BeiDou Orbits and Clocks

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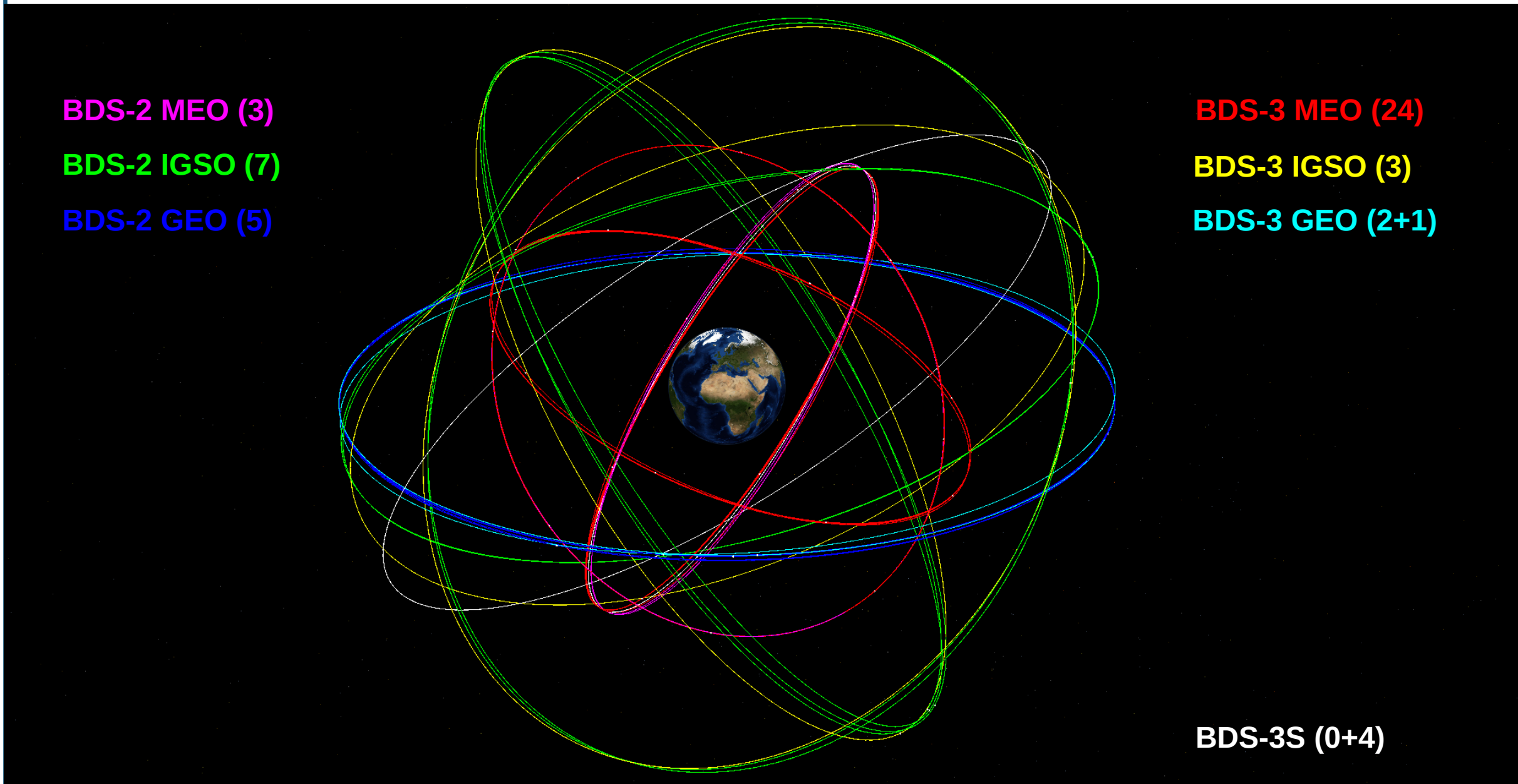
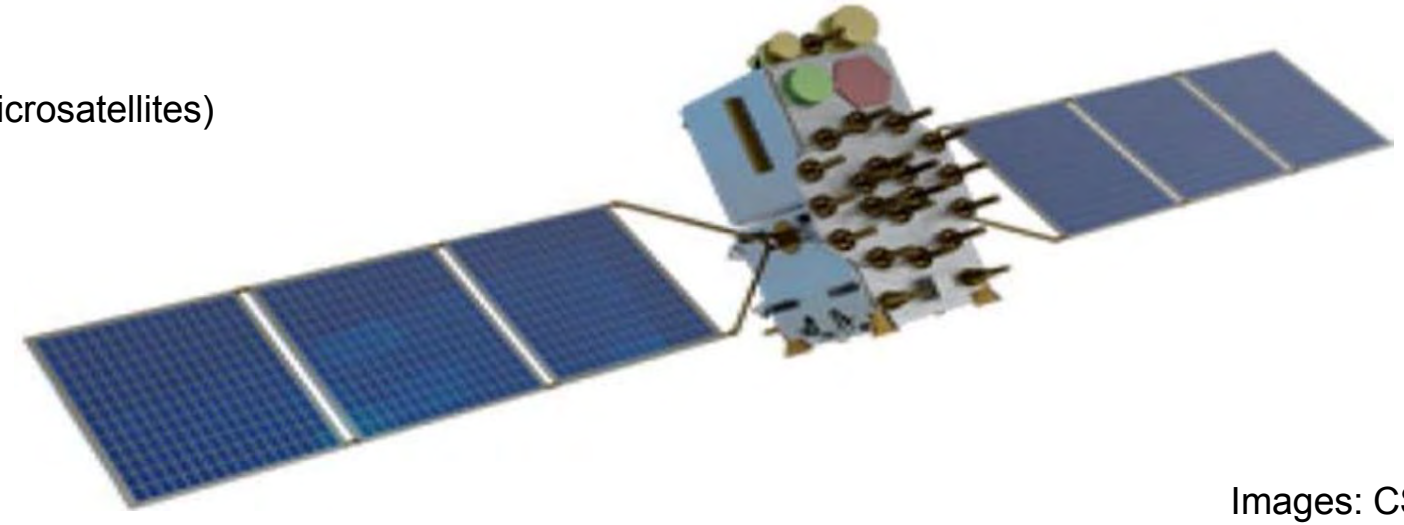
Current BeiDou Constellation



