ITRF2020 and the ILRS Contribution

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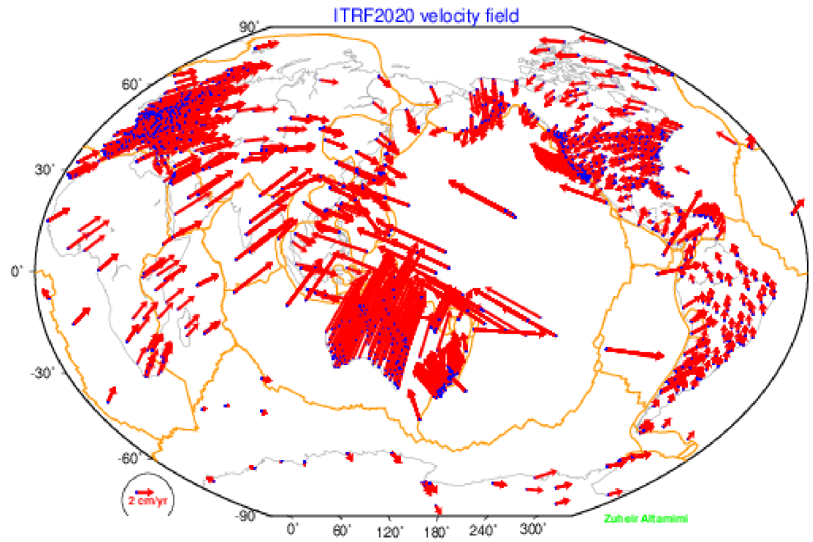
Key Points:

- ITRF2020 and its innovations: modelling of nonlinear station motions



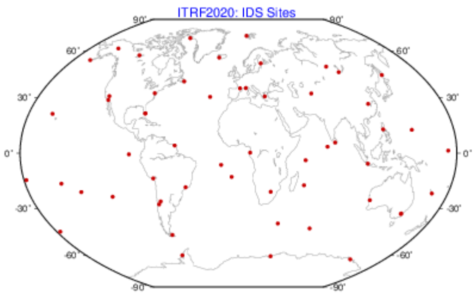
- ILRS Contribution
  - Quality (WRMS)
  - TRF parameters (origin & scale)

- Usage of ITRF2020 kinematic model

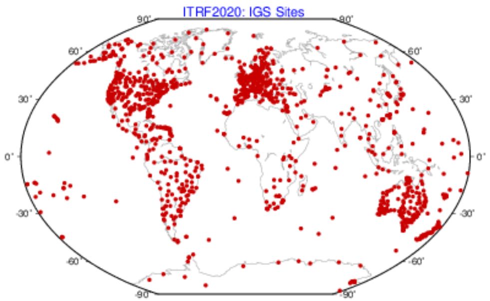
ITRF2020 Input Data

TC	# of solutions	Time-span	# of sites	Theoretical Frame Origin
IDS/DORIS	1456 weekly	1993.0 – 2021.0 (28 yrs)	87	CM
IGS/GNSS/GPS	9861 daily	1994.0 – 2021.0 (27 yrs)	1159	CN
ILRS/SLR	243 fortnightly 1460 weekly	1983.0 – 1993.0 1993.0 – 2021.0 (38 yrs)	100	CM
IVS/VLBI	6178 session-wise	1980.0 – 2021.0 (41 yrs)	117	CN

