National report of Ukraine

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Introduction

During last years the main activities have the following directions: (1) the development of the permanent GNSS network, (2) further extension of the new State reference coordinate system UCS-2000 in the areas of municipal separate networks, (3) new regular (2'x3') grid of the Bouguer anomalies for geodetic aims, (4) preparations to the readjustment of the State vertical network, and (5) estimation of the strain rate tensor from GPS observations in the Eastern Europe. A special work for modeling the gravity field in the Ukraine area was started based also on the gravity gradients of GOCE data. Further densification of GPS-leveling data to a number of 4000 GPS-leveling points is continue for new quasigeoid solution based on gravimetry, altimetry, GOCE, and GPS-leveling data.

1. Development of the permanent GNSS network

Further development of the Ukrainian permanent GNSS network allows densification of the velocity field and estimation of strain rate tensor from GPS observations.
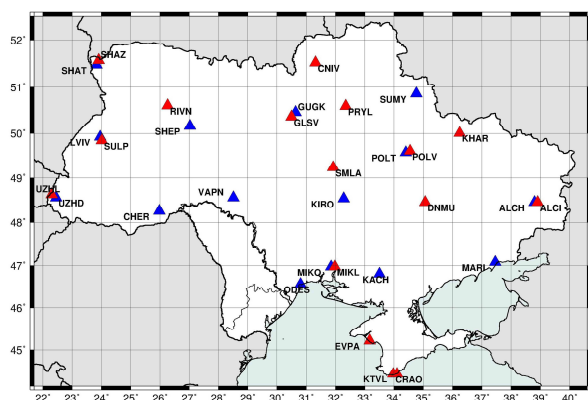
Fig. 1. Ukrainian network of permanent (4) and periodically observed (4) GNSS-stations

This estimation was based on the common processing of GNSS observations from permanent stations and periodical observations developed from the solution of the Research Institute of Geodesy and Cartography. There are 16 permanent sites and 16 periodically observed stations. At present part of permanent stations were included in the EPN or IGS permanent networks. **Fig.1** illustrates current Ukrainian permanent GNSS network and periodically observed stations.

2. Development of reference coordinate system UCS-2000

The extension of the new State reference coordinate system UCS-2000 given by Research Institute of Geodesy and Cartography was based on the redefinition the adopted horizontal system S-42 (Pulkovo) with possible keeping old maps of the scale 1:10000 or smaller in the S-42 system. In addition the accurate connection between the reference system UCS-2000 and the coordinate systems ITRS/ITRF2005 and ETRS89 was derived. After combining GNSS observations and classic terrestrial data the UCS-2000 system was developed to 24657 points of the State Geodetic Network (SGN). Coordinates of all points were obtained through combined adjustment of GNSS observations and classical terrestrial observations using the GeoLab software. **Table 1** demonstrates accuracy estimates of the position of geodetic points in the UCS-2000 system. For the support and densification of the Ukrainian SGN all destroyed and new points were developed. On the whole new 650 points were added. A special work for the transformation from UCS-2000 to different municipal (local) coordinate systems was started. At present there are 18 municipal coordinate systems where parameters of the transformation must be derived from new observations. Among these local coordinate systems connected with various municipal areas (cities) new 12 geodetic networks were constructed for solving this problem.

Table 1. Accuracy estimation of the position of geodetic stations given in the UCS-2000 system

