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ABSTRACTS

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МОНГОЛ УЛСЫН ШИНЖЛЭХ УХААНЫ АКАДЕМИ
ОДОН ОРОН, ГЕОФИЗИКИЙН ХҮРЭЭЛЭН

МОНГОЛ УЛСЫН ШИНЖЛЭХ УХААНЫ АКАДЕМИ
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Table of Contents

Algeria

A GNSS Processing Approach to Establish a Large Geodetic Network (RGSH2020) for Petroleum Applications

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As part of the project relating to the establishment of the geodetic network (RGSH2020) for the Algerian petroleum company (SONATRACH) by the use of the GNSS technique, a network of twenty two (22) stations distributed over the Algerian national territory (covering an area greater than 2.38 million kilometers) is observed in static mode with Trimble NetR9 GNSS receivers and Geodetic Zephyr Model 2 and Choke Ring antennas. GNSS observations are collected in two (02) continuous campaign sessions: from Febru-ary 10 to 12 and from March 6 to 09, 2020 with five (05) common stations for both ses-sions. Data from sixteen (16) IGS (International GNSS Service) stations closest to RGSH2020 network are included in the processing. The processed baselines vary from 300 km to over 2000 km. A densification of this network is done by adding 200 second-ary points using GPS and GLONASS observations.

GPS data are analyzed by using “Bernese v5.0” software. Daily (24h) sessions are pro-cessed in order to average errors such as the day/night alternation effect on the tropo-sphere and the ionosphere and the effect of the geometric variation of the satellite con-stellation. The final combined IGS orbits are used. The Earth's rotation and its variations during observation campaign are modeled from parameters provided by the IERS (Inter-national Earth Rotation and Reference Systems Service). The polar solid tides model is used. As well, the elastic response effects to ocean tides are modeled using the FES2004 model. The modeling of the delay undergone by the GPS signal when crossing the tropo-sphere is initialized by applying the Saastamoinen model for the hydrostatic part, and by estimating a zenith delay parameter for each site every hour. For the ionosphere, the Iono-sphere-Free combination is used to eliminate its effect.

To assess the results quality and validate the estimated solution, several indicators are used (RMS, repeatability, percentage of resolved ambiguities, difference between float and fixed solutions, and comparison of the estimated solution to a set of a reference IGS stations). The obtained RMS and the daily station coordinates repeatabilities are at the millimeter level for the horizontal and vertical components. The resolved ambiguities rates are greater than 76% which indicate the good quality of the solutions. The obtained results show that the differences between the "fixed and float" solutions are less than 02 cm which confirms that the fixed solutions do not include errors that may be due to incorrect fixing of ambiguities.

Another factor of validation is the agreement of the estimated solution with a known set of IGS reference stations, and their calculated coordinates are compared to the true coordinates after a Helmert transformation. The obtained residuals from a subset of IGS sites are slightly larger than the repeatabilities but they are of the same order of magnitude.

These statistics show that the RGSH2020 network is determined with millimeter accuracy (<1 cm). This accuracy is considered sufficient for all applications carried out by SONATRACH (geodesy, GIS, etc.). The RGSH2020 is linked to the IGS14 reference frame at the median epoch of observation (February 24, 2020).

Algeria

Real studies and simulation of EGNOS system in Algeria

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EGNOS (European Geostationary Navigation Overlay Service), is an augmentation system developed by the Europeans, it offers to users a high performance, better than the currently available by GPS. It will improve position accuracy by correcting several sources of errors affecting GPS system and will provide users information on the integrity of GPS signals in real time. The improvement of GPS accuracy by EGNOS essentially based on the use of the various corrections, which merit to be studied, tested and compared.

The motivation of this presentation is to evaluate the quality of GPS/EGNOS positioning in different latitudes in Algeria, taking into account that no RIMS (Ranging and Integrity Monitoring Station) station is installed until now. The EGNOS results obtained are compared, for several Algerian sites at different latitudes on February 2020, to those provided by precise GPS bi-frequency relative positioning processed from IGS stations using the Bernese Software.

The results of the analysis showed a significant improvement in the present accuracy of EGNOS values for sites located at latitude greater than 27° compared to the results obtained for sites below this latitude. The results revealed that the accuracy of GPS + EGNOS is significantly better than GPS alone. This is mainly due to corrections provided by EGNOS, in particular the ionospheric corrections. Nevertheless, for low latitudes (less than 27°) the accuracy using EGNOS corrections can exceed 13.86 m when it is not more than 3 m in GPS only.

This study confirmed that the distance from the RIMS network is significant in relation to the consistency of the corrections transmitted by EGNOS. These corrections are progressively degraded when the sites are located far from the service area covered by the RIMS stations. The installation of RIMS stations can improve the results, particularly in southern Algeria.

In the second part, the study is carried out on the simulation feasibility of setting up of two EGNOS RIMS stations and the optimal choice of a second station in the south of Algeria, considering a station in North. The results show that the performances of EGNOS system in terms of availability and ionospheric grid are improved, in particular in the area between 0° and 5° in longitude and 25° in latitude. These preliminary results, which are particularly useful for civil aviation applications, can be extended with the availability of more complete coverage in Algeria, with the planned installation of two RIMS stations.

Brazil

Education and Research Activities Related to GNSS Performed in the Graduate Program in Engineering at INPE

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The National Institute for Space Research (INPE) is a federal institute located in Brazil, which aims to study and develop activities related to space. Besides research and applications, it has several graduate programs in the space field, all of them included in the federal Internationalization Program called PrInt, organized by a federal funding agency called Capes. This program started in 2019 and it is giving an increase in the mobility of students. One of those graduate programs is the Engineering and Space Technology Program, which is a graduate program covering master and doctoral levels. Several aspects of aerospace engineering are covered in this program, including astrodynamics, orbit and attitude control, material science applied to spacecraft, propulsion and combustion, management of aerospace projects, etc. Among other types of satellites, global navigation space systems are also studied in all those aspects, since the field of GNSS is a very important theme in space activities, both in terms of the space system itself and in terms of possible applications. There are many aspects that need to be considered for research in terms of theoretical foundations of new techniques that may appear, as well as applications of well known engineering tools. Those topics are worth studying at all levels, including masters and doctoral levels. In this sense, education in GNSS-related fields is an important part of our activities to get the most out of these systems. It is very important to have new generations with technical skills to use and/or make improvements to one of these systems.

The course now has about 10% of international students, and is working to increase this international participation, since we were selected to be part of the internationalization program PrInt. Under this program we receive financial support for scholarships to bring visitor professors to our institute for shorter periods (up to three months) and pos-doctoral researches for 24 months to develop joint research with our professors and students. We also have funding for our students and professors to stay abroad, for up to one year for students and three months for professors. Master and doctoral international students can also apply for acceptance and our regular scholarships, although there is no specific funding from PrInt for those levels. Our courses have no tuition fees and the usual requirements and length of the courses are: 1) two years for the Masters program, usually eight months of classes and sixteen months of research, which should result in an individual thesis to be presented to a faculty committee; 2) Four years for the PhD program, with about twelve months in disciplines and 32 months to develop an original research, which has to result in a Dissertation, also to be submitted to a committee of professors. The program also has a "qualification exam", which covers all aspects of the main courses. This new Program was interrupted in 2020 due to the pandemic situation, but is expected to be open again to exchange students in 2022.

China

Development of BeiDou Navigation Satellite System (BDS)

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On July 31st, 2020, President Xi Jinping of the People's Republic of China, announced to the world that the BeiDou-3 Navigation Satellite System was completed and officially put into operation. Since the official operation of BDS-3, the system has been running smoothly. According to worldwide test and assessment, the average measured global positioning accuracy of BDS is 2.34 meters.

At present, BDS can provide seven kinds of services. The positioning, navigation and timing service, global short message and international search and rescue are global services; while satellite-based augmentation, ground-based augmentation, precise point positioning and regional short message communication are the regional services covering the Asian Pacific areas.

With the improvement of the service capability of BDS, the application industry chain is improving. At present, BDS has built a complete industry chain integrating chips, modules, antennas, boards, terminals, and operation services. The BDS chips and modules supporting BDS-3 have entered the mass production stage.

In the past decade, the total output value of China's satellite navigation and location-based service industry has increased by more than 20% on an average annual basis, exceeded RMB 400 billion Yuan in 2020.

BDS has fully served transportation, public safety, disaster relief, agriculture, forestry, animal husbandry and fishery, urban governance, and other industries, integrated into the power, finance, communications and other infrastructure, extensively entered the field of mass consumption, shared economy, and people's livelihood, profoundly changed people's production and life style, and produced significant economic and social benefits. In mass market, the applications of BDS become more and more popular.

With the purpose of “serving the world and benefiting mankind”, BDS adheres to the development principle of “independence, openness, compatibility and gradual progress”, carries out practical international cooperation and exchanges, and jointly promote the development of GNSS community.

China

Construction of an Integrated Intelligent Supervision Platform for Mongolian Mining Based on BeiDou Short Messages

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Based on the “China-Mongolia Economic Corridor Mine Integration Project (CM-ECMIP)” jointly signed by China and Mongolia in 2019, relying on a variety of “BeiDou +” technical means including BeiDou short message, BeiDou high-precision positioning, UAV high-precision mapping, remote sensing high-precision mapping and so on, we aim to build a Mine Intelligent Supervision Platform for the implementation of the “CM-ECMIP”. The specific construction content includes: (1) Monitoring system of open pit mining based on remote sensing; (2) UAV Mining Area 3D visualization system based on GIS; (3) Mining vehicle supervision system based on high-precision location service; (4) Transportation vehicle dispatching management system based on BeiDou short message. By building a Mine Intelligent Supervision Platform for the “CM-ECMIP”, we can solve the current problems of imperfect information monitoring methods, limited location information communication, vehicle communication loss, and outdated job evaluation methods during the mining process of the Tavan Tolgoi mine (TT mine) in Mongolia, and provide service support for coal mining of TT mine, road transportation in Mongolia and warehousing logistics, etc. The construction of Mine Intelligent Supervision Platform also serves as a reference and demonstration role for the comprehensive applications of various “BeiDou+” technical means like BeiDou short message and BeiDou high-precision across the world.

China

High Precision GNSS Application in Mongolia Mining

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In recent years, as global navigation satellite systems, regional systems, and augmentations developed, the stability and reliability of GNSS positioning have been comprehensively improved. And with more commercial companies joining the research of GNSS technology, GNSS end-user products are becoming more cost-efficient. Meanwhile, the great application of GNSS in smart terminals and various professional tools is bringing about a positive impact to people's daily life, economic growth, and industrial development.

Mining, as one of the most important industries throughout the development of human society, plays an important role in economic growth and people's daily life. Combined with the typical cases and projects carried out in Mongolia, this presentation introduces the applications of BDS-based high-precision equipment in mining, especially geological disaster warning and monitoring, mine surveying and mapping, as well as safety monitoring system for vehicles and personnel in mining area. The wide-ranging applications have greatly promoted intensive mining, improved productivity and production safety in mining, making a great contribution to local economic development.

