

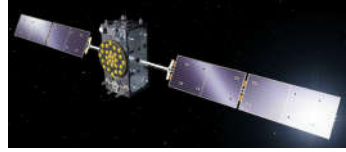


Danijel Šugar, Luka Blagus, Željko Bačić

Assessment of CROPOS GNSS stations stability after the Petrinja 2020-2021 earthquake series

GNSS SEMINÁŘ 2023

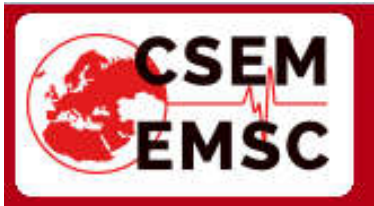
Brno, 2nd February 2023



Outline:

- Petrinja earthquake series
- CROPOS
- PPP method and PPP-PP services
- Processing results
- Permanent displacement estimation
- Conclusions

Petrinja earthquake series 2020-2021



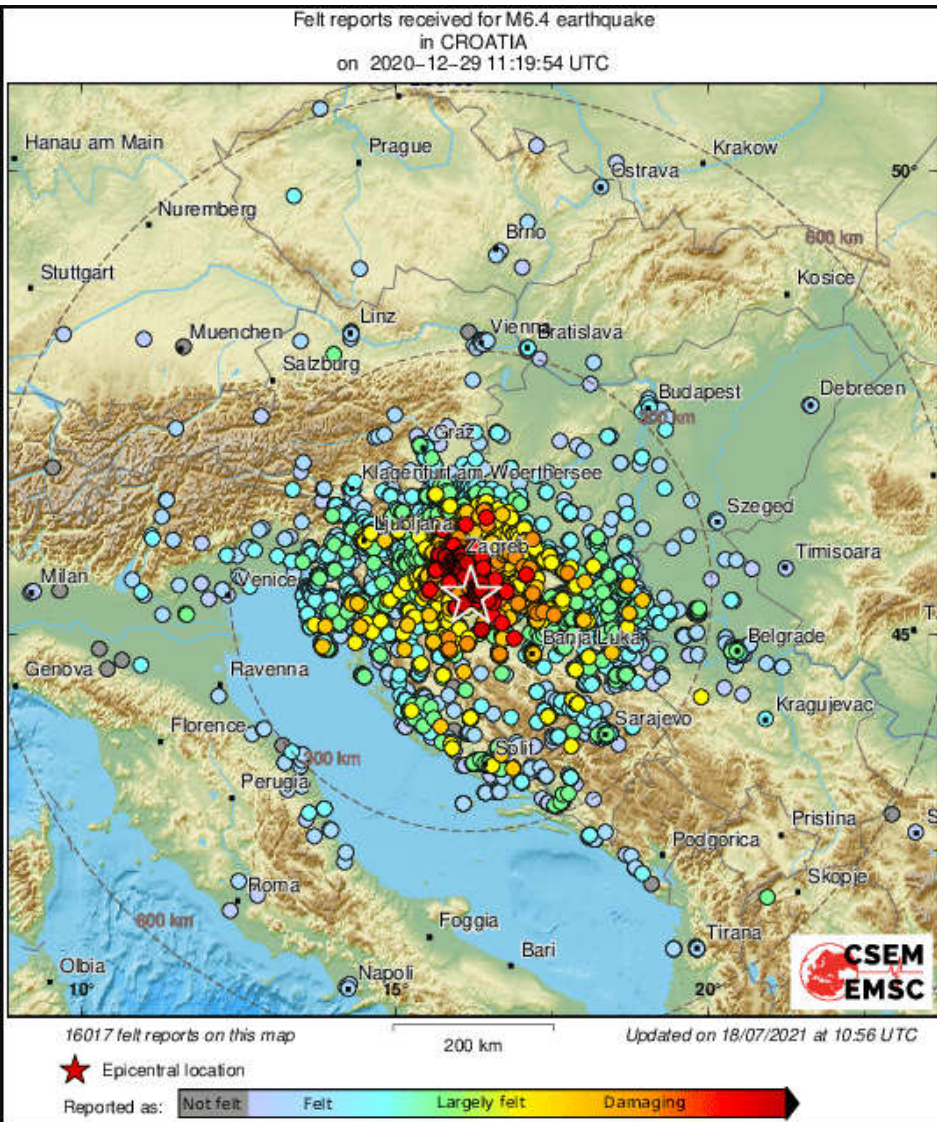
<https://www.emsc-csem.org/>


Period (YYYY-MM-DD) to
 Location (in degrees) < latitude <
 < longitude <
 Depth (in kms) Min Max
 Magnitude Min Max

Citizen Response		Date & Time ▲ UTC		Latitude degrees		Longitude degrees		Depth km	Mag[+]	Region name	[+]
1											
3325		V	2020-12-28	05:28:07.1	45.42	N	16.22	E	10	5.2	CROATIA
1484		V	2020-12-28	06:49:56.8	45.42	N	16.28	E	10	5.0	CROATIA
3051		VII	2020-12-29	11:19:54.1	45.42	N	16.21	E	10	6.4	CROATIA
3505		IV	2020-12-30	05:15:04.7	45.44	N	16.18	E	10	4.8	CROATIA
1616		IV	2020-12-30	05:26:40.6	45.44	N	16.21	E	10	4.7	CROATIA
1											

Bold : Earthquakes with a magnitude ≥ 4.5 in Euro-med, or ≥ 5.5 in the world
Red : Earthquakes with a magnitude ≥ 5 in Euro-med, or ≥ 6 in the world

Petrinja earthquake on 29th December 2020



 **M 6.4 - CROATIA - 2020-12-29 11:19:54 UTC**

- Magnitude **Mw 6.4**
- Region **CROATIA**
- Date time **2020-12-29 11:19:54.1 UTC**
- Location **45.42 N ; 16.21 E**
- Depth **10 km**

