Processing of SLR observations with an optimal Wiener filter - an alternative way to calculate normal points

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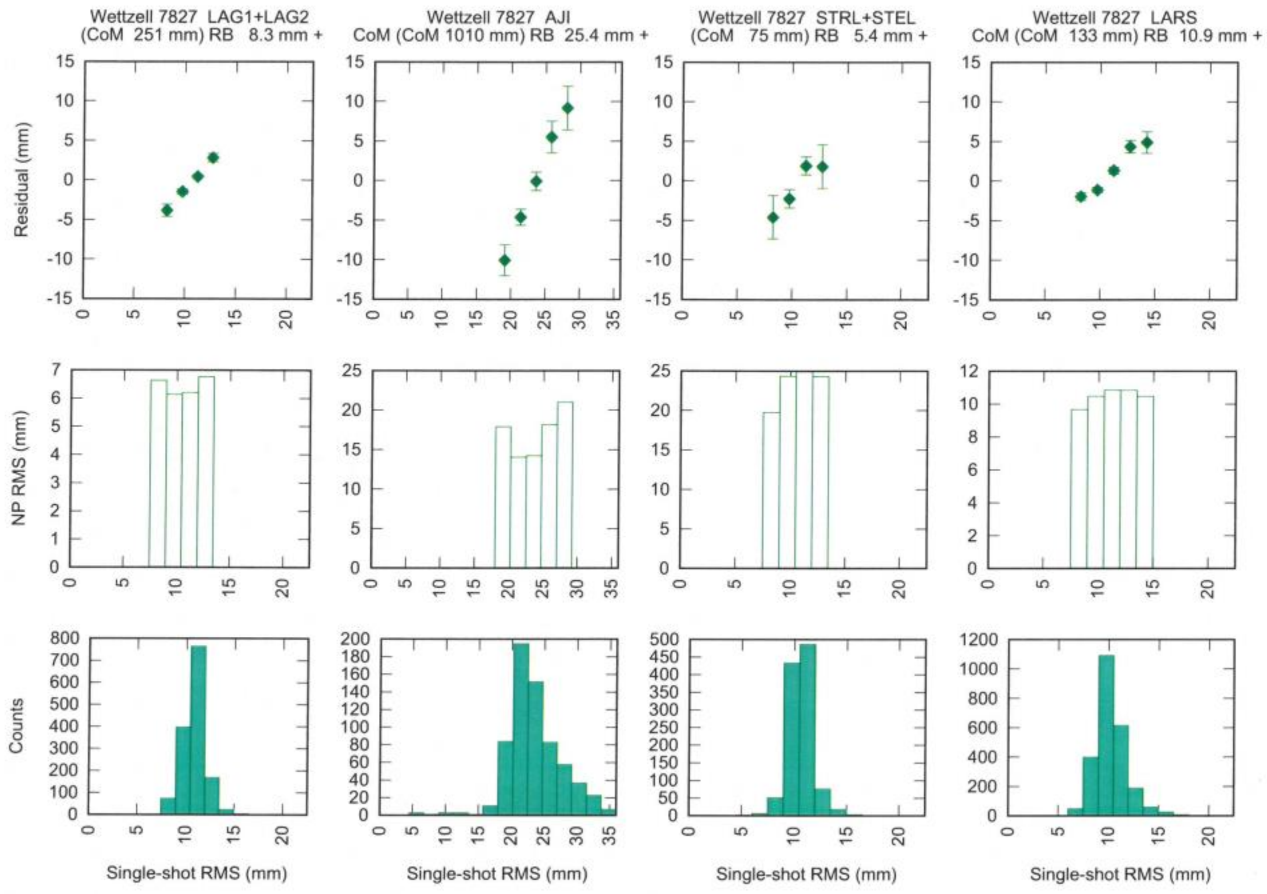
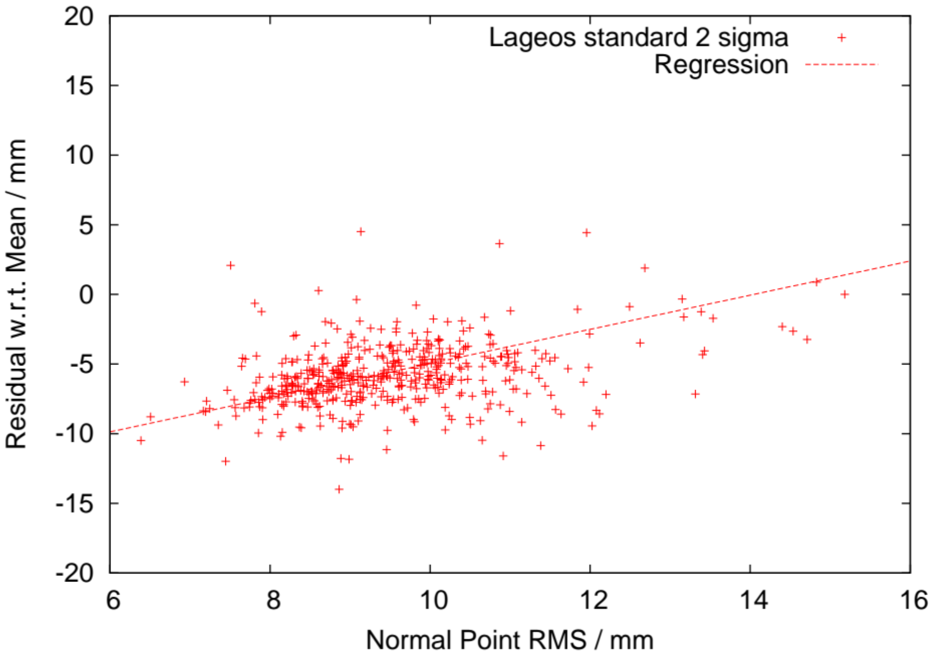
Motivation



Wettzell 7827 LAG1+LAG2
(CoM 251 mm) RB 8.3 mm +
Wettzell 7827 AJI
CoM (CoM 1010 mm) RB 25.4 mm +
Wettzell 7827 STRL+STEL
(CoM 75 mm) RB 5.4 mm +
Wettzell 7827 LARS
CoM (CoM 133 mm) RB 10.9 mm +
Residual (mm)
NP RMS (mm)
Counts
Single-shot RMS (mm)

