Technical Aspects in the Upgrading and Implementation of PRS92

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GeoAnalytika

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"Geodetic standards specify the absolute and/or relative accuracy of positions. Standards are independent of the measurement equipment and the methodology. Standards should have a long life, that is, they should not be rewritten merely because new technology becomes available. Rather, standards should be derived from the objectives of the geodetic network in terms of fulfilling the needs of professionals and the society. Thus, standards may require revision as the uses of geodetic networks change. "

Alfred Leick, University of Maine

Author of the book GPS Satellite Surveying.

BACKGROUND

The earth is a dynamic planet that is constantly changing and moving. Land masses move away or toward each other leading to collisions and deep trenches. These changes and movements are known, studied and have been defined for some time now. The geoid as we know it, is not a constant surface but also exhibits a periodic cycle of shifting over time.

As the definition of the "shape of the earth" improves through current scientific efforts, so must the datum change with it. Modern scientific studies using a global network of GPS reference stations also show evidence of changing and shifting land masses. This affects the general notion in the practice of geodetic engineering that points of reference on the earth are fixed and do not change or at least change very little through time.

THE DATUM

A **datum** is defined as a system of reference consisting of a set of constants specifying the coordinate system used for geodetic control (i.e. for calculating coordinates of points on the Earth). At least eight constants are needed to form a complete datum: 3 to specify the location of the origin, 3 to specify the orientation of the coordinate system and 2 to specify the dimensions of the reference ellipsoid (National Geodetic Survey).

The datum represents the foundation of geodetic practice since it is the starting point for all major geodetic control points to be established. The practice of old was to generate a network of geodetic controls through a network of triangulation stations using the Philippine geodetic datum as a starting reference point. This practice is already outdated and there is no known national effort to check the validity and accuracy of existing local geodetic controls in the country, let alone our Bureau of Lands Location Monuments (BLLM) which serves the local surveying profession.

Comparison Between Traditional Datum and Modern Datum

Traditional	Modern
Origin is a fixed point on the earth's surface with geodetic coordinates (a,b,c) (e.g. Philippine datum is at Balanacan)	Origin is Earth centered (geocentric) with coordinates (0,0,0)
Uses a best fit ellipsoid for a region (e.g. Philippines uses Clarke Spheroid of 1866)	Best Fit ellipsoid for entire Earth (Geocentric Reference System GRS80)
Vertical datum is also fixed at a point with assumed MSL elevation	Vertical Datum is derived empirically and is not a fixed point but an equipotential surface equivalent to the MSL
The land masses are considered homogenuous throughout and assumes datum to be fixed and immovable.	Reference Frame takes actual movement of the earth's land masses into consideration.

Advantages of a Modern Geocentric Datum

- reduce the effect of distortions in the official datum to an acceptable level and achieve uniformity;
- reduce the need for multiple coordinate systems;
- overcome the limited territorial extent of the current datum;
- achieve compatibility with global datums;
- overcome the inability of the existing system to account for earth deformation;
- achieve universal compatibility for survey control;
- economical in the long run

For the Philippines, our datum (horizontal and vertical) is still fixed to a determined point on the surface of the earth. This does not fulfill the requirements of a modern datum.

CURRENT STATE-OF-THE-ART

Global Positioning System

Studies on Global Positioning System (GPS) from the past two decades have shown this technology to be capable of achieving accuracies of 1-2 ppm between stations for distances 10-15 km in length using single frequency (L1) receivers. This degree of accuracy exceeds the set accuracy standards for most 1st order geodetic networks everywhere.

Recent advances in GPS design and modern processing techniques have also shown that we can now achieve the same accuracies for longer baselines hundreds and even thousands of kilometers in length at lower cost using a network of GPS reference stations.

The International Terrestrial Reference Frame (ITRF)

The International Terrestrial Reference Frame (ITRF) produced by the International Earth Rotation Service (IERS) is considered a realization of an ideal reference system or datum.

The ITRF origin is at the center of mass of the whole Earth, including the oceans and the atmosphere. Its length unit is the meter (SI), defined in a local Earth frame in the meaning of a relativistic theory of gravitation. The orientation of its axes is consistent with that of the BIH System at 1984.0, according to the resolutions of the IUGG (International Union of Geodesy and geophysics) and the IAU (International Astronomical Union). Its time evolution in orientation is selected such that it has no residual rotational horizontal velocity relative to the Earth's crust.

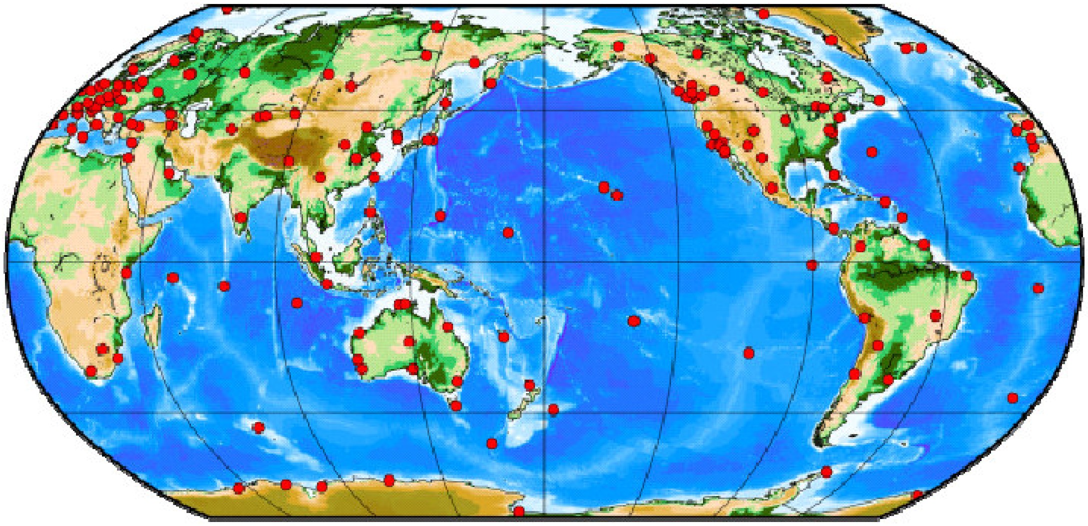
In order to define a terrestrial reference frame (TRF), four datum components should be clearly defined:

a. orientation
b. origin
c. scale
d. time evolution.

The IGS (International GPS Service for Geodynamics) through cooperation with IERS undertake the realization of the ITRF using analysis results from the IGS global community. The IGS cumulative solution (IGS-SSC) is one such solution and is currently aligned to the ITRF97 reference frame. However, an ITRF2000 solution is already available as of this time and has been published.

Established by the International Association of Geodesy in 1993, the International GPS Service for Geodynamics (IGS) is an international effort designed to support a wide range of geodetic and geophysical research activities by providing several GPS data products. The technical foundation of the IGS is a global network of GPS data collection sites. About 40 of these installations are designated as core stations and are in permanent CORS configuration. During specific campaigns, this network is augmented by an additional 150 to 200 fiducial stations that are either CORS facilities and temporary stations.

The products that the IGS derives from the GPS observations include high accuracy satellite ephemerides and clock information, earth rotation parameters, positions and rates of movement of the stations contributing to the network, and ionospheric information. These high accuracy products, are suitable to support a variety of scientific activities such as earth rotation, geodesy, deformation of the solid earth, sea level and ice sheet monitoring. They are also used for the realization and improvement of the International Terrestrial Reference Frame (ITRF), monitoring the ionosphere, and satellite orbit determination.

