Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)
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Investigating the datum parameters of new solutions by IVS AC DGFI-TUM

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Solutions investigated

- **dgf2020a** resembles DGFI-TUM's **contribution to the ITRS 2020 realizations** (plus reduction of non-tidal atmospheric loading) and contains the respective models (e.g., the gravitational deformation for EFLSBERG, GILCREEK, MEDICINA, NOTO, ONSALA60, YEBES40M).

- **dgf2023a** is the **current operational solution** based on a priori values from the new **ITRF2020** and containing 7 **additional gravitational deformation** models.

- To investigate the impact of these two changes, the following **(intermediate) setups** have been analysed with the DGFI Orbit and Geodetic parameter estimation Software (**DOGS**):

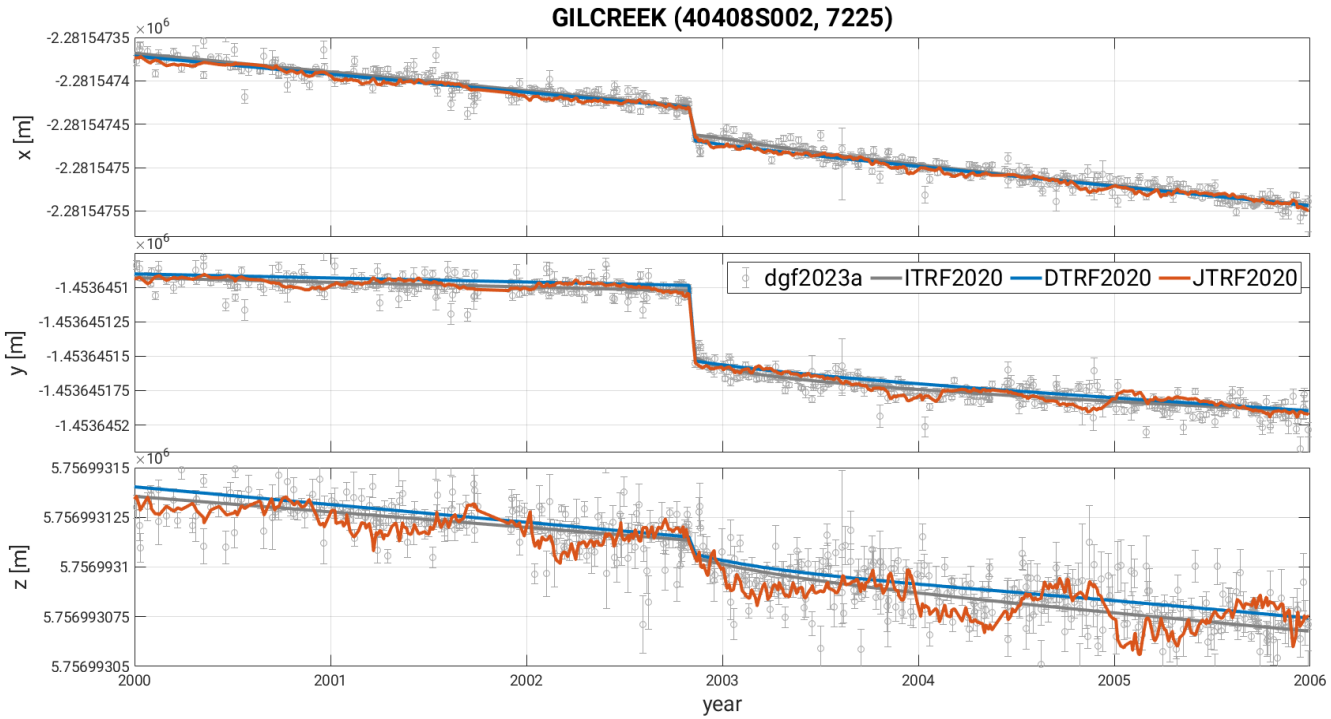
solution	a priori TRF	gravitational deformation (GD)	datum stations
dgf2020a	ITRF2014	first 6 antennas	all except for 6 GD antennas
dgf2023a old GD*	ITRF2020	first 6 antennas	all except for 6 GD antennas
dgf2023a old GD	ITRF2020	first 6 antennas	all
dgf2023a*	ITRF2020	first 6 + 7 new antennas	all
dgf2023a	ITRF2020	first 6 + 7 new antennas	all except for 7 new GD antennas
dgf2023a JTRF	JTRF2020	first 6 + 7 new antennas	all except for 7 new GD antennas
dgf2023a DTRF	DTRF2020	first 6 + 7 new antennas	all except for 7 new GD antennas

ITRS 2020 realizations

- **ITRF2020**
  - secular terrestrial reference frame (TRF) with reduction of **seasonal (and draconitic) signals** and **post-seismic deformation (PSD)**
  - combined at the **solution level**

- **JTRF2020**
  - **epoch** reference frame
  - sequentially determined with a **square-root information filter** and smoother algorithm

- **DTRF2020**
  - secular TRF with reduction of **non-tidal loading** (NTL) and **PSD**
  - combined at the **normal equation level**
  - NTL based on **geophysical models**, reduced at normal equation level

