How Much Do Satellite Techniques Depend on UT1 from VLBI?

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Overview

What are we doing in the satellite techniques?

Interaction between Earth-fixed and quasi-inertial frames

How do other celestial bodies do effect the data analysis?

How stable is the cumulated GNSS-based LOD series?

Conclusions

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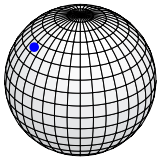

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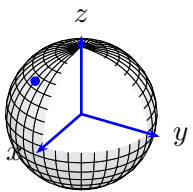

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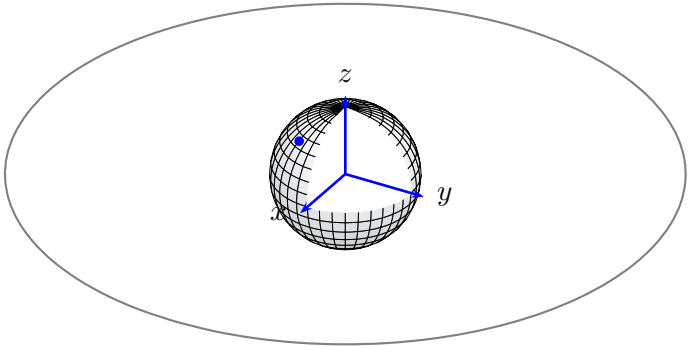

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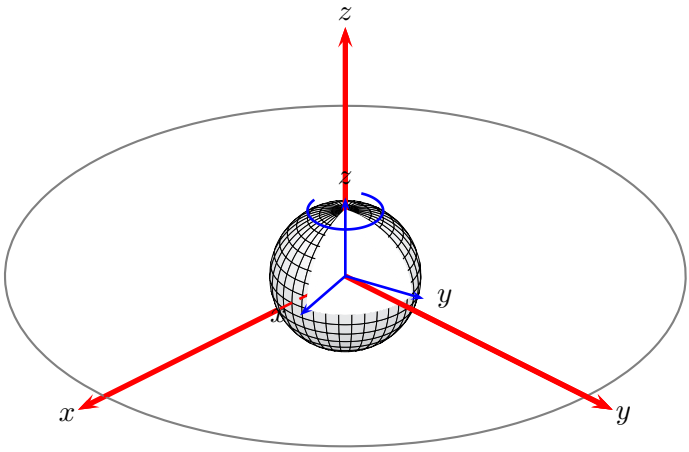

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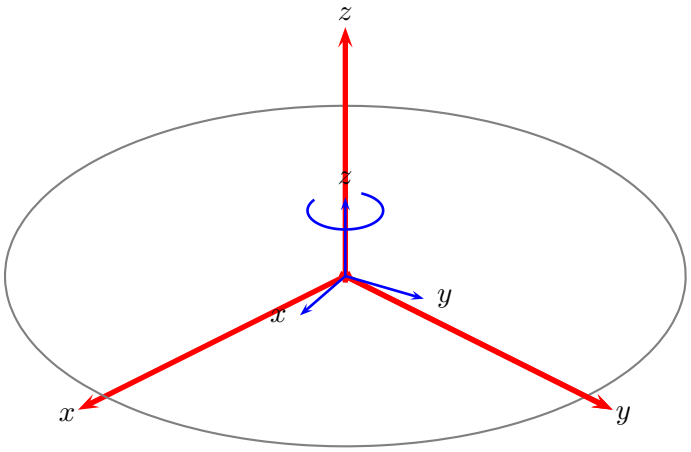

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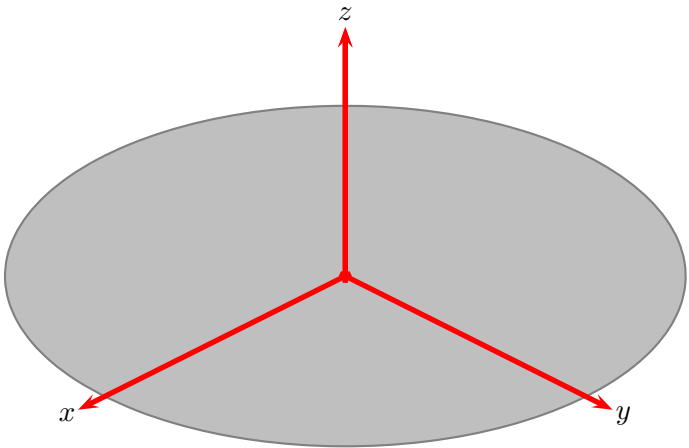

