# "Frequency analyses for stationary and nonstationary hydrological data"

Jun-Haeng HEO
*Professor, School of Civil & Environmental Engineering,*
*Yonsei University, Seoul, Korea*

Frequency analysis has been widely used to provide the magnitude of extreme events and occurrence frequency in hydrologic system and the related fields. In general, frequency analyses can be categorized into four parts depending on the methodology and characteristics of data as shown in Table. In the conventional at-site and regional frequency analyses, the hydrological data are assumed to be independent and stationary. The assumption of independence implies that each random variable has the same probability distribution as the others and all are mutually independent. And the assumption of stationarity implies that the occurrence of samples and the statistical characteristics (e.g., mean and variance) of the observations do not change over time irrespective of long-term climatic variability and human-induced change. However, nowadays the nonstationary problem occurs in hydrological processes because of the inherent variability of the oceanic-atmospheric system and the increasing anthropogenic influences on the climate and environment. In recent years, there has been a gradual change with the evidences of nonstationary phenomena (e.g., trends of observations and long-term variability of hydrological data) and a recognition of the influence of climate change and urbanization on hydrological processes.

| Method / Data type | At-site frequency analysis(ASFA) | Regional frequency analysis (RFA) |
|---|---|---|
| Stationary | Stationary ASFA | Stationary RFA |
| Nonstationary | Nonstationary ASFA | Nonstationary RFA |

For nonstationary at-site application, nonstationary frequency analysis employs various dependent covariates or moments such as time, oceanic-atmospheric components (e.g. ENSO, SOI, SST, PDO, and NAO) and statistics (e.g. mean and variance). Several probability distributions such as the Gumbel, GEV, generalized Pareto, generalized logistic models have been used for nonstationary at-site frequency analysis with several covariates. For regional frequency analysis, the index flood method has been widely used since 1960. And this method can be applied to stationary and nonstationary cases. For nonstationary cases, three types of nonstationary index flood method are possible depending on the variabilities of index and growth curve with time.

It is very important to select an appropriate probability model for applied hydrologic data. As the goodness of fit test, the chi-square, Kolmogorov-Smirnov, Cramer von Mises, probability plot correlation coefficient, and modified Anderson Darling tests are used for conventional stationary cases. And the Akaike information criterion (AIC), corrected AIC (AICc), Bayesian information criterion (BIC), and likelihood ratio test (LR) have been used for selecting an appropriate models for nonstationary cases.

In real applications, four types of frequency analyses are applied to stationary and nonstationary annual maximum precipitation data from Korea Meteorological Administration to figure out the performances of those methods based on the stationary and nonstationary Gumbel and/or GEV models with time as covariate. In addition, four goodness of fit tests such as AIC, AICc, BIC, and LR for nonstationary cases are compared with each other based on the several slopes and parameter sets using the Monte Carlo simulation and then the best goodness of fit test is recommended depending on the nonstationarity, parameters, and sample sizes.