

GEOL 306 – Earth’s Lithosphere II: Field Geology

Basic Notes on Geodesy and Coordinate Systems

Web Page References

<http://www.colorado.edu/geography/gcraft/notes/datum/datum.html>

<http://www.colorado.edu/geography/gcraft/notes/coordsys/coordsys.html>

Acknowledgements

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SOME BASIC NOTES ON GEODESY

Introduction to Geodetic Datums

- Geodetic datums define the size and shape of the earth and the origin and orientation of the coordinate systems used to map the earth. Hundreds of different datums have been used to frame position descriptions since the first estimates of the earth's size were made by Aristotle. Datums have evolved from those describing a spherical earth to ellipsoidal models derived from years of satellite measurements.
- Modern geodetic datums range from flat-earth models used for plane surveying to complex models used for international applications which completely describe the size, shape, orientation, gravity field, and angular velocity of the earth. While cartography, surveying, navigation, and astronomy all make use of geodetic datums, the science of geodesy is the central discipline for the topic.
- Referencing geodetic coordinates to the wrong datum can result in position errors of hundreds of meters. Different nations and agencies use different datums as the basis for coordinate systems used to identify positions in geographic information systems, precise positioning systems, and navigation systems. The diversity of datums in use today and the technological advancements that have made possible global positioning measurements with sub-meter accuracies requires careful datum selection and careful conversion between coordinates in different datums.

The Figure of the Earth

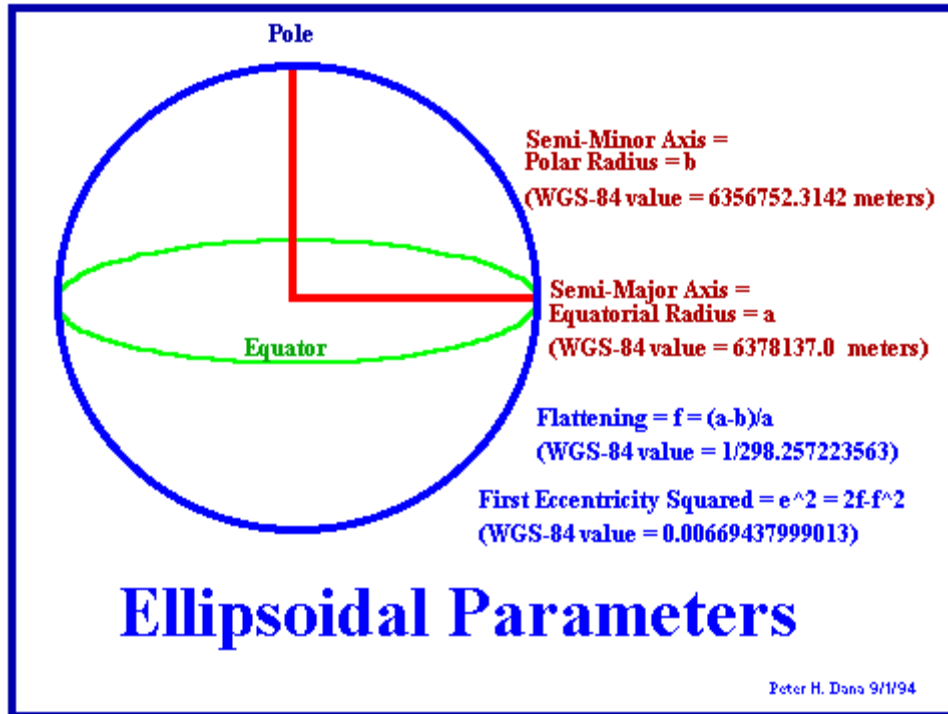
- Geodetic datums and the coordinate reference systems based on them were developed to describe geographic positions for surveying, mapping, and navigation. Through a long history, the "figure of the earth" was refined from flat-earth models to spherical models of sufficient accuracy to allow global exploration, navigation and mapping. True geodetic datums were employed only after the late 1700s when measurements showed that the earth was ellipsoidal in shape.

