Changing from ITRF2014 to ITRF2020 in the Routine VLBI Analysis: First Investigations

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Abstract The IVS Analysis Center at BKG took part in the activity to build the next generation ITRF2020. Here we present the first results of the implementation of the preliminary release ITRF2020P in our routine analysis. The a priori station coordinates and velocities are updated as well as the PSD model coming along with ITRF2020P. The most prominent improvement is recognized for the new VGOS stations, which are particularly valuable for the different types of the VGOS sessions (IVS VGOS, mixed mode sessions, and local ONTIE observations) observed in the last few years. The advancement of the PSD model is validated at the affected stations. We consider the product of the Intensive session solution to verify the PSD model performance. The rest of the reductions are applied along with to the current bkg2020a solution. While we focus our study on the verification of the VGOS station positions, we also look into the EOP time series variations derived from the 24-hour session solution.

Keywords VLBI Analysis, ITRF2020, IVS products

1 Introduction

The most recent International Terrestrial Reference Frame ITRF2020 [12] was released after the 12th IVS General Meeting; thus the preliminary version of the ITRF2020P release was used in this paper. The final release is not expected to introduce any significant differences. The a priori station positions, as provided by ITRF, is one of the central reductions in the VLBI Analysis. Due to the lack of observations, the accurate a priori corrections of the new stations are crucial for the generation of reliable IVS products at the IVS Analysis Center. In this case, this work focuses on the station positions of the new VGOS antennas. In order to support an operational analysis the a priori station positions of VGOS antennas were obtained internally at BKG by means of the single technique VLBI solution. The actual operational bkg2020a time series is parameterized with respect to the ITRF2020 campaign requirements, where ITRF2014 [1] is applied as the a priori corrections for the station positions. The aforementioned internal VLBI solution is employed for the stations, which are not present in ITRF2014, such as VGOS stations. Here we compare the application of ITRF2020P by considering our two VLBI solutions, in which the only difference is the applied a priori station position corrections. Hereinafter, itrf2020p refers to the solutions, while ITRF2020P is the a priori model. The PSD model is utilized in the analysis procedures to be consistent with ITRF2020P. Its advance is verified in the station positions' variations. The Intensives session product is also used to validate the PSD model: the station positions in their parameterization are fixed to the a priori corrections, thus any offset would have to be related to the deficiencies of the a priori model.

2 Data and Analysis

The processed data of the operational 24-hour session solution bkg2020a can be found in the Data Center [7], where the corresponding daily SINEX files are provided for each processed session along with the EOP

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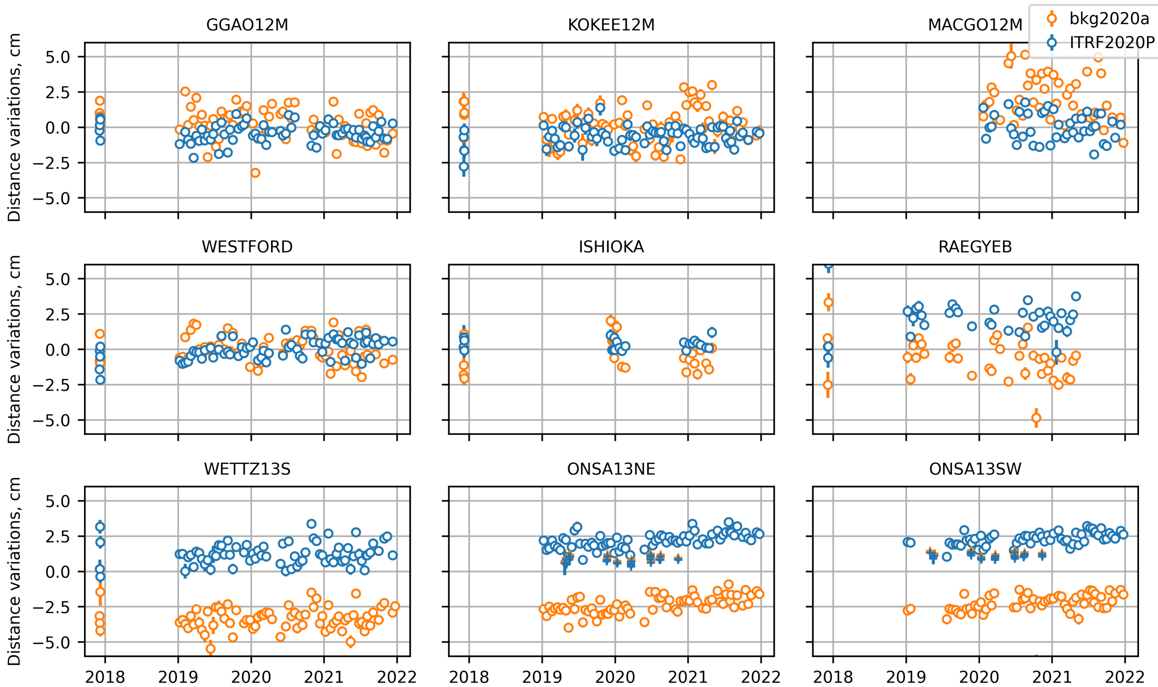

