DTRF2020: the ITRS 2020 realization of DGFI-TUM

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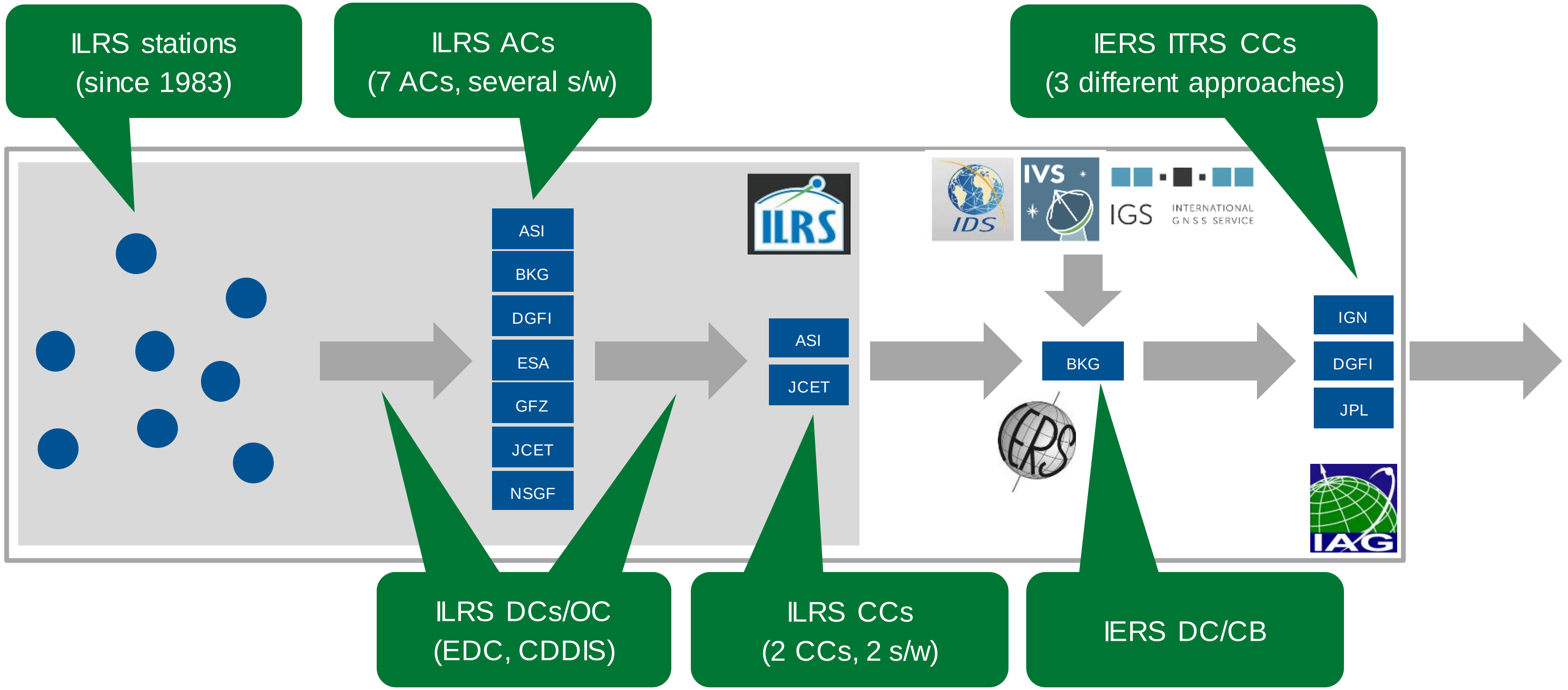
The ITRS 2020 realization – the IAG, IERS, ILRS, …

- The computation of an ITRS realization is an effort of numerous entities of the geodetic infrastructure of the IAG!



ILRS stations
(since 1983)

ILRS ACs
(7 ACs, several s/w)

ASI
BKG
DGFI
ESA
GFZ
JCET
NSGF

ASI
JCET

BKG

IGN
DGFI
JPL

IERS ITRS CCs
(3 different approaches)

ILRS DCs/OC
(EDC, CDDIS)

ILRS CCs
(2 CCs, 2 s/w)

IERS DC/CB

	Current realization
IGN	ITRF2020
DGFI-TUM	DTRF2020
JPL	JTRF2020

- Based on **identical input data** provided by the **IAG Services** of the four techniques **GNSS**, **SLR**, **VLBI** and **DORIS**, the three CCs compute **ITRS realizations** using **different combination strategies and software**
- **ITRS realizations are computed every 5-6 years to ensure a high accuracy and precision**

Input data provided by IAG Services

Input data:

Technique / IAG Services	#SINEX files*	Time span	Years
VLBI/IVS	6210	1979-2021.0	41
SLR/ILRS	**1704**	**1983-2021.0**	**38**
GNSS/IGS	9851	1994-2021.0	27
DORIS/IDS	1456	1993-2021.0	28

* different temporal resolutions

Parameters included: station coordinates & EOP

	Pole offsets	Pole rates	UT1-UTC	LOD	Nutation offsets
IVS	x	x	x	x	x
ILRS	**x**			**x**	
IGS	x	x		x	
IDS	x				

New situation for DTRF2020 compared to DTRF2014

- ➢ **longer observation time spans** for each technique
- ➢ **new stations**, **new hardware at stations**, **new launched satellites**, **new measured local ties**
- ➢ **several new models** had been adopted
  - ▪ new general models (e.g., secular pole model)
  - ▪ new technique-specific models (e.g., GNSS satellite z-PCVs → **GNSS provides an independent scale realization!**
    e.g., SLR target signatures and long-term mean range biases → **SLR scale changes!**)

→ **impact on station coordinates, velocities, EOPs as well as on the DTRF geodetic datum is expected**

Main characteristics of DTRF2020 computation strategy

- based on the **combination of NEQs**
- **Processing line (2-step approach)**

  1) analysis of data and computation of one **TRF per technique**
     - reduction of non-tidal loading (NTL) and post-seismic deformation (PSD)
     - analysis of station position time series and datum parameter and EOP time series
     - introduction of station velocities

