GPS Based Ionosphere Mapping Using PPP Method

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Introduction

The ionosphere is a part of the upper atmosphere, starting at height of 50 km and extending to 1000 km. In that region free electron density affects the propagation of radio frequency electromagnetic waves.

Spatial and temporal characteristic effects of the ionosphere on radio wave propagation, interest various study areas including space-based observation systems as well as communication systems and safety-critical systems (Liu and Gao, 2004). The wide spread effect of the ionosphere on various areas has made ionospheric studies popular subject for about 40 years.

Ionospheric mapping is defined as a technique applying simultaneously measured total electron content(TEC) values to generate TEC maps referred to a specific time epoch (Stanislawska et. al. 2000).

With the help of large number of tracing stations, GPS observations can be used for monitoring ionospheric conditions during disturbed and quiet geomagnetic conditions. Ex: GNSS analysis centers provide GIMs(Global Ionosphere Maps) on a daily basis.

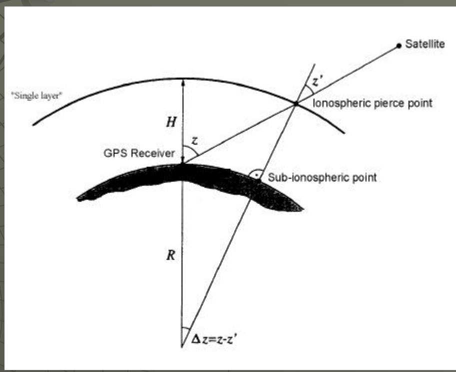
In this study, two stations have been selected from high-latitude and mid-latitude regions. By the help of these stations, regional ionosphere maps have been generated for both quiet and stormy days by using Bernese 5.0 PPP modul.

TEC Mapping

Ionospheric information can be obtained from single station for the specific area. Dimension of this specific area can be expressed by the concept of “coverage circle “ which can be obtained for each station using equation 1 and 2(Hugentobler et. al. 2001).

$$\sin z' = \frac{R}{R + H} \sin z \qquad \tan(z - z') = \frac{r}{R + H}$$

where, R is the radius of the earth, H is the single layer height, z and z' are satellite zenith angles at the receiver and IPP respectively, r is the radius of the coverage circle. When the, z=75, R=6370 km and H= 450 km is used, r is estimated as 1270 km.



The TEC maps have been generated with the Bernese software using PPP modul and output is in standard IONEX format. MSLM has been used for mapping the TEC. In this model it is assumed that all the free electrons are contained in a shell of infinitesimal thickness at altitude H. The altitude of this layer has been selected 450 km, which is generally used. Using MSLM noted above, vertical TEC map can be obtained at IPP.

ISTA and SODA IGS station, which are located in mid-latitude and high-latitude regions respectively, have been chosen. In order to determine the geographical location of the regional maps,

latitudes	longitudes	
35^o - 45^o	20^o - 40^o	ISTA
60^o - 70^o	15^o - 35^o	SODA

Stormy (2003, DOY 302) and quiet (2003, DOY 285) days

In order to see the level of storm, kp index values for pertinent days are given in figure 1 and 2.

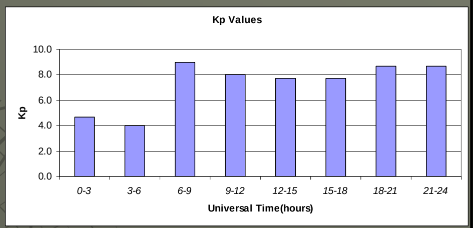


Figure 1. Kp values for 2003, DOY 302

As it can be seen in figure 1, geomagnetic storm is extreme for 6-9, 18-21 and 21-24 time periods and it is severe for 9-12, 12-15 and 15-18. However there is no storm occur for the DOY 285(figure 2)

