Jason 3 GPS orbits with ambiguity fixing

Flavien Mercier (CNES), Hanane Ait Lakbir (CS-SI), Alexandre Couhert (CNES)

OSTST 2017, Miami

Summary

Introduction

Some Jason 3 receiver characteristics
- pseudo-range biases
- widelane properties

Zero difference ambiguity fixing
- method
- global statistics

Orbit performance
- GRD-E orbit comparisons
- normal bias
- SLR residuals

Context

GPS receivers on altimetry satellites

- **Jason 1** : the possibility of ambiguity fixing has been demonstrated
  (2004, double differences (JPL), 2009, zero differences (CNES))

- **Jason 2** : half cycles ambiguities, half cycle slips (SNR issues),
  reliable ambiguity fixing not possible

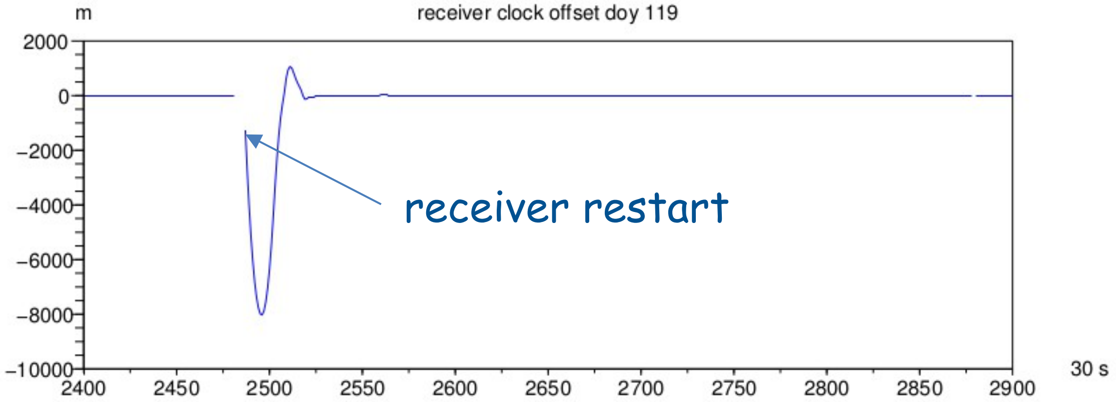
- **HY2A** : correct ambiguity fixing (2012, not operationally implemented)

- **Sentinel 3A** : half cycle ambiguities observed in the CPOD rinex files,
  reliable ambiguity fixing not possible

For **Jason 3** : very good quality of the measurements, no more SNR problems
zero difference ambiguity fixing operational orbits are possible (2017)

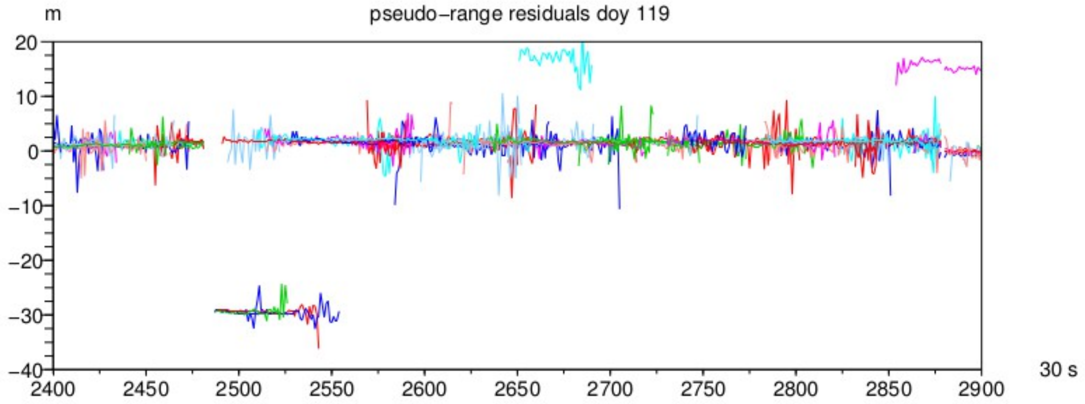
Jason receiver measurements characteristics

Receiver clock



Pseudo-range residuals

(solution with downweighted pseudo-range)

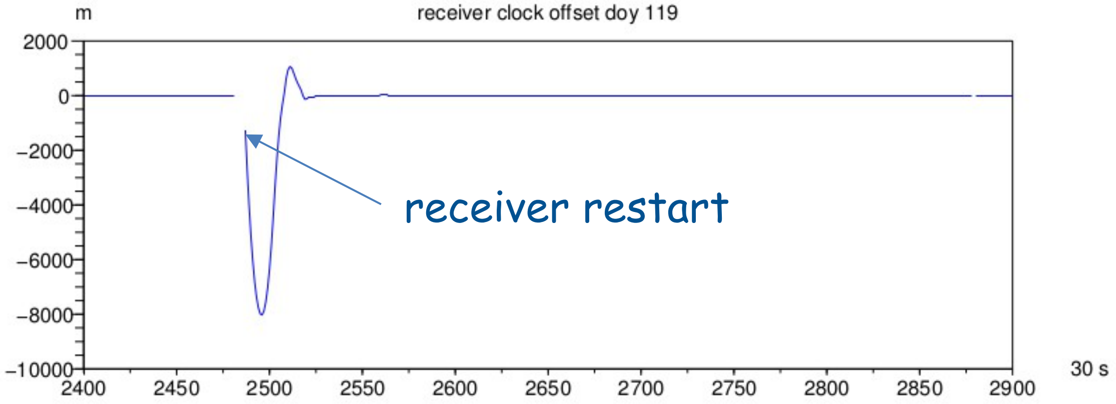


Jason receiver measurements characteristics

Pseudo-range biases :

- some isolated passes biased (15 meters), on C1,P1,P2

Receiver clock



one pass

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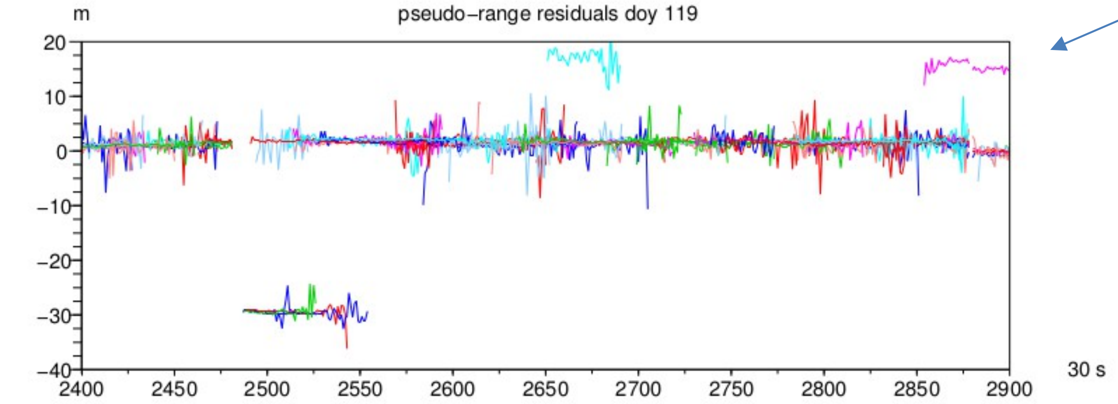
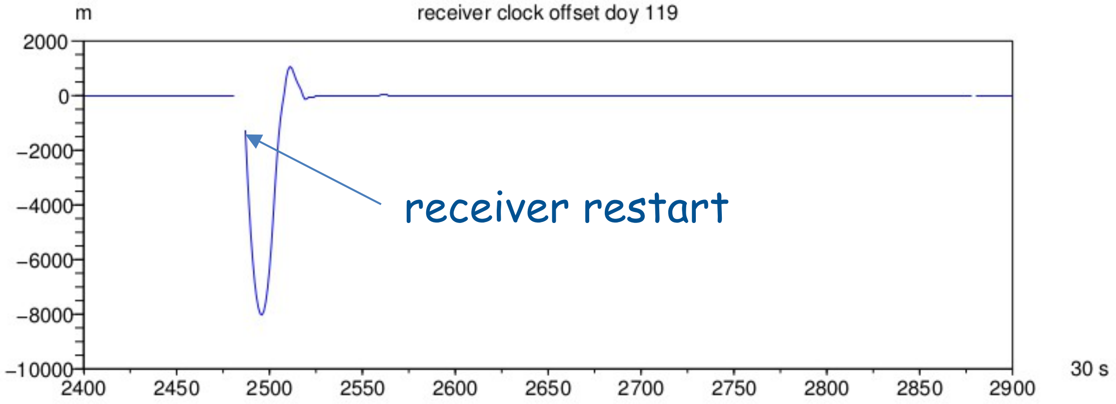


Jason receiver measurements characteristics

Pseudo-range biases :

- some isolated passes biased (15 meters), on C1,P1,P2
- systematic simultaneous biases observed during recevier restarts, on C1,P1,P2

Receiver clock



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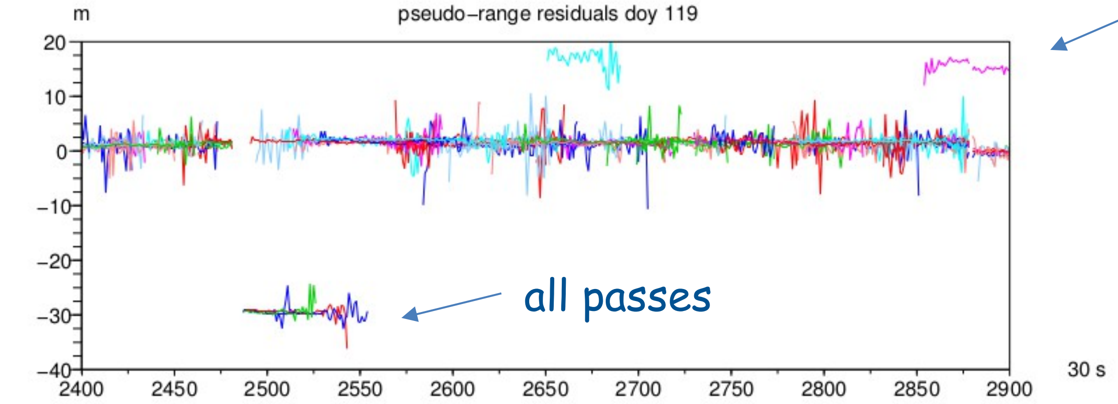
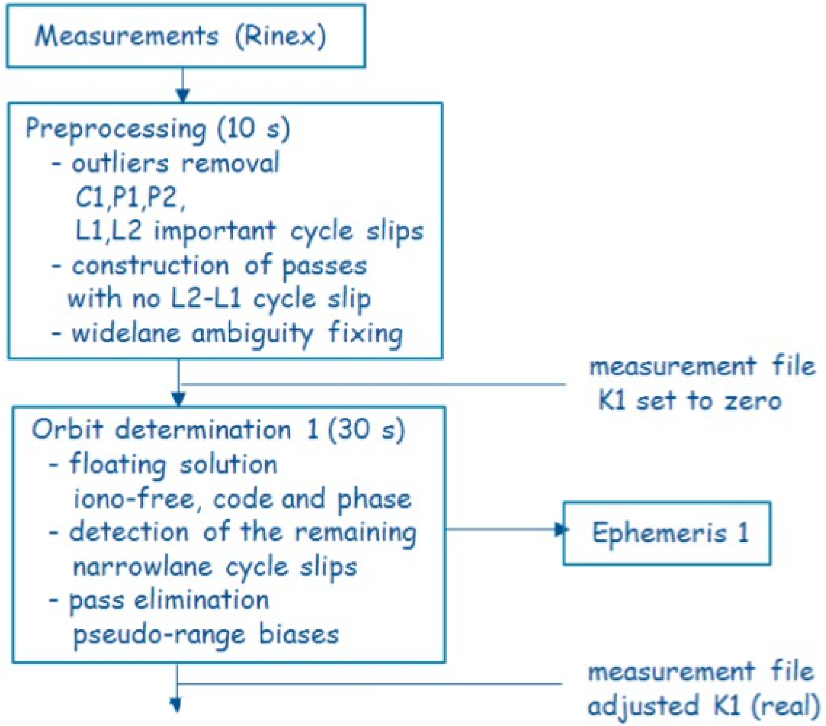
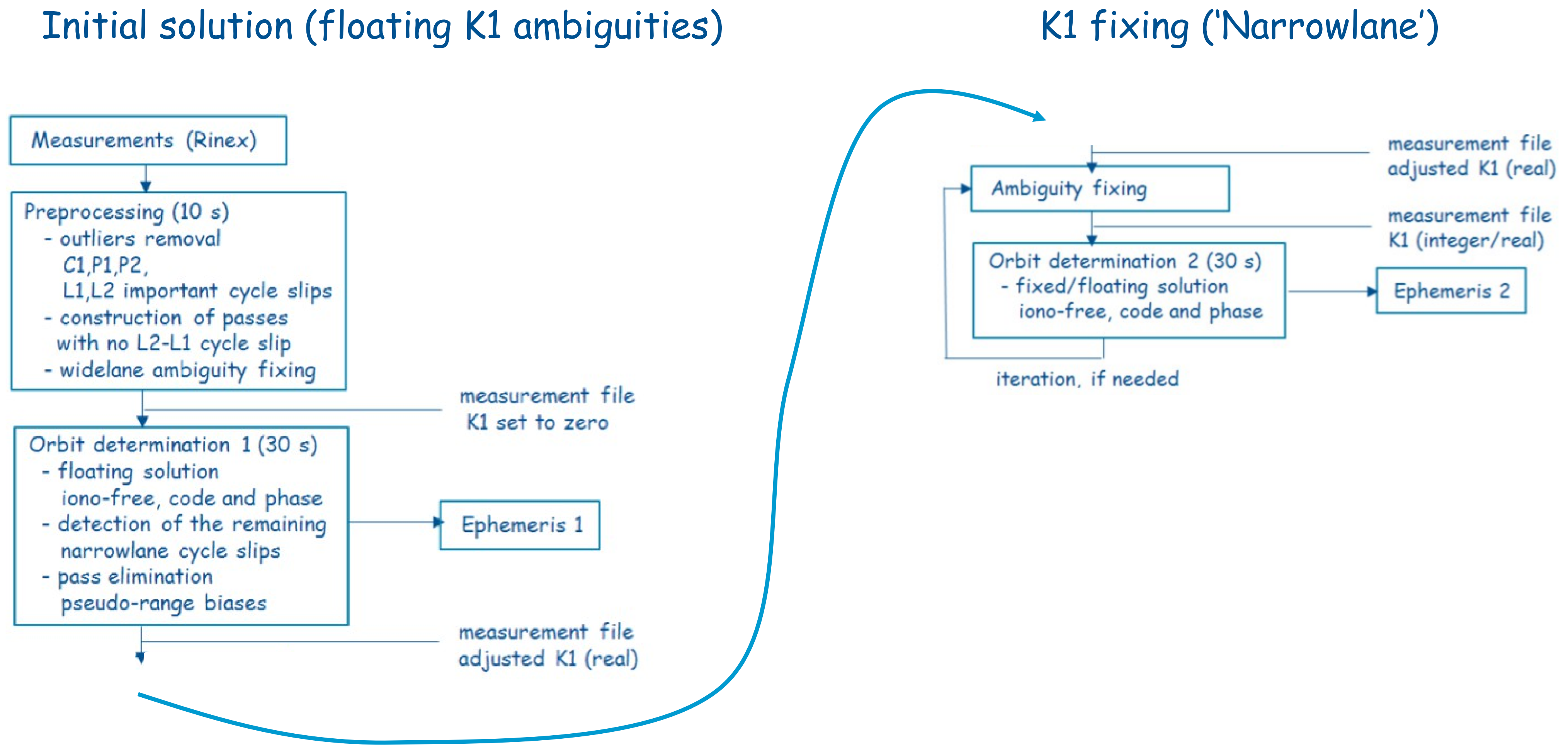


