PRECISE REAL-TIME GNSS POSITIONING USING DIFFERENT CORRECTION REPRESENTATION

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Introduction

- **For real-time GNSS applications, the well-known RTK method is most often used.**

- **Network-side observations and the configuration of reference stations strongly influence RTK accuracy.**

- **Precise Positioning Positioning (PPP) uses only data from one receiver, and its accuracy depends on the precise modeling of error terms.**

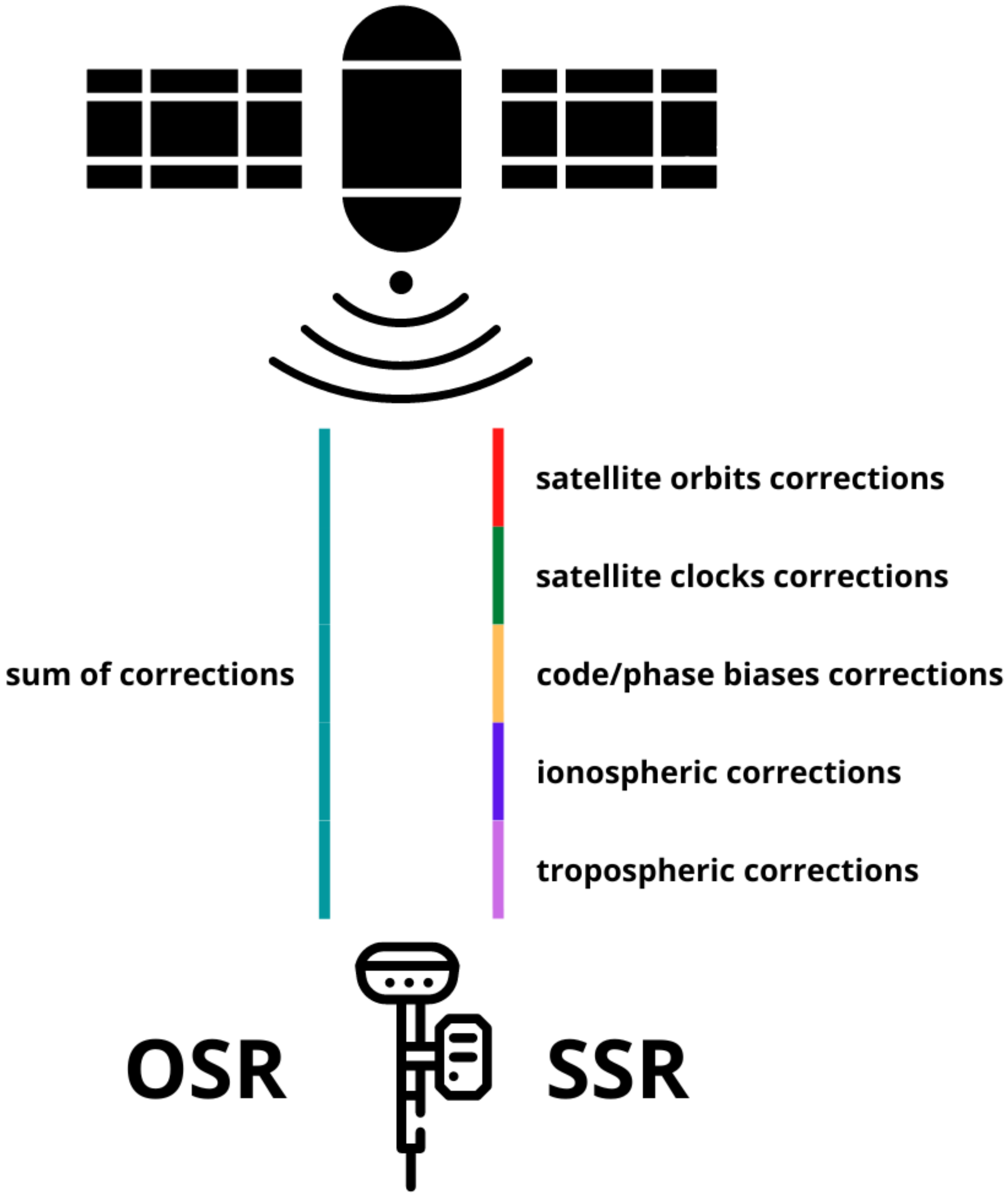
- **PPP with fast ambiguity resolution (PPP-RTK) is an alternative to RTK because a dense GNSS stations network is not needed.**

