Geophysical Research Abstracts
Vol. 19, EGU2017-16053, 2017
EGU General Assembly 2017

Designing basin-customized combined drought indices via feature extraction

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The socio-economic costs of drought are progressively increasing worldwide due to the undergoing alteration of hydro-meteorological regimes induced by climate change. Although drought management is largely studied in the literature, most of the traditional drought indexes fail in detecting critical events in highly regulated systems, which generally rely on ad-hoc formulations and cannot be generalized to different context. In this study, we contribute a novel framework for the design of a basin-customized drought index. This index represents a surrogate of the state of the basin and is computed by combining the available information about the water available in the system to reproduce a representative target variable for the drought condition of the basin (e.g., water deficit). To select the relevant variables and how to combine them, we use an advanced feature extraction algorithm called Wrapper for Quasi Equally Informative Subset Selection (W-QEISS). The W-QEISS algorithm relies on a multi-objective evolutionary algorithm to find Pareto-efficient subsets of variables by maximizing the wrapper accuracy, minimizing the number of selected variables (cardinality) and optimizing relevance and redundancy of the subset. The accuracy objective is evaluated trough the calibration of a pre-defined model (i.e. an extreme learning machine) of the water deficit for each candidate subset of variables, with the index selected from the resulting solutions identifying a suitable compromise between accuracy, cardinality, relevance, and redundancy. The proposed methodology is tested in the case study of Lake Como in northern Italy, a regulated lake mainly operated for irrigation supply to four downstream agricultural districts. In the absence of an institutional drought monitoring system, we constructed the combined index using all the hydrological variables from the existing monitoring system as well as the most common drought indicators at multiple time aggregations. The soil moisture deficit in the root zone computed by a distributed-parameter water balance model of the agricultural districts is used as target variable. Numerical results show that our framework succeeds in constructing a combined drought index that reproduces the soil moisture deficit. Moreover, this index represents a valuable information for supporting appropriate drought management strategies, including the possibility of directly informing the lake operations about the drought conditions and improve the overall reliability of the irrigation supply system.