Complete process

Initial solution (floating K1 ambiguities)



Complete process



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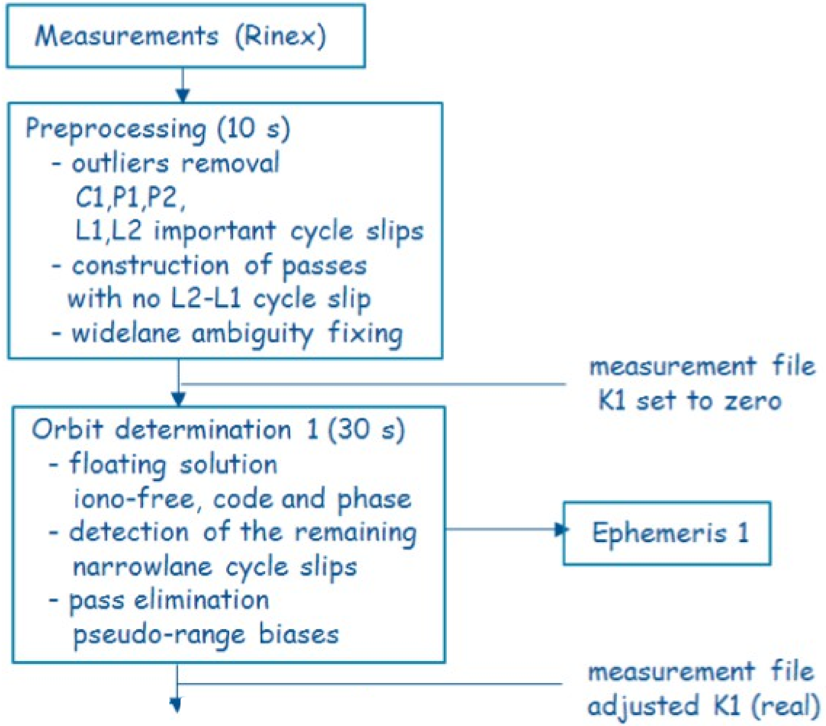
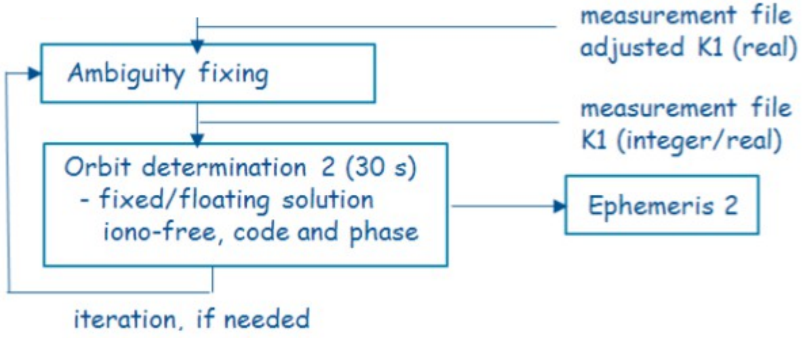


K1 fixing ('Narrowlane')



The final measurement file can be used in other configurations

Rapid solutions :
equivalent to code only solution

Longer arcs : other dynamical models ...

Orbit parameterization for fixing (floating ambiguities)

Parameterization :

Direction	type	number of segments	duration
Tangential	1/rev	2	14 hours
	constant	13	2 hours, 3 hours at the ends of the arc
Normal	1/rev	2	14 hours
	constant	2	14 hours

Phase : 2 cm
Pseudo-range : 2 m
Phase map : JPL pre-launch phase map

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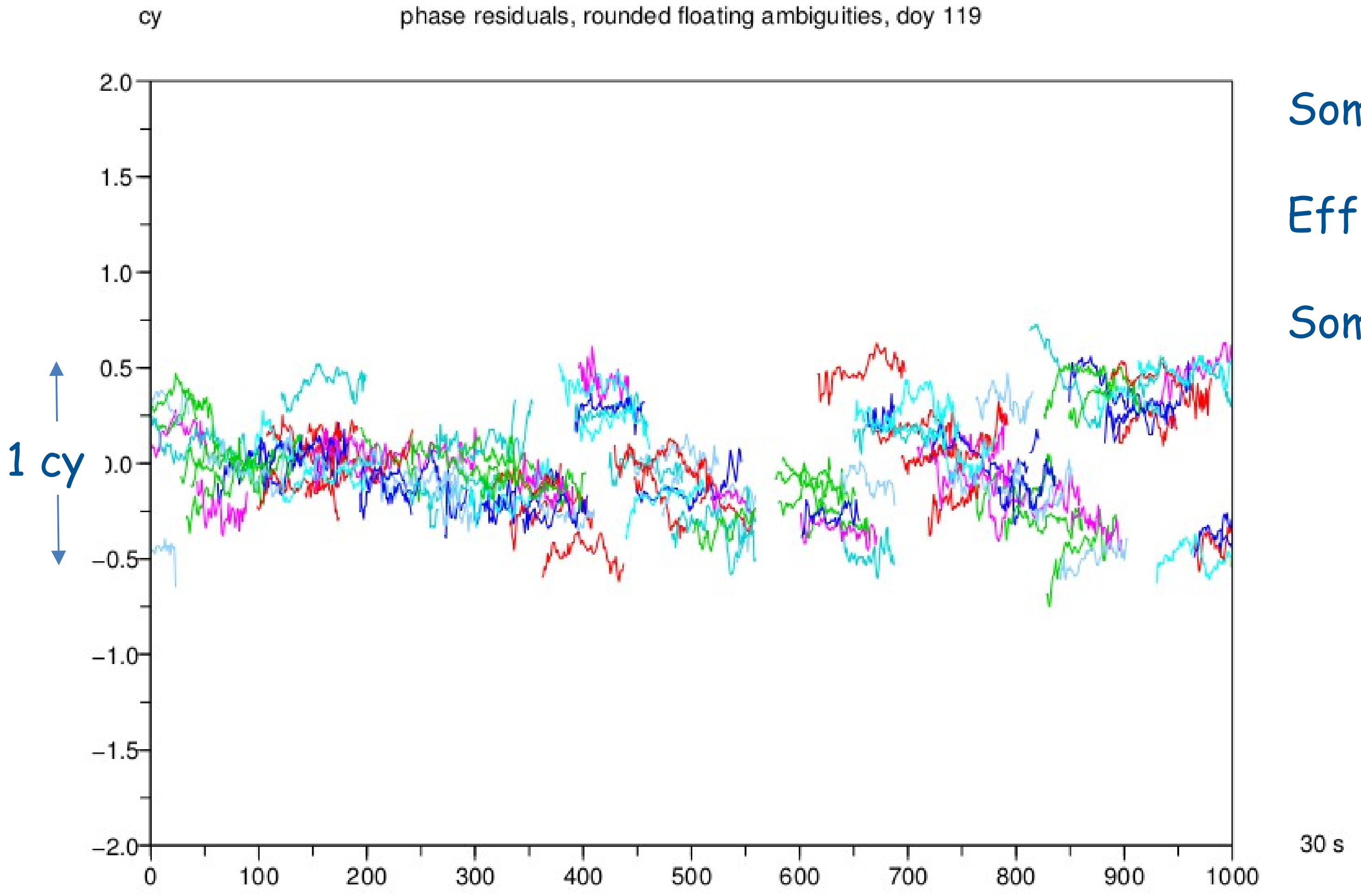
A normal constant empirical acceleration was needed for good ambiguity fixing rates

