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Non-stationary frequency analysis of extreme Lake Malawi levels

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Conventional frequency analyses are premised on time-invariance (or stationarity) in the parameters of the underlying probability distribution functions (pdfs). With evidence of hydrological impacts of climatic change, low frequency climate variability (e.g. El Nino and Southern Oscillation-ENSO) and other human related stressors such as land use changes, frequency analysis is now a key challenge as it has to incorporate (non-stationarity) or time-variation of the underlying distribution parameters. In this study, frequency analysis of extreme levels of Lake Malawi in Southern Malawi is performed incorporating non-stationarity. The lake is a critical transboundary water resource between Malawi, Mozambique, and Tanzania. The lakeshore areas are prone to extreme lake level variations which affects both infrastructure and life. With the lake undergoing considerable recession since 1980, there is a need to update the design extreme lake levels by incorporating non-stationarity. The study used observed mean lake levels from 1899 to 2017 from which annual maximum (AM) lake levels and partial duration series (PDS) were extracted. In the frequency analysis, the data area were firstly subjected to conventional analyses for evidence of non-stationarity using the Mann-Kendall (MK) test, Kwiatkowski–Phillips–Schmidt–Shin (KPSS) and the Augmented Dickey-Fuller Test (ADF). This was followed by the application of various routines in R software incorporating both stationary and non-stationary frequency analysis approaches such as the generalised additive model for location, scale and shape (GAMLSS) and Maximum likelihoods (ML). Goodness of fit was tested using the Akaike Information Criteria (AIC). The results are very critical in flood zoning especially with various planned infrastructural developments around the lakeshore.