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Towards Ionospheric TEC and GPS Scintillation Monitoring from the Oceanic Region

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ABSTRACT

A significant challenge in comprehensive characterization and predictive modeling of the ionosphere is that there are too few ionospheric sensors available world-wide providing real-time data with high fidelity. The dearth of ionospheric data is most acute in the oceanic region. Our ability to monitor the geospace environment from the vast stretches of open ocean remains a technological challenge. This is a problem because oceans cover about 70% of the Earth's surface. This state of affairs is illustrated in Figure 1 [1], which shows values of Total Electron Content (TEC) from measurements by dual frequency GPS receivers around the globe. Each colored pixel indicates the availability of a measurement. The measurements come predominantly from the US, Europe, Japan and Australia. The white areas are locations where no data were available – especially Africa, South America, the Middle East, and the oceans. Traditional instruments used for ionospheric monitoring, such as ionosondes, all-sky imagers, and radars are too bulky and power intensive to be deployed on resource-constrained buoys in the oceanic region. Thus far, these instruments have not been demonstrated to successfully operate from a platform in the open ocean. Even smaller and lower power instruments, such as dual-frequency GPS receivers, remain impractical in the oceanic region due to logistical challenges and the harshness of the environment. Under certain circumstances, because of the dominant west-to-east drift of the ionosphere, near-term forecasting requires measurements that are several hundred km upstream (i.e. to the west) of the region of interest. For many locations, this requires making measurements in the ocean, which is currently inaccessible for continuous monitoring of the ionosphere.

Presently, the only means to monitor the ionosphere over the oceanic region is from satellite platforms. Most of the satellite missions dedicated to ionospheric monitoring are in Low Earth Orbit (LEO) and because of the orbital precession they are unable to provide persistent observations over a fixed geographic location. A new class of observation platforms and sensors are needed to provide persistent ionospheric measurements from the oceanic region.

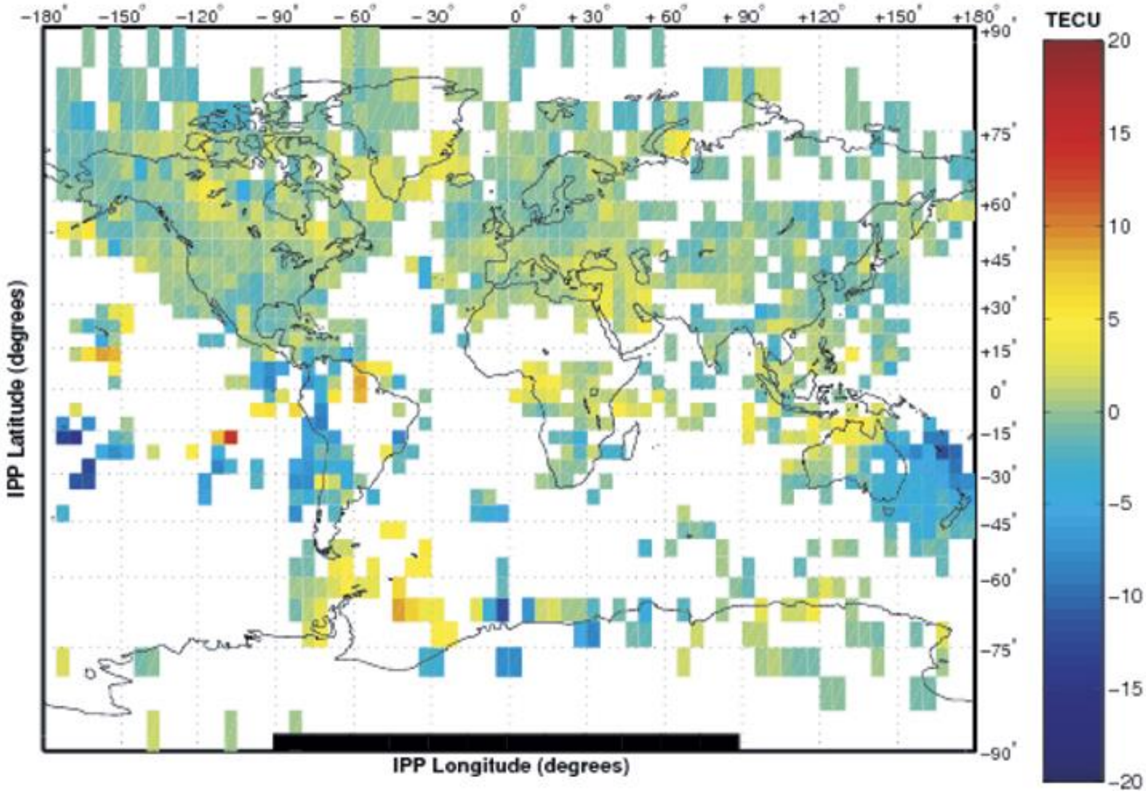

Figure 1. Global Map of the ionospheric Total Electron Content (TEC) showing measurements from ground-based dual-frequency GPS instruments. [1].

