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Investigation of spatial and temporal variability of groundwater flow process by using higher-order partial correlation functions: theoretical considerations

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Hydrological time series are influenced by various space-time-variant processes involved in the transfer of water in hydrological cycle. The effects of all these processes are exhibited in the autocorrelation and cross-correlation function. Consequently, it is very difficult to distinguish the contribution of each process in practical applications of these functions, so ambiguities with respect to the effects encoded in the correlation functions exist. This problem has been solved by using partial correlation functions. The main objective of this work is to present a theoretical basis for interpretation of several basic forms of partial correlation functions that has been obtained in investigations of groundwater flow. The theoretical basis is developed by means of a conceptual mathematical model. In this process, the functioning of subsurface hydrological system is simulated with the conceptual mathematical model consisting of series of linear reservoirs. The inputs into the model are synthetic time series representing rainfall on catchment and the resulting output time series from the model represents discharge from spring. Three issues causing spatial and temporal variability of groundwater flow process are in focus: the spatial variability of retention characteristics of underground, the spatial and temporal variability of rainfall on surface, and the existence of inflows and outflows from neighboring catchments. The results of conceptual model show that the internal structure of linear and time-invariant hydrological model can be determined from the input and output time series although the input time series are spuriously correlated, so the contribution of each part of model to the output can be evaluated. Practically, it means that partial correlation functions can provide information about the spatial variability of groundwater flow process including the recognition of areas of dominant supply and the detection of areas belong to neighboring catchments by using only time series of rainfall and spring discharge. A schematic presentation of possible relationships between the input rainfall signals, the output discharge signal from subsurface hydrological system and the values of partial correlation functions is presented. Generally, the obtained results confirm that the partial correlation functions are capable to provide valuable information about the spatial and temporal characteristics of subsurface processes that cannot be obtained by the classical correlation analysis.