Understanding Survey GPS Readings – By Scott Ralston

GPS coordinates, particularly elevation is derived in 3 parts. First is triangulation, second is differential correction, 3rd is geoid correction or reference to mean sea level.

Triangulation

Satellites orbit the earth based on the earth's center of gravity. Essentially the distance from a satellite to the earth's center of gravity is fixed

A satellite constantly sends out message signals with the time the message was sent which are basically just highly accurate time stamps. All time stamps/clocks on all satellites are synchronized so they all read exactly the same time.

GPS receivers on the ground also have the same synchronized clock as the satellites. The GPS receiver reads the signal sent by the satellite. By comparing the time the message was sent from the satellite in the signal to the time it was received you know the time the signal took to travel from the satellite to the GPS receiver on the ground.

Satellite signals travel at a fixed know speed (basically speed of light). Thus if you know the time it took to travel from A to B and the speed it was traveling you can calculate the distance.

Simplified a GPS uses a time signal to measure the distance between the satellite and the receiver

If you have at least 3 satellites you can triangulate your position

Differential Correction

There is some error associated with the triangulation. Satellite signals might not travel a perfect straight line due to atmospheric distortions thus miscalculate their distances slightly giving you the wrong triangulated position.

Fixed control points have been developed all over the country and world with exact know coordinates. They also have fixed GPS receivers on these locations constantly receiving the satellite signals. By comparing the position the triangulated GPS signal position against the known fixed coordinates you can get an error correction for that position.

GPS receivers with differential correction will receive signals broadcast by the nearest fixed control point and use the correction factor from that control point to correct it's own position location. In some cases GPS units use more than one near control points for correction.

The X, Y, & Z coordinates in raw form are just a distance measured from the orbiting satellites. To put it into a perspective of the earths surface we use various projected coordinate systems which is basically a grid pattern laid out on the earth's surface. Generally it is in some format of angular degrees from longitude and latitude lines around the globe and then converted to a 2 dimensional display. Since there are many different coordinate systems and projections available, make sure to choose the one appropriate to your area and when comparing 2 sets of data make sure they are in the same coordinate system or you will get errors due to the different distortions they use in various projection types. Distortions are from making a spherical earth display on a flat map. Generally the least distortion comes from a coordinate system that is designed for a smaller area such as the county coordinate systems used in many states. Most default GPS data is in WGS84 with specific UTM zones.

Between the triangulated position and the differential correction you now have a very accurate X, Y and Z coordinate on earth however this position is only relevant in reference to the satellites orbiting the earth

Elevation - Geoids

The next step is to compare it to mean sea level for elevation

The problem is mean sea level is not constant relative to the center of gravity of the earth. The earth is not a perfect sphere. Mean sea level is also not a perfect sphere. Even if we didn't have factors like wind, wave action, currents and tides the oceans would not be flat/spherical. If we didn't have those external influences you would still travel on a ship at sea and the GPS would read changes in elevation as you travel across the world. This is due to the gravitational pull is different on different parts of the world which in turn pulls down more or less on the water making high or low points in the water surface. Essentially higher mass/dense areas have stronger gravity than lower mass areas. This can be due to differences in magma zones in the earth or variations in the earths crust due to things like mountains vs deep sea trenches. A concept known as a geoid has been developed. The geoid is the shape of the earth surface based on it's gravitational pull compared against and idealized perfect sphere. Another way to think about it is if the planet were a perfect sphere covered all in water with no wind, waves, currents or tides with the only influence on the water surface elevation was how much pull gravity had on that location the geoid is the surface of that water. So in some places like in parts of Minnesota the geoid is approximately 80ft higher than the idealized sphere. If the idealized perfect sphere of the earth is 0ft mean sea level then the corrected mean sea level under MN landmass is 80ft. Then there is another roughly 1,000ft of earth's crust above that geoid mean sea level to get average land surface elevation above MSL.

Notice there are different formulas for calculating geoids (version 2003, 2009, 2012 etc.). As you can imagine it is a complicated process so different mathematical procedures have been applied in attempts to create more accurate geoids. Thus not all geoids produce exactly the same MSL elevation for the same location. It is very important to use the same geoid when comparing 2 points or you may be getting errors because one geoid has a higher or lower MSL elevation than another. Lidar Data in MN uses Geoid 2003 so GPS data compared to the LIDAR should be collected in Geoid 2003 also.

Summary: Survey grade GPS units thus triangulate the position using the GPS time signals, then correct any errors in the triangulation using differential correction from known control points, then determine MSL elevation by comparing the GPS position height above the geoid for that location.