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Coordinates

Volume X, Issue 05, May 2014

THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

Prediction of EARTHQUAKES with GNSS

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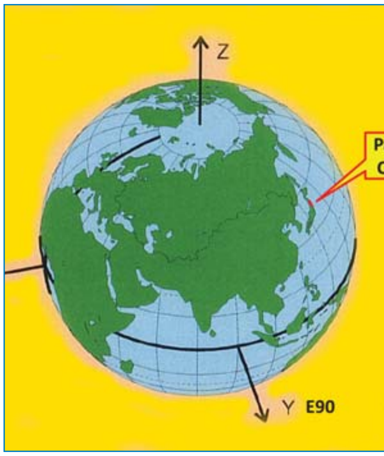

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Mailing Address
A 002, Mansara Apartments
C 9, Vasundhara Enclave
Delhi 110 096, India.
Phones +91 11 22632607, 98102 33422, 98107 24567
Fax +91 11 22632607

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[information] talktous@mycoordinates.org
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Outsmarting outages

The reported outages in Glonass

Not once, but twice in the last month

Triggers enough warning signals

Towards GNSS vulnerability.

Some of the experts have been alerting the GNSS community

On various threats and vulnerability,

Though many considered them as exaggeration.

With such incidences

And with increasing dependence on GNSS

Especially mission critical applications,

Hope actions will precede disasters

And not the other way round.

Bal Krishna, Editor
bal@mycoordinates.org

ADVISORS Naser El-Sheimy PEng, CRC Professor, Department of Geomatics Engineering, The University of Calgary Canada, George Cho Professor in GIS and the Law, University of Canberra, Australia, Professor Abbas Rajabifard Director, Centre for SDI and Land Administration, University of Melbourne, Australia, Luiz Paulo Souto Fortes PhD Associate Director of Geosciences, Brazilian Institute of Geography and Statistics -IBGE, Brazil, John Hannah Professor, School of Surveying, University of Otago, New Zealand

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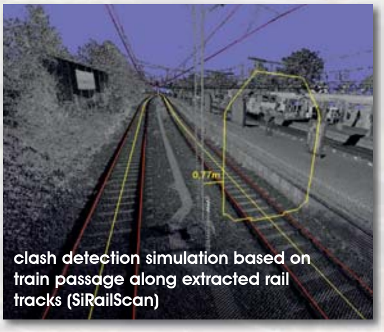
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BeiDou Navigation Satellite System is operating continuously and stably

Says TIAN Miao, International Cooperation Center,
China Satellite Navigation Office

Would you like to update our readers with the status of BeiDou?

In the aspect of system development, BeiDou Navigation Satellite System (hereinafter referred to as "BDS") has successfully accomplished the second step of the mission under the "three-step" development strategy, and already formally possessed Full Operational Capability (FOC) for the Asia-Pacific region. At present, the system is operating continuously and stably, while the performance values are steady and rising. Meanwhile, the third step of the BDS development is well under way. BeiDou satellites with better performance will be launched this year. It is planned to completely establish the BDS with global coverage by about 2020.

In the aspect of application promotion, The BDS-related industries have made remarkable progresses, and already formed a complete application industry chain, which consists of fundamental products, user terminals, system applications and operating services. All-round breakthroughs have been made in some key technical areas, such as BDS core chips and modules. The related products have been used in transportation, marine fisheries, hydrological monitoring, geodetic surveying, disaster relief and reduction, mass market, and many other fields.

In the aspect of international cooperation, BDS has been continuously implementing compatibility and interoperability coordination with GPS, GLONASS, GALILEO, and other systems, accelerated to push forward BDS to join international organizations, such as the International Civil Aviation Organization (ICAO), International Maritime Organization (IMO), and Third-Generation mobile communication standard Partnership Project (3GPP). At the same time, we have established cooperation mechanism with some countries in the Asia-Pacific region, through jointly organizing "BeiDou Asia-Pacific Tour", and carrying out extensive cooperation in sectors of precision agriculture, disaster prevention and reduction, etc.

BDS has brought more navigation satellites resources to the Asia-Pacific region, where the positioning accuracy can reach 10 meters; while in some areas, especially those with low geographic latitude, the positioning accuracy is much better and can reach 5 meters

Which are the coverage areas benefitted by BeiDou?

Since BDS possessed FOC, it mainly provides positioning, navigation and timing services for the Asia-Pacific region, and the coverage area is from 55 degree south latitude to 55 degree north latitude, 55 degree to 180 degree east longitude.

BDS has brought more navigation satellites resources to the Asia-Pacific region, where the positioning accuracy can reach 10 meters; while in some areas, especially those with low geographic latitude, the positioning accuracy is much better and can reach 5 meters.

Owing to the unique hybrid, asymmetric constellation, which consists of GEO, IGSO and MEO satellites, BDS enjoys outstanding advantages and anti-shielding capabilities based on the large number of satellites positioned in high elevation orbits. Users can enjoy more qualified services, particularly in the city canyon, multi-level interchange, and trees-sheltered environment.

With the launch of additional satellites for global constellation deployment, BDS expects to witness the gradual expansion of coverage area and increasingly enhancement of service performance. Ultimately, worldwide users will be able to enjoy free-of-charge open services provided by BDS.

BDS always upholds the principles of "openness, cooperation, resources sharing", adheres to the concept of "BeiDou is of China, and also of the world", and extensively participates in international exchange and cooperation, so as to realize the compatibility and interoperability among GNSS

What are your plans to ensure interoperability? What are the issues related to interoperability?

BDS always upholds the principles of "openness, cooperation, resources sharing", adheres to the concept of "BeiDou is of China, and also of the world", and extensively participates in international exchange and cooperation, so as to realize the compatibility and interoperability among GNSS.

In the upcoming 5th session of China Satellite Navigation Conference (CSNC'2014), an interoperability workshop will be hosted by the Working Group-A under the framework of the International Committee on GNSS, on May 23rd, in Nanjing, Jiangsu Province. We plan to inquire related users and industries about the demands on interoperability, so as to provide reference for interoperability design among GNSS. During this workshop, international famous experts will discuss following technical matters in the field of interoperability, mainly including interoperable signals, GNSS differential system interoperability, time system interoperability, etc.

BDS is the advocator and facilitator of interoperability. In future, we plan to keep carrying out compatibility and interoperability coordination with GPS, GLONASS, GALILEO, and other systems, comply with international standards, and strengthen cooperation in sectors of system performance monitoring and assessment, system performance standards, so as to jointly provide better services for the world.

What is the progress in developing user standards?

In order to enable users to gain a better understanding about BDS and to make BDS serve the users better, China Satellite Navigation Office released the "BDS Signal-In-Space Interface Control Document (version 1.0)" on Dec 27th, 2012, as well as the "BDS Open Service Performance Standard (version 1.0)" and the "BDS Signal-In-Space Interface Control Document (version 2.0)" on Dec 27th, 2013. Both Chinese and English versions of above document are available on the official BeiDou website (http://www.beidou.gov.cn).

Among which, the "BDS Open Service Performance Standard (version 1.0)" provides detailed descriptions for BDS overall structure, SIS characteristics and performance specifications, system performance characteristics and specifications, etc. The "BDS Signal-In-Space Interface Control Document (version 2.0)" defines the specification related to open service signal B1I and B2I between the space segment and the user segment of BDS, identifies the coordinate system and time system adopted by BDS, specifies B1I and B2I signal structure, basic signal characteristics and ranging code, and provides NAV message. With the publication of the ICD (version 2.0), BDS has become the first system which possesses two civil navigation signal frequencies with full service capability, while relevant enterprises can develop dual-frequency, high-precision BDS receivers, to enable the users enjoy navigation services with higher accuracy.

What are your plans in developing BeiDou market?

With the aim of developing BDS market, firstly, we will make our commitment with responsibility that BDS will provide open services free-of-charge, currently for the Asia-Pacific region and eventually worldwide; secondly, we will continue to implement BDS/GNSS application demonstration and experience campaign, through promoting enterprises exchanges, organizing technical symposiums, constructing demonstration programs, to enable international users gain a better insight into BDS and practically enjoys the benefits of BDS; thirdly, we will improve and enrich the development plan of BDS and related industries, enhance policy guarantee to push forward the exploration of market and boosting of application industries; fourthly, we will keep upgrading core technologies, speed up constructing BDS ground-based augmentation system and China Location-Based Network, to lay a foundation for industrial ecosystem of BDS.

Could you highlight the challenges before BeiDou?

So far, BDS has completed the 2nd step of development plan smoothly. In the near future, it will focus on ensuring continuous and stable operation, offering stable and reliable PVT services for users; facilitating industrial applications and development; promoting the joint development of GNSS, to enable resource-sharing and mutual complementarity among GNSS.

Since the GNSS industry has entered into a multi-sytem integration era instead of a single system, satellite navigation is developing towards better performance, more reliability and higher efficiency. During such a process, BDS is faced up with the long-term challenges to provide stable and reliable PVT services for users, make not only neighboring users but also global users benefit from the development of BDS, and accomplish the objective of "serve the world and benefit the mankind" at the earliest stage. All above are the challenges we are confronted with.

Towards the prediction of Earthquakes with GNSS data

The paper aims to validate the use of Global Navigation Satellite System (GNSS) signals prior to the occurrence of earthquakes as a means of earthquake prediction, by referring to the Great East Japan Earthquake

Dr Shunji Murai
Professor Emeritus, University of Tokyo, Japan and Advisor to Japan Earthquake Science Exploration Agency (JESEA)

Dr Harumi Araki
Head, Environmental Geological Laboratory, Japan and Advisor to JESEA

Dr Hideharu Yanagi
Chief Researcher, JESEA

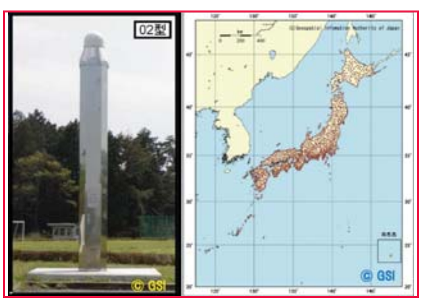

Figure 1: GNSS based control stations and their distribution

The paper aims to validate the use of Global Navigation Satellite System (GNSS) signals prior to the occurrence of earthquakes as a means of earthquake prediction, by referring to the Great East Japan Earthquake (hereafter called the Great Earthquake). The Great Earthquake occurred on March 11, 2011 with Richter Scale M 9.0 and it killed about 18,000 people mainly due to the subsequent Tsunami. The validation is based on data analysis of GNSS signals at GNSS-based Control Stations, about 1,200 of which have been installed all over Japan by Geospatial Information Authority (GSI) since 1996.

The objective of the study is to detect signals before the Great Earthquake using various indicators computed from the daily GNSS data, with a view to their being used in future for the prediction of earthquakes. The study succeeded to detect several pre-signals six months, five months, one month and three days before the Great Earthquake in the daily data, averaged weekly data, weekly maximum deviations, height changes over two years and/or accumulated changes.

The most important finding in this paper is that the detection of pre-signals as well as the pre-slips in the three days prior to the Great Earthquake could have led to the prediction of the forthcoming seismic event, when it has previously been claimed to be impossible to do so with existing measuring techniques.

Introduction

Since GSI commenced releasing GNSS daily data (in the beginning only GPS data) on the Internet in 2002, correlation analyses between abnormal changes in position and elevations detected in the GNSS signals have been made before seismic events (called pre-signals in this paper), and the location and magnitude of subsequent earthquakes. 162 earthquakes which occurred in Japan larger than M6 in the eight years between January 2000 and December 2007 were checked to determine whether or not pre-signals existed. Surprisingly, the investigation proved that all earthquakes showed some kind of pre-signals, which means that GNSS data should be useful in predicting earthquakes. Although, the authors were able to detect some pre-signals before the Great Earthquake, public release of this information was prohibited as only the governmental authority was officially permitted to make public statements about the prediction of earthquakes. However after the Great Earthquake, any private sector is allowed to start a business for predicting earthquakes. Since then the authors have supported a private company called Japan Earthquake Science Exploration Agency (JESEA: http://www.jesea.co.jp), which was established in January 2013 for developing earthquake prediction methods and predicting the risk of earthquakes. JESEA initiated the business in February 2013 by providing the weekly 'MEGA earthquake prediction information' through mail magazine to registered individuals and organization members at a low cost.

In 2013, eight large earthquakes occurred in Japan for which the pre-signals were validated and publicized to JESEA members. The prediction method has been developed and validated using the GNSS pre-signals study of the Great Earthquake as described in this paper. Murai, S and Araki, H acquired a Japanese patent for the prediction of earthquakes and volcanic eruption using GNSS data in 2006, and another patent was submitted in September 2013 together with JESEA which is now pending approval.

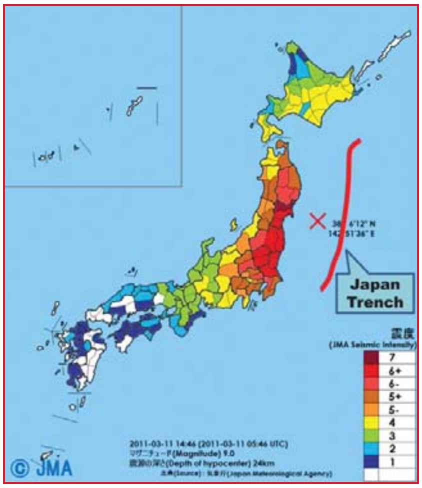

Figure 2: Japan Meteorological Agency Seismic Intensity Scale

Figure 3: The Three Prefectures in Tohoku District for Validation Test

GNSS data used

Every week, seven days of GNSS data for the period from Sunday to Saturday are downloaded, based on the precision ephemeris, following its release on each Monday by GSI, two weeks after its acquisition. Figure 1 shows an example of a GNSS-based control station and the distribution of GSI's GNSS-based control stations in Japan. The GNSS data include geocentric coordinates of X, Y and Z, as well as converted latitude, longitude and ellipsoidal height (H), acquired by the US GPS, the Russian GLONASS and the Japanese Quasi-Zenith Satellite Systems (QZSS). The F3 level data have an accuracy of about 2 to 3 mm. According to the results of past validation studies, the changes of ellipsoidal height (H) have been mainly used, although X, Y and Z are also supplemented as reference.

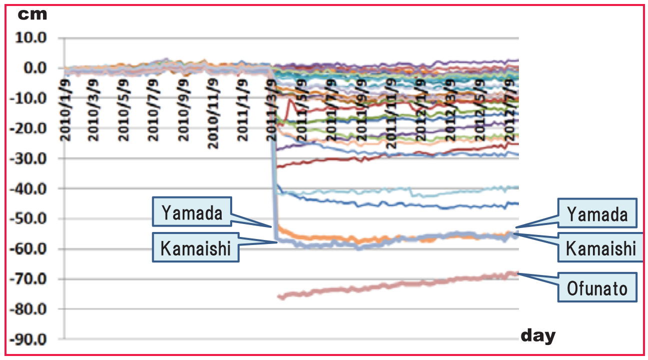

Figure 4: Dramatic subsidence at Ofunato, Kamaishi and Yamada in Iwate Prefecture

Validation areas

As Tohoku district is the closest to the epicenter and also suffered most damage due to the Great Earthquake and Tsunami as shown in Figure 2, which shows the Japan Meteorological Agency seismic intensity data, the validation areas have been selected mainly on the Pacific Coast of the three prefectures of Iwate, Miyagi and Fukushima as shown in Figure 3. The epicenter is located 130 km offshore east-east-south of Miyagi Prefecture. Other areas are also referred to for the pre-earthquake validation. The dramatic height changes caused by the Great Earthquake are clearly visible in the data for the GNSS-based control stations in Iwate, Miyagi and Fukushima Prefectures in Tohoku District as shown in Figures 4, 5 and 6 respectively. The largest subsidences in height of over 50 cm were in order, - Ojika (111 cm), Iwaki (90 cm), Onagawa (85 cm), Ofunato (76 cm), Kesennuma (65 cm), Shizugawa (65 cm), Kahoku (65 cm), Kamaishi (59 cm), Odaka (56 cm) and Yamada (55 cm), the locations of which are shown by red dots in Figure 3. Ojika showed the largest horizontal movement of 5.3 m in the direction to east-east –south, which is perpendicular to the Japan Trench.

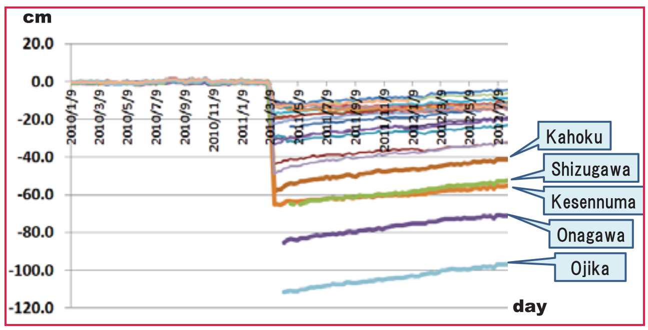

Figure 5: Dramatic subsidence at Ojika, Onagawa, Kesennuma, Shizugawa and Kahoku in Miyagi Prefecture

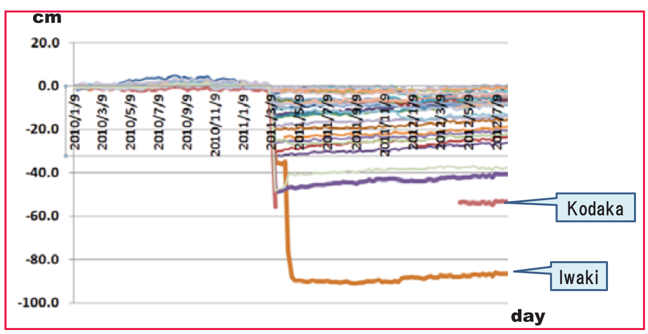

Figure 6: Dramatic subsidence at Iwaki and Odaka in Fukushima Prefecture

Indicators for detecting pre-signals

Various indicators have been used as shown below to detect pre-signals before the Earthquake. The indicators are classified into short term of daily and weekly span, and long term of two years' span.

Short term span:

1) Daily height change
2) Averaged weekly height change
3) Weekly maximum deviation (height difference between the maximum and minimum in a week)

Long term span:

4) Daily changes of X, Y, Z and H over two years; it was considered that data from two years prior to a seismic event could demonstrate normal position information unaffected by earthquakes
5) Accumulated daily changes of X, Y, Z and H over the two years

Recognition of the pre-signals

Close attention was paid to simultaneous dramatic changes at multiple sites at district scale to recognize pre-signals before earthquakes. Before larger earthquakes more points change simultaneously in position than before smaller earthquakes. A review of one year of GNSS data in Tohoku District from March 2010 to March 2011, prior to the Great Earthquake, revealed the first pre-signals which were abnormal simultaneous changes in height at around September 11, 2010 in Iwate, Miyagi and Fukushima Prefectures as shown in Figures 7, 8 and 9 respectively, although abnormal changes commenced from around August 2010. The second pre-signals were detected around October 23, 2010, while the third was detected around the January 8, 2011. It should also be noted that several points in particular showed extraordinary behavior in Fukushima Prefecture, but the tendency seems similar to other points. As shown in Figure 10, the week from September 5-11, 2010 and the following week from September 12-18, 2010 (about six months before the Great Earthquake), showed abnormal weekly maximum deviations in red (a critical level over 5 cm) and yellow (moderate level over 4 cm). Not only the Tohoku District but also many other districts showed abnormal changes prior to this huge earthquake. It may be a mistake to consider only the movement of local faults near the epicenter. After the three dramatic pre-signals referred to above, the Japanese Islands remained relatively calm until three days before the Great Earthquake. It is recognized that there should be a calm period after such dramatic simultaneous changes, although the duration of the calm period cannot be estimated. A question arises, how can we predict impacts such as those that occurred in the critically affected areas shown in Figure 3, because the pre-signals referred to above were detected all over Japan?

