Status of ITRF and interest of GENESIS-1

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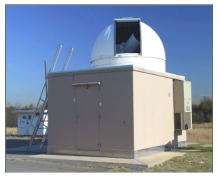
Key points

- Introduction
- Why is the ITRF needed ?
- Uncertainty evaluation of the ITRF solutions
  - Currently operating sites
  - Reference frame definition/specification: origin, scale & orientation
  - Agreement between terrestrial ties and space geodesy estimates at colocation sites
- Future needs to sustain and improve the accuracy of the ITRF
  - Contribution of GENESIS-1 type mission: Expected benefit
- Conclusion & questions for discussion

The International Terrestrial Reference Frame (ITRF): Realization of the International Terrestrial Reference System (ITRS)

- Realized and maintained by ITRS Center of the IERS, hosted by IGN
- Materialized by a set of station positions and velocities (+ parametric models), estimated by combination of VLBI, SLR, GPS and DORIS individual TRF solutions
- Based on Co-location sites

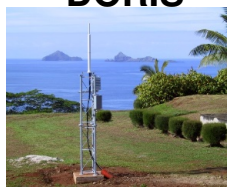
SLR/LLR



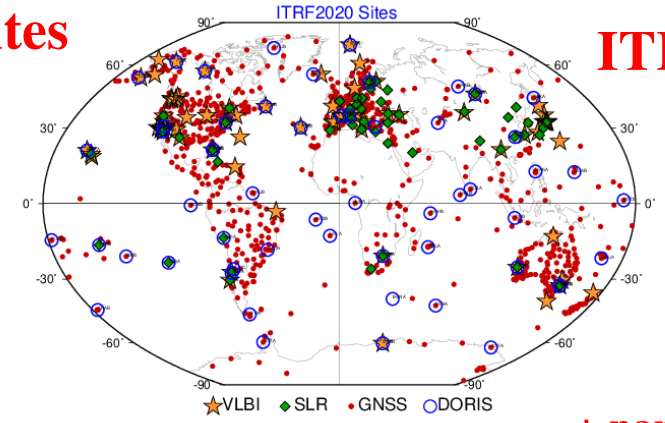
VLBI

GNSS

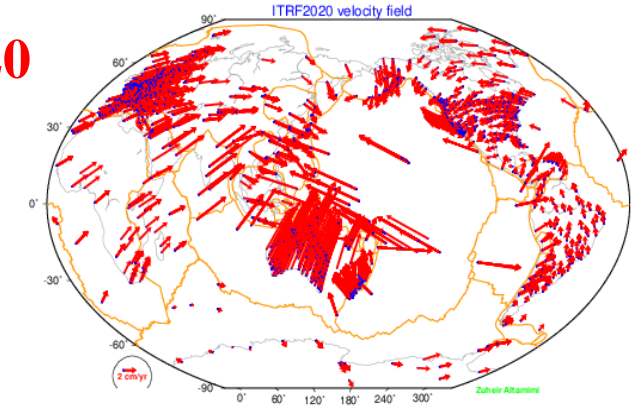
DORIS



http://itrf.ign.fr

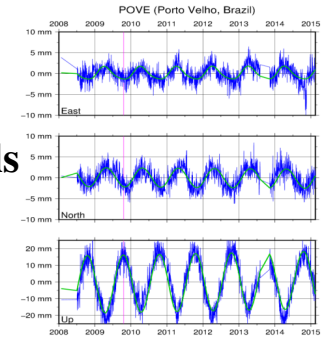


ITRF2020

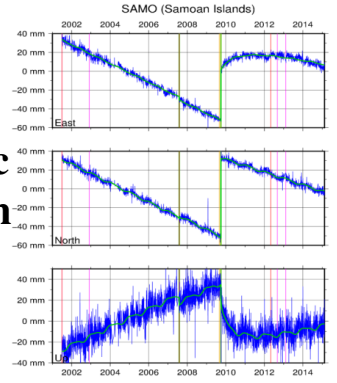


+ parametric models

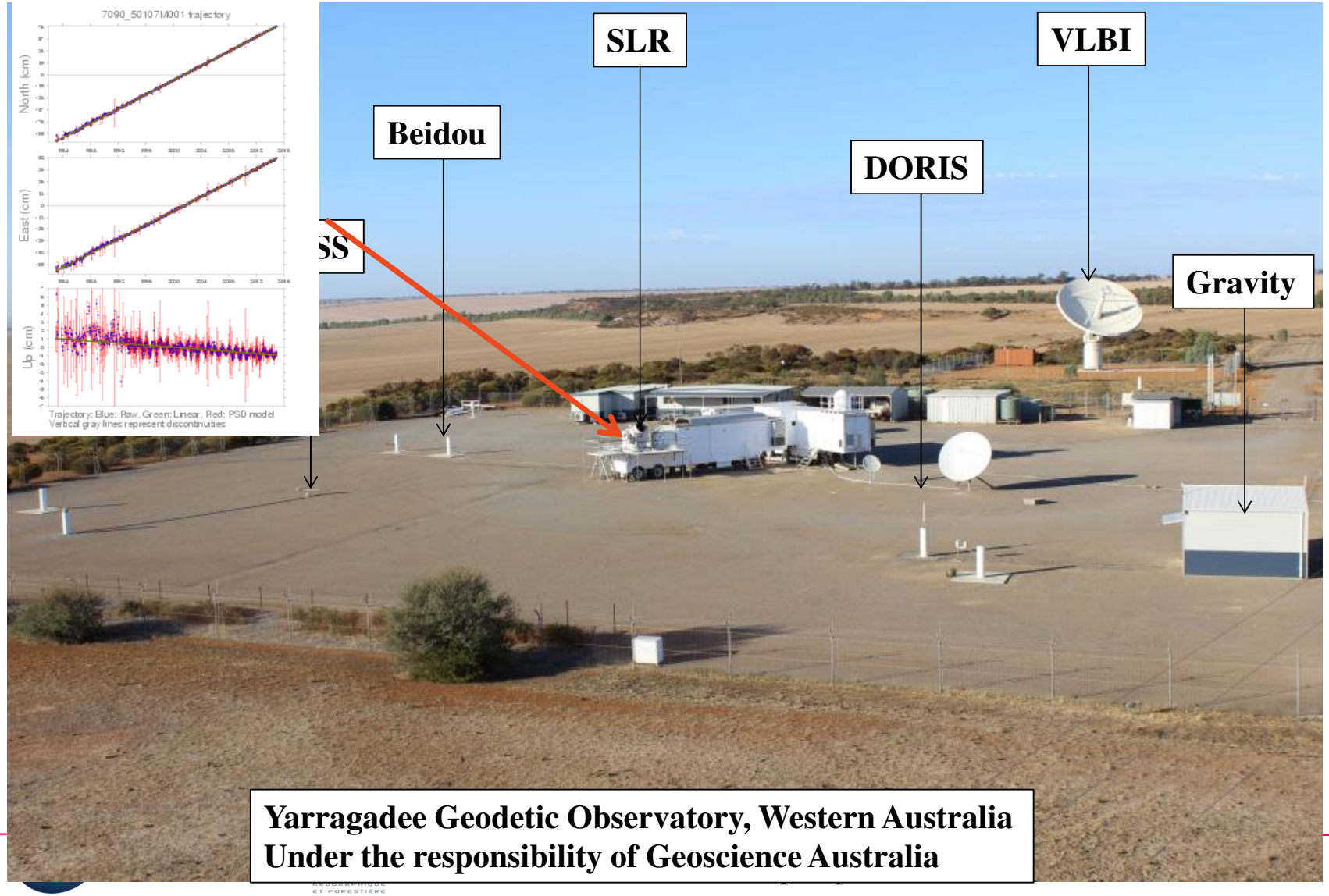
Seasonal signals



Post-seismic deformation



Yarragadee : A famous co-location site



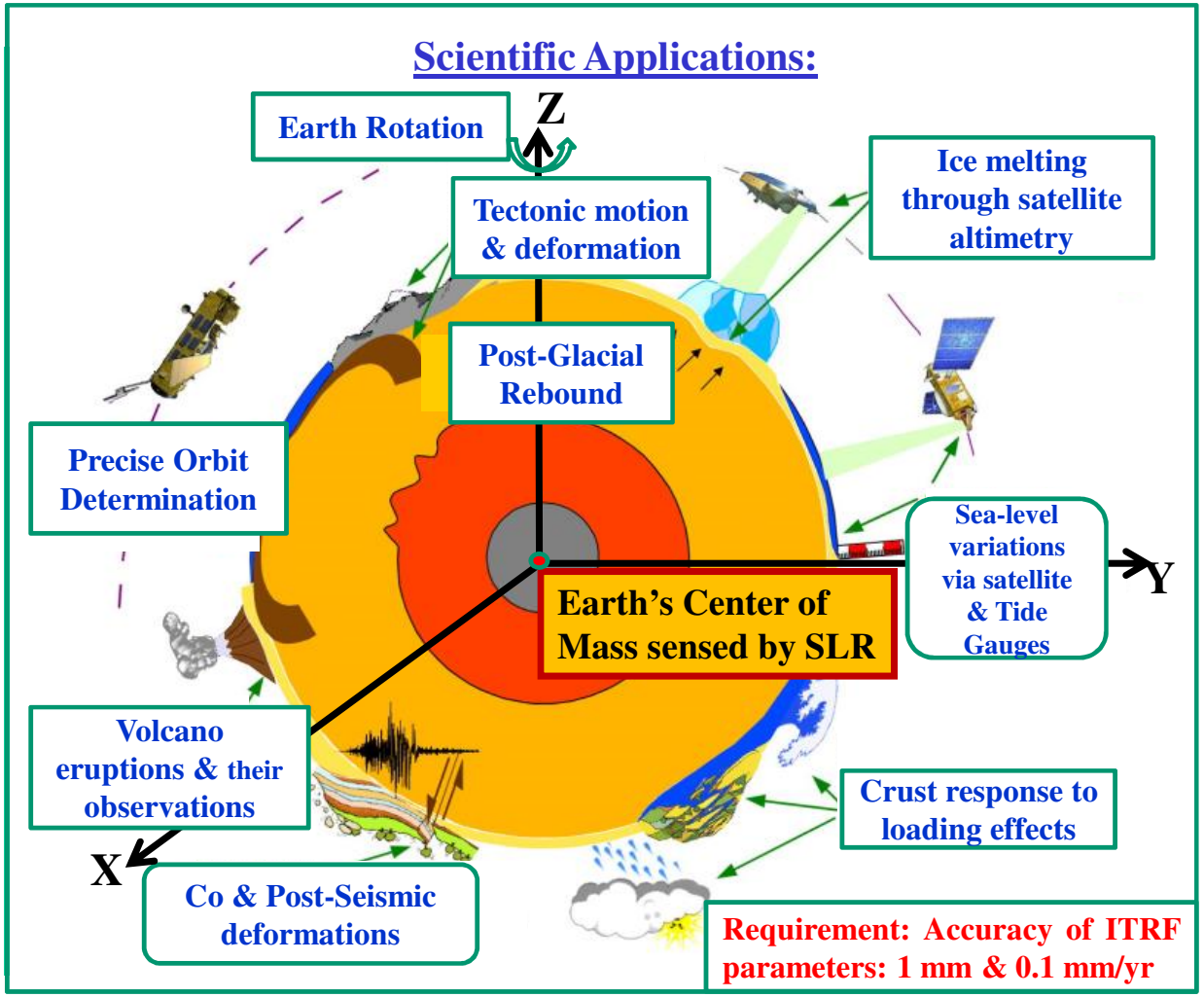
Why is the ITRF needed?

Operational geodesy applications:

- National geodetic systems/frames
- Positioning : Real Time or a posteriori
- Navigation: Aviation, Terrestrial, Maritime
- Today: via GNSS only!
- Require the availability of the orbits and the reference frame (ITRF)
- Many, many users…

