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SLR Tracking of GNSS Constellations at Zimmerwald

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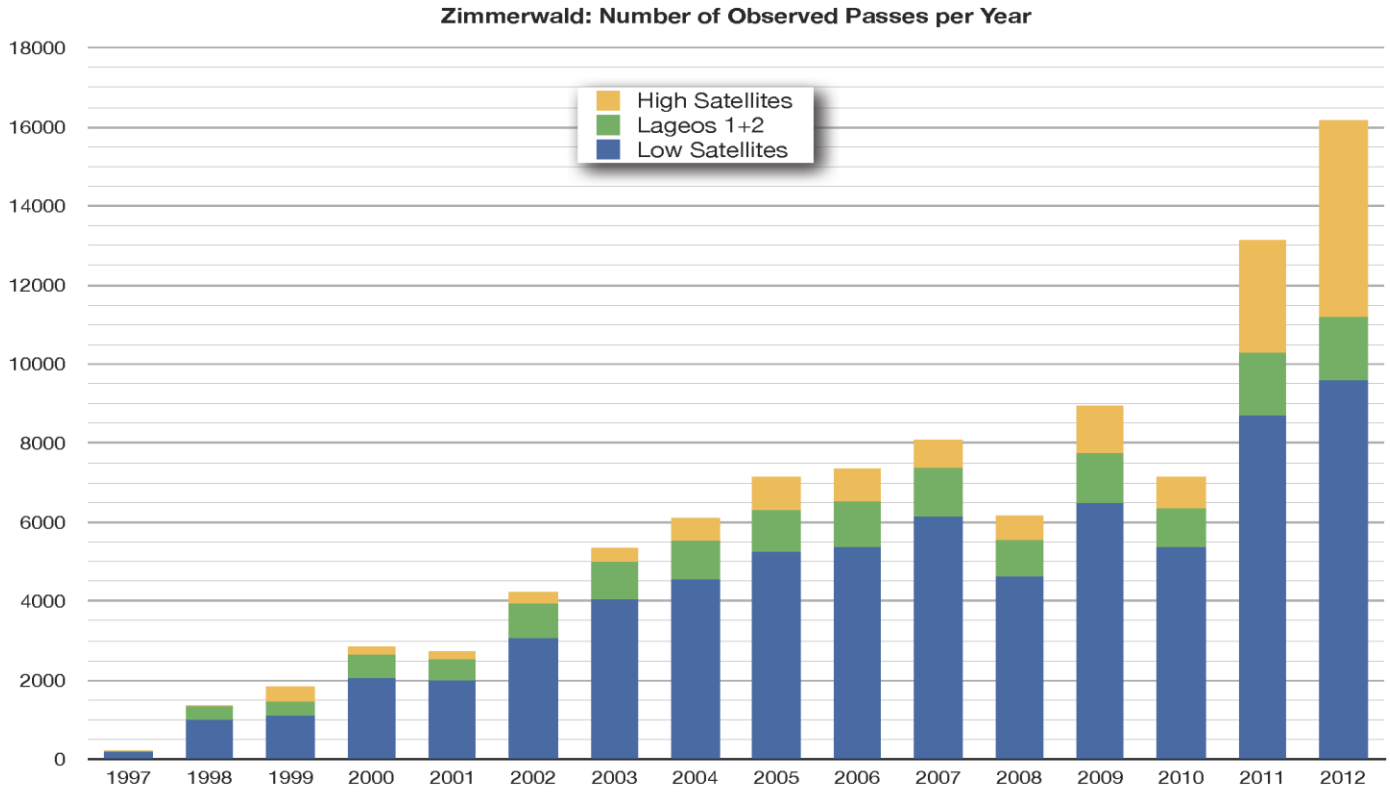
GNSS Constellations

- GPS
  - Block II: 35
  - Block IIA: 36
- GLONASS
  - Early GLONASS Coated: 114, 116, 117, 118
  - Early GLONASS Uncoated: 115, 126, 127, 128, 129
  - GLONASS-K Coated: 105, 106, 110, 111, 119 ,120, 121
  - GLONASS-K Uncoated: 130
  - GLONASS-M Coated: 101, 102, 103, 107, 109
  - GLONASS-M Uncoated: 122, 123 ,124
- Galileo
  - 101, 102
- Compass
  - M1
  - M3

