# ITRF2020 Updates and consequences for ETRS89 realization

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# Key Points

- Regular (yearly) update of ITRF2020
- Motivation
- ITRF2020 Update Specifications
- Some Early/Preliminary Results
- Consequences for ETRS89 realization
- Conclusion

# Regular (yearly) update of ITRF2020

- **ITRF2020 strategy: stacking of all technique time series all together**
  - **==> Adding extended time series is easy to handle**
- **Motivation:**
  1. **Errors in ITRF station coordinates are more and more amplified as they are extrapolated after the end of the ITRF input data;**
  2. **ITRF stations subject to equipment changes or earthquakes posterior to the end of the ITRF input data cannot be used anymore as reference frame stations;**
  3. **Most of the TCs regularly update their own realizations of the ITRF;**
  4. **==> Increase ITRF2020 lifetime and may postpone the need for the next version of the ITRF;**
  5. **The scale agreement between SLR and VLBI is now at the level of 1 mm**
  6. **We do not expect significant changes for the origin and the scale by adding a few years of new data**
  7. **==> This will simplify the life of a number of users, with no "datum" change in their applications**
  8. **==> Simplify the (I)ETRF2020 relationship**

# Transformation Parameters: From ITRF2020 to past ITRFs

Transformation parameters from ITRF2020 to past ITRFs at Epoch 2015.0

| SOLUTION | Tx | Ty | Tz | D | Rx | Ry | Rz |
|---|---|---|---|---|---|---|---|
| UNITS----------> | mm | mm | mm | ppb | .001" | .001" | .001" |
| | . | . | . | . | . | . | . |
| RATES | Tx | Ty | Tz | D | Rx | Ry | Rz |
| UNITS----------> | mm/y | mm/y | mm/y | ppb/y | .001"/y | .001"/y | .001"/y |
| ITRF2014 | -1.4 | -0.9 | 1.4 | -0.42 | 0.00 | 0.00 | 0.00 |
| rates | 0.0 | -0.1 | 0.2 | 0.00 | 0.00 | 0.00 | 0.00 |
| ITRF2008 | 0.2 | 1.0 | 3.3 | -0.29 | 0.00 | 0.00 | 0.00 |
| rates | 0.0 | -0.1 | 0.1 | 0.03 | 0.00 | 0.00 | 0.00 |
| ITRF2005 | 2.7 | 0.1 | -1.4 | 0.65 | 0.00 | 0.00 | 0.00 |
| rates | 0.3 | -0.1 | 0.1 | 0.03 | 0.00 | 0.00 | 0.00 |
| ITRF2000 | -0.2 | 0.8 | -34.2 | 2.25 | 0.00 | 0.00 | 0.00 |
| rates | 0.1 | 0.0 | -1.7 | 0.11 | 0.00 | 0.00 | 0.00 |

# ITRF2020 Update Specifications

- Same analysis strategy as for ITRF2020
- Plan to preserve the frame and seasonal signal defining parameters in origin, scale, and orientation for the ITRF2020 updates
- ITRF2020 updates will be delivered using the same file format as ITRF2020
- First update : Beginning of 2024
  - Submissions by the 4 techniques are now complete
- TCs are invited to adhere to the same models and strategy used in their contribution to the ITRF2020
- BUT: TCs are free to use updated models that are judged to be superior, improved and more accurate than models used for the ITRF2020 contribution.

# ITRF2020 New Analysis Strategy

**Input data:**

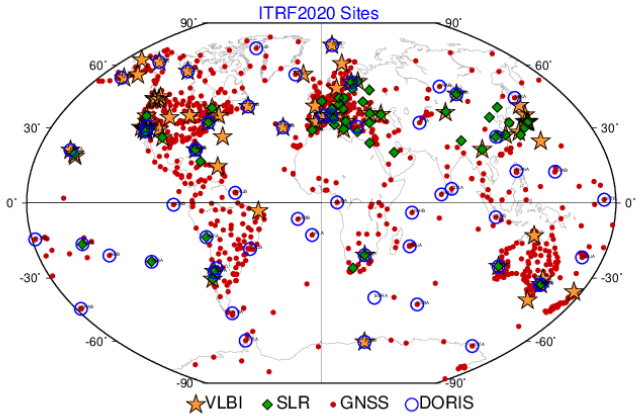
- **Space geodesy time series**
  - DORIS/IDS weekly
  - GNSS/IGS daily
  - SLR/ILRS weekly
  - VLBI/IVS: Session-wise
- **Local ties: 253 vectors**
- **Co-motion constraints at colocation sites:**
  - Station velocities & seasonal signals

