

Guidelines for Implementation of EGM-08 elevation model for processing of NOC application in NOCAS

Vertical (height) Reference System:-

A vertical (height) reference system can be defined by only two parameters. A point with a known elevation from which vertical differences are calculated (ARP, Aerodrome elevation, SOI Bench mark point etc.) and the reference surface (MSL, AGL, EGM84, EGM 96 and EGM2008 etc.)

MEAN SEA LEVEL- the current system:-

Mean sea level (MSL) is an average level of the surface of one or more of Earth's oceans from which heights such as elevations may be measured. All elevations are measured Above Mean Sea Level (AMSL). It is a measurement of the average height of the sea between high and low tide.

Mean Sea Level adopted by survey of India for reference, is located at Mumbai High (500–041): 0.79 +/- 0.11 mm/Yr. (Before independence it was Karachi but after the independence we have shifted it to the Bombay High).

But, few things need to be kept in mind.

(1.) Earth is not a perfect sphere. It has uneven surface, mountains, valley. It bulge around the equator by a few km.

(2) Gravitational force is not same everywhere.

The ocean is constantly in motion which results in spatial and temporal variability of its topography, which is, moreover, extremely complex to consider MSL (TIDAL DATUM) as a standard datum.

Irregularity In MSL:-

The mean sea level along the east coast of India is higher than that along the west coast which means mean sea level along the coast of India is higher in the Bay of Bengal than in the Arabian Sea.

The difference in sea level between Vishakhapatnam and Mumbai being about 30 cm and that the mean sea level at Chennai is 17 cm higher than that at Mangalore (differences in surface salinity, surface temperature, and atmospheric pressure and due to Monsoon as well).

So, scientists came up with *Earth Gravitational model (EGM)* which gave us a standard to measure elevation of a place above or below mean sea level. GNSS uses it to give the elevation of a place on surface of earth.

Geoid – Earth Gravitational Model (EGM)

The geoid is the equipotential surface of the earth's gravity field, chosen at a certain level (approximately Mean Sea Level (MSL)) which serves as the reference surface for height measurements. Globally, the difference in elevation between the geoid and the geocentric WGS 84 ellipsoid is between $\pm 100\text{m}$. The Earth Gravitational Models (EGMs) are geopotential models of the Earth consisting of spherical harmonic coefficients published by the Office of Geomatics at National Geospatial-Intelligence Agency (NGA). Over EGM96, EGM2008 represents improvement by a factor of six in resolution, and by factors of three to six in accuracy, depending on gravitational quantity and geographic area.

EGM2008 represents a milestone and a new paradigm in global gravity field modeling, by demonstrating for the first time ever, that given accurate and detailed gravimetric data, a single global model may satisfy the requirements of a very wide range of applications. Detailed explanation may be found in the Annexure-1.

(Reference taken from Attachment A -Vertical Reference system-ICAO DOC AIS-AIMSG/6-SN/5)

Implementation by Survey and Cartography Section:-

As EGM-08 datum are more accurate as compared to MSL datum of Survey Of India and as per ICAO mandate, AAI survey and Cartography department is carrying out the airports survey in reference to WGS-84 and EGM-08 for publishing the aeronautical data.

EGM-08 data updation in NOCAS :-

AAI Survey/Carro section provided the aerodrome data in reference to EGM-08 datum and the same are being updated in NOCAS. More than 50 airports elevations data has already been updated in reference to EGM-08 datum. Since NOCAS data of these airports is in reference of EGM-08 datum, it is necessary that the site elevation data provided by the applicants for NOC applications should also be in reference of EGM-08 datum.