Phase residuals, rounded floating ambiguity

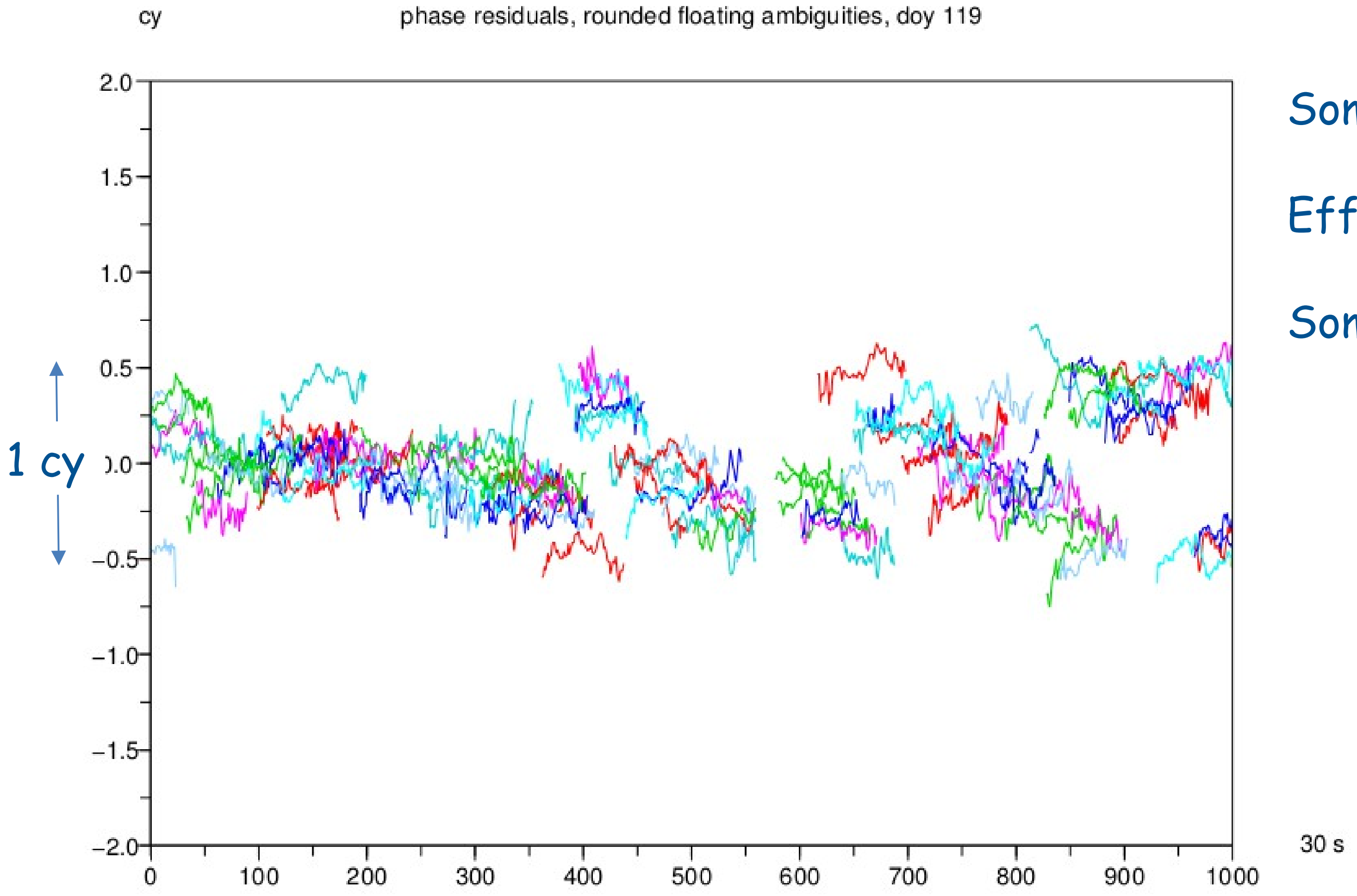


Some passes can be fixed

Effect of the coupling with the clock

Some passes have non integer ambiguities

Phase residuals, rounded floating ambiguity



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Effect of the coupling with the clock

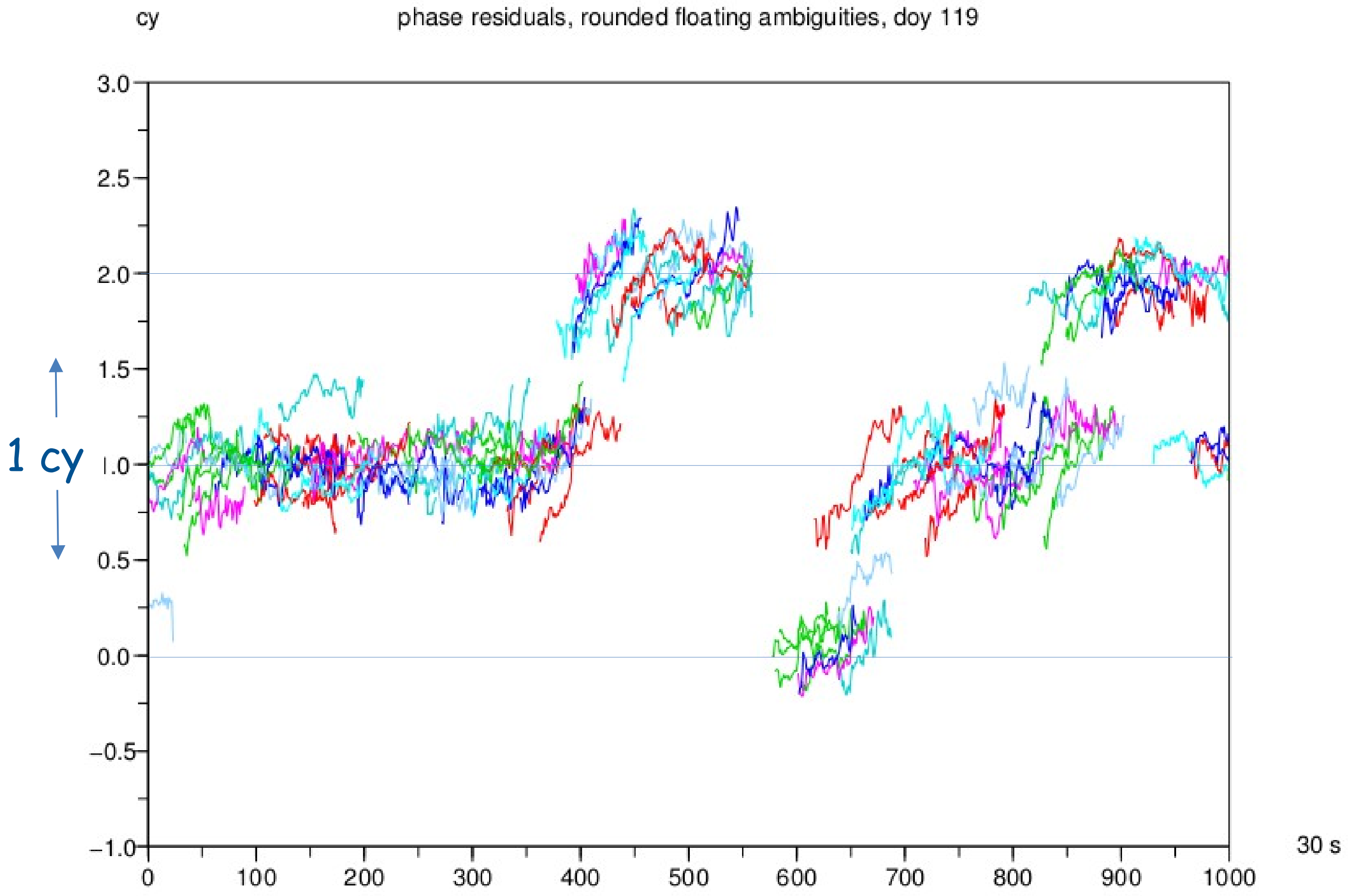
Some passes have non integer ambiguities

↓

Simultaneous solution
- clock offset
- integer ambiguities

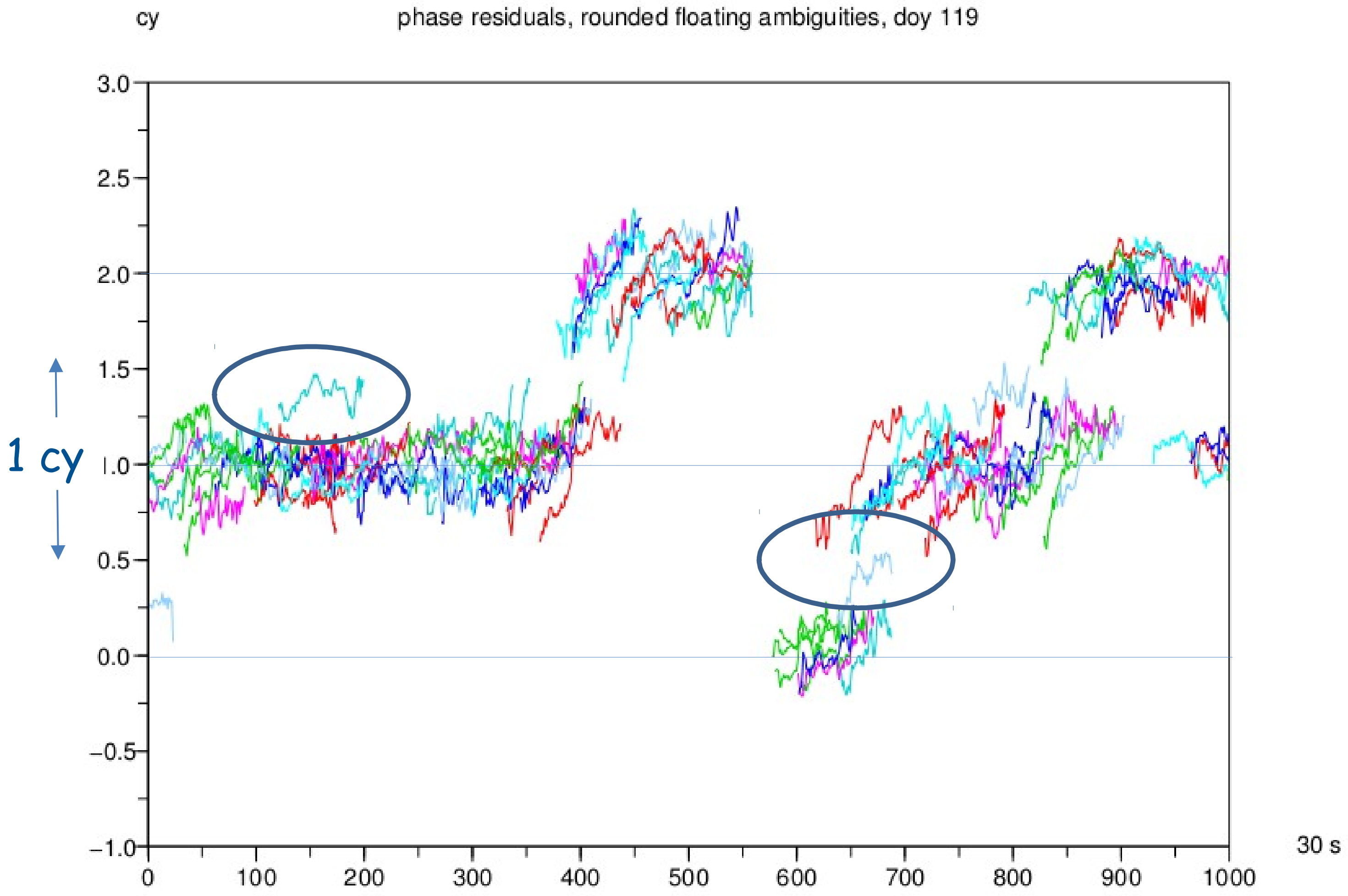
All passes

Phase residuals, integer ambiguities and clock solution



The ambiguities are fixed

Phase residuals, integer ambiguities and clock solution



The ambiguities are fixed

Some passes have important residuals

- receiver anomaly ?
- wrong widelane fixing
- GRG clocks anomaly

Statistics (cycles 8-52)

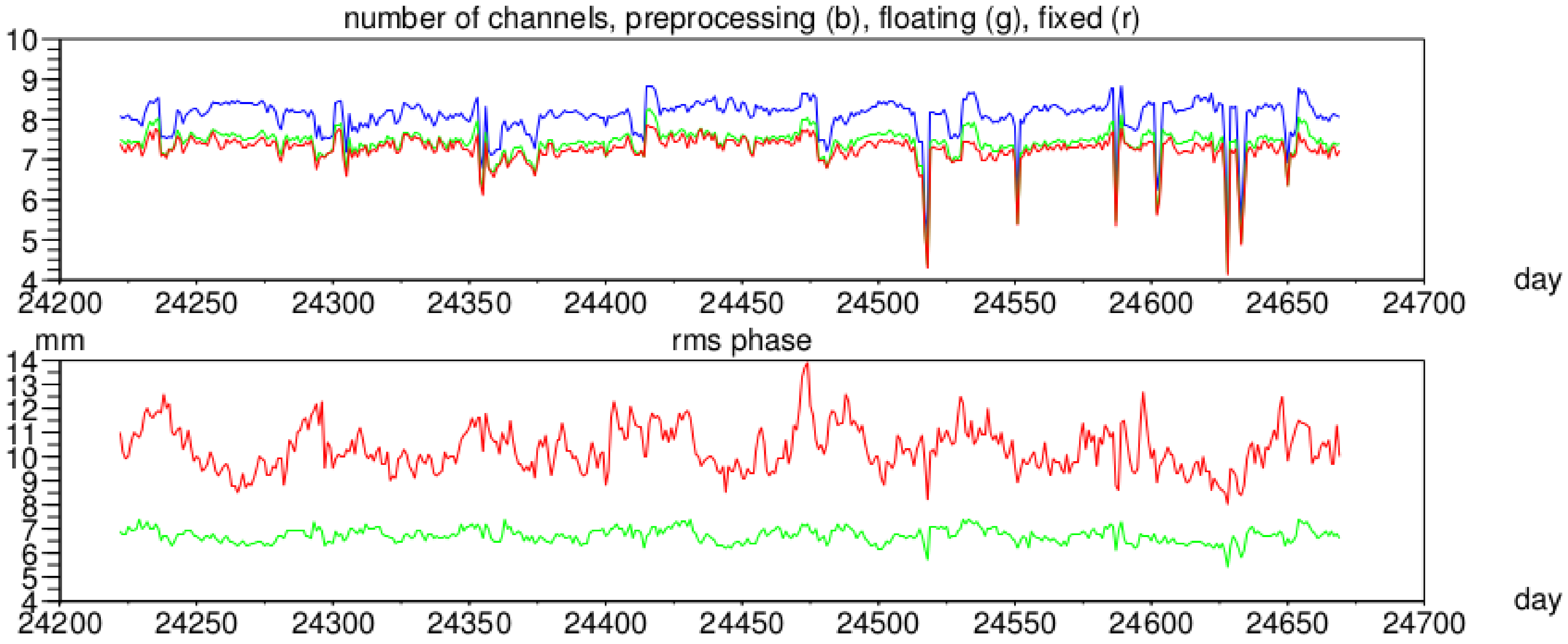
initial data

floating solution

(some eliminations, pseudo-range biases…)

fixed solution

(fixed amb. only)



