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Construction of initial national quasi-geoid model VIGAC2017, first step to national spatial reference system in Vietnam

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ABSTRACT

Vietnam national WGS-84 reference ellipsoid was obtained in 1999 from results of an orientation of the global WGS-84 reference ellipsoid. However, usage of the broadcast satellite messages doest not give high accuracy in determination of national quasi-geoid heights. Based on the determined geopotential of the Hon Dau local geoid and constructed initial mixed quasi-geoid model VIGAC2014, this scientific article presents results of building of initial national quasi-geoid model VIGAC2017. Used data consisting of geodetic coordinates *B, L, H* of 164 first and second orders benchmarks of the national leveling networks was obtained from GPS data processing in ITRF according to global WGS-84 ellipsoid with satellite ephemeris accuracy at level of ± 2,5 cm, and the initial mixed quasi-geoid model VIGAC2014 was constructed from the EGM2008 model. The orientation of the WGS-84 ellipsoid was accomplished under conditions of it's best fitting to the Hon Dau local quasi-geoid and the parallelism of its axes to the corresponding axes of the national WGS-84 reference ellipsoid allows get national quasi-geoid heights ζ and coordinate transformation parameters $dX_0,\ dY_0,\ dZ_0$, that have been used for conversion of the mixed quasi-geoid heights from the VIGAC2014 quasi-geoid model to the initial national quasi-geoid model VIGAC2017.

Along withquasi-geoid heights ζ^*, which were obtained from the initial national quasi-geoid model VIGAC2017, an estimation of the accuracy of differences ($\zeta - \zeta^*$) shows that quasi-geoid heights ζ^* have the accuracy at the level of ± 6,2 cm. Apart from that determination of seven coordinate transformation parameters $dX_0,\ dY_0,\ dZ_0,\ \varepsilon_X,\ \varepsilon_Y,\ \varepsilon_Z,\ \Delta m$ leads to the building of the initial national spatial reference system in Vietnam.

Keywords: Global quasi-geoid, local quasi-geoid, mixed quasi-geoid, orientation of ellipsoid.

1. Introduction

In history of construction of national vertical reference systems in the world, starting from point of view of German mathematician Carl Friedrich Gauss (1777 - 1855) in 1828 (Gauss C.F., 1828) about a coincidence of the geoid with an undisturbed mean sea level on the oceans and proposal of German mathematician Johann Benedict Listing (1808 - 1882) in 1873 (Listing J.B., 1873) about the usage of the geoid for initial surface of the vertical ref-

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erence systems, every country or group of different countries used a mean sea level at the zero tide gauge station. In Vietnam, tide gauge station of Hon Dau is used for the construction of national or regional vertical reference system. At present, we know that the geoid didn't coincide with the mean sea level on oceans, geopotential $\overline{W_0} = 62636856{,}0\ m^2.s^{-2}$ on the surface of the global geoid had been determined by altimetry data (Bursa M., Kenyon S, et al., 2007)and accepted by IERS (Petit G., Luzum B., 2010). Abovementioned achievement gives ability to determine the geopotential W_0 of the local geoid, best fitting to mean sea level at zero tide gauge station. In Vietnam, geopotential $W_0 = 62636847{,}2911\ m^2.s^{-2}$ of the Hon Dau local geoid was announced in (Ha Minh Hoa et al., 2012; Ha Minh Hoa, 2013b; Ha Minh Hoa, 2014b). Because the Hon Dau local quasi-geoid coincides with the Hon Dau local geoid on the sea and it has been used for the initial surface of vertical reference system of Hai Phong 1972 (HP72), the usage of the Hon Dau local quasi-geoid for solving the task of ellipsoid orientation creates important base of construction of the high accurate national quasi-geoid model.

In Vietnam GNSS technology is widely used for research of the Earth crustal movement or ionosphere disturbances during the magnetic storm (Le Huy Minh et al., 2016; Vy Quoc Hai et al., 2016, Ha Minh Hoa, Dang Hung Vo et al., 2005) proposed the construction of the national dynamic coordinate system, that in fact is national spatial reference system with the purpose of closely connecting to ITRF. In addition, the construction of the national spatial reference system is the most important content of Development Strategy of Geodesy and Cartography to the 2020 year by Decision No. 33/2008/QĐ-TTg of the prime minister on 27 February 2008.

Thanks to GNSS technology, we get high accurate geodetic coordinates B, L in VN2000 2D. However, getting geodetic height H requires the high accurate national quasi-geoid model. (Ha Minh Hoa et al., 2012; Ha Minh Hoa, 2014a) analyzed scientific base for the construction of the national dynamic coordinate system, in which the most important task is a creation of the high accurate national quasi-geoid model with accuracy more than ±4 cm to get spatial coordinates of geodetic points with relative accuracy at level 10^{-9} by international regulation. For that, we must return to solve the task of the orientation of global WGS-84 ellipsoid best fitting to the Hon Dau local quasi-geoid.