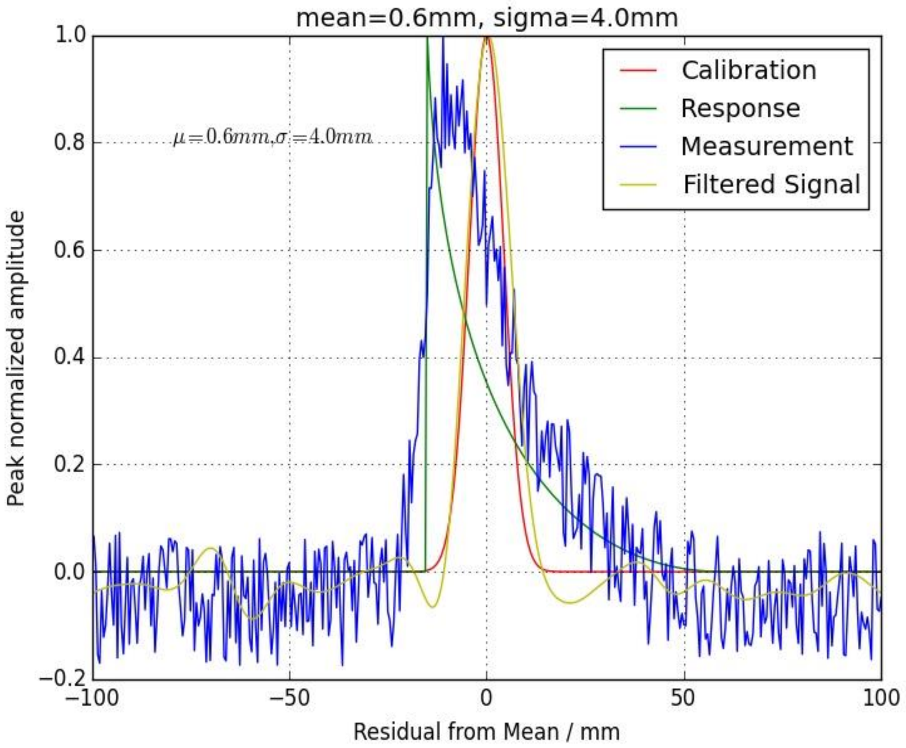
Systematic Effect visible in normal point residuals generated on site

- 12 months Lageos1 and Lageos2 normal points from 2017
- Effect is supposed to be a data editing problem (2sigma iterative data clipping)
- Trend of HIT-U analysis is reproduced



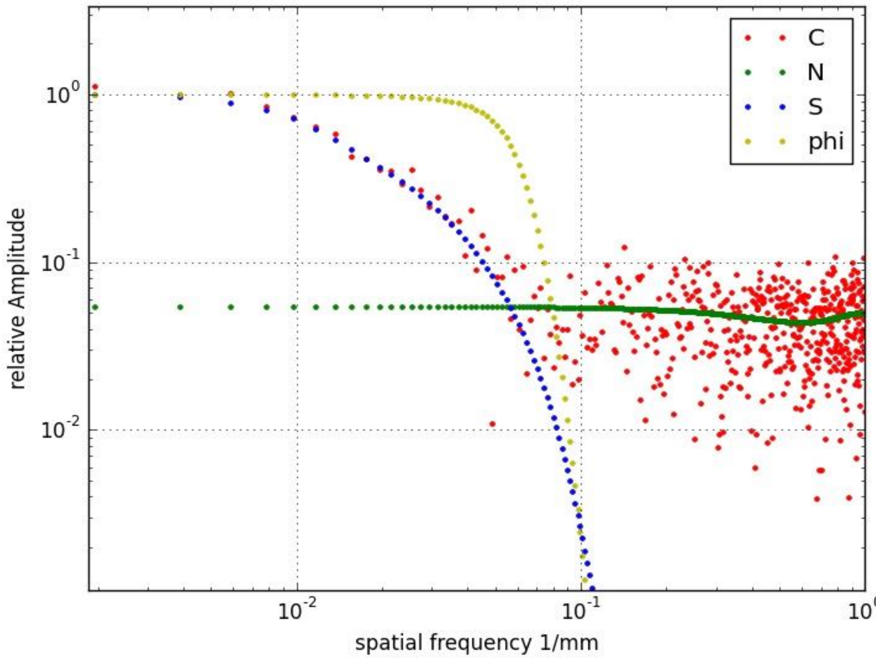
Optimal Wiener (deconvolution) Filter

- Proposed by N.Wiener (1949)
- Statistical Filter based on least square method
- Seems to be made for SLR
- Eliminates skewness of data distribution
- Data clipping systematics don't exist
- Removes noise
- Procedure:
- → Calculate histogram for every normal point window
- → Deconvolve Transfer function and do statistics on filtered signal

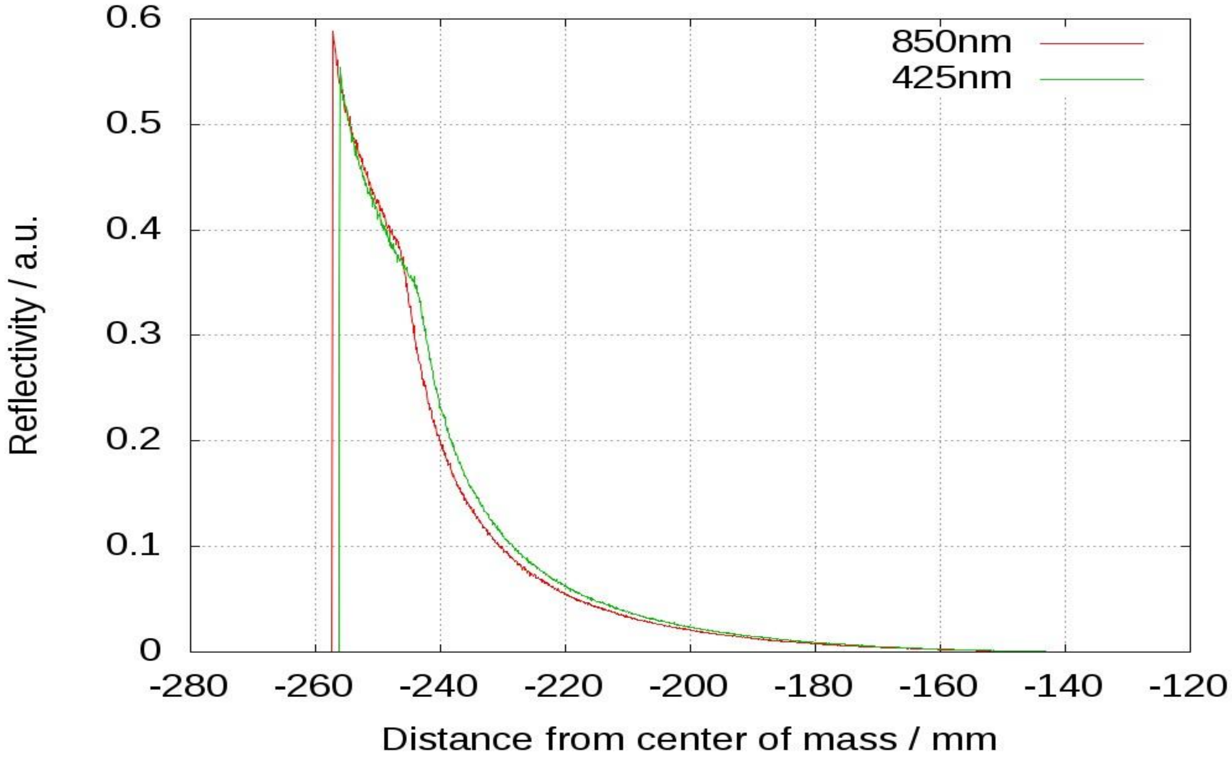


Wiener Filter works in frequency space

- C – Measured signal spectrum
- N – Noise spectrum modeled from high frequency components in C
- S – Signal spectrum modeled from theoretical transfer function (R) and calibration
- phi – resulting filter coefficients
- Fourier transform of filtered signal:
- Us=C*phi/R, phi=S²/(N²+S²)

