Implementing Consistent Clipping in the Reduction of SLR Data from SGF, Herstmonceux

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Introduction

To take SLR measurements that are stable from pass to pass and over the long-term, a station must:

- Monitor for and eliminate bias, in collaboration with the ILRS QC services.
- Make observations in a consistent manner (for example, single photon).
- Post-process range data in a consistent way that does not introduce variability.
- Define the methods used so that an accurate centre-of-mass correction can be applied.

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Introduction

The SGF, Herstmonceux SLR station generates flattened range residuals in post-processing by adjusting the orbit prediction and then forms normal points.

We are reviewing how best to clip these residuals for certain satellites, with the intention of adopting a more robust method.

The aim is to be more consistent from pass to pass and hopefully improve the quality of our SLR output.

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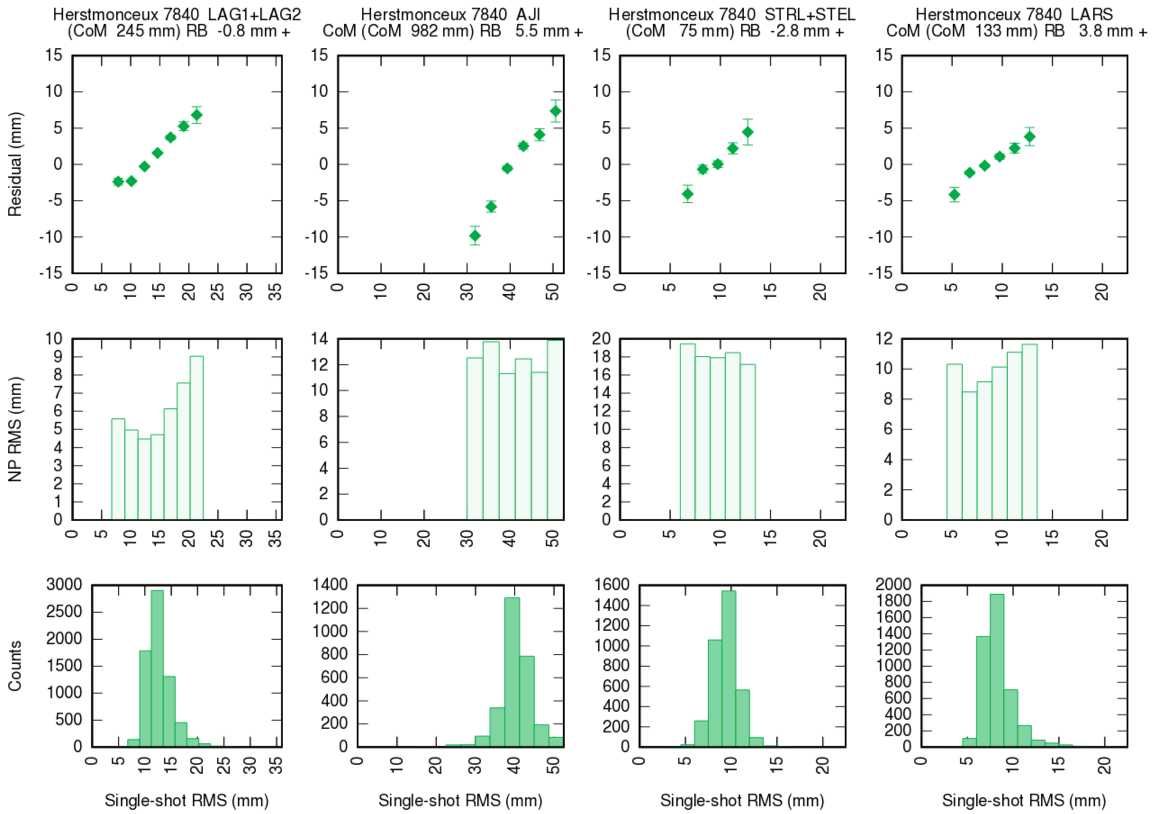
Range vs RMS

It was shown for LAGEOS and other geodetic sphere satellites that the Herstmonceux station has a range residual dependency with single shot RMS.



Otsubo, Systematic Range Error, IWLR, Annapolis 2014. *https://cddis.nasa.gov/lw19/Program/index.html*

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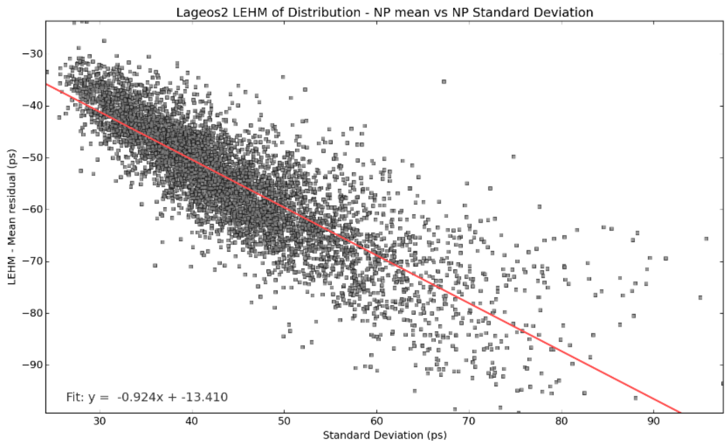
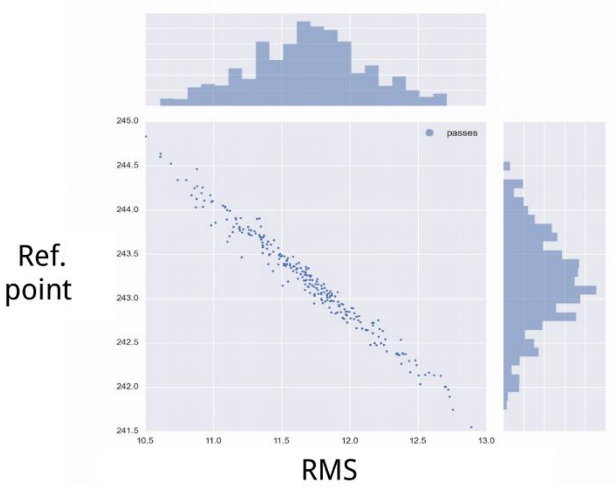
Range vs RMS

This was also seen directly in the range data by plotting the distribution leading-edge-half-maximum (LEHM) and the NP mean difference against RMS.



Wilkinson, Systematics at the SGF, Herstmonceux, IWLR Potsdam, 2016. *https://cddis.nasa.gov/lw20/docs/2016/papers/41-Wilkinson_paper.pdf*

And this trend was shown to be partly caused by the variable orientation of LAGEOS from simulations of the satellite response.



