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Can the observed ITRF2020-JTRF2020 frame discrepancies be reconciled with the stochastic error budget of ITRF2020 ?

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Introduction

- ITRF2020, JTRF2020, DTRF2020: state-of-the-art realizations of ITRS
same observations, different frame modeling/estimation strategies
- **Quality assessment of these solutions** relies on daily Helmert transformations of their respective realizations in SGT networks
- **Study's objective:** compare the observed JTRF2020-ITRF2020 frame discrepancies against the stochastic uncertainty of the ITRF2020 solution

** DTRF2020 is excluded due to length/time limitations of the presentation*

Data and Methodology

INPUT DATA

JTRF2020

- Daily SNX files
- Outliers file

*SLR, VLBI,
GNSS, DORIS*

ITRF2020

- Multi-year SNX file
- Annual signals (CM) + STDs
- Post-seismic deform SNX file

Exclude ITRF2020 stations:

- with PSD
- $\sigma(X_o, Y_o, Z_o) > 3 \text{ cm}$
- $\sigma(V_x, V_y, V_z) > 3 \text{ mm/yr}$

DAILY PROCESSING LOOP (1980 - 2025)

Form daily JTRF network

- Read CRD, full COV, epoch
- Remove outlier stations

Identify common
stations between
JTRF and ITRF

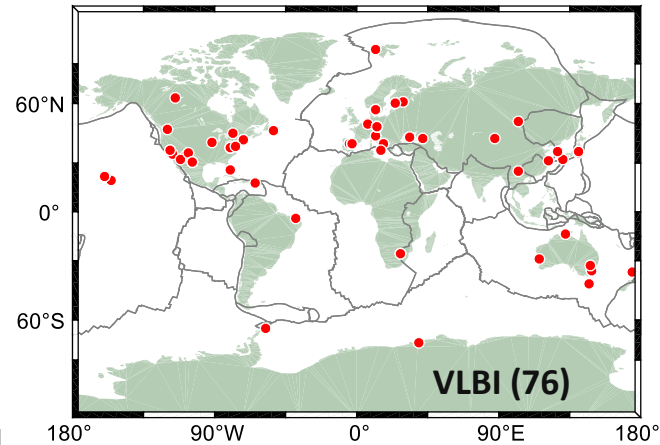
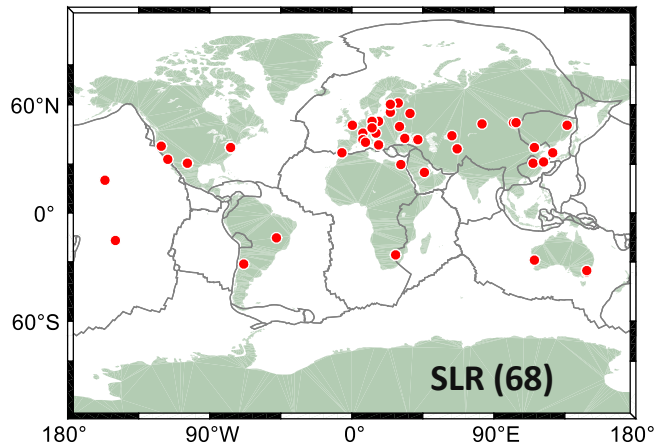
Form daily ITRF network

- Identify SOL for each station that includes (or is closest to) daily epoch
 - Compute ITRF2020 daily coords and their full COV matrix
- $\mathbf{X}(t) = \mathbf{X}(t_o) + \mathbf{VEL} + \text{annual signal}$
& covariance propagation

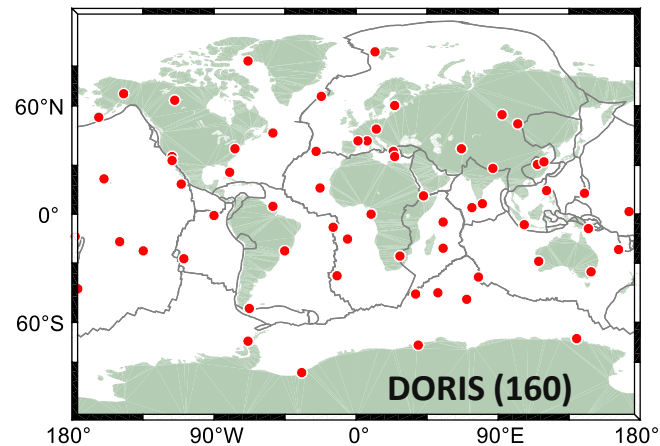
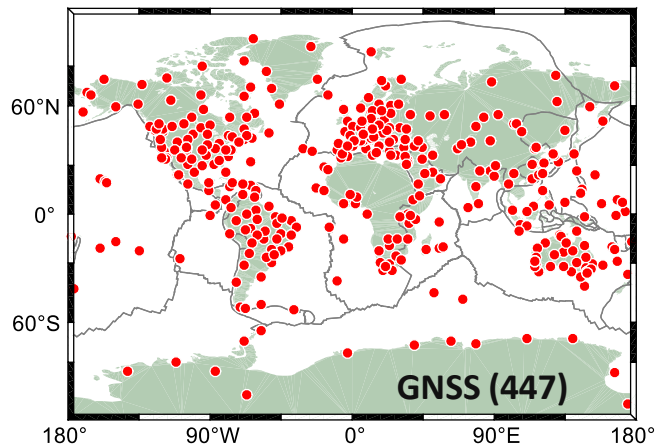
Daily estimation of 7 HPs btw ITRF2020 & JTRF2020