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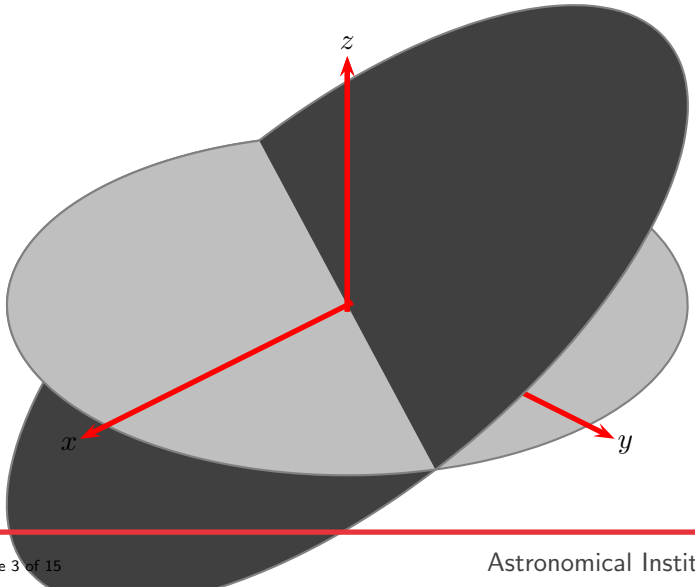

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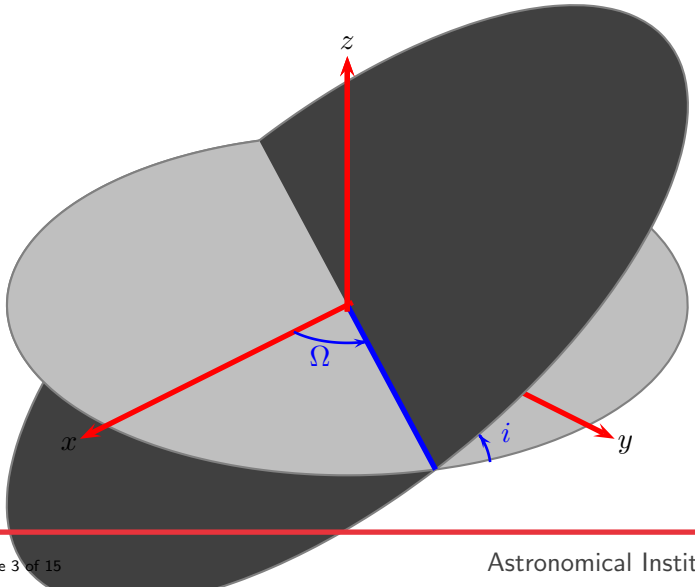

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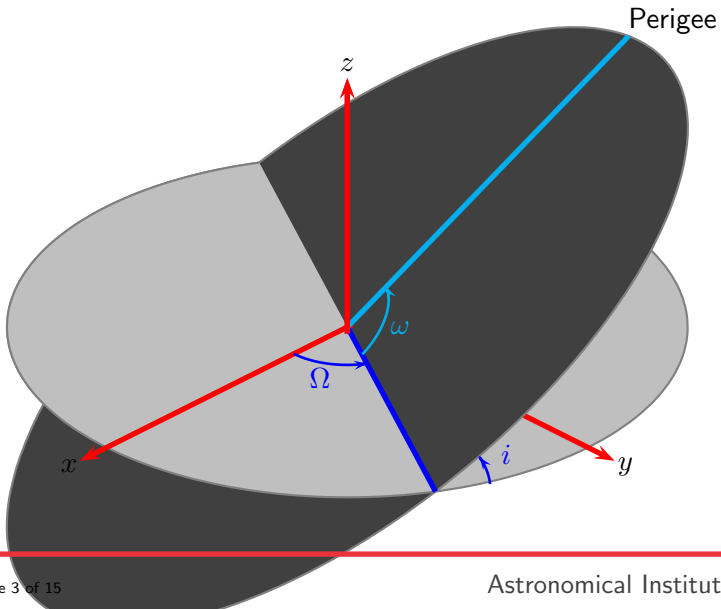

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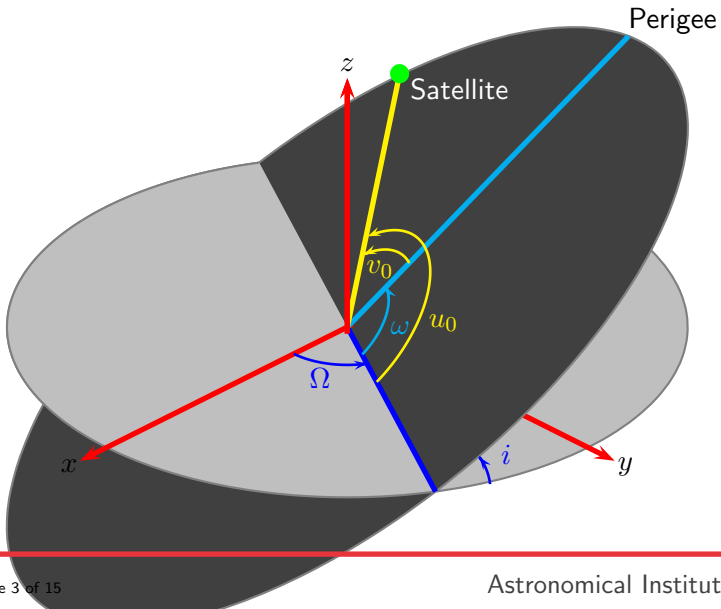

