ESA Multi-GNSS Products

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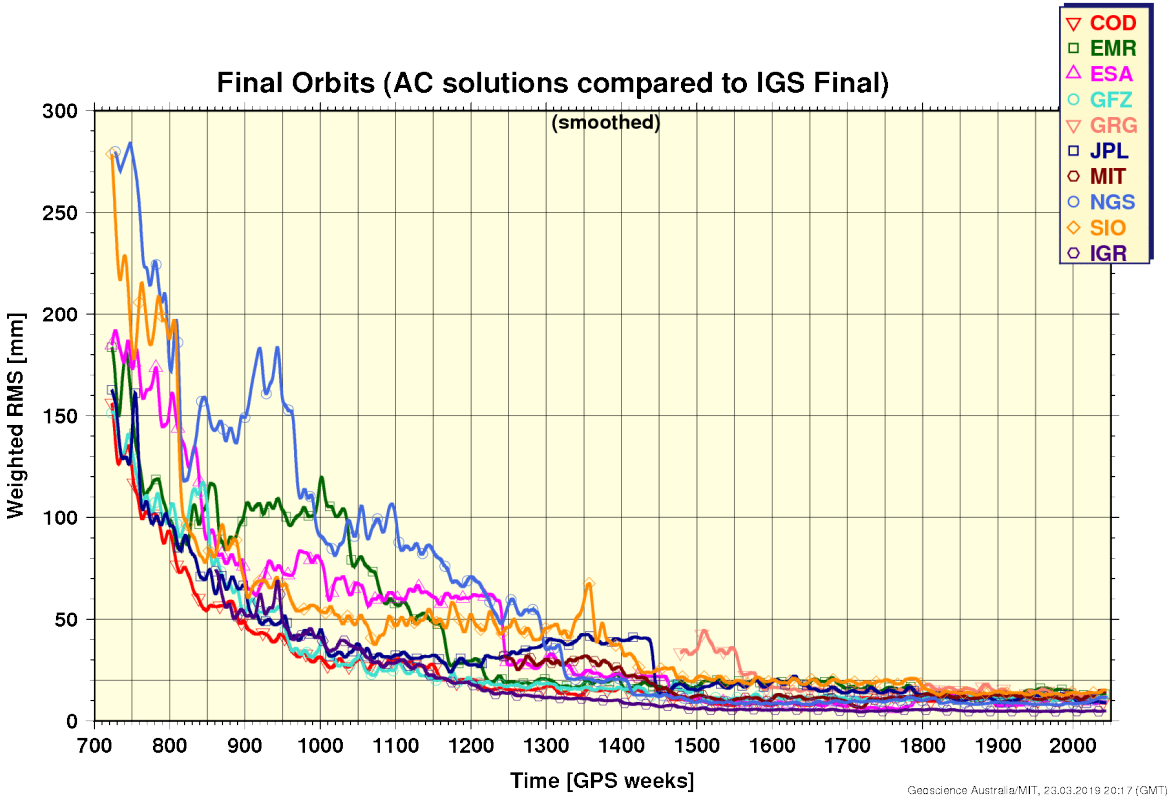
ESOC Navigation Support Office

