# OzEWEX

# 2016

THE AUSTRALIAN ENERGY AND WATER EXCHANGE RESEARCH INITIATIVE

3rd national workshop

*Fostering a research community culture: catalysing collaboration between universities, agencies and decision makers*

## SCHEDULE AND ABSTRACTS

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## SCHEDULE

OzEWEX

| Time | Wednesday, 14 December | |
|---|---|---|
| 8:30 | Registration | |
| 9:00 | **Plenary session** | |
| | Albert van Dijk: Welcome and update on OzEWEX | |
| | Andy Pitman (invited): One perspective on the way forward for land surface science at the interface of climate and hydrology | |
| | Richard Thornton and Michael Rumsewicz (invited): Natural disasters: The importance of all-sector collaboration in managing the inevitable | |
| 11:00 | morning tea | |
| 11:15 | **Observation networks and enhancing data sharing** (Marta Yebra, Chris Rudiger) | **Community modelling and data assimilation systems** (Luigi Renzullo, Gab Abramowitz) |
| | Alex Held (invited): Update on the TERN AusCover remote sensing data infrastructure partnership | Michael Naughton (invited): ACCESS NWP system resources for the national research community |
| | Peter Isaac (invited): Oz-WHAT? A Network for Observing Surface Fluxes of Water and Carbon Across Australia | Andy Hogg (invited): The ACCESS Climate Model as Research Infrastructure |
| 12:30 | lunch & poster session | |
| 13:30 | David Summers: “Australia’s Environment”: a community-based approach to national environmental information | Amgad Elmahdi (invited): AWRA Community Modelling System |
| | Belinda Medlyn: Identifying Regions of High Drought Mortality Risk | Andrew Frost: Evaluation of the Australian Water Resource Assessment model: AWRA-L |
| 14:30 | afternoon tea | |
| 14:45 | Norman Mueller (invited): An update on the Australian Geoscience Data Cube and its products | Rachel Law (invited): Managing the CABLE land surface model as a community modelling system |
| | Leon Majewski (invited): Advanced geostationary observations for the OzEWEX community | Vanessa Haverd: Carbon cycle responses of semi-arid ecosystems to positive asymmetry in rainfall |
| | Jingbo Wang (invited): <NCI data collections> | Martin De Kauwe (project proposal): Towards a representation of Eucalyptus trees in vegetation models |
| 16:15 | **Plenary session** | |
| | Nadeem Samnakay (invited): Science and knowledge needs for Basin-scale planning | |
| | Pauline Grierson (invited): Collaborative research to solve Australia’s water and climate challenges - perspectives from the West | |
| 17:30 | celebration drinks | |

## SCHEDULE

| Time | Thursday, 15 December | |
|---|---|---|
| 9:00 | **Plenary session** | |
| | Rob Vertessy (invited): Reflections on travelling with the hydrology community and the virtues of collectivism | |
| | Helen Cleugh (invited): Earth Systems and Climate Change Hub: Earth system science for a productive and resilient Australia | |
| | poster award | |
| 10:45 | morning tea | |
| 11:00 | **Collaborative research to address Australia's climate and water challenges** (Seth Westra) | **Towards unified and diversified streamflow prediction – connecting research, operations and decision making** (Albert van Dijk, Dongryeol Riu) |
| | David Post (invited): Data transparency in the Bioregional Assessment Programme | Carlos Velasco (invited): Quantitative precipitation estimation and forecast in the Bureau of Meteorology: current and near-future status of real-time rainfall products |
| | Garry Willgoose: A technical assessment of water issues and coal seam gas exploration and extraction: problems, research needs, and possible solutions | David Robertson (invited): Short-range precipitation forecasts – lessons for hydrological forecasting applications |
| | Angus Simpson: Selecting a Discount Rate for Economic Evaluation of Water Projects – the Sustainability Controversy | |
| 12:30 | lunch & poster session | |
| 13:30 | Elyssa de Carli (invited): Palaeolake Mannum – a unique record of Murray Darling Basin palaeofloods and a proxy for Southern Hemisphere's Holocene hydroclimate | Rory Nathan (invited): Event vs continuous modelling: dogma or context? |
| | Anthony Kiem (presentation and project proposal): Water availability across Australia during the last 2000 years: implications for water security | Albert van Dijk: Towards spatially and temporally continuous hydrological forecasting |
| 14:45 | afternoon tea | |
| 15:00 | Hong Do: A global-scale investigation of trends in annual maximum streamflow | Marie Ekstrom (invited): We need to talk about runoff projections |
| | Jason Evans: NARCliM: Climate projections for decision makers. A collaboration between UNSW and NSW government | Margarita Saft: Predicting shifts in rainfall-runoff partitioning during multiyear drought: roles of dry period and catchment characteristics |
| | Michael Leonard (project proposal): A typology of compound events | Lisa Blinco: Pump Operations for Alternative Water Sources - a Decision Support Tool |
| 16:20 | **Plenary session** | |
| | Workshop Summary and Next Steps | |
| 17:00 | - close - | |

## Poster Session

**Lanre Abiodun**: Comparison of Modis and Swat Evapotranspiration Over Complex Terrain at Different Spatial Scales

Robert **Andrew**: Dynamic water storage fuels large-scale ecosystem production in water-limited environments

Mohammad **Azmi**: Comparative evaluations between an advanced drought index and Exceptional Circumstance (EC) maps in Queensland, Australia

Lisa **Blinco**: Optimizing Pump Operations for a Harvested Stormwater and Managed Aquifer Recharge System

Josephine **Cairns**: Vertical Soil Moisture Movement in Mineral Soils: A case study from the Saint Marys Range, New Zealand.

AFM Kamal **Chowdhury**: Sensitivity of Stochastic Rainfall Models to the Characteristics of Calibration Data

Cuong **Do**: Near real-time state estimation in water distribution systems using particle filtering

Rodolfo Jr **Espada**: Vulnerability assessment and interdependency analysis of critical infrastructures for climate adaptation and flood mitigation

Valentin **Heimhuber**: Modeling multi-decadal surface water inundation dynamics and key drivers across the Murray-Darling Basin, Australia, using multiple time series of Earth-observation and river flow data

Chiara **Holgate**: Comparison of remotely sensed and modelled soil moisture data sets across Australia

Hung **Pham**: A method for combining digital elevation models without using reference data

Jianxiu **Shen**: Incorporating remote sensing methods into crop-climate relationships across the rain-fed cropland belt in NSW, Australia

Natthachet **Tangdamrongsub**: Exploiting complete GRACE information for improving soil moisture and groundwater estimates over Australia

Elisabeth **Vogel**: Impacts of climate extreme events on global crop yields – an assessment using random forests

Man **Xiao**: Improving competition models for predicting toxic cyanobacterial blooms

Jinyan **Yang**: Optimal steady-state leaf area index based on historical water balance for Australian natural ecosystems

Songyan **Yu**: Quantifying and characterizing the presence of intermittent streams in south-eastern Queensland

# Comparison of Modis and Swat Evapotranspiration Over Complex Terrain at Different Spatial Scales

**L. Abiodun**[a], **O. Batelaan**[a], **H. Guan**[a]

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In most hydrological systems, evapotranspiration (ET) together with precipitation are the largest components of the water budget, yet the most difficult to estimate, particularly over complex terrain. In recent years, the advent of remotely-sensed data based ET algorithms (R-S ET) and distributed hydrological models has significantly improved ET estimation. However, information on the relative performance of these methods at various spatial scales is limited in literature.

This study compares the ET estimates from the MOD16 R-S ET dataset and the ET calculations from a SWAT hydrological model. The analyses are performed on monthly timescales with a 6-year calibration period (2000 – 2005) and 7-year validation period (2007 – 2013). The ET over the Sixth Creek Catchment of the Western Mount Lofty Ranges of South Australia, is evaluated in this study. The SWAT model is calibrated in SUFI-2 by fitting simulated streamflow to observed streamflow and the MOD16 ET is compared to the evapotranspiration calculated by the calibrated model.

Differences of up to 56% were observed at $1km^2$ spatial scale between the methods, 16% at $5km^2$ and only 6% at the $16km^2$ spatial scale. Biome mis-match between the two methods and catchment scale averaging of input climate data in the SWAT semi-distributed model were identified as the principal sources of weaker correlations at finer spatial scales.

***Keywords:*** *Sequential Uncertainty Fitting algorithm version 2 (SUFI-2)*

# Dynamic water storage fuels large-scale ecosystem production in water-limited environments

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**Abstract:** Vegetation dynamics are an essential part of climate change studies, playing a large role in the carbon cycle. Gross primary productivity is the product of many factors, and in most parts of the world the most influential of these is water. When water transpires from a vegetative system, plant growth occurs as a result of photosynthesis, creating a link between the outgoing water flux and productivity. Here we analyse gross primary productivity against annual dynamic water storage estimated from GRACE amplitude, which represents the ecosystem-accessible water moving through a system. The results show that the dynamic water storage amplitude is a strong driver of biomass production. Strong correlations between gross primary production and annual amplitudes of total water storage exist in water limited ecosystems globally. The use of total water storage amplitude provides a novel approach linking the dependence of vegetation growth to water that is available and actually used by ecosystems. With predictions of decreased water availability in systems which are already water limited, this relationship could be of great use for future predictions of carbon fluxes and vegetation dynamics.

***Keywords:*** *Dynamic water storage, Biomass production, Primary production, GRACE*

# Comparative evaluations between an advanced drought index and Exceptional Circumstance (EC) maps in Queensland, Australia

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Drought and water stress index validation is a difficult task, requiring reference data encompassing several decades, so that the entire hydrological spectrum is covered. The recently developed Data Fusion-based Drought Index (DFDI) has shown its ability to monitor water stress conditions across the diverse range of terrestrial ecosystems in Australia, by combining different data sources of various lengths. This is possible as DFDI comprehensively considers all types of drought through a selection of indices and proxies associated with each individual drought type. Here, a long-term modelled dataset (1911-2016) from the Australian Water Resources Assessment Landscape model (AWRA-L) along with spectral measurements from the MODIS-Terra instrument (2000-2016) have been utilized to derive gridded 3-month (moving average) DFDI values across Queensland, Australia. In order to validate the results, Exceptional Circumstance (EC) maps provided by the Queensland government, were considered as a ground truth of water stress conditions. EC maps are derived based on a variety of hydrometeorological variables such as precipitation as well as reports from the local population, particularly farmers. Here, the similarities and discrepancies between the water stress maps derived from DFDI and EC are compared for a 3.5-year period (since January 2013). At first, a variety of drought thresholds as well as percentiles for the calculation of the final DFDI for each sub-region were considered. The results show that in 69% of events the DFDI matches the EC maps by considering the 50th percentile of a drought-indicative threshold of -0.37. Furthermore, 3-month standardized precipitation index (SPI) maps are also compared against EC maps for regions that showed around 40% similarity. Therefore, it can be concluded that the DFDI can be considered as a reliable state-of-the-art drought index to be applied in water stress monitoring of regions with highly complex geographical and climate conditions.

***Keywords:*** *Drought index, Exceptional Circumstances maps, Queensland.*

# Pump Operations for Alternative Water Sources – a Decision Support Tool

**A.Marchi[a,b] , L.J. Blinco[a, b], A.R. Simpson[a,b], M.F. Lambert[a,b]**

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**Abstract:** Pump operations in traditional water distribution systems (WDSs) use a large amount of energy, and in alternative water source systems, such as those using harvested stormwater and imported water, often use significantly more energy, therefore incurring a significant cost. There have been many investigations into the energy use of pumps in traditional WDSs, as well as optimization of operating strategies to minimize the cost of pumping. As climate change and a growing population heighten water security concerns, alternative water sources are being implemented to reduce stress on existing sources. While some effort has been put into optimizing the design of alternative water sources, there has not been any investigation into optimizing their pumping operations.

Methodologies that have been applied to traditional WDSs can be applied to alternative water source systems, however, modifications are required to take into account the additional complexity of these systems, and different objectives. Pumping operations in traditional WDSs can be modelled using only hydraulic simulation, with the assumption that there is always water available in a supply reservoir. For some alternative water sources, for example harvested stormwater, there is not always water available, and hydrologic or mass balance modelling may be required to take into account factors such as rainfall, streamflow and evaporation. Hydraulic modelling is still required to determine the pump operating point (and how it changes throughout the simulation period), and to therefore provide an accurate energy cost calculation. There may also be additional components such as injection and extraction bores for groundwater, and small scale treatment plants that need to be incorporated in models of alternative water source systems.

