EOF Analysis For Spatio-temporal Variability In Groundwater And Rainfall Data

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Abstract:
Quantification of recharge to regional aquifer systems and analysing information with regard to controls and processes affecting groundwater dynamics is critical for sustainability of groundwater resources especially in semi-arid regions. The spatio-temporal trends of groundwater dynamics in a catchment are often controlled by complex processes influenced by climate, physical characteristics of the catchment and human activities which are all part of the hydrological settings. Study of climate variability and human-induced land use change on hydrology and water resources has become important area of research in hydrology.

There is a necessity to establish relationships between the groundwater dynamics of the areas having a similar pattern of significant trends and the weather variables. Therefore, there is clearly a need to examine the general trends of local rainfall variation and analyze the relationship between these trends and groundwater level fluctuations. In particular, a method is needed to identify distinct underlying patterns of spatial variations of groundwater dynamics and their linkage to rainfall variations in a way that accounts for these patterns and their temporal evolution. In this study, analysis through Empirical Orthogonal Functions (EOF) is proposed and applied to characterize the groundwater dynamics of areas with similar spatio-temporal patterns and their relationship to annual and decadal variations in rainfall along with temporal evolution of groundwater irrigation. EOF analysis is commonly used in the meteorological field to characterize spatio-temporal variables.

The changes in the Kabini river basin area in South India are investigated in this study. The objective is to determine the spatio-temporal trends in monthly groundwater levels (GWLs) and rainfall in this region, and find the extent of influence/effects of rainfall variability and human activities on GWLs. The objective is also to obtain a better understanding of the observed signals of rainfall and GWLs and delineate homogeneous groups of stations based on the controlling parameters. EOF analysis is performed on independent and joint data sets of monthly rainfalls and GWLs over a period 1976 to 2006 (30 years), to investigate the controls on the rainfall and groundwater levels. Rain gauge data at 46 stations and GWLs at 65 observation wells are used. For the analysis, monthly rainfall series as well as a cumulative rainfall departure (CRD) is used depending on the cases. Similarly the groundwater data is used as monthly groundwater storage change as well as monthly GWLs.

EOF analysis is applied to three broad cases. The first case pertains to the analysis with several station data of rainfall. The second case pertains to analysis of GWLs data. The third case deals with analysis of the joint data set of the rainfall and the GWLs. Significantly, the long term trends in groundwater levels are found to follow the CRD trend especially in the early years when the pumping was insignificant. In the later years, the correlation between GWLs and CRD

is found to get reduced due to the effects of pumping. Joint EOF analysis of groundwater levels and cumulative rainfall departure series has helped to characterize groups of stations with GWLs trends similar/dissimilar to that of the rainfall. Maps derived through GIS are used extensively to represent spatial patterns whereas temporal patterns are presented as graphical plots.

Keyword: Emperical Orthogonal Functions (EOF), Spatio-temporal variability, groundwater levels, rainfall, GIS