VLBI data analysis at ESA

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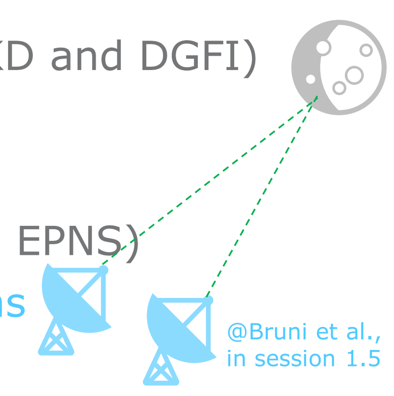
Introduction

ESA VLBI activities include:

1. Standard analysis of S/X and VGOS data
   - integrate standard VLBI analysis in the ESA Precise Navigation System (EPNS)
   - automatic processing triggered by new vgosDBs in Data Centers
   - extend the Office portfolio to support the geodetic supply chain with all space geodetic techniques and supply inputs to the ESA ERP Service (under testing).
2. ESA ERP Service - daily estimates and forecasts
   - operational since January 2023 (using VLBI products from BKD and DGFI)
   - upgrade to EOP Service in progress
3. VLBI to synthetic targets
   - GENESIS (software development to integrate data analysis in EPNS)
   - Exploring the potential of VLBI transmitters on future missions

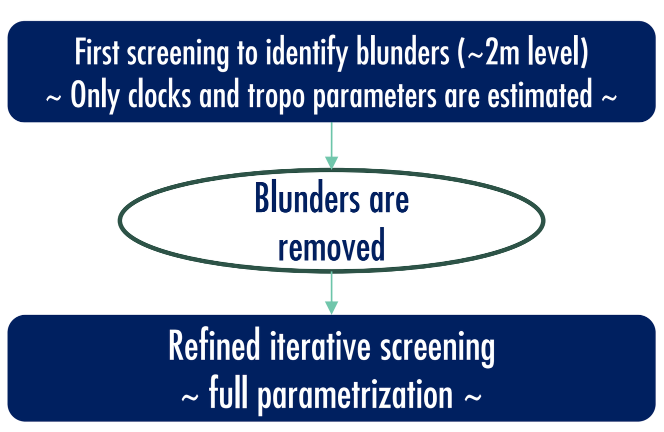


This contribution will present ESA's VLBI processing setup, report on its status and future development.

VLBI analysis overview (24h sessions)

Displacement of reference points	
Solid Earth tides	IERS 2010
Solid Earth pole tides	IERS 2010, mean pole removed (ITRF2020 model)
Oceanic pole tides	Not applied
Ocean tidal loading	Consistent with IERS 2010, site-dependent amps/phases from free ocean tide loading provider (Bos and Scherneck, 2017) for FES-2004 (Lyard et al., 2006) tide model including centre of mass correction
Atmospheric pressure loading	Not applied
Non-tidal loading	Not applied
Technique-specific effects	
• Antenna axis offset	Applied using the antenna information file provided by A. Nothnagel (v. 2022-07-19)
• Cable delay	Delay correction applied from observation file
• Thermal antenna deformation	Applied following Nothnagel 2009
• Antenna Gravity deformation	IVS model v. 2023-01-24
• Source structure	Not applied
Ionospheric delay Ionospheric	Delay correction applied from observation file
A priori tropospheric delay model	
A priori hydrostatic zenith delay	Hydrostatic zenith delay Saastamoinen model (Saastamoinen, 1972), with meteorological data from observation file
A priori wet zenith delay	None
Mapping function	GMF dry (Böhm et. al, 2006)
A priori gradients	None
Geometric/relativistic delay model	
Consensus	IERS 2010 Conventions
Planetary ephemerides	DE405 (Standish, 1998) for all planets, Sun, Moon using coordinate time TDB as input
Parametrization	
Polar motion offsets/rates	Daily estimates, constraints: 45 mas/ 3mas/s
Nutation Offsets	XY corrections w.r.t. IAU20006/2000 precession-nutation model, constraints: 3 mas
UT1-UTC	Daily estimates, constraints: 3 ms
LOD	Daily estimates, constraints: 3 ms
Station coordinates	NNR + NNT constraints over all stations
Station clocks	estimated piece-wise linear every 6 hours (w.r.t. a fixed reference clocks)
Troposphere	Wet zenith delay: estimated piece-wise linear every 1 hours Mapping function: partial is GMF wet (Böhm et. al, 2006) Gradients: North and East gradients estimated piece-wise linear per 24 hours
Source coordinates	fixed

