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Beacon Satellite Symposium Session 5B - June 30th 2016 Radio Occultation Techniques and Measurements

Aragon Angel M.A.

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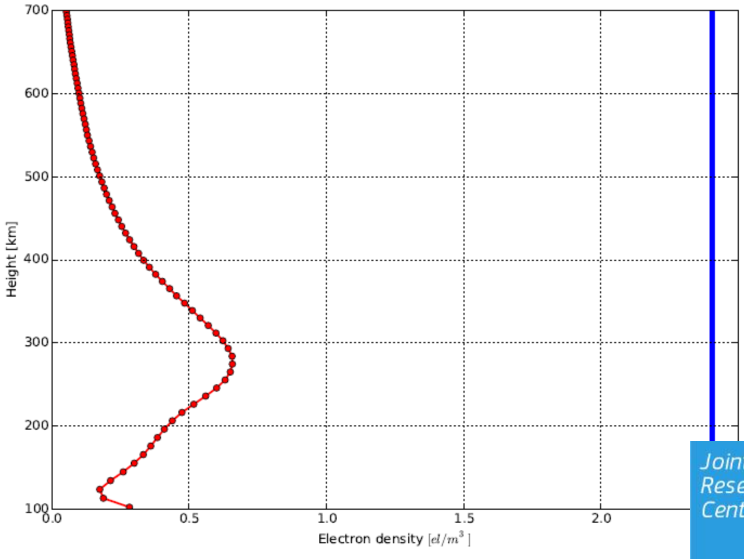

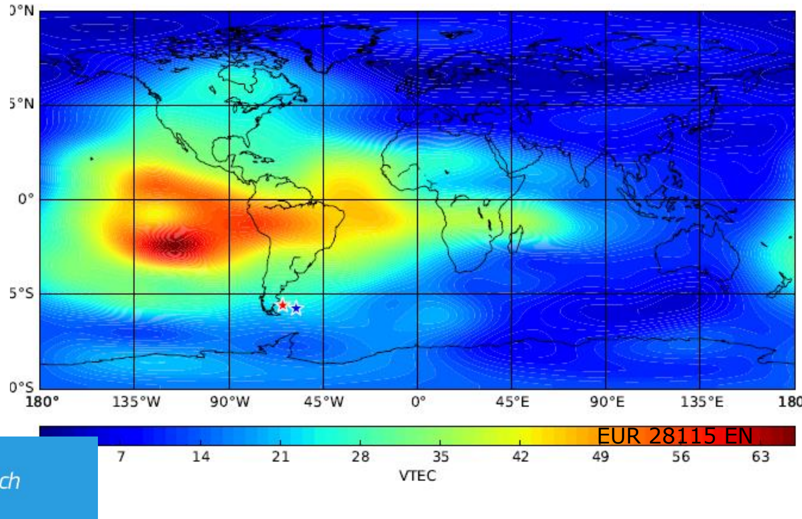

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Abstract

During the Beacon Satellite Symposium, held in Trieste, Italy, between June 26 and July 1 2016, the JRC chaired the session 5B: Radio Occultation Techniques and Measurements. The corresponding abstract of the session is provided as follows:

Since the mid-1960s, the GNSS based radio occultation technique has been used to study the structure and properties of the atmospheres of not only Earth but also other planets, such as Venus, Mars, some other outer planets, and many of their moons. By measuring the phase delay of radio waves from GNSS satellites as they are occulted by the Earth's atmosphere, the vertical density profiles of the bending angles of radio wave trajectories can be estimated using measurements onboard LEO satellites. The success of the GPS/MET mission in 1995 inspired a number of follow-on missions that include radio occultation experiment, including the CHAMP, GRACE, SAC-C, COSMIC, Metop-A/B, C/NOFS, and upcoming COSMIC-2 satellites. The combined profiles from these different LEO satellites provide excellent opportunities to explore the dynamics and structure of the ionosphere, especially in the regions that have been devoid of ground-based instruments, allowing for investigation of the longitudinal variability of the ionospheric density structure. This session seeks contributions that advance the application of RO technique for space weather studies. In addition, we welcome presentations exploring innovative methodologies that address the current problem on RO inversion technique at the equatorial region where ionospheric irregularity, such as sporadic E and spread F, present and degrade the linear combination technique that affect the quality of density profile extracted in the region.

