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Estimating orbital elements from VLBI observations and GNSS measurements

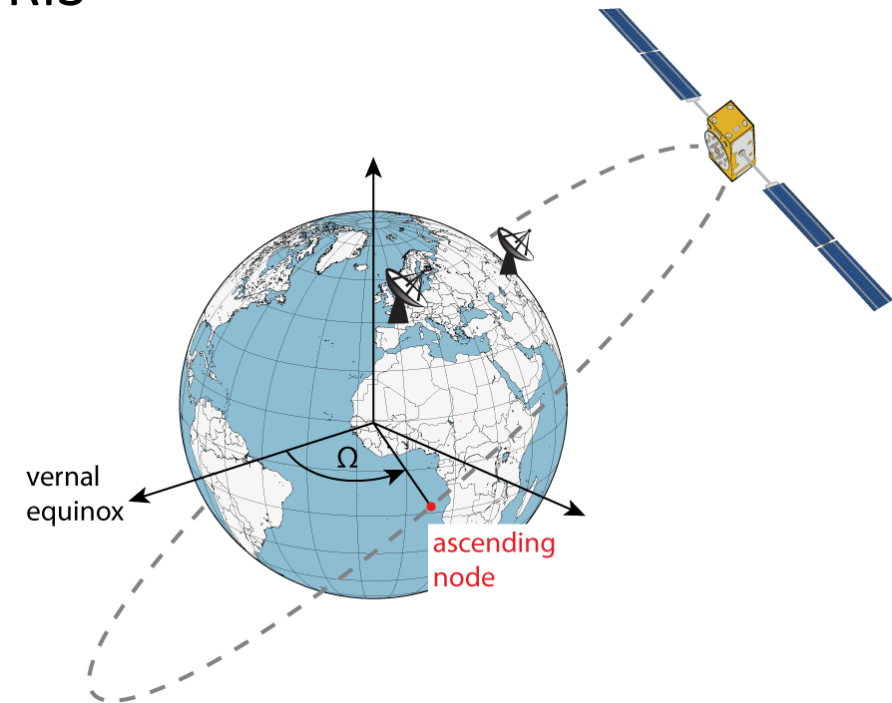
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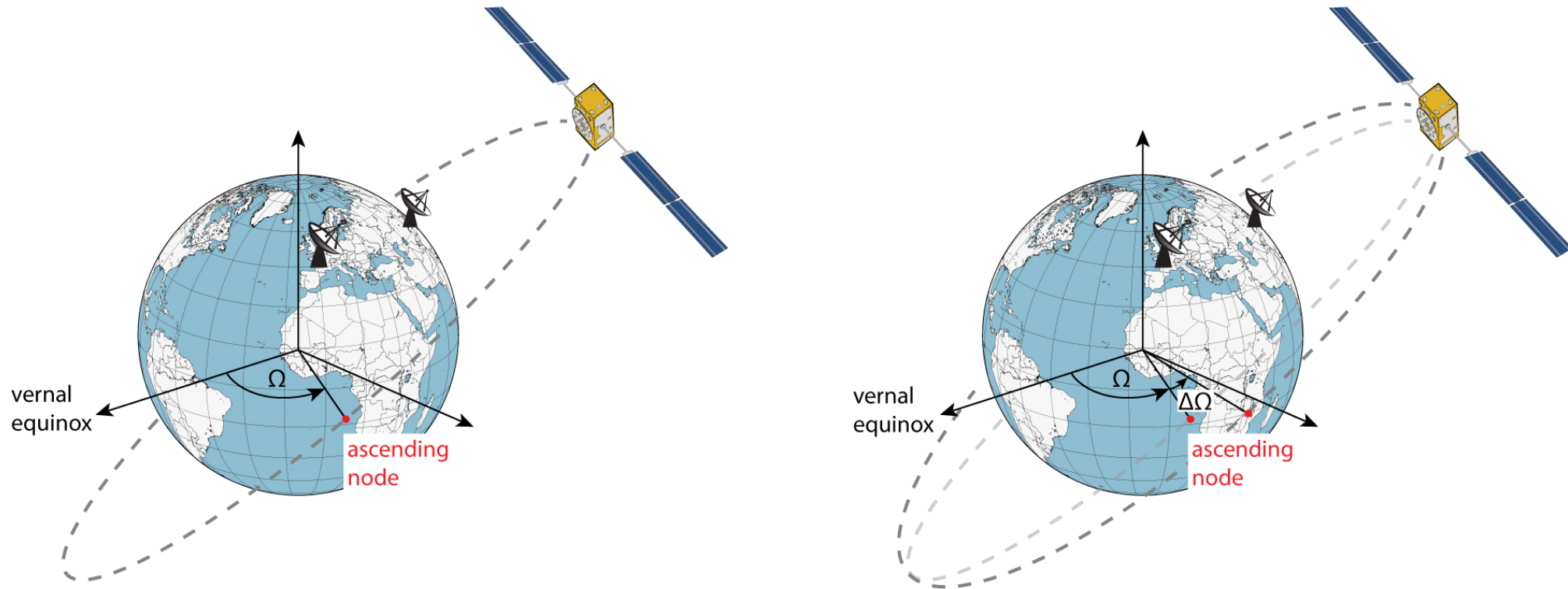
Why observing satellites with VLBI?