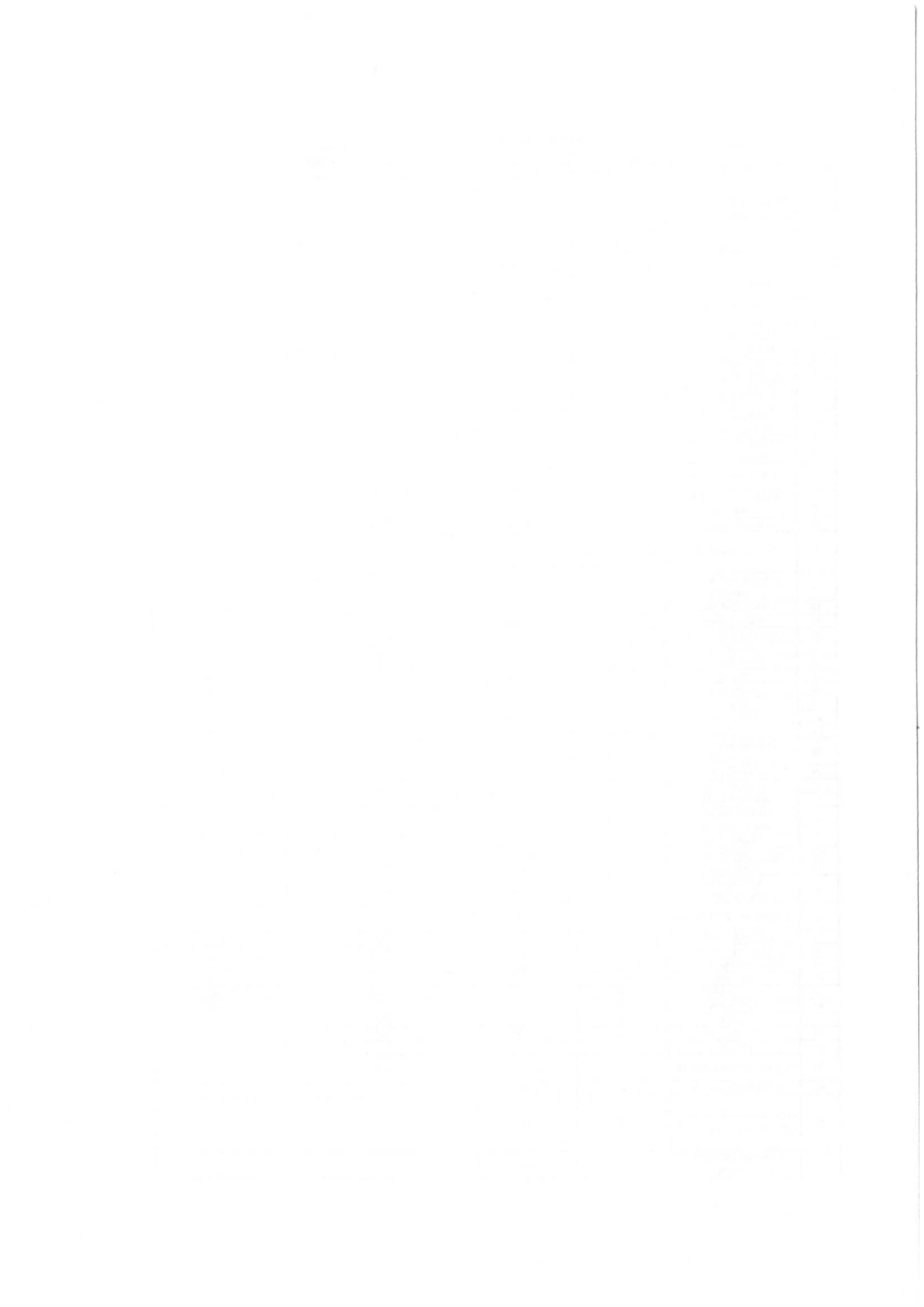
In the past, a few meetings were also held with concerned stakeholders for implementation of EGM-08 datum in phase wise. Now it is decided that for the 50 airports (list may be found in the attachment), the NOC application, site certificates/undertakings will be accepted in reference of EGM-08 elevation model from 15.08.2020 onwards.

