Data Descriptor

Long-Term GNSS Tropospheric Parameters for the Tropics (2001-2018) Derived from Selected IGS Stations

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Abstract

This paper describes dataset "Tropospheric parameters derived from selected IGS stations in the tropics for the years 2001-2018" contains GNSS-derived zenith tropospheric delay (ZTD), a posteriori corrected zenith wet delay (ZWD), and precipitable water vapour (PWV) time series. These troposphere-related data were estimated for the Jan 2001 – Dec 2018 period for 43 International GNSS Service (IGS) stations located across the global tropics. As one coherent strategy for the processing of the GNSS observations was adopted, the dataset is a robust source of long-term, homogeneous tropospheric time series, which can be used in meteorological and climate-related studies. It enables the examination of moisture patterns on numerous time scales, including seasonal and interannual variability.

Keywords: GNSS, PWV, water vapour, tropics, climate monitoring

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Specification table (data records)

Subject area	Meteorology, Climate, Remote Sensing
More specific subject area	Atmospheric water vapour variability
Type of data	Text

How the data was acquired	The data were created based on GNSS observations (Jan 2001 – Dec 2018) from 43 IGS stations located across the global tropics and the ERA5 model as a source of meteorological parameters
Data format	Formatted ASCII files
Experimental factors	GNSS observations were processed using Bernese GNSS Software ver. 5.2
Data source location	MOST Wiedzy Open Research Catalog, Gdańsk University of Technology, Gdańsk, Poland
Data accessibility	The dataset is accessible and is publicly and freely available for any research or educational purposes

Background

The global navigation satellite systems (GNSS) signal passing through a neutral atmosphere is delayed due to atmospheric refraction. The size of this delay significantly affects coordinate estimation and thus has to be estimated during advanced processing of the GNSS observations. It was agreed to express its value towards the zenith direction (zenith tropospheric/total delay, ZTD) although it is estimated based on the slant direction between a receiver and each of the observed satellites. In general, it consists of delays caused by the hydrostatic (zenith hydrostatic delay, ZHD) and wet (zenith wet delay, ZWD) components of the atmosphere.

Due to the fact that determination of precise and accurate coordinates requires accurately estimated ZTDs, GNSS-derived tropospheric parameters have become a valuable source of meteorological and climate data, especially considering the fact that the GNSS permanent network has been operating since 1996. Although the ZTD alone can be used for climate and meteorological analysis (Baldysz et al., 2015), it can also be used for ZWD extraction, which is strongly related to the water vapour content in the atmosphere. In addition, using selected meteorological parameters, it can be converted into the precipitable water vapour (PWV) parameter (Bevis et al., 1992), which directly refers to the total water vapour content in the atmosphere. This is, in turn, the most important natural greenhouse gas. It is characterised by the single highest positive feedback on the surface temperature (Hansen et al., 1984) and dominates the effect of the Earth's surface temperature increase (Kiehl and Trenberth, 1997). It is also a key factor in the formulation of weather conditions, including severe weather events. Thus, monitoring of the water vapour content in the atmosphere as it changes over time, on numerous time scales from seasonal to interannual, is an important task in understanding its role in a changing climate.

Despite the fact, that GNSS is not a direct method of measuring PWV, application of an appropriate processing strategy enables utilisation of GNSS PWV time series as a valuable source for long-term analysis. Its accuracy is similar to the PWV derived from radio sounding measurements (Baldysz et al., 2018).

The special role which the tropics plays in formulating global climate results from the fact that they are a major centre of atmospheric convection. Through atmospheric teleconnections, tropical weather patterns also have a significant impact on mid- and high-latitude weather conditions. As a consequence, analysis of the variability of GNSS-derived tropospheric parameters over the tropics, such as ZTD, ZWD and PWV, is an important task in climate monitoring.

Methods

ZTD is usually estimated during advanced processing of GNSS observations according to the following formula:

$$ZTD = ZHD + ZWD = mf_h(el) \cdot SHD + mf_w(el) \cdot SWD + mf_g(G_N \cos\alpha + G_E \sin\alpha) \quad (1)$$

where: and are the hydrostatic and wet slant delays in the direction of a satellite, and are mapping functions, dependent on the elevation angle () used to project them on the zenith direction, and denote azimuth () dependent gradients defined to the north and east direction, while is the gradient mapping function. Although during GNSS observation processing, ZTD estimation relies on the same steps, there are number of models, numerical approaches and calculation assumptions that affect its final reliability. Thus, they can limit the credibility of conclusions drawn based on them. In this dataset, the adopted GNSS processing strategy was verified through long-term comparison of the GNSS PWV and radio-sounding PWV, thus ensuring its high accuracy (Baldysz and Nykiel, 2019). Detailed information about the adopted processing strategy is given in Tab. 27.1.