OSR vs SSR

- **Observation Space Representation (OSR) represents the sum of all errors observed by a network of reference stations.**
- **OSR requires the processing of the same signals on each reference station (homogeneous network) and the support of these signals by the user.**

- **State Space Representation (SSR) represents decorrelated and estimated errors for each component (satellite orbits, clocks, biases, ionosphere,…).**

OSR vs SSR


satellite orbits corrections
satellite clocks corrections
sum of corrections
code/phase biases corrections
ionospheric corrections
tropospheric corrections
OSR
SSR

SSR corrections formats

- Most of the SSR formats do not fully support PPP-RTK processing.
- We use the SSRZ format from Geo++, which, unlike other formats, also provides local and gridded ionosphere and troposphere corrections.

Product			SSRG	SSR	SSRZ	Compact SSR	IGS-SSR	SPARTN
Developer			Geo++	RTCM	Geo++	Melco	IGS	Sapcorda
SV orbit			available	available	available	available	available	available
SV clock			available	available	available	available	available	available
SV code bias			available	available	available	available	available	available
SV phase bias			available	tested	available	available	available	available
ionosphere	global	VTEC		tested	available		available	available
	global	STEC			available			
	regional	STEC			available	available		available
	residual	gridded	available		available	available		available
troposphere	global				in preparation			
	regional				available			available
	residual	gridded	available		available	available		available
complete SSR model			yes	not yet	yes	yes	not yet	yes

RTK and PPP-RTK model

- **RTK**
  - uncombined dual/multi-frequency observations
  - precise products: none or OSR

$$\Delta\nabla P_{r1,r2,j}^{s1,s2} = \Delta\nabla\rho_{r1,r2}^{s1,s2} + \Delta\nabla OSR_{r1,r2}^{s1,s2} + \sout{c(dt_r - dt^s) - \mu_j I_r^s + T_r^s + c(b_{r,j} - b_j^s) + \varepsilon_{r,j}^s}$$

$$\Delta\nabla L_{r1,r2,j}^{s1,s2} = \Delta\nabla\rho_{r1,r2}^{s1,s2} + \Delta\nabla OSR_{r1,r2}^{s1,s2} + \sout{c(dt_r - dt^s) + \mu_j I_r^s + T_r^s + \lambda_j\left(N_{r,j}^s + B_{r,j} - B_j^s\right) + e_{r,j}^s}$$