A low power dual-frequency GPS receiver, developed by ASTRA, fills in this gap in ionospheric monitoring from the oceanic region by providing a reliable solution for real-time monitoring of Total Electron Content (TEC) and scintillation from moving platforms (including aircrafts, oceanic buoys, and unmanned marine vehicles). In this paper, we describe a recent successful demonstration of ASTRA's real-time GPS-based monitoring capability from an oceanic buoy for ionospheric TEC and scintillation measurements. We present a brief overview of the new GPS receiver called "GPS Autonomous Micro-Monitor" (GAMMA), which can be optimized for operations from an extremely dynamic platform such as an ocean buoy or an aircraft. The paper presents initial measurements of ionospheric TEC and GPS scintillations made during a field experiment while deployed in the ocean off the coast of Lima, Peru in January 2015. As a validation of the data collected by GAMMA deployed on a buoy, we compare the TEC data from the buoy with that from an identical GPS receiver deployed on the ground in Lima. Figure 2a shows VTEC from the GAMMA receivers deployed in Lima, on dry land. Figure 2b shows VTEC from the GAMMA receiver on the Wave Glider buoy, using the high rate data (100 Hz) collected on-board the receiver. The VTEC measurements from the buoy show good agreement with those from the GAMMA receiver in Lima, Peru.

The GAMMA GPS receiver, described here, represents a small size, weight and power ionospheric sensor that is capable of successful operation on moving platforms. We have developed novel signal processing techniques to remove the effects of platform motion on measurements of phase scintillation, amplitude scintillation, and total electron content.

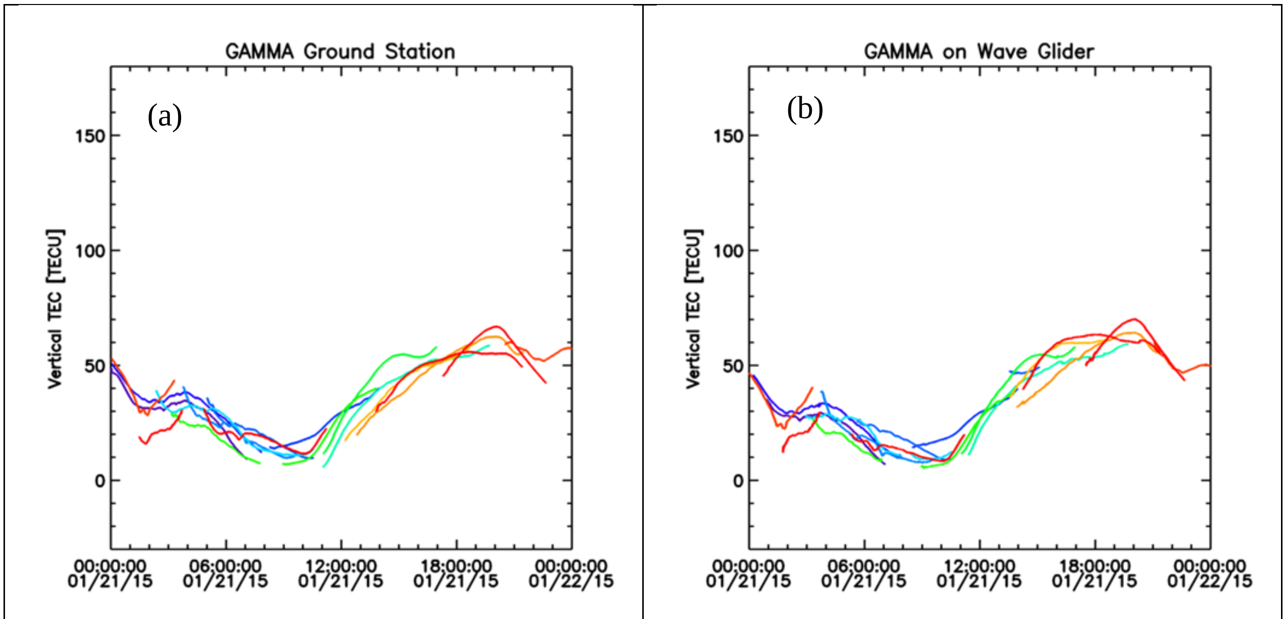

Figure 2. (a) VTEC from a GAMMA GPS receiver located at Lima, Peru (12 miles from the Wave Glider), (b) VTEC from the GAMMA GPS receiver on the Wave Glider while deployed 11 miles off the coast of Lima.

We anticipate that this new capability will open up many new applications for passively monitoring the ionosphere and its perturbations from previously inaccessible regions, such as the ocean, and from moving vehicles. For example, data from GAMMA receivers deployed on a constellation of buoys can be utilized to estimate characteristic wave parameters of Travelling Ionospheric Disturbances or generate spatial maps of GPS scintillation indices [2,3].

Key words: GPS, Scintillation, TEC, Buoys, Traveling Ionospheric Disturbance, Low Power

References:

[1] Occhipinti, G., A. Komjathy, and P. Lognonné (2008), Tsunami detection by GPS: How Ionospheric Observations Might Improve the Global Warning System, GPS World, pp 50-56.

[2] Kintner, P., T. Humphreys, and J. Hinks (2009), GNSS and Ionospheric Scintillation: How to Survive the Next Solar Maximum, in *Inside GNSS*, Vol. 4, No. 4, pp. 22–30.

[3] Crowley G., I. Azeem, A. Reynolds, J. Santana, and Q. Wu, Nighttime Medium-Scale Traveling Ionospheric Disturbance (MSTID) in GPS TEC Measurements , Proceedings of the 2013 International Technical Meeting of The Institute of Navigation, January 29 - 27, 2013, San Diego, California.