VLBI Data Analysis at ESA/ESOC

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Outline

- Motivation
- Overview of the VLBI Data Analysis at ESA/ESOC
  - NAPEOS
  - Operational setup
- Results of the analysis of R1 and R4 sessions for the period 2017-2021
- Conclusions

ESA’s Navigation Support Office.

ESA’s Navigation Support Office is responsible for providing an independent reference in Europe for precise navigation.

- Providing precise navigation for GNSS and spacecraft in different orbital regimes (ranging from LEO, MEO, HEO and up to the Moon)
- Providing the geodetic reference for ESA missions, and acting as Coordinator of the Galileo Reference Service Provider (GRSP) to provide the Geodetic reference and corresponding EOP’s to Galileo
- Providing the operational time for ESA’s missions
- Operating a global network of navigation real-time GNSS stations

ESA's Navigation Support Office. Why processing VLBI?

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ESA's Navigation Support Office will provide an independent VLBI solution for a number of IVS sessions.

- Complete ESA's portfolio of products submitted to the Services of the International Association of Geodesy (IAG) that contribute to the realization of the ITRF
- The solutions of rapid turnaround and intensive sessions will be used as an input for the ESA ERP Estimation and Prediction Service
- Contribute to ensuring the unrestricted access to space for ESA, EC and European industry

NAPEOS

- ESA/ESOC GNSS, SLR and DORIS solutions are generated with the ESA's NAvigation Package for Earth Orbiting Satellites (NAPEOS). https://www.esa.int/Enabling_Support/Operations/NAPEOS
- Adjustment method implemented in the Software: Bayesian weighted least squares
- NAPEOS has been used to generate the ESA/ESOC GNSS, SLR and DORIS contributions to ITRF2020
  - Software is compliant with the latest modelling standards
  - Computational efficiency

NAPEOS extended with VLBI capability

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- NAPEOS has been used to generate the ESA/ESOC GNSS, SLR and DORIS contributions to ITRF2020
  - Software is compliant with the latest modelling standards
  - Computational efficiency
- NAPEOS has been extended to enable the processing of VLBI S/X observations
  - Galactic aberration and antenna deformations are currently under development
  - NAPEOS will be further developed to also support the analysis of VGOS sessions.

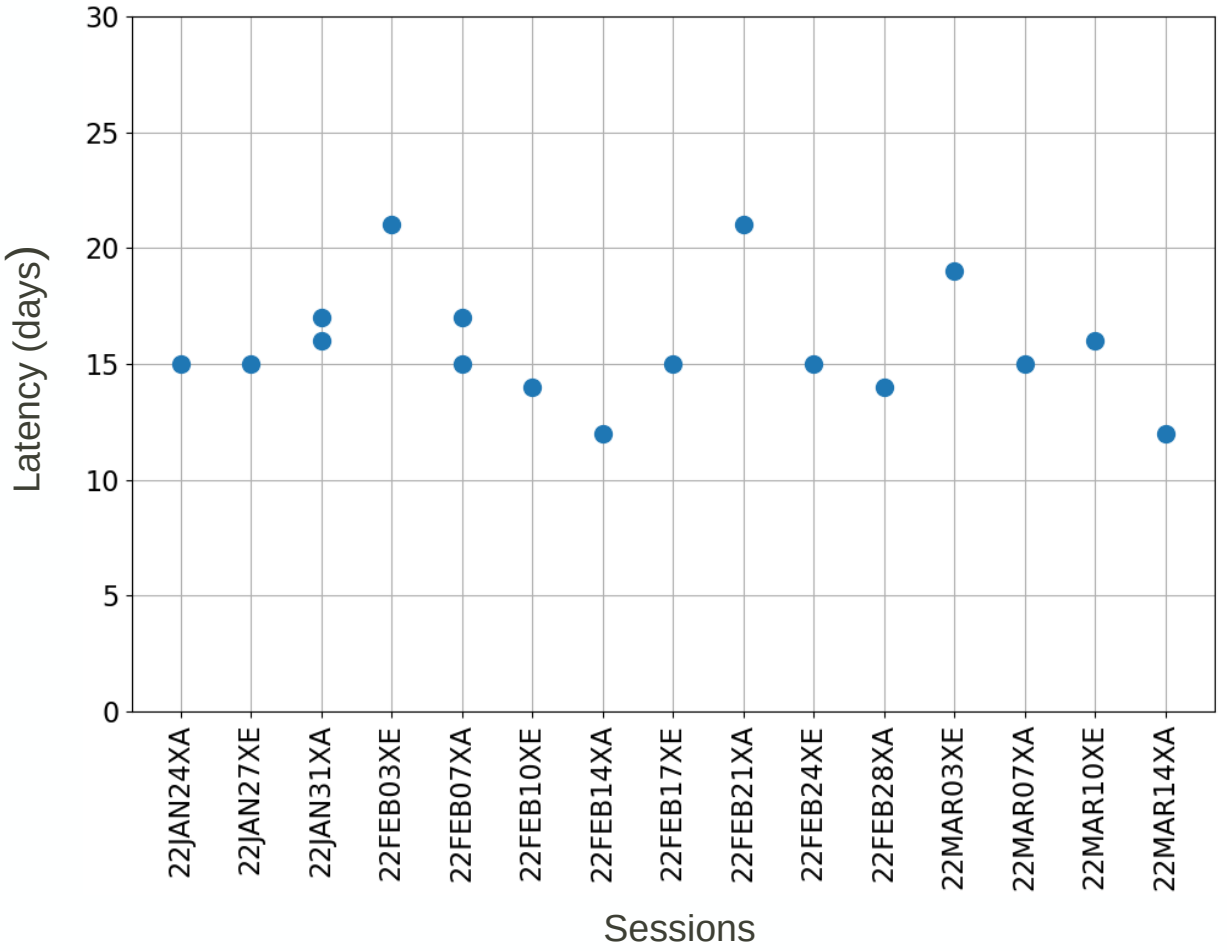
- **The development of the VLBI analysis capability will enable NAPEOS to combine all space-geodetic techniques at the observation or normal equation level**