**Data analysis:**

- Time series analysis & stacking of individual technique frames
- Assign discontinuities
- Determine PSD Parametric Models using GNSS data
- Estimate and remove the first 8 GPS draconitic harmonics
- **Accumulate the full 4 technique time series all together, adding local ties and co-motion constraints**

**Output:**

- Station positions & velocities
- EOPs
- PSD models
- Seasonal Signals in the CM SLR and CF frames
- Seasonal Geocenter Motion

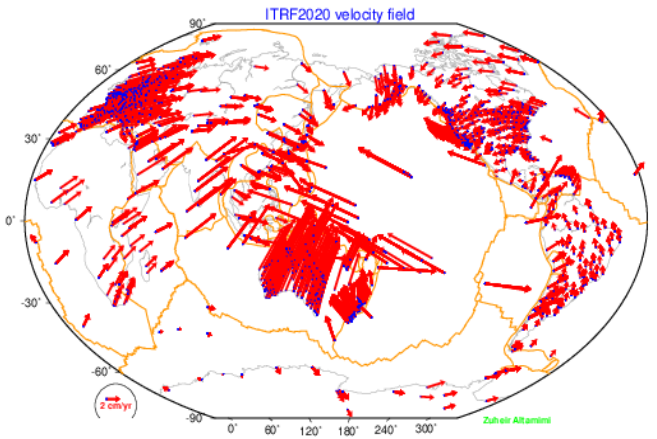



**ITRF2020 Specifications:**

**Origin**: SLR

**Scale**: Average of SLR & VLBI

**Orientation**: Alignment to ITRF2014



# Reference Frame & the rank deficiency problem

- Use the concept of minimum constraints (Dermanis, 2003):

$$\boldsymbol{A^T.\Delta X = 0}$$

But in CATREF (Altamimi et al. 2007) we use:

$$\boldsymbol{(A^T A)^{-1} A^T (X_R - X_E) = 0}$$

$\boldsymbol{X_R}$ & $\boldsymbol{X_E}$: Reference & Estimated coordinates

The columns of A are in the null space of the design matrix of CATREF model

$$A = \begin{pmatrix} . & . & . & . & . & . & . \\ 1 & 0 & 0 & x_0^i & 0 & z_0^i & -y_0^i \\ 0 & 1 & 0 & y_0^i & -z_0^i & 0 & x_0^i \\ 0 & 0 & 1 & z_0^i & y_0^i & -x_0^i & 0 \\ . & . & . & . & . & . & . \end{pmatrix}$$

- Or/and: Internal constraints, a minimum-type of constraints (Altamimi et al., 2007), applied to the transformation parameters : For a given time series of a parameter $\boxed{P_k}$

$$\begin{cases} \sum_{k \in K} P_k = 0 \\ \sum_{k \in K} (t_k - t_0) P_k = 0 \end{cases}$$

# Periodic signals & the rank deficiency problem (1/2)

**Sine & Cosine Function**

$$\Delta X_f = \sum_{i=1}^{n_f} a^i \cos(\omega_i t) + b^i \sin(\omega_i t)$$

- 2 parameters per station, component & frequency: (a , b)
- Use the concept of minimum constraints:

- $(A^T A)^{-1} A^T \begin{pmatrix} a^i_{xR} - a^i_x \\ a^i_{yR} - a^i_y \\ a^i_{zR} - a^i_z \end{pmatrix} = 0$
- $(A^T A)^{-1} A^T \begin{pmatrix} b^i_{xR} - b^i_x \\ b^i_{yR} - b^i_y \\ b^i_{zR} - b^i_z \end{pmatrix} = 0$

$$A = \begin{pmatrix} . & . & . & . & . & . & . \\ 1 & 0 & 0 & x^i_0 & 0 & z^i_0 & -y^i_0 \\ 0 & 1 & 0 & y^i_0 & -z^i_0 & 0 & x^i_0 \\ 0 & 0 & 1 & z^i_0 & y^i_0 & -x^i_0 & 0 \\ . & . & . & . & . & . & . \end{pmatrix}$$

- $a^i_{xR}$ & $a^i_x$ are Reference & Estimated coefficients
- $a^i_{xR}$ can be set to zero or to external seasonal deformation model

# Periodic signals & the rank deficiency problem (2/2)

**Sine & Cosine Function**

$$\Delta X_f = \sum_{i=1}^{n_f} a^i \cos(\omega_i t) + b^i \sin(\omega_i t)$$

- **Or/and use internal constraints upon the time series of transformation parameters**