Our research group has worked closely with the Orange City Council to develop a tool to optimize pump operations in their integrated supply system, called the Pump Operations for Alternative Water Sources (POAWS) tool. Water supplies for the town of Orange in NSW come from four different sources: the natural catchment, groundwater bores, stormwater schemes and imported water from the Macquarie River. The POAWS tool combines a mutli-objective genetic optimization algorithm – NSGAII, EPANET hydraulic simulation software, additional code to include rainfall, evaporation, and other processes, and an excel interface to allow the user to easily apply the tool. Figure 1 shows the process the user would go through when using the tool; Orange City Council plans to use the tool every three to six months, updating the climate forecast each time to find operating strategies that will reduce pumping costs. Results from test runs show that different sources will be favored depending on the selected objectives and climate data.

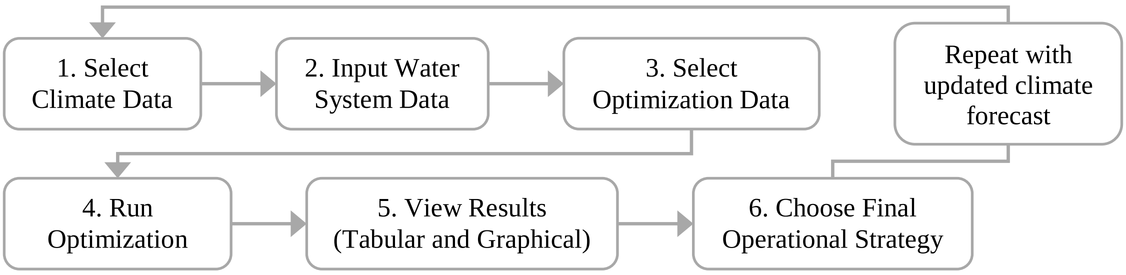


**Figure 1: Process of the POAWS Tool**

***Keywords:*** *Alternative water sources, decision support tool, optimization, pump operations*

# Optimizing Pump Operations for a Harvested Stormwater and Managed Aquifer Recharge System

**L.J. Blinco**[a, b], **A.R. Simpson**[a,b], **M.F. Lambert**[a,b], **A.Marchi**[a,b]

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[b] *Cooperative Research Centre for Water Sensitive Cities, PO BOX 8000, Monash University LPO, Clayton, Victoria 3800, Australia*
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**Abstract:** Harvested stormwater systems are becoming increasing popular as a means to supplement potable water supplies, and thereby improve water security. They are often used in conjunction with managed aquifer recharge systems, allowing long-term storage of large quantities of water such that water harvested during wet periods can be utilized in dryer periods. Significant research effort has been put in to ensuring water quality and hydrological impacts of harvested stormwater systems are improved, as well as optimizing the design of the systems. Pumping in all types of water systems is a significant contributor to cost and therefore optimizing the pumping operations of harvested stormwater systems is important.

The Ridge Park Harvested Stormwater and Managed Aquifer Recharge System is in the City of Unley in South Australia. During winter, water is collected from an urban waterway, Glen Osmond Creek, and pumped to treatment through a Bioretention Basin, UV and Micro-Filter. It is then injected into an aquifer for storage (Figure 1). During summer, water is extracted from the aquifer and used to irrigate parks and reserves in the City of Unley; some irrigation demands are on a pressure distribution system, and some on a gravity line. The distinct seasons means that the simulation and optimization of the system was split over the winter and summer operations. Trigger levels in storages that control Pumps 1, 2 and 3 were optimized for the winter operation, and for the summer operation, trigger levels for the Bore Pump and the irrigation schedule were optimized. Objectives of maximizing the volume harvested and minimizing pump energy costs were considered in winter, while only the cost objective was considered for summer operations. For the winter pumping and aquifer injection system, different streamflow series' (from recorded data) were incorporated using two different methods: considering individual streamflow series' to produce optimal solutions for each particular series, and looping through the multiple streamflow series' to find robust optimal solutions.

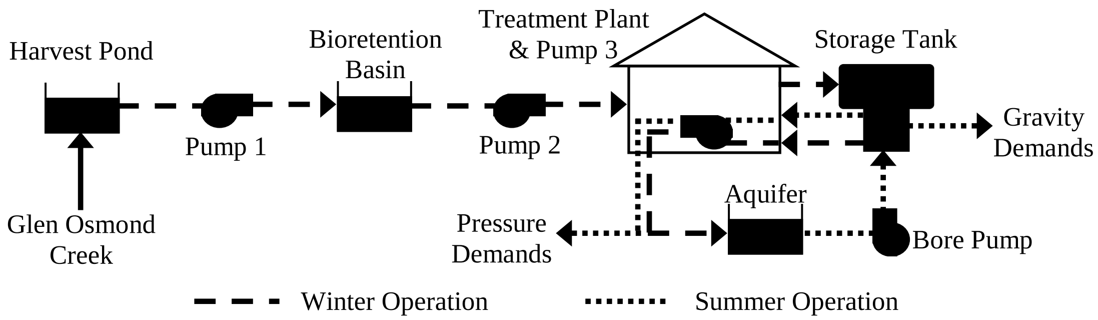


**Figure 1: Schematic of the Ridge Park Case Study System**

Analysis of the system operation before optimization showed that Pumps 1, 2 and 3 were not operating at similar flow rates, and Pumps 2 and 3 also had very low efficiencies. New replacement pumps were sized such that the flows through the system would be relatively even, and efficiencies would be improved. The optimization found improvements in cost compared to the current operation in both winter and summer. Replacing Pumps 1, 2 and 3 provided significant benefits for both cost and yield in the winter system. Using trigger levels that are more widely spaced in all storages was optimal in both winter and summer. The optimal irrigation schedule had all of the reserves on the pressure line scheduled at the same time, as this resulted in Pump 3 being able to operate at a more efficient point. Irrigation of reserves on the gravity line was then distributed such that the total demands were relatively even across different nights of the week.

***Keywords:*** *Harvested stormwater, managed aquifer recharge, optimization, pump operations*

# Vertical Soil Moisture Movement in Mineral Soils: A case study from the Saint Marys Range, New Zealand.

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**Abstract:** Tussock grasslands of the South Island of New Zealand have high water yields as a result of their low evapotranspiration rates and ability to intercept precipitation from fog. This study built on current research into water yields and tussock grasslands, using a soil moisture budget approach combined with direct measurements of soil moisture to determine the fine scale perturbations in soil moisture. Time domain reflectometry probes were installed in a tussock grassland catchment site in conjunction with an automatic weather station to build a record of precipitation, runoff and meteorological observations over a three week period. These data were used to develop a soil moisture budget for the study site. This study will aid in developing a better hydrological understanding that accounts for the distinctively high water yields that occur under tussock grasslands and contribute to the development of a framework for valuing and preserving the hydrological function of high country tussock in water allocation in the region.

***Keywords:*** *Soil moisture; TDR; infiltration rate; tussock grasslands*

# Sensitivity of Stochastic Rainfall Models to the Characteristics of Calibration Data

**AFM Kamal Chowdhury[a], Natalie Lockart[a], Garry Willgoose[a], George Kuczera[a], Anthony S. Kiem[b], and Nadeeka Parana Manage[a]**

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**Abstract:** Stochastic rainfall models are used to incorporate long-term variability of climate for urban drought security assessment. Commonly, stochastic models with parameters calibrated to available short-period (e.g. 50-100 years) climate data are used to generate long synthetic series (e.g. 1000 years) of rainfall so that a wide-range of future climate variability can be captured in the system. However, the ability of the stochastic models to capture the climate variability outside of the calibration period (i.e. validation periods) is generally sensitive to the characteristics of calibration data.

This study has assessed the ability of two stochastic models in capturing the rainfall and streamflow variability of validation periods and their dependence to the record length and wetness of calibration period. The two stochastic models are: (1) a decadal and hierarchical Markov Chain (MC) model, which we developed in a previous study and (2) a semi-parametric MC model developed by Mehrotra and Sharma (2007). Our hierarchical model uses decade-varied parameters of MC and stochastic parameters of Gamma distribution, while the semi-parametric model uses a modified MC process with memory of past periods and kernel density estimation.

Each model was calibrated to high-resolution gridded daily rainfall data for east coast of Australia. A SimHyd hydrology model was used to generate synthetic streamflow for each model. For calibration period, both models satisfactorily reproduce the distribution and autocorrelations of wet-dry periods, rainfall depths, and streamflow volumes at daily to multiyear resolutions. However, the hierarchical model tends to underestimate and the semi-parametric model tends to overestimate the mean of annual rainfall depths and streamflow volumes. For the distribution statistics of rainfall and streamflow of validation period, the hierarchical model performs better than semi-parametric model if the calibration period is wetter than the validation period, while the semi-parametric model performs better than the hierarchical model if the calibration period is drier than the validation period. Sensitivity of each model to the record length and wetness of calibration period and their implications for urban drought security assessment will be discussed.

***Keywords:*** *Stochastic rainfall models, calibration and validation.*

# Earth Systems and Climate Change Hub: Earth system science for a productive and resilient Australia

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The Australian government's National Environmental Science Programme (NESP) was launched in 2014 with the goal of providing the environmental research needed to inform Australian decision makers; with a focus on biodiversity and climate. The Earth Systems and Climate Change Hub is a national partnership, established in 2015, that brings together world-leading capability in multi-disciplinary Earth system science and modelling to provide the information needed to support a productive and resilient Australia. This presentation will provide an overview of the Hub's research priorities, goals and outcomes; along with the overarching research plan. With a strong outcome-focus, commitment to significant stakeholder engagement, and links to the other five NESP Hubs (Threatened Species, Clean Air and Urban Landscapes, Marine Biodiversity, Tropical Water Quality and Northern Australia Resources), the Hub provides an opportunity to ensure that environmental decision and policy-making is informed by the best available climate science.

# Palaeolake Mannum – a unique record of Murray Darling Basin palaeofloods and a proxy for Southern Hemisphere's Holocene hydroclimate

**Elyssa De Carli[1]*, Tom Hubble[1], Dan Penny[1], Dave Petley[2], Tom Job[1], Rebecca Hamilton[1], Samantha Clarke[1], Patricia Gadd[3], Helen E. A. Brand[4], Anna Helfensdorfer[1]**

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**Abstract**

The 1.07 million km$^2$ Murray-Darling River Basin (MDB) drains 14% of Australia's landmass, incorporates Australia's most economically important agricultural region, and represents one of Australia's most important and contentious environmental management and water security challenges. The Murray and Darling River catchments extend from the sub-tropics to the mid latitudes of eastern Australia, with Basin precipitation driven by distinct synoptic-scale oceanic-atmospheric processes. Long-term palaeorecords of south-east Australian (SEA) hydroclimate are crucial for documenting fluvial response to shifting flood and drought regimes, particularly in light of a projected fall in cool season rainfall over the Basin during the 21st century, and a likely increase in the frequency of extreme events. Further, recent research indicates that the Australian instrumental record (~100 years in length) does not cover the full range of hydroclimatic variability, with significantly longer and more frequent wet and dry periods experienced in the pre-instrumental period.

Here we report the discovery of a regionally extensive laminated deposit at the terminus of the MDB, deposited within a previously unrecognised palaeolake, which we term Palaeolake Mannum. Holocene-aged sediment deposited within Palaeolake Mannum provides the first *in-situ* high-resolution proxy archive of palaeodischarge and peak flood behavior from the MDB system, from which evidence of synoptic-scale Southern Hemisphere climate forcing may be decomposed. The Darling River palaeofloods providing a far-field record of north-eastern Australia's hydroclimate and summer precipitation driven by the ASM, IOD, ENSO, and IPO, and Murray River palaeofloods provide a proxy record of precipitation and seasonal spring snow melt within that catchment, strongly influenced by the SW and SAM. Future collaborative research on this unique record, and a reconstruction of MDB flood frequency can be used to validate, or hindcast, current palaeoclimate reconstructions based on the instrumental record, contributing important research to solve Australia's water security challenges in the face of a changing climate.