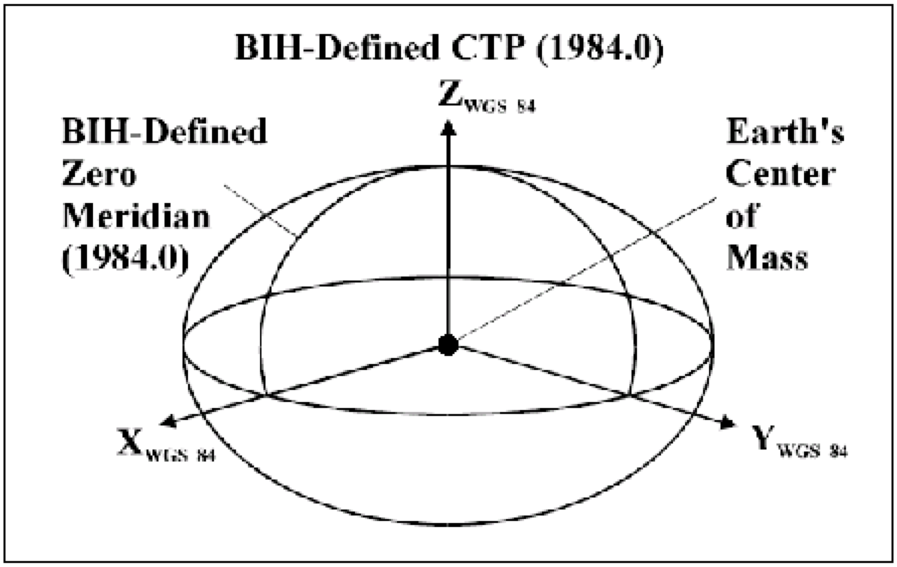


Worldwide IGS Monitoring Stations

A Philippine IGS

The **Philippines** has one CORS station considered by IGS as a Global station (i.e. a core station). It is maintained by NASA/JPL and is located at the back of the Manila Observatory, Ateneo. It has a published coordinate of Longitude 121.0777 and Latitude 14.6357 and Ellipsoidal Height of 95.4934. Based on the residual errors gathered from this station, observation data appears to be of high quality. It offers hourly IGS data.

WORLD GEODETIC SYSTEM of 1984 (WGS84)



The WGS 84 Coordinate System is a Conventional Terrestrial Reference System (CTRS). The definition of this coordinate system follows the criteria outlined in the International Earth Rotation Service (IERS). These are:

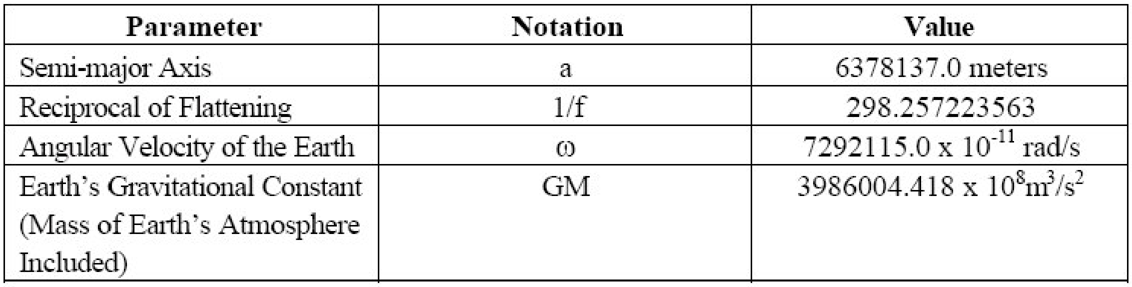
- It is geocentric, the center of mass being defined for the whole Earth including oceans and atmosphere
- Its scale is that of the local Earth frame, in the meaning of a relativistic theory of gravitation
- Its orientation was initially given by the Bureau International de l'Heure (BIH) orientation of 1984.0
- Its time evolution in orientation will create no residual global rotation with regards to the crust

The WGS84 is a right-handed, Earth-Centered Earth-Fixed (ECEF) orthogonal coordinate system with the Earth's center of mass as its point of origin.

The original WGS84 established in 1987 (and was used up until 1994) used Navy Navigation Satellite System (NNSS) or TRANSIT (Doppler) station coordinates and (surprisingly!) no GPS. The new WGS84(G873) replaces this model.

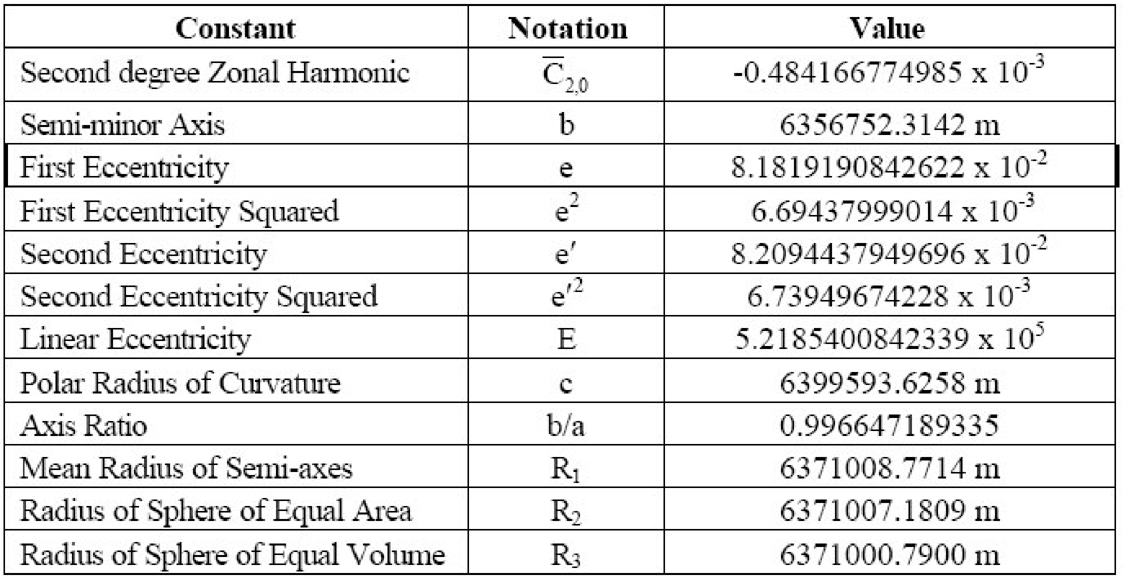
The WGS 84 (G730) reference frame (the precursor of the WGS G873 model) was shown to be in agreement (using a best fitting 7-parameter transformation) with the ITRF92 at a level approaching 10 cm. Similar studies to compare WGS 84 (G873) and ITRF94 are still underway. However, extensive daily orbit comparisons between the NIMA precise ephemerides (WGS84 (G873) reference frame) and corresponding IGS ephemerides (ITRF94 reference frame) show systematic differences to be less than 2 cm.

WGS 84 Four Defining Parameters



Parameter	Notation	Value
Semi-major Axis	a	6378137.0 meters
Reciprocal of Flattening	1/f	298.257223563
Angular Velocity of the Earth	ω	$7292115.0 \times 10^{-11}$ rad/s
Earth's Gravitational Constant (Mass of Earth's Atmosphere Included)	GM	$3986004.418 \times 10^{8} m^{3}/s^{2}$

WGS 84 Ellipsoid Derived Geometric Constants



Constant	Notation	Value
Second degree Zonal Harmonic	$\overline{C}_{2,0}$	$-0.484166774985 \times 10^{-3}$
Semi-minor Axis	b	6356752.3142 m
First Eccentricity	e	$8.1819190842622 \times 10^{-2}$
First Eccentricity Squared	e^2	$6.69437999014 \times 10^{-3}$
Second Eccentricity	e'	$8.2094437949696 \times 10^{-2}$
Second Eccentricity Squared	e'^2	$6.73949674228 \times 10^{-3}$
Linear Eccentricity	E	$5.2185400842339 \times 10^{5}$
Polar Radius of Curvature	c	6399593.6258 m
Axis Ratio	b/a	0.996647189335
Mean Radius of Semi-axes	R_1	6371008.7714 m
Radius of Sphere of Equal Area	R_2	6371007.1809 m
Radius of Sphere of Equal Volume	R_3	6371000.7900 m

The WGS84 reference frame underwent several enhancements to become the WGS (G730) and to the present WGS84 (G873); the 'G' meaning that GPS was used to derive the new parameters.

