EUPOS® real time monitoring tools

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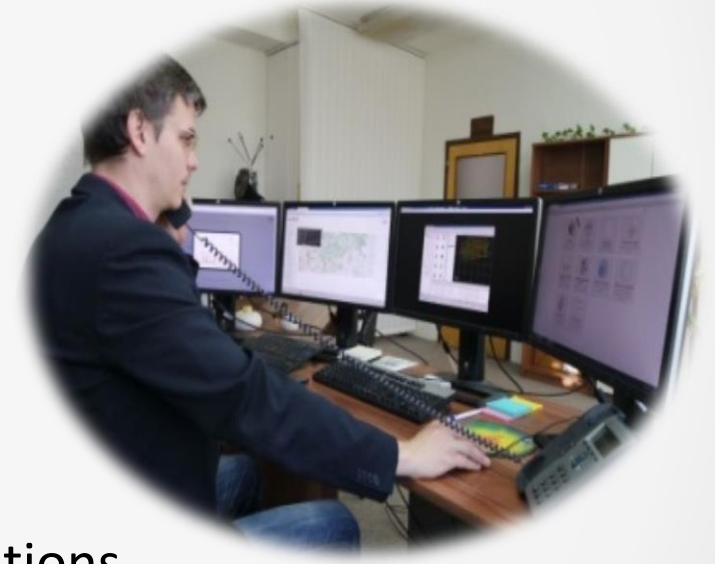
Tutorial: (Open) Real-Time Infrastructure and Applications in Europe (and beyond)
EUREF Symposium 2017, Wroclaw, Poland, May 16, 2017

What is EUPOS ?

- International non-profit initiative of public institutions providing GNSS augmentation services



- Established in 2002 in Berlin

- Goals:
  - Act as a European-wide DGNSS service providers branch organization
  - Collaborate with international organizations and bodies to represent European DGNSS service providers
  - Collaborate with scientific institutions and promote scientific use of EUPOS data

EUPOS chairmanship (in 2017)

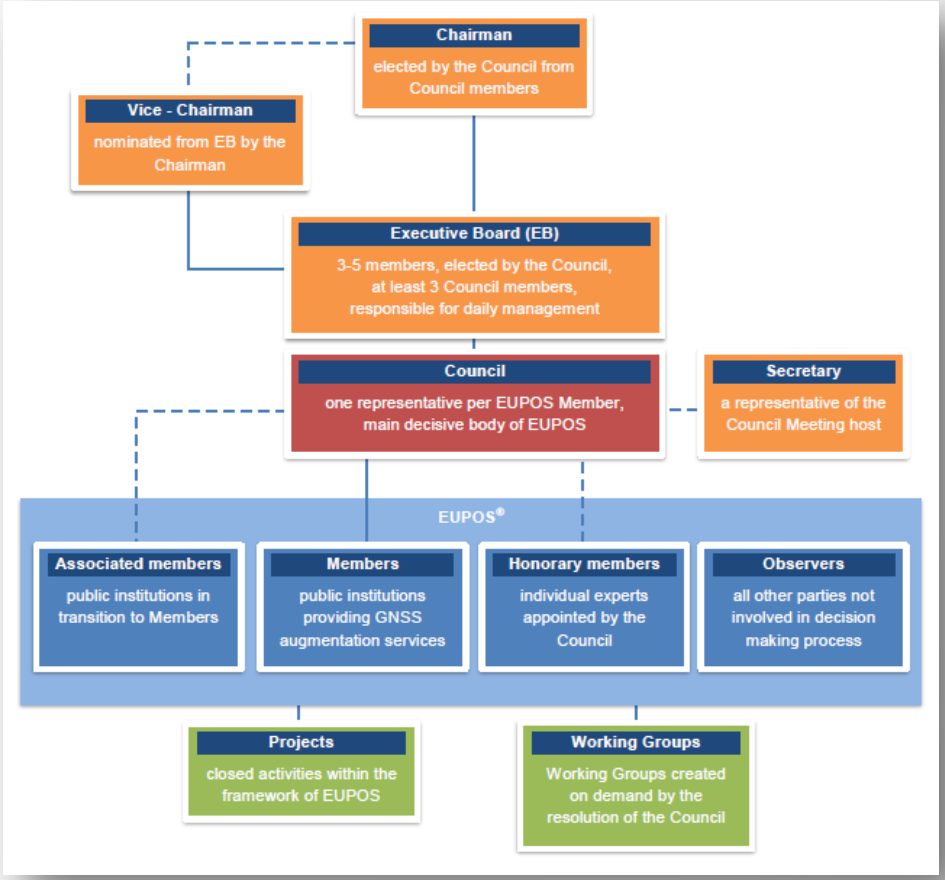
- **Chairman**:

Jaroslav Šimek (Czech rep.)

- **Vice-chairman**:

Branislav Droščák (Slovakia)

- **EUPOS Executive board**:
  - Ambrus Kenyeres (Hunagry)
  - Janis Zvirgzds (Latvia)
  - Szymon Wajda (Poland)

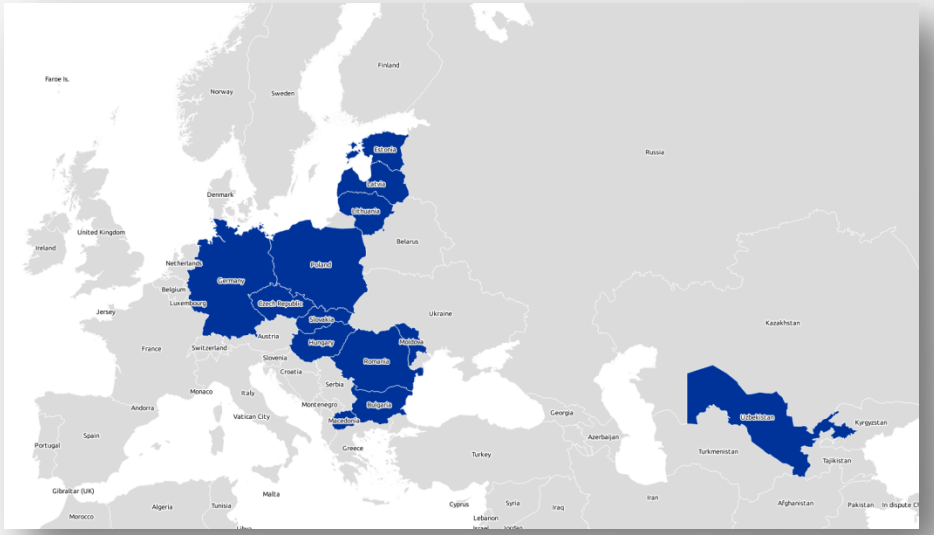


EUPOS membership (in 2017)

	Member / Abb. of the Institution	Country
1	GKÚ Bratislava	Slovakia
2	VUGTK Zdiby	Czech republic
3	ZÚ Praha	Czech republic
4	SGO Penc	Hungary
5	Land Board Tallinn	Estonia
6	GuGIK Warszawa	Poland
7	Academy of science	Bulgaria
8	NAfCaLR	Romania
9	University of Latvia	Latvia
10	Riga City Council DD	Latvia
11	LGIA	Latvia
12	AfLRaC	Moldova
13	AREaC	Macedonia
14	Senatstadt Berlin	Germany
15	Geodetic Institute	Lithuania

	Observer / Abb. of the Institution	Country
1	BKG Frankfurt u/Main	Germany

	Associated member / Abb. of the Institution	Country
1	National Uzbekistan university	Uzbekistan
2	ALBPOS	Albania



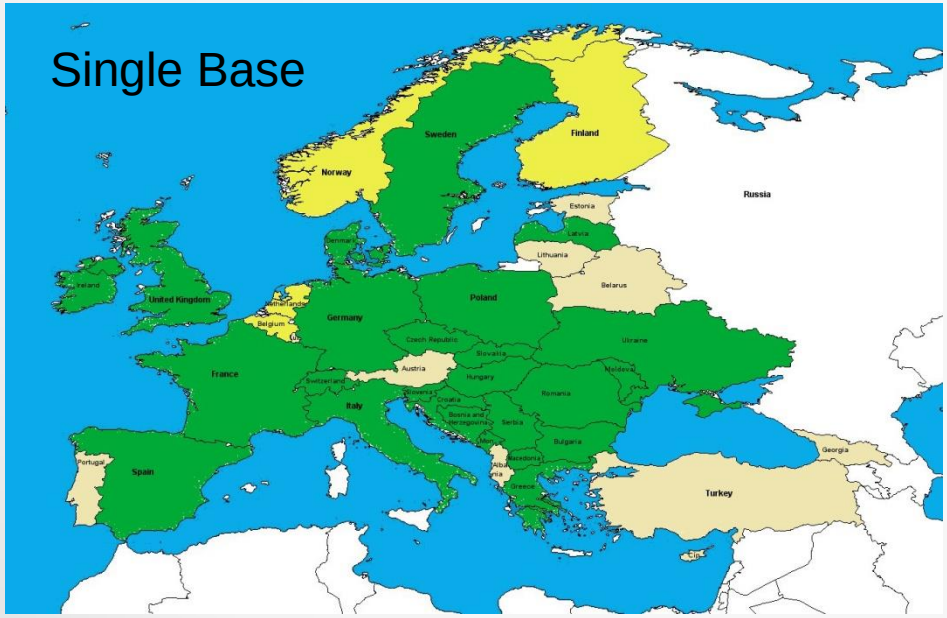
EUPOS standards and guidelines

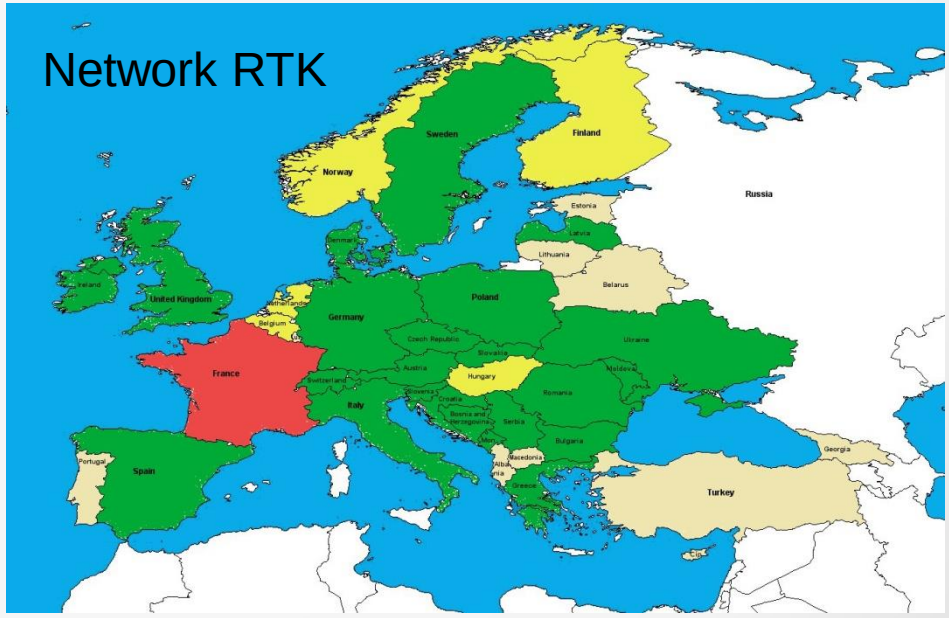
- EUPOS Terms of Reference
- EUPOS Technical Standards
- EUPOS Guideline for Single Site Design
- EUPOS Guideline for Cross-Border Data Exchange

