Comparison of IGS final troposphere estimates with ray-traced delays

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1 Introduction

At the 2012 workshop of the International GNSS service (IGS) the members of the IGS troposphere working group resolved to work on an automated on-line comparison of the final troposphere estimates with different techniques. In this context we present results of a 52-months comparison campaign in which IGS tropospheric delays are compared with those derived by ray-tracing through operational analysis data from the European Centre for Medium-Range Weather Forecast (ECMWF).

2 IGS final troposphere estimates

Since April 2011 the United States Naval Observatory (UNSO) provides the final troposphere estimates - zenith tropospheric delays (ZTD), gradients (GE, GN) and its formal errors - from observation data of about 350 GNSS sites of the IGS network. Therefore GNSS observations are processed undifferenced with the software package Bernese 5.0 using 27h observation batches and IGS final orbit and clock products. The estimates are provided on a daily basis in the SINEX tropo format with a temporal resolution of 5 min and with a latency of 22 days (see Byram & Hackman 2012).

All available SINEX files since 2012 are downloaded from the USNO server (ftp://maia.usno.navy.mil/GPS/tropo). Table 1 and Figure 1 give an overview about the available dataset covering the period from 01/2012 to 04/2014 (52 months).

year	# stations	# files
2012	375	110730
2013	380	118857
2014	356	35651

Table 1: SINEX tropo files provided by UNSO

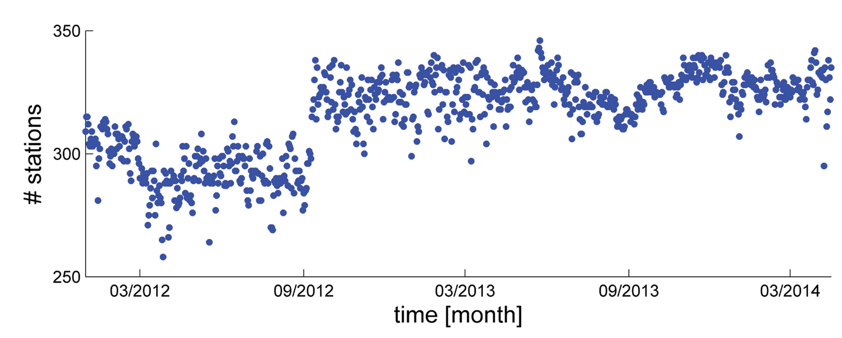
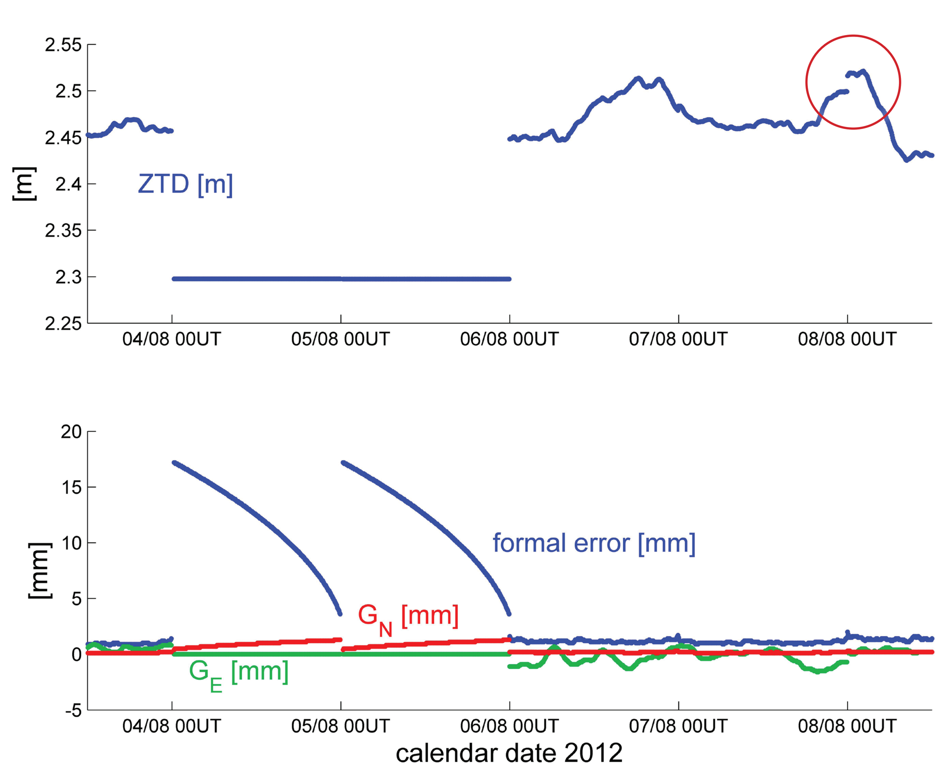


