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Potential of VLBI for Orbital and Solar Radiation Pressure Parameter Estimation

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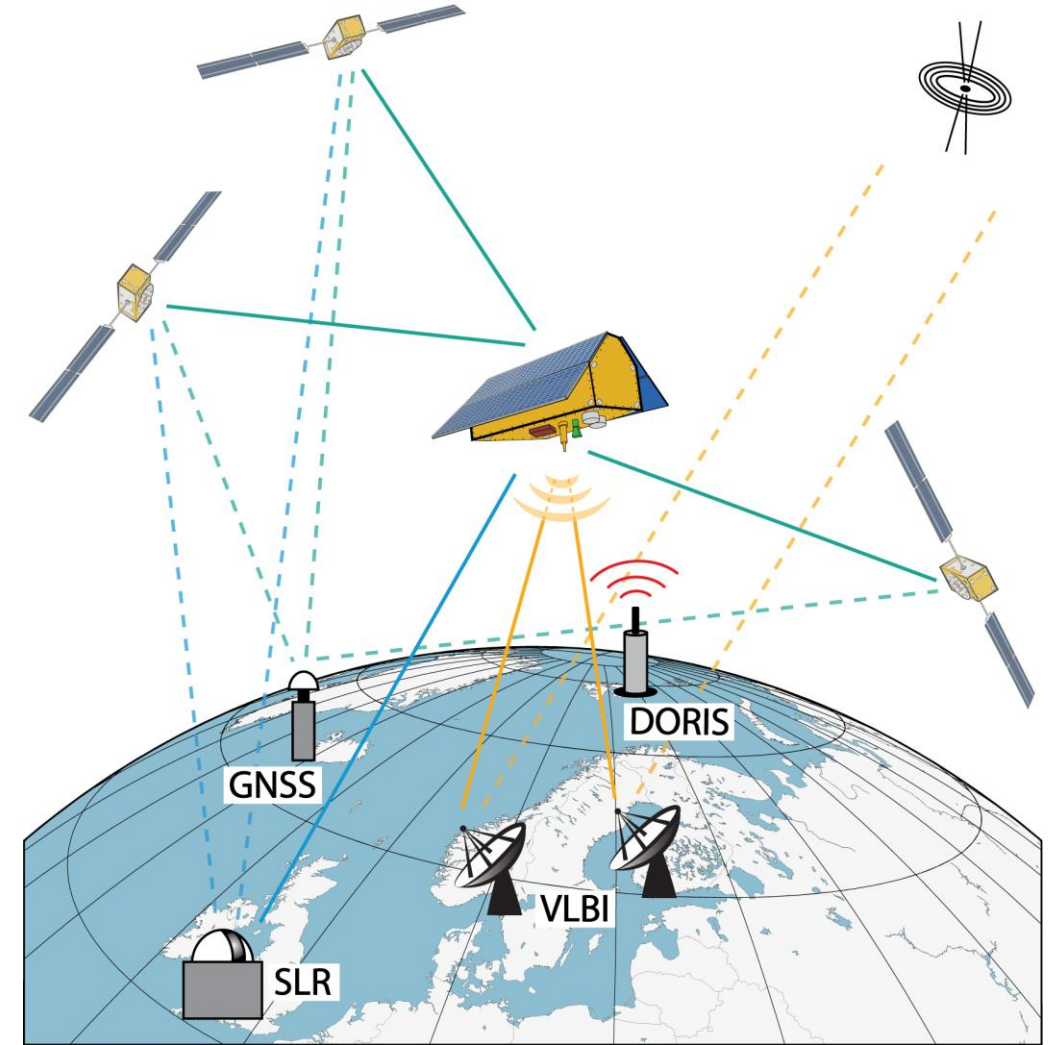
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- VLBI transmitter on board of Genesis

- satellites are routinely observed with GNSS, SLR, and DORIS

- VLBI observations allow the direct estimation of satellite orbits in the celestial frame