GNSS (RTK) NETWORKS QUALITY MANAGMENT IN EUROPE

RTK networks in Europe
Some facts

- RTK networks represents the corner-stone of the geodetic controls services at almost whole European countries
- There are Network RTK corrections nearly at every country having Single Base RTK corrections
- The most common concept of Network RTK corrections is the VRS (and MAC in Leica SmartNets)

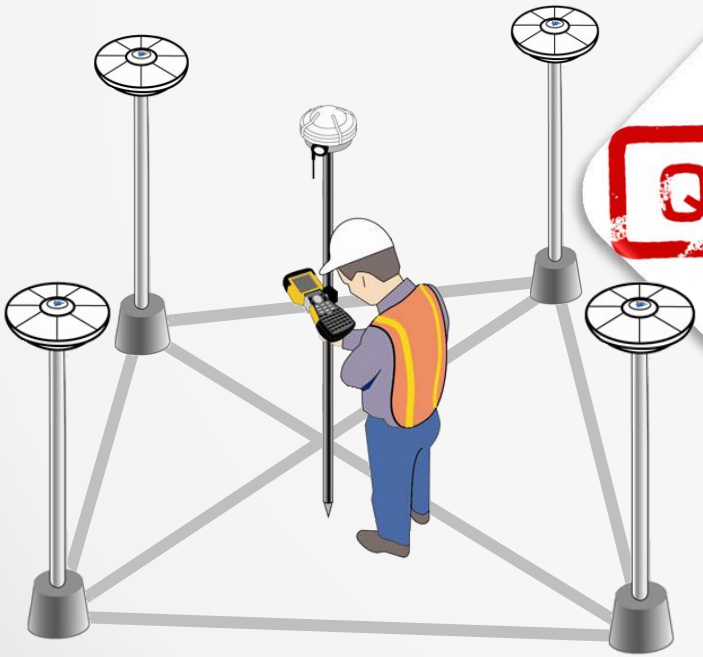


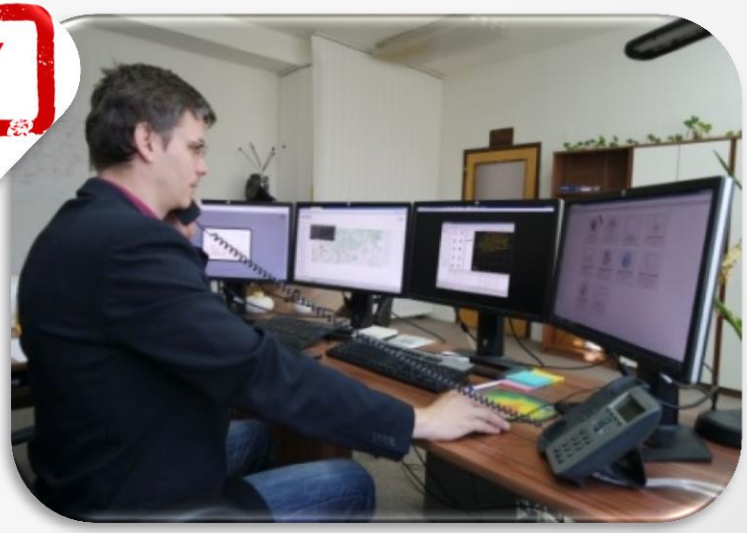


Braunmuller, P.: *GNSS in Europe*, EUPOS ISC, Berlin, 29.-30.10.2013

RTK network administrators needs

- RTK networks administrators need:
  - some tool for the Network RTK quality evaluation in the real time which can provide information about the service quality to users and to administrators as well

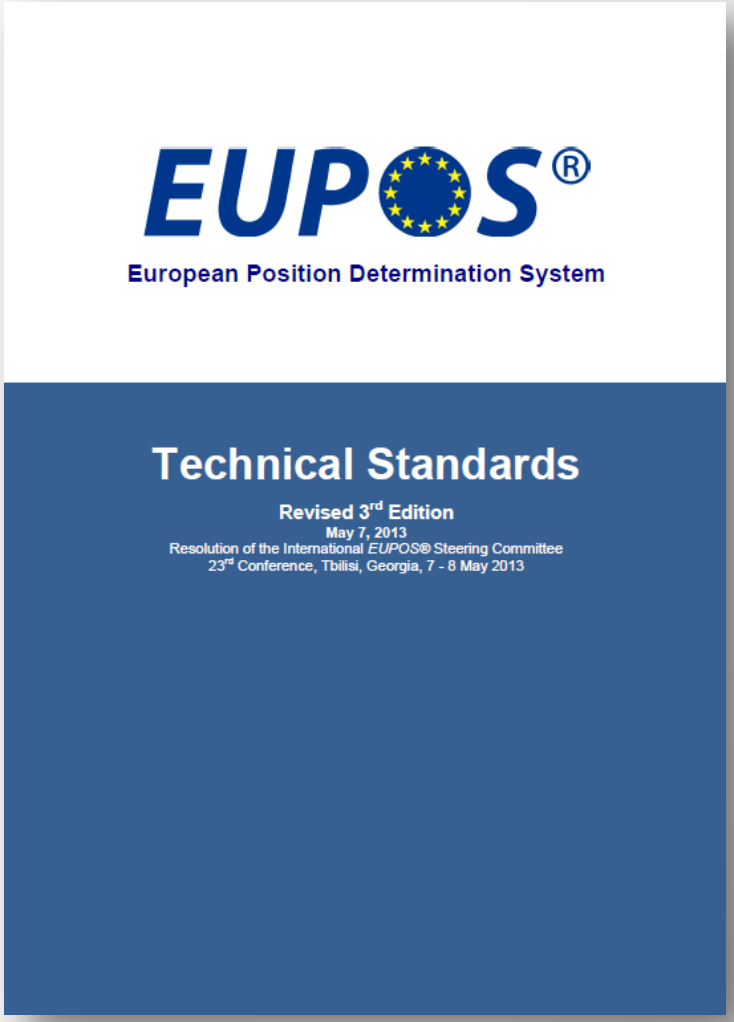




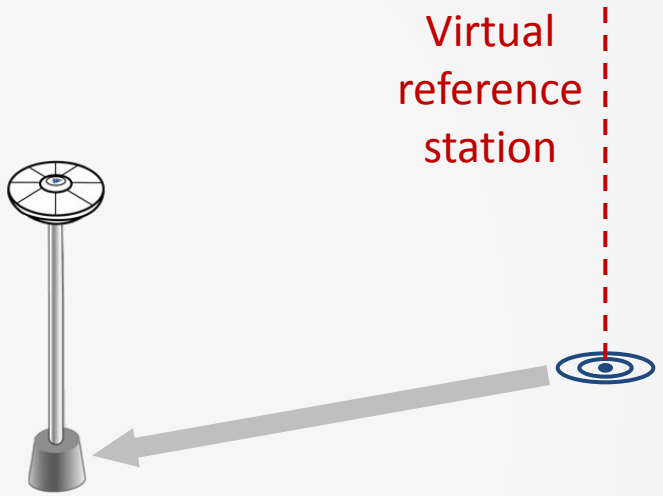
RTK quality management in EUPOS TS

- **2.3.1** For precise real-time position determination with an accuracy ≤ 2 cm (horizontal RMS) ***EUPOS*** provides network RTK correction.

- **3.4.2.3** ***EUPOS*** quality management measures continuous reception and check of provided ***EUPOS*** DGNSS and Network RTK by monitoring stations in real time and also continuously monitoring and checking of ***EUPOS*** Geodetic RINEX data;



How we can monitor Network RTK quality?



Monitoring by physical monitoring stations

- real values of deviations
- higher costs
- the inability to monitor the entire network

Monitoring by Virtual stations

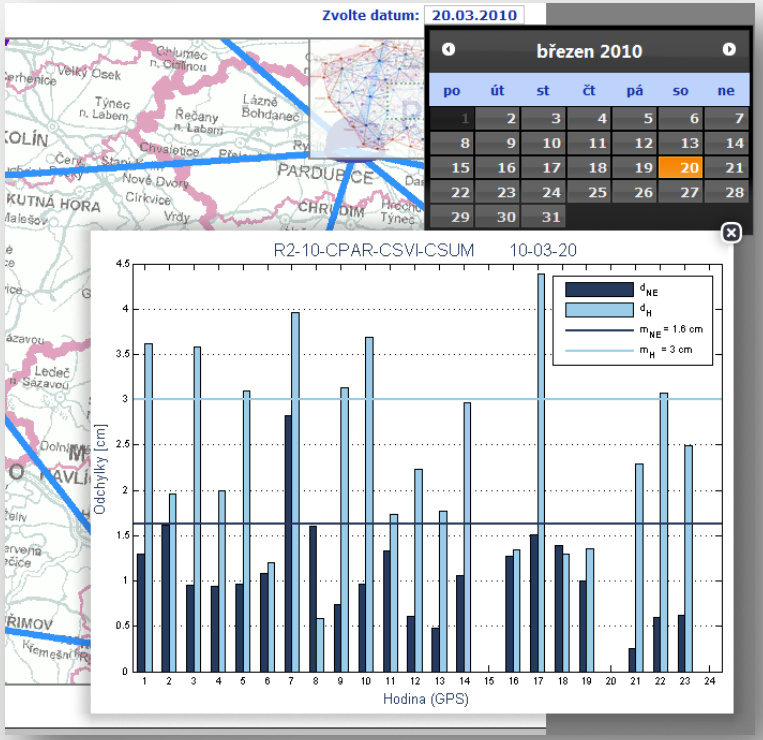
- no physical monitoring stations
- lower costs
- monitoring of the entire network
- virtual principle ≠ real deviation

Monitoring of the Network RTK quality based on the virtual monitoring stations

- First time was developed and set up for use in Czech republic and Slovakia in **2009** resp. **2013**

http://czepos.cuzk.cz/_graphSearch.aspx

http://monitoringskpos.gku.sk



EUPOS WG on Service Quality Monitoring

- established in 2014 in Riga by the resolution 25.5 of the 25th Conference of the EUPOS Steering committee

- Inspired by Czech and Slovakian solution

- Aims:
  - creation of the uniform common network RTK quality monitoring tool based on virtual monitoring stations for all EUPOS member countries
  - set it up and do analysis on outputs
  - implementation into EUPOS TS

RESOLUTION 25.5 OF THE 25TH CONFERENCE OF THE EUPOS STEERING COMMITTEE OF MAY 6-7, 2014 IN RIGA, LATVIA; AGENDA ITEM NO. 14.1: SKPOS (EUPOS) NETWORK SOLUTION MONITORING APPLICATION.

