

GENESIS Contribution to the ITRF ?

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Key points

- **Introduction**
- **Why is the ITRF needed ?**
- **ITRF Uncertainty Evaluation**
 - **Currently operating sites and colocations**
 - **Reference frame definition/specification: origin, scale & orientation**
 - **Agreement between terrestrial ties and space geodesy estimates at colocation sites**
- **Technique systematic errors**
- **Future needs to sustain and improve the accuracy of the ITRF**
 - **Contribution of GENESIS type mission: Expected benefit (?)**
- **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



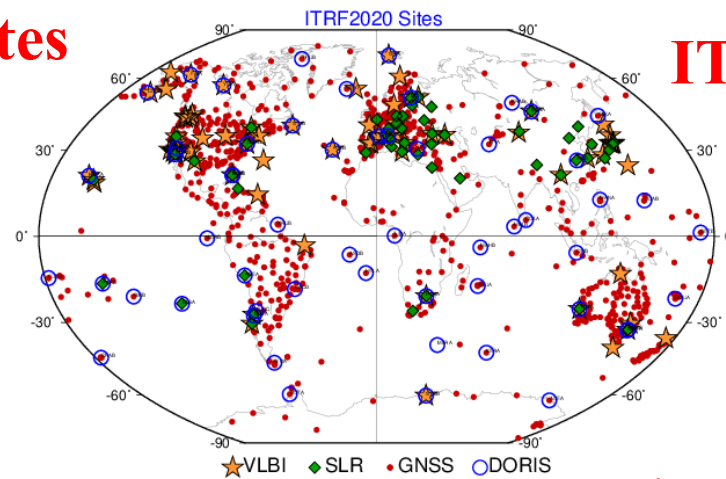
VLBI



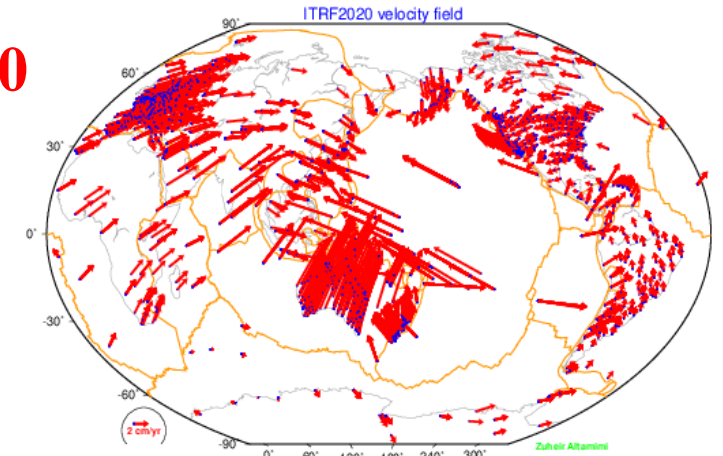
GNSS



DORIS

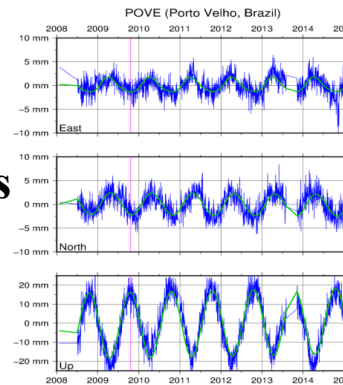


ITRF2020

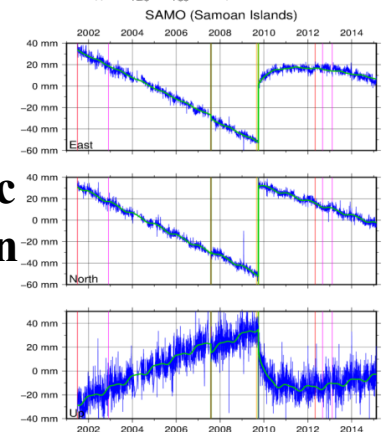


+ parametric models

Seasonal signals

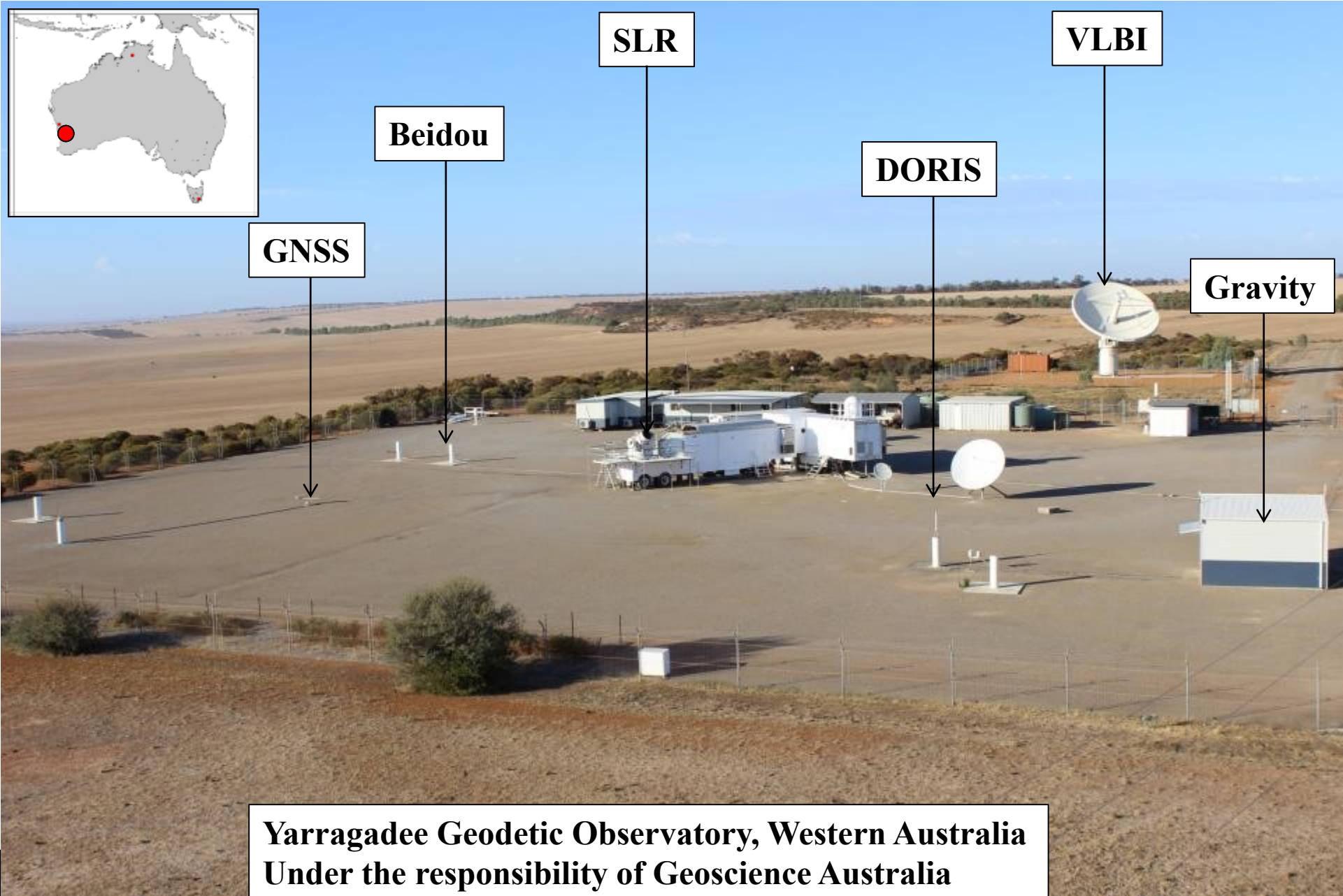


Post-seismic deformation



<http://itrf.ign.fr>

Yarragadee : A famous co-location site



**Yarragadee Geodetic Observatory, Western Australia
Under the responsibility of Geoscience Australia**

Why is the ITRF needed?

