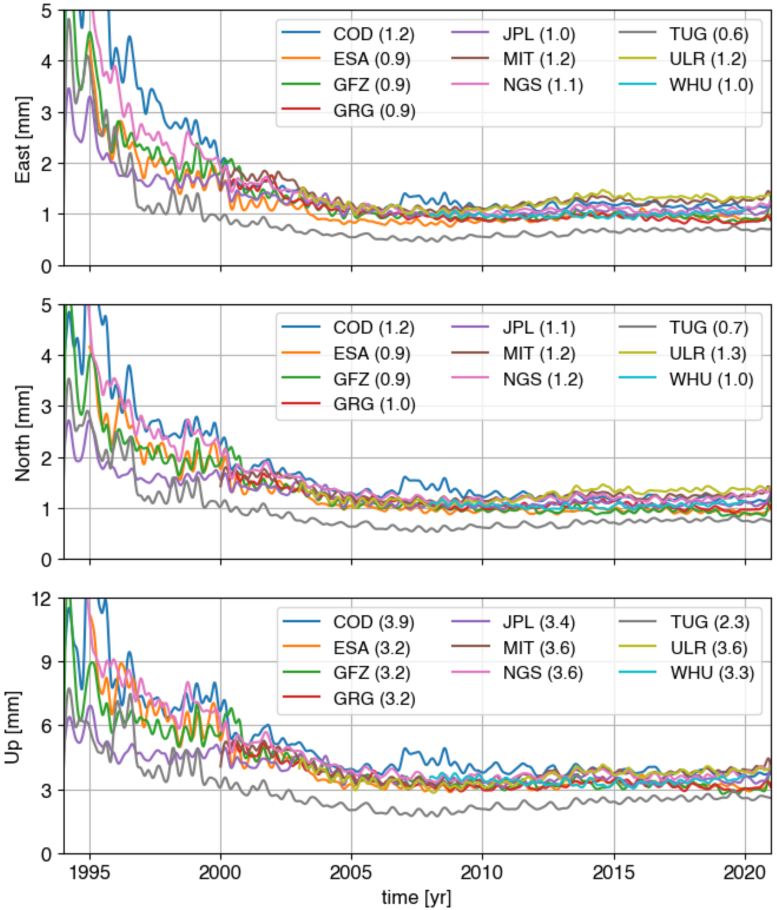
IGS repro3:

Terrestrial frame combination outcomes

Paul Rebischung

IGS 2022 Virtual Workshop, 30 June 2022

Precision of AC terrestrial frame solutions



← (Smoothed) median formal errors of station positions in re-weighted daily AC solutions

= estimated 'precision' of daily AC solutions

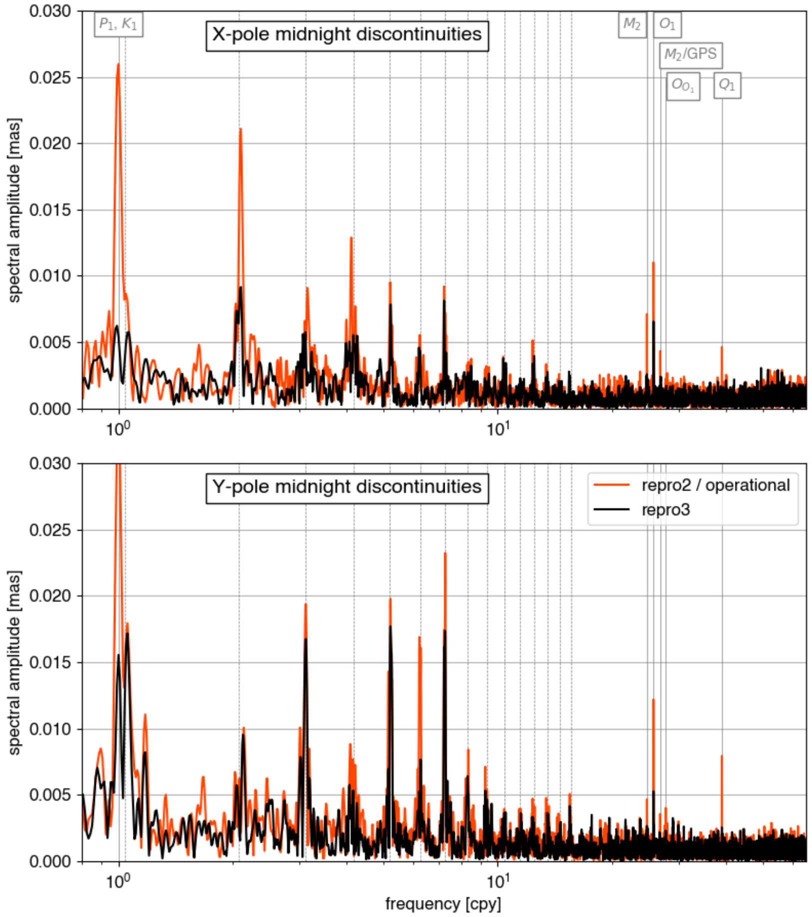
= proxy for the AC weights in the daily combinations