- station weighting enabled
- concurrent estimation of extra "frame quality metrics" (see next slides)

Technique networks used in this study



1980-2025



Issues to be considered in the frame comparisons

- **Weighting schemes for daily station coordinates**
ITRF-based, JTRF-based
- **ITRF2020 inner uncertainty of frame realization**
- **GGOS-specified level for frame accuracy/stability**

Different weighting schemes

Estimation of daily HT parameters btw ITRF2020 and JTRF2020

$$\boldsymbol{\theta}(t) = (\mathbf{A}^T \mathbf{W} \mathbf{A})^{-1} \mathbf{A}^T \mathbf{W} (\mathbf{X}^{JTRF}(t) - \mathbf{X}^{ITRF}(t))$$

Two different weighting schemes were tested:

$$\mathbf{W} = \begin{cases} (\boldsymbol{\Sigma}_{\mathbf{X}(t)}^{ITRF})^{-1} & \text{Using daily CRD-COV matrices of ITRF2020} \\ & \text{(from our own propagation – see next slide)} \\ \\ (\boldsymbol{\Sigma}_{\mathbf{X}(t)}^{JTRF})^{-1} & \text{Using daily CRD-COV matrices of JTRF2020} \\ & \text{(from daily SNX files)} \end{cases}$$

Determination of ITRF2020 inner uncertainty

Step 1: Daily CRD covariance propagation from full SNX info

$$\begin{pmatrix} \Sigma_{X(t_o)} & \Sigma_{X(t_o), \dot{X}} \\ \Sigma_{\dot{X}, X(t_o)} & \Sigma_{\dot{X}} \end{pmatrix}, \Sigma_{\{a_i, b_i\}}^{diag} \longrightarrow \Sigma_{X(t)}^{ITRF} \quad \text{per technique network}$$

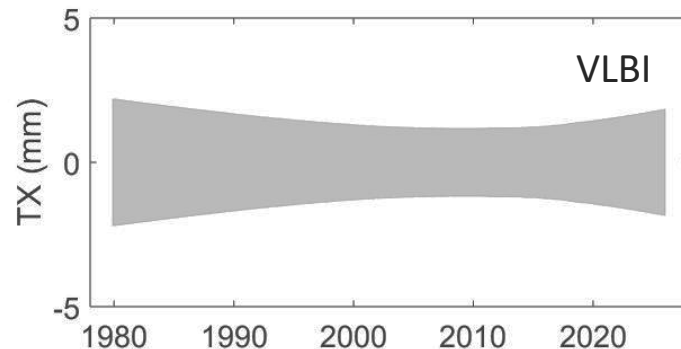
Step 2: Covariance projection to frame parameter space (7 HPs)

$$\Sigma_{\theta(t)}^{ITRF} = (A^T A)^{-1} A^T \Sigma_{X(t)}^{ITRF} A (A^T A)^{-1}$$



**deduce “ITRF2020 realization uncertainty”
in each technique network on daily basis**

e.g.



GGOS frame quality specifications

- Standard levels for frame accuracy at reference epoch ($t_o = 2015.00$) and long-term frame stability:

$$\sigma_{\theta_i}(t_o) = 1 \text{ mm} \quad \sigma_{\dot{\theta}_i} = 0.1 \text{ mm/yr}$$

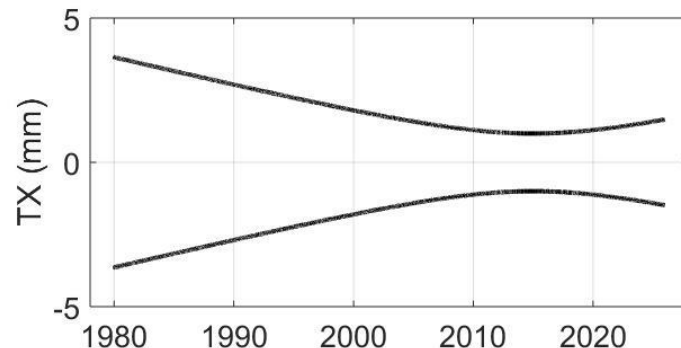
- Empirical inference of “instantaneous” frame accuracy level

$$\sigma_{\theta_i}^2(t) = \sigma_{\theta_i}^2(t_o) + \sigma_{\dot{\theta}_i}^2 \times (t - t_o)^2$$



