


WROCŁAW UNIVERSITY OF ENVIRONMENTAL AND LIFE SCIENCES

QUALITY ANALYSIS OF LOW-COST MULTI-BAND GNSS RECEIVERS AND ANTENNAS

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MOTIVATION

STATUS OF GNSS MEASUREMENTS:

- well established tool
- widely used in geoscience applications
- provide centimeter and sub-millimeter accuracy for real-time and post-processing, respectively
- four global satellite systems

Source: Understanding Different Satellite Systems

CHALLENGES:

- reducing the cost of using GNSS
- improving performance from low-cost devices
- building denser networks to study phenomena on a local scale[1]

[1] Marut, G., Hadas, T., Kaplon, J., Trzcina, E., & Rohm, W. (2022). Monitoring the water vapor content at high spatio-temporal resolution using a network of low-cost multi-GNSS receivers. *IEEE Transactions on Geoscience and Remote Sensing*, *60*. https://doi.org/10.1109/TGRS.2022.3226631

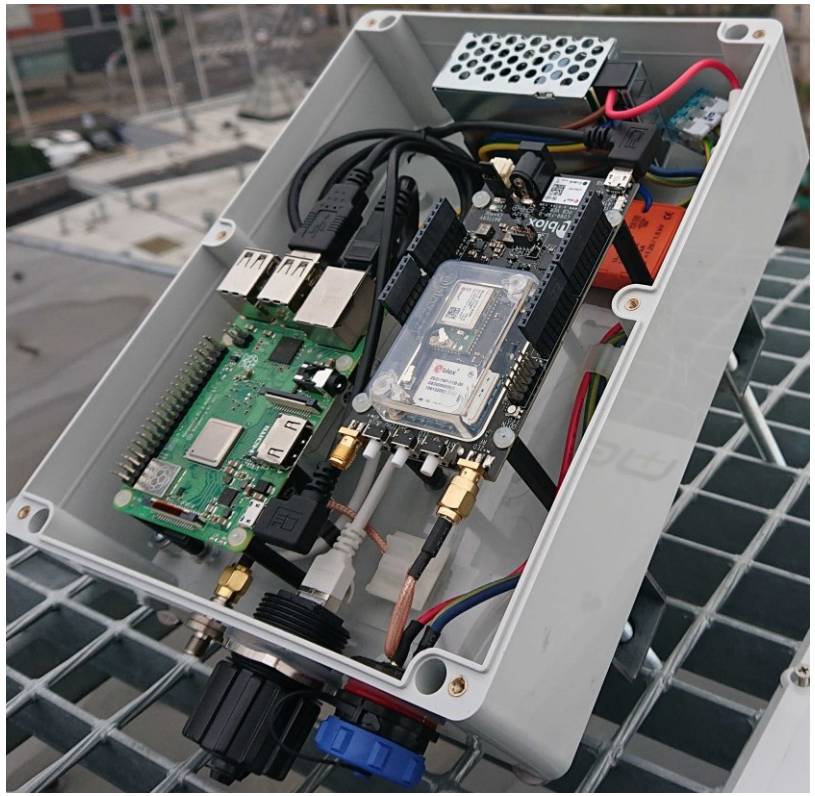
Field of study

Place of experiment

Used antennas

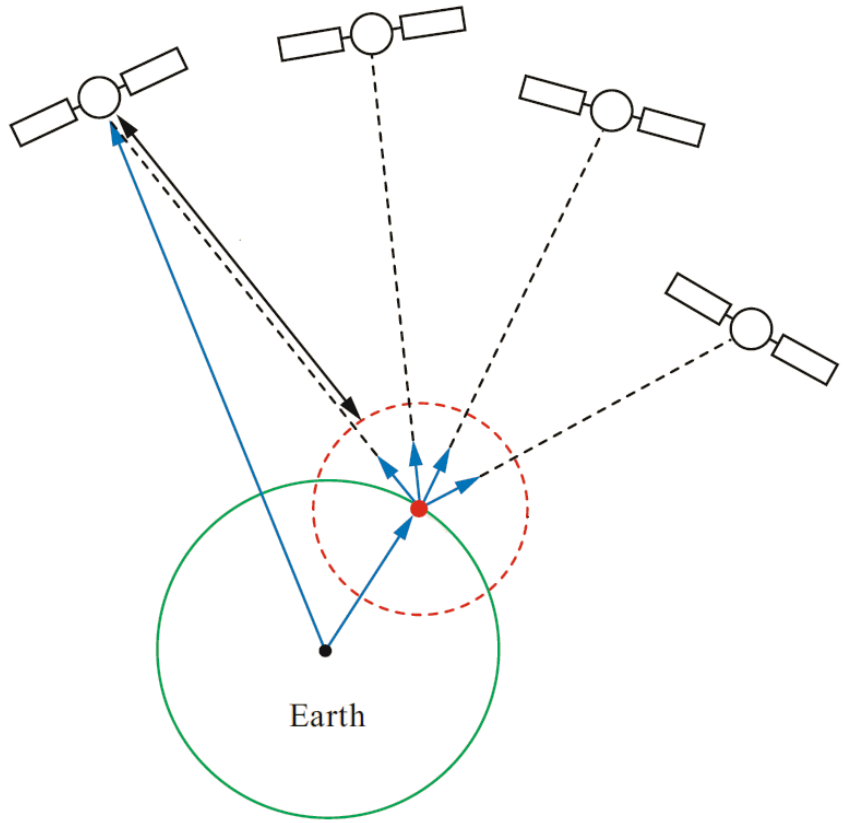
	JAVD Javad GrAnt G5T 1717 €		LEIC Leica AS10 1384 €		AS3C ArduSimple ANT3B Calibrated 199 €		TALL Tallysman TW3972 230 €		UBLX u-blox ANN-MB-00-00 75€
	WROC Leica AR25.R4 > 3000 €		AS2S ArduSimple ANT2B Survey 89 €		TGCL Taoglas Colloseum 113 €		TGMA Taoglas MagmaX2 72€		