- satellites are routinely observed with GNSS, SLR, and DORIS
- satellite techniques alone don't allow to distinguish between a rotation of orbital plane and a rotation of the Earth (UT1-UTC)
- plans of VLBI transmitter on board of Galileo satellites
 - VLBI observations allow the direct estimation of satellite orbits in the celestial frame



Estimation of Orbital Elements

- right ascension of the ascending node as a first test
- partial derivatives are built numerically (changing Ω by 0.5°)

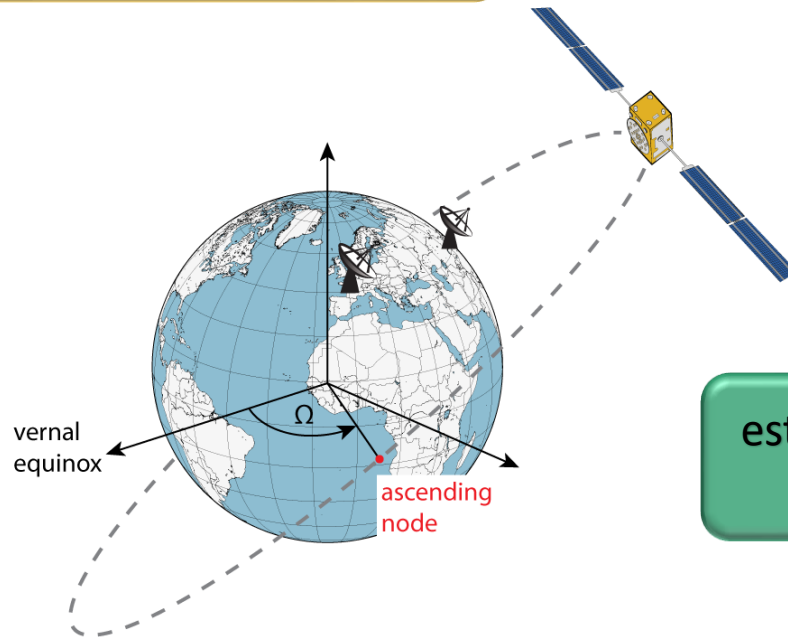


Estimation of Orbital Elements

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FSO-file (orbits)

FRP-file (derivatives)



estimation of piecewise linear offsets for Ω

VieVS

$r(t)$ and $v(t)$

$$\frac{\partial r(t)}{\partial \Omega}, \frac{\partial v(t)}{\partial \Omega}$$

$$\frac{\partial \tau}{\partial r(t)} \cdot \frac{\partial r(t)}{\partial \Omega} = \frac{\partial \tau}{\partial \Omega}$$

Least squares adjustment

Estimation of Orbital Elements

schedule

creating a schedule including quasar and satellite observations

- satellite scans with 10 seconds duration every 90 seconds
- remaining part of schedule is filled with quasar scans
- quasar scans fixed to 10 seconds



