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DTRF2020:
the ITRS 2020 realization of DGFI-TUM

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International Terrestrial Reference Frame (ITRF)

- „A Terrestrial Reference System (TRS) is a **spatial reference system co-rotating with the Earth** in its diurnal motion in space.“ (Petit & Luzum [2010]).

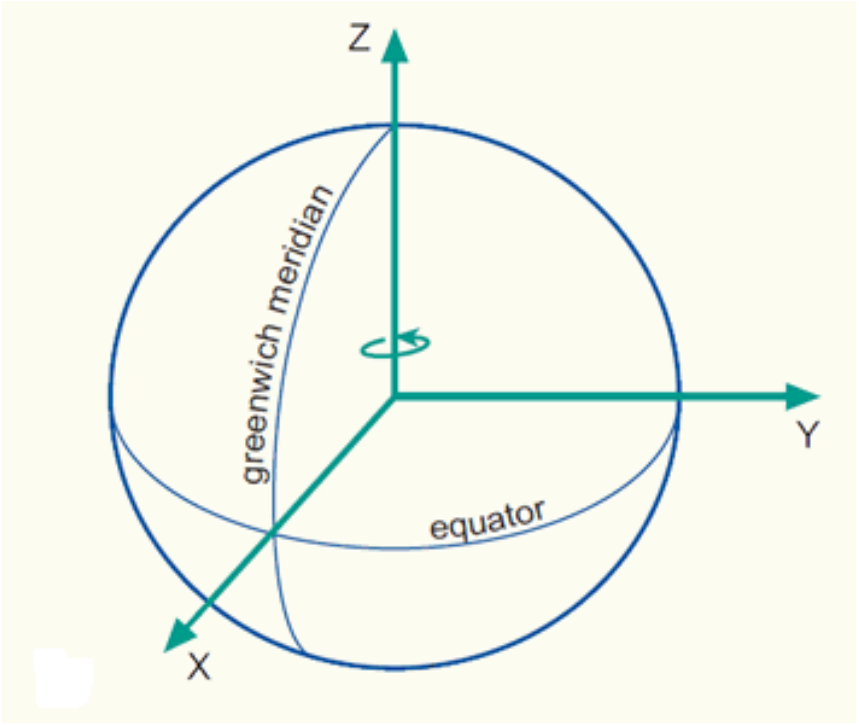
- The **origin** of the TRS is close to **center of mass** of the Earth, the TRS has an **equatorial orientation** (i.e. the z-axis is close to the mean axis of Earth rotation, the x-axis points towards the Greenwich meridian), and its unit length (**scale**) is close to the **SI meter** (see figure).

- The **realization** of a TRS (i.e., of the origin, orientation and scale) through a set of precisely defined reference point coordinates and velocities is called a **Terrestrial Reference Frame** (**TRF**).

- **IERS** (International Earth Rotation and Reference Systems Service) **ITRS** (International Terrestrial Reference System) **Combination Centers**:

Institution	Frame
Institut National de l’Information Géographique et Forestière (**IGN**)	ITRF
NASA’s Jet Propulsion Laboratory (**JPL**)	JTRF
Deutsches Geodätisches Forschungsinstitut der TU München (**DGFI-TUM**)	DTRF

- The Centers use the **same data**, but **different computation approaches**.



https://kartoweb.itc.nl/geometrics/Bitmaps/ITRSd.gif

History of DGFI-TUM realizations

- Like the other Combination Centers, we use the data of **all four geodetic space techniques** (DORIS, GNSS, SLR and VLBI). The first two ITRS realizations by DGFI-TUM have been generated in 2000 (DTRF2000) and 2005 (DTRF2005).

- Since then, the DTRF solutions evolved like this (new features are given in blue):

DTRF2008

- Combination at normal equation (NEQ) level
- Earth orientation parameters (EOP) included

Release contained:
- SINEX files
- EOP file

Reference:
Seitz et al. 2012

DTRF2014

- Combination at NEQ level
- EOP included
- → Non-tidal loading (NTL) considered (atmosphere and hydrology)

Release contained:
- SINEX files
- EOP file
- → Time series for
  - Station residuals
  - NTL corrections
  - SLR translation (DTRF2014 origin)

