What’s in a ‘position’

- Put a stake in the ground; that object does not move with respect to the planet.
- The stake does not move but the description of it does.
38˚N, 84.5˚W
WGS 1984 v. NAD 1927

38N, 84.5W

37.9992208N, 84.50006169W
Must know the datum that is the basis for the coordinates you are getting from GPS

- GPS system uses WGS1984, but units can be set to calculate & display coordinates in other datums

- Vital to incorporating GIS & GPS data
  - Datum, coordinate system, projection, & units (m, ft) must all be the same
Why wouldn’t I use WGS 1984?

- Doing calculations with lat & long can be complex because units are in degrees (requires math based on angles)
- Does not always work well for mapping purposes – think trying to plot 3D coordinates on a paper
“Geodesy, the oldest earth science, is the discipline that deals with the measurement & representation of the earth, including its gravity field, in three-dimensional time varying space”

Vanicek & Krakiwsky, 1986
~2250 ybp, Eratosthenes (person who developed lat/long), calculated the circumference of Earth by

\[(360° \div \theta) \times (s)\]

‘s’ = distance between two north/south lying points,
\(\theta\) = subtended angle of the arc between these points relative to center of earth
- Column shadow was 7.12°
- Distance between points is 4,400 stades
- \( \frac{360°}{7.12°} = 50 \)
- 50 \times 4,400 equals 220,000 stades, or about 25,000 miles
- The accepted measurement of the Earth's circumference today is about 24,855 miles
The earth is NOT round!
Actual shape of the Earth

http://www.slate.com/blogs/bad_astronomy/2015/09/22/earth_without_water_nope.html
Geoid

- Used to describe the unique & irregular shape of the Earth
- Geoid approximates mean sea level; shape of the reference ellipsoid is based on the hypothetical equipotential gravitational surface
- Mathematical models do not actually represent the real Earth
\[ h = H + N \]

Topo surface (earth surface or GPS antenna)

h = ellipsoid height
H = orthometric height
N = geoid height
Geoid & GPS

- GPS can measure height based on
  - **Mean Sea Level** - this is not a simple surface – it is also influenced by the gravitational pull
  - **Height Above Ellipsoid** – uses the reference ellipsoid (based on the vertical datum)

- Global vertical datum was required to establish a zero surface that was consistent & accurate worldwide – Earth Geodetic Model (EGM96)
Datum & Ellipsoid

- A **Reference Ellipsoid** is used to represent a geometric model of the Earth
- A **Geodetic Datum** is a coordinate system used to locate places on Earth based on a reference ellipsoid
Reference Ellipsoid

- A reference ellipsoid is defined by:
  - A semi-major axis (equatorial radius)
  - Flattening
  - A semi-minor axis (polar radius)
Geodetic datum

- Each Datum uses a different reference ellipsoid
- Differ by size & shape
- Using the wrong datum can lead to positional error of hundreds of meters!
Geodetic datum

- Vertical positions are usually less accurate than horizontal ones
- Horizontal positions are always relative to an ellipsoid
- Vertical positions (altitude) are related to either:
  - the EGM96 geoid or
  - the GRS-80 ellipsoid (essentially the same as WGS84)
The take away….

- Always collect GPS data using WGS84
- Export your files however you wish by
  - changing the export coordinate system in Pathfinder and adding a projection file
  - Using WGS84, and then re-projecting in ArcGIS
Coordinate Systems

- A set of rules for specifying positions on Earth’s surface
- Referenced to a particular datum and often to a projection
- Always has an origin and a central meridian
Cartesian Coordinates (projected)

Point with X and Y Coordinates of X = +7 and Y = +6
Expressed as Ordered Pair (+7, +6)

Cartesian Coordinates in a Plane
A Point Defined by X and Y Coordinates
Cartesian coordinate system, 3D

Distance between points

Three-Dimensional Cartesian Coordinates
X, Y, Z

Distance Between
Three-Dimensional Cartesian Coordinates
(X1, Y1, Z1) and (X2, Y2, Z2)

\[ \text{Distance} = \sqrt{(X1-X2)^2+(Y1-Y2)^2+(Z1-Z2)^2} \]
Geographic Coordinate Systems

- **Earth Centered, Earth Fixed** Cartesian coordinates define a position with respect to center of ellipsoid or geoid.
- Expressed as latitude and longitude in degrees, height (feet or meters).
- Negative latitude is south of the equator; negative longitude is west of Greenwich.
Geographic coordinate systems:
Earth Centered, Earth Fixed
Geographic Coordinate Systems

- **World Geodetic System 1984 (WGS84)**
  - The ECEF was realized to this datum
  - All GPS satellites currently send these coordinates
  - Can be used throughout the world

- **North American Datum 1983 (NAD83)**
  - ECEF realized to a slightly different ellipsoid
  - Nearly identical horizontal positions to WGS84
  - Vertical off by up to 0.5m (it uses a MSL geoid)
  - Legal datum in North America
Projected Coordinate Systems

- **Universal Transverse Mercator**
  - Realized to NAD83
  - Defines two dimensional, horizontal, positions referenced to a central meridian
UTM
UTM

126°W 120°W 114°W 108°W 102°W 96°W 90°W 84°W 78°W 72°W 66°W

10 11 12 13 14 15 16 17 18 19
UTM

- Coordinates are in “Northings” and “Eastings”
- Northings are relative to the equator;
- “Eastings” are relative to false origin 500,000 meters west of the zone’s central meridian
State Plane Coordinate Systems
Lots of Datum(s)

- WGS84
- NAD83, with Subsequent realizations including:
  - NAD83 HARN (RLIS)
  - NAD83 CORS94
  - NAD83 CORS96
  - NAD83 (NSRS2007)
  - Current realization is NAD83 (2011)
- NAD27
The take away, part 2…. 

- Best to collect GPS data in WGS84
- Differentially correct the data using the “use reference position from base provider” option
- Export the data as WGS84 and if not, be sure to include the correct projection file
- Reproject that data in Arc, if necessary (http://support.esri.com/en/knowledgebase/techarticles/detail/24159)
- When using old data, make sure you know the datum used to collect and process the data