Attitude effects (cycles 8-52)

measurements

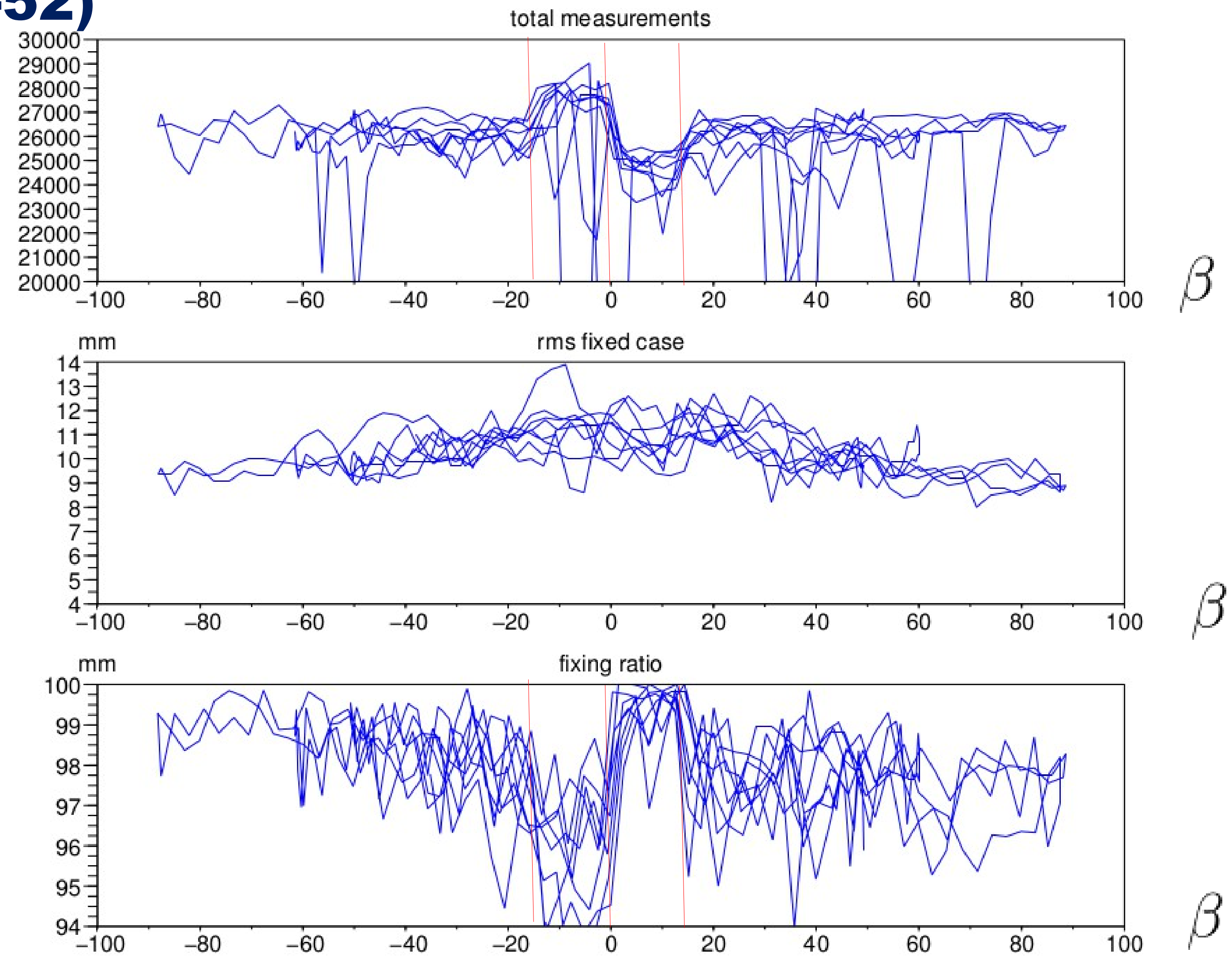
-15-0 degrees : backward
more measurements
fixing ratio ~97 %

0-15 degrees : forward
less measurements
fixing ratio ~99 %

rms

Fixing ratio not symmetric
better for beta < -15

fixing ratio

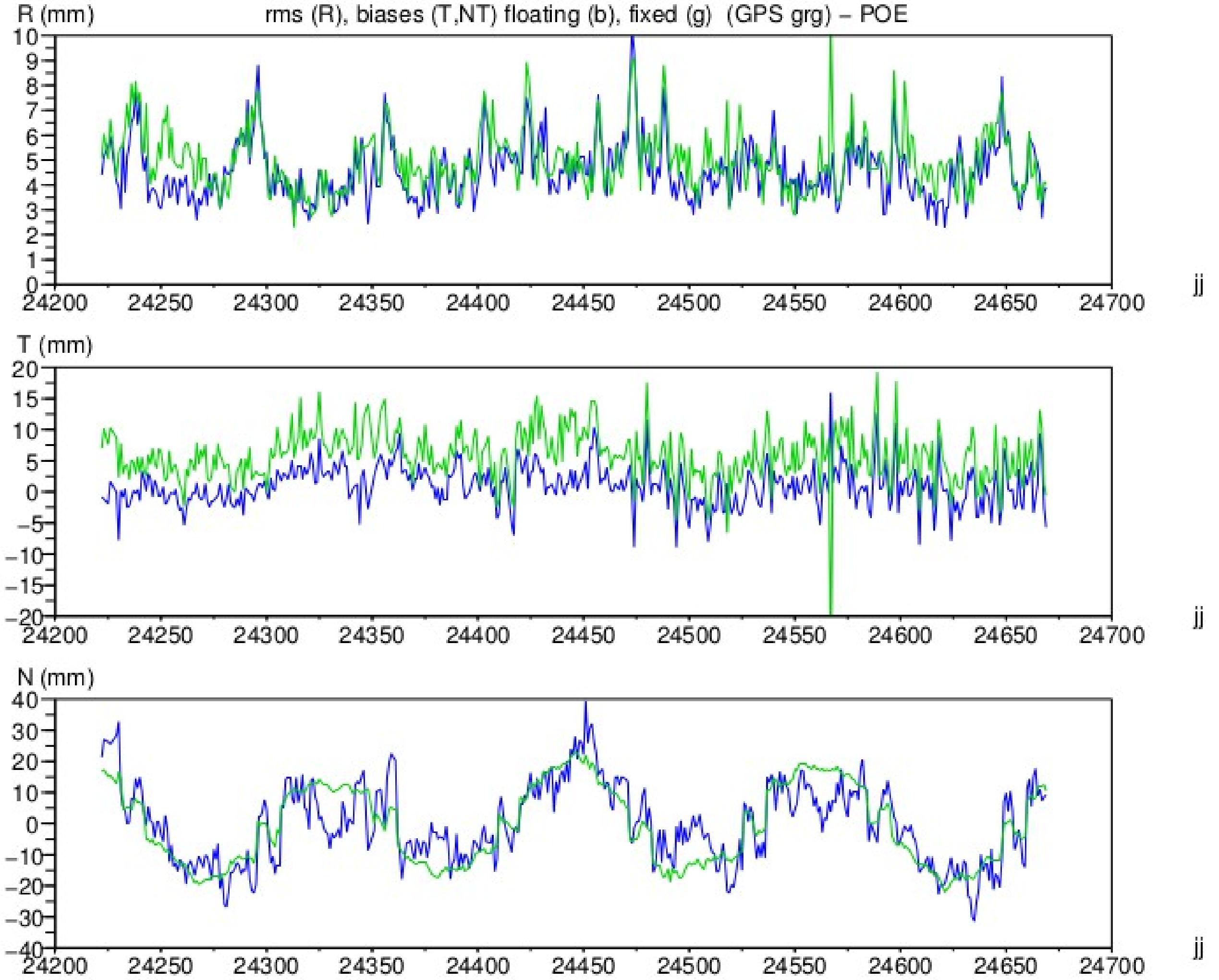


Comparison with GDR-E

Radial rms
floating, fixed

10 mm

Equivalent radial rms



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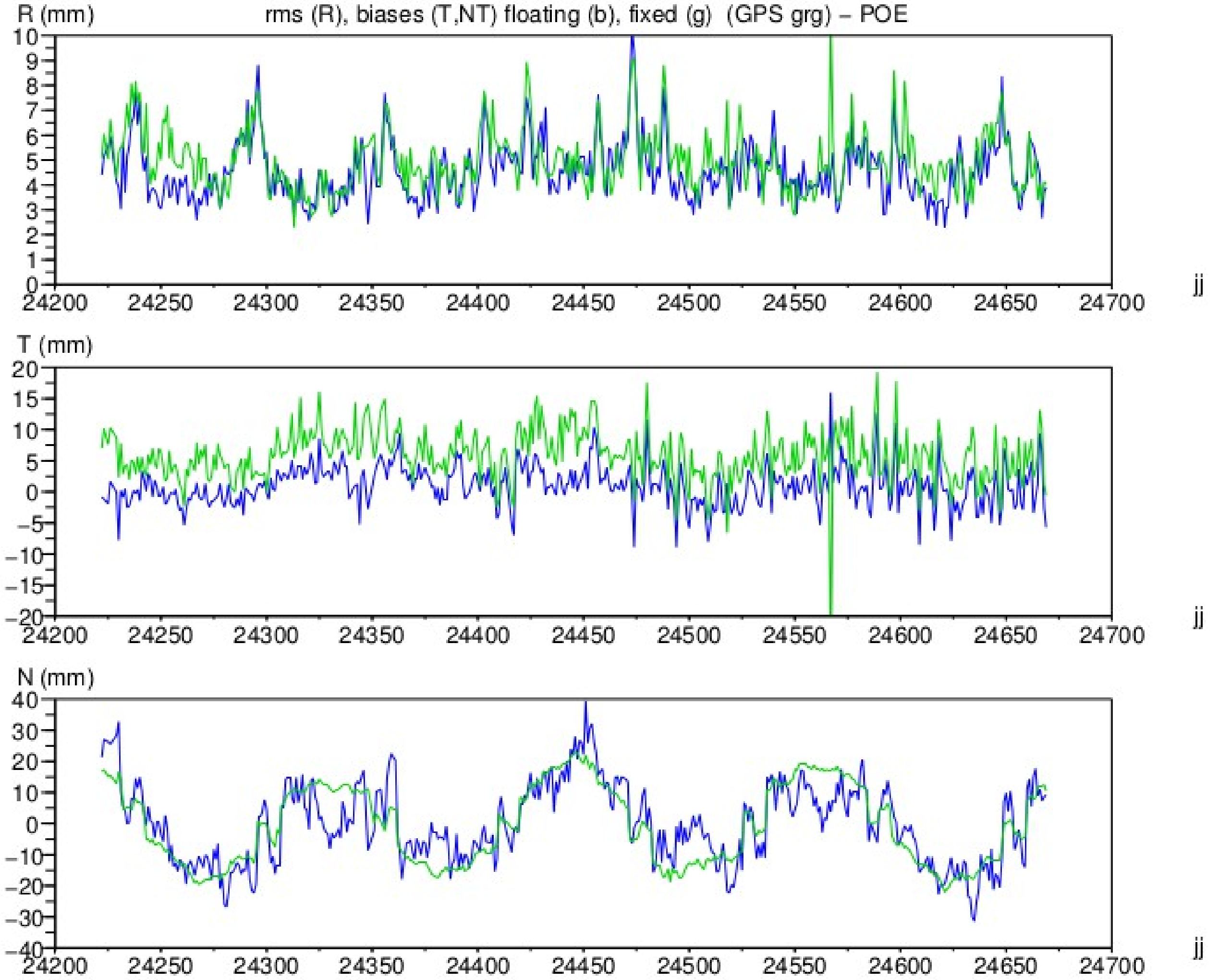
Equivalent radial rms

