Experiences with (free) online global post-processing positioning services

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Presentation topics

- Short overview of the services, including
  - *Basic processing approach*
  - *Input and output data*
  - *Similarities and differences between them*
- ITRF(t) to ETRS89(t_0) transformation issues
  - *Country-specific procedures*
  - *Geo-kinematic model required for cm accuracy*
- Test results from Slovenia, using
  - *AUSPOS Online GPS Processing Service*
  - *CSRS-PPP Online Positioning Service - NRCan*
  - *Trimble CenterPoint RTX Post-Processing Service*

Online global post-processing service

- Basic characteristics:

  - *For dummies and free of charge (at least basic functionality)*
  - *Global service for processing static GNSS surveys (independent of national GNSS networks)*
  - *PPP processing approach (with some exceptions)*
  - *Processing in the curent ITRF release at the epoch of observations*
  - *You send/upload RINEX data and receive/download coordinates*
- Should not be confused with GBAS services, such as
  - *HxGN SmartNet Processing … Hexagon & Leica Geosystems*
  - *Trimble Online Processing App … within Trimble Pivot Platform*
  - *Online Positioning User Service – OPUS … with NGS' CORS net*

Some global post-processing services

- **AUSPOS** Online GPS Processing Service
  (Australian Government, Geoscience Australia)
- CSRS-PPP Online Positioning Service – **NRCan**
  (The Canadian Geodetic Survey, Natural Resources Canada)
- Trimble **CenterPoint RTX** Post-Processing Service
  (Trimble Navigation, Ltd, USA)
- Automated Precision Positioning Service – **APPS**
  (NASA's Jet Propulsion Laboratory, USA)
- GNSS Analysis and Positioning Software – **GAPS**
  (University of New Brunswick, Canada)
- **magicGNSS**
  (GMV Aerospace & Defence, Spain)

Post-processing services comparison

	AUSPOS	NRCan	CenterPoint RTX	APPS	GAPS	magicGNSS
Processing approach	NETWORK – with 15 closest IGS stations	PPP	PPP	PPP	PPP	PPP
GNSSs	GPS only	GPS & GLONASS	GPS, GLONASS, Galileo, BeiDou, QZSS		GPS, Galileo, BeiDou	GPS, GLONASS, Galileo, BeiDou, QZSS
Orbits etc.	IGS products	IGS products		JPL, GDGPS	IGS+CODE products, VMF1	IGS+GMV products
Input data	RINEX v2&3 file(s) + antenna info	RINEX file	RINEX v2&3 file + tectonic plate	RINEX v2 file	RINEX v2&3 file + cutoff angle, etc.	RINEX file
Sign in is required	NO	YES	YES	YES	NO	YES
Basic limitations	max 20 files	max 300 MB			max 20 MB	data after 2013
Free users limitations			max 1 year	data volume limit, certain features excl.		certain features excl.
Output data	pdf-report + SINEX file	pdf-report + files of coordinates ...	pdf&xml-report		html-report + files of coordinates ...	
Resulting coordinates	ITRF2014 epoch of observation	ITRF2014 epoch of observation	ETRS89, ITRF2014 epoch of observation	ITRF2014 epoch of observation	IGb14 epoch of observation	ITRF2014 epoch of observation
Software behind	Bernese			GipsyX/RTGx		

Post-processing results – AUSPOS

PDF Report + SINEX file

Australian Government
Geoscience Australia

AUSPOS GPS Proc

October 28,

This document is a report of the GPS data process
GPS Processing Service (version: AUSPOS 2.4)
ing Service uses International GNSS Service (IG
depending on availability) to compute precise c
Reference Frame (ITRF) anywhere on Earth and
within Australia. The Service is designed to proce

An overview of the GPS processing strategy is in

Please direct any correspondence to GNSSAnalys

Geoscience Australia
Cnr Jerrabomberra and Hindmarsh Drive
GPO Box 378, Canberra, ACT 2601, Australia
Freecall (Within Australia): 1800 800 173
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Geoscience Australia
Home Page: http://www.ga.gov.au

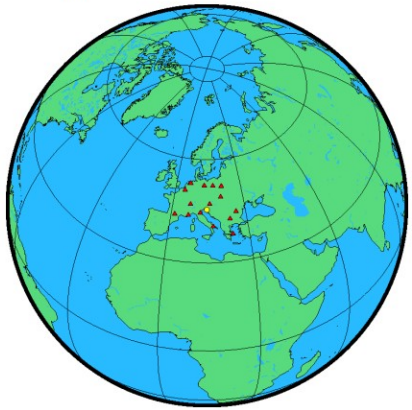
Australian Government
Geoscience Australia

1 User Data

All antenna heights refer to the vertical distance from the Ground Mark to the Antenna Reference Point (ARP).

Station (s)	Submitted File	Antenna Type	Antenna Height (m)	Start Time	End Tim
JELS	JELS_12.22o	JAV_RINGANT_GST NONE	0.600	2022/10/11 12:00:30	2022/10

2 Processing Summary



Date	User Stations	Reference Stations	Orbit Type
2022/10/11 12:00:30	JELS	BOR1 BRUX BUCU DYNG GANP GRAC GRAZ JOZ2 MAT1 MEDI POTS SOFI TLSE WSRT ZIMM	IGS rapid

Australian Government
Geoscience Australia

3 Computed Coordinates, ITRF2014

All coordinates are based on the IGS realisation of the ITRF2014 reference frame. All the given ITRF2014 coordinates refer to a mean epoch of the site observation data. All coordinates refer to the Ground Mark.

