TECHNISCHE UNIVERSITÄT WIEN

FWF Österreichischer Wissenschaftsfonds

Optimal requirements for determining frame ties using VLBI observations to satellites

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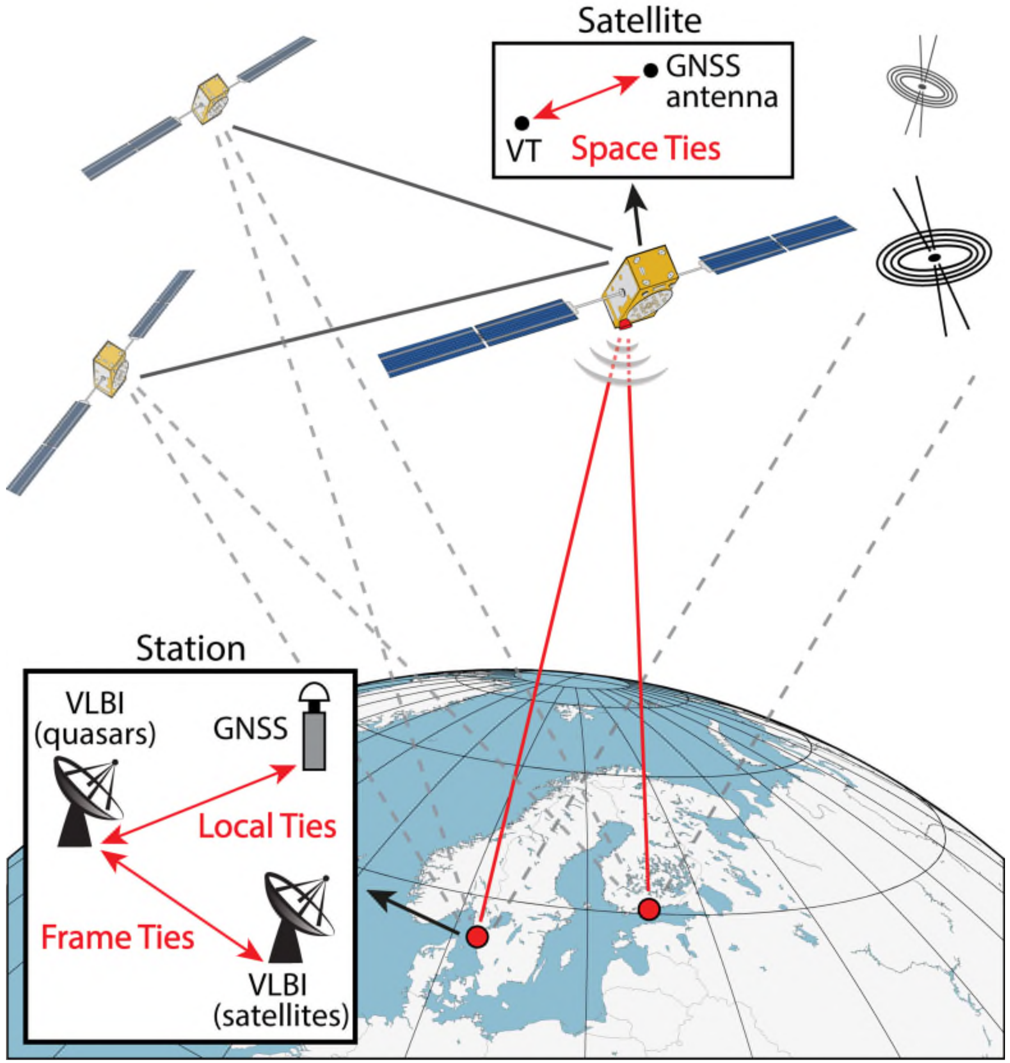
Local Ties and Space Ties

- **local tie →** vector between geodetic instruments at co-location site
  - errors in local ties on the ground are limiting factor for the accuracy of the terrestrial reference frame

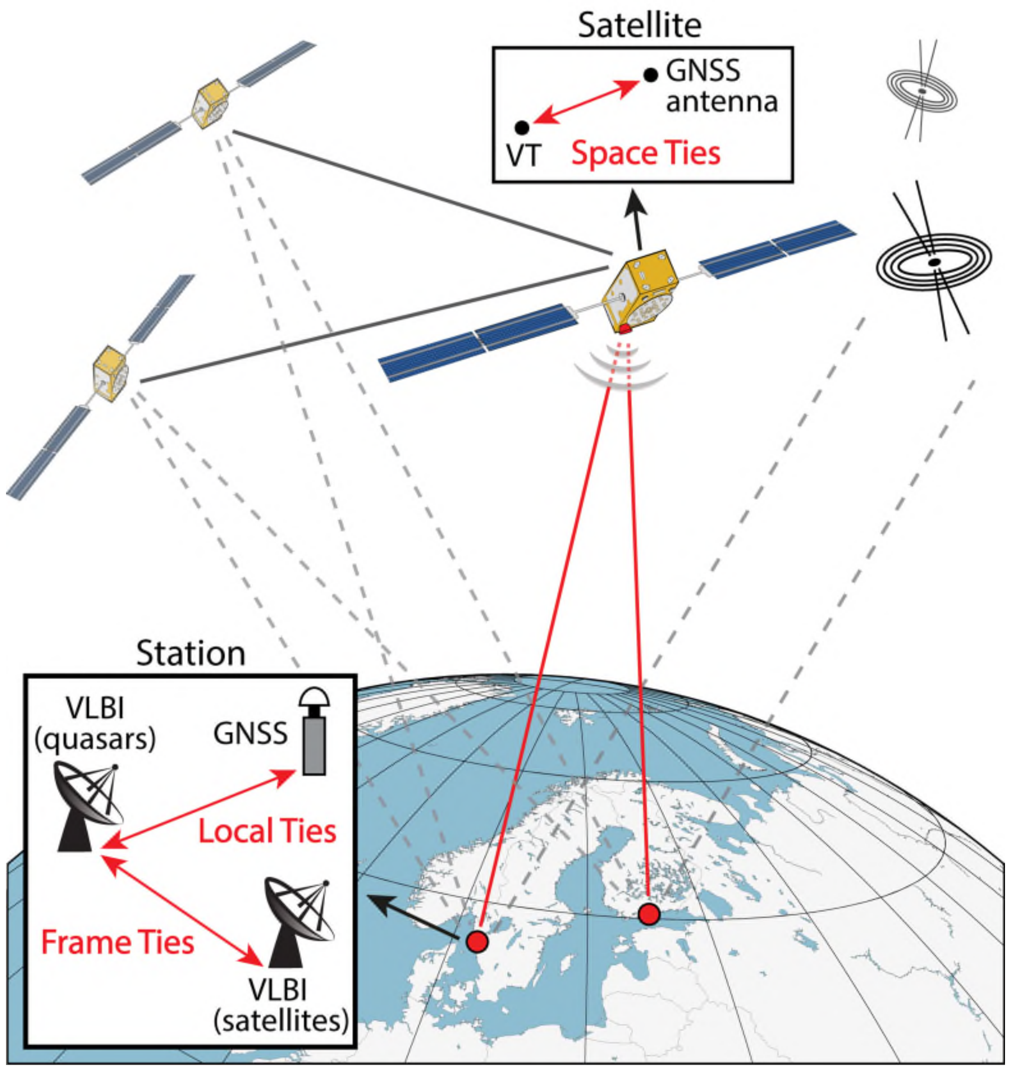
- **space tie →** vector between VLBI transmitter and GNSS antenna (on board of satellite)
  - high-precision tying of different space geodetic techniques