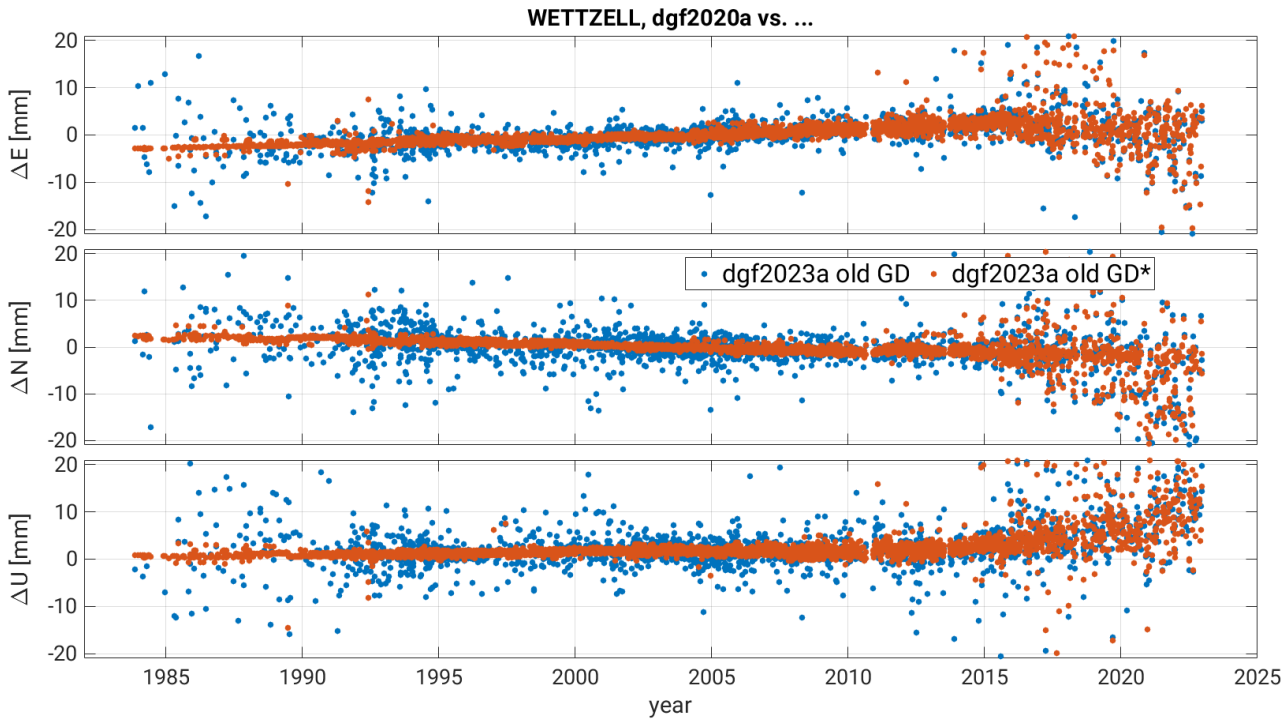


Solution **dgf2023a** with ITRF2020 (secular plus PSD) as a priori TRF and 7 new gravitational deformation models. Only the **secular and PSD parts** of both ITRF2020 and DTRF2020 are given for comparison.

Impact of new a priori TRF

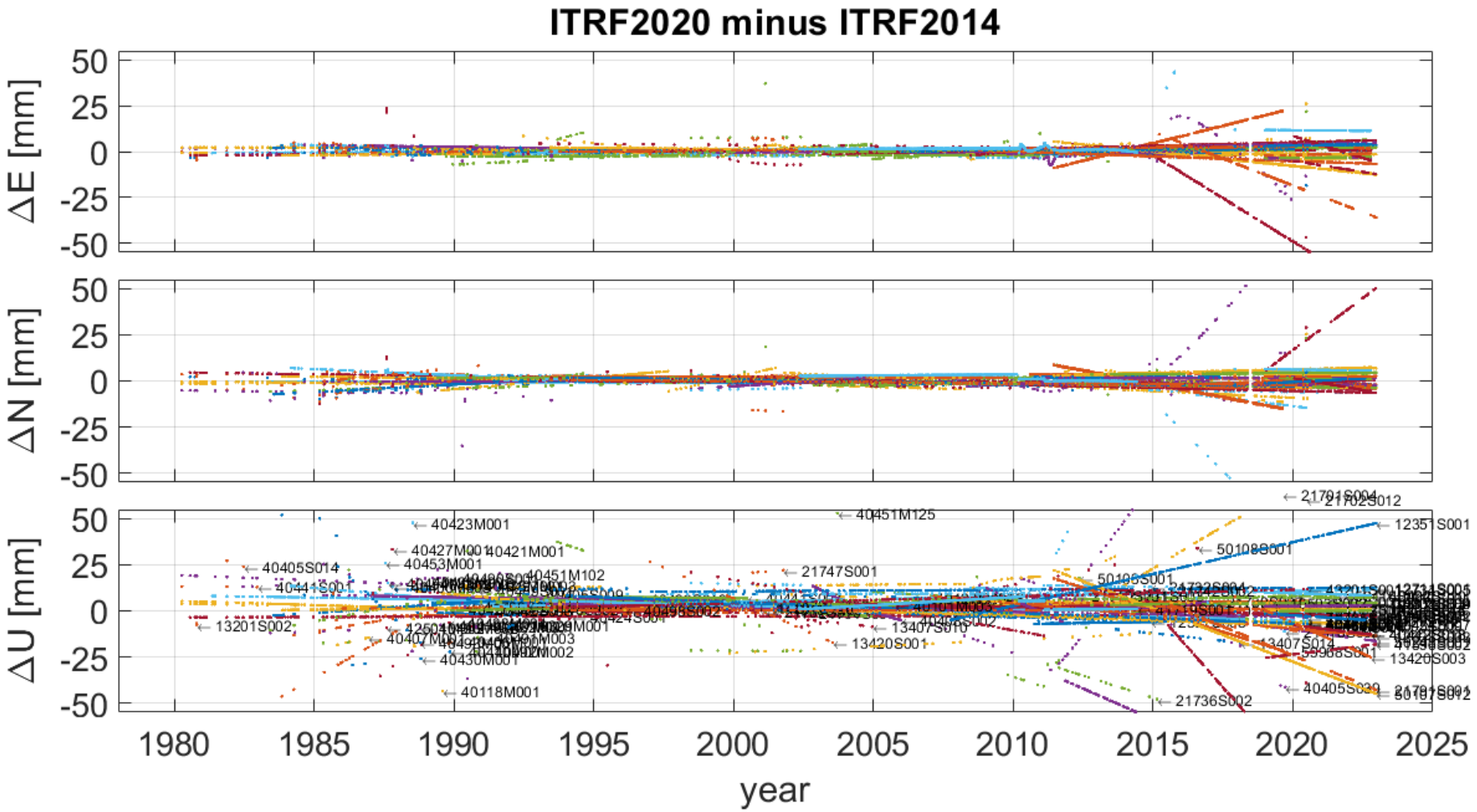
solution	a priori TRF	gravitational deformation (GD)	datum stations
dgf2020a	ITRF2014	first 6 antennas	all except for 6 GD antennas
dgf2023a old GD*	ITRF2020	first 6 antennas	all except for 6 GD antennas
dgf2023a old GD	ITRF2020	first 6 antennas	all

- If the other models do not change, a new a priori TRF **does not change** the antenna **network geometry**.
- However, the no-net-translation (**NNT**) and no-net-rotation (**NNR**) conditions **affect the final coordinate estimates**.
- If the **set of datum stations remains constant**, the impact is comparatively small if the antenna coordinates in a session network do not change much (red dots in figures).
- **Changing the set of datum stations** creates **additional noise** (blue dots).
- After 2015, there are **significant changes** for both choices of **datum station sets** (compare next slide).