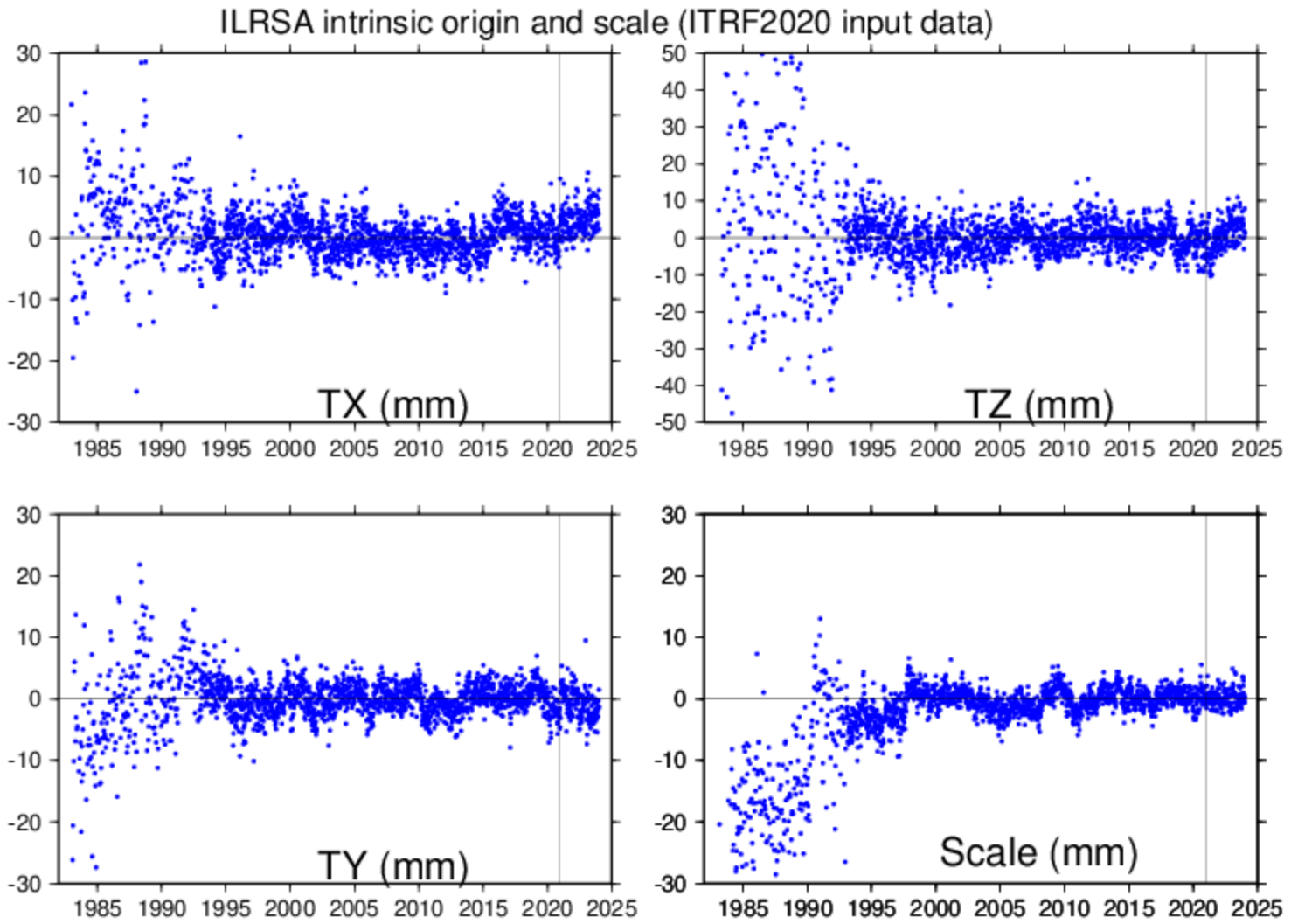
$$(B^T B)^{-1} B^T [P(t_1), \ldots, P(t_k)]^T = 0$$

