The New Barcelona Ionospheric Mapping Function for North Mid Latitude GNSS applications

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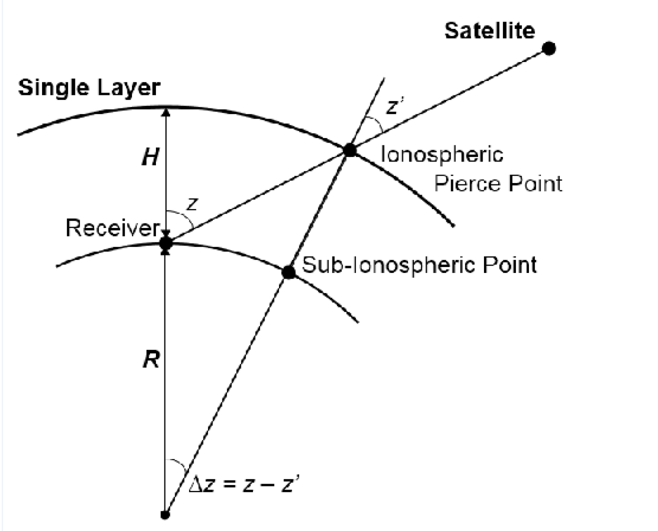
IGS Workshop 2017, 3-7 July 2017, Paris, France

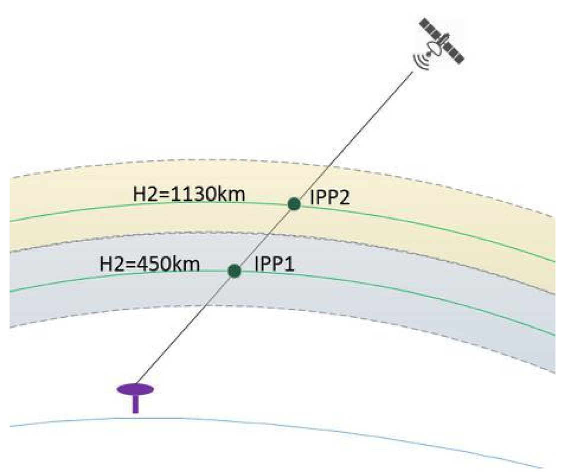
1. Introduction

- Ionospheric delays have an important role in GNSS positioning, both in absolute positioning mode and in relative positioning mode.
- Traditionally, standard ionospheric mapping function based on the assumption of single layer at one fixed height neglects the variation of electron density, which can lead to big mapping errors for the measurements with low elevation.
- In order to reduce the mapping error, a new mapping function-Barcelona Ionospheric Mapping function has been proposed. In this work, we focus on northern mid-latitude regions.



Single layer model for the ionosphere (Schaer, 1999)

2. Barcelona Ionospheric Mapping function(BIM)



$$STEC = N_1 l_1 + N_2^{'} l_2^{'}$$
$$= H \cdot \frac{N_1 l_1}{H} + H \cdot \frac{N_2^{'} l_2^{'}}{H}$$
$$= P_1 \cdot M_1 + P_2^{'} \cdot M_2^{'}$$
$$= M_1 \cdot \mu_1 V + M_2^{'} \cdot \mu_2^{'} V^{'}$$
$$= (1-\mu_2) M_1 V + \mu_2^{'} M_2^{'} V^{'}$$

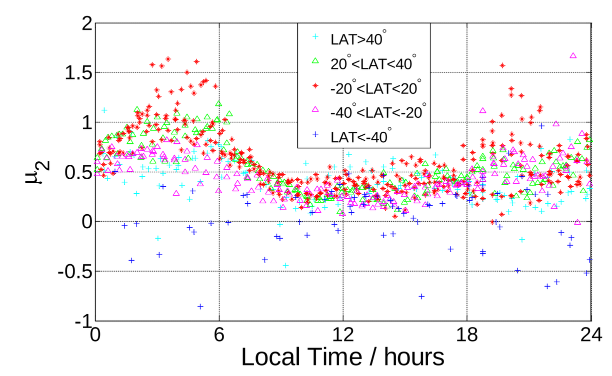
$$\mu_1 = \frac{N_1}{N_1 + N_2} = \frac{P_1}{P_1 + P_2} = \frac{P_1}{V}$$

$$\mu_2 = \frac{N_2}{N_1 + N_2} = \frac{P_2}{P_1 + P_2} = \frac{P_2}{V}$$

For GNSS users

$$STEC = \left(1 - \mu_2^{ipp1}\right) M^{ipp1} V^{ipp1} + \mu_2^{ipp2} M^{ipp2} V^{ipp2}$$

