Analysis of legacy and VGOS Intensives at IVS AC DGFI-TUM

Matthias Glomsda, Manuela Seitz, Detlef Angermann

Deutsches Geodätisches Forschungsinstitut,
Technische Universität München (DGFI-TUM)

13th IVS General Meeting & 25th Anniversary
Session 4

Tsukuba, Japan
March 6, 2024

Considered session types and properties

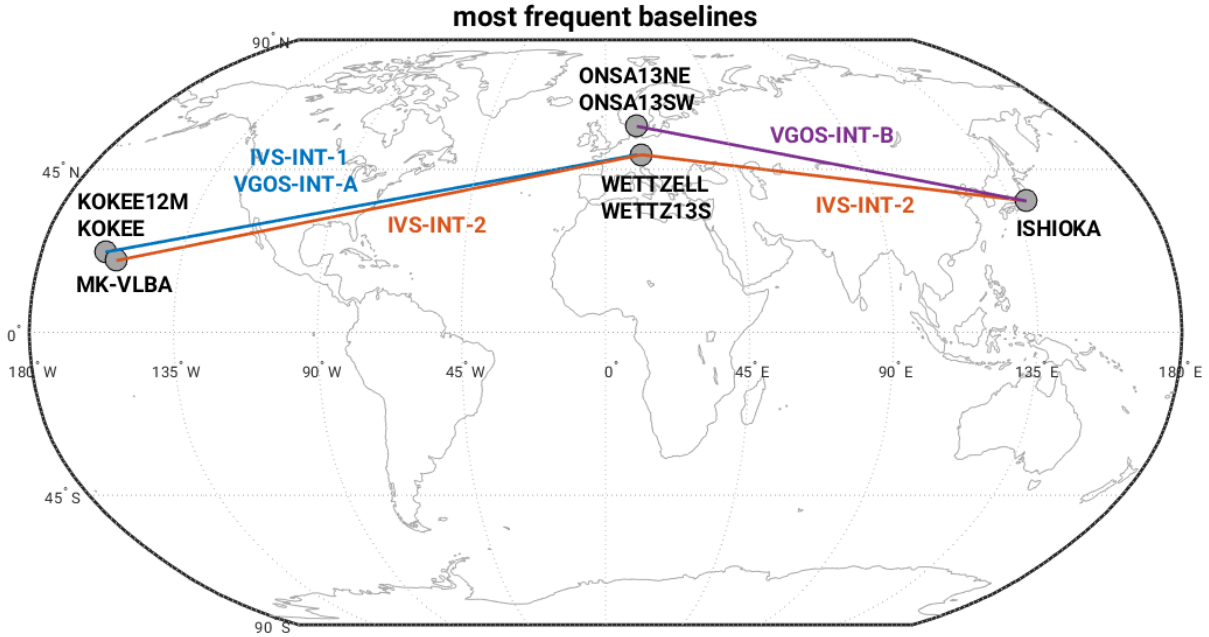
- **Two (mostly) simultaneous Intensive sessions** available per day, one each in **legacy and VGOS** mode:

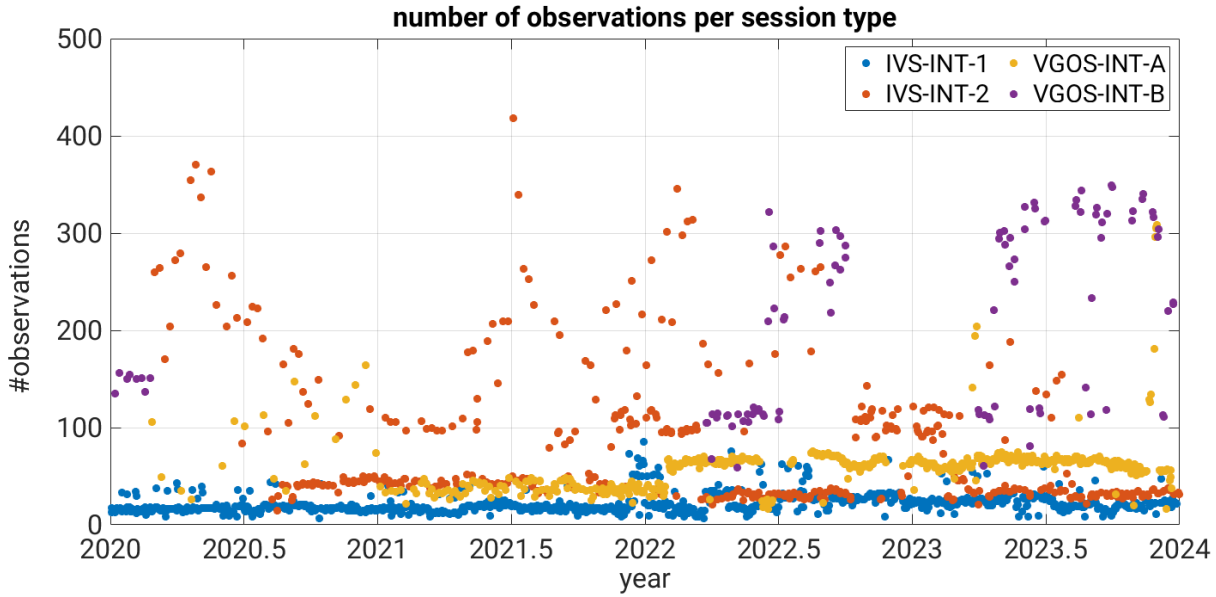
type	mode	code	observation time [UTC]	most frequent station networks / baselines
IVS-INT-1	legacy	i (XU)	Mon-Fri 18:30 (before 10/23) 17:30 (since 10/23)	KOKEE, WETTZELL (~81%) KOKEE, WETTZELL, SVETLOE (~5%) MK-VLBA, WETTZELL (~4%)
IVS-INT-2	legacy	q (XK)	Sat-Sun 07:30	MK-VLBA, WETTZELL (~57%) MK-VLBA, WETTZELL, ISHIOKA (~19%) KOKEE, WETTZELL and WETTZELL, ISHIOKA (~11%)
VGOS-INT-A	VGOS	v (VI)	Mon-Fri 18:30 (before 10/23) 17:30 (since 10/23)	KOKEE12M, WETTZ13S (~83%) KOKEE12M, ONSA13NE (~11%)
VGOS-INT-B	VGOS	b (VB)	Sat-Sun 07:30 (03/22-09/23) 05:30 (since 10/23)	ISHIOKA, ONSA13NE, ONSA13SW (~65%) ISHIOKA, ONSA13NE (~22%) ISHIOKA, ONSA13SW (~13%)

- Our data sample: **all corresponding sessions between 2020.0 and 2024.0** (percentages above refer to this period). Other Intensive series, mostly on single weekdays, are ignored.

Considered session types and properties

- Other occasionally involved stations: **SVETLOE** (IVS-INT-1); **NYALE13S, NYALES20, SESHAN25** (IVS-INT-1 and IVS-INT-2); **GGAO12M, MACGO12M** (VGOS-INT-A).
- Usually, **more observations per baseline in VGOS** Intensives (faster-slewing broadband antennas).
- **VGOS-INT-B** with 3 baselines: the most observations in general, but **only observing regularly since 2022**.





Analysis setup

- Radio Interferometry component of **DGFI Orbit and Geodetic parameter estimation Software** (DOGS-RI) applied.

- Estimated parameters in our **1h Intensives**:
  - **constant DUT1**
  - **the quadratic clock offset** (3 parameters per station) w.r.t. the reference station clock
  - **a single zenith wet delay** per station

- Station positions, quasar coordinates, and remaining Earth orientation parameters (EOP) fixed to **ITRF2020** (incl. post-seismic deformation, excl. signals), **ICRF3**, and **IERS 20 C04**, respectively.

- In our **24h sessions**:
  - **all above parameters** estimated (NNT/NNR w.r.t. a priori values).
  - **linear DUT1** (offset plus drift)
  - above reference frames and EOP series used as a priori values.
  - **piecewise-linear tropospheric parameters** estimated
    (zenith delay: 1/h legacy, 4/h VGOS; gradients: 4/d legacy, 1/h VGOS).