Rodríguez, Variability of LAGEOS normal point sampling: causes and mitigation. Riga ILRS Technical Workshop, 2017. *https://cddis.nasa.gov/2017_Technical_Workshop/docs/presentations/session2/ilrsTW2017_s2_Rodriguez.pdf*

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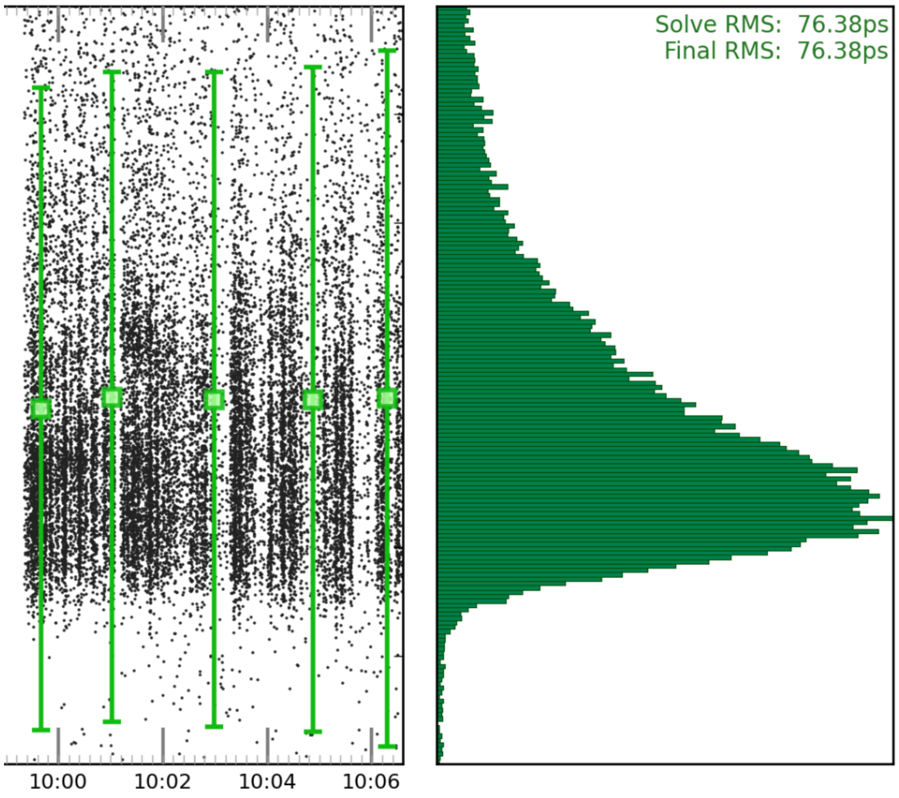
Forming Normal Points

Flattened residuals form a histogram distribution that is well defined for kHz stations.

A normal point is the residual mean applied to a range at a central epoch for a fixed timespan.

The normal point result will change according to the level of the range residuals included.



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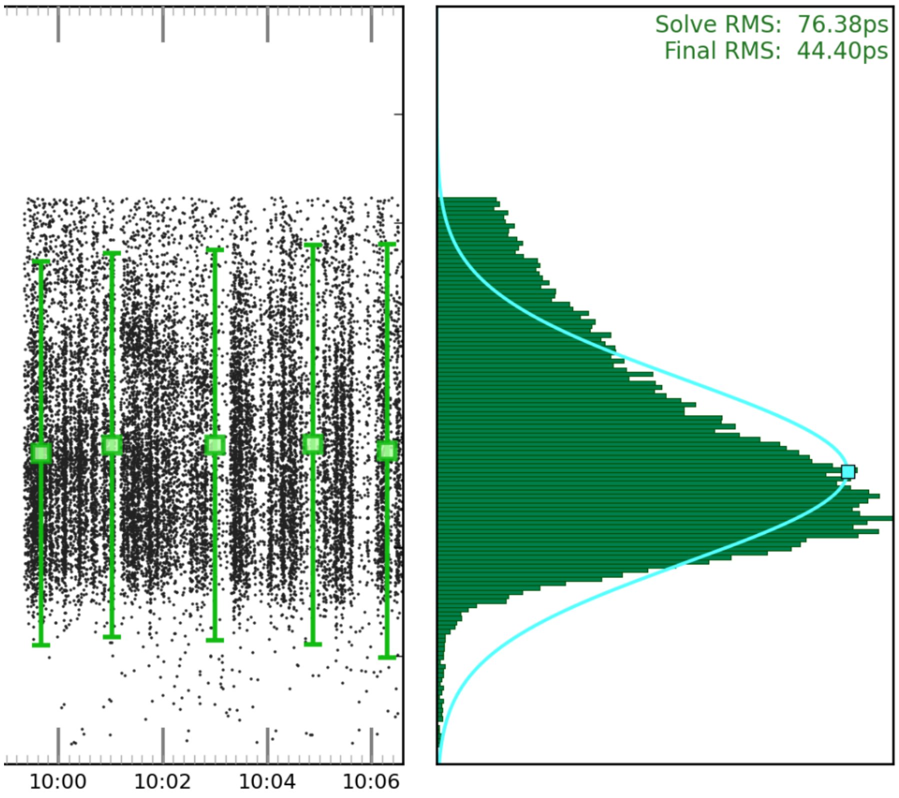
Forming Normal Points

At Herstmonceux, currently the clipping is applied at ± 3σ from the centre of a Gaussian fit.

The σ value depends on the level of signal to noise and the satellite response profile.