simulations

1000 simulations with

- tropospheric turbulence
- clock errors
- 10 ps white noise for satellite scans



analysis

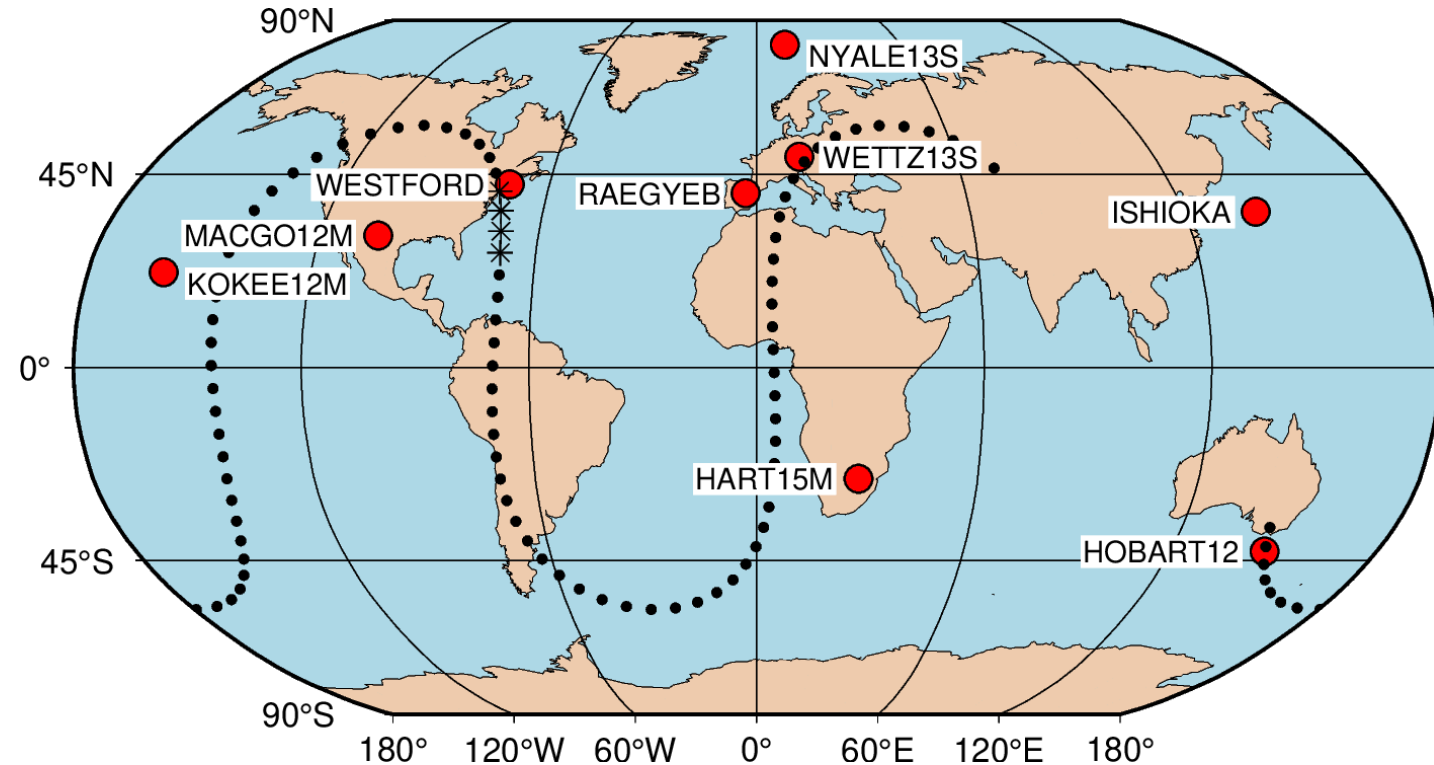
estimation of piecewise linear offsets from a-priori orbit for Ω

