# DTRF2020: the ITRS 2020 realization of DGFI-TUM

Manuela Seitz, Detlef Angermann, Mathis Bloßfeld, Matthias Glomsda, Sergei Rudenko, Julian Zeitlhöfler

Deutsches Geodätisches Forschungsinstitut, Technische Universität München (DGFI-TUM)

Session 1 – Global Reference Frame Theory, Concepts and Computations, 2022-10-19

# Outline

- Input data series
- Processing strategy: overview
- Reduction of non-tidal loading and post-seismic deformation
- Datum realization
- DTRF2020: preliminary results

# Input data

**Input data** (same as for ITRF2020)

| Technique/Service | #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 coord & 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 satellites**, **new 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!**)

→ **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 (2step-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**

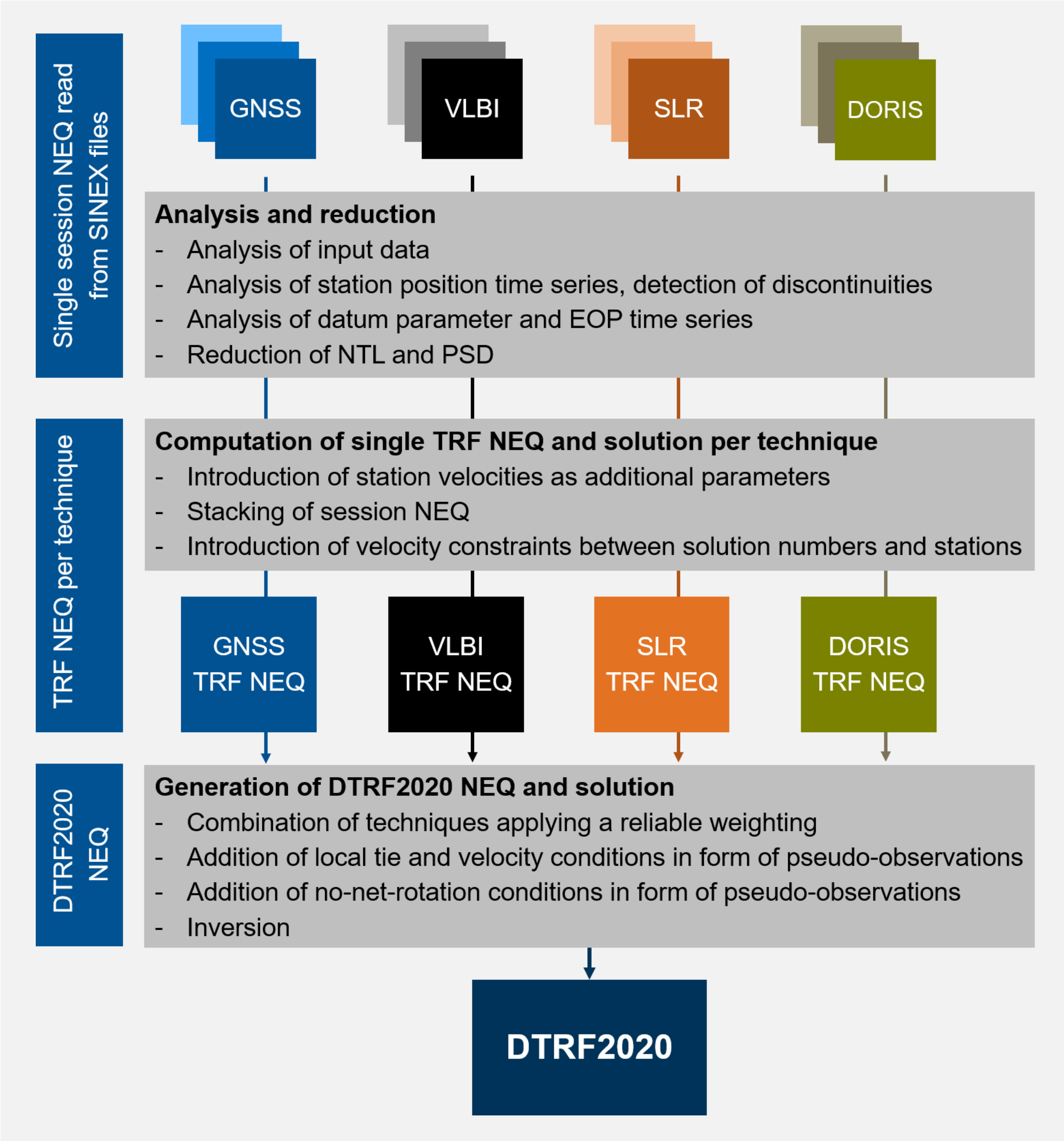
## New in DTRF2020

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

  all three components (atmospheric, hydrological and oceanic) are provided by GGFC and reduced at the NEQ level