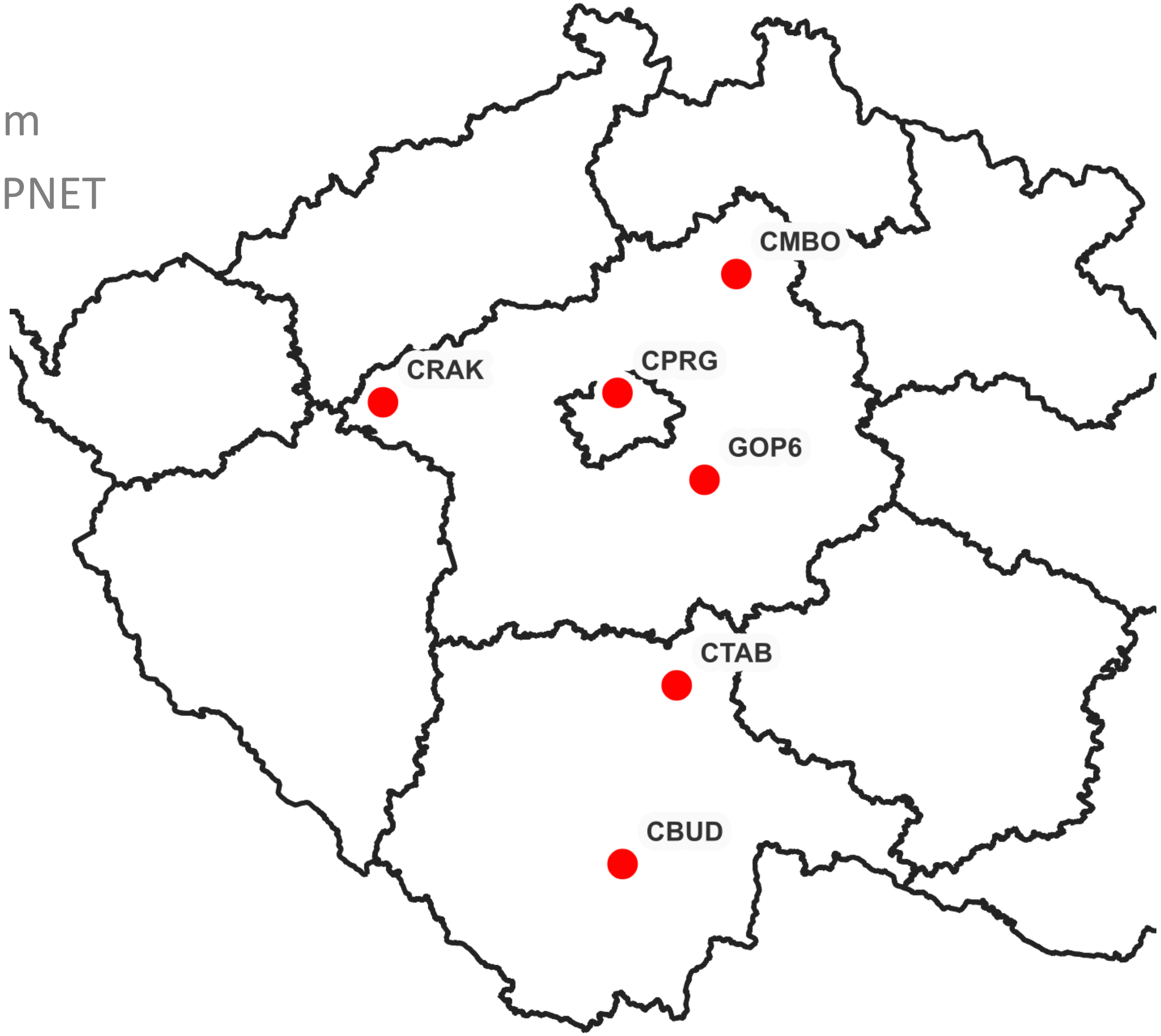
- **PPP-RTK**
  - uncombined dual/multi-frequency observations
  - precise products: orbits, clocks + code/phase biases + STEC

$$P_{r,j}^s = \rho_r^s + c(dt_r - dt^s) - \mu_j I_r^s + T_r^s + c(b_{r,j} - b_j^s) + \varepsilon_{r,j}^s$$

$$L_{r,j}^s = \rho_r^s + c(dt_r - dt^s) + \mu_j I_r^s + T_r^s + \lambda_j\left(N_{r,j}^s + B_{r,j} - B_j^s\right) + e_{r,j}^s$$

Data

- 28–30 August 2022
- 6 selected stations
- 1 s real-time data from CZEPOS RTCM stream
- As reference stations were used VESOG/TOPNET permanent stations
- SSRZ corrections by Geo++
- GOP consolidated broadcast orbits