3.1 Cartesian, ITRF2014

Station	X (m)	Y (m)	Z (m)	ITRF2014 @
JELS	4340475.881	1104230.534	4526638.907	11/10/2022
BOR1	3738358.151	1148173.988	5021815.922	11/10/2022
BRUX	4027881.333	306998.794	4919499.043	11/10/2022
MAT1	4641951.116	1393053.998	4133281.123	11/10/2022
MEDI	4461400.417	919593.915	4449504.968	11/10/2022
POTS	3800689.352	882077.668	5028791.490	11/10/2022
SOFI	4319371.781	1868688.108	4292064.086	11/10/2022
TLSE	4627851.615	119640.360	4372993.758	11/10/2022
WSRT	3828735.591	443305.241	5064884.890	11/10/2022
ZIMM	4331296.817	567556.197	4633134.142	11/10/2022

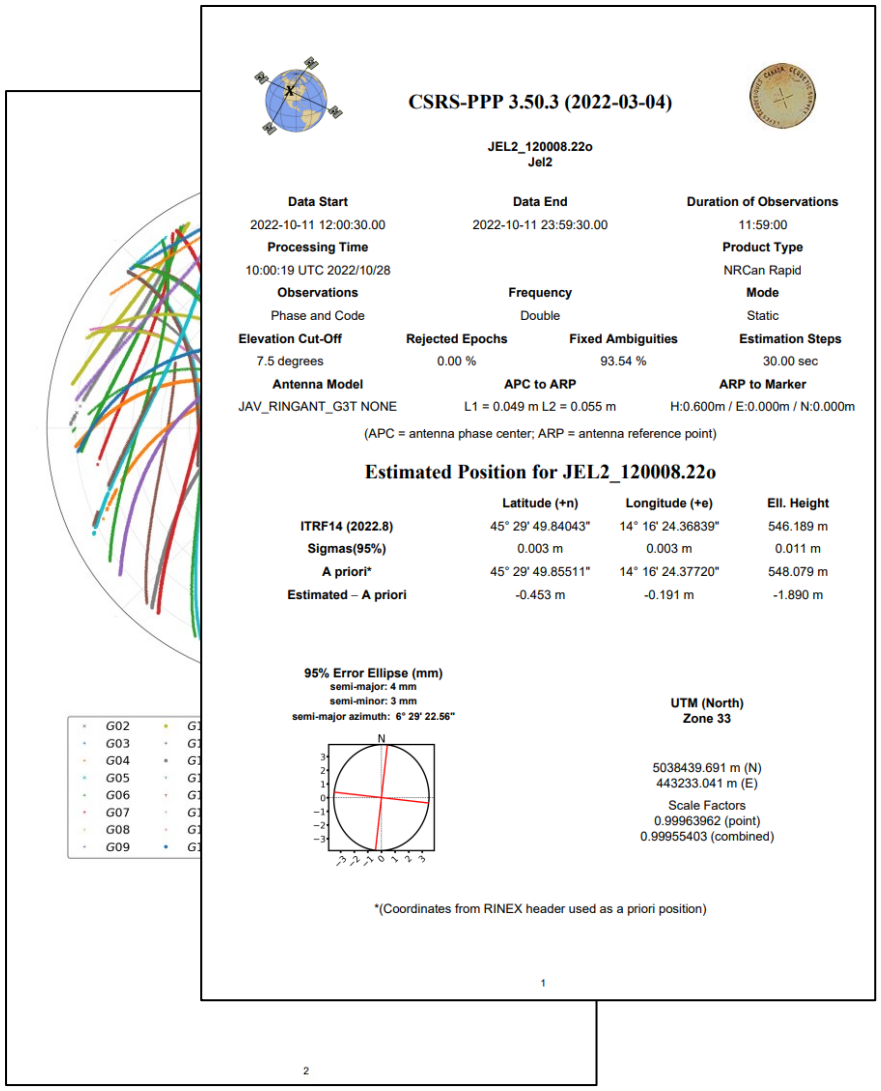
X (m)	Y (m)	Z (m)	ITRF2014 @
4340475.881	1104230.534	4526638.907	11/10/2022

3.2 Geodetic, GRS80 Ellipsoid, ITRF2014

Geoid-ellipsoidal separations, in this section, are computed using a spherical harmonic synthesis of the global EGM2008 geoid. More information on the EGM2008 geoid can be found at http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm2008/.

Post-processing results – NRCan (CSRS-PPP)

PDF Report



CSRS-PPP 3.50.3 (2022-03-04)

JEL2_120008.22o
Jel2

Data Start	Data End	Duration of Observations
2022-10-11 12:00:30.00	2022-10-11 23:59:30.00	11:59:00
Processing Time		**Product Type**
10:00:19 UTC 2022/10/28		NRCan Rapid
Observations	**Frequency**	**Mode**
Phase and Code	Double	Static
Elevation Cut-Off	**Rejected Epochs**	**Fixed Ambiguities**	**Estimation Steps**
7.5 degrees	0.00 %	93.54 %	30.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
JAV_RINGANT_G3T NONE	L1 = 0.049 m L2 = 0.055 m	H:0.600m / E:0.000m / N:0.000m

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

Estimated Position for JEL2_120008.22o

	Latitude (+n)	Longitude (+e)	Ell. Height
ITRF14 (2022.8)	45° 29' 49.84043"	14° 16' 24.36839"	546.189 m
Sigmas(95%)	0.003 m	0.003 m	0.011 m
A priori*	45° 29' 49.85511"	14° 16' 24.37720"	548.079 m
Estimated – A priori	-0.453 m	-0.191 m	-1.890 m

95% Error Ellipse (mm)
semi-major: 4 mm
semi-minor: 3 mm
semi-major azimuth: 6° 29' 22.56"

UTM (North) Zone 33

5038439.691 m (N)
443233.041 m (E)

Scale Factors
0.99963962 (point)
0.99955403 (combined)

*(Coordinates from RINEX header used as a priori position)

1

2

Email with the final coordinates + uncertainties

```
The estimated coordinates ITRF14 2022-10-11 for the JEL2_120008.22o RINEX file are as follows:

Latitude        N45° 29' 49.8404"       ± 0.003 m (95%)
Longitude       E14° 16' 24.3684"       ± 0.003 m (95%)
Ellipsoidal Height      546.189 m       ± 0.011 m (95%)
[45.49717790,14.27343566,546.189]
UTM Zone 33 (North)
Northing        5038439.691 m
Easting 443233.041 m
Scale factor (point)    0.99963962
Scale factor (combined) 0.99955403
[5038439.691,443233.041,546.189]

Cartesian coordinates
X       4340475.878     ± 0.008 m (95%)
Y       1104230.534     ± 0.003 m (95%)
Z       4526638.909     ± 0.008 m (95%)
[4340475.878,1104230.534,4526638.909]
Orbits and Clocks Used: NRCan Rapid
GNSS Data: GPS & GLONASS
GRS80 ellipsoid used for (x,y,z) to (lat,lon,h) transformation
```

```
Cartesian coordinates
X       4340475.878     ± 0.008 m (95%)
Y       1104230.534     ± 0.003 m (95%)
Z       4526638.909     ± 0.008 m (95%)
```

Other files attached:

1- SUM file : Contains the parameters and the results of the PPP processing.

