Impact of GNSS Orbit Modelling on Reference Frame Parameters

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Overview

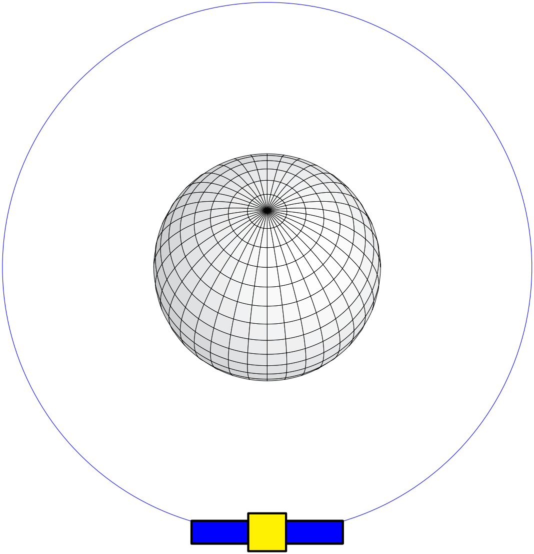
Solar Radiation Pressure for GNSS Satellites

Impact on the GNSS Satellite orbits

Impact on the Reference Frame Parameters

Long–Arc Solutions

Observing the satellite from the Sun



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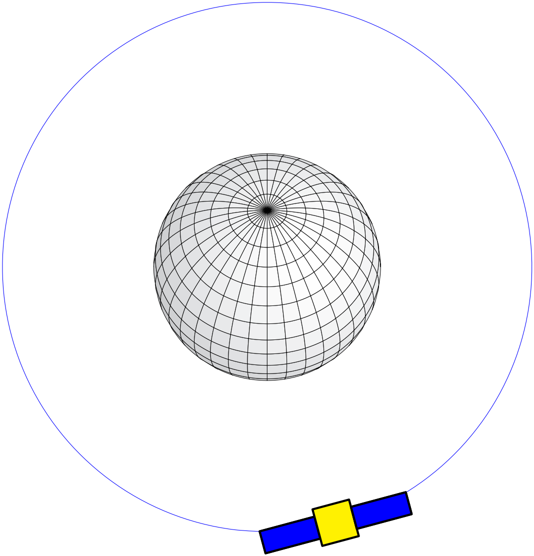

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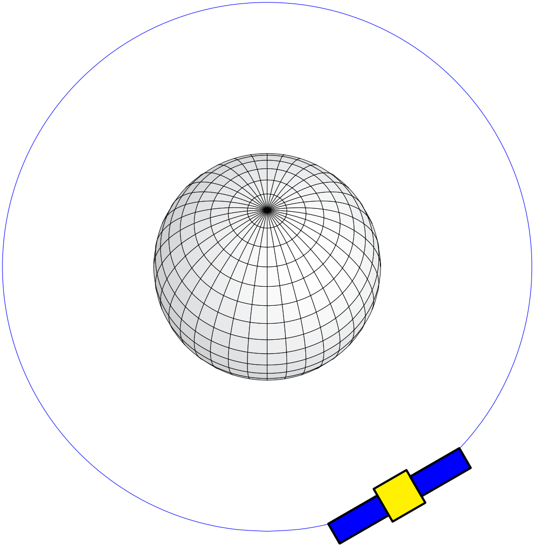

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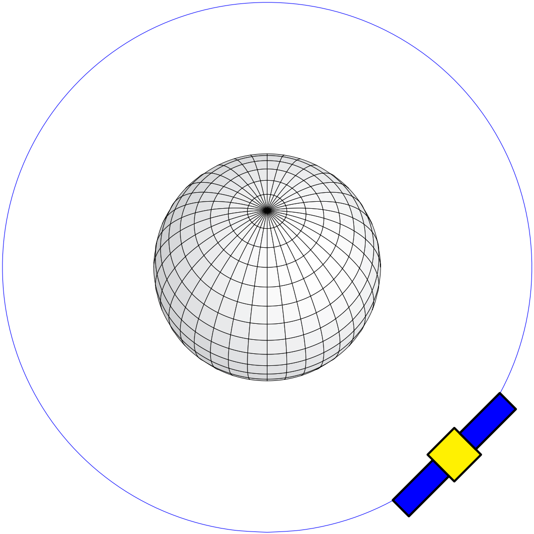

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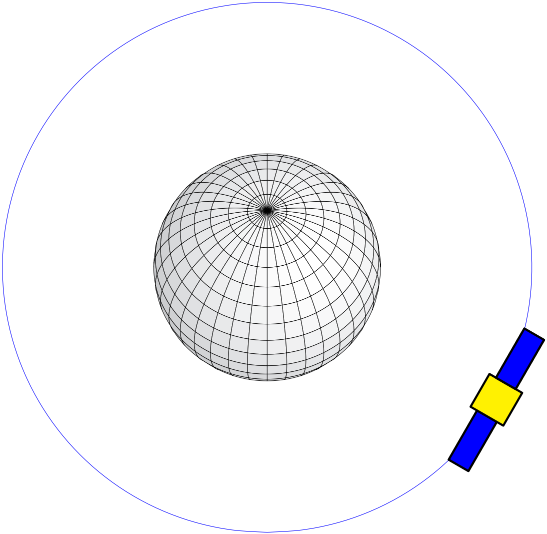

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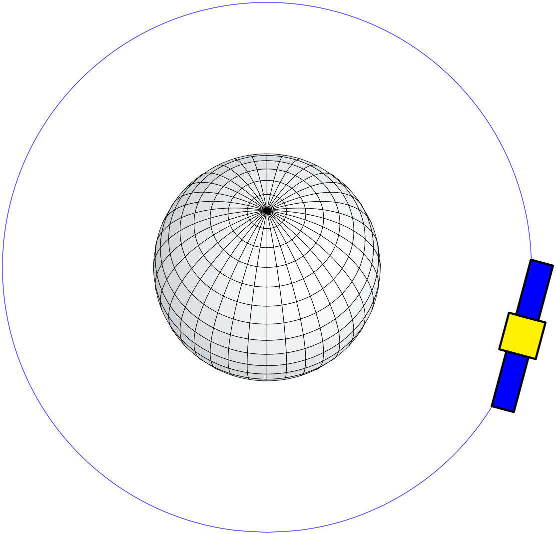

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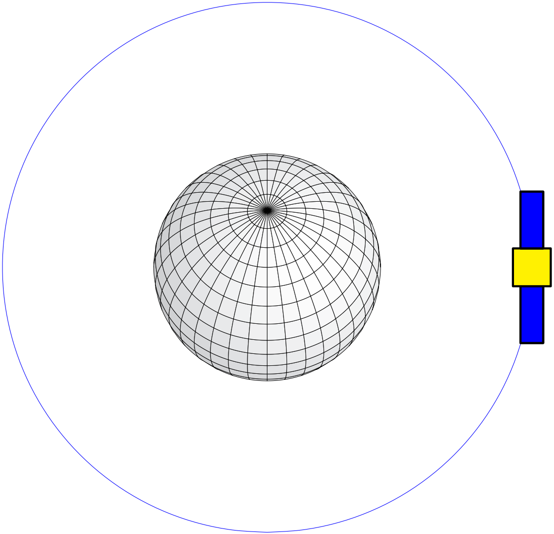

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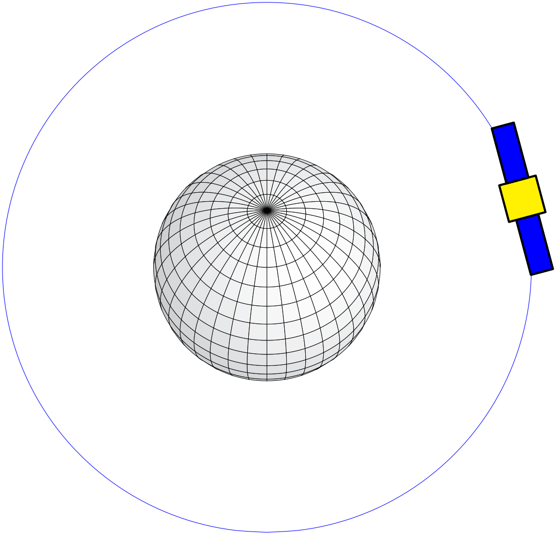

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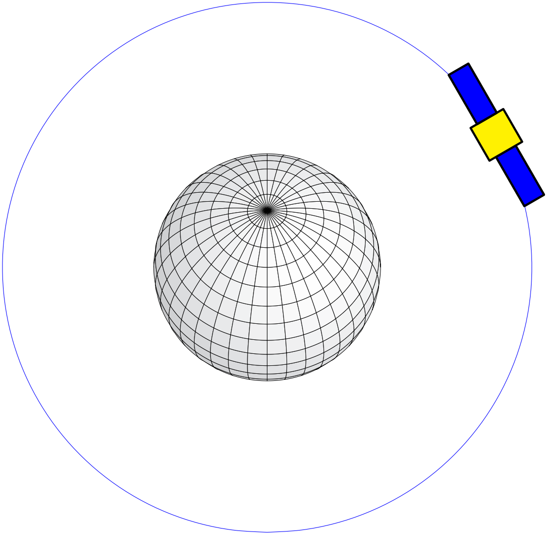

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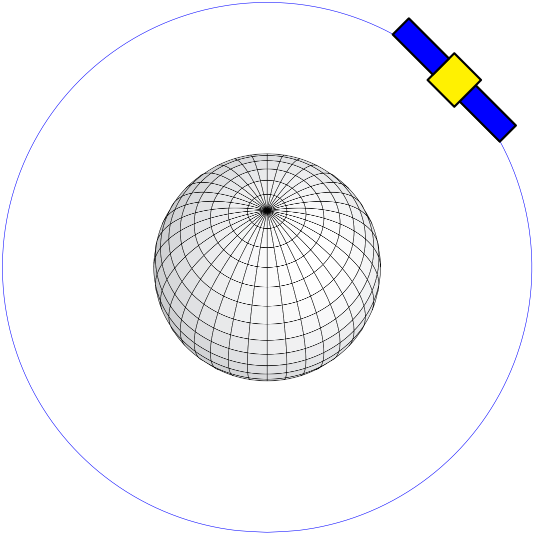

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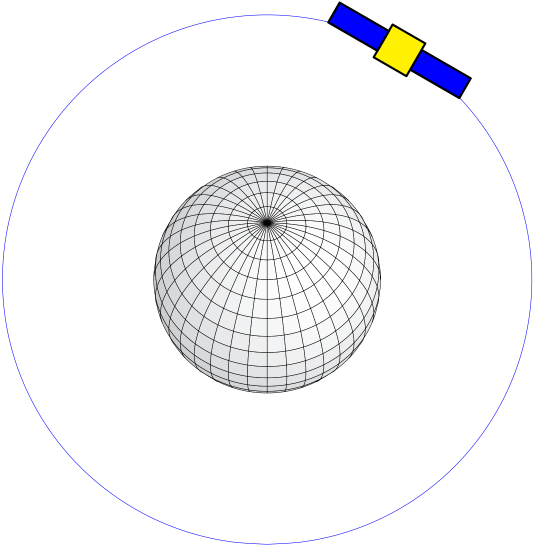

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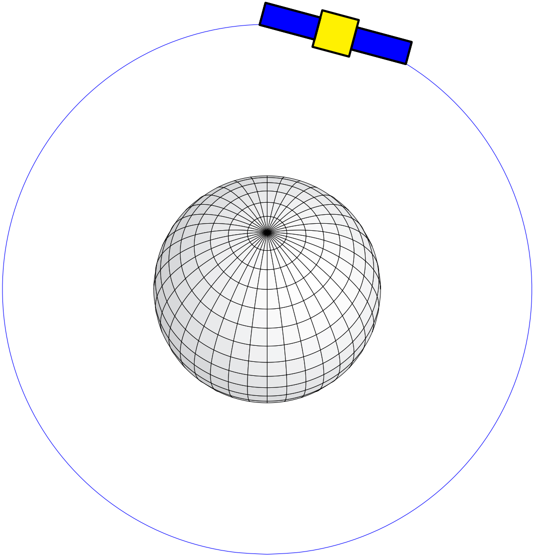

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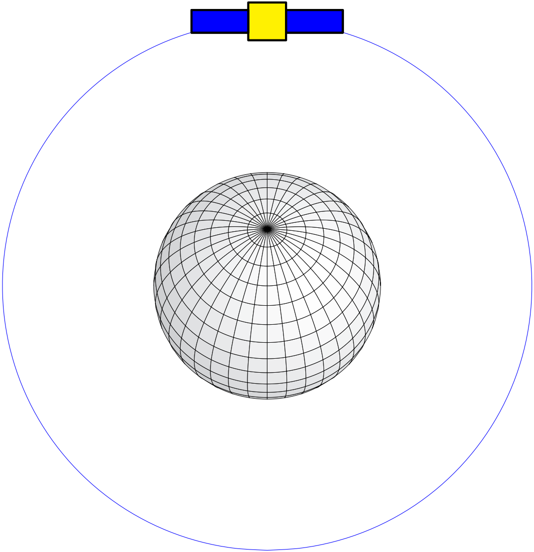

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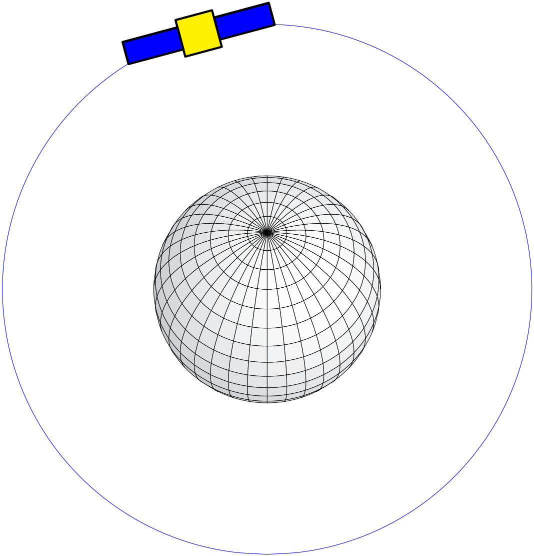

