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Contents

Algeria

Algerian Satellite Based Augmentation System Based on Alcomsat-1: Characteristics and Preliminary Performance Tests

S. KAHLOUCHE [(1)], L. TABTI [(1)], A., B. BENBOUZID [(2)], F. OUTAMAZIRT [(2)]
[(1)] Department of Space Geodesy, Centre of Space Techniques, Algerian Space Agency
[(2)] Centre of Exploitation of Satellite Communication Systems, Algerian Space Agency
kahlouche@asal.dz

The use of space technologies is a basic pillar operationalization of the Single Air Transport Market. SBAS services are foundational strategic enablers of a harmonized airspace continuum, particularly in Africa, which is an essential pillar for the implementation of the Space Policy and Strategy of the African Union which calls for the establishment of native system of increase continental level for navigation.

Algeria has been taking all the possible efforts to contribute for achieving this goal. As part of these efforts, Algeria through its Algerian Space Agency (ASAL) is developing « The Algerian Satellite Augmentation System (AL-SBAS) in collaboration with China. The overall AL-SBAS service delivery strategy is to meet user needs with an incremental approach in terms of coverage and performance, while considering scalability to the next generations (Multi Frequency and Constellation).

Algeria is in the process of taking short, medium and long term measures to make AL-SBAS comply with the ICAO standards, the corresponding minimum operational performance specifications of the RTCA (Radio Technical Commission for Aeronautics) and the EUROCAE (European Organization for the civil aviation equipment). This will make it interoperable with other SBAS, ensuring a seamless transition for aircraft going to and from other SBAS service areas.

AL-SBAS contains a Network of Reference Stations (NRS), Mission Control Centers (MCC), Uplink Stations, an SBAS Wide Area Data Transport Network, and a Space Segment based actually on Algerian satellite «Alcomsat-1» (24.8°W) using a temporary code (PRN148). The Al-SBAS correction messages are calculated at the level of Mission Control Centers (MCC) by algorithms using data from the GPS constellations, collected by a network of 18 reference stations (NRS) whose geographical distribution makes it possible to optimize observation satellites and their signal propagation conditions.

For the first test performance accuracy, a station belonging to the wide area precise GNSS network (RGSH'2020) were used, it set up by ASAL for petroleum applications and linked to the IGS-2014 reference frame with a millimetric accuracy. This large network (up to 1500 km baseline) with geodetic multi-frequency receivers and processed using Bernese Software. The preliminary results obtained are very close to the SBAS requirements.

The first experimental test was conducted on site located at 35° of latitude and based on initial analysis of real data during one-week observation in October 2022. The accuracy obtained for the GPS+AL-SBAS is better than GPS only. The 3D RMS accuracy is between 1.89 m and 2.38 m, by using AL-SBAS; nevertheless for GPS only, this precision can reach 7 m. The results are near that those provided by EGNOS in the same site, covered by the system. On the other hand, integrity, provided by

Stanford diagram, is still not assured for all observation periods in the context of civil aviation, the availability for APV-1 is in an average of 99.88%.

As a perspective, the final tests will be conducted, considering the worst cases of the coverage, at the borders of the country, and the redundancy will be ensured for the OACI certification of the AL-SBAS.

KEYWORDS: GPS, AL-SBAS, Navigation

Australia

Space weather, a key vulnerability to GNSS

Zahra BOUYA, Vickal Kumar, Richard Marshall
Bureau of Meteorology, Australia
zahra.bouya@bom.gov.au

Global Navigation Satellite Systems (GNSS) signals are used across a wide range of crit-ical infrastructures. Space weather is one of the major limiting factors for the precision and reliability of services from GNSS, both in terms of the impacts of the ionosphere on the radio signals and the space environment on satellite infrastructure. Understanding and forecasting space weather storms and their impacts on GNSS is becoming increasingly important in the design and operations of many technical systems. The space weather Research to Operations team at the Australian Bureau of Meteorology focuses on devel-oping warning systems and models to protect technological systems against space weather events. This paper will discuss the main space weather phenomena, the effects of these phenomena on GNSS signals, and operational services for informing and supporting GNSS users.

KEYWORDS: space weather, impacts, GNSS

Canada

Performance of Low-Cost GNSS Receivers for Ionospheric Studies

Anton KASHCHEYEV[1], Bruno Nava[2]
[1] University of New Brunswick
[2] The Abdus Salam International Centre for Theoretical Physics
anton.kashcheyev@unb.ca, bnava@ictp.it

Electromagnetic waves propagating through the Earth's ionosphere are subjected to changes in group and phase velocities, refraction, dispersion, and diffraction. For systems relying on the usage of radio signals affected by the ionosphere, it is of crucial importance to account for these effects. In order to predict ionospheric delays and the probability of scintillation occurrence in radio signals, different classes of ionospheric models were implemented. Nevertheless, with the advent of new applications relying on navigation systems, the need for even more accurate description of the ionosphere emerged.

Existing models use experimental data from a variety of ground-based and spaceborne instruments, the most widespread of which are the dual-frequency GNSS receivers. The existing ground-based GNSS receiver networks can provide information on a global scale, but, like all sensors located on landmasses, they have limitations in sounding over some areas.

The low- and high-latitude ionosphere is particularly known for the presence of a wide range of instabilities, making the mitigation of its effects challenging. To improve our knowledge about the processes in the ionosphere where the existing network coverage is sparse, an increase in the instrument density is needed. The cost of the devices has indeed constituted a major impediment, especially for the developing nations. Nevertheless, with the significant advance of software-defined radio, the situation is changing through the availability of low-cost solutions.

The present work will discuss the performance of the available off-the-shelf low-cost dual-frequency GNSS receivers, testing them in the real-world environment and comparing the derived data with scientific-grade instruments. The accuracy of the collected ionospheric data, such as total electron content (TEC) and rate of change of TEC (ROT) will be analysed. A possibility to use low-cost receivers for ionospheric scintillation monitoring will be discussed.

KEYWORDS: low-cost, GNSS, ionosphere

Croatia

Mitigation of GNSS ionospheric effects using statistical learning-based self-adaptiveness to positioning environment conditions, embedded in GNSS SDR user equipment

Renato FILJAR
University of Applied Sciences Hrvatsko Zagorje Krapina,
Krapina, Croatia
renato.filjar@gmail.com

Traditional approach to GNSS position estimation constrains the opportunities for GNSS positioning performance improvements, and development of the GNSS resilient to natural and artficial sources of GNSS performance disruptions and degradations. Here we argue that recent advancements in mathematics, statistics, and computer science may allow for development and utilisation of the Positioning-as-a-Service concept, which detaches position estimation from RF and Base-band segments of a traditional blackbox GNSS receiver, and establishes more related connection with GNSS applications and their requirements. We demonstrate the concept with the scenario og the GNSS ionospheric effects mitigation through utilisation of positioning environment space weather situation awareness at the point of position estimation, as well as with utilisation of the statistical learning-based self-adaptive correction models. The two major contributors to self-adaptiveness of the GNSS position estimation process are deployed effortlessly using Software-Defined Radio (SDR) approacg, rendering the GNSS positioning estimation algorithm a computationally distributed feature.

