Prospecting fitness of VN2000 datum to EGM2008

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ABSTRACT

Based on the Earth Gravitational Model EGM2008 with 1minx1min resolution, this paper presents the fitness of the VN2000 datum oriented by using transformation parameters published by the MONRE. The results showed that VN2000 datum is better than WGS84 datum in Vietnam territory. Because rotation parameters are quite small, the author suggest ignoring the influence of the three rotation angles when positioning and transforming from VN2000 to WGS84. This helps simplify processing of calculating baselines measured by GPS technology from WGS84 to VN2000.

Key words: *EGM2008, VN2000 datum, WGS84, Geoid, Ellipsoid, GPS.*

INTRODUCTION

The shape of the earth is very complex. Geoid is defined as a physical equipotential surface that represents the shape of the Earth, which is also used to determine the surface elevation of a point in space. Distance according to the plumb line from one point to Geoid called orthometric height H. Since geoid surface is not mathematical surface, ellipsoid is used to determine the coordinates of point with latitude B, longitude L and geodetic height h. The distance between the geoid and ellipsoid known as Geoid height N, is expressed through the following equation:

$$h = H + \zeta \qquad (1)$$

A reference system (geodetic datum) is based on conditions that match the following equation:

$$\sum_{i=1}^{\infty} \zeta_i^2 = \min \qquad (2)$$

Depending on the data ζ_i of the equation (2), global datum (as WGS84) or local datum (as VN2000) will be defined. The transformation of coordinates from a global datum to the local datum is performed by the Bursa-Wolf formula [1]:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{VN\,2000} = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{WGS\,84} + \begin{bmatrix} \Delta s & \omega_z & -\omega_y \\ -\omega_z & \Delta s & \omega_x \\ \omega_y & -\omega_x & \Delta s \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{WGS\,84} + \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} \qquad (3)$$

On 27/2/2007, MONRE announced 7 parameters transformation of coordinates by decision 05/2007/QĐ-BTNMT [2] as following:

ΔX = -191.90441429m; ΔY = -39.30318279m, ΔZ = -111.45032835m; ω_x = -0.00928836”; ω_y = 0.01975479”; ω_z = -0.00427372”; $\Delta s = 0.252906278 * 10^{-6}$

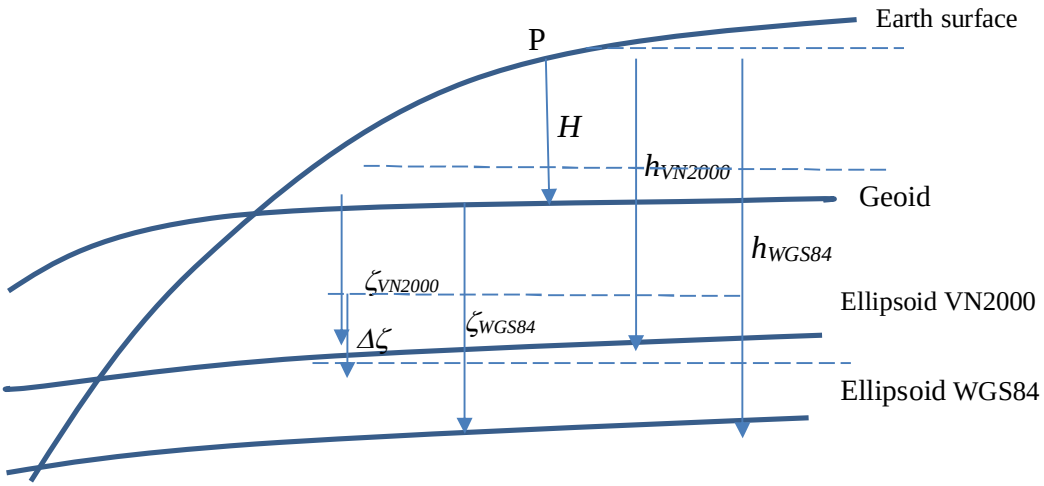

Figure 1. The relationship between the geodetic height above the ellipsoid WGS84 and VN2000

According (1): $h_{WGS84} = H + \zeta_{WGS84}$ and

$$h_{VN2000} = H + \zeta_{VN2000}$$

$$\Rightarrow \quad \zeta_{VN2000} = \zeta_{WGS84} - \Delta\zeta \qquad (4)$$

With $\Delta\zeta$ - distance from Ellipsoid VN2000 to WGS84.

