

Compatibility between disclosed GNSS satellite phase center offsets and their induced scale

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GNSS scale comparisons: test setup

What will be presented?

- IGS Repro3 is based on Galileo induced scale
- BeiDou and QZSS are not included
- Disclosed BeiDou and GPS BLOCK IIIA PCO values allow comparisons between different GNSS
- Study based on ca. 22 month (Jan. 2020 - Oct. 2021)
- Based on CODE's MGEX solution (1-day solution)

Current situation

GNSS	Satellite	Receiver
<i>GPS (BLOCK I-II)</i>	estim	calib
<i>GPS (BLOCK III)</i>	calib	calib
<i>GLONASS</i>	estim	calib
<i>GALILEO</i>	calib	calib
BEIDOU	calib	calib
QZSS	calib	calib

included in the IGS contribution to the next ITRF (repro3 campaign)

Experiment setup

- Based on 2020 and 2021
- Using extended Repro3 ANTEX
- Including GPS, Galileo, GLONASS, BeiDou, and QZSS
- Based on CODE 1-day MGEX solutions
- Total of 140 stations used

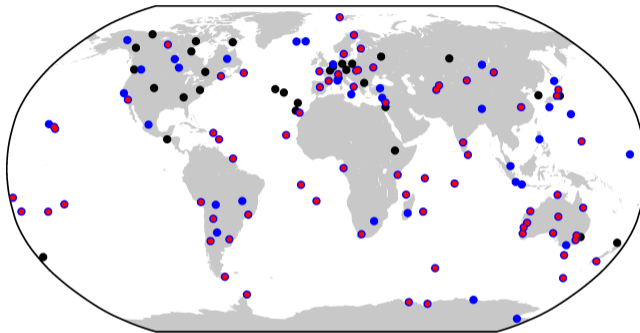
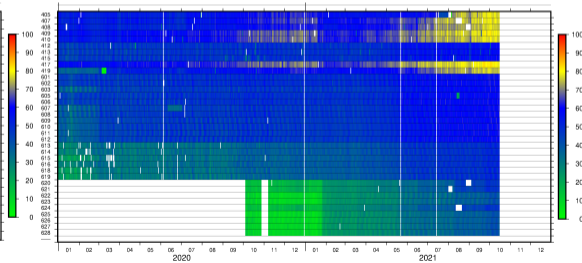
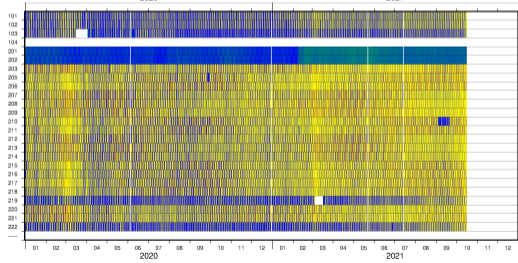
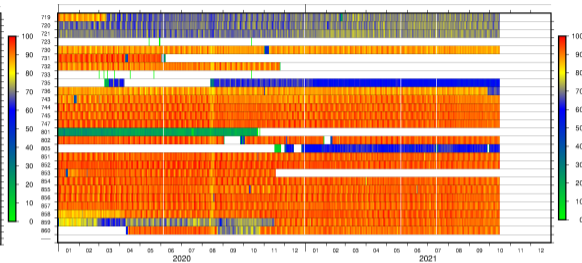
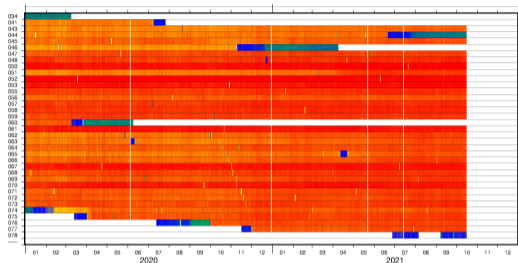


Figure: Tracking situation: GPS-only Galileo BeiDou
(Network 1. January 2021)

Percentage of observations compared to GPS



Villiger et al.: GNSS scale compatibility
AGU 2021, 17. December 2021, Online

Setup summary

Number of stations:

(total processed: 140)

GNSS	early 2020	late 2021
GPS	140	140
Galileo	106	115
BeiDou	70	90

Number of observations / satellites

Type	#1000 obs	% of GPS
BLOCK IIIA	150	100
GALILEO-2	120	80
BeiDou 2M	65-100	45-65
BeiDou 3M	65-100	45-65

- GPS satellites (except of the latest GPS BLOCK IIIA) well observed
- Galileo mostly well observed (avg. 80% of the GPS observations)
- BeiDou MEO satellites are observed significantly weaker compared to GPS (45-65%)
- Potential reason for scale comparison discrepancies

Scale comparison

Scale comparisons and experiments

- Compatibility between the different GNSS PCOs:
→ estimation of system-wise PCO corrections while constraining the PCOs of one GNSS
- Consistency of the disclosed PCOs of one GNSS:
→ scale introduced by setting up a zero mean condition on the chosen GNSS
- Analyzing the time stability of the PCOs:
→ PCO estimation using a sliding window of 30-days

Datum definition

- PCO fixed: PCO tightly constrained
- zero mean condition:

$$\sum_{GNSS} PCO_{sat} = 0$$

PCO estimation:

Estimation of PCO corrections w.r.t. their a priori values.

