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GNSS OBSERVATIONS TO FIND THE RELATIONSHIP BETWEEN THE GLOBAL DATUM WORLD GEODETIC SYSTEM WGS84 AND THE LOCAL DATUM KARBALA 1979. A CASE STUDY OF ERBIL-DUHOK TERRITORY

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ABSTRACT

Over the last few years, the Global Navigation Satellite System GNSS was seen as an innovatory method in the disciplinary of geodetic engineering as compared to other classic measuring methods. It is familiar to everyone that the height acquired from GNSS observations is the ellipsoidal height (h), which is the distance over the vertical to the global datum World Geodetic System WGS84. The value of (h) is endowed with a physical meaning relating to engineering applications for identification of the orthometric height (H), after the conversion from the global datum to the local datum. So far, in the Iraqi- Kurdistan region, there is no specific local datum that can be utilized to identify the exact orthometric height over a local vertical datum. This research aims to define the relationship between the global datum WGS84 and the Iraqi local datum Karbala 1979 based on ellipsoid Clark 1880, through extracting the Digital Terrain Model DTM for both datums in the case study area (Duhok-Erbil territory). The obtained results show that there is a significant change in the relationship between the two datums over the study area, and the difference between them is propagated between (-1.751 m) up to (+4.236 m) along with this territory. It is found that the two surfaces are intersected at the midway approximately, between Erbil and Duhok.

KEYWORDS: World Geodetic System1984, Karbala1979, Datum and GNSS.

1. INTRODUCTION

Due to the arrival of satellite-based technology, specifically the (GNSS), and its universal spread out and utilization on various disciplinaries of geomatics and surveying, it is possible and very easy to get hold of three-dimensional coordinates latitude, longitude, and ellipsoid height (h), related to ellipsoid surface WGS84, with high accuracy. Most of engineering projects utilize the orthometric height (H) as a base for elevation measurements, respect to the geoid surface characterized by Mean Sea Level (MSL). So as to alter ellipsoid heights into orthometric heights, it is necessary to identify the difference between these two heights, and this process is referred to as geoid undulation (N) (Miky & Yaagoubi, 2017).

In spite of the differences among these three values, essentially as far as the geodetic meaning is concerned, accuracy and observational methods should achieve the simple geometrical relationship:

$$N = h - H \qquad (1)$$

Where:

H – Is the orthometric height of a point, which is the distance, along the normal, between the natural ground surface and the reference vertical datum Mean Sea Level (MSL).

h – Is the ellipsoidal height of a point, which is the distance, along the normal, between the natural ground surface and the ellipsoid (reference datum).

N – Is the distance between the geoid and a precise ellipsoid, which is known as the undulation (separation).

Figure (1) below illustrates the geometrical relationship between these three elements.

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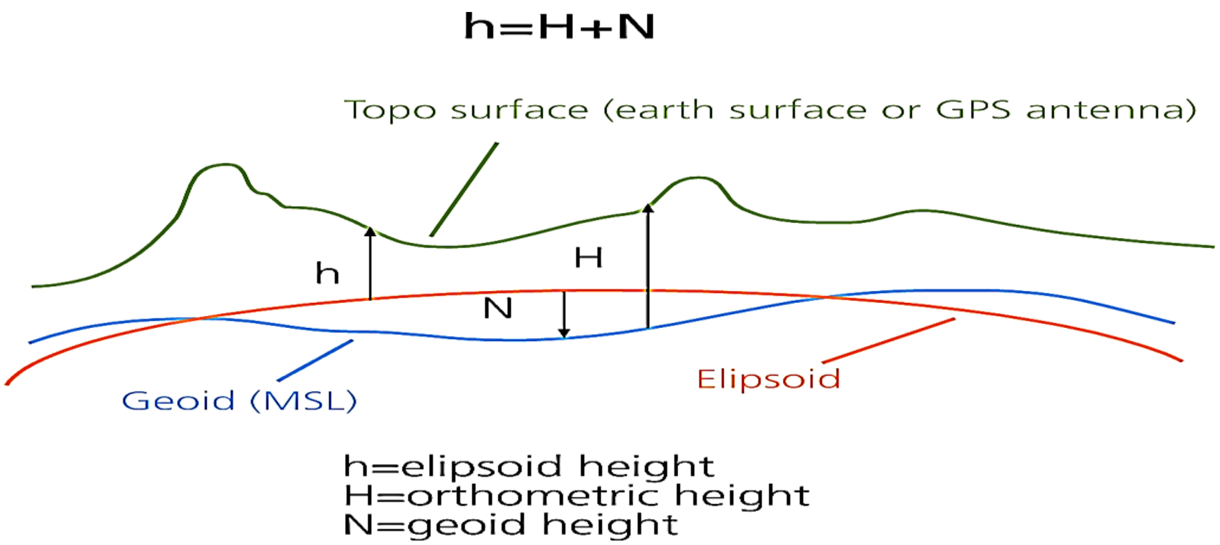

