Opportunities and challenges in delivering water availability forecasts – sharing the Australian experience

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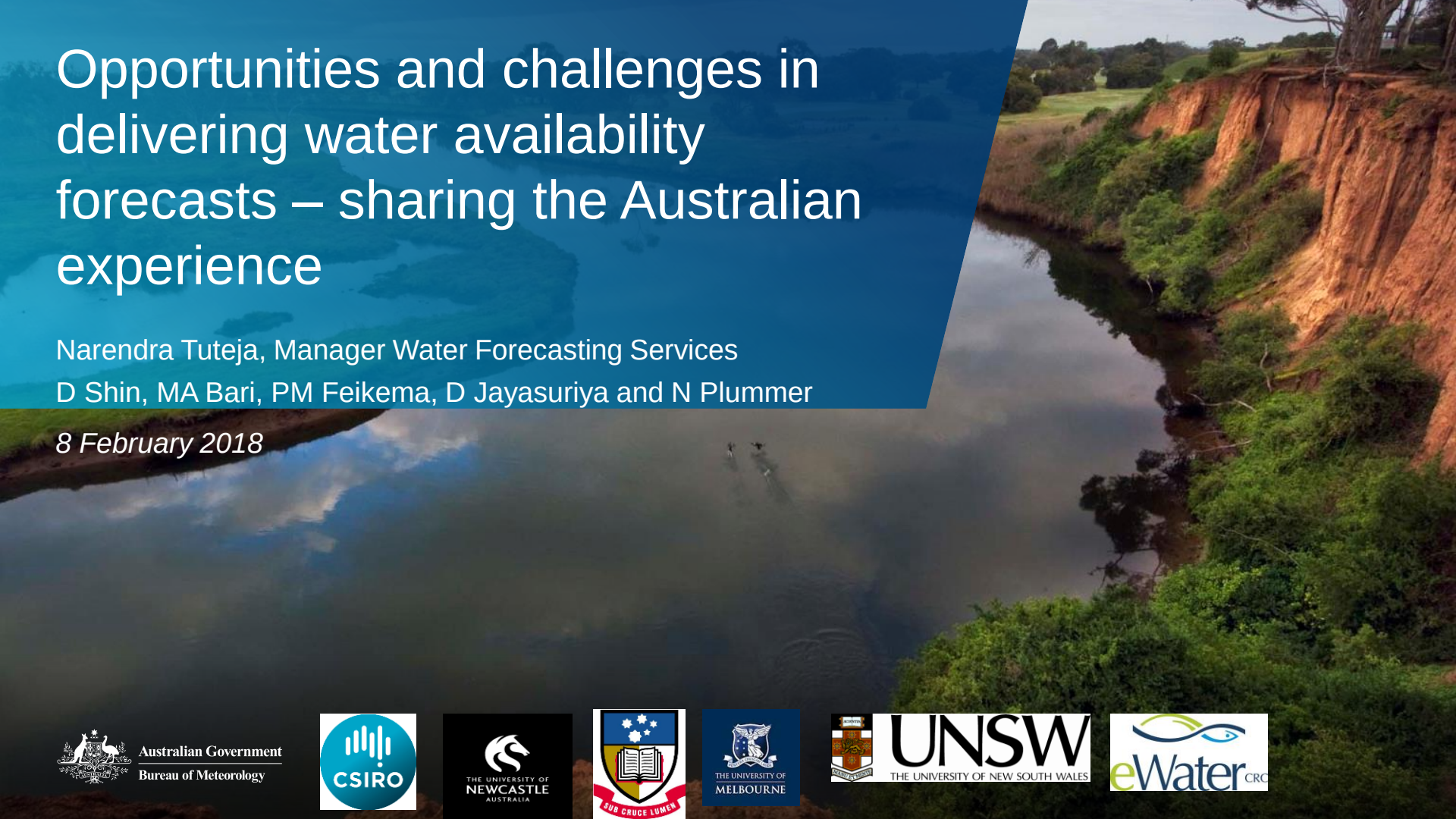
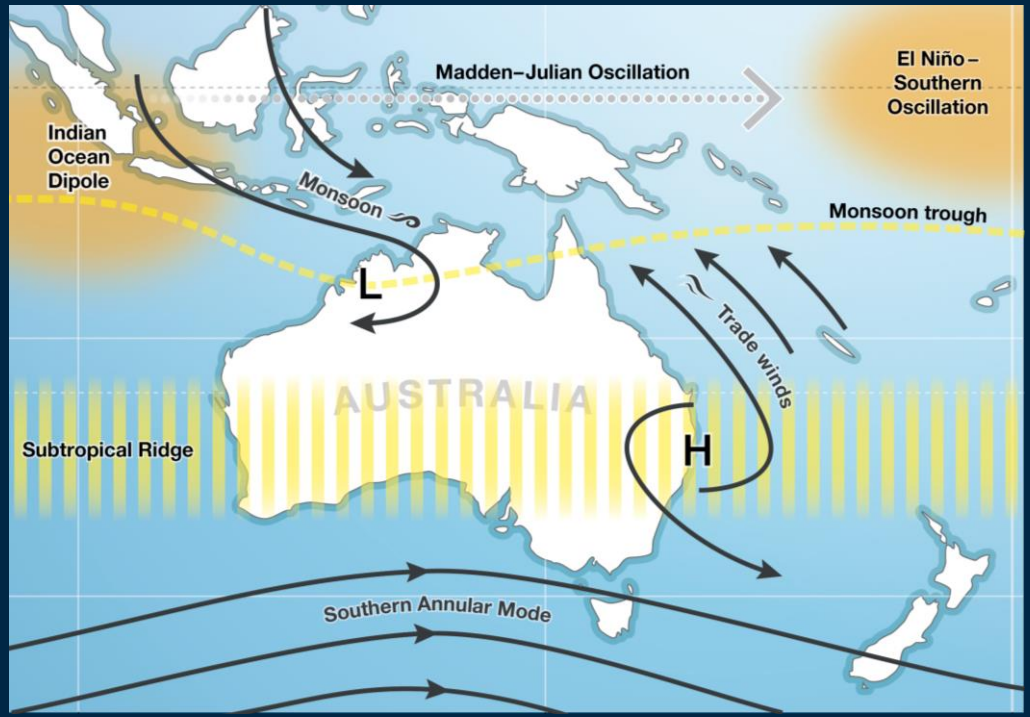
D Shin, MA Bari, PM Feikema, D Jayasuriya and N Plummer