2- POS file : Contains the positioning information for each epoch processed.

3- CSV file : A comma-separated (.csv) format text file containing the positioning and clock information for each epoch processed.

4- TRO file : Contains dry and wet zenith path delay and tropospheric gradient for each epoch processed.

5- CLK file : A RINEX_CLOCK format file containing the receiver clock offset and the clock offset sigma (95%) for each epoch processed.

Post-processing results – CenterPoint RTX (Trimble)

PDF Report

Trimble

Post-Processing Service Based on RTX Technology

TrimbleRTX.com

Contributor: sandi.berk@gmail.com
Reference Name: JEL2_120008.22o
Upload Date: 10/28/2022 10:16:38 UTC

Report Time Frame:
Start Time: 10/11/2022 12:00:30 UTC
End Time: 10/11/2022 23:59:30 UTC
Observation File Type(s): RINEX
Observation File(s): JEL2_120008.22o
Antenna:
Name: JAV_RINGANT_G3T
Height: 0.600 m
Reference: Bottom of antenna mount
Receiver Name: JAVAD TR_LS2
Coordinate Systems: ITRF2014
Tectonic Plate: Eurasia (Auto-detected)
Tectonic Plate Model: MORVEL56
Processing Interval: 30 s

Statistics

# Total Obs	# Usable Obs	# Used Obs	Percent
1439	1439	1435	99

Used Satellites

# Total Satellites:	63
GPS:	G02 G03 G04 G05 G06 G07 G09 G10 G11 G12 G13 G14 G15 G16 G17 G18 G19 G20 G22 G23 G24 G25 G26 G29 G30 G31 G32
GLONASS:	R01 R02 R03 R04 R05 R07 R08 R09 R11 R12 R13 R14 R15 R17 R18 R19 R21 R24
Galileo:	E03 E04 E05 E07 E09 E10 E11 E12 E13 E19 E21 E24 E25 E26 E27 E30 E31 E33

Processing Results

ITRF2014 at Epoch 2010.0		
Coordinate	**Value**	**σ**
X	4340476.070 m	0.006 m
Y	1104230.337 m	0.006 m
Z	4526638.788 m	0.005 m
Latitude	45° 29' 49.83453" N	0.003 m
Longitude	14° 16' 24.35745" E	0.006 m
El. Height	546.199 m	0.007 m

ITRF2014 at Epoch 2022.78		
Coordinate	**Value**	**σ**
X	4340475.886 m	0.006 m
Y	1104230.542 m	0.006 m
Z	4526638.914 m	0.005 m
Latitude	45° 29' 49.84033" N	0.003 m
Longitude	14° 16' 24.36866" E	0.006 m
El. Height	546.200 m	0.007 m

Report Information

Trimble RTX Solution ID: 26860616
Solution Type: Static
Software Version: 8.5.1.20196
Creation Date: 10/28/2022 10:17:26 UTC

Disclaimer
Trimble Navigation Limited does not guarantee availability, reliability, and performance of the current RTX Post-Processing service and accepts no legal liability arising from, or connected to, the use of information on this document or use of this service.

ITRF2014 at Epoch 2022.78		
Coordinate	**Value**	**σ**
X	4340475.886 m	0.006 m
Y	1104230.542 m	0.006 m
Z	4526638.914 m	0.005 m
Latitude	45° 29' 49.84033" N	0.003 m
Longitude	14° 16' 24.36866" E	0.006 m
El. Height	546.200 m	0.007 m

Post-processing results – GAPS

HTML Report

GAPS
GNSS ANALYSIS AND POSITIONING SOFTWARE

GAPS v6.0.1

GENERAL INFO

Station: JELS
Observation File: JELS_12.22o
Begin Processing: 12:0:30
End Processing: 23:59:30
Date of Observation: 2022/10/11
Date of Submission: 28-Oct-2022 05:38:48
Processing Time: 558.83 seconds

PROCESSING OPTIONS

Positioning Type: Static
GPS Orbit and Clock Products: NRCan Final orbits & NRCan Final clocks
GPS Observables Processed: Pseudorange (P1/P2) and Carrier-phase (L1/L2)
Linear Combination: Iono-free
A Priori Carrier-Phase Std Dev: 0.015 m
A Priori Pseudorange Std Dev: 2.000 m
Cutoff Elevation Angle: 5 degrees
Ocean Tidal Loading: Yes
Body Tidal Loading: Yes
Maximum Iterations: 5
Positional Convergence Condition: 1 m

EQUIPMENT INFO

Receiver Name: JAVAD TR_LS2
Antenna Type: JAV_RINGANT_G3TNONE
Antenna Calibration: IGS ANTEX - Absolute
Marker to ARP: 0.600 m
ARP to APC: 0.040 m

NEUTRAL ATMOSPHERE

NAD model: UNB3m (VMF1type unavailable)
Initial A Priori NAD: 2.264 m
A Priori NAD Std Dev: 0.100 m
NAD Process Noise: 5.0 mm/sqrt(h)
Mapping Functions: Niell Mapping Function (Vienna MF: Unavailable)
Gradient Estimation: Not Estimated

A PRIORI COORDINATES

Cartesian (X,Y,Z): 4340476.8015 1104230.9661 4526640.5742 (m)

Geodetic (Lat,Long,h): 45 29 49.8551, 14 16 24.3772, 548.0786 (dd mm ss.ssss, dd mm ss.ssss, m)

A Priori Coordinate Std Dev: unconstrained

FINAL COORDINATES (IGb14 - Epoch 2022.8)

Cartesian (X,Y,Z): 4340426.0014 1104304.6913 4526635.4547 (m)

Std. Dev. (X,Y,Z): 0.2376 0.1368 0.1694 (m)