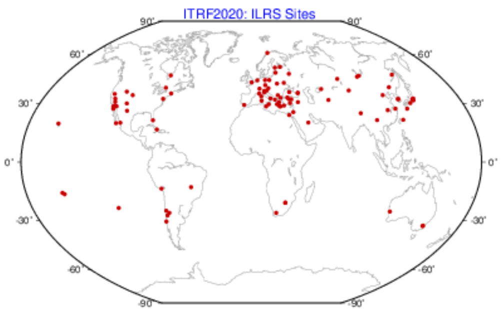
IDS/DORIS



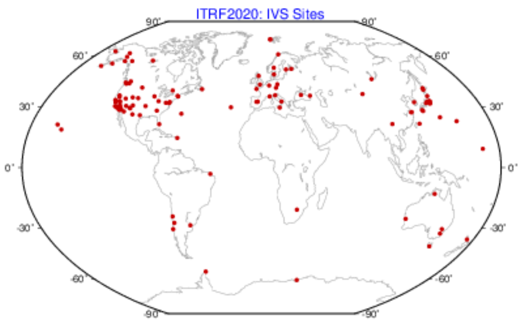
IGS/GNSS



ILRS/SLR

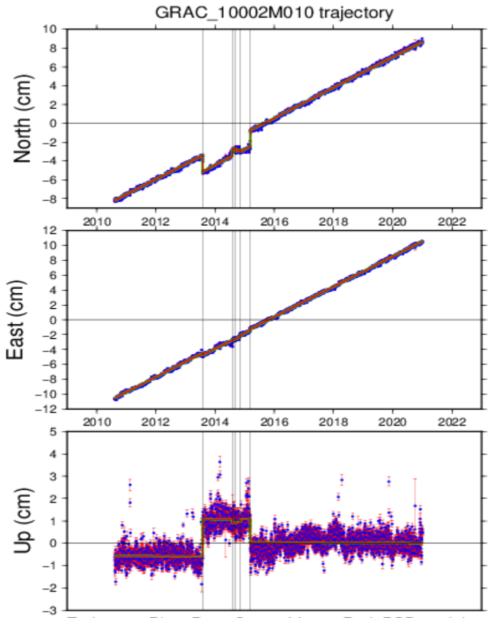


IVS/VLBI

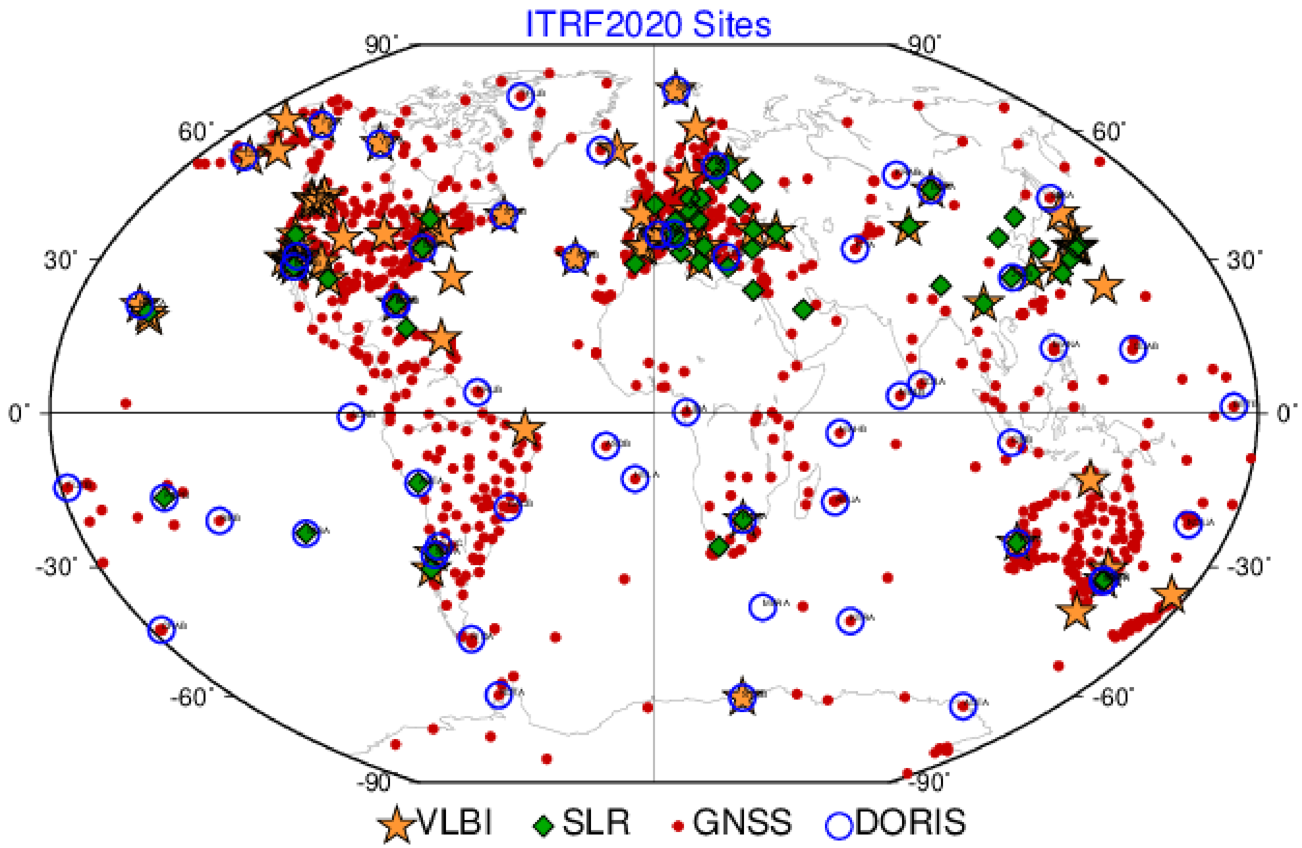


ITRF2020 Network

- 1223 sites
  - 878 Northern hemisphere
  - 355 Southern hemisphere
- 1800 stations
- 3106 discontinuities
- ~1159 GNSS sites
  - 1344 stations
  - 2938 discontinuities