*where*

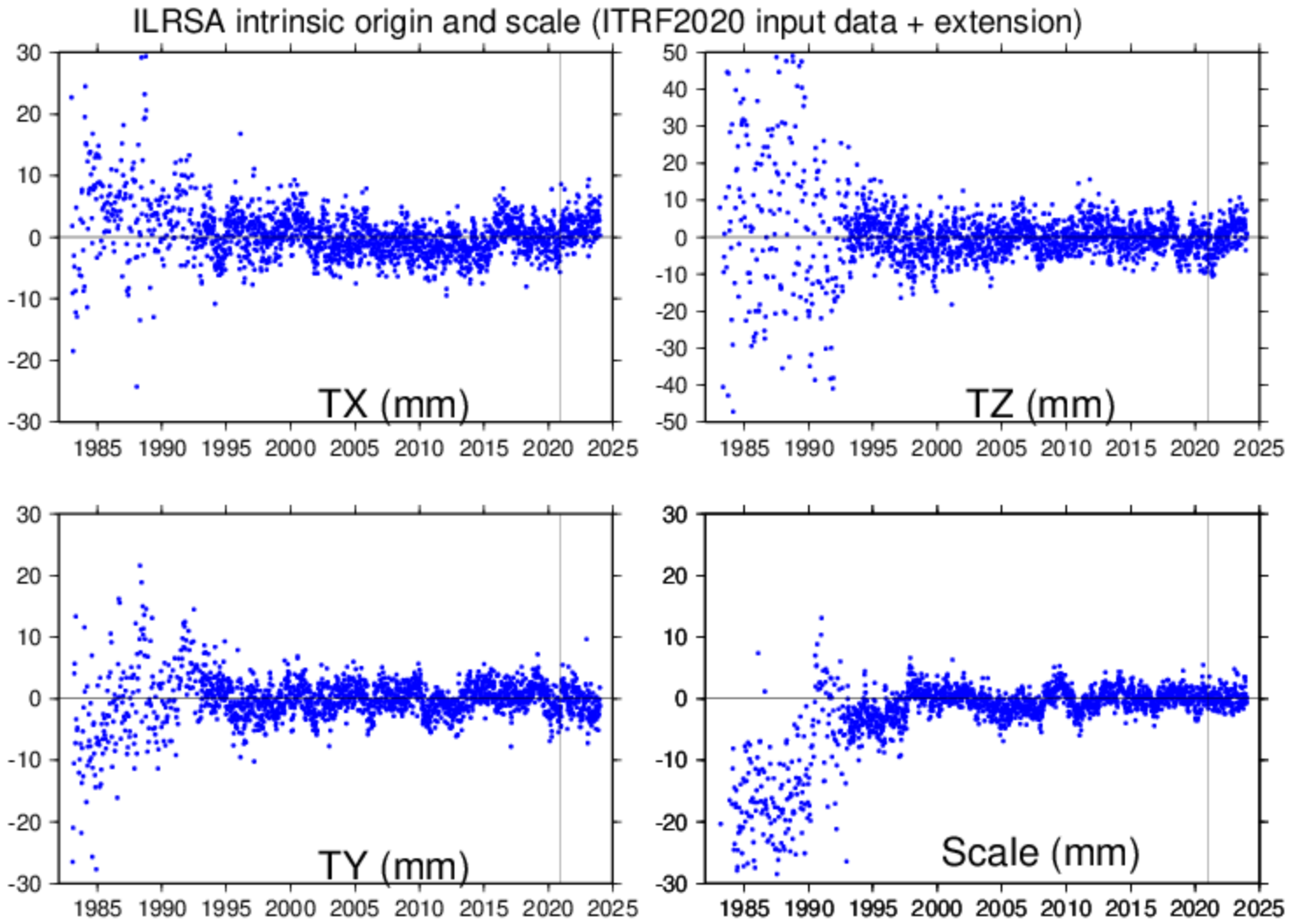
$$B = \begin{pmatrix} cos(\omega_i . t_1) & sin(\omega_i . t_1) \\ \vdots & \vdots \\ cos(\omega_i . t_k) & sin(\omega_i . t_k) \end{pmatrix}$$

