UNITED NATIONS
Office for Outer Space Affairs

Workshop on the Applications of Global Navigation Satellite Systems

Organized by

The University of the South Pacific

Co-sponsored by

The United Nations Office for Outer Space Affairs
&
The International Committee on Global Navigation Satellite Systems

Suva, Fiji

24 - 28 June 2019

ABSTRACTS

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Angola

Angola-Russia Cooperation in the development of GNSS Monitoring Ground Station: Capacity Building for Angolan Specialists

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In now days the Global Navigation Satellite Systems (GNSS) is a component of the national and international infrastructure, and for the socio-economic applications has become a transversal good for the development of countries. However, the necessity to expand the number of ground stations, improve or maintain the high-precision positioning of consumers at global level is still a challenge.

In the last five years the Republic of Angola has made very significant investments in the creation of space infrastructure building its first satellite Mission Control Center (MCC). Looking at the geographical localization of the MCC, this presentation describes the regional impact of the development of cooperation between the Angolan Ministry of Telecommunications and Information Technology and the Russian Space Agency “ROSCOSMOS”, to install and operate a GNSS ground station which allows to increase the local accuracy giving precise point positioning of consumer navigation from units of meters (2-5 m) to tens of centimeters (10-30 cm). It also presents the continuous national efforts to promote the national capacity building in space technology.

Australia

Monitoring and mitigating Space Weather Effects for GNSS applications

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The ionosphere has long been understood to affect radio communications and has got the attention of the scientific community. The ionosphere is also a major contributor to the total error in GNSS positioning applications. For precise GNSS applications, where the highly precise but ambiguous phase of the GNSS satellite signal is used, it seen as a bottle neck as it hampers integer ambiguity resolution. As a result, near real-time, precise positioning applications rely on accurate ionospheric corrections to achieve the desired positioning performance. In aviation, Satellite-Based Augmentation Systems (SBAS) are used to improve the accuracy and integrity of GNSS-based positioning for aircraft. The availability of augmented positioning within the required tolerance is affected by ionospheric or space weather disturbances. Precise GNSS applications such as Network Real Time Kinematic (N-RTK) estimate ionospheric corrections at the network level but are susceptible to large non-linear spatio-temporal gradients in the ionosphere. The Australia's National Positioning Infrastructure (NPI) project aims to achieve fast precise position for the GNSS user, by providing external sources of correction, one of which is the ionospheric correction. The required accuracy of the ionospheric corrections is better than 4 cms. We present work being done within the Bureau of Meteorology Space Weather Service on real time monitoring and modelling of ionospheric conditions for precise GNSS applications.

Australia

On the predictability of Equatorial Plasma Bubbles for Global Navigation Satellite System Users

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Industries such as mining, agriculture, construction and aviation heavily rely on Global Navigation Satellite Systems (GNSS) signals in their daily operations. Thus, GNSS contributes significantly to the global economy. This fact has motivated research efforts towards ensuring the resilience and robustness of GNSS applications against a variety of disruptions; e.g., radio interference and "spoofing". A natural source of GNSS signal disruption is the presence of ionospheric irregularities, which induce random fluctuations in the signal amplitude and phase (called "scintillations"), potentially causing receivers to lose lock. Therefore, there exists a present need to reliably predict the presence of ionospheric irregularities specifically for GNSS users. Equatorial Plasma Bubbles (EPBs) – also referred to as Equatorial Spread F due to their appearance in ionogram traces – are common sources of plasma irregularities that occur during the nighttime hours in the low-latitude region. The generation of EPBs is understood to be caused by the Generalized Rayleigh-Taylor (R-T) plasma instability, in which a strong vertical plasma density gradient and an upward plasma drift combine to destabilize the plasma. The R-T instability growth rate magnitude exhibits both a seasonal and daily dependence, which is important to consider in the prediction of EPBs. The seasonal trends are rather well understood, but the daily variability remains a significant challenge. Recently, R-T growth rates were calculated from global coupled ionosphere-thermosphere models and were shown to exhibit a similar daily variability to the observed EPB occurrence in multiple locations and periods. Such progress motivates our current efforts to translate these findings into an operational forecast for GNSS users in low-latitude regions. As this research proceeds towards translation into operations, effective measures of forecast skill and success must be determined and used to track progress, compare against other models and techniques, and to identify room for improvement to ensure that the need for reliable GNSS scintillation forecasts is being met. In this contribution, GNSS and VHF scintillation data collected by the Scintillation Network Decision Aid (SCINDA) network around the world in 2013-2014 is analyzed and compared against the R-T growth rates calculated using the most recent

Thermosphere Ionosphere Electrodynamics General Circulation Model. As part of this comparison, the usefulness of various forecast skill metrics for the prediction of EPBs for GNSS users is explored.

Australia

GNSS Precise (Point) Positioning: Where to from here?

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GNSS technology has revolutionized many aspects of the modern global economy. It provides essential support for everything from precision agriculture, construction and mining, to our understanding of the processes of plate motions, all of which require one thing: precise (and accurate) position information.

Today we are seeing a new generation of GNSS correction services and hardware enabling cheaper, more compact and truly scalable high-precision GNSS solutions. At the same time, GNSS and RNSS satellites are also evolving to include next generation augmentation capabilities to improve PNT services. This revolution in precise positioning is helping to realize new applications for example in the automation industry and unlock opportunities in new markets.

This presentation aims to provide an overview of the changing landscape of GNSS precise positioning solutions. It also endeavors to address the need for standardization and interoperability of GNSS precise point positioning (PPP) services in order to fully embrace the possibilities that this wave of disruption has to offer.

Australia

The Australian SBAS Program: Progress and motivations for a PPP Service

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Since June 2017, Geoscience Australia has been involved in a Satellite-Based Augmentation System (SBAS) test-bed. The Australian test-bed has included the provision of Precise Point Position (PPP) services, augmenting both the GPS and Galileo constellations. This presentation will overview the results achieved by these PPP test services and the findings of an economic benefits analysis of free and open PPP. Finally, Australia's perspectives on the standardization and interoperability of PPP services will be overviewed.

Canada

On the Interoperability of GNSS Clock and Bias Products for Precise Point Positioning with Ambiguity Resolution

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The technique of precise point positioning (PPP) enables global centimeter-level positioning by providing precise GNSS satellite orbit and clock corrections to users. Adding an additional layer of corrections in the form of code and phase biases allows for a faster convergence of the solution thanks to ambiguity resolution (PPP-AR). In a near future, several sources of corrections will be available to users in real time from regional augmentation services and even from GNSS satellites. While multiple sources of corrections are clearly beneficial, how users should handle this redundancy is not obvious. Switching from one provider to another implies either a discontinuity in user position or sophisticated algorithms for the alignment of correction streams. To gain more insights into this issue, the International GNSS Service (IGS) has initiated a new working group (WG) on PPP-AR. An initial study performed by the WG has shown that, even though analysis centers disseminate satellite clock and bias corrections having different interpretations, a transformation to a common observable-specific signal bias (OSB) representation can be defined to ensure interoperability. However, providing OSBs is not a sufficient condition for interoperability. Once interoperable corrections are available, the next step consists of obtaining consistent corrections by adopting standard models and conventions. Since there is no convention defining satellite attitude, this information should be disseminated to users to minimize modeling discrepancies, especially during satellite eclipses.

China

Application of Beidou in Natural Disaster Emergency Management in China

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China is one of the countries with high frequency of most serious natural disasters in the world. Diverse disasters resulted in many casualties and huge economic losses. Much effort should be made for disaster mitigation management. In view that Beidou system integrates positioning, navigation, timing and short message, it has played an important role in disaster emergency management. In recent years, Chinese government has made much effort to promote the Beidou application in the fields of disaster prevention, mitigation and relief. We have built the Beidou Comprehensive Disaster Reduction Application System, developed and distributed exclusive-relief Beidou terminals for countrywide relief personnel and vehicles. Beidou short message function has become an auxiliary communication mode , which solved problems of emergency communication and information report after disaster area communication interrupted. The integration of communication and position functions is the most significant advantage of Beidou We have developed five operational applications based on this: 1) Real-time monitoring location and status of relief personnel and vehicles all over the country; 2) Collecting and reporting disaster information attached high-precision location by mobile terminals; 3) Searching and rescuing persons trapped by disaster of flood, earthquake, landside, etc. 4) Trailing real-time and on-line location and route of relief material transportation ; 5) Directionally releasing disaster information for all kinds of persons in the disaster-affected area according to their location and person feature. At present, we have established the Beidou disaster reduction application platform, developed a suit of operational software and APP, and compiled standard training materials to promote Beidou application all over the country. The application of Beidou in disaster emergency management has been expanded to 13 provinces in China, while other provinces are also actively piloting. In future, the main direction of Beidou application in disaster emergency management in China will focus on disaster risk monitoring, early warning and fire rescue. Beidou high-precision positioning and integration with indoor navigation are two key fields. The Chinese government has been vigorously promoting the nationwide emergency management informatization. The unique characteristic of Beidou system, which integrates positioning, navigation, timing and short message, provides a broader development space for the application of Beidou disaster emergency management.

