

# Adjustment of orbital elements of Galileo satellite arcs with simulated VLBI observations

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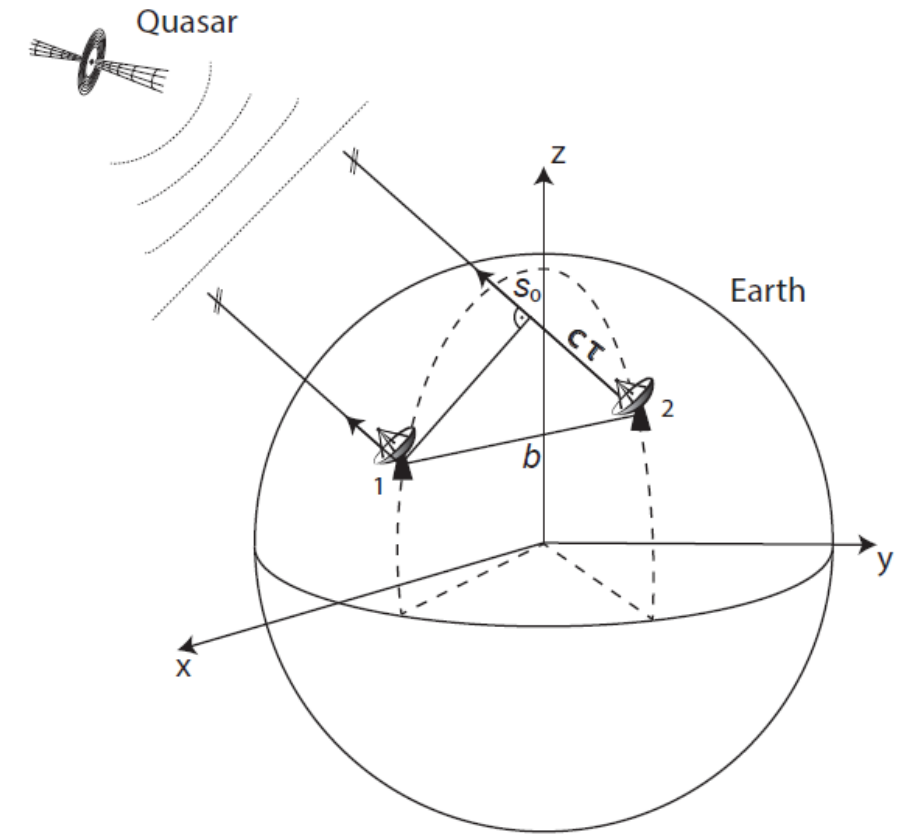
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# VLBI Principle

- Very Long Baseline Interferometry (VLBI) measures the time difference  $\tau$  between the arrivals of the radio signal from quasars at different telescopes

$$\tau = - \frac{\mathbf{b} \cdot \mathbf{s}_0}{c} = t_2 - t_1$$

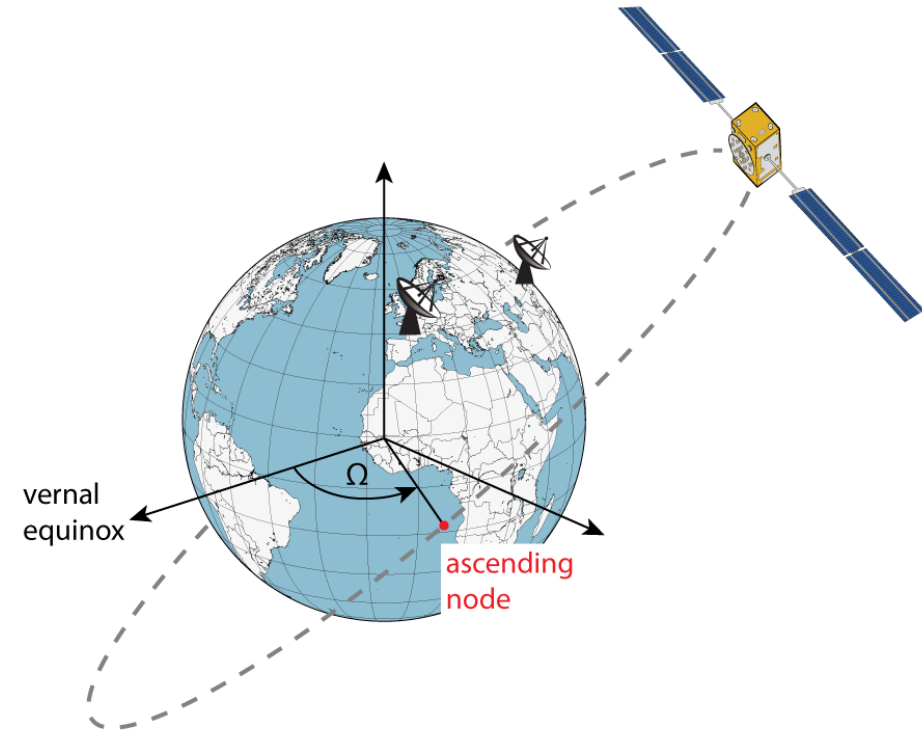
- VLBI essential for
  - International Terrestrial Reference Frame
  - International Celestial Reference Frame
  - Earth orientation parameters



(Gruber, 2022)

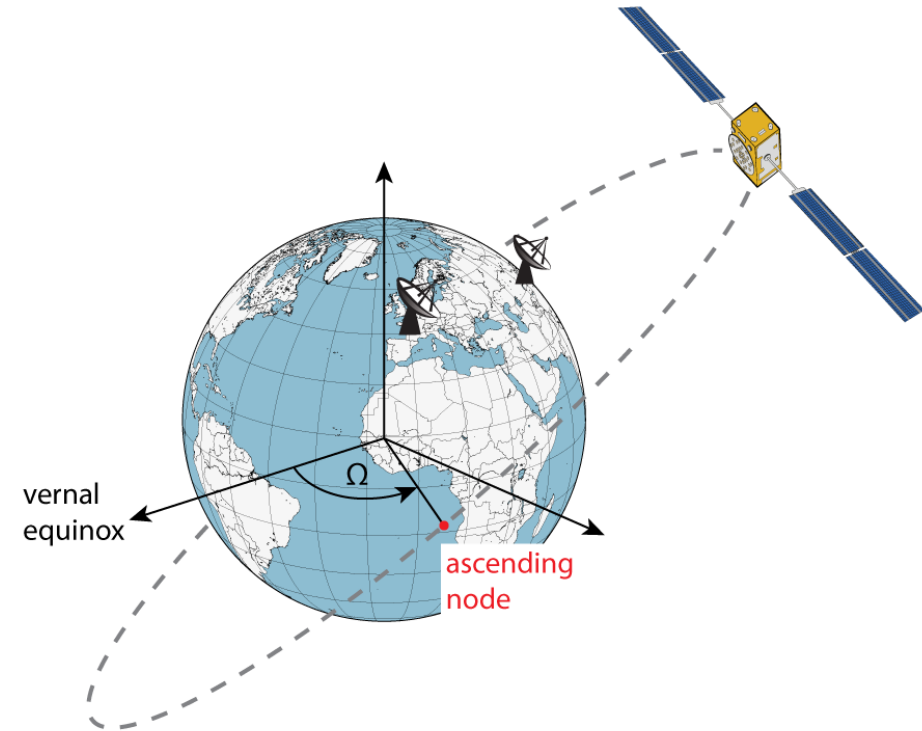
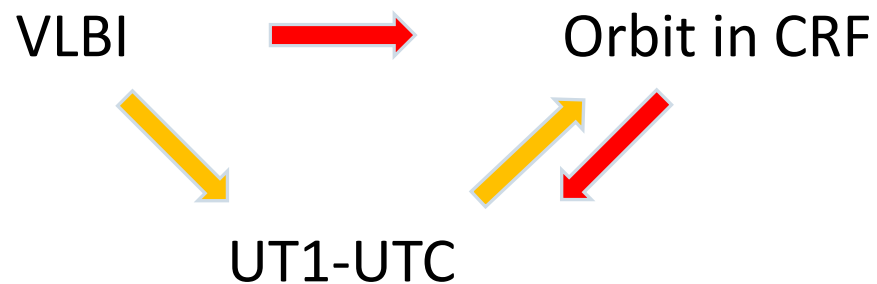
# Why observing satellites with VLBI?