Detected pre-slips

Pre-slip is defined as the abnormal crustal changes just before an earthquake, which it has been said in Japan, would be impossible to detect by the existing measurement methods. If one can detect pre-slip a few days before an earthquake, it would be really helpful in alerting people to be better prepared for evacuation. The pre-slip can become clearer if one checks the daily height changes over two years at critical points. Figure 11 shows the daily changes of X, Y and Z over two years at Kesennuma at the most critical location in which dramatic falls in the X, Y, Z values can be seen on the last three days (March 8, 9 and 10) before the Earthquake. In particular, the largest fall of 3 cm occurred in the Y values over these three days. Figure 12 shows very clearly the height changes at the 10 worst points with large pre-slips on the last three days. A reason why the Y values showed the maximum pre-slip can be explained as follows. Firstly, the Pacific coast of the Tohoku District which is almost parallel to

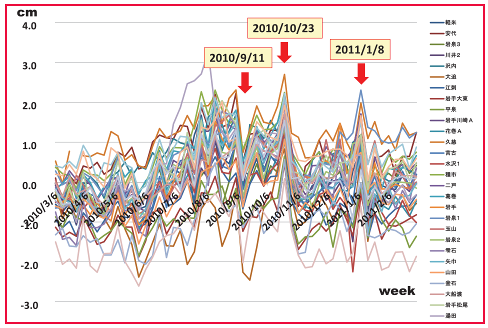

Figure 7: Pre-signals detected in weekly height changes in Iwate Prefecture prior to the Great Earthquake

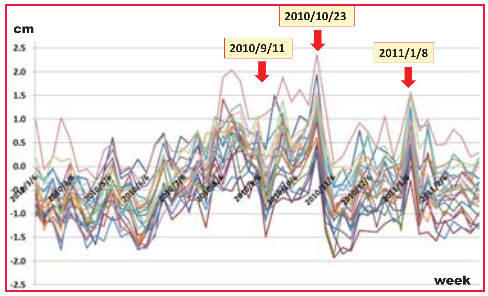

Figure 8: Pre-signals detected in weekly height changes in Miyagi Prefecture prior to the Great Earthquake

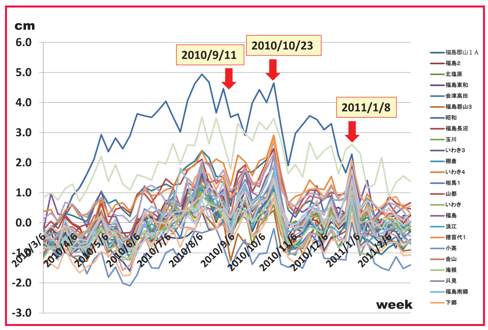

Figure 9: Pre-signals detected in weekly height changes in Fukushima Prefecture prior to the Great Earthquake

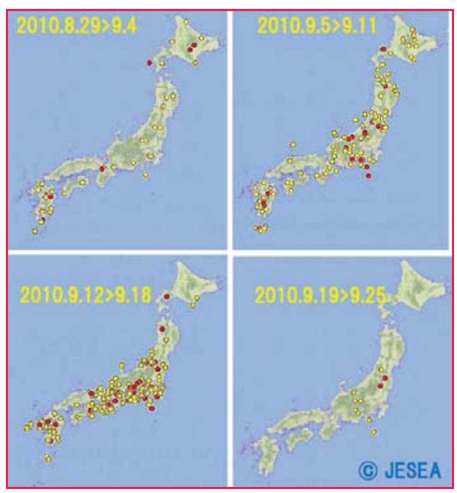

Figure 10: The first pre-signals about 6 months before the Great Earthquake

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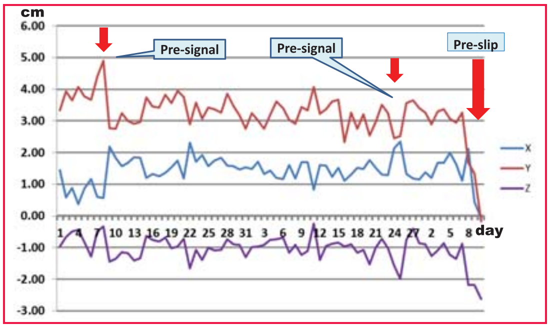

Figure 11: Pre-slip detected in daily changes of X, Y, Z at Kesennuma

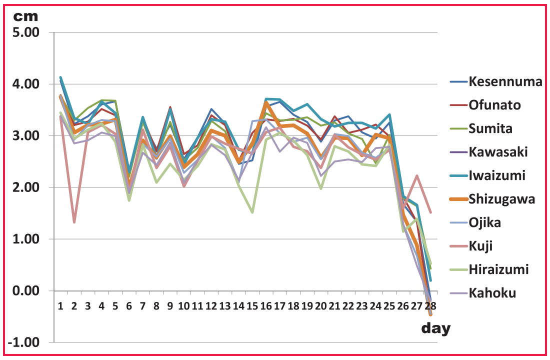

Figure 12: Pre-slips on the last 3 days at critical points

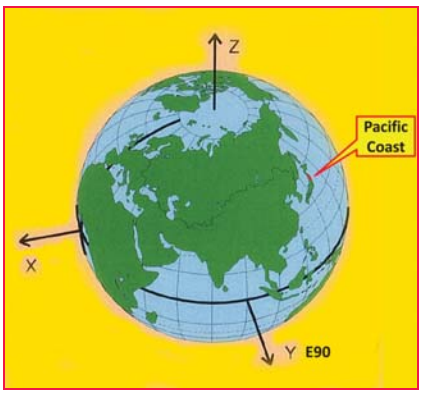

Figure 13: Geocentric coordinate system and the Pacific coast of the Tohoku District (red line)

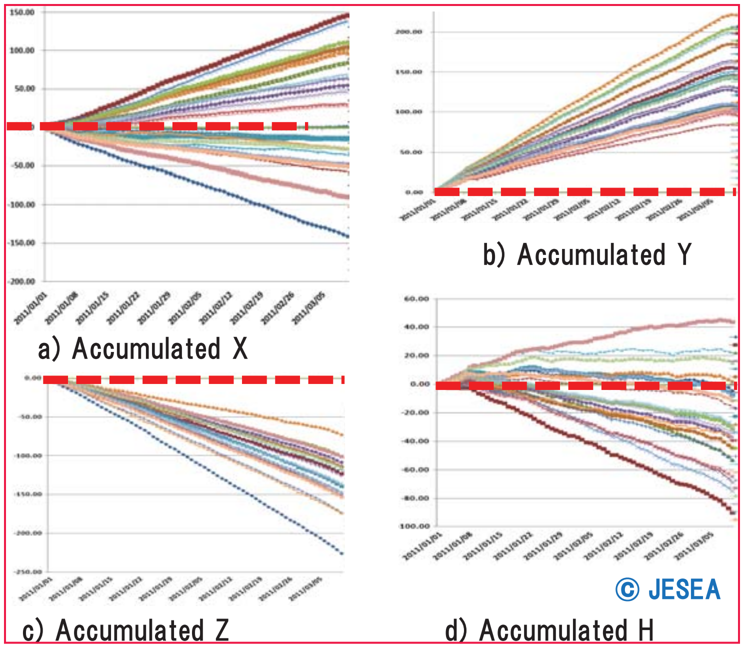

Figure 14: Accumulated daily changes of X, Y, Z and H in Miyagi

the Japan Trench (a border between the Pacific Plate and the North American Plate), and the direction of which almost coincides with that of the Y axis as shown in Figure 13. Secondly, the increase of the Y value means a movement upwards and to the west with an oblique angle to the horizontal direction, while a decrease of the Y value means a movement downwards and to the east with the opposite direction of the oblique angle to the horizontal direction, since the Pacific coast at the Tohoku District is located roughly on a longitude meridian of E 142°and 52°east along the Y axis. The actual movement of the Pacific coast at the Tohoku District during and after the Great Earthquake consisted of a south-east-east horizontal movement and downward vertical movement, which is almost equivalent to the decrease of Y values.

Accumulated changes during two years

In order to find the most appropriated indicator to determine the critical areas and alert timing before the earthquake, the accumulated changes of X, Y, Z and H during two years in the three prefectures were checked. A comparative study was also conducted to determine the best parameters out of X, Y, Z or H which best fit the critical points shown in Figure 3. The accumulated daily changes of X, Y, Z and H in Miyagi Prefecture are shown in Figure 14. The red line in the figures shows zero level for each parameter. The accumulated X values show little correlation between the larger value and the critical areas, and does not seem to be the best parameter. The accumulated Y values above a threshold of 150 mm are most strongly correlated with the critical points, while the accumulated Z and H values show little correlation. The Y values may show the accumulated deformation energy. In addition, Y values show more clearly the pre-slips in the last three days as shown in the figure. Figure 15 shows the enlarged graph of the accumulated daily changes of Y values in Miyagi Prefecture, where a threshold of 150 mm was set as a signal that the deformations had reached a critical situation though the threshold is not based on a theoretical approach, but just trial and error. The authors adopted 150mm as the threshold because the value showed best fit to seriously affected areas. The Y values initially exceeded the threshold of 150 mm at Kesennuma on February 13, 2011 about a month before the Earthquake. Several GNSS-based control stations in Iwate Prefecture also exceeded the threshold, as shown in Figure 16. Those points where the Y values exceeded the threshold of 150 mm are Kesennuma (222 mm), Shizugawa 204 mm), Ojika (198 mm), Kahoku (185 mm), Oketani (162 mm), Yamoto (161 mm), Towa (155 mm) and Diawa (151 mm) in Miyagi Prefecture and Ofunato (215 mm), Sumita (215 mm), Kawasaki (215 mm), Iwaizumi (207 mm), Kuji(194 mm), Hiraizumi (186 mm), Daito (174 mm), Taneishi (172 mm), Mizusawa (163 mm), Yamada (161 mm), Miyako (157 mm), and Kawai (157 mm) in Iwate Prefecture. Figure 17 shows the distribution of the critical points, which are located mostly in the regions seriously affected by the Great Earthquake. The location of critical areas could have been predicted from the accumulated values of Y in this case.

Consideration

This validation study was made not in advance of, but after the Great Earthquake. Therefore, there is no assurance that it would be possible to apply the same method in advance for predicting other earthquakes, as this case might be a very special one. However, one can at least obtain a hint of how GNSS data could be useful for predicting earthquakes based on various indicators computed from GNSS data.

The following problems are identified for future development of the prediction method.

1) The location and the intensity could be predicted from GNSS data as indicated in this paper, but the exact date of earthquake occurrence cannot be predicted well. The calm period after several pre-signals cannot be estimated. In this case, there was a period of about 6 months after the first pre-signal before the Great Earthquake.
2) It would be possible to determine the best fit indicator to detect critical areas in advance for considering or estimating the direction of deformation by an earthquake. The validation in this paper showed the best fit to the accumulated Y values correlated well with the movement of the Pacific coast at the Tohoku District. In the case of the different types of earthquakes and different crustal conditions, the best fit indicator would be different.
3) The pre-slip was detected after the Earthquake as the GNSS data was only obtained after the event. However, it is difficult to obtain near real time GNSS data (called R3 data), because GSI does not release such data to the private sector. Open data but with two-week delay will be too late to detect the pre-slip.
4) The long term indicators in this paper are based on a two year span for convenience, but it would be better to determine the averaged normal trend curve for several normal years.

Conclusion

It is possible to detect pre-signals and pre-slips with GNSS data before an earthquake as demonstrated from the data acquired prior to the Great Earthquake. This is a new development in earthquake prediction. Not only short term indicators, but also long term indicators are necessary to detect pre-signals.

Simultaneous dramatic changes at multiple points enable the identification of pre-signals. These pre-signals were detected not only over a narrow area, but also a much wider area in case of this huge earthquake. Accumulated daily changes of Y over two years were the best fit indicator to predict the most affected areas in this validation study.

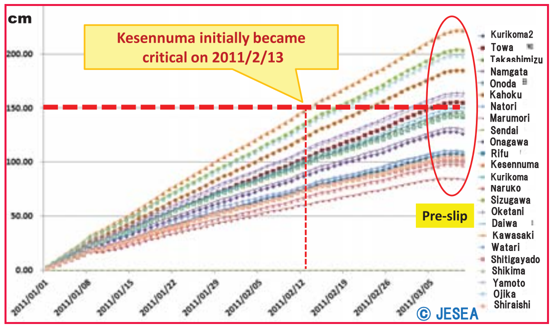

Figure 15: Accumulated daily changes of Y in Miyagi

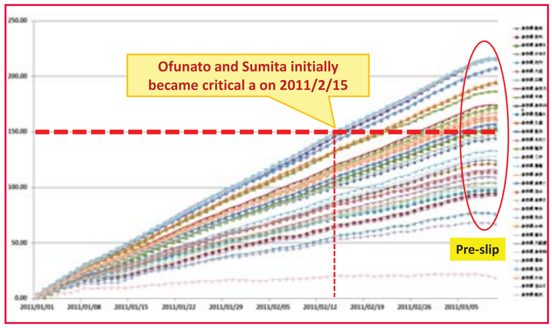

Figure 16: Accumulated daily changes of Y in Iwate

Figure 17: Distribution of critical points which exceeded the threshold

Acknowlegements

The authors deeply express thanks to Geo-spatial Information Authority (GSI) for providing open GNSS data on the Internet. The authors also thank Mr Toshihiro Kitta, President of JESEA and also Mr Toshihiko Tanigawa, Executive of JESEA for supporting the validation study. We also thank Prof Dr John Trinder for editing the language grammar of this paper.

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Suitability of projection for Defense Series Maps

It's right time to close the discussion once for all and cement the choice of suitable projection for DSM


Lt Col PVGS Jayaram
General Staff Officer (Software & GIS), Project Management Organisation, Directorate General of Information Systems, Integrated Headquarters of Ministry of Defence, New Delhi, India


Dr T Vijaya Lakshmi
Assistant Professor, Dept of Environment, Institute of Science and Technology, JNTUH, Hyderabad, India


Maj Gen RC Padhi
Additional Surveyor General & Head, Indian Institute of Surveying and Mapping, Hyderabad, India

National mapping policy 2005 has recommended the usage of UTM as projection for Open Series Maps (OSM), however there were reservations on adopting UTM for Defense Series Maps (DSM). Accordingly LCC with certain proprietary modifications was found suitable for DSM. Probably, we would be the only country in the world with two projection systems being maintained at the national level. There were extensive arguments against this approach, forcing the map making agencies to contemplate on seeking UTM for DSM as well. There were however no valid technical reasons submitted at the apex to change the projection from LCC to UTM for DSM. Barring the administrative constraints in maintaining data in two projection systems at the national level, no other issues were found relevant in changing the projection for DSM to UTM. Varied views have been issued by number of experts in the Armed Forces towards selection of a particular projection, some purely administrative and some technical in nature. It is essential to study the effects in choosing two separate projections for OSM and DSM, besides the technical merits and demerits that such a policy would attribute to the systems and agencies involved in using data. The preparation of a report card on advantages and disadvantages, if any, in adopting any particular projection, from the perspective of Armed Forces, is quintessential. The nature of usage of maps in Armed Forces in view of the areas that are required to be mapped in the neighbourhood need a pragmatic approach in choosing a projection.

Introduction

It would not be exaggerating if it's said that the Geospatial data utility literally grew from the way military leaders started demanding data. The military demand for usage of Geospatial data is not just in having the data, but in having accurate data. The continuous quest for accurate data grew over the years and no matter what kind of accuracy is feasible today, the scope for improvement still exists. Map reading skill is considered a basic skill for every military leader. National agencies are making incessant attempts in providing accurate data through paper maps since India's independence. The everest maps were used in a number of battles with polyconic projection and LCC grid till date. The problems in maintaining such maps regionally, towards meeting global aspirations were taken note of and accordingly the datum has been earmarked for future mapping as WGS-84. The debate on what would be the basic projection and what would be the suitable secondary grid for future Defense Series Maps (DSM) is on for over three years now. This paper attempts to bring out the perspective of Armed Forces and the necessity of using map data and the suitability of the projection, by bringing out the merits and demerits involved with each projection and the secondary grid.

Suitable Projection for DSM

Basic

A map projection is used to depict all or part of the spherical Earth on a flat surface. Without certain distortion, this is not feasible. Every projection has its own set of merits and demerits. There cannot be a "best" projection. The map making agency must select one best suited projection meeting their necessities, reducing distortion of the most important features. Map making agencies and researchers have devised almost boundless ways to project the image of the globe onto paper. The choice of projection depends upon the location of mapping, the Shape and Size of the region to be mapped and the theme or purpose of the map. If map is to be used for measuring areas, Equal area projection will suit, alternatively if the map is to be used for surveying and navigational purposes, as is the case for Armed Forces, the shape must be preserved at all costs, hence conformal/ orthomorphic projection would suit. A good projection is that which has an accurate scale factor close to unitary value in the entire region.

Methods of Choosing Projection

In trying to achieve this, there may be a necessity to select multiple projections over a large area. Multiple projections may not be permitted in all scenarios, specially for Armed Forces, hence projecting such a large area becomes really complex. This was partially followed regionally, by using polyconic projection with LCC grid, so far. Transverse Mercator projection is universally projected into multiple zones and projected independently. The nature of usage of maps dictates what kind of initiative is employed in choosing a projection. The north – south extent or east – west extent will certainly dictate the nature of projection. Incidentally, the extraneous and inherent parameters set for any operational needs established will dictate the projection.These are discussed below:

Extraneous Parameters:

[01] Existential Projection Type:- Planar, Cylindrical or Conical
[02] Focus of Projection:- Oblique, Normal or Transverse
[03] Placement of Projection:- Tangent or Secant

Inherent Parameters:-

[01] Preservation of Property:- Equi-Distant, Conformal or Orthomorphic and Equivalent or Equal area
[02] Generation:- Geometric, Semi Geometric or Mathematical

Existential Projection Type

India as a country is unique, where in both North – South and East – West extents are almost same, if the adjacent regions are not considered for mapping. The maps issued in everest datum have been from Turkey in the North to Yemen in the South as Western boundary and Gulf of Thailand in the South to Chinese eastern areas to the North as Eastern boundary. For mapping the Indian region, the general area extending in the east – west is approximately 90 degrees, which is much larger as compared to the North – South extent chosen for mapping. The suitability of a conical form of projection for the regions with the east – west extent is well known.

Focus of Projection

To cover the East – West extent of the Indian region accurately, the focus of a cone in the normal form will be adequate. In case the cylindrical form of projection is to be chosen, the normal or oblique coincidence does not suit, however the transverse coincidence can be customized to suit the region accurately. The cone will most suitably connect the adjunctions at the extremities; whereas the cylinder in the transverse position may have to be suitably adjusted to connect to adjunction. Accordingly, the choice of LCC stands out.

Placement of Projection

The East – West extent of the Indian region through conical nature can be mapped accurately with Secant positioning of the cone. The twin parallels to the standard parallel will augment the accuracy and reduce the distortion. The provision of having a unique central meridian passing through the centre of the cone will bring in mathematical simplicity. The cylindrical nature of projection with transverse coincidence, if adopted, the region will have to have separate central meridians based on the division of region into multiple zones. The mapping from the secant position will enable the ease of mapping.

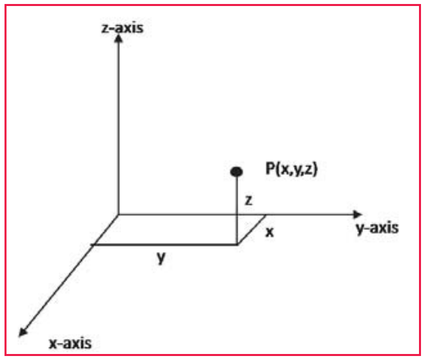

Figure 1: P(x,y,z) – 3d Cartesian Coordinates

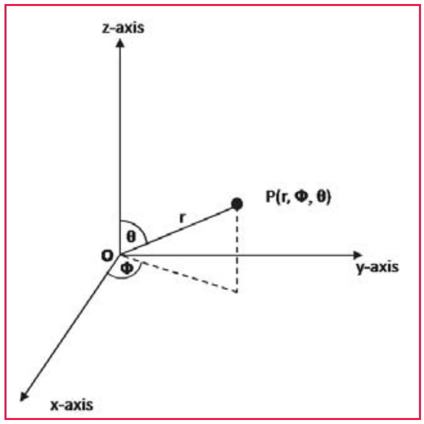

Figure 2: P (r,Φ, θ) - 3d Geographical Coordinates

Preservation of Property

Map or parts of a map can show one or more—but never all—of the following:

True Distances, True directions, True areas or True shapes. The basic orthomorphic maps maintain shapes and directions. On the Mercator projection a straight line drawn anywhere within its bounds shows a particular type of direction, but distances and areas are grossly distorted near the map's Polar Regions.

Distances are true only along particular lines such as those radiating from a single point selected as the center of the projection on an equidistant map, whereas on every equal-area map, shapes are distorted. Sizes of areas are distorted on conformal/ orthomorphic maps, but the shapes of small areas are shown correctly. The degree and kinds of distortion vary with the projection used in making a map of a particular area. At higher latitudes on a small-scale Mercator map, the distortions are existent, though on a

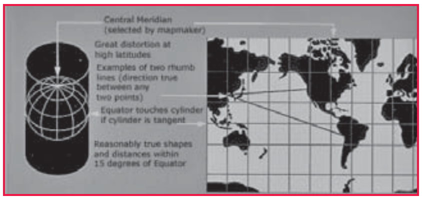

Figure 3

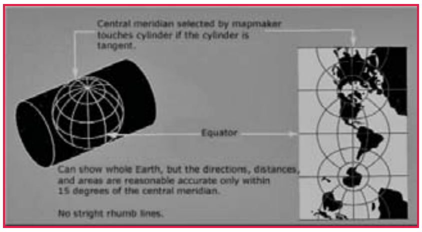

Figure 4

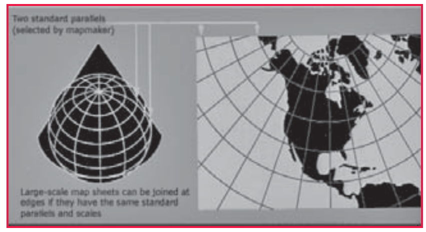

Figure 5

large-scale Transverse Mercator map of a small area in the same high latitudes, the distortion is almost non-existent.

Generation

The projection for Mercator is going to be semi-geometric whereas the generation of LCC will be a combination of geometric and mathematical. The mathematical linking of topology will be essential for maps of a small area or large area.

