Short description of DTRF2020

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1st August 2023

1. Input data

1.1 Space-geodetic techniques

GNSS/IGS	1994-2021.0	daily solutions: free NEQ (rank deficiencies w.r.t. origin and orientation) reconstructed from SINEX
VLBI/IVS	1979-2021.0	session-wise NEQ (rank deficiencies w.r.t. origin and orientation)
SLR/ILRS	1984-2021.0	weekly, fortnightly solutions; loosely constrained; the loose constraints remain on the NEQ reconstructed from SINEX
DORIS/IDS	1993-2021.0	weekly solutions; datum conditions not booked in SINEX; rank deficiencies w.r.t. origin, orientation and scale are restored by setting up seven parameters of a similarity transformation per input NEQ

1.2 Local ties

- Local ties provided for ITRS 2020 and previous ITRS realizations

1.3 Non-tidal loading (NTL) displacements

- Provided by IERS GGFC (http://loading.u-strasbg.fr/GGFC/)
- Include atmospheric (ATM), hydrological (HYD) and oceanic (OCN) loading displacements with different temporal resolutions
- Based on the following models
    - ERA5 IB (Atmosphere)
    - ERA5 TUGO-m (Ocean)
    - ERA5 hydro (Hydrology)
- Station-wise CM-related loading time series per components [ATM, HYD, OCN] and [North, East, up]. CM-related values are applied for all techniques. The choice of the origin (CM/CF) for the corrections is free for VLBI, GNSS and DORIS as their NEQs are singular w.r.t. origin.

2. Parameters

Parameters provided by the different techniques and of the DTRF2020.

	Station positions	Station velocities	x/ypole	x/ypole rate	LOD	dUT1	Nutation X/Y
GNSS	x		x	x	x	x	x
VLBI	x		x	x	x		x
SLR	x		x		(x)		
DORIS	x		x				
DTRF2020	**x**	**x**	**x**	**x**	**x**	**x**	**x**

(x) SLR LOD series is not used in the combination, because it shows significant tidal signals w.r.t. the other techniques and the latest IERS series, IERS 08 C04 and IERS 14 C04.

3. DTRF2020

3.1 Reference epoch: 2010.0

3.2 Combination strategy

- Combination of NEQs following a 2-step approach (see Fig. 1)

Step 1

- Reduction of epoch-wise mean NTL displacements and post-seismic deformation (PSD) from epoch-wise (daily, weekly, session-wise) NEQs
- Identification of discontinuities and outliers
- Accumulation of NEQ series per technique, with station velocities introduced as new parameters
- Computation of a TRF solution (NEQ) per technique by applying intra-technique velocity conditions (equating velocities of consecutive solution number of one station and of co-located instruments of one technique as far as they do not differ significantly)

Step 2

- Combination of TRF-NEQs (resulting from the previous step) taking into account relative weights (see below)
- Introduction of local ties and velocity conditions (equating velocities of co-located sites) as pseudo-observations
- DTRF2020 datum realization

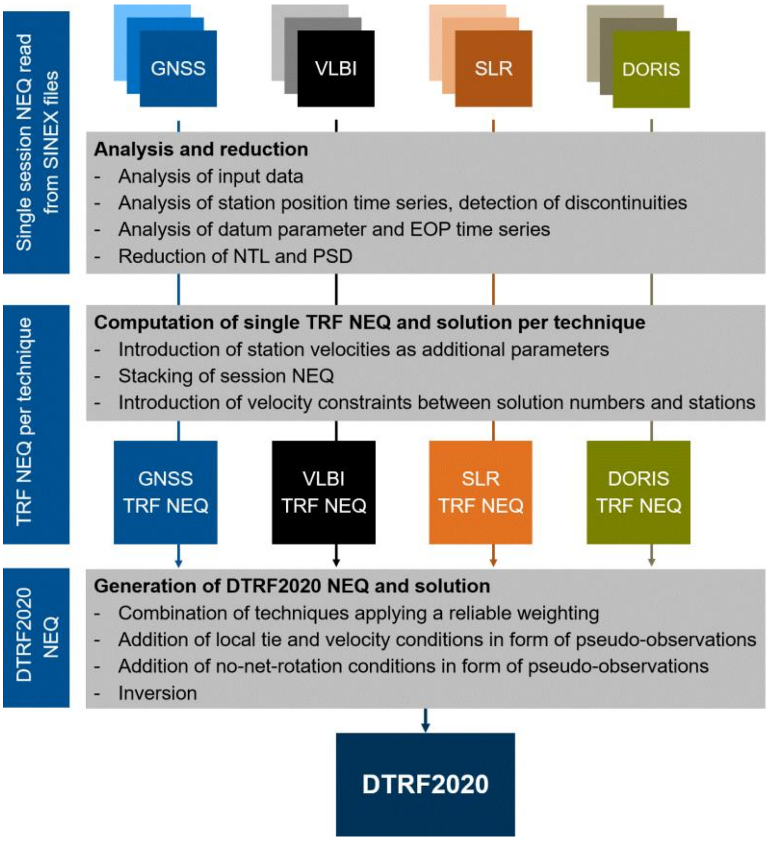

Fig. 1: DTRF2020 computation strategy.