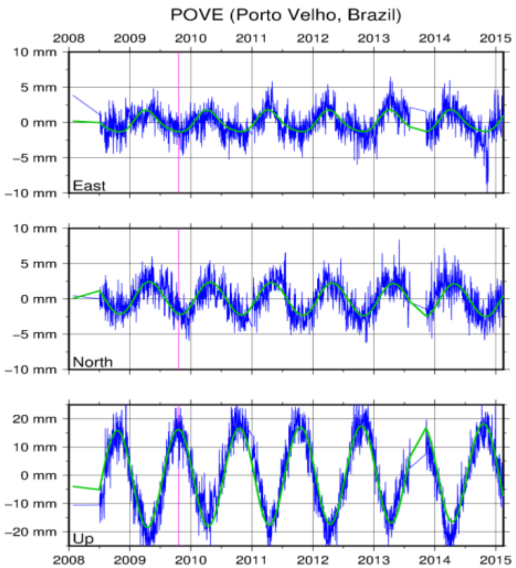


Trajectory: Blue: Raw, Green: Linear, Red: PSD model
Vertical gray lines represent discontinuities



ITRF2020: Modelling nonlinear station motions

Impact of Periodic Signals

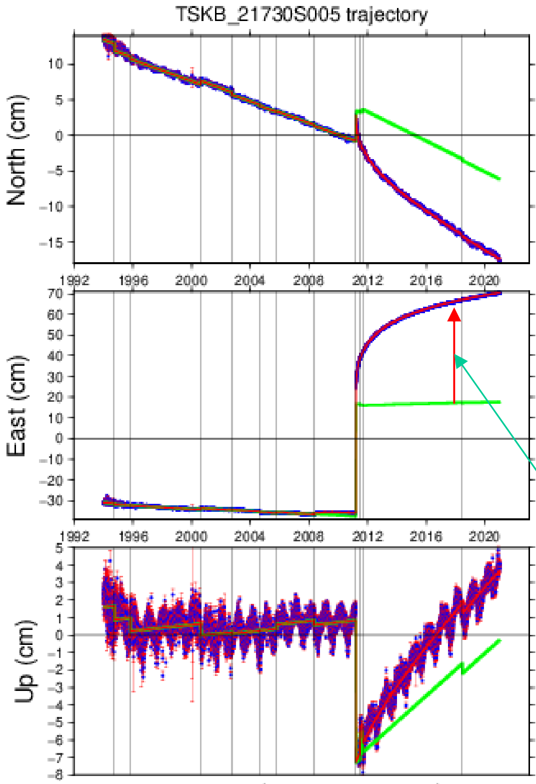


Sine wave function

$$\Delta X_f(t) = \sum_{j=1}^{n_f} a_j^i \cos(\omega_j t) + b_j^i \sin(\omega_j t)$$

Impact of major earthquakes

Post-Seismic Deformation (PSD)



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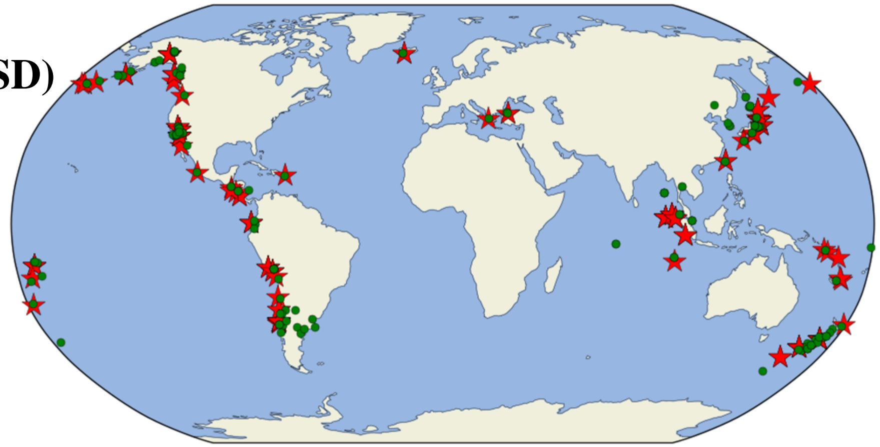


Red Stars: EQ Epicenters (65)
Green circles: ITRF2020 sites (118)

Refined PSD Parametric models:

1. Logarithmic Function
2. Exponential Function
3. Logarithmic + Exponential
4. Two Exponential Functions
5. Two Logarithmic Functions

$$\delta L(t) = \sum_{i=1}^{n^l} A_i^l \log\left(1 + \frac{t - t_i^l}{\tau_i^l}\right) + \sum_{i=1}^{n^e} A_i^e \left(1 - e^{-\frac{t - t_i^e}{\tau_i^e}}\right)$$

