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Comparison of Troposphere Models Used in Commercial GPS Softwares

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Keywords
Tropospheric models
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Atmospheric parameters
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ABSTRACT

The Global Navigation Satellite System (GNSS) is one of the most important inventions in the history of the survey. GPS in 1974 and GLONASS in 1976 were established and used for military purposes, and they were opened to civil use since 1980 and 1982 respectively and started to be used in daily life. The GNSS system has developed very rapidly in line with technological studies and these rapid developments have directed scientists to develop new methods that can meet the needs of users and get the most accurate results. One of the best studies to minimize the effect on GNSS signals in the atmosphere is the use of dual-frequency GNSS receivers. These receivers can eliminate errors on GNSS signals in the ionosphere layer. However, they cannot eliminate the errors occurring in the troposphere layer. To eliminate these errors, the tropospheric effect can be minimized by measuring the humidity, temperature and pressure values at each point of the survey and using these values in calculations. But since this process will take a lot of time and is very costly, tropospheric models have been made by scientists. By using these models in GNSS software, the effect of the troposphere layer on the signals can be minimized. In this study, four different survey campaigns were conducted to observe the effect of Troposphere models under different atmospheric conditions. Topcon Tools ver.7 and Leica Geo Office 7.0 software were used to evaluate these campaigns. The effects of troposphere models on these calculations have been observed. The atmospheric values measured at the time of the session and the atmospheric values are taken from the General Directorate of Meteorology were included in the calculations and the results were compared.

1. INTRODUCTION

Global Navigation Satellite System (GNSS) is one of the navigation systems widely used in many civil and military fields. The number of people using Global Positioning Systems, which is developing each passing day, is increasing day by day (Koca and Ceylan, 2018). Today, the system, whose generic name is GNSS, has many satellite systems (GPS, GLONASS, GALILEO, BEIDOU / COMPASS, QZSS, IRNSS) (Ateş, 2011). The vast majority of existing error sources in this system is between the moment of the signal out from the satellite and the moment the GNSS receivers are received. When the signals broadcasted from GNSS satellites enter the atmosphere, they pass through the ionosphere and troposphere, respectively, reaching the GNSS receptors and diverging when passing through the atmosphere. This divergence is divided into two as signal path curvature and diffusion delay. The most important effect is the diffusion delay, which can be divided into ionospheric and tropospheric. The effect of the neutral (non-ionized) atmosphere on electromagnetic waves emitted in radio frequencies is called the tropospheric delay effect (or tropospheric refraction). This effect causes the electromagnetic wave to slow down and bend (Kahveci, 2011).

The signal propagation delay in the troposphere layer accounts for 80% of the total delay, and this delay is called the tropospheric delay (Hopfield, 1971). When talking about the troposphere, it is

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generally meant the lower part of the earth's atmosphere. Tropospheric delay is divided into dry delay and wet delay. The dry component can be determined with high accuracy with many tropospheric delay models prepared by surface meteorological measurements, and this part can be easily modelled with the law of ideal gases since it is in hydrostatic equilibrium. The wet part is difficult to calculate (estimate) due to the uneven distribution of liquid water and water vapour in the troposphere. The neutral atmosphere consists of dry air and water vapour. There is no significant change in the composition of dry air depending on latitude and altitude (Smith and Weintraub, 1953). The troposphere consists of two ideal gas mixtures, dry air and water vapour. Dry air is dependent on the gas density in the atmosphere, changes in the gas distribution, causing 90% of the total atmospheric delay. The pressure measured at the measurement point can be modelled with 2% error in the direction of temperature and humidity and zenith. It is much more difficult to model the existing water vapour component between the receiver and the satellite along the signal path, as the water vapour changes rapidly concerning for to the ground and time. Due to the water vapour component, the delay is 5–30 cm in medium latitudes and can be determined with a sensitivity of 2–5 cm. Troposphere errors can be reduced by using 92% suitable troposphere model (Saastamonien and Hoppfield) (Kınık, 1999). The effects of errors on the measurements can be minimized by using GNSS receivers and calculation and modelling methods in evaluation programs. In the tropospheric delay calculation, Saastamoinen and Hopfield models are widely used in the evaluation of GPS observations, together with atmospheric parameters independent of time and actual meteorological conditions (Özuğur, 2019). In meteorological applications, it is very difficult to represent the spatial and temporal distribution of water vapour in the atmosphere precisely. The numerical estimation quality of Precipitable Water (PW), which can be converted into precipitation, depends on the correct determination of the distribution of atmospheric moisture information (Glowacki et al., 2006).

