Formation of a GNSS network in space based on geodetic satellite missions

ETH zürich

SPACE GEODESY

Formation of a GNSS network in space based on geodetic satellite missions

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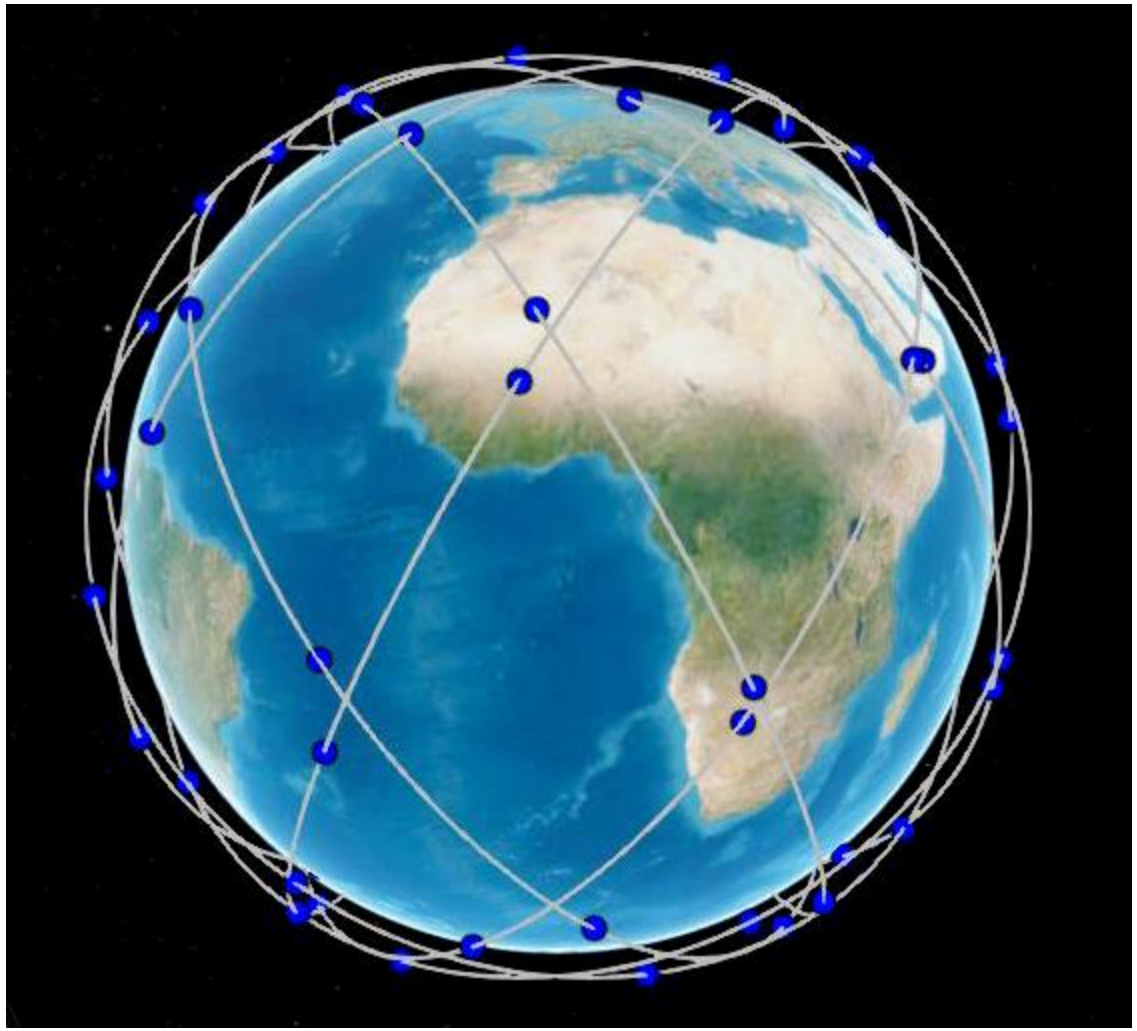
Motivation



- Increasing number of LEOs with GNSS receivers
- Possibility to form GNSS baselines connecting multiple satellites
  - Double-difference processing
  - Polyhedron in space with highly accurate relative geometry
- Idea: use space-based GNSS double-differences to estimate
  - LEO and GNSS satellite orbits
  - Earth’s gravity field
  - Ionospheric tomography
- Study: Formation of a pseudo-constellation using GNSS data from geodetic Earth observation missions

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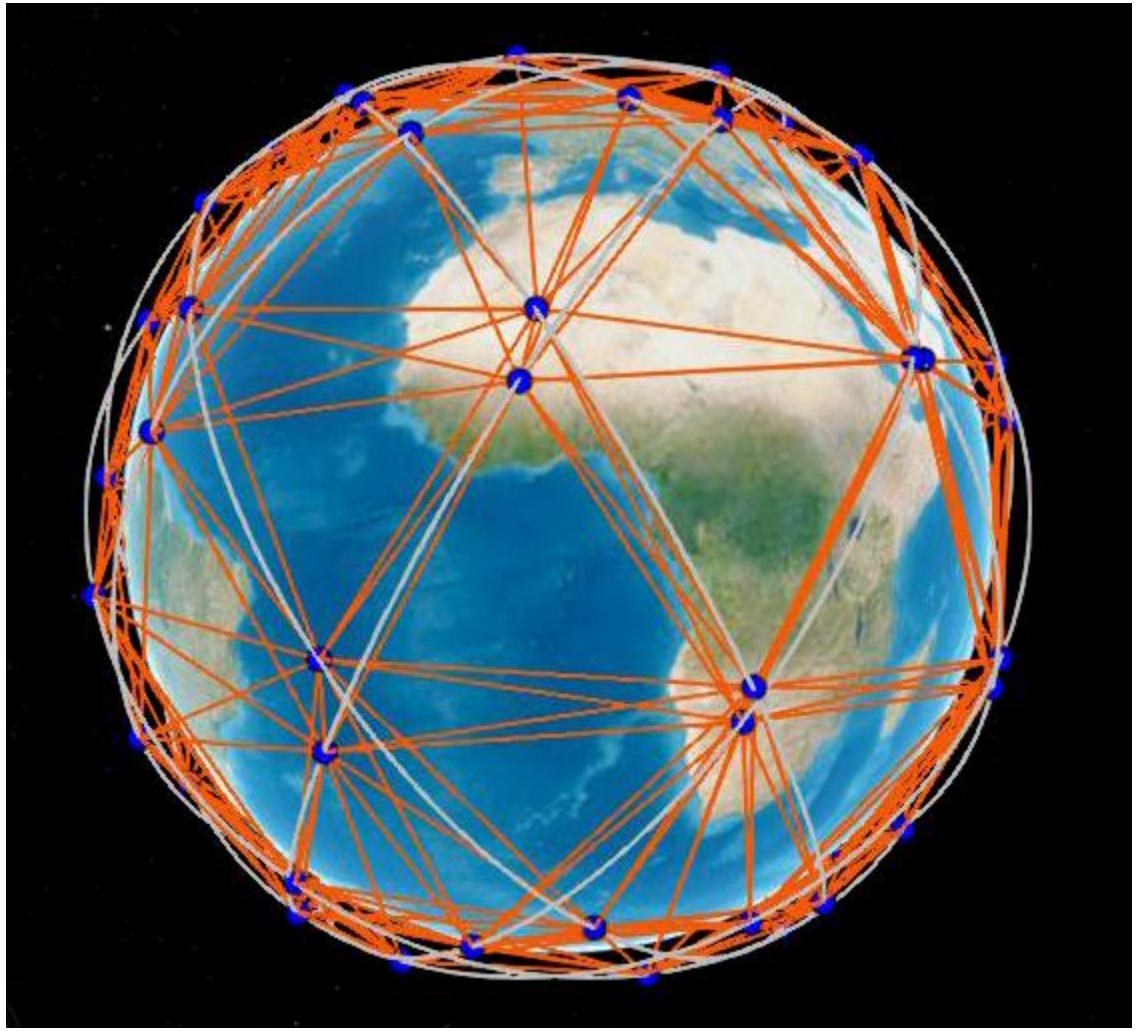