Used devices



METHODOLOGY

- Receiver: u-blox C099-F9P
- Antennas: 12 x low-costs and 2 x geodetic grade
- Observed systems: GPS, GLONASS, Galileo
- Calculated systems: GPS, GLONASS
- Software: GNSS-WARP, Bernese 5.2, Anubis Free 3.3
- Products: Final MGEX CODE
- Measurements techniques: Precise Point Positioning (PPP), Double-Differenced Positioning, Single Point Positioning
- Calculation interval: 30 sec / 15 min



Source: Springer Handbook of Global Navigation Satellite Systems[1]

[1] Springer Handbook of Global Navigation Satellite Systems. (2017). In P. J. G. Teunissen & O. Montenbruck (Eds.), *Springer Handbook of Global Navigation Satellite Systems*. Springer International Publishing. https://doi.org/10.1007/978-3-319-42928-1

RESULTS – SIGNALS (1)

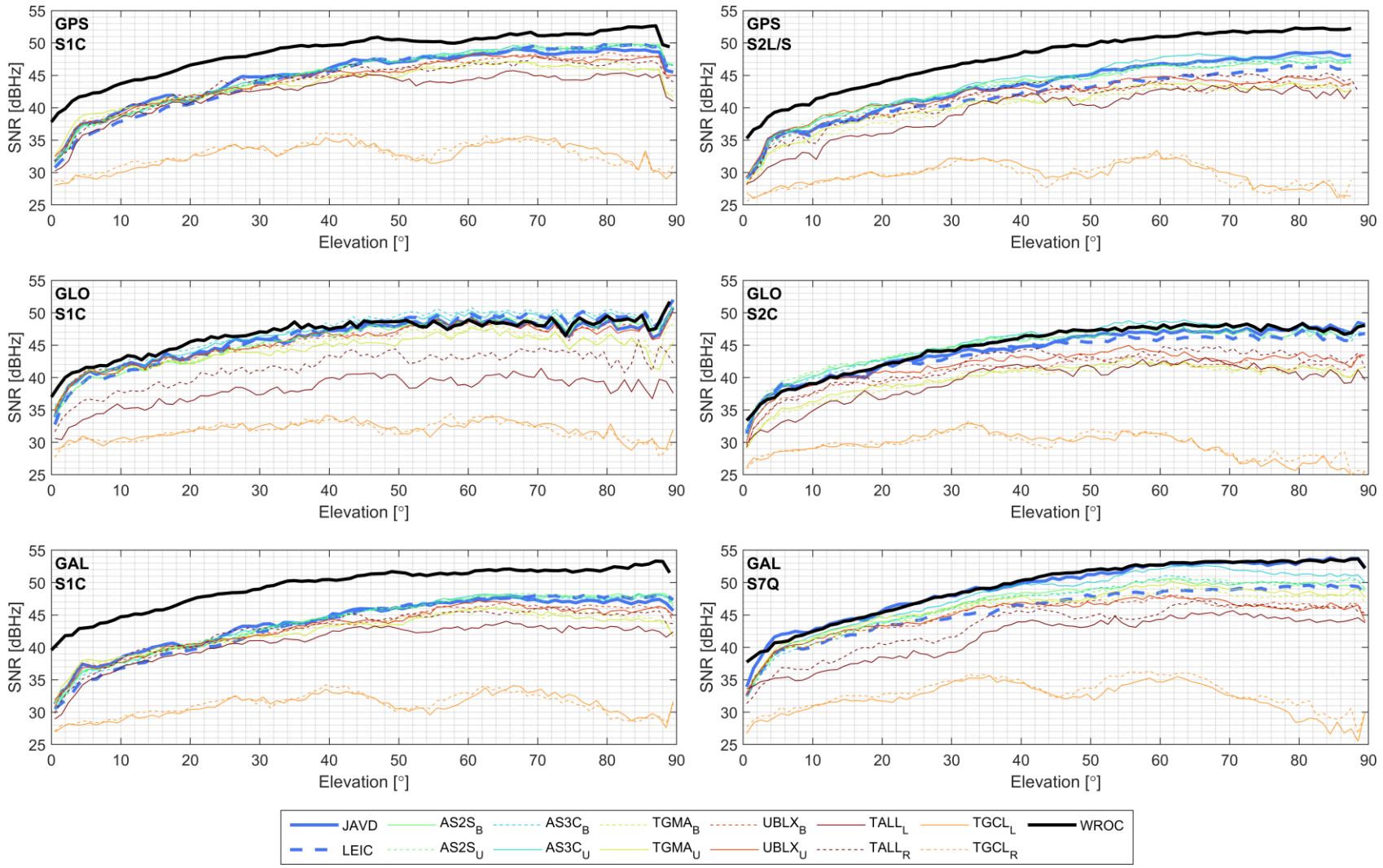
- Good satellite tracking on the first frequency
- Worse tracking ability of GPS and GLONASS satellites on the second frequency compared to Galileo
- TALL and TGCL antennas the weakest of the low-cost antennas
- Results comparable to geodetic grade antennas (excluding TALL and TGCL)