***Keywords:*** *Palaeofloods, Murray-Darling Basin, Holocene, Hydroclimate*

# Towards a representation of Eucalyptus trees in vegetation models

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**Abstract:** Eucalyptus trees are a defining feature of the Australian landscape, with ~900 species growing across arid, coastal, sub-alpine and temperate regions of the continent, dominating forest and woodland vegetation. This genus has many unique features, giving rise to the expectation that the functional responses of vegetation to environment will differ from similar vegetation on other continents. However, the models currently used to represent vegetation in Australia do not take account of the uniqueness of this vegetation type. Instead, they assume that Australian trees can be represented by a generic description of plant functional type: one which depicts the behaviour of an Oak tree in England, as well as that of the Amazon rainforest. Ecological understanding of Eucalypt function suggests that these trees should be modelled differently; yet the notion that Eucalypts behave fundamentally differently from other groups has never been tested.

The goal of this proposal is to establish a working group to bring together key datasets to quantify functional differences between Eucalypts and other dominant vegetation types. We will begin the process of developing the missing process representation needed to inform new evidence-based functions for the Australian Community Atmosphere Biosphere Land Exchange (CABLE) model. We seek funds to cover travel and meeting expenses for a 2-day meeting in Sydney in 2017. We will use this meeting as an opportunity to synthesise a range of existing experimental and field observations of Eucalyptus function, and to outline a roadmap to use these data to improve CABLE.

The working group will draw on expertise from a range of sources and institutions. Potential contributions include large plant trait databases (Mark Westoby, Ian Wright, Rachael Gallagher, Macquarie University), plant ecophysiological studies (Owen Atkin, Australian National University, David Ellsworth, Brendan Choat, Western Sydney University), and eddy covariance datasets (Jason Beringer, University of Western Australia, and Lindsay Hutley, Charles Darwin University).

Co-funding for this workshop will be available from the Australian Research Council Centre of Excellence for Climate System Science. A commitment to build outcomes into CABLE and test these outcomes against Ozflux measurements has been made by the Centre. Further, experiments in a coupled framework, most likely in high resolution (Weather Research and Forecasting; WRF) simulations with independent validation with meteorological observations will be undertaken with resources from the Centre. In short, the OzEWEX funding will be matched by Centre funding in a partnership of national significance.

***Keywords:*** *Eucalypts, forest ecosystems, land surface models, climate change*

# A global-scale investigation of trends in annual maximum streamflow

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**Abstract:** This study investigates the presence of trends in annual maximum daily streamflow data from the Global Runoff Data Centre database, which holds records of 9,213 stations across the globe. The record was divided into three reference datasets representing different compromises between spatial coverage and minimum record length, followed by further filtering based on continent, Köppen-Weiger climate classification, presence of dams, forest cover changes and catchment size. Trends were detected using the Mann-Kendall nonparametric trend test at the 10% significance level, combined with a field significance test. The analysis found substantial differences between reference datasets in terms of the stations that exhibited significant increasing or decreasing trends, highlighting an important role of sampling variability on the trend results. The results were more consistent at the regional scale, with decreasing trends for a large number of stations in western North America and the data-covered regions of Australia, and increasing trends in parts of Europe, eastern North America, parts of South America and southern Africa. Interestingly, neither the presence of dams nor changes in forest cover had a large effect on the trend results, but the catchment size was important, as catchments exhibiting increasing (decreasing) trends tended to be smaller (larger). Finally, there were more stations with significant decreasing trends than significant increasing trends across all the datasets analysed, indicating that limited evidence exists for the hypothesis that flood hazard is increasing when averaged across the data-covered regions of the globe.

***Keywords:*** *Global flood hazard; trend analysis; climate change; annual maximum streamflow*

# Near real-time state estimation in water distribution systems using particle filtering

**N.C. Do[a], A.R. Simpson[a], J. Deuerlein[b] and O. Piller[c]**

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[b] *3S Consult GmbH, Karlsruhe, Germany*
[c] *Irstea, UR ETBX, Department of Waters, Bordeaux, France*

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**Abstract:** Water distribution systems are built to provide adequate quantity and quality water to customers. The problem of ensuring a satisfactory and reliable service is complicated by population growth, aging systems and rapid urbanization. Integrating real-time observational data into water distribution models to improve operational and management decisions has, therefore, become a challenge for hydraulic researchers.

In this work, a particle filter model that implements a predictor corrector approach is introduced for the estimation of water demand multiplier factors (DMFs) in near real-time (Figure 1). The demand forecasting model presented by van Zyl et al. (2008) has been applied to predict DMFs at each time step. The hydraulic solver EPANET (Rossman, 2000), which simulates the hydraulic behaviour of water distribution systems, was used to compute the nodal pressures and flow rates at measurement locations. These computed values were then integrated with the corresponding field measurements in order to update the predicted DMFs. After each iteration, the best estimate of DMFs was selected for uncertainty quantification. The uncertainty of the DMFs caused by the measurement errors was calculated by the first order approximation method. In addition, a systematic resampling algorithm was also applied to resample the DMFs so as to prevent particle filter degeneracy problem.

The results from a case study show that the proposed model is able to provide reliable estimates of the demand multiplier factors in a near real-time context.

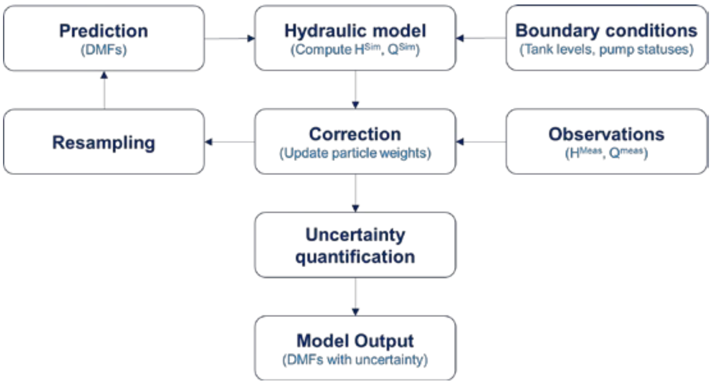


Figure 1: Particle filter model for near real-time state estimation in water distribution systems

***Keywords:*** *Water distribution systems, real time state estimation, particle filter, uncertainty, data integration*

## References

Rossman, LA 2000, 'EPANET 2: Users' Manual', US Environmental Protection Agency (EPA), USA.

van Zyl, JE, Piller, O & le Gat, Y 2008, 'Sizing municipal storage tanks based on reliability criteria', *Journal of Water Resources Planning and Management*, vol. 134, no. 6, pp. 548-555.

# We need to talk about runoff projections

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**Abstract:** The CSIRO has a long tradition of providing estimates of future change to regional runoff. These estimates serve to support long-term planning of water resources under global warming, providing useful insights into physically plausible changes to future water supply. Key projection products were produced through the sustainable yields projects (Murray-Darling Basin (2007), Tasmania (2009), South-west Western Australia (2009) and Northern Australia (2009)), followed by work in the Southeast Australian Climate Initiative (2010) and more recently the Victorian Climate Initiative (2016). Other projection products exist, such as the Climate Futures for Tasmania (2010) and the future climate and runoff projections (~2030) for New South Wales and Australian Capital Territory (2008). These projection products span nearly 10 years (2007 to 2016) and most of these use a similar methodology, namely the combination of empirically scaled global climate model output in combination with hydrological modelling, essentially very little progress has occurred in the way we produce runoff projections. Is this a problem? Maybe, maybe not … most likely it depends on the geographical region of interest and the intended application of the runoff projection.

Empirical scaling drapes a change signal derived from global climate models onto observed datasets. In doing so, spatial and temporal dependencies in observed data are preserved and only distributional changes are imposed (or mean change if data is scaled by the change to the mean). In empirical scaling, the climate change signal has the spatial resolution of the GCM and the temporal resolution of the scaling factor. Hence, the climate change signal has a spatial resolution of about 100-250km. Any spatial variability on finer resolutions are due to variability in observed data. Temporally variability on finer time steps than that of the scaling factor is also due to variability in observed data. Hence if a monthly scaling factor is used, then there is little point in using the runoff projections to look at change in daily sequencing characteristic, whilst meaningful events that manifest on longer time scales would still be captured (e.g. averages, drought).

A major stumble block for advancement in runoff projections is the lack of knowledge about the regional climate change signal. This information is typically sought from ‘downscaling’ methods, i.e. techniques applied to global climate model output so to translate their coarse resolution data to finer resolved projections. Few existing downscaled datasets have national coverage and in regions where there is spatial overlap by several datasets there can be significant differences in the projected change signal. Without national coordination and financial support to create ensembles of regional projections (and to understand/interpret the differences between methods) it is difficult to see this situation changing in the near future.

A second limitation is the use of hydrological models, optimized for particular flow regimes against historical observations, in climate change impact studies. In a climate change perspective, it is possible that calibration settings based on historical data is unsuitable to represent conditions in the future. Changes to catchment land surface conditions, groundwater-surface water connectivity, and vegetation-use of water in a warming climate and enhanced $CO_2$ world with potentially significant changes in rainfall characteristics, are all factors that could influence model performance. This is part of the non-stationarity problem that hydrologists are well aware of. Until researchers are able to account for these processes in hydrological models it is possible that projections have systematic biases due to inadequate flexibility in estimating runoff under changing environmental conditions.

To begin to tackle some of these challenges we need to recognize the limitations in our current work, and focus on method development. This require problem-focused collaboration across scientific disciplines as well as support from our stakeholders who ultimately rely on our guidance and knowledge.

***Keywords:*** *Runoff projections, climate change signal*

# Vulnerability assessment and interdependency analysis of critical infrastructures for climate adaptation and flood mitigation*

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**Abstract:** In general, the aim of this study was to develop a new spatially-explicit analytical approach for urban flood risk assessment and generation of climate adaptation capacity metrics for assessing critical infrastructure vulnerability (Espada, 2013). By applying this novel approach, we further examined the vulnerability and interdependency of critical infrastructures through the network theory in GIS setting in combination with literature & government reports. Specifically, the objectives of this study were to generate the network models of critical infrastructure systems (CISs), particularly electricity, roads & sewerage networks; to characterize the CISs' interdependencies; and to outline the climate adaptation (CA) and flood mitigation measures of critical infrastructure systems (CISs).

Using the January 2011 flood in Queensland (Australia) with the core suburbs of Brisbane City as the study area and based on the premise of individualised approach in the past, we developed a spatially-explicit analytical technique identified as *flood risk-adaptation capacity index/metrics-adaptation strategies (FRACIAS) linkage model* which allowed the integration of flood risk and climate adaptation assessments (Espada *et al.*, 2013). The generated model revealed that 214ha (9%) and 255ha (11%) of the study area were very highly impacted by the January 2011 flood as indicated by the very high flood risk metrics and the very low adaptation capacity metrics, respectively. The generated network models of critical infrastructures at single-system level revealed the following results: 1) seventy-five (75) electricity assets were found to be within areas of very high flood. Using these highly vulnerable critical electricity assets as flag junctions in the network analysis, electricity supplies were considerably disrupted along the 627 and 212 km transmission lines in the North East to South West and South East areas, respectively; 2) one hundred seventy (170) km of road network were located within areas of very high flood risk; and 3) four hundred fifty five (455) out of the 2,525 sewage sources (as assumed points of sewerage blockage) were identified as highly vulnerable sewerage network assets being found within areas. Flagging them as critical junctions in the utility network model, analysis revealed that 33 km (91 per cent), 32 km (78 per cent) and 16 km (81 per cent) of the sewerage main trunk, reticulation and pressure rising networks were potentially affected by the January 2011 flood.

Using the multi-system level approach or geographic interdependency, for example, we generated a map showing the co-location and close proximity of electricity infrastructure, residential premises and sewerage networks on areas characterized by very high flood risk. The map revealed the affected critical infrastructures due to unavailability of electricity both to flooded and non-flooded premises. Finally, we established the hierarchical framework of understanding climate resilience for critical infrastructures in relation to the 2010/2011 floods in Queensland in the following order: elimination, isolation, substitution, augmentation, modification, administration and protection.

By providing this information, government-owned corporations, critical infrastructure managers and other concerned stakeholders will allow to 1) identify infrastructure assets that are highly critical; 2) identify vulnerable infrastructures within areas of very high flood risk; 3) examine the interdependency of critical infrastructures and the effects of cascaded failures; 4) identify ways of reducing flood risk and extreme climate events; and 5) prioritize DRR measures and CA strategies.

