

GLONASS Satellite Orbit Modelling

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D. Arnold¹, L. Prange¹, S. Schaer^{1,2}, A. Jäggi¹

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IGS Workshop

Session #08: Orbit Modelling

03–07. July 2017, Paris, France

Overview

Motivation

Investigating indicators for orbit characteristics

Estimating satellite antenna offsets

Applying the estimated satellite antenna offsets

Discussion and summary

Motivation



PS07-10: U. Meyer, Y. Jean, D. Arnold, A. Jäggi

EGSIEM: scientific combination service for monthly gravity fields

Motivation



GNSS Reprocessing in 2015:

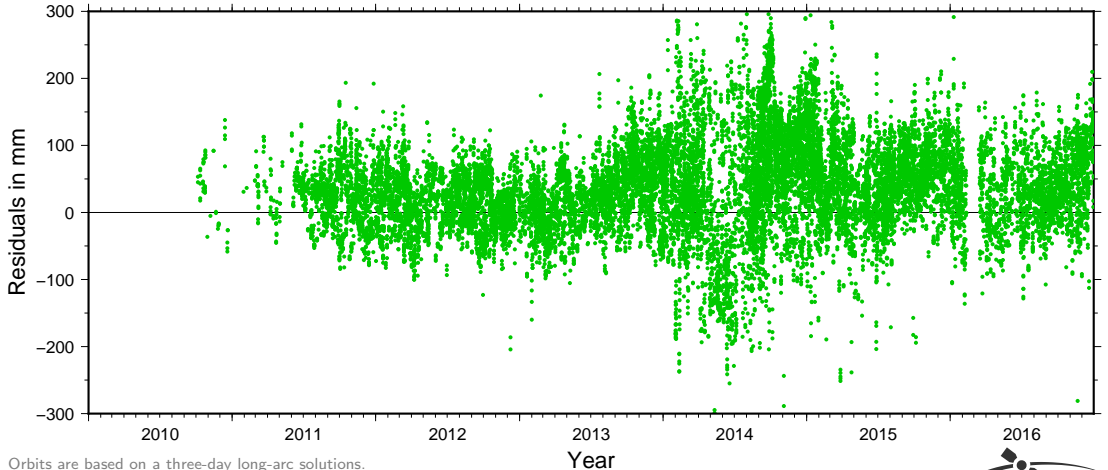
Product availability:

	GPS	GLONASS
GNSS satellite orbits:	since 1994	since 2002
GNSS satellite clock corrections:		
sampling 30 s:	since 2000	since 2008
sampling 5 s:	since 2003	since 2010

PS08-04: A. Sušnik, D. Arnold, A. Villiger, R. Dach, A. Jäggi
Validating EGSIEM Reprocessing Products by LEO POD and PPP

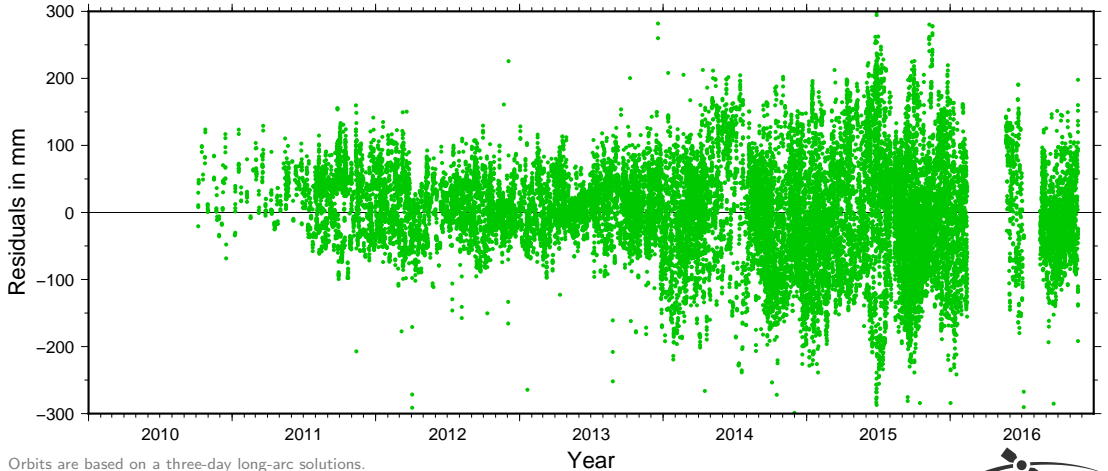
Motivation

SLR residuals for satellite SVN 736 (R09/R16)



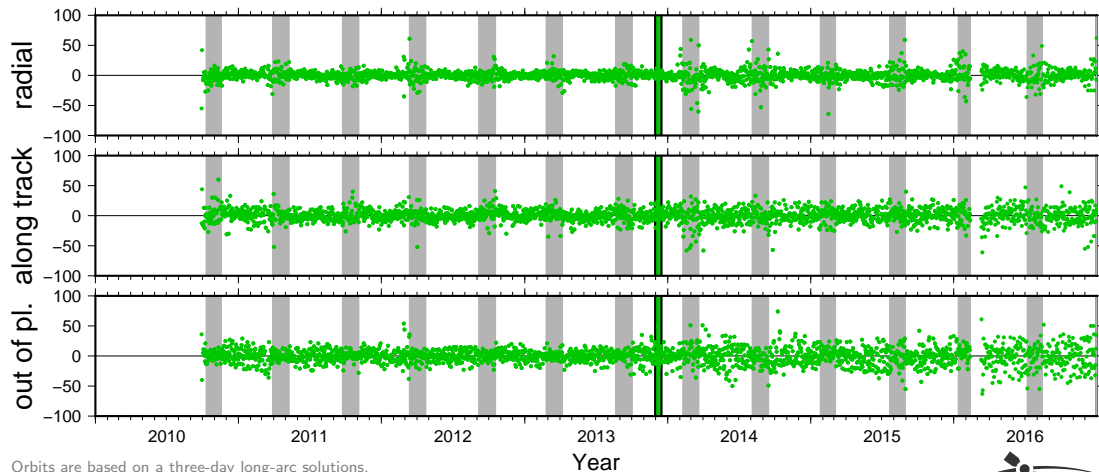
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SLR residuals for satellite SVN 737 (R12)



Investigating indicators for orbit characteristics

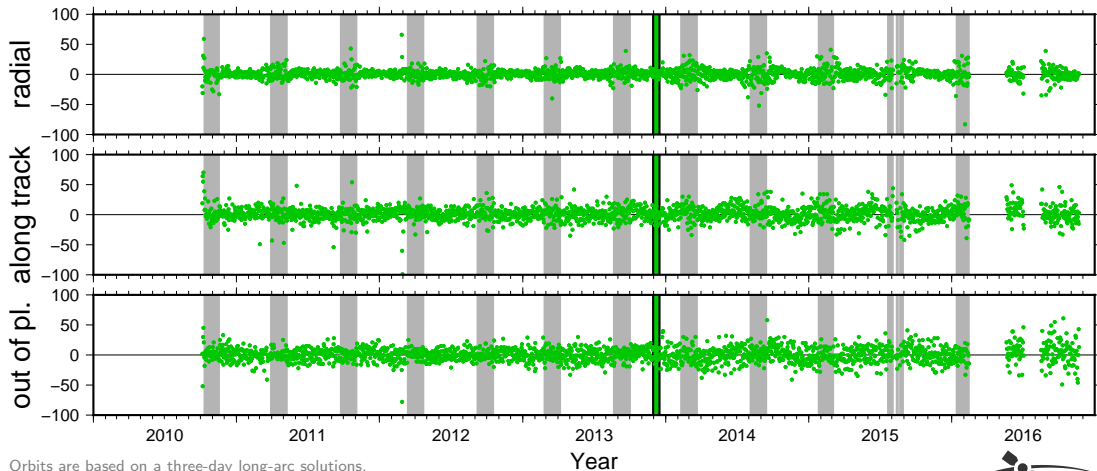
Orbit misclosures for satellite SVN 736 (R09/R16) in mm



Orbits are based on a three-day long-arc solutions.

