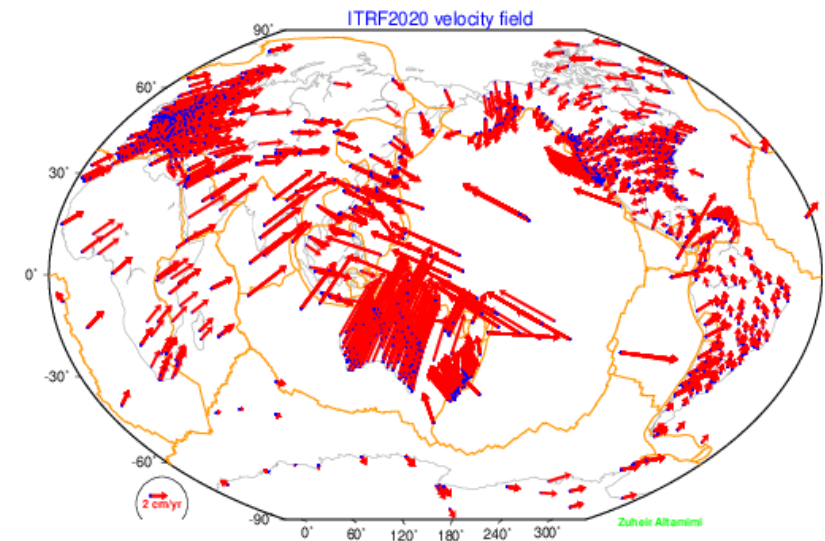


# ITRF2020 and the IDS Contribution

Zuheir Altamimi, Paul Rebischung, Xavier Collilieux, Laurent Métivier, Kristel Chanard  
IGN-IPGP, France

## Key Points:

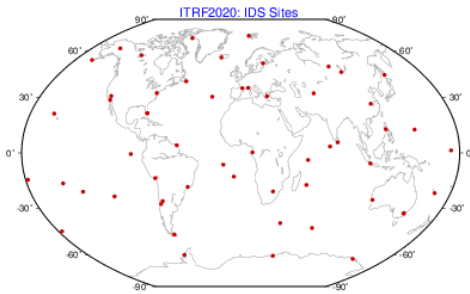
- **ITRF2020 and its innovations: modelling of nonlinear station motions**
- **IDS Contribution**
  - **Quality (WRMS)**
  - **TRF parameters (origin & scale)**
- **Usage of ITRF2020 kinematic model**



