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Drought modelling and evaluation in south-east Australia

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ABSTRACT

Droughts are complex in nature and affect more people than any other natural hazard. An adequate monitoring on different aspects of droughts is required for effective water resources management. This study focuses on the droughts in south-east Australia covering the New South Wales (NSW) and Victorian (VIC) states. Australia experienced major droughts during the last two decades. The ramifications of droughts in southeast Australia have had dire impacts such as wildfires, farming income losses, ecological imbalance, and water shortage. To fill the current research gaps, drought modelling, which comprises of drought characterisation and space-time analysis, has been undertaken in this doctoral study. This research evaluates and develops Standardized Precipitation Index (SPI), Effective Drought Index (EDI) (meteorological drought indices) and Streamflow Drought Index (SSFI) (hydrological drought index). These drought indices have not been applied in a comprehensive manner in Australia before to quantify droughts. In this research, characteristics of meteorological and hydrological droughts have been made in terms of areal coverage, drought quantities (e.g. intensity, duration and severity) with their onset-end, hazard and frequency at different space and time scales. Drought Hazard Index (DHI) and Drought Frequency Index (DFI) have been developed to find drought-prone parts within the study area. Furthermore, temporal changes and trends in rainfall, streamflow, meteorological and hydrological droughts have been investigated using autocorrelated and modified Mann-Kendall (A-MK and M-MK) tests and Sen's slope estimator. Abrupt changes in historic rainfall and streamflow data have been detected by the Pettitt test, the SNHT for a single break, the Buishand range test and the Von Neumann ratio test. This research has also identified propagation time from meteorological to hydrological drought. Comparison of meteorological (SPI, EDI) and hydrological (SSFI) drought indices have been made using Pearson's and Spearman's rank correlations. It has been found that EDI has similarities at different accumulation periods of SPI for different meteorological drought quantities at different spaces. Overall, performance of EDI has been found to be superior to SPI in semi-arid regions. It has also been found that south-east Australia faced one of the most intense droughts during 2013 to 2019, and that the longest duration of drought has been in southern and eastern coasts of the study area. Finally, it has been found that the A-MK and M-MK tests are powerful in detecting significant trends by eliminating serial correlation. Based on probability of drought occurrences and the Thiessen polygon approach, it has been found that DHI is a convenient conceptual model to identify spatial patterns of drought hazard, which is a key component of drought risk. Based on the number of drought occurrences and time spans, it has been found that DFI is an efficient method to estimate frequency of drought for different accumulation periods, either meteorological or hydrological. It also has been found that hydrological drought can be estimated using meteorological drought indices, SPI and EDI. SPI has been found to be highly correlated in estimating hydrological droughts based on 12- and 24-month accumulation periods, whereas EDI has been found to be more capable in estimating short term hydrological drought (3-month accumulation period), especially in semi-arid regions of the study area. Moreover, drought propagation time between meteorological and hydrological drought can be modelled applying 'theory of run' depending on the degree of correlations between meteorological and hydrological indicators. This doctoral thesis is under examination now. Four journal articles were prepared based on this study; two have been published, one has been accepted and one is under review.