Simulations of VLBI observations to satellites enabling co-location in space

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Motivation

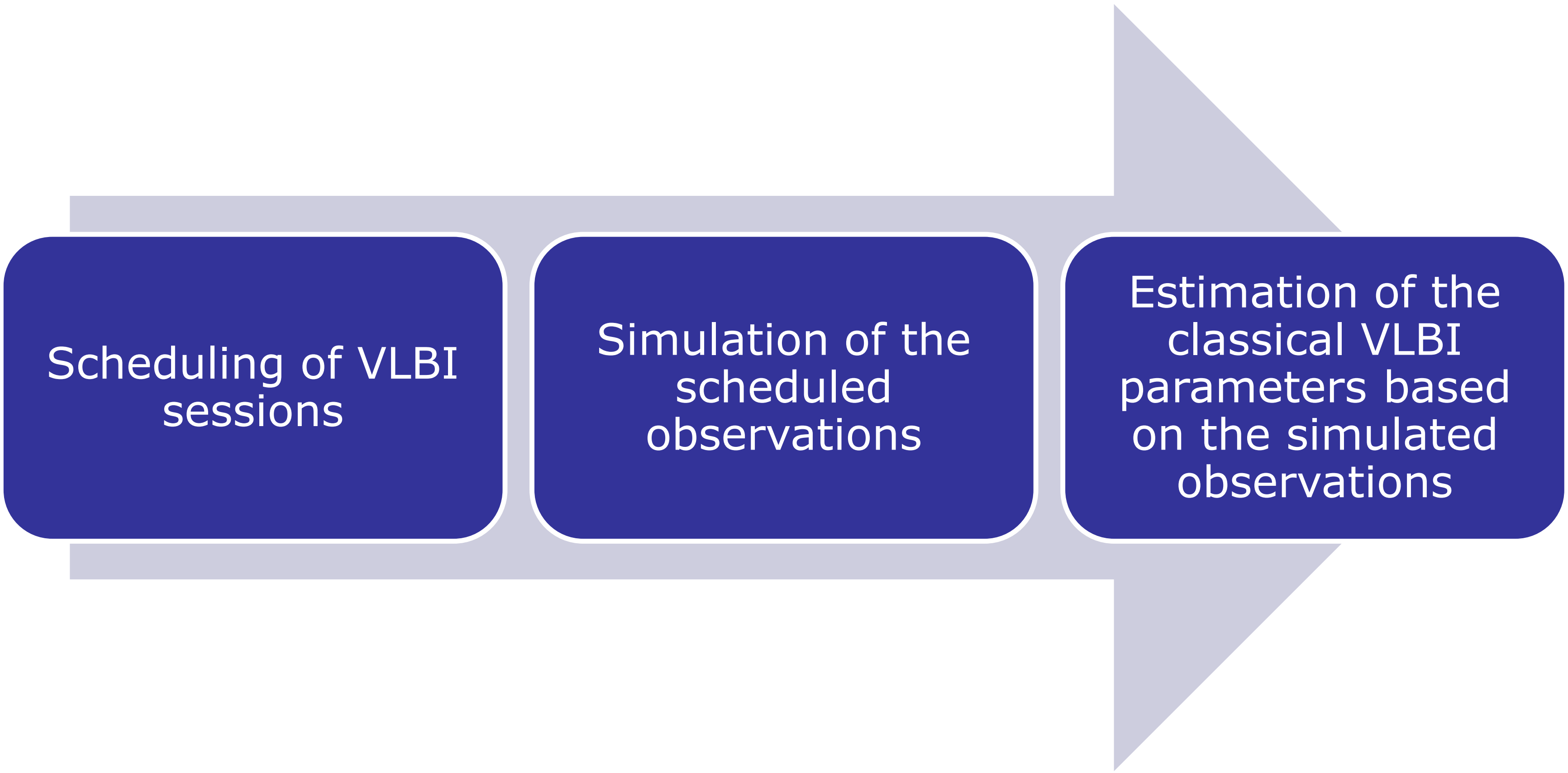
Orbit errors affect the VLBI observations