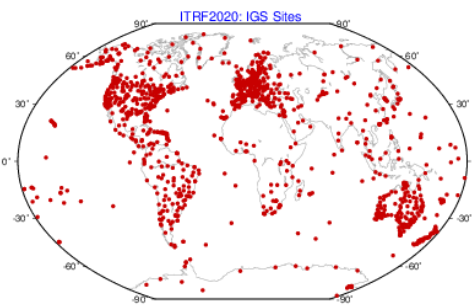
# ITRF2020 Input Data

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

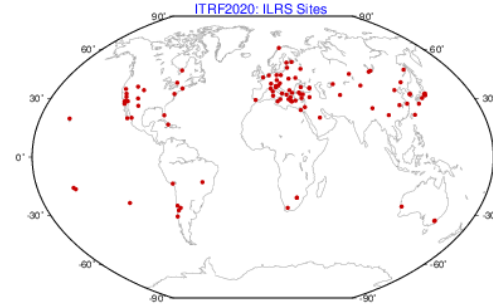
IDS/DORIS



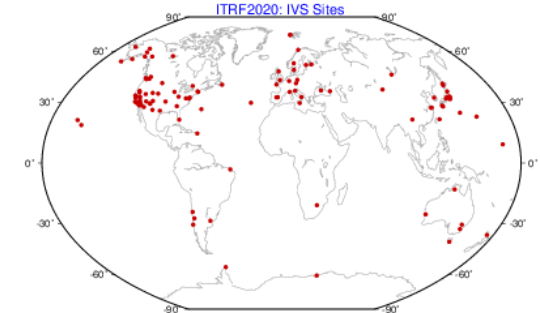
IGS/GNSS



ILRS/SLR

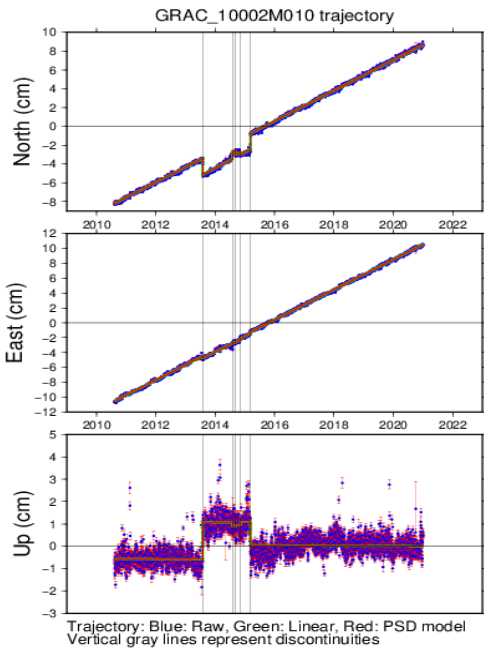


IVS/VLBI

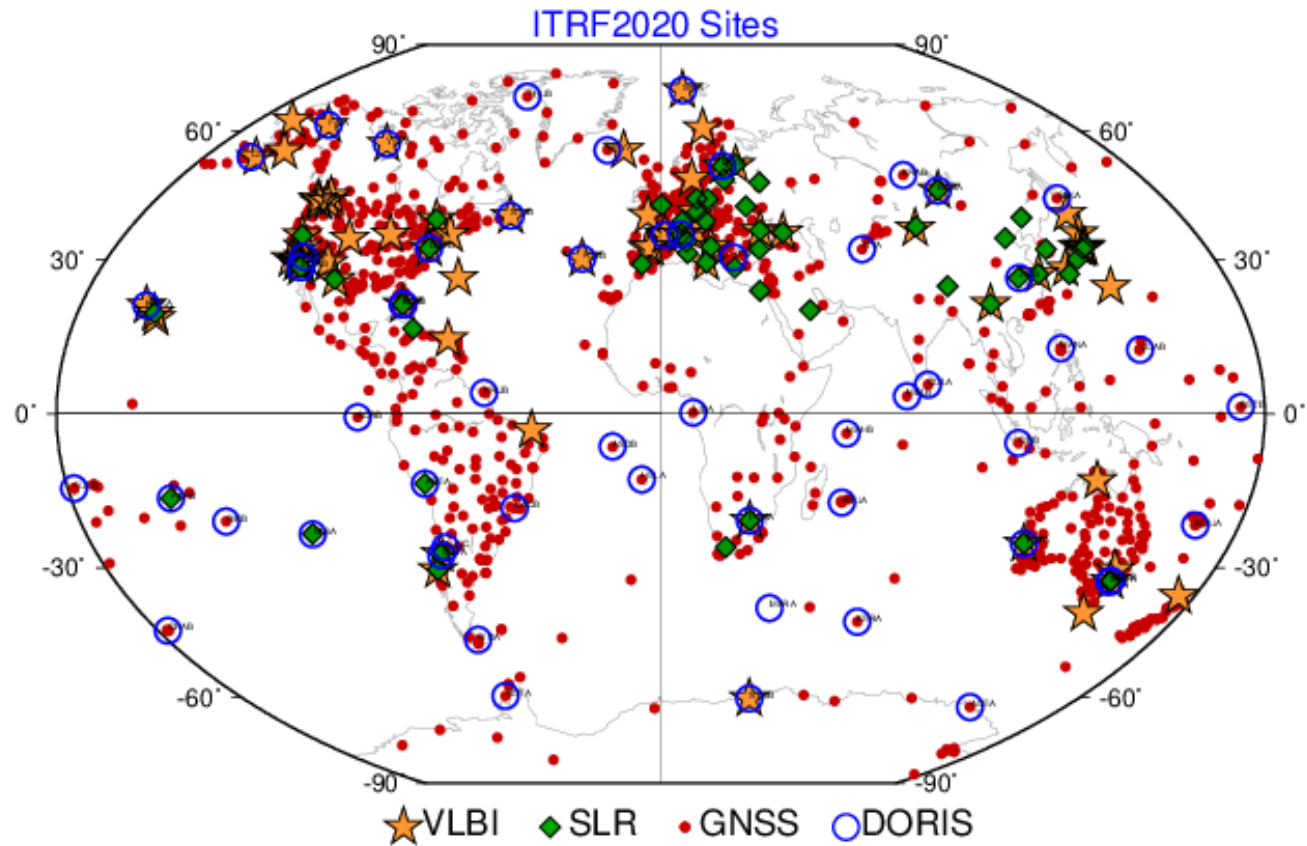


# ITRF2020 Network

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

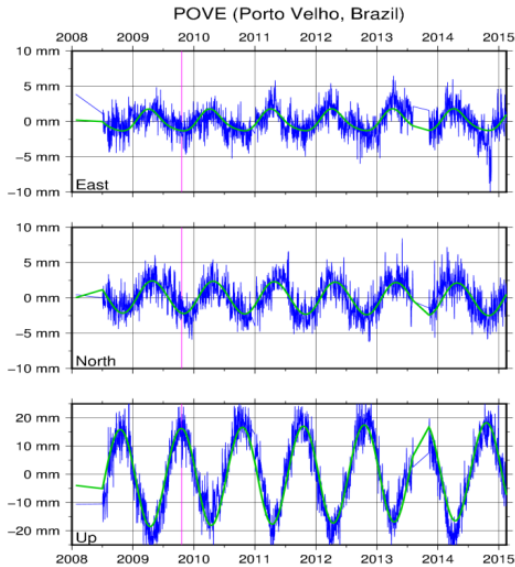


Trajectory: Blue: Raw, Green: Linear, Red: PSD model  
Vertical gray lines represent discontinuities