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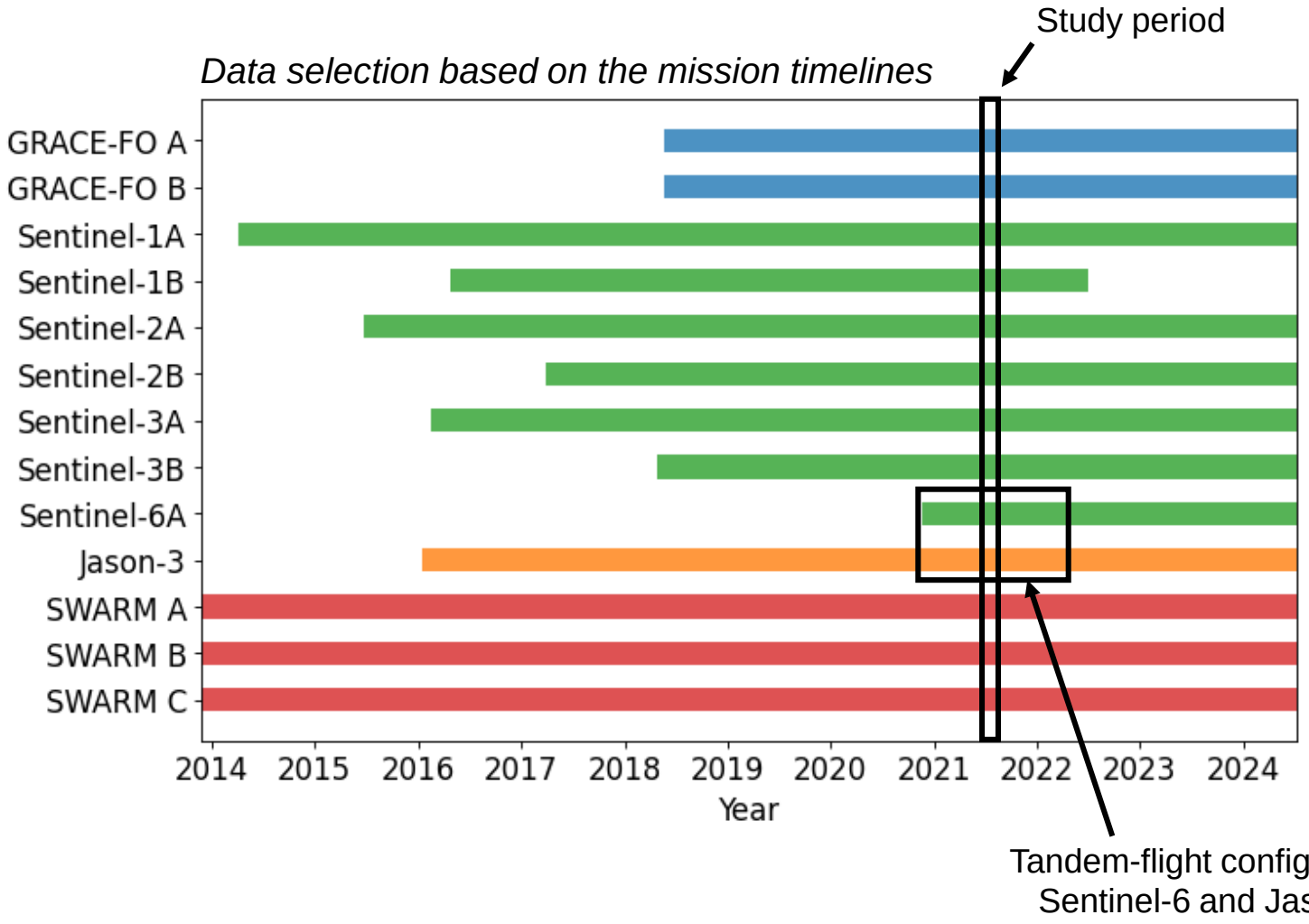
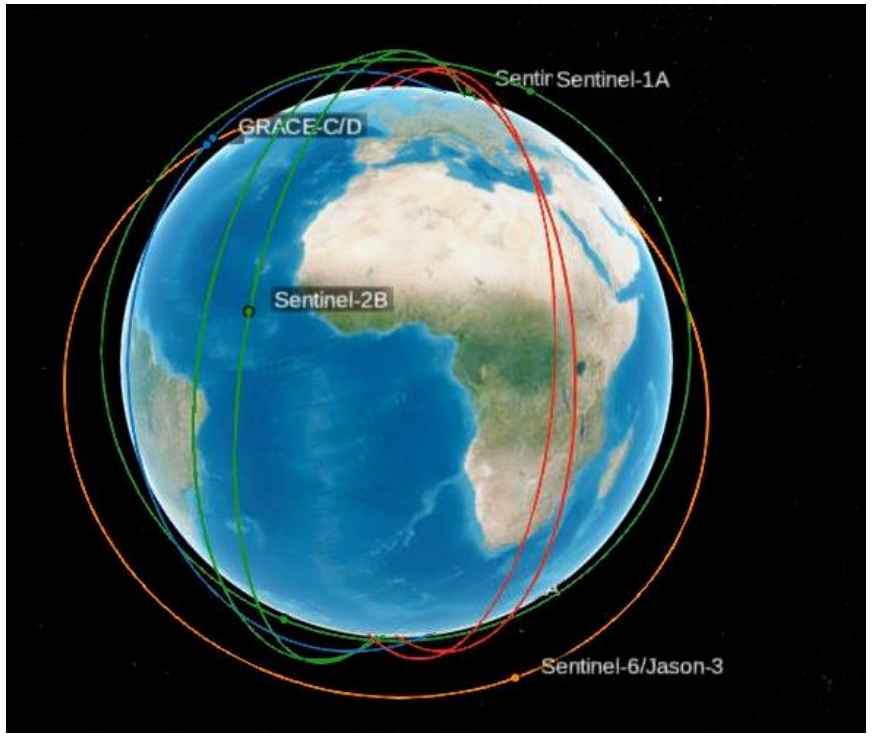
Data