8 February 2018

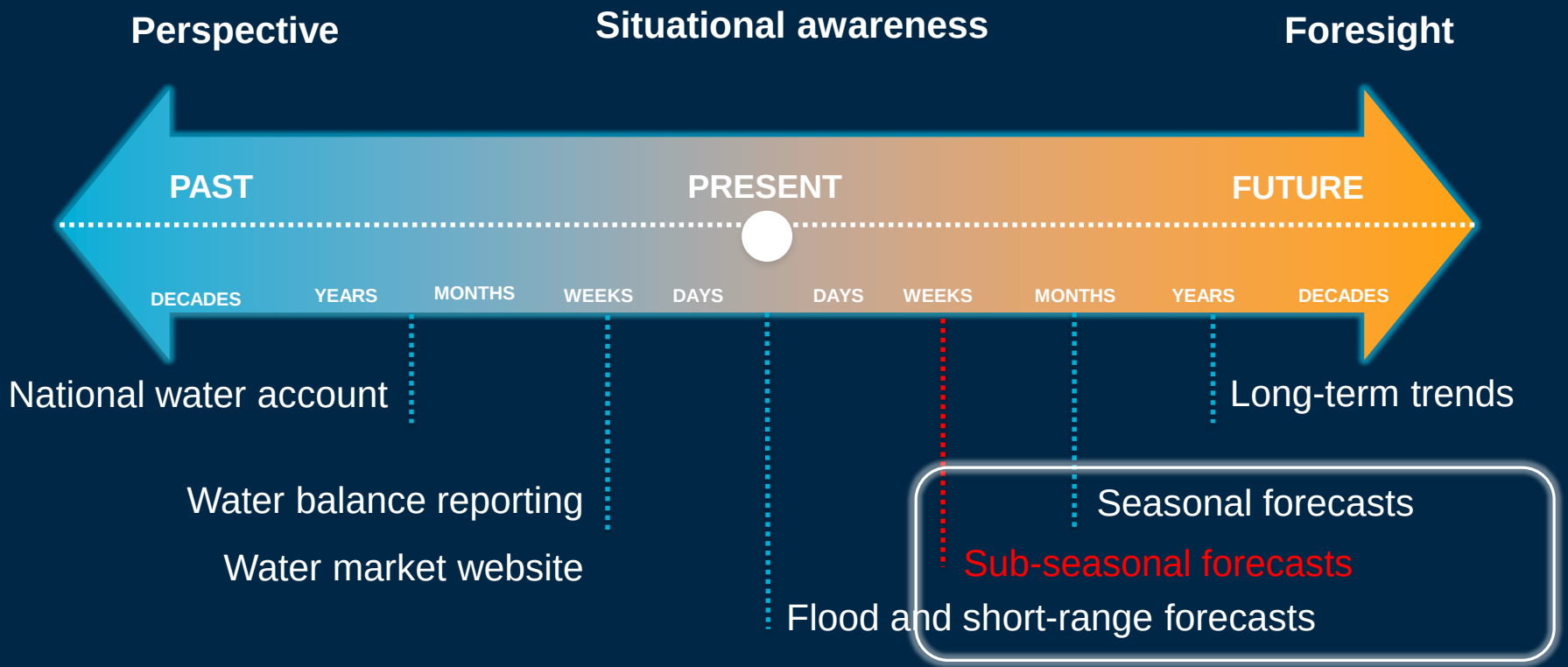


Australia has highly variable rainfall

We frequently lurch from drought to flood and back



Water information products



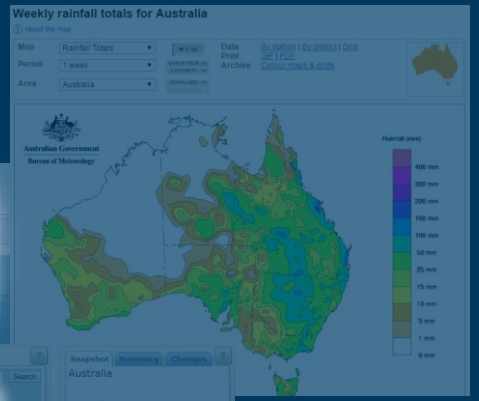
Water forecasting in Australia

Emergency Services

User needs

Water dat

Data sharing

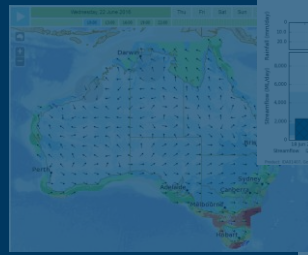


Climate data

Storage

Research

Communication



Forecasts products

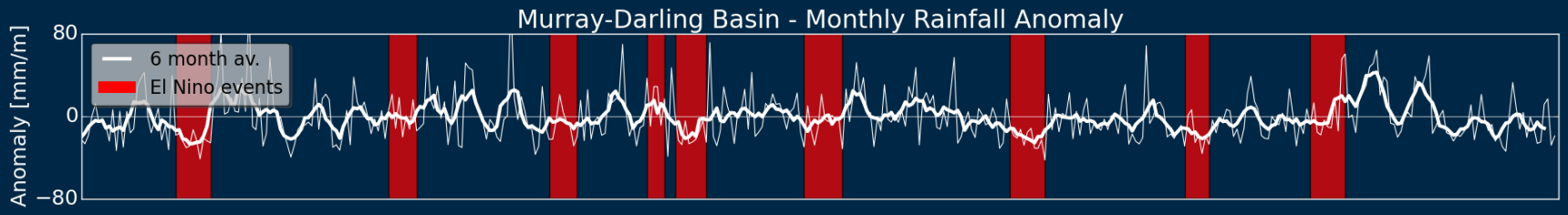
Systems

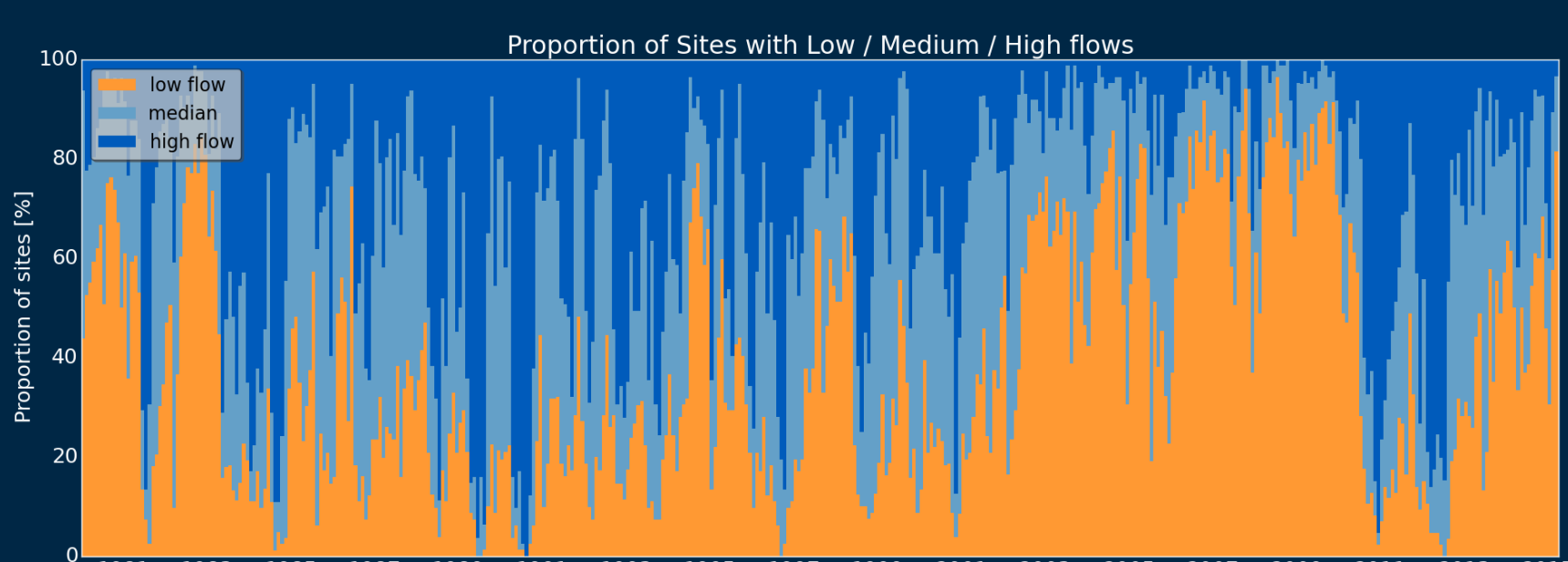
Statistical Models

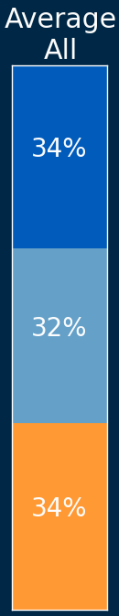
User needs – water forecasting

- Workshops conducted in each jurisdiction
- Cooperative arrangements with Commonwealth agencies (MDBA, CEWO)
- Participants included lead water agencies, water utilities, environmental agencies
- Quarterly meetings with JRGWI since late 2008 – *Jurisdictional Reference Group for Water Information*
- Identified strategic partners and champions in each jurisdiction – ongoing engagements