- AC contributions of very homogeneous quality, except for TUG

- Higher precision of TUG solutions confirmed by inter-comparison of AC station position time series

→ **Which analysis specificities can explain the higher precision of TUG solutions?**

Midnight polar motion discontinuities



← Spectra of repro2 and repro3 midnight polar motion discontinuities

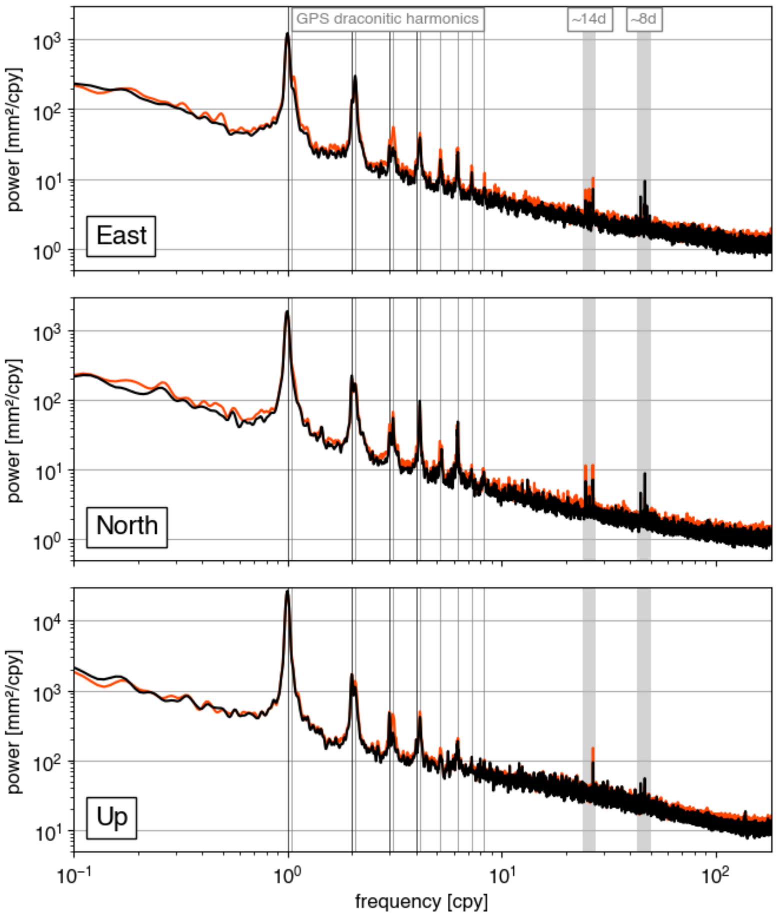
- Include essentially the aliased signatures of sub-daily errors, in particular sub-daily EOP tide model errors;
- Plus long-period errors in pole rate estimates.

- All peaks at tidal aliasing frequencies (vertical plain lines) are reduced from repro2 to repro3.
  - Some almost completely (M_2, Oo_1, Q_1)
  - Others only partially (P_1/K_1, O_1)

→ Desai & Sibois (2016)'s sub-daily EOP tide model clearly superior to previous IERS model

- All peaks at GPS draconitic harmonics (vertical dashed lines) are also reduced from repro2 to repro3.

