TURKGEO
TURKISH JOURNAL OF GEOSCIENCES

ISSN: *2717-7696*
Research Article
Vol; 4, Issue; 1, pp. 29-36, 2023
DOI: *10.48053/turkgeo.1277051*
Journal homepage:
https://dergipark.org.tr/en/pub/turkgeo

Comparison of classical-RTK and network-RTK surveying methods in coastal regions

Şeri Dilan Oğuz*[1], Kemal Yurt [1]

[1]*Aksaray University, Faculty of Engineering, Department of Geomatics Engineering, Aksaray, Turkey*

Keywords
Classic-RTK
Network-RTK
Static

ABSTRACT

Since the beginning of human life, human beings have wanted to know their location, and have therefore tried to find out where they are and where they are going throughout their lives. Researches and inventions that have shaped this situation have followed one another. Throughout history, the methods used to obtain location information have improved day by day, and the possibilities of obtaining precise location information faster with more ergonomic devices have emerged. Recently, the Real Time Kinematics have attracted attention in this respect. In this study, "Comparison of Classical-RTK and Network-RTK surveying methods in Coastal Regions" was conducted in Coastal Regions. For this purpose, 12 point locations were determined by creating two separate study areas in two different regions with an approximate surface area of 3.078 km2 and 1.346 km2 in the coastal region. When a base was created between TUSAGA-Active points namely, N4, N5, N6, IN1, IN2, IN3 were located in the inside and N1, N2, N3, DN1, DN2, DN3 points were located in the outside part of the network structure. Static, Classical-RTK and Network-RTK measurement methods were used at 12 points in the study areas in both regions. First of all, static measurements were made at 12 points were taken into account as a reference values for the comparison of the measurements from both Classical-RTK and Network-RTK methods. The differences of the static measurement values and the measurement values obtained by Classical-RTK and Network-RTK measurement methods were taken respectively. These measurement differences were analyzed and compared in various aspects.

1. INTRODUCTION

When the paths followed to access location information since the past and the researches carried out for this purpose, the methods discovered and developed are examined, engineering applications and geodetic research have become more and more important day by day. One of the most significant developments in this regard has been the Global Positioning System (GPS). Its introduction to civilian use in the 1980s opened up avenues for research in cartography, surveying, geodetic applications, tracking changes in the Earth's crust, vehicle navigation systems, and engineering services (Telli et al., 2014).

Throughout history, the methods used to obtain location information have evolved with each passing day, and this development has tended to obtain faster and more precise location information with more ergonomic devices (Sickle, 2015). Some situations brought about by developing and changing conditions have paved the way for the discovery of new position determination methods and techniques, and the new position determination methods and techniques discovered have been included in Global Navigation Satellite Systems (GNSS) systems (Telli et al., 2014). Classical-RTK (Real Time Kinematic) measurement method is a GNSS measurement method, briefly defined as Classical-RTK, which allows the position information to be obtained in the field at the time of measurement by sending data from the fixed reference receiver in the field to the mobile receiver for measurements and enables precise results to be obtained in a short time (Lachapelle and Ryan, 2002). A limitation of the classical RTK surveying method is that the mobile receiver is dependent on a fixed reference station and there is a limit to the distance to this fixed station. In the light of these ideas, a new positioning method called Network-RTK or also known as CORS (Continuously Operating Reference Station) has been developed to

* **Corresponding Author**

*(serioguz@gmail.com) ORCID ID 0000-0002-9812-6669
(kemalyurt@aksaray.edu.tr) ORCID ID 0000-0002-1029-4052

Received: 04/04/2023; Accepted: 12/06/2023

Cite this article

Oğuz, Ş.D., & Yurt, K. (2023). Comparison of classical-RTK and network-RTK surveying methods in coastal regions. Turkish Journal of Geosciences 4(1), 29-36.

overcome the existing limitations (Raquet, 1998; Landau et al., 2002). Network-RTK has assumed the role of an alternative measurement method by minimizing the limitations of the Classical-RTK measurement method to almost the minimum level (Mekik, 2004). To use this technique, also known as Network-RTK or CORS, many countries have established a network of fixed stations for continuous observation. For the use of this technique in our country, a system called TUSAGA-AKTIF (Turkey National Fixed GNSS Stations Network- Active) or CORS-TR, consisting of 158 fixed reference stations, has been established since 2009 to cover the entire country (Kalkan and Alkan, 2005).