BeiDou-3 MEO Satellites

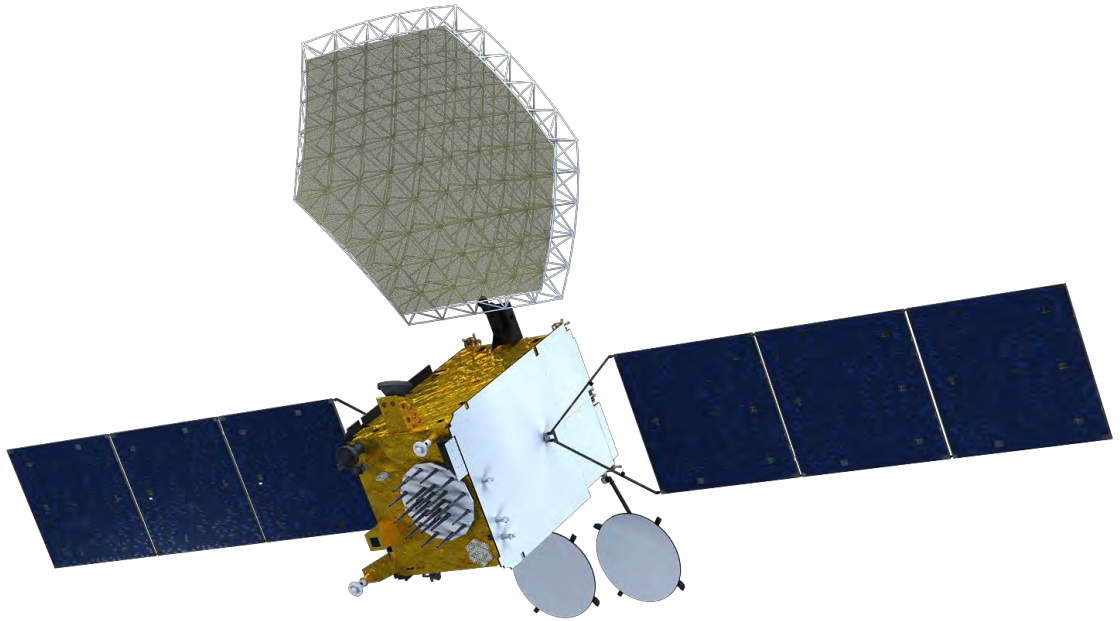
MEO CAST
(China Academy of Space Technology)

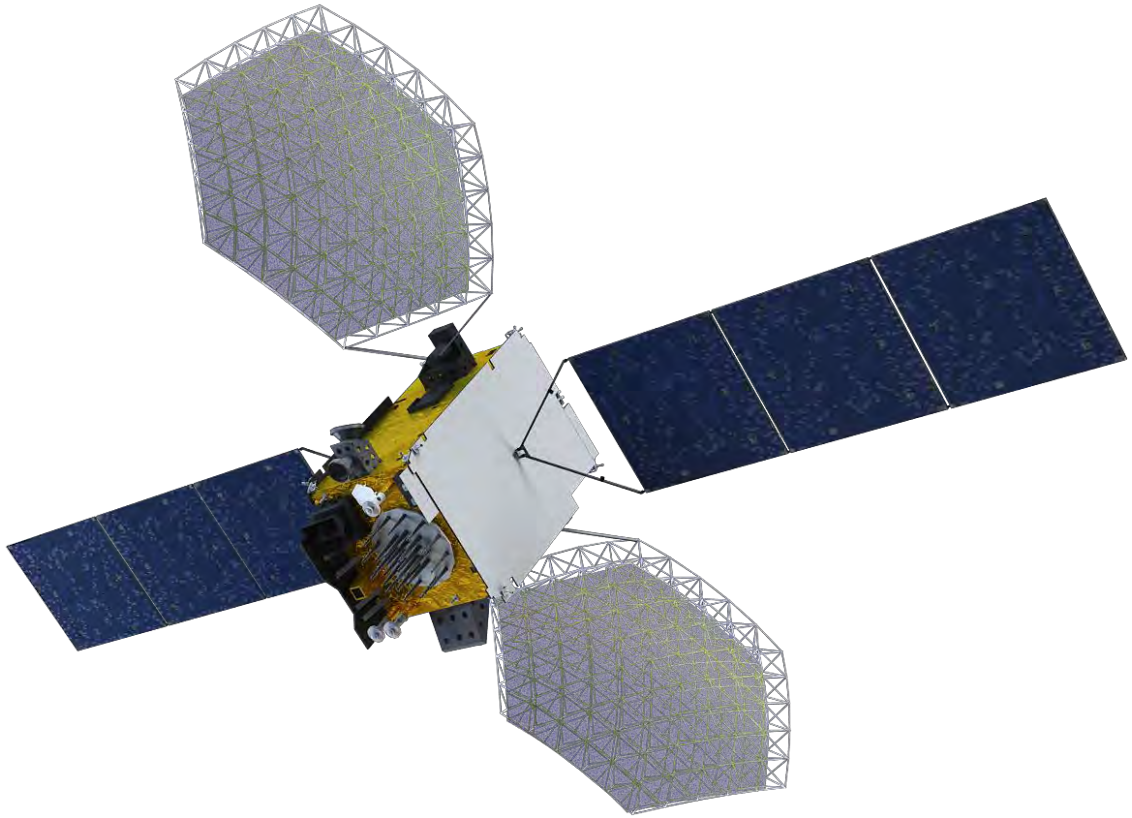
MEO SECM
(Shanghai Engineering Center for Microsatellites)



Images: CSNO/TARC; SECM

BeiDou-3 IGSO and GEO Satellites





Images: CSNO/TARC

MGEX Analysis Centers

Five out of seven analysis center of the Multi-GNSS Pilot Project (MGEX) provide BeiDou-2 and BeiDou-3 orbit and clock products