China

BeiDou International Application – Dam Deformation Monitoring in Salez Lake

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The report is mainly introduced in three parts: 1. Describe the global demand for ubiquitous deformation monitoring and the mature and widely successful application of Beidou deformation monitoring technology; 2. Introduce the dam deformation monitoring scheme of Salez Lake based on Beidou technology, including dam background, preliminary investigation, overall scheme, communication hardware scheme, positioning technology scheme, software scheme, monitoring test, etc.; 3. Describe the design and use about the open service platform of Beidou deformation monitoring.

China

Space Weather Science and GNSS System

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The relationship between space weather science and GNSS system was presented, especially the importance of GNSS signal in the ionosphere detection subject. Also, some space weather research cases were reported, such as application of GNSS signal in the detection of the interplanetary shock, application of GNSS satellite observations in prediction of high-energy electron storm in Von Allen radiation belt. According to the prediction that the solar activity will be stronger in future several years and considering the space weather event will be global change of the space environment, a suggestion was proposed that different GNSS systems should stand together to meet the threat of severe space weather event. At last, list of space weather payloads onboard BeiDou satellites was demonstrated.

China

Application of BeiDou/GNSS in spacecraft autonomous navigation

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This report introduces the requirements of spacecraft autonomous navigation, the various applications of BeiDou / GNSS system in low-orbit and high-orbit spacecraft, including the challenges, methods and application effects of GNSS spacecraft applications. The full report is divided into four parts.

1. Spacecraft autonomous navigation requirements

In view of the limitations of existing measurement and control methods for on-orbit spacecraft, the urgency of autonomous navigation needs is compared. According to the GNSS application requirements of spacecraft with different orbit heights, the GNSS application technologies of spacecraft are classified and analyzed.

2. Application of BeiDou / GNSS in LEO spacecraft

There are two kinds of BeiDou/GNSS applications of LEO satellite. One is relative measurement technology, which has been used in Chinese space station rendezvous and docking. And the other is BeiDou / GNSS high-precision orbit determination, which has been used in most LEO satellites orbit determination.

3. Application of BeiDou / GNSS in high-orbit spacecraft

This part focuses on the BeiDou / GNSS leak signal orbit determination technology and application effect in high-orbit deep space exploration, which is represented by lunar exploration.

4. Future application prospect

With the development of GNSS technology, the integrated BeiDou/GNSS/Short Message measurement and control applications will be realized. Multi GNSS signals will be used for environmental monitoring.

China

Applications of BeiDou System in Transportation

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The transportation industry is one of the largest industry users of satellite navigation. This report introduces the applications of BeiDou system in the transportation industry through typical application cases. The report is divided into three parts, the overview of BeiDou applications in the transportation industry, the application cases of BeiDou in the transportation industry, and the development prospects. Starting with the application requirements of safety supervision, digital intelligence transformation, safety communication, and distress search and rescue in the transportation industry, this report introduces the typical application cases of the BeiDou system in road transportation, smart ports, maritime safety, and international search and rescue, with RNSS, high-precision positioning, short message communication, and MEOSAR involved.

Croatia

Environment-adaptive GNSS position estimation deployed in distributed GNSS software-defined radio receiver

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Satellite navigation has become an essential cornerstone of modern civilisation, and an indispensable component of the national infrastructure. The increasing number of both navigation and non-navigation applications utilise the GNSS Positioning, Navigation, and Timing (PNT) service for technology and business development, daily operation of technology and socio-economic systems, and improvement of the quality of life. The inherent shortcomings and limitations of GNSS ask for a transition towards the GNSS resilient to natural and artificial detrimental effects, which degrade the GNSS positioning performance. Here an environment-adaptive GNSS position estimation process is proposed, comprising a novel GNSS software-defined radio architecture and position estimation algorithm, based on the recent developments in statistical learning, sensor information fusion, and computer science. The proposal facilitates sensor information fusion-based situation awareness and tailored statistical learning-based adaptive correction models self-development and deployment, thus declining the need for the expensive GNSS augmentation infrastructure deployment and operation. The advanced computer science developments allow for formulation of the Satellite Positioning-as-a-Service (SpaaS) position estimation process independent from a traditional GNSS augmentation infrastructure, as the new fundamental paradigm for resilient GNSS. Finally, the effects of the SpaaS on the wide range of GNSS applications in science, economy, and society are discussed. The contributions to SPaaS concept and the related developments through the application of statistical learning, mathematical methods and models development, and applications discussed result from the author's involvement in numerous international strategic, technology, regulatory, standardisation, business, and academic education development and collaboration activities.

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Croatia

A Risk Assessment of Geomagnetic Conditions Impact on GPS Positioning Accuracy Degradation in Tropical Regions Using DST Index

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A risk assessment of GNSS PNT service degradation determines quality of services (QoS) of GNSS-enabled applications. Space weather, geomagnetic and ionospheric conditions were found to be the major causes of the GNSS positioning performance degradation. Here we address the problem of estimating the long-term risks of the GNSS PNT quality degradation for GNSS-based applications, especially for GNSS air, maritime, and Location-Based Services (LBS) applications in tropical regions. We collected a large database of single-frequency GPS positioning error vector estimates calculated from experimental stationary GPS pseudorange observations at the International GNSS Service (IGS) reference station at Darwin, NT, and merge it with the Kobe University hourly Dst index of geomagnetic activity estimates. We analysed the statistical properties of the GPS positioning error vectors in classes of geomagnetic conditions, determined with Dst index values. Failure of single-frequency non-aided GPS positioning accuracy to meet the recognised requirements for GNSS air, maritime and Location-Based Services is found. Furthermore, we find of a number of cases in which the smoothed GPS positioning error vector exceeded the limits acceptable for GNSS air, maritime, and LBS applications, serving as outliers. The expected risk based on the long-term GPS positioning error vector observations is determined from the number of outlier cases of selected GNSS air, maritime, and LBS applications in selected ranges of Dst index values. This allows for the risk estimation of GPS positioning performance not meeting the requirements of GNSS applications requirements in specific geomagnetic conditions, as determined with Dst values. Finally, we consider the other potential GPS positioning performance disruption candidate descriptors, validate, and identify those that may serve in the GNSS deployment risk assessment for targeted GNSS-based applications.

Employment and use of GNSS in the Republic of Cuba

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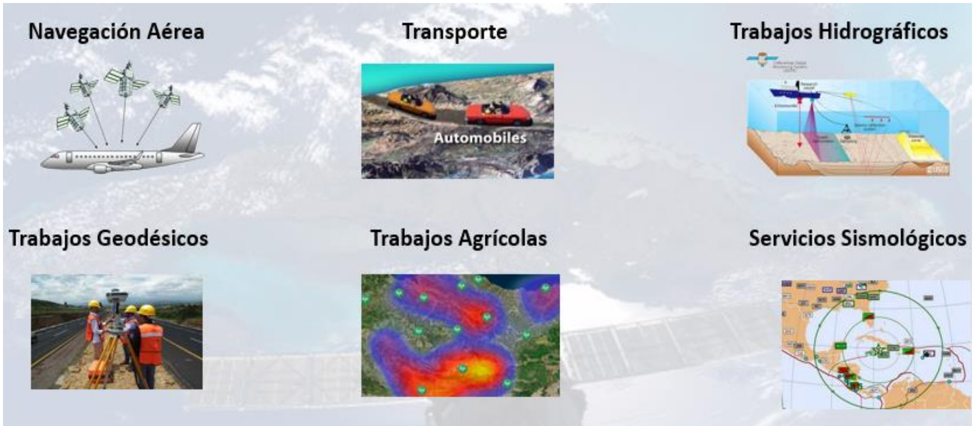
A global navigation satellite system (GNSS) is a constellation of satellites that transmit ranges of signals used for positioning and location in any part of the globe (whether on land, sea or air) example of these satellite navigation systems we find the GPS, GLONASS and the recent Galileo.

These satellites allow the altitude and geographic coordinates of a given point to be calculated as a result of receiving signals from constellations of artificial satellites on Earth for various purposes such as:



How does our country use Global Navigation Satellite Systems (GNSS)?

Transportation: In 2006 in our country, the introduction of a fleet control system began gradually, which has been improving, maintaining as its main purpose the contribution to greater efficiency in the operation of transportation and saving fuel, we currently have a software called MovilWeb, it is a Web-based vehicle location application for mobile tracking on vector and raster cartography, designed to control fleets within a client-server architecture. This tool allows the monitoring of mobiles remotely over a communications network, making it possible to reconstruct the behavior of the vehicle in a certain period of time, reworking its trajectory and analyzing its speed, stops at authorized or not authorized destinations, etc. Through the information stored in a historical database, it provides the user with a group of tools for the management of maps, similar to the tools of professional software for the management of Geographic Information Systems.

Air Navigation: In 1998 a network of 20 stations was formed, called the Fundamental GPS Network (RGF), determined in a measurement campaign with the use of the high precision Global Positioning System (GPS), referred to the datum of the International Framework Terrestrial Reference of the year

1996 (ITRF96), 1998 time for the adoption of the World Geodetic System of the year 1984 (WGS84) in the inter-est of the civil aeronautics of Cuba.

Agricultural Work: the use of GPS allows farmers to collect data on their farmland, either during harvest or prior to it, in such a way that today, crops no longer necessarily have to be treated as an area of terrain with homogeneous characteristics, but can be treated according to their spatial characteristics.

Hydrographic works: Currently, thanks to technological advances and the improvements that satellites are having for the study of the marine environment, topographic surveys are carried out using satellites and the use of remote sensing. This technology allows the use of high resolution satellite images to determine depth ranges based on the wavelength of the spectral bands in the image.

Geodetic Works: Having the use of global positioning techniques by satellites, we have been able to satisfy the needs of topographic mapping at different scales as well as different scientific-technical applications at the national level for the Economy and Defense of the country. Studies of the earth's crust and climate changes have been carried out, supported by a Permanent Network of Global Navigation Satellite Systems (GNSS), studies have been carried out for the delimitation of hydrographic basins using digital terrain elevation models, topographic surveys with GPS of a specific area, has allowed us to determine areas for livestock development and comprehensive environmental studies.

The Global Navigation Satellite Systems (GNSS) are also used for the Seismological Service of our country, all permanent, telemetric and field seismic stations use GPS receivers of a single channel, guaranteeing the UTC time and the compatibility of the scale of time for data exchange and analysis.

Results achieved in the modernization of the State Geodetic Network through the use of GNSS.

High Precision Geodetic Networks

The created High Precision Networks are divided into two GNSS orders:

- First order: Composed of the Fundamental Geodetic Network (RGF), the GNSS Validation Polygons (PVG) and the Permanent Geodetic Network (RGP).
- Second order: Composed of the Basic Geodetic Network (RGB2).

The essential GNSS networks

The RGF is made up of 41 stations and was built in two stages: from April to November 2015 and in March 2017. In turn, the first was created in two moments: 20 points were occupied for a space of 3 days (RGF1), while in the second (RGF2) in two sessions of 12 hours, in all cases forming quadrilateral figures with common sides.