The session was organized among:
Chairman and Convener: Angela Aragon-Angel, Joint Research Centre.
Co-Conveners: Volker Bothmer, Mahmut Onur Karslioglu, Andrzej Krankowski, Marco Limberger. The session consisted of both oral and poster presentation parts.

This document presents the process of the session preparation within the Beacon Satellite Symposium organization. Moreover, the abstracts of the different contributions accepted to the session are also included for completeness.

1 Introduction

This is a triennial event organized by the Beacon Satellite Studies Group of URSI Commission G – an interdisciplinary group, servicing science, research, applications and engineering aspects of satellite signals observed from the ground and in space. The Beacon Satellite Symposium 2016 edition has been held in Trieste, Italy, between June 26 and July 1 2016, at the Abdus Salam International Centre for Theoretical Physics (ICTP). The JRC has chaired one session related to Radio Occultation Techniques and Measurements.

This distinctive symposium represents the efforts of the Beacon Satellite Studies group sponsored by Commission G of the International Union of Radio Scientists (URSI). The current meeting has attracted a wide variety of international researchers from over 40 countries who use Beacon satellites to study the earth's ionosphere and thermosphere for basic research and applications with societal impacts. This worldwide level of interest is unprecedented in the history of the Beacon Satellite Symposiums. It exemplifies the ever growing importance of ionospheric radio wave propagation in the modern world.

In this edition, we had overwhelming response to the call for abstracts with nearly 200 abstracts for oral presentation and 50 abstracts for poster presentation. Unfortunately, the symposium could only support up to 100 oral presentations and a poster session. With so many papers, the organizers decided that all papers (invited or contributed) would have 15 minutes for presentation and questions. In principle, the symposium was going be held in single session (not parallel), as this has been the format for all former Beacon Symposiums. In the end, some parallel sessions needed to be scheduled. This is somewhat unprecedented for the Beacon Symposium but it was absolutely necessary this time. Sessions that had the highest number of abstracts were placed in sessions that were not in parallel with another one (see Figure 1). This was considered a reasonable solution by all conveners since it was a difficult decision to disregard contributions due to the quality of many of the papers, which was outstanding. These are all indications that this particular edition of the Beacon Satellite Symposium was a very successful and interesting event.

INTERNATIONAL BEACON SATELLITE SYMPOSIUM - PROGRAM AT A GLANCE								
Sunday - 26 June	Monday - 27 June	Tuesday - 28 June		Wednesday - 29 June		Thursday 30 June		Friday - 1 July
	Budinich Lecture Hall	Budinich Lecture Hall	Euler Lecture Hall	Budinich Lecture Hall	Euler Lecture Hall	Budinich Lecture Hall	Euler Lecture Hall	Budinich Lecture Hall
	Registration at the Leonardo Building Entrance (8:00 to 10:00)	Session 2: Irregularities and Scintillation Measurements and Effects (8:30 - 10:30)		Session 4A: Polar (high-latitude) Effects on GNSS (8:30 - 10:30)	Session 4B: Data Assimilation Modeling (8:30 - 10:30)	Session 5A: Advances in Ionosphere-Thermosphere Modeling and the Challenge of Validation (8:30-10:30)	Session 5B: Radio Occultation Techniques and Measurements (8:30-10:30)	Session 6: Ionospheric Effects on Satellite Based Navigation (08:30-09:30) Session 7: Space Weather Effects (9:30-10:30)
		Coffee Break		Coffee Break	Coffee Break	Coffee Break	Coffee Break	Coffee Break
	Opening Ceremony (10:00 to 12:20)	Session 2: Irregularities and Scintillation Measurements and Effects (10:50 - 12:30)		Session 4A: Polar (high-latitude) Effects on GNSS (10:50 - 12:50)	Session 4B: Data Assimilation Modeling (10:50 - 12:50)	Session 5A: Advances in Ionosphere-Thermosphere Modeling and the Challenge of Validation (10:50-12:50)	Session 5B: Radio Occultation Techniques and Measurements (10:50-12:50)	Session 7: Space Weather Effects (10:50-12:50)
	Lunch Break	Lunch Break		Lunch Break	Lunch Break	Lunch Break	Lunch Break	Lunch Break
Registration will begin at the Adriatico Guest House 18:30-20:00	Session 1: Space and Ground Based TEC and Measurements (13:30 - 15:40)	Session 3A: Monitoring Natural Hazards (13:40 - 15:40)	Session 3B: Theory and Modeling of Ionospheric Scintillation and Irregularities (13:40 - 15:40)	Excursion to Aquileia Friuli-Venezia Giulia UNESCO World Heritage Site (Depart at 14:00)		Session 6: Ionospheric Effects on Satellite Based Navigation Systems (14:00-15:40)		Session 7: Space Weather Effects (14:00-15:00)
	Coffee Break	Coffee Break	Coffee Break			Coffee Break		Coffee Break
Welcome Reception on the Adriatico Guest House Patio 19:00-20:30	Session 1: Space and Ground Based TEC and Measurements (16:00 - 18:00)	Session 3A: Monitoring Natural Hazards (16:00 - 17:20)	Session 3B: Theory and Modeling of Ionospheric Scintillation and Irregularities (16:00 - 17:20)			Session 6: Ionospheric Effects on Satellite Based Navigation Systems (16:00-17:20)		Beacon Satellite Studies Group Meeting, Awards Ceremony and Close (15:20 - 16:00)
		Poster Session and Reception (17:30 - 19:30)				Banquet at Ristorante Le Terrazze at Hotel Riviera 19:00		