The areas where location information is needed have expanded over time, and cartography activities have become increasingly widespread. Some situations brought about by evolving and changing conditions have initiated searches for new location determination methods and techniques. As a result, newly discovered location determination methods and techniques have been included in GNSS systems (Telli et al., 2014).

Coastal regions in the world can be preferred in many different areas such as tourism, transportation, industry and settlement. This situation is also preferred in our country in the same way and some damages occur at the same time (e.g. unplanned development, destruction of nature, etc.) (Aykut et al., 2005). As a result of changes in the earth's surface, the instantaneous position of any location can be affected by this change and the accuracy of the position can change accordingly.

The satellite-based positioning system, which was initially determined only by the GPS satellite system produced by the United States of America, was later expanded with different satellites accompanying GPS satellites, satellites developed by the leading countries of the world, America, Russia, the European Union, China, Japan and India, and a large GNSS network was created. The satellite systems, called GNSS for short, consist of GPS, GLONASS, GALILEO, COMPASS/BEIDOU, etc. (Cansız, 2013). A large system for location information has been created by developing different artificial satellites that can access location information. Although these developed systems are different, it is likely that they have used similar infrastructures in the same areas since they basically serve the same purpose (Kahveci and Yıldız, 2007). GNSS, in particular GPS, provides ellipsoidal height when used for position determination. Ellipsoidal height is a measure of height calculated relative to the reference ellipsoid. The relation between orthometric height and ellipsoidal height is H=h-N (Yurt, 2005).

There have been many research studies on GNSS measurement methods and techniques from past to present. Some of these are as follows:

1- “Performance of Single Base RTK GNSS Method versus Network RTK” in this study, the Performance of Single-Base RTK GNSS Method against Network RTK is investigated. The CORS-TR network RTK solution was used at the same points and the results were compared The performance tests of the YLDZ station were carried on in two stages.

In the first stage, the coordinates of YLDZ station were determined in the CORS-TR network by real-time measurements using the VRS method. As a result of this measurement, the precision of coordinates and standard deviations of the YLDZ point was calculated in the CORS-TR network system datum. In the second stage, test surveys were carried out in 5 pillar-constructed benchmarks with a 5 repeatability up to 50 kilometers from YLDZ single base station, in distances of 10, 15, 25, 40 and 50 kilometers respectively. As a result of the measurements carried with the CORS-TR network at the benchmark points, the differences between the known and measured coordinates are under 3-4 cm horizontally and vertically. The results of the measurements with 5 repeatability are close to each other at the same benchmark points. The standard deviations of these are near/under 1 cm horizontally and 3-4 cm vertically. The coordinate differences determined by the two RTK solutions were under 1.5 cm with 99% of measured epochs (Aykut et al., 2015).

2- In a different study, locations of the points in 10 regions with thirty points each determined in two different ways, using only GPS satellites and GPS, GLONASS satellites. Measurement results of 300 points located in different regions, comparison was made as a whole. The average errors were found to be between ±2.21 cm ±7.81 cm. The highest differences were observed in heights (Inal et al., 2015).

3- Another example of a study is the usability of GNSS mass market receivers for cadastral surveys, considering RTK and NRTK techniques. For this, 4 different areas were identified and 16 points two different techniques have been investigated: the RTK single-base positioning considering both master and rover L1 multi constellation receivers and the NRTK positioning using the VRS and NRT corrections. Considering the same points used for single-base positioning, the NRTK survey has been done using the VRS correction. 16 points have been considered in four different areas, along different boundaries of cadastral parcels, performing a single-base RTK survey. The mass-market master device has been placed on well-known point about 1, 3, 5, 8 and 10 km far from the rover site. It has been observed that if the distance between the main and roving receivers is less than 5 km, a single-base methodology can be exploited, while if the distance inter-station increases, it is better to use NRTK positioning if a CORS network is available (Dabove, 2019).