GPS observations from 13 geodetic satellite missions in August 2021

Data selection based on the mission timelines

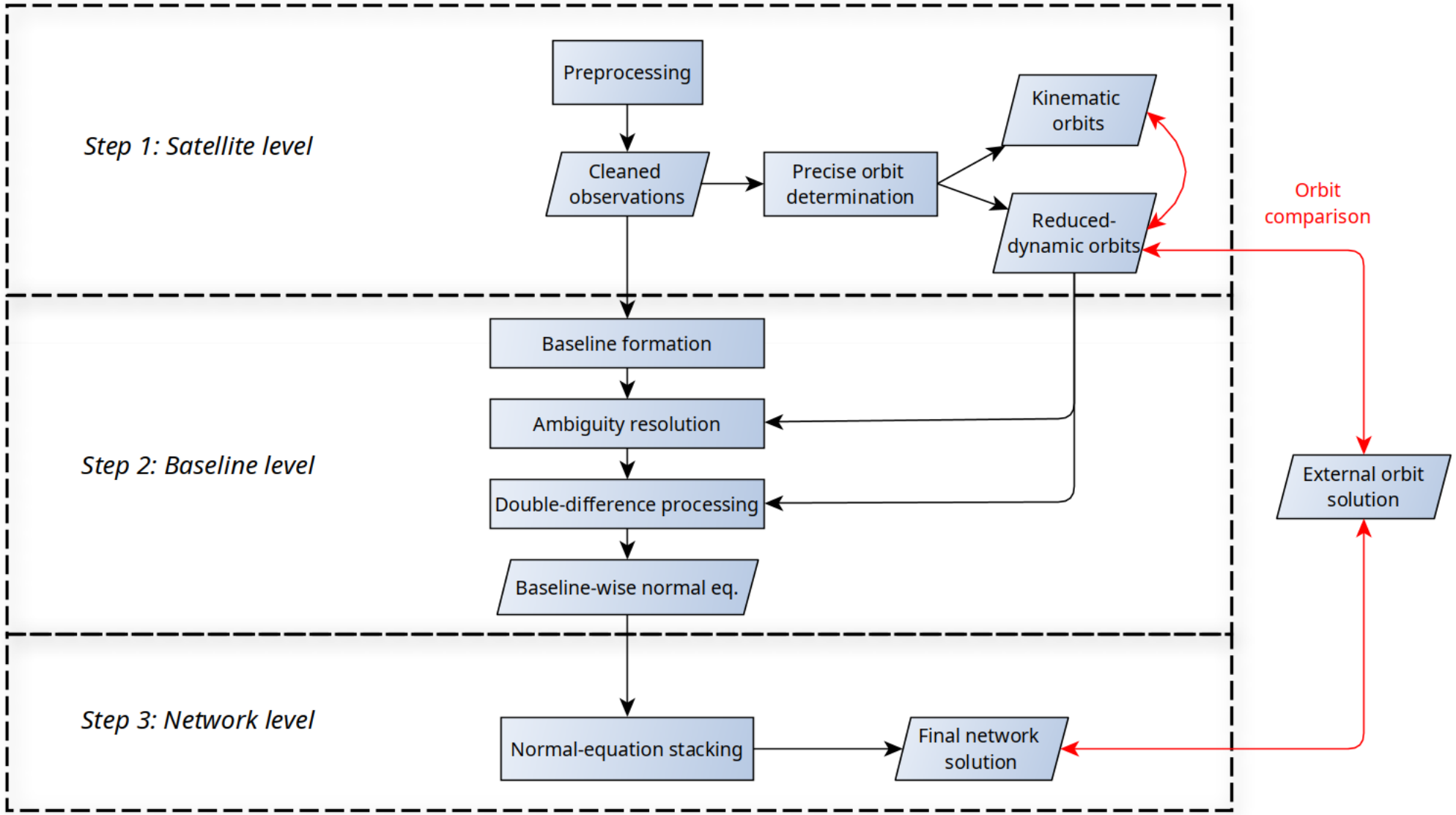


Orbits on 01/08/2021



Method

Network processing setup



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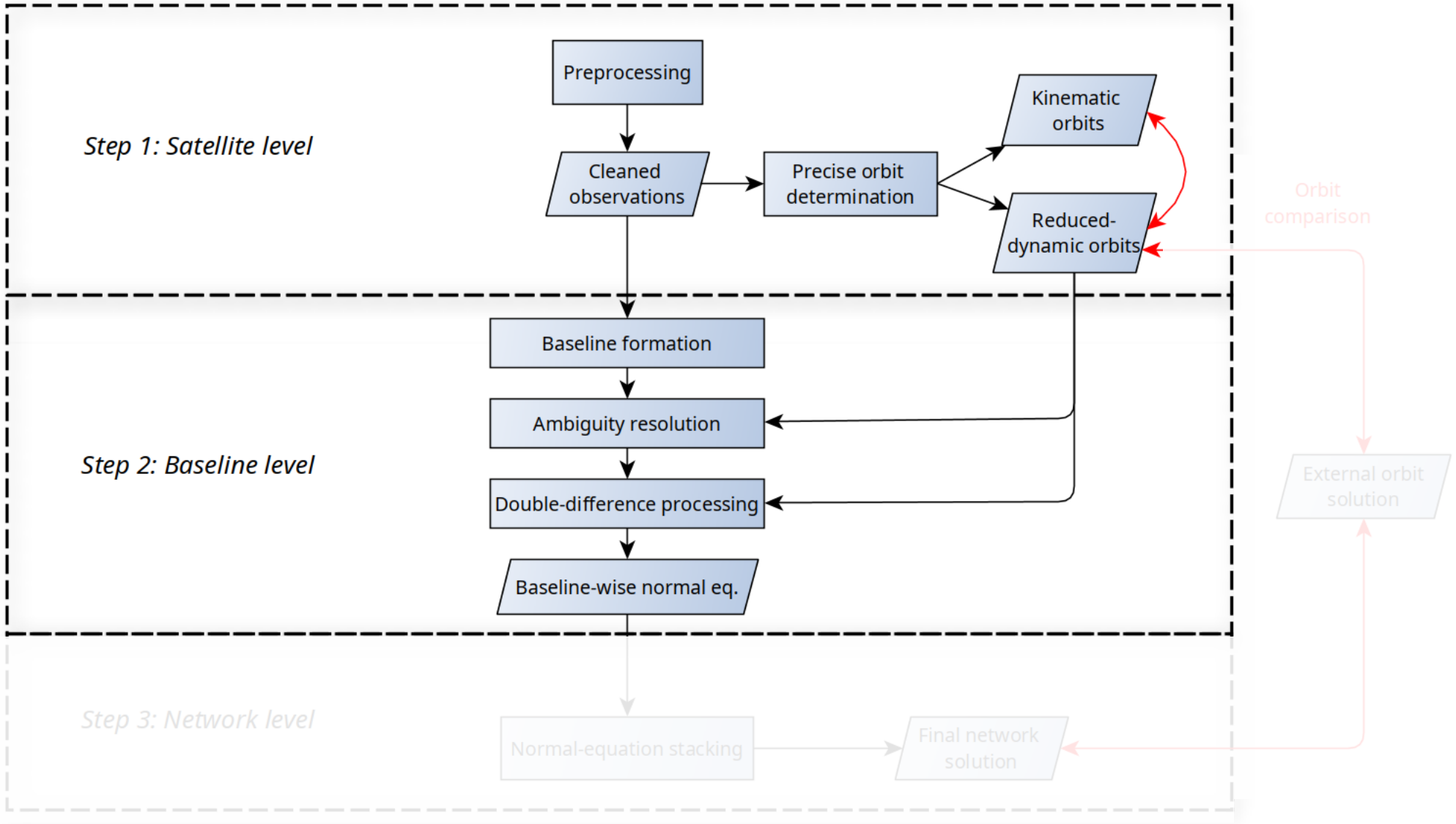


