ESA/ESOC - Precise Orbit Determination for Sentinel 6A based on Galileo and GPS observations

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ESA/ESOC

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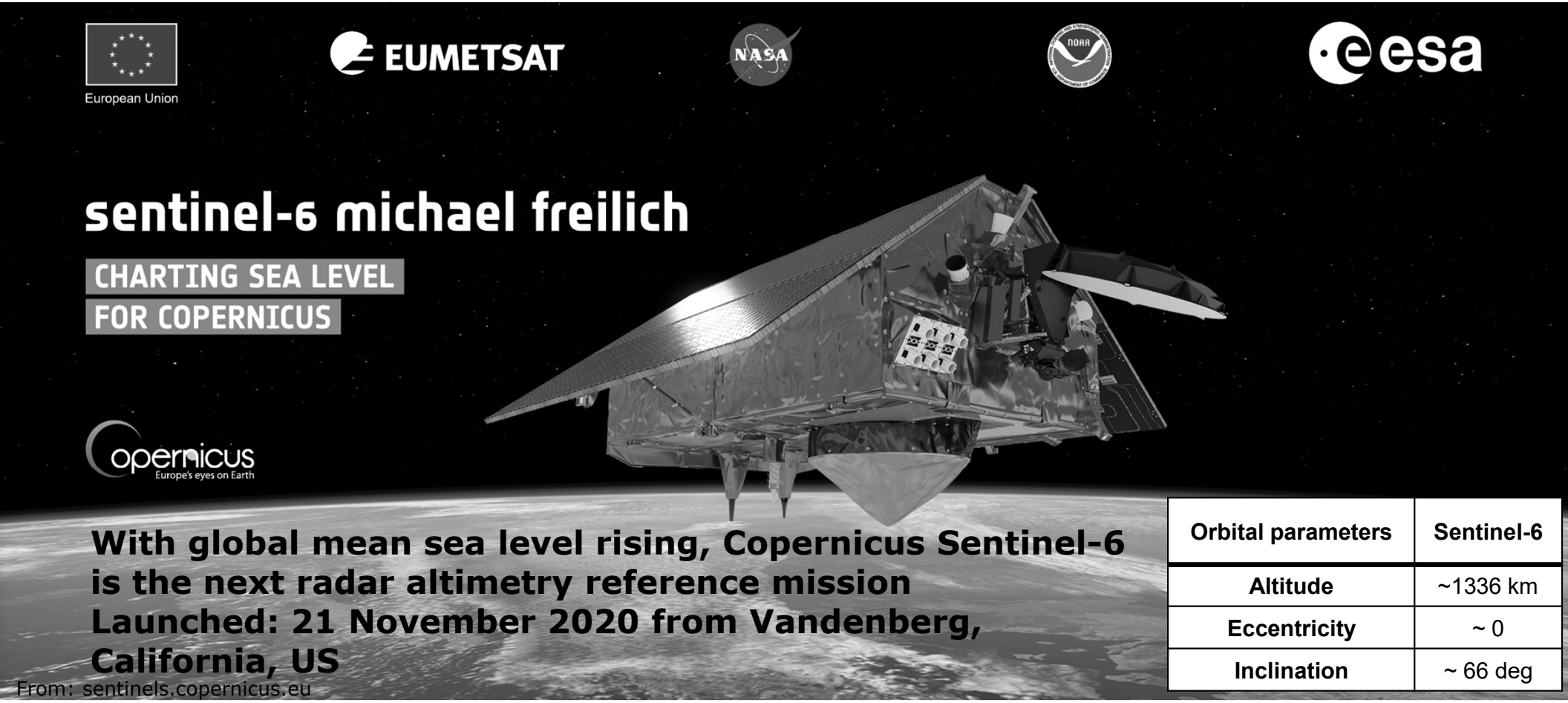
The Copernicus Program

Copernicus is the European Union's Earth observation programme, looking at our planet and its environment to benefit all European citizens. It offers information services that draw from **satellite Earth Observation and in-situ (non-space) data.**

The Sentinel 6 Michael Freilich Mission



Orbital parameters	Sentinel-6
Altitude	~1336 km
Eccentricity	~ 0
Inclination	~ 66 deg

From: sentinels.copernicus.eu

Sentinel - Operational POD Processing at ESA/ESOC

For all Sentinels*

GNSS

Generation of **accurate Galileo and GPS products** (orbits, clocks, Bias and UPDs)

RINEX

GNSS Data Conversion of Sentinels Telemetry (L0) into observations (RINEX) nominal & redundant receiver