- satellite techniques alone don't allow to distinguish between a rotation of orbital plane and the rotation of the Earth (UT1-UTC)
  - i.e., due to errors in solar radiation pressure modelling accumulated Length-of-Day (LoD) values from GNSS drift away with  $-22.4 \mu\text{s/day}$  (Zajdel et al., 2020)
- VLBI observations to satellites enable the detection of systematic differences between the techniques



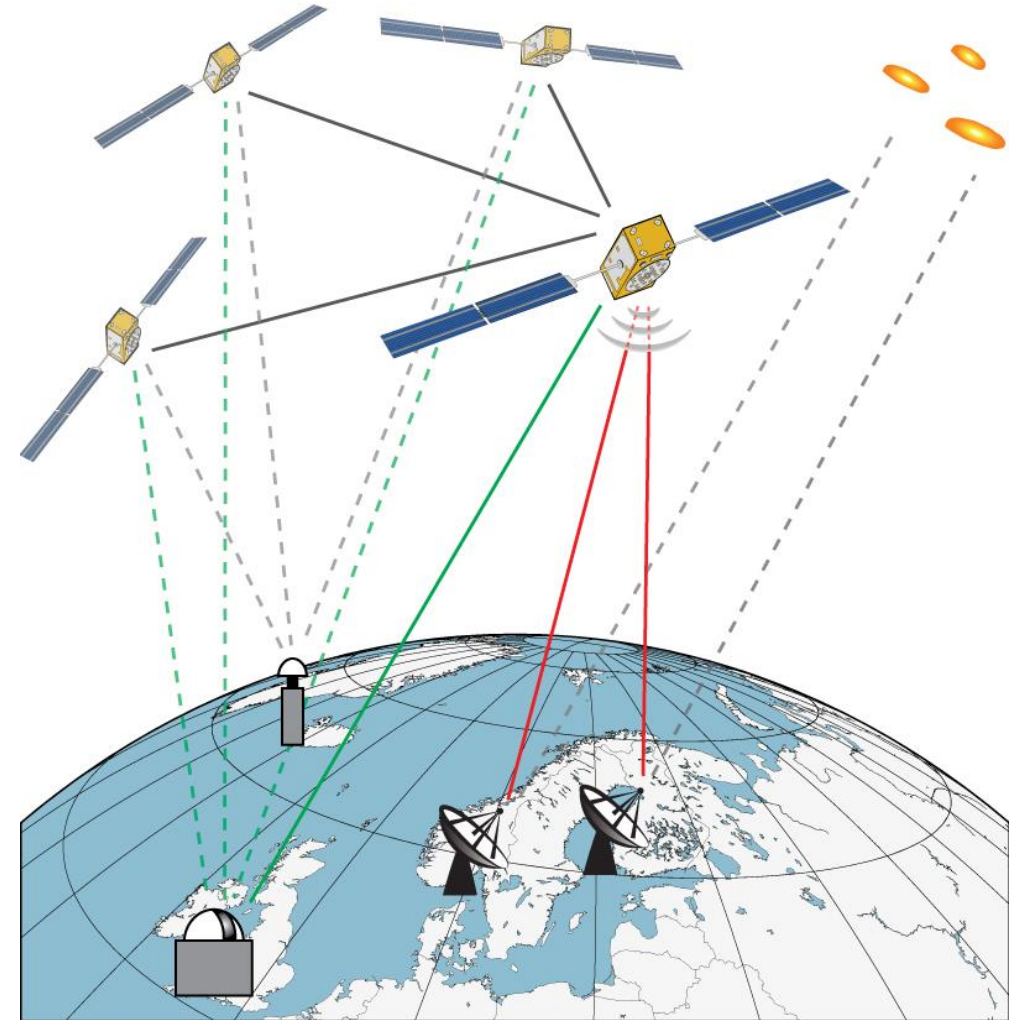
# Why observing satellites with VLBI?

- satellites are routinely observed with GNSS, SLR, and DORIS
  - VLBI observations to satellites are missing in space geodesy
- VLBI observations allow the direct estimation of satellite orbits in the celestial frame
  - without going via UT1-UTC



# Why observing satellites with VLBI?

- realising ties on-board of a satellite
- high-precision tying of different space geodetic techniques
- improvement of the terrestrial reference frame
  - errors in local ties on the ground are limiting factor for the accuracy of the terrestrial reference frame



# Estimation of Orbital Elements

schedules

creating schedules including quasar and satellite observations

- satellite scans with 10 seconds duration every 40 seconds
- remaining part of schedule is filled with quasar scans



simulations

1000 simulations with

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



analysis

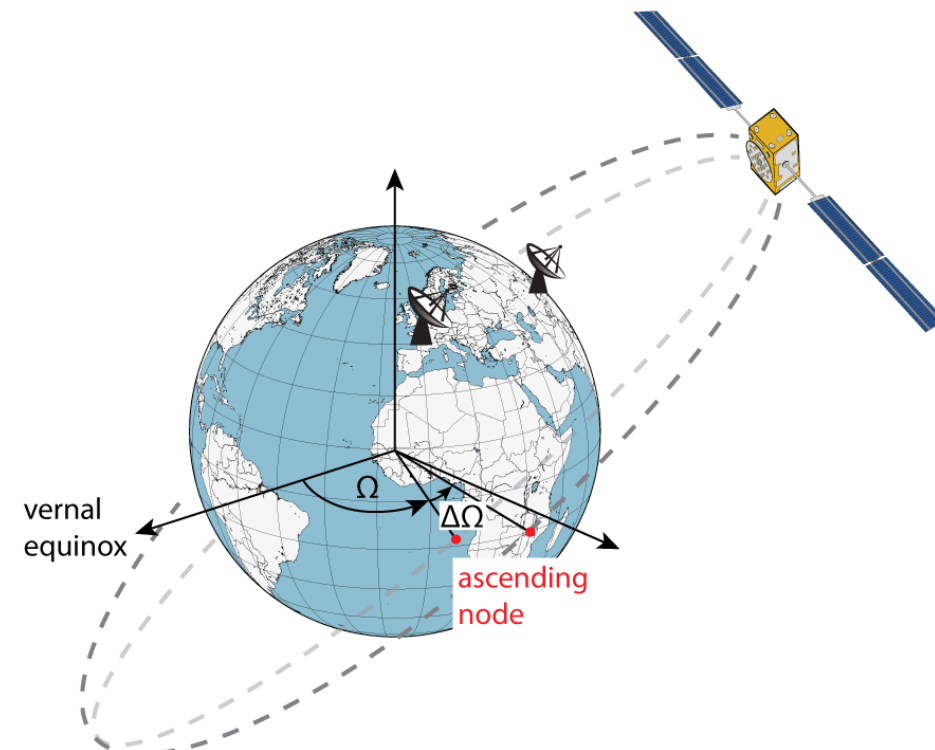
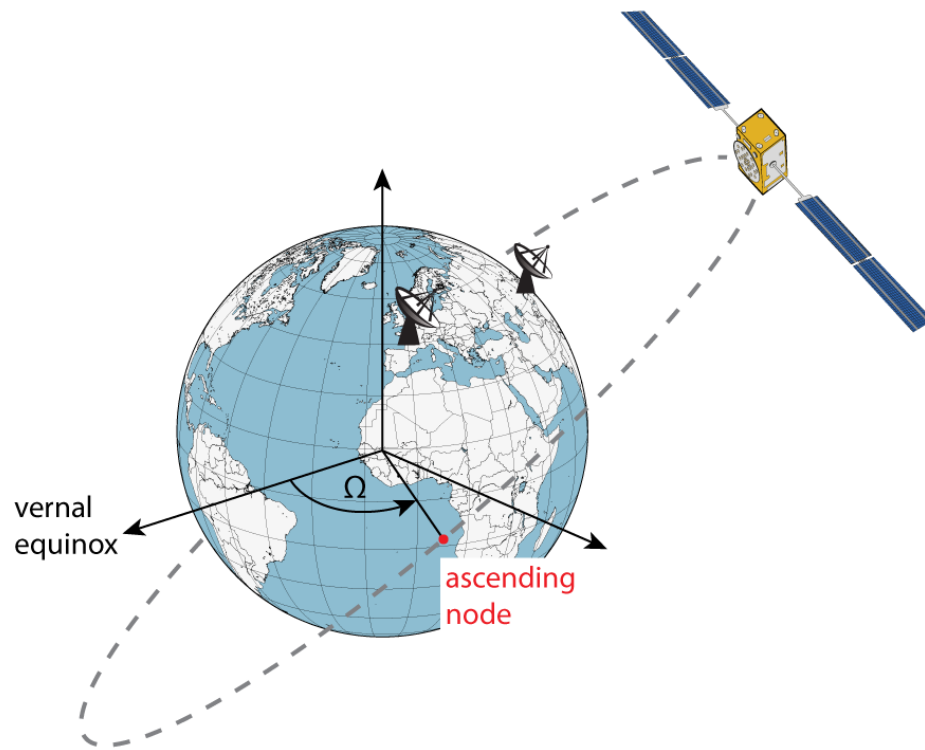
estimation of piecewise linear offsets from a-priori orbit for  $\Omega$