# ITRF2020: Modelling nonlinear station motions

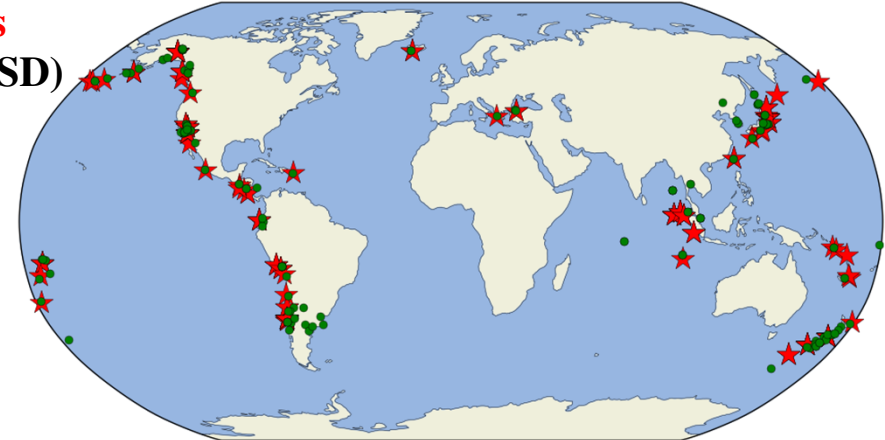
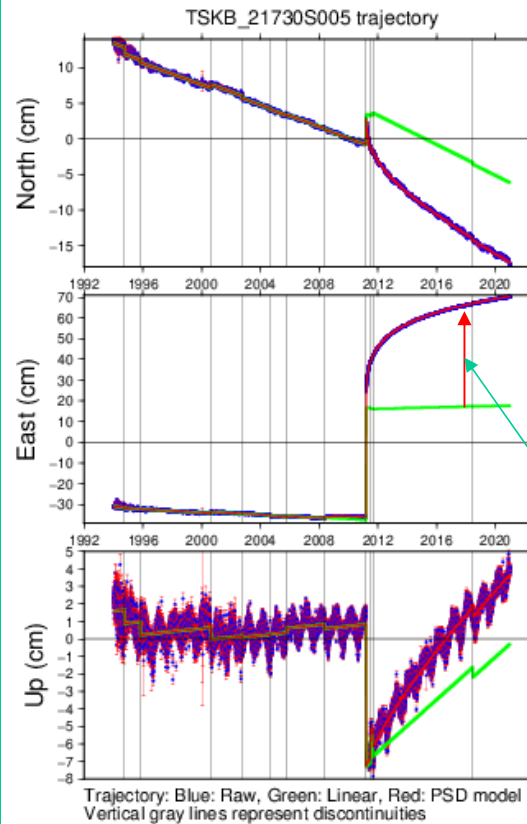
## Impact of Periodic Signals



## 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)



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:

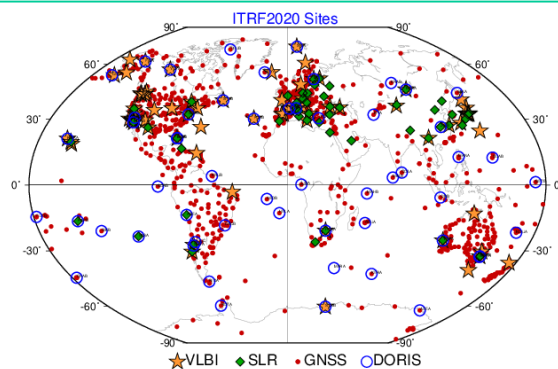
- **Space geodesy time series**
  - DORIS/IDS weekly
  - GNSS/IGS daily
  - SLR/ILRS weekly
  - VLBI/IVS: Session-wise
- **Local ties: 253 vectors**
- **Co-motion constraints at colocation sites:**
  - Station velocities & seasonal signals