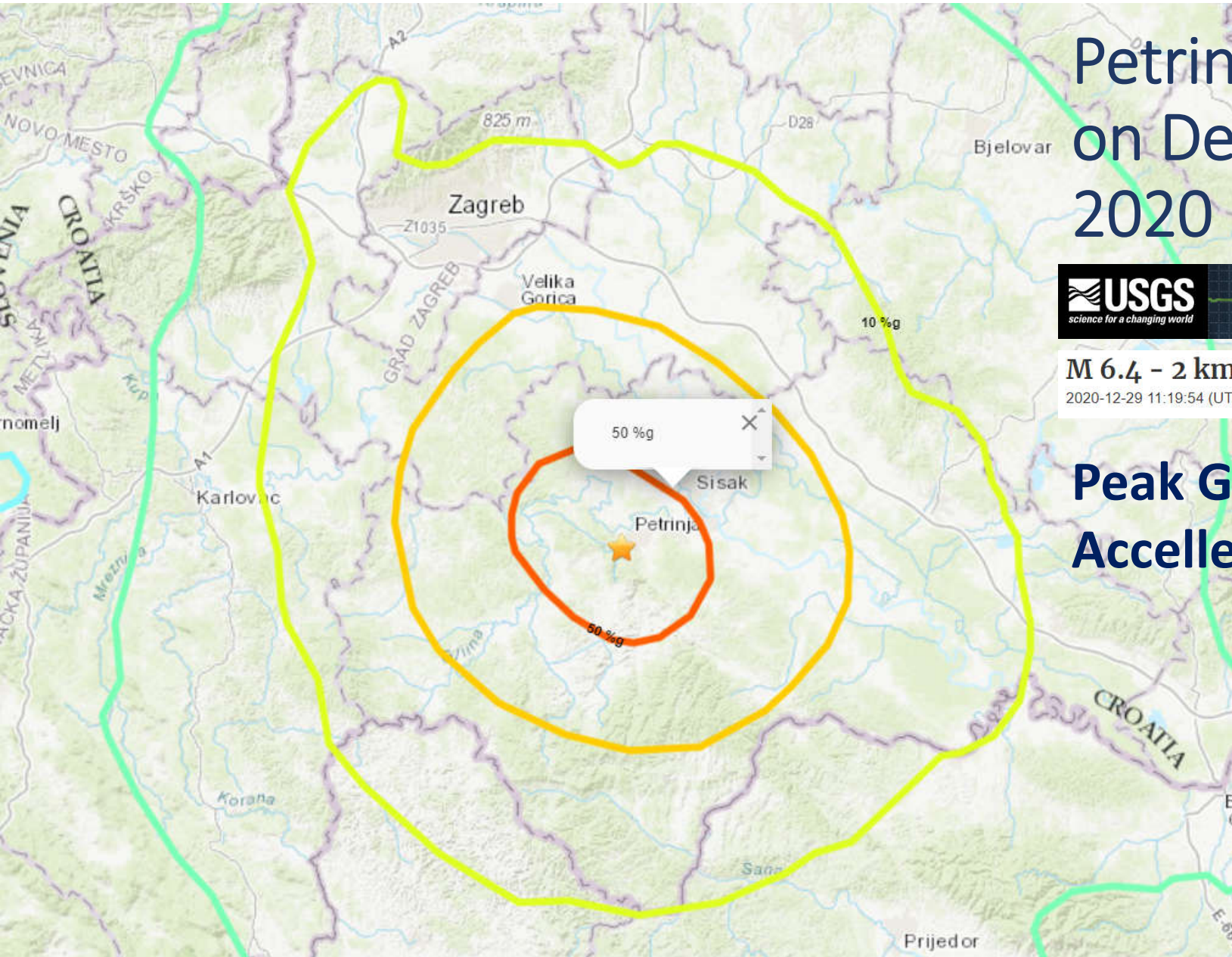


Petrinja earthquake on December 29th 2020




M 6.4 - 2 km WSW of Petrinja, Croatia
2020-12-29 11:19:54 (UTC) | 45.424°N 16.257°E | 10.0 km depth

Peak Ground Acceleration - PGA



Petrinja earthquake on 29th December 2020

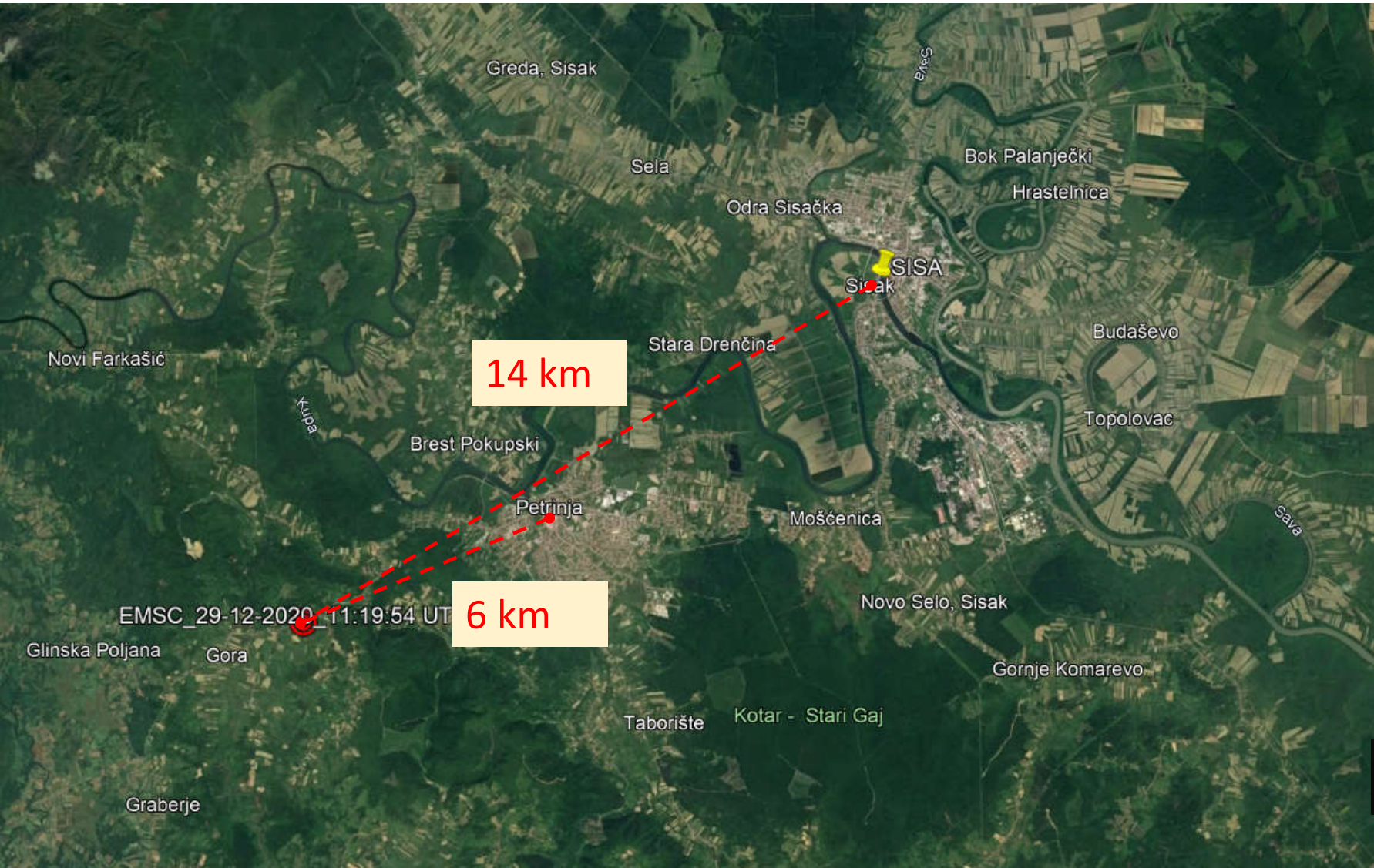
 M 6.4 - CROATIA - 2020-12-29 11:19:54 UTC



Petrinja, 29th December 2020

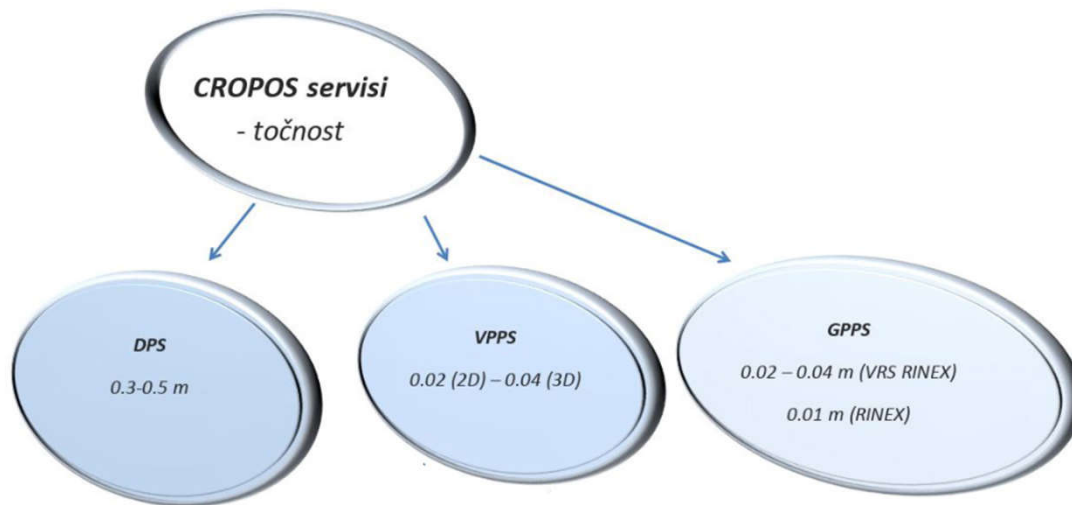
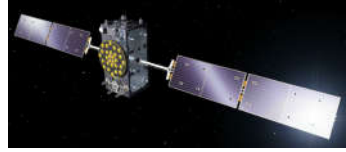


