The Development of the Normal Heights System in Azerbaijan by the Satellite Methods

Magsad GOJAMANOV, Azerbaijan and Alishir ISMAILOV, Azerbaycan

Key words: normal height, geodetic coordinates, satellite, ellipsoid, potential.

SUMMARY

It is known that as a result of satellite definitions are received spatial geodetic coordinates X, Y, Z of the observation points of Artificial Earth Satellites. However, geodetic height is unsuitable for the decision of problems, connected with works in the gravity field of the Earth. Therefore, there is a need to move from geodetic height to height in the gravity field. In the paper it was considered a principle to establish a system of the satellite normal heights and on its basis was developed a modern concept of constructing a system of the altitude provision on the territory of the Azerbaijan Republic. The main idea of this concept is that as the plane coordinate system and the high-altitude system are implemented by the same set points of geodetic networks of HGN (high-precision geodetic network) and the SGN-1 (satellite geodetic network).

Məlumdur ki, peyk təyinetmələrinin nəticəsi olaraqYerin Süni Peyklərinin müşahidə nöqtələrinin X,Y,Z fəza geodezik koordinatları və onlara əsasən geodezik yüksəklik tapılır. Lakin Yerin qravitasiya sahəsində işlərin yerinə yetirilməsində geodezik yüksəklikdən istifadə əlverişli deyildir. Ona görə də geodezik yüksəklikdən qravitasiya sahəsi yüksəkliyinə keçmək tələb olunur. Bu məqalədə peyk normal yüksəklik sisteminin qurulma prinsipinə baxılmış və onun əsasında Azərbaycan Respublikası ərazisində yüksəklik təminatı sisteminin qurulmasına dair müasir konsepsiya işlənmişdir. Bu konsepsiyanın əsas ideyası ondan ibarətdir ki, plan, eləcə də yüksəklik koordinatları sistemləri eyni toplumda Yüksək dəqiqlikli Geodeziya Şəbəkəsi (YGŞ) və Peyk Geodeziya Şəbəkəsi (PGŞ-1) məntəqələri ilə təsbit olunur.

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1. INTRODUCTION

When studying and assessing the effects of natural disasters most important role are played geodetic measurements and based on them the geodetic systems of altitudinal and plane coordinates. State Geodetic Network (SGN), if it has not been systematically updated and improved, gradually aging, loses part points, loses accuracy in its separate parts, especially due to modern crustal movements of Earth.

Development of a system of normal heights is a constituent and integral part of the solution to the General problem of the reconstruction and development of the system of geodesic provision on the territory of Azerbaijan Republic (AR) on the basis of satellite methods of the coordinate definitions [Mamedov, 2002].

At solving the problem of reconstruction and development of the State Geodetic Network should be consider that at the present stage has considerably expanded the Arsenal of means and methods of construction of geodetic networks. This primarily refers to the latest satellite technologies based on the use of GPS / GLONASS systems.

2. A MODERN CONCEPT OF THE NATIONAL LEVELING FRAMEWORK OF AZERBAIJAN

As is known, the height of the USSR, including in Azerbaijan, was determined in the Baltic system of heights from Kroonstad sea-gauge. At present the communications between the leveling networks of Azerbaijan Republic and neighboring countries and access to the Unified European Leveling Network (UELN); participation in the European network using GPS measurements (EUVN) and other international projects require the determination of the normal heights on the territory of Azerbaijan Republic in worldwide system of heights.

One of the main advantages of the new system of geodesic provision is that the same sets of geodetic points are implemented as planned and high-altitude coordinate systems. Leveling rappers, points of Satellite Geodetic Network (SGN-1) in the system of heights will serve as a tool for distribution of this system of normal heights throughout the territory of Azerbaijan. This principle of establishing the system of normal heights and the way of its distribution throughout the territory of the Republic corresponds to the new system of geodesic provision based on modern satellite technologies, and strongly and unequivocally agree geodetic height, determined from GPS/GLONASS measurements with data of high-precision leveling. Satellite measurements at the level measured posts will serve as a tool to study the Caspian Sea level on a unified zero for the whole Earth.

The concept of restructuring the national level framework involves a combination of measurements made on land (determination of geodetic provisions, geometrical leveling, gravimetric) and the sea (satellite altimetry, hydrostatic leveling). At that a means to reduce of all measurements, both on land and at sea, to a single worldwide date of reference of normal heights for the whole territory of the AR is the solution of a boundary value geodetic tasks, in the result are determined the difference of the potential on the reference points of the State Geodetic network, level measured posts, in points altimetry measurements in the sea.