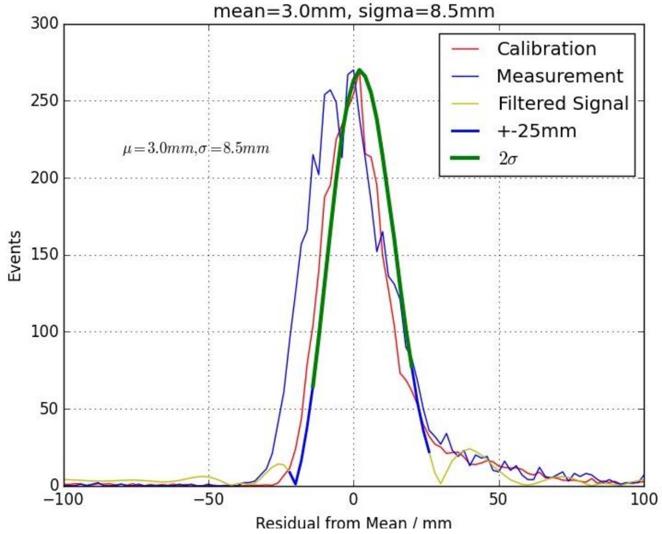


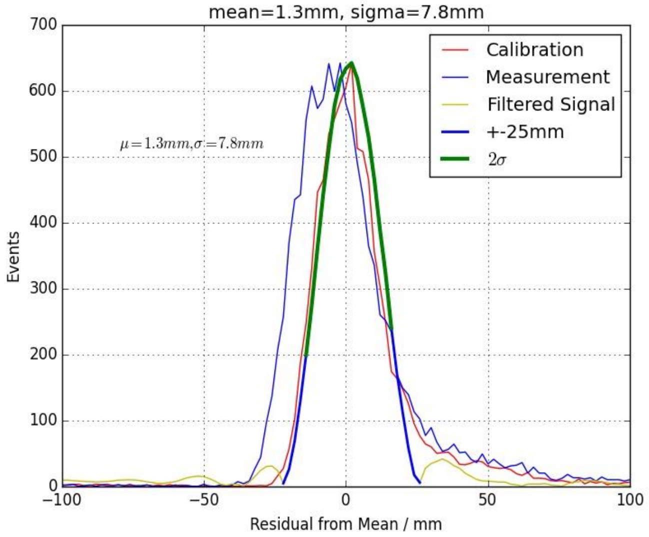
Lageos transfer function (kindly provided by J.Rodriguez)

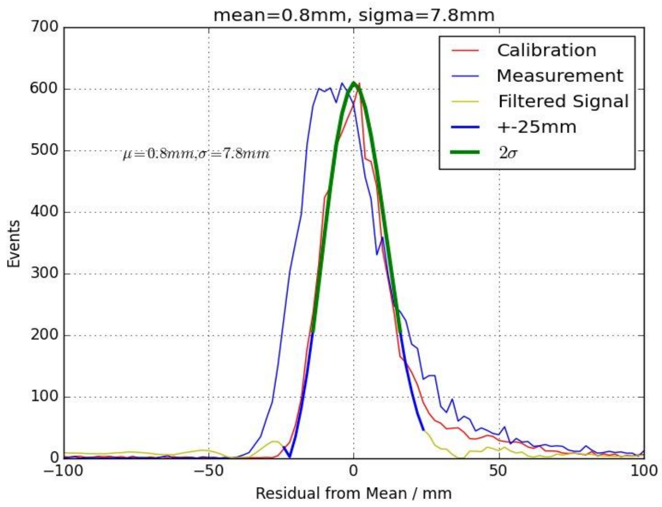


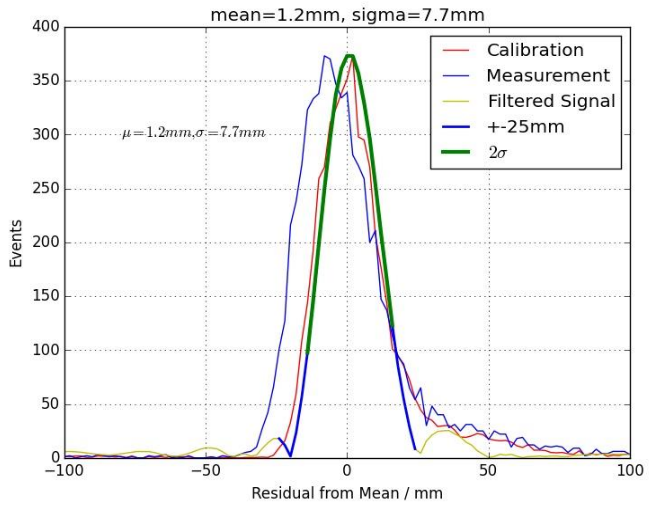
- Numerical Calculation
- Proper Group Refractive Index taken into account
- 0.1mm bin spacing
- Decay ~ ea^n is modelled with n=1 (should be n=1.1 according to Otsubo and Appleby, System-dependent center-of-mass correction for spherical geodetic satellites, Journal of Geophysical Research (2003))

