IGS BeiDou-3 Satellite Antenna Calibration Campaign

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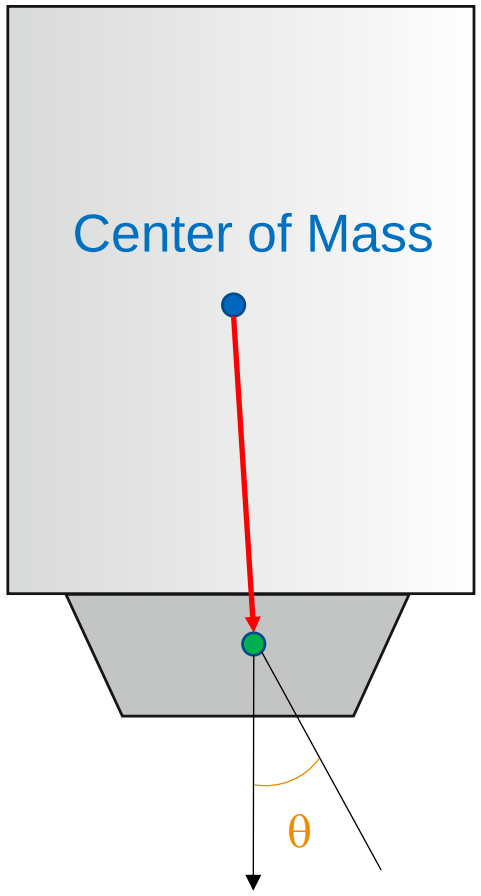
DLR

Motivation

- **Inclusion** of **BDS-3** and **QZSS** in **operational IGS products** to cover all available constellations
- Correlation of satellite antenna parameters and the **reference frame scale**
- **Consistent** set of satellite antenna phase center offsets and patterns **compatible** with the **IGS20** reference frame

GNSS Satellite Antenna Phase Center Modeling

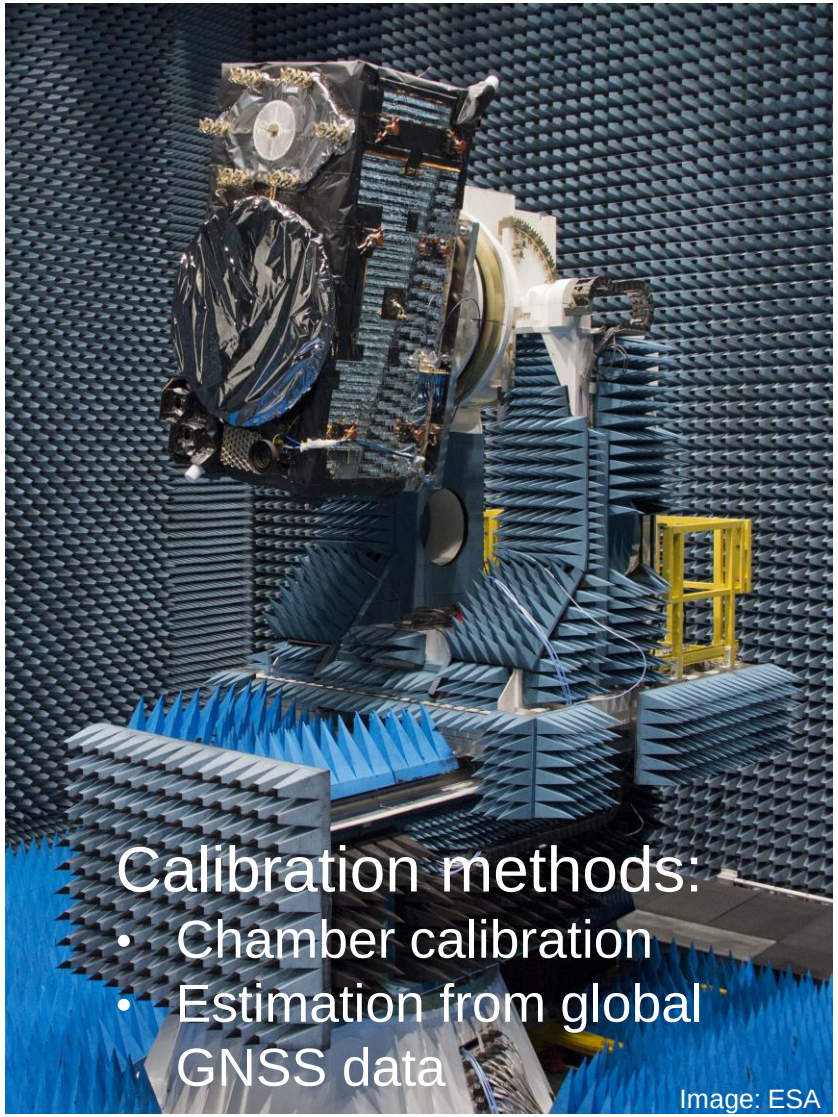


Off-boresight direction

Phase Center Offset (**PCO**)