Geodetic (Lat,Long,h): 45 29 50.4562, 14 16 28.2446, 522.6601 (dd mm ss.ssss, dd mm ss.ssss, m)

FINAL ORTHOMETRIC HEIGHT (EGM2008 - Epoch 2022.8)

Orthometric Height: -999.0000 (m)

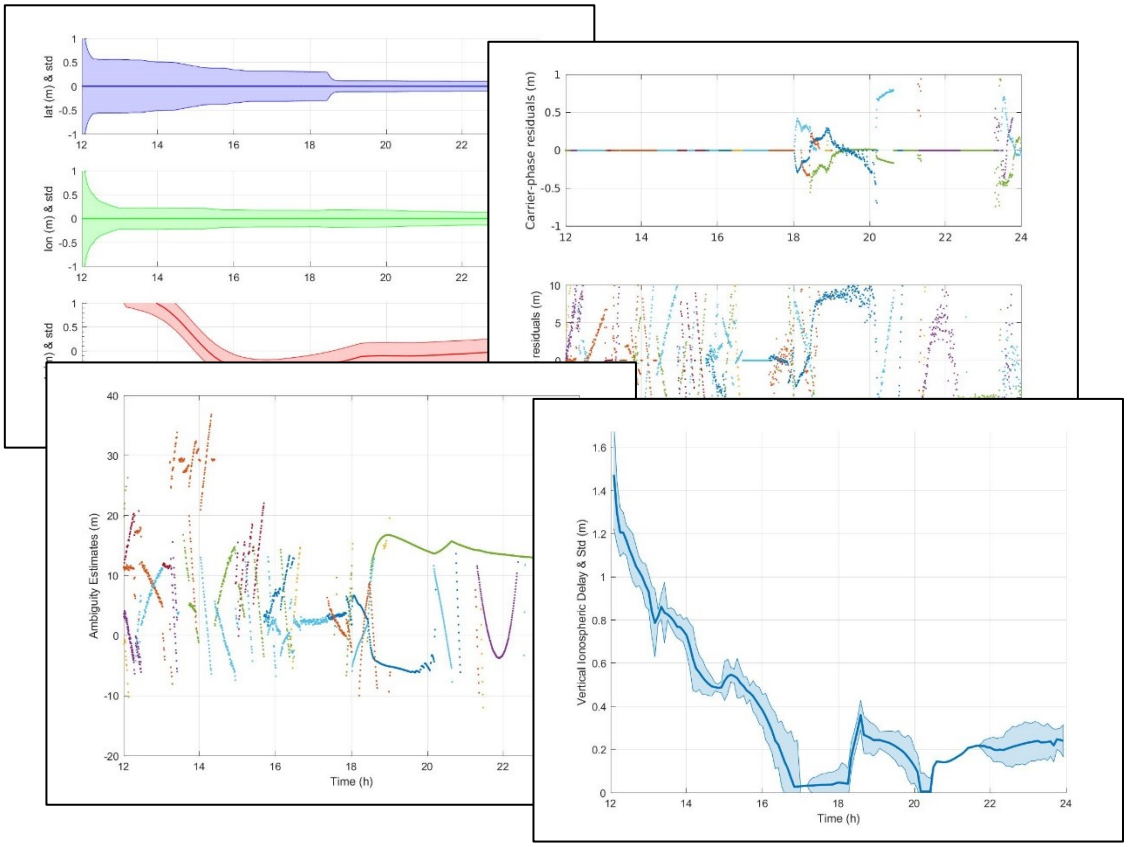
FINAL OFFSETS W.R.T. A PRIORI COORDINATES

Cartesian (X,Y,Z): -50.8001 73.7252 -5.1195 (m)

Geodetic (Lat,Long,h): 13.4584 79.4975 -39.2593 (m)

Horizontal/3D: 80.6286 89.6787 (m)

Graphs as JPG files



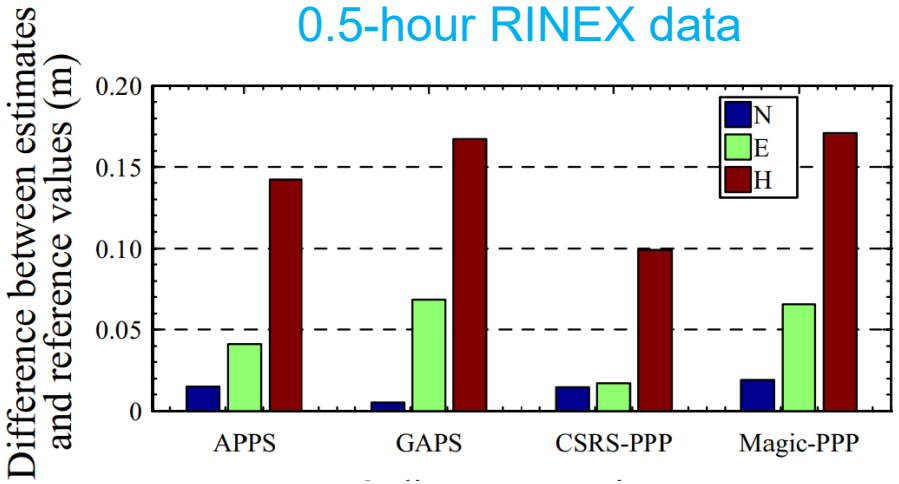
FINAL COORDINATES (IGb14 - Epoch 2022.8)

Cartesian (X,Y,Z): 4340426.0014 1104304.6913 4526635.4547 (m)