Fig. 1 The obtained distance variations of the VGOS stations are plotted as derived from two solutions: bkg2020a and itrf2020p. The ONTIE sessions are marked with "plus" sign and the other VGOS sessions with circles.

products in both formats (eops and eoxy). These products are updated every time the new session is available for the analysis. The operational EOP products of solution bkg2020a do not include the corresponding results of the VGOS sessions, even though the corresponding SINEX files are provided.

The itrf2020p solution is built for the exact same data set as bkg2020a and the same parameterization is applied. That means, in the case of the VGOS sessions, that all stations are evaluated with NNR/NNT uniform constraints defined by the sigma 0.1 mm. The source positions are estimated with the NNR uniform constraints defined by the sigma of 0.2 as applied to the ICRF3-SX defining sources, and by the sigma of 2 mas to all of them imposed on declination and right ascension, where ICRF3-SX is the a priori catalog [3]. The EOP time series are obtained once per session with respect to the Bulletin A [10], including modeling for the high-frequency part Desai&Sibois/Egbert [4] and precession-nutation variations IAU2006/2000 [8]. The corresponding constraints of 45 mas and 3 ms are applied to the estimates of the polar motion and dUT1 and 45 mas/day and 3 ms/day to the polar motion and LoD rates. The computed nutation is unconstrained. The clocks at each station are modeled as a quadratic spline at a one-hour interval with the rate constraint of 5^{-14}, with the exception of the referenced. The troposphere is adjusted by evaluating the wet part of the hourly zenith delay with the rate constraint of 50 ps/hour and gradients at the beginning and the end of the session as a linear spline, with an offset constraint of 0.5 mm and rate constraint of 2.0 mm/day.

The obtained station position variations from solutions bkg2020a and itrf2020p are plotted for the VGOS stations in Figure 1. Here the station position variations of the total values defined as the distance $\sqrt{x^2+y^2+z^2}$ are reduced by the common mean of the weighed average. The largest reductions are seen in the European stations, while the stations located in the USA do not show such irregularity and the station positions of ISHIOKA in Japan are affected slightly. The same station position variations obtained from ONTIE session solutions show very small differences between the two solutions (see the "plus" marks depicting ONTIE sessions on Figure 1). However, the ONTIE session solutions are different from bkg2020a. The station positions of ONSALA60 are fixed to the applied a priori model, the station positions of twin antennas are not