Spectra of station position time series



← Average periodograms of repro2 and repro3 station position time series

- 215 selected stations
- Trends, offsets, outliers and post-seismic displacements removed

- **Slight reductions in:**
  - background noise
  - draconitic signals (also seen in polar motion, geocenter)
  - fortnightly signals

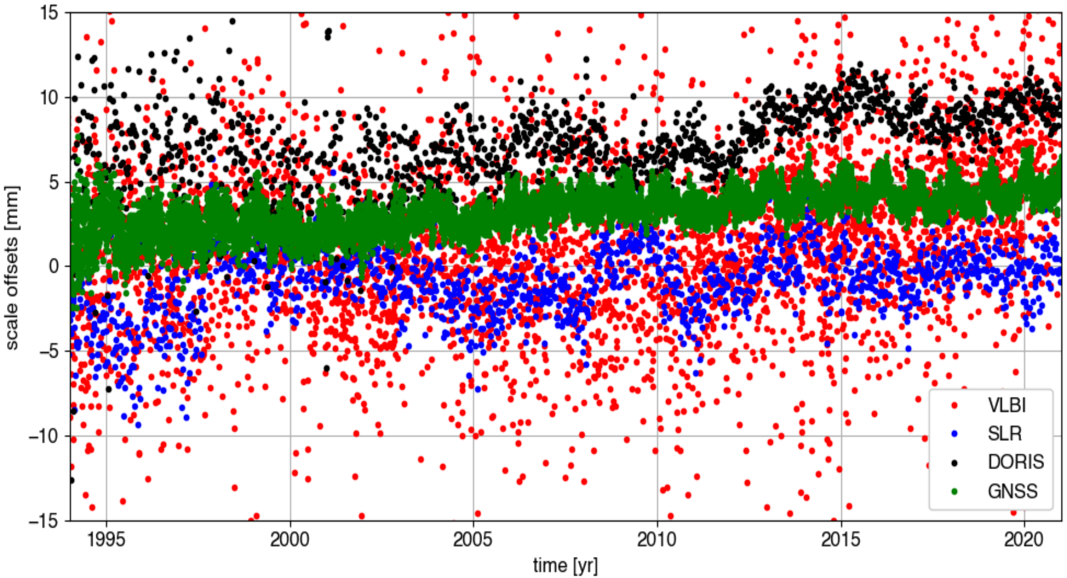
- **New GLONASS-related errors at ≈8 d & harmonics**

→ **Progress still possible and encouraged in:**

- orbit dynamics modeling
- background tide models

GNSS-derived terrestrial scale

Scale offsets between ITRF2020 input solutions & ITRF2020



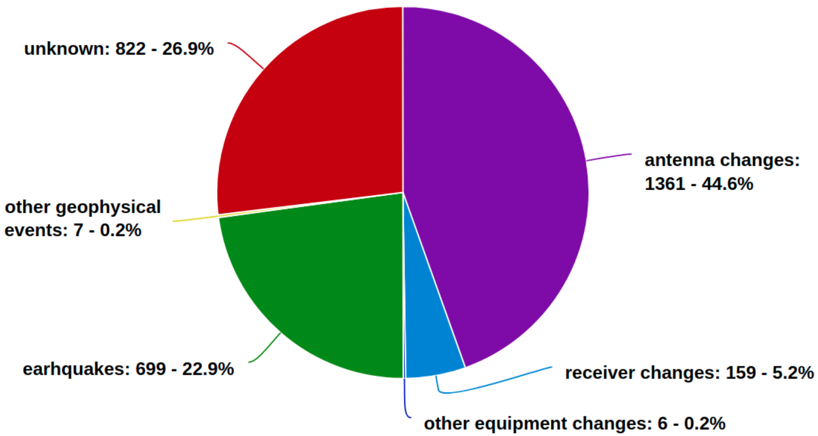
- **Mean scale offset between IGS repro3 & ITRF2020: +4 mm @ 2015.0**
  - Mean IGS repro3 scale induced by calibrated Galileo satellite z-PCOs
  - Scale induced by calibrated GPS Block III satellite z-PCOs consistent with Galileo-based scale (Villiger et al., EGU2022)

- **Scale rate between IGS repro3 & ITRF2020: +0.1 mm/yr**
  - IGS repro3 scale rate induced by the assumption of no-net-drift of GNSS satellite z-PCOs

→ What can explain the scale [rate] differences between GNSS and the other space geodetic techniques?