VieVS-VLBI

Processing of VLBI observations to quasars **and satellites**



Estimation of parameters such as

✓ **Station coordinates**

✓ **Earth orientation parameters**

✓ **Source positions**

✓

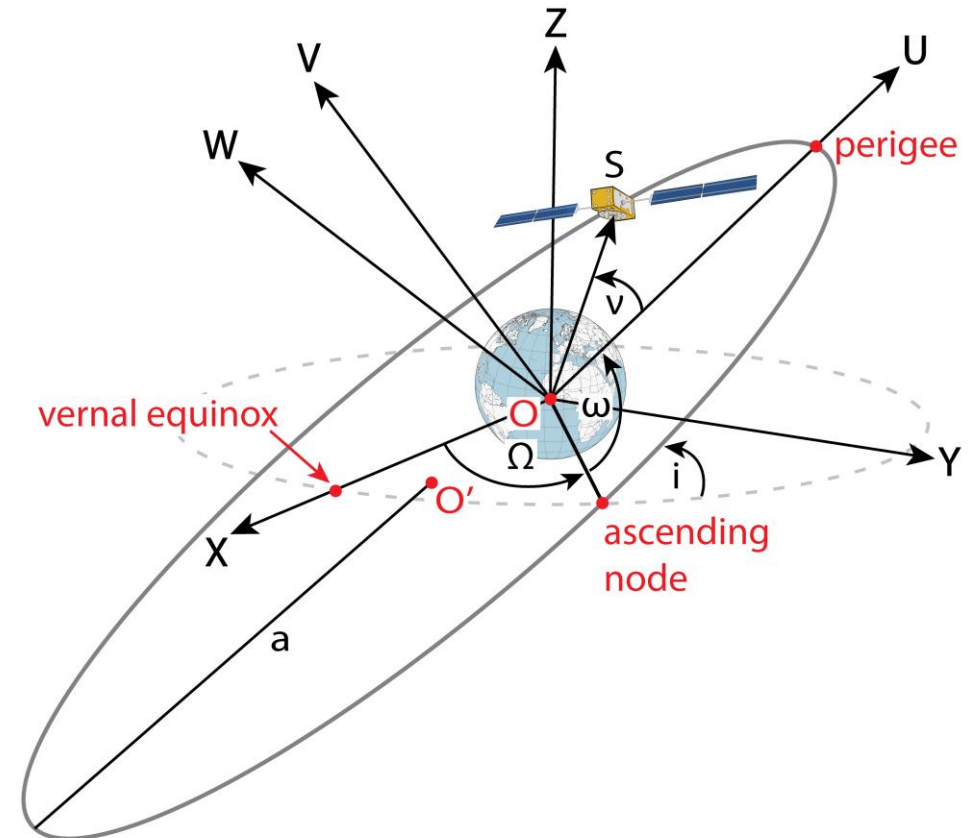


Satellite orbit ⇒ **as orbit parameters**

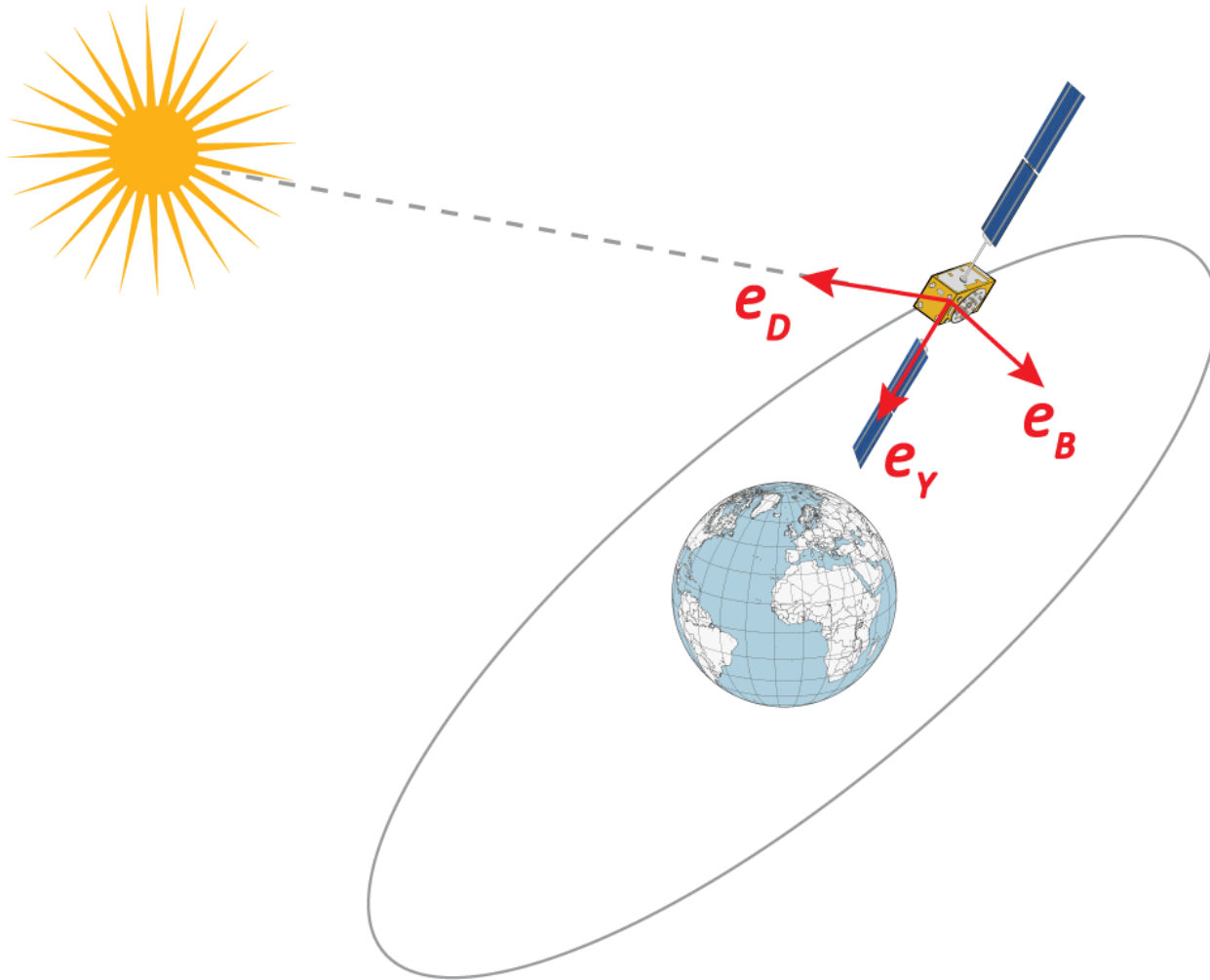
*Checkmark icons created by Kharisma
Hourglass icons created by mavadee - Flaticon
Gears icons created by Design Circle - Flaticon*