## 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**

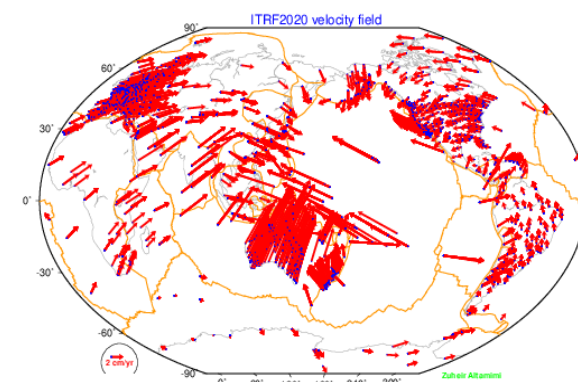


## ITRF2020 Specifications:

**Origin:** SLR

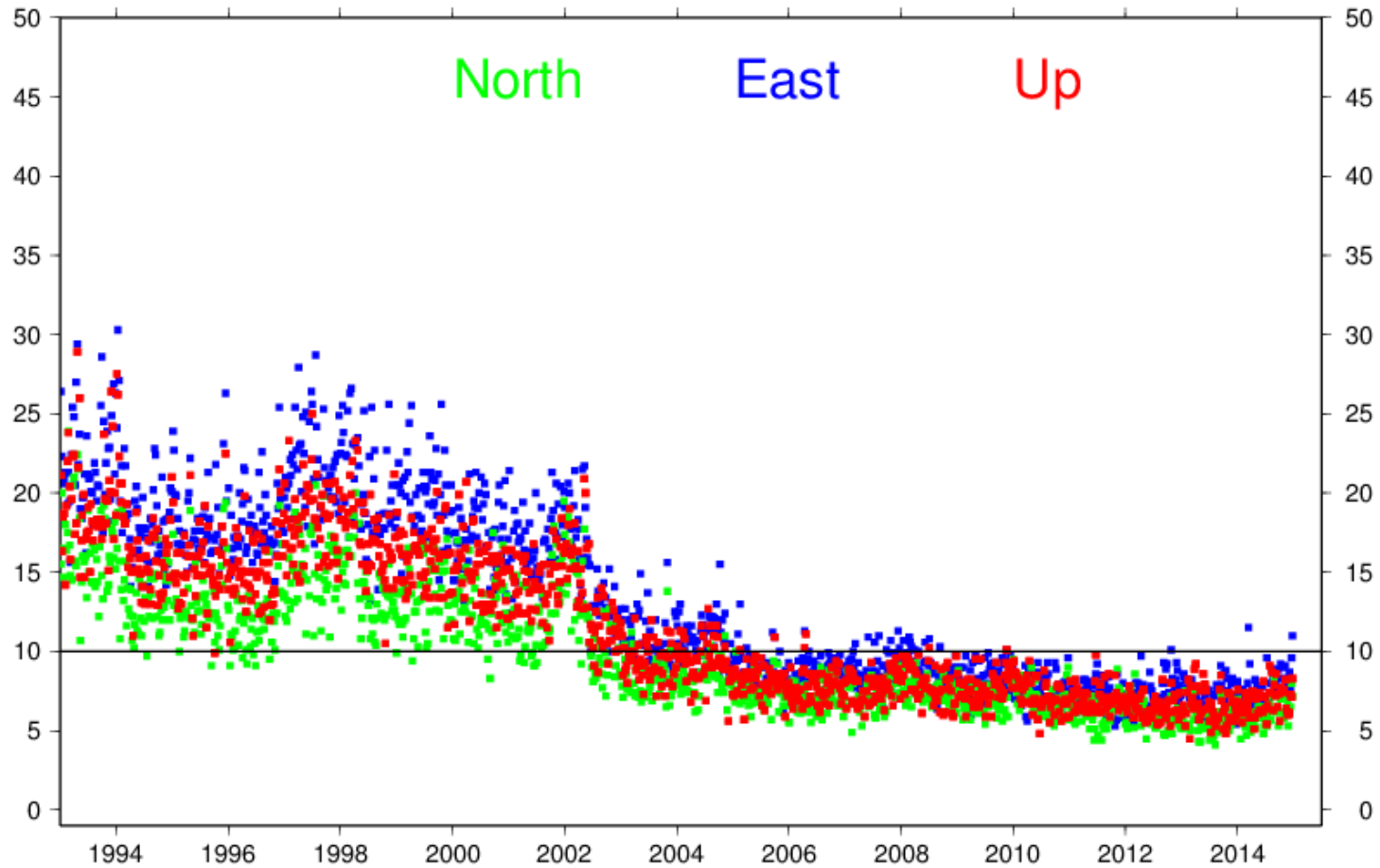