Geometric Earth Models

- Early ideas of the figure of the earth resulted in descriptions of the earth as an oyster (The Babylonians before 3000 B.C.), a rectangular box, a circular disk, a cylindrical column, a spherical ball, and a very round pear (Columbus in the last years of his life).
- Flat earth models are still used for plane surveying, over distances short enough so that earth curvature is insignificant (less than 10 kms).
- Spherical earth models represent the shape of the earth with a sphere of a specified radius. Spherical earth models are often used for short range navigation (VOR-DME) and for global distance approximations. Spherical models fail to model the actual shape of the earth. The slight flattening of the earth at the poles results in about a twenty kilometer difference at the poles between an average spherical radius and the measured polar radius of the earth.
- Ellipsoidal earth models are required for accurate range and bearing calculations over long distances. Loran-C, and GPS navigation receivers use ellipsoidal earth models to compute position and waypoint information. Ellipsoidal models define an ellipsoid with an equatorial radius and a polar radius. The best of these models can represent the shape of the earth over the smoothed, averaged sea-surface to within about one-hundred meters.

Reference Ellipsoids

- Ellipsoidal earth models are required for precise distance and direction measurement over long distances.
 - Ellipsoidal models account for the slight flattening of the earth at the poles. This flattening of the earth's surface results at the poles in about a twenty kilometer difference between an average spherical radius and the measured polar radius of the earth.
 - The best ellipsoidal models can represent the shape of the earth over the smoothed, averaged sea-surface to within about one-hundred meters.
- Reference ellipsoids are defined by either:
 - *semi-major* (equatorial radius) and *semi-minor* (polar radius) axes, or
 - the relationship between the semi-major axis and the flattening of the ellipsoid (expressed as its *eccentricity*).



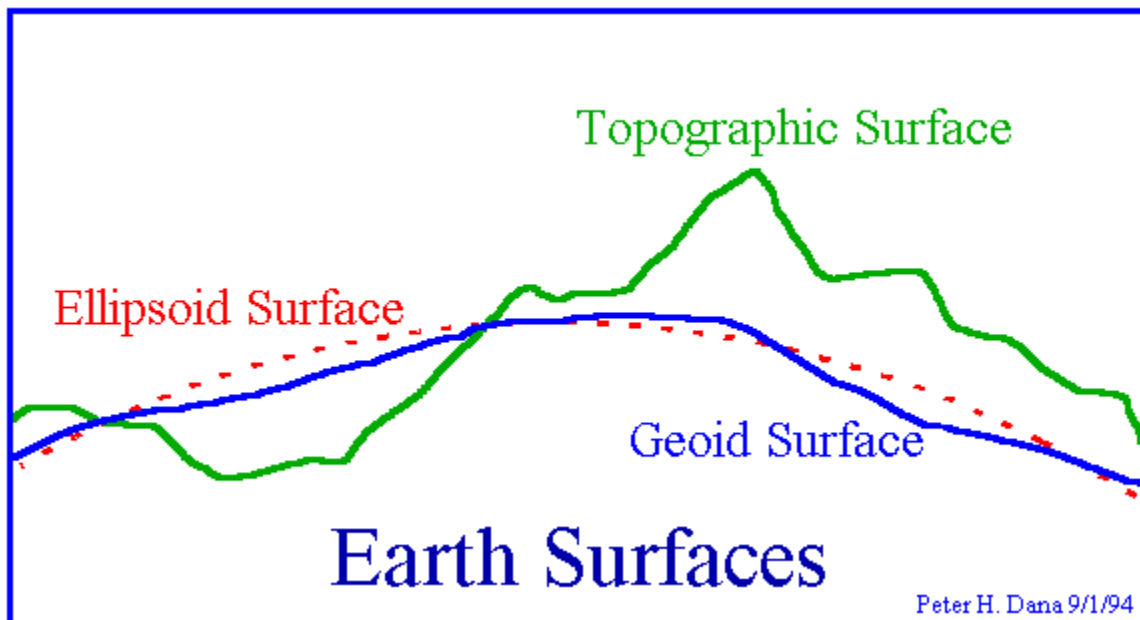
- Many reference ellipsoids are in use by different nations and agencies.
- Reference ellipsoids are identified by a name and often by a year
 - for example, the Clarke 1866 ellipsoid is different from the Clarke 1858 and the Clarke 1880 ellipsoids.

