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

# The time of emergence of climate change in Australian rivers

**A. John**, **R. Nathan, A. Horne, K. Fowler, M. Stewardson, M. Peel and J.A. Webb**

*Environmental Hydrology and Water Resources Group, Department of Infrastructure Engineering, University of Melbourne, Parkville, Australia*
*Email: andrew.john@unimelb.edu.au*

**Abstract:** Climate change impacts on river flows are leading to substantial changes in water availability for human and natural systems. For many systems, the significance of these impacts largely depends on the degree of change relative to natural variability. For example, river ecology or human infrastructure adapted to highly variable hydrology may be resilient to a larger absolute change in river flows compared with a system with lower variability or more consistent seasonal flow conditions (Horne et al. 2019). The 'time of emergence' (ToE) is the point in time when the signal of climate change emerges from the noise of background variability, the latter of which can be very large in Australia relative to other parts of the world. The ToE has been assessed for some climate variables but rarely streamflows. Here we discuss the results from John et al. (2023), where we assessed ToE of climate change across Australian rivers. We investigate ToE of changes in streamflow for various characteristic periods relevant to different water management objectives. For example, the emergence of changes to the flow regime over a short period may be critical to short-lived species of freshwater fish but may not be as important to longer-lived riparian vegetation. Similarly, changes over a sequence of two to five years may be enough to trigger short-term water restrictions in regulated systems, but changes over a much longer period (say, 20 years) may affect the viability of long-term water entitlements, or longer-lived fish species. We assess the uncertainty in ToE estimates from different emissions pathways and a large ensemble of CMIP6 climate model projections. We also compare ToE for annual precipitation and annual flow regimes, and additionally to John et al. (2023), specific daily-timescale flow metrics relevant to freshwater ecology (through the Indicators of Hydrological Alteration).

ToE is likely to occur earlier in hydrologic systems subject to low natural variability than those subject to high variability, and to systems that are vulnerable to failure over longer rather than shorter periods. There are clear regional differences in the patterns of ToE, with changes first emerging in south-west regions of Australia, followed by the south-east, then east and north. We estimate that ToE has already occurred relative to a baseline 1945–1984 hydroclimate in over 10% of sampled rivers for longer characteristic periods, primarily in south-west Australia. Importantly for planning, the results show that at an annual timescale, ToE in flows can precede ToE in precipitation by up to 50 years due to compounding effects of changes in annual precipitation, precipitation seasonality, and increasing temperatures. However, the ToE of ecologically relevant flow metrics can further precede that of the annual flow regime. In addition, some catchments showed emergence in ecologically relevant flows which was not apparent for the wider annual flow regime. The most common ecologically relevant flows to first emerge were daily average flows during August to October, and annual maxima over 30 and 90-day periods. The number of catchments projected to have reached ToE by 2080 is heavily influenced by the trajectory of future emissions. A low emissions pathway consistent with aspirational goals of the Paris Climate Agreement (SSP1-2.6) substantially delays the emergence of significant hydrological change by up to 50 years, or negates emergence entirely by 2080, depending on location. Our methods can be applied to catchments globally, and our findings have implications for the prioritisation of climate adaptation efforts across different river systems and the urgency of continued action on climate change mitigation.

## REFERENCES

Horne, A. C., Nathan, R., Poff, N. L., Bond, N. R., Webb, J. A., Wang, J., & John, A., 2019. Modeling flow-ecology responses in the anthropocene: challenges for sustainable riverine management. BioScience, 69(10), 789–799.

John, A., Nathan, R., Horne, A., Fowler, K., Stewardson, M., Peel, M., & Webb, J. A., 2023. The time of emergence of climate-induced hydrologic change in Australian rivers. Journal of Hydrology, 619, 129371.

***Keywords:*** *Time of emergence, river systems, hydroclimate variability, climate change adaptation*