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Effect of broadcast & precise ephemeris and GPS & GPS+GLONASS use on evaluation accuracy in commercial software

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ABSTRACT

The data obtained from the GPS system is made meaningful by means of software. The software used today is divided into academic, web-based and commercial software. Researches generally focus on academic software and web-based services that have become widespread in recent years. Commercial software is often used by daily users, mostly in classical geodesy. These softwares differ from each other; users, their purpose of use, processing methods, accuracy, users knowledge level etc. Global Positioning System (GPS), which has entered every aspect of human life since its first appearance, has become widespread with the introduction of other systems (GLONASS, BEIDOU, QZSS, IRNSS etc.). Today, the common name of all systems, Global Navigation Satellite Systems (GNSS) continue to exist in our lives. Various studies have attempted to determine the GPS position accuracy, especially from the day it existed in order to determine the accuracy depending on base length and session duration. Both the development of the satellite systems, the increase in the variety and the products that provide services for GNSS systems (IGS, CODE, JPL, etc.) have contributed positively on position accuracy. When the system was first released, changes and innovations continued inevitably in measurement methods, estimation methods and software applied for positioning. In this study, it was tested whether the use of GPS+GLONASS data together and precise ephemeris which is the product of IGS makes a significant contribution to baseline processing accuracy in commercial software Topcon Magnet (Ver 4.0.1). In the first experiment, 16 stations and 8 bases were determined from 1 to 100 km around California, USA. In the second experiment in Turkey near Istanbul in the Marmara region 16 bases in 15 km from the 106 kilometers of the base distance (Turkey-CORS system and of ISKICORS stations) were determined. The experiments were conducted in a 10-day data interval (1, 2, 3, 4, 6, 8, 12 and 24 hour sessions). With commercial software Topcon Magnet (Ver 4.0.1), it was found that the use of broadcast and precise efemeris in baseline processing had no effect on base solution results, and the results of both solutions were very close to each other. It is considered that a user using commercial software does not need to wait 2 weeks for the precise ephemeris to be published to evaluate the data obtained. In the second experiment, if only the data collected from the GPS or GPS + GLONASS system were included in the evaluation process, no significant difference was found when the standard deviations of the obtained results (based on the base distance and observation time) were examined.

Keywords: GPS, GLONASS, broadcast ephemeris, precise ephemeris, commercial software, Topcon magnet.

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INTRODUCTION

Various studies have attempted to determine the GPS position accuracy, especially from the day it existed. Eckl et al. (2001) showed that GPS-derived relative position sensitivity is a function of distance between stations and observation time. They conducted the experimental study with the PAGES software, where the base distance was

26 to 300 km and the observation time was 4 to 24 hours with 10-day data of 1998 and for n (North), e (East), u (Up) components and calculated the formulation. Eckl et al. (2001) similar studies to other researchers Dong and Bock (1989), Larson and Agnew (1991), Feigl et al. (1993) produced experimental formulation. In their study, they investigated the effect of distance when the base distance was less than 500 km (L < 500 km) during 7-hour session periods. Observations of Dong and Bock (1989), Larson and Agnew (1991) and Feigl et al. (1993) were carried out before 1992 and with the existing GPS system, a maximum observation time of 7 hours was possible. Betti et al. (1999) conducted different experiments on GPS sensitivity and accuracy for deformation control. Soler et al. (2005), 5 USA CORS stations used OPUS (Online Positioning Service) on June 30, 2004 for 30-day observation data with sub-1, 2, 3 and 4-hour observations on location accuracy based on observation time. Presented a prediction function similar Eckl et al. (2001) to the experimental formula. Häkli et al. (2008), in their study, where GPS positioning accuracy was evaluated in 2008 based on interstation distance and observation time, evaluations for 2003-2005 for 10 to 24 hours observation time from 0.6 km to 1069 km on 10000 baselines processed with Trimble Total Control commercial software. They have developed formulas on distance and observation time, and accuracy that can be achieved in the case of broadcast or precise ephemeris. They have made comparisons with previous studies. Contrary to other results, short-term observations have shown that accuracy depends on distance in their own experimental results. Şanlı and Engin (2009) In their studies on the accuracy of GPS positioning in over-regional areas in 2009. Geng et al. (2010), they investigated the 7-day data of 12 stations in Europe for the PPP strategy for shortest observation periods (1, 2, 3 and 4) and optimal solution of ambiquity. They observed that they could reach the millimeter accuracy required for engineering applications with at least 3 hours of observation. Tiryakioğlu et al. (2010) investigated the effects of number and duration of observations on positioning accuracy in measurement campaigns in 2010 to determine tectonic movements. According to the results obtained with the GAMIT/GLOBK software, it is necessary to perform at least 8 hours and repeated observations. Öztürk and Şanlı (2011) combined the two studies in 2011 and evaluated the accuracy of GPS position determination as a sensitive function both on a regional and global scale with GIPSY software on baselines from 3 km to 3000 km and compared the results. Şanlı and Kurumahmut (2001) in the test network in the USA in 2011, 26 baselines were kept constant around 10 km and the difference in height varied from 50 meters to 1500 meters depending on the duration of the GPS observations (1, 2, 3, 4, 6, 8, 12 and 24 h). Firuzabadi and King (2012), the distribution of reference stations and the effect of GPS positioning on the accuracy of the determination of the location of the 31-day data for 2006, 1, 2, 3, 6, 12 and 24-hour observation files and 26 to 585 km and GAMIT/GLOBK software at 2 to 16 reference stations. El-Mowafy (2011) AUSPOS and CSRS-PPP tested the static processing results of the services. AUSPOS mm-cm, CSRS-PPP dm level with a accuracy can be achieved, he said. Rapinski and Cellmer (2011) tested the performance of ASGEUPOS, AUSPOS and APPS services. AUSPOS and APPS for a no restriction, but good results with ASG-EUPOS more than 720 epoch in order to be able to determine that they need. Jha et al. (2016) compared and interpreted the results of GPS online assessment services (OPUS and AUSPOS). Tariq et al. (2017) compared and interpreted the results of GPS online evaluation services (OPUS and AUSPOS) and Leica Geo Office commercial software on a short basis in a fast static method. Isioye et al. (2019) compared and interpreted the results of GPS web-based services on the test network (NIGNET) in Niger.

Most of the research done so far is based on evaluations made with academic software or web-based services. Of course, the results obtained with academic software are closest to the ideal because evaluation strategies take into account a lot of extra effects. On the other hand web-based servises use generally academic software on its backround. Studies on the accuracy of GNSS (Global Navigation Satellite Systems) solutions produced with commercial software have been limited to date. Observation times, interstations distances and height differences were also limited in the applications. Daily users (classic geodetic measurements, engineering measurements etc.) mostly use commercial software.

Nowadays, it has been shown that the accuracy of GPS varies depending on the observation time. However, for this to happen; ambiguity should be solved, IGS (International GNSS Service) precise ephemeris should be used and atmospheric effects between the base points should be eliminated.

In this study, the use of Broadcast & Precise ephmeris and observation data (depending on base distance and observation time) obtained from GPS and GPS & GLONASS (Global Navigation Satellite System or Globalnaya navigatsionnaya sputnikovaya sistema) systems with TOPCON MAGNET (Ver 4.0.1) (TOPCON Company Commercial Software) commercial software were tested and interpreted. It was aimed to make practical comments for daily users.

With experiment-1 and experiment-2 to compare the results obtained in the United States and Turkey achieved and intended to be interpreted in terms of daily users.