Abb.	Institution	Type	MEO	IGSO	GEO
CODE	Center for Orbit Determination in Europe	FIN	x	x	
GFZ	Deutsches GeoForschungsZentrum	RAP	x	x	x
IAC	Information and Analysis Center	FIN	x	x	x
SHAO	Shanghai Observatory	RAP	x	x	x
WU	Wuhan University	FIN	x	x	(x)

Selected BDS-3 Modeling Options

IGS INTERNATIONAL GNSS SERVICE

Abb.	CODE	GFZ	IAC	SHAO	WU
Arc length	72 h	24 h	48 h	24 h	24 h
A priori SRP	None	None	Box-wing	Box-wing	Box-wing
SRP param.	ECOM-2	ECOM	ECOM-based	ECOM	ECOM
	D0,Y0,B0,BC,BS, D2C, D2S	D0,Y0,B0,BC,BS	Sc,Y0,BC,BS $\lvert\beta\rvert < 5°$ D0, B0 $\lvert\beta\rvert > 5°$ D1C, D1S	D0,Y0,B0,BC,BS	D0,Y0,B0,BC,BS
Albedo/IR	--	--	X	--	X

Orbit Signal-in-Space Range Error

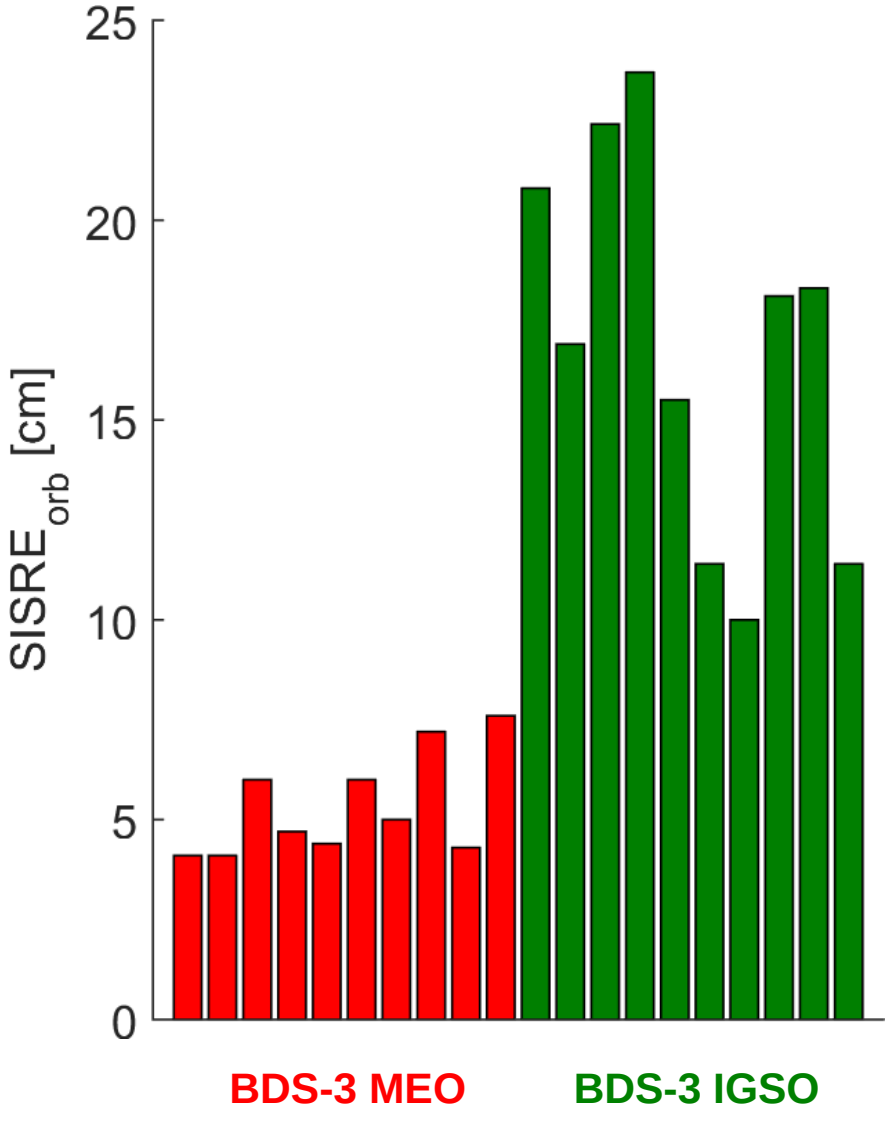
$$\mathrm{SISRE_{orb}} = \sqrt{w_1^2 R^2 + w_2^2 \left(A^2 + C^2\right)}$$

computed from RMS orbit differences:

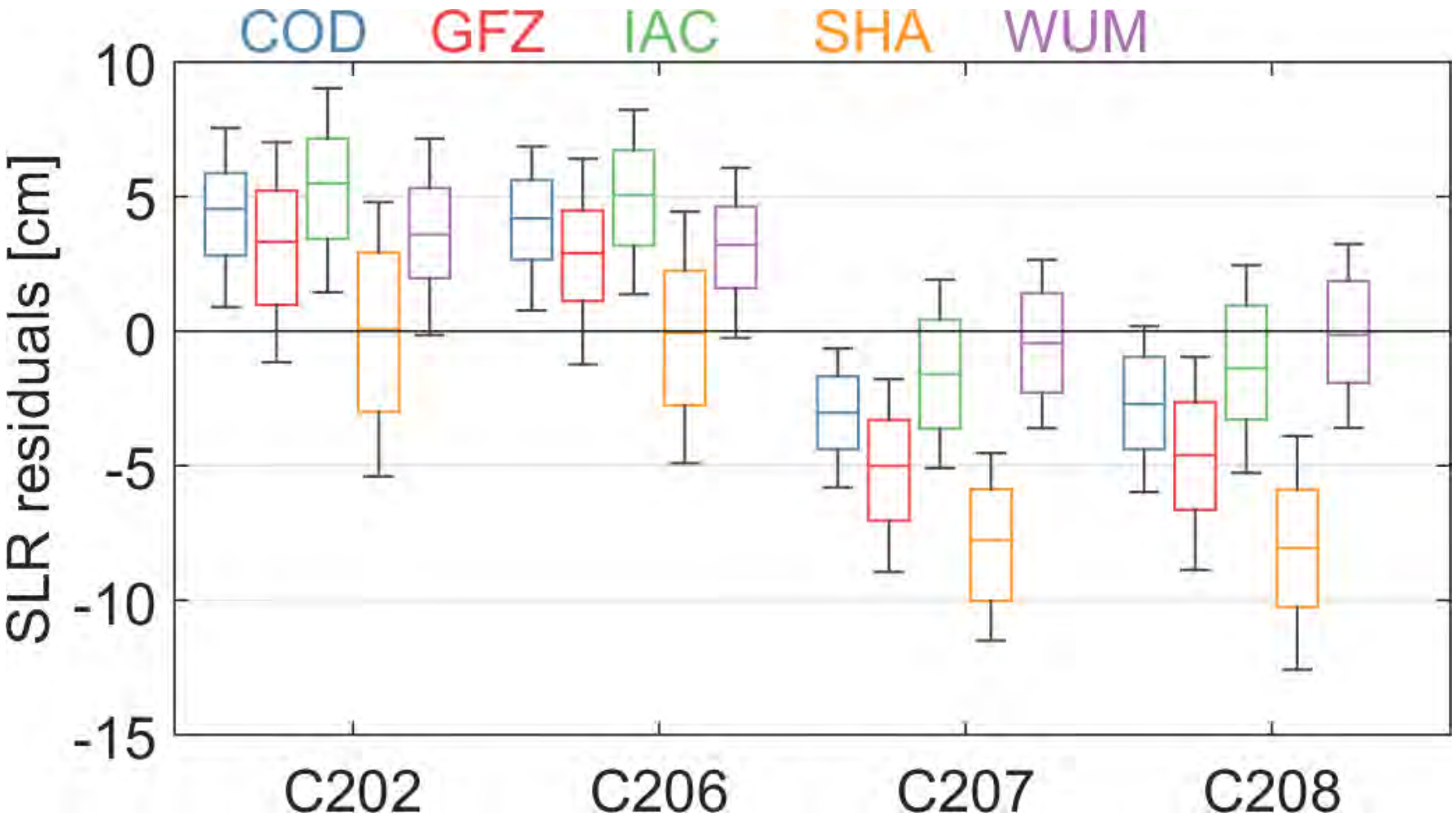
R	radial
A	along-track
C	cross-track

and weighting factors $w_1,\ w_2$

between pairs of analysis centers