Mean Phase Center

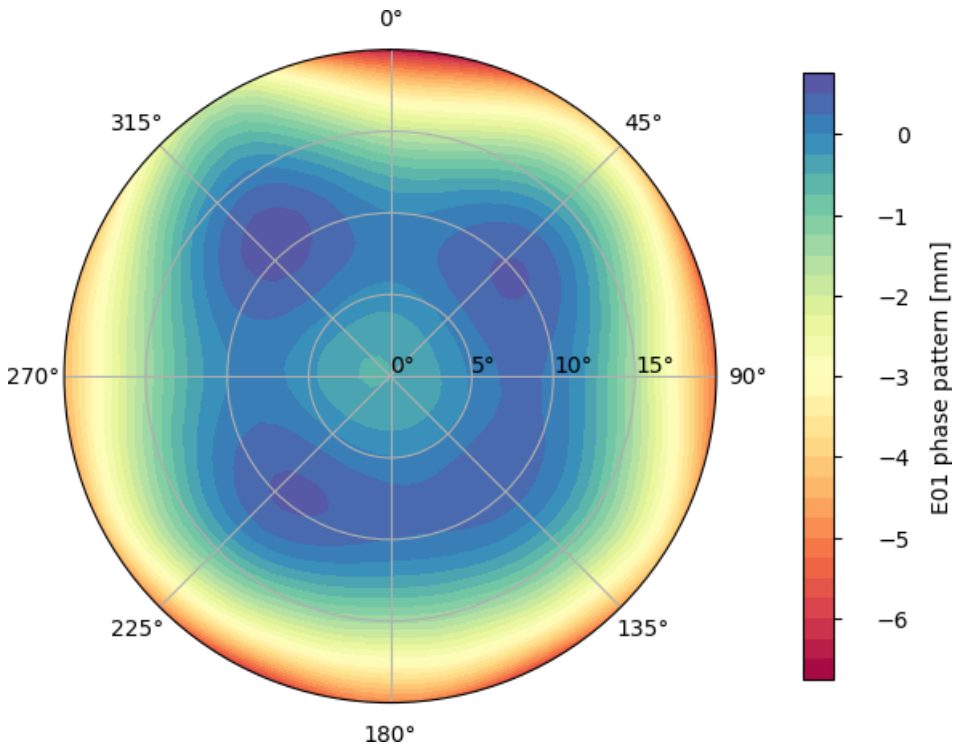
Off-boresight angle θ (and azimuth)-dependent **Phase Patterns**

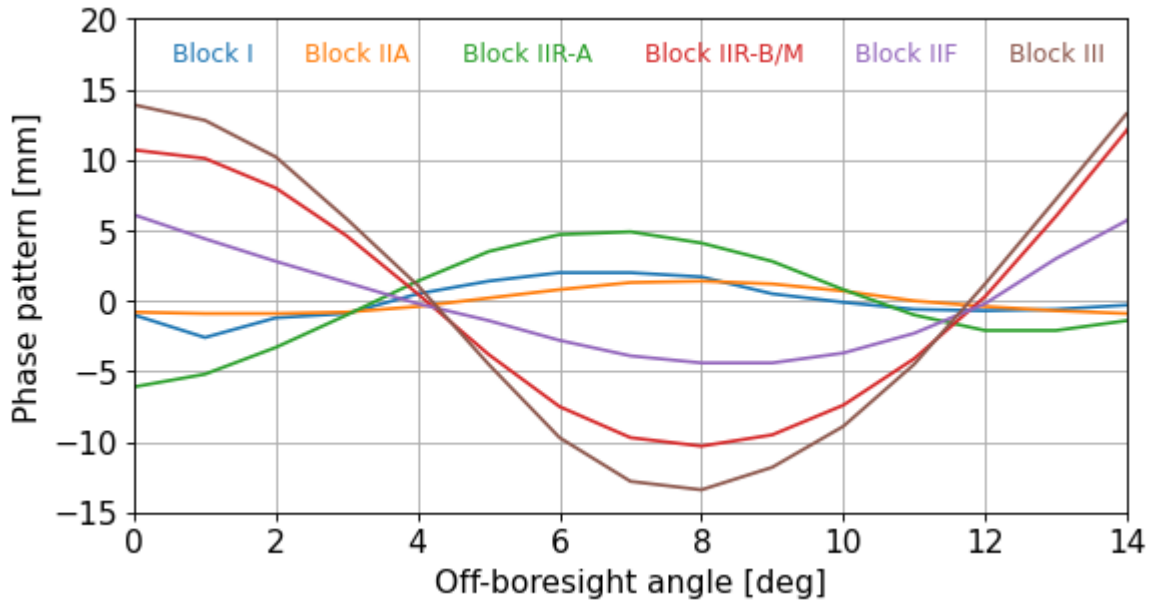


Current Status: Satellite Antenna Calibrations

Current IGS antenna phase center model: **`igs20.atx`**

Const	Phase Patterns	PCOs	IGS20
GPS	Estimated	Estimated Chamber + dZ	☑
GLO	Estimated	Estimated	☑
GAL	Chamber	Chamber + dZ	☑
BDS	--	Chamber	
QZS	Chamber	Chamber	

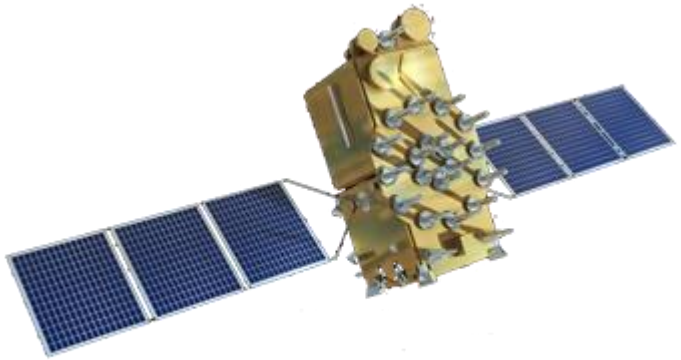




BDS-3 Satellites

Medium Earth Orbit (MEO)

Shanghai Engineering Center for Microsatellites (SECM)



China Academy of Space Technology (CAST)

