The Comparison of Accuracies of Results Obtained from Bernese v5.2 Software and Web-Based PPP Services

Seyda GELİSKAN, Cevat INAL, Sercan BULBUL and Ahmet Mete GUNDUZ, Turkey

Key words: PPP, Web-based PPP services, Bernese v5.2, Accuracy

SUMMARY

Type the English summary here (about ½ page) .... Precise Point Positioning (PPP) technique has been developed as a technique which is providing absolute and high positioning accuracy, using satellite and clock corrections, with a single GNSS receiver. In this method, with a single receiver which has double frequency using code and carrier phase observations point positioning accuracy can be obtained at cm/dm level. The most important problem in precise point positioning is that convergence time required for phase ambiguities is long.

In this study, on a mechanism created, it is aimed to determine the point positions by a PPP method by shifting the GNSS receiver at 1-cm intervals at east-west direction. While raw data were collecting, record interval was selected as 30 seconds and session duration was taken as 24 hours. The raw data were evaluated with Bernese v5.2 GNSS software and Web-based PPP services (CSRS PPP and Magic GNSS). Coordinates obtained after the evaluation were compared with 1 cm, 2 cm, 3 cm, 4 cm and 5 cm differences. In conclusion, it is observed that at 1 cm, 2 cm, 3 cm and 5 cm, the best results were obtained by CSRS PPP, Magic GNSS and Bernese v5.2 GNSS software, respectively. Also for 4 cm, the best results were given by the Magic GNSS method, Bernese v5.2 GNSS software and CSRS PPP, respectively.

The Comparison of Accuracies of Results Obtained from Bernese v5.2 Software and Web-Based PPP Services

Seyda GELISKAN, Cevat INAL, Sercan BULBUL and Ahmet Mete GUNDUZ, Turkey

1. INTRODUCTION

The point position was first determined by the post process using Global Navigation Satellite System (GNSS) technique. Thanks to the development of the technology, the point positioning have started to be determined in real time. One more reference receiver is needed in point location with post processing and this makes it impossible the point positioning with a single GNSS receiver. Due to the conditions such as geographic locations of the point, density of structuring, the excess of wooded areas, etc, satellite configuration is adversely affected and accuracy of point positioning falls (Cai ve Gao, 2007; Azab et al., 2011; Rizos et al., 2012; Anquela et al., 2013; Chen et al., 2013; Alkan et al., 2014).
To overcome point positioning with one more GNSS receivers, Precise Point Positioning (PPP) technique which is enabling point positioning with a single GNSS receiver has been widely started to be used in recent years (Zumberge et al., 1997). The PPP technique has become increasingly popular in recent years (Pan et al. 2017). The PPP method is a special case of the zero difference method and there is no need to reference stations and simultaneous observation for the PPP technique like point positioning methods such as Differential GPS and Real Time Kinematic (RTK). The point positioning is determined by the PPP technique using the GNSS satellite orbit and clock corrections published by centres such as International GNSS Service (IGS), Center for Orbit Determination in Europe (CODE), Jet Propulsion Laboratory (JPL). With the PPP technique, cm / dm accuracy can be achieved with dual frequency receivers in a global reference frame. However, many other effects such as receiver clock error, tropospheric delay, satellite antenna error, satellite phase rotation (windup) effect, tidal effect, etc., must be taken into consideration in order to obtain these accuracies. In addition, the quality of the receiver-antenna equipment used, the measurement duration and the satellite visibility conditions, the accuracy of the information received from outside (precision orbit, satellite clock error etc.), the modelling success of the software used, etc. the accuracy of the PPP technique can reach the accuracy of cm or even more than cm (Kouba nd Héroux, 2001; Li and et al., 2014; Yigit et al., 2016; Kouba, 2003; El-Raggabny, 2006). Also, ambiguity resolution in the PPP technique can further improve the positioning accuracy to some extent and shorten the convergence time of PPP technique (Ge et al., 2008, Collins et al. 2008, Laurichesse et al., 2009, Geng et al., 2009, Li and Zhang, 2012, Li et al., 2015). Even if the PPP technique provides great profits in terms of cost, the disadvantage of this method is that the measurement duration is minimum 20 minutes (Alçay et al., 2013).
Bernese GNSS software and web-based PPP services ((CSRS-PPP (URL-1) and Magic GNSS (URL-2)) are widely used to obtain point positions in PPP technique.
In this study, on a mechanism created, it is aimed to determine the point positions by a PPP method by shifting the GNSS receiver at 1-cm intervals at east-west direction. While raw data