Tangential
(bias ~5 mm)
20 mm

Bias due to underweighting
of the pseudo-range in floating solutions



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Bias due to underweighting
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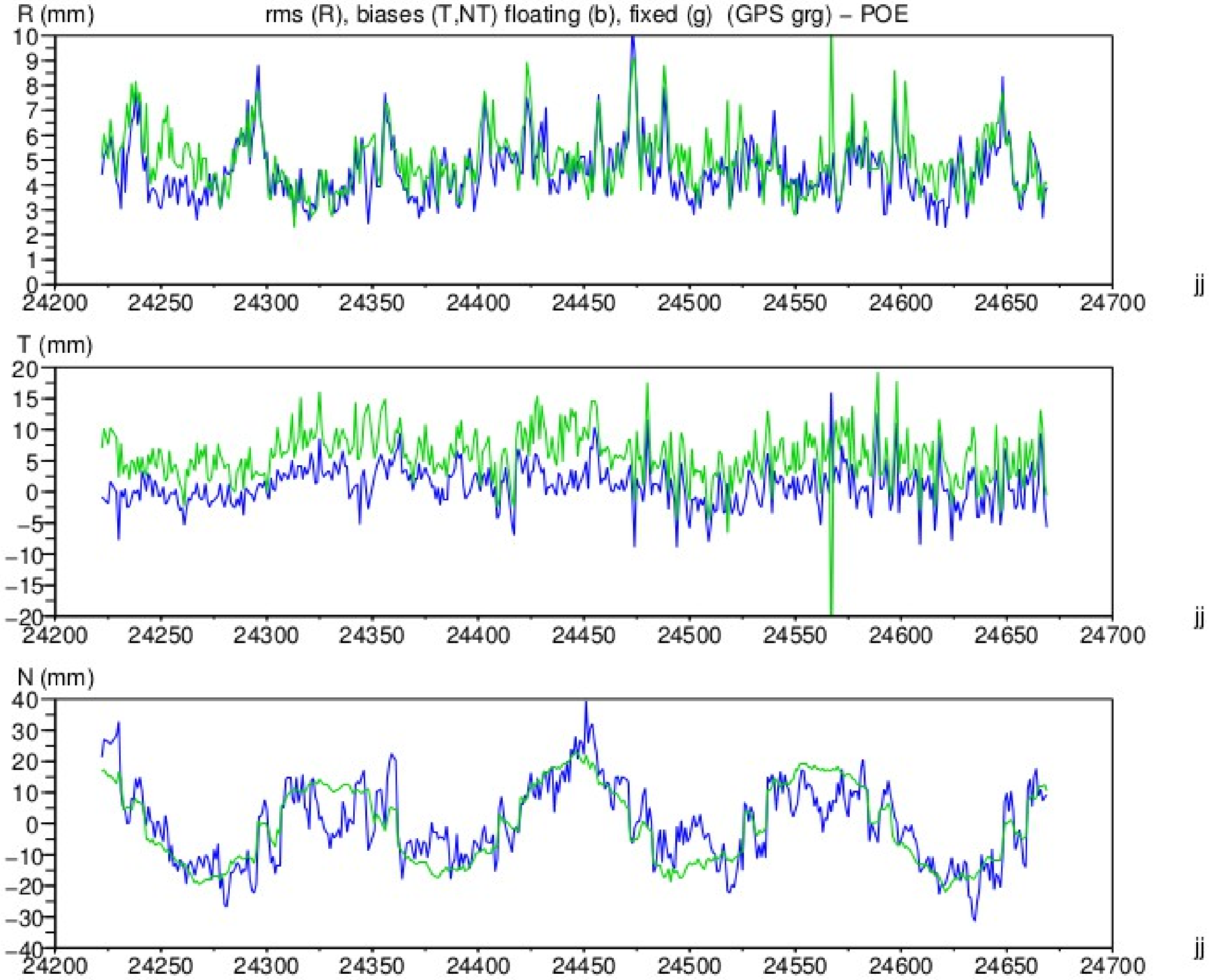
Normal
40 mm

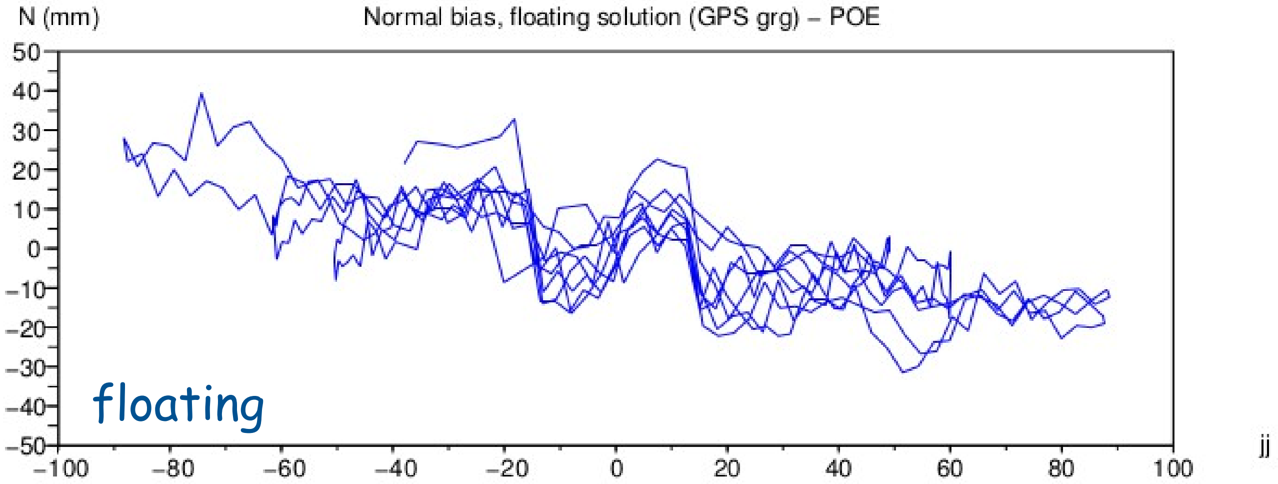
Important errors in the normal
direction, beta angle dependency

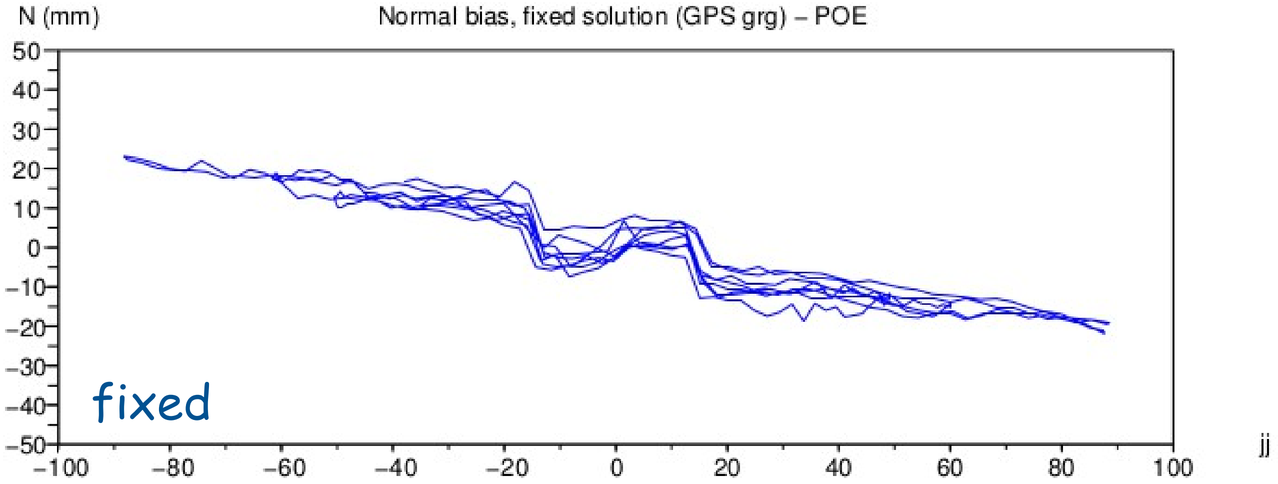


Normal bias function of beta

40 mm

Possible error in the geometry
or in the SRP model ?





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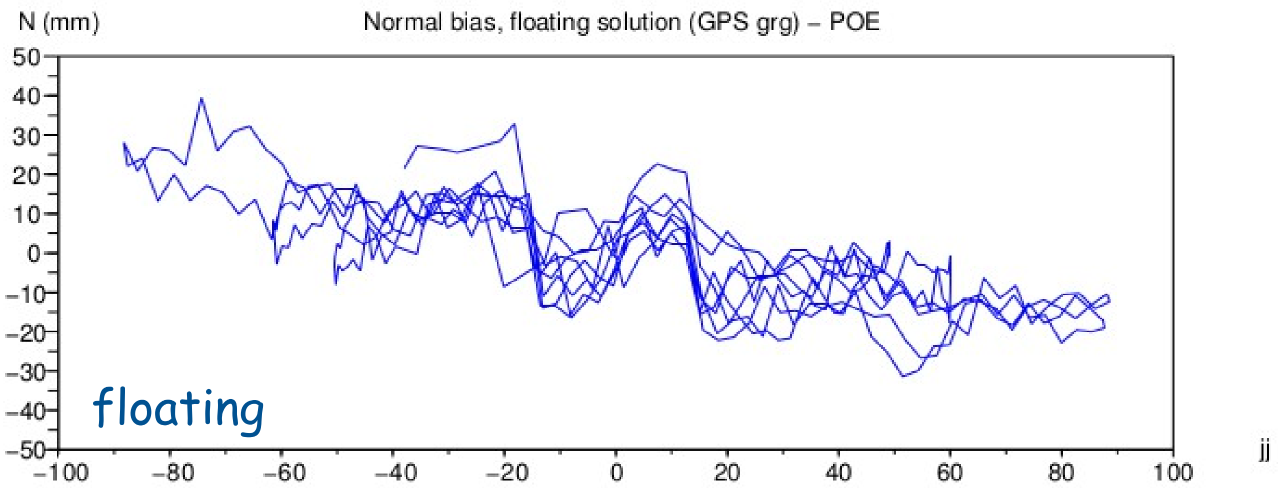


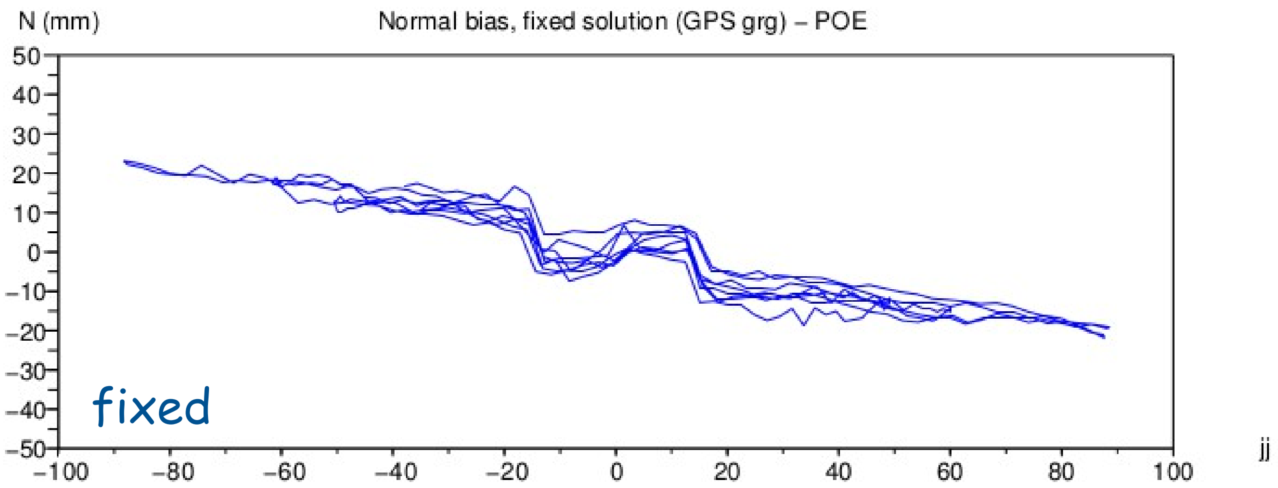
Possible error in the geometry
or in the SRP model

The current SRP model is correct for
the in-plane behaviour

error in the x-antenna location ?
(high beta values, 2 cm bias)

Fixed yaw cases

5 mm, radiation pressure, y-antenna ?