Petrinja earthquake on 29th December 2020



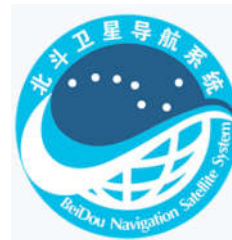
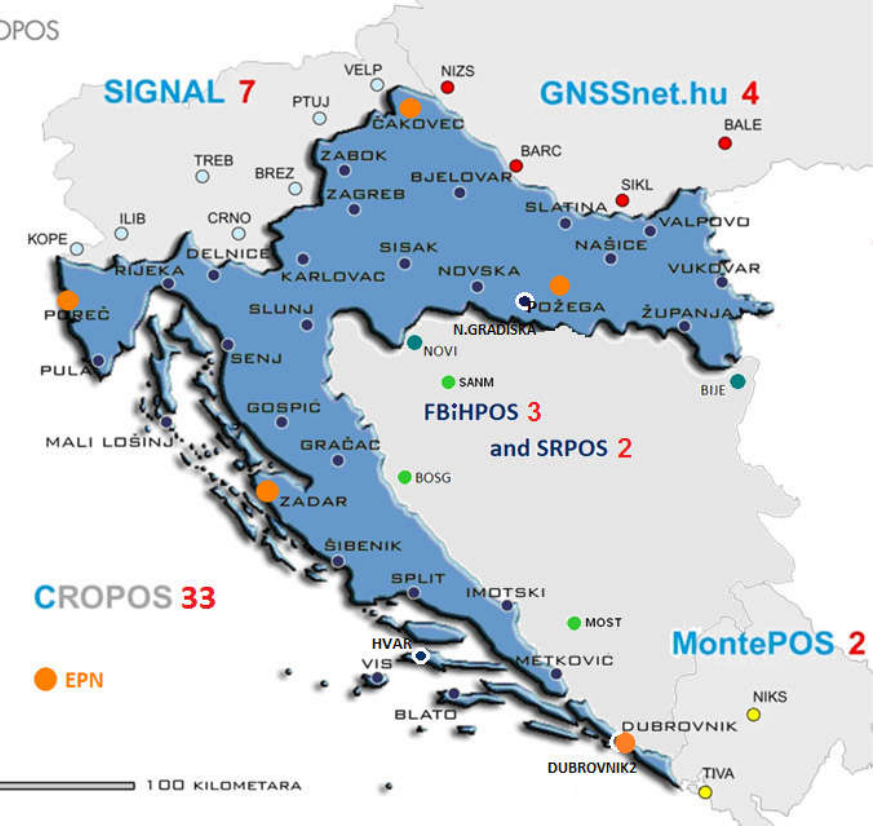
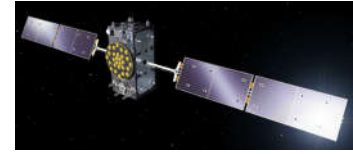
CROPOS:

- National permanent GNSS network of Croatia
- Established in 2008 (30 stations)
- ETRF00 (R05), $e = 2008.83$
- services: DSP, VPPS, GPPS



CROPOS:

- Network enlargement:
(HR 30 + 3) + (SLO 7 + HU 6 + BiH 5 + MNE 2) = 51
- EPN: 5 stations
- modernization: 2019
- Trimble Alloy & Zephyr Geodetic 3 (TZGD)
- GPS + GLO + GAL + BSD



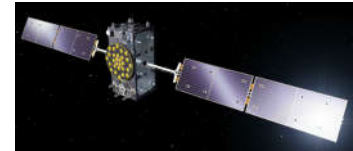
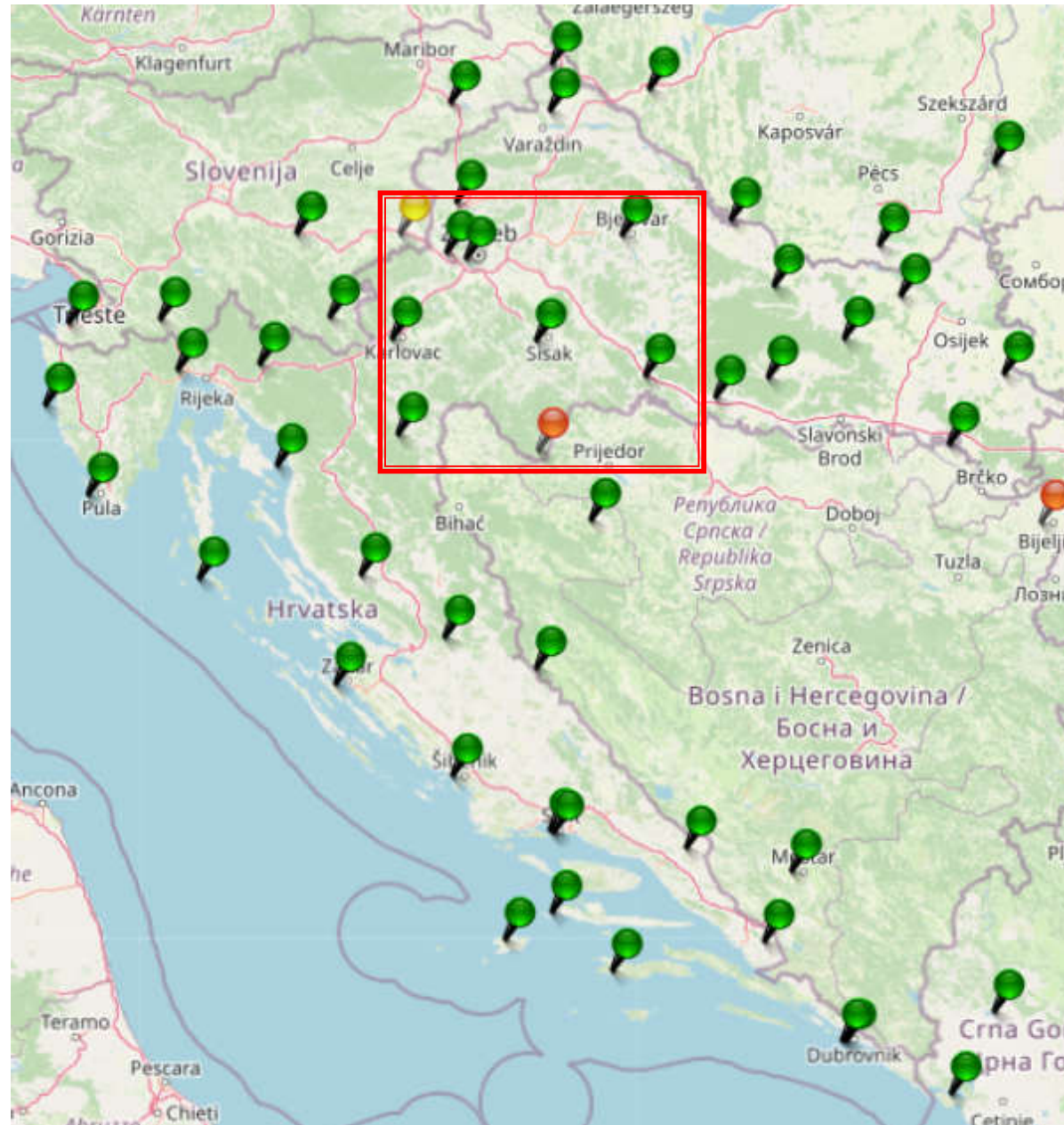
CROPOS:

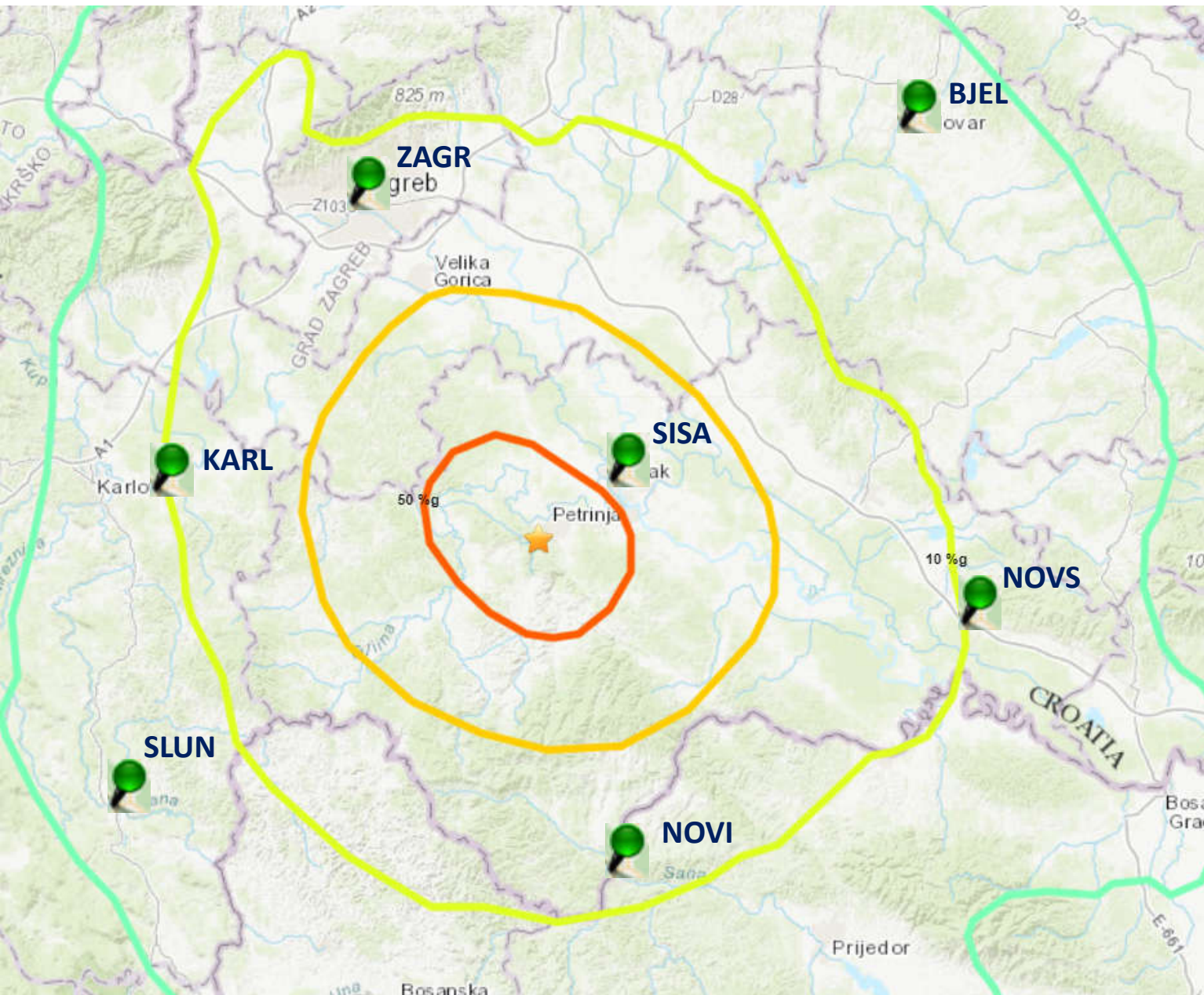
- **GPSS - Geodetic Precise Positioning System**



Trimble® Pivot Web

<http://195.29.198.194/Map/SensorMap.aspx>





Observation data set:

- SISA, BJEL, NOVS, NOVI, SLUN, KARL, ZAGR
- 23 – 27 December 2020
- **28 & 29 December 2020**
- 30 December 2020 – 3 January 2021

- T02
- logging interval 15 s
- RINEX 3.04

Precise Point Positioning (PPP):

Kouba et al. (2017): „The PPP approach uses undifferenced, dual-frequency, pseudorange and carrier-phase observations along with precise satellite orbit and clock products, for standalone static or kinematic geodetic point positioning with centimeter precision.”

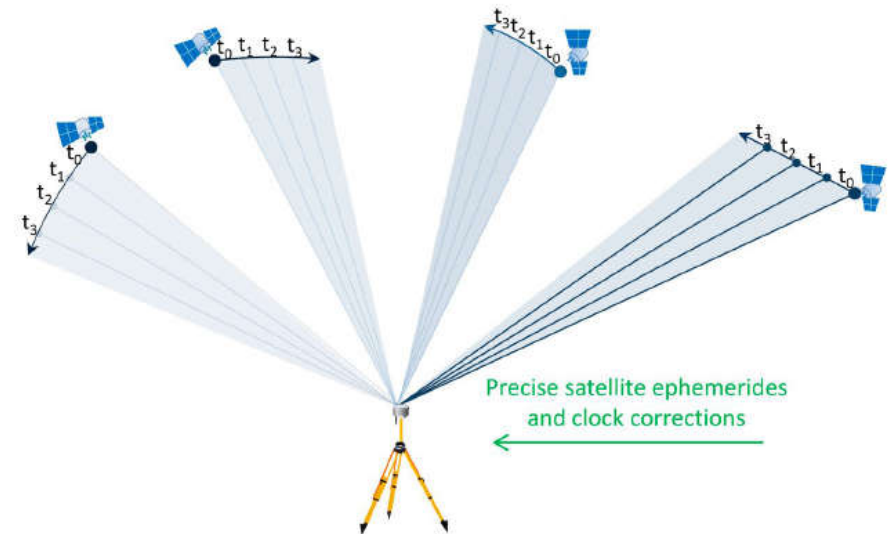
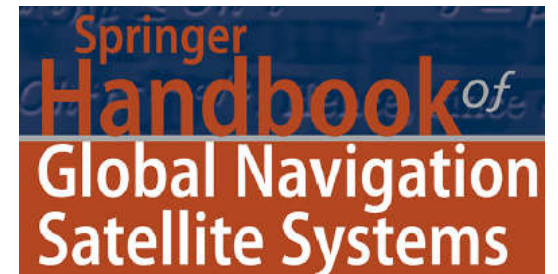


Figure 3.2: Precise Point Positioning.

