ESOC – State-of-the-art Precise Orbit Determination

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04/09/2019

Outline

- Small Networks - Impact of different POD setups
- Small Networks - Benefits of using LEOs in GNSS POD setups
- Galileo POD based on SLR only
- ESOC’s Sentinel POD product performance
- Conclusions

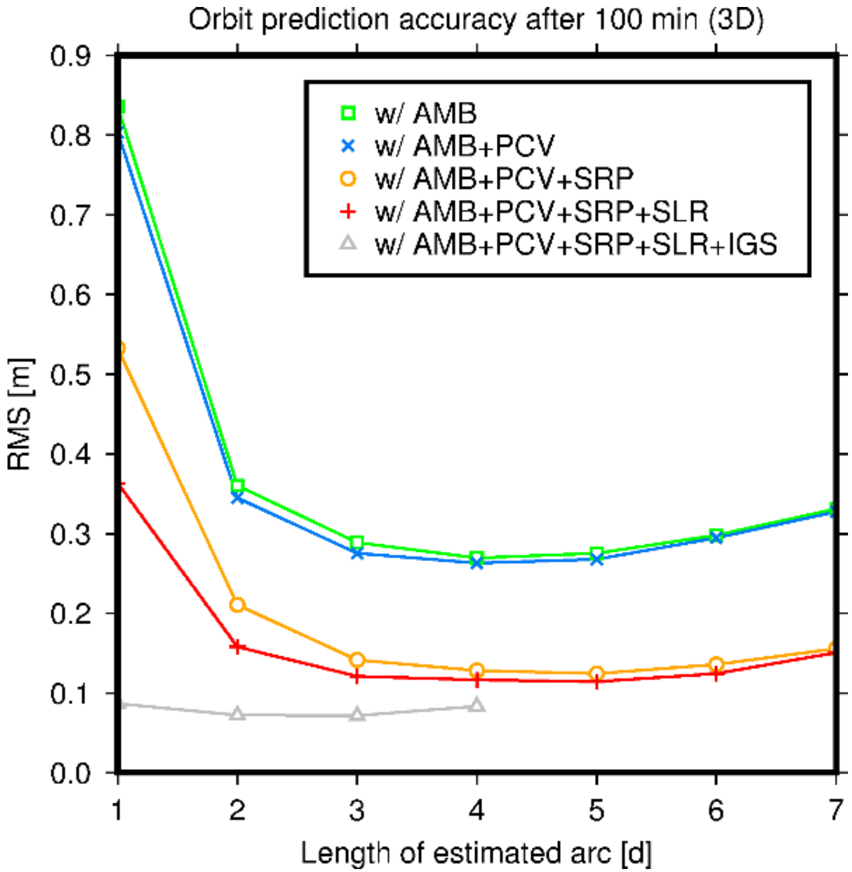
Small Networks - Impact of different POD setups

Overall processing strategy

- Generate Galileo orbit and clock solutions spanning 10 weeks
- Start out with small Galileo ground station network (# 14 sites)
- Incrementally increase orbital data arc lengths (1 – 7 days)
- Use standard 5-parameter ECOM approach with a-priori radiation model turned on/off (Box-wing for IOV and ARPA for FOC)
- Combine radiometric with Galileo satellite laser ranging (SLR) data from 2nd ILRS LARGE campaign on observation level
- Use additional GNSS tracking data from IGS network