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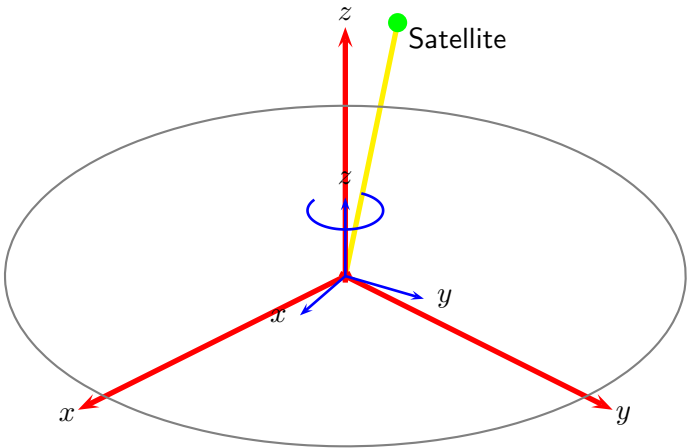

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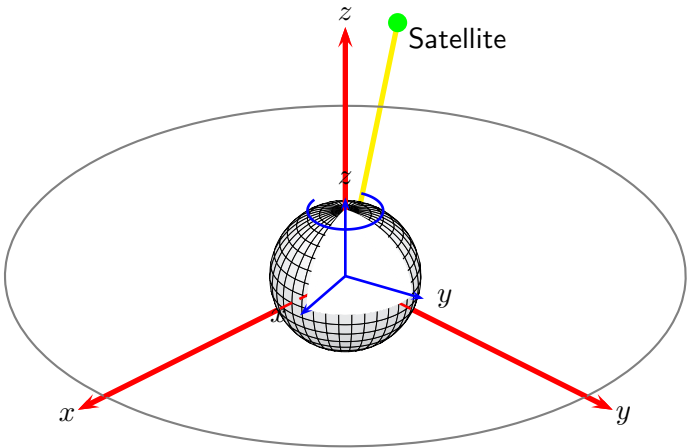

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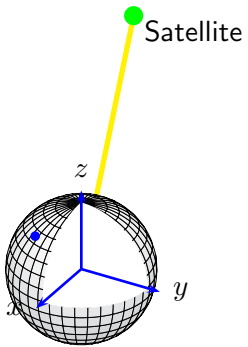

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The positions of Sun, Moon and bigger planets are needed for

- direct and indirect solar radiation pressure modeling on the satellite,
- computing entrance and exit epochs for satellite eclipse intervals,
- solid Earth tide correction computation for ground stations,
- gravitational force modeling due to the celestial bodies.

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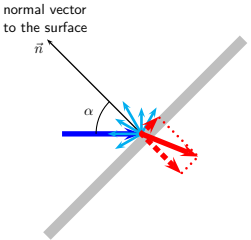
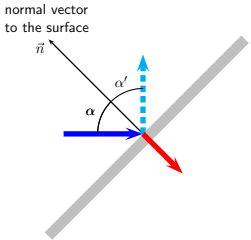
Diffuse reflection



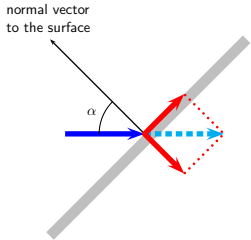
$$\vec{C}_d = \left(\frac{\vec{r}_{sat} - \vec{r}_{Sun}}{|\vec{r}_{sat} - \vec{r}_{Sun}|} - \frac{2}{3}\vec{n} \right) \cdot \cos\alpha$$

Specular reflection



$$\vec{C}_s = -2 \cdot \cos^2\alpha \cdot \vec{n}$$

Absorption



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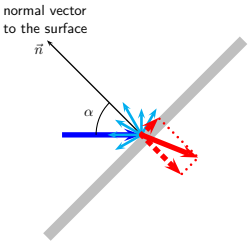

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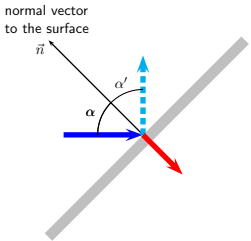

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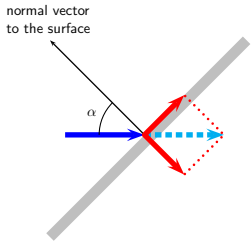