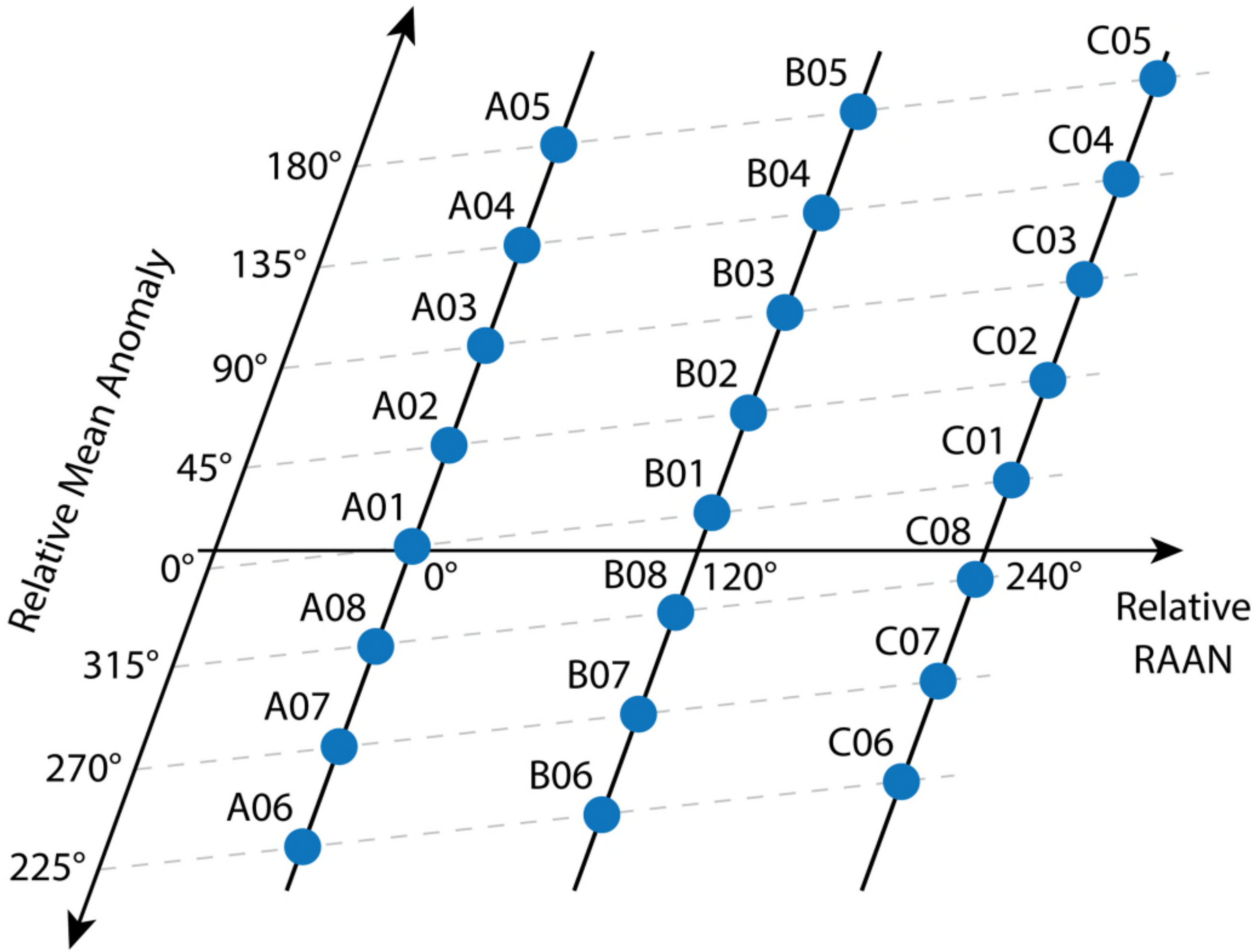
Frame Ties

- estimation of station coordinates from satellite obs.
  → VLBI station coordinates in satellite frame
- estimation of station coordinates from quasars obs.
  → VLBI station coordinates in quasar frame
- tie between satellite and quasar frame
  → **frame tie**

Publication Wolf & Böhm (2023) published in Earth, Planets and Space

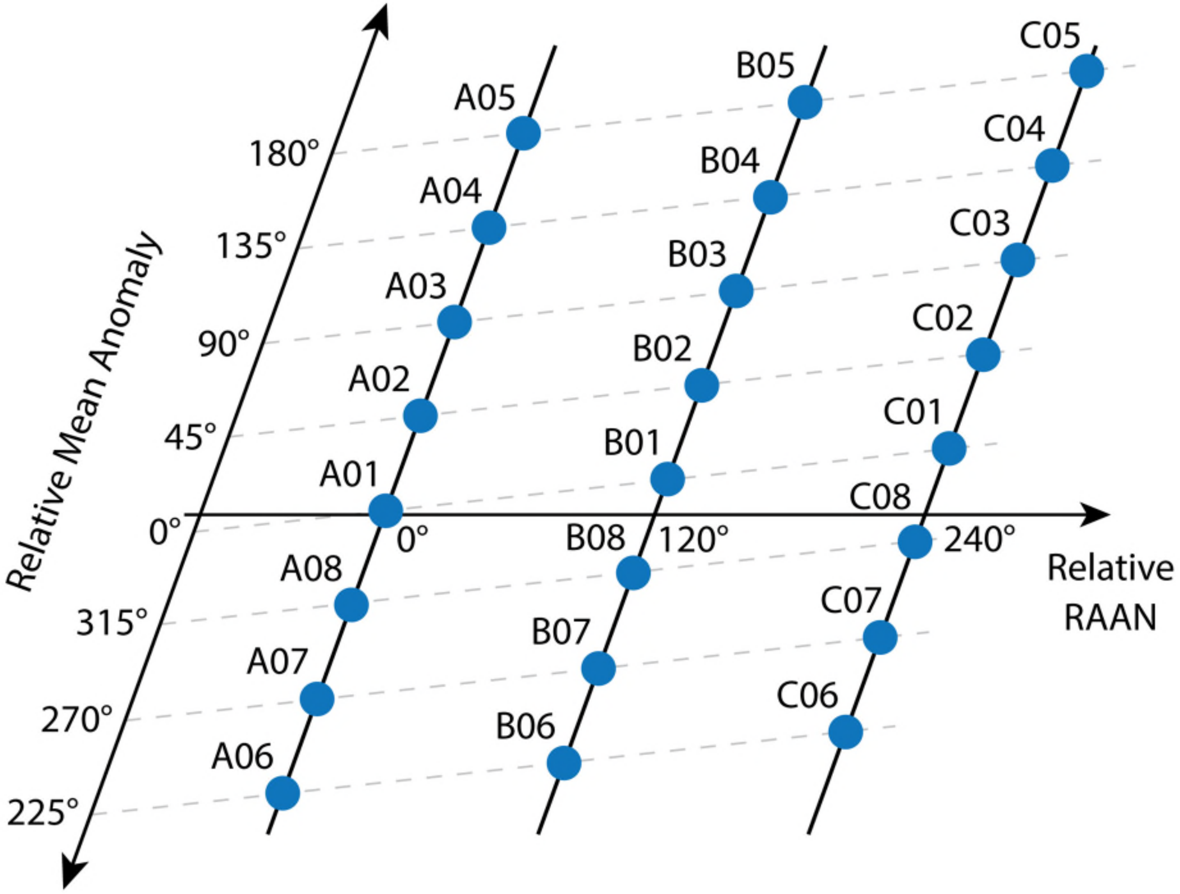


Galileo



Relative Mean Anomaly
180°
135°
90°
45°
0°
315°
270°
225°
A05
A04
A03
A02
A01
A08
A07
A06
B05
B04
B03
B02
B01
B08
B07
B06
C05
C04
C03
C02
C01
C08
C07
C06
0°
120°
240°
Relative RAAN

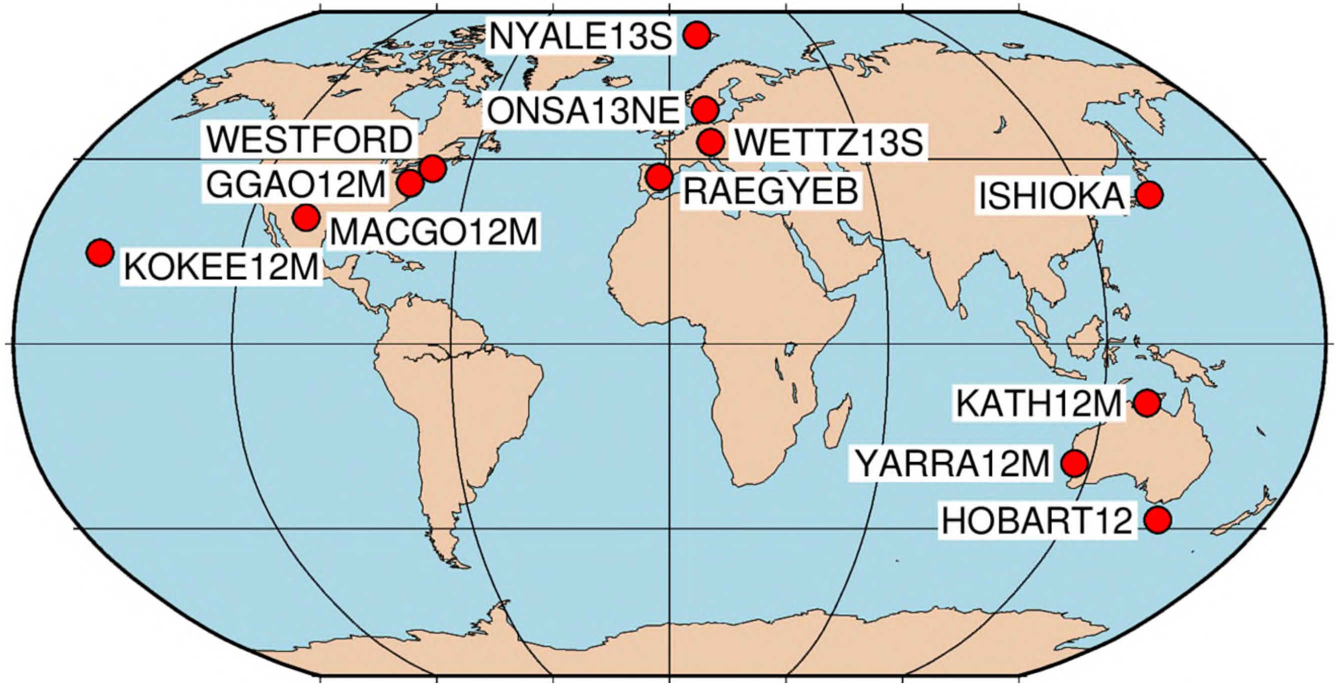
Galileo



Questions:

- How many satellites should be equipped with a VLBI transmitter (VT)?
- Which satellites should be equipped with a VT?

Study



Scenario	Satellites		
1 in A, B, C	A01 (E31)	B08 (E26)	C07 (E08)
3 in A	A01 (E31)	A03 (E21)	A05 (E30)
1 in A, 2 in B	A01 (E31)	B06 (E12)	B08 (E26)
2 in A	A01 (E31)	A05 (E30)	-
1 in A, B	A01 (E31)	B08 (E26)	-

→ 24 hour session on August 27, 2022 at 00:00:00 UTC

Estimation of station coordinates

schedule

creating a schedule including quasar and satellite observations

- satellite and quasar scans with 10 seconds duration
- different ratios of satellite and quasar scans

simulations

1000 simulations with

- tropospheric turbulence
- clock errors
- 10 ps white noise
- no errors in satellite orbit

analysis

estimation of station coordinates **from satellite scans only**

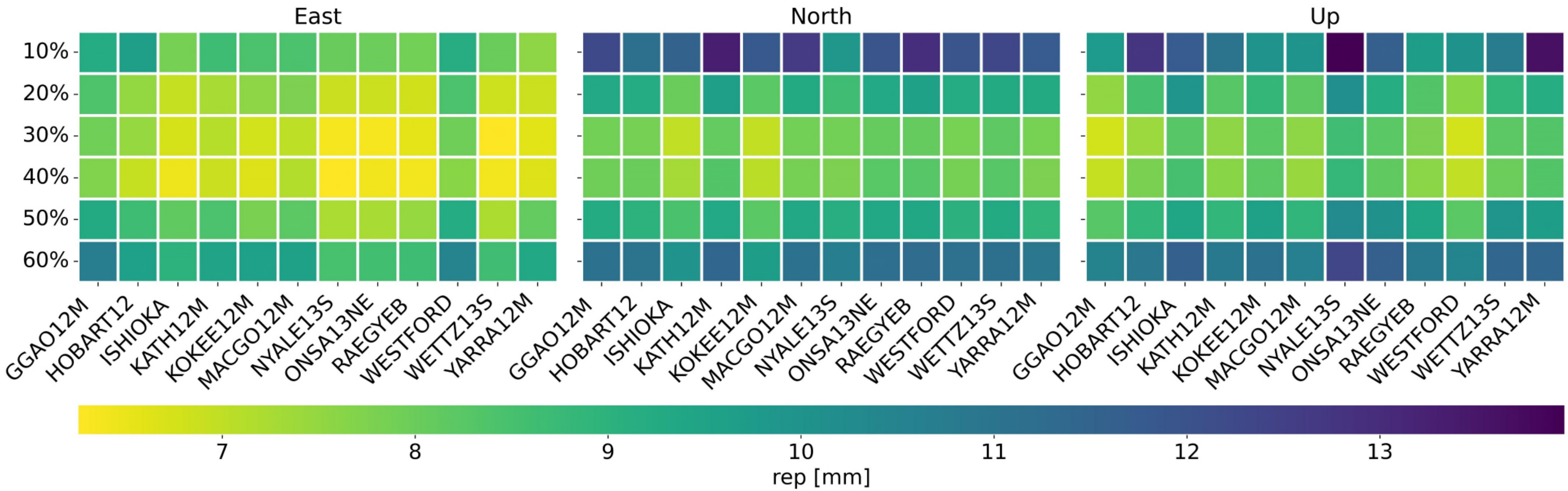
- quasars, EOPs and satellite orbits are fixed
- no datum constraints (no NNR and no NNT)
- no vector btw. VT and center-of-mass of satellite modelled

Schedules

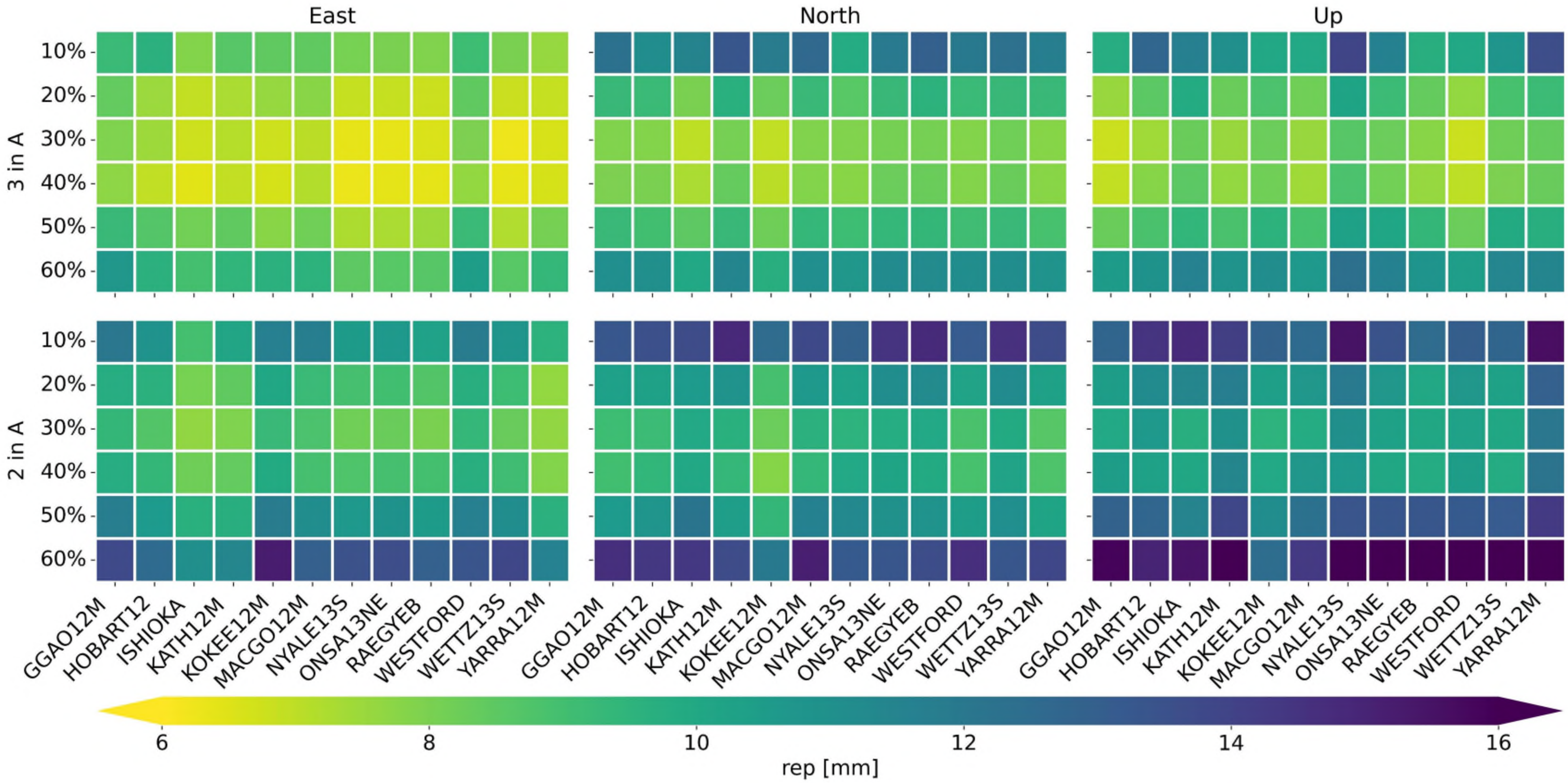
scenario	1 in A, B, C	3 in A	1 in A, 2 in B	2 in A	1 in A, B
X% satellite obs. from total number of obs.	10% 20% 30% 40% 50% 60%	10% 20% 30% 40% 50% 60%	10% 20% 30% 40% 50% 60%	10% 20% 30% 40% 50% 60%	10% 20% 30% 40% 50% 60%