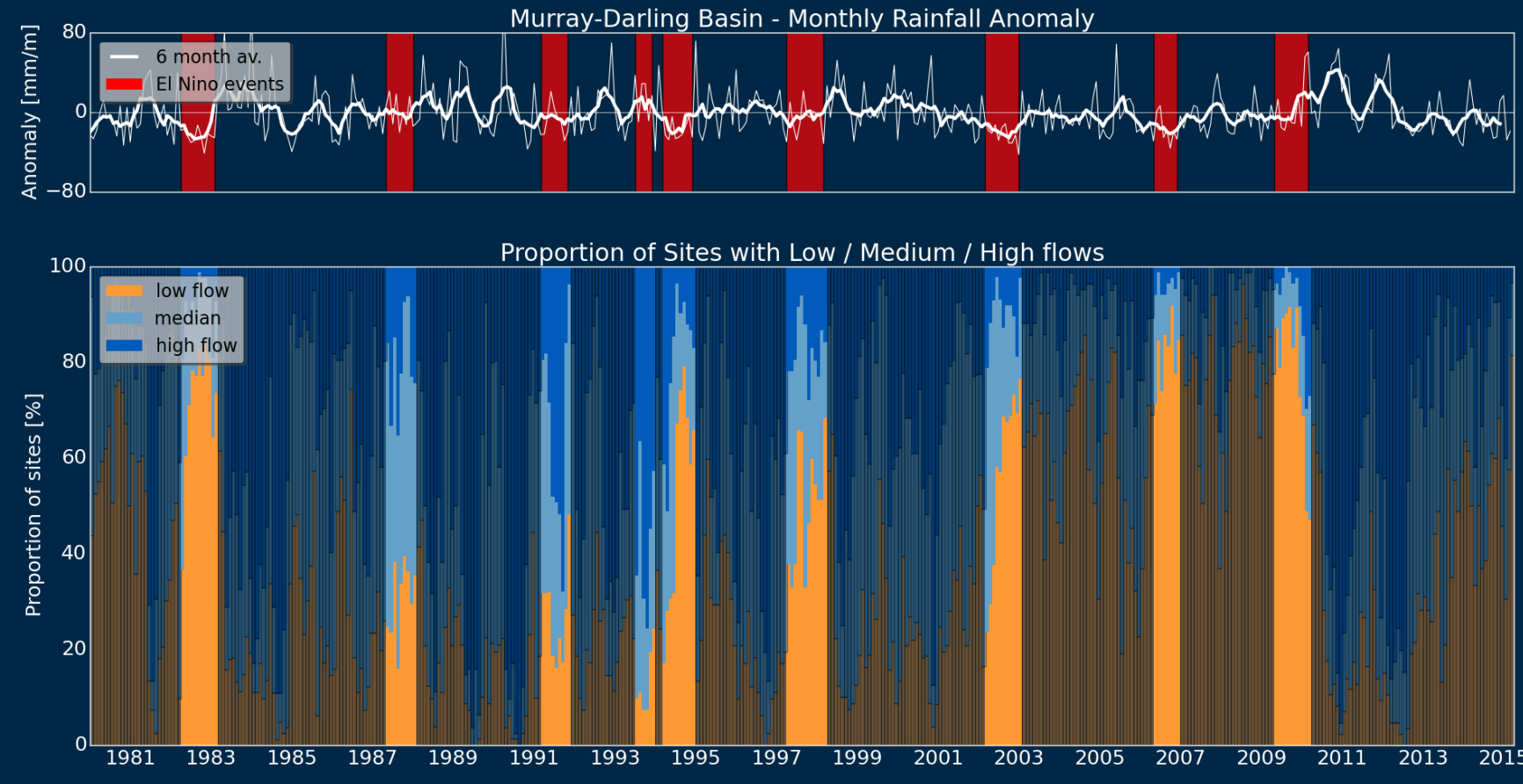
Impact of El Niño conditions on Streamflow





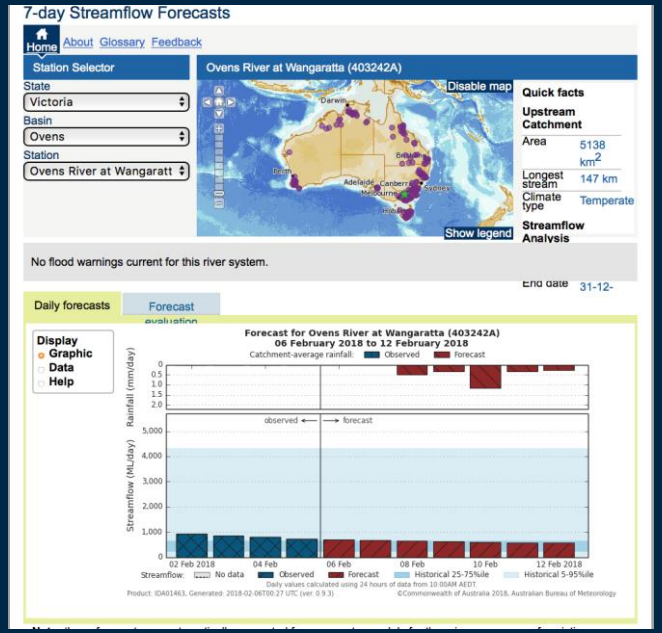


Impact of El Niño conditions on Streamflow



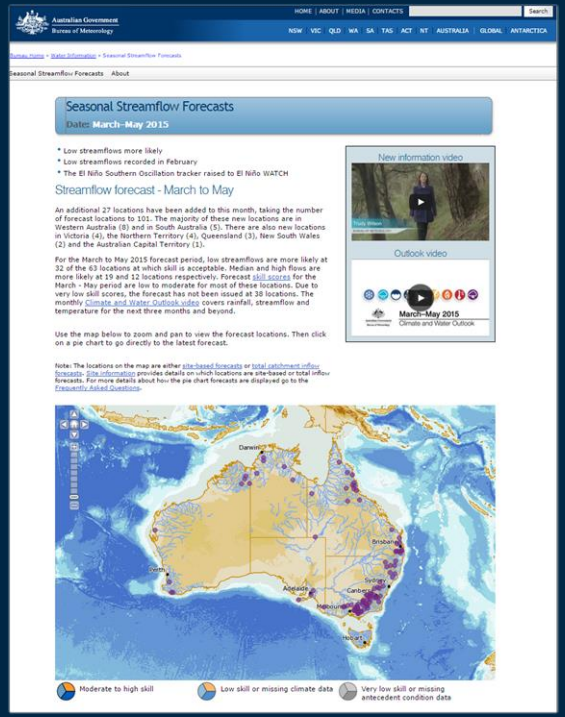
Water forecast services in Australia: www.bom.gov.au/water

