

APPLICATIONS OF ONLINE SATELLITE IMAGERY IN SURVEYING AND ASSESSING ITS RELIABILITY USING GNSS TECHNOLOGY

Gincho Kostov, Bulgaria

The usage of WEB based services in geodesy and surveying is getting quite popular recently: [www.naviteq.net] – site in the area of geodetic satellite determinations, [www.metzgerwillard.us/ngscs/ngscs.html] – for land surveying research tools, etc. Application Google Earth (GE) [www.google.com/earth/index.html] offers both free and paid WEB services - satellite imagery, which can be applied for a lot of purposes. Some publications exist, describing the applications of GE in the area of surveying. One different study (treating the reliability of the used imagery and its possible applications for specific activities like visualization, cadastre, etc.) will be given in this paper. As it is known, the accuracy of the uploaded imagery varies, depending for instance on the region on the Earth. Information about the varying accuracy of imagery of GE can be found on the WEB at [http://en.wikipedia.org/wiki/Google_Earth#Imagery_and_coordination]. To perform this study, a number of places in the central part of Bulgaria, with the necessary good resolution of the satellite imagery were chosen. The reliability of the online map was investigated, conducting fast static geodetic GPS and GLONASS (GNSS) measurements. Control points on specific places on the terrain were created and measured using contemporary geodetic GNSS equipment, the last tuned with specific values of the parameters (cut-off angle set to 5 degrees, occupation time of 5 min. and record rate set to 1 sec.). The raw satellite measurements were processed using firmware Geomax Geo Office [<http://www.geomax-positioning.com>], which calculated the results – WGS84 coordinates of the control points, as well as various quality criteria. Computed latitude and longitude were uploaded and visualized on the online map (GE), using the application Geomap [<http://www.geozemia.com>] (in this particular case to input the values of geodetic geographical coordinates in a *.kml file). The computed positions of the control points were used as to perform the necessary analysis over the online imagery, also to determine the eventual discrepancies (translation and/or rotation) which may appear between the points and the online map under study. According to the derived geodetic geographical coordinates and used imagery, graphs with the control points and the discrepancies were created and conclusions about the possible usage of the online map for specific geodetic purposes were done. Respectively, recommendations for future work were done.

1. INTRODUCTION

Nowadays the WEB-based services and applications in geodesy offer the users various possibilities. Recently, they became quite useful, as they are applied for a lot of practical tasks in the area of geodesy, surveying, cadastre, etc.

On one hand, as it is known, RTK mode is fast and very productive method for surveying [Minchev et al., 2005]. On the other hand fast static method for geodetic determinations is one of the most precise ones, see [<http://facility.unavco.org/>]. It can be used when high accuracy is required and the productivity is not a prior factor for the measurements.

According to the literature [Wellenhof et al., 2002] it is known, that the day time is preferred for conducting of satellite measurements, taking in mind the required organization within the survey crew. This key moment was taken into account, according to the specifics of the work, when performing the GNSS measurements, used in this experiment.

In [Valev et al., 1995] is stated, that GPS measurements should be conducted in open areas, with cut-off angle minimum of 15 degrees. An experiment using contemporary GNSS equipment was performed, which shows that the cut-off angle could be lowered to 0-5 degrees and to deliver very good results [Kostov, 2010]. According to the last, setting in the GNSS software with 5 degrees cut-off angle was used in this study.

Several applications exist (interacting in one way or another with GE and WEB), see [<http://www.gmat.unsw.edu.au/currentstudents/ug/projects/Leach/Mitchell%20Leach.htm>], [<http://www.metzgerwillard.us/ngscs/ngscs.html>], [<http://www.kolma.bg/>] and [<http://code.google.com/p/google-earth-plotter/>], which are able to prepare data and to visualize them in GE in *.kml file format. One other application will be described here and experiments with online satellite imagery will be performed. The aim is to determine the reliability of the online map, provided in GE, especially for the needs of surveying and cadastre. The examined satellite imageries have several sources, as written on them: DigitalGlobe [<http://www.digitalglobe.com>], Tele Atlas [<http://www.teleatlas.com/>] and GeoEye [<http://www.geoeye.com>].

2. USE OF ONLINE SATELLITE IMAGERY IN GEODETIC APPLICATIONS. GE'S ACCURACY DISCUSSION

Google Earth is a virtual globe, map and geographical information program, available online [http://en.wikipedia.org/wiki/Google_Earth] and seems to be one modern and useful software application for visualization of various types of objects onto the World map. New features are appearing as enhancements in GE, see [<http://www.spatialsource.com.au/2010/12/14/article/Google-Earth-launches-satellite-imagery-tool/KJAAJUOEX.html>]. It should be noted one Chinese rival of GE, which can be found at [<http://www.chinaonmap.cn/map/index.jsp>] and may deliver to the users a new set of services and/or possibilities.

The online satellite imagery could be used in many ways in the area of geodesy and surveying. Some examples will be given here.

1. Google Earth Plotter [<http://code.google.com/p/google-earth-plotter/>] – a program to plot surveying data from Great Britain on Google Earth;
 2. Mkad [<http://www.kolma.bg/>] – this application is able to visualize for example parcels on Google Earth in case that the coordinate system in the digital model is correctly defined;
 3. SAGE 2006
[<http://www.gmat.unsw.edu.au/currentstudents/ug/projects/Leach/Mitchell%20Leach.htm>] – this is a DXF to KML converter;
- All these softwares provide output of specific data (e.g. points or contours) on the online map of GE in order to fulfil specific geodetic activities.

Parallel with the emerging usage of the online map, number WEB-sites, for example in Bulgaria, see [<http://www.geonet.bg/>], [<http://www.naviteq.net>] and [<http://www.smartnet.bg>] provide services in the area of GNSS determinations.

Several discussions and information about the accuracy of the GE's satellite imagery can be found on the Internet, see [http://www.gearthblog.com/blog/archives/2006/02/why_google_eart.html] and [http://en.wikipedia.org/wiki/Google_Earth#Resolution_and_accuracy]. From these sources it can be seen, that for different places on the Earth, the quality and accuracy have big variations. This shows, that it is recommended for the surveyor who uses the online map - such as GE to have an idea about the reliability of the satellite imagery for the region of the performed geodetic activities. One experiment and analysis about the reliability of the online World map in the central part of the country, using contemporary GNSS equipment will be given in this paper.