Figure 1: Program Overview and Sessions Timetable

Finally, we were advised that the final decision on accepted papers would be left to the organizers as a function of logistics and financial availability with the exception of invited papers that were indicate on the spreadsheet by the conveners. In this sense, we were asked not to notify authors of our decisions but through the official channels.

2 Oral presentations

In the following subsections the finally accepted contributions to be orally presented at the symposium are presented.

2.1 Aspects of ionospheric measurements extracted from ionosondes and COSMIC satellites

Authors: Tanmay Das [1] and Haris Haralambous

Affiliations: Electrical Engineering Department, Frederick University, 7 Y. Frederickou Street, Nicosia 1036, CYPRUS.

This study presents aspects of collocated ionospheric measurements by FORMOSAT-3/COSMIC satellites in terms of GPS radio occultation technique and ionosondes performing vertical soundings over certain regions all over the globe. The purpose of the investigation is to explore the electron density discrepancy in the bottomside and topside ionosphere as measured by these two different techniques and the conditions that give rise to this discrepancy. Furthermore scintillation measurements measured by COSMIC satellites are also contradicted to digisonde ionograms to verify any ionospheric conditions that may give rise to such scintillation events. This study is based on a dataset of several thousands of manually scaled ionograms obtained by digisondes as part of DIDBase (Digital Ionogram Database) in the period 2007-2015. The cases considered correspond to COSMIC radio occultation measurements within 2.5° of digisonde position at less than 15 min time difference in the F2 layer peak measurement.

Key words: FORMOSAT-3/COSMIC, Ionosonde, Scintillation, GNSS

2.2 Hemispheric and Annual asymmetry of Nmf2 observed by FORMOSAT-3/COSMIC Radio Occultation observations

Authors: V. Sai Gowtam [1], S. Tulasi Ram [2], K. K. Ajith [3]

Affiliations: [1] Indian Institute of Geomagnetism, Navi Mumbai, India. [2] Indian Institute of Geomagnetism, Navi Mumbai, India. [3]Indian Institute of Geomagnetism, Navi Mumbai, India.

Globally, the hemispheric averaged NmF2 values in December solstice are significantly higher than those at June solstice at all longitudes. This is known as F2 - layer annual asymmetry. This phenomenon was observed and reported several decades ago but the possible mechanisms are not yet clearly understood. Four types of anomalies, equatorial ionization anomaly, winter or seasonal anomaly, semiannual anomaly and annual anomaly or annual asymmetry, are often found in the F2 layer. Apart from the above four anomalies, recently Liu et al. (2009) and Chen et al. (2010) reported two different anomalies. Those are Weddell Sea Anomaly (WSA) and Mid-latitude summer night-time anomaly (MSNA). All the above anomalies are well understood except annual anomaly. Few studies on annual asymmetry can be found in the literature. All the above studies show that the asymmetry has significant local time, longitudinal and solar cycle variations. One possible mechanism is the varying sunearth distance (about 0.983 AU for December and 1.017 AU for June). But varying Sun – Earth distance can explain only 25% of the total observed asymmetry. Similar asymmetry was found in thermospheric neutral density and they attributed this to the varying Sun – Earth distance. But, ionospheric behavior is different from the thermosphere because of its complex electrodynamics and transport processes involved. Zeng et al. [2008] found significant