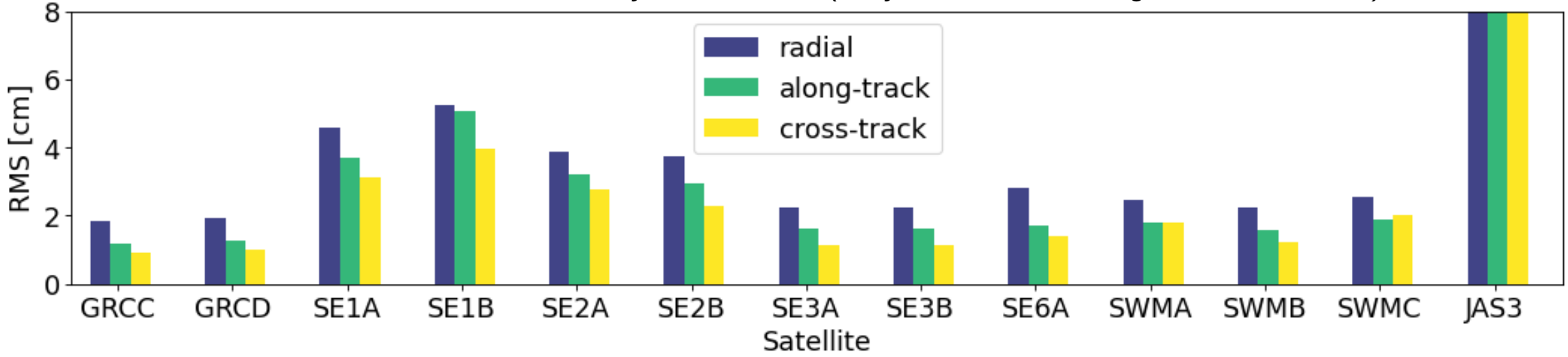
Single-satellite orbit determination

Processing strategy

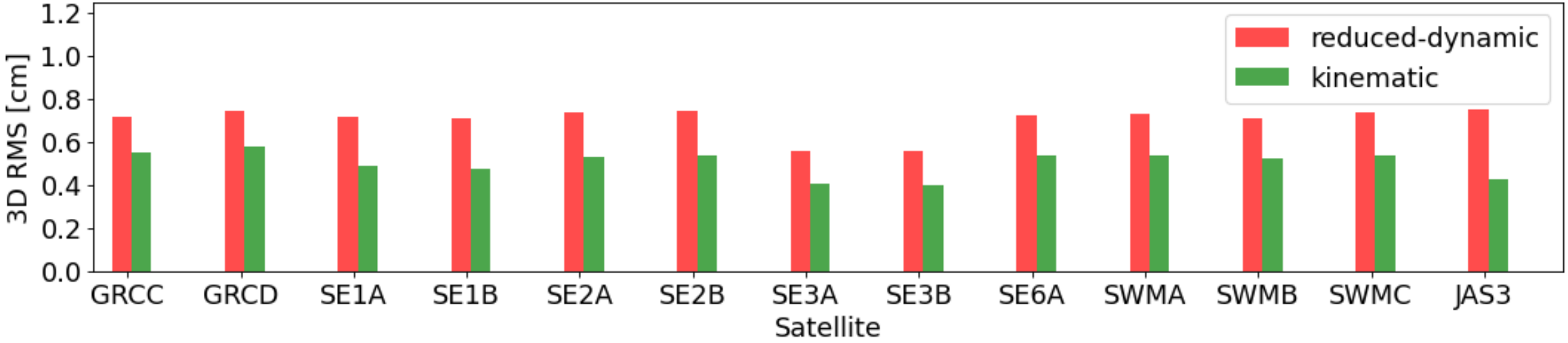
Software	Bernese GNSS software 5.3
Observations	GPS L1/L2 phase and code observations
Gravity model	GOCO06s
Non-gravitational forces	No modelling
Antenna offset, PCV, PCO	applied
Parameterization	- Constant accelerations (r,s,w) - Once-per-revolution periodicity (r,s,w) - Piecewise-constant accelerations every 6 min
Arc-length	1 day
Sampling	10 s

Single-satellite orbit determination

Differences between kinematic and reduced-dynamic orbit fits (Daily RMS values averaged over one month)