Mathematical Correlation between Cartesian Coordinates and Geographical Coordinates

The seamless conversion of 3-dimensional coordinates from Cartesian to Geographical and vice versa is simple and pure mathematics. The mathematical formulas along with the figures of 3d Cartesian and 3d polar coordinates given below can be used seamlessly for conversion from each other:-

The conversion equivalent parameters are:-
$\mathbf{x = r \sin\theta \cos\Phi}$, $y = r \sin \boldsymbol{\theta} \ \mathbf{\sin\Phi}$,
$z = r \cos \boldsymbol{\theta}$, $\mathbf{r} = \mathbf{Sqrt\ (x^2 + y^2 + z^2)}$,
$\mathbf{\cos\theta = z/r}$

Mercator Projection

The point of discussion is to choose between UTM and LCC for DSM. The characteristics of Mercator projection and UTM will highlight the relevant issues concerning selection of projection for DSM. The basic Mercator projection, displayed at Figure 3, is primarily used for navigation or mapping equatorial regions. Any straight line on the map is a rhumb line, and the directions along a rhumb line are true between any two points on map, but a rhumb line is usually not the shortest distance between points. Distances are true only along the Equator, but are reasonably correct within 15° of Equator; special scales are to be used to measure distances along other parallels. Areas and shapes of large areas are distorted.

Distortion increases away from the Equator and is extreme in Polar Regions. A map, however, is conformal in those angles and shapes within any chosen small area. A map is not perspective, equal area, or equidistant, in which the equator and other parallels are straight lines, though spacing increases toward poles. The meridians, which are equally spaced straight lines, however meet the parallels at right angles.

Transverse Mercator

Lambert's stroke of genius was to change the way the imaginary piece of paper touched the Earth. Instead of touching the Equator, he had it touching a line of Longitude (any chosen line of longitude). This touch point is called the Central Meridian of a map. This meant that accurate maps of places with north-south orientated places could now be produced. The map making agency only needed to select a Central Meridian which ran through the middle of the map. The Transverse Mercator maps, which can be seen in Figure 4, are used for preparing quadrangle maps at scales from 1:24,000 to 1:250,000 for USGS. More quadrangle maps can be joined at the edges only if they fall in the same zone having the same central meridian. These are used generally for mapping large areas that are mainly north–south in extent. Distances are true only along the central meridian selected by the mapmaking agency or else along two lines parallel to it. But all distances, directions, shapes, and areas are reasonably accurate within 3° of the central meridian. The highlight here is that the distortion of distances, directions, and size of areas increase rapidly outside the 3° band. The accuracy of any Transverse Mercator projection quickly decreases from the central meridian. Graticule spacing increases away from the central meridian. The equator is straight and all other parallels are complex curves concaving near the pole. Central meridian and each meridian 90° from it are straight. Other meridians are complex curves concave toward central meridian. NATO recognised that the Mercator/ Transverse Mercator projection was highly accurate along its Standard Parallel/ Central Meridian and currently the prevalent projection has minimal distortion, as far as 5° away from the Standard Parallel/Central Meridian. Using this NATO designed a regular system for the Earth whereby it was divided into a series of 6° of longitudinal wide zones. There are a total of 60 longitudinal zones and these are numbered 1 to 60 – east from longitude 180°. A central meridian is placed in the middle of each longitudinal zone. The UTM system, hence, is not a single map projection. The problems are likely to occur in joining the individual zones and these are more prone while visualising larger areas in the East- West extent.

Lambert Conformal Conic

Presented by Lambert in 1772, projected mathematically on a cone, LCC projection is used primarily to map countries/ regions that are mainly east – west in extent. This is conceptually secant at two standard parallels. Despite extensive usage of UTM projection, LCC is still the most widely used map projection across the world. LCC retains conformality and the distances are true, the basic depiction of which is given in Figure 5. They are reasonably accurate elsewhere in adjacent regions. The distortion of shapes and areas are minimal at standard parallels, but increases away from them. Shapes

Table 1

Projection	Type	Conformal	True Direction
Mercator	Cylinder	Yes	Partly
Transverse Mercator	Cylinder	Yes	Yes
LCC	Cone	Yes	Yes

Table 2

Projection	Continent/ Ocean	Region/ Sea	Scale	
			Med	Large
Mercator	No	Yes	No	No
Transverse Mercator	Yes	Yes	Yes	Yes
LCC	Yes	Yes	Yes	Yes

Table 3

Projection	Topo map	Geo map	Thematic map	Prese ntations	Navigation
Mercator	Yes	Yes	No	No	Yes
T/ Mercator	Yes	Yes	No	No	No
LCC	Yes	Yes	No	Yes	Yes

on large-scale maps of small areas essentially are true. Map is conformal but is not perspective, equal area, or equidistant. By varying standard parallels in preparing map series, in various combinations in 7.5 and 15 minute size, the distortions can be drastically brought down. Map making agencies must suitably choose standard parallels keeping in view the North – South extent, to keep the distortion levels at higher latitudes within acceptable limits. LCC projection best suits large area mapping. For small area large scale mapping, the shapes and distances are maintained in LCC to the desired accuracy levels. Hence the aeronautical charts used by the Airforce, use LCC. The directions in LCC are true along long distances. This aspect influences the decision of choosing suitable projection for Armed forces in DSM.

Summary of Projection Properties

The summary of projection properties for the three projections discussed in the previous paragraphs in this paper can be summarized in the following tables, 1, 2 & 3. It is evident that all are conformal and maintain true directions and shapes. The tables are given below in the next page.

Effects of Projection to Armed Forces

Though OSM & DSM are likely to follow two projection systems, barring the administrative constraints, no operational reasons could be considered seriously impinging on the operational effectiveness or the interoperability at the apex level. Since the maps for hinterland and the trans-frontier areas would be issued in DSM, Armed forces will not face any situation of operating on two projections at any point in time. The inter service transfer of data; can continue to be undertaken in Geo-coordinate form, which can seamlessly be distinguished in respective systems in any projection of the user's choice. It can be highlighted that the East – West extent to be covered in mapping has direct influence over the way the mapping needs to be organized. The conical nature with secant position will suit the projection type for East – West extent. The kind of projection to be used for DSM actually is influenced by the way maps are used. Military commanders will use paper maps in innumerous situations. Map reading is an inherent art possessed by military leaders. Survey and navigation in an unknown territory will be undertaken studying the paper maps. In such a scenario, having shapes and directions maintained, besides extending topology over zones and maps, is a mandatory necessity.

Conclusion

It's right time to close the discussion once for all and cement the choice of suitable projection for DSM. National Mapping Policy 2005 has recommended rightfully the usage of UTM as projection for Open Series Maps (OSM), and LCC for Defence Series Maps (DSM). There are valid technical reasons why LCC suits DSM when compared to UTM. The projection however, can be interchanged in to each other without losing the accuracy or value. Hence, the discussion of proceeding ahead with any projection will only affect the way maps are printed, but will have no impact on the way the networked systems operate under tactical command, control, communication and intelligence environment. The systems at national level exchange Geospatial information in Geographical form, which can thereafter be displayed in the desired form of projection.

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Precision analysis of IGS long baseline Processing based on GAMIT/GLOBK

The paper expounds the main module of GAMIT GPS data processing software, basic steps and treatment scheme of the data processing and quality evaluation system of the GAMIT data processing. This paper introduces the main application, steps of data processing of the software GLOBK and the problems that people need to be aware of

Erhu WEI
PhD, Professor, PhD supervisor, School of Geodesy and Geomatics, Laboratory of Geospace Environment and Geodesy, Ministry of Education, Wuhan University, Wuhan, China.

Jiandong LIU
Master Candidate, School of Geodesy and Geomatics, Wuhan University, Wuhan, China

After years of development, as the representative of GNSS, GPS technology has been gradually replacing the conventional triangulation techniques and has become the main means of access to ground control point coordinates. From the initial decimeter magnitude to the current sub-centimeter or even millimeter level, the coordinate precision of ground points has been highly improved upon[1]. However, baseline solution software accompanied with a receiver, for various reasons, has been increasingly unable to meet the high precision of the data processing requirements. In recent years, with the introduction of GAMIT/GLOBK, Bernese, GIPSY and other scientific GPS data processing software, the level of GPS data processing improved quickly, especially with the introduction of GAMIT/GLOBK software to the 'National GPS network of China' and the 'China Crustal Movement Observation Network', and successfully applied to obtain a large number of high-precision results .

The various high precision GNSS data processing software above are GAMIT/GLOBK, Bernese, GIPSY and PANDA. Bernese and PANDA were developed by the University of Bern in Switzerland and Wuhan University in China, thus they are not free of charge and the code of the software is not publicly available. The GIPSY software with a strong military background is not easy to obtain, and only GAMIT/GLOBK is a free software that can be obtained from public sources.

Observations of the precision positioning software used can generally be divided into two types - One is the double difference observation; this is what we used, and another is the non-difference observation. Double difference observation can better eliminate or greatly weaken GPS satellite clock error and receiver clock error. Dual differential observation model is mostly used in attached software (mainly for short baseline processing in engineering networks), a model also for high-precision positioning software.

GAMIT software was originally developed by Massachusetts Institute of Technology, after the United States SCRIPPS Institute of Oceanography to develop improvements together [2]. GAMIT software continued to release an updated version; the latest version being GAMIT10.4. GAMIT software is one of the best GPS positioning orbit software in the world; and using double-difference model, when using the precise ephemeris and precision starting point, the relative accuracy of long baseline can reach 10^{-9}, the accuracy of short baseline is better than 1 mm [3]. GAMIT is characterized by its high operation speed, short update cycle and higher degree of automation in accuracy within the permitted range. As a result, the application of the software is quite extensive.

The GAMIT software is composed of many different function modules which can be run independently. Their functions can be divided into two parts - data preparation and data processing. In addition, the software also comes with a powerful SHELL program.

The ideological core of the surveying adjustment software GLOBK is the Kalman filter; its main purpose is to deal with the integrated and multivariate measure data. The main input of the software is h-file and the approximate coordinates, which have been treated by GAMIT [4]. Of course, it has been successfully applied to process the integration data of other GPS software (e.g., Bernese and GIPSY) produced and other geodetic observations, including SLR data.

The main output of GLOBK is time series of station coordinates, the average coordinates of the station, station speed and multi-period orbit parameters[4]. GLOBK can effectively test the effects of different constraints on the adjustment results. Single-period analysis uses very loose constraints; therefore the parameter constraints can be enhanced directly in GLOBK.

The following section of this article briefly describes the role of the main modules of the GAMIT software and the function of each module. Later, in the core part of the paper, we provide a detailed statement of the data processing step of GAMIT software, which gives the results compared with Bernese software, and draw the appropriate conclusions.

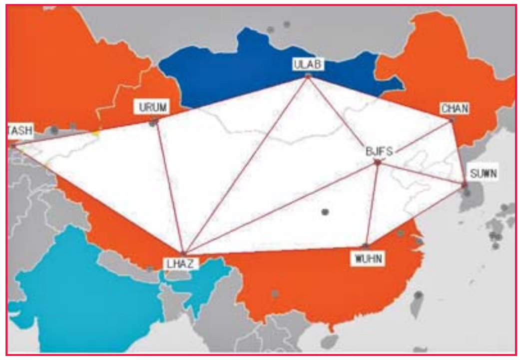
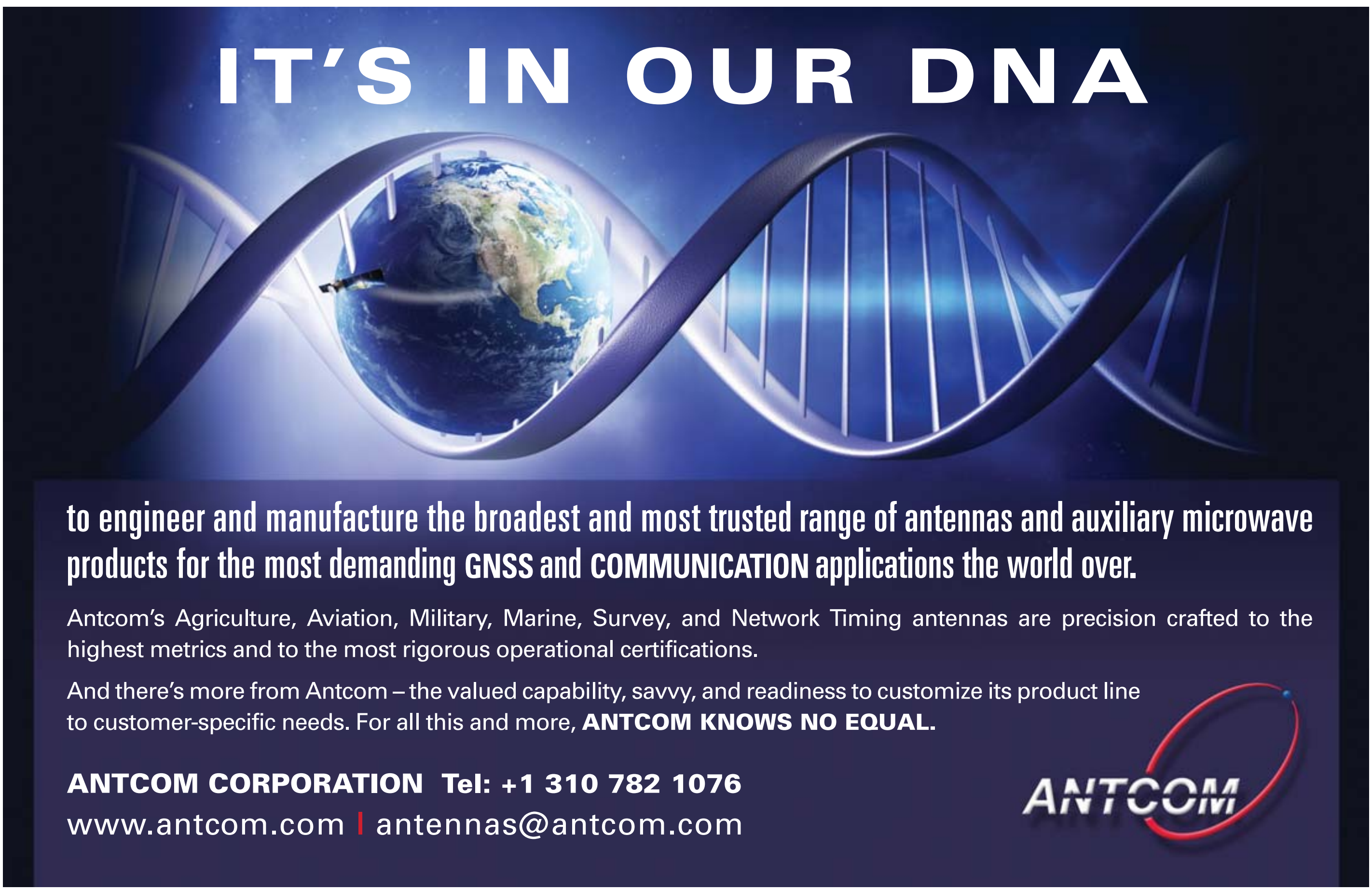


Figure 1: IGS station used in the paper

The main module of GAMIT

GAMIT software mainly consists of five modules: ARC of orbit integration module for satellite motion equations numerical integration to determine the satellite orbit; MODEL of partial derivatives to generate observation equation; AUTCLN of automatic repair cycle slips; the cycle slip repair modules, which also includes: SINCLN (single station automatic repair cycle slips), DBLCLN (double station automatic repair cycle slips), CVIEW (artificial repair cycle slips); CFMRG module to create the observation method file (M-file) for the SOLVE, define and select the relative parameters; The module of SOLVE used double difference observations by the least squares method to solve the various parameters.



Other modules are: MAKEXP is the driver of the data preparation module; MAKEJ generates the satellite clock error file; MAKEX can convert the original observation data (RINEX) into file format of GAMIT desired; BCTOT (NGS. TOT) will convert standard ephemeris (RINEX, SP3, SP1) into the desired file format of GAMIT. FIXDRV is the driver of data processing module.

Instructions of data processing of GAMIT

Data preparation

Prepare project file

The data processing, using a total of eight IGS stations were bjfs, chan, lhaz, urum, wuhn, suwn, tash, ulab, which are depicted in Figure 1. The data used is in 2013's annual day of 67, a total of 1 day. Post-processing precise ephemeris SP3 of IGS is used.

First of all, create a new folder named 2013 under the main project directory file, and then create new files respectively named brdc, igs, rinex and 067.

Prepare data files and update tables

The updates of Tables can be downloaded from ftp://garner.ucsd.edu/archive/garner/gamit/tables/; or http://sopac.ucsd.edu/processing/gamit/ to update the file you may need.

Files need to be updated everyday, which include Earth rotation parameters ut1 and pole (the command sh_get_orbits used to download IGS files. The two files will automatically be downloaded). Files need to be updated annually, including nutation table nutabl., Sun table soltal., Moon table luntab and leap seconds table leap.sec. When a new receiver or antenna is added, it needs to be updated rcvant.dat; and the new satellite launched needs updating svnav.dat. The encoded file dcb.dat needs updating on a monthly basis.

Since sopac and cddis server cannot log on with a blank password, and the ftp information in ftp_info recorded in the tables file of GAMIT (gg> tables> ftp_info), password and wpassword are empty, and therefore need to be modified, they will have to modify their password as a valid e-mail address, shenying1215@126.com.

Download data

After the password has been modified, you can download the data. It can be manually downloaded; or use the command to download it, and the procedure is as follows:

Observation files of IGS stations can be downloaded in the first step. The process - type command (code: cd 2013/rinex) in the terminal then slip into the rinex directory. Download rinex observation files, command is as follows: sh_get_rinex -archive cddis -yr 2013 -doy 67 -ndays 1 -sites bjfs chan lhaz urum wuhn suwn tash ulab; the program of GAMIT will be automatically downloaded and unzipped to get an observation o-file. If the internet speed is poor, you can add -ftp_prog wget after the above command. If the downloaded file is a d-file (compressed rinex observation files), you can use the command crx2rnx to convert it into an o-file (sh_crx2rnx –c n –d y - f *. Z or crx2rnx *. 13d).

Secondly, enter igs directory in the terminal, using the command sh_get_orbits -archive cddis -yr 2013 -doy 67 -ndays 1 -makeg no to download precise sp3 ephemeris.

Finally, enter brdc directory in the terminal, using the command sh_get_nav -archive cddis -yr 2013 -doy 67 -ndays 3 to download navigation ephemeris.

Table 1 Baseline and its RMS (GAMIT)

station	station	Baseline(GAMIT)	Rms
bjfs	chan	919176.94985	0.00820
bjfs	suwn	1006481.84179	0.00879
bjfs	wuhn	1015585.54231	0.00785
bjfs	ulab	1158265.40536	0.00761
bjfs	lhaz	2499815.09132	0.01566
ulab	urum	1568534.45579	0.01195
ulab	lhza	2426261.92495	0.01462
ulab	chan	1491723.38865	0.01058
suwn	wuhn	1387616.83404	0.01254
suwn	chan	735792.04691	0.00550
uru	tash	1521302.65855	0.01276
uru	lhaz	1597151.76141	0.01014
tash	lhaz	2341573.87475	0.01508
lhaz	wuhn	2228800.54822	0.01645

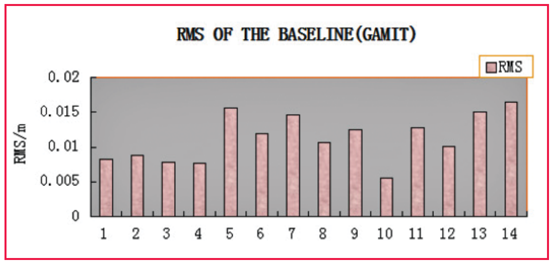


Figure 2: RMS of the baseline (GAMIT)

Connect tables to the project directory

After all updates have been done, run the command (in the terminal) in the project directory 2013: sh_setup-yr 2013[5]. At this point, the project directory is also automatically generating a tables file.

Generate the control documents

Documents needed to be prepared in GAMIT include lfile., Station.info, process.defaults, sestbl., Sittbl., and Sites.defaults. Documents need to be manually produced including station.info and lfile. documents.