Differences between latest ITRFs

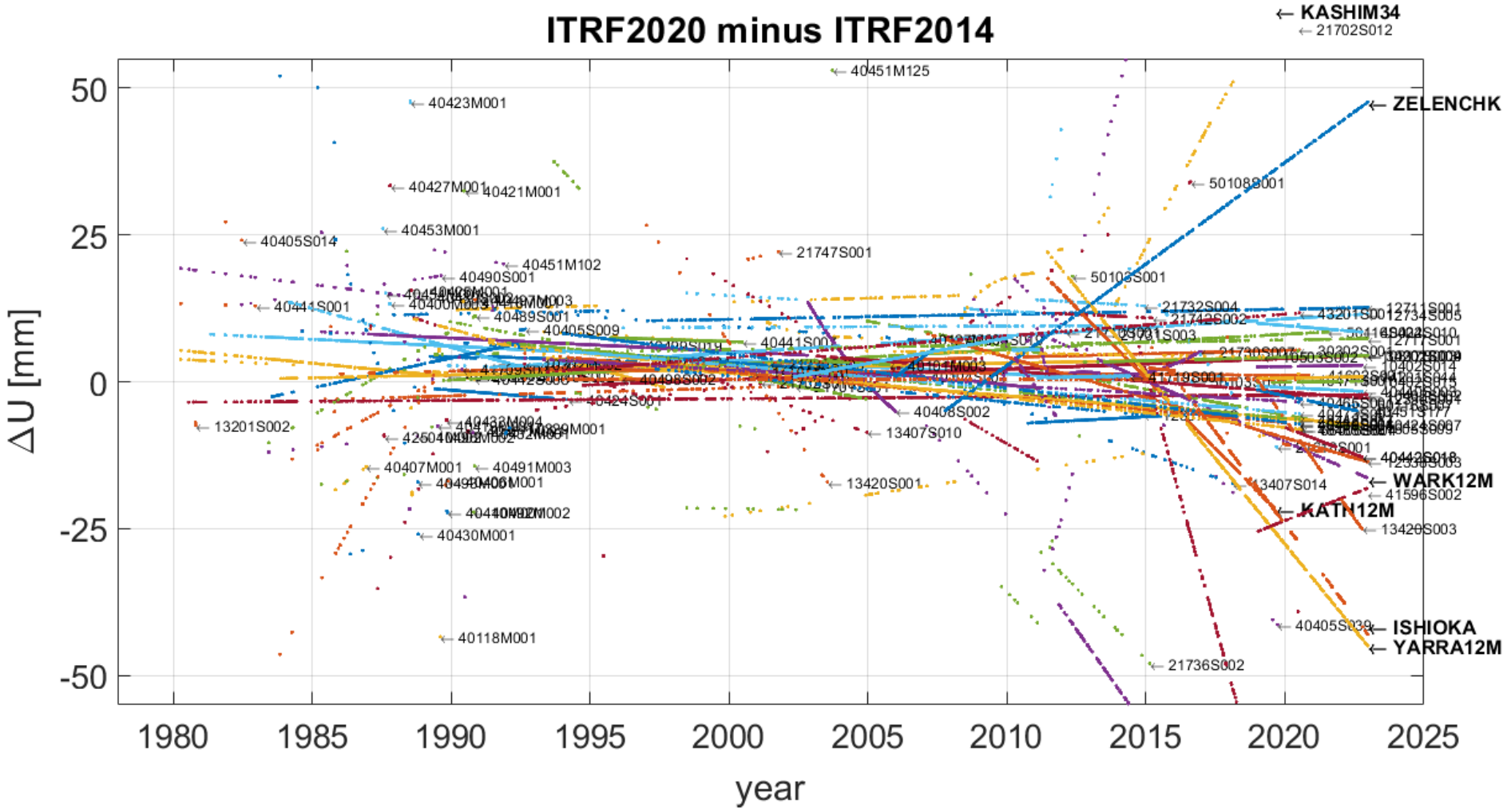
- After 2015, there are significant **changes in linear motions of "young" stations:**



Each color represents the difference time series for one VLBI station (secular + PSD parts only).

Differences between latest ITRFs (up)

- After 2015, there are significant **changes in linear motions of "young" stations:**



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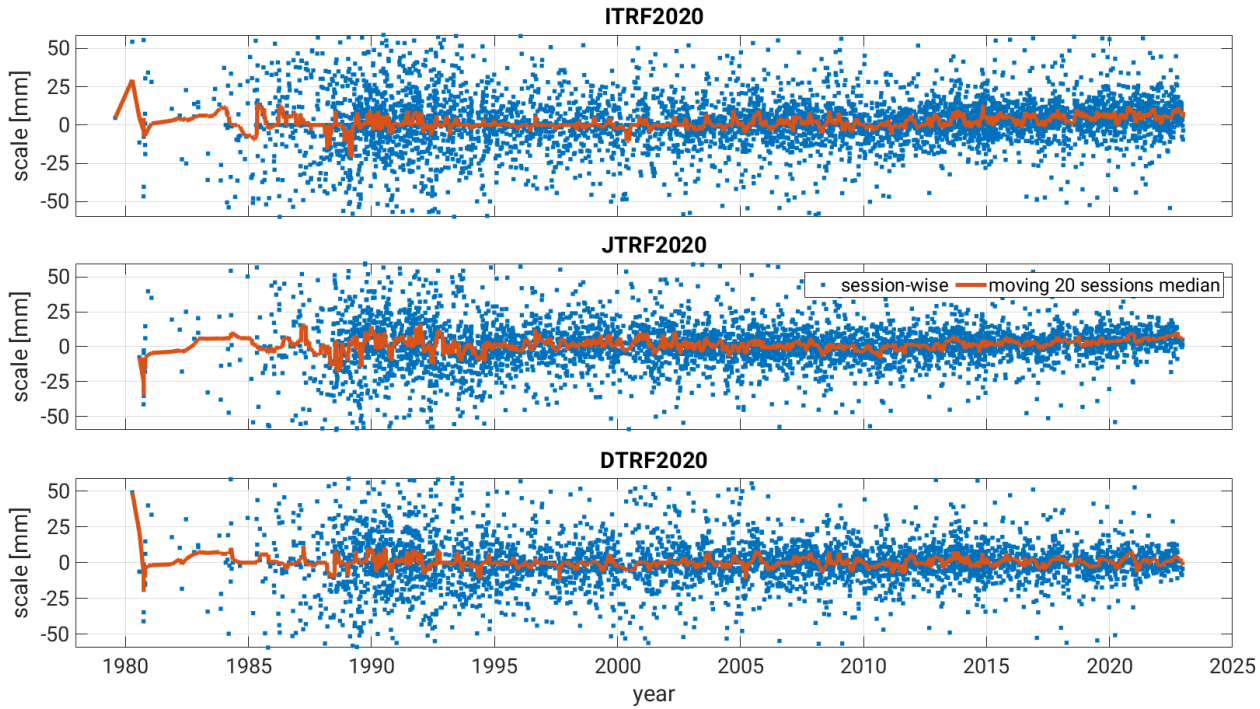
Datum (scale) parameter time series: ITRS 2020 realizations