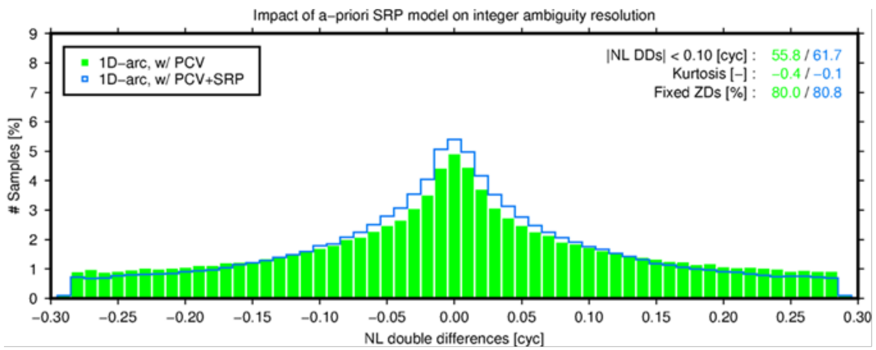
Orbit prediction accuracy

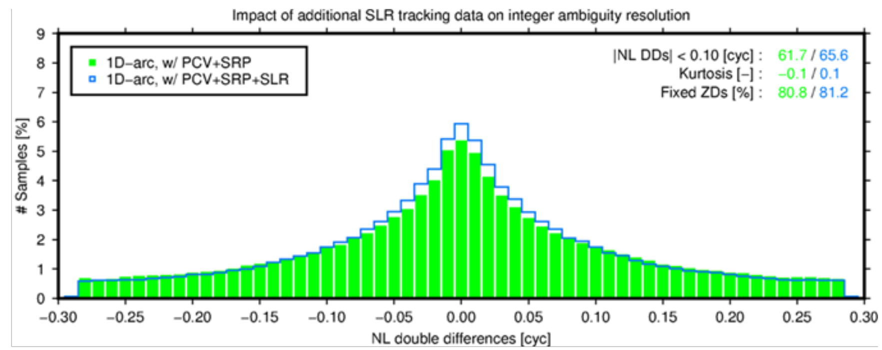
- Propagate orbits over 24 hours (shown 100 min)
- Compare predicted against 'true' reference orbit
- Compute 1-way SLR residual RMS over predicted arc as measure for radial prediction accuracy

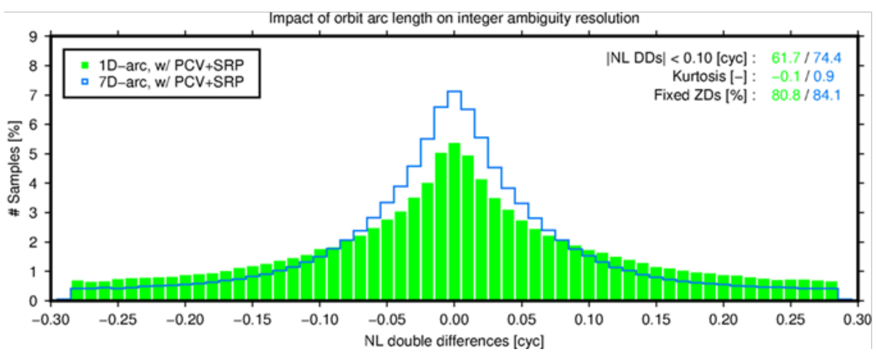


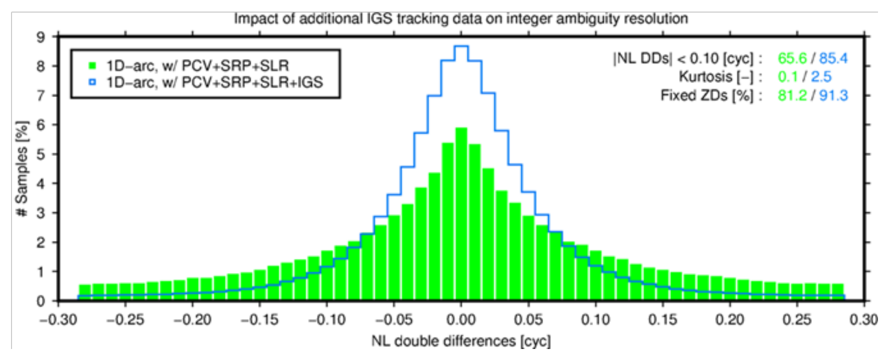
- **Results:**
  - Selection of data arc length and SRP model show strong impact on prediction accuracy
  - Factor 3 improvement when going from 1-day to 4-day arcs
  - Further reduction in RMS when adding SLR data; 30% improvement over 1-day arc solution w/o SLR
  - Effect of satellite antenna PCVs is considered small
  - Orbit prediction degradation for longer orbit data arcs show orbit model deficiencies