- a - semi-major axis
- e - eccentricity
- i - inclination
- Ω - right ascension of ascending node
- ω - argument of perigee
- u_0 - argument of latitude
 $u_0 = \omega + v(t_0)$

⇒ **6 orbital elements**



Solar Radiation Pressure Parameters



e_D → direction of Sun
 e_Y → along solar panel
 e_B → completing right hand system

$$D(u) = D_0 + D_C \cos(u) + D_S \sin(u)$$

$$Y(u) = Y_0 + Y_C \cos(u) + Y_S \sin(u)$$

$$B(u) = B_0 + B_C \cos(u) + B_S \sin(u)$$

→ 3 parameters in each direction
 ⇒ **9 SRP parameters**

- a - semi-major axis
- e - eccentricity
- i - inclination
- Ω - right ascension of ascending node
- ω - argument of perigee
- u_0 - argument of latitude
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⇒ **6 orbital elements**

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$$D(u) = \mathbf{D}_0 + \mathbf{D}_C \cos(u) + \mathbf{D}_S \sin(u)$$

$$Y(u) = \mathbf{Y}_0 + \mathbf{Y}_C \cos(u) + \mathbf{Y}_S \sin(u)$$

$$B(u) = \mathbf{B}_0 + \mathbf{B}_C \cos(u) + \mathbf{B}_S \sin(u)$$

→ 3 parameters in each direction

⇒ **9 SRP parameters**

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 $u_0 = \omega + \nu(t_0)$

⇒ **6 orbital elements**

- e_D → direction of Sun
- e_Y → along solar panel
- e_B → completing right hand system

15 orbital parameters

$$+ D_C \cos(u) + D_S \sin(u)$$

$$+ Y_C \cos(u) + Y_S \sin(u)$$

$$B(u) = B_0 + B_C \cos(u) + B_S \sin(u)$$

→ 3 parameters in each direction

⇒ **9 SRP parameters**

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Processing of VLBI observations to quasars and satellites



Needed: partial derivative of **delay τ** w.r.t. **15 orbit parameters**

$\frac{\partial \tau}{\partial p_i}$ with $p_i \in 15$ orbit parameters*

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

*{ $a, e, i, \Omega, \omega, u_0, D_0, Y_0, B_0, D_C, Y_C, B_C, D_S, Y_S, B_S$ }

Puzzle Icons created by Freepik - Flaticon

Gears icons created by Design Circle - Flaticon



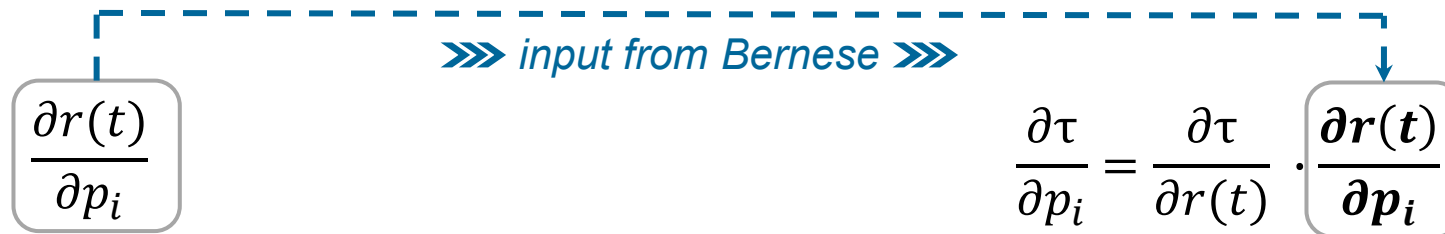
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Processing of **GNSS** observations