solution	a priori TRF	gravitational deformation (GD)	datum stations
dgf2023a	ITRF2020	first 6 + 7 new antennas	all except for 7 new GD antennas
dgf2023a JTRF	JTRF2020	first 6 + 7 new antennas	all except for 7 new GD antennas
dgf2023a DTRF	DTRF2020	first 6 + 7 new antennas	all except for 7 new GD antennas

- The figures show the **scale** parameter of **7 parameter Helmert transformations** of the session-wise solutions w.r.t. their a priori TRFs (outliers: |scale| > 60 mm).
- The running 20 session median reveals an **annual signal for the secular TRFs** and a similar signal for the JTRF2020.
- There is a **scale drift for ITRF2020 and JTRF2020**, but none for DTRF2020.
- **Translations** and **rotations** vary around **zero**.



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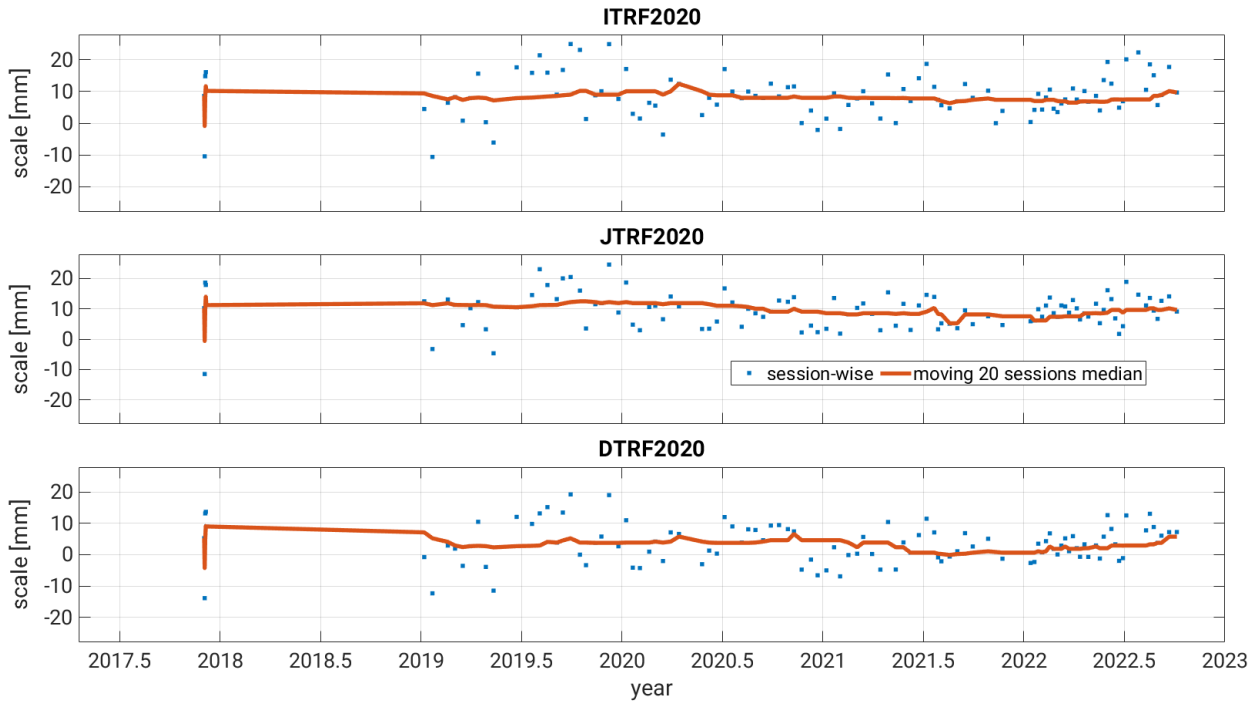
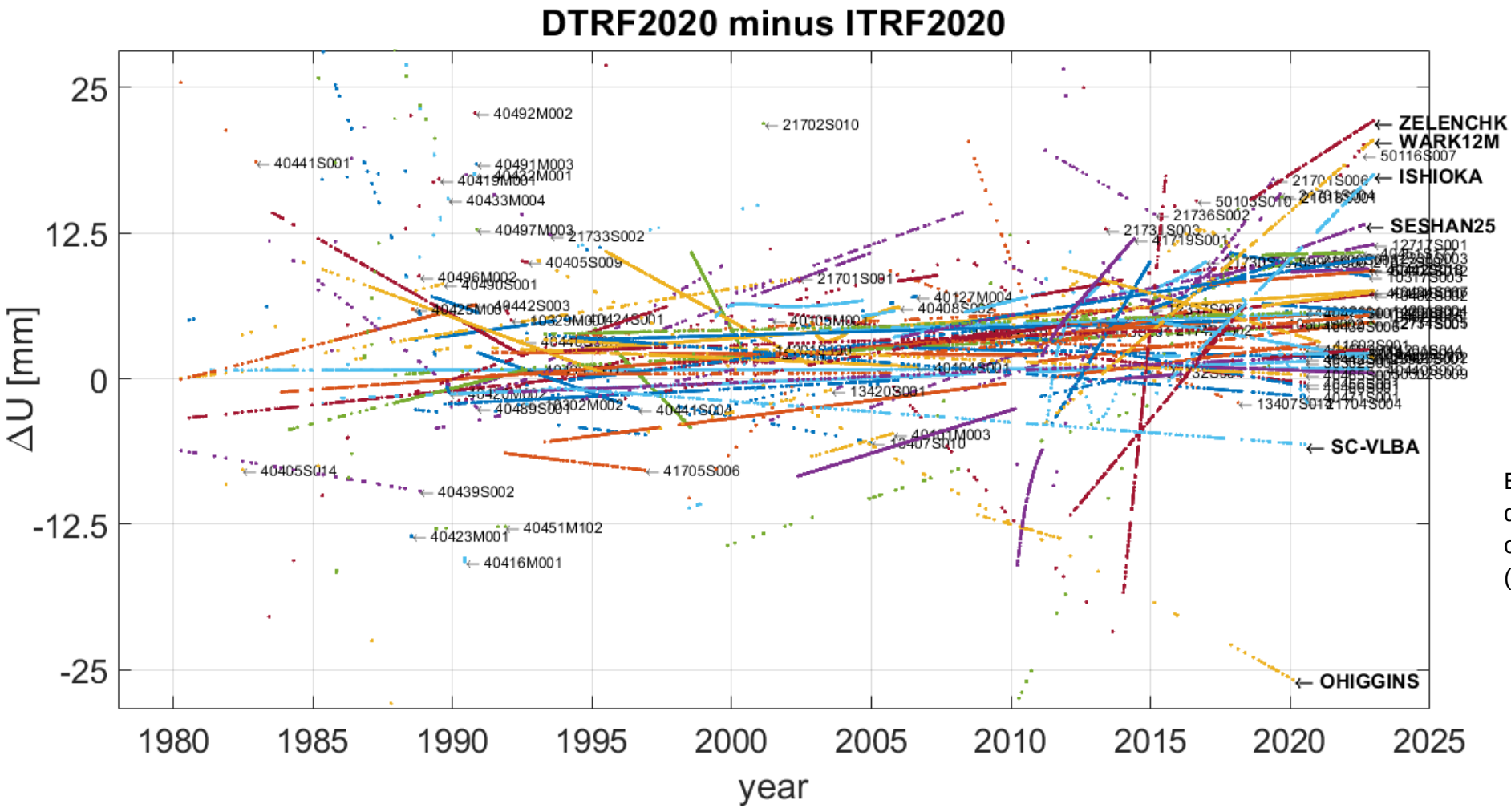
- The running 20 session median reveals an **annual signal for the secular TRFs** and a similar signal for the JTRF2020.
- There is a **scale drift for ITRF2020 and JTRF2020**, but none for DTRF2020.
- **Translations** and **rotations** vary around **zero**.
- For ITRF2020 and JTRF2020, basically all **scales for the VGOS sessions** are positive!



