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

Disentangling hydrological mixtures

Rajitha Athukorala [a,b], **Joshua Simmons** [a], **Sally Cripps** [c,d,e] **and R. Willem Vervoort** [a,b]

[a] *ARC Industrial Transformation Training Centre in Data Analytics for Resources and Environments, Sydney, Australia*
[b] *School of Life and Environmental Sciences, The University of Sydney, Australia*
[c] *Human Technology Institute, The University of Technology Sydney, Australia*
[d] *School of Mathematical Sciences, The University of Technology Sydney, Australia*
[e] *School of Aerospace, Mechanical and Mechatronic Engineering, The University of Sydney, Australia*
Email: rajitha.athukorala@sydney.edu.au

Abstract: Streamflow timeseries in different parts of the world have their own unique features, posing challenges for hydrological modelling. In Australia, more than 70% of the rivers are non-perennial (i.e. rivers which have no flow for at least part of the year) (Shanafield et al., 2020) and the transition from zero or low flows to high flows is often rapid, resulting in flash floods. Therefore, any forecasting model for the mean and variability of Australian streamflow needs to account for these unique features.

To account for rivers which have no streamflow for part of the year we propose a Bayesian Hierarchical Mixture of Experts (BHME) model where the streamflow distribution has two components. The first component of the mixture is a point mass at zero for zero flows, and the second is a Gamma distribution for non-zero flows. As in all hydrological modelling, streamflow data is derived from river height observations via a *rating curve* which maps river heights to discharge rates. In this paper we take a Bayesian approach and use the posterior mean of stream discharge given river height data for this mapping. To identify zero streamflow, we take the lowest recorded river height, compute the expected value of stream flow given this height, and its corresponding 95% credible interval. If a streamflow observation is lower than the lower limit of this credible interval, then we categorise it as zero. The probability of streamflow at any given day, belonging to either the zero or non-zero flow component is modelled using a logistic regression. The logistic regression model as well as the parameters of the Gamma distribution are parameterized to depend on upstream streamflow and rainfall from the previous day.

The second approach is another BHME model with two components to model sudden changes in non-zero flow regimes common to Australian rivers. The two components in this approach are both Gamma densities which are parameterized to depend on upstream streamflow and rainfall from the previous day. The mixture weights in this approach depends on the same set of covariates through a logit link function as in the first approach.

The models are estimated in a Bayesian framework using Hamiltonian Monte Carlo with the No-U-Turn Sampler (NUTS) (Homan and Gelman, 2014), to perform the required multidimensional integration and generate samples from the posterior distribution of the quantities of interest.

These approaches provide a statistically robust method to model zero observations as well as sudden changes in streamflow. The logistic regression in the first approach provides useful information regarding the transition from flow to no flow (and vice versa) which a single component model cannot provide. The two-component model in the second approach provides better fit to the data and better predictive densities compared to a single component model. The transitions from one component to another in the second approach provides useful information in sudden changes in flow regimes commonly seen in Australia.

REFERENCES

Homan, M.D. and Gelman, A. 2014. The no-u-turn sampler: adaptively setting path lengths in hamiltonian monte carlo. J. Mach. Learn. Res., 15(1):1593–1623

Shanafield, M., Godsey, S., Datry, T., Hale, R., Zipper, S.C., Costigan, K., Krabbenhoft, C.A., Dodds, W.K., Zimmer, M., Allen, D.C., Bogan, M., Kaiser, K.E., Burrows, R.M., Hammond, J.C., Busch, M., Kampf, S., Mims, M.C., Burgin, A., Olden, J. D. 2020. Science gets up to speed on dry rivers. Eos Science News by AGU, (101).

Keywords: *Streamflow, Bayesian model, hierarchical mixture of experts, ephimeral rivers*