AMOUNT OF SIGNAL TRACKED COMPARED TO IGS WROC

	Code/Phase 1st freq.			Code/Phase 2nd freq.		
	G [%]	R [%]	E [%]	G [%]	R [%]	E[%]
JAVD	99.6	99.8	99.5	72.4	86.4	99.4
LEIC	99.4	99.7	99.5	72.6	86.4	99.4
$AS3C_U$	99.6	99.8	99.7	72.4	86.3	99.3
$AS3C_B$	99.6	99.9	99.7	72.3	86.3	99.2
$AS2S_U$	99.4	99.7	99.6	72.5	86.4	99.2
$AS2S_B$	99.5	99.8	99.3	72.5	86.4	99.4
$TGCL_L$	98.7	89.6	95.5	64.4	81.8	86.8
$TGCL_R$	99.6	94.7	98.0	67.4	82.6	94.8
$TALL_L$	99.2	96.4	99.5	71.5	86.1	90.8
$TALL_R$	99.2	99.1	99.1	72.1	86.0	98.3
$TGMA_U$	99.8	99.9	99.7	72.2	86.2	98.3
$TGMA_B$	99.8	99.9	99.7	72.1	86.0	97.9
$UBLX_U$	99.5	99.9	99.6	72.6	86.3	99.2
$UBLX_B$	99.7	99.9	99.7	72.4	86.2	96.1