Figure 1: Processed GNSS stations per day

In a first run files containing conspicuous records are identified and removed.



These records are:

- outliers in the ZTD time series
- erroneous characters like '******' or just
- a priori ZTDs (see Figure 2)

Figure 2: Troposphere estimates for GNSS site Les Abymes (Guadeloupe). The upper plot shows the ZTD [m]. Between 04/08 00UT and 06/08 00UT just the a priori ZTD is stored in the SINEX files. This goes along with a large formal error.

In addition Figure 2 highlights discontinuities at the day border (red circle). Although 27 h batches are processed these effects cannot be avoided entirely.

4 IGS vs. ray-traced troposphere delays (global)

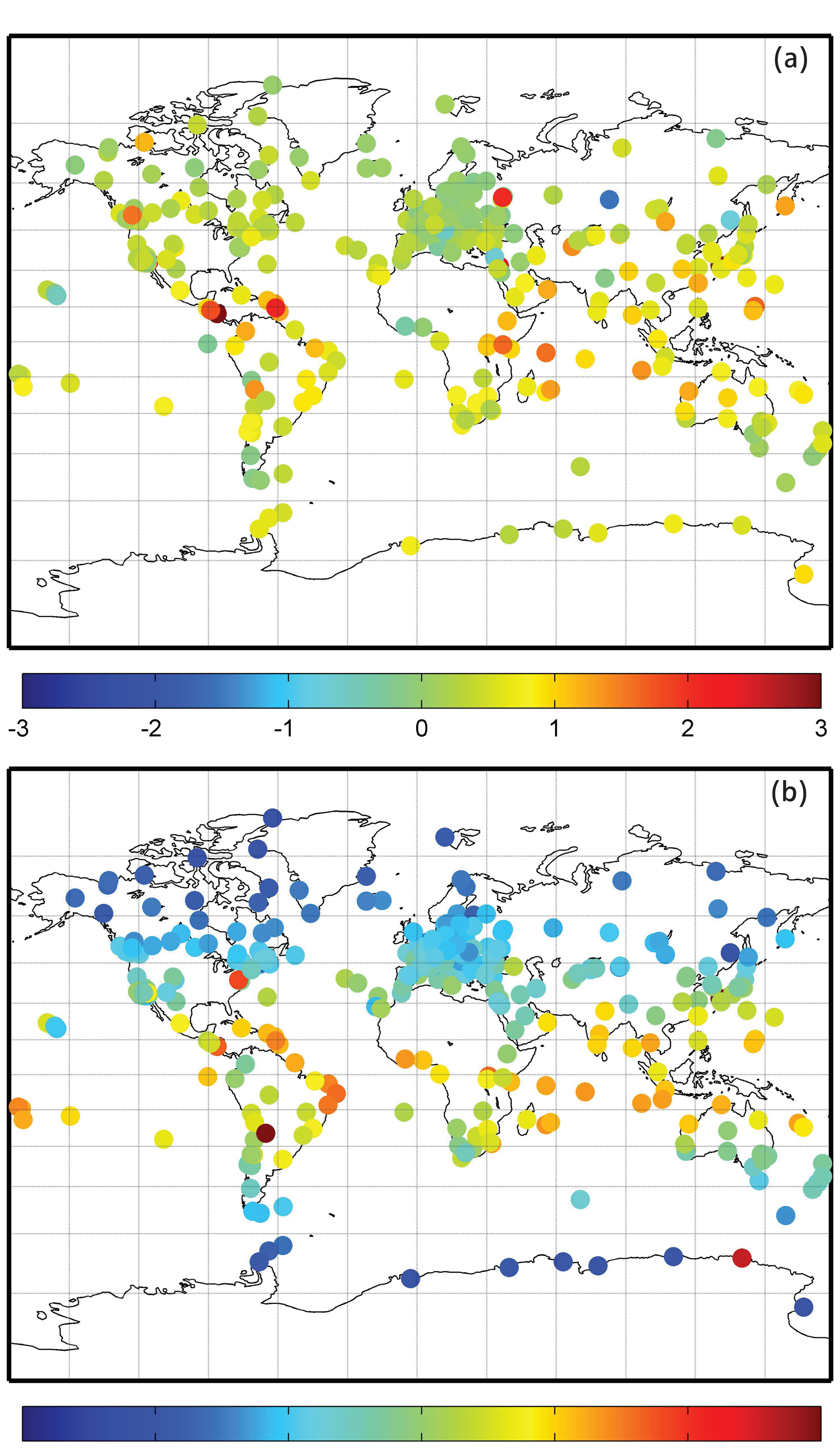


Figure 3: Bias (a) and Standard deviation (b) of the differences in ZTD in [cm]

For the comparison of IGS and ray-traced ZTDs 379 common GNSS stations have been identified. For each station the differences in ZTD and further statistical parameters are computed. Figure 3 (a) shows the bias and Figure 3 (b) the standard deviation of the differences in ZTD derived over a period of 52 months (01/2012 to 04/2014).

Both, the IGS and the ray-traced ZTDs are sensitive to weather phenomena. Hence the residuals between both datasets are rather small (in 95% within the range of -1.7 cm and 3.0 cm). Nevertheless, ray-traced ZTDs are slightly smaller than IGS ZTDs which leads in 80 % to a positive bias.

The standard deviation of the ZTD correlates highly with the distribution of water vapour. It varies between 0.4 cm and 3.4 cm with largest values in the tropics or subtropics and smallest values at higher latitudes.