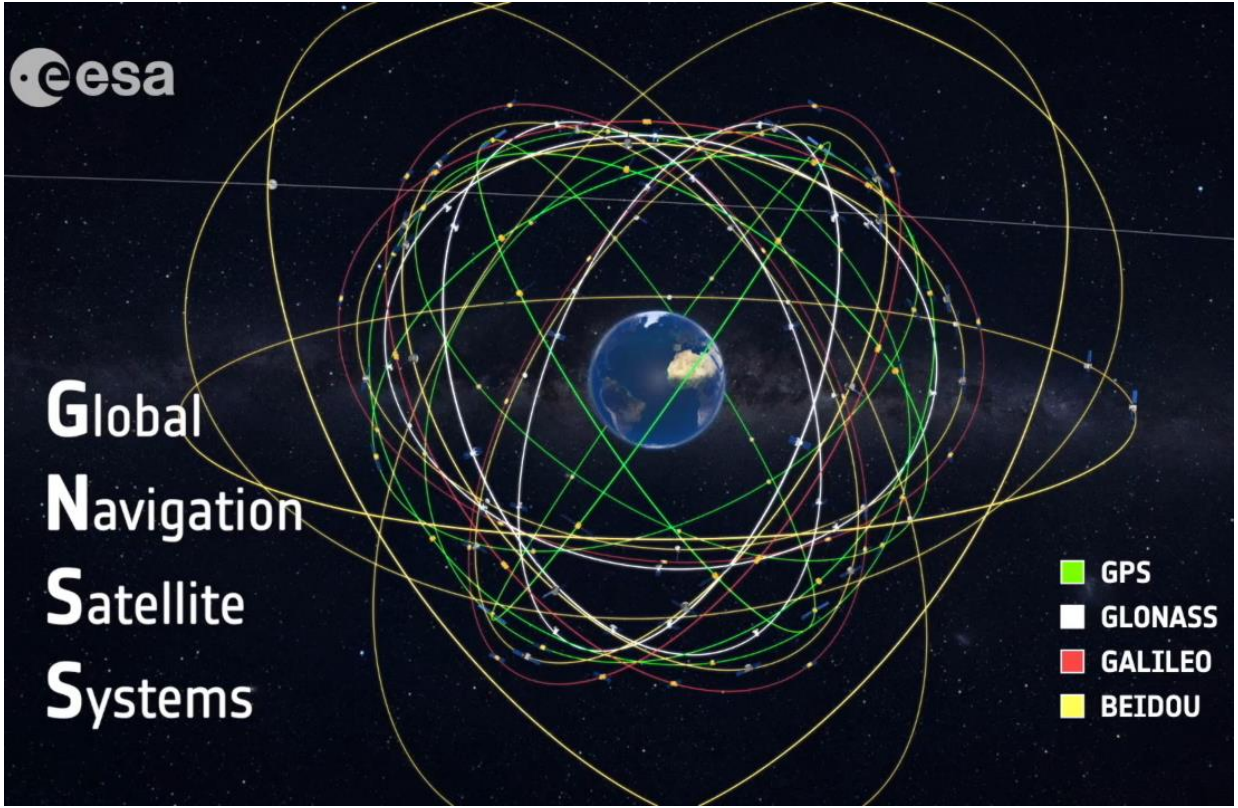
- Located at the European Space Operations Centre in Darmstadt
- Providing high precision GNSS orbit and clock products since 1992:
  - IGS (GPS+GLONASS)
  - GRAS GSN
  - GGSP/OVF (+Galileo)
  - Copernicus
  - etc.



Multi-GNSS

- All projects push to exploit advantages of Multi-GNSS

	In Operation	In Orbit
GPS	31	32
GLO	24	26
GAL	22	26
BEI	33	38
QZS	4	4
Total	114	126