- quasars and stations are fixed
- repeatabilities



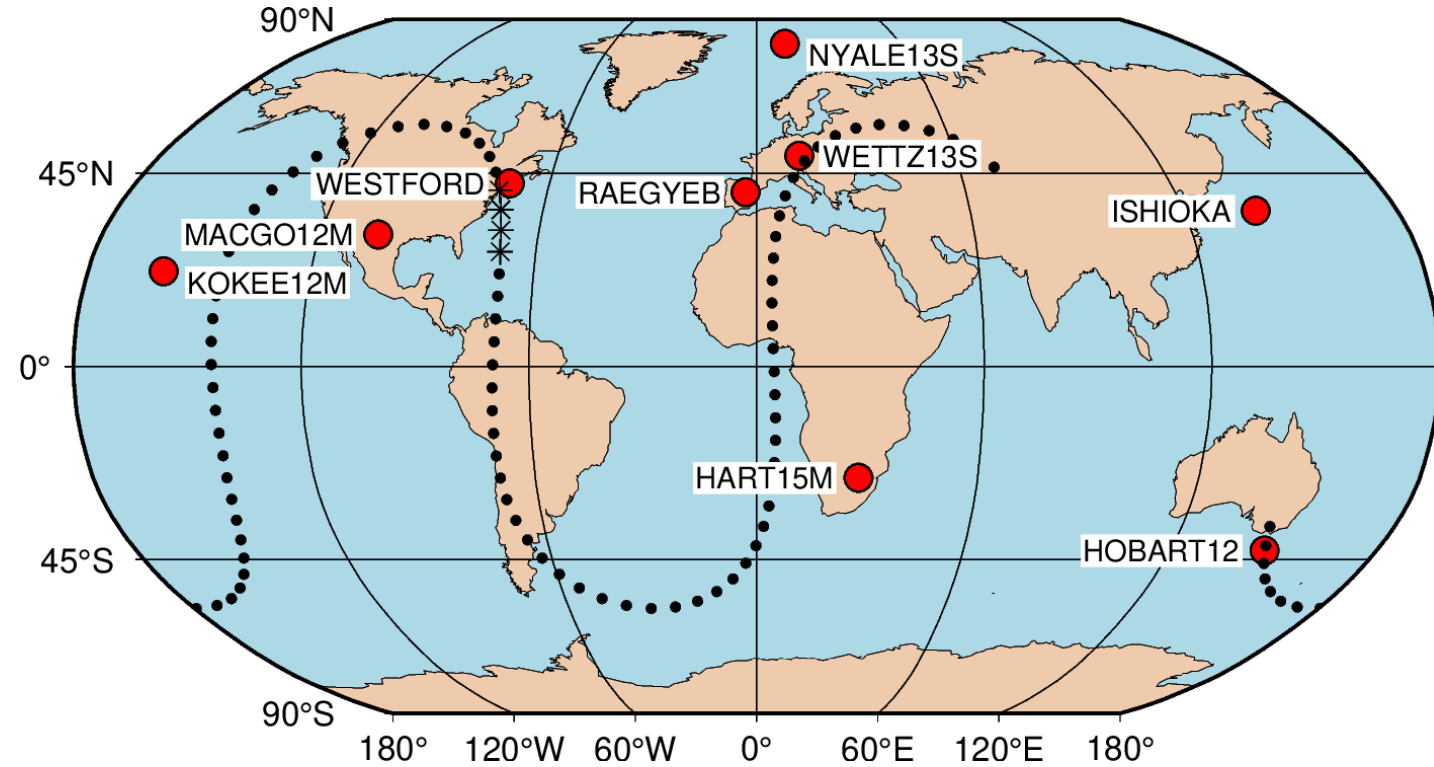
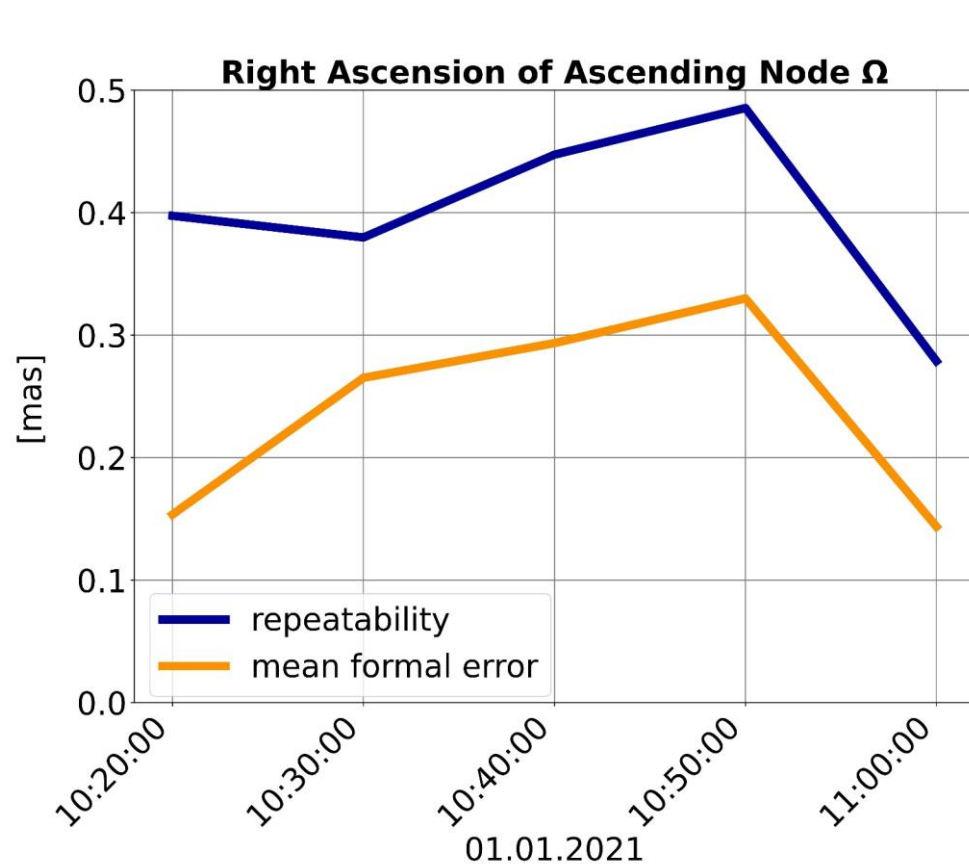
Estimation of Orbital Elements