4- Statistical analysis of accuracy and precision of GNSS receivers used in network RTK, another example of a study called, accuracy and precision of GNSS receivers are tried to determine depending on different correction techniques. For this purpose, 12-h GNSS observations were performed at SLCK-Turkish National Fundamental GPS Network (SLCK-TNFGN) point. The observations were adjusted based on CORS-TR. N-RTK measurements were performed with different GNSS receivers, and accuracies of the receivers were investigated.

Measurements were performed by using four different GNSS receivers and three different correction techniques at the SLCK-TNFGN point located in Selçuk University Campus Area. In the measurements, the same survey team, the same atmospheric conditions and the same satellite configuration were used. A comparison was made in terms of accuracy and precision at the 2D position and the height of the receivers used. The 2D position accuracy and precision of the receivers were found to vary depending on the height correction techniques (Inal et al., 2018).

In geodetic studies, Classical-RTK and Network-RTK (CORS) measurement methods are almost exclusively used for ease and speed of processing. Investigations of the location accuracies obtained by these methods were carried out in the inner regions of the network of TUSAGA-Active points, but not in the edges. In this study, measurements were made at the edges of the network and the accuracy between Classical-RTK and Network-RTK was investigated.

2. REAL-TIME KINEMATIC MEASUREMENT METHOD (RTK)

Previously, the information obtained as a result of measurements made using Static and Real-Time Kinematic measurement methods could only be used by evaluating it in various software. This is not the case for every study, and some studies in particular required instantaneous location data at the moment of measurement in the field (Leick, 1995).

2.1. Classical-RTK

In the classical-RTK method, the fixed GNSS receiver at the reference station transmits the error corrections calculated at the fixed point to the roving receiver over radio frequency between the fixed GNSS receiver and the roving GNSS receiver. GNSS rover-receivers that receive the correction in this way can instantly display the coordinates of each point to be located on the GNSS receiver screen during the measurement (Sezer, 2008). In the classic-RTK surveying method, the distance between the reference station and the rover GNSS receiver varies up to 10-15 km in order to obtain precise measurement results (Kahveci, 2009; Mekik and Arslanoğlu, 2003).

2.2. Network-RTK

The constantly evolving and changing world of technology has positively affected and promoted the GNSS measurement methods. To this end, a large number of research have been conducted with the aim of removing the mandatory constraints of the previous methodology. One of these research was carried out to diminish the limitations of the Classical-RTK namely the Network-RTK or network supported real-time kinematic measurement method was introduced. Obvious the Network-RTK technique was developed based on the idea of creating a network of many fixed reference stations for this purpose (Raquet, 1998).

How the Network-RTK system works: quickly resolve phase ambiguity and calculate atmospheric corrections and coordinate corrections to rover receivers with appropriate data transmission methods. Receiving these corrections, the rover receiver determines the precise point locations (Kahveci, 2009).

3. TUSAGA-ACTIVE

Turkey National Basic GNSS Stations Network-Active (TUSAGA-AKTIF), also known as CORS-TR, is carried out as an R&D project supported by TÜBITAK in partnership with the General Directorate of Land Registry and Cadastre and the General Directorate of Maps (HGM), was initiated in 2006. Within the scope of this project, 158 fixed GNSS stations were established throughout Turkey and the Turkish Republic of Northern Cyprus. When communication facilities are available, location information is obtained within seconds at a random place and time (Url-1).

This project is specifically targeted at areas where location information will be needed to design and implement projects for the development of residential areas;

- Cadastral and cartography studies
- Infrastructure and superstructure services
- Execution and management of spatial projects
- Making meteorological forecasts
- Geographic Information Systems (GIS) studies
- Urban Information Systems studies etc.

It is expected that the TUSAGA-Active project, developed by using the possibilities of technology in cases where its use is mandatory in land and land-oriented studies in similar areas, will provide services for obtaining location information quickly and with high accuracy (Uzel and Eren, 2008).