ITRF2020 New Analysis Strategy

Input data:

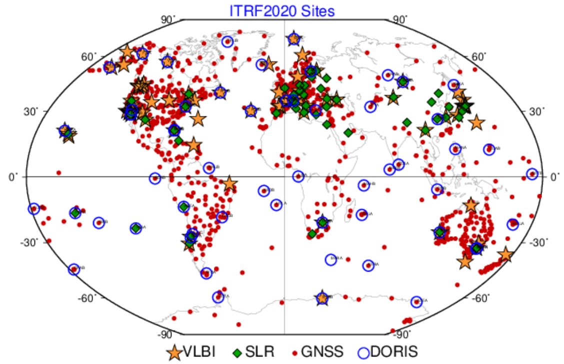
- Space geodesy time series
  - DORIS/IDS weekly
  - GNSS/IGS daily
  - SLR/ILRS weekly
  - VLBI/IVS: Session-wise
- Local ties: 253 vectors
- Co-motion constraints at colocation sites:
  - Station velocities & seasonal signals

Data analysis:

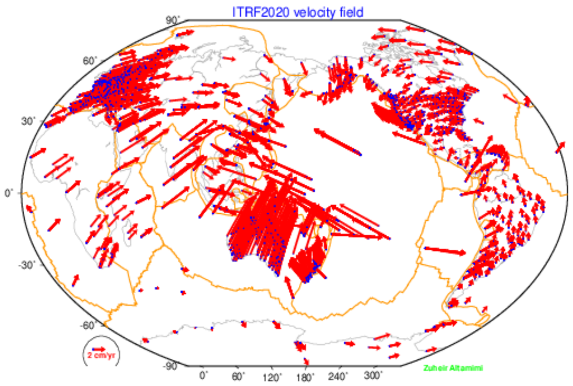
- Time series analysis & stacking of individual techniques
- Assign discontinuities
- Determine PSD Parametric Models using GNSS data
- Estimate and remove the first 8 GPS draconitic harmonics
- Accumulate the full 4 technique time series all together, adding local ties and co-motion constraints

Output:

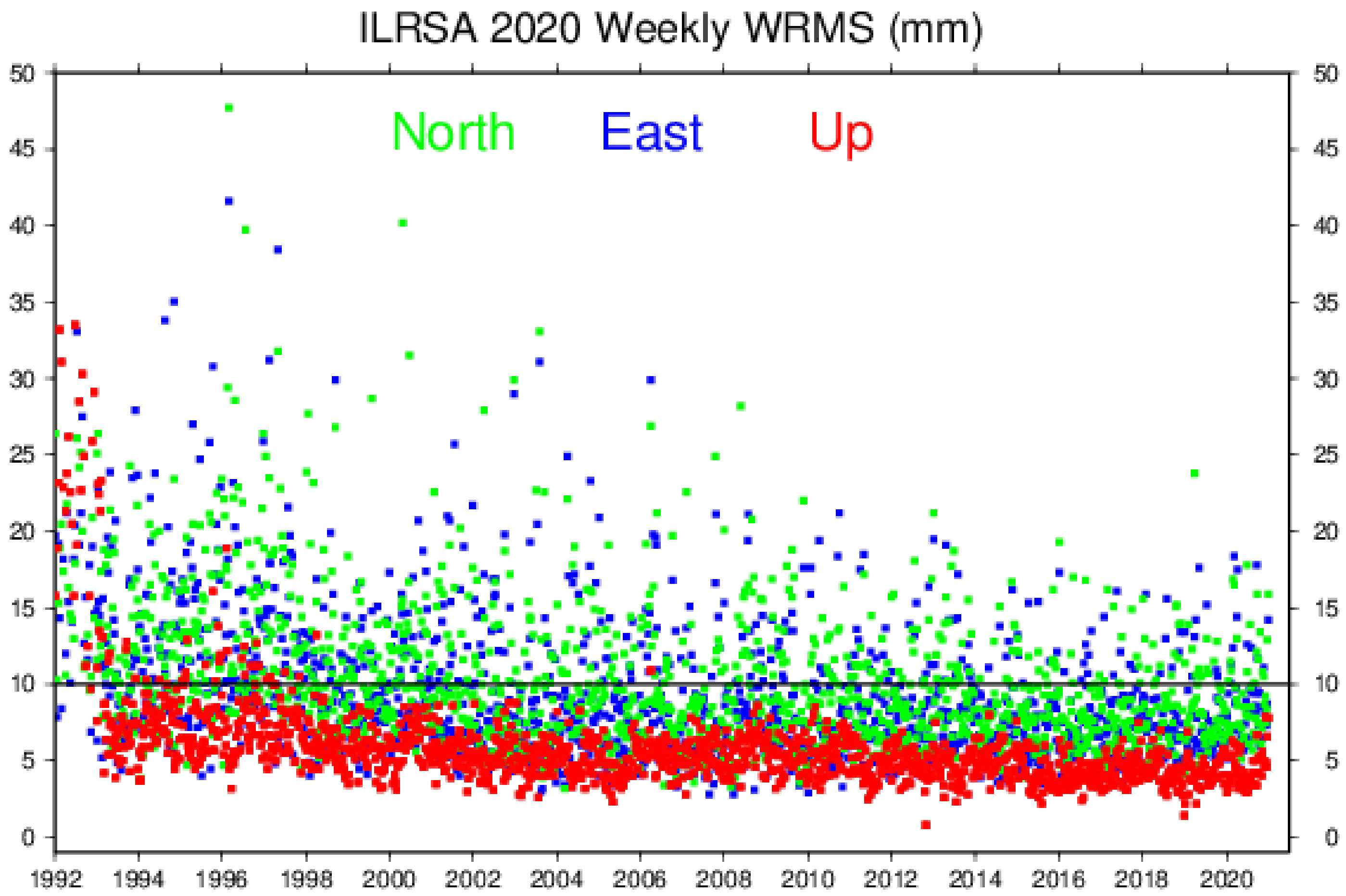
- Station positions & velocities
- EOPs
- PSD models
- Seasonal Signals (annual & semi-annual) expressed in the CM of SLR