Outlier screening procedure (unsupervised)

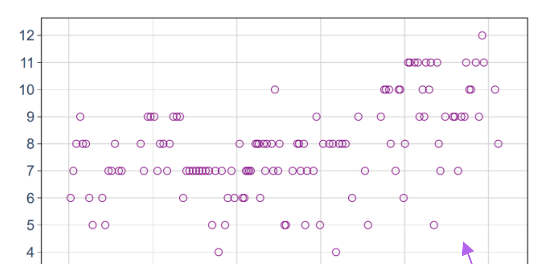


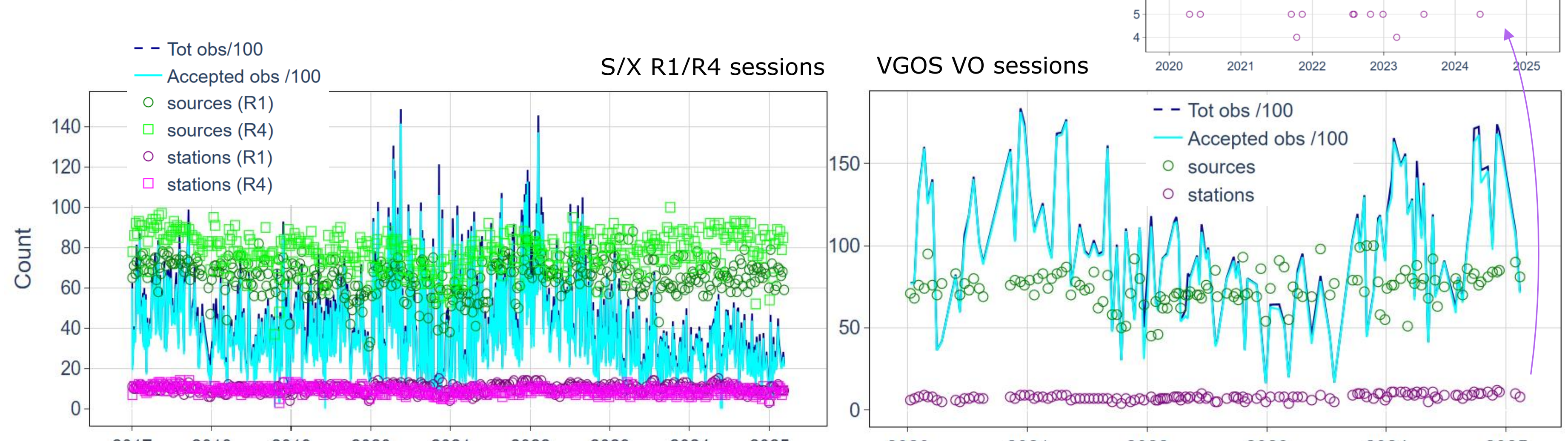
- Each box represents an iterative screening process based on 2 different criteria. Residuals are flagged as possible outliers if:
  - Residual > $thresh_{SuW}$*SuW
  - Residual > editing_threshold

  Both thresholds can be adjusted as a function of the iteration number
- Within each box, all observations flagged as potential outliers are evaluated again at each iteration with the updated configuration and can be un-flagged.

Observation statistics

Fig 1. Observation statistics for the R1/R4 (left) and VO (right) sessions processed for this study. The close-up highlights the evolution of the number of stations participating to the VO sessions