# Some preliminary results using the extended data

# ILRS/SLR intrinsic (ITRF2020 input data) origin & scale

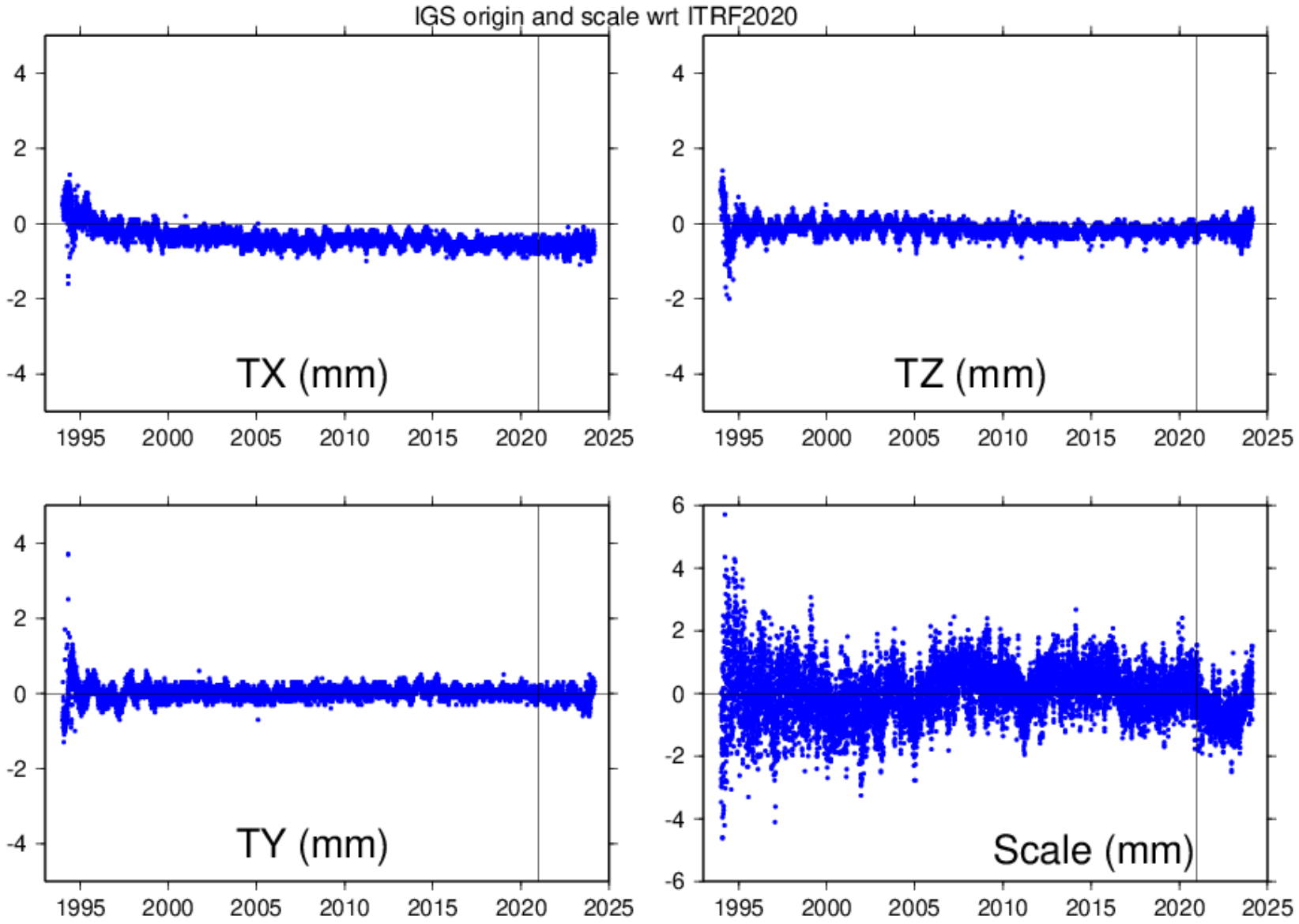


