CHAPTER THREE

THE MAP DATUM

3.1 General Introduction

A datum is a mathematical model which approximates the shape of the Earth. It allows calculations such as position and area to be done in a consistent and accurate manner. The datum is physically represented by a framework of ground monuments whose positions have been accurately measured and calculated on the reference surface control point .Every chart has a map datum reference and is usually listed in the title block of the chart e.g. the datum of topographic map is listed in the maps legend.

A datum is the traditional answer to the practical problem of making an accurate map. If you do not have a very accurate location on a benchmark in your area, you make a map by choosing a mark and defining it as the reference point. You then survey outward and make a map. It may not match other maps from adjacent areas at high accuracy because you are on a different datum.

In fact there may be several datums, one for horizontal, one for vertical etc. These are important because they define the reference system that is used for the coordinates.

Different nations are using different map datums as the bases for coordinate systems which may cause an error up to several of meters if the wrong datum written or used in calculations .e.g. drawing a chart based on WGS84 while writing a different datum in the legend Clark 1880.

A datum can be defined by specifying the ellipsoid and the coordinates. The point ties down the ellipsoid to the physical earth and also implicitly defines the placement of the center of the earth. This location is called the primary reference point.

3.2 Practical way to define a datum

The practical way to define a datum is with a whole set of reference markers and their associated coordinates. They should be carefully surveyed together. This gives a network that serves as a "realization" of the datum. This provides a practical set of points spread out over the region covered. Surveyors use the closest survey marker that meets the accuracy needs .

This means that datums are the reference frames used in the construction of maps. Things are complicated in practice as the same area may have two datums giving each point two different coordinates. In addition datums were often generated by individual countries, and did not match at the boundaries.

While there are about 20 common ellipsoids, most ellipsoids are used in multiple datums. For example the number of datums on some popular ellipsoids are:

Table (3.1) Number of datums on some popular ellipsoids

Ellipsoid	Number of Common Datums
Airy 1830	2
Bessel 1841	7
Clarke 1866	7
Clarke 1880	26
International 1924	47

The uses of different ellipsoids arise from the variations in the shape of the true earth and the difficulty of estimating the ellipsoid shape from a “limited” portion of the world, such as Europe of North America. The scientist in each region took the data they had and fit it to an ellipsoid.

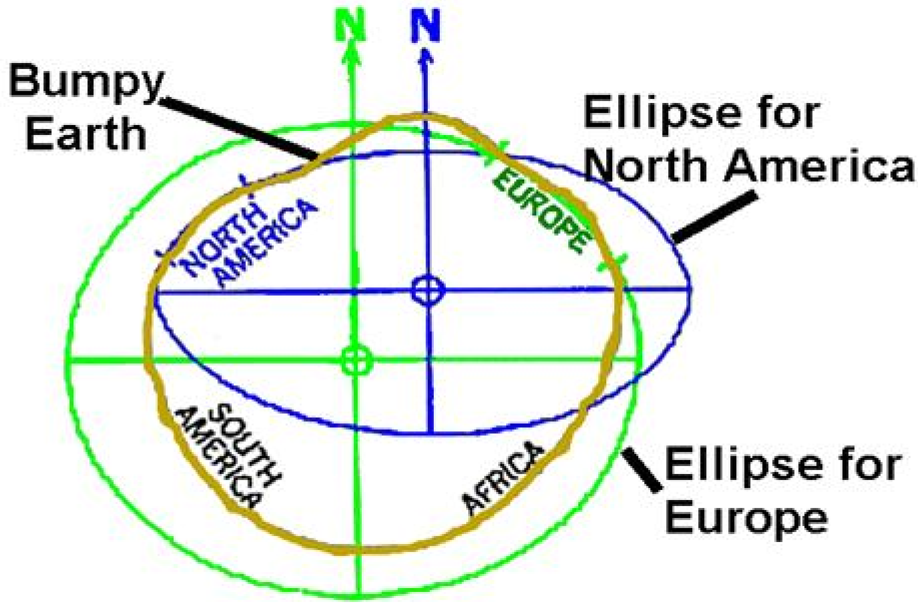

Figure (3.1) Different ellipsoids from fitting different regions of earth

This often resulted in different ellipsoid parameters (axis lengths) and center location. The above figure exaggerates the differences between the European datum ellipsoid and that for North America, but is essentially correct. Often the origin shift is the largest difference in datum ellipsoids.

3.3 Why and How Datums Happen

When people first began to map accurately using surveys in an area, they sometimes have the choice to extend some existing survey point set or beginning anew. When there is no land connection between the new and old areas, there was no choice until the advent of satellite surveying they had to begin a new datum. If the old surveys were very far away, a new datum was almost always begun.