The EUPOS International Steering Committee (ISC),

noting the importance of the EUPOS service quality monitoring,

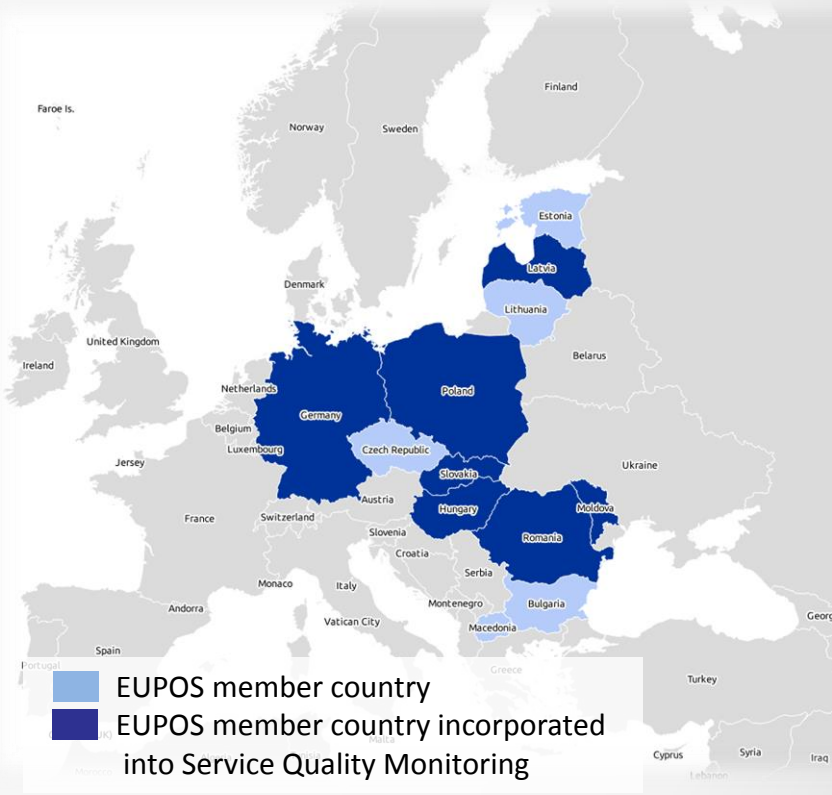
appreciating the development of an early tool for the quality monitoring of the EUPOS Network RTK service that could supplement the necessity to implement physical monitoring stations into the GNSS reference stations network,

decides to create a EUPOS Working Group on Service Quality Monitoring and

requests Dr Branislav Droscak to chair this Working Group.

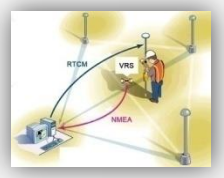
EUPOS WG on Service Quality Monitoring

- Working group members
  - Branislav Droščák (Slovakia) – chair
  - Karol Smolík (Slovakia) - SKPOS
- WG cooperators
  - Szymon Wajda (Poland) – ASG-EUPOS
  - István Galambos (Hungary) – gnssnet.hu
  - Vlad Sorta (Romania) – ROMPOS
  - Christian Trautvetter (Germany) – SAPOS
  - Ivars Degainis (Latvia) – EUPOS-RIGA
  - Pavel Ivancenco (Moldova) - MOLDPOS



EUPOS service quality monitoring tool
General information

- Concept copies the design of Slovankian SK*POS*® network RTK solution quality monitoring application
- Monitoring is independent from the GNSS service provider control software
- Fully automatic solution
- VRS principle (no physical monitor stations)



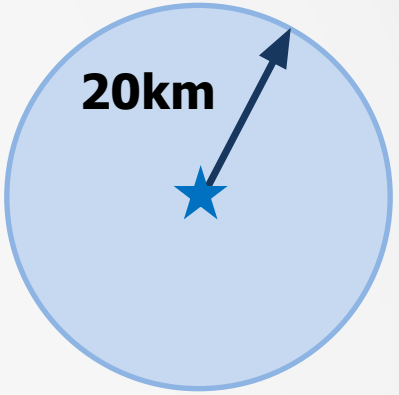
- Monitoring tool could monitor whole territory of country
- Test points are generated randomly
- Baseline processing done by open source RTKNAVI software

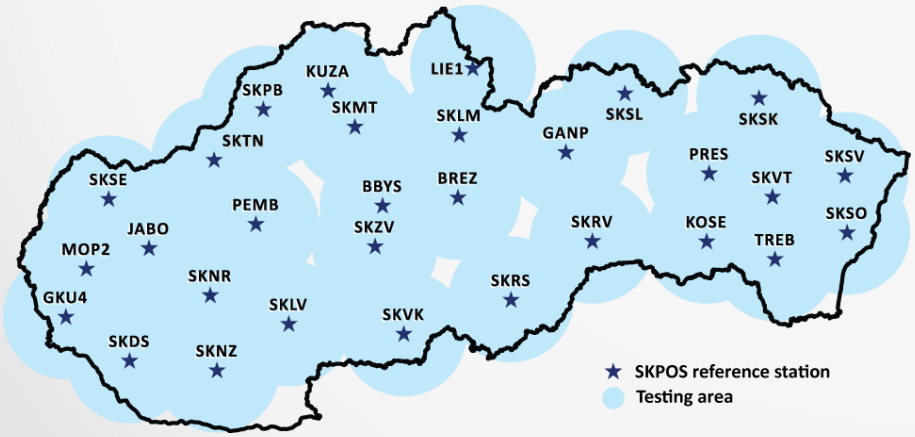
RTKNAVI
www.rtklib.com

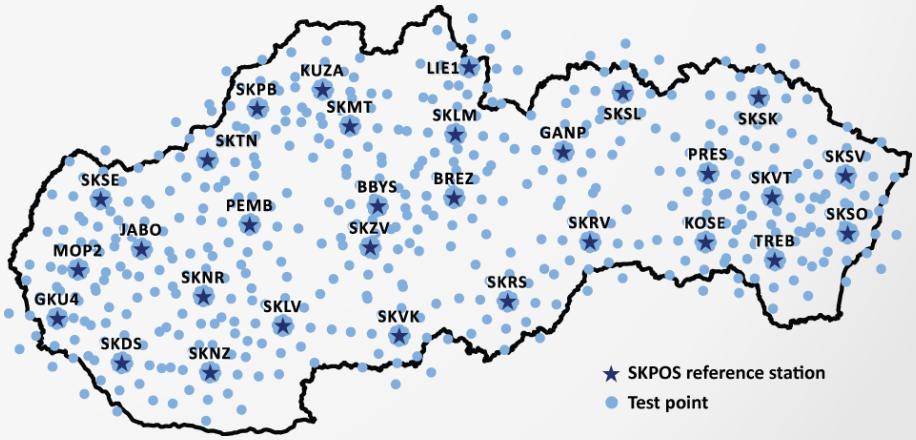
- Results are available via web/mobile application

EUPOS service quality monitoring tool
Test points distribution

- Each country is divided into circle regions with the reference stations in theirs centers
- Distances from the centers to the testing points are: **2km**, **11km**, **20km**
- Azimuths of the testing points baselines are: **0°**, **45°**, **90°**, ..., **315°** (45° span)

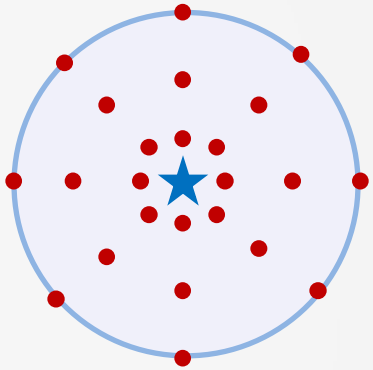






EUPOS service quality monitoring tool
Selection of test points for computation

- Combination of distance and azimuth = 24 possibilities of the test points within one circle region

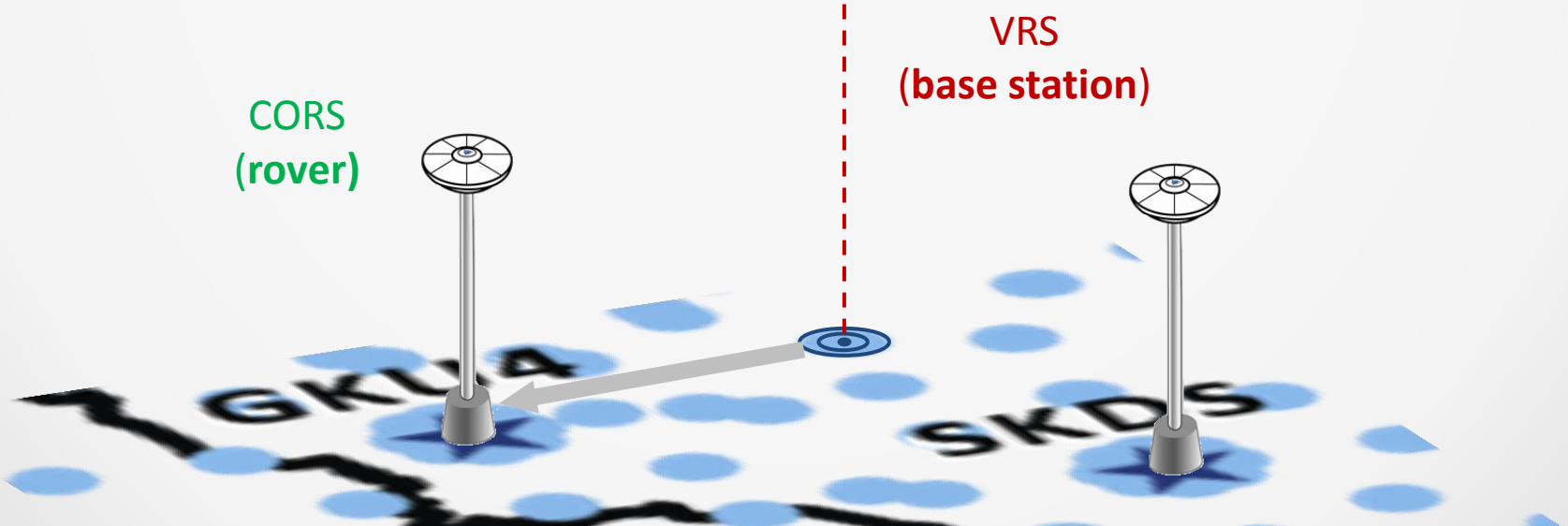


- Each locality is tested one time per hour
- Random generation of azimuth/distance combination is used
- One test takes 2 minutes

EUPOS service quality monitoring tool Principle

- RTKNAVI computes the baseline composed of VRS (simulates the physical monitoring station) and the nearest reference station, where VRS is fixed.
- Differences between computed and original reference station coordinates are visualized and they represents the network RTK quality.