SOS-W normal point samples obtained from Lageos measurements

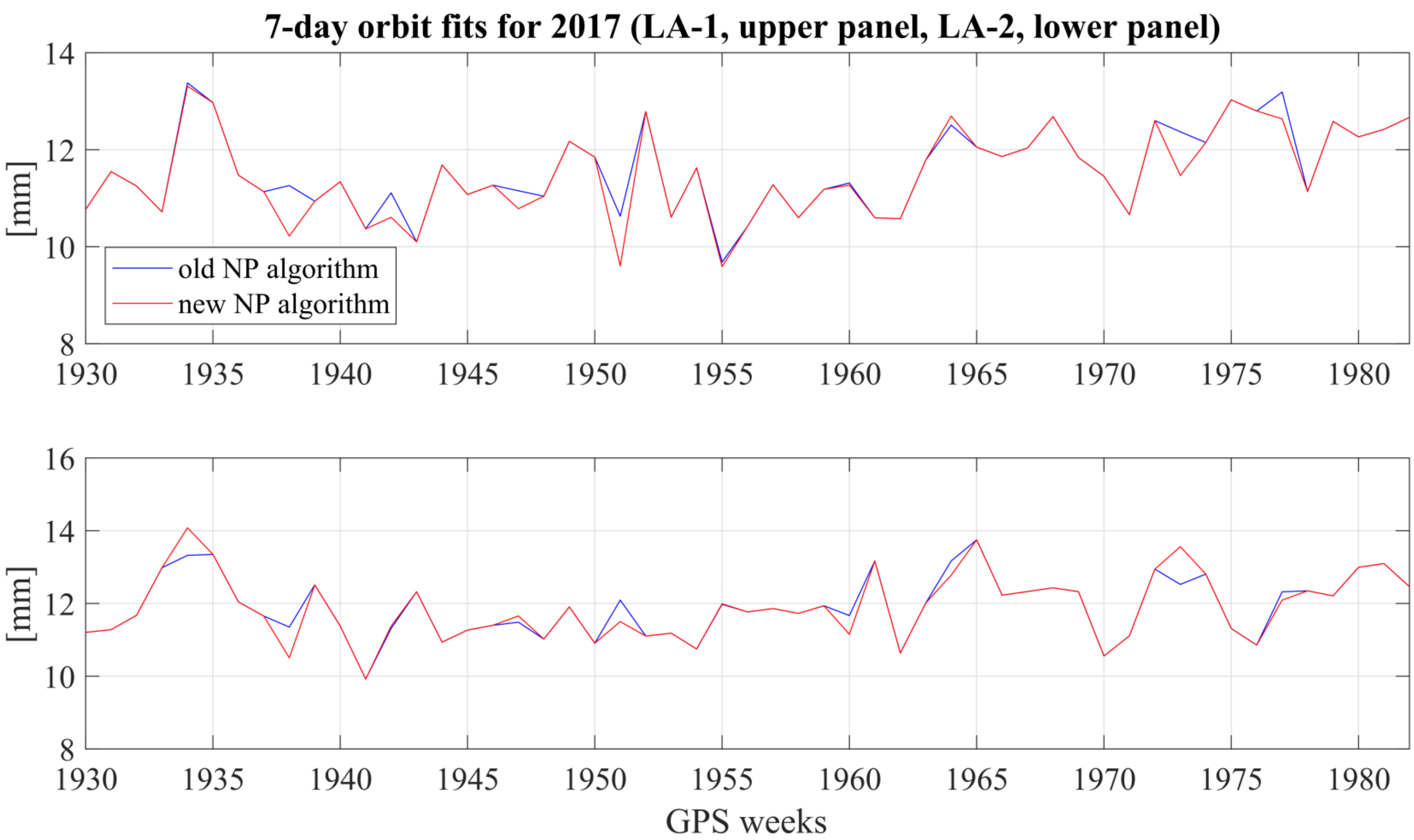




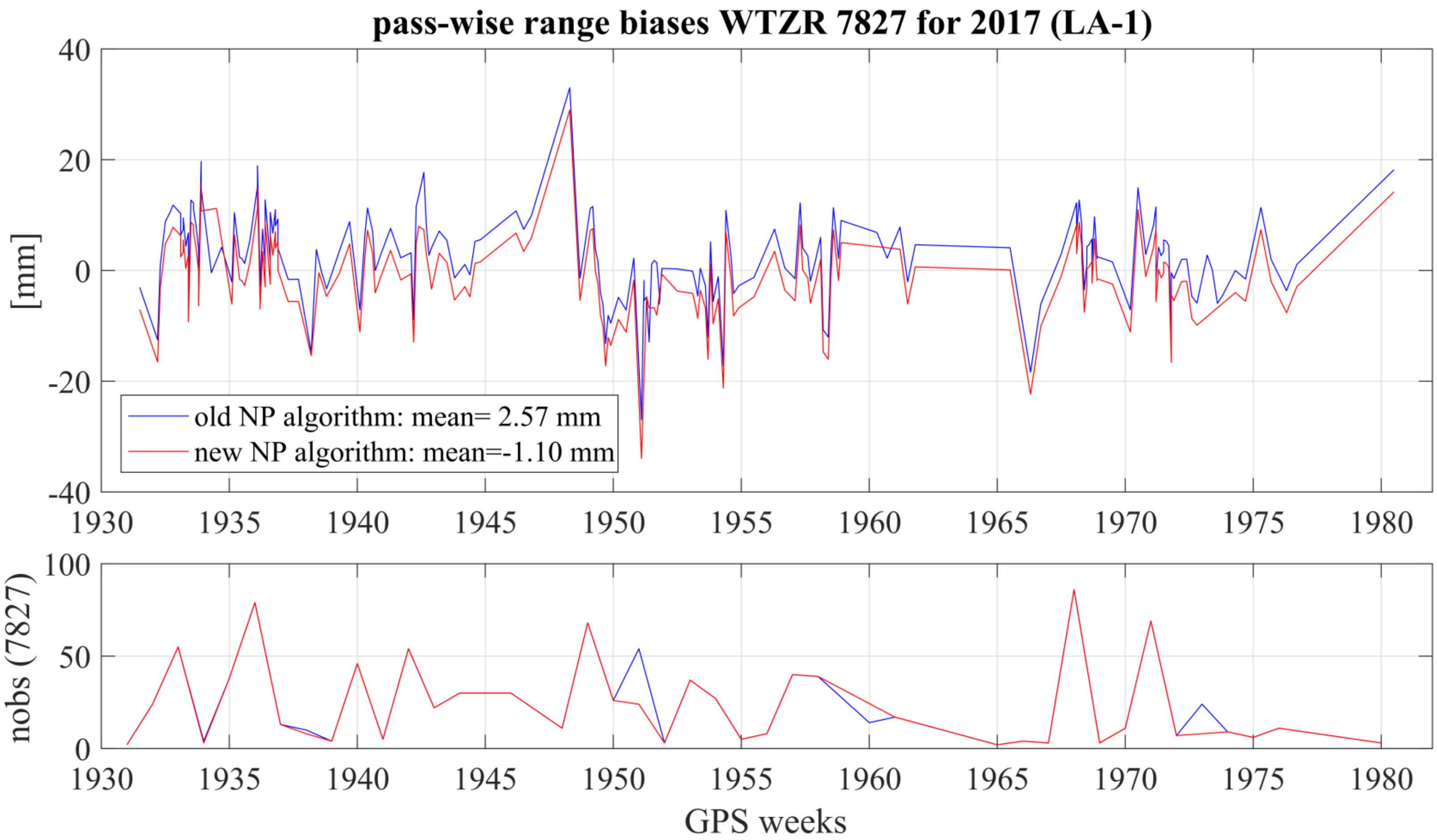




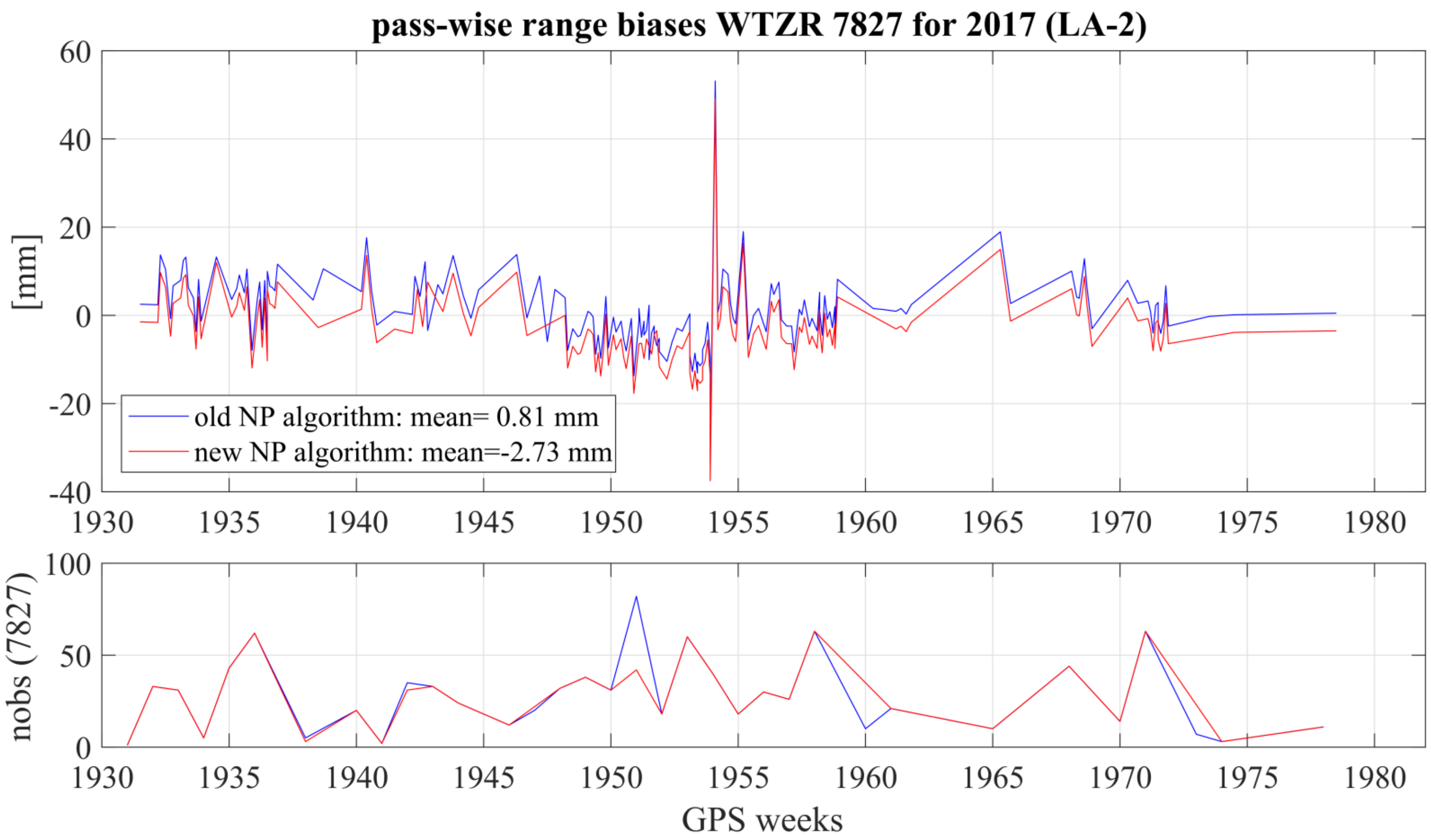
Application to Lageos
Orbit fit quality



Application to Lageos
Bias estimation Lageos 1



Application to Lageos
Bias estimation Lageos 2



