A GPS TEC-based Ionospheric-M Index over Malaysia

Sadia Mostofa
Space Science Center, Institute of Climate Change.
University Kebangsaan Malaysia.
Bangi, Selangor, Malaysia-43000
sadiamostofa9@gmail.com

Mardina Abdullah
Dept. of Electrical, Electronic and Systems Engineering.
Space Science Center, Institute of Climate Change
University Kebangsaan Malaysia.
Bangi, Selangor, Malaysia-43000
mardina@ukm.edu.my

Mohammad Tariqul Islam
Dept. of Electrical, Electronic and Systems Engineering.
University Kebangsaan Malaysia.
Bangi, Selangor, Malaysia-43000
tariqul@ukm.edu.my

Siti Aminah Bahari
Space Science Center, Institute of Climate Change.
University Kebangsaan Malaysia.
Bangi,Selangor, Malaysia-43000
sitiaminahbahari@ukm.edu.my

Mohammad Badal Ahmmed
Faculty of Computing
University Malaysia Pahang
Pekan, Malaysia-26620
badalahmmed@gmail.com

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Abstract*—Space weather can have a profound impact on trans-ionospheric radio signals. Through quantifying the intensity of a space weather event, from its genesis at the Sun to its effect on the ionosphere, many physical parameters must be extracted from scientific data. Consequently, they are used for the quick conveyance of a streamlined but sufficient space situational awareness. Nevertheless, space weather-driven ionospheric phenomena can impact many consumers in the communication and navigation domains, which are not adequately served by the existing indices. Here we propose and discuss the advantage of the new ionospheric index, known as M index over the Malaysian region in terms of disturbed storm time (Dst) and Total Electron Content (TEC). We took a geomagnetic storm event on 1st and 2nd June 2013. It has been found that the storm started effects over this region with a time delay of approximately 21 hours. The suggested ionospheric disturbance index may overcome several shortcomings of previous ionospheric measurements and may be appropriate as a possible driver for an ionospheric space weather scale.

Keywords*— Ionosphere, Ionospheric disturbance, Geomagnetic storm, ionospheric index, total electron content, disturbed storm time

I. INTRODUCTION

The ionosphere is a shell of electrons and electrically charged atoms and molecules that surround the earth, stretching from a height of about 50 kilometers to more than 1,000 kilometers. The sun's UV rays are mostly responsible for its existence. Radiation consists of photons with a specific amount of energy. When the photons impinge on the atoms and molecules in the upper atmosphere, the photon's energy breaks some of the bonds that hold electrons to their parent atoms. The end product is a large number of free electrons with a negative charge, as well as ions, which are positively charged atoms and molecules. The transmission of radio waves is influenced by the free electrons present in the ionosphere. Long-distance communication is possible because the ionosphere works nearly like a mirror for radio waves with frequencies below 30 MHz, refracting them back toward Earth. Radio waves at higher frequencies, such as those utilized by GPS, travel directly through the ionosphere. They continue to be influenced by it [1]. The signals sent by GPS satellites use two carrier frequencies. Due mainly to free electrons in the ionosphere, simultaneous measurements of the pseudo-range and carrier phase of these two signals vary. A dual-frequency GPS receiver or external data-processing software analyses the discrepancies between observations on the two frequencies to calculate correction values, effectively eliminating the influence of ionospheric refraction on the data. Consequently, it is commonly assumed that dual-frequency GPS observations eliminate all GPS user issues resulting from ionospheric refraction. However, this is only true for an undisturbed mid-latitude ionosphere.

The earth's natural ionosphere is divided into three main geographic zones from the standpoint of a GPS user. The equatorial area experiences numerous unpredictable shifts, whereas mid-latitude zones see the fewest disturbances [2]. Total electron content (TEC) is the number of electrons in a column across the ionosphere with a cross-sectional area of one square meter. Its diurnal behavior may be predicted statistically with reasonable accuracy. Frequently, the aurora and polar areas host major disturbances such as extreme phase scintillations. Their incidence is strongly tied to magnetic activity and exhibits some diurnal dependency. Within an area extending 30° on each side of the Earth's magnetic equator, you'll find the highest TEC values, the largest large-scale variations in TEC, and the most severe disruptions.

NOAA's (National Oceanic and Atmospheric Administration) space weather scales quantify the intensity of chosen observables of the space environment in relation to their typical impacts on humans and technological systems at each level. Such a scale relating to ionospheric disturbances has been demanded for a long time by user groups in the fields of communication and navigation but has not yet been satisfactorily implemented owing to the complexity of the ionospheric response to space weather events. Space weather-induced ionospheric disturbances may effectively affect or even interrupt positioning systems such as GPS. Consequently, a complete ionospheric scale must include the ionospheric response to such disturbances [2]. Numerous papers [3]–[12],[15]-[23] have highlighted investigations of ionospheric disturbances and storms. The M index displays TEC behavior ranging from a quiet condition (M=+1 to -1) to an intense storm (M=+4 to -1). As a proxy index for space weather, it is more accurate than geomagnetic indices alone.