Kouba, J., Lahaye, F. & Tétreault, P. (2017): Precise Point Positioning, pp. 723-751, in Springer Handbook of Global Navigation Satellite Systems, Peter J.G. Teunissen, Oliver Montenbruck (Eds.), Springer International Publishing AG.

Lipatnikov, L.A. and Shevchuk, S.O. (2019): Cost Effective Precise Positioning with GNSS, FIG Report Commission 5, International Federation of Surveyors (FIG).

Precise Point Positioning (PPP):

- PPP is able to provide position solutions at cm-level: accuracy performance can be even better, e.g., sub-centimeter level, in post-processing and in static mode

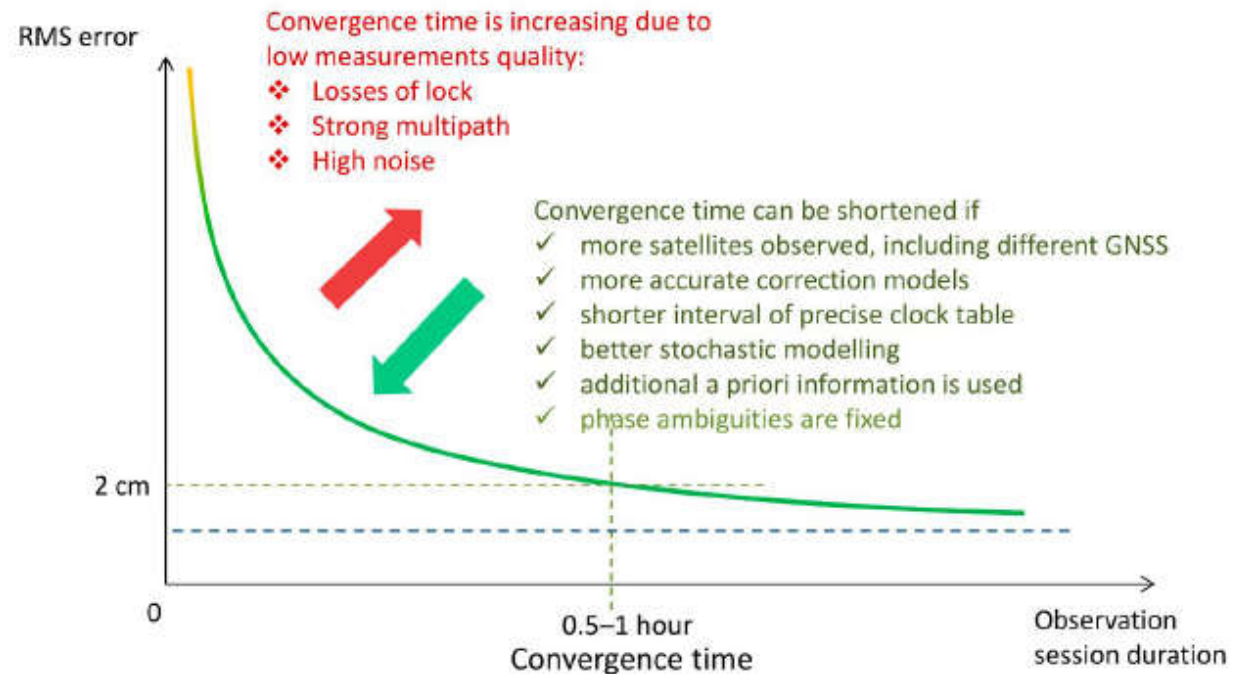


Figure 3.3: PPP convergence time.

PPP-PP services: CenterPoint RTX Post-Processing



CenterPoint RTX Post-Processing

Post-Processing

Register

Support

Contact Us

WELCOME TO THE TRIMBLE CENTERPOINT RTX POST-PROCESSING SERVICE



Welcome to the Trimble CenterPoint® RTX post-processing service. Trimble RTX® is a global GNSS technology providing centimeter-level positioning accuracy.

- <2cm Horizontal Accuracy
- GNSS Compatibility
- No Base Station Required

Register for Unlimited Access

Please register to get unlimited access to the CenterPoint RTX post-processing service for one year.

Register

If you have already registered, please select Post-Processing to begin your session.

Post-Processing

Trimble CenterPoint® RTX post-processing service must not be re-sold to 3rd parties unless explicitly permitted by Trimble Inc.



CenterPoint RTX Post-Processing

Post-Processing

Register

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WELCOME TO TRIMBLE CENTERPOINT® RTX POST-PROCESSING SERVICE

Trimble RTX® is a global GNSS technology that provides centimeter-level positioning, worldwide, at any time.

This application allows you to upload GNSS observation data to the CenterPoint RTX post-processing service and receive positioning calculations. The positioning calculations are performed in the observation epoch (current epoch) of ITRF2008 for data sets that were collected prior to March 23rd 2017, and ITRF2014 for data sets that were collected on or after March 23rd 2017. Transformation can be performed by selecting a different coordinate system and tectonic plate. Complete the form below to receive your calculations via email.

1. Select a coordinate system and tectonic plate:

Coordinate System: ITRF2014

Tectonic Plate: (Autodetect)

2. Select a file to upload:

Choose File No file chosen

New Enhancements

The CenterPoint RTX post-processing service now supports all dual frequency GNSS receivers.

Antennas must be on the Supported Antennas list. The post-processing service will not process unsupported antennas. See also: [Supported Antennas](#)

Observation files must meet the following requirements:

- Data formats accepted include Trimble proprietary data formats (e.g. DAT, T01, T02, T04, Quark) and the standard RINEX 2 and RINEX 3 data formats
- For optimal processing results, it is recommended to provide at least 60 minutes of observations.
- Data files cannot exceed 24 hours in length
- Data files must be static only
- Data files must contain dual frequency pseudorange and carrier phase observations (L1 and L2)
- Data must have been collected after 14 May 2011
- BeiDou data is included since 04 Jun 2014
- Galileo data is included since 01 Jan 2017
- If your observation data consists of several files, please compress them to a ZIP archive and upload the zipped file. All files in the ZIP archive must belong to the same station.

3. Provide your email address:

Email: dsugar@geof.hr



Post-Processing Service Based on RTX Technology

TrimbleRTX.com

Contributor: blagus.luka@gmail.com
 Reference Name: BJEL3580.t02
 Upload Date: 12/16/2022 21:09:15 UTC

Report Time Frame:
 Start Time: 12/23/2020 00:00:00 UTC
 End Time: 12/23/2020 23:59:45 UTC

Observation File Type(s): T02
 Observation File(s): BJEL3580.t02

Antenna:
 Name: TRM115000.00 TZGD
 Height: 0.000 m
 Reference: Bottom of antenna mount

Receiver Name: TRIMBLE ALLOY
 Coordinate Systems: ITRF2014
 Tectonic Plate: Eurasia (Auto-detected)
 Tectonic Plate Model: MORVEL56
 Processing Interval: 15 s

Statistics

# Total Obs	# Usable Obs	# Used Obs	Percent
5760	5760	5760	100

Used Satellites

# Total Satellites:	80
GPS:	G01 G02 G03 G04 G05 G06 G08 G09 G10 G12 G13 G15 G16 G17 G18 G19 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 G32
GLONASS:	R01 R02 R03 R04 R05 R07 R08 R09 R12 R13 R14 R15 R16 R17 R18 R19 R20 R21 R22 R24
Galileo:	E01 E02 E03 E04 E05 E07 E08 E09 E11 E12 E13 E15 E19 E21 E24 E25 E26 E27 E30 E31 E33 E36
BeiDou:	C06 C07 C08 C09 C10 C11 C12 C13 C14