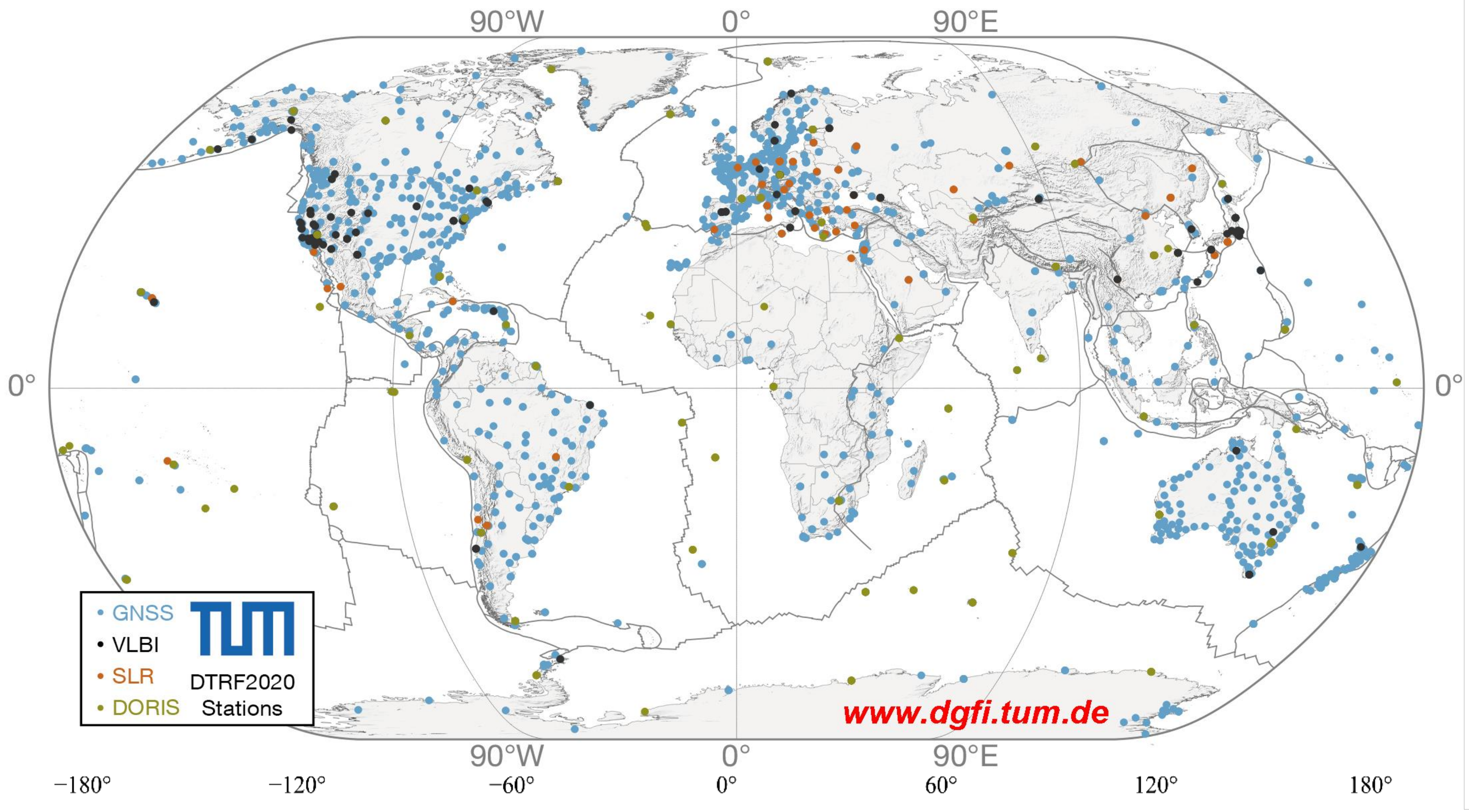
- **Post-seismic deformation (PSD):**

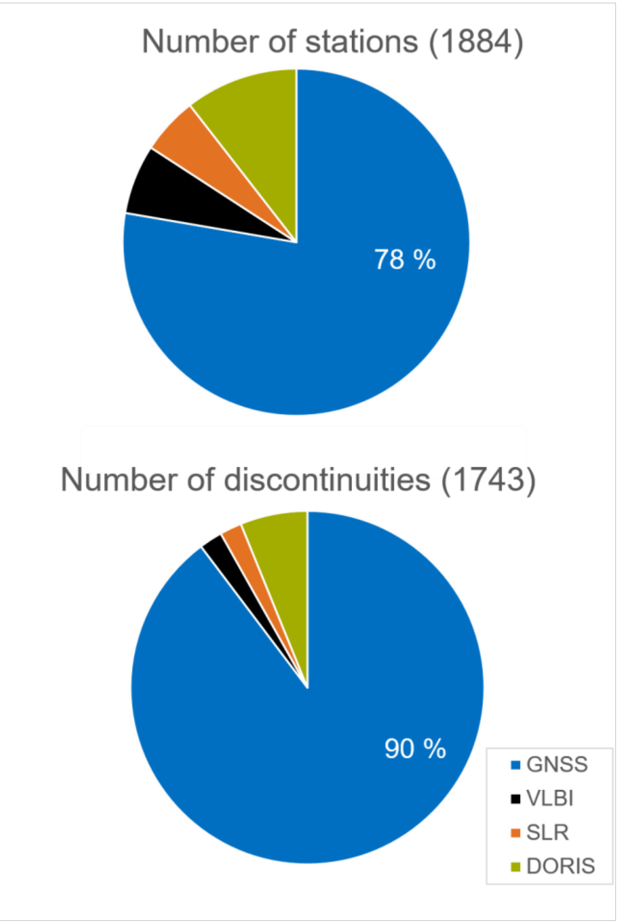
  approximated by a combination of logarithmic and exponential functions and reduced at the NEQ level



# DTRF2020 station network: discontinuities

For **DTRF2020** we process data of about 1880 observing stations. GNSS provides by far the largest number of stations.



# Reduction of non-tidal loading (NTL) corrections

**NTL input data**

- **provided by IERS Global Geophysical Fluid Center (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 not a systematic effect on station velocties