Otherwise:

$$X = (N+h)\cos B\cos L$$
$$Y = (N+h)\cos B\sin L$$
$$Z = \left[N(1-e^2)+h\right]\sin B$$

(5)

With

$N = \dfrac{a}{\sqrt{1-e^2\sin^2 B}}$ - radius of curvature in the prime vertical.

$$L = \arctan\left(\frac{Y}{X}\right);\ B = \arctan\left(\frac{Z+Ne^2\sin B}{\sqrt{X^2+Y^2}}\right)$$

and $h = \dfrac{\sqrt{X^2+Y^2}}{\cos B} - \dfrac{a}{\sqrt{1-e^2\sin^2 B}}$ (6)

Earth Gravitational Model EGM2008 [3]: The official Earth Gravitational Model EGM2008 has been publicly released by the U.S. National Geospatial-Intelligence Agency (NGA) EGM Development Team. This gravitational model is complete to spherical harmonic degree and order 2159, and contains additional coefficients extending to degree 2190 and order 2159. Full access to the model's coefficients and other descriptive files with additional details about EGM2008 are provided in website of NGA.

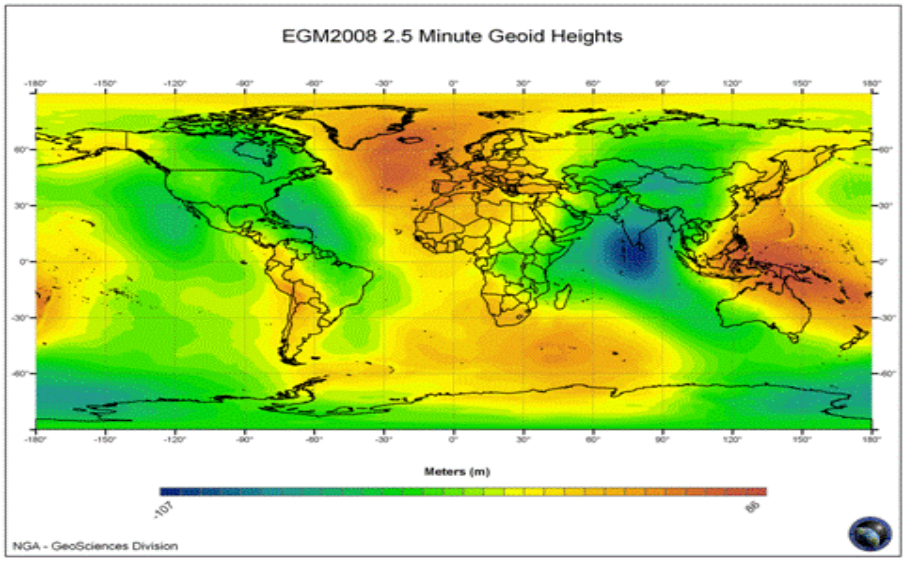

Figure 2. EGM2008 2.5 minute geoid heights

PROCESS AND DATA PREPARATION

From the model EGM2008, the author determined 1.0 minute geoid heights in WGS84 of Vietnam's territory consists of land, sea and islands (see Figure 3) with geodetic coordinates (in WGS84) are shown in Table 1.