# ILRS/SLR intrinsic origin & scale with extension

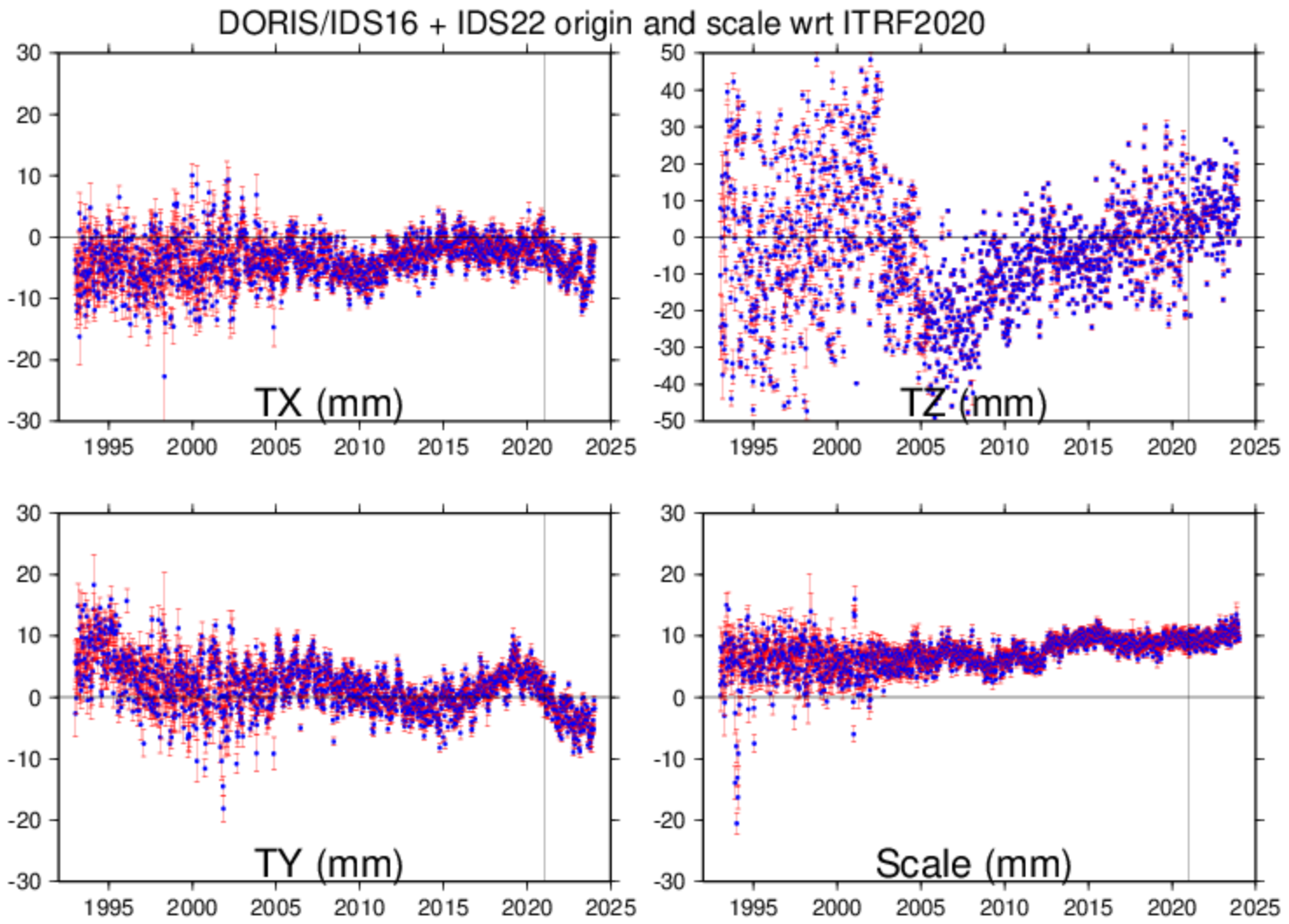



**SLR Origin & scale accuracy at 2015.0 below 1 mm and scale stability at the level of 0.1 mm/yr**