**Scale:** Average of SLR & VLBI

**Orientation:** Alignment to ITRF2014



# IDS 2014 WRMS

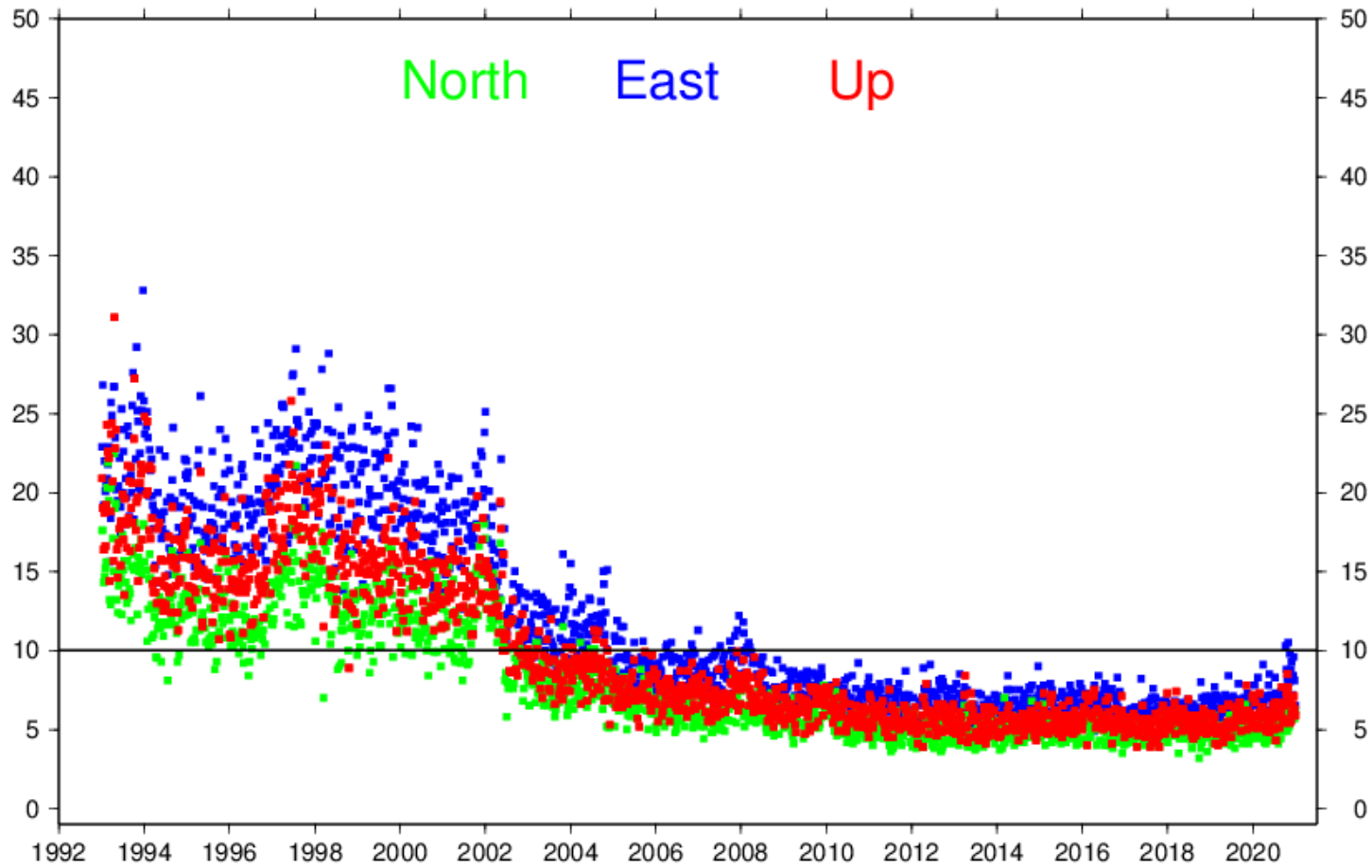
IDS/DORIS Weekly WRMS (mm)