Images: microsat, CSNO/TARC

Inclined Geosynchro-nous Earth Orbit (IGSO)

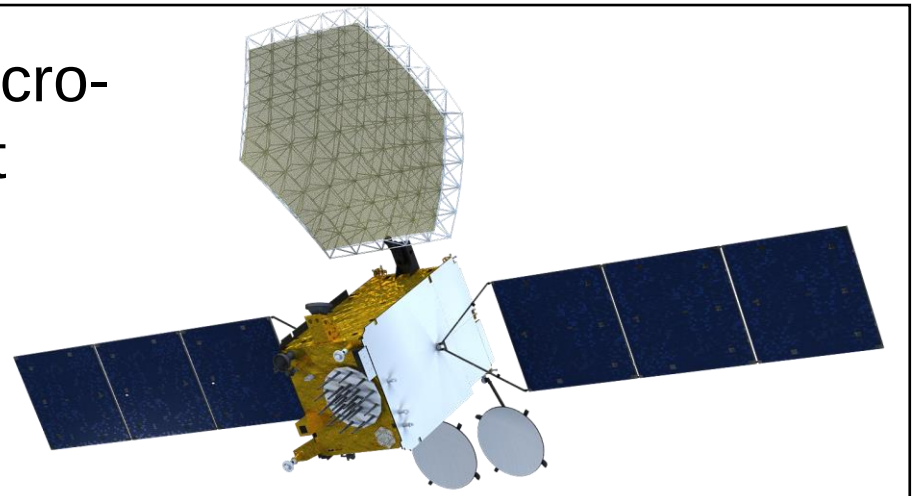


Image: CSNO/TARC

Geostationary Earth Orbit (GEO)

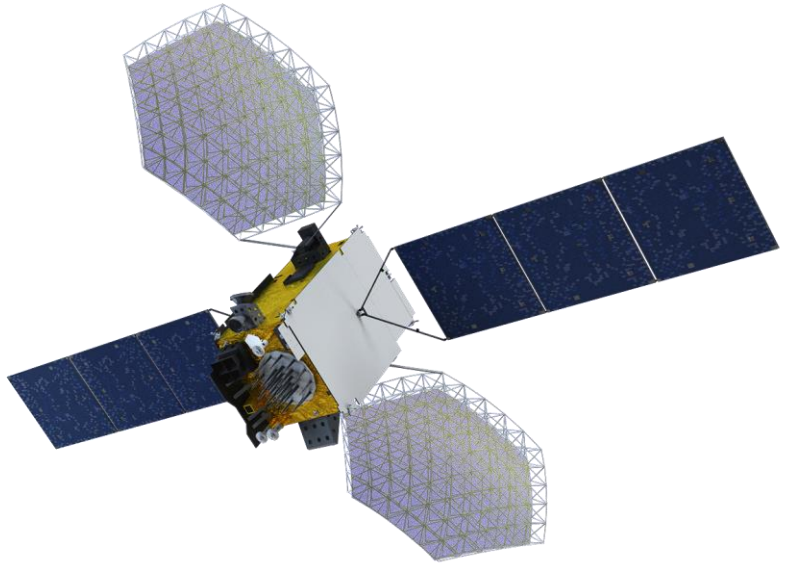


Image: CSNO/TARC

Current Status: BeiDou-3 Satellite Antenna Model

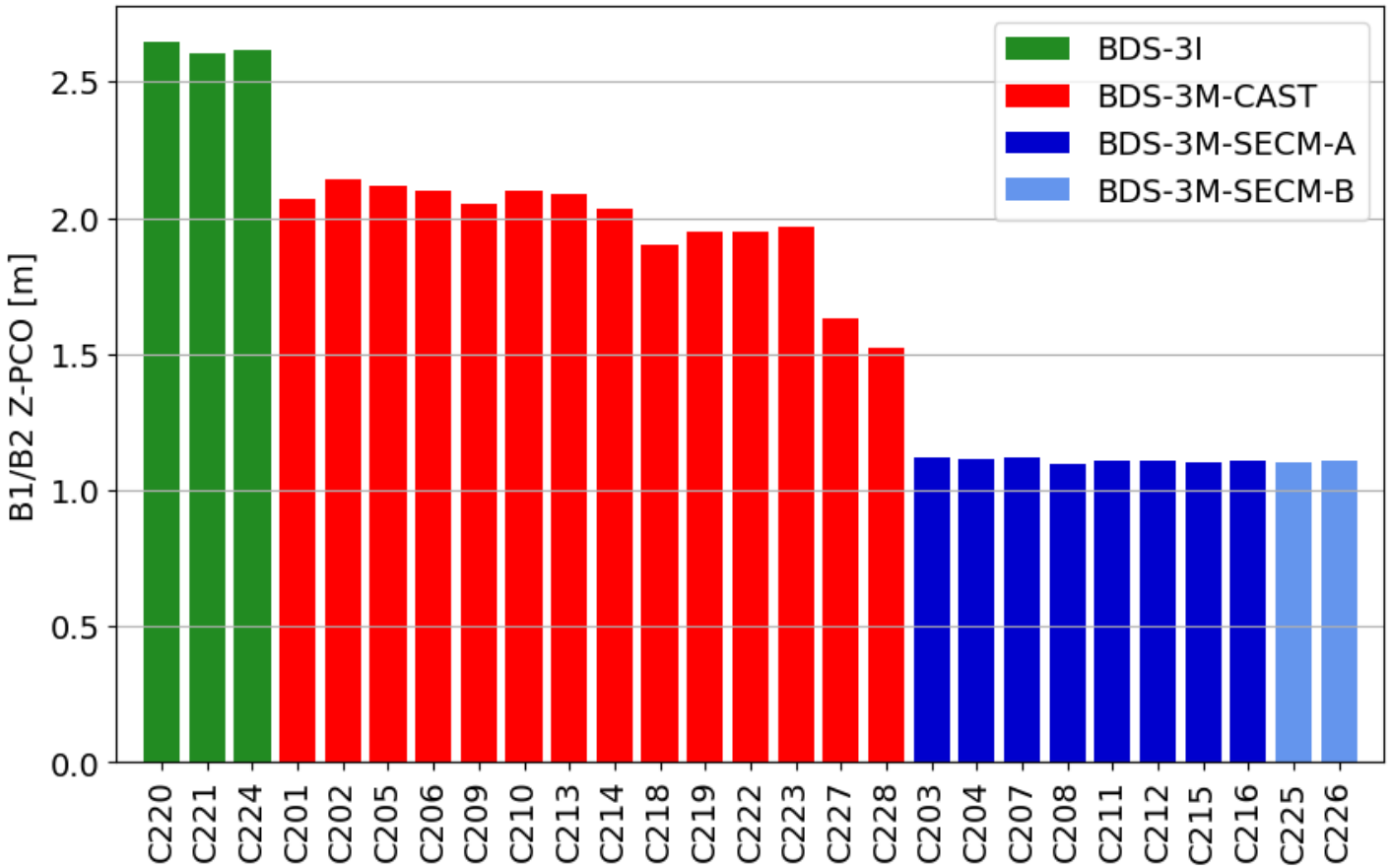
PCOs provided by the Test and Assessment Research Center (TARC) of the China Satellite Navigation Office (CSNO)