Solving above-mentioned task, we will get coordinate transformation dX_0, dY_0, dZ_0, which are spatial coordinates of the center of the WGS-84 global reference ellipsoid according to the center of the WGS-84 national (local) reference ellipsoid. Hence we will obtain two types of data:

- Data of type 1: Geodetic coordinates B, L, H of GNSS points, with being used for solving the task of the orientation of ellipsoid in the national spatial reference system VN2000 - 3D. Global WGS-84 reference ellipsoid oriented under the condition of the best fitting to the Hon Dau local quasi-geoid will become the WGS-84 national (local) reference ellipsoid (Figure 1);
- Data of type 2: National quasi-geoid heights ζ of GNSS points.

For the purpose of construction of the high accurate national quasi-geoid model, we are only interested in data of type 2. Thus, the high accurate national quasi-geoid model is the model of quasi-geoid heights ζ of specific points on the surface of the Hon Dau local quasi-geoid according to the surface of the WGS-84 national reference ellipsoid.

For solving the task of orientation of ellipsoid, we must create a GNSS network on whole territory of Vietnam and accomplish processing of GNSS data in ITRF on base of the using of satellite ephemeris with accuracy at the level ± 2,5 cm, which allows getting global geodetic $\overline{H}$ (Figure 1) with accuracy at the level ± 1,4 cm. After processing of GNSS data in ITRF, we obtain spatial coordinates $\overline{X}$, $\overline{Y}$, $\overline{Z}$ and global geodetic coordinates $\overline{B}$, $\overline{L}$, $\overline{H}$ of GNSS points according to the WGS-84 global reference ellipsoid. Apart from that, GNSS points have national normal heights H^{γ} obtained by first and second orders differential leveling from first and second orders national benchmarks and determined from the surface of the Hon Dau local quasi-geoid (Figure 1). Aforementioned GNSS points have been called as orientation points.

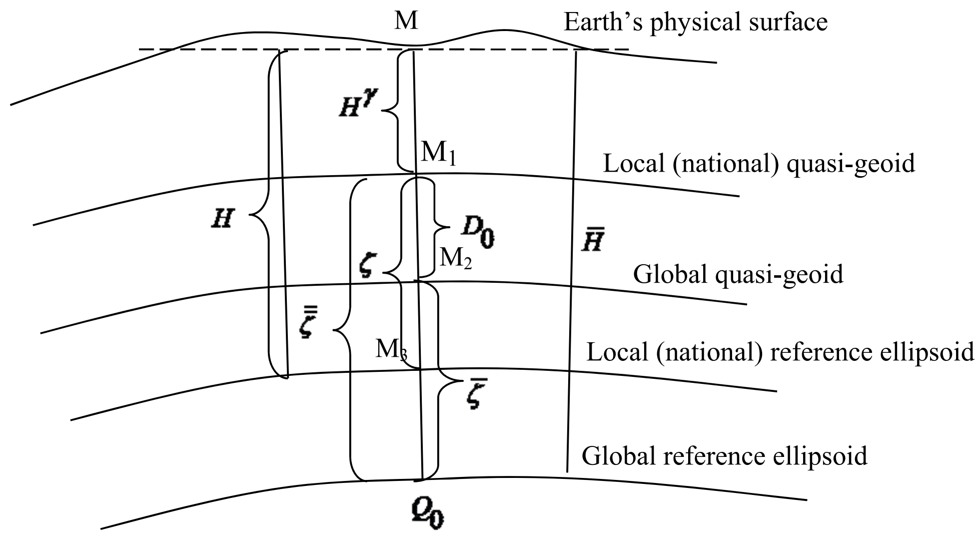

Figure 1. Relationships between local quasi-geoid, global quasi-geoid, local ellipsoid and global ellipsoid

The national quasi-geoid model is the model of heights of points M_1 on the surface of the Hon Dau local quasi-geoid according to the surface of the WGS-84 national reference ellipsoid, in addition, points M_1 corresponds to points M on the Earth's physical (Figure 1).

In Figure 1, we symbolize ζ as local quasi-geoid height (national quasi-geoid height) of point M and is equal to segment M_1M_3, $\overline{\overline{\zeta}}$ as mixed quasi-geoid height of point M and is equal to segment M_1Q_0, $\overline{\zeta}$ as global quasi-geoid height of point M and is equal to segment M_2Q_0, $D_0 = M_1M_2$ as height of point M_1 on the Hon Dau national (local) quasi-geoid according to the global quasi-geoid.

Result of the orientation of the global ellipsoid under the condition of best it's fitting to the Hon Dau national quasi-geoid allows obtaining the national quasi-geoid height (local quasi-geoid height) ζ and the local geodetic height H of GNSS point so that $H = H^{\gamma} + \zeta$. High accurate national quasi-geoid heights ζ of GNSS points are very precious data for serving the construction of the high accurate national quasi-geoid model and the determination of the 07 coordinate transformation parameters from ITRF to national spatial reference system VN2000 - 3D by formula of Bursa - Wolf with the purpose of a close connection between two those spatial reference systems. The results of solving tasks of the orientation of the WGS-84 global reference ellipsoid under the condition of the best it's fitting to the Hon Dau local quasi-geoid, the construction of the high accurate national quasi-geoid model and the determination of the 07 coordinate transformation parameters from ITRF to national spatial reference system VN2000 - 3D by formula of Bursa - Wolf will be presented in this scientific article.