Fig. (1): the relationship between the Orthometric, Ellipsoidal, and Geoid height

The geoid is formed by the gravity area of Earth. It is a potential balance surface of the gravity field, representing that the gravity potential is continuous and the gravity's direction is vertical at all spots on this surface. This would be the exterior part of the oceans if they were to flow spontaneously and cover the whole earth (in the absence of winds, tide, and currents). Both surfaces: that of the oceans and that of the geoid would align. The geoid is the best global estimation of the mean sea level (MSL) which is utilized as a reference in measuring features elevation (Miky & Yaagoubi, 2017)

2. KARBALA 1979 DATUM

During the 1970s, a novel geodetic system spreading all of Iraq was prepared by the Polish State Enterprise for Geodesy and Cartography GEOKART, functioning as part of a wider international support organization named Polservice. This was a classic astro-geodetic control network comprising 2778 points with a typical inter-point space of 15 km. Karbala 1979 was utilized in aggregation with the Universal Transverse Mercator UTM system of map projections, as well as with a devoted TM Transverse Mercator projection, identified as the Iraq National Grid whose part in use is all of Iraqi onshore (IOGP , 2015).

3. LITERATURE REVIEW

(Ali A. M., 2016) Calculated the geoidal height for different ground control points (GCPs) distributed inside Baghdad University campus based on the difference between the ellipsoidal height and the orthometric height of the same point. EGM08 has been used to calculate the maximum and the minimum values of the geoid undulation. However, the calculation of geoidal height or geoid undulation needs to be performed for a wide area with well points distribution.

(Ali S. H., 2008) Derived Ellipsoidal heights were from GPS measurements concerning WGS84 at specific positions in the campus of the University of Mosul. The orthometric heights of the studied area were then achieved according to undulation (geoid height) given by the global model of the geoid (The Earth Gravitational Model 1996: EGM96). The obtained results indicated that the chosen of EGM96 global geoid presented a good approximation for the geoid height and orthometric height of an exciting small area inside Mosul University. Based on the existing data from the GPS receiver and EGM96 global geoid, gained the average value of the undulation of the whole study area, it can be utilized as a correction factor between GPS ellipsoidal height and the orthometric height.

4. METHODOLOGY AND MATERIAL - STUDY AREA

Three different areas have been selected for this research. The first one was within Duhok territory (inside and outside of Duhok). The one outside Duhok city (Zakho), the selected area is approximately 97 km^2 designed as regular

(500x500)m grid making (434) points. The one inside Duhok city, forty points distributed all over the city: this area is about 30 km^2. The second one was Erbil city; ninety-seven points are distributed and designed as a circle according to the city's streets: the area is approximately 150 km^2. The third one was the strip along the Erbil - Duhok road: the length of this strip is about 180 km covered by twenty-eight points (see figure 2 & 3).