Tracking of GNSS Constellations at Zimmerwald

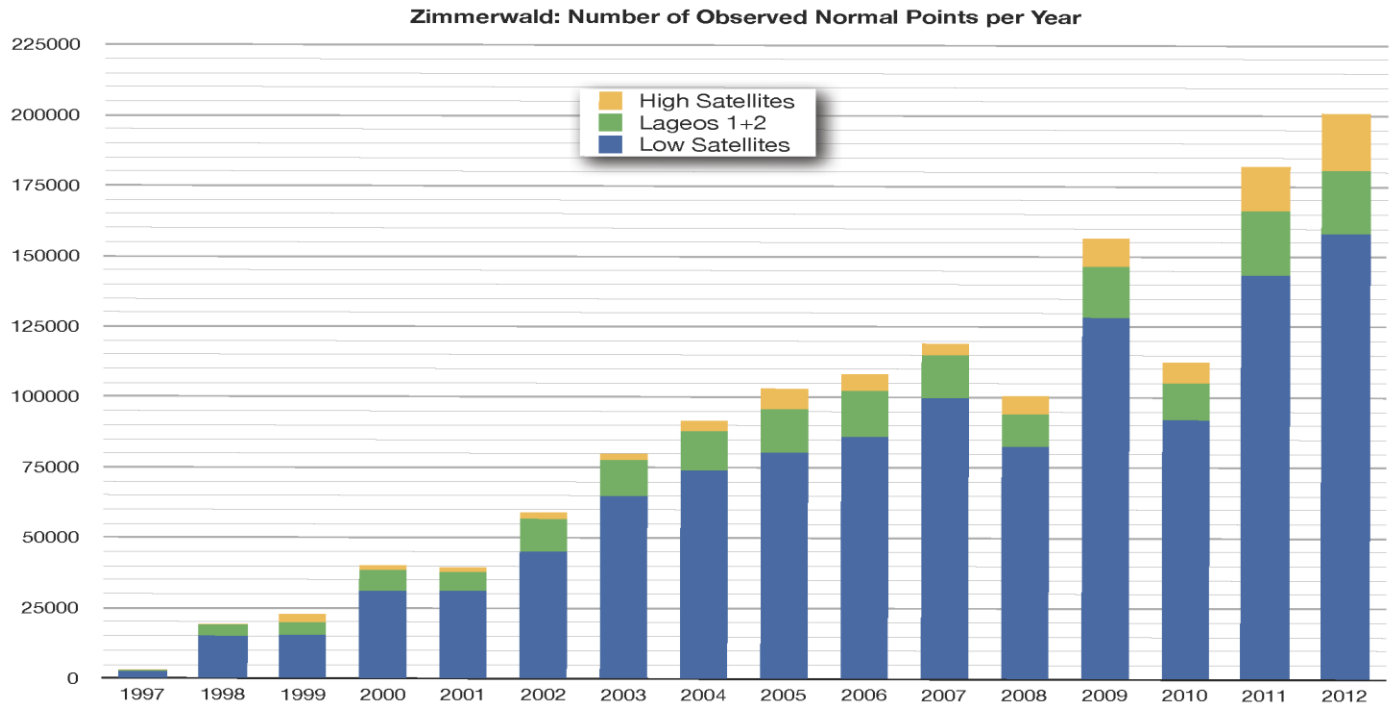
- Telescope ZIMLAT: Ritchey Cretien System, 1m primary mirror
- Laser (since 2008)
  - *100 Hz Nd:YAG Sytem*
  - *Pulselength: 58ps*
  - *Energy: 8mJ per single pulse*
- During nighttime observationtime is shared with optical observations (CCD)
- High level of automation
  - *Switch between satellites is done automatically*
  - *Scheduler: Timeslot 4min, maximum 1000 OBS/NP for high satellites*
  - *Automatic searchalgorithm (switched off in case of cloudy weather)*
  - *Switch between SLR and CCD is done automatically within 20 seconds*
- Mountmodel of the telescope is calculated frequently (every 2 months) from Glonass observations during night time
- During daylight observations additional corrections in azimuth and elevation are applied because of the distortion of the telescope tubus (sun light!)
- Since summer 2010 all GNSS satellites equipped with CCRs are tracked (currently 28)
- Tracking is done 24h per day, 365 days per year (if weather conditions are ok)