It is necessary to underline that it was seen in 1999 the accomplished orientation of the WGS - 84 global reference ellipsoid under the condition of the best fitting to the Hon Dau local quasi-geoid in the proves of the construction of the plane coordinate reference system VN2000-2D based on the GPS data of the 25 GPS points. However, in that period, the GPS data has not been processed in ITRF with the using of satellite ephemeris with accuracy at level ±2,5 cm by software Bernese, rather being processed in WGS-84 with the usage of broadcast satellite message by software GPSuvey. Because global geodetic coordinates $\overline{B}, \overline{L}, \overline{H}$ of GPS points did not achieve high accuracy and national quasi-geoid heights with the accuracy only at level ±1,6 m (Scientific report, p.125). This accuracy satisfied requirement of reduction of measurements to ellipsoid for adjustment of the national astro - geodetic network, but did not meet the requirement of the construction of the high accurate national quasi-geoid model.

In order to construct the high accurate national quasi-geoid model, we must solve 03 problems:

Problem 1. Based on n orientation points, accomplishing the orientation of the WGS-84 global reference ellipsoid under the condition of the best it's fitting to the Hon Dau local quasi-geoid, we will get 03 coordinate transformation parameters dX_0, dY_0, dZ_0 from ITRF according to the WGS-84 global reference ellipsoid to VN2000 - 3D according to the WGS084 national reference ellipsoid and national quasi-geoid heights ζ of the n abovementioned points of orientation. This problem will be solved in 3.1.

Problem 2. Creation of relationship between the mixed quasi-geoid model and the national quasi-geoid model with the purpose of propagation of the national quasi-geoid model for the whole territory of Vietnam; Construction of the national quasi-geoid model VIGAC2017 and estimation of the accuracy of this model. This problem will be solved in 3.2.

Problem 3. Estimation of differential rotations $\varepsilon_X, \varepsilon_Y, \varepsilon_Z$ and differential scale change Δm between ITRF and VN2000 - 3D based on geodetic coordinates B, L in VN2000 2D, national normal heights H^{γ}, global geodetic coordinates $\overline{B}, \overline{L}, \overline{H}$ of orientation points and results of solution of problem 2. This problem will be solved in 3.3.

2. Data

In order to solve the above-mentioned problems, we can have set of orientation points covering the whole territory of Vietnam. Accomplishing project "Construction of local geoid model on territory of Vietnam" in period 2009 - 2010 Vietnam Department of Surveying and Cartography carried out GPS observations on 290 first order benchmarks, 199 second order benchmarks and GPS data processing in ITRF by software Bernese on base of the using of satellite ephemeris with accuracy at level ±2,5 cm. Because of the displacement of some first and second orders benchmarks from social - economic activities and Earth's crustal movements, on base of Smirnov's statistic criterion selected the 89 most stable first order benchmarks and the 75 most stable second order benchmarks (Ha Minh Hoa et al., 2016a; Luong Thanh Thach, 2016). Thus, we have all 164 first, second orders benchmarks, covering over the whole territory of Vietnam, with high accurate global geodetic coordinates

$\overline{B}$, $\overline{L}$, $\overline{H}$ according to the WGS-84 global reference ellipsoid, and use them as orientation points for solving abovementioned problems. Ha Minh Hoa, et al., (2012); Ha Minh Hoa, (2013b); Ha Minh Hoa et al., (2016a) determined geopotential $W_0 = 62636847,2911\ m^2.s^{-2}$ of the Hon Dau local geoid and height $D_0 = 0,890\ m$ of the Hon Dau local quasi-geoid according to the global quasi-geoid. Estimation of height D_0 shows that it is constant on whole territory of Vietnam (Ha Minh Hoa, et al., 2012; Nguyen Tuan Anh, 2015) and in global scale (Ha Minh Hoa, 2016b). With above-presented research results,we can calculate mixed quasi-geoid height $\overline{\overline{\zeta}}^*$ from global quasi-geoid height $\overline{\zeta}$ by the following formula:

$$\overline{\overline{\zeta}}^* = \overline{\zeta} + D_0 = \overline{\zeta} + 0,890\ m \qquad (1)$$

where $\overline{\zeta}$ is the global quasi-geoid height determined from the EGM2008.