	all stations	max (station)
Bias	0.44 cm	3.96 cm (MANA)
Std. dev	1.35 cm	3.36 cm (UNSA)

Table 2: Statistics over all GNSS sites - calculated over the period from 01/2012 until 04/2014. Outliers have been removed in advance.

3 Ray-traced vertical delays

The ECMWF provides a broad range of meteorological datasets. Ray-tracing through operational pressure level data of the ECMWF is carried out to get the coefficients ah and aw for the Vienna Mapping Function (see Böhm et al. 2006). Zenith hydrostatic and wet delays are a kind of by-product. Both are provided on a routine basis since 2002 with a temporal resolution of six hours. They can be downloaded with a latency of less than 34 hours from our webpage (http://ggosatm.hg.tuwien.ac.at/DELAY/) - either on global grids or for selected IGS, IVS and IDS stations. The ellipsoidal coordinates (name, latitude, longitude, height, domes number) of the GNSS stations are downloaded from the IGS webpage and updated regularly.

In order to compare the tropospheric estimates with those derived by IGS the zenith hydrostatic and wet delays are added to obtain the ZTD. For every IGS site a time series of the ZTD is created covering the period of 52 months as defined for the IGS troposphere delays (see Chapter 2).

5 IGS vs. ray-traced troposphere delays (site-wise)

Figure 4 highlights GNSS stations which have been identified in Figure 3 showing large deviations. A closer look into the ZTD time series discloses systematic errors.