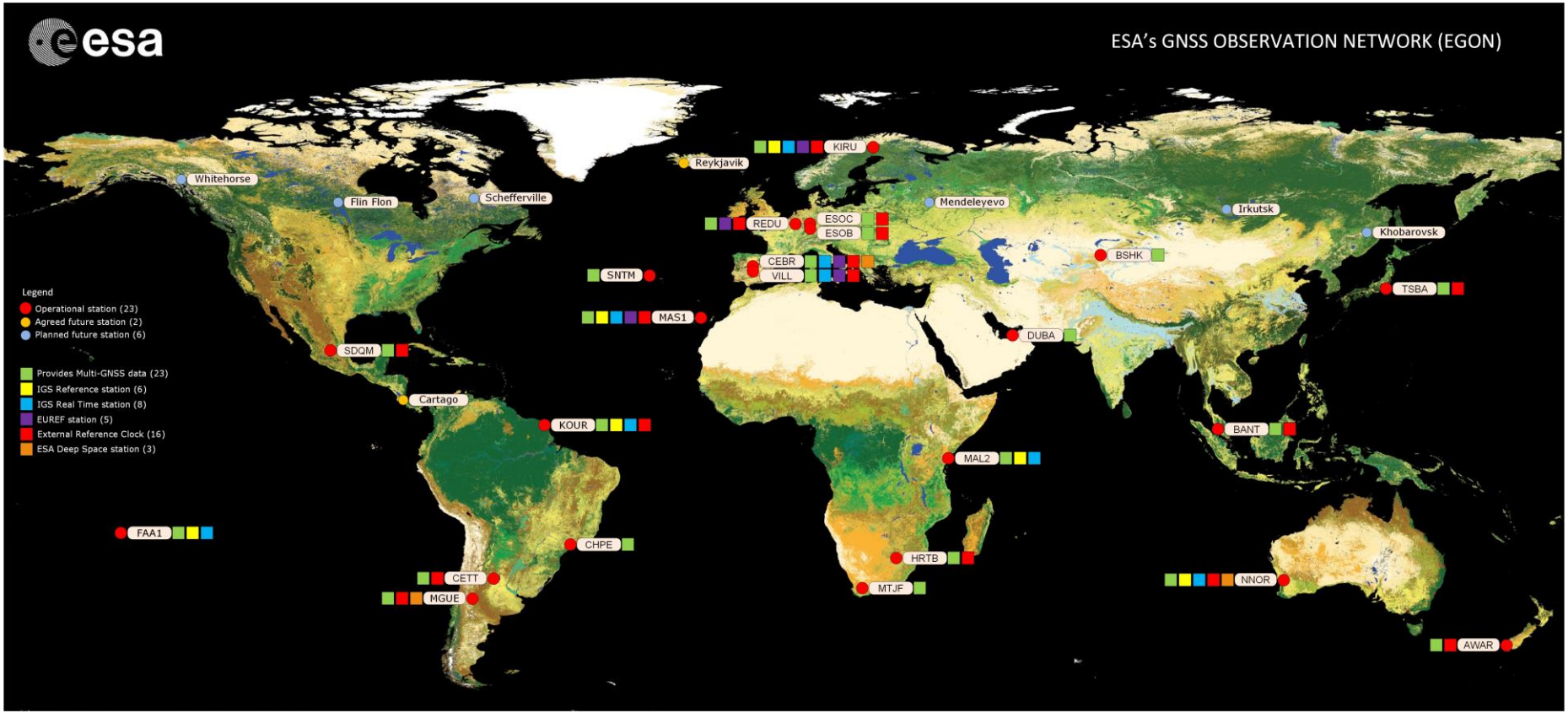


Multi-GNSS Efforts at ESOC

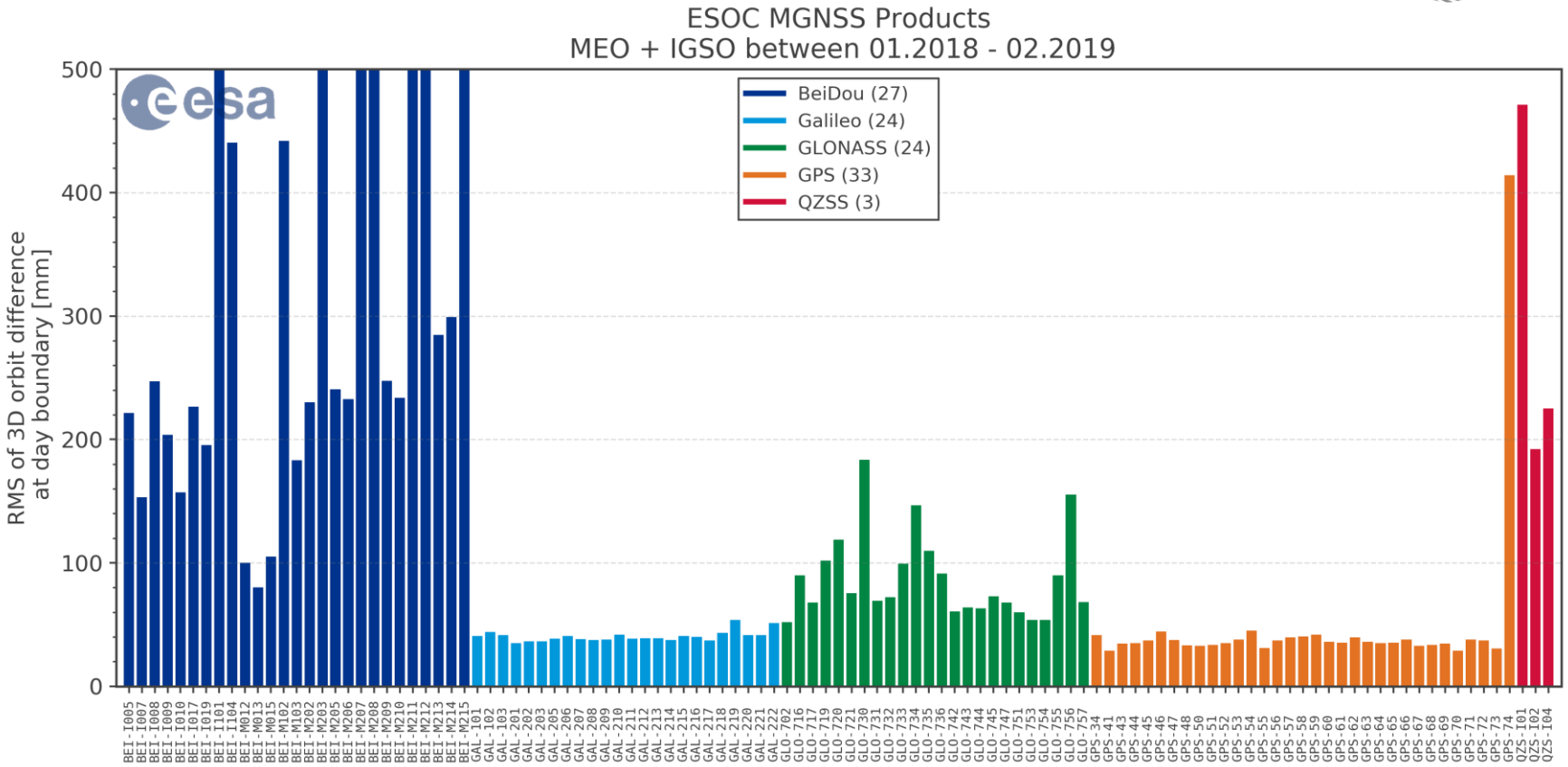
- Daily processing routine of multi-GNSS, based on IGS routine
  - Minimal-constraint 24 hours network-solution of all operational GNSS satellites
  - Started in 2005 as experiment to study characteristics of the new constellations

