Towards precise GNSS tropospheric modeling with TOMION Software

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Summary

The aim of this poster is to show the progress achieved in troposphere modeling using the The TOmographic Model of the IONospheric electron content (TOMION) software already functional for ionospheric and precise geodetic applications, as well as the dependencies on the sites coordinates with the tropospheric error.

Introduction

When a radio wave travels through the lower atmosphere a delay is produced with respect to the time it would spend if traveling in the vacuum (S path in fig. 1).

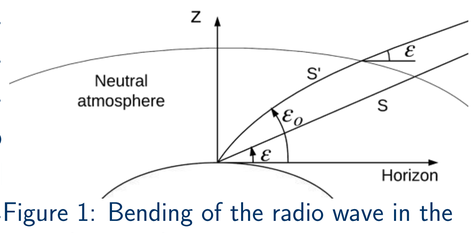


Figure 1: Bending of the radio wave in the neutral atmosphere.

The actual path (S') occurs when the medium produces a change in the refractive index. The tropospheric delay is commonly divided into two parts: hydrostatic and wet. Furthermore each component will be considered as the product of a zenith quantity and a function that projects this latter quantity into the line of sight, according to the elevation ε of the transmitter:

$$ZTD = ZHDm_h(\varepsilon) + ZWDm_w(\varepsilon), \quad [7] \quad \text{where}$$

$$ZHD = 10^{-6}K_1R_h\frac{P_s}{g_m} \quad [9] \quad \text{and}$$

$$ZWD = 10^{-6}[K_2' + \frac{K_3}{T_m}]\frac{R_h}{(\Lambda+1)g_m}e_s \quad [1]$$

are the zenith tropospheric hydrostatic and wet delays; and m the corresponding Mapping Functions (MF). The parameters atmospheric surface pressure P_s, mean temperature of the column of air above the site T_m, water vapor pressure e_s and its decrease factor Λ, are to be determined for each site and epoch, while the constant for gases in hydrostatic equilibrium R_h, the mean gravitational acceleration of the column of air above the site g_m, and the refractivity values K_i are constants. MF involved in this work are Niell MF (NMF, [8]) and Vienna MF (VMF1, [2]). Both follow the same expression:

$$m(\varepsilon) = \frac{1 + \frac{a}{1 + \frac{b}{1+c}}}{sen(\varepsilon) + \frac{a}{sen(\varepsilon) + \frac{b}{sen(\varepsilon)+c}}},$$

but they differ in their way of computing the coefficients a, b and c, for both MF (wet and dry). VMF1 proposes in its fast version to obtain the a_h and a_w parameters through raytracing and $b_{h,w}$ and $c_{h,w}$ as follows:

$$b_h = 0.002905 \qquad b_w = 0.00146$$

$$c_h = 0.0634 + 0.0014cos(2\varphi) \qquad c_w = 0.04391$$

NMF has tabulated coefficients with a resolution of 15° in latitude, φ, independent of longitude. Their time variation and correction in height, for the epoch t, are described as:

$$x = x_{avr} + x_{amp}cos\left(\frac{2\pi(t - T_0)}{365.25}\right) \quad \text{and} \quad \Delta m(\epsilon) = \frac{dm(\varepsilon)}{dh}H$$

where T_o=28d is the phase

Methodology: Data & Experiments

We have implemented VMF1 in TOMION software [5, 6] as another option to the already implemented NMF for 20 years. In fig. 2 we are schematizing the flow of implementation of the new MF: as the processing begins, the software would automatically download the file from the web [4] for the corresponding date which contains the coefficients a_h and a_w. This coefficients will serve as input go the *Vienna* function that will give the parameters m_h and m_w that will later take part of the design of the matrix for the Kalman filter. On the other hand, it would also download the grid where temporal variations with annual and semiannual terms of the P_s, T_m, e_s and Λ parameters are modeled for each point with a resolution of 1 x 1° and the subroutine *gpt2_w* will perform the interpolation for the coordinates of the site. These four computed values are introduced in the computations of *ZHD* and *ZWD*, and used for the *prefit* of the filter again.

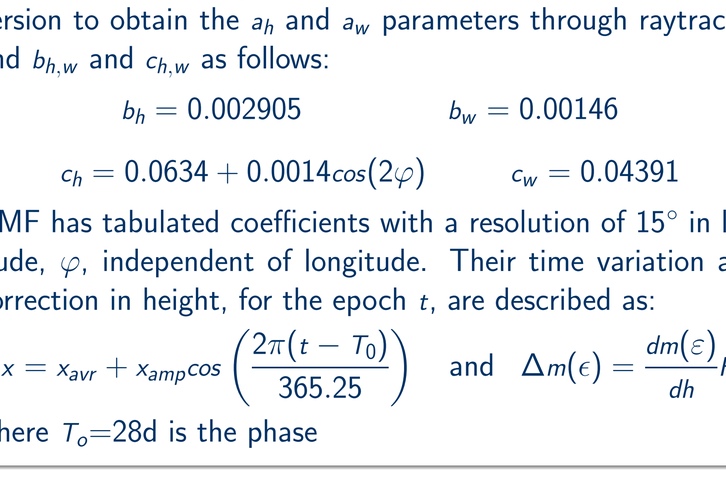


Figure 2: TOMION's Mapping Functions.