  2) **combination of technique NEQs to DTRF2020 solution**

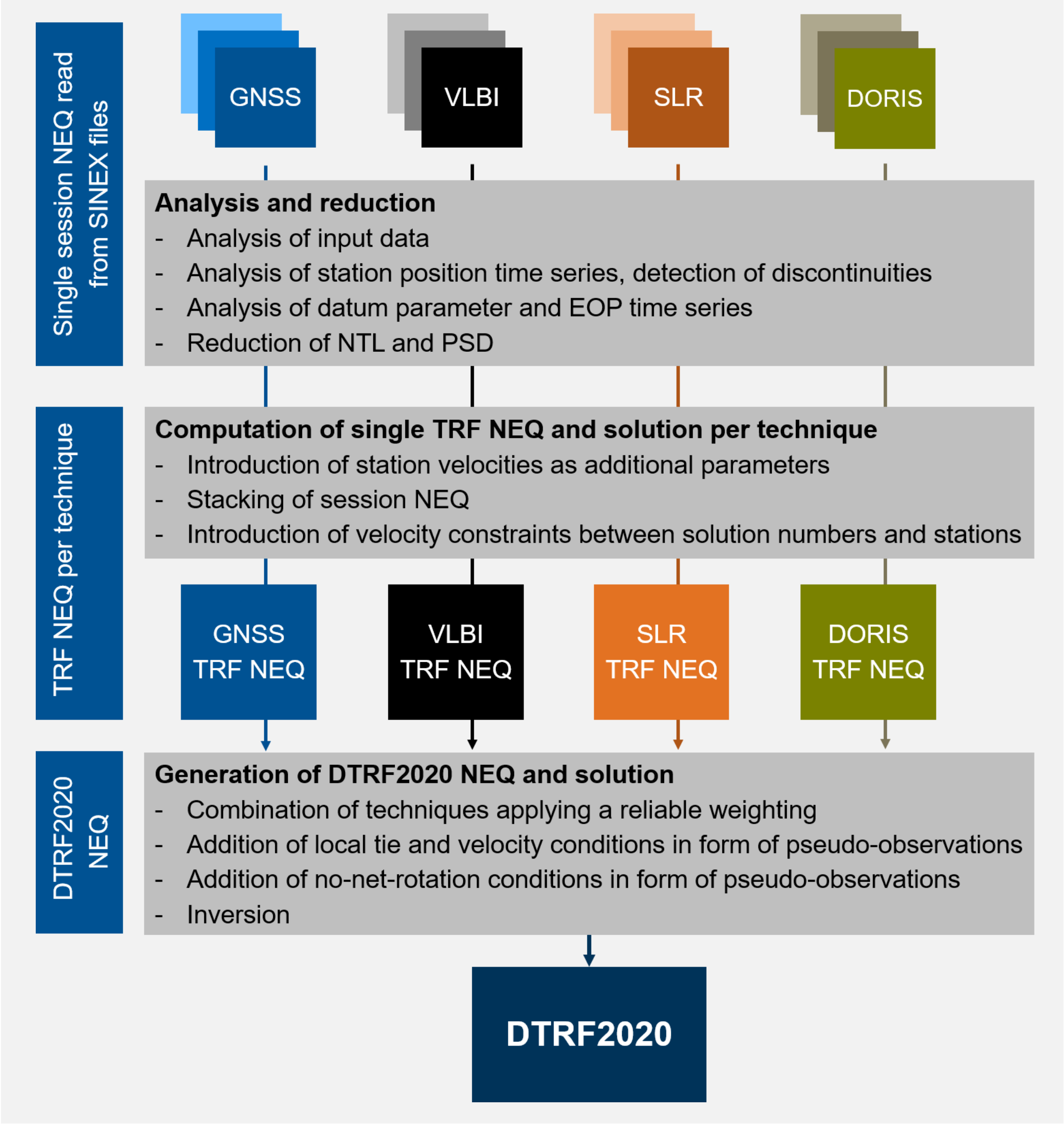
New in DTRF2020

- **Non-tidal loading (NTL)**:

  all three components (atmospheric, hydrological and oceanic) are provided by GGFC* and reduced at the NEQ level
- **Post-seismic deformation (PSD)**:

  approximated by a combination of logarithmic and exponential functions and reduced at the NEQ level

* GGFC: Global Geophysical Fluid Centre



Analysis and reduction
- Analysis of input data
- Analysis of station position time series, detection of discontinuities
- Analysis of datum parameter and EOP time series
- Reduction of NTL and PSD

Computation of single TRF NEQ and solution per technique
- Introduction of station velocities as additional parameters
- Stacking of session NEQ
- Introduction of velocity constraints between solution numbers and stations

Generation of DTRF2020 NEQ and solution
- Combination of techniques applying a reliable weighting
- Addition of local tie and velocity conditions in form of pseudo-observations
- Addition of no-net-rotation conditions in form of pseudo-observations
- Inversion

Reduction of non-tidal loading (NTL) corrections

NTL input data

- **provided by IERS GGFC**
- **atmospheric**, **hydrological** and **oceanic** NTL corrections for station positions based on ERA5/ECMWF (Hersbach et al. 2020) and TUGOm ocean dynamic model (Carrere and Lyard, 2003)

$$\delta \boldsymbol{x}_{\mathbf{load}} = \boldsymbol{\delta x}_{\mathbf{NTL-ATM}} + \boldsymbol{\delta x}_{\mathbf{NTL-CWS}} + \boldsymbol{\delta x}_{\mathbf{NTL-OCN}}$$

- **detrended**, to ensure that there is no systematic effect on station velocities

NTL is considered by a reduction of each single input NEQ

$$\tilde{\boldsymbol{N}} = \boldsymbol{N}$$

$$\tilde{\boldsymbol{y}} = \boldsymbol{y} - \boldsymbol{N}\delta \boldsymbol{x}_{\mathbf{load}}$$

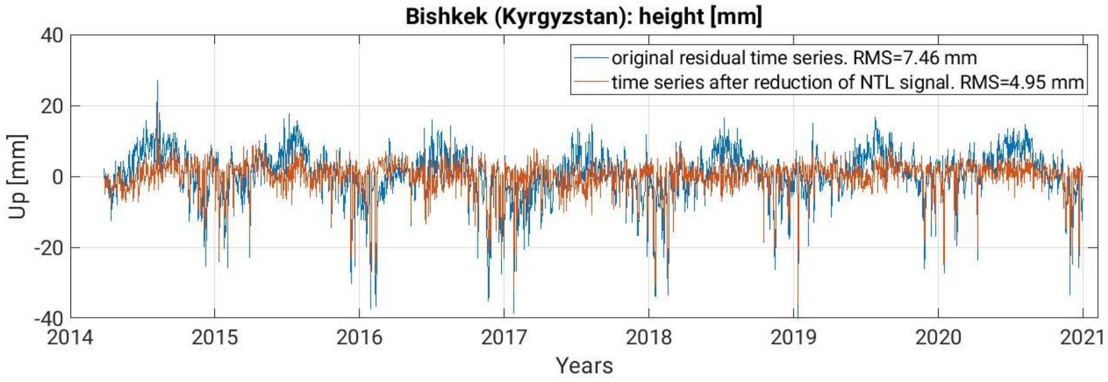
$$\tilde{\boldsymbol{l}}^T \tilde{\boldsymbol{P}} \tilde{\boldsymbol{l}} = \boldsymbol{l}^T \boldsymbol{P} \boldsymbol{l} + \delta \boldsymbol{x}_{\mathbf{load}}^T (\boldsymbol{N}\delta \boldsymbol{x}_{\mathbf{load}} - 2\boldsymbol{y})$$

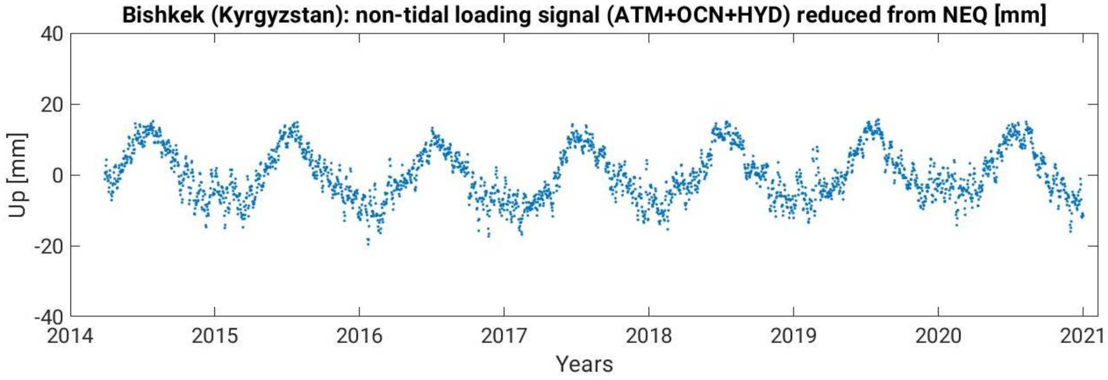
$$\tilde{\boldsymbol{x}}_{\mathbf{0}} = \boldsymbol{x}_{\mathbf{0}}$$