China

Development and application of national Beidou ground-based augmentation system

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This Presentation is dedicated to introduce the National BeiDou Ground-Based Augmentation System in China. It is divided into three parts, The first part describes the basic principles and how does the BD-GBAS work. The second part introduce the BD-GBAS Overall Design Scheme, including the system composition, distribution of reference Stations, GBAS data processing and high precision service index. The third part is the application of the system.

China

Beidou Short Message and High-Precision Positioning Integration Application

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Based on the high precision positioning of Beidou satellite navigation system and foundation enhancement system, as well as the transmission ability of Beidou multi-card cluster equipment, a set of information system in strange areas is constructed. It has the ability of multi-user high precision positioning, information interaction and footprint navigation without road network in strange and complex environment. Through multi-carton patrol mode, the transmission rate and length of Beidou short message are effectively expanded, the transmission ability of voice, picture and video is realized by narrowband compression technology, and the data convergence is realized through background management system. Analysis and service push ability. It solves the problems of poor communication, unclear location in complex areas such as plateau, jungle, desert, sea and so on.

The system is composed of Beidou information service vehicle and Beidou mobile terminal, which is mainly used in remote areas and strange areas, and provides users with high precision positioning navigation and short message communication services under all-weather and regional conditions.

The Beidou information service vehicle has the function of differential data distribution and information processing. It mainly adopts mobile 4G and radio communication mode to provide users with high precision positioning and information broadcasting. The mobile terminal has the functions of positioning and navigation, Beidou WeChat and so on, and has the functions of mobile 4G, wireless receiving module and Beidou short message communication. The high precision positioning is realized by receiving the differential data broadcast by the service vehicle, and the information interaction with other users is realized by Beidou WeChat.

China

Development of BDS and study of PPP timing

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The presentation contains two parts, one part is the development of BDS and the second part is about the study of PPP timing.

For the first part, we will introduce the BDS overall construction planning, the international GNSS monitoring and assessment system, and the National BDS ground augmentation (BDS-PPP) For the second part, we will talk the overview of PPP timing, and then discuss the continuity, consistency and other analysis of PPP timing.

China

GNSS Receiver Autonomous Integrity Monitoring based on Vector Tracking Loop

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Global Satellite Navigation System (GNSS) plays a major part in both economic and industrial development for each country. GNSS applications have seen a boom in the many industries such as space, marine, aviation, roads & transport, surveying & mapping, and even precise timing. Continuous monitoring and availability of GNSS signal is very important for providing autonomous position, navigation & time information worldwide 24/7. These monitoring parameters are considered to raise an alarm if misleading information or hazardous has occurred. Therefore, the need arises to develop a GNSS signal integrity algorithm or techniques. However, techniques can't improve the ability of GNSS receiver to record the weak signals. However, it can increase its robustness against various sources of signal degradation.

Since, number of research studies has been done in many countries in the field of receiver architectures to overcome the vulnerability of GNSS signal. Vector tracking loops is one of the advanced techniques of receiver architecture that uses to overcome the issue of robustness for safety-critical and liability-critical applications in dense urban environments. However, if the error occurs in one channel, other channels may be corrupted and tracking solution performance may decrease.

This research discusses in-depth analysis of vector tracking integrity monitoring. Algorithms were simulated for different scenarios and tested in different environments with simulation data. The research is also concluded by comparing studies between the traditional Receiver Autonomous Integrity Monitoring (RAIM) scalar loop and the Receiver Autonomous Integrity Monitoring (RAIM) vector loop.

Fiji

GPS and Satellite Image Analysis at The University of Fiji: A Case Study

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The use of Global Positioning System (GPS) and satellite imagery has historically been for military reconnaissance. However, later it became evident that these technologies could be used for a wide array of non military applications which have a direct implication in improving life on earth. From addressing sustainable development goals and disaster risk management to finding a good restaurant; GPS and satellite imagery are proving to be a pivotal tool in complex analysis. However, these tools are also readily available for use by ordinary people from platforms like Google Maps.

Through a research grant from USAID, the University of Fiji embarked to use satellite imagery to map shallow water benthic habitats at two sites in Fiji. This project led to massive capacity building within the University and this created opportunities for further research. The University of Fiji is now looking at developing research programs which use satellite imagery coupled with ground truthing data. The first program is to carryout high resolution mangrove and seagrass mapping to estimate blue carbon in these ecosystems. Change Detection study is another program that is under developed.

For image classifications, it is very important to have ground control points which define the different themes intended to be mapped for example different land-use. Equally important are a secondary set of points called ground truthing points which will then help statistically quantify the accuracy hence the usability of the classified image. Weather these points are collected using a hand held device or using an aerial or aquatic drone; they all require precise and accurate location information. Hence GPS forms an integral part of all the programs that are being envisioned.

Fiji

The Pacific GIS and Remote Sensing Council, a Network to support GNSS Applications

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The Pacific GIS and Remote Sensing Council (PGRSC) was finally founded in 2017 and registered in Fiji. However, this Council has a much longer history in organising and supporting spatial applications in Pacific island countries. Starting 1991 in Fiji, GIS, GPS and Remote Sensing (RS) applications were discussed and coordinated on a monthly basis through GIS&RS User Meetings, where technicians of all Government and private organisations met. They reported results of the last four weeks and explained the plan for the next months. Presentations of new data and methods were the highlights of these meetings. Duplication of work was avoided through these meetings.

These meetings lead into a Fiji national GIS/GPS/RS User Conference in 1998, more than 20 years ago. This developed into a yearly Conference which became a few years later the Pacific Islands GIS and RS User Conference. Also, the GIS&RS User Meetings were “exported” though a EU funded projects to most other Pacific island countries.

There are other vehicles of information dissemination created in the early nineties, which are operated by the Council, now. The Pacific Island GIS and RS Newsletter was launched in 1993. This newsletter also reflects on the GPS development during the last 25 years as it is the platform where Pacific islands can publish their applications. Also, most historical newsletters can be downloaded from the Council website: http://www.picgisrs.org/gis-remote-sensing-newsletter/. After two years of delay the newsletter is back on track since one year. It can help to distribute news about GNSS applications, where Pacific islanders not only see new developments but also applications from colleagues in other Pacific islands.

The e-mail distributing list GIS-PacNet is another vehicle created in the nineties for GIS, RS and GPS support. The list is operated by the Council and has currently more than 700 subscribers sitting in all Pacific island countries. The subscribers are only partly decision makers, mainly officers handling practical applications are the active members. News about new methods to apply GNSS are well distributed when utilising this list.

The Council also has its own Council network. Nearly all Pacific island countries selected a Council Focal Point. These are persons active in spatial environment, most of them organising the

GIS&RS User Meetings mentioned above. They receive regular “Circulars” from the Board of the Council and inform the local user groups. This network will also distribute GNSS related information.

Finally, there is the PGRSC website www.picgisrs.org , which will have a dedicated section in the next months. This section will reflect on GIS, GNSS and RS projects, where methods can be scaled and copied to local applications.

