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EVALUATION OF IONOSPHERIC MODELS UNDER MAGNETIC STORM CONDITIONS FOR GAGAN SYSTEM

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1 INTRODUCTION

Adverse space weather may severely disrupt satellite based, communications, and navigation systems. Investigation of space weather effects on SBAS systems is very crucial to achieve the CAT-1 PA requirements of aircraft landings. The geomagnetic storms drastically affect the TEC of GPS signals, especially for Indian region as it comes under low latitude region. Therefore, there is a necessity to incorporate a provision in the ionospheric models for detecting the ionosphere anomalies and magnetic storms. In this paper, the performance of three prominent ionospheric models namely Modified Planar Fit Method (MPFM), Minimum Mean Square Error (MMSE) and Spherical Harmonics Functions (SHF) models are investigated for adverse ionospheric conditions. For the analysis data from Indian SBAS popularly known as GPS Aided Geo Augmented Navigation (GAGAN) is used for the estimation of IGP delays and results are interesting.

2 GEOMAGNETIC STORM OF 7-11 NOVEMBER 2004

A geomagnetic storm occurred in the month of November 7-11, 2004. The maximum DST value of -373nT is occurred on 8th November 2004 with a maximum Kp index of 9. During 10th November 2004, the maximum DST value is -119 nT. 8th and 10th November 2004 storms are ranked as 3rd and 8th biggest storms in the solar cycle of 23.

3 IONOSPHERIC TIME DELAY MODELS

The ionospheric delay error, which is a function of Total Electron Content (TEC), is one of the predominant errors in Satellite Based Augmentation System (SBAS). To model the ionospheric time delay, MPFM, MMSE and SHF ionospheric models are investigated using adverse space weather conditions data.

3.1 Modified planar fit model

The "decorrelation function parameter" in the Planar fit method proposed by Walter et al.[1] is assumed as constant. This model is supplemented with ionospheric irregularity detector which uses Chi-square test and adaptable decorrelation method[2]. Chi-square test is also used to test the correctness in delay estimations made by the model

3.2 MMSE model

Minimum Mean Square Error (MMSE) estimator is one of the popular techniques in signal processing and statistical applications. MMSE is based on the principle of post estimation of the expectation of the square of the error between the measured and estimated vertical ionospheric delays. MMSE technique is proposed by Lejeune et al.,[3] is implemented for computing the vertical delay at each Ionospheric Grid Point (IGP) values.

3.3 SHF model

The SHF model is a two-dimensional Fourier series and can be used for estimating ionospheric delays[4,5]. For this purpose, IPP delays and locations are calculated using TEC data of 17 GPS stations. The IPP delays and locations are given as input to the SHF model for estimating coefficients. The SHF coefficients are used for the IGP delay estimation.

4 RESULTS AND DISCUSSIONS

To understand the behaviour of magnetic storm effects on TEC, in addition to storm day data, both pre and post storm days data is also considered. A total of 5 days (7-11, November, 2004) GPS data due to 17 stations across the Indian region is used in the ionospheric delay models. Using this data, the IGP delays and GIVE values are estimated. In this analysis a low latitude crest region IGP location (25º N, 75ºE) is considered. IGP delay and DST Index with respect to time are presented in Fig.1.

Pre storm day (7th November, 2004): All the models show diurnal ionospheric variations. Even though the maximum peak of IGP delays due to MPFM, MMSE and SHF models are 8.91m (15.00 hrs), 8.46m (16.41 hrs) and 9.4m (15.41 hrs) and are occurred at different times, they have shown the same trend. As expected, it is observed that IGP delay variations are in a state of quiet conditions (Fig.1).

1st storm day (8th November, 2004): A severe storm with a maximum DST index value of -373 nT at 12.16 hrs was occurred. In MPFM model, the maximum IGP delay is 7m (14.58 hrs). The corresponding peak values of MMSE and SHF models are 7.36 (16.25 hrs) and 7.76m (13.24hrs). Compared to pre storm day data, it can be seen that the maximum IGP delays of the models are less. It is found that IGP delays are depleted during the main phase of storm around 12.16 hrs (Fig.1).

Post storm day (9th November, 2004): Maximum peak IGP delays due to MPFM, MMSE and SHF models are 11.02m(15.00 hrs), 10.61m (15.66 hrs)and 11.6m (13.48 hrs). It is evident that, the maximum IGP delays of all the models are more compared to the maximum delays on the storm day. It can be seen from the results that the maximum IGP delays due to all the models are increased during the recovery phase of the storm to its near-to-quiet conditions (Fig.1).

2nd storm day (10th November, 2004): On this day a maximum DST index of -119nT is noted. The maximum peak of IGP delays of MPFM, MMSE and SHF models are 8.99m (17.33 hrs), 9.47m (17.00 hrs) and 8.03m (16.26 hrs) respectively. It is found that IGP delays due to the three models are again depleted during the main phase of storm. The mean, maximum, standard deviation of IGP delays for these days due to the models are shown in Table 1. From the Table, it is observed that the standard deviations of MPFM model is less compared to the other models. The standard deviations of SHF and MMSE with respect to MPFM model are shown in the Table. From the Table, it can be seen that the standard deviation of MPFM model with respect to other models varied between -0.06m to -0.43m during these days. The MPFM model consists of adaptable decorrelation and irregularity detectors so that this model would provide better ionospheric estimation under severe ionosphere conditions also.