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Ecuador

Ionospheric Total Electron Content (TEC) above Ecuador

Ericson D. LOPEZ
Observatorio Astronómico de Quito y Departamento de Física de la Facultad de Ciencias
Escuela Politécnica Nacional, Quito, Ecuador
ericsson.lopez@epn.edu.ec

The equatorial ionosphere over the Ecuadorian territory has not been previously studied, although there are some studies in other equatorial geographical positions, local research is required to characterize the ionospheric magneto-active plasma in this region.

In this study, for the first time in Ecuador, using pseudo-phase and pseudo-range data from the satellite signals of the GPS system, detected at the Riobamba-Ecuador (RIOP) station, the Total Electronic Content (TEC) is estimated in the period between the years 1999 and 2019. The TEC values and their daily, weekly, monthly and annual variation are calculated and compared with the observed data of the IGS network (International GNSS Service). The fit of the observed series with the series of the dispersive model has a goodness of fit of 0.88, which is quite acceptable. The adjustment can be improved by incorporating data from new local stations, as well as instrumental errors and delays in the received signals, not all of which were considered in the present work.

KEYWORDS: TEC, ionosphere, GPS-Ecuador

France

Advances in Space Weather using GNSS in Asia over the past decade

Christine AMORY-MAZAUDIER
Sorbonne Université, Ecole polytechnique, Institut Polytechnique de Paris, Université Paris Saclay, Observatoire de Paris, CNRS, Laboratoire de Physique des Plasmas (LPP), 75005 Paris, France
christine.amory-mazaudier@lpp.polytechnique.fr

The GNSS technique is useful for research studies in very different fields seismology for the movement of tectonic plates, meteorology for weather forecasting and space meteorology for the study of the impact of solar events on the electromagnetic environment of the earth

The GNSS allows to study the ionosphere, using the TEC (Total Electron Content), the ROTI index and the S4 index. The various studies carried out in Asia concerned:

- The climatology of the ionosphere from TEC observations made during more than one solar cycle (Nepal)
- The disturbances of the ionosphere due to solar events such as CME (Coronal Mass Ejections) or HSSW (fast solar winds) from coronal solar holes impacting the TEC (India, Nepal, Pakistan and Vietnam)
- The ROTI and S4 indices related to ionospheric plasma irregularities at the origin of the scintillations of the GNSS signal (India, Vietnam)
- The relationship between the TEC and the QBO (Quasi Biennial Oscillation) of the stratosphere (Vietnam)
- The climatology of TEC during two solar cycles 23 and 24 for different latitudes in the two hemispheres (Pakistan)
- etc…

KEYWORDS: Space weather, GNSS, Ionosphere

India

TEC variability and comparison of models during solar cycle 23 and 24 over equatorial low latitude IGS station, Bangalore (13.02∘ N, 77.57∘ E)

Prajakta CHOUGULE[1], Susmita Chougule[1], Karishma Maner[1], Dadaso Shetti[1]
[1] Smt. Kasturbai Walchand College, Sangli, India
prajakta23798@gmail.com

The Total Electron Content (TEC) is estimated from low latitude Bangalore IGS GPS station (13.02˚ N, 77.57˚ E) for the period 1996 to 2021, which covers two solar cycles 23 and 24. The TEC data is analyzed for the quiet and disturbed times for the said period. The solar radiation plays a vital role in the dynamics of ionosphere. The geomagnetic storm, solar flare also influences globally the ionospheric density distributions. In this study, data analyzed from the GPS station which is in the low latitude equatorial region, is largely influenced by the plasma bubbles, midnight temperature maxima (MTM). These phenomenon induces large variation in the ionospheric electron density as compared to mid and high latitude regions. Therefore, the prediction of ionospheric behavior using model is challenging especially over Indian equatorial region. The estimated TEC is compared with IRI and NeQuick Models for entire period of two solar cycles. In this paper, the results obtained from the analysis of TEC derived from the IGS station and models during these solar cycle periods are discussed. The results include the variations of TEC with low and high solar activity, ascending and descending phase of the solar cycles. The seasonal comparison between models and TEC during quiet and disturbed period over a low-latitude region is also discussed.

KEYWORDS: GPS-TEC, TEC from model, TEC variation with Solar Cycle

India

Analysis of multi-GNSS data of continuous sites in Indian subcontinent

Chiranjeevi GANAPA Vivek[1,2,], Sridevi Jade[1,2]*
CSIR Fourth Paradigm Institute (CSIR-4PI), Bangalore, India
Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, India
**vivek@csir4pi.in*

We processed and analyzed the multi-GNSS (Global Navigation Satellite System) data of 17 continuous mode stations in Indian subcontinent to calculate the position and velocity estimates. GPS (Global Positioning System) and Glonass observations of cGNSS stations along with the IGS (International GNSS Service) stations for bench marking with data span of 6 years (2015-2021) are processed using Bernese software. Our main aim of this study is to know the impact of multi-GNSS signals on precise position and velocity estimates. It is observed that scatter is more in standalone Glonass (GLO) time series compared to standalone GPS (GPS) time series. Combined GPS-Glonass (GGL) solution does not indicate any significant improvement of scatter in daily position estimates. Velocity estimates are comparable for the GPS, GLO and GGL observations. Noise is estimated using CATS (Create and Analyze Time Series) software which uses Maximum Likelihood Estimation to fit a multi-parameter model for any time series. White noise and flicker noise is calculated for the multi-GNSS sites located between -25oE to 45oE to study the noise amplitudes dependency on latitude. Even though the velocity estimates of GPS, GLO and GGL solutions are comparable, white noise is lowest for all the three components (North, East and Up) in GPS time series compared to GGL and GLO time series. But flicker noise in North component is less for GLO time series compared to the GGL and GPS, which needs to be further investigated. Flicker noise is highest in East and Up components of GLO time series similar to the white noise. For the first time, comparative study of position, velocity and noise estimates is carried out to know the impact of multi-GNSS signals for geodetic studies in the Indian subcontinent. Further, other operational global constellations Galileo and BeiDou data will be included for similar studies in future.

KEYWORDS: Position, Velocity, Noise

India

Initial Results of Total Electron Content over Low Latitude Station, Sangli (16°52'N, 74°34'E)

D.J. SHETTI[1], M.S. Manjarekar[1], T.S. Vasagade[2] and O.B. Gurav[3]*
[1] Smt. Kasturbai Walchand College, Sangli - 416416
[2] Annasaheb Dange College of Engineering and Technology, Ashta – 416301
[3] Indian Institute of Geomagnetism, Navi Mumbai - 410218
Corresponding author: shettidj2002@yahoo.co.in*

IRNSS (Indian Regional Navigation Satellite System) is India's independent regional navigational satellite system. This system works with two frequencies L5 (1176.45 MHz) and S band (2492.08 MHz). The present paper comprises the basic details of IRNSS system first and further extends to present first result of TEC (Total Electron Content) estimation using IRNSS data. The estimation of TEC is the major parameter to analyze performance of navigation system. Hence, these results will surely play important role to have an idea of present working scenario of IRNSS with respect to efficiency and effect of space weather on it. All these estimation is carried out using data from low latitude station, Sangli (16° 52' 0" North, 74° 34' 0" East). IRNSS-UR is the software, used for receiving and extracting the data. Codes are developed in MATLAB programming tool for estimating TEC using RINEX 3.03 Data Format.