- quasars and stations are fixed
- repeatabilities



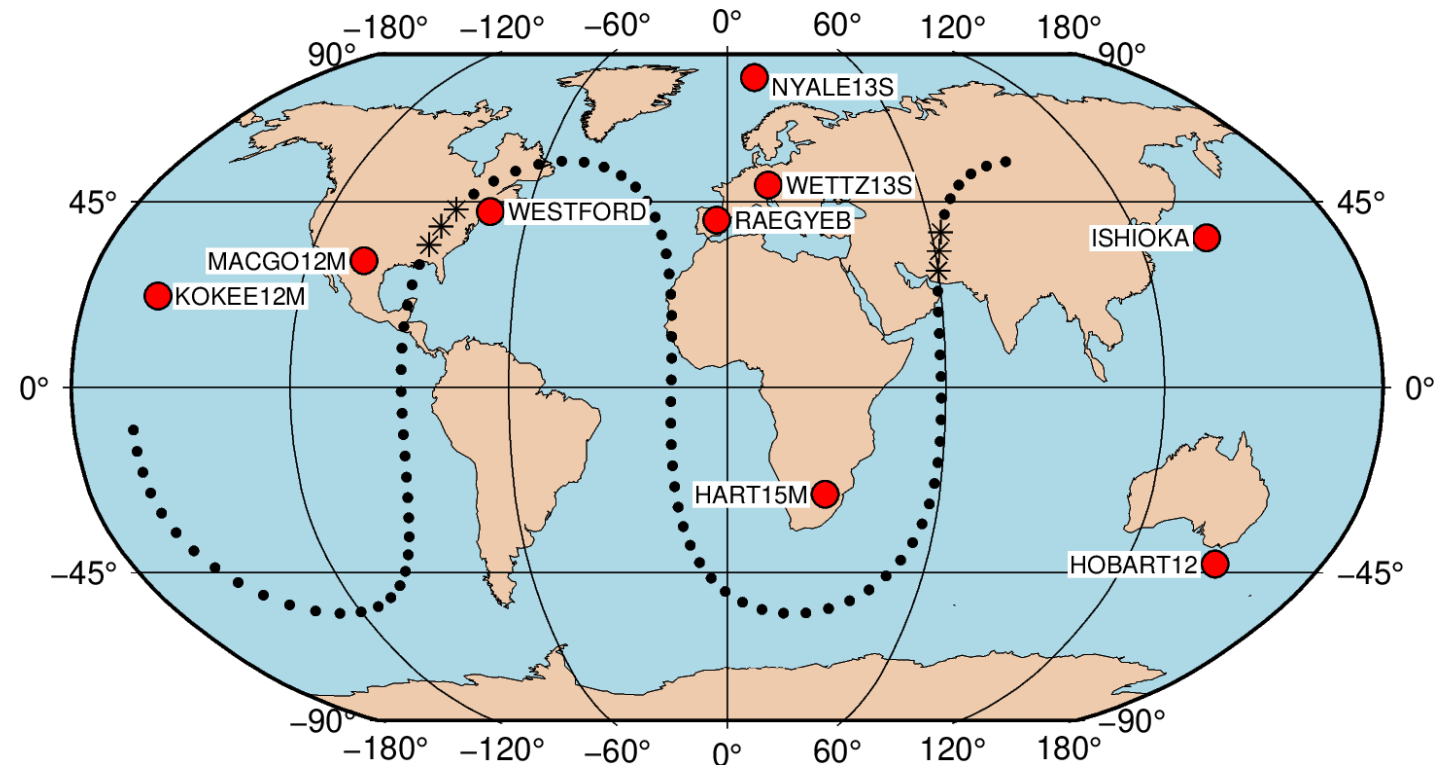
# Estimation of Orbital Elements

- right ascension of the ascending node as a first test
- partials derivatives are built numerically (changing  $\Omega$  by  $0.5^\circ$ )



# Estimation of Orbital Elements

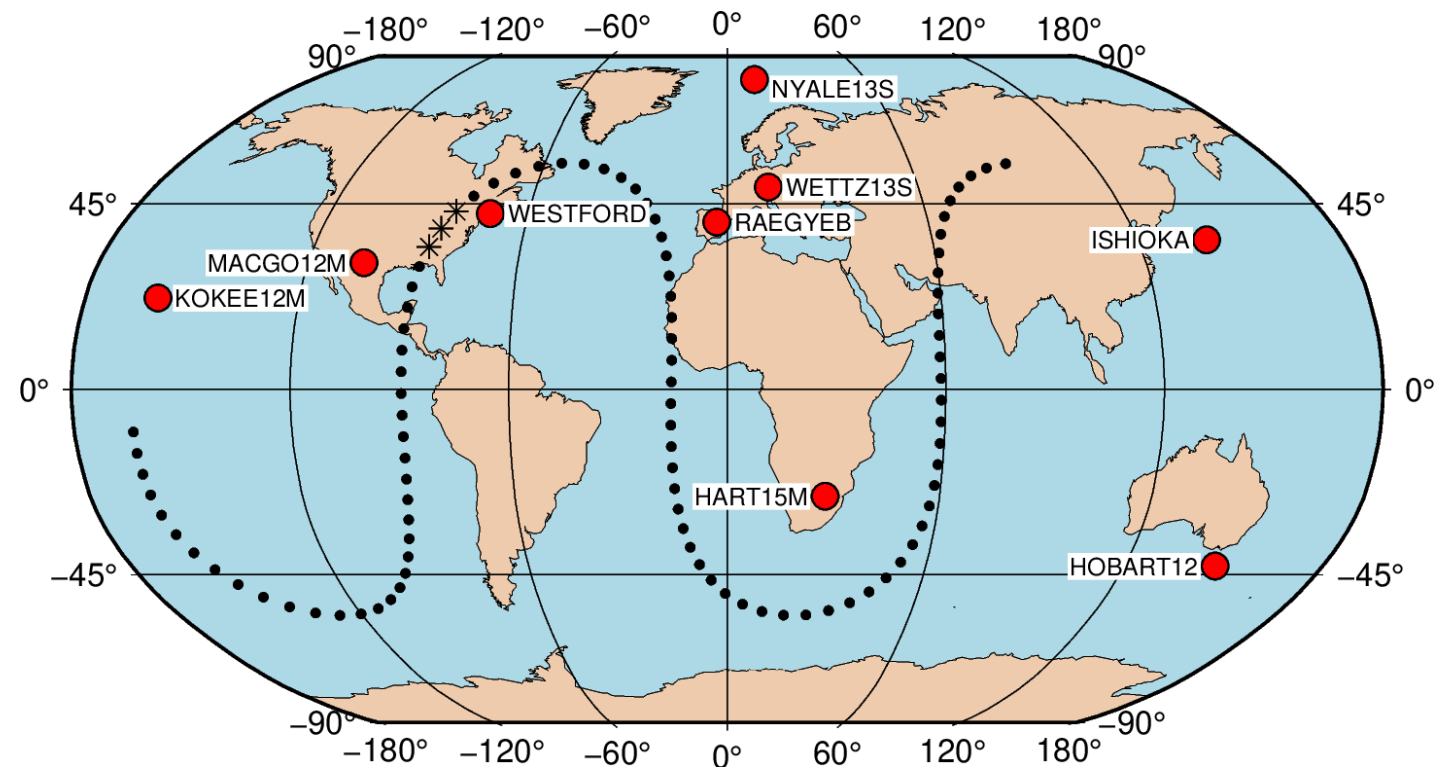
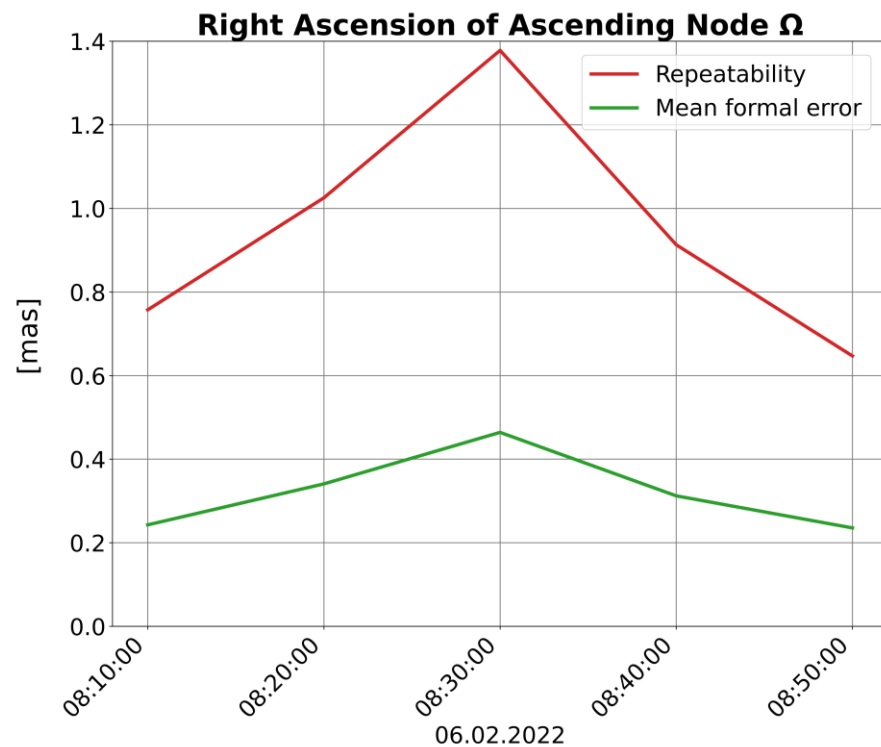
- Example: Feb. 2, 2022 00:00 – 24:00
  - 9 station network
  - 2 satellite observation periods with 40-min duration
  - estimation of right ascension  $\Omega$  as piecewise linear offsets