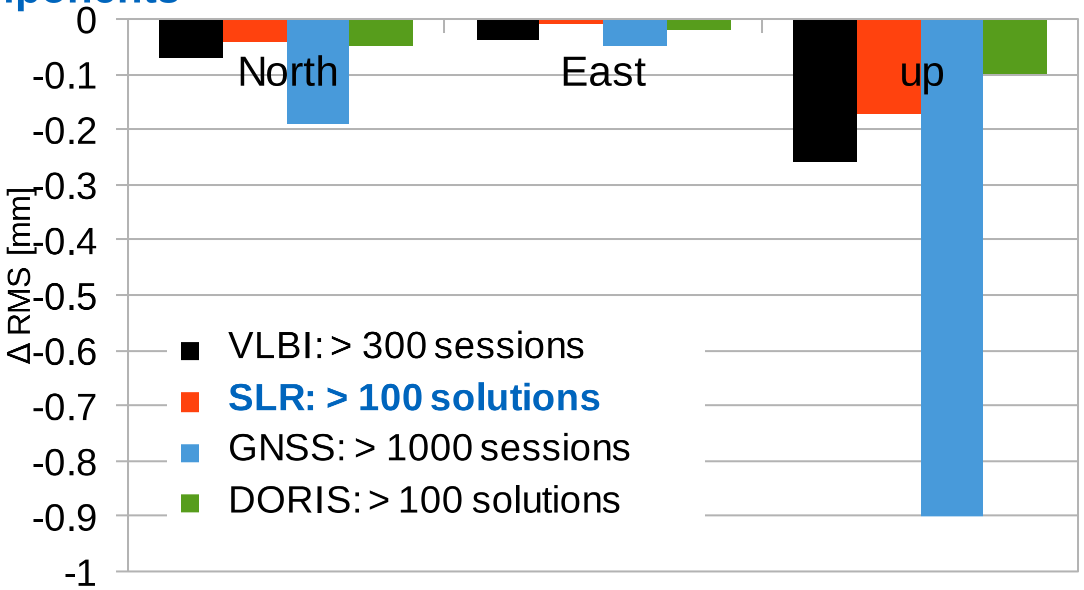
see also
Glomsda et al. 2021

Impact of reducing NTL: station coordinates

- **Improved station repeatability in particular for the up components**





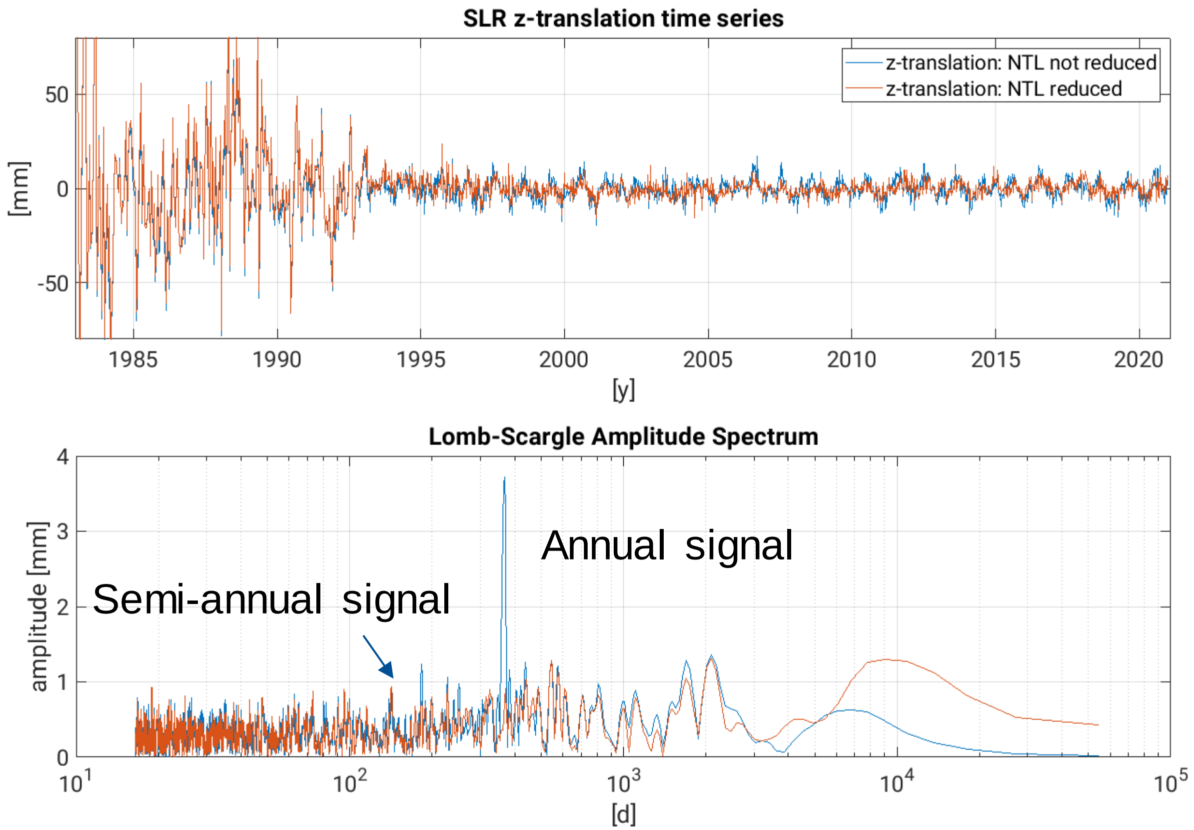


Median of RMS change [%]

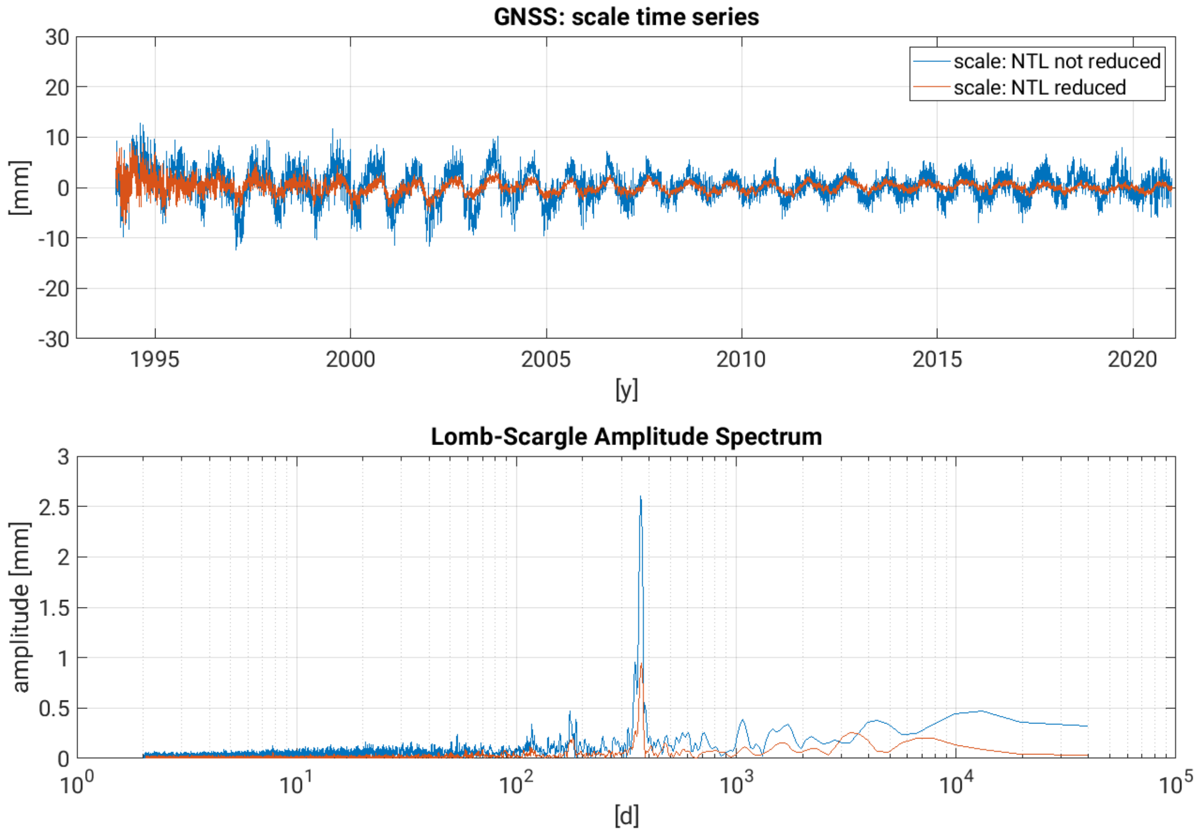
Technique / IAG Service	# stations	North	East	Up
VLBI/IVS	72	-2.2	-1.3	-2.1
SLR/ILRS	**85**	**-0.2**	**-0.1**	**-0.6**
GNSS/IGS	2256	-5.5	-3.3	-16.7
DORIS/IDS	195	-0.6	-0.2	-0.9

Impact of reducing NTL: datum parameters (examples)

SLR origin, **z-component** (intrinsic translation time series)



GNSS scale (intrinsic scale time series)



➢ Reduction of RMS and the (semi-)annual signal for all SLR origin components and the **VLBI**, **SLR** and **GNSS scale**

Reduction of post-seismic deformation (PSD)

Software APROPOS

- approximation by combined logarithmic and exponential functions

$$\delta x_{\mathbf{PSD}} = \sum_{i=1}^{n} A_{li} \log\left(1+\frac{\Delta t}{\tau_{li}}\right) + \sum_{j=1}^{m} A_{ej}\left(1-\exp\left(-\frac{\Delta t}{\tau_{ej}}\right)\right)$$