Offsets in GNSS station position time series

Distribution of offsets detected in repro3 station position time series



- **Offsets are a limitation to the long-term stability of the ITRF.**
  - In repro3: 1 offset every 6.3 yr in average
  - Half of them due to equipment (mostly antenna) changes
  - Conversely, 73% of antenna changes induce visible offsets, pointing to imperfect antenna calibrations.
- **Possible (complementary) remedies:**
  - In situ antenna calibrations, either absolute or relative (from one antenna to the next installed)
  - Next generation of station installations, less subject to environmental errors
  - Keep limiting equipment changes at RF stations

Proposed recommendations

1. Understand higher precision of TUG station position estimates compared to other ACs.

2. Aim at further reducing spurious periodic signals in IGS station position time series, by further advances in orbit and tide modeling.

3. Investigate terrestrial scale [rate] differences between GNSS and the other space geodetic techniques.

4. Aim at mitigating the impact of offsets on the long-term stability of the ITRF by:
   - investigating in situ antenna calibrations, either absolute or relative;
   - considering next generation of station installations, less subject to environmental errors;
   - limiting equipment changes at RF stations.

Preparation & implementation of the IGS20/igs20.atx framework

Paul Rebischung

Preparation of IGS20/igs20.atx

1. **Update of ground antenna calibrations from igsR3.atx to igs20.atx (A. Villiger)** **16 June**
   – **A second round of updates is being prepared by Geo++. Should we incorporate them as well in igs20.atx?**

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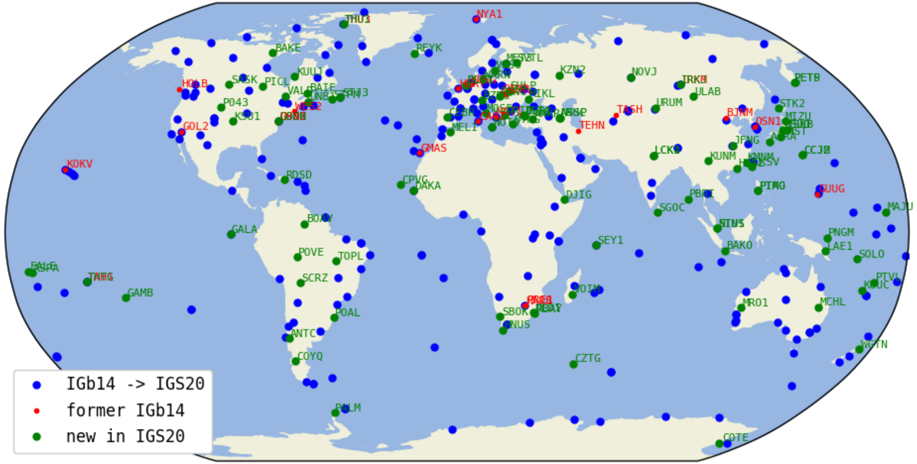
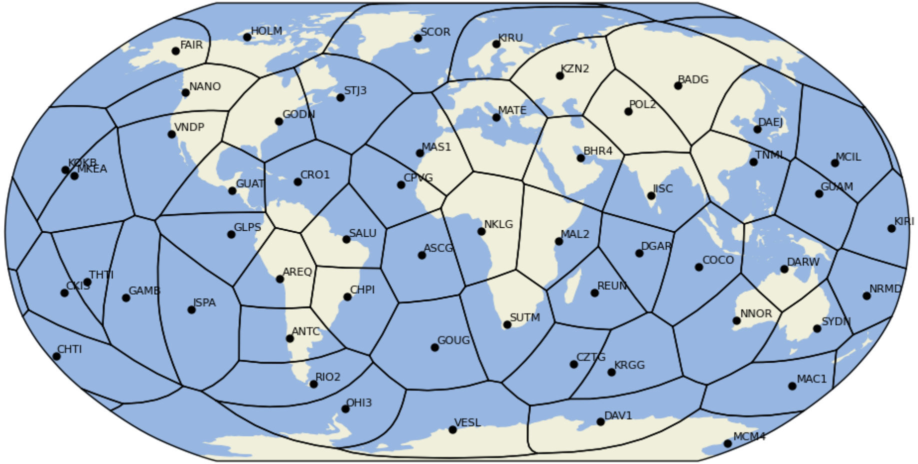
2. **Selection of IGS20 reference frame stations within ITRF2020 (P. Rebischung)**
   - First selection based on precision & extrapolatibility of ITRF2020 coordinates — 7 June
   - IGS20 'core' network: well-distributed sub-network designed for the alignment of global solutions
   - Selection adjusted according to feedback received from station operators, ACs and RFWG
   - Feedback still welcome!