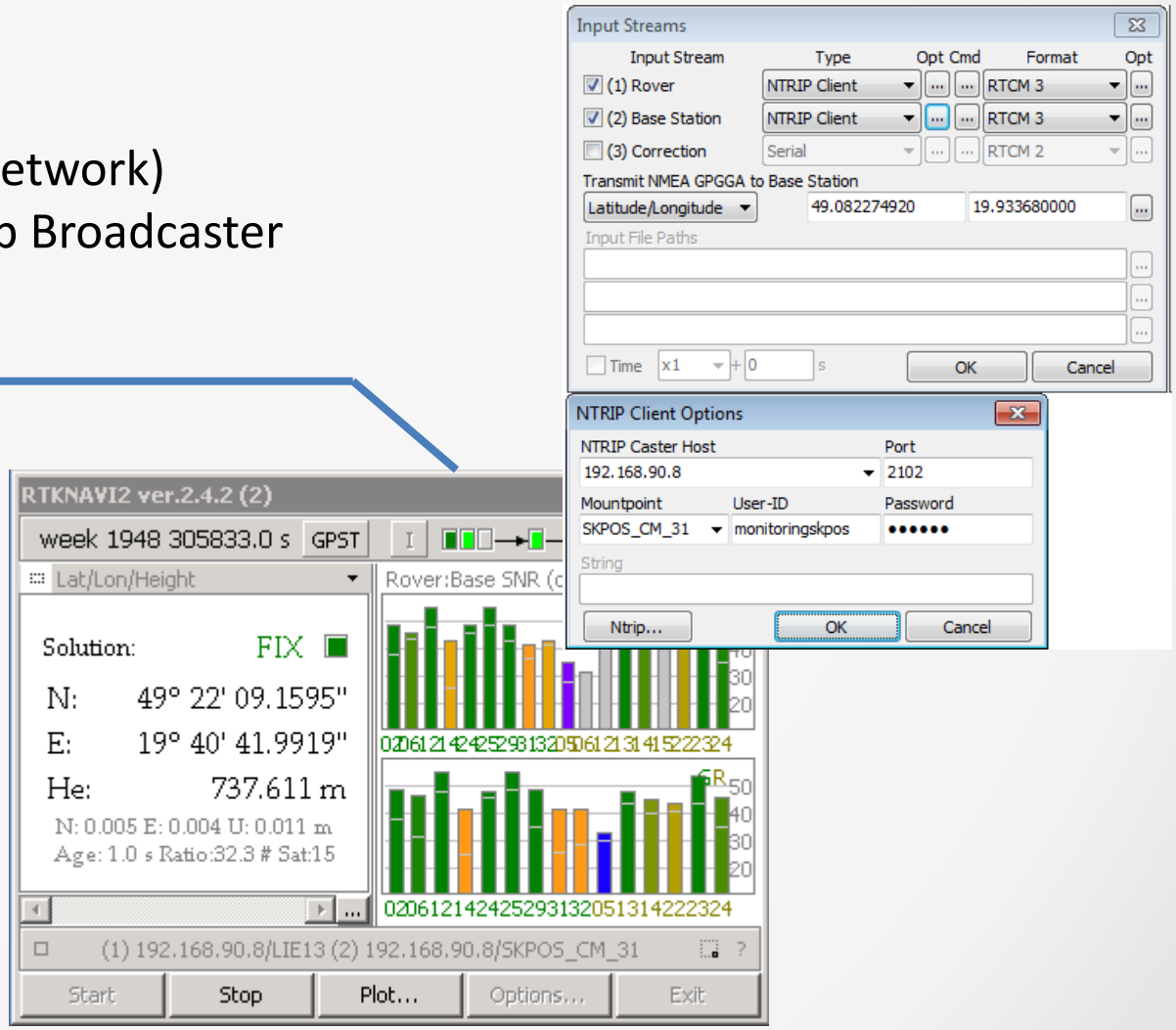
RTKNAVI
www.rtklib.com



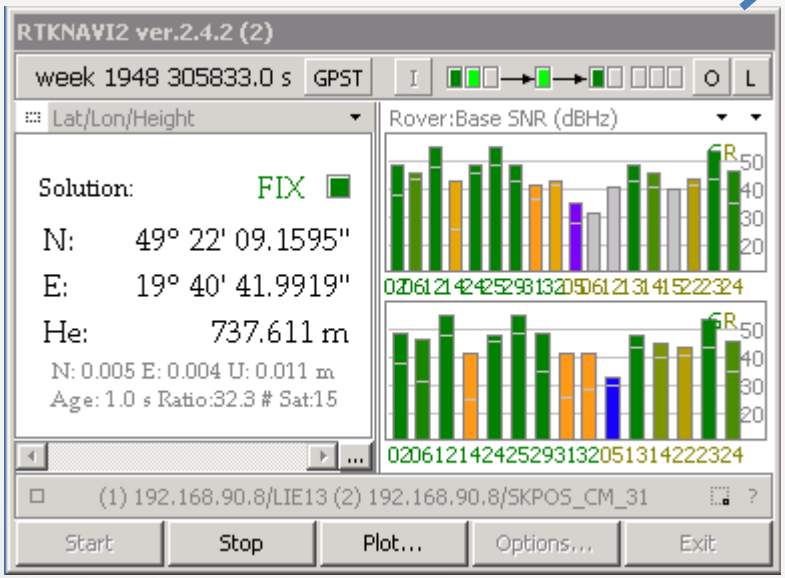
EUPOS service quality monitoring tool
RTKNAVI Input settings (real-time streams)

Rover: CORS
Base station: VRS (RTK network)
Ephemeris: IGS-IP Ntrip Broadcaster

Input: RTCM 3 streams



EUPOS service quality monitoring tool
RTKNAVI Output



Results: 1 Hz log file

Output: CSV file

CSV file contains:

- ϕ, λ, h coordinates
- Time
- Information about solution quality (FIX, Float, ...)

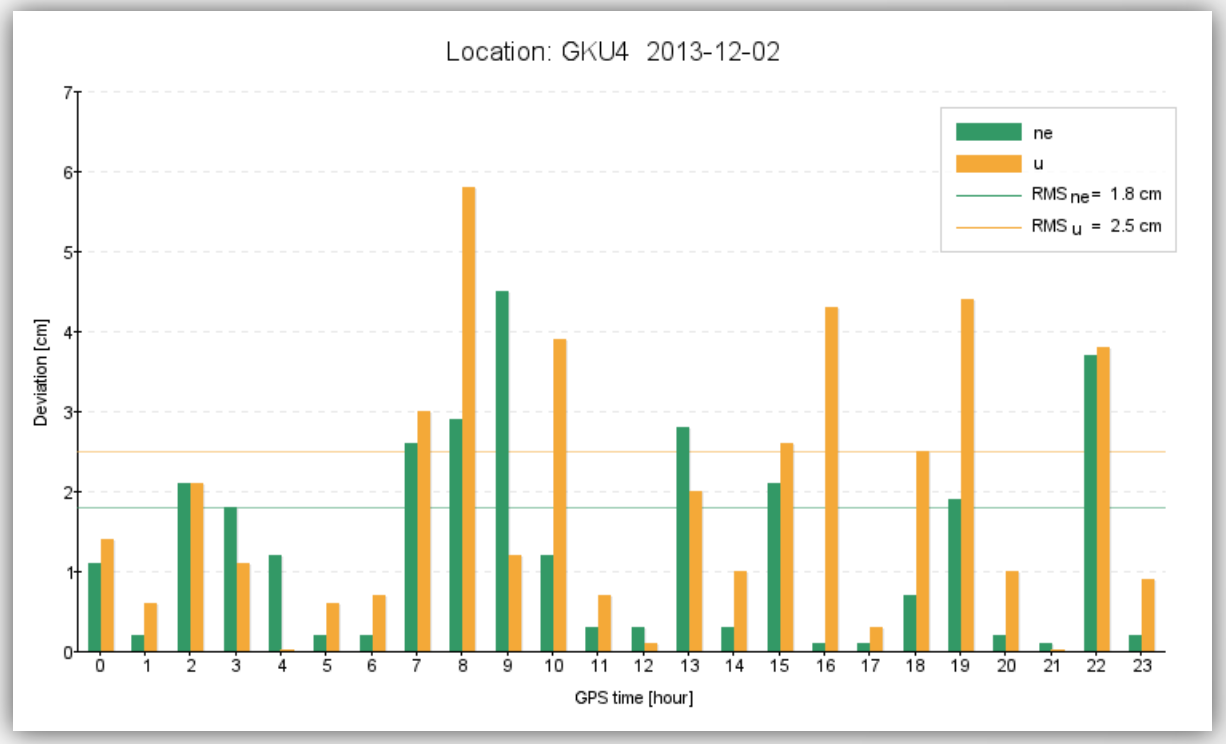
EUPOS service quality monitoring tool Outputs (deviations and RMS)

Fix √
~~**Float**~~

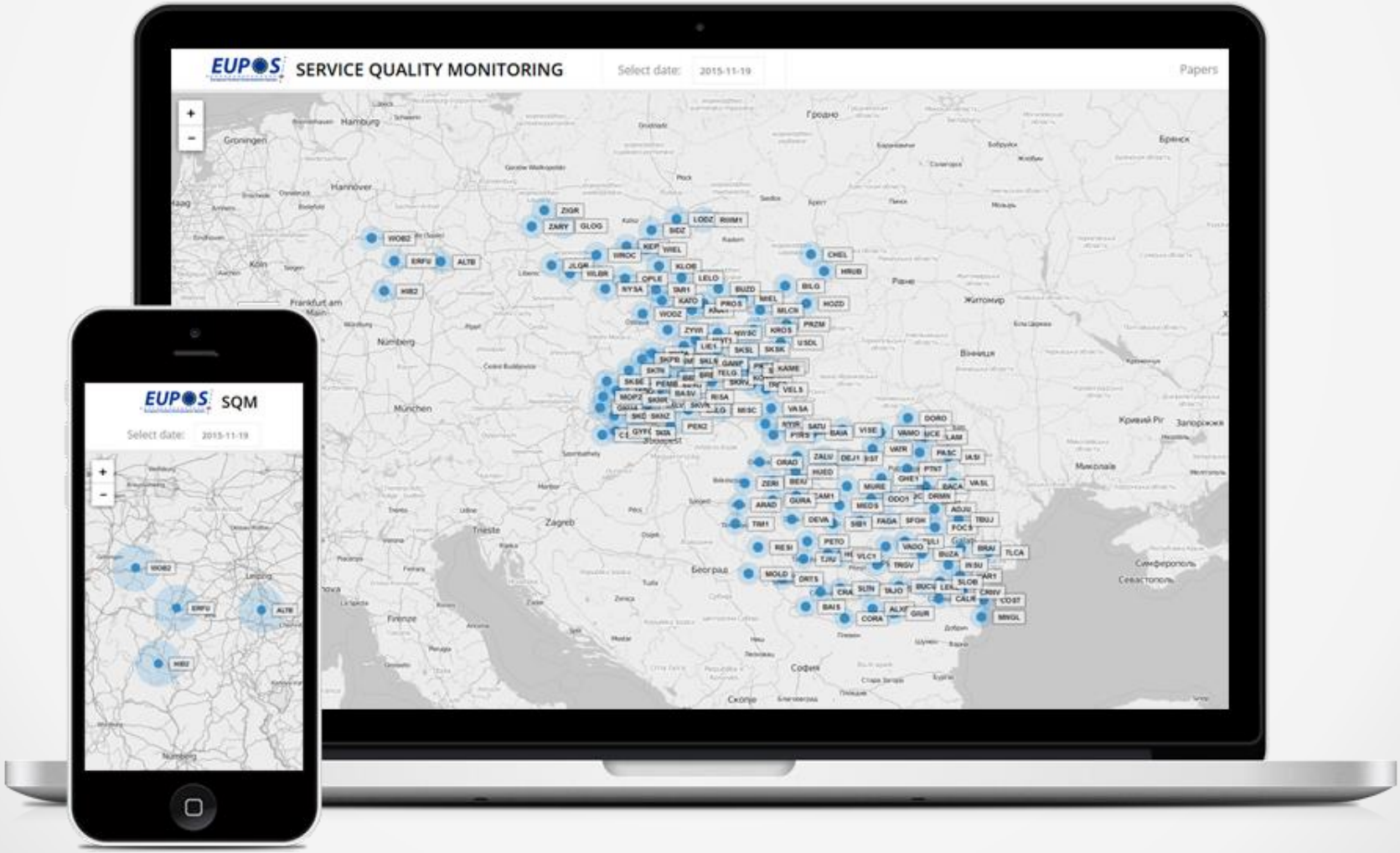
Grubbs test
(errors elimination)