Number of Observed Passes since 1997



- Break down of the laser system in 2009/2010 for more than 2 months
- Since 2011 significant increase of observed passes of GNSS satellites

Number of Observed NPs since 1997

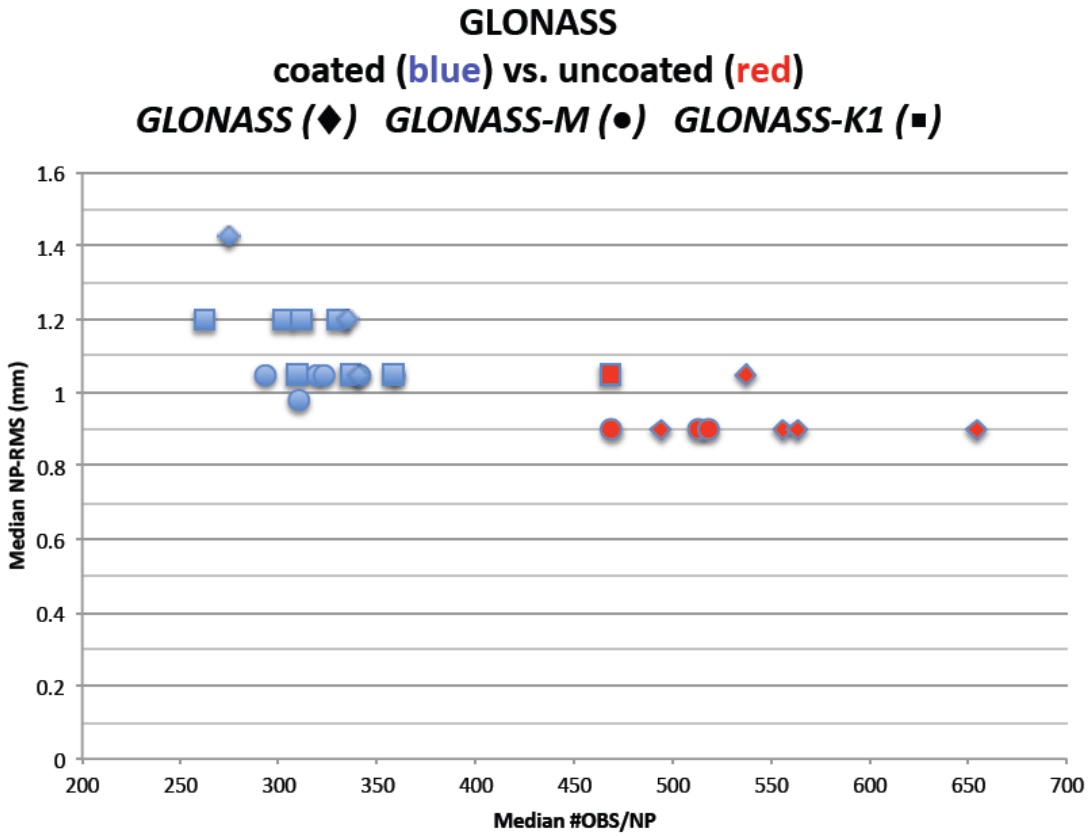


Minor improvements in the number of observed NPs/Year for GNSS satellites, increasing number can be seen for all type of satellites (LEOs, LAGEOS, GNSS) due to improvements in the steering of the rotating shutter.