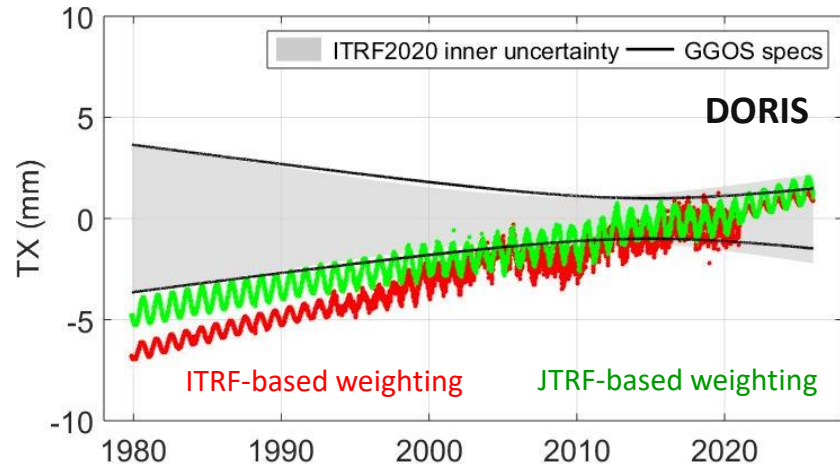
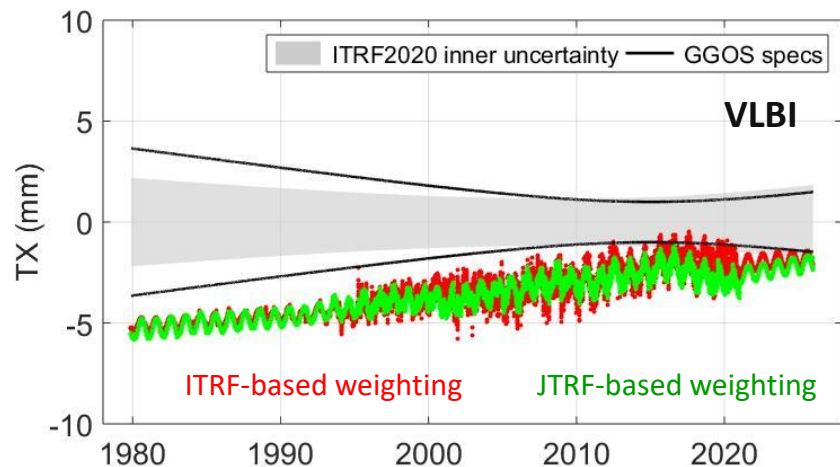
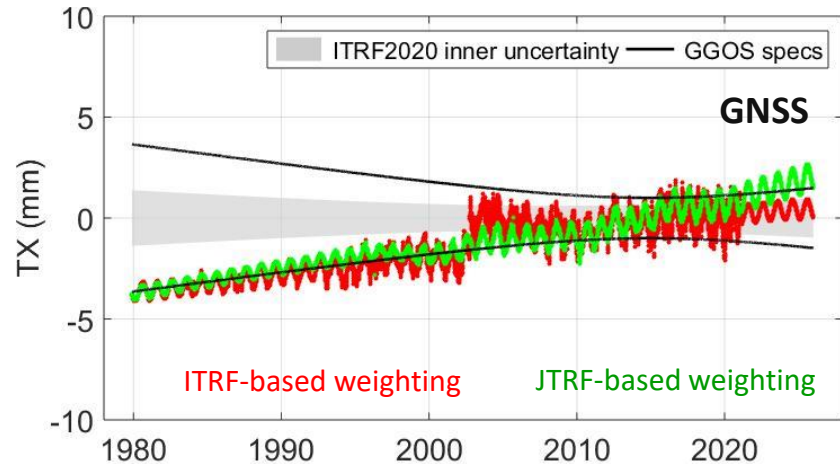
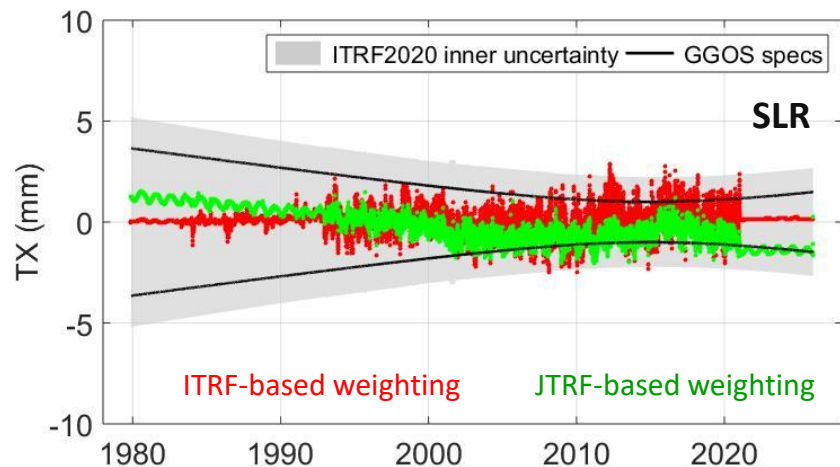
obtain admissible range of daily estimated HPs
in global frame comparisons

e.g.