POD

Precise Orbit Determination parallel processing chains:

- Sentinel-1,-2,-3 A&B: GPS-based POD
- Sentinel-6A: Galileo, GPS, and Combined POD

- Operational chain with GNSS-based POD Rapid (24h) and final (7days)

*Sentinel-5P does not downlink GNSS raw observations

Sentinel 6 POD - Galileo and GPS Observations

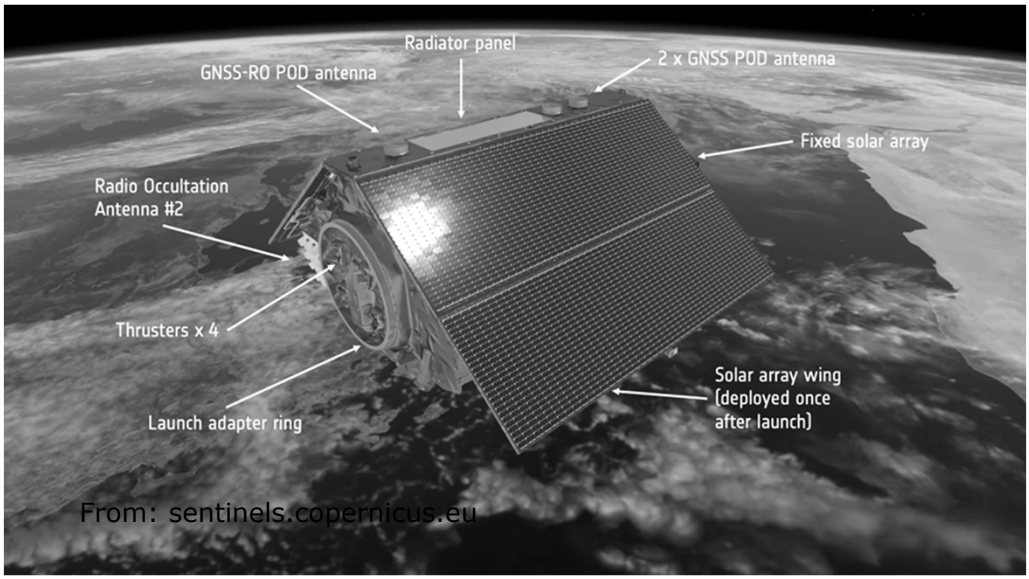
2 redundant GNSS receivers (RUAG PODRIX) onboard Sentinel-6, which provide:

- Galileo signals: E1-C, E5a-Q
- GPS signals:
  - L1 P(Y), L2 P(Y) – Block IIR
  - L1 C/A, L2C-L – Blocks IIR-M, IIF, III
  - L5 signals could be tracked

ESOC's POD solutions for Sentinel-6A:

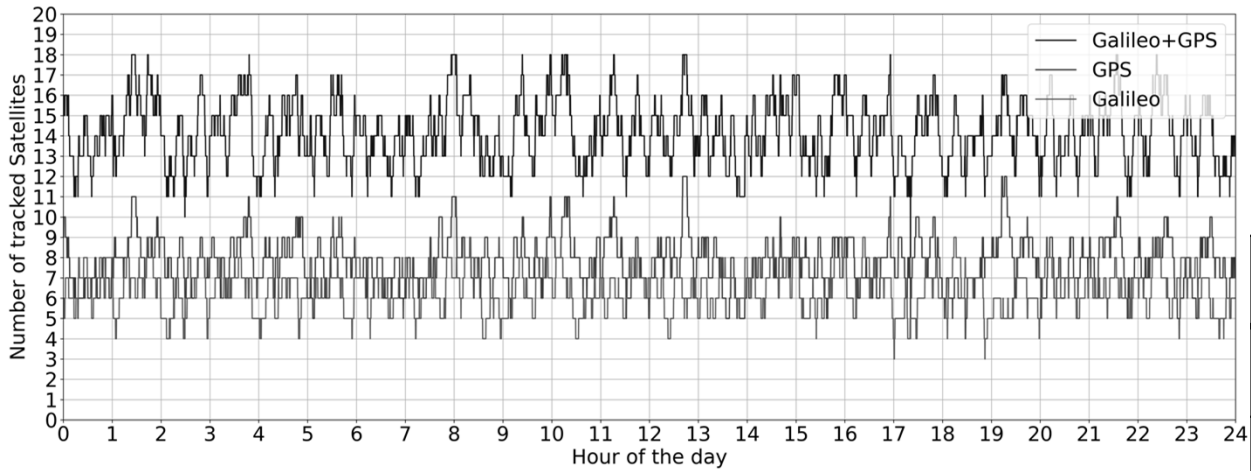
- Galileo-only solution
- GPS-only solution
- Galileo + GPS solution