The WGS84 reference frame is determined by a network of permanent GPS tracking stations which are aligned with the ITRF through a globally distributed set of IGS and CORS with very high accuracy ITRF coordinates.

The improved WGS 84 (G873) reference frame is coincident with the ITRF at the 5 cm level. WGS 84 geodetic positions can be determined with uncertainties at the 25-50 cm level or better worldwide depending upon the method and technique used to derive the coordinates.

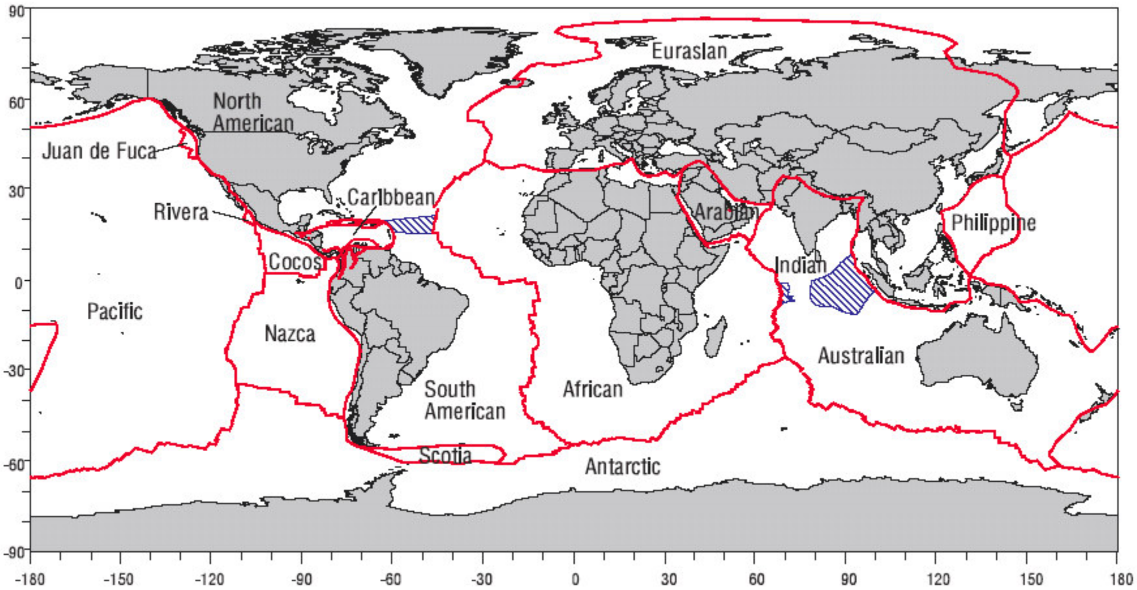
Most of the improvements to WGS84 do not have significant effects on mapping, charting and navigation applications since accuracy requirements are at the meter level or larger. They will however impact applications of geodetic or scientific nature.

PLATE TECTONICS

To maintain centimeter-level accuracy, GPS station positions (represented at a particular epoch) must be updated for the effects of plate tectonic motion (movement of earths' land masses). Control station coordinates slowly 'degrade' as they ride along these tectonic plates. The solution to this problem is to estimate velocity parameters along with the station positions. An application of a plate motion model can be used to account for the horizontal motions as determined from a starting epoch. The current recommended plate motion model which is widely used is NNR-NUVEL1A. However, for more localized and fragmented regions like the Philippines (see Galgana, 2003), a model still needs to be defined.

Of course the amount of correction will depend on the selected epoch of a stations coordinates and the required geodetic accuracy.

Figure 2.2 Tectonic Plate Map

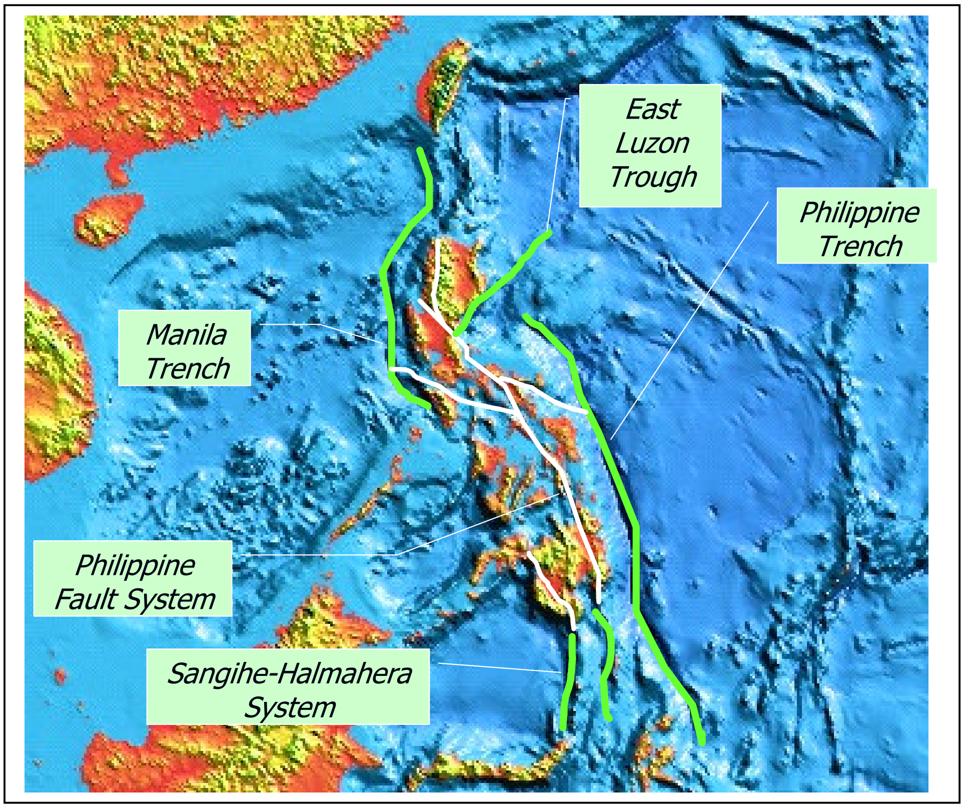


Present-day Major Tectonic Plates and Plate Boundaries

*Several minor plates not shown

Refinements to WGS 84 from research have reduced the uncertainty in the coordinates of the reference frame, the uncertainty of the gravitational model and the uncertainty of the geoid undulations.

The Philippine Tectonic Scenario



THE GEOID

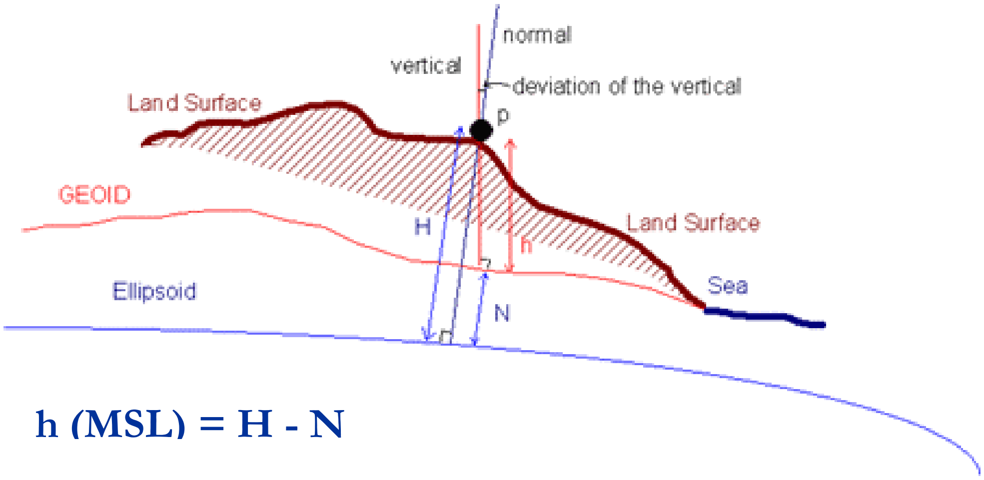
The ***geoid*** is an equipotential surface of the Earth's gravity field approximately coinciding with the mean sea level (MSL). According to recent studies the geoid is in agreement to the actual MSL only to within +/- one meter. The geoid represents the physical figure of the Earth including its size and shape. It is of particular importance to the geo-sciences, especially geodesy, because it defines the **vertical datum** (a zero level) for **orthometric (above mean-sea level) heights**.