longitudinal variations in the asymmetry values. Their case controlled simulation indicate that the solstice difference of Sun-Earth distance, offset between geomagnetic and geographic center and the tilt of geomagnetic pole will play important role on the annual asymmetry, however, the detailed physical mechanisms of how the geomagnetic configurations effects the annual asymmetry were still unexplained. There were no detailed studies on effects of thermospheric neutral winds on the annual asymmetry. Hence, the main objective of this paper is to study the local time, longitudinal and solar activity variations of annual asymmetry and its responsible neutral and electrodynamic mechanisms.

2.3 First ionospheric radio occultation measurements from GNSS Occultation Sounder on the Chinese Feng Yun 3C satellite

Authors: Tian Mao [1], Lingfeng Sun [2], GuanglinYang [1] and Xinan Yue [2]

Affiliations: [1] Key Laboratory of Space Weather, National Center for Space Weather, China Meteorological Administration, No. 46 Zhongguancun South Str.， Beijing, China. [2] Key Laboratory of Earth and Planetary Physics, Institute of Geology and Geophysics, Chinese Academy of Sciences, 19 Beituchengxi Avenue, Beijing, China.

The Global Navigation Satellite System (GNSS) Occultation Sounder (GNOS) has been planned for the 5 Feng-Yun 3 series (FY3) weather satellites since 2013, the first of which, the FY3C satellite, was launched successfully at 03:07 UTC on 23 Sep 2013 from Taiyuan Satellite Base, Shanxi Province of China, into the orbit of 836 km altitude and 98.75° inclination. In addition to the Global Positioning System (GPS), the FY3C/GNOS is capable of tracking occultation signal of the BeiDou Navigation Satellite System (BDS) (also called COMPASS) from space for the first time. The quality of BDS radio occultation has been verified in terms of signal-to-noise ratio. In this study, the electron density profiles (EDP) observed by FY3C/GNOS from both GPS RO and BDS RO, which were processed and archived in the National Satellite Meteorological Center of China Meteorological Administration (NSMC/CMA), are compared with 32 globally distributed ionosonde observations, And then we compare GPS RO EDPs with ionosonde observations at Mohe (52.0ºN, 122.5ºE), Beijing (40.3ºN, 116.2ºE), Wuhan (31.0ºN, 114.5ºE), and Sanya (18.3ºN, 109.6ºE). FY3C/GNOS EDPs show good agreement with ionosonde measurements, with larger discrepancies near the equatorial ionization anomaly region at Wuhan and Sanya. The ionospheric peak density (NmF2) and peak height (hmF2), derived from FY3C/GNOS EDPs are also compared with those obtained from the globally distributed ionosondes for the day of year 274-365 in 2013. In generally, NmF2 and hmF2 has a higher correlation coeficiente in the middle-high latitude than those in lower latitude region, due to the difference of ionospheric horizontal inhomogeneity. What’s more, we compare the NmF2 and hmF2 measured by ionosondes with those obtained by GPS RO and BDS RO from FY3C during from DOY 274-327 in 2013. The correlation coefficients for NmF2 (GPS RO) and (BDS RO) are 0.88 and 0.90, and the correlation coefficients for hmF2 (GPS RO) and (BDS RO) are 0.90 and 0.94. The agreement is a little better for hmF2 than for NmF2. We also compared the NmF2 and hmF2 map between FY3C/GNOS and the International Reference Ionosphere 2012 (IRI-2012) model. However, the wave number 4 structure, which can be indicated clearly from FY3C/GNOS observations, could not be reproduced well by IRI-2012. Further investigations show that the nighttime EDPs have obvious ionization enhancement around ionospheric E layer over Aurora and the South Atlantic Anomaly region due to the energetic particle precipitation indicated by the Space Environment Monitor (SEM) observations on board FY3C.

Keywords: FY3C/GNOS, GNSS, Radio Occultation, Ionosonde

2.4 Ionospheric New Findings and Space Weather by FORMOSAT-3/COSMIC Radio Occultation Sounding

Authors: J.Y. Liu [1] and TIGER [1]

Affiliation: Taiwan Ionospheric Group for Education and Research). Institute of Space Science, National Central University, Chung-Li, TAIWAN.