- *Generate station information file station.info*
  Firstly, create a new blank document in rinex folder named station.info (2013>rinex>station.info). Secondly, find station.info file in tables folder (2013>tables>station.info). Then copy the header information of the station.info file to the new station.info file in the rinex folder. Finally, enter the rinex folder in terminal,

Table 2: Baseline and its RMS (Bernese)

station	station	Baseline by Bernese	RMS	GAMIT-bernese
bjfs	chan	919176.9483	0.0001	0.0015
bjfs	suwn	1006481.8391	0.0004	0.0027
bjfs	wuhn	1015585.5439	0.0003	-0.0016
bjfs	ulab	1158265.3997	0.0002	0.0057
bjfs	lhaz	2499815.0861	0.0008	0.0052
ulab	urum	1568534.4462	0.0002	0.0096
ulab	lhza	2426261.9230	0.0008	0.0019
ulab	chan	1491723.3794	0.0005	0.0093
suwn	wuhn	1387616.8310	0.0005	0.0030
suwn	chan	735792.0456	0.0002	0.0013
urum	tash	1521302.6603	0.0002	-0.0018
urum	lhaz	1597151.7547	0.0005	0.0067
tash	lhaz	2341573.8669	0.0007	0.0079
lhaz	wuhn	2228800.5454	0.0008	0.0028

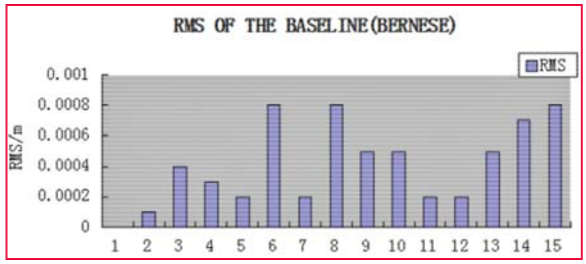


Figure 3: RMS of the baseline (Bernese)

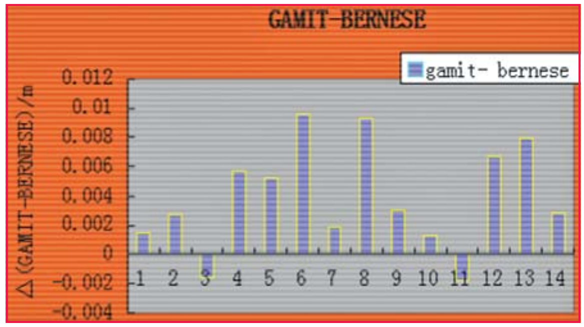


Figure 4: Baseline difference between GAMIT and Bernese

enter the command: sh_upd_stnfo -files *.13o. The station.info file can be automatically updated. Check the station.info file content, and compare the format of the file with station.info file in the tables folder, and ensure the stations are in the correct format.

- *Generate approximate coordinates lfile. Document* According to the manual of GAMIT, error of the approximate coordinates of the station cannot exceed 10 m; and approximate coordinates of the satellites can not exceed 100 m. Since IGS station coordinates is more accurate, it can reach the centimeter level; therefore, the approximate coordinates of the station can be extracted from the o-file. Enter in rinex folder, using the command grep POSITION *.13o>lfile. rnx which will crawl approximate coordinates in the o-file to lfile.rnx file. Check the lfile.rnx if the approximate coordinates of the station in lfile. rnx is 0, or if the process of crawl is unsuccessful, the approximate coordinates can be copied directly from the o-file to the file lfile.rnx, or calculate the approximate coordinates using pseudorange point positioning method. For example, command sh_rx2apr -site bjfs0670.13o -nav ../brdc/ brdc0670.13n –ref ../igs/igs17650.sp3 –apr ../ tables/itrf08.apr can generate two files: bjfs.apr and lfile.bjfs, , respectively, the station coordinates is represented by BLH and XYZ. After you have obtained the approximate coordinates of a station, the station coordinates XYZ can be copied from the file to lfiles.rnx file. When the approximate coordinates of all stations have been received, use the command rx2apr lfile.rnx 2013 067 to format the rnx-file to apr-file lfile.rnx. apr. Finally, convert the apr-files into lfile. file, command gapr_to_l lfile.rnx.apr lfile. "" 2013 067.
- *Other documents* Under normal circumstances, the control file of data process process.defaults, station lists file sites. defaults, solver control file sestbl., Precision control file sittbl. All can keep the default values, based on the main purpose of the calculation and then take the specific modifications. The data for the baseline solution, sestbl., has been set to Choice of Experiment = BASELINE. Data processing does not consider the impact of ocean tides; ocean tides model file otl.grid can be disabled. Need to set sestbl file for: Tides applied = 23; Use otl.grid = N;

Table 3: the adjustment results of GLOBK

Station	X	Y	Z
BJFS	-2148744.3363	4426641.2268	4044655.8514
CHAN	-2674427.4554	3757143.1385	4391521.5706
LHAZ	-106941.8127	5549269.8206	3139215.1045
SUWN	-3062023.0949	4055447.9086	3841818.1790
TASH	1695944.9800	4487138.5710	4190140.6975
ULAB	-1257408.7525	4099404.3381	4707992.5926
URUM	193030.3809	4606851.2906	4393311.4814
WUHN	-2267749.6727	5009154.2216	3221290.6008

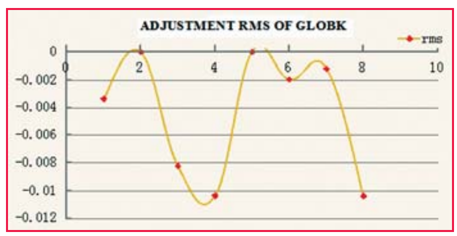


Figure 5: Adjustments RMS (m)of GLOBK

- *File replace* After all the preparation of documents to be produced are ready, copy station.info and lfile. file to tables file (2013>tables) in the project folder 2013.

Data processing

Using batch mode, command: sh_GAMIT -s 2013 67 67 -orbit IGSF -expt expt -eops usno -nogifs y, enables automatic data processing. Baseline solution

Table 4: station coordinates by Bernese

Station	X(m)	Y(m)	Z(m)
BJFS	-2148744.3509	4426641.2251	4044655.8667
CHAN	-2674427.4690	3757143.1332	4391521.5825
LHAZ	-106941.8242	5549269.8208	3139215.1217
SUWN	-3062023.1086	4055447.9055	3841818.1913
TASH	1695944.9653	4487138.5699	4190140.7157
ULAB	-1257408.7692	4099404.3390	4707992.6114
URUM	193030.3682	4606851.2944	4393311.5031
WUHN	-2267749.6864	5009154.2152	3221290.6130

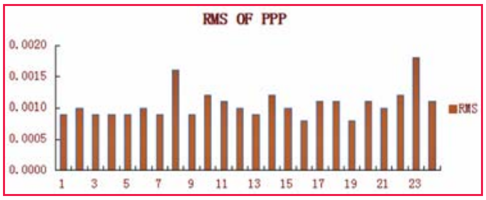


Figure 6: RMS (m) of PPP

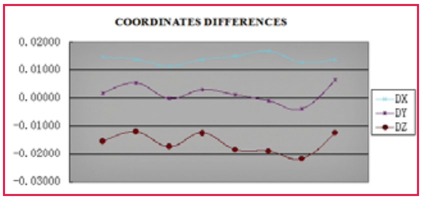


Figure 7: Station coordinate difference(m) between GAMIT and Bernese

results located in the file qexptq or qexpta (simplified file of qexptq) file of 067 folder, you can get the following baseline results. Posterior NRMS = 0.2158 <0.3, baseline solution is correct.

To test the validity of the results, Bernese software is used to process the same station, and compare the two results.

The analysis revealed that the baseline RMS value of the GAMIT solver is several centimeter, while baseline RMS of the BERNESE solver is at sub millimeter. This is mainly because the BERNESE software uses the PPP solver as initial value of the baseline solver, the overall improvement of RMS about an order of magnitude. Both baseline differences are consistent less than 1 cm in millimeter level. Relative accuracy of the baseline in GAMIT solver maintained at level 10^{-9}.

GLOBK (Global Kalman Filter) is a Kalman filter, which can be combined to solver space geodesy and ground observation data. The data for processing is valuation of the 'quasi-observation' and its covariance matrix, 'quasi-observation' means station coordinates obtained from the original observations, i.e., Earth rotation parameters, orbital parameters and target location and other information.

Adjustment of the GLOBK needs a two-step process, the first step is to convert the text h-file of GAMIT treatment resulting to binary H-file, which would be, copy the h-file in the session folder (067) to glbf folder, then enter glbf folder, run the command htoglb / tables/ expt.svs h*; you can get H-file. Then use the command ls *.glx>expt.gdl to get a gdl-file for GLOBK to get the right path when processing documents.

The second step, prepare process control documents GLOBK_comb.cmd and glorg_comb.cmd according to the GAMIT manual (Reference GLOBK manual, a detailed description of these two files for each constraint). These two documents will be placed into gsoln folder, and finally run the command in the project folder 2013: sh_glred -s 2013 067 2013 067 -expt expt -opt E G H, you can get a GLOBK_comb.org file, the adjustment results (WGS84 coordinates) is saved in this file.

Particular attention: If error of the approximate coordinates in the lfile more than 10 m, during the Kalman filter processing, GLOBK program will automatically delete the station in which errors overrun (three times in error), and the coordinate of that station will be 0. The results were compared with the Bernese precise point positioning (PPP) results. All stations adjustment results are mentioned in Table 3.

According to Figure 7, we can be sure that the station coordinates process results by GAMIT consistent with BERNESE within 1 to 2 cm. The results showed that the GAMIT software is suitable for handling long baseline and the results are reliable [6].

Conclusions

The results of the experiment show that the precision of inner coincidence of baseline solution by GAMIT can reach centimeter level. Compared with the Bernese software, the difference in baseline is about millimeter, difference of coordinate component is about 1-2 cm, and the precision is quite high. The experiments were selected long baseline, indicating that GAMIT has a great capability in processing baseline, and the performance of the software is reliable.

Acknowledgments

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The boundary stones of Tutankhamun's father - Akhenaten's city of the sun

The paper describes the design and layout of these impressive ancient surveyor's boundary stones along with contemporary history leading up to the most recent events affecting Akhenaten's Stelae as a spectacular example of the vital importance of surveyors during this turbulent period of the Great Egyptian Civilisation

John Francis Brock
Director, Brock Surveying, Australia

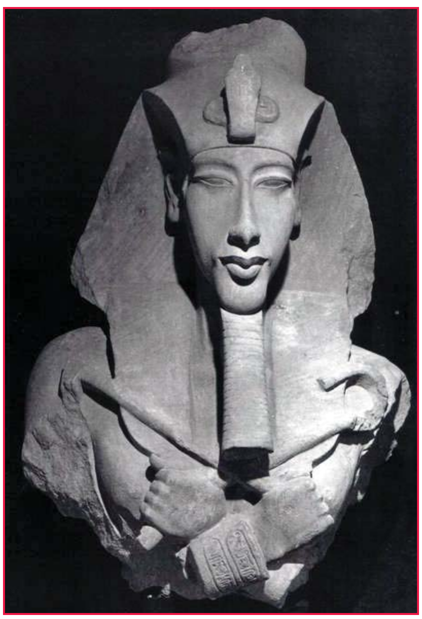


Figure 1: Akhenaten

During his relatively short reign of 17 years the highly controversial pharaoh of ancient Egypt derogatorily described as "The Heretic King" caused the most disruptive religious upheaval of the entire period of the legendary civilisation. Akhenaten took the throne of New Kingdom Egypt under his birth name of Amenhotep IV after the death of his father Amenhotep III in 1353 BC. After a few years in charge he changed his name to Akhenaten and his brief time on the throne even brought about a stylistic variation to the artistic depictions of Egyptian art. Even though his rule was so noteworthy it is one of his wives, Nefertiti, and his son, Tutankhaten (who changed his name to the more traditional Tutankhamun after his father's somewhat mysterious death?) who are the most renowned individuals of the ancient civilisation. Tutankhamun's golden death mask and the splendid coloured marble bust of his stepmother, Nefertiti, would be the most identifiable artefacts out of any recovered from the historic era of affluence during which they were crafted.

Not only did this determined despot try to replace the established principal God, Amun together with his pantheon of subsidiary gods, with a single deity called the Aten (simply identified as the Sun Disk) he even relocated the capital of the nation at a place which he purported was chosen by his Aten at a site previously unoccupied by humans as far back as Egyptian history could identify. The chosen area for his new capital called Akhetaten (of course!) was in central Egypt between high cliffs to the west and lower highlands along its eastern edge with the life-giving River Nile flowing through the city.

This eccentric Egyptian ruler may have been despised by the temple bureaucracy who resented his dictatorial decree to install a new monotheistic religion over the thousands of years of their established system, he must have been equally revered by his Scribes of the Fields – partly represented by the Cadastral Scribe Surveyors. As a demonstrative sign of the spiritually chosen city site Akhenaten engaged his boundary creators to place most substantial boundary stelae around the perimeter of his new city along its western and eastern sides. The distinctive boundary markers consisted of images of the Pharaoh and his family in adoration of the Aten with the sun's rays bathing the group along with extensive hieroglyphic recitals declaring how the site was selected and the distances from each stone carving to the next. His obsession with everything "Aten", even to the extreme of naming ALL of his children with that nomen as a suffix, Merytaten, Meketaten and Tutankhaten can be identifiable with his equally obsessive preoccupation with his new city. Through his insistence on the placement of such impressive boundary monuments and the declaration of the distances from one stela to those adjoining it signifies the essential importance cast upon those Cadastral Scribe Surveyors entrusted with the duty of bringing this perimeter demarcation into reality. Through his own proclamations the boundaries of his capital, literally meaning "Horizon of the Aten", were established for eternity and divinely protected by the God and his reincarnation on earth, Akhenaten himself.

During the 1980's an exhaustive re-analysis of each of the surviving boundary stelae was carried out by a team mainly funded by the Committee on Research of the American Philosophical Society under the leadership of William J. Murnane and Charles C. Van Siclen III such field exercise being titled "The El Amarna Boundary Stelae Project." A very excellent text based on the findings of this project was published which is a most authoritative and thorough treatise on these monuments to the might of the Cadastral Scribe Surveyors of Akhenaten.

Introduction

Akhenaten's obsession with his instatement of The Aten as the sole Egyptian deity was ultimately rejected and refuted by the majority of the populace led stoically by the religious bureaucracy who resented the dislocation of thousands of years of established theocracy. The new Pharaoh even relocated the capital of his dominion to a desolate area of middle Egypt previously uninhabited said to have been bestowed upon him by his new God. Along with the substantial capital construction necessary for the presentation of the required status to portray the image of the nation's main city Akhenaten also demonstrated the major significance he placed upon the accurate location and prominence of the monumentation to delineate the boundaries of his new metropolis.

Clearly the Cadastral Scribe Surveyors were among the VIPs in the heretic pharaoh's divine workforce being responsible for the marking out of the city limits for the new capital with most distinctive stelae carved with the Royal decrees of their omnipotent leader. Placed at strategic positions around the perimeter of the city territory these superb examples of city boundary demarcation have lasted for in excess of 3300 years since their installation, but in more recent times the greed of the ancient artifacts dealers have brought about the destruction of the formerly best preserved example of these stone boundary markers. Hapless thieves tried to steal the Stela S at the south eastern border area by blowing the stone face from the cliff wall with explosives but all they succeeded in achieving was the complete disintegration of the precious link with the revered ancient civilisation. It is hoped that these dunderheads have learnt a lesson from this feeble-minded effort so that there are no further attempts to desecrate the remainder of these priceless ancient landmarks.

The following paper will describe the design and layout of these impressive ancient surveyor's boundary stones along with contemporary history leading up to the most recent events affecting Akhenaten's Stelae as a spectacular example of the vital importance of surveyors during this turbulent period of the Great Egyptian Civilisation.

Akhenaten's accession to power

When Amenhotep III died his son Amenhotep IV ascended to the throne ultimately bringing with him the seeds of unprecedented revolution which would emanate from the throne of the King Himself. The year was 1353 BC and the great empire was already confronting serious challenges to her borders from aspiring tribes led by warrior leaders.

At first there was little suggestion of the major upsets to be thrust upon the unexpecting population and stunned temple bureaucracy but the consequences would be major.

Shortly after assuming his divine position the new pharaoh changed his name to Akhenaten and had instated the representation of the solar disc, The Aten, as the sole god to be worshipped by his resistant minions. His next major disruption to the establishment was to start construction of a new capital city at a previously uninhabited area of central Egypt straddling the Nile in the area now known as El Amarna. His first component in the creation of his new Egyptian Administration Centre was to have his Scribe Surveyors place imposing boundary stelae at the significant points around the perimeter of his new domain to display his control over his metropolis along with the Regal decree to demonstrate the divine selection of this site.

Figure 2: Nefertiti and Tutankhamun

Akhenaten was a very family orientated ruler and he often has himself depicted upon his carved stone imagery nursing or touching his children together with his wives represented at the same level of proportion as himself such presentation being a departure from prevailing standards of art.

His most favoured wife was the beautiful Queen Nefertiti famously immortalised in the superb coloured marble bust held in the Cairo Museum while the most recognised image and character of all from the ancient race is of course Tutankhamun whose treasures focused unequalled interest in ancient Egypt when Howard Carter found his undisturbed tomb cache in 1922. Tut's mother was another wife named Tiy and his birth name was Tutankhaten which he had changed to the more well known version quite quickly after his father's mysterious death to reconcile his patriarch's damage to the morale of his nation.

Modern discovery of the Stelae

The first modern traveller to make note of Stela A was the Jesuit priest Claude Sicard in 1714 and it was only mentioned once again in the eighteenth century in 1777. Next Joseph Bonomi viewed it in 1825 with Robert Hay making sketches of the site in 1827 having possibly been informed of it by John Gardner Wilkinson. The largest of the boundary monuments, Stela U, was discovered by A.C. Harris and George Gliddon in 1840. Various other tourists noted and made drawings of some of the stelae being Nestor L'Hote, George Lloyd, E. Prisse d'Avennes and Karl Richard Lepsius during the 1840's.

However the most significant and thorough discovery and recording of the majority of the stelae was made by The Father of Egyptology, William Matthew Flinders Petrie, in 1892. You may notice the middle names of this prolific figure of modern Egyptology because he is the grandson of the legendary marine surveyor of Australia Matthew Flinders and with such an illustrious pedigree in scientific discovery it is not surprising that Petrie revolutionised the recording of ancient sites through the introduction of accurate surveying techniques for the chronicling of all discoveries.

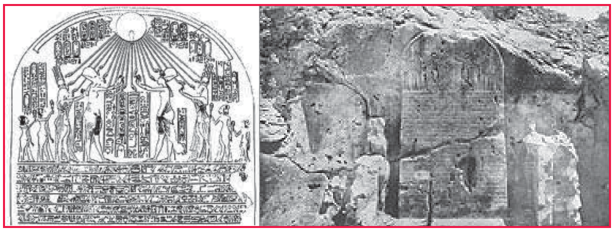


Figure 4: Stela S detail and insitu before its destruction in 2004

In more recent times a more intensive investigation of these phenomenal in-situ boundary stones was undertaken under the leadership of William J. Murnane and Charles C. Van Siclen III in the early 1980's. The El Amarna Boundary Stelae Project was funded by the Committee on Research of the American Philosophical Society, the Oriental Institute and the American Research Center in Egypt and produced a brilliant book titled "The Boundary Stelae of Akhenaten" first published in 1993 by Kegan Paul International Ltd., London.

Two types of boundary stelae have been identified by the scholars who have analysed the great monuments. The different styles are known as The Earlier Proclamation and the Later Proclamation with the first placements being made in the King's Regnal Year 5. The remaining extant stelae are numbered with letters starting with Stela A in an anticlockwise direction up to F on the western side across the southern boundary to Stela P then northerly to Stela X at the north eastern corner to define the northern boundary back across to the starting Stela A. Stelae K, M and X are the only monuments which bear this initial decree also showing his first daughter Meritaten only while the remaining carvings were made in Akhenaten's sixth Regnal year and later. The stones containing the Later Proclamation are of somewhat more interest to surveyors as they define the dimensions of the city's limits, measuring from the stelae on the east

bank to those on the western borderline. Southern stelae bear a codicil dating to early in Akhenaten's eighth year which records a royal visit to these sites. After a relative period of inactivity there seems to have been a rejuvenation of effort by the capital works team subsequent to these Royal visitations with the King's two later daughters being added to the imagery and text sculpted onto the monuments during his eighth year.

A most tragic incident took place in early 2004 when antiquities thieves completed destroyed Stela S with explosives leaving just a gaping hole in the rock where the great monument had proudly stood for over 3,300 years. The only fortunate feature of this recent vandalism is that at least we have thorough and comprehensive recordings of this remarkable symbol of the outstanding society which set it in stone all of those many years ago for the rest of posterity of which artifacts robbers are not inclusive.

Apart from the King's declaration as to the divine choice for his new capital he also adds the following decree to the titulary on the south eastern stela:

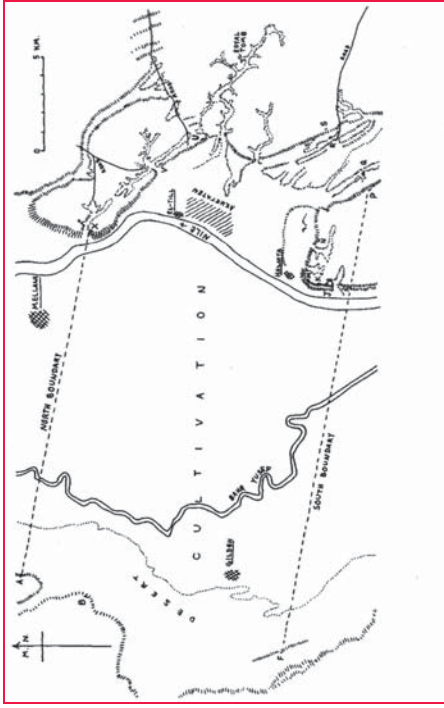
> "As for the southern stela which is on the eastern mountain of 'Horizon of the Orb', it is the stela of 'Horizon of the Orb', the one beside which I make my stand. I shall not go past it to the south forever and ever. Make the south-western stela across from it on the western mountain of 'Horizon of the Orb' exactly!
>
> "As for the intermediate stela on the eastern mountain of 'Horizon of the Orb', it is the stela of 'Horizon of the Orb', the one beside which I make my stand on the mountain of the orient-(side) of 'Horizon of the Orb'. I shall not go past it to the orient forever and ever. Make the intermediate stela which is on the western (side) of 'Horizon of the Orb' across from it on the western mountain of 'Horizon of the Orb' exactly! I shall not go past it to the west forever and ever.
>
> "As for the north-eastern stela of 'Horizon of the Orb' by which I make my stand, it is the northern stela of 'Horizon of the Orb'. I shall not go past it downstream forever and ever. Make the north-western stela which is on the western mountain of 'Horizon of the Orb'across from it exactly!"