Most countries defined their own map reference system or their datum. This means that at political boundaries the maps would not quite line up. Today there are regional datums as well as global ones. But maps still exist on different datums, sometimes even for the same area.

3.4. Multiple Datums Confusion and Error

However one collection, or datum, may not fit some other set (datum). It is in error with respect to the second collection of points. This occurs periodically as datums are updated with new information and survey techniques. It happens about twice a century in the US. In the last major datum change in the US, points typically “moved” by about 100 m (300 ft).

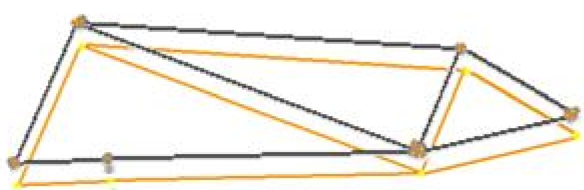

Figure (3.2) control points in two datum

Mismatched datums are also commonly happen when two sets of control points are separated by large distances or over an ocean. Accurate use of a map depends on knowing the datum it is on. On modern topographic maps the datum is often given in the map legend.

3.5 Example Of International And Local Datum

Currently the most common reference ellipsoid used, in the context of the Global Positioning System, is the one defined by WGS-84. Traditional reference ellipsoids or geodetic datums are defined regionally and therefore non-geocentric, e.g. ClARKE-1880.

3.5.1 World Geodetic System 1984

Responsible Organization, National Geospatial - Intelligence Agency Abbreviated Frame Name , WGS 84 . Associated TRS, WGS 84. Coverage of Frame , Global. Type of Frame, 3-Dimensional. Last Version, WGS 84 (G1674). Reference Epoch, 2005.0.

3.5.1.1 Brief Description:

WGS 84 is an Earth-centered, Earth-fixed terrestrial reference system and geodetic datum. WGS 84 is based on a consistent set of constants and model parameters that describe the Earth's size, shape, and gravity and geomagnetic fields. WGS 84 is the standard U.S. Department of Defense definition of a global reference system for geospatial information and is the reference system for the Global Positioning System (GPS). It is compatible with the International Terrestrial Reference System (ITRS).

3.5.1.2 Definition of Frame:

World Geodetic System 1984 frame can be defined by:

Origin:

Earth's center of mass being defined for the whole Earth including oceans and atmosphere

Axes:

Z-Axis = The direction of the IERS Reference Pole (IRP). This direction corresponds to the direction of the BIH Conventional Terrestrial Pole (CTP) (epoch 1984.0) with an uncertainty of 0.005″

X-Axis = Intersection of the IERS Reference Meridian (IRM) and the plane passing through the origin and normal to the Z-axis. The IRM is coincident with the BIH Zero Meridian (epoch 1984.0) with an uncertainty of 0.005″

Y-Axis = Completes a right-handed, Earth-Centered Earth-Fixed (ECEF) orthogonal coordinate system

Scale:

Its scale is that of the local Earth frame, in the meaning of a relativistic theory of gravitation. Aligns with ITRS

Orientation:

Given by the Bureau International de l'Heure (BIH) orientation of 1984.0

Time Evolution:

Its time evolution in orientation will create no residual global rotation with regards to the crust.

3.5.1.3 Coordinate. Systems:

Cartesian Coordinates (X, Y, Z). WGS 84 (G1674) follows the criteria outlined in the International Earth Rotation Service (IERS) Technical Note 21. The WGS 84 Coordinate System origin also serves as the geometric center of the WGS 84 Ellipsoid and the Z axis serves as the rotational axis of this ellipsoid of revolution. WGS 84 geodetic coordinates are generated by using its reference ellipsoid.

3.5.1.4 Defining Parameters:

WGS 84 identifies four defining parameters. These are the semi-major axis of the WGS 84 ellipsoid, the flattening factor of the Earth, the nominal mean angular velocity of the Earth, and the geocentric gravitational constant as specified below.

Table (3.2) WGS84 parameters

Parameter	Notation	Value
Semi-major Axis	a	6378137.0 meters
Flattening Factor of the Earth	1/f	298.257223563
Nominal Mean Angular Velocity of the Earth	ω	7292115 x 10-11 radians/second
Geocentric Gravitational Constant (Mass of Earth's Atmosphere Included)	GM**	3.986004418 x 1014 meter3/second2

3.5.2 Adindan

Adindan is a geodetic datum first defined in Sudan and is suitable for Eritrea and Ethiopia. The references of Adindan is CLARKE-1880 ellipsoid and Greenwich prime meridian. Its origin is a fundamental point station 15, latitude 22˚10´7.11˝N longitude 31˚29´21.608˝. The 12^{th} parallel traverse of 1966-70 (point 58 datum, code 6620) is connected to Adindan network in western Sudan. This has given rise to misconceptions that the Adindan network is used in west Africa.