Statistics	Accuracy estimation (in m) of geodetic stations of different orders				
	1st order, 813 pts	2nd order, 5586 pts	3rd order, 10084 pts	4th order, 8174 pts	Total: 24657 pts
Min	0.001	0.001	0.001	0.003	0.001
Max	0.026	0.112	0.099	0.143	0.143
Mean	0.003	0.020	0.032	0.032	0.028
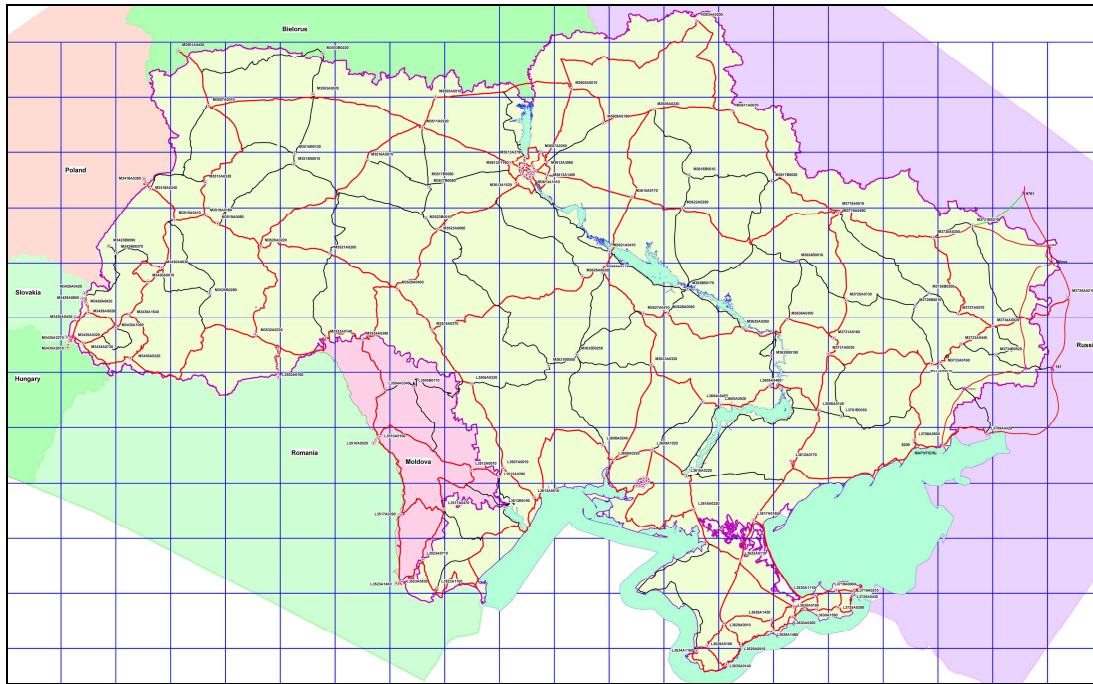
Fig. 2. Leveling lines of 1st (−) and 2nd (−) orders in the Ukraine and Moldova area

3. Current status of the Ukrainian vertical reference system

Since 1977 the official vertical system in the Ukraine area became the Baltic 1977 height system determined from leveling data of 1st and 2nd orders. Leveling stations are fixed by fundamental, ground, rocky, etc. benchmarks. The Baltic 1977 height system was build via adjustment in normal heights and has inhomogeneous accuracy estimates in the studying area. Basic characteristics of vertical reference networks of 1st and 2nd orders are listed in **Table 2**. **Fig. 2** illustrates leveling lines of 1st and 2nd orders.

To extend the European Vertical Reference Frame EVRF2000 to the Ukraine area and make available the connection with the United European Leveling Network by means of geopotential numbers the following tasks were solved:

- all leveling polygons from **Fig.2** by the 1st order leveling between Ukraine and neighboring countries were close,

- gravity measurements at the necessary stations according to the EUREF requirements were made,

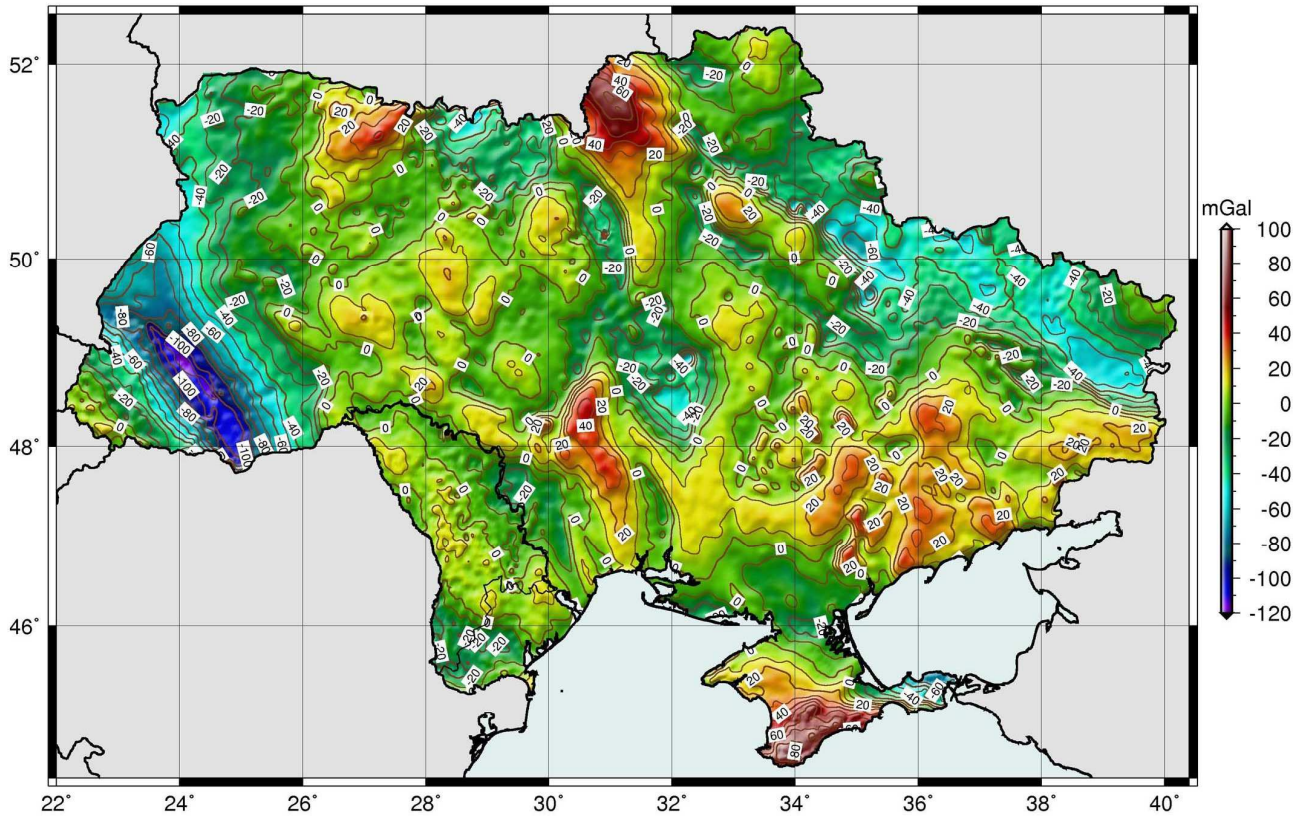- new regular (2'x3') grid of the Bouguer anomalies for calculation of geopotential numbers was constructed (**Fig. 3**),