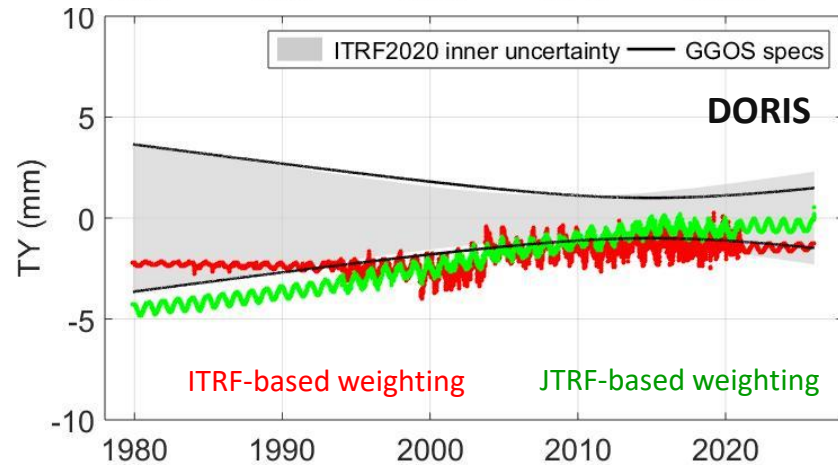
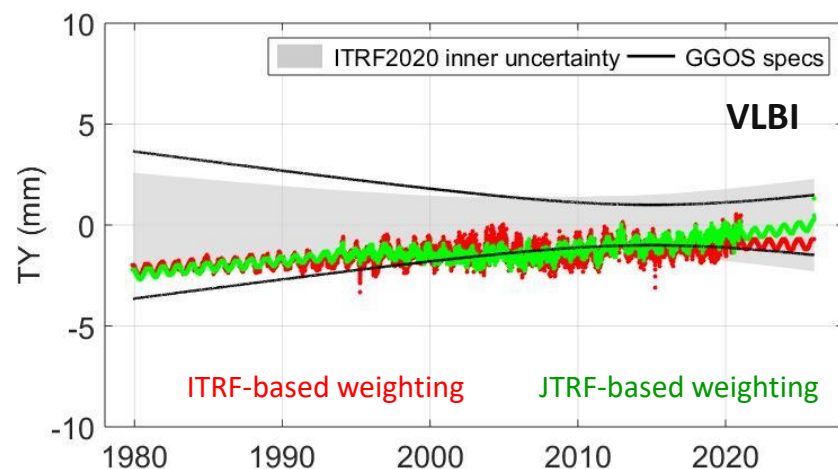
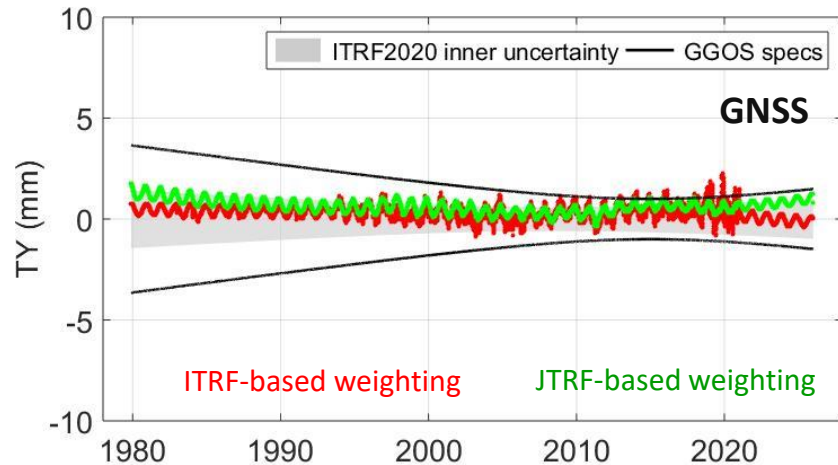
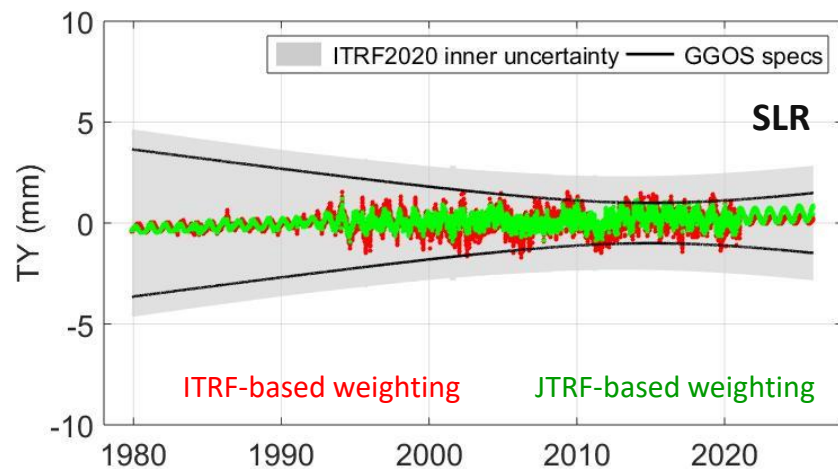
ITRF2020 vs. JTRF2020