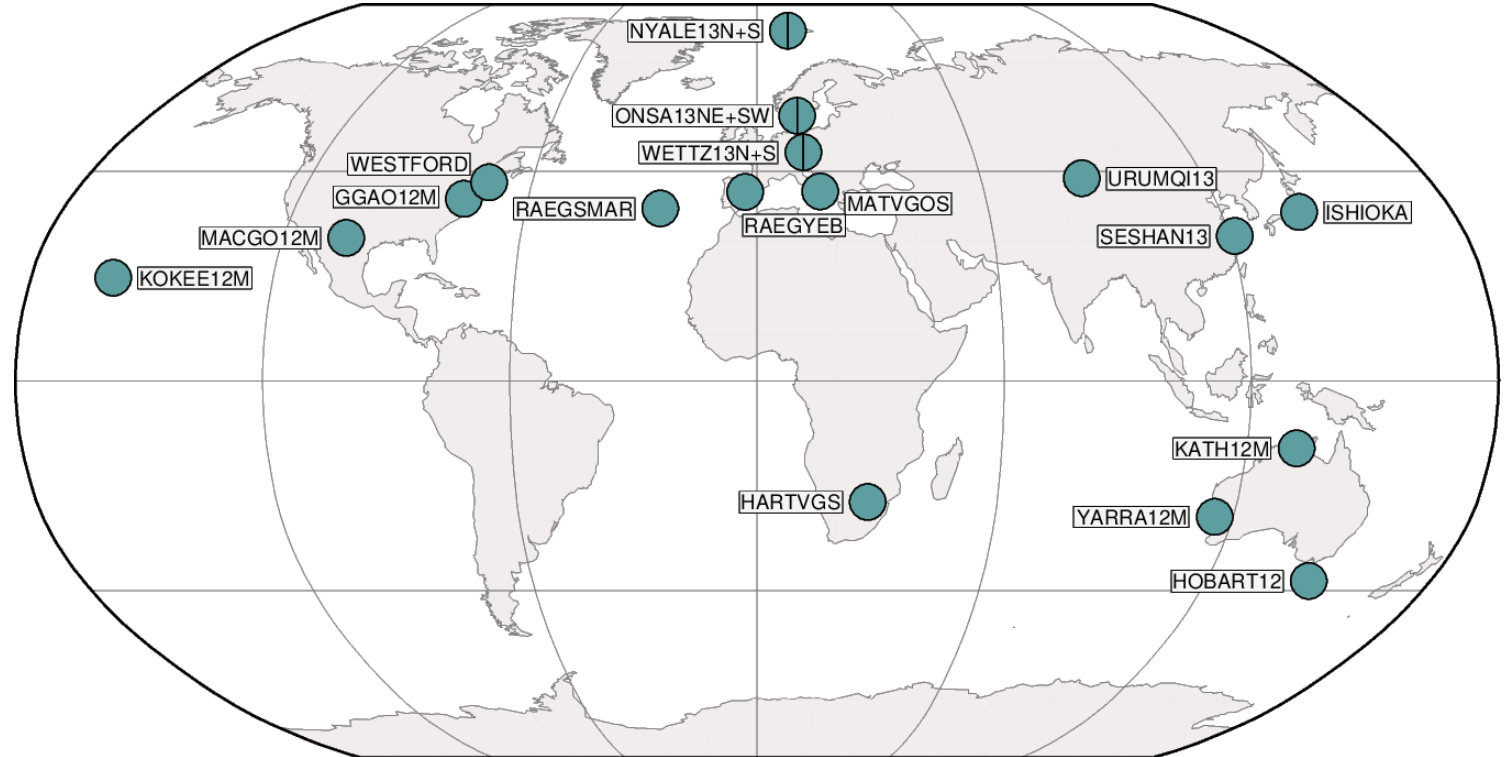
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Processing of **VLBI** observations to quasars and satellites



Estimation of orbital parameters using VLBI observations

- 24-hour session starting on August 27, 2022 00:00:00 UTC
- 20 VGOS stations
- Galileo satellite GSAT0203 (E26)



Study Setup

schedule



1000 simulations



1000 estimates

- schedule with 19% satellite scans
- 1000 simulations
- estimation of **orbital elements** and/or **SRP parameters**
 - one offset for 24 hours
 - no vector between VLBI transmitter and center-of-mass of satellite modelled