- B1, B2, B3 frequencies
- No phase patterns
- Recent satellites missing

Signal	BDS-2	BDS-3
B1I	**X**	**X**
B2I	X	
B3I	**X**	**X**
B1C		**X**
B2a		**X**
B2b		X

MGEX (current)

IGS (future)



IGS BDS/QZSS Satellite Antenna Calibration Campaign

Initiated by Reference Frame Committee with support from MGEX Pilot Project and Antenna Committee

Step 1: Estimation of BDS-3 **phase patterns** (see IGS Workshop 2024)

Step 2: Estimation of BDS-3 and QZSS **phase center offsets**

Step 3: Evaluation of **impact on** IGS OPS **products**

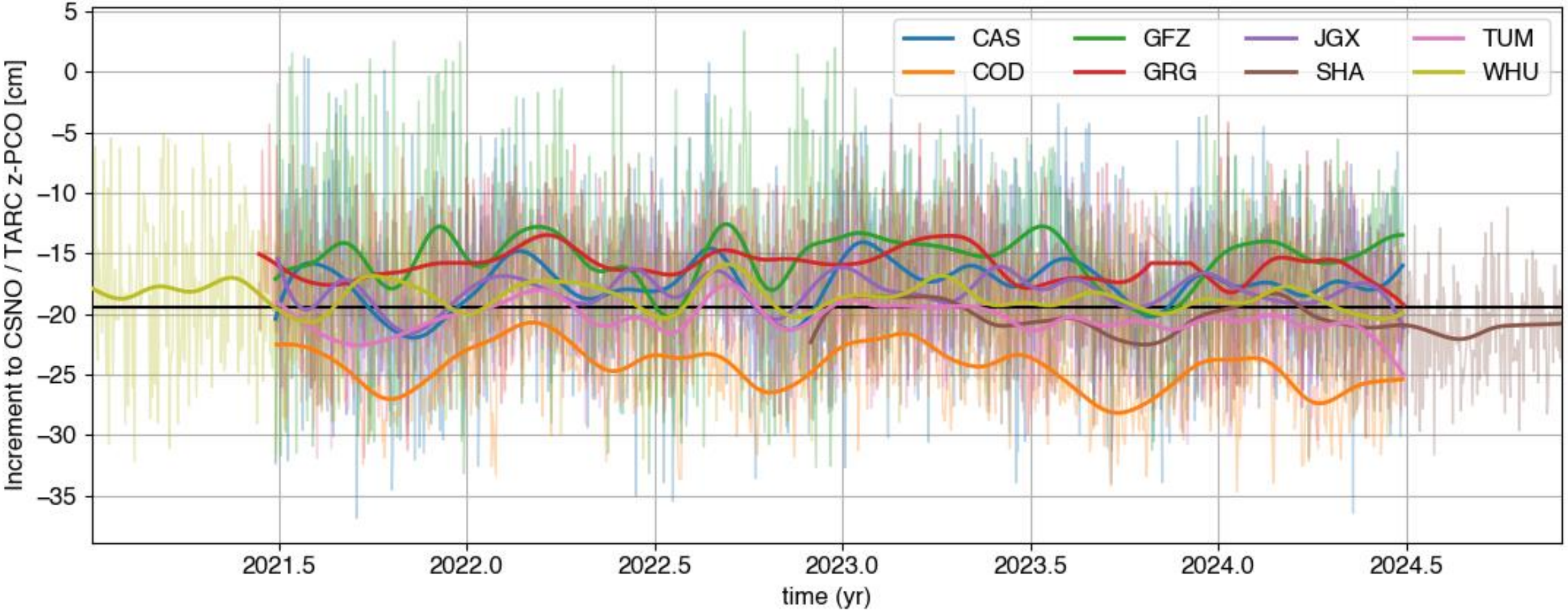
Phase Center Offset Estimation

- Consistent with IGS20 reference frame
- 2.5 – 3 years period (July 2021 – June 2024)
- Signal selection
  - BeiDou-3: B1C/B2a
- SINEX files
  - Station coordinates, ERPs, PCOs