SLR residuals analysis

Different solutions :

- current solutions, using JPL orbits/clocks (GDR-E standards)

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Different solutions :

- current solutions, using JPL orbits/clocks (GDR-E standards)

- new solution, floating, (JPL orbits/clocks)
- new solution, floating, (JPL orbits/clocks), normal bias adjusted

SLR residuals analysis

Different solutions :

- current solutions, using JPL orbits/clocks (GDR-E standards)

- new solution, floating, (JPL orbits/clocks)
- new solution, floating, (JPL orbits/clocks), normal bias adjusted

- new solution, fixed, (GRG orbits/clocks), normal bias adjusted

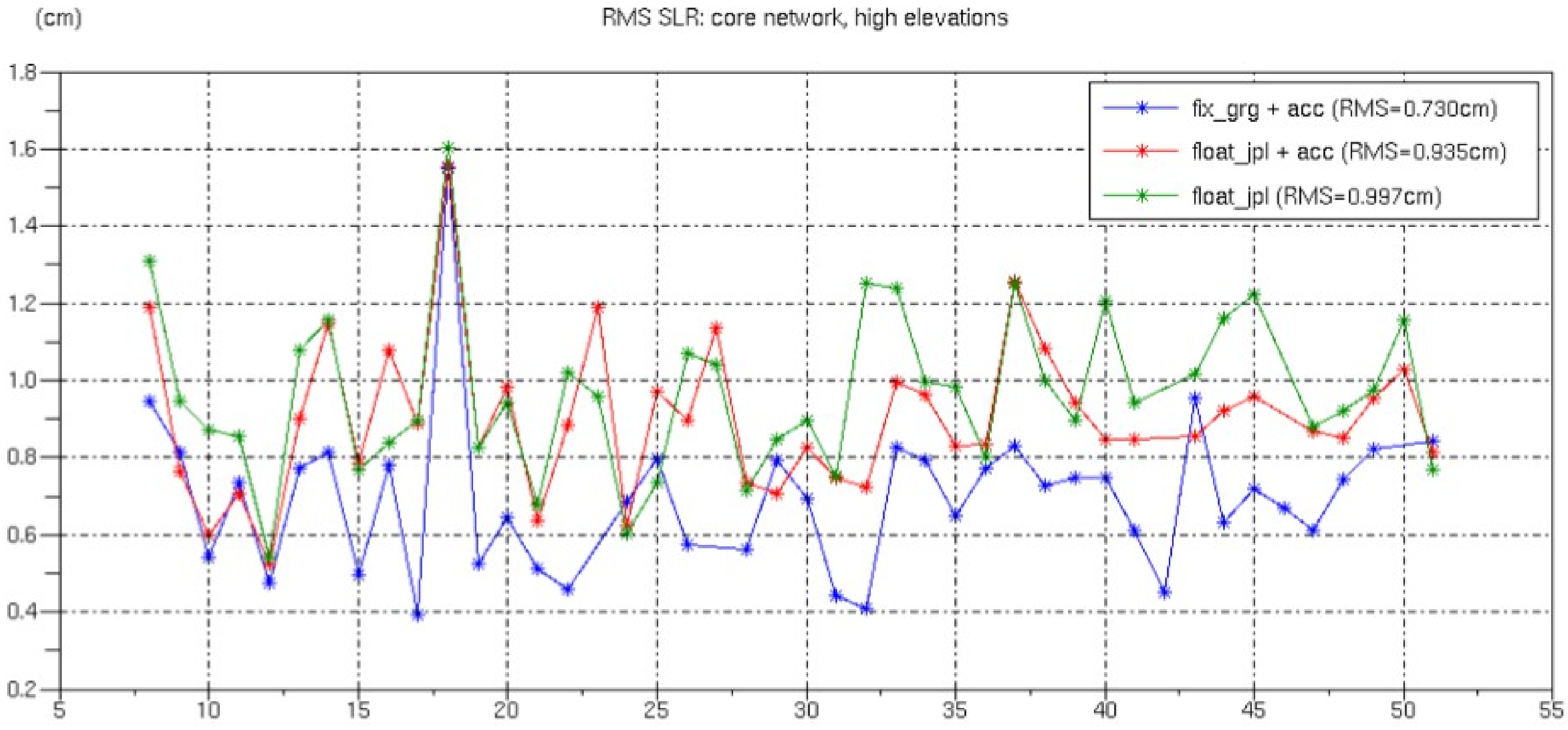
Analysis of SLR high elevation residuals, core network

SLR residuals, high elevations, core network, new solutions

Floating, no normal bias 10.0 mm

Floating, normal bias 9.4 mm

Fixed, normal bias 7.3 mm



Significant improvement for the high elevation SLR residuals due to :

- normal bias
- fixed ambiguities

SLR residuals, core network, high elevations, new/old orbits

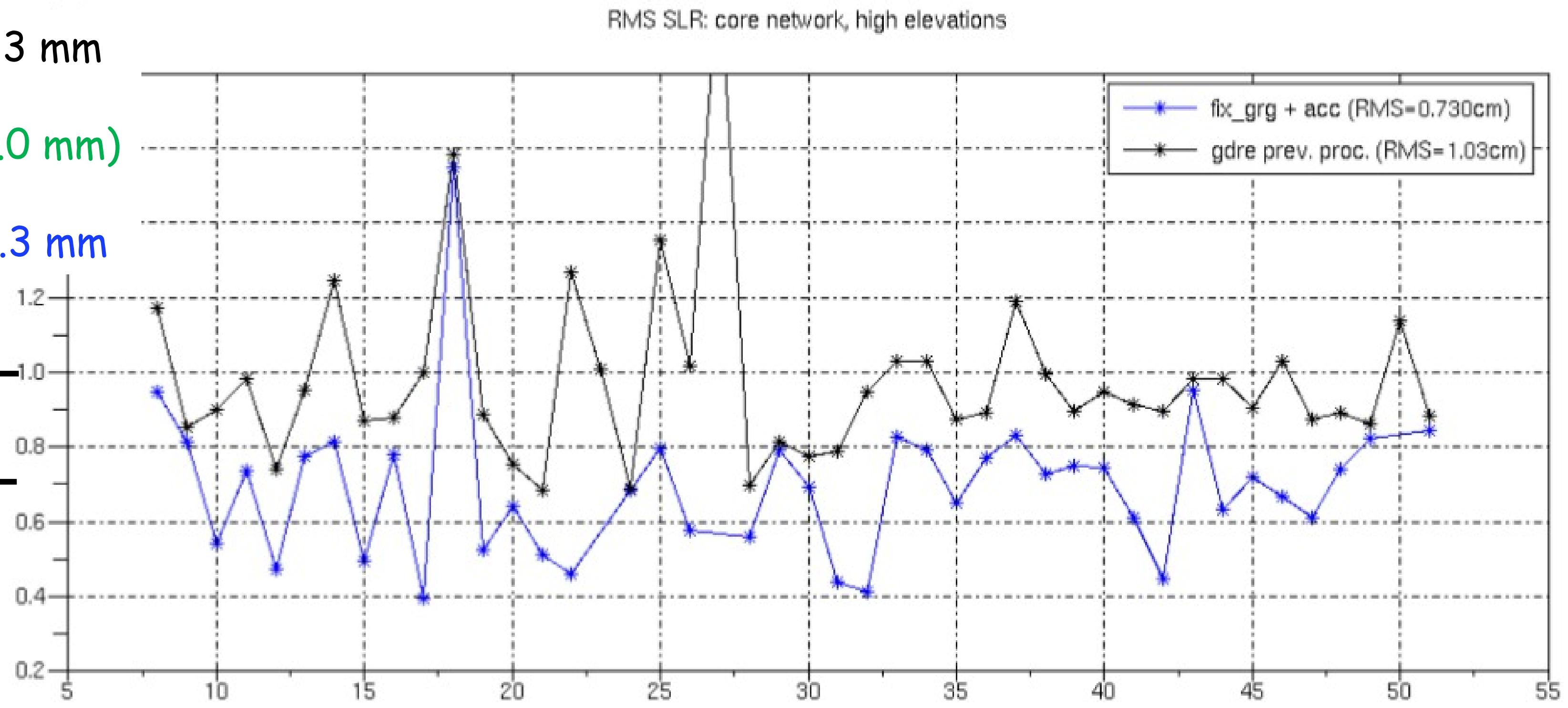
Floating (current orbits, no N) 10.3 mm

(Floating (new orbits, no N) 10.0 mm)

Fixed, normal bias 7.3 mm

10 mm

7 mm



Small improvement for same kind of parametrization (float, no normal bias)
Significant improvement with fixed and normal bias : 3 mm better
Almost all cycles are now below 8 mm rms

Conclusion

Jason 3 orbits with zero difference ambiguity fixing

- use IGS grg solution (CNES/CLS analysis center) for GPS orbits and clocks
- high fixing ratios (> 95 %), but dependencies with the attitude law
- the process can work operationally

New orbits (GDR-F preliminary), with fixed ambiguities

- are close to the GDR-E orbits (5 mm rms radial)
- correct the observed along track biais, consistent with Doris now.
- normal direction accelerations (radiation pressure, or antenna location ?)
- better SLR residuals rms (all elevations and high elevations)

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Significative improvements of the SLR high elevation residuals (cycles 8-51)
Current orbits : 10.3 mm
New orbits : 7.3 mm 30% improvement

Further work

Normal bias :

investigations for the origin of this bias

- SRP ?
- GPS centre of phase ?
- ...

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Measurement processing

passes with erroneous K1 (widelane, pseudo-range biases, …)
high rms flying backward, small rms flying forward
higher fixing ratio flying forward, but less passes

investigations :
- widelane anomalies ?
- measurement weighting, elimination of low horizontal elevation mesurements ?
- phase map improvement (phase map estimation with fixed ambiguities) ?
- consequences for yaw steering phases

Thank you

Summary

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Zero difference ambiguity fixing
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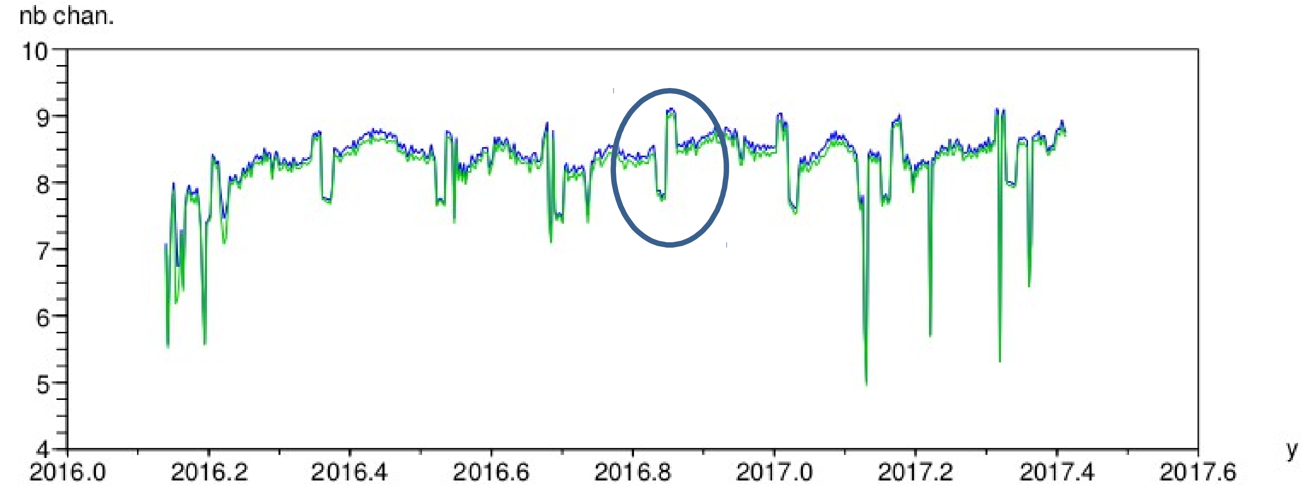
For Jason 3 : very good quality of the measurements, no more SNR problems
zero difference ambiguity fixing operational orbits are possible (2017)

