VLBI data analysis at ESA

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Introduction

- **Expansion of ESA's Geodetic Capabilities:** the Navigation Support Office at ESA/ESOC is integrating VLBI into the ESA Precise Navigation System (EPNS), complementing existing GNSS, SLR, and DORIS products and enhancing ESA's contribution to the ITRF and future missions like GENESIS.
- **Operational VLBI Processing Chain:** a fully automated pipeline routinely processes R1/R4, VGOS-OPS, and intensive sessions. The analysis strategy yields reliable results for nearly all sessions, though it can lead to increased noise when station performance is degraded.
- **Towards IVS Contribution:** ESOC is preparing for regular IVS submissions, with a major milestone already achieved through the reprocessing and test submission of 25 years of VLBI data for the latest IVS ITRF combination.

Session statistics

- First ever (test) submission of ESA products to IVS-ITRF2020-u2025 repro
  - 3982 sessions submitted, including S/X and VOGS sessions
  - Processed period: 2002-2025
  - Full compliance with ITRF standards for VLBI except for the estimation of quasar positions, and for the use of the Vienna Mapping Function (GPT is used instead)

…We are looking forward to the IVS feedback!

- This poster focuses on R1/R4 and VGOS-OPS sessions.
  - In total, 2437 S/X rapid-turnaround and 165 VOGS-OPS sessions are considered (2026 sessions available until March 30th are also included).

S/X R1/R4 sessions | VGOS-OPS sessions

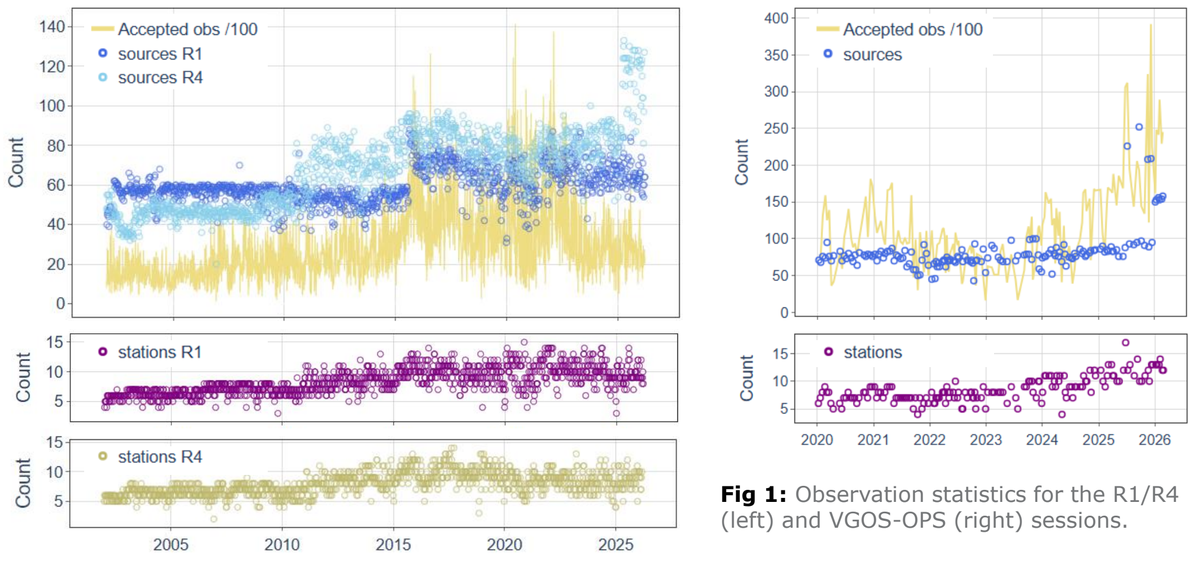


Fig 1: Observation statistics for the R1/R4 (left) and VGOS-OPS (right) sessions.