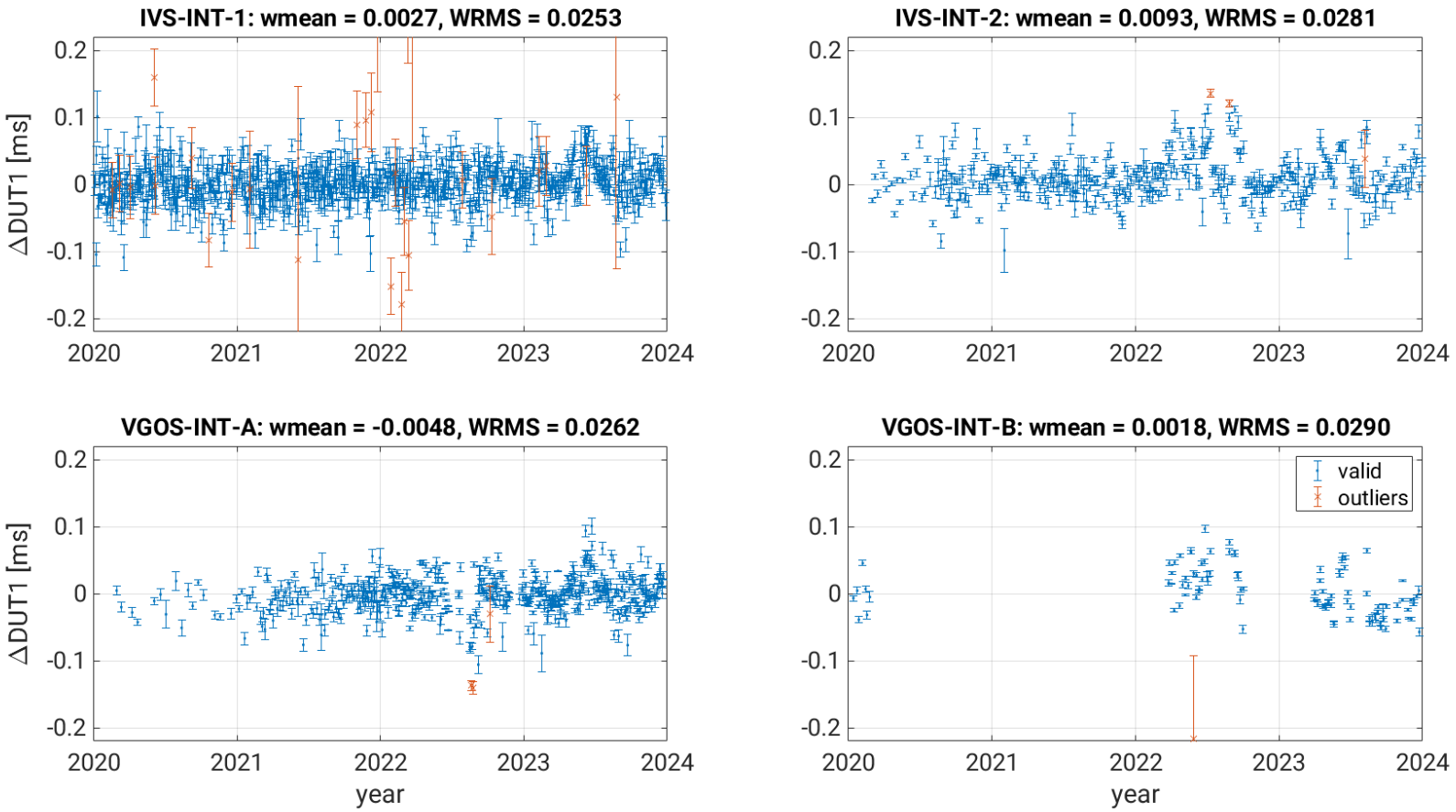
Internal results: DUT1 and formal errors

- Figures: DUT1 **corrections to a priori** IERS 20 C04 with (formal) error bars separated by Intensive session type.

- **Formal errors** generally largest for INT-1 (legacy) and smallest for INT-B (VGOS).

- Better precision for DUT1 in INT-2:
  - **MK-VLBA** has **larger sensitivity** than KOKEE, enabling more observations.
  - **improved scheduling** since mid-2020 (both Schartner et al., 2022).

- Outliers: formal error > 40 µs, or |ΔDUT1| > 120 µs.