TX results



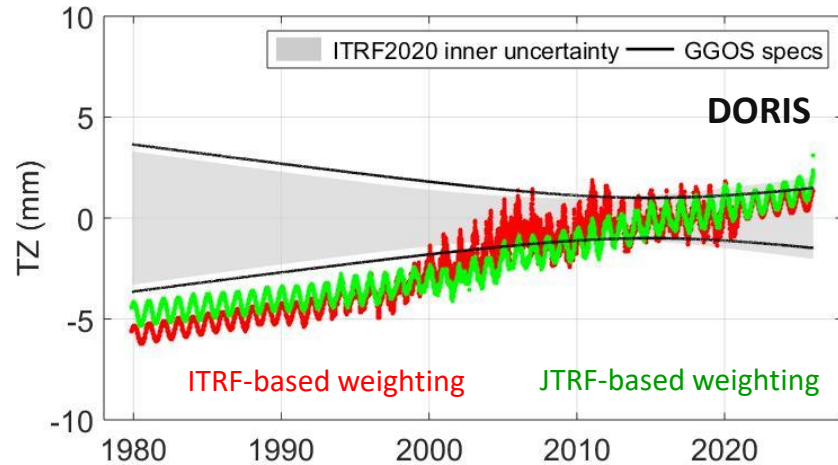
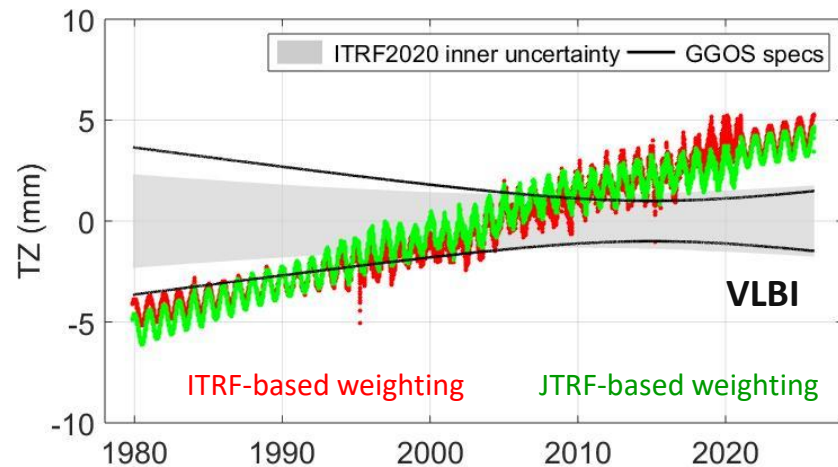
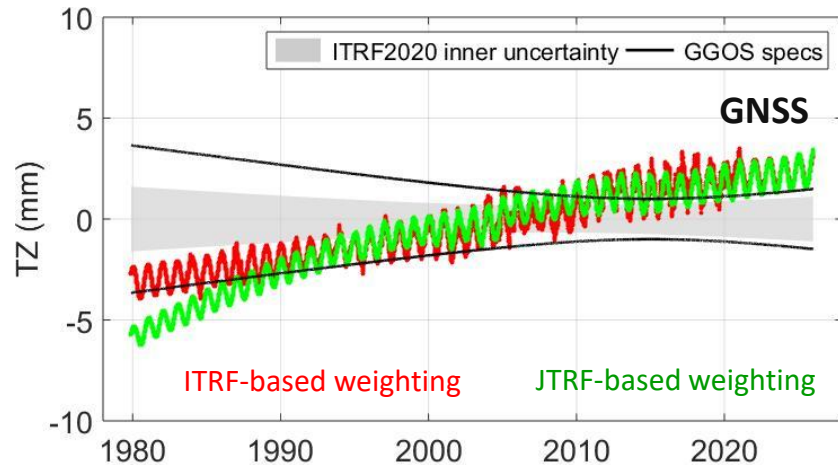
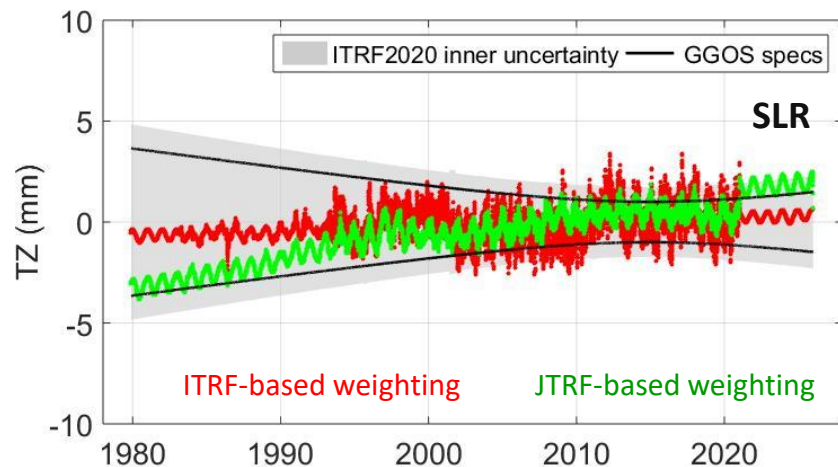
ITRF2020 vs. JTRF2020

