Seasonal station variations in the Vienna VLBI terrestrial reference frame VieTRF16a

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Abstract

The special analysis center of the International Very Long Baseline Interferometry (VLBI) Service for Geodesy and Astrometry (IVS) at TU Wien (VIE) routinely analyses the VLBI measurements and estimates its own Terrestrial Reference Frame (TRF) solutions. We present our latest solution VieTRF16a (1979.0 – 2016.5) computed with the software VieVS version 3.0. The VieTRF16a is determined in the form of the conventional model (station position and its linear velocity) simultaneously with annual and semi-annual harmonic station variations as global parameters together with the celestial reference frame and Earth orientation parameters. In this work, we concentrate on the seasonal station variations and compare our TRF with the three combined TRF solutions ITRF2014, DTRF2014 and JTRF2014.

Vienna TRF solution VieTRF16a

- 5825 observing sessions provided by the IVS
- 1979.7 – 2016.5

- VieVS Software 3.0
- IERS Conventions 2010 (Petit & Luzum, 2010)
- Non-tidal atmosphere loading applied a priori (TU Wien, Wijaya et al., 2013)

- Session-wise parameters
  - Clock, zenith wet delay, troposphere gradients, EOP
  - Coordinates of stations with < 15 sessions and an observation time < 3 years (if the velocity could not be constrained to a neighbouring telescope)
  - Coordinates of special handling sources

Parameter	Interval [min]	Relative constraints
Clock	60	1.3 cm after 1 hour
Zenith wet delay	60	1.5 cm after 1 hour
Troposphere gradients	360	0.5 mm after 6 hours
EOP	1440	0.1 µas after 1 day

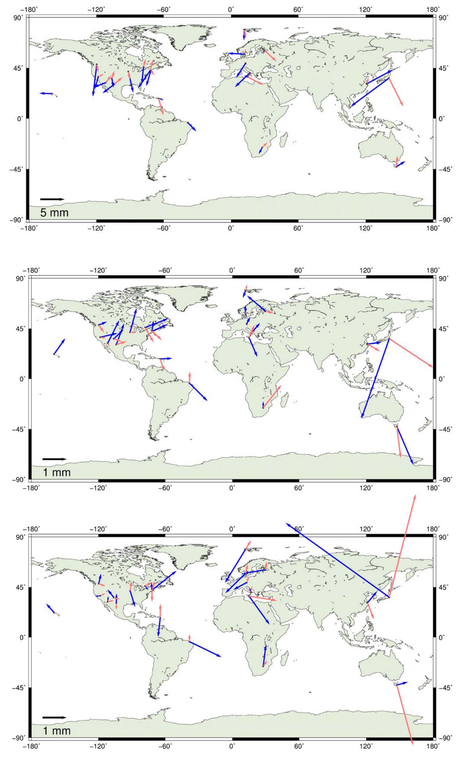
- Global parameters
  - TRF – position + linear velocity (102 stations)
  - CRF – position (4097 sources)
  - Sine and cosine amplitudes for the annual and semi-annual period of the station displacement at the 22 datum stations

    - NNR/NNT condition on station coordinates of ITRF2014 (22 stations)
    - NNR condition on coordinates of ICRF defining sources in GSFC2015b

Comparison of the VieTRF16a w.r.t. DTRF2014, ITRF2014 and JTRF2014

Harmonic signal at the **annual** and **semi-annual** period within VieTRF16a

- Up
- East
- North



The length of the arrow depends on the estimated amplitude and the direction depicts the month of the maximum displacement starting in the north direction for January continuing clock-wise.

Selected VLBI stations plotted w.r.t. ITRF2014 (IGN, Paris) (offset + rate)

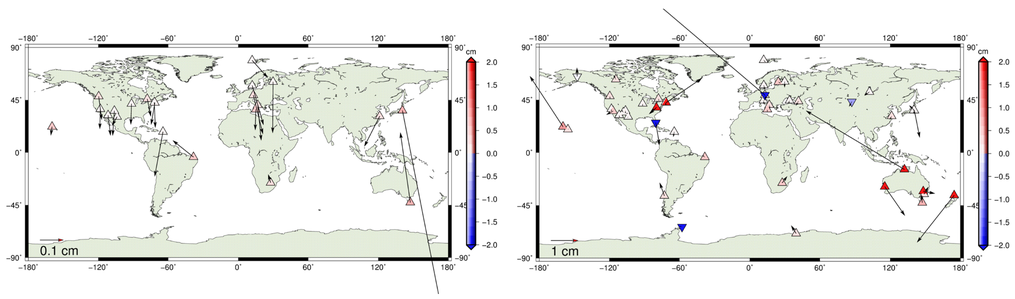
- DTRF2014 (DGFI-TUM, Munich) – offset + rate + NT-CWSL (non-tidal hydrology loading) corrections
- JTRF2014 (JPL, Pasadena) – weakly positions (deterministic part in Kalman filter consists of a linear trend and annual and semi-annual periodic terms)
- VieTRF16a (TU Wien, Vienna) – offset + rate + annual and semi-annual harmonic corrections from a global adjustment