Station coordinates

S/X R1/R4 sessions | VGOS-OPS sessions

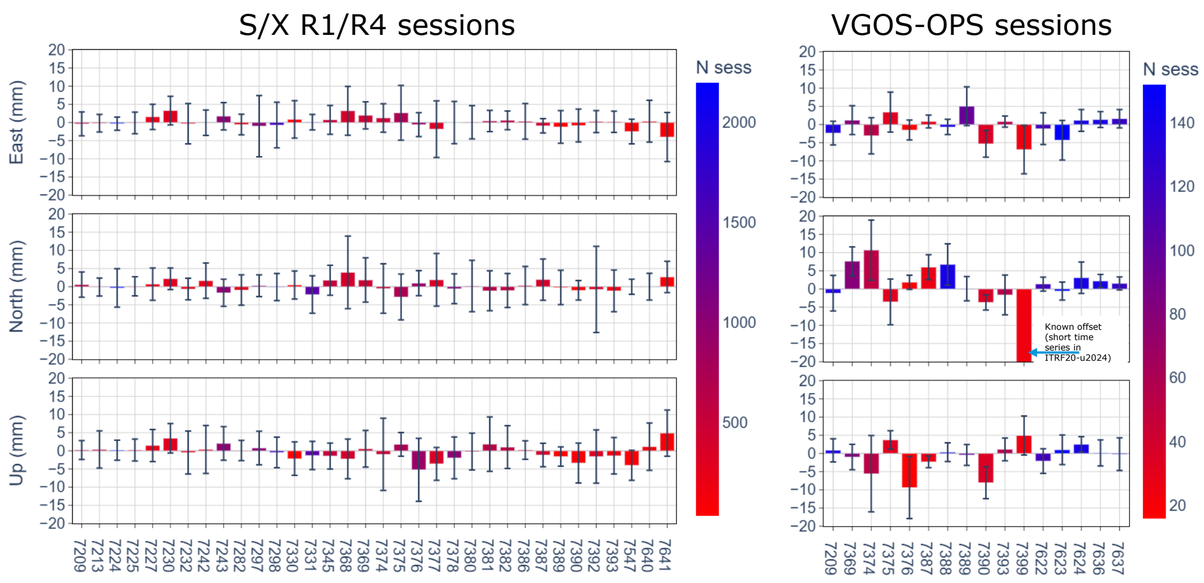


Fig 2: Statistics of the differences between the estimated and the a priori (ITRF2020-u2024) station coordinates: bar heights