FORMOSAT-3/COSMIC (F3/C) constellation launched on 15 April 2006, which consists of six micro-satellites in the low-earth orbit, is capable of monitoring the ionosphere by using the powerful technique of radio occultation (RO). With more than 1500 observations per day, it provides an excellent opportunity to monitor three-dimensional (3D) structures and dynamics of the electron density. Fluctuations on the electron density profile triggered earthquakes, tsunami, solar eclipses, magnetic storms, etc, are scanned by the RO sounding. The 3D global eléctron density allows us having new findings on the ionospheric plasma caves [1] and ionospheric depletion bays, as well as better understandings on the equatorial ionization anomaly, midlatitude trough, and high-latitude Weddell Sea/Yakutsk anomaly. The F3/C tropospheric/stratospheric, and ionospheric RO soundings provide a unique chance to study the solar-ionosphere-atmosphere coupling processes due to solar storms, atmospheric tides, and stratospheric sudden warming. The RO data also demonstrate that an improvement in ionospheric space weather of the global electron density specification is achieved by assimilating the F3/C observations into existing ionospheric physics and/or empirical models to develop ionospheric monitoring, nowcast, and forecast models. Meanwhile, by using F3/C ionospheric observation, an empirical model of ionospheric S4 [2] scintillation has been accomplished, which could be used to evaluate/predict the quality of the communication, positioning, and navigation of GPS L1 band. Finally, impact of the F3/C follow-on, FORMOSAT-7/COSMIC-2, which consists of twelve (six, low inclination 24-deg, 550 km altitude and six, high inclination 72-deg, 800 km altitude) small-satellites [3] and will be launched in 2016 and 2017, mission on ionospheric weather and climate will be briefed. F3/C constellation has provided ionospheric electron density profiles with high vertical resolution through radio occultation measurements, while F7/ C2 constellation will further provide more than 4 times the number of the F3/C occultation soundings [4]. Nevertheless, F7/C2 RO observations can reconstruct 3-D ionospheric structure with a data accumulation period of 1 hour, which can advance studies of small spatial/temporal scale variation/signatures in the ionosphere.

Key words: FORMOSAT-3/COSMIC, Ionospheric Space Weather, Plasma Cave, Scintillation, FORMOSAT-7/COSMIC-2.

2.5 COSMIC GPS Radio Occultation Observations: Algorithm Improvements and Science Applications

Auhtors: Nicholas Pedatella [1] and William Schreiner [1]

Affiliations: [1] COSMIC Program Office, University Corporation for Atmospheric Research, Boulder CO, USA.

The launch of the Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) in April 2006 revolutionized the study of the global ionosphere using space-based navigation signals. By using the technique of Global Positioning System (GPS) radio occultation (RO), the COSMIC provides near global sampling of the ionosphere eléctron density from ~100 to 800 km, with a high vertical resolution. This presentation will provide an overview of recent improvements in the processing of ionospheric GPS RO observations within the COSMIC Data Analysis and Archive Center

(CDAAC). In particular, we have recently implemented an improved electron density inversion that does not rely on the Abel inversion. Other developments include a soon to be released monthly mean ionospheric reanalysis based on combining multiple low-Earth orbit missions and ground-based GPS observations. Select highlights of the application of COSMIC GPS RO ionosphere observations for scientific studies will also be presented. Finally, a status update of the COSMIC-2 mission will be presented.

Key words: COSMIC, radio occultation, GNSS

2.6 Statistical Distribution of Seasonal Variation of Refractivity Gradient in Lagos, Nigeria

Authors: Oluropo F. Dairo [1] and Lawrence B. Kolawole [1]

Affiliations: [1] Department of Physical Sciences, College of Natural Sciences, Redeemer's University, P.M.B. 230 Ede, Osun State 232101, Nigeria

The study of the refractivity gradient has continued to be of interest because of its application to microwave radio communications. The parameters on which refractivity depends – temperature, pressure and water vapour – change with time and space resulting in corresponding temporal and spatial variation of refractivity gradient. The present study is a statistical distribution of the refractivity gradient of the first kilometre using the in-situ upper air data obtained from the Nigerian Metrological Agency (NiMET). The statistical measures include median for the interval −300 N-units/km ≤ $D\mathrm{n}$ ≤ −40 N-units/km computed from the probability, $P0$, that the refractivity gradient is lower than or equal to $D\mathrm{n}$ and the cumulative probability $P1$ of $D\mathrm{n}$ for $D\mathrm{n} \leq Med$.