were collecting, record interval was selected as 30 seconds and session duration was taken as 24 hours. The raw data were evaluated with Bernese v5.2 GNSS software and Web-based PPP services (CSRS PPP and Magic GNSS). Coordinates obtained after the evaluation were compared with 1 cm, 2 cm, 3 cm, 4 cm and 5 cm differences.

2. GNSS SOFTWARES USED IN THE STUDY

Scientific and commercial software can be used in evaluating GNSS measurements. Bernese v5.2 GNSS software and web-based PPP services (CSRS-PPP and Magic GNSS PPP) were used in evaluating the data in this study.

2.1 Bernese v5.2 GNSS software

The Bernese GNSS Software is a scientific, high-precision, multi-GNSS data processing software developed at the Astronomical Institute of the University of Bern (AIUB). The Bernese GNSS Software, Version 5.2, continues in the tradition of its predecessors as a high performance, high accuracy, and highly flexible reference GPS/GLONASS (GNSS) post-processing package (Figure 1).

Figure 1. Display of main screen of Bernese v5.2

Typical users of the software are;

- Scientists for research and education
- Survey agencies responsible for high-accuracy GNSS surveys (e.g., first order networks)
- Agencies responsible to maintain arrays of permanent GNSS receivers
- Commercial users with complex applications demanding high accuracy, reliability, and high productivity (URL-3)

The features and highlights of the software are;

- Available on Unix/Linux, Mac and Windows platforms
- User-friendly GUI with a built-in HTML-based help system
- Multi-session parallel processing for reprocessing activities
- Ready-to-use BPE examples for different applications:
- PPP (basic and advanced versions)

- RINEX-to-SINEX (double-difference network processing)
- Clock determination (zero-difference network processing)
- LEO precise orbit determination based on GPS-data
- SLR validation of GNSS or LEO orbits
- All examples are designed for combined GPS/GLONASS processing.
- Some of them are prepared for an hourly processing scheme.
- Program for automated coordinate time series analysis (FODITS)
- Ambiguity resolution for GPS and GLONASS
- Flexible parameter handling on normal equation level
- Modern troposphere models (e.g., VMF1, GMF/GPT)
- Ionosphere modelling including higher order ionosphere corrections
- IGS and IERS 2010 conventions compliance
- Combination of different receiver and antenna types
- Galileo processing capability (URL-3)

Typical applications of the software are;

- Rapid processing of small-size single and dual frequency surveys
- Automatic processing of permanent networks
- Any type of post-processing from near-real time to reprocessing years of GNSS data
- Processing of data from a large number of receivers
- Combined processing of GPS and GLONASS observations
- Analysis of real kinematic receivers (even on airplanes)
- Ionosphere and troposphere monitoring
- Clock estimation and time transfer
- Orbit determination for GNSS and Low Earth orbiting satellites together with related parameters (e.g., Earth orientation parameters)
- SLR orbit validation

2.2 Web-based PPP services

According to commercial and scientific software, web-based PPP services are free online services are available for users who do not require long-term professional training, do not need any additional software knowledge, and can easily and effortlessly use different levels of users. Even if there are some restrictions such as membership requirement, quota of data volume, version of loaded data, evaluation of data which are collected receivers which have single/double frequency and evaluation of used GNSS antenna according to brands and models, they draw a lot of attention.

Table 1 lists properties of the web-based PPP services that are widely used in the world.