represent the median values; whiskers display the interquartile range. Stations participating to less than 21(S/X)/5(VGOS) sessions were disregarded.

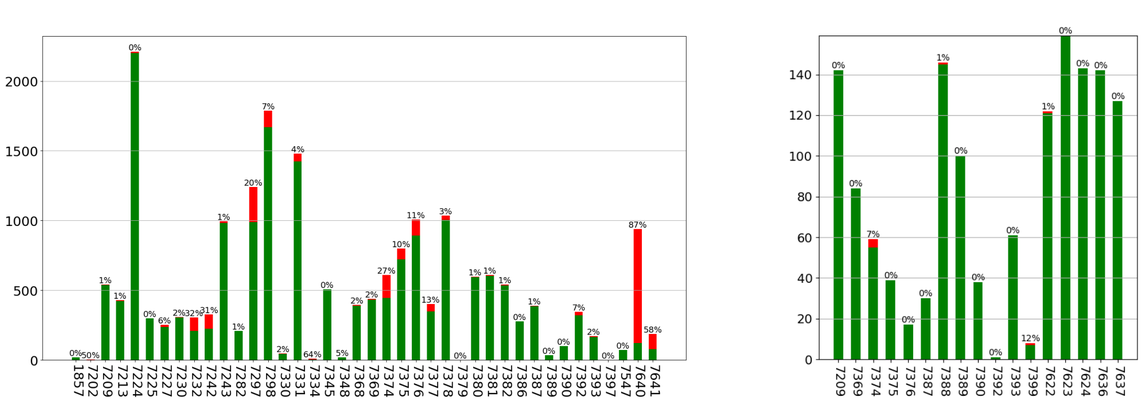
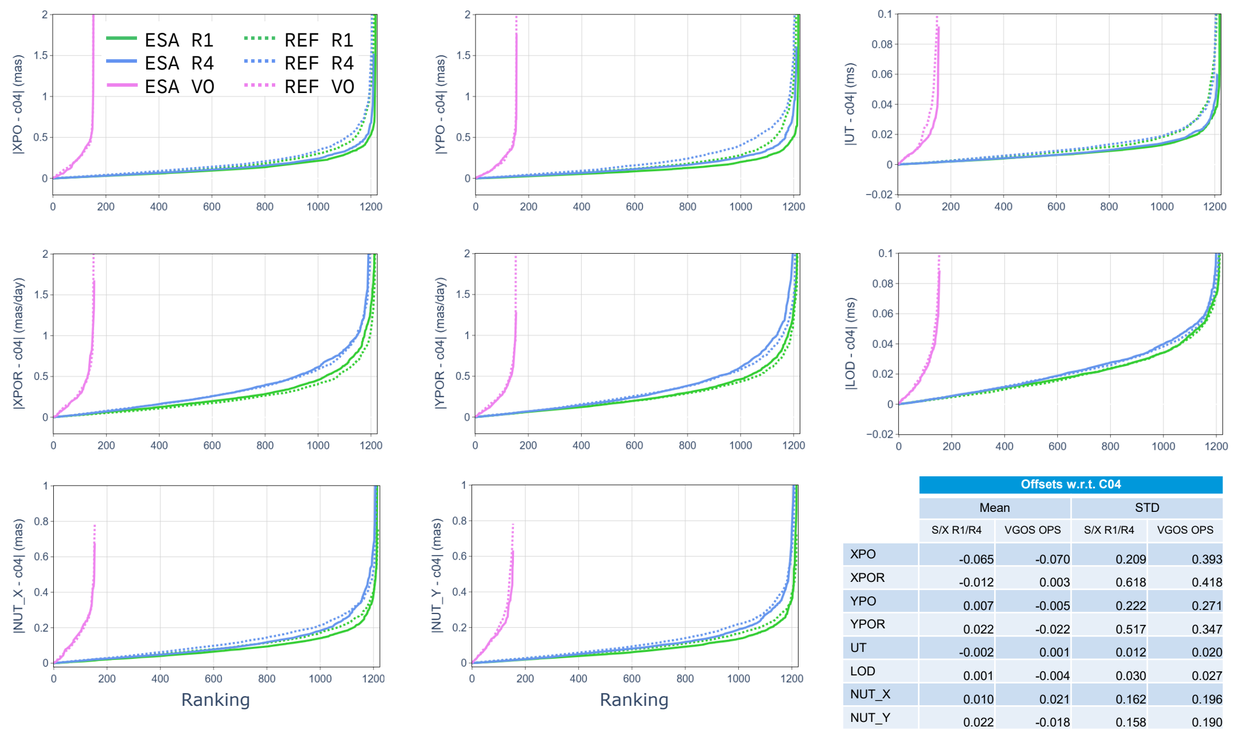