ϕ, λ, h → n, e, u

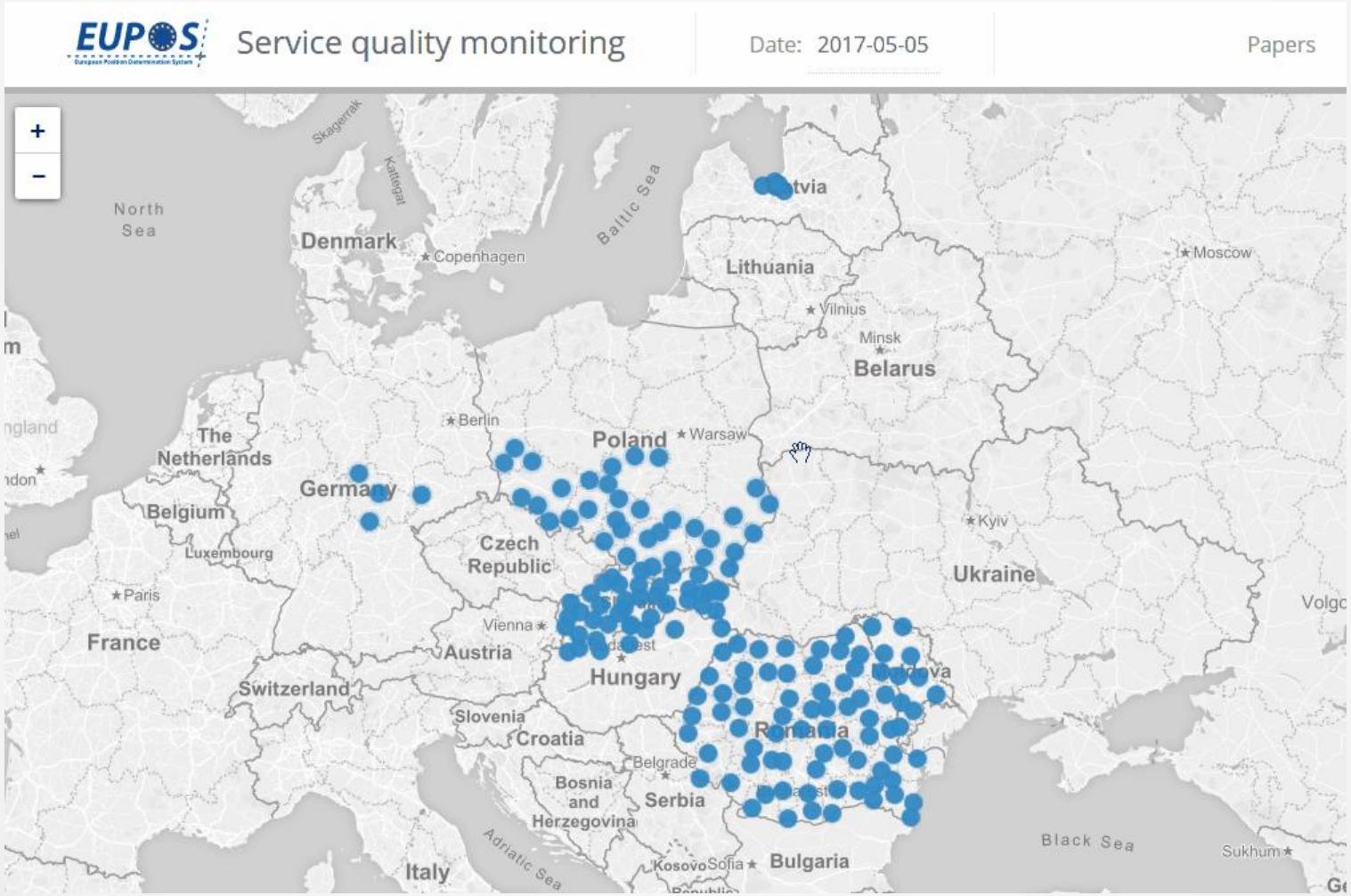
Deviations computation
north, east (Horizontal components)
up (Vertical component)



EUPOS service quality monitoring
User interface



EUPOS service quality monitoring
Video demonstration



VERIFICATION AND RELIABILITY EVALUATION OF THE EUPOS SERVICE QUALITY MONITORING TOOL

Accuracy verification and evaluation of the virtual monitoring reliability

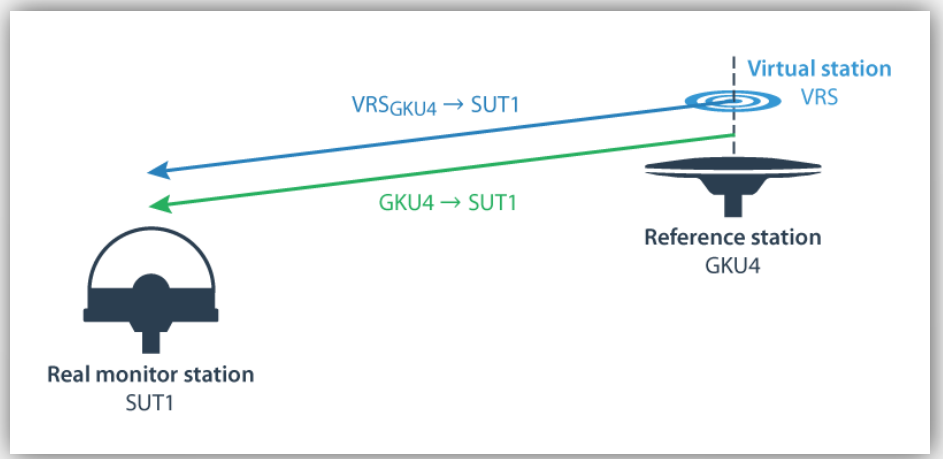
Hypothesis :

Is virtual principle = real measurement

Test:

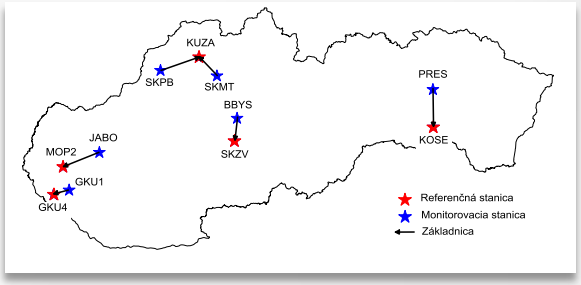
Computation two baselines in the same time:

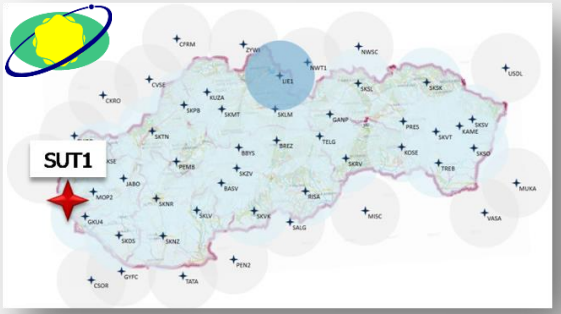
- 1. baseline composed of VRS (generated for reference station coordinates) and physical monitoring station
- 2. baseline composed of reference station and physical monitoring station

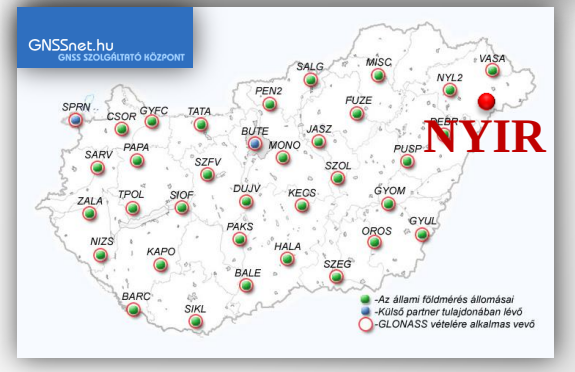


Accuracy verification and evaluation of the virtual monitoring reliability

- Test 1
  - 6 monitor station in Slovakia
  - Test took: 5 days
  - Baselines length: 20 m – 32 km
- Test 2
  - 1 monitor station in Slovakia
  - Test took: 5 months
  - Baselines length: 4 km
- Test 3
  - 1 monitor station in Hungary
  - Test took: 37 days
  - Comparison one time per hour





