Multi-year GNSS monitoring of atmospheric IWV over Central and South America for climate studies

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1 Introduction

Although the past decade has seen a significant development of the GNSS infrastructure in Central and South America, its potential for atmospheric water vapour monitoring has not been fully exploited. With this in mind, we have performed a regional, seven-year-long and homogeneous analysis, comprising 136 GNSS tracking stations, obtaining high-rate and continuous observations of column integrated water vapour (IWV) and troposphere zenith total delay (ZTD).

As a preliminary application we have computed regional and local trends of water vapour content, together with realistic uncertainties, studying the correlation between these parameters and several climate regimes. In addition, we have analysed the regional performance of the troposphere model GPT2w (Dach et al., 2013).

2 Methods

GNSS data analysis

The observations were processed with the Bernese GNSS Software (Dach et al., 2015) at a double-difference level, and models recommended by the International Earth Rotation and Reference Systems Service (IERS) were used.

In addition, troposphere zenith total delays (ZTDs) were modelled as 30-minutes linear piecewise estimates, applying the wet term of the Vienna Mapping Function (VMF) (Fernández et al., 2013), together with daily gradients according to Böhm and Herring (1997).

A homogenous set of reprocessed GPS-GNASS precise orbits and clocks, generated by the Center for Orbit Determination in Europe (CODE), were used. In particular, we made use of the co2 orbits, clocks and EOPs generated as part of CODE’s rep2 re-analysis, from three-day long-arc solutions (Friedinger et al., 2014).

Computation of IWV time series

Zenith hydrostatic delays (ZHDs) were computed according to Dach et al. (2015), employing observed atmospheric pressure. Then, the computed ZHDs were subtracted from the observed ZTDs to retrieve the wet terms (i.e., ZWDs).

Finally, the ZWDs were scaled by a proportionality constant, as described by Böhm and Herring (1997), to obtain IWV estimates every 30 minutes.

We employed atmospheric pressure data sets provided by the University of Wyoming (UW), by the National Oceanic and Atmospheric Administration (NOAA) and by the IGS (RIMEX m-dex).

We derived the weighted mean temperature (Tm) from the 6-hourly model levels of the ERA-Interim NWP (Dee et al., 2011). For each GNSS site, Tm was computed at atmospheric levels corresponding to the nearest NWP model level above the GNSS benchmark. Then, interpolating linearly at the site’s location and at the observation epoch.

References

Böhm, R. and Herring, G. (2000). Evidence of drying of the troposphere in the mid-latitudes of South America has been found, at a mean IWV rate of approximately 2%, particularly in south Brazil and central-eastern Argentina.

3 Results

GNSS processing evaluation

We performed a site-per-site comparison with three different data sets produced by IGS (Table 1). In general, all the compared ZTD solutions show a good agreement, with long-term mean inter-biases lower than half a millimeter. The quality of our ZTD estimates is on par with both IGS repro-analysis and it surpasses the consistency of the operational products (Figs. 1 and 2).

Some of the systematic biases observed in South America seems to be related to the insufficient resolution of the GPT2w’s underlining topographic model to accurately reproduce the highly variable topography near the Andes.

IWV retrieving and analysis

Our IWV estimates (Fig. 4) were compared with co-located radiosonde observations from both radiosonde network and NWP. The estimated accuracy of our IWV estimates is almost better than 3 m kg m⁻², and satisfies the required accuracy for regional climate studies within the Global Climate Observing System (GCOS) specifications.

The estimated trends do correlate within regions with similar climate type (Table 3, Fig. 5). In particular, temperate regions in South America seem to be drying (Fig. 6), whereas the tropical areas in Central and South America and the Caribbean, as a whole, seem to experience a decrease in surface temperatures (Fig. 7).

4 Conclusions

Evidence of drying of the troposphere over temperate regions in South America has been found, at a mean IWV rate of approximately 2%, particularly in south Brazil and central-eastern Argentina.

This regional, multi-year, GNSS analysis has made also possible a robust performance assessment of the GPT2w blind model. The results showed the general good agreement between observed and modelled mean delays, but also scaled some limitations (up to 20 mm in ZTD).

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Table 1: The IGS products employed for the ZTD estimate evaluation.

Table 2: Comparison between IWV retrieved with co-located radiosonde and our GNSS derived estimates.

Table 3: Mean IWV trends computed within regions of similar climate types, in Central and South America and the Caribbean, between January 2007 and December 2013. NWP: ERA-Interim. The IGS products employed for the ZTD estimates evaluation.