KEYWORDS: IRNSS system; TEC estimation, Estimation of Group delay and Phase Delay for IRNSS

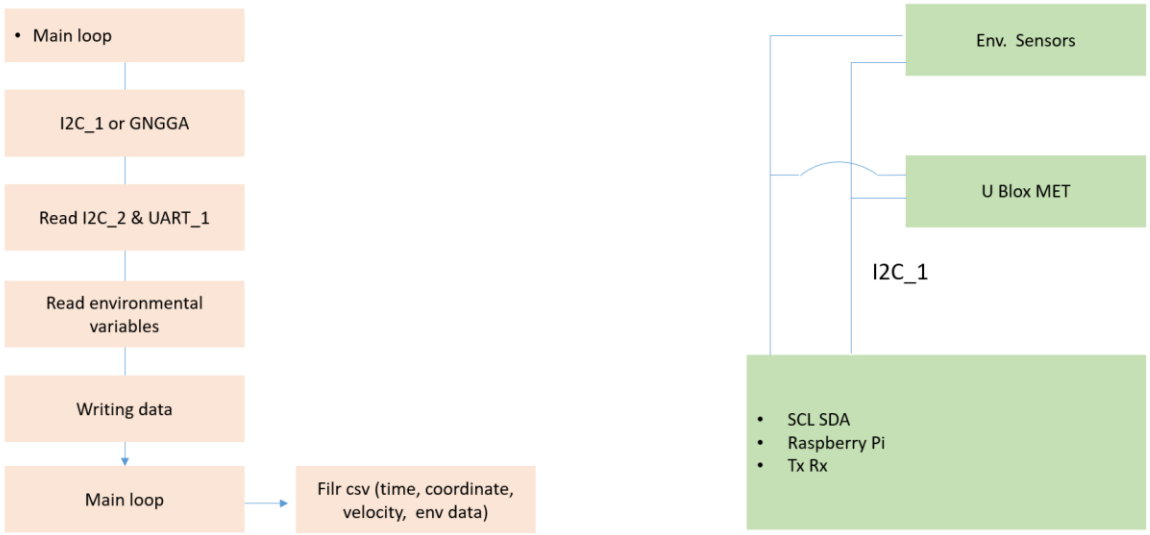
Indonesia

Development of Integrated Technology of GNSS Receiver and Environmental Sensor: Navigation Study of Urban Traffic and Air Pollution in Jakarta

Garrin Alif NANDITHO
Urban Studies Department, School of Strategic and Global Studies, Universitas Indonesia
Center for Spatial Data and Analysis, School of Strategic and Global Studies, Universitas Indonesia
garrin.alif@ui.ac.id

Rapid urban growth has caused complex issues in big cities. Among the issues is traffic congestion in the city center and surrounding, as well as the access towards the sub city center or buffer zones. Jakarta experiences the massive traffic congestion problem with range of significant problems including the low work productivity, high energy demand, and air pollution. Meanwhile, the issue of air pollution continues poorly in Jakarta. Jakarta was ranked among top polluted city in the world in 2019, and recently in June 2022. The carbon emissions from the air pollution creates lots of environmental, social, and economic issues, and the direct impact towards the development of climate change. Indonesia is in the process of mapping the policy on the carbon tax as the strategic solution to mitigate the carbon emission especially from the transportation sector. Ranges of research on the urban traffic and air pollution intensity are expected to strengthen the regulation on the carbon emission mitigation. Besides, the urban mobility issues in Jakarta during the pandemic was technically and strongly managed by range of urban social mobility restriction incorporates with traffic policies. However, the strategies and policies need to be technically reviewed. A study has been conducted to investigate Jakarta's urban traffic and the factors that causes congestion, poor urban mobility, and poor air pollution by using the empirical navigation approach. The study used the GNSS (Global Navigation Satellite System) with PPK (Post Processed Kinematic) and PPP (Precise Point Positioning), as well as HT 2000 as the Environmental Sensor. The study was conducted in two main routes of Jakarta. The result shows that the urban traffics were affected by the trip schedules and routes. The social mobility restriction during the pandemic crisis significantly affected the traffic volume. The air pollution was also significantly correlated with the vehicle speed. The finding of this study is recommended to suggest the better urban traffic and mobility, as well as the air pollution management in Jakarta. Furthermore, the study also recommends to continue further research on development of integration technology between the GNSS receiver and the environmental sensor to get the low cost, real time, and precise urban mobility data incorporated with other environmental variables. However, it needs holistic study with significant collaboration among experts.

Proposed Integrated Technology



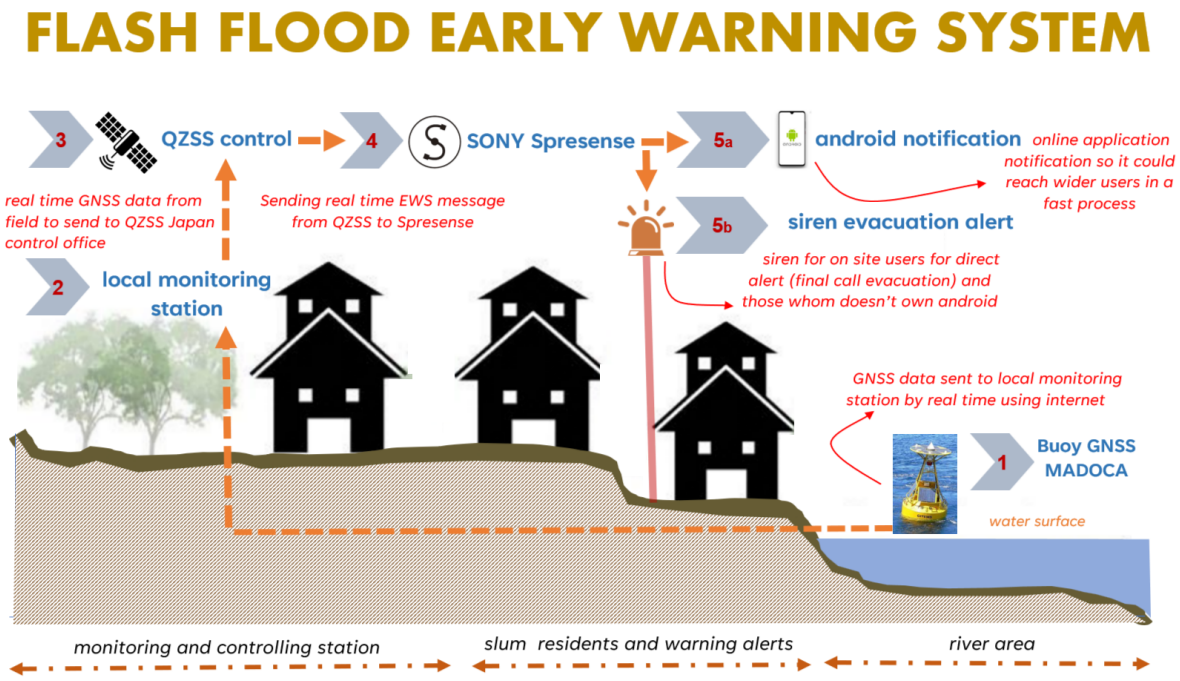
KEYWORDS: Urban Traffic, Air Pollution, GNSS