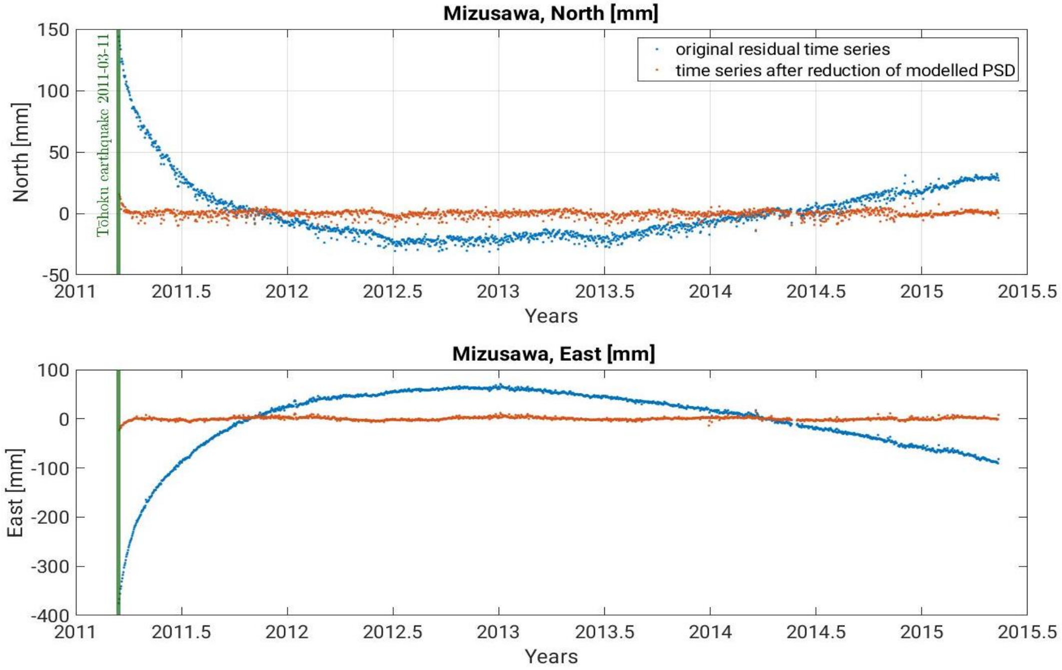
A	Amplitude of transient function (log or exp)
τ	relaxation time of transient function
Δt	time difference to the Earthquake epoch

- relaxation times τ are also parameterized → non-linear optimization problem
- approximation per component [XYZ] or [NEU]

Reduction of PSD model values from input NEQ (like the reduction of NTL)

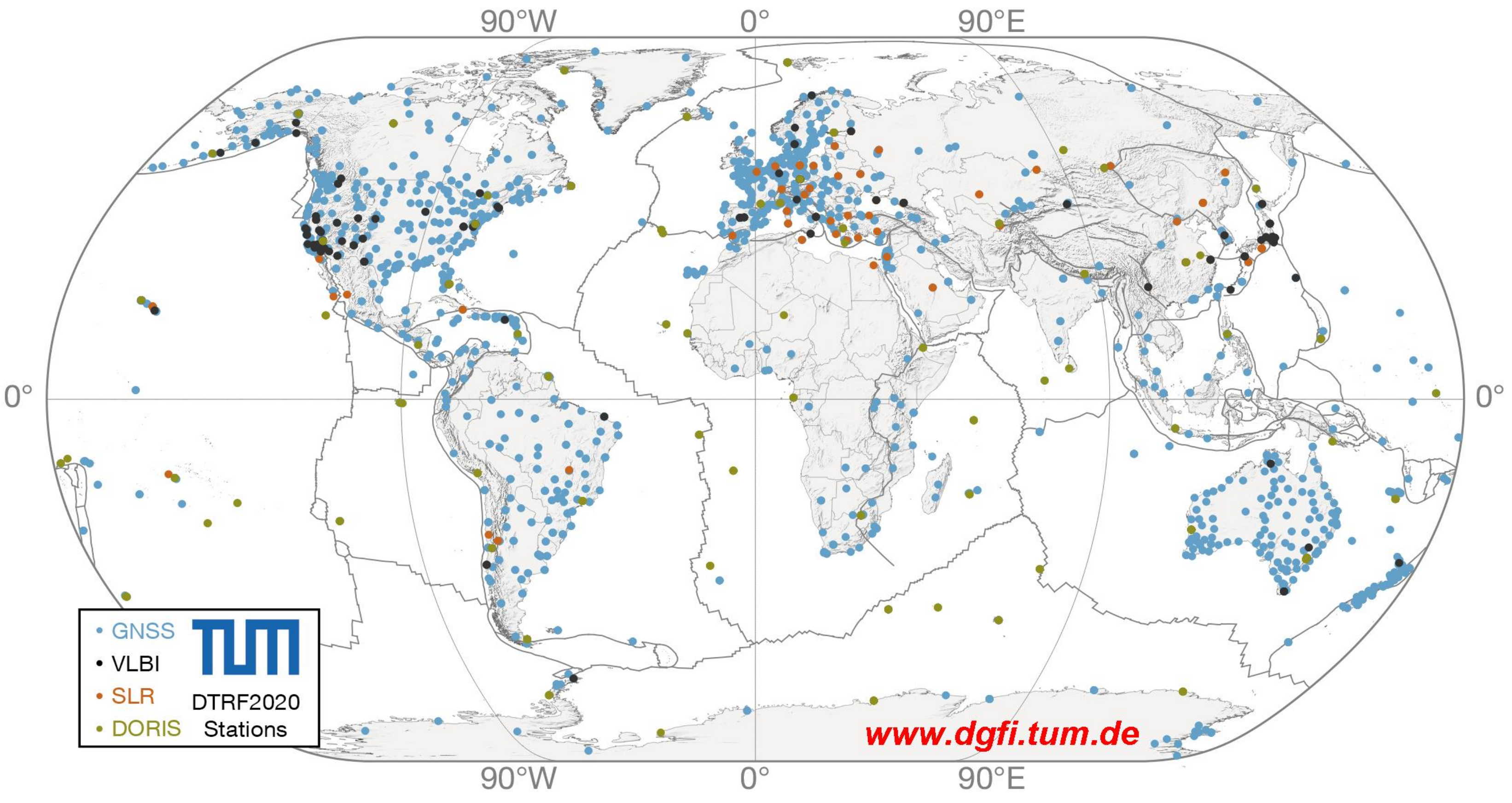
	Number of stations
GNSS	63
SLR	**2 (TIGO, Arequipa)**
VLBI	7
DORIS	1

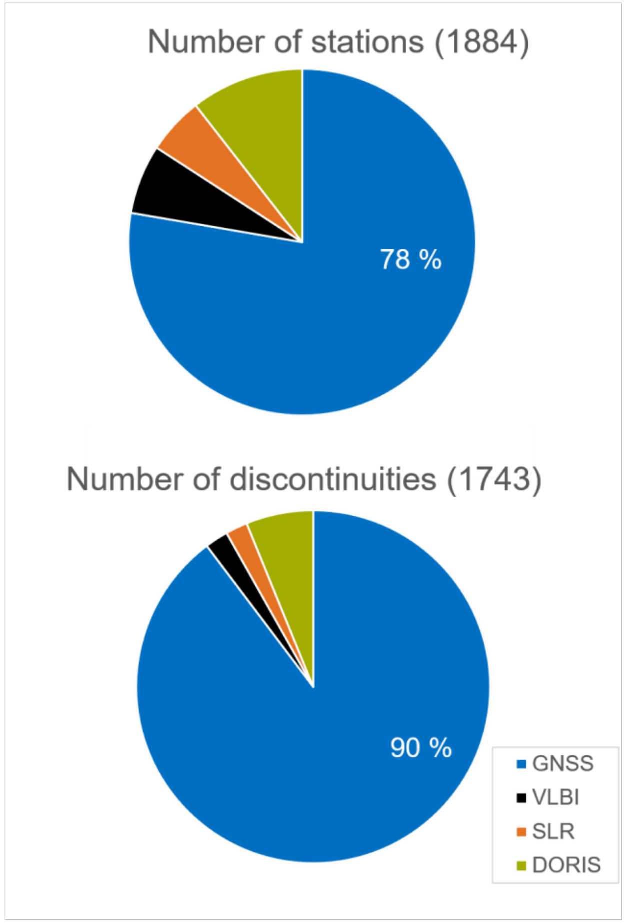
Example:
GNSS station Mizusawa, Japan (MIZU) after the Tōhoku Earthquake 2011-03-11