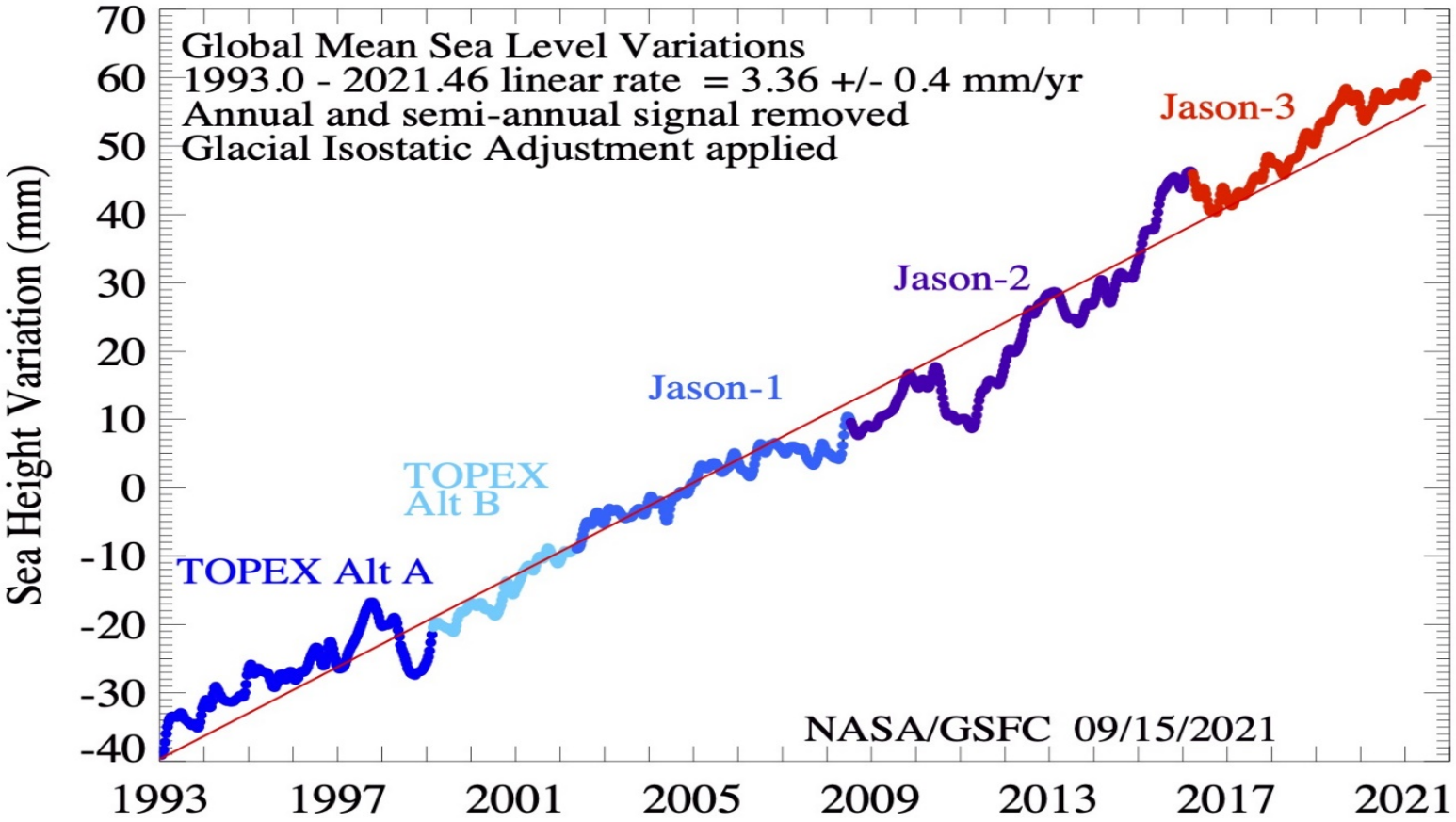
GNSS-specific reference frames:

- GTRF, WGS84, PZ-90, CGCS2000, JGS
- All are aligned to the ITRF



Continuous observations are fundamental

Mean sea level change



A small drift of 1 mm/yr in the ITRF origin, translates into apparent 0.9 mm/yr sea level rise at high latitudes

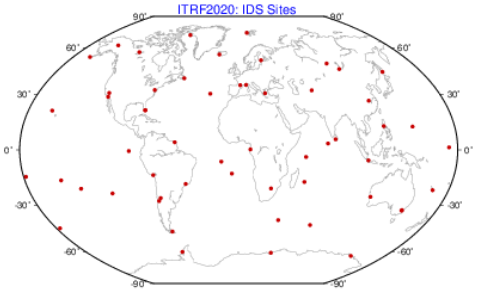
Resolutions on ITRS & ITRF

- **IUGG2007: adopted the ITRS as the preferred Geocentric Terrestrial Reference System (GTRS) for scientific and technical applications**
- **CGPM2011: recommends that the ITRS, as defined by the IUGG and realized by IERS, be adopted as the unique international reference system for terrestrial reference frames for all metrological applications**
- **ICG: recommendation to align GNSS-specific reference frames (WGS84, PZ90, GTRF, CGCS2000, JGS) to the ITRF**
- **IUGG2019: recommend to the user community that the ITRF be the standard for positioning, satellite navigation and Earth Science applications, …**
- **UN-GGIM-2019: adoption of the ITRS and the ITRF as the standard for scientific, geospatial and operational geodetic applications**
- **ISO Standard on ITRS/ITRF**