Table 1. Web-based PPP services

Properties	Techniques	
	CSRS-PPP (URL-1)	**MagicGNSS PPP (URL-2)**
Name	Canadian Spatial Reference System	MagicGNSS

Organization	Natural Research Canada(NRCan)	GMV Innovation Solution
Web pages	http://webapp.geod.nrcan.gr.ca	http://magicgnss.gmv.com/ppp
Reference system	NAD83 / ITRF08	ITRF08 / ETRS89
Antenna corrections	IGS	IGS
Satellite orbit and clock corrections	IGS Final / Rapid / Ultra Rapid	IGS Final / Rapid / Ultra Rapid
Elevation masks	minimum 10^0	minimum 10^0
GNSS system	GPS / GLONASS	GPS / GLONASS / GALILEO-ready
Software used	CSRS_PPP	Magic GNSS 5.3
Number of Files to Upload	Max 1 file	-
Processing mode	Static / Kinematic	Static / Kinematic
Frequency	single/double frequency	single/double frequency
Data Upload Method	webpage, e-mail	webpage, e-mail
Data format	RINEX or Hatanaka	RINEX or Hatanaka

3. APPLICATION

In this study, a single GNSS receiver was shifted by 1 cm interval in the east-west direction on the created mechanism (Figure 2).

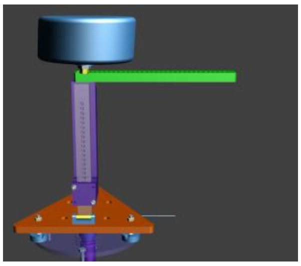

Figure 2. Created mechanism

Data were collected as 24 hours. The data record interval was taken as 5 seconds and the elevation mask was chosen as 10o. The collected data were evaluated with Bernese v5.2 GNSS software and web-based PPP services. It has been researched how close the shift amounts calculated from the obtained coordinates are to the real value. As a test point in the study, the point which was established the form of a pillar in the garden of Ministry of Environment and Urbanisation,Kutahya Provincial Directorate was used (Figure 3).

Figure 3. The pillar and its location

The coordinates obtained from Bernese v5.2 GNSS software and web-based services have been converted to projection coordinates. The coordinates obtained after the conversion have been given in Table 1.
Table 2. The obtained projection coordinates after evaluations (x=499320+, y=4366070+, h=970+)

Table 2. The obtained projection coordinates after evaluations (x=499320+, y=4366070+, h=970+)

ID	Bernese v5.2 GNSS			CSRS-PPP			Magic GNSS PPP		
	x	**y**	**h**	**x**	**y**	**h**	**x**	**y**	**h**
1	3.1443	3.2253	3.7136	3.1378	3.2411	3.8287	3.1434	3.2387	3.8118
2	3.1596	3.2247	3.7136	3.1500	3.2381	3.8324	3.1507	3.2402	3.8180
3	3.1662	3.2253	3.7066	3.1618	3.2366	3.8280	3.1606	3.2349	3.8152
4	3.1730	3.2271	3.7210	3.1681	3.2367	3.8373	3.1667	3.2343	3.8293
5	3.1869	3.2310	3.7392	3.1827	3.2358	3.8400	3.1827	3.2352	3.8282
6	3.2021	3.2286	3.7267	3.1914	3.2369	3.8370	3.1911	3.2367	3.8270
7	3.1993	3.2301	3.7307	3.2015	3.2376	3.8331	3.2004	3.2350	3.8290
8	3.2110	3.2307	3.7192	3.2087	3.2371	3.8321	3.2081	3.2362	3.8266
9	3.2297	3.2288	3.7145	3.2241	3.2372	3.8287	3.2272	3.2335	3.8344
10	3.2350	3.2291	3.7067	3.2343	3.2401	3.8237	3.2362	3.2366	3.8178
11	3.2418	3.2278	3.7172	3.2414	3.2414	3.8347	3.2433	3.2387	3.8390
12	3.2477	3.2282	3.7218	3.2572	3.2361	3.8286	3.2547	3.2348	3.8272
13	3.2658	3.2279	3.7277	3.2607	3.2371	3.8321	3.2649	3.2367	3.8291
14	3.2715	3.2267	3.7142	3.2757	3.2335	3.8239	3.2774	3.2324	3.8188
15	3.2824	3.2235	3.7247	3.2830	3.2324	3.8299	3.2884	3.2338	3.8301
16	3.2918	3.2235	3.7375	3.2931	3.2347	3.8349	3.2952	3.2345	3.8321