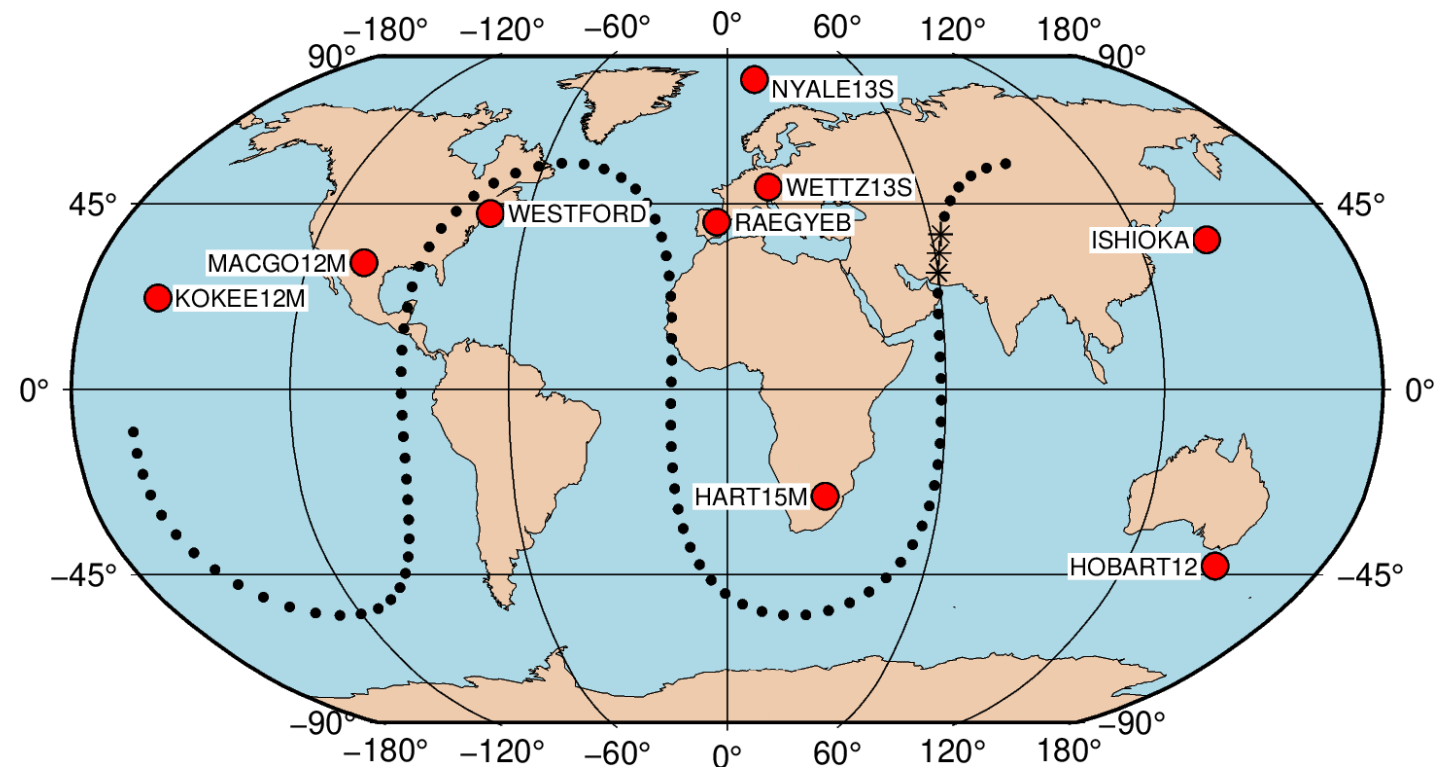
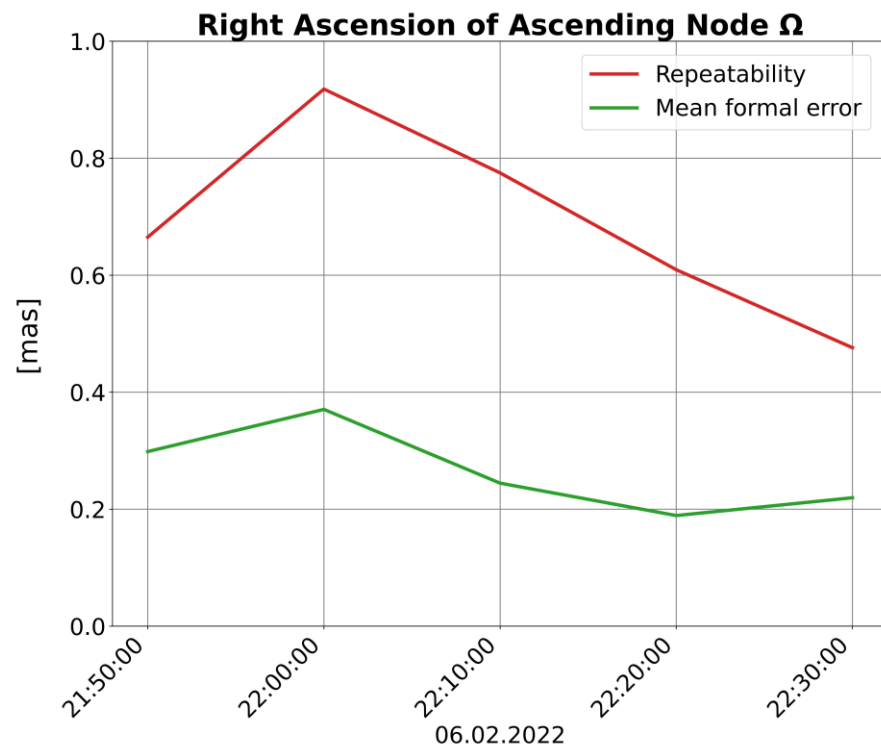
# Estimation of Orbital Elements

- satellite observations from 08:10 – 08:50 with 6 stations



# Estimation of Orbital Elements

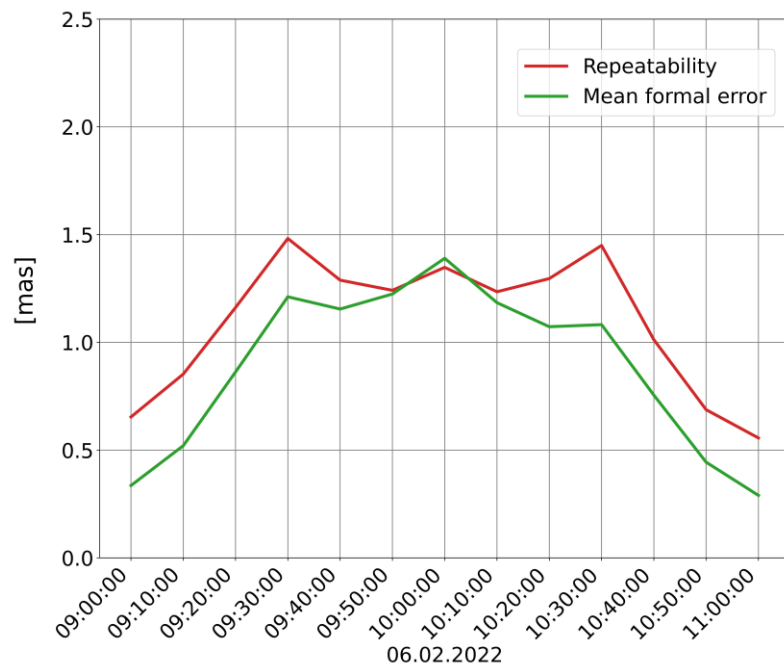
- satellite observations from 21:50 – 22:30 with 5 stations