STUDY AREA AND BASELINES

The stations and bases used in the application are consist of the California Spatial Reference Center (CSRC) and IGS network stations which are continuously monitoring the USA National Geodesy Network. The California

Spatial Reference Center (CSRC) is responsible for "Establishing and maintaining an accurate state-of-the-art network of GPS control stations for a reliable spatial reference system in California." The CSRC was established in 1997 as a partnership with surveyors, engineers, GIS professionals, the National Geodetic Survey (NGS), the California Department of Transportation (Caltrans), and the geodetic and geophysical communities. Stations (16 units), bases (8 bases), base distances and height differences between stations determined for the first application are presented in Figure 1 and Table 1.

In the second part of the application, the data obtained from GPS and GPS+GLONASS systems are evaluated and interpreted in commercial software. Identified stations (15 to 16 base stations) in the Marmara region, Turkey, is located near Istanbul. The distance between the stations is 0 to 100 km and the difference in height between stations is provided to be 122 meters. These stations are located in TKGM-CORS (Turkey National CORS Network) and ISKI-UKBS (Istanbul Municipality's Local CORS Network) network.

The determined stations, bases, base distances and elevation differences between stations are as presented in Figure 2 and Table 2.

It was carried out together with the determination of the data for which day of the year at the stations determined. Even if more suitable bases were identified, there was no data for the common day, so we had to change several times. www.solarham.net, www.ncdc.noaa.gov and www.gfz-potsdam.de internet web sites and services were used to determine the most suitable day.

Days 4 to 13 of December 2012 (338 to 347 GPS days; 10 days) were determined because there is common data for all stations and the ionosphere activity is minimum in order to create ideal conditions (Figure 3).

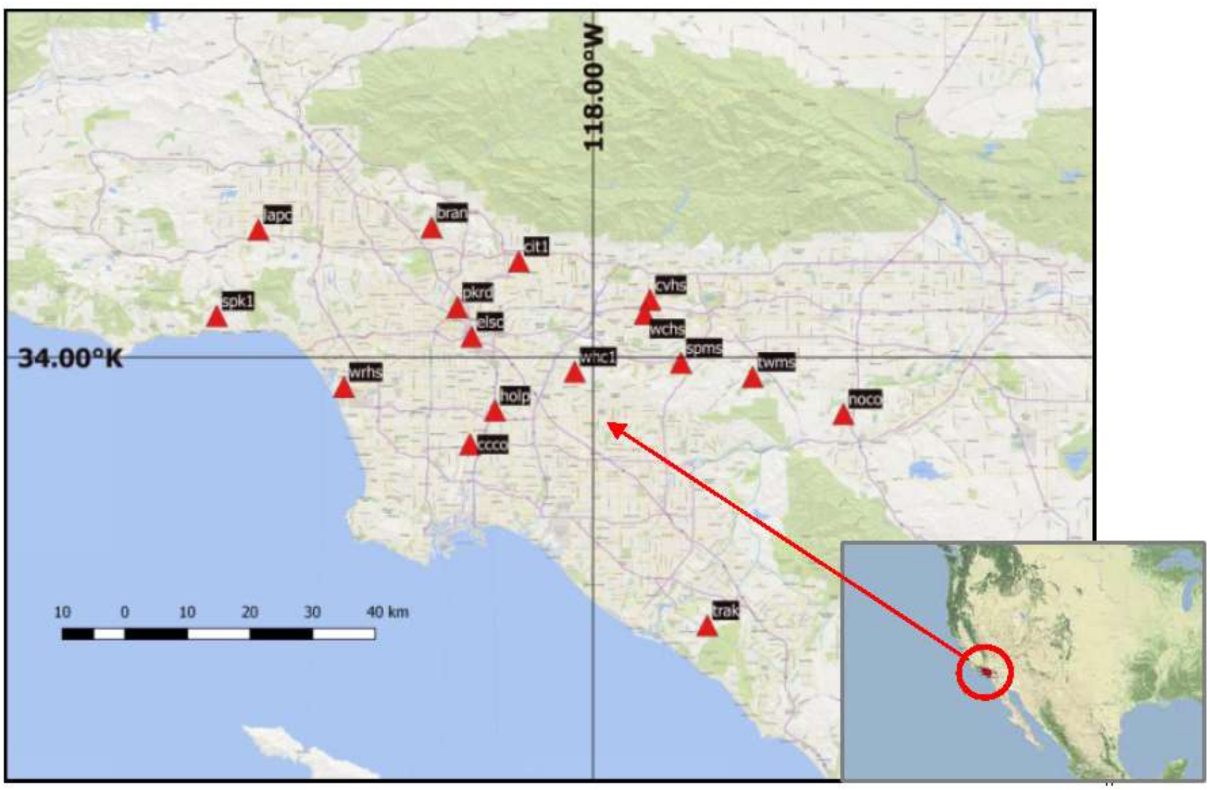

Figure 1. Stations determined for Experiment-1 and their distributions.

Table 1. Determined based on increasing baseline distance for experiment-1.

No	Baseline	Base.Length (km)	Height Diff. (m)	No	Baseline	Base.Length (km)	Height Diff. (m)
1	CVHS-WCHS	1.55	19	5	BRAN-SPMS	41.28	39
2	HOLP-CCCO	4.74	10	6	TRAK-WRHS	61.53	108
3	ELSC-CIT1	9.93	154	7	TWMS-LAPC	79.45	0
4	WHC1-PKRD	19.47	37	8	SPK1-NOCO	99.83	253

Figure 2. Stations determined for Experiment-2 and their distributions (Sile and Pala stations).

Table 2. Bases determined for the 2nd experiment.

No	Baseline	Base.Length (km)	Height Diff. (m)	No	Baseline	Base.Length (km)	Height Diff. (m)
1	BEYK-PALA	15	69	9	KCEK-SLVR	59	15
2	KCEK-PALA	18	48	10	KCEK-YALI	66	36
3	BEYK-KCEK	33	21	11	PALA-YALI	71	84
4	TERK-YALI	37	39	12	BEYK-YALI	75	15
5	PALA-TUZL	40	115	13	SILE-TERK	80	32
6	BEYK-SILE	44	22	14	BEYK-SLVR	85	37
7	SILE-TUZL	48	24	15	ISTN-SARY	92	122
8	SLVR-TERK	55	90	9	KCEK-SLVR	59	15

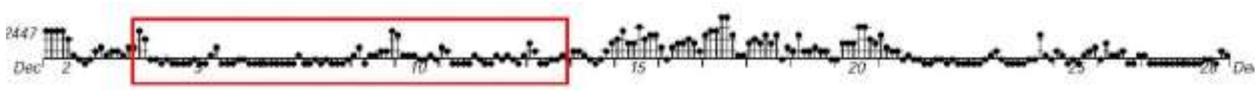

Figure 3. 2012 December 4 to 13 Days KP Index Chart (www.gfz-potsdam.de).

According to the weather information received from weatherspark.com, it is determined that the weather is in the normal season and there is no extreme situation. In the 10-day data set for our study (4 to 13 days of December 2012), it was determined that ionospheric activity was at a minimum (Figure 3) and tropospheric activities were at seasonal normals. The aim of this study is to provide a clear indication of the GPS baseline solution accuracy of commercial software with minimal atmospheric effects on GPS observations. On the other hand, the high standard of the stations (IGS) used in the study, environmental impacts (Multipath, no signal interfering obstacles, etc.) and user errors (antenna installation, antenna height measurement errors, etc.) on the observation results have been very low or even negligible. Thus, it is aimed to clearly demonstrate the accuracy of experiment-1 (Broadcast and Precise ephemeris), experiment-2 (GPS and GPS+GLONASS) base solution results of commercial software.