The GNSS Validation Polygons (PVG)

Two polygons were created: in the western (Western GNSS Validation Polygon) and eastern (Eastern GNSS Validation Polygon) of the country. The main objective of these is to have a network of geodetic points with precise coordinates, which serve as a standard to validate the GPS technology available to the GEOCUBA Companies. This will allow you to meet the quality requirements imposed for the certification of your metrological laboratory.

Permanent GNSS Network

The RGP began to be created at the end of 2016, starting as a network in mid-2017 and currently consists of twelve stations. The results obtained in the mathematical elaboration of the RGP show the high quality of the geodetic positioning in its stations, so that the values of its coordinates can also serve as a reliable reference for GNSS determinations in the framework of different projects and applications. By obtaining the values of the annual coordinate velocities, in terms of mm per year, it is possible to reduce these magnitudes to the desired time and provide a higher level of certainty during precise GNSS determinations in different projects, since the framework of reference is no longer static.

Permanent GNSS Network

As a frame of reference for determining the coordinates and speeds, 16 IGS (International Navigation Systems Service) stations located around Cuba were used, of which 14 are global stations, with average distances with respect to the geometric center of the country, corresponding 1000 km (RDSD station) and 3200 km (NIST station). Figure 5 shows the distribution of these IGS stations.

The Basic Geodetic Network of 2nd order

RGB2 is made up of 95 stations. The works for its construction were developed during 2016 and early 2017.

Conclusion

Currently, work is under way to create RGB3, which will be made up of about 900 points (simple monuments). This, together with the RGF, the PVG, the RGB2 and the RGP will constitute the State Geodetic Network of the country. The RGN is expected to have a density of 1 point per 100 km2.

El Salvador

The use of GNSS systems in the Geodesy management of the National Registry Center

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History of Geodesy in El Salvador

Throughout the history of El Salvador, various works have been carried out aimed at determining the shape and dimensions of the national territory. These works gave rise to different networks materialized as points on the ground with higher or lower coverage densities and acceptable precision values. Achieving that in the decade of the 50's and 60's the first geodesic networks were established with an approximate of 1500 points or vertices throughout the country.

It is in the 90's when the first measurement works with GPS equipment began in the country and the handling of raw data and its post-processing in special programs for the handling of satellite information.

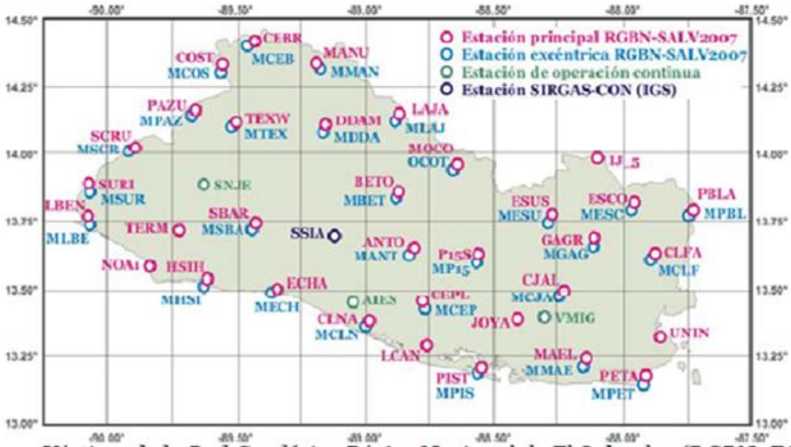
The vertices SOLEDAD, SCORPIÓN, and SAN DIEGO NORTH, were the first points measured over 72 hours continuous (absolute measurement) and post-processed by the National Imagery Mapping Agency (NIMA).

National Geodesic Network

The coordinates on the surface of the Earth vary as a function of time as a consequence of the movements of tectonic plates, the abrupt movements caused by earthquakes that change the coordinates sporadically and randomly. That is why the position of the geodesic vertices in El Salvador can vary from 1 to 3 cm per year. Due to this, maintenance and updating of the departmental geodetic networks is necessary. The National Basic Geodesic Network of El Salvador (RGBN_ES2007) is made up of 38 stations distributed homogeneously over the national territory. The main objective of RGBN_ES2007 is to provide a modern, accurate and reliable reference platform to producers and users of georeferenced information in the country.

National Basic Geodesic Network

Next, the National Basic Geodetic Network is presented, which serves as a reference for adjusting the networks and thus obtaining geodetic positions directly referred to the current ITRF.



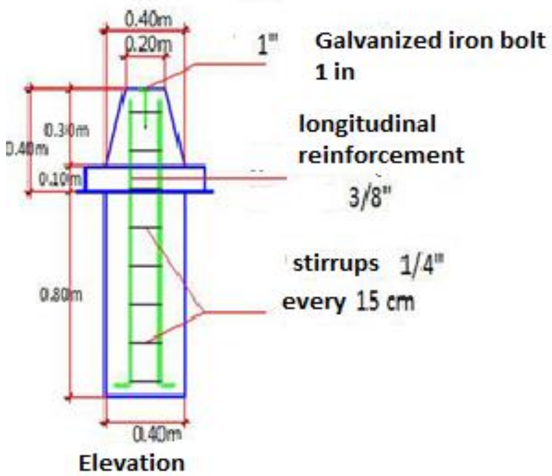
Vértices de la Red Geodésica Básica Nacional de El Salvador (RGBN_ES2007).

ITRF: International Terrestrial Reference System

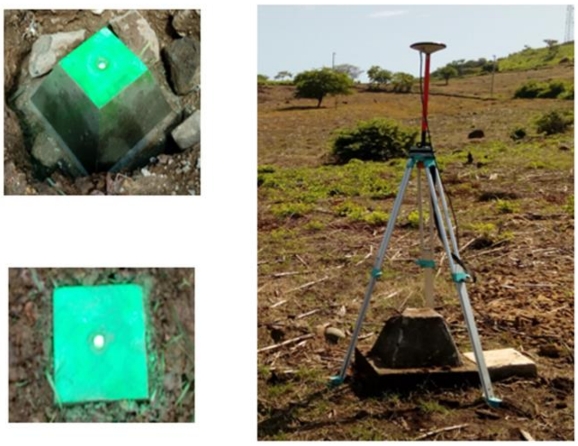
Vertice Geodesic and Marks of Azimut

Geodetic vertices and Azimuth Marks (MKZ) or vertex of back view, are points whose horizontal and vertical position have been obtained from high-precision geodetic surveys with the use of differential GPS, physical-ly materialized on the ground by means of a cairn or Truncated pyramidal concrete monument with a central plate or pin with a mark embedded in concrete.

Geodetic Vertice Materialization



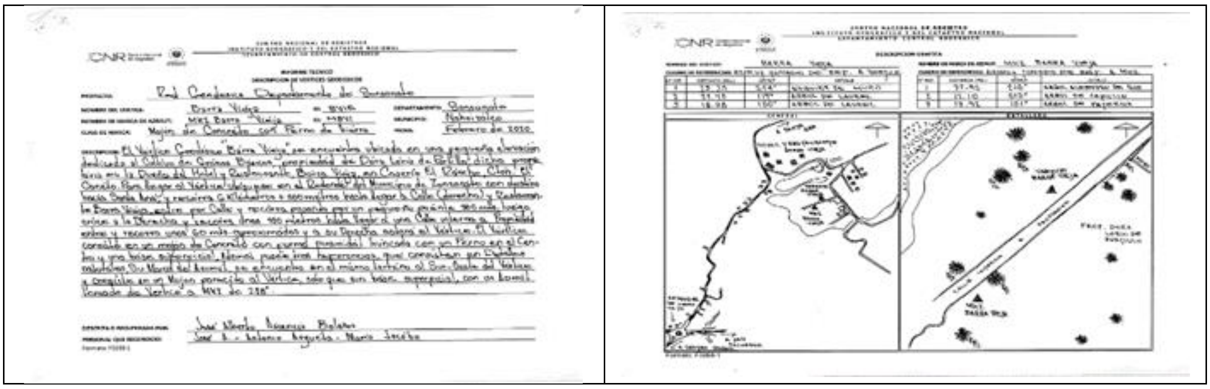
Detail of reinforcement monument "Modified Type III" Cairn (truncated pyramid)



Measurement stage with GNSS equipment

Description of Vertice Geodesico and Brand of Azimut

These descriptions have references with angles and distances, which al-low the user to easily reach where the vertex and Azimuth Mark are located.

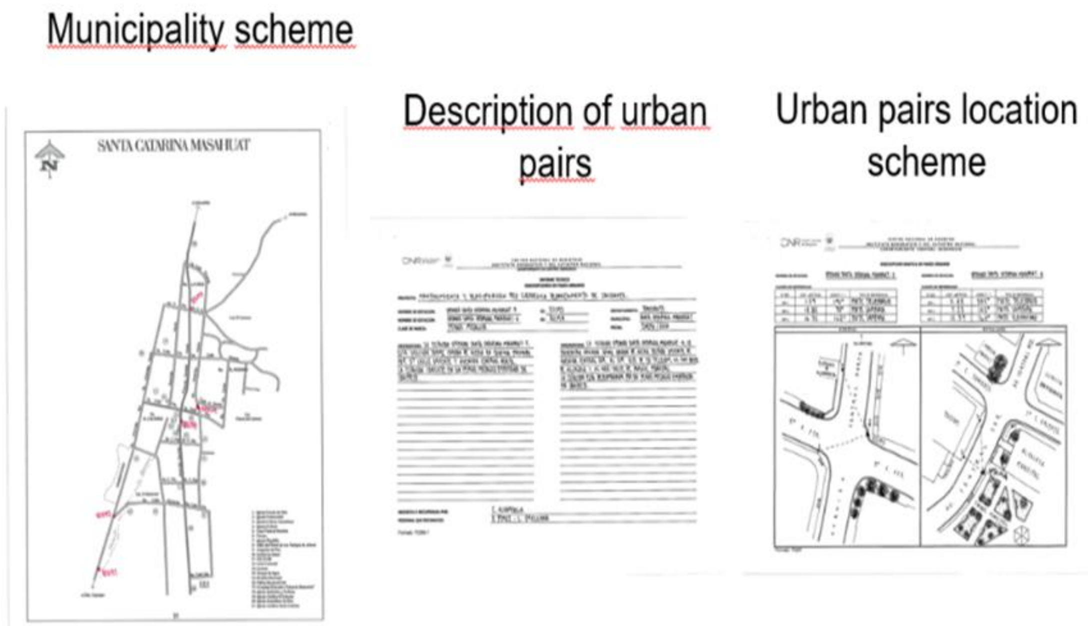


RTK Bases and Urban Pairs

The RTK bases and urban pairs are points whose horizontal and vertical position have been obtained from high-precision geodetic surveys with the use of the RTK system. These are found in urban centers throughout the national territory. Physically materialized on the ground by means of a metal bolt.