4. METHOD

A research was conducted for "comparison of Classical-RTK and Network-RTK Surveying Methods in Coastal Regions". For this, two separate study areas were established in two different regions. These two areas of work are also divided into internal and external parts. The locations of

TUSAGA-AKTIF fixed stations were used to determine the point locations. Triangular closed areas were created from these fixed stations in two different regions. The closed areas created by utilizing the fixed CORS-TR stations AYD2-DIDI-MUG1 (Figure 1) and FETH-KAAS-FINI (Figure 2) were characterized as first study area and second study area, respectively. The first region has an area of approximately 3,078 km^2 and the second region has an area of approximately 1,346 km^2. A total of 12 points were located in both study areas, 3 points in the interior and 3 points in the exterior of the closed areas (Figure 3) and (Figure 4). While determining the locations of the points, it was taken into consideration that their distance from each other was approximately 1 km or more.

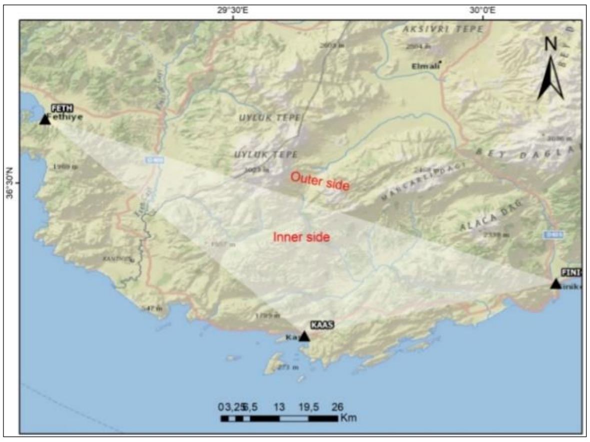

Figure 1. First study area.

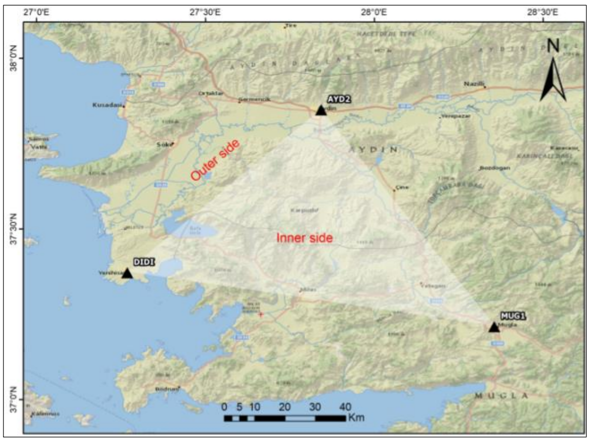

Figure 2. Second study area.

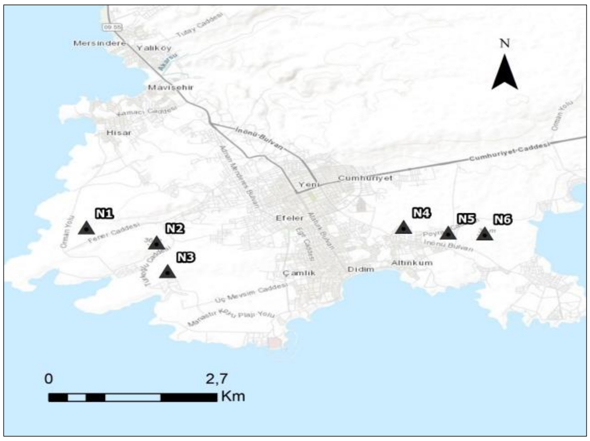

Figure 3. Six points in the first study area.