Investigating indicators for orbit characteristics

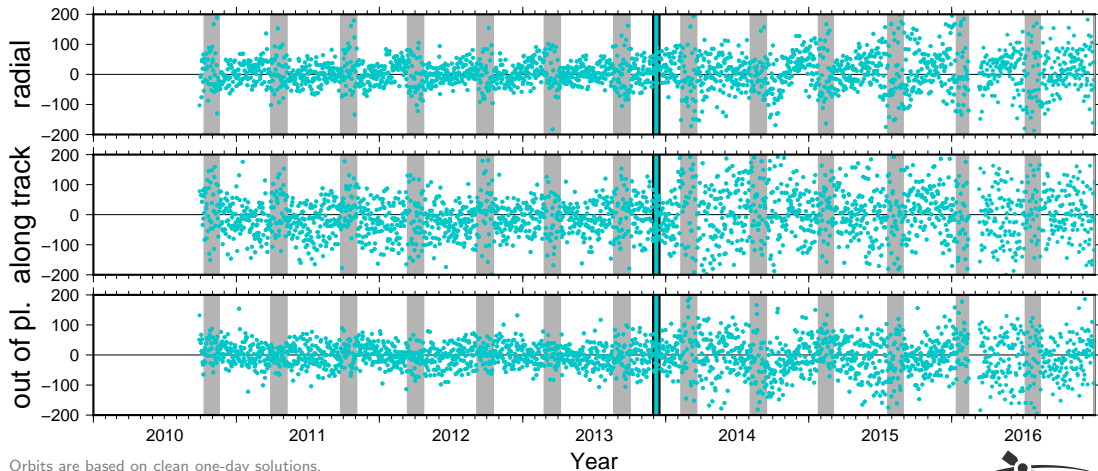
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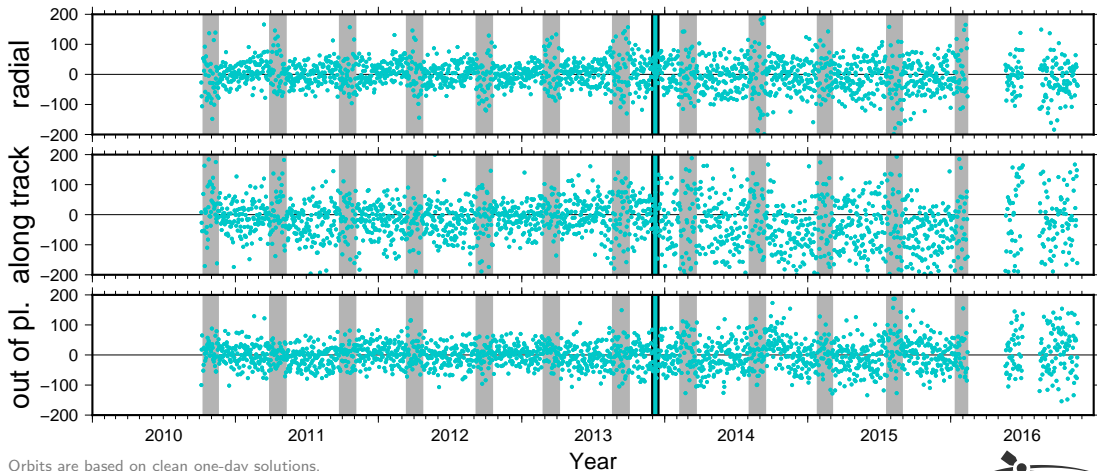
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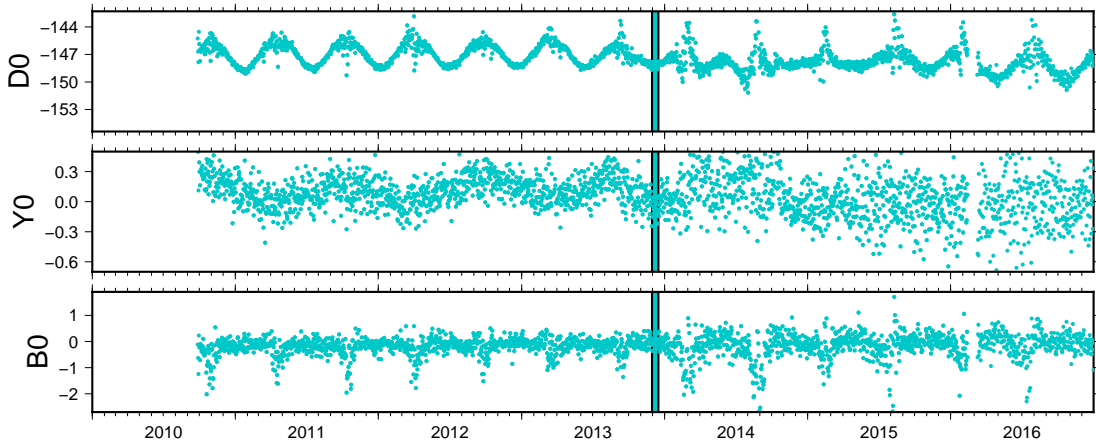
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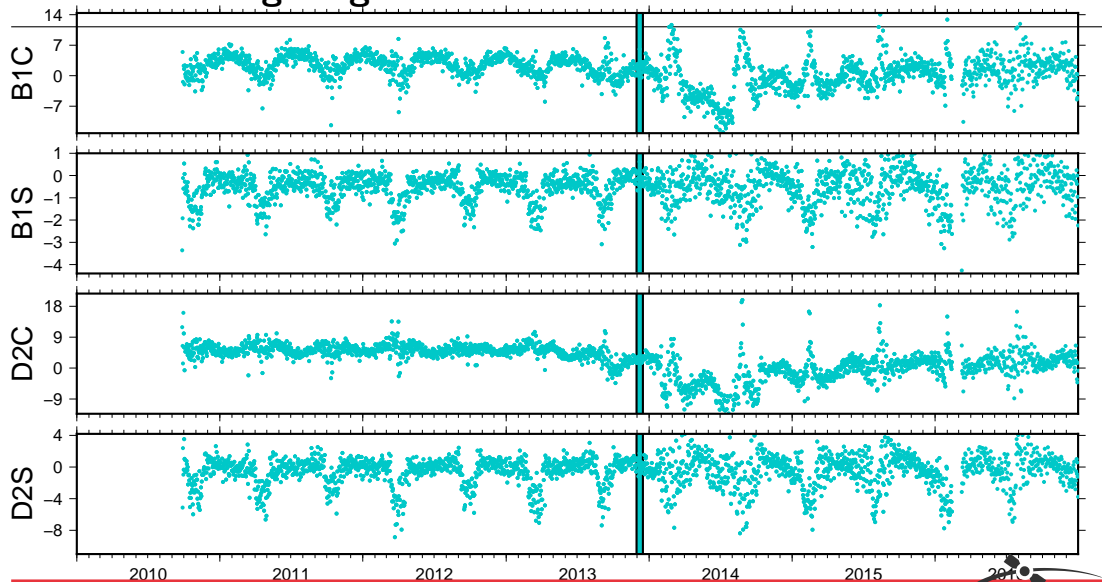
Investigating indicators for orbit characteristics

Estimated SRP parameters for satellite SVN 736 (R09/R16) in nm/s^2



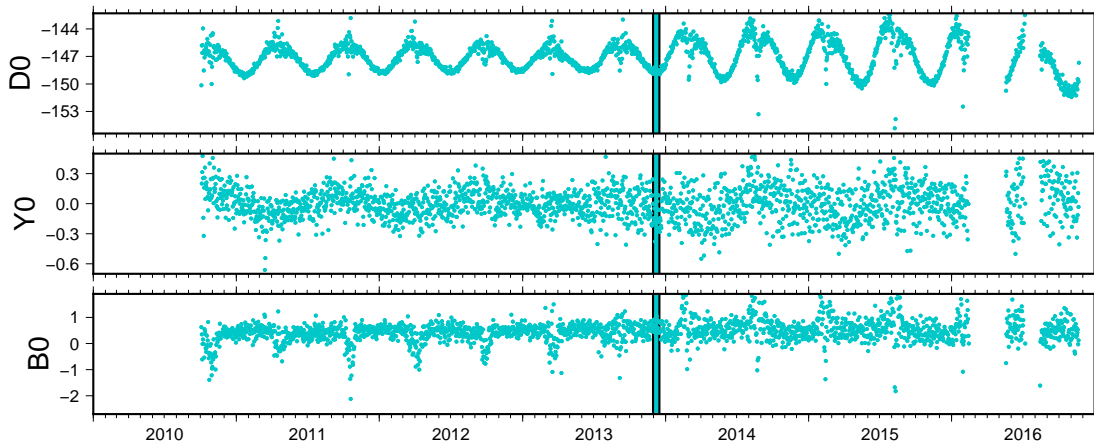
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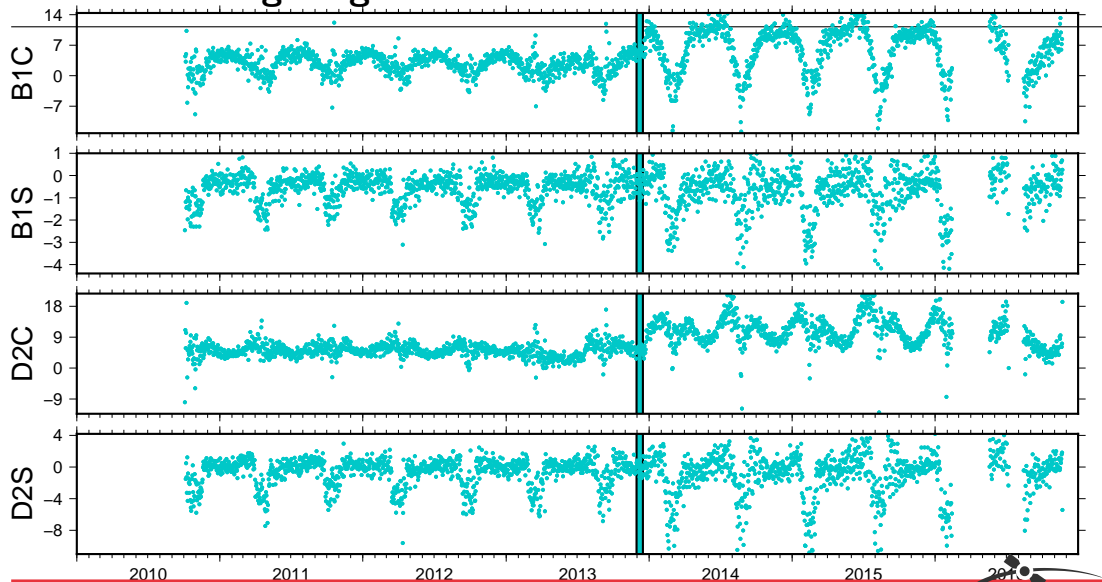
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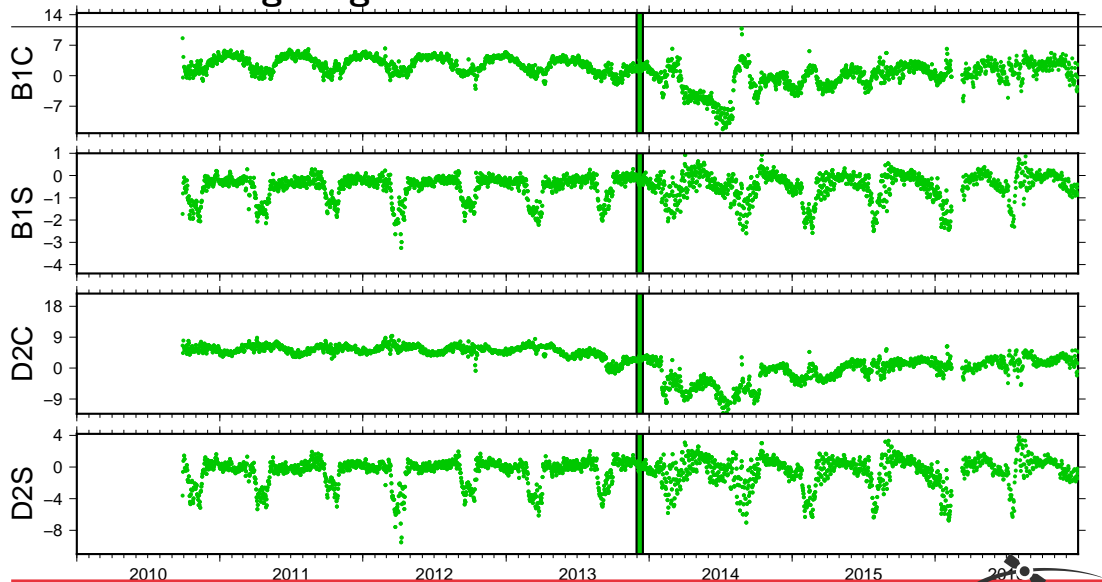
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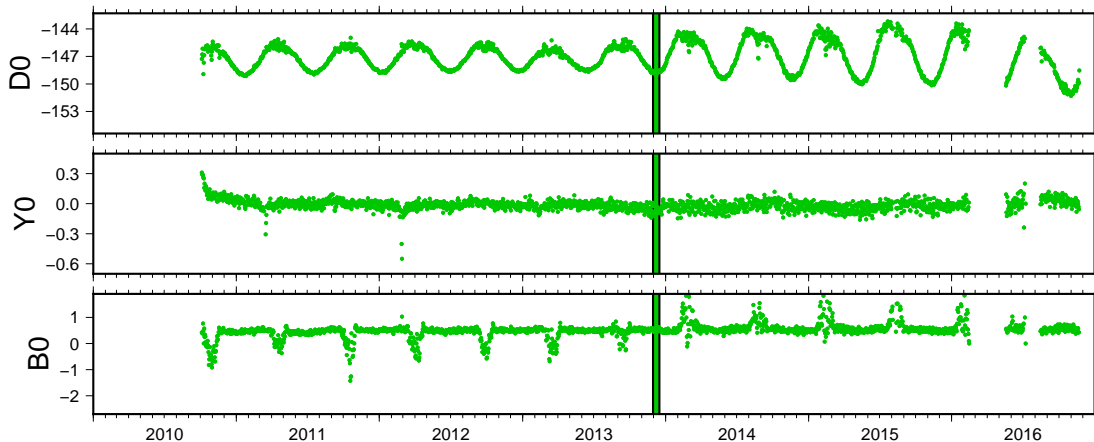
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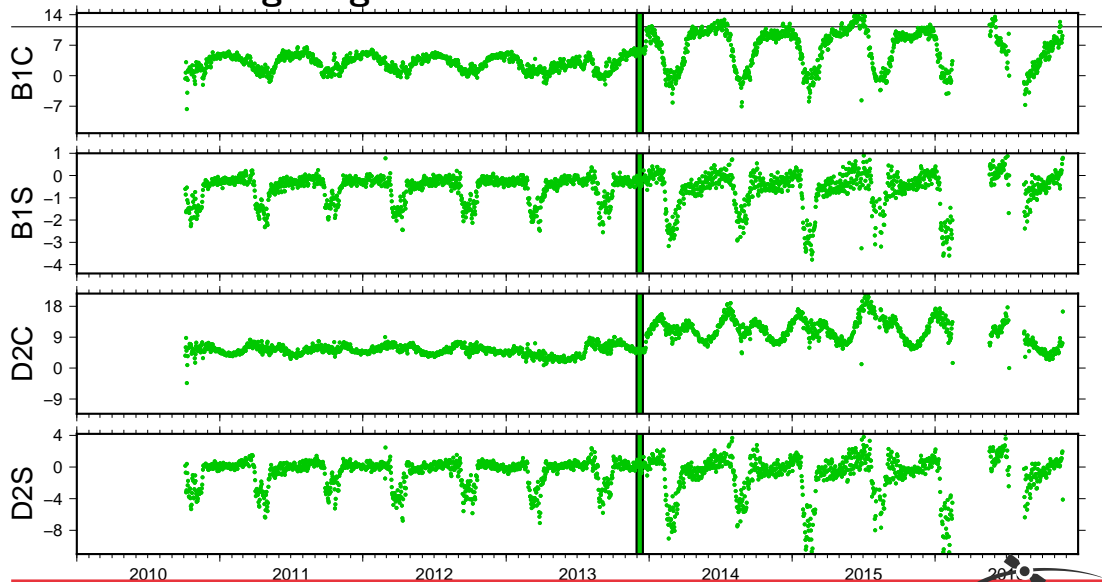
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What do we know so far?