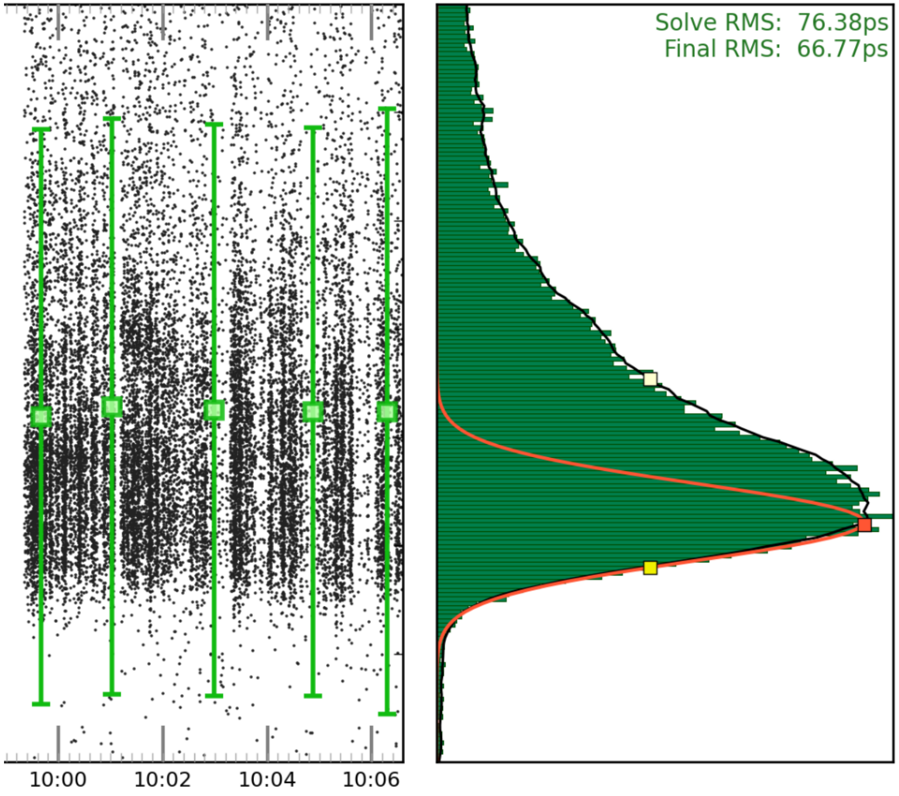
Because the profile is not Gaussian, if tighter clipping is applied, due to a lower σ, then the normal point range will be shorter than if looser clipping were applied.



Forming Normal Points

To apply consistent clipping a stable point on the distribution is required, such as the leading-edge-half maximum (LEHM).

To determine the LEHM, a Gaussian profile fit is made to the **front only** of the distribution, which is closer to being Gaussian.



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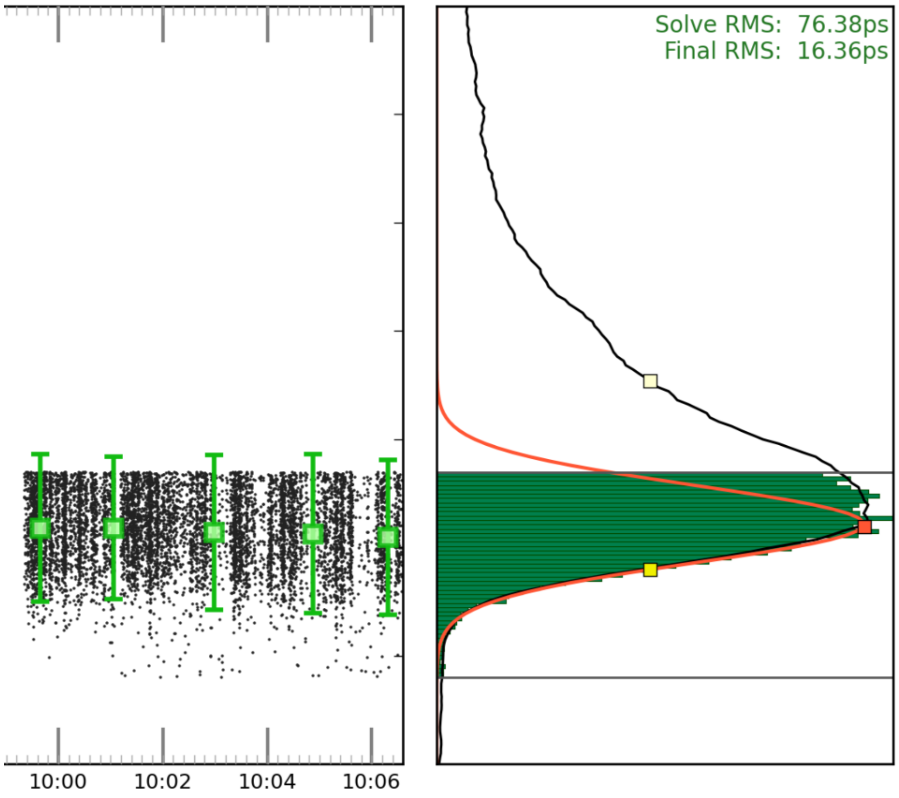
Clipping for Normal Points

From the LEHM, fixed clipping can be applied that is set for all passes.

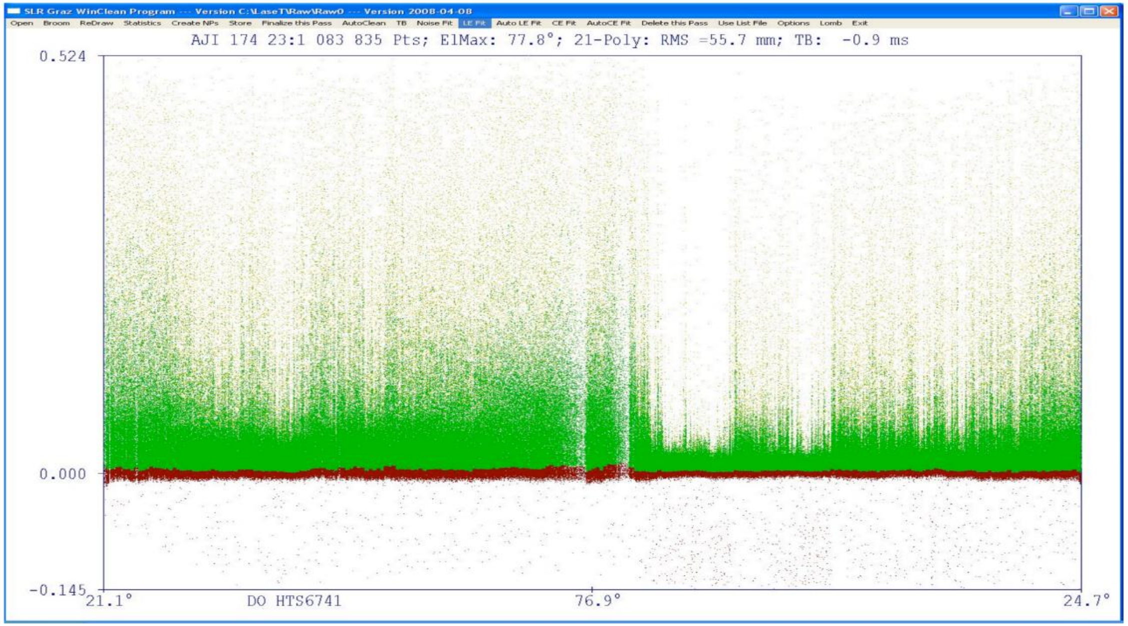
But, what level of clipping is best?



Front Clipping at Graz

This is leading us towards the front edge clipping that is in use at Graz.

This alternative method, used for certain satellites, clips range residuals close to the front of the distribution.