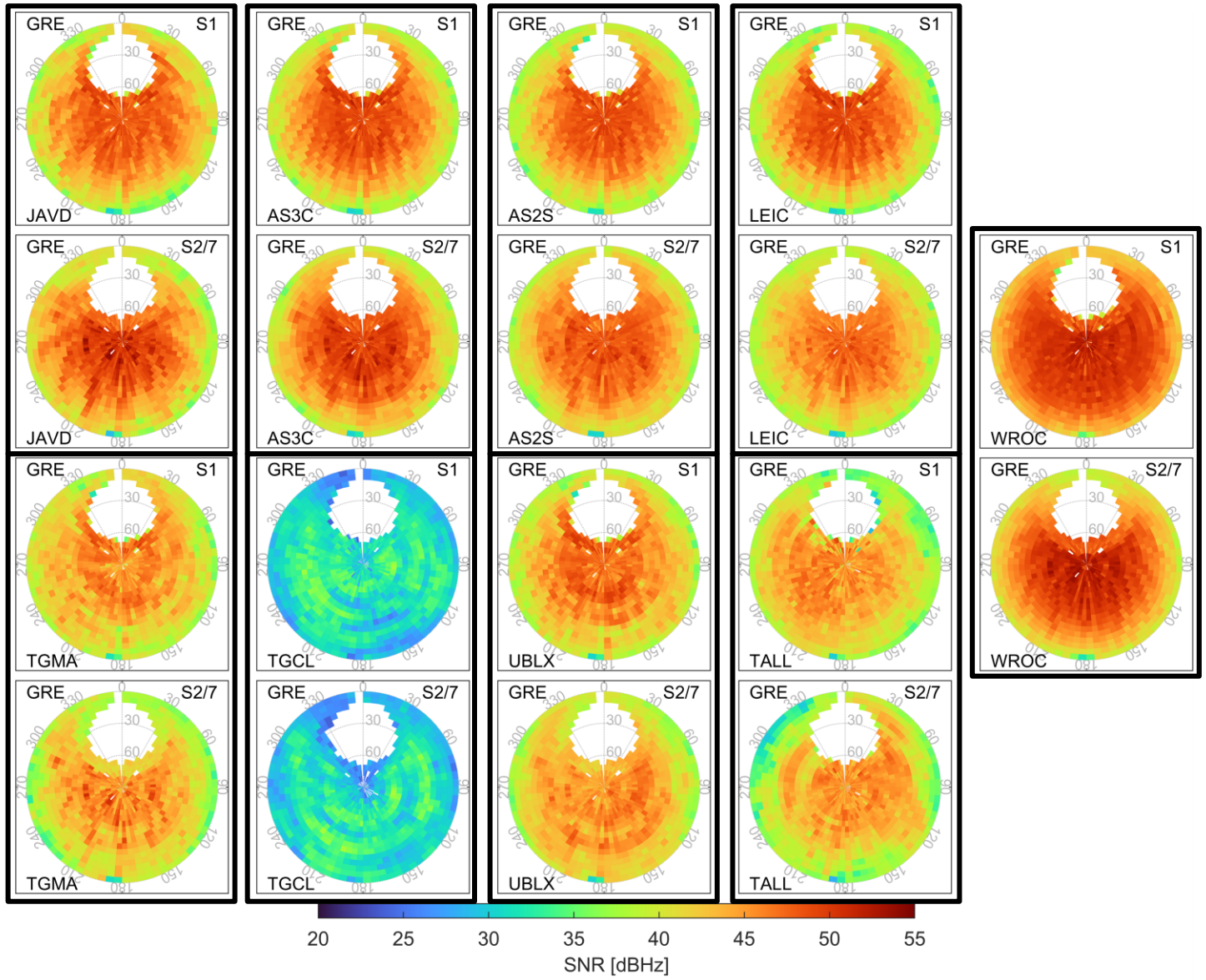
RESULTS – SNR (1)

- Consistent signal-to-noise ratio between pairs of antennas (excluding GLONASS S1C for TALL antennas)
- TGCL antennas again weaker than other antennas
- Low-cost antennas comparable to geodetic