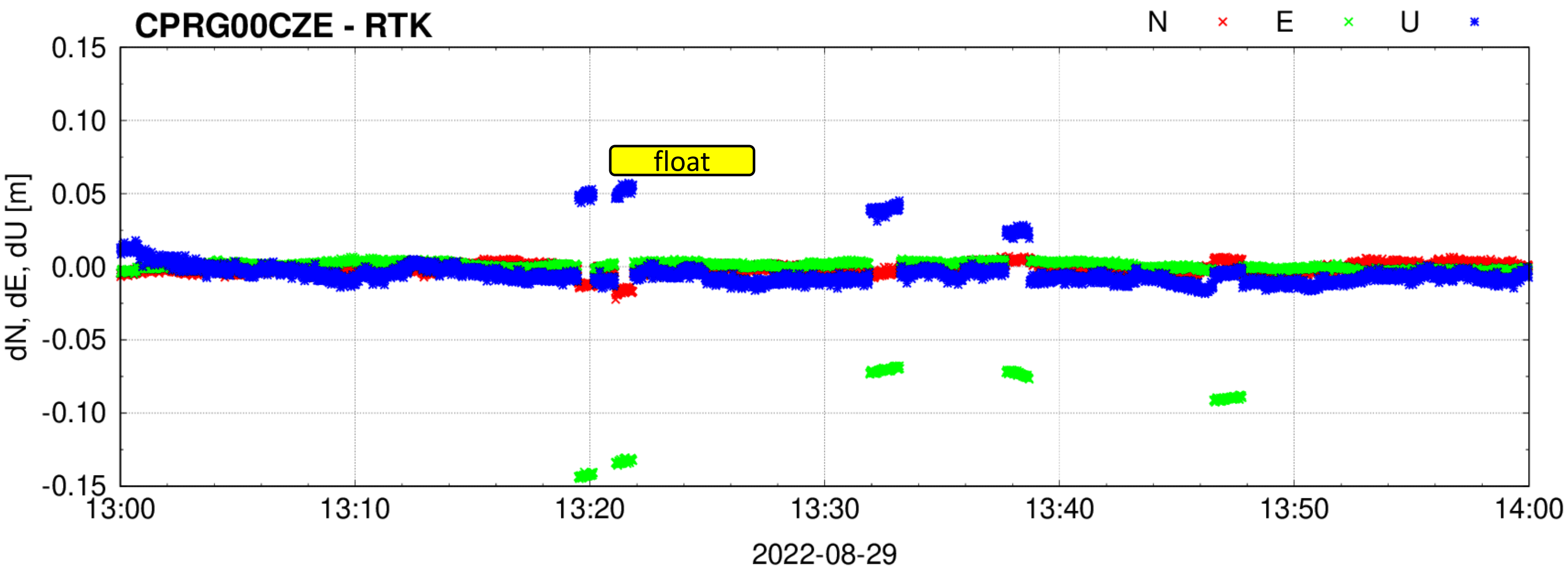


Processing

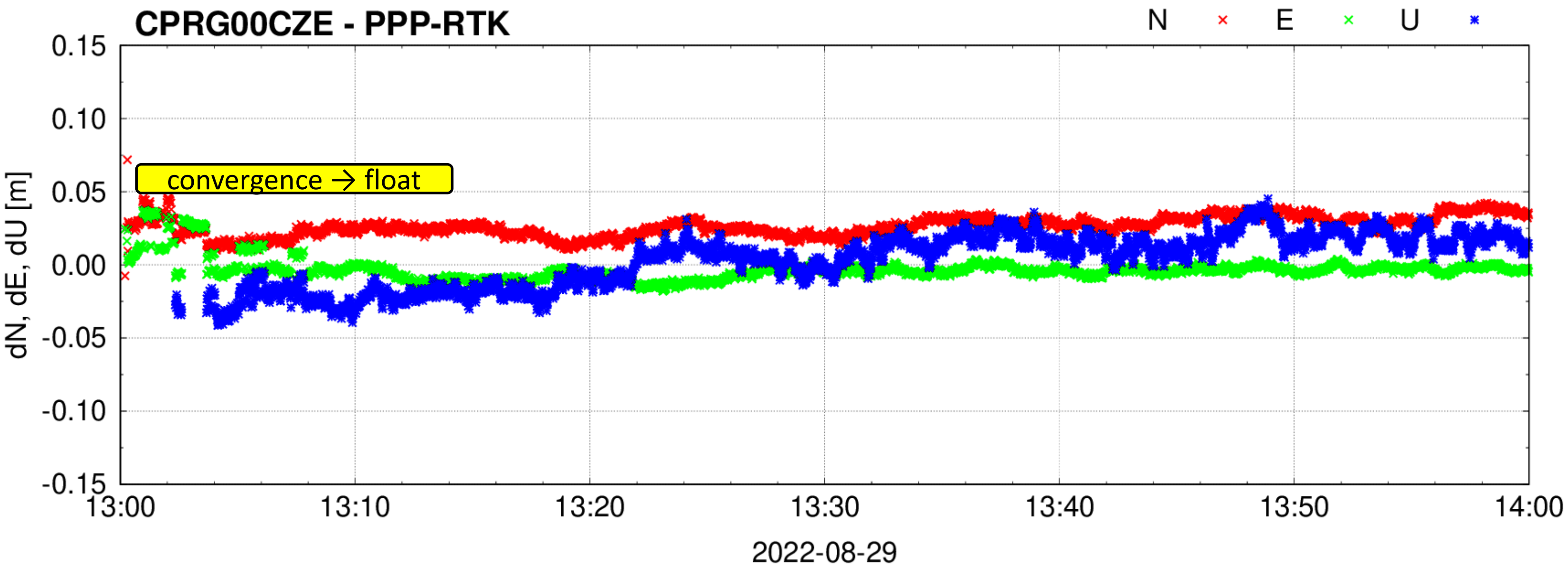
- **RTK**
- Software: **RTKLIB 2,4,3**
- Observation combination: **uncombined** (GPS L1, L2; GLONASS L1, L2; Galileo E1, E5a)
- Orbits & clocks: **broadcast**
- Ionosphere, troposphere: **eliminated by double-difference**
- Sampling rate: **1 s**
- **PPP-RTK**
- Software: **G-Nut/Geb RT**
- Observation combination: **uncombined** (GPS L1, L2; GLONASS L1, L2; Galileo E1, E5a)
- Orbits & clocks: **broadcast + SSRZ corrections**
- Ionosphere, troposphere: **SSRZ regional corrections**
- Sampling rate: **1 s**

