25th International Congress on Modelling and Simulation, Darwin, NT, Australia, 9 to 14 July 2023
mssanz.org.au/modsim2023

Can drought regimes undergo shifts?

Pallavi Goswami [a,b], Tim J. Peterson [c], Arpita Mondal [d,e] and Christoph Rüdiger [f,c]

[a] *IITB Monash Research Academy, IIT Bombay, Mumbai, India*
[b] *School of Earth, Atmosphere and Environment, Monash University, Clayton, Victoria, Australia*
[c] *Department of Civil Engineering, Monash University, Clayton, Victoria, Australia*
[d] *Department of Civil Engineering, Indian Institute of Technology Bombay, Mumbai, India*
[e] *Interdisciplinary Program in Climate Studies, Indian Institute of Technology Bombay, Mumbai, India*
[f] *Bureau of Meteorology, Melbourne, Victoria, Australia*
Email: Pallavi.Goswami@monash.edu

Abstract: Hydrological variables of a catchment and their corresponding extreme characteristics have a possibility of switching regimes, particularly when a catchment undergoes protracted dry periods. This can result in a catchment experiencing a flow anomaly that is even more extreme than what was historically considered an extreme low flow event for the catchment. Existing studies suggest that extreme events may be changing with time; it is thus important to understand whether extremes in flows also have the potential to exist in multiple states. Goswami et al. (2022) established that low flows exhibit non-stationarity induced by climate modes (i.e., covariate-based non-stationarity in low flows). Our present work investigates if low flows exhibit a more complex form of non-stationarity, in the form of state (or regime) changes beyond the routine covariate-based non-stationarity as explored in Goswami et al. (2022). This work is also an extension of the study by Peterson et al. (2021), which showed complex dynamics for flows in catchments in southeast Australia. Peterson et al. (2021) established that a catchment's annual and seasonal mean flows can switch into alternative stable states, resulting in a catchment producing less streamflow than normal for a given precipitation. The term 'switching of states' or 'regime-switching' relates to a shift in the underlying probability distribution of a variable. Our study looks specifically at extreme (low) flows to investigate if they undergo regime changes, and at a much finer temporal resolution. We studied intensity, duration, and frequency (IDF) of low flows for 161 unregulated catchments in southeast Australia. A Hidden Markov Model-based approach was used to examine shifts in the low flow characteristics.

The key findings are:
(1) Low flow regimes can switch states which may lead to the intensification of low flow events.
(2) Existence of sustained warm and dry atmospheric conditions can cause the switching of catchments into an intensified low flow state.
(3) Information from precipitation, though useful, may not be sufficient to explain the variability in low flow extremes.

The findings confirm that catchments can exhibit shifts in regimes of low flows. Importantly, this means that regimes of extremes can also change. This may lead to catchments experiencing an intensification of low flows. Simulation of extreme data is usually a challenge. To this end, we developed a configuration of the Hidden Markov Models that renders them capable of simulating low flow intensities, along with reliably checking for temporal state changes. We found very strong evidence of low flow intensity exhibiting two distinct states for at least 34 (21%) catchments out of 161 catchments investigated in the region, providing convincing reasons to believe that extremes in low flows can and have undergone regime changes. The second state of these catchments is often associated with higher values of low flow intensities. Simulation of the duration and frequency of these events, however, needs improvement with the current approach and may be better studied by accounting for climate indicators that may more suitably explain them. Impacts from a changing climate may enhance the triggering of low flows into alternate states, which calls for water managers to plan for changing regimes of extremes.

REFERENCES

Goswami, P., Peterson, T. J., Mondal, A., & Rüdiger, C. 2022. Non-stationary Influences of Large-scale Climate Drivers on Low Flow Extremes in Southeast Australia. Water Resources Research, *58*(7), e2021WR031508.

Peterson, T.J., Saft, M., Peel, M.C., John, A., 2021.Watersheds may not recover from drought. Science 372(6543), 745–749.

Keywords: *Low flow droughts, states of IDF of low flows, antecedent precipitation index, regime-switching, Hidden Markov Model*