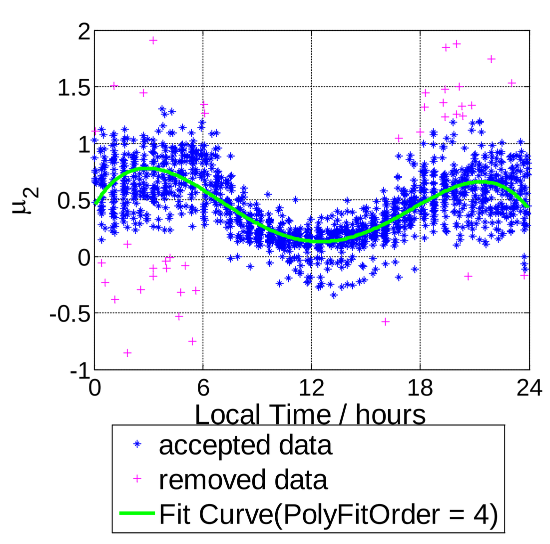
3. BIM modeling based on μ_2



μ_2 daily variations of different latitude ranges on day 349 of the year 2006

Step 1.

polynomial fitting for single day



$$\mu_2(th) = a_0 + a_1 \cdot th + a_2 \cdot th^2 + a_3 \cdot th^3 + a_4 \cdot th^4$$

Step 2.

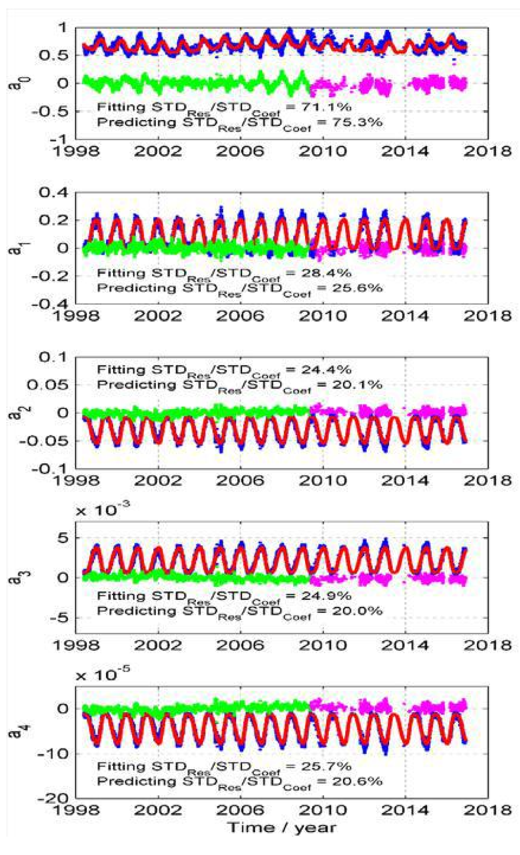
Fourier series fitting for each coefficient

Data

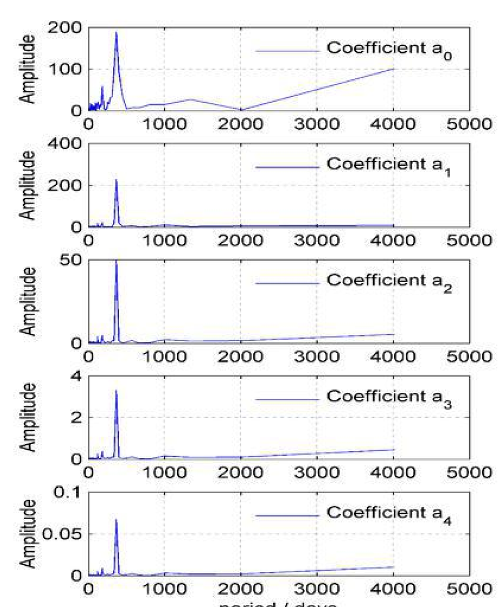
Fitting value

Fitting residual

Predicting residual



Results



Fast Fourier transform of five coefficients time series data from the daily TOMION runs from 1998.4 to 2009.4