grade antennas (excluding TALL and TGCL)
- In the case of GLONASS and Galileo S7Q, antennas connected to the low-cost receiver are not much worse than IGS WROC station (excluding TALL and TGCL)



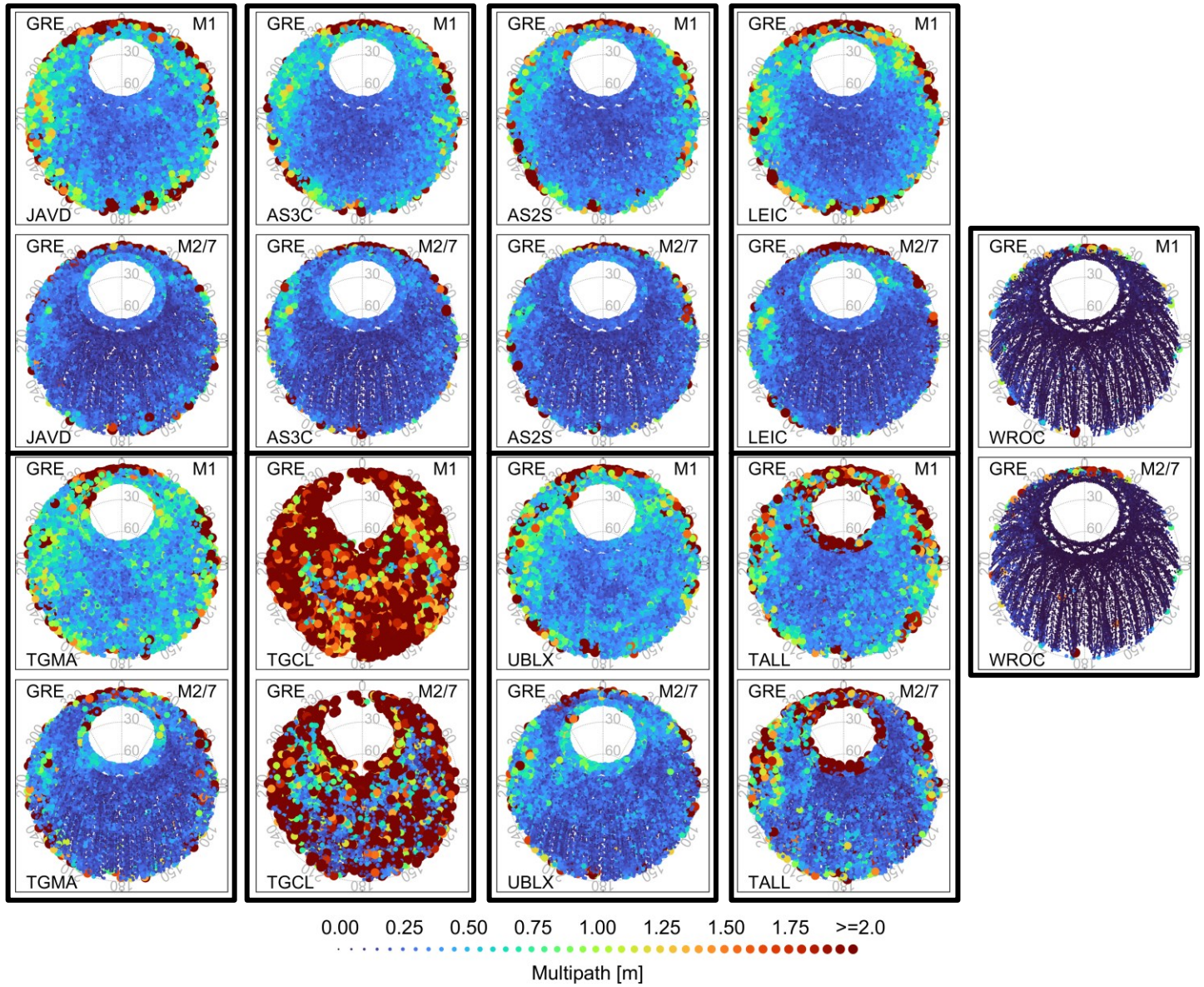
RESULTS – SNR (2)