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- Some of the GLONASS satellites show unexpected big SLR residuals after a few years of lifetime.

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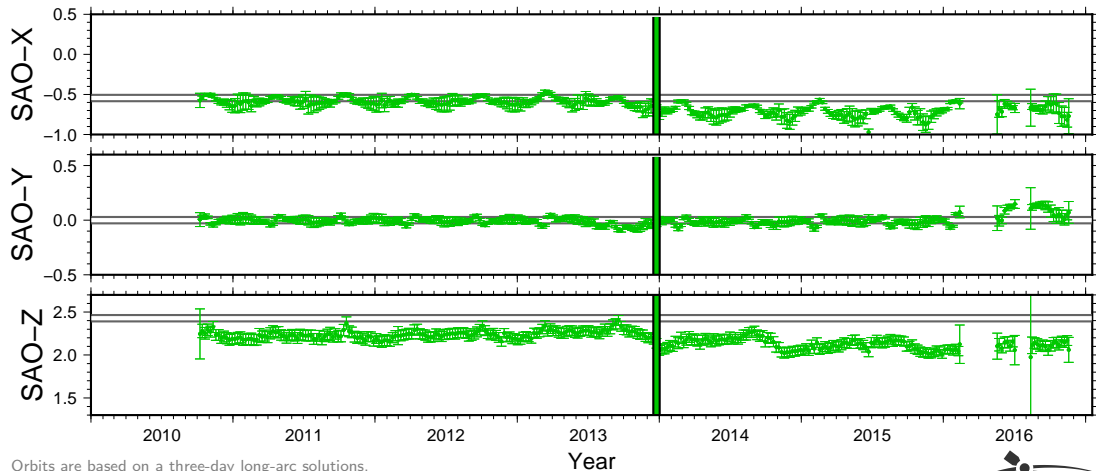
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- Orbit misclosures do only marginally react on this phenomena for three-day arc. A bigger effect is visible for one-day arcs.
- The SRP parameters show a clear deviation from the usual pattern in these periods.
- The shown effects are more pronounced in the ECOM2 than with the classical ECOM (periodic terms in D -direction added).

Estimating satellite antenna offsets

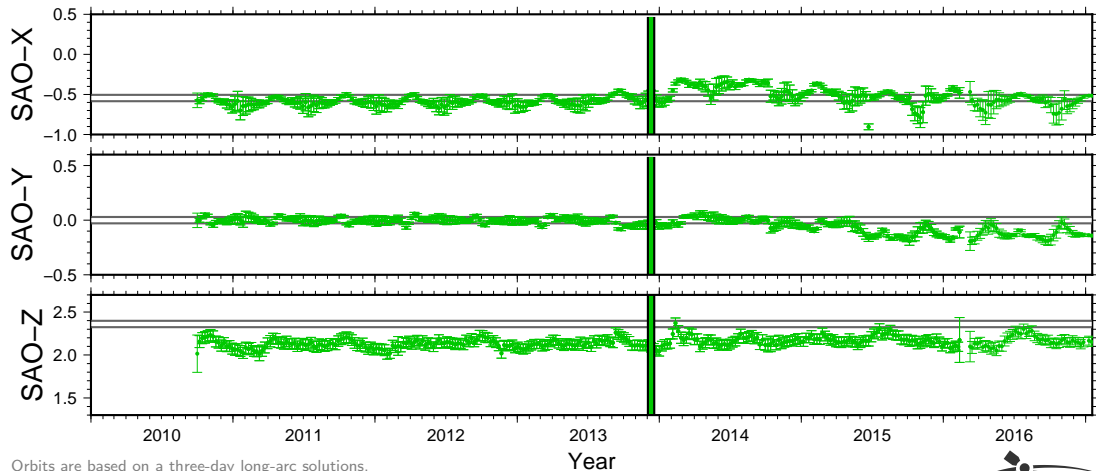
Estimated satellite antenna offsets (SAO) for satellite SVN 737 (R12) in m



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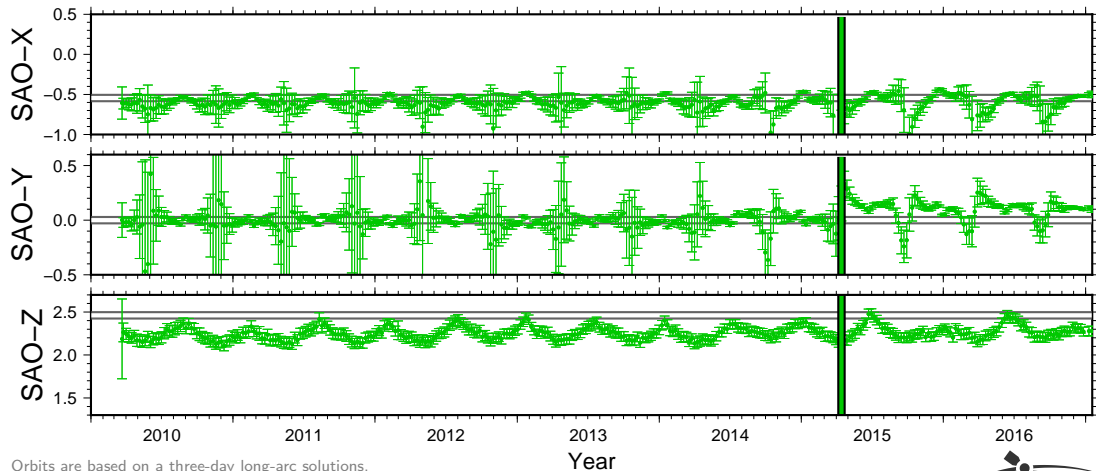
Estimating satellite antenna offsets

Estimated satellite antenna offsets (SAO) for satellite SVN 736 (R09/R16) in m



Estimating satellite antenna offsets

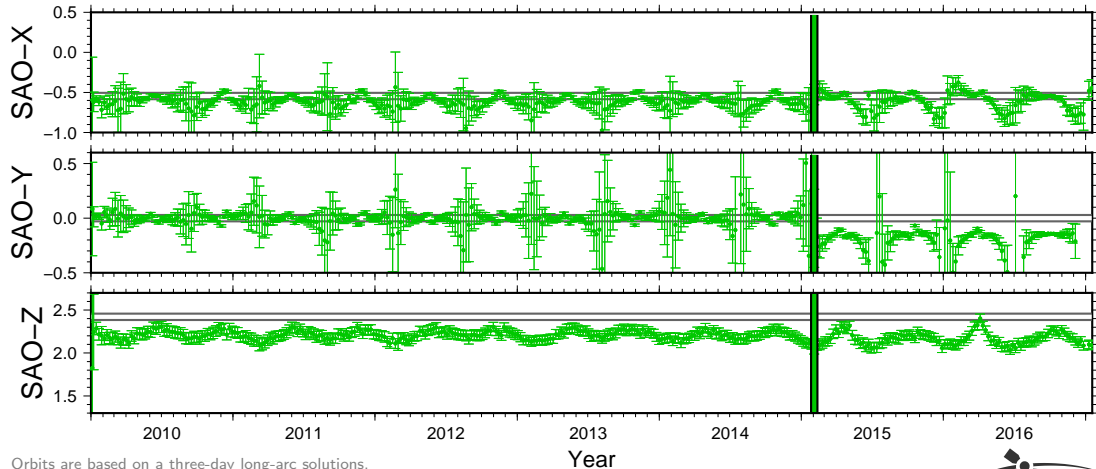
Estimated satellite antenna offsets (SAO) for satellite SVN 735 (R24) in m



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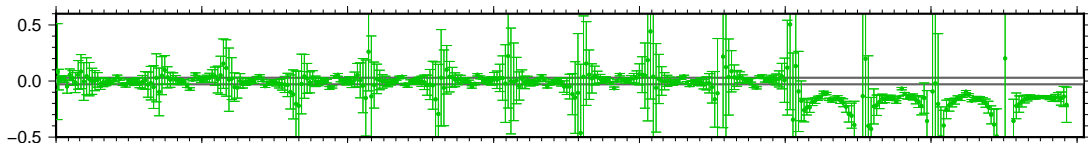
Estimated satellite antenna offsets (SAO) for satellite SVN 734 (R05) in m



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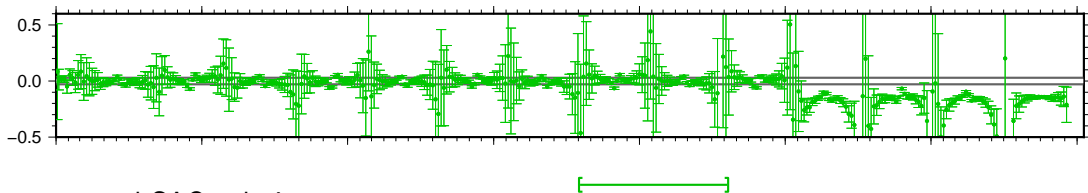
Detecting discontinuities

How reliably detect the discontinuities?