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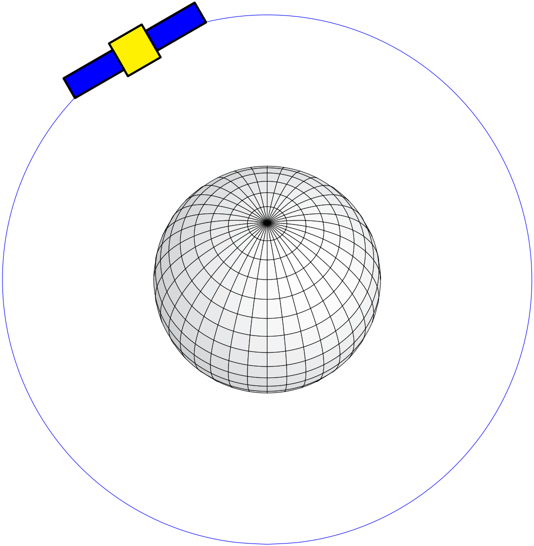

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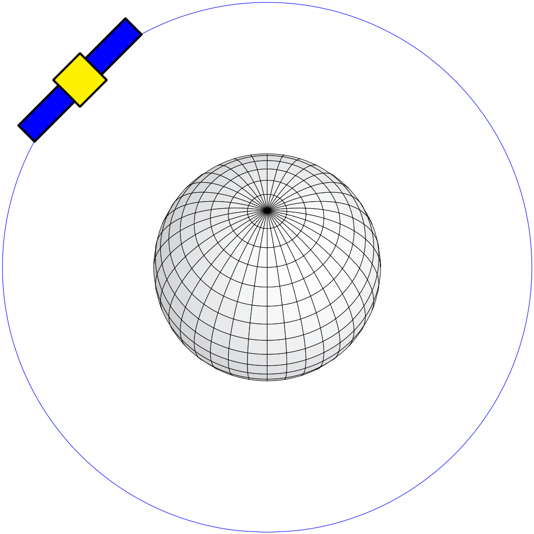

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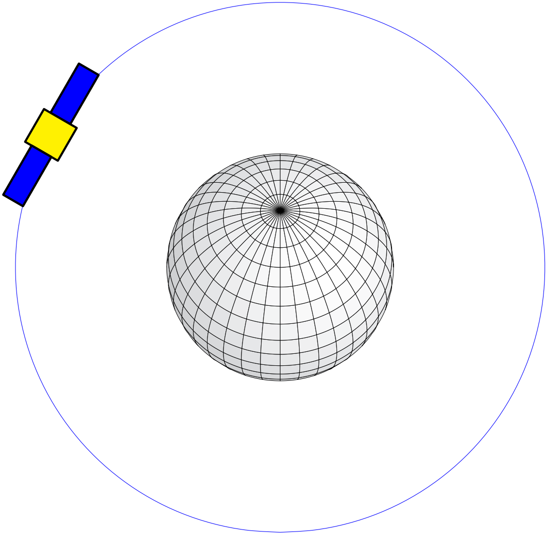

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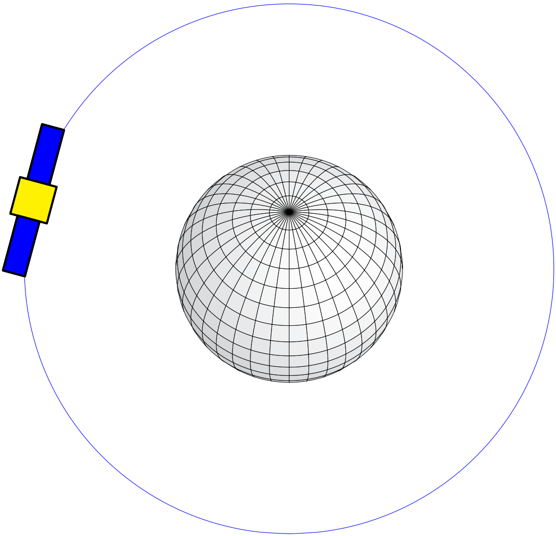

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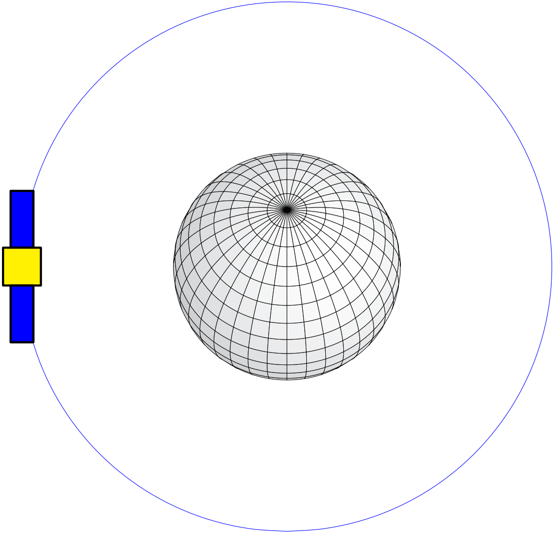

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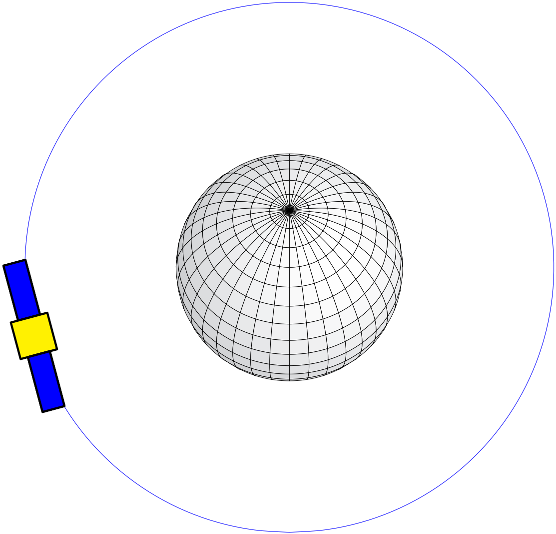

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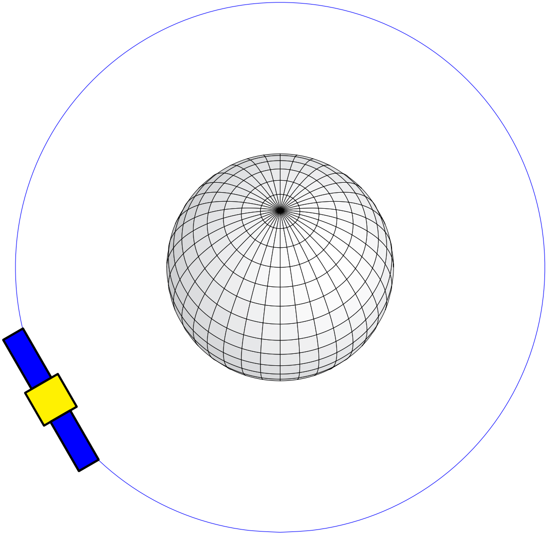

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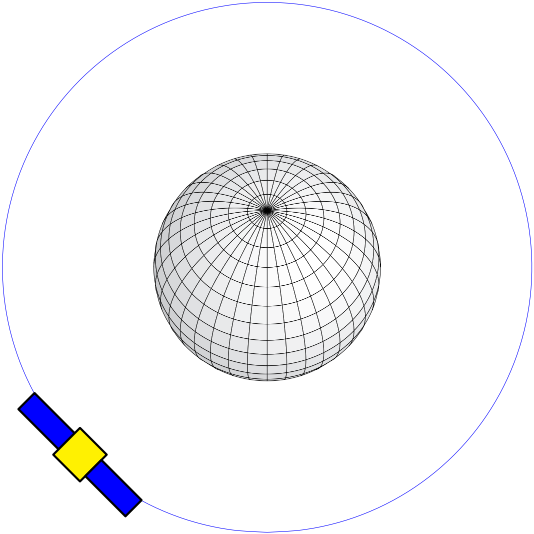

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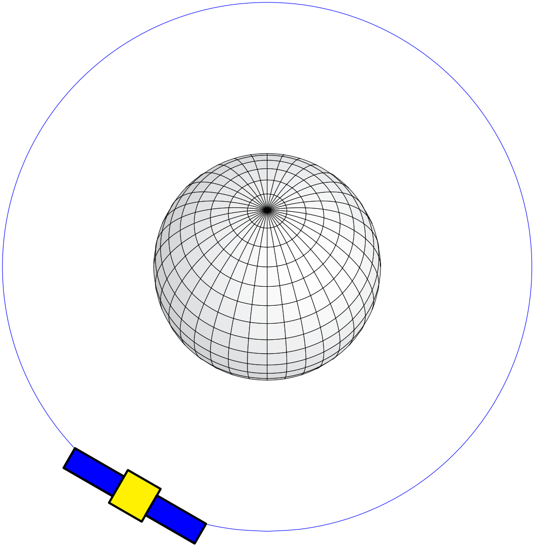

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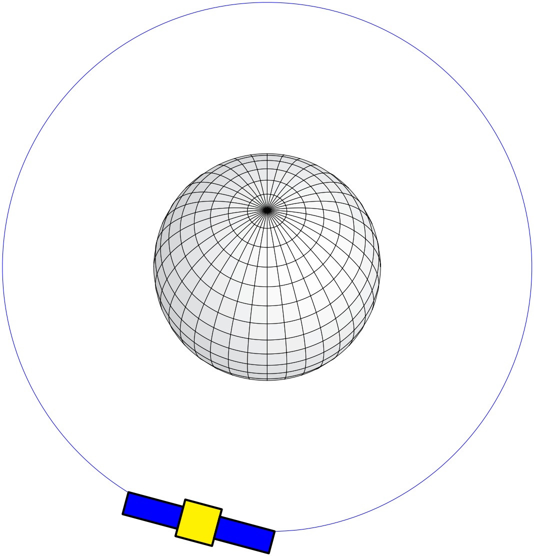

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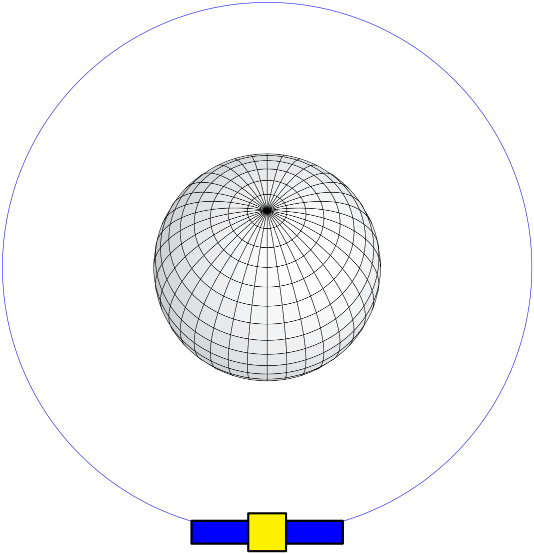

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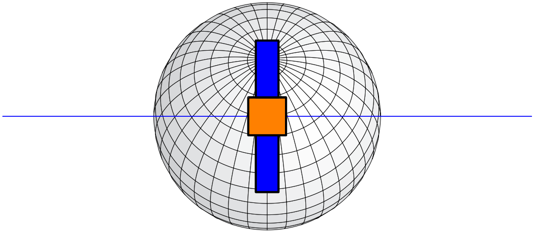

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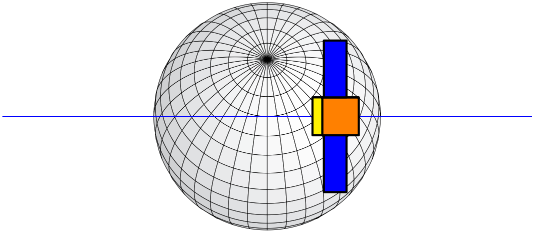

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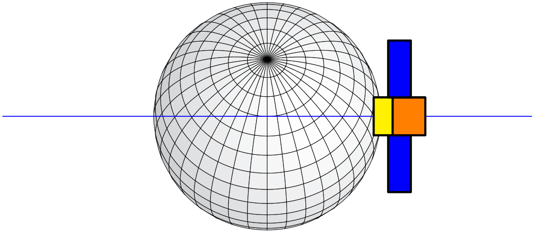

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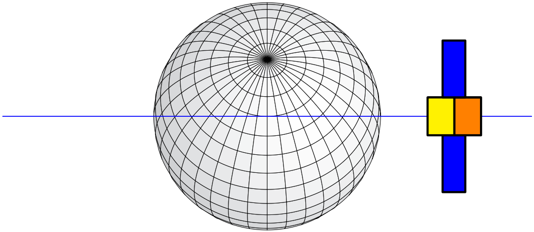

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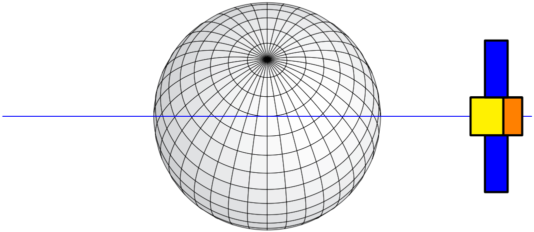

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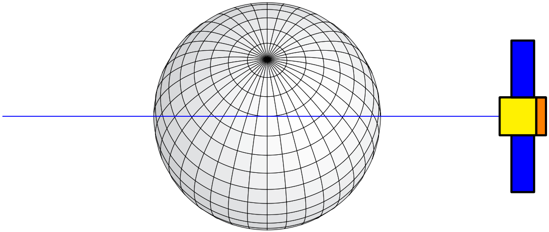

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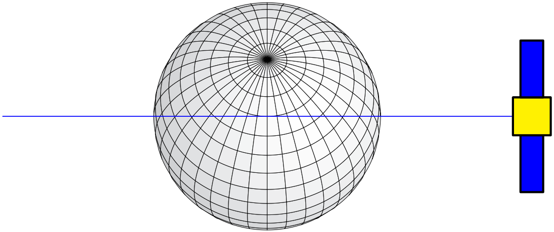