Application to Lageos - results and comparison

- No systematics remain
- Normal Points distributed around mean of transfer function as expected
- Applied COM 245mm for standard 2sigma data
- Applied COM 241mm for Wiener filtered data (mean of transfer function)
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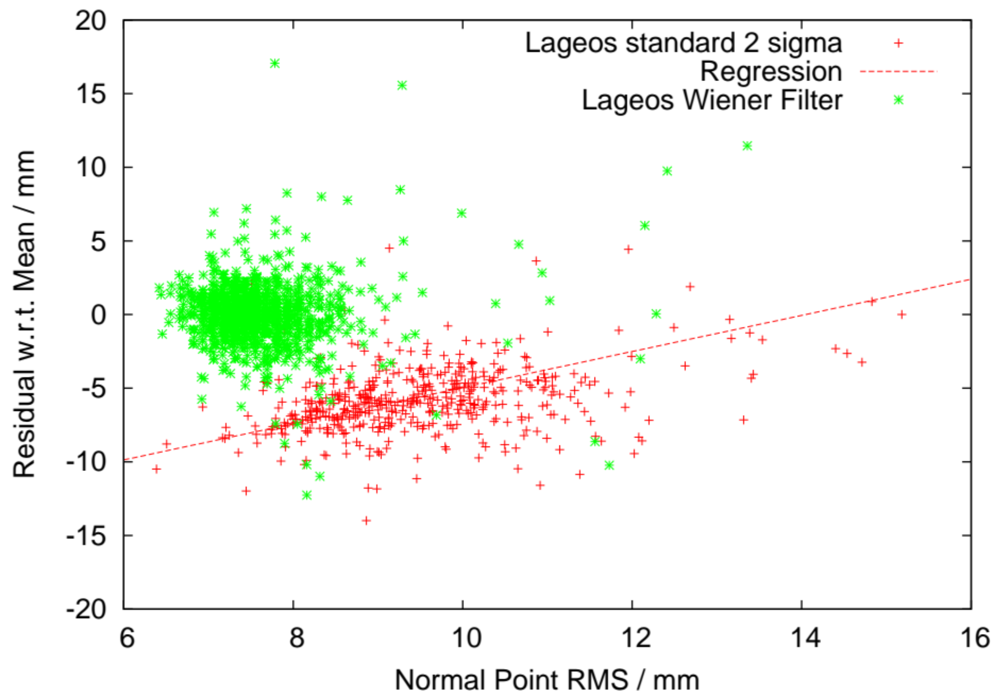