- TGCL antenna outperforms other antennas
- Weaker results were also obtained for patch antennas TGMA and TALL antennas
- AS2S and AS3C antennas achieved results comparable to geodetic grade antennas
- All antennas connected to low-cost receivers acquire worse signals coming from lower elevations compared to WROC stations



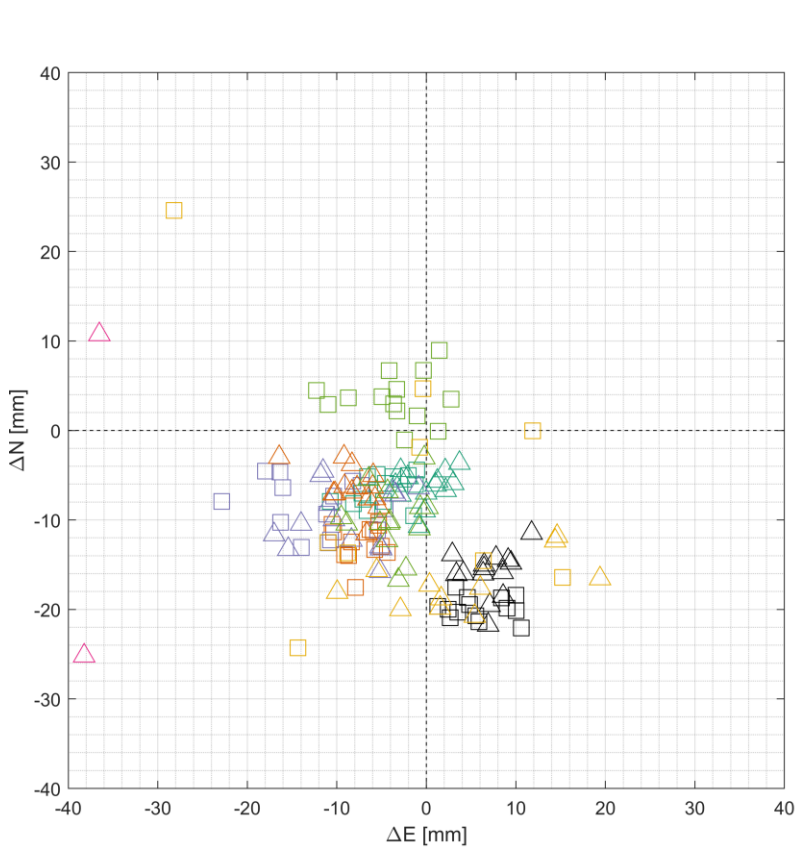
RESULTS - MUTLIPATH

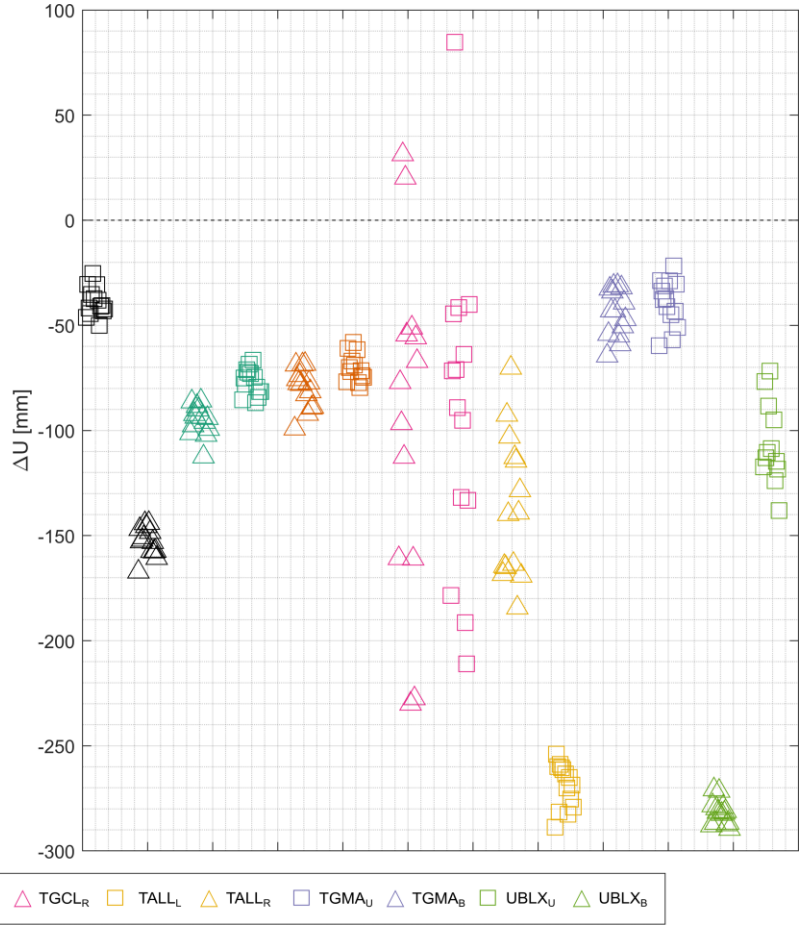
- TGCL antenna is characterised by the greatest influence of multipath effect reaching even more than 2 m regardless of elevation and azimuth angle
- JAVD and LEIC geodetic class antennas are characterised by greater multipath effects than AS3C and AS2S antennas
- For all antennas, the second first frequency is affected by a higher multipath effect compared to the second frequency



RESULTS – GNSS-WARP WITHOUT PCOs

- Calculations were performed with null model for all antennas
- Used antennas have high repeatability both, horizontally and vertically (excluding TGCL and TALL)
- The vertical offsets are noticeably larger than horizontal reaching up to almost 30 cm ($UBLX_B$)!
- Incompatibility between used UBLX antennas

