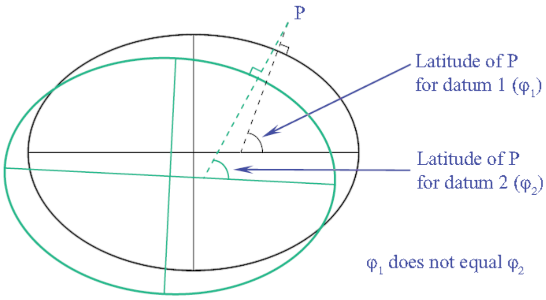
Datums

It is used to define the position of the origin, the scale and the orientation of the axis or axes of a coordinate system with respect to an object. And it is called a Geodetic datum when the object is the earth.

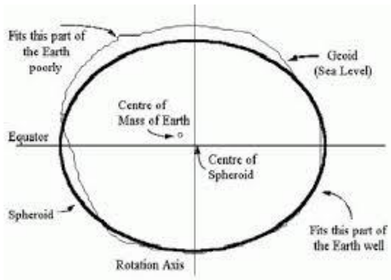


Two different datums defining the ellipsoid

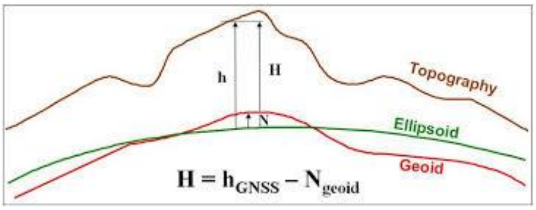
A few hundred of these local horizontal datums are defined worldwide. Recent years have seen that globalisation leads to the definition of global (or geocentric) datums, such as the ITRF or WGS84.

1.1. Types of Datum

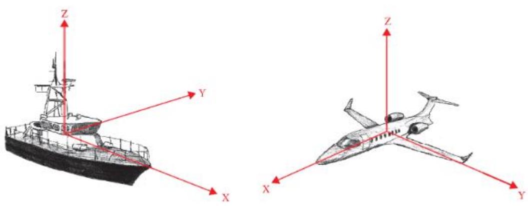
- **Geodetic datum** describes the relationship of coordinate systems for an ellipsoidal (or spherical) model of the Earth with the real Earth. Also, it is used to define the mechanism of the relationship between ellipsoid and Geoid.



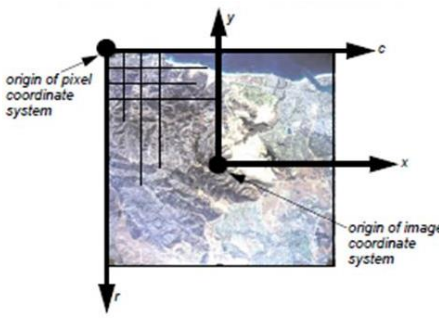
- **Vertical datum** – a datum is describing the relationship of gravity-related heights with the Earth.



- **Engineering datum** – a datum that describes the relationship of a coordinate system to a local reference. The reference can be any moving object, such as a vehicle, an aircraft, or a ship as (as illustrated in the below figure). But it can also be a small site on the Earth, for example a construction site or an industrial plant. In general, we can say that an engineering datum is any that is not specifically geodetic or vertical.



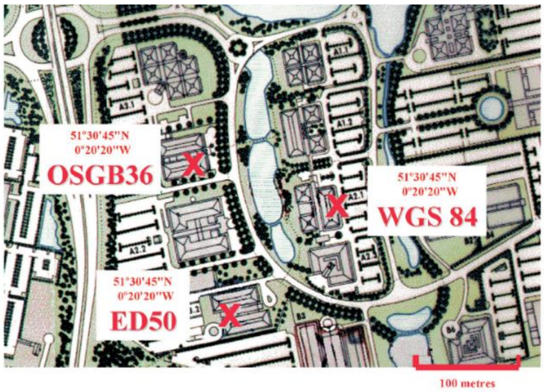
- ***Image* datum** – a type of engineering datum that describes the relationship of a coordinate system to an image. It is distinguished from an engineering datum by having attributes describing the origin of a cell-based coordinate system.



1.2. Identifying the Coordinate System

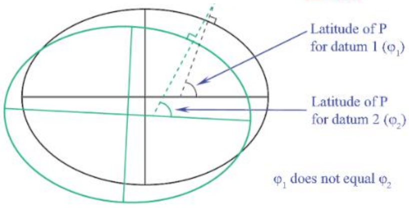
The coordinate system must be identified when the number is located on the map. Otherwise, the given coordinates will be ambiguous. For example, as shown below, three different coordinates system are shown: the Ordnance Survey of Great Britain 1936, the World Geodetic System of 1984 (WGS 84) and the European datum of 1950 (ED50).

The mentioned horizontal difference between the same coordinate values reference to different geodetic datums is typically 50 to 500m, but in extreme cases, it can exceed 1.5km.