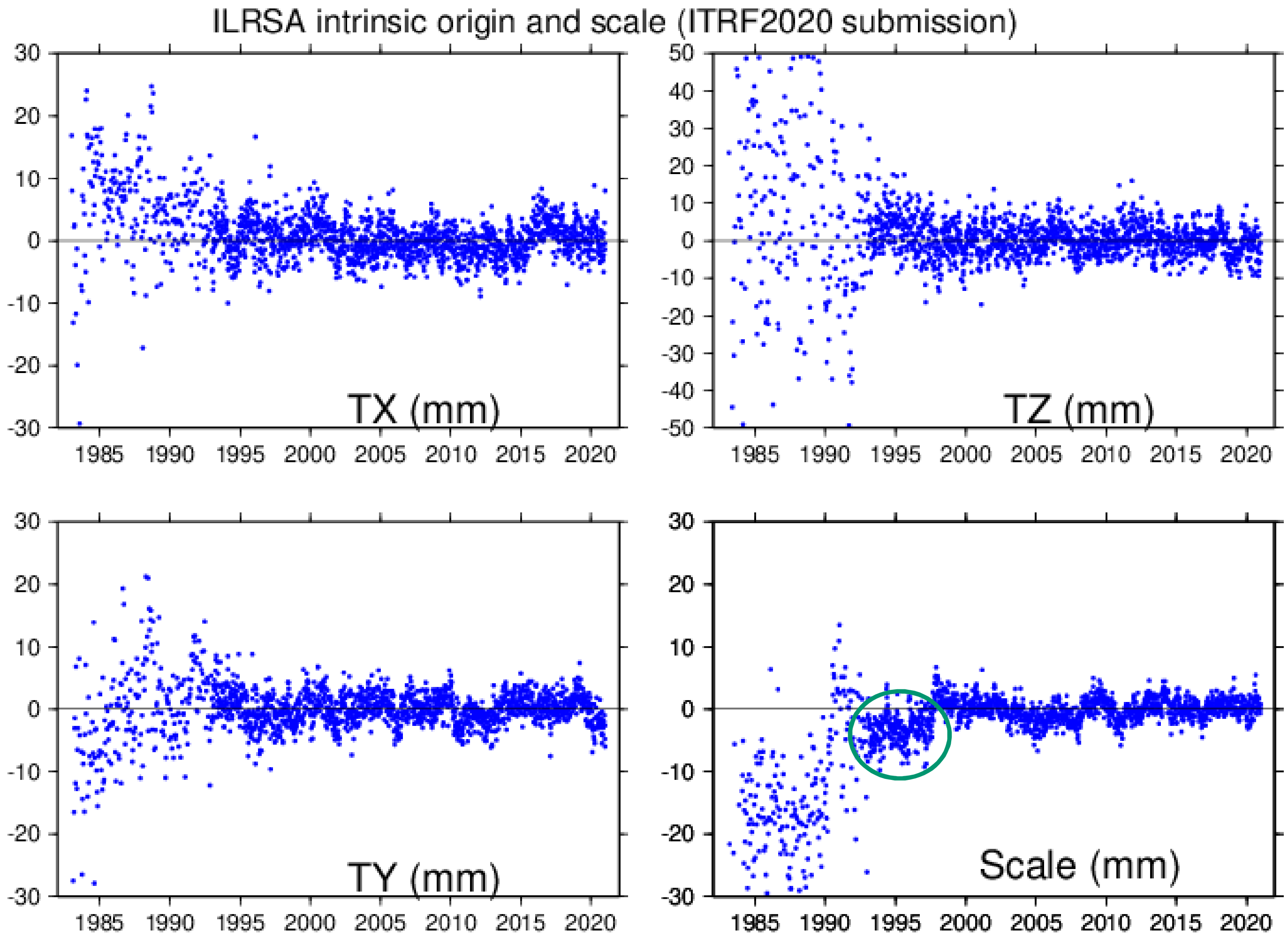
ITRF2020 Specifications:
Origin: SLR
Scale: Average of SLR & VLBI
Orientation: Alignment to ITRF2014



