SLR Tracking of GNSS Constellations at Zimmerwald

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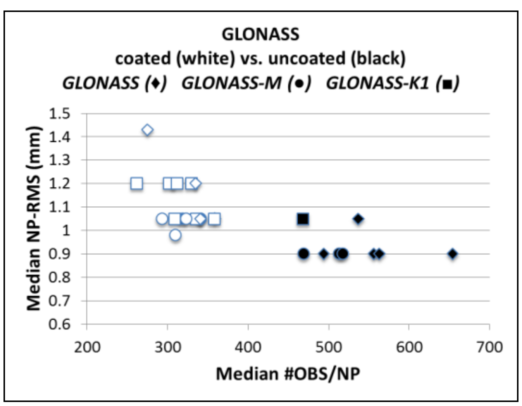
At the observatory of Zimmerwald ranging to satellites equipped with reflectors is done with the 1 Meter Ritchey Chrétien telescope ZIMLAT (Zimmerwald Laser and Astrometric Telescope) and a 100 Hz Nd:YAG lasersystem with a pulse length of 58 ps and an energy of about 8 mJ per single pulse. It is a monostatic system, the switch between transmit and receive path is done by a special coated mirror located in the Coudé path. During nights the observation time is shared with optical observations (CCD). A high level of automation could be reached for the SLR as well as for the CCD observations during the last years. A scheduler switches automatically not only between the satellites, but also between SLR and CCD observations. For each GNSS satellite a timeslot of 4 minutes is provided by the scheduler. If 1000 observations per normal point are exceeded before the end of the timeslot, the scheduler switches to the next satellite. If the return rate drops below a limit or no returns can be detected, an automatic search algorithm is invoked. A mount model of the telescope is calculated every 2 months from Glonass nighttime observations. The goal of the frequent mount model updates is to keep the RMS of the pointing accuracy below a limit of 2" despite of some instabilities of the optical system of the telescope. The high pointing accuracy of ZIMLAT is of particular importance during changing weather conditions allowing the tracking of satellites without invoking a time-consuming search algorithm.

Since summer 2010 the complete Glonass constellation (currently 24 satellites) is ranged at Zimmerwald. The number of observations per normal point (#OBS/NP) is almost a factor of 2 higher for Glonass satellites equipped with uncoated reflectors than for those with coated reflectors (Figure 1). The difference in #OBS/NP is a result of the higher return rate for satellites with uncoated reflectors. The lower RMS of the normal points for uncoated reflectors can be explained by the higher #OBS/NP. No significant differences can be seen between different types of Glonass satellites (Glonass, Glonass-M and Glonass-K). Underlined numbers are for the 6 Glonass satellites currently tracked by ILRS. The high #OBS/NP for Glonass 128 is a consequence of manual interactions of the operators. For unknown reasons the scheduler was switched frequently to manual mode during passes of Glonass 128. In manual mode the scheduler will not switch automatically to the next satellite even if the limit of 1000 OBS/NP is exceeded. The poor value of 1.4mm for the NP-RMS of Glonass 117 is not significant due to the fact that only a few normal points were available so far.



GLONASS			**GLONASS M**			**GLONASS K**		
NR	OBS	RMS	NR	OBS	RMS	NR	OBS	RMS
114	359	1.1	101	341	1.1	105	330	1.2
116	341	1.1	102	310	1.0	106	336	1.1
117	275	1.4	103	319	1.1	110	302	1.2
118	335	1.2	107	323	1.1	111	309	1.1
115	**556**	**0.9**	109	293	1.1	119	262	1.2
126	**563**	**0.9**	**122**	**513**	**0.9**	120	312	1.2
128	**654**	**0.9**	**123**	**469**	**0.9**	121	358	1.1
129	**537**	**1.1**	**124**	**518**	**0.9**	**130**	**468**	**1.1**

Figure 1: Differences in #OBS/NP and NP-RMS between Glonass satellites equipped with coated and uncoated reflectors (bold). Underlined numbers are for the 6 Glonass satellites currently tracked by ILRS.

A closer look at the temporal distribution of the NPs within one day reveals remarkable inhomogeneities especially for the Glonass satellites 126 and 130 (Figure 2). During some hours almost no NPs could be measured. Further investigations are required to identify the reason for this effect. No correlation can be seen between elevation and number of NPs, even at low elevation angles. The cutoff angle for GNSS satellites is set to 20 degrees and the maximum allowed elevation of ZIMLAT is 87 degrees.

Noticeable differences in the RMS of NPs as function of #OBS/NP appear between satellites of the currently 4 measured GNSS constellations at Zimmerwald (GPS, Glonass, Compass and Galileo). Within one GNSS constellation there are only small differences. For the illustration in Figure 3 one satellite per GNSS constellation was selected as an example, namely GPS 36, Glonass 130, Compass M1 and Galileo 101. For achieving an NP-RMS better than 1mm, the following #OBS/NP are necessary: > 200 OBS/NP for GPS, > 400 OBS/NP for Compass, > 700 OBS/NP for Galileo, > 800

OBS/NP for Glonass. The histogram of #OBS/NP (Figure 3, 2nd column) reflects the return rates. Due to the fact that the scheduler will switch to the next satellite after exceeding a limit of 1000 OBS/NP, a high value in the histogram at the level of 1000 OBS/NP indicates a high return rate. The highest return rates can be seen for Glonass 130 and Galileo 101, followed by Compass M1. GPS 36 shows the lowest value. The median values of the NP-RMS (Figure 3, 3rd column) show the lowest values for GPS 36 and Compass M1, the highest value for Glonass 130. Despite of the low return rates of GPS satellites, the goal of 1mm RMS for the NPs can be much easier achieved than for Glonass satellites.