Fig 3: Number of sessions with well-(green) and ill-determined (red) station coordinates. Some stations show systematic issues… any suggestion?

Validation of EOP estimates (24h sessions)



Offsets w.r.t. C04	Mean		STD	
	S/X R1/R4	VGOS OPS	S/X R1/R4	VGOS OPS
XPO	-0.065	-0.070	0.209	0.393
XPOR	-0.012	0.003	0.618	0.418
YPO	0.007	-0.005	0.222	0.271
YPOR	0.022	-0.022	0.517	0.347
UT	-0.002	0.001	0.012	0.020
LOD	0.001	-0.004	0.030	0.027
NUT_X	0.010	0.021	0.162	0.196
NUT_Y	0.022	-0.018	0.158	0.190

Fig 4: Sorted offsets between ESA EOP estimates and IERS C04 values. The results achieved by an established IVS AC are shown for comparison. Both solutions (ESA and REF) were submitted to the IVS as part of the ITRF2020-u2025 repro activity. The comparison is restricted to sessions successfully computed by both ACs.

Impact of using ESA VLBI products in the ERP combination

- Since 2023, ESA publishes daily updates of ERP estimates and predictions up to 119 days in the future · https://navigation-office.esa.int/products/erp/ESA_pre.erp

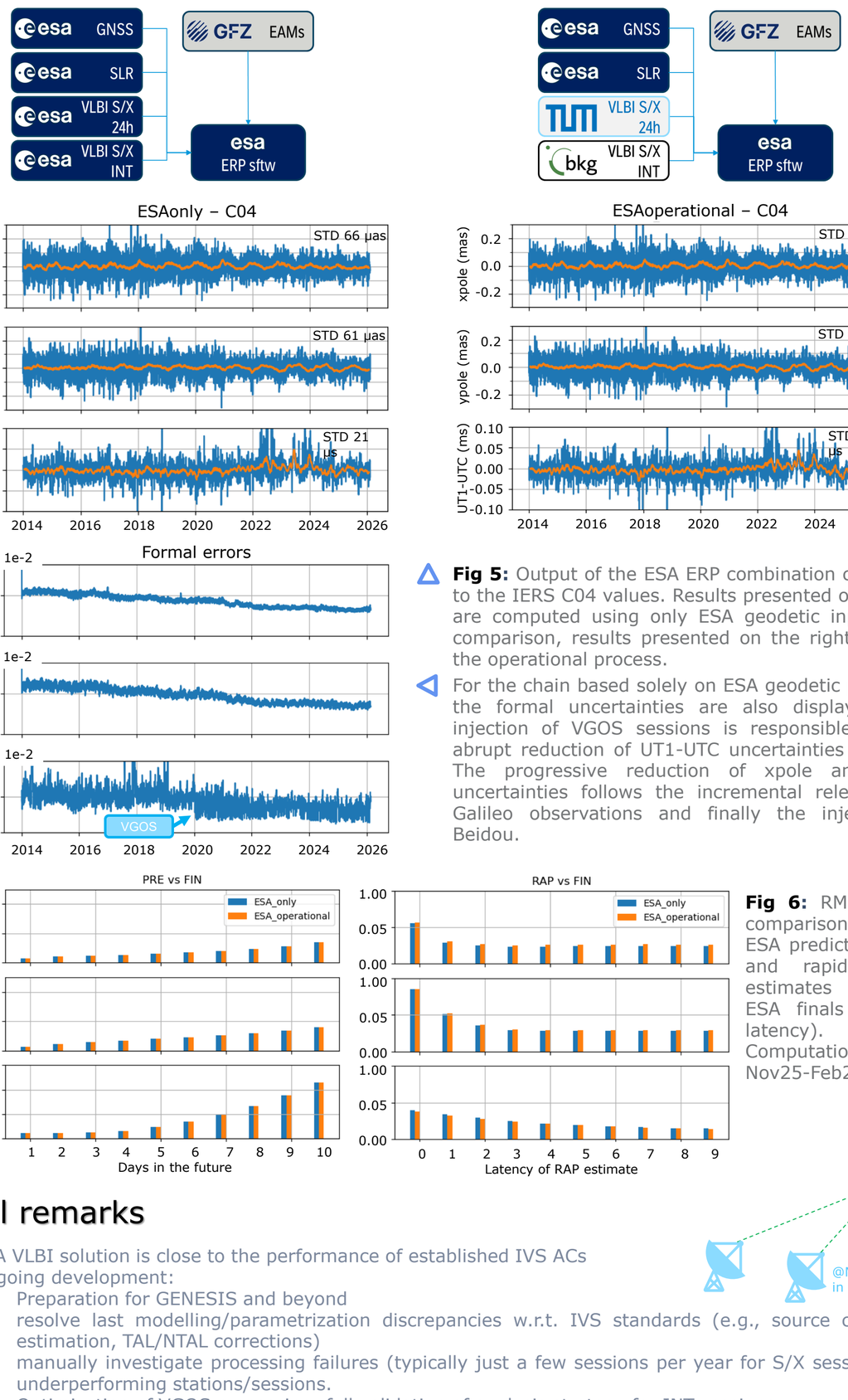


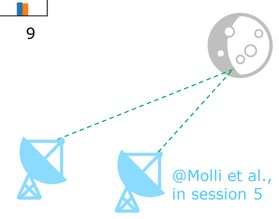
Fig 5: Output of the ESA ERP combination compared to the IERS C04 values. Results presented on the left are computed using only ESA geodetic inputs. For comparison, results presented on the right refer to the operational process.

For the chain based solely on ESA geodetic products, the formal uncertainties are also displayed. The injection of VGOS sessions is responsible for the abrupt reduction of UT1-UTC uncertainties in 2020. The progressive reduction of xpole and ypole uncertainties follows the incremental relevance of Galileo observations and finally the injection of Beidou.

Fig 6: RMS of the comparison between ESA prediction (left) and rapid (right) estimates against ESA finals (30-day latency).
Computation period: Nov25-Feb26.

Final remarks

- ESA VLBI solution is close to the performance of established IVS ACs
- Ongoing development:
  - Preparation for GENESIS and beyond
  - resolve last modelling/parametrization discrepancies w.r.t. IVS standards (e.g., source coordinate estimation, TAL/NTAL corrections)
  - manually investigate processing failures (typically just a few sessions per year for S/X sessions) and underperforming stations/sessions.
  - Optimization of VGOS processing; full validation of analysis strategy for INT sessions
- ERP estimates and predictions generated using ESA VLBI products are comparable to those generated with the current operational processing (predictions are under evaluation)



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