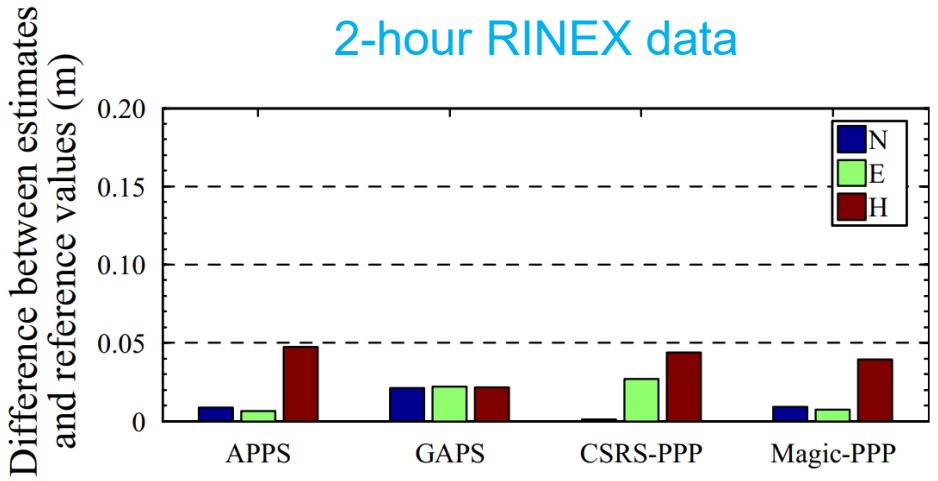
Std. Dev. (X,Y,Z): 0.2376 0.1368 0.1694 (m)

Obtained coordinate accuracy in the ITRF2014@t_{obs}

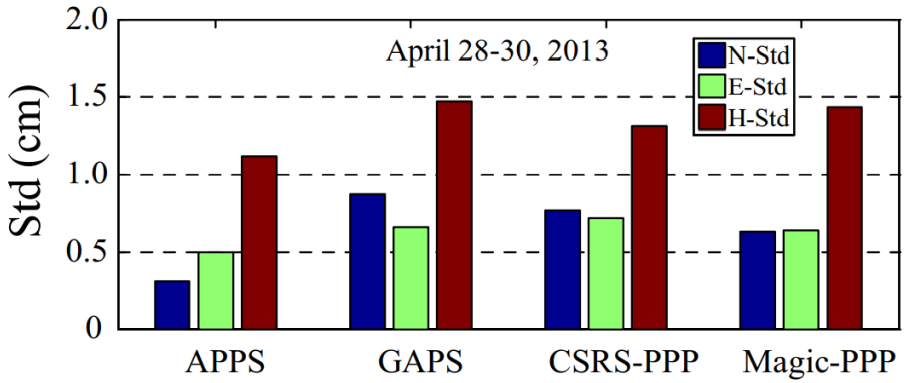
0.5-hour RINEX data



2-hour RINEX data



Daily RINEX data



Source:

Guo, Q. (2015). Precision Comparison and Analysis of Four Online Free PPP Services in Static Positioning and Tropospheric Delay Estimation. GPS Solutions, 19 (4), 537–544. DOI: 10.1007/s10291-014-0413-5.

Transformation of the obtained coordinates (ITRS → ETRS89)

- All services provide coordinates in the current release of ITRF at the epoch of observations (at the moment ITRF2014@2022.8)
- Users require coordinates in their national realization of ETRS89 (in Slovenia ETRS89/D96-17)
- The transformation steps are:

1) ITRF2014@2022.8 → ITRF2000@2022.8
2) ITRF2000@2022.8 → ETRF2000@2022.8
3) ETRF2000@2022.8 → ETRF2000@2016.75 (ETRS89/D17)
4) ETRS89/D17 → ETRS89/D96-17 (optional, country-specific step)

Velocity estimation required!

Transformation step 3) (ETRF2000@2022.8 → ETRF2000@2016.75)

- Transformation to the national realization of ETRS89 requires velocity estimation in the ETRF2000 (velocities relative to the stable part of Europe)
- Options are:
  - Zero velocities (if not known)
  - Estimation of velocities (time series analysis)
  - Interpolation of velocities (national geokinematic model)

Coordinate errors of few cm may appear

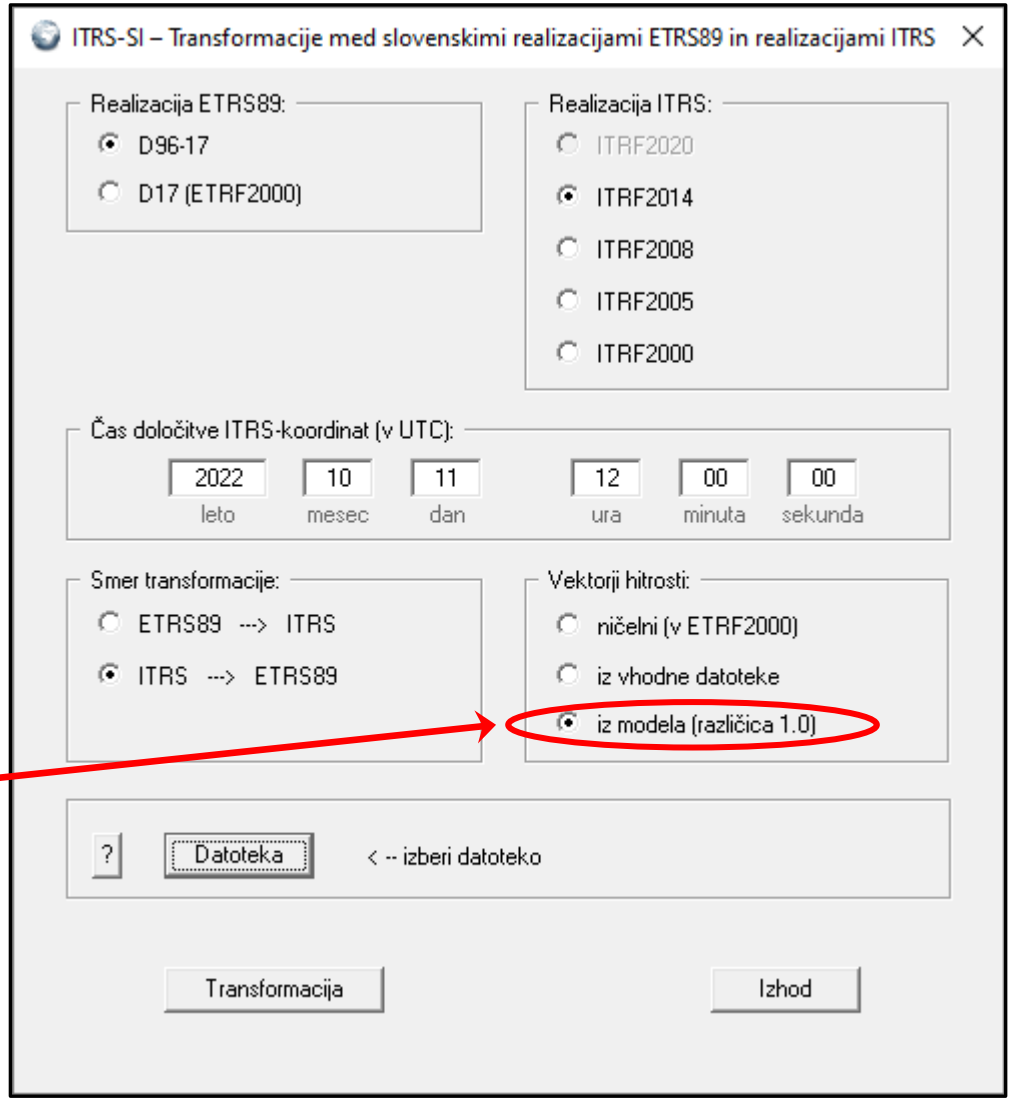
Permanent GNSS stations only!