TY results



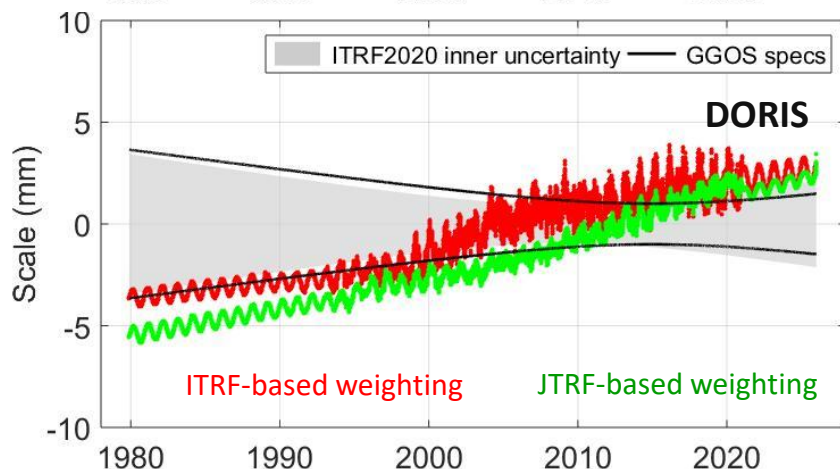
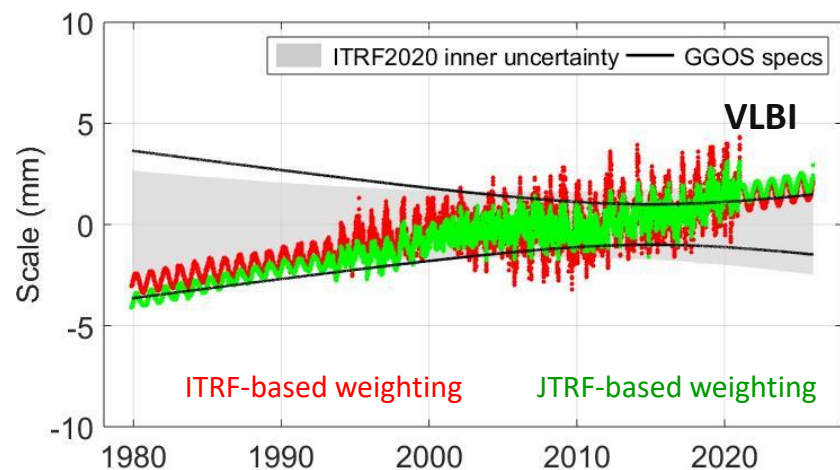
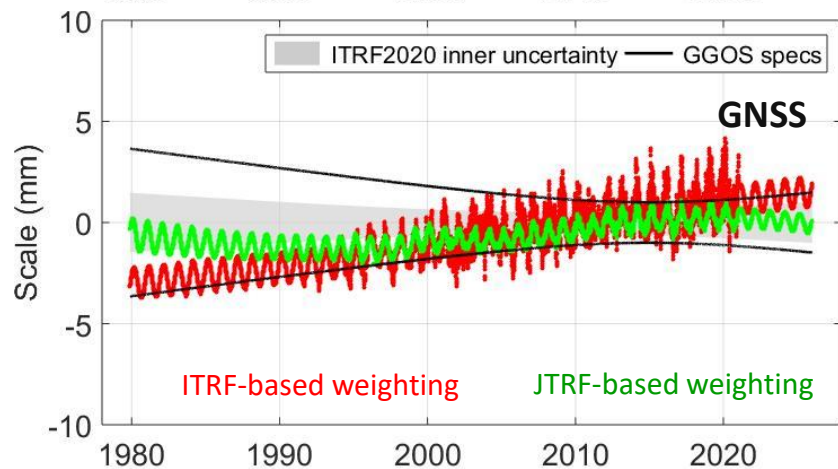
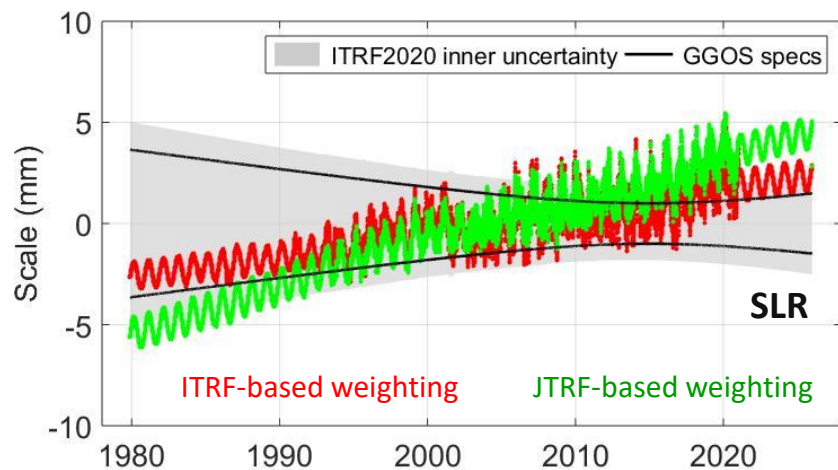
ITRF2020 vs. JTRF2020