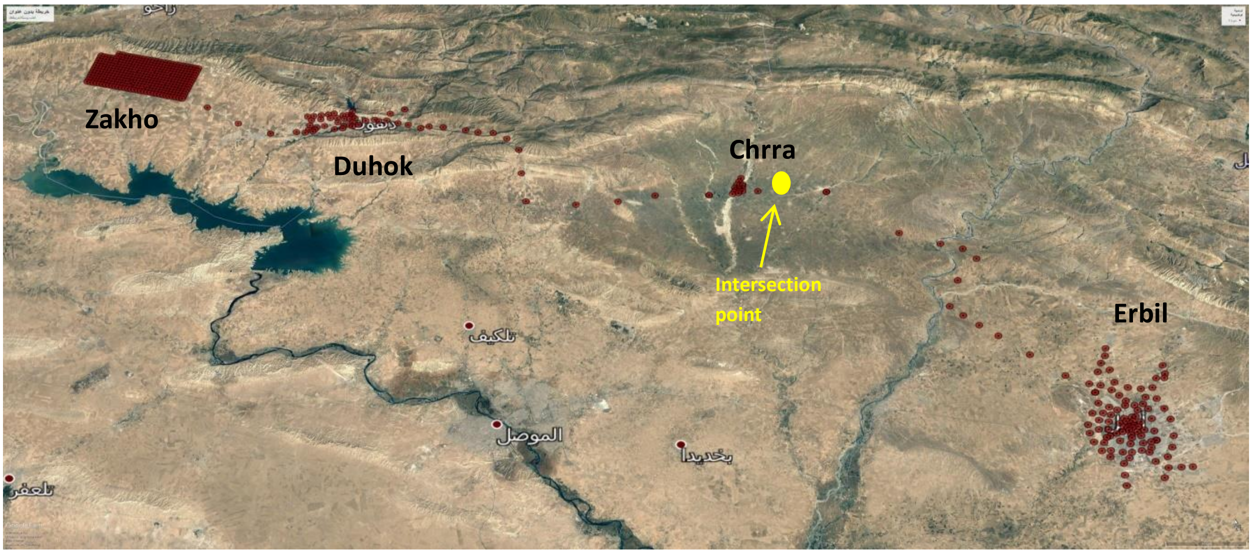

Fig. (2): Satellite Image of Study areas (Google Earth)

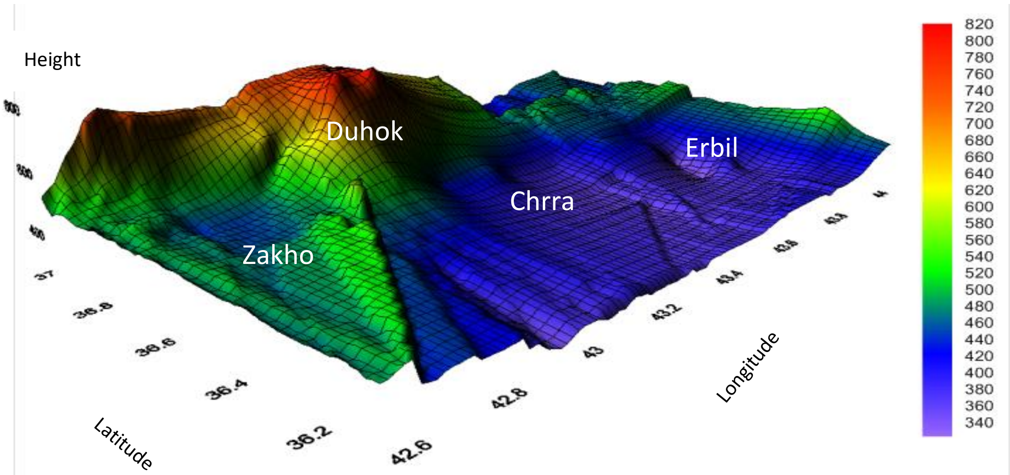

Fig. (3): 3D surface of the study area

5. Data Collection

GNSS observations are done according to the Differential Global Positioning System DGPS technique using the Continuously Operating Reference Station (CORS) in Duhok as the base station for data collection across the whole case study areas. However, 600 points were precisely observed by GNSS (Topcon GR 5) system. The three-dimensional coordinates (Longitude, latitude and Ellipsoid height) of all points are transformed to the Iraqi local datum Karbala1979 using the international standard parameters obtained from European Petroleum Survey Group (EPSG). The transformation is done with the aid of the online program “Georepository,” according to the website link: https://georepository.com/calculator/convert/crs_a/4743/crs_b/4326/operation_id/5078