Jason receiver measurements characteristics

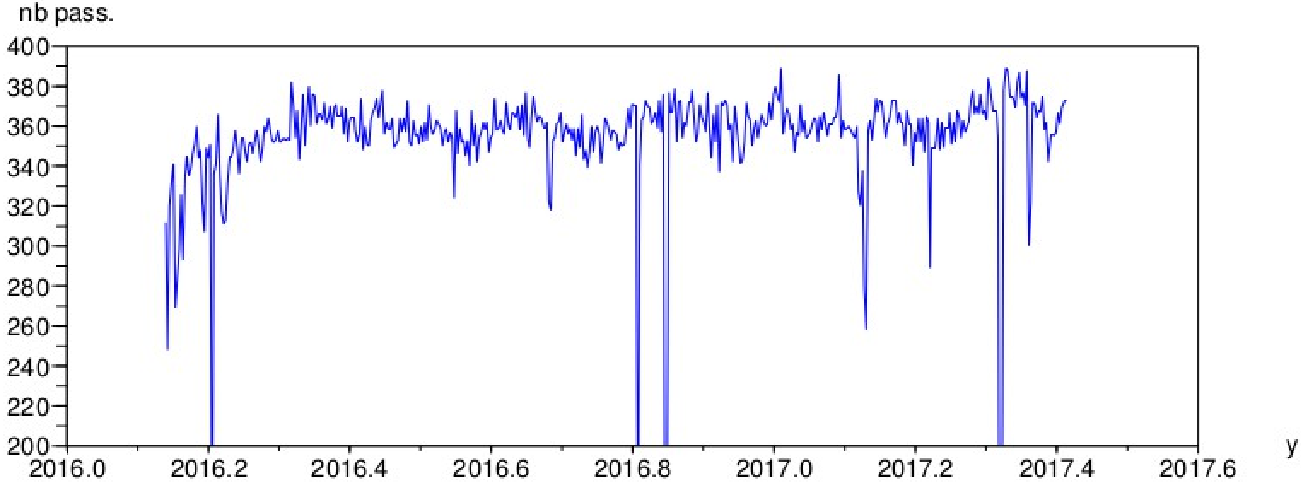
Average number of channels (28 h)
- initial
- used



Attitude law effects
- fixed, backwards ~8.5 chan.
- fixed, forward ~7.5 chan.
- yaw-steering ~8 chan.

Limitation : 10 deg elevation relative to antenna axis

number of passes (28 h)



widelane (Melbourne – Wubbena) ambiguity fixing

Iono-free and geometry-free combination,
Used for L2-L1 ambiguity determination, integer value Kw for each pass

integer

GPS satellite bias (from GRG/IGS solution)

$$N_w = K_w + \tau_i - \tau_{jas}$$

Pseudo-range and phase combination

Jason 3 bias

widelane ambiguity fixing results

Good stability of τ_{jas}

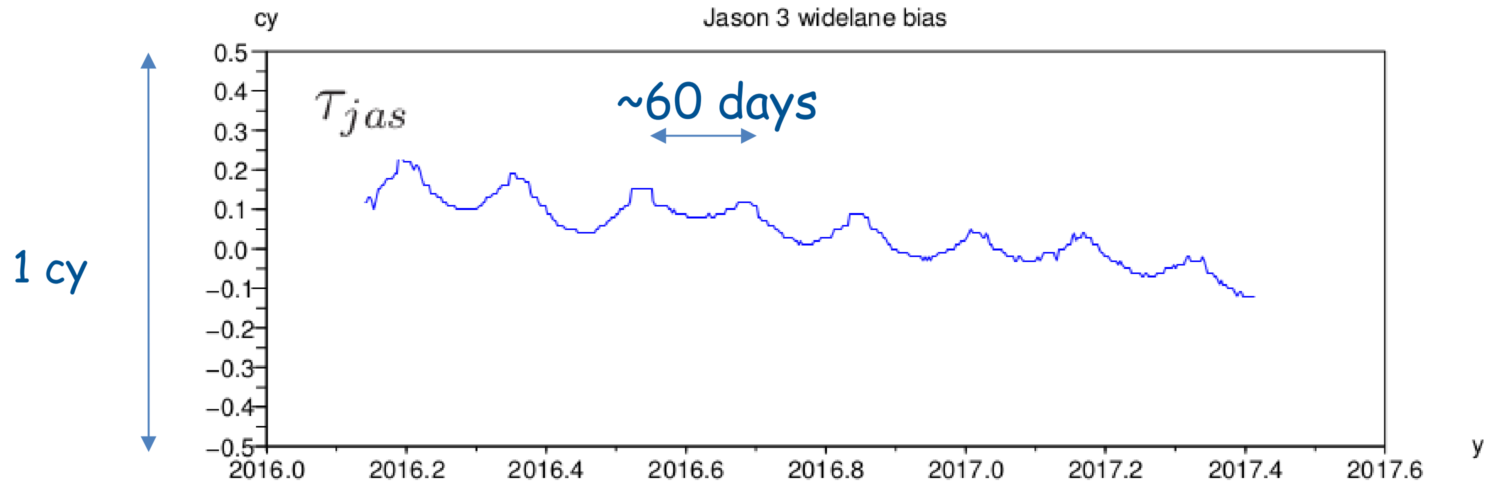
(constant value ?)

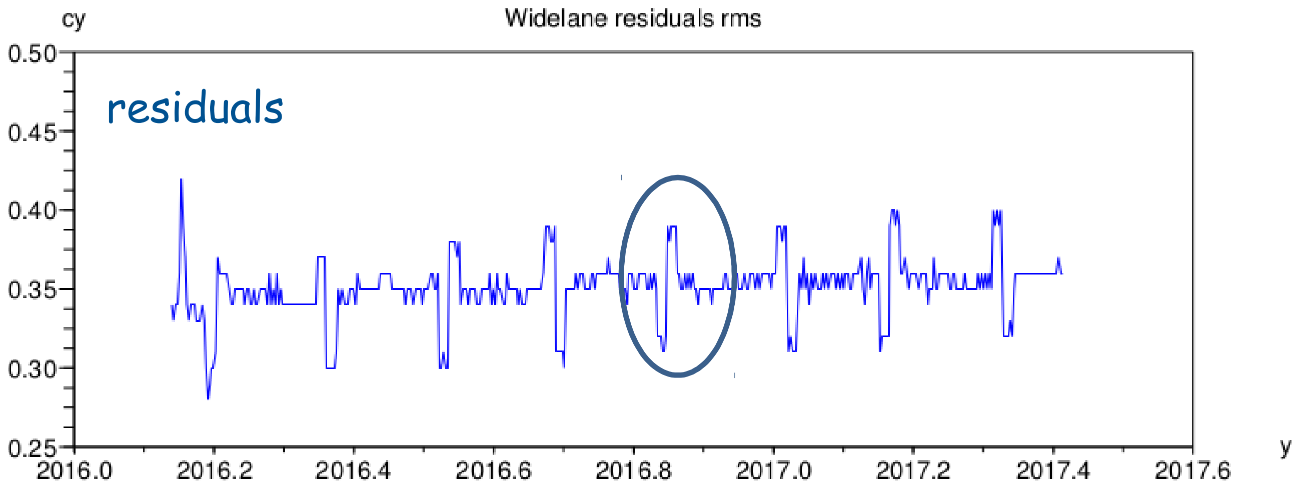
All passes are fixed

- no pass elimination

- $N_w - \tau_i + \tau_{jas}$ rounded to the closest integer

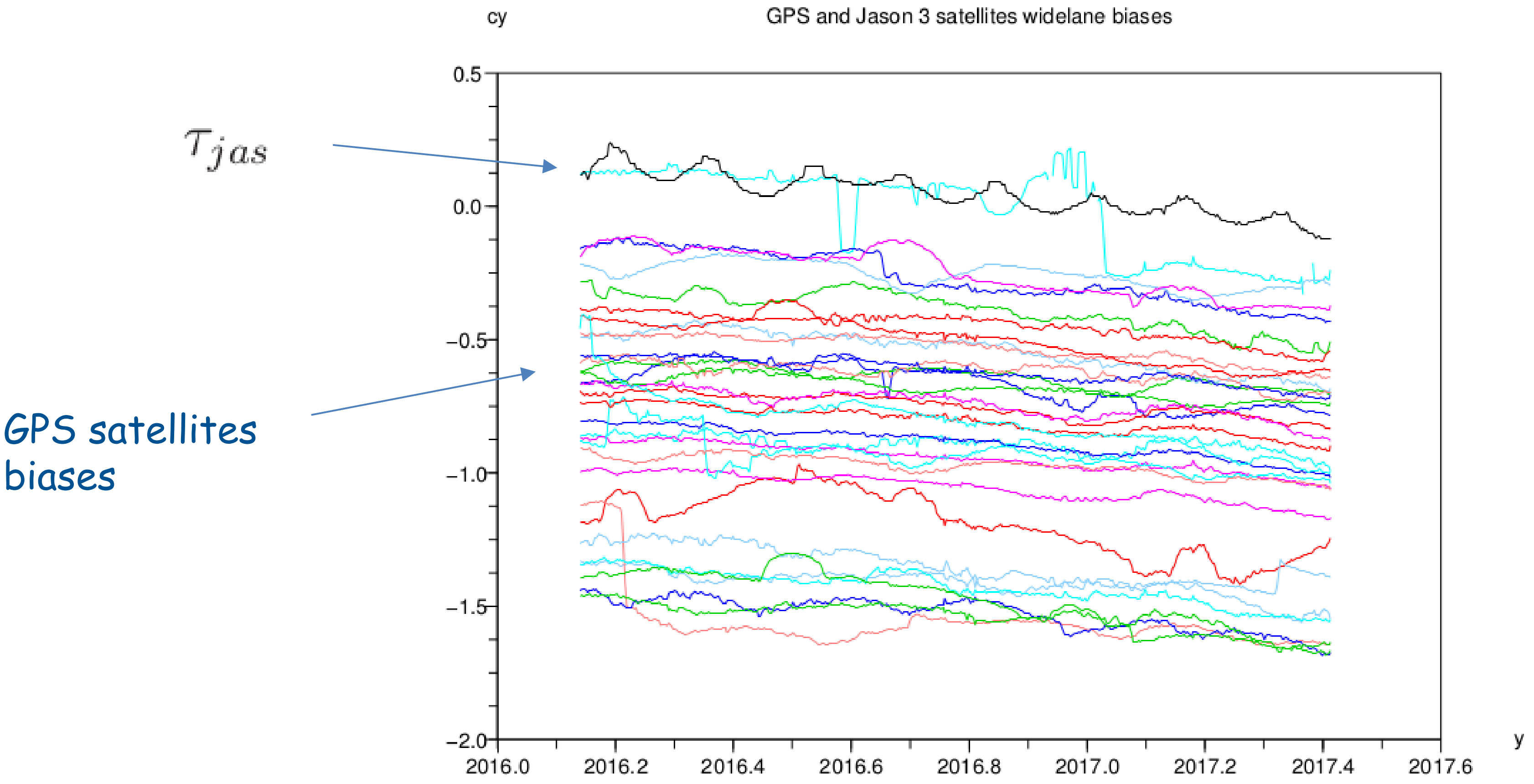
- small draconitic effects on τ_{jas}
  attitude effects on residuals rms





widelane biases drift ?