Statistical Analysis

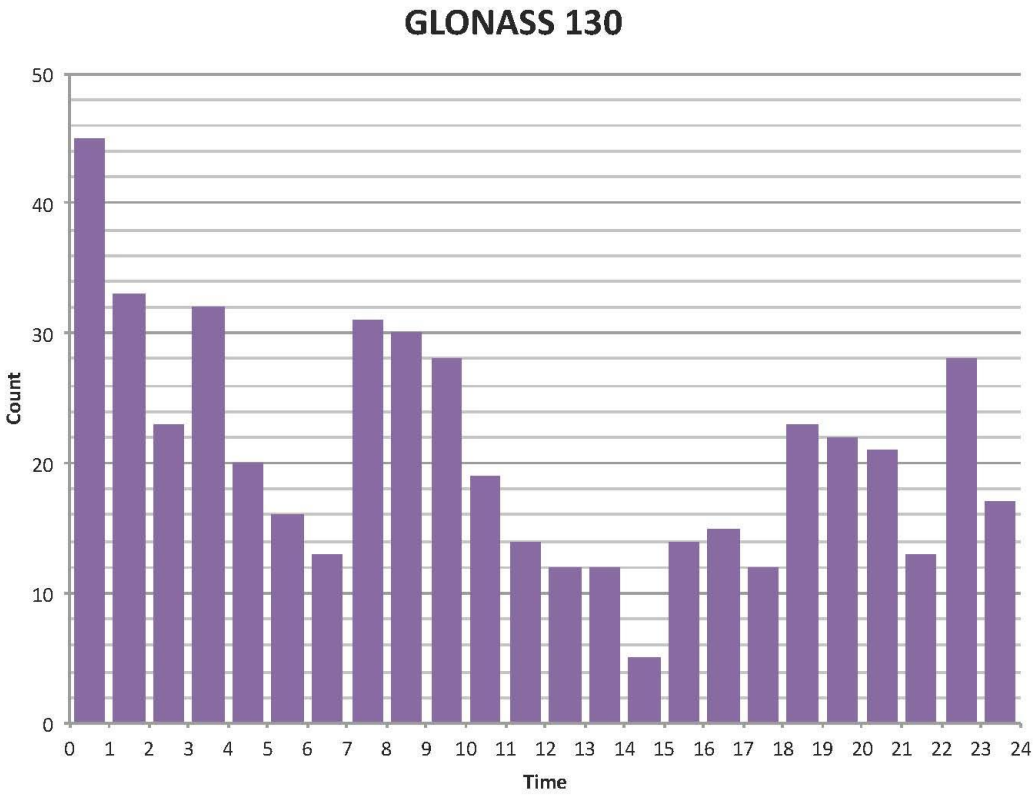
- Are there any siginificant differences in the echo rate and RMS of normal points
  - within 1 GNSS constellation?
  - Between day/night observations?
  - Depending on the observed elevation?
- How many observations per normal points are necessary for an RMS < 1.0mm?
- Are there any significant differences in the echo rate and RMS of normal points between the GNSS constellations GPS, GLONASS, GALILEO and COMPASS?

GLONASS Satellites



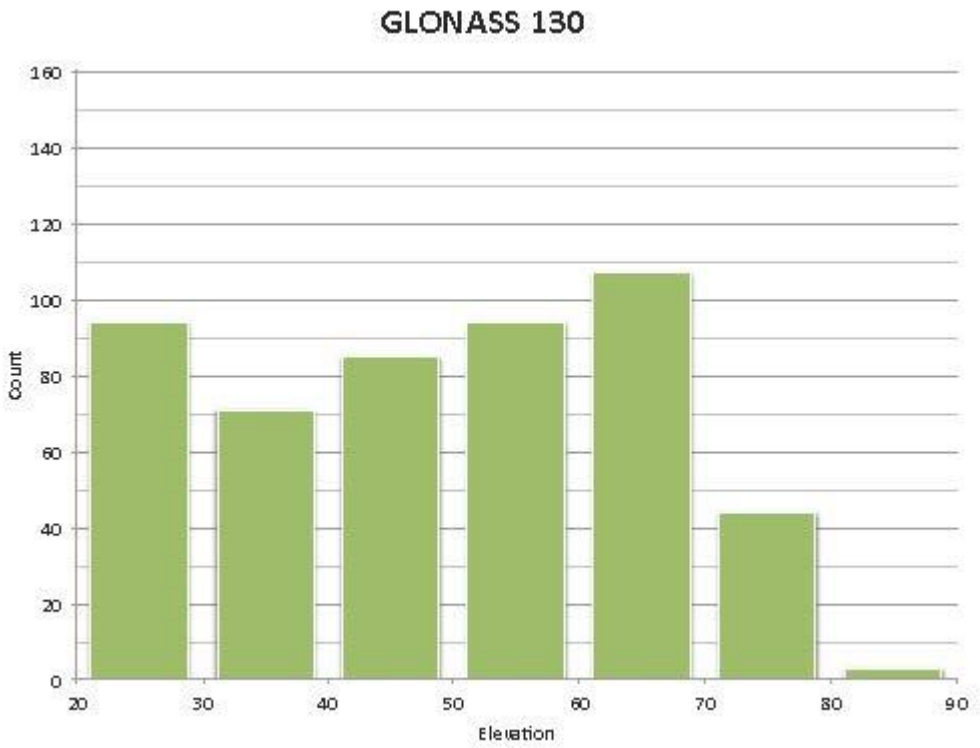
- Glonass Satellites with uncoated reflectors have a much higher echo rate than those with coated reflectors (factor 2)
- There is no significant difference between different types of Glonass satellites
- The lower RMS of the NP is probably a result of the higher #OBS/NP and not a result of a higher precision of the single shots