→ in total **30 schedules**

Repeatabilities 3 in A



Repeatabilities 3 in A vs 2 in A



Conclusion

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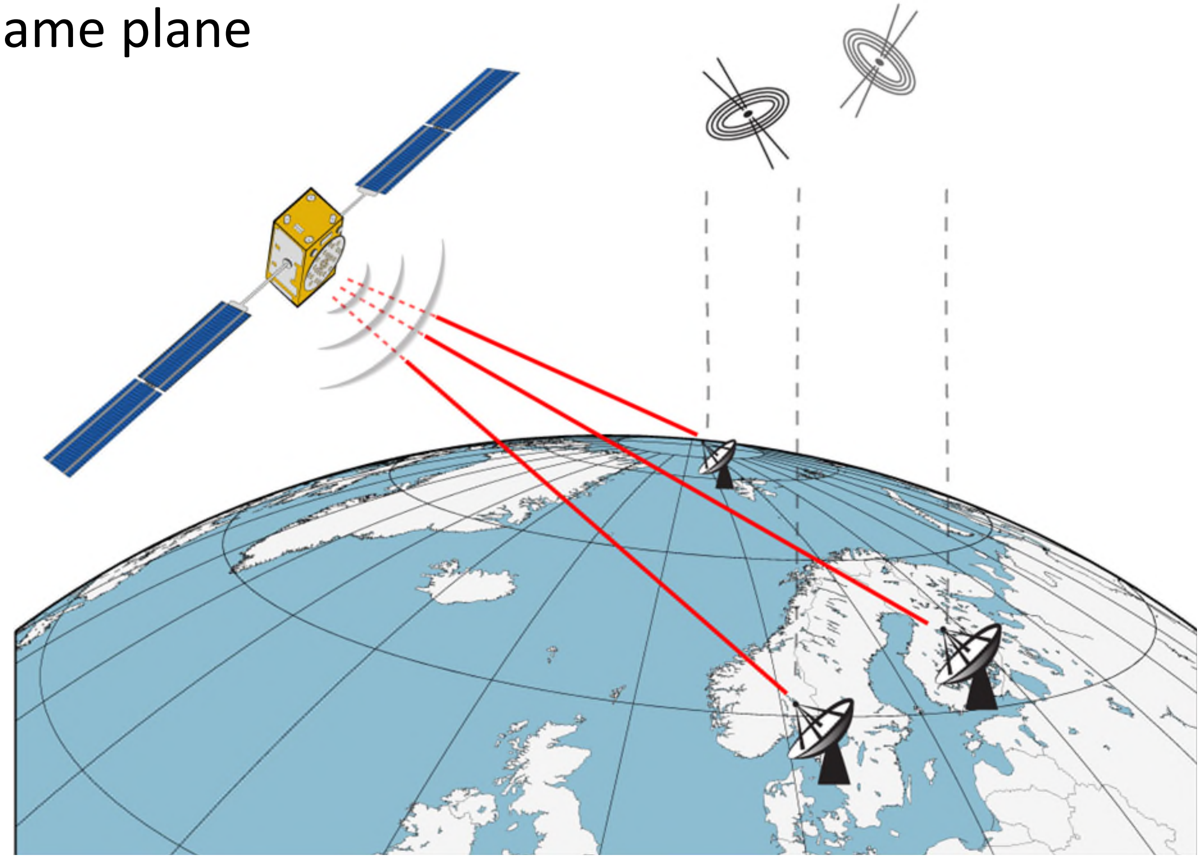
- station coordinates from satellite observations alone → frame ties
- one satellite with VT not enough (repeatabilities above 30 mm)
- optimal placing of 2 and 3 satellites would be in same plane
- quasar scans are very important for determination of troposphere
- ratios of 30% - 40% lead to the best results

- How many weeks of satellite observations are necessary for frame ties with 1 mm precision?



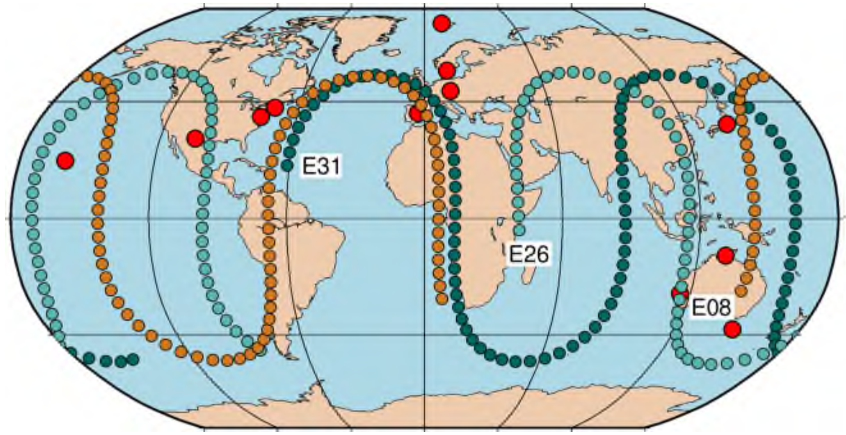
We thank the Austrian Science Fund for supporting this research.

References

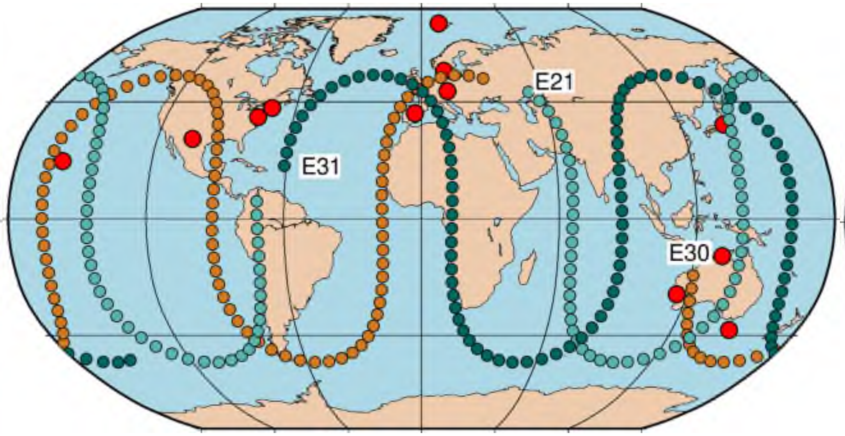
- Wolf & Böhm (2023): *Optimal distribution of VLBI transmitters in the Galileo space segment for frame ties.* Earth, Planets and Space 75, 173.
- Wolf H. (2021): *Satellite Scheduling with VieSched++.* Master Thesis, Technical University of Vienna.
- Wolf et al. (2022): *Dilution of Precision (DOP) factors for evaluating observations to Galileo satellites with VLBI*. International Association of Geodesy Symposia, Springer, Berlin, Heidelberg.
- Schartner M. (2019): *Optimizing geodetic VLBI schedules with VieSched++*. Doctoral Thesis, Technical University of Vienna.
- VieSched++: https://github.com/TUW-VieVS/VieSchedpp/