Fiji

GNSS Technology and the Pacific Community

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The Pacific Community (SPC) is the pacific island region's principal technical and scientific organization. It delivers technical, scientific, research, policy and training support to pacific island countries and territories in fisheries, agriculture, forestry, water resources, geoscience, transport, energy, disaster risk management, public health, statistics, education, human rights, gender, youth and culture. SPC was established in 1947 and employs over 700 staff. Its headquarters are in Noumea, New Caledonia, with other offices in Fiji, Federated States of Micronesia, Solomon Islands and Vanuatu. SPC has 26 member countries and territories including its founding members, Australia, France, New Zealand and the United States of America, which contribute a large proportion of its funding. Other major development partners are the European Union; global fund to fight aids, tuberculosis and malaria; United Nations agencies; Asian Development Bank; World Bank and Global Environment Facility.

SPC's vision for the region is a secure and prosperous pacific community, whose people are educated and healthy and manage their resources in an economically, environmentally and socially sustainable way.

Our mission is to help pacific island people position themselves to respond effectively to the challenges they face and make informed decisions about their future and the future they will leave for the generations that follow.

The islands and atolls in the pacific are widely spread out and they have the largest ocean space. The livelihoods of the people in the pacific depends highly on the ocean resources.

The Pacific Community has been providing technical support with respect to accurate positioning and measurement of these islands and atolls with respect to locational information whether there is a natural disaster, climate change or coastal changes.

Global Navigational Satellite System (GNSS) technology is well utilized to accurately map the pacific islands and atolls by SPC. The use of Receivers on the ground, Unmanned Aerial System in air space and Multi Beam System in the ocean which uses the GNSS technology for positioning and navigation is available in SPC and is of good expertise.

All the surveys and mapping are carried out in one reference system; therefore, the oceanographers, surveyors, geospatial experts and hydrographers are working together to adopt the global geodetic reference system for a well-defined Vertical Reference Frame and Horizontal Reference for the islands and atolls in the pacific.

Therefore, a well-established network of Continuous Operating Reference Stations (CORS) and Tide Gauge Stations in the following participating countries; Cook Islands, Fiji, Federated States of Micronesia, Kiribati, Marshall Islands, Nauru, Niue, Papua New Guinea, Solomon Islands, Tonga, Tuvalu, Vanuatu and Samoa as part of the Pacific Sea Level & Geodetic Monitoring Project funded by Australia is working very well in the region. Following that Fiji, Tonga and Vanuatu are establishing their network of CORS in their countries for geospatial and survey activities which encompasses their national strategic goal for socio-economic development.

The Pacific Geospatial & Surveying Council (PGSC) supported by the SPC Partnership Desk was established in 2014, mandatorily to support the geospatial and surveying capacity in the region and is instrumental for good collaboration nationally, regionally and internationally.

Fiji

The USP Bachelor of Geospatial Science – Capacity Building and Community Engagement using GNSS

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The University of the South Pacific has been offering Geospatial Science courses since 1994. In 2015 we introduced the new Bachelor of Geospatial Science. This programme is now in its 5th year and will graduate its second cohort in 2019. Concomitant with the new programme, USP has been offering students practical opportunities to apply geospatial techniques and methods through our Summer of Research Programme, the Tradition and Technology Project and South Pacific Flying Labs.

The benefits have been great, engendering ground up capacity building for our students and graduates who now operate in variety of projects both in their workplace, in research and at undergraduate level by participating in field survey courses. Focus has been on using high precision RTK GNSS equipment in conjunction with Unmanned Aerial Vehicles (UAV) via the USP South Pacific Flying Labs which focuses on solving local and regional issues. USP now has 6 Certified Remote Pilots with training provided to four Fijian and one Ni-Vanuatu to broaden capacity during times of disaster. All pilots are also conversant with our GNSS base station and rovers for both image ground control and topographic surveying.

We will cover our activities to date, our engagement with Coastal Fijian Villages and Informal Settlements on Viti Levu. The Village profiling project seeks to assess, in biophysical terms, the resources available to these communities in terms of mapping and modelling for flood and storm vulnerability assessment, Fiji Mangrove Health, Forest Degradation, Infrastructure assessment and Organic Farm Mapping. GNSS has been key to tying these projects to the Fiji National Mapping Grid and height datum.

The Geospatial Science Programme has received two Australian Spatial Excellence Awards and is now collaborating with many different external organizations both international, regional and local. This in turn gives increasing relevance to the work our students undertake creating a truly self-sustaining local capacity building programme.

Fiji

Updating Fiji’s Maritime Survey ITRF 2005 to ITRF 2014

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The Fiji Geodetic Datum (FGD) 1986 on WGS 72 ellipsoid is the official datum and has been used to date. FGD 1986 later adopted the name Fiji Map Grid (FMG) 1986 (Hannah, J. and Maseyk, J, 1989). This is about to change with the recent installation of 8 continuously operating reference station (CORs) station that will generate a network Real Time Kinematic (RTK) solution across the islands, which will lead to the definition of a new geodetic datum. These changes will have an impact on geospatial datasets. GIS is an evolving science that is constantly being challenged by new technologies. In particular, access to high precision navigation and positioning is an important development that will impact GIS users. The recent announcement for the development of a sovereign satellite-based augmentation system (SBAS) in Australia will allow access to centimetre (cm) precision for all users using any device. In Fiji, Spatial datasets are referenced to two main coordinate systems: WGS 84 UTM Zone 60s and Fiji Map Grid 1986. With precision surveying becoming a reality, users’ will need to understand that WGS 84 should not be considered a one size fit all datum (Qiao, 2014 and Brunner,F 1998). Geoscience Australia (2017) stated that Australian are not able to achieve better accuracies as they cannot access WGS84 via a differential measurement directly to the DoD network of stations. WGS84 coordinate accuracy is meaningless unless epoch metadata are provided. This and others are the reason why Fiji is updating its national datum. Geoscience Australia in 2005 conducted a GNSS survey for Fiji’s maritime boundary. The coordinates for all these survey marks were transformed from FMG 1986 to ITRF 2005. Part of my research, I updated the ITRF 2005 to the latest reference frame (ITRF 2014) , adopted a set of codes from Geographic Information Systems Stack Exchange (2015) and transform the coordinates using Helmert transformation parameters in order to map movement that has occurred on the survey mark which will indicate movements in the tectonic plates. This movements can then be calculated and incorporated into a distortion model which GIS users can then use to align their spatial datasets to minimize shifts.

GLONASS: Present and Future

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GLONASS is a fully operational, active and individual component of GNSS available globally. We have observed GLONASS availability and its performance as a stand- alone solution provider from our fixed location at Burdwan, West Bengal, India which is situated in eastern part of India. After modernization number of GLONASS is stable and it is always available with a stable position solution as well. But some of its drawbacks have been observed which are discussed in this paper those restrict the popularization of GLONASS.

In our first study, we have used GLONASS as a stand-alone solution provider in open sky using all available GLONASS and under constraint environment (i. e., urban canyon) when GLONASS visibility is restricted. Both of these results obtained simultaneously are shown in Figures 1 and 2. There is always uninterrupted solution error under open sky whereas, position solutions are frequently interrupted in urban canyon using only GLONASS.

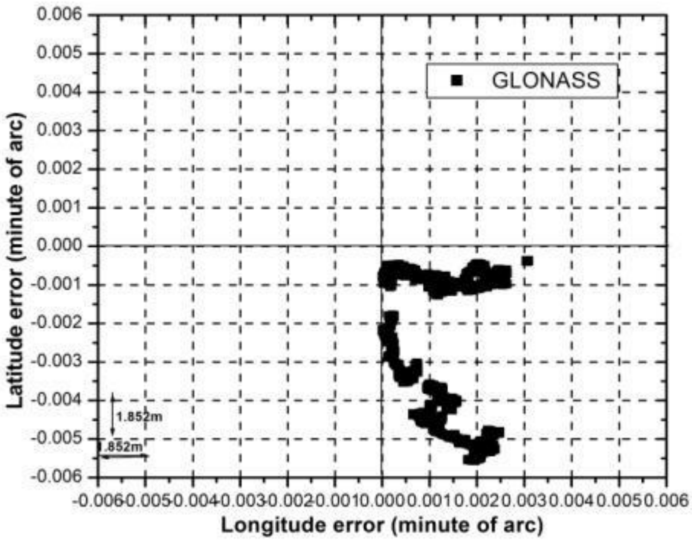

Figure 1: GLONASS position solution errors (under open sky); 10 January 2019; one- hour data at 1 Hz rate, Burdwan, India. Dark lines indicate the reference coordinates.