Users of GPS technology know that measurements derived from a geodetic network are expressed in terms of ellipsoidal (geodetic) coordinates. What is desired however, is orthometric height. Thus we need to derive orthometric heights using ellipsoidal heights from GPS processing. This is possible if we can compute the geoid undulations N.

The relationship between orthometric (levelled) heights h and derived geodetic (ellipsoidal) heights H is:

$$h = H - N$$

where the geoidal height *N* is a radial distance between the Earth-centered reference ellipsoid and the geoid.



The gravimetric solution to determine the geoid is based on gravity, and the solution to the geodetic boundary-value problem represented by spherical Stokes's formula

$$N(\Omega) \doteq \frac{R}{4\pi\gamma} \cdot \iint_{\Omega'} \Delta g(\Omega') \cdot S(\Omega, \Omega')\, d\Omega',$$

R = radius of the reference Earth-centered sphere,
γ = magnitude of normal gravity,
Δg = gravity anomaly, and
S = spherical Stokes function relating the computation point Ω and integration point Ω'.

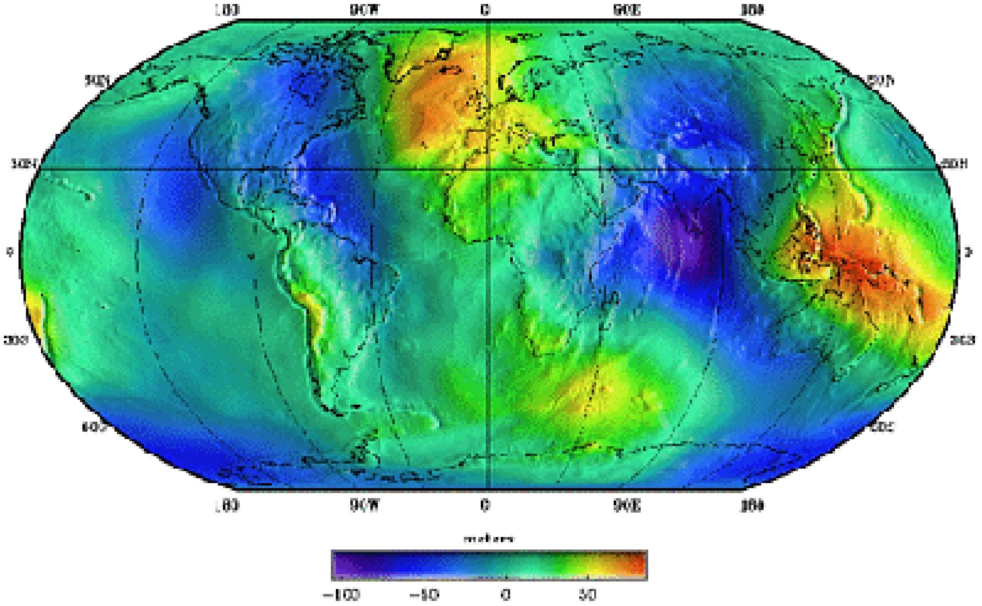
The accuracy (one sigma) of WGS 84 coordinates directly determined by GPS Satellite Point Positioning, precise ephemerides and ground-based satellite tracking data acquired in static mode, in terms of geodetic latitude, geodetic longitude, and geodetic height are:

Horizontal (lat, long) = ± 1m (1 C)
Vertical (h)= ± 1 ... 2 m (1 σ)

These errors include observational error and errors associated with placing the origin of the WGS 84 coordinate system at the earth´s centre of mass and determining the correct scale and should not be confused with accuracies that can be obtained through DGPS.

The conventional method of deriving orthometric heights is through spirit leveling or gravity measurements. Recently, advanced techniques to determine the geoids' dimensions rely on satellite interferometry and altimetry to measure minute gravity anomalies.

The EGM96 (Earth Geopotential Model 1996)



This gravity model was produced with the joint effort of NIMA, the NASA Goddard Space Flight Center (GSFC) and The Ohio State University during a three year study. The result of this joint effort is a new global model of the Earth's gravitational field: Earth Gravitational Model 1996 (EGM96). For most applications, this model replaces the now-outdated original WGS 84 gravitational model developed more than ten years ago.

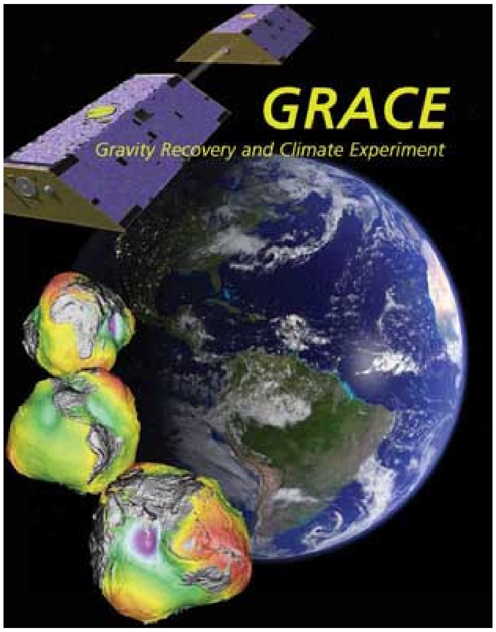
The form of the EGM96 model is a spherical harmonic expansion of the gravitational potential. The model, complete through degree (n) and order (m) 360 (approx. 100 km), is comprised of 130,317 coefficients.

A refined WGS 84 geoid has been determined from the EGM96 gravitational model and is available as a 15 minute grid of geoid undulations which exhibit an absolute accuracy of +/- 0.5 to +/- 1.0 meters (one σ) or better worldwide for a single point and ΔH to < 1 meter. This refined geoid is referred to as the WGS 84 EGM96 Geoid. This model is currently being used as a geodetic reference to the WGS-84. In addition, it is also being used as a state-of-the-art model for precise orbit, oceanographic, and geophysical studies.

Most modern GPS processing software incorporate the use of the EGM96 model or other more precise geoids.

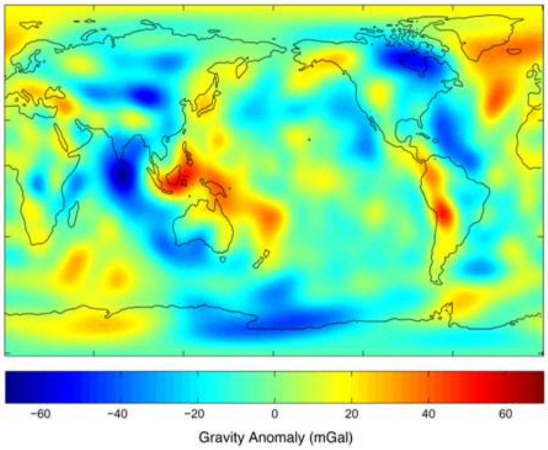
ORBITAL MISSIONS

GRACE

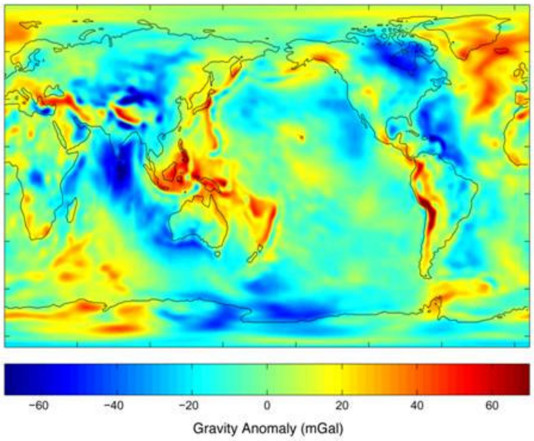


Launched by NASA in March 17 2002, Gravity Recovery and Climate Experiment **(GRACE)** uses high precision GPS, micron level inter satellite links, precision accelerometers, and accurate star cameras to produce precise gravity field maps of the Earth and reduce uncertainties in geoid heights. For a short 111 days of observation since its launch the program has produced a gravity model called GGM01 released only last July 2003 with geoid accuracy of 2 cm up to degree 70 and 6 cm up to degree 90 and 10 cm up to degree 120 (approximately 300 km width). This was done using no other external sources of data.

