Vertical Datums:

An Introduction and Software Review

Areas to Cover

- Theoretical Introduction
- Representation in EPSG
- Representation in OGC WKT
- Incorporation in PROJ.4
- Incorporation in GDAL
- Future Work

Introduction to Vertical Datums

- Basis for measuring elevation values.
- Generally “0” is roughly sea level
- Often local and national datums exist.
- Three Classes of Vertical Datums
  - Ellipsoidal
  - Orthometric
  - Tidal

Ellipsoidal Vertical Datums

- Height is measured from the ellipsoid.
- Height is normal to the ellipsoid surface
- Ellipsoid positioning determined by horizontal datum.
- Traditional GIS height model.
- eg. NAD83, WGS84, ITRF90

Tidal Datums

- Based on observations of water levels.
- Means computed over a stated time period (often a 19 year epoch)
- Affected by various physical factors (wind,etc)
- eg.
  - LMSL (Local Mean Sea Level)
  - MLW (Mean Low Water)

Orthometric Vertical Datums

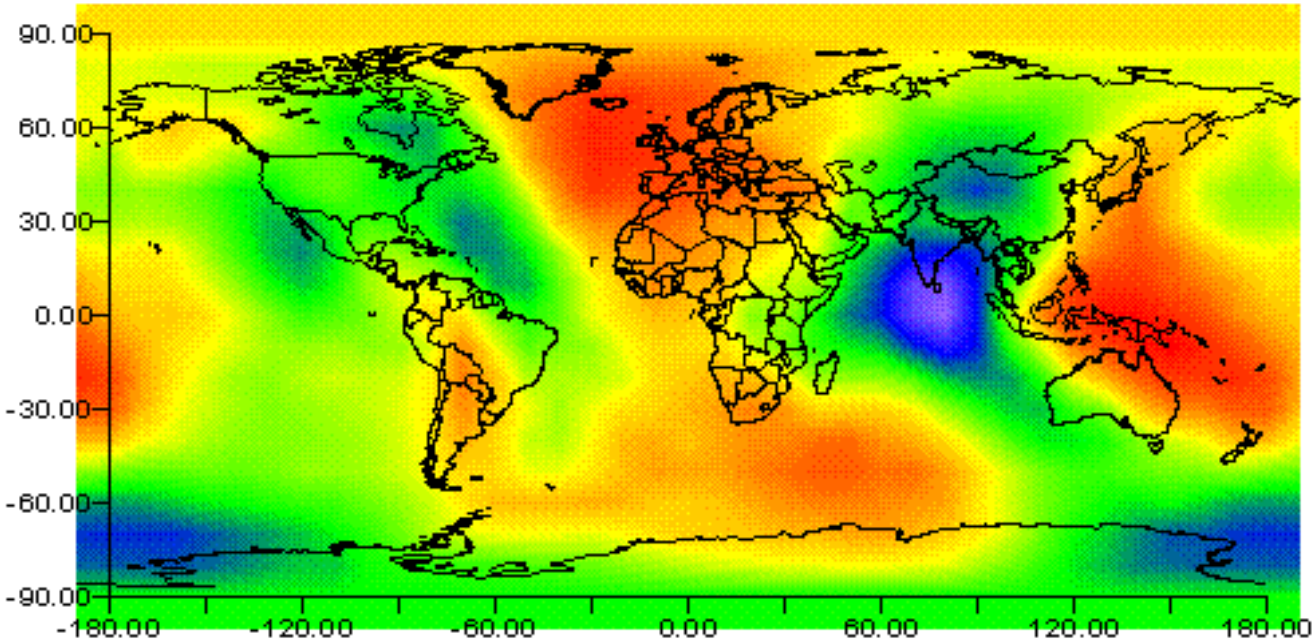
- Height is measured from the Geoid
- Measured along a plumb line
- Many national and regional implementations:
  - NGVD29 (National Geodetic Vertical Datum 1929)
  - NAVD88 (North American Vertical Datum 1988)
  - IGLD85 (International Great Lakes Datum of 1985)