3. USED METHODOLOGY FOR ASSESSMENT OF THE RELIABILITY OF THE ONLINE WORLD MAP IN GE. PERFORMED GNSS MEASUREMENTS

In order to investigate the reliability of the online World map in several regions, GNSS measurements were conducted. The raw data from the satellite measurements were post-processed with the GNSS firmware. To do this experiment, the following methodology was used. A number of places with the necessary good resolution of the satellite imagery were chosen. Control points on specific objects on the terrain were created. Then points were measured using fast static mode. The control points were uploaded on the online World map /see chapter 6/ and their measured positions were compared with their expected places on the satellite imagery. Results from the geodetic measurements were analyzed according to the derived by the firmware quality criteria.

A number of regions /see details below/ from the online World map, with various dates of the satellite imagery - from 2007 y. till 2010 y. were subject of this study. Geodetic measurements, using one and the same reference point were performed in various places - town, villages, and open areas. Their names are given in alphabetical order:

- a) region of Chirpan – imagery date - 2007 y;
- b) region of Dimitrovgrad – imagery date - 2010 y;
- c) region of Galabovo – imagery date - 2009 y;
- d) region of Gurkovo – imagery date - 2010 y;
- e) region of Nikolaevo – imagery date - 2010 y;
- f) region of Nova Zagora – imagery date - 2009 y;

- g) region of Opan – imagery date - 2010 y;
- h) region of Pamukcii – imagery date - 2010 y;
- i) region of Stara Zagora – imagery date - 2008 y.

The GNSS system was tuned with specific values of the parameters: record rate of the satellite signals set to 1 sec., cut-off angle set to 5 degrees and occupation time of up-to 5 min. [Kostov, 2009] and [Kostov, 2010]. The sites were situated in open areas, well recognizable on the online World map. The geodetic measurements were conducted in day time. Permanent reference network was not used.

4. SOURCES OF ERRORS IN THE GPS MEASUREMENTS AND DATA PROCESSING, INFLUENCING THE OVERALL QUALITY OF THE RESULTS

There are several factors, which should be taken into account when performing GPS measurements. According to the literature [Minchev et al., 2005], the main sources of errors in satellite determinations and data processing are: errors from synchronizing of clocks/the time/ in satellites and receiver, satellite orbit, troposphere refraction, ionosphere refraction, variations in the phase centre of the antenna, multipath.

Explanations about the various sources of errors in GPS measurements can be found also in [Wellenhop et al., 2002].

Here is given only brief information, details can be found in the references.

5. USED CRITERIA FOR OVERALL QUALITY ASSESSMENT OF THE PERFORMED GEODETIC DETERMINATIONS

In this paper the following quality criteria were used:

- a) Quality in position and height M_{3D} ;
- b) Elements of the co-variance matrix Q_{xx} , Q_{yy} and Q_{zz} ;
- c) Number GDOP(max);
- d) Number PDOP(max).

The numbers GDOP and PDOP are part from DOP factor for accuracy, described in details in [Wellenhop et al., 2002].

6. INPUT OF THE COORDINATES OF THE CONTROL POINTS ONTO THE ONLINE WORLD MAP

In order to do this study, several software applications were involved /given in the order of their usage/:

- 1. Geomax Geo Office – details can be found at [\[http://www.geomax-positioning.com/geomax-ggo-version-20_424.htm\]](http://www.geomax-positioning.com/geomax-ggo-version-20_424.htm);
- 2. GNSSTransformations – for more information, see [\[http://www.geozemia.com/EnglishVersion/GeodeticSoftwareEng.html\]](http://www.geozemia.com/EnglishVersion/GeodeticSoftwareEng.html);
- 3. Geomap – description of the application at [\[http://www.geozemia.com/EnglishVersion/GeodeticSoftwareEng.html\]](http://www.geozemia.com/EnglishVersion/GeodeticSoftwareEng.html);
- 4. Google Earth [\[http://www.google.com/earth/index.html\]](http://www.google.com/earth/index.html).

The performed procedure for visualization of the control points onto GE, using GNSS equipment is:

- Import of the raw data from the satellite measurements in Geomax Geo Office. Processing of the data and export of both the coordinates of the measured points and the relevant quality criteria in external files.

- Conversion of the coordinates in an easy to use format, using GNSSTransformations.

- Applying of Geomap – this means that the name of the point (ID) and its WGS84 coordinates are input in the application. The last generates *.kml file, which is imported in GE. In this way on the World map can be input and visualized easily points, measured using various surveying instruments – in our specific case, coordinates calculated using GNSS technology.

- GE is used as to visualize the measured control points on the online World map.

7. RESULTS

Assuming that the steps, described in the previous chapter are completed, we already have the coordinates (in the coordinate system of GE – WGS84) of each control point and the values of the relevant quality criteria. The control points were visualized on the online World map.

In tabular type below are given the results from the quality assessment for each measured control point for every region, where studies for reliability of the World map were done. Graphs with the online map, input control points and the denoted discrepancies are also attached below.

7.1. Quality assessment of the geodetic measurements and analysis of the online World map for Chirpan region

Point ID	M_{3D}	Q_{xx}	Q_{yy}	Q_{zz}	GDOP (max)	PDOP (max)
100	0.0007	0.00000630	0.00000294	0.00000547	1.9	1.6
200	0.0008	0.00000674	0.00000285	0.00000599	2.2	1.9
300	0.0007	0.00000760	0.00000288	0.00000700	2.0	1.7
400	0.0007	0.00000846	0.00000288	0.00000714	1.9	1.6

Table 1

From the given in table 1 values, the following facts could be noted. Almost the same values for M_{3D} - 0.0007 m. and 0.0008 m. were calculated. DOP values are with the maximum of 2.2, which could be marked as good, see [\[http://en.wikipedia.org/wiki/Dilution_of_precision_%28GPS%29\]](http://en.wikipedia.org/wiki/Dilution_of_precision_%28GPS%29). All mentioned information in the table leads to the conclusion for a good overall quality of the geodetic determinations for these control points.



Figure 1

The data on figure 1 show the satellite imagery for Chirpan region and the visualized measured control points. The red arrows clearly indicate the discrepancy between the true position of each control point and its place on the online World map.

7.2. Quality assessment of the geodetic measurements and analysis of the online World map for Dimitrovgrad region

Point ID	M_{3D}	Q_{xx}	Q_{yy}	Q_{zz}	GDOP (max)	PDOP (max)
500	0.0009	0.00000801	0.00000358	0.00000878	2.2	1.8

Table 2

From the results, listed in table 2 it could be concluded the following. DOP factors have largest value of 2.2. Quality criterion M_{3D} has quite low value - 0.0009 m. Taking in mind these facts, it could be noted that the performed measurements for the control point have good quality and reliability.