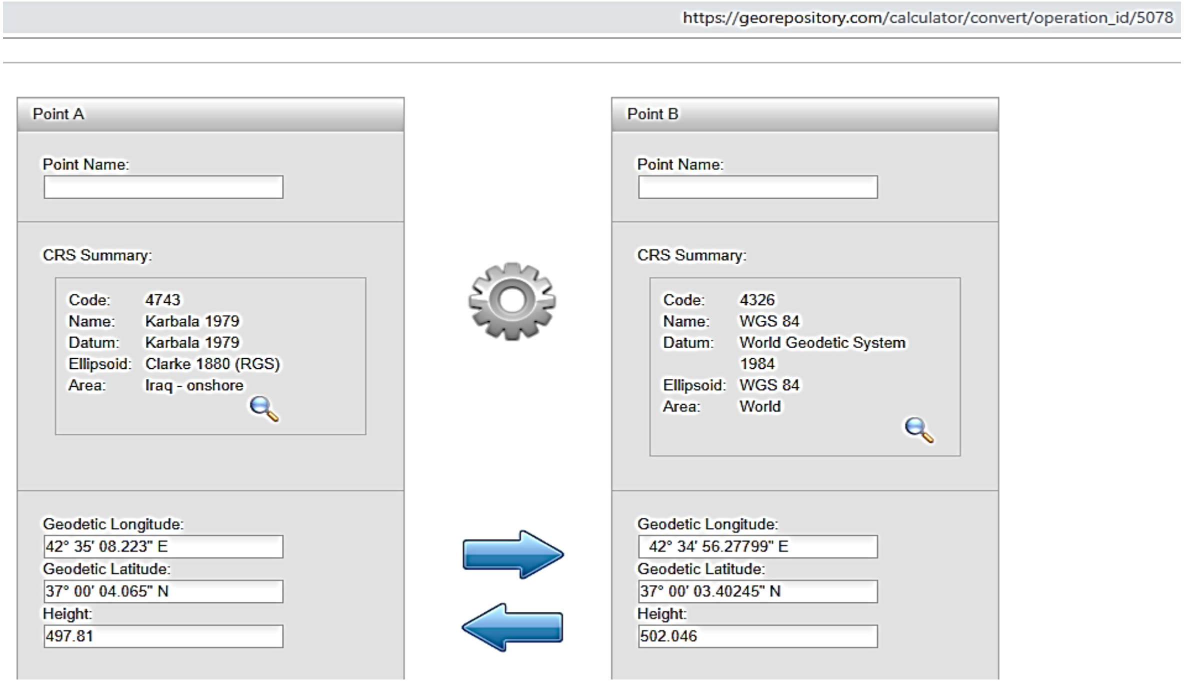

Fig. (4): online transformations between two datums.

In order to determine all seven parameters, both geodetic systems must be converted to cartesian system, and then the Bursa-Wolf similarity transformation model is employed. The Bursa-Wolf model is one of the most commonly used transformation methods in geodetic applications. It is a 3D conformal transformation which is also known as 3D similarity transformation or Helmert 3D transformation or 7-parameter transformation. Equation (2) is the mathematical representation of the Bursa-Wolf model (Okwuashi & Eyoh, 2012).

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} + \mu . R\,(\alpha_1, \alpha_2\,, \alpha_3) . \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

(2)

Where:

μ - the scale factor.

R - denotes the total rotation matrix.

$\alpha_1, \alpha_2\,, \alpha_3$ - the three rotation angles around the main axes x, y, and z, respectively.

$\Delta X, \Delta Y, \Delta Z$: denote the three translations parameters.

$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix}$ - the coordinates of points on the global datum WGS84.

$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$ - the coordinates of the same points on the local datum Karbala 1979.