GNSS DATA ANALYZE

SOPAC, The Scripps Orbit and Permanent Array Centre, serves as data archive for SCIGN (The Southern California Integrated GPS Network). SOPAC archives

GPS site RINEX (Receiver Independent Exchange Format) files each day for SCIGN and other regional GPS networks. SOPAC is an International GNSS Service (IGS) Global Data Centre and provides and calculates other IGS products such as polar motion, precise satellite orbits and Earth rotation variations. SOPAC generates time series of daily three-dimensional positions for the global permanent GNSS stations with respect to the ITRF (International Terrestrial Reference Frame). We used SOPAC browsers at http://sopac.ucsd.edu/ to download the GPS data of the permanent GPS stations used in experiment-1. The locations of the permanent GPS stations used in this study are shown in Figure 1 and Table 1.The GPS data was obtained in the RINEX format and sampled with 30 second recording intervals and 15 degree elevation cut-off angle.

The stations presented in Figure 2 and Table 2 were obtained from TKGM-CORS and ISKI-UKBS web service. The GPS data was obtained in the RINEX format and sampled with 15 degree elevation cut-off angle and 30 second recording intervals.

Observation files were downloaded from SOPAC, TKGM-CORS (https://www.tusaga-aktif.gov.tr/) and ISKI-UKBS (https://ukbs.iski.gov.tr/) archives. Each observation data was subdivided into mutually none-overlapping 1, 2, 3, 4, 6, 8 and 12 h sessions.

First, the exact positions of the stations were obtained by the average of the values obtained from the GIPSY-PPP (ver 6.4), 24 h observation data from all the stations:

- All observation sessions (1, 2, 3, 4, 6, 8,12 and 24 h) were processed using the commercial software, TOPCON Magnet (Version 4.0.1)
- Elevation Mask : 15˚
- Minimum Observation Session Duration: 60”
- Ephemeris: GPS (Broadcast and Precise) (Exper.1)
- Satellite System: GPS and GPS+GLONASS (Exper.2)
- Process : Auto Mode (Baseline Solution Method)
- All processes were based on a fixed solution

The average position from the ten 24 h sessions was then adopted as the ‘true’ position of the point. For each baseline, the differences in north, east and height from this true position were determined for every observing session. The RMS values of each component were then computed for each baseline distance and each value of T. Any individual component of a positional difference that exceeded its corresponding RMS value by more than a factor of three was discarded as an outlier and the corresponding RMS value was recomputed.

In terms of the results we obtained, for the technique related to GPS evaluation software, it is insufficient to compare the differences between the results obtained with another GPS evaluation technique. Although a single commercial software was used in the application, it is known from previous studies that the results of commercial software are similar to each other (because their operation, the models they use, etc. are similar) Our experience is based only on GPS observations and is not supported by other measurement techniques (VLBI; Very Long Baseline Interferometry, SLR; Satellite Laser Ranging, EDM; Electronic Distance Measurement). The accuracy obtained as a result of our experiment reflects the internal accuracy of the GPS system.

Our experience is limited to a 10-day period. Ionospheric activity is minimum and atmospheric effects is in seasonal normal has been tried to be chosen for long-term effects; seasonality and solar activity effects.

EVALUATION AND RESULTS

With Topcon Magnet software (Figure 4, “Web Import” interface), broadcast or precise ephemeris files can be imported from the IGS database into the program and easily used in the base evaluation process.

In Experiment-1, 9600 evaluations were planned. 9295 units have been solved as fix and the realization rate is 97% (Table 3). All three components of the baseline processing results obtained for the 10-day (338 to 347 GPS days, December 3 to 14 days of December 2012) data for the baselines used in Experiment-1 are North (n), East (e) and Up (u), which are presented in Figure 5, 6 and 7. In the graphs, the horizontal axis refers to the baselines (baselines lenght shows in Table 1) and the vertical axis refers to the error of average values (RMS) in millimeters depending on the observation time (1, 2, 3, 4, 6, 8, 12 and 24 h broadcast and precise ephemeris results).

Column B-1h, B-2h...B-24h shows the results of Broadcast ephemeris, column P-1h, P-2h...P-24h shows the precise ephemeris results presented in Figures 5, 6 and 7, and Tables 4, 5 and 6.

In the experiment-2, Topcon Magnet commercial sofware's "Web Import" screen, GPS and GPS + GLONASS broadcast ephemeris file were added and evaluations were made. The results obtained are presented in Figures 7, 8, 9 and Tables 7, 8 and 9. In Experiment-2, 19200 evaluations were planned. 18881 units have been solved as fix and the realization rate is 98% (Table 3).

All three components of the baseline processing results obtained for the 10-day (338 to 347 GPS days, December 3 to 14 days of December 2012) data for the baselines used in Experiment-2 are North (n), East (e) and Up (u) the results for Figures 8, 9, 10 and Tables 7, 8, 9 are presented. In the graphs, the horizontal axis refers to the baselines (baselines lenght shows in Table 2) and the vertical axis refers to the error of average values (RMS) in millimeters depending on the observation time (1, 2, 3, 4, 6, 8, 12 and 24 h only GPS and GPS+GLONASS results).

Figure 8, 9 and 10 and Tables 7, 8 and 9 in the columns (G+G); The results of the evaluation of GLONASS and GPS data together, (GPS); it only shows the results of the

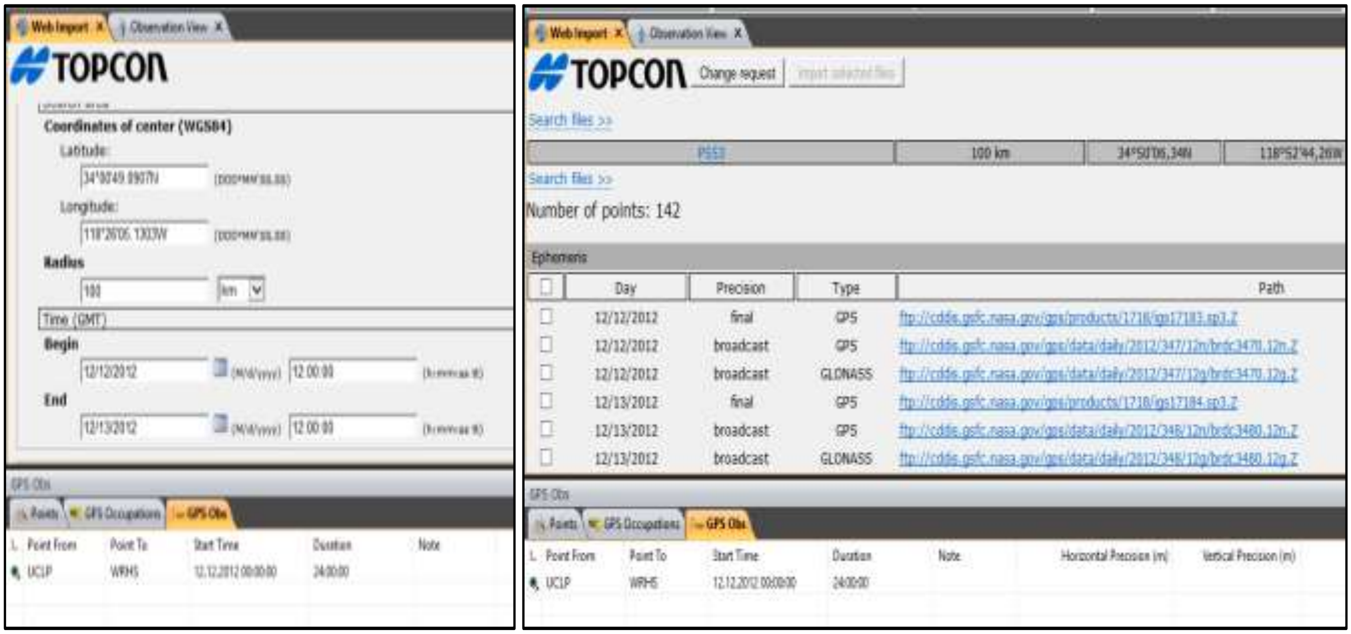

Figure 4. TOPCON Magnet Web Import Screen.