- in the process of preparation to the readjustment of the State vertical network all necessary data of the leveling of 1st and 2nd orders between Ukraine and bordering countries were transmitted to Bundesamt für Kartographie und Geodäsie (BKG),

- creation of the database for the adjustment of leveling networks of 1st and 2nd orders via geopotential numbers,

- building of the special geodynamic polygons in the areas of atomic power station,

- After densification of GPS-leveling data in 2011 from current state (**Fig. 4**) to a number about 4000 GPS-leveling points the new quasigeoid solution based on gravimetry, altimetry (Black Sea and Azov Sea areas), GOCE, and GPS-leveling data is planning.

All these activities make possible a readjustment of the Ukrainian Vertical Network via geopotential numbers and construction in this way the corresponding gravity-related height system.

Table 2. Characteristics of vertical reference networks of 1st and 2nd orders

Order	Number of lines	Length of lines, km			Number of polygons	Perimeter, km	
		Min	Max	Total		Min	Max
I	29	70.7	1301.9	11975.0	18	135.5	2234.9
II	62	37.5	383.9	11179.5	72	218.0	883

Fig. 3. New regular grid (2′x3′) of the Bouguer anomalies in the Ukraine and Moldova area
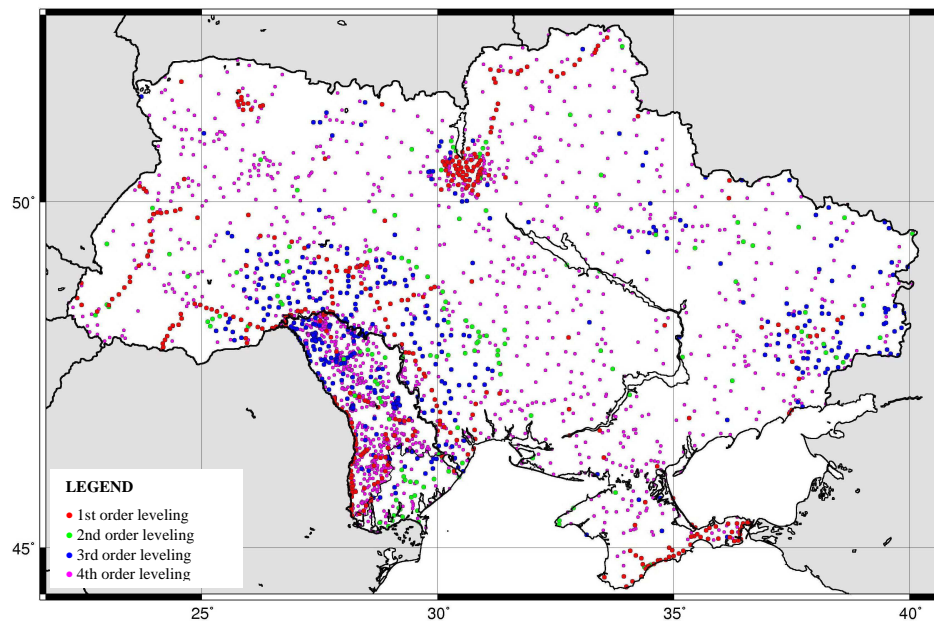
Fig. 4. Distribution of GPS-leveling data in the Ukraine and Moldova area