Guidelines for applicants

In view of the above, it is stated that the applicant shall fill the data in NOC application (i.e. requested height, site elevation) in EGM-08 datum and accordingly will upload the certificate of site coordinate in WGS-84 and site elevation in EGM-08 datum, elevation in undertakings etc. in reference of EGM-08 datum. Licensed Surveyors/ AAI Empanelled Surveyors will issue the site coordinate and site elevation certificate as according to above.

VERTICAL DATUM - AMSL TO EGM-08

SL. NO.	NAME OF THE AIRPORT	ARP ELEVATION IN M. (AMSL)	ARP ELEVATION IN M. (EGM-08)	DIFFERENCE BETWEEN AMSL & EGM-08 OF ARP ELEVATION (AMSL-EGM08=)	PERIOD OF SURVEY
1	BENGALURU INTERNATIONAL AIRPORT (BIAL) DEVANHALLI	900.45	900.93	-0.48	Apr-18
2	CHENNAI	10.36	11.002	-0.642	Apr-19
		Not Available at New ARP location	(New ARP Location) 11.206	-	
3	KOLKATA (NSCBI AIRPORT)	5.33	4.546	0.784	Jan-19
4	AHMEDABAD (SVBPI AIRPORT)	54.724	54.747	-0.023	Apr-18
5	GUWAHATI(LGBI AIRPORT)	48.158	48.272	-0.114	Nov-18
6	LUCKNOW(AMOUSI)	122	122.235	-0.235	Aug-18
7	JAIPUR (SANGANER)	385.054	386.128	-1.074	Nov-18
8	KOZHIKODE (CALICUT)	101.157	101.253	-0.096	Mar-18
9	THIRUVANANTHAPURAM	4	4.56	-0.56	May-18
10	PATNA	51.18	52.578	-1.398	Sep-19
11	BHUBNESHWAR (BIJU PATNAIK AIRPORT)	44.5	45.149	-0.649	Nov-19
12	INDORE DEVI AHILYABAI HOLKAR AIRPORT	560.954	561.369	-0.415	Aug-18
13	COIMBATORE (PEELAMEDU)	399.6	400.134	-0.534	Feb-19
14	NAGPUR (SONEGAON) (MIHAN)	308.46	309.371	-0.911	Oct-18
15	VARANASI (BABATPUR)	79.857	80.754	-0.897	
16	AMRITSAR (RAJA SANSI)	229.409	230.193	-0.784	Oct-18
		Not Available at New ARP location	(New ARP Location) 230.747	-	Sep-18
17	RANCHI(BIRSA MUNDA AIRPORT)	646	646.236	-0.236	Sep-18
18	MANGALORE (BAIPE)	101.629	102.418	-0.789	Oct-19
19	RAIPUR(MANA)	313.074	313.686	-0.612	Sep-19
20	TIRUCHIRAPALLI (TRICHY)	85.04	85.916	-0.876	Feb-19
21	MADURAI	136.292	137.389	-1.097	Jun-18
22	RAJAHMUNDARY	44.5	45.127	-0.627	Nov-18
23	TIRUPATHI	103.4	103.692	-0.292	Jun-18
24	VIJAYAWADA	22.626	23.165	-0.539	Sep-18
25	RAJKOT	133.35	133.947	-0.597	Apr-18
26	VADODARA	36.88	37.321	-0.441	Sep-19
27	HUBLI	665.19	663.61	1.58	Mar-18
28	BHOPAL (RAJA BHOJ AIRPORT)	521.612	522.122	-0.51	Jul-18
29	JABALPUR	494.425	495.383	-0.958	Dec-17
30	JUHU (MUMBAI)	2.78	3.1	-0.32	Feb-20
31	IMPHAL(TULIHAL)	773.04	773.97	-0.93	Jul-19
32	UDAIPUR (MAHARANA PRATAP AIRPORT)	509.28	509.727	-0.447	Feb-19
33	AGARTALA	14.325	16.88	-2.555	Sep-17
34	DEHRADUN (JOLLYGRANT)	554.32	554.513	-0.193	Mar-18
35	BHAVNAGAR	6.095	5.79	0.305	Nov-17
36	AURANGABAD (CHIKALTHANA)	580.43	582.046	-1.616	Jul-18
37	DIBRUGARH (MOHANBARI)	109.728	108.956	0.772	Oct-18
38	BELGAUM (SAMBRA)	758.43	758.81	-0.38	Mar-18
39	GAGGAL(KANGRA)	759.57	760.1	-0.53	Jun-18
40	SHIMLA (JUBBARHATTI)	1539.715	NA	-	Oct-16
41	KHAJURAH	NA	217.14	-	Jan-18
42	PONDICHERY	39.9	40.34	-0.44	Feb-18
43	TUTICORIN	NA	25.58	-	Jan-18
44	AGATTI	3.495	2.908	0.587	Jan-18
45	PANTNAGAR	233	233.59	-0.59	Dec-17
46	MYSORE	NA	NA	-	
47	DELHI IGI AIRPORT (PALAM)	226.77	227.28	-0.51	-
48	MUMBAI (CSI AIRPORT)	NA	NA	-	-
49	HYDERABAD INTERNATIONAL AIRPORT(HIAL) SHAMSABAD	NA	NA	-	-
50	COCHIN INTERNATIONAL AIRPORT(LTD(CIAL)	NA	NA	-	-