Detecting discontinuities

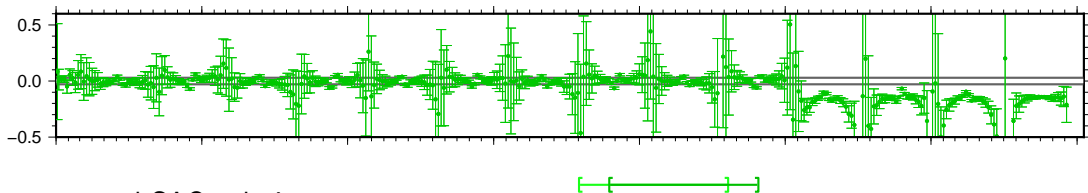
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- annual SAO solutions

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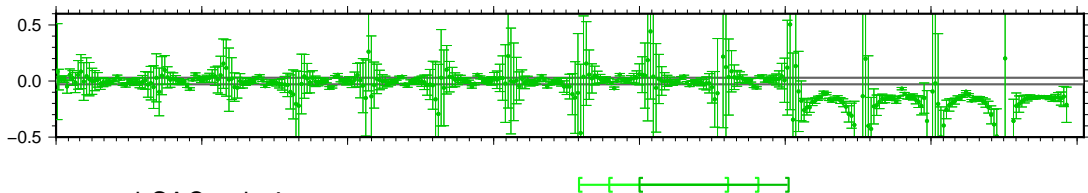
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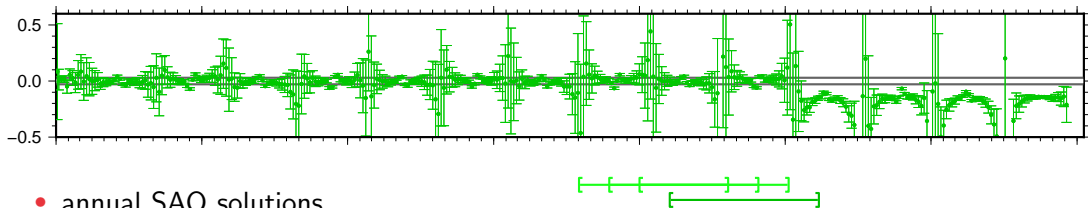
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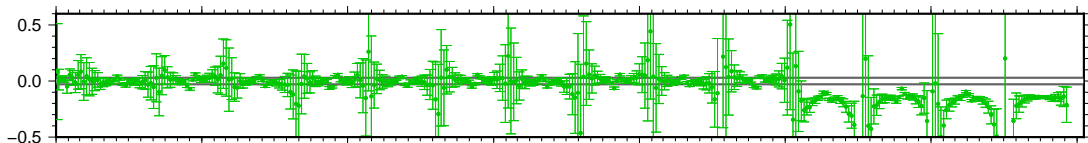
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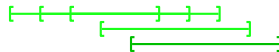
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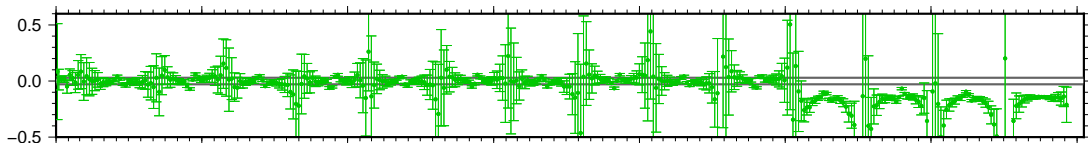


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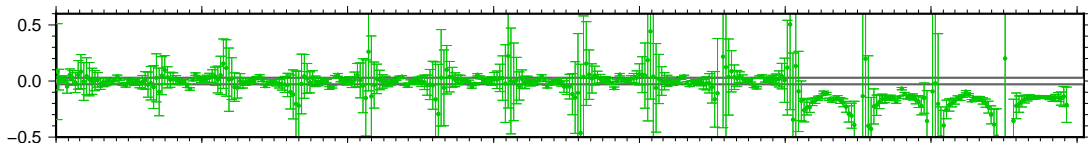
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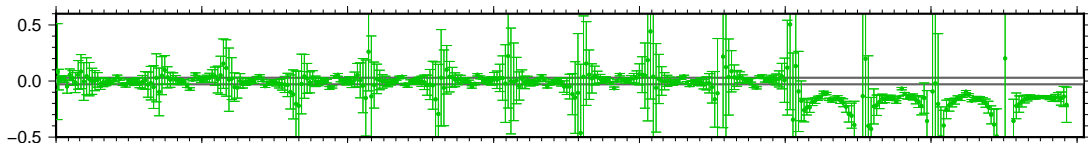
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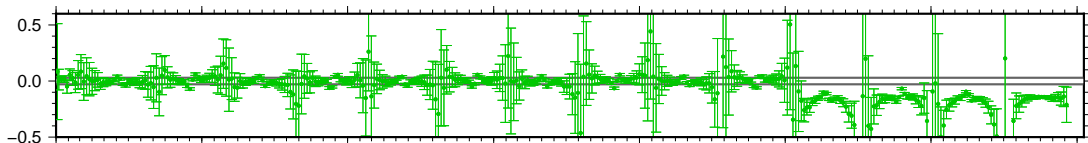
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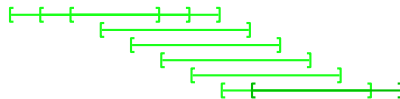
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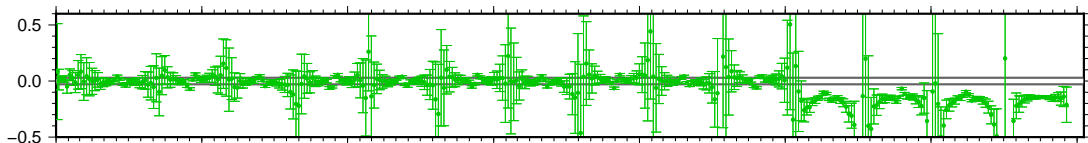


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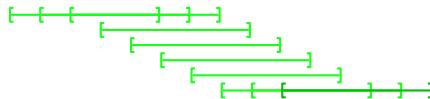


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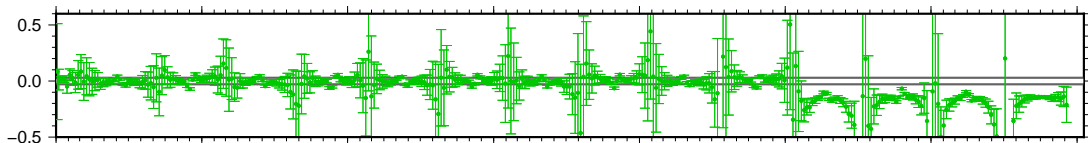


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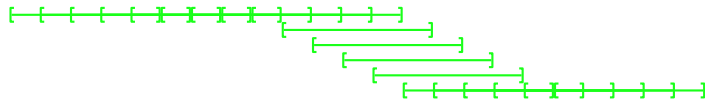


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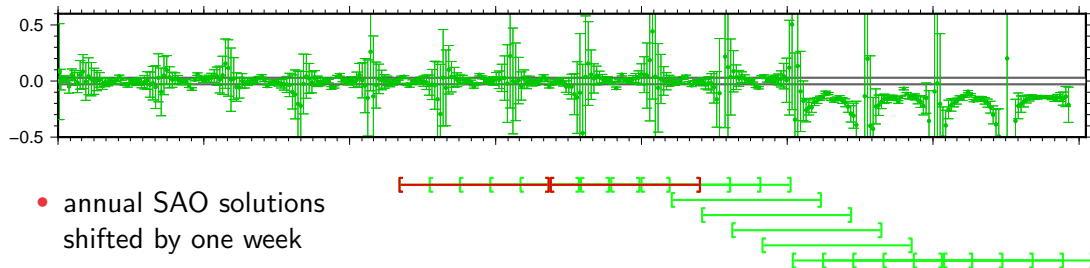


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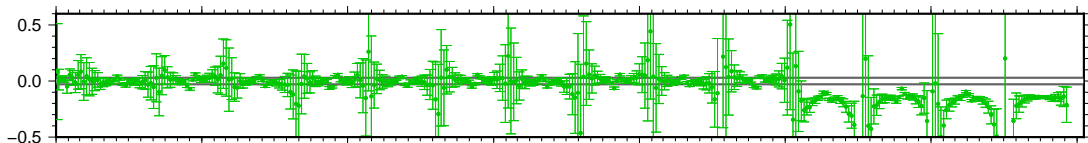
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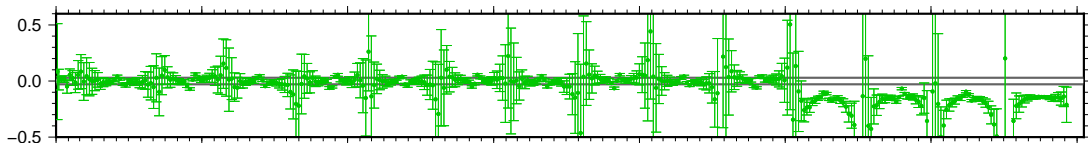


- annual SAO solutions shifted by one week
- compute differences between solution n and $n + 50$



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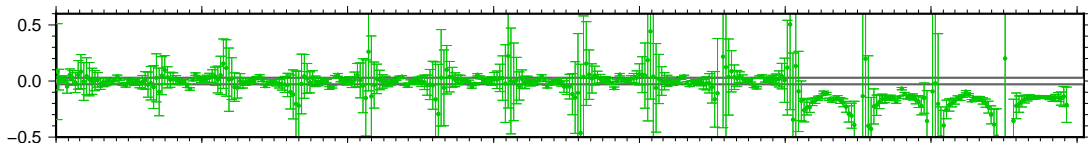


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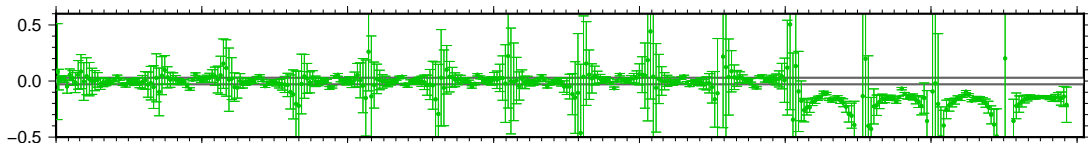