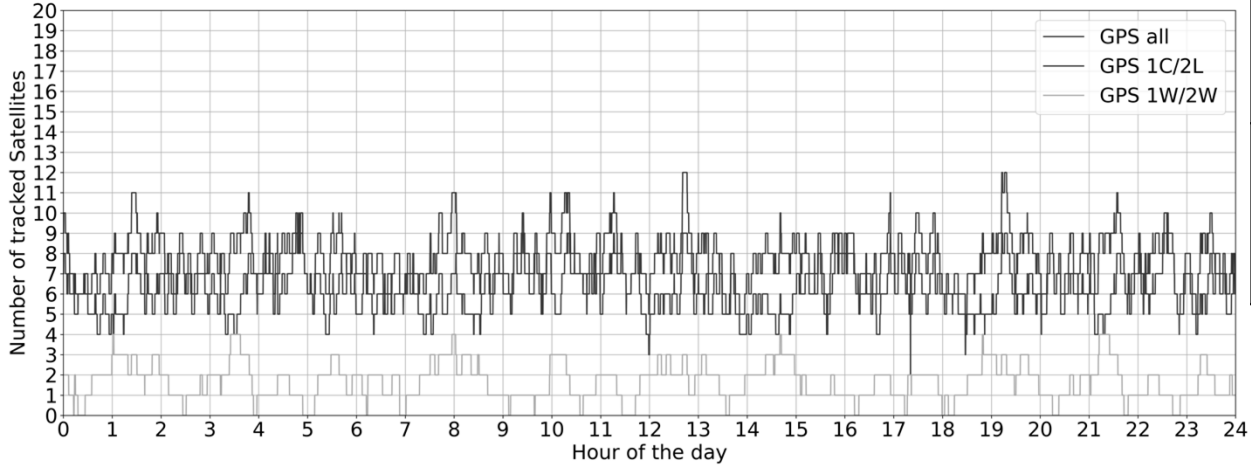
SLR observations are used only for validation purposes



RUAG PODRIX receiver, from: ruag.com

Sentinel 6 POD - Number of GNSS observations





Observations	Galileo	GPS		Galileo + GPS
Frequency & Signal	E1-C E5a-Q	L1 C/A L2C-L	L1 P(Y) L2 P(Y)	all
Total 24h #obs.	55k	53k	14k	122k
		67k		
Average #obs. per epoch	6.4	6.1	1.7	14.2
		7.8		

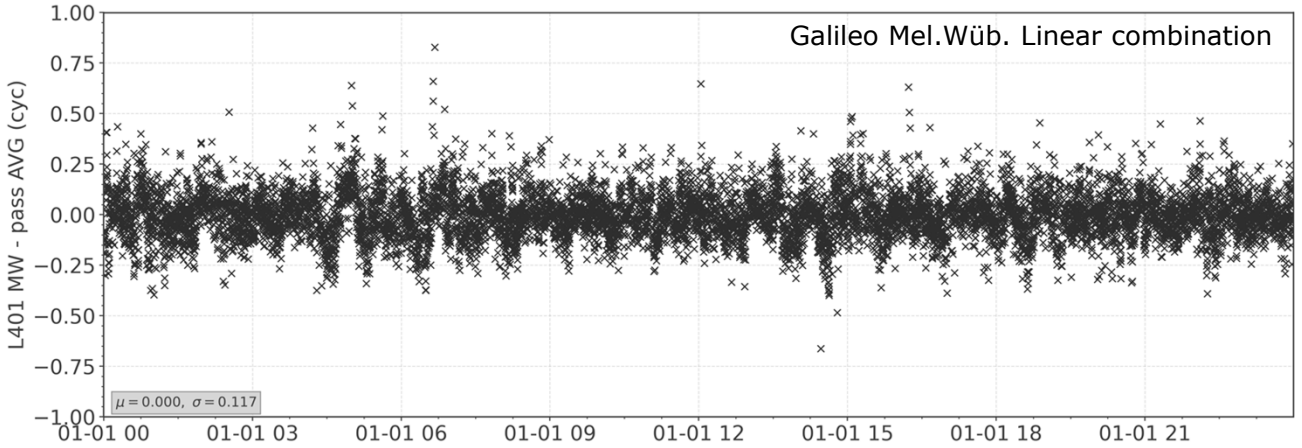
*1 obs. = dual-freq code+phase obs.