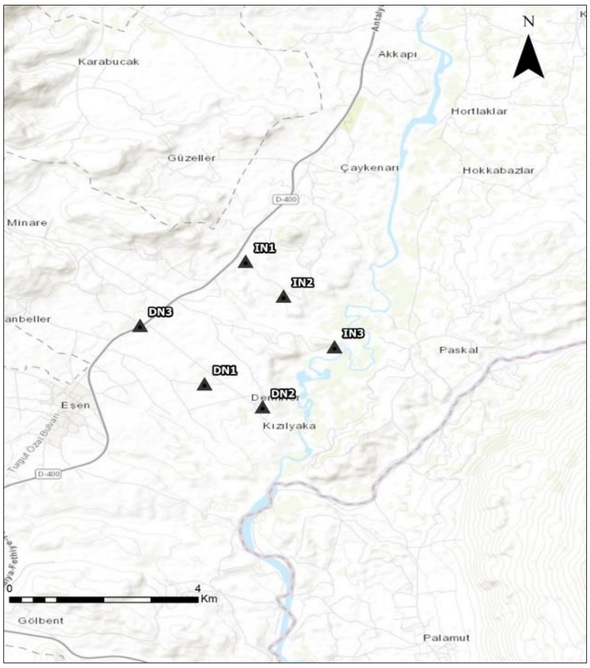

Figure 4. Six points in the second study area.

5.1. Static Measurement

In order to determine the precise position information of 12 points located in Aydın-Didim and Muğla-Fethiye regions, data were collected with two different Topcon GNSS receivers on October 29.2022 and September 11.2022 by first performing static measurement sessions at these points. Approximately 1.5 hours of static measurement was performed at each measurement point. The first static measurement session in this study area was carried out at point N4 between 11:31-13:28 hours (Figure 5).

Figure 5. An image from a static measurement.

5.2. Classical-RTK and Network-RTK Measurement Methods

Classical-RTK and Network-RTK surveying methods were used at 12 points in the study areas in both regions. The measurements made at 12 points with Classical-RTK and Network-RTK measurement techniques were completed with a data collection interval of 1 s and fifteen epochs. A fixed GNSS receiver was installed at 3 of the (N3, N4, DN1) 12 points whose precise coordinates were determined by static surveying method, and the fixed receiver was connected to the mobile receiver simultaneously and the Classical-RTK measurement was performed (Table1) and (Table2).

Table 1. Coordinate values of 6 points in the first study area obtained by the Classical-RTK measurement method.

Point Id	Easting (Y)	Northing (X)	Ellip. Height (Z)
N1	519159.0590	4135831.9770	37.5080
N2	520607.0830	4135409.1170	36.7290
N3	520833.0480	4134594.3495	38.6980
N4	525678.6957	4135861.6737	54.2300
N5	526600.5310	4135701.4700	40.2340
N6	527349.1280	4135682.5350	35.7950

Table 2. Coordinate values of 6 points in the second study area obtained by the Classical-RTK measurement method.

Point Id	Easting (Y)	Northing (X)	Ellip. Height (Z)
IN1	438846.1800	4039560.8040	124.2100
IN2	439488.5110	4038782.4410	124.4430
IN3	440346.8870	4037649.3410	100.5280
DN1	438121.3946	4036838.5625	111.2580
DN2	439111.4010	4036317.5700	107.8650
DN3	437030.8800	4038148.8340	133.1810

By connecting to the TUSAGA- AKTIF system, which has actively used in Turkey, Network-RTK measurements were made at 12 points in the study areas in the two regions on October 29, 2022 in the first study area (Table 3) and August 11, 2022 in the second study area (Table 4). With the Network-RTK measurement method, measurements were made at 12 points with a recording interval of 1 s, 15 epochs and an elevation angle of 10°.

Table 3. Network-RTK measurement values of 6 points in the first study area.

Point Id	Easting (Y)	Northing (X)	Ellip. Height (Z)
N1	519158.9710	4135832.2130	37.720
N2	520606.8410	4135409.3760	36.940
N3	520832.9120	4134594.5530	38.874
N4	525678.5990	4135861.8960	54.451
N5	526600.4320	4135701.7410	40.434
N6	527348.9500	4135682.7240	36.005

Table 4. Network-RTK measurement values of 6 points in the second study area.