Impact on integer ambiguity resolution









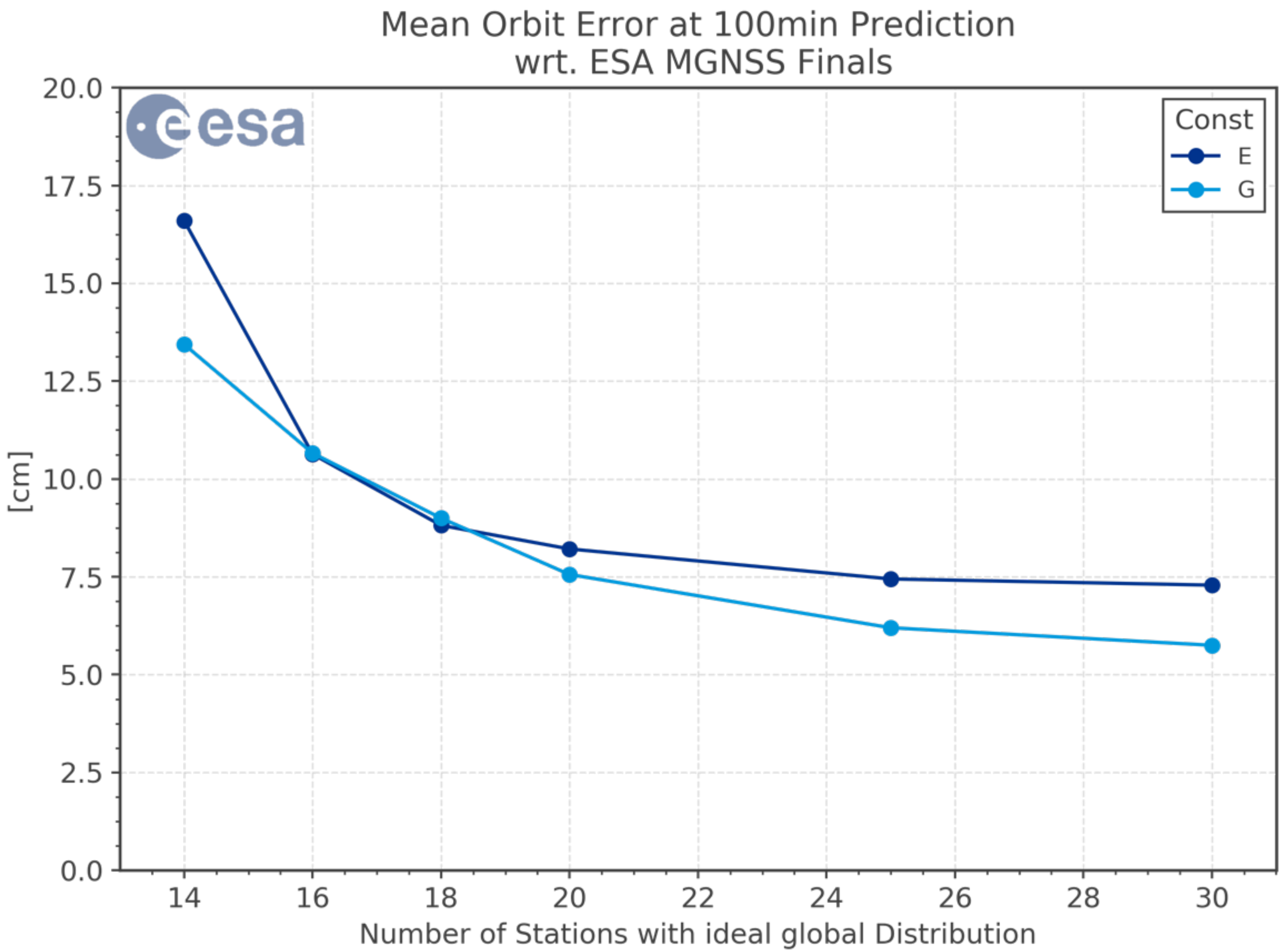
Significant improvements for GNSS POD, if longer GNSS data arcs and also more stations are used

Orbit prediction accuracy - Impact of network size

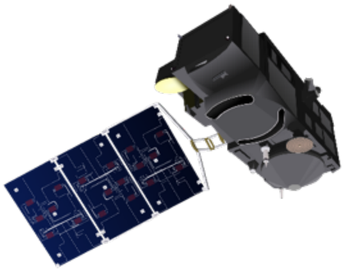
Processing strategy

- Use standard 5-parameter ECOM approach with a-priori box-wing model turned on/off
- Arc length 48hours of GNSS data used for GNSS POD
- Orbit prediction for 100 min

Orbit prediction accuracy (100min)
For different network sizes



Small Networks - Benefits of using LEOs in GNSS POD setups



Combined GPS Satellite POD including Sentinel GPS Data

- **Idea:**

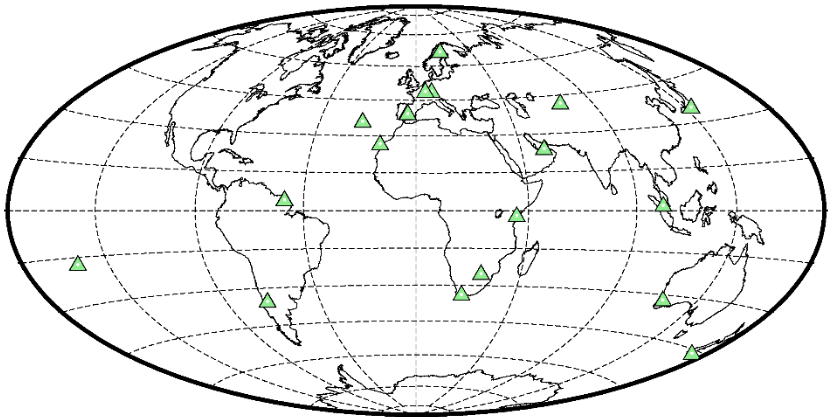
  Take advantage of Sentinel's excellent spatial-temporal sampling of the GPS constellation