The great Pharaoh even goes further with his attention to survey detail by adding dimensions to his Holy City:

> "Now, as for 'Horizon of the Orb', starting from the southern stela of 'Horizon of the Orb' as far as the northern stela, measured between stela to stela on the eastern (var. western) mountain of 'Horizon of the Orb', it makes six iter, one and three-quarter rods and four cubits.
>
> "Similarly, starting from the south-western stela of 'Horizon of the Orb'to the north- western stela upon the western mountain of 'Horizon of the Orb', it makes six iter, one and three-quarter rods and four cubits similarly, exactly!"

Conclusion

In the modern metric system these stated ancient Egyptian dimensions are said to be equivalent to 20,000 cubits (10.5 kms) for the iter or itrw, one rod (or sacred rod of chord) is 100 cubits (52.5 metres) and one cubit is 0.525 metre. Thus the stated separation distances between the stelae is 63 kilometres and 93.975 metres north to south with an east-west line at 192 kms from Stela A to Stela X as well as 200 kms in the south of 200 kms from Stela F to Stela J which would make the area of the capital city about 12,500 square kilometres plus (about 7800 sq. miles plus) This area figure is subject to much more refinement due to the irregularities of the stela positions along the western and eastern boundaries of the city. However such substantial distances to be verified by the Cadastral Scribe Surveyors (Scribes of the Field) would have been a major undertaking with the knotted ropes available to these most skilled ancient surveyors but extant structures like the Pyramids and temples are positive indicators set in stone of the capabilities of their accurate measurement skills.



The territory of Akhenaten's city, showing the positions of the boundary stelae on both sides of the Nile.

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Search for the plate transition zone in Bulgaria with GPS

The main objectives of this study are the estimation of Euler rotation vector and Euler pole and on the base of obtained results to attempt to determine the transition boundary of the Eurasia plate in the Bulgarian territory

Keranka Vassileva
Associate Professor, National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Sofia, Bulgaria

Mila Atanasova-Zlatareva
Assistant Professor, National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Sofia, Bulgaria

The region of Balkan Peninsula and in particular, the territory of Bulgaria characterizes with active tectonics and seismotectonics. A number of geological, geophysical and geodetic investigations demonstrate the recent activity of the region, and have tried to give a reasonable and adequate interpretation of the obtained results [2], [4], [6], [8], [11], based on the analysis of estimated stations velocities from GPS data processing.

This work is an attempt to contribute to clarify the boundaries of the Eurasian plate in the country by applying another approach for boundary determination, i.e., by applying the theory of Euler rotation pole to the estimated coordinates and velocities of freely accessible GNSS permanent stations operating in Bulgaria and nearby areas.

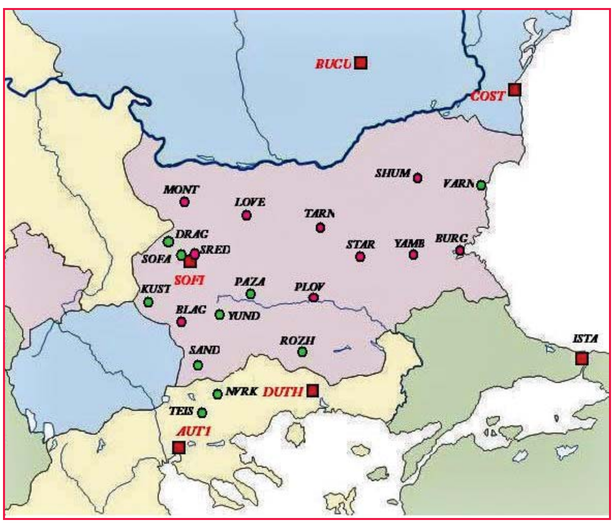

Figure 1: GNSS permanent stations involved in this study

GPS data processing

For purposes of the study, data from 26 GNSS permanent stations have been used as 19 of them are in the territory of Bulgaria, 2 permanent stations in Romania, 4 permanent stations in northern Greece and 1 permanent station in north-east Turkey (*Figure 1*).

Velocity vectors used in this study were obtained earlier in two time frames [12], [13]. Station velocity vectors were estimated in [12], for the investigation of geodynamics of the territory of the Balkan Peninsula. For their estimation, one week of GPS data of every year from 2006 to 2010 were processed with the Bernese software, version 5.0 in ITRF2005. Part of the results obtained from these stations are used for this study, i.e., DRAG, SOFA, KUST, PAZA, YUND, SAND, VARN, ROZH, and SOFI. The other part of the stations was involved in a later investigation [13] of GNSS BULiPOS permanent network [9]. One week of GPS data of BULiPOS stations were processed with the same software, in the same coordinate system, every year from 2009 to 2011. To be consistent and comparable station velocity results in both works, all GPS data of BULiPOS network are reprocessed with the same IGS stations for datum definition as they are used in Vassileva, 2013a. New estimations of station coordinates and station velocity components (V_X, V_Y, V_Z) are obtained from their combined solutions in ITRF2005, referred to epoch 2000.0. For the local movements of the stations, which are more important for their behavior, the ETRF horizontal station velocity vectors (*Figure 2*) have been obtained by applying ETRF components of the Eurasia plate rotation pole [1] to the obtained ITRF2005 velocity vectors. Then they have been transformed into ETRF2000.

The magnitude of the obtained horizontal station velocities varies from 0,2mm/yr up to 3,8mm/yr for the Bulgarian stations, and up to 10mm/yr for stations in northern Greece. Such small magnitudes

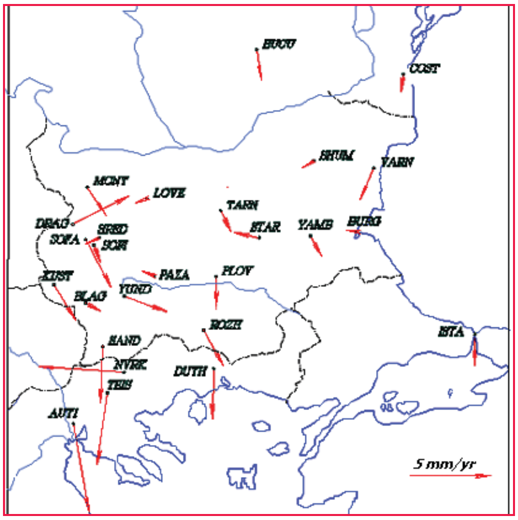

Figure 2: Obtained ETRF2000 horizontal velocity vectors of participated GNSS permanent stations

of movements of points over the territory of the country have been also obtained by other researchers [2], [3], [5].

Estimation of the parameters of the Euler rotation pole

The main objective of this item is the computation of different Euler rotation vectors and Euler poles, which give information about the motion of the respective plate.

Each tectonic plate included in some kinematic plate model (absolute or relative) has altogether six parameters: Euler rotation vector Ω (Ω_X, Ω_Y, Ω_Z) and Euler pole (φ, λ, Ω). The relation between estimated parameters of a single station – Cartesian geocentric coordinates (X, Y, Z) and station velocity components (V_X, V_Y, V_Z), and unknown values of the Euler rotation vector - Ω (Ω_X, Ω_Y, Ω_Z) gives the linearized observation equation for the station. Using the estimated coordinates and velocities of GPS stations, it is possible to estimate the plate kinematic model by applying the least squares method. GPS velocities in a Cartesian geocentric frame can be modelled as [10]:

$$\vec{V} = \vec{\Omega} \times \vec{P}$$

or

$$\begin{bmatrix} V_X \\ V_Y \\ V_Z \end{bmatrix} = \begin{bmatrix} 0 & -\Omega_Z & \Omega_Y \\ \Omega_Z & 0 & -\Omega_X \\ -\Omega_Y & \Omega_X & 0 \end{bmatrix} . \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

where P (X, Y, Z) is the vector defining the position of the GPS station, V (V_X, V_Y, V_Z) is the velocity vector at that station, and Ω (Ω_X, Ω_Y, Ω_Z) is the rotation vector defining the motion of the plate carrying the station.

Estimating Euler rotation vector Ω (Ω_X, Ω_Y, Ω_Z), it is possible to calculate the Euler pole (φ, λ, Ω).

$$\varphi = arctan \left(\frac{\Omega_Z}{\sqrt{\Omega_X^2 + \Omega_Y^2}} \right)$$

$$\lambda = arctan \left(\frac{\Omega_Y}{\Omega_X} \right)$$

$$\Omega = \sqrt{\Omega_X^2 + \Omega_Y^2 + \Omega_Z^2} .$$

Nine sets of stations with their estimated ITRF2005 coordinates and velocities have been configured considering the tectonic setting of the territory of the country and respective parameters of the Euler rotation pole have been estimated.

Burchfiel et al., 2006 and Kotzev et al., 2008 suggest that the northern boundary of the Aegean extensional region passes through Central Bulgaria. Other researchers [3], [4], [7] also suggest that the boundary of the Eurasian plate follows the Balkan mountain chain. By this reason, two main sets are configured from all stations in northern Bulgaria and two stations in Romania (NB2), and respectively from all stations in southern Bulgaria, northern Greece and northern Turkey (SB2). The other sets are configured in such a way that stations from southern Bulgaria gradually are added to the northern set NB2, in order to be followed the changes of the estimated Euler parameters. The obtained results for Euler pole (φ, λ, Ω) of all sets are given in *Table 1*.

Table 1. EUREF Euler parameters and Euler parameters estimated from this study

Set	φ [°]	λ [°]	Ω [Mas/yr]	Station data used
EUREF	260.59	57.96	0.934	
NB1	274.21	64.14	0.778	MONT, LOVE, TARN, SHUM, BUCU, COST
NB2	256.56	54.68	0.701	MONT, LOVE, TARN, SHUM, BUCU, COST, VARN
NSB3	270.07	62.46	0.760	MONT, LOVE, TARN, SHUM, BUCU, COST, VARN, YAMB, BURG
NSB4	245.72	44.55	0.707	MONT, LOVE, TARN,SHUM, BUCU, COST, VARN, SOFA, SOFI, SERD, DRAG
NSB5	246.06	44.53	0.705	MONT, LOVE, TARN, SHUM, BUCU, COST, VARN, YAMB, BURG SOFA, SOFI, SERD, DRAG
NSB6	245.16	44.00	0.700	MONT, LOVE, TARN, SHUM, BUCU, COST, VARN, YAMB, BURG, SOFA,SOFI, SERD, DRAG, PLOV, BLAG, KUST, ISTA
NSB7	264.97	62.03	0.759	MONT, LOVE, TARN, SHUM, BUCU, COST, VARN, YAMB, BURG, SOFA, SOFI, SERD, DRAG, PLOV, BLAG, KUST, ISTA SAND, AUT1, DUTH,
SB1	239.42	36.26	0.702	YAMB, BURG, SOFA, SOFI, SERD, DRAG, PLOV, BLAG, KUST, ISTA
SB2	260.81	60.82	0.740	YAMB, BURG, SOFA, SOFI, SERD, DRAG, PLOV, BLAG, KUST, ISTA SAND, AUT1, DUTH,

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From all nine sets the closest result of the Euler rotation pole parameters to the estimated and officially accepted EUREF parameters (plate EUREF in *Table 1*) is the NB2 set, which consists of stations only in northern Bulgaria and two stations in Romania and SB2 set, which consists of stations only in southern Bulgaria, northern Greece and northern Turkey. Considering the results from other researches [2], [3], [4], [6], it is not quite understandable that the estimations of SB2 set show the belonging to the Eurasia plate as this territory is characterized with extensional processes. Differences of Euler rotation pole estimations between the other sets of stations and EUREF Euler rotation pole estimations varies between 10^{o}- 15^{o} in latitude φ and between 6^{o}- 13^{o} in longitude λ (*Figure 3*). These sets are combinations of stations from northern and southern Bulgaria.

Discussion

The results obtained in this study indicate that the majority of added stations to the northern territory of Bulgaria do not belong to the Eurasia plate. But for a few of the southern stations (set NSB7), it could be assumed that they also belong to the Eurasia plate. Therefore, the results obviously do not show quite a clear distinction between the transition zones, which is also an assumption of other studies (Stangl, 2011). Otherwise, all sets agree well in estimated angular velocity of the Euler pole **Ω.**

From the analysis of the obtained parameters of the Euler rotation poles, it can be assumed that the North Bulgarian territory, northern from the Balkan Mountain chain and probably a small part of the central-eastern Bulgaria belong to the Eurasia plate.

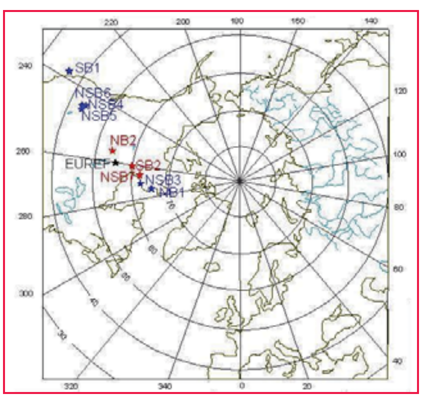

Figure 3: Euler poles for different sets

Conclusion

The estimated parameters of Euler pole of the study territory on the basis of GPS processed measurements confirm the suggestion that the northern Bulgaria belongs to the Eurasia plate, but still its boundary, e.g., the transition zone cannot be clearly defined. Denser network of GNSS stations spread over the territory of the country could contribute to the clarification of the transition zone.

Acknowledgements

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Accuracy and repeatability investigation of CSRS-PPP online processing service

This paper investigates the accuracy and repeatability of the Canadian Spatial Reference System (CSRS) Precise Point Positioning (PPP) or known briefly as (CSRS-PPP) online processing service at different latitude regions

M Abdelazeem
Geomatic Engineering Department,
Istanbul Technical University, Turkey

R N Çelik
Geomatic Engineering Department,
Istanbul Technical University, Turkey

With the advent of Global Navigation Satellite System (GNSS) technology and its data accessibility, many precise geodetic applications such as deformation mentoring have been achieved simply by saving time and efforts. Over the last decades, the differential technique has been the prevalent operational mode for precise positioning despite its need for at least two receivers and a reference station. Precise Point Positioning (PPP) is an alternative positioning method that employs a single GNSS receiver relying on the availability of precise ephemeris and clock products from International GNSS Service (IGS) or other organizations, and the usage of both carrier-phase and code range measurements. This technique has the merit that it needs only a single receiver and is without any requirements for establishing a reference station. In order to obtain accurate solutions, phase wind-up corrections, satellite and receiver antenna phase centre corrections, solid earth tide corrections and ocean loading corrections are necessary. On the other hand, the most important drawback in PPP is the long convergence time necessary for the float solution of ambiguity resolution, thus limiting its use for real-time applications and short static observations sessions.

In recent years, a number of free online GNSS processing services have been established. Those services provide users with the opportunity to freely obtain highly accurate coordinates with respect to a well-defined datum. The services use their dependent scientific software and each service has its specific procedure of data processing. The merits of these services are unlimited access, free of charge and do not require any prior experience with processing software packages. The role of the user is only to upload the observation file in RINEX format to the service's webpage, and the results will be sent a few minutes later. The results are provided in the geographic coordinate's formats or in a recognized datum like the International Terrestrial Reference Frame 2008 (ITRF2008). These online services are sponsored by a number of national organizations such as Natural Resources Canada (CSRS-PPP), National Geodetic Survey U.S.(OPUS) and Geoscience Australia (AUSPOS). Some of these services process only dual frequency observations and some can also process kinematic observations.

This study aims to assess the accuracy and repeatability of the CSRS-PPP online processing service at different latitude regions. For this purpose, dual frequency GPS data from four IGS stations distributed in different regions of the

CSRS-PPP provides geographic coordinates, projected coordinates and Cartesian coordinates. The convenience of the service leads to its wide usage in different surveying applications.

world, at high latitude, equatorial and mid latitude regions, have been used. The observations were collected in January and July and processed using CSRS-PPP online service. The results were compared with the true coordinates of the stations. It is shown that the CSRS-PPP produces an accuracy at the ±(1 to 4) mm and ±(2 to 7) mm level for the horizontal and height components respectively. Furthermore, the repeatability ranges from ±(1 to 5) mm for both directions.

Online processing service

Recently, an alternative processing method to the traditional method has begun to be used widely. This method is internet-based online GNSS processing services. By using these services, the collected GNSS data are uploaded to particular internet sites and then the coordinates can easily be obtained a few minutes later. These services have several benefits, e.g. unlimited, free of charge, saving time without any need for processing software and saving money by operating with one receiver only. These services proved their accuracy, since a single receiver user can obtain accuracy in mm level [Enber and Featherstone, 2008]. Currently, there are five online processing services such as AUSPOS operated by the Geoscience Australia, CSRS-PPP supervised by the Geodetic Survey Division of Natural Resource Canada, OPUS established by the U.S. National Geodetic Survey, SCOUT developed by Scripps Orbit and Permanent Array Center (SOPAC), and APPS (formerly Auto-GPISY) operated by Jet Propulsion Laboratory (JPL). Each service has its advantages, limitations and procedures for processing. For comparison among them, see [Ghoddousi and Dare, 2006].

Several studies on the performance of these processing services have been published [Ghoddousi and Dare, 2006 and Dawod et al., 2007]. For example, [Tsakiri, 2008] investigated the results of four online processing services such as CSRS, Auto-GIPSY, SCOUT and AUSPOS for both static and kinematic data processing. In static mode, observations from eight selected IGS stations were processed by each service. Solutions for 24 hour data were generally repeatable at 1 to 2 cm level within the accuracy of ±3 to ±4 cm level. However, the quality of results decreased as the time window decreased. In kinematic mode, two data sets were used. The first data set, 24 hour RINEX files from two IGS stations were processed by using kinematic mode in CSRS-PPP. The results were compared with their known coordinates. The second data set has collected on a moving vehicle. The CSRS-PPP kinematic results were compared with a reference trajectory computed from Differential GPS. The positioning accuracy achieved on the kinematic mode was 5to 10cm level. Moreover, [Subaşi and Alkan, 2011]analyzed the accuracy of the AUSPOS, OPUS and SCOUT services by processing dual frequency observations of 6 Continuously Operating Reference Stations (CORS) located in Istanbul/Turkey. Two 24 hour RINEX files were used covering two different days where each file was divided into four sub-files. The observations were processed using the aforementioned processing services and the results were compared with their known coordinates computed from BERNESE software. The results indicated an overall accuracy level of 1to 22 cm from all services. However, SCOUT provided the best solutions.

Abdelazeem et al., 2011 compared the CSRS service and traditional differential processing technique for single frequency observations collected over three points, located in Egypt, forming three different baseline lengths and covering three different time windows. The findings revealed an overall 2Ddifference between the CSRS solution andthe differential solution at few decimeters level.

In this study, the CSRS-PPP online processing service is selected due to several reasons:

1. Its simple user interface and rapidity for sending solution to the user.
2. It processes both static and kinematic, single and dual frequency observations.
3. The service provides solution for data collected from any place in the world, in other words no region restriction.
4. It provides detail outputs such as pseudo-range residuals sky distribution, estimated tropospheric zenith delay and station clock offset.
5. CSRS-PPP processing results and achieved accuracies have been discussed in other previous studies, e.g., [Enber and Featherstone, 2008] used GPS observations of 46 points of a geodetic network, and compared the obtained CSRS-PPP results with the results of Bernese software. This study shows that the mean coordinate difference is 3.3 mm in east direction, 4.8 mm in north direction and 11.8 mm in height direction. Furthermore, [Grinter and Janssen, 2012] investigated the accuracy of CSRS-PPP solutions for 20 CORS stations' observation, located in Australia, based on different observation periods and then compared the results obtained with the true coordinates of these stations. This study shows that the accuracy specification defined as 25 mm in both Easting and Northing components, and 35 mm in Ellipsoidal Height for at least 4 hours data processed by CSRS-PPP.

Processing strategies of CSRS-PPP

As stated previously, the aim of this paper is to evaluate the performance of the CSRS-PPP online processing service for dual frequency observations at different latitude regions which reflect different ionospheric and tropospheric conditions. Therefore, this section concerns the procedures adopted by the CSRS-PPP for the correction of the ionospheric and tropospheric delays. However, for more details about service specifications, required steps for use, and description of output files, see [Natural Resources Canada, 2006].

For the ionospheric delay correction, for the L1 observations the service uses the global ionospheric maps produced at 2-hour interval in IONEX format by IGS [Schaer et al., 1998]. On the other hand, for the L1&L2 observations, the L1&L2 ionospheric-free combination of

Figure 1: Location of the selected IGS stations

the code and phase observations is used [Hofmann-Wellenhof, et al., 2008].

In case of tropospheric zenith delay determination, the service utilizes the Davis model for hydrostatic delay [Davis, et al., 1985] and the Hopfield model for wet delay [Hofmann-Wellenhofet al., 2008] depending on surface meteorological data. In addition to, Global Mapping Function (GMF) is used to determine the slant tropospheric delay [Boehmet, et al., 2006].