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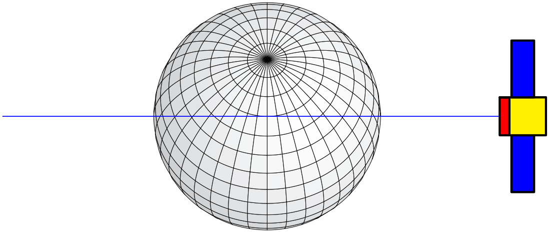

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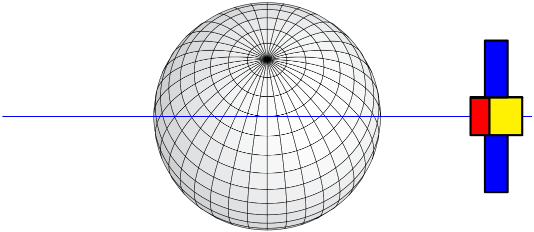

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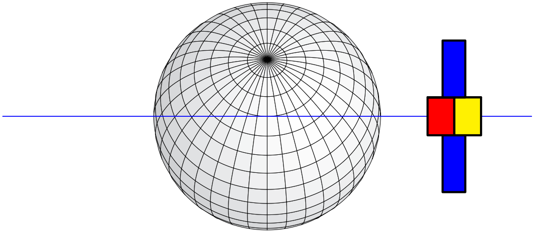

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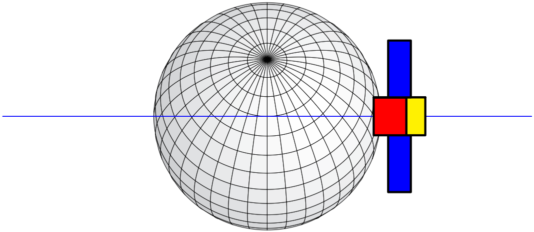

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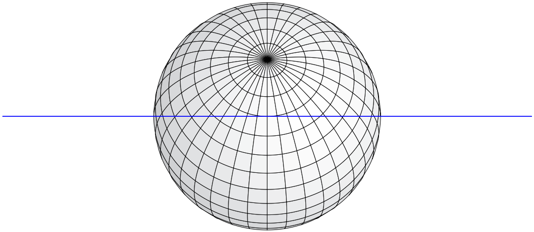

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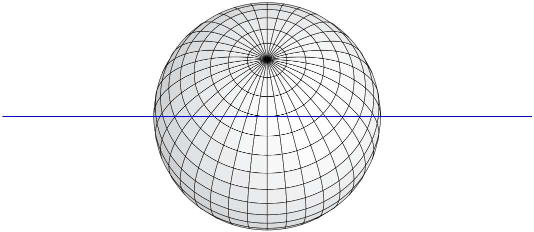

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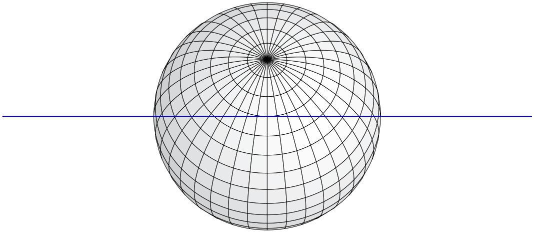

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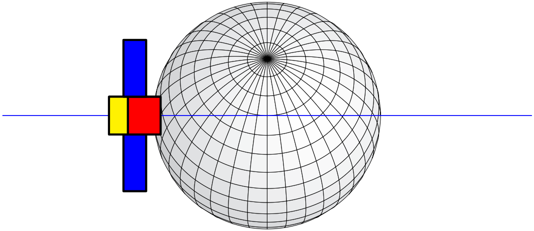

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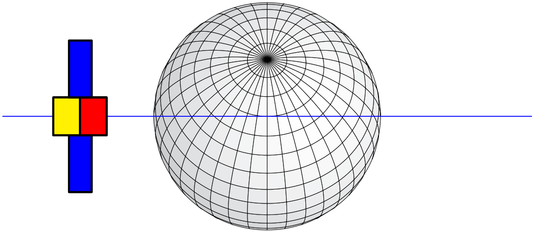

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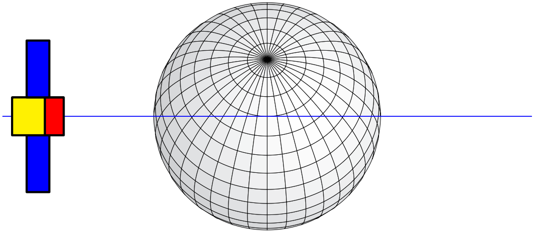

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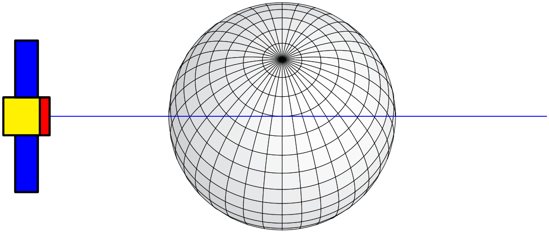

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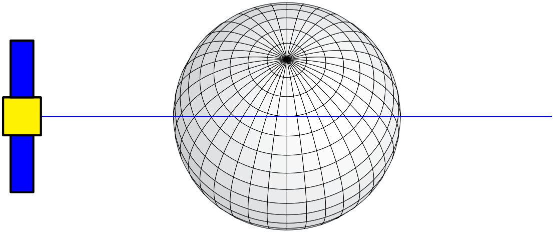

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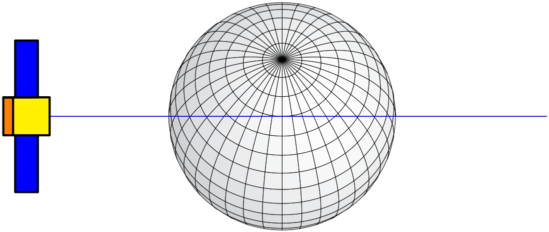

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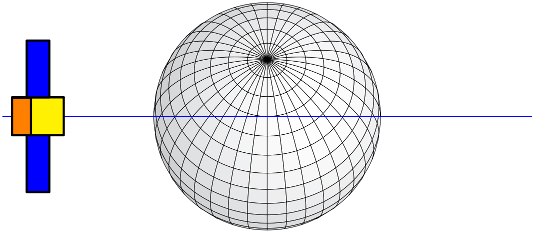

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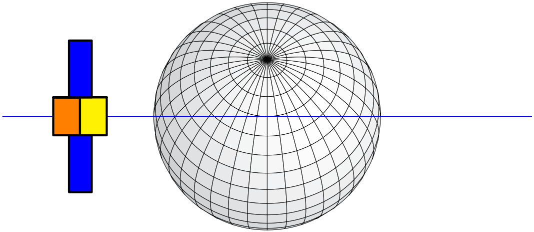

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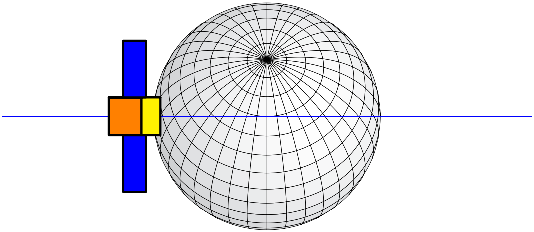

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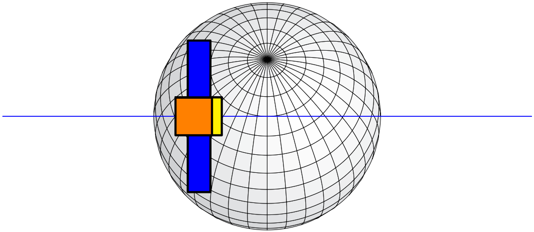

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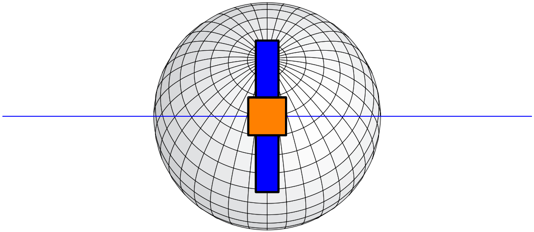

Conclusions

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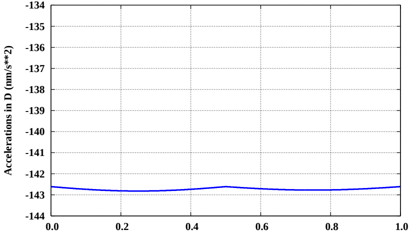
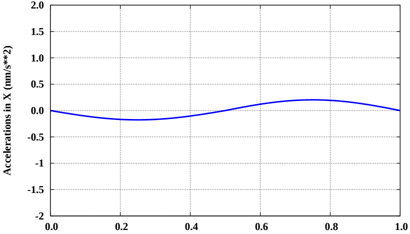
- If the Sun is perpenticular to the orbital plane no periodic solar radiation pressure perturbations are expected.
- If the Sun is located in the orbital plane a once–per–revolution signal is expected in the X–direction and a twice–per–revolution signal in the D–direction.
- These periodic signals are the more pronounced the more the satellite body deviates from a sphere
  (less for a cube – GPS – than a cylinder – GLONASS)

Accelerations derived for GLONASS satellites from a boxwing model[1]

D component



X component



Computed for $\beta = 88°$

[1] as proposed by Carlos Rodriguez–Solano for the IGS based on Ziebart (2001)

Solar radiation pressure from models

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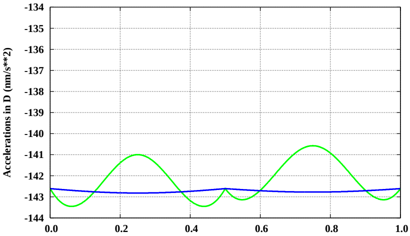

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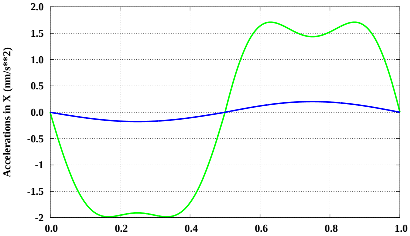
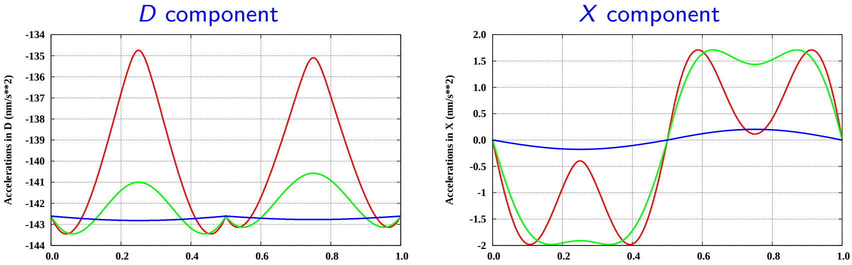


Computed for $\beta = 45°$ $\beta = 88°$

[1] as proposed by Carlos Rodriguez–Solano for the IGS based on Ziebart (2001)

Accelerations derived for GLONASS satellites from a boxwing model[1]



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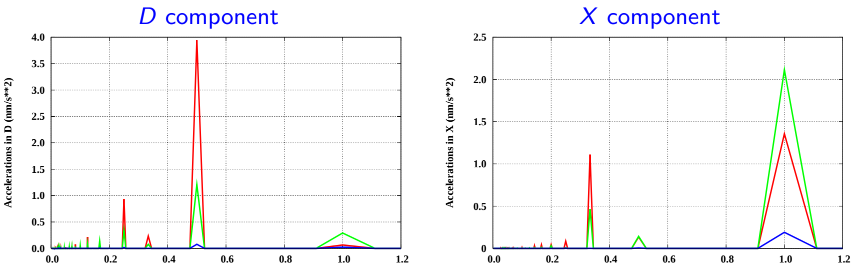

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Accelerations derived for GPS (Block IIA) satellites from a boxwing[2] and Rock-S[3] model

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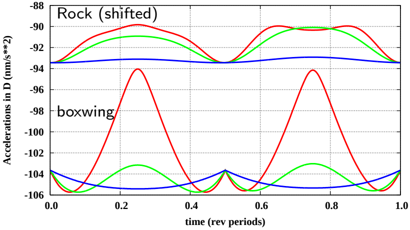
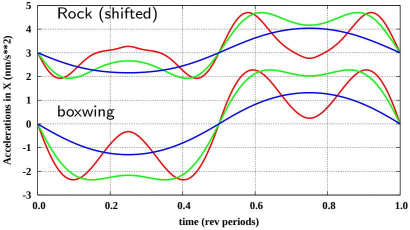


X component



Computed for $\beta = 10°$ $\beta = 45°$ $\beta = 78°$

[2] as proposed by Carlos Rodriguez–Solano based on Fliegel et al. (1992)
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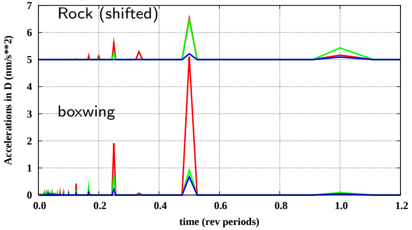
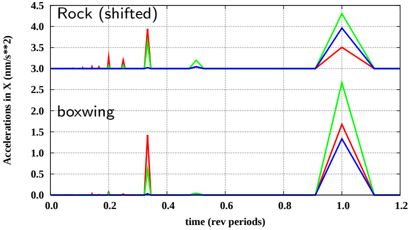


X component



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$$u' = u_{sat} - u_{Sun}$$

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$$u' = u_{sat} - u_{Sun}$$

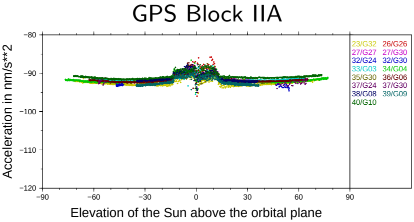
- Solar radiation pressure for satellites flying according to the previously mentioned models can be represented by:

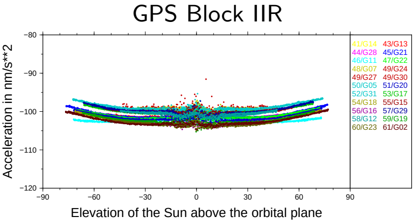
$$\begin{aligned} D &= D_0 + D_2 \cos(2u') + D_4 \cos(4u') + \ldots \\ Y &= (Y_0) \\ X &= \quad X_1 \cos(1u') + X_3 \cos(3u') + \ldots \end{aligned}$$

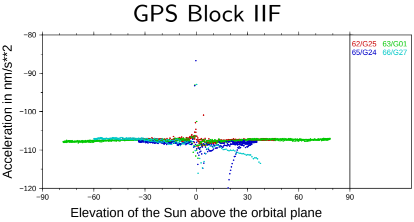
$Y_0 \neq 0$ if the satellite is flying "missaligned" with a Y–bias (e.g., GPS, except for Block IIF).