TZ results



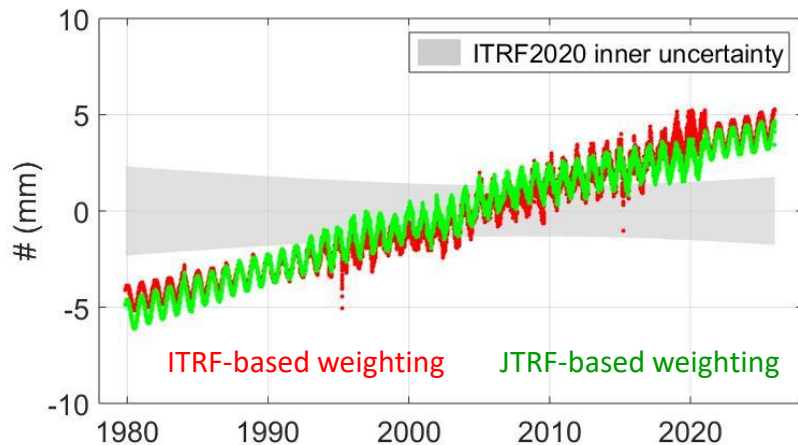
ITRF2020 vs. JTRF2020

Scale results



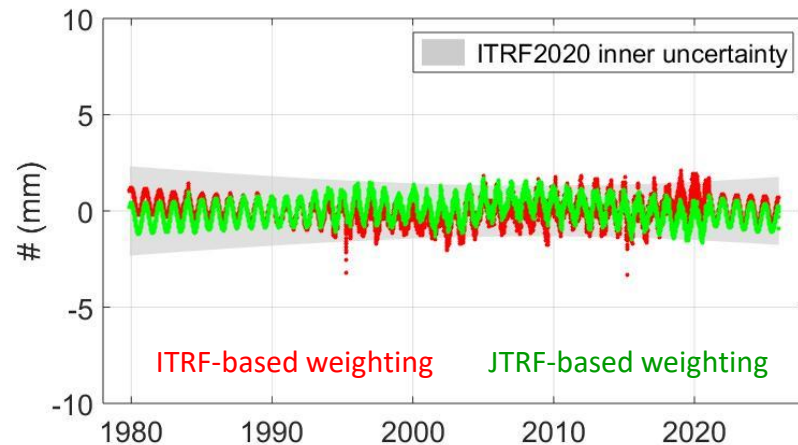
Next steps

Original time series of HPs



Infer offsets and drifts via simple
least squares fitting

De-trended time series of HPs



Check statistical consistency wrt.
ITRF2020 inner uncertainty

Estimated drifts in mm/yr

	ITRF-based weighting				JTRF-based weighting			
	$\dot{T}_X$	$\dot{T}_Y$	$\dot{T}_Z$	$\dot{S}$	$\dot{T}_X$	$\dot{T}_Y$	$\dot{T}_Z$	$\dot{S}$
SLR	0.0	0.0	0.0	0.1	-0.1	0.0	0.1	0.2
GNSS	0.1	-0.0	0.1	0.1	0.1	-0.0	0.2	0.0
VLBI	0.1	0.0	0.2	0.1	0.1	0.0	0.2	0.1
DORIS	0.2	0.0	0.2	0.2	0.1	0.1	0.1	0.2

