Hydrological modelling in Australia

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Introduction

There are many types of hydrological models, which may operate over different spatial scales and time steps and are developed for various applications. These range from models for estimating catchment and continental water availability to models for planning and managing water resources across regulated river systems.

The need for hydrological models is increasing both in terms of coverage and functionality. The types of people that require access to hydrological models and in particular model results is also increasing. Hydrological models need to be more robust, transparent and defensible as they are increasingly relied on to make informed decisions on sharing and managing Australia's limited water resources.

The different needs of hydrological modelling are so complex that it is beyond the scope of any organisation to continue developing models on its own. The way forward is for modelling experts across Australia to work together in model development in a collaborative environment. There is no better opportunity to do this than now, with the various research partnerships across Australia (e.g., eWater CRC, WIRADA, CACWR) and the strong national support (e.g., NWC, BoM, AWRIS, DEWR, state water agencies) for providing water information by combining hydrological models and integrated data systems.

There will continue to be different types of hydrological models because they are required for different purposes. However, to provide a consistent language and interpretation for water accounting, water forecasting, policy development and legislation across river basins, states and territories, the water fluxes and system states simulated by the different models must have a consistent or similar meaning across time and space scales. For example, simulations from a higher resolution model when aggregated up should match the same simulation from a lower resolution model.

To develop a realistic vision for future hydrological modelling development, the various modelling communities need to appreciate the different model types and purposes. This is particularly important where hydrological models are used together with other models, like climate models. In some applications, the different models need to be linked directly because feedbacks between models are very important. In other applications, the different modelling can essentially be carried out separately with outputs from one model used to drive the other model.

This talk will present the different types of hydrological models, grouped into key modelling applications in Australia (summarised in the next section), and discuss the different hydrological modelling requirements for different time scales and objectives (summarised in the last section).

Typical features of main types of hydrological models

Daily conceptual rainfall-runoff models

- Used to estimate daily runoff from daily rainfall and potential evapotranspiration, mainly to extend streamflow records, to estimate catchment, regional or continental water availability, and to estimate catchment inflows into river system models.
- Increasingly adapted and used to estimate climate and development impact on runoff.
- 5–20 parameters, generally calibrated against observed streamflow data, and regionalisation method used to transfer parameter values for use in ungauged catchments.
- Essentially lumped catchment or subcatchment representation (although some models use distribution functions to represent spatial variability and sub-daily rainfall characteristics).
- Literally thousands of conceptual rainfall-runoff models in the literature, commonly used models in Australia include Sacramento, SIMHYD, AWBM and IHACRES.

Sub-daily hydrological models

- Used mainly to estimate catchment runoff for forecasting (e.g., flood forecasting and river operations).
- Sub-daily rainfall (intensity, amount and spatial distribution) is the key driver of the models.
- Accurate knowledge of antecedent soil water conditions is important. The use of remotely-sensed data can improve estimation of antecedent conditions, but to meaningfully assimilate remotely-sensed data, models require direct representation of surface layer moisture observed by satellites.
- Except for loss functions used in flood forecasting, and models used in experimental and research studies, sub-daily hydrological models have not been widely used in Australia for water applications and catchment runoff forecasting.

River system models

- Used by state water agencies and MDBC (e.g., REALM, IQQM, MSM-Bigmod) to simulate river flows and water uses across regulated river systems for water accounting and planning.
- Link-node network used to represent river system, and key model components include: rainfall-runoff models to estimate catchment inflows; routing algorithms to rout flows; models of surface-groundwater interaction in river reaches and floodplains; empirical functions of irrigation and environmental water demand; and system and reservoir operating rules that describe water sharing and allocation. Models run on either a daily, weekly or monthly time step.
- There is a hydrological modelling initiative in Australia involving research institutions and industry partners, which is attempting to truly integrate rainfall-runoff, river system and groundwater models (both in terms of modelling algorithms and in system-wide calibration and model parameterisations) to improve water accounting and estimation of climate and development impacts on water uses throughout managed river systems.

Land surface models

- Used in numerical weather prediction (NWP) and global climate models (GCMs) to model land surface processes.
- Lumped parameterisations over climate model grids of 20–500 km^2, with many parameters whose value need to be specified for all grids across the globe.

- Unlike the above model types, accurate modelling of atmosphere-surface feedbacks, in particular partitioning of net radiation into latent and sensible heat fluxes, is important. Because land surface models are linked to atmospheric models, they run over time steps of less than 30 minutes. Simulation of runoff and runoff components are usually poor.
- Numerous land surface models have been developed and used by various climate modelling groups worldwide. The ACCESS climate modelling initiative between CSIRO, BMRC and universities uses the CABLE scheme as the land surface model.

Hydrological modelling requirements for different time scales and objectives

Up to 2–3 days
Forecast based on current hydroclimate information (hydrologic memory)

- Sub-daily catchment hydrological modelling.
- Sub-daily river routing models for floods and sub-daily river operation model for river operation.
- Real-time data ingestion, data assimilation and states update/correction.
- Sub-daily rainfall from gauges and radar, and initial states are very important.

3–4 days to several weeks
Probabilistic forecast based on current hydroclimate information and NWP model forecast (hydrologic memory and climate/weather memory)

- Same as above, but with NWP model forecast to extend forecast lead time.
- Real-time data ingestion and data assimilation into NWP land surface model and/or catchment hydrological model (either the one model or some reconciliation of the two models).
- Initial states are very important.

Months/seasons
Probabilistic forecast based on seasonal hydroclimate forecast

- Daily catchment rainfall-runoff modelling and river system modelling using climate forecast inputs.
- Seasonal hydroclimate forecast from statistical methods and/or statistical–climate model hybrid.
- Start from known initial system state.

Several years
Probabilistic prediction based on climatology or low-skill long-term climate forecast

- Ensemble hydrological modelling starting from current system state to provide probabilistic indication of future water availability (for example, given the current dry conditions and low system storages, water availability and water allocation are likely to remain low for several more years even with average rainfall conditions).

More than 10 years
Scenario modelling for planning
(modelling requirements for historical water accounting are similar)

- Daily catchment hydrological modelling and river system modelling.

- Scenario modelling for future water availability and impact on water uses throughout river systems (impact of climate change, development/management, etc…).
- For climate change impact assessment, projections from GCMs are used, either to modify historical climate series to obtain future climate series or to statistically or dynamically downscale to obtain future climate series at the catchment scale to drive the hydrological models.
- Initial state is not important.