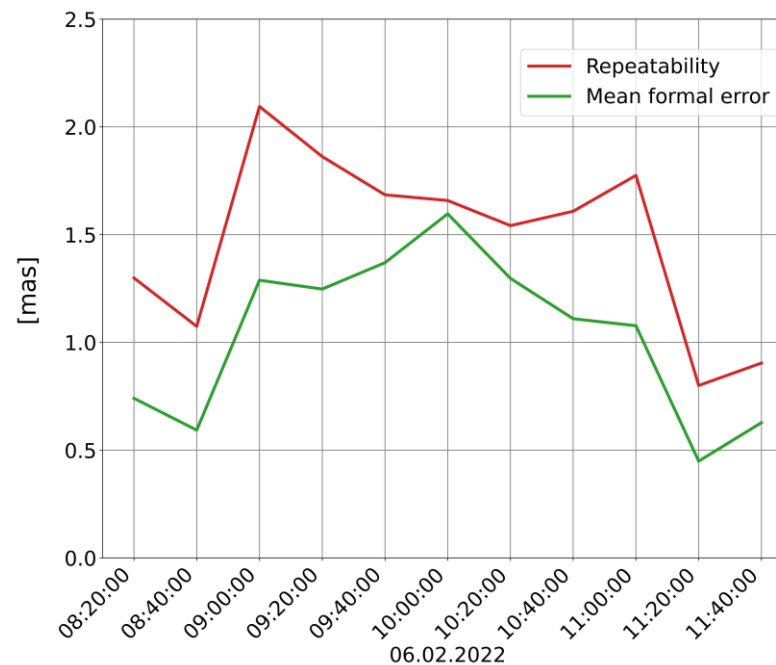
# Estimation of Orbital Elements

- deficiencies in estimation of troposphere (e.g. zwd) with longer periods of satellite observations  
→ reduced accuracy for the estimation of right ascension  $\Omega$  for longer observation periods

**2 hours of satellite observations**



**3 hours of satellite observations**



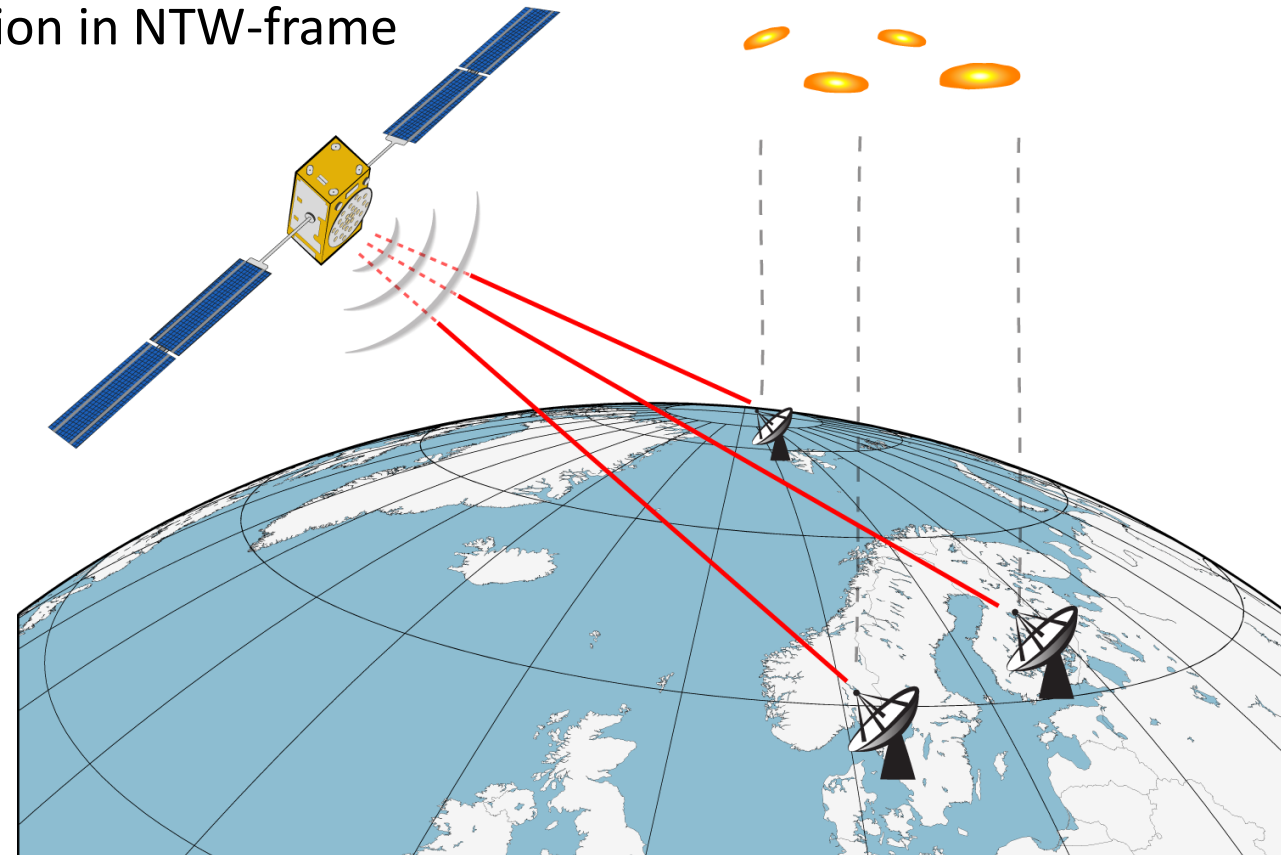
**3,5 hours of satellite observations**



# 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
- estimation of other orbital elements

**FWF**  
Der Wissenschaftsfonds.



# References

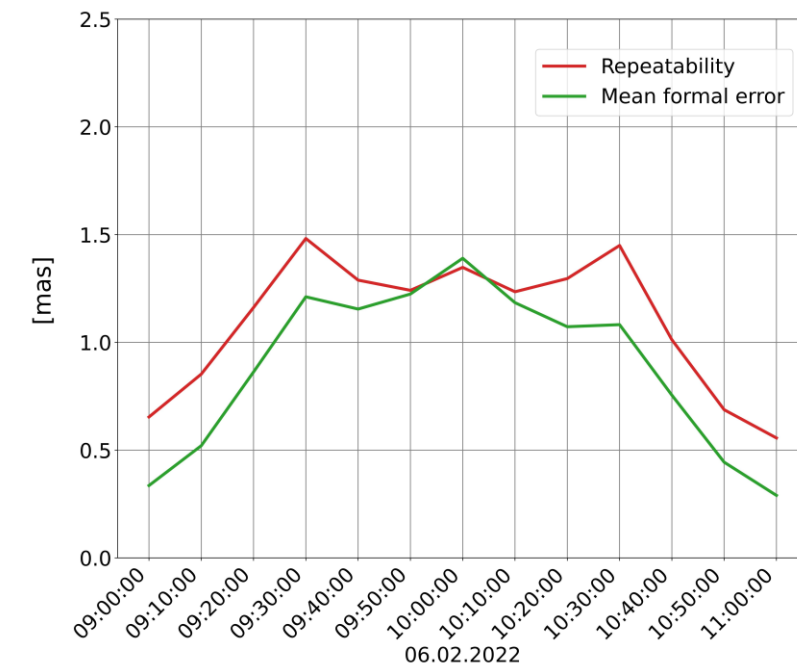
- Wolf H. (2021): *Satellite Scheduling with VieSched++*, Master Thesis, Technical University of Vienna.
- Wolf et al. (2022): *Dilution of Precision (DOP) factors for evaluating observations to Galileo satellites with VLBI*, International Association of Geodesy Symposia, Springer, Berlin, Heidelberg.
- 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/>