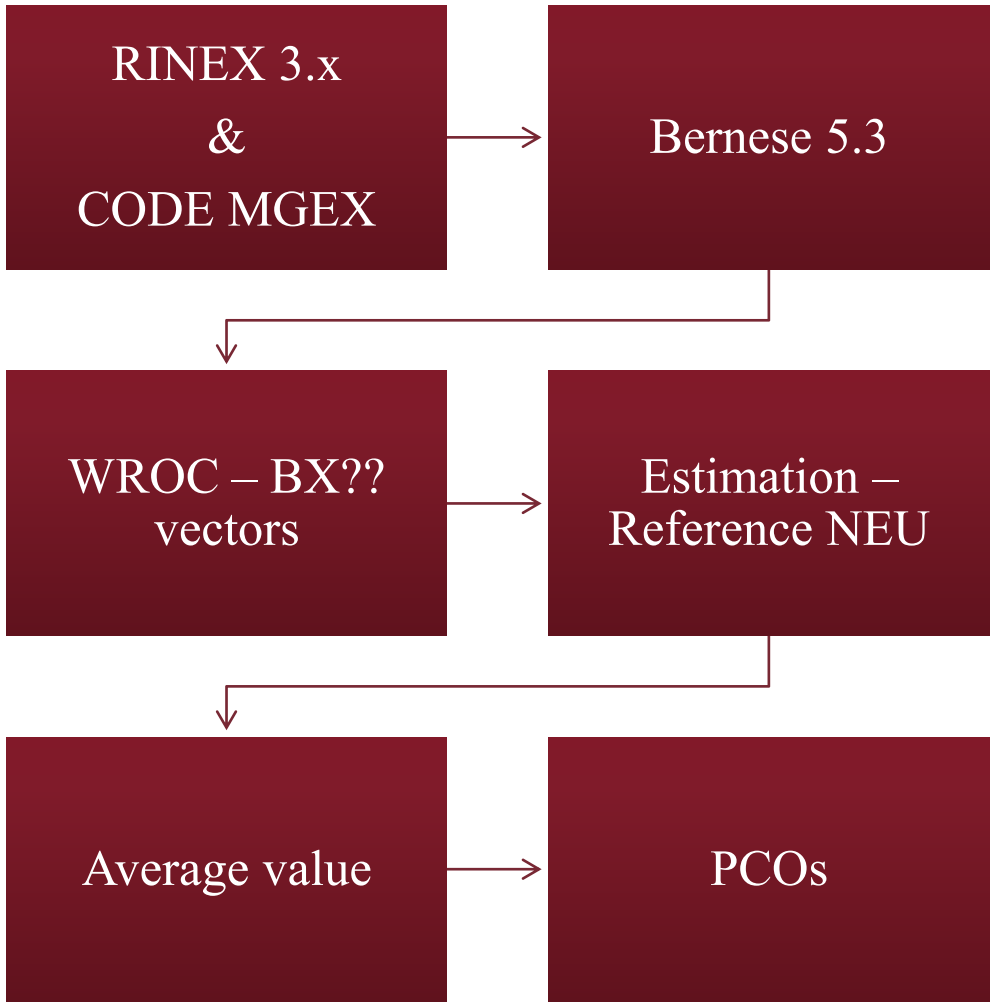




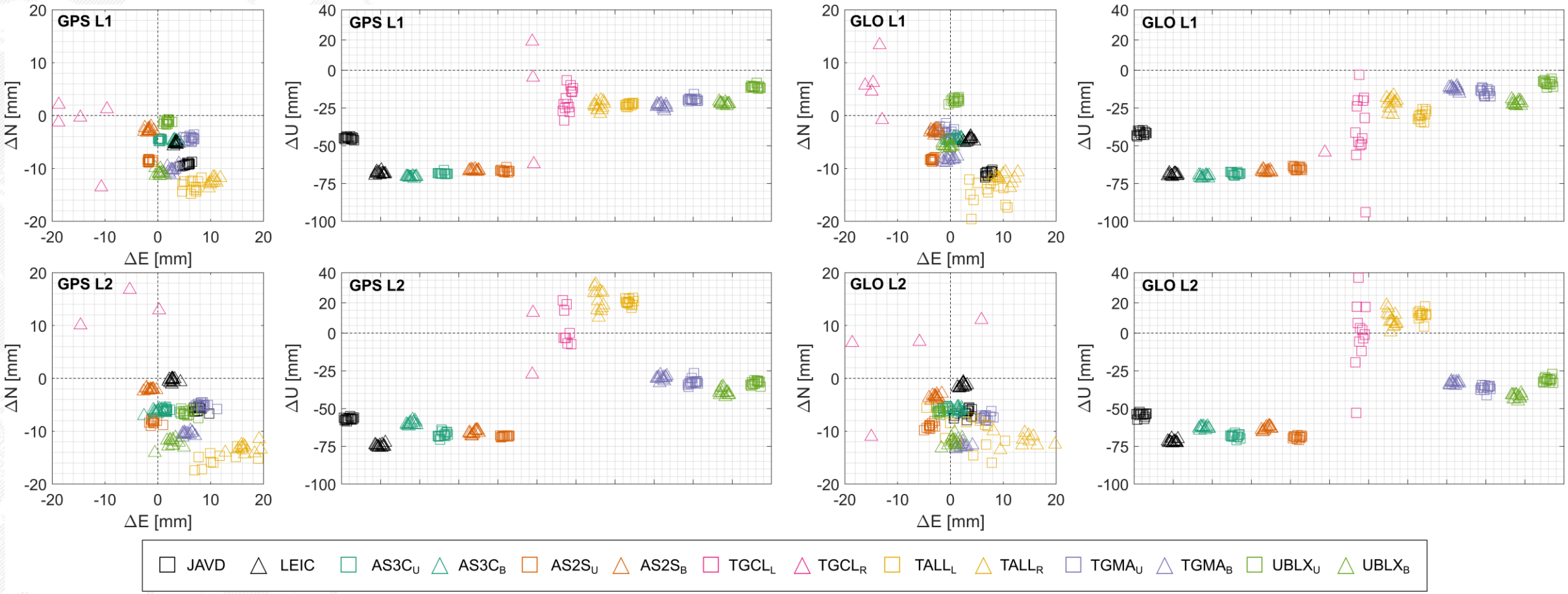
METHODOLOGY FOR PCO'S DETERMINATION

- Technique: Baseline positioning
- Products: CODE MGEX
- Troposphere: VMF-1
- The procedure is performed separately for each system and each frequency recorded by the receivers

		Reference		Estimation		Differences	
		JAVD	LEIC	JAVD	LEIC	JAVD	LEIC
		Up [mm]				ΔUp [mm]	
G	L1	39,27	58,32	44,8	68,3	-5,6	-10,0
	L2	40,08	55,54	56,8	74,8	-16,7	-19,3
R	L1	39,48	58,32	41,6	69,2	-2,1	-10,9
	L2	37,82	55,54	54,3	72,0	-16,5	-16,4