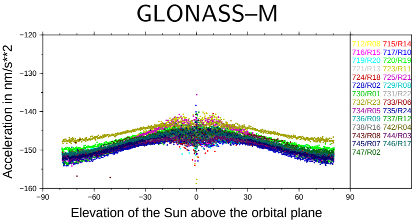
Estimated solar radiation pressure

Component: D_0



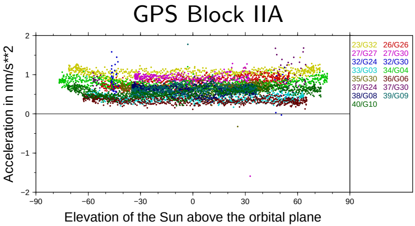


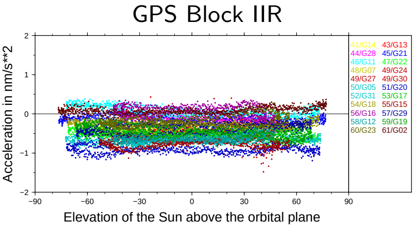


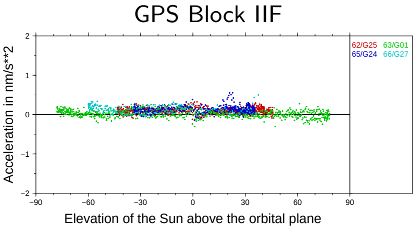


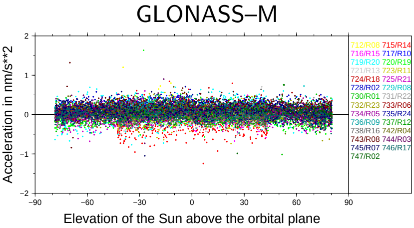
Estimated solar radiation pressure

Component: Y_0 (small scale)





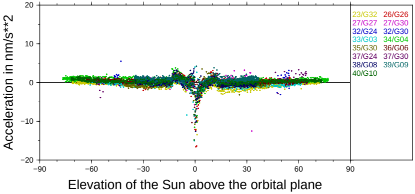




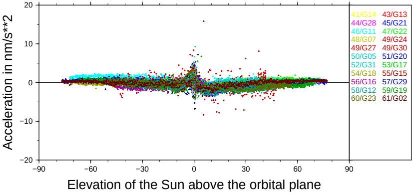
Estimated solar radiation pressure

Component: $X_1 \cdot \cos(1u')$

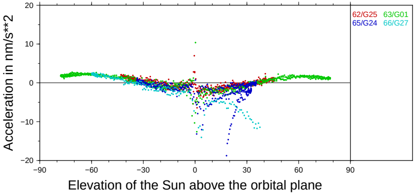
GPS Block IIA



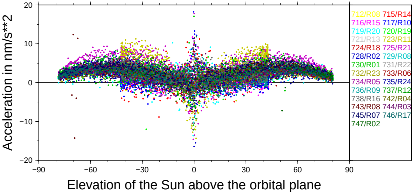
GPS Block IIR



GPS Block IIF

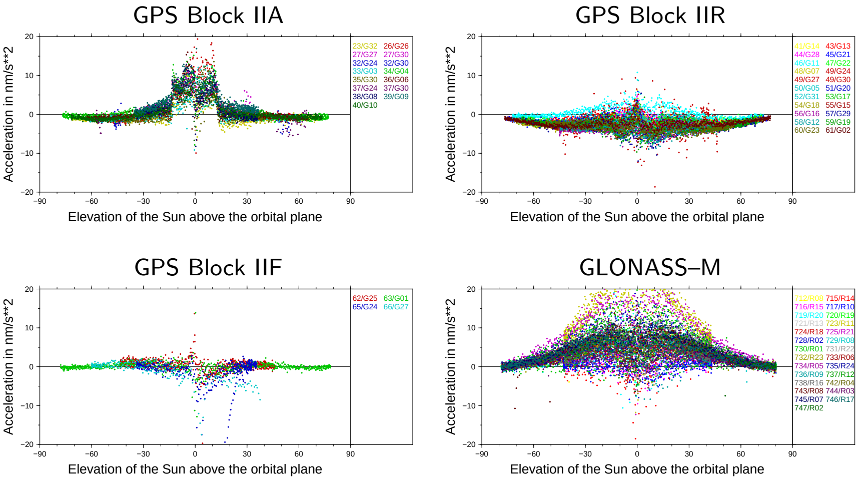


GLONASS–M



Estimated solar radiation pressure

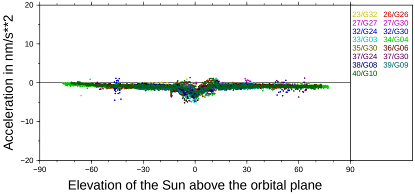
Component: $D_2 \cdot \cos(2u')$



Estimated solar radiation pressure

Component: $X_1 \cdot \sin(1u')$

GPS Block IIA



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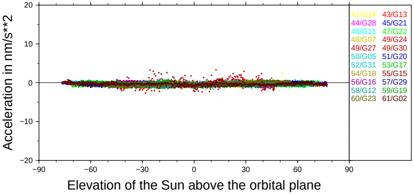

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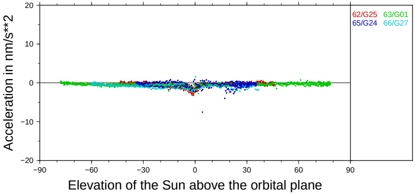
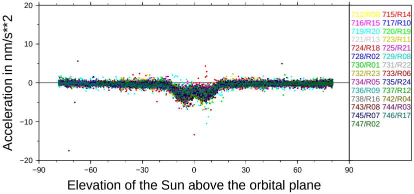


GLONASS–M



Estimated solar radiation pressure

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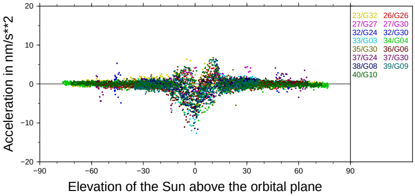
GPS Block IIA



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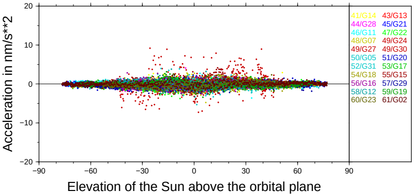
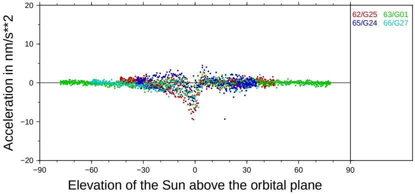
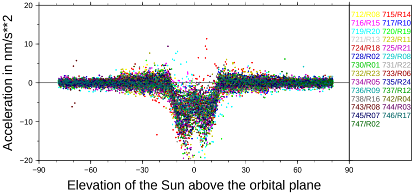


GPS Block IIF

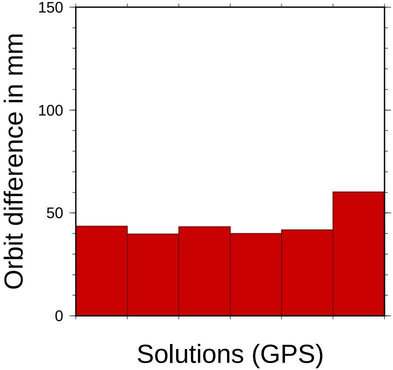


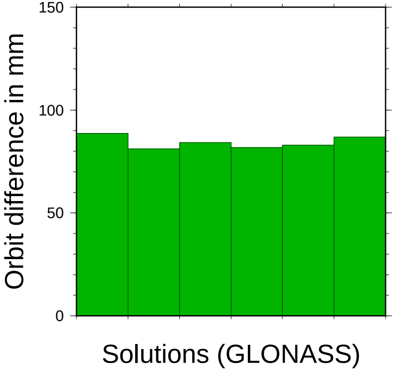
GLONASS–M



Impact on the GNSS Satellite orbits

Orbit overlaps from one–day solutions (mean over all components)





Components of the orbit model:

X

D

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Impact on the GNSS Satellite orbits

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REFAG 2014: 13-17 October, 2014 Kirchberg

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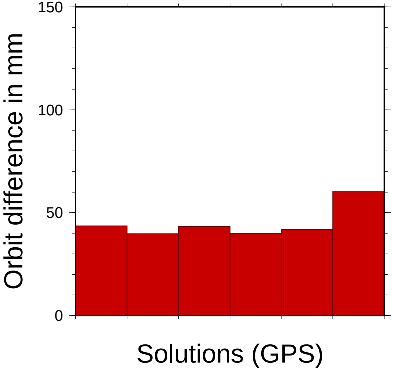
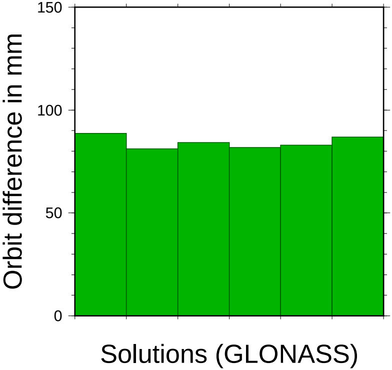


Components of the orbit model:

X $1u'$

D –



Components of the orbit model:

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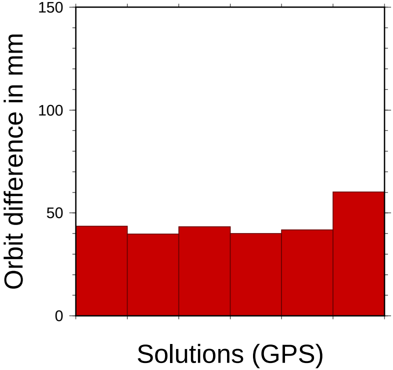
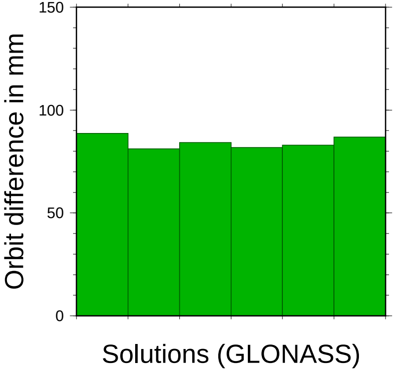


Components of the orbit model:

X $1u'$ $1u'$

D – $2u'$



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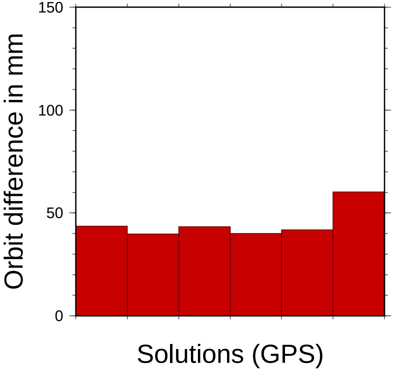

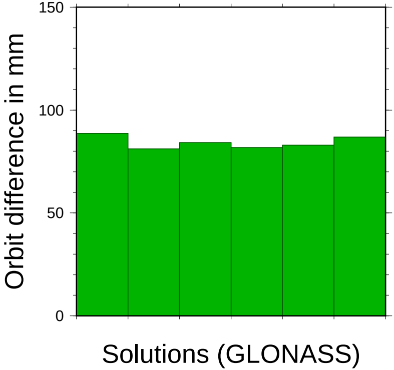

Components of the orbit model:

X	$1u'$	$1u'$	–
D	–	$2u'$	$2u'$

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Impact on the GNSS Satellite orbits

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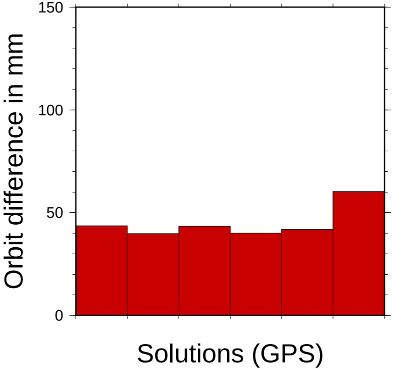
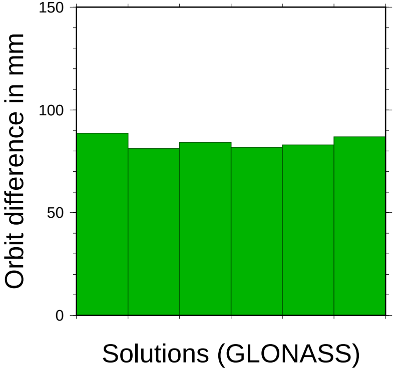


Components of the orbit model:

X	$1u'$	$1u'$	–	$1u'$
D	–	$2u'$	$2u'$	$2u'$ $4u'$



Components of the orbit model:

X	$1u'$	$1u'$	–	$1u'$
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Impact on the GNSS Satellite orbits