Table 3. Number of planned and realized observations.

Stations baselines	Number of processing planned	Number of processing realized	Realized ratio (%)
Experiment-1			
16Sta. 8 Base.	9600	9295	97
Experiment-2			
15 Sta. 16 Base.	19200	18881	98
Summary	28800	28176	97.8

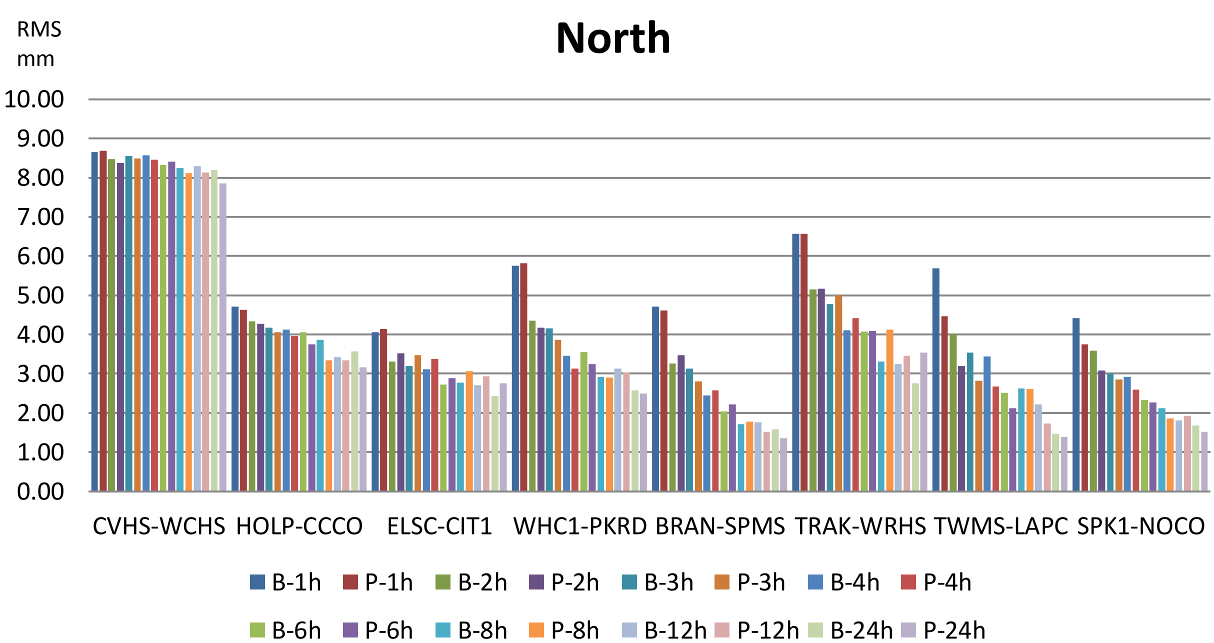

Figure 5. Experiment-1 (USA) broadcast-precise efemeris differences North (n) component results (mm).

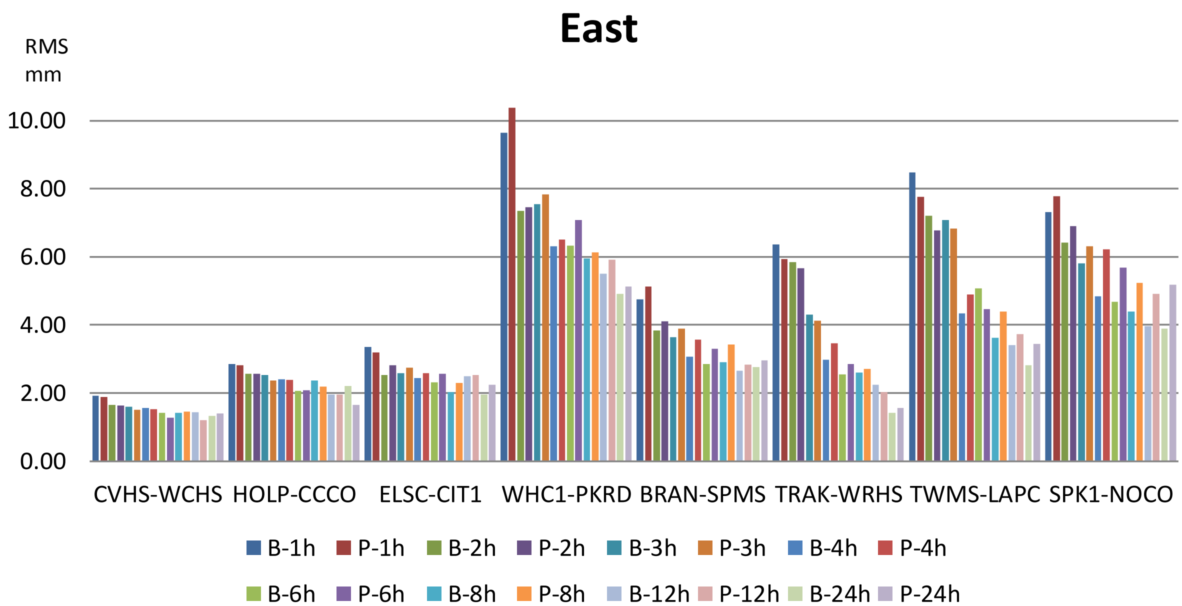

Figure 6. Experiment-1 (USA) broadcast-precise efemeris differences East (e) component results (mm).

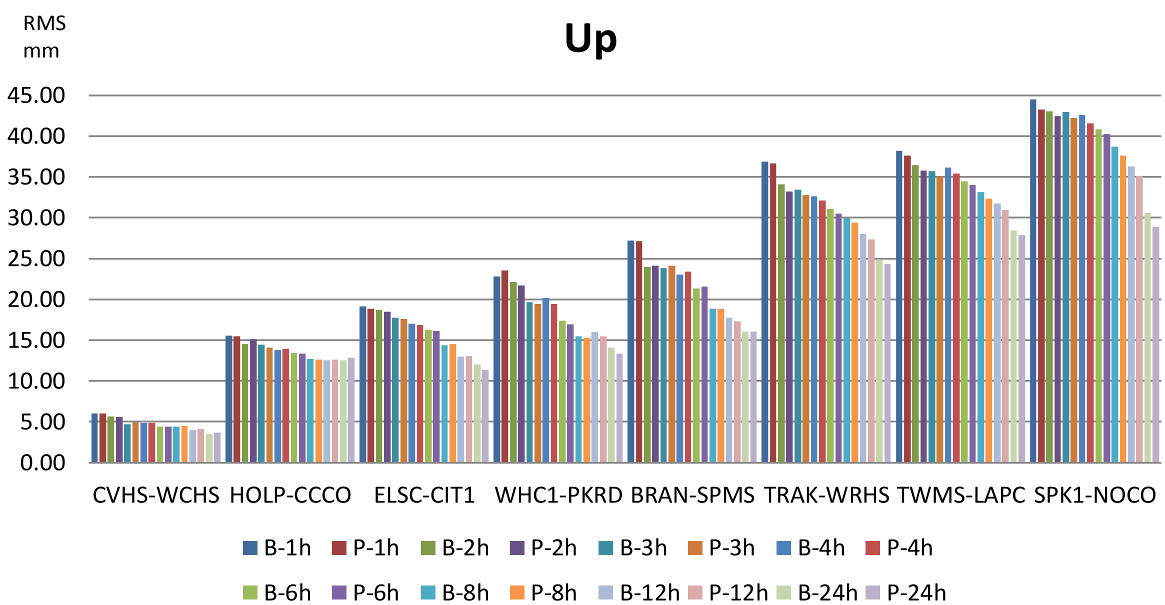

Figure 7. Experiment-1 (USA) broadcast-precise efemeris differences Up (u) component results (mm).