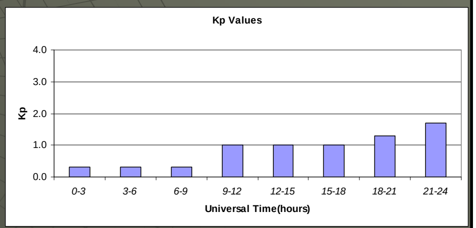


Figure 2. Kp values for 2003, DOY 285

Results

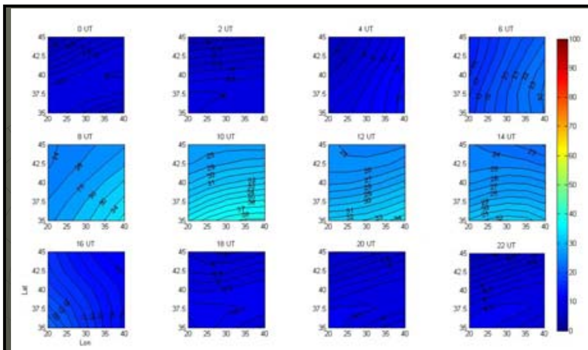


Figure 3. TEC maps for ISTA station, DoY 285-2003

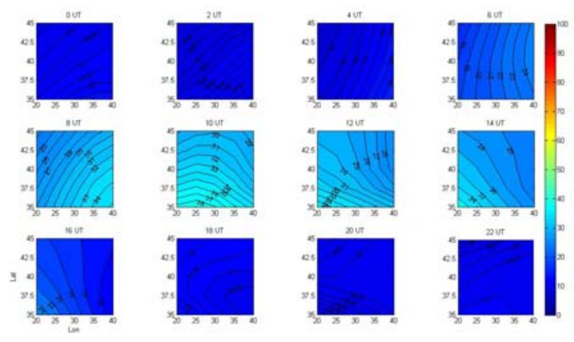


Figure 4. TEC maps from GIM, DoY 285-2003

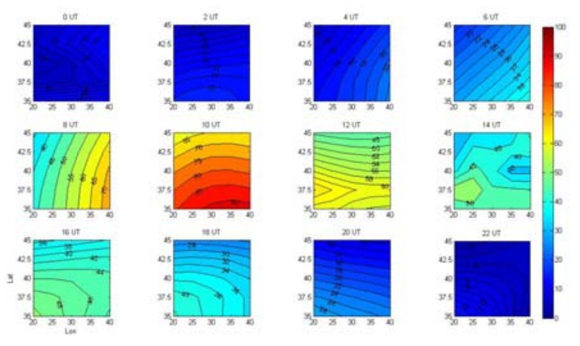


Figure 5. TEC maps for ISTA station, DoY 302-2003

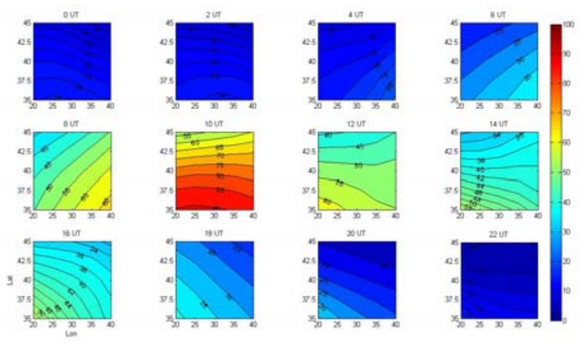
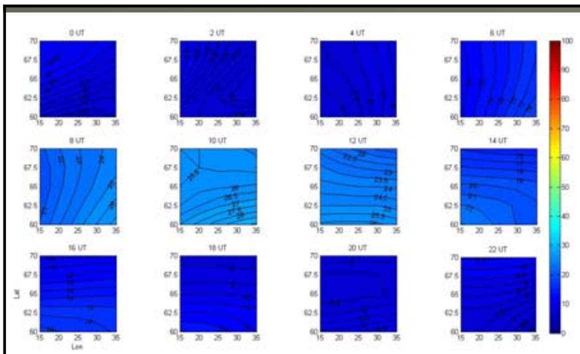


Figure 6. TEC maps from GIM, DoY 302-2003



Also comparison between GIMs and vertical TEC map for high-latitude station, SODA, is given in figures 7-8 and 9-10 for DOY 285 and 302 respectively.