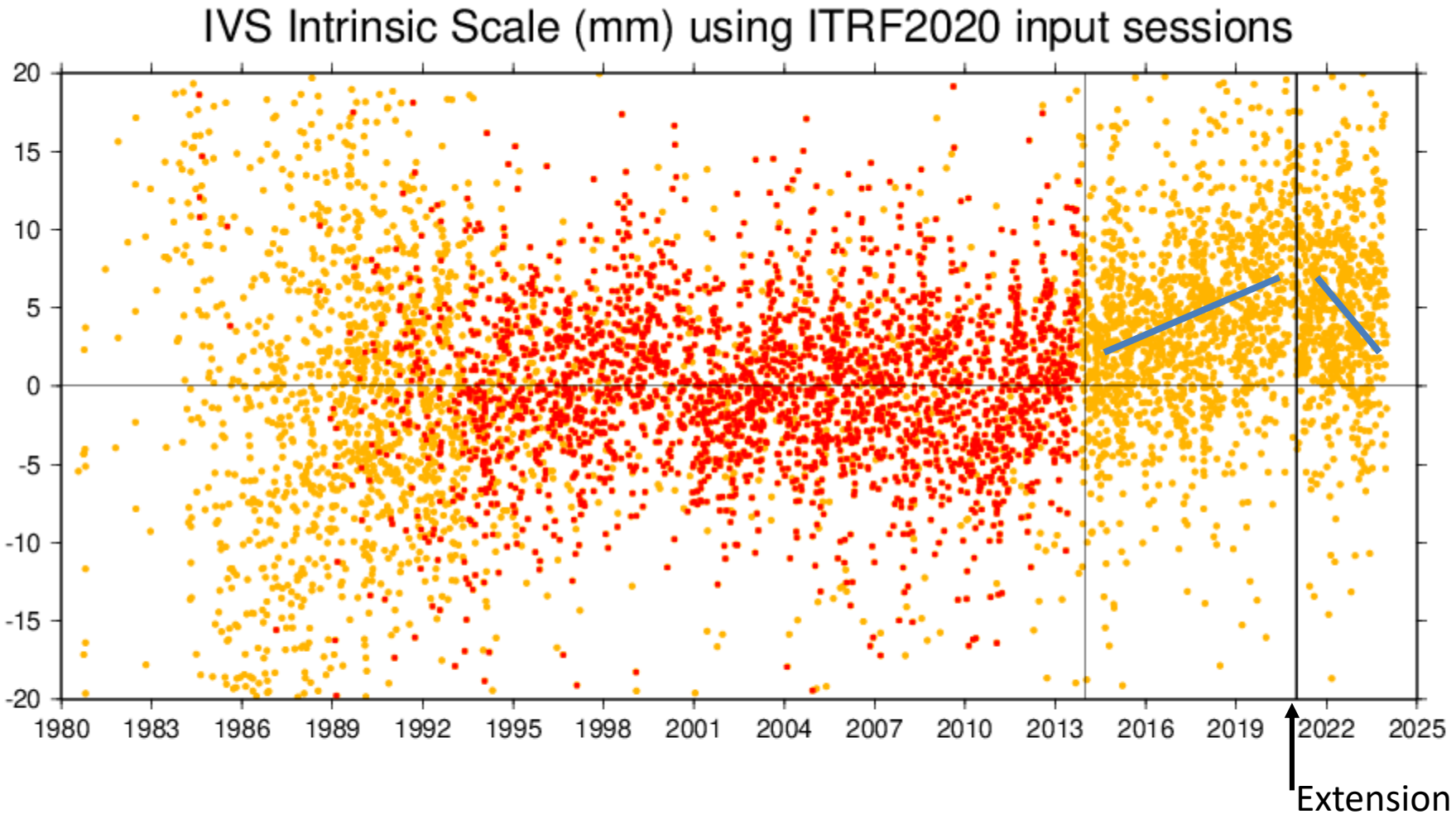
# IGS/GNSS origin & scale wrt ITRF2020



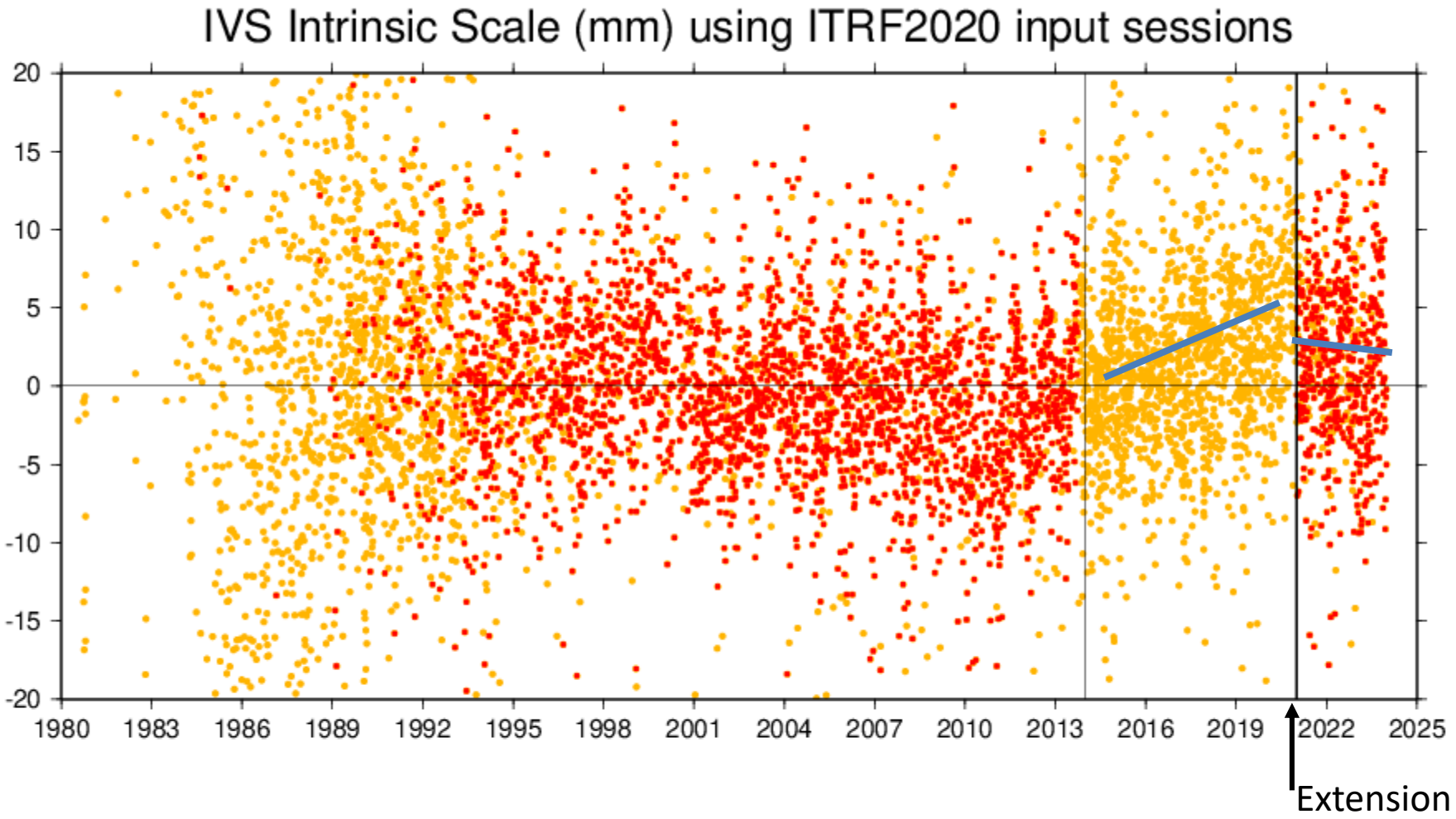
# IDS/DORIS origin & scale wrt ITRF2020 with extension