In the calculating shifting values after obtained coordinates, the length between i and j points is calculated;

$$s_{ij} = \sqrt{\left(y_j - y_i\right)^2 + \left(x_j - x_i\right)^2} \qquad (1)$$

The difference between the shifting values and the actual value is calculated;

$$\varepsilon = k - s_{ij} \qquad (k = 1,2,3,4,5) \qquad (2)$$

The maximum and minimum differences are calculated for the determined differences and are shown in Table 3.

Table 3. Calculated maximum and minimum differences for determined differences (mm)

Used software	Difference statistics	1 cm	2 cm	3 cm	4 cm	5 cm
Bernese v5.2	Max	6.8	10.9	12.0	7.1	10.3
	Min	- 8.8	-10.4	-6.1	-4.3	-7.9
CSRS-PPP	Max	6.4	2.7	4.0	4.1	3.1
	Min	-6.7	-5.8	-5.2	-8.5	-6.0
Magic GNSS PPP	Max	3.9	3.1	6.3	2.2	2.5
	Min	-9.3	-8.1	-6.2	-6.6	-10.5

The root mean squares(rms) for determined differences are calculated

$$m = \pm\sqrt{\frac{[\varepsilon\varepsilon]}{n}} \tag{3}$$

Where, n is the interval number. For example, for 1 cm, n is 15. The rms for determined differences were shown in Table 4.

Table 4. The rms for determined differences (mm)

Used software	1cm	2 cm	3 cm	4 cm	5 cm
Bernese v5.2	±0.33	±0.55	±0.44	±0.21	±0.54
CSRS-PPP	±0.20	±0.11	±0.12	±0.23	±0.16
Magic GNSS PPP	±0.25	±0.22	±0.22	±0.18	±0.37

The graphical representations of the differences were given in Figure 4-8.