4. Current status of the Struve Arc points in the Ukraine area

Practical activity on the search of points of Struve Arc was begun in 2009 after an interruption in a few years. This work includes the calculation of coordinates of Struve Arc points, which are placed in the Ukraine area, their instrumental search, establishment of the status of centers, and preparation of scientific and technical information about Struve points. In particular, the inspection of northern part of triangles was observed in summer 2009. Southern part of triangles was provided

in 2010. All above-mentioned works were carried out by the special group of Research Institute of Geodesy and Cartography of Ukraine. Coordinates of the point positions were measured. It has to be pointed out that according to observed points of Struve Arc in the Ukraine area they could be split onto three parts with the following features.

First one is destroyed points illustrated by **Table 3**. Second one is the replaced by centers of points of State Geodetic Network (SGN) also given in **Table 3**. Third one is existent points of Struve Arc in a good order, which is demonstrated by **Table 4**. **Fig.5** shows one of the Struve Arc point Izmail, which is located at the cupola of bell tower of the Orthodox temple of Saint Mikolay. **Fig. 6** illustrates typical center of Struve Arc points with the lead plate in the center.

Finally we can conclude. Among 63 points of Struve Arc in the Ukraine area only 15 point are saved. According to **Table 3** a large number of Struve Arc sites – 26 points were destroyed and 22 points were replaced in the Ukraine area by the center of the State Geodetic Network points. **Table 4** illustrates 15 saved points of Struve Arc.

Table 3. Destroyed points of Struve Arc and replaced by the center of SGN point of State Geodetic Network

No	Struve No	Point Name	Result	No	Struve No	Point Name	Result
1	189	Bolschaja-Gluscha	Destroyed	25	263	Borska	Destroyed
2	190	Schlapan	Destroyed	26	STK	Staro-Konstantinow	Destroyed
3	191	Tscherwischtsche	Destroyed	27	TAS	Taschbunar I	Destroyed
4	193	Tscheremoschna	Destroyed	28	WAI	Waissal	Destroyed
5	194	Datin	Replaced by SGN point	29	ZAP	Sapadinzi	Destroyed
6	195	Kowel	Destroyed	30	192	Gutakamenskaja	Replaced by SGN point
7	197	Osmigowitschi	Destroyed	31	202	Smordwa	Replaced by SGN point
8	198	Roschischtsche	Destroyed	32	204	Gurniki	Replaced by SGN point
9	199	Tortschin	Replaced by SGN point	33	210	Turowka	Replaced by SGN point
10	200	Krupi	Replaced by SGN point	34	212	Montschinzi	Replaced by SGN point
11	201	Schabtscha	Destroyed	36	214	Kriwotschinzi	Replaced by SGN point
12	203	Borbin	Destroyed	39	219	Hanowka	Replaced by SGN point
13	209	Beloserka	Destroyed	40	257	Karakurt	Replaced by SGN point
14	245	Ploska	Destroyed	41	WER	Werborodinzi	Replaced by SGN point
15	247	Nesselrode	Destroyed	42	WOL	Wolizakerekeschina	Replaced by SGN point
16	248	Nikolajewka	Replaced by SGN point	54	205	Kremenetz	Replaced by SGN point
17	249	Kulmskaja	Replaced by SGN point	55	217	Tschernowody	Replaced by SGN point
18	252	Malojaroslawetzkaja	Replaced by SGN point	56	220	Karatschkowzi	Replaced by SGN point
19	253	Taraklia	Replaced by SGN point	57	221	Ssuprunkowzi	Replaced by SGN point
20	258	Katlabuch	Destroyed	58	222	Sagorjane	Destroyed
21	259	Katlabuch-Ssuchoi	Replaced by SGN point	59	223	Woltschenetz	Destroyed
22	260	Taschbunar II	Destroyed	60	GRU	Grubni	Destroyed
23	261	Kairaklia	Destroyed	61	Roman	Romankautsy	Destroyed
24	262	Ssafianowka	Destroyed	63	TSC	Tschubutinzi	Destroyed
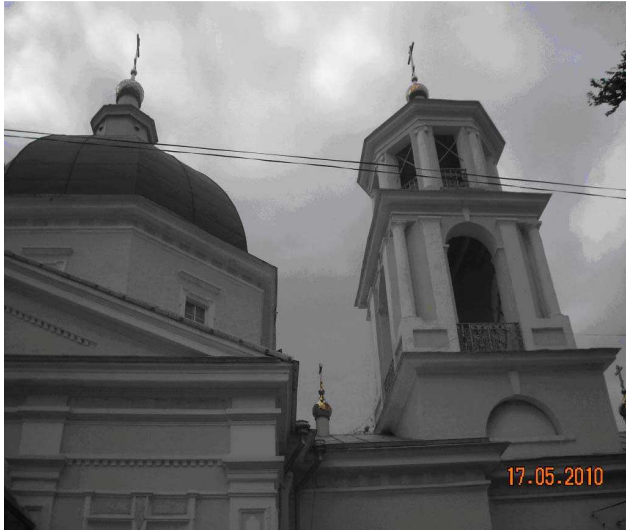
Fig. 5. Struve Arc point Izmail – cupola of bell tower of the Orthodox temple of Saint Mikolay
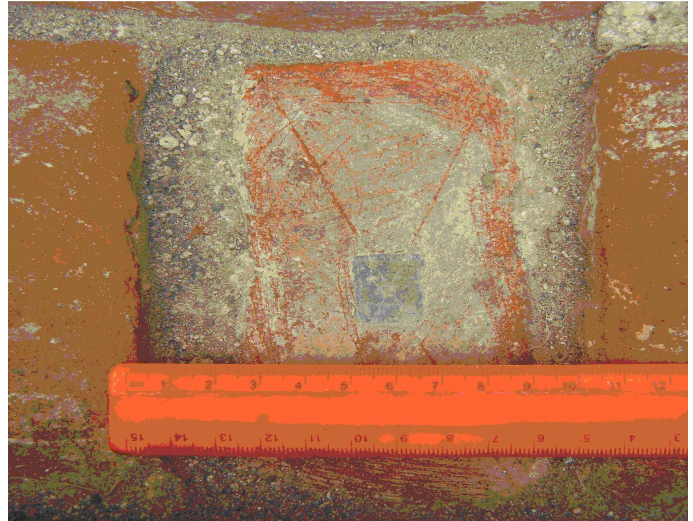
Fig. 6. Struve Arc center of the Golobi point filled by the lead