- **Approach:**
  - Combined processing of ground- and space-based tracking data
  - Use code/phase measurements from ESOC- EGON station network
  - Use accurate "box-wing" models for all GPS and Sentinel spacecrafts
  - Start out generating GPS orbits and clocks without Sentinel
  - Then include data from the LEOs
  - Resolve all GPS carrier phase ambiguities (station-to-station, station-to-LEO, LEO-to-LEO)

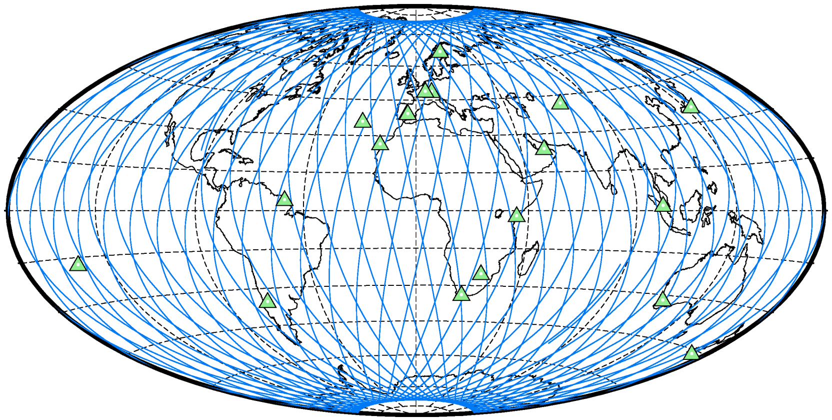
Improved observation geometry

- Polar-orbiting Sentinel constellation providing homogenous global coverage over both hemispheres

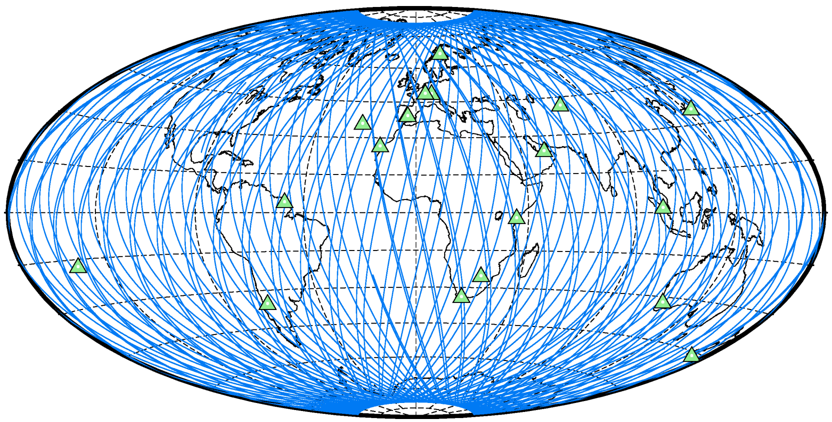
ESOC ground network as of July 2018 (# 19 stations)



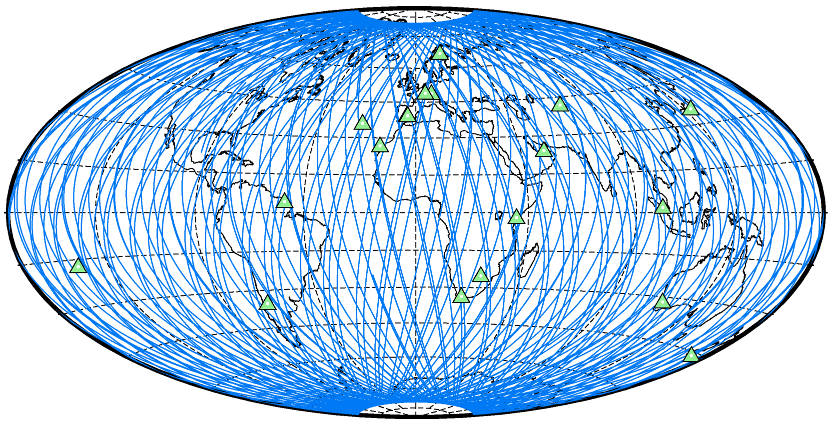
ESOC stations together with one–day ground tracks of Sentinel–1AB (# 2 SVs)



ESOC stations together with one–day ground tracks of Sentinel–1AB/2AB (# 4 SVs)