**NTL is considered by a reduction of each single input NEQ**

$$\widetilde{\boldsymbol{N}} = \boldsymbol{N}$$

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

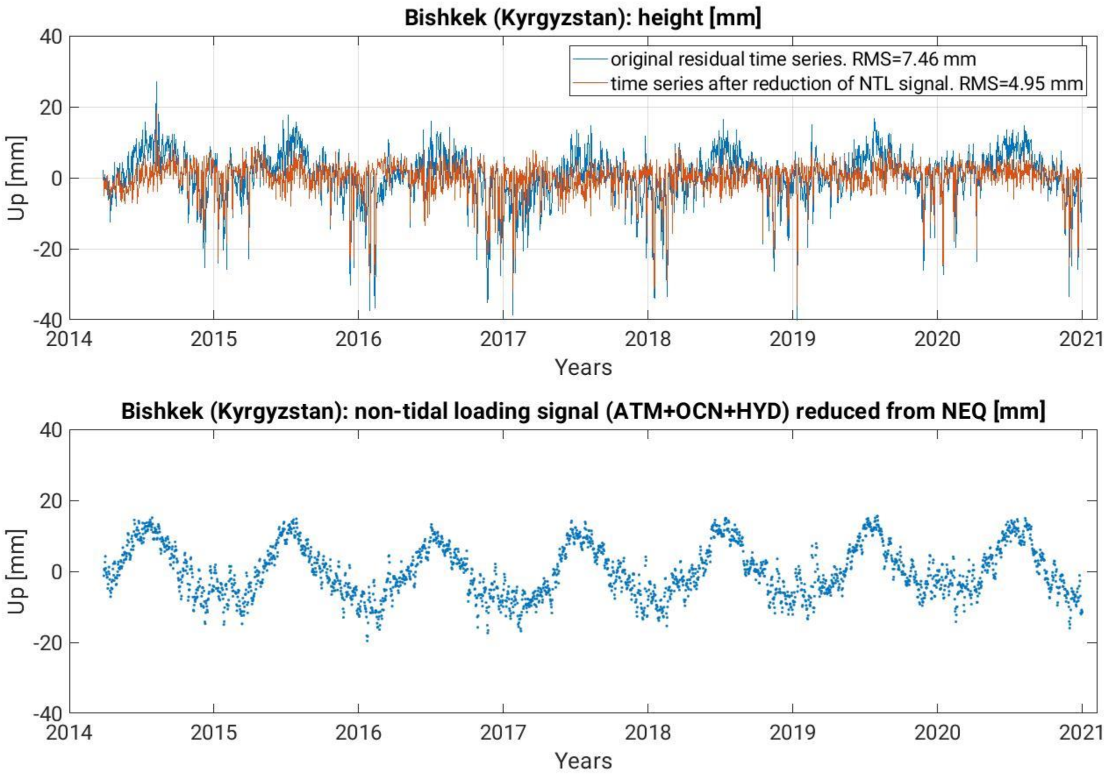
$$\widetilde{\boldsymbol{l}}^{\boldsymbol{T}}\widetilde{\boldsymbol{P}}\widetilde{\boldsymbol{l}} = \boldsymbol{l}^{\boldsymbol{T}}\boldsymbol{P}\boldsymbol{l} + \delta\boldsymbol{x}_{\mathbf{load}}^{\boldsymbol{T}}\left(\boldsymbol{N}\delta\boldsymbol{x}_{\mathbf{load}} - 2\boldsymbol{y}\right)$$

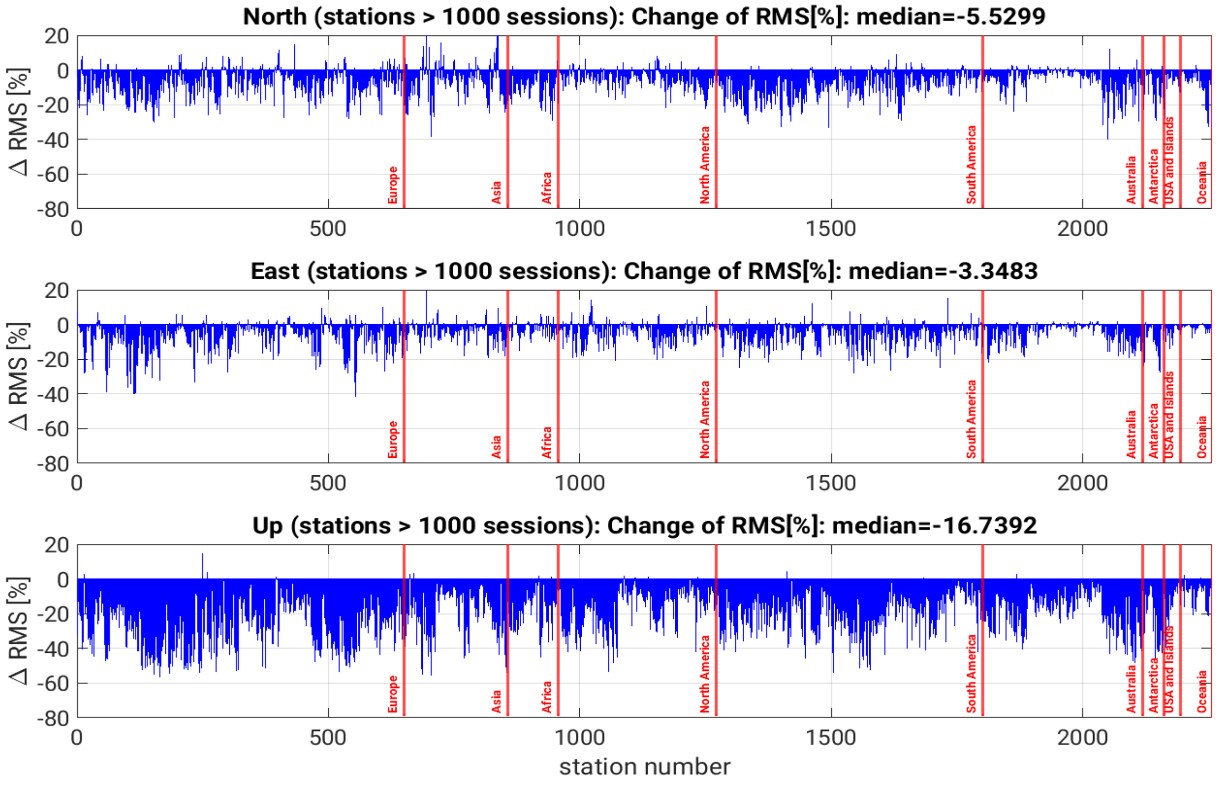
$$\widetilde{\boldsymbol{x}_{\mathbf{0}}} = \boldsymbol{x}_{\mathbf{0}}$$