A MATLAB program was used to find the seven parameters of transformation between the two datums WGS84 and Karbala1979 using the least-squares technique. Twelve points (four points for each selected area), which are known on both systems, have been used for this purpose, as shown below:

$$x = (A^T A)^{-1}\, A^T\, b$$

(3)

Where:

$$b = \begin{bmatrix} X' - X \\ Y' - Y \\ Z' - Z \end{bmatrix}; \quad A = \begin{bmatrix} 1 & 0 & 0 & 0 & -Z & Y & X \\ 0 & 1 & 0 & Z & 0 & -X & Y \\ 0 & 0 & 1 & -Y & X & 0 & Z \end{bmatrix}; \quad x = \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \\ \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \Delta\mu \end{bmatrix} = \begin{bmatrix} 211.0000002 \\ -207 \\ -13.99999965 \\ 1.68199 * 10^{-14} \\ -4.64628 * 10^{-14} \\ 2.81983 * 10^{-18} \\ 1.55431 * 10^{-15} \end{bmatrix}$$

Thus, the difference between the ellipsoidal height (h) over WGS84 and that over Clarke1880 for each measured point, is to be found using equation (4) below.

$$\Delta h = h_{WGS84} - h_{Karbala\ 1979} \quad (4)$$

Where:

Δh – the difference in ellipsoidal height between the two datums.

h_{WGS84} – the ellipsoidal height according to global datum WGS84.

$h_{Karbala\ 1979}$ - the ellipsoidal height according to Iraqi local datum Karbala 1979 based on ellipsoid Clark 1880.

6. RESULTS AND DISCUSSION

The resulting (Δh) for all measured points over the case study territories, regarded as the value that defines the relationship between the two studies datum. Figure (5) illustrates the obtained differences in ellipsoidal heights (Δh) between the global datum WGS84 and the local datum Karbala 1979 over the three territories, Erbil province, Duhok province, and the road between them. The obtained results show that there is a significant difference between the two datums surfaces over the studied territories which propagated between (+4.236 m and -1.751 m), and these datums are intersected over the territory of Chrra township, which is located on the Erbil - Duhok main road.

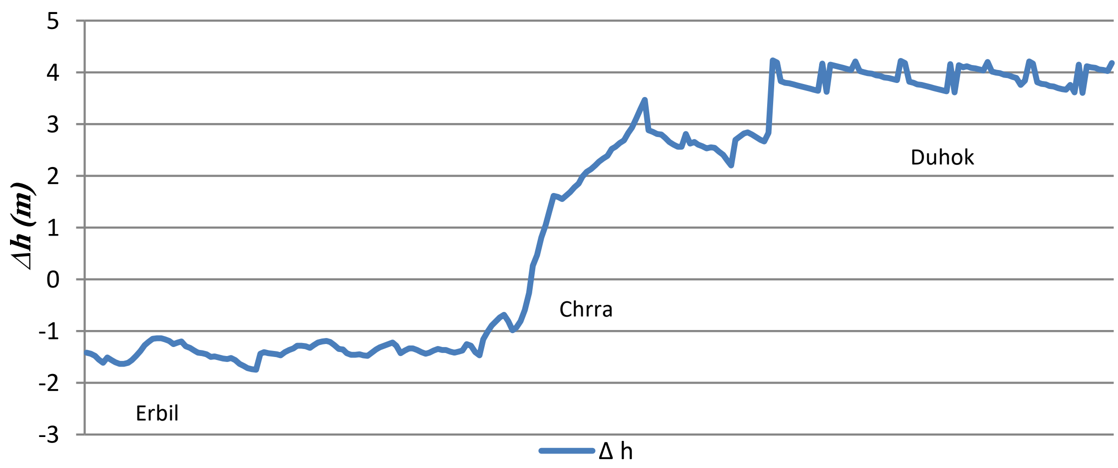

Fig. (5): the difference in height between WGS84 and Karbala1979

Table (1) and (2) illustrate the coordinates were measured by GNSS and then transformed to local datum Karbala1979, in order to determine the geodetic height for all measured points. The difference between the ellipsoidal heights on both datums is calculated to find the value of undulation on the local datum Karbala1979.