Such errors can lead to the distortion of the derived classical VLBI parameters

Focus of the study

Investigation of orbital errors’ effect on the radio-antenna position determination

Methodology



Schedule and simulation inputs

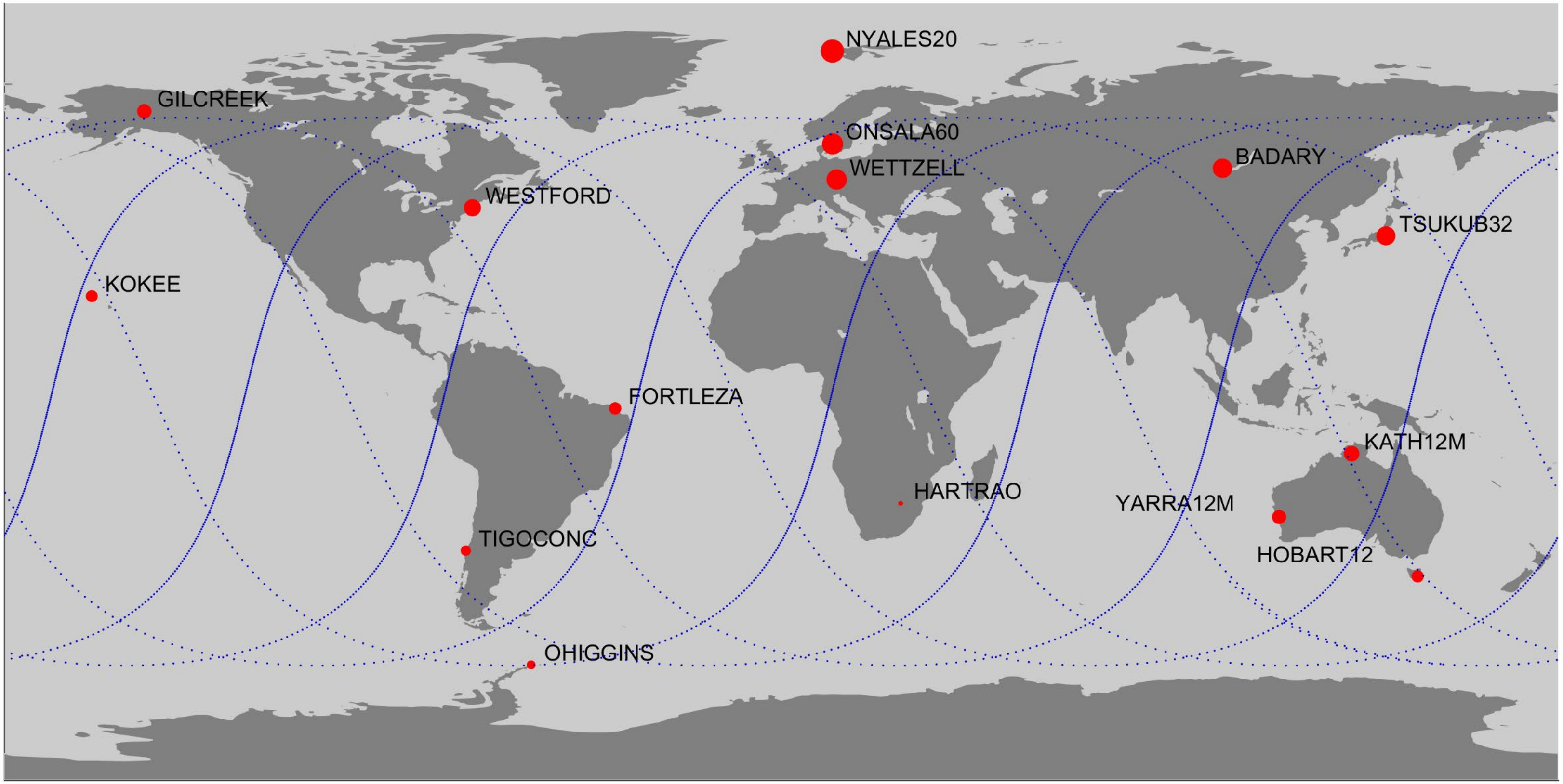
Observations are scheduled for:

- 15 globally distributed stations
- Observing one LEO satellite
- Experiment duration is one week (7 x 24h sessions)
- Only VLBI to spacecraft observations are scheduled

Simulations:

- Computed delays are generated based on the reference orbit (no error)
- Different orbit variations are employed to obtain simulated observed delay

Network stations and satellite’s ground track



- Size of the red points represents number of observations (station/per day)
- Blue dots represents ground track of the satellite

Reference orbit

Initial state:

	Perigee [km]	Apogee [km]	Inclination [o]	Eccentricity
LEO satellite	762	7472	63.4	0.32

Perturbation forces investigated within this study:

- Solar radiation pressure
- Atmospheric drag
- Gravity field of the Earth

Solar radiation pressure

acceleration of a near-Earth satellite due to the solar radiation pressure

$$\ddot{r}_{sol} = \kappa \left[\frac{A}{R}\right]^2 C_R \frac{a}{m} \frac{\vec{R}}{R}$$

$\kappa =$ Solar constant
$A =$ Astronomical unit
$R =$ Heliocentric radius vector to the satellite
$a =$ Cross−sectional area of the satellite perpendicular to $\vec{R}$
$m =$ Satellite mass
$C_R =$ reflectivity coefficient

Atmospheric drag

(de)acceleration of a near-Earth satellite due to the atmospheric drag

$$\ddot{r}_{atm} = -\frac{1}{2}\frac{C_D a}{m}\rho v^2$$

C_D = Drag coefficient
a = Cross−sectional area of the satellite
m = Mass
ρ = Atmospheric mass density*
v = velocity w.r.t atmosphere

* Atmosphere mass density is calculated based on the NRLMSISE-00 empirical atmosphere density model (For further reading see [3])

Gravity field of the Earth

acceleration of a near-Earth satellite due to the gravity field of the Earth

$$\ddot{r}_{grv} = \frac{GM}{r} f(C_{nm}, S_{nm})$$

G = gravitational constant
M = Mass of the Earth
r = Distance between center of the Earth and satellite
C_{nm}, S_{nm} = Geopotential coefficients (60x60)*

* The Earth's potential is calculated here based on:

1. GRACE Gravity Model 05S (GGM05S)
   - Grace only model (For further reading see [4])

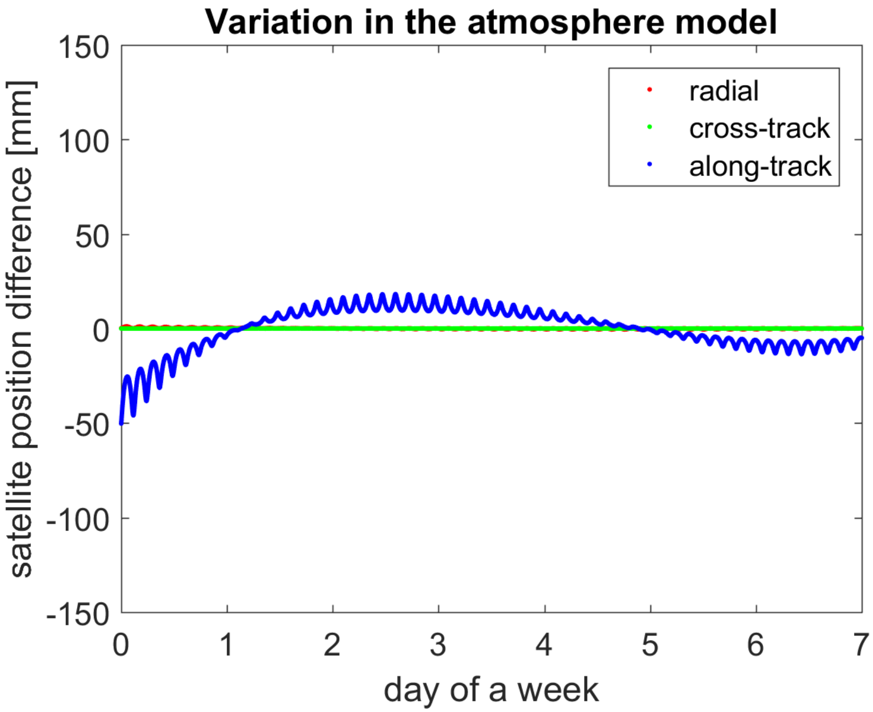
2. European Improved Gravity model of the Earth by New techniques(EIGEN-6C)
   - combination of the different satellite and surface data sets (For further reading see [5])