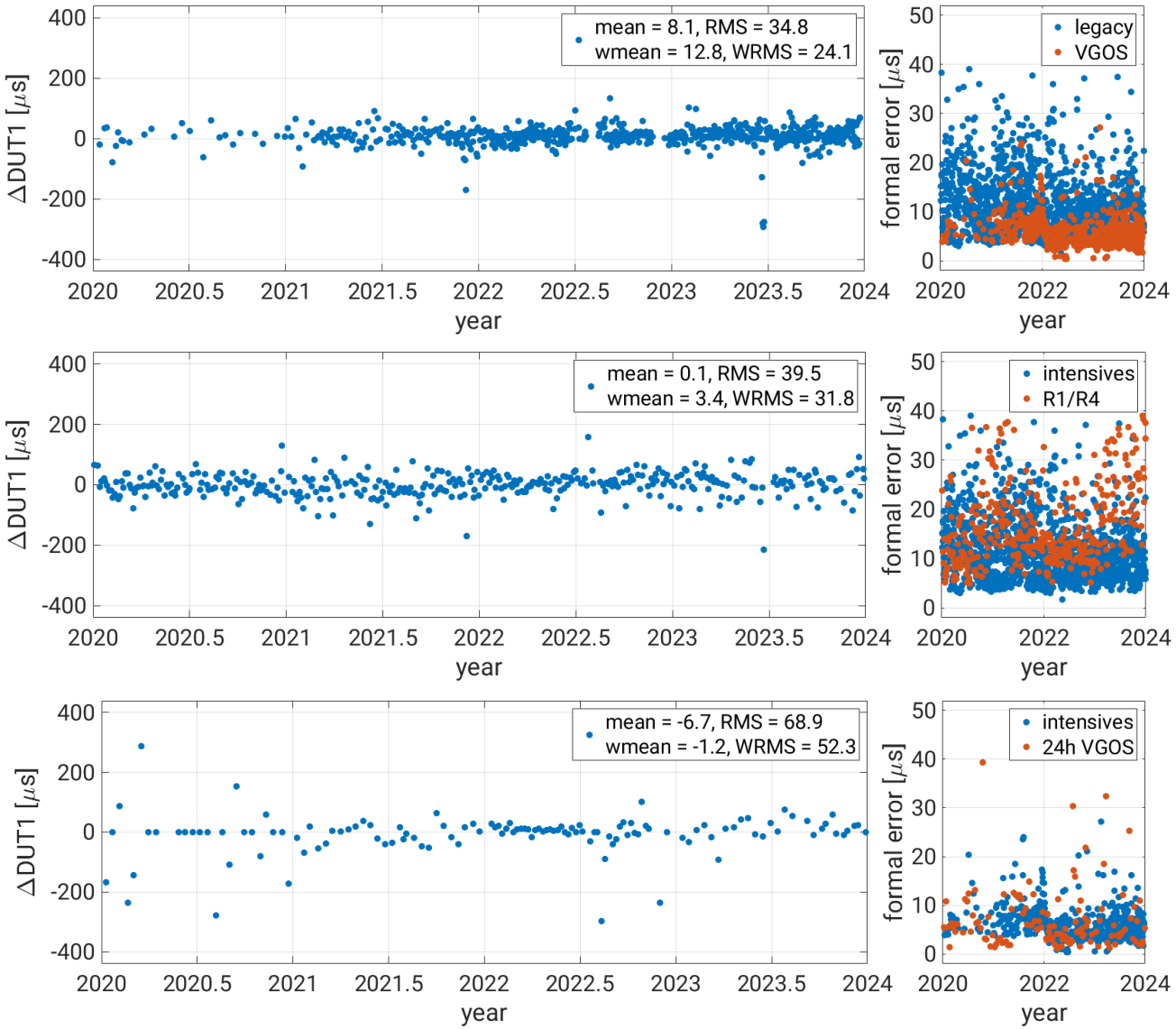


Internal results: comparison with 24h sessions (dgf2023a)

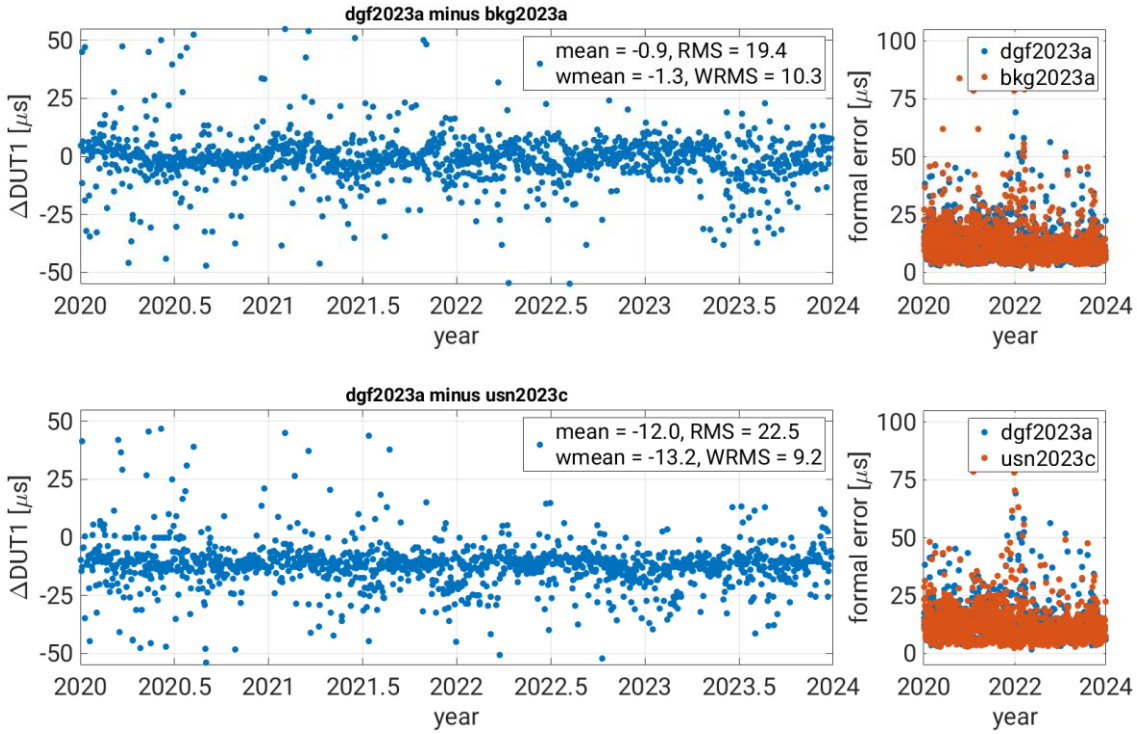
- **Intensives: legacy vs. VGOS**
  - weighted mean offset of about 13 µs, larger than mean formal error for VGOS
  - formal errors larger for legacy (fewer observations, less precise measurements)