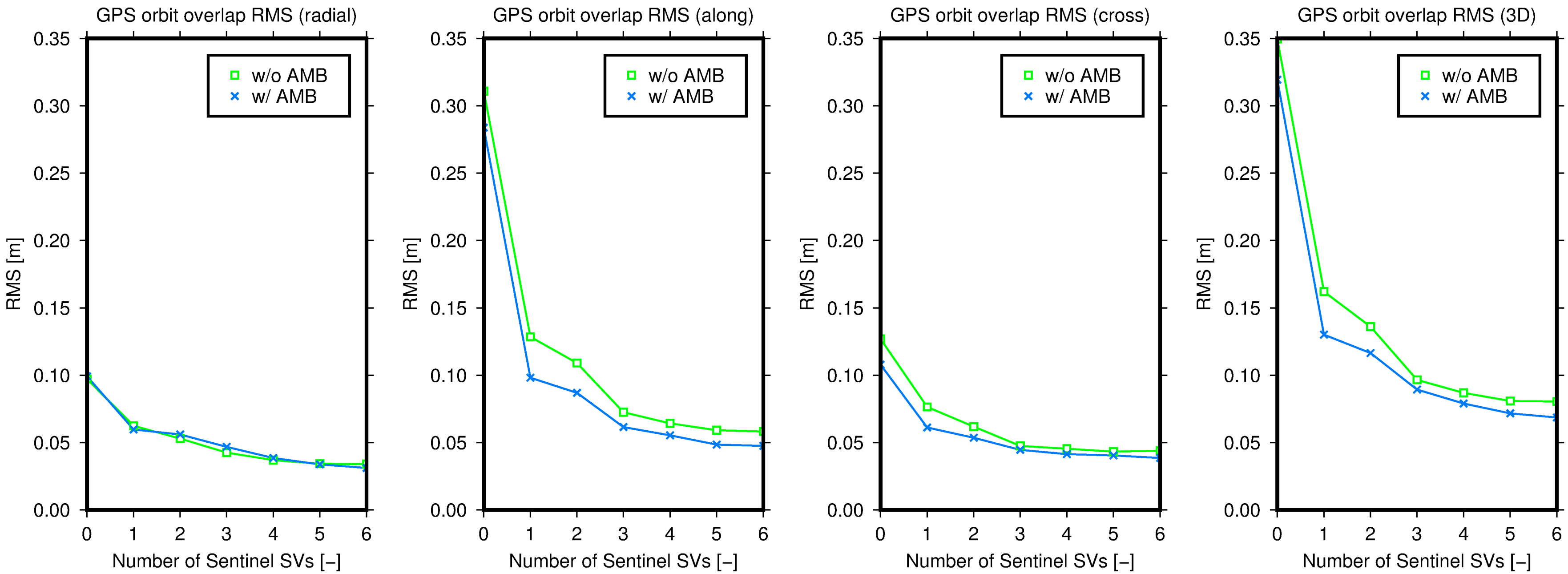


ESOC stations together with one–day ground tracks of Sentinel–1AB/2AB/3AB (# 6 SVs)



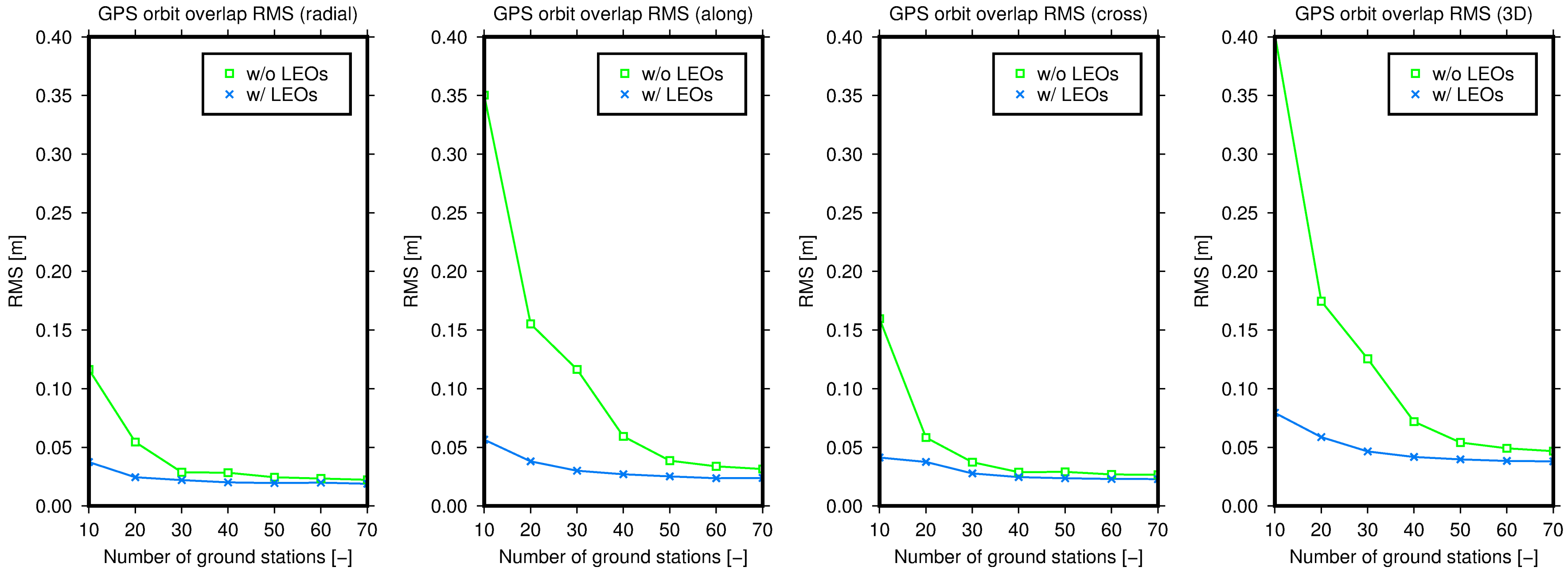
Impact of number of LEOs on GPS orbit overlaps