Point Id	Easting (Y)	Northing (X)	Ellip. Height (Z)
IN1	438845.9130	4039560.8810	124.399
IN2	439488.2840	4038782.5020	124.418
IN3	440346.7100	4037649.3980	100.537
DN1	438121.2000	4036838.6590	111.414
DN2	439111.2620	4036317.6980	107.488
DN3	437030.6890	4038148.8790	133.197

5.3. Processing of Static Measurement Data

The process of evaluating and adjusting the static measurement data consists of three stages. These are;

- Transferring the data collected by static measurement method to the computer,
- Data conversion to The Receiver Independent Exchange Format (RINEX) format and reorganization according to point names,
- Evaluation and stabilization in Leica Geo Office 7.0 software.

The GNSS measurement evaluation for the application in both regions was made in Leica Geo Office 7.0 software as 2 different projects for each study region. As a result of the process, the precise location coordinates of 12 points in the study areas in both regions were obtained.

5.4. Comparison of Classical-RTK and Network-RTK Measurement Methods

With the reference coordinate values determined as a result of adjustment of the static measurement values in the study areas in both regions the differences of the measurement results obtained by Classical-RTK and Network-RTK measurement methods were taken respectively. In this study, the difference (delta H) of the values obtained with Classical-RTK and Network-RTK with Static measurements was analyzed. As the N geoid heights of the points are the same in all three measures, there will be no effect when the differences are taken. Therefore, ellipsoidal heights were used in this study. The location information obtained at each point is indicated as position in Easting (Y), Northing (X) and Height (Z), and the measurement differences are indicated as Δy, Δx, Δz. The mathematical values of the measurement differences were accepted in absolute value and accordingly, the average of the determined measurement differences were taken and analyzed. Since N3, N4 and DN1 points were taken as fixed points in Classical-RTK measurements, they were not subjected to the comparisons made for Classical-RTK measurement method. Some analyzes were made as follows;

- With adjusted static measurement results of 6 points in the first study area the differences of measurement results obtained by classical-RTK measurement method (Table 5).
- With adjusted static measurement results of 6 points in the second study area the differences of measurement results obtained by Network-RTK measurement method (Table 6).
- With adjusted static measurement results of 6 points in the second first area differences of measurement results obtained by classical-RTK measurement method (Table 7).
- With adjusted static measurement results of 6 points in the second study area differences of measurement results obtained by Network-RTK measurement method (Table 8).
- Differences between the results of the adjusted static measurements of 6 points located in the inner part of both study areas and the results obtained by the Classical-RTK surveying method (Table 9).
- Differences between the results of the adjusted static measurements of 6 points located in the inner part of both study areas and the results obtained by the Network-RTK surveying method (Table 10).

Table 5. Static and Classical-RTK measurement differences of 6 points in the first study area.

Point Id	Δy	Δx	Δz
N1	0.0778	0.0987	0.1639
N2	-0.0768	-0.0059	0.0103
N3	0.0000	0.0000	0.0000
N4	0.0000	0.0000	0.0000
N5	0.0608	0.0195	0.0127
N6	-0.0668	-0.0177	0.1740

Table 6. Static and Network-RTK measurement differences of 6 points in the first study area.

Point Id	Δy	Δx	Δz
N1	0.1658	-0.1373	-0.0481
N2	0.1652	-0.2649	-0.2007
N3	0.1360	-0.2035	-0.1764
N4	0.0967	-0.2223	-0.2215
N5	0.1598	-0.2515	-0.1873
N6	0.1112	-0.2067	-0.0360

Table 7. Static and Classical-RTK measurement differences of 6 points in the second study area.

Point Id	Δy	Δx	Δz
IN1	-0.0395	-0.0305	-0.0074
IN2	-0.0388	-0.0356	-0.0156
IN3	0.0136	-0.0296	-0.0151
DN1	0.0000	0.0000	0.0000
DN2	0.0570	0.0463	-0.0293
DN3	-0.0086	-0.0598	-0.0179

Table 8. Static and Network-RTK measurement differences of 6 points in the second study area.

Point Id	Δy	Δx	Δz
IN1	0.2275	-0.1075	-0.1964
IN2	0.1882	-0.0966	0.0094
IN3	0.1906	-0.0866	-0.0241
DN1	0.1946	-0.0965	-0.1557
DN2	0.1960	-0.0817	0.3477
DN3	0.1824	-0.1048	-0.0339

Table 9. Static and Classical-RTK measurement differences of 6 points located in the interior of both study areas.