SLOKIN project in progress in Slovenia

ITRS-SI – a freeware tool for transformation of coordinates (ITRS → ETRS89)

Formats:

- CRD & VEL
- CSV
- TXT
- XYZ



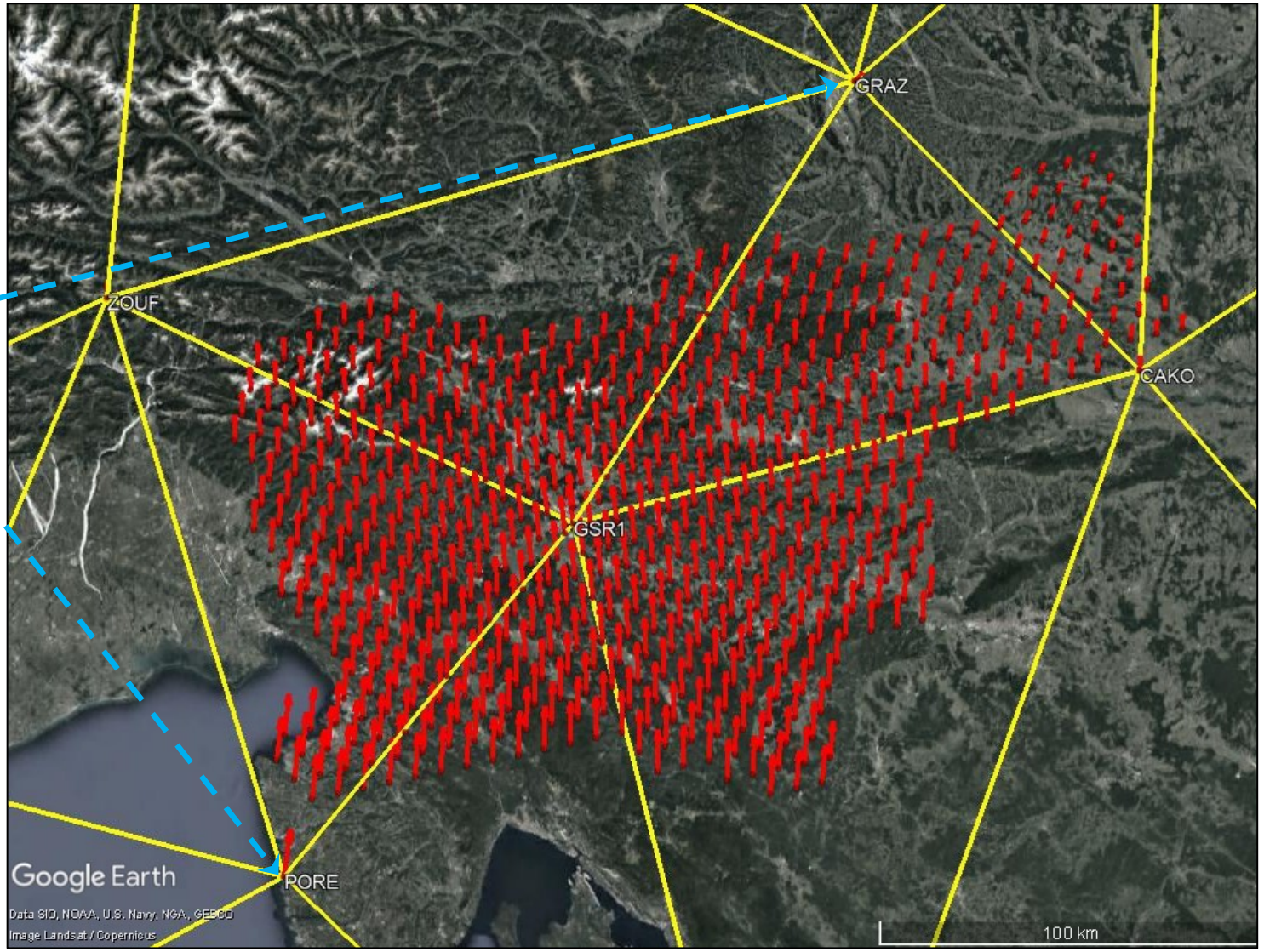
Temporary velocity model

EPN-based temporary velocity model

Range of Hz velocities in ETRF2000

0.60 mm/yr (GRAZ)

2.53 mm/yr (PORE)