JTRF2020 minus ITRF2020

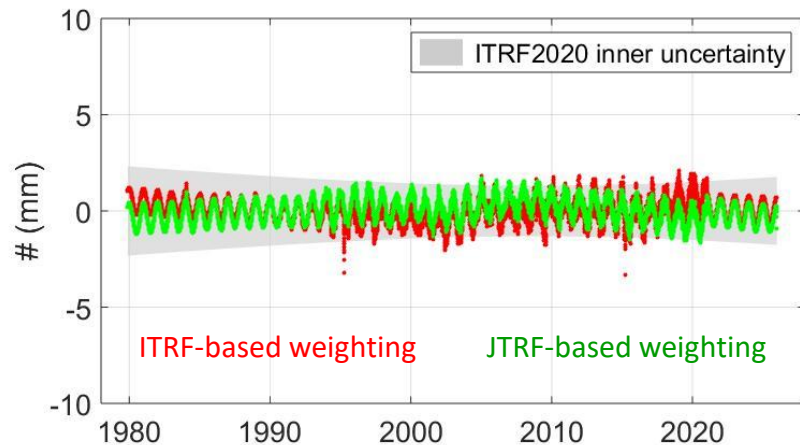
Estimated offsets in mm (at $t_0=2015.0$)

	ITRF-based weighting				JTRF-based weighting			
	T_X	T_Y	T_Z	S	T_X	T_Y	T_Z	S
SLR	0.1	0.1	0.1	1.2	-0.9	0.2	0.7	2.2
GNSS	-0.2	0.2	1.3	0.5	0.2	0.5	1.4	-0.2
VLBI	-2.5	-1.1	2.2	0.7	-2.8	-0.8	2.1	0.7
DORIS	-0.8	-1.6	-0.3	1.3	-0.3	-0.9	-0.5	0.3

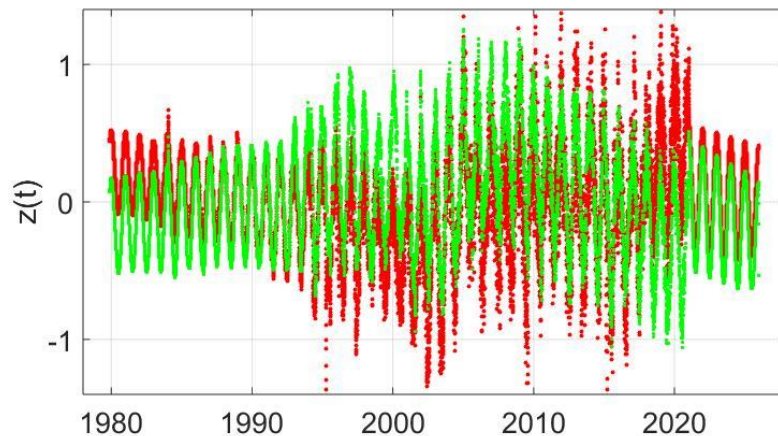
JTRF2020 minus ITRF2020

Normalization of daily HP time series

De-trended time series of HPs



Normalized time series of HPs



Statistical checks: $\begin{cases} P(|z(t)| < 1) \approx 68\% \\ P(|z(t)| < 2) \approx 95\% \end{cases}$

$$z(t) = \frac{\theta(t) - \mu(t)}{\sigma_{\theta(t)}}$$



ITRF2020's inner stochastic uncertainty

Results of 1- σ statistical check

	ITRF-based weighting				JTRF-based weighting			
	T_X	T_Y	T_Z	S	T_X	T_Y	T_Z	S
SLR	99.9%	100%	98.6%	98.3%	100%	100%	100%	99.6%
GNSS	80.8%	94.6%	84.3%	75.5%	87.4%	98.0%	73.1%	86.8%
VLBI	98.1%	99.9%	98.3%	96.1%	99.9%	100%	99.2%	99.9%
DORIS	98.4%	98.9%	92.4%	95.2%	99.3%	100%	99.0%	99.8%

Much more than 68% of the frame discrepancies (after trend removal)
lie within the 1 σ ITRF2020 uncertainty bounds

Results of 2- σ statistical check

	ITRF-based weighting				JTRF-based weighting			
	T_X	T_Y	T_Z	S	T_X	T_Y	T_Z	S
SLR	100%	100%	100%	100%	100%	100%	100%	100%
GNSS	95.3%	99.9%	99.6%	93.7%	99.5%	100%	99.9%	100%
VLBI	100%	100%	99.9%	100%	100%	100%	100%	100%
DORIS	100%	100%	99.2%	99.9%	100%	100%	100%	100%

Nearly all of the frame discrepancies (after trend removal)
lie within the 2 σ ITRF2020 uncertainty bounds

Conclusions

- **Systematic differences btw ITRF2020 and JTRF2020 are small:**
 - origin/scale drifts do not exceed 0.1-0.2 mm/yr
 - origin/scale offsets at epoch 2015.0 at the 1 mm level (except for VLBI origin: ≈ 3.5 mm in 3D)
 - weak annual signals (< 0.5 mm) reflecting seasonal “geocentricity errors” (?)
- The residual origin/scale discrepancies (after linear trend removal) btw ITRF2020 and JTRF2020 **are well within the propagated precision level of the ITRF2020 solution**
- Similar evaluation results are obtained with ITRF2020- and JTRF2020-based station weighting schemes