2.7 GPS Radio Occultation for Global Scintillation Specification

Authors: Ronald G. Caton [1], Keith M. Groves [2] and Charles S. Carrano [2]

Affiliations: [1] Air Force Research Laboratory, Space Vehicles Directorate, Kirtland AFB, NM, USA. [2] Boston College, Institute for Scientific Research, Chestnut Hill, MA, USA

Current state-of-the-art models providing specification of the equatorial ionospheric scintillation environment utilize near real-time data streams from ground-based sensors at locations of opportunity. While this technique provides highly accurate regional nowcasts and short-term forecasts of anticipated scintillation activity, it suffers from a reliance on climatology to fill the large gaps in denied regions such as over the vast ocean areas. Use of space-based receivers onboard Low Earth Orbiting (LEO) spacecraft capable of high-rate recordings of signals from occulting GPS satellites provides the opportunity to expand of our knowledge of the ionospheric scintillation environment to a global scale. Doing so, however, requires sophisticated algorithms for accurate geolocation of the ionospheric irregularities resulting in scintillated signals during GPS radio occultations (RO).

Key words: GPS Radio Occultation, Equatorial Ionosphere, Scintillation, COSMIC-2

2.8 Imaging the global vertical density structure from the ground and space

Authors: Endawoke Yizengaw
Affiliations: Institute for Scientific Research, Boston College, Chestnut Hill, Massachusetts, USA

Although satellite observations demonstrate that there are large longitudinal differences in the ionospheric density distributions, the availability of uneven distribution of ground-based instruments hinders us not to understand the physics behind the global ionospheric density distributions. For example, understanding the physics behind the unique equatorial ionospheric irregularities in the African sector is still becoming a problem due to lack of ground-based instruments. The space-based GPS measurements on board Low Earth Orbiting (LEO) satellites are rather good datasets to monitor the ionosphere and plasmasphere on global scale. In this paper, we present diferente capabilities of GPS measurements onboard LEO satellites, providing (a) radio occultation (RO) density profiles to routinely monitoring the global ionospheric region below the LEO orbiting altitude and (2) topside ionosphere and plasmasphere integrated density values that can be used for space-based tomographic reconstruction techniques to remotely image the vertical structure of the topside ionosphere and plasmasphere density profiles.

2.9 Assessment of the F2-layer electron density peak inferred from Formosat-3/COSMIC radio occultations over half a Solar Cycle

Authors: Angela Aragon-Angel [1], Marco Limberger [2], Manuel Hernández-Pajares [3], David Altadill [4], Denise Dettmering [2]

Affiliations: [1] European Commission, Joint Research Centre (JRC), Institute for the Protection and Security of the Citizen, Ispra, Italy, [2] Deutsches Geodätisches Forschungsinstitut der Technischen Universität München (DGFI-TUM), Arcisstr. 21, 80333 München, Germany, [3] Universidad Politécnica de Cataluñya, IonSAT research group, Jordi Girona, 1-3, Mod. C-3 Campus Nord,08034 Barcelona, Spain, [4] Observatori de l'Ebre (OE), CSIC, Universitat Ramon Llull, Horta Alta 38, 43520 Roquetes, Spain.

GNSS radio occultation (RO) measurements have become crucial to provide valuable information on the vertical electron density structure of the Ionosphere. Ionospheric key parameters such as the maximum electron density (NmF2) and the corresponding peak height of the F2 layer (hmF2) can be easily derived. In the current work, in order to assess the accuracy of NmF2 and hmF2 inferred from Formosat-3/COSMIC (F-3/C) RO measurements, an efficient electron density retrieval method, previously developed at the UPC (Barcelona, Spain), has been applied for a period of more than half a solar cycle between 2006 and 2014. Ionosonde measurements from the Space Physics Interactive Data Resource (SPIDR) network have been used as reference. Results show that relative variations of NmF2 differences are in the range of 22% – 30% and 10% – 15% for hmF2. Equatorial and midlatitude sectors at daytime and dawn present the highest consistency whereas degradations have beendetected in the polar regions during night. Moreover, it has been found that the solar activity can be traced by means of the global averages of NmF2 and hmF2 derived from F-3/C RO, hence becoming alternative indicators of solar activity trends.