Figure 7. TEC maps for SODA station, DoY 285-2003

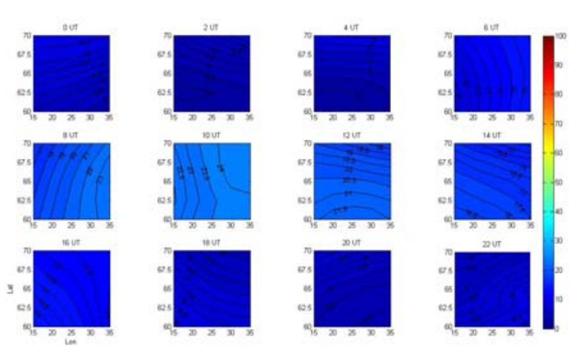


Figure 8. TEC maps from GIM, DoY 285-2003

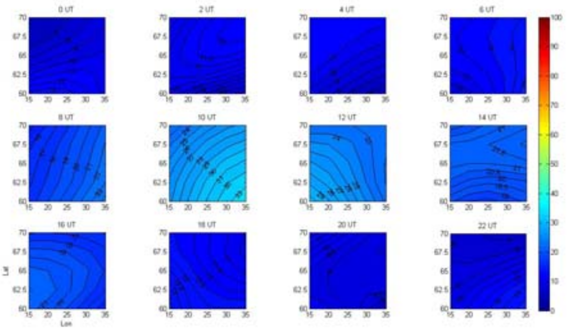


Figure 9. TEC maps for SODA station, DoY 302-2003

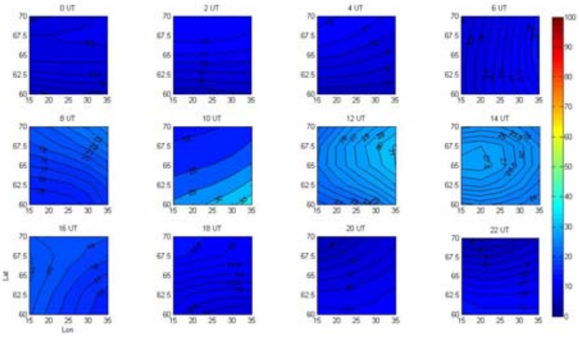


Figure 10. TEC maps from GIM, DoY 302-2003

In order to understand the difference between them whether they are systematic or random, we calculated mean and its standard deviations for each hour. Mean and standard deviation of differences between GIM values and PPP-derived can be seen in table 1

Table 1:Difference between GIM and PPP-derived (TECU)

	Doy 285, 2003				DoY 302, 2003			
	ISTA		SODA		ISTA		SODA	
	Mean	Std.D.	Mean	Std.D.	Mean	Std.D.	Mean	Std.D.
0^h	3.0	1.1	-1.7	0.5	2.9	3.3	-0.7	3.0
2^h	1.5	0.9	-3.4	1.2	-0.5	1.3	-0.3	1.6
4^h	1.1	0.7	-2.7	2.2	-1.5	2.4	-0.6	1.1
6^h	1.3	0.8	-3.0	0.9	-1.5	1.6	-2.3	0.9
8^h	1.1	0.9	-2.7	0.8	-2.9	5.5	-0.8	3.7
10^h	0.6	2.4	-2.9	1.4	-2.4	4.2	-6.1	4.3
12^h	1.4	2.9	-3.8	0.4	-4.7	2.7	1.2	5.1
14^h	1.6	3.2	-2.2	1.3	-1.4	4.5	5.3	1.1
16^h	2.0	1.1	-1.9	2.5	-3.5	2.6	-0.1	1.8
18^h	2.3	1.4	-3.3	1.2	-4.9	3.1	-1.4	2.1
20^h	1.7	0.9	-2.9	1.3	-2.4	2.7	0.0	2.7
22^h	2.1	0.7	-1.6	2.6	0.5	1.7	0.0	1.8

Time series of the mean and standard deviations can be also seen in figure 11 and 12.

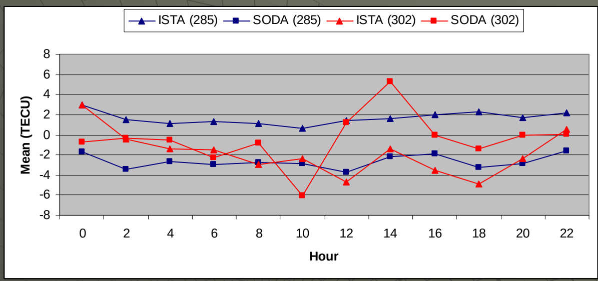


Figure 11. Mean of TECU difference between GIM and PPP-derived

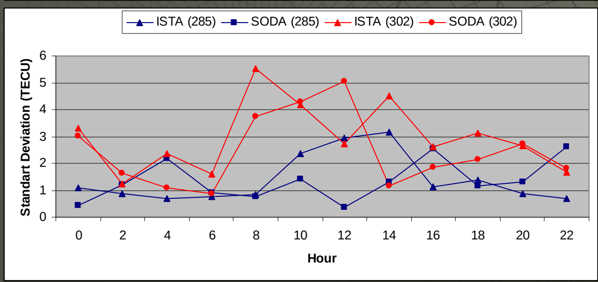


Figure 12. Standart Deviation of TECU difference between GIM and PPP-derived

Concluding Remarks

In order to characterize the ionospheric behaviour, which is necessary in many ways(Ex: its importance for satellite based positioning), TEC map are needed. Many studies have been performed for TEC mapping. In this study, single station based regional ionosphere model have been generated by PPP technique.
In order to investigate the compatibility of these maps with GIMs, which is generally used as a reference, two stations have been selected from mid-latitude and high-latitude regions.

Regional vertical TEC maps have been obtained by using Bernese 5.0 PPP modul for both quiet and stormy days. In order to determine the geographical location of the regional maps, coverage circle concept has been taken into consideration.

Results confirmed that, for both mid-latitude and high-latitude stations, regional vertical TEC maps are generally compatible with GIMs particularly when the quiet day is considered.


Thank you for your interest