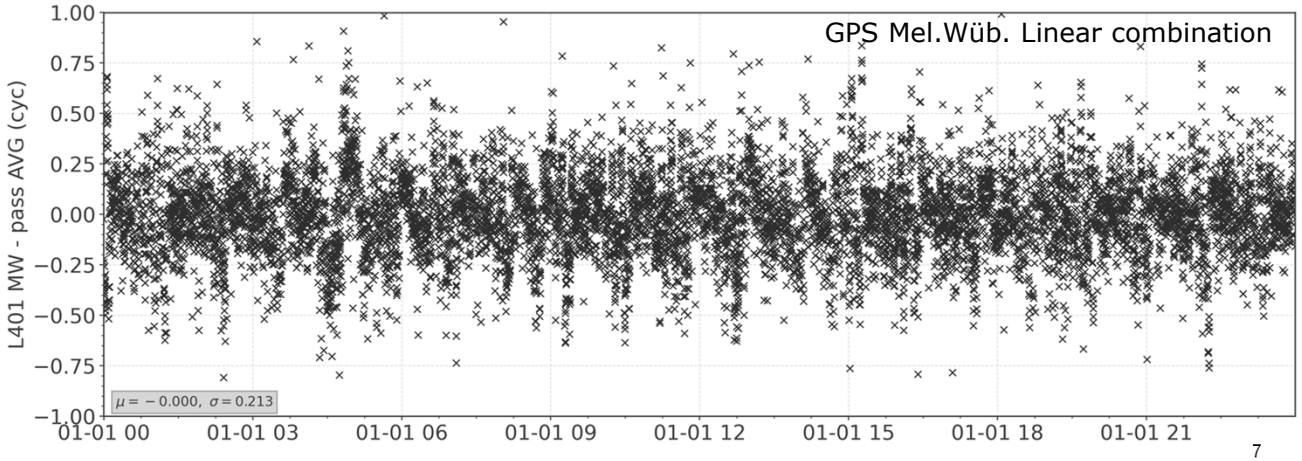
Sentinel 6 POD - Quality of the observations

Observations quality

	Galileo	GPS
Melbourne-Wübbena (cm)	**8**	18
Iono Free Code-Carrier (cm)	**28**	56

- High quality of ALL observations
- High-accurate Galileo observations in space
- Galileo shows half the noise of GPS particularly thanks to the excellent code observations