Appendix

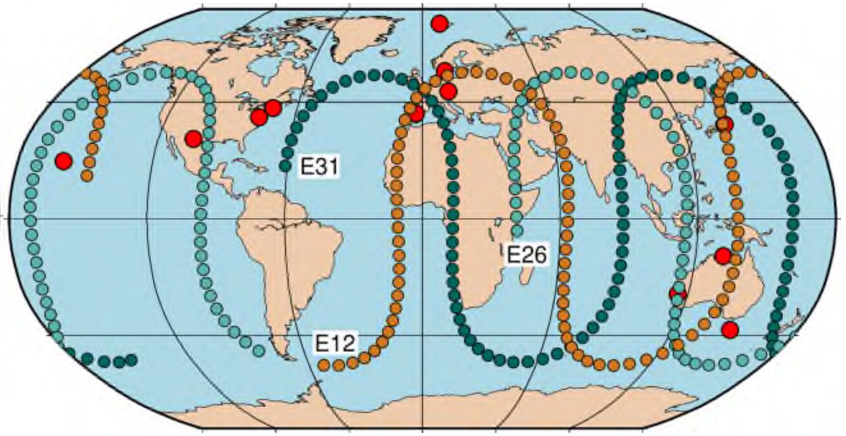
Scenarios



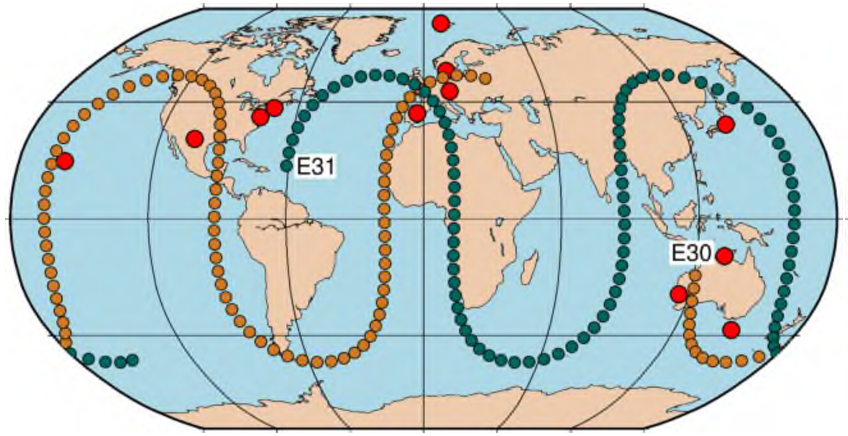
1 in A, B, C



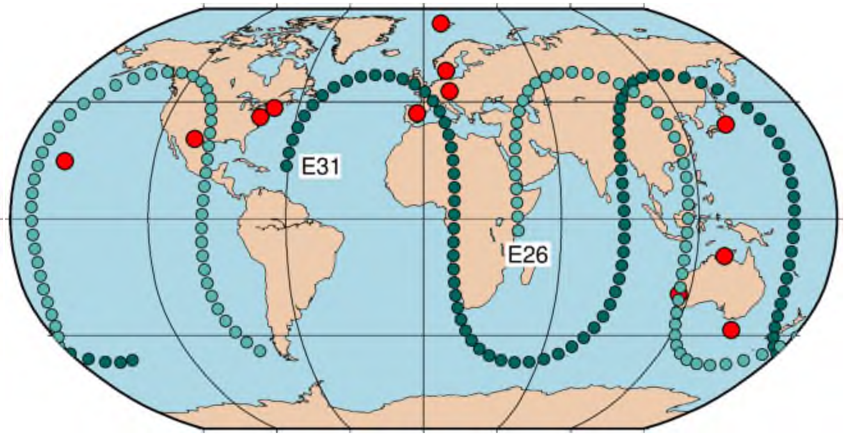
3 in A



1 in A, 2 in B

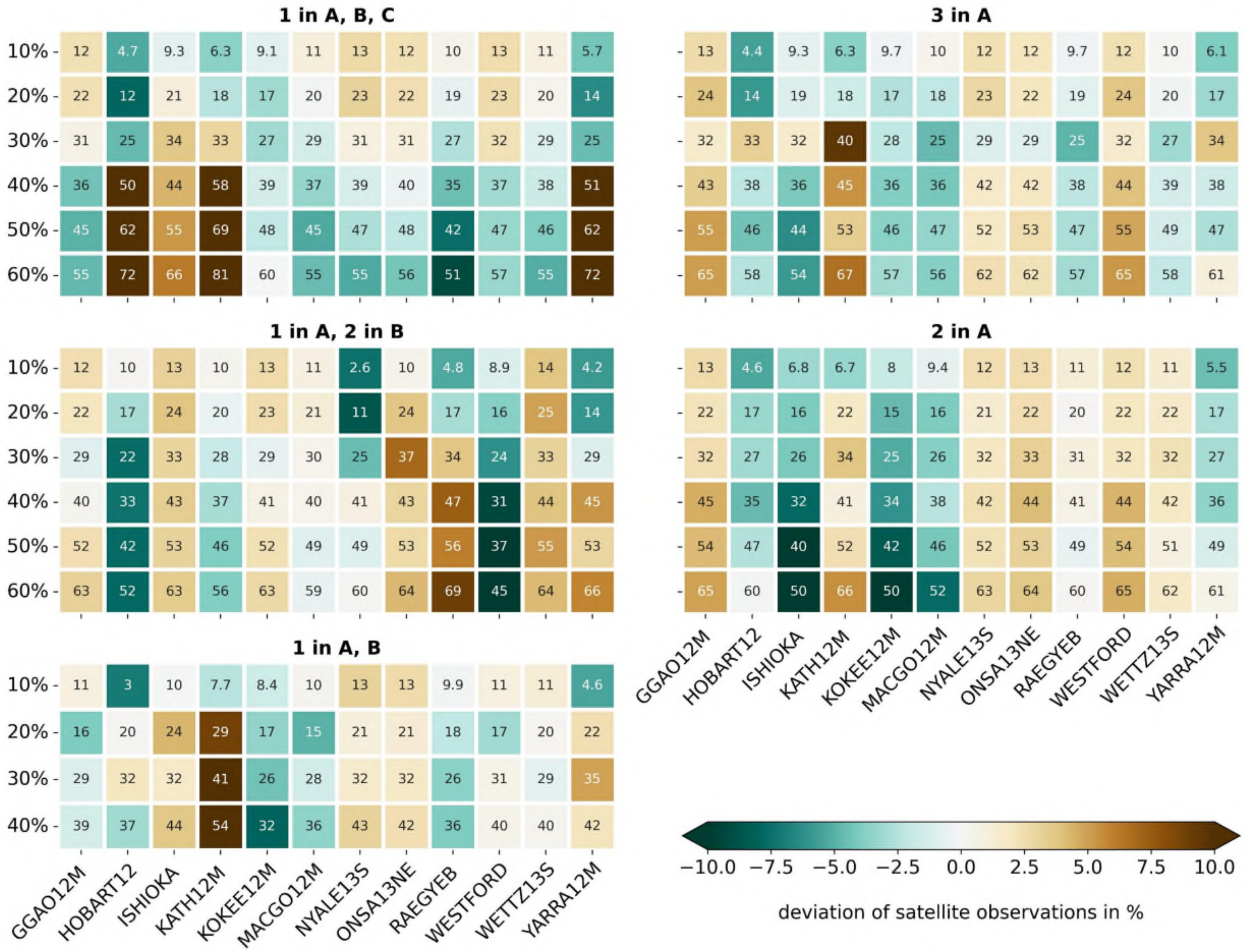