Point Id	Δy	Δx	Δz
N4	0.0000	0.0000	0.0000
N5	0.0608	0.0195	0.0127
N6	-0.0668	-0.0177	0.1740
IN1	-0.0395	-0.0305	-0.0074
IN2	-0.0388	-0.0356	-0.0156
IN3	0.0136	-0.0296	-0.0151

Table 10. Static and Network-RTK measurement differences of 6 points located in the interior of both study areas.

Point Id	Δy	Δx	Δz
N4	0.0967	-0.2223	-0.2215
N5	0.1598	-0.2515	-0.1873
N6	0.1112	-0.2067	-0.0360
IN1	0.2275	-0.1075	-0.1964
IN2	0.1882	-0.0966	0.0094
IN3	0.1906	-0.0866	-0.0241

When the network data consisting of CORS-TR points are balanced, the error ellipses at the points on the edges will be higher than the error ellipses at the points inside the network. In the classical-RTK method, the error will increase as you move away from the reference point. Considering this situation, the highest difference between the two measurements may be due to the fact that the measurements were made on the coasts where there is no TUSAGA-AKTIF point in the south and west directions.

6. CONCLUSIONS

In this study, the locations of the points were determined precisely depending on the geographical features and conditions in the coastal area, also paying attention to the distances of the points from each other. Static, Classical-RTK and Network-RTK measurements were carried out at 6 points in a study area of about 307 hectares in Didim district and at 6 points in a study area of 131 hectares between Fethiye and Kaş. Measurement points N3, N4 and DN1 were not subjected to comparison since they were taken as fixed points in Classical-RTK measurements.

When the coordinate differences of the N1, N2, DN2, DN3 measurement points located in the outer part of both study areas are examined, it is seen that the largest difference in the easting for Classical-RTK is 0.0778 m, the smallest difference is 0.0086 m, the average difference is 0.0123 m, the largest difference in the northing is 0.0987 m, the smallest difference is 0.0059 m, the average difference is 0.0198 m and the largest difference in the height is 0.1639 m, the smallest difference is 0.103 m, the average difference is 0.0318 m.

The coordinate differences of the points located in the outer part of both study areas, N1, N2, N3, DN1, DN2, DN3 measurement points for the Network-RTK, the largest difference in the easting is 0.1960 m, the smallest difference is 0.1360 m, the average difference is 0.1733 m, the largest difference in the northing is 0.2649 m, the smallest difference is 0.0965 m, the average difference is 0.1481 m and the largest difference in the height is 0.3477 m, the smallest difference is 0.0339 m, the average difference is 0.0445 m.

When the coordinate differences of N5, N6, IN1, IN2 and IN3 measurement points located in the inner part of both study areas are examined, it is seen that the largest difference in the easting is 0.0668 m, the smallest difference is 0.0136 m, the average difference is 0.0141 m, the largest difference in the northing is 0.0356, the smallest difference is 0.0177 m, the average difference is 0.0188 m and the largest difference in the height is 0.1740 m, the smallest difference is 0.0074 m, the average difference is 0.0297 m.

When the coordinates of the N5, N6, IN1, IN2 and IN3 measurement points located in the inner part of both study areas are analyzed, it is seen that the largest difference in the easting for the Network-RTK is 0.2275 m, the smallest difference is 0.0967 m, the average difference is 0.1623 m, the largest difference in the northing is 0.2515 m, the smallest difference is 0.0866 m, the average difference is 0.1619 m and the differences in the height are 0.2215 m, the smallest difference is 0.0094 m, the average difference is 0.1093 m.

According to these results, it is understood that the measurement values obtained with the Classical-RTK measurement method are mostly closer to the static measurement values and in general, the results obtained with the Classical-RTK measurement method are better than the results obtained with the Network-RTK measurement method.

Acknowledgement

This article was produced from Şeri Dilan OĞUZ's MSc thesis.