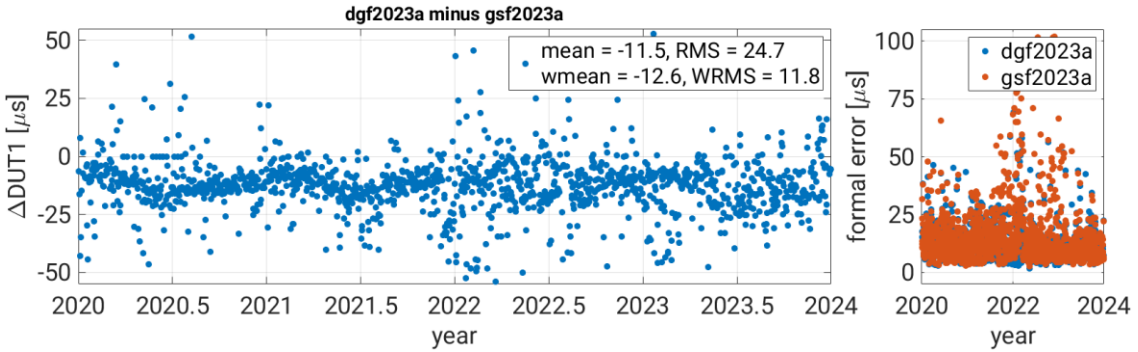
- **Legacy: Intensives vs. 24h sessions**
  - R1/R4 sessions only
  - no significant offset in DUT1
  - formal errors do not differ systematically (remember different DUT1 parameterization)

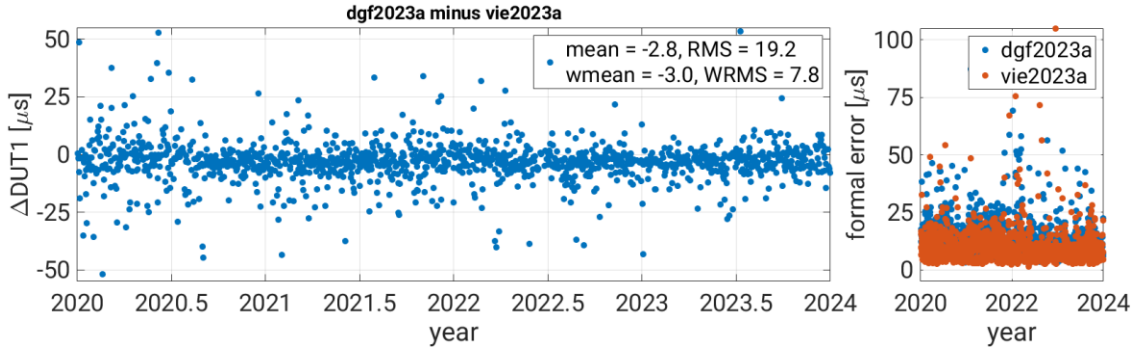
- **VGOS: Intensives vs. 24h sessions**
  - no significant offset
  - largest (W)RMS, but scarce data
  - formal errors of 24h sessions mostly smaller?