Test methodology

This study aims to evaluate both the accuracy and repeatability of the CSRS-PPP online processing service for dual frequency observations at different latitude regions. For this purpose, four different IGS stations have been selected at different latitude regions where the points located in high latitudes, at the equator, in middle-latitude and at the coast of Pacific ocean (Figure 1). Table 1 lists the name of each station, their location, type of receiver, type of the installed antenna and operation date. The time of data sets were chosen to reflect seasonal variations in atmospheric status during the year, where two subsets of two complete weeks of data were involved. The first week is GPS week 1669 starting from 1 January 2012. The other is GPS week 1695 starting from 1 July 2012.

Table 1: Selected points [IGS, 2013]

Station ID	Station Name	Country	Receiver Type	Antenna Type	Operation Date
KIRU	Kiruna	Sweden	SEPT POLARX4	SEPCHOKE_ MC SPKE	08-07-1993
BRFT	Eusebio	Brazil	LEICA GRX1200PRO	LEIAT504 NONE	06-09-2005
HARB	Pretoria	South Africa	TRIMBLE NETR9	TRM59800.00 NONE	09-08-2000
AIRA	Aira	Japan	TRIMBLE NETR9	TRM59800.00 SCIS	05-12-1997

Each test week has different atmospheric conditions from the other. For the ionospheric delay, it is eliminated by using free linear combination. With regard to tropospheric effect, it depends on pressure, temperature, humidity and water vapor pressure at the observed point. Therefore, the temperature and pressure values at the tested points are taken from the solution file provided by

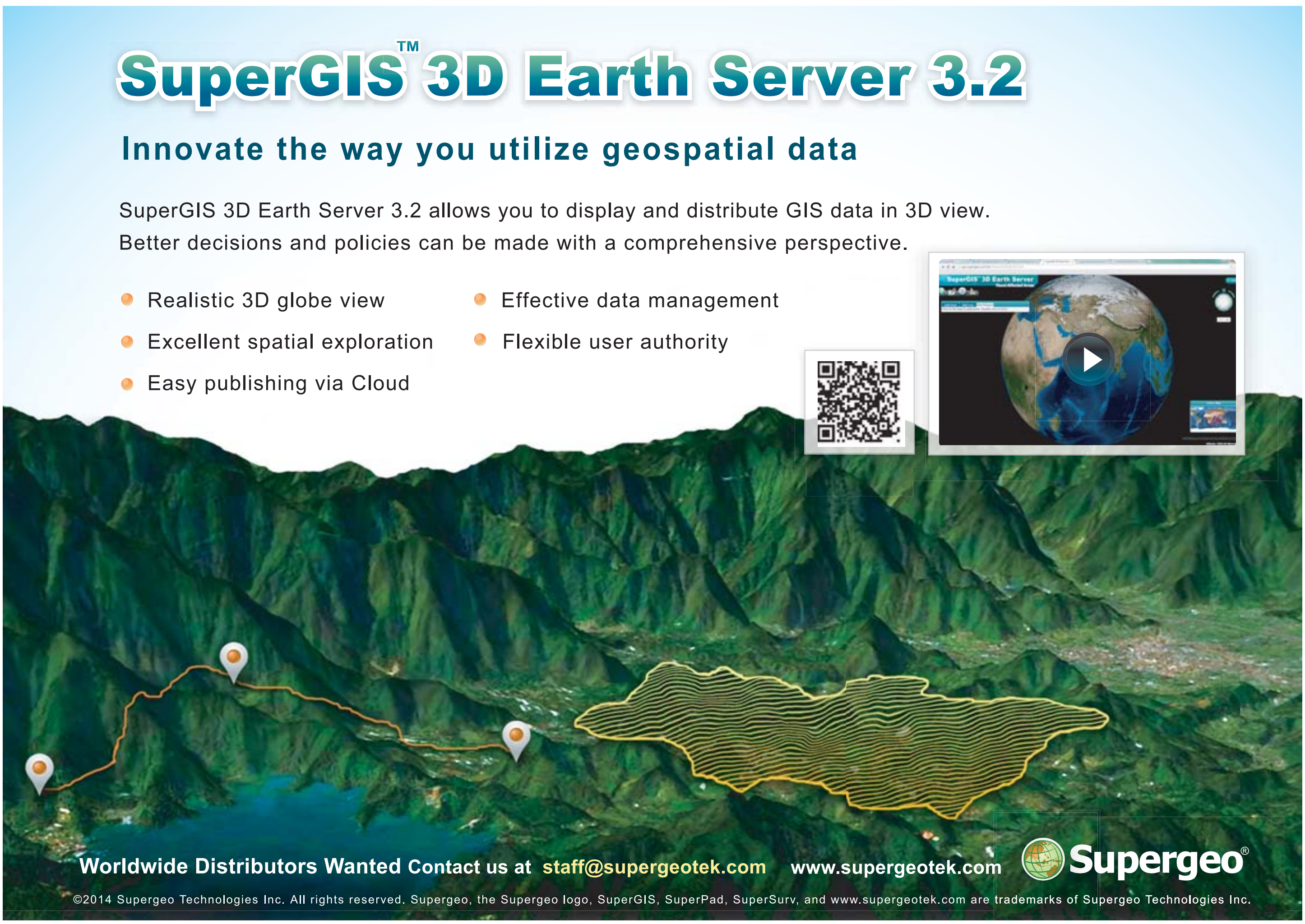

Table 2: Surface meteorological data

Station	GPS Week	Day	Temperature (C°)	Pressure (mb)	GPS Week	Day	Temperature (C°)	Pressure (mb)
KIRU	1669	0	-3.67	959.09	1695	0	8.30	971.27
		1	-3.72	959.04		1	8.35	971.32
		2	-3.77	958.99		2	8.40	971.38
		3	-3.81	958.94		3	8.45	971.42
		4	-3.86	958.89		4	8.50	971.47
		5	-3.9	958.85		5	8.54	971.52
		6	-3.94	958.81		6	8.59	971.56
BRFT	1669	0	25.95	1004.53	1695	0	27.32	1007.21
		1	25.95	1004.52		1	27.32	1007.23
		2	25.94	1004.52		2	27.33	1007.24
		3	25.94	1004.50		3	27.34	1007.26
		4	25.93	1004.48		4	27.34	1007.27
		5	25.93	1004.48		5	27.35	1007.28
		6	25.92	1004.47		6	27.35	1007.30
HARB	1669	0	16.62	846.13	1695	0	13.79	850.95
		1	16.63	846.08		1	13.77	850.86
		2	16.65	846.2		2	13.76	850.85
		3	16.66	846.29		3	13.75	850.88
		4	16.68	846.31		4	13.74	851.00
		5	16.67	845.99		5	13.73	850.97
		6	16.69	846.08		6	13.72	851.05
AIRA	1669	0	8.13	984.69	1695	0	24.64	973.57
		1	8.06	984.73		1	24.72	973.53
		2	8.00	984.78		2	24.78	973.48
		3	7.93	984.82		3	24.85	973.43
		4	7.87	984.86		4	24.92	973.39
		5	7.81	984.91		5	24.98	973.35
		6	7.75	984.94		6	25.04	973.31

Table 3: Weekly-averaged true coordinates for the stations [IGS, 2013]

Station	Week No.	Latitude (dms)	Longitude (dms)	Ell. Height (m)
KIRU	1669	67 51 26.4691 N	20 58 6.4197 E	391.034
	1695	67 51 26.4693 N	20 58 6.4204 E	391.037
BRFT	1669	3 52 38.8054 S	38 25 31.9351 W	21.672
	1695	3 52 38.8052 S	38 25 31.9352 W	21.672
HARB	1669	25 53 13.0623 S	27 42 26.0851 E	1558.078
	1695	25 53 13.0620 S	27 42 26.0854 E	1558.078
AIRA	1669	31 49 26.6176 N	130 35 58.5402 E	314.654
	1695	31 49 26.6173 N	130 35 58.5407 E	314.655

the service (Table 2), where those values are calculated by Global Pressure and Temperature (GPT) model [Boehmet, et al., 2007] with a default value for the relative humidity as 50% for the all points.

Each 24 hour dual frequency observation file in RINEX format for each station, with total number of 56 files (4×7×2), was submitted to CSRS-PPP for processing. The RINEX files were downloaded directly from [SOPAC, 2013]. The examination of coordinates obtained from CSRS-PPP includes; a comparison of the coordinate accuracy at individual stations and a comparison of the coordinate repeatability at individual stations.

As it is well known that, accuracy measures the absolute closeness of a measured quantity to its true value while, precision measures the degree of consistency between measurements depending on the size of the differences in a data set. Precision indicates the repeatability of the measurements since there is no need for the true value. In addition to, precision is dependent upon the environment of the observations, the quality of the instrument and the observer's skills during the observation process.

Results and analysis

In order to evaluate the accuracy of the coordinates, the true Cartesian (X, Y, Z) coordinates for the four stations are referenced to ITRF-2008 [Altamimi et al., 2011] at epoch of observations and are obtained from [ITRF, 2013]. The daily ITRF08 coordinates for each station is obtained and then the average solution of each week is calculated resulting to two true values for each station, i.e. week 1669 and week 1695. After that, the Cartesian coordinates are converted to geographical coordinates (φ, λ, h), for two different weeks; for week 1669 and 1695, referenced to the adopted GRS-80 ellipsoid [Schwieger, et al., 2009] and given in Table 3.The linear distances for longitude and latitude differences are calculated by using the algorithms given in [Clynch, 2006] with the usage of GRS-80 parameters [Moritz, 2000] inTable 4.

In addition, a statistical analysis for the coordinate differences are performed and provided in Table 5 for each station. As a measure of the accuracy, the standard deviation values for the differences from the true values are determined and given in Table 6 and Figure 2.

Based on Table 5 and with regards to week 1669, it can be seen thatthe average 2D differenceat high latitude region, KIRU station, is the closest to the true coordinates, while the solution is larger at BRFT, HARB and AIRA respectively. On the other hand for the height differences, the solution is at the

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Table 4: Coordinate differences for each station

Station	Day of week 1669	Coordinate Difference				Day of week 1695	Coordinate Difference			
		Δφ (m)	Δλ (m)	2D (m)	Δh (m)		Δφ (m)	Δλ (m)	2D (m)	Δh (m)
KIRU	0	0.003	0.001	0.003	0.003	0	0.003	0.001	0.003	0.003
	1	0.003	0.002	0.004	0.004	1	0.003	0.002	0.004	0.005
	2	0.003	0.000	0.003	0.006	2	0.003	0.003	0.004	0.007
	3	0.000	0.002	0.002	0.006	3	0.003	0.001	0.003	0.009
	4	0.000	0.002	0.002	0.003	4	0.000	0.002	0.002	0.006
	5	0.003	0.001	0.003	0.009	5	0.003	0.007	0.008	0.004
	6	0.003	0.000	0.003	0.008	6	0.003	0.002	0.004	0.007
BRFT	0	-0.003	0.006	0.007	-0.003	0	-0.009	0.003	0.009	0.005
	1	-0.003	0.003	0.004	0.008	1	-0.003	0.009	0.009	-0.004
	2	-0.006	0.009	0.011	0.004	2	-0.006	0.009	0.011	-0.006
	3	-0.003	0.003	0.004	0.008	3	-0.012	0.006	0.013	-0.003
	4	-0.003	0.006	0.007	0.001	4	-0.009	0.009	0.013	0.001
	5	-0.003	0.009	0.009	0.006	5	-0.009	0.003	0.009	0.007
	6	-0.003	0.006	0.007	0.007	6	-0.006	0.009	0.011	0.003
HARB	0	-0.003	0.008	0.009	-0.025	0	-0.006	0.008	0.010	-0.011
	1	-0.003	0.008	0.009	-0.017	1	-0.003	0.006	0.007	-0.016
	2	-0.006	0.008	0.010	-0.026	2	-0.003	0.008	0.009	-0.015
	3	-0.006	0.006	0.008	-0.020	3	-0.003	0.008	0.009	-0.017
	4	-0.003	0.006	0.007	-0.025	4	-0.003	0.011	0.011	-0.015
	5	-0.006	0.006	0.008	-0.020	5	-0.003	0.011	0.011	-0.019
	6	-0.003	0.003	0.004	-0.022	6	-0.003	0.011	0.011	-0.018
AIRA	0	-0.012	-0.005	0.013	-0.004	0	-0.012	-0.018	0.022	-0.003
	1	-0.009	-0.011	0.014	-0.008	1	-0.006	-0.021	0.022	-0.009
	2	-0.012	-0.008	0.014	-0.007	2	-0.003	-0.016	0.016	-0.014
	3	-0.012	-0.008	0.014	-0.007	3	-0.003	-0.018	0.018	-0.025
	4	-0.012	-0.011	0.016	-0.005	4	-0.012	-0.008	0.014	-0.011
	5	-0.012	-0.013	0.018	-0.006	5	-0.006	-0.011	0.013	-0.012
	6	-0.012	-0.011	0.016	-0.004	6	-0.015	-0.018	0.023	-0.014

Table 5: Statistical analysis for coordinate differences

Station	Week No.	2D			Δh		
		Average (m)	Max. (m)	Min. (m)	Average (m)	Max. (m)	Min. (m)
KIRU	1669	0.003	0.004	0.002	0.006	0.009	0.003
	1695	0.004	0.008	0.002	0.006	0.009	0.003
BRFT	1669	0.007	0.011	0.004	0.005	0.008	0.001
	1695	0.011	0.013	0.009	0.004	0.007	0.001
HARB	1669	0.008	0.010	0.004	0.022	0.026	0.017
	1695	0.010	0.011	0.007	0.016	0.019	0.011
AIRA	1669	0.015	0.018	0.013	0.006	0.008	0.004
	1695	0.018	0.023	0.013	0.013	0.025	0.003

same level for the all regions, except for HARB station at mid-latitude zone.

Regarding to week 1695 (Table 5), it can be seen that for the horizontal difference the solution is close to the true value at KIRU, and increases for the other stations especially at coastal station AIRA. Moreover, for the height differences, the results show closer values to the true value of KIRU and BRFT. The average difference increases at AIRA, while it decreases at HARB.

As a measure of the accuracy, Table 6 and Figure 2 demonstrate that for the first data set the accuracy is at the same level approximately for all stations with little increment at BRFT. For the second data set, the accuracy is the same for KIRU and BRFT, while it degrades at AIRA especially for the height component.

For point to point analysis, it can be seen from Table 6 and Figure 2 that for KIRU, the solution is at the same accuracy level for both data sets. For BRFT, the accuracy is at ±2-3 mm level in the two components for the two data samples. With regards to HARB which is characterized by its / or high altitude 1500m, the accuracy in the height component is equal for the two weeks and higher than the 2D component. For the fourth point AIRA, the accuracy decreased in week 1695 with respect to week 1669 in the two components. One of the reasons for that may be due to variation in atmospheric conditions,

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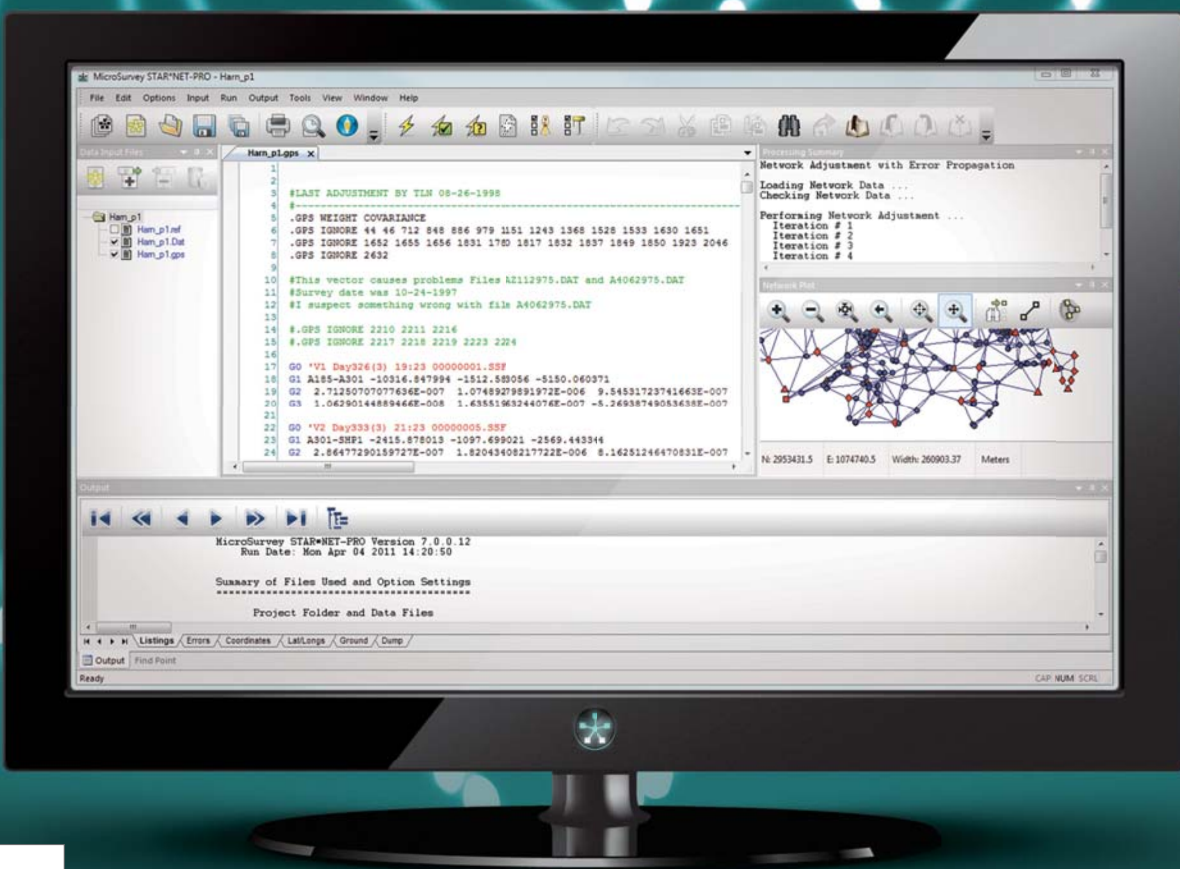

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Table 6: Coordinate accuracy for each station

Station	Week No.	Standard Deviation			
		σ_φ (m)	σ_λ (m)	σ_{2D} (m)	σ_h (m)
KIRU	1669	±0.001	±0.001	±0.001	±0.002
	1695	±0.001	±0.002	±0.002	±0.002
BRFT	1669	±0.001	±0.002	±0.003	±0.003
	1695	±0.003	±0.003	±0.002	±0.002
HARB	1669	±0.002	±0.002	±0.002	±0.003
	1695	±0.001	±0.002	±0.001	±0.003
AIRA	1669	±0.001	±0.003	±0.002	±0.002
	1695	±0.005	±0.005	±0.004	±0.007

Table 7: Coordinate repeatability for each station

Station	Week No.	Repeatability	
		σ_{2D} (m)	σ_h (m)
KIRU	1669	±0.001	±0.002
	1695	±0.002	±0.001
BRFT	1669	±0.002	±0.003
	1695	±0.002	±0.003
HARB	1669	±0.001	±0.002
	1695	±0.001	±0.001
AIRA	1669	±0.001	±0.001
	1695	±0.004	±0.005

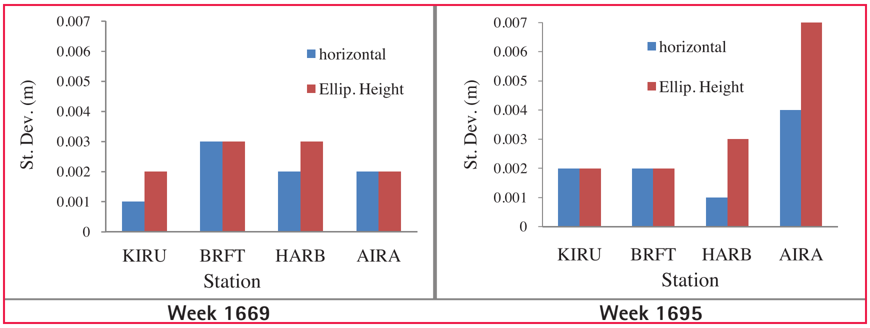

Figure 2: Coordinate accuracy

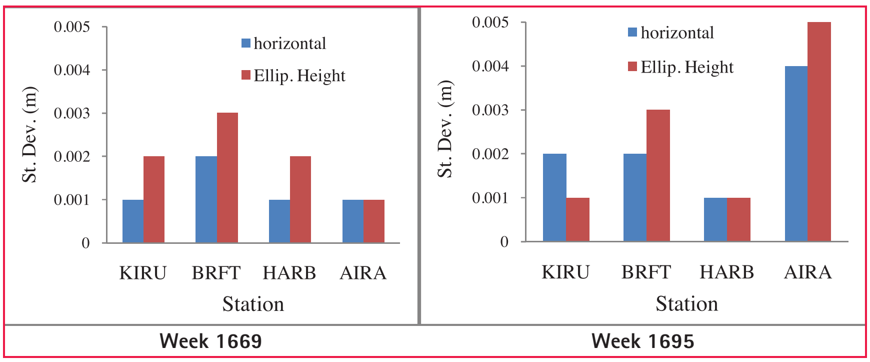

Figure 3: Coordinate repeatability

especially for temperature where it increased by three times in week 1695 comparing with week 1669 (Table 2).

