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Fast error analysis of continuous GPS observations

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Time series analyses of the estimates of continuous GPS positions have received a lot of attention in the last few years. It has been established that GPS residuals show some form of temporal correlations and these correlations have typically been described by a power-law plus white noise stochastic model. The preferred analysis method for this work has been maximum likelihood estimation (MLE) because it allows consistent estimates of the components of the covariance function and the parameters of the time-dependent model of the data. However, its main disadvantage is the computation burden, with several components requiring $O(N^3)$ operations. Analysing 10 years of daily GPS solutions of a single station can take several hours on a regular computer. When one analyses large networks with hundreds of stations or when one analyses hourly instead of daily solutions, the long computation times become a problem. In this paper we show that the MLE computations can be simplified to a $O(N \log N)$ process where N is the number of observations for the case where the signal consists of power-law noise only. For the general case of power-law plus white noise (and even First-Order Gauss Markov plus white noise), we also present a modification of the MLE equations that allows us to reduce the number of computations within the algorithm from a cubic to a quadratic function of the number of observations when there are no data gaps. In addition, this modification removes a very important implicit assumption that there is no environment noise before the first observation. In practise, these modifications achieve a reduction in computation time on the order of 10 to 100 without loss of accuracy. We will demonstrate this using datasets from several GPS networks (global and regional). Finally, we present an analytical expression for the uncertainty of the estimated trend if the data contains only power-law noise.