Description of RTK Bases

Technical description with diagram, allows the user to reach the site where the urban pair is located without any difficulty. They include: Out-line of the municipality, description of how to get there and the graphic lo-cation scheme with its references.

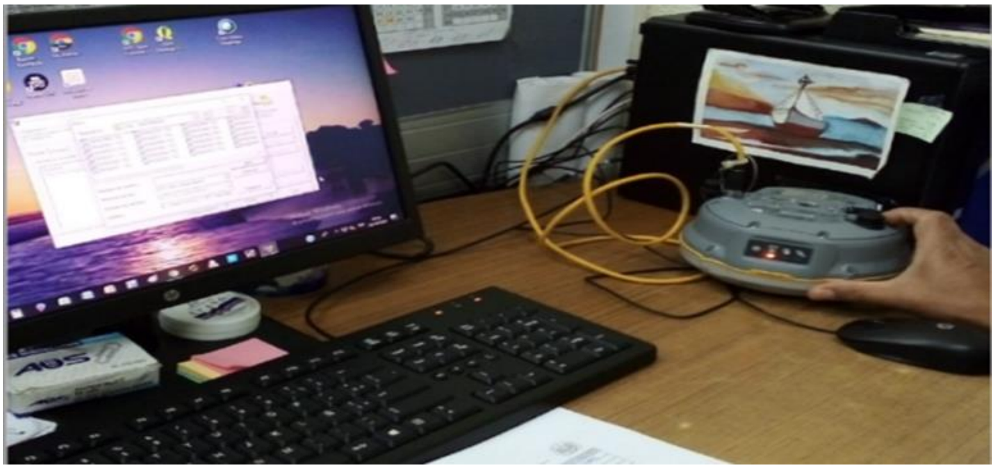


Calculation and Processing

The Calculation and Processing Unit of the Geodesy Management is responsible for calculating and processing all measurements and works concerning vertices and level lines (First and Second Order); This in order to keep the geodetic information of all our national territory updated in order to have accurate and reliable data at all times. The Calculation Unit is made up of four technicians in charge of processing and updating geodesic networks nationwide.

Download Process and Calculation of Horizontal Networks

The raw data collected during the week by each Field Brigade is downloaded by the Calculation technicians directly from the Trimble Teams.



Raw data download by calculation technician

Processing of Vertices and Azimut Marks

For the processing of the data they are downloaded with * .DAT and * .T02 extension of GNSS observations areuses TRIMBLE TOTAL CON-TROL (TTC) software or TRIMBLE BUSINESS CENTER (TBC).

Starting the processing with the height check, antenna type, GPS receiv-er model and time of observation; information that is verified with the Reports field (Fig. 3), which the technicians present, and thus do the measurement processing in the software Below is an image of a geodetic network in which the data loading process and the configuration of the parameters of each of these have already been carried out in the software and is ready for processing.

After analysis, processing and adjustment, it is generated a report of the results, which presents the Geographic coordinates SIRGAS-ES2007 and these in turn, its transformation to the LAMBERT SIRGAS-ES2007 projection

Trimble **Revisión de Coordenadas**

Copyright (C) 2001 - 2002 by Trimble Navigation Limited

PROYECTO: XXXXXX – RED VERTICES

Nombre del usuario	CNR	**Fecha y hora**	7:41:54 1/8/2020
Sistema de coordenadas	EL SALVADOR	**Zona**	LAMBERT EL SALVADOR
Datum del proyecto	NAD 27 EL SALVADOR	**Modelo de geoide**	ESGeoide
Unidades de coordenadas	Metro		
Unidades de distancia	Metro		
Unidades de altitud	Metro		
Unidades de ángulo	Grados		

Número de Puntos 6

1. WGS84 - Coordenadas Geográficas

Nombre de Punto	Latitud	Longitud	Altitud
R GUEZ	N 14° 52' 40.32159"	O 89° 54' 22.61885"	147.4506m
LOS_PORT	N 14° 52' 42.50965"	O 89° 66' 32.56101"	256.2299m
EL_BAJ	N 14° 51' 4.334312"	O 89° 73' 10.07269"	369.9251m
RODR	N 14° 48' 45.40141"	O 89° 21' 17.75741"	369.5060m
VER.BETO	N 14° 48'47.04715"	O 89° 38' 74.98925"	654.3400m
VERST.ESTAC59	N 14° 50' 41.45847"	O 89° 45' 99.05089"	358.6660m

2. Coordenadas de Cuadrícula Nacionales

Nombre de Punto	Direc. norte	Direc. este
R GUEZ	275982.5475m	658856.6123m
LOS_PORT	555732.9234m	555766.5541m
EL_BAJ	526862.8156m	567372.6290m
RODR	369342.8854m	504950.4947m
VER.BETO	874179.9000m	509562.9684m
VERT.ESTAC59	574994.3518m	504426.9811m

Página 1/1

Image Report of the results

Precisions of Geodetic Vertices and Marks of Azimut

The precision of the vertex coordinates will be better than the following:

- Acuracy Planimetry :+/- 0.15 mts.
- Acuracy Altimetry:+/- 0.33 mts.

RTK Base and Urban Point

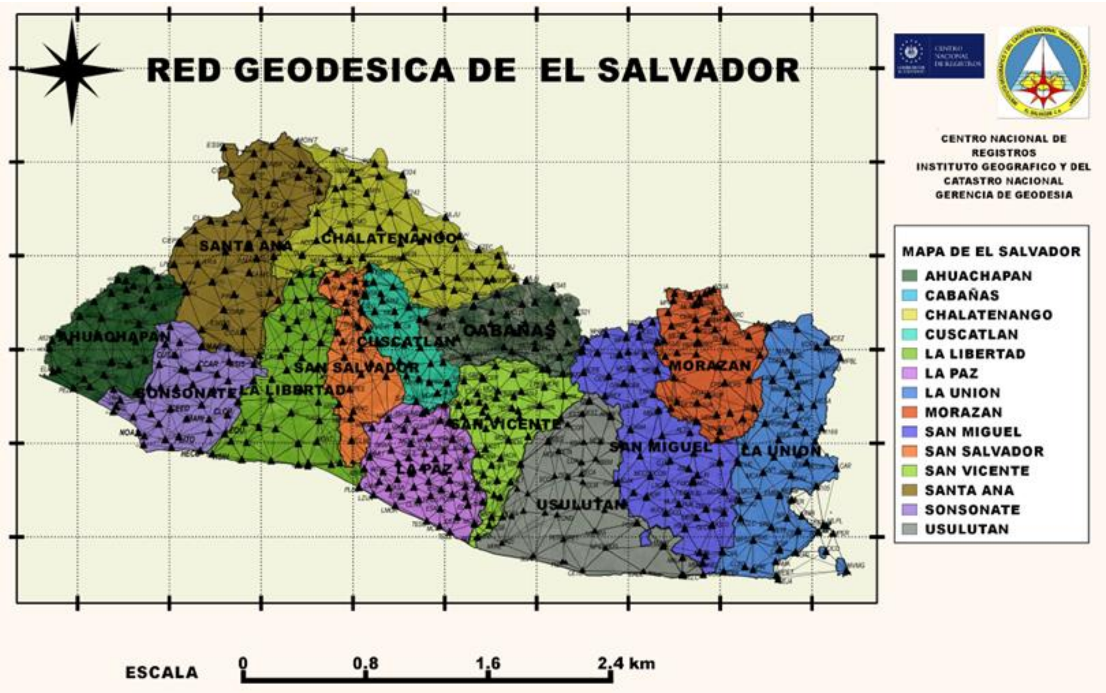
The maximum distance from the urban pair to the point that you want to position, depends on the level of visibility you have and the equipment that will be used:

1. Total station distance of 100mt max
2. GPS receiver max 20km distance

Geodetic Networks Data to Deliver:

WGS84 and Lambert coordinates. Accuracy +/- 7mm

National Geodetic Network


RED GEODESICA DE EL SALVADOR
CENTRO NACIONAL DE REGISTROS
INSTITUTO GEOGRAFICO Y DEL CATASTRO NACIONAL
GERENCIA DE GEODESIA
MAPA DE EL SALVADOR
AHUACHAPAN
CABAÑAS
CHALATENANGO
CUSCATLAN
LA LIBERTAD
LA PAZ
LA UNION
MORAZAN
SAN MIGUEL
SAN SALVADOR
SAN VICENTE
SANTA ANA
SONSONATE
USULUTAN
ESCALA
0
0.8
1.6
2.4 km

FPGA Implementation of a NavIC Disciplined 10MHz Reference for SATCOM Networks

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Delhi Earth Station, Space Applications Centre, ISRO
kritikhatri@gmail.com

SATCOM network can be established using microwave signals with accurate, stable and low noise frequencies. Many frequency-based devices with independent local oscillators are used in an Earth Station to generate and convert carrier frequencies and modulate/demodulate data. Even RF measurement instruments like Frequency Counters, Signal generators, Spectrum Analyzers have reference oscillators that need periodic calibration. It is essential to connect these instruments to a common reference, with low phase noise and long term stability of an atomic frequency standard in order to minimize frequency drift issues and for supporting higher data rates.

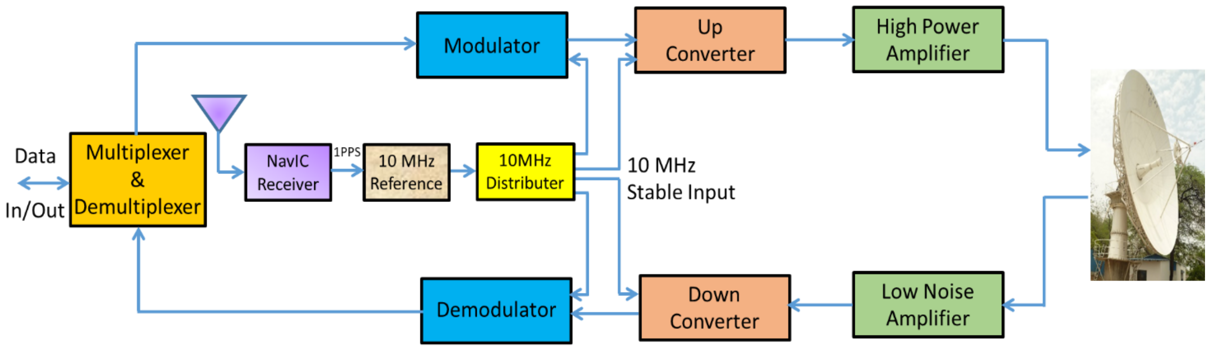

Figure 1: Earth Station Synchronization using NavIC-derived 1 PPS Signal

A high precision 1 PPS pulse derived from the navigation signal of Indian Navigation Satellite Constellation, NavIC was used to discipline a 100MHz OCXO signal to derive the requisite 10MHz reference output. This stable 10MHz signal is then used for the synchronization of an Earth Station (see Figure 1). We have implemented the circuit design comprising of phase detector, limiter, loop filter, NCO and clock divider in hardware using FPGA.