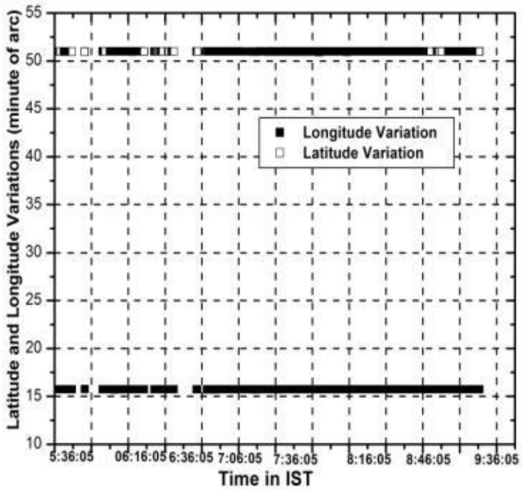

Figure 2: Variation of Latitude and Longitude with time under Constraint condition (urban canyon); 10 January 2019; one- hour data at 1 Hz rate, Burdwan

Increase in PDOP values during the experiment are also verified from IAC, Russia particularly from south- eastern part of the globe which is shown in Figures 3 and 4. Sometimes it rises to 4 or more.

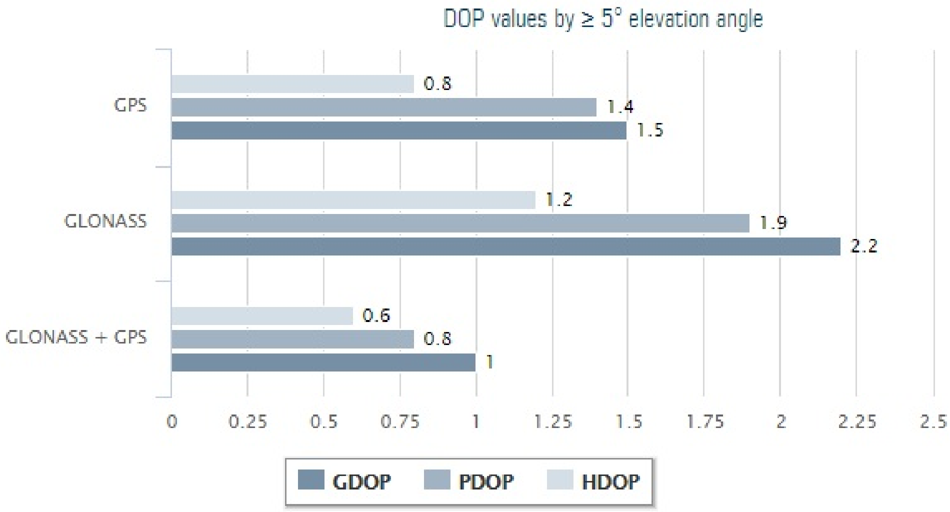

Figure 3: GDOP, PDOP and HDOP; values from IAC, Russia (10/01/2019; 8:17:00 IST)

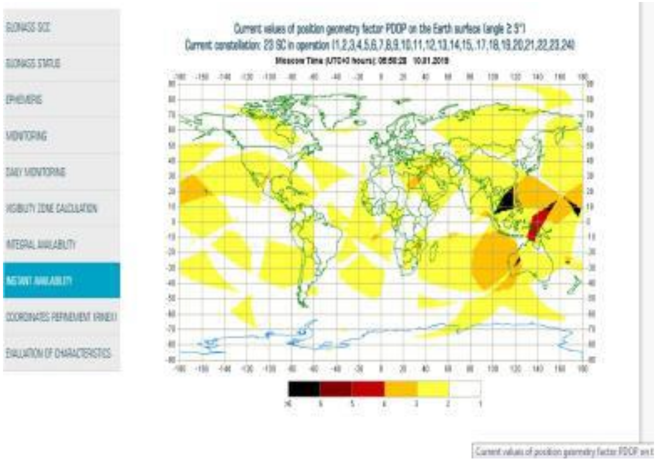

Figure 4: PDOP across the globe from IAC, Russia (10/01/2019; 8:20:00 IST)

This increase in PDOP values are frequently observed for GLONASS stand- alone solutions from south- eastern part of the globe.

We have tried to mitigate this solution problem introducing IRNSS along with GLONASS. Therefore, in an another day we have collected data under open sky using all available GLONASS and IRNSS and repeated the same experiment under constraint environment. These results are shown in Figures 5 and 6.

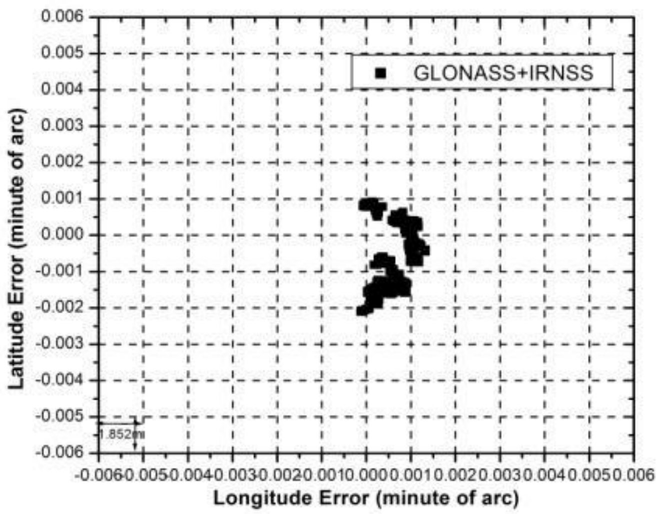

Figure 5: GLONASS + IRNSS position solution errors (under open sky); 5 February 2019; one- hour data at 1 Hz rate, Burdwan, India.

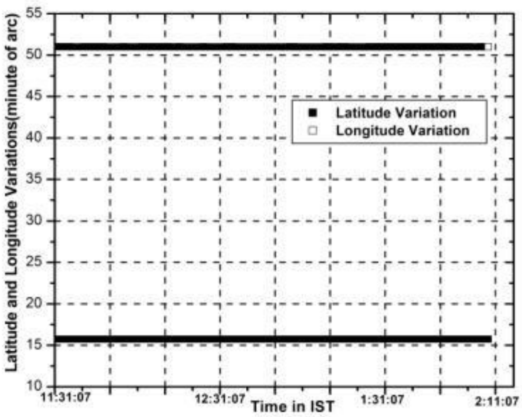

Figure 6: Variation of Latitude and Longitude with time under constraint condition (urban canyon); 5 February 2019; one- hour data at 1 Hz rate, Burdwan, India.

When IRNSS is used along with GLONASS, error variations are lesser than stand- alone GLONASS and uninterrupted solution is always available using IRNSS along with GLONASS in urban canyon.

In another experiment, it is interesting to note that, introduction of GLONASS along with a fixed number of pre-chosen GPS with moderate PDOP helps improving the solution accuracy. But this is more helpful with a low number of used GPS (=4) and the situation doesn't change much with higher number of GPS satellites (>4). This is may be attributed due to still existing interoperability issues between GPS and GLONASS which have to be taken care of for using GPS- GLONASS in tandem in future.

Limited GNSS visibility from high elevation angles during some parts of the day from India is observed including GLONASS constellation. In restricted visibility conditions from lower elevation angles simultaneous absence of GLONASS from higher elevation angles may pose serious threat for seamless navigation. The phenomenon is orbit- design specific, so, proper measure must be taken care of the problem during mission planning using GLONASS.

Some of the drawbacks of GLONASS from the Indian sub- continent are noticed that are discussed in this paper. Introduction of IRNSS could mitigate those problems of GLONASS particularly from south- eastern part of the globe.

Indonesia

Simulating Ionospheric mitigation on GNSS-based application

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GNSS applications in Indonesia have spread to various fields. But coordination is still needed to accelerate its forwarding. But Indonesia is in the active ionosphere. The ionosphere is one of the main sources of errors in the GNSS application. This is indicated by the ionospheric anomaly correlation and error position. The augmentation system was built to reduce the ionospheric effect on flight GNSS application systems such as SBAS and GBAS. Ionospheric mitigation initialization on SBAS and GBAS has begun in Indonesia but is still in the form of a simulation.