Operational setup at ESOC – selected parametrization

Parameters			Parametrization	Interval	Constraints
EOP	Polar motion (offsets and rates)	✓	constant+drift	24 h	45 mas
	UT1-UTC	✓	constant	24 h	3 ms
	LOD	✓	constant		
	Nutation offsets	✗			
Source coordinates		✗			
Station coordinates		✓	constant	24 h	NNR/NNT
Station clocks*		✓	piece-wise linear offset	6 h	100 ms
Tropo	Wet zenith delays	✓	piece-wise linear offset	1 h	1 m
	Gradients	✓	constant	24 h	1 m

* The handling of clock breaks is currently under development. Clock break events will be identified on the basis of the information provided within the vgosDb file.

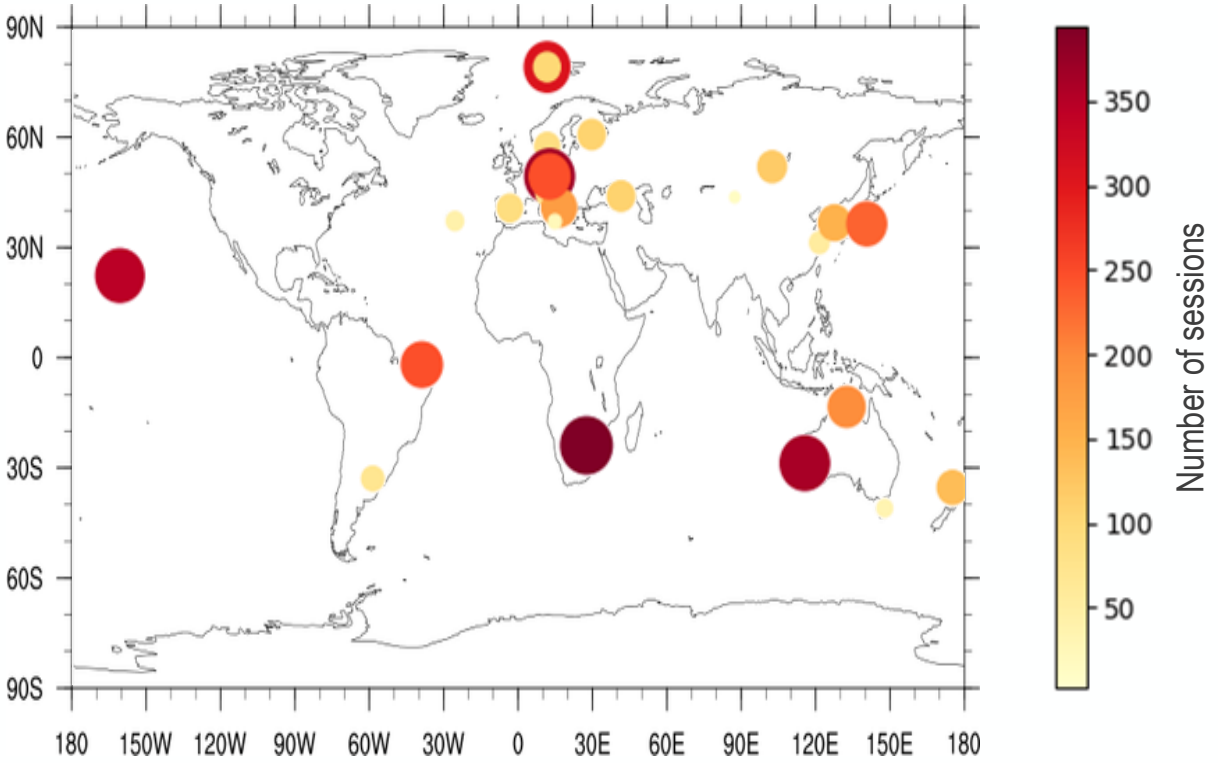
Operational setup at ESOC



Latency of the ESA VLBI solutions for R1 and R4 sessions correlated since the end of January 2022

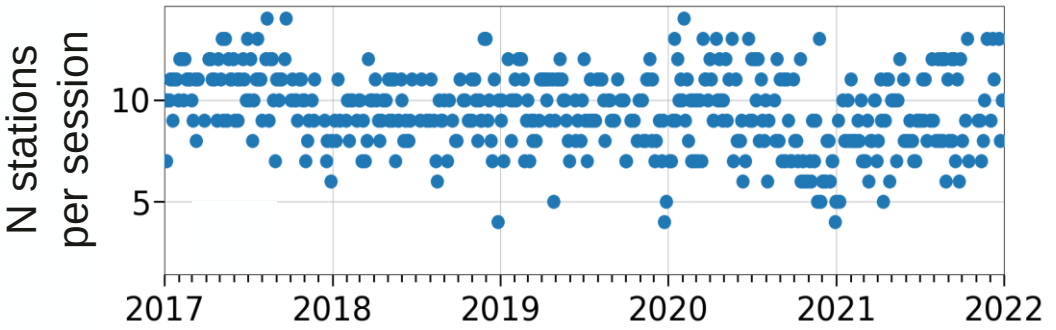
- Automatic procedure to analyse R1 and R4 session:
  - check IVS archives on a daily basis;
  - download vgosDbs published in the previous 24h (maximum observation latency: 50 weeks);
  - Trigger the analysis.
- Timely (re)processing of the latest available archives.

