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IONOSPHERIC RETRIEVAL USING GPS DURING EQUATORIAL SPREAD F EVENTS

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Abstract. This paper details a complete new software for pre-processing the RAW RINEX data and retrieval of GPS-TEC using code and carrier phase measurements using available and modified algorithms for a stand-alone dual frequency GPS receiver. The significance of this software lies in the fact that it retrieves all the corrupted TEC data points during random multiple cycle slip events which are oft-occurring phenomena during ESF in equatorial and low latitudes. Some other software flag such data (as unusable), which may form important data-set for ionospheric research and other applications as well.

1 INTRODUCTION

It is well known that the equatorial plasma bubbles (EPBs) are generated by large scale instability processes (like Generalized Rayleigh-Taylor) in post sunset equatorial ionospheric F region. Hierarchy of plasma density irregularities, encompassing a wide range of scale sizes from a few hundred km down to a few cm, is associated with the EPBs and collectively known as equatorial spread F (ESF). The largest of these scales sizes are known to be plasma density depletions. From an altitude of about 20000 km, when the GPS signal traverses through these depletions and reach the receiver at ground, they reflect as total electron content (TEC) depletions in the line of sight. In the rising phase of the EPB, the irregularities evolve rapidly and produce random variations of phase and amplitude of the traversing GPS signal at that time, known as scintillations. For GPS, the signal is most scintillated from the irregularities of 300-400 m scales size and most often in rising phase of EPB the TEC depletions and the scintillations are concurrent. The GPS receiver is vulnerable to both, the phase and the amplitude scintillations, as the receiver may lose lock on both carrier and code signals on both frequencies.

Estimation of total electron content (TEC) is a must to utilize the GPS signal for ionospheric research and not many software are available automatize the complex task. The estimation of true TEC during non-ESF duration from raw GPS data itself is a lengthy and complex task and requires knowledge of sophisticated computer programming skills, satellite orbital geometry and many other aspects like GPS signal structure and satellite and receiver specific information etc. The estimation of satellite and receiver biases is one more step left before getting true TEC. During scintillations, the loss of lock in the receiver results either in data loss or sharp gradients in the recorded delays; more often for phase than code. Raw GPS data n form of accumulated phase in radians and total distance by code in meters show random multiple cycle slips in phase and random data loss. Thus, the corrupted phase and code data has to be corrected first before further processing to obtain TEC.

Almost all available algorithms flag such data for no further use. Hence, no TEC can be estimated during multiple cycle slip events within few minutes from raw GPS data. But, for ionospheric research this forms a useful dataset.

2 APPROACH

Attempted to correct the phase and code information during such ionospheric events has been made. New algorithms have been formed and successfully applied for TEC estimation during ESF events. I would present the results of computation of true TEC from raw GPS data during ESF and non-ESF events and compare with available algorithms.

The task begins with reading the RINEX observation and navigation files. Then the algorithm is set to process the data PRN-wise and then PRN pass-wise. All the missing data points for each pass of the PRN (absence of code or/and carrier data) are treated as NaN while preserving the time epochs. Then, such NaN values are utilized to further break the data in different non-NaN data arcs. This step ensures fewer burdens on the cycle slip detection procedure, else the data gaps would be treated as cycle slips in next step. Thus, in next step, for each non-NaN data arc, the cycle slips are detected. We need to modify the cycle slip detection algorithm of Blewitt (1990). Because the gradients in low latitude slant TEC, which sometimes, become so large that Blewitts algorithm detects false slips. The modified Blewittss algorithm was tested for two-three years of continuous TEC data from different latitudes in Indian zone and found stable against all kind of cycle slips, with no false alarm.

Once the time epochs of the carrier phase cycle slips are known, all phase connected arcs are stored. Then a parameter, more commonly known as bdelta (from widelane combination) is estimated for each such arc. The phase connected arc which shows minimum bdelta is then utilized as a base arc. The P1 and P2 codes are used here to remove the ambiguity term in each phase connected arc independently. Finally all arcs are joined to give a continuous phase connected arc. We found that it is not possible to correct cycle slips using Blewitts algorithm (1990), as all the critical parameters cross the threshold during rapid multiple cycle slips (during ESF events). In such a case, it had been suggested to remove all such data points or flag them for no further use (Blewitt, 1990). But, in our case the cycle slip correction are done by arc-wise ambiguity removal and which comes over the limitations otherwise imposed.

The continuous phase connected arc is then used for elevation angle dependent code-carrier leveling. This provides the final product as phase smoothed slant TEC. All the PRN specific parameters of interest such as Week, TOW, elevation and azimuth and slant TEC is stored in a new data file.

The biases are removed in next step. The satellite and receiver biases are presently being estimated suing the algorithm of Arikane et al. (2008). However, we cross-check the biases with the ones provided by CODE (AIUB) whenever applicable.

3 RESULTS

Complete new software has been developed with modified and new algorithms, which is working successfully for a stand-alone dual frequency GPS receiver. All the source codes have been written in MATLAB®. Significance of the software lies in the fact that it retrieves all GPS-TEC data points even during rapid multiple cycle slip events, which are oft-occurring phenomena in EIA zone. It is being utilized for ionospheric research regarding ESF successfully.

The results pertaining to the same would be presented with step-wise procedure for many such examples and results.

4 CONCLUSION

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