The data used for this work was GPS (Global Positioning System) pseudoanges in the ionospheric-free combination, both in Code and Phase (P_C and L_C). The processing mode was Precise Point Positioning (PPP) and the corrections applied were: Geometric Range, Correction Clock, Instrumental Delays, Atmospheric Effects, Carrier Phase Wind-up Effect, Antenna Phase Centre Correction and Earth Deformation Effects, among others.

Experiment:

- Annual Run
- 8 IGS stations SE Australia
- Year 2014
- Reference: **site**

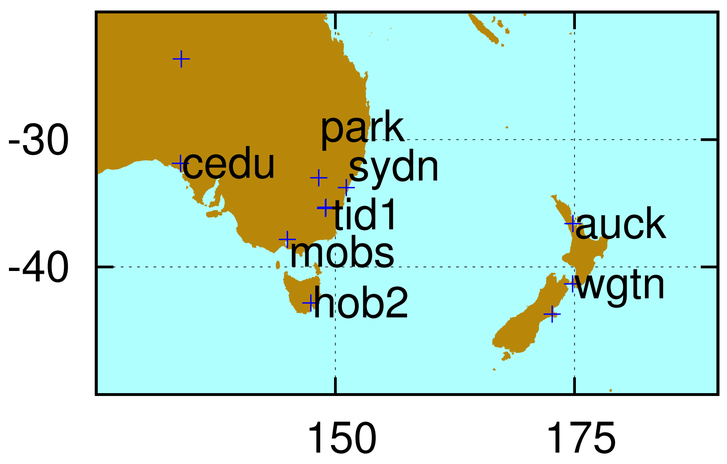
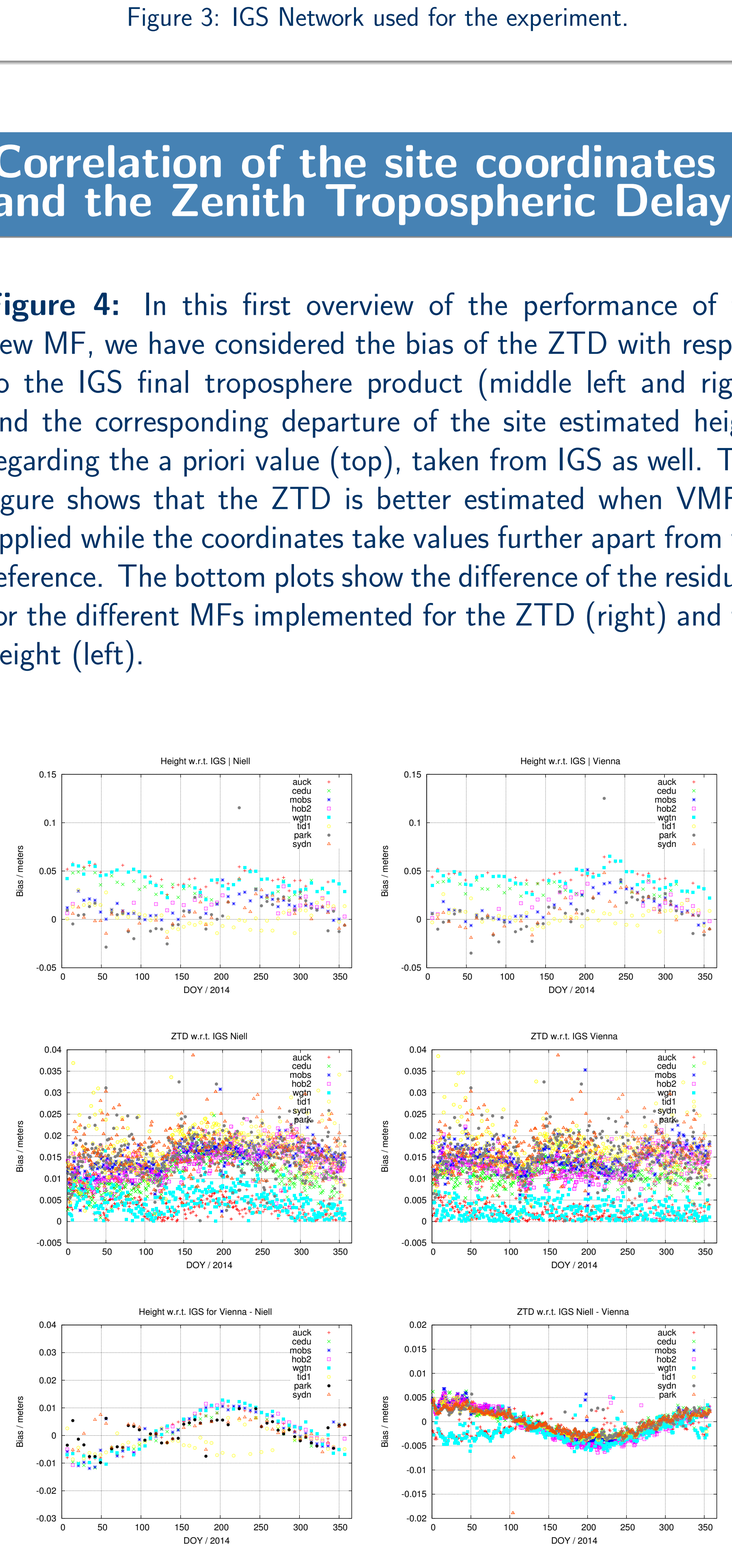


