URSI AP-RASC 2019, New Delhi, India, 09 - 15 March 2019

Coordinated Observations of Ionospheric Irregularity Structures at Optical and Radio Wavelengths from an Anomaly Crest Location during the Unusual Solar Minimum Period 2008-2010

Dibyendu Sur* [(1)], Haris Haralambous [(2)], and Ashik Paul[(1)]
(1) Institute of Radio Physics and Electronics, University of Calcutta, Kolkata, India, e-mail: dibyendumalay@ieee.org; ap.rpe@caluniv.ac.in
(2) Electrical Engineering Department, Frederick University, Nicosia, Cyprus; e-mail: eng.hh@frederick.ac.cy

Satellite-based optical imaging of the Earth's ionosphere is a useful tool to complement ground-based measurements. Institute of Radio Physics and Electronics, University of Calcutta operates dual-frequency GPS receiver under the **SCI**ntillation **N**etwork **D**ecision **A**id (SCINDA) program of the US Air Force since 2006. The **C**onstellation **O**bserving **S**ystem for **M**eteorology, **I**onosphere, and **C**limate (FORMOSAT-3/COSMIC) uses the **T**iny **I**onospheric **P**hotometer (TIP) to characterize the night time ionosphere directly below each spacecraft. TIP is a compact, narrow-band, and ultra violet photometer operating at the 135.6-nm wavelength [1]. One of the most important features of TIP is the ability to observe the equatorial anomaly. A TIP pass over the anomaly region observes primarily the latitudinal structure of the anomaly. At the equator, 40° of latitude is sampled in about 10-min. Since the orbital inclination of the COSMIC satellites is 72°, this same 10-min pass also traverses about 10° in longitude. Another important feature of TIP is the ability to observe low latitude depletions and bubbles and the ionospheric context in which they form and evolve. It is extremely important to note that, to the best of our knowledge, there are no optical instruments available for sensing the atmosphere at regions around the northern crest of the Equatorial Ionization Anomaly (EIA) in the eastern and north-eastern parts of India.
During the unusually prolonged solar minimum period spanning 2006-2010, very few cases of amplitude scintillations were found affecting GPS links from Calcutta [2, 3]. The present work illustrates some cases during this period when carrier-to-noise (C/N_0) ratio fluctuations and depletions in Total Electron Content (TEC) on GPS corresponded to ionization density bite-outs evaluated from TIP radiance measurements over a common ionospheric volume around the same time interval. TIP passes were filtered to extract ionospheric information specifically over the Indian longitude sector.
A case of collocated optical and radio observations of ionospheric irregularity structure occurred on February 2, 2008 from Calcutta when TIP observations of irregularity structures at 135.6nm corresponded with GPS TEC bite-outs and carrier-to-noise ratio (C/N_0) fluctuations at L1 frequency. From fluctuations in radiance at 135.6nm fluctuation during a TIP pass from 15.6-16.54UT (21.6-22.54LT) on February 2, 2008 and indication of S_4 along the track, signatures of irregularity structures could be noted around 16:00UT (22:00LT). GPS TEC and C/N_0 measurements on the SV16 link from Calcutta also exhibited depletions in TEC and corresponding scintillation patch during 15:30-16:00UT. Thus from coordinated measurements with the photometer and GPS, it may be possible to identify irregularity structures at different wavelengths and of different scale sizes, the ones affecting GPS links being of 300-400m dimension.

1. K. F. Dymond, S. A. Budzen, C. Coker, and D. H. Chua, "The Tiny Ionospheric Photometer (TIP) on the Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC/FORMOSAT‐3)", *Journal of Geophysical Research,* **121,** 10, 2016, pp. 10614–10622, doi: 10.1002/2016JA022900.

2. A. Paul, B. Roy, S. Ray, A. Das and A. DasGupta, "Characteristics of intense space weather events as observed from a low latitude station during solar minimum", *Journal of Geophysical Research,* **116,** A10307, 2011, pp. 1-17, doi: 10.1029/2010JA016330.

3. B. Roy and A. Paul, "Impact of space weather events on satellite‐based navigation," *Space Weather,* **11,** 12, 2013, pp. 680–686, doi: 10.1002/2013SW001001.