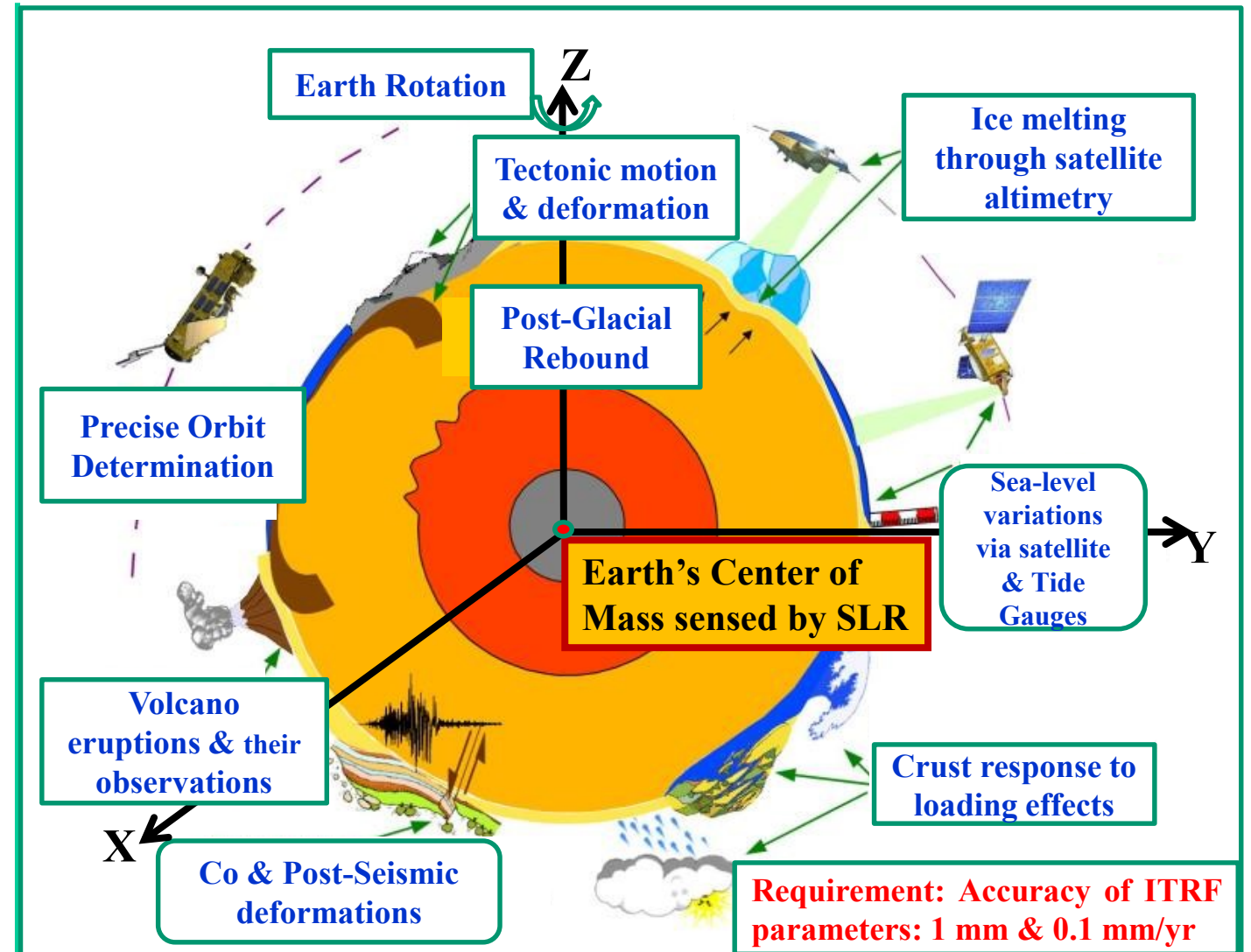
Operational geodesy applications:

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

GNSS-specific reference frames:

