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What can hydrologic signatures teach us about a multiyear drought?

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The internal dynamics of a catchment can be shifted by multiyear dry periods. While there is consensus that annual streamflow decreases for a given annual rainfall in the case of multiyear dry period significantly more than during isolated dry years (thus representing a shift in hydrologic response), the mechanism of this shift remains debated. As the hydrological shifts were investigated on an annual and, to a lesser extent, seasonal scale, little is known regarding what parts of the flow regime (e.g. high flows, low flows, recessions) are affected and how. An event-scale analysis using process-linked hydrologic metrics (or signatures) can reveal hidden patterns in catchment response to multiyear drought and shed light on the otherwise hidden hydrological processes. Additionally, understanding whether some parts of flow variability experienced a more pronounced impact from the drought may be important for the water management decision-making. Here we investigate long-term changes in catchment response on daily to sub-monthly timescales to aid both hydrological processes understanding and water management practice.

We calculate over 30 hydrologic signatures characterising different aspects of flow regime and hydrological processes before, during, and after a decade-long drought and compare the results. The signatures are calculated with the Toolbox for Streamflow Signatures in Hydrology (TOSSH) which combines signature sets from several earlier studies. We use a well-known multiyear drought, the Millennium Drought (MD) in Australia as our case study. This drought spanned ~13 years (1997-2009) and affected over 1 million square kilometres of land including 156 semi-natural study catchments in Victoria.

Our results suggest that on average both high and low flows were affected in similar proportion while the shape (i.e. slope) of the flow duration curve was largely preserved. The tendency to generate less runoff for a given rainfall has been demonstrated in a range of signatures from event to total flow volumes and thus is independent of the timescale. When analysing signatures related to catchment storage, we observe that the decline continues post-drought. Baseflow index and recession signatures show some evidence of multiyear catchment storage buffering. There is also evidence of lower hydrologic connectivity in the hillslopes affecting the event runoff. However, there are marked differences in signature behaviour between different catchments reflecting the differences in catchment internal structure and dominant hydrologic processes.