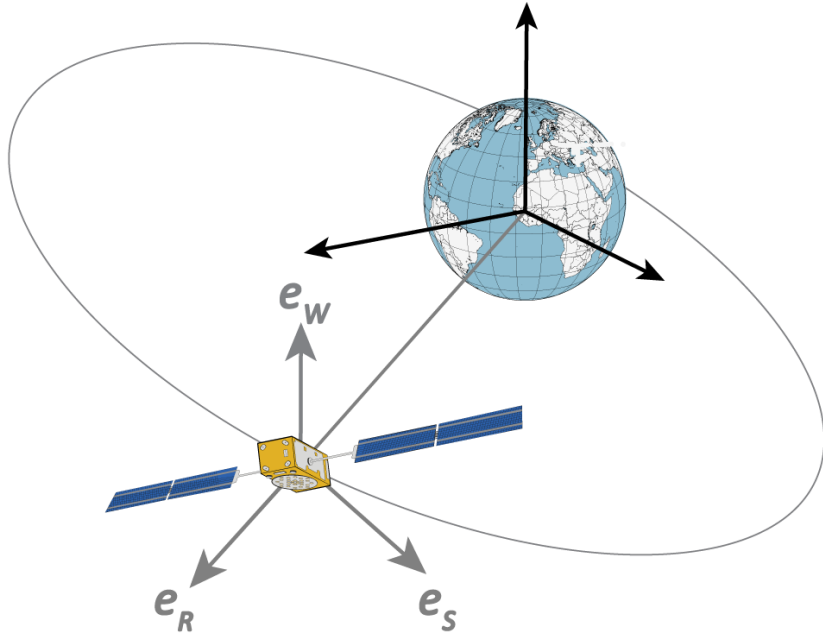
orbit parameters
 $\Delta p_i = \{\Delta a, \Delta e, \Delta i, \dots\}$

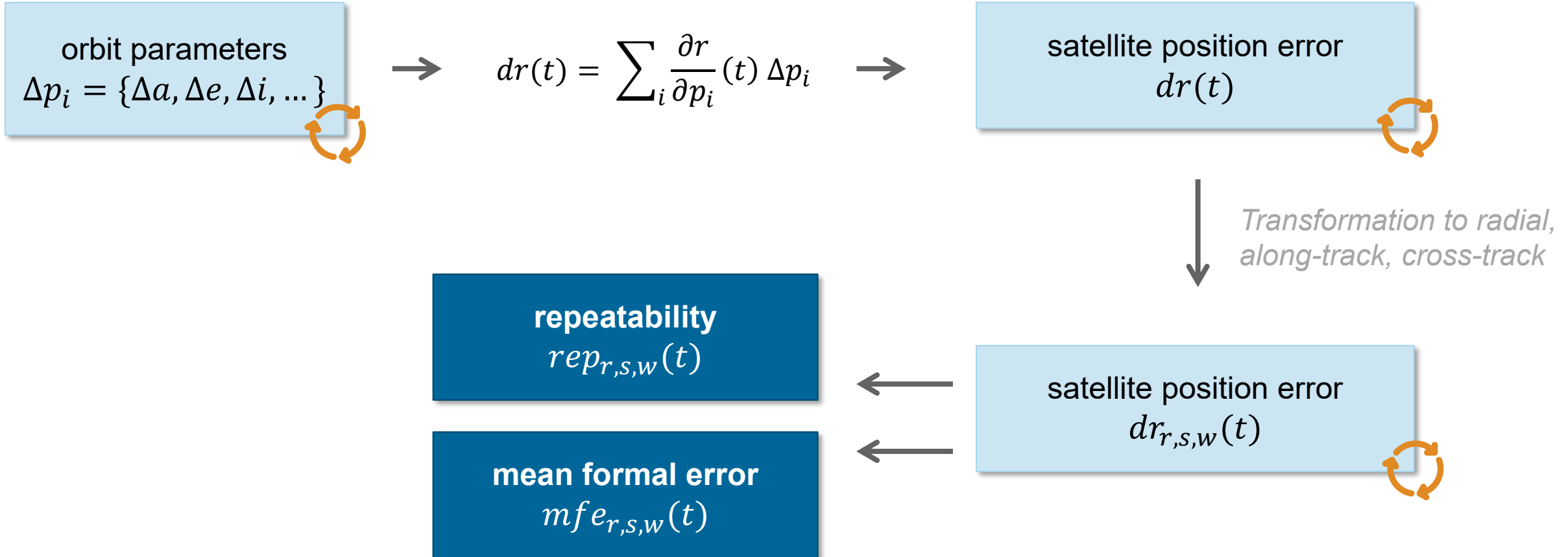
$$dr(t) = \sum_i \frac{\partial r}{\partial p_i}(t) \Delta p_i$$