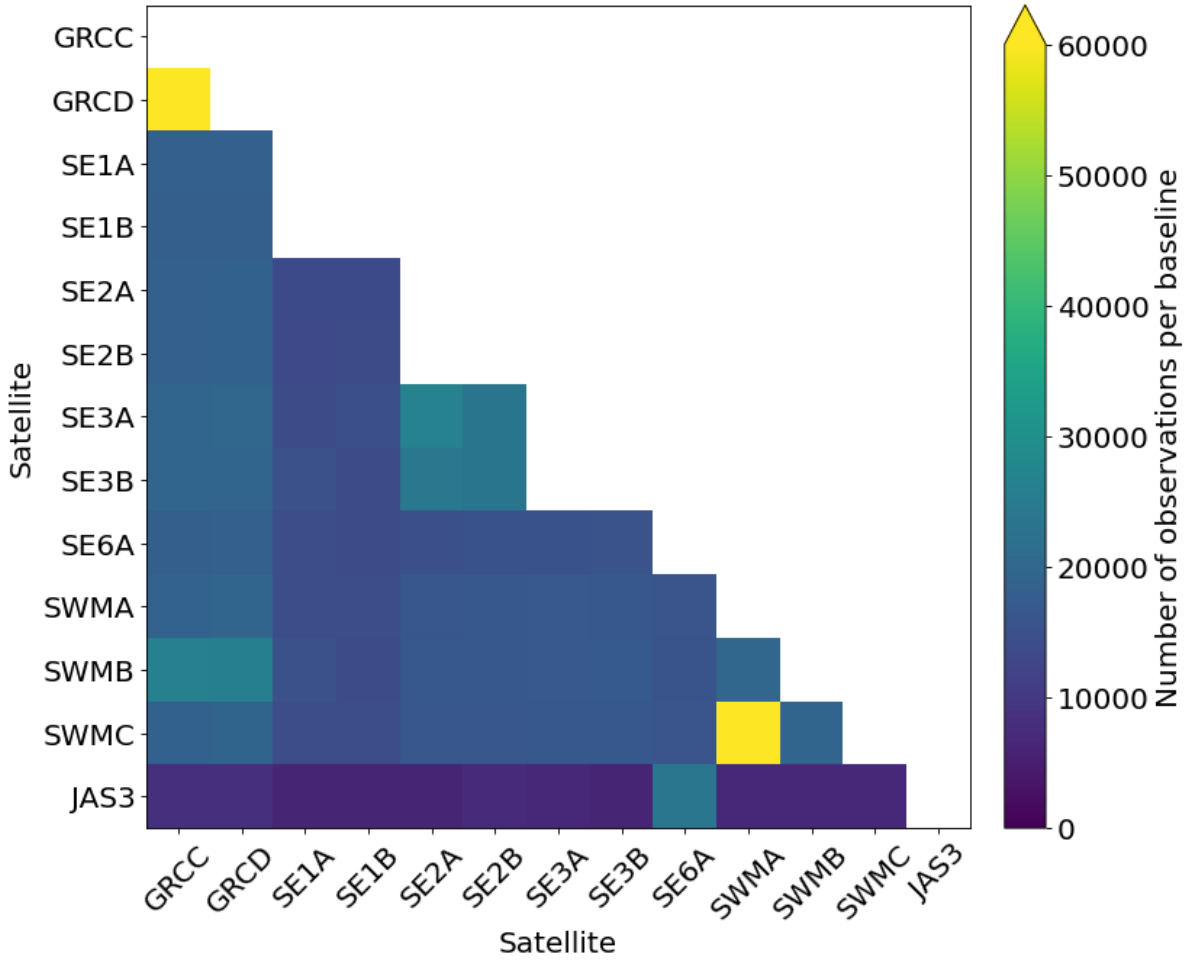


Carrier-phase L3 residuals



Baseline formation

Daily number of GPS L1+L2 averaged over one month

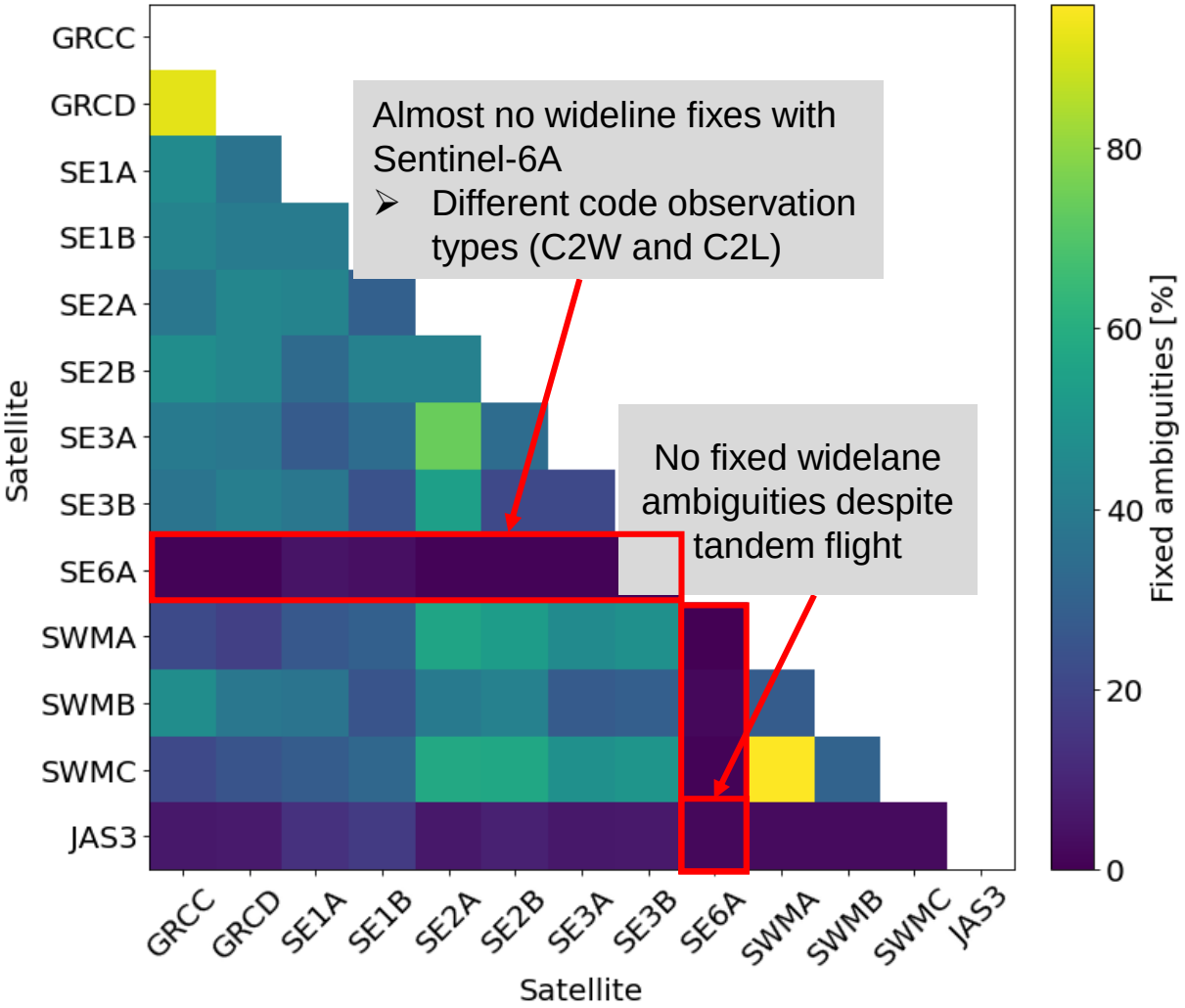


- Most baseline observations for formation-flying satellites
  - GRACE-C and -D
  - SWARM-A and -C
- Smaller number of observations for the tandem Sentinel-6 and Jason-3
- Generally fewer observations for Jason-3
  - Orbit height
  - Data screening on zero-difference level