Baseline length variability

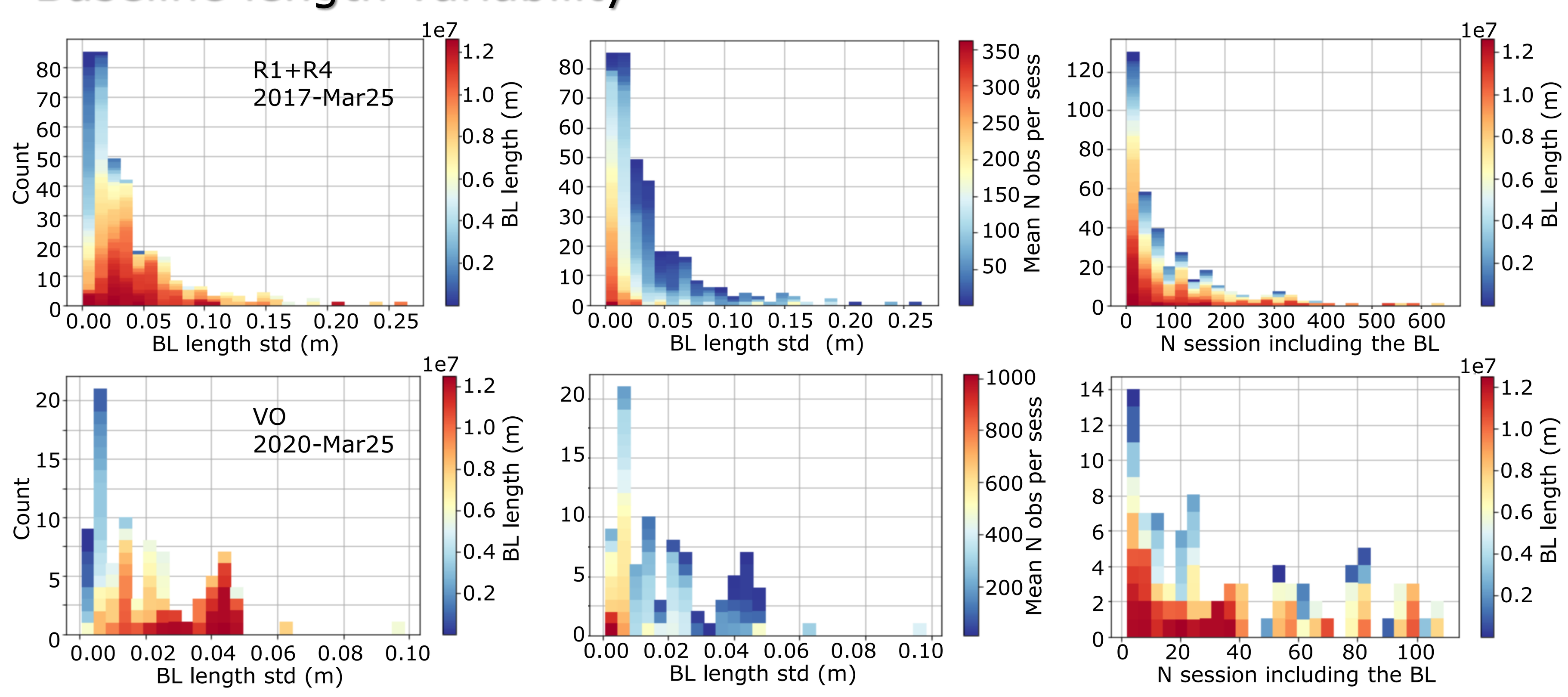


Fig 2. Standard deviation of the baseline lengths over the whole analysis interval. No global solution was computed. No outliers were removed. Stations coordinates were not compensated for atmospheric loading. Please note the different scales used for S/X (upper row) and VGOS (lower row) sessions, respectively.

Validation of EOP estimates (24h sessions)