Kirchner et al, Millimeter Accuracy from Centimeter Targets, IWLR, Poznan 2008.
https://cddis.nasa.gov/lw16/docs/papers/rep_2_Kucharski_p.pdf

Regenerating Normal Points

To assess the impact of this new method, *unclipped* full-rate data files were generated using the raw SLR data file and the original full-rate data files for LAGEOS 1 and 2 for 2015 to 2017 inclusive.

Using a program called orbitNP.py, these files were reduced, forming normal points, with fixed one-way range clipping values of:

Lower Clipping Point from LEHM (ps)	**Upper** Clipping Point from LEHM (ps)
-50	150
-50	120
-50	90
-50	65
-50	45

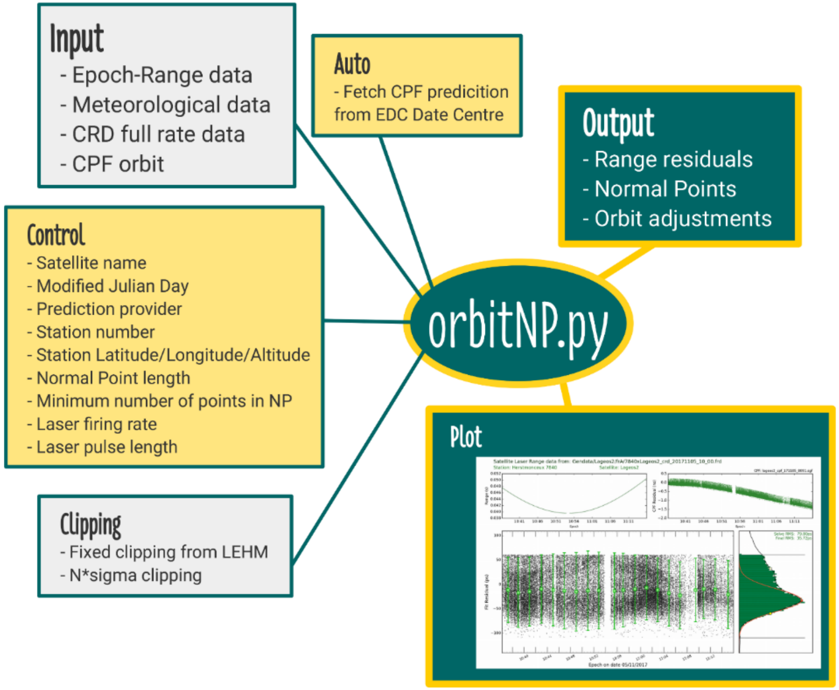
OrbitNP.py

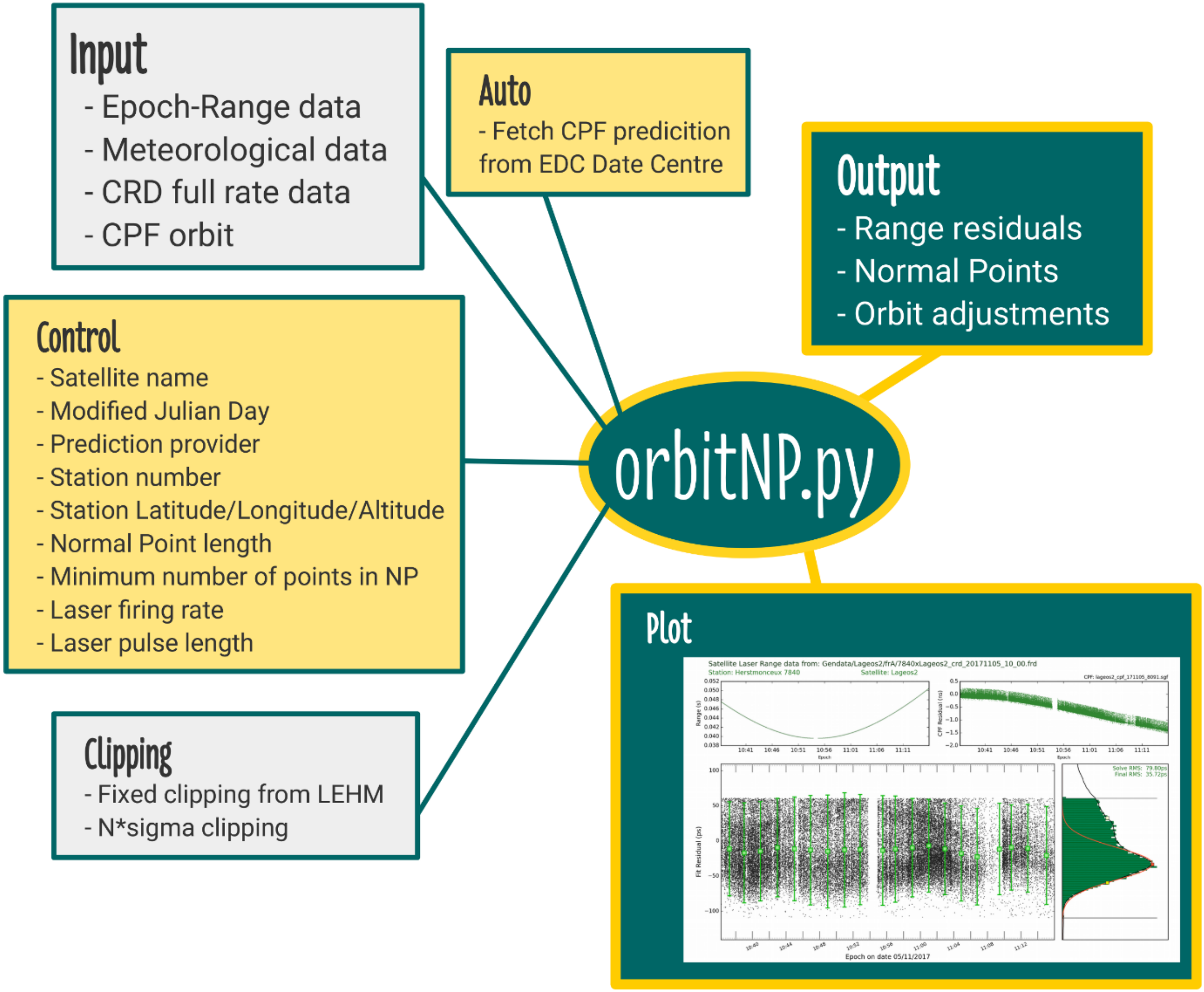
The SGF uses a FORTRAN program named ‘solve’ to produce flattened residuals for normal point formation.

This was translated in to PYTHON and made more versatile and universal to run on the command line.

