Relating the Nigerian Reference Frame and AFREF

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Reference Systems and Reference Frames
- Reference Ellipsoid
- Other reference parameters

Reference Ellipsoid in use in most African Nations
- Clark 1880
  a = 6,378,249.145
  f = 1/293.465

Other parameters (datums)

Several reference systems from one reference ellipsoid

The Nigerian Reference Frame

Reference Ellipsoid - Clarke 1880

Datum - Minna (local)
Station L40 of Nigerian Primary Triangulation Network near Minna with

Latitude, Ø = 09º 38' 09"

Longitude, λ = 06º 30' 39"

Height, H = 279.6 meters above the geoid

Defects and Deficiencies in the Nigerian Reference Frame

Minna Datum has a number of inherent deficiencies which introduce serious distortions in the Nigerian Primary Triangulation Network (Uzodinma 2005):
- scale defects arising from use of wrong conversion factors in computing lengths
- orientation defects arising from insufficient constraints
- scale and orientation defects arising from poor definition of the network origin
- scale defects arising from wrong reduction of observed data to the ellipsoid due to the absence of geoid height model.

Modern Reference Frames

(a) WGS 84
  a = 6,378,137.0
  f = 1/298.257223563
  Continues to undergo refinements.
  Is the reference system for sustainable geodetic operations.

(b) ITRS
  a = 6,378,137.0
  f = 1/298.257222101
  Almost every year a new combination of precise tracking results is performed and is identified by the year epoch.
  ITRF also gives velocities of the stations due to plate tectonics. It is suitable for scientific investigations.

(c) PZ 90
  a = 6,378,136.0
  f = 1/298.257839303
  It is the reference system of the Global Navigation Satellite System developed by the Russian Federation.

(d) Vertical Reference Frame
  This is traditionally tied to the geoid. Given the ellipsoidal height from GPS observations and the orthometric height from classical geodetic levelling, the geoid can be determined.

AFREF Project

The African Reference Framework (AFREF) project is an African initiative with international support designed to unify the coordinate reference systems in Africa using Global Navigation Satellite Systems (GNSS) and, in particular, the GPS as the primary positioning tool. The several objectives of the project include:
- To define a continental geodetic reference frame
- To establish a precise and uniform African geoid
- To establish permanent GPS base stations throughout the continent which will become part of the world-wide International GPS Service (IGS)
- To determine the transformation parameters between the local and the global reference systems.

Challenges of Relating Ancient and Modern

- Remedying the Defects and Deficiencies in the Old System
  - scale check program aimed at removing distortion by re-measuring the base nets and re-adjusting the whole network of chains should be completed and additional measurements made in parts of the country where they are sparse
  - more Laplace stations can be observed to ensure their even spread throughout the country
  - the correction to the Lagos datum ∂_n can be calculated from the relationship

$$\partial_n = h84 - Hs - \Delta h$$

where h84 is height of Minna datum above WGS 84 ellipsoid and can be obtained from GPS observation, Hs is height above Lagos datum. Δh may be obtained from Standard Molodensky transformation formula.

Challenges of Relating … (cont'd)

Also using accurate geodetic coordinates of Minna Datum provided by GPS observations, components of the deviation of the vertical can be computed from Laplace equations.

$\xi_o = \Phi_o - \emptyset_o$

$\eta_o = \Lambda_o - \lambda_o$

Where Φ_o and Λ_o are the origin's astronomic latitude and longitude, respectively.

- the question of the absence of values for geoidal undulations is already being addressed by the Federal Surveys of Nigeria through densification of GPS points whose orthometric heights could be determined.

Contributing to Continental and Global Efforts

Nigeria can contribute to continental and global geodetic efforts by providing GPS stations that would assist in improving the determination of the earth's center of mass. The center of mass of the earth is related to its size and shape as follows:

$$V = r_e [\mu/(r_e + h)^3]^{0.5}$$

Where v is effective velocity of the satellite over the ground (at its sub-nadir point), ignoring earth rotation

r_e is the earth's radius

μ is the earth's gravitational constant ($3.986 \times 10^{14} m^3/s^2$)

h is the altitude of the satellite above the earth.

Since WGS 84 enables satellite positions in their orbits to be expressed as a function of time, the position of the GPS satellite at any instant (and thus its velocity) is known. Therefore, by observing GPS satellites from various points on the globe, including Nigeria, the center of mass of the earth and hence the origin of WGS 84 can be pinpointed. Any change in the location of the earth's center of mass will subsequently affect the location and orientation of the Cartesian axes.

Determining Transformation Parameters between Old and New Systems

Transformation from a local geodetic datum to WGS 84 can be performed using the following relationships (NIMA 1987):

$$\emptyset_{WGS\ 84} = \emptyset_{local} + \Delta\emptyset$$

$$\lambda_{WGS\ 84} = \lambda_{local} + \Delta\lambda$$

$$h_{WGS\ 84} = h_{local} + \Delta h$$

where ΔØ, Δλ, Δh are the corrections to transform local geodetic datum coordinates to WGS 84 values and are provided by the Standard Molodensky transformation formulas.

Three variables required in the transformation, namely ΔX, ΔY, and ΔZ are given in the table as -92, -93 and +122 respectively, for Nigeria. There may be slight changes when these values are re-determined after the steps discussed above are implemented. In order to re-determine the values of ΔX, ΔY and ΔZ, the absolute coordinates of ground based collocated points in both coordinate systems are compared. The points to be transformed must be bounded by these collocated points. These steps will also remedy the internal defects in the existing system.

Thank you for your attention!!!