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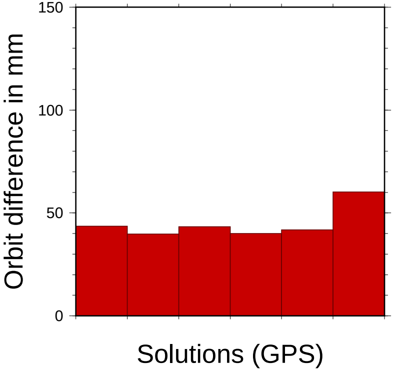
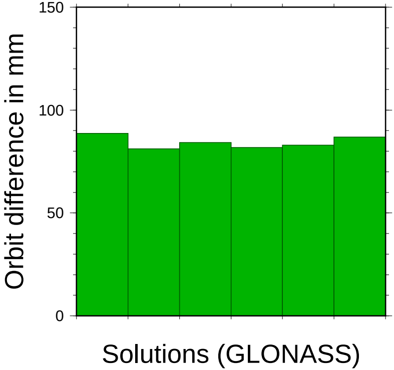


Components of the orbit model:

X	$1u'$	$1u'$	–	$1u'$	$1u'$ $3u'$
D	–	$2u'$	$2u'$	$2u'$ $4u'$	$2u'$



Components of the orbit model:

X	$1u'$	$1u'$	–	$1u'$	$1u'$ $3u'$
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Impact on the GNSS Satellite orbits

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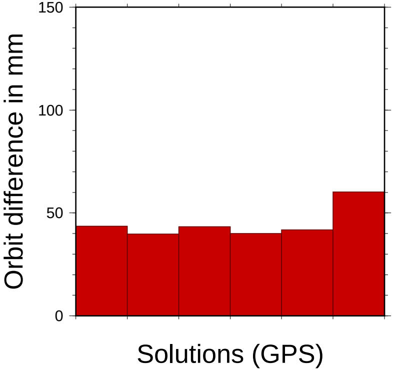
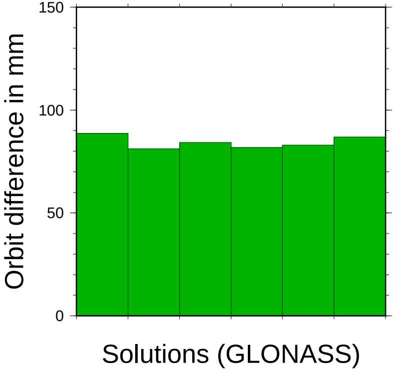


Components of the orbit model:

X	$1u'$	$1u'$	–	$1u'$	$1u'$ $3u'$	$1u'$ $3u'$
D	–	$2u'$	$2u'$	$2u'$ $4u'$	$2u'$	$2u'$ (cos)



Components of the orbit model:

X	$1u'$	$1u'$	–	$1u'$	$1u'$ $3u'$	$1u'$ $3u'$
D	–	$2u'$	$2u'$	$2u'$ $4u'$	$2u'$	$2u'$ (cos)

Conclusions

- The new definition of the angular argument ($u' = u_{sat} - u_{Sun}$ instead of u_{sat}) allows it to better interpret of estimated parameter series, e.g., w.r.t. the elevation of the Sun above the orbital plane.

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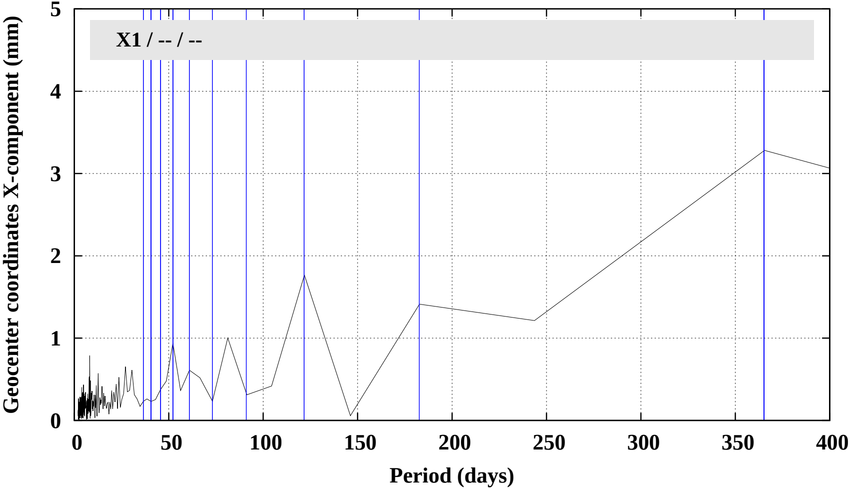
Impact on the GNSS Satellite orbits

Conclusions

- The new definition of the angular argument ($u' = u_{sat} - u_{Sun}$ instead of u_{sat}) allows it to better interpret of estimated parameter series, e.g., w.r.t. the elevation of the Sun above the orbital plane.
- Adding twice–per–revolution terms in D-component improves the orbit solution.
- Even if the sin-terms are not necessary according to theory they are needed for representing real satellite trajectories.

Impact on the Geocenter Estimates

Spectra from geocenter estimates: X component



Impact on the Geocenter Estimates

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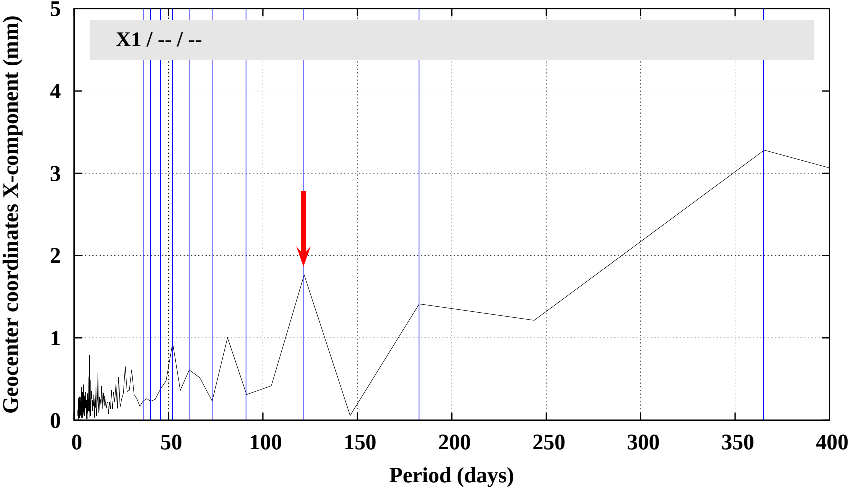

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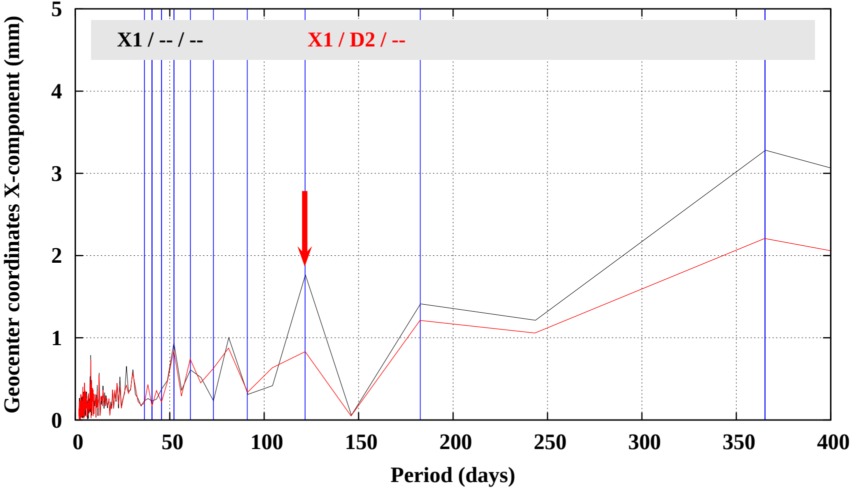

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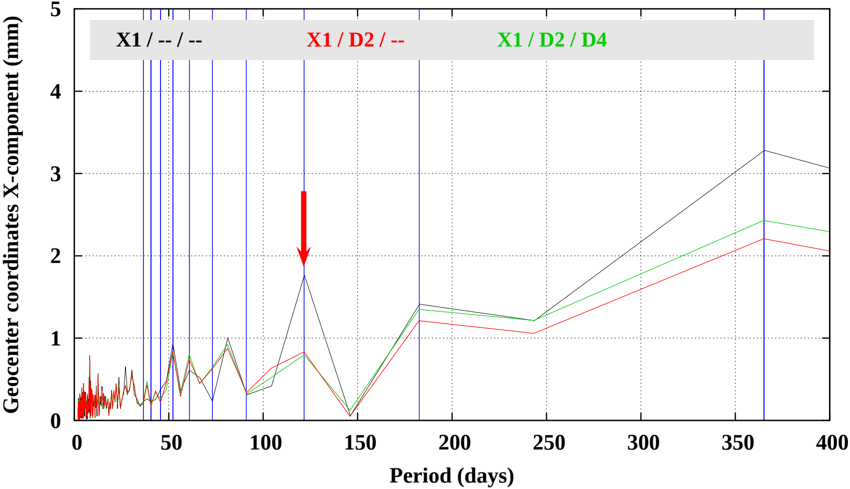

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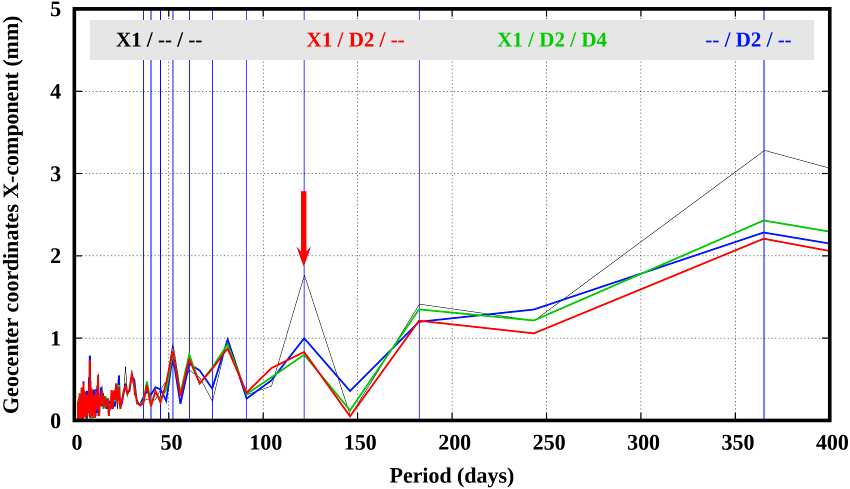

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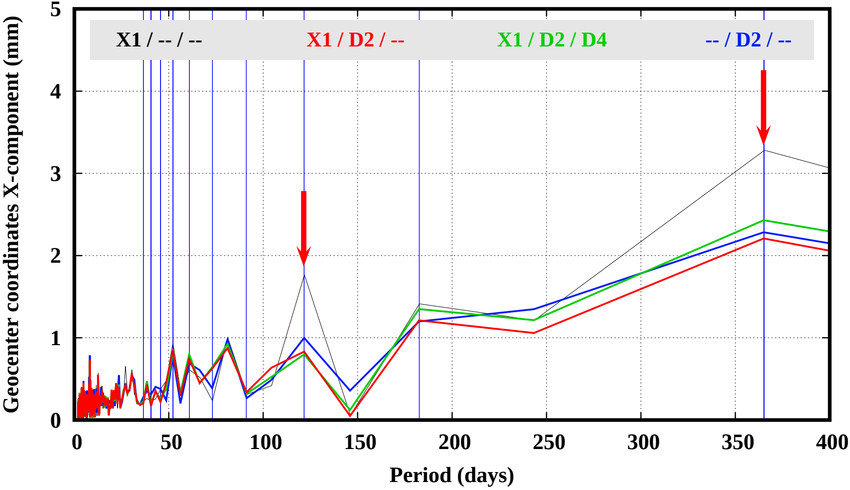
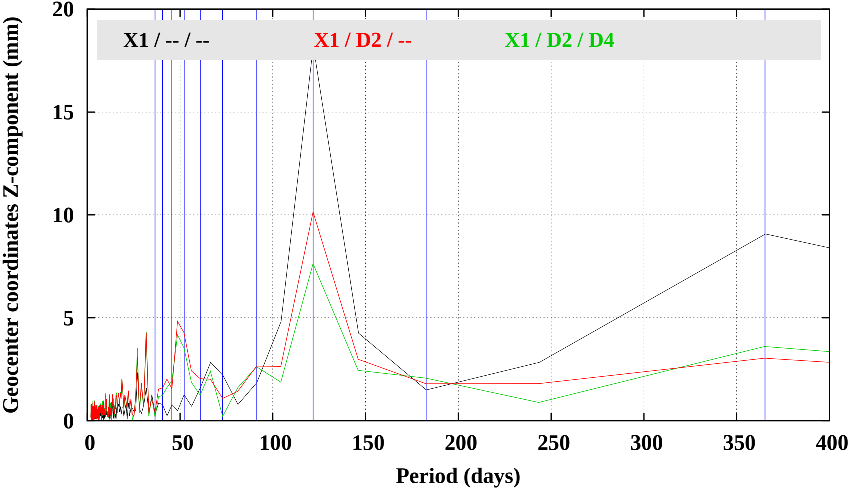