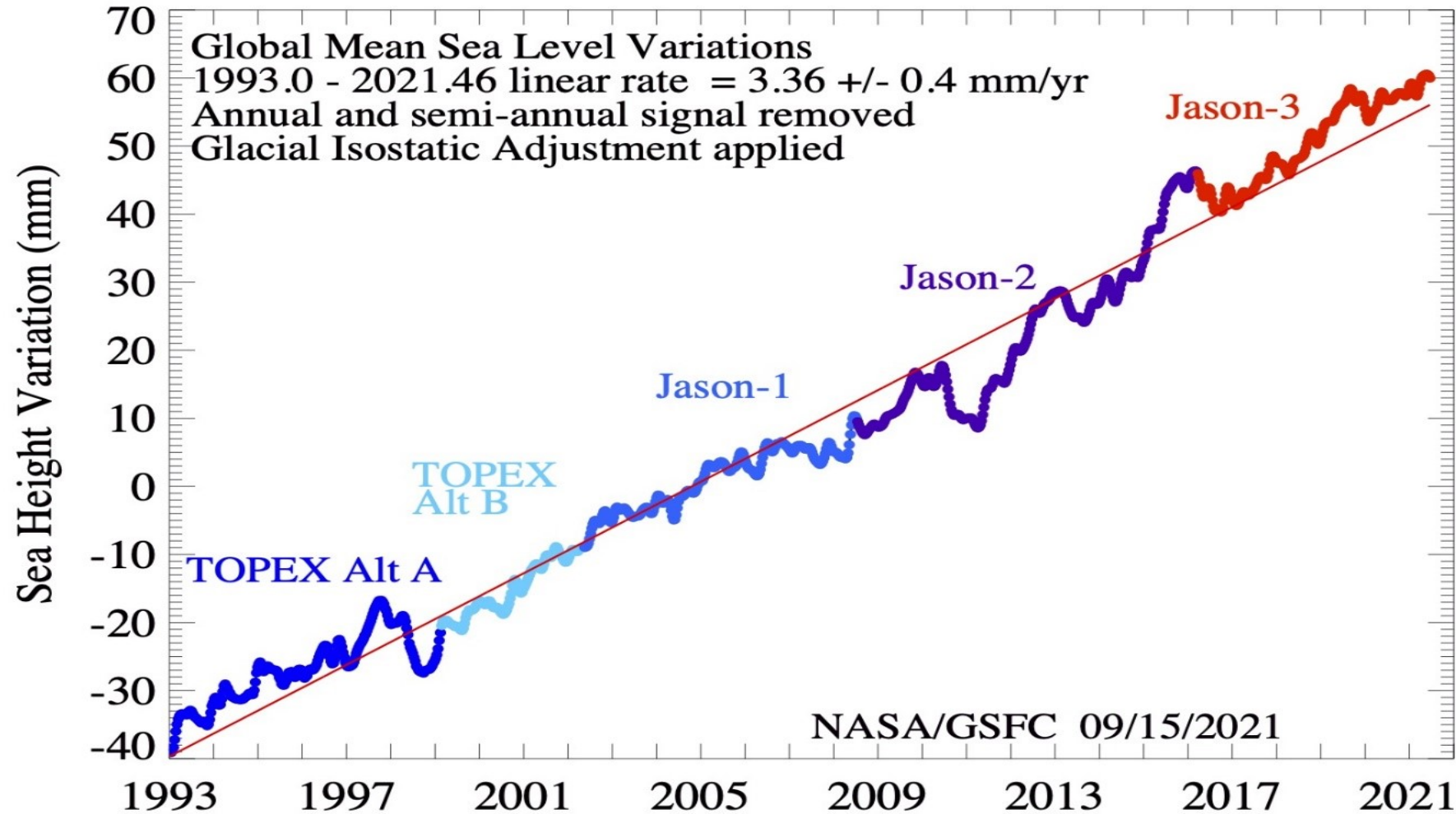
- GTRF/Galileo, WGS84/GPS, PZ-90/GLONASS, CGCS2000/Beidou, JGS/QZSS
- All are aligned to the ITRF

Scientific Applications:



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

Current situation ?

Technique systematic errors

- **DORIS**: mis-modelling of the solar radiation pressure \implies inaccurate determination of the geocenter components, and nonlinearity in the long-term TRF scale
 - **GNSS** have multiple weaknesses in recovering the Earth center of mass position and the TRF scale (in the absence of satellite metadata)
 - **SLR** range biases have significant impact on the TRF scale
 - **VLBI** antenna gravitational deformation \implies impact on the TRF scale
-
- **Progress towards improving the TRF scale determination :**
 - GNSS : Metadata are now available for Galileo, Beidou, QZSS, GPS Block III
 - SLR : ILRS adjusts RBs since ITRF2020, improving the scale and its agreement with VLBI
 - VLBI : Deformation models for a number of antennas are now available
 - DORIS : Investigations by IDS are in progress

Current ITRF colocations (with GNSS)