Author Contributions

Şeri Dilan Oğuz: Methodology, Software, Validation, Formal analysis, Writing-Original Draft, Visualization. **Kemal Yurt**: Supervision, Writing-Original Draft.

REFERENCES

Aykut, N.O., Gülal, E., & Akpinar, B. (2015). Performance of single base RTK GNSS method versus network RTK. *Earth Sciences Research Journal*, 19(2), 135-139.

Aykut, N.O., Doğan, U., Ata, E., & Arı, A. (2005). Determination of Coastline with GPS, The Case of Karaburun. *2nd Engineering Surveying Symposium, November* 23-25, Istanbul, Turkey.

Cansız, Y. (2013). The effect on location precision of the satellite elevation angle and number of epoch at network RTK applications (MSc thesis). Yıldız Technical University, Istanbul, Turkey (in Turkish).

Dabove, P. (2019). The usability of GNSS mass-market receivers for cadastral surveys considering RTK and NRTK techniques. *Geodesy and Geodynamics*, 10(4), 282-289.

Inal, C., Bulbul, S., & Bilgen, B. (2018). Statistical analysis of accuracy and precision of GNSS receivers used in network RTK. *Arabian Journal of Geosciences,* 11, 1-8.

Inal, C., Gündüz, A.M., & Bulbul, S. (2015). Comparison of Classic-RTK and Network-Rtk Methods. *Selcuk University Journal of Engineering*, Science and Technology, 2(2), 21 - 30.

Kahveci, M., & Yıldız, F. (2007). GPS (Global Positioning System). *Nobel Publication Distribution*, 3rd Edition, 1-215, Ankara Turkey.

Kahveci, M. (2009). Kinematic GNSS and RTK CORS Networks. *1st Edition Zerpa Publication*, Ankara, Turkey.

Kalkan, Y. & Alkan, R.M. (2005). Deformation Measurements in Engineering Structures. *Engineering Surveying STB Commission 2nd Engineering Surveying Symposium*, 64-74 Turkey.

Lachapelle, G., & Ryan, S. (2002). Servicing the GPS user, Chapter 14 in Manual of Geospatial Science and Technology, J. Bossler, J. Jenson, R. McMaster & C. Rizos.

Landau, H., Vollath, U., & Chen, X. (2002). Virtual reference station systems. *Journal of Global Positioning Systems*, 1(2), 137-143.

Mekik, Ç., & Arslanoğlu, M. (2003). 'Accuracy Analysis of Real-Time Kinematic GPS Locations and a Sample Application. *9th Turkish Map Scientific and Technical Congress*, March 31 - April 04, 2003, 549-558, Ankara, Turkey.

Mekik, Ç. (2004). Positioning with Real Time Kinematic GPS Network (Network RTK). *TUJK-Engineering Surveys Geodetic Networks Workshop, Session IV*, 202-207, October, Zonguldak, Turkey.

Raquet, J. (1998). Development of a Method for Kinematic GPS Carrier-Phase Ambiguity Resolution Using Multiple Reference Receivers (PhD thesis). University of Calgary, Calgary Canada.

Sezer, S. (2008). Organizing the data of static GPS stations in the computer and designing a database and web page to present in internet (MSc thesis). Selçuk University, Konya, Turkey (in Turkish).

Sickle, V.J. (2015). GPS for Land Surveyors, 4th Edition, CRC Press Inc., Boca Raton, Florida, USA.

Telli, A.K., Pırtı, A., & Hoşbaş, R.G. (2014). Next Generation Surveying System and the Evric GNSS. *Journal of Geoinformation and Land Management* 101,2.

Uzel, T., & Eren, K. (2008). Establishment of National Cors System and Datum Conversion Project. *TUSAGA-AKTİF (CORS-TR) 3rd Workshop* November 28-29, Turkey.

Yurt, K. (2005). Local geoid determination and modeling by geometric and gravimetric methods: Case study for Trabzon municipilaty (PhD thesis). Karadeniz Technical University, Trabzon, Turkey (in Turkish).

Url-1: https://www.tusagaaktif.gov.tr/Web/SSS_Teknik.aspx (last accessed 27 February 2023)