Processing of 2017-2021 R1 and R4 sessions

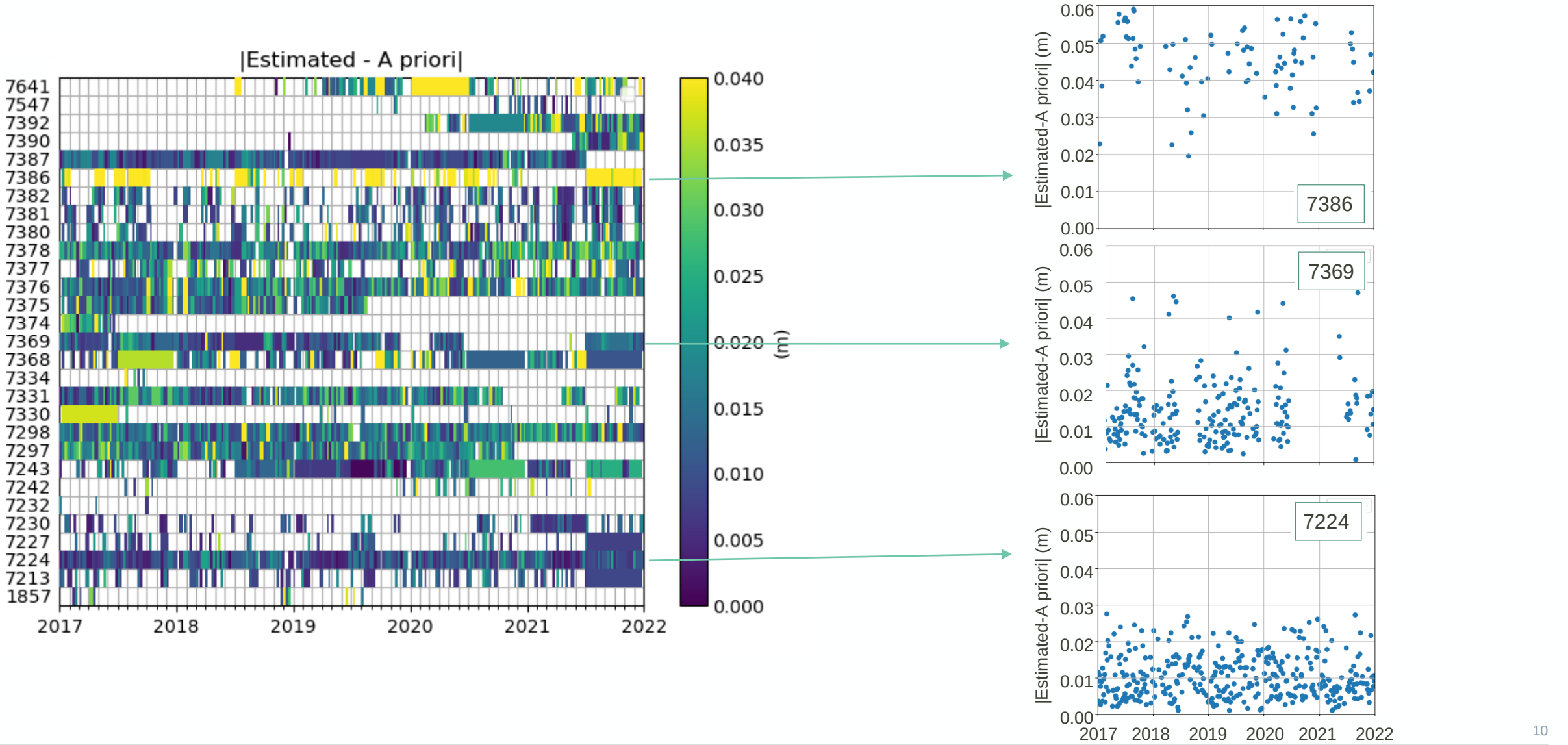


Processed ground network. Marker size and colour indicate the number of sessions in which each station participated. vgosDb files from: cddis.nasa.gov/archive/vlbi/ivsdata/vgosdb/

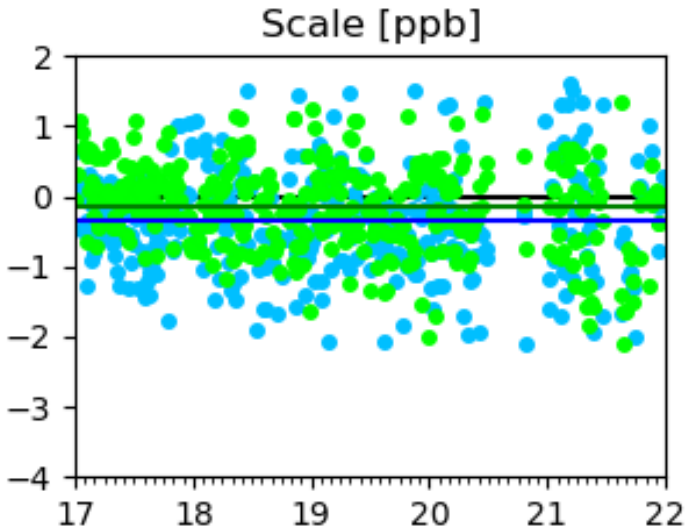
- 452 successfully processed sessions. The processing of about 60 sessions failed for the occurrence of clock breaks that are not yet handled by the software.
- A total of 29 stations participated to the different sessions
- Average number of station per sessions: 9.4