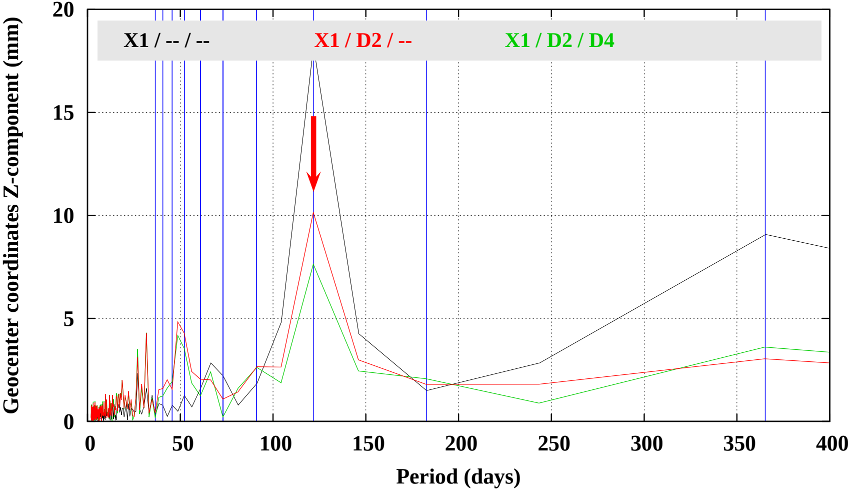
Impact on the Geocenter Estimates

Spectra from geocenter estimates: Z component



Impact on the Geocenter Estimates

Spectra from geocenter estimates: Z component



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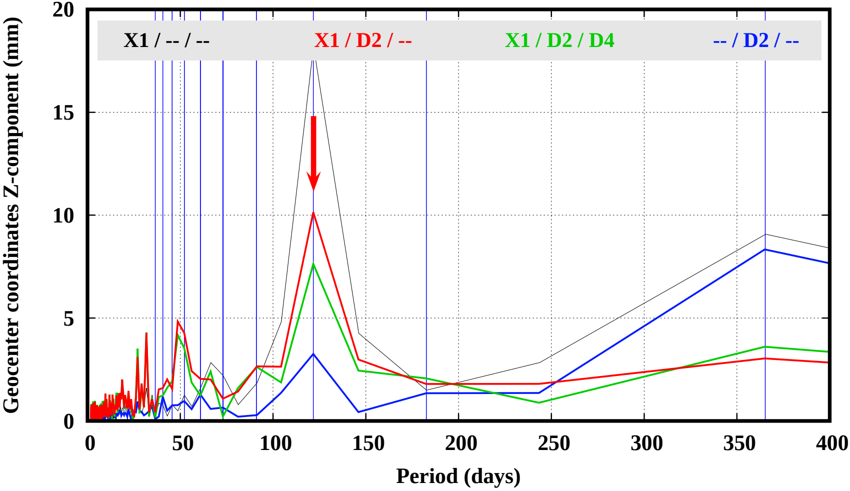
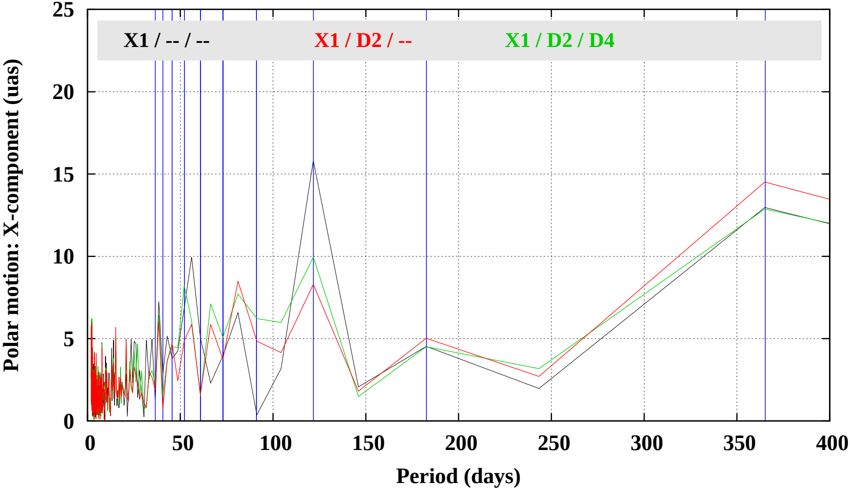


Impact on the Earth Rotation Parameters

Spectra from ERP solution: Polar motion – X



Differences w.r.t. IERS C04 series (related to ITRF2008) has been analysed.

Impact on the Earth Rotation Parameters

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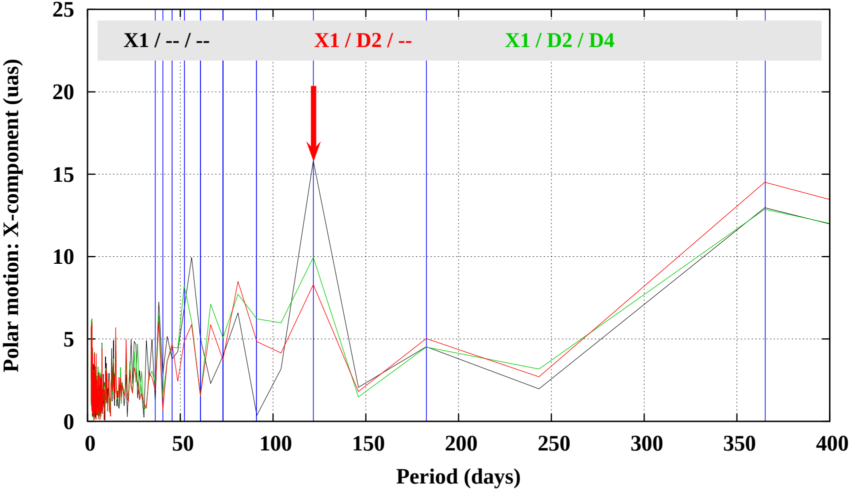

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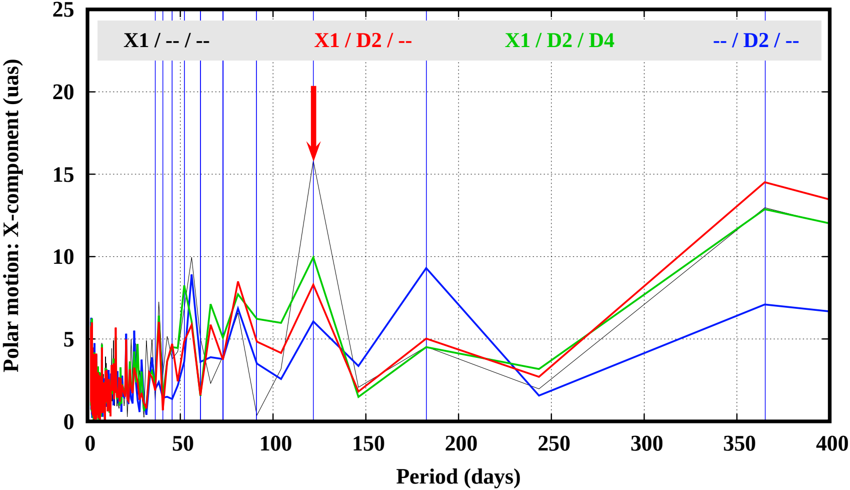

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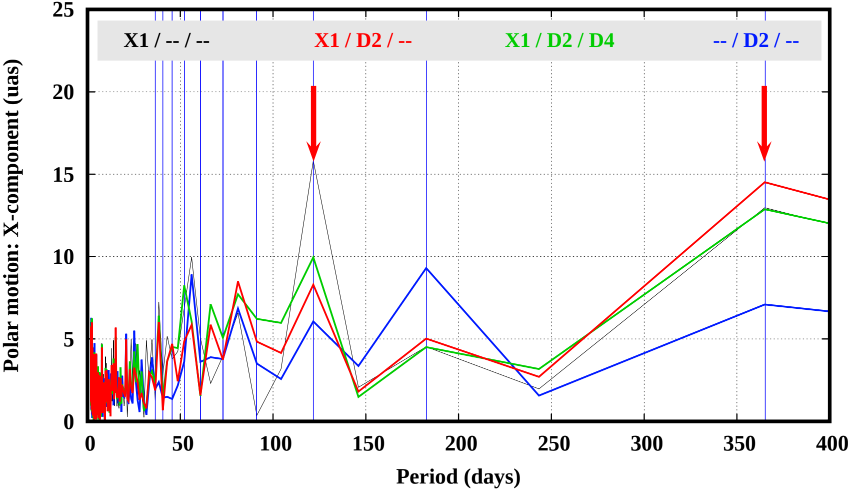

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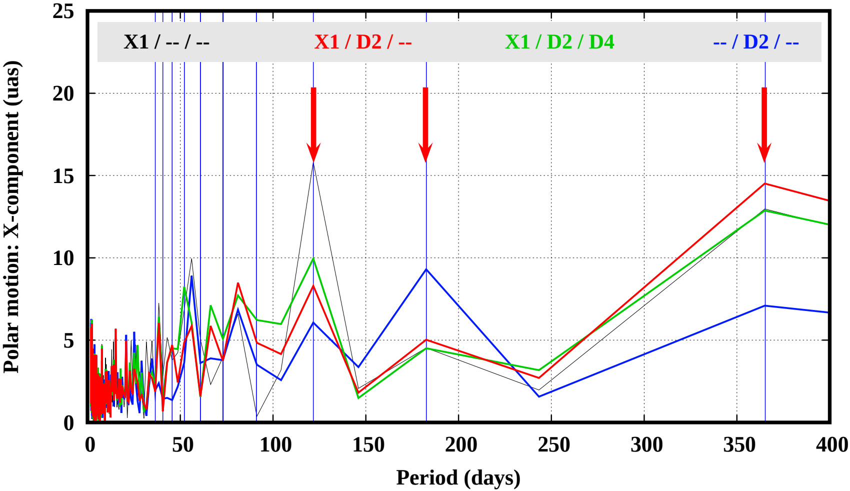

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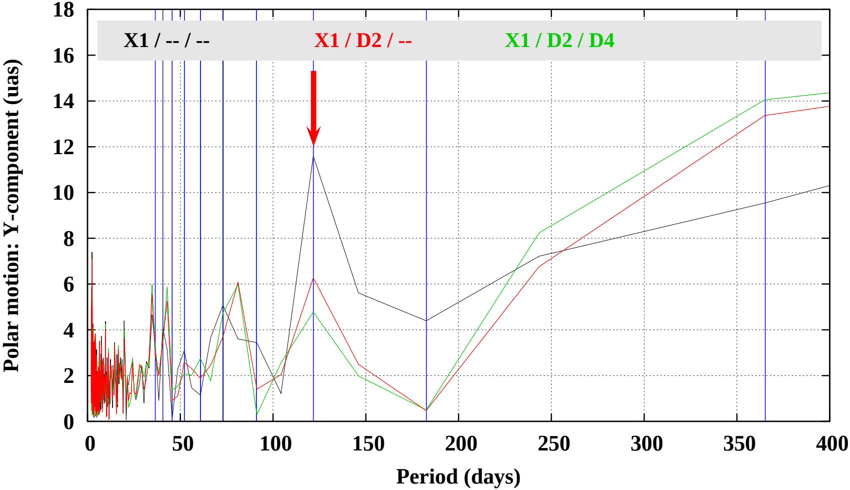
Impact on the Earth Rotation Parameters

Spectra from ERP solution: Polar motion – Y



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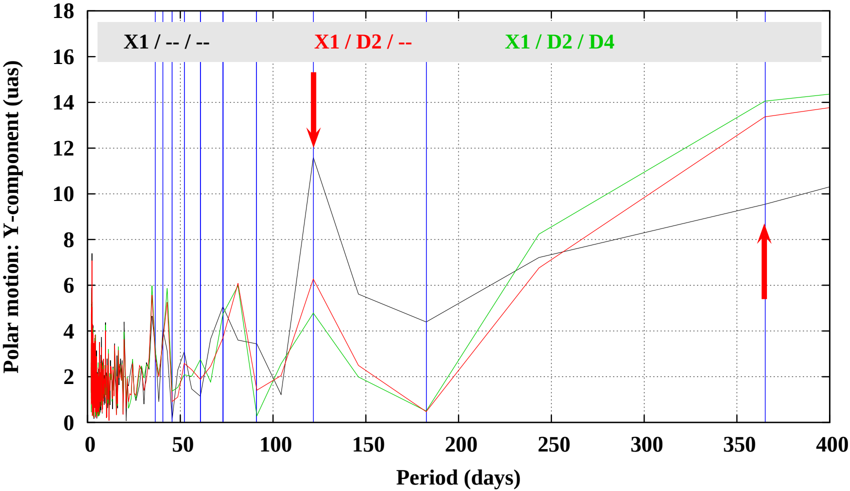
Impact on the Earth Rotation Parameters

Spectra from ERP solution: Polar motion – Y



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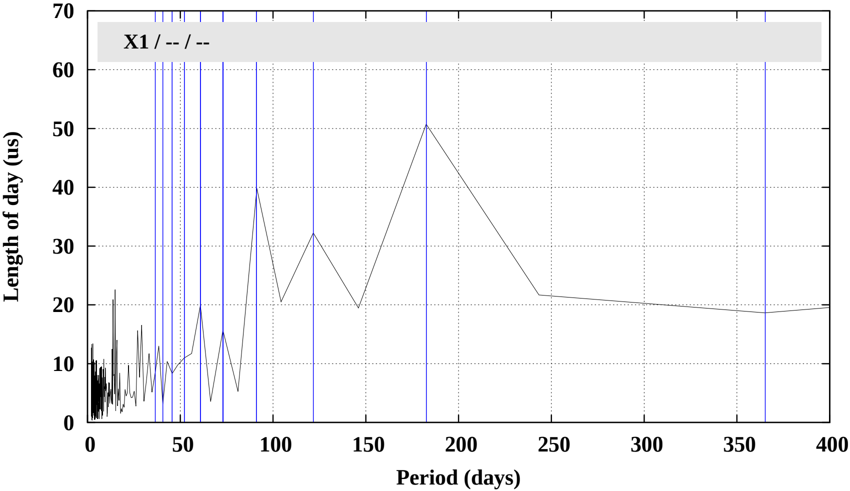
Impact on the Earth Rotation Parameters

Spectra from ERP solution: length of day



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Impact on the Earth Rotation Parameters