# Appendix

# Deficiencies in Estimation of Troposphere

## 2 hours of satellite observations

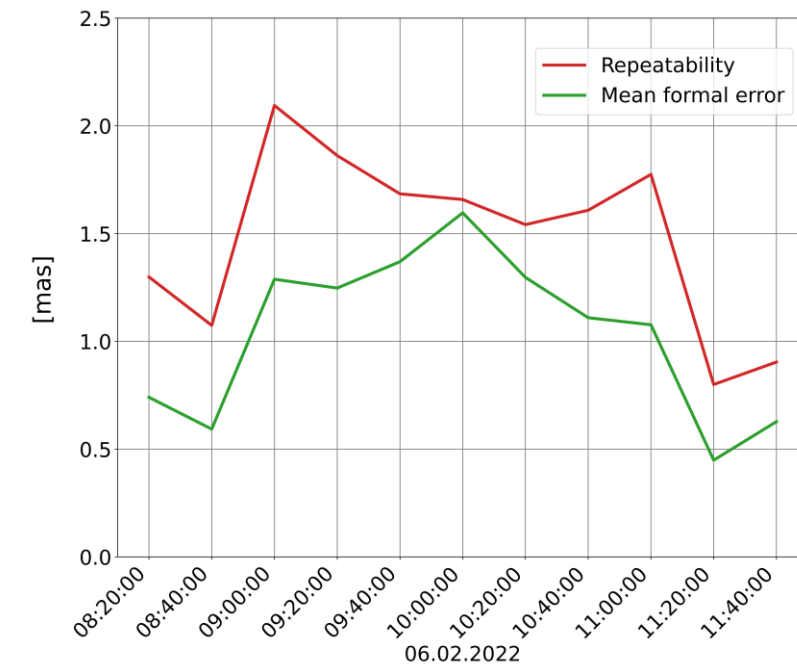
| Time             | Zenith Wet Delay (mfe) |          |          |          |         |          |          |         |          |
|------------------|------------------------|----------|----------|----------|---------|----------|----------|---------|----------|
|                  | ISHIOKA                | KOKEE12M | MACGO12M | NYALE13S | RAEGYEB | WESTFORD | WETTZ13S | HART15M | HOBART12 |
| 06.02.2022 00:00 | 0,210                  | 0,511    | 0,229    | 0,424    | 0,240   | 0,340    | 0,251    | 0,363   | 0,429    |
| 06.02.2022 00:30 | 0,197                  | 0,352    | 0,231    | 0,422    | 0,182   | 0,286    | 0,189    | 0,226   | 0,352    |
| 06.02.2022 01:00 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 06:30 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 07:00 | 0,158                  | 0,217    | 0,183    | 0,490    | 0,134   | 0,134    | 0,186    | 0,225   | 0,225    |
| 06.02.2022 07:30 | 0,185                  | 0,133    | 0,190    | 0,324    | 0,191   | 0,139    | 0,142    | 0,108   | 0,195    |
| 06.02.2022 08:00 | 0,123                  | 0,188    | 0,183    | 0,347    | 0,139   | 0,209    | 0,192    | 0,207   | 0,343    |
| 06.02.2022 08:30 | 0,137                  | 0,160    | 0,182    | 0,297    | 0,138   | 0,235    | 0,143    | 0,244   | 0,234    |
| 06.02.2022 09:00 | 0,133                  | 0,212    | 0,666    | 0,612    | 0,185   | 0,457    | 0,233    | 0,204   | 0,222    |
| 06.02.2022 09:30 | 0,091                  | 0,181    | 1,508    | 1,051    | 1,162   | 1,283    | 0,994    | 0,227   | 0,228    |
| 06.02.2022 10:00 | 0,154                  | 0,252    | 1,552    | 1,359    | 1,487   | 1,617    | 1,391    | 0,216   | 0,188    |
| 06.02.2022 10:30 | 0,157                  | 0,274    | 1,059    | 1,060    | 1,231   | 1,398    | 1,215    | 0,151   | 0,187    |
| 06.02.2022 11:00 | 0,165                  | 0,233    | 0,245    | 0,339    | 0,167   | 0,372    | 0,145    | 0,180   | 0,286    |
| 06.02.2022 11:30 | 0,225                  | 0,165    | 0,203    | 0,220    | 0,199   | 0,219    | 0,104    | 0,120   | 0,203    |
| 06.02.2022 12:00 | 0,185                  | 0,219    | 0,374    | 0,237    | 0,195   | 0,304    | 0,133    | 0,200   | 0,155    |
| 06.02.2022 12:30 | 0,225                  | 0,214    | 0,238    | 0,375    | 0,196   | 0,276    | 0,161    | 0,263   | 0,245    |
| 06.02.2022 13:00 | 0,208                  | 0,183    | 0,215    | 0,374    | 0,371   | 0,362    | 0,259    | 0,376   | 0,299    |
| 06.02.2022 13:30 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 23:00 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 23:30 | 0,177                  | 0,386    | 0,236    | 0,343    | 0,192   | 0,221    | 0,173    | 0,246   | 0,303    |
| 07.02.2022 00:00 | 0,313                  | 0,320    | 0,302    | 1,142    | 0,503   | 0,328    | 0,259    | 0,317   | 0,854    |



# Deficiencies in Estimation of Troposphere

## 3 hours of satellite observations

| Time             | Zenith Wet Delay (mfe) |          |          |          |         |          |          |         |          |
|------------------|------------------------|----------|----------|----------|---------|----------|----------|---------|----------|
|                  | ISHIOKA                | KOKEE12M | MACGO12M | NYALE13S | RAEGYEB | WESTFORD | WETTZ13S | HART15M | HOBART12 |
| 06.02.2022 00:00 | 0,205                  | 0,497    | 0,224    | 0,416    | 0,234   | 0,331    | 0,244    | 0,353   | 0,417    |
| 06.02.2022 00:30 | 0,192                  | 0,342    | 0,225    | 0,415    | 0,177   | 0,279    | 0,185    | 0,220   | 0,343    |
| 06.02.2022 01:00 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 06:30 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 07:00 | 0,155                  | 0,211    | 0,183    | 0,484    | 0,139   | 0,130    | 0,183    | 0,215   | 0,219    |
| 06.02.2022 07:30 | 0,184                  | 0,128    | 0,186    | 0,326    | 0,202   | 0,139    | 0,146    | 0,100   | 0,187    |
| 06.02.2022 08:00 | 0,121                  | 0,184    | 0,182    | 0,352    | 0,178   | 0,208    | 0,187    | 0,195   | 0,329    |
| 06.02.2022 08:30 | 0,123                  | 0,199    | 0,252    | 0,374    | 0,314   | 0,395    | 0,155    | 0,169   | 0,237    |
| 06.02.2022 09:00 | 0,136                  | 0,223    | 1,589    | 1,047    | 1,146   | 1,358    | 0,811    | 0,287   | 0,231    |
| 06.02.2022 09:30 | 0,103                  | 0,186    | 1,848    | 1,323    | 1,533   | 1,628    | 1,282    | 0,167   | 0,195    |
| 06.02.2022 10:00 | 0,123                  | 0,236    | 1,771    | 1,542    | 1,731   | 1,880    | 1,609    | 0,215   | 0,169    |
| 06.02.2022 10:30 | 0,095                  | 0,185    | 1,368    | 1,325    | 1,573   | 1,816    | 1,575    | 0,141   | 0,185    |
| 06.02.2022 11:00 | 0,151                  | 0,348    | 0,851    | 1,059    | 1,277   | 1,523    | 1,350    | 0,174   | 0,112    |
| 06.02.2022 11:30 | 0,213                  | 0,189    | 0,281    | 0,256    | 0,247   | 0,327    | 0,330    | 0,177   | 0,150    |
| 06.02.2022 12:00 | 0,204                  | 0,176    | 0,271    | 0,350    | 0,308   | 0,328    | 0,269    | 0,280   | 0,243    |
| 06.02.2022 12:30 | 0,225                  | 0,178    | 0,255    | 0,337    | 0,245   | 0,240    | 0,119    | 0,151   | 0,264    |
| 06.02.2022 13:00 | 0,214                  | 0,239    | 0,444    | 0,354    | 0,269   | 0,256    | 0,176    | 0,412   | 0,239    |
| 06.02.2022 13:30 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 23:00 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 23:30 | 0,178                  | 0,230    | 0,195    | 0,300    | 0,202   | 0,216    | 0,127    | 0,279   | 0,291    |
| 07.02.2022 00:00 | 0,212                  | 0,525    | 0,249    | 0,595    | 0,374   | 0,260    | 0,512    | 0,343   | 0,759    |