Formula (1) has been used for the construction of the mixed quasi-geoid model VIGAC2014 in the state order science - technological theme (Ha Minh Hoa et al., 2016a). The accuracy of mixed quasi-geoid model VIGAC2014 has obtained at level ±7 cm based on the 89 first-order benchmarks (Ha Minh Hoa et al., 2016a) and at level ±8 cm based on the 75 second order benchmarks (Luong Thanh Thach, 2016). Above-mentioned levels of accuracy fully correspond to levels of accuracy of the first and second orders national normal heights (Ha Minh Hoa, 2014b). However, those levels of accuracy do not satisfy the requirement of accuracy more than ±4 cm of the national quasi-geoid model used for the construction of the national spatial reference. Apart from that, the mixed quasi-geoid model VIGAC2014 is not the national quasi-geoid model. That is why we must solve problem of orientation of the WGS-84 global reference ellipsoid, best fitting to the Hon Dau local quasi-geoid, with purposes of transformation of the mixed quasi-geoid model VIGAC2014 to the national quasi-geoid model and it's accuracy estimation.

With the purpose of calculation of national normal heights by the mixed quasi-geoid model VIGAC2014 and GNSS technology, (Ha Minh Hoa, 2014b) constructed criterion for base points of mixed quasi-geoid model VIGAC2014. The result determined 09 base points such as I(HN-VL)6-1, I(HN-VL)28-1, I(HN-VL)64, I(HN-VL)72, I(VL-HT)98, I(VL-HT)158, I(BH-HN)33, I(BH-TH)65, I(BH-TH)122A. Those base points have been the accomplished transmission of national normal heights to 30 GNSS points of the North Vietnam geodynamic network, the Cuu Long delta geodynamic network and 02 GNSS points on islands Con Dao, Phu Quoc with the maximal distance of transmission at the level of 1,500 km. On every GNSS point deviation from 09 obtained normal heights does not exceed 1,5 cm (Ha Minh Hoa et al., 2016a). This shows that differences of mixed quasi-geoid heights between arbitrary two points from the mixed quasi-geoid model VIGAC2014 have very high accuracy. So the mixed quasi-geoid model VIGAC2014 is very important data resource for the construction of the high accurate national quasi-geoid model.

3. Applied methods

By IAG resolution No.16 (June 1983) in Hamburg (Germany) (International Association of Geodesy (IAG), 1984), all geodetic data must be processed in the zero tide system. (Ha Minh Hoa, 2014b) presented formulas for conversion of normal height H^{γ} from the mean tide system to the zero tide system, of global geodetic height $\overline{H}$ and global quasi-geoidheight $\overline{\zeta}$ from the free - tide system to the zero tide system. In the next research of this article we understand that all normal heights, geodetic heights and quasi-geoidheights belonged to the zero tide system.

3.1. Method of orientation of WGS-84 ellipsoid for it's best fitting to the Hon Dau local quasi-geoid

It is assumed that we have set of n orientation points. By regulation of IERS, national reference ellipsoid must be oriented so that its axes are parallel to corresponding international axes. Because the main axes of the WGS-84 global reference ellipsoid are parallel to corresponding international axes, we must orient the WGS-84 global reference ellipsoid under the condition of the best fitting to the Hon Dau local quasi-geoid so that the axes of the WGS-84 national reference ellipsoid are parallel to the corresponding axes of the WGS-84 global reference ellipsoid.

Then for i-th orientation point (i = 1,2,…, *n*) relationship between the local geodetic height H_i according to the WGS-84 national reference ellipsoid and the local geodetic height $\overline{H}_i$ according to the WGS-84 global reference ellipsoid is presented in the following form:

(Ha Minh Hoa, 2013a):

$$H_i = \overline{H}_i + A_i \cdot \begin{pmatrix} dX_0 \\ dY_0 \\ dZ_0 \end{pmatrix}, \qquad (2)$$

where coefficient matrix A has form:

$$A_i = (\cos \overline{B}_i \cdot \cos \overline{L}_i \quad \cos \overline{B}_i \cdot \sin \overline{L}_i \quad \sin \overline{B}_i),$$

$\overline{B}_i$, $\overline{L}_i$, $\overline{H}_i$ are global geodetic coordinates of i-th point according to the WGS-84 global reference ellipsoid. Symbolizing H_i^{γ} as national normal height of i-th orientation point, on account of $\zeta_i = H_i - H_i^{\gamma}$, $\overline{\overline{\zeta}}_i = \overline{H}_i - H_i^{\gamma}$, where $\overline{\overline{\zeta}}_i$ is the mixed quasi-geoidheight of i-th point, from (2) we have the relation:

$$\zeta_i = \overline{\overline{\zeta}}_i + A_i \cdot \begin{pmatrix} dX_0 \\ dY_0 \\ dZ_0 \end{pmatrix}. \qquad (3)$$

From (3) we get observation equation in following form:

$$\zeta_i = A_i \cdot \begin{pmatrix} dX_0 \\ dY_0 \\ dZ_0 \end{pmatrix} + l_{\zeta_i}, \qquad (4)$$

Where constant term $l_{\zeta_i} = \overline{\overline{\zeta}}_i$.