Differences between secular ITRS 2020 realizations (up)



Each color represents the difference time series for one VLBI station (secular + PSD parts only).

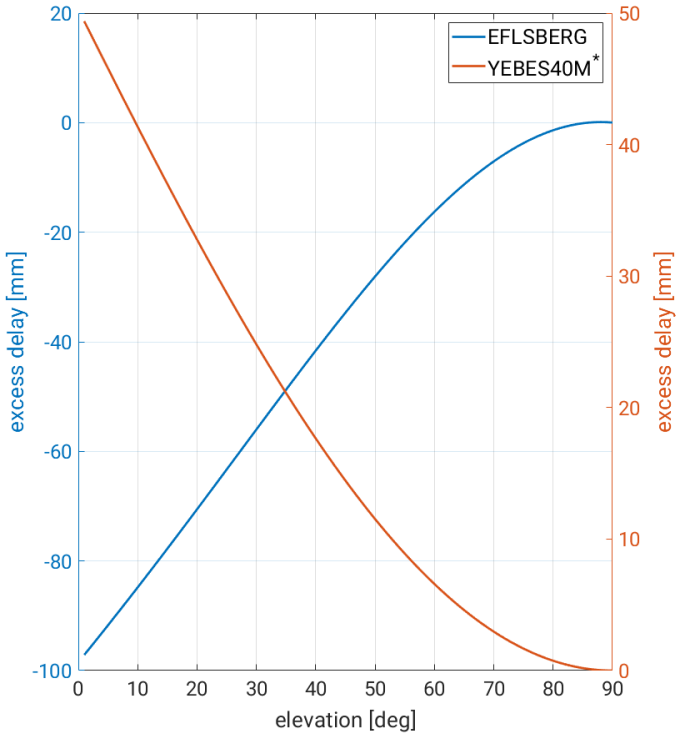
Further models for gravitational deformation (1)

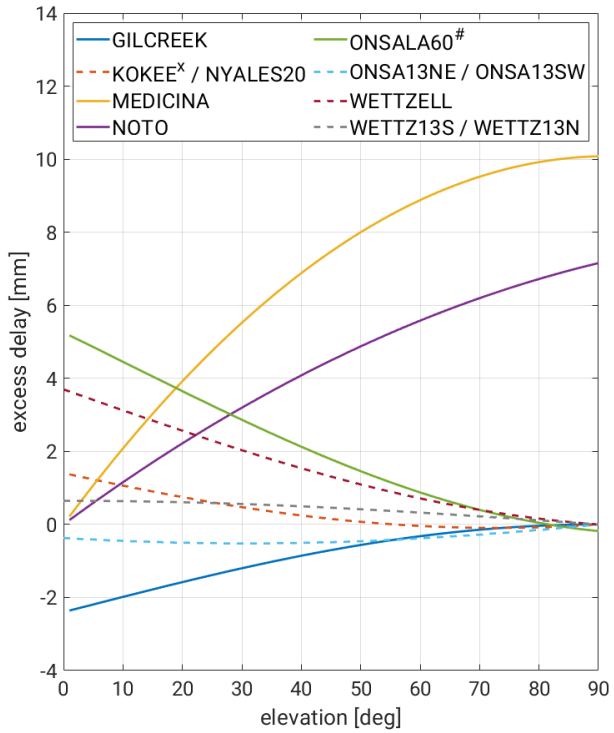
- As of January 2023, there are **7 more antennas** with gravitational deformation (GD) models available (compare file compiled by J.Gipson):
  - **NYALES20**
  - **KOKEE**
  - **ONSA13NE** (VGOS)
  - **ONSA13SW** (VGOS)
  - **WETTZELL**
  - **WETTZ13N**
  - **WETTZ13S** (VGOS)

- GD **mainly affectes the estimated antenna heights**, which are proportional to $-\sin\epsilon$.