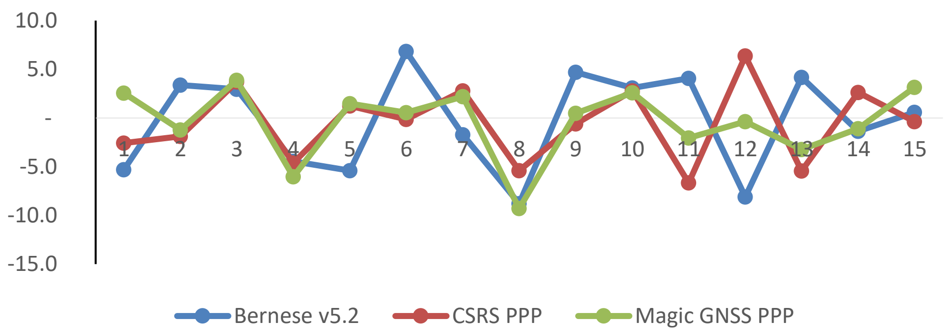

Figure 4. Differences from 1 cm

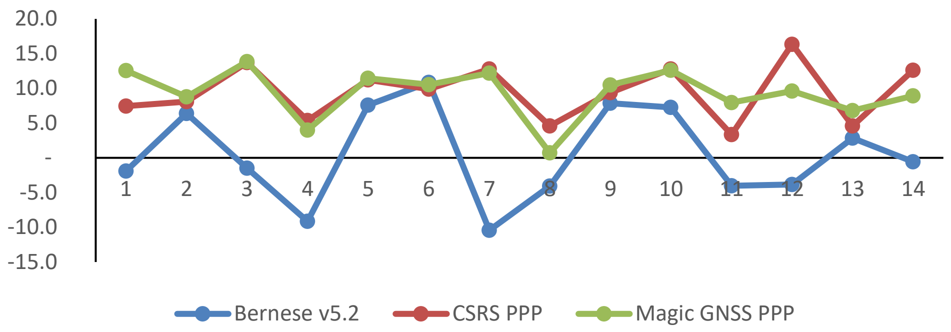

Figure 5. Differences from 2 cm

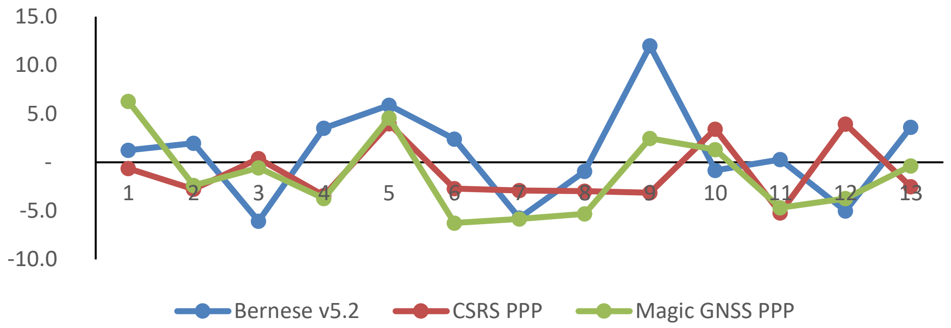

Figure 6. Differences from 3 cm

Figure 7. Differences from 4 cm

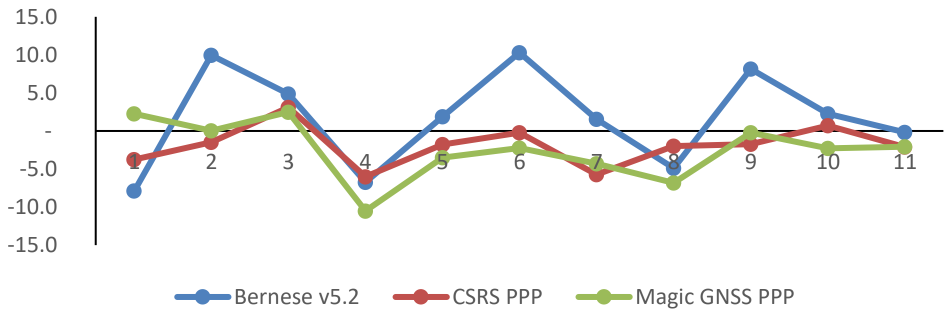

Figure 8. Differences from 5 cm

4. RESULTS

Depending on the technology that has evolved in recent years, it is possible to determine the point locations with a single GNSS receiver in cm / dm accuracy. In this context, PPP technology is being used effectively.

Point positions with PPP technique are determined by both academic software (Bernese v5.2) and web based PPP services. The greatest disadvantage in determining the point locations with the PPP technique is the long measurement durations.

When the Table 3-4 and Figure 4-8 are examined, on a mechanism created, it is aimed to determine the point positions by a PPP method by shifting the GNSS receiver at 1-cm intervals at east-west direction. While raw data were collecting, record interval was selected as 30 seconds and session duration was taken as 24 hours. The raw data were evaluated with Bernese v5.2 GNSS software and Web-based PPP services (CSRS PPP and Magic GNSS). Coordinates obtained after the evaluation were compared with 1 cm, 2 cm, 3 cm, 4 cm and 5 cm differences. In conclusion, it is observed that at 1 cm, 2 cm, 3 cm and 5 cm, the best results were obtained by CSRS PPP, Magic GNSS and Bernese v5.2 GNSS software, respectively. Also for 4 cm, the best results were given by the Magic GNSS method, Bernese v5.2 GNSS software and CSRS PPP, respectively.