It is hoped that by next year the mission will be able to produce < 5cm. worldwide accuracy up to degree 360(~100 km grid).

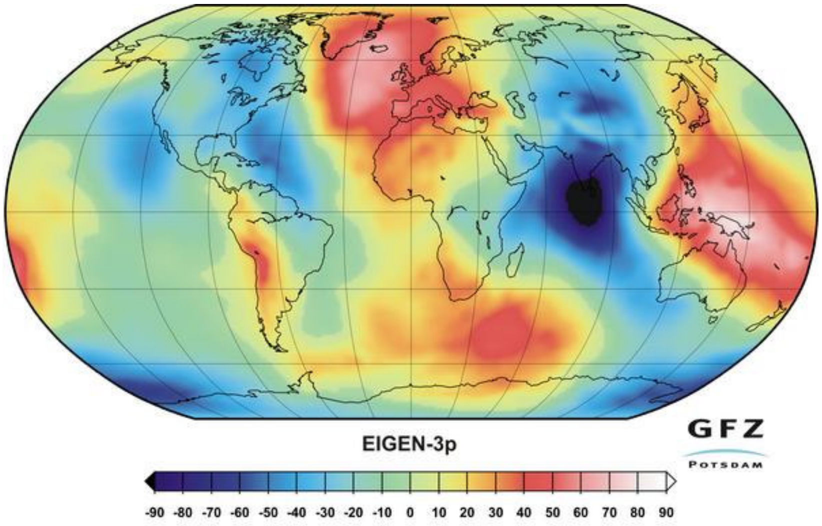


Old Gravity Potential



GGM01 by GRACE

CHAMP (CHAllenging Minisatellite Payload)

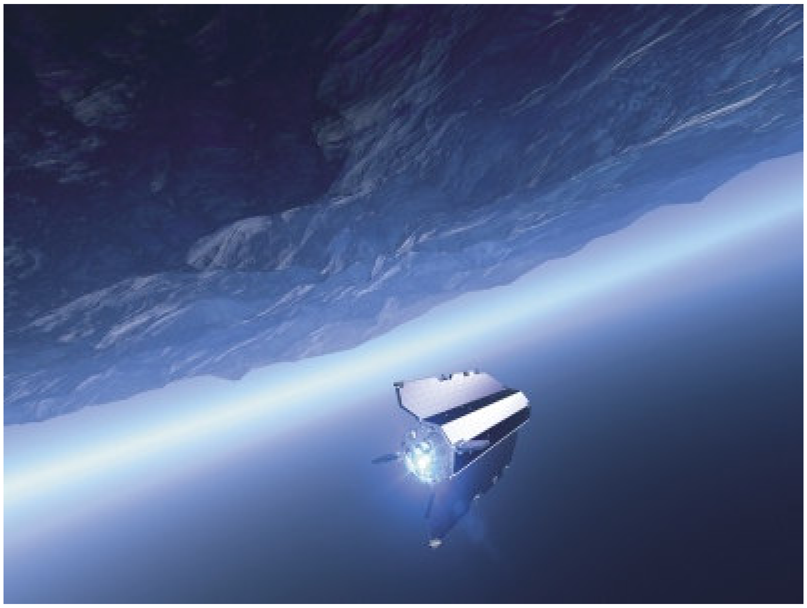


CHAMP is a German small satellite mission for geoscientific and atmospheric research and applications, managed by GFZ. It is equipped with highly precise, multifunctional and complementary payload elements (magnetometer, accelerometer, star sensor, GPS receiver, laser retro reflector, ion drift meter) and its orbit characteristics is near polar at low altitude. CHAMP is designed to generate simultaneously highly precise gravity and magnetic field measurements for a 5 year period. This will allow scientists to detect not only spatial variations of both fields but also their variability with time.

In addition with the radio occultation measurements onboard the spacecraft and the infrastructure developed on ground, CHAMP will become a pilot mission for the pre-operational use of space-borne GPS observations for atmospheric and ionospheric research and applications in weather prediction and space weather monitoring.

So far the CHAMP program has produced a highly accurate gravity field model called EIGEN-3p (EIGEN-3 preliminary) from the period July 2000 through June 2003 with expected geoidal accuracy of <10 cm.

GOCE



The primary aim of the Gravity Field and Steady-State Ocean Circulation Mission **(GOCE)** to be implemented by ESA is to provide unique models of the Earth’s gravity field and of its equipotential reference surface (geoid), on a global scale with very high spatial-resolution and accuracy to 1 cm. accuracy at a 100 km grid.

GOCE will help to develop a more detailed understanding of how the Earth's interior system works. This will provide further insight in a wide range of geoscience research disciplines and applications such as solid Earth physics, oceanography and geodesy. Anticipated launch for GOCE will be in 2006.

TECHNICAL CONSIDERATIONS IN UPGRADING PRS92

There are four items considered paramount for ensuring the success of a geodetic control project. Regardless of how the observations were obtained, the completed network must provide the following:

- Elimination or reduction of known and potential systematic error sources.
- Sufficient redundancy to clearly demonstrate the stated accuracy.
- Adequate analysis and data processing.
- Sufficient documentation to allow verification of the results.

To state that a survey has been conducted to this document's standards, three groups of criteria must be satisfied:

- Adherence to the specifications for methodology, data collection, and processing.
- Achievement of accuracy standards by the survey's results.
- Preparation and archiving of documentation showing compliance with these specifications and standards.

California Geodetic Control Committee

The correct treatment of GPS observations require a deeper knowledge of GPS adjustment theory and geodetic concepts beyond what is being taught in our local curriculum. The objective evaluation of the quality of any survey work (especially of geodetic nature) requires the use of tools and methods for quantifying the statistical (probable) error of the computed results and applying careful adjustment to the measurements. Only a limited number of professionals in the country have the tools and/or have that kind of knowledge or experience. Even those who are equipped with expensive GPS receivers have not fully realized its use due to lack of sufficient knowledge and understanding. As a consequence, doubts about this technology continue to fester.

To meet network or local accuracy classification, a GPS project must be connected to sufficiently accurate and well distributed existing control. The absolute accuracy of an individual station depend on its relative accuracy with its neighboring stations due to network adjustment. As such, when new stations are integrated into an old network, new positions are calculated leading to an upgrading or improvement of the old network. There should be a constant upgrading and improvement of existing control from new observations whether from control of lower order or from research.

The availability and use of software tools and computers has however been a welcome change for practitioners and users. Today, there are low cost or even free software and services available through the internet to process GPS observation data.

Current local methods to determine the relative and absolute accuracy of surveys no matter what order they are, are not sufficient to determine the objective accuracy of control establishment. Local standards and specifications are not fault tolerant and are prone to misuse by the ill prepared, untrained, and unprofessional.

Knowledge gained through further education, experience, and the open exchange of ideas and experiences in the profession remains the best means to ensure that geodetic control is constantly monitored by users and maintained by the proper authority or agency.