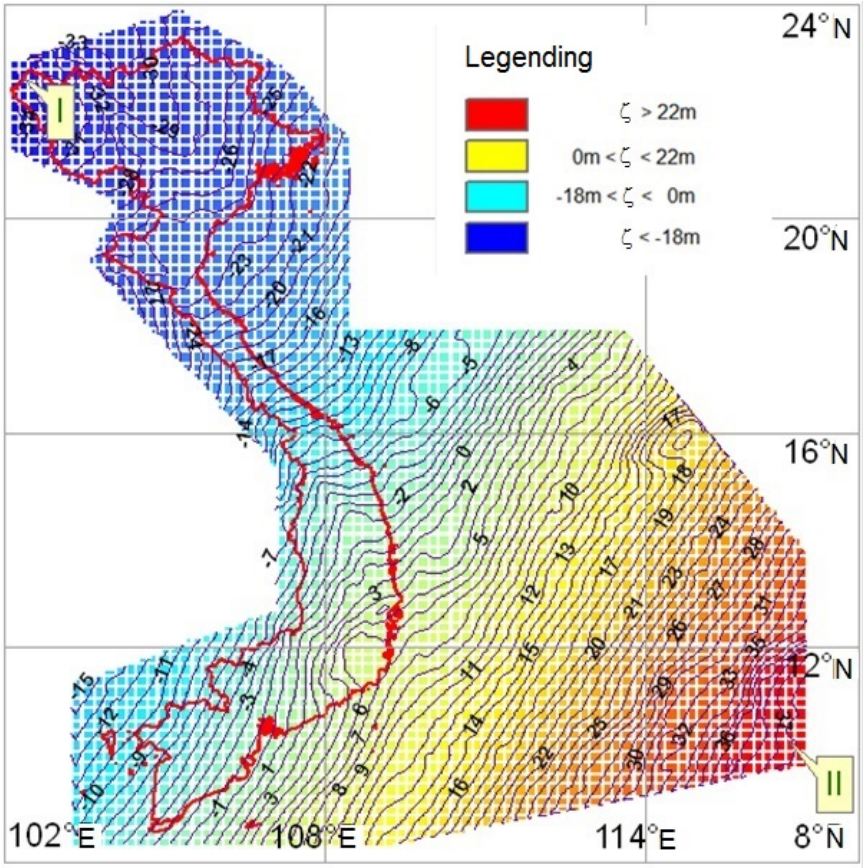

Figure 3. EGM2008 1.0 minute geoid heights in WGS84

Table 1. Geodetic coordinates (in WGS84) of Vietnam and neighboring territory

No	Latitude (Degree)	Longitude (Degree)	No	Latitude (Degree)	Longitude (Degree)
1	23.893	105.298	9	08.259	103.262
2	22.818	107.223	10	11.278	103.262
3	21.488	108.468	11	12.687	107.086
4	17.931	108.467	12	15.404	107.086
5	17.922	113.619	13	19.178	103.614
6	13.744	117.048	14	20.285	104.168
7	09.819	117.048	15	21.291	102.105
8	08.259	108.897	16	22.901	102.105

Using above formula (3),(4),(5),(6) and parameters transformation from WGS84 to VN2000 we used 458.909 points from 1'x1' grid to processing. The result is as following:

In WGS84: The maximum geoid height $\zeta^{max}_{WGS84} = +40.12m$, the minimum geoid height $\zeta^{min}_{WGS84} = -35.34m$, the average of geoid height $\overline{\zeta}_{WGS84} = 0.80m$ and standard deviation $\sigma_{WGS84} = 18.67m$

In VN2000: The maximum geoid height $\zeta^{max}_{VN2000} = +8.62m$, the minimum geoid height $\zeta^{min}_{VN2000} = -6.13m$, the average of geoid height $\overline{\zeta}_{VN2000} = 0.4m$ and standard deviation $\sigma_{VN2000} = 2.90m$ (see Figure 4)

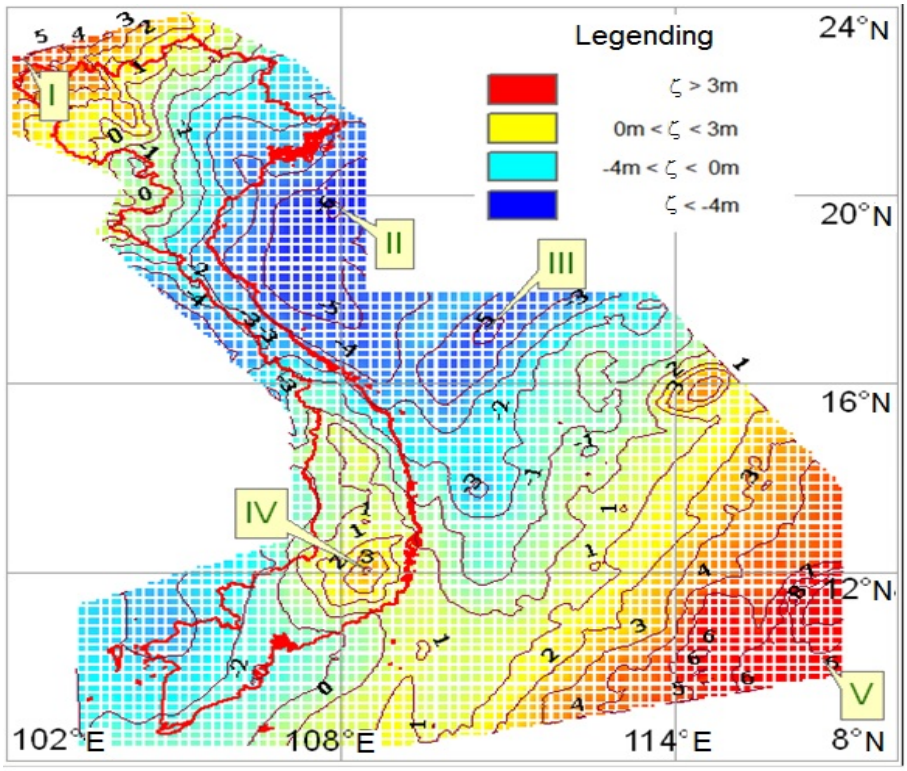

Figure 4. EGM2008 1.0 minute geoid heights in VN2000

In addition, we found that the range geoid height in the VN2000 reduced 5 times compared with WGS84 (from 75.455m to 14.743m); standard deviation decreased by nearly 6.5 times. That suggests that the VN2000 (WGS84 ellipsoid used) are positioned fitting within model EGM2008 than WGS84.