Yılmaz (2013), reported in his study that the calculations made using meteorological data yielded 5mm better results than standard troposphere models.

Erkan (2008), also tested the PW values calculated with the global pressure and temperature model used in cases where meteorological parameters are not available at GPS stations. As a result of the test, it was observed that the differences between the actual meteorological values present in the GPS station and the use of these values from the model are compatible with approximately 1 mm standard deviation. However, if meteorological data are measured at GNSS stations, or if these values can be obtained from a numerical weather forecast model, the need to include these data in the assessment has been proven by many scientific articles.

Erdönmez (2008) came to the conclusion that the determining factor of the total delay is a wet delay, which varies according to the water vapour pressure and relative humidity, and the main factor affecting the delay is water vapour, which is an important factor due to the temperature.

In this study, three different GNSS sessions were held in order to identify the best results by comparing the troposphere models in the GNSS software used to minimize the errors caused by the broadcast delay.

The evaluations are also for GPS signal data as the GNSS receivers used only use data from GPS satellites. Therefore, in the next steps, GPS expression will be used instead of GNSS expression.

2. MATERIALS AND METHODS

2.1. Studying Area

In order to evaluate the effects of troposphere models in GPS software on GPS evaluation results, 3 different applications were made.

Application 1 with the long-edge (150 km * 250 km) GPS network, the point named NIGD established as part of the TUSAGA-Aktif project is taken as TUSAGA reference, and TUSAGA points named AKSR, FEEK, HALP, KAPN, KAYS, NEVS, NGDE, POZA, TUFA are connected to the GPS network in a suitable distribution. It was aimed to observe the effects of different troposphere models, at the long-distance measured bases between these points, which are between 7 km and 147 km with reference, at different atmospheric conditions and different satellite elevation angles. Selected observation points are located in settlements (Figure 1).

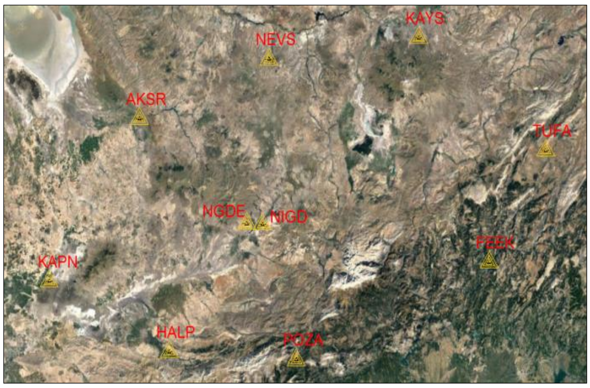

Figure 1. Application 1 project area and locations of points

Application 2 TUTGA points at a distance of 19 to 55 km from each other named L28-G001, L29-G001, L29-G002, M28-G001 and M29-G001 in the centre of Konya and L2810012, C1 degree triangulation point included in mid-range (40 km * 55 km) network (Figure 2).

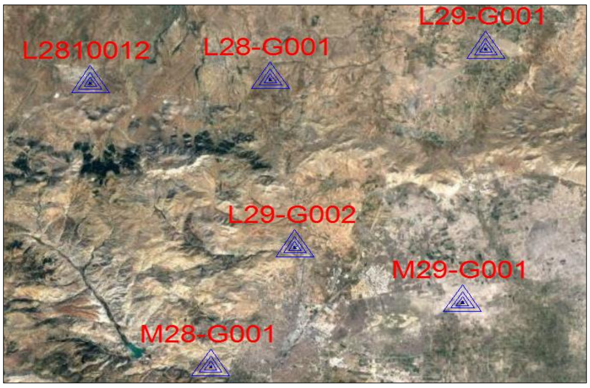

Figure 2. Application 2 project area and locations of points

Application 3 12 points have been identified and included in the network where the land changes character, started from Askarlihoyugu around Konya-Adana highway, along the Konya-Afyon highway in the direction of Istanbul road (north-south) to Calinbas Hill in the north of Karacaören Ciftligi (Figure 3).