*see also Glomsda et al. 2021*

# Impact of reducing NTL: station coordinates

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



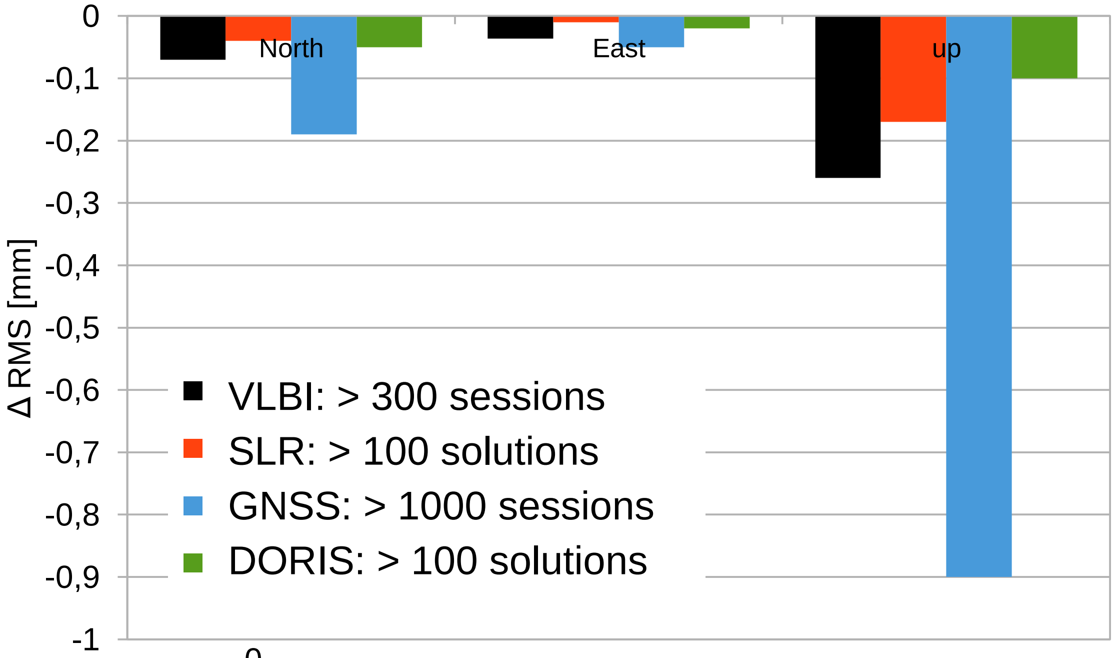



# Impact of reducing NTL: station coordinates

## Reduction of RMS: overview over all techniques

Median of RMS change [%]