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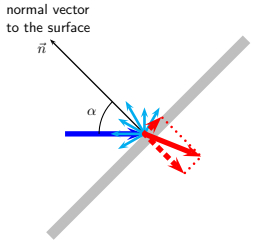

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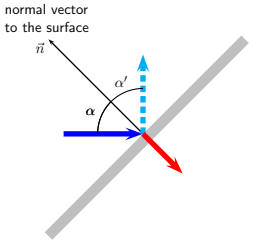

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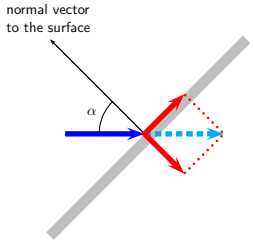

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One percent error in the $\cos\alpha$-term corresponds to 0.5 degree or 2 minutes (in UT1); the optical properties are typically much more uncertain.

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- For different types of satellites such parameters are computed in various coordinate systems. The resolution in time or revolution dependent setups are in use.
- For GNSS is for instance a coordinate system widely used that is oriented from the satellite towards the Sun, which get of course also misoriented in case of a misplacement of the Sun.
- Even an UT1 misorientation of 1 minute has an effect on the satellite positions of less than $1 \ldots 2\,\mathrm{mm}$.

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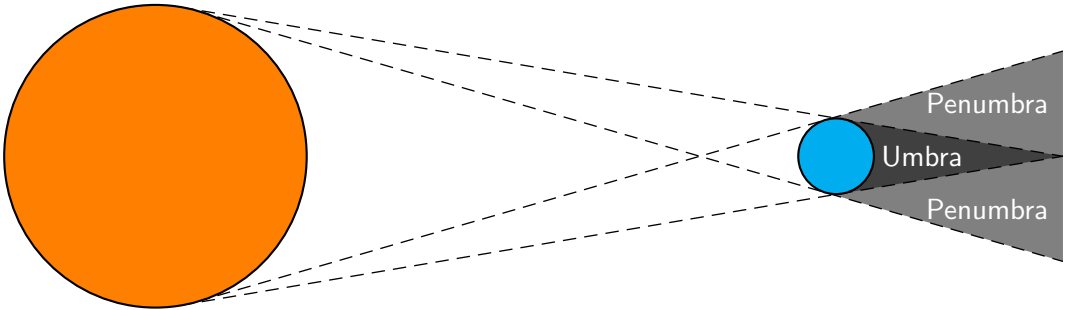

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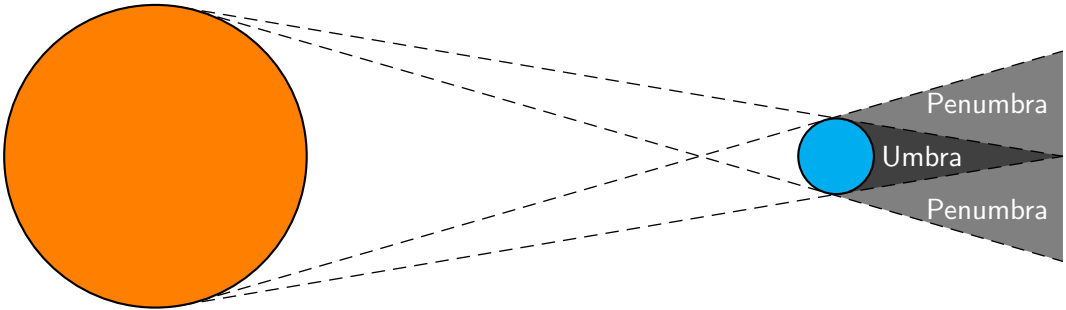

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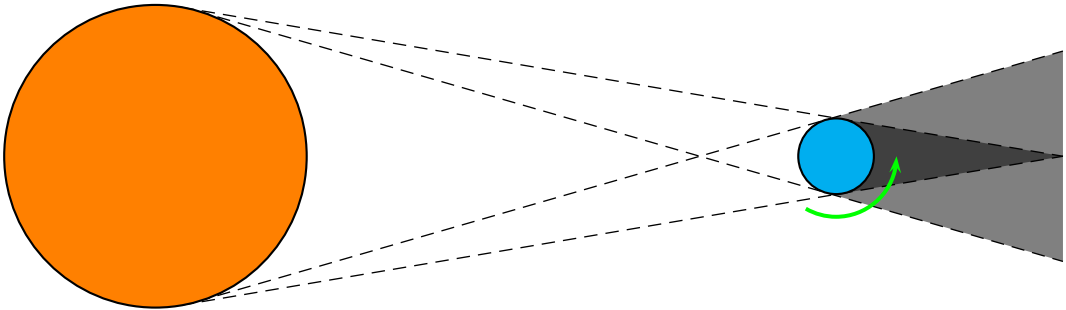