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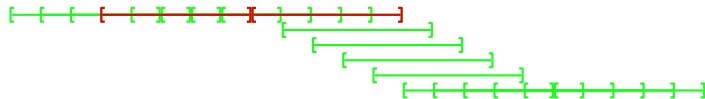


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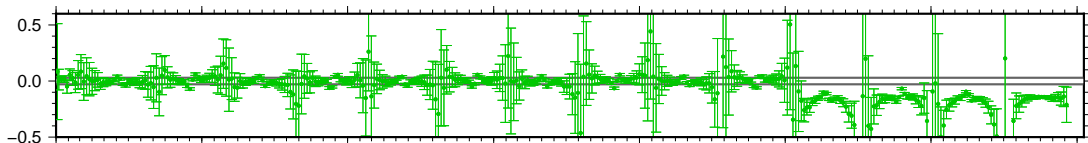


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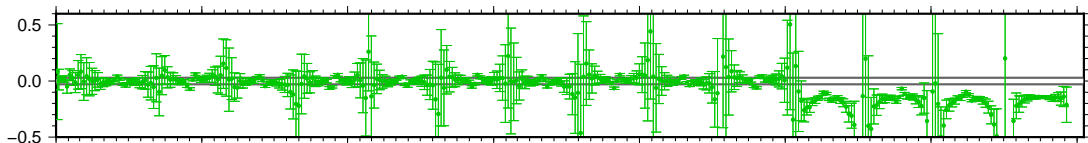


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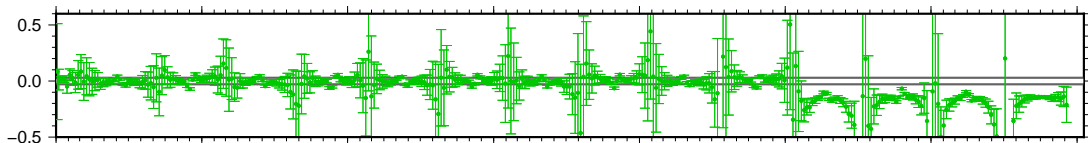


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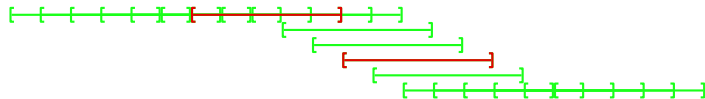


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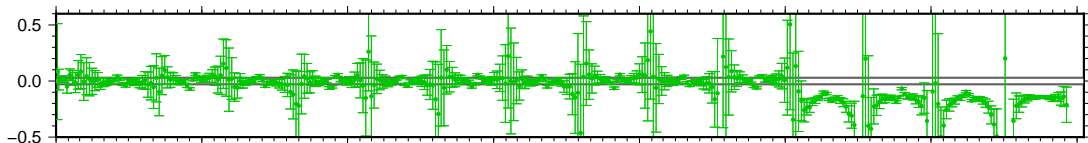


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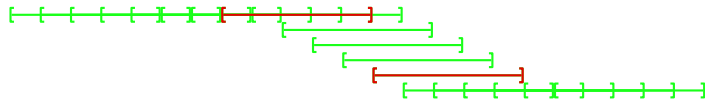


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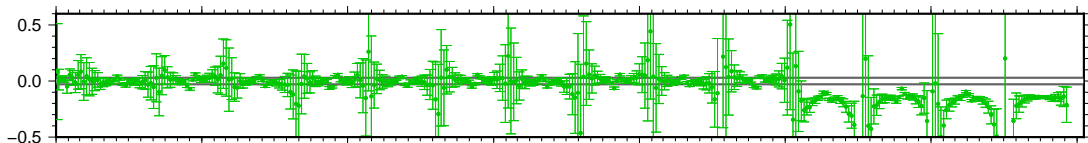


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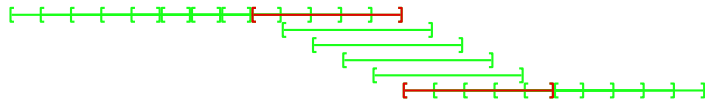


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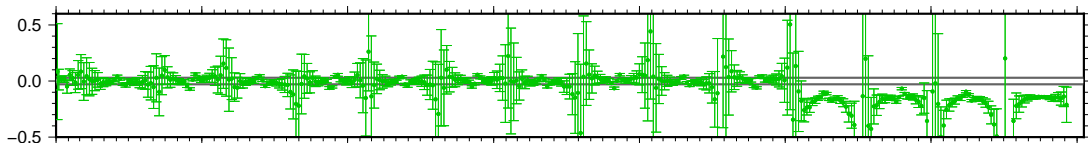


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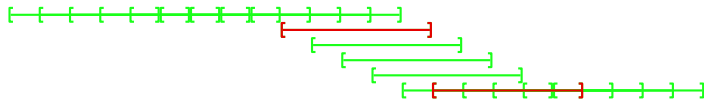


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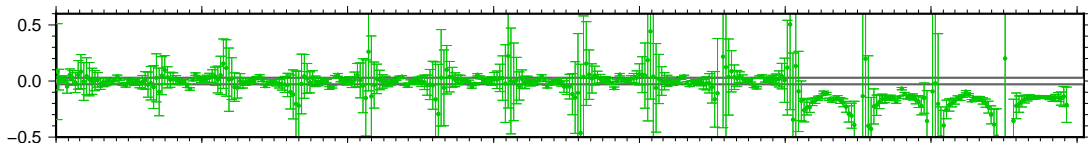


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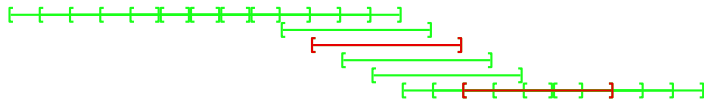


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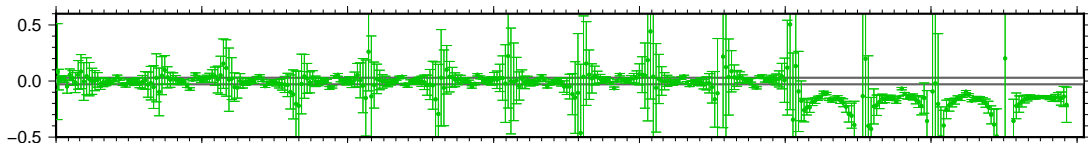


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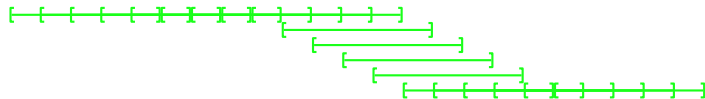


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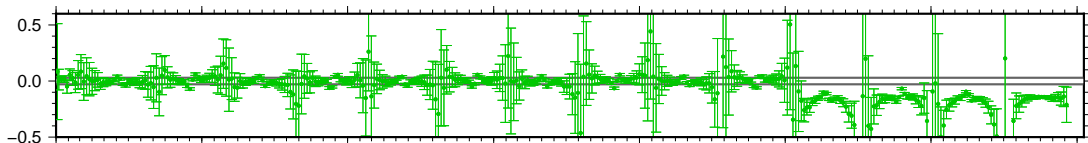


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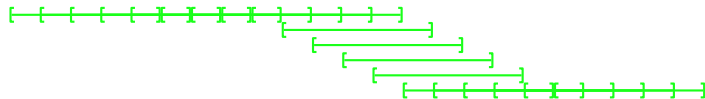


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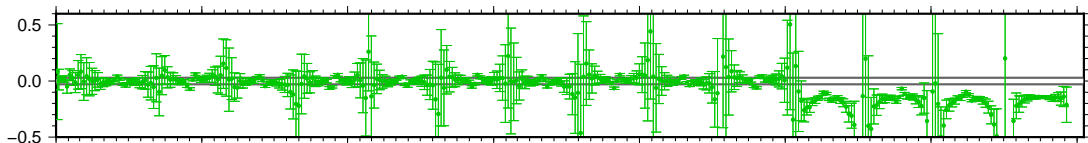


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- compute differences between solution n and $n + 50$
- search local extrema in the differences

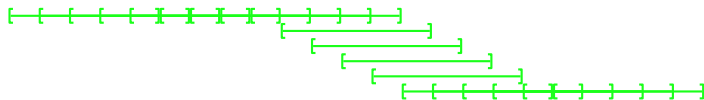


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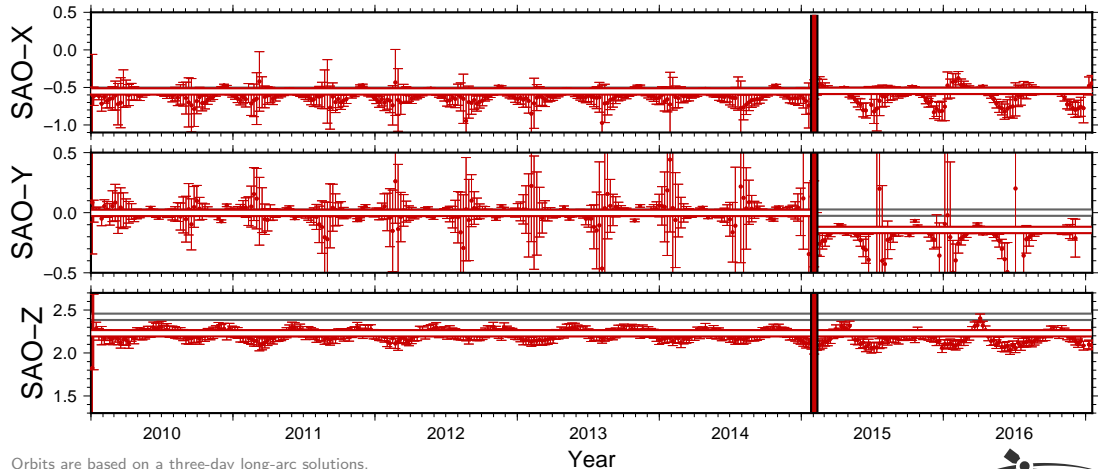


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- compute differences between solution n and $n + 50$
- search local extrema in the differences
- discontinuity is assumed if extrema has a magnitude of at least be 3 cm