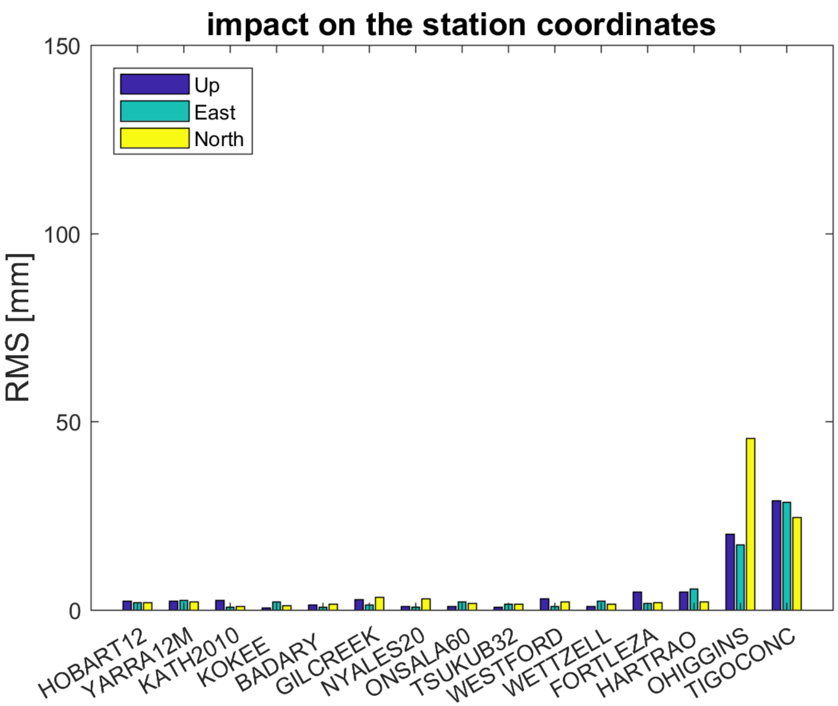
Orbital variations

Simulated observed delays are obtained based on the following orbital variation scenarios

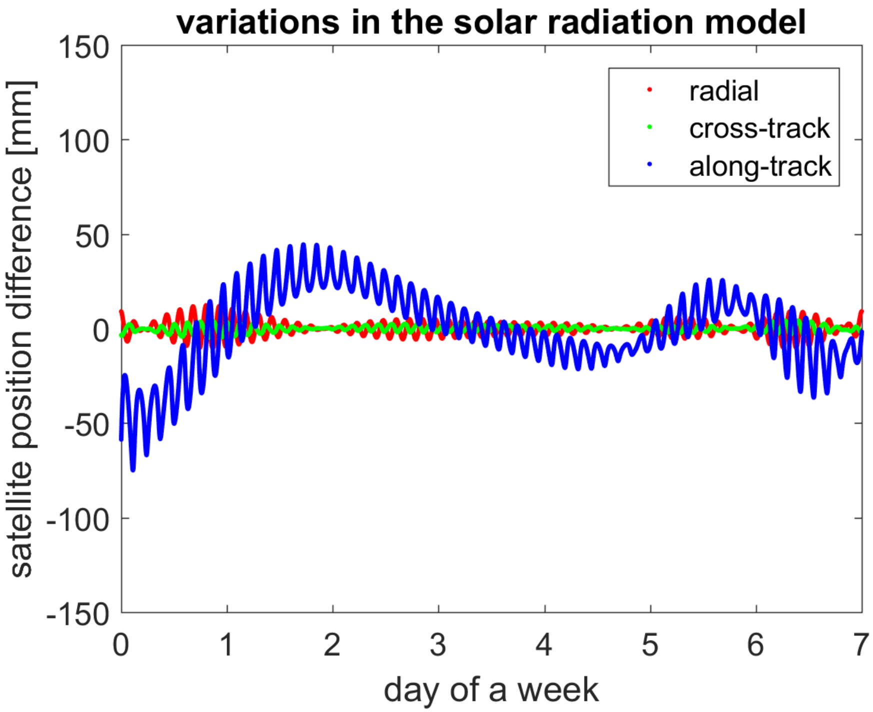
- Variations in the atmospheric drag
- Variations in the solar radiation model
- Initial state elements biased by 8 microseconds
- Initial state elements biased by 10 microseconds
- GGM05S instead of EIGEN-6C as a-priori gravity field model