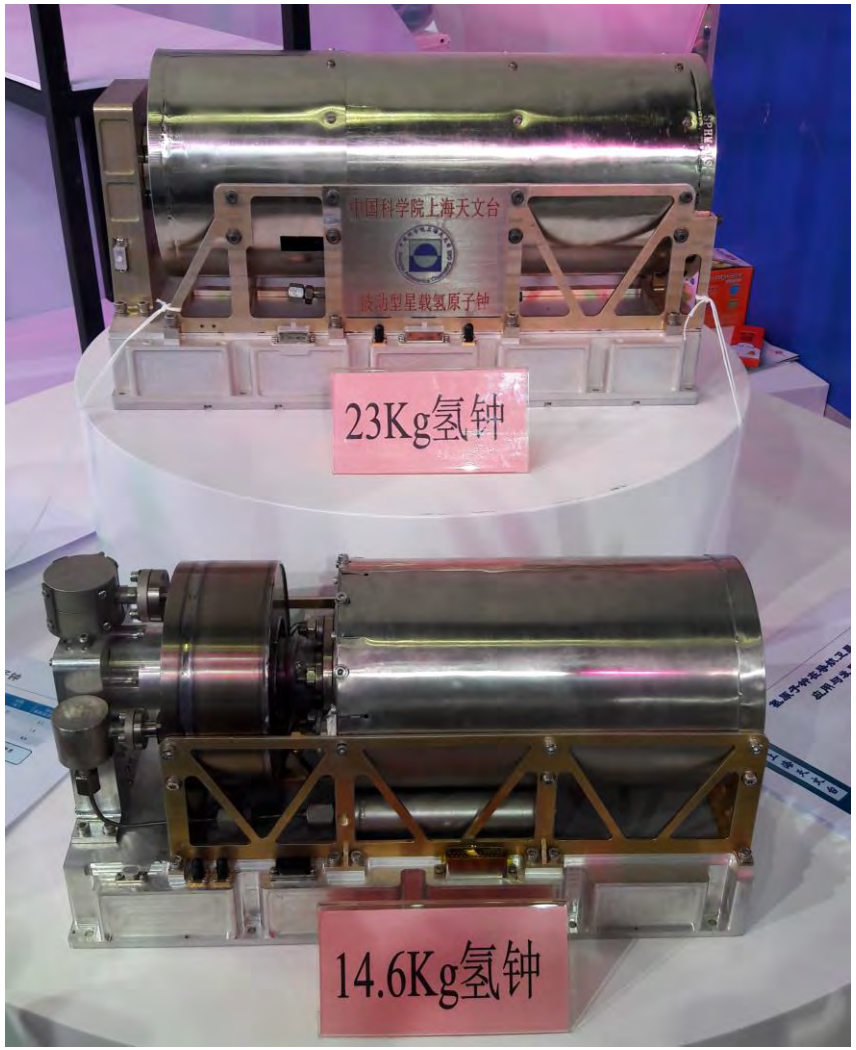


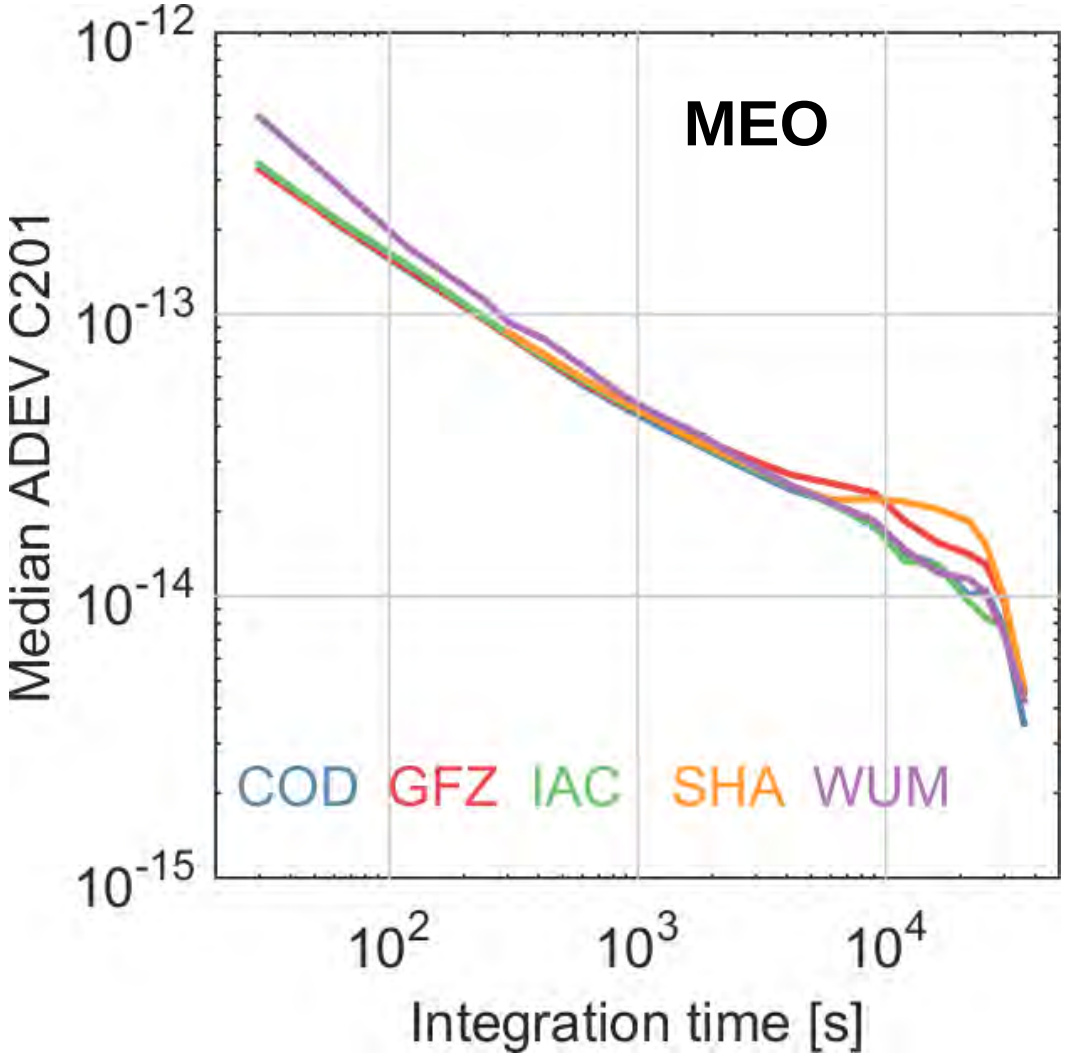
BeiDou-3 Satellite Laser Ranging Residuals