Table 4. Experiment-1 (USA) broadcast-precise efemeris differences North (n) component results (mm).

Baseline	B-1h	P-1h	B-2h	P-2h	B-3h	P-3h	B-4h	P-4h	B-6h	P-6h	B-8h	P-8h	B-12h	P-12h	B-24h	P-24h
CVHS-WCHS	8.65	*8.68*	8.47	*8.37*	8.55	*8.49*	8.57	*8.45*	8.33	*8.41*	8.24	*8.11*	8.29	*8.14*	8.20	*7.85*
HOLP-CCCO	4.71	*4.64*	4.33	*4.26*	4.17	*4.06*	4.13	*3.96*	4.05	*3.75*	3.87	*3.33*	3.43	*3.34*	3.56	*3.16*
ELSC-CIT1	4.06	*4.14*	3.31	*3.53*	3.20	*3.47*	3.12	*3.37*	2.72	*2.89*	2.77	*3.06*	2.71	*2.94*	2.43	*2.76*
WHC1-PKRD	5.76	*5.82*	4.35	*4.17*	4.16	*3.86*	3.45	*3.13*	3.56	*3.25*	2.93	*2.90*	3.12	*3.03*	2.58	*2.50*
BRAN-SPMS	4.71	*4.62*	3.25	*3.47*	3.14	*2.80*	2.45	*2.57*	2.04	*2.21*	1.72	*1.79*	1.76	*1.52*	1.58	*1.35*
TRAK-WRHS	6.56	*6.58*	5.15	*5.16*	4.78	*5.01*	4.11	*4.41*	4.07	*4.09*	3.30	*4.13*	3.24	*3.46*	2.76	*3.54*
TWMS-LAPC	5.69	*4.47*	4.00	*3.20*	3.54	*2.83*	3.44	*2.67*	2.50	*2.12*	2.62	*2.61*	2.21	*1.73*	1.46	*1.38*
SPK1-NOCO	4.41	*3.75*	3.59	*3.08*	3.01	*2.86*	2.92	*2.60*	2.33	*2.27*	2.12	*1.87*	1.81	*1.92*	1.68	*1.52*

Table 5. Experiment-1 (USA) broadcast-precise efemeris differences East (e) component results (mm).

Baseline	B-1h	P-1h	B-2h	P-2h	B-3h	P-3h	B-4h	P-4h	B-6h	P-6h	B-8h	P-8h	B-12h	P-12h	B-24h	P-24h
CVHS-WCHS	1.92	*1.88*	1.66	*1.64*	1.60	*1.50*	1.55	*1.53*	1.42	*1.28*	1.41	*1.45*	1.44	*1.21*	1.34	*1.39*
HOLP-CCCO	2.84	*2.82*	2.56	*2.56*	2.54	*2.37*	2.40	*2.38*	2.07	*2.08*	2.36	*2.19*	1.96	*1.96*	2.20	*1.64*
ELSC-CIT1	3.35	*3.20*	2.53	*2.81*	2.57	*2.74*	2.43	*2.58*	2.32	*2.57*	2.02	*2.29*	2.49	*2.54*	1.96	*2.24*
WHC1-PKRD	9.64	*10.37*	7.35	*7.45*	7.54	*7.84*	6.31	*6.51*	6.32	*7.08*	5.96	*6.13*	5.51	*5.92*	4.91	*5.12*
BRAN-SPMS	4.75	*5.12*	3.84	*4.11*	3.64	*3.90*	3.07	*3.56*	2.85	*3.30*	2.90	*3.42*	2.65	*2.83*	2.76	*2.97*
TRAK-WRHS	6.36	*5.93*	5.85	*5.67*	4.31	*4.12*	2.98	*3.46*	2.54	*2.84*	2.60	*2.71*	2.25	*2.02*	1.42	*1.57*
TWMS-LAPC	8.48	*7.76*	7.20	*6.77*	7.08	*6.84*	4.34	*4.90*	5.07	*4.46*	3.63	*4.39*	3.40	*3.73*	2.81	*3.45*
SPK1-NOCO	7.30	*7.78*	6.42	*6.90*	5.80	*6.31*	4.85	*6.23*	4.68	*5.68*	4.40	*5.23*	3.97	*4.91*	3.88	*5.18*

Table 6. Experiment-1 (USA) broadcast-precise efemeris differences Up (u) component results (mm).

Baseline	B-1h	P-1h	B-2h	P-2h	B-3h	P-3h	B-4h	P-4h	B-6h	P-6h	B-8h	P-8h	B-12h	P-12h	B-24h	P-24h
CVHS-WCHS	6.00	*6.05*	5.63	*5.56*	4.73	*4.93*	4.82	*4.88*	4.42	*4.37*	4.38	*4.48*	3.93	*4.12*	3.51	*3.70*
HOLP-CCCO	15.57	*15.51*	14.52	*15.14*	14.48	*14.11*	13.81	*13.96*	13.42	*13.35*	12.68	*12.60*	12.52	*12.61*	12.52	*12.81*
ELSC-CIT1	19.14	*18.86*	18.67	*18.48*	17.72	*17.59*	17.01	*16.83*	16.28	*16.10*	14.35	*14.55*	12.95	*13.03*	12.00	*11.39*
WHC1-PKRD	22.82	*23.53*	22.17	*21.69*	19.68	*19.47*	20.15	*19.41*	17.36	*16.98*	15.46	*15.24*	15.96	*15.44*	14.12	*13.36*
BRAN-SPMS	27.20	*27.13*	23.96	*24.12*	23.82	*24.14*	23.00	*23.38*	21.37	*21.59*	18.83	*18.87*	17.74	*17.28*	16.09	*16.05*
TRAK-WRHS	36.87	*36.65*	34.13	*33.20*	33.46	*32.81*	32.67	*32.11*	31.11	*30.49*	29.92	*29.40*	28.00	*27.32*	24.88	*24.31*
TWMS-LAPC	38.20	*37.59*	36.41	*35.75*	35.71	*35.05*	36.15	*35.40*	34.49	*34.00*	33.18	*32.34*	31.72	*30.98*	28.47	*27.88*
SPK1-NOCO	44.54	*43.30*	43.05	*42.44*	42.95	*42.25*	42.62	*41.61*	40.85	*40.23*	38.74	*37.59*	36.29	*35.10*	30.57	*28.93*