# IVS/VLBI Intrinsic Scale (ITRF2020 Sessions)



# IVS/VLBI Intrinsic Scale (ITRF2020 Sessions + Extension)




**==> δD = + 0.35 ppb,  0.025 ppb/yr**

# ITRS <==> ETRS89

# ITRS to ETRS89 Transformation formula

**Positions:**

$$X^E_{yy}(t) = X^I_{yy}(t) + T_{yy} + \begin{pmatrix} 0 & -\dot{R}3_{yy} & \dot{R}2_{yy} \\ \dot{R}3_{yy} & 0 & -\dot{R}1_{yy} \\ -\dot{R}2_{yy} & \dot{R}1_{yy} & 0 \end{pmatrix} \times X^I_{yy}(t).(t - 1989.0)$$

**Velocities:**

$$\dot{X}^E_{yy} = \dot{X}^I_{yy} + \begin{pmatrix} 0 & -\dot{R}3_{yy} & \dot{R}2_{yy} \\ \dot{R}3_{yy} & 0 & -\dot{R}1_{yy} \\ -\dot{R}2_{yy} & \dot{R}1_{yy} & 0 \end{pmatrix} \times X^I_{yy}$$

# Realization of the ETRS89

## Transformation From ITRF2000 to ETRF2000

| | T1 mm | T2 mm | T3 mm | D 10-9 | R1 mas | R2 mas | R3 mas | Epoch y |
|---|---|---|---|---|---|---|---|---|
| | 54.0 | 51.0 | -49.0 | 0.0 | 0.891 | 5.390 | -8.712 | 00:001 |
| Rates | 0.0 | 0.0 | 0.0 | 0.0 | 0.081 | 0.490 | -0.792 | |

Angular velocity of Eurasia

## Transformation From ITRF2014 to ETRF2014

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 89:001 |
| Rates | 0.0 | 0.0 | 0.0 | 0.0 | 0.085 | 0.531 | -0.770 | |

## Transformation From ITRF2020 to ETRF2020

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 89:001 |
| Rates | 0.0 | 0.0 | 0.0 | 0.0 | 0.086 | 0.519 | -0.753 | |

Will NOT change

# Conclusion

- No major issue so far with technique extended data
- Stability of SLR/ILRS origin and scale, with the extension, is at the level of or better than 0.1 mm/yr
- The IVS/VLBI scale comes back to “normal”, after the extension, starting at 2021.0
- Expected release date : summer 2024!

- There will be no change to the frame parameters (origin, scale, orientation) between ITRF2020 and its 1$^{st}$ update

- No change to the ITRF2020 and ETRF2020 relationship