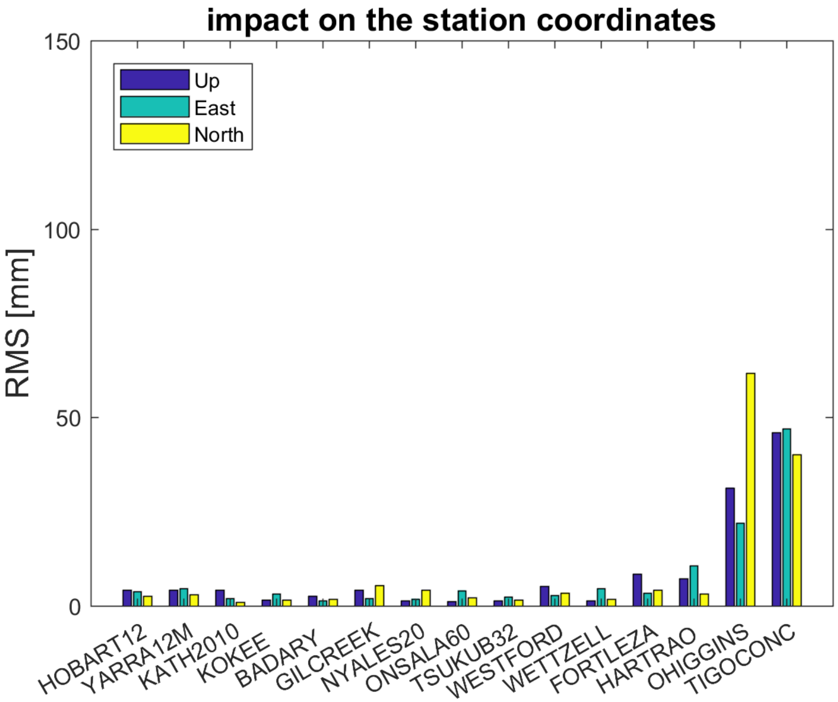
Variations in the atmospheric drag



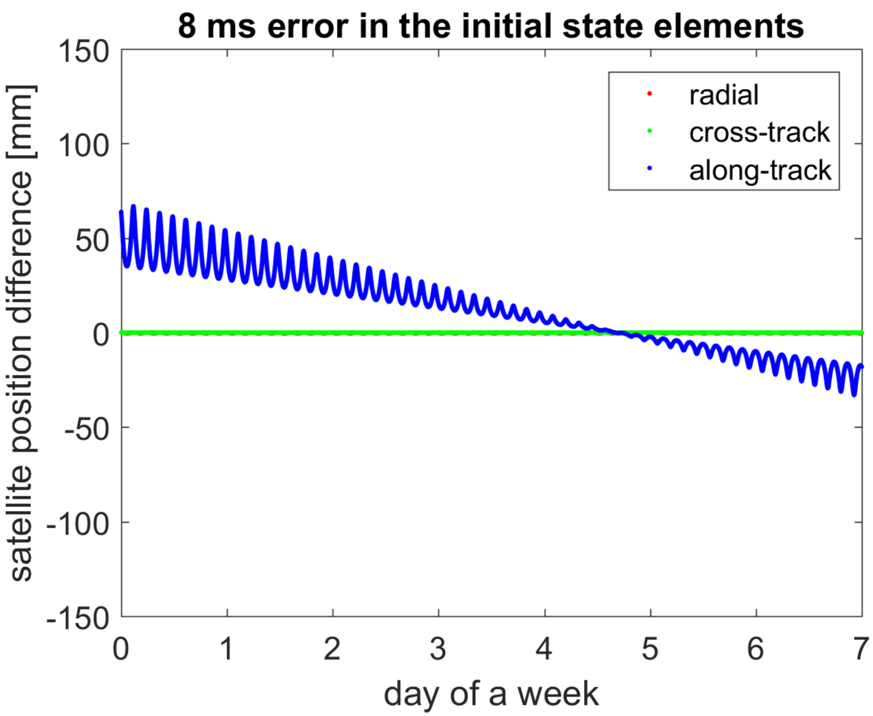


