Abstract

Spatio-temporal re-distribution of hydro-meteorological variables, due to changing climate and dynamic terrestrial environment, leads to the alteration of many hydrological processes. These changes/alterations may often negatively impact the socio-economic development and are often incomprehensible due to its complex characteristics. Alteration of the system under such conditions raises question on the stationarity assumption, i.e., the system responses fluctuate within an unchanging envelope of variability. Models developed under such questionable stationarity assumption is bound to become obsolete over time, or to perform sub-optimally at best. Thereby, alternative methodologies that deal with such non-stationary systems may improve the performance of hydroclimatic models. In this thesis, a time-varying framework is proposed as a potential solution to modelling in a changing climate that may impart non-stationarity in the hydrological system. The proposed framework is able to deal with two major drawbacks of the existing hydroclimatic models: (i) the inability of the model to represent the true dependence structure among a large pool of variables associated in a complex way, and (ii) the unaccountability of the time-varying characteristics imparted due to changing climate and dynamic terrestrial conditions. The proposed framework is based on the concept of temporal networks, characterized by time-dependent links between variables that may change over time, i.e. appear, disappear, reappear, or it may change in terms of its connection strengths. Evolution of network structures over time, obtained through Graphical Modelling (GM), depicts the changes in the model inputs as well as model parameters over time. The proposed concept indicates that the time interval after which the model needs to be updated/recalibrated, referred to as Optimum Recurrence Interval (ORI) of model re-calibration. The ORI is problem specific and it is optimized to achieve the best model performance. The efficacy of the proposed approach is established by applying the developed framework for modelling different primary (precipitation), secondary (streamflow and soil moisture) and tertiary (hydrological and agricultural drought) hydrological variables.

Firstly, a time-varying framework is developed for long-lead seasonal prediction of Indian Summer Monsoon Rainfall (ISMR) over Homogeneous Monsoon Regions across India. The time-varying association between ISMR and large-scale climatic indices is modelled using the proposed approach. The proposed model yields a good prediction performance with a prediction lead time of 5 months. Secondly, month-wise streamflow prediction is carried out at basin-scale using the time-varying concept. The proposed concept not only depicts a notable change in the potential predictors for the high and low flow months, but also establishes the different extent of temporal variability for different months. Thirdly, time-varying framework is used for characterization and prediction of hydrological droughts using hydro-meteorological triggers. The results indicate that the cause-effect relationship between hydroclimatic variables and extreme hydrological phenomena like drought needs to be updated every 2 to 3 years, depending on the climatological conditions, and the proposed time-varying modelling framework very well captures the above and below-normal events. Finally, spatio-temporal variation in the association between hydro-meteorological variables and surface soil moisture is modelled in addition to one-month ahead prediction of agricultural drought through the developed time-varying framework. Successful application of the model shows its potential for being utilized as a remedial measure to handle similar cases through a proper assessment of the time-varying cause-effect relationship among a large pool of influencing variables.