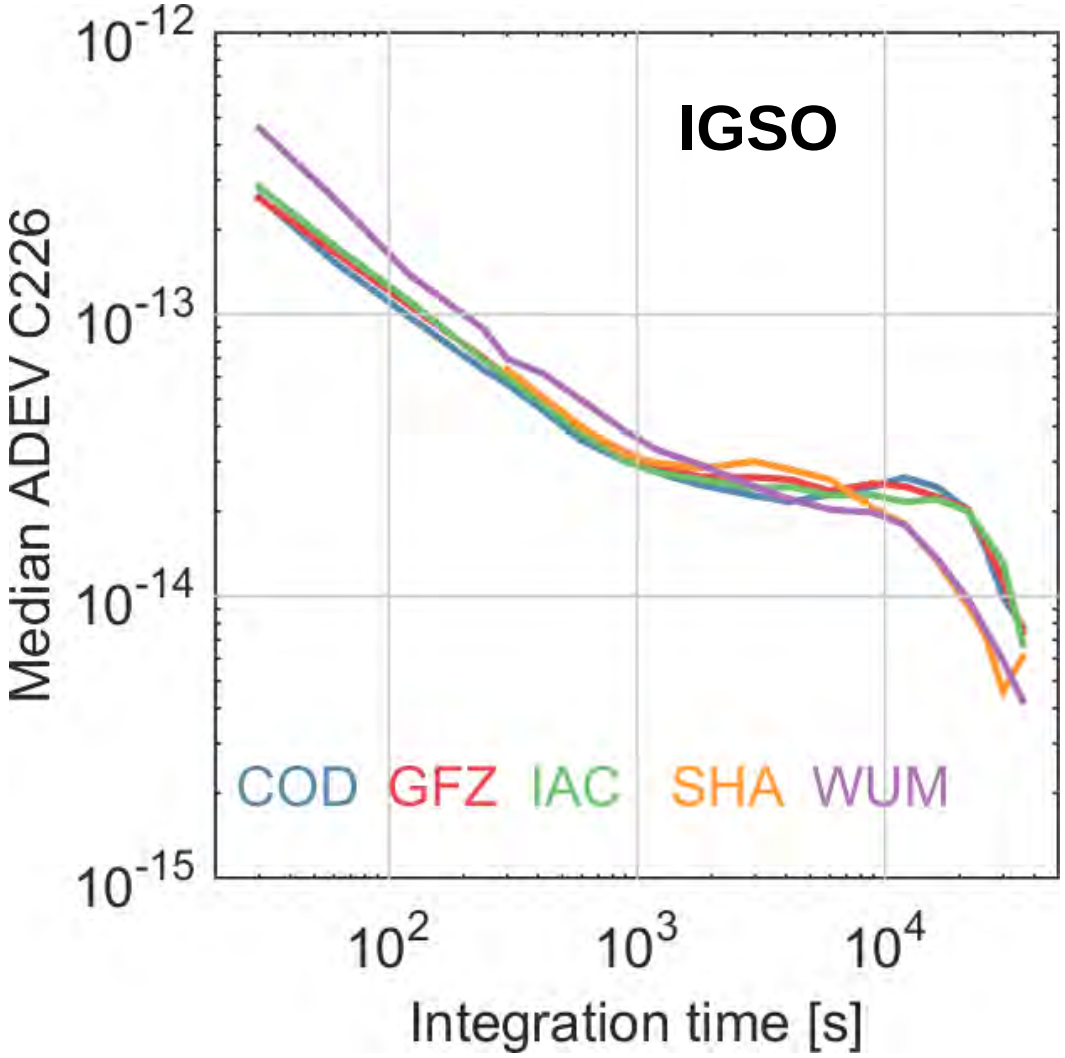
MEO CAST **MEO SECM**

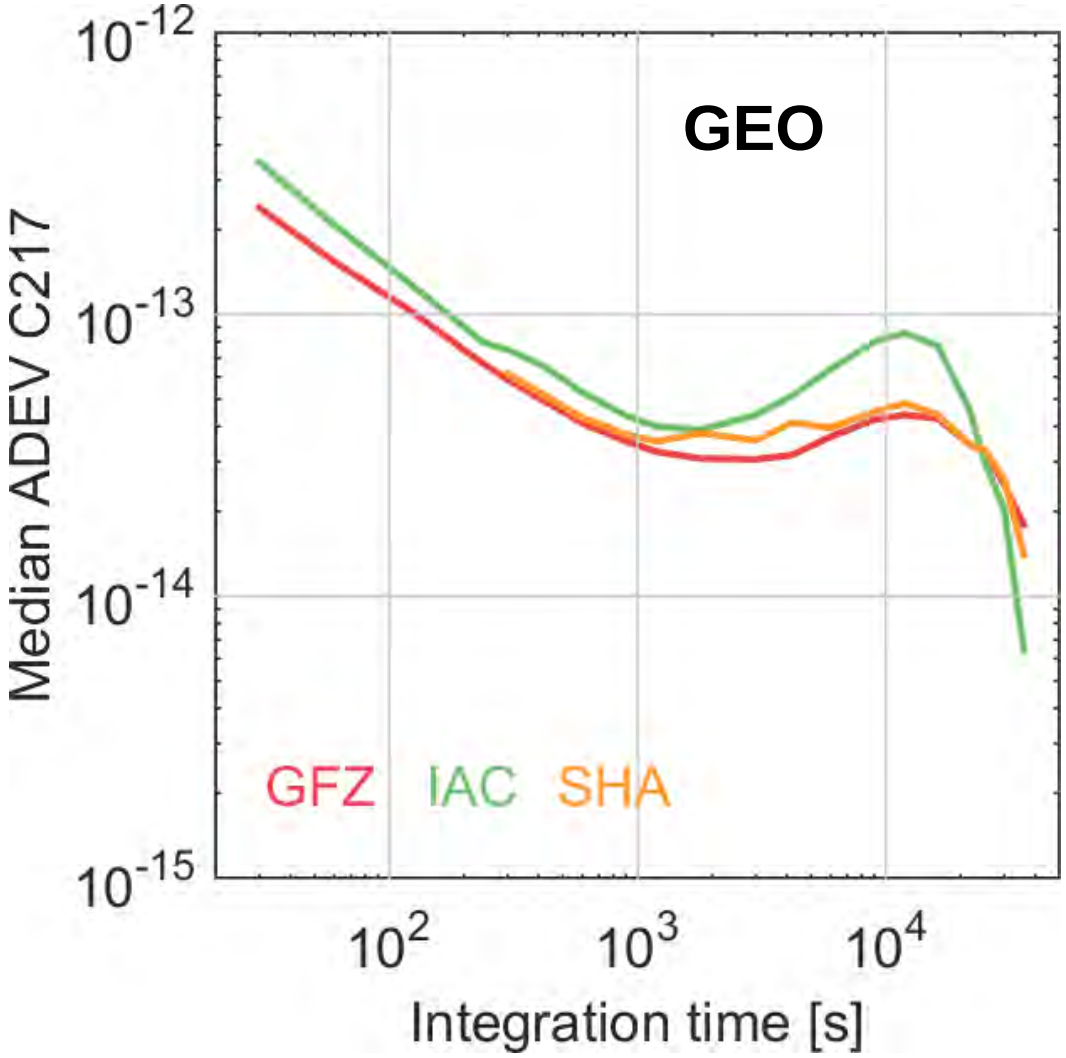
BeiDou-3 Satellite Clocks



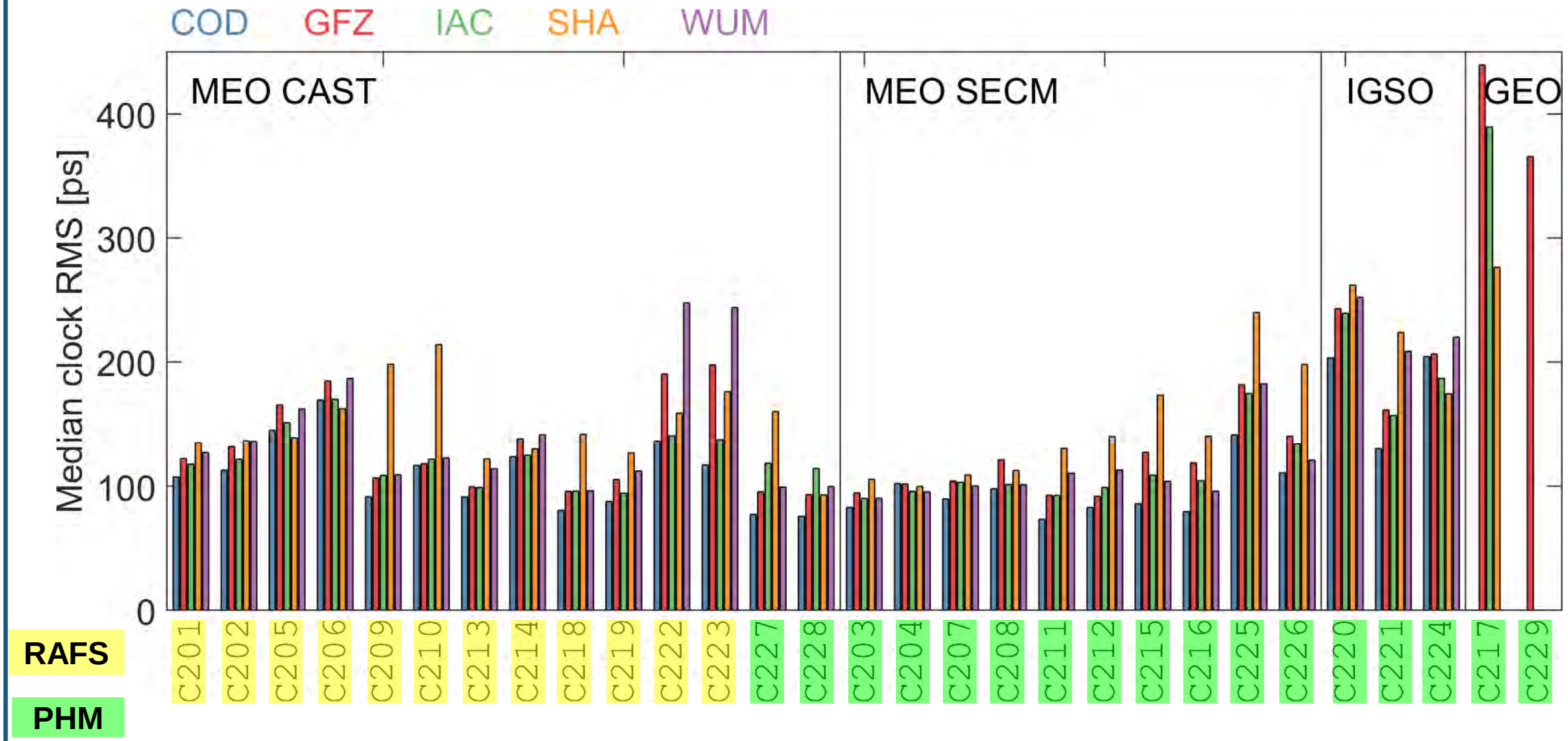


BeiDou-3 Satellite Clocks





BeiDou-3 Satellite Clocks

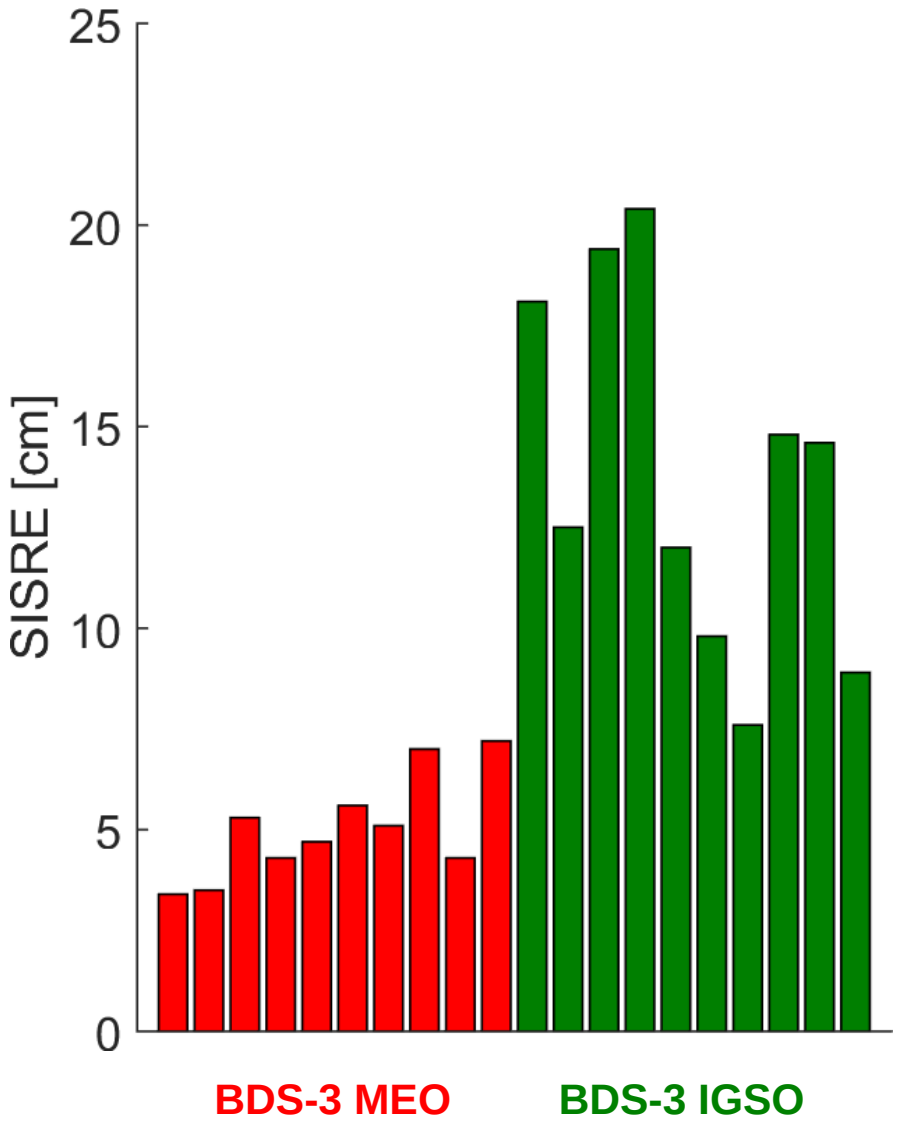


Signal-in-Space Range Error

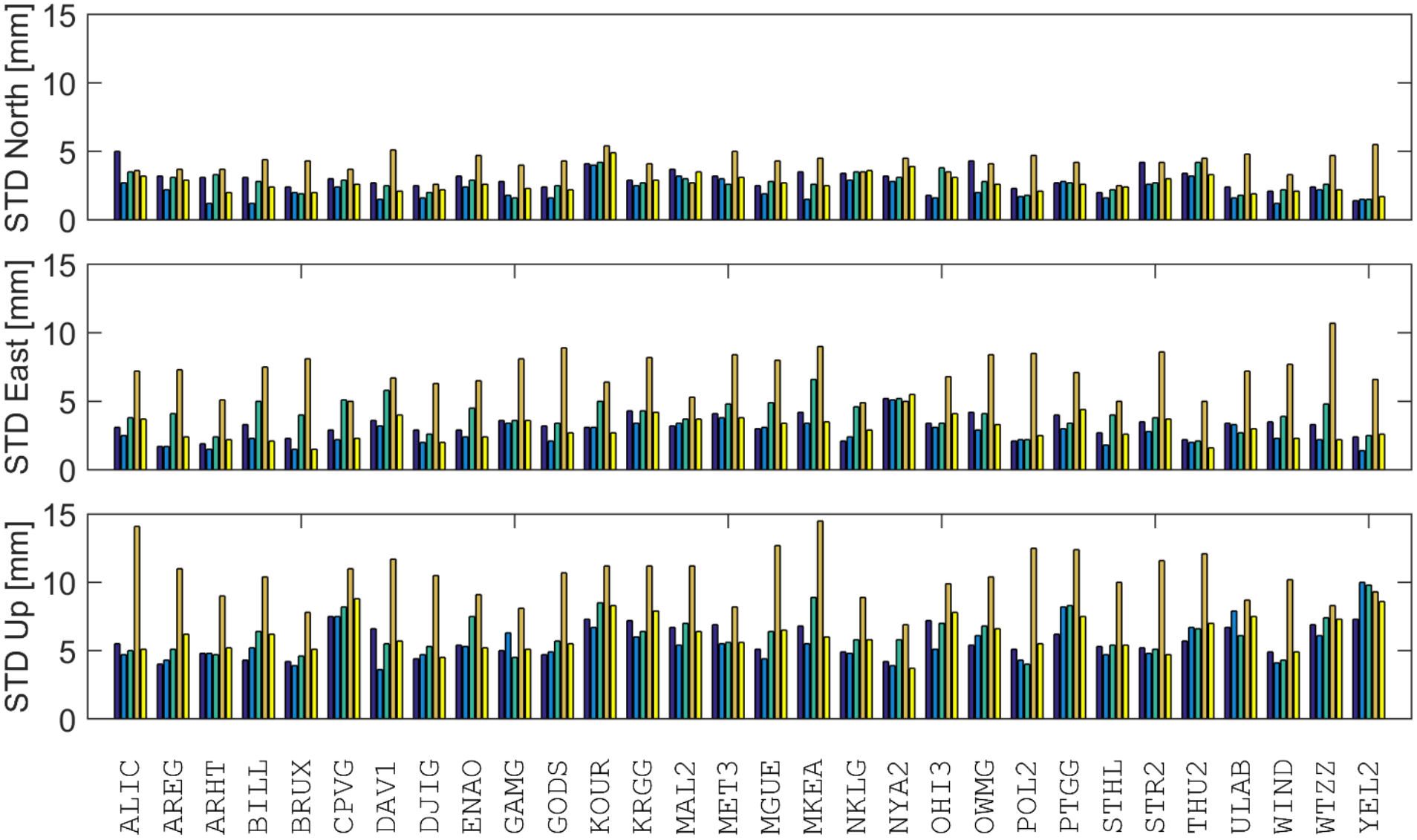
$$\mathrm{SISRE} = \sqrt{w_1^2 R^2 - 2 w_1 R T + T^2 + w_2^2 \left(A^2 + C^2\right)}$$

T clock differences

compensation of orbit-related errors by corresponding errors in the estimated satellite clocks



Precise Point Positioning Performance



- December 2021
- 30 stations
- BDS-3 MEO
- Daily coordinates

Average 1-σ repeatability per AC:

- N: 2 – 4 mm
- E: 3 – 7 mm
- U: 5 – 11 mm
- 3D: 7 – 13 mm

COD GFZ