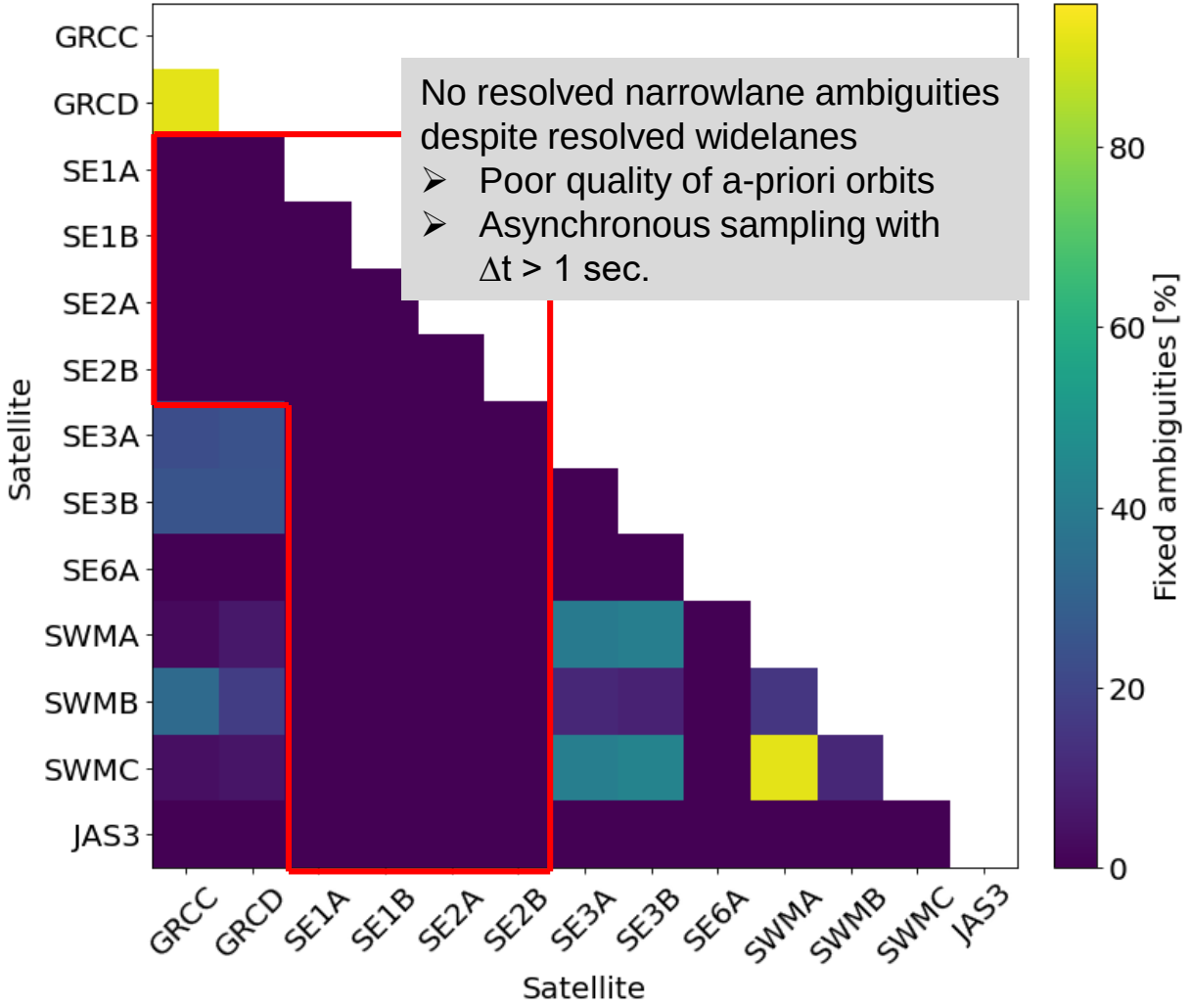
Baseline formation

Integer ambiguity resolution: Median over one month

Widelane ambiguities



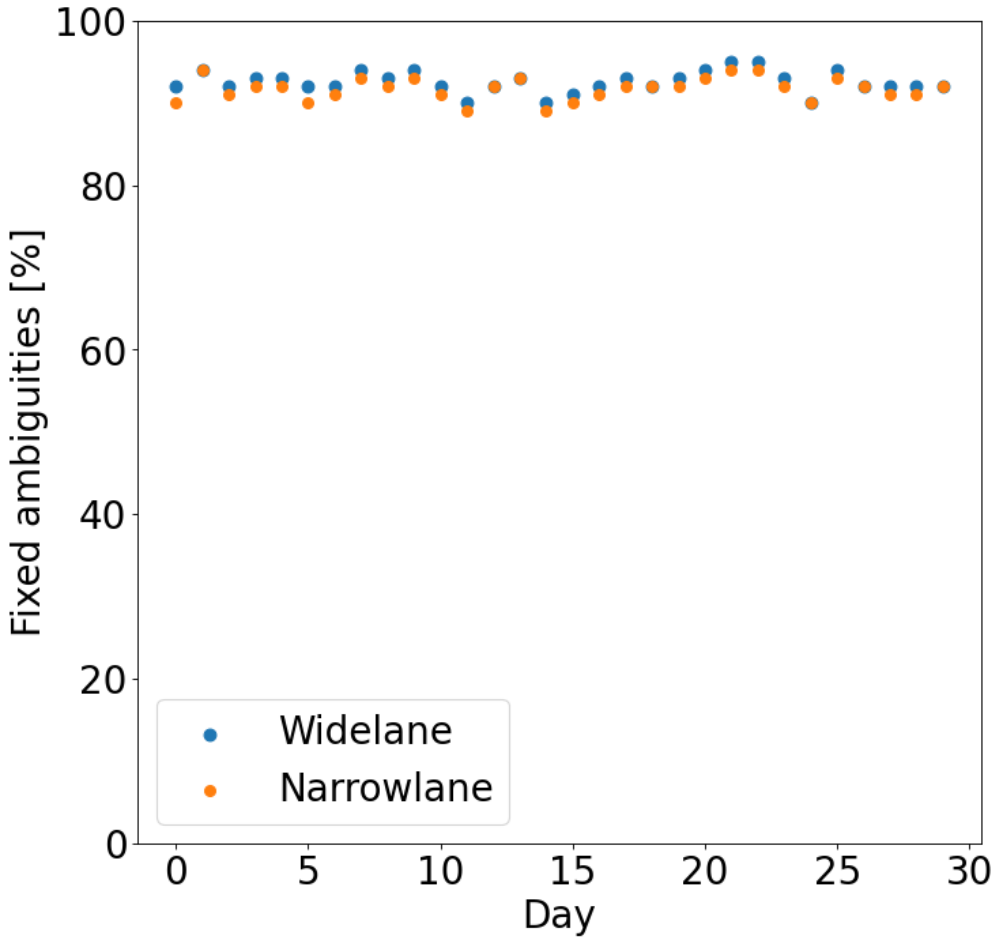
Narrowlane ambiguities