DORIS ~46 sites



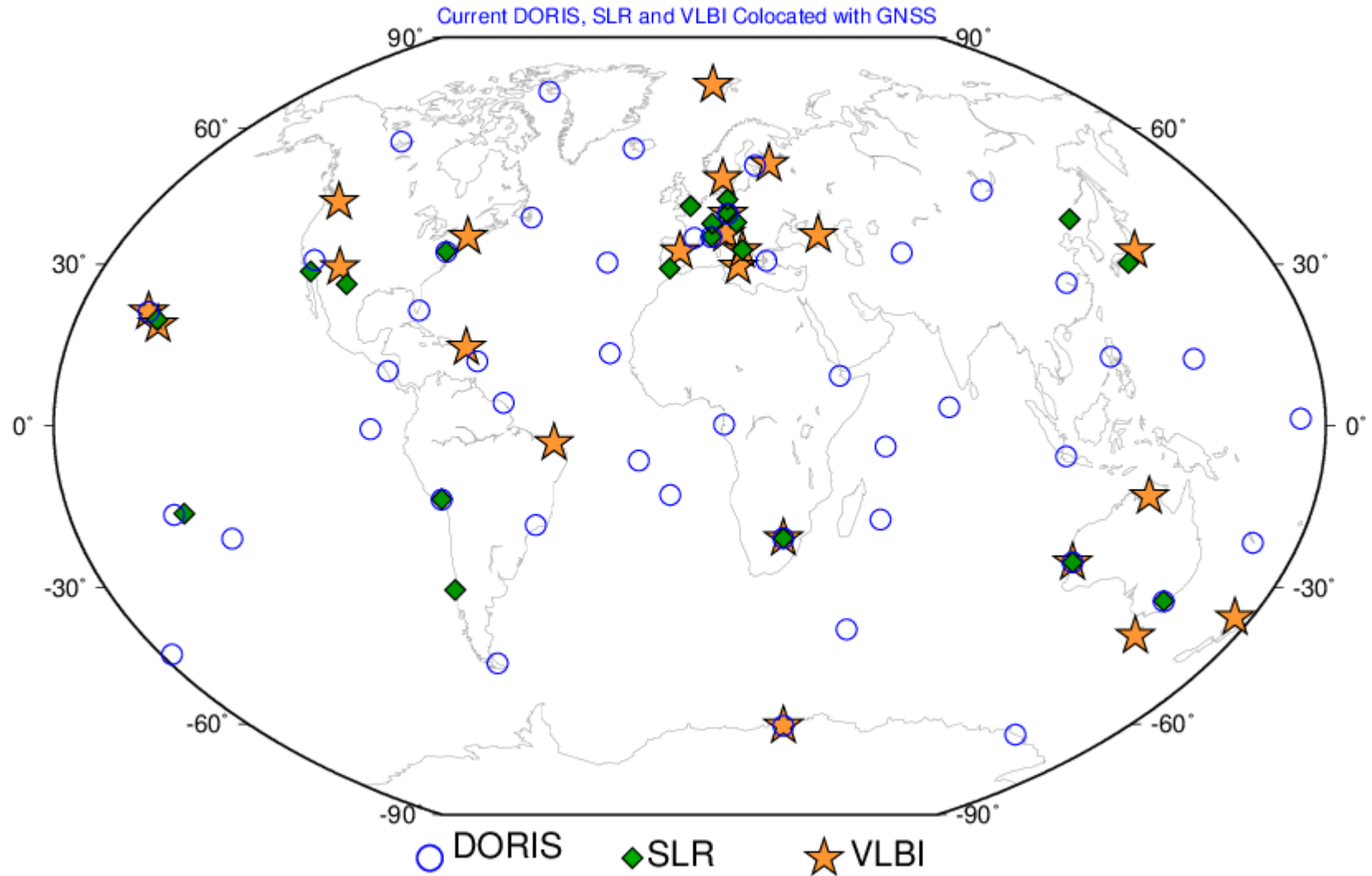
SLR ~30 sites



VLBI ~44



Ny-Ålesund. Photo: Björn-Owe Holmberg



Current ITRF colocations

SLR ~30 sites

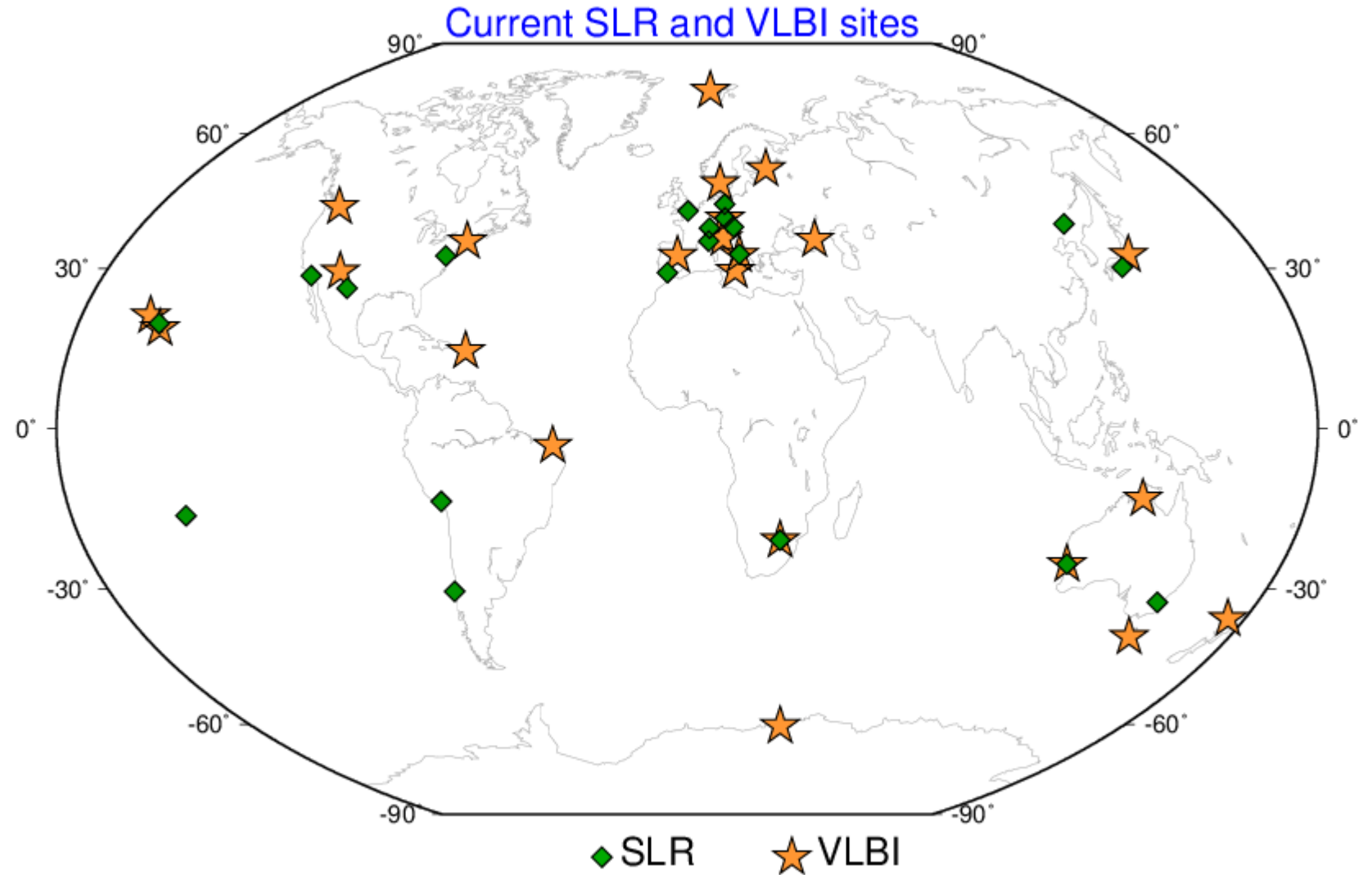


VLBI ~44