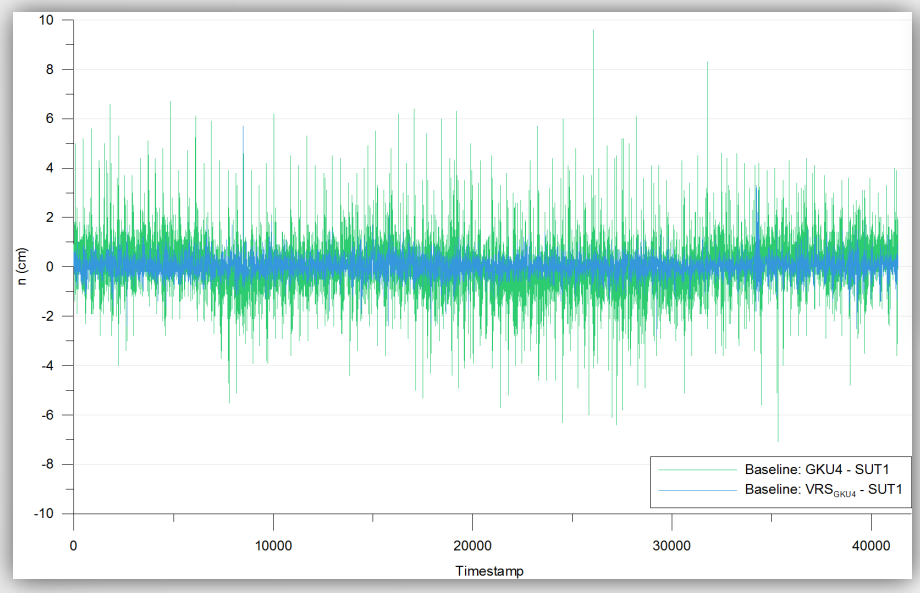


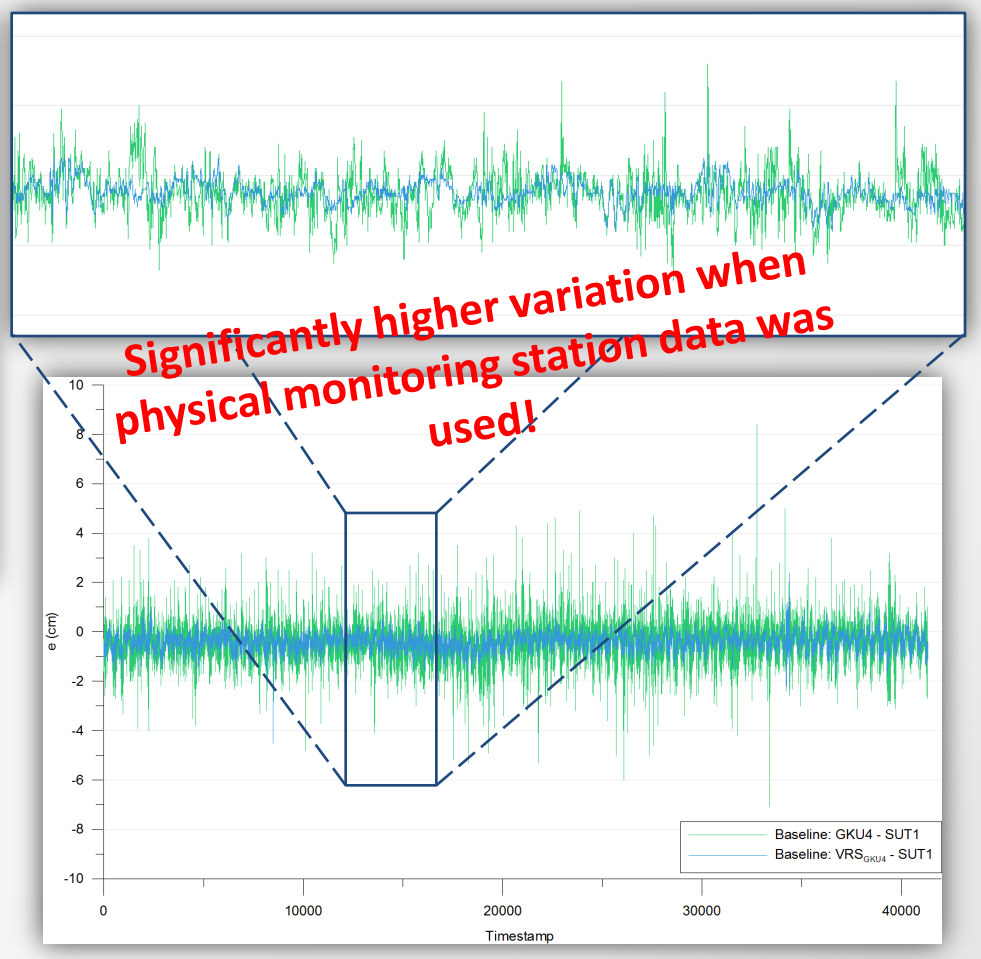
Accuracy verification and evaluation of the virtual monitoring reliability

Test	Baseline	Number of values	Deviations		
			n	e	u
Test 1	GKU1 – GKU4 JABO – MOP2 BBYS – SKZV SKPB – KUZA PRES – KOSE SKMT – KUZA	777	**0.4 cm**	**0.3 cm**	**0.5 cm**
Test 2	GKU4 – SUT1	41 334	**0.6 cm**	**0.4 cm**	**1.0 cm**
Test 3	VRS – NYIR	720	**0.6 cm**	**0.6 cm**	**1.8 cm**

Virtual solution vs. physical monitoring station
Test results

- Graphics of Horizontal components (n, e) differences



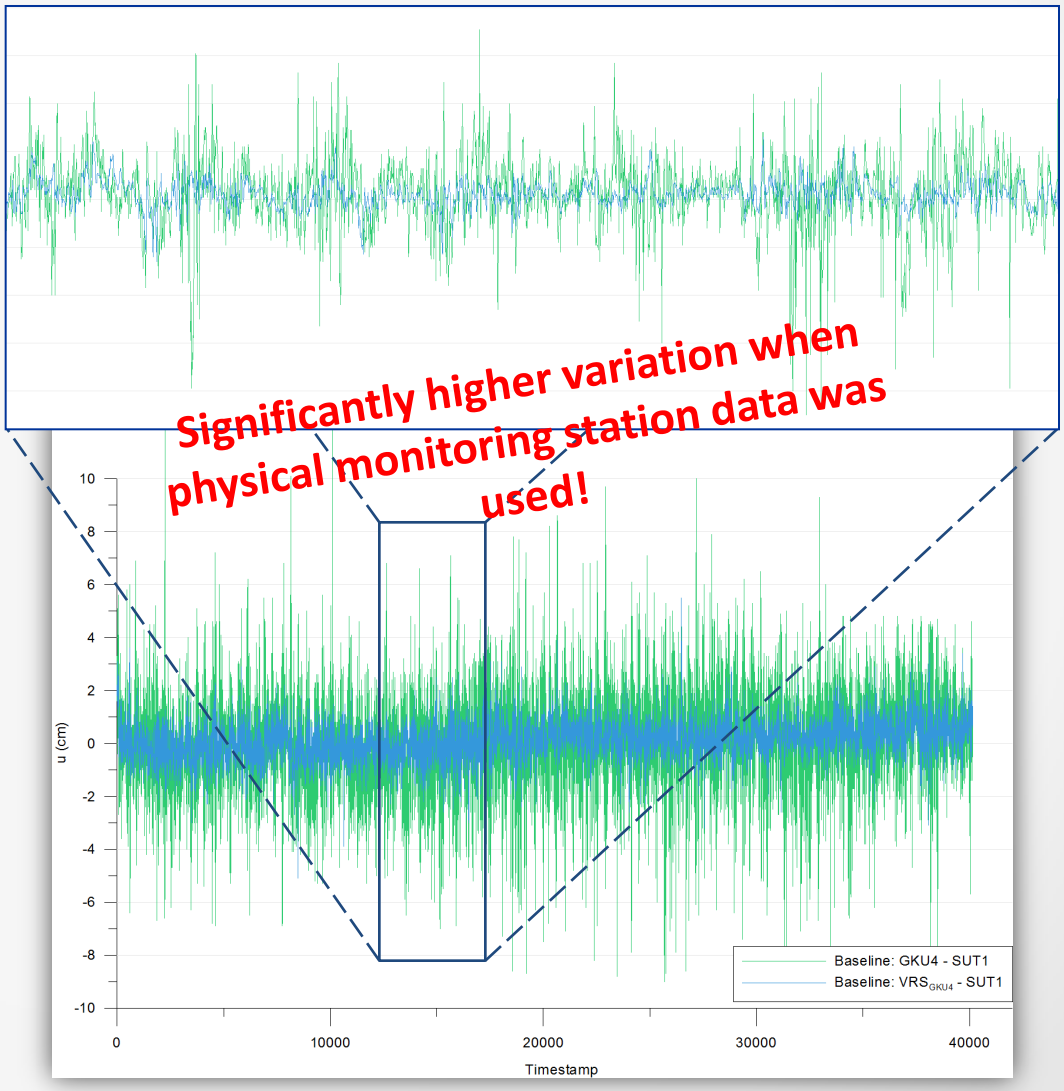


Physical monitoring station

Virtual monitoring station

Virtual solution vs. physical monitoring station
Test results

- Graphics of Vertical component (u) differences



Physical monitoring station

Virtual monitoring station

Virtual solution vs. physical monitoring station
Test results

- Comparison of mean values and dispersions

	σ^2_n	σ^2_e	σ^2_u	E(n)	E(e)	E(u)
Baseline with physical monitoring station	0.78 cm	0.45 cm	2.87 cm	0.03 cm	-0.43 cm	0.00 cm
Baseline with virtual monitoring station	0.11 cm	0.11 cm	1.10 cm	0.02 cm	-0.41 cm	0.03 cm

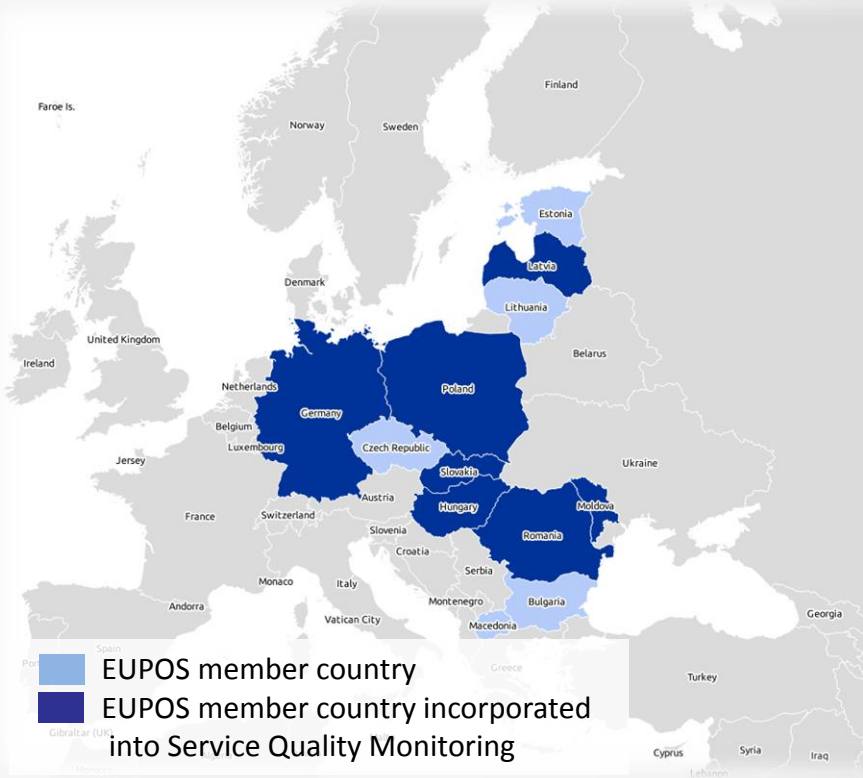
Significant differences in dispersions! Is it correct? Yes!

Very good consistency of mean values !