Proposed IGS20 network



Primary stations of proposed IGS20 core network

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3. **Estimation of position offsets due to igsR3.atx → igs20.atx ground antenna calibration updates (CODE, GFZ, GRGS, TUG, others?)**
   - For IGS20 RF stations (current updates: 47 antennas; additional updates: 211 antennas) — 17 July
   - For other repro3 stations (current updates: 198 antennas; additional updates: 728 antennas) — End of November

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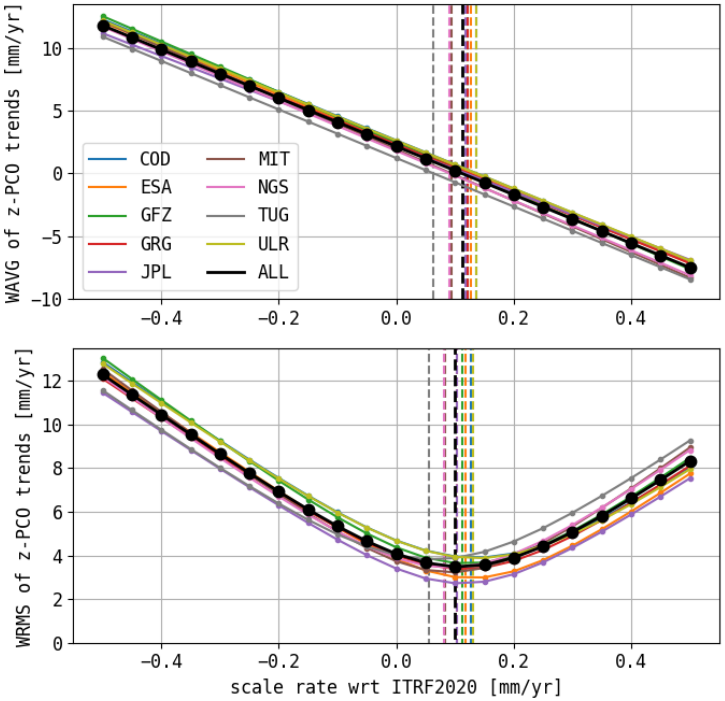
4. **Re-estimation of satellite z-PCOs consistent with ITRF2020 scale (P. Rebischung, A. Villiger)**

Estimation of igs20.atx satellite z-PCOs

- **Data and pre-processing:**
  - Daily repro3 SINEX solutions from 9 ACs
  - Constraints removed
  - Satellite x- & y-PCOs and UT1-UTC offset fixed to a priori values
  - Normal equations inverted with no-net-rotation, translation nor scale constraints wrt ITRF2020, but satellite z-PCOs freely estimated.