Japan

PPP activity update and plans of QZSS

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The Cabinet Office in Japan started to provide Positioning, Navigation and Timing (PNT) services using four satellites of Quasi-Zenith Satellite System (QZSS) from November 1, 2018. QZSS also provides three types of navigation augmentation services; Sub-meter Level Augmentation Service (SLAS) that corrects pseudo-ranges of GPS and QZSS for DGNSS method, Centimeter Level Augmentation Service (CLAS) for PPP-RTK method, and high accuracy augmentation service for PPP method (with satellite orbit and clock error corrections produced by MADOCA). The service areas of SLAS and CLAS are limited to the vicinity of Japan, where reference stations are located. On the other hand, PPP service can be provided to the Asia-Oceania region where users can be received QZSS RF signals.

This presentation introduces the performance evaluation results and future plans for two services of CLAS and PPP service which are the augmentation services using PPP-RTK and PPP methods. CLAS achieves a horizontal positioning accuracy (static) of several centimeters and Time-To-First-Fix (TTFF) of less than 60 seconds (95%) in almost all areas of Japan. Even for PPP service, although it is a test service, it achieves several centimeters in horizontal positioning accuracy (static) after solutions are converged.

Japan

Recent activity of International Standardization for high-accuracy GNSS correction service

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On emerging wide-area high-accuracy open PPP/PPP-RTK correction service and low-cost multi-frequency GNSS receivers, the centimeter level high-accuracy positioning will be widely used in the field of agriculture, construction, drone, and automobile. For such applications, the interoperability between different correction service and receivers should be maintained to minimize the production and operational cost.

In this presentation, the recent activities for international standardization of PPP/PPP-RTK will be introduced.

The international standardization of format has been conducted in RTCM SC-104, published as RTCM SSR. However, it doesn’t support PPP-AR/PPP-RTK yet, and it is not sufficiently effective for satellite-based narrow band correction service.

Recently, Compact SSR, which is a highly efficient open format for PPP/PPP-RTK was proposed and applied for QZSS CLAS. It is also planned to be applied as the baseline of Galileo HAS.
The high-accuracy GNSS positioning is also demanded in mobile communication for LTE/5G, 3GPP is also working to define the PPP-RTK standard based on Compact SSR.

The other useful information such as the integrity, the authentication of correction data, the grid definition, the precise coordinate transformation, and the service maintenance could also be standardized.

Japan

Low-cost GNSS receiver system for high-precision GNSS data collection

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Recently, GNSS receiver manufacturers have released low-cost GNSS modules in L1 band as well as in multi-bands (L1, L2, L5). These low-cost receivers are very important for GIS data collection, education (teaching and training), IoT, ITS, agriculture and drone mapping etc. The mass market users need low-cost, low-power, small size and high-accuracy receivers. Since, there are more than 30 visible GNSS satellites, it is now possible to output high-accuracy PVT data than before when there were only GPS and GLONASS. Many of these low-cost receivers also output necessary raw data for carrier-phase based PVT solutions. Accuracies of few tens of centimetres are now possible for a base-length within 5km. Thus, the availability of low-cost receivers with high-precision will open many new applications which otherwise would not have been possible. We have developed various versions of low-cost receiver systems based on Android devices or board micro-processors so that data can be logged in the field quite easily without the need of computers. Our target is to make a receiver system that is less than US $100, provides an accuracy better than 100cm and weighs less than 100g. We will present about these devices, android apps to perform RTK and analysis of results.

Kiribati

GNSS applications: Kiribati Maritime Boundaries Project

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In 2007, Kiribati embarked on a project to delimit its maritime boundaries. The approach Kiribati undertook was to utilize old charts, maps and satellite imagery as means to determine its territorial sea baselines. With most of the charts and maps being based off local datums, and the use of satellite imagery for such a purpose was relatively new (at the time), it was important to understand what the positional accuracies of these datasets were. GNSS technology was used to verify the positional accuracies of the charts, maps and satellite imagery. GNSS survey work was conducted on selected islands in Kiribati and results from the survey showed that the positional accuracy of the satellite imagery provided the best solution for delineating the territorial sea baselines. Consequently, Kiribati was able to complete the delimitation of its maritime boundaries with great confidence and accuracy; fulfilling its obligations to the United Nations Convention on Law of the Sea.

Malaysia

Modelling the Ionospheric Tec Over Malaysia Using SCHA

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Ionospheric refraction is one of the major error sources in the propagation of radio signal such as Global Positioning Systems (GPS) and space-based radio system due to its dispersive nature. The error can be calculated and forecast based on total electron content (TEC). An index will help to inform users on the development of ionospheric disturbances that can affect the GPS signals. TEC varies with time, location and solar activity; thus, developing a reliable model to forecast the TEC remains a challenging task. Therefore, the main objective of this work is to develop a new technique for modeling the ionospheric TEC and introduce a TEC disturbance index over Malaysia. A model based on modified spherical cap harmonic analysis (SCHA) was developed to estimate vertical TEC over the region using GPS observations. GPS data for the year 2010 and 2014 from 78 stations in Malaysia were processed and used to map the ionospheric TEC over Malaysia. The SCHA model was based on longitudinal expansion in Fourier series and fractional Legendre co-latitudinal functions over a spherical cap-like region. The spherical cap coordinate system was defined based on the pole and half angle of the spherical cap where the pole was 3 N, 99.5 E and the half angle was 10. Based on spatial resolution and computing load, the degree and order of SCHA over Malaysia was 6. The model coefficient was estimated and used to derive two-dimensional maps of TEC with spatial resolution of 0.15x0.15 in latitude and longitude, respectively. These maps were validated with the global TEC map and was used to establish the regional model. The climatology and ionospheric disturbance index (M index) over Malaysia were then determined based on the developed model. The range of disturbance index was divided into four categories - negligible, weak, strong and very strong TEC disturbances. It was found that SCHA model had better mapping with the accuracy of less than 4 TECU compared to other models. Throughout the years of analysis, it was observed that the diurnal pattern of mean TEC exhibited a predawn minimum which steadily increased from about sunrise to post-noon, and gradually decreased to attain a minimum before sunset. Daily mean TEC showed a highier positive correlation with the solar activity compared to geomagnetic activity. Strong M index was observed during high solar activity while weak conditions mostly occurred during low solar activity. The model which was based on the data from GPS receivers around Malaysia showed an increase in the mapping accuracy

and could provide good local knowledge on the time varying characteristics of the regional ionosphere. Additionally, it can also be used to mitigate ionospheric errors in GPS operations.

Mozambique

Implementation of coastal port vessels traffic system

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Maritime safety is essential for passenger and cargo vessels, because of the heavy traffic and dangers inherent to the sea.

This project was born from the necessity of flowing of the ships in the channel of Mozambique that transport passengers and cargo, some currying larger quantities of hydrocarbons and become in need of control of the same ones.

In order to ensure greater safety and control of marine pollution that can be caused by tankers when washing their waste.

By controlling their movement and coupled with the pollution control system, it can ensure that the Indian Ocean waters that bathe the 2700 km of Mozambique's coast line can be protected.

On the other hand it can facilitate the traffic control of several illegal deals practiced by some infidel Ship-owners and much more to avoid that the Mozambican coast is considered the black coast, where some Ship-owners for wanting easy profits comes to sow the tired ships or below the standards as in the past occurred with the famous case of KATINA P, and other vessels allegedly because it was blind coast.

By deploying this system on the Mozambican coast will betray more ships carrying tourists as it is well known we have the beautiful beaches and favorable climate for diving both amateur and professional or even visit our beautiful tourist stays.

This support system for navigation in the land side is a tool that helps the management of the fleet.

Two applications should be developed to meet the objectives: first, an on-board navigation support system for monitoring the voyage and recording incoming travel data in Mozambican ports; second, will be for monitoring maritime traffic and analyzing the travel records of the ships that pass through the Mozambique Channel, following all its activities related to the prevention and combat of marine pollution.

Both applications collect the navigation data from the Automatic Identification System nautical information sharing system. It will also be developed a support application, the Map Calibrator, to geographically refer and prepare nautical charts for the first and second charts.