EUPOS SERVICE QUALITY MONITORING RESULTS AND EXPERIENCE

EUPOS service quality monitoring Status (May 2017)

SKPOS	34 stations
ASG eupos	32 stations
GNSSnet.hu GNSS SZOLGÁLTATÓ KÖZPONT	7 stations
ROMPOS Romanian Position Determination System	68 stations
SAPOS	4 stations
RIGA EUPOS	5 stations
MOLDPOS	10 stations
	160 stations



GNSS receiver manufacturers

- Trimble
- Leica
- Topcon
- Javad
- Astech

Network softwares:

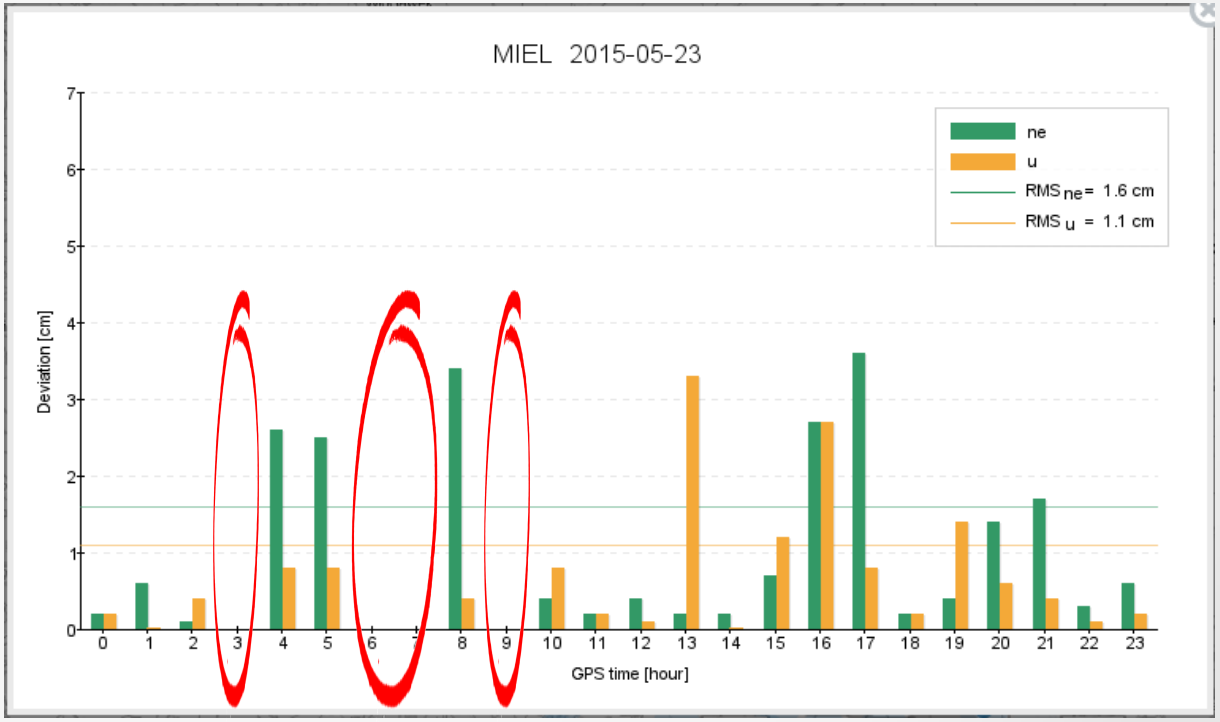
- Trimble Pivot Platform
- Geo++ GNSMART
- Leica Spider

EUPOS networks deviations comparison Statistics

RTK network		SKPOS	ASG eupos	GNSSnet.hu GNSS SZOLGÁLTATÓ KÖZPONT	ROMPOS	SAPOS	RIGA EUPOS	MOLDPOS	EUPOS
Software		Trimble Pivot Platform	Trimble Pivot Platform	Geo++ GNSMART	Leica Spider	Trimble Pivot Platform	Geo++ GNSMART	Leica Spider	Σ
Time period		1 399 days	1 009 days	913 days	877 days	667 days	559 days	137 days	
Number of monitored stations		34	34	7	68	4	5	10	**160**
Number of values		1 038 838	552 128	149 336	1 211 405	50 490	64 854	30 508	**3 097 559**
Maximal	ne	49.9 cm	44.6 cm	48.6 cm	49.7 cm	49.9 cm	35.3 cm	12.8 cm	
	u	49.8 cm	49.2 cm	49.9 cm	49.9 cm	37.5 cm	49.3 cm	19.1 cm	
Average	ne	1.1 cm	0.9 cm	1.2 cm	1.2 cm	0.9 cm	1.0 cm	1.0 cm	**1.0 cm**
	u	2.4 cm	1.2 cm	1.3 cm	2.6 cm	1.4 cm	1.8 cm	1.3 cm	**1.7 cm**
No fix		14%	7%	15%	18%	9%	25%	28%	**17%**

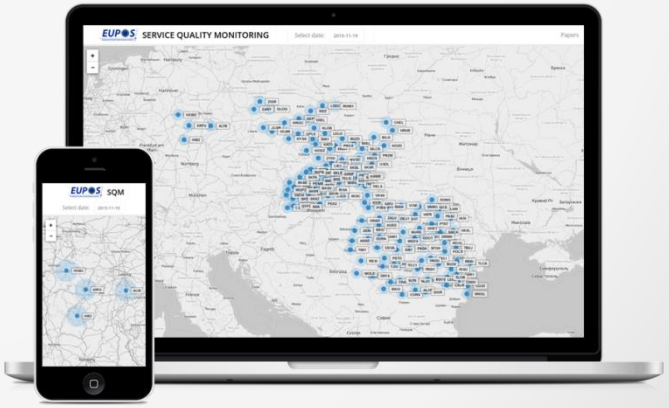
EUPOS networks deviations comparison „No fix“ value

- What does „No fix“ value mean?
- „No fix“ = no value in graphics = no ambiguity resolution
- Possible reasons:
  - processing failure
  - high ionosphere
  - service out of order
  - not know
  - etc.



EUPOS service quality monitoring tool is more then quality monitoring tool

- Archived results can serve for different analysis and can reveal a lot of interesting information
- What about to do analyzes of deviations according to different parameters like:
  - RTK network control software
  - reference stations density
  - dependency on ionosphere (day/night deviation comparison)
  - brand type of receiver
  - geographical position



Analyzes of deviations according to RTK network control software

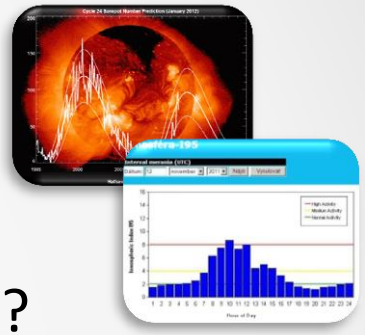
RTK network		SKPOS, ASG eupos, SAPOS	GNSSnet.hu, RIGA EUPOS	ROMPOS, MOLDPOS
Software		**Trimble Pivot Platform**	**Geo++ GNSMART**	**Leica Spider**
Number of monitored stations		70	12	78
Number of values		1 641 456	214 190	1 241 913
Maximal	ne	49.9 cm	48.6 cm	49.7 cm
	u	49.8 cm	49.9 cm	49.9 cm
Average	ne	**1.0 cm**	**1.1 cm**	**1.0 cm**
	u	**1.7 cm**	**1.6 cm**	**2.0 cm**
No fix		**10%**	**21%**	**23%**

Analyzes of deviations according to reference stations density

- Test assumption: Reference station density have positive affect to results!
- Density means: one station per xy km^2
- Density values were computed as fraction: country area/number of CORS

RTK network		RIGA EUPOS	SKPOS, SAPOS	ASG eupos, GNSSnet.hu, ROMPOS, MOLDPOS
Density		**< 1000 km^2**	**1000 km^2 – 2000 km^2**	**> 2000 km^2**
Number of monitored stations		5	38	114
Average	ne	1.0 cm	1.0 cm	1.1 cm
	u	1.8 cm	1.9 cm	1.6 cm
No fix		25%	12%	17%

Analyzes of „No fix“ values according to dependency on high ionosphere = Day/night values comparison



- Test assumption: Ionosphere is during night lower!
- Q: Are „no fix“ values from monitoring lower at nights?

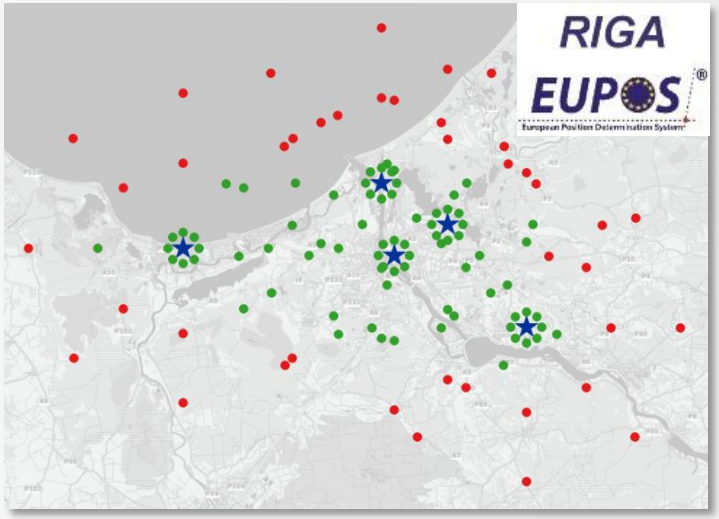
		SKPOS	ASG eupos	GNSSnet.hu	ROMPOS	SAPOS	RIGA EUPOS	MOLDPOS	EUPOS
Number of values		1 038 838	552 128	149 336	1 211 405	50 490	64 854	30 508	3 097 559
Average value „day“	ne	1.3	1.2	1.6	1.6	1.1	1.3	1.4	1.4
	u	2.4	1.3	1.3	1.4	1.4	1.9	1.6	1.6
Average value „night“	ne	0.9	0.7	1.2	1.0	0.7	0.8	0.9	0.9
	u	2.4	1.2	1.3	1.3	1.2	1.8	1.5	1.5
No fix „day“		17%	8%	19%	20%	12%	30%	30%	19%
No fix „night“		11%	6%	11%	16%	6%	20%	25%	14%

Analyzes of „No fix“ values according to dependency on high ionosphere
Control software day/night comparison

RTK network		SKPOS, ASG eupos, SAPOS	GNSSnet.hu, RIGA EUPOS	ROMPOS, MOLDPOS
Software		Trimble Pivot Platform	Geo++ GNSMART	Leica Spider
Number of values		1 082 406	116 117	92 238
Average value „day“	ne	1.2	1.5	1.6
	u	1.7	1.7	1.3
Average value „night“	ne	0.8	0.9	1.2
	u	1.6	1.6	1.3
No fix „day“		15%	26%	20%
No fix „night“		8%	16%	16%