- Remaining biases:
- standard 2sigma NPs: -2.6mm (LA1), -0.8mm (LA2)
- Wiener filtered NPs: -1.1mm (LA1), -2.7mm (LA2)
- Remaining issue:
- decay of transfer function (this study n=1.0)
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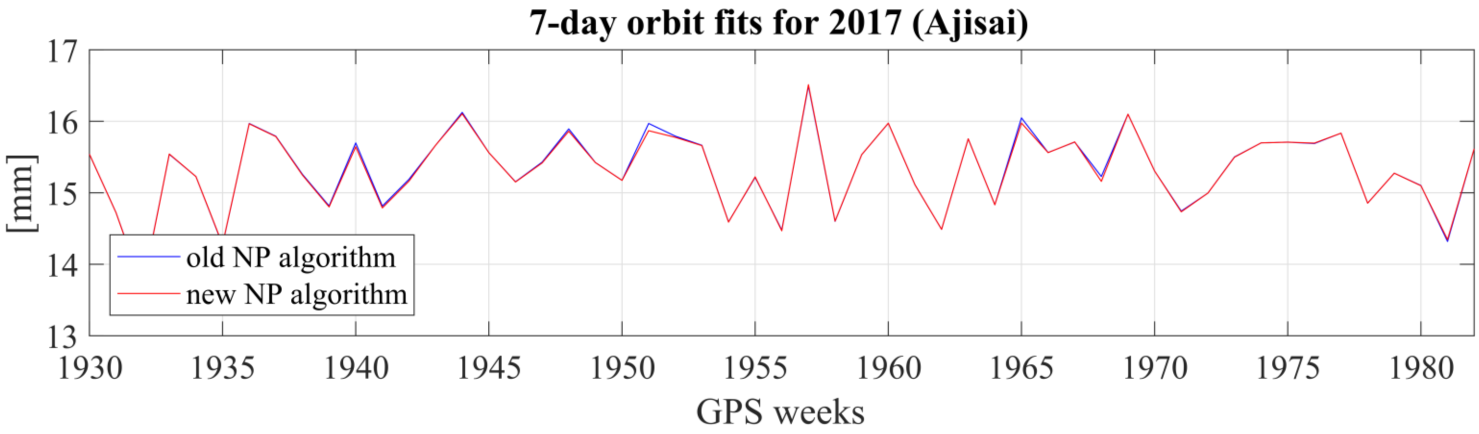
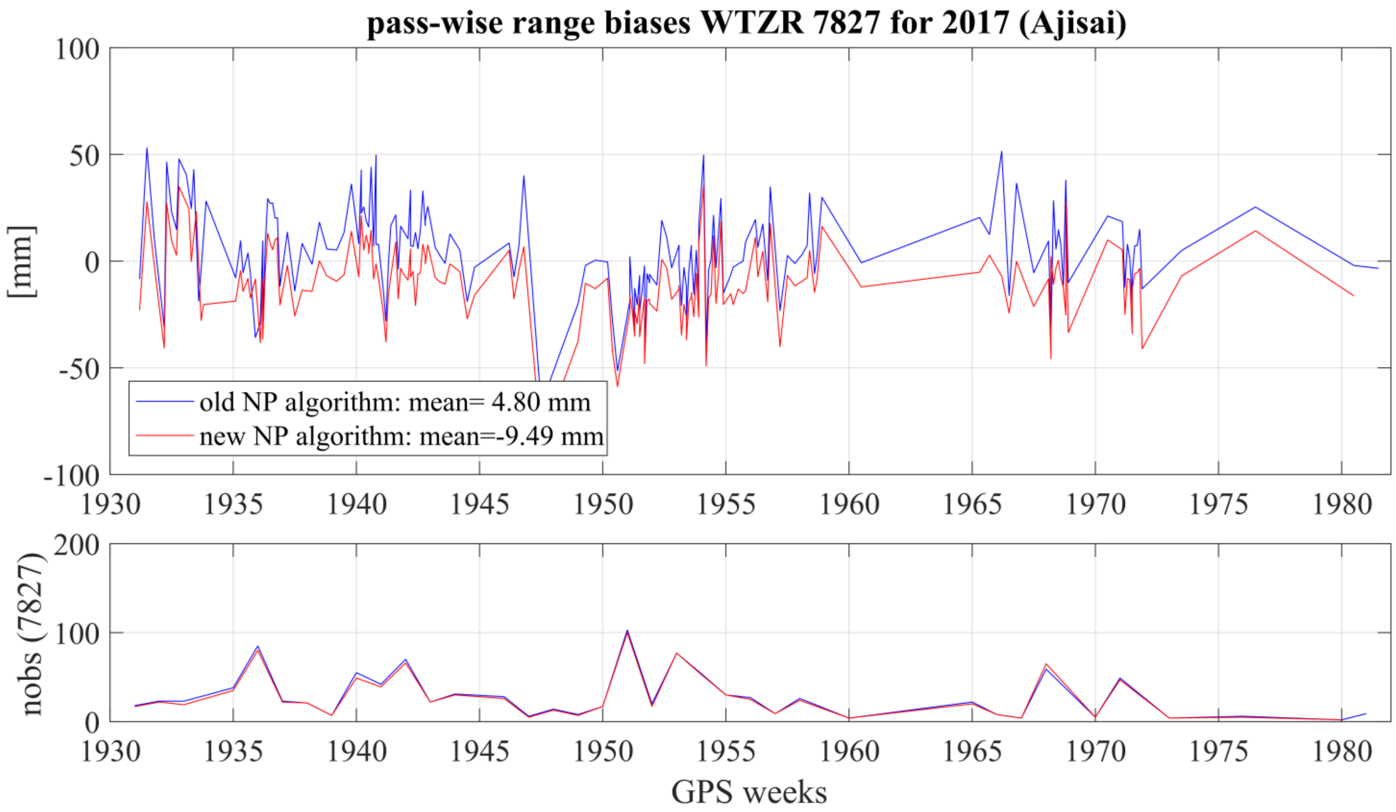
Application to Ajisai
Orbit fit quality