| Technique/ 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 |

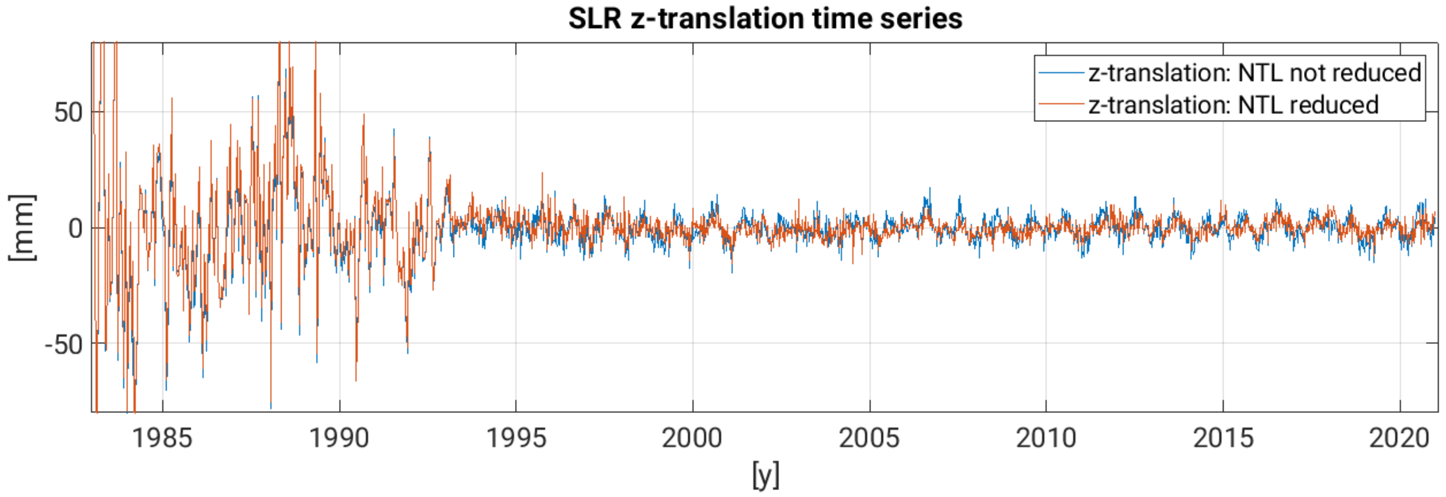


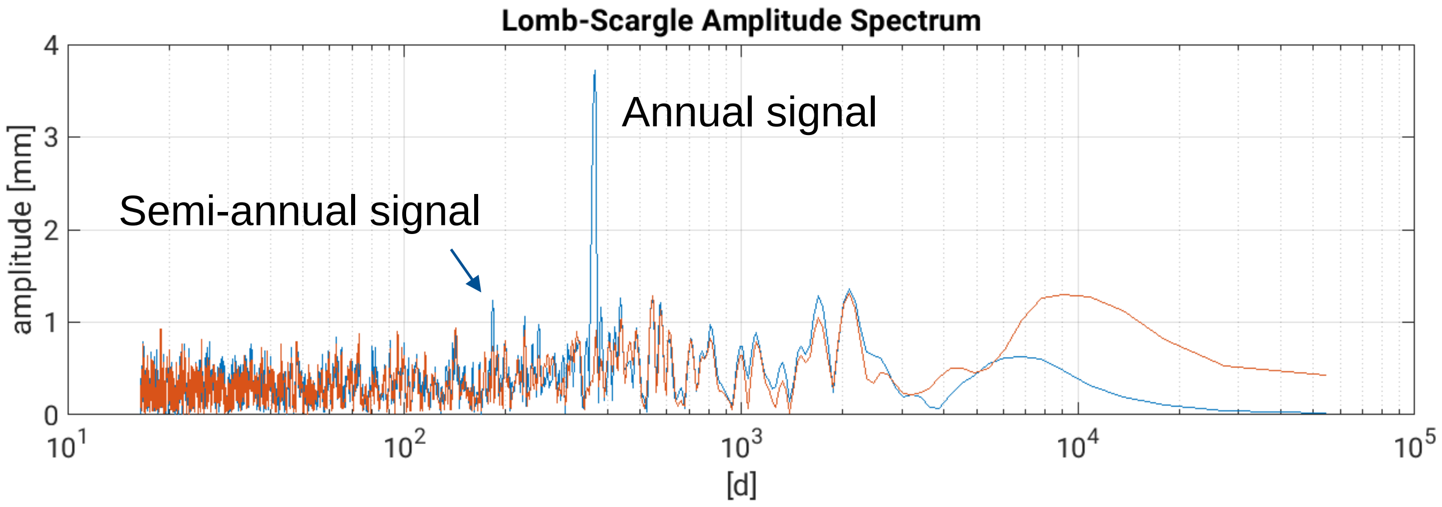

**all techniques and all components benefit:**

- GNSS benefits most, followed by VLBI
- the benefit in North is 2-4 times higher than in East
- the benefit in Up is 4 times of the effect in North (except for DORIS)

# Impact of reducing NTL: datum parameters

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



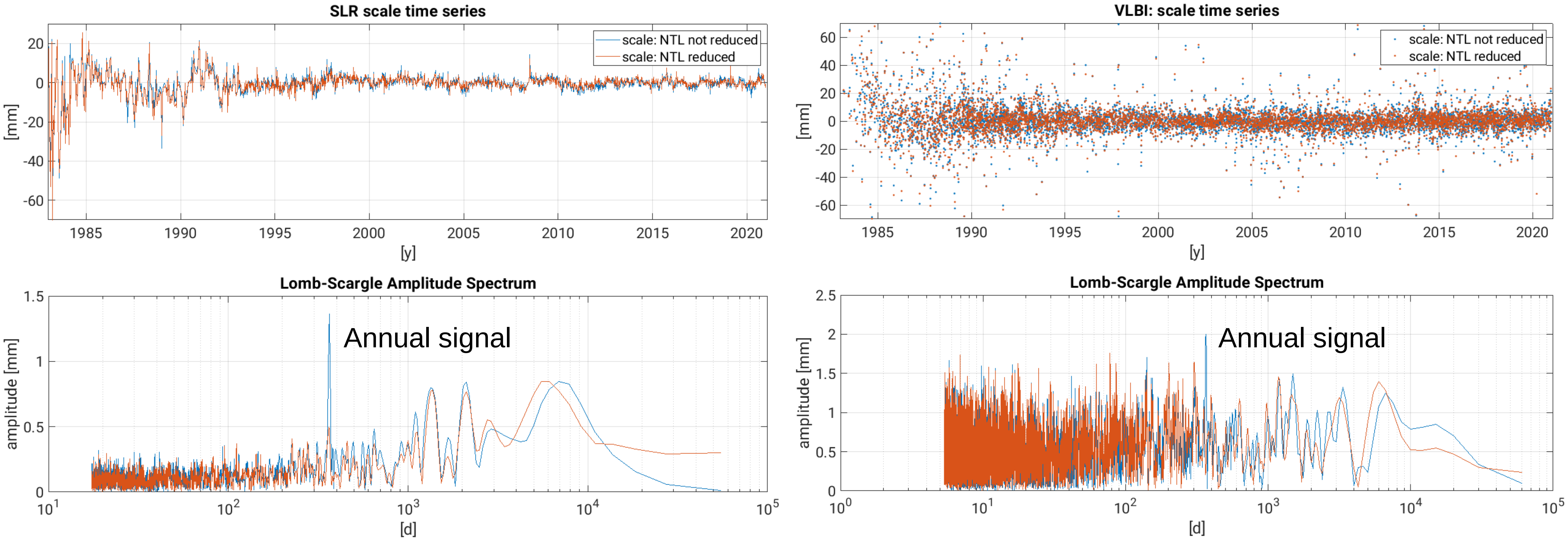




**SLR translation:**

- Reduction of RMS and annual signal.
- The semi-annual signal is also slightly reduced.