Key words: Radio occultations, Inversion methods, Electron density retrieval, Formosat-3/COSMIC

2.10 Monthly Climatology of Thermospheric Neutral Winds Obtained from COSMIC Radio Occultation Measurements

Authors: L. Scherliess [1], and L. Lomidze [2]

[1] Center for Atmospheric and Space Sciences, Utah State University, 4405 Old Main Hill, Logan, U.S.A. [2] Department of Physics and Astronomy, University of Calgary, 2500 University Drive NW, Calgary, Alberta, Canada.

Radio Occultation (RO) data from the six Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) satellites provide an invaluable source of information about the ionosphere/thermosphere system. A new method has been developed to use these data to estimate the monthly climatology of the zonal and meridional components of the thermospheric neutral wind at low and middle latitudes. The method is based on using a Kalman filter technique. First, the climatology of the magnetic meridional wind is obtained by assimilating seasonal maps of F region ionosphere peak parameters (NmF2 and hmF2), obtained from COSMIC radio occultation data, into the Global Assimilation of Ionospheric Measurements Full Physics (GAIM-FP) model. GAIM-FP provides the 3-D electron density throughout the ionosphere, together with the magnetic meridional wind. Next, the global zonal and meridional wind components are estimated using a newly developed Thermospheric Wind Assimilation Model (TWAM). TWAM combines the magnetic meridional wind data obtained from the assimilation of the COSMIC RO data into GAIM-FP with a physics-based 3-D thermospheric neutral wind model using an implicit Kalman filter technique. Ionospheric drag and ion diffusion velocities, needed for the wind calculation, are also taken from GAIM-FP. We present na overview of the method of our wind estimation from COSMIC RO observations and compare individual horizontal wind components to their corresponding empirical model values and to measurements made by interferometers.

Key words: COSMIC Radio Occultation, Ionosphere, Thermosphere, Neutral Wind, Data Assimilation.

2.11 Investigation of the Latitude Dependent Discrepancy between foF2 values extracted from DIAS maps and COSMIC measurements over Europe

Authors: Tanmay Das [1] and Haris Haralambous [1]

Affiliations: Electrical Engineering Department, Frederick University, 7 Y. Frederickou Street, Nicosia 1036, CYPRUS.

During recent years various studies have been published indicating a latitude dependente discrepancy between the critical frequency of the F2-layer (foF2) measured by FORMOSAT-3/COSMIC satellites in terms of GPS Radio Occultation (RO) technique and ionosonde performing vertical soundings over certain regions. These findings were based on limited datasets within the proximity of ionosonde stations. This paper exploits the excellent coverage of the European area provided by DIAS (European Digital Upper Atmosphere Server). This is a service based on a pan-European digital data collection on the state of the upper atmosphere, which offers real-time information and historical data collections provided by most operating ionospheric stations in Europe. An investigation is therefore presented on the comparison between values of the critical frequency of the F2-layer (foF2) measured by FORMOSAT-3/COSMIC satellites in terms of GPS radio occultation technique and foF2 maps produced by the DIAS system. Values of foF2 were obtained using NmF2 values from electron density profiles as measured by FORMOSAT-3/COSMIC over Europe during the period from January 2007 to December 2015. Discrepancies between the two datasets are examined and discussed.

Key words: FORMOSAT-3/COSMIC GPS RO technique, DIAS, foF2, NmF2

2.12 CASSIOPE e-POP Radio Occultation Observations of High Latitude Ionization Structures

Authors: Chris Watson [1], Richard. B. Langley [2], Andrew Yau [1], and P. T. Jayachandran [3]

Affiliations: [1] University of Calgary Department of Physics and Astronomy, Calgary, Alberta, Canada. [2] University of New Brunswick Department of Geodesy and Geomatics Engineering, Fredericton, New Brunswick, Canada. [3] University of New Brunswick Physics Department, Fredericton, New Brunswick, Canada.