***Keywords:*** *Flood risk assessment, climate adaptation capacity, flood mitigation, climate resilience, critical infrastructure interdependency*

Reference:

Espada Jr., R. and Apan, A. and McDougall, K. (2013) *Using spatial modelling to develop flood risk and climate adaptation capacity metrics for assessing urban community and critical electricity infrastructure vulnerability.* In: 20th International Congress on Modelling and Simulation (MODSIM 2013): Adapting to Change: The Multiple Roles of Modelling , 1-6 Dec 2013, Adelaide, Australia.

* Espada Jr., Rodolfo and Apan, Armando and McDougall, Kevin (2015) *Vulnerability assessment and interdependency analysis of critical infrastructures for climate adaptation and flood mitigation.* International Journal of Disaster Resilience in the Built Environment, 6 (3). pp. 313-346. ISSN 1759-5908.

# NARCliM: Climate projections for decision makers.
## A collaboration between UNSW and NSW government.

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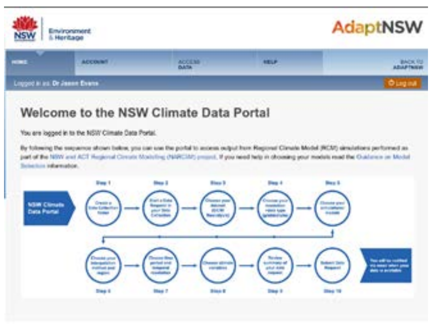
NARCliM (NSW / ACT Regional Climate Modelling project) is a collaboration with NSW and ACT governments to produce a climate projection ensemble that can be used across government departments to include future climate change in planning processes in a systematic and consistent way. The project was designed with an end user focus but also explicitly acknowledged the need for continued research on the modelling system and projection data produced.

To maximize end user engagement and ensure outputs are relevant to the planning process, a series of stakeholder workshops were run to define key aspects of the model experiment including spatial resolution, time slices, and output variables. This co-design of the project helped ensure end-user buy-in to the project. Collaboration and end-user engagement was maintained throughout the project through the established governance structure. The structure included a project management team that included a science management lead and a policy support lead from NSW Office of Environment and Heritage (OEH), and a climate modelling lead from UNSW. The project management team were in regular contact throughout the project, discussing progress, next steps and troubleshooting issues as they arose. A project steering group was also established. It consisted of representatives of key ACT and NSW government agencies and water authorities. The steering group met twice a year to discuss progress against milestones and priorities for the next 6 months. Finally, an end-user reference group was established that had access to portions of the data during the project and provided feedback on data delivery mechanisms and usability of data formats. This feedback helped to shape the data dissemination tools developed within the project.

Three distinct groups of user were identified through the end-user engagement. General users that are interested in a summary of the projections for their region at a non-technical level; impacts and adaptation researchers that would like to use specific subsets of the data that are relevant to their system of interest and may be used to drive models of that system; and climate scientists that want access to the full dataset to investigate climate processes. General users are catered for through the creation of the AdaptNSW website (http://climatechange.environment.nsw.gov.au). This website has a map view that provides access to summary reports and change data for particular locations. Impacts and adaptation researcher can use the NSW climate data portal (https://climatedata.environment.nsw.gov.au/) that steps them through a series of decision in order to extract the data they desire in the format they desire. Climate scientists should contact UNSW for access to the full dataset.


AdaptNSW map view




NSW Climate Data Portal

***Keywords:*** *Regional Climate Projections, south-east Australia, WRF, climate data*

# Evaluation of the Australian Water Resource Assessment model: AWRA-L

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**Abstract:** The Australian Water Resource Assessment Modelling System (AWRAMS) has been developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Bureau of Meteorology (the Bureau) towards fulfilling the Bureau's water reporting requirements specified in the Water Act (2007). Operational outputs from the AWRA-L (the landscape component of AWRA) daily 0.05 degree gridded soil moisture, runoff, evapotranspiration, and deep drainage outputs available from yesterday back to 1911 online through the Australian Landscape Water Balance website www.bom.gov.au/water/landscape.

The operational AWRAMS has been used towards supplying retrospective water balance estimates published by the Bureau within Water in Australia (an annual national picture of water availability and use in a particular financial year), Water Resource Assessments produced prior to Water In Australia, Regional water information water resource assessments and the National Water Account (an annual set of water accounting reports for ten nationally significant water resource management regions. Adelaide, Burdekin, Canberra, Daly, Melbourne, Murray–Darling Basin, Ord, Perth, South East Queensland and Sydney). Further, initial trials are underway using AWRA-L for assessing antecedent conditions for operational flood forecasting. The model outputs are also finding widespread use across industry.

In addition to the operational AWRAMS, the AWRA-L modelling system has recently been released as a Community Modelling System, to enable different applications (for example local/regional scenario assessment) and further development by researchers and organisations external to the Bureau.

This work details the evaluation of the Bureau of Meteorology's operational Australian Water Resources Assessment Landscape (AWRA-L version 5) modelling system using a range of the best available measurements/estimates of hydrological data including streamflow, soil moisture, actual evapotranspiration (ET) and groundwater recharge across the selected catchments/sets of point measurements at the continental scale. In addition, the performance of the operational AWRA-L version 5 model is compared to two other national gridded land-surface peer models i.e. CABLE-SLI and WaterDyn. AWRA-L is also compared with individual conceptual rainfall runoff models using at-site calibration and nearest neighbour regionalisation for streamflow prediction purposes.

AWRA-L and the peer models are assessed and compared according to various performance statistics for each set of evaluation data. Select key indicators of AWRA-L model performance are provided. These *benchmark* statistics provide a baseline over which future model improvements can be compared against using the same comparison data. Aspirational targets for overall performance are also provided.

AWRA-L v5 performs relatively well according to streamflow nationally (with 295 unimpaired catchments used in calibration, and 291 separate catchments used in validation), rootzone (0-100cm) soil moisture, but relatively under perform in comparison for these two models for ET. Preliminary comparison of AWRA-L model deep drainage output against a long term average and annual time-series recharge dataset showed that observed drainage biases are driven predominantly by the saturated hydraulic conductivity rather than rainfall variability, noting high uncertainty in these recharge estimates. The better performance of AWRA-L model according to streamflow is due to better nationwide calibration and conceptual hydrological structure. CABLE is equivalent to AWRA-L in terms of soil moisture, and better according to ET as expected from its purpose as a model for land/atmosphere exchange model, along with calibration to flux tower and derived catchment ET. WaterDyn performs well for ET, but performs relatively worse for streamflow and root zone soil moisture.

***Keywords:*** *Water resource assessment, soil-moisture, evapotranspiration, recharge, runoff*

# Collaborative research to solve Australia's water and climate challenges - perspectives from the West

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**Abstract:** Adaptation to changing climate and planning for management of Australia's water resources is contingent on understanding the risks associated with high rainfall variability and the nature of extreme droughts and pluvials across the continent. In particular, there is a critical need for better characterisation of climate variation across western and northern Australia (where there is a dearth of records and significantly less research "effort" compared to the southeast) in order to better explain mechanisms of rainfall delivery to the rest of the continent. We are now working with colleagues both within and outside Australia to develop the first comprehensive "drought atlas" for the Australian continent through the development of a network of novel tree ring proxies that can be used to characterise the scales and drivers of variability in rainfall over at last the last 500 years. The research will compare extremes and periodicities between eastern and western Australia to find over-arching common signals in the joint climate modes. Benefits of improved collaboration across Australia include greater capacity for organised responses to environmental and policy problems and the return on research infrastructure investment can increase many-fold. Our experience confirms that the success of collaboration nationally and internationally relies on building respectful partnerships and trust, recognising interdependence, and generating a collective vision, which are all contingent on regular and inclusive communication.

***Keywords:*** *tree rings, hydroclimate variability, drought atlas, risk management*

# Carbon cycle responses of semi-arid ecosystems to positive asymmetry in rainfall

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**Abstract:**

Recent evidence shows that warm semi-arid ecosystems are playing a disproportionate role in the inter-annual variability and greening trend of the global carbon cycle given their mean lower productivity when compared with other biomes.[1] Using multiple observations (land-atmosphere fluxes, biomass, streamflow and remotely sensed vegetation cover) and two state-of-the-art biospheric models (CABLE and LPJ-GUESS), we show that climate variability and extremes lead to positive or negative responses in the biosphere, depending on vegetation type. We find Australia to be a global hot-spot for variability, with semi-arid ecosystems in that country exhibiting increased carbon uptake due to both asymmetry in the interannual distribution of rainfall (extrinsic forcing), and asymmetry in the response of gross primary production (GPP) to rainfall change (intrinsic response). The latter is attributable to the pulse-response behaviour of the drought-adapted biota of these systems, a response that is estimated to be as much as half of that from the $CO_2$ fertilization effect during 1990-2013. Mesic ecosystems, lacking drought-adapted species, did not show an intrinsic asymmetric response. Our findings suggest that a future more variable climate will induce large but contrasting ecosystem responses, differing among biomes globally, independent of changes in mean precipitation alone. The most significant changes are occurring in the extensive arid and semi-arid regions and we suggest that the reported increased carbon uptake in response to asymmetric responses might be contributing to the observed greening trends there. These results were recently reported in Global Change Biology.[2]

[1]Ahlström, A. et al..: The dominant role of semi-arid ecosystems in the trend and variability of the land CO2 sink, *Science*, 348, 895-899, 2015.

[2]Haverd, V., Ahlstrom, A., Smith, B., Canadell, J.G.: Carbon cycle responses of semi-arid ecosystems to positive asymmetry in rainfall, *Global Change Biology*, doi: 10.1111/gcb.13412, 2016.

***Keywords:*** *semi-arid ecosystems, rainfall asymmetry, greening trend, global carbon cycle, Australia*

# Modeling multi-decadal surface water inundation dynamics and key drivers across the Murray-Darling Basin, Australia, using multiple time series of Earth-observation and river flow data

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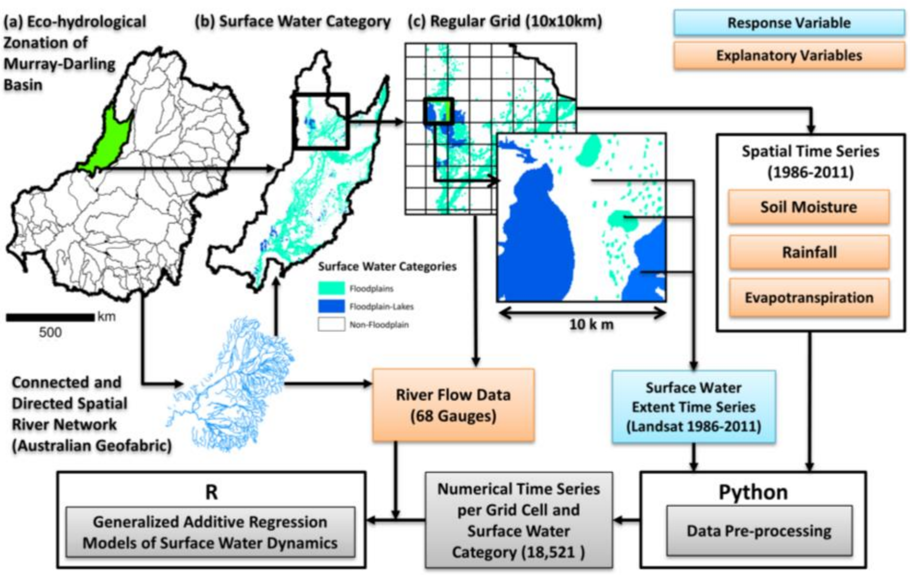
**Abstract:**

Periodically inundated surface water (SW) areas are hotspots of biodiversity and provide a broad range of ecosystem services but have suffered alarming declines in recent history. Despite their importance, their long-term SW dynamics and hydro-climatic drivers remain poorly quantified on continental scales. The main objective of our research was to model SW dynamics from a unique, statistically validated Landsat-based time series (1986–2011) continuously through cycles of flooding and drying across a large and heterogeneous river basin, the Murray–Darling Basin (MDB) in Australia. We fitted generalized additive models (GAM) between SW extent as the dependent variable and river flow data from 68 gauges, spatial time series of rainfall (P, BoM historical gridded daily rainfall), evapotranspiration (ET, AWRA-L) and soil moisture (SM, active passive microwave satellite remote sensing) as predictor variables. We used a fully directed and connected river network (Australian Geofabric) in combination with a variety of ancillary data, to develop a spatial modeling framework (see. Figure) consisting of 18,521 individual modeling units, made up of 10x10 km grid cells, each split into floodplain, floodplain-lake and non-floodplain areas. Average goodness of fit of models was high across floodplains and floodplain-lakes ($r^2 > 0.65$), which were primarily driven by river flow, and was lower for non-floodplain areas ($r^2 > 0.24$), which were primarily driven by rainfall on the grid cell. Our results further indicate that local climate conditions (i.e. P, ET, SM) were more relevant for explaining SW dynamics in the northern compared to the southern basin and had the highest influence in the least regulated and most extended floodplains in the north-west of the basin. We also applied statistical models of two contrasting floodplain areas to predict SW extents of cloud-affected time steps in the Landsat time series during the large 2010 floods with high validated accuracy ($r^2 > 0.97$). Our study illustrates the good potential of integrating multiple remote sensing and modeling-based spatial time series of hydro-climatic variables for improving the management of SW resources over very large areas. The modeling framework is applicable to other complex river systems across the world and enables a more detailed quantification of large floods and drivers of SW dynamics compared to existing methods.