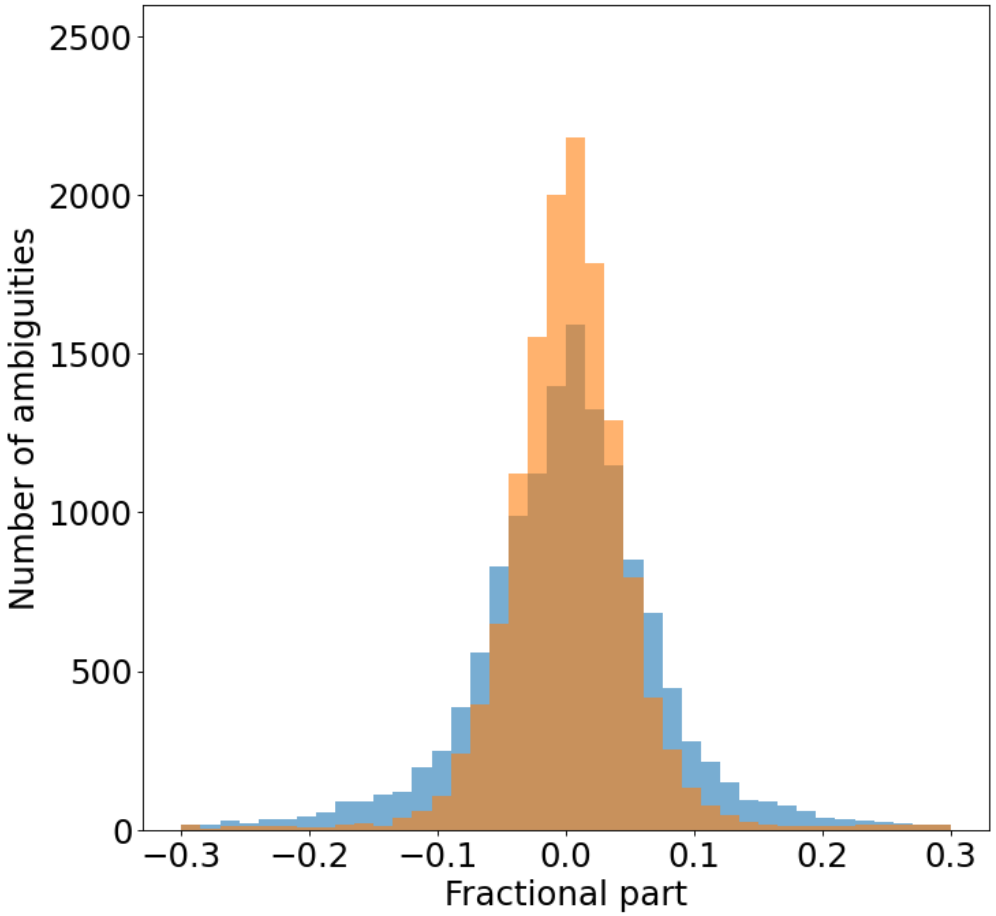
Baseline formation

Integer ambiguity resolution: GRACE-C/D

Fixing rate per day



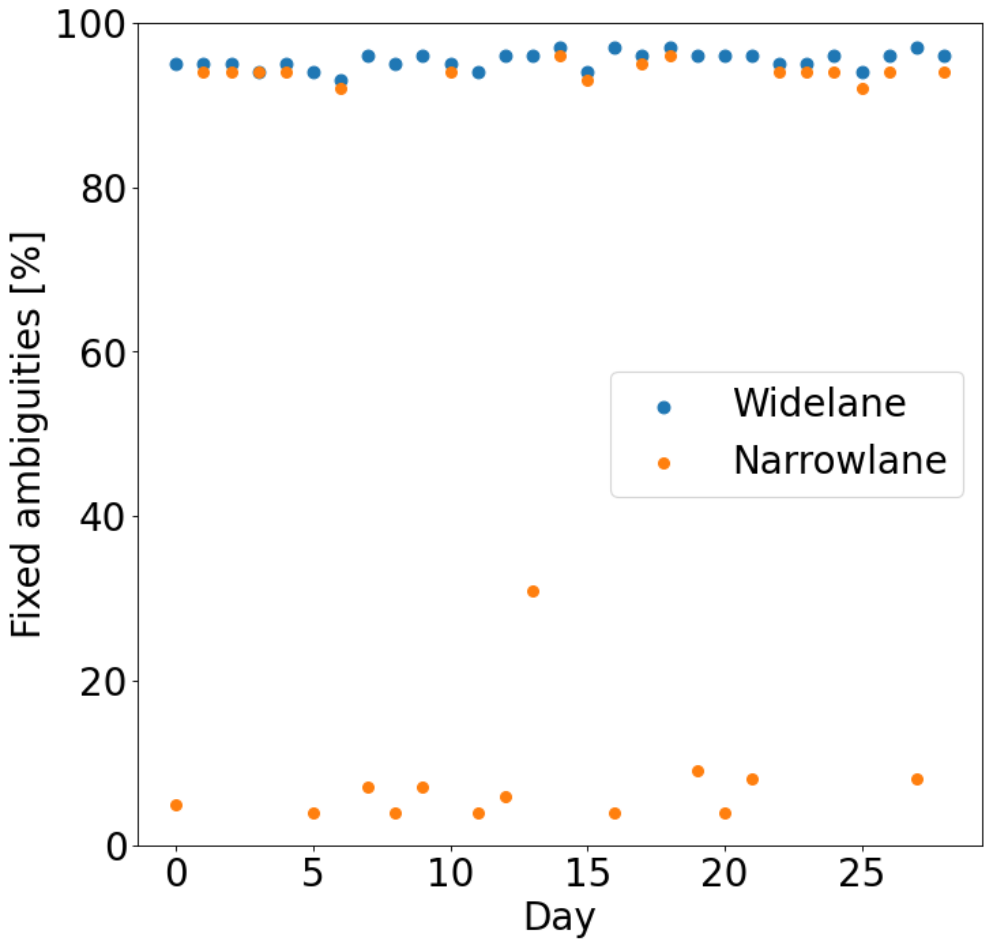
Fractional parts of estimated ambiguities