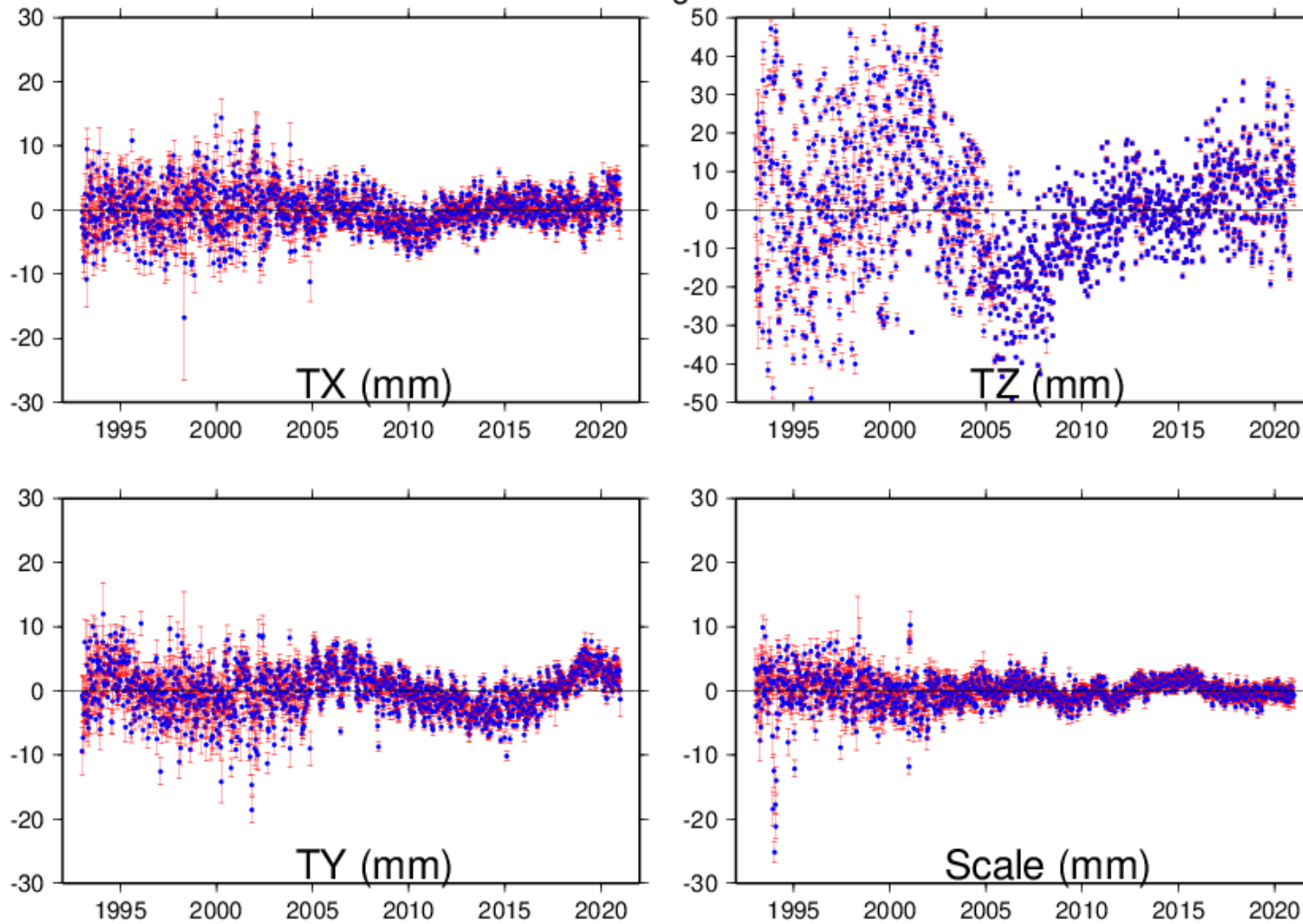
# IDS 2020 WRMS

IDS 2020 Weekly WRMS (mm)



# IDS 2020 intrinsic origin & scale

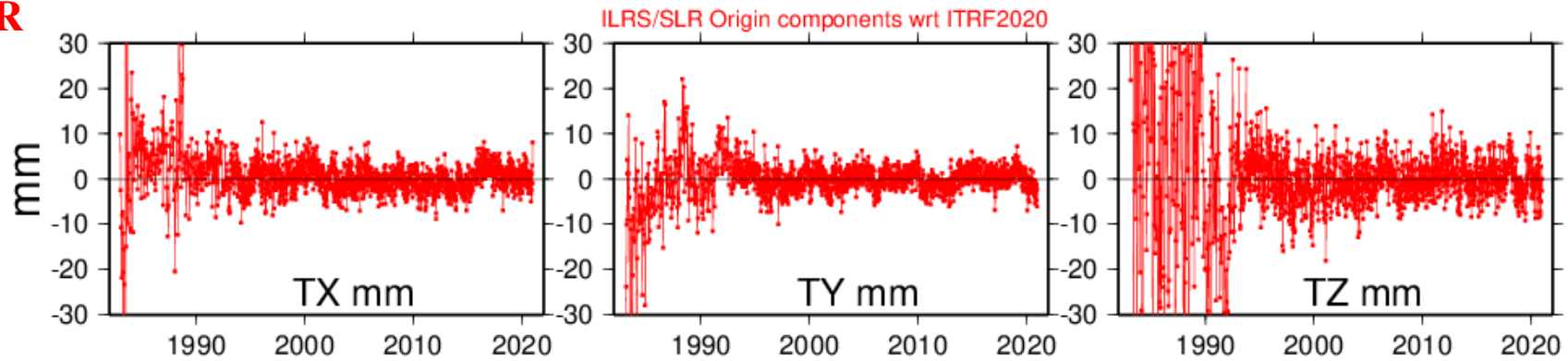
DORIS/IDS WD16 intrinsic origin and scale time series