7 Day forecasts



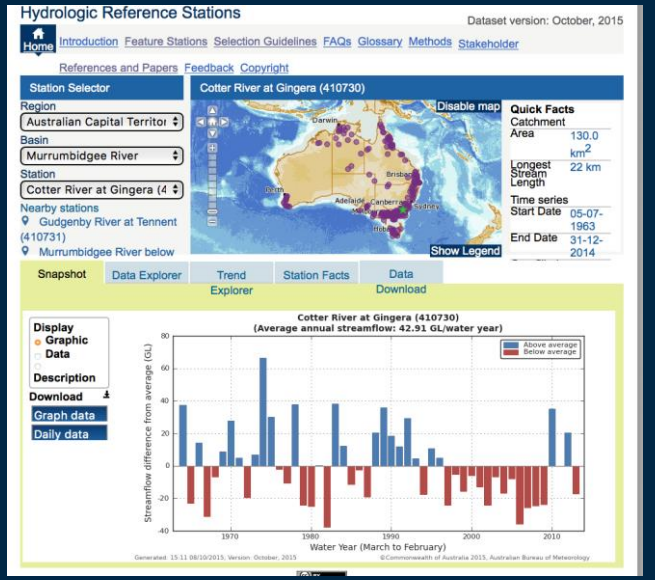
(daily updates)

Seasonal forecasts



(monthly updates)

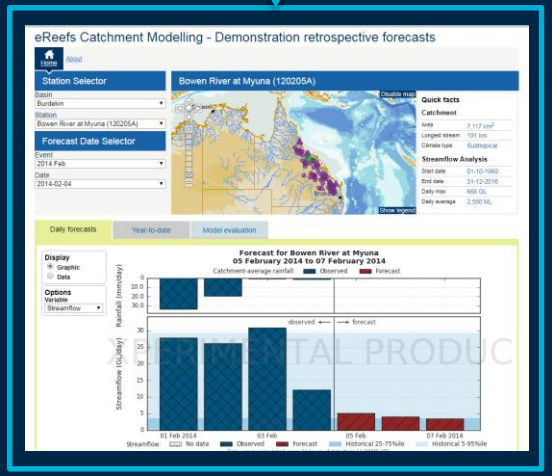
Hydrologic Reference Stations



(biennial updates)

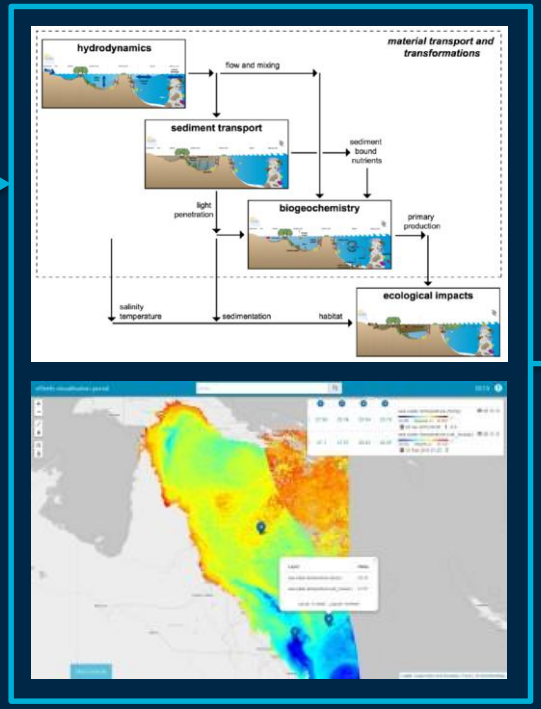
Operational Catchments Service

- Streamflow
- Concentration
- Load



Catchments Website

SHOC/BGC, ROMS, eReefs Portal



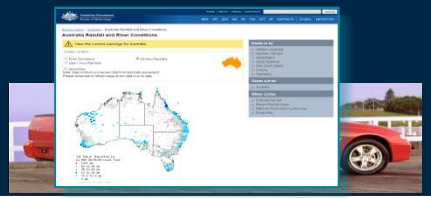
Now-casts & Forecasts

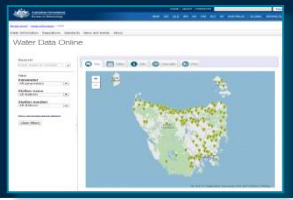
- Plumes
- Currents
- Water availability
- Vulnerable Areas

Great Barrier Reef catchments: water, sediment and nutrient now casting and forecasting (2019)