Table (1): Selection from Duhok territory

Id	Longitude WGS84	Latitude WGS84	Ellipsoid height WGS84	Undulation EGM2008 WGS84	TO	Longitude Karbala1979	Latitude Karbala1979	Ellipsoid height Karbala1979	Δh h_{WGS84}- $h_{karbala1979}$	Undulation Karbala1979 (N_{wgs84}-Δh
1	42° 34' 56.27799" E	37° 00' 03.40245" N	502.046	18.0335		42° 35' 08.223" E	37° 00' 04.065" N	497.81	4.236	13.7975
2	42° 35' 32.85255" E	36° 59' 49.56853" N	519.439	18.0174		42° 35' 44.796" E	36° 59' 50.230" N	515.25	4.189	13.8284
3	42° 41' 01.85479" E	36° 57' 44.91057" N	527.513	17.8965		42° 41' 13.781" E	36° 57' 45.559" N	523.68	3.833	14.0635
4	42° 41' 20.12801" E	36° 57' 37.97961" N	528.894	17.8905		42° 41' 32.053" E	36° 57' 38.627" N	525.09	3.804	14.0865
5	42° 41' 38.39249" E	36° 57' 31.04800" N	530.537	17.8845		42° 41' 50.317" E	36° 57' 31.695" N	526.75	3.787	14.0975
6	42° 41' 56.66378" E	36° 57' 24.11096" N	530.932	17.8787		42° 42' 08.587" E	36° 57' 24.757" N	527.16	3.772	14.1067
7	42° 42' 14.93242" E	36° 57' 17.17550" N	526.059	17.8736		42° 42' 26.855" E	36° 57' 17.821" N	522.31	3.749	14.1246
8	42° 42' 33.19645" E	36° 57' 10.24016" N	526.012	17.8686		42° 42' 45.118" E	36° 57' 10.885" N	522.28	3.732	14.1366
9	42° 42' 51.45848" E	36° 57' 03.30107" N	530.969	17.8638		42° 43' 03.379" E	36° 57' 03.945" N	527.26	3.709	14.1548
10	42° 43' 09.72737" E	36° 56' 56.36523" N	520.914	17.8588		42° 43' 21.647" E	36° 56' 57.008" N	517.23	3.684	14.1748

Table (2): Selection from Erbil territory

Id	Longitude WGS84	Latitude WGS84	Ellipsoid height WGS84	Undulation EGM2008 WGS84	TO	Longitude Karbala1979	Latitude Karbala1979	Ellipsoid height Karbala1979	Δh h_{WGS84}- $h_{karbala1979}$	Undulation Karbala1979 (N_{wgs84}-Δh)
1	44° 01' 15.30736" E	36° 06' 09.19734" N	429.944	10.7703		44° 01' 26.936" E	36° 06' 09.607" N	431.36	-1.416	12.1863
2	44° 01' 23.67937" E	36° 06' 54.62463" N	427.464	10.8555		44° 01' 35.309" E	36° 06' 55.036" N	428.9	-1.436	12.2915
3	44° 02' 04.93091" E	36° 07' 38.00285" N	430.835	10.9381		44° 02' 16.561" E	36° 07' 38.415" N	432.32	-1.485	12.4231
4	44° 03' 09.65819" E	36° 07' 29.51590" N	447.833	10.9254		44° 03' 21.286" E	36° 07' 29.926" N	449.39	-1.557	12.4824
5	44° 04' 06.95413" E	36° 07' 21.66239" N	458.654	10.9182		44° 04' 18.579" E	36° 07' 22.070" N	460.27	-1.616	12.5342
6	44° 02' 26.00246" E	36° 08' 29.23500" N	436.792	11.0449		44° 02' 37.634" E	36° 08' 29.648" N	438.3	-1.508	12.5529
7	44° 03' 10.41725" E	36° 09' 10.74457" N	450.602	11.1404		44° 03' 22.049" E	36° 09' 11.158" N	452.16	-1.558	12.6984
8	44° 03' 43.92837" E	36° 10' 03.78132" N	462.131	11.2641		44° 03' 55.561" E	36° 10' 04.195" N	463.74	-1.609	12.8731
9	44° 04' 07.42092" E	36° 11' 26.02609" N	466.444	11.4593		44° 04' 19.056" E	36° 11' 26.442" N	468.08	-1.636	13.0953
10	44° 04' 01.26930" E	36° 12' 22.66933" N	485.693	11.5879		44° 04' 12.907" E	36° 12' 23.088" N	487.33	-1.637	13.2249