ATTACHMENT A
ANNOTATED AIS-AIMSG/4-SN/14 ATTACHMENT

Vertical Reference Systems

1 Background Terms and Information

Vertical Reference System

A vertical (height) reference system can be defined by only two parameters: A point with a known elevation from which vertical differences are calculated, and the reference surface. The vertical height relationships are shown in Figure 1 below.

Ellipsoidal Heights

The ellipsoid, which is used as part of the definition of a geodetic datum, can be used as a reference surface. The Ellipsoidal Height (h) is the orthogonal distance between a point and the reference ellipsoid. Therefore, it does not take into account the Earth's gravity field.

Orthometric Heights

The Orthometric Height is the distance (H) along a line of force from the geoid to a given point (P) on the physical surface of the earth (the line is perpendicular to the equipotential surfaces at different levels).

Normal Heights

The Normal Height (H*) of a point is computed from its geopotential difference to that of sea level. It takes into account the normal gravity, computed along the plumb line of the point (height difference of a point to the quasi-geoid). The difference between the Normal Height and the Ellipsoidal Height is called height-anomaly or quasi-geoid-height.

Geoid – Earth Gravitational Model (EGM)

The geoid is the equipotential surface of the earth's gravity field, chosen at a certain level (approximately Mean Sea Level (MSL)) which serves as the reference surface for height measurements. Globally, the difference in elevation between the geoid and the geocentric WGS 84 ellipsoid is between ± 100m. This difference in elevation is the geoid undulation (N).

Global and local geoids differ in several aspects: in the past global geoids considered only the long- and middle-wave parts of the entire earth's gravity field, such as EGM96. Local geoids consider the long-, middle-, and short-wave parts of a smaller region the earth's gravity field, such as CARIB97 that is valid only for the Caribbean Sea. One of the world's best global geoid models is the Earth Gravitational Model (EGM) 2008¹. EGM2008 offers modeling to degree and order 2159 - thus considering a fuller range of the middle- and short-wave parts than previous global geoids. Global geoids are used when consistent orthometric heights, over long distances (continent or earth surveying), are required

¹ <http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm2008/>

For local engineering applications and cadastre-surveying, global geoids are not as accurate as needed. For such applications, local geoid models are calculated. These can only be developed using local field measurements. They offer centimetre accuracy over several hundred kilometres, with a high resolution. Local geoids are not suitable for height comparison over large distances since they are based on different origins and reference heights (different equipotential levels).