IAC SHA
WUM

Summary and Conclusions

- 5 IGS analysis center provide BeiDou orbit and clock products
- Processing options not as homogeneous as for other constellations
- BDS-3 MEO orbit **consistency** on the **4-8 cm** level, SLR residuals have RMS values of **3-9 cm**
- **Extended** coverage of **SLR tracking** of the BDS-3 constellation is strongly encouraged
- **Solar radiation pressure** modeling is **challenging**, in particular for IGSO and GEO satellites
- **Incomplete** set of **satellite metadata** available, publication of further data encouraged
- BeiDou-3 is a complement to GPS and other GNSSs and can already make valuable contributions to geodesy and precise positioning

Resources

- IGS MGEX Products: https://igs.org/mgex/data-products/#orbit_clock
- BeiDou Satellite Parameters: http://www.csno-tarc.cn/en/datacenter/satelliteparameters
- Steigenberger P, Deng Z, Guo J, Prange L, Song S, Montenbruck O (2022) BeiDou-3 orbit and clock quality of the IGS Multi-GNSS Pilot Project, Advances in Space Research, https://doi.org/10.1016/j.asr.2022.08.058
- Duan B, Hugentobler U, Selmke I, Marz S, Killian M, Rott M (2022) BeiDou Satellite Radiation Force Models for Precise Orbit Determination and Geodetic Applications. IEEE Transactions on Aerospace and Electronic Systems 58:2823–2836. https://doi.org/10.1109/taes.2021.3140018
- Zhao Q, Guo J, Wang C, Lyu Y, Xu X, Yang C, Li J (2022) Precise orbit determination for BDS satellites. Satellite Navigation 3. https://doi.org/10.1186/s43020-021-00062-y