5. ACKNOWLEDGMENT

This study was derived from the graduate thesis that had been prepared at Konya Selçuk University, The Graduate School of Natural and Applied Science, Department of Geomatics Engineering by Seyda Gelişkan and entitled as "Determination of Deformations with Precise Point Positioning" and consulted by Prof. Dr. Cevat İNAL.

REFERENCES

Alcaç, S., Yigit, C.O., Ceylan, A., 2013, Comparison of the CSRS-PPP, MagicGNSS and APPS Web Based Software's Static PPP module, Electronic Journal of Map Technologies, Vol: 5, No: 1, 2013 (1-12).

Alkan, R.M., İlçi, V. and Ozulu, İ.M., (2014). Performance Analysis of PPP Technique Using GPS-only and GPS+GLONASS in Urban Environment, Proc. of the Melaha 2014 Resilience Navigation, Alexandria, Egypt.

Anquela, A.B., Martin, A., Berné, J.L. and Padín, J., (2013). GPS and GLONASS Static and Kinematic PPP Results, Journal of Surveying Engineering, 139 (1), 47-58.

Azab, M., El-Rabbany, A., Shoukry, M.N. and Khalil, R., (2011). Precise Point Positioning Using Combined GPS/GLONASS Measurements, Proc. of the FIG Working Week 2011, 18-22 May, Marrakech, Morocco.

Cai, C. and Gao, Y., (2007). Precise Point Positioning Using Combined GPS and GLONASS Observations, Journal of Global Positioning Systems, 6 (1), 13-22.

Chen, J., Xiao, P., Zhang, Y. and Wu, B., (2013). GPS/GLONASS System Bias Estimation and Application in GPS/GLONASS Combined Positioning, Proc. of the China Satellite

Navigation Conference (CSNC) 2013, Lecture Notes in Electrical Engineering 244, DOI:10.1007/978-3-642-37404-3-29, Springer-Verlag, Berlin, Heidelberg.

Collins, P., Lahaye, F., Heroux, P., Bisnath, S., 2008, Precise point positioning with ambiguty resolution using the decoupled clock model. In: Proceedings of ION GNSS 2008, Institute of Navigation, Savannah, Georgia, pp. 1315-1322.

El- Rabbany, A. (2006). Introduction to GPS: The Global Positioning System. 2 nd edition, Artech House Publisher.

Ge, M., Gendt, G., Rothacher, M., Shi, C., Liu, J., 2008, Resolution of GPS carrier-phase ambigutiess in precise point positioining (PPP) with daily observations, J. Geod. 82 (7), 389-399.

Geng, J., Teferle, F.N., Shi, C., Meng, X., Dodson, A.H., Liu, J., 2009, Ambiguity resolution in precise point positioning with hourly data. GPS Solut. 13(4), 263-270.

Kouba, J. (2003). Measuring seismic waves induced by large earthquakes with GPS. Stud Geophys Geod, 47, 741–755.

Kouba, J., Héroux, P. (2001). GPS Precise Point Positioning Using IGS Orbit and Clock Products. GPS Solutions, 5(2), 12-28.

Laurichesse, D., Mercier, F., Berthias, J.P., Broca, P., Cerri L., 2009, Integer ambiguity resolution on undifferenced GPS phase measurements and its application to PPP and satellite precise orbit determination. Navigation 56(2), 135-149.

Li, P., Zhang, X., Ren, X., Zuo, Z., Pan, Y., 2015, Generating GPS satellite fractional cycle bias for ambiguity-fized precise point positioning, GPS solut. http://dx.doi.orf/10.1007/s10291-015-0483-z.

Li, T., Wang, J., Laurichesse, D. (2014). Modeling and quality control for reliable precise point positioning integer ambiguity resolution with GNSS modernization. GPS Soluttions, 18(3), 429- 442.

