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Using dynamically downscaled GCM outputs in hydrological models: a case study from Tasmania, Australia

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Modelling future runoff by running meteorological projections from global climate models (GCMs) directly through hydrological models presents considerable technical challenges, but promises several advantages over the so-called ‘perturbation method’. The Climate Futures for Tasmania project has projected water yield in Tasmania, Australia to 2100. This paper describes how the Climate Futures for Tasmania project used dynamically downscaled climate projections directly in hydrological models to produce useable information for water managers and industry.

Tasmania is a difficult region for climate change hydrology studies. Tasmanian rainfall is generated by complex regional weather systems such as atmospheric blocking that are not always well-represented in GCM-scale projections. Further, the spatial resolution of GCMs is too coarse to represent the complex distribution of Tasmanian rainfall. Rainfall changes caused by changes in these regional weather systems may not be predicted by GCMs.

Previous studies of climate change impacts on Tasmanian rivers have used the ‘perturbation method’, where historical rainfall and evaporation data are modified to reflect changes predicted by GCMs. In this method rainfall events occur exactly as often as in the historical record – only the magnitude of events changes. This can mask long-term effects on runoff caused by changes in the timing or duration of rainfall events due to climate change. We avoided this problem by dynamically downscaling six GCMs with the regional climate model CCAM to a spatial resolution of 0.1 degrees under the A2 SRES emissions scenario. Dynamical downscaling is computing-intensive, but can simulate changes to rain-bearing weather systems (e.g. increases in convective storms).

Downscaled hindcasts generally showed excellent spatial and temporal agreement with climate observations. However, some spatial biases were still evident. To account for these biases, modelled rainfall and evaporation were bias-adjusted by percentile to observations for 1961-2007. A premise of bias-adjustment is that discrepancies between observed and modelled data are constant through time. A leave-one-decade-out test was devised to demonstrate that the biases were constant through time.

Existing statewide hydrologic models were adapted to accept the bias-adjusted dynamically downscaled GCM projections. Five runoff models were available: AWBM, Ihacres, Sacramento, Simhyd, and SMARG. Each of these models reacts differently to climate inputs. The uncertainty in projected changes to runoff due to the choice of hydrological model was assessed for one GCM.

Downscaled projections from all six GCMs were run through the Simhyd model to produce runoff at a 0.05 degree statewide grid. Runoff was aggregated to river basins, and human activities such as irrigation and hydropower generation were accounted for. Model hindcasts of river flows showed very good agreement with observed flows.

Impacts on future runoff were highly spatially heterogeneous, demonstrating the value of high resolution downscaling for hydrologic projections. There was some evidence that changes in rain-bearing systems – such as the incidence of convective storms - will influence water yields in certain catchments.

The result is one of the most detailed regional climate change hydrology studies in Australia. The hydrologic projections have been tailored to the needs of water managers and industry, ensuring the research will be understandable and useable.