An early version or this program is now available through the ILRS Software Study Group.

It can be used as example code for SLR data reduction or as an analysis tool to interrogate full-rate date from the ILRS Data Centres.

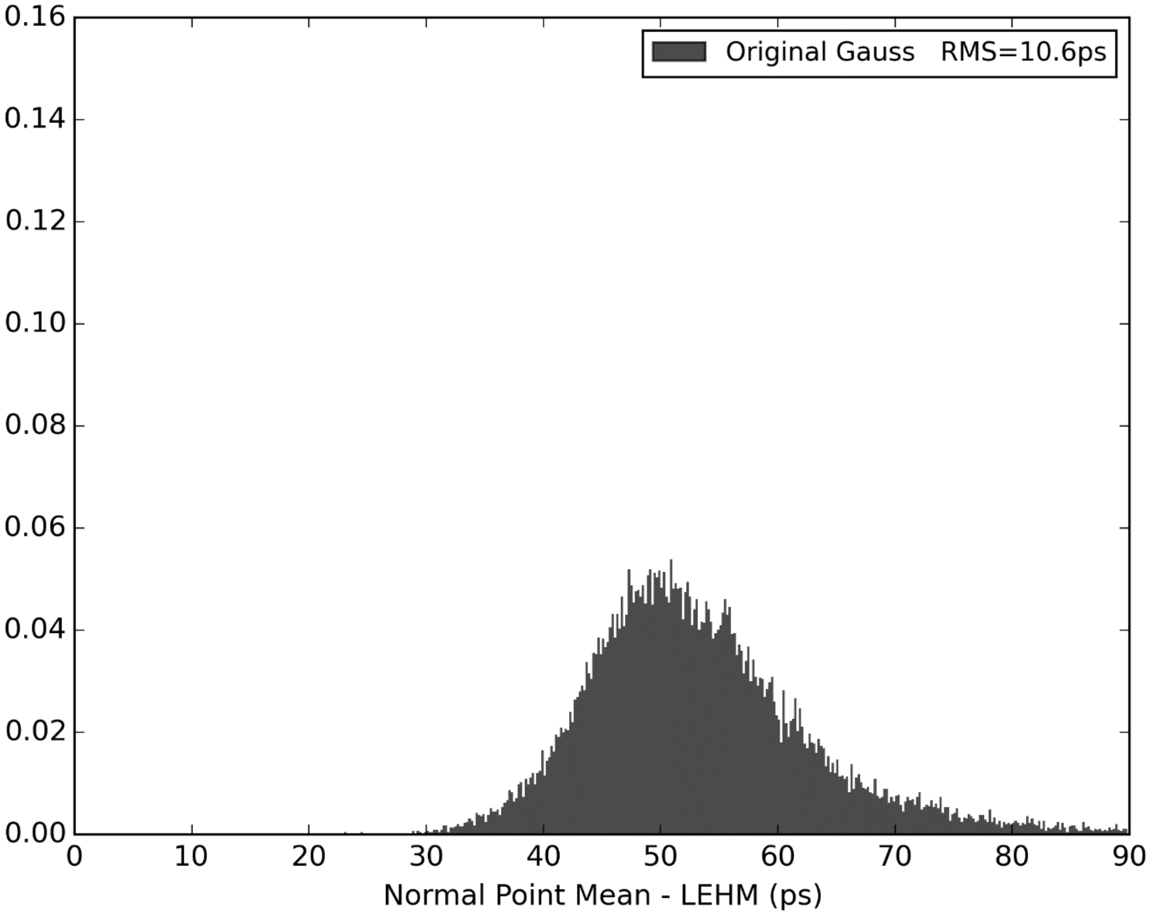



Input
- Epoch-Range data
- Meteorological data
- CRD full rate data
- CPF orbit
Auto
- Fetch CPF predicition from EDC Date Centre
Output
- Range residuals
- Normal Points
- Orbit adjustments
Control
- Satellite name
- Modified Julian Day
- Prediction provider
- Station number
- Station Latitude/Longitude/Altitude
- Normal Point length
- Minimum number of points in NP
- Laser firing rate
- Laser pulse length
orbitNP.py
Clipping
- Fixed clipping from LEHM
- N*sigma clipping
Plot
Satellite Laser Range data from: Gendata/Lageos2/frA/7840xLageos2_crd_20171105_10_00.frd
Station: Herstmonceux 7840
Satellite: Lageos2
CPF: lageos2_cpf_171105_8091.sgf
Range (s)
CPF Residual (ns)
Epoch
Fit Residual (ps)
Solve RMS: 79.80ps
Final RMS: 35.72ps
Epoch on date 05/11/2017

Clipping Results

To assess the normal point measurement variability, a histogram of the normal point means from the LEHM is plotted.

The distribution of this distance for our current Gauss fit method for 3 years of LAGEOS 1 and 2 data has a standard deviation of 10.6ps



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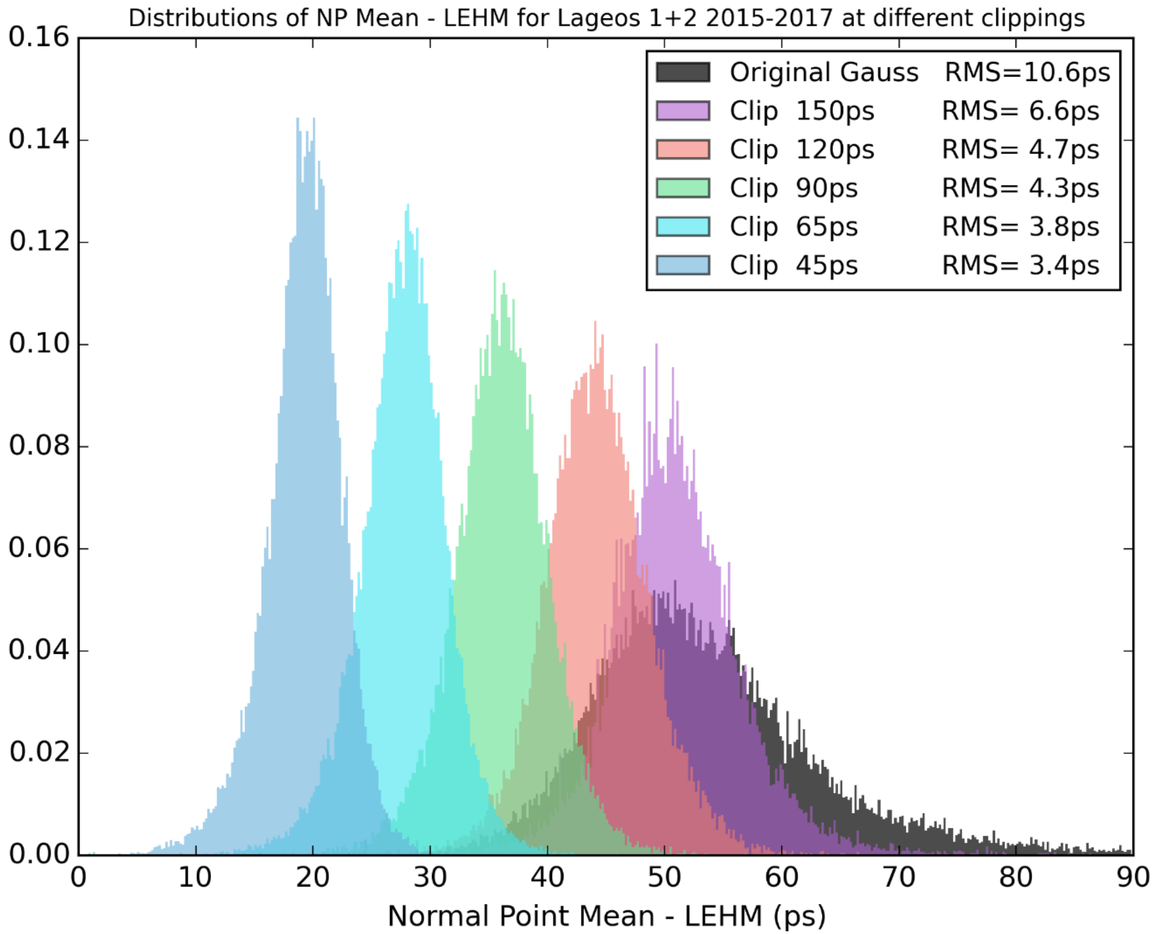
Clipping Results