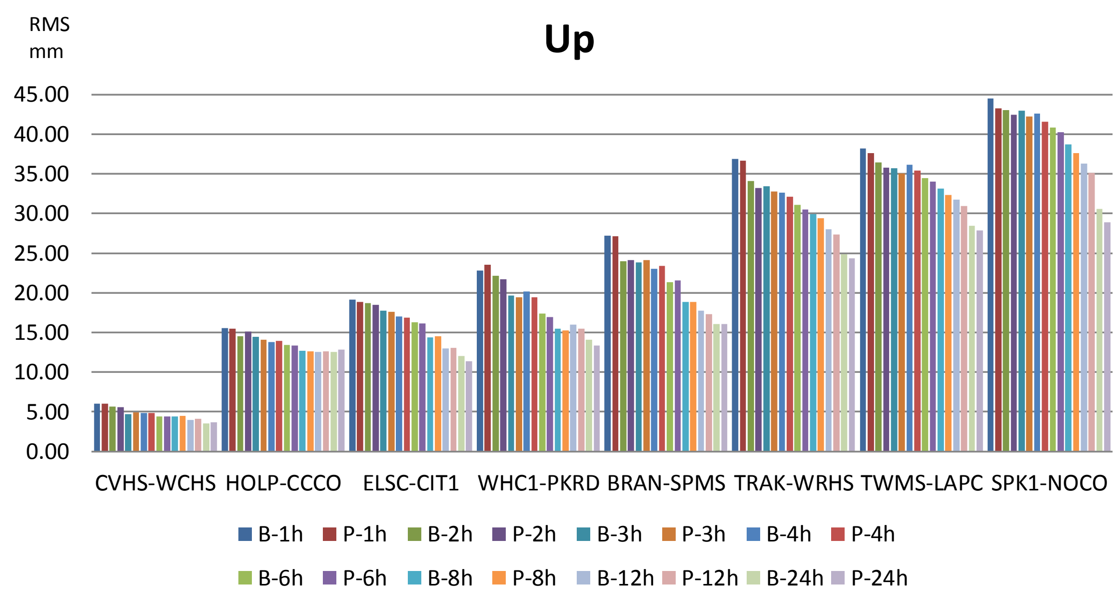

Figure 7. Experiment-1 (USA) broadcast-precise efemeris differences Up (u) component results (mm).

evaluation of the GPS observation data.

CONCLUSIONS

The International GNSS Service (IGS) has ensured open access, high-quality GNSS (Global Navigation Satellite Systems) data products since 1994. These products enable access to the definitive global reference frame for scientific, educational, and commercial applications – a tremendous benefit to the public, and key support element for scientific advancements. The IGS collects, archives,

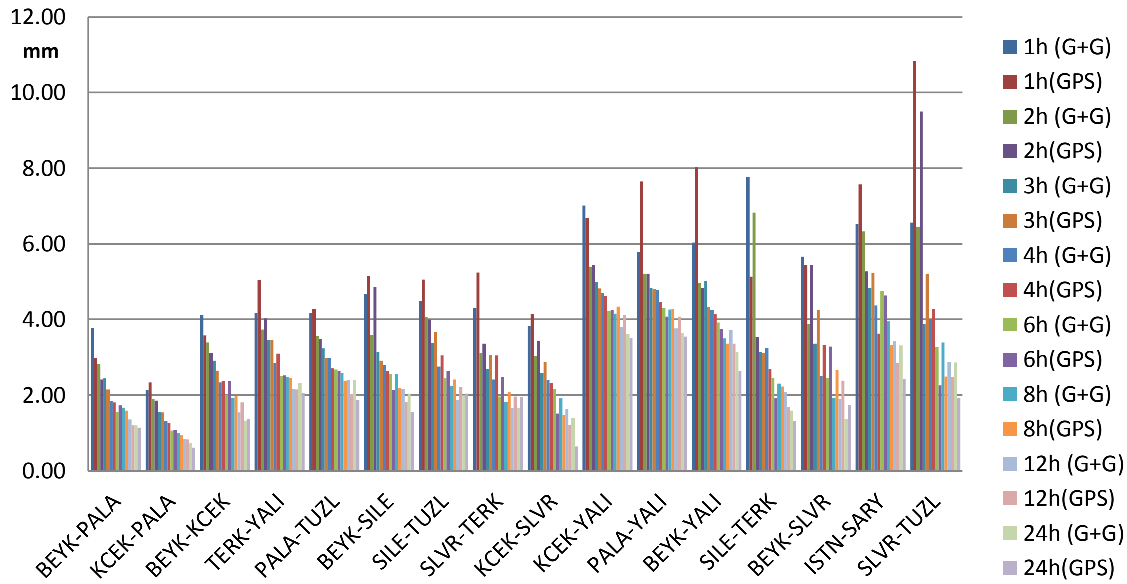

Figure 8. Experiment-2 (Turkey) broadcast (GPS) & broadcast (GPS+GLONASS) efemeris North (n) component results (mm).

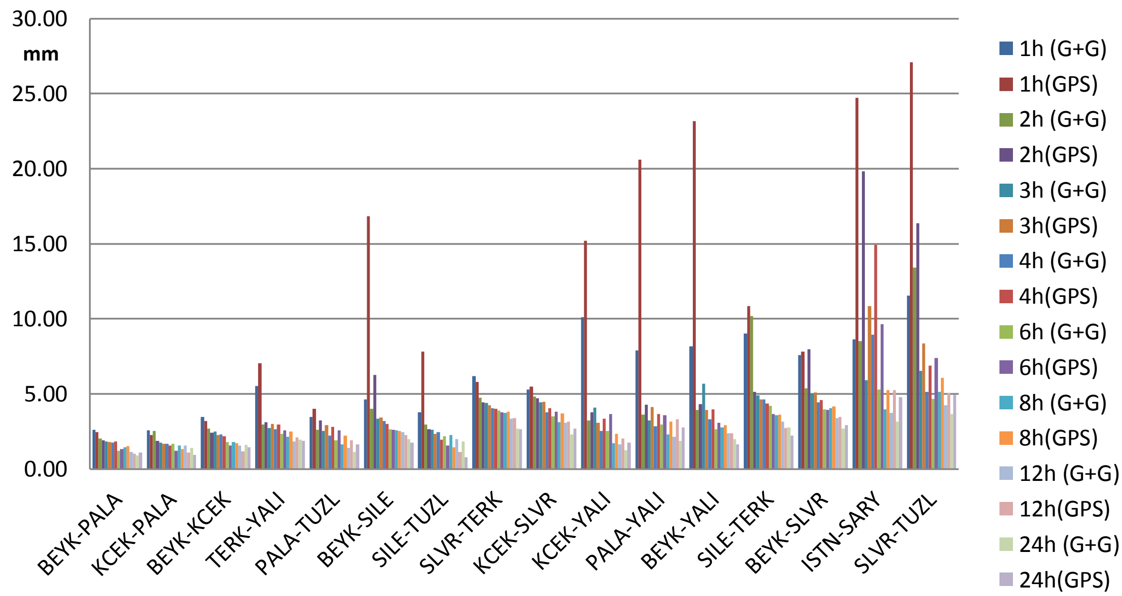

Figure 9. Experiment-2(Turkey) broadcast (GPS) & broadcast (GPS+GLONASS) efemeris East (e) component results (mm).

and distributes GPS (Global Positioning System) observation data sets of sufficient accuracy to satisfy the objectives of a wide range of applications and experimentation. These data sets are used by the IGS to generate the data products which are made available to interested users through website https://www.igs.org/ or ftp. Broadcast ephemeris file is published by IGS with 100cm accuracy and real time. The IGS Final products have the highest quality and internal consistency of all IGS products. They are made available on a weekly basis, by each Friday, with a delay up to 13 (for the last day of the week) to 20 (for the first day of the week) days. Precise ephemeris file is published by IGS with an accuracy of 2.5cm and in the range of 12 to 18 days.