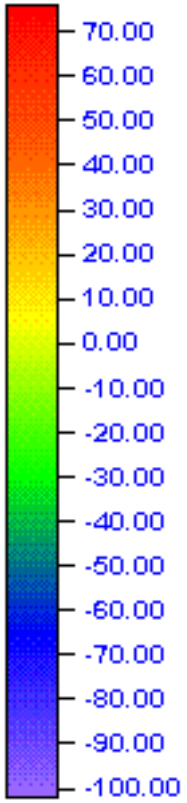
Geoid

- Equipotential gravity surface
- Least squares best fit with global mean sea level
- Undulates significantly due to mountains, rock density, etc.
- Varies by up to 100m from geocentric ellipsoid
- Various approximations available based on physical readings and interpolation.
- eg USA Geoid2003, global EGM 96

OSGeo
Your Open Source Compass

WGS-84 Geoid Height



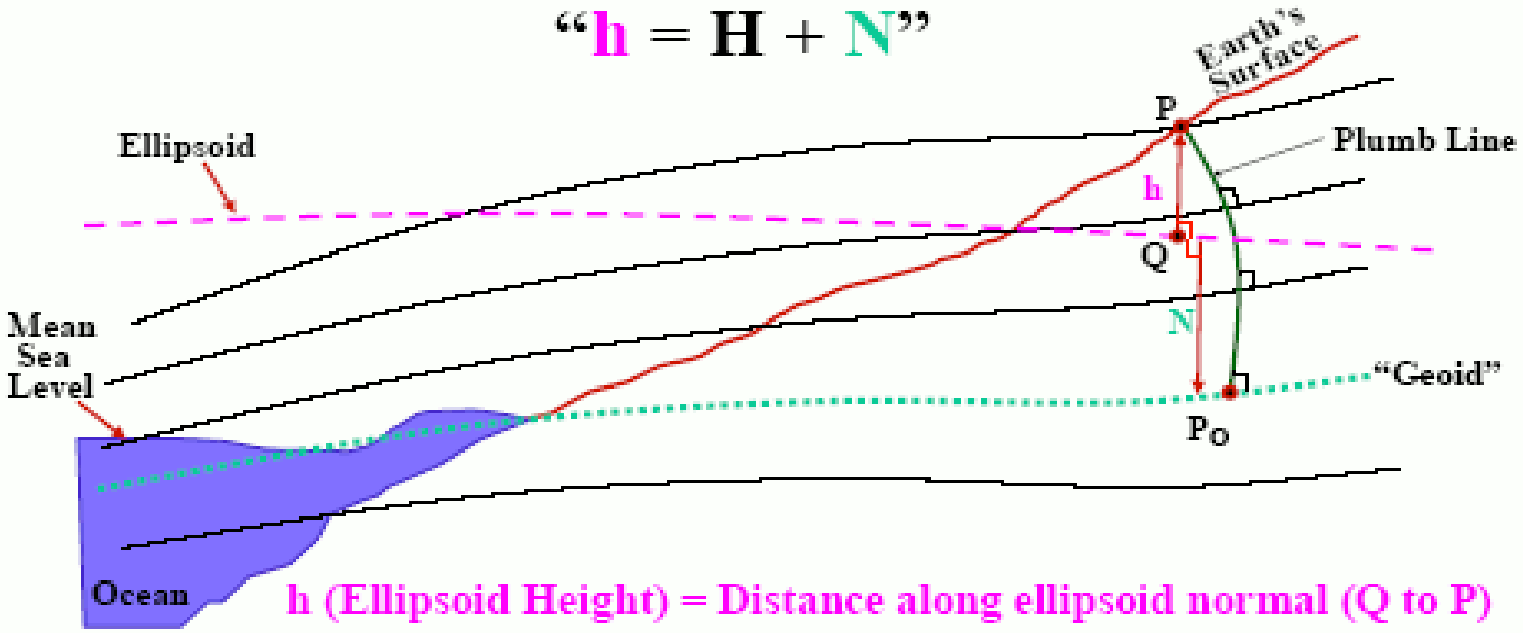


From DMA 10 by 10 Degree Geoid Height Grid

Peter H. Dana 11/05/95

Ellipsoid, Geoid, and Orthometric Heights

"h = H + N"



h (Ellipsoid Height) = Distance along ellipsoid normal (Q to P)