***Keywords:*** *Surface water dynamics, flood inundation modeling, Landsat time series, satellite remote sensing*



# The ACCESS Climate Model as Research Infrastructure

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**Abstract:** Over the last decade Australia's research community (CSIRO, Bureau of Meteorology and universities, with international partners) collaborated to build ACCESS, an advanced weather and climate simulation system. ACCESS significantly improves forecasting skill and is benchmarked in the top five global climate models. The ACCESS framework provides a clear research pathway to impact by direct contribution to operational weather and climate prediction tools. While the ACCESS infrastructure has driven effective research collaboration (the Earth Systems and Climate Change Hub being one example), the focus has been on operationally robust systems, rather than on applications designed to support research. In this talk, I will argue that we should treat complex software (such as climate models) in a similar way to physical research infrastructure. View from this angle, ACCESS is arguably the single most important piece of infrastructure underpinning future weather and climate prediction in Australia. Providing the ACCESS infrastructure as a national weather, climate and environmental research platform, located at a national high-performance computing centre, will have significant immediate and long-term benefits for Australia.

***Keywords:*** *Climate models, software infrastructure*

# Comparison of remotely sensed and modelled soil moisture data sets across Australia

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**Abstract:**

This study compared surface soil moisture from 11 separate remote sensing and modelled products across Australia in a common framework. The comparison was based on a correlation analysis between soil moisture products and *in situ* data collated from three separate ground-based networks: OzFlux, OzNet and CosmOz. The correlation analysis was performed using both original data sets and temporal anomalies, and was supported by examination of the time series plots. The interrelationships between the products were also explored using cluster analyses. The products considered in this study include: Soil Moisture Ocean Salinity (SMOS; both Land Parameter Retrieval Model (LPRM) and L-band Microwave Emission of the Biosphere (LMEB) algorithms), Advanced Microwave Scanning Radiometer 2 (AMSR2; both LPRM and Japan Aerospace Exploration Agency (JAXA) algorithms) and Advanced Scatterometer (ASCAT) satellite-based products, and WaterDyn, Australian Water Resource Assessment Landscape (AWRA-L), Antecedent Precipitation Index (API), Keetch-Byram Drought Index (KBDI), Mount's Soil Dryness Index (MSDI) and CABLE/BIOS2 model-based products. The comparison of the satellite and model data sets showed variation in their ability to reflect *in situ* soil moisture conditions across Australia owing to individual product characteristics. The comparison showed the satellite products yielded similar ranges of correlation coefficients, with the possible exception of AMSR2_JAXA. SMOS (both algorithms) achieved slightly better agreement with *in situ* measurements than the alternative satellite products overall. Among the models, WaterDyn yielded the highest correlation most consistently across the different locations and climate zones considered.

All products displayed a weaker performance in estimating soil moisture anomalies than the original data sets (i.e. the absolute values), showing all products to be more effective in detecting interannual and seasonal soil moisture dynamics rather than individual events. Using cluster analysis we found satellite products generally grouped together, whereas models were more similar to other models. SMOS (based on LMEB algorithm and ascending overpass) and ASCAT (descending overpass) were found to be very similar to each other in terms of their temporal soil moisture dynamics, whereas AMSR2 (based on LPRM algorithm and descending overpass) and AMSR2 (based on JAXA algorithm and ascending overpass) were dissimilar. Of the model products, WaterDyn and CABLE were similar to each other, as were the API/AWRA-L and KBDI/MSDI pairs. The clustering suggests systematic commonalities in error structure and duplication of information may exist between products. This evaluation has highlighted relative strengths, weaknesses, and complementarities between products, so the drawbacks of each may be minimised through a more informed assessment of fitness for purpose by end users.

***Keywords:*** *Soil moisture, Comparison, Cluster analysis*

# Water availability across Australia during the last 2000 years: implications for water security

**A.S. Kiem[a], F. Johnson[b], S. Westra[c] and other co-authors of Kiem et al. (2016)**

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**Abstract:** A recent OzEWEX collaboration produced the paper "Natural hazards in Australia: droughts" (Kiem et al., 2016)[1], which documented what is known and unknown about drought in Australia and also outlined several key research challenges that need to be addressed to better understand and deal with drought in Australia.

This presentation focusses on the challenges associated with documenting and explaining historical (instrumental and pre-instrumental) variation in drought across the different drought classifications. These challenges need to be addressed in order to provide more robust estimates of baseline drought characteristics (i.e. frequency, magnitude, timing, duration, location and spatial extent), enable more rigorous identification and attribution of drought events or trends, inform/evaluate hydrological and climate modelling, and give insights into how best to ensure current and future urban and rural water security in Australia.

This requires compilation of longer-term and more spatially complete hydroclimatic histories via the merging of palaeoclimate information with instrumental, satellite, and reanalysis data to: (i) better understand instrumental and pre-instrumental hydroclimatic behaviour; and (ii) put droughts observed in the instrumental record into context with respect to what has occurred in the pre-instrumental past. Some examples of such work, concentrating on drought in Australia, are emerging from the palaeoclimate community and reveal huge potential. We will discuss some of that emerging research here and also outline the work that is required to address the knowledge gaps identified in (Kiem et al., 2016)[1], and translate the science into practically useful information.

This research required to address the knowledge gaps identified includes:

- Continue to collect and produce palaeo-records, and develop methods that better utilise the existing palaeoclimate information to reconstruct hydroclimatic histories over at least the last 2000 years;
- Increase collaboration between palaeoclimatologists, hydroclimatologists, climate modellers and water resource managers and better integrate methods, datasets and models such that longer-term hydroclimatic histories (and futures) can be compiled (including information on atmosphere, soil moisture, land-surface and groundwater conditions so that all drought categories are considered);
- Develop improved methods to identify the causes of drought. This includes disentangling the role of large-scale ocean-atmospheric processes, climate variability, anthropogenic climate change and direct anthropogenic influences (e.g. land use change, water abstraction etc.) and their relationships with the different categories, and spatial and seasonal characteristics, of drought;
- Translate information on historical drought into practically useful information for decision makers and water resource managers responsible for ensuring water security. Despite previous research demonstrating the invalidity of the stationary climate assumption, simple stochastic models that do not account for climate variability or change and are based on short instrumental records are still popular for developing long-term drought management and planning strategies in Australia. While there have been some developments in stochastic modelling that incorporate instrumental and pre-instrumental variability to better articulate the probability of severe droughts, the uptake in practice has been limited. Techniques to assess drought severity-frequency-area-duration also exist but these are currently limited to meteorological drought and only use instrumental observations that do not adequately capture the spatial and temporal variability of drought.

***Keywords:*** *Drought, water security, sustainability, decision making under uncertainty*

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[1] Kiem, A.S., Johnson, F., Westra, S., van Dijk, A., Evans, J.P., O'Donnell, A., Rouillard, A., Barr, C., Tyler, J., Thyer, M., Jakob, D., Woldemeskel, F., Sivakumar, B. and Mehrotra, R. (2016): Natural hazards in Australia: droughts. *Climatic Change*, doi:10.1007/s10584-016-1798-7.

# Proposal – Water availability across Australia during the last 2000 years: implications for water security

**A.S. Kiem**[a], **F. Johnson**[b], **S. Westra**[c] **and other co-authors of Kiem et al. (2016)**Error! Bookmark not defined.

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**Proposal**: A recent OzEWEX collaboration documented what is known and unknown about drought in Australia and outlined several key research challenges that need to be addressed to better understand and deal with drought in Australia.[1]

We propose to focus on the challenges associated with documenting and explaining historical (instrumental and pre-instrumental) variation in drought across the different drought classifications. This will provide more robust estimates of baseline drought characteristics (i.e. frequency, magnitude, timing, duration, location and spatial extent), enable more rigorous identification and attribution of drought events or trends, inform/evaluate hydrological and climate modelling, and give insights into how best to ensure current and future urban and rural water security in Australia.

This requires compilation of longer-term and more spatially complete hydroclimatic histories via the merging of palaeoclimate information with instrumental, satellite, and reanalysis data to: (i) better understand instrumental and pre-instrumental hydroclimatic behaviour; and (ii) put droughts observed in the instrumental record into context with respect to what has occurred in the pre-instrumental past. Some examples of such work, concentrating on drought in Australia, are emerging from the palaeoclimate community and reveal huge potential. To fulfil this potential we aim to:

a. Continue to collect and produce palaeo-records, and develop methods that better utilise the existing palaeoclimate information to reconstruct hydroclimatic histories over at least the last 2000 years;
b. Increase collaboration between palaeoclimatologists, hydroclimatologists, climate modellers and water resource managers and better integrate methods, datasets and models such that longer-term hydroclimatic histories (and futures) can be compiled (including information on atmosphere, soil moisture, land-surface and groundwater conditions so that all drought categories are considered);
c. Develop improved methods to identify the causes of drought. This includes disentangling the role of large-scale ocean-atmospheric processes, climate variability, anthropogenic climate change and direct anthropogenic influences (e.g. land use change, water abstraction etc.) and their relationships with the different categories, and spatial and seasonal characteristics, of drought;
d. Translate information on historical drought into practically useful information for decision makers and water resource managers responsible for ensuring water security. Despite previous research demonstrating the invalidity of the stationary climate assumption, simple stochastic models that do not account for climate variability or change and are based on short instrumental records are still popular for developing long-term drought management and planning strategies in Australia. While there have been some developments in stochastic modelling that incorporate instrumental and pre-instrumental variability to better articulate the probability of severe droughts, the uptake in practice has been limited. Techniques to assess drought severity-frequency-area-duration also exist but these are currently limited to meteorological drought and only use instrumental observations that do not adequately capture the spatial and temporal variability of drought.

We request support from OzEWEX for the following activities:

- Year 1: a 1-2 day workshop (~$15k) involving key researchers and practitioners working in hydroclimatology and water resources management to discuss and scope the tasks, data requirements, personnel and budget required to achieve the objectives a-d listed above. The workshop will be invitation only (~20 people), with co-authors on Kiem et al. (2016)[1] representing the research community and industry/government representatives that these researchers have ongoing collaborations with representing practitioners. The workshop will focus not just on scoping the research that needs to be done but also on: (i) identifying sources for funding and (ii) clearly identifying the pathways to impact (i.e. How to conduct this research so that the outcomes are as practically useful as possible? What data or tools need to be produced to help government and industry deal with existing and future drought and water security problems?).
- Year 1: development of an application (or applications) for research funds to conduct the tasks identified at the workshop. We request in-kind support from OzEWEX in the form of assistance in pursuing cash funding for the project(s) scoped at the workshop. It is anticipated that funding we will likely apply for will be ARC Linkage grants or, if feasible, an ARC Industrial Transformation Training Centre/Hub or Cooperative Research Centre (CRC) Project.
- Years 2-5: ongoing in-kind support from OzEWEX is requested for secretarial tasks, data/model access and communication of project progress and outcomes to the wider OzEWEX/GEWEX community and the general public. This in-kind support will be matched by support from the organizations of the participating researchers and will form a critical component of our funding applications (i.e. to demonstrate to funding bodies the collaborative nature of the proposed work and that we have the backing of the broader OzEWEX/GEWEX community).