The first will be installed at the strategic points of entry of the ports and has proved to be an important complement to the control of the movement of ships in a safe way in the ports and controlled all on-board equipment and their state of government or maneuverability. The second will be to control all ships that pass through the Mozambique Channel, deserving emergency assistance in case of emergency this system will have visualized in real time for the coastal traffic safety command.

As is well known today, maritime shipping plays a predominant role in trade, where most of the raw materials and products we consume are transported by sea. It also has an important role in terms of passenger transportation in coastal cities, separated by rivers, or on the banks of lakes. Man also sees in the sea a source of pleasure, having in leisure vessels a means of contact with the Sea and with its vast and mysterious natural environment, giving him a unique and defiant sensation of freedom.

For all these reasons, maritime traffic has become more and more intense. As the seas are always an unpredictable and dangerous environment, it is necessary to regulate at sea international laws to make navigation safer.

As such Current technological means has increased safety and facilitated maritime guidance. Technologies such as global positioning systems, such as GPS, that allowed man through a constellation of artificial satellites, orient themselves as our ancestors guided themselves through the constellations of stars, but with a much greater precision. Other technologies, such as integrated bridge systems or the Automatic Identification System, have provided much greater situational awareness and security, giving the navigator access to very complete information systems.

This equipment will be used to help control the Mozambican coast using the guidelines of Resolution A.857 (20) of the IMO adopted on 27 November 1997 and its amendments, as well as other relevant international instruments applied for these matters.

Myanmar

National geodetic reference frame of Myanmar

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Since 1905, under the British rule, all the surveying works have been undertaken by the Survey of India. At the end of World War II, the British government separated surveying works of Myanmar from Survey of India. On 1st November 1946, Burma Survey Department was formed under the Ministry of Finance and Revenue by the British government. Topographic Maps that have been used since pre World War II time were based on Lambert Projection. Myanmar is a State where extent of North- South direction is larger than that of East-West direction. In such condition, UTM mapping system is suitable for Myanmar. In year 2000, Myanmar survey department had created Myanmar datum 2000 by the technical supporting Finnmap Co. Ltd. Nine Primary reference station were established and observed connect with ITRF 1996 base on Everest 1830 Ellipsoid. For nationwide coverage, (1134) map sheets at 1: 50,000 scale, (322) map sheets at 1: 100,000 scale and (93) map sheets at 1:250,000 scale were completely published. Earthquakes pose a hazard for many locations throughout the country as Myanmar is located on one of the two main earthquake belts in the world. After year 2000, at least 7 earthquakes occurred along the Central Lowland where the Sagaing Fault passes. That is why, Myanmar survey department need to re-observation on the nine primary Pillars for their movement. Recently, Myanmar survey department try to establish (5) CORS in Myanmar for National Geodetic Reference Frame and RTK network in 2019.

Nepal

SW maps for low cost GNSS receiver systems

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Low cost GNSS systems can now provide sufficient position accuracy for engineering surveys and mapping tasks, for a fraction of the cost of commercial survey grade receivers. However, there is a lack of easy to use software for data collection and processing using such receivers.

This paper discusses the development of a complete solution for high accuracy mapping using low cost receivers. A receiver has been developed using the u-blox M8T module, which can communicate with a smartphone via Bluetooth or USB. The popular mobile GIS application SW Maps was modified to include RTK and PPK capabilities with the low-cost receiver system, and was tested successfully in survey of rural and urban water supply projects. SW Maps allows users to have a lot more flexibility in their data collection workflow than traditional handheld receivers but is limited to the location accuracy of the smartphone. By using a high precision low-cost external receiver with SW Maps, it can be used for high precision mapping as well. This technology could be very attractive for small surveying firms and local governments who cannot afford high end receivers.

For regions having limited access to mobile internet, Post Processed Kinematic (PPK) can be utilized for high accuracy mapping. A tool was developed to automatically download correction data from CORS stations for post processing a SW Maps project containing raw data recorded from the u-blox M8T based receiver.

New Zealand

Bridging the gap between high-altitude remote sensing and ground survey for marine conservation planning

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Recent enhancements in satellite remote sensing has increased the value of remotely sensed data for marine ecologist. With a ground sample distance of 31cm for panchromatic nadir and 1.24m for multispectral nadir (WorldView-4) commercial satellite imagery remains best suited for large scale assessment of benthic marine habitats. Yet, this imagery struggles to provide significantly finer details in areas with heterogenous biogenic habitats in temperate marine environments. This presentation will focus on low altitude remotely sensed data to fill the gap in fine scale sampling along the intertidal zone. Seasonal RGB and multispectral data will be collected at Meola Reef, Auckland, New Zealand at variable tides to survey, monitor and assess biogenic habitats (seagrass & oysters) from low altitude remote sensing for marine conservation planning. A remotely piloted aircraft system (RPAS) with RGB (CMOS) sensor and a MicaSense RedEdge multispectral sensor retrofitted used to collect seasonal data at 164ft altitude with an open source (Pix4D capture) flight planner. Combined with structure from motion (SfM) photogrammetry, a ground sampling distance of 1.35cm/px (RGB-3band) & 3.45cm/px (Multispectral-5 band) was achieved. Along temperate coasts of New Zealand, there is a gap in exploring the potential of RPAS as a low altitude aerial photography tool for sampling fine scale biogenic marine habitats. This technique would elevate data collection efficiency and ground coverage considering tidal variations with negligible timings. High spatial resolution remotely sensed data could minimize human footprints during on ground surveys. While the other methods of data collection in the marine environment are still valuable and cannot be replaced, RPAS data can complement these datasets for marine conservation planning before these ecological sensitive habitats reach their tipping point.

Differential GPS supporting Lidar Technology for applications to road surveys

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The latest of technology applications to Surveying and Mapping by terrestrial and airborne drone with LiDAR technology has made so much of economic savings on time, human resource manpower (surveyors) and finally the cost of data acquisition in surveying for design and construction. The LiDAR output product with bright colour maps are attractive to the eyes but fails to produce and provide the necessary data output for land surveyors and engineers.

Cost of project mobilising on setting up the LiDAR system together with the GPS component, the supporting software and computer processing involved is enormous. However, the end product fails to meet the expectations and basic requirements of the very necessary coordinates for the field practicing land surveyor to design road alignments as well to produce longitudinal sections for volume on earth works analyses, hence the final LiDAR product is attractive and SMART looking but may not be so Intelligent a data set to surveyors and design engineers.

This paper attempts to illustrate with the procedure from GPS data acquisition to superimposing LiDAR images and the coordinate transformation process from the ellipsoid surface onto EGM2008 for the vertical component. The transformation to the plane topographic surface coordinates from the ellipsoid is also done to enable the true representation of topographic distances that is required by surveyors and engineers. Finally, an approach to investigate the uncertainty of vertical heights from EGM2008 with the actual topographic surface with reference to the mean sea level (MSL) from the GPS data captured along the road, on a test case made in Lae, Papua New Guinea.

The Philippines

Linking the different coordinate systems in the Philippines using GNSS

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There are three different reference systems used to produce spatial data in the Philippines with a fourth system being proposed based on the ITRF. A cadastre includes documents and maps that describe parcels in terms of the reference system, size, shape and land area. The primary purpose of a cadastre is to facilitate land tenure and taxation. Cadastre is the most fundamental and vital in the development of a land administration system. A cadastre is dependent on the reference system used in the land survey and processing of the parcels. The resulting cadastre of the different municipalities and cities has different quality. This can be observed when a municipality's cadastre is combined with another cadastre. Problems encountered include but not limited to overlaps and gaps between parcel boundaries up to political boundaries. The UP Training Center for Applied Geodesy and Photogrammetry (UP TCAGP) collaborated with the Department of Environment and Natural Resources- Land Management Bureary (DENR-LMB) in implementing the Land Sector Modernization (LandS Mode) Research Project. A study was performed to aid in the development of a standard procedure in linking the three reference systems. Furthermore, another related study was done to assess the possible migration to a geocentric reference system, the ITRF. The three existing reference systems of the Philippines are, the Local Plane Coordinate System (LPCS), the Philippine Plane Coordinate System - Transverse Mercator / Luzon 1911 (PPCS-TM/Luzon1911), and the PPCS-TM / Philippine Reference System of 1992 (PPCS-TM/PRS92). The proposed reference system being named as the Philippine Geodetic Datum of 2020 (PGD2020) is based on the International Terrestrial Reference Frame (ITRF). In addition, the research study also dealt with the review, analysis and determination of the appropriate methodology in the transformation and unification of the different cadastral data in pilot areas in the country. The methodology of the research includes the recovery of existing reference monuments scattered all over three adjacent municipalities, GNSS observations of the recovered monuments, GNSS post-processing, and common-point analysis. Localized 2-dimensional Conformal Transformation parameters were derived for each municipality in order to relate them to the homogenous network established for the three municipalities. It was then shown that the utilization of GNSS technology and common-point analysis in coordinate transformations reduce the residuals in transformations, provide a homogenous relationship between the existing reference systems, and establish feasibility for the linkage and possibility to transition to PGD2020. Finally, the transformation parameters obtained were implemented in transforming the cadastral parcels to a common reference system. The success of the transformation was analysed in terms of parcellary analysis specifically the effect of the transformation at the azimuth and distance of the parcel boundary lines & position and overlay analysis to determine the fitness of a transformed cadastre to another adjoining cadastre. The result shows an improved fitness in the overlay between adjoining cadastres and minimal change in the transformed parcel description.