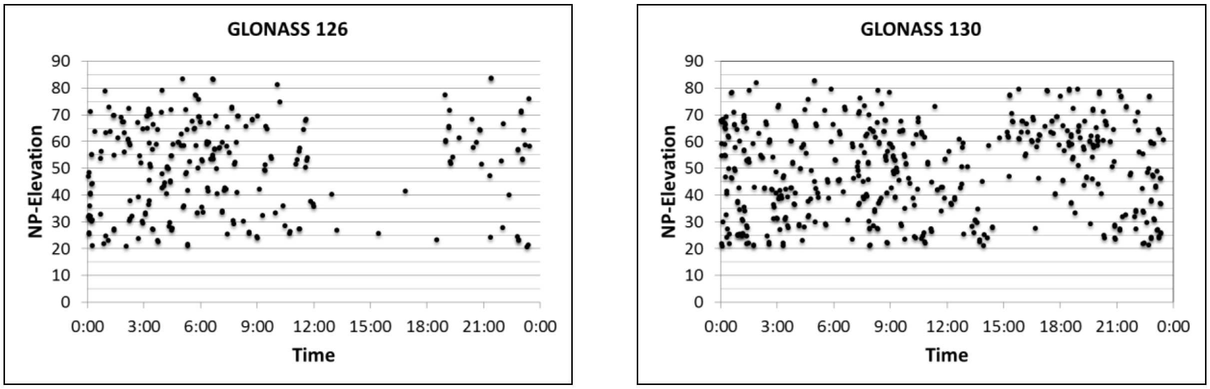


Figure 2: Temporal distribution of NPs within one day for Glonass 126 and 130

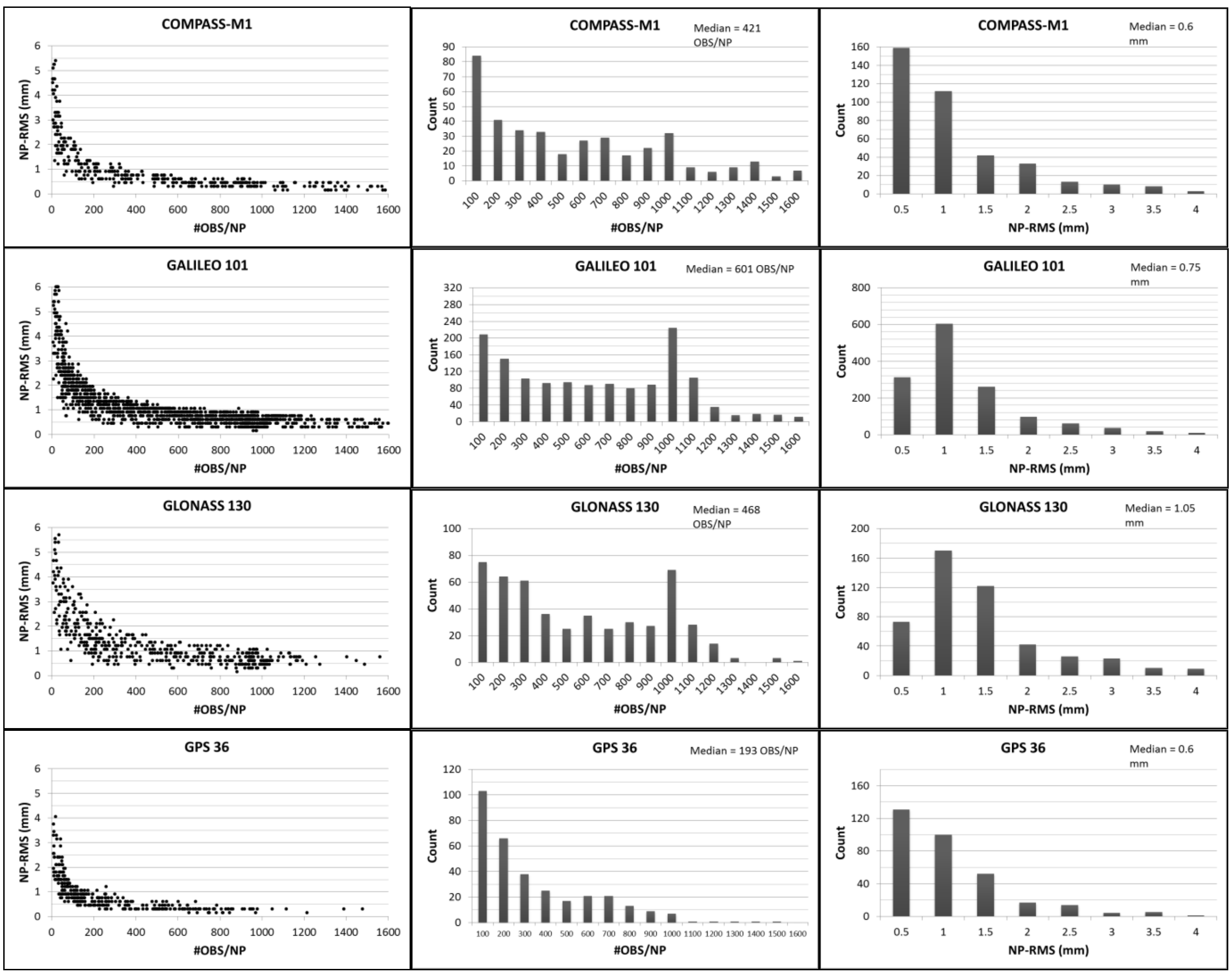


Figure 3: Comparision of the 4 measured GNSS constellations at Zimmerwald