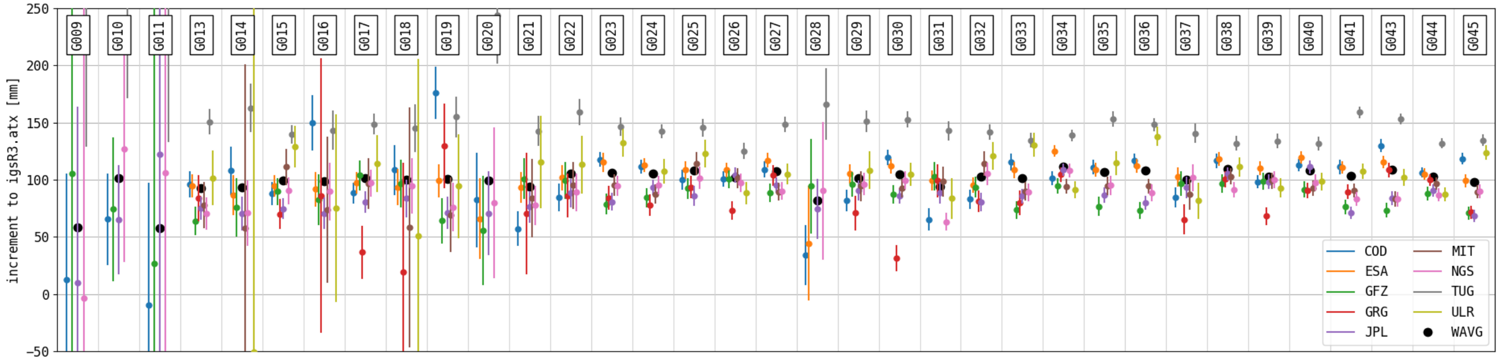
- **Time series of daily z-PCO estimates inspected for possible offsets. None found except:**
  - For GLONASS satellites R730 & R737 (already accounted for in igsR3.atx)
  - For several Galileo satellites in March 2017 (likely artificial → will be ignored)

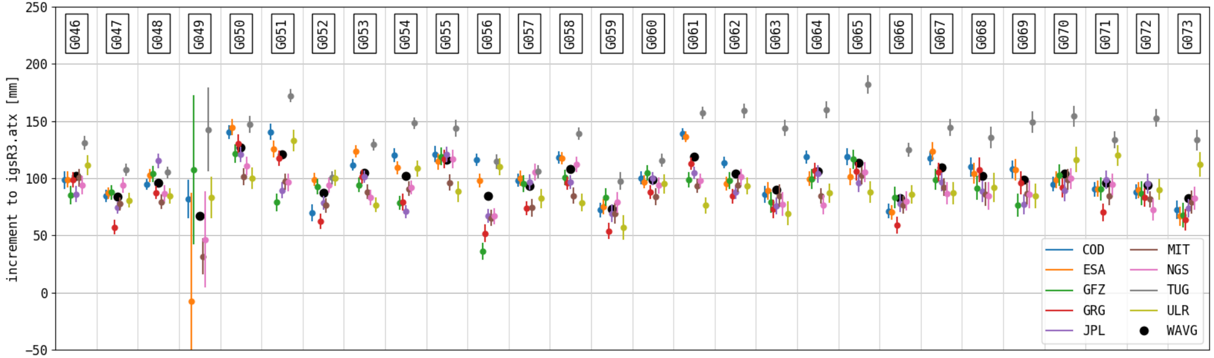
- **Look for correction to ITRF2020 scale rate which minimizes trends in z-PCO time series (+0.11 mm/yr)**
- **Re-invert normal equations wrt 'corrected' ITRF2020**

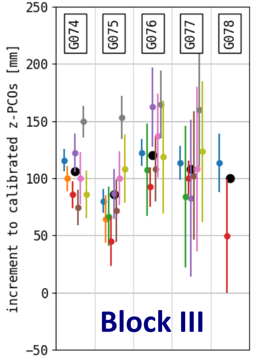


Estimation of igs20.atx satellite z-PCOs

- **Compute average z-PCO estimates, at first separately for each AC and satellite:** **GPS**
  - **Clear bias between TUG estimates and other ACs (?)**
  - **Increments to calibrated z-PCOs consistent within ± 3 cm across Block III satellites**