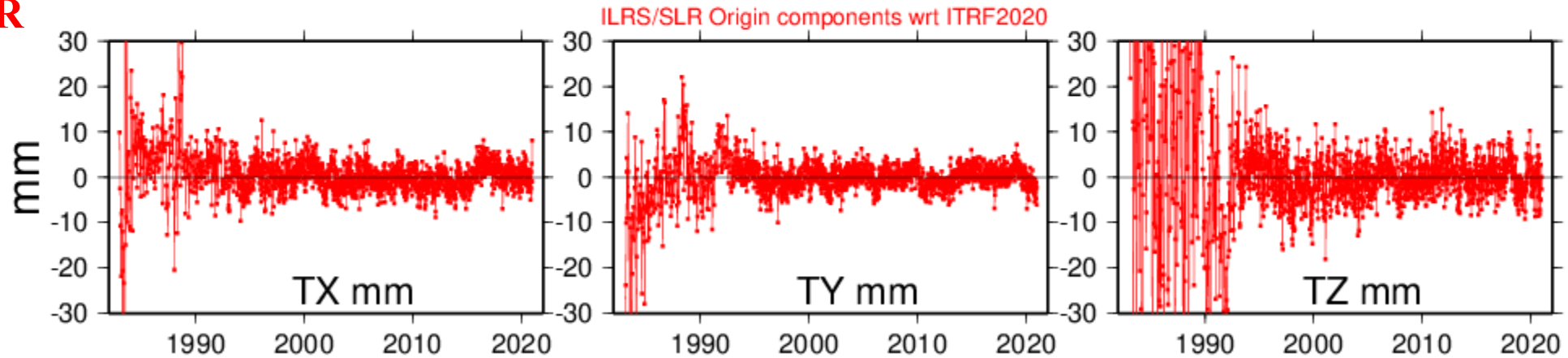
Ny-Ålesund. Photo: Bjorn-Owe Holmberg

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

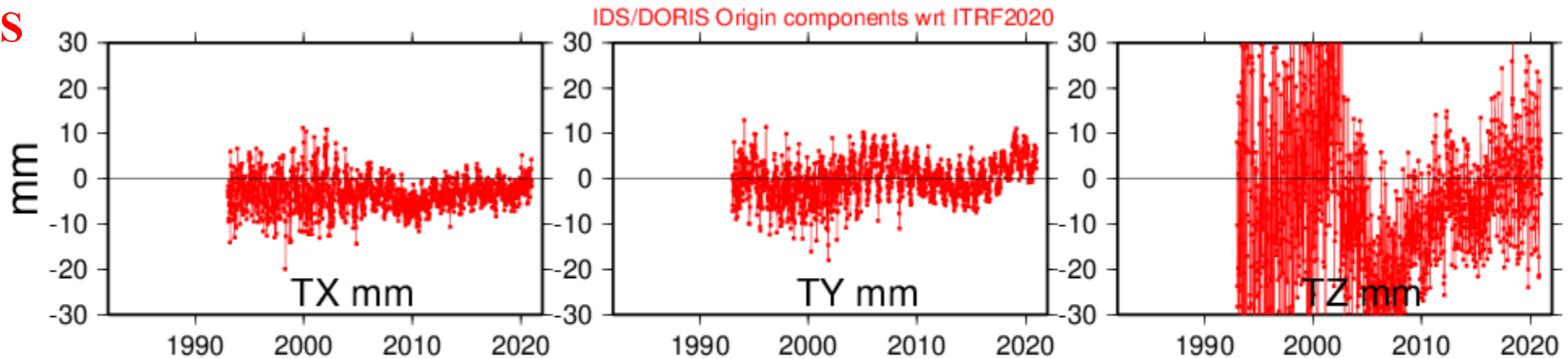


ITRF Origin: Inherited from SLR long-term CM origin

ILRS-SLR

