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Are we able to retrieve the time-changeable variations of geophysical origin from the GNSS position time series?

Marta Gruszczynska (1), Anna Klos (1), Severine Rosat (2), and Janusz Bogusz (1)

(1) Military University of Technology, Faculty of Civil Engineering and Geodesy, Warsaw, Poland (marta.gruszczynska@wat.edu.pl), (2) Institut de Physique du Globe de Strasbourg, IPGS – UMR 7516, CNRS/Université de Strasbourg (EOST), France

Seasonal variations in GNSS position time series can be arise from real geophysical and spurious effect. This research is focused on verification of the following hypothesis: geodetic position time series are characterised by common spatio-temporal seasonal signals which are time changeable with the optimal method for their investigation being Multichannel Singular Spectrum Analysis (MSSA). In order to verify this hypothesis, we will perform the analysis of GNSS position times series (from PPP solution obtained by JPL and also from IGS stations contributed to ITRF2014) by using three non-parametric methods: clustering, Singular Spectrum Analysis (SSA) and Multichannel Singular Spectrum Analysis. In this research, we used the GNSS position time series and environmental loading (hydrological loading from MERRA, non-tidal ocean loading from ECCO$_2$ and atmospheric loading from ERAIN) models. Firstly, we analysed the GNSS position time series from the selected European stations by using the clustering method. Each of time series were stacked from January to December. Then, final approximation with a Mayer wavelet for data was computed. On this basis, we divided the stations into sub-networks called clusters for each continents. In Europe, we obtained seven clusters and median signal for each clusters. In the second analysis, we used the SSA and MSSA approach to determine the time-changeable annual seasonal signals. Singular Spectrum Analysis and its multivariate extension are based on the Karhunen–Loève theory to decompose the time series into non-linear trend, time-changeable oscillations and noise. SSA is an useful tool to analyse the time series on a station-by-station basis, MSSA to study the set of stations by the Principal Component's property (pattern of the common signal). We showed the main advantage of SSA and MSSA over commonly used Least Squares Estimation (LSE). In our research, we also proposed the new idea of subtraction of annual signal from the GNSS position time series using environmental loadings. We noticed that a direct removal of environmental loading changes the power spectrum between 4 and 80 cpy. The MSSA approach allowed us to perform the spatio-temporal analysis of common annual seasonal signal from the environmental loading models for 16 different sections related to the climate zones and continents. The CME (Common Mode Error) estimates proved that MSSA do not change the stochastic part after removing MSSA-derived seasonal signals. It is worth to underline, that MSSA can extract the common seasonal signal which reflect the correlation of geophysical sources in GNSS position time series. The presented results allow us to verify the research hypothesis.