Indonesia

GNSS Application for Jakarta's Flash Flood Early Warning System

Dr. Lin YOLA
School of Strategic and Global Studies, Universitas Indonesia
lin.yola@ui.ac.id

Urban and regional development has caused significant impact on the environmental degradation, especially on the climate change. Jakarta experiences increase of climate change symptom, including the sea level rise, the high annual rainfall and the extreme weather. As result, the flood disaster occurs more than the yearly flood pattern, longer flood duration and bigger city damage and victims which also influences almost all sectors of economic, social and environment. Besides, the emerge of more flash flood in the city center especially in the low area and riverside makes the worsen city flood disaster. The flash flood causes the significant impacts to the informal city dwellers live by the riverside. Besides the adaptive city public policy, the holistic studies on strategic alternatives to mitigate the risks of flood disaster are encouraged to get the best flood problem solving. Jakarta has implemented a step on applying disaster warning system tool in four locations in improving the urban dwellers' preparation in facing the flash food in riverside area. However, the tools were not effective as it was in form of manual siren, high cost, experiencing so many faulty, and only cover limited area. Therefore, a study is proposed to create a better tool and holistic system by using technology of Post-Processed Kinematic Global Navigation Satellite System (PPK-GNSS) with Trimble NetR9 receiver base station, with the focus of real time and precision data of water level rise. Furthermore, this study also uses the SPRESENSE technology to deliver the Early Warning System message to the users, including urban dwellers, private sectors, and policy maker through manual (siren) and smart technology (digital mobile application). It proposes the 'Flash Flood Early Warning System' (FFEWS) with the main concept is the integration of both disaster detection and disaster early warning system, as the holistic approach to answer the said urban disaster issue. It proposes an integrated technology, low cost, real time, precision and more options for disaster warning system. This concept needs various expertise and range of stakeholders to make the integrated technology implemented. The researcher team has approached local authority to work on it, however, other international actors are strongly recommended for further project collaborators.



KEYWORDS: Flash Flood, Early Warning System, GNSS PPK

Japan

Low-Cost GNSS Receiver Systems for High Accuracy, Space Weather and Technology Promotion

Dinesh MANANDHAR
Center for Spatial Information Science (CSIS), The University of Tokyo
dinesh@csis.u-tokyo.ac.jp

GNSS receivers are widely used in many applications that require position and time data. There are several applications that also require high-accuracy of few tens of centimeters. The increased applications have also demanded development of low-cost, low-power and smaller size receiver systems without compromising performance. In this presentation, we discuss about low-cost GNSS receiver systems that can be developed from COTS (Commercial Off The Shelf) GNSS receivers and antenna. Such receivers can be used for RTK and PPP to provide centimeter or decimeter level of position accuracy. We have done system integration of hardware components and customized freely available software such as RTKLIB for low-cost GNSS receiver systems. The customized software such as RTKDROID for RTK using Android, MAD-WIN, MAD-PI and MADROID (MADOCA-PPP for Windows, RaspberryPi and Android respectively) are available free of cost upon request. We are also exploring the use of low-cost GNSS receiver systems for space-weather related applications such as computation of TEC and S4 indices.

Capacity and human resource development in the field of GNSS requires conduction of training, workshops and seminars. Since several units are required for the conduction of training to perform real-time field survey, data analysis etc., it is not possible to purchase a receiver that costs few thousand dollars. Thus, low-cost GNSS receiver systems are also indispensable for GNSS technology promotion.

KEYWORDS: Low-Cost GNSS Receiver, RTK, Space Weather

Japan

Overview of GNSS Spoofing and test results of signal authentication

Dinesh MANANDHAR
Center for Spatial Information Science (CSIS), The University of Tokyo
dinesh@csis.u-tokyo.ac.jp

GNSS spoofing is one of the problems that may affect critical services that use PNT data from GNSS signals. Spoofing attacks are different from interference and jamming. Interference and jamming attacks can be detected, however spoofing attacks are difficult to detect. The current GNSS civilian signals do not have capabilities to detect spoofing attacks.

In the recent years, Galileo has announced OSNMA signal authentication capabilities for Galileo Open Signals to detect spoofing attacks. Tests signals are now being broadcasted. QZSS has also announced signal authentication services for QZSS, GPS and Galileo signals.

In this presentation, we present about spoofing attacks, spoofing test procedures, concept of GNSS signal authentication and some test results from our GNSS signal authentication tests.

KEYWORDS: Spoofing, Authentication, Jamming

Kenya

Application to Mitigate Space Weather Effects on GNSS Transmissions

Brian Oure (OMOLLO)
Kenya Space Agency
brian.oure@ksa.go.ke

Space weather affects the electromagnetic properties of in the upper layers of the atmosphere by varying the Total Electric Content. The number of free electrons or negatively charged ions has a direct link to the electrical conductivity, and radio wave transparency or reflectivity of the affected layer.

Communication in GNSS relies on a specific set of radio frequencies to transmit data between satellites, ground stations and navigation devices. Any physical changes in the primary transmission medium could bring about errors in signal timing (resulting in incorrect calculation of distances) or inconsistent signal attenuation (hence poor connectivity).

This project the development of a space weather application can be able to monitor these significant changes in conductivity in the various layers of the atmosphere and the approximate effects of a GNSS signal travelling through these layers can be calculated based on theoretical or practical models. The navigation satellites can then be instructed accordingly to switch to more efficient transmission frequencies (so that the signal gets through the ion rich region to the target receiver) or to alter the directivity of transmitting antenna to achieve optimal transmission (so as to counter the effects of refraction or reflection within the ion rich region).

KEYWORDS: Electronic Radio Communication

Mongolia

GPS, GNSS based Online Data Processing System - MONPOS

Zolzaya LKHAMSUREN
Agency for Land Administration, Management Geodesy and Cartography
zolzaya.l@gazar.gov.mn

As of 2022, 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.

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.

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.

KEYWORDS: GNSS, RTK, geodetic network, GPS online processing

Mongolia

Capacity Development Activities on GNSS

Otgonjargal TERBISH
The Mongolian Geospatial Association
otgoomgl88@gmail.com, otgonjargal@geomedeelel.mn

It has been 64 years since mankind launched its first satellite for peaceful purposes, and it has been 60 years since Mongolia joined the United Nations Commission on the Peaceful Uses of Outer Space. During this time, technology has been updated and improved, and today most countries are launching their own satellites for sustainable development and civilian use.

Mongolia has been using satellite technology /GNSS/ since 1997, and now we have 67 permanent stations. The use of satellite positioning systems is used in all sectors of Mongolia, especially in agriculture, urban areas, land relations, geodesy and cartography.