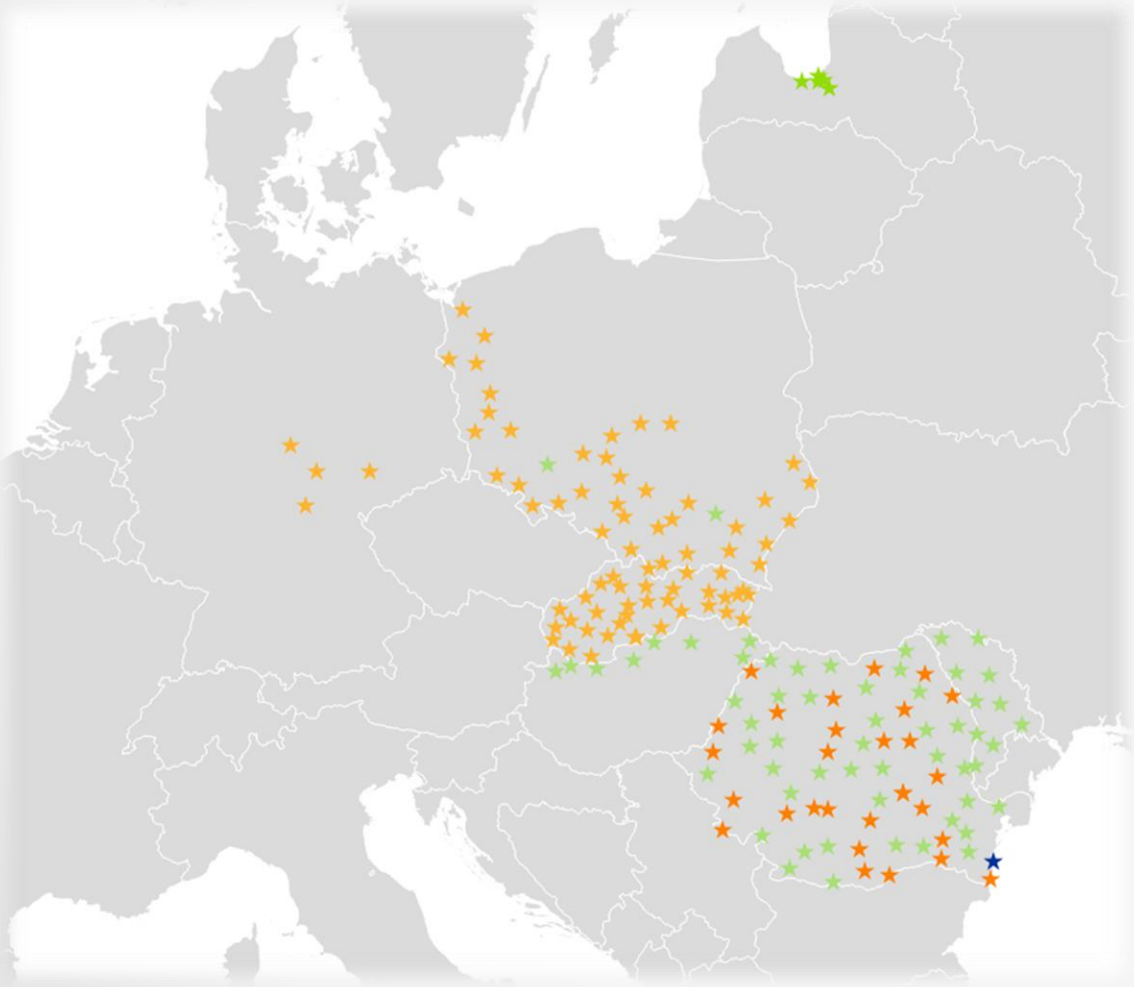
Analyzes of deviations according to testing points extra/intra-polation

- RIGA-EUPOS = regional city network
- Only 5 reference stations
- Many testing points are extrapolated



Test points		Inside the network	Outside the network
Average	ne	1.0 cm	1.1 cm
	u	1.8 cm	1.9 cm
No fix		25%	25%

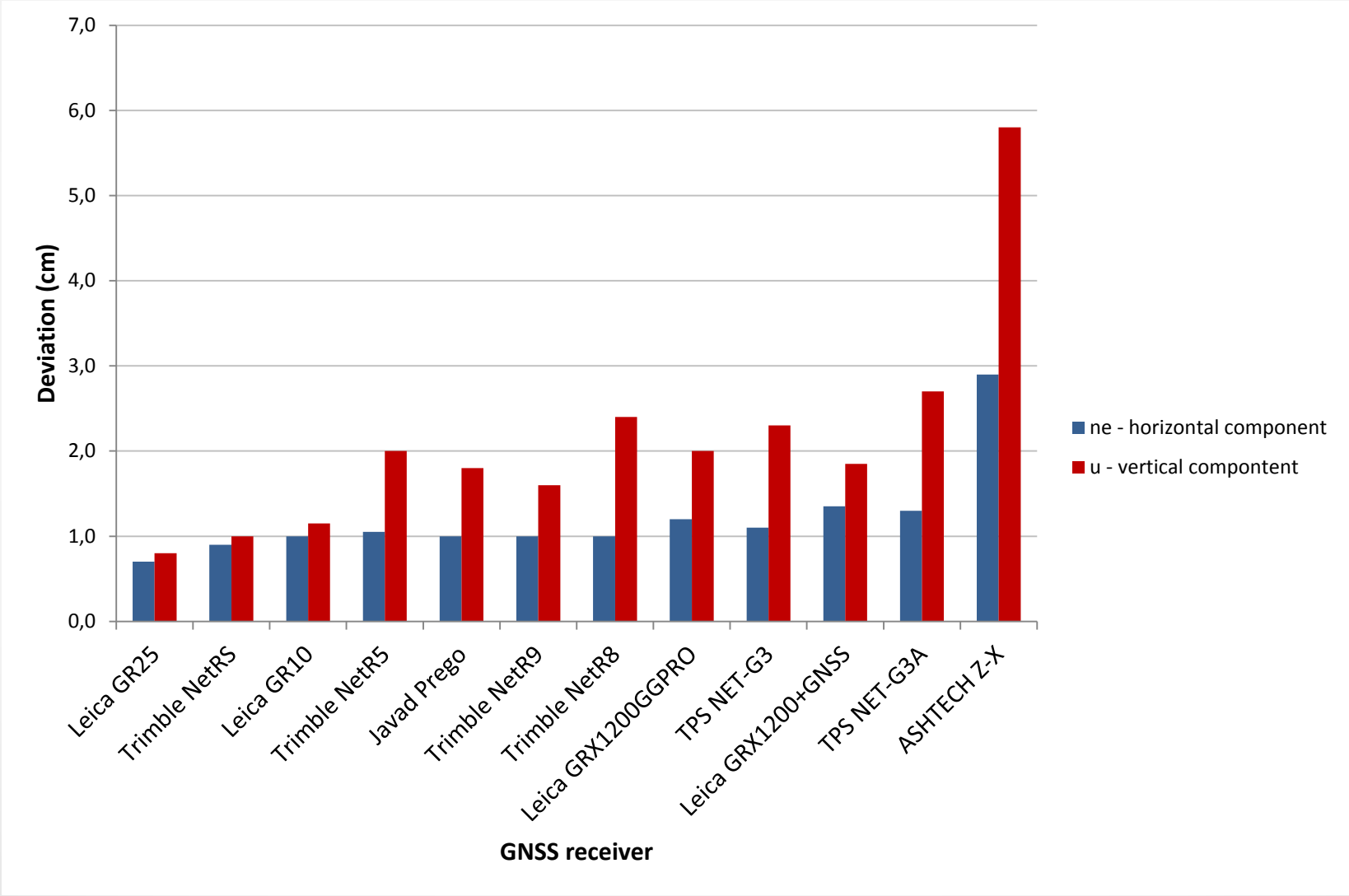
Analyzes of deviations according to brand of the receiver



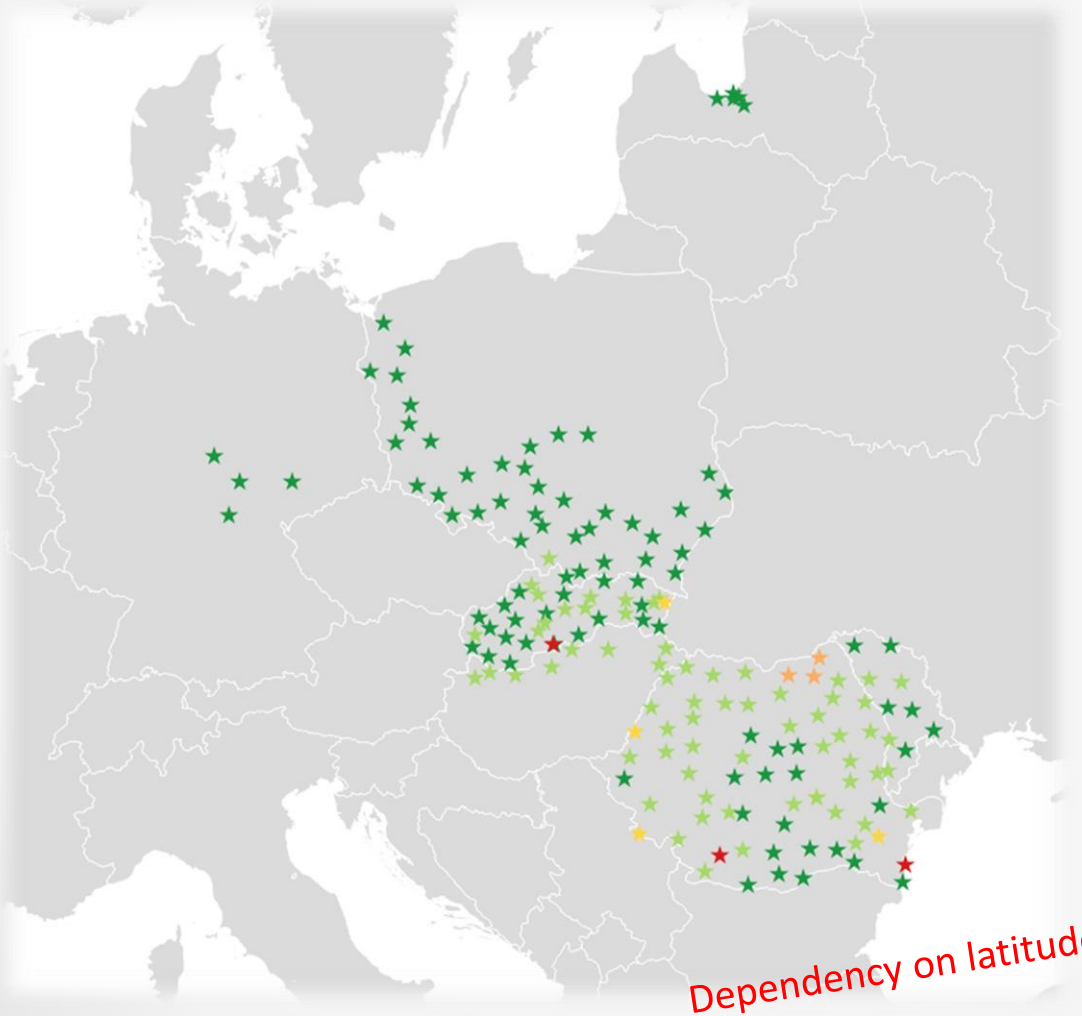
GNSS receiver manufacturers:

- Trimble
- Leica
- Topcon
- Ashtech
- Javad

Analyzes of deviations according to brand of the receiver



Analyzes of horizontal deviations according to geographical position



Horizontal deviation (cm)

- 0,0 – 1,0
- 1,0 – 1,5
- 1,5 – 2,0
- 2,0 – 2,5
- 2,5 – 7,0

Dependency on latitude or?

Summary and conclusions

- ***EUPOS*** network RTK quality monitoring tool works right
- tool is available for public on http://monitoringEUPOS.gku.sk
- results from the monitoring confirm „cm“ quality of EUPOS countries network RTK
- performed analysis confirm:
  - „no fix“ values dependency on high ionosphere
- performed analysis do not confirm deviations dependency on:
  - network RTK control software
  - reference stations network density
  - brand of the receiver
  - geographical position
- we plan to continue our activity and do more analysis in future

Would like to join us?

- Contact us on mails:
  - branislav.droscak@skgeodesy.sk
  - karol.smolik@skgeodesy.sk

- What we need from candidates:
  - login and password which allows us to get
    - access to the network RTK solution (VRS concept)
    - access to all permanent stations via NTRIP Caster
  - corrections provided in RTCM 3.x format
  - CORS coordinates

Thank you for your attention

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