- Example: Jan. 1, 2021 00:00 – 24:00
 - 9 station network
 - GSAT0101 (E11)
 - satellite observation period with 40-min duration
 - estimation of right ascension Ω
 - as piecewise linear offsets
 - one value for the 40-min period



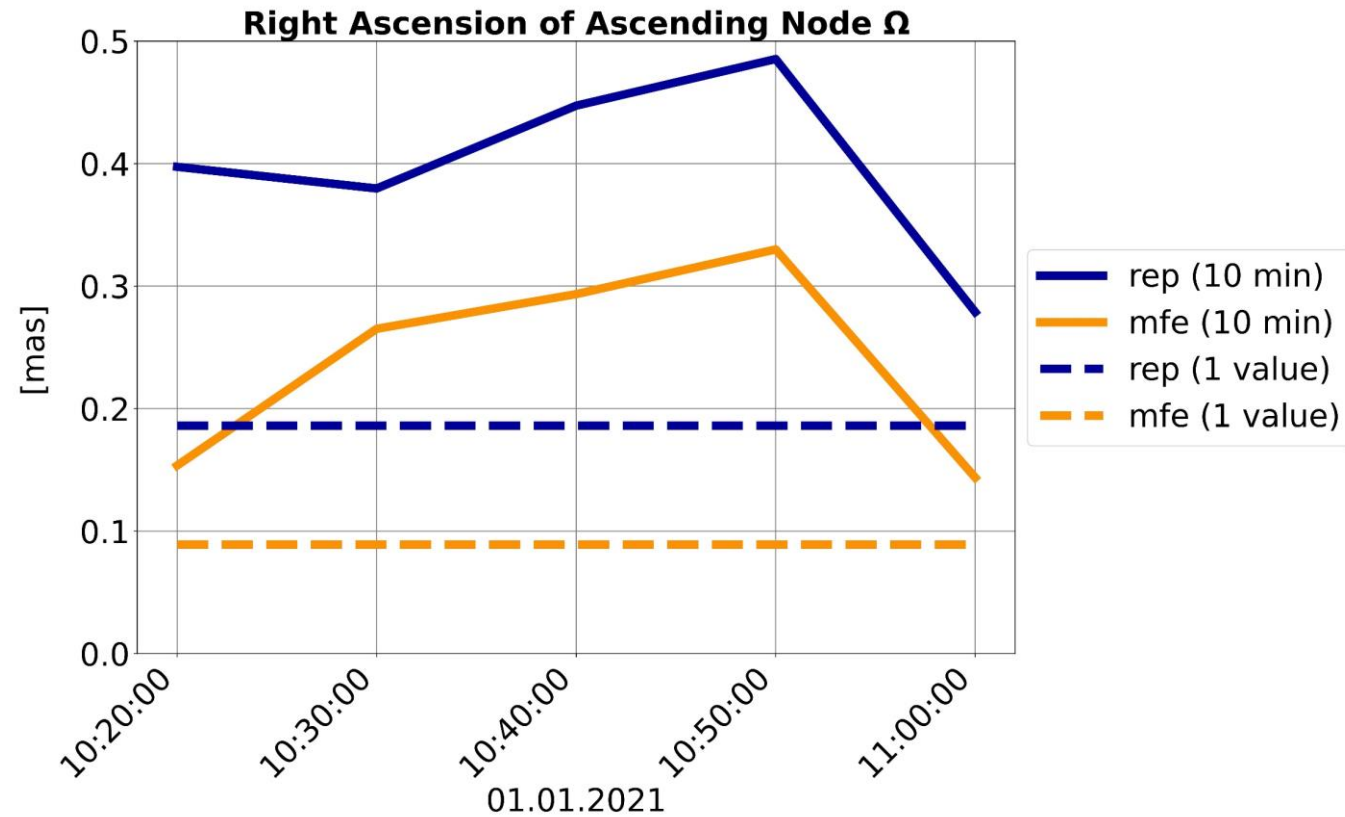
Estimation of Orbital Elements

- satellite observations from 10:20 – 11:00 with 5 stations



Estimation of Orbital Elements

- satellite observations from 10:20 – 11:00 with 5 stations



Outlook

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FSO-file (orbits)