Tab. 27.1

GNSS processing strategy used in this study.

GNSS processing parameter	value/name
software	Bernese 5.2 GNSS Software (Dach et al., 2015)
method	Precise point positioning (PPP)
data	30-second GPS
a priori ZHD	Vienna Mapping Function 1 (Boehm et al., 2006)
a posteriori ZHD	Saastamoinen model (1972)
troposphere mapping function	Vienna Mapping Function 1

gradients mapping function	Chen and Herring (1997)
cut-off angle	5°
ephemerides (clocks and orbits)	CODE R2 (Steigenberger et al., 2014)
antenna models	IGS08
reference frame	IGb08
ZWD estimation	Saastamoinen model using meteorological parameters from the ERA5 model
ZWD to PWV conversion	Water vapour weighted mean temperature based on the Bevis formula (Bevis et al., 1992) and the temperature from the ERA5 model

Generally, in the advanced processing of GNSS observations, the ZHD value is a priori and adopted from the numerical weather (or empirical) model, while the ZWD is estimated as an additional, unknown parameter. The sum of these two values is expressed as the ZTD. Nevertheless, the ZWD obtained in such a way contains both the wet delay and correction to the inaccurately modelled ZHD. Thus, in GNSS meteorology, the ZHD is also estimated a posteriori (based on observational or re-analysed meteorological data) and subtracted from the ZTD. For this purpose, the Saastamoinen (1972) model dependent on the total air pressure at the antenna height (, in hPa), station ellipsoidal latitude () and altitude (, in metres) is commonly used:

$$ZHD = \frac{0.0022767 \cdot P}{1 - 0.00266 \cdot \cos(2\varphi) - 2.8 \cdot 10^{-7} \cdot h} \quad (2)$$

Obtained in such a way, the ZWD is strictly related to the water vapour content in the atmosphere and consequently can be converted into the PWV, using the dependency:

$$PWV = \Pi(T_m) \cdot ZWD \quad (3)$$

where: is a dimensionless quantity dependent on the water vapour weighted mean temperature which can be retrieved via the following formula:

$$\Pi^{-1} = 10^{-8} \cdot \rho \cdot R_v \cdot (K_3/T_m + K_2') \quad (4)$$

where: is the specific gas constant of water vapour and equals 461.5 J/kg, is the density of water, while and are constant parameters related to the air refractivity (used values proposed by Ruger (2002)). In this dataset, was calculated using the Bevis formula (Bevis et al., 1992) and the surface temperature was derived from the ERA5 model (Hersbach et al., 2020).

The approach presented above was used to deliver hourly ZTD, ZWD (using a posteriori ZHD) and PWV for the 43 stations belonging to the International GNSS Service

(IGS) network (Johnston et al., 2017). The calculations covered the period from January 2001 to the end of December 2018. Fig. 27.1 shows the locations of the used stations.

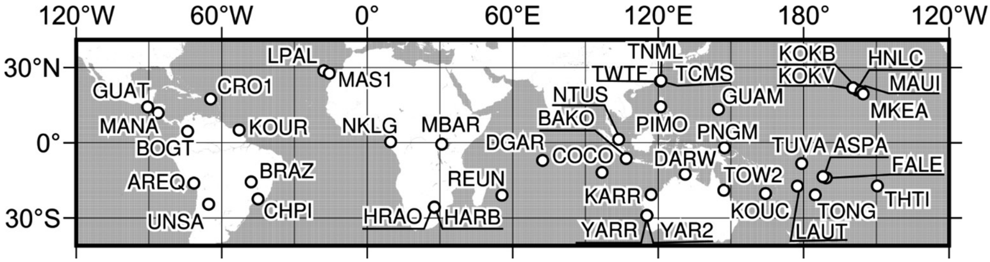

Fig. 27.1. Location of the IGS stations for which GNSS tropospheric parameters were estimated

Data quality and availability

GNSS ZTD, ZWD and PWV daily solutions were calculated as an average from hourly data. Daily solutions were adopted as reliable only when at least 16 hourly values were available (if less, the solution was removed). During the screening process, daily solutions exceeding the 3σ criterion were also removed. Note that the GNSS ZTD, ZWD and PWV daily solutions obtained in such way are not continuous. They may contains gaps related to the lack of observational data, its poor quality, etc. Also, we did not remove shifts that may have occurred as a result of a change in equipment at the station.

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