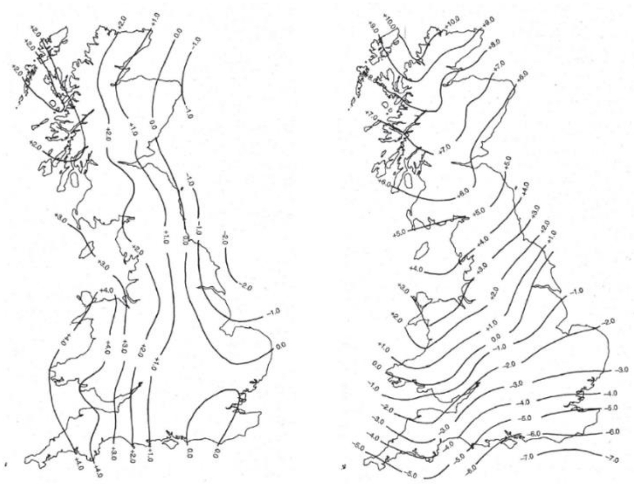


Identifying the geodetic datum is not critical for low accuracy application, which is not better than 1 km or mapping at a scale of 1:500 000 or smaller (1:1 000 000, 1:2 500 000, etc..).

In the figure-right, it can be seen that the two different values for latitude, the angle measured from ellipsoidal normal and the equatorial plane, were obtained using different geodetic datums.



In addition, to specify the horizontal datum, it is also necessary to identify the vertical reference system. As shown in the right figure, the same Geoid has been used with two different reference systems. The left coordinate reference system represents the British coordinate reference system OSGB 1936, and the right represents the European coordinate reference system.



1.3. Vertical datum

The Geoid is used to describe heights, to establish the Geoid as a reference for heights, the ocean's water level is registered at coastal places over several years using tide gauges.

Averaging the registrations largely eliminates variations in the sea level with time. The resulting water level represents an approximation to the Geoid and is called the ***mean sea level*** *or* (also called ***local vertical datums***)

Several realisations of local mean sea levels (also called local vertical datums) worldwide exist. They are parallel to the Geoid but offset by up to a couple of meters,

N.B. Care must be taken when using heights from another local vertical datum, for example:

- Two neighbouring countries have two different M.S.L. as shown in the below figures.
- Or even with in the country itself there may be different mean sea level, as in the case of the USA and the difference of M.S.L. between Atlantic to the Pacific coast, which is about 0.6m to 0.7m.

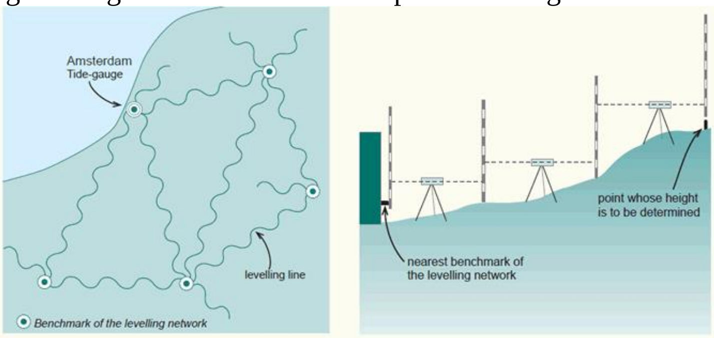
This variation happens because depending on the average tide level.

Every nation or group of countries have established those mean sea level points, which are typically located close to the area of concern. The local mean sea level is realised for the Netherlands and Germany through the Amsterdam tide-gauge (zero height).

1.4. Establishing local Vertical Datums

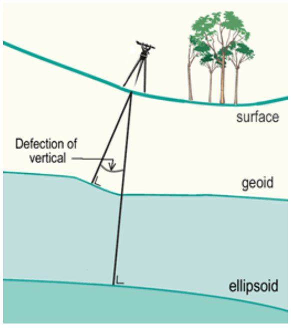
1.4.1. Tidal datums are determined by averaging the level of water at a tide gauge over time. Some simple examples of these are Mean Sea Level (MSL), Mean Low Water (MLW) and Mean Higher High Water (MHHW).

1.4.2. Geodetic datums are predominantly determined through a process of surveying known as geodetic levelling, determining the height differences between points in the ground known as benchmarks.



1.4.3. Deflection of the vertical

The levels and theodolites used to determine the geodetic datum are levelled with spirit bubbles. The bubbles follow the influence of the Earth's gravity, meaning that the computations have to be corrected with respect to the ellipsoid. Without these corrections, the computations may be distorted by some <u>centimetres</u> or even <u>decimetres</u> because of the local difference between the direction of the plumb line (the normal to the Geoid) and the vertical direction on the ellipsoid (the normal to the ellipsoid).

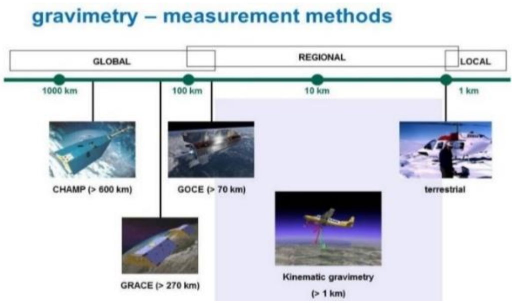


Gravity measurements are used to determine these vertical deflections.