# Impact of reducing NTL: datum parameters

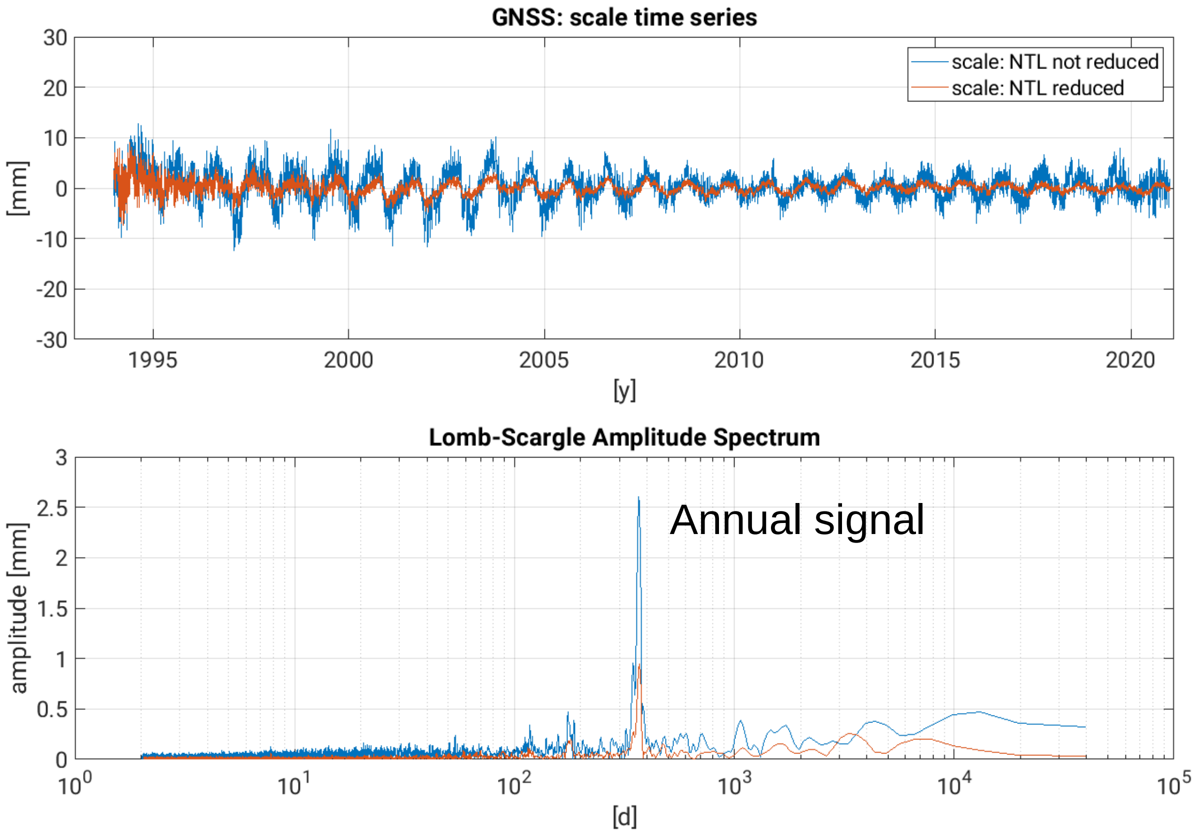
## SLR, VLBI and GNSS scale




**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




**GNSS:**

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

# Reduction of post-seismic deformation (PSD)

**Software APROPOS**

- approximation by combined logarithmic and exponential functions

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

| | |
|---|---|
| $A$ | Amplitude of transient function (log or exp) |
| $\tau$ | relaxation time of transient function |
| $\Delta t$ | time difference to the Earthquake epoch |

- relaxation times $\tau$ are also parameterized → non-linear optimization problem
- Approximation per component [XYZ] or [NEU]

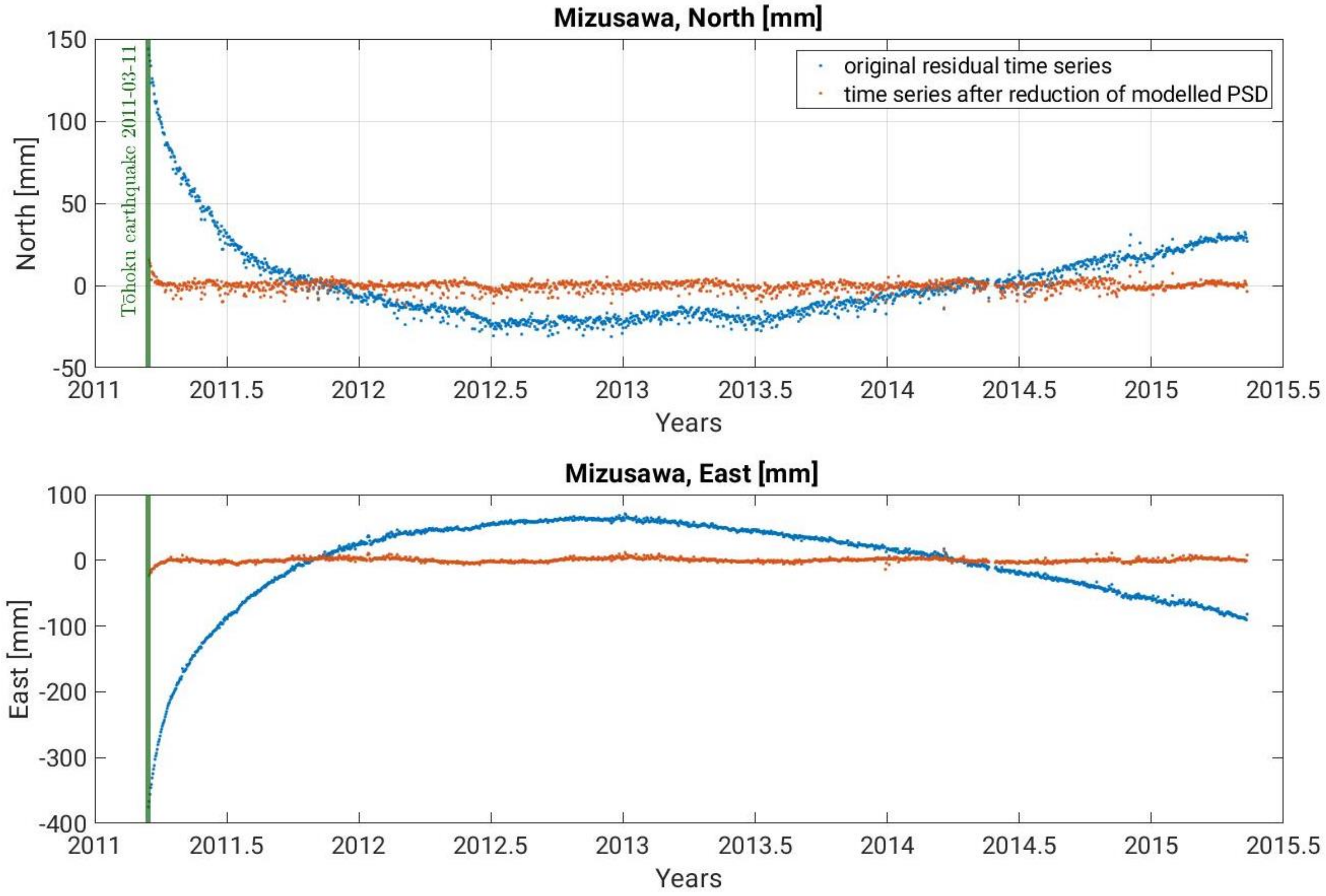
- Reduction of PSD model values from input NEQ (like the reduction of NTL)

| | Number of stations |
|---|---|
| GNSS | 63 |
| SLR | 2 |
| VLBI | 7 |
| DORIS | 1 |