GLONASS Satellites



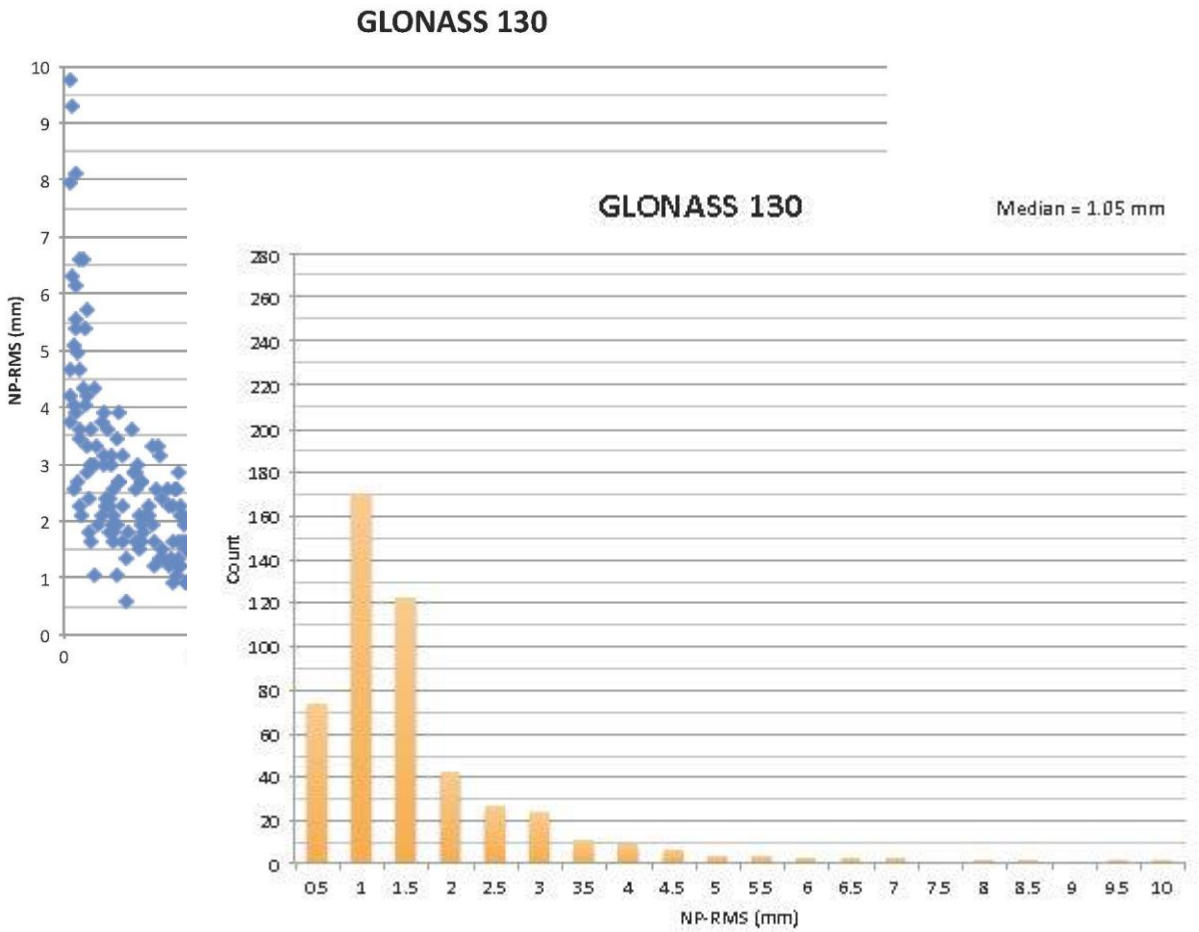
- Slightly higher number of observations during night time
- Almost no observations for Glonass 126 between 2 and 6 pm
- During night time observation time is shared with CCD observations!