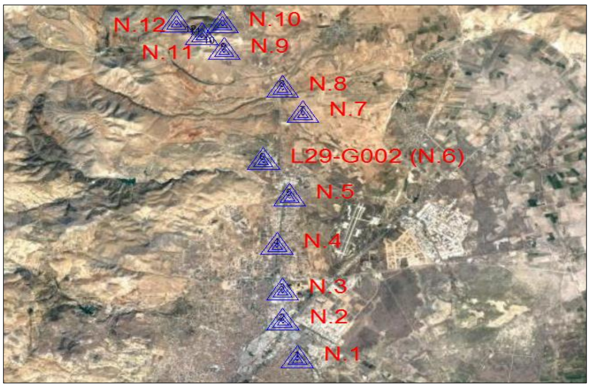

Figure 3. Application 3 project area and locations of points

2.2. Topcon Hiper Pro and Topcon Hiper Plus Receivers

Topcon Hiper Pro and Topcon Hiper Plus receiver, which is used in observations in application areas 2 and 3 and has wireless operation technology, can survey more than 14 hours and has 40 channeled receivers. It is waterproof and its sensitivity in static and fast static surveying methods is 3mm + 0.5ppm in positioning, 5mm + 0.5ppm in levelling. In Real Time Kinematics (RTK) application, precision is 10mm + 1.0ppm in positioning, 15mm + 1.0ppm in levelling.

2.3. Javad GNSS Receiver

The GPS branded Javad used in the Application 2 field, 2 SIM cards can be inserted and have the feature of bluetooth wireless technology. It has 216 channels and can work for 15 hours. In static and fast static surveying methods, the sensitivity is 0.3cm + 0.5ppm in positioning, 0.5cm + 0.5ppm in levelling. In Real Time Kinematics (RTK) application, precision is 1cm + 1.0ppm in positioning, 1.5cm + 1.5ppm in levelling.

2.4. Vaisala PTU 307 Meteorological Sensor

PTU307 is the sensor option developed for open and demanding meteorology applications of PTU300 series, which has the ability to measure three parameters at the same time, such as barometric pressure, humidity and temperature. PTU307 with the additional hot probe, total precision in barometric pressure measurement -40/+60°C, precision in relative humidity measurement +15/+25°C ±1.0 %RH, temperature measurement +20°C ±0.2 °C. With Vaisala PTU 307 meteorological sensor, pressure, humidity and temperature values were measured in the Application 2 area.

2.5. Ashtech Z Surveyor Receiver

Ashtech Z Surveyor receivers, which are used 2 in Application 3 field, are 12-channelled, dual-frequency GPS receivers. The sensitivity of the receiver, which can work up to 10 hours, in static and fast static surveying methods, is 5mm + 1ppm in positioning, 10mm + 1ppm in levelling.

2.6. Trimble 5700 Receiver

The Trimble 5700 receiver, a 24-channelled, dual-frequency GNSS receiver, can operate for up to 8 hours. The sensitivity of the receiver in static and fast static surveying methods is 5mm + 0.5ppm in positioning, 5mm + 1ppm in levelling. In Real Time Kinematics (RTK) application, precision is 10mm + 1ppm in positioning and 20mm + 1ppm in levelling.

2.7. Topcon Tools Ver.7 Software

Topcon Tools (TT) software, which is an adjustment software that can evaluate RTK observations and GPS static survey data, contains modules for different solutions. Free and based adjustment in application areas were made with Topcon Tools (TT) software.

2.8. Leica Geo Office 7.0 Software

Leica Geo Office (LGO) software, commercial software of Leica, was used in free and based adjustment steps in the application area. Troposphere models in the software are Hopfield, Simplified Hopfield, Saastamenion, Essen and Froome, No Troposphere and Computed models.

3. RESULTS

The calculation was made by entering the meteorological data of the locations close to the reference station in Table 1 requested for

Table 1. Requested meteorological data

T.C.