2 in A

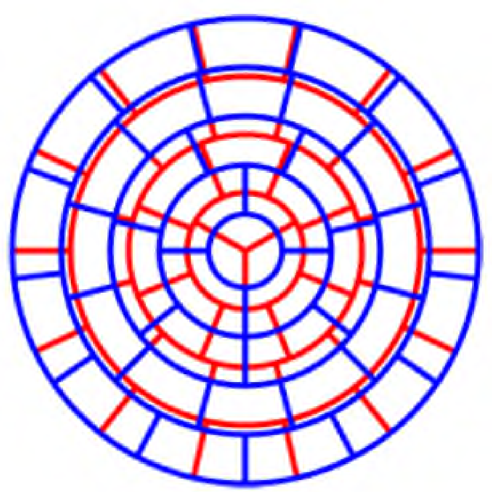


1 in A, B

Ratio of obs. for individual stations

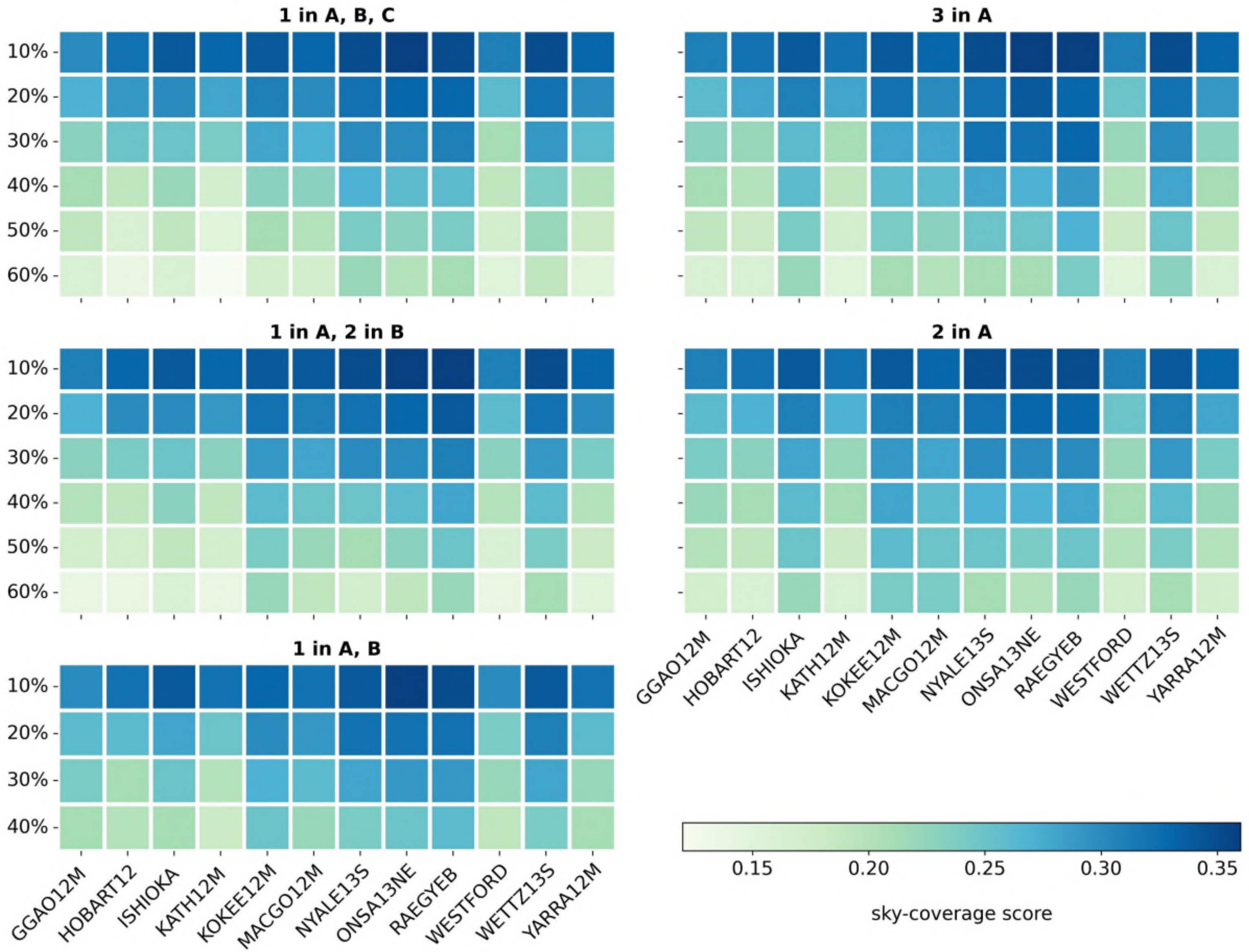


Sky-coverage

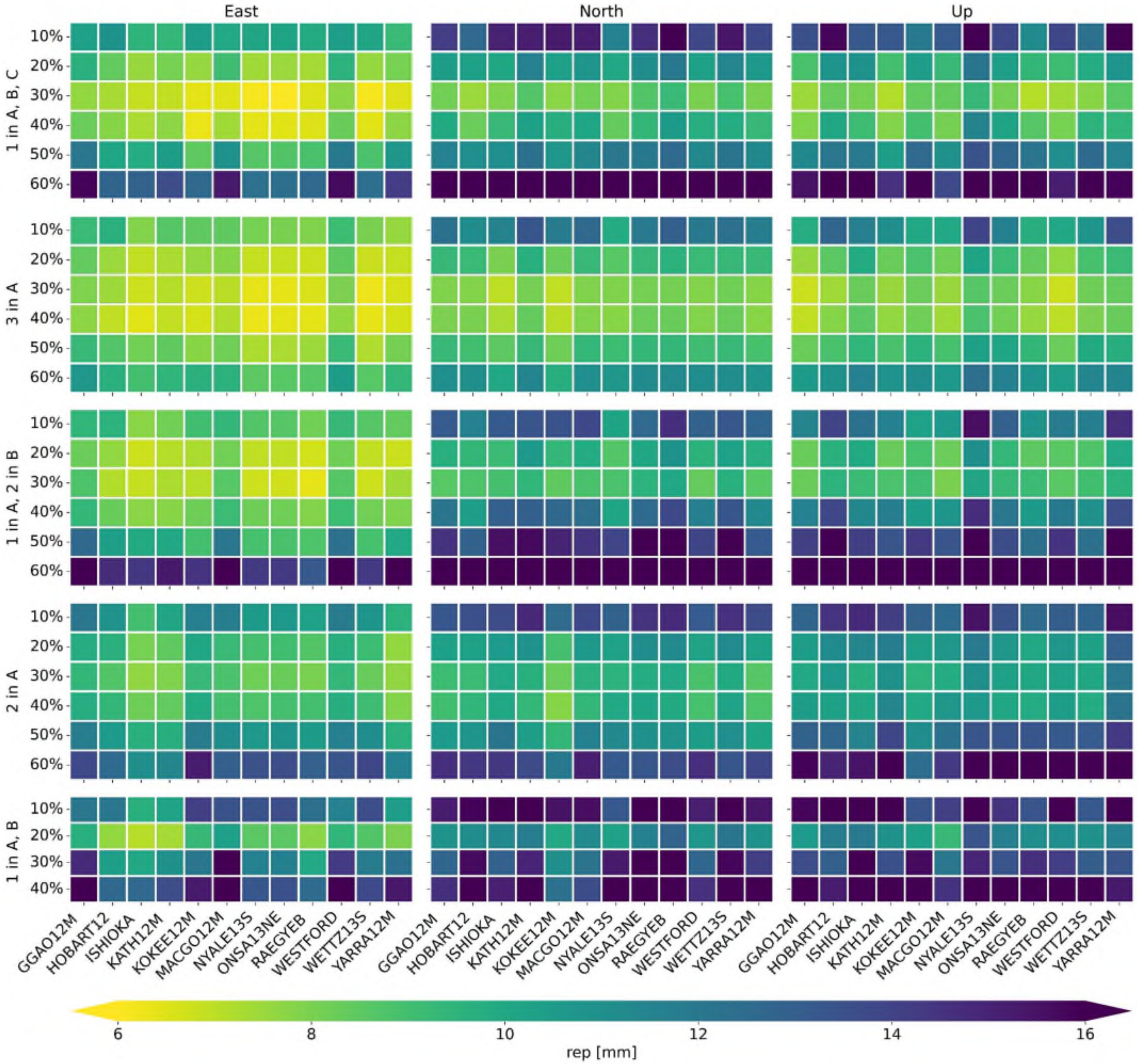


(Schartner 2019)