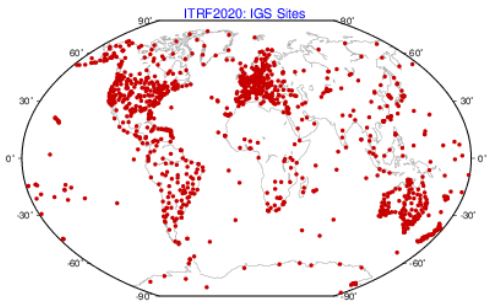
ITRF2020 Input Data

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

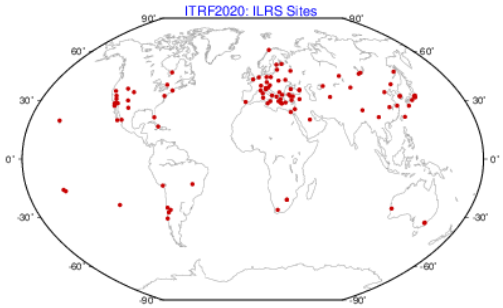
IDS/DORIS



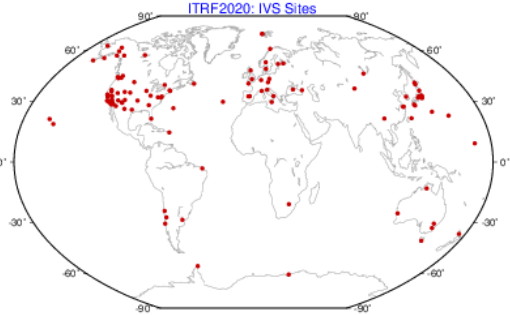
IGS/GNSS



ILRS/SLR

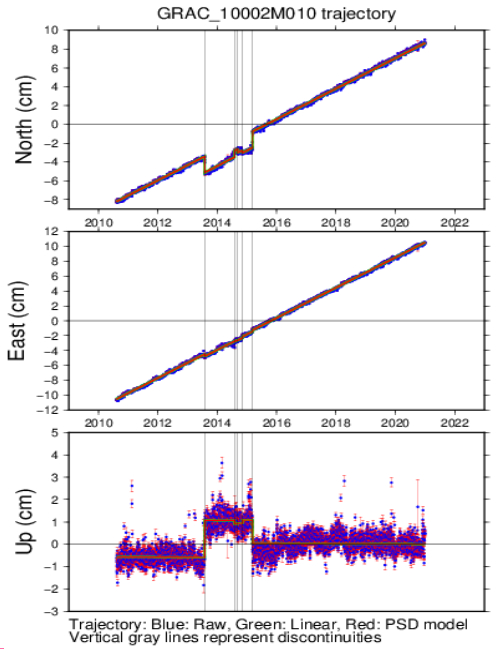


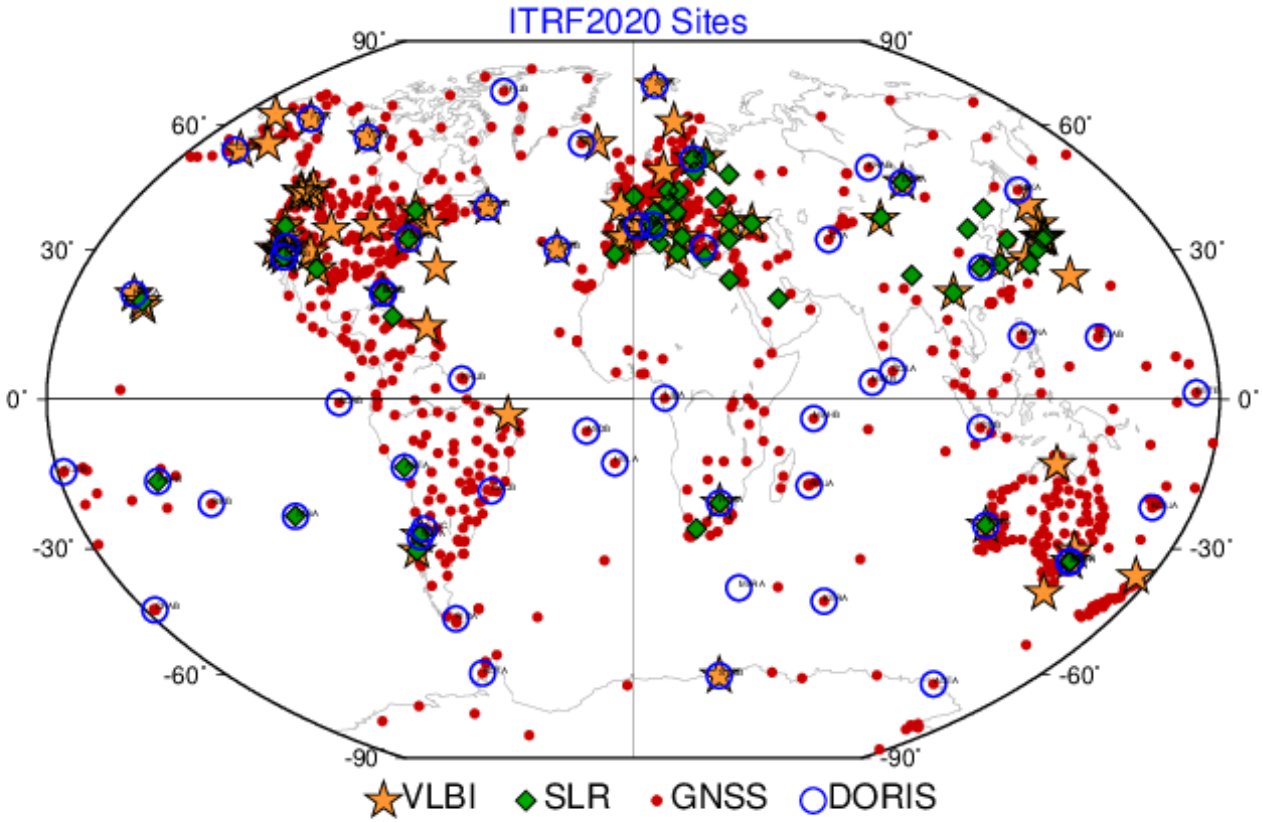
IVS/VLBI



ITRF2020 Network

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





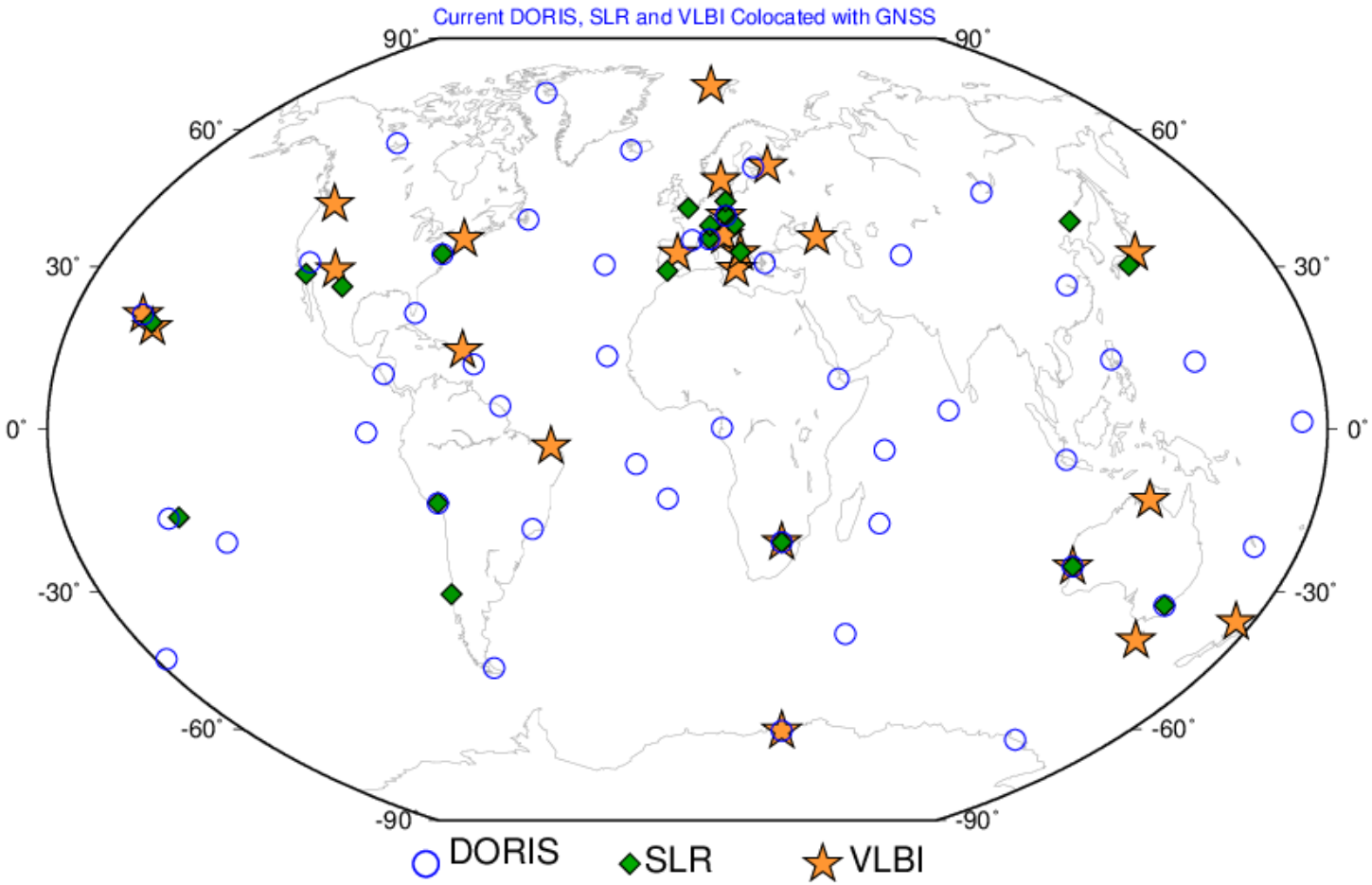
Current ITRF colocations (with GNSS)