- Significant improvement in GPS orbit overlap residuals when including Sentinel LEO GPS data
  - Reduction in along-track RMS by factor 3 when adding 1 LEO, and by factor 6 when adding all 6 Sentinel Satellites
  - 3D overlap RMS of 7 cm with 19 ground stations and 6 LEOs

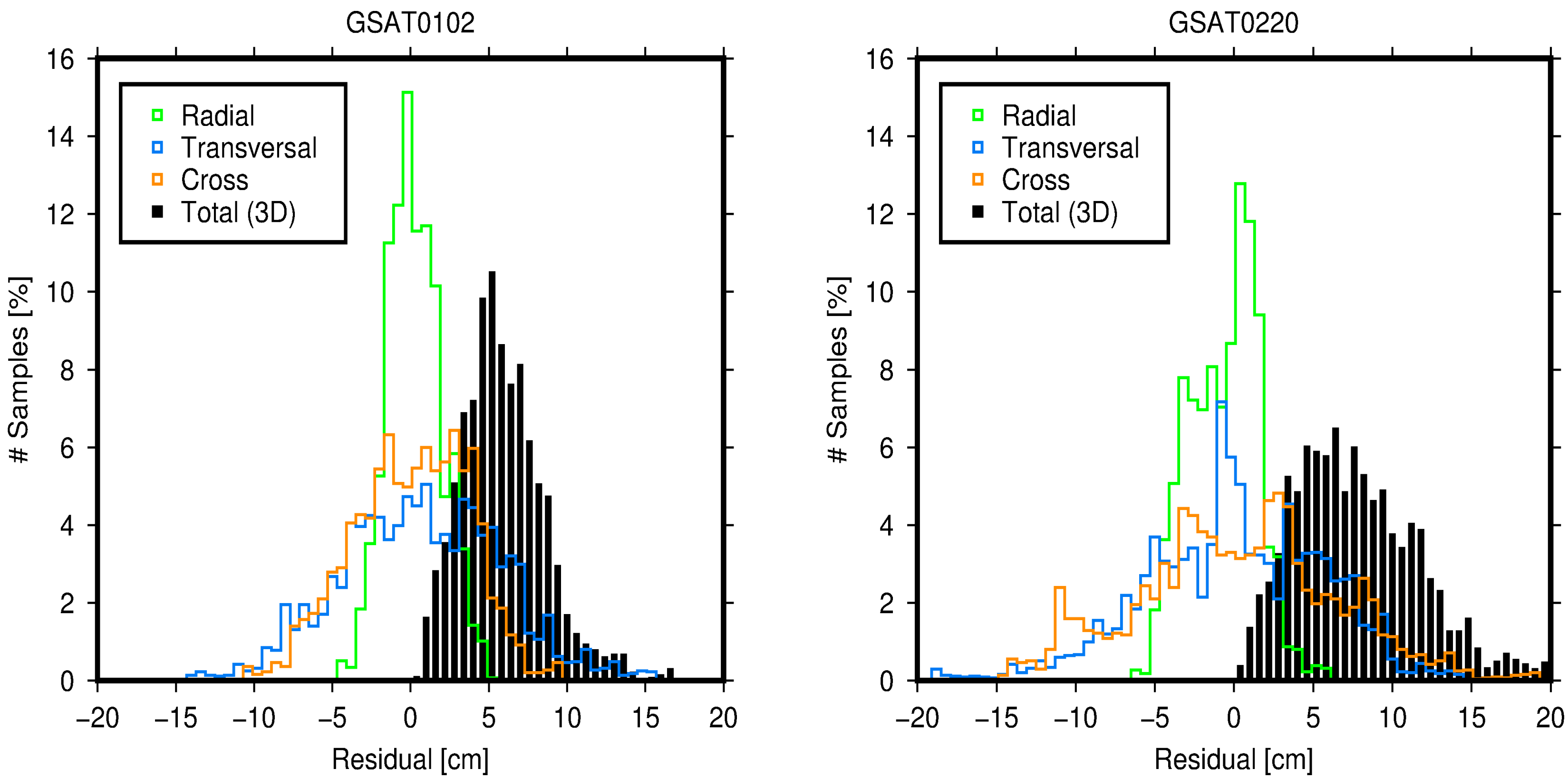


Impact of LEOs in larger ground networks

- Benefit of additional LEO GPS data depends on coverage provided by the ground network
  - The higher the number of sites, the lower the improvement due to the LEOs
  - Only little improvement beyond 70 stations