The concept of building a modern system of height provision includes realization of the full potential of the method of geometrical leveling, as the most accurate method of relevant traditional kinds of geodetic measurements. At the same time to create effective modern system of geodesic provision is also needed for development of the method of satellite leveling as alternatives to the traditional method of geometrical leveling. In developing satellite technology of leveling in any way not intended to replace the full geometrical leveling method in the system of geodetic [Gojamanov, 2004; Zhdanov, 1998]. In areas not provided with necessary data about the height of quasigeoid to determine the normal heights is allowed even the use of trigonometric leveling [Demyanov, 2000].

3. A TRANSITION FROM THE GEODETIC HEIGHTS TO HEIGHTS IN THE GRAVITY FIELD

As is known, the satellite definitions receive spatial geodetic coordinates X, Y, Z in the observation points of Artificial Earth Satellites (AES). It is therefore appropriate ellipsoidal geodetic coordinates B, L, H calculate together, completely not defining geodetic height in a single task. After selecting the reference ellipsoid with parameters ***a,*** **α**, geodetic coordinates B,L,H find the well-known formulas of [Boyko, 2003].

However geodesic height is unfit for the resolve of problems linked with the works in the field of the gravitational forces of Earth [Gojamanov,2001; Eremeev, 1971]. That is why the transition necessity appears from geodesic height to height in the field of gravitational forces.

We shall consider the capability of such transition with the help of fig.1. Let point P (X, Y, Z) is point of physical Earth's surface, in which are measured geocentric coordinates X, Y, Z. Through P_0 shall denote the projection of P on the reference ellipsoid to normal to him. Fragment P_0P of normal to ellipsoid is geodesic height.

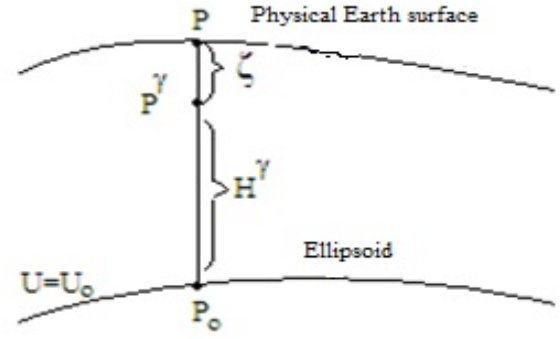

Fig.1. The Satellite system of normal heights

We will to consider accepted reference ellipsoid by the level ellipsoid of U= U_0 normal gravitational potential. For the occurrence of the external field of this ellipsoid amply to known characteristics *a, α*, (or J_2) to add geocentric gravitational continued *GM* and the angular velocity of ω - Earth rotation.

In the field of the level ellipsoid the height of point *P* will be the arc $P_0\breve{P}$ of normal power line

$$P_0\breve{P} = \frac{U_0 - U_P}{\gamma_m^{P_0P}}, \qquad (1)$$

Where *Up* - the potential of ellipsoid in point *P*, $\gamma_m^{P_0P}$ – the mean integral value of the normal gravitational force of ellipsoid alongside arc $P_0\breve{P}$.

For territory AR in mean latitude to 40^0 and maximal height 4500 m difference

$$P_0\breve{P} - P_0P = \frac{\beta^2\mu^3}{6R^2}\sin^2 2B \ ,$$

where $\beta = \frac{\gamma_P - \gamma_t}{\gamma_t}$ - the relative excess of gravitational force on pole compared with equator; R - the mean radius of Earth; B - geodetic latitude of arc distance $P_0\breve{P}$ of power line from P_0 *P* fragment of the normal to ellipsoid compounds $1*10^{-5}$ mm, that is why to distinguish them will not.

We shall present normal potential U_P in the form $U_P = W_P - T_P$,

where W_P - real, - T_P - anomalous potential in point P homologous.

We shall write down geodesic height so:

$$H = \frac{U_0 - W_P + T_P}{\gamma_m^{P_0P}} \ .$$

Dimension $U_0 - W$ can be viewed as difference of normal potentials between ellipsoid and point P^γ, in which normal potential to U_{P^γ} identically equal real potential in point *P* .

$$U_{P^\gamma} \equiv W_P. \qquad (2)$$

In other words, on fragment P_0P is searched such point, in which potential of reference level ellipsoid to equal real potential in point P earth's surface. Using (2), for geodesic height find

$$H = \frac{U_0 - U_{P^\gamma}}{\gamma_m^{P_0P^\gamma}} + \frac{T_P}{\gamma_m^{P^\gamma P}} \ , \qquad (3)$$

where $\gamma_m^{P_0P^\gamma}$, $\gamma_m^{P^\gamma P}$ - the mean integral value of normal gravitational force on fragments P_0P^γ and $P^\gamma P$ homologous. The first term of right part (3) is normal height H^γ, second - the anomalous of height, i.e. (3) can be written in the form

$$H = H^\gamma + \zeta \ . \qquad (4)$$

Thus, in satellite determining normal height is height of point over accepted reference ellipsoid, in which normal potential is equal real (valid) potential of the surface point of Earth.