Mongolia also participates in the measurement of the Asia-Pacific Geodetic GPS Network (APRGP) based on the results of measurements of 6 stations located in Khovd, Murun, Arvaikheer, Sainshand, Dalanzadgad and Choibalsan aimags every year.

The Mongolia's long-term development policy "VISION-2050“ contains a number of provisions on remote sensing and the use of satellite systems, and this is reflected in the Action Plan of the Government of Mongolia for 2020-2024.

The Mongolian Geospatial Association established in 2014, since the establishment, our organization organizes various activities and workshops on the capacity building to not only government organization but also other stakeholders.

Since 2015, our members and board members have been attending the international and local workshops, out of the 40 different countries there are 10 workshops which related to the GNSS.

China proposed GNSS service performance should be monitored by some international third-party organization. IGMA task group co-chaired by China, IGS and Japan was setup with its objective and tasks to promote international GNSS monitoring and assessment activities, Mongolia Government, member of APSCO, is granted to our association for the local institution of APSCO-IGMA project implementation. APSCO International GNSS Monitoring and Assessment” (IGMA) project in Mongolia is implemented with our members, New Mongol Institution of Technology and Chandmani Survey, LLC, Since 2018.

At the end we need to cooperate with counterparts to learn international best practices and develop the use of the GNSS, GNSS activities, implement and build capacity building as well as to engage the young students to promote the GNSS.

KEYWORDS: Initiatives, Cooperation on GNSS

Nepal

Establishment of GNSS Lab at Pashchimanchal Campus Tribhuvan University, Pokhara, Nepal

Krishna Prasad BHANDARI, Director/ Associate Professor
Center for Space Science and Geomatics Studies, Pashchimanchal Campus, Tribhuvan University
bhandarikrishna@wrc.edu.np
D. Manandhar, Associate Professor (Project)
Center for Spatial Information Science (CSIS), The University of Tokyo
dinesh@csis.u-tokyo.ac.jp

Pashchimanchal Campus, Tribhuvan University established Bachelor Degree in Geomatics Engineering in 2013 and Master of Science in Geospatial Engineering in 2020 to meet the demands of Geospatial engineering human resources in Nepal. Center for Space Science and Geomatics Studies (CSSGS), at Pashchimanchal Campus has initiated the establishment of GNSS Lab for capacity building in the field of Global Navigation Satellite Systems (GNSS) with a goal to become a Center of Excellence in this field to provide services towards GNSS based applications, system development, research and capacity development for academic, industry and government organizations at engineering level as well as policy and decision-making levels. CSSGS has collaboration with national and international institutes for the establishment and development of the GNSS lab. CSSGS has been providing GNSS training in collaboration and support from International Committee on GNSS (ICG), Center for Spatial Information Science (CSIS), The University of Tokyo and University Grants Commission (UGC), Nepal. CSSGS has established one CORS system and will be establishing more CORS systems thought out the Gandaki Province in the coming years. We have been conducting several GNSS based research projects. Several Master students have selected GNSS as a part of their Master Thesis. In our efforts towards becoming a Center of Excellence in the GNSS field, we would also like to invite you to join us to achieve this goal together and help promote GNSS technology in Nepal further that will help improve the socio-economic development of the country. We will also present about our activities related with CORS establishment, ionospheric and tropospheric data analysis, Low-cost GNSS receiver systems for traffic congestion monitoring, dynamic air-quality monitoring and high-accuracy positioning based on RTK and MADOCA-PPP.

Key Words: GNSS, Air-Quality, MADOCA-PPP, Space-Weather

Nigeria

On the Performance and prospects of Low-cost Global Navigation Satellite Systems Receiver in monitoring space weather at African low latitudes

Babatunde Rabiu[1,2], Oluwakemi DARE-IDOWU[1], Daniel Okoh[1,2], Aderonke Obafaye[1], Gopi Seemala[3], Anton Kashcheyev[4], Bruno Nava[5]

[1] Centre for Atmospheric Research, National Space Research and Development Agency, Anyigba, Nigeria

[2] Institute for Space Science and Engineering, African University of Science and Technology, Abuja, Nigeria

[3] Indian Institute of Geomagnetism, Navi Mumbai, India

[4] University of New Brunswick, Fredericton, Canada

[5] The Abdus Salam International Centre for Theoretical Physics (ICTP) T/ICT4D, Trieste, Italy]

tunderabiu2@gmail.com

This study presents some results of the ionospheric Total Electron Content (TEC) measurements obtained from a newly installed low-cost multi-frequency Global Navigation Satellite System (GNSS) U-BLOX receiver installed at Abuja-Nigeria (Geographic: 8.99o N, 7.38o E; Geomagnetic: 1.6o S) within the African equatorial sector. Measurements from the U-BLOX are compared with those drawn from a nearby high-cost GNSS receiver, and with those from COSMIC–RO (Constellation Observing System for Meteorology Ionosphere and Climate–Radio Occultation). Furthermore, the above was also compared with estimates from the AfriTEC and NeQuick ionospheric models. The results showed that measurements from the U-BLOX and high-cost GNSS receiver are very comparable. Furthermore, COSMIC values were observed to be consistently lower than the U-BLOX and high-cost receiver values. This behaviour could be attributed to the difference in TEC integration heights used for both systems. Nevertheless, the correlation coefficients between the U-BLOX values and values from the other four data sets are mostly greater than 0.9, with root-mean-square differences (RMSDs) lower than 5 TECU. Furthermore, a performance assessment was carried out between two co-located U-BLOX receivers. The antenna (ZED-F9P) deployed with the UBLOX receiver was retained with one receiver, and a new TOPGNSS 3-12V RTK GNSS antenna was installed with the other receiver. Results showed that the new antenna offers better noise protection. Overall, the U-BLOX is a good candidate for TEC studies over financially-handicapped regions that are unable to deploy high-cost receivers.

KEYWORDS: U-BLOX, GNSS receiver, Total electron content

Nigeria

Continental Cost Benefit Analysis (CBA) for Utilization of GNSS Applications and Implementation of SBAS Services in Africa

Dr. Lasisi Salami LAWAL
Nigerian Communications Satellite Ltd
lasisi@nigcomsat.gov.ng

Utilization of Global Navigation Satellite System (GNSS) is increasingly becoming important to fast track considerable attainments of United Nations Sustainable Development Goals beyond Positioning, Navigation and Timing (PNT). In consideration of the importance of GNSS applications, nations and regions are investing and adopting its services as an emerging technology for adaptation. African continent is not left out and Satellite Based Augmentation (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 to positioning, navigation, and timing in the aviation sector that involves safety of life (SOL) with verified performance on integrity of signal-in-space (SiS) and increasing applications and services in non-aviation sectors such as maritime, rail & road transport, oil & sector, agriculture, safety of public infrastructure such as dams, bridges & high-rise buildings, survey, civil engineering, mass market applications, atmospheric weather & landslide monitoring, among others. The paper provides some insights, summary and outcome on Continental Cost Benefit Analysis (CBA) of implementation of SBAS in Africa organized recently by African Union Commission (AUC) and African Civil Aviation commission (AFCAC); specialized arm of African Union (AU) on aviation matters with takeaways and recommendations to African member states including need for stakeholders and specialized institutions to embrace capacity building, awareness and sensitization activities to encourage rapid adoption of SBAS applications in aviation and non-aviation sectors.

