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On the issues of probability distribution of GPS carrier phase observations

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In common practice the observables related to Global Positioning System (GPS) are assumed to follow a Gauss-Laplace normal distribution. Actually, full knowledge of the observables' distribution is not required for parameter estimation by means of the least-squares algorithm based on the functional relation between observations and unknown parameters as well as the associated variance-covariance matrix. However, the probability distribution of GPS observations plays a key role in procedures for quality control (e.g. outlier and cycle slips detection, ambiguity resolution) and in reliability-related assessments of the estimation results. Under non-ideal observation conditions with respect to the factors impacting GPS data quality, for example multipath effects and atmospheric delays, the validity of the normal distribution postulate of GPS observations is in doubt.

This paper presents a detailed analysis of the distribution properties of GPS carrier phase observations using double difference residuals. For this purpose 1-Hz observation data from the permanent SA*POS*® (Satellite *Positioning Service* of the German State Survey) network are processed for a period of 21 days concerning baseline length (30∼200 km) and site multipath impact. Additionally, surface meteorological data are used to validate the effects of atmospheric variations on distribution stability. A total of 272 outlier-free residual time series (3600 values each) are analysed and the statistic inferences are made using sample moments (first through fourth) as well as various hypothesis tests. Furthermore, graphic tools such as histograms and quantile-quantile plots are generated to verify the probability distribution. In addition to normal distribution, the von Mises distribution based on circular directional statistics is applied as an alternative with the corresponding goodness-of-fit tests and inferences on distribution parameters. The test results show distinct correlation between test statistics and atmospheric parameters (e.g. relative humidity) and significant influences of multipath impact on the normal distribution assumption as well. Nevertheless, the normal distribution seems to be a valid assumption for the whole residual database and the use of von Mises distribution within this study does not significantly improve the results of distribution fitting.