The Annex 15 requirements currently identify the use of EGM96 for WGS84 heighting. This was the best available at the time of adoption when the heighting decisions were made although its accuracy was not sufficient globally to meet the accuracy requirements of Annex 15 and for this reason, whilst the recommendations below refer to the use of EGM96, it also identifies that other models should be used where EGM96 is not sufficiently accurate. For example, the latest global geoid model, EGM2008 may be used as a means to achieve greater accuracy. It was determined using satellite tracking, gravity anomalies and satellite altimetry. Its estimated global accuracy is in the range of ± 0.05 m (oceans) and ± 0.5 m (on land). This accuracy is higher in flat regions than in topographically mountainous terrain but EGM08 meets all requirements and if applied would avoid the need to undertake an assessment of the local accuracy of EGM96.

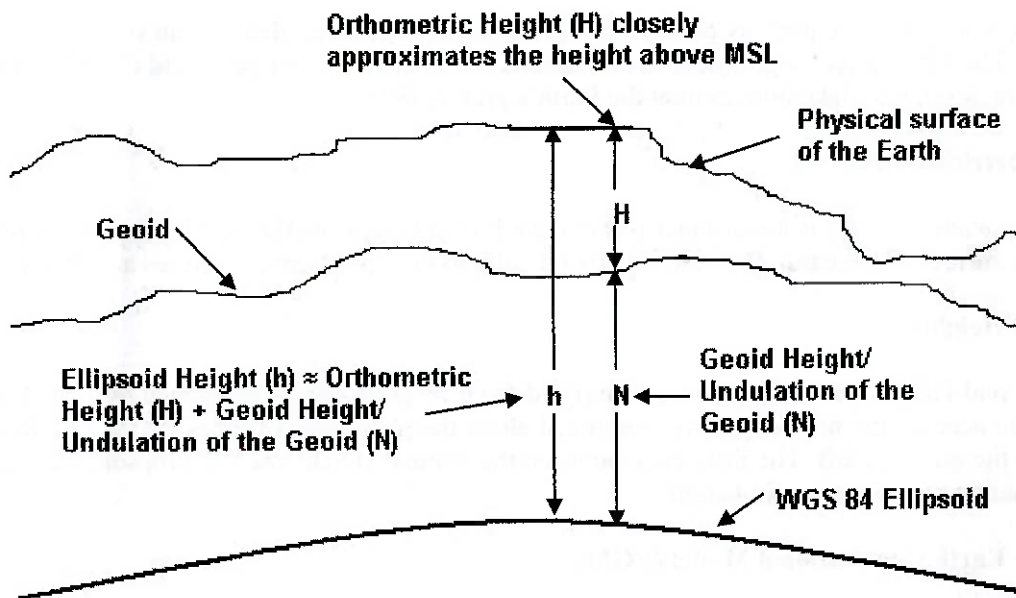


Figure 1 Vertical Height Relationships

Caution is necessary in the use of Tide-Free models such as EGM96/EGM2008 as opposed to Zero-Tide models such as the European Vertical Reference System (EVRS). Additional error can be introduced owing to the differing assumptions underlying the different models. Additionally, the use of EGM2008 is appropriate where the density of gravity data was adequate in the development of the model to support the full resolution. In specific regions a target of 25cm can easily be achieved. However, in regions where the density of gravity data in developing the model was sparse, comparisons to GPS leveling are on the order of 40cm and will not meet the targeted 25cm accuracy specification. A local geoid may still have to be used in areas where the gravity point density was spatially poor in extent for EGM2008.

European Vertical Reference System

The European Vertical Reference System (EVRS) is an example of a system that has been built to reflect the globalisation of Geographic Information System (GIS) applications and the need for continental-wide, consistent height information. EVRS is a gravity-related height reference system, i.e. the height values provided are Normal Heights. The EVRS is a tidal zero system. The EVRS is realised in the European Vertical Reference Frame (EVRF) by the geopotential numbers and Normal Heights of nodal points of the United European Levelling Network 95/98 extended for Estonia, Latvia, Lithuania and Romania, in relation to the Normaal Amsterdams Peils (NAP). The geopotential number at NAP is zero.