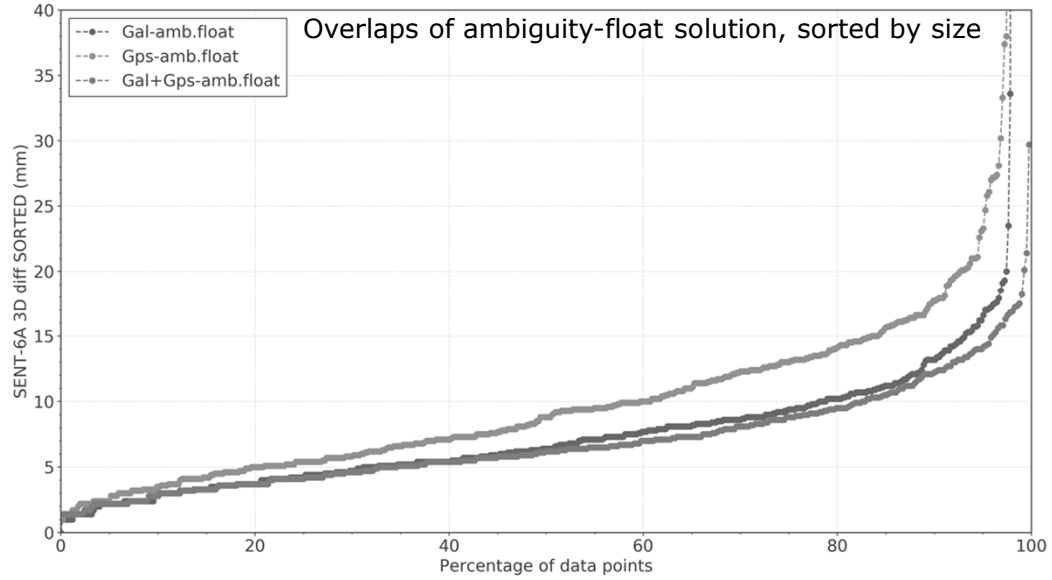


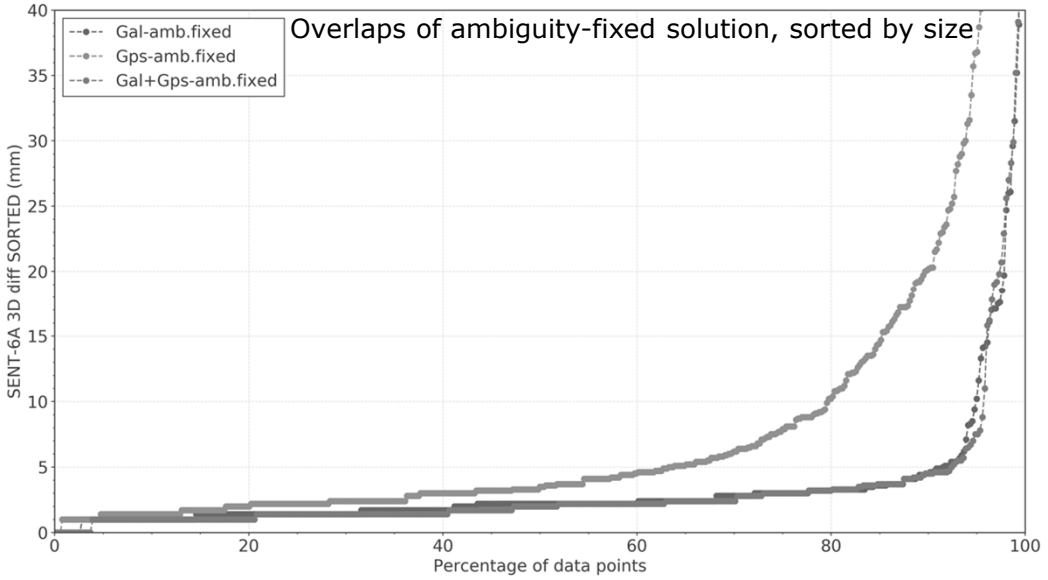
Sentinel 6 POD - Internal consistency – Day-Boundary Orbital Overlaps

Day-boundary Overlaps* statistics at 80% & 95%

	Galileo		GPS		Galileo + GPS	
	80%	**95%**	**80%**	**95%**	**80%**	**95%**
Ambiguity-Float sol.	< 10 mm	< 16 mm	< 14 mm	< 23 mm	< 9 mm	< 14 mm
Ambiguity-Fixed sol.**	**< 3 mm**	**< 10 mm**	< 10 mm	**< 35 mm**	**< 3 mm**	**< 8 mm**

*Daily arcs are 30h long, overlaps are at the midnight point **amb.fix success rate: GAL~100%, GPS~86%, Gal+GPS~98%