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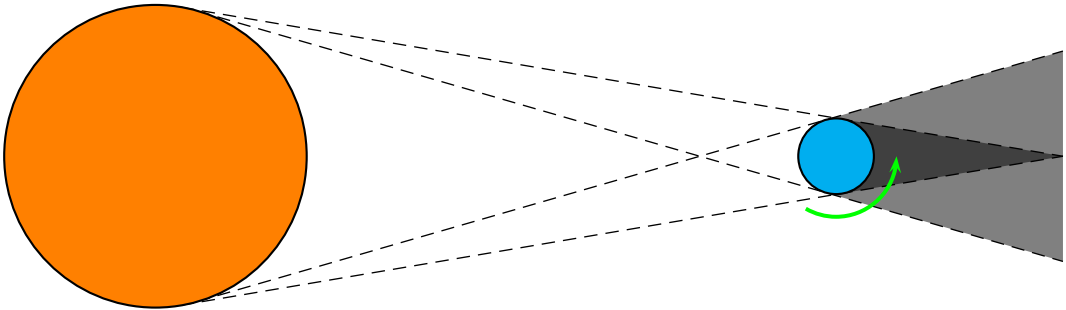
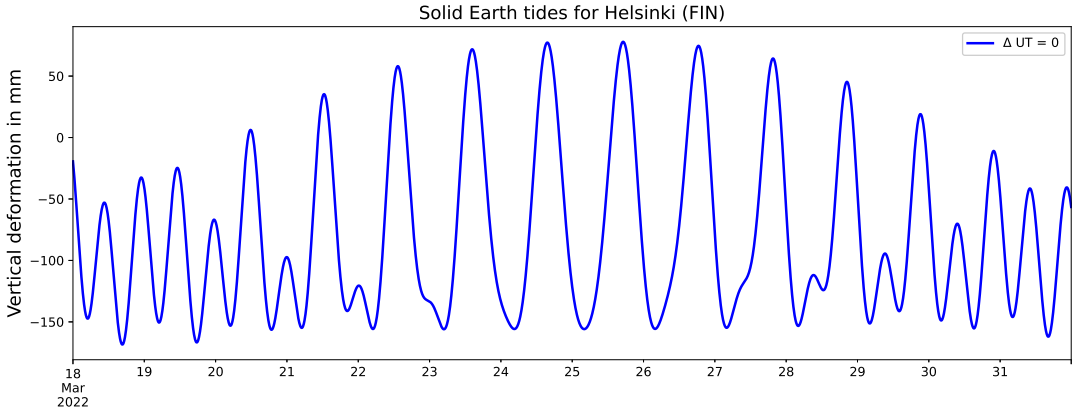


One minute error in UT1 results in a wrong shadow entrance and exit time of 1 minute for the satellite in an orbit along the equator.

Position of the Sun and Moon for solid Earth tides

Solid Earth tides are computed based on the positions of the Sun and Moon as well.



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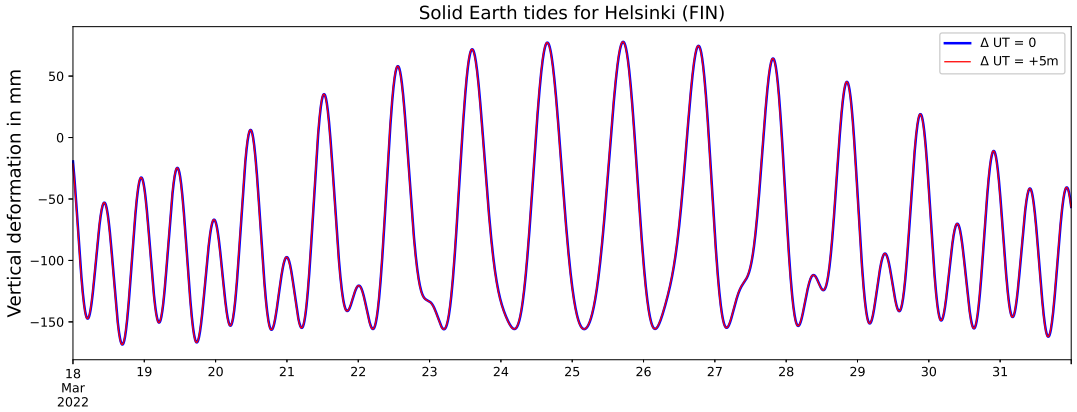