satellite position error
 $dr(t)$

Transformation to radial,
 along-track, cross-track

satellite position error
 $dr_{r,s,w}(t)$





Analysis Scenario A

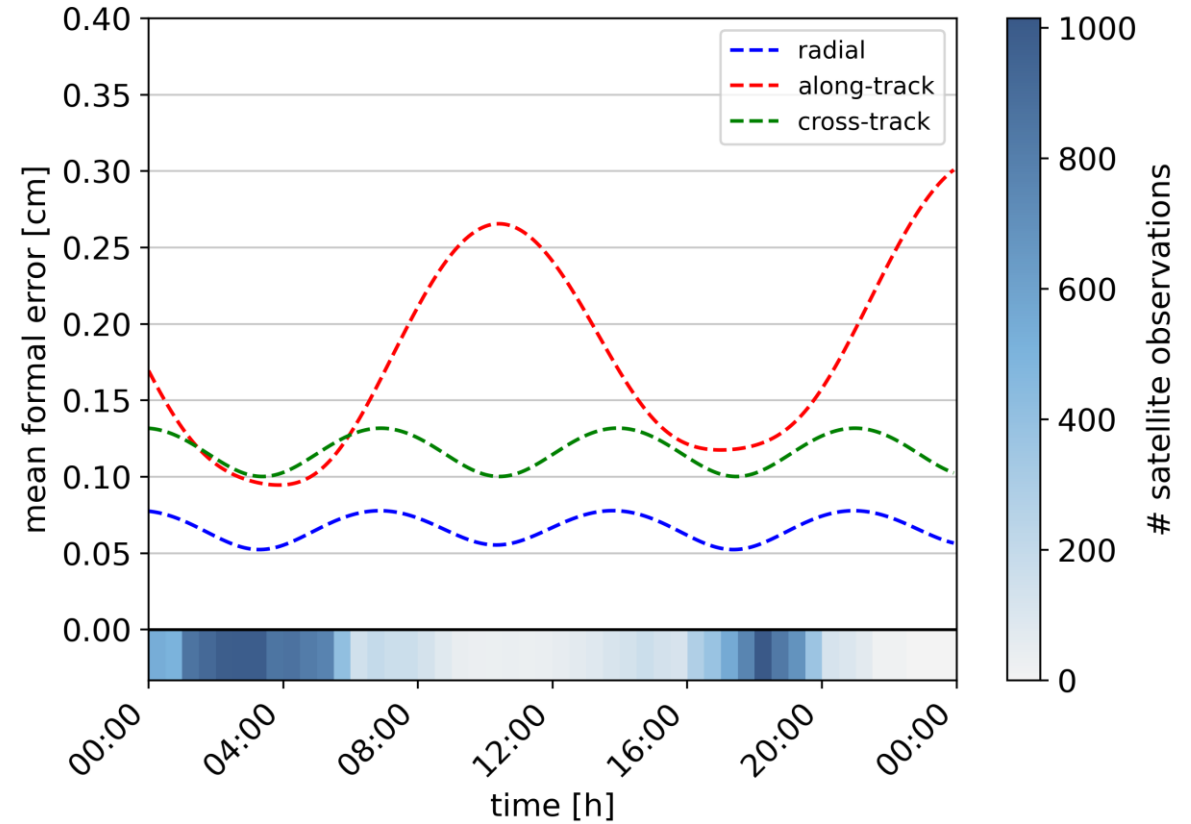
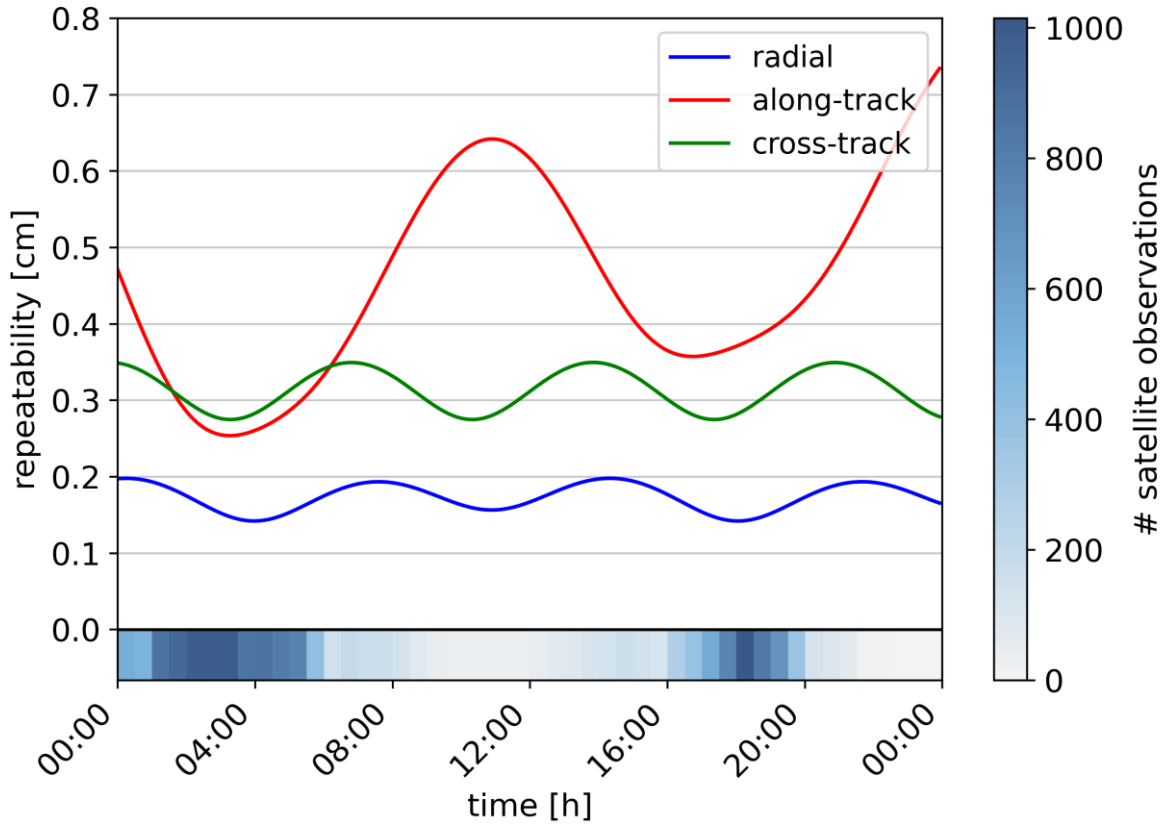
- *estimated*
 - EOP
 - 6 orbital elements
- *fixed*
 - station coordinates
 - source coordinates
 - 9 SRP parameters