Processing Results

ITRF2014 at Epoch 2010.0		
Coordinate	Value	σ
X	4255938.302 m	0.003 m
Y	1288569.454 m	0.003 m
Z	4557372.026 m	0.003 m
Latitude	45° 53' 46.84501" N	0.002 m
Longitude	16° 50' 41.01255" E	0.002 m
El. Height	188.377 m	0.004 m

ITRF2014 at Epoch 2020.98		
Coordinate	Value	σ
X	4255938.138 m	0.003 m
Y	1288569.627 m	0.003 m
Z	4557372.131 m	0.003 m
Latitude	45° 53' 46.84985" N	0.002 m
Longitude	16° 50' 41.02245" E	0.002 m
El. Height	188.378 m	0.004 m

PPP-PP services: CenterPoint RTX Post-Processing

ITRF2014 at Epoch 2020.98		
Coordinate	Value	σ
X	4255938.138 m	0.003 m
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Z	4557372.131 m	0.003 m
Latitude	45° 53' 46.84985" N	0.002 m
Longitude	16° 50' 41.02245" E	0.002 m
El. Height	188.378 m	0.004 m

(Fi, La) → UTM 33 North → (E, N)



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PPP-PP services: Canadian Spatial Reference System CSRS - PPP

<https://webapp.csrscs.nrcan-rncan.gc.ca/>

Processing mode

Static Kinematic

NAD83

ITRF

- The epoch will be the same as the GPS data.
- A UTM zone will be calculated from the longitude.

Vertical datum

CGVD2013

Contribute to passive control maintenance? ([What is this?](#))

Authorize the Canadian Geodetic Survey to archive and publish CSRS-PPP submission and solution

Official Canadian federal or provincial geodetic marker number

▶ More options

RINEX observation file(s), 300 MB max (.zip, .gz, .Z, .tar, .??O)

Note: You may submit multiple RINEX files in a single .zip or .tar archive

Choose File No file chosen

Remove plots from CSRS-PPP solution PDF report ([Why?](#))

Submit to PPP



Government of Canada

Gouvernement du Canada



CSRS-PPP 3.54.2 (2022-11-10)



PPP-PP services: Canadian Spatial Reference System CSRS - PPP

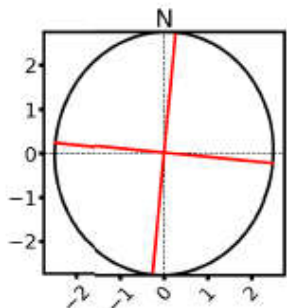
BJEL3580.20o
BJEL

Data Start 2020-12-23 00:00:00.00	Data End 2020-12-23 23:59:30.00	Duration of Observations 23:59:30
Processing Time 12:57:23 UTC 2022/12/17		Product Type NRCan/IGS Final
Observations Phase and Code	Frequency Double	Mode Static
Elevation Cut-Off 7.5 degrees	Rejected Epochs 0.00 %	Fixed Ambiguities 98.98 %
Antenna Model TRM115000.00 TZGD	APC to ARP L1 = 0.064 m L2 = 0.057 m	ARP to Marker H:0.000m / E:0.000m / N:0.000m
		Estimation Steps 30.00 sec

(APC = antenna phase center; ARP = antenna reference point)

95% Error Ellipse (mm)
semi-major: 3 mm
semi-minor: 2 mm
semi-major azimuth: 5° 30' 47.38"

**UTM (North)
Zone 33**



5084185.645 m (N)
643107.348 m (E)
Scale Factors
0.99985177 (point)
0.99982225 (combined)

Estimated Position for BJEL3580.20o

	Latitude (+n)	Longitude (+e)	Ell. Height
ITRF14 (2021.0)	45° 53' 46.84982"	16° 50' 41.02260"	188.367 m
Sigmas(95%)	0.002 m	0.002 m	0.007 m
A priori*	45° 53' 46.83159"	16° 50' 40.99114"	188.374 m
Estimated – A priori	0.563 m	0.678 m	-0.007 m

Comparison of results (daily solutions): 23.12.2020. – 03.01.2021.



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Trimble RTX-PP

vs.

CSRS - PPP

	Range E [m]	Range N [m]	Range el. H [m]
BJEL	0,001	0,002	0,008
KARL	0,002	0,002	0,008
NOVI	0,004	0,007	0,014
NOVS	0,002	0,003	0,009
SISA	0,010	0,005	0,008
SLUN	0,002	0,002	0,009
ZAGR	0,002	0,003	0,010

Comparison of results (daily solutions): 23.12.2020. – 03.01.2021.



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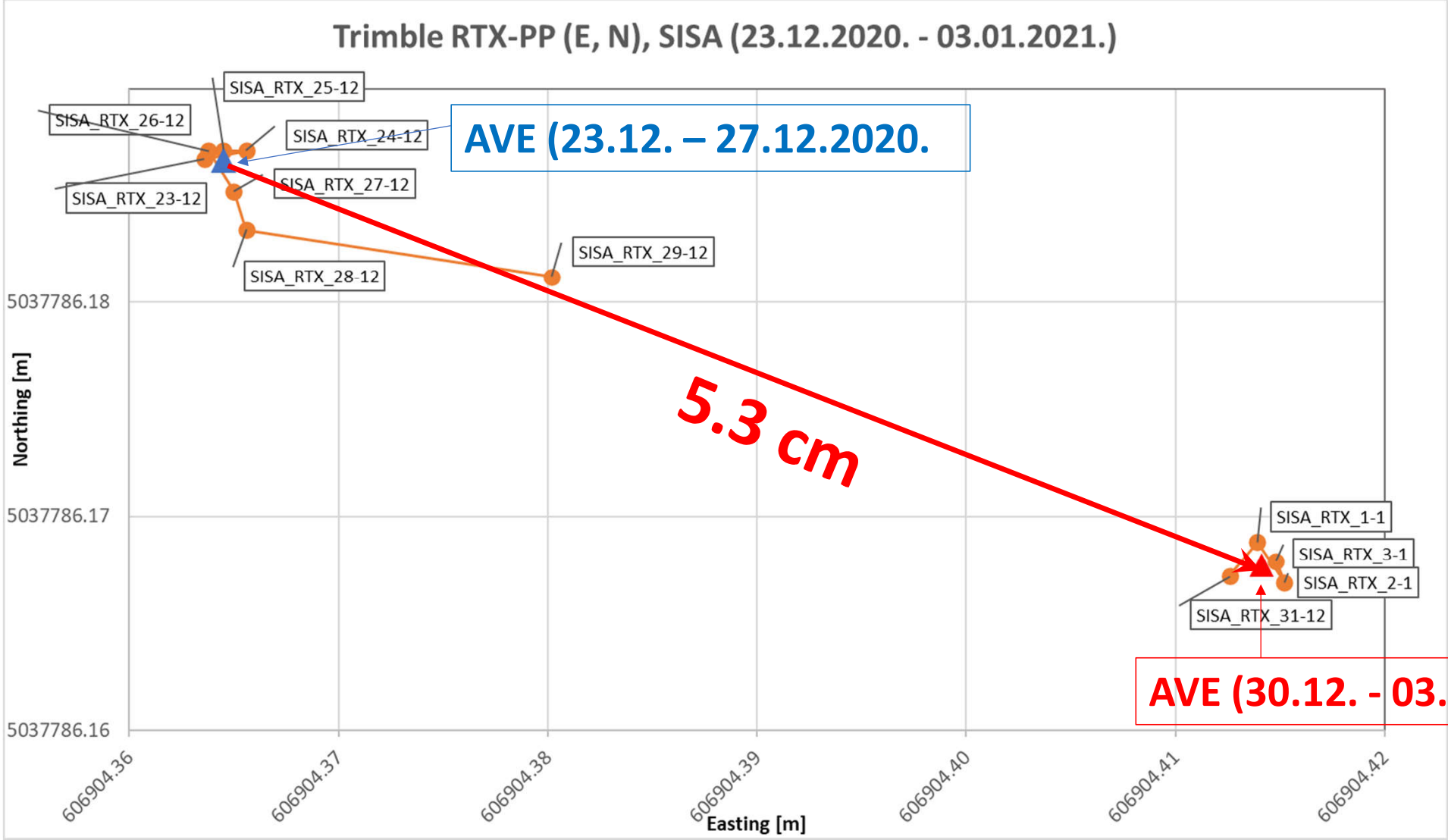
Trimble RTX-PP