In Figure 3 and Figure 4, geoid height changes over four levels in order of decreasing color: red, yellow, blue, dark blue. In particular, the red and yellow is presented in case geoid is higher than ellipsoid; and blue and dark blue - geoid is lower than ellipsoid and the boundaries of the blue and yellow is a intersection between the geoid and ellipsoid.

Because the value of the rotation parameters (ωx,ωy,ωz) published by MONRE is quite small (less than 5*10-2 arcs of second), so we examined the problem of datum transformation under the following cases:

+ 7 parameters

+ 4 parameters (without angle rotation,)

+ 3 parameter (without angle rotation and ratio)

Using the formula (3),(4),(5),(6) again, the result is in the table 2

Table 2. The suitability of VN2000 according to the coordinate's transformation parameters

	$\zeta^{\min}_{VN2000}$ (m)	$\zeta^{\max}_{VN2000}$ (m)	$\overline{\sigma}_{VN2000}$ (m)	σ_{VN2000} (m)
7 parameters	-6.126	8.617	-0.4	2.90
4 parameters	-6.126	8.617	-0.4	2.90
3 parameters	-4.513	10.230	1.2	2.90

From Table 2, it is found that, ignoring the rotation parameters (rotation angle is quite small) will not affect the local ellipsoid positioning. Meanwhile, if the removing additional 4th parameter (parameter ratio), the result will be worse. The mean of geoid heights is changed from -0.4m to 1.2m and the distance between the geoid and the ellipsoid will be larger than the previous cases.

On the other hand, when using 4 parameters instead of using 7 parameters, the maximum deviation in the latitude component is $2x10^{-6}$ degrees (equals to 0.2m on the Earth surface), longitude component is $4x10^{-6}$ degrees (equals to 0.4m on the Earth surface) and in the geoid height component is only 1mm. This allows users should not use parameters of rotation to the transformation from WGS84 to the VN2000. In that case, the transformation of baselines processed from GPS carrier measurements (in WGS84) to VN2000 is quite simple by using the formula :

$$\begin{bmatrix} dX_{ij} \\ dY_{ij} \\ dZ_{ij} \end{bmatrix}_{VN2000} = (1+\Delta s)\begin{bmatrix} dX_{ij} \\ dY_{ij} \\ dZ_{ij} \end{bmatrix}_{WGS84} \quad (7)$$

With $dX_{ij}, dY_{ij}, dZ_{ij}$ – baseline vectors processed from GPS carrier measurements

CONCLUSION

The results of the comparison between the geoid height in WGS84 and VN2000 shows that the repositioning reference ellipsoid in VN2000 system is necessary and in accordance with Vietnam's territory. However, the mean of geoid heights not so good when it is near 0.5 meters.

On the other hand, the author suggest ignoring three parameters of angle rotation when using transformation parameters announced by MONRE. This is useful when using GPS technology to establish geodetic network. The calculation of baseline from WGS84 to VN2000 is simply to plus it with (1+Δs), is convenience for calculator. On the other hand, the

transformation of geodetic coordinates B, L, h would be less complicated by just using the standard Molodensky's formula, instead of using Molodensky's formula with 7 parameters or Bursa-Wolf's formula.

Khảo sát sự phù hợp của hệ qui chiếu VN2000 trên mô hình trọng lực trái đất EGM2008

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TÓM TẮT:

Dựa trên mô hình trọng lực trái đất EGM2008 với độ phân giải 1'x1', bài báo trình bày sự phù hợp của hệ qui chiếu VN2000 khi định vị lại theo các tham số chuyển đổi tọa độ được công bố bởi Bộ Tài nguyên và Môi trường. Kết quả nghiên cứu cho thấy hệ qui chiếu VN2000 phù hợp hơn rất nhiều so với hệ WGS84 tại Việt Nam. Vì các tham số góc xoay được công bố là khá nhỏ, tác giả đã đề xuất bỏ qua các tham số xoay này khi định vị và chuyển đổi hệ qui chiếu từ VN2000 sang WGS84 nhằm đơn giản hóa quá trình chuyển đổi các đường đáy đo bằng công nghệ GPS từ hệ WGS84 sang VN2000.

Từ khóa: *Mô hình EGM2008, hệ qui chiếu VN2000, hệ tọa độ WGS84, Geoid, Ellipsoid, GPS.*

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