The enhanced polar outflow probe (e-POP) onboard the Cascade, Smallsat and Ionospheric Polar Explorer (CASSIOPE) satellite is a scientific instrument suite designed for detailed observation/study of the high latitude ionosphere and its coupling to the magnetosphere and solar wind. In 2013, CASSIOPE/e-POP was launched into a polar, elliptical low Earth orbit (325-1500 km), and includes a high-data-rate (20-100 Hz) Global Positioning System (GPS) receiver for radio occultation (RO) measurements of the ionosphere's plasma density [1]. The high inclination of e-POP, combined with the high resolution of e-POP RO measurements, allows for detailed observation of high latitude ionospheric structuring from a new perspective [2]. In addition, simultaneous total electron content (TEC) measurements of the e-POP RO receiver and groundbased GPS receivers in high latitude regions (e.g. Canadian High Arctic Ionospheric Network (CHAIN) [3]) allows for observation of small-scale ionization structures in both vertical and horizontal directions. Preliminary e-POP RO observations of small-scale structuring in the auroral and polar ionosphere will be presented, including simultaneous e-POP RO and ground based TEC observations of these structures.

3 Poster presentations

In the following subsections the finally accepted contributions to the associated poster session are presented.

3.1 IGOSat student satellite project to measure ionospheric occultations and gamma rays

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The students of the university of Paris Diderot are developing the nano satellite Ionosphere and Gamma-ray Observations SATellite (IGOSAT). It is a 3U cubesat (10x10x30 cm) with two scientific payloads. The first one is aiming at monitoring the ionosphere through radiooccultation of GPS signals. The second one will measure in-situ the flux of cosmic rays. This project is supported by the French space agency, CNES, in the framework of its educational programs. Initiated in 2013, it has already seen more than 100 students involved in the development of all the subsystem of the satellite and its ground stations. The constrains of a small cubesat, both in terms of space and power, will allow to activate alternatively each instruments, imposing a careful design of satellite operations. Nevertheless measurements campaigns using both instruments at the same time are also planned for a limited time. This mission will use its own telemetry ground stations. The first one in Paris university and the second in Hanoi university. We aim at obtaining measurements of TEC for setting occultations from an altitude of 650 km to the bottom of the ionosphere. Ionospheric scintillations will also be measured. TEC data will be inverted to reconstruct the mean vertical profile of electron density in the occultation region. We present the current status of the development of the satellite, focusing on the radiooccultation payload subsystem.

Key words: Cubesat, Radio Occultation, TEC

3.2 Characterizing Blanketing Sporadic E in the Vicinity of Magnetic Dip Equator Using Ground-Based Station and GNSS Radio Occultation Measurements

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In the vicinity of the magnetic dip equator, two basic types of sporadic E (Es) are observed equatorward of dip latitude (Φ) at approximately ±5 º, namely, the equatorial types Esq and Esb. Esq type is produced by Bragg scattering of radio signals from small-scale field-aligned irregularities embedded in the equatorial electrojet (EEJ). The Esb type is the most common type observed in the equatorial region and is produced by the reflections from a thin layer of enhanced plasma density (N); the layer itself is formed

from the convergence in the altitude of long-lived metallic ions, which result from a vertical shear in the zonal neutral wind (U). The term “blanketing” denotes that N in Esb is dense enough to prevent the travel of radio signals up to the F layer, which causes the disappearance of the F trace in an ionogram at such frequencies.

Key words: Blanketing Sporadic E, Ionosphere, GNSS, Scintillation, Radio Occultation

4 Conclusion

The session co-organized and co-chaired by the JRC at the Beacon Satellite Symposium 2016 has been a great success. The topic was very well received by scientists, which resulted into a vast submission of abstract to the session, way beyond the capacities of the time allocated for it by the congress organization. It was needed to carefully review and rate these contributions considering novelty of the topic, methodology and impact of the results to obtain a fair punctuation that would allow us to define the final program of the session.

This distinctive symposium represents the efforts of the Beacon Satellite Studies group sponsored by Commission G of the International Union of Radio Scientists (URSI). The current meeting has attracted a wide variety of international researchers from over 40 countries who use Beacon satellites to study the earth's ionosphere and thermosphere for basic research and applications with societal impacts. This worldwide level of interest is unprecedented in the history of the Beacon Satellite Symposiums. It exemplifies the ever growing importance of ionospheric radio wave propagation in the modern world.

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