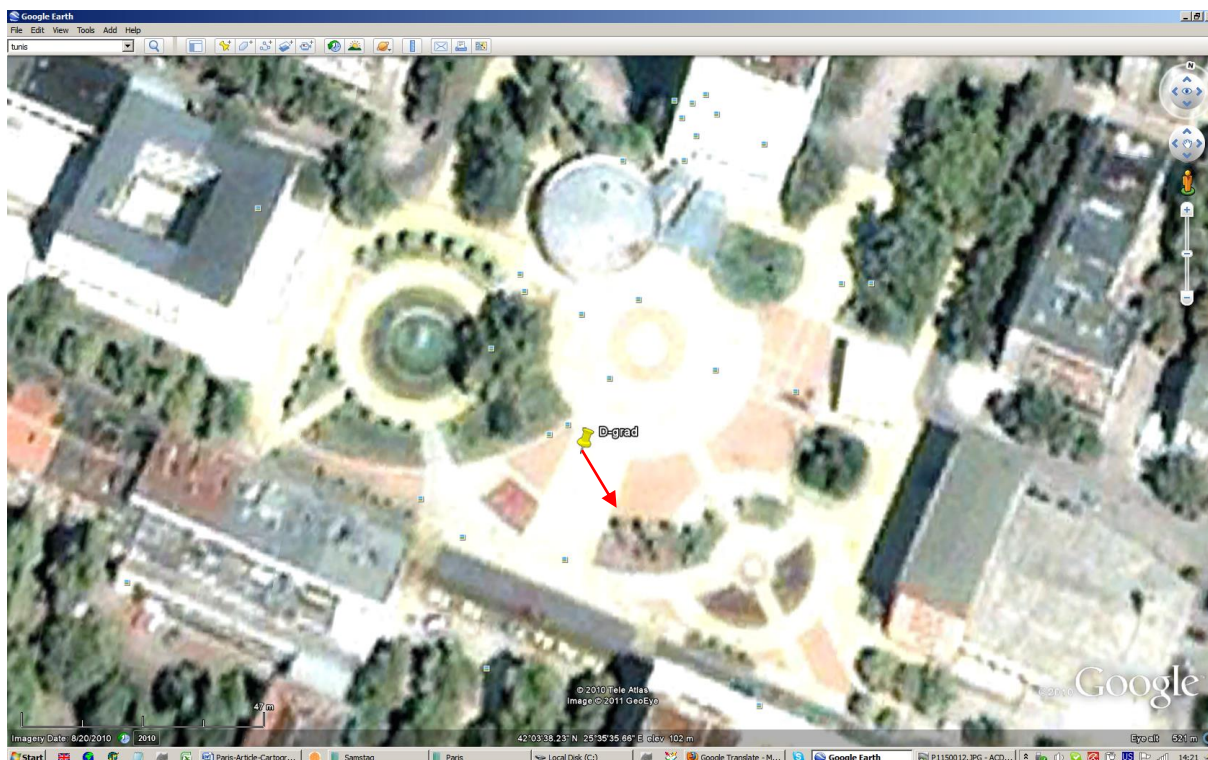


Figure 2

The information included in figure 2 depicts the satellite imagery for centre of town - Dimitrovgrad. The arrow denotes the shift from the measured position of the control point and its expected place on the online World map.

7.3. Quality assessment of the geodetic measurements and analysis of the online World map for Galabovo region

Point ID	M_{3D}	Q_{xx}	Q_{yy}	Q_{zz}	GDOP (max)	PDOP (max)
10	0.0007	0.00000709	0.00000274	0.00000511	1.9	1.6
11	0.0007	0.00000642	0.00000259	0.00000459	1.9	1.7
12	0.0007	0.00000618	0.00000249	0.00000454	1.8	1.6

Table 3

From the numeric values of each criterion, given in table 3 it could be summarized. DOP values have their maximum at 1.9, which can be treated as excellent, according to [\[http://en.wikipedia.org/wiki/Dilution_of_precision_%28GPS%29\]](http://en.wikipedia.org/wiki/Dilution_of_precision_%28GPS%29). M_{3D} quality criterion has one and the same small value of 0.0007 m. Taking in mind this information, we have very good overall quality for these results from the geodetic measurements.