KEYWORDS: Cost Benefit Analysis (CBA), GNSS Applications, SBAS Implementation

Pakistan

Low-Cost Location Accuracy Improvement Solution for Developing Countries

Maria ZUBAIR
Punjab Information Technology Board
Zubair.rajput@gmail.com

The advancement in technology and availability of certain tech and data has evolved the world fast. Anything worth improving is improved already or will be in the near future. Being part of the cluster of 'World', called "Developing countries", this progress is a bit slow. Availability of L5 signal for non-commercial use is one of a major milestone for GNSS based solutions which can accelerate progress towards advancement, in developing countries. The mobiles are advancing in terms of physical appearance as well as chipset. Most of the mobile devices come with an embedded dual antenna receiver. These antennas can be used to improve location accuracy of the devices while coupling them with cheap receiver setup.

As GIS professionals, for the past few decades we have been working with GPS handheld devices or mobile phones to monitor and calculate activity in the field e.g., crop survey, uploading disease data, recording traffic ticket on highways etc. These devices are usually expensive and the more expensive the setup is the more the accuracy can be achieved. And then there is an issue of inaccuracy in location data, that hinders the output performance, for data analysis, conducted later.

In order to address the above issues, we have been exploring the idea of using a cheap movable network for our projects. In our organization there are approximately 200+ projects where location-based data is collected and then processed for spatial data science. This project will be piloted for a project, in our organization, which intensively uses location data to record activity. Multiple users of this project will be using this network to record data. We would be using low-cost receivers, for this project, along with mobile's capacity to use dual antennas. Mobile based variable calculations will improve location accuracy. The receiver and antenna for communication will be integrated on a raspberry pi.

KEYWORDS: GNSS, Accuracy, RTK

Peru

Augmentation Systems to Improve Navigation Procedures in Low Latitude Region

Jorge GARCIA VILLALOBOS
CORPAC S.A
jgarcia@corpac.gob.pe; jorgesan_garcia@yahoo.com

This article tries to discuss a technical point of view of cost-benefit analysis by using Augmentation Systems ABAS (Aircraft), SBAS (Satellite) and GBAS (Ground), to improve Navigation Procedures according to the ICAO Concept for GNSS.

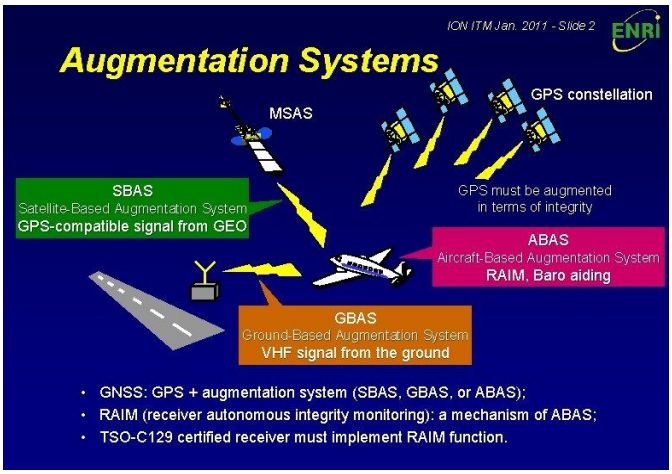


Figure 1. Augmentation Systems

There are four essential criteria: i) Accuracy, ii) Integrity, iii) Continuity, and iv) Availability, in correspondence with the Performance Based on Navigation (PBN) procedure which permits flying direct routings, precise navigation capability, permits efficient operations in terrain constrained or congested airspace, flight time reduction and fuel saving.

The PBN is a shift from sensor-based navigation to performance-based navigation; there are two kinds of Navigation Specifications: i) RNAV (Required Area Navigation), it is based on area navigation that does not include the requirement for monitoring and alerting board performance, designated by the prefix RNAV, eg RNAV 5, RNAV 1. ii) RNP (Required Navigation Performance), it is based on area navigation that includes the requirement for monitoring and alerting board performance, designated by the prefix RNP, eg RNP 4, RNP APCH.

PBN enables the airspace concept, describing the intended operations within an airspace, improved safety, increased air traffic capacity, improved efficiency, mitigation of environmental impact and as a result more efficient use of air space.

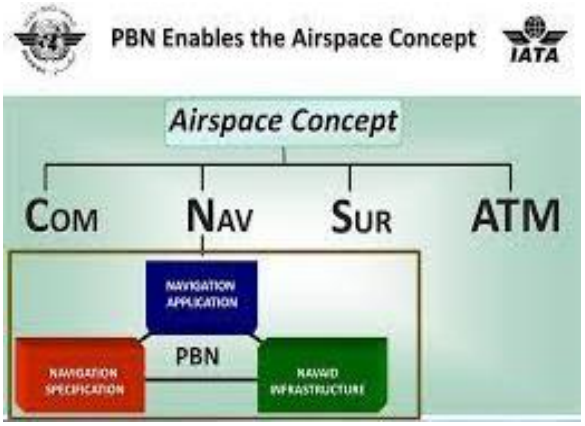


Figure 2. Diagram of PBN-Airspace Concept

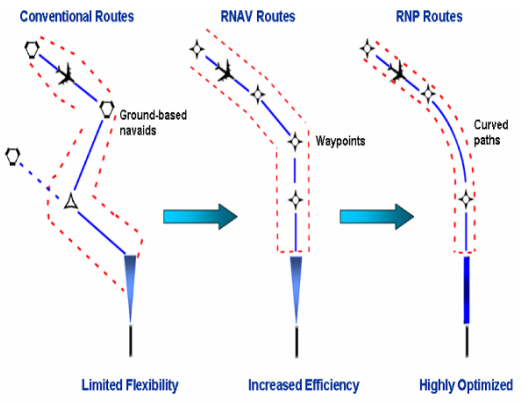


Figure 3. Applications of PBN (CENAE)

Likewise, as part of peruvian experience there are procedures obtained at the Cusco Airport and Caxamarca Airport

However, there are challenges to analyze in order to use the mentioned aumengtation systems to improve the navigation procedures in low latitude region like Peru in Southamerica.

In short, the main challenge is the ionosphere effects over GNSS signals at low latitude, due to Lima-Peru is the Geomagnetic Equator in Southamerica Region (low latitude), that is why the peruvian airspace environment has an intense ionosphere activity, as well as countries located between 20° N and 20° S (aprox) from the geomagnetic equator, especially during periods of maximum solar activity.