Estimating satellite antenna offsets

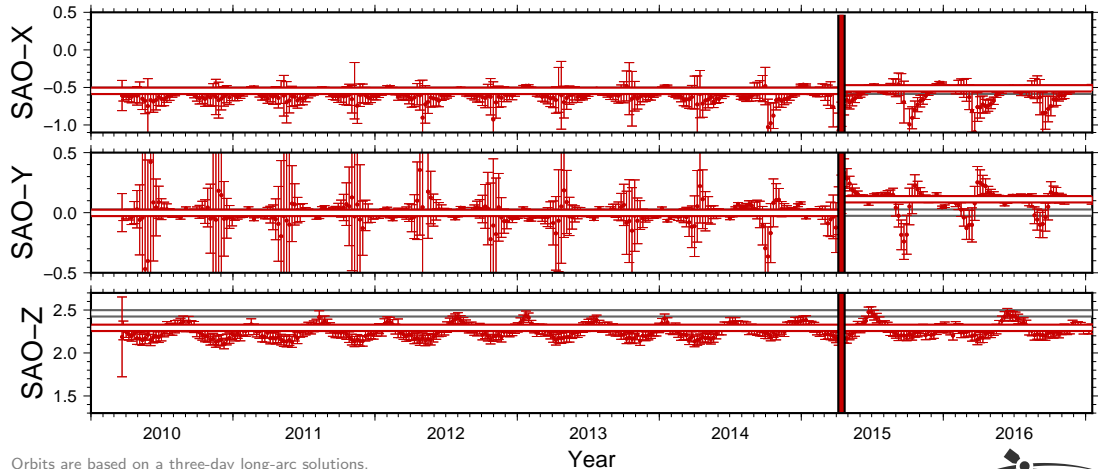
Estimated satellite antenna offsets (SAO) for satellite SVN 734 (R05) in m



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Estimating satellite antenna offsets

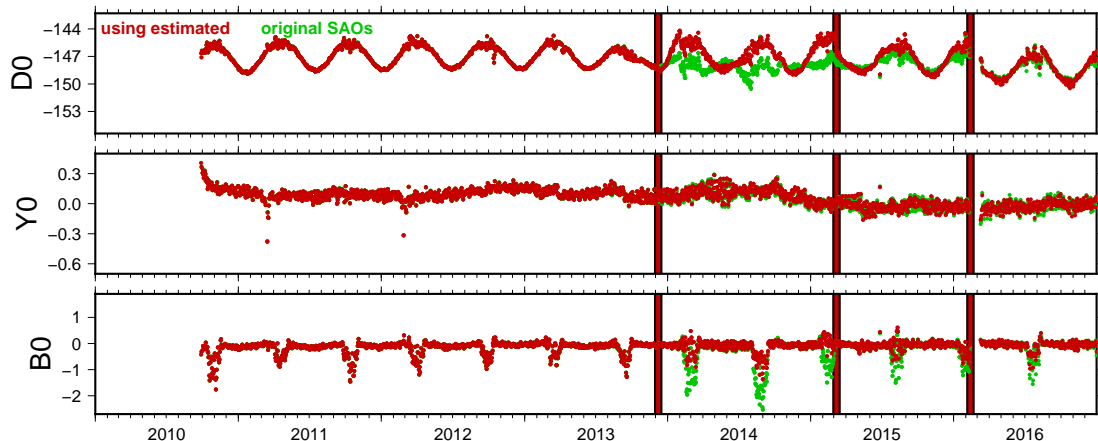
Estimated satellite antenna offsets (SAO) for satellite SVN 735 (R24) in m



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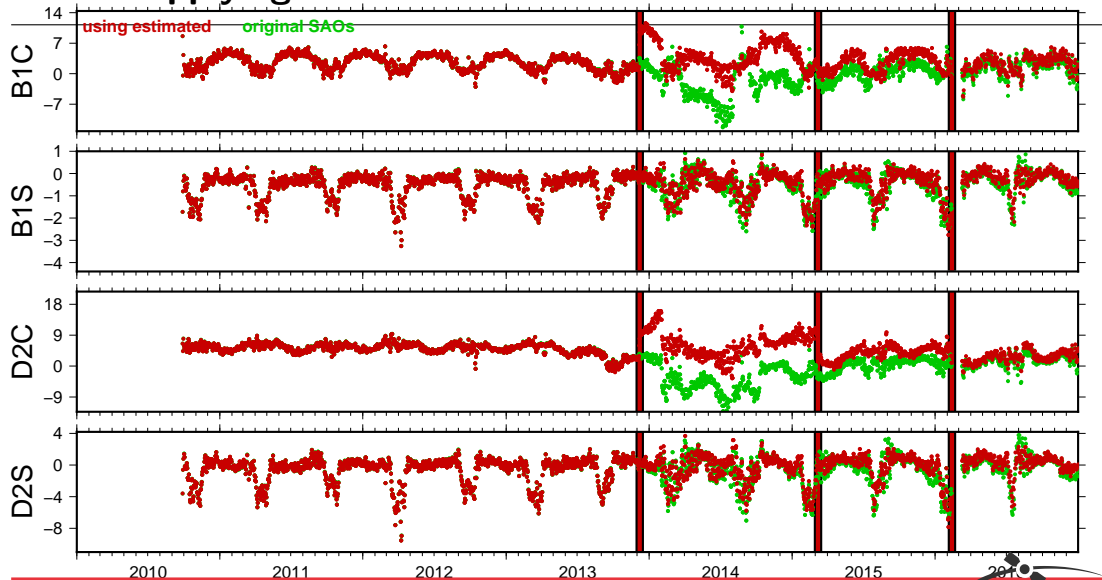
Applying the estimated satellite antenna offsets

Estimated SRP parameters for satellite SVN 736 (R09/R16) in nm/s^2



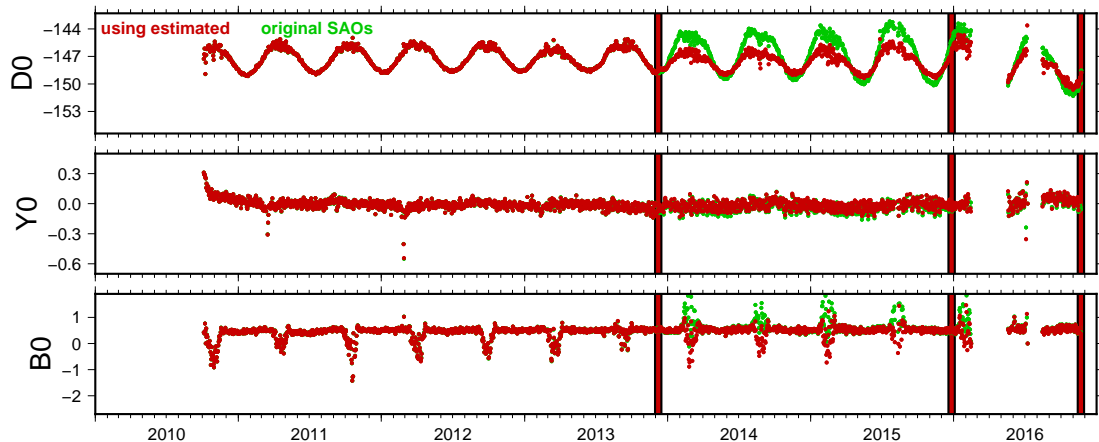
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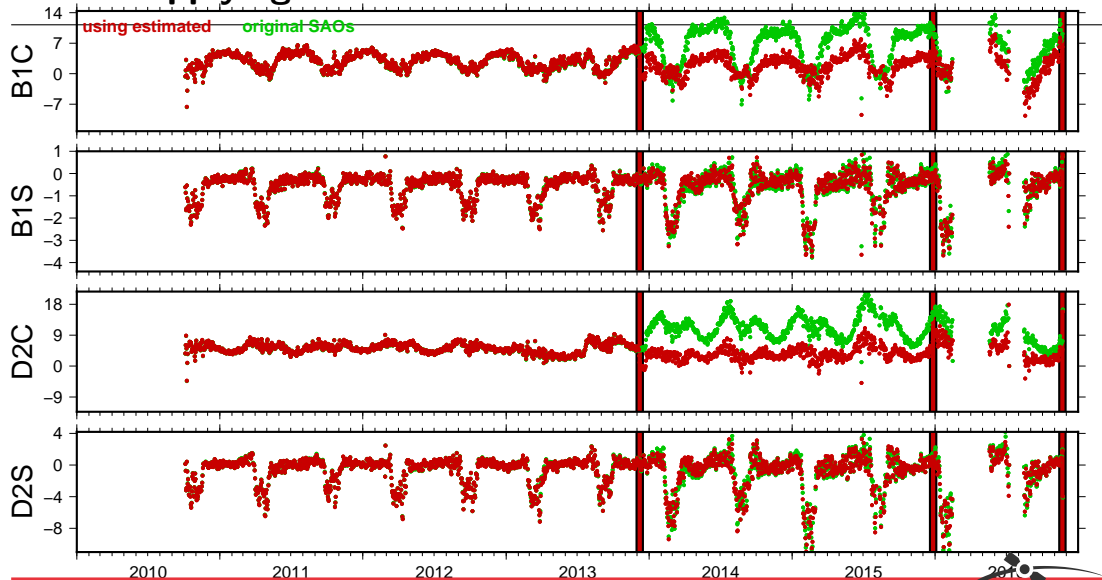
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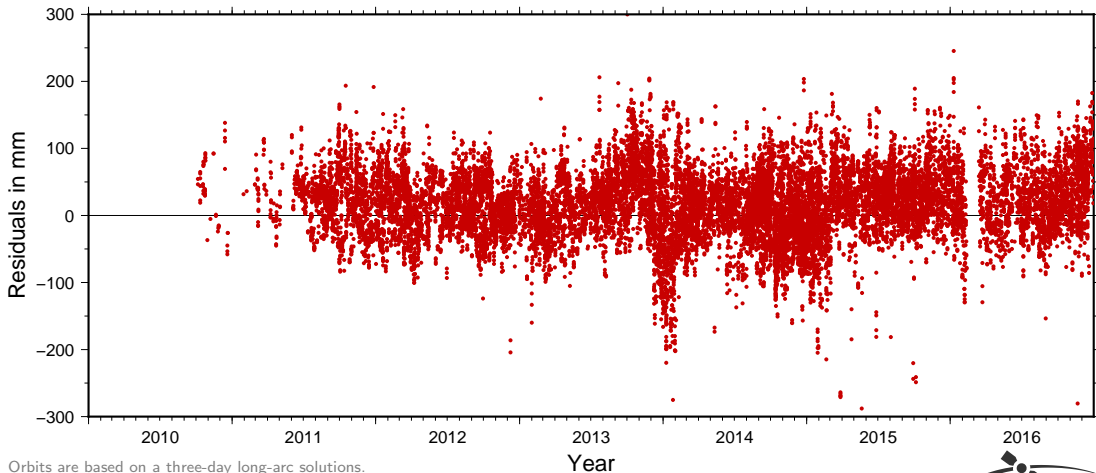
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Applying the estimated satellite antenna offsets