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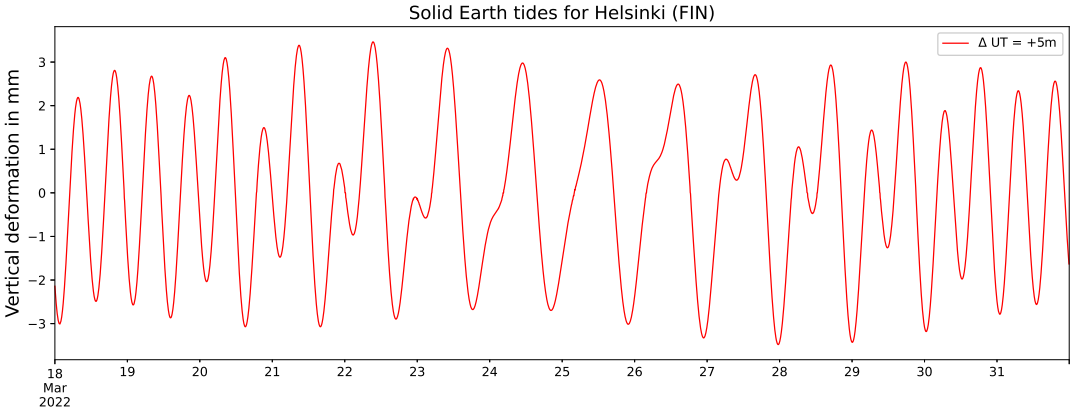

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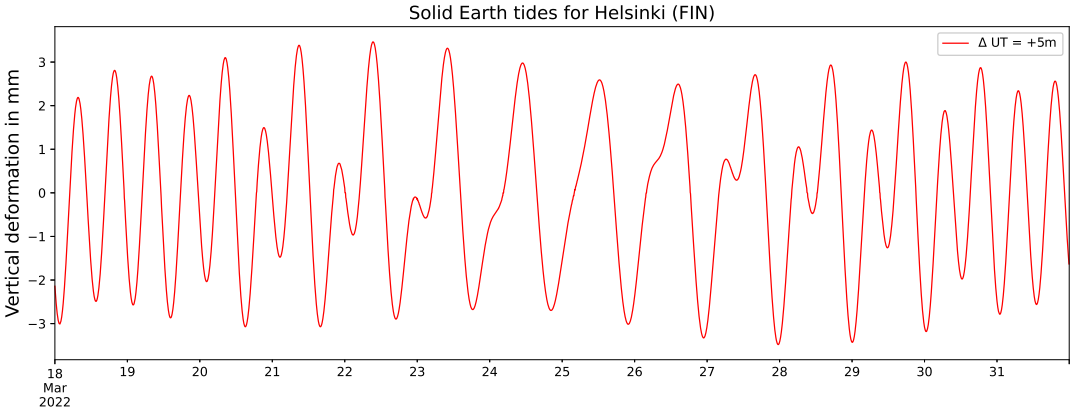

With a shift of one minute in UT1, the error of the Solid Earth tides is below 1 mm.

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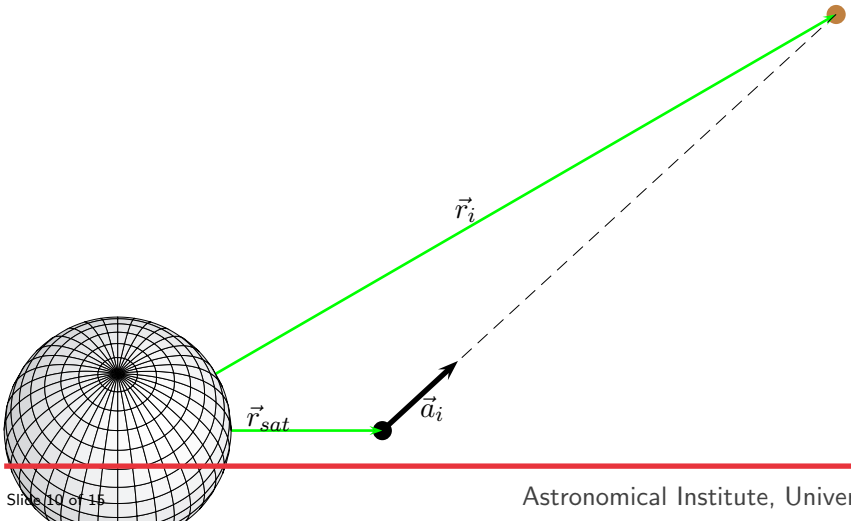