Comparison of VieTRF16a in terms of the position offset and linear velocity

Position differences (UEN) of VieTRF16a w.r.t. ITRF2014 at epoch 2010.0

Datum stations

Stations with position rms < 5 mm



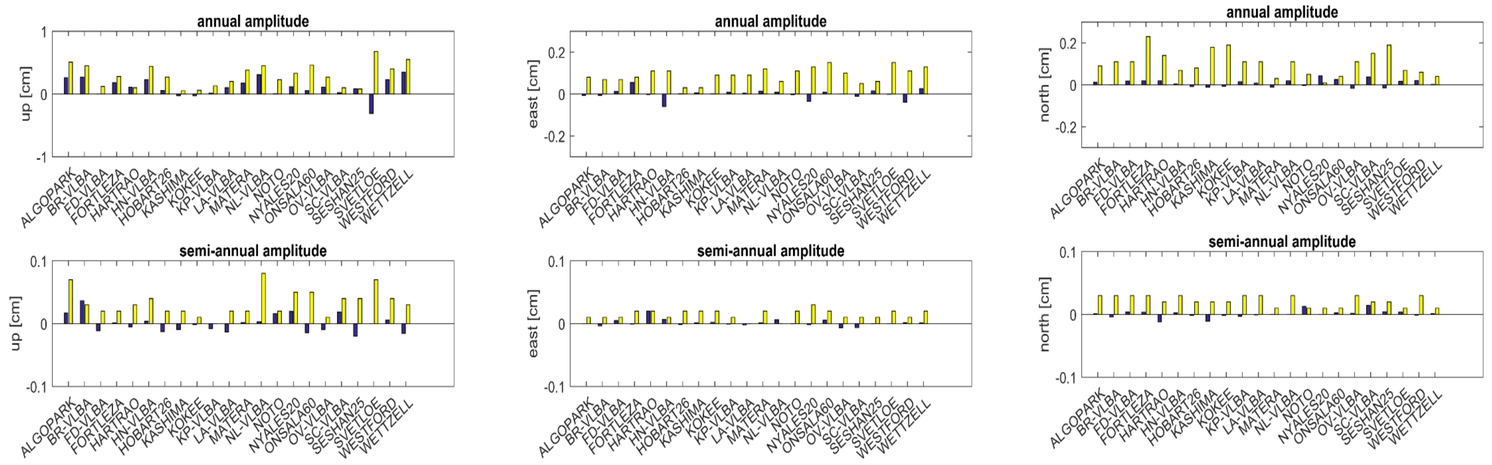
Height difference is colour-coded, displacement in the horizontal plane is depicted with the arrow.

Epoch 2010.0	ITRF2014		DTRF2014	
	position rms < 5 mm	all stations	position rms < 5 mm	all stations
Tx [mm]	-0.5 ± 0.6	-0.9 ± 1.1	2.3 ± 2.1	2.0 ± 1.9
Ty [mm]	1.5 ± 0.6	1.4 ± 1.0	-0.5 ± 2.0	-0.6 ± 1.9
Tz [mm]	-1.7 ± 0.6	-1.4 ± 1.0	-2.1 ± 2.0	-1.9 ± 1.9
Rx [µas]	-17 ± 22	-15 ± 40	12 ± 79	14 ± 73
Ry [µas]	-28 ± 23	-43 ± 41	-34 ± 81	-43 ± 75
Rz [µas]	22 ± 18	20 ± 33	116 ± 64	115 ± 60
Scale [ppb]	0.72 ± 0.09	0.77 ± 0.16	0.02 ± 0.31	0.06 ± 0.28
δTx [mm/y]	-0.1 ± 0.2	-0.2 ± 0.4	1.1 ± 0.7	1.1 ± 0.7
δTy [mm/y]	0.0 ± 0.2	0.0 ± 0.4	0.7 ± 0.7	0.6 ± 0.7
δTz [mm/y]	0.0 ± 0.2	0.0 ± 0.4	0.5 ± 0.7	0.5 ± 0.7
δRx [µas/y]	-1 ± 8	-2 ± 14	2 ± 28	4 ± 26
δRy [µas/y]	-2 ± 8	-4 ± 15	-13 ± 29	-15 ± 27
δRz [µas/y]	-2 ± 7	-3 ± 12	66 ± 23	63 ± 21
δScale [ppb/y]	0.02 ± 0.03	0.03 ± 0.06	-0.05 ± 0.11	-0.05 ± 0.10
Weighted Helmert parameters to VieTRF16a from ITRF2014 and DTRF2014, respectively .				