# Reduction of post-seismic deformation (PSD)

**Impact on station position (residual) time series**

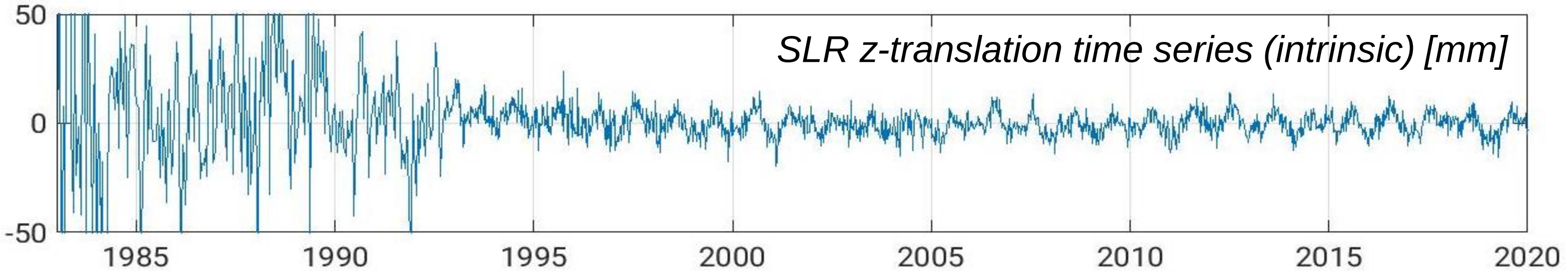
Example:
GNSS station Mizusawa, Japan (MIZU)
after the Tōhoku Earthquake 2011-03-11



# Datum realization of DTRF2020

## 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**

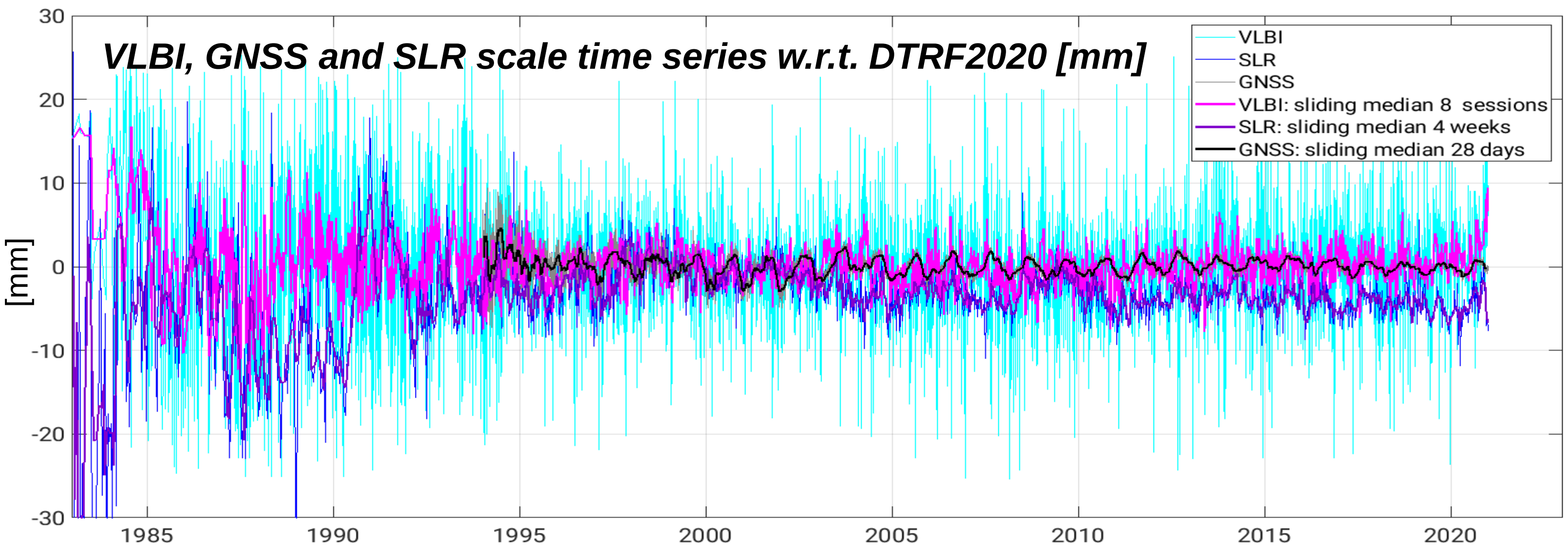
- by computing DTRF2020 solutions with **individual scale parameters** set up **for GNSS, SLR** and **VLBI** or two of them.