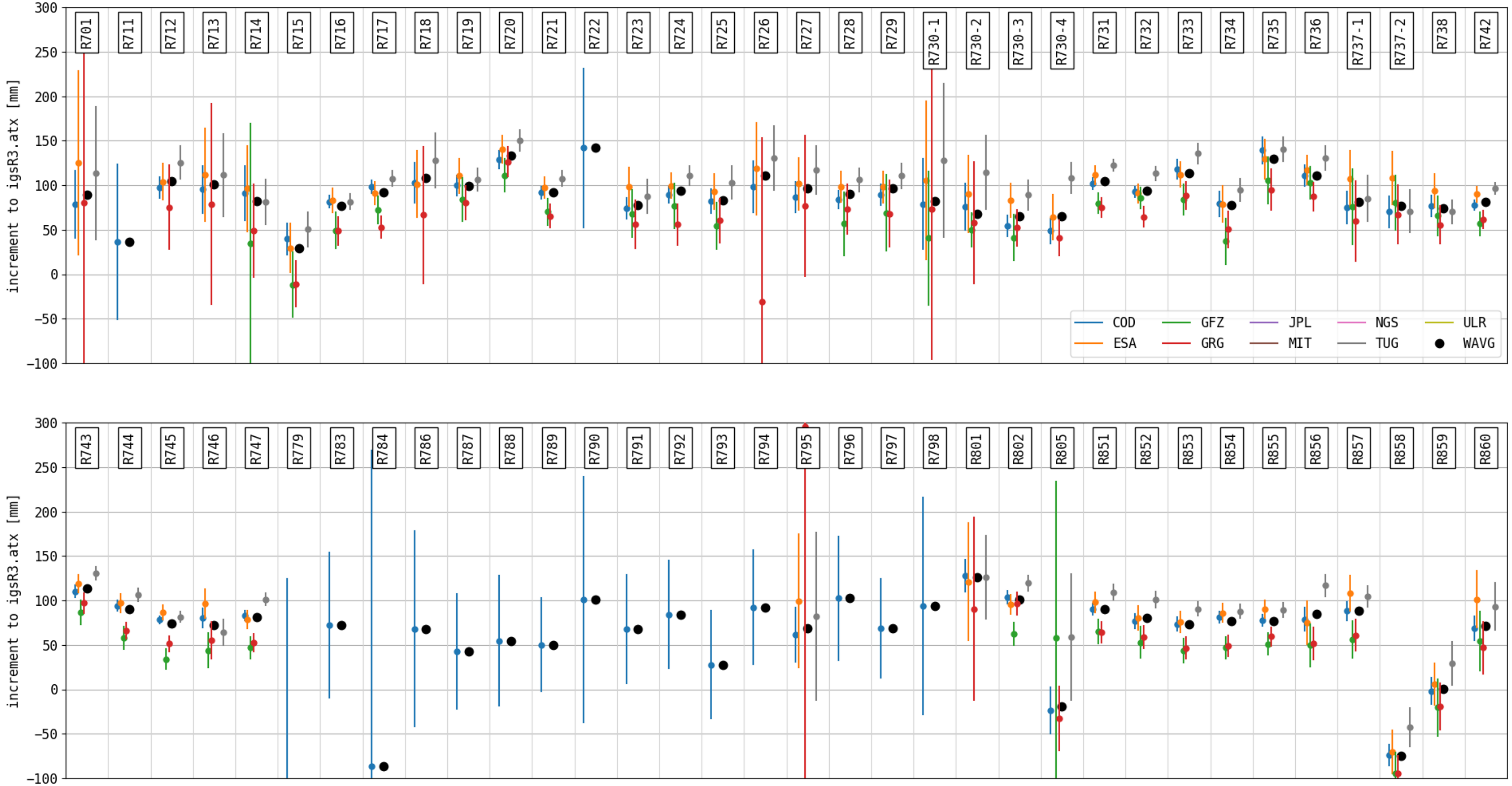






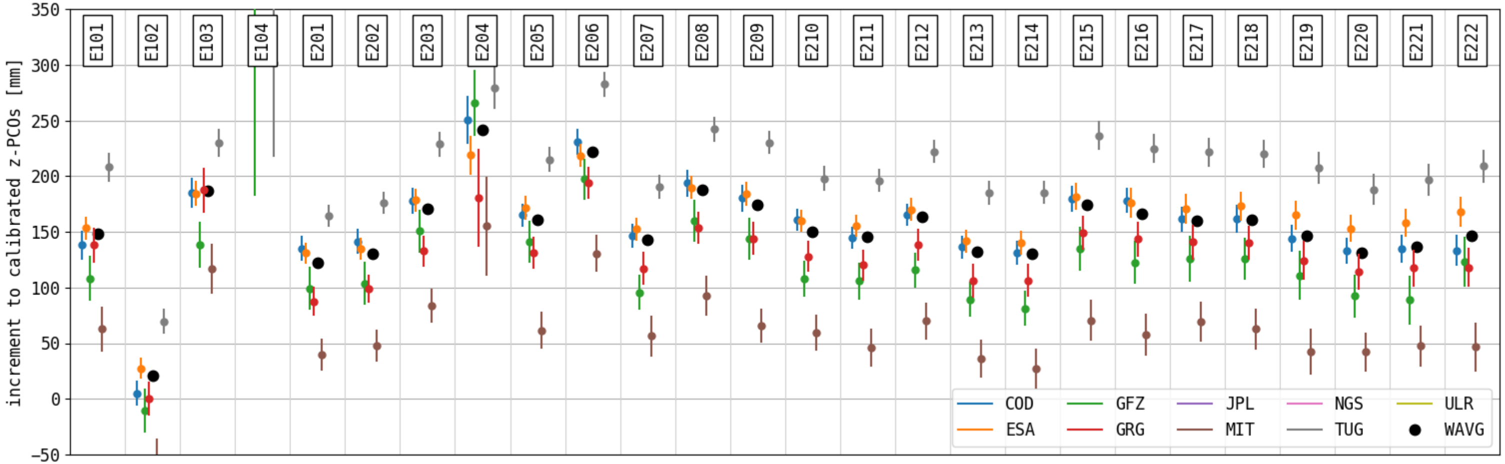
Estimation of igs20.atx satellite z-PCOs

- Compute average z-PCO estimates, at first separately for each AC and satellite: **GLONASS**



Estimation of igs20.atx satellite z-PCOs

- **Compute average z-PCO estimates, at first separately for each AC and satellite:** **Galileo**
  - **Clear inter-AC biases. MIT and TUG particulary stand out. (?)**
  - **Increments to calibrated z-PCOs consistent within ± 3 cm across most Galileo satellites**
  - **E102 is a clear exception (and was already dealt as such in igsR3.atx).**



Estimation of igs20.atx satellite z-PCOs

- **Compute average z-PCO estimates, at first separately for each AC and satellite.**

- **Final z-PCO estimation:**
  - Exclude TUG for GPS
  - Exclude TUG and MIT for Galileo
  - Estimate one single increment to all calibrated GPS Block III z-PCOs
  - Estimate one single increment to all calibrated Galileo z-PCOs (E102 excepted)
  - Estimate satellite-specific z-PCOs for all other satellites

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4. Re-estimation of satellite z-PCOs consistent with ITRF2020 scale (P. Rebischung, A. Villiger) — 20 June

→ Publication of IGS20/igs20.atx (P. Rebischung, A. Villiger) — 22 July

Implementation of IGS20/igs20.atx

• Test period with IGS20/igs20.atx & repro3 standards (ACs, ACC, RFWG)	August – September
• Official switch to IGS20/igs20.atx & repro3 standards (ACs, ACC, RFWG)	2 October / wk 2230
– Includes switch to long product filenames, to be coordinated with DCs	
• Backfilling of repro3 products for 2021 (ACs, ACC, RFWG)	End of November
• Backfilling of repro3 products for 2022 (ACs, ACC, RFWG)	End of November
• New IGS cumulative solution compliant with IGS20/igs20.atx and repro3 standards (P. Rebischung)	December