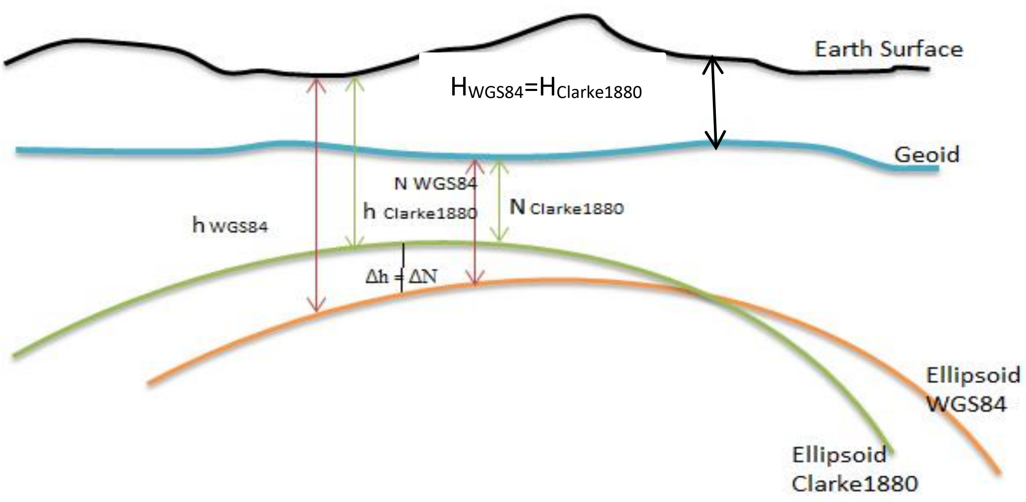

Fig.(6): the relationship between ellipsoid WGS84 and Clarke1880

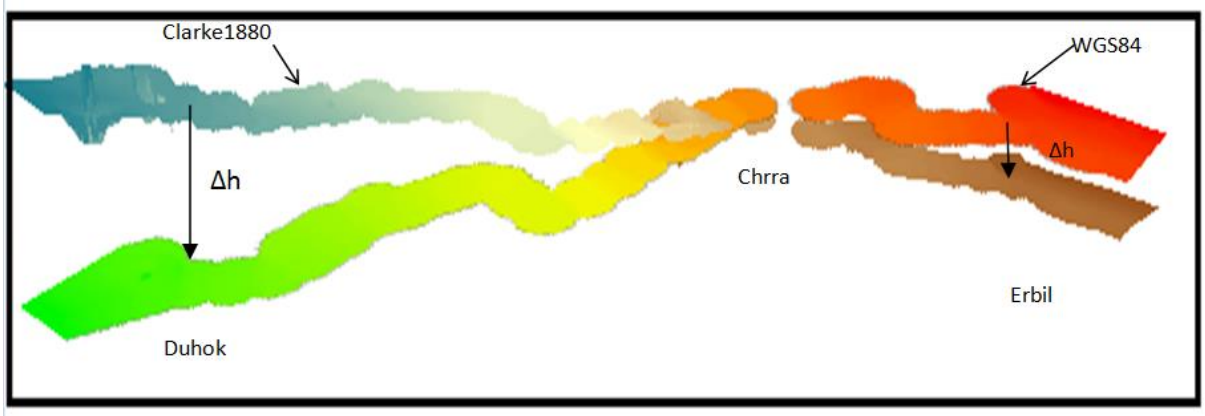

Fig. (7): DTM of difference in height for ellipsoid WGS84 and Clarke1880

7. CONCLUSION

1- The online transformation can serve as an active method to extract the parameters of transformation between the global datum WGS84 and local datum Karbala 1979.

2- The geodetic height above the ellipsoid (value of undulation N) can be used to explain the relationship between the different datums in addition to the transformation of seven parameters.

3- The obtained results show that there is a significant difference between the global datum WGS84 and the local datum Karbala 1979 over the studied territory, which is propagated between (+4.236 m and -1.751 m).

4- The results clarify that these two datums (WGS84 and Karbala 1979) are not parallels over the study area and they intersect over the area of Chrra Township that is located on the mid-way between Duhok and Erbil.

5- The obtained relationship between the global and local datums in this paper can be important for the relevant studies that are concerned with the elevations and orthometric heights over the case study area.

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