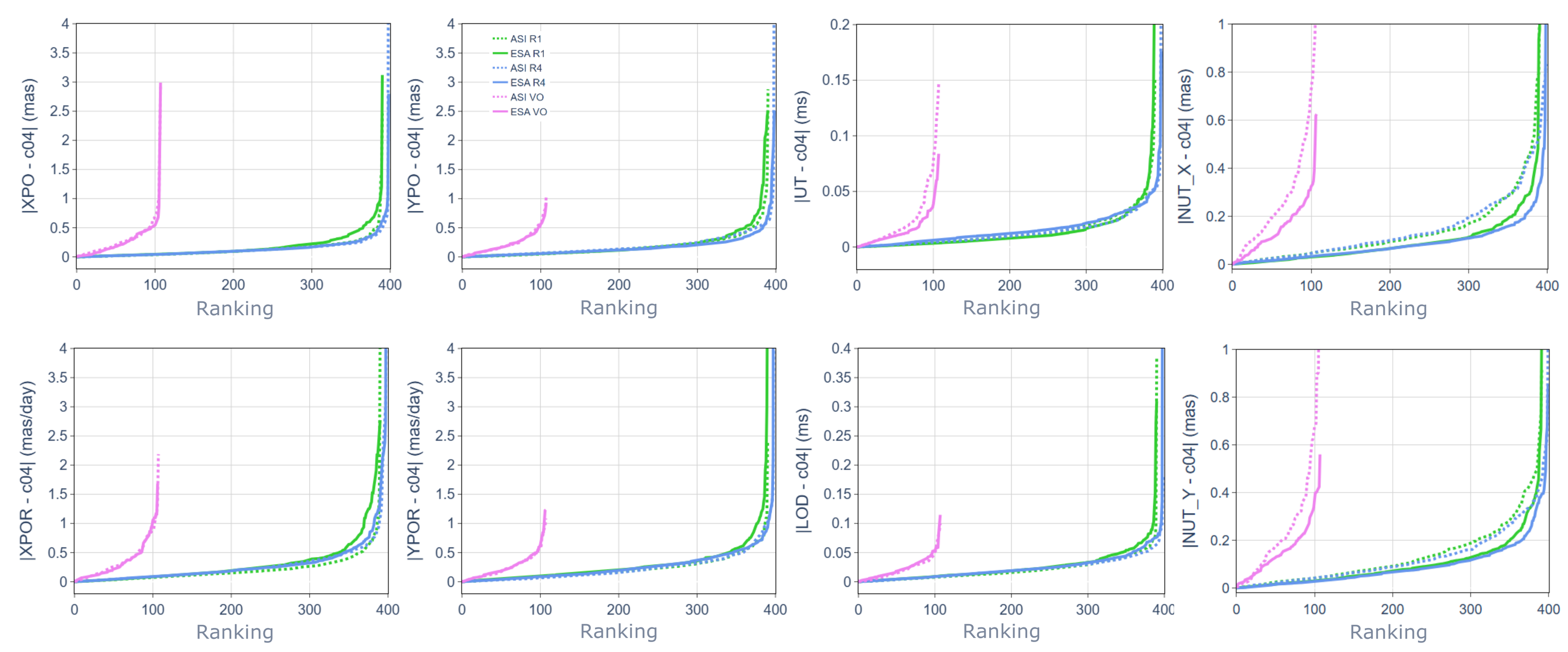
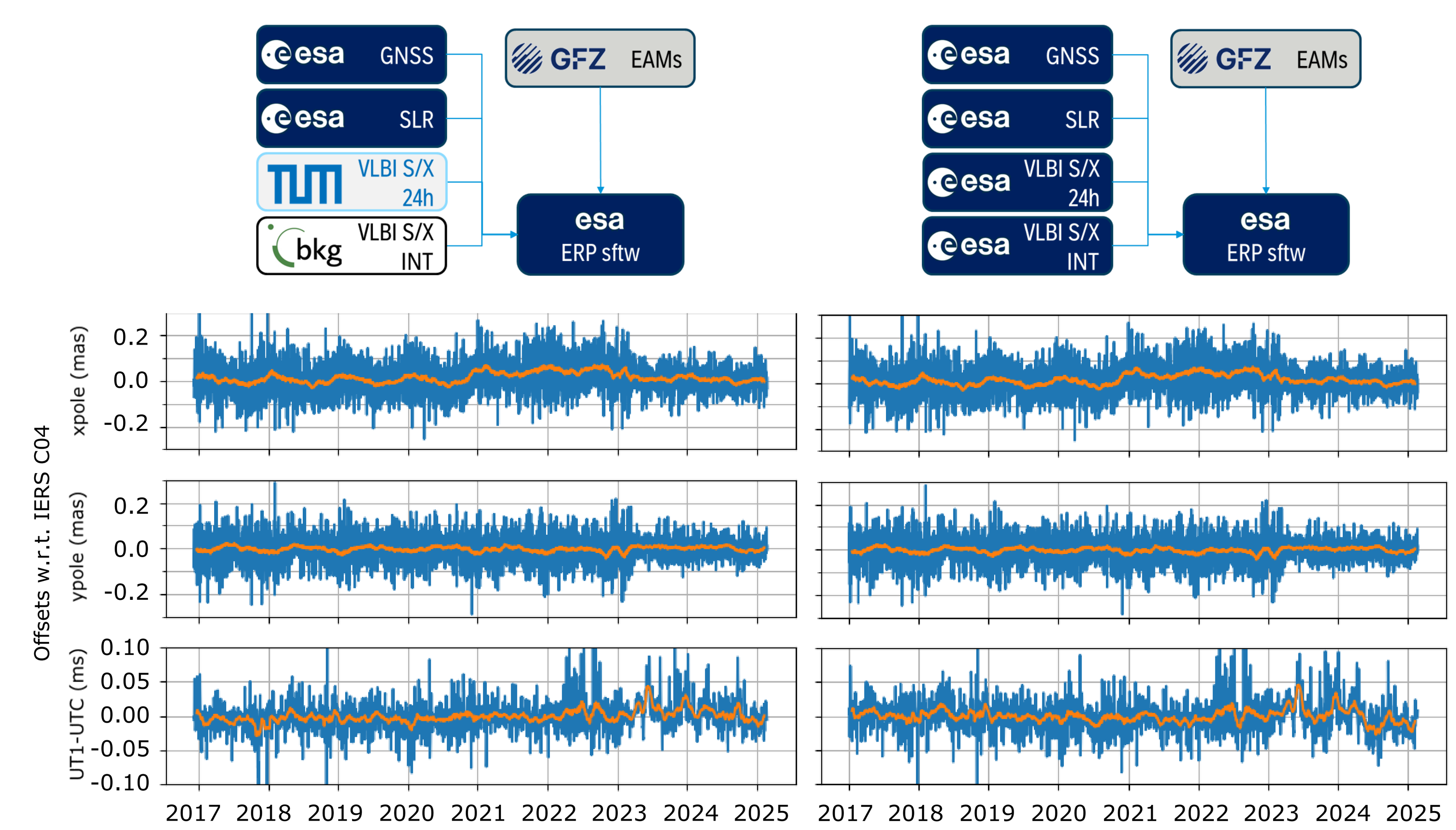