Selected Reference Ellipsoids

| Ellipse | Semi-Major Axis (meters) | 1/Flattening |
|------------------------|-----------------------------|---------------|
| Airy 1830 | 6377563.396 | 299.3249646 |
| Bessel 1841 | 6377397.155 | 299.1528128 |
| Clarke 1866 | 6378206.4 | 294.9786982 |
| Clarke 1880 | 6378249.145 | 293.465 |
| Everest 1830 | 6377276.345 | 300.8017 |
| Fischer 1960 (Mercury) | 6378166.0 | 298.3 |
| Fischer 1968 | 6378150.0 | 298.3 |
| G R S 1967 | 6378160.0 | 298.247167427 |
| G R S 1975 | 6378140.0 | 298.257 |
| G R S 1980 | 6378137.0 | 298.257222101 |
| Hough 1956 | 6378270.0 | 297.0 |
| International | 6378388.0 | 297.0 |
| Krassovsky 1940 | 6378245.0 | 298.3 |
| South American 1969 | 6378160.0 | 298.25 |
| WGS 60 | 6378165.0 | 298.3 |
| WGS 66 | 6378145.0 | 298.25 |
| WGS 72 | 6378135.0 | 298.26 |
| WGS 84 | 6378137.0 | 298.257223563 |

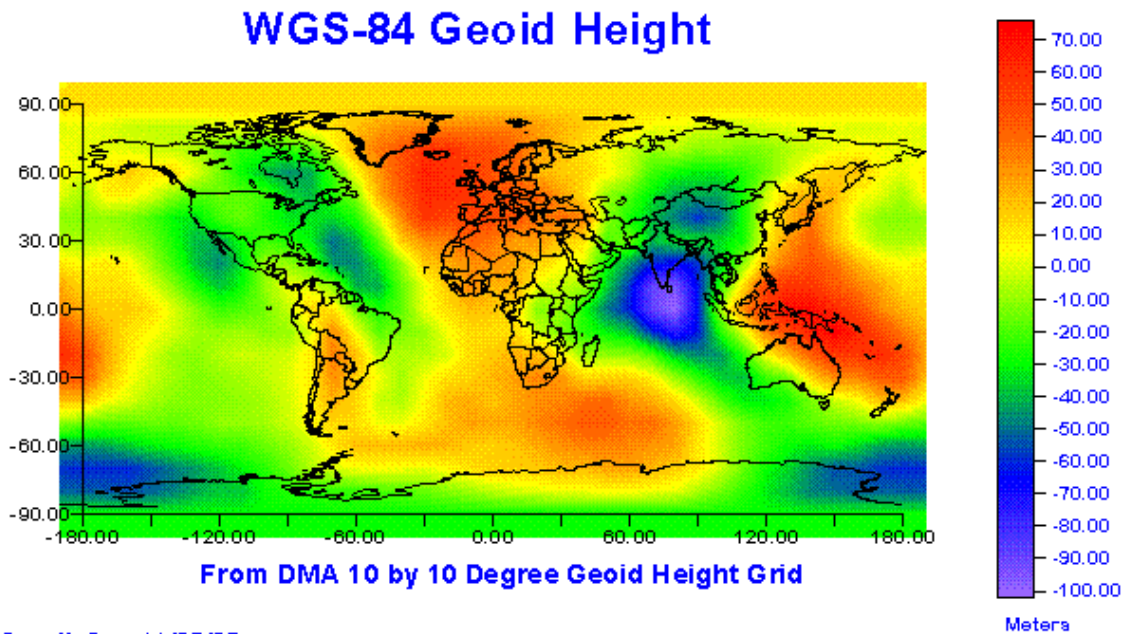
Earth Surfaces

- The earth has a highly irregular and constantly changing surface. Models of the surface of the earth are used in navigation, surveying, and mapping. Topographic and sea-level models attempt to model the physical variations of the surface, while gravity models and geoids are used to represent local variations in gravity that change the local definition of a level surface.