In our first experiment with broadcast and precise ephemeris, the results of which are presented in Figures 5, 6 and 7, and Tables 4, 5 and 6; There was no significant difference in all sub-observations (1, 2, 3, 4, 6,

Table 7. Experiment-2 (Turkey) broadcast (GPS) & broadcast (GPS+GLONASS) efemeris North (n) component results (mm).

Baseline	1h (G+G)	1h(GPS)	2h (G+G)	2h(GPS)	3h (G+G)	3h(GPS)	4h (G+G)	4h(GPS)	6h (G+G)	6h(GPS)	8h (G+G)	8h(GPS)	12h (G+G)	12h(GPS)	24h (G+G)	24h(GPS)
BEYK-PALA	3.77	2.99	2.82	2.41	2.44	2.15	1.84	1.81	1.56	1.72	1.67	1.59	1.35	1.21	1.19	1.13
KCEK-PALA	2.13	2.33	1.90	1.85	1.56	1.54	1.32	1.26	1.05	1.07	1.00	0.94	0.84	0.83	0.74	0.60
BEYK-KCEK	4.12	3.58	3.40	3.12	2.91	2.65	2.34	2.37	2.00	2.36	1.94	1.97	1.54	1.81	1.32	1.38
TERK-YALI	4.17	5.04	3.74	4.02	3.45	3.45	2.85	3.10	2.51	2.52	2.48	2.46	2.16	2.14	2.31	2.05
PALA-TUZL	4.17	4.27	3.57	3.48	3.24	2.99	2.99	2.71	2.68	2.63	2.59	2.39	2.39	2.03	2.39	1.86
BEYK-SILE	4.67	5.15	3.59	4.86	3.14	2.91	2.81	2.63	2.55	2.14	2.55	2.18	2.17	1.82	2.03	1.55
SILE-TUZL	4.50	5.05	4.06	4.00	3.38	3.67	2.76	3.05	2.44	2.64	2.25	2.42	1.87	2.22	1.99	2.04
SLVR-TERK	4.31	5.25	3.12	3.36	2.69	3.07	2.42	3.05	1.97	2.47	1.82	2.09	1.65	1.96	1.67	1.95
KCEK-SLVR	3.82	4.15	3.04	3.44	2.59	2.87	2.40	2.32	2.17	1.51	1.91	1.47	1.64	1.21	1.39	0.64
KCEK-YALI	7.01	6.69	5.40	5.44	4.99	4.82	4.70	4.63	4.24	4.25	4.15	4.34	3.79	4.12	3.61	3.51
PALA-YALI	5.79	7.66	5.22	5.22	4.84	4.81	4.78	4.47	4.30	4.07	4.26	4.29	3.77	4.07	3.65	3.55
BEYK-YALI	6.03	8.02	4.96	4.84	5.03	4.33	4.25	4.14	3.92	3.75	3.51	3.36	3.72	3.36	3.15	2.64
SILE-TERK	7.78	5.14	6.82	3.53	3.15	3.11	3.26	2.70	2.46	1.92	2.30	2.23	2.09	1.68	1.59	1.30
BEYK-SLVR	5.67	5.44	3.88	5.44	3.36	4.24	2.51	3.33	2.47	3.28	1.93	2.66	1.91	2.38	1.37	1.74
ISTN-SARY	6.53	7.57	6.34	5.28	4.83	5.23	4.37	3.62	4.76	4.64	3.95	3.34	3.43	2.85	3.32	2.44
SLVR-TUZL	6.57	10.84	6.46	9.50	3.87	5.21	4.02	4.27	3.26	2.26	3.39	2.50	2.88	2.47	2.87	1.93

Table 8. Experiment-2 (Turkey) broadcast (GPS) & broadcast (GPS+GLONASS) efemeris East (e) component results (mm).

Baseline	1h (G+G)	1h(GPS)	2h (G+G)	2h(GPS)	3h (G+G)	3h(GPS)	4h (G+G)	4h(GPS)	6h (G+G)	6h(GPS)	8h (G+G)	8h(GPS)	12h (G+G)	12h(GPS)	24h (G+G)	24h(GPS)
BEYK-PALA	2.62	2.47	2.01	1.91	1.83	1.78	1.74	1.82	1.20	1.32	1.45	1.52	1.13	1.02	0.89	1.09
KCEK-PALA	2.57	2.25	2.54	1.89	1.77	1.70	1.68	1.55	1.66	1.22	1.57	1.31	1.58	1.09	1.43	0.92
BEYK-KCEK	3.47	3.19	2.71	2.43	2.50	2.27	2.30	2.19	1.78	1.58	1.81	1.73	1.55	1.18	1.60	1.46
TERK-YALI	5.52	7.05	2.97	3.12	2.72	3.02	2.67	2.95	2.36	2.56	2.13	2.51	1.85	2.10	1.94	1.89
PALA-TUZL	3.47	4.02	2.63	3.24	2.54	2.91	2.22	2.83	1.93	2.59	1.62	2.22	1.43	1.93	1.15	1.64
BEYK-SILE	4.65	16.82	4.03	6.28	3.36	3.43	3.20	3.02	2.66	2.61	2.57	2.52	2.48	2.28	1.99	1.75
SILE-TUZL	3.79	7.82	2.98	2.64	2.60	2.36	2.46	1.97	2.20	1.57	2.27	1.44	1.99	1.13	1.83	0.78
SLVR-TERK	6.18	5.79	4.76	4.45	4.40	4.26	4.04	4.01	3.90	3.79	3.75	3.83	3.34	3.38	2.67	2.64
KCEK-SLVR	5.28	5.49	4.81	4.72	4.44	4.47	3.79	4.07	3.53	3.81	3.14	3.70	3.06	3.15	2.31	2.68
KCEK-YALI	10.12	15.21	3.25	3.77	4.10	3.07	2.52	3.35	2.52	3.65	1.73	2.35	1.62	2.03	1.25	1.74
PALA-YALI	7.91	20.62	3.64	4.30	3.23	4.14	2.84	3.65	2.95	3.59	2.32	3.17	2.16	3.33	1.87	2.77
BEYK-YALI	8.16	23.18	3.95	4.34	5.67	3.95	3.29	3.99	2.65	3.09	2.77	2.94	2.37	2.36	2.00	1.64
SILE-TERK	9.04	10.84	10.20	5.15	4.89	4.62	4.62	4.36	4.19	3.67	3.59	3.62	3.15	2.72	2.75	2.24
BEYK-SLVR	7.58	7.82	5.36	7.97	5.04	5.09	4.45	4.60	3.98	3.95	4.04	4.17	3.39	3.45	2.68	2.92
ISTN-SARY	8.64	24.74	8.54	19.83	5.91	10.86	8.93	14.93	5.28	9.65	3.98	5.27	3.74	5.26	3.18	4.80
SLVR-TUZL	11.56	27.08	13.43	16.38	6.55	8.36	5.15	6.91	4.66	7.41	5.15	6.07	4.23	5.07	3.65	4.94

Table 9. Experiment-2 (Turkey) broadcast (GPS) & broadcast (GPS+GLONASS) efemeris Up (u) component results (mm).