Finally, consider that there is no SBAS and GBAS operation in Peru and Southamerica (SAM) Region yet, and also is needed to make a cost - benefit analysis

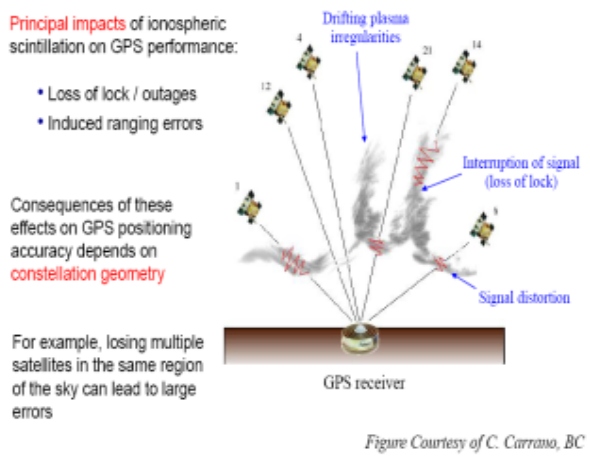


Fig. 4. Scintillations generate fading over GNSS signals

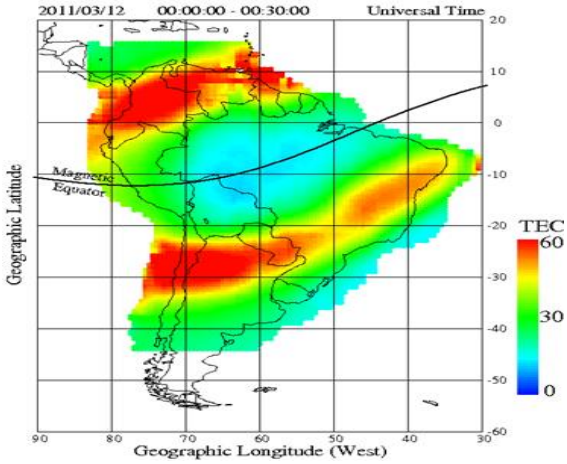


Fig. 5. TEC measurements made by LISN (Low-latitude Ionosphere Sensor Network)

Acknowledgements:

Sources courtesy of: CORPAC/ICAO/BOSTON COLLEGE/FAA/DECEA/NOOA/LISN/ROJ

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CNS: Communications, Navigation and Surveillance
ATM: Air Traffic Management
ICAO: International Civil Aviation Organization
IATA: International Air Transport Association

KEYWORDS: GNSS, PBN, Ionosphere

Philippines

Keeping Pace with Global Standards – Modernizing the Philippine Geodetic Reference Frame

Ma. Almalyn A. BALLADARES, Charisma Victoria D. Cayapan and Ronaldo C. Gatchalian
National Mapping and Resource Information Authority (NAMRIA) - Philippines
maaballadares@namria.gov.ph

GNSS has transformed the way we do things, including how geodetic reference frames are realized. In the Philippines, the country is currently modernizing its geodetic reference frame, to better respond to global events (e.g., climate change, sea level rise, and land uplifts) and take full advantage of advancements in positioning technologies. The initiative is also in support to the worldwide call to adopt and contribute to the development of a global geodetic reference frame (GGRF) for sustainable development (*UN General Assembly Resolution A/RES/69/266 of 26 February 2015*).

The modernization effort is spearheaded by the National Mapping and Resource Information Authority (NAMRIA), the central mapping agency of the Philippines. The modern Philippine Geodetic Reference System (PGRS) is envisioned to provide an accurate, up-to-date, and four-dimensional position reference by aligning to a GGRF and taking into account the effects of ground deformation on positioning. It is comprised of a geometric reference (Philippine Geocentric Datum of 2020, PGD2020), and a height reference (Philippine Geodetic Vertical Datum of 2020, PGVD2020). Supplementing these are deformation and geoid models, and a distortion grid to relate the datums to the latest GGRF realization and make them compatible with GNSS measurements. Capacity building of implementers and stakeholders, as well as issuance of updated standards and guidelines are also programmed to ensure accurate implementation of strategies and avoid confusion in the use of the new system. The modernization also includes the establishment of the ICT infrastructure needed to promote FAIR (findable, accessible, interoperable, reusable) geodetic products and services.

This paper shares the experience of the Philippines as the country attempts to upgrade its outdated reference frame. It provides the status of the modernization, and discusses the challenges faced by a country located in a tectonically active region, from difficulty in strengthening the geodetic infrastructure to addressing the competency gap in the country for modern geodetic reference frame realization. It also presents the strategies the country adopted to address some of these challenges given its limited resources. The recommendations highlight the need for effective messaging to encourage buy in from stakeholders, particularly from political leaders and decision makers. Emphasis is also given to the vital role that UN, FIG, and other organizations play to build capacities, particularly among the developing countries, to ensure that 'no one gets left behind'.

KEYWORDS: global geodetic reference frame, GNSS, Philippines

Poland

Development of the new IGS ionospheric product - ROTI maps and its synergies with the International LOFAR Telescopes

Andrzej KRANKOWSKI
University of Warmia and Mazury in Olsztyn (UWM), Space Radio-Diagnotsics Research Centre (SRRC/UWM)
kand@uwm.edu.pl

The International GNSS Service (IGS) diurnal ROTI maps ionospheric product was developed to characterize ionospheric irregularities occurrence over the Northern hemisphere and has been available for the community since 2014. Currently, the diurnal ROTI maps database hosted by NASA CDDIS covers the period from 2010 to now. Here, we report the ROTI maps product operational status and important changes in the product availability and access. Apart from actual ROTI maps product production, we work on the extension of ROTI maps to cover not only the Northern hemisphere but also the area of the Southern hemisphere and equatorial/low latitude region. Such extended ROTI maps are important for ionospheric irregularities climatology research and ionospheric responses to space weather. We present recent development toward the new ROTI maps product and the updated data format. To evaluate extended the ROTI maps performance, we analyzed the ability to represent key features of ionospheric irregularity occurrence over the Southern hemisphere and low latitudes. For auroral and midlatitudes, we present the cross-comparison of ROTI-derived irregularities patterns over the Northern and Southern hemispheres. For low latitudes, we examined the sensitivity of the resulted ROTI maps to detect plasma irregularities associated with equatorial plasma bubbles development for low, middle, and high solar activity periods.

We also present its synergies with the monitoring of dTEC and S4 scintillation index from International LOFAR Telescopes

KEYWORDS: Ionosphere, IGS, LOFAR

Rwanda

Space weather study through analysis of solar radio bursts detected by a single-station CALLISTO spectrometer

Jean UWAMAHORO
University of Rwanda
mahorojpacis@gmail.com

This article summarises the results of an analysis of solar radio bursts (SRBs) detected by the Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO) spectrometer hosted by the University of Rwanda. The data analysed were detected during the first year (2014–2015) of the instrument operation. Using quick plots provided by the e-CALLISTO website, a total of 201 intense and well- separated solar radio bursts detected by the CALLISTO sta- tion located in Rwanda, are found consisting of 4 type II, 175 type III and 22 type IV radio bursts. It is found that all analysed type II and ∼37% of type III bursts are associated with impulsive solar flares, while the minority (∼ 13 %) of type IV radio bursts are associated with solar flares. Furthermore, all type II radio bursts are associated with coronal mass ejections (CMEs), ∼ 44 % of type III bursts are associated with CMEs, and the majority (∼ 82 %) of type IV bursts were accompanied by CMEs. With aid of the atmospheric imaging assembly (AIA) images on board the Solar Dynamics Observatory (SDO), the location of open magnetic field lines of non-flare-associated type III radio bursts are shown. The same images are used to show the magnetic loops in the solar corona for type IV radio bursts observed in the absence of solar flares and/or CMEs. Findings from this study indi- cate that analysis of SRBs that are observed from the ground can provide a significant contribution to the early diagnosis of solar transients phenomena, such as solar flares and CMEs, which are major drivers of potential space weather hazards.