Another analysis of the results depends on the coordinate repeatability at single stations. The repeatability indicates the precision of the station solution, and as a measure of precision the standard deviation in horizontal and height components for the two successive difference values are calculated and given in Table 7. Further, the standard deviation values are given in Figure 3.

It can be concluded from Table 7 and Figure 3 that the repeatability error of the stations in case of the first week is in the ±1-3 mm range for the 2D and height differences. For week 1695, the repeatability error has the same range like week 1669 for KIRU, BRFT and HARB, while it decreases for AIRA in both components.

Looking at an individual station (Figure 3), e.g., KIRU in a high latitude region, it can be seen that the solution is repeatable in the range of ±1-2 mm. For BRFT at the equator, the repeatability of CSRS-PPP is at the same level for the two data sets in±2-3 mm range. Moreover, CSRS-PPP provides a repeatability at the ±1-2 mm level for HARB. With regards to AIRA, the repeatability of CSRS-PPP varies from week 1669 to week 1695 by evidence values, and one of the reasons might be due to large variations in tropospheric parameters especially in temperature values.

Conclusion

The free of-charge and effective CSRS-PPP online processing service provides accurate results for static mode. Also it provides a solution for kinematic observation mode for single and double frequency observations. CSRS-PPP provides geographic coordinates, projected coordinates and Cartesian coordinates. The convenience of the service leads to its wide usage in different surveying applications.

The objective of this study is to evaluate the accuracy and repeatability of CSRS-PPP at different latitude regions by processing dual frequency GPS data from four IGS stations located in different regions around the world where the tested points are KIRU in a high latitude region, BRFT at the equator, HARB at mid-latitude region and AIRA on the coast of the Pacific Ocean. The data sets cover two sessions with a 24 hours time window.

For station KIRU, CSRS-PPP provides accuracy and repeatability in the range of ±1-2 mm. With regards to BRFT, the accuracy and repeatability of CSRS-PPP is at the same level for the two data sets in ±2-3 mm range. Moreover, CSRS-PPP provides in the range of ±2-3 mm and at the ±1-2 mm level for HARB. With regards to AIRA, the accuracy of CSRS-PPP varies from week 1669 to week 1695 by noticeable values as well as for the repeatability. Finally, the attained results show that CSRS-PPP provides the horizontal accuracy at ±(1 to 4) mm level and the vertical accuracy at ±(2 to 7) mm level. Regarding to the repeatability error, it is at ±(1 to 5) mm level for both the components.

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SNIPPETS

At a Glance

- Proteus Delivers Phase 1 of Abu Dhabi Land/Marine Mapping Ahead of Schedule
- UTEC Survey has awarded Veripos an exclusive three-year contract for provision of high-precision GNSS positioning services
- CEdMA Honors Bentley Systems with Its Innovation Award for a Second Year Running
- Airbus Defence and Space signs contract to deliver Street Factory 3D urban mapping solution to PASCO
- CompassData certified by FAA to collect and verify data for aviation mapping
- UltraCam Eagle purchased by TopGis in Czech Republic
- Peru has signed an agreement with France to purchase a $213 million satellite.
- Esri launches Explorer for ArcGIS app
- Fugro acquires 3D mapping company Roames
- Intermap bags contract worth $1-million to provide digital elevation data and ortho rectified radar imagery from its NEXTMap database
- Ordnance Survey, Openreach sign agreement worth £23 million
- Scene Sharp™ USA unveil Fuze Go™ V2.0 Image Fusion Software
- DAT/EM Systems International Selected as Photogrammetric Software Provider for the Ordnance Survey, Great Britain

The one-of-a-kind GNSS convention returned, reloaded

Munich Satellite Navigation Summit, 25-27 March, 2014

With the theme "GNSS - New Challenges" the Munich Satellite Navigation Summit returned ‚reloaded' after a one-year break. Once again the organizing Institute of Space Technology and Space Applications (ISTA) of the Universitaet der Bundeswehr Muenchen invited experts from all over the world to discuss the latest developments and challenges in the field of GNSS.

Bavaria – Heart of German aerospace industry

The conference started off on March 25, 2014 with the ceremonial opening in the historical Court Church of All Saints. About 300 participants from 25 nations received a warm welcome by the Bavarian State Minister of Economic Affairs and Media, Energy and Technology, Ilse Aigner as well as Prof. Dr. Merith Niehuss, president of the Universitaet der Bundeswehr Muenchen, and Prof. Dr. Bernd Eissfeller, chairman of the conference. Ilse Aigner valued Bavaria as the heart of aerospace industry in Germany and said that approximately 65.000 people are working in this sector in Bavaria. In particular young engineers and entrepreneurs are encouraged by fundings.

From left to right: Prof. Dr. Manfred Fuchs (OHB), Jean-Jacques Dordain (ESA), Matthias Petschke (European Commission), Giuseppe Viriglio (Telespazio), Claus Kruesken (Moderator)

Opening Plenary – Focus on Integrated Applications

The opening plenary discussion was all about Integrated Applications and featured high-ranking representatives from the European Commission, ESA, DLR, European GNSS Agency (GSA), Airbus Defence & Space, OHB and Telespazio. Matthias Petschke, Director of EU Satellite Navigation Programmes at the European Commission, pointed out that applications lead to more business interactions and show that earth observation and satellite navigation are moving closer together. Jean-Jacques Dordain, Director General at ESA, mentioned that EGNOS services are now fully available and that four IOV satellites are already in orbit. Overall, the discussion showed that Integrated Applications and the promotion of space technology are essential and that it is important to focus on the users and their needs.

Program Highlights

The technical program on the following two conference days offered a broad variety of interesting sessions, starting with an overview on the global, regional and augmentation systems. One of the highlights was a special session on QZSS that showed that the development of the Japanese system is moving forward quickly. Related to the overall theme, one of the major challenges in satellite navigation nowadays, the explosive topic of the malicious or unintentional interference with GNSS and other navigation signals was discussed during a session that was chaired by Prof. Vidal Ashkenazi, Chief Executive of the U.K.-based Nottingham Scientific Ltd. He asked the panel members about what is being proposed to be done about detecting and countering interference, such as jamming and spoofing. David Turner, Deputy Director at the Office of Space and Advanced Technology at the U.S. Department of State, explained that they are working under a policy framework in order to support international acitivities regarding the detection and mitigation of interferences. Dominic Hayes, Policy Advisor for GNSS Signals and Frequencies at the European Commission, added that jammers are illegal in Europe and that each member state is responsible that jammer devices are not available on the market. Regarding the malicious interference and related penalties, he said it is important to educate the users with regard to the impact of jammers. Satoshi Kogure, Mission Manager at the Japan Aerospace Exploration Exploration Agency (JAXA), agreed that most of the users are not aware of the harm that Personal Privacy Devices (PPDs) can cause.

Besides the technical sessions the conference was again completed by an exhibition with 16 companies and institutions that presented their business and products during the three conference days.

The Munich Satellite Navigation Summit 2015 will take place on March 24 - 26, 2015. Up-to-date information can be found on www.munich-satellite-navigation-summit.org

- Kristina Kudlich

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Spatial Innovation and Good Practices in Land Administration Forum

March 28, 2014, World Bank, Washington DC

This one-day 'Spatial Innovation and Good Practices' forum was jointly convened by the World Bank and the International Federation of Surveyors (FIG) on March 28, 2014 at the World Bank's headquarters in Washington DC as part of the ongoing collaborative activities between the Bank and FIG. The Forum was open to all registered participants to the annual World Bank Land and Poverty Conference. The Forum covered a number of themes focusing on the contribution of spatial technologies, innovation and practices to support the Post-2015 Development Agenda. This year's Annual World Bank Annual Land and Poverty Conference attracted some 1,200 registrants from around the globe, making it the largest such conference in the world. For the past three years, FIG has collaborated with the World Bank to jointly convene a special side-event in conjunction with the Annual Conference, focusing on spatial enablement in support of land administration.

Spatial technologies and practices are becoming pervasive, affordable, linked and manageable and it is now in the hands of the citizens, the consumer and no longer confined to the domain of the professionals. The roles of the spatial professionals, innovators and technologist will always be there within the drive towards an environment that is spatially enabled. The fact remains that spatial capacities and capabilities are changing at an ever faster rate and co-evolving with allied technologies. Today we have better imaging satellites, global navigation satellite systems, aerial sensors, unmanned low altitude aerial sensors, terrestrials scanners and measurement systems providing us big spatial datasets into the petabytes, exabytes and zettabytes, giving us global normalized digital maps as an example and more excitingly, providing a myriad of possibilities. The Forum was consistently reminded by speakers that it is time for the global development community to take advantage of these affordable and accessible spatial technologies and practices. The Forum recognized ongoing issues with standards, interoperability, authoritativeness and privacy and all these are being addressed and can be resolved over time. Today, there exist the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) and bodies such as the Open Geospatial Consortium (OGC) and FIG to address these issues collaboratively including that of global governance within this realm.

The Forum witnessed the launch of the joint World Bank and FIG *Declaration on Fit-for-Purpose Land Administration* providing the framework on getting the right data and information, the right processes and technologies, all for the right purposes. The World Bank and UN are also finally developing solid global indicators that can support the measurement and monitoring including that for the Post-2015 Development Agenda goals and targets, and will provide us all with the transparency and accountability that is needed.

The Forum observed a move beyond land administration to pervasive spatial integration of society. The partners and participants at the Forum are at the forefront, channeling these developments for progressive global change. Country level experiences shared at the Forum affirmed this good news, as there are good progresses.

At the same time, the Forum heard the challenge of the "two-speed" world we are in, where in one world, a technology savvy kid can use the marvels of global navigation satellite systems and mobile computing and communication to find the best cup of coffee and in another world, 80% of humanity live below US$10.00 a day or where 75% of humanity do not have clear spatially and legally defined land or property rights and where communities have inadequate access to this global normalized digital maps. We have to accept that there exist this disconnect between spatial technological sophistication that is available today and the outcomes of decades of development initiatives and programs. However, the situation is definitely more complex than this, as there are probably three speeds on the dial covering Low-Income, Middle-Income and High-Income countries, each with different access to resources, capacity and priorities for land administration and spatial enablement. So it is definitely not a one-size fits all world. Closing the gap between the "haves" and the "have nots", is no easy task, especially in spite of the rhetoric that technology is now affordable, for the have nots, access is often beyond reach.

The Forum concluded that the barriers to closing this gap are no longer technological, spatial technologies and practices are today pervasive, affordable and accessible, but rather political, institutional, and of capacity. It is now overdue to bring these worlds together, where it is deemed appropriate and fit-for-purpose. The partners and participants at the Forum have yet to make significant stride in political, institutional and capacity development at scale. This is the bad news!

Is it possible to change the paradigm where the "spatial" is fully integrated into human development and progress to realize "the Future We Want for All", the world of Post-2015 UN Development Agenda? The Forum heard of current and future spatial technological envelope that is co-evolving with other technologies particularly that of mobile computing and communication, enabling and empowering citizens and communities and providing unparalleled possibilities. The Forum heard of good concepts (fit-for-purpose, easy-to-use, leapfrogging), great ideas (global campaign for secure tenure, massive global and spatially enabled private-public-partnerships) and of boldness to borrow from or linking up with playbooks from global public health initiatives, from global media and entertainment reach, from multi-national business, and learning from social phenomena inspired by the likes of Google and Facebook. Changing the paradigm to finally deliver the desired difference. Having said this, the Forum recognized that technology is an enabler of improving land administration and access to land rights, but it is not the solution. That is also fundamental to FFP. Specifically regarding spatial technology, we should reflect on the hierarchy of evidence of land ownership determination, which gives greatest weight to physical features and marks which define the limits or boundaries of individual or community rights. The evidence of least weight is measurement, which in modern spatial technology parlance, means coordinates. Further, the evidence of rights is enhanced through maps, or again in modern parlance GIS. But GIS, needs to be considered along with other forms of presentation of rights.

Citizen engagement in identification of land rights, often using affordable tools such as hand-held GPS- enabled cell phones holds great promise for closing the gap between those who have rights and those who don't. However, to take advantage of the power of collaborative land mapping or Volunteer Geographic Information (VGI) requires government protocols that cover standards for the acquisition and submission of these maps. The authority of government land agencies to validate all mapping and other information and provide access to assured land information is fundamental to good land governance.

The Partners and participants, most of who have been converging under the spatial sub-theme at the annual World Bank Conference on Land and Poverty since 2012 are the people who can close this gap, and bring this change in our lifetime, realizing the transformative potential that our unique position, as the "intersection" between the spatial and development community, creates.

The realization is that "business-as-usual' will not lead us to this bold new world and spatial technologies, innovation and practices may well be those disruptive elements needed within the transformation for which is called.

- Malcolm Childress & Keith C Bell (World Bank) CheeHai Teo (FIG)

Declaration

Fig-World Bank Declaration on Fit-for-Purpose Land Administration

There is an urgent need to build cost-effective and sustainable systems which identify the way land is occupied and used and accordingly provide for secure land rights. When considering the resources and capacities required for building such systems in less developed countries, the concepts of mature, sophisticated systems as predominantly used in developed countries may well be seen as the end target, but not as the point of entry. When assessing technology and investment choices, the focus should be on a "fit-for-purpose approach" that will meet the needs of society today and that can be incrementally improved over time.

A fit-for-purpose approach includes the following elements:

- **Flexible** in the spatial data capture approaches to provide for varying use and occupation.
- **Inclusive** in scope to cover all tenure and all land.
- **Participatory** in approach to data capture and use to ensure community support.
- **Affordable** for the govenment to establish and operate, and for society to use.
- **Reliable** in terms fo information that is authoritative and up-to-date.
- **Attainable** to establish the system within a short timeframe and within available resources.
- **Upgradeable** with regard to incremental improvement over time in response to social and legal needs and emerging economic opportunities.

A country's legal and institutional framework must be revised to apply to dlements of the fit-for-purpose approach. This means that the fit-for-purpose approach must be enshrined in law and that the information be made accessible to all users.

A fit-for-purpose approach will ensure that appropriate land administration systems are built within a relatively short time frame and affordable costs. The systems allow for incremental updating and upgrading. This approach will facilitate economic growth, social equity and environmental sustainablity to be better supported, pursued and achieved.

Galileo update

Europe weighs Galileo-compatibility mandate for Smartphones

The European Commission is now weighing whether to mandate Galileo adoption not only in European critical infrastructures but also in selected areas including smartphones. The European Union is adopting a system called eCall, which when installed in automobiles automatically sends out a signal to emergency-service providers when a crash or other anomaly is detected. The European Parliament is preparing eCall regulations that are based on satellite positioning, navigation and timing signals. What the commission is considering is to take that a step further by requiring that mobile phones and perhaps other devices such as tablets as well, be equipped with Galileo receivers that would automatically send location information as part of an emergency call using Europe's 112. *www.spacenews.com*

Maritime trial route of Galileo

The Belgian frigate *Leopold I-F930*, participating in the end-of-year trials, carried the most up-to-date equipment possible, with multiple Galileo receivers for both its public Open Service (OS) and secure Public Regulated Service (PRS). The frigate sailed first from the Dutch marine base of Den Helder to Stavanger in Norway. From there it progressed north in very rough seas with 10m high waves, coming close to the Arctic circle – a first for Galileo PRS observations – before heading home. The testing provided tangible in-situ evidence of Galileo signal stability across both its operating frequencies up at high latitudes, equaling low satellite elevations in the local sky. The trials were performed by the Royal Military Academy of the Belgian Ministry of Defense, the UK Space Agency in collaboration with satnav-specialist company Nottingham Scientific Ltd and ESA, serving to ensure PRS signals were available whenever the four Galileo satellites currently in orbit came into view.

GMV – Consortium considerations for Galileo

The European Commission has awarded the contract for the development of the Galileo Commercial Service Demonstrator to a GMV-led consortium. The technology multinational will take on the tasks of developing and testing different Commercial Service (CS) solutions, including real Galileo Signal In Space (SIS) tests, and facilitating the testing of other solutions by external service providers. This 30-month project has a total budget of 4 million Euros. The CS is one of the services offered by Galileo which will provide improved performance and data with greater added value than Galileo's Open Service and other GNSS signals. GMV will take on responsibility for the design, development, testing, integration, operation and maintenance of the CS Demonstrator with the overall aim of validating Galileo's capacity of providing commercial high-accuracy (HA) and positioning-authentication services. *www.gmv.com*

MDA, Neptec win CSA contracts

The Canadian Space Agency (CSA) has awarded a $1.35-million contract to Ontario's Neptec Design Group for work on Canada's contribution to the Japan Aerospace Exploration Agency (JAXA) next-generation space observatory. Neptec is building the Canadian ASTRO-H Metrology System (CAMS), a measuring system that will be used to calibrate the observatory's main telescope and enhance the images it captures. ASTRO-H marks the first time Canada is part of an X-ray astronomy mission. *www.canadianmanufacturing.com*

Dutch parliament allows drone surveillance

The Dutch parliament has voted in favor of legislation that will allow drone surveillance where public safety is at risk. In the near future, Dutch municipalities will be allowed to use mobile cameras, including drones, to monitor residents. The change to the legislation immediately sparked privacy concerns, although the new legislation does make a clear distinction between the use of mobile cameras and airborne cameras. Mobile cameras, such as the head-mounted cameras currently used by Dutch police, can be used to prevent public disorder; however, drones cannot. *www.zdnet.com*

FAA to establish center of excellence

FAA will establish a Center of Excellence (COE) for Unmanned Aerial Systems (UAS) within the next year, consisting of representatives from government, academia, and industry to conduct unmanned aircraft research, education, and training. The FAA will initially issue cooperative agreements to selected university teams, as well as define and pay for UAS projects through matching grants over the life of the COE, which will be responsible for matching all money granted to establish, operate and conduct related research, and may contract with others as appropriate. *www.avionics-intelligence.com*

Brazil to test drones in monitoring the Amazon rainforest

Brazilian municipalities are planning to use drones to map properties and monitor forest cover as they move to step up enforcement of the country's Forest Code. The municipality of Altamira in the state of Pará recently purchased a drone for a pilot monitoring project that aims to support the development of the Cadastro Ambiental Rural (CAR), a government-managed database that will contain details on all properties in the Amazon region. The drone has become a necessity because Brazil's current satellite-based system isn't timely or accurate enough to ensure implementation at a property-level scale. *www.news.mongabay.com*

Egyptian satellite placed in orbit

Egyptsat, an Egyptian remote sensing satellite launched from Baikonur cosmodrome has successfully entered terrestrial orbit. It was designed and manufactured by Energia rocket and Space Corporation for the Egyptian State Committee for Land Remote Sensing and Space Studies. The resolution of its images will be 1 meter in panchromatic mode and 4 meters in multispectral mode. *www.voiceofrussia.com*

SimActive's one-click solution for UAVs

SimActive Inc. announced a new one-click solution for UAV imagery. The new Correlator3D™ version 5.2 allows the automatic processing of an entire project in only one easy step. The full workflow, which includes generation of a DSM, DTM and orthomosaic, can be performed in minutes only. This new one-click solution completely eliminates the need for training and allows users with no photogrammetry background to produce accurate results. *www.simactive.com*

Headwall Hyperspec III software

Headwall has released its Hyperspec III application software featuring a set of hyperspectral data acquisition management tools. It represents an easy-to-use platform for controlling hyperspectral sensors across applications ranging from manned aircraft to UAV airborne remote sensing. *www.novuslight.com*

UAV application in varied sector like agriculture etc.

At the Indian Institute of Science in Bangalore, K M Ramesh along with a team of researchers has built a miniature remote controlled vehicle that can hover above farmland and gather data that helps monitor the growth of crops, detect diseases and estimate crop yield months ahead of the harvest. The UAV was used to collect data at tomato farms in Karnataka's Kolar district for three months at the end of 2013.

"The farmers were enthused by our technology," said Ramesh, who quit his job as a senior manager at Infosys to pursue a masters in electronics and communication. Ramesh stumbled upon the project at a yoga lesson where he met IISc professor S N Omkar. "Ten years ago, it was difficult to find people who could even operate these vehicles. Now, we see lots of them who design and fly the vehicles themselves," said Omkar, chief research scientist at the Department of Aerospace Engineering, who is overseeing Ramesh's work. *http://economictimes.indiatimes.com*

Fines up to R50k for Drone flyers in S. Africa

The South African Civil Aviation Authority (SACAA) is set to clamp down on the illegal flying of Unmanned Aircraft Systems (UAS), or drones, in civil airspace.

According to a statement sent out by SACAA, the move was prompted by recent reports of UAS already operating in the South African civil aviation airspace. Current civil aviation legislation does not provide for certification, registration and/or operation of UAS in the South African civil aviation airspace.