Baseline	1h (G+G)	1h(GPS)	2h (G+G)	2h(GPS)	3h (G+G)	3h(GPS)	4h (G+G)	4h(GPS)	6h (G+G)	6h(GPS)	8h (G+G)	8h(GPS)	12h (G+G)	12h(GPS)	24h (G+G)	24h(GPS)
BEYK-PALA	9.81	8.69	8.01	7.84	7.59	7.74	6.78	6.68	6.03	6.01	5.78	5.65	5.02	4.93	4.53	4.35
KCEK-PALA	8.88	9.20	7.97	8.12	7.45	7.73	7.29	7.34	6.55	6.13	5.95	5.54	5.41	4.89	3.85	4.04
BEYK-KCEK	16.01	15.09	13.99	13.57	13.49	12.93	12.36	12.20	10.77	10.39	10.21	9.79	8.55	8.31	7.50	7.45
TERK-YALI	21.59	21.29	21.52	21.70	20.27	20.42	19.52	20.18	16.72	17.87	14.07	14.64	12.25	12.30	9.29	9.52
PALA-TUZL	24.14	23.74	23.26	23.09	21.04	20.92	20.88	20.33	17.13	17.44	16.92	16.59	15.53	15.47	14.35	13.76
BEYK-SILE	23.97	26.16	21.89	25.15	20.72	20.67	20.66	20.17	16.44	16.31	17.29	16.84	15.04	14.63	13.16	12.64
SILE-TUZL	17.74	18.69	15.82	15.80	16.13	16.28	13.48	13.71	12.05	12.10	11.09	10.91	9.85	9.77	7.97	7.80
SLVR-TERK	26.17	24.58	24.58	24.51	24.13	24.50	23.37	23.39	20.70	20.80	19.66	19.75	16.43	16.74	13.74	14.28
KCEK-SLVR	33.78	28.53	33.09	27.99	33.99	27.78	33.51	27.66	27.85	24.75	25.66	22.90	21.62	20.61	17.83	19.25
KCEK-YALI	33.71	38.60	32.76	32.18	34.86	32.35	31.04	30.31	26.53	27.28	22.66	21.78	18.95	18.43	16.00	15.27
PALA-YALI	40.31	43.94	37.81	36.72	37.58	38.18	36.25	35.54	31.76	30.77	26.70	25.56	21.85	21.72	18.37	17.32
BEYK-YALI	43.13	41.83	40.35	35.51	40.60	33.36	38.52	33.80	34.77	30.23	29.65	25.62	24.72	23.23	20.25	19.55
SILE-TERK	47.00	37.83	43.21	35.64	36.48	33.19	37.88	34.21	31.89	29.62	30.26	29.68	25.15	25.99	22.45	22.01
BEYK-SLVR	43.85	48.45	42.01	40.20	42.43	40.84	41.02	39.79	36.52	34.43	33.80	32.19	27.88	26.99	24.24	23.53
ISTN-SARY	43.32	48.42	44.77	43.31	44.14	44.94	41.87	42.40	36.39	37.08	31.17	29.11	27.31	26.19	23.74	22.55
SLVR-TUZL	57.85	66.48	57.52	57.24	54.22	55.06	53.17	54.06	48.24	45.35	41.94	40.34	36.24	35.61	31.87	31.37

8, 12 and 24 h) in the North (n), East (e) and Height (u) components.

It is considered that it is not necessary to wait 2 weeks for the publication of precise ephemeris to evaluate the

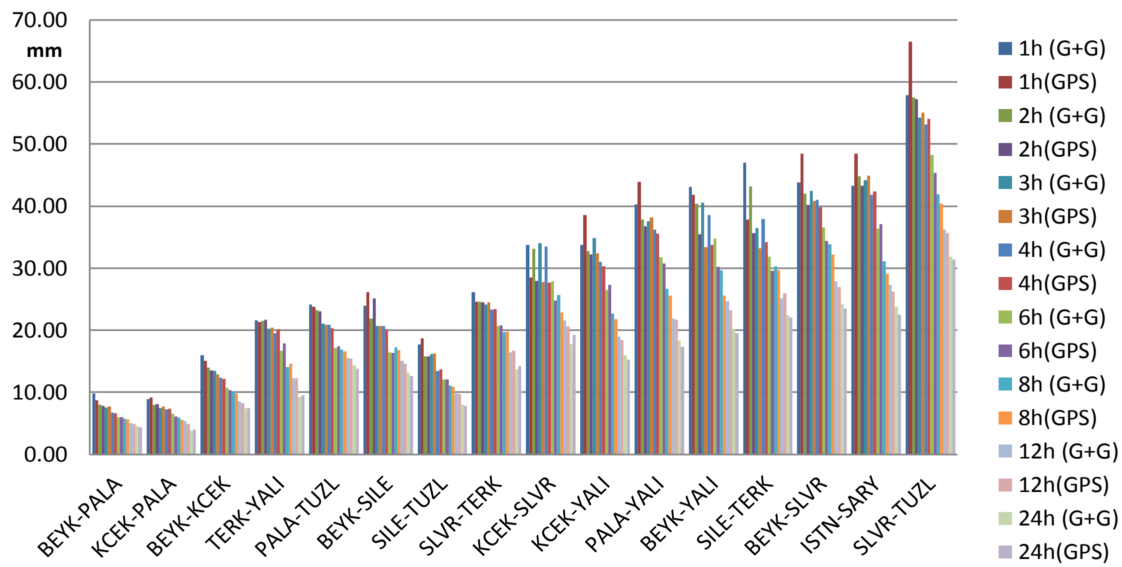

Figure 10. Experiment-2 (Turkey) broadcast (GPS) & broadcast (GPS+GLONASS) efemeris Up (u) component results (mm).

GPS observation data in commercial software. For daily users, time loss can be prevented.

According to our results, the accuracy of the position obtained with the commercial software (Topcon Magnet ver 4.0.1) depends not only on the duration of the session but also on the base distance (especially on the up component).

From the graph of the vertical component (u) when the Figure 8 and Figure 10 is examined, it is seen that the accuracy of the vertical component is worse than the horizontal components (n and e). This is an expected situation and the fact that the satellites resulting from the general design of GNSS systems can only be monitored in the positive hemisphere, especially in short-term observations due to bad satellite-receiver geometry effect, loading effects (atmospheric, ocean, loading of different water bodies).

In particular, the increase in interstation distance has a greater effect on the vertical component, and the main reason for this may be the lack of modeling of atmospheric models as the distance increases.

In the second experiment which results are presented in Figures 8, 9, 10 and Tables 7, 8 and 9, broadcast (GPS) and boradcast (GPS+GLONASS) use was evaluated and interpreted. When only GPS or GPS+GLONASS data were included in the evaluation process, it was found that there was no significant difference when the standard deviations of the results obtained (based on the base distance and observation time) were examined. In commercial software, it may be statistically significant to include data from different satellite systems (on the other hand to increase the number of observations/ measurements) in the evaluation process.

According to experiment 1 and experiment 2 results in the USA and Turkey, close results were obtained for all three components. In both experiments, it can be said that the observation time for the three components (north, east and up) affects accuracy.

When the observation time for horizontal components (north and east) is over 2 hours, the accuracy obtained is very close to each other and as the observation time is increased, it improves a little more.

Negative effects such as satellite visibility, ambiguity, multipath in short observation times (such as 1 or 2 hours) affect the accuracy from time to time. It is important for users to make observations as long as possible for all three components. In addition to this situation It has been determined that it is also important to consider the baseline distance for the vertical component (up). For daily users, the comments we make from the results obtained from the experiments are thought to be important in terms of GNSS observation planning and the accuracy they will get from the GNSS system.

DATA AVAILABILITY STATEMENTS

Some or all data, models, or code used during the study were provided by a third party (GPS observations files, atmosferic data, precise ephemeris files). Direct request for these materials may be made to the provider as indicated in the Acknowledgments.

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