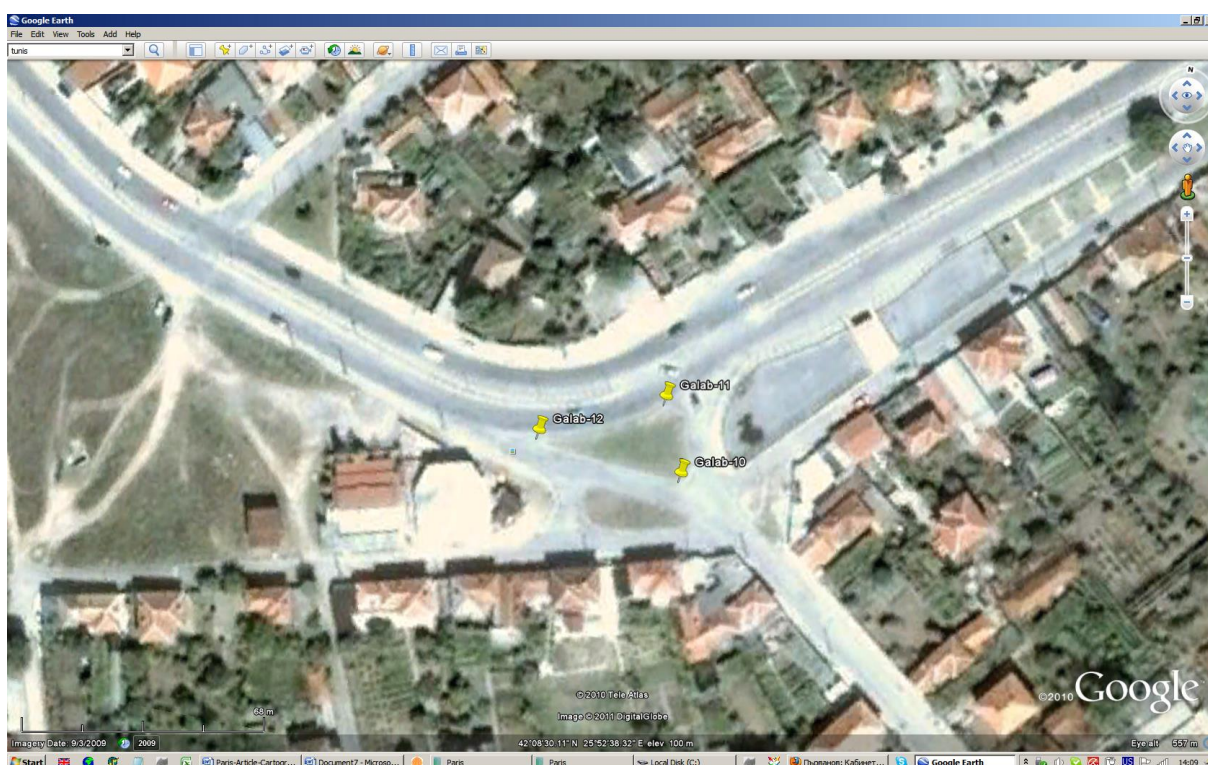


Figure 3

Here on figure 3 the control points fit very well on the satellite imagery. No (significant) discrepancies can be found.

7.4. Quality assessment of the geodetic measurements and analysis of the online World map for Gurkovo region

Point ID	M_{3D}	Q_{xx}	Q_{yy}	Q_{zz}	GDOP (max)	PDOP (max)
444	0.0007	0.00000502	0.00000159	0.00000334	1.7	1.4
222	0.0008	0.00000544	0.00000377	0.00000665	4.1	3.3
333	0.0008	0.00000569	0.00000451	0.00000762	2.7	2.3
111	0.0008	0.00000789	0.00000327	0.00000580	2.6	2.2
222a	0.0007	0.00000522	0.00000183	0.00000382	2.0	1.7

Table 4

If the above values of the criteria are analyzed (see table 4) it could be noted the following. DOP factors (except for point 222) are with the maximum value of 2.7. It can be stated that these values aren't problematic, according to [Minchev et al., 2005]. In Gurkovo region the

quality criterion M_{3D} has values of either 0.0007 m. or 0.0008 m., which could be treated as very good.



Figure 4

The satellite imagery, located in figure 4 shows the centre of town Gurkovo with three control points. The visible offset from their measured on the Earth surface and expected positions on the online map can be seen. The shift has direction south-east, as seen on the graph.

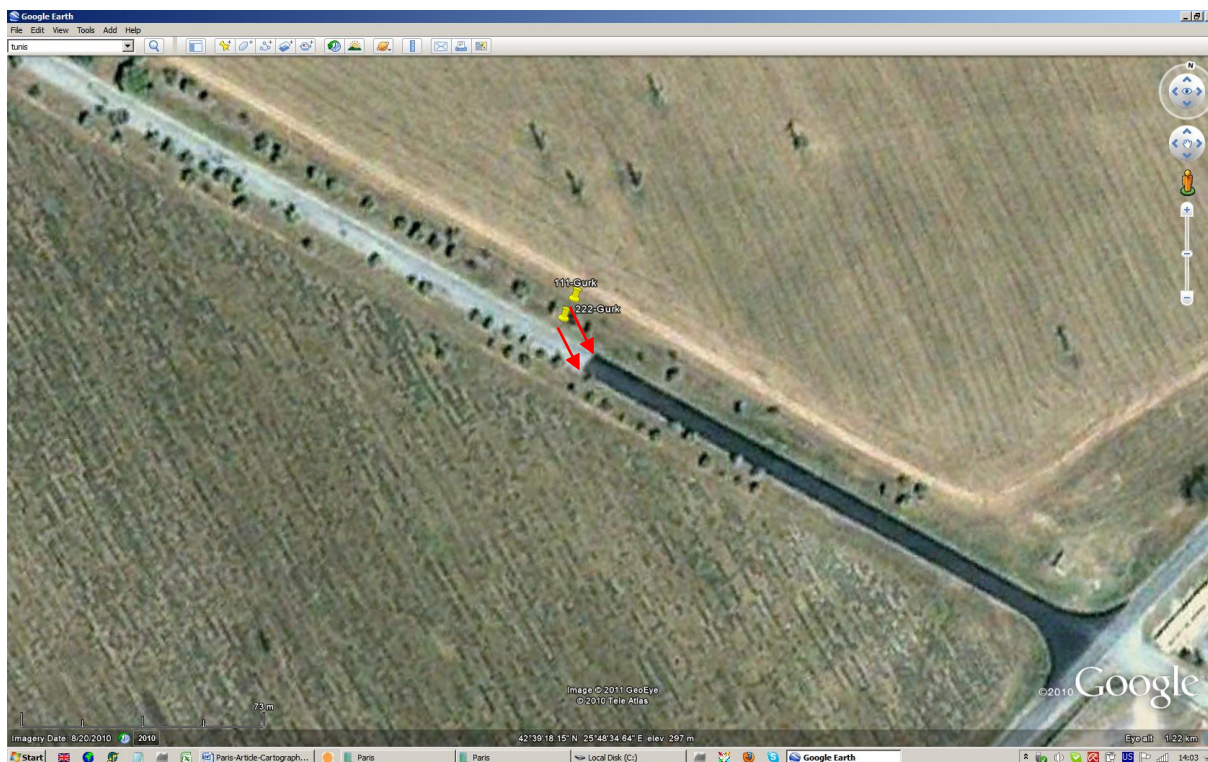


Figure 5

The satellite imagery shown in figure 5 illustrates the main road before entrance the town Gurkovo and two control points. A visible offset between the measured positions of the control points on the Earth's surface and their expected place on the satellite imagery was observed. The discrepancies have south-east direction.

7.5. Quality assessment of the geodetic measurements and analysis of the online World map for Nikolaevo region

Point ID	M_{3D}	Q_{xx}	Q_{yy}	Q_{zz}	GDOP (max)	PDOP (max)
1	0.0009	0.00000749	0.00000196	0.00000772	1.9	1.7
2	0.0009	0.00000746	0.00000204	0.00000762	3.3	2.8

Table 5

In table 5 are given the results from the quality assessment of the two control points, situated in the vicinity of Nikolaevo. The largest DOP value is 3.3 and could be accepted as “good”, according to http://en.wikipedia.org/wiki/Dilution_of_precision_%28GPS%29. Same values for M_{3D} were calculated for the two control points – 0.0009 m.