While this was hardly problematic before, a surge in demand for the use of drones - especially for commercial purposes - has prompted the SACAA to integrate the use of drones into the South Africa airspace as speedily as possible. In the mean time, until regulations have been put in place, anyone caught operating a UAS could face fines of up to R50 000, a prison sentence of up to 10 years or both. *www.news24.com*

Dubai Sat-2 operational

An image from space of Dubai's Palm Jumeriah taken by Eiast satellite

The Emirates Institution for Advanced Science and Technology (EIAST) has announced that DubaiSat-2's in-orbit commissioning is complete and the satellite is now fully operational. *www.emirates247.com*

National Space Science Agency launched in Bahrain

The agency's new board, led by Mohammed al-Amer, chairman of the Central Informatics and Telecommunications Organisation, met April 9th to discuss the possible ratification of international space-related agreements such as the Outer Space Treaty, the Rescue Agreement, the Space Liability Convention, the Registration Convention and the Moon Agreement.

The new agency seeks to establish sound infrastructure for the observation of outer space and the earth, make Bahrain a leader in space science and technology, build a culture and methodology of scientific research within the kingdom and encourage technical innovation, among other goals.

GIS map of pipelines to pinpoint leaks, defects

The Kerala Water Authority (KWA) is vetting a proposal to prepare 3D GIS-aided maps of pipelines in the city's distribution system. The maps would help the KWA to get a correct picture of the distribution lines that crisscross the city and would also help in tracing any defect, leakage or any other disorder in water and sewage lines. *www.thehindu.com*

NOAA launching storm surge mapping system

A new NOAA mapping project is designed to change perceptions about the multiple risks of storm events. The National Oceanic and Atmospheric Administration (NOAA) will begin mapping coastal regions in varying hues to represent the danger represented by storm surge. The new maps are intended to provide residents of coastal areas a clearer understanding of the multiple risks posed by Hurricanes. Forty-eight hours prior to the landfall of a hurricane, the NOAA will begin releasing color-coded maps indicating the risk of flooding, updating them every six hours. *www.planetizen.com*

GIS market in South Korea

The analysts forecast that the GIS market in South Korea will grow at a CAGR of 6.90 percent over the period 2012-2016. One of the key factors contributing to this market growth is the increasing demand from the Government sector. The GIS market in South Korea has also been witnessing the increasing demand for mobile-based applications. However, the increasing threat of rivalry could pose a challenge to the growth of this market. *www.digitaljournal.com*

GIS for Mekong Delta region in Vietnam

The Ho Chi Minh City National University is working together with the southwest provinces of Dong Thap, Soc Trang, Can Tho and Long An to implement the Mekong Delta Geographic Information System (MDGIS) which will integrate disparate spatial databases into a unified platform. By having the MDGIS in place, the local governments in the region can have access to updated information on the status of natural resources and that would allow them to study and measure the socio-economic impact of climate change and natural disasters. *www.futuregov.asia*

Revamped AGIS for Abuja residents

With the rapidity of changes in today's technology-driven world and the emergence of more sophisticated requirements of the real estate and ICT infrastructure required to guarantee systems security and operational efficiency, the Abuja Geographic Information System (AGIS) recently carried out an overhaul of its system.

The new systems infrastructure are necessary fundamentals for facilitating the proposed revenue generating operations of AGIS and also for ensuring sterling service delivery as well as customer/stakeholder satisfaction, in line with the vision of AGIS to "become a comprehensive, all-inclusive fool proof and state of the art computerised geospatial data infrastructure for the FCT." Senator Bala Mohammed is pivotal to the implementation of this transformation in the Federal Capital Territory. The overhaul of AGIS infrastructure by the FCT Minister through the Executive Director AGIS, Mrs Jamila Tangaza, was with the implicit purpose of guaranteeing security, efficiencies and innovative workflows and a process to impede gaps in all areas. *www.tribune.com.ng/*

WorldDEM launched

Airbus Defense and Space has commercially launched WorldDEM, a Digital Elevation Model (DEM) that provides pole-to-pole coverage of unprecedented accuracy. It allows customers to improve the quality of DEM applications in a host of industries including defense and aviation, oil, gas and mining. The new model is based on data acquired by the high-resolution radar satellites TerraSAR-X and TanDEM-X and will provide 12-metre grid spacing globally. *www.airbus-group.com*

SuperGIS 3D Earth Server 3.2 launched

Supergeo Technologies officially released SuperGIS 3D Earth Server 3.2, the GIS software designed to publish and overlay terrain data and 3D models with spatial data, as well as to display the spatial data in 3D view. The GIS software can help users better explore geographic space and the spatial relation among data. *www.supergeotek.com*

Cadastral feature on OneMap app in Singapore

Singaporeans can now access comprehensive information on land parcels right in the palm of their hands using mobile app Pocket OneMap. It is the mobile version of OneMap, an integrated map system, providing a wide range of government information from more than 70 thematic layers of information and value-added services ranging from education, culture, community, to the environment free of charge. Developed by Nanyang Polytechnic, Singapore Land Authority's (SLA) Academic Institution Partner, it is an authoritative mobile app which allows users to conveniently locate buildings or roads on the go.

Dr Vanessa Lawrence mapping out new career direction

Dr Vanessa Lawrence CB, who has led Britain's national mapping authority for almost 14 years as its director general and chief executive, will focus on the growth plans of Ordnance Survey internationally as Secretary General of Ordnance Survey International for the rest of the year. In addition, she will continue her role as co-chair of the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM). Dr Lawrence will formally leave Ordnance Survey at the end of 2014. *www.spatialsource.com.au*

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US decision to freeze construction of GLONASS stations

Russia's Deputy Prime Minister Dmitry Rogozin has described as politically motivated the USs' decision to freeze the construction of GLONASS signal calibration stations in its territory. Rogozin recalled that 11 signal calibration stations were deployed in 11 Russian regions. *www.en.itar-tass.com*

Russia, China eye cooperation of GLONASS and BeiDou

Russia and China see prospects of cooperation related with satellite navigation systems GLONASS and BeiDou in regional support and development of chipsets, said Russian Deputy PM. *www.en.ria.ru*

GLONASS disruption caused location errors of up to 55km

The General Lighthouse Authorities of the UK and Ireland (GLAs) stressed the vulnerability of satellite navigation systems as they unveiled data showing that a GLONASS disruption caused location errors of up to 55km. In April, all the satellites of the Russian constellation reportedly produced corrupted information for almost 12 hours. The GLAs published readings of its GLONASS receiver based in Harwich (England). During the disruption, the receiver - which is located on land – showed positions of up to 55km out at sea. All satellite navigation systems share the same failure points, the GLAs say. They operate in a limited frequency band and their distance from Earth make their weak signals susceptible to both accidental and deliberate interference as well as the upload of faulty data, thought to have caused the GLONASS problems. *www.thedigitalship.com*

GPS based aircraft tracking mandated by 2020

The Federal Aviation Administration (FAA) is accelerating the implementation of the next generation of aviation tracking following the disappearance of the Malaysian Airline Boeing 777. The agency has been working on a system called Automatic Dependent Surveillance Broadcast, or ADS-B, radio network. It allows controllers to monitor an aircraft from the time it takes off to the time it lands, using GPS satellite tracking, rather than ground-based radar. Of the 230 air traffic facilities across the US, only 100 use the system now. The FAA announced it will be mandatory for all facilities to use it by 2020. *www.9news.com*

Russian lawmakers approve satellite navigation hub in Nicaragua

Russian lawmakers have endorsed draft legislation to allow the country to set up a satellite navigation monitoring system in Nicaragua. "The agreement is aimed at creating an organizational and legal framework for mutually beneficial partnership between Russia and Nicaragua in terms of exploring and using space for peaceful purposes," an official statement explained. *www.spacedaily.com*

Russia plans to install GLONASS Stations in more countries

Ground-based stations for GLONASS could be installed in several countries, including in Europe, but the current political situation is interfering with the process. "It is currently difficult to say exactly when and where [stations could be installed]. We are ready to sign an agreement with one of the European countries," said Sergey Saveliev, the deputy head of the Russian space agency Roscosmos. "Another station is preparing for launch in Brazil, but its functional profile is slightly different. *www.en.ria.ru*

Advanced research for indoor GNSS positioning

Researchers at Telecom SudParis, a part of the Institut Mines-Telecom, an education and research institution in the fields of information and communication technology, are working on a solution to provide indoor continuity for GNSS positioning. The idea is to deploy a minimal transmission infrastructure in order to allow a standard receiver to measure pseudo-ranges and carrier phases, thus leading to an indoor accurate positioning. The infrastructure consists of a few antennas fed through optical fibers with a GNSS-like signal. In order to achieve positions accurate to a few decimeters, the locations of the various indoor antennas had to be accurately known. This was achieved with the Spectra Precision FOCUS 8 total station in a local reference frame. *www.spectraprecision.com*

5th Boeing GPS IIF Satellite Joins GPS

The accuracy of the GPS has been improved with the recent handover of a fifth Boeing GPS IIF satellite to the U.S. Air Force. The newest addition to the GPS constellation increases the precision of position, navigation and timing data sent to users around the world. *www.boeing.com*

Aircraft GPS System Being Rolled out in Australia

The disappearance of Malaysia Airlines MH370 has raised questions about how much authorities actually know about the location of aircraft in the sky. The answer is: a lot when they are in areas of radar coverage over land, but much less once they are over remote areas or over ocean.

Current onboard data transmissions from the separate Aircraft Communications Addressing and Reporting System (ACARS), a system similar to text messaging, sends very limited data about a plane's whereabouts and the transmissions can leave gaps of 15-30 minutes. However, new satellite based systems, similar to GPS in a car, are being rolled out by a number of countries including Australia that will provide much more detailed information on the location of the aircraft. The system, known as Automatic Dependent Surveillance – Broadcast, uses a combination of satellites and ground stations to identify the location and velocity of a plane equipped with the system with pinpoint accuracy. The aircraft sends out a signal every second to base stations and to satellites, which are then plotted in real time. Websites such as Flightrader24 are already using this information for their services. *www.smh.com.au* Source: *Sydney Morning Herald*

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TI Bluetooth(R) Smart technology

Texas Instruments announced the launch of SimpleLink(TM) Bluetooth(R) low energy CC2541-Q1, a highly-integrated wireless microcontroller (MCU) that delivers low power, low cost, and simplified automotive connectivity to emerging smartphone-controlled and wire-replacement applications. *www.ti.com*

Alibaba to acquire AutoNavi

Alibaba Group Holding Ltd has agreed to acquire Beijing-headquartered digital mapping and navigation firm AutoNavi Holdings Ltd for about $1.5 billion. Alibaba will integrate AutoNavi's mapping service to its technology allowing its customers to access peer review of shops and restaurants, and thereby increase its revenues. The transaction is expected to be complete by the third quarter of this year. Post the transaction, AutoNavi will become a wholly-owned subsidiary of Alibaba. *www.techcircle.vccircle.com*

Parking App Wins Sydney Trip for Indian Students

An idea for an app to make parking easier and save fuel has resulted in the school excursion of a lifetime for a group of Indian students. The team from Anand Niketan Satellite School in Ahmedabad is coming to Sydney as the winner of the Creativity Meets Technology IT competition organised by UTS and UTS: Insearch.Their winning entry *Spot the Parking Space* was to develop an app that helped people find a parking space utilising Google maps. This app would save fuel by facilitating faster parking, resulting in cleaner air. http://newsroom.uts.edu.au/ *Source:* UTS

GPS in cars gets insurers'

With GPS-based devices becoming popular in cars and commercial vehicles as a navigation tool, insurers are looking at such installations positively, with many contemplating discounts on motor premiums for vehicles with these installations. *www.timesofindia.indiatimes.com*

NovAtel® introduces commercially exportable IMU

NovAtel Inc. has added the IMU-KVH1750 as an inertial measurement unit (IMU) option in its SPAN GNSS/INS line of positioning products. A high-performance commercial off-the-shelf (COTS) sensor, the IMU-KVH1750 offers excellent bias stability and repeatability and integrates easily with NovAtel's OEM6 series of receivers to provide a tightly coupled 3D navigation solution. *www.novatel.com*

The tridicon® APM Trio solution

Tridicon® APM Trio, a software solution that simplifies the generation of oblique point matching and aerial triangulation (AT) of multi-view oblique and nadir imagery taken with the Leica RCD30 Oblique camera system. *www.tridicon.com*

Imajing reinvents transportation network mapping

imajbox® L, imajbox® S and imajbox® T can be used for roadway, railway, urban areas or trails surveys to map, inventory, geo-reference and assess infrastructure and equipment conditions along transportation networks, with a single pass survey. The new range of imajbox® is a mobile mapping system integrating an IMU, a GNSS receiver and a CCD sensor. It integrates its own battery, stores data on USB media or via ethernet and can be operated via Wi-Fi from a tablet or a smartphone. Mounted either inside or outside any vehicle, imajbox® is adaptable to any environment for daily data collection. *www.imajing.eu*

TerraStar offers revenue-sharing opportunities

TerraStar GNSS Ltd, a wholly-owned subsidiary of Aberdeen-based Veripos Ltd, is offering GNSS equipment manufacturers unique revenue-sharing opportunities, including the possibility to launch their own precise GNSS augmentation services via endorsed rebranding of its services as a re-seller. This will provide a recurring service revenue stream to GNSS manufacturers which has not been previously available within the industry. *www.terrastar.net*

New generation of DAT/EM photogrammetric suite

DAT/EM Systems International® released the 7.0 edition of DAT/EM software products including Summit Evolution™, Landscape™, Capture™, MapEditor™, Ortho+Mosaic™, Airfield3D™ and Contour Creator™. *www.datem.com*

New MobileMapper 20 Handheld

Spectra Precision's MobileMapper® 20 GIS handheld offers enhanced

Leica News

ScanStation P15 – entry-level laser scanner

Leica Geosystems has launched ScanStation P15, a high performance entry level 3D laser scanner with a user-friendly interface. Suitable for a wide range of non-surveying applications, including interior and short-range uses, the ScanStation P15 offers high performance 3D scanning technology with high measurement speed and accuracy of up to 40 meters. *www.leica-geosystems.com*

ATHENA program

'Advanced Technology for Higher Education and Non-profit Associations' (ATHENA) aims to introduce the latest GNSS Reference Station and Structural Monitoring technology to the academic and research communities. Leica Geosystems has updated its ATHENA program with up-to-date products available in GNSS measurement technology. 2014 bundles include the latest future proof Leica GR10/GR25 reference station servers and GM10 and GMX902 GNSS monitoring receivers at specially discounted prices. AR20 choke ring antenna as well as the AR10 compact geodetic antenna are also offered. *www.leica-geosystems.com* capabilities: a new bright VGA color touch screen display, a 5 MP camera for higher resolution images, doubled memory capacity and 3.5G cellular performance. It also comes with a standard 2-year warranty and provides real-time GPS accuracy of better than 2 meters and post-processed accuracy of a half meter using MobileMapper Office software. *www.spectraprecision.com*

Trimble 3D scanning extension for SketchUp

Trimble released Trimble® Scan Explorer Extension for SketchUp Pro; a tool enabling architects, engineers and geospatial professionals to create models from 3D scanning data. It dramatically reduces the time required to generate a SketchUp Pro 3D model from scan data. Streamlined tools and one-touch features allow users to quickly extract construction points and lines that are used as a guide to simplify and expedite the modeling process. Automated plane extraction tools further increase modeling efficiency, particularly when modeling building interiors and facades. *www.trimble.com*

Built-in navigation Satellite Communicator by DeLorme

DeLorme has announced the upcoming launch of its newest product, inReach Explorer, incorporating a new range of navigation functions. inReach Explorer integrates route planning, waypoints and navigation with global two-way text messaging, GPS tracking and SOS alerting – all in one handheld device. *www.inreachdelorme.com*

RIEGL LMS-Q1560 deployed at NASA's Jet Propulsion Laboratory

NASA's Jet Propulsion Laboratory (JPL) has recently deployed *RIEGL* LMS-Q1560 airborne laser scanner system. It is being utilized to more completely and accurately measure snowpack depth of major mountain watersheds. This will be accomplished through the use of innovative airborne LiDAR from *RIEGL* to better gauge the volume of water that travels down rivers and streams as runoff from snowpack.

Low-power GPS modules target wearables

CSR and OriginGPS, Israel have announced new GNSS modules using CSR's SiRFstarIV and SiRFstarV product lines. The new modules are 70% smaller than current solutions and deliver a 30% reduction in Time To First Fix (TTFF). All modules integrate the LNA, SAW filter, TCXO, RTC crystal and RF shield. *www.csr.com*

Programmable GNSS Receiver Modules measure 10 x 10 x 1.3 mm

Venus858F-GL GPS/GLONASS receiver module, Venus858F-BD GPS/Beidou receiver module, and Venus838F GPS receiver module integrate SkyTraq Venus8 positioning engine, 1 MB Flash memory, LNA, SAW filter, 0.5 ppm TCXO, RTC crystal, and other passive components.

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Smallest configuration requires only antenna and power to fix position and generate NMEA output. All modules are pin compatible, support additional QZSS and SBAS signal, and offer better than -160 dBm tracking sensitivity. *www.news.thomasnet.com*

Spirent enables integration in consumer devices

Spirent Communications introduced the GSS6300M range of multi-channel GPS and multi-GNSS simulators for receiver integrators, application developers, aftercare and production testing environments. The entry-level test system readily enables laboratory evaluation of GPS performance across different locations and routes. The GSS6300M has everything required to start testing immediately and can be controlled from a tablet or smartphone, or via remote commands across multiple interfaces. *www.spirent.com*

Cyclo Bicycle Navigation GPS Line by Magellan

Magellan is launching its Cyclo 315 and 505 GPS cycling computers in North America that are designed to provide the most routing options, sensor support and connectivity for the serious cyclist. The Cyclo 505 is the first GPS cycling computer to include Shimano Di2 gear data display and recording*, Bluetooth Smart HRM/SAC sensor support, Android and iOS smartphone support for call and SMS notifications, Indoor ANT+ trainer support and enhanced ANT+ power meter support. *www.magellangps.com*

Common navigation space established

Russia, Belarus and Kazakhstan have agreed on establishing common navigation space, Kremlin administration head Sergei Ivanov said recently. He noted that national navigation systems will be integrated while the quality and reliability of navigation services will be improved. *www.en.itar-tass.com*

MARK YOUR CALENDAR

May 2014

GEO Business
28 – 29 May
London, UK
www.geobusinessshow.com

June 2014

Hexagon Conference 2014
2 – 5 June
Las Vegas USA
http://hxgnlive.com/

5th International Conference on Cartography and GIS
15 – 21 June 2014
Riviera, Bulgari
http://iccgis2014.cartography-gis.com/Home.html

ION Joint Navigation Conference 2014
16 – 19 June
Orlando, United States
www.ion.org/jnc

INSPIRE Conference
16-20 June 2014
Aalborg, Denmark
http://inspire.jrc.ec.europa.eu/events/conferences/inspire_2014/

XXV FIG Congress
16 – 21 June
Kuala Lumpur, Malaysia
www.fig.net

International Congress on Remote Sensing and GIS
25-27 June 2014
Casablanca, Morocco
http://siggtcasablanca.univcasa.ma/

July 2014

AfricaGEO 2014
1 - 3 July
Cape Town, South Africa
www.africageo.org

GI Forum 2014
1 – 4 July 2014
Salzburg, Austria
www.gi-forum.org

Esri International User Conference
14 – 18 July 2014
San Diego, USA
www.esri.com

ESA/ JRC International Summer School on GNSS 2014
21- 31 July 2014
Ostrava, Czech Republic
www.congrexprojects.com/2014-events/14m34/introduction

September 2014

ION GNSS+ 2014
8-12 September
Tampa, Florida, USA
www.ion.org

October 2014

Second symposium on service-oriented mapping
6 - 8 October
Hasso Plattner Institute at University of Potsdam, Germany
http://somap.cartography.at

INTERGEO 2014
7 - 9 October
Berlin, Germany
www.intergeo.de

GIS Forum MENA
8 – 10 September 2014
Abu Dhabi, UAE
www.gisforummena.com

ISGNSS2014
22 - 24 October
Jeju Island, Korea
www.isgnss2014.org

35th Asian Conference on Remote Sensing
27-31 October
Nay Pyi Taw, Myanmar
www.acrs2014.com

November 2014

Trimble Dimensions 2014
3 - 5, November
Las Vegas, USA
www.trimbledimensions.com

5th ISDE Digital Earth Summit
9 - 11 November
Nagoya, Japan,
www.isde-j.com/summit2014/

4th International FIG 3D Cadastre Workshop
9-11 November 2014
Dubai, United Arab Emirates
www.gdmc.nl/3DCadastres/workshop2014/

2014 UPINLBS
20 – 21 November
Corpus Christi, Texas, USA
http://upinlbs.tamucc.edu/

11th International Symposium on Location-based Services
26 -28 November
Vienna, Austria
www.lbs2014.org/

December 2014

PTTI 2014: Precise Time and Time Interval Systems and Applications Meeting
1 – 4 December
Boston, Massachusetts, U.S.A.
www.ion.org/ptti/future-meetings.cfm

March 2015

Munich Satellite Navigation Summit 2015
24 – 26 March 2015
Munich, Germany
www.munich-satellite-navigation-summit.org

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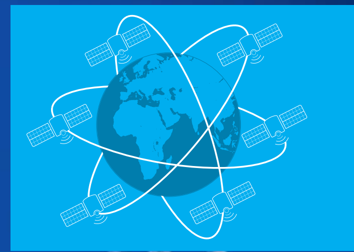

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