DORIS ~46 sites

SLR ~30 sites

VLBI ~44

Ny-Ålesund. Photo: Bjørn-Owe Holmberg



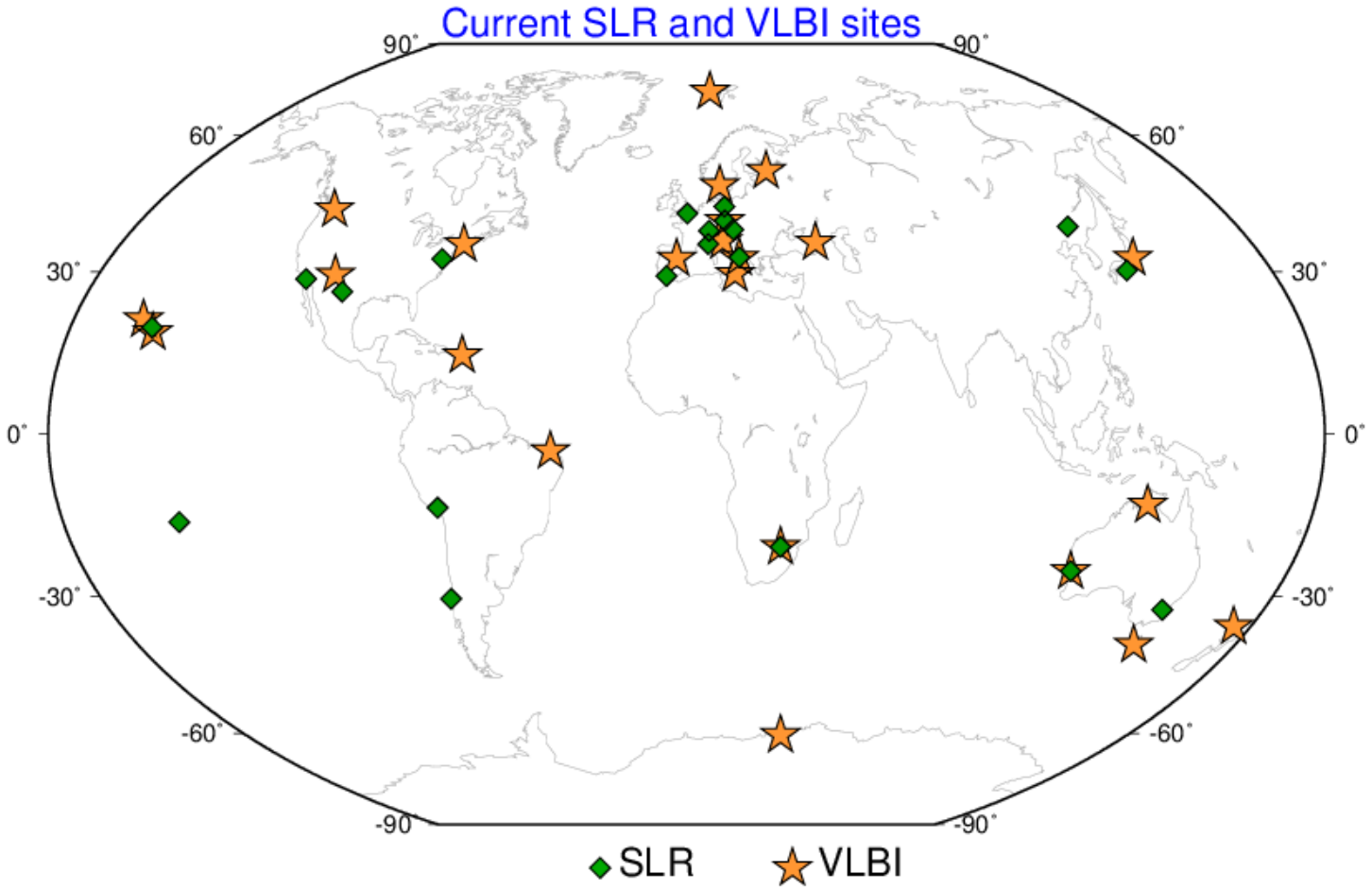
Current ITRF colocations

SLR ~30 sites

VLBI ~44

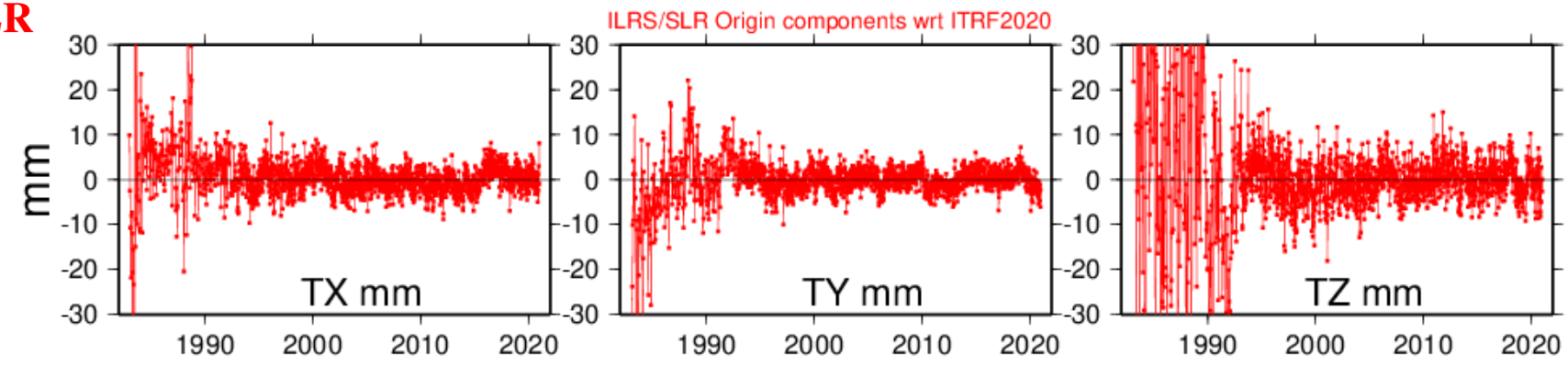
Ny-Ålesund. Photo: Bjørn-Owe Holmberg

- **SLR & VLBI are fundamental**
- **Poor/uneven distribution**
- **> 50 % old-generation systems**

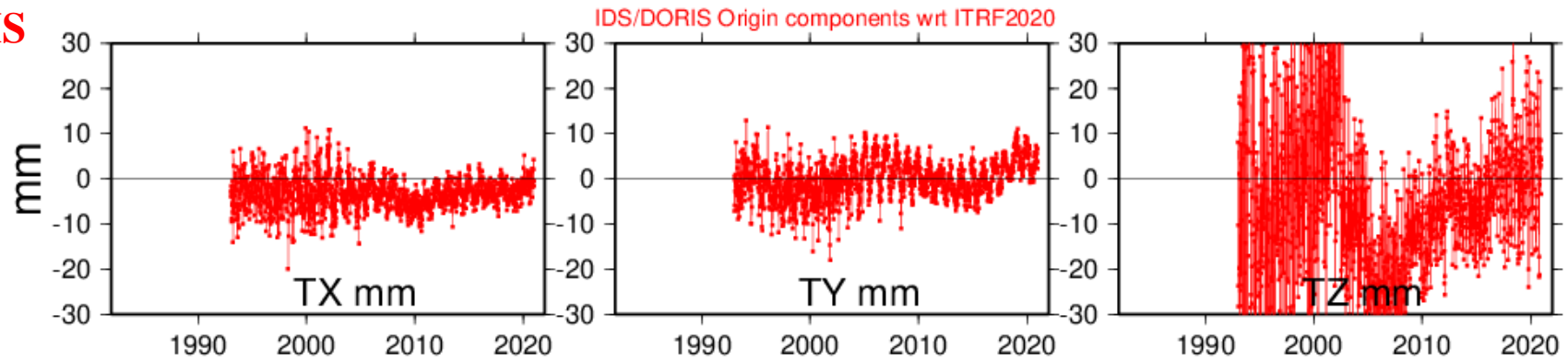