Solving system of observation equations (4) under the condition of the best fitting of the WGS-84 global reference ellipsoid to the Hon Dau local quasi-geoid, i.e. under the condition $\sum_{i=1}^{n} \zeta_i^2 = \min$, we will get coordinate transformation parameters dX_0, dY_0, dZ_0.

From (4) we will obtain the national (local) quasi-geoid heights ζ of the n orientation points. The estimation of the accuracy of the national (local) quasi-geoid heights ζ will be considered in 3.2.

3.2. Determination of relationship between mixed quasi-geoid model VIGAC2014 and national quasi-geoid model VIGAC2017

As above presented, model VIGAC2014 is only the mixed quasi-geoidmodel, but is not the nationalquasi-geoidmodel. With national normal height H^{γ} of geodetic point, mixed quasi-geoid height $\overline{\overline{\zeta}}^{*}$ (1) from the VIGAC2014 is calculated by formula $\overline{\overline{\zeta}}^{*} = \overline{H} - H^{\gamma}$, where $\overline{H}$ is the global geodetic height according to the WGS84 global reference ellipsoid, meanwhile, nationalquasi-geoidheight ζ is calculated by formula $\zeta = H - H^{\gamma}$, where H is the local geodetic height according to the WGS84 national reference ellipsoid. Model

VIGAC2014 can be used for calculation of the national normal height H^{γ} based on global geodetic height $\bar{H}$ obtained from GNSS technology, but can not be used for determination of local geodetic height H by formula $H = H^{\gamma} + \zeta$.

In order to construct the national quasi-geoid model from the mixed quasi-geoid model VIGAC2014, taking account of formula (3), we get the formula of conversion of the mixed quasi-geoid height $\bar{\bar{\zeta}}^{*}$ to the national quasi-geoid height ζ^{*} in the following form:

$$\zeta_i^{*} = \bar{\bar{\zeta}}_i^{*} + A_i \cdot \begin{pmatrix} dX_0 \\ dY_0 \\ dZ_0 \end{pmatrix} + C, \qquad (5)$$

where coordinate transformation parameters dX_0, dY_0, dZ_0 have been determined in 3.1, C is correction from existence of systenatic error in the VIGAC2014 model.

The mixed quasi-geoid model VIGAC2014 is used for the construction of the national quasi-geoid model VIGAC2017 by formula (5) in taking account of two it's outstanding advantages:

- The mixed quasi-geoid model VIGAC2014created from the EGM2008 model allows getting difference of quasi-geoid heights between two arbitrary points with very high accuracy.
- The mixed quasi-geoid model VIGAC2014 allows propagating quasi-geoid heights to big distances on the whole territory of Vietnam, even to territories of neighbor countries.

With two independent series: series of national quasi-geoid heights ζ obtained from the results of ellipsoid orientation in 3.1 and series national quasi-geoid heights ζ^{*} achieved by formula (5) from the VIGAC2014 model, based on method of double observation processing we will accomplish the accuracy estimation of the national quasi-geoid model VIGAC2017 and determine correction C in formula (5).

3.3. Determination of differential rotations ε_X, ε_Y, ε_Z and differential scale change Δm

Although WGS84 national reference ellipsoid has axes, paralleling to corresponding axes of the WGS-84 global reference ellipsoid, but between ITRF and VN2000 - 3D exist differential rotations ε_X, ε_Y, ε_Z and differential scale change Δm, with being arise from error accumulation and propagation in process of approximate calculation of coordinates of the national first and second orders astro - geodetic points in VN2000 - 2D. Values ε_X, ε_Y, ε_Z, Δm with parameters dX_0, dY_0, dZ_0, obtained in 3.1, creating 07 coordinate transformation parameters in Bursa - Wolf's formula in the following form:

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} \bar{X} \\ \bar{Y} \\ \bar{Z} \end{pmatrix} + \begin{pmatrix} dX_0 \\ dY_0 \\ dZ_0 \end{pmatrix} + \begin{bmatrix} \Delta m & \varepsilon_Z & -\varepsilon_Y \\ -\varepsilon_Z & \Delta m & \varepsilon_X \\ \varepsilon_Y & -\varepsilon_X & \Delta m \end{bmatrix} \cdot \begin{pmatrix} \bar{X} \\ \bar{Y} \\ \bar{Z} \end{pmatrix}, \qquad (6)$$

where $\bar{X}$, $\bar{Y}$, $\bar{Z}$ are global geodetic coordinates of geodetic points according to the WGS-84 global reference ellipsoid, X, Y, Z are national (local) geodetic coordinates of this geodetic point according to the WGS-84 national reference ellipsoid.

In case of spatial coordinates $\bar{X}$, $\bar{Y}$, $\bar{Z}$ of geodetic point are known in ITRF, but national spatial coordinates X, Y, Z of this geodetic point in VN2000 - 3D are calculated by formula:

$$X = (N + H).\cos B.\cos L,$$
$$Y = (N + H).\cos B.\sin L,$$
$$Z = [N.(1 - e^2) + H].\sin B.$$

where B, L are geodetic coordinates of geodetic point in VN2000 - 3D; the prime vertical radius of curvature N of this point is calculated by formula:

$N = \dfrac{a}{\sqrt{1 - e^2.\sin^2 B}}$; national geodetic height $H = H^{\gamma} + \zeta^*$ with national quasi-geoid height ζ^*, determined by formula (5).