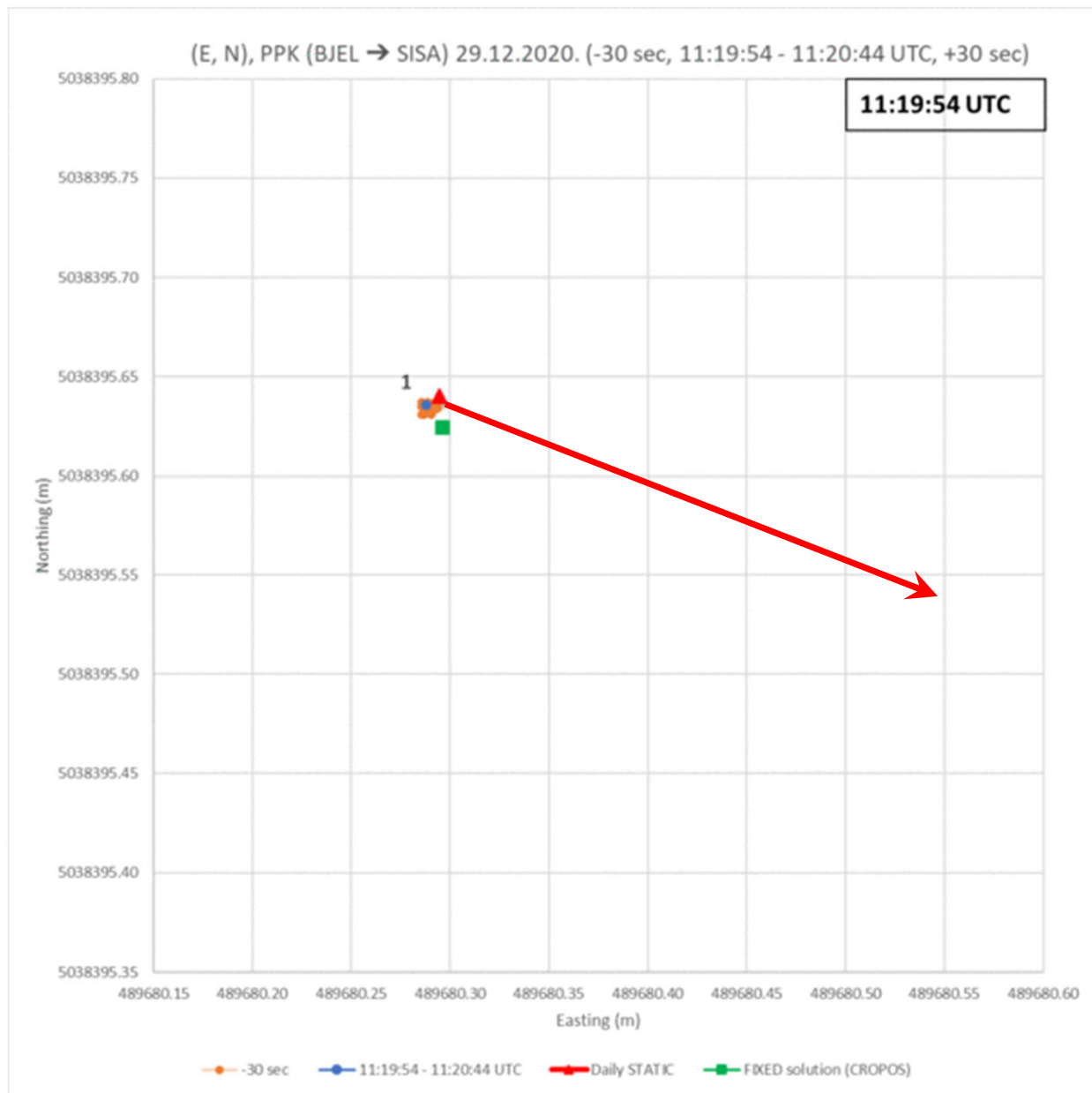
vs.

CSRS - PPP

	max σ_E [m]	max σ_N [m]	max $\sigma(\text{el. H})$ [m]
BJEL	0,003	0,003	0,008
KARL	0,003	0,003	0,008
NOVI	0,009	0,005	0,011
NOVS	0,003	0,003	0,008
SISA	0,014	0,007	0,020
SLUN	0,003	0,003	0,008
ZAGR	0,003	0,004	0,008

SISA: daily solutions (RTX-PP), 23.12.2020. – 03.01.2021.





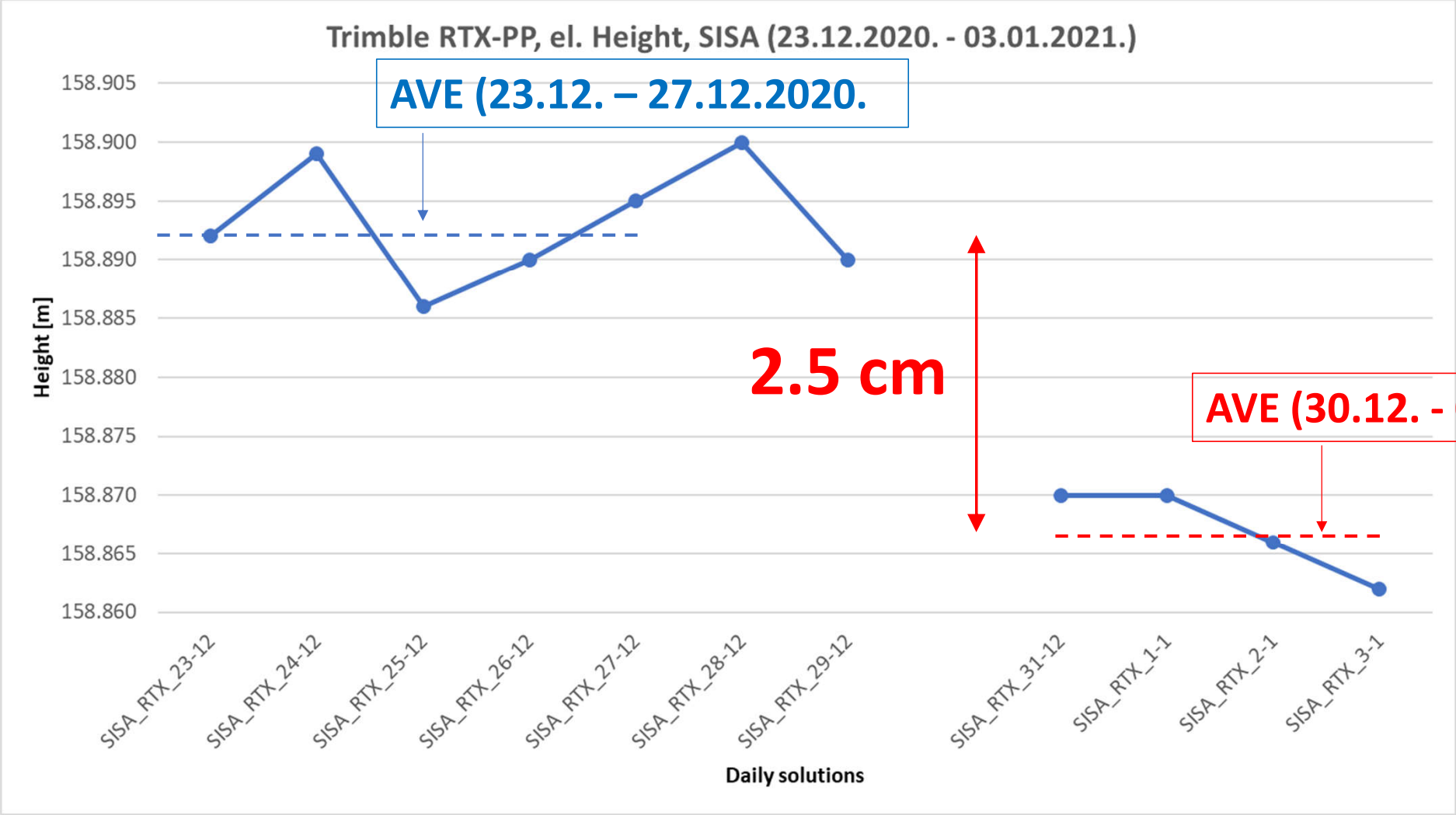
Kinematic motion M6.4 SISA, 29.12.2020.

