STATISTICAL ANALYSIS OF THE TIME SERIES OF PERMANENT GPS STATIONS

Time series of the horizontal coordinates of 21 GPS stations of the EUREF Permanent Network in the Alpine Mediterranean area with three or more years of continuous tracking have been computed with the intent of estimating velocities and their uncertainties, taking into account the detailed structure of their noise.

The power spectral densities demonstrate that colored noise, mostly flicker (1/f) noise, can be present at frequencies below six cycles per year, while at higher frequencies the spectrum tends to a regime of white (i.e. frequency independent) noise. This statistical information is used to obtain more accurate estimates of station velocities and of their uncertainties than by standard least squares. Following an approach well known in the analysis of time series of frequency standards, the stability of each time series is computed as a function of time, in the sense of a two-samples Allan variance. The power spectral density of the time series is used to infer the variance of the change in the slope, with 1σ probability, of two consecutive, equal length batches of a given time series, and this as a function of the length of the batch. The power spectral density of each time series is then converted into an autocorrelation function. Taking into account the correct correlations of pairs of samples as a function of their lag, the slope of each time series is estimated by least squares, with a non-diagonal weight-matrix. We show that in all the examined cases the uncertainties in the velocities computed taking into account the detailed noise spectrum are larger by a factor of 4 +/-1 than the formal uncertainties obtained by least squares under the assumption of pure white noise. Estimating the slope of a time series taking into account the autocorrelation of the samples yields velocities not significantly different from those obtained assuming uncorrelated samples (Tab. 1). We conclude that the reason for the velocity uncertainty estimated by standard least squares being unrealistically small is the neglect of the cumulative effect of uncorrelated and correlated noise. Neglecting the correlated noise does not, however, affect the velocity. Contrary to earlier investigations based on more limited (< 3 years) data sets, we find that the velocity uncertainty does decrease as the time series increases, and the value of the velocity uncertainty can be predicted from the power spectral density, as the length of the time series increases. The time series are finally analyzed in the space domain. After removal of common mode terms, typically represented by sinusoids of annual period, correlation coefficients are computed for pairs of stations and plotted as a function of their distance. We find that the time series de-correlate already at very short distances (< 100 km). This suggests that random errors affecting the coordinates of clusters of stations such as, for example, atmospheric refraction or mismodeling of the orbits are negligible in our time series. The estimates of the velocities and uncertainties of the permanent stations obtained by spectral analysis form the basis for a subsequent investigation of the present-day, large scale strain rate field in the Alpine Mediterranean area, which is implied by these scattered surface displacements.
Statistics of the time series of horizontal coordinates of stations with tracking history longer than three years. The columns give the total span, number of weeks, r.m.s of the time series after removal of slope and periodic terms of semiannual, annual and Chandler period, the estimated horizontal velocities using the program ADDNEQ of Bernese v. 4.2, the square root of the Allan variance computed from the spectrum for a time equal to the total span, the correction to the velocity obtained using the appropriate correlation function, and an estimate of the spectral index and of its formal uncertainty. The uncertainty on the velocity in the sense of Allan variance is the maximum change to be expected, with 1σ probability for the next T years, where T represents the total span in the second column. This uncertainty is, on average, a factor of 4+/1 larger than the corresponding formal error computed with the program ADDNEQ and listed in the last two columns. Formal errors of the reference stations used to realize the ITRF2000 velocity datum are assumed small and indicated with a ‘Ref.’ label. The corrections to the velocities estimated by least squares and assuming uncorrelated samples are negligibly small, when the correlation among the samples is taken into account; the formal errors of such corrections are again very small and not listed. The spectral indexes indicate that for all the examples a noise model consisting of white noise for periods shorter than six months, and white (spectral index equal to 0) or flicker (spectral index equal to -1) noise for longer periods is appropriate.
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