ILRSA 2020 WRMS

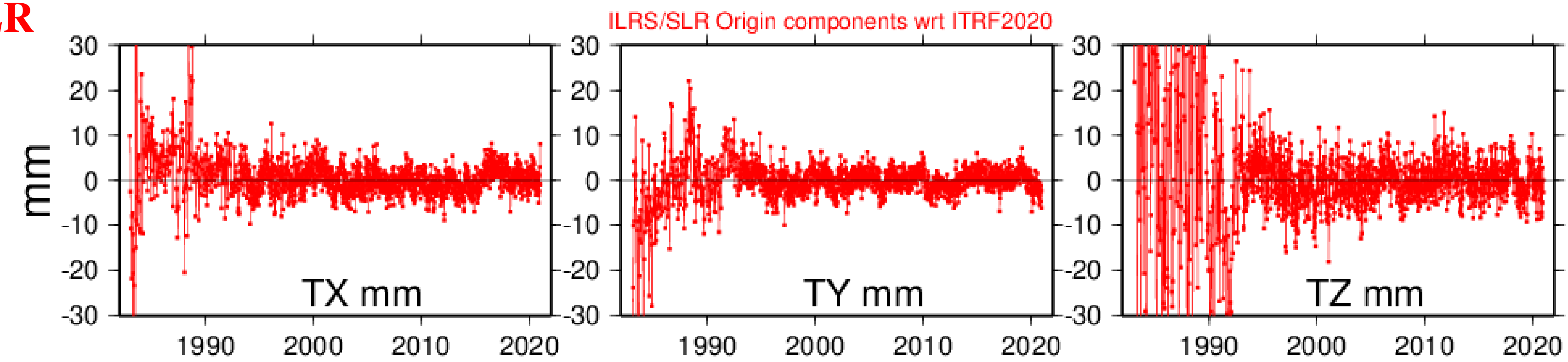


ILRS 2020 intrinsic origin & scale

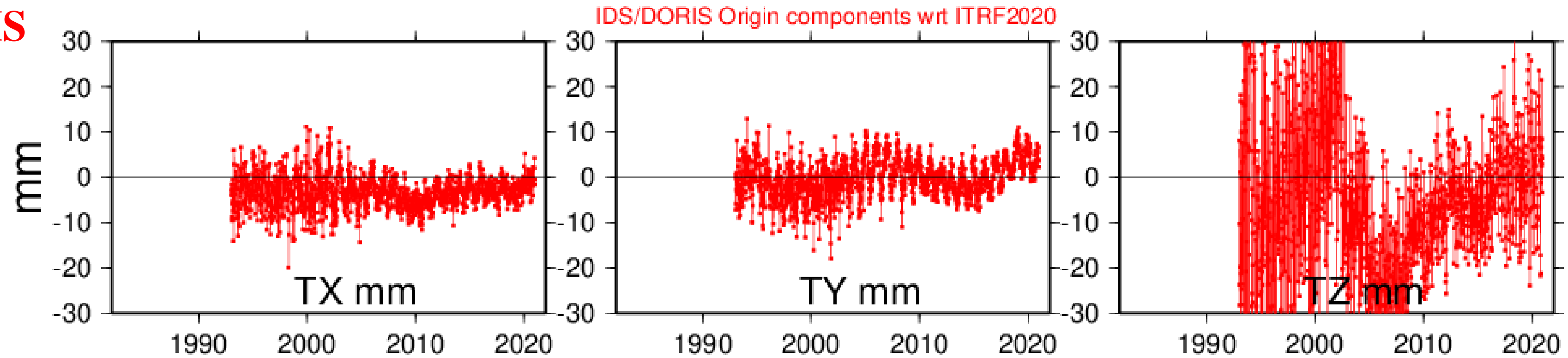


ITRF2020 Origin: Inherited from SLR long-term CM origin

ILRS-SLR

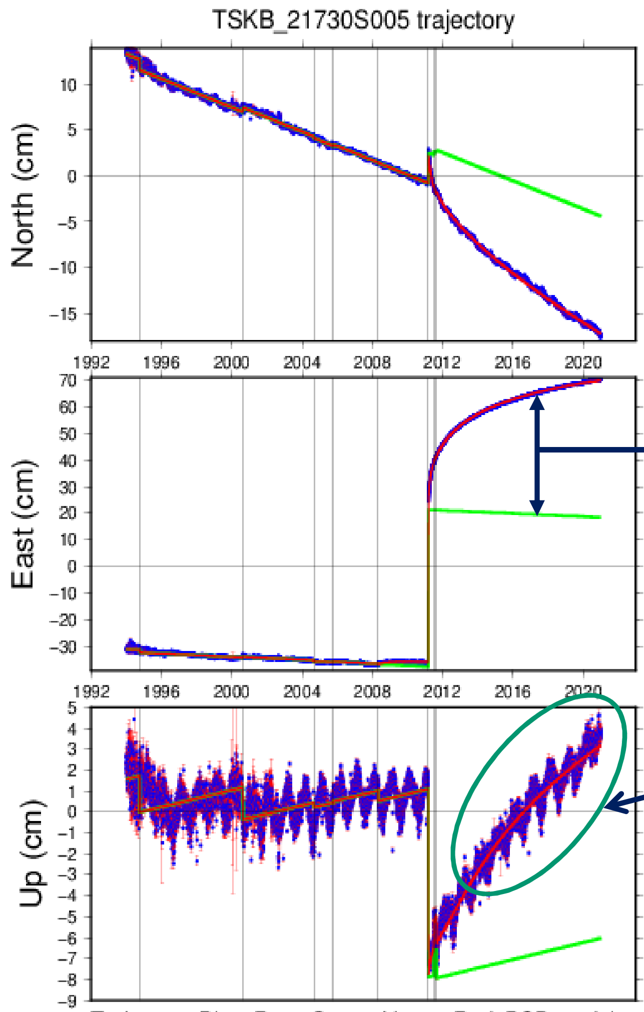


IDS-DORIS



GNSS frame origin is not reliable

ITRF2020: Augmented Parametric Reference Frame



Trajectory: Blue: Raw, Green: Linear, Red: PSD model
Vertical gray lines represent discontinuities

ITRF2020 Kinematic Model:

$$X(t) = \underbrace{X(t_0) + \dot{X}.(t - t_0)}_{\text{Linear part}} + \underbrace{\delta X_{PSD}(t) + \delta X_f(t)}_{\text{Nonlinear part}}$$

∑ Post-Seismic Deformations (PSD)
Refined Parametric models