By comparison, the NP mean – LEHM distributions from the clipped datasets are tighter.

Clearly, as the clipping applied is tighter the distance from the NP mean and the LEHM is reduced and the measurement is made closer to the front of the satellite.

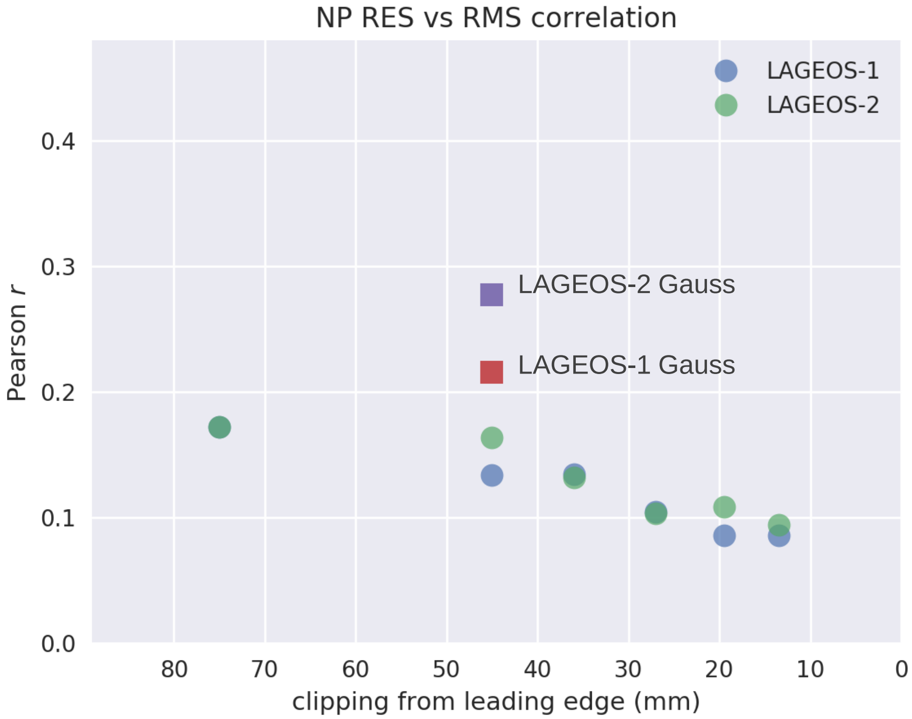


Analysis Results

These new normal point datasets were submitted for analysis using the SGF SATAN orbit software. Weekly solutions were made from 2015 to 2018 for each dataset.

The correlation between the LAGEOS normal point range residuals and RMS was calculated for each dataset.

It reduces as the clipping is applied closer to the LEHM, to a low Pearson r value of < 0.1 with the tightest value.



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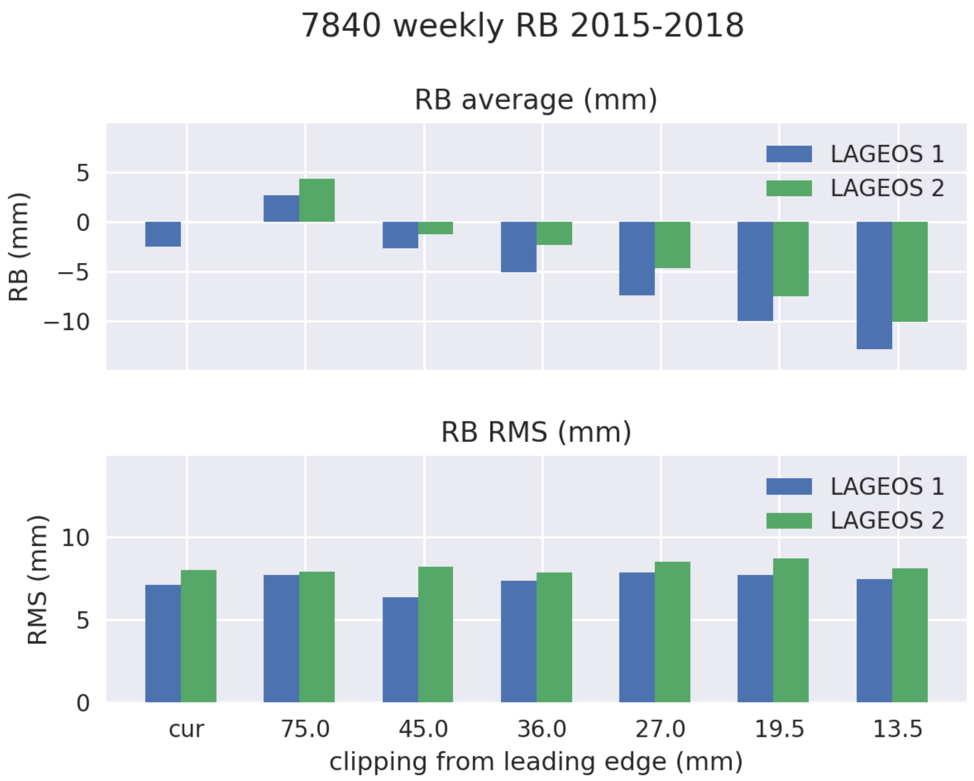
Analysis Results

The weekly solutions include an estimate of range bias for a station. The 3 year averages are plotted here.