5 CONCLUSIONS

Space weather effects on SBAS systems are one of the major concerns for developing an ionospheric model. An attempt is made to compare the performance of three prominent ionospheric models during magnetic storm conditions. It is confirmed from the results that IGP delays due to all the models are depleted during the main phase of storm. It is observed that the standard deviations of MPFM model is less compared to the other models. The results also show that the MPFM model would provide better ionospheric estimation even under severe ionosphere conditions. Analysis with more data is under progress.

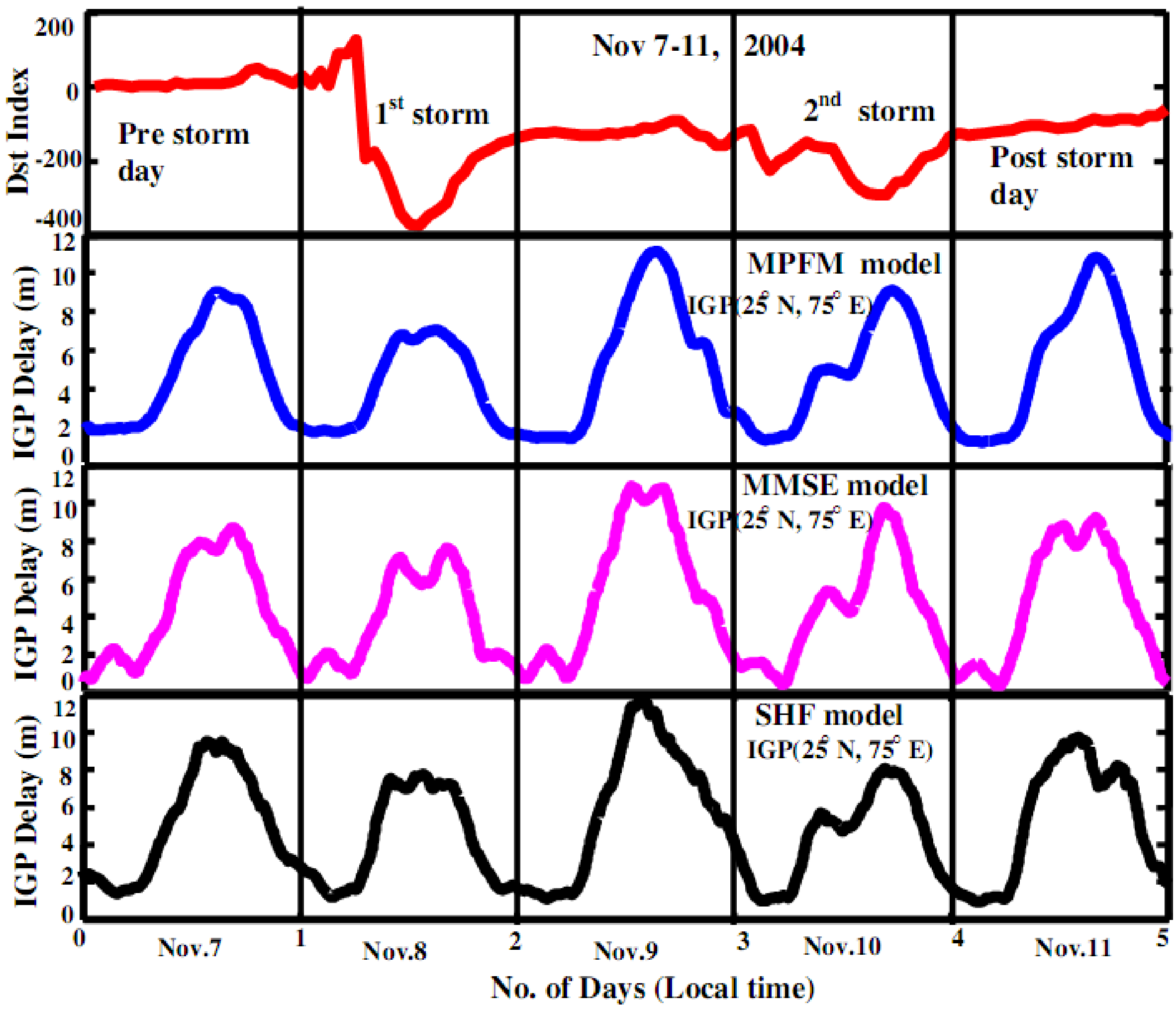

Fig.1. IGP delay variations at an IGP (25º N, 75º E) with DST index is given for storm period (7-11 November, 2004).

8th November, 2004					
S. No	**Ionospheric model**	**Mean (m)**	**Maximum (m)**	**Standard deviation(m) (Individual)**	**Standard deviation(m) (w.r.t MPFM model)**
1	SHF	4.25	7.76	2.47	-0.34
2	MPFM	4.16	7.06	2.13	-----
3	MMSE	3.80	7.60	2.30	-0.17
9th November, 2004					
1	SHF	5.95	11.68	3.60	-0.19
2	MPFM	5.41	11.15	3.41	-----
3	MMSE	5.46	10.90	3.57	-0.16
10th November, 2004					
1	SHF	4.32	8.04	2.30	-0.06
2	MPFM	4.62	9.10	2.24	----
3	MMSE	4.26	9.79	2.67	-0.43

Table 1: Statistics of IGP delays (8th to 10th November, 2004)

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