GLONASS Satellites



- No significant correlation with elevation
- Remarkable high number of observations in lower elevations

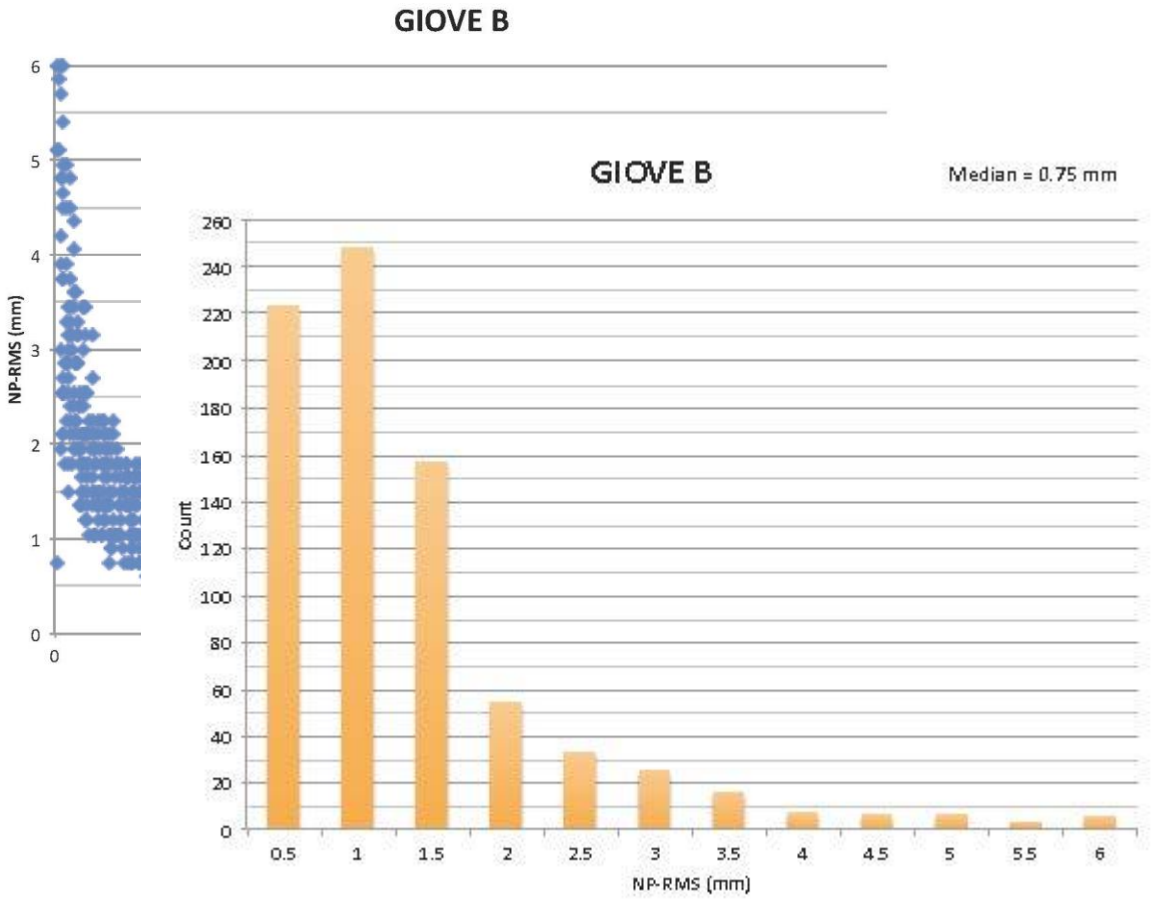
RMS of NPs for GLONASS



Coated:
102: 310 OBS/NP
109: 293 OBS/NP
110: 302 OBS/NP
118: 335 OBS/NP
Uncoated:
129: 537 OBS/NP
130: 468 OBS/NP