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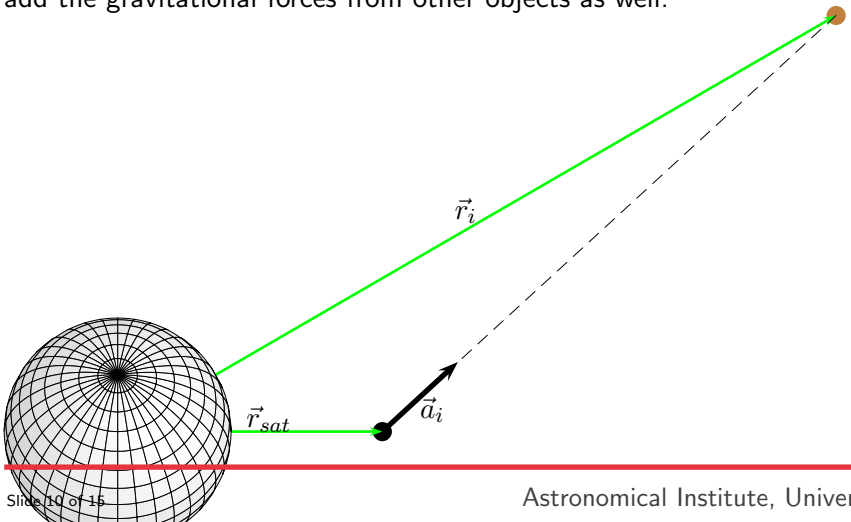

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without Moon	RMS $\approx 70\,\mathrm{m}$
without Sun	RMS $\approx 20\,\mathrm{m}$
without Mars	RMS $< 1\,\mathrm{mm}$
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Orbit fit means that positions from a correctly modeled set of GNSS orbits are represented by a manipulated orbit model (including all usual empirical orbit parameters).

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Orbit fit after rotating the positions of all bodies		
UT1 $+1\,\mathrm{ms}$	RMS $<$	$1\,\mathrm{mm}$
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Applying the rule of thumb from Baueršíma (1983) the orbit error Δ_{orb} in a GNSS solution propagates with $\frac{network\ extension}{orbit\ height} \cdot \Delta_{orb}$ into the coordinate network solution.

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Orbit fit after rotating the positions of all bodies

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UT1 $+10\,\mathrm{ms}$	RMS $\approx$	$1\,\mathrm{mm}$
UT1 $+100\,\mathrm{ms}$	RMS $\approx$	$2\,\mathrm{mm}$
UT1 $+1\,\mathrm{s}$	RMS $\approx$	$2\,\mathrm{cm}$
UT1 $+5\,\mathrm{s}$	RMS $\approx$	$8\,\mathrm{cm}$
UT1 $+10\,\mathrm{s}$	RMS $\approx$	$15\,\mathrm{cm}$

Applying the rule of thumb from Baueršíma (1983) the orbit error Δ_{orb} in a GNSS solution propagates with $\frac{network\ extension}{orbit\ height} \cdot \Delta_{orb}$ into the coordinate network solution.

Computed from one day GNSS-constellations – 2 revolutions

How do other celestial bodies do effect the data analysis?

Since the Earth is not the only mass in the universe acting on the satellite, we have to add the gravitational forces from other objects as well.

Orbit fit after rotating the positions of all bodies

UT1 $+1\,\mathrm{ms}$	RMS $<$	$1\,\mathrm{mm}$
UT1 $+10\,\mathrm{ms}$	RMS $\approx$	$1\,\mathrm{mm}$
UT1 $+100\,\mathrm{ms}$	RMS $\approx$	$4\,\mathrm{mm}$
UT1 $+1\,\mathrm{s}$	RMS $\approx$	$5\,\mathrm{cm}$
UT1 $+5\,\mathrm{s}$	RMS $\approx$	$12\,\mathrm{cm}$
UT1 $+10\,\mathrm{s}$	RMS $\approx$	$30\,\mathrm{cm}$

Applying the rule of thumb from Baueršíma (1983) the orbit error Δ_{orb} in a GNSS solution propagates with $\frac{network\ extension}{orbit\ height} \cdot \Delta_{orb}$ into the coordinate network solution.

Computed from three days GNSS-constellations – 6 revolutions

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Orbit fit after rotating the positions of all bodies

UT1 $+1\,\mathrm{ms}$	RMS $<$	$1\,\mathrm{mm}$
UT1 $+10\,\mathrm{ms}$	RMS $\approx$	$1\,\mathrm{mm}$
UT1 $+100\,\mathrm{ms}$	RMS $\approx$	$8\,\mathrm{mm}$
UT1 $+1\,\mathrm{s}$	RMS $\approx$	$8\,\mathrm{cm}$
UT1 $+5\,\mathrm{s}$	RMS $\approx$	$20\,\mathrm{cm}$
UT1 $+10\,\mathrm{s}$	RMS $\approx$	$50\,\mathrm{cm}$

Applying the rule of thumb from Baueršíma (1983) the orbit error Δ_{orb} in a GNSS solution propagates with $\frac{network\ extension}{orbit\ height} \cdot \Delta_{orb}$ into the coordinate network solution.

Computed from six days GNSS-constellations – 12 revolutions

How stable is the cumulated GNSS-based LOD series?