DTRF2020 station network: discontinuities

- for the **DTRF2020**, about 1880 observing stations are processed
- GNSS provides by far the largest number of stations



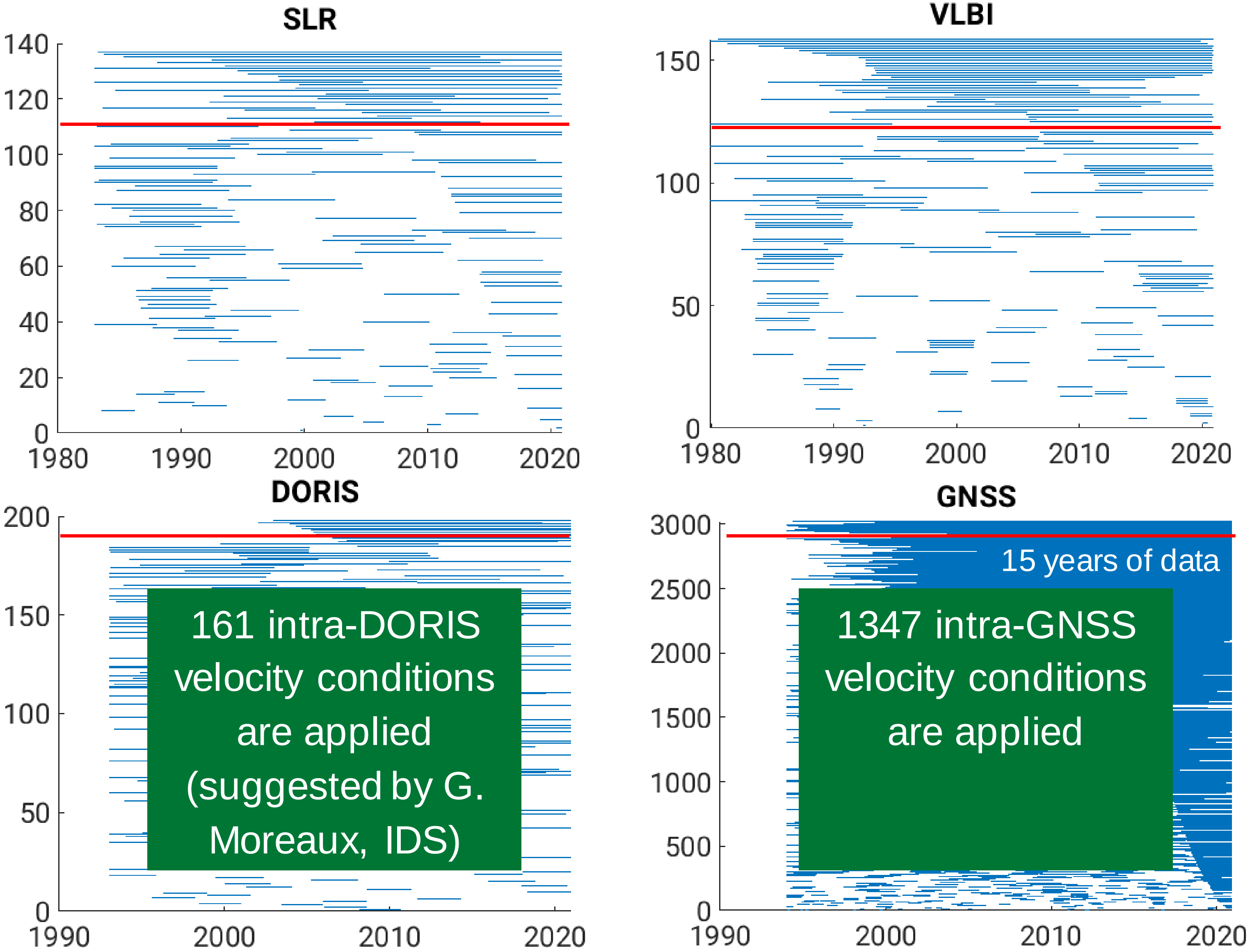


DTRF2020 station network: discontinuities

- ➢ Stations sorted by length of observation time span
- ➢ **SLR and VLBI provide a solid basis** of overlapping station observation time spans of 15 years and more
- ➢ The large number of discontinuities leads to a **fragmentation of GNSS and in particular DORIS TRF**

→ drift changes in translation time series at reference epoch

- ➢ **Long-term stability of TRF can be ensured only by a combination of station velocities** of
  - solution numbers or
  - intra-technique co-locations
- ➢ **How to decide**, which velocity constraints shall be applied when TRF solutions are unstable?



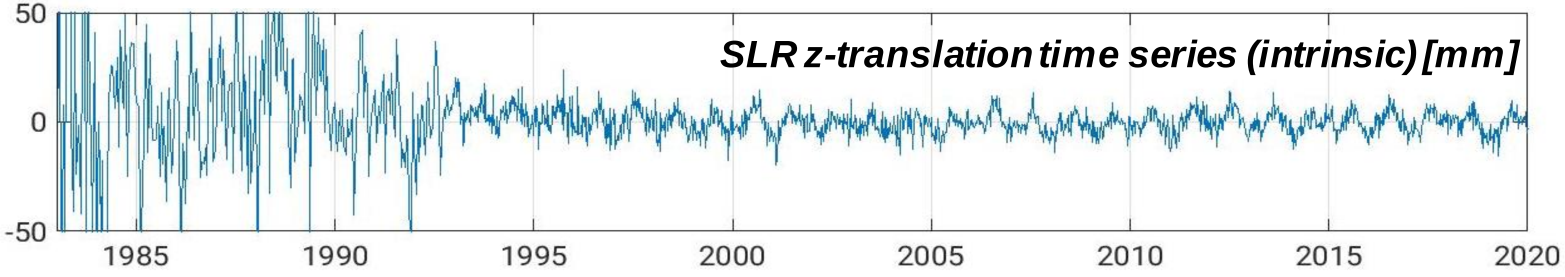
161 intra-DORIS velocity conditions are applied (suggested by G. Moreaux, IDS)

1347 intra-GNSS velocity conditions are applied

Datum realization of DTRF2020 – origin and orientation

DTRF2020 origin

- Realized from the **full history** of SLR observation data



DTRF2020 orientation

- By no-net-rotation conditions for positions and velocities w.r.t. DTRF2014 using a subset of globally distributed GNSS stations; **reference epoch 2010.0**

Datum realization of DTRF2020 - scale

- VLBI, SLR and for the first time GNSS provide an **independent scale**

Analysis of scale agreement

- by solving DTRF2020 solutions setting up **individual scale parameters for GNSS, SLR** and **VLBI** or both of them.

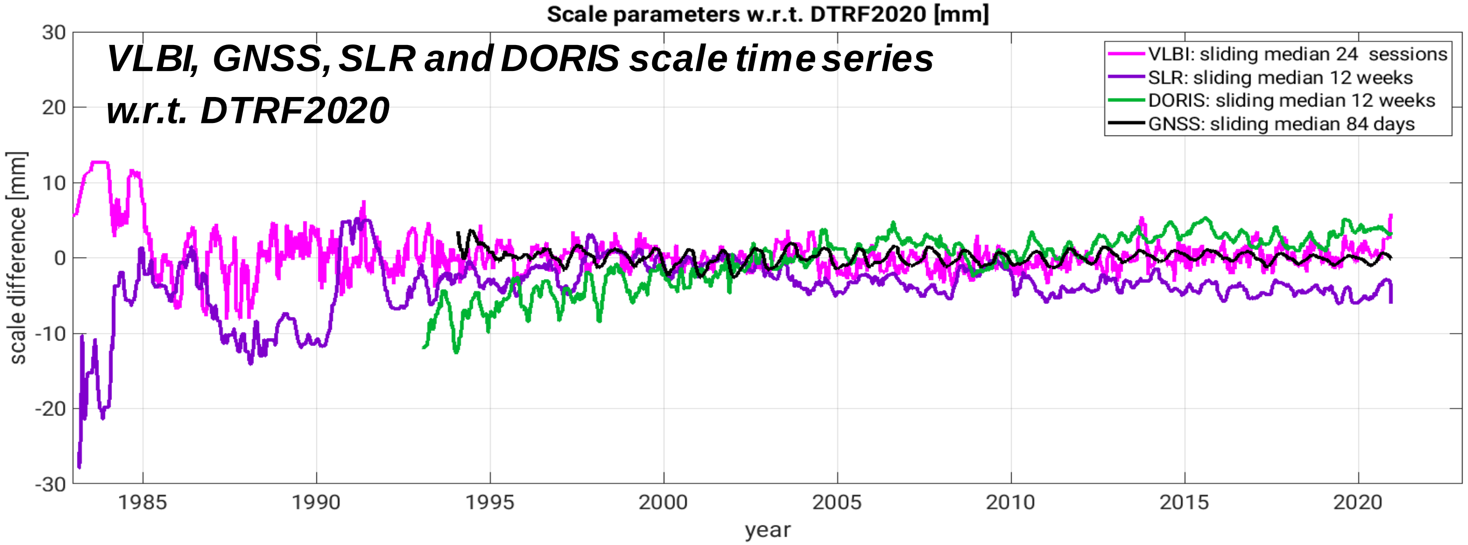
Results

- **VLBI and GNSS**: agree within **0.25 mm** (epoch 2010.0) and **0.05 mm/yr**
- **SLR**: small offset and drift w.r.t. **GNSS and VLBI** of **-2.2 mm (epoch 2010.0)** and **-0.1 mm/yr**