Application to Ajisai - bias estimation



Application to Ajisai - results and comparison

- Transfer Function provided by T.Otsubo (with n=1.2)
- Applied COM of 993mm for standard 2sigma data
- Applied COM of 962 for Wiener filtered data
- Improved normal point statistics
- When using the transfer function as provided a positive bias of 5mm remains for standard 2sigma and -9.5mm for Wiener filtered normal points
- Similar effect also visible in Herstmonceaux data (DGFI Bias analysis)
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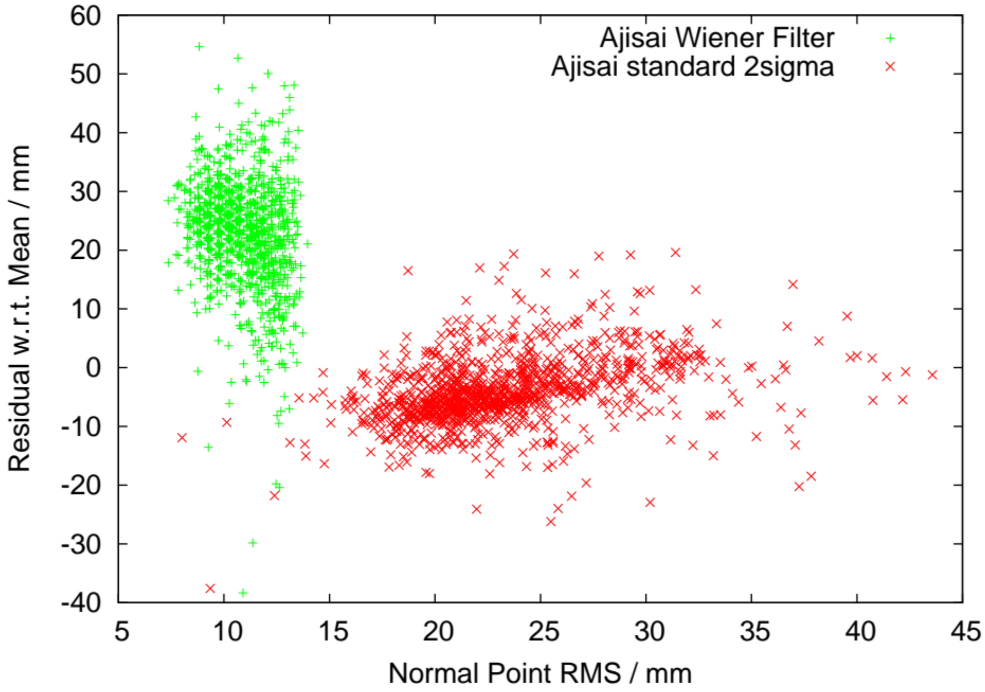
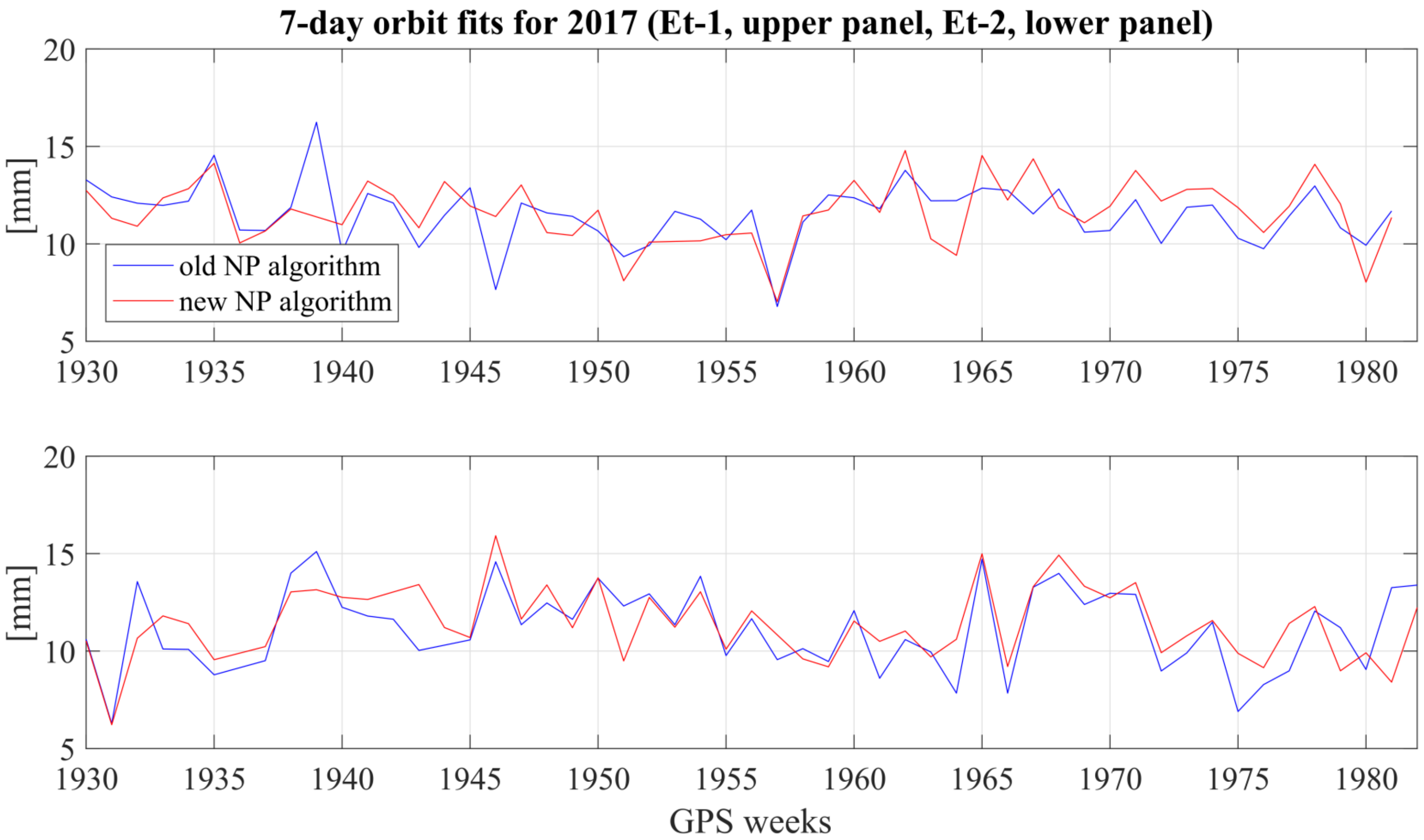
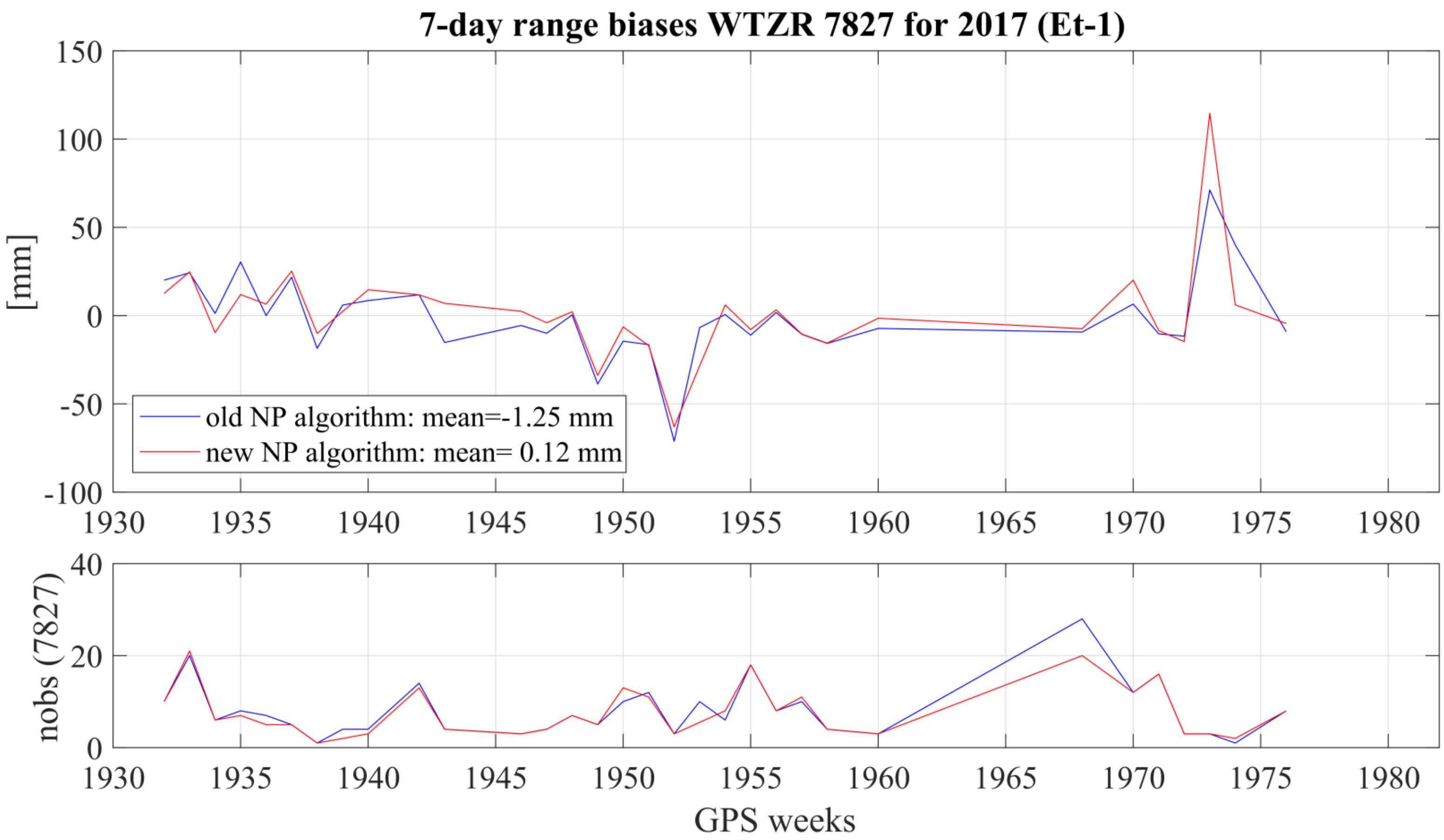