- The topographical surface of the earth is the actual surface of the land and sea at some moment in time. Aircraft navigators have a special interest in maintaining a positive height vector above this surface.
- Sea level is the average (methods and temporal spans vary) surface of the oceans. Tidal forces and gravity differences from location to location cause even this smoothed surface to vary over the globe by hundreds of meters.
- Gravity models attempt to describe in detail the variations in the gravity field. The importance of this effort is related to the idea of leveling. Plane and geodetic surveying uses the idea of a plane perpendicular to the gravity surface of the earth, the direction perpendicular to a plumb bob pointing toward the center of mass of the earth. Local variations in gravity, caused by variations in the earth's core and surface materials, cause this gravity surface to be irregular.
- Geoid models attempt to represent the surface of the entire earth over both land and ocean as though the surface resulted from gravity alone. Bomford described this surface as the surface that would exist if the sea was admitted under the land portion of the earth by small frictionless channels.
- The WGS-84 Geoid defines geoid heights for the entire earth.

- The U. S. National Imagery and Mapping Agency (formerly the Defense Mapping Agency) publishes a ten by ten degree grid of geoid heights for the WGS-84 geoid.



Datums in Use

- Hundreds of geodetic datums are in use around the world.
- The Global Positioning system is based on the World Geodetic System 1984 (WGS-84).
- Parameters for simple XYZ conversion between many datums and WGS-84 are published by the Defense Mapping Agency.

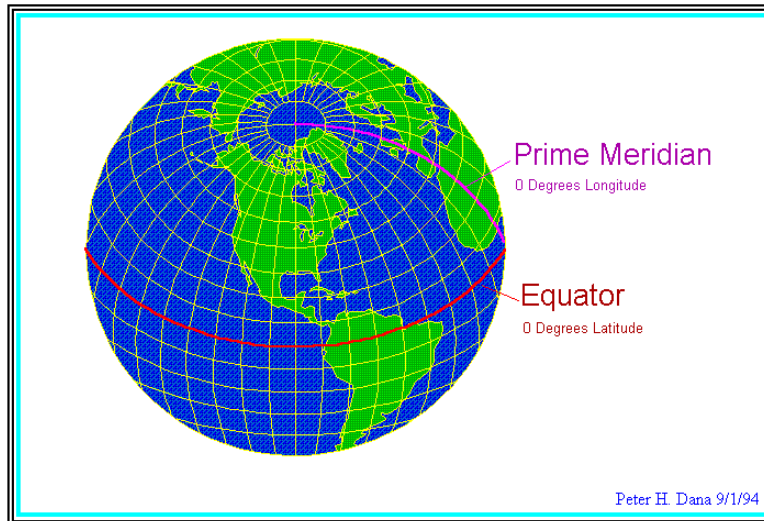
SOME BASIC NOTES ON COORDINATE SYSTEMS

Global Coordinate Systems

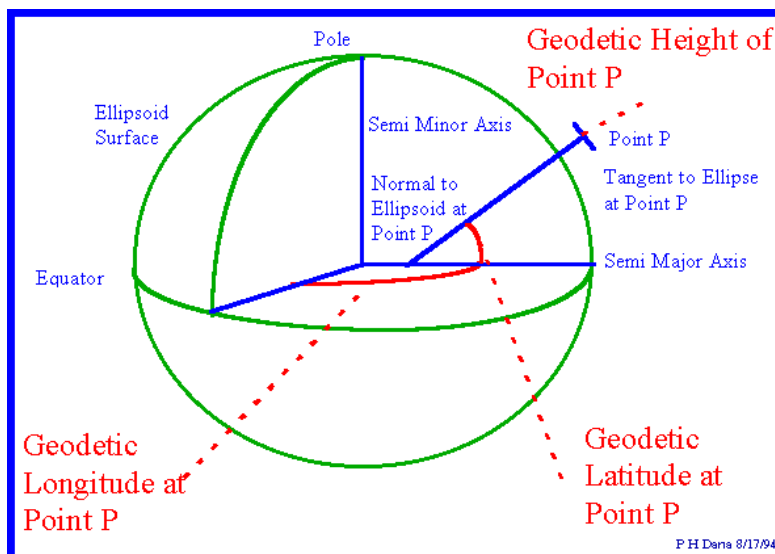
- Coordinate systems to specify locations on the surface of the earth have been used for centuries. In western geodesy the equator, the tropics of Cancer and Capricorn, and then lines of latitude and longitude were used to locate positions on the earth. Eastern cartographers like Phei Hsiu used other rectangular grid systems as early as 270 A. D.
- Various units of length and angular distance have been used over history. The meter is related to both linear and angular distance, having been defined in the late 18th century as one ten-millionth of the distance from the pole to the equator.