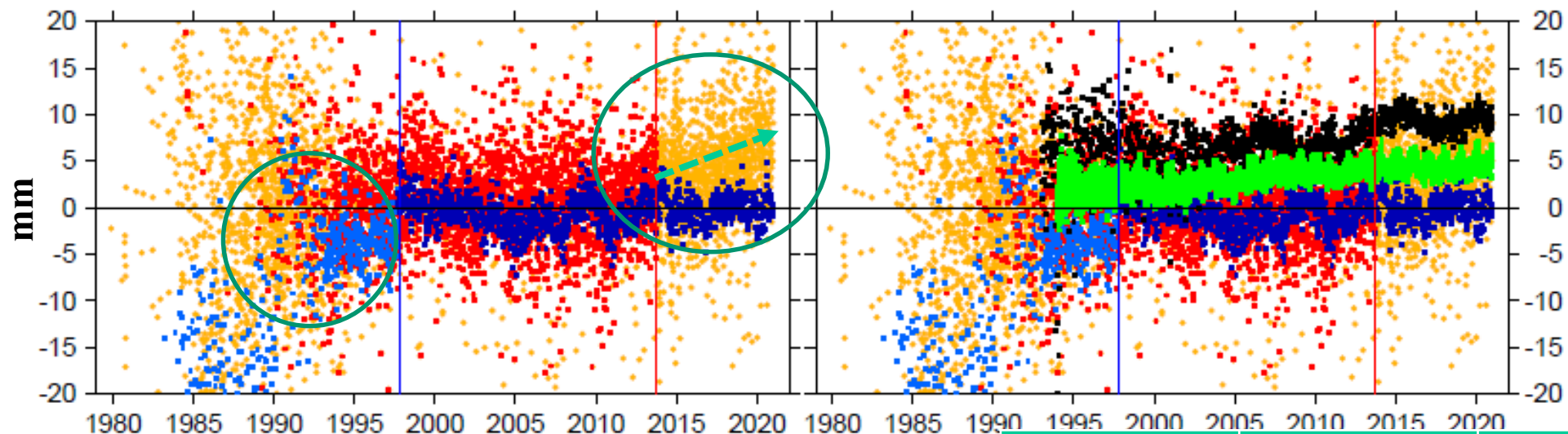


IDS-DORIS



GNSS frame origin is not reliable

Scales with respect to ITRF2020



- **Orange:** all VLBI Sessions
- **Red:** Selected VLBI Sessions (Solid 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)**