Ministry of Agriculture and Forestry

Turkish State Meteorological Service

Station Number	Station Name	Year	Month	Day	Average Temperature	Maximum Temperature	Minimum Temperature	Average Humidity	Total Precipitation	Average Air Pressure hPa	Calculated Average Air Pressure mbar	Average Cloud Amount	Average Wind Direction	Average Wind Speed	Maximum Wind Direction	Maximum Wind Speed	Maximum Wind Time
17192	AKSARAY	2012	1	15	2.8	5.6	0.1	82.2	0	899.8	996.8	4.5	241WSW	3.3	220SW	10.8	05:10
17193	NEVŞEHİR	2012	1	15	1.8	4.9	-1.1	75.8	0	868.0	994	3.7	209SSW	3.1	170S	11.3	01:23
17248	EREĞLİ	2012	1	15	7.4	11.6	2	52.3	0	890.8	995.4	4	208SSW	3.6	210SSW	14.4	11:00
17250	NİĞDE	2012	1	15	4.2	7.4	1.2	68.2	0	873.5	994.6	3.3	227SW	3.8	240WSW	11.3	18:44
17902	KARAPINAR	2012	1	15	3.8	7.4	1.1	79.7	0.5	896.1	995.7	0	138SE	2.9	207SSW	9.4	07:14
17934	POZANTI	2012	1	15	4.3	8	-7.2	79.8	0	889.6	997.6	0	271W	1.6	203SSW	7.2	13:03
17192	AKSARAY	2012	6	15	26.9	34.2	18.1	30.9	0	904.8	1001.8	1.9	354N	1.7	70ENE	10.3	23:23
17193	NEVŞEHİR	2012	6	15	25.6	32.8	17.5	27.5	0.2	875.5	1001.5	4	23NNE	1.8	50NE	7.7	17:39
17248	EREĞLİ	2012	6	15	25.3	34.5	15.9	42	3.6	896.2	1000.8	1.3	78ENE	1.2	170S	4.1	17:30
17250	NİĞDE	2012	6	15	25.5	34.2	15.3	30.8	0	879.6	1000.7	2.4	40NE	1.8	30NNE	6.2	19:40
17902	KARAPINAR	2012	6	15	26.7	35.3	15.8	32.1	0	901.2	1000.8	0	352N	1.9	308NW	6.3	11:39
17934	POZANTI	2012	6	15	26.4	35	17.3	30.2	0	892.6	1000.6	0	284WNW	2.1	283WNW	10.5	14:33

NOTES: 1 – Time Given is UTC (Coordinated Universal Time). Turkey to translate the winter time 2 hours, according to the daylight saving time is added 3 hours. 3 hours in 2016 and after are added. The information up to the last 35 days has not passed the quality control, values may change at a later date. The system and data have been edited, there may be occasional differences with the previous data. 2 – The air temperature is measured in the shade at a height of 2 meters in degrees Celsius (° C). 3 – The days when the Daily Minimum Temperature drops below 0 ° C are expressed as Frost Day. 4 – In the Wind Table; Calm (C): 0.0-0.2 m / s (0 Bofor), Breeze: 0.3-1.5 m / s (1 Bofor), Light Wind: 1.6-3.3 m / s (2 Bofor), Sweet Wind: 3.4-5.4 m / s (3 Bofor), Medium Wind: 5.5-7.9 m / s (4 Bofor), Strong Wind: 8.0-10.7 m / s (5 Bofor), Strong Wind: 10.8-13.8 m / s (6 Bofor), Storm Wind: 13.9-17.1 m / s (7 Bofor), Storm: 17.2-20.7 m / s (8 Bofor), Strong Storm: 20.8-

Application 1 into the Topcon Tools program. NIGD TUSAGA station was taken as reference, and other models were compared according to Hopfield troposphere model. Although there are also changes in Y and X coordinates in model comparison, comparisons have been made for the point heights most affected by tropospheric models. Based on the 15° elevation angle in January and the solution in the Hopfield layer shown in Table 2, monthly changes compared to the same parameters in other months were seen. As a result of the application, the height change in the points varies between -450mm and +450mm depending on the model used. Since the troposphere effect cannot be corrected by using GPS or any other method, the model that can give the best effect and the most accurate result should be selected according to the model survey area and weather.

As a result of the application, Hopfield and Saastamoinen models in the LGO program and Goad & Goodman models in the TT program were observed to give the best results compared to other models. In Table 2, the results obtained by meteorological methods and program data were compared on the Goad & Goadman model. After all; the height differences calculated were very small due to the fact that there are close values with the standard atmosphere model and the distance between the stations is large, it allows the entry of meteorological data belonging to only one point in the program and the points in the assessment are in different geographical regions but in similar weather conditions.