Using a fixed centre-of-mass value of 245mm, the calculated range bias for the Herstmonceux station increases with tighter clipping.

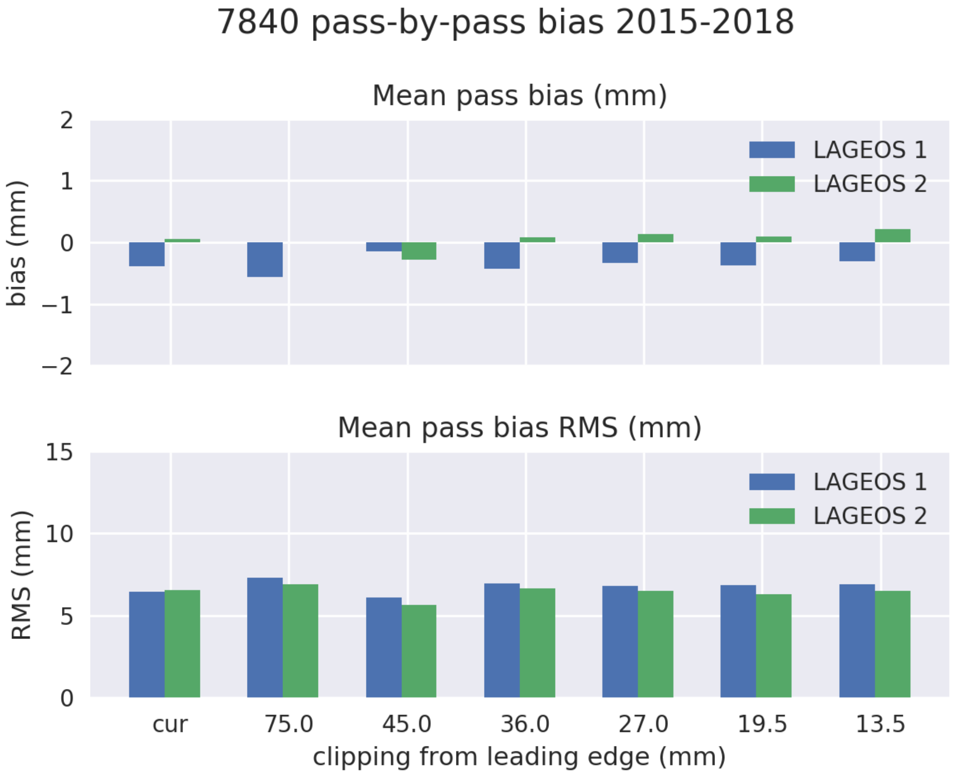
This is to be expected as the normal point range is being measured closer to the front of the satellite.



Analysis Results

The clipping does not have much effect on the average pass range bias or the RMS of pass range bias.

An alternative way to look for any improvement is to account for modelling error in the solutions using a polynomial fit to each pass.

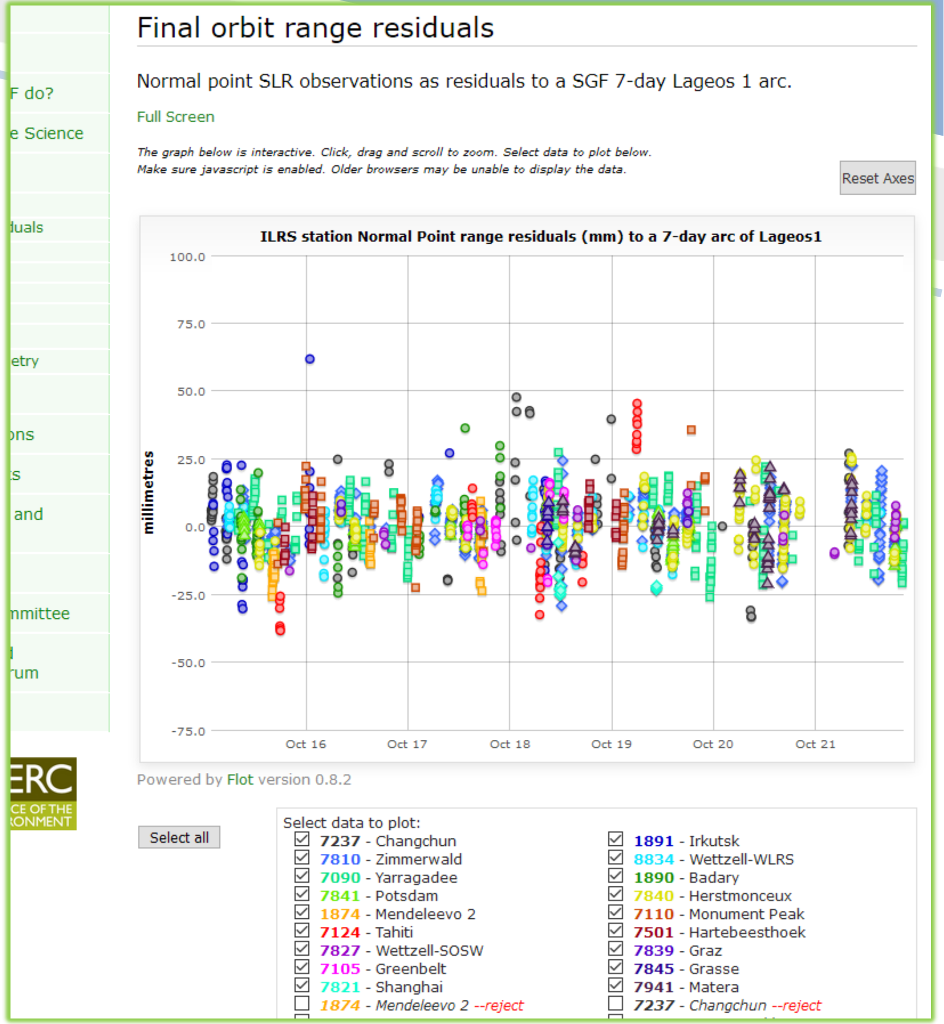


Analysis Results

A quadratic polynomial was removed from every pass to account for modelling errors.

The RMS of the remaining residuals was then calculated for each dataset for LAGEOS 1 and 2.