→ score based on 37 areas
with an 8-min time interval

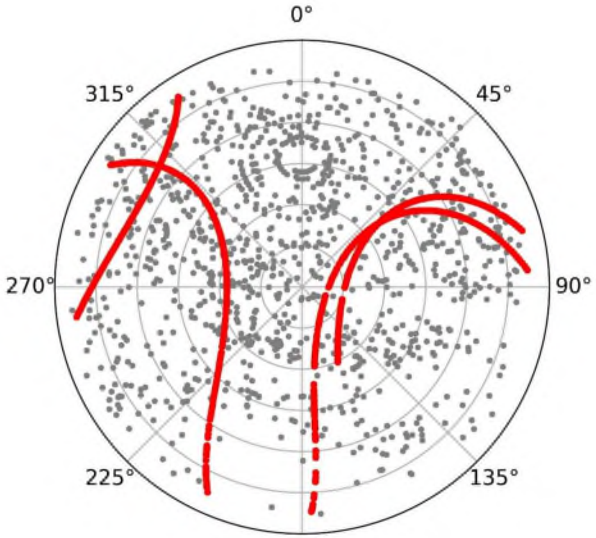


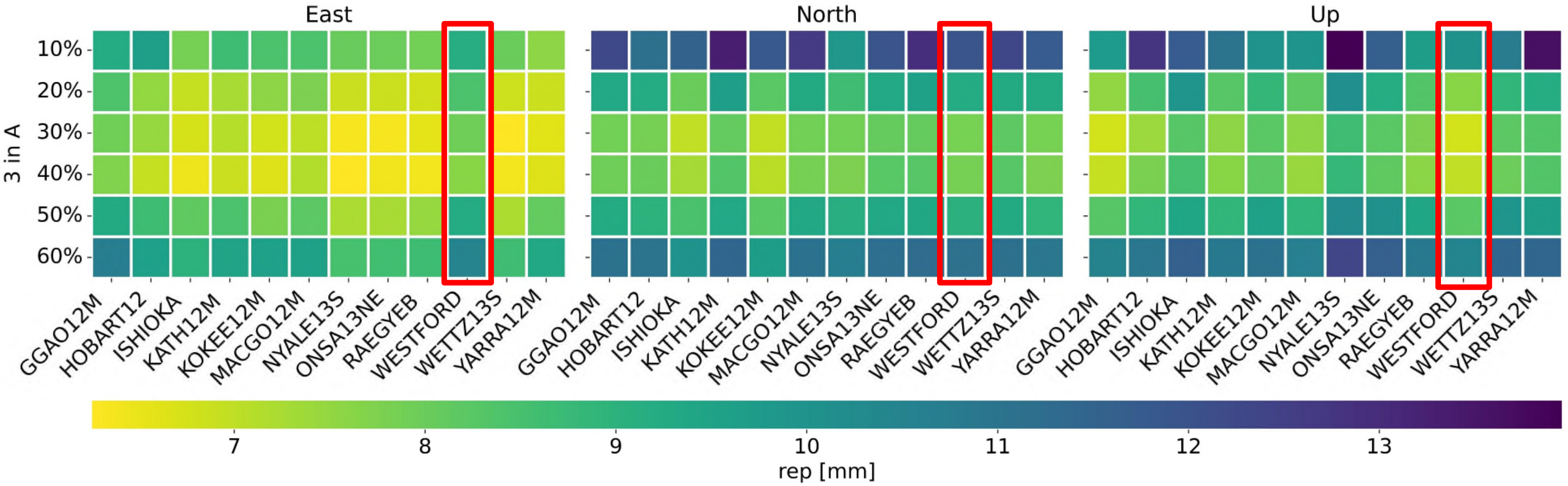
Repeatabilities



Repeatabilities 3 in A

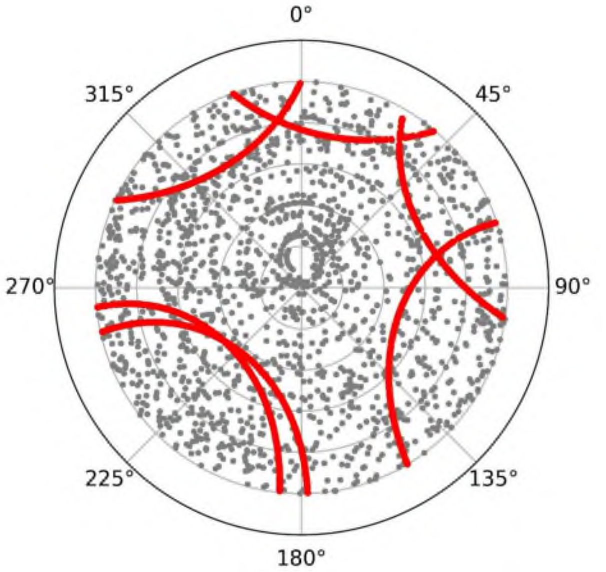
WESTFORD

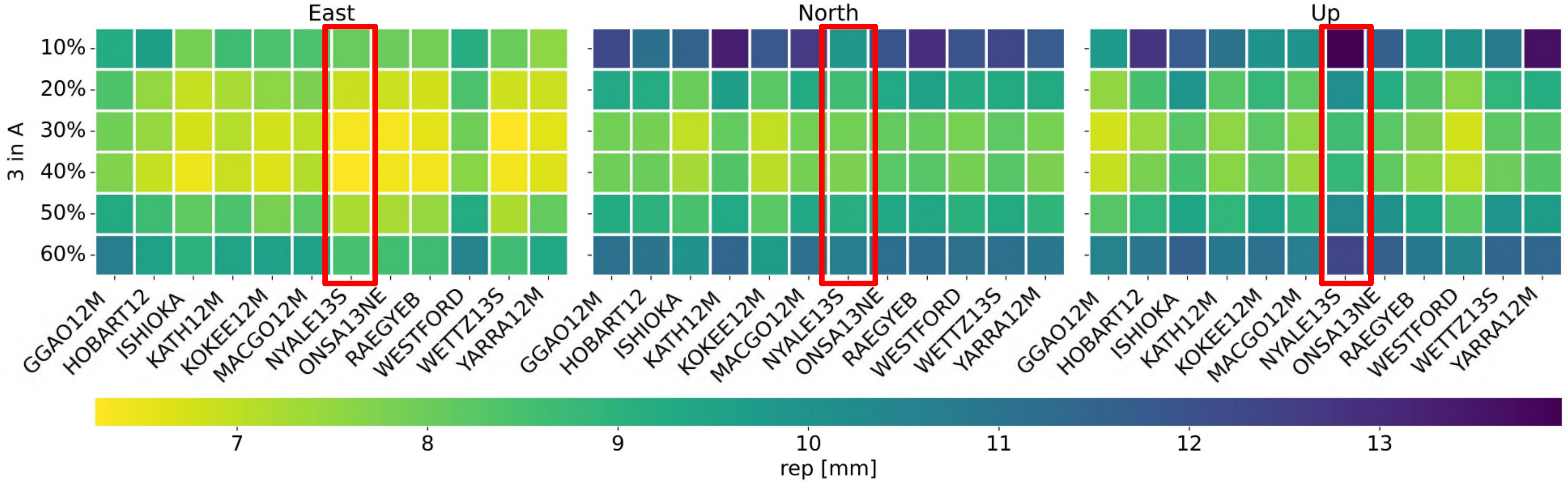




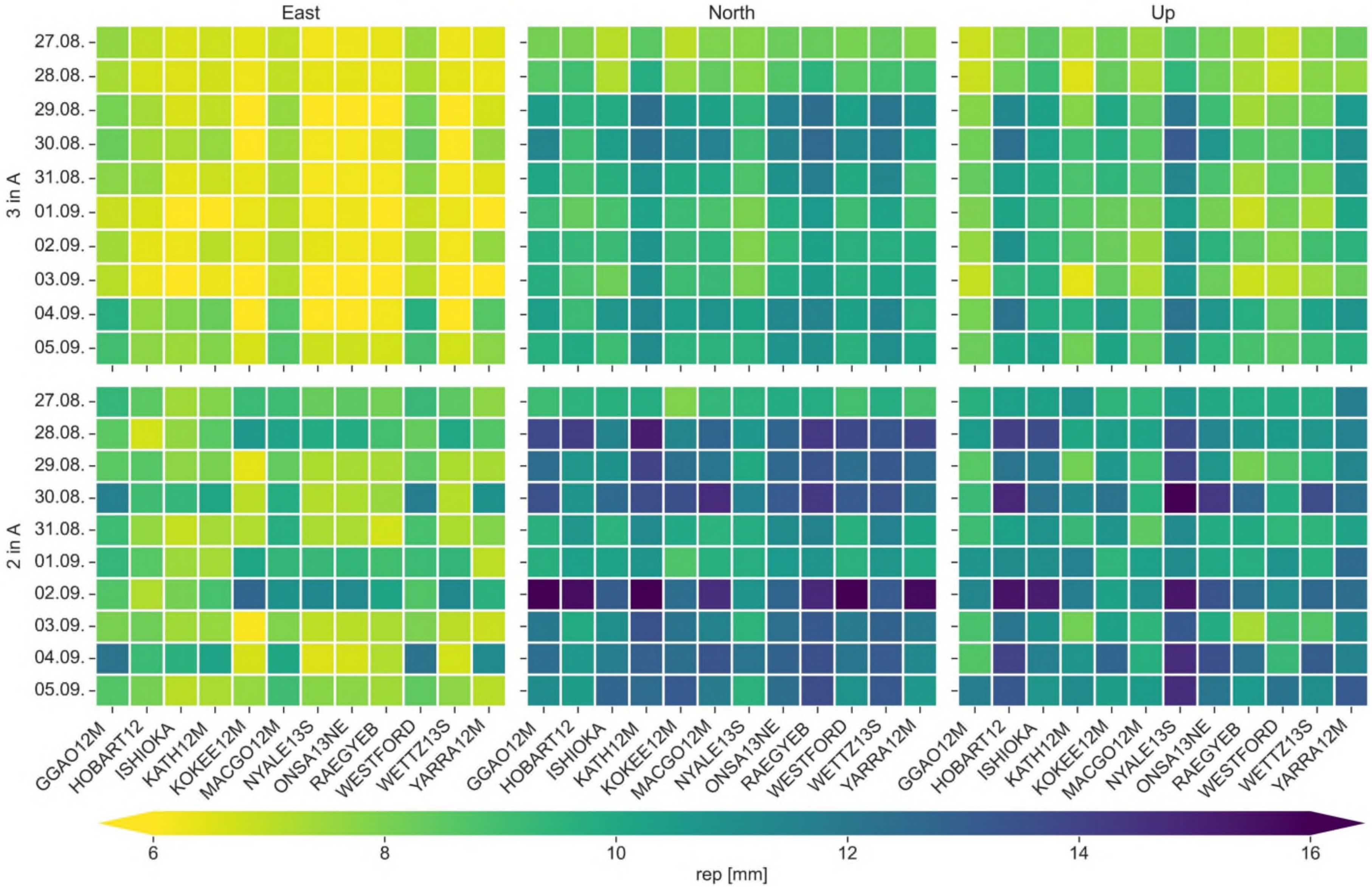
Repeatabilities 3 in A

NYALE13S





Repeatabilities over 10 days



Adding VTs on further Galileo satellites

Results showed

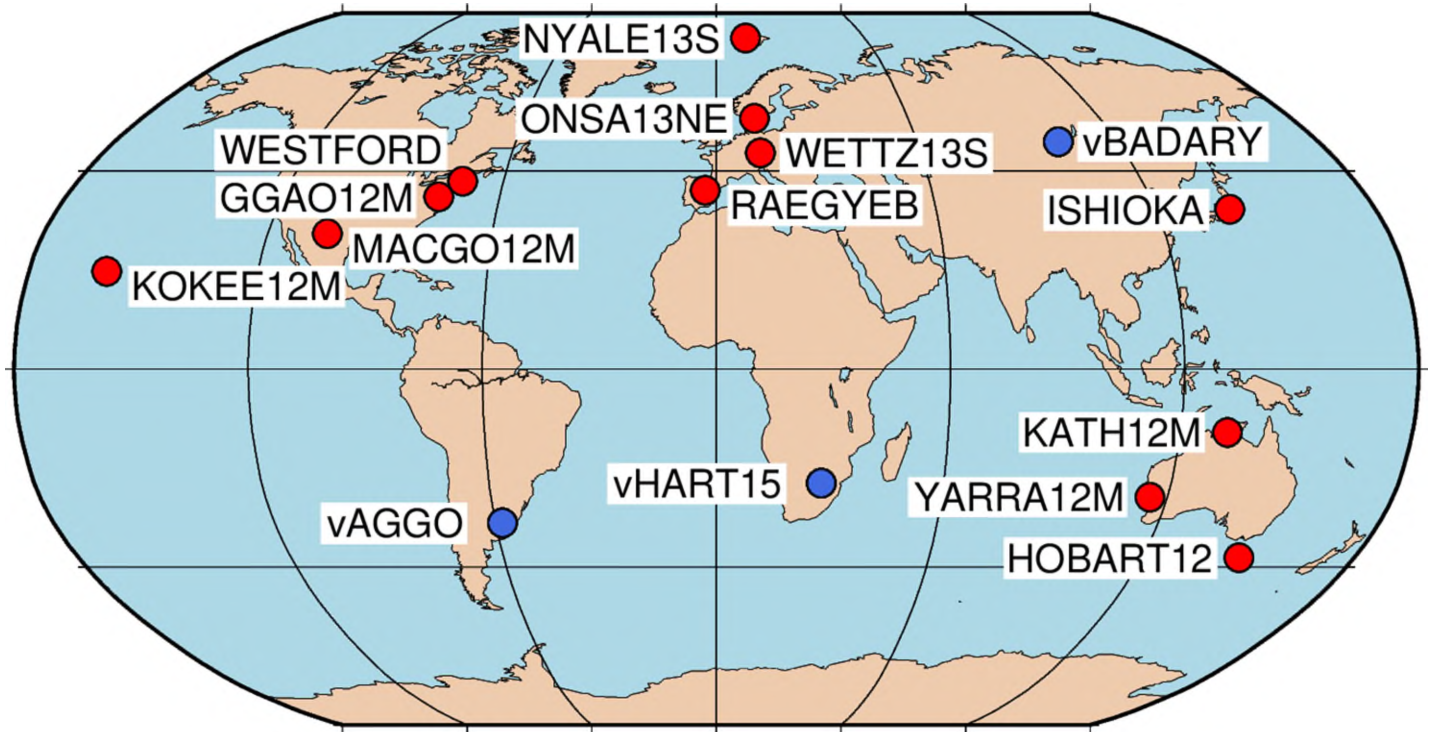
- 2 satellites in same plane with VT sufficient
- 3 satellites in same plane lead to better results than 2 satellites in same plane

Improvement of station coordinate repeatabilities with **4 or 5 satellites** in the same plane?