Navic Receiver	
Frequency Band	L5
1PPS Accuracy	60 ns
TTFF	~120 sec (Cold Start)
Update Rate	1 Hz
OCXO Timebase	
Oscillator Type	Oven controlled, SC-cut Crystal
Temp. Stability	$\pm$ 30 x 10^{-9}
Ageing	$\pm$ 2 x10^{-9} per day
Warm up time	3 min to reach within ± 0.01ppm
10MHz Output	
Amplitude	+2.5 dBm
Harmonic Level	-60dBc

Frequency Stability @ 25ºC	short term stability (1 sec): 2.1 x 10^{-10} Long term stability (10,000 sec): 1.7 x 10^{-10}
Phase Noise	
10Hz	-98.15 dBc/Hz
100Hz	-101.64 dBc/Hz
1KHz	-106.74 dBc/Hz
100KHz	-108.14 dBc/Hz

Table 1: Specifications of NavIC disciplined 10MHz Reference

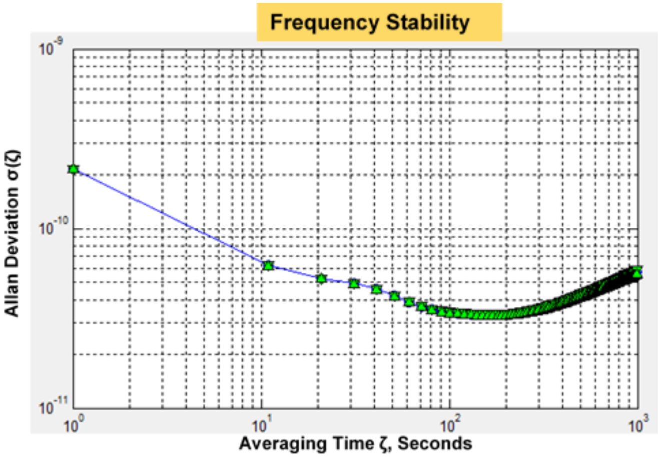

Figure 2: Measured Frequency Stability

Specifications of NavIC disciplined 10MHz Reference is given in Table 1. The disciplined 10MHz is measured to have a short term (1 sec) stability of 2.1 x 10-10 and a long term (10,000 sec) stability of 1.7 x 10-10 (see Figure 2) with phase noise better than Industry-standards (see Table 1). In case of non-availability of NavIC 1PPS, the circuit is designed to work with internal 1PPS signal. This highly stable 10MHz signal can be used as reference signal for up/down converters, modems, spectrum analyzers etc to eliminate frequency drift issues.

Carrier Frequency Offset	IESS 308/309 maximum allowable phase noise	NavIC Disciplined 10MHz Signal phase noise
10 Hz	-30 dBc/Hz	-98.15 dBc/Hz
100 Hz	-60 dBc/Hz	-101.64 dBc/Hz
1 KHz	-70 dBc/Hz	-106.74 dBc/Hz
100 KHz	-90 dBc/Hz	-108.14 dBc/Hz

Table 2: Phase Noise of 10MHz Signal vs Industry standards

India

Review of Continuously Operating Reference Stations Activities in India: Way Forward

Subhalakshmi KRISHNAMOORTHY
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subhalakshmi_k@yahoo.in

Continuously Operating Reference Stations (CORS) is a multi-purpose cooperative network of stations that provide GNSS data consisting of carrier phase and code range measurements in support of 3D positioning, meteorology, space weather and geophysical applications. Government, academic and private organizations having independently owned/operated sites share their data with NGS; NGS analyzes and distributes data free of charge. CORS network with 2000+ reference stations across the globe by multiple organisations monitors Earth's crust, natural and man-made structures, geodetic control, surveying, engineering, GIS data collection, machine control, precise positioning etc. This paper reviews the activities carried out by research entities, government departments, Academia in India for CORS, their status and future roadmap.

In India, CORS will contribute for high accuracy positioning, geodynamics, meteorology, space weather applications with a network of NavIC/GNSS receivers connected to master-server for data processing. NavIC-Navigation with Indian Constellation–is India's Regional Navigation Satellite System-IRNSS-Dual band (L5+S, tri-band in future with L1).

NAVIC-CORS has many advantages---lower ionospheric errors, continuous coverage in Indian sub-continent, NavIC penetration is low, etc.

Space Applications Centre (SAC-ISRO) has done work on code and carrier phase based precise positioning algorithms and software in differential mode using NavIC-L5 signals in real-time. NavIC-PPP engine is under development in collaboration with Academia. Development of precision geodetic grade NavIC/GNSS receiver, Tri-band antenna, NavIC-PPP receiver, RTK receiver, advanced algorithms are being addressed by SAC.

CORS provides seamless, consistent and uniform framework of the country through accurate DGPS/geo-positioning service with improved speed, efficiency, solving the problem of real-time data acquisition. Survey of India plans to use CORS in the construction of large infrastructure projects, generation/updation of revenue maps augmenting with NAVIC/GNSS networks.

Council of Scientific and Industrial Research -CSIR- Fourth-Paradigm-Institute is working on GNSS/NAVIC for CORS---Application and Positioning.

CSIR-National Geophysical Research Institute (NGRI) studied geodynamics and earthquake processes through GPS based crustal deformation measurements in Himalayas. Seismic hazard in Indo-Burmese Arc were studied, rupture modelling is under study.

National Centre for Geodesy, Indian Institute of Technology-Kanpur has done Geodetic VLBI studies for realizing ITRF and estimating Earth Orientation Parameters (EOPs)

National Remote Sensing Centre (NRSC-ISRO) has constructed 8 GNSS-CORS along Himalayan thrust belts for geodynamics studies--Central Seismic Gap monitoring. Computation of velocity of Indian plate done from 10 Stations & 3 streams of GAGAN Indian-Reference-Stations [INRES] CORS data.

Sardar Vallabhai National Institute of Technology, along with SAC-ISRO has studied "Intentional and Un-intentional Interference effect on NavIC".

GNSS Laboratory, University of Burdwan has studied GNSS-PPP using geodetic receivers. A 24x7 CORS measured precise antenna coordinates using online PPP service (AUSPOS).

International GNSS Service (IGS), a voluntary federation of International Association of Geodesy (IAG) ensures open access high quality GNSS data to scientific community and commercial applications. With a global network of 500+ stations, IGS provides the highest quality GNSS data, products& services to GPS, Galileo, GLONASS, Beiduo, QZSS and SBAS. The applications of IGS include precise coordinate estimation, study of crustal dynamics, Ionospheric irregularities measurement, Tropospheric modeling.

The IGS products include GNSS satellite ephemeris, Earth rotation parameters, Global tracking station coordinates and velocities, Satellite/ tracking station clock information, Zenith tropospheric path delay, Global ionosphere maps. With widespread IGS network, the improved measurement database at NavIC Control Center generates accurate broadcast navigation parameters using NavIC-POD software.

ISRO Telmetry Tracking and Command Network (ISTRAC-ISRO) has installed NavIC enabled 24x7 IGS stations at Lucknow, Port Blair, Jodhpur, Shillong, Dehradun and expanding.4 are in Asia Pacific Reference network managed by Geo-Science Australia.

UR Rao Satellite Centre-ISRO is working on precise product generation for NavIC using geodetic recievers.

ISRO has a Roadmap :

- Proof-of-Concept NavIC-CORS network; pilot project to demonstrate S-band usability in CORS/RTK
- Country-wide CORS network
- Improved NavIC receiver to overcome jamming, interference, spoofing
- NavIC-RTK Positioning demonstration
- Indigenous NavIC Receivers
- Analyse TEC variations during Geomagnetic Storm
- IP of NavIC receiver for CORS.

India

Compact GNSS Modules for GNSS Research and Training

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Compact, multi-constellation cost and power-efficient GNSS modules (CGM) are now being increasingly available in the global market from various manufacturers with the cost varying between USD 100-500. These modules operate in single or dual frequencies and may be used for Standard Positioning Service (SPS), Real Time Kinematic (RTK) and Precise Point Positioning (PPP) purposes. The CGM modules provide real time data both in ASCII National Marine Electronics Association (NMEA) format and/ or in binary raw format, that can be used by various GNSS data processing software for RTK or post processing. Performance study of such single-frequency CGM modules for single or multi-GNSS constellation(s) in static operation from India is conducted for different positioning methods. CGM modules with survey grade and low-cost antennas are first tested for SPS vis-à-vis survey grade receivers to explore their capabilities for stand-alone positioning. The modules then are tested as Rover for RTK operation while a survey-grade receiver with antenna is used as the Base, and then two CGMs with commercial low-cost antenna are tested for RTK both for the Rover and the Base. Static RTK positioning performance comparison for short and long-base lines have been made for such different configurations vis-à-vis the performance of survey-grade receivers. The CGM modules also provide received signal strength values in the NMEA data stream. The signal-strength variations may be monitored to study the ionospheric disturbances and therefore may be used for cost-effective, networked GNSS-based atmospheric monitoring purposes. Integrated with single-board computers (e.g., Raspberry Pi), CGM modules are used as low-cost GNSS data loggers. This presentation contains the results of such studies and efforts that may be useful in understanding the potential of such modules. In static, single-frequency, standalone operation using a survey grade antenna the modules show better than 1.5 m (2σ) 2d position accuracy for GPS-only operation. Over a short baseline, for RTK multi-GNSS operation, with a survey-grade receiver and antenna as the Base, a CGM module with a survey-grade antenna provides centimeter level 2d solution accuracy (2σ) and 75% RTK Fixed solution. In case of compact modules used both as Base and Rover, the 2d solution accuracy is found to be in decimeter level (2σ) with around 75% RTK fixed solutions. Therefore, these modules may be used for precision GNSS applications. A preliminary study on signal strength comparison between the values obtained from a survey grade and a CGM module is carried out. The result suggests lower resolution of C/N0 values, but a comparable signature of signal strength variation pattern in case of the CGM compared to the survey-grade receiver. With proper calibration, the CGMs have the potential for use in atmospheric research. In real-life GNSS-based applications, the CGM modules would be useful due to their size, cost and power efficiencies. The CGMs also have the potential for use in GNSS research and training, and also for user friendly location data collection system in geomatic applications, especially for the students. Similar NavIC (L5)-enabled CGMs are now being available in the market those show better than 3m 2d solution accuracy. These modules would be useful in augmenting GNSS visibility in constrained environments and for NavIC-based application development from India and the surrounding region. Future studies in this aspect would be in using the dual-frequency CGM modules for enhanced-accuracy positioning, atmospheric probing and timing

purposes. With availability of dual-frequency GNSS data, such modules would also be explored for PPP in case of high-precision geodetic applications.

India

Multi-scale Size Ionospheric Irregularities Impacting Signal-in-Space Performance of Satellite-based Communication and Navigation Links

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The morphology of equatorial ionospheric irregularities and their effects on satellite-based systems and services have been well documented in literature using active and passive systems over several decades. However interesting features continue to emerge from the geophysically sensitive Indian longitude sector, particularly from regions around the northern crest of the Equatorial Ionization Anomaly (EIA). The electrodynamics of the equatorial ionosphere could be understood using different orientations of geomagnetic field lines with respect to the direction of radio signals.