The movement from an independent computation (wherein we are only concerned with the internal and relative precision of our work) to dependent computation (wherein our work should be tied to sufficient external control of required accuracy), as practiced outside of the country should make us realize that our typical attitude towards surveying practice needs to be changed.

Issues such as network design, data collection methods, data processing methods including least squares adjustment, geoid modeling, and documentation need to be addressed to fully realize the potential of GPS technology.

The use of least squares adjustment has not been popular before due to the lack of computing capabilities. Definitely, least squares does not lend itself to manual computation. Given today's computing power available through widely available desktop computers, there is no reason now not to use this method for determining accuracy of survey work. A most useful feature is being able to do planning (i.e. estimating the probable error of the work ahead) to help in ensuring that the work to be done will meet the required standard of accuracy in the specifications.

Blunder detection and skewed observations leading to biases, and hidden systematic errors which are costly, sometime elusive and time consuming to correct cannot be taken for granted. It is therefore important to have redundant observations not only to detect but also to correct. Tests for this error are common and present in most post processing systems. The question is if these statistical tools are being used properly begs to be asked.

There is a need to make available data of observations and well defined position data to surveyors for their use. This encourages continued use and builds confidence in the technology.

Clear cut and well defined specifications to standards have to be clearly specified so that there would be no question as to whether they were met or not and in what way.

Of greater challenge however, is the maintenance of quality control and quality assurance for the established network of geodetic control. A proper network established using least squares adjustment makes it possible to assess the quality of the observations, validate the correctness of the statistical data, and detect blunders and errors.

CONTINENTAL EXPERIENCES

NORTH AMERICA

The North American Datum 1983 (which uses the GRS80 datum) has undergone several changes over time. The NAD 83 adjustment was based on geodetic measurements taken up until the adjustment began. Very Long Baseline Interferometry (VLBI), Doppler, and Satellite Laser Ranging (SLR) was used to help define the geodetic datum. Additionally, historical measurements based on triangulation, trilateration, traversing, and astronomic observations were also used within the adjustment.

The discovery of errors in the original NAD83 datum led individual states in the U.S. to establish High Precision Geodetic Networks, which are now called the High Accuracy Reference Network (HARN). As each state developed their own HARN, and the National Geodetic Survey (NGS) adjusted the NAD 83 reference system based on those HARN stations and this is referred to as the NAD 83 (HARN).

Three additional realizations have been developed. These are the continuously operating reference stations (CORS) established by NGS. In order to simplify the process of relative GPS positioning, many organizations are establishing automated reference station facilities. These unstaffed, permanently configured facilities continuously collect and record GPS data. The reference station data are then made available to users through a service. In a simple scenario, a user could collect data in the field with a single GPS receiver, later retrieve the data collected during the same time span by a nearby reference station(s), and combine the two datasets to perform single-handed, post-processed relative positioning. Such a procedure is well suited for mapping grade (few meter level accuracy) GPS work designed for applications such as geographic information system (GIS) data collection. Survey grade (few centimeter level accuracy) GPS work can also be supported by such a reference station, but it usually involves more than one field receiver operating simultaneously to provide for redundancy an error correction.

EUROPE

The **EUREF** (EUropean REference Frame) programme is an excellent example of the civil application of GPS on the international scale. It covers the large part of Europe and provides very precise control network for a very wide range of applications such as geodynamics, mapping, civil engineering, navigation etc. The programme is co-ordinated by the International Association of Geodesy (IAG).

The concept consists in the creation of the high precise continental network, uniform in geometry and accuracy and related to the geocentric reference frame but not very sensitive to the time changes. EUREF is conceptually defined by set of stations located on the stable part of the Eurasian plate for which internal deformation is negligible in the few years time interval. The origin epoch 1989.0 was adopted because it was the year of the first EUREF solution. EUREF coincides and is compatible with the WGS-84 system. The sole measurement method of this network is the static GPS phase measurement.

The EUREF coordinate system is now accepted as an official geodetic reference frame in European Union and other European countries. Many countries have already (and are in the process) of shifting to this new reference.

However, due to plate tectonics the co-ordinates of European stations slowly change by about 2 cm/year. Therefore it was decided that ETRF should rotate with the stable part of Europe, so that the station to station relations are kept fixed. Of course, from such a decision it results that the relationship to positions defined in ITRF may slowly change. Transformation parameters with the ITRF are established on a regular basis.

The geoid model adopted by the EUREF is Ordnance Survey Geoid Model, known as OSGM02. It is estimated to be accurate to +/- 5 cm for most of mainland Europe or better in some parts.

AUSTRALIA

The Geocentric Datum of Australia (GDA94) is the new Australian coordinate system, replacing the Australian Geodetic Datum (AGD). GDA94 is compatible with a global coordinate reference frame and is directly compatible with the Global Positioning System (GPS). It is the culmination of more than a decade of work by the Inter-governmental Committee on Surveying and Mapping (ICSM; formerly the NMC).

Reference Ellipsoid.- Geodetic Reference System 1980 (GRS80) ellipsoid

Reference Frame.- conforms to the International Earth Rotation Service Terrestrial Reference Frame 1992 (ITRF92) at the epoch of 1994:

Datum	Geocentric Datum of Australia (GDA)
Geographical coordinate set	Geocentric Datum of Australia 1994 (GDA94)
Grid coordinates	(UTM using the GRS80 ellipsoid) Map Grid of Australia 1994 (MGA94)
Reference Frame	(International Terrestrial Reference Frame 1992)
Epoch	1994.0
Ellipsoid	GRS80
Semi-major axis	6,378,137.0 metres
Inverse flattening (1/f)	298.257222101

SOUTH AMERICA

The establishment of a South American Geocentric Reference System (Sistema de Referencia Geocéntrico para América del Sur, SIRGAS) was initiated in October 1993 and organized by the International Association of Geodesy (IAG), the Panamerican Institute of Geodesy and History (PAIGH), and the U.S. Defense Mapping Agency (DMA; now called NIMA). The objectives of the project were to define, establish and maintain the reference system for South America and define the datum to be used by the countries in this continent. The decision was to establish a reference system that will coincide with the IERS standards and refer to the IERS Terrestrial Reference Frame (ITRF), which means creating a geocentric datum with ellipsoid parameters adopted to the GRS80. Three working groups were formed to tackle three major issues: Reference System, Geocentric Datum (horizontal), and Vertical Datum.

Fifty Eight (58) sites across the South American mainland and surrounding areas were selected to form the main framework. These sites were observed simultaneously during a continuous GPS campaign from May 26, 1995, 0:00 UT to June 4, 1995, 24:00 UT. The collected observation data were made available at two data centers at Deutsches Geodaetisches Forschungsinstitut (DGFI), Munich, Germany and Instituto Brasileiro de Geografia e Estatística (IBGE), Rio de Janeiro, Brazil.

The data processing was done separately by DGFI and the National Imagery and Mapping Agency (NIMA), USA using two different softwares (Bernese at DGFI and GIPSY at NIMA). The independent results were combined and transformed to the ITRF 94 using nine identical stations of the International GPS Service (IGS). The precision of the main station coordinates is in the sub-centimeter level.