- Centre-piece of ongoing development work at ESOC:
  - Orbit & Clock modelling
  - Cycle Ambiguity resolution
  - Differential Code/Carrier Biases
  - L-Band signal combinations (all available signals)
  - ESA Earth Orientation Parameters (based on GNSS, VLBI, SLR and DORIS)
  - POD of Formation Flying and Constellations
  - GNSS Space Service Volume

ESA's GNSS Observation Network (EGON)

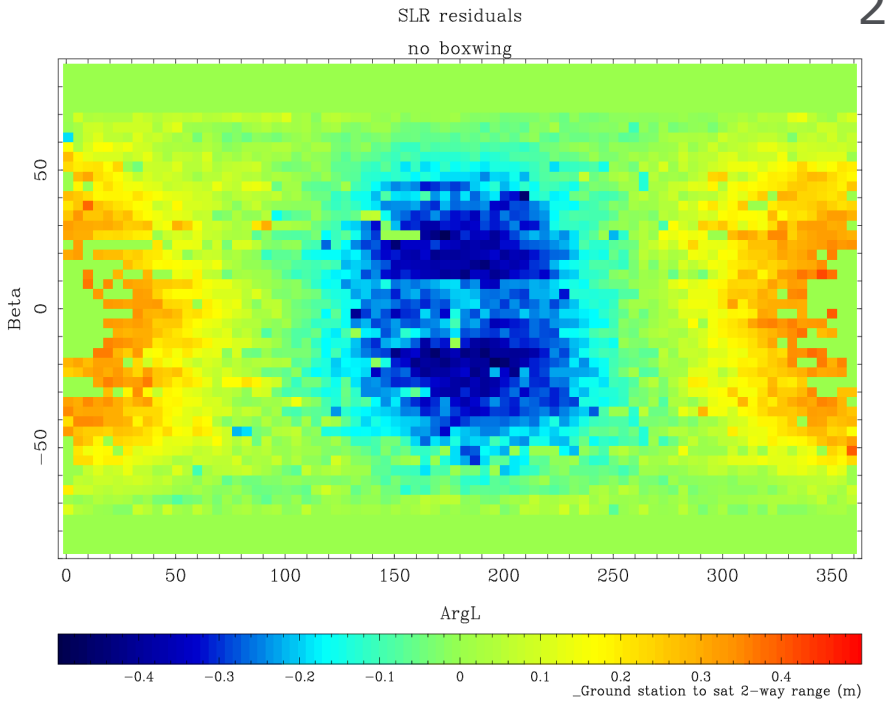


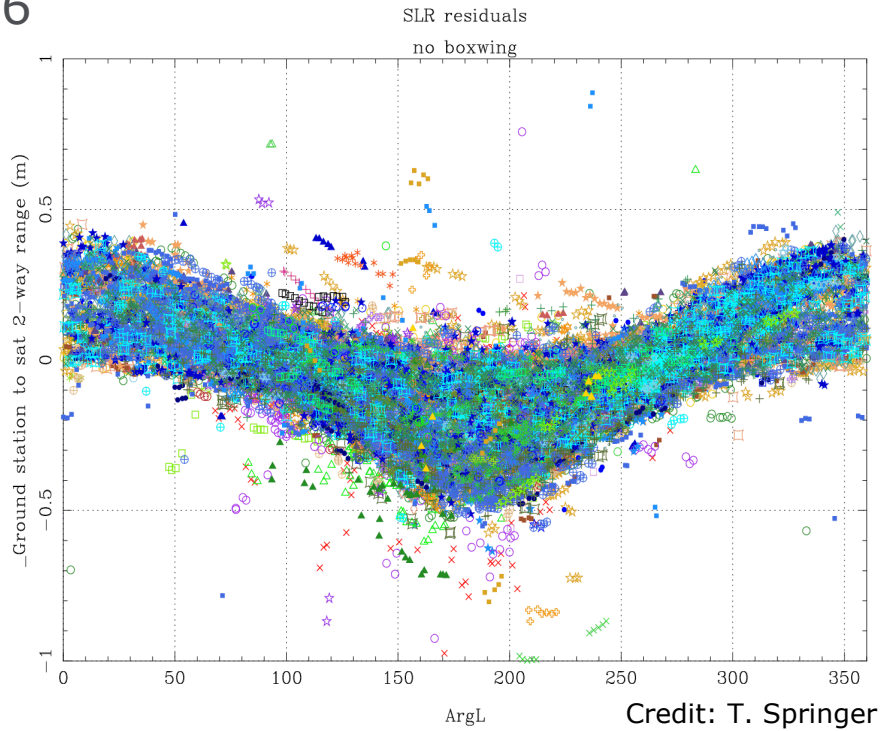
Day-boundary orbit differences (worst case)