- 4 satellites → improvement by about 2 mm compared to 3 satellites
- 5 satellites → improvement by about 0.5 mm compared to 4 satellites

→ **no gain in precision with every additional satellite**

Future VGOS network



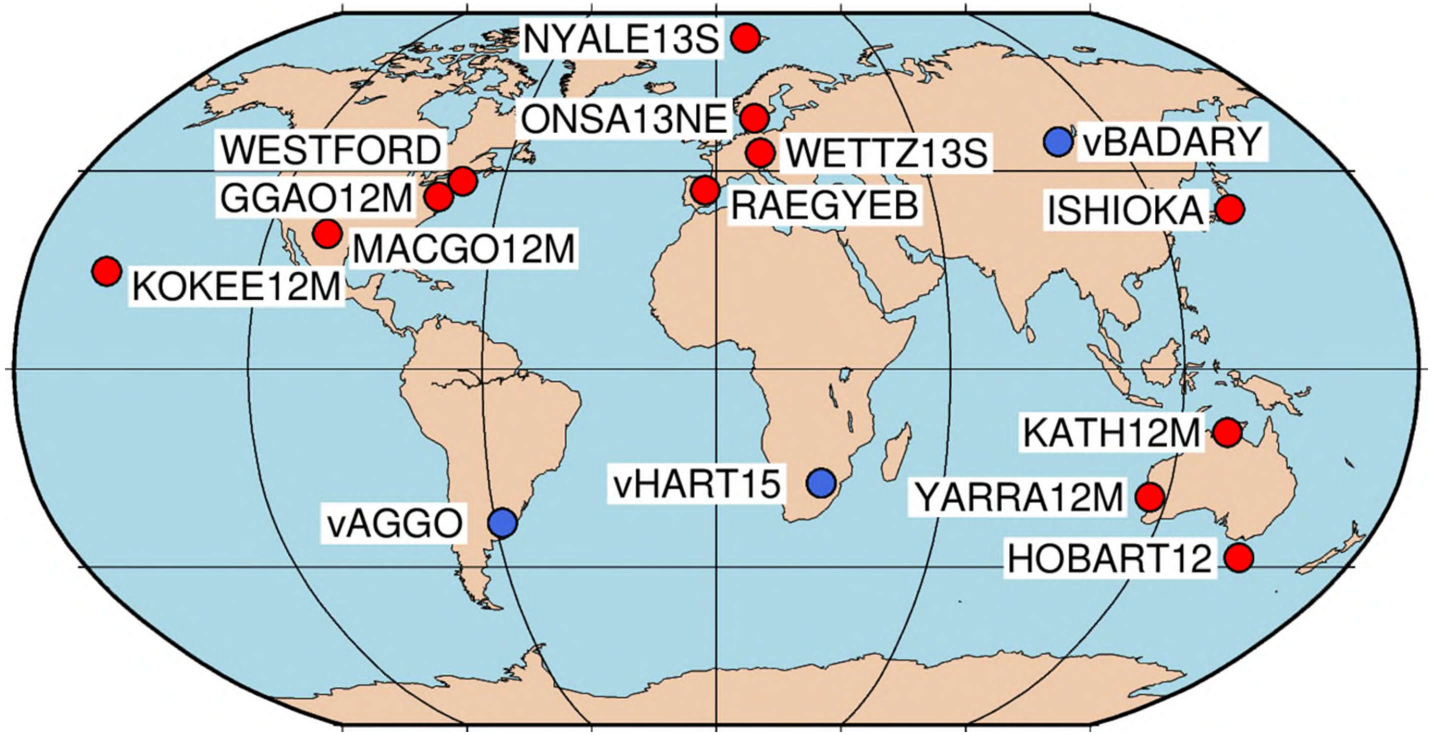
3 fictive VGOS stations at the sites

- AGGO
- BADARY
- HART15M

with same specifications as WETTZ13S

- 13.2 meters diameter
- 12°/s azimuth slew rate
- 6°/s elevation slew rate

Future VGOS network



15 station network leads to

- better visibility
- better geometry
- improved precision of station coordinates

3 in plane A with ratio of 30%:

→ improvement between **2 and 5 mm** for the individual stations compared to 12 station network