Abb.	Analysis Center
CAS	Chinese Academy of Sciences
COD	Center for Orbit Determination in Europe
GFZ	Helmholtz Centre for Geosciences
GRG	CNES/CLS
JGX	Japanese Aerospace Exploration Agency Geospatial Information Authority of Japan
SHA	Shanghai Observatory
TUM	Technische Universtität München
WHU	Wuhan University

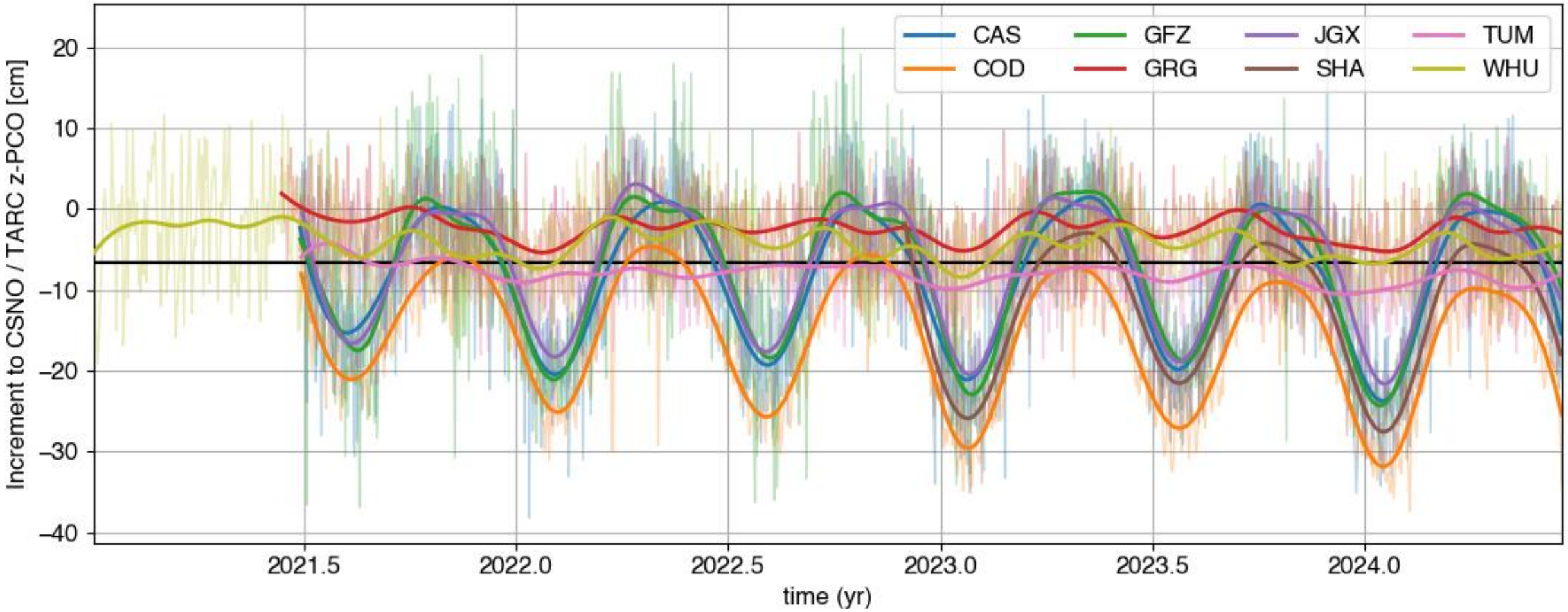
Z-PCO Time Series

C202 MEO CAST: typical well-performing satellite



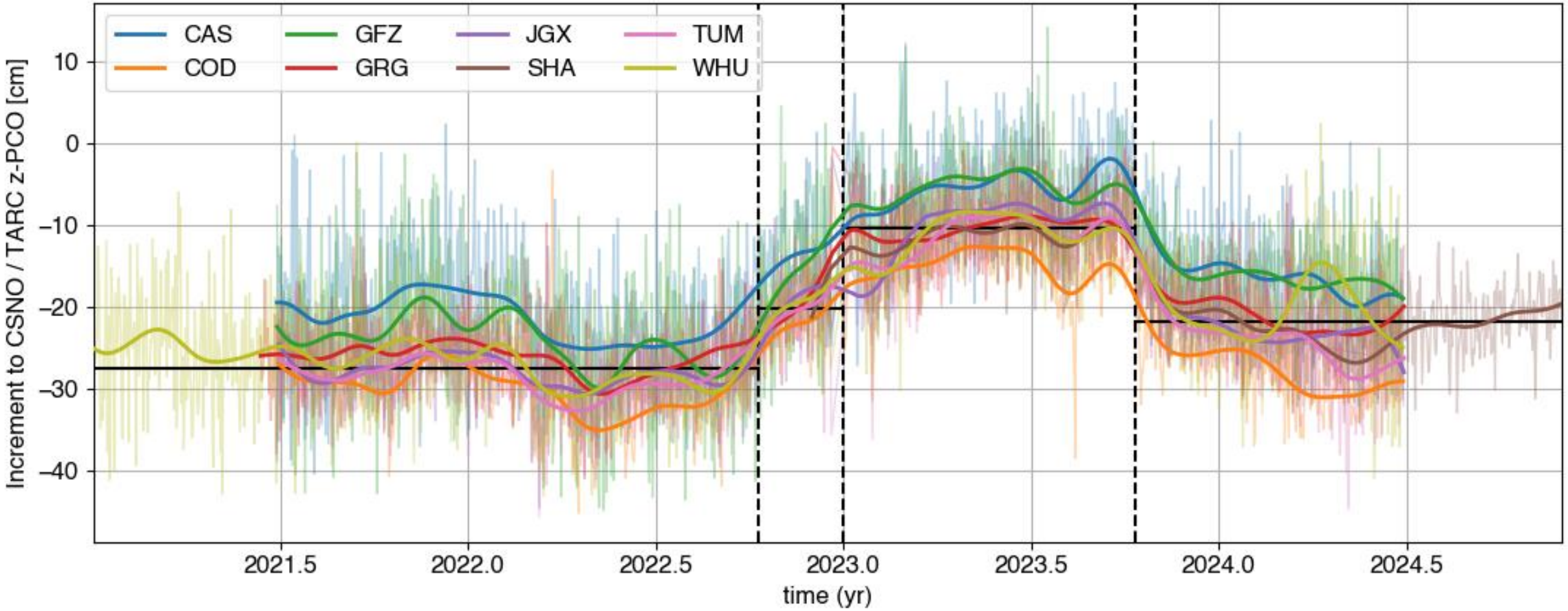
Z-PCO Time Series

C222 MEO: orbit modeling deficiencies of some ACs



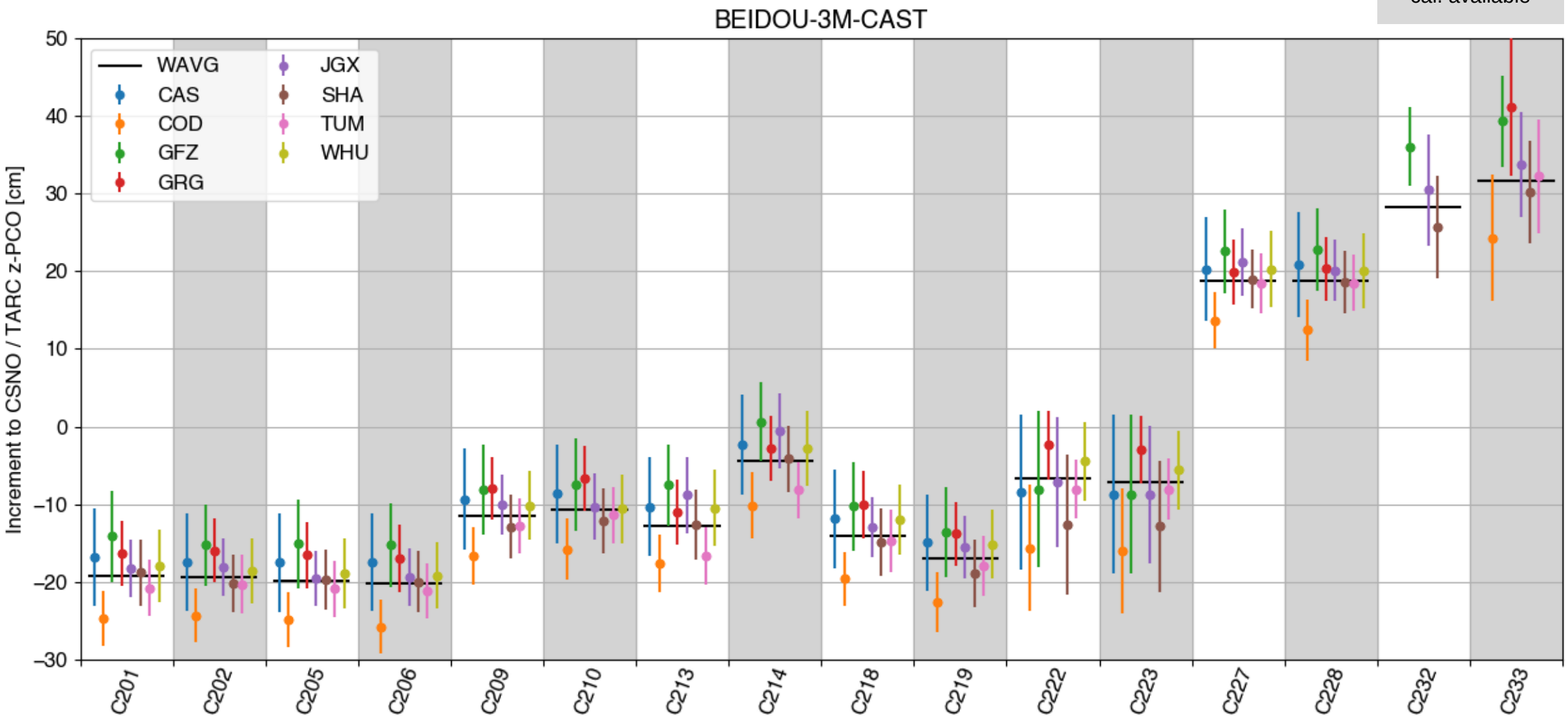
Z-PCO Time Series

C215 MEO SECM