GALILEO Radiation Pressure Modelling
SLR Residuals with only ECOM (empirical model)

2016

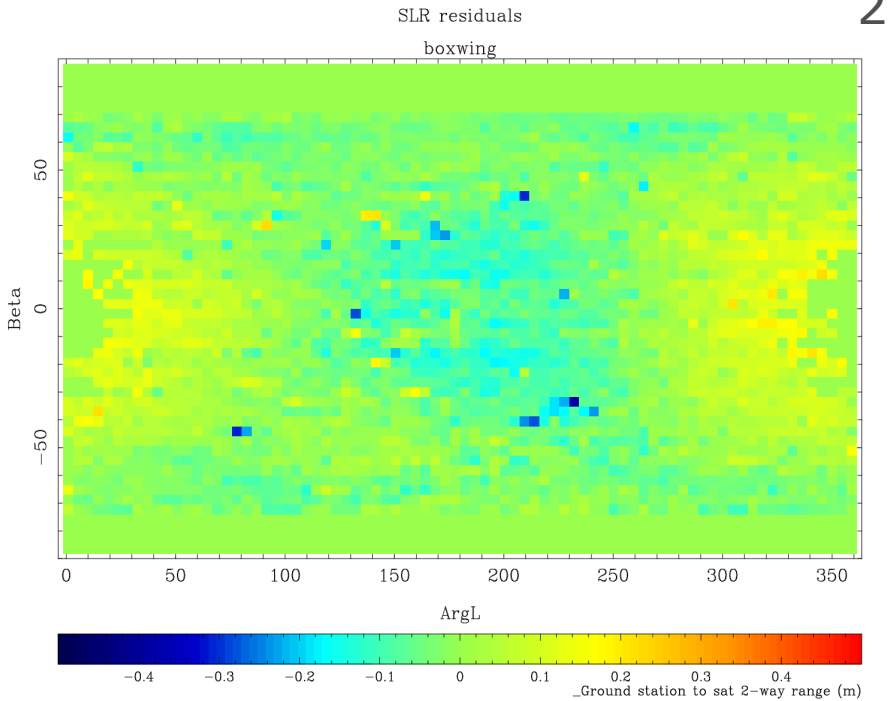


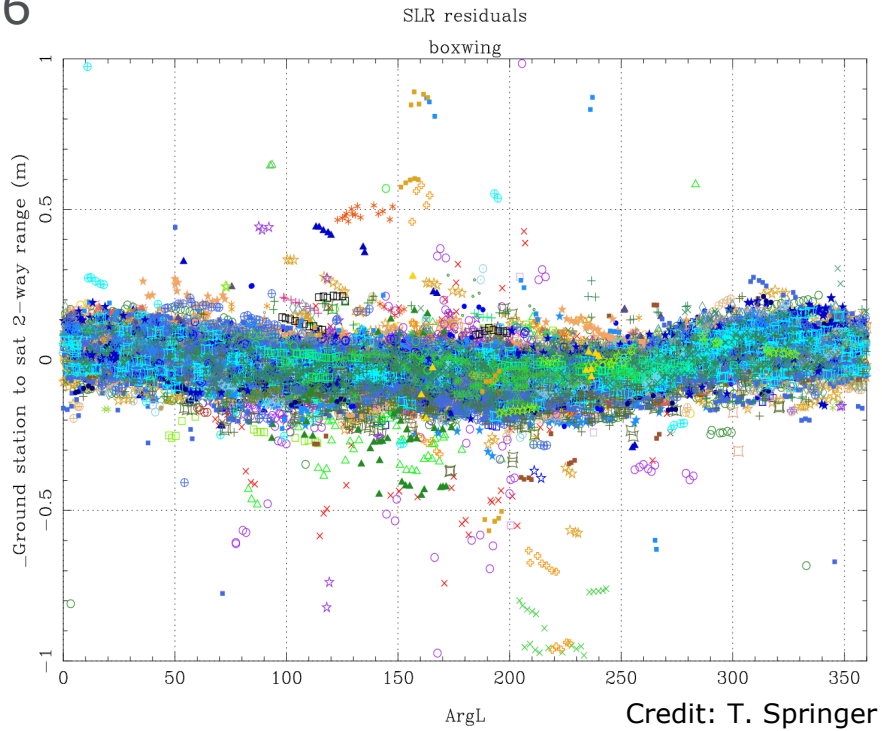


Credit: T. Springer

GALILEO Radiation Pressure Modelling
SLR Residuals with Box-Wing model (physical model)