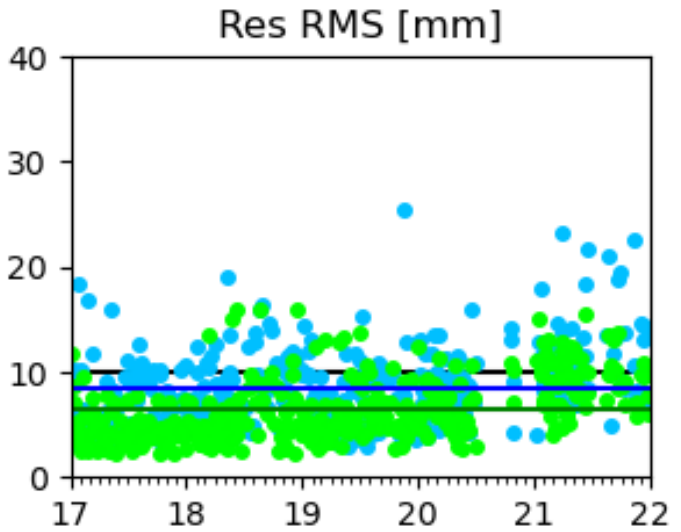
Station coordinate repeatability



Results: Helmert transformation comparison



Blue: scale factor between ESA and IVS-combined solutions
Green: scale factor between ASI and IVS-combined solutions



RMS of station position residuals after performing a Helmert transformation between: ESA and IVS combined solution (blue), ASI and IVS combined solution (green)

For each series, the horizontal lines mark the relevant mean values (same colour convention used for markers).

ESA solution are slightly noisier, but there are no appreciable systematics.

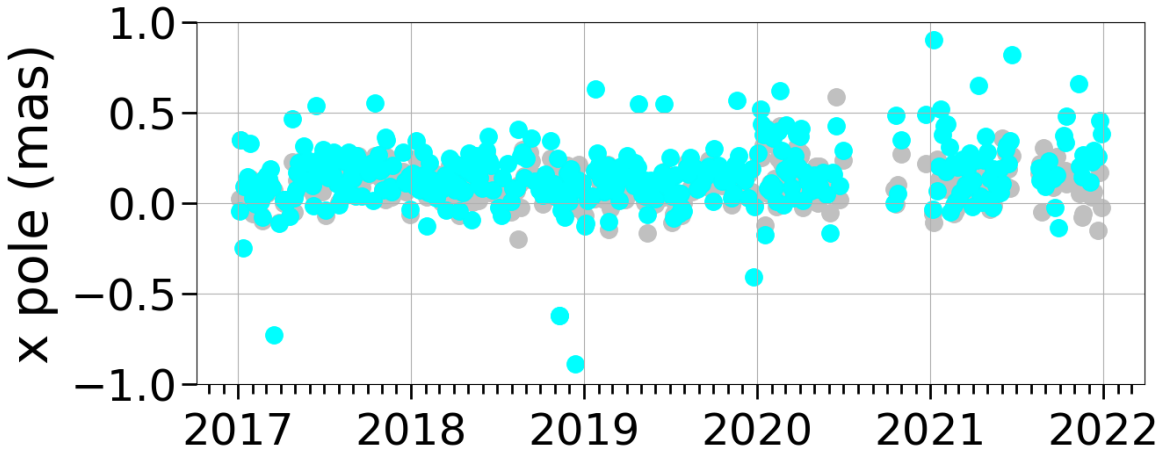
Likely causes for the noise:

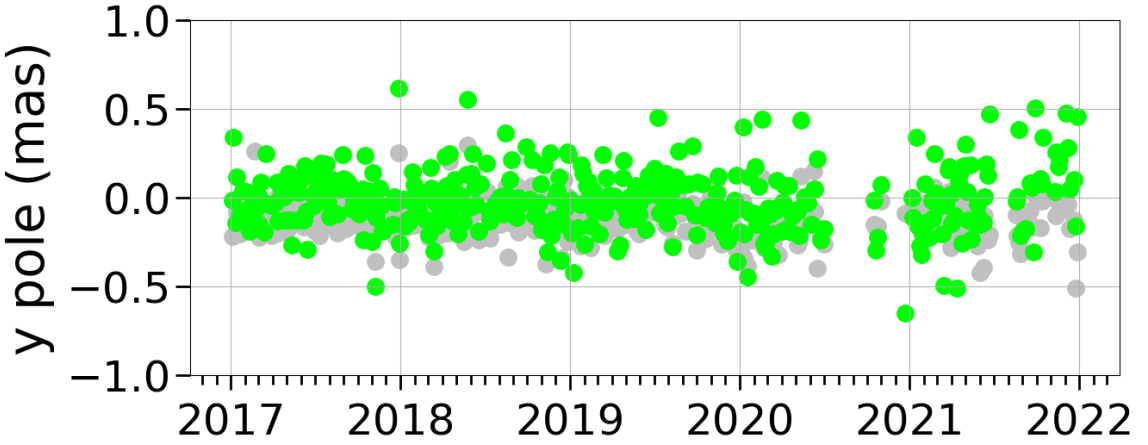
- Clock breaks are not yet handled
- No manual screening of the residuals has been performed
- A few IVS-specific models are currently under development (not yet used in the analysis)

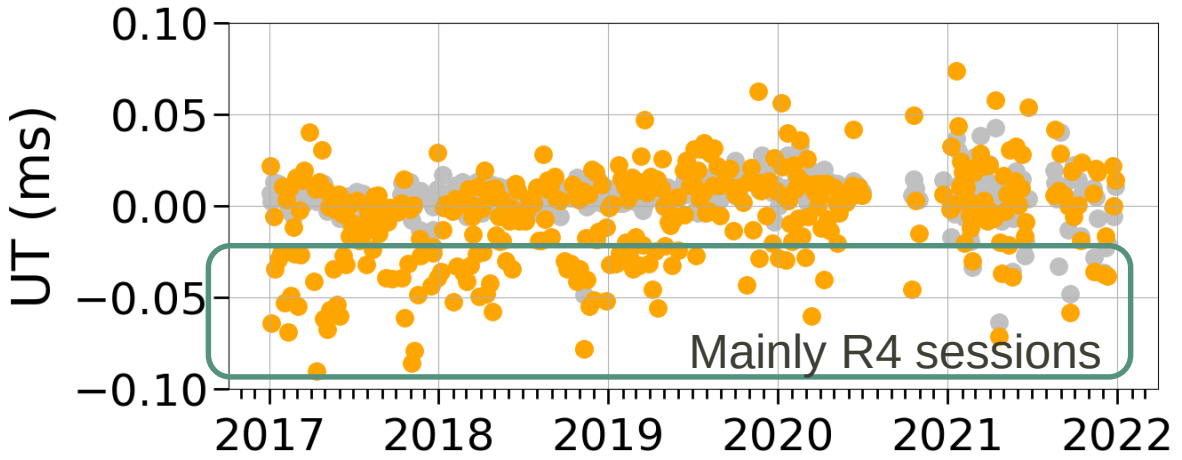
IVS and ASI solutions from: ivs.bkg.bund.de/pub/vlbi/ivsproducts/daily_sinex/<AC ID>2020a/

Results: ERP estimates w.r.t. C04 series

Coloured dots: ESA results
Silver dots: IVS combined solutions







		x pole (mas)	y pole (mas)	UT1-UTC (ms)
ESA	mean	0.15	-0.01	-0.01
	std	0.19	0.18	0.05
ASI	mean	0.18	0.11	0.01
	std	0.17	0.24	0.05
IVS	mean	0.10	-0.12	0.01
	std	0.10	0.11	0.01

Conclusions

- Over the last years, ESA's Navigation Support Office has been developing and integrating the VLBI data analysis capability in NAPEOS

- The analysis of R1 and R4 sessions is currently being tested routinely on ESOC's pre-operational infrastructure

- The analysis of 5 years of past sessions provided
  - cm-level coordinate repeatability
  - consistent scale realization w.r.t. IVS combined solution
  - consistent ERP estimates w.r.t. IVS combined solution and other ACs
  - noise levels are ~20% larger than those observed for other ACs (clock breaks, data editing)

- We have identified a number of activities that will further improve our products

- We are working on the finalisation of the modelling to support our participation in the IVS as associated AC

- The ESA/ESOC VLBI solution will be included in ESA's ERP Estimation and Prediction Service to ensure the highest possible consistency among all geodetic inputs.

Thank you for your attention

and for your support!

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