GPS and its Applications in Geosciences

Navigation and positioning are crucial to most human activities and yet the process has always been quite cumbersome.  Trying to figure out where he is and where he is going has probably been one of man's oldest pastimes.  Over the years all kinds of technologies have tried to simplify the task but every one has had some disadvantage.

Finally, the U.S. Department of Defense decided that the military had to have a super precise form of worldwide positioning. And fortunately they had the kind of money ($12 billion!) it took to build something really good.

The result is the GPS or Global Positioning System, a system that changed navigation forever. GPS is the only system today that is able to show you your exact position on the Earth anytime, in any weather, anywhere on or above the earth’s surface.  It is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations.

GPS satellites orbit at 11,000 nautical miles (1 nautical mile = 1852 m) above the Earth. Ground stations located worldwide continuously monitor them.  The satellites transmit signals that can be detected by anyone with a GPS receiver. Using the receiver, you can determine your position accurate to a matter of meters. In fact, with advanced forms of GPS you can make measurements to better than a centimeter.  In a sense it's like giving every square meter on the planet a unique address.

Presently, GPS is finding its way into cars, boats, planes, construction equipment, movie making gear, farm machinery, and even laptop computers and cell phones.  Soon GPS will become almost as basic as the telephone. Indeed, it just may become a universal utility.

Components of the GPS:

GPS has 3 parts – the space segment, the control segment, and the user segment.

**Space Segment (GPS Satellites)**

The complete GPS space system includes 24 satellites, 10,900 nautical miles (20187 km) above the Earth, which take 12 hours each to go around the Earth once (one orbit). They are positioned so that we can receive signals from six of them nearly 100 percent of the time at any point on Earth. GPS satellites are equipped with very precise clocks that keep accurate time to within three nanoseconds. This precision timing is important because the receiver must determine exactly how long it takes for signals to travel from each GPS satellite. The receiver uses this information to calculate its position.

The first GPS satellite was launched in 1978. The first 10 satellites were developmental satellites, called Block I were launched by 1985. From 1989 to 1993, 23 production satellites, called Block II, were launched. The launch of the 24th satellite in 1994 completed the system.

* Name: NAVSTAR
* Manufacturer: Rockwell International
* Altitude: 10,900 nautical miles
* Weight: 1900 lbs (in orbit)
* Size: 17 ft with solar panels extended
* Orbital Period: 12 hours
* Orbital Plane: 55 degrees to equatorial plane
* Planned Lifespan: 7.5 years
* Current constellation: 24 Block II production satellites
* Future satellites: 21 Block II satellites developed by Martin Marietta

**Control Segment (Ground Stations)**

The GPS control, or ground segment consists of the following unmanned monitoring stations located around the world which track and monitor the GPS satellites:

* Hawaii and Kwajalein in the Pacific Ocean
* Diego Garcia in the Indian Ocean
* Ascension Island in the Atlantic Ocean; and
* Colorado Springs, Colorado

Apart from these, a master ground station at Schriever (Falcon) Air Force Base in Colorado Springs, Colorado; and four large ground antenna stations broadcast control signals to the satellites.

These stations monitor the GPS satellites, checking both their operational health and their exact position in space. The master ground station receives and analyses satellite signals and transmits corrections for the satellite's ephemeris constants and clock offsets back to the satellites themselves. The satellites can then incorporate these updates in the signals they send to GPS receivers.

**User Segment (GPS Receivers)**

GPS receivers vary greatly in size and complexity.  They can be hand carried or installed on aircraft, ships, tanks, submarines, cars, and trucks.  These receivers detect, decode, and process GPS satellite signals. Although more than 100 different receiver models are presently in use, their basic design is rather simple.  The typical receiver is composed of an antenna and preamplifier, radio signal microprocessor, control and display device, data recording unit, and power supply.

The GPS receiver decodes the timing signals from the 'visible' satellites (four or more) and, having calculated their distances, computes its own latitude, longitude, elevation, and time. This is a continuous process and generally the position is updated on a second-by-second basis, output to the receiver display device and, if the receiver display device provides data capture capabilities, stored by the receiver-logging unit.

The typical hand-held receiver is about the size of a cellular telephone, the newer models are even smaller. The hand-held units distributed to U.S. armed forces personnel during the Persian Gulf War weighed only 28 ounces.

How does GPS Work

GPS works in 5 logical steps:

1. The basis of GPS is "triangulation" from satellites.
2. To "triangulate," a GPS receiver measures distance using the travel time of radio signals.
3. To measure travel time, GPS needs very accurate timing, which it achieves (with some tricks) with its own and satellite clocks.
4. Along with distance, you need to know exactly where the satellites are in space. High orbits and careful monitoring are the secret.
5. Finally you must correct for any delays the signal experiences as it travels through the atmosphere.

Accuracy

Since the implementation of GPS in 1990, an intentional random error was added to the GPS signals to give a positional inaccuracy of about 100 m, so that hostile forces could not use it to guide ballistic missiles with any degree of accuracy.  This error was not truly random, and the US Army receivers had codes which allowed them to compensate for this error. From 2nd May 2000 this selective availability was withdrawn, and the positional uncertainty has been reduced to 5 m.  This means that a good GPS receiver capable of processing 6 or more signals simultaneously, and used in ideal conditions can give a horizontal accuracy of 5 m and a vertical accuracy of ±10 m.  The accuracy of GPS positioning can be enhanced by using using Differential GPS of implementation of the Wide Area Augmentation Service as explained hereunder.