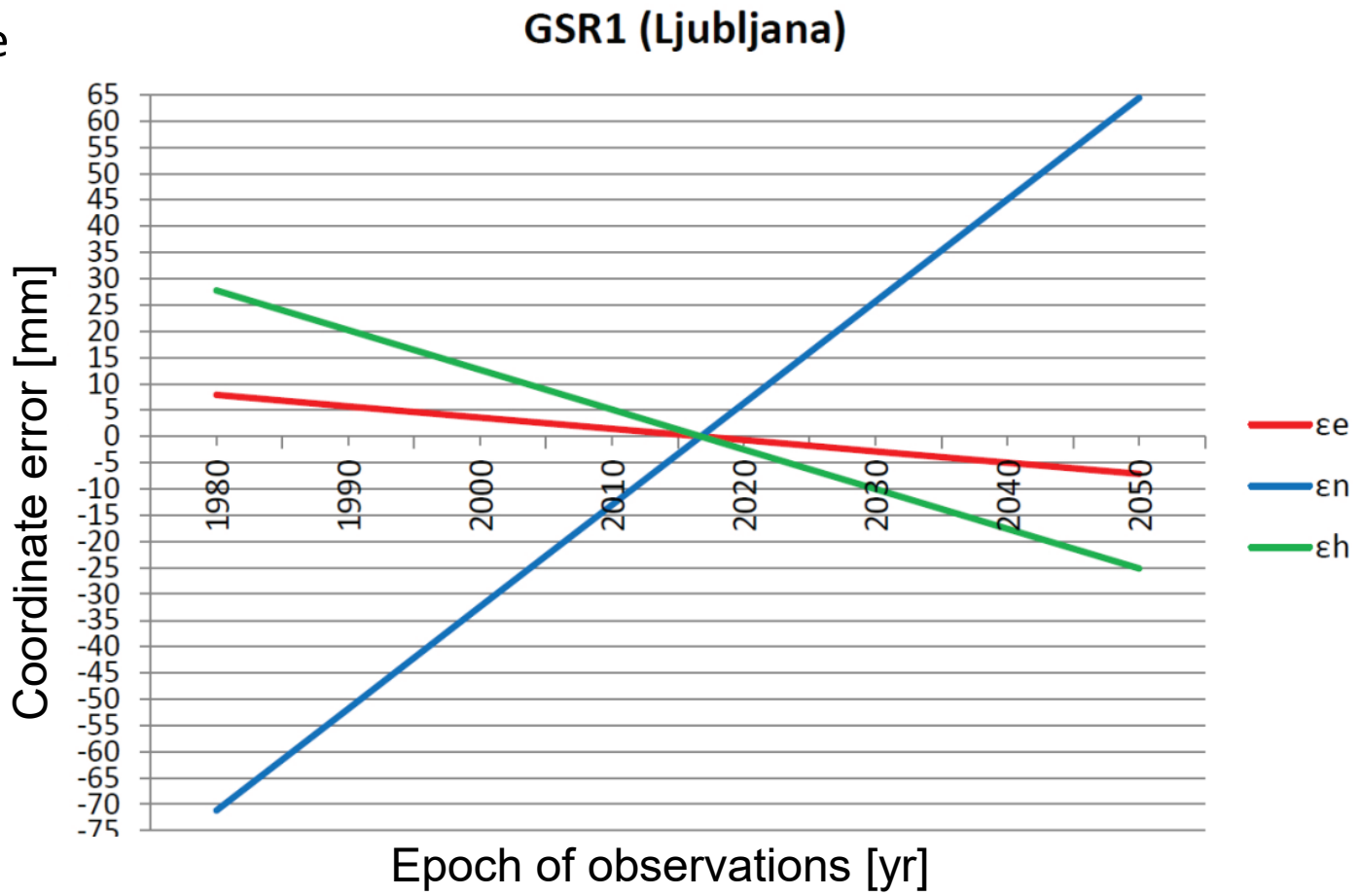
Coordinate errors when ignoring velocities relative to the stable part of Europe

Northing coordinate errors:

0 mm
(October 2016)

10 mm
(November 2021)

100 mm
(May 2068)



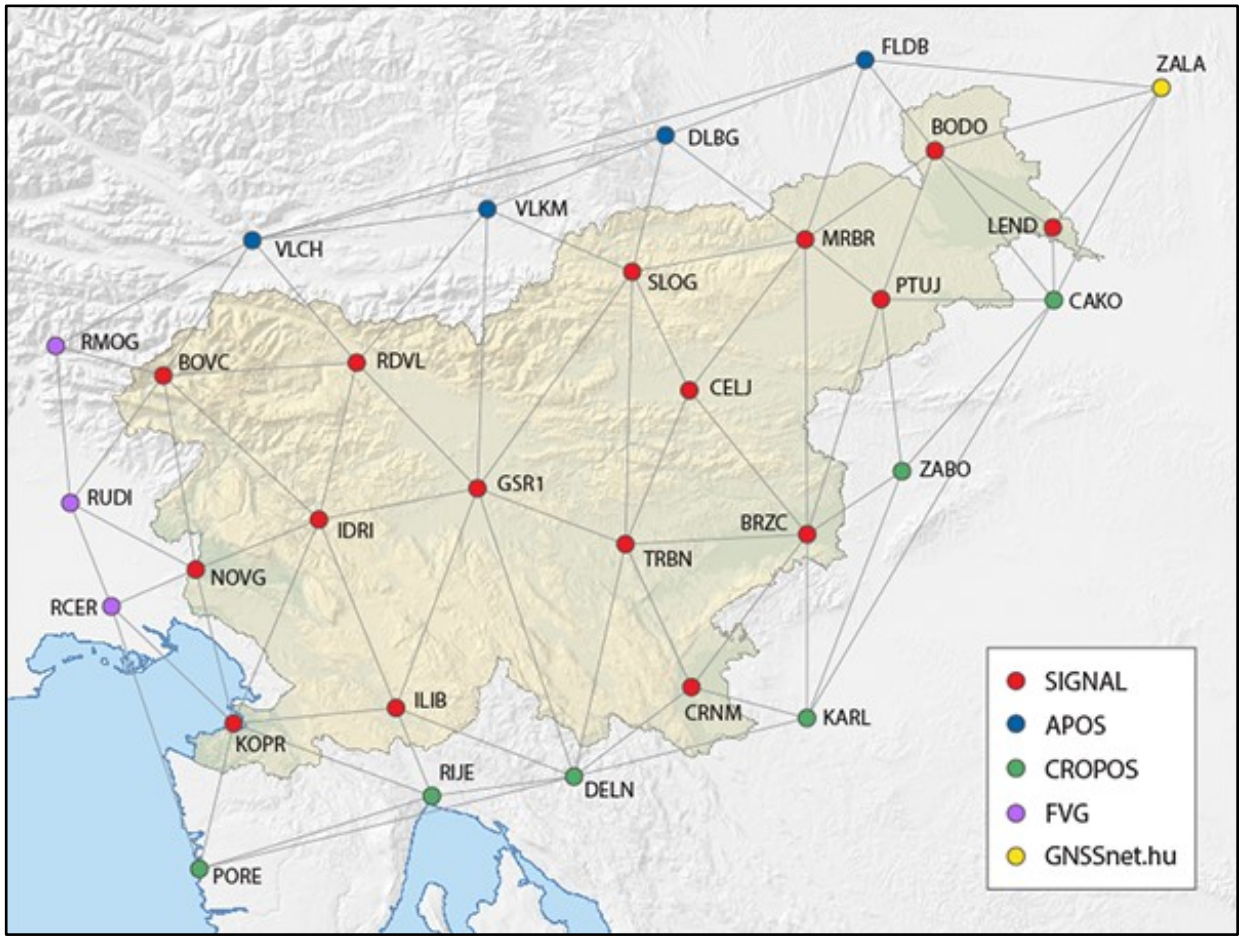
Source:
Berk, S., Medved, K. (2021). Transformations between the Slovenian and International Terrestrial Reference Frames. Geodetski vestnik, 65 (3), 361–384. DOI: 10.15292/geodetski-vestnik.2021.03.361-384.