With known coordinate transformation parameters $dX_0,\ dY_0,\ dZ_0$ in 3.1, from (6) we have observation equations:

$$\begin{aligned} v_X &= -\overline{Z}.\varepsilon_Y + \overline{Y}.\varepsilon_Z + \overline{X}.\Delta m + l_X, \\ v_Y &= \overline{Z}.\varepsilon_X - \overline{X}.\varepsilon_Z + \overline{Y}.\Delta m + l_Y, \\ v_Z &= -\overline{Y}.\varepsilon_X + \overline{X}.\varepsilon_Y + \overline{Z}.\Delta m + l_Z, \end{aligned} \quad (7)$$

where constant terms $l_X = \overline{X} + dX_0 - X$, $l_Y = \overline{Y} + dY_0 - Y$, $l_Z = \overline{Z} + dZ_0 - Z$.

Based on the set of orientation points, we wiil solve system of observation equations in form (7) under condition $\Sigma\left(v_X^2 + v_Y^2 + v_Z^2\right) = \min$ and wiil get unknown parameters $\varepsilon_X,\ \varepsilon_Y,\ \varepsilon_Z$ and Δm.

By such way we will obtain the 07 coordinate transformation parameters $dX_0,\ dY_0,\ dZ_0,\ \varepsilon_X,\ \varepsilon_Y,\ \varepsilon_Z,\ \Delta m$ for conversion of coordinates from ITRF according the WGS-84 global reference ellipsoid to VN2000 - 3D according the WGS-84 national reference ellipsoid.

3. Results

Based on global geodetic coordinates $\overline{B}_i,\ \overline{L}_i,\ \overline{H}_i$ on n = 164 orientation points (i = 1,2,…,164) we solved system of observation equations (4) under the condition $\sum_{i=1}^{164}\zeta_i^2 = \min$ and had the following coordinate transformation parameters:

$$dX_0 = 204{,}511083\ m,\ dY_0 = 42{,}192468\ m,\ dZ_0 = 111{,}417880\ m, \quad (8)$$

national quasi-geoid heights ζ (4) of the 164 orientation points.

Minimal national quasi-geoid height 0,042 m belongs to the second order benchmark II(PLK - PL)24 and maximal national quasi-geoid height 4,524 m belongs to the first order benchmark I(BH - TH)59. Accomplishing estimation of two independent series ζ nad ζ^* on the 164 orientation points by method of double observation processing, we had got correction C = -0,023 m. Differences $d_i = \zeta_i - \zeta_i^*$, i = 1,2,..., 164, have been presented in Table 1. RMS of every from two abovementiond series is equal to

$$m_\zeta = \pm\sqrt{\frac{\sum_{i=1}^{164} d_i^2}{2x164}} = \pm\sqrt{\frac{1,265}{328}} = \pm\ 0,062\ m.$$

Limited maximal absolute value of defferences d has been determined by formula $|d|_{\max} = t.\sqrt{2}.m_\zeta$. With t = 2,0; $m_\zeta = 0{,}062\ m$, value $|d|_{\max} = 0{,}175$. In Table 1, number of absolute values of differenses d in interval (0 – 17,5 cm) is160 (97,56 %). With t = 2,5; $m_\zeta = 0{,}062\ m$, limited maximal absolute value $|d|_{\max} = 0{,}219$. Mean while, number of differences d with absolute values in the interval (17,6 - 19,5 cm) is only 4 (2,46%). Hence, differences d in Table 1 satisfy limited value, in addition differences d with small absolute values occupy vast majority. That attestes reliability of the initial national quasi-geoid model VIGAC2017, with being constructed from the mixes quasi-geoidVIGAC2014 by formula (5).

Based on the 164 orientation points with those geodetic corrdinates B, L in VN2000, we solved the system of observation equations in form (7) and had unknown parameters ε_X, ε_Y, ε_Z and Δm with following values:

Ex <second> = - 0”,011168229 or Ex <radian> = - 0,000000054

Ey <second> = 0”,085600577 or Ey <radian> = 0,000000415

Ez <second> = - 0”,400462723 or Ez <radian> = -0,000001941

Dm = 0,000000000

Abovepresented parameters ε_X, ε_Y, ε_Z, Δm with parameters dX_0, dY_0, dZ_0 (8) created set of the 07 coordinate transformation parameters from ITRF to VN2000 - 3D and guarantee close connection between those spatial reference systems.

