Assessment of different variables influence to determinate the tropospheric delay with near real-time GNSS

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1. Introduction

The interest of meteorology in GNSS measurements is motivated by their high sensibility in relation to the content of water vapour of the atmosphere. Fast and accurate signal delay estimation enables to improve the numerical weather prediction models. The European project **E-GVAP (EUMETNET EIG GNSS water vapour programme)** looks for achieving this purpose. National Geographic Institute of Spain participates in the hourly and near real-time estimation of tropospheric signal delay.

Zenith Total Delay (ZTD) determination is possible by using GNSS observations. The ZTD is the zenith projection of the total delay in the oblique ray direction satellite-receiver. This parameter can be modelled to obtain Integrated Water Vapour (IWV) that is necessary in numerical weather prediction models.

The final accuracy of ZTD estimation is related to different variables, such us: orbits, network design, constrained coordinates of the stations, a priori tropospheric model or the use of atmospheric and ocean tidal loading corrections. To evaluate the influence of these factors in the final estimation is essential for achieving the optimal processing strategy.

2. Goal

The aim of the present work is to **estimate the ZTD under different assumptions and to evaluate the final results** by comparing them with the EUREF troposphere delay solution used as a reference. The EUREF solution is the result of combining different analysis centres estimations with an hourly sample rate.

The assumptions are:

- To evaluate the impact in the **final solution by using orbits and ERPs from the Centre for Orbit Determination in Europe (CODE) or from the International GNSS Service (IGS).** In both cases GPS and GLONASS satellites are considered.
- To estimate the differences between **use only GPS or GPS+GLONASS observations** in the ZTD estimation.
- To analyse how **changes in the constrained coordinates of the stations** affect ZTD.
- To process the ZTD with different **network designs**.
- To **considerate or not ocean and atmospheric tidal loading corrections**.
- To use distinct a priori tropospheric models: **Global Mapping Function (GMF) or Vienna Mapping Function (VMF).**

3. Materials and Methods

GNSS data: **Only EUREF and IGS stations** have been considered for the evaluation of the different cases (**82 stations**). The processing has been carried out at near real-time (each hour during the 1817 GPS week). This temporal window has been selected because of its high humidity percentage in the Iberian Peninsula. Wet component of the ZTD is the most spatial and temporal variable and difficult to modelate. For this reason its influence is the most interesting to evaluate.

Software : Bernese 5.2.

Orbits and Earth Rotation Parameters:
Ultra Rapid CODE orbits and ERPs.
Ultra Rapid (half predicted) IGS orbits and ERPs.

Ocean loading tidal model: FES2004.

A priori tropospheric model:
Vienna Mapping Function Fast Coefficients.

4. Results

1. IGS vs CODE orbits and ERPs

Two ZTD estimations have been calculated with different ultra rapid orbits and ERPs. The results are shown below:

Mean absolute ZTD difference between the solutions with IGS or CODE products (GPS+GLONASS observables): **0.2 mm.**

Mean absolute ZTD differences between these solutions and the EUREF combined product: **4.4 mm** in both cases.

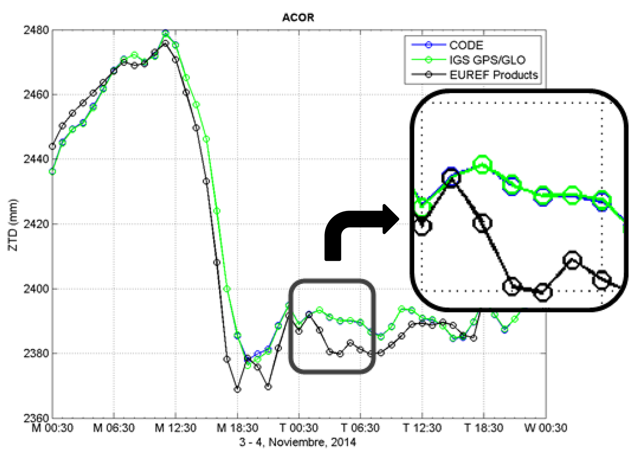

***Figure 1**. ZTD for ACOR station. Black: EUREF ZTD solution; Blue: ZTD solution with CODE orbits and ERPs; Green: ZTD solution with IGS (GPS+GLONASS) orbits and ERPs.*

2. GPS vs GPS+GLONASS observables

Only GPS observables have been taken into account in the first case and GPS+GLONASS in the second one. In both estimations IGS products have been used. The results are shown below:

Mean absolute ZTD difference between both solutions: **2.2 mm**

Mean absolute ZTD differences between these solutions and the EUREF combined product: **5.5 mm** with only GPS observables and **4.4 mm** with GPS + GLONASS observables.