Differential GPS (DGPS): In this method one GPS receiver is fixed on the ground at a known location (acting as a static reference point), the others are the roving (mobile) receivers performing the usual survey work. The roving GPS can record all its measured positions and the exact time it made each measurement and later this data can be merged with the corrections recorded by the stationary reference GPS receiver. With such a setup, the differential GPS can eliminate virtually all errors in the system, whether they are from the receiver clocks, the satellite clocks, the satellite positions or the ionosphere and atmospheric delays.

Another way of doing DGPS is for the correction factors to be transmitted from the static reference GPS receiver to all the roving receivers by a radio link in real time.  Differential GPS gives sub centimetre accuracy.

Wide Area Augmentation Service (WAAS): WAAS corrects for GPS signal errors caused by ionospheric disturbances, timing, and satellite orbit errors, and it provides vital integrity information regarding the health of each GPS satellite.  WAAS consists of approximately 25 ground reference stations positioned across the United States that monitor GPS satellite data. Two master stations, located on either coast, collect data from the reference stations and create a GPS correction message. This correction accounts for GPS satellite orbit and clock drift plus signal delays caused by the atmosphere and ionosphere. The corrected differential message is then broadcast through one of two geostationary satellites to all hand held receivers in the operational area viz., North America and the Hawaiian Island.  The information is compatible with the basic GPS signal structure, which means any WAAS-enabled GPS receiver can read the signal and give an enhanced accuracy.

GPS Applications in Geosciences

GPS technology has matured into a resource that goes far beyond its original design goals. These days scientists, sportsmen, farmers, soldiers, pilots, surveyors, hikers, delivery drivers, sailors, dispatchers, lumberjacks, fire-fighters, and people from many other walks of life are using GPS in ways that make their work more productive, safer, and sometimes even easier.

Understanding some of the things a GPS receiver can do will help you understand what all it can be used for.  Some of the geological uses are described below, but first, just think of the GPS as a calculator - it calculates distances and directions from your current location.

* A GPS unit can record in memory, its current location (and 499 other locations) in latitude and longitude, or in map grid format.
* Each location can be given a name or number, and time and date (automatically if you wish).
* It can then calculate distance and bearing between any of those logged locations (called waypoints)
* It can guide you from and to any location, with a graphic highway symbol, and tell you if you veer off path.
* It can automatically log your geological traverse, and then guide you back over the same trail.
* It can be used as a hand-held, in a boat, or can be mounted under the windscreen of a car, or within the panel of a boat control station for practical route guidance. It can be hooked up to a 12-volt supply.
* It can store locations in routes, and the whole route can be retained and recalled.
* You can download all of this information to a computer, and backload it to any other GPS at any time.
* In use, the GPS will act as a compass, indicating your heading and bearing (true north or magnetic), and will display your speed very accurately.
* Many GPS units also show sunrise and sunset, battery strength, satellite positions and signal strengths, DOP (DOP is dilution of precision, read more about GPS to understand what this is), graphic displays and feature mapping of waterways, roads, rivers and railways.

The most stringent of GPS applications in geosciences is surveying and mapping.  Using GPS saves time and money. GPS makes it possible for a single surveyor to accomplish in a day what used to take weeks with an entire team. And they can do their work with a higher level of accuracy than ever before.

Today, mapping is the art and science of using GPS to locate items, and then create maps and models of everything in the world.

Geological mapping is the first step in geological investigations. The concept of mapping has all together changed with the arrival of the modern techniques of investigations like GPS, Geographic information system and Remote sensing technique.  GPS is the only system today to show one’s exact position on the earth anytime, in terms of longitudes and latitudes, giving accuracy up to 1mm to 1 cm.

* Mountains, rivers, forests and other landforms.
* Roads, routes, and city streets.
* Endangered animals, minerals and all sorts of resources.
* Damage and disasters, trash and archeological treasures.

GPS technology is, now a days ,being used as a tool in many applications at the implementation stage even in engineering works, as has been observed in the construction of the tunnel under the English Channel.  During its construction British and French crew started digging from the opposite ends. They relied on GPS receivers outside the tunnel to check their positions along the way to make sure they met exactly in the middle. The accuracy and correction factors of GPS technique, in the same way can be applied to give authenticity to geological mapping.

In the case of geological mapping with GPS there is no need of the measurement of horizontal distance as well as the measurement of horizontal direction as we get the location of the observation point directly in terms of longitude and latitude. More over the altitude of the observation point can be noted down directly from the GPS reading.

Since Global positioning system is most accurate of all the known methods to determine location, it is highly useful for mapping based operations such as mineral prospecting and exploration, geo-engineering application such as construction of tunnel and dam and mapping of ocean floor.  GPS is already being used for tracking the movement of lithospheric plates, crustal deformation and the geomorphological change with the help of remote sensing satellites.

Watershed management project are being carried out across different part of the country by using the technique of GPS, being supplemented with GIS and remote sensing technique. Land use pattern of any area can be prepared with high accuracy if GPS is used along with satellite imagery.  GPS can be used in any vehicle such as car or any public transport system. It is also being used in aircraft in aerial surveys or on board ships during marine surveys, or for positioning jack-up and off-shore rigs.

In view of all these observation it can be termed as history’s most exciting and revolutionary development which has the capacity to establish a new concept in the different area of academic interest, industry or day to day life.

Advantage of GPS over other Conventional Method

The GPS system can be of great help in finding a location anywhere on or above the Earth to within about 5 m. Even greater accuracy, usually within less than 1 m can be obtained with corrections calculated by a GPS receiver at a known fixed location (DGPS).

The most important advantage of the GPS during geological mapping is the speed of the mapping operation and a large area that can be covered within very small time.