Russian Federation

GNSS metrology development in Russian Federation

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Today the use of direct GNSS measurements or calculations based on GNSS measurements have become a necessary element needed to find the solution to a wide range of problems in such fields as geodesy and cartography, transport, building, agriculture, fundamental research and lots of others. At the same time the operation of GNSS itself is based on the use of various measurement systems included in every part of GNSS: space complex, augmentation systems, fundamental complex. The possible consequences of using invalid GNSS measurements can affect the rights and legal interests of citizens, society and the State. Due to the importance of this problem the metrology of GNSS measurements is one of the most rapidly developing fields of metrology in Russian Federation.

The system of ensuring the uniformity of measurements (system of metrology) for GNSS (and especially for GLONASS) in Russian Federation include:

- state primary standards;
- means for transmitting measurement units from the state primary standards to the means of direct metrological assurance of working measuring instruments;
- means for metrological assurance (testing, calibration and validation of characteristics) of working measuring instruments.

It should be noted that in Russian Federation every GNSS receiver or GNSS measurement system used in such fields as geodetic and cartographic activities, hydrometeorology, environmental monitoring, execution of orders of the court, prosecutors, state executive bodies, road safety has to pass the procedure of verification of measuring instrument every 1-5 years (depending on the GNSS receiver reliability).

In the last few years several new complexes for testing and calibration of GNSS elements were developed. They include the complexes for calibration of GLONASS systems, but more importantly in terms of GNSS application – they also include several systems and methods for testing and calibration of GNSS navigation equipment.

Those systems presented in this article include:

- system of GNSS simulators calibration;
- system of GNSS antennas calibration;

- system of GNSS receivers calibration using spatially separated emitters in a shielded anechoic chamber;
- system of absolute GNSS receivers calibration.

Samoa

GNSS applications to make lives better in the Pacific – SkyEye Pacific

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At SkyEye Pacific, our main goal is to make lives better. We do this by utilising and understanding technology to help individuals and companies manage their resources. SkyEye Pacific is a family owned company that has been operating for almost 6 years. The company was established in Samoa and now has branches in Solomon Islands, Vanuatu and Tonga. Our products and services include Vehicle Tracking Systems, Aerial Surveying using UAV, GIS and Remote Sensing and ICT.

One of the biggest problems we face in the Pacific is poor data and resource management due to factors that include many products and softwares not being available for use in our region, the price of technology, not many people pursuing this career path therefore the lack of skills and understanding to comprehend the features of certain technologies etc. This is why we, SkyEye Pacific have been forced to innovate easier, efficient and money saving ways to help our people. We have taught ourselves using the internet and opensource to build our own versions of things like the creation of our own Geodetic Network called SkyEye Precision Network (SPN).

One of our main services is Aerial Surveying in Real Time Kinematic and Post Processing Kinematic. This is done by using our drones (short and long range) and base stations to capture imagery then processing them to produce geolocated photos, point clouds and digital models. These maps and imagery are used by our clients to manage their assets and resources such as counting coconut trees over a large area, mapping and geocoding the location of 700 organic farms in Samoa that are the sole suppliers of virgin coconut oil for the Body Shop, mapping to predict which parts of our villages will submerge under sea if it raises by a few more meters, mapping many areas and resources that were damaged by a tropical cyclone and many more.

Many of our clients need down to a submeter accuracy when it comes to monitoring and maintaining their resources especially underground utilities (drainage, electric power cable, water pipes etc) hence why we needed to create SPN. SPN is our new and developed geodetic network to provide down to 1cm absolute accuracy imagery. This accuracy is not only for our drone imagery and orthophotos produced, we also have digital forms that are used by our clients for asset collection and monitoring that involves collecting geo-location. These maps and imagery have been very useful to our clients for locating exact locations of their utilities without wasting resources to find them but instead saving money and time.

Thailand

GNSS time transfer: Receiver internal delay determination

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National Institute of Metrology (Thailand), NIMT, time and frequency laboratory maintains caesium atomic clocks ensemble to generate Coordinated Universal Time at NIMT; UTC(NIMT) and compares this time scale with UTC by measuring time offset between GPS system time (GPST) and receiver clock time specified as UTC(NIMT). The computed UTC(NIMT) is later disseminated as reference frequency signals to other measurement standards through calibrations and in the internet time synchronisation system as Thailand standard time.

Precise GPS system time synchronisation and transmission times from GNSS are needed to be obtained and measured to achieve accurate time transfer. GNSS errors need to be defined and estimated. This work describes receiver internal delay definition, calibration performed and results of UTC(NIMT) time comparisons results by focusing its corresponding measurement uncertainties especially the systematic uncertainty.

The experiments are simultaneously observed GNSS satellites by GPS and GNSS receivers with two separate antennas with short baseline, where both receivers are connected identically to the external caesium frequency standard at the specified UTC(NIMT). The GPS receiver internal delay is determined and known through comparisons using an internationally recognised method called GPS common-view time transfer; the same GPS satellites are observed at the same time, in the Asia-Pacific metrology programme inter-laboratory comparisons. Once the receiver internal delay of this GPS receiver is known at NIMT, this GPS receiver is used as a reference to calibrate the GNSS geodetic receiver using a precise point positioning algorithm to determine unknowns; namely, receiver position, tropospheric delay and receiver clock offset before analysing the receiver internal delay.
The calibrated GPS receiver used in international time transfer significantly improves the accuracy of the time comparisons between UTC and UTC(NIMT) around 5 times. Multi GNSS observations and geodetic processing algorithm could characterise the receiver internal delay as of 346.0 nanoseconds on GPS C1 code.

Tuvalu

Applications of GNSS in Tuvalu

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The application of GNSS technology in Tuvalu is still at its infancy stage. Although this has been used in the past two decades under the Sea Level and Climate Monitoring Project to define local Absolute Sea Level for Tuvalu (Tuvalu CGPS Core Station 1998), and in 2004 for defining Tuvalu Maritime Boundary “Baseline”;

Tuvalu has two GNSS Core stations on capital island Funafuti established under the Sea Level and Climate Monitoring Project supported by the Government of Australia and SPC. These Core stations are also used by the Department of Lands & Survey, and other GNSS users on the island as Base for GNSS survey. The application of GNSS technology stemmed from the department’s strategic goal of 2015 to upgrade and modernize its national reference frame which was based on local grids, and to adopt a new global reference frame ITRF2014. Present and future positioning and mapping activities will be reference to the global reference frame.

Tuvalu completed its first Geodetic Survey campaign using GNSS survey on all nine islands in the group, with technical and infrastructure support provided by PGSC- Partnership Desk of SPC, Geoscience Australia and UKHO.