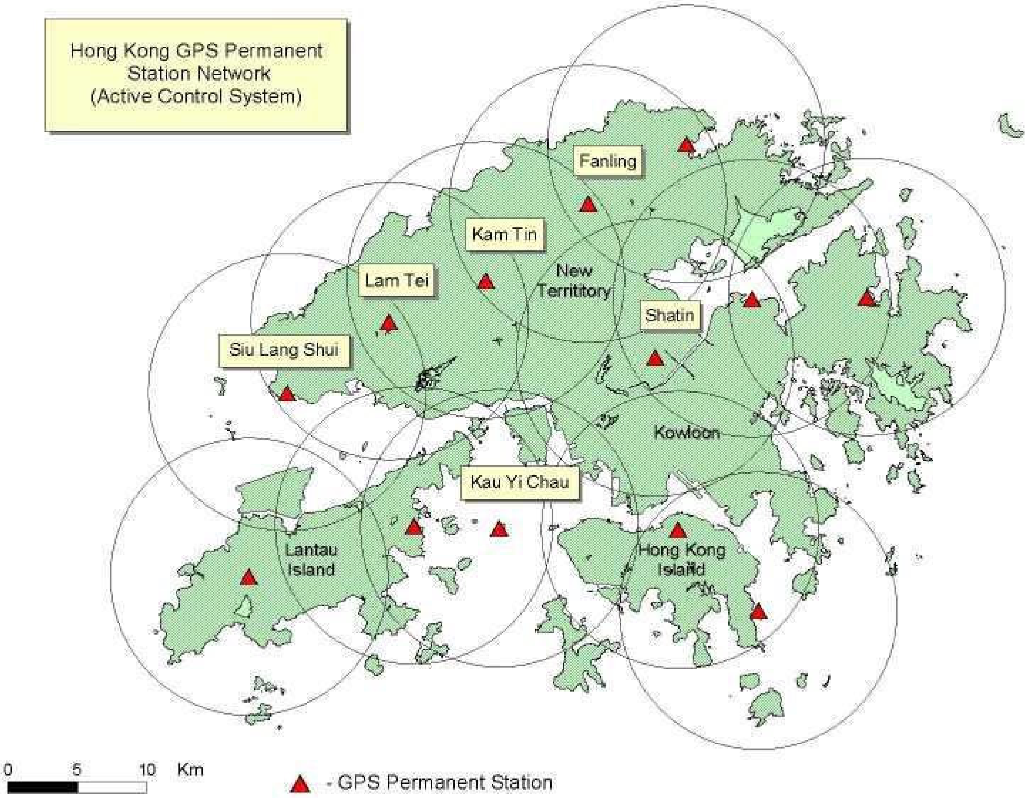
The processing methods and results were discussed during project meetings held in 1996 and 1997. The final station coordinate solution was adopted as the official SIRGAS reference frame and recommended to be used by all South American countries as the basis for their national reference frames.

At present, nearly all South American countries have adopted the SIRGAS frame with new GPS network stations being installed including the tying of old triangulation networks. The typical spacing between stations is 100 km. Further densification for lower order networks have also begun.

For the vertical datum it was recommended to include normal heights aside from the ellipsoidal heights. A network of stations for this process (as of 1998) realizing the vertical reference frame and being observed by GPS is in preparation.

ASIA

HONGKONG



The Lands Department in HongKong has established an active permanent GPS Station control network consisting of 13 geodetic stations that continuously collect GPS data (similar to CORS). These stations will be used to define the geodetic framework.

KOREA

Korea have changed their geodetic coordinate system to geocentric using GPS technology. This is to be able to establish a more accurate national control of points for 2003. In order to meet the international standard, they revised their Survey Law to make possible the use of satellite technology.

To avoid confusion however, they have informed the public that all surveys can use both Tokyo Datum and International Geodetic system until December 31, 2006. (Ministry Construction and Transportation, Notification #2002-304, 02.12.31).

Their new geodetic datum is KTRF with the following parameters:

Spheroid	Geodetic Coordinate System
Ellipsoid (GRS80) - major axis : east-west direction 6,378,137m - minor axis : south-north direction 6,356,752.3m	ITRF2000
Geoid Model	EGM96

The degree of accuracy degree of the GPS control stations is expected to be horizontally 3cm and vertically 10cm.

Their specifications are as follows:

GPS Permanent Observation Network: 1st order control point
GPS permanent observation stations arranged every 50 Km all over the country. (14 stations are running now. It is being discussed to install more stations or use GPS permanent observations stations with other organizations.)

GPS Geodetic Control Point Network: 2nd order control point
GPS stations 240 points among the 1st and 2nd order triangulation points and the 1st order leveling points all over the country are assigned at intervals of 20-30km.

The National Control Point Maintenance: 3rd order control point
Currently consisting of 16,000 control points tied to second order network

JAPAN

The Geographical Survey Institute (GSI) has a new geodetic reference frame for Japan using space geodetic techniques. Due to the large internal distortion of the previous datum (Tokyo Datum) and there was a shift to a geocentric reference frame.

The new framework is compatible to ITRF94 (International Terrestrial Reference Frame 1994) at the epoch of 1997.0. The coordinates of the Kashima VLBI station are determined in ITRF94 using the data from international VLBI observations. Positions of two additional VLBI stations are determined referenced to Kashima VLBI station using the data from domestic VLBI observations. The coordinates of 950 stations in the nationwide permanent GPS array were determined using these three VLBI stations as anchor points. The coordinates of the first- to third-order triangulation points are calculated by referring to the GPS array. GSI resurveyed 6300 of first- to third-order triangulation points using EDM or GPS.

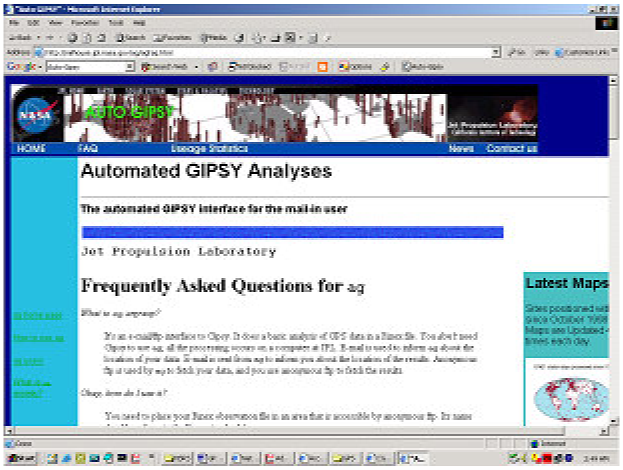
The coordinates newly determined for VLBI stations, GPS stations, and triangulation points are the realization of Japan's new geodetic reference system. GSI named the new datum as the Japanese Geodetic Datum 2000 (JGD2000).

The Geographical Survey Institute of Japans' GEONET used for scientific and geodetic research uses almost a thousand continuously receivers (both dual and single frequency receivers) with station separation of 20-30km.

AVAILABLE ONLINE/WEB-BASED GEODETIC PRODUCTS AND SERVICES

Listed below are online services which offer GPS post processing of worldwide data. The offered services are different from site to site.

USA



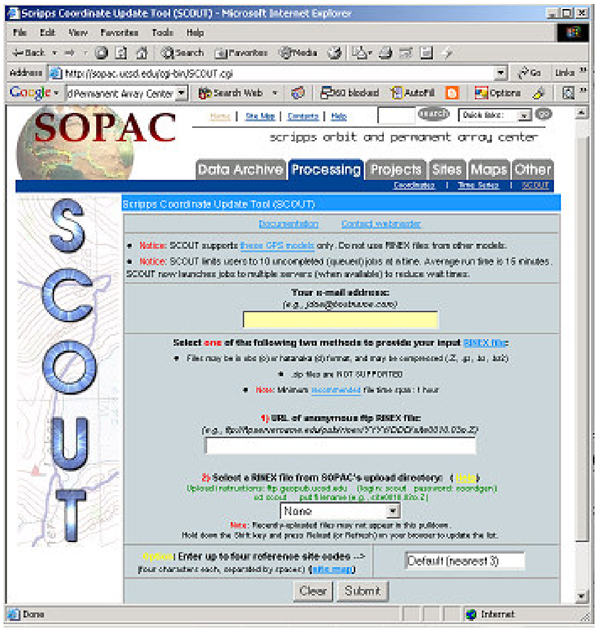
Automated GIPSY Analyses

The automated GIPSY interface for the mail-in user

Jet Propulsion Laboratory

Frequently Asked Questions for ag

The NASA Jet Propulsion Laboratory's Auto-Gipsy Service is a mail-in processing service where a user has to have an email account and access to an anonymous ftp server on which to store the GPS data. The user simply needs to send an email to a certain URL address. A reply email with the title "Output" will be sent to the user within 5-10 minutes, depending on the number of jobs in the queue. The body of the email will contain the ftp addresses of the results file.