Fig 3 Sorted offsets between ESA/ASI EOP estimates and IERS C04 values at same epoch. Note that ESA results were generated in a consistent repro (using IERS C04 as a priori) while ASI 2023a operational products were used for the comparison. The comparison is restricted to sessions successfully computed by both ASI and ESA.

Impact of using ESA VLBI products in the ERP combination



Effect of adding VGOS solutions:

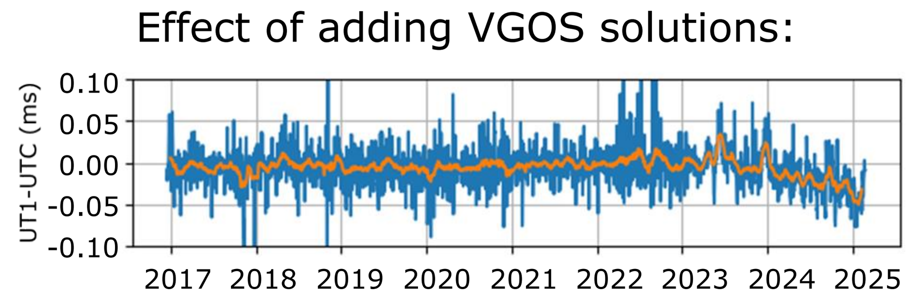


Fig 4. Output of the ESA ERP combination compared to IERS C04 values. Results presented in the left column, refer to the standard operational process (either excluding, upper plot, or including VGOS sessions, lower plot). Results presented on the right are computed using only ESA geodetic inputs.

Final remarks

- ESA VLBI solution is close to the performance of established IVS ACs
- Ongoing development:
  - 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 sessions. VGOS analysis requires further validation
- ERP estimates generated using ESA VLBI products are comparable to those generated with the current operational processing (predictions are under evaluation)

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