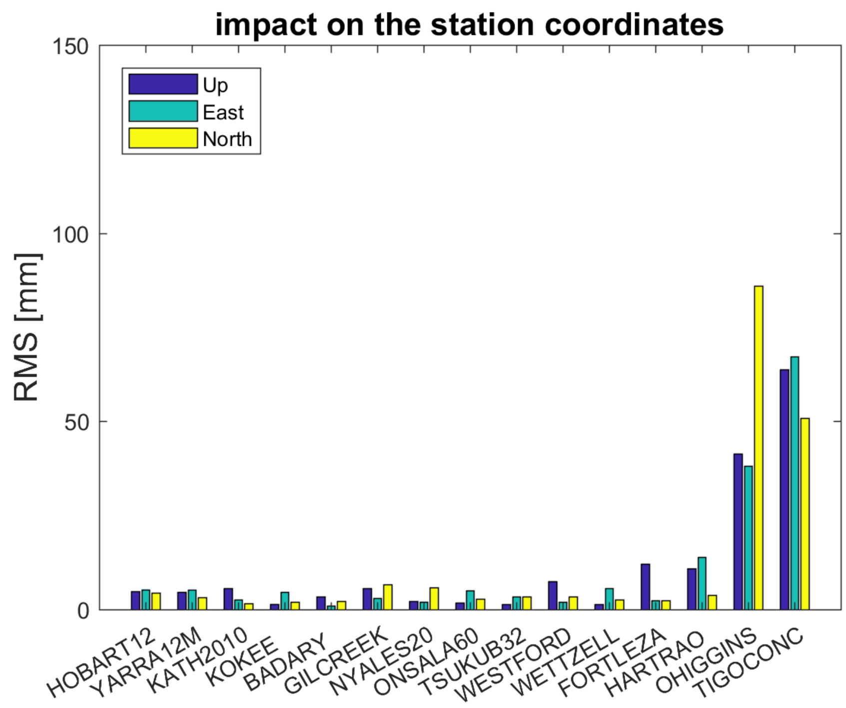
Variations in the solar radiation model



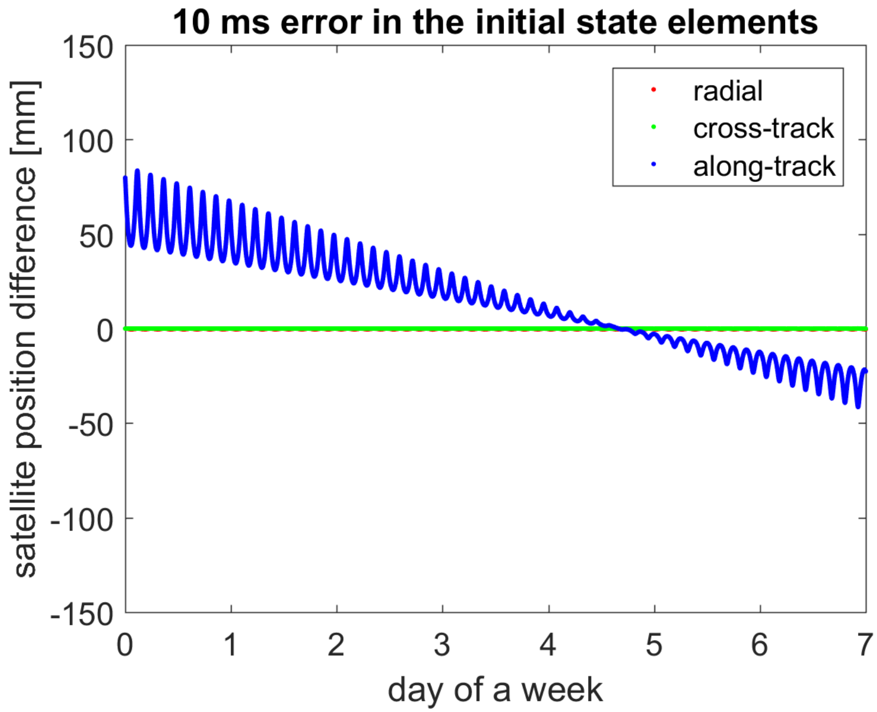