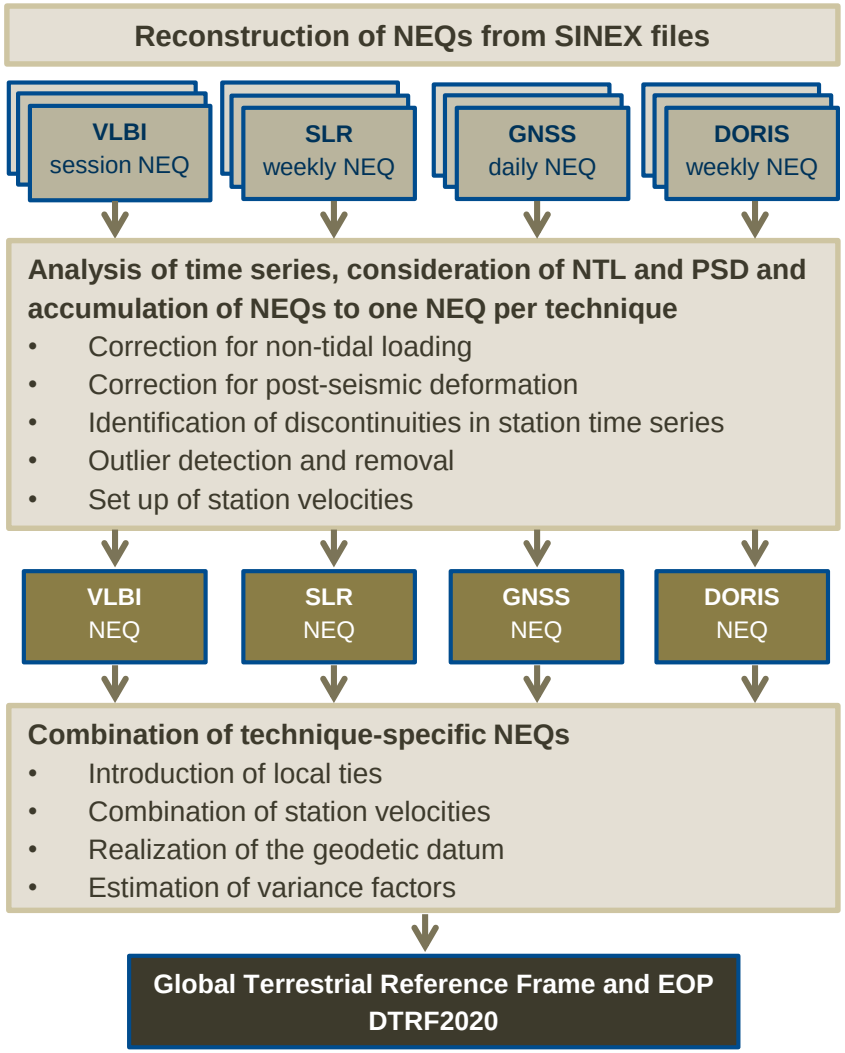
Reference:
Seitz et al. 2016

DTRF2020

- Combination at NEQ level
- EOP included
- NTL considered (atmosphere and hydrology) plus oceanic component
- → Post-seismic deformation (PSD) considered

Release shall contain:
- SINEX files
- EOP file
- Time series for
  - Station residuals
  - NTL corrections
  - SLR translation (DTRF2020 origin)
- → Parameters of PSD models

DTRF2020: computation strategy



- Like its predecessors, DTRF2020 will be based on the **combination of the input data at normal equation level**.

- **First step: intra-technique combination** after correcting each normal equation for NTL and PSD,

$$\tilde{\boldsymbol{y}} = \boldsymbol{y} - \boldsymbol{N}\,\delta\boldsymbol{x}_{\mathbf{NTL/PSD}},$$
$$\tilde{\boldsymbol{l}}^{\boldsymbol{T}}\tilde{\boldsymbol{P}}\tilde{\boldsymbol{l}} = \boldsymbol{l}^{\boldsymbol{T}}\boldsymbol{P}\boldsymbol{l} + \delta\boldsymbol{x}^{\boldsymbol{T}}\left(\boldsymbol{N}\,\delta\boldsymbol{x}_{\mathbf{NTL/PSD}} - \mathbf{2}\boldsymbol{y}\right),$$

  and the introduction of station velocities.

