mean daily NTAL deformation. The computation of the NTAL time series follows the procedure outlined in section 3.1 for the NEWC processing.

We describe the impact of the NTAL reduction on the residual RMS and amplitudes of the annual signals of the selected stable sites in Sec. 4.1. We added the NTAL reduced combined coordinate time series to Tab. 1 and calculated the median PSDs, adding an additional column to Fig. 7. We found a reduction of the residual RMS of $0.2\,\mathrm{mm}$ and $0.9\,\mathrm{mm}$ for the north and up component, respectively. We added a short paragraph outlining reduction in residual RMS and amplitude of the annual signal.

edited lines: 424 - 430

The effect of NTAL induced deformations was removed from the combined coordinate time series to form infer the final data set. A number of studies discussed the influence of NTAL effects on GPS time series, leading to a reduction in the amplitude of annual signals and the residual RMS depending on the site location (Männel et al., 2019; Mémin et al., 2020). For the selection of stable sites we find a mean reduction of the residual RMS of 0.2, 0.0 and $0.9\,\mathrm{mm}$ (see Tab. 1) and a mean reduction of the annual amplitude of 0.1, 0.0 and $0.6\,\mathrm{mm}$ for north, east and vertical, respectively. The maximum reduction of the vertical annual amplitude was found for the site FALL with $2.5\,\mathrm{mm}$. An increase in the annual amplitude was identified for sites in Dronning Maud Land, with a maximum of $1.6\,\mathrm{mm}$ for the site ABOA.

RC 1.6*: The TUD group is the only one that applied corrections for the orientation of the ground antenna patterns. Some of the IGS stations in Antarctica report antennas not oriented to north (DAV1, OHI3, maybe others). However, the antenna orientations were not considered to compute the IGb14 reference frame. Due to the small number of reference stations used for the alignment, I wonder if the inconsistency of the TUD antenna corrections could partly explain the different frame bias of this solution shown in Fig. 3. In other words, the level of agreement with the reference frame needs to be considered for each selected station used in the alignment.*

We clarified the description of the TUD processing. A correction of the antenna misalignment was not applied to IGS reference sites and is, therefore, not the reason for the frame bias seen in Fig. 3.

edited lines: 225 - 227

The Bernese Software v5.2 allows ~~for the consideration of~~ to consider the misalignment of ground antennas from true north. If the station meta data include information on the antenna orientation, the azimuth-dependent phase center corrections were applied accordingly. This does not apply to reference stations to maintain consistency with the IGb14 conventions.

RC 1.7: *The authors use the Lomb-Scargle periodogram to validate the overall quality of the combined series. However, it is not clear if the standard normalized LS periodogram was used. The standard LS periodogram is normalized by the series variance, and thus it provides information about the relative distribution of power at different periods, which is very convenient for stacking series of different quality. However, for the same reason, there is not much one can say about the absolute noise levels or absolute* *peak amplitudes when comparing normalized periodograms from different datasets, unless they have the same overall variance. The later might be the case for the individual solutions if their noise levels are similar, but this may not be the case according to the previous comments (frame noise and NTAL). Note that not only the noise levels between globally and regionally aligned series can differ, but also the shape of their power spectra. The same applies between series corrected for NTAL or not. In any case, since the authors claim that the combined series have smaller variance, which would be expected, the normalized periodogram of the combined solution is not fully comparable to the others. As an example, for systematic periodic variations that have not been affected by the combination, like the fortnightly aliasing and the draconitic harmonics, a smaller variance in the series would make them look apparently stronger.*

We understand that it is necessary to clarify what was done in this respect, since the ways of scaling the PSD or LS periodograms (LSP), respectively. In order to infer a realistic noise level we would not prefer a normalized LSP which gives values between 0 and 1. We used the un-normalized LSP, where the PSD takes values similar to the FFT analysis, but differing by a factor of 2. We included a sentence to clarify the used scaling of the LSPs.

edited lines: 405 - 408

To further characterise the spectral properties of the residual time series ~~, we used~~ we calculated the Lomb-Scargle periodogram (LSP), a representation of the power-spectral density for ~~discrete, scattered~~ non-uniformly sampled data (VanderPlas, 2018). ~~LSPs~~ We used un-normalized LSPs where the power spectral density takes values similar to FFT analysis, differing by a factor of two in the case of a complete time series.

RC 1.8: *Some specific and minor comments:*

It would be interesting to add error bars to the values of the parameter rates shown in Fig. 3a and maybe discuss about the significance of the differences.

The formal error of the estimate rates if the Helmert Parameters are 1-2 magnitudes smaller than the estimates rates and would, therefore, not be visible in Fig. 3a. We instead added a short sentence to the caption of the figure.

edited caption of Figure 3:

A positive angle describes a clockwise rotation. The formal uncertainties are negligible, with a range of one to two magnitudes below the estimated values.

Eq. 3: when computing the scaled variances, the length and period considered for each series must be similar among the solutions. This is because the series are not stationary (as shown in Fig. 7) with a noise variance that increases with the length considered. The noise level can also change over time, especially for series starting in the 90s.