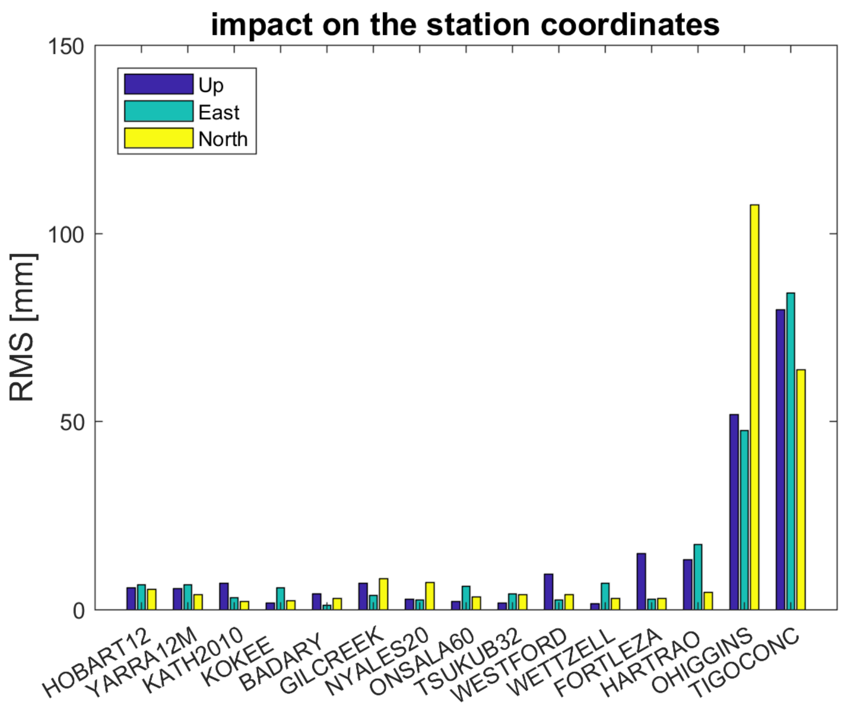
Initial state elements biased by 8 microseconds