Tests of three online post-processing services in Slovenia: Input data

19 GNSS stations in the SIGNAL Network

Daily RINEX data for:

- **03/11/2021**
- **03/12/2021**
- **03/01/2022**

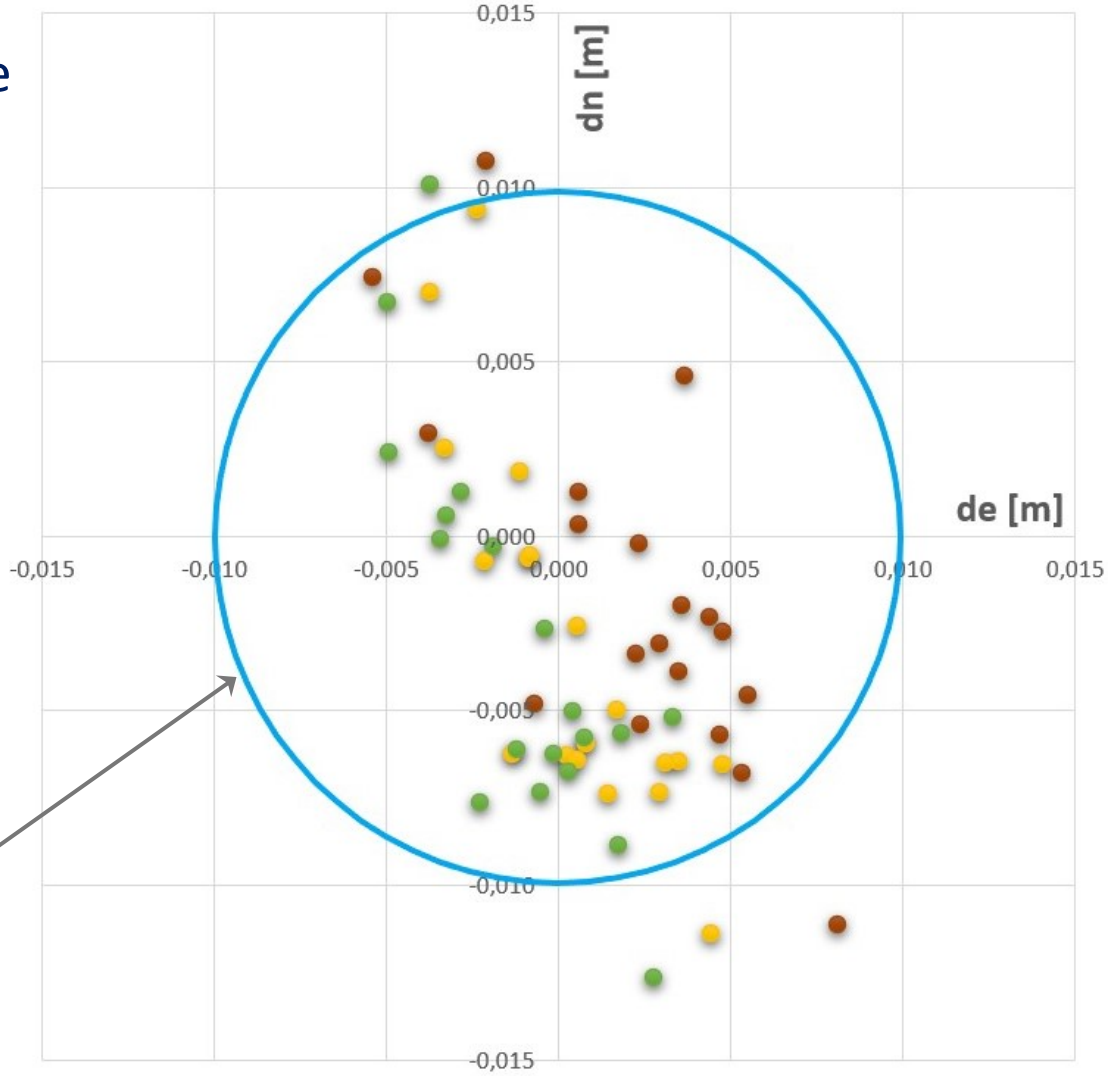


Tests of three online post-processing services in Slovenia: Results

Positional differences from the reference **ETRS89** coordinates for each station obtained with:

- **AUSPOS** service (orange dots)
- **NRCan** (CSRS-PPP) service (green dots)
- **CenterPoint RTX** service (red dots)

For the large majority of stations, the obtained Hz positions are within the **1-cm circle**.



Conclusions

Online global post-processing positioning services can provide **sub-centimetre accuracy** (from daily RINEX data) in the current release of ITRF at the epoch of observations.

However, sub-centimeter accuracy in ETRS89 can only be achieved by **modelling velocities**.

Ignoring velocities relative to the stable part of Europe can cause significant errors that increase with the time elapsed since the reference epoch of the national realization of ETRS89.

Initiative to the EUPOS members

1. Check the quality of the connection between the ITRF2014@t_{obs} and ETRS89 in your country.

2. Provide guidelines for the transformation procedure, which include the velocity model(ling).

Thank you for your attention!