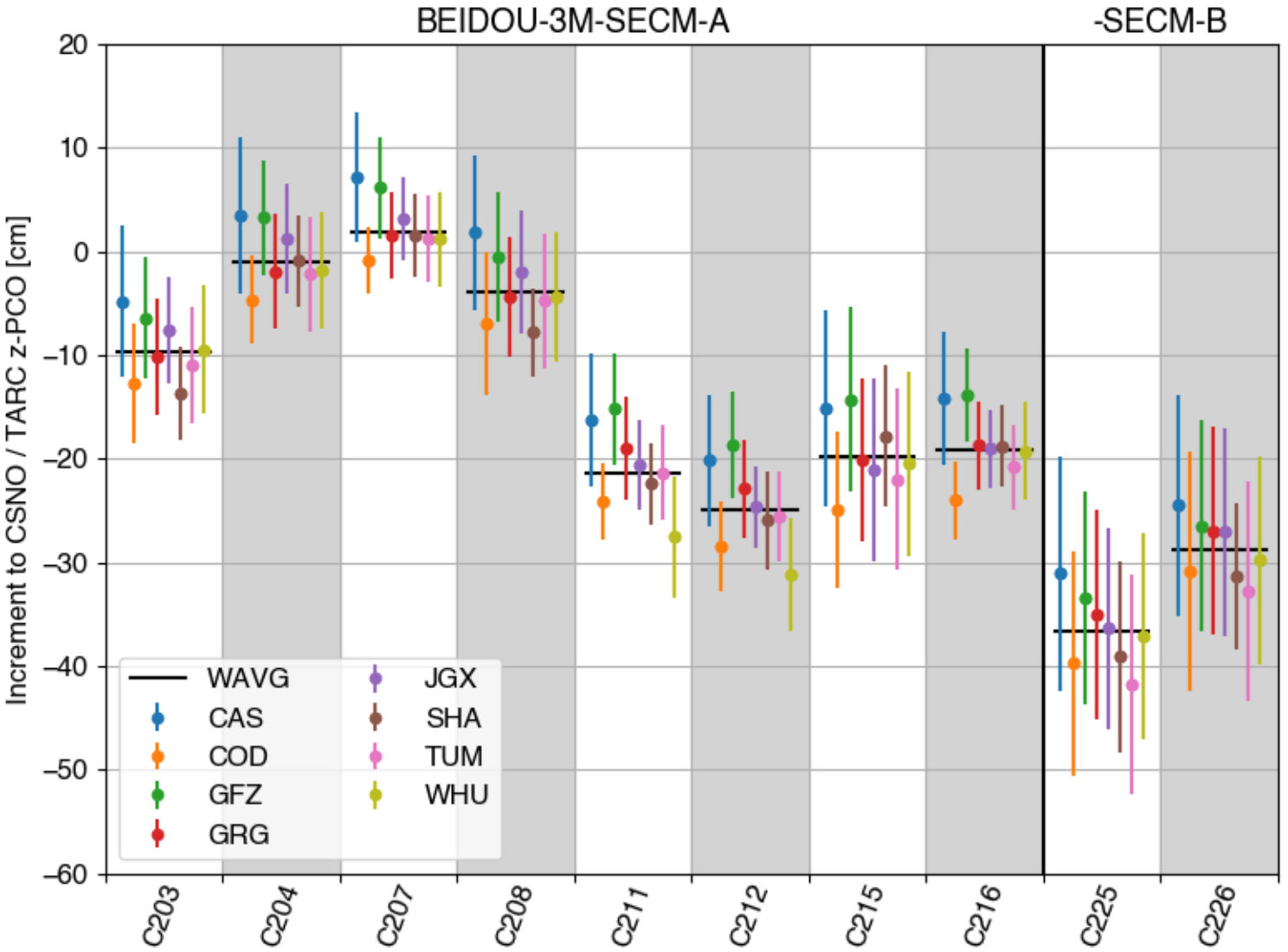


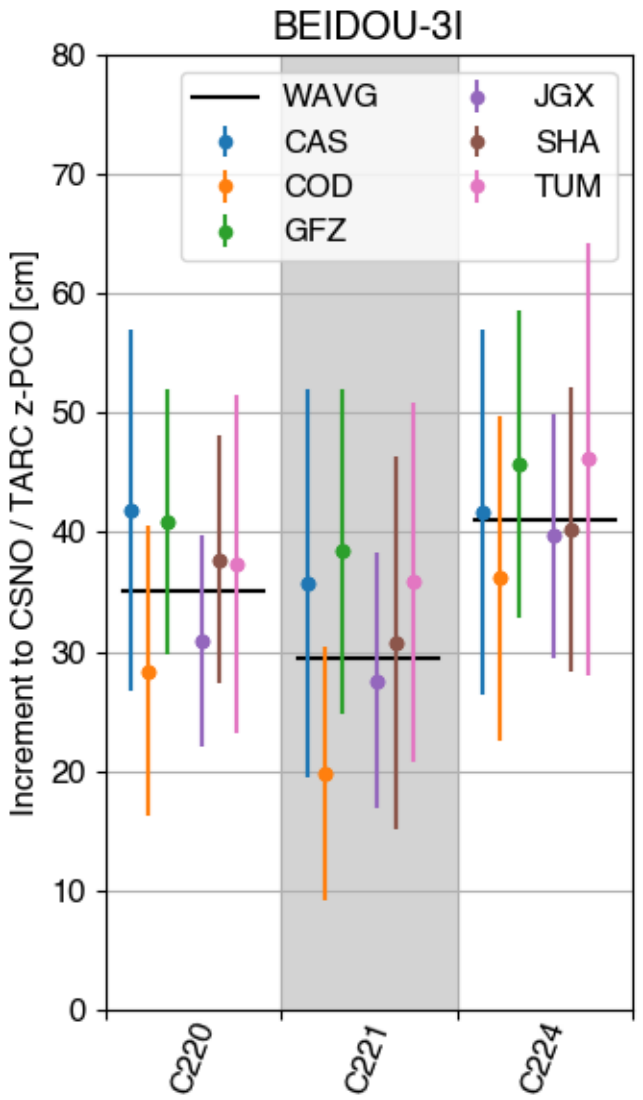
Mean Z-PCOs: CAST

No CSNO/TARC cal. available



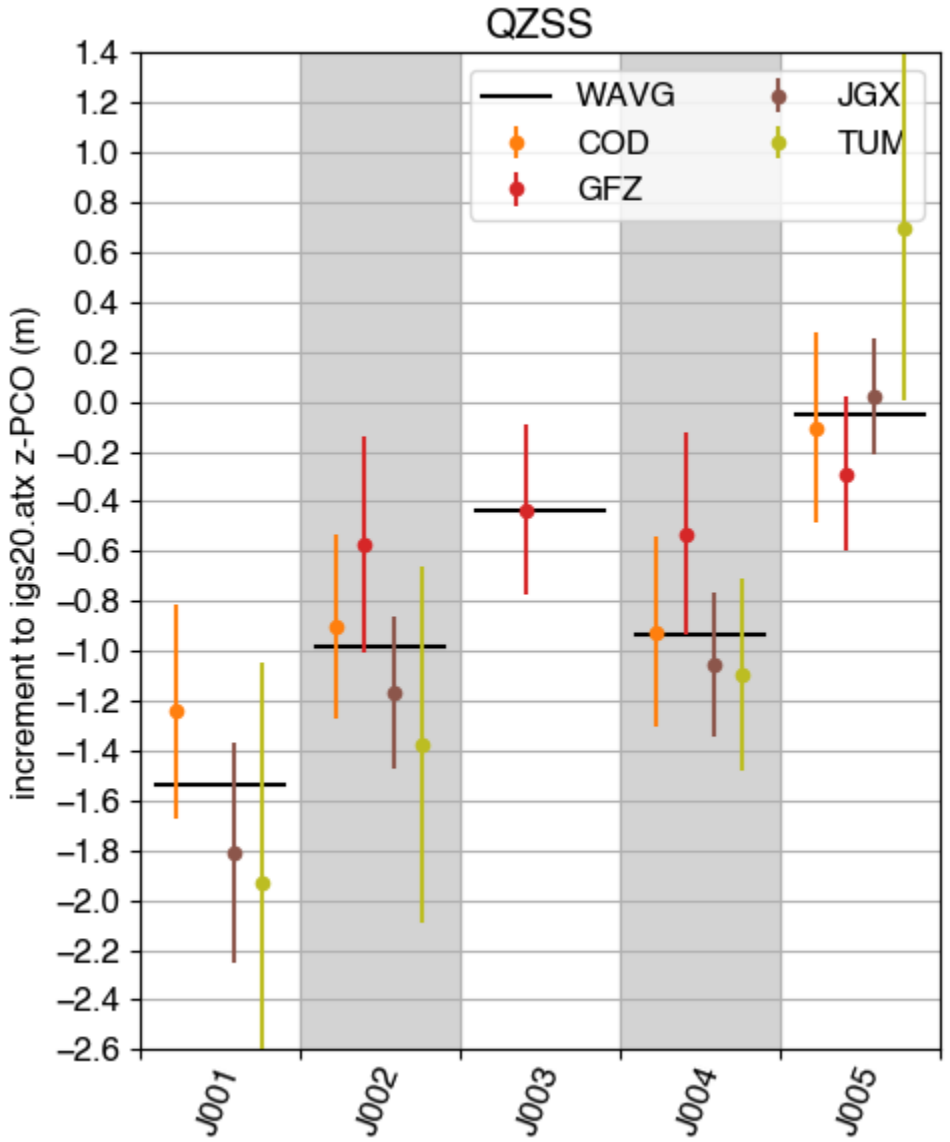
Mean Z-PCOs: SECM and IGSO





QZSS Antenna Model

- igs20.atx contains satellite-specific L1/L2/L5/L6 phase patterns (except for QZS-1) and PCOs provided by Cabinet Office, Government of Japan (CAO)
- Estimation of satellite-specific L1/L5 Z-PCOs
  - Large and unexplained differences for J001, J002, and J004
- New model:
  - Limited to L1/L5 (no L2 for Block III satellites)
  - Phase patterns by CAO
  - J001, J002, J004: CAO X/Y-PCOs, estimated L1/L5 Z-PCOs for L1 and L5