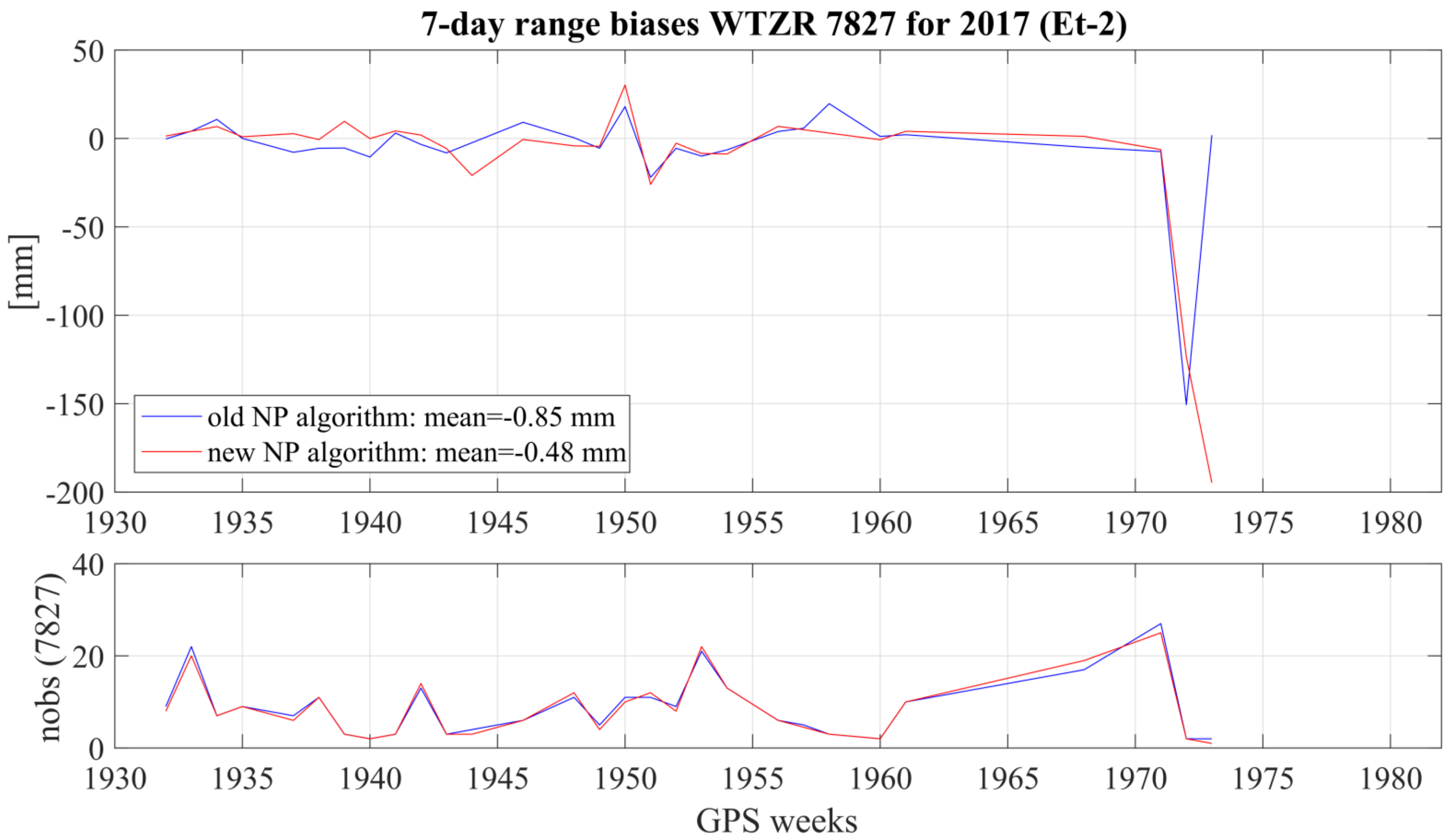
Application to Etalon
Orbit fit quality



Application to Etalon
Bias estimation Etalon 1

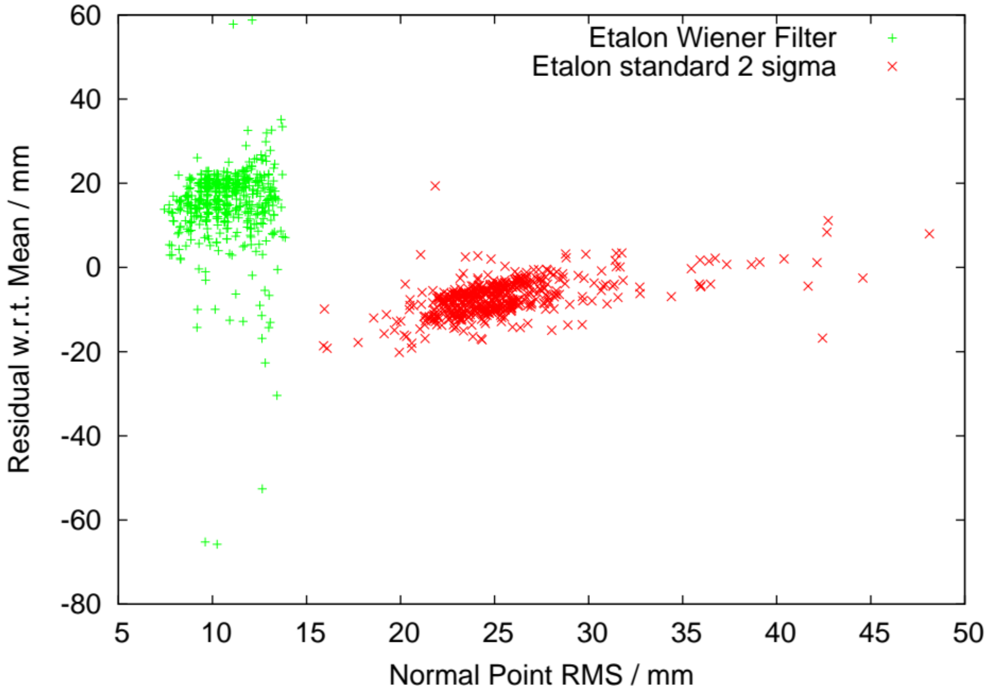


Application to Etalon
Bias estimation Etalon 2



Application to Etalon - results and comparison

- Transfer Function provided by J.Rodriguez (with n=1.3)
- Applied COM 579mm for 2sigma normalpoints
- Applied COM 554.5mm for Wiener filtered normalpoints
- Bias analysis shows equal results for both Etalons
- Even with sparse data the Wiener filter algorithm performs equally well



- Remaining biases:
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- standard 2sigma NPs: -1.3mm (ET1), -0.9mm (ET2)
- Wiener filtered NPs: -0.9mm (ET1), -0.5mm (ET2)
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Conclusion

- Comparison of standard 2 sigma iterative edited normal points with Wiener filtered normal points has been performed for Lageos, Ajisai and Etalon satellites
- Bias analysis shows in general equal results for Wiener filtered and standard 2sigma normal points
- Normalpoint residual vs. normalpoint RMS systematics are improved using the Wiener filter algorithm
- Etalon analysis shows that the Wiener filter algorithm yields same volume of normalpoints even with sparse data, biases agree for both methods
- Biases for Ajisai remain unexplained
- Lageos biases agree within 2mm. Discrepancy of Wiener filtered normalpoints might be due to the transfer function (n=1.0) used.
- Biases of Lageos1 and Lageos2 differ by about 1.6mm for both standard 2sigma (-1.8mm) and Wiener filtered normal points (+1.6mm)