Analysis Scenario B

- *estimated*
 - EOP
 - 6 orbital elements
 - 9 SRP parameters
- *fixed*
 - station coordinates
 - source coordinates

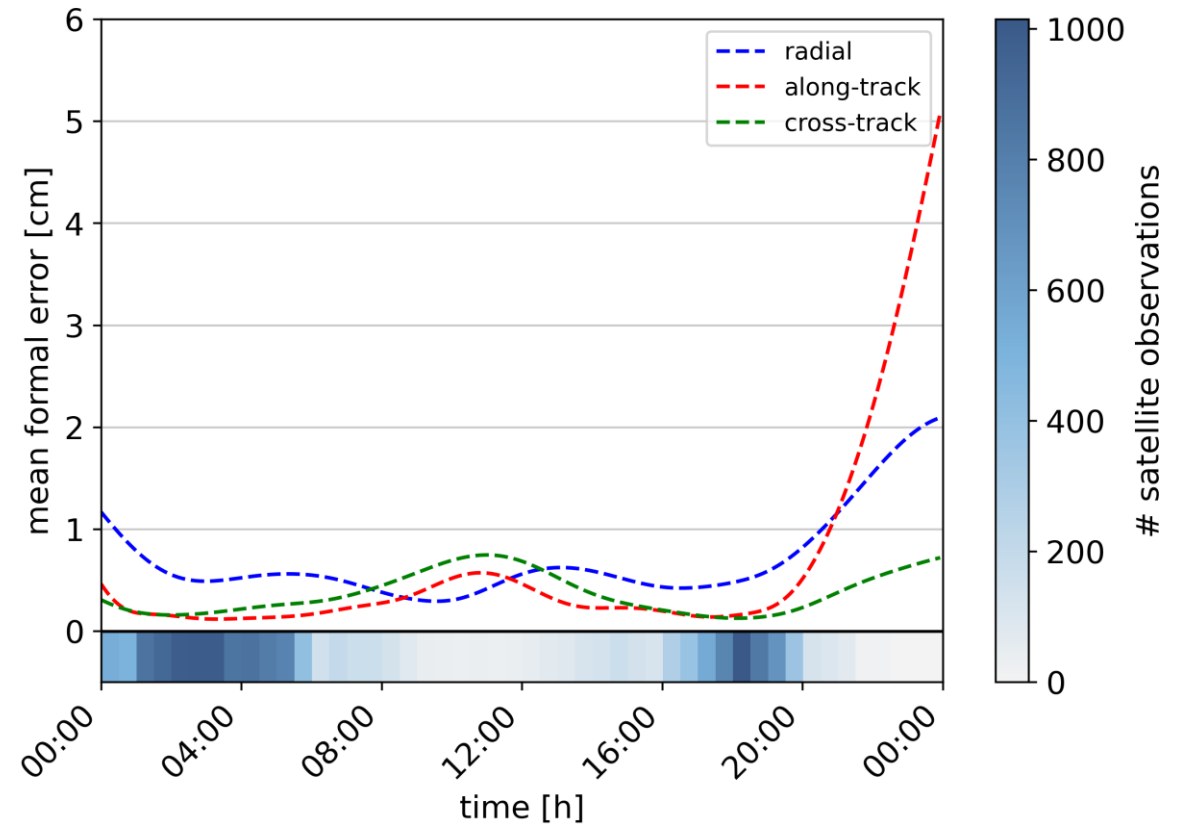
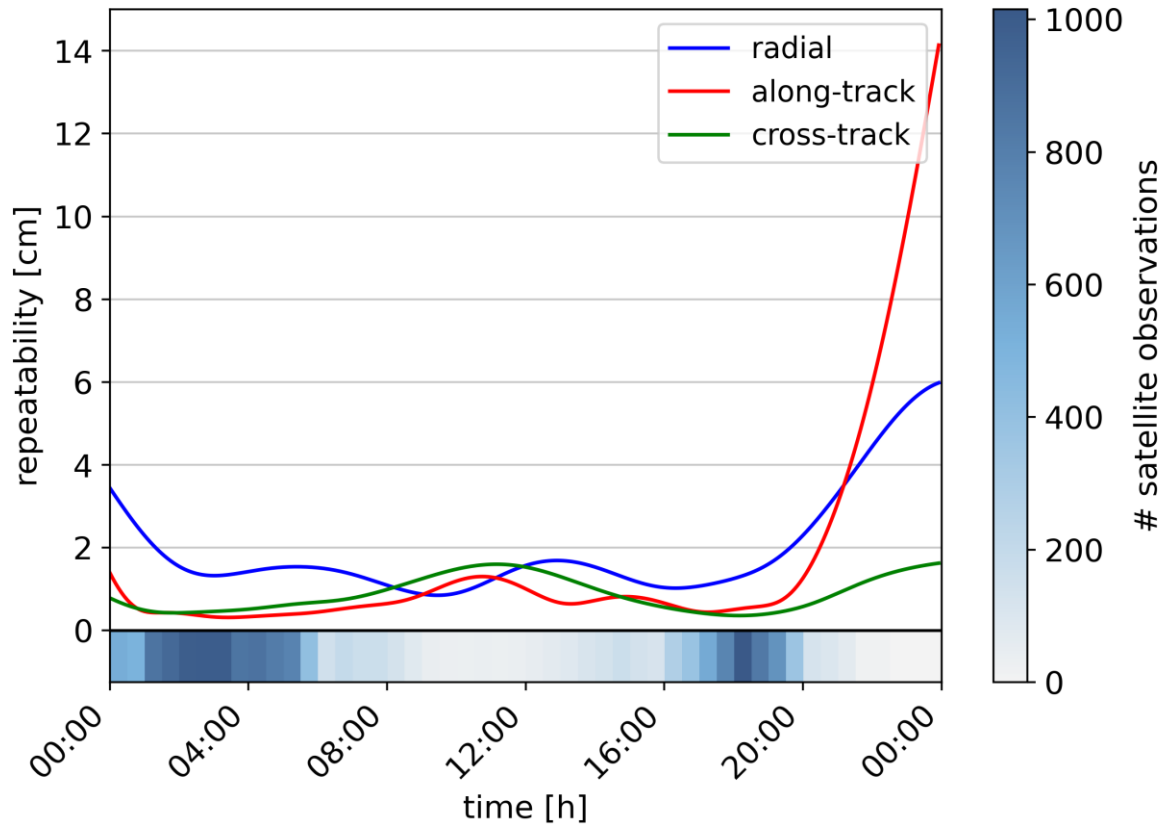
Analysis Scenario A

- *estimated*
 - EOP
 - 6 orbital elements
- *fixed*
 - station coordinates
 - source coordinates
 - 9 SRP parameters



Analysis Scenario B

- *estimated*
 - EOP
 - 6 orbital elements
 - 9 SRP parameters
- *fixed*
 - station coordinates
 - source coordinates



- VieVS-VLBI can estimate dynamic orbit parameters without internally modeling the orbital dynamics
- orbits and corresponding partial derivatives can be imported from an external software package
 - consistency of the applied force model
- Future Goal: Combination of orbit solutions on the normal equation (NEQ) level



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Processing of **GNSS** observations

estimation of satellite orbit



NEQ



combination at
NEQ level



NEQ



VieVS-VLBI

Processing of **VLBI** observations
to quasars and satellites

estimation of satellite orbit



NEQ