Of course, you are correct. We added a sentence to point out the limitation, that result from the differing temporal coverage and sampling.

edited lines: 350 - 352

A limitation of this approach results from the differing temporal coverage and sampling of the individual solutions of the non-stationary coordinate time series.

Line 358-359: this sentence may not be clear for the reader. The scaling factor of the variances is only relevant for the weighted combination. The variances of the estimated combined values, in a station-by-station basis, should not be affected by optimistic or pessimistic variance factors.

We removed the sentence.

edited lines: 372 - 373

for solving more campaigns.~~We note that this approach leads to an overly optimistic scaling of the variances and in consequence smaller assigned scaled variances to eGPS sites in comparison to cGPS sites, in an absolute sense.~~

2 Responds to RC2

RC2.1: *The aim of the paper was to process the GPS data consistently during the considered time span and obtain consistent combined position time series. However, the differences in processing strategies could be noticed between the individual AC solutions, which could potentially decrease their mutual consistency. For example, NEWC AC applied non-tidal atmospheric loading displacements for stations; these corrections were not applied by the other three ACs. TUD AC was the only one to apply atmospheric tidal loading displacements and correct the for the antenna misalignments towards true north (correcting for these misalignments is also not consistent with the IGS14/IGb14 framework used in this study). Regarding an elevation mask, TUD used 5 degrees while UTAS and NEWC used 10 degrees (for OSU the value is not provided). Also, two ACs used orbit products from the IGS repro3 project together with the igs14.atx antenna model and IGb14 terrestrial reference frame, which are not consistent with the antenna model and reference frame used for deriving the IGS repro3 products. Maybe the authors could add a comment on these discrepancies and their potential impact on the results. Nevertheless, for future reprocessing it would be important to harmonize the processing strategies among the participating ACs. It could be also reasonable if all the analysis were carried out in the latest and most precise IGS framework (IGS20/igs20.atx). It could also allow for a consistent extension of the product by next (operational) solutions.*

You are absolutely right, there are differences in the processing choices of the individual ACs. In future reprocessing efforts, we will strive for a more harmonized strategy to further improve the consistency between the solutions and, in turn, the quality of the combined data product.
We regard the reduction of S1/S2 atmospheric tidal loading effects (as in the TUD solution) as small, since the amplitudes are well below $0.3\,\mathrm{mm}$ for the polar regions (according to the model of Ray and Ponte (2003) we applied). Likewise, the correction would be omitted in a future reprocessing to enhance the consistency between the individual solutions.
We clarified the section regarding the correction of the antenna azimuth in the TUD solution. You and RC1 noted correctly, that this correction is not consistent with IGS14/IGb14 conventions. Therefore, in the TUD solution the antenna azimuth correction was applied only for those sites, which have not been used to define the reference frame in the solution.

edited lines: 224 - 227
The Bernese Software v5.2 allows ~~for the consideration of~~ to consider the misalignment of ground antennas from true north. If the station meta data include information on the antenna orientation, the azimuth-dependent phase center corrections were applied accordingly. This does not apply to reference stations to maintain consistency with the IGb14 conventions.

W.r.t. the NTAL inconsistency, we refer to the our answer to RC1 (RC 1.5).

The inconsistency of the NEWC solution with regard to the use of repro3 and igs14.atx/IGb14 will probably result in a small scaling effect. We added a short sentence to emphasize on this inconsistency.

edited lines: 266 - 267
~~Similar to other ACs, satellite~~ Satellite orbit parameters remained fixed to the IGS final repro3 orbit product values. This might introduce a small scaling effect due to the inconsistency of the repro3 product series with IGb14 and igs14.atx.

Of course, you are right to use the latest reference frame solution. However, at the time of the re-processing the IGS20 solution has not been available yet. In a next reprocessing we will use IGS20/IGb20 (or whichever version will be the most recent one). We included a sentence to explain our choice of reference frame.

edited lines: 204 - 207

The individual analysis methods of the ACs differ in the analysis software, the processing strategies (e.g. double differencing or zero differencing), auxiliary products, and the strategies to realise the terrestrial reference frame~~. All ACs based their analysis on~~ , while all ACs adopted the same version of the ITRF to ensure consistency. At the time of the initial processing, the latest version, the ITRF2020 (Altamimi et al., 2023) was not available. Therefore, all ACs realised the IGb14 reference frame, the GNSS-only realisation of the ITRF2014 (Altamimi et al., 2016), and adopted the associated absolute antenna corrections for satellite and ground antennas provided by the IGS (igs14.atx).

RC 2.2: *Before a combination of AC solutions, each daily AC solution was transformed to the IGb14 to minimize the systematic differences between the solutions. The authors decided to use 6-parameter transformation, which should be sufficient to obtain consistent position time series. However, using a 7-parameter transformation could probably improve the consistency between AC solutions and also the repeatability of the position time series (especially for stations at the edges of the network).*

We did not include the scale factor as the scale parameter in the Helmert transform, since the reference to the IGb14 was done in a regional sense, and then scale factor and translation in z-direction are strongly correlated.

