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Estimation and Assessment of GNSS-derived Zenith Tropospheric Delays from SIRGAS-CON network, with application to Satellite Altimetry

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Introduction

Satellite Altimetry is one of the main techniques for observing the oceans on a global scale and has contributed to the knowledge of the Mean Sea Level (MSL) and its variations. The main measurement of altimetric satellites is the distance between the satellite and the ocean surface (Range), which is incorrect owing to errors caused by the interaction of the signal with the atmosphere and the sea surface, requiring corrections to account for these effects. The Wet Tropospheric Correction (WTC) is one of the required corrections, mainly due to the atmospheric water vapour, and it is symmetrically equivalent to Zenith Wet Delay (ZWD). The altimetric satellites are equipped with instruments called Microwave Radiometers (MWR), which measure the amount of water vapour under the satellite path, providing information for the estimation of the WTC. MWR fails in coastal regions and inland waters, due to land contamination present in these areas. In view to recover the WTC in these regions, the GNSS (Global Navigation Satellite System) derived Path Delay Plus (GPD+) method (Fernandes and Lázaro, 2016), developed by the University of Porto, uses Zenith Tropospheric Delays (ZTD) from GNSS global and regional networks' stations combined with other sources of information, such as valid on-board MWR measurements, Scanning Image Microwave Radiometer (SI-MWR) and atmospheric models, providing a combined solution of WTC for all along-track altimeter points. In order to densify the existing dataset used by GPD+, it is necessary to add new stations, mainly in the southern hemisphere, in regions such as South America, Africa and Oceania.

Objectives

The major goal of this study is to exploit the SIRGAS-CON ZTD (Mackern et al., 2020), from January 2014 to December 2020, to densify the set of GNSS stations in Latin America used by GPD+ algorithm.

Materials and Methods

First, from the SIRGAS-CON set of ZTD, the ZWD was calculated, subtracting the Zenith Hydrostatic Delay (ZHD) calculated from ERA5 atmospheric models, provided by the European Center for Medium-Range Weather Forecasts (ECMWF), since ZTD is the sum of ZHD and ZWD. The accuracy and stability of the ZWD were evaluated by comparison with ZWD from IGS solutions for stations that are part of both networks and ZWD from ERA5 for all stations. From this analysis, stations within the defined criteria (number of observations greater than 800, mean of differences with ERA5 less than 2.5 cm, standard-deviation of differences with ERA5 less than 2.5 cm and no descontinuities in time series) were selected for use in GPD+.

Two runs of the algorithm were carried out to calculate the WTC; one with the current operational networks used by GPD+ (GPD+1) and another one adding SIRGAS-CON (GPD+2). To assess the impact of SIRGAS-CON on the algorithm performance, a comparison between both sets of GPD+ WTC with GNSS-derived WTC has been performed for Sentinel-3A (S3A), Sentinel-3B (S3B) and CryoSat-2 (CS2) altimetry points. Calculation and statistical analysis were performed in MATLAB 2021 and Excel. The fluxogram in figure 1 shows the main steps of this work.

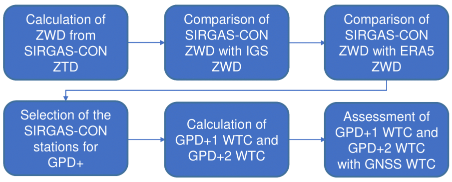

Figure 1 – Work fluxogram.

Results and conclusions

A total of 366 stations were selected as eligible to be included in GPD+. From a total number of 467 stations with available ZTD, 38 stations were rejected by the defined criteria and 63 were not considered in the selection because they are already included in GPD+, since they are part of the IGS network.

As for the final results, there was a decrease in the RMS of the differences between GNSS-derived WTC and the GPD+2 when compared to the differences with GPD+1 (figure 2) for the three satellites, from January 2014 to December 2020 for CS2 and from the beginning of the missions until December 2020 for S3A and S3B. The impact is greater at the points closer to the coast, where the MWR fails, extending up to 25 km away from the coast for points in S3A and S3B, while for CS2 this impact is up to 70 km away from the coast, since this satellite has no on-board MWR. With these results, it can be concluded that the objective of improving the performance of the GPD+ with the SIRGAS-CON stations addition was achieved.

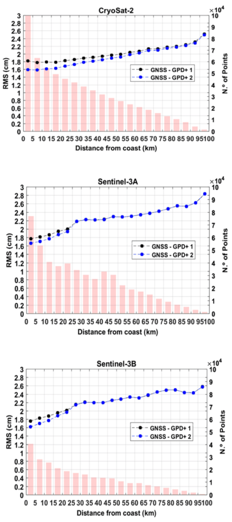

Figure 2 – RMS of differences between GNSS-derived WTC and GPD+1 WTC (black) and between GNSS-derived WTC and GPD+2 WTC (blue) for CS2 (top), S3A (middle) and S3B (bottom) points.