**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**

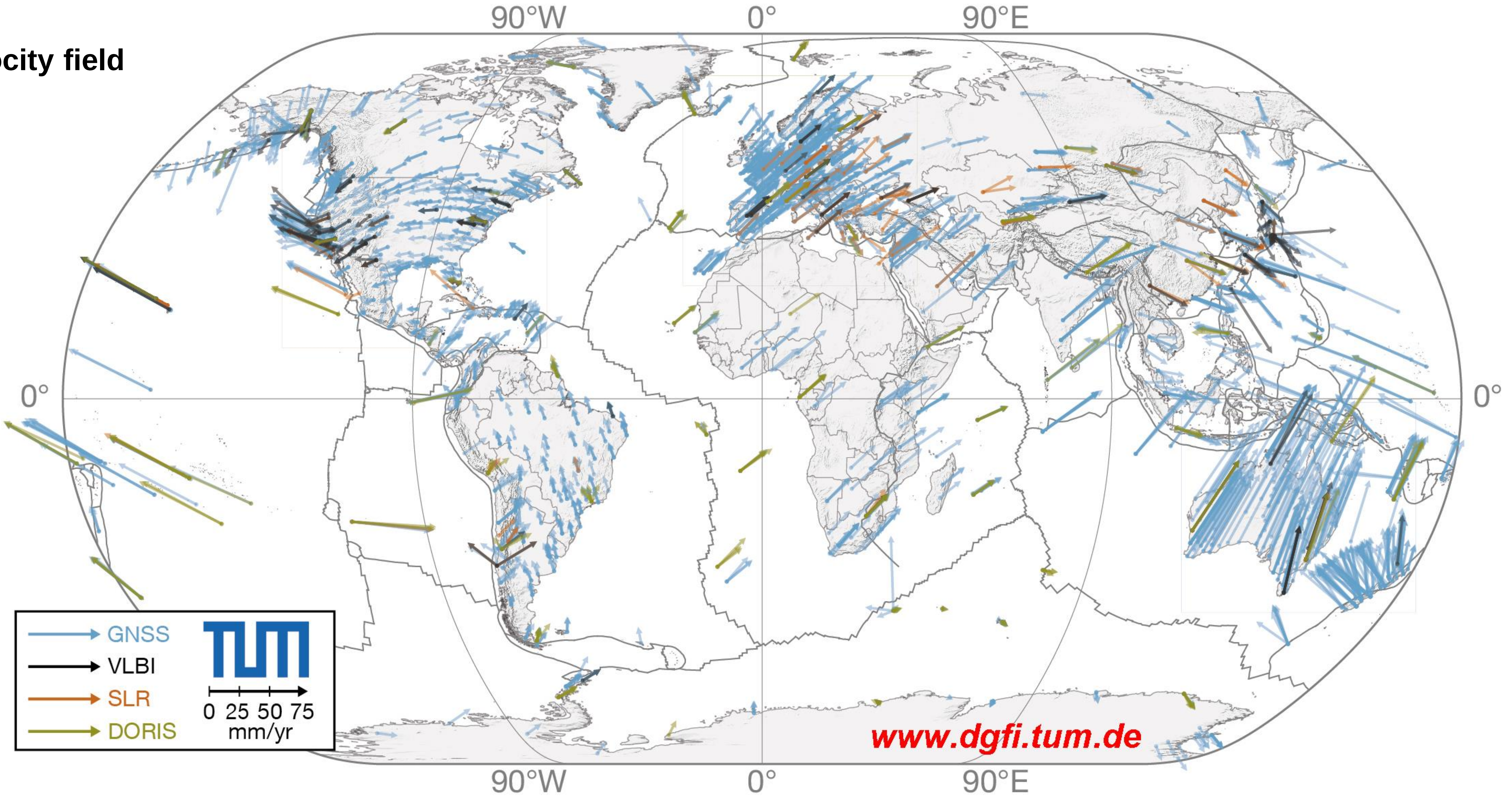
→ SLR does not affect the DTRF2020 scale

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



# DTRF2020 preliminary solution

**Horizontal velocity field**



# 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 |

# 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 |

good agreement

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 |

# 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

# 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

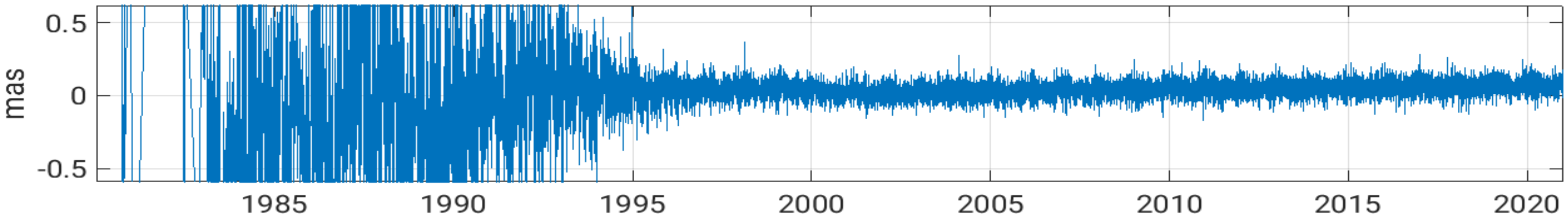
# DTRF2020 preliminary solution: EOP

**Contribution to combined EOP series**

| | terr. pole offsets | ΔUT1 | Nutation | terr. pole rates | LOD |
|---|---|---|---|---|---|
| GNSS | | | | | |
| SLR | | | | | |
| VLBI | | | | | |
| DORIS | | | | | |

**LOD:** SLR shows periodic signals w.r.t. GNSS and VLBI

**EOP difference series w.r.t. IERS 20 C04: terrestrial x-pole**




**WRMS of EOP time series w.r.t. IERS 20 C04**

| Xpole [μas] | Ypole [μas] | Δ UT1 [μs] | Nut_x [μas] | Nut_y [μas] | Xpole rate [μas/d] | Ypole rate [μas/d] | LOD [μs/d] |
|---|---|---|---|---|---|---|---|
| 56.2 | 48.4 | 28.6 | 77.0 | 79.7 | 108.2 | 110.0 | 19.7 |

**ΔUT1:**
periodic signal of 13.66 days, and amplitude of 38 μs w.r.t. IERS 20C04.
→ Modelling differences?

# Outlook and DTRF2020 release

**Outlook**

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

**The DTF2020 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 approxiation time series
- Station position residual time series
- SLR origin (translation) time series

# DTRF2020: the ITRS 2020 realization of DGFI-TUM

Manuela Seitz, Detlef Angermann, Mathis Bloßfeld, Matthias Glomsda, Sergei Rudenko, Julian Zeitlhöfler

Deutsches Geodätisches Forschungsinstitut, Technische Universität München (DGFI-TUM)

Thank you for your attention!

REFAG 2022
THESSALONIKI - GREECE

Session 1 – Global Reference Frame Theory, Concepts and Computations, 2022-10-19