2016

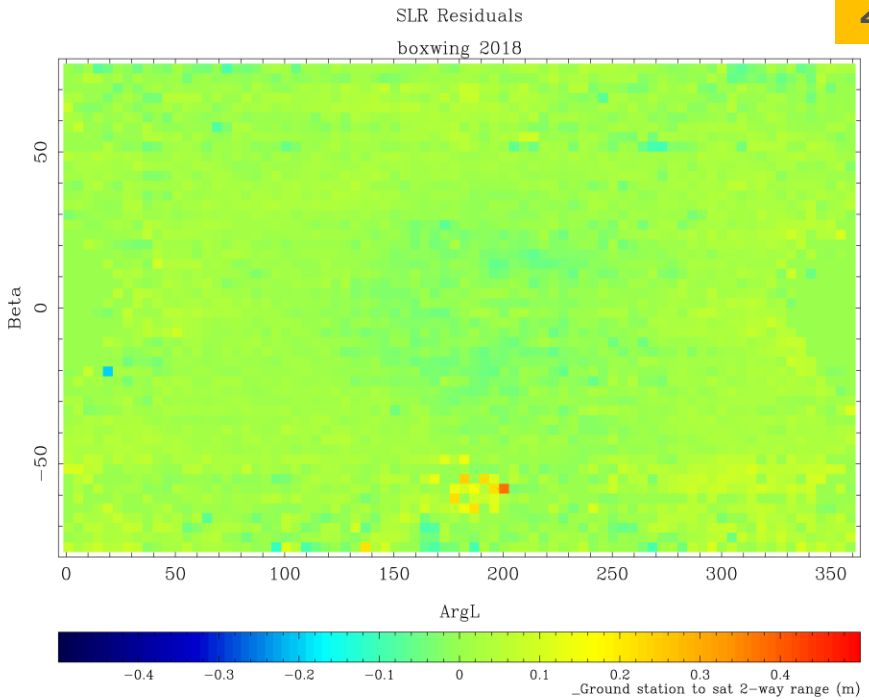


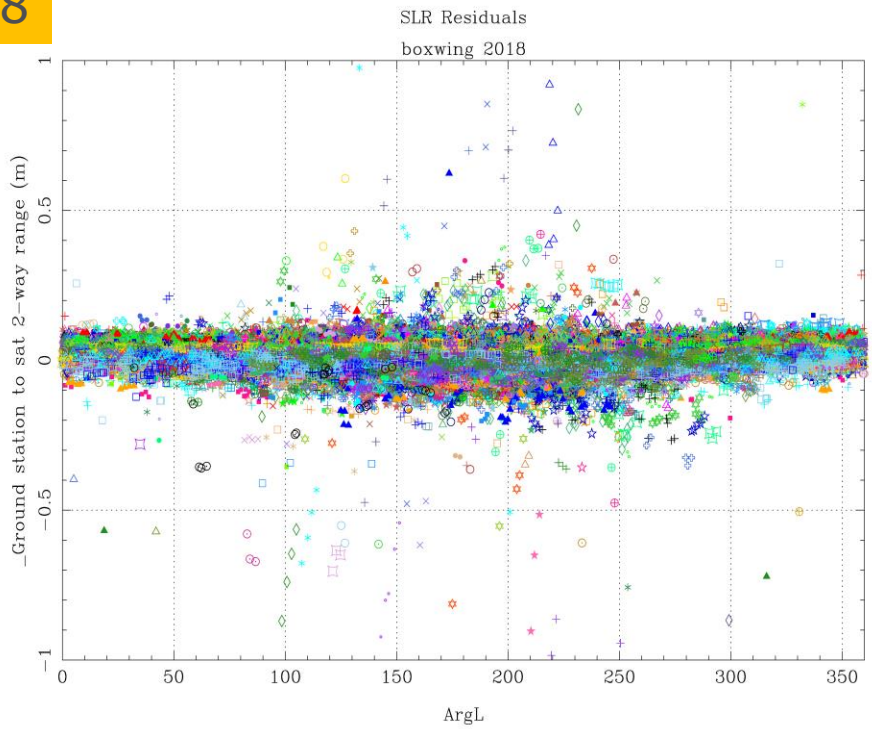


Credit: T. Springer

GALILEO Radiation Pressure Modelling
SLR Residuals with Box-Wing model (physical model, improved)