To find of normal height it follows from geodesic height take away the anomalous of height

$$H^{\gamma} = H - \zeta . \qquad (5)$$

In formulas (3) - (4) normal field in both terms of right part should be strictly agreed.

3. A ASSIGNMENT OF THE NORMAL HEIGHTS SYSTEM IN AZERBAIJAN BY THE SATELLITE METHODS

For the assignment of the system of normal heights by satellite determining it is amply in some one point of State Geodetic Network to receive coordinates X, Y, Z by the absolute method of Satellite Geodesy and to calculate the geodesic height and the anomalous of height in the field of accepted-level ellipsoid. In State Geodetic Networks of Azerbaijan Republic for such point follows to accept the incipient point No 001, linked with Fundamental Astronomical-geodetic network (FAGS) of Russian Federation (RF).

It is notable, what in such choice of the system of normal heights does not appear the necessity of the introduction of the notion of sea level or geoids and potential W_0 on these surfaces. This especially suitably for AR situated in the deep of continent and not have in its networks the points located on the ashore of Global Ocean.

In formulas (1) - (5) can be used any ellipsoid. If to choose the ellipsoid of system PZ-90 (The Characteristics of The Earth 1990 year) [Demyanov, 1999]:

$$GM = 398600{,}44 \text{ км}^3\text{с}^{-2} \quad ;$$
$$J_2 = 1082{,}6257 \cdot 10^{-6} \quad ;$$
$$\omega = 7{,}292115 \cdot 10^{-5} c^{-1} \quad ;$$
$$a = 6378136 \text{ м} \quad ,$$

Than the system of normal heights AR will be assented to altitude system of State Geodetic Network of Russian Federation.

If to use international ellipsoid WGS-84[Fukuda, 1996]:

$$GM = 398600{,}5 \text{ км}^3\text{с}^{-2} \quad ;$$
$$J_2 \Big/ \sqrt{5} = 484{,}16685 \cdot 10^{-6} \quad ;$$
$$\omega = 7{,}292115 \cdot 10^{-5} c^{-1} \quad ;$$
$$a = 6378137 \text{ м} \quad ,$$

the system of normal heights AR will coincide with the World system.

For all the rest of the points of the satellite network defined of relative starting foreground point No 001, it follows to compute the differences of normal heights

$$H_i^{\gamma} - H_{001}^{\gamma} = \Delta H + \zeta_i - \zeta_{001} \quad , \qquad (6)$$

i.e. to fulfill satellite leveling.

Here ΔH measured difference of geodesic heights. Because is planned measurement of the differences of coordinates in closed figures, appears the capability of determining of the differences of normal heights as to the sides of these figures and their next adjustment.

REFERENCES

Boyko E.G.: 2003, Higher geodesy, part II: Geodesy on the ellipsoid, Moscow, Kartgeotsentr-geodezizdat, 144.

Demyanov Q.V.: 1999, The scientific and technical collection for geodesy, aerospace photography and cartography, Physical geodesy, CNIIQAiK, Moscow, 120.

Demyanov Q.V.: 2000, The satellite determines of heights:1996-1999, Abstract bibliographic directory, CNIIQAiK, Moscow, 100.

Gojamanov M.H.: 2004, The satellite leveling and the requirements to the accuracy of the model of quasigeoid, Materials of international scientific - technical conference, dedicated to the 225th anniversary of MIIGAiK, Moscow, 71-74.

Gojamanov M.H.: 2001, The determination of the normal heights in geodetic networks with the use of GPS, Materials of the 1-st scientific - practical conference "Modern state, problems and prospects of development of geodesy and cartography in the Republic of Azerbaijan" , Baku, BSU, 62-68.

Eremeev V.F., Yurkina M.I.: 1971, The theory of heights in the Earth gravitational field, Moscow, Nedra, 144.

Mamedov G.Sh., Gojamanov M.H.: 2002, About the concept of developments and the reconstructions of State Geodetic Network of Azerbaijan Republic, Geodesy and Cartography, No12, Moscow, 38-42.

Fukuda Y., Kuroda J., Takabatake J., Iton J. Murakami V.: 1996, Improvement of JGEOID 93 by the geoidal heights, derived from GPS/leveling survey, International Symposium Gravity, Geoids and Marine Geoid (GraGeoMar 96), Njrej, Sept.30-okt.5, 1996: Programm and Abstract, Tokyo, 168.

. Zhdanov N.A., Makarenko D.H.: 1998, About the transition concept of the topographic-geodetic production to the autonomous satellite methods of coordinate definitions, Geodesy and cartography, No 3, Moscow, 1-5.

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