> 800 OBS/NP for RMS < 1.0mm!

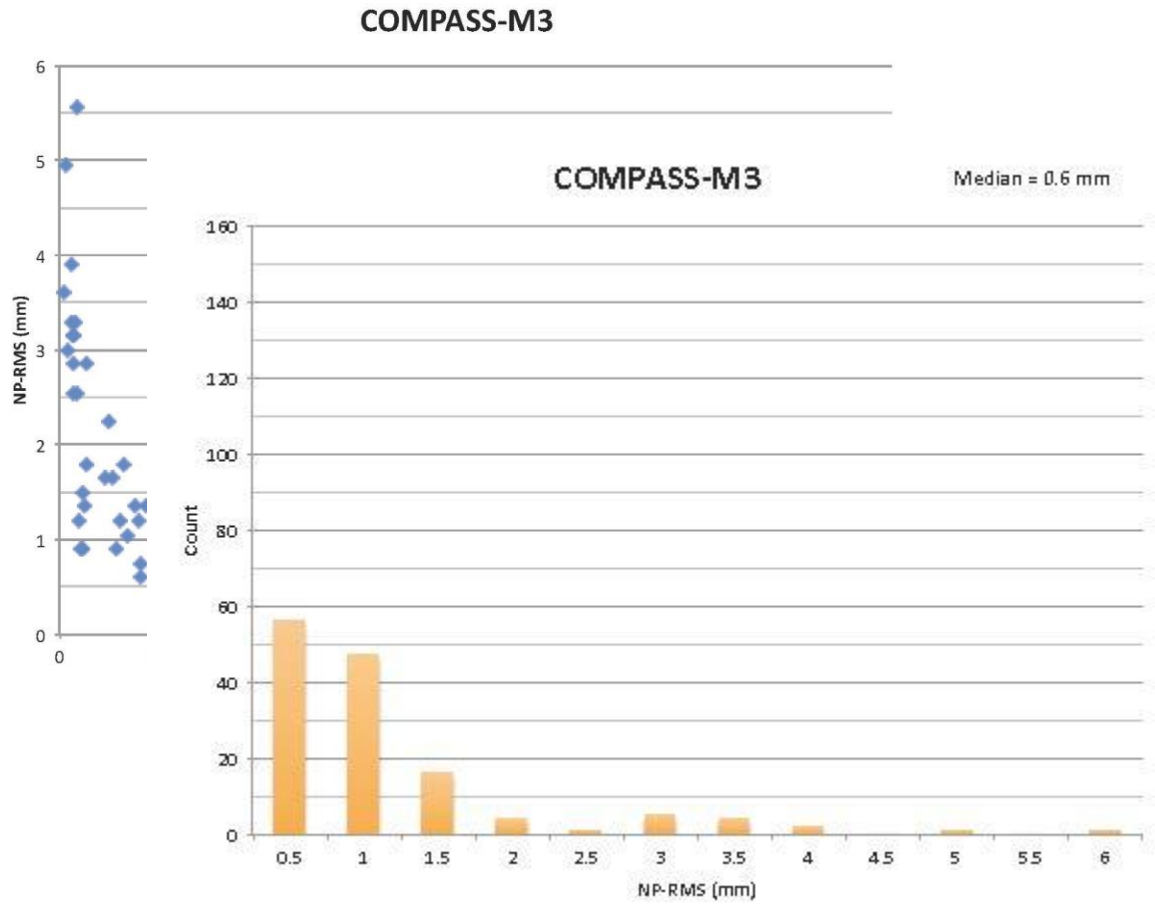
RMS of NPs for Galileo



Galileo:
101: 601 OBS/NP
102: 560 OBS/NP
Giove:
A: 338 OBS/NP
B: 265 OBS/NP

> 700 OBS/NP for RMS < 1.0mm

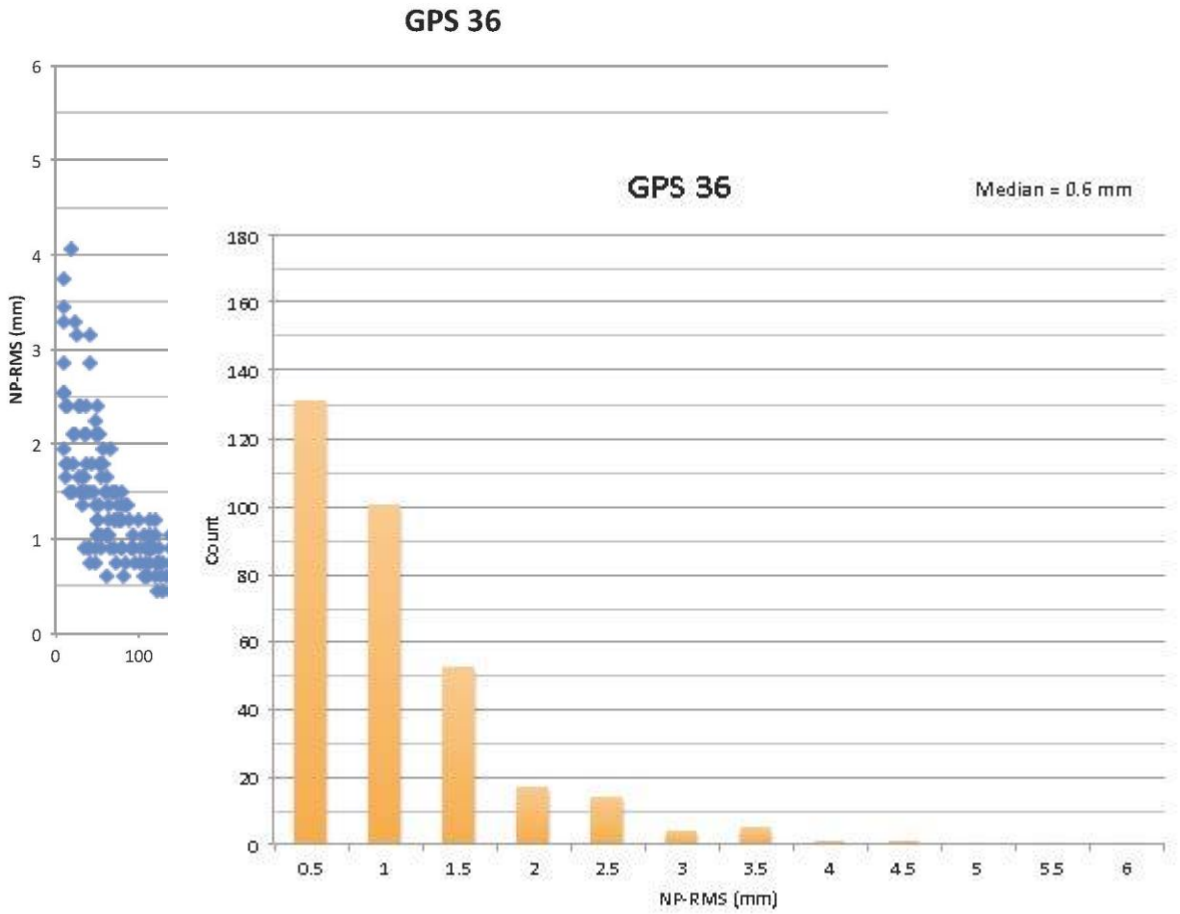
RMS of NPs for Compass



Compass:
M1: 421 OBS/NP
M3: 444 OBS/NP

> 400 OBS/NP for RMS < 1.0mm

RMS of NPs for GPS



Block II
35: 139 OBS/NP
Block IIA
36: 193 OBS/NP

> 250 OBS/NP for RMS < 1.0mm

Thank you very much for your attention!