L2910012, L28-G001, L29-G001, M28-G001 and M29-G001 points calculated by using the free adjustment method by using the troposphere models in Leica Geo Office (LGO) and Topcon Tools (TT) program by taking reference the point numbered L29-G002 in the Application 2 area. Points numbered L28-G001, L29-G001 and M29-G001 were also calculated by taking the based balancing methods.

In addition to the based adjustment(s) made with the troposphere models in LGO and TT programs, there are small differences between the standard meteorological values in the TT program and the free and based adjustment(s) made by entering the meteorological data in the valuation of the days in 10.03.2012 and 11.03.2012 according to the meteorological data measured in the field in Table 3. In the evaluation of the days of 11.06.2013 and 12.06.2013, between the standard models in the TT program and the based adjustment(s) made by entering meteorological data, it has been shown to affect up to 10 mm. With the meteorological data entered in the Niell and UNBabc models in the TT program, +/-20 cm was seen that it made errors in calculations.

In the project site where the elevation range is between 1008 m and 1731 m as a result of GPS measurements made in the north-south direction of the Application 3 Area, which is given free adjustment results in Table 4; it was observed that the change in satellite cutting angles seen in Table 4 affected the heights between 1 and 5 mm. In the comparison of the troposphere models, it was observed that the models failed according to the height of the measured points.

4. DISCUSSION AND CONCLUSION

As a result of the calculations, when the results obtained from the troposphere models are compared among themselves based on the best model, it has been observed that it affects only the vertical position and the effect of the horizontal position is very small. Although the LGO program does not allow meteorological data to be entered, Hopfield model and Saastamoinen models selected automatically by the program have been shown to give the best results even in different weather conditions, on long-distance and short-distance bases, and even in flat or unevenness of the surveyed terrain. The sensitivity of the model disappears as the height difference between the reference point where the Simplified Hopfield model gives good results on the rough terrain and the point where GPS observation changes. As can be seen from the results of the application, in the comparison made with the 15° Hopfield model for the point height lower than the reference point, it gives a negative error and for the point height higher than reference point, it gives the positive error. Essen Froome model is a model suitable for use on relatively flat terrain and as seen in Application 3, it gives an error in the range of +6 cm and -6 cm even in less uneven terrain. Like the Simplified Hopfield model, the Essen Froome model also gives a negative error for the point height lower than the reference point and a positive error for the point heights above the reference point. Calculations made with the No Troposfer option will most likely give accurate results when calculating GPS signals with the same tropospheric effect in the same region and for points with the same altitude. We are very unlikely to encounter such an event in the project sites where we practice. Unlike the Simplified Hopfield and Essen Froome models, in the calculations that do not apply the troposphere model, it gives a negative error for the heights above the reference point and a positive error for the low heights. Computed model is a model with different tropospheric conditions and where the height difference between the points is high, it will be more suitable to use in the long-based calculations if Hopfield and Saastamoinen models cannot be used in long-based calculations.

The TT program allows the use of measured meteorological values, thanks to its menu that allows adding meteorological data. Goad & Goodman, Niell and UNBabc models used in the program give very close results in comparison of the program itself. Meteorological data fixed in the TT program; pressure is 1013.2 mbar, the temperature is 20 °C, humidity is 50%. While