Comparison with other ACs: legacy Intensives

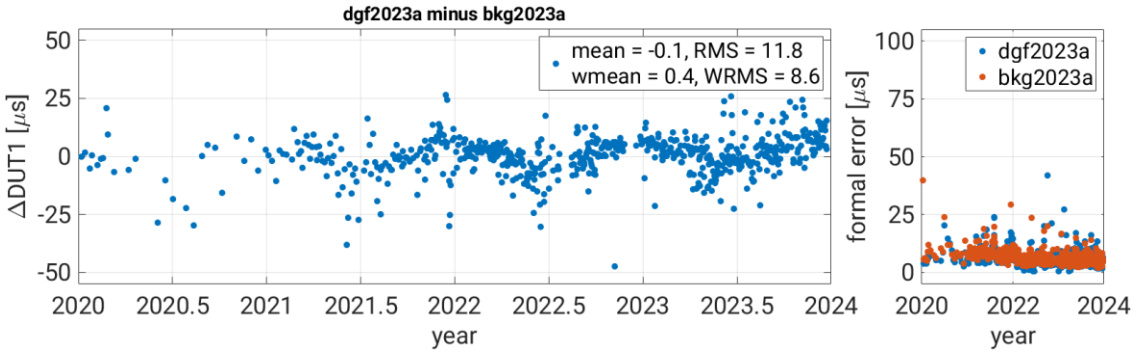


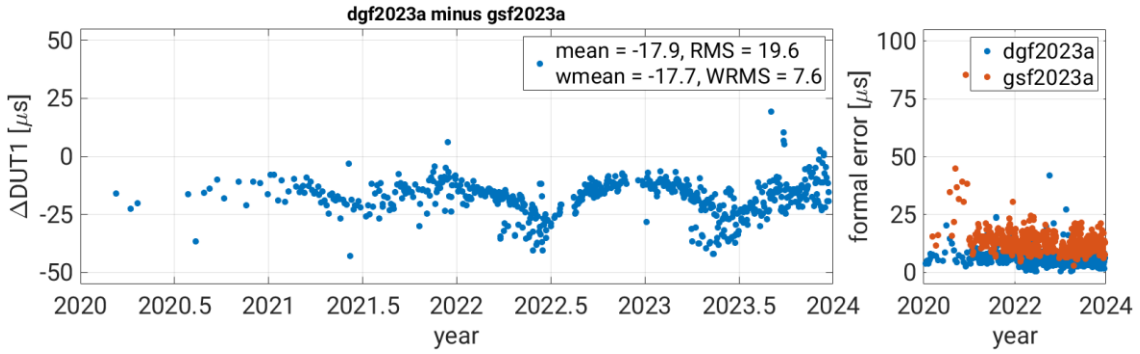


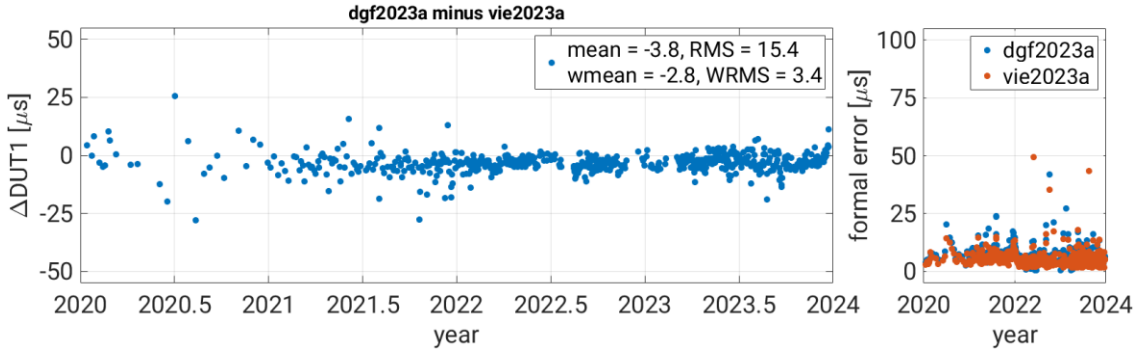


- Data taken from **.eopi files at CDDIS**.
- **About -13 µs offsets** w.r.t. GSFC and USNO, **annual signal** w.r.t. BKG and GSFC.
- **Formal errors similar**, smallest for TU Vienna.