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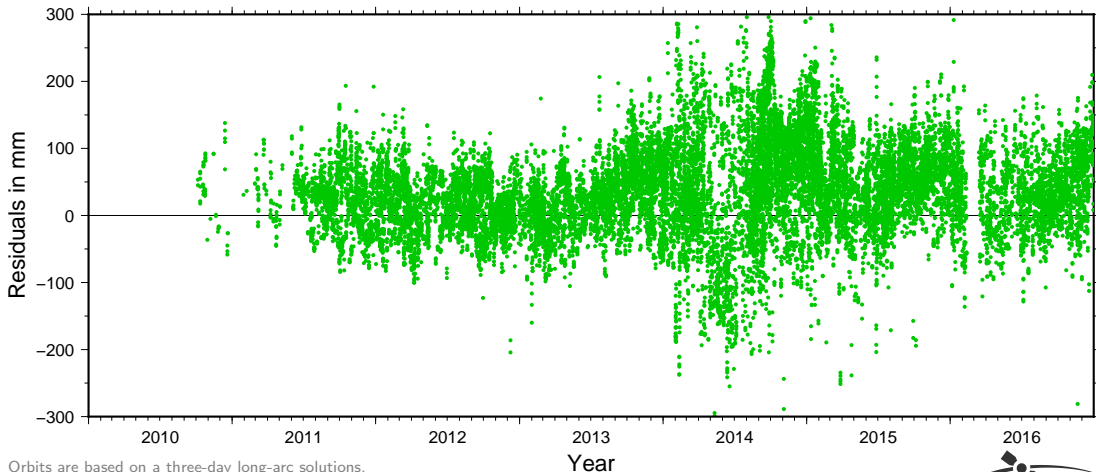
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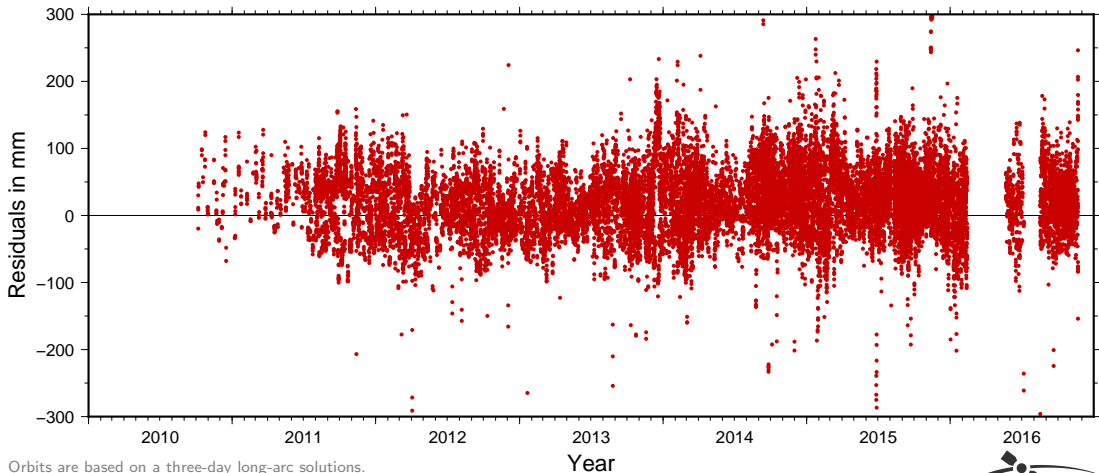
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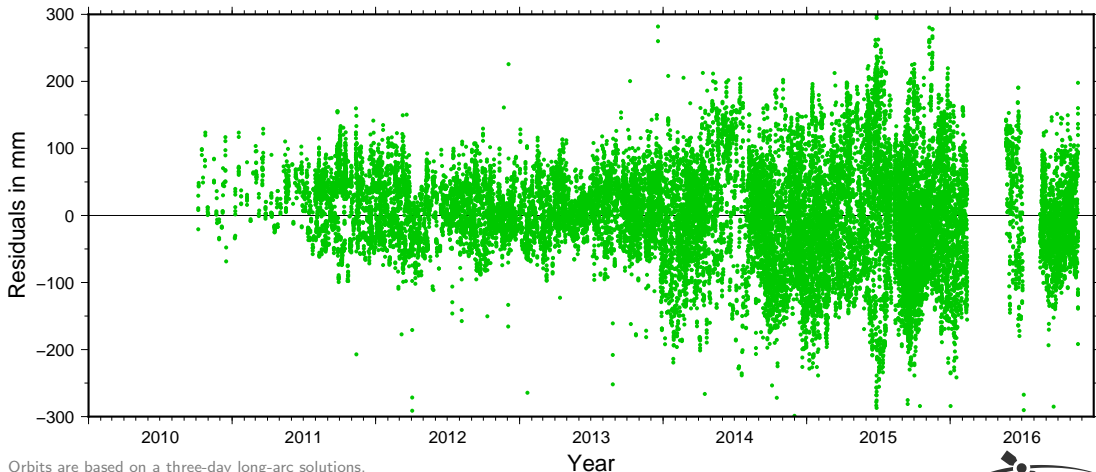
Applying the estimated satellite antenna offsets

SLR residuals for satellite SVN 737 (R12)



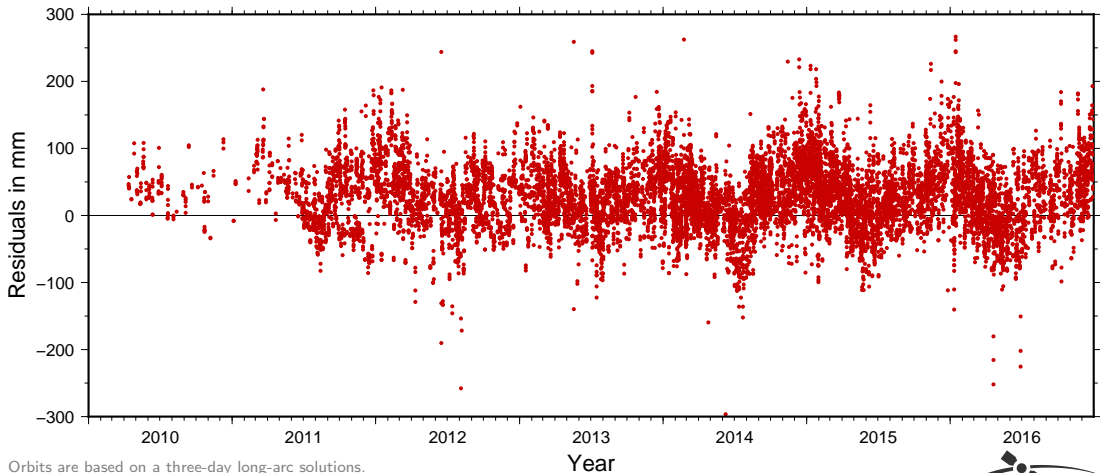
Applying the estimated satellite antenna offsets

SLR residuals for satellite SVN 737 (R12)



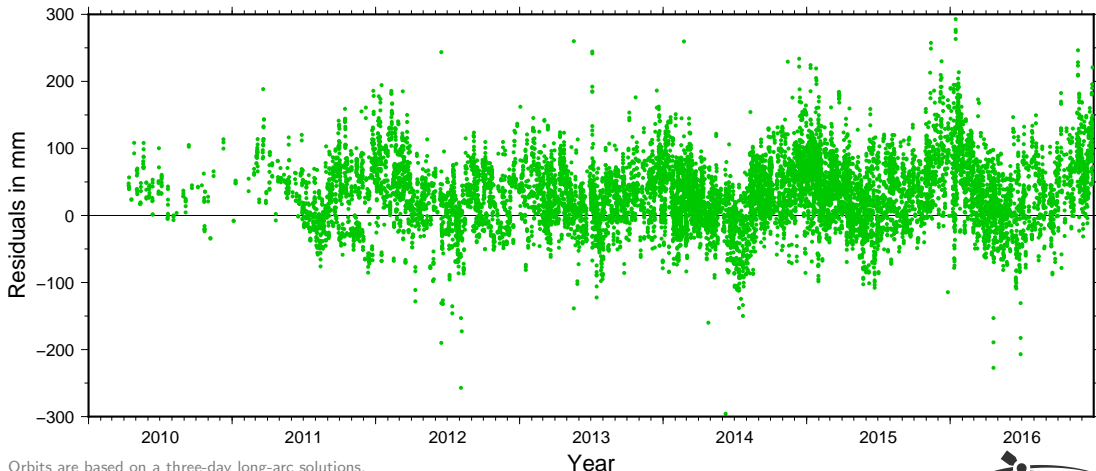
Applying the estimated satellite antenna offsets

SLR residuals for satellite SVN 735 (R05)



Applying the estimated satellite antenna offsets

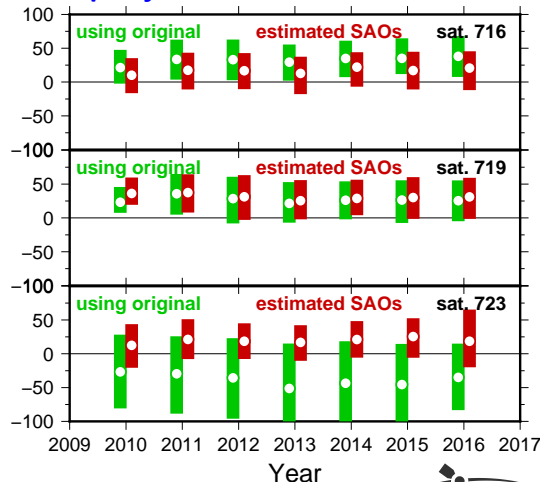
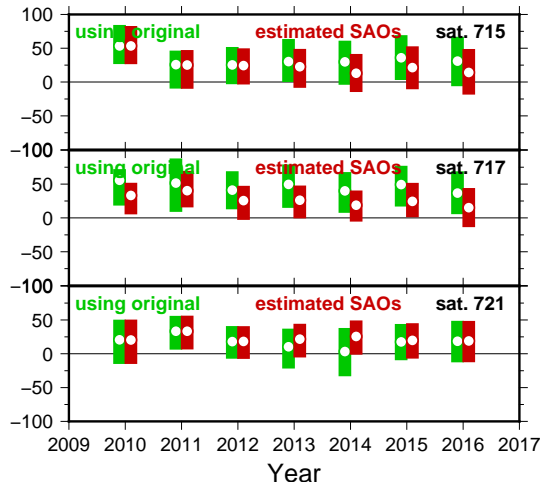
SLR residuals for satellite SVN 735 (R05)



Orbits are based on a three-day long-arc solutions.