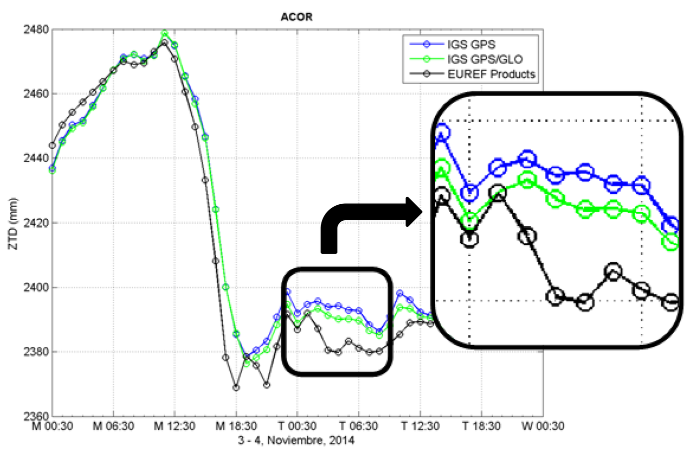

***Figure 2**. ZTD for ACOR station. Black: EUREF solution; Blue: ZTD solution with only GPS; Green: ZTD solution with GPS+GLONASS .*

3. Constrained stations coordinates

For evaluating how global changes in the constrained coordinates affect in the estimation, an offset of 5 cm is added in the up component of all the stations. The results are shown below:

Mean absolute ZTD difference between both solutions: **0.3 mm**.

Mean absolute ZTD difference between these solutions and the EUREF combined product: **4.4 mm** in both cases.

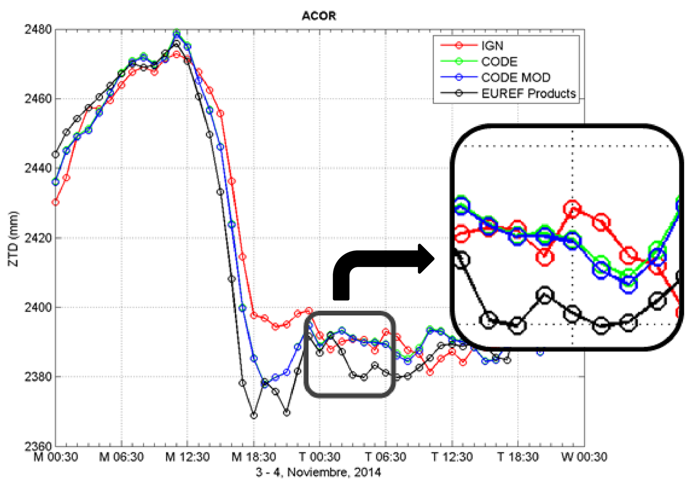

***Figure 3**. ZTD for ACOR station. Black: EUREF solution; Green: ZTD solution with accurate constrained coord.; Blue: ZTD solution with modify constrained coord.; Red: IGN solution.*

In order to see how local changes can affect ZTD. A new experiment is carried out modifying only the coordinates of one station (ALME). The up component is changed 5 cm (local deformation) and in this case the ZTD suffers an important change. The near stations are affected too (MALA, CEU1) and the influence is lower in far stations (ACOR,BADH).

Station	ZTD *not modify coord.*	ZTD *modify coord.*	Absolute Difference
ACOR	2467.7 mm	2467.9 mm	0.2 mm
ALME	**2431.7 mm**	**2425.6 mm**	**6.1 mm**
MALA	2443.0 mm	2443.3 mm	0.3 mm
CEU1	2450.3 mm	2450.7 mm	0.4 mm
BADH	2368.6 mm	2368.7 mm	0.1 mm

***Table**. ZTD before and after modifying the a priori coordinates in the up component of ALME station.*

4. Network design

Two networks have been processed. The first one with 82 stations and a reduced network with 67 stations. The results are shown below:

Mean absolute ZTD difference between these networks: **1.5 mm.**

Mean absolute ZTD differences between these solutions and the EUREF combined product: **4.4 mm** in both cases.

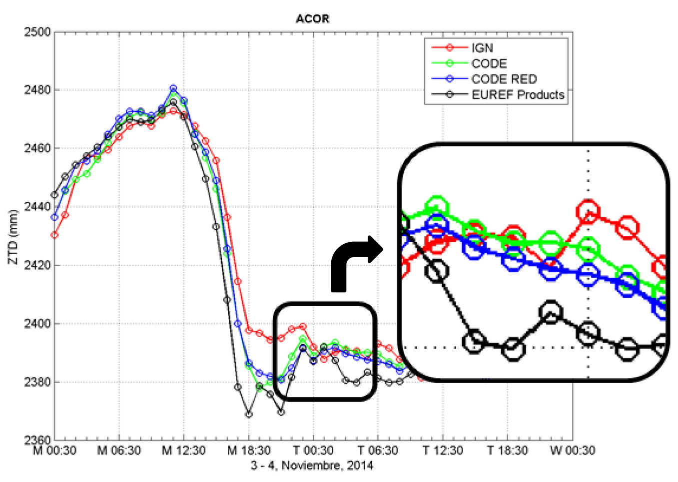

***Figure 4**. ZTD for ACOR station. Black: EUREF solution; Green: ZTD solution with 82 stations; Blue: ZTD solution with 67 station; Red: IGN solution (about 350 stations).*