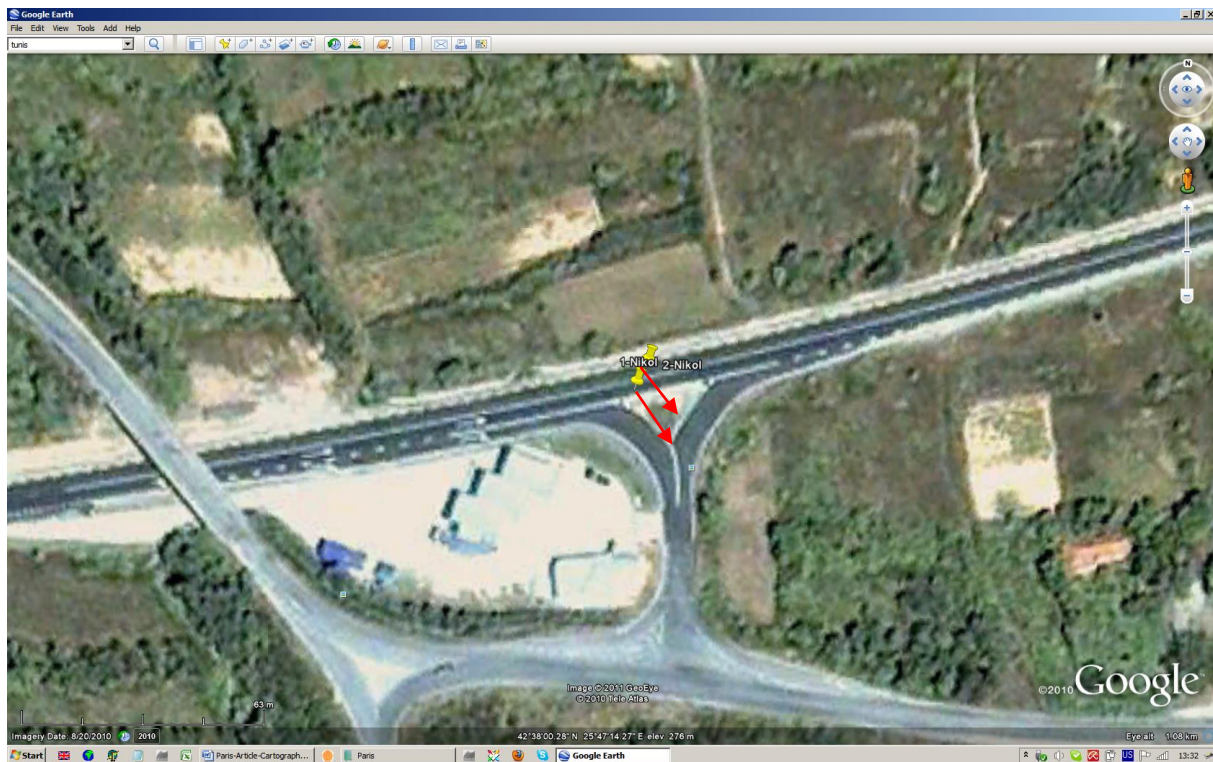


Figure 6

Figure 6 captures the satellite imagery next to town of Nikolaevo and the added control points. It can be clearly seen the significant offset between their place on the satellite imagery and the position of the measurements. The offset has south-east direction.

7.6. Quality assessment of the geodetic measurements and analysis of the online World map for Nova Zagora region

Point ID	M_{3D}	Q_{xx}	Q_{yy}	Q_{zz}	GDOP (max)	PDOP (max)
666	0.0012	0.00000875	0.00000404	0.00000926	2.3	1.9

Table 6

In table 6 are listed the values of the quality criteria for the measured control point in town Nova Zagora. Here the maximum DOP value is 2.3 - small enough and within the boundary, defined in [Minchev et al., 2005]. The criterion M_{3D} has low value – 0.0012 m. This information shows the good quality of the geodetic determinations for the region Nova Zagora.

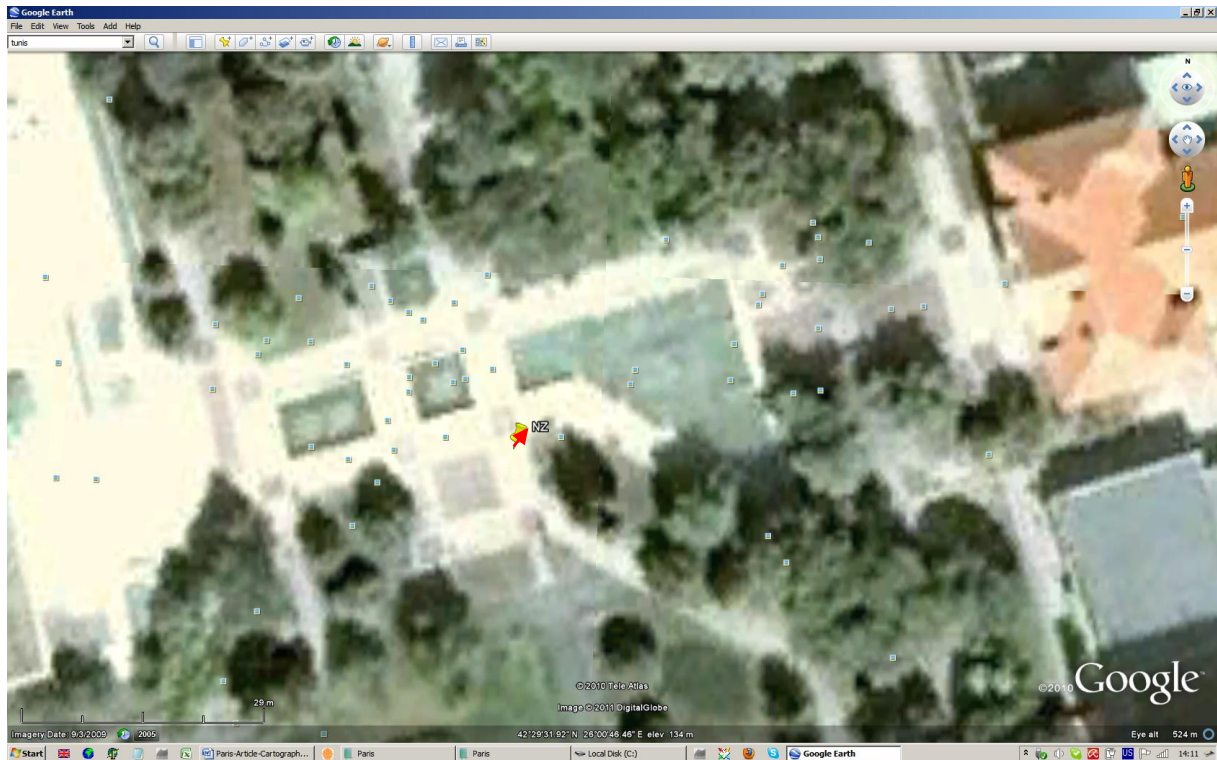


Figure 7

On figure 7 are shown both the satellite imagery and the control point in the centre of Nova Zagora. For this object there is a small discrepancy, indicated with red arrow, with direction north-east.