Note: Satellite-based measurements (e.g. GPS) are not involved with these vertical deflections because the GPS receiver directly relates the measurements to the reference ellipsoid.

1.4.4. Gravity measurements

Determining the Earth's gravity field is one of the essential areas in geodesy for determining the Geoid and predicting dynamical parameters of low Earth-orbiting satellites and others.



Traditionally, the gravity signal is determined by measuring its magnitude with a gravimeter and the deflections of the vertical, defined by the difference of the directions between the natural gravity and normal gravity vector, by astronomical observations. Although this produces highly accurate gravity vector information, it is extremely expensive and time-consuming.

1.4.5. Geoid model, Geoid modelling is a process of developing mathematical algorithms to represent the Geoid. This is the reference surface for orthometric height. Geoid is one of the geodetic surfaces.

name	geoid	grid
egm84-30	EGM84	30'
egm84-15	EGM84	15'
egm96-15	EGM96	15'
egm96-5	EGM96	5'
egm2008-5	EGM2008	5'
egm2008-2_5	EGM2008	2.5'
egm2008-1	EGM2008	1'

The primary goal of geodesy is to develop a geoid model, which is then used to connect the three values.
Given N, we can compute H or h from the other.
Now there are available different refined global gravity models based on terrestrial gravity and satellite data, e.g. EGM2008
(Ref: http://geographiclib.sourceforge.net/html/geoid.html#geoidinst)

Example: based on the Google earth Map, the coordinate of point has given the following 3D geographical coordinates (ϕ *= 36° 08' 29.4" N,* λ *= 44° 01' 34.3" E, H=413m) specified to* WGS84. Find the orthometric height of the mentioned if you know that the geoid *undulation equal to +14.548 (meters) based on the geoid model EGM96.*

Solution: it is possible to calculate the orthometric height using the equation:

H=h-N,

H=orthometric height, required?
h=the height ab0ve ellipsoid and it is equal to 413.0m
N=geoid separation or undulation, which is equal to +14.548m

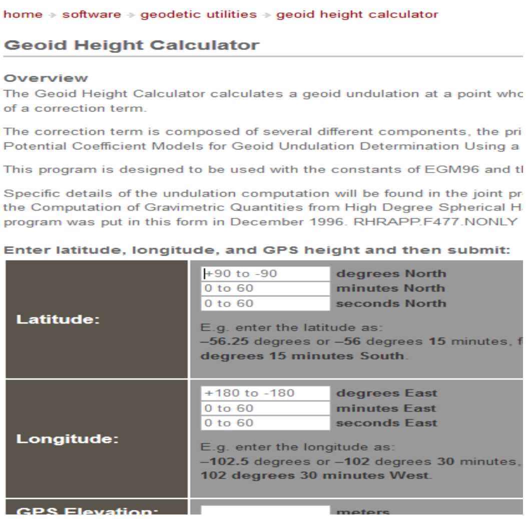
Then the orthometric height based on the geiod EGM96 is:

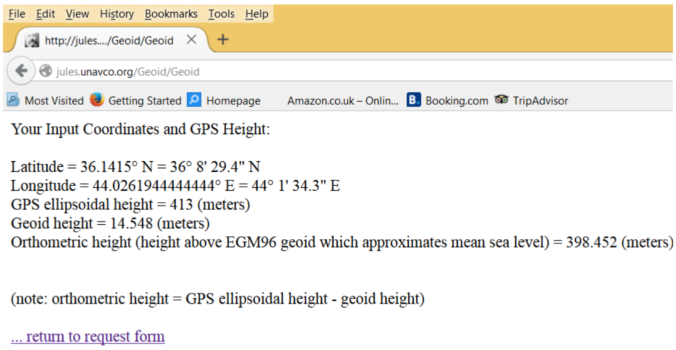
H=413.0-14.548=**398.452m.**

1.5. Online Geoid calculator

It is possible to calculate the geoid undulation using online geoid model. The UNAVCO consortium (stands for University NAVSTAR Consortium) based in Colorado, USA. It has provided a link to calculate the geoid separation online in addition to the orthometric height calculation.

The link can be accessed by using the official site of UNAVCO "https://www.unavco.org/" and then, on the **software tab,** click on Geoid height calculator. The available web site calculates the geoid undulation, based on EGM96 geoid model, at any specific coordinate on the ground.





Entering the given values of the above example to the "Geoid height calculator" web site, it will be possible to find the geoid separation and orthometric height as shown in the below screen

H.W. using the above web site https://www.unavco.org/, find the ellipsoidal height of the point P if you know that the coordinate of point P is (ϕ *= 52° 02' 29.4" N,* λ *= 4° 01' 34.3"W),and the orthometric height is 74.054m above mean seal level.*