THE DIGITAL REVOLUTION - WHITHER NOW?

Global Spatial Data Model

Traditional horizontal and vertical datum have two separate origins: respectively Earthâ€™s centre of mass as origin for horizontal, and mean sea level (the geoid) as origin for vertical. The author suggests an alternative option for spatial-data users: a Global Spatial Data Model (GSDM) that has a single origin for geospatial data.

With the advent of computers, electronic files and modern measuring systems, geospatial data is now digital and 3D. In years past, an analogue map stored in a flat file was typically both the end-product of a survey and the storage medium for geospatial information. Now spatial data is stored digitally in electronic files and map users enjoy many more options than those available to users of an analogue map. Of course, paper maps are still used, but these are now generated on demand from data stored in an electronic file and the use or destruction of a paper map does not diminish the value of the spatial data stored in this.

Origins of Datum
Automated processes have enormously enhanced productivity of data collection and map compilation. Maps, paper and otherwise, are now more readily available to everyone than ever before. Further, the use of digital geospatial data has gone beyond the map and now, using web-based software like Google Earth, anyone can view digital geospatial data for any location on Earth from almost any perspective. It seems weâ€™ve reached geospatial Nirvana. From a lay perspective it appears that everything fits together quite nicely, and it does. This is a tribute to human ingenuity and adaptability. But from a technical perspective the digital revolution has created an opportunity yet to be fully realised. Modern measurement systems such as GPS, remote sensing systems and even the electronic total station, all collect digital 3D spatial data. Yet the conceptual spatial-data models used to organise and process measurements are separated into horizontal and vertical components. This is not in itself a problem. The problem is that traditional horizontal and vertical datum has two separate origins: Earthâ€™s centre of mass is the origin for horizontal and the geoid is the origin for vertical. In many cases, geoid and mean sea level are used interchangeably because the geoid closely approximates sea level at rest. However, the reference for vertical is the geoid, not mean sea level.

Mean Sea Level
The tough question is where is the geoid? The geoid is an equipotential surface all points of which are perpendicular to the plumb-line. The number of equipotential surfaces is infinite but the geoid is the one geopotential surface which, in a global sense, best fits mean sea level. The definition is simple and understandable for anyone standing at the coast or on the deck of a ship. In the past, mean sea level was taken to be the average of tide-gauge readings. The Mean Sea Level Datum of 1929 in the US was based upon 26 tide gauges located around the coast of North America. The implication of a mean sea-level datum is that a zero elevation contour staked out on the beach might be used to mark the boundary between what is ocean and what is not. But this is not the case. In order to avoid confusion, on 16th May 1973 the Mean Sea Level Datum of 1929 was renamed the National Geodetic Vertical Datum of 1929. No published elevations were changed: only the name of the datum.

Zero Elevation
In preparation for a readjustment of the vertical control network in the US, loops of very precise levels were run throughout North America. It was shown that the relative internal consistency of the new and existing levelling loops was better than the absolute values provided by the 26 tide-gauge stations. Therefore only one existing benchmark elevation was held (BM Father Point/Rimouski, Quebec, Canada) and all other North American Vertical Datum of 1988 (NAVD88) elevations published with respect to that one elevation. This means the elevation reference surface in North America is arbitrary. Zero elevation is still intended to approximate mean sea level despite the formal dissociation of the vertical datum from mean sea level in 1973. The question now is how closely the NAVD88 zero elevation approximates the geoid and what are the implications of the answer to this? Other relevant questions include which of the quantities in Figure 1 can be determined the most accurately? What is the difference, if any, between the relative and the absolute accuracy of the measured quantity? What quantity does the spatial-data community need and/or use? And is this relative or absolute? Will ellipsoid height ever be adopted for elevation in place of ortho-metric height? And what spatial-data model is most appropriate for use with the previous answers?

Recommendation
Using a spatial-data model having a single origin for 3D data has certain advantages. But the elusive geoid presents an even stronger argument in favour of using the GSDM. The GSDM should be used because it

- provides a consistent 3D model for geospatial data that has a single origin
- is compatible with modern technology and digital spatial data
- includes a stochastic component for handling error propagation
- supports a concise mathematical definition for network accuracy and local accuracy

- will allow most spatial-data users to continue performing quality spatial-data manipulations without the need to worry about the subtleties of geoid modelling. Geoid modelling will still be needed and used by those still searching for that elusive geoid.

Comments

1. Conventional differential levelling is capable of producing very precise relative orthometric height differences. The procedure can be very efficient for local applications but can be quite costly and time-consuming for large areas.

2. With current GPS positioning procedures the National Geodetic Survey (NGS) routinely determines within millimetres the position of continuously operating reference stations (CORS) in the Federal Base Network (FBN). The positions of other high-accuracy reference network (HARN) stations are also published by the NGS. Absolute ellipsoid heights can be derived from the geocentric X, Y, Z coordinates of such CORS and HARN points.

3. The user community is routinely capable of using GPS to determine high-quality ellipsoid height differences. When competently conducted within a network environment and using appropriate software, reliable statistics for all newly established points are readily available. Local and network accuracies for such points can also be computed.

4. A reliable geoid height is easily determined if a new GPS position is observed on a known NAVD88 benchmark. But if the ellipsoid height is an absolute quantity and the orthometric height is a relative quantity, what can be said about the quality of such a geoid height?

5. According to principles of physical geodesy, the absolute geoid height at a point can be determined from perfect knowledge of the gravity field. Such gravity data can also be used to determine the slope of the geoid with respect to the ellipsoid normal. Since â€˜perfectâ€™ gravity measurements are not available, users settle for an approximation based upon the best data available. There are two points here: one, computing an absolute geoid height at a point requires lots of high-quality gravity data but, two, the relative geoid height between two points (slope of the geoid) can be approximated with far less data. Stated differently, given an imperfect set of gravity data, the shape of the local geoid can be determined better than its precise location.

6. The geoid is also complicated by the fact that Earth tides and other factors lead the geoid to fluctuate by an amplitude approaching 20cm: CORS and HARN stations also rise and fall with Earth tides. What implication does this all have for spatial-data users and efforts to find and use geoid heights as a means of obtaining orthometric heights from GPS data and geoid modelling? When, or should, time be included as the fourth dimension?

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Further Reading

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