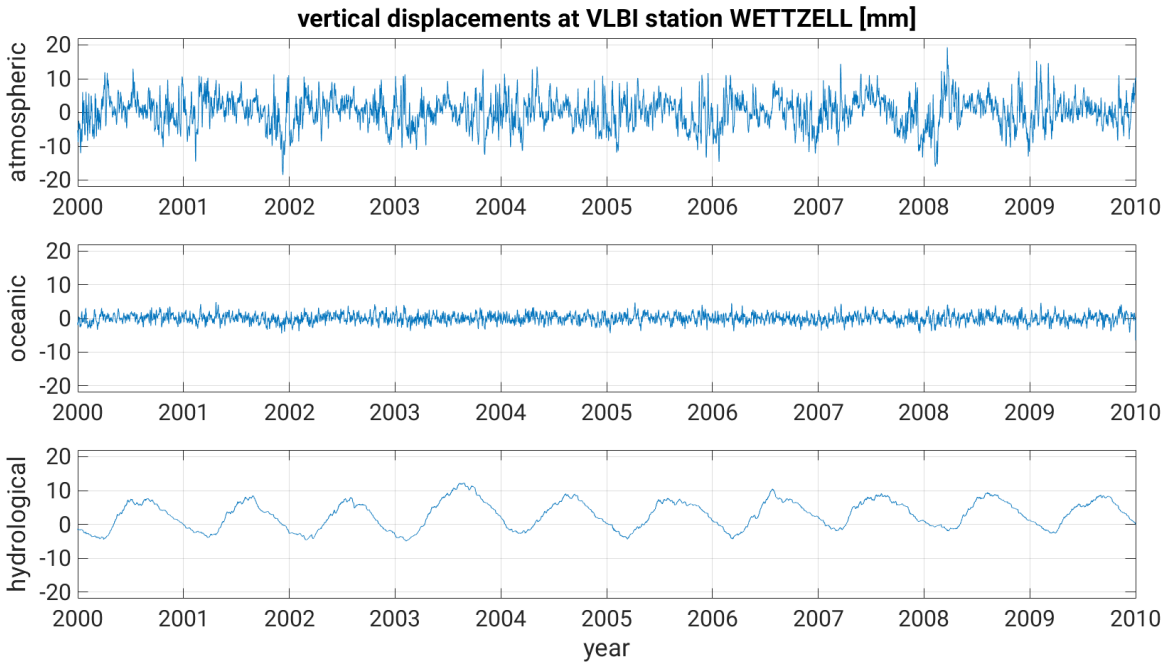
- **Second step: inter-technique combination** comprising the introduction of local ties and the equalization of station velocities.

- The **origin** is realized by SLR, the **orientation** by no-net-rotation conditions w.r.t. DTRF2014 using a subnet of GNSS stations, and the **scale** by SLR and VLBI (and if appropriate by GNSS).

DTRF2020: non-tidal loading

- We plan to apply NTL **site displacements** based on geophysical models.
- Compared to DTRF2014, we now **include the oceanic NTL**, and the underlying geophysical models have changed.
- Like for DTRF2014, the correction for NTL is supposed to **reduce the WRMS and the annual signal** in particular in the time series of station heights, and thus has an impact on the estimated parameters and their **standard deviations**.
- We will use the displacement data (see figure) of the **IERS Global Geophysical Fluids Center** (**GGFC**, loading.u-strasbg.fr/ITRF2020/). It provides different components (see table) and ensures **mass conservation** among them.

component	underlying model
atmospheric	ECMWF ERA5 + inverse barometer (IB) hypothesis
atmospheric + oceanic	ECMWF ERA5 + TUGO-m
hydrological	ECMWF ERA5



DTRF2020: post-seismic deformation

- For the first time, the **post-seismic deformation** for stations affected by earthquakes will be considered by reducing a corresponding modelled signal (see figures) **at the normal equation level**.

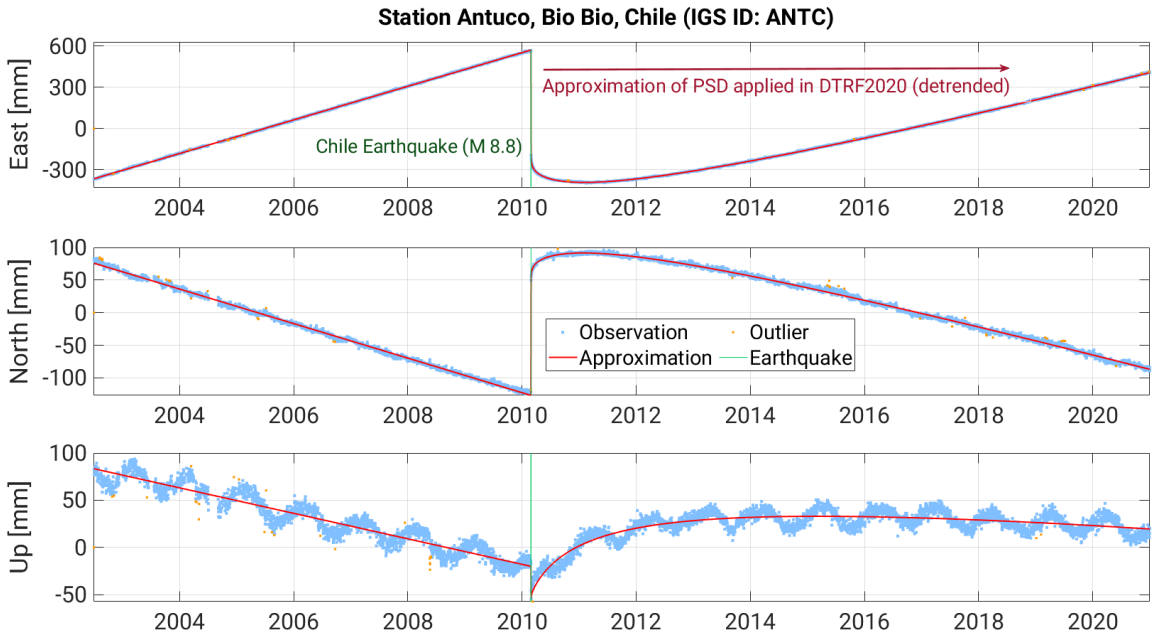
- We use a software developed at DGFI-TUM, **APROPOS**, which examines combinations of **logarithmic** and **exponential functions** for approximating the signal, e.g.,