→ SLR does not affect the DTRF2020 scale

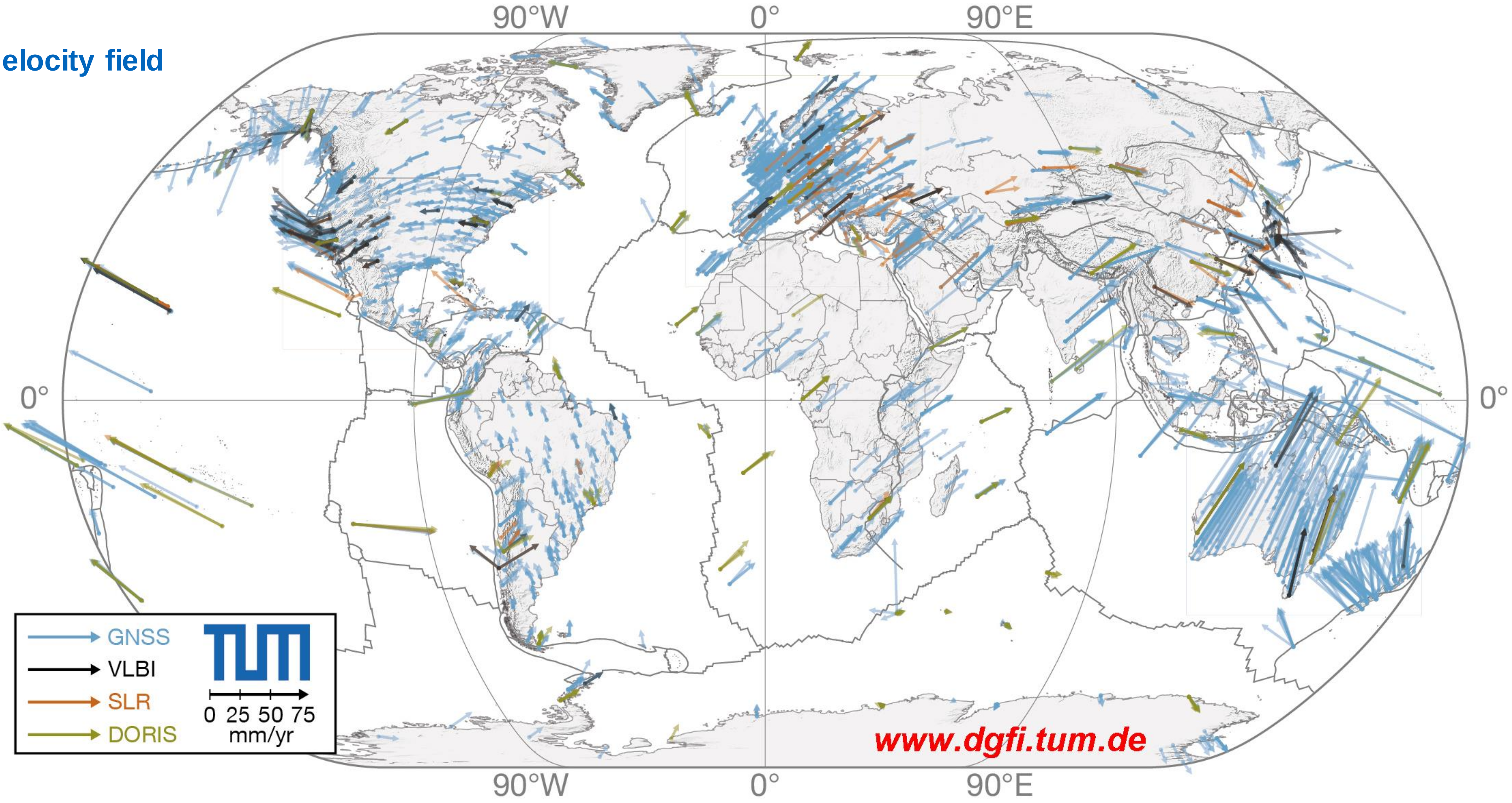
→ But to keep the small offset and drift “visible” for further studies, DTRF2020 scale is realized from VLBI and GNSS only.

→ no decision about “right” or ”wrong”



DTRF2020 preliminary solution

- **Horizontal velocity field**



Outlook and DTRF2020 release

Wrap up

- Thanks to the ILRS, a high-quality SLR-TRF contribution was provided to the ITRS CCs (some minor issues remain)
- In the DTRF2020 solution, SLR is uniquely used to realize the origin, the scale is realized by VLBI and GNSS

Outlook

- A DTRF2020 preliminary solution will be available within the next weeks
- Some initial external validations are currently being carried out

The DTRF2020 release will contain

- SINEX files of the combined solution and per technique (station coordinates only) with full variance-covariance matrix (full SINEX file of DTRF2020 solution on request)
- EOP data file
- NTL model values (time series per station and removed offset and drift)
- PSD: parameters of approximation functions as well as approximation time series
- Station position residual time series
- SLR origin (translation) time series

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Thank you for your attention!

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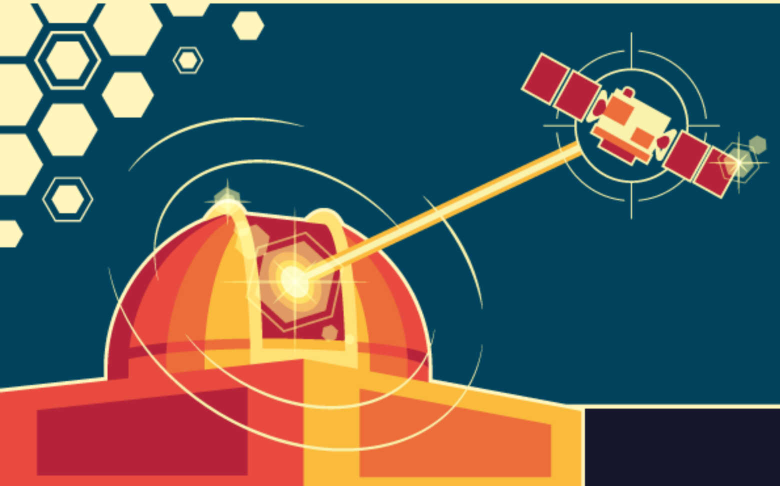


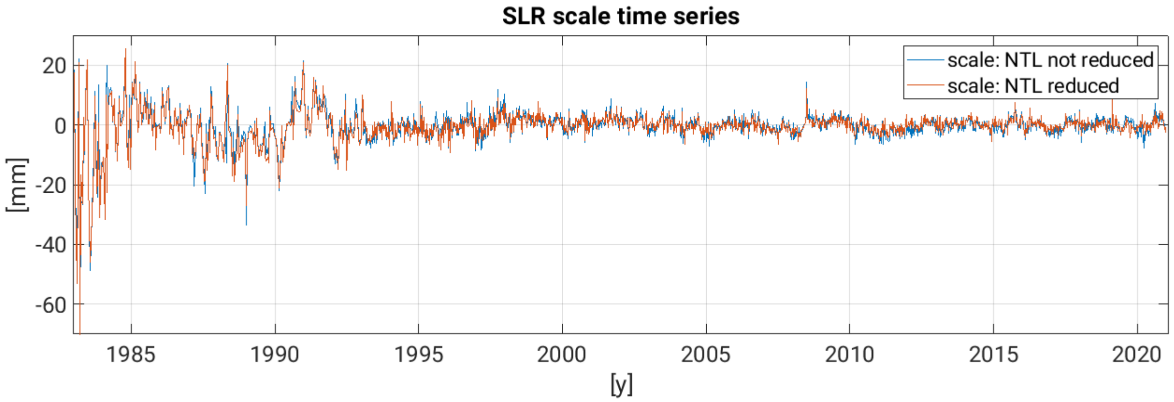
22ND INTERNATIONAL WORKSHOP
ON LASER RANGING