2018

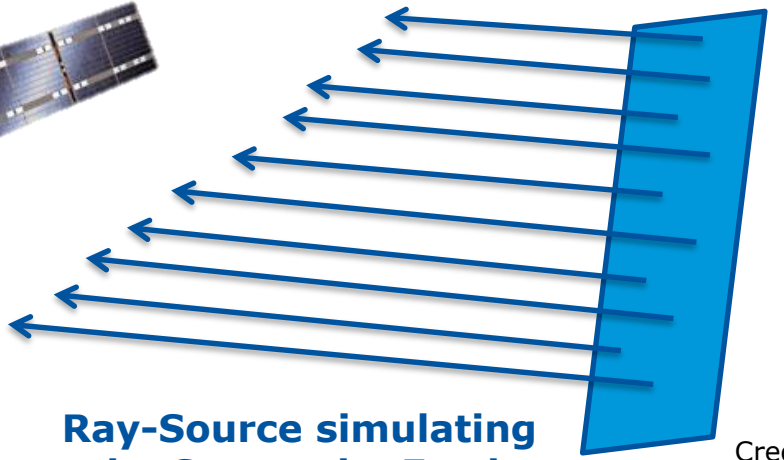




Next Generation Radiation Pressure Model
ARPA (Aerodynamics and Radiation Pressure Analysis)

- **In Testing:**
  Replacement of Box-Wing model by **Raytracing** Procedure
- Detailed information about satellite geometry and surface properties allows improved modelling of **Radiation Pressure** and **Air Drag** (LEO)