∑ Seasonal Signals, expressed in the CM-SLR frame

Station seasonal signals, geocenter motion and the reference frame definition

$$\boldsymbol{X(t) = X(t_0) + \dot{X}.(t - t_0) + \delta X_{PSD}(t) + \delta X_f(t)}$$

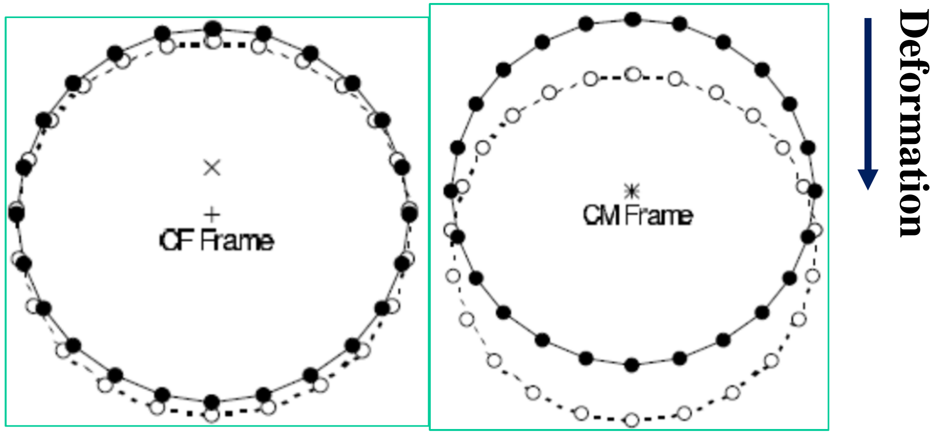
$$\delta X_f(t) = \sum_{i=1}^{2} \begin{pmatrix} a_x^i \\ a_y^i \\ a_z^i \end{pmatrix} \cos(2i\pi \cdot t) + \begin{pmatrix} b_x^i \\ b_y^i \\ b_z^i \end{pmatrix} \sin(2i\pi \cdot t)$$

- δX_f **:** ***a*** **&** ***b*** **are estimated in SLR CM-frame**

$$\boldsymbol{X_{CM(t)} = X_{CF}(t) + \Delta X_G(t)}$$ **(Geocenter motion)**

CM : Center of Mass Frame

CF : Center of Figure Frame



(Blewitt, 2003)