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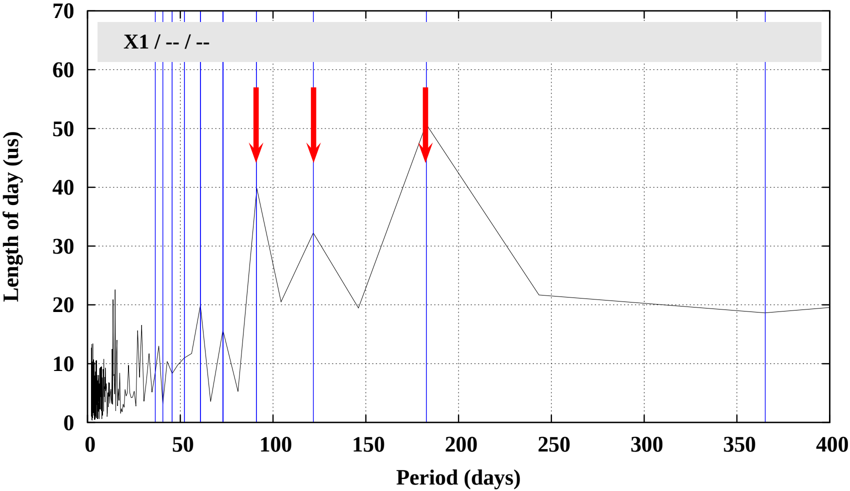

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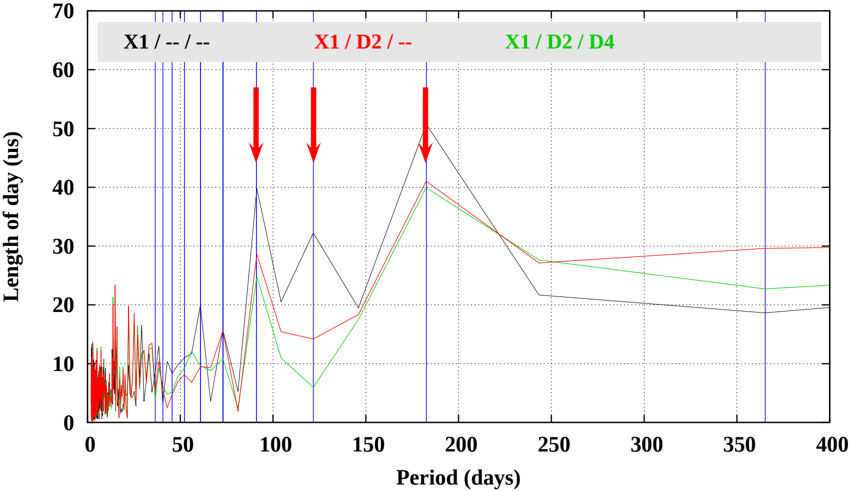

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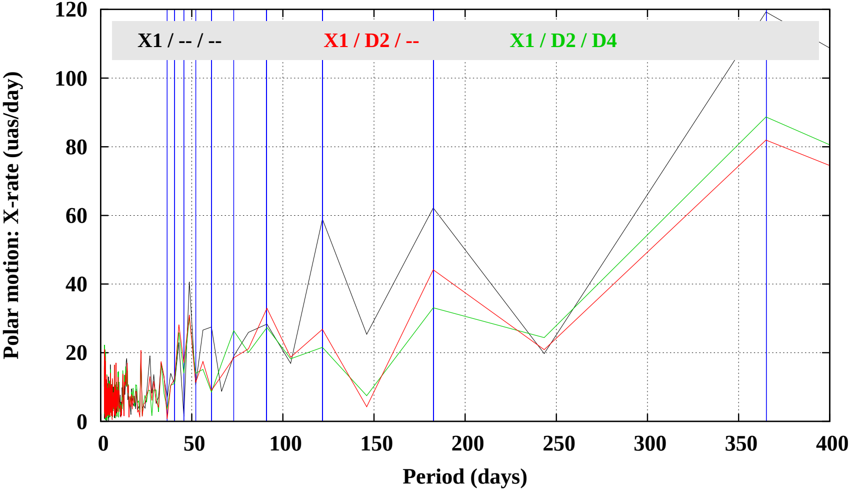
Impact on the Earth Rotation Parameters

Spectra from ERP solution: Polar motion – X rate



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Impact on the Earth Rotation Parameters

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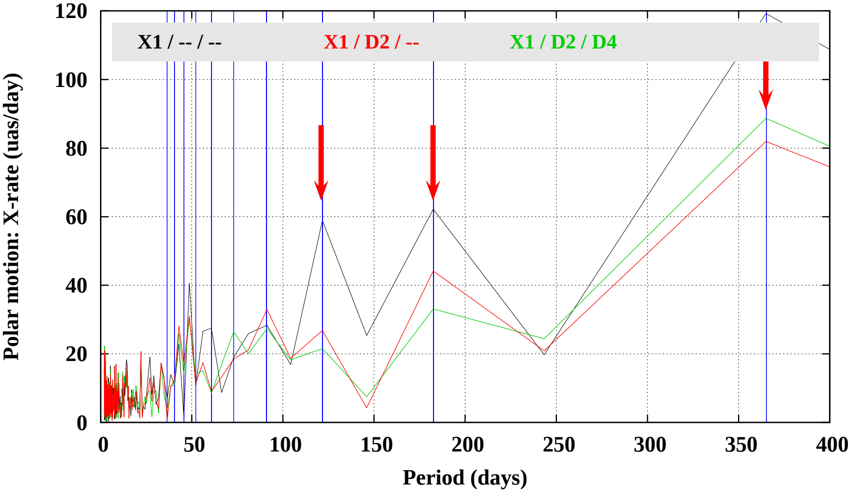

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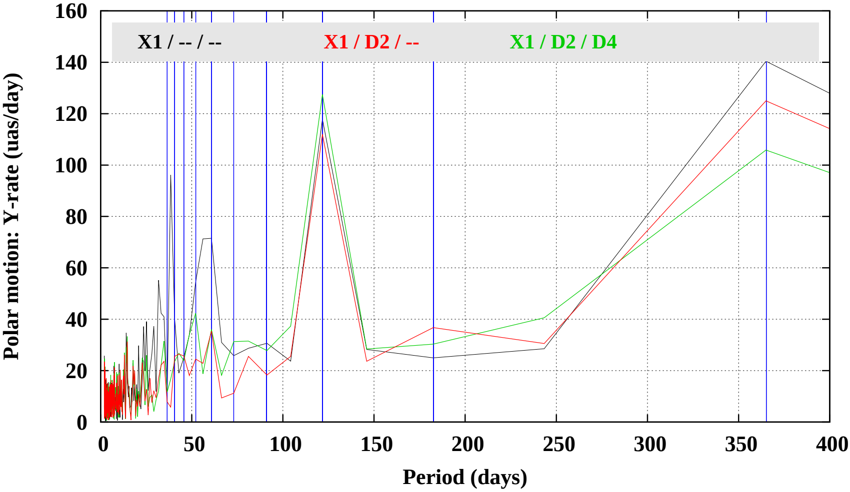

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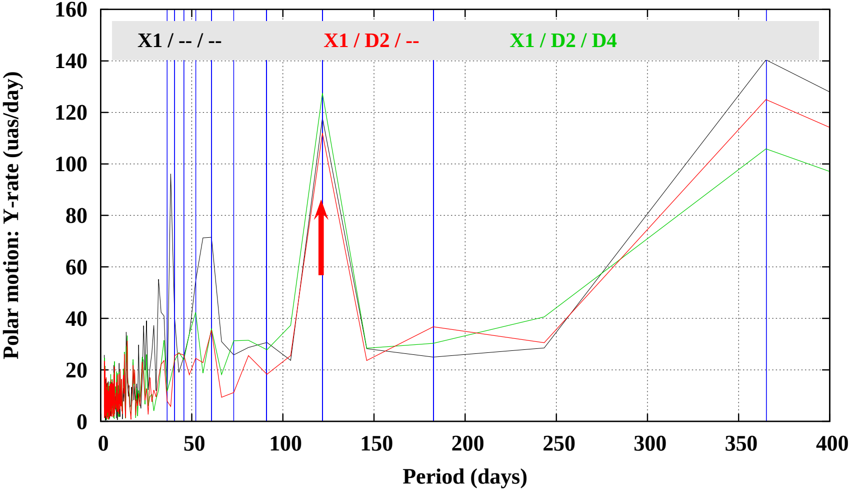

Differences w.r.t. IERS C04 series (related to ITRF2008) has been analysed.

Conclusions

- The different orbit parametrizations have no impact on the station coordinate time series after applying the seven datum parameters (that's why not shown here).

Impact on the Reference Frame Parameters

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- The most promising orbit parameter setup is: X_1, D_2 (and D_4).

Long–Arc Solutions

Strategy for the long-arc solution

Classical approach to generate three–day solutions at CODE:

NEQ from day -1	NEQ from day ± 0	NEQ from day $+1$
ORB	ORB	ORB
ERP	ERP	ERP
CRD	CRD	CRD
TRP	TRP	TRP
⋮	⋮	⋮

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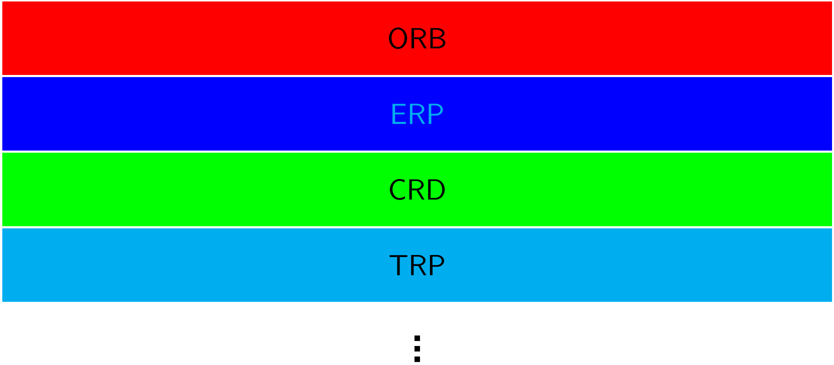

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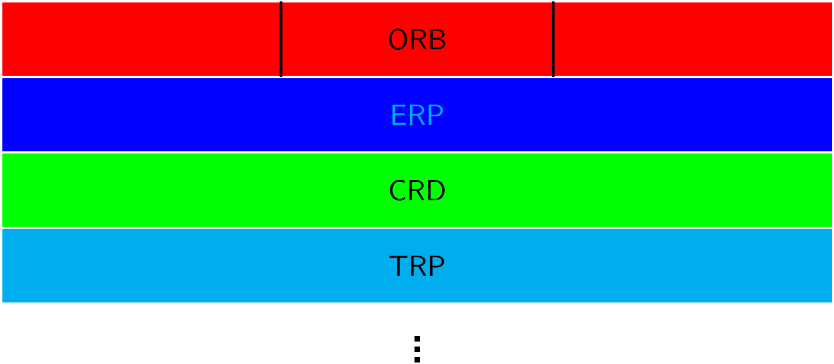

Long–Arc Solutions

Strategy for the long-arc solution

Alternative approach for a three–day long–arc solutions:

NEQ from day -1	NEQ from day ± 0	NEQ from day $+1$
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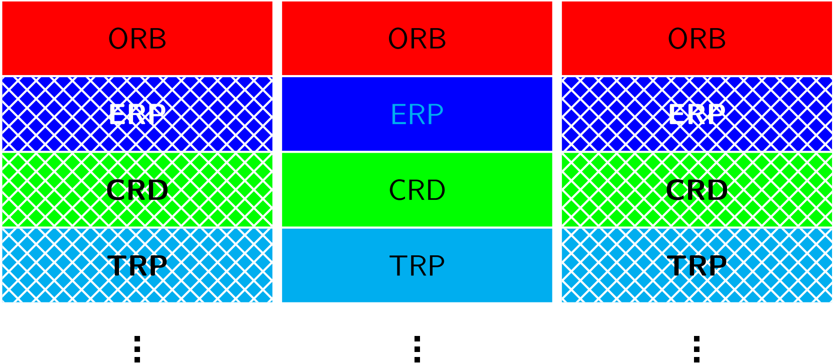

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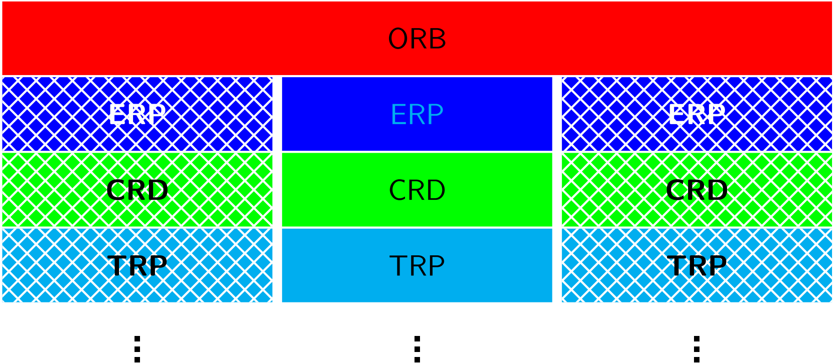

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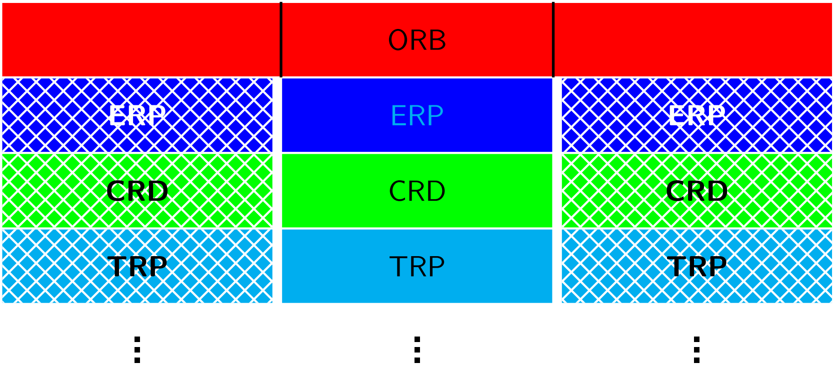
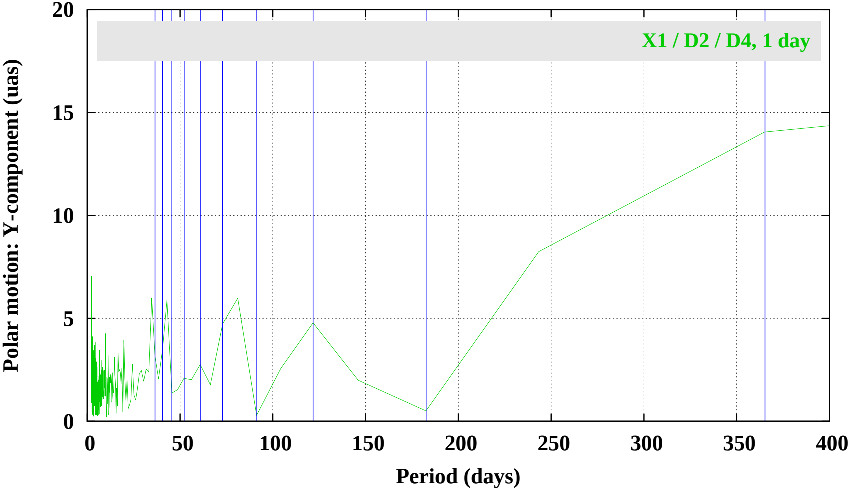