5. Ocean and atmospheric tidal loading models

ZTD solutions with and without ocean and atmospheric tidal loading corrections have been calculated. The results are shown below:

Mean absolute ZTD difference between both solutions: **0.7 mm**. Higher values have been obtained in near coast stations (~ 1.5-3 mm) than in the remainding stations (~ 0.3mm).

Mean absolute ZTD differences between these solutions and the EUREF combined product: **4.4 mm** with correction models and **4.6 mm** without them.

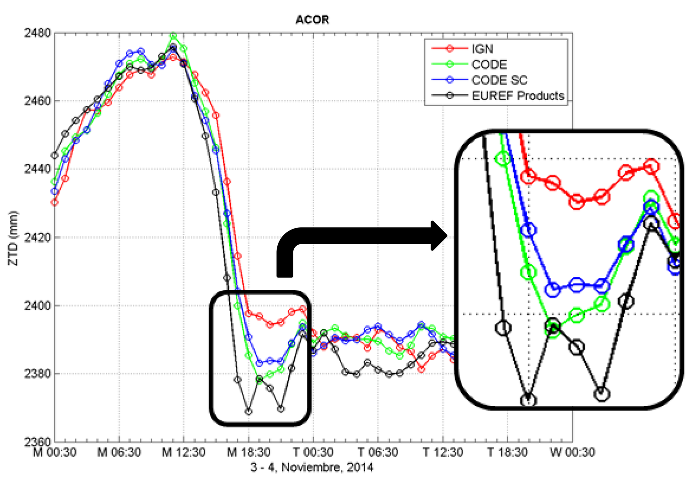

***Figure 5**. ZTD for ACOR station. Black: EUREF solution; Green: ZTD solution with correction models; Blue: ZTD solution without correction models; Red: IGN solution .*

6. A priori troposphere model

A priori troposphere models are used to modelate the dry component of the ZTD. These models are essential due to dry component means about 90% of the total delay. ZTD estimations with two models have been compared: The Global Mapping Function (GMF) and the Vienna Mapping Function (VMF). The results are shown below:

Mean absolute ZTD difference between both solutions: **7.6 mm.**

Mean absolute ZTD differences between these solutions and the EUREF combined product: **4.4 mm** with GMF and **8.6 mm** with VMF.

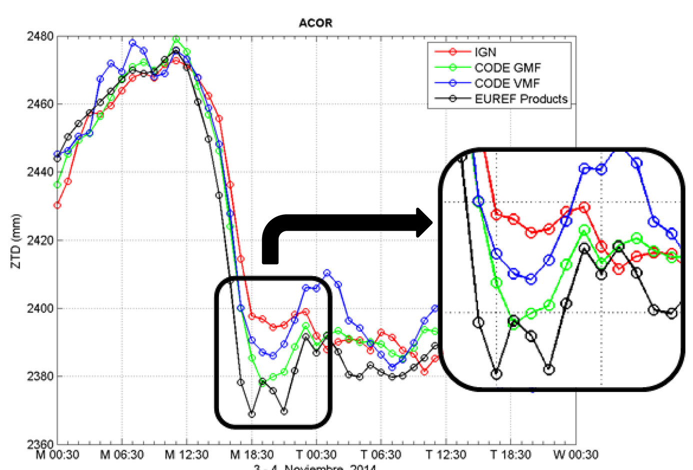

***Figure 6**. ZTD for ACOR station. Black: EUREF solution; Green: ZTD solution with GMF; Blue: ZTD solution with VMF; Red: IGN solution.*

5. Conclusions

- No relevant differences have been obtained in the ZTD estimation with ultra rapid CODE or IGS orbits and ERP. Consequently, both products can be used equally.
- Significant differences have been found between the determinated ZTD results with only GPS or GPS + GLONASS. The second solution is the most similar to the EUREF troposphere solution.
- Relative variations in the constrained coordinates have influence in the ZTD estimation. Updated coordinates are needed for the optimal ZTD determination.
- Network configuration is closely related to ZTD estimation but real ZTD values would be necessary for understanding this relationship.
- Atmospheric and ocean tidal loading models are essential for achieving an accurate ZTD solution mainly in near coast stations.
- The a priori troposphere model has an important impact in the final ZTD. Better results have been obtained with GMF in the rapid processing than with VMF Fast Coefficients.

6. Bibliography

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