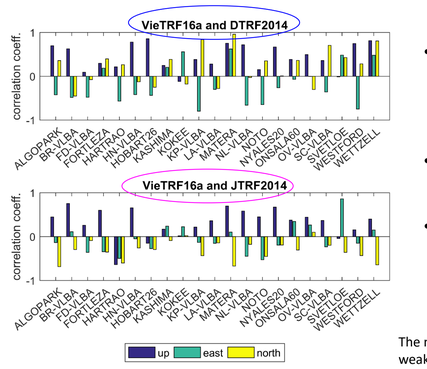
Harmonic signals in TRF solution with/without applying hydrology loading model corrections

Amplitudes of the annual and semi-annual signal

- fitted to the hydrology loading displacement provided by the NASA GSFC VLBI group
- difference between the default VieTRF16a solution (S1) and a solution (S2) with applied hydrology loading displacement (GSFC) a priori in the VLBI analysis (S1 – S2)



Correlation coefficients between VieTRF16a, DTRF2014 and JTRF2014



- Mean correlation coefficients between

  VieTRF16a and DTRF2014: U: 0.45, E: -0.20, N: 0.21
  VieTRF16a and JTRF2014: U: 0.32, E: -0.06, N: -0.31

- High correlation especially in the height component at stations with large periodic signal

- The lower correlation with JTRF2014 is partly caused by the stochastic part in the station time series and by the fitting to the atmospheric and non-tidal oceanic loading models

The negative sign means that the DTRF2014/JTRF2014 time series have very weak annual or semi-annual pattern (especially in the horizontal plane).

Conclusions

- The current version of the Vienna terrestrial reference frame VieTRF16a is introduced with the focus on the harmonic station displacement.

- In the VieTRF16a the non-tidal atmospheric loading is reduced a priori. Therefore the estimated annual and semi-annual signal within the global adjustment contains mainly the unmodelled contribution from the hydrology loading with the amplitude in the height component reaching several millimetres.

- High correlation between the VieTRF16a and DTRF2014, and between the VieTRF16a and JTRF2014 is found especially in the height component at stations with a high amplitude of the hydrology loading signal.

- Comparison of the VieTRF16a at the epoch 2010.0 in terms of the 14 parameters Helmert transformations to the ITRF2014 shows a scale offset of 0.72 ± 0.09 ppb, while comparison to the DTRF2014 only 0.02 ± 0.31 ppb.

References

- Böhm, J., Böhm, S., Nilsson T., Pany, A., Plank, L., Spicakova, H., Teke, K., & Schuh, H. 2012, The New Vienna VLBI Software VieVS, Geodesy for Planet Earth, Proceedings of the 2009 IAG Symposium, pp. 1007 - 1012
- Altamimi, Z., Rebischung, P., Métivier L., & Xavier, C. 2016, ITRF2014: A new release of the International Terrestrial Reference Frame modeling nonlinear station motions, J. Geophys. Res. Solid Earth 121, pp. 6109–6131
- Seitz, M., Bloßfeld, M., Angermann, D., Schmid, R., Gerstl, M., & Seitz, F. 2016 The new DGFI-TUM realization of the ITRS: DTRF2014 (data). Deutsches Geodätisches Forschungsinstitut, Munich
- Krásná, H., Malkin, Z., & Böhm, J. 2015, Non-linear VLBI station motion and their impact on the celestial reference frame and Earth orientation parameters, J Geod 89, pp. 1019-1033
- Nothnagel, A., Alef, W., Amagai, J., et al. 2015 (GFZ Data Services, Helmoltz Centre, Potsdam, Germany)
- Petit, G. & Luzum, B. 2010, IERS Conventions 2010, ed. G. Petit & B. Luzum (IERS Technical Note No. 36)
- Wijaya, D.D., Böhm, J., Karbon, M., Krásná, H., & Schuh, H. 2013, Atmospheric pressure loading, ed. J. Böhm & H. Schuh. Atmospheric Effects in Space Geodesy, pp. 137-157
- Wu, X., Abbondanza, C., Altamimi, Z., Chin, T.M., Collilieux, X., Gross, R.S., Heflin, M.B., Jiang, Y., & Parker, J.W. 2015, KALREF - A Kalman Filter and Time Series Approach to the International Terrestrial Reference Frame Realization, J Geophys Res-Sol Ea 120, pp. 3775-3802

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