Results

RTK

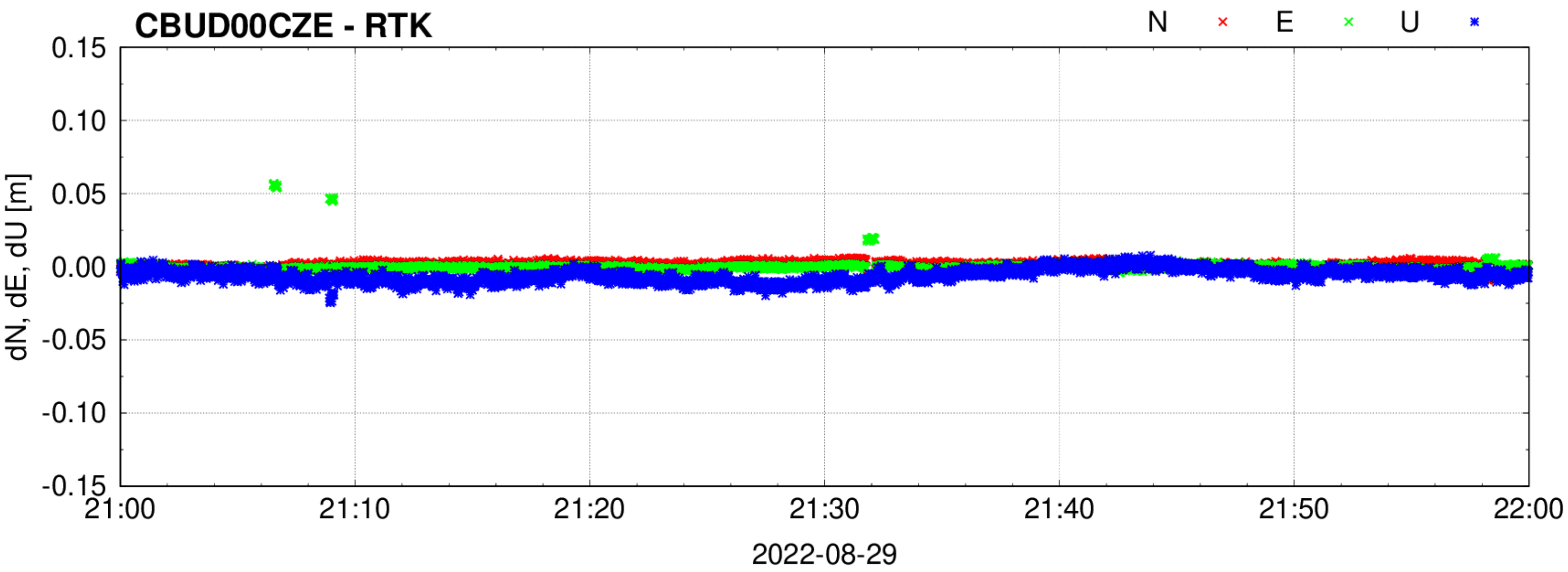


PPP-RTK

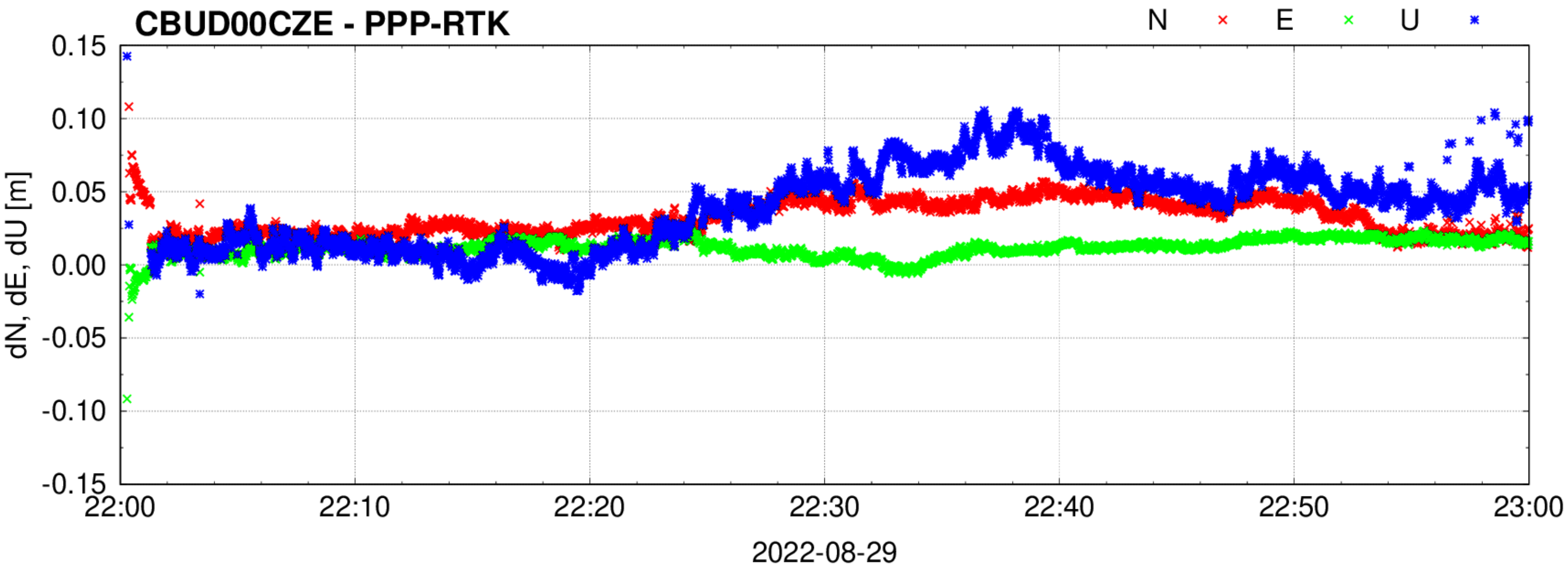


Results

RTK

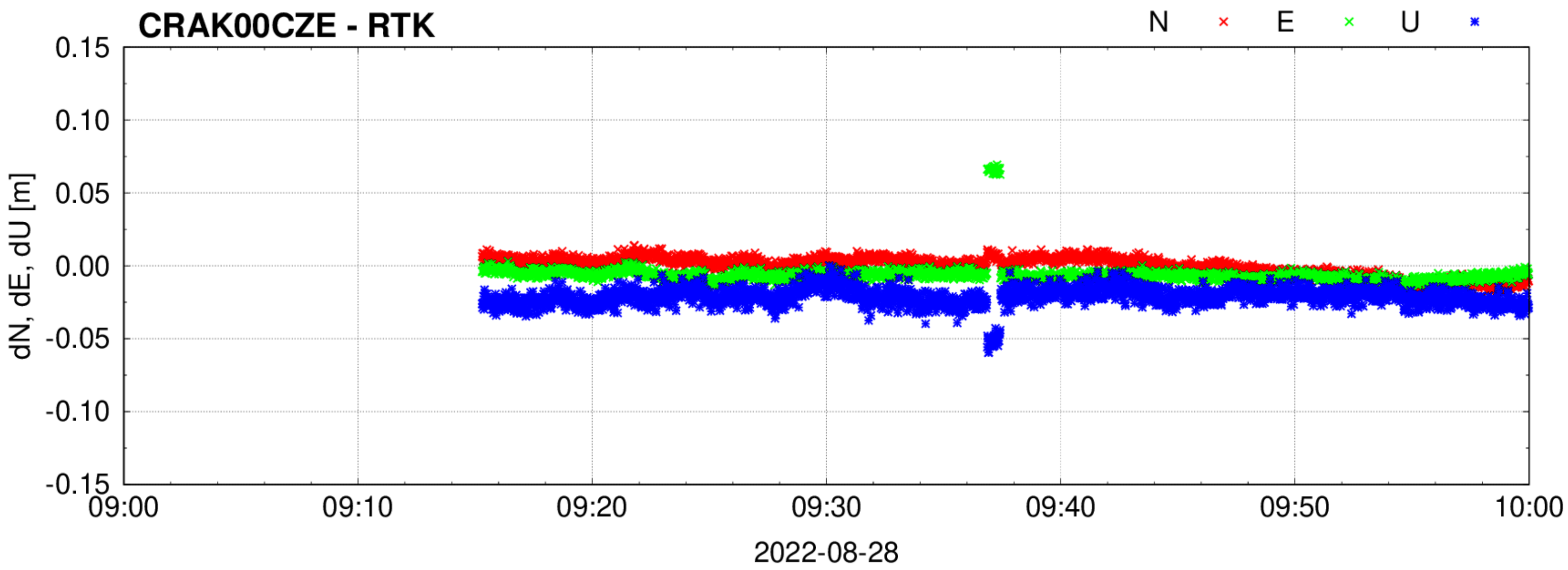


PPP-RTK

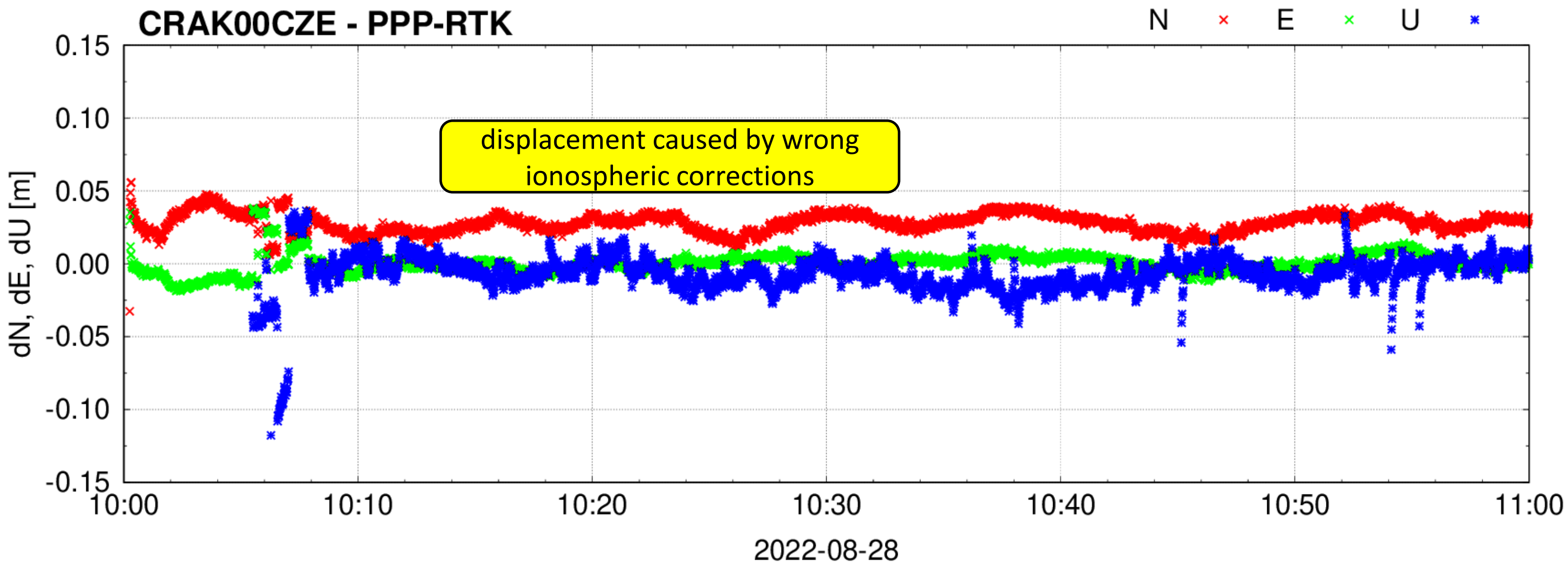


Results

RTK



PPP-RTK



Results

Station	RTK s_N	RTK s_E	RTK s_U	PPP-RTK s_N	PPP-RTK s_E	PPP-RTK s_U
CBUD	0,0021	0,0015	0,0036	0,0142	0,0094	0,0275
CMBO	**0,0882**	**0,1177**	**0,1817**	0,0081	0,0061	0,0158
CPRG	0,0026	0,0017	0,0044	0,0073	0,0055	0,0157
CRAK	0,0041	0,0028	0,0068	0,0091	0,0064	0,0191
CTAB	0,0055	0,0047	0,0109	0,0096	0,0051	0,0159
GOP6	0,0012	0,0009	0,0023	0,0196	0,0173	**0,0629**
ALL	**0,003**	**0,002**	**0,006**	**0,011**	**0,009**	**0,028**

Conclusion

- **RTK method still provides better results than PPP-RTK.**

- **PPP-RTK accuracy may be decreased due to downward corrections accuracy.**

- **Nevertheless, PPP-RTK results allow obtaining results with an accuracy of up to 10 cm and are therefore also usable for some geodetic applications.**

THANK YOU FOR ATTENTION

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