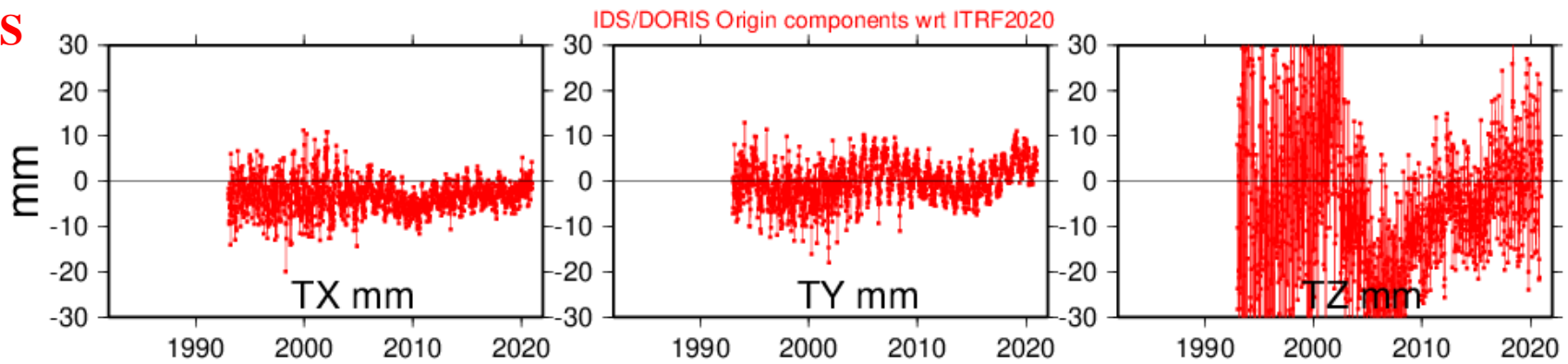


# ITRF2020 Origin: Inherited from SLR long-term CM origin

ILRS-SLR



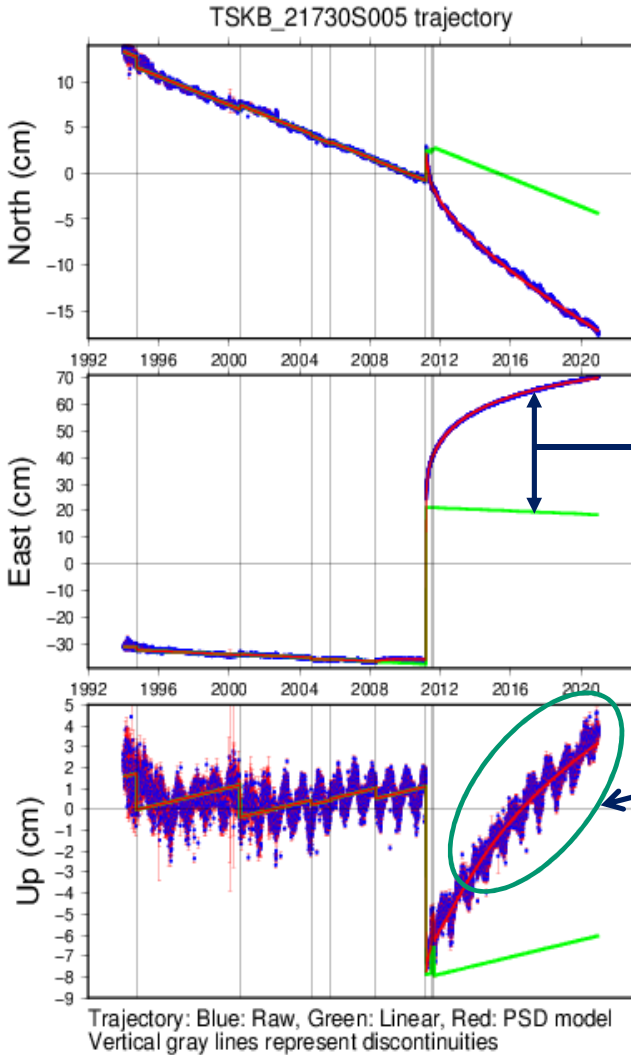
IDS-DORIS



**GNSS frame origin is not reliable**

# ITRF2020: Augmented Parametric Reference Frame

## ITRF2020 Kinematic Model:



Linear part

Nonlinear part

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

$\Sigma$  Post-Seismic Deformations (PSD)  
Refined Parametric models

$\Sigma$  Seasonal Signals, expressed in the **CM-SLR** frame

# Station seasonal signals, geocenter motion and the reference frame definition

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

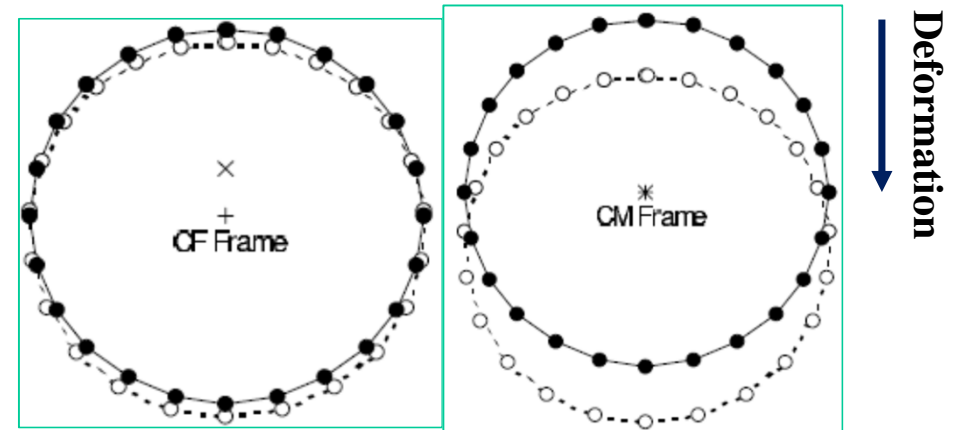
$$\delta X_f(t) = \sum_{i=1}^2 \begin{pmatrix} a_x^i \\ a_y^i \\ a_z^i \end{pmatrix} \cos(2i\pi \cdot t) + \begin{pmatrix} b_x^i \\ b_y^i \\ b_z^i \end{pmatrix} \sin(2i\pi \cdot t)$$

- $\delta X_f$  :  $a$  &  $b$  are estimated in **SLR CM-frame**

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

CM : Center of Mass Frame