Table 4. Saved points of Struve Arc in the Ukraine area

No	Struve No	Point Name	Result	No	Struve No	Point Name	Result
35	213	Katerinowka	UNESCO	48	211	Bazalia	Found
37	215	Felschtin	UNESCO	49	216	Alexandrowka	Found
38	218	Baranowka	UNESCO	50	264	Izmail	Found (cupola of bell tower of temple)
43	196	Golobi	Found	51	265	Staro-Nekrassowka	UNESCO
44	206	Matwejewzi	Found	52	KUS	Kusmin	Found
45	207	Mosty	Found	53	POG	Pogarelaja	Found
46	208	Ssiwki	Found	62	Sselyshe	Sselyshe	Found
47	256	Pandaklia	Found				

Conclusions

Common adjustment of GNSS observations and classic terrestrial data have led to the construction of the State geodetic network consisting of 24562 points given in the UCS-2000, ITRS and ETRS89 systems with accuracy from 1 to 3 cm. The UCS-2000 reference system has accurate parameters of transformation with the ITRS and ETRS systems and 12 municipal areas around different cities. Thus, the horizontal system UCS-2000 becomes homogeneous and has the accurate connection with ITRF2000 and ETRS89. The vertical system as completely geometrical Baltic 1977 height system requires the readjustment via geopotential numbers to get a consistent gravity-related height system having the correct connection with EVRF. To make available the connection with the United European Leveling Network by means of geopotential numbers new regular (2'x3') grid of the Bouguer anomalies for calculating geopotential numbers was constructed. Preparation to the readjustment of the State vertical network all necessary data of the leveling of 1st and 2nd orders between Ukraine and neighboring countries included also data transition to BKG. Redefinition of the Baltic 1977 system will lead to the recompilation of GPS/leveling data and new quasigeoid solutions associated with the corresponding reference level of a common gravity-related height system covering Europe. A special work for the construction of tailored model of the gravity field in the Ukraine area was started and includes as initial data gravity gradients of GOCE data. Further densification of GPS-leveling data in 2011 to a number of about 4000 GPS-leveling points allows new quasigeoid solution based on gravimetry, altimetry (Black Sea and Azov Sea areas), GOCE, and GPS-leveling data.