The drift observed in τ_{jas} is probably due to the GRG solution



→ Robust widelane ambiguity fixing, independent for each pass

Second ambiguity fixing

Global fixing on a reduced problem :

ambiguity per pass and receiver clock bias per epoch

the orbit is fixed (the floating ambiguities orbit precision is sufficient)

$$R = R_0 + \lambda_c K_1 - h_{jas}$$

complete residual
(7 mm rms in floating solution)

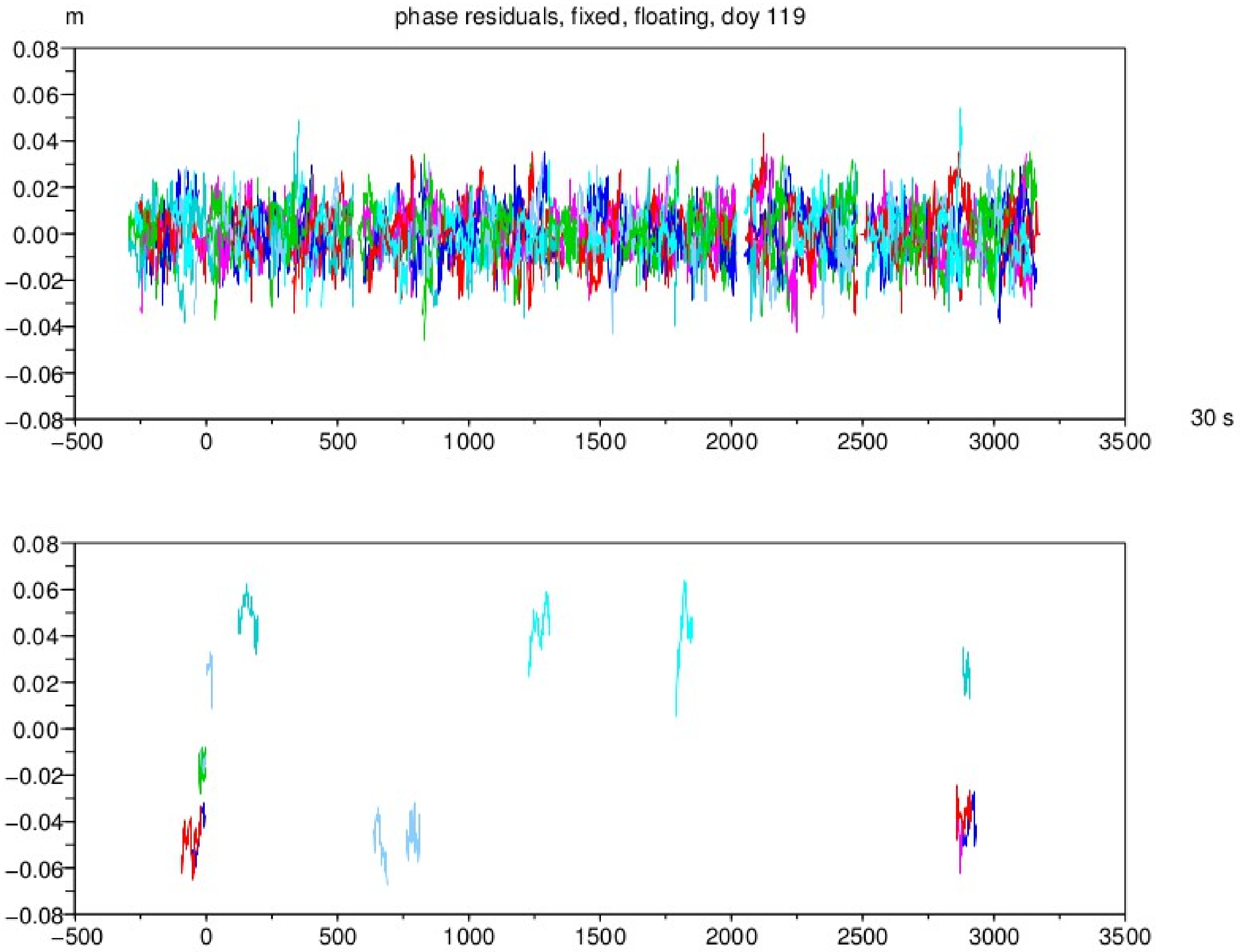
iono-free phase measurement residual
(no ambiguity, no receiver clock)

ambiguity (real or integer valued)

receiver clock

What are the results when K1 is rounded to the closest integer ?

Residuals after ambiguity fixing



Fixed

Floating

New orbits

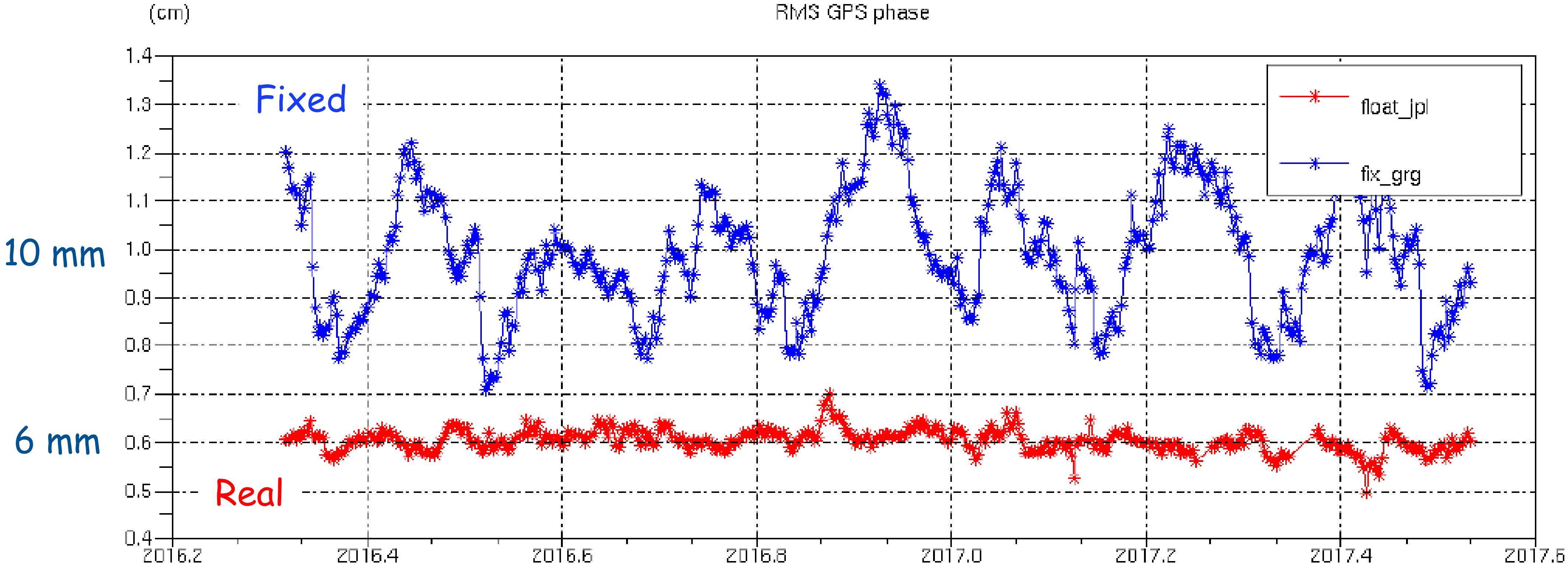
GDR-F standards (geocentre, tides…)

Effect of the normal bias

Floating or fixed ambiguities

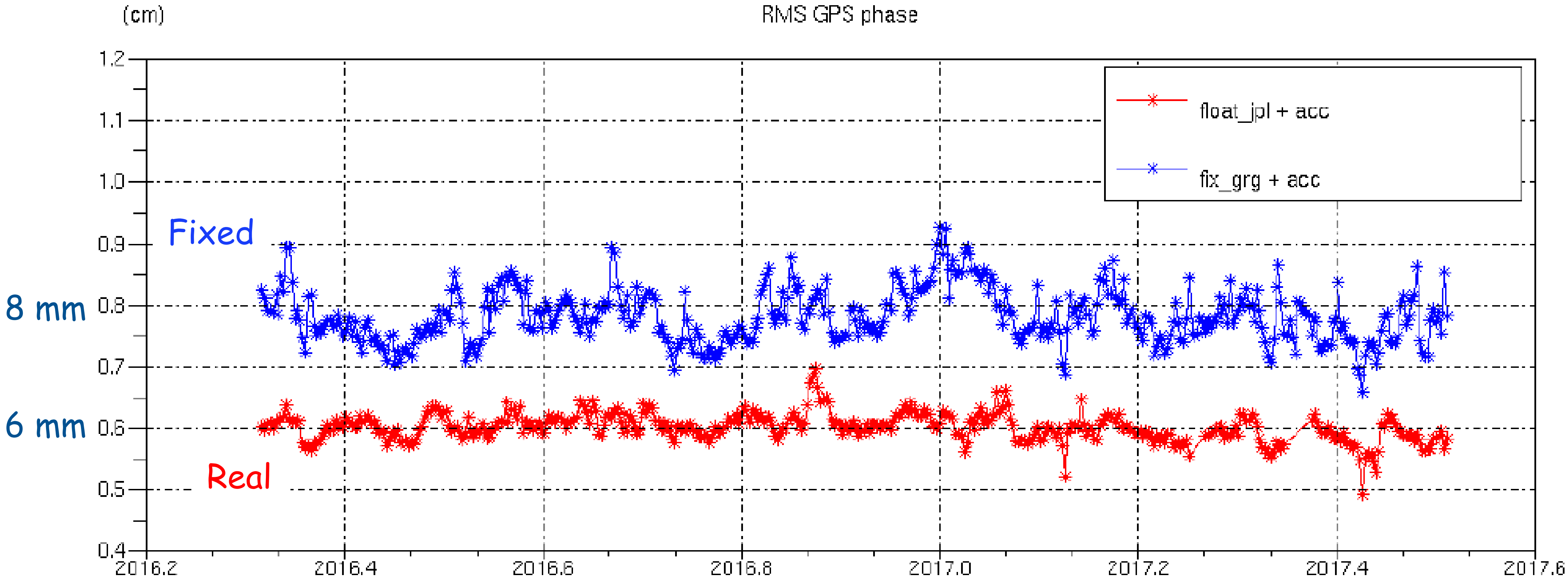
SLR validations

Effect of fixing ambiguities



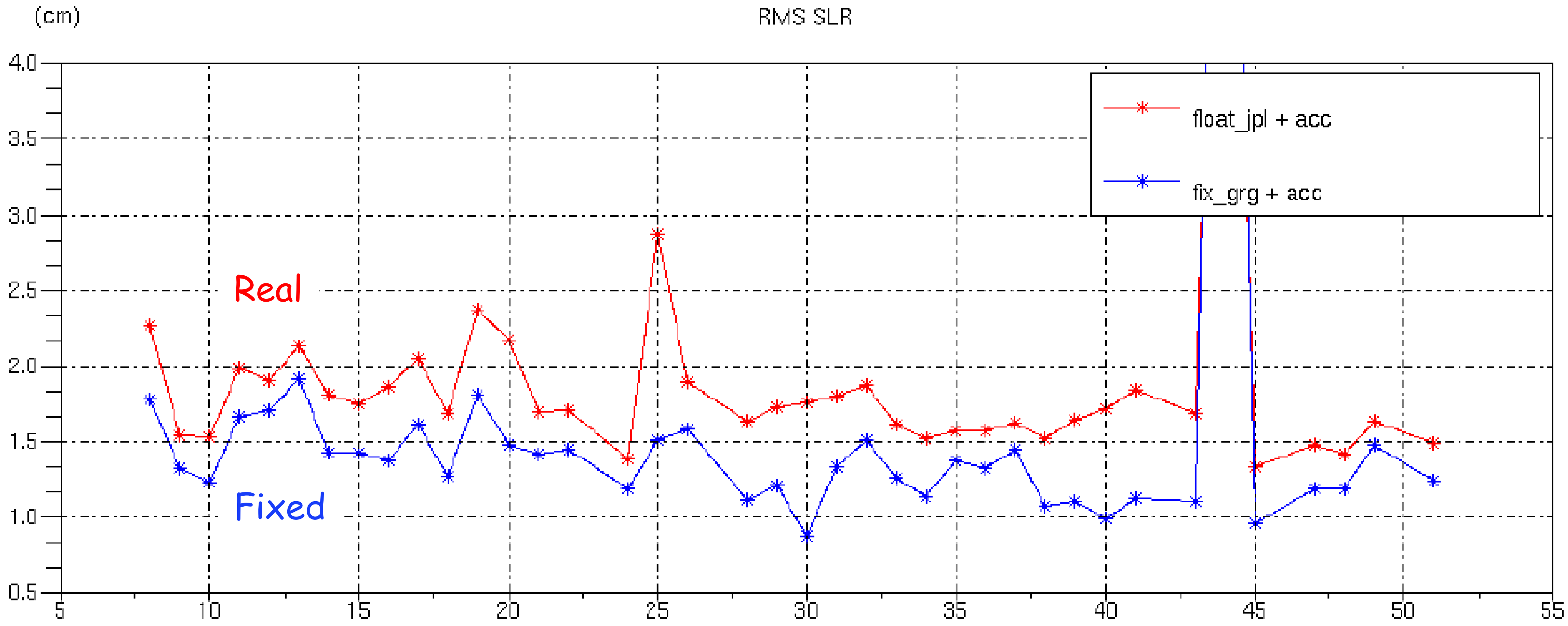
The fixed solutions rms values have important fluctuations, correlated with beta angle (no normal acceleration bias adjusted)

Effect of fixing ambiguities and adjusting normal bias



The beta angle dependency is minimized for the fixed ambiguities solutions (normal acceleration bias adjusted)

SLR residuals, all stations, all elevations



Improvements mainly due to the along track bias removal