7.7. Quality assessment of the geodetic measurements and analysis of the online World map for Opan region

Point ID	M_{3D}	Q_{xx}	Q_{yy}	Q_{zz}	GDOP (max)	PDOP (max)
50	0.0009	0.00000750	0.00000614	0.00000834	1.8	1.5
10	0.0006	0.00000449	0.00000300	0.00000478	1.5	1.3

Table 7

In table 7 are given the quality criteria's values for control points in Opan region. In this case, the maximum DOP value is 1.8. Taking in mind the literature, treating the DOP factor, this value is "excellent". The values for M_{3D} in Opan regions are less than 1mm.

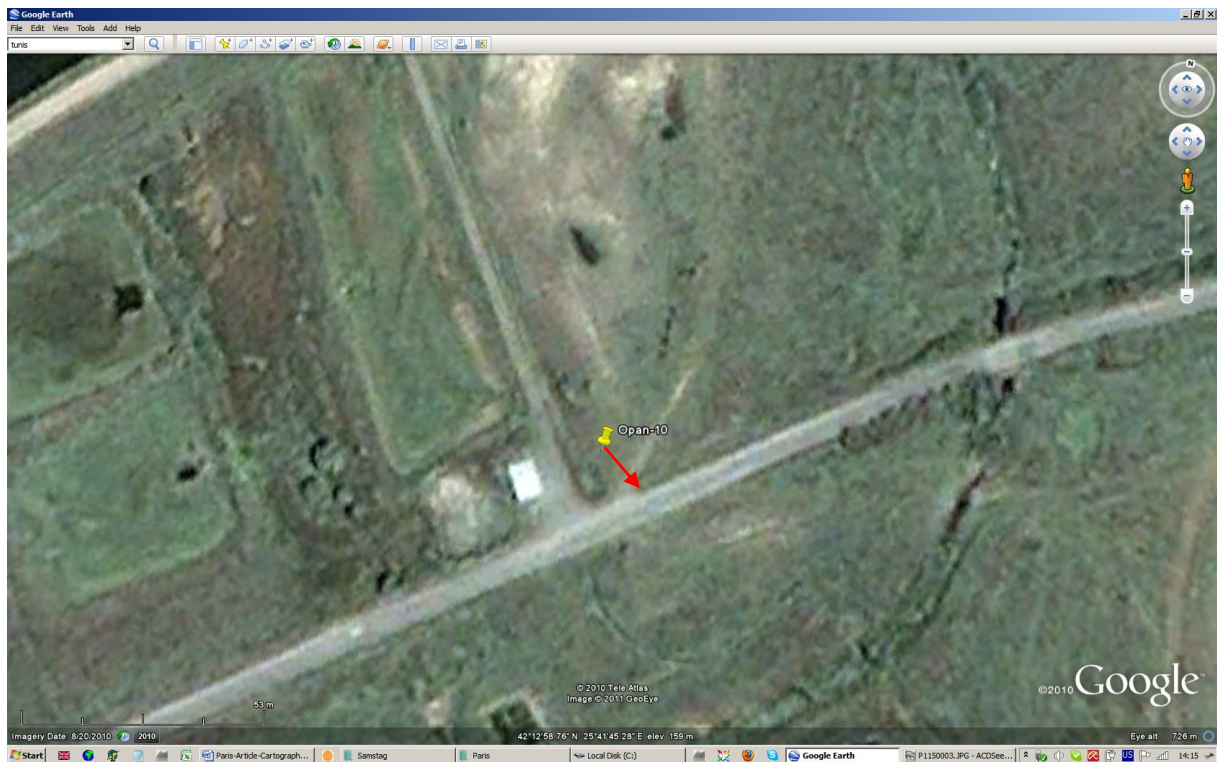


Figure 8

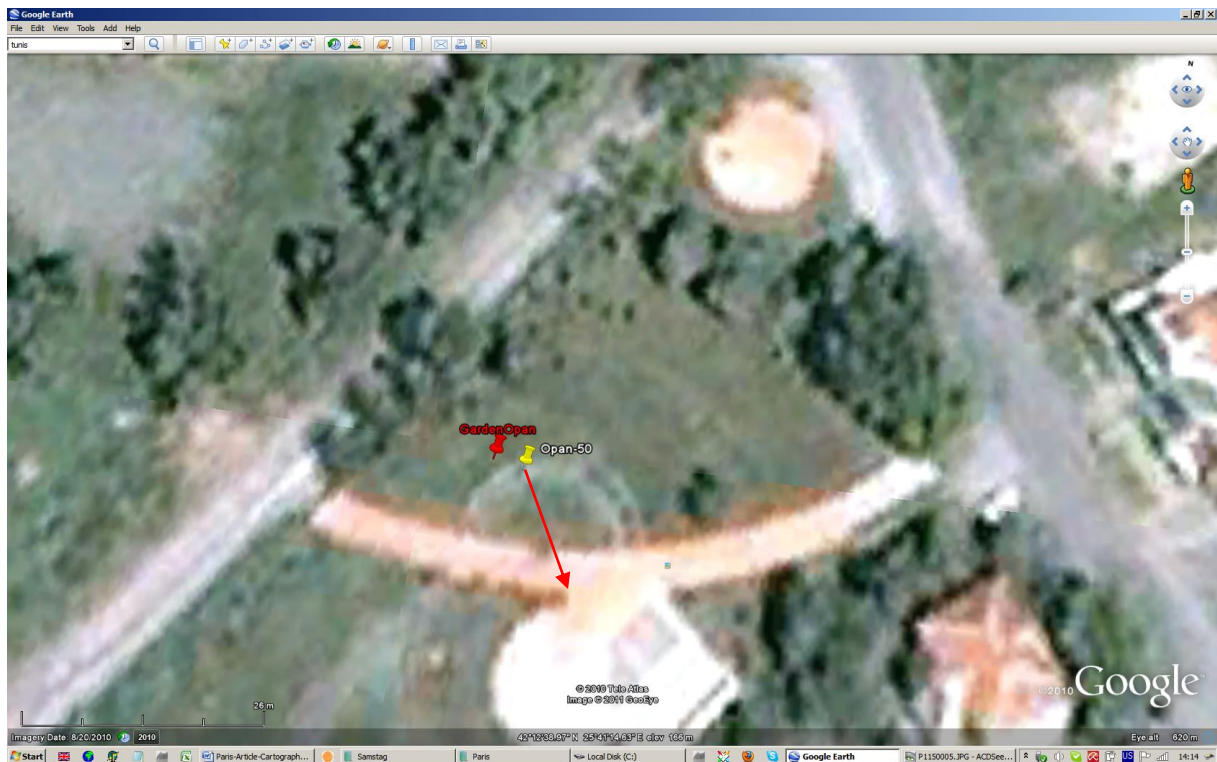


Figure 9

Figures 8 and 9 show the satellite imagery and the control points in the Opan region. The existing discrepancy with direction south-east is well visible on the given graphic.

7.8. Quality assessment of the geodetic measurements and analysis of the online World map for Pamukcii region

Point ID	M_{3D}	Q_{xx}	Q_{yy}	Q_{zz}	GDOP (max)	PDOP (max)
111	0.0003	0.000000042	0.000000013	0.000000057	2.1	1.8
55	0.0004	0.000000039	0.000000016	0.000000052	2.0	1.7

Table 8

Table 8 gives the values of the quality criteria for the control points in Pamukcii region. For this region, the maximum DOP value is 2.1. Quality criterion M_{3D} has very low value – 0.0004 m.