ITRF Origin: Inherited from SLR long-term CM origin

ILRS-SLR



IDS-DORIS

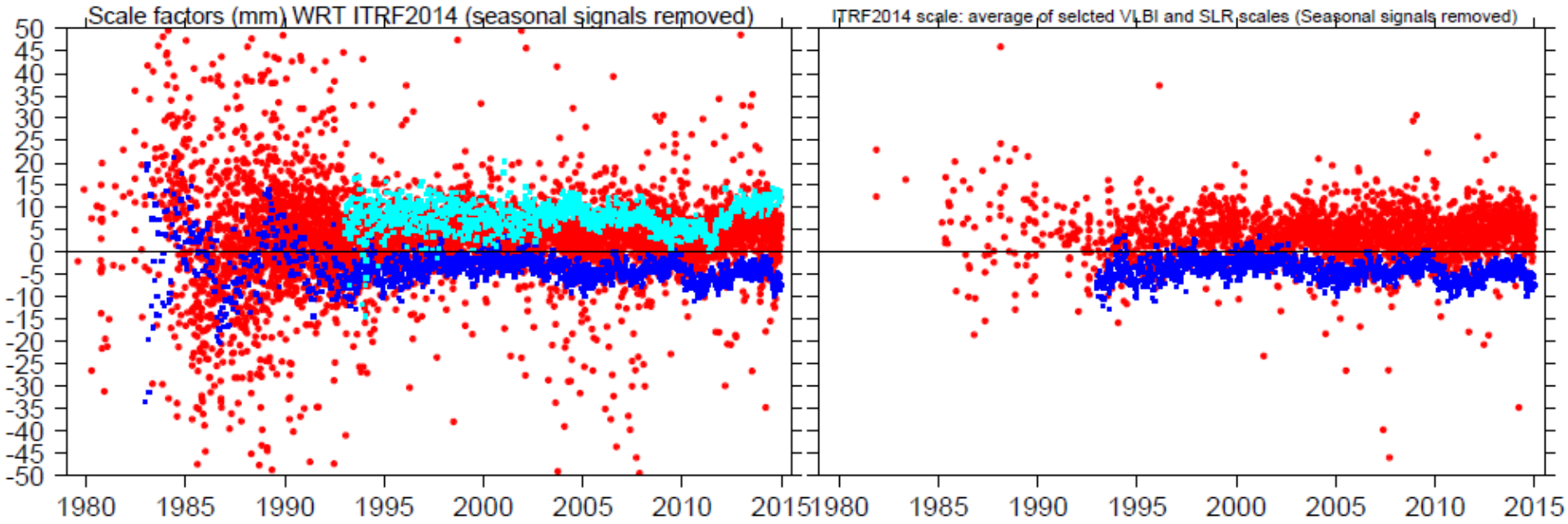


GNSS frame origin is not reliable

DORIS, SLR & VLBI scales wrt ITRF2014

Full time series of scale factors

Scale factors of SLR and VLBI solutions selected to define ITRF2014 scale



DORIS **SLR** **VLBI**

SLR to VLBI scale offset : 1.4 ppb = ~8 mm.