Latitude, Longitude, and Height

- The most commonly used coordinate system today is the latitude, longitude, and height system.
- The Prime Meridian and the Equator are the reference planes used to define latitude and longitude.

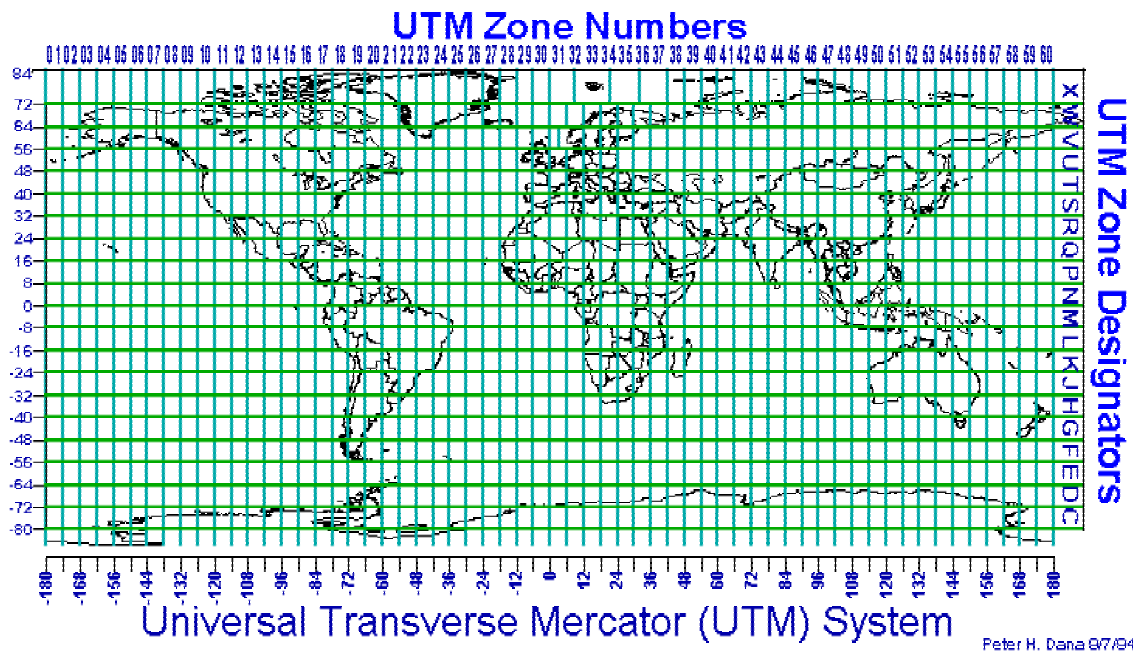


- The geodetic latitude (there are many other defined latitudes) of a point is the angle from the equatorial plane to the vertical direction of a line normal to the reference ellipsoid.
- The geodetic longitude of a point is the angle between a reference plane and a plane passing through the point, both planes being perpendicular to the equatorial plane.
- The geodetic height at a point is the distance from the reference ellipsoid to the point in a direction normal to the ellipsoid.