***Keywords:*** *Drought, water security, sustainability, decision making under uncertainty*

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[1] Kiem, A.S., Johnson, F., Westra, S., van Dijk, A., Evans, J.P., O'Donnell, A., Rouillard, A., Barr, C., Tyler, J., Thyer, M., Jakob, D., Woldemeskel, F., Sivakumar, B. and Mehrotra, R. (2016): Natural hazards in Australia: droughts. *Climatic Change*, doi:10.1007/s10584-016-1798-7.

# Managing the CABLE land surface model as a community modelling system

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**Abstract:** The Community (originally CSIRO) Atmosphere Biosphere Land Exchange (CABLE) model was first released to the scientific community around 2006 (CABLEv1.4b). The released version was for standalone use only (forced with meteorological datasets), although CABLE is also coupled into a number of different atmospheric models. This initial release also had no formal mechanism for bringing user developments back into the code. In 2012, CABLE2.0 was released to the community through a subversion repository hosted at NCI. This repository, along with an associated wiki/trac facility (https://trac.nci.org.au/trac/cable/wiki) provided the needed infrastructure to manage code development across the community. CABLE2.0 supports both standalone (offline) and Australian Community Climate and Earth System Simulator (ACCESS) applications. Significant code revisions are 'tagged' in the code repository with a naming convention that differentiates science and technical updates. In 2015, licensing arrangements for CABLE were changed to Open Source, allowing CABLE to be freely distributed, including with other software packages if required. Access to the CABLE repository still requires a user registration.

Here we will reflect on what we have achieved over the last 10 years of CABLE community use and development, in particular around the key recommendations of the CABLE Roadmap for 2012-2017 (http://www.cawcr.gov.au/static/technical-reports/CTR_057.pdf). We will describe our governance arrangements for CABLE and the procedures we have adopted for code management. Working with those procedures has been challenging, for a range of reasons including the cultural shift required, the need for adequate (and easy) bench-marking of proposed code changes, and allocating sufficient time for technical support. Nevertheless, we are encouraged by continuing growth in the CABLE community, with access to the CABLE repository provided to around 120 people from 21 Australian institutions and 14 other countries.

***Keywords:*** *Community model, code management*

# Identifying Regions of High Drought Mortality Risk

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Overstorey woody species are crucial for many ecosystem services including streamflow regulation, carbon sequestration and habitat provision for other taxa. For many Australian species, future climate change will cause them to occur outside their current climatic envelopes, but not all species will be equally impacted. Those species whose distribution is directly limited by their tolerance of climatic stress are most at risk. In such cases, climate change may cause large-scale mortality events due to drought and heat stress. Such events are increasingly being reported worldwide, including in Australian woody ecosystems. These events can have severe impacts on ecosystem function, with significant consequences for streamflow, fire risk, and regional climate.

We are currently undertaking an ARC-Linkages funded project, in conjunction with NSW Office of Environment and Heritage, to identify woody species and ecosystems in NSW that are most at risk from drought mortality under climate change. We are using two qualitatively different, mutually complementary modelling methods to address this question. The combined use of multiple methods is a powerful and innovative way to build confidence in project outcomes. Process-based ecophysiological modelling is based on experimental data on heat and drought tolerance from field and glasshouse studies. Species distribution modelling is being used to identify species distributional limits that are strongly correlated with climatic variables related to water availability and/or upper temperatures, indicating likely limitation by climatic stress. Both modelling approaches are being validated with remotely-sensed data obtained during the Millennium Drought period. Both modelling approaches will then be used to estimate drought mortality risk under future climates, and combined to develop spatial risk profiles for indicator species. Our initial goal is to inform biodiversity management but our work should also inform, and be informed by, community climate and hydrological modelling efforts.

***Keywords:*** *vegetation, drought, water use, mortality*

# Event vs. continuous models: dogma or context?

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**Abstract:** Continuous simulation models have been recommended to modelers for many years as a rigorous solution to the estimation of initial conditions in flood forecasting. It has also been argued that adoption of continuous simulation models provide the best means of solving the joint probability issues that potentially bias the probability-neutrality transformation of rainfalls into design flood estimates. Despite all the good reasons advanced by hydrologists for using continuous approaches, many practitioners still prefer to use event-based models for design flood estimation and for flood forecasting. Does this apparent dichotomy represent the difference between "good science" and "engineering practice", or are there fundamental differences between modelling objectives? This presentation examines the relative efficacy of the two modelling approaches, and discusses the differing operational and design contexts.

***Keywords:*** *Event-based models, continuous models, forecasting*

# A method for combining digital elevation models without using reference data

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**Abstract:** Digital Elevation Models (DEMs), such as the Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Models (ASTER GDEM) and the Shuttle Radar Topography Mission (SRTM), have been extensively used because of their free accessibility and global availability. However their accuracy at local or regional scales remains a hindrance to their universal application. Many studies have used high resolution DEMs or spot height points to improve the accuracy of the global DEMs. In the absence of such reference datasets, how can the accuracy of global DEMs be improved? To solve this challenge, we propose a linear combination approach that combines the ASTER GDEM (1 arc-second) and SRTM (1 arc-second) to generate a more accurate combined DEM. First, we develop the relationships between the land slope and the linear combination weights at sites with reference data. Then we applied these relationships to similar geomorphology sites where reference data is not available to estimate the linear combination weights from the slopes. Finally, the weights are used to combine the two global DEM to generate the combined DEM. The combined DEMs had significant improvement in mean bias, root-mean square error (RMSE) and correlation in comparison with the two global DEMs. We also found that the combined DEM-derived drainages had higher level of accuracy than the global DEMs-derived drainages. The results highlighted the potential of the proposed approach to generate more accurate topographic input data from the global DEMs for hydrological and hydrodynamic models or other applications in regions without reference data.

***Keywords:*** *Digital Elevation Model (DEM), SRTM, ASTER, DEM combination, slope position*

# Data transparency in the Bioregional Assessment Programme

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**Abstract** A bioregional assessment is an analysis of the ecology, hydrology, geology and hydrogeology of a bioregion in order to determine the potential impacts of coal seam gas and large coal mining developments on water resources and water-dependent assets.

Delivered through a collaboration between the Department of the Environment, the Bureau of Meteorology, CSIRO and Geoscience Australia, the outputs of the programme will allow coal resource companies, governments and the community to focus on the areas where impacts may occur so that these can be minimised.

A core tenet of the programme is transparency, and one way this transparency is being achieved is through making the datasets used and produced by the programme freely available for download. These datasets can be accessed via the Bioregional Assessment Information Platform at http://www.bioregionalassessments.gov.au/

# Short-range precipitation forecasts – lessons for hydrological forecasting applications.

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**Abstract:** Streamflow forecasts for the coming seven to ten days have a wide range of applications, including in determining water releases for irrigation and environmental users, planning of flood responses and supporting community decisions around recreational water use. At lead times that are shorter than a catchment's time of concentration, forecast skill is primarily derived from knowledge of the initial conditions of soil moisture, groundwater, river channel and other water stores in a catchment arising from rainfall falling before the forecast issue time. As the forecast lead time extends, the skill of streamflow forecasts is increasingly dependent on precipitation forecasts.

Many precipitation forecast products are available in Australia that can be used for streamflow forecasting applications. Numerical weather prediction (NWP) models are routinely run by meteorological agencies around the world to generate weather forecasts, including for precipitation. Various post-processing methods are employed to combine the output of different NWP models and improve the accuracy of precipitation forecasts.

In this talk we will present learnings from research work undertaken by CSIRO, in collaboration with the Bureau of Meteorology, in the application of precipitation forecasts for generating streamflow forecasts. Research to be highlighted includes: evaluation of the quality of different rainfall forecast products at the catchment-scale across Australia, the role of post-processing methods in improving catchment rainfall forecasts, and the contribution of rainfall forecasts to the skill of short-term streamflow forecasts. We will discuss the challenges faced in developing short-term streamflow forecasting systems and how these flow on to end-users. We will close the talk by giving a brief summary of current and future work.

***Keywords:*** *Streamflow forecasting, numerical weather predictions, forecast skill, ensemble forecasts.*

# Predicting shifts in rainfall-runoff partitioning during multiyear drought: roles of dry period and catchment characteristics

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**Abstract:** The Millennium drought in Australia triggered shifts in the rainfall-runoff response in some catchments. These shifts in catchment behaviour increased the challenge of managing water resources during the multiyear dry period. Previous research to explain why this unexpected behaviour occurred mostly came down to the question of how the Millennium drought was different from other known dry periods. Some studies also investigated why changes in response happened in some catchments but not in others. Overall, a number of factors responsible for the shifts have been suggested, including drought characteristics such as elevated air temperatures, decrease in rainfall variability, and disproportional rainfall reductions during the cold part of the year. Moderate rainfall low relief catchments were suggested to be more prone to shifted behaviour. Saft et al. [2016] built on the previous research and explored the relative importance of 37 potential explanatory factors to re-evaluate the previously suggested hypotheses and develop new ones. We explained the variability in shifts in the catchment behaviour for a large set of catchments using Akaike information criteria and multimodel inference to compare the informative power of the potential predictors.

Five predictors stood out as important for explaining the shift in catchment behaviour (in order of decreasing importance):

- Pre-drought climate aridity (or wetness);
- Pre-drought variability in the minimal annual 7-day flow (proxy for the catchment-specific groundwater storage variability);
- Drought anomaly of the spring rainfall;
- Pre-drought variability of monthly rainfall (mostly related to the strength of seasonal signal); and
- Mean soil depth.

Our results confirm that more arid catchments experienced larger magnitudes of shift in catchment behaviour. But the pre-drought variability in minimal annual 7-day flow (~ typical groundwater storage variability) was nearly as important as aridity. Catchments with more variable groundwater storage also exhibited larger departures from the normal rainfall-runoff response to shorter droughts. The importance of pre-drought monthly rainfall variability and soil thickness indicates that less seasonal catchments and catchments with deeper soils are more prone to a shift in behaviour. These factors suggest that the seasonal soil moisture pattern reorganisation mechanisms might play a key role in shifting the rainfall-runoff response. The only drought characteristic which helped explaining the shifts was the spring rainfall anomaly, which reflects the hydrological importance of this time of the year in many of the study catchments. Interestingly, four out of five major predictors represented catchment qualities, which suggests that the problematic shifts in rainfall-runoff response can be predicted nearly independently of the drought. Some insight might also be gained from the factors which were not found informative in this analysis. For example, low influence of the % woody coverage might be seen as indirect indication of limited importance of farm dams. Elevated temperatures and large autumn rainfall reductions were also not found to be related to the magnitude of shift in rainfall-runoff response.

We were able to explain about two thirds of the variance in the difference between expected and observed runoff response during the Millennium drought. Understanding the changes in catchment functioning under changing climatic conditions is crucial for drought preparedness, optimal water management during the drought, and for facing potential changes in regional climate.

Saft M, MC Peel, AW Western, L Zhang (2016), Predicting shifts in rainfall-runoff partitioning during multiyear drought: Roles of dry period and catchment characteristics, *Water Resour. Res.*, *52*, doi:10.1002/2016WR019525.

***Keywords:*** *drought, rainfall-runoff relationship, hydrologic change, multimodel inference*

# Science and Knowledge Needs for Basin-scale Planning

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**Abstract:** This presentation will outline the breadth of scientific knowledge required to inform Basin-scale management and policy responses and emphasise the increasing need for transdisciplinary knowledge.

The Murray – Darling Basin Authority is chartered to develop the Basin Plan on the 'basis of the best available scientific knowledge and socioeconomic analysis'. The work of the Authority, which includes managing operations of the Murray River, on behalf of participating Governments, draws upon an extensive scientific and technical knowledge base.

The Authority draws substantially on scientific literature as well as maintains substantial relationships with the research community. Increasingly, Basin management requires skills beyond a base level of hydrological understanding given the often competing demands for scarce water resources.

The presentation will provide an introduction to the core science disciplines required to inform policy and management decisions, present an adaptive management framework that assists in outlining the need for integrating different disciplines (transdisciplinarity) and outlines some priority themes for improving Basin planning and policy decisions.