$$\text{log-log:}\quad \delta x_{PSD}(t) = \sum_{i=1}^{2} A_i \log\left(1 + \frac{\Delta t}{\tau_i}\right)$$

$$\text{log-exp:}\quad \delta x_{PSD}(t) = A_l \log\left(1 + \frac{\Delta t}{\tau_l}\right) + A_e \left[1 - \exp\left(-\frac{\Delta t}{\tau_e}\right)\right]$$

- The amplitudes $\boldsymbol{A}$ and relaxation times $\boldsymbol{\tau}$ are unknowns and have to be determined in a **non-linear optimization (NLO)** problem. $\boldsymbol{\Delta t}$ is the time lag to the earthquake epoch.

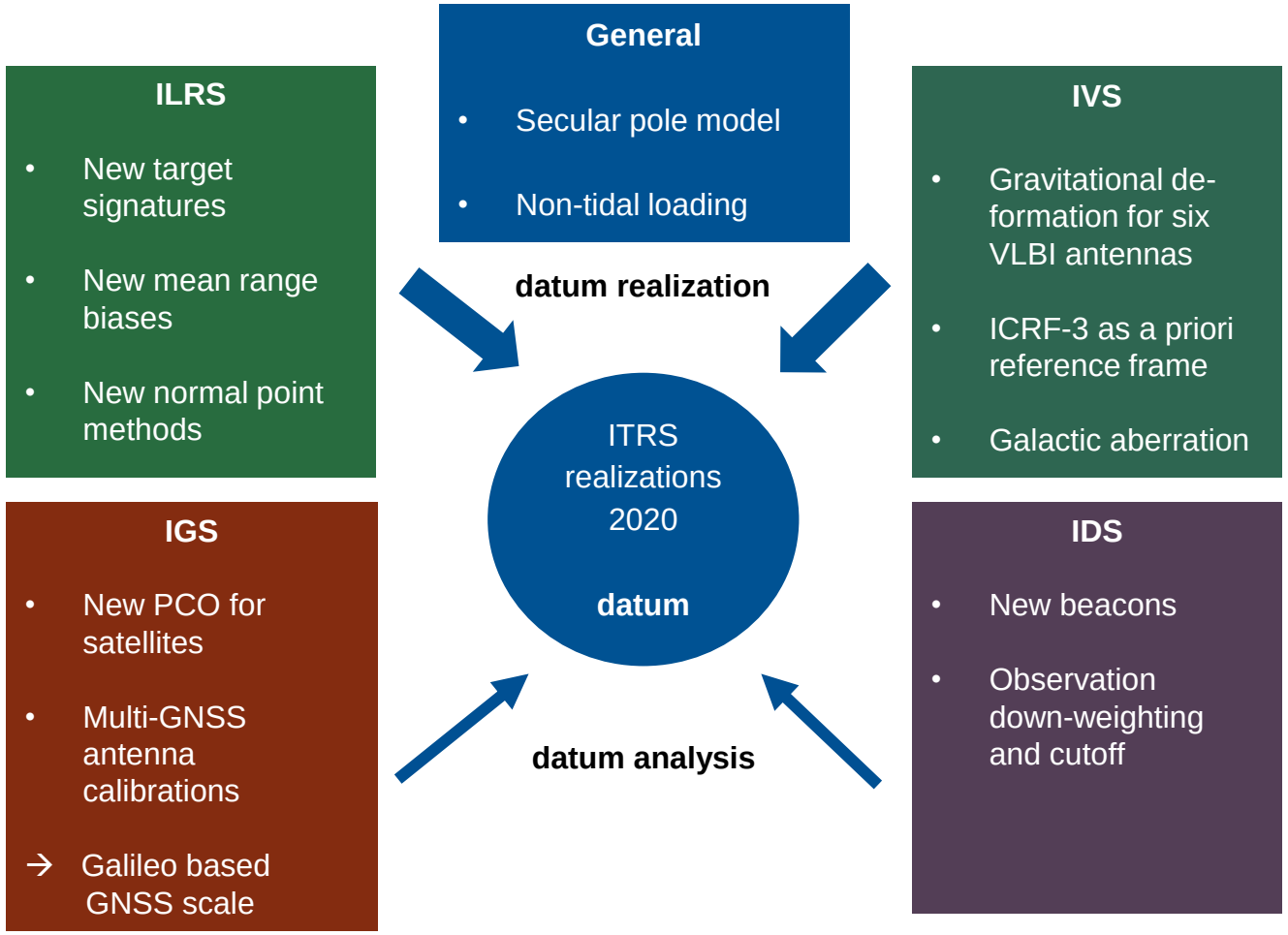
- APROPOS contains **three different algorithms** to solve the NLO problem per station coordinate.