KEYWORDS: Solar activity; Solar Radio Bursts; e-CALLISTO; Space weather

Saudi Arabia

DEM Study on Hydrological Response in Makkah City, Saudi Arabia

*Mohamed ELHAG[*1,2,3,4], Asep Hidayatulloh[1], Anis Chaabani[1] and Lifu Zhang[2]*

[1] Department of Hydrology and Water Resources Management, Faculty of Meteorology, Environment & Arid Land Agriculture, King Abdulaziz University, Jeddah 21589, Saudi Arabia.

[2] The State Key Laboratory, of Remote Sensing, Aerospace Information Institute, Chinese Academy of Science, Beijing 100101, China.

[3] Department of Geoinformation in Environmental Management, CI-HEAM/Mediterranean Agronomic, Institute of Chania, Chania 73100, Greece

[4] Department of Applied Geosciences, Faculty of Science, German University of Technology in Oman, Muscat 1816, Oman,

**Correspondence: melhag@kau.edu.sa*

The changes in catchments can be analyzed through the generation of DEM, which is important as input data in hydrologic modeling. This study aims to analyze the effect of anthropogenic activities on hydrological studies based on DEM comparison and GIUH hydrograph. The four DEM datasets (SRTM, ALOS, Copernicus, and Sentinel-1) were compared to the topographic map of Makkah City and GPS data in order to assess the quality of the DEM elevation. The GIS Arc Hydro toolbox was used to extract morphometric and Horton-Strahler ratios characteristics to generate a GIUH hydrograph of the catchments of Wadi Nouman and Wadi Ibrahim inside Makkah City. Based on the DEM comparison, Copernicus and SRTM have the highest accuracy, with R2 = 0.9788 and 0.9765 and the lowest RMSE= 3.89 m and 4.23 m, respectively. ALOS and Sentinel-1 have the lowest R2= 0.9687 and 0.9028, and the highest RMSE= 4.27 m and 6.31m, respectively. GIUH Copernicus DEM on Wadi Nouman has a higher q_p and lower t_p (0.21 1/hr and 2.66 hr) than SRTM (0.20 1/hr and 2.75 hr), respectively. On Wadi Ibrahim, the SRTM has a greater q_p and lower t_p than Copernicus due to the wadi having two shapes. Based on the anthropogenic effect, the stream network in the mountain area is quite similar to SRTM and Copernicus due to fewer anthropogenic influences. In urban areas, the variation of stream networks is very high due to high anthropogenic influences. The Copernicus DEM has the best performance of the others with high accuracies, less RMSE, and the stream flow direction following the recent condition.

KEYWORDS: DEM; Anthropogenic activities; Hydrological study; Sentinel-1; Makkah City

Thailand

Precise time and frequency measurements and comparisons using GNSS

Thayathip THONGTAN
National Institute of Metrology Thailand
thayathip@nimt.or.th

GNSS is used for precise and accurate time and frequency disseminations and comparisons of remote clocks. Reference time and frequency standards operated in Thailand in order to provide national time scale; of UTC(NIMT), are caesium atomic clocks and active hydrogen masers. Their generated timing and frequency signals are inserted to both geodetic and timing receivers for data and correction services since the UTC(NIMT) are reference time scales for civil users from scientific calibration laboratories, geodetic and astronomic systems, aviation and transportation, critical infrastructure such as telecommunications and power supply to assure their positioning navigation and timing services.

The GNSS observations are continually compared with the GPS system time in order to characterise the time different between UTC and UTC(NIMT) in terms of clock drift, trend, accuracy (fractional frequency offset), precision (measured and systematic error) and stability (Allan deviation). GNSS time and frequency transfer methods comprise of common-view, all-in-view and precise point positioning using multi-constellations and multi-frequency observables.

This presentation shows an overview of time and frequency metrology in Thailand, international precise time comparison solutions and its linkage to the international reference system. The focus is on the improvement of international time transfer using GNSS observations and determining both measurement and systematic errors at the ground station using common clock scenarios.

KEYWORDS: Time and frequency metrology, GNSS time and frequency comparisons

United Kingdom

GNSS and UAV's - The emergence of technology and systems: The blurring of boundaries in Space? Positive and Negative Outcomes

Professor-Dr Sarah Jane FOX
Main contact point: dr.sjfox@hotmail.com
University of Leicester, UK | DePaul University, US
(Institutional – sjf48@leicester.ac.uk | sfox20@depaul.edu)

As the use of 'space' above us intensifies, there is a noticeable blurring of boundaries in terms of the use of air and outer space, the segregation and determination for both still remaining undefined.

Whilst there are obvious synergies between these two areas – it is argued that this merging of sectors and interdependencies will invariably lead to confusion, and, potentially also conflict. GNSS serves as a case in hand – increasingly UAV's (drones) are dependent upon this technology for positive but perhaps also paradoxically, negative, uses. For while the technological side rapidly increases, there is debatably a failure to revisit or adhere to treaties and agreements that are in place internationally; whilst, also accepting, that, there remain obvious lacunae. Nationally (and regionally) States are looking to maximize on the use of outer space, and, at the same time, are revisiting their use of air space – particularly with the emerging opportunities that UAV's present – commercially and for good-use purposes.

This presentation will consider the *paradox of virtue* in relation to the use of space (outer *and air*) for the positive outcomes that benefit man (human) kind, whilst, at the same, it will factor in the potential for outer space to serve as a tool (a source) that could have negative consequences on Earth. The primary focus therefore will be on GNSS and the relationship and application to UAV's (drones) used for civilian and protective purposes (i.e. for the latter, in respect to police use and the saving of lives).

This presentation is linked to my current research (listed below) and relates to rethinking definitions and boundaries of 'space' use and activities – with focus, on this occasion, of the emergence and development of UAV's in air and outer space. It factors in the need for ethical approaches to using outer space to control technologies, in this case, UAV's, which are used within the Earth's atmosphere. The research is approached from a legal/policy – sociolegal perspective.

The findings are that there remains a need to take a more proactive and 'ethical' approach to ensuring legal/policy protections for citizens on Earth in order to maximise on opportunities – meaning, technologies, used on Earth, (on this occasion, within the air) which increasingly rely on technology that has a presence in outer space.

SDG relevance: SDG 3; SDG 9 and SDG11

Linked Research of the proposer – Sarah Jane Fox relating to this presentation
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Accepted and In Press

- Securing the "Space" Above Us: Reflections on the Past – *to Consider Tomorrow's Challenges . ….Today*
- 'Exploiting – land, sea and space: mineral superpower': In the name of peace: a critical race to protect the depths and heights.

KEYWORDS: UAV's; Civil/Protection;