***Keywords:*** *Keyword 1, keyword 2*

# Incorporating remote sensing methods into crop-climate relationships across the rain-fed cropland belt in NSW, Australia

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**Abstract:** Cropping systems in Australia are dominated by rain-fed farming practices that are essentially vulnerable to climate variability. Most conventional methods to quantify climate factor impacts on crop phenology and productivity have been conducted using field site observations or model simulations. However, there remains scant knowledge of spatial variations of such impacts across large scale rain-fed croplands. In this study, we analysed crop-climate relationships through incorporation of MODIS EVI products to spatially and temporally differentiate the impacts of extreme hydroclimatic events on crop growth across the agro-climatic zones in NSW, Australia. It was observed that: Firstly, integrated EVI (iEVI) had a significant linear relationship with actual *in-situ* yields, both among the field trials in individual years and across all sites. The overall $R^2$ was 0.76. Secondly, the southern plains was the zone in which crop growth was least affected by hydroclimatic extreme events. Thirdly, we demonstrate that remote sensing observations can serve as a near-real time, large-scale crop production monitoring system to aid in stakeholder decision making for agricultural departments and farmers.

***Keywords:*** *Crop-climate relationship, Remote sensing, MODIS EVI, NSW cropland belt*

# Selecting a Discount Rate for Economic Evaluation of Water Projects – the Sustainability Controversy

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**Abstract:** Sustainability of urban infrastructure systems has been attracting attention over the last decade. Water distribution systems produce greenhouse gases during the manufacture, transport and installation of pipes and particularly in pumping operations when electricity is derived from the burning of fossil fuels. Typically in a life cycle analysis for the planning of new water distribution system infrastructure, that involves pumping, a present value analysis is carried out to convert annual operating costs for pumping into a present value. The way in which time preferences are incorporated into the calculations strongly affects the outcomes. Many water utilities around the world use a discount rate equal to the interest rate of between 6 and 8%. As a result the operating costs in years 40 onwards of a projects life end up being so heavily discounted that they play little role in the present value cost analysis of a project. Thus there is a tendency to build systems with small pipes and large pumps to minimize the initial capital cost. The disadvantage is that future generations are burdened with the pumping operating costs due to pumping the head loss component of the pumping head. The associated disbenefit is the extra greenhouse gases produced due to the additional pumping head that needs to be overcome. The question arises as to whether intergenerational equity is achieved when discount rates of 6 to 8% are used for evaluating projects. In other words: is it fair to pass onto future generations both the extra operating costs and the associated additional greenhouse emissions?

Over the last 15 years or so England has been using a discount rate for evaluating projects of 3.5% and declining to 1% between 30 and 301 years. The Stern Review: The Economics of Climate Change published in 2006 recommended that a very low interest rate of 1.4% be used for evaluating projects that lead to the production of greenhouse gases. A number of economists believe that “we are actually a lot less sure about what interest rate should be used for discounting climate change than is currently acknowledged.” Arguments have been posed about how much insurance we need to buy to offset a small chance of a ruinous catastrophe that is difficult to compensate for by ordinary savings. There are potential implications of large consequences with small probabilities if climate change is not addressed. The Stern Review predicted that dire consequences will occur if $CO_2$-equivelent greenhouse gases exceed 550 ppm and recommended that immediate drastic and decisive action be taken to progressively cut emissions by 3% per annum over the next century. This will be very expensive. The analysis presented in the Stern Report has been criticized by a number of economists who believe that market interest rates (6 to 8% as indicated above) should be used as the discount rate in the life cycle analysis of projects that involve both capital costs and operating costs. In contrast there are many economists who believe either low discount rates or a declining interest (both referred to as social discount rates) with time should be used in life cycle analysis. The possible outcomes of significant global warming over the next century due to climate change is extremely uncertain. One thing that is certain is that the concentration of CO2-equivalent gases in the Earth’s atmosphere has been increasing dramatically over the last century and continues to grow at alarming rates. Climate change models are predicting a temperature rise of between 2 and 6 degrees Celsius unless action is taken to reduce emissions. The Stern Review has raised the level of debate in relation to how quickly we need to act and what parameters we should be using for analysis of projects with greenhouse gas implications.

This presentation will explore the different options and the resulting outcomes for discount rates proposed by various economists and will also consider the arguments for and against using the standard 6 to 8% or a lower discount rate of say 1.4% that is based on societal preferences. The implications on the design of water distribution systems will be assessed. Based on the arguments of Stern (2006) and Weitzman (2007) it is recommended that discount rates that are lower than the cost of capital should be used for present value analysis of water distribution system projects.

References

Stern, N. (2006). *The Economics of Climate Change: The Stern Review*, Cambridge University Press.

Weitzman, M. (2007). "A review of the Stern Review on the economics of climate change." *Journal of Economic Literature* Vol. XLV: 703–724.

# "Australia's Environment": a community-based approach to national environmental information

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**Abstract:** Water, energy and carbon are a fundamental component of environmental condition. Spatial information on environmental condition is needed to understand environmental change, to improve the efficiency of natural resource use, and avoid environmental degradation. The production of broad-scale data from remote sensing and landscape modelling has created unparalleled potential for systematic, accurate and reliable information on environmental condition. However, much of this information is not yet being used to inform decision making and policy development. There is a pressing need to bridge the gap between research and application. Unfortunately, there often appears to be a chicken-and-egg situation: the development of new information systems by operational agencies requires substantial investment and user uptake, but in turn, creating such demand requires a well-advanced prototype or experimental system.

We attempted to help bridge this gap through a Bureau of Meteorology (BoM) and ARC funded 'pathfinder' project. Our aim was to develop a web-based means for intuitive and fast access to comprehensive, systematic and national-scale environmental information that required no specialised equipment and minimal technical knowledge. Simply called "Australia's Environment", the resulting web site visualises and summarises environmental indicators covering themes like land cover, bushfire, water availability, rivers and wetlands, landscape health, and carbon storage. Quantitative summaries through maps and graphs at different levels of detail provide a gateway for non-specialist users to the underlying more complex environmental data.

Creating "Australia's Environment" at a small budget would have been impossible only a few years ago. It has only become possible because of advances in community collaboration and infrastructure. Adoption of open data sharing principles by individuals and organisations meant that much spatial data (provided by, e.g., NASA, ECMWF, CSIRO, TERN, BoM and Geoscience Australia) could be accessed and reinterpreted readily. NCI's community computational resources, data storage and curation, and web mapping services were fundamental for our small research group. Similarly, rapid and relatively low-cost web site development was possible because of code sharing in the web development community. Acknowledging this reliance on the community, we have also made all data and code produced as part of "Australia's Environment" publicly available.

A key challenge in designing the web application was finding a balance between, on the one hand, generality to make it valuable to the widest range of possible users, and on the other hand, providing enough detail and complexity to make it valuable to specific needs. Following the release of the website, users have requested subtle tweaks to the analysis and presentation including slightly different variables, summary calculations or regional definitions. Further customisation would make the web site more useful for additional users, but also increases the complexity in navigating the data, and increases the processing required. The web site features links to the underlying data that users can download and reanalyse themselves. Hence, building data analysis capacity in the user community is one solution to meet individual requirements, but not always a realistic one.

We intend to maintain "Australia's Environment" as long as needed, but the longer-term future of the various components developed lies with the community and with operational organisations. For example, some of the data layers are generated with a version of the BoM's AWRA-L model, and the recent release of AWRA-L as a community modelling system will facilitate the transfer of our innovations to the community and to BoM's operational services. Ultimately it is hoped that pathfinder projects such as "Australia's Environment" increase the appreciation and demand for environmental information and help justify its provision by operational organisations, thereby bridging the gap between research and application.

***Keywords:*** *Environmental information, community data, community processing*

# Exploiting complete GRACE information for improving soil moisture and groundwater estimates over Australia

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**Abstract:** An accurate estimation of Terrestrial Water Storage Variation (TWSV) is essential for monitoring the availability of the water supply for domestic and agricultural sector. TWSV can be simulated from the hydrology model, but the accuracy of the result is commonly limited due to the inaccurate model physics, as well as the uncertainties in model parameters and meteorological forcing data. In order to improve the TWSV estimates, several studies assimilated TWSV derived from the Gravity Recovery and Climate Experiment (GRACE) into the hydrology model. However, the GRACE-derived TWSV was generally computed based on the standard products (e.g., land grid), which were subjected to two main drawbacks, the signal attenuation/distortion caused by (often ad hoc) posteriori filters, and no error covariance information properly accounted for. In order to mitigate such caveats in GRACE grid data products, empirical and cumbersome approaches need to be taken, for example, applications of scale factors computed from LSM models to GRACE and device of the GRACE uncertainty not necessarily following the original GRACE data.  All can lead to an inaccuracy of the TWSV estimate.

To exploit the complete GRACE information, this study derives TWSV directly from the raw Level-1B (L1B) GRACE data. The approach combines the GRACE's least-squares normal equation with the results from the Community Atmosphere Land Exchange (CABLE) to improve the soil moisture and groundwater estimates. This study is the first time the GRACE normal equation is used to improve the model estimated water storage. The proposed approach presents four main advantages. First, the GRACE normal equation data sets (such as from the ITSG-Grace2016 product) contain full GRACE signal and error information down to ~200 km spatial resolution. Second, full GRACE error variance-covariance information is available. Thirdly, the approach is developed for optimal least-squares combination, which utilizes the model and observation strength while simultaneously supressing their weaknesses. Finally, the method bypasses empirical, multiple-step, post-processing filters.

The soil moisture and groundwater were estimated over 10 Australian river basins and the results were validated against the satellite soil moisture observation (the Advanced Microwave Scanning Radiometer aboard EOS (AMSR-E) product) and the in-situ groundwater data. This is the first time the GRACE value on the top soil moisture component is investigated. A preliminary result showed a fair improvement of the top soil moisture estimate, where six out of ten basins, the GRACE-combined top soil moisture outperformed the model-only version (spatially-averaged Nash-Sutcliffe coefficient of 0.63 compared to 0.56). The long-term trend of the groundwater estimates was also improved; the GRACE-combined groundwater trend was 15% closer to the value estimated by the in-situ data. It is clear that the proposed approach delivered an improved water storage estimate, and the approach can be used to update the model initial states in the data assimilation process.

***Keywords:*** GRACE, CABLE, normal equation, soil moisture, groundwater

# Towards spatially and temporally continuous hydrological forecasting

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**Abstract** The Bureau of Meteorology operationally produces forecasts of flood progression and seasonal river flows using very different approaches, as do most overseas agencies that provide both. While there are good reasons for this, there is a gradual transition towards methods that can serve to provide both types of forecasts within a single, physics-based spatial hydrological modelling framework. Such an approach does not necessarily offer the greatest benefit for intensively measured rivers with experienced forecasters. Rather, its potential lies in the provision of guidance forecasts where observations or experienced forecasters are sparse – as is the case for the large majority of rivers world-wide. Additional benefits are that it creates the opportunity for temporally, but also spatially 'seamless' forecasting, as well as to provide forecasts for other useful variables (e.g., soil moisture, crop water requirements).

Many barriers to the implementation of seamless forecasts in Australia have been overcome thanks to increases in computational resources, the availability of foundational data sets such as the Australian Geofabric and ACCESS weather forecasts, and the know-how and capability of *open* modelling software components for water balance modelling (e.g. AWRA-L, CABLE), routing (e.g., RAPID), data assimilation (e.g., OpenDA) and forecast management (e.g., Delft-FEWS). These developments have empowered the research community outside operational agencies to also take on a role in the development of new applications and prototype systems. The developments in Australia mirror those internationally and this has given a new purpose to international collaboration through mechanisms such as HEPEX (https://hepex.irstea.fr/). Indeed, research is currently going on to integrate some or all of the components mentioned above. I will discuss two examples: the National Flood Interoperability Experiment carried out in the US through a collaboration between an operational agency (the NOAA National Water Centre) and a consortium of universities (CUAHSI), and the Global Flood Forecasting Information System (GLOFFIS) that involves an international collaboration that has integrated (a global version) of AWRA-L, Delft-FEWS and ECMWF weather forecasts for spatially continuous flood forecasting across the US CONUS.

There are, however, remaining impediments to encouraging more and faster innovation in hydrological forecasting. Two of them are highlighted here.