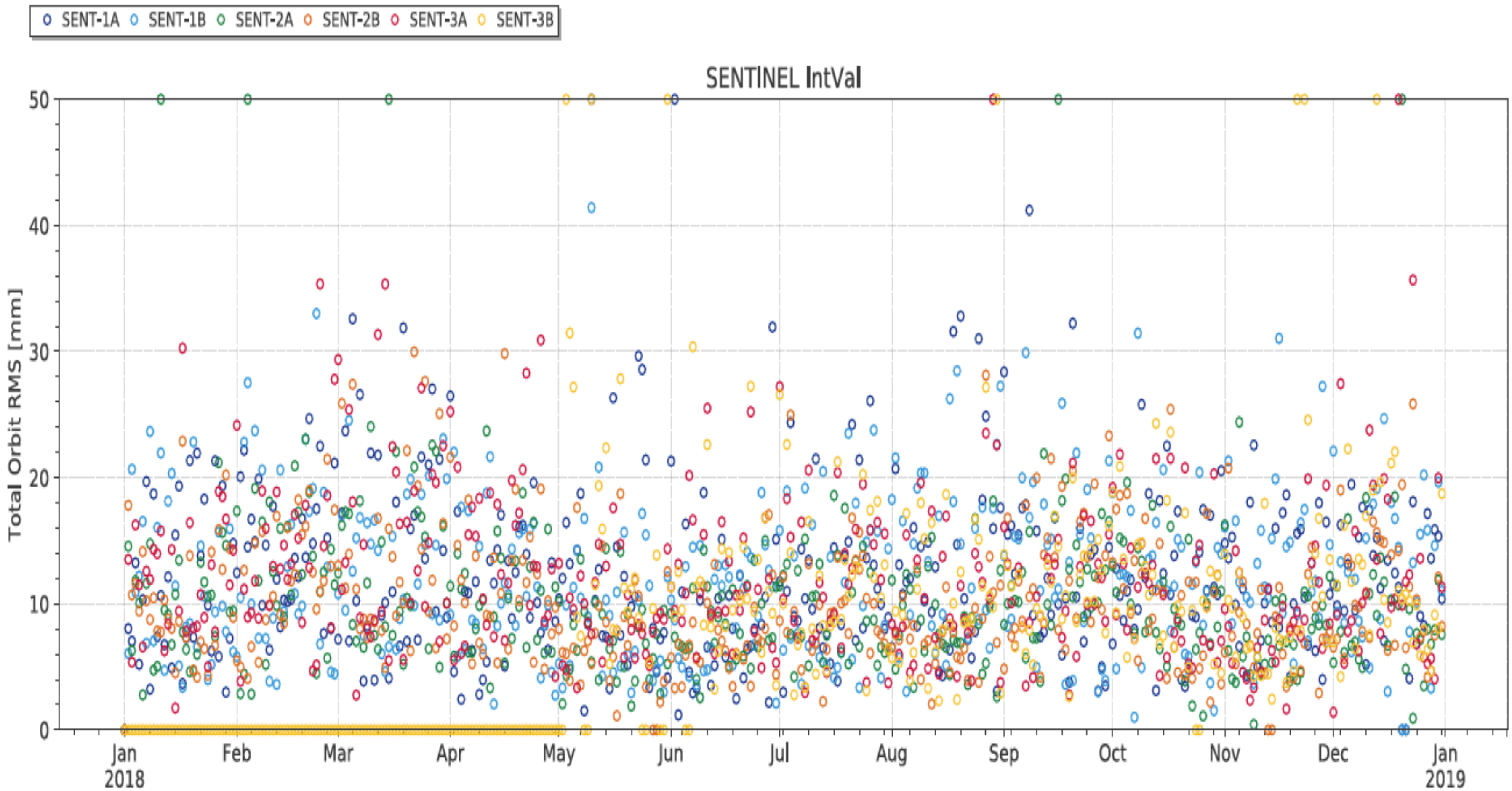


Galileo POD based on SLR only
For Galileo satellites in EUROLAS SUCCESS campaign



SVN	Radial [mm]	Transversal [mm]	Cross [mm]	Total (3D) [mm]
102	17	51	37	66
220	22	56	63	87