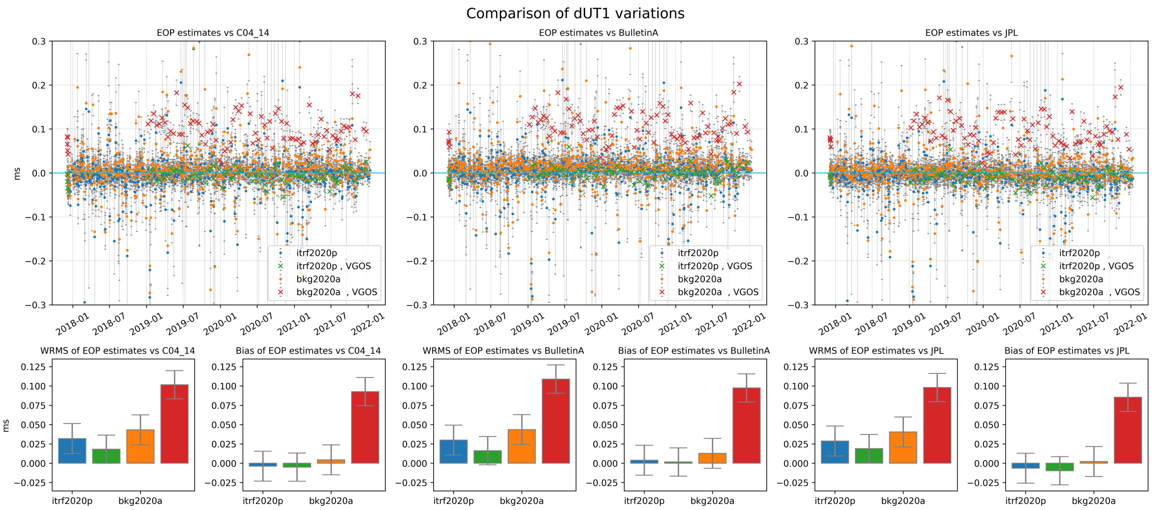

Fig. 2 The comparison of the dUT1 variations is plotted in the upper panel with respect to the three a priori EOP time series: C04 14, Bulletin A, and JPL. The lower panel contains pair plots of WRMS and bias corresponding to the a priori model above. Each of the solutions, bkg2020a and itrf2020p, is additionally divided to highlight the results derived from VGOS sessions in contrast to the S/X sessions.

constrained, and the atmospheric parameters are not estimated for ONSA13NE. This parameterization of the ONTIE sessions is along with the one suggested by the group in Onsala [9], who designed, conducted, and analyzed these sessions. These inaccuracies of the VGOS station positions propagate directly to the ERP time series evaluation, while LoD and celestial pole offsets seem to show a substantial resemblance. The effect is shown in Figure 2 for dUT1. The ERP time series estimates are compared against three a priori time series: C04 14 [2], Bulletin A, and JPL [11] (upper panel: left to right). The differences to the a priori corrections for the dUT1 variations are shifted by 0.1 ms on average, and for the two components of the polar motion the offsets are of about 1 and -2 mas correspondingly. The solution itrf2020p, however, shows the results from the VGOS sessions to be aligned with the results of the rest of the sessions. The WRMS and bias of the differences plotted in the upper panel are shown in the lower panel of the Figure 2. A sizable reduction in the WRMS and the bias is recognized where the new ITRF2020P is applied. The prominent offset in the ERP time series estimates is the reason why the EOP products are not populated with VGOS sessions in the operational solution version bkg2020a.

The same comparison is done in the Intensive sessions. An offset is detected in the results derived from the VGOS Intensives only as shown in Figure 3. The standard S/X Intensive sessions are unaffected: the regularly participating stations set is fixed and limited to the reliable stations—their coordinates are well-known as a rule. However, a considerable number of the Intensive sessions were observed at the Kashima and Tsukuba stations, where some severe discontinuities were detected. In the last two ITRF releases, the PSD model was applied to take into account the station position variations after these earthquakes. In the previous work [6] when we have considered the analysis of the BKG Intensives time series, it was shown that the PSD model is sufficient to take those effects into account. Before ITRF2014 was released, the station positions were derived from the 24-hour sessions observed at about the same time as the Intensives with Kashima and Tsukuba [5]. The implementation of the new PSD model provided with ITRF2020P shows a high consistency with the previous release.

3 Conclusions

The preliminary ITRF2020 version benefits from the inclusion of the VGOS sessions, namely the station position corrections that provide a better agreement with observations and the obtained EOP time series that are aligned with the results from the 24-hour S/X ses-

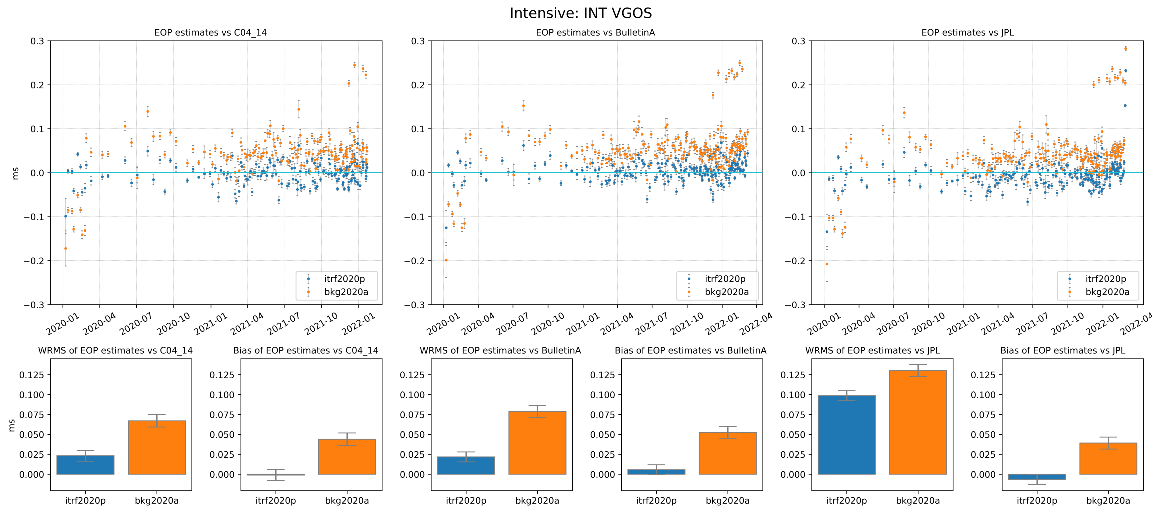

Fig. 3 The comparison of the dUT1 variations from the analysis of the different types of the VGOS Intensive sessions is plotted in the upper panel with respect to the three a priori EOP time series: C04 14, Bulletin A, and JPL. The lower panel contains pair plots of WRMS and bias corresponding to the a priori model above.