Table 2. Adjustment results of other stations compared to NGDE reference station

Survey Days	Points			LEICA GEO OFFİCE							TOPCON TOOLS						METEOROLOGICAL DATA		
											PROGRAM DATA						Data of NIGD station		
	Station	Height (Ellipsoidal)	Distance to Reference M.	HOPFIELD 15°	HOPFIELD 15°	SIMPLIFIED HOPFİEID 15°	SAASTAMOINEN 15°	ESSEN FROOME 15°	NO TROPOSPHERE 15°	COMPUTED 15°	GOAD& GOODMAN 15°	NEILL 15°	UNBABC 15°	GOAD& GOODMAN 15°	NEILL 15°	UNBABC 15°	Average Temperature	Average Humidity	Average Pressure
15.01.2012	AKSR	1005.803	75194.356	0	0	27	0	174	-159	2	16	-2	26	14	-186	-186	2.8°	82	996.80
	FEEK	600.315	109635.274	0	0	73	0	459	-427	38	-39	-37	-48	-46	-535	-535	4.3°	80	997.60
	HALP	1252.456	71877.256	0	0	0	0	0	7	-50	0	-4	-1	1	-1	-1	7.4°	52	995.40
	KAYS	1138.758	111294.034	0	0	13	0	75	-89	-11	-8	5	15	0	-90	-90	1.8°	93	994.00
	NEVS	1292.459	73059.724	0	0	-4	0	-26	81	5	-4	-12	-3	-4	24	23	1.8°	93	994.00
	NGDE	1410.622	7641.969	0	0	-17	0	-102	110	-14	7	7	9	6	128	128	4.2°	68	994.60
	NIGD	1252.326	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.2°	68	994.60
	POZA	826.403	61941.176	0	0	48	0	283	0	-10	-18	-6	-5	-21	-332	-332	4.3°	80	997.60
	TUFA	1459.39	139300.83	0	0	-23	0	-147	135	5	-1	2	-1	5	142	142	4.3°	80	997.60
15.06.2012	AKSR	1005.803	75194.356	1	0	28	0	161	-152	24	-9	5	4	-6	-190	-190	27.9°	9	1001.80
	FEEK	600.315	109635.274	-6	0	76	0	457	-440	-3	1	1	-26	-1	-483	-483	26.4°	0	1000.60
	HALP	1252.456	71877.256	-3	0	0	0	0	44	32	25	3	22	20	20	21	26.2°	2	1000.80
	KAYS	1138.758	111294.034	0	0	12	0	74	-95	56	-8	2	-3	-2	-72	-73	25.6°	8	1001.50
	NEVS	1292.459	73059.724	1	0	-4	0	-26	29	40	4	6	0	4	30	30	25.6°	8	1001.50
	NGDE	1410622	7641.969	-8	0	-17	0	-102	109	11	-6	6	6	8	127	127	25.5°	1	1000.70
	NIGD	1252.326	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25.5°	1	1000.70
	POZA	826.403	61941.176	-7	0	42	0	283	-290	14	14	4	-1	7	-314	-312	26.4°	0	1000.60
	TUFA	1459.39	139300.83	-7	0	-21	0	-130	85	13	7	2	13	20	144	144	26.4°	0	1000.60

Table 3. Adjustment results based on Application 2 site

Survey Days	Station Name	LEICA GEO OFFİCE						TOPCON TOOLS								
		HOPFIELD	SIMPLIFIED HOPFIELD	SAASTOMONİEN	ESSEN AND FROME	NO TROPOSFER	COMPUTED	GOAD& GOODMAN 15°	NİELL 15°	UNBABC 15°	GOAD& GOODMAN 15°	NİELL 15°	UNBABC 15°	GOAD& GOODMAN 10°	GOAD& GOODMAN 5°	GOAD& GOODMAN 1°
10.03.2012		Program Data; Pressure 1013.2 Mb Temperature: 20°C Humidity: 50									Avg. Pressure:1014.42 Temp:12 Humidity:%47					
	L2810012	0	-11	0	-31	33	-16	0	-1	-1	1	26	26	-1	-3	-3
	L29-G001	0	14	0	56	-80	-15	0	1	1	-2	162	162	-3	-5	-5
	M28-G001	0	-26	0	-136	198	-3	0	-2	-3	3	-148	-148	-1	-8	-8
11.03.2012		Program Data; Pressure 1013.2 Mb Temperature: 20°C Humidity: 50									Avg. Pressure::1015.56 Temp:6 Humidity:%48					
	L2810012	0	-9	0	-47	46	-50	4	8	1	4	23	23	7	7	8
	L29-G001	0	14	0	55	-92	1	22	24	25	21	189	189	20	20	19
	M28-G001	0	-28	0	-144	176	-4	-10	-10	-14	-9	-174	-174	-2	-2	-6
12.03.2012		Program Data; Pressure 1013.2 Mb Temperature: 20°C Humidity: 50									Avg. Pressure::1014.00 Temp:12 Humidity:%47					
	L2810012	0	-9	0	-44	43	-35	9	-18	-18	-34	7	31	14	15	15
	L29-G001	0	15	0	74	-94	1	21	-7	-7	-40	160	189	25	36	32
	M28-G001	0	-28	0	-145	167	-23	1	-7	-8	-7	-158	-149	-3	-8	-9
10.06.2013		Program Data; Pressure 1013.2 Mb Temperature: 20°C Humidity: 50									Avg. Pressure::1003.49 Temp:24 Humidity:%35					
	L2810012	0	-5	0	-28	36	17	-15	-18	-19	-15	6	6	-27	-29	-29
	L29-G001	0	20	0	117	-132	44	-4	-8	-10	-6	144	144	-8	-10	-9
	M28-G001	0	-22	0	-135	151	30	-30	-33	-38	-30	-184	-184	-43	-46	-46
11.06.2013		Program Data; Pressure 1013.2 Mb Temperature: 20°C Humidity: 50									Avg. Pressure::1003.126 Temp:31 Humidity:%20					
	L2810012	0	-5	0	-26	37	5	-18	-29	-22	-14	61	61	-25	-26	-26
	L29-G001	0	18	-2	107	-128	-2	-14	-12	-12	-5	174	174	-6	-4	-3
	M28-G001	0	-21	0	-134	148	21	-28	-35	-37	-36	-114	-114	-43	-44	-44
12.06.2013		Program Data; Pressure 1013.2 Mb Temperature: 20°C Humidity: 50									Avg. Pressure:1004.299 Temp:28 Humidity:%20					
	L2810012	0	-5	0	-28	39	11	-17	-13	-19	-15	8	4	-15	-16	-16
	L29-G001	0	20	0	112	-128	14	-1	-3	-10	6	146	146	4	10	10
	M28-G001	0	-22	0	-133	151	20	-29	-31	-28	-32	-164	-164	-36	-35	-35