Institute of Radio Physics and Electronics, University of Calcutta, Calcutta, India operates a number of active and passive radio systems around the northern crest of the EIA in the Indian longitude sector. Location of a station around the northern crest of EIA provides an unique opportunity to receive backscattered radar echoes from ionization density irregularities located north of the station, where the condition of orthogonality of radio ray path with geomagnetic field lines is satisfied, during early evening hours. During late night hours, enhanced levels of GNSS amplitude scintillations could be experienced when viewing irregularities 'end-on' with alignment of radio link with the field lines, south of the station. These operational systems record different manifestations of ionospheric irregularities in the form of radar backscattered signals in HF active phased array radar (53 MHz), TEC depletions in LEO satellite beacons (150, 400MHz), amplitude scintillations on geostationary VHF satellite beacon (250MHz), carrier-to-noise ratio, TEC and received phase fluctuations in multi-frequency multi-constellation GNSS (L-band) and IRNSS (L5 and S-band).

Since the condition of Quasi-Transverse (QT) propagation condition, which corresponds to perpendicular direction of the geomagnetic field lines with respect to the radar beam, is satisfied around 28°-29°N geographic, the radar beam was pointed towards north during the observations. These results are unique being the first active phased array ionospheric measurements from the eastern and north-eastern parts of India around the northern crest of EIA. The present paper aims to highlight the impact of equatorial and low-latitude ionospheric irregularities covering largely varying scale sizes on satellite-based systems and services. Further, these observations were made under geomagnetic quiet periods implying that geomagnetic disturbed conditions may impose an additional metric to the already deeply involved dynamic geophysics of this region.

Tropospheric Delay Models Analysis for NavIC

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The GNSS signal is getting affected in terms of delay by two major atmosphere layers: Troposphere and Ionosphere. There are correcting models for Ionosphere as well as Troposphere delay modeling. Our focus is to analyze the various tropospheric delay model combination and create study results for NavIC. NavIC is the regional navigation system developed for India by ISRO. It covers the whole of India with 1500km around the Indian region. As the NavIC is an emerging regional navigation system, it is highly recommended to have a study on various errors causing the delay to offer a quantification of the neutral atmospheric effect for NavIC users who seek better accuracy. Hence, the objective of this paper is to present various tropospheric delay model characteristics for the NavIC signal with certain tropospheric delay correction model using synchronizes ground meteorological and NavIC data at the same point can provide better accuracy.

India

SDR-based GNSS Acquisition Techniques

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BITS-PILANI K.K. Birla Goa Campus, India
P20170424@goa.bits-pilani.ac.in

In the current world scenario, navigation and positioning plays a major role in industry and transport etc. In positioning, the algorithm is divided into three sub-parts: Acquisition, Tracking, and Navigation. The acquisition is the first and foremost task in any navigation process. So, it should be fast and precise, and also work during weak signal reception. The developed SDR (software-defined radio) is in the LabVIEW platform. Traditionally acquisition is categorized on the basis of serial search (SS), parallel frequency space search (PFS) and parallel code phase search (PCS). The PCS based acquisition is faster among all as it takes only 41 repetitions compared to others (SS=41,943 & PFS=1023). Based on this comparison, we used the PCS based technique for our algorithm. The PCS based technique the incoming data is split into I (in-phase) and Q (quadrature-phase) signals after carrier removal, and separate FFT is done for both of these signals. In rapid FFT, after carrier removal signal is not split into I and Q, therefore only one FFT block is used. In our approach to faster implementation of GNSS acquisition, we removed the PRN (Pseudo-Random Noise) generator by the fixed PRN for each satellite subset. The PRN code generator generates the PRN for each satellite subset to correlate it with the incoming signal to see which satellite is visible to the user antenna. And to generate the PRN two generator is required (i.e., G1 generator and G2 generator), which increases the unnecessary load on the system performing GNSS positioning and burns the power. So, by removing the PRN generator with the fixed predefined PRN for each satellite and process all satellite in parallel and also eliminates the generation part. This reduced the processing time for acquisition. Further for each satellite instead of generating carrier signals to search the Doppler can be replaced by the fixed carrier signals and adding the acquisition steps at the correlation also increases the performance by reducing the execution time. However, the SDR is implemented in LabVIEW it has the advantages of parallel for loop execution. We used this feature to reduce the execution time taken by the whole GNSS acquisition part. Thus, we are successfully able to do the fast and precise acquisition with 80% less execution time compared with available literature. These algorithms are developed in LabVIEW environments and it is real-time which can be very helpful for students and researchers.

Indonesia

Application of GNSS for Forest Surveying and Mapping in Indonesia

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Forest Planning Agency Region VIII Denpasar, Ministry of Environment and Forestry,
The Republic of Indonesia
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The presence of distinctive forest boundary in the field, which is match with forest land/area map and its supporting documents, is a necessity nowadays to ensure sustainable forestry development. Forest area in Indonesia has been appointed and settled since colonial era. At the time, forest boundary lines in the field marked with stone piles based on terrestrial measurement using conventional tools such as compass, magnetic theodolite, or angle/directional theodolite. In the modern era, the boundary lines marked with poles made of concrete, or wood, at interval of around 100 m. The terrestrial measurements mapped with local coordinates, also documented with boundary measurement book, boundary measurement official report, and decree of forestry minister.

As the emerge of GIS technology, the analog forest area maps were transformed into digital maps (Esri SHP files). The process (digitizing, geo-referencing, and polygonising) results difference in size (area), boundary length, and boundary position, due to adjustments during map transformation, difference in calculation method, and level of accuracy.

To minimize the differences between digital map and forest area boundary in the field, in 2014 was published a regulation of Director General for Forestry Planning pertaining the application of GNSS for forest boundary surveying and mapping, which is stating the use of GPS with minimum accuracy of 7.5 m. For this purpose, we use differential GPS to reconstruct forest area boundaries, and to record the boundary poles positions by referring to forest boundary's official documents, and forest boundary marks (stone piles, or wood/concrete poles) found in the field.

For the current days, initial forest boundary measurement also must using differential GPS. We operate the base section in our office, with maximum service range of 600 Km. We are even using real time kinematic (RTK) GPS for measurements demanding more detail accuracy (by request), e.g. land parcel clarification.

In forest inventory, we also utilize GNSS technology. The inventory is carry out in a 1-Ha sample plot with an interval grid of 10 x 10 Km. The coordinate of the lowest-left corner of the plot is recorded using GPS. The plot is divided into 16 record unit, RU. Position of every tree in the plot is mapped based on the horizontal distance and azimuth from the center of the RU. The trees position is brought into GIS environment for further analysis, e.g. species distribution, stand health (on high-resolution imagery), or height estimation correction using point clouds data.

Recently, we use GPS for collecting ground control points (GCPs) of aerial photo/surveying using drone or microlight trike. The aerial photo is a valuable data for forest area monitoring, for land reform/redistribution analysis, ground-truthing for landuse interpretation, and other purposes. The spatial resolution of the aerial photo is quiet high (9 – 13 cm), which needs high accuracy GCPs.

Japan

Low-Cost High-Accuracy GNSS Receiver System based on QZSS MADOCA Signal

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GNSS positioning accuracy of about 10 meters is now possible with a standard GNSS receiver. However, this positioning accuracy level can be further increased by using special error correction techniques. GNSS measurements are affected by satellite clock errors, orbit errors (ephemeris), ionospheric effects, tropospheric effects, receiver circuit errors and multipath. All these effects except multipath can be either removed or reduced by using proper signal observation methods and signal processing techniques. One of the methods is differential observation where a reference station is installed at a known position location so that exact measurement errors can be computed. This provides high-accuracy of few centimeters. This process is generally known as RTK (Real-Time Kinematic) processing. Another methodology is to provide satellite related error (clock and orbit) data from the satellite itself using a separate signal or link. In the case of QZSS, this is called MADOCA. MADOCA broadcasts satellite orbit and clock error data for GNSS signals. Thus, a dual-frequency receiver can provide high-accuracy using MADOCA correction data. This avoids the necessity of a separate reference station. MADOCA correction data are also broadcasted through internet so that users where QZSS is not visible can also use MADOCA for high-accuracy positioning. In this paper, we present how a low-cost GNSS receiver system can be made based on QZSS MADOCA signal for high-accuracy.

Mongolia

Ionospheric TEC Anomalies Over Mongolia as Detected by GPS Observations

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Astronomical Observatory, Institute of Astronomy and Geophysics, Mongolian Academy of Sciences
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In this study we present ionospheric anomalies detected over Mongolia by monitoring continuous GPS observations in terms of total electron content (TEC). The primary data set we use for identifying anomalous behavior in TEC comes from the long-term TEC time series at four permanent stations spanning the period of 2008-2019 which covers whole 24th Solar cycle. The time series analysis of all four stations exhibits the semiannual anomaly with the equinoctial maximum and solstice minimum and the annual anomaly expressed by the higher TEC values in winter solstice than in summer, characteristic for mid-latitude region. This trend is observed during the deep solar minimum (2009), moderate (2016) and as well as at deep maximum (2014) phases. Anomalies associated with space weather extremes and seismic activities are also considered.

Mongolia

2021 CHC Navigation CORS Network Introduction

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The rapid development of CORS networks is seen by the geospatial communities as a major way to increase the accuracy and efficiency of surveying and mapping applications. CHCNAV's CORS network solutions encompass multiple industries such as surveying, mapping and GIS, precision agriculture, UAV, marine surveys, unmanned navigation, deformation monitoring, civil engineering, academic and scientific research.

CHCNAV provides turnkey solutions for the implementation of CORS networks, from the initial site survey, GNSS station construction, IT infrastructure to the end-to-end management of GNSS RTK correction services. With over 4,000 CORS GNSS stations in operation in more than 30 countries, the CHCNAV's CORS solution provides users with reliable and uninterrupted centimeter-level positioning. The GNSS P5 geodetic receiver (used for the Mount Everest Elevation Survey), advanced GNSS antennas and the CPS GNSS RTK Network Computation Software provide robust precise positioning, real-time quality control, and user management, making CORS Networks deployment affordable.

With a worldwide presence, distributors in more than 100 countries, over 1,300 employees and 400+ GNSS-related patents, CHC Navigation (CHCNAV) is today recognized as one of the fastest growing companies in geospatial technology.