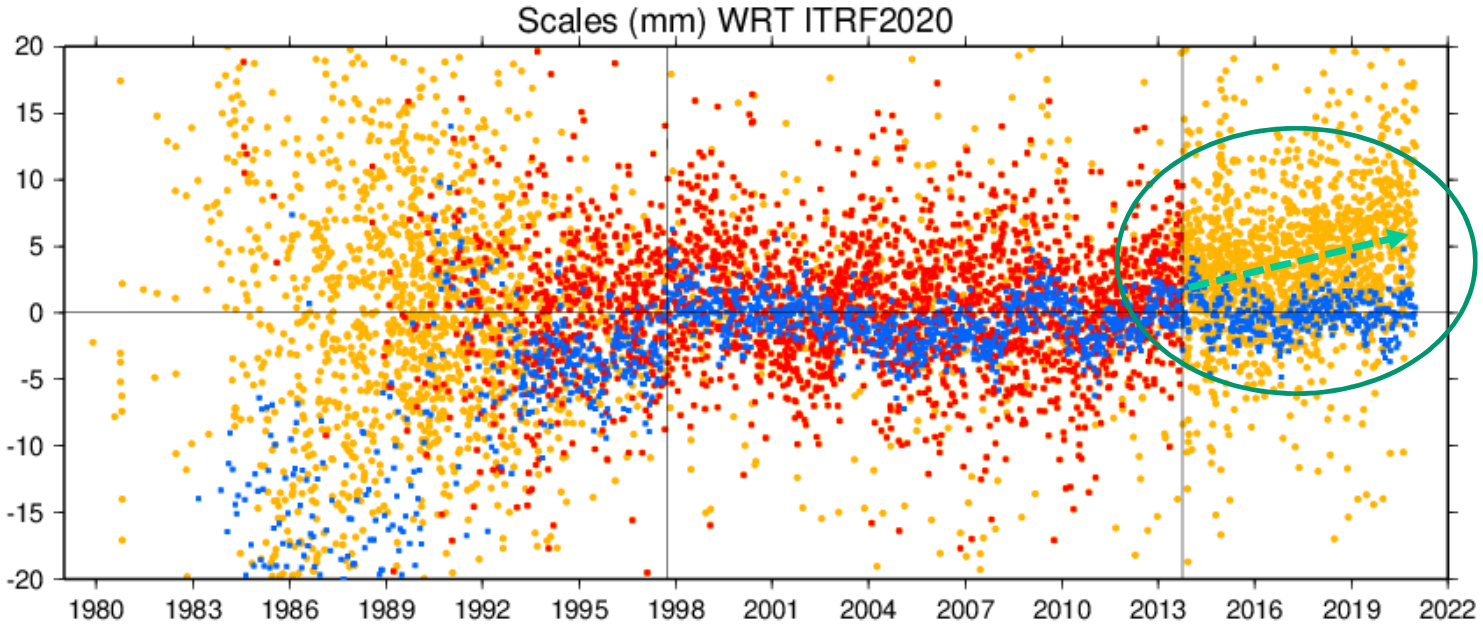
Scale of ITRF2020?

- **This is the first time of ITRF history where we have 4 independent and competitive scales stemming from the 4 techniques (DORIS, GNSS, SLR and VLBI)**

- **IGS / GNSS scale is based on z-PCOs for Galileo Satellites, using 3.7 yrs of Galileo data**

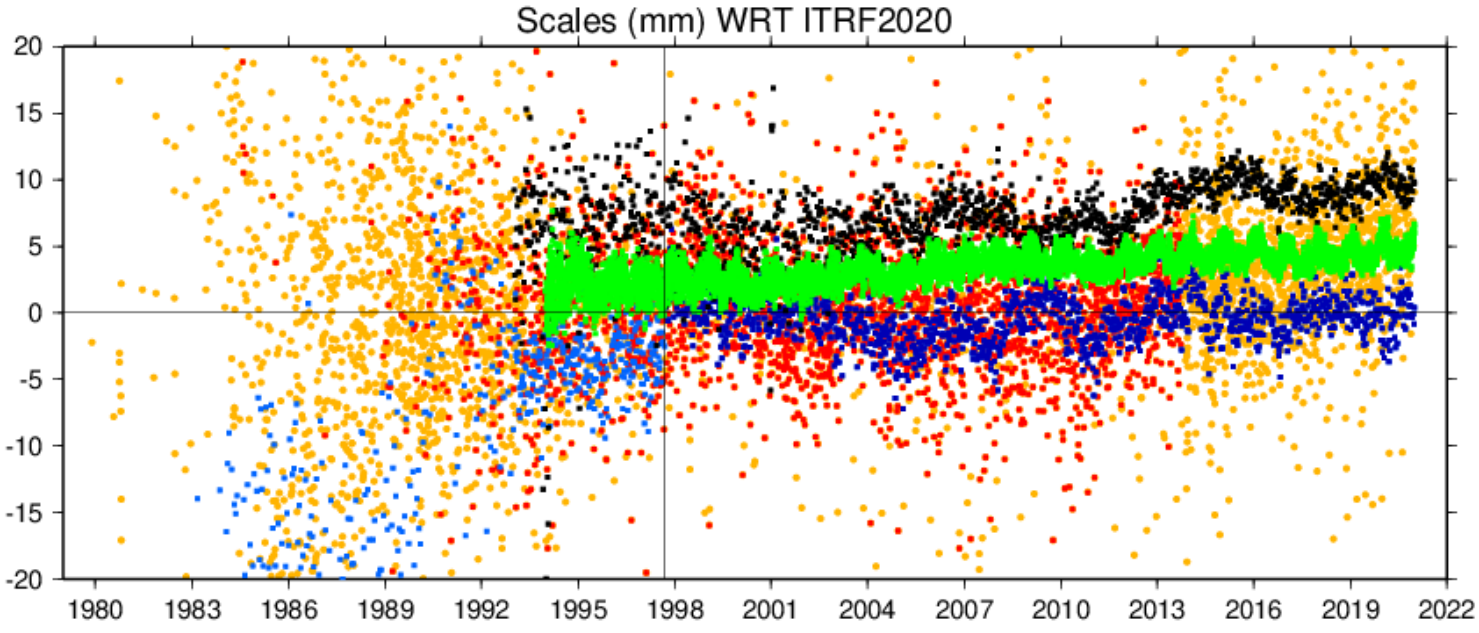
- **Improved ILRS / SLR scale determination with enhanced handling of range biases**