  - J003, J005, J007: keep CAO values



Evaluation of Impact on Operational IGS Products

- Evaluation to be carried out on a **case-by-case basis**, i.e., every time an AC wishes to add BDS-3 and/or QZSS in their operational products
- **Parallel** “OPS+” **solution** series to be generated, preferably with detailed levels of extension, e.g., +BDS MEOs, +BDS MEOs/IGSOs, +BDS MEOs/IGSOs + QZSS, …
- Evaluation of **impact on SINEX products** by Reference Frame Committee
- Evaluation of **impact on** (GPS, GLO, GAL) **orbit/clock products** by ACC
- **Final decision** on incorporation of new GNSSs into OPS products of individual ACs

Summary

- New antenna model for BDS-3 IGSO and MEO satellites
  - Based on estimates from B1C/B2a observations
    - Block-specific phase patterns
    - Satellite-specific z-PCOs
  - Aligned to IGS20 reference frame scale
  - Z-PCO corrections of -50 … +30 cm for MEO satellites
- Partly new antenna model for QZSS
- Updated igs20.atx model available at
  - https://files.igs.org/pub/resource/working_groups/antenna/igs20_test.atx
- Next steps
  - Inclusion of new models in operational igs20.atx
  - Evaluation of impact on operational IGS products (at ACs' request)
  - Inclusion of BDS-3 and QZSS in operational IGS products