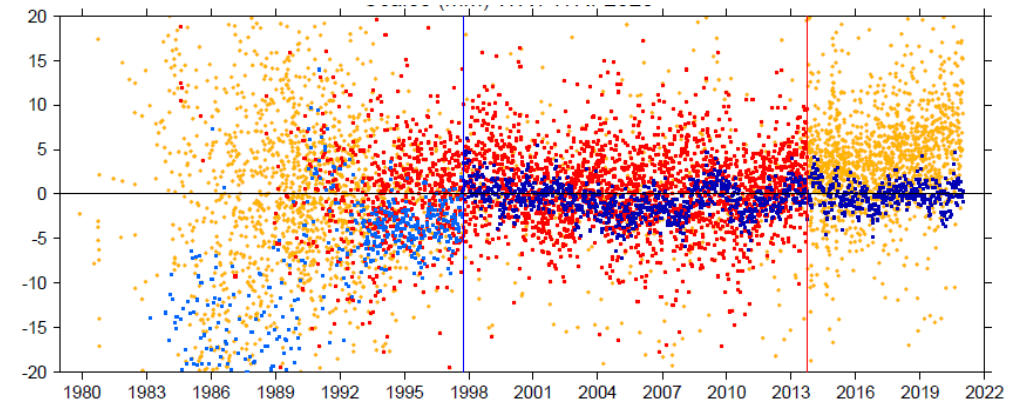
**Scale offset between SLR & VLBI is 0.15 ppb
(1 mm at the equator)**

Solution	Scale at 2015.0 (ppb)	Scale rate ppb/yr
IGS/GNSS	0.682 ± 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

ITRF : Uncertainty in the frame definition/specification

- **Origin: Rely on one technique : SLR**
 - Long-term uncertainty: at epoch 2015.0: up to **5 mm**
 - Stability / rate : up to **0.5 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!!**

Solution	TX	TY	TZ
ITRF2014	-1.4	-0.9	1.4
Rates	0.0	-0.1	0.2
ITRF2008	0.2	1.0	3.3
Rates	0.0	-0.1	0.1
ITRF2005	2.7	0.1	-1.4
Rates	0.3	-0.1	0.1



- **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 **30 μ as (1mm)**

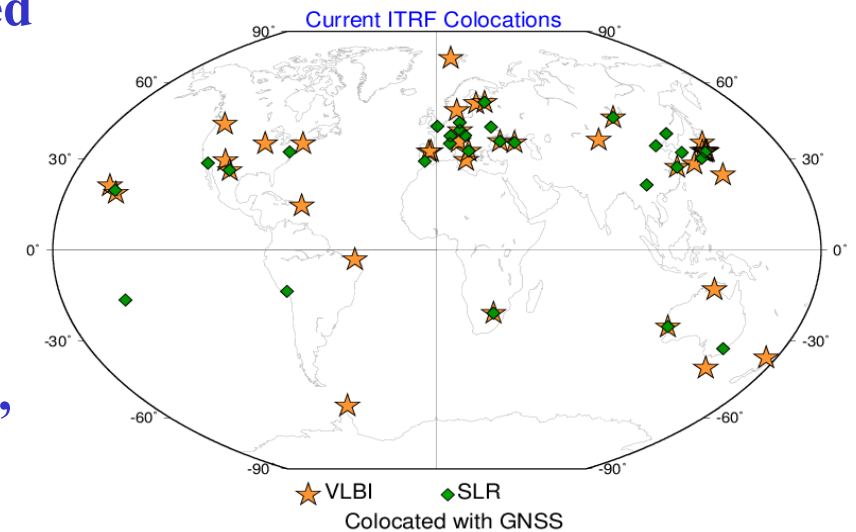
ITRF2020: Local tie Discrepancies

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

- **ITRF current status:**
 - Fundamentally based on **colocations**: Strengthen ITRF parameters (origin, scale, orientation)
 - ITRF parameters needs improvement by a factor of 5, 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?**



ITRF and space ties

- **Alternative: GENESIS_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: GENESIS contribution ?**
 - Which type of “GENESIS solution” at the observation level: alone or combined ?
 - How to mitigate technique systematic errors ?
 - How to improve the ITRF origin / geocenter: Adding an accelerometer ?
 - How to improve the long-term ITRF scale ?
 - **Lifetime (?) of GENESIS_type mission, noting the need for continuous observations**
 - **Multiple GENESIS missions ?**
 - How to improve the Ground Infrastructure (?), especially SLR & VLBI