Comparing the cumulated GNSS-based LOD series to the IERS C04(14) series.

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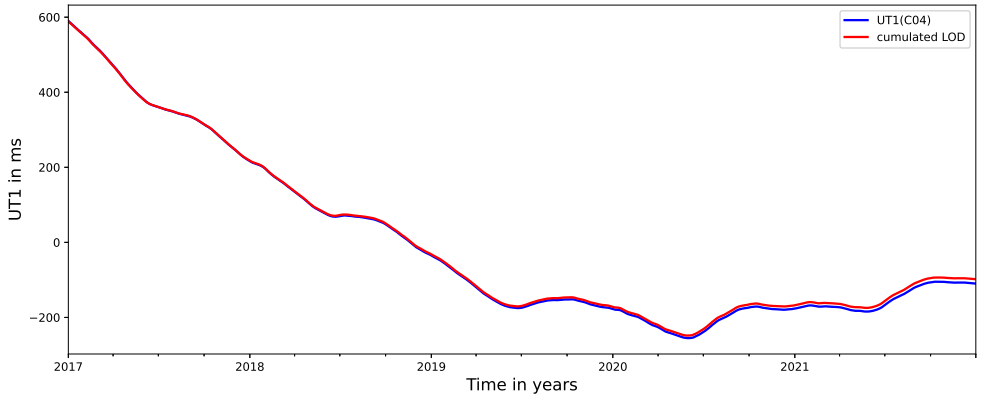

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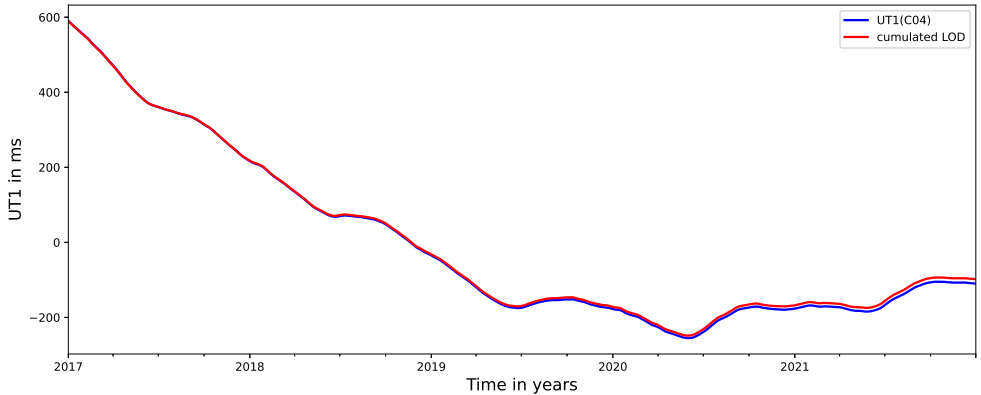

Multi-GNSS, long-arc GNSS solution with PWL-ERP representation from ≈250 stations.

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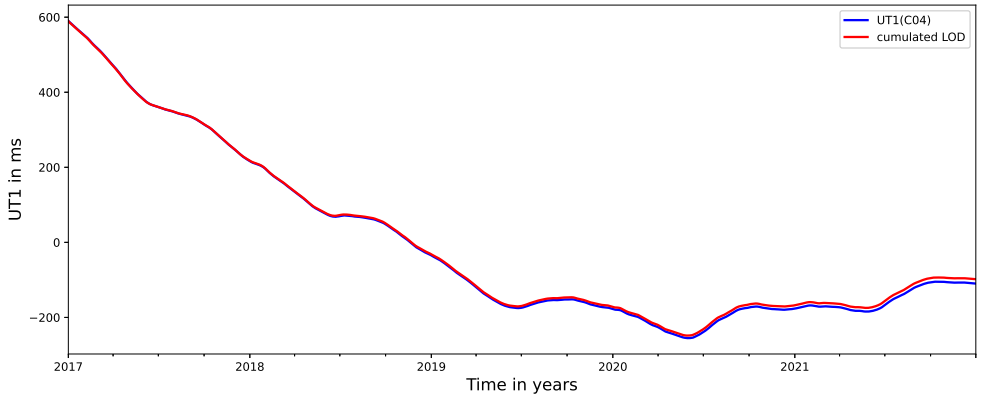

For other satellite techniques (e.g., SLR) it does not look that good...

Summary

How much do satellite techniques depend on UT1 from VLBI?

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- With a GNSS solution the cumulated LOD parameters may follow UT1 over years. Other techniques have there less favorable capability for reconstructing LOD.

I would feel much more comfortable if the orientation of the Earth is provided by VLBI also in future than just doing a propagation into the blue sky...

THANK YOU

for your attention

Publications of the satellite geodesy research group:

http://www.bernese.unibe.ch/publist