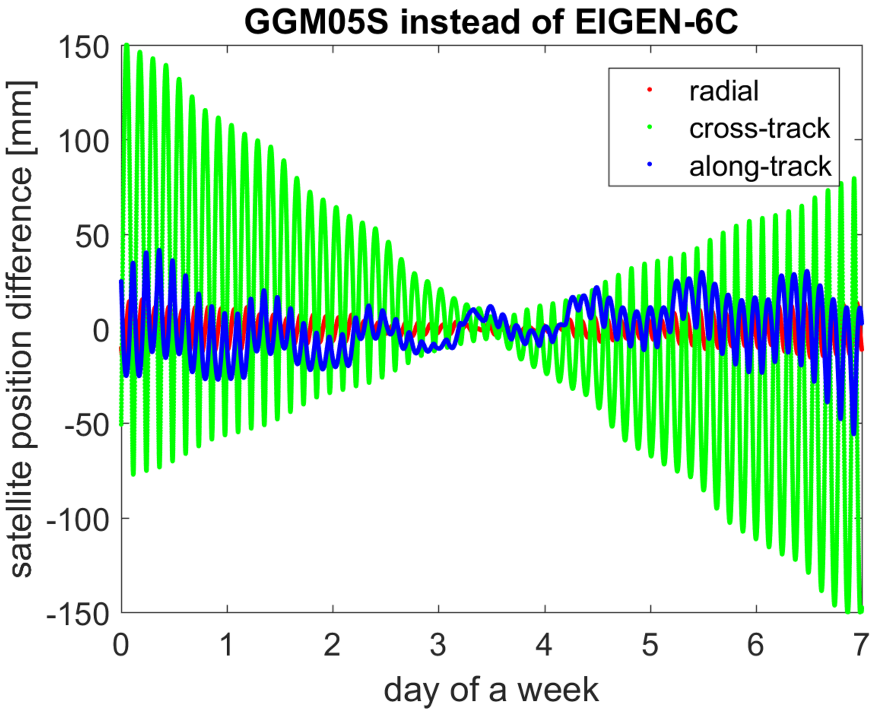


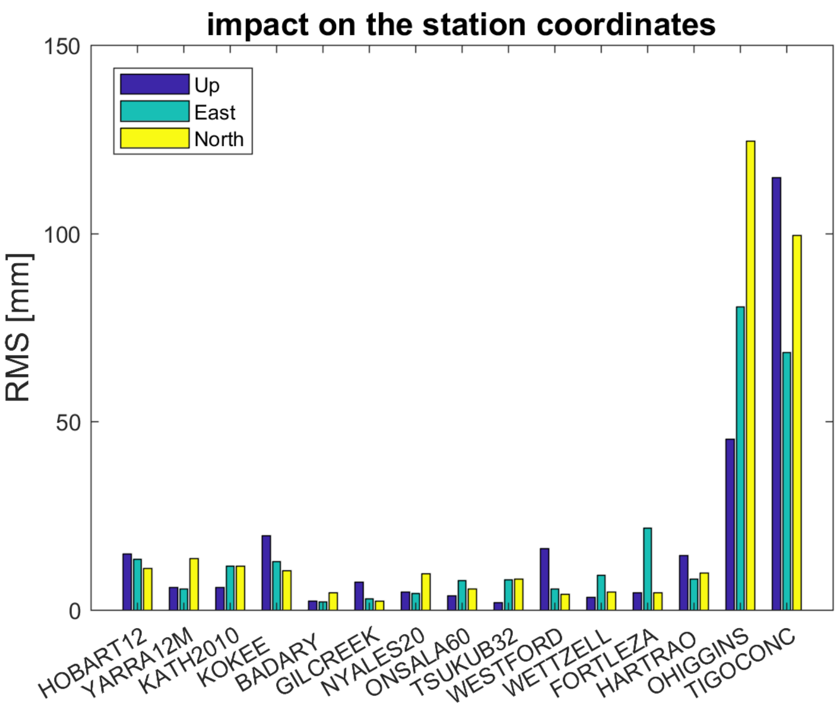
Initial state elements biased by 10 microseconds





GGM05S instead of EIGEN-6C as a-priori gravity field model





Conclusion

In this study, the impact of orbital errors on the stations position derived by VLBI to satellite observations has been investigated

Biased orbits have been generated based on gravitational and non-gravitational perturbations

Station positions are represented in weekly RMS up, east and north components

Remote network stations represent large errors

Position of more observed stations are better estimated than less observed stations

Large errors in the north component is due to the correlation between ZWD and the station height

Orbital errors in

- along-track mainly degrade up component
- cross-track degrades east component of the stations position

References

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5. Shako, R., Förste, C., Abrykosov, O., Bruinsma, S., Marty, J.-C., Lemoine, J.-M., Flechtner, F., Neumayer, K.-H., Dahle, C. (2014): EIGEN-6C: A High-Resolution Global Gravity Combination Model Including GOCE Data

Thanks for your interest!

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