Table 4. Application 3 site free adjustment results

	NETWORK ADJUSTMENT RESULT														
	LEİCA GEO OFFİCE									TOPCON TOOLS					
Station Name	15° HOPFIELD	10° HOPFIELD	5° HOPFIELD	0° HOPFIELD	SIMPLIFIED HOPFIELD	SAASTAMOINEN	ESSEN FROOME	NO TROPOSFER	COMPUTED	UNBABC	GOOD & GOODMAN	NİELL	Distance to Reference m.	Ellipsoidal Height	Orthometric Height
N.1	0	-2	-3	-4	-18	0	-106	116	29	-22	-11	-22	13835.06	1048.26	1012.50
N.2	0	-3	-5	-5	-17	0	-104	115	38	-24	-10	-25	11163.68	1043.94	1008.17
N.3	0	-3	-4	-5	-16	0	-95	104	27	-19	-8	-19	9082.26	1061.21	1025.46
N.4	0	-1	-2	-3	-15	0	-92	99	37	-3	-1	-3	5908.12	1067.02	1031.22
N.5	0	-2	-3	-4	-8	0	-50	54	28	-13	-8	-13	2872.37	1130.69	1094.87
N.6													0.00	1204.22	1168.27
N.7	0	-1	-1	-1	-4	0	-23	24	42	-12	-6	-12	3925.38	1171.09	1135.16
N.8	0	1	2	3	3	0	16	-18	1	-7	4	-7	5149.34	1228.39	1192.39
N.9	0	1	2	3	26	0	162	-173	29	-14	-8	-14	7949.32	1449.41	1413.19
N.10	0	1	2	3	36	0	223	-229	29	-12	-12	-12	8577.51	1561.68	1525.42
N.11	0	1	2	3	58	-1	359	-362	35	9	8	9	9487.22	1768.76	1732.45
N.12	0	1	2	4	56	-1	348	-324	30	8	7	8	9698.85	1767.50	1731.16

entering the measured or provided meteorological data into the program, the Goad&Goodman model gives similar results according to its closeness to the fixed parameters, while the Niell and UNBabc model gives very distant results by entering the meteorological data. Niell and UNBabc models should not be used while calculating with meteorological data in Topcon Tools program.

It is not a problem to calculate the troposphere models used in local calculations or in programs for less uneven terrain with models suitable for the application area and location. Since the moisture, temperature and pressure values in different regions will be different in calculations to be made as a result of broad-based GPS observations (such as TUSAGA application), the use of a standard troposphere model may give erroneous results according to the application area. Therefore, it will be appropriate to measure meteorological data in high-presentation measurements and to make calculations in the programs in which these data can be loaded.

In an academic study to be done to get a more effective result from the comparison of Troposphere models with the measurement of atmospheric data; measuring the atmospheric data of the points at the seaside and the points in the inner parts that have different height and pressure values will be more useful at the point of comparing the troposphere models.

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