Table 1. Estimation of the differences $d = \zeta - \zeta^*$ on the 164 first and second order benchmarks

No	Points	Differences d (m)	No	Points	Differences d (m)
Differences with absolute values not more 17.5 cm					
1	IBH-TH122A	0.029	50	IVL-HT158	0.023
2	IBH-TH119	0.049	51	IDN-BT74	0.045
3	IBH-HN33	0.032	52	IBH=-LS88-1	0.047
4	IBH-HN39	0.037	53	IVL-HT98	0.032
5	IBH-HN42	0.009	54	IBH-LS.85-1	0.051
6	IHN-VL4-1	0.046	55	IBH-LS93	0.049
7	IHN-VL6-1	0.017	56	IBH-LS71	0.054
8	IVL-HT152-1	-0.023	57	IBT-APD56	0.034
9	IHN-VL34-	-0.049	58	IVL-HT87	0.051
10	IHP-MC48A	-0.045	59	IVL-HT247A	0.045
11	IBH-TH3-1	-0.021	60	ILS-TY1	0.065
12	IVL-HT181	-0.061	61	IDN-BT83	0.052
13	ILS-TY4	-0.037	62	IVL-HT78	0.055
14	IVL-HT309A	-0.058	63	ILS-HN36	0.065
15	IVL-HT317	-0.053	64	ILS-HN29	-0.022
16	IVL-HT187	-0.049	65	IHN-VL28-1	0.032
17	IVL-HT170-1	-0.048	66	IIDK-TM41	0.021
18	IHP-MC41	-0.019	67	IIBH-XL11-1	-0.045
19	IHN-VL56	0.051	68	IIBH-XL17	0.003
20	IBH-TH11	0.064	69	IIBS-CD12	-0.047
21	IHN-VL40-1	0.057	70	IIBS-CD3	0.001
22	IVL-HT130	-0.035	71	IICD-VC4-1	-0.020
23	IBH-TH5	-0.015	72	IICT-GD10	0.001
24	IHN-VL38-1	-0.019	73	IICT-GD15-1	-0.036
25	IVL-HT197	-0.032	74	IICF-VT1	-0.039
26	IBT-APD63	-0.032	75	IIGD-AB12	-0.057
27	IVL-HT127-3	-0.026	76	IIGD-AB9-1	-0.036
28	IBT-APD59-1	-0.029	77	IIGD-APD6-1	-0.036
29	IVL-HT278-1	-0.023	78	IIHN-AB11	-0.064
30	IVL-HT108	-0.015	79	IIHN-AB3	-0.062
31	IDN-BT77	-0.012	80	IIHN-MT5	-0.019
32	IBT-NH17-1	-0.015	81	IILC-TG19A	-0.020
33	IVL-HT83	-0.009	82	IIMC-XM7-1	-0.056
34	IBH-HN17	0.006	83	IIMT-TH4	-0.026
35	IHN-VL45-1	0.053	84	IINB=HN15	0.060
36	IBH-TH65	0.015	85	IIPLK-PL12	-0.034
37	IVL-HT178	0.001	86	IIPLK-PL2	0.061
38	IVL-HT103	0.008	87	IIPLK-PL8	-0.037
39	IHN-VL64	0.017	88	IISC-VT3-1	-0.040
40	IVL-HT141-	0.009	89	IITX-TL25	-0.050

41	IVL-HT329A	0.009	90	IITX-TL6	-0.048
42	IHN-VL72	0.024	91	IIYB-CN18	-0.055
43	IHN-VL10A	-0.070	92	IVL-UT150	-0.072
44	IDN-BT16	-0.074	93	IBH-LS77	0.066
45	IDN-BT28	-0.068	94	IVL-HT71	0.074
46	IIBS-CD7-1	0.068	95	IIGD-AB3-1	-0.069
47	IIHN-AB23	-0.071	96	IILC-TG15	0.072
48	IINB-HN27-1	0.067	97	IILC-TG31	0.073
49	IINK-PT10	0.075	98	IIPLK-PL16	-0.067
99	IBH-LS97	0.116	130	IIMT-TH25	-0.148
100	IHN-HP7	0.082	131	IIMT-TH7	-0.148
101	IVL-HT121	0.082	132	IIMT-TV11	-0.141
102	IVL-HT325-1	0.098	133	IIMX-DC34	-0.148
103	ILS-HN7	0.078	134	IINB-HN11-1	0.089
104	IBT-APD49-1	0.115	135	IINB-HN24	0.102
105	IBH-TH59	0.097	136	IINK-PT13	0.139
106	IVL-HT173-2	0.079	137	IISC-PL29	-0.132
107	IBH-TH70A	0.098	138	IITL-TV5-1	-0.135
108	IHN-VL50	0.093	139	IITL-TV7	-0.129
109	IVL-HT123	0.087	140	IITX-TL14	-0.098
110	ILS-HN12	0.102	141	IITX-TL20-1	-0.129
111	IHP-MC4-1	0.108	142	IIYB-CN24-1	-0.135
112	IBH-LS80	0.110	143	IICD-HN6	0.085
113	IDN-BT86	0.092	144	IICD-VC4	-0.133
114	IVL-HT320A	0.090	145	IICT-GD1	0.130
115	IHP-NB14A	-0.099	146	IICT-GD4	0.142
116	ILS-HN22	-0.094	147	IIDK-TM29	-0.101
117	IBH-HN16A	0.096	148	IIDK-TM45	-0.136
118	IBH-HN48	0.146	149	IIDL-PR31	-0.145
119	IHN-HP2A	0.136	150	IIGD-APD2-1	0.090
120	IIAB-CL5	-0.105	151	IIHN-AB17	-0.122
121	IIAS-KS10	-0.138	152	IIHN-AB20	-0.090
122	IIAS-KS16	-0.092	153	IIHN-AB7	-0.134
123	IIAS-KS22	-0.132	154	IIHN-MT15	-0.102
124	IIAS-KS32	-0.115	155	IIBMT-DT12	-0.112
125	IIBH-XL6	0.097	156	IIBS-CD14	0.147
126	IHN-HP5	0.170	157	IINK-PT6-1	-0.165
127	IIBMT-DT14	-0.158	158	IIPLK-PL24	-0.164
128	IIBMT-DT4	0.151	159	IITT-TK29	-0.153
129	IIBN-QT11-1	0.166	160	IIAS-KS35	-0.169
Differences with absolute values more 17.5 cm and not more 20 cm					
161	IBMT-APD30	0.182	163	IINB-HN32-1	0.178
162	IVL-HT95	0.177	164	IVL-HT73	0.195