Mongolia

The Use of Space-based Systems and Equipment in Air Navigation Services of Mongolia

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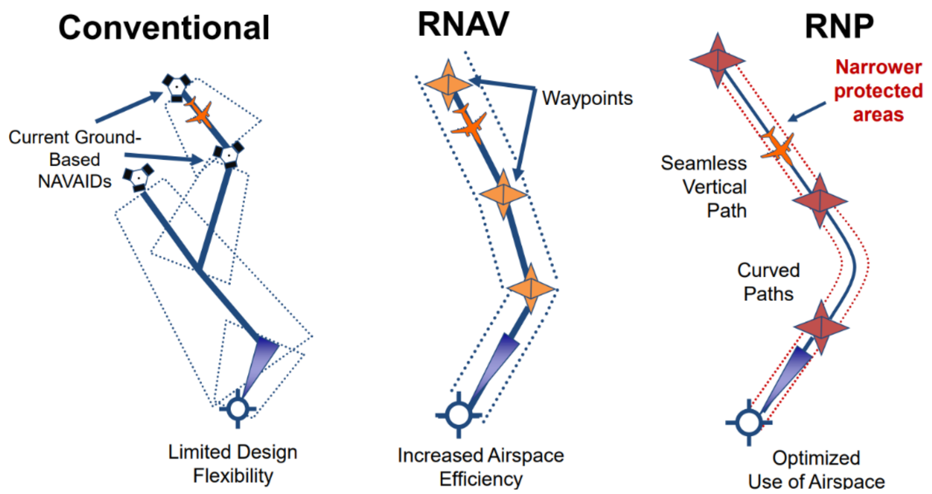
Current use of GNSS Performance Based Navigation

What is PBN?

PBN defines performance requirements for aircraft navigating on an ATS route, on a terminal or on an approach procedure. Those routes and procedures are composed of way-points which are expressed by WGS 84 coordinates rather than fixes expressed by radial/bearing and distance from ground navigation aids and permit the flexibility of point-to-point operations.

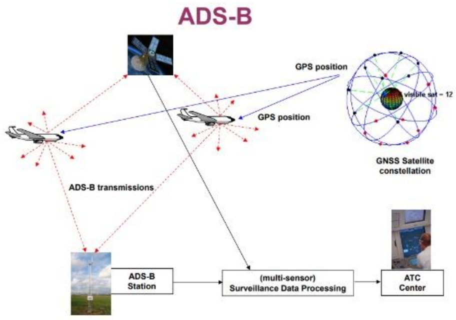
Benefits of PBN

Through the application of Area Navigation (RNAV) and Required Navigation Performance (RNP) specifications, altogether components of PBN, PBN can provide the means for flexible routes and terminal procedures, reduce aviation congestion, conserve fuel, protect the environment, reduce the impact of aircraft noise, improve safety and accessibility to challenging airports, and increase airspace capacity.



- The International Civil Aviation Organization (ICAO) has been promoting the Performance Based Navigation (PBN) program since 2007.
- In 2009, Mongolia submitted a plan to implement PBN program to ICAO.
- To date, Mongolia has successfully implemented Phases I and II of PBN plan.

- Within the framework of Phase I and II
  - 10 RNAV ATS routes established
  - 23 PBN flight procedures at 9 locations

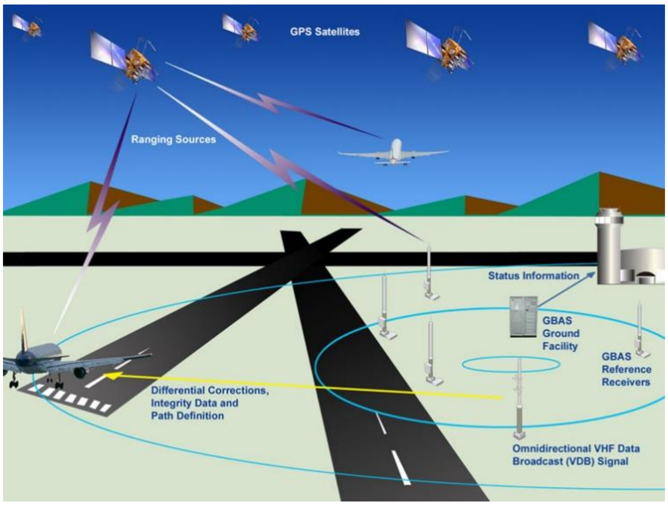


Automatic Dependent Surveillance Broadcast (ADS-B)

- Since 2013, there have been plans to use the ADS-B Automatic Dependent Surveillance System in Mongolia.
- It is planned to be used for air traffic control at altitudes above 8900 meters from November 2021.

Planning for Future Use “GBAS, SBAS”

A Ground Based Augmentation System (GBAS) augments the existing Global Positioning System (GPS) used in airspace by providing corrections to aircraft in the vicinity of an airport in order to improve the accuracy of, and provide integrity for, these aircrafts' GPS navigational position. The goal of GBAS implementation is to provide an alternative to the Instrument Landing System (ILS) supporting the full range of approach and landing operations.

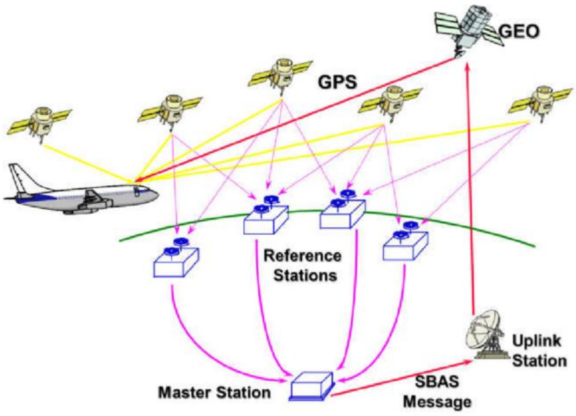


- The performance of Global Navigation Satellite Systems (GNSSs) can be improved by regional Satellite-based Augmentation Systems (SBAS), such as the European Geostationary Navigation Overlay Service (EGNOS). SBAS improves the accuracy and reliability of GNSS information by correcting signal measurement errors and by providing information about the accuracy, integrity, continuity and availability of its signals.
- SBAS uses GNSS measurements taken by accurately located reference stations deployed across an entire continent. All measured GNSS errors are transferred to a central computing centre, where differential corrections and integrity messages are calculated. These calculations are then broadcast over the covered area using geostationary satellites that serve as an augmentation, or overlay, to the original GNSS message.

Existing SBAS

Several countries have implemented their own Satellite-based Augmentation System. For example, in Europe EGNOS covers the majority of the European Union (EU), along with some neighbouring countries and regions. Other national SBASs include:

- **USA:** Wide Area Augmentation System (WAAS)
- **Japan:** Michibiki Satellite Augmentation System (MSAS)
- **India:** GPS-aided GEO-Augmented Navigation (GAGAN)



- **China:** BeiDou SBAS (BDSBAS) (in development)
- **South Korea:** Korea Augmentation Satellite System (KASS) (in development)
- **Russia:** System for Differential Corrections and Monitoring (SDCM) (in development)
- **ASECNA:** SBAS for Africa and Indian Ocean (A-SBAS) (in development)
- **Australia and New Zealand:** Southern Positioning Augmentation Network (SPAN) (in development)

Issues related to the use of GNSS

- Reliable operation of GNSS system
- GPS outage
- Complex, and high-tech equipment is required
- Training and developing employees

Mongolia

Geodynamic Study in Mongolia based on GNSS

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The recent development and establishment of GPS/GNSS geodetic networks in Mongolia make it possible to define an increasingly detailed spatial and temporal resolution of the ongoing crustal deformation and to visualize the complex interplay between different orogens in Central Asia. The requirements for establishing permanent stations are based on both off-line and real-time data availability, imposed by global, regional geodetic, and local survey actions. In Mongolia, several Continuous GNSS stations are operated and managed by different agencies, private companies, and national scientific institutions. These stations have been built for purposes such as topography, cartography, cadastral surveying, and crustal movement monitoring. All available GPS/GNSS raw data from both campaign mode and continuous sites in the time span 1994-2020 has been analyzed by using the Gamit/Globk software. Constructed time series of GNSS stations referenced to an ITRF2014 common reference frame that can give fundamental information for regional geodynamic studies and finally produced the tectonic velocity field providing an updated detailed picture of the kinematics (velocity map) and deformation pattern (strain rate map) of the Mongolian area. The research method of geodynamic parameters fulfilled in the plate tectonics of active regions of Mongolia, and numerical values of modern deformations received from these methods. Results can be further used for geo-kinematics purposes, and for a better understanding of the recent geodynamic processes that are deforming the lithosphere in Mongolia and surrounding regions and will be implemented for assessment of global deformation of the Earth's surface.

Mongolia

GNSS CORS Network and Application in Mongolia

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The first GNSS CORS was installed in 2000 by State agency of Geodesy and Cartography. Currently, twelve organizations operate 65 GNSS stations nationwide and Agency for Land Administration and Management, Geodesy and Cartography has established a network of 43 CORS in order to ensure the normal operation of the stations and distribute RTK corrections to customers.

Mongolia has been participating in GNSS network measurement by Asia Pacific Regional Geodetic Project (APRGP) since 1999. Data of five CORS, located in Ulaanbaatar city /ub01/, Dornod province /doa1/, Uvurkhangai province /ova1/, Umnugovi province /oma1/ and Khuvsgul province /huv1/, have been sent since 2017.

GNSS CORS network is being applied to the following:

- National fundamental GNSS network
- International joint research and experiments
- Crustal movement study in Mongolia
- Meteorological and environmental analysis and research
- Producing topographic and cadastral mapping by real-time kinematic measurement (RTK)
- Daily geodetic measurements for construction, urban development, civil aviation, mining, agriculture, railways and roads

Academy of science and over 300 licensed companies are end users of GNSS CORS network.

Mongolia

GNSS Network Development in Mongolia

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2nd, 3rd, and 4th class triangulation network of Mongolia with over 15000 points was established from 1936 to 1954 based on primary triangulation network of USSR and measured on Krasovskii Ellipsoid and adjusted in Pulkovo 1942 coordinate system.

By the time when GPS technology was introduced in geodetic production and services internationally, GPS network consisting of 34 points was established in Mongolia and adjusted by Bernese software connecting to the IRKJ, TSUK, XIAN and LHAS CORS of IGS network in WGS84 coordinate system and ITRF97 epoch. Primary GPS network of Mongolia was named MONREF 97.

MONREF 97 was densified from 2003 to 2013.

As of 2021, a primary, first and secondary class of GNSS network of Mongolia consists of 3,500 points, and the coordinates have been determined in the ITRF2008 epoch. The GNSS network is being utilized for surveying and mapping nationwide.

GNSS's a primary, first and secondary class networks were computed using the BERNESE software to determine the coordinates. Additionally, the GNSS online processing system “MONPOS”, based on the GNSS permanent station network, was introduced.

The transformation parameters between the WGS84 coordinate system and Pulkovo 1942 coordinate system were calculated and utilized to digitize 1210 sheets of 1: 100,000 scale topographic map, which covers whole country.

Mongolia

Policy and Regulatory Issues on Satellite Technology and Communications in Mongolia

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We are now in an era of digital transformation that is fundamentally changing our economies and societies and improving service delivery and in many other sectors. The use of satellite applications including GNSS and ICTs during the COVID-19 pandemic are examples of opportunities and challenges. Appropriate legal environment, effective policy and regulatory framework are required to ensure the modernization of national geometric network with GNSS CORS and all participating authorities of Mongolia need in collaboration with research and private sectors, and cross-sector coordination, by ensuring connectivity, reliability of the existing network, and cooperation with international organizations and foreign partners, etc.