3.3 Consideration of NTL and PSD

- NTL time series are converted to the temporal resolution of the input NEQs (daily, fortnightly or weekly), tailored to the individual station observation time span and detrended
- PSD is approximated per station and component by combinations of exponential and logarithmic functions (Note: for the GNSS station TSK2, a small offset caused by a discontinuity shortly after the earthquake is included in the approximation)
- NTL and PSD are reduced from input NEQs on daily, weekly or session basis

3.4 Weighting strategy

- Consideration of a-posteriori variance factors
- Considering weighting factors obtained by relating estimated formal errors and formal errors obtained for a mean station position from station time series analysis (VLBI, SLR and DORIS)
- For GNSS we analyzed time series of a selected set of stations by applying suitable noise models for their non-linear station motions in order to adjust the over-estimation of GNSS velocity precisions. We applied the HECTOR (Bos et al.,2013) software for this using as noise model *power law plus white noise*. We obtained an

overestimation of the accuracy for the velocities of stations with a long observation history (>12 years) by a factor of about 20, and for young stations with short observation periods of six years by a factor of about 10. These factors are not considered in the GNSS weighting factor applied in the combination as they would lead to an unjustified down-weighting of the GNSS station positions and the consistently estimated EOP. Therefore, we accept the over-estimation of GNSS velocity precisions within the combination and provide the obtained factor as additional information to the users.

3.5 Datum realization

- Origin: the DTRF2020 origin is realized from the full set of SLR data provided by ILRS
- Scale: the DTRF2020 scale is realized from the full set of VLBI and GNSS data provided by IVS and IGS, respectively. SLR does not contribute to the DTRF2020 scale because of a small scale offset and drift w.r.t. VLBI and GNSS. The SLR scale shows a very stable intrinsic time series and thus no scale parameters are set up for each SLR weekly/fortnightly NEQ but only one scale offset and scale drift for the combined SLR TRF NEQ. This ensures that SLR benefits from its high internal scale stability.
- Orientation: the DTRF2020 orientation is realized by no-net-rotation conditions w.r.t. DTRF2014 (Seitz et al., 2016, 2022) using a subset of GNSS stations

3.6 DTRF2020 comprises

- ~ 97,600 parameters
- Coordinates of 3200 individual station position solutions (solution numbers)
- EOP (see table above): ~76,800

4. DTRF2020 data

- SINEX files of DTRF2020 per technique with full variance-covariance matrix (note: there is a list of GNSS stations without DOMES numbers)
    - DTRF2020_{technique}.snx.gz

- EOP file of DTRF2020 in IERS 20 C04 format
    - DTRF2020_EOP.20C04_format.txt

- NTL corrections in [x,y,z] and [North,East,up] applied in DTRF2020 as time series per station. The time series refer to the center of mass of the Earth (CM). In addition, we provide NTL series referring to the center of figure (CF) of the Earth in the same format. Both types of series are provided from the respective start of the observation period of a technique until 2021.0. The NTL series are reduced by offset and drift obtained for the valid observation time

span of the individual station. The offsets and drifts are also provided (see below).
  - NTL_{CM|CF}_{technique}_{xyz|neu}.tar

- Mean offsets and drifts removed from individual NTL correction time series before applying them in DTRF2020 (for atmospheric, hydrological and oceanic effect and the sum) in [x,y,z] and [North,East,up]. The values are provided for the applied CM-referred series and for the CF-referred series (see above).
  - NTL_{CM|CF}_{technique}_reduced_offsets_and_drifts.tar

- PSD corrections in [x,y,z] applied in DTRF2020 as time series per station affected by a significant post-seismic deformation. For solution numbers with an observation period beyond the end of the DTRF2020 period, long time series are provided up to epoch 2031-01-01.
  - PSD_{technique}.tar

- Station position residual time series in [North, East, up] resulting from 7-parameter similarity transformations of technique-specific solution series with respect to DTRF2020. Important note: The solution series for the individual techniques are based on the NEQs that are used for the DTRF2020 calculation, i.e., the NEQs reduced by the NTL displacements.
  - Station_Residual_Time_Series_{technique}.tar

- SLR translation time series with respect to DTRF2020
  - SLR_translation_wrt_DTRF2020.txt

5. Application of DTRF2020

- Addition of PSD approximation time series to DTRF2020 linear station motions provides the full post-seismic motion for stations affected by an earthquake. Time series for PSD are accessible for extrapolation of DTRF2020 until January 1, 2031.

- Addition of NTL model time series referring to CM[1] provides geocentric station position time series including the non-tidal loading signal. For the extrapolation of DTRF2020 please use the NTL series provided by GGFC on the website http://loading.u-strasbg.fr/ITRF2020/displa/CM/. ERA5_IB_notide, ERA5_TUGO_notide and ERA5_hydro are the respective atmospheric, oceanic and hydrological non-tidal loading components. For a correct continuation of the series applied in DTRF2020 it is important to reduce the GGFC data by the offsets and drifts by which also the series applied in DTRF2020 were reduced. The offsets and drifts are provided in the DTRF2020 release (see above).

[1] CM, as represented by SLR in long-term linear mean plus non-linear variations provided by the NTL models

- Addition of NTL model time series referring to CF provides station position time series referring to the center of figure including the non-tidal loading signal of the respective station only. For the extrapolation of DTRF2020 please use the NTL series provided by GGFC on the website http://loading.u-strasbg.fr/ITRF2020/displa/CF/. ERA5_IB_notide, ERA5_TUGO_notide and ERA5_hydro are the respective atmospheric, oceanic and hydrological non-tidal loading components. For a correct continuation of the series provided in the DTRF2020 release, please reduce the GGFC data by the offsets and drifts also provided for the CF-related NTL displacements in the DTRF2020 release (see above).

- DTRF2020 EOP are consistent with the linear DTRF2020 (SINEX files). Applying DTRF2020 with adding the NTL displacements to the linear station positions means that the resulting non-linear station positions are not fully consistent with the DTRF2020 EOP.

References

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