Experimental results show that in combination with the initial national quasi-geoid model VIGAC2017, the national geodetic coordinates B, L, H of geodetic point in VN2000 - 3D allow getting the national normal height H^{γ} with the second order national normal height accuracy on the whole territory of Vietnam. In addition, the national geodetic coordinates B, L, H of geodetic pointreceived from conversion of the global geodetic coordinates $\overline{B}$, $\overline{L}$, $\overline{H}$ of this geodetic point, obtained from the processing of GNSS data in ITRF according to the WGS-84 global reference ellipsoidwith the using of satellite ephemeris with accuracy at level ±2,5 cm, to VN2000 - 3D. Experimental results will be presented in the next scientific article. It is necessary to pay attention to the factthat, at present, more 60% first and second orders benchmarks have been displaced on the terrain surface of Vietnam's territory. So with the purpose of development of the national spatial reference system in Vietnam, we must perfect the national first and second orders leveling networks in the near future.

4. Discussions

Abovepresented research results show that the initial national quasi-geoid model VIGAC2017 has the high accuracy and allows starting the construction of the initial spatial reference system, which guarantees to get the second order normal height by GNSS technology. That is seenas the first step to the perfectible construction of the national spatial reference system in the future.

However, with the accuracy at level ±0,062 m the inital national quasi-geoid model VIGAC2917 does not satisfy the requirement of accuracy more than ±0,040 m for the construction of the national spatial reference system by international regulation. An increase of accuracy of the final national quasi-geoid model will be accomplished by an increase of accuracy of the mixed quasi-geoidmodel VIGAC2014 based on usage of detailed gravimetric data on territory of Vietnam.

The physical geodesy exists two methods for determination of quasi-geoid height by gravimetric data:

- The first method: Calculation of quasigeoif height by Stokes's integral.
- The second method: Correction of spherical harmonic coefficients of Earth's Gravitational Model (EGM) by approach of Colombo O.

The first method requires existence of gravimetric data around computational point with radius of near zone at 3°. This requirement can't be sastified for narrow and long country like Vietnam in the near futute. In addition, at present, there is no detailed gravimetric data in Lao and Campuchia. So the second method becomes more realistic and has been proposed to use (Ha minh Hoa, 2013c; Ha Minh Hoa, 2014a; Ha Minh Hoa, 2014b; Ha Minh Hoa et al. 2016a). Apart from that correction of spherical harmonic coefficients of EGM can be carried out based GNSS data on the first and second orders (Ha Minh Hoa, Nguyen Thi Thanh Huong, 2015a). Vietnam Institute of Geodesy and Cartography will carry out project "Detailed gravimetric measurement in mountainous regions of Vietnam" in the near future.

5. Conclusions

In the epoch of application of GNSS technology, the task of the construction of the national spatial reference system becomes the most important research content of high geodesy, that concentrates in itself the most important achievements in fields of the physical geodesy and geometrical geodesy. The key problem of the aforementioned task is the construction of the high accurate national quasi-geoid model. This scientific article presented results of the construction of the initial national quasi-geoid model with accuracy at the level of ±6,2 cm and determination of the 07 coordinate transformation parameters from ITRF according to the WGS84 global reference ellipsoid to VN2000 - 3D according to the WGS84 national reference ellipsoid. The increase of accuracy of this national quasi-geoid model to level more than ± 4,0 cm will be performed by the method of correction of spherical harmonic coefficients of Earth Gravitational Model EGM2008 based on detailed gravimetric data on the territory of Vietnam in the future.

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