Relative Scales



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

Relative Scales



- Orange: all VLBI Sessions
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- Light blue: all SLR time series
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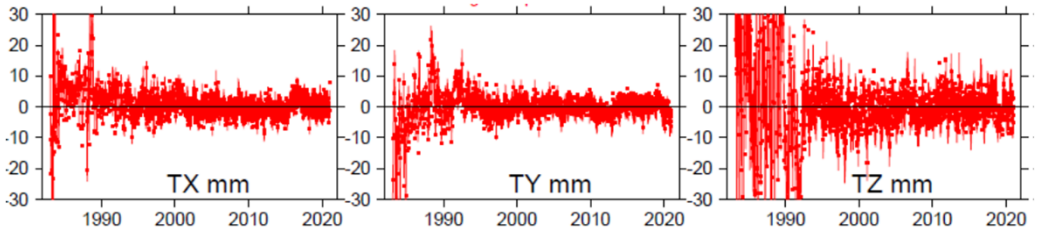
- Green: IGS/Repro3
- Black: DORIS

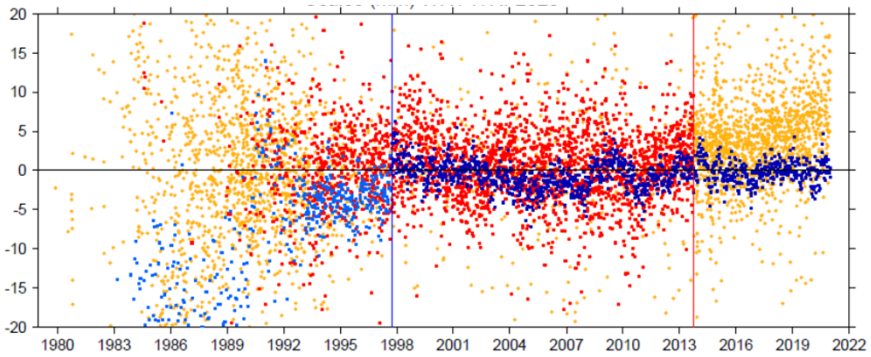
Solution	Scale at 2015.0 (ppb)	Scale rate ppb/yr
IGS	0.682 ±0.018	0.018 ±0.001
IVS	0.075 ±0.040	0.000 ±0.003
ILRS	-0.075 ±0.038	0.000 ±0.004
IDS	1.386 ±0.037	0.028 ±0.003

ITRF : Uncertainty in the frame definition/specification

- **Origin**: Rely on one technique : SLR
  - Long-term uncertainty: at epoch 2015.0: up to 3 mm
  - Stability / rate : up to 0.3 mm/yr



- **Scale**: Average of SLR & VLBI
  - Long-term uncertainty (level of agreement between SLR & VLBI):
    - ITRF2014: 1.4 ppb (~8 mm at the equator)
    - ITRF2020: 0.15 ppb (~1 mm at the equator)
  - Stability / rate : depend on "agreement of site velocities"
  - SLR & VLBI scale time series are not linear!!



- **Orientation**: Alignment of successive ITRF solutions using a selection of reference frame stations
  - Long-term & stability / rate uncertainty : dictated by the so-called network effect: up to 30µas (1mm)

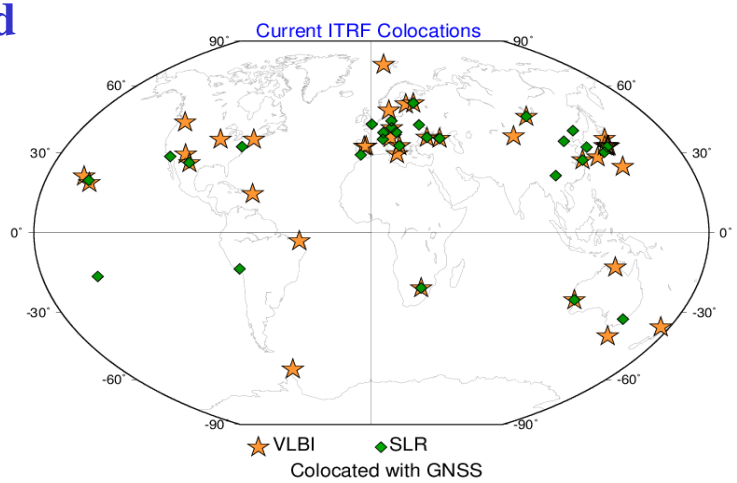
ITRF2020: Local tie Discrepancies

LT Discrepancies: Differences between terrestrial ties and space geodesy estimates
Local tie vectors between GNSS and the 3 other techniques at co-location sites

GNSS to :	Total tie vectors ITRF2014 / ITRF2020	Discrepancy < 5 mm	% Discrepancy < 5 mm
VLBI	60 / 77	27 / 38	45 / 50
SLR	49 / 53	14 / 19	29 / 36
DORIS	103 / 123	23 / 39	22 / 32

Summary (1/2)

- **ITRF current status:**
  - **Fundamentally based on colocations: Strengthen ITRF parameters (origin, scale, orientation)**
  - **ITRF parameters needs improvement and sustainability by a factor of 3, at least.**
  - **SLR & VLBI are critical for the frame definition : origin (SLR), scale (SLR & VLBI)**
  - **SLR & VLBI collocations (~ 10 sites) are poorly distributed**
  - **> 50 % of SLR & VLBI are old-generation systems**
  - **Quantitatively : Data yield is poor for both techniques**
  - **GNSS links together SLR, VLBI & DORIS networks**
  - **More than 50 % of tie discrepancies are larger than 5 mm,**
  - **Caused mainly by technique systematic errors**



- **What are the alternatives to improve and sustain the ITRF in the long-term?**

Summary (2/2): ITRF and space ties

- **Alternative: GENESIS-1_type mission:**
  - **Should include sensors of the 4 techniques (DORIS, GNSS, SLR & VLBI) at one platform**
  - **Core colocation site in space**
  - **Fully calibrated satellite-based platform: this is fundamental**

- **Questions for discussion:**
  - **How to mitigate technique systematic errors ?**
  - **How to improve the ITRF origin / geocenter: Adding an accelerometer ?**
  - **How to improve the long-term ITRF scale ?**
  - **How to improve the Ground Infrastructure (?), especially SLR & VLBI**
  - **Lifetime (?) of GENESIS-1_type mission, noting the need for continuous observations**
  - **Multiple GENESIS missions ?**