Li, X.X., Zhang, X.H., 2012, Improving the estimation of uncalibrated fractional phase offsets fo PPP ambiguity resolution, J. Navig. 65(3), 513-529.

Pan, Z., Chai, H., Kong, Y., 2017, Integrating multi- GNSS to improve the performance of precise point psitioning, Advances in Space Research, 60(2017), 2596-2606.

Rizos, C., Janssen, V., Roberts, C. and Grinter, T., (2012). Precise Point Positioning: Is the Era of Differential GNSS Positioning Drawing to an End ?, Proc. on FIG Working Week 2012, 6-10 May 2012, Rome, Italy.

URL-1, CSRS-PPP, https://webapp.geod.nrcan.gc.ca/geod/tools-outils/ppp.php

URL-2, Magic GNSS, https://magicgnss.gmv.com/

URL-3, Bernse GNSS, http://www.bernese.unibe.ch/features/

Yigit, C. Ö., Kizilarslan, M., Caliskan, E., (2016), Evaluating Positioning Performance of Static GPS-PPP and GPS/GLONASS-PPP Methods Based On Observation Durations, Harita Teknolojileri Elektronik Dergisi, e-ISSN: 1309-3983, DOI: 10.15659/hartek.16.03.289 Vol.8, No.1, pp. 22-39.

Zumberge, J.F., Heflin, M.B., Jefferson, D.C., Watkins, M.M. and Webb, F.H., (1997). Precise Point Positioning for the Efficient and Robust Analysis of GPS Data from Large Networks, Journal of Geophysical Research, 102(B3), 5005-5017.

BIOGRAPHICAL NOTES

Mrs. Seyda Geliskan is MSc student at the Selçuk University of Konya. She a BSc from Selçuk (2015), in Geomatics Engineering. Her research interests; PPP, deformation, deformation analysis, GNSS, engineering measurement, surveying technique.
Dr. Cevat INAL is a Prof. Dr. of Geomatics Engineering at the Selçuk University of Konya, Turkey. He has been with Selçuk University since 1981. He completed his PhD study at Yildiz Technical University (1988). He has an MSc from Yildiz Technical University, Department of Geomatics Engineering (1984), and a BSc from Selçuk University (1982), in Geomatics Engineering. His research interests; deformation, deformation analysis, GNSS, engineering surveys, surveying technique.
Mr. Sercan BULBUL is a Research assistant of Geomatics Engineering at the Selçuk University of Konya, Turkey. He has an MSc from Selçuk University, Department of Geomatics Engineering (2013), and a BSc from Selçuk University (2009), in Geomatics Engineering. His research interests; deformation, deformation analysis, GNSS, engineering surveys, MATLAB, surveying technique, Bernese GNSS software, time series analysis, Network-RTK.
Mr. Sercan BULBUL is engineer at Kütahya Environment and Urban Ministry Provincial Directorate, Turkey. He has an MSc from Selçuk University, Department of Geomatics Engineering (2013), and a BSc from Selçuk University (2011), in Geomatics Engineering. His research interests; deformation, deformation analysis, GNSS, engineering surveys, surveying technique, Bernese GNSS software, Network-RTK.

CONTACTS

Seyda Geliskan
Selçuk University Faculty of Engineering
Department of Geomatics Engineering
Konya / TURKEY
Tel. +90 332 223 19 23
Email: seyda.glskn@gmail.com

Cevat Inal
Selçuk University Faculty of Engineering
Department of Geomatics Engineering
Konya / TURKEY
Tel. +90 332 223 19 43
Email: cevat@Selçuk.edu.tr

Sercan Bulbul
Osmaniye Kokurt Ata University Faculty of Engineering
Department of Geomatics Engineering
Osmaniye / TURKEY
Tel. +90 332 223 19 46
Email: sercanbulbul@gmail.com

Ahmet Mete Gunduz
Selçuk University Faculty of Engineering
Department of Geomatics Engineering
Konya / TURKEY
Tel. +90 332 223 19 23
Email: gunduz1989@hotmail.com