Modern State Geodetic Frame of Russia

A.V. GORBOV and N.L. MAKARENKO, Russia

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SUMMARY

By present time all the required provisions have been made to go over into CS-95 coordinate system. Simultaneously, the geodetic frame is being further developed and upgraded based on global navigation systems.
Between 1999 and 2002 GLONASS and GPS satellite observations were carried out on more than 160 points. Currently their results are being processed.
State-of-the-art geodetic frame of Russia is a complex high precision construction that comprises classic astronomic-geodetic, satellite and gravimetric networks as well as high precision leveling network.

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At present the state geodetic frame of Russia is made up of geodetic, leveling and gravimetric networks.
The State Geodetic Network (StGN) implements the system of geodetic coordinates of 1995 (CS-95) introduced since the 1st of July 2002 by the Decree of the Russian Federation Government instead of the geodetic coordinate system of 1942 (CS-42).
Despite general similarity of CS-95 and CS-42 (both being geodetic reference-systems; the same Pulkovo reference point coordinates and Krasovsky reference ellipsoid being used in both systems), the two systems have basic differences. For CS-42 system the geodetic datum and reference ellipsoid orientation was determined by classical method per grade measurements, thus, the geodetic network implementing CS-42 was a free geodetic construction based on the reference point. During 50 years this coordinate system provided geodetic support for the territory of the full Soviet Union.

By early 1980s development of classic geodetic network for the entire territory of the country had been completed. By 1990s two more networks had been developed – high precision Spatial Geodetic Network (SGN) comprising 26 points and based on the observation set made by dedicated geodetic satellite GeoIK (USSR), as well as Doppler Geodetic Network (DGN) comprising 131 points and based on processing of Doppler observations made by TRANSIT navigation system satellites (USA).

A decision was taken to mutually process all the three constructions. To pursue this task, Astronomic Geodetic Network (AGN) involving 164,306 polygonometry and triangulation points of the 1st and 2nd classes was adjusted as a free geodetic construction and the coordinates of 134 linking points combined with SGN and DGN were obtained. Then SGN, DGN and the linking AGN points were adjusted and this allowed creating a single geodetic network involving 134 points with the consistent system of plane coordinates and altitudes with the following precision parameters (mean square errors):

- reference to the Earth mass center ± 1 m along each of the spatial coordinates;
- orientation in relation to the mean pole and longitude datum to a precision not more than ± 0”1 along each axis;
- network scale error not more than $1*10^{-7}$;
- precision of relative position depending on a distance between points - ±0.2–0.9m by altitude, ±0.2-0.6m by latitude, and ±0.2 m–0.7 m by longitude.

The network of fundamental points obtained by mutual adjustment and covering the full territory of the former USSR - a distance between adjacent points being within 200 and 1,000 km, and a mean distance equaling 400-500 km - was used as a rigid base to finally adjust AGN and to determine the coordinates of astronomic geodetic network points.

Astronomic geodetic network points, and extension network points of the 3rd and 4th classes adjusted on their base, allowed spreading CS-95 system on the entire territory of Russia (on the average, 1 point per 50 sq km.)

Development of satellite technologies made it possible and cost-effective to build a new fundamental geodetic frame that would come up to the coordinate determinations made by satellite navigation systems in relation to its precision and organizational management.
By now more than 160 points of fundamental and high precision geodetic networks have been measured and mainly processed. In the nearest time these networks are planned to complete, while providing on the average 1 point per nearly 80,000 sq km with maximum coordinate precision that could be reached by GPS/GLONASS observations i.e., of the order of 2-3 cm along each coordinate in mutual position.

Development of the state leveling network of Russia by geometric leveling method was started since the last quarter of the 19th century. By present time the total extent of the Russian leveling network of the 1st class is more than 160,000 km and that of the 2nd class – more than 200,000 km. The network was built as polygons with a perimeter of several hundred kilometers in populated areas and up to 1,000-2,000 km in the north and east of the country. On the spot, all the state leveling lines of the 1st and 2nd classes are fixed at approximately 5 km with permanent ground rock and wall marks, and at 50-60 km – with fundamental marks which provide long time conservation and availability.

As a result of the leveling network adjustment, a mean square error in altitude transfer from the zero of the Kronstadt depth gauge (Baltic altitude system) to Chukotskiy Peninsula (nearly 8,000 km) is a value of the order of 15-20 cm, and a mean square error for 1 km line calculated by errors in polygon closures is about 2 mm for the 1st class and about 3 mm for the 2nd class.

Practically, the main part of leveling lines of the 1st and 2nd classes is being repeatedly leveled on 15-25 years basis to get quantitative parameters of current vertical Earth surface motions. Study of such motions is of great importance for seismic countries and regions subject to man-caused exposures.

It should be noted, that at present high precision leveling could be independently controlled at comparatively large distances with GLONASS/GPS determinations. However, this is connected with calculation of quasi-geoid altitude increase to an accuracy that could be at least compared with an accuracy of normal altitude increase determination.

The reached accuracies (better than 5-7 mcGal) of absolute and relative determinations of gravity allow to some extent using these determinations to interpret modern vertical motions of the Earth's crust. Anyway, if during 15-20 years point altitudes changed at 1.5-2 cm, this should correlate with gravity change at these points equaling 5-6 mcGal. Otherwise, the causes of discrepancy between the two factors should be investigated.

The State Gravimetric Network is a constituent part of the State Geodetic Frame.

By early 1990s on the territory of Russia, the high precision State Gravimetric Network has been built. It comprises the Fundamental Gravimetric Network (FGN) (8 points) and the 1st class network (approximately 900 points.) At the points of the fundamental network, gravity was determined with a ballistic gravimeter with a mean square error of 6-8 mcGal. Metrological parameters of the gravimeter were confirmed by its comparison with similar devices in Sevres.

Per the program of fundamental gravimetric point establishment, gravity determination is now planned to carry out at the points of the Fundamental Astronomic Geodetic Network (FAGN), while FGN points will in future be combined or linked with those of FAGN. This will provide for complex investigation of the Earth's crust motions and gravitational field changes with time. Surely, to pursue this task, an appropriate program should be developed that would account for geodetic, geophysical, geological, hydrological, and other aspects of its implementation.

CONTACTS

A.V. Gorbov
Federal Service of Geodesy and Cartography of Russia
ul. Krzhizhanovskogo 14-2
117997, Moscow
RUSSIA
Email: roskart@dol.ru

N.L. Makarenko
Central Research Institute of Geodesy, Aerial Surveying and Cartography
Onezhskaya ul., 26
125413, Moscow
RUSSIA
Email: insgak@id.ru