FRP-file (derivatives)

N - Matrix



VieVS

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N - Matrix



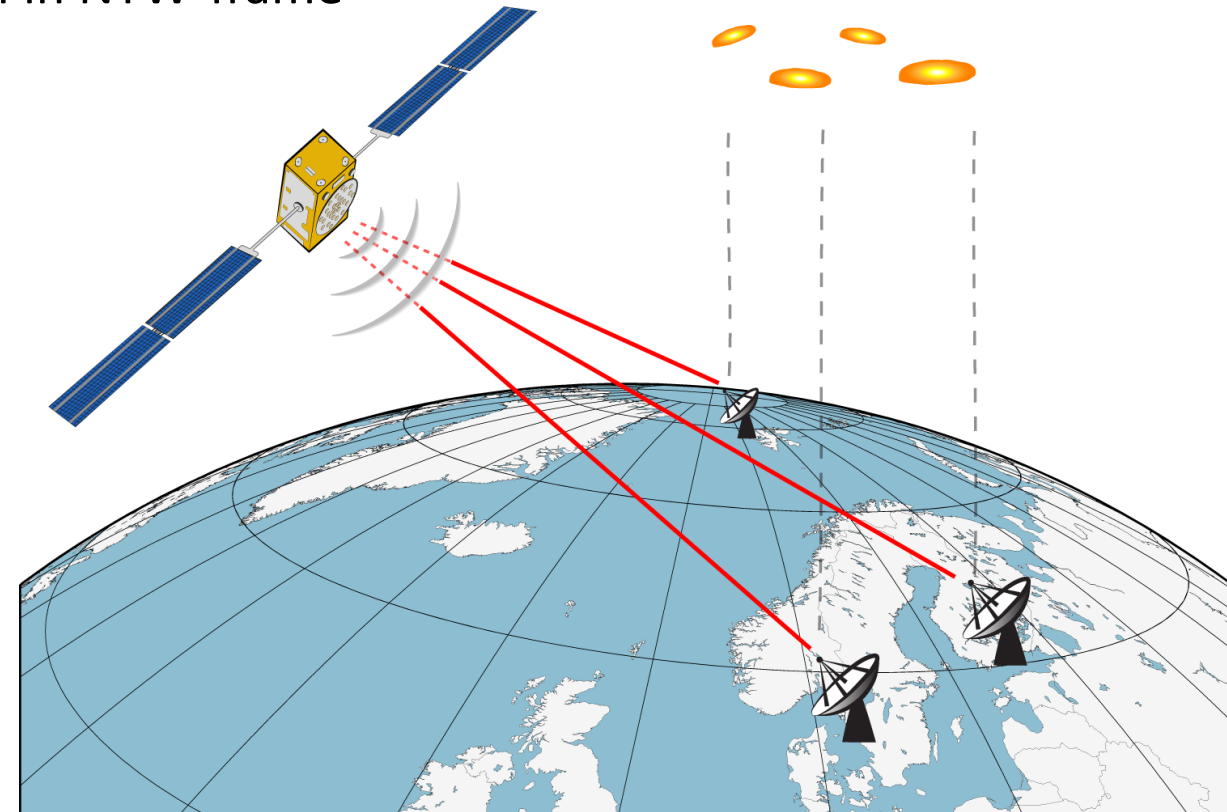
ADDNEQ2

combination at
NEQ level



Conclusion

- more investigations needed, e.g.,
 - how many quasar scans in between for sufficient troposphere determination
 - relationship with estimated satellite position in NTW-frame
 - dependence on observation geometry
- frequency of estimation
 - estimation interval
 - one value for 24-hour session
- estimation of other orbital elements
- combination at NEQ level



References

- 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.
- Belli F. (2020): *Transfer of absolute orientation to Galileo orbits with VLBI*, Master thesis, Technical University of Munich.
- Hellerschmied A. (2018): *Satellite Observations with VLBI*, Doctoral Thesis, Technical University of Vienna.
- Zajdel et al. (2020): *System-specific systematic errors in earth rotation parameters derived from GPS, GLONASS, and Galileo*, GPS Solut 24, 74.
- VieSched++: <https://github.com/TUW-VieVS/VieSchedpp/>