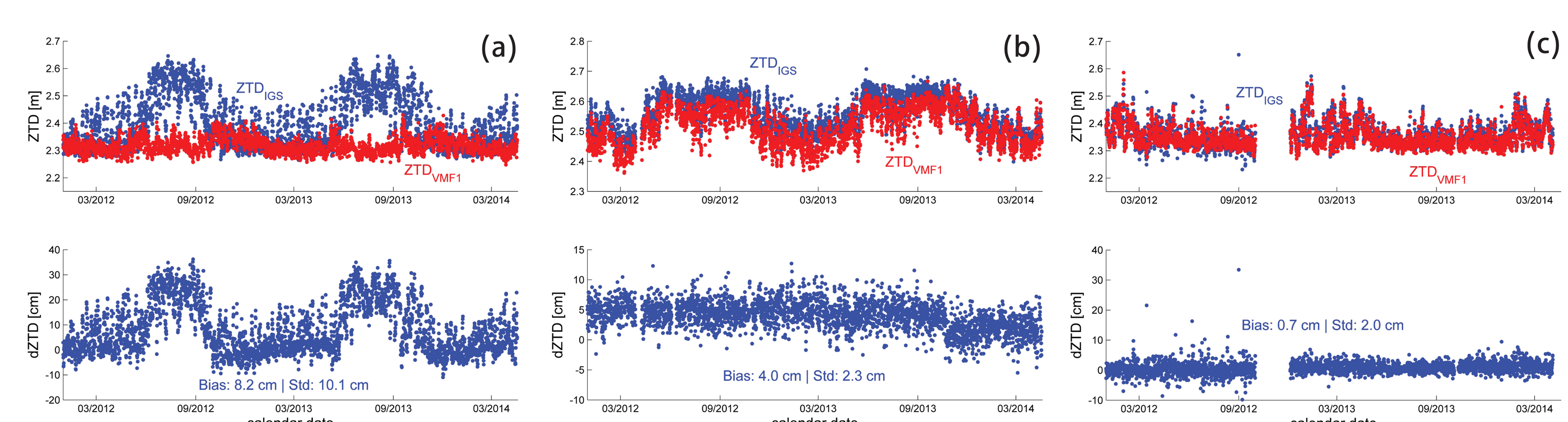


Figure 4: ZTD time series for GNSS station (a) Aira (Japan), (b) Managua (Nicaragua), (c) New Norcia (Australia)

Station Aira, as visualised in Figure 4 (a), is an extreme example. So far the effects causing such an extraordinary behaviour have not been revealed.

One reason could be inconsistencies in the station coordinates. Hence we compared the approximate coordinates provided by IGS (which are used to derive the ray-traced delays) with the precise coordinates estimated together with the tropospheric estimates by UNSO as well as with the ITRF2008 coordinates provided by the ITRF (http://itrf.ensg.ign.fr/). In Table 3 stations are listed with inconsistencies in height larger than 20 m (50 m).

Figure 4 (b) shows the effect if a wrong station height is introduced to the ray-tracing algorithm. An error in height of 100 m leads to a bias in ZTD of about 4 cm. In October 2013 this has been corrected - at least for station Managua. We appreciate an update of the approximate coordinates of the other GNSS stations by IGS.

criteria	stations
dh_{ell} > 20 m	CONT, GUAO, HOLM, KIT3, NICO, POTS, SSIA, ULAB
dh_{ell} > 50 m	DRAG, MANA, ZWE2

Table 3: IGS sites with poor approximate positions, dh_{ell} is the difference in height w.r.t. the reference height.

Undocumented changes of the equipment or poor calibrated GNSS antennas are a large error source as well. Figure 4 (c) illustrates the effect of an equipment change at GNSS site New Norcia. In December 2012 antenna ASH701945C_M was replaced by SEPCHOKE_MC. Since that time the ZTD time series are mainly devoid of outliers.

6 Conclusions & Outlook

- The agreement of GNSS estimated ZTDs with those derived by ray-tracing can be specified with 0.5 cm in bias and 1.4 cm in standard deviation.
- These precision allows to identify systematic errors in both techniques - like inconsistencies in station coordinates or undocumented equipment changes.
- The GNSS delays as well as the ray-traced delays are already provided on a routine basis. A fully automated comparison as well as an online comparison tool is discussed in the IGS troposphere working group.

References

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