- 30 sec
- 11:19:54 – 11:20:44 UTC
- +30 sec

MAX dist: 11 → 12: 0.273 m

MAX dist: 11 → 14: 0.497 m

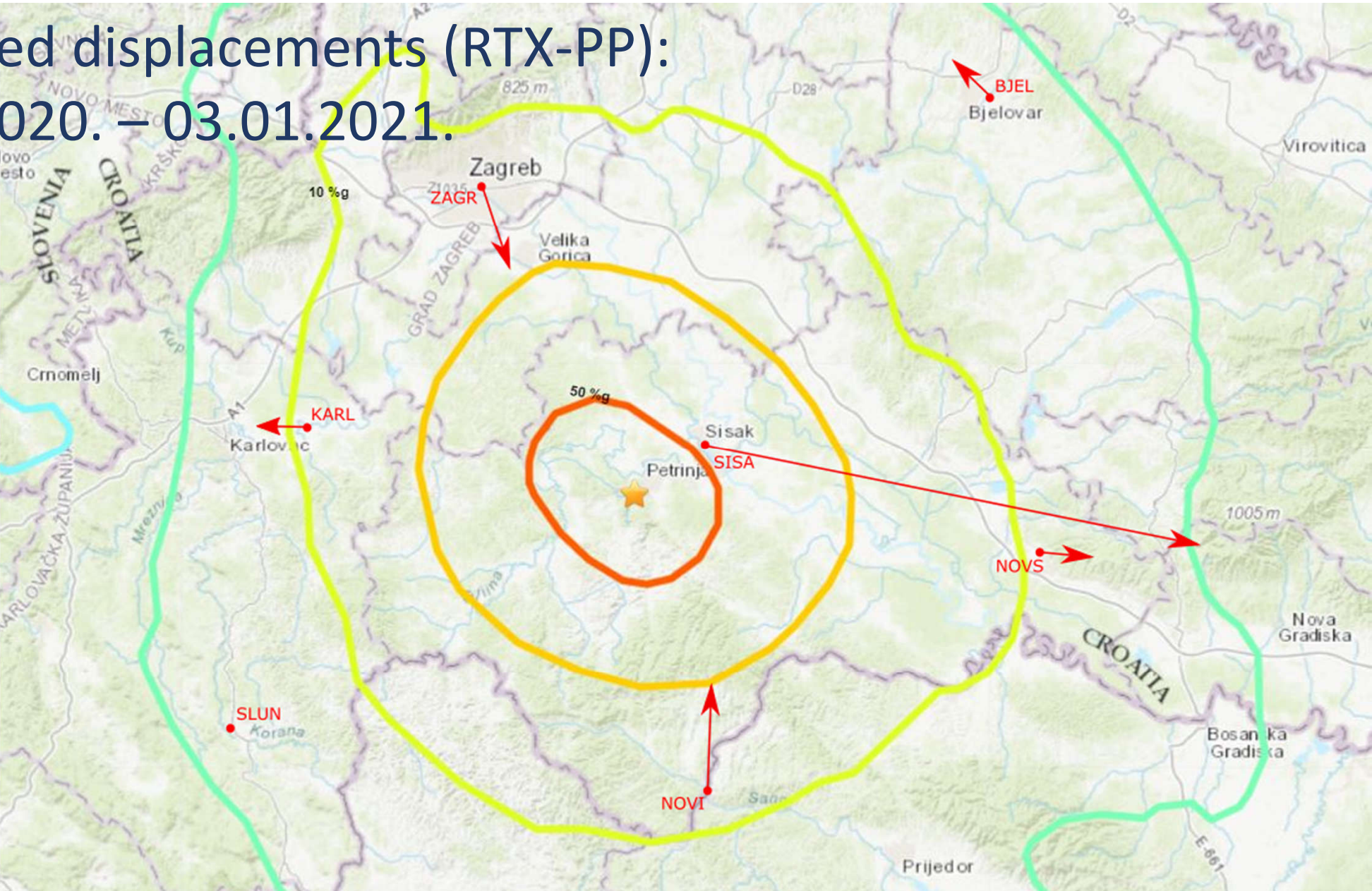
SISA: daily solutions (RTX-PP), 23.12.2020. – 03.01.2021.

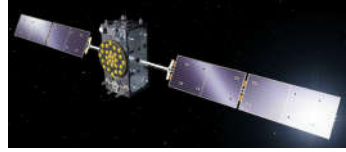


Estimated displacements (RTX-PP): 23.12.2020. – 03.01.2021.

	ΔE [m]	ΔN [m]	Δ ell. H [m]	Planar displ. [m]	Dist (epcn. – CORS) [km]
BJEL	-0,003	0,004	-0,004	0,006	71
KARL	-0,005	0,000	-0,005	0,005	54
NOVI	0,000	0,011	-0,001	0,011	43
NOVS	0,006	0,000	-0,007	0,006	59
SISA	0,050	-0,019	-0,025	0,053	14
SLUN	-0,002	0,000	-0,004	0,002	62
ZAGR	0,002	-0,009	-0,006	0,009	48

Estimated displacements (RTX-PP): 23.12.2020. – 03.01.2021.





Conclusions:

- PPP-PP daily solutions have revealed (indicated) the presence of permanent displacements
- PPP-PP has provided an estimation of displacements magnitude and direction
- all stations have shown a subsidence
- it is not possible to discern whether a permanent displacements come from a man-made building displacement or soil displacement. Or both.
- Scientific SW, e.g. Bernese



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Assessment of CROPOS GNSS stations stability after the Petrinja 2020-2021 earthquake series

[e-mail: dsugar@geof.hr](mailto:dsugar@geof.hr)

GNSS SEMINÁŘ 2023

Brno, 2nd February 2023