- system-wise PCO: one offset per system
- individual offset: one offset per satellite

System-wise PCO corrections for different GNSS scale definitions

Results of system-wise PCO z -offset estimation in cm

GPS	GLO	GAL	BDS*
-	2.1	0.3	-24.0
-0.8	-	-1.2	-25.3
0.6	2.3	-	-23.8
21.9	21.9	26.9	-*

*: BeiDou3 MEO satellites w/o SVN latest two BDS 3 satellites

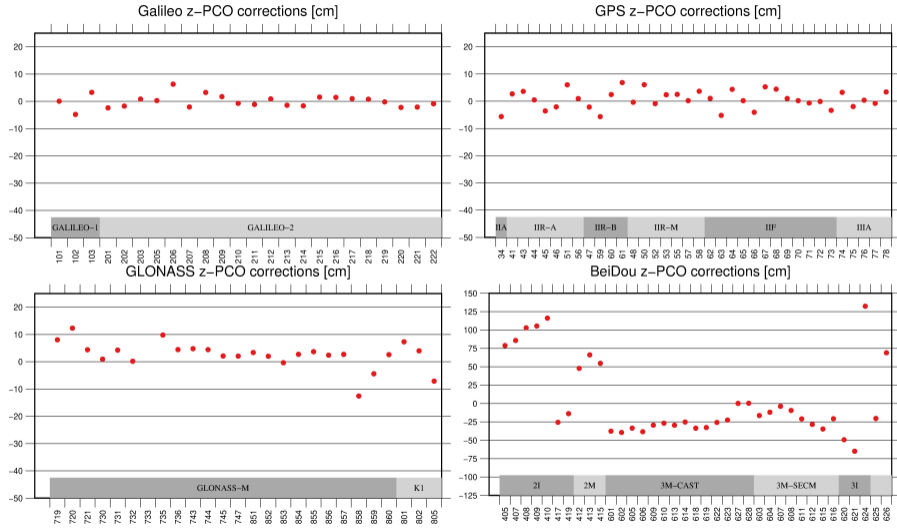
- QZSS PCO correction due to their IGSO orbits not listed (high correlation between clock and z PCO)
- GPS, GLONASS, and Galileo are consistent - which is to be expected (GPS and GLONASS PCOs are based on Galileo scale)
- BeiDou offset is about 20cm. The reason for this is still unclear.

Detailed study details for Galileo and BeiDou will be presented in the next slides.

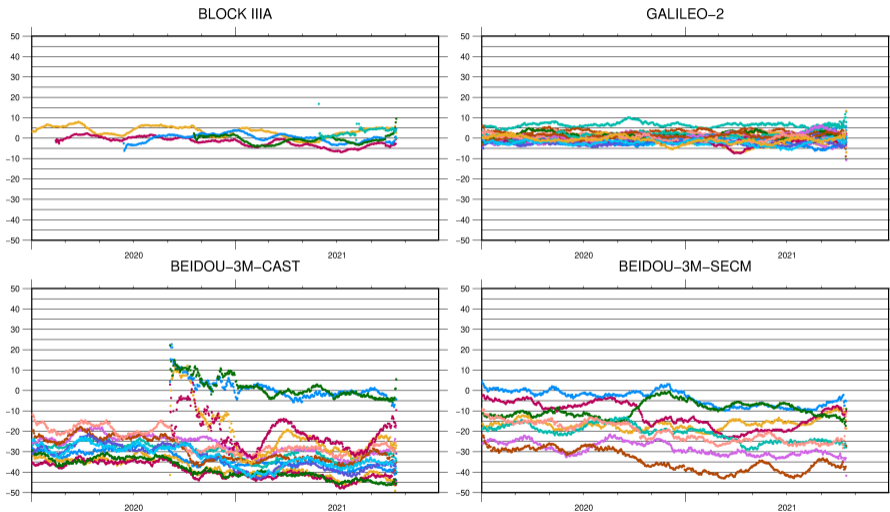
Galileo induced scale

Datum: zero mean condition over all Galileo satellite PCOs

Galileo induced scale: z-PCOs in cm



Stability over time: 30-day solutions (z-PCO in cm)