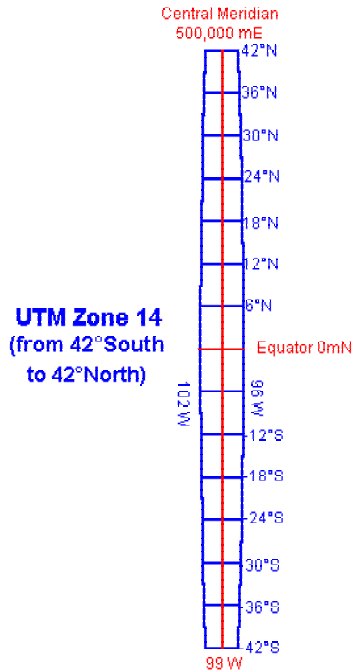


Universal Transverse Mercator (UTM)

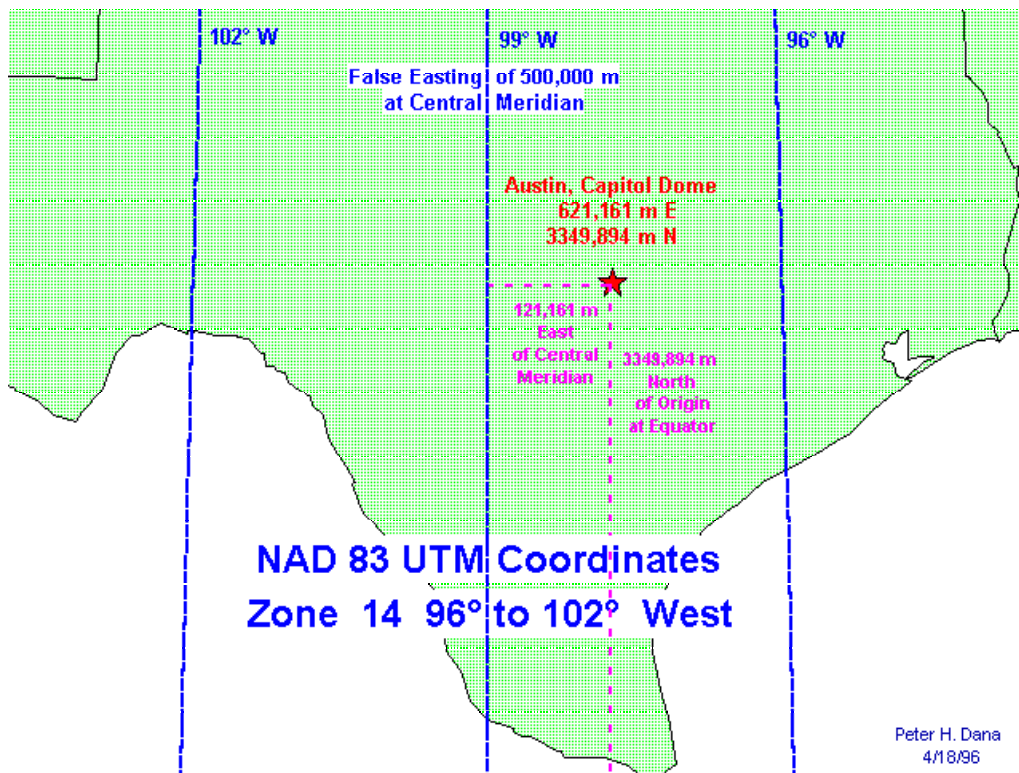
- Universal Transverse Mercator (UTM) coordinates define two dimensional, horizontal, positions.
- UTM zone numbers designate 6 degree longitudinal strips extending from 80 degrees South latitude to 84 degrees North latitude.
- UTM zone characters designate 8 degree zones extending north and south from the equator.
- There are special UTM zones between 0 degrees and 36 degrees longitude above 72 degrees latitude and a special zone 32 between 56 degrees and 64 degrees north latitude.



- Each zone has a central meridian. Zone 14, for example, has a central meridian of 99 degrees west longitude. The zone extends from 96 to 102 degrees west longitude.



- Eastings are measured from the central meridian (with a 500km false easting to ensure positive coordinates).
- Northings are measured from the equator (with a 10,000km false northing for positions south of the equator).



- The State Plane System 1983 is based on the North American Datum 1983 (NAD83).
 - NAD 83 coordinates are based on the meter.
- State plane systems were developed in order to provide local reference systems that were tied to a national datum.
- Some smaller states use a single state plane zone.
- Larger states are divided into several zones.
- State plane zone boundaries often follow county boundaries.