2 Recommendations for Determining Heights Relative to EGM-96

2.1 Introduction

The ICAO SARPS mandate that all height information should be published relative to MSL. Orthometric heights very closely approximate the height above MSL. To determine the geoid undulation, the Earth Gravitational Model 1996 (EGM96) should be used but may be replaced by a more accurate geoid model where the accuracy of EGM96 is not sufficient.

The most stringent accuracy requirements covered by the standards are geoid undulations for several on-aerodrome facilities. These accuracy requirements are 0.25m (95% confidence interval) for the measurements. This can be readily achieved for computing ellipsoidal heights using appropriate GNSS equipment. However, achieving these accuracy requirements for geoid undulations is more difficult at the present time. Recommended methodologies for determining the geoid undulations are provided below.

Because the elevation values of a point may not differ significantly between Ellipsoidal height, EGM96 height or any other vertical reference system height the surveyor should ensure that with each elevation value, the vertical reference frame is stored.

2.2 Method 1

When a new feature is surveyed using GNSS means, the primary reference frame for the determination of a coordinate is the ellipsoid. It is common that GNSS sensors (or their processing software) have an EGMxx² integrated, therefore allowing the direct determination of height above MSL (in EGMxx). When a new survey point is determined by GNSS, the elevation above EGMxx should be directly determined.

If neither the sensor nor the GNSS processing software have the capability to integrate the EGMxx undulation for a surveyed point, the ellipsoidal height should be stored for the required point. The geoid undulation should then be determined by interpolation from EGMxx for the given latitude and longitude of the point.

The same method may also be used for an airborne data acquisition method when the position of the sensor platform is determined by GNSS.

2.3 Method 2

A national geodetic body may have scientifically determined a geoid. Provided this geoid is of sufficient accuracy and is referenced to a horizontal reference frame which allows transformation to WGS 84/ITRF without a loss of accuracy, then, for given values of the latitude and longitude of a point, the geoid undulation should be interpolated directly from the data.

A description of the geoid model used including the parameters required to allow a transformation between the model and EGMxx or any other reference frame should be published by the State aviation authority.

2.4 Method 3

If a national / regional levelling system is free from limiting systematic biases, and the offset between the national tide gauge datum and the geoid is known (ΔH), then geoid undulations should be computed by measuring the height of a point above the levelling datum (H) and the ellipsoid (h). The geoid undulation (N) at that point is then given by the relationship:

² With EGMxx, the xx means either 96 or 2008.

$$N = h - H + \Delta H$$

A realistic estimate of the quality of the heighting network should be obtained from the relevant authorities prior to carrying out the survey work. The accuracy of the heighting network should be documented, together with the data set as metadata.

The method should only be used when the benchmark values are known with sufficient accuracy.

3 Deriving Elevation Information from Existing Sources

Some of the elevation information does not have very stringent quality requirements (distance measuring equipment (DME), minimum altitudes). In many regions, digital terrain models (DTM) exist which may be used for deriving the elevation information. The sources of error in such models should be fully evaluated to ensure the accuracy requirements can be met. The accuracy of the DTM should be at least 1.5 times higher than the data quality requirement of the required feature. The resolution of the DTM should be adequate for the topography to ensure that the highest elevation of the real world is maintained in the digital data set.

The DTM should be available in the same horizontal reference system as the required feature.

For linear or polygonal features, the elevation information should be derived by determining the highest value within the area of interest. For point features, the potential horizontal displacement between the two data sets should be taken into account.

4 Resources

Useful Websites:

- The NASA Goddard Space Flight Center (GSFC) and National Imagery and Mapping Agency (NIMA) Joint Geopotential Model EGM96³;
- The Earth Gravitational Model 2008 (EGM2008)⁴;
- European Vertical Reference System (EVRS) website.⁵

³ <http://cddis.nasa.gov/926/egm96>.

⁴ <http://earth-info.nga.mil/GandG/wqs84/gravitymod/egm2008>.

⁵ <http://www.bkg.bund.de/geodIS/EVRS>.