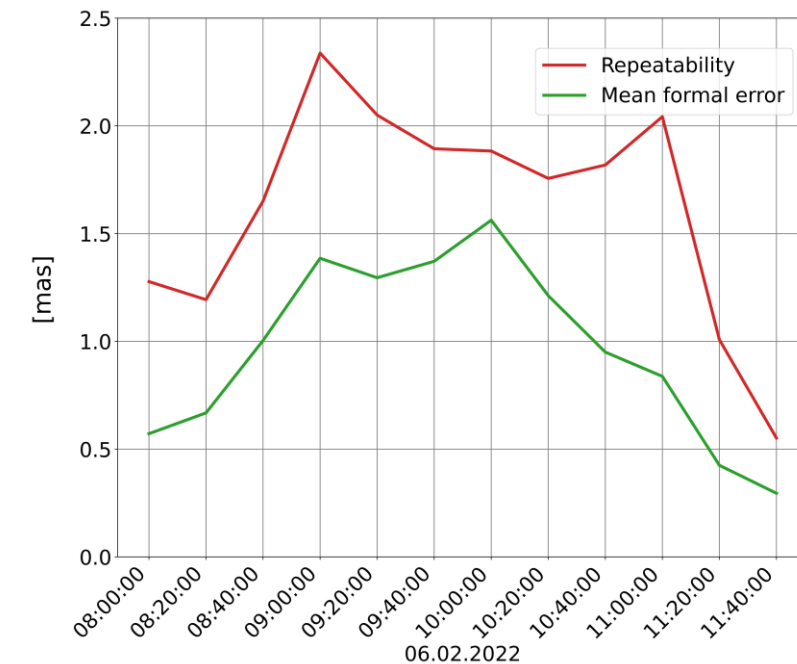




# Deficiencies in Estimation of Troposphere

3,5 hours of satellite observations

| Time             | Zenith Wet Delay (mfe) |          |          |          |         |          |          |         |          |
|------------------|------------------------|----------|----------|----------|---------|----------|----------|---------|----------|
|                  | ISHIOKA                | KOKEE12M | MACGO12M | NYALE13S | RAEGYEB | WESTFORD | WETTZ13S | HART15M | HOBART12 |
| 06.02.2022 00:00 | 0,203                  | 0,496    | 0,225    | 0,418    | 0,234   | 0,331    | 0,244    | 0,352   | 0,416    |
| 06.02.2022 00:30 | 0,190                  | 0,341    | 0,227    | 0,418    | 0,177   | 0,278    | 0,185    | 0,219   | 0,342    |
| 06.02.2022 01:00 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 06:30 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 07:00 | 0,153                  | 0,210    | 0,191    | 0,485    | 0,136   | 0,130    | 0,184    | 0,218   | 0,220    |
| 06.02.2022 07:30 | 0,183                  | 0,127    | 0,191    | 0,336    | 0,200   | 0,139    | 0,150    | 0,104   | 0,177    |
| 06.02.2022 08:00 | 0,105                  | 0,177    | 0,209    | 0,311    | 0,177   | 0,207    | 0,177    | 0,187   | 0,291    |
| 06.02.2022 08:30 | 0,112                  | 0,193    | 1,230    | 0,567    | 0,620   | 0,872    | 0,398    | 0,203   | 0,251    |
| 06.02.2022 09:00 | 0,170                  | 0,257    | 1,897    | 1,161    | 1,288   | 1,575    | 0,942    | 0,278   | 0,236    |
| 06.02.2022 09:30 | 0,116                  | 0,203    | 2,001    | 1,406    | 1,616   | 1,777    | 1,371    | 0,218   | 0,138    |
| 06.02.2022 10:00 | 0,157                  | 0,277    | 1,851    | 1,599    | 1,779   | 1,984    | 1,666    | 0,224   | 0,194    |
| 06.02.2022 10:30 | 0,106                  | 0,183    | 1,415    | 1,389    | 1,611   | 1,909    | 1,627    | 0,153   | 0,150    |
| 06.02.2022 11:00 | 0,196                  | 0,261    | 0,875    | 1,134    | 1,322   | 1,626    | 1,415    | 0,173   | 0,114    |
| 06.02.2022 11:30 | 0,254                  | 0,202    | 0,323    | 0,411    | 0,321   | 0,671    | 0,480    | 0,161   | 0,181    |
| 06.02.2022 12:00 | 0,222                  | 0,182    | 0,284    | 0,225    | 0,284   | 0,200    | 0,219    | 0,211   | 0,229    |
| 06.02.2022 12:30 | 0,154                  | 0,146    | 0,221    | 0,259    | 0,194   | 0,149    | 0,111    | 0,124   | 0,182    |
| 06.02.2022 13:00 | 0,208                  | 0,279    | 0,247    | 0,348    | 0,249   | 0,227    | 0,204    | 0,412   | 0,250    |
| 06.02.2022 13:30 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 23:00 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 23:30 | 0,159                  | 0,243    | 0,171    | 0,498    | 0,360   | 0,250    | 0,413    | 0,185   | 0,402    |
| 07.02.2022 00:00 | 0,281                  | 0,572    | 0,260    | 0,499    | 0,237   | 0,317    | 0,158    | 0,376   | 0,418    |



# Deficiencies in Estimation of Troposphere

9:00 – 11:00 → 2:00h

| Time             | Zenith Wet Delay (mfe) |          |          |          |         |          |          |         |          |
|------------------|------------------------|----------|----------|----------|---------|----------|----------|---------|----------|
|                  | ISHIOKA                | KOKEE12M | MACGO12M | NYALE13S | RAEGYEB | WESTFORD | WETTZ13S | HART15M | HOBART12 |
| 06.02.2022 00:00 | 0,210                  | 0,511    | 0,229    | 0,424    | 0,240   | 0,340    | 0,251    | 0,363   | 0,429    |
| 06.02.2022 00:30 | 0,197                  | 0,352    | 0,231    | 0,422    | 0,182   | 0,286    | 0,189    | 0,226   | 0,352    |
| 06.02.2022 01:00 | 0,151                  | 0,162    | 0,179    | 0,353    | 0,153   | 0,225    | 0,232    | 0,196   | 0,225    |
| 06.02.2022 01:30 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 06:30 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 07:00 | 0,158                  | 0,217    | 0,183    | 0,490    | 0,134   | 0,134    | 0,186    | 0,225   | 0,225    |
| 06.02.2022 07:30 | 0,185                  | 0,133    | 0,190    | 0,324    | 0,191   | 0,139    | 0,142    | 0,108   | 0,195    |
| 06.02.2022 08:00 | 0,123                  | 0,188    | 0,183    | 0,347    | 0,139   | 0,209    | 0,192    | 0,207   | 0,343    |
| 06.02.2022 08:30 | 0,137                  | 0,160    | 0,182    | 0,297    | 0,138   | 0,235    | 0,143    | 0,244   | 0,234    |
| 06.02.2022 09:00 | 0,133                  | 0,212    | 0,666    | 0,612    | 0,185   | 0,457    | 0,233    | 0,204   | 0,222    |
| 06.02.2022 09:30 | 0,091                  | 0,181    | 1,508    | 1,051    | 1,162   | 1,283    | 0,994    | 0,227   | 0,228    |
| 06.02.2022 10:00 | 0,154                  | 0,252    | 1,552    | 1,359    | 1,487   | 1,617    | 1,391    | 0,216   | 0,188    |
| 06.02.2022 10:30 | 0,157                  | 0,274    | 1,059    | 1,060    | 1,231   | 1,398    | 1,215    | 0,151   | 0,187    |
| 06.02.2022 11:00 | 0,165                  | 0,233    | 0,245    | 0,339    | 0,167   | 0,372    | 0,145    | 0,180   | 0,286    |
| 06.02.2022 11:30 | 0,225                  | 0,165    | 0,203    | 0,220    | 0,199   | 0,219    | 0,104    | 0,120   | 0,203    |
| 06.02.2022 12:00 | 0,185                  | 0,219    | 0,374    | 0,237    | 0,195   | 0,304    | 0,133    | 0,200   | 0,155    |
| 06.02.2022 12:30 | 0,225                  | 0,214    | 0,238    | 0,375    | 0,196   | 0,276    | 0,161    | 0,263   | 0,245    |
| 06.02.2022 13:00 | 0,208                  | 0,183    | 0,215    | 0,374    | 0,371   | 0,362    | 0,259    | 0,376   | 0,299    |
| 06.02.2022 13:30 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 22:30 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 23:00 | 0,102                  | 0,230    | 0,272    | 0,300    | 0,312   | 0,176    | 0,254    | 0,230   | 0,337    |
| 06.02.2022 23:30 | 0,177                  | 0,386    | 0,236    | 0,343    | 0,192   | 0,221    | 0,173    | 0,246   | 0,303    |
| 07.02.2022 00:00 | 0,313                  | 0,320    | 0,302    | 1,142    | 0,503   | 0,328    | 0,259    | 0,317   | 0,854    |