CF : Center of Figure Frame



(Blewitt, 2003)

# Usage of ITRF2020 Seasonal Signals

The ITRF2020 kinematic model:

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

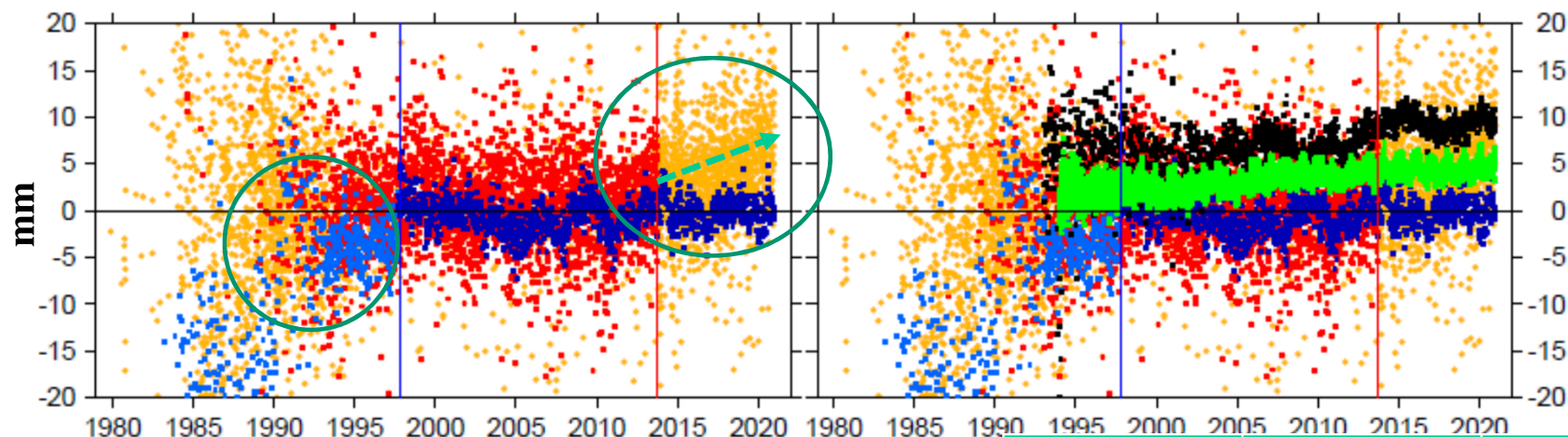
Precise Orbit Determination : Use CM-based seasonal signals

Alignment of global solutions: 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

Alignment of local or regional solutions: 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  $\geq 10^{19} \text{ m}^3$ )
- **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 $\pm 0.018$	0.018 $\pm 0.001$
IVS/VLBI	0.075 $\pm 0.040$	0.000 $\pm 0.003$
ILRS/SLR	-0.075 $\pm 0.038$	0.000 $\pm 0.004$
IDS/DORIS	1.386 $\pm 0.037$	0.028 $\pm 0.003$

# 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**
- **IDS Contribution:**
  - Improved quality, especially the more recent weeks
  - **Non-linearity of IDS origin and scale needs to be investigated**



**Thank you**



Altamimi et al., IDS Workshop, Venice, 31 Oct – 01 Nov, 2022