N (Geoid Height) = Distance along ellipsoid normal (Q to P_O)

H (Orthometric Height) = Distance along plumb line (P_O to P)

Vertical Coordinates in EPSG

Compound Coordinate Reference System (crs table):

- Horizontal CRS (ie. UTM 11 WGS84)
- Vertical CS (ie. NAVD88)

Vertical Coordinate Reference System (crs table):

- Vertical Datum
- Linear Units
- Axis (direction)

Vertical Coordinates in EPSG

Vertical Datums (datum table):

- Area of use, comments, etc.

Transformations:

- Based on Vertical CRS
- Often many defined for one Vertical CRS.
- Many transformation methods defined.
- No obvious “pivot vertical datum”

EPSG Transformation Methods

- Simple offset (ie. Baltic Sea vs. Black Sea)
- Offset+Slope (spatial slope)
- Grid Shift Files (VERTCON, geoid, many distinct transformation methods)
- Others I don't understand and haven't reviewed

OGC Well Known Text Representation

```
COMPD_CS["OSGB36 / British National Grid + ODN",
    PROJCS["OSGB 1936 / British National Grid",
        GEOGCS["OSGB 1936",
            DATUM["OSGB_1936",
        ...
        AUTHORITY["EPSG","27700"]],
    VERT_CS["Newlyn",
        VERT_DATUM["Ordnance Datum Newlyn",2005,
            AUTHORITY["EPSG","5101"]],
        UNIT["metre",1,AUTHORITY["EPSG","9001"]],
        AXIS["Up",UP],
        AUTHORITY["EPSG","5701"]],
    AUTHORITY["EPSG","7405"]]
```

OGC Notes

- No TOWGS84[] comparable method to represent transformations.
- VERT_DATUM “type” has no equivalent in EPSG
- Ellipsoidal vertical datums not COMPD_CS

Liblas Vertical Datum Support

- Liblas is a LAS (Lidar format) library (liblas.org)
- Funding from US ACE via Howard Butler for vertical datum support
- Liblas uses PROJ.4, libgeotiff, GDAL for coordinate system handling
- Goal:
  - Las2las -t_srs NAD83+NAVD88 in.las out.las

Libgeotiff Changes

- Modify the “build_pcs.py” script to produce:
  - vertcs.csv – vertical crs + transformation
  - compdcs.csv – compound crs list
  - primarily for use of GDAL EPSG lookups
- Clarify representation of vertical crs:
  - VerticalCSTypeGeoKey
  - VerticalDatumGeoKey
  - No equivalent to compound crs

GDAL Changes

Complete:

- ImportFromEPSG() support for VERT_CS
- ImportFromEPSG() support for COMPD_CS
- gtx (vertical grid shift format) read/write

To Do:

- to/from Proj.4 vertical grid shift parameters
- WKT EXTENSION for vertical shift parameters
- VERT_CS, COMPD_CS verification

PROJ.4 Changes

Done:

- +geoidgrid= parameter
- .gtx vertical grid shift reader
- Ellipsoidal vertical datum conversion

To Do:

- Chaining +geoidgrid= ?
- Compound crs in epsg init file?
- Vertical offsets?

Notes

- WGS84 ellipsoidal as pivot vertical datum
- .gtx picked as vertical datum format
- Translate to gtx with GDAL
- Convert 0-360 longitude files to -180 to 180
- NOAA VDatum used extensively for tutorial materials, grid shift files and validation

Software Review

- Not Comprehensive, or Accurate!

CSMap (Autodesk/Mentor):

- Includes support for geoid using gtx
- Many gtx files distributed with software

GeoToolbox (Java):

- Support COMPD_CS WKT
- Geoid transform can be requested specifically (using spherical harmonics model)

Conclusions

- Ellipsoidal datums ok for many GIS purposes
- Geoid needed for many formal vertical datums (such as NAVD88)
- Vertical datums particularly important on coast
- Word underway to incorporate support in liblas, libgeotiff, GDAL and PROJ.4.