# Deficiencies in Estimation of Troposphere

8:30 – 11:30 → 3:00h

| Time             | Zenith Wet Delay (mfe) |          |          |          |         |          |          |         |          |
|------------------|------------------------|----------|----------|----------|---------|----------|----------|---------|----------|
|                  | ISHIOKA                | KOKEE12M | MACGO12M | NYALE13S | RAEGYEB | WESTFORD | WETTZ13S | HART15M | HOBART12 |
| 06.02.2022 00:00 | 0,205                  | 0,497    | 0,224    | 0,416    | 0,234   | 0,331    | 0,244    | 0,353   | 0,417    |
| 06.02.2022 00:30 | 0,192                  | 0,342    | 0,225    | 0,415    | 0,177   | 0,279    | 0,185    | 0,220   | 0,343    |
| 06.02.2022 01:00 | 0,147                  | 0,158    | 0,174    | 0,348    | 0,149   | 0,219    | 0,226    | 0,191   | 0,219    |
| 06.02.2022 01:30 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 06:30 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 07:00 | 0,155                  | 0,211    | 0,183    | 0,484    | 0,139   | 0,130    | 0,183    | 0,215   | 0,219    |
| 06.02.2022 07:30 | 0,184                  | 0,128    | 0,186    | 0,326    | 0,202   | 0,139    | 0,146    | 0,100   | 0,187    |
| 06.02.2022 08:00 | 0,121                  | 0,184    | 0,182    | 0,352    | 0,178   | 0,208    | 0,187    | 0,195   | 0,329    |
| 06.02.2022 08:30 | 0,123                  | 0,199    | 0,252    | 0,374    | 0,314   | 0,395    | 0,155    | 0,169   | 0,237    |
| 06.02.2022 09:00 | 0,136                  | 0,223    | 1,589    | 1,047    | 1,146   | 1,358    | 0,811    | 0,287   | 0,231    |
| 06.02.2022 09:30 | 0,103                  | 0,186    | 1,848    | 1,323    | 1,533   | 1,628    | 1,282    | 0,167   | 0,195    |
| 06.02.2022 10:00 | 0,123                  | 0,236    | 1,771    | 1,542    | 1,731   | 1,880    | 1,609    | 0,215   | 0,169    |
| 06.02.2022 10:30 | 0,095                  | 0,185    | 1,368    | 1,325    | 1,573   | 1,816    | 1,575    | 0,141   | 0,185    |
| 06.02.2022 11:00 | 0,151                  | 0,348    | 0,851    | 1,059    | 1,277   | 1,523    | 1,350    | 0,174   | 0,112    |
| 06.02.2022 11:30 | 0,213                  | 0,189    | 0,281    | 0,256    | 0,247   | 0,327    | 0,330    | 0,177   | 0,150    |
| 06.02.2022 12:00 | 0,204                  | 0,176    | 0,271    | 0,350    | 0,308   | 0,328    | 0,269    | 0,280   | 0,243    |
| 06.02.2022 12:30 | 0,225                  | 0,178    | 0,255    | 0,337    | 0,245   | 0,240    | 0,119    | 0,151   | 0,264    |
| 06.02.2022 13:00 | 0,214                  | 0,239    | 0,444    | 0,354    | 0,269   | 0,256    | 0,176    | 0,412   | 0,239    |
| 06.02.2022 13:30 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 22:30 |                        |          |          |          | ...     |          |          |         |          |
| 06.02.2022 23:00 | 0,163                  | 0,308    | 0,259    | 0,290    | 0,268   | 0,186    | 0,227    | 0,214   | 0,335    |
| 06.02.2022 23:30 | 0,178                  | 0,230    | 0,195    | 0,300    | 0,202   | 0,216    | 0,127    | 0,279   | 0,291    |
| 07.02.2022 00:00 | 0,212                  | 0,525    | 0,249    | 0,595    | 0,374   | 0,260    | 0,512    | 0,343   | 0,759    |

# Deficiencies in Estimation of Troposphere

8:10 – 11:40 → 3:30h

| Zenith Wet Delay (mfe) |         |          |          |          |         |          |          |         |          |
|------------------------|---------|----------|----------|----------|---------|----------|----------|---------|----------|
| Time                   | ISHIOKA | KOKEE12M | MACGO12M | NYALE13S | RAEGYEB | WESTFORD | WETTZ13S | HART15M | HOBART12 |
| 06.02.2022 00:00       | 0,203   | 0,496    | 0,225    | 0,418    | 0,234   | 0,331    | 0,244    | 0,352   | 0,416    |
| 06.02.2022 00:30       | 0,190   | 0,341    | 0,227    | 0,418    | 0,177   | 0,278    | 0,185    | 0,219   | 0,342    |
| 06.02.2022 01:00       | 0,146   | 0,157    | 0,176    | 0,351    | 0,149   | 0,219    | 0,226    | 0,190   | 0,219    |
| 06.02.2022 01:30       |         |          |          |          | ...     |          |          |         |          |
| 06.02.2022 06:30       |         |          |          |          | ...     |          |          |         |          |
| 06.02.2022 07:00       | 0,153   | 0,210    | 0,191    | 0,485    | 0,136   | 0,130    | 0,184    | 0,218   | 0,220    |
| 06.02.2022 07:30       | 0,183   | 0,127    | 0,191    | 0,336    | 0,200   | 0,139    | 0,150    | 0,104   | 0,177    |
| 06.02.2022 08:00       | 0,105   | 0,177    | 0,209    | 0,311    | 0,177   | 0,207    | 0,177    | 0,187   | 0,291    |
| 06.02.2022 08:30       | 0,112   | 0,193    | 1,230    | 0,567    | 0,620   | 0,872    | 0,398    | 0,203   | 0,251    |
| 06.02.2022 09:00       | 0,170   | 0,257    | 1,897    | 1,161    | 1,288   | 1,575    | 0,942    | 0,278   | 0,236    |
| 06.02.2022 09:30       | 0,116   | 0,203    | 2,001    | 1,406    | 1,616   | 1,777    | 1,371    | 0,218   | 0,138    |
| 06.02.2022 10:00       | 0,157   | 0,277    | 1,851    | 1,599    | 1,779   | 1,984    | 1,666    | 0,224   | 0,194    |
| 06.02.2022 10:30       | 0,106   | 0,183    | 1,415    | 1,389    | 1,611   | 1,909    | 1,627    | 0,153   | 0,150    |
| 06.02.2022 11:00       | 0,196   | 0,261    | 0,875    | 1,134    | 1,322   | 1,626    | 1,415    | 0,173   | 0,114    |
| 06.02.2022 11:30       | 0,254   | 0,202    | 0,323    | 0,411    | 0,321   | 0,671    | 0,480    | 0,161   | 0,181    |
| 06.02.2022 12:00       | 0,222   | 0,182    | 0,284    | 0,225    | 0,284   | 0,200    | 0,219    | 0,211   | 0,229    |
| 06.02.2022 12:30       | 0,154   | 0,146    | 0,221    | 0,259    | 0,194   | 0,149    | 0,111    | 0,124   | 0,182    |
| 06.02.2022 13:00       | 0,208   | 0,279    | 0,247    | 0,348    | 0,249   | 0,227    | 0,204    | 0,412   | 0,250    |
| 06.02.2022 13:30       |         |          |          |          | ...     |          |          |         |          |
| 06.02.2022 22:30       |         |          |          |          | ...     |          |          |         |          |
| 06.02.2022 23:00       | 0,200   | 0,314    | 0,241    | 0,336    | 0,257   | 0,320    | 0,209    | 0,224   | 0,317    |
| 06.02.2022 23:30       | 0,159   | 0,243    | 0,171    | 0,498    | 0,360   | 0,250    | 0,413    | 0,185   | 0,402    |
| 07.02.2022 00:00       | 0,281   | 0,572    | 0,260    | 0,499    | 0,237   | 0,317    | 0,158    | 0,376   | 0,418    |