Data challenges: water observations products

High level functional requirements



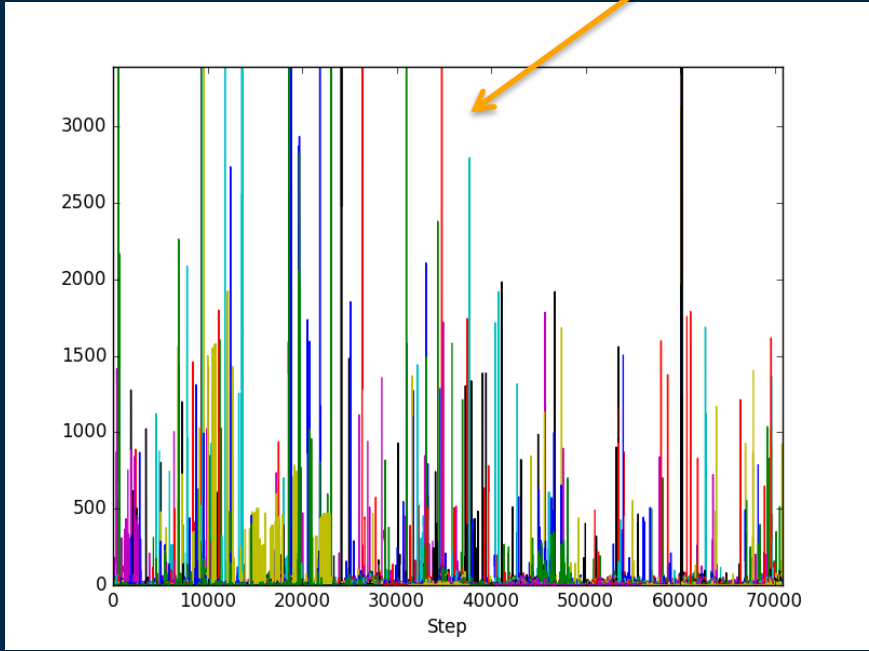


Requirement	Flood	Regulations data
Near real time data – very frequent updates	✓	✗
High availability – Level 1 system support	✓	✗
Accept large volume data deliveries	✗	✓
Interested in retrospective quality edits	✗	✓
Full history of validated data	✗	✓
Extensive station metadata	✗	✓

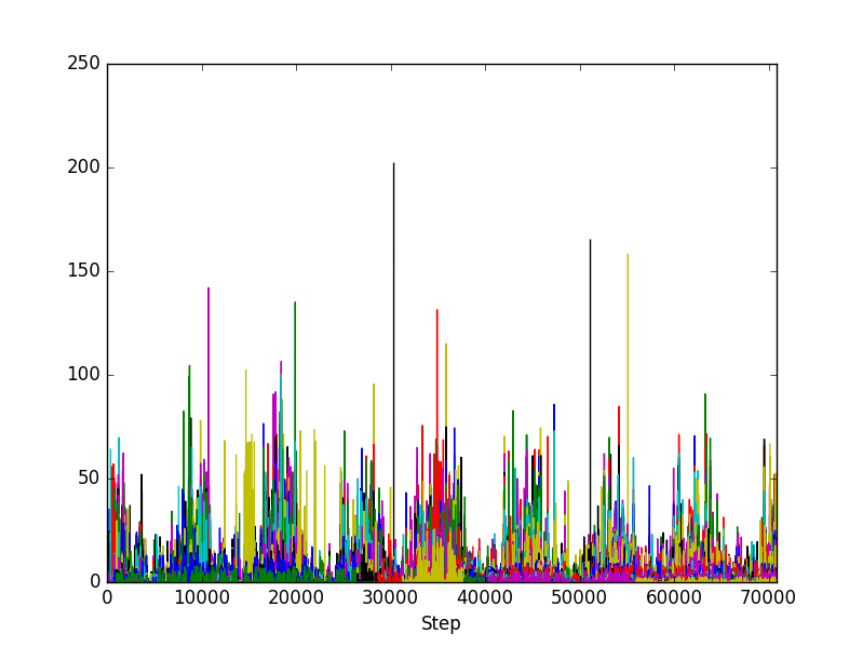
Processing input data – example 1455 hourly rainfall gauges