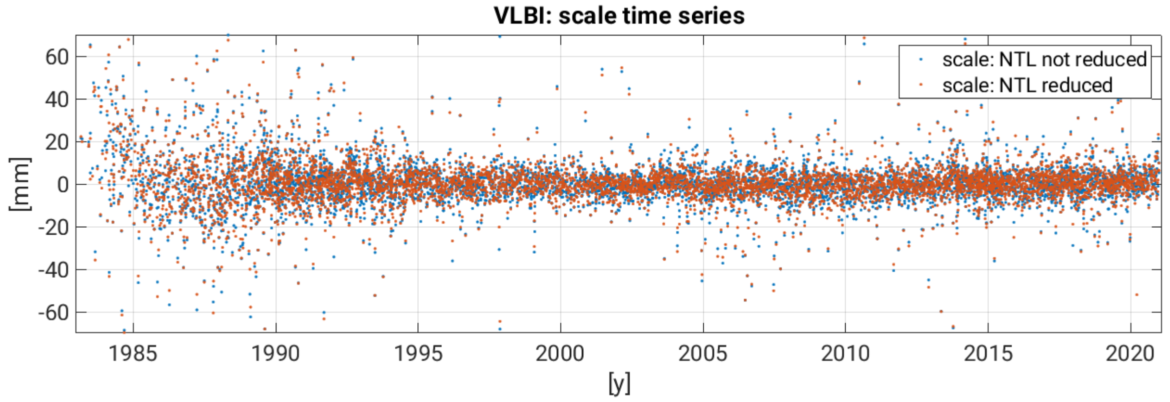
7-11 November 2022
Yebes, Spain

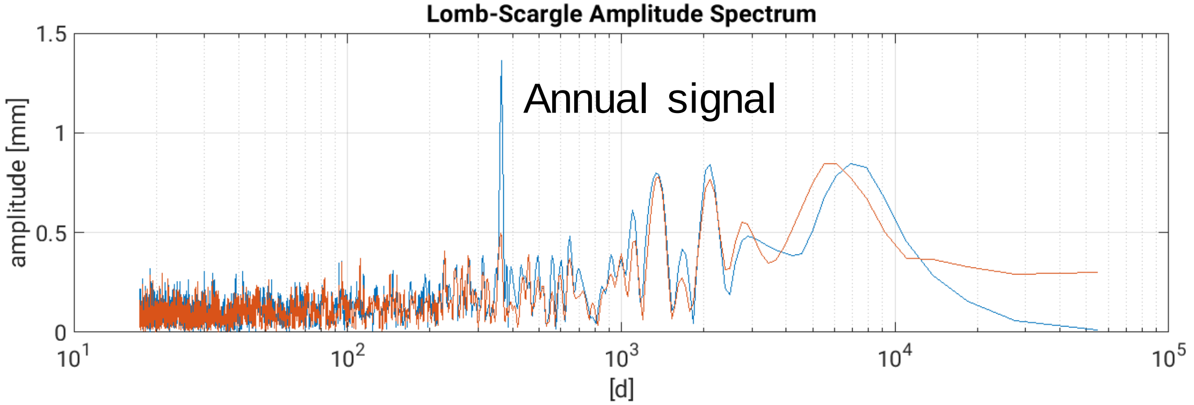
RECONNECTING THE ILRS COMMUNITY

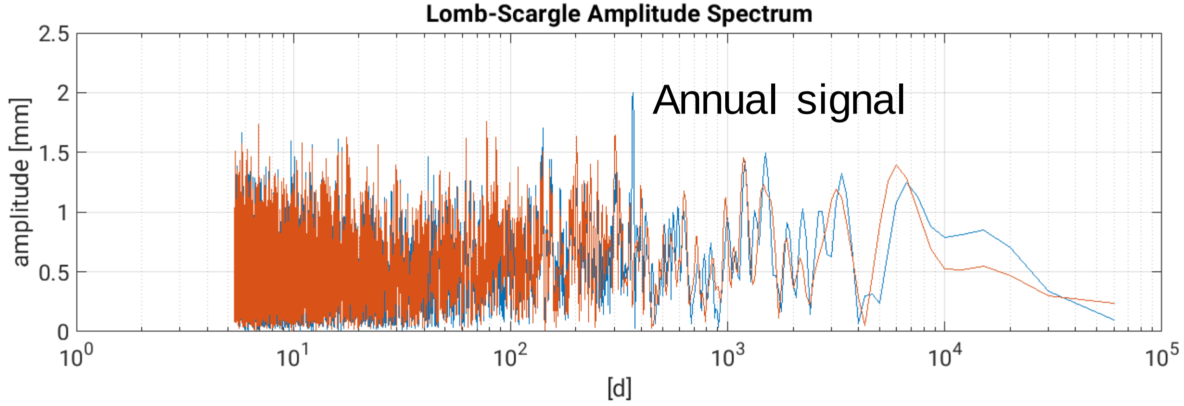
Impact of reducing NTL: datum parameters

- **SLR**, **VLBI** and **GNSS scale**


SLR scale time series


VLBI: scale time series

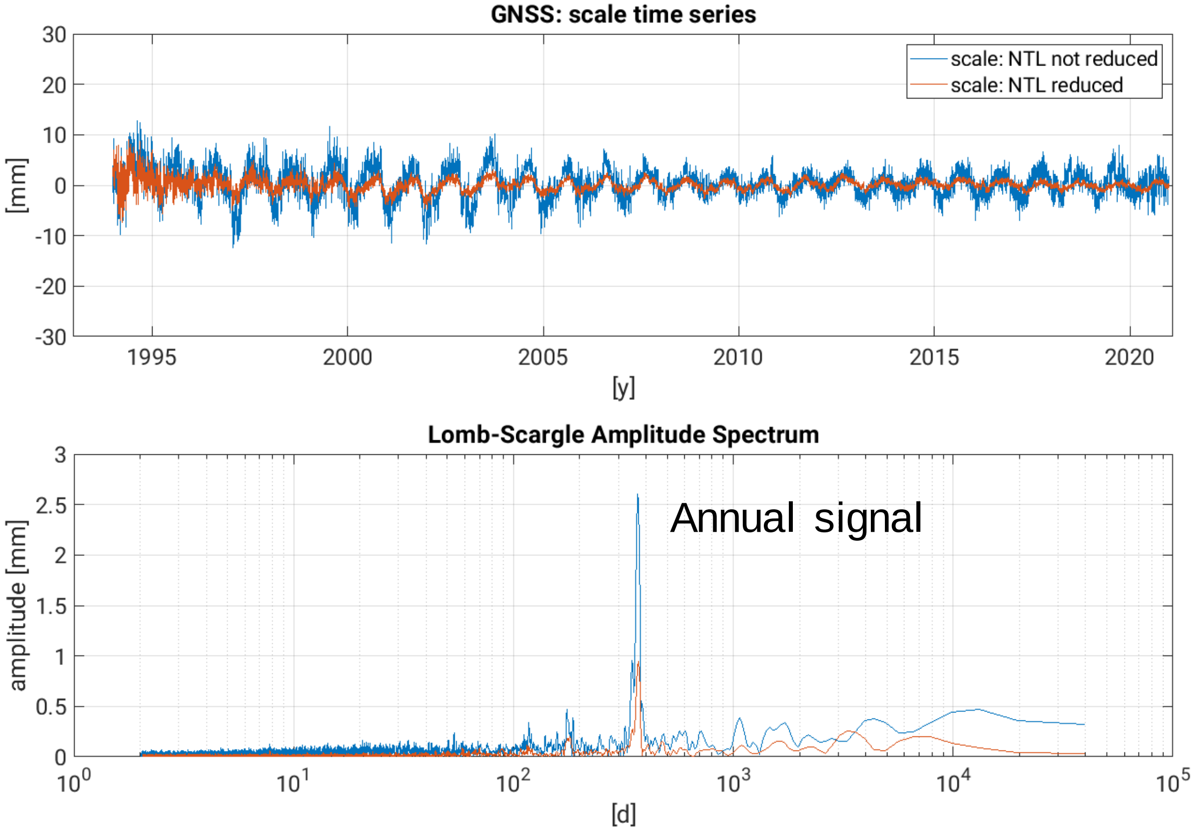

Lomb-Scargle Amplitude Spectrum


Lomb-Scargle Amplitude Spectrum

- **SLR and VLBI**: Reduction of RMS and annual signal. Amplitude decreases from 1.4 mm to 0.5 mm (SLR) and from 2 mm to about 1 mm (VLBI).