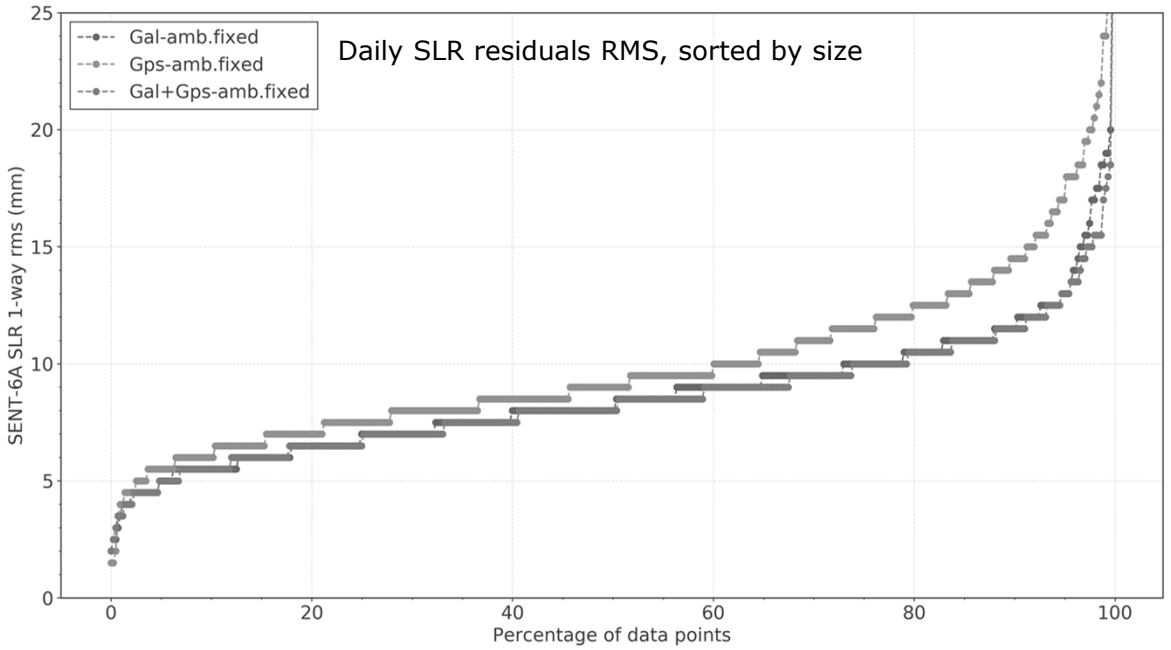




Sentinel 6 POD - External validation – Laser Ranging residuals

- High performance of all 3 solutions with the SLR independent validation
- In terms of residuals mean all solutions show a bias of ~1mm
- In terms of residuals RMS, the combined solution performes the best, followed by Galileo (within a sub-millimeter difference)
- The GPS-only solution shows again higher residuals than the other two solutions

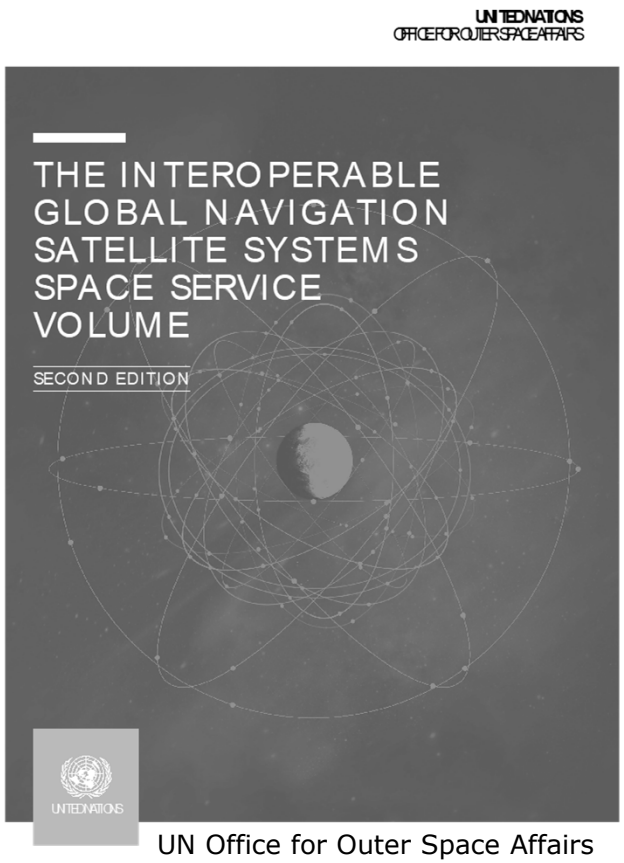
	Galileo	**GPS**	**Galileo + GPS**
SLR res. Mean (mm)	1.1	0.9	1.1
SLR res. RMS (mm)	8.6	9.9	8.4



GNSS Interoperability

In the context of GNSS Interoperability, the Sentinel 6 Michael Freilich mission is an important milestone for the multi-GNSS-based navigation in space

- **Thanks to its dual constellation PODRIX receiver, Sentinel-6A demonstrates:**
  - The excellent performance of the solutions based on the combined processing of the Galileo and GPS signals
  - The combined processing even leads to overcome the limitations of a single constellation
- **Some points are still under investigation:**
  - The combined solution shows higher-than-expeced Carrier-phase residuals, with respect to the 2 single constellation solutions
  - Larger-than-expected orbital differences between the solutions based on the Galileo-only and GPS-only processing



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Conclusions & Future activities

Conclusions

- Excellent performance of Galileo observations based on high quality and fully operational space receiver
- The combination of the Galileo and GPS observations leads to the best solution in terms of orbital overlaps and SLR residuals showing the superiority of the systems interoperability
- Room for further improvements related to GNSS interoperability observations processing

Future activities

- Investigate higher-than-expected POD results (e.g., overlaps, SLR) based on the GPS observations
- Include in the POD processing the GNSS observations from the TriG receiver (NASA/JPL)
- Operationally set up and process Sentinel 6, all other Sentinels and other LEOs (e.g., SWARM A,B,C) in a GNSS Network approach