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Estimation of the crustal motion and noise properties from the time series of Estonian permanent GNSS stations

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The Earth's crust is moving continuously due to the processes such as plate tectonics, Earth and ocean tides, glacial isostatic adjustment (GIA), local deformations, atmospheric and hydrological mass variations. Accordingly, the effect of those processes are expected on the measured coordinates of continuously operating GNSS stations. Simultaneously, the imperfections of GNSS such as clock and orbit errors, antenna phase center variations, atmospheric delay, shortcomings due to the site selection and construction, snow accumulation on the antenna radome, etc., generate spurious signals and noise in the observation data.

In Estonia and its surrounding, the GIA process is the main cause of the long-term intra-continental deformations and the motion of the permanent GNSS stations. Therefore, the purpose of this contribution was to estimate the long-term velocities and GIA-related signal relied on the coordinate time series of Estonian GNSS stations. For the accurate estimation of GIA-related velocity, known signals were modelled and the properties of spurious signal and noise were analysed.

Raw data from the GNSS stations were processed independently with programs GIPSY 6.4 (precise point positioning with fixing ambiguities) and Bernese 5.2 (double difference processing). Accordingly, for every GNSS station two solutions in IGb08 reference frame for the north, east, and up coordinates were computed to form 10 years long time series (from 2007 to 2016). The ITRF2008 velocity model was used to model and subtract the effect of Eurasian plate tectonic motion from data. For the estimation of long-term velocity, the linear trend model complemented with the sinusoidal and step functions (for annual, semi-annual signals and discontinuities in time series) was fitted separately to the north, east, and up coordinate series.

Initially, power spectral density was plotted to assess and visualize the noise properties of the residual time series. Additionally, different stochastic models (e.g. white noise, power-law noise, etc.) were included into the time series analysis to estimate impact of temporally correlated, "colored" noise on the velocities and their uncertainties. The analysis was performed using different methods and software packages such as CATS, Hector, and Midas. While CATS and Hector are both based on the maximum likelihood estimation, then Midas uses more robust Theil-Sen median trend estimator. The estimated velocities and their uncertainties were evaluated by comparing the results from different approaches and with the predictions from different land uplift and GIA models.

Keywords: GNSS permanent stations, time series, crustal motion, noise models, glacial isostatic adjustment, Estonia