RC 2.3: *Also, the authors did not write, if daily coordinates of IGb14 stations which were used as reference for the estimation of transformation parameters were verified against the catalogue coordinates. In case of too large differences, it would be important to exclude such stations from the estimation of transformation parameters to avoid biases in the alignment.*

We verified the quality of the transformation by investigating the post-fit residuals for each site. If the residuals exceeded the threshold of $15\,\mathrm{mm}$, $15\,\mathrm{mm}$ or $30\,\mathrm{mm}$ for the north, east and up respectively, the site is not considered for the transformation. We included a sentence describing the procedure.

edited lines: 294 - 295

If the post-fit residuals of a potential reference site exceeded the limits of $15\,\mathrm{mm}$,$15\,\mathrm{mm}$ or $30\,\mathrm{mm}$ in north, east and up, respectively, it was excluded from the list of reference sites and the estimation was repeated.

RC 2.4: *The authors combined the AC solutions according to the site-wise approach. The presented approach is appropriate for obtaining the combined station coordinate time series. I noticed, however, that the resulting combined coordinates were not transformed to the IGb14 (like individual solutions), so I suspect that these solutions may not be optimally aligned to the IGb14.*

This is completely correct. While the individual solutions were regionally aligned to the IGb14, the combined solution might not be perfectly aligned to the IGb14. Here we refer to comment RC 1.3 of RC1, who proposes a two-step approach. In a first step the individual solutions are “internally” alignment without an external reference. Now the individual solutions can combined by a site-wise approach. In a last step the combined solution could then by aligned to the ITRF using the selection of regional IGS sites. We will consider this approach in a next re-processing. As we could expect a better internal alignment, as well as alignment to the ITRF.

RC 2.5: *In the supplement also three other variants of site-wise approach were described. The other possibility, however, could be a combination of daily AC solutions on the normal equation or covariance matrix level, together with the alignment of the resulting combined solutions to the IGS reference frame (e.g., using minimum constraints conditions). I wonder if the authors considered this approach for the creation* *of the combined position time series as well or see some disadvantages of it in relation to the site-wise approach.*

Thank you very much for this comment. Yes, we also discussed the idea of stacking the normal equations. One problem could be that the provided PPP solution (UTAS processed with GIPSY) is based on a site-by-site processing and, therefore, does not provide inter-site covariance information. Here some empirical approach would be needed. Another problem might arise in the weighting of the normal equations (NQs) from the different ACs. A big advantage of the NQs-stacking approach would be that we conserve the information on the inter-site covariances. We will consider the NQ-stacking approach in a future re-processing and compare the results to the approach presented in this paper.

RC 2.6: *Minor remarks*

The TUD AC used Bernese GNSS Software version 5.2 to compute its solution. The authors wrote that the VMF3 was used for the troposphere modelling. However, as far as I know, in the official release of version 5.2 it is not possible to use VMF3; this capability is available in the next version (5.4). Please add a comment to clarify this.

We used a technical modification to make the VMF3 product available in the Bernese Software v5.2. We will add a comment in the manuscript to make clear that this is not a standard feature of the Bernese Software v.5.2. In future, the Bernese Software v5.4 will be used where the VMF3-grids are supported by default.

edited lines: 216 -217
A-priori zenith path delays (ZTD) were realised by employing the dry ZHD (hydrostatic delay in zenith) and the Vienna Mapping Function (VMF3) (Landskron and Böhm, 2018). In order to apply the VMF3 a modified version of Bernese GNSS Software v5.2 was used.

In Fig. 3a the authors provided the values of rotation rates. It could be useful to add the information in the text on the used convention in Eq. 1 for the positive rotation of the coordinate system (clockwise or counterclockwise).

We added a sentence for clarification.

Edited the caption of Fig. 3:
A positive angle describes a clockwise rotation. The formal uncertainties are negligible, with a range of one to two magnitudes below the estimated values.

Technical corrections
In line 357 the closing bracket is missing.

Corrected.

3 Other changes

Other changes to the manuscript were made to correct grammatical errors and to improve the readability. We also updated Fig. 10 using the combined coordinate time series with NTAL removed. We updated the figure to be more consistent with the style of Fig. 2, 3 and 6. The updated colormap should better emphasize the variability in the vertical deformation rates between $-10\,\mathrm{mm\,yr^{-1}}$ to $10\,\mathrm{mm\,yr^{-1}}$.

4 Updates to the supplement

We updated Tab. S2 w.r.t. the correction of antenna azimuth misalignments of the TUD processing (see RC 1.6) and the handling of the NTAL correction in NEWC processing (see RC 1.5).
The update of the NEWC individual solution and consecutive the combined solution required an update of the values in Tab. S3, where we find a small increase of the residual RMS for all combination approaches. Fig. S1 war updated to display the updated GR combined coordinate time series.

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