This paper has several aims: a) ICT sector policy and regulatory frameworks, and legal reform, b) Role of regulatory authority in relation frequency license and type approval, radio frequency monitoring, c) Review of national policy and programs related to satellite technology/communications and applications in Mongolia, Finally, paper proposed the improved ways and recommendations to address regulatory policy to fostering the potential of emerging technologies. It includes, Government (Policy and Regulatory authority) need to establish appropriate legal environment, to build cross-institutional links fostering the collaboration among all stake-holders academics, ICT, industrial promotion, science and technology to devise and jointly implement policies. It means that all stakeholders of the ICT and geodetic ecosystem should work together to create an enabling environment for the next stage of development GNSS CORS network in Mongolia.

Nigeria

Adoption of SBAS technology in aviation sector at continental level of Africa

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The importance and application of global navigation satellite systems (GNSS) has never been greater; there is increasing demand for both commercial and government projects as an emerging technology for adoption; indeed, owning and operating a GNSS facility has become a matter of national esteem especially as it concerns Satellite-based augmentation system (SBAS). SBAS; a less ambitious system than GNSS is a satellite-based system that aids a Global Navigation Satellite System (GNSS) in providing further accuracy, integrity, availability for professional use and application in critical sectors that involves safety of life (SOL) i.e Aviation sector that requires verified performance with integrity.

Less than 20% of Runways at continental level of Africa are equipped with Instrument Landing Systems (ILS) driving needs assessment considering reduced costs of acquisition and maintenance compared to legacy systems as well as calibration requirements.

In addition, IATA 2016 annual review between 2011-2015 shows that 20% of fatalities in Controlled Flights into Terrain (CFITs) mostly occurs in the approach and landing phase and associated with imprecise approach.

The paper provides insights and progress being made in African continent and many benefits and applications of Satellite Based Augmentation Systems as it concerns improvement of safety and reduction in operational costs and environment. SBAS Technology adoption aligns with the Single African Air Transport Market (SAATM) agenda of African Union (AU); a flagship project of the AU agenda 2063 to advance the liberalization of civil aviation in Africa through a unified sky and acting as an impetus to the continent’s economic integration agenda.

Pakistan

The GNSS Landscape in Pakistan

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Pakistan is pursuing a space program for socio-economic development of the country. SUPARCO (www.suparco.gov.pk) is the National Space Agency, which is responsible for its implementation. It also undertakes various programs for introduction and promotion of space applications in the country. GNSS technology has recently made significant penetration in various application domains in Pakistan. SUPARCO with the sponsorship of the Federal and Provincial Ministries has played a key role in this regard by undertaking various GNSS applications pilot projects. In continuation of its efforts to further promote the applications of GNSS technology in the country commensurate with the current state of the art, it is also in the process of application for ICG membership.

The subject presentation will present the GNSS landscape in Pakistan: key national stakeholders, national level GNSS initiatives and the spectrum of GNSS applications in Pakistan with details of some application cases. It will also present an overview of the national Space Based Augmentation System (SBAS) being planned for implementation.

Pakistan

Empirical Orthogonal Function Modelling of GPS TEC over Nepal Region and Comparison with The Global GIM and IRI- Predicted TEC Values

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This analysis uses 3 years hourly observations of total electron content (TEC) from 5 global positioning system (GPS) station across Nepal to analyze the spatial trend. For this purpose, empirical orthogonal function modeling is used to investigate the annual and monthly variation inside the country. Empirical orthogonal function base functions and associated coefficients of TEC variability over Nepal have been studied to establish the relationship between observed and modeled TEC values. Both the observed GPS TEC values and the empirical orthogonal function modeled TEC values are compared with the global ionospheric models (global ionospheric map and international reference ionosphere) TEC values. The study shows an hourly pattern of TEC variation in which the TEC rises from dawn, reaches the highest TEC values about 40 TEC units during the peak hours of the day, then decreases at evening at the lowest diurnal values about 5 TEC units. Monthly TEC values over all sites are higher during the march and April (about 38 TEC unit), while they are lower values during December and January (about 10 TEC unit). Although the correlation coefficients between the GPS TEC values and the global modeled TEC values are higher, while it becomes highest with empirical orthogonal function modeled TEC values for both cases of hourly and monthly variations. We examined the root mean square errors between observed and modeled TEC values at each site by using tailor correlation plots and found that they are lower in case of empirical orthogonal function model. Monthly residuals between observed and empirical orthogonal function modeled TEC values are always lower as compared to other global modeled TEC values. These kinds of comparative analysis in the present work indicates that empirical orthogonal function model by using global geomagnetic activity works very well and is capable of depicting TEC variations accurately.

Thailand

GNSS Time and Frequency Transfer and Applications

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Thailand national time and frequency standard is maintained at the National Institute of Metrology (Thailand) (NIMT). GNSS is an essential tool to link the common global time scale; Coordinated Universal Time (UTC), and our national time scale; UTC(NIMT). The national time standards' characteristics are later described in terms of accuracy and stability and will be a reference in the country. Our provided services vary from calibrations of oscillators; namely, quartz, rubidium and caesium frequency standards to disseminations on official and legal time of day. This timing reference system also complements to national geodetic reference systems.

GNSS time and frequency measurements and its quality assessments need to be precisely determined in order to achieve accurate time and frequency comparisons of distance atomic clocks. GNSS measurement errors including synchronisation errors between the local clock; UTC(NIMT), and the reference time scale of the GNSS have to be determined in corresponding with their measurement uncertainties. This is achieved by inserting the external frequency signals of 10 MHz and 1 pps from a caesium frequency standard to GNSS receivers so that the synchronisation error between the internal receiver clock and external clock can be continuously measured. GNSS observations are simultaneously obtained from both geodetic and timing receivers. Synchronisation errors are then compared and analysed using a time transfer methods for remote clocks of common-view and all-in-view observations. Their synchronisation errors are within 100 nanoseconds. This accuracy can be improved by applying carrier-phase measurements which have lower noise than code pseudoranges.

United States of America

Supporting GNSS Capacity Building within the UN GGIM-World Bank Integrated Geospatial Information Framework

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In response to the need for developing, integrating, and optimizing geospatial management in all countries, the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) and World Bank have made considerable efforts to develop a strategic approach to implementing an Integrated Geospatial Information Framework (IGIF). Recent developments in the use of both the IGIF's Overarching Strategic Framework and Implementation Guide for the purpose of geodetic capacity building will be discussed, with examples from countries currently using the IGIF to develop Country-level Action Plans.

An overview of recent initiatives in the UN GGIM Subcommittee on Geodesy, Education Training and Capacity Building Working Group in response to IGIF guidance will be presented, as well as linkages to relevant UN Sustainable Development Goals and Sendai Framework for Disaster Risk Reduction targets.

Using the Method of Trilateration for Uzbekistan Tectonics

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This paper deals with the determination of the coordinates of points of the geodynamic network and the distances between them by the method of trilateration. When constructing geodetic networks, optical instruments were used, which were designed to measure angles and elevations. The distance between the points was calculated analytically, observing all the requirements for the class of the geodetic network. Later, light and radio range finders were developed, with the help of which the sides of triangles and the polygonometric line were measured, but the accuracy of such measurements was low for geodynamic research. Nevertheless, attempts were made to study the horizontal and vertical displacements of the upper part of the lithosphere with the classical geodetic instruments OT-02, NA-1.

In 1980-2000, several geodynamic polygons were created on the territory of the Republic of Uzbekistan, where triangulation and leveling of orders 1 and 2 were performed. The most intensive work was carried out at the Tashkent geodynamic polygon, where minor displacements of soil horizontally and vertically, due to internal processes, were revealed. Multiple repeated leveling of I and II orders at the Tashkent geodynamic testing ground made it possible to reveal a correlation between changes in the rates of vertical movements and deformations of the earth's crust. The geodetic method for determining the deformation of plates is the most effective and economical in comparison with other methods. The most difficult part of this method is the geometric leveling of the hilly terrain.

With the progress of modern technology, such as electronic total stations and laser measurements, the accuracy of determining coordinates and distances has increased. In this regard, it became possible to study changes in coordinates and basis again. The traditional method of trilateration has become in demand due to the fact that modern geodetic instruments Trimble M3, M5 allow fixing the distances between points with an accuracy of 1-3 mm. With such accuracy, it is possible to determine insignificant changes in tectonic faults over a short period of time. This is especially effective in seismic zones and areas where natural anomalies occur. In such places, a geodetic quadrangle is built, the vertices of which are points of the geodynamic network located on various local microplates. Based on the results of repeated measurements, it is possible to calculate not only the changes in coordinates, but also the deformation of the sides of the quadrangle. In this case, the two sides of this figure should be located on different blocks or tops, approximately parallel to the direction of the fault between the plates.

For the Tavaksay geodynamic polygon, several quadrangles can be used, the points of which are located on the tops of the hills where the Karzhatau fault passes. At this polygon, GNSS and tacheometric measurements of points of the geodetic network and one point of the Central Asian geodynamic network were carried out using a laser rangefinder of an electronic total station Trimble M5. For the reliability and validity of the obtained distances, 20 measurements of the sides of the quadrangle were made. Based on the statistical processing of the measurement results, the accuracy was at the level of 1-2 mm. This accuracy is acceptable for the study of tectonic displacements.

Establishing a connection between modern vertical movements of the earth's crust and tectonic movements of past geological periods allows us to reveal the patterns of change in the fault. To monitor changes, a regional tracking system for geodynamic phenomena should be developed using high-precision geodetic and GNSS measurements.

Assessment of the GPS receiver in the Venezuelan Remote Sensing Satellite to Get Radio Occultation Information

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The paper shows the evaluation made to the positioning system of the first Venezuelan remote sensing satellite (VRSS1) in order to check the possibility of its use in radio occultation techniques. Once the concepts have been established to understand the relationship between the incidence of atmosphere and the behavior of the GPS signal based on the Doppler Effect. The first step comprises the procedure of representing the orbit precision making use of the VRSS-1 orbital parameters through the TLE (Two Lines Elements) of the satellite for the period of time that coincides with the telemetry provided by the control earth station. Simultaneously, the simulation of the GPS constellation was carried out using the status almanac in the same time interval to check the positioning relationship with the received satellites and their respective capture and unlocked information to compare it with the telemetry provided by the ground station. The VRSS-1 navigation data is transmitted through the S-band telemetry channel to be processed in the control and monitoring earth station. The VRSS1 navigation information received was compared with the technical information presented in the manuals. This information was analyzed and used not only to determine VRSS-1 navigation coordinates based on GPS satellites, but also to represent radio occultation geometry. So if you know the positions and speeds of the GPS and VRSS-1 satellites in the simulation and the Doppler Effect data, the angle of curvature of the signal and the impact parameter for each ray can be estimated.