- Leaving antennas with GD models among the set of (NNT) datum stations **transfers vertical to horizontal changes** (compare Gipson [2019]).

- When **switching to ITRF2020** as a priori TRF, the **first 6** antennas can be **considered as datum stations again**, because their GD models are part of this TRF.



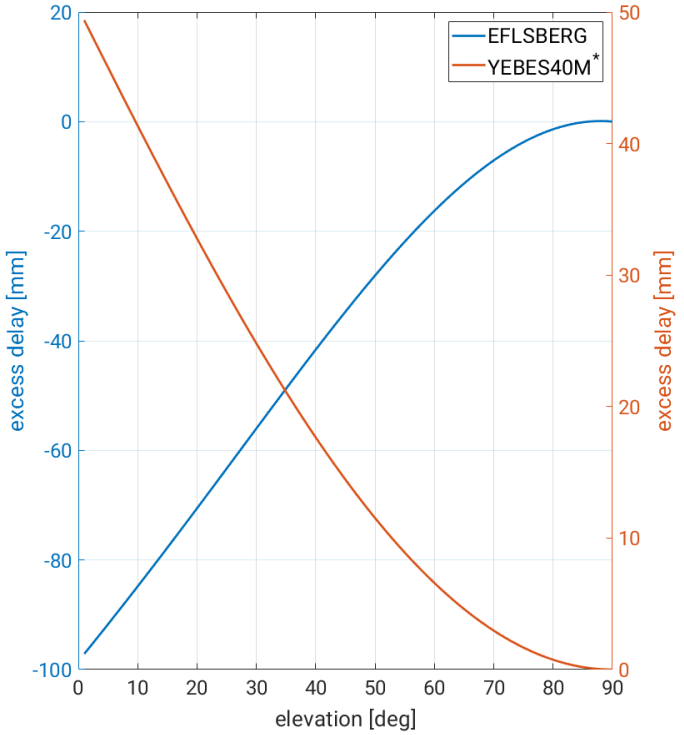


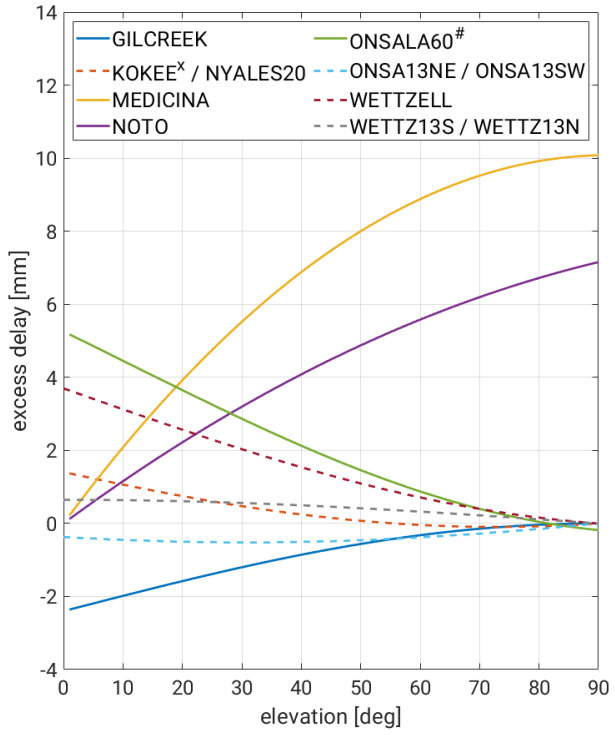
* **YEBES40M**: only valid from 2011-11-11
x **KOKEE**: values adopted from NYALES20
\# **ONSALA60**: original values -4.7 mm to adjust reference temperature w.r.t. thermal deformation

New models represented by dashed lines.

Further models for gravitational deformation (2)

- The actual change in estimated antenna heights (see table*) depends on the **maximum model excess delay** and the **sign of its slope** (w.r.t. elevation).
- The maximum delays for the 7 new antennas are **mostly smaller** than those for the 6 old ones.
- We expect an **increase in heights for the new Onsala twin telescopes only**, and a decrease for the other 5 antennas.
- However, dropping antennas with **long observation histories and/or remote locations** (like KOKEE, NYALES20, WETTZELL) from the datum set is little desirable.
- What is the **best approach**?