Scripps Coordinate Update Tool (SCOUT)

- Notice: SCOUT supports these GPS models only. Do not use RINEX files from other models.
- Notice: SCOUT limits users to 10 uncompleted (queued) jobs at a time. Average run time is 15 minutes. SCOUT now launches jobs to multiple servers (when available) to reduce wait times.

Your e-mail address:

Select one of the following two methods to provide your input RINEX file:

1) URL of anonymous ftp RINEX file:

2) Select a RINEX file from SOPAC's upload directory: (Help)

Option: Enter up to four reference site codes -->

The Scrippts Orbit and Permanent Array Centre **(SOPAC)** Coordinate Generator has a user friendly web interface including useful help links.

AUSTRALIA

The Australian Surveying and Land Information Group's (AUSLIG) Online GPS Processing Service (AUSPOS) provides users with the facility to submit via the Internet (i.e. upload GPS RINEX data), dual frequency GPS RINEX data observed in a 'static' mode and receive precise coordinates quickly. Results are sent via email or anonymous ftp. The service is free and provides both ITRF and GDA94 coordinates. This internet based service takes advantage of both the International GPS Service (IGS) product range and the IGS GPS network and it works with GPS data collected anywhere on Earth.

AUSPOS has the following features:

- an easy to use web page interface;
- dual frequency geodetic GPS data processing capability;
- standard web-browser direct upload or ftp;
- highest quality global GPS processing standards;
- 24 hour x 7 days a week service;
- rapid processing turnaround, < 15 minutes/file;
- results returned by email and ftp server;
- applicable anywhere on Earth; and
- GDA94 compliant for Australian users, ITRF elsewhere.

Research and Development

Research over the last few years has demonstrated the advantages of carrier phase-based, integrated positioning techniques that take advantage of *network-based processing strategies* (in place of conventional single baseline processing) such that:

- Rapid static and kinematic GPS positioning techniques can be used over baselines many tens of kilometres in length.

- Single-epoch OTF-AR algorithms can be used for GPS positioning, at the same time ensuring high accuracy, availability and reliability for critical applications.

- Rapid static positioning is possible using low-cost, single-frequency GPS receivers, even over tens of kilometres.

- Baseline-dependent biases can be modelled using multiple reference stations.

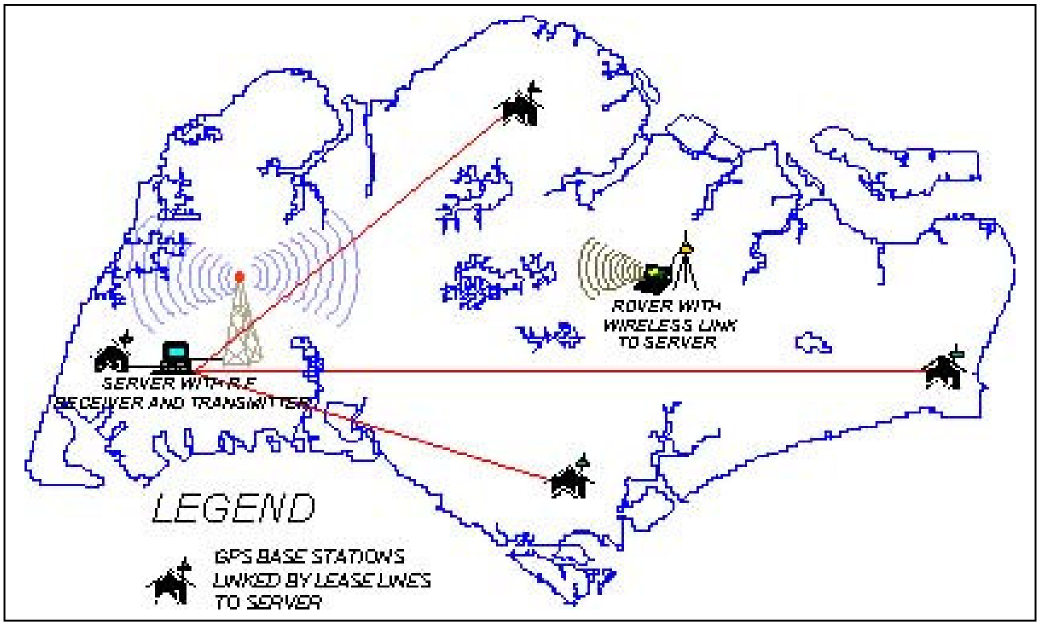
The technical benefits for this technique are:

- Elimination of orbit bias and ionosphere delay.
- Reduction of troposphere, multipath and observation noise.

Applications being foreseen are:

- Instantaneous ambiguity resolution can be extended to medium-range.
- Low-cost single frequency receivers can be used for rapid static positioning over shortrange,
- and also medium-range.
- Very high accuracy applications using GPS positioning techniques.

Using redundant vectors where we can tie our station not only using one base (minimally constrained) but to two or more redundant base stations (over constrained solution), studies have shown that the effective distance can be increased tremendously by more than a factor of three and still achieve a less than 1ppm accuracy level with observation times of 1 to 5 hours.
An existing system is now available in Singapore and Japan with accuracies of 1-2 ppm being achieved for station lengths of up to 60 km.



Research and Development in data modeling has already advanced to a point using (advanced code and carrier phase post processing techniques such as integrated smoothing and doppler) that we can already readily achieve high accuracy even at longer baseline measurements.

GPS receiver design have improved tremendously over the past decade such that receivers have better tracking and locking capabilities, more resistant to multi-path, have less noise (higher SNR), can cope with anti-spoofing, yield full wavelength carrier phases on L1 and L2, and can observe both GPS and GLONASS satellites.

A new range of applications are opening up not only surveying/geodetic applications, but also for location based services, mobile applications, tracking, monitoring, scientific research, engineering and civil aplications, GIS applications, etc. These enhancements will help in paying off the operational expense of setting-up and maintenance of these stations. These stations can be operated for free by government or by pay-per-service by private companies. In addition to supplying GPS observational data needed for relative positioning, a reference station may also, depending on its configuration, contribute to a variety of efforts such as the generation of precise satellite ephemerides and clock correction data for crustal motion monitoring, and atmospheric and earth rotation studies.

This development also helps the surveyor in that he does not have to acquire expensive dual frequency receivers (single frequency will do). In addition, a single GPS receiver will do the entire job.

Separate studies in the US and Canada have shown that using dual frequency GPS receivers and conventional static processing method and only using broadcast ephemeris data, that it is possible to get 0.052 PPM horizontally and 0.217 PPM vertically between CORS stations which on the average span distances greater than 1000 km. Convergence to these accuracies was possible with a minimum observation time of 6 hours. The use of precise ephemeris data can further improve these results.

We are nearing the end of the 11 year solar cycle where the effects of solar activity is at its minimum this coming 2004, therefore ionospheric effects is also at its minimum allowing us use of low cost single frequency receivers and enabling shorter GPS observation times.

RECOMMENDATIONS

1. Intensify efforts to determine our need to improve and upgrade our existing geodetic network.

2. Intensify collaborative and collective research and development in academe, private and government.

3. It is recommended to upgrade the local surveying profession to be informed and educated on modern methods and technologies which emphasize on quality assurance and control.

4. It is recommended to upgrade the local standards and specifications to meet internationally accepted standards.

5. Intensify information dissemination on GPS technology and standards.

6. It is recommended that the Philippines adopt a new geocentric datum that is aligned with WGS84 or ITRS (ITRFxx).

7. It is recommended that points coordinated in the datum not have fixed coordinates but the coordinates be continously monitored, maintained and upgraded as required due to earth movement (i.e due to crustal deformation and geoid changes).

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