td=mjd-50965

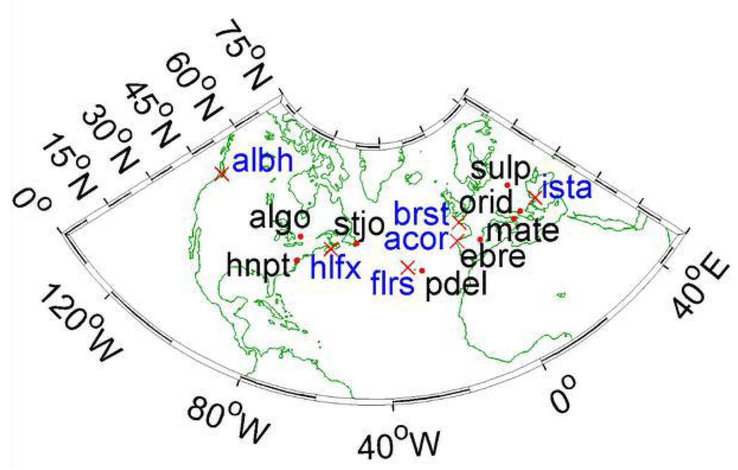
th: local time of IPP, in hours

Provided in Coefficient Tables

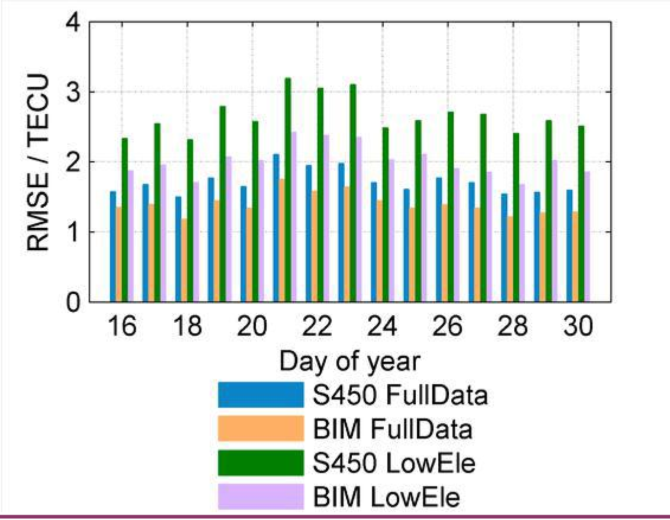
$$\boldsymbol{\mu_2(td, th)} = a_0(td) + a_1(td) \cdot th + a_2(td) \cdot th^2 + a_3(td) \cdot th^3 + a_4(td) \cdot th^4$$

$$a_i(td) = C_i^{(0)} + \sum_{k=1}^{n\_T_{a_i}} \left(C_i^{(2k-1)} \cdot \sin\left(2\pi \cdot \frac{td}{T_i^{(k)}}\right) + C_i^{(2k)} \cdot \cos\left(2\pi \cdot \frac{td}{T_i^{(k)}}\right) \right)$$