The Tuvalu Geodetic Survey Project (TGSP) started in January 2016 and was completed in December 2018. TOR of TGSP are as follows;

- Provide capacity support to local staff; in- office and field training on GNSS application and instrumentation
- To re- survey (occupy) all existing Survey Control Stations (BMs) on each of the islands in Tuvalu using GNSS, and to replace or establish new Control Stations (BMs) where it is needed
- UAV/ drone survey (Phantom4 and Matrice 200 – DJI & Pix4D) of selected areas on each island. Few smaller islands had full UAV survey coverage
- Photogrammetric GNSS Control survey – geo reference of GCPs and UAV images
- Cadastral survey – GNSS survey of existing boundary marks, boundary monuments for utility leases, village boundaries, land parcels

- GNSS pole to gauge tide level monitoring (establish datum for elevation/ height (MSL) on each island) – deploy portable tide gauge 3 – 6 months in ocean to collect tide data to derive LAT, MSL and HAT.
- Derive new transformation parameters between Local Grid on each island and GNSS

Department of Lands & Survey received funding support from Tuvalu- GIZ/ SPC and the Tuvalu Coastal Adaptation Project (TCAP) to purchase 2 new GNSS R10 unit and accessories and S7 Robotic Total Station. These are now in full operational along with our 2 drones (Phantom4 and S200).

A Lidar Survey Project funded by TCAP is schedule for May this year and Furgro as Contractor. Lidar survey will cover all land and coastal areas (foreshore & reef- flats), including lagoons and outer- reef areas around each island, and will also provide sounding data that reach 50 metres below sea level.

With full island coverage of high resolution (5 cm res) of lidar data (500 metres altitude) of all islands of Tuvalu, the department will only need to conduct UAV/drone (2 – 5 cm resolution) updates after extreme events (cyclones, tidal surges – damages on vegetation, properties and coastal erosion.). The UAV update will be over- layed over Lidar data to derive the changes between these two data. The trend in the application of satellite imagery to users has now change, especially for developing countries like Tuvalu. Early SPOT or Landsat data 4 metres resolution to QuickBird and World View 50 – 60 cm res, and then Lidar 5 cm res and UAV data 2 – 5 cm resolution. The quality of data in terms of its resolution is critical in a small island country like Tuvalu, as every square metres of land loss or part of the coastline matters.

Resolving boundary disputes by the Land Surveyor played a critical role in the islands, high precision is required to redefine a boundary line. A transition towards real time positioning of digital cadastre overlayed against high resolution (2 – 5 cm resolution) UAV image on a Tablet is seen as potential way forward to resolve land issues in the islands.

Tuvalu is vulnerable to extreme natural and weather events like tsunamis and tidal surges, cyclones, droughts and sea level rise. The collective application derived from good geospatial information compromised with precision GNSS data enable users to locate, measure, quantify and model these data for planning and decision making. Quote from the Minister of Natural Resources responsible for the Department of Lands & Survey in her intervention at the UN- ESCAP Conference on Satellite Applications for Sustainable Development in Asia & the Pacific 2018. **Satellite Technology and its Applications as the "the Eyes and Ears in the sky" that provides critical data and crucial information for the sustainable development benefit and wellbeing of human- kind.**

United States of America

Concepts of creating a Geodetic Adjustment

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The National Geodetic Survey (NGS), within the United States Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) mission is "to define, maintain and provide access to the National Spatial Reference System (NSRS) to meet our nation's economic, social, and environmental needs." NSRS is the system of latitude, longitude, elevation, and related geodetic/geophysical models and tools which collectively comprise the nation's foundational positioning infrastructure.

NGS supports surveyors and others with high-accuracy Global Navigation Satellite System (GNSS) data, ground control marks, models and tools, guidelines and tutorials. To properly ingest internal and external survey data into the NSRS, accurate orbits must exit, GNSS antennas must be calibrated, least squares adjustments software must exist, a network of CORS must be monitored, just to name a few of procedures that must be followed. This presentation will discuss project layout, observations, data processing, analysis of baselines, and adjustments which follow NGS method ingesting data into the NSRS.

United States of America

Transitioning to the United States 2022 National Coordinate System Without Getting Left Behind

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The National Geodetic Survey (NGS), within the United States Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), traces its roots to 1807 with the Survey of the Coast, making it the oldest federal scientific agency in the United States. The National Geodetic Survey's mission is to "define, maintain and provide access to the National Spatial Reference System to meet our nation's economic, social, and environmental needs." NGS is, for the United States and its territories, ground zero for precise positioning information, including latitude, longitude, elevation, gravity, shoreline, and other positioning standards. From defining the nation's spatial reference systems to free on-line services for survey position refinement, the NGS provides research and services vital to the surveying, civil engineering, and GIS interests of the USA.

NGS has for several years been developing - and promoting - the ongoing modernization and evolution of NSRS, toward the 2022 goal of replacing the North American Datum of 1983 (NAD83) and the North American Vertical Datum of 1988 (NAVD88). The new positioning paradigm will better leverage the utility of modern positioning technologies - notably the Global Navigation Satellite System (GNSS) - and will impact all users of geospatial data, either directly or indirectly. This presentation will discuss the whats, whys, hows, and whens of 2022 Datum effort.

United States of America

Ionospheric Scintillation of GNSS signals: Impacts and mitigation

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Ionospheric disturbances can cause rapid fluctuation or scintillation of satellite signals at or near the earth's surface. This phenomenon is most intense at night within 20 degrees of the earth's magnetic equator, which occupies more than one-third of the globe's surface. Such scintillations have been shown to disrupt and degrade GNSS navigation as well as satellite communications and represent the most significant space weather impact on both civil and military space-based radio systems. Boston College has developed a network of ground-based sensors that provide real-time measurements of scintillation from GNSS and other beacon satellites to generate global nowcasts of scintillation activity. Currently we are working to fuse space-based data from so-called radio occultation (RO) satellites equipped to receive GNSS signals from low earth orbit (LEO). The primary purpose of the on-board GNSS receivers is to provide profiles of temperature and humidity in the troposphere through the radio occultation technique that exploits measurements of GNSS signals when the ray-path between the LEO satellite and the GPS satellite passes through the lower atmosphere. Such occultations necessarily require that a portion of the ray-path also passes through the ionosphere and may be used to identify turbulent regions where electron density irregularities exist that cause scintillations of the signals. A combination of space-based occultations and ground-based beacon observations can be used to develop a global scintillation monitoring capability and Boston College is currently working to integrate these techniques with its existing Scintillation Network Decision Aid (SCINDA) technology.

Vanuatu

The use of GNSS based technology in Vanuatu

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Over the past few decades, the Global Navigational Satellite System (GNSS) based technologies such as smartphones, drones, internet and GPS trackers have improved the livelihood of the people of Vanuatu. This presenting paper will highlight the use of GNSS based technology in Vanuatu. Recently, GPS based drone was used to deliver vaccines to one-month old baby in remote island of Vanuatu, which is usually accessible by foot or locally operated boats. GNSS technique such as satellite altimetry have been used to map the spatial and temporal variations of sea surface heights with global coverage and overall excellent precision. However, in some marine subduction areas in Vanuatu, like the Vanuatu archipelago, Kinematics GPS system have been utilized to reconstruct well resolved sea surface map (e.g. in Santo Island) with a better precision of 5-15 cm. The Pacific GNSS project, an approach chart based on GPS for Vanuatu, was installed in December 2016 which included the installation of nine GPS system in Vanuatu airports. The airports in Vanuatu now have up to date charts and procedures which means it is now safe to fly in Vanuatu, also allows airline operators to pre-select the safest, fastest and most fuel-efficient routes to each destination. Furthermore, the metrological department of Vanuatu is using GNSS for atmospheric monitoring to improve the numerical weather predictions. Unmanned Aerial Vehicle (UAV) and RTK GNSS topography survey have been conducted in Tanna island of Vanuatu to construct the hazard mapping during tropical cyclone Pam. Researchers in Vanuatu are using GNSS based technologies to conduct a wide range of experiments and research. Scientist have used measurement from more than 45 GPS stations and analysed horizontal and vertical interseismic velocity fields along the Vanuatu arc subduction zone to study the seismic monitoring for Earthquake hazards in Vanuatu. The Australian Bureau of Meteorology (BoM) and Geoscience Australia (GA) have been maintaining the operation of the GNSS Continuous operating Reference Stations (CORS) for the past few years for the Pacific Sea Level Monitoring Project (PSLMP). The Continuous Global Positioning System (CGPS) is also installed to support the precise differential levelling survey of the deep bench mark in Port Vila, Vanuatu.