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Studies on spatio-temporal filtering of GNSS-derived coordinates

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The information about lithospheric deformations may be obtained nowadays by analysis of velocity field derived from permanent GNSS (Global Navigation Satellite System) observations. Despite developing more and more reliable models, the permanent stations residuals must still be considered as coloured noise. Meeting the GGOS (Global Geodetic Observing System) requirements, we are obliged to investigate the correlations between residuals, which are the result of common mode error (CME). This type of error may arise from mismodelling of: satellite orbits, the Earth Orientation Parameters, satellite antenna phase centre variations or unmodelling of large scale atmospheric effects. The above described together cause correlations between stochastic parts of coordinate time series obtained at stations located of even few thousands kilometres from each other. Permanent stations that meet the aforementioned terms form the regional (EPN – EUREF Permanent Network) or local sub-networks of global (IGS – International GNSS Service) network. Other authors (Wdowinski et al., 1997; Dong et al., 2006) dealt with spatio-temporal filtering and indicated three major regional filtering approaches: the stacking, the Principal Component Analysis (PCA) based on the empirical orthogonal function and the Karhunen-Loeve expansion. The need for spatio-temporal filtering is evident today, but the question whether the size of the network affects the accuracy of station's position and its velocity still remains unanswered. With the aim to determine the network's size, for which the assumption of spatial uniform distribution of CME is retained, we used stacking approach. We analyzed time series of IGS stations with daily network solutions processed by the Military University of Technology EPN Local Analysis Centre in Bernese 5.0 software and compared it with the JPL (Jet Propulsion Laboratory) PPP (Precice Point Positioning). The method we propose is based on the division of local GNSS networks into concentric ring-shaped areas. Such an approach allows us to specify the maximum size of the network, where the evident uniform spatial response can be still noticed. In terms of reliable CMEs extraction, the local networks have to be up to 500-600 kilometres extent depending on its character (location). In this study we examined three approaches of spatio-temporal filtering based on stacking procedure. First was based on non-weighted (Wdowinski et. al., 1997) and second on weighted average formula, where the weights are formed by the RMS of individual station position in the corresponding epoch (Nikolaidis, 2002). The third stacking approach, proposed here, was previously unused. It combines the weighted stacking together with the distance between the station and network barycentre into one approach. The analysis allowed to determine the optimal size of local GNSS network and to select the appropriate stacking method for obtaining the most stable solutions for e.g. geodynamical studies. The values of L1 and L2 norms, RMS values of time series (describing stability of the time series) and Pearson correlation coefficients were calculated for the North, East and Up components from more than 200 permanent stations twice: before performing the filtration and after weighted stacking approach. We showed the improvement in the quality of time series analysis using MLE (Maximum Likelihood Estimation) to estimate noise parameters. We demonstrated that the relative RMS improvement of 10, 20 and 30% reduces the noise amplitudes of about 20, 35 and 45%, respectively, what causes the velocity uncertainty to be reduced of 0.3 mm/yr (for the assumption of 7-years of data and flicker noise). The relative decrement of spectral index kappa is 25, 35 and 45%, what means lower velocity uncertainty of even 0.2 mm/yr (when assuming 7 years of data and noise amplitude of 15 mm/yr̂-kappa/4) . These results refer to the growing demands on the stability of the series due to their use to realize the kinematic reference frames and for geodynamical studies.