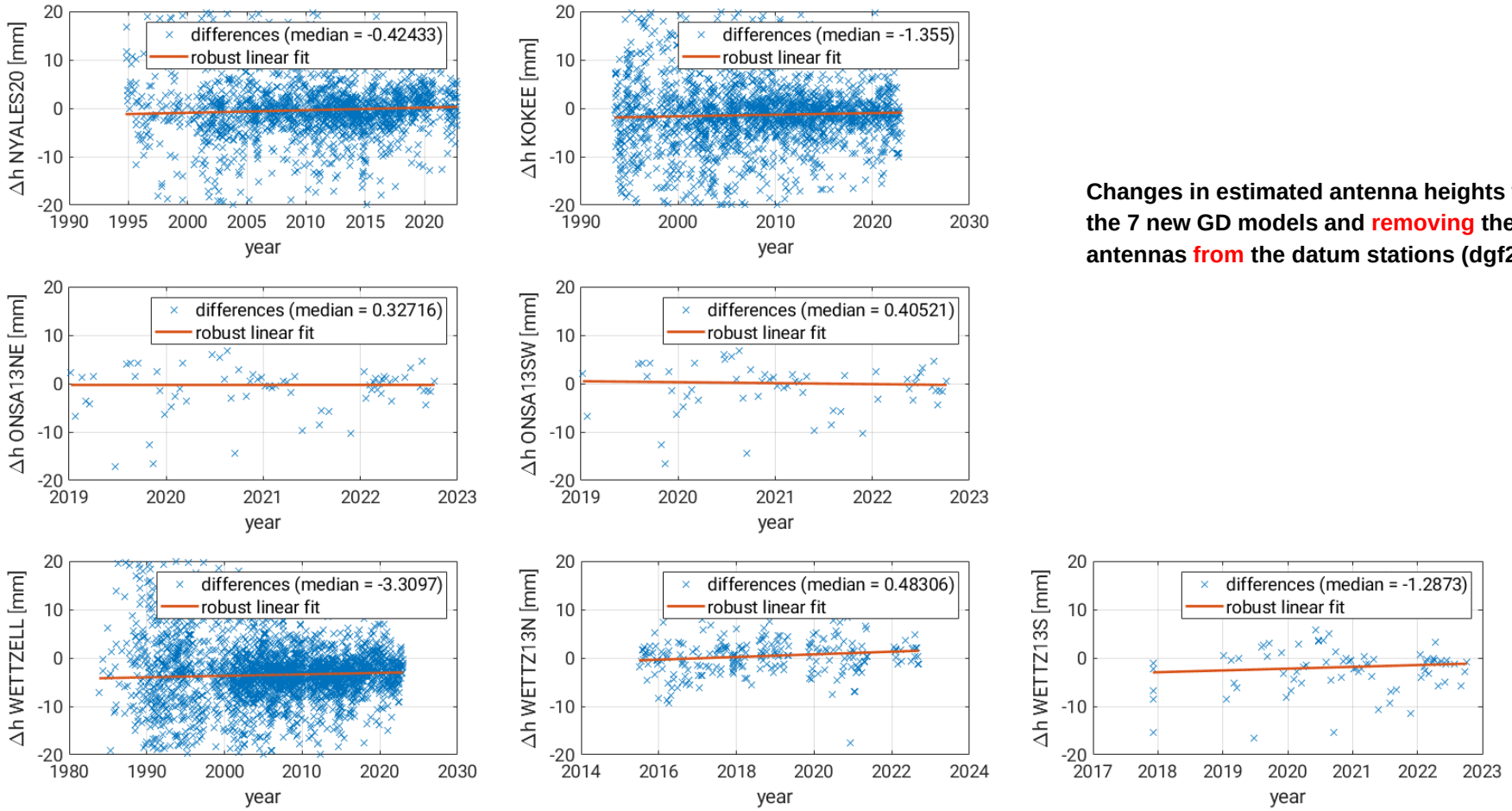




	EFLSBERG	GILCREEK	MEDICINA	NOTO	ONSALA60	YEBES40M
GSFC estimated Δh [mm]	118.70	2.46	8.87	7.26	-4.92	-37.44
DGFI-TUM wmean Δh [mm]	119.1	2.4	9.2	7.2	-5.7	-49.6

* J.Gipson, *Impact of Gravitational Deformation of VLBI Antennas on Reference Frame*, UAW 2019;
M.Glomsda et al., *Impact of new models for the ITRF2020 in VLBI analysis at DGFI-TUM*, AGU 2020

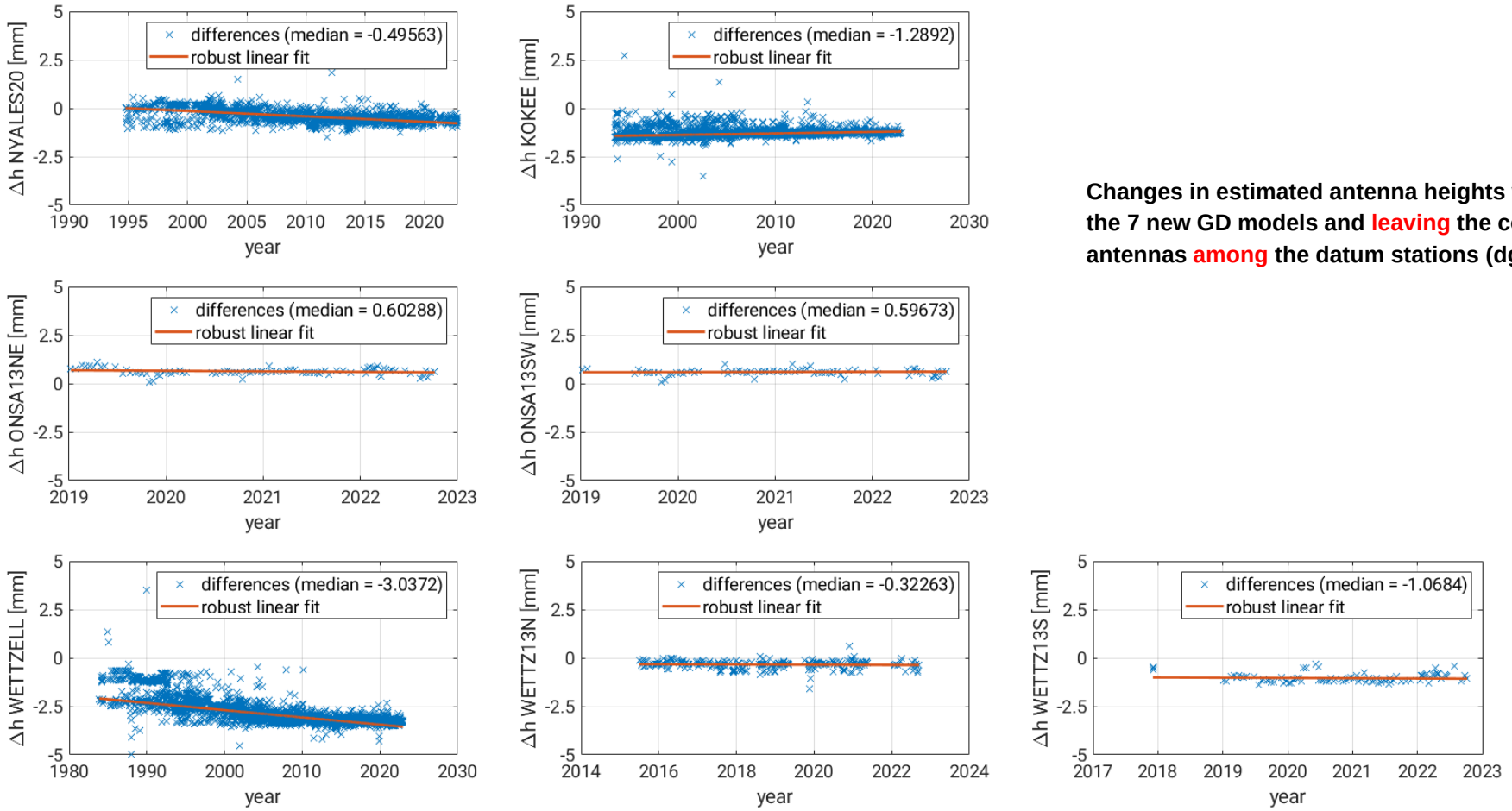
Impact on estimated antenna heights: changed datum station set