Lots of outliers

Before Quality Assurance



After Quality Assurance



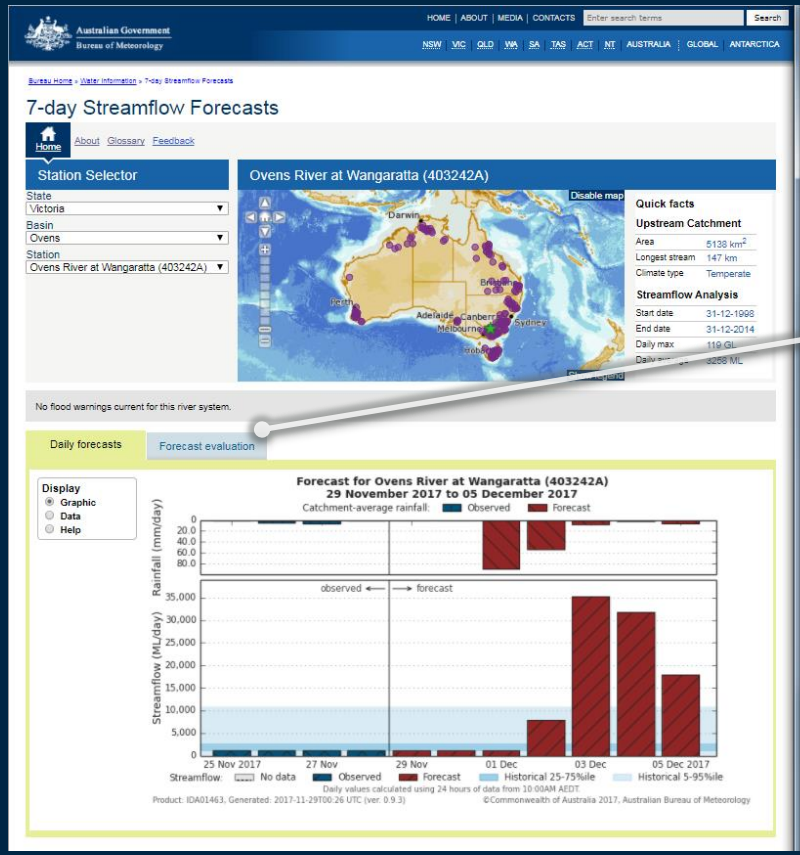
Different scales

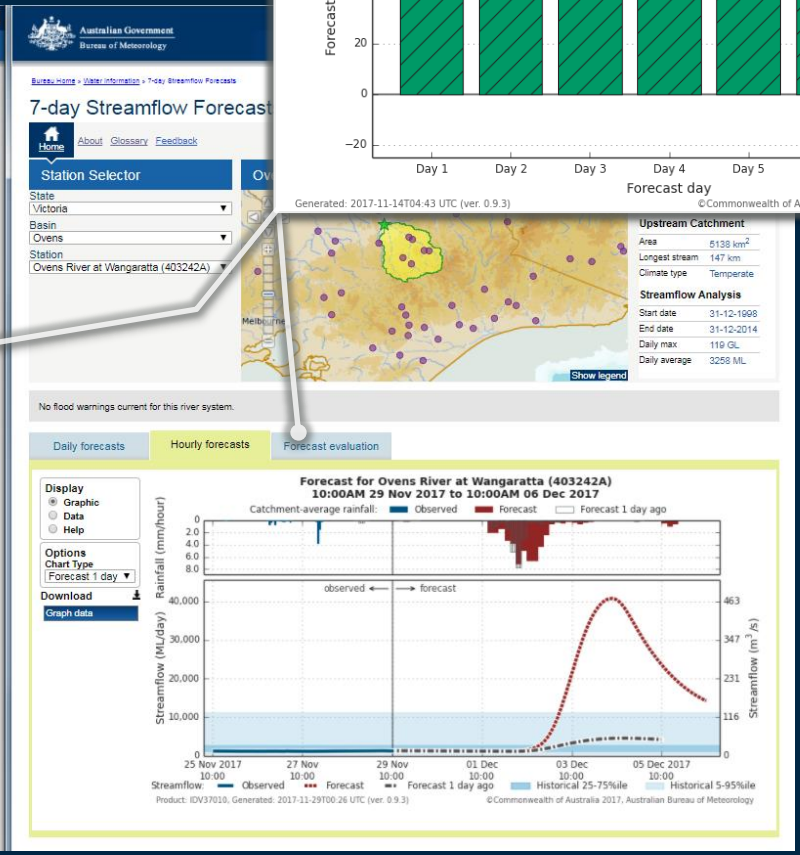
Research challenge – water forecasting

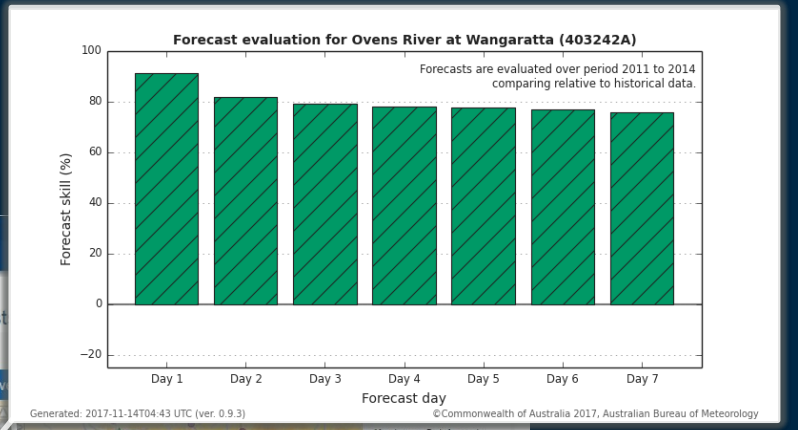
- Do we have the right partners?
- Is the research well targeted?
- Are the researchers well resourced?
- Short term (tactical) versus long term (strategic) research priorities
- Adaptive approach to cater to evolving needs
- University sector role is critical
- Competition amongst researchers and/or research teams
- Meaningful partnerships between specialists from meteorology, climate and hydrologic science disciplines
- What weather and climate forecast products do we use?
- Are the research tools consistent with operational technology stacks?