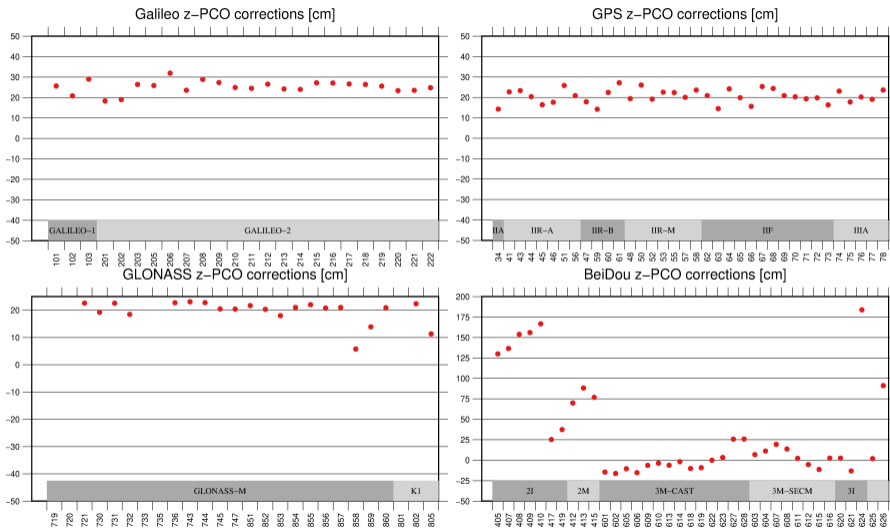
Galileo induced scale

- GPS BLOCK IIIA and Galileo PCO calibrations are compatible with each other
- Galileo and GPS PCO estimations vary between +/- 5 cm
- Non-BLOCK IIIA GPS and GLONASS PCOs values are based on Galileo scale
- High variations for BeiDou IGSO satellites (→ expected, different geometry)
- → BeiDou MEO satellites show a higher scatter (and offset)
Potential issues: network, less tracked (ca. 50% observations w.r.t. GPS) in our experiment; orbit modeling issues
- New opportunities with the disclosed PCO values. Further studies may lead to a better understanding.
- Impact of phase variations needs to be further investigated

BeiDou 3 MEO satellite induced scale

*Datum: zero mean condition over all BeiDou 3 MEO satellite PCOs
(exception of the latest two BeiDou3 satellites)*

BeiDou 3 MEO induced scale: z-PCO in cm



Percentage of observations compared to GPS

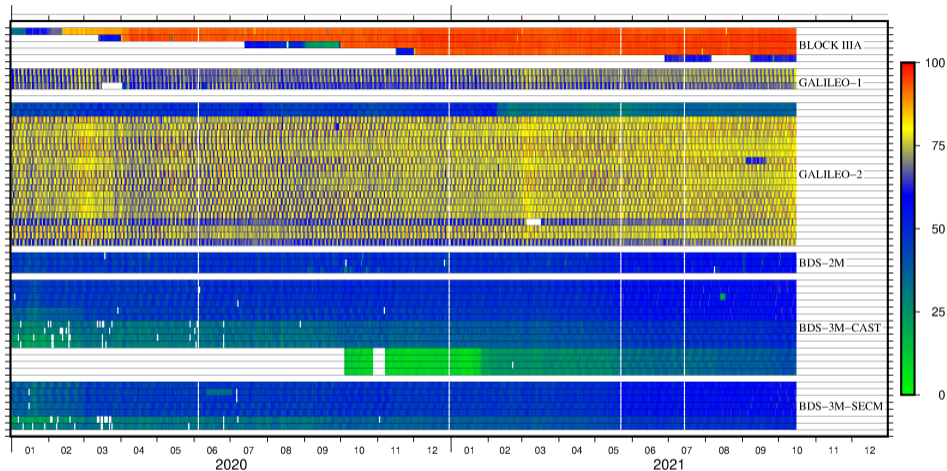


Figure: 100% is defined as the satellite with most observations per day

BeiDou 3 MEO induced scale

- The BeiDou PCO values are not consistent with the Galileo scale
- Similar findings were confirmed by other groups (e.g Qu et al. 2021, Remote Sens.)
- The PCO offsets are not constant among different satellite types
- The estimated z -PCO corrections vary much more between satellites (compared to Galileo, or compared to the Galileo case)
- BeiDou satellites are less observed compared to GPS and Galileo in our study
- IGSO satellites are less affected by scale → difficult to estimate (high correlation with satellite clock)
- Potential issues: Satellite modeling deficiencies?
→ needs still further analysis