Time series of station positions with fitted PSD signals.

https://en.wikipedia.org/wiki/2010_Chile_earthquake

DTRF2020: implications of new models



- The phase center offset (PCO) for Galileo satellites is transferrable to the other GNSS satellites, and hence **the TRF scale might be realizable with GNSS** next to SLR and VLBI.
- Many model changes are **related to the station heights**, e.g., the mean range biases (SLR) and the gravitational deformation (VLBI), which will affect the TRF scale as well.
- Hence, the **scale realization will generally deviate significantly** from that of the DTRF2014. A potential **scale offset** between SLR and VLBI is still an open issue.

DTRF2020: input data and status of processing

➢ Input data

technique/service	# SINEX files	resolution	time span	years	# stations	x-, y-pole	x-, y-pole-rate	UT1-UTC	LOD	nutation offsets
GNSS/IGS	9851	daily	1994.0 - 2021.0	27	1906	X	X		X	
DORIS/IDS	1456	weekly	1993.0 - 2021.0	28	200	X				
SLR/ILRS*	1461	weekly	1993.0 - 2021.0	28	108	X			X	
VLBI/IVS	6135	session-wise	1979.8 - 2021.0	41	151	X	X	X	X	X

** Data for 1983-1992 will be provided soon*

➢ Status of processing

- All available input SINEX files are analysed; datum-free normal equations are reconstructed.
- The normal equations are processed; time series and first intra-technique TRF solutions computed.
- Discontinuities are identified (e.g., GNSS number of discontinuities: 1725).
- PSD is approximated (GNSS: 65 individual station motions).
- NTL corrections are analysed and prepared (daily, session-wise, or weekly corrections per station).
- **Next step**: computation of final intra-technique TRF solutions considering PSD models and NTL corrections.

Summary

- DGFI-TUM‘s realization of the ITRS 2020 is the **DTRF2020**, which is based on a **combination of normal equations**.
- Compared to the DTRF2014, we now include **non-tidal oceanic loading** in addition to the atmospheric and hydrological ones.
- Another DTRF2020 novelty is the correction for **post-seismic deformation** at the normal equation level. The corresponding approximations by logarithmic and exponential functions are computed with our software **APROPOS**.
- The **model innovations** for the four geodetic space techniques DORIS, GNSS, SLR and VLBI, as well as the **new and longer data series** between the ITRS 2014 and ITRS 2020 realizations will significantly affect the new TRFs.
- In particular, we expect (also based on preliminary analyses) a **significant impact on the TRF scale**. Next to SLR and VLBI, it might also be realized from GNSS this time.

References

- *Petit G., Luzum B. (Eds.):* **IERS Conventions**. IERS Technical Note 36, Verlag des Bundesamts für Kartographie und Geodäsie, Frankfurt a.M., 2010.

- *Seitz M., Angermann D., Bloßfeld M., Drewes H., Gerstl M.*: **The 2008 DGFI realization of the ITRS: DTRF2008**. Journal of Geodesy, 86(12), 1097-1123, 10.1007/s00190-012-0567-2, 2012.

- *Seitz M., Bloßfeld M., Angermann D., Schmid R., Gerstl M., Seitz F.*: **The new DGFI-TUM realization of the ITRS: DTRF2014 (data)**. Deutsches Geodätisches Forschungsinstitut, Munich, 10.1594/PANGAEA.864046, 2016.

Thank you very much for your attention!

Are there any questions?