Figure 3: IGS Network used for the experiment.

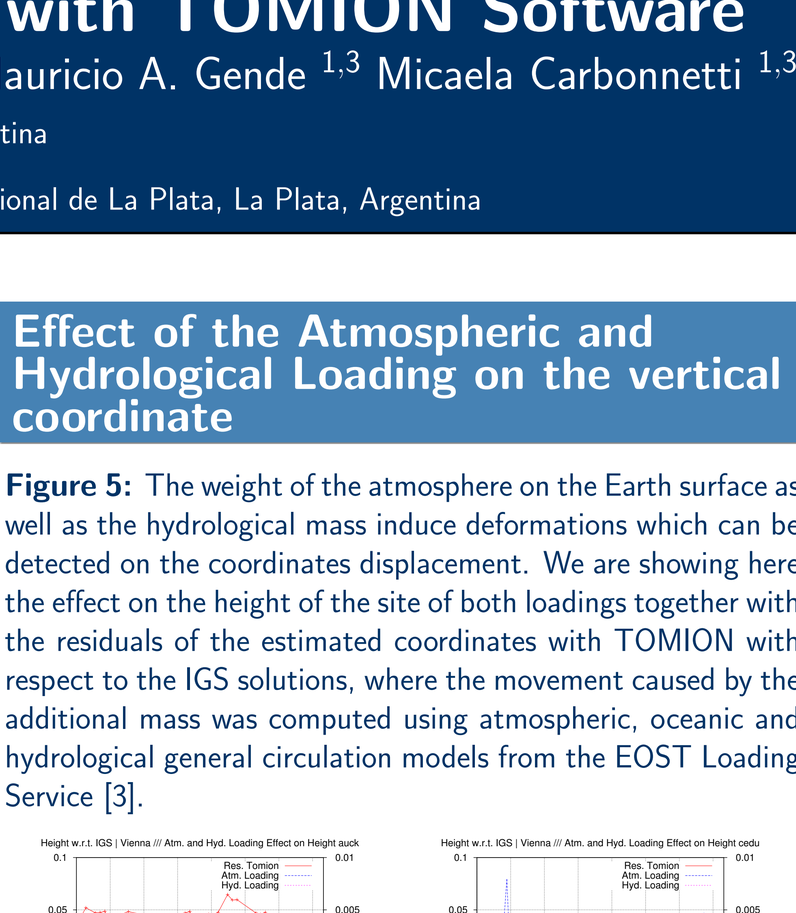
Correlation of the site coordinates and the Zenith Tropospheric Delay

Figure 4: In this first overview of the performance of the new MF, we have considered the bias of the ZTD with respect to the IGS final troposphere product (middle left and right) and the corresponding departure of the site estimated height regarding the a priori value (top), taken from IGS as well. This figure shows that the ZTD is better estimated when VMF is applied while the coordinates take values further apart from the reference. The bottom plots show the difference of the residuals for the different MFs implemented for the ZTD (right) and the height (left).



Effect of the Atmospheric and Hydrological Loading on the vertical coordinate

Figure 5: The weight of the atmosphere on the Earth surface as well as the hydrological mass induce deformations which can be detected on the coordinates displacement. We are showing here the effect on the height of the site of both loadings together with the residuals of the estimated coordinates with TOMION with respect to the IGS solutions, where the movement caused by the additional mass was computed using atmospheric, oceanic and hydrological general circulation models from the EOST Loading Service [3].



Conclusions/Discussion

- The result of implementing a new troposphere mapping function in TOMION, Vienna MF (VMF1), led to a better estimation of the Zenith Tropospheric Delay.
- The use of Niell Mapping Function for projecting the ZTD into the line of sight can drive to a misinterpretation of the vertical coordinate of the site, in some of the cases.
- We have identified a potential correlation between the residual of TOMION's estimates of the height of the site and the displacement caused by the mass of the atmosphere and water on the Earth's surface, but further research regarding their relationship must be carried out.

References

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