sions. Besides, the dUT1 estimates derived from the Intensive sessions observed on the new VGOS antennas are improved substantially, mainly because the station positions are fixed to the a priori values in the analysis. The new PSD model provided along with ITRF2020P seems to be very similar to the previous version. The dUT1 estimates derived from itrf2020p solutions show a very good agreement with the current solution bkg2020a, including sessions where Kashima and Tsukuba, for which PSD model is applied, participate. The southern mixed mode and all S/X Intensives reveal no impact of the a priori station position corrections in the obtained dUT1 variations. The comparison of the dUT1 with the three different a priori models indicates the high quality of the VGOS and mixed mode intensives, which is on the level with the operational INT1, INT2, and INT3 products. In the case of the southern Intensives, Onsala Intensives (data base code, dbc, VB), and MgWs Intensives (VJ) a bias might be seen due to the small number (8–9) of sessions.

References

1. Z. Altamimi, P. Rebischung, L. Metivier, and X. Collilieux, ITRF2014: A new release of the International Terrestrial Reference Frame modeling nonlinear station motions, J. Geophys. Res. Solid Earth, 121, doi:10.1002/2016JB013098, 2016.
2. C. Bizouard, S. Lambert, C. Gattano, et al. (2019) The IERS EOP 14C04 solution for Earth orientation parameters consistent with ITRF 2014, J Geod 93(5):621-633, https://doi.org/10.1007/s00190-018-1186-3, 2019.
3. P. Charlot, C. S. Jacobs, D. Gordon, S. Lambert, A. de Witt, J. Böhm, A. L. Fey, R. Heinkelmann, E. Skurikhina, O. Titov, E. F. Arias, S. Bolotin, G. Bourda, C. Ma, Z. Malkin, A. Nothnagel, D. Mayer, D. S. MacMillan, T. Nilsson and R. Gaume. The third realization of the International Celestial Reference Frame by very long baseline interferometry A&A, 644 A159, DOI: https://doi.org/10.1051/0004-6361/202038368, 2020.
4. Desai and Sibois, "Evaluating predicted diurnal and semidiurnaltidal variations in polar motion with GPS-based observations", J. Geophysical Research: Solid Earth, 121, pp. 5237–5256, doi:10.1002/2016JB013125, 2016.
5. G. Engelhardt, V. Thorandt, D. Ullrich. Refinement of the rapid UT1 estimation derived from Tsukuba VLBI measurements after the 2011 earthquake. In: D. Behrend, K. D. Baver, K. Armstrong, editors, *International VLBI Service for Geodesy and Astrometry 2016 General Meeting Proceedings*, NASA/CP-2016-219016, 225–228, 2016.
6. A. Girdiuk, D. Thaller, D. Ullrich, G. Engelhardt, R. Wojdziak, C. Plötz. Analysis of Intensive Sessions at BKG. In: R. Haas, S. García-Espada, J. A. López Fernández, editors, *Proceedings of the 24th European VLBI Group for Geodesy and Astrometry Working Meeting*, Centro Nacional de Información Geográfica (CNIG). 2019.
7. A. Nothnagel, T. Artz, D. Behrend, Z. Malkin, "International VLBI Service for Geodesy and Astrometry – Delivering high-quality products and embarking on observations of the next generation", *Journal of Geodesy*, Vol. 91(7), pp. 711–721, July 2017. DOI 10.1007/s00190-016-0950-5.
8. Petit, Gerard and Luzum, Brian, IERS Conventions (2010), IERS Technical Note 36, 2010.

9. E. Varenius, R. Haas, T. Nilsson, Short-baseline interferometry local-tie experiments at the Onsala Space Observatory, *Journal of Geodesy* 95, 54, https://doi.org/10.1007/s00190-021-01509-5, 2021.
10. https://www.iers.org/IERS/EN/Publications/Bulletins/bulletins.html
11. https://eop2-external.jpl.nasa.gov/
12. https://itrf.ign.fr/en/solutions/ITRF2020