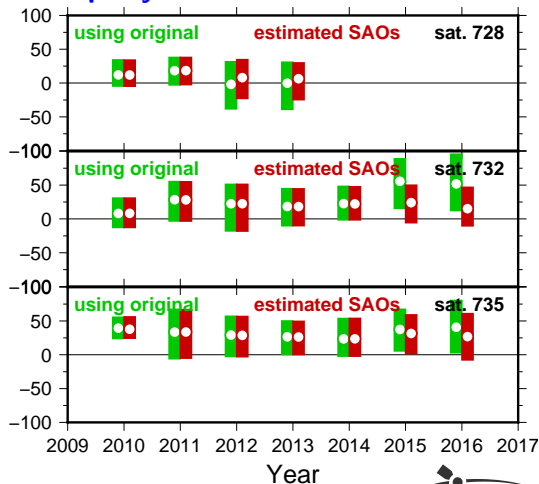
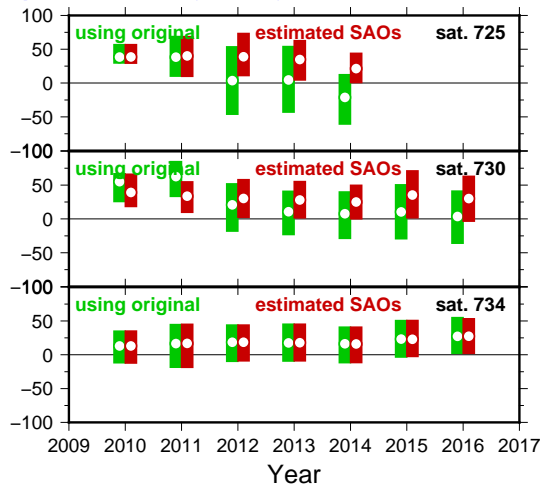
Applying the estimated satellite antenna offsets

Quantile 25%, 50%, and 75% of SLR residuals per year in mm



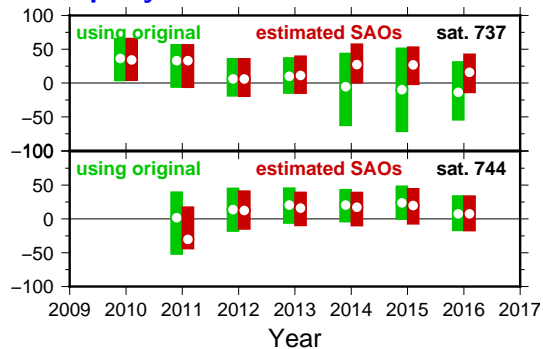
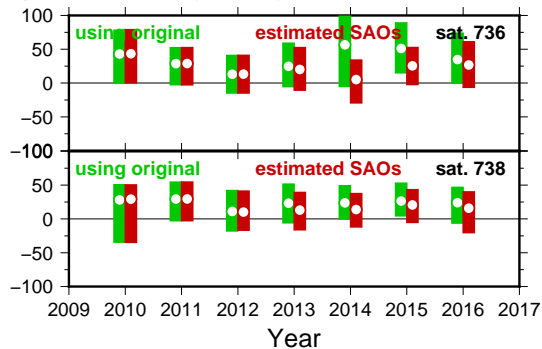
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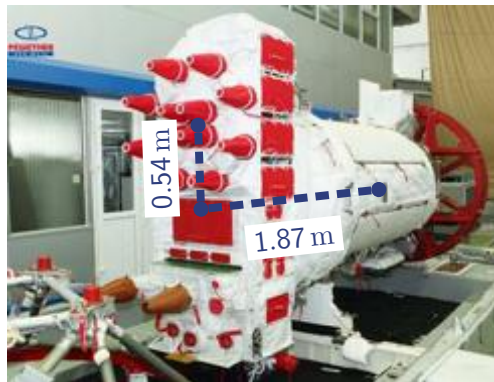
Orbits are based on a three-day long-arc solutions.

Discussion and summary

What could be the reason at the spacecraft?

Shift of the center of mass:

If the satellite has roughly a mass of 1500 kg, 150 kg need to be shifted by 1 m in order to generate a COM shift of 10 cm.



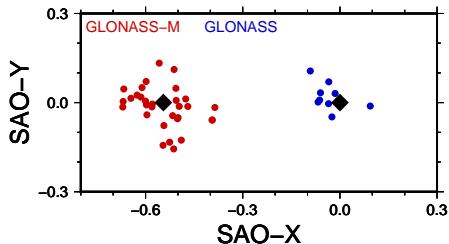
<http://spaceflight101.com/spacecraft/glonass-m/>

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Not likely because SAO-Z is not affected in most cases and the SAO-X/Y estimates do not show a pattern



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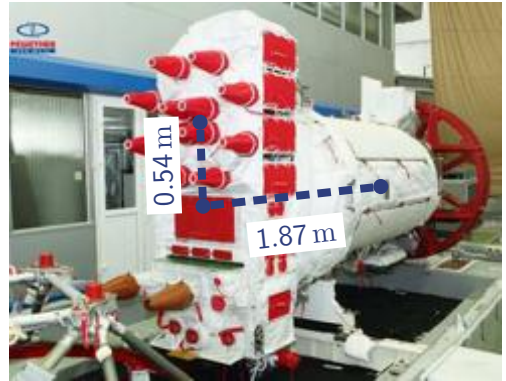
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Satellite attitude misorientation:

The satellite plane with the navigation antenna and the SLR reflector is about 2 m away from the center of mass.

A shift of 10 to 15 cm results in a tilt of the 3 to 4 degree of the satellite body.



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The usage of the estimated SAOs obviously helps to reduce the SLR residuals.

List of estimated satellite antenna offsets

Satellite		from		to	ΔX	ΔY	SAO-X	SAO-Y	Satellite type
701	R06	2008 04 27 00 00 00		2009 06 16 23 59 59	-0.1240	0.0037	-0.6691	0.0037	GLONASS-M
713	R24	2005 12 25 00 00 00		2010 02 28 23 59 59	-0.0507	-0.0412	-0.5957	-0.0412	GLONASS-M
714	R06	2010 04 28 00 00 00		2010 09 30 23 59 59	0.1507	-0.0586	-0.3943	-0.0586	GLONASS-M
714	R17	2010 12 16 00 00 00		2010 03 18 23 59 59	0.1507	-0.0586	-0.3943	-0.0586	GLONASS-M
715	R03	2011 10 02 00 00 00		2013 03 06 23 59 59	0.0016	-0.0772	-0.5434	-0.0772	GLONASS-M
715	R14	2013 03 07 00 00 00			0.0319	-0.1560	-0.5131	-0.1560	GLONASS-M
716	R15	2006 12 25 00 00 00			0.0387	0.0479	-0.5063	0.0479	GLONASS-M
717	R10	2006 12 25 00 00 00			0.0488	-0.0127	-0.4962	-0.0127	GLONASS-M
718	R17	2007 10 26 00 00 00		2010 12 15 23 59 59	0.0454	-0.0505	-0.4996	-0.0505	GLONASS-M
719	R20	2007 10 26 00 00 00		2011 03 05 23 59 59	-0.0660	0.0504	-0.6110	0.0504	GLONASS-M
719	R20	2011 03 06 00 00 00			-0.0128	0.1329	-0.5578	0.1329	GLONASS-M
721	R13	2013 10 20 00 00 00		2015 01 17 23 59 59	-0.0533	0.0712	-0.5983	0.0712	GLONASS-M
722	R09	2007 12 25 00 00 00		2010 09 30 23 59 59	-0.0354	-0.0144	-0.5804	-0.0144	GLONASS-M
723	R11	2007 12 25 00 00 00		2010 07 17 23 59 59	-0.0550	0.0049	-0.6000	0.0049	GLONASS-M
723	R11	2010 07 18 00 00 00		2016 03 02 23 59 59	-0.1222	0.0457	-0.6672	0.0457	GLONASS-M
725	R21	2011 11 06 00 00 00		2014 07 31 23 59 59	-0.1002	0.0144	-0.6452	0.0144	GLONASS-M
726	R22	2008 09 25 00 00 00		2010 02 28 23 59 59	-0.0343	-0.0050	-0.5793	-0.0050	GLONASS-M
728	R02	2012 05 06 00 00 00		2013 06 29 23 59 59	-0.0523	-0.0077	-0.5973	-0.0077	GLONASS-M
730	R01	2009 12 14 00 00 00		2010 12 18 23 59 59	0.0396	0.0073	-0.5054	0.0073	GLONASS-M
730	R01	2010 12 19 00 00 00		2012 07 14 23 59 59	0.0688	0.0121	-0.4762	0.0121	GLONASS-M

List of estimated satellite antenna offsets

Satellite		from	to	ΔX	ΔY	SAO-X	SAO-Y	Satellite type
730	R01	2012 07 15 00 00 00		-0.0694	0.0184	-0.6144	0.0184	GLONASS-M
732	R23	2015 02 01 00 00 00		0.0753	-0.0130	-0.4697	-0.0131	GLONASS-M
734	R05	2015 02 01 00 00 00		-0.0009	-0.1437	-0.5459	-0.1437	GLONASS-M
735	R24	2015 04 12 00 00 00		0.0329	0.1116	-0.5121	0.1116	GLONASS-M
736	R09	2013 12 08 00 00 00	2015 03 07 23 59 59	0.1589	-0.0166	-0.3861	-0.0166	GLONASS-M
736	R09	2015 03 08 00 00 00	2016 02 12 23 59 59	0.0554	-0.1265	-0.4896	-0.1265	GLONASS-M
736	R16	2016 03 07 00 00 00		0.0192	-0.1335	-0.5258	-0.1335	GLONASS-M
737	R12	2013 12 08 00 00 00	2015 12 26 23 59 59	-0.1254	-0.0149	-0.6704	-0.0149	GLONASS-M
737	R12	2015 12 27 00 00 00	2016 11 20 23 59 59	-0.0814	0.0252	-0.6264	0.0252	GLONASS-M
738	R16	2012 12 16 00 00 00	2016 02 13 23 59 59	0.0434	-0.0545	-0.5016	-0.0545	GLONASS-M
744	R03	2011 12 01 00 00 00	2015 11 07 23 59 59	0.0285	-0.0440	-0.5165	-0.0440	GLONASS-M
779	R01	1999 01 01 00 00 00	2002 07 08 23 59 59	0.0936	-0.0116	0.0936	-0.0116	GLONASS
783	R18	2000 10 13 00 00 00	2004 06 26 23 59 59	-0.0600	0.0330	-0.0600	0.0330	GLONASS
783	R18	2004 06 27 00 00 00	2007 05 24 23 59 59	-0.0914	0.1064	-0.0914	0.1064	GLONASS
788	R24	2003 09 07 00 00 00	2005 12 11 23 59 59	-0.0345	0.0698	-0.0345	0.0698	GLONASS
789	R03	2001 12 01 00 00 00	2008 12 24 23 59 59	-0.0149	0.0308	-0.0149	0.0308	GLONASS
791	R22	2002 12 25 00 00 00	2007 10 25 23 59 59	-0.0247	-0.0482	-0.0247	-0.0482	GLONASS
792	R21	2006 05 21 00 00 00	2008 09 24 23 59 59	-0.0626	0.0083	-0.0626	0.0083	GLONASS
796	R01	2004 12 26 00 00 00	2009 12 13 23 59 59	-0.0352	-0.0035	-0.0352	-0.0035	GLONASS
798	R19	2005 12 25 00 00 00	2007 10 25 23 59 59	-0.0675	0.0018	-0.0675	0.0018	GLONASS

THANK YOU

for your attention



Publications of the satellite geodesy research group:

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