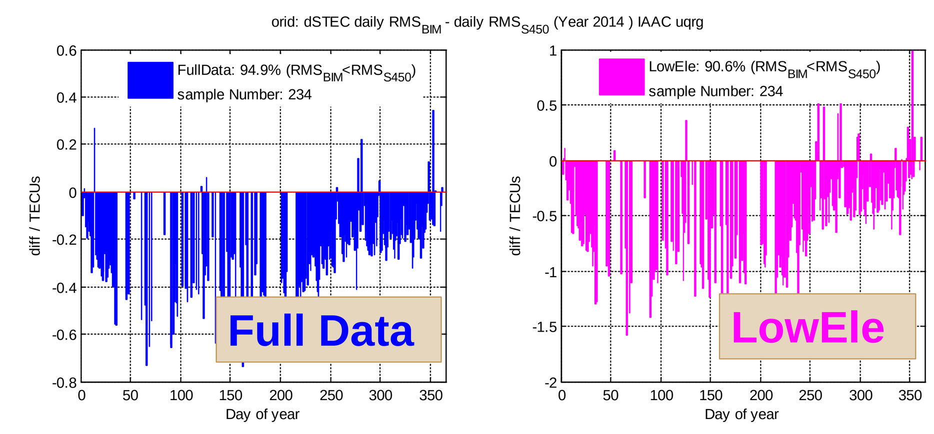
4. dSTEC Assessment



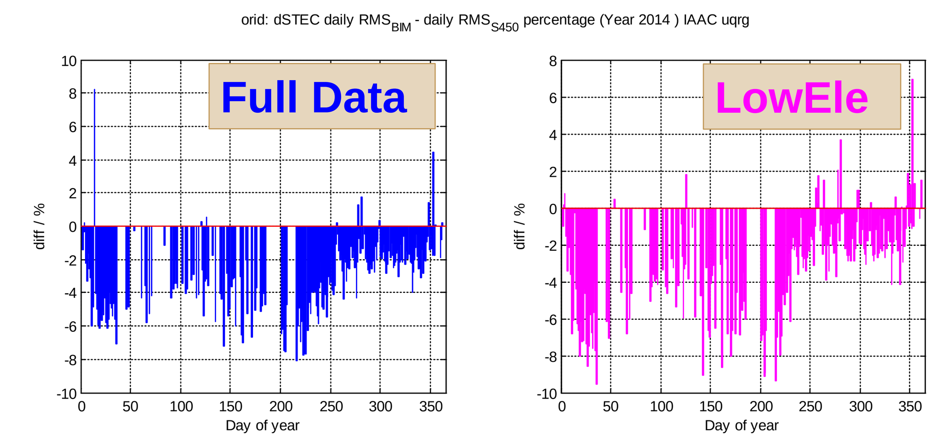
IGS stations that are not used for the generation of UQRG GIM in 2014 for external assessment of BIM performance. The stations in blue were not used for statistics due to very limited data in only a few available days.



orid station: dSTEC daily RMSE with BIM and S450 for UQRG GIMs from doy 16 to 30 of the year 2014. The bars in blue and in orange are the results for all data. The bars in green and in magenta are the results for the elevation of the given line-of-sight ray lower than 40°, and difference with the reference ray at least 20°above.



orid station: the differences of dSTEC daily RMSE with BIM minus dSTEC daily RMSE with S450(standard mapping function with the fixed height of 450km) for the year 2014, applied on the UQRG GIMs.



The upper plot is absolute differences and the bottom plot is the percentage of differences with respect to the dSTEC RMS with S450.

Table 1. Statistical results for different stations using JPLG in 2014

Site Name	Percentage (daily $RMSE_{BIM}$< daily $RMSE_{S450}$)		Sample Number
	Full Data	Elevation <40°& difference(ele)>20°	
acor	78.7%	71.3%	202
albh	98.4%	99.2%	248
algo	89.6%	91.2%	251
ebre	79.5%	87.0%	239
flrs	89.1%	94.8%	248
hlfx	90.1%	94.4%	252
hnpt	96.3%	98.3%	240
ista	98.4%	98.4%	245
mate	91.7%	96.8%	252
orid	96.2%	97.0%	236
pdel	81.0%	95.2%	248
stjo	84.0%	88.0%	250
sulp	96.6%	95.8%	118

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Acknowledgements: We are very grateful to the European Union's H2020 Programme, China Scholarship Council and the International GNSS Service for providing a professional and friendly framework for collaboration.

Conclusions and Future Work

- In this work focusing on the regions between 30°N and 60°N, such as Europe, a new mapping function-BIM is climatologically defined and proposed for GNSS users in order to improve the accuracy of STEC converted from VTEC.
- The model of the key parameter of BIM - μ2, the shape function value at the second top layer is established, which is climatic and can be used for predictions.
- In terms of model assessment, GIMs from different IGS Ionosphere Associate Analysis Centers are used to obtain the VTEC values and precise dSTEC measurements are chosen as evaluation criteria. It is shown that, compared to standard mapping functions with the shell height at 450km and 350km, BIM statistically improved the STEC estimation from GIMs at mid-latitude significantly. Indeed, the improvement is clear not only for UPC GIMs, which already use a tomographic model (up to 15% and 8% of improvement for shell heights of 350km and 450km respectively during the whole 2014) but especially for other analysis centers' GIMs, like the CODE ones (up to 32% and 22% respectively) and JPL GIMs (up to 29% and 21% respectively).
- The new mapping function will be optimized and generalized globally in the future.