Baseline formation

Integer ambiguity resolution: SWARM-A/C

Fixing rate per day



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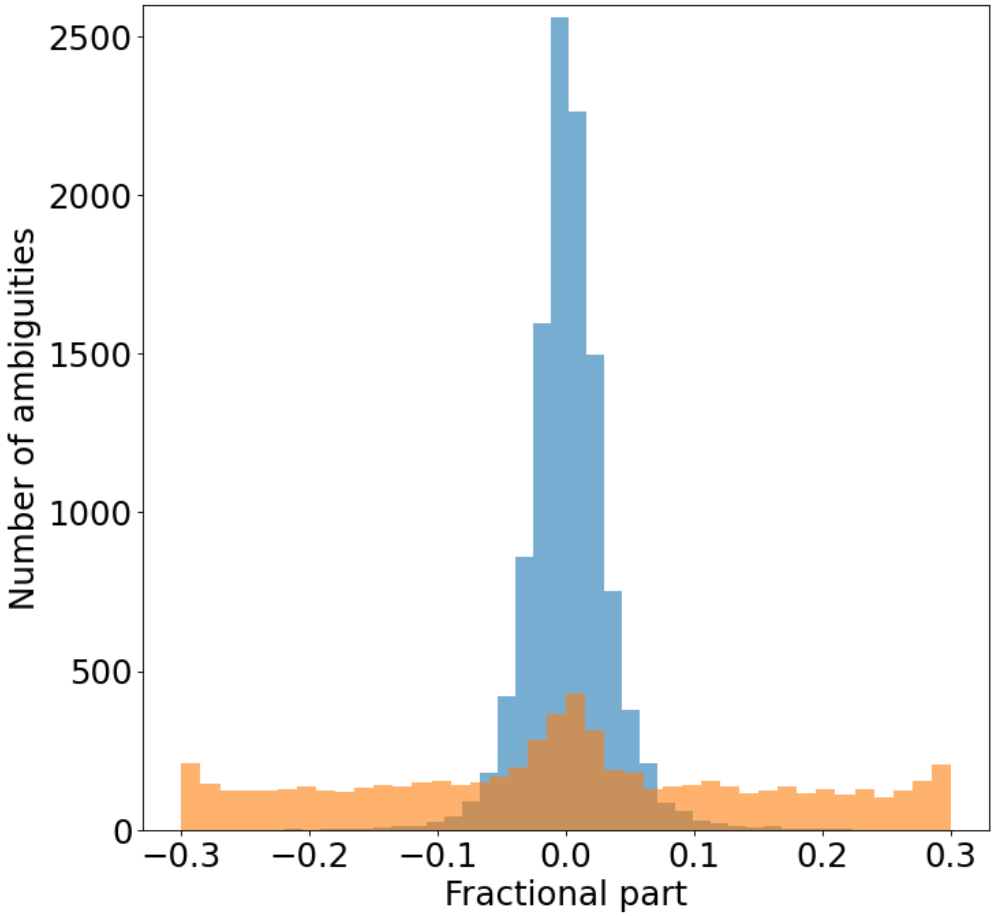
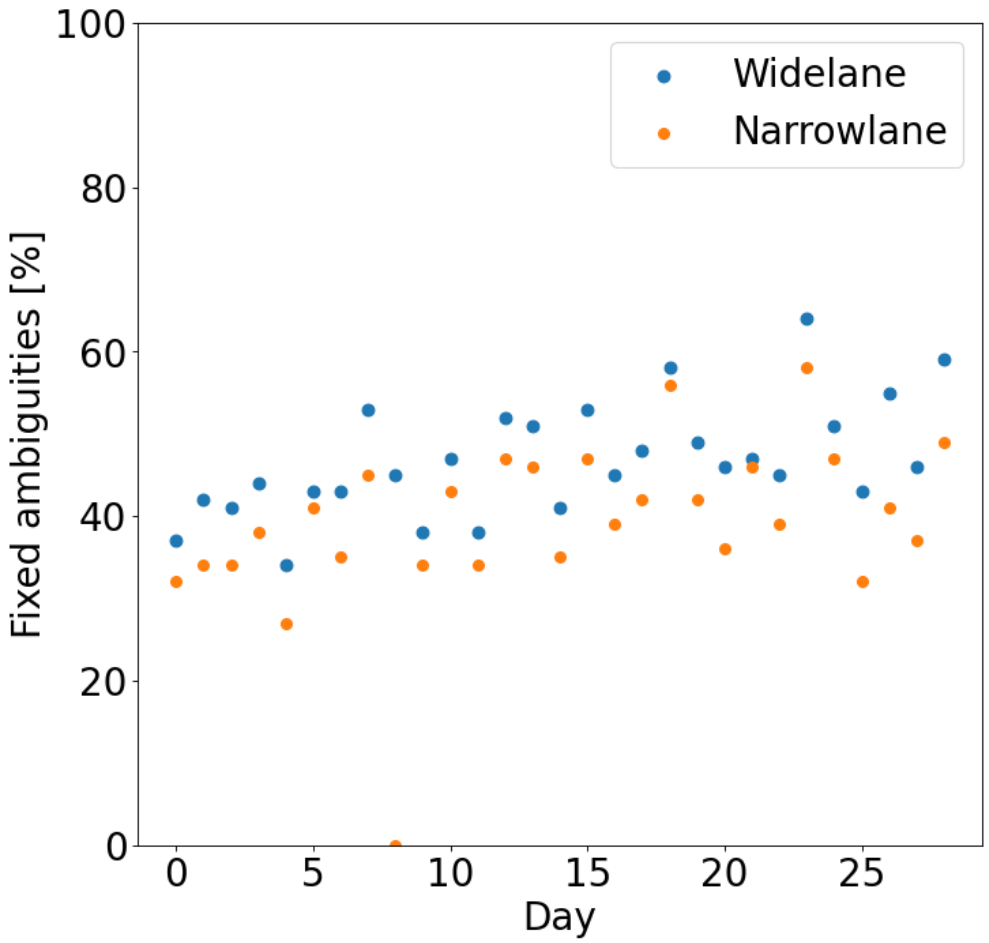


Baseline formation

Integer ambiguity resolution: SWARM-A – Sentinel-3A

Fixing rate per day



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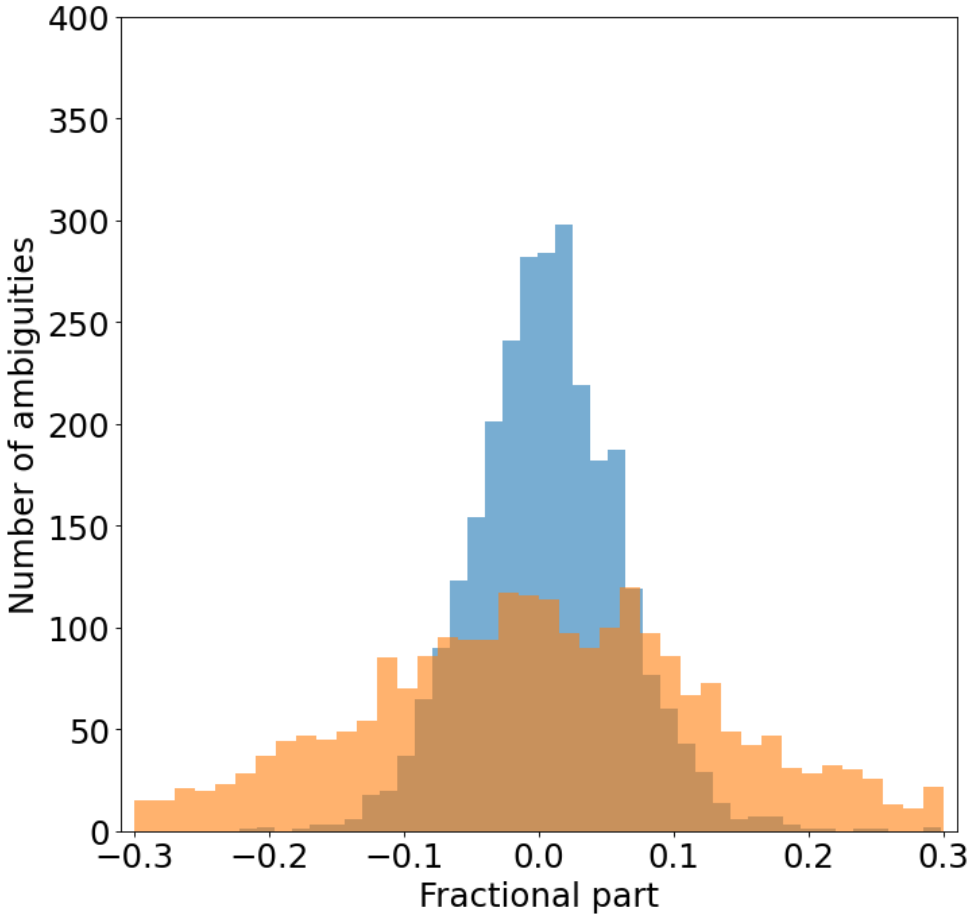

Conclusions

- Good ambiguity fixing rates mainly for GRACE-FO C/D and partly for SWARM A/C
- No resolved narrowlane ambiguities at all for baselines involving Sentinel-1 and -2
  - ➢ Poor a-priori orbits and time difference > 1 sec between combined observations
- No resolution of widelane ambiguities for the Sentinel-6A and Jason-3 tandem
  - ➢ General problem with wideline fixing with Sentinel-6A due to different types of code observations
  - ➢ Poor quality of Jason-3 code observations
- The advantages of network processing in space will only take effect with a high number (> 50) and a uniform distribution of satellites

Next steps

- Improvements of force modelling → inclusion non-gravitational forces
- Refined estimation of PCOs/PCVs
- Better strategies for ambiguity-resolution, e.g. bootstrapping with iterations over the entire constellation