Impact of reducing NTL: datum parameters

- ➢ **SLR**, **VLBI** and **GNSS scale**



Annual signal

GNSS:

- ➢ Reduction of RMS.
- ➢ Reduction of the annual signal. Amplitude decreases from 2.6 mm to 1 mm.

DTRF2020 preliminary solution

➢ **Transformation of ITRF2020 to DTRF2020, epoch 2010.0**

Positions:

	TX [mm]	TY [mm]	TZ [mm]	Scale [mm]	RMS [mm]	# stat
GNSS	1.9	-2.1	0.2	-4.0	0.3	104
SLR	0.2	-0.3	0.1	-2.5	3.0	29
VLBI	2.8	-3.2	-2.7	-2.3	1.1	28
DORIS	0.9	-4.8	-2.1	-9.0	1.0	20

Velocities:

	TX [mm/yr]	TY [mm/yr]	TZ [mm/yr]	Scale [mm/yr]	RMS [mm/yr]	# stat
GNSS	-0.18	0.05	0.05	-0.09	0.05	104
SLR	0.05	-0.12	0.00	-0.11	0.26	29
VLBI	-0.10	-0.10	0.03	-0.12	0.15	28
DORIS	-0.03	0.17	0.07	0.30	0.21	20

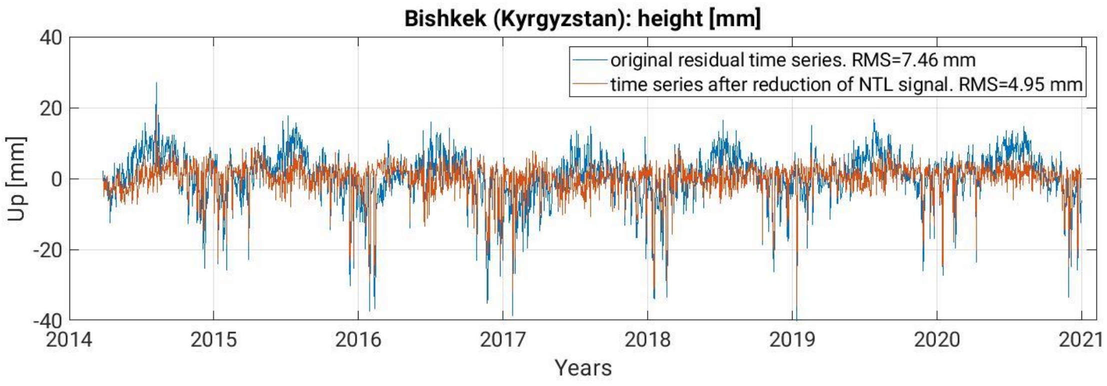
🟩 good agreement

🟡 systematic differences in scale offset and drift

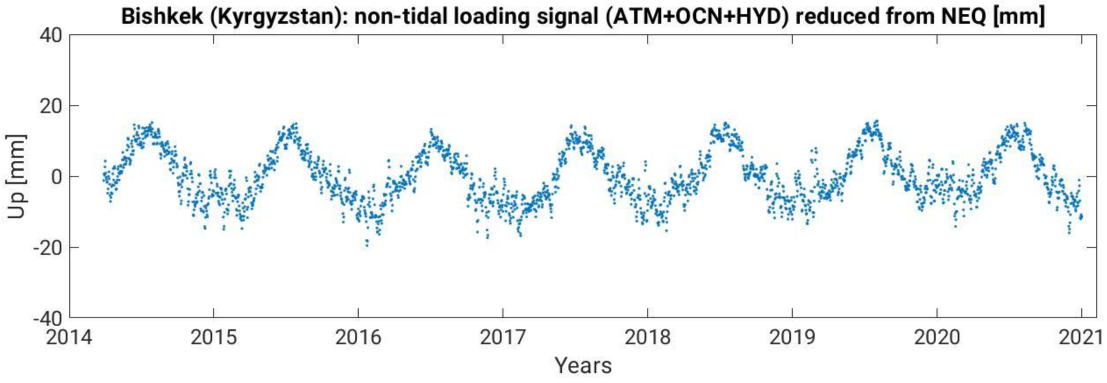
⭕ large difference in scale offset and drift for DORIS

Impact of reducing NTL: station coordinates

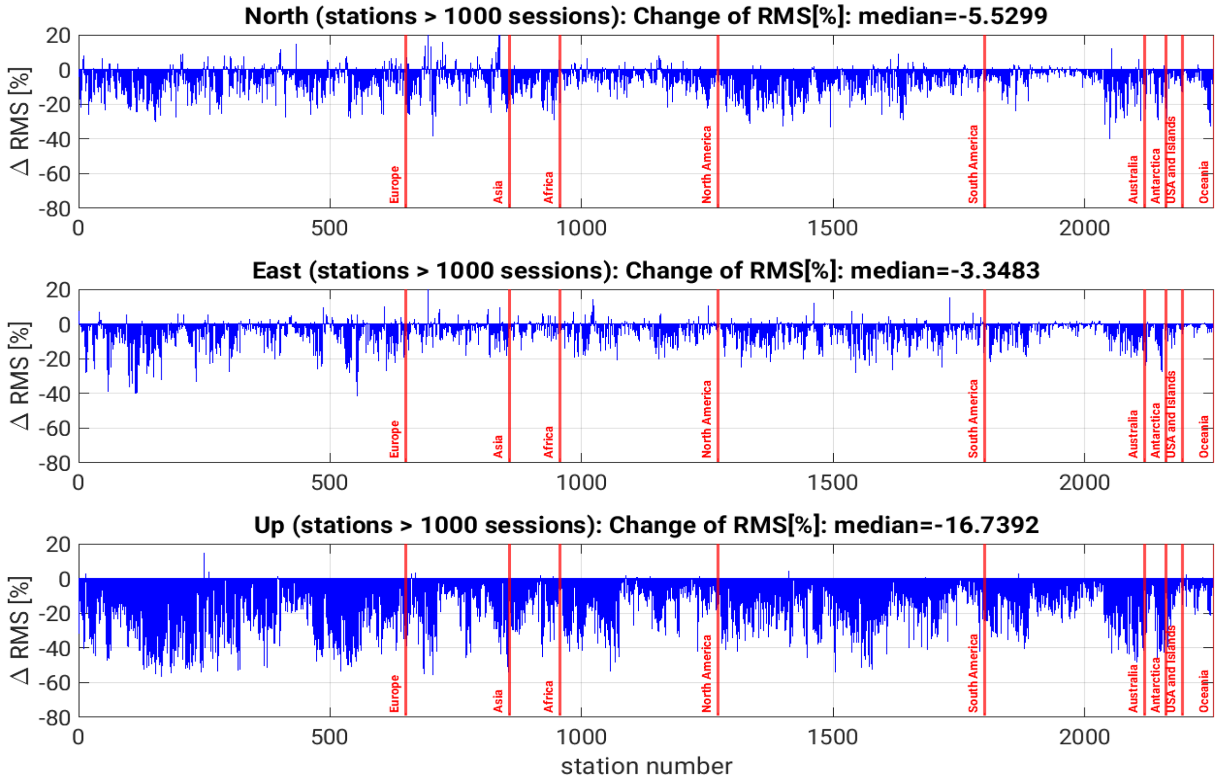
- **Reduction of RMS in particular for the up components: all GNSS stations with > 1000 sessions**



Bishkek (Kyrgyzstan): height [mm]



Bishkek (Kyrgyzstan): non-tidal loading signal (ATM+OCN+HYD) reduced from NEQ [mm]



North (stations > 1000 sessions): Change of RMS[%]: median=-5.5299

East (stations > 1000 sessions): Change of RMS[%]: median=-3.3483

Up (stations > 1000 sessions): Change of RMS[%]: median=-16.7392