Impact on the Earth Rotation Parameters

Spectra from ERP solution: Polar motion – Y



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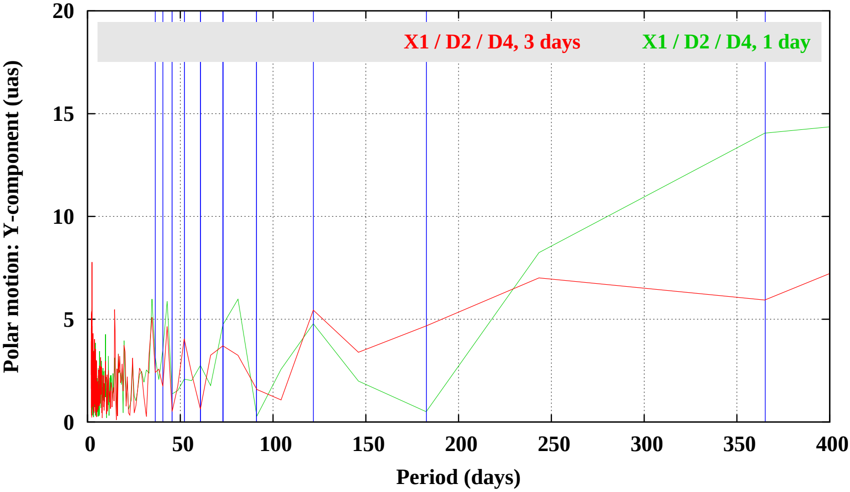

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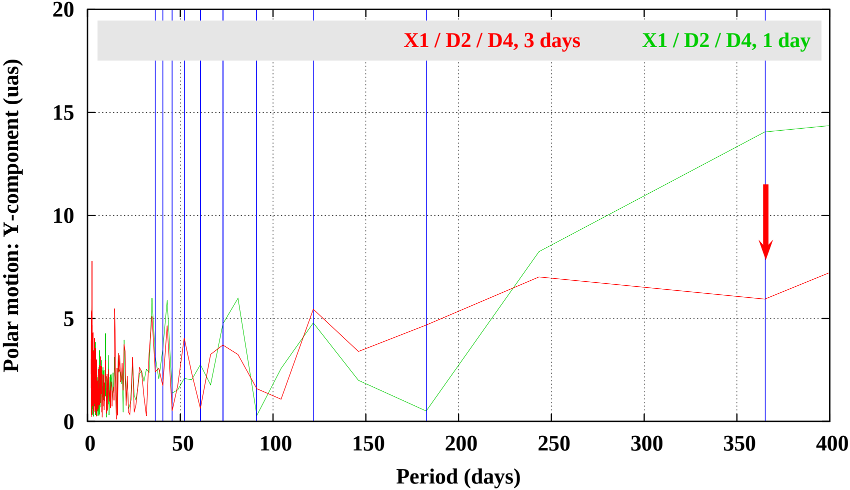

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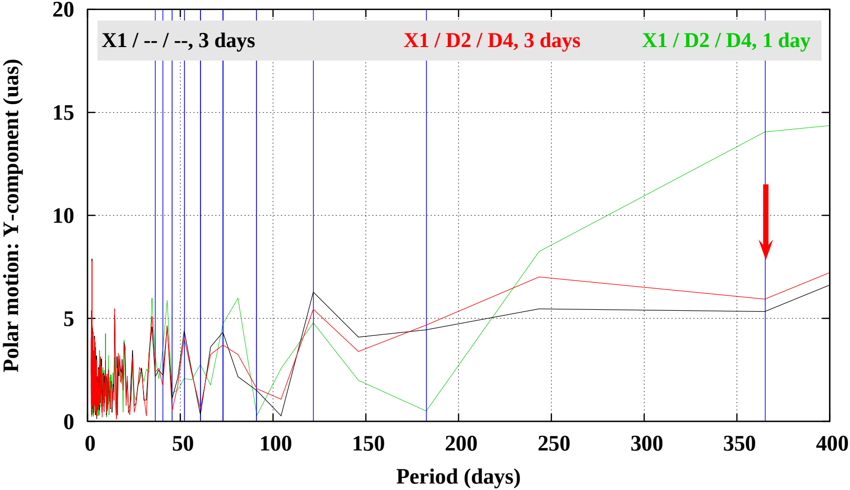

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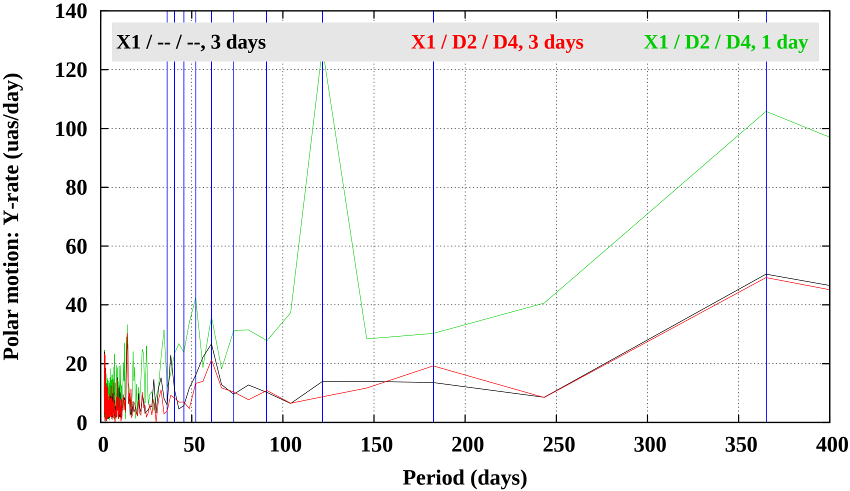

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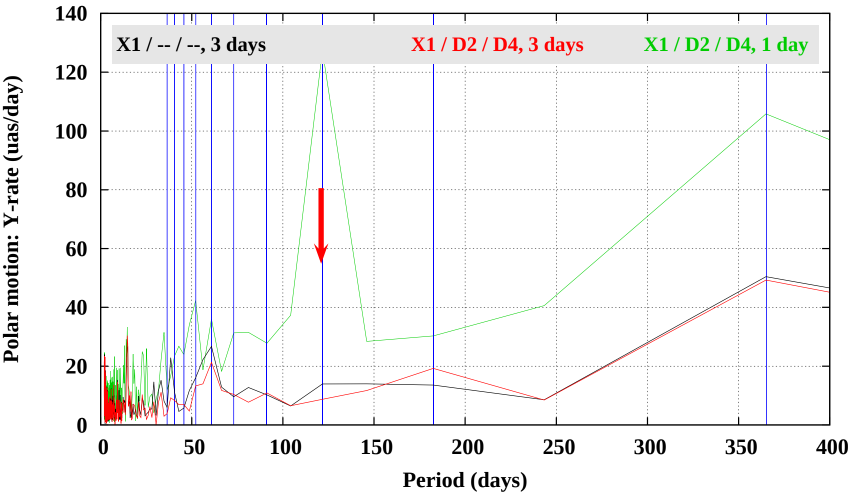

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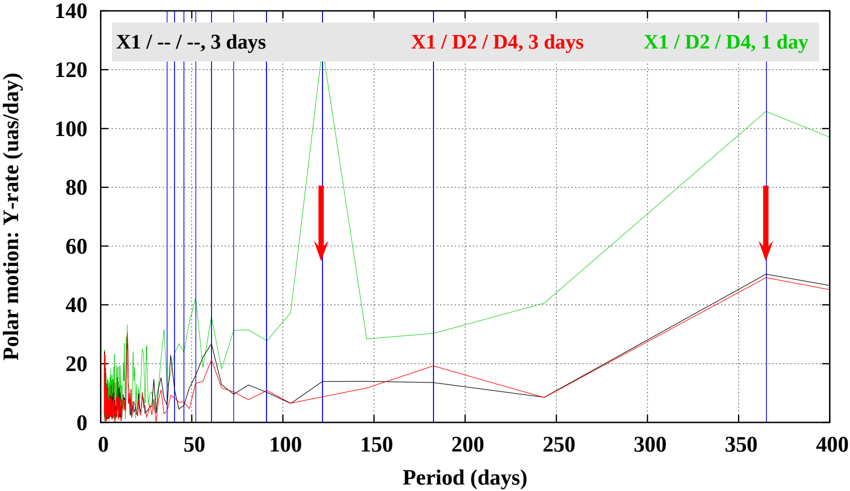

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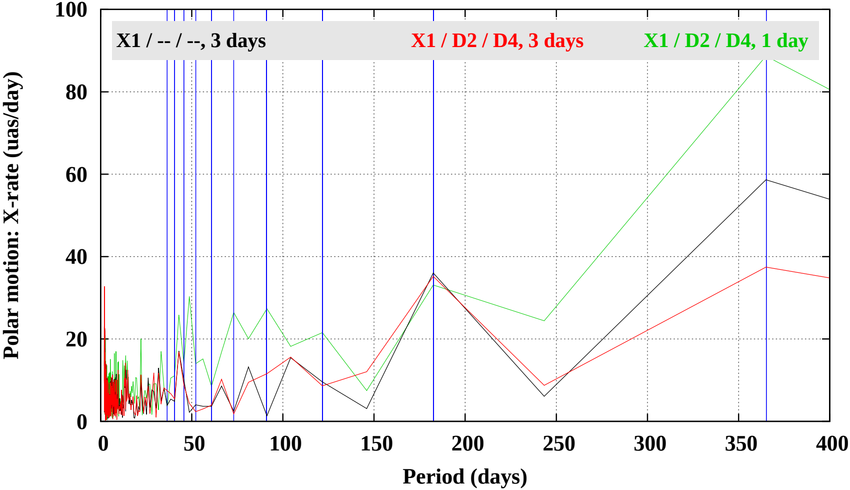

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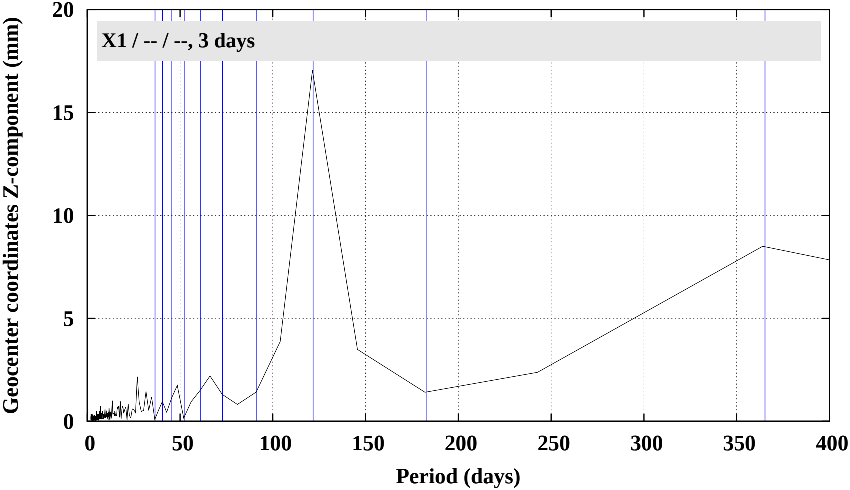
Impact on the Geocenter Estimates

Spectra from geocenter estimates: Z component



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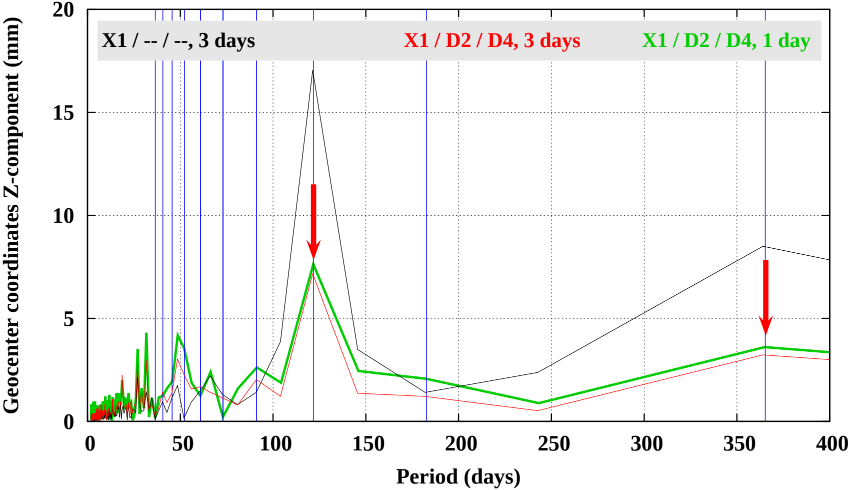

Conclusions

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Long–Arc Solutions

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- The improvement for the rates in polar motion ($\dot{X}$ and $\dot{Y}$) and in the length of day component are remarkable.
- In the geocenter series the orbit paramtrization is more important than the arc length.
- **CODE is currently preparing the transfer of this new orbit model into its operational IGS processing.**

THANK YOU
for your attention

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