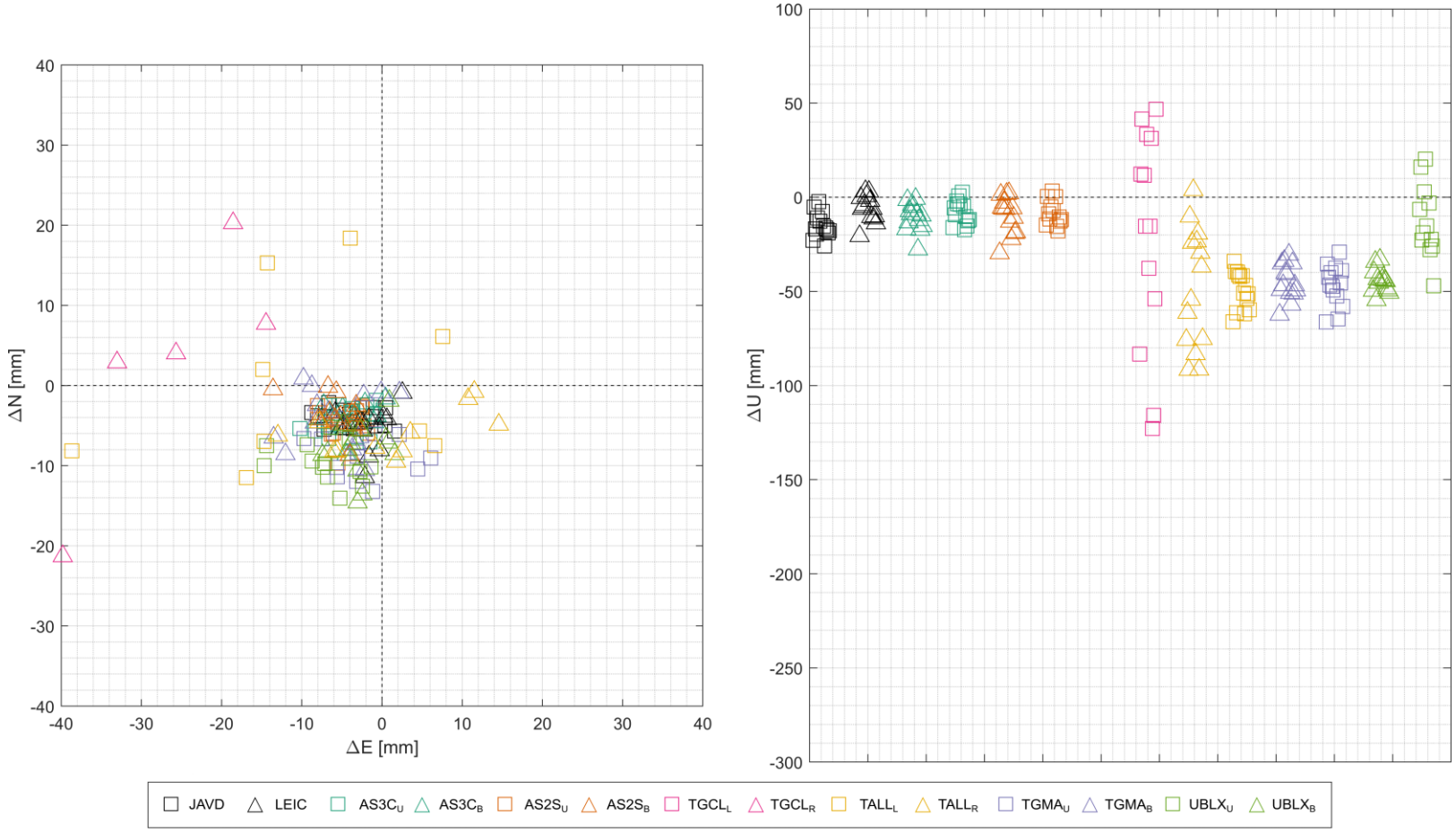


RESULTS OF PCO'S DETERMINATION



RESULTS – GNSS-WARP WITH PCOs

- An individual offset for each antenna was used
- Receivers have improved horizontal position to within about 1 cm
- Most of antennas have improved vertical position to close zero
- Minimal improvement for TGMA antennas was observed



Conclusions

- Signals tracked by low-cost receivers are mostly compatible with professional receivers
- Most of the antennas obtained similar SNR's levels to geodetic grade antennas
- Low-cost antennas have similar multipath effects compared to antennas used in geodesy
- A check of the reference coordinate network should be carried out to exclude the transmission of determination errors
- Determination error of used method should be computed using a geodetic grade receiver
- Change the calculation of PCO from arithmetic mean to weighted mean
- The use of the computed offsets has significantly improved the coordinate determination for most of used antennas

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Thank you for your attention!

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