First and foremost among these is the lack of operationally relevant 'test beds' – selected systems for which the available observations, forecast inputs and outputs and performance criteria from the current generation forecasting systems is made available, to serve as a benchmark when evaluating potential innovations. I strongly advocate for the establishment of such a pilot test bed through a collaboration between the Bureau of Meteorology and the broader research community – through OzEWEX or otherwise.

A second challenge is data assimilation. Current spatial forecasting systems rely heavily on weather forecast forcing (rather than observational analysis products) to derive initial state estimates of the hydrological model for the next forecast. It is clear that this approach is not perfect and that data assimilation can help to overcome some of the weaknesses of this approach. If river discharge data are not available, other observations are needed to constrain forecast initialisation. I will discuss an opportunity to do so through the assimilation of satellite-based river flow estimates.

***Keywords:*** *Hydrological prediction, forecasting, flooding, seasonal flows*

# Impacts of climate extreme events on global crop yields – an assessment using random forests

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**Abstract:** The frequency and/or intensity of different types of weather extreme events is predicted to increase in a number of regions across the globe under climate change (IPCC, 2012). The global food system is particularly affected due to its dependence on climatic conditions for agricultural production and its increasing global connectedness (GFSP, 2015; Puma et al., 2015). Extreme events, such as droughts, heavy rainfall and temperature extremes can adversely impact crop production with implications for the livelihoods and food security of a large fraction of the world population, particularly in developing countries. To improve the resilience of the agricultural sector to extreme weather events and to increase crop yields in a changing climate, it is critical to better understand the impact of extreme events on the world's crop yields in the past and present.

Our study aims at quantifying the impact of meteorological extreme events on crop yields at the global scale and identifying the types of extremes that exhibit the largest influence on yield variability. We combined high-resolution crop yield time series with data on past weather conditions as well occurrences of weather extremes and applied a machine learning algorithm, called random forests, to the dataset to 1) understand the relationships between climate predictors and agricultural yields and 2) to develop statistical prediction models for agricultural yield anomalies. Our results show that for maize and wheat yields at the global scale, temperature related variables (mean and extreme temperatures) have greater impacts on yield variability than precipitation related factors, with implications for the predictability of climate change impacts as well as for adaptation efforts.

**References:**

GFSP, 2015. Extreme Weather and Resilience of the Global Food System. Final Project Report from the UK-US Taskforce on Extreme Weather and Global Food System Resilience. The Global Food Security programme, UK.

IPCC, 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York.

Puma, M.J., Bose, S., Chon, S.Y., Cook, B.I., 2015. Assessing the evolving fragility of the global food system. Environ. Res. Lett. 10, 024007. doi:10.1088/1748-9326/10/2/024007

***Keywords:*** *Climate extreme events, crop yields, random forests*

# Improving competition models for predicting toxic cyanobacterial blooms

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**Abstract:**

Toxic cyanobacteria pollute our drinking water reservoirs, causing problems for public health. *Microcystis aeruginosa* and *Cylindrospermopsis raciborskii* are two harmful cyanobacterial species that dominate freshwaters globally and in Australia. Their competition and successive dominance have been found in many water systems. Yet, how environmental changes affect their competition, is poorly understood. Therefore, in this study we modelled paired competition between multiple strains of the two species. The model was improved by incorporating strain specific parameters from laboratory growth experiments conducted under four light intensities: 10, 30, 50 and 100 μmol photons $m^{-2}$ $s^{-1}$; and two temperatures: 20 and 28°C.

To model the competition between the two species, an existing competition model was modified in two ways: 1. by accounting for the effect of self-shading on light availability due to the growing cell biomass; 2. by estimating the light dependent growth characteristics, i.e., the maximum growth rate ($\mu_{max}$), half-saturation irradiance ($H_I$) and the photoinhibition ($\beta$) of the strains. The best regression was selected from with and without photoinhibition. Then, paired competition was conducted with the estimated growth characteristics under a well-mixed system. The competition started with the same initial cell concentration or total biovolume for all strains. Competitiveness was ranked from the winning probability of one strain against the other for each paired competition.

The results showed that not all strains were affected by photoinhibition under the light intensity of 100 μmol photons $m^{-2}$ $s^{-1}$, indicating strain variation in effect of light intensity The competition outcome of the strains showed neither species had an advantage, rather outcomes were strain dependent. Temperature altered the competiveness of the strains. Therefore, the model demonstrated that the intraspecific variation was more important than the interspecific variation in predicting competition between *M. aeruginosa* and *C. raciborskii*. *C. raciborskii* strains were more likely to win at higher temperature, corresponding with their higher optimal temperature for growth.

This study provides new insights into the extent of strain variation under light and temperature conditions and how this relates to species competition between *M. aeruginosa* and *C. raciborskii*.

***Keywords:*** *Competition models; Microcystis aeruginosa; Cylindrospermopsis raciborskii; photoinhibition*

# Optimal steady-state leaf area index based on historical water balance for Australian natural ecosystems

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Leaf area index (LAI) is a measurement of the canopy foliage and thus, determines the exchange of energy, water and carbon between the vegetation surface and the surrounding atmosphere. Despite its importance, LAI is difficult to predict; for example, some models (e.g. CABLE) rely on a satellite-derived LAI phenology, while others assume a fixed proportion of net primary production is used to grow leaves. The first approach sacrifices predictability, which is problematic as plants may modulate their LAI in response to climate change. The second approach relies on the model correctly determining the carbon flux, which is linked to the LAI, and the allocation of carbon to foliage growth— another uncertainty in current models. Furthermore, despite the regularity of water stress across Australia, models are known to poorly represent the impact of water stress in dry ecosystems, which may result in unrealistically high LAI values.

Alternatively, LAI can potentially be constrained by water balance: with a limited amount of water, plants need to balance the canopy conductance (water use per unit leaf area; defined by atmospheric demand and stomatal regulation) and solar radiation intercepted (defined by LAI); However, plant carbon uptake is positively related to both conductance and light absorption. Ideally, plants can regulate its conductance and leaf area so that water balance is maintained without sacrificing carbon uptake. Assuming this regulation is the result of adaptation and thus optimised to long-term climate, we construct an optimisation model that predicts steady-state LAI according to long-term water balance.

We found that the optimal LAI declines with aridity index (AI; potential evapotranspiration over precipitation) nearly exponentially, identifying water balance as the main driver in the model. The same trend is also observed in general additive model fit to ground-based measurements— 33.6% of deviance explained by four climatic factors. Compared to ground-based measurements, the model achieves a root mean square error of 0.09 ($m^2$ $m^{-2}$), while nine-year mean satellite data (MODIS) has 0.10, suggesting that the simple model with four climatic inputs can constrain LAI to a comparable accuracy to MODIS product. Additionally, model outputs correlate with MODIS with an adjusted $R^2$ of 0.71, which is similar to the value of the inter-comparison of different satellite-derived products. The results suggest that the optimal LAI based on long-term water balance is consistent with both ground measurements and satellite-derived data. Our approach offers a viable climate-constrained LAI reference to land surface models with the potential to improve their performance in Australian natural ecosystems, and potentially other water-limited systems.

***Keywords:*** *Leaf area index model, water and energy balance, carbon flux, optimisation*

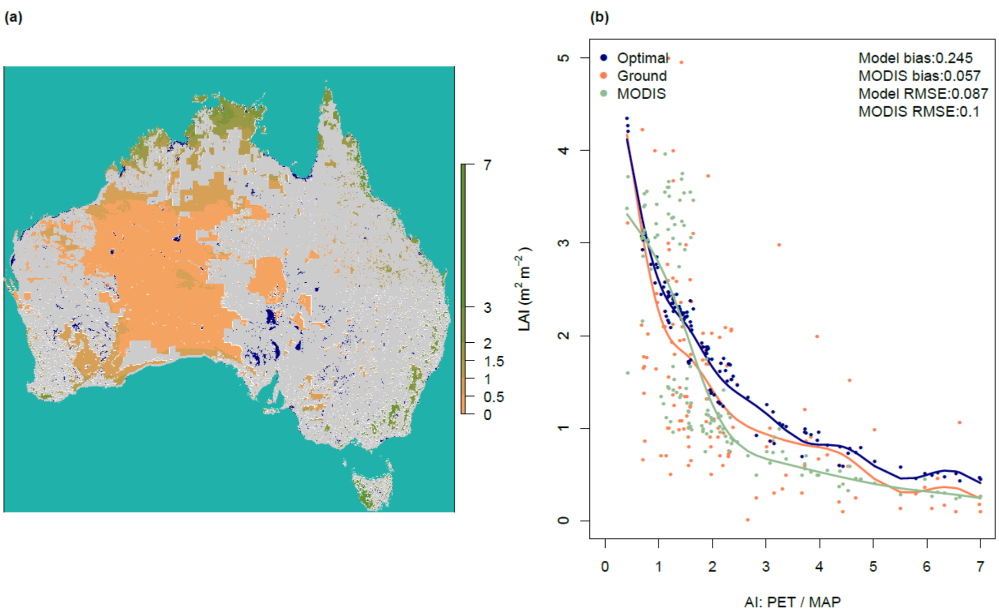


FIG.1. (a) Optimal LAI for Australian natural ecosystems. Land use other than natural reserves is in grey with water covered in blue. (b) Optimal, ground, and MODIS LAI plotted against AI (aridity index). The ground data are site mean. MODIS data are the nine-year averages.

# Quantifying and characterizing the presence of intermittent streams in south-eastern Queensland

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**Abstract:** Intermittent streams comprise at least 50% of global river length, and their prevalence is projected to increase in regions experiencing drying trends related to climate change and increases in water abstraction for socio-economic use. However, many intermittent streams are currently ungauged by traditional gauging systems, and thus unmapped and under-studied. Recently, monthly water balance data have been made available in continental Australia, produced by the WaterDyn model, which is developed by CSRIO Marine and Atmospheric Research, the Australian Bureau of Meteorology and the Bureau of Rural Science over the Australian Water Availability Project (AWAP). Here, I develop an efficient way to convert the spatially contiguous water balance data to runoff data, in order to characterize and quantify the distribution of intermittent streams in south-eastern Queensland (SEQ). There are four steps included in this research.

- Convert the water balance data to runoff data. I modified some essential functions in an R package “catchstats” by Chris Walsh and Nick Bond to a parallel processing version.
- Identify a catchment-specific threshold in the converted data that is equivalent to zero flow in the gauged data. I identify the threshold by applying the principle that the proportion of values below a specific flow value (i.e. threshold) in the converted data is equal to that of zero flow in the gauged data. All streams segments within a catchment apply the same threshold.
- Test the accuracy of the stream classification method of the flow duration metric (Table 1) on gauged sites. Results shows that only 2 out of thirty-one sites are wrongly predicted to be intermittent streams while they are most likely to be perennial based on gauged data.
- Apply the stream classification method to all stream segments to derive a predicted distribution of intermittent streams in SEQ (Figure 1).

The development of mapping intermittent streams can help to identify variation in flow intermittency due to climate change and human impact.

Table 1. The stream classification method based on flow duration (% of months with flowing water across the 48 year period of record (1965-2012).

| **Stream class** | **Value range** (% of months) |
|---|---|
| Perennial streams | >90% |
| Intermittent streams | [30,90%] |
| Ephemeral streams | <30% |

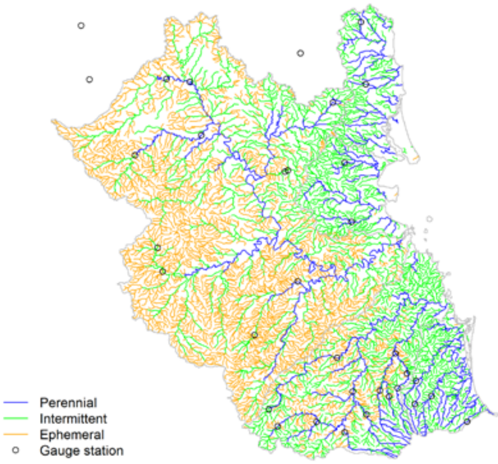


Figure1. The predicted distribution of intermittent streams in south-eastern Queensland.

***Keywords:*** *Intermittent streams, The Australian Water Availability Project (AWAP), Distribution, The flow duration, South-eastern Queensland (SEQ)*