Changes in estimated antenna heights when adding the 7 new GD models and removing the corresponding antennas from the datum stations (dgf2023a).

- Except for WETTZ13N, the **median changes in height** have the **expected sign**.
- The **most significant impact is given for WETTZELL** (which has the largest maximum excess delay) and **KOKEE**.

Impact on estimated antenna heights: unchanged datum station set



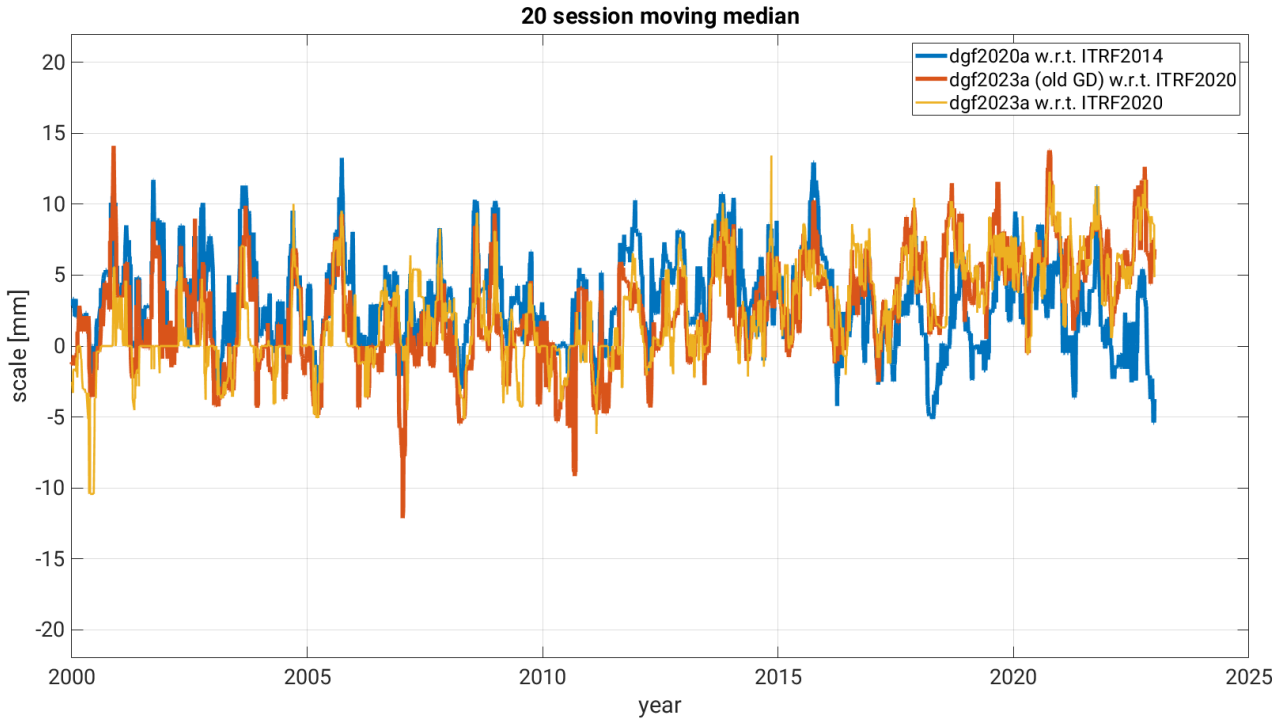
Changes in estimated antenna heights when adding the 7 new GD models and leaving the corresponding antennas among the datum stations (dgf2023a*).

- Basically **all session-wise changes in height** have the **expected sign**.
- The **median changes are similar** while the **variation of changes is much smaller** compared to the previous case.

Datum (scale) parameter time series: ITRF2014 and GD

solution	a priori TRF	gravitational deformation (GD)	datum stations
dgf2020a	ITRF2014	first 6 antennas	all except for 6 GD antennas
dgf2023a old GD	ITRF2020	first 6 antennas	all
dgf2023a	ITRF2020	first 6 + 7 new antennas	all except for 7 new GD antennas

- The figure shows the moving 20 session median of the **scale** parameter of **7 parameter Helmert transformations** of the session-wise solutions w.r.t. their a priori TRFs (outliers: |scale| > 60 mm).
- **Until about 2015**, the median scales w.r.t. ITRF2014 and ITRF2020 are **very similar**.
- There is **no continuous scale drift** between **dgf2020a** and the **ITRF2014** (blue) afterwards.
- The **7 new gravitational deformation models** seem to have **no significant impact** on the scale (yellow).



Conclusions

- The most significant change with the secular ITRS 2020 realizations is given for **stations with a small observation history before 2015**.
- The impact of switching the a priori TRF in VLBI analysis is **more pronounced if the set of datum stations** is also altered.
- A drift is observed in the **scale w.r.t. the ITRF2020** and **apparently also w.r.t. the JTRF2020**, starting shortly before 2015 as well.
- The scale drift is **not observed w.r.t. DTRF2020** (are there systematic differences in up direction, or is the choice of techniques for realizing the scale, i.e., SLR vs. GNSS, relevant?) **and ITRF2014**.
- The impact of the new **gravitational deformation models** on the estimated heights of the corresponding antennas is **as expected on average**, but it also depends on the **chosen set of datum stations**.
- The **scale is hardly affected** by the new gravitational deformation models, which have **comparatively small excess delays**.