Comparison with other ACs: VGOS Intensives





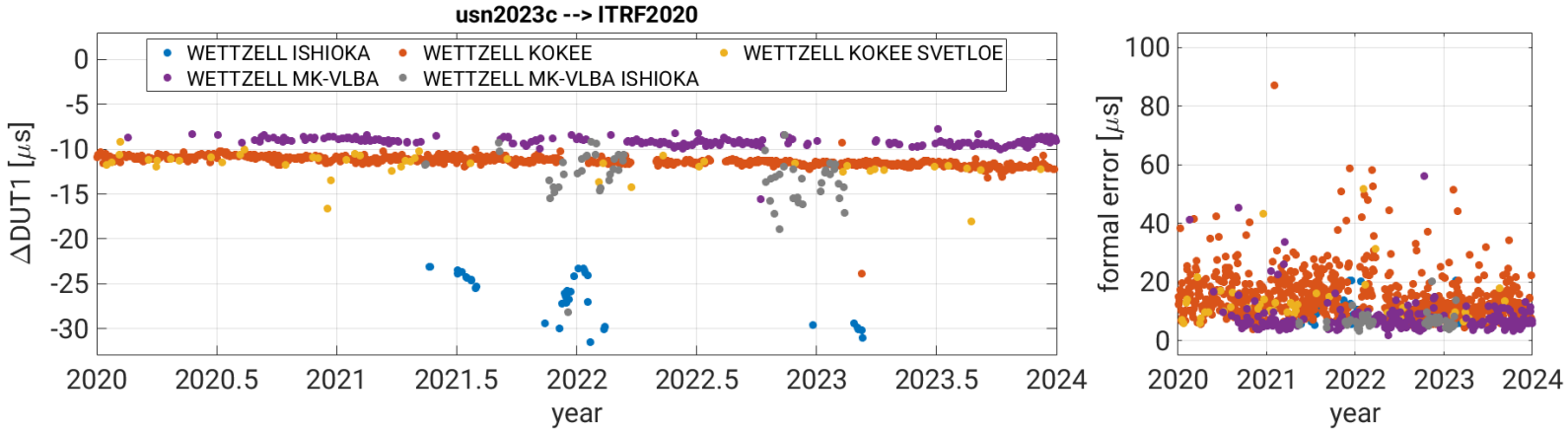


- No VGOS results for USNO in .eopi file.
- **Increased offset of about -18 µs** w.r.t. GSFC, **clear annual signal** w.r.t. BKG and GSFC, but **none w.r.t. TU Vienna**.
- Formal errors of **GSFC generally larger**.

Impact of a priori antenna positions

- bkg2023a, vie2023a and dgf2023a use **ITRF2020 (excl. signals) for a priori positions**, usn2023c and gsf2023a use **own global solutions**.

- **Baseline dependent offset in DUT1** when changing the a priori TRF (compare Dieck & Johnson, 2023), e.g., in our solution:

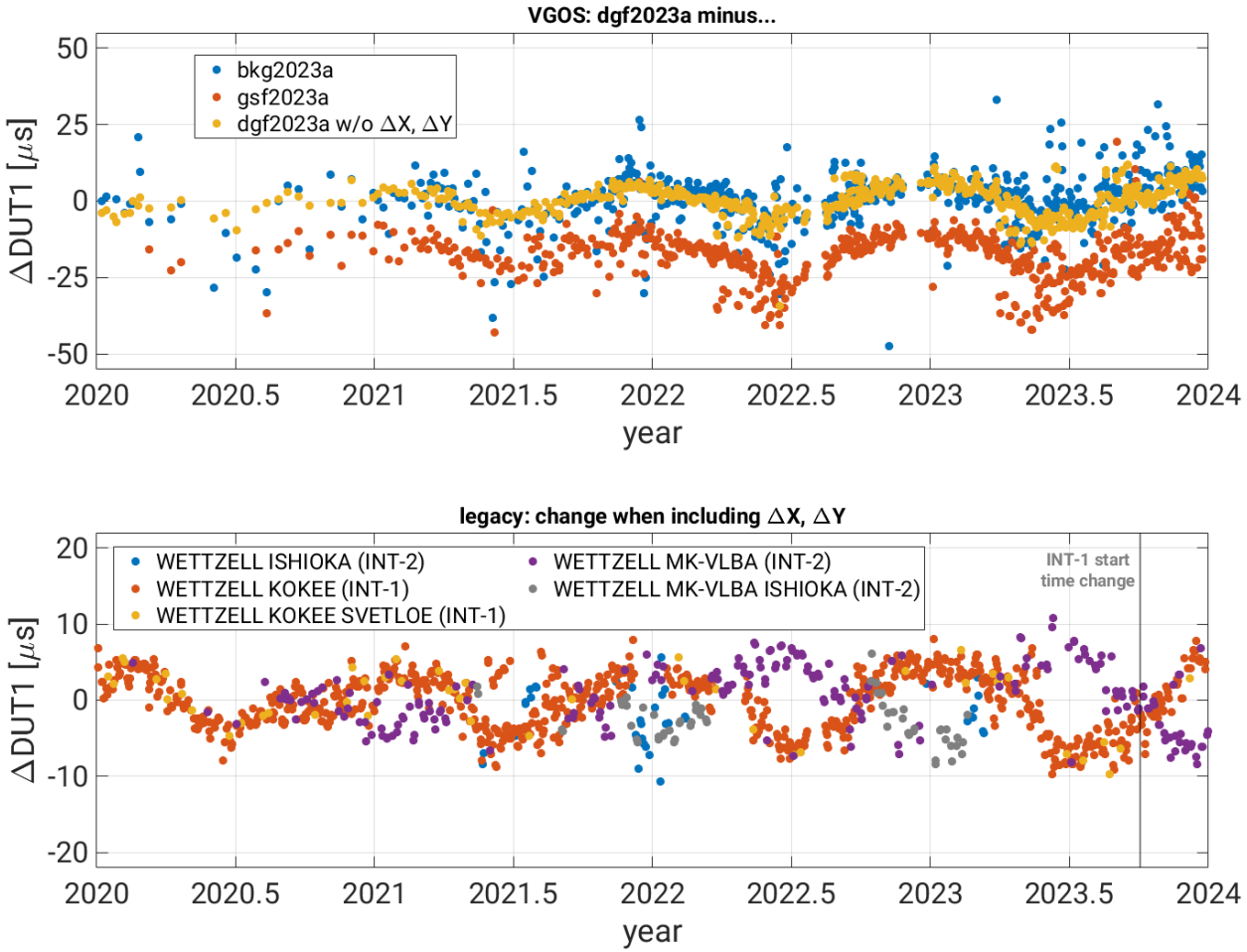


- **Derivatives $\partial DUT1/\partial\vec{p}$** from Nothnagel & Schnell (2008) **provide similar offsets**, e.g., for November 2022 (however, the authors expect much more scatter for WETTZELL KOKEE and WETTZELL MK-VLBA):

baseline	WETTZELL ISHIOKA	WETTZELL KOKEE	WETTZELL MK-VLBA
$\Delta DUT1$	-36.13 µs	-11.13 µs	-9.80 µs

Impact of celestial pole offsets (CPOs)

- **Annual signal in differences explained by application of CPOs**, i.e., corrections ΔX, ΔY to precession-nutation model (compare Malkin, 2011; Dieck, 2023).
- GSFC and BKG do not apply precession-nutation corrections.
- Impact on DUT1 **depends on sidereal time** (Nothnagel & Schnell, 2008), Intensive sessions start at **different solar times**: hence, annual signals with phase lags.
- Curious: phase shift much more pronounced for legacy sessions, and not observed by Malkin (2011).



Differences w.r.t. combined DUT1 series (2020.0 – 2024.0)

IERS 20 C04 vs.	legacy wmean [µs]	legacy WRMS [µs]	VGOS wmean [µs]	VGOS WRMS [µs]
gsf2023a	-22.0	32.6	-17.2	30.4
usn2023c	-21.7	31.4	-	-
bkg2023a	-9.8	34.8	-3.1	31.7
vie2023a	-13.2	33.3	-7.6	31.7
dgf2023a	-8.7	30.4	-2.8	28.3

ESA EOPs vs.	legacy wmean [µs]	legacy WRMS [µs]	VGOS wmean [µs]	VGOS WRMS [µs]
gsf2023a	-17.1	21.0	-14.5	22.3
usn2023c	-16.1	18.9	-	-
bkg2023a	-4.6	22.2	4.3	18.2
vie2023a	-6.9	20.8	0.3	19.1
dgf2023a	-3.6	20.7	4.1	19.2

USNO finals 2000A vs.	legacy wmean [µs]	legacy WRMS [µs]	VGOS wmean [µs]	VGOS WRMS [µs]
gsf2023a	-16.6	20.8	-13.5	20.4
usn2023c	-16.2	18.9	-	-
bkg2023a	-4.4	21.5	4.8	18.8
vie2023a	-6.1	20.6	1.1	19.3
dgf2023a	-3.3	20.7	3.2	18.1

- **WRMS errors similar** across ACs and observation modes, again **(additional) offset for gsf2023a and usn2023c**.

Conclusions

- **DUT1** results and **formal errors** of dgf2023a Intensives **generally match** those of other ACs.
- (Weighted) mean **offsets** in DUT1 between ACs can be explained with **different a priori antenna positions**.
- **Annual signals** in DUT1 differences are created by **omission of precession-nutation corrections**.
- dgf2023a reveals (weighted) mean **offset of about 13 µs** between DUT1 from **legacy and VGOS** Intensives.
- **Relation of DUT1 precisions** between (legacy and VGOS) Intensive series quite **as expected**.
- **Baseline geometry and session time relevant** for (differences in) results.

Acknowledgements

- We thank **Karen Baver** (GSFC), **Chris Dieck** (USNO), **Sigrid Böhm** (TU Vienna), and **Anastasiia Walenta** (BKG) for providing and helping us understand their Intensives data.

References

- C. Dieck and M. Johnson [2023]: **A new the Wiggle in the Wobble?**
  Proceedings of the IVS GM 2022

- C. Dieck [2023]: **Eliminating the Wiggle in the Wobble**
  Presentation at EVGA WM 2023

- Z.M. Malkin [2011]: **The impact of celestial pole offset modelling on VLBI UT1 intensive results**
  Journal of Geodesy

- A. Nothnagel and D. Schnell [2008]: **The impact of errors in polar motion and nutation on UT1 determinations from VLBI Intensive observations**
  Journal of Geodesy

- M. Schartner et al. [2022]: **Improvements and comparison of VLBI INT2 and INT3 session performance**
  Journal of Geodesy

THANK YOU
FOR YOUR ATTENTION!

ARE THERE
ANY QUESTIONS?