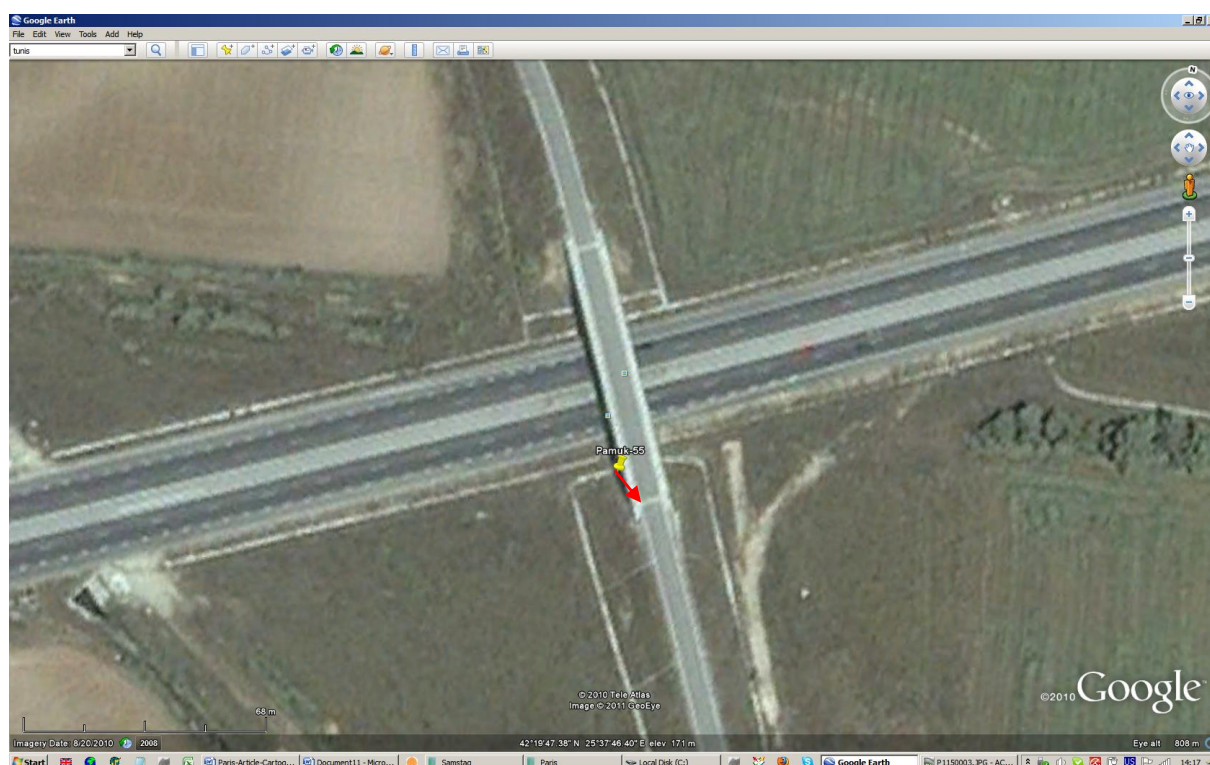


Figure 10

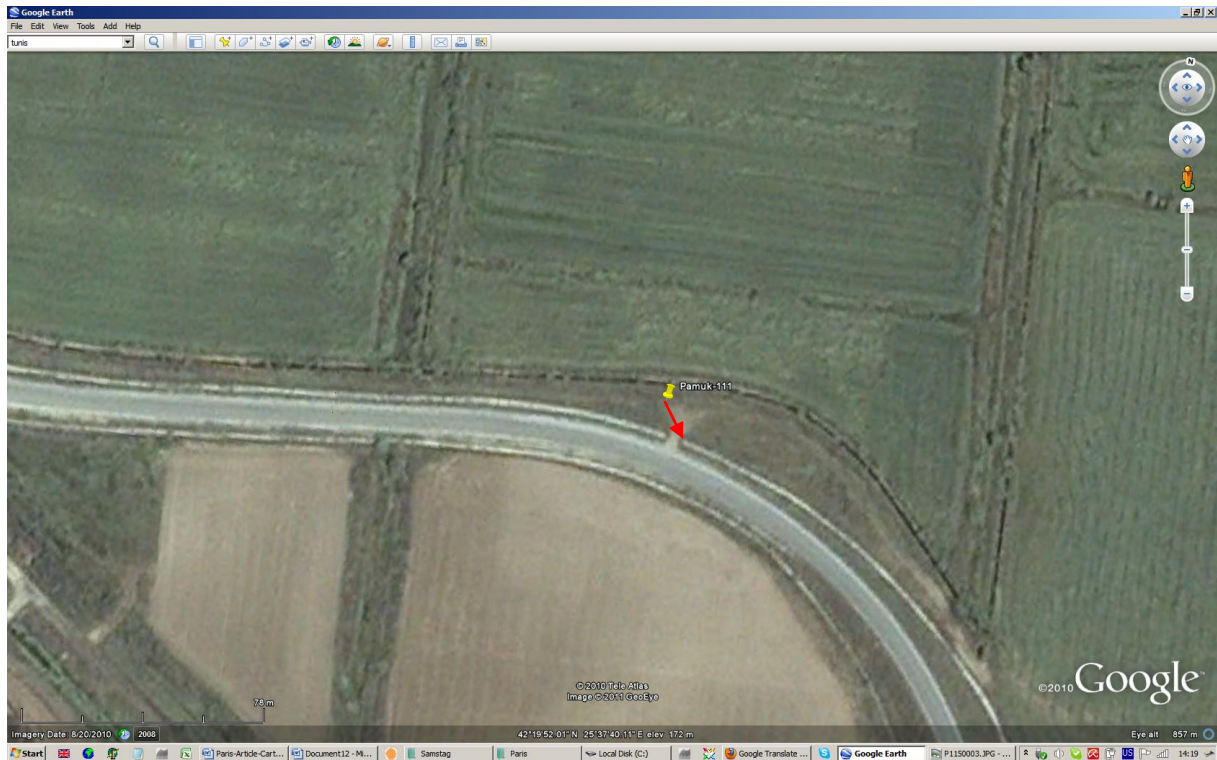


Figure 11

Figures 10 and 11 indicate the discrepancy, found in the satellite imagery and the coordinated control points in Pamukcii region. The direction of the shift is south-east, well noticeable on the online map.

7.9. Quality assessment of the geodetic measurements and analysis of the online World map for Stara Zagora region

Point ID	M_{3D}	Q_{xx}	Q_{yy}	Q_{zz}	GDOP (max)	PDOP (max)
1	0.0002	0.000000041	0.000000016	0.000000029	1.7	1.5
2	0.0003	0.000000041	0.000000016	0.000000028	1.6	1.4
3	0.0003	0.000000044	0.000000017	0.000000032	1.4	1.3

Table 9

Table 9 includes the quality criteria for the three measured control points in Stara Zagora region. In this case, the DOP factors have values less than 2. M_{3D} criterion has extremely low value – 0.0002 m. and 0.0003 m. These facts lead to the conclusion, that the points are very well determined.



Figure 12

On figure 12 can be found the discrepancies, which exist between the places of the control points on the online satellite imagery and their measured positions for Stara Zagora region. The direction of the offset is north-west, marked with red arrow on the online map.

From the experiments, done in this study, the following facts could be summarized. The attached graphs from the online satellite imagery with added control points show various discrepancies between the places of the control points on the online map and their true (measured) positions on the Earth surface. It must be noted that not in all cases such shifts exist. However, the “movements” have various direction and visible size.

According to the given information from point 7.1 till 7.9 it can be concluded that most of the discrepancies have similar direction i.e. there is “offset” between the measured position on the surface of the Earth and the places of the control points on the online satellite imagery, with direction to south-east. In Nova Zagora the offset is with direction to north-east. For Stara Zagora and Chirpan regions the movement is with direction to north-west. For completeness of the conclusions it should be noted again that in Galabovo region no visible offset was detected. Here “offset” denotes a direction from the *position of the measured control point to its expected place on the online satellite imagery*.

8. CONCLUSION

According to the results from the satellite determinations and the used online World map in GE, it could be concluded:

Online satellite imagery in GE could be used successfully for (rough) visualization purposes. Despite of the fact that several geodetic softwares provide functionality for visualization of surveying and cadastral data in GE, if planning to apply the last in the area of geodesy, the possible discrepancies should be carefully taken in mind. Places, where low resolution of the imagery is found or large discrepancies exist, should not be used in order to avoid possible misleading between the existing situation on the terrain and the used precise geodetic data.

The used application Geomap could be updated to a higher version, which means several improvements (adding of new possibilities for data import, allowing the user to change parameters in the KML file, etc). This could facilitate its use and would extend its capabilities.

REFERENCES

- Kostov, G., 2009, Using of Fuzzy logic for some studies over GNSS determination in fast static mode, UACEG, pp 3-7, Sofia (in Bulgarian)
- Kostov, G. Some Studies on the Quality of GNSS Determinations Under Specific Conditions. FS 1H - GNSS CORS Networks - Positioning Infrastructure, Analysis and Applications I. FIG Congress 2010 Facing the Challenges – Building the Capacity Sydney, Australia, 11-16 April 2010
- Minchev, M., Iv. Zdravcev, Iv. Georgiev, 2005, Foundations of the application of GPS in geodesy, pp 112-118, Sofia UACEG (in Bulgarian)
- Valev, G. M. Minchev, 1995, Instruction for determination of coordinates with GPS, pp 12-15, “Cartography” Ltd., Sofia (in Bulgarian)
- Wellenhof, B., Herbert Lichtenegger, James Collins, 2002, GPS Theory and practice, Springer-Verlag/Wien, pp183, Austria (in Bulgarian)

WEB:

<http://code.google.com/p/google-earth-plotter/>
http://en.wikipedia.org/wiki/Dilution_of_precision_%28GPS%29
http://en.wikipedia.org/wiki/Google_Earth
http://en.wikipedia.org/wiki/Google_Earth#Resolution_and_accuracy
<http://facility.unavco.org/>
<http://www.chinaonmap.cn/map/index.jsp>
<http://www.digitalglobe.com/>
http://www.gearthblog.com/blog/archives/2006/02/why_google_eart.html
<http://www.geoeye.com/>
<http://www.geonet.bg/>
<http://www.geozemia.com>
<http://www.gmat.unsw.edu.au/currentstudents/ug/projects/Leach/Mitchell%20Leach.htm>
<http://www.google.com/earth/index.html>
<http://www.kolma.bg/>
<http://www.mapworld.cn/en/index.asp>
<http://www.metzgerwillard.us/ngscs/ngscs.html>
<http://www.naviteq.net>
<http://www.smartnet.bg>

<http://www.spatialsource.com.au/2010/12/14/article/Google-Earth-launches-satellite-imagery-tool/KJAAAJUOEX.html>
<http://www.teleatlas.com/>

Used software:

Geomap - information at <http://www.geozemia.com>;
Geomax Geo Office - information at <http://www.geomax-positioning.com>;
GNSSTransformations - information at <http://www.geozemia.com>;
Google Earth - information at <http://www.google.com/earth/index.html>.