Using this method, it can be seen that the clipping reduces the normal point to normal point variation.



http://sgf.rgo.ac.uk/analysis/nporbit.html

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Analysis Results

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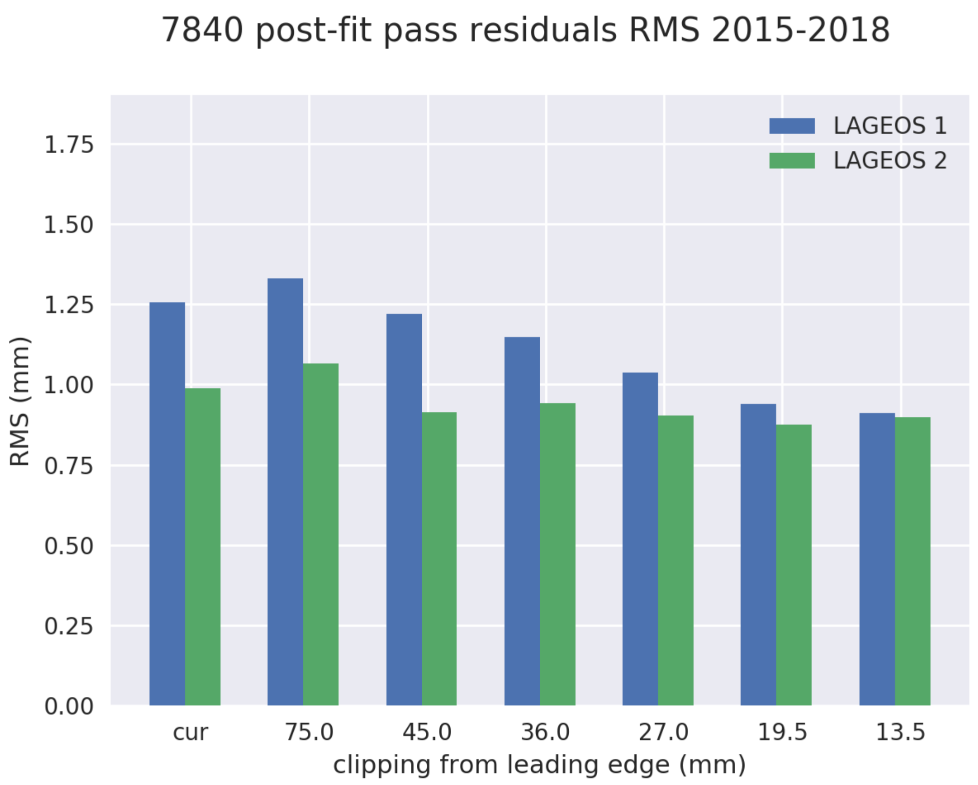
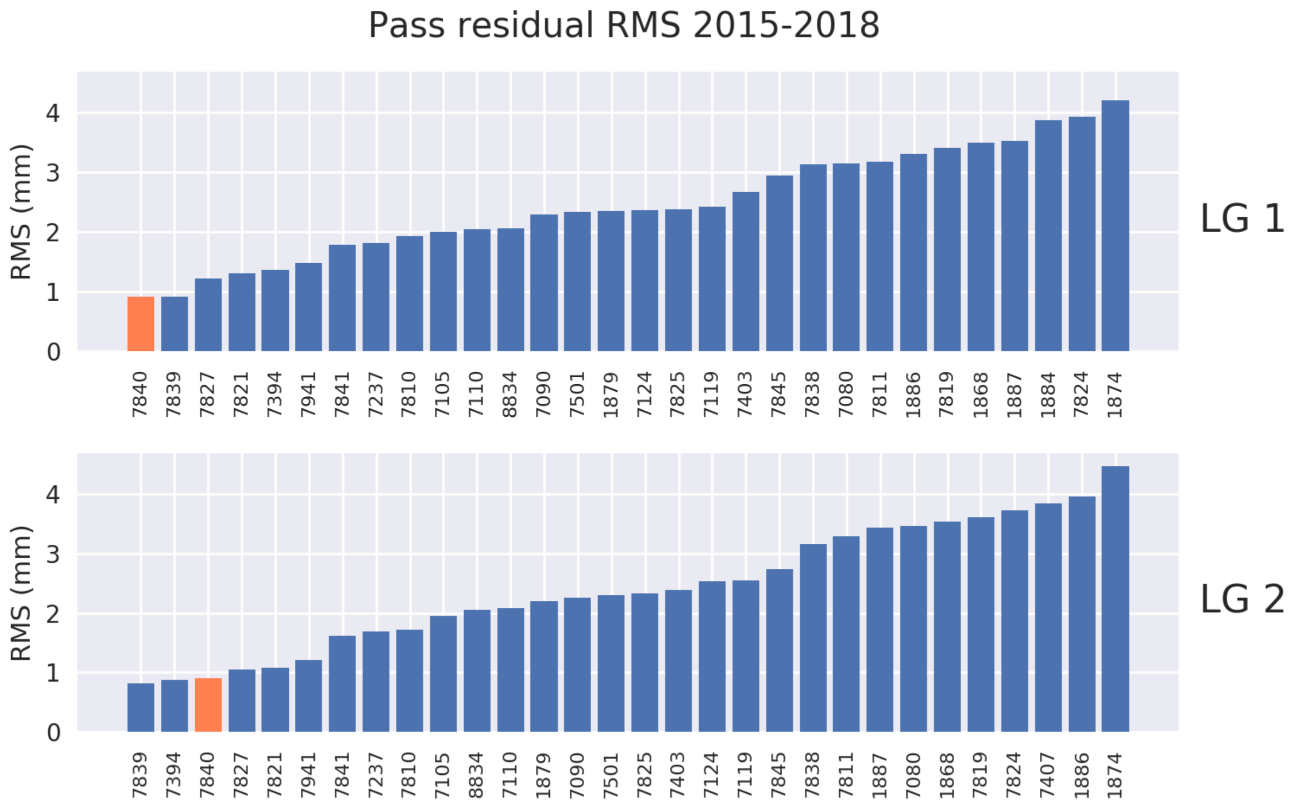


Analysis Results

Using this polynomial fit method, the RMS of the remaining residuals was calculated for each station.

This value reduces for Herstmonceux for both LAGEOS 1 and 2 with tighter clipping.



Conclusions

- How stations process laser ranges matters and needs to consistent.
- The normal point range residual dependency on single shot RMS can be minimised with controlled clipping about a well defined point on the satellite distribution.
- We have not found any evidence of this correlation having an impact on the analysis products.
- However, this does improve the quality of the SLR measurements from Herstmonceux by decreasing the normal point variability.
- The orbitNP.py software is available to assist users in using orbit correction to produce flattened range residuals

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