Galileo FOC.
Credit: ESA-P. Carril

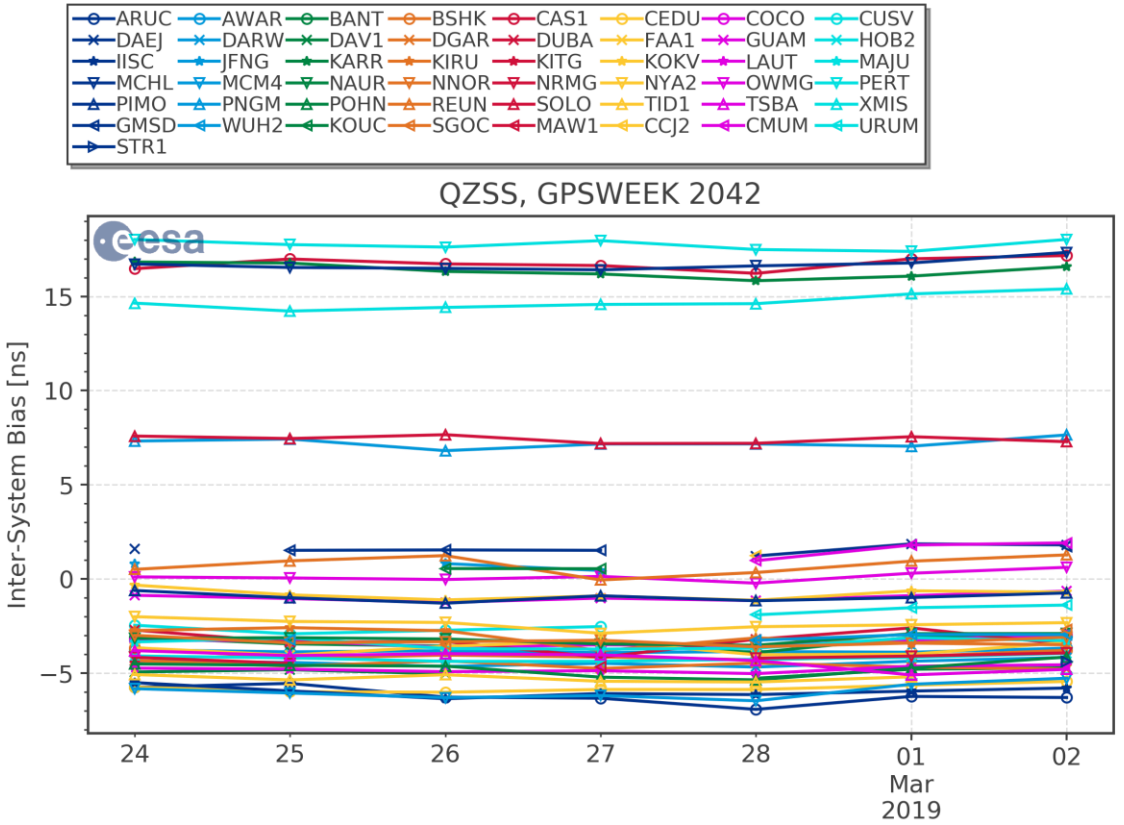


Ray-Source simulating the Sun or the Earth

Credit: F. Gini

QZSS Inter-System Bias

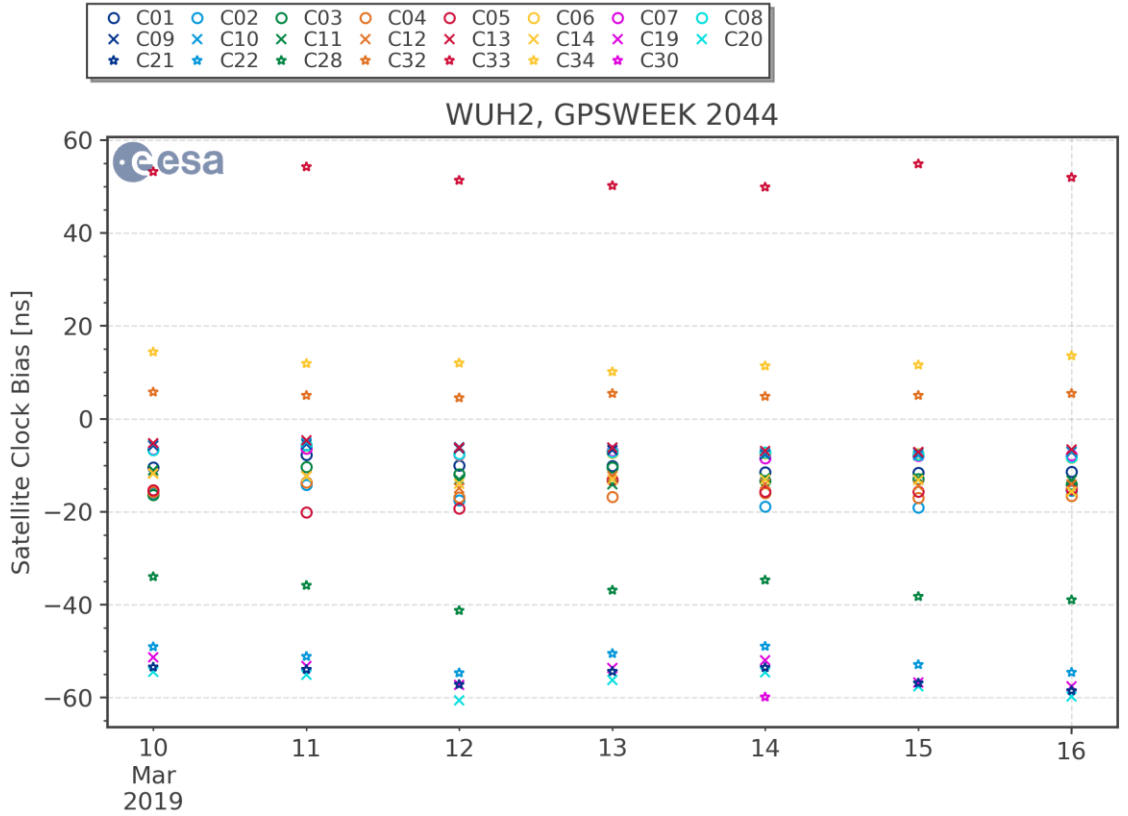
- In 2017 the number of QZSS satellites increased from one to four.
- One receiver model is tracking QZSS with a significant ISB:
  - GPS-QZSS Inter Ambiguity Resolution not possible (anymore)
  - Alternative: QZSS-QZSS DD ~5% Improvement in orbit



BeiDou-3 Satellites Clock Bias

- Ideal Case:
  One Inter-System Clock Bias per Station w.r.t. GPS
  - True for Galileo
  - True for QZSS
  - (Mostly) True for BeiDou-1/-2

- BeiDou-3 Clock Biases are not aligned
  - Requires one bias per station per satellite
  - Ambiguity fixing impossible



ESOC MGNSS Final Products

- Final products with 13 – 6 days delay

Products	Format	Ext.	Interval	Period
Ephemeris	SP3	.sp3	300 s	24 h
Clocks	CLK RINEX	.clk	30 s	24 h
Inter-System Bias	SINEX	.bias	24 h	24 h
Earth Rotation Parameter	ASCII	.erp	24 h	24 h
Summary file	ASCII	.sum		1 week
SLR Residuals Quick Look	ASCII	.sls		1 week

- Available at:
  - http://navigation-office.esa.int
  - (soon) GNSS Science Support Centre https://gssc.esa.int

Application of MGNSS solution at ESOC

- Test environment and template for ongoing and future projects, e.g.
  - Copernicus POD
  - GRSP (Galileo Reference Frame)

- Performance Monitoring for:
  - **E**SA's **G**NSS **O**bservation **N**etwork (EGON)
  - UTC(ESA)
  - Reference solution for external projects
- Galileo Predictions for the ILRS
- IGS-IGMA Pilot Project (International GNSS Monitoring and Assessment)