ESOC's Sentinel POD product performance



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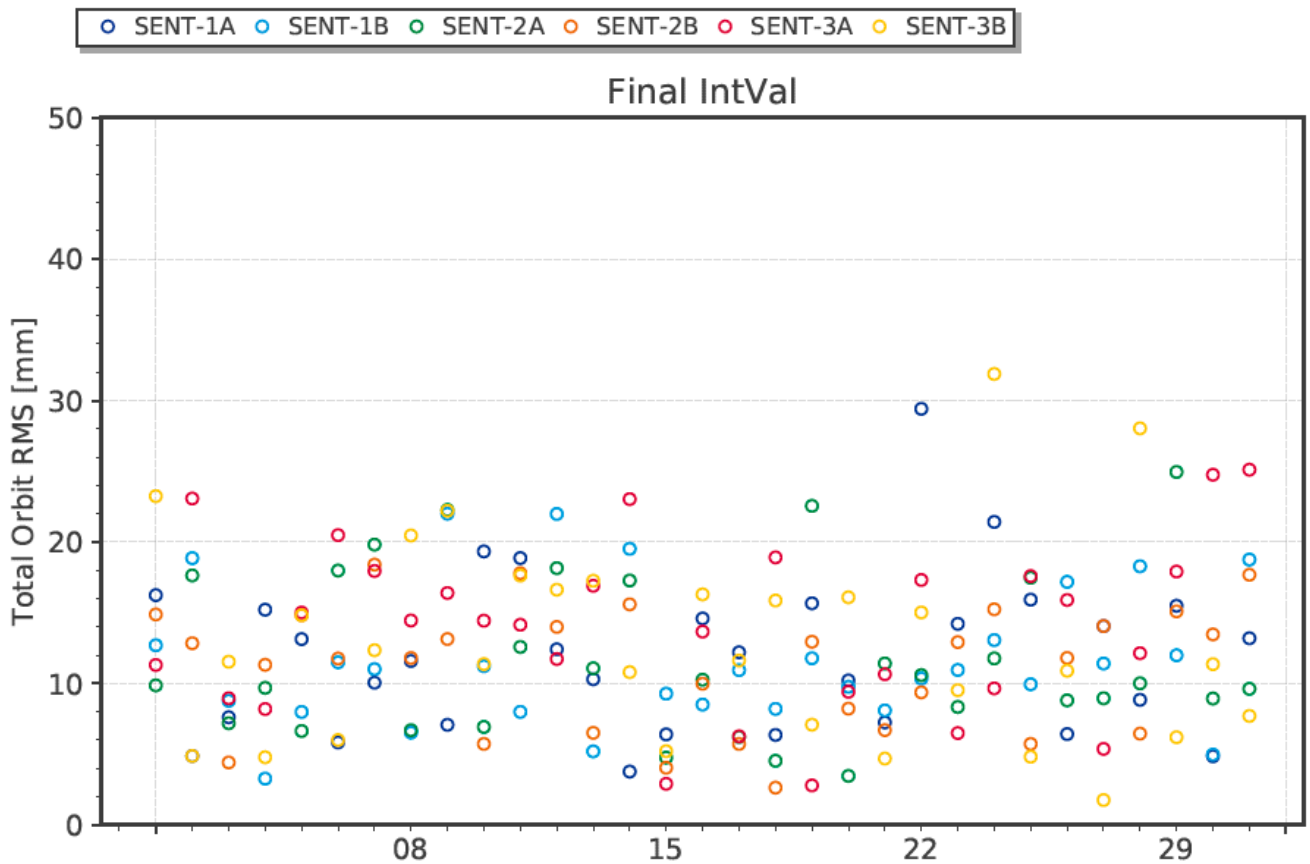

3D Day boundary overlaps at midnight epoch (mm) for July 2019

Sentinel orbits: Final

Conclusions

- High-fidelity radiation modelling is important for GNSS POD, especially in case of small networks
  - Factor 2 improvement in Galileo orbit predictions when turning a-priori models on
- Selection of GNSS data arc length is important for GNSS satellite orbit prediction accuracy
  - 'Optimal' arc length for ESOC POD processing turned out to be 4 – 5 days
  - Orbit starts degrading again when going to longer arcs as residual SRP error cannot be accommodated by single set of ECOM parameters

Conclusions

- Effect of using SLR in addition to GNSS data is improving the GNSS orbit accuracy
  - 30% improvement over solution w/o SLR, mainly in along-track
  - But the longer the data arc length, the smaller the benefit of the SLR data
- Including Sentinel GPS observation data in GPS satellite POD improves the POD accuracy, especially in case of a small networks
- ESOC POD accuracy for Sentinel Satellites is in the order of 1-2 cm total RMS

Thank you very much for your attention

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