Usage of ITRF2020 Seasonal Signals

The ITRF2020 kinematic model:

$$\boldsymbol{X(t) = X(t_0) + \dot{X}.(t - t_0) + \delta X_{PSD}(t) + \delta X_f(t)}$$

<u>Precise Orbit Determination</u> : Use CM-based seasonal signals

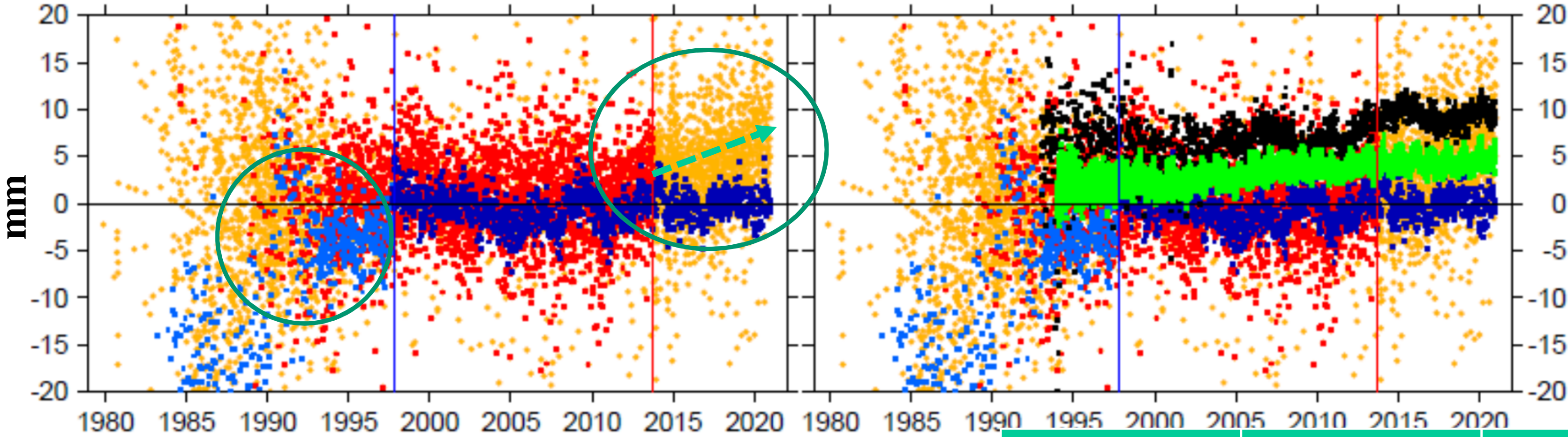
<u>Alignment of global solutions</u>: Use either CM or CF seasonal signals

==> (1) Avoid aliasing the seasonal signals into the Helmert parameters &
(2) Seasonal signals will accurately be retained in the aligned solutions

1. **If CM: translational motion common to all stations (i.e., seasonal geocenter motion) will be transferred to the aligned solutions**
2. **If CF: the aligned solutions will be free from seasonal geocenter motion**

<u>Alignment of local or regional solutions</u>: No seasonal signals to be used in order to avoid seasonal common mode in the aligned solutions

Scales with respect to ITRF2020



- Orange: all VLBI Sessions
- Red: Selected VLBI Sessions (convex hull volume ≥ 10^{19} m^3)
- Light blue: all SLR time series
- Dark blue: Selected SLR time series
- Green: IGS/Repro3
- Black: DORIS

ITRF2020 scale: Average of red (VLBI) and dark blue (SLR)

Scale offset between SLR & VLBI is 0.15 ppb
(1 mm at the equator)

Solution	Scale at 2015.0 (ppb)	Scale rate ppb/yr
IGS/GNSS	0.682 ±0.018	0.018 ±0.001
IVS/VLBI	0.075 ±0.040	0.000 ±0.003
ILRS/SLR	-0.075 ±0.038	0.000 ±0.004
IDS/DORIS	1.386 ±0.037	0.028 ±0.003

Summary of ILRS Key Contribution to the ITRF2020

- Long-term origin of the ITRF2020
- Access to the instantaneous CM ==> Origin of the ITRF2020 Seasonal Signal
- Transfer of an accurate geocenter motion to the 3 other techniques
- Contribute to the scale definition

Conclusion

ITRF2020

- A step further in improving the ITRF determination
- Adequately modelling nonlinear station motions : PSD & Seasonal Signals
- For the first time in the ITRF history, the scale agreement between SLR & VLBI is at the level of 0.15 ppb (1 mm at the equator)
- Some nonlinearities in the scale time series still exist for SLR, VLBI and DORIS

Thank you