Operational Service

http://www.bom.gov.au/water/7daystreamflow/

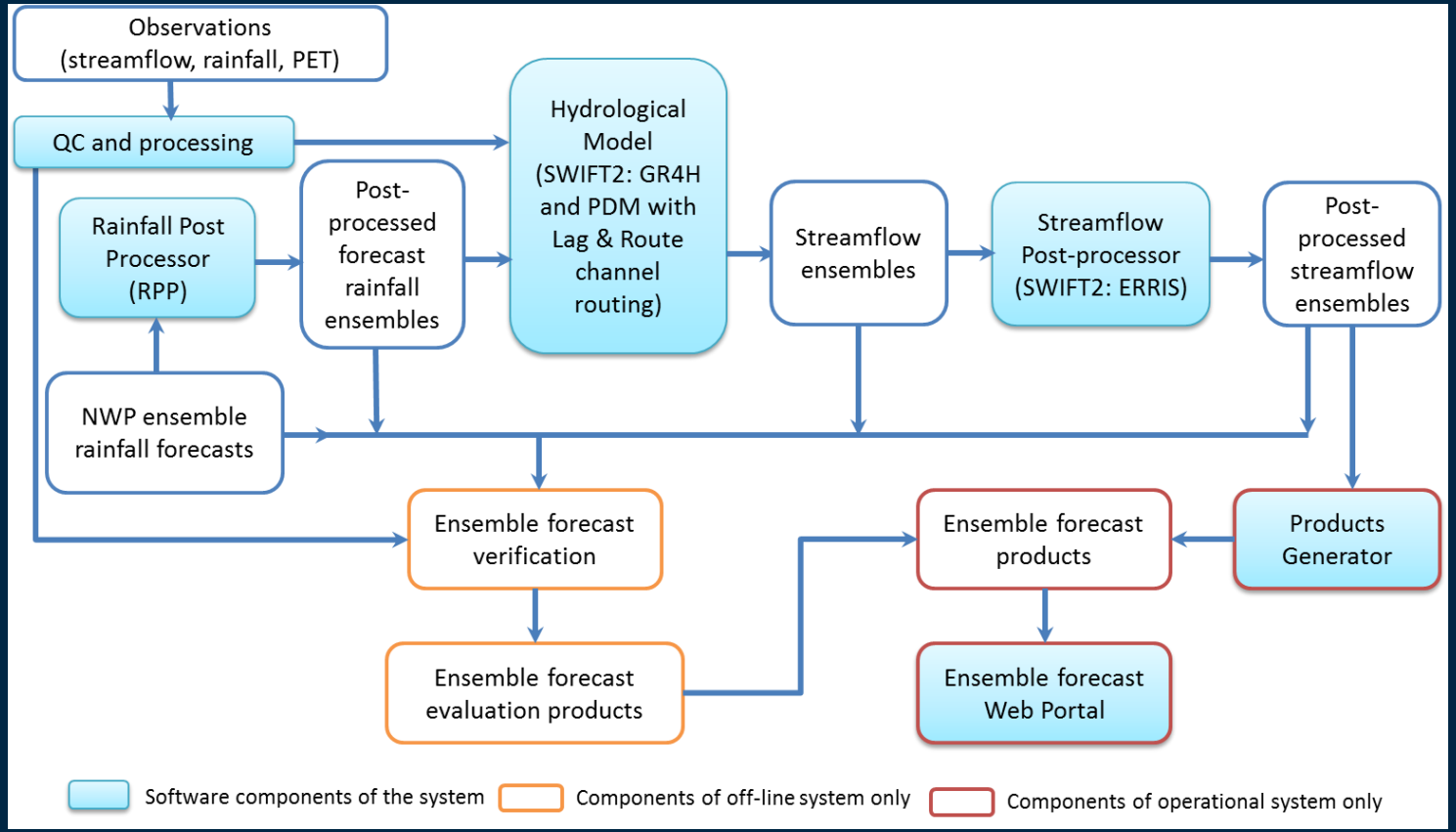




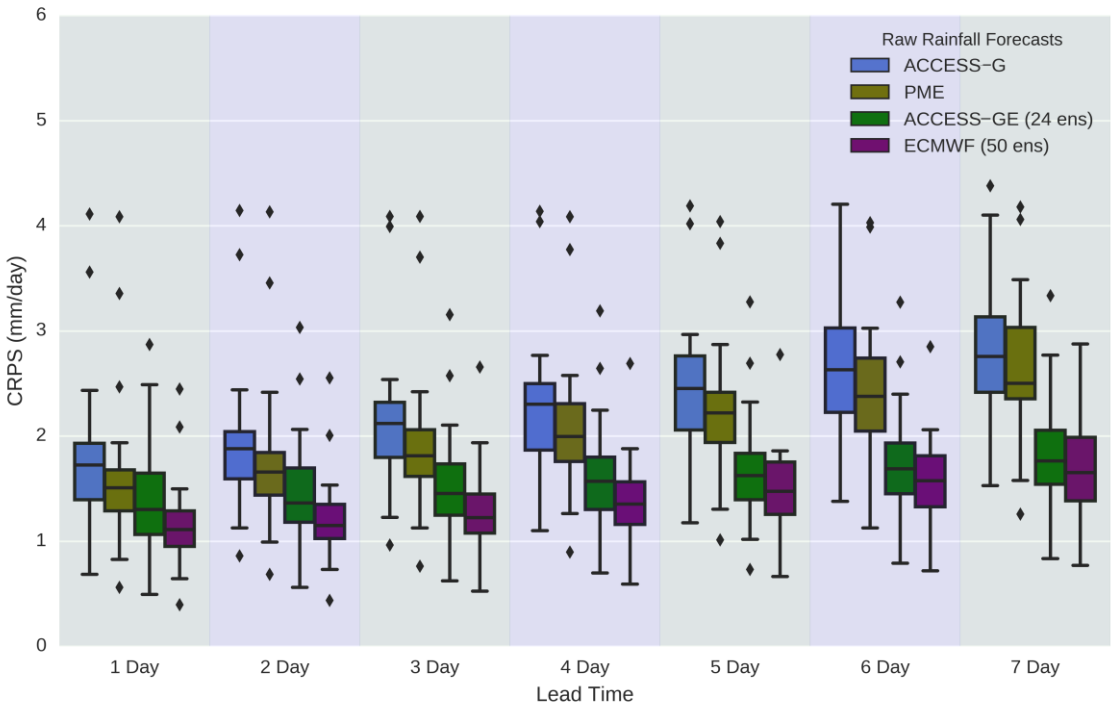


7-Day ensemble streamflow forecasts

- Operational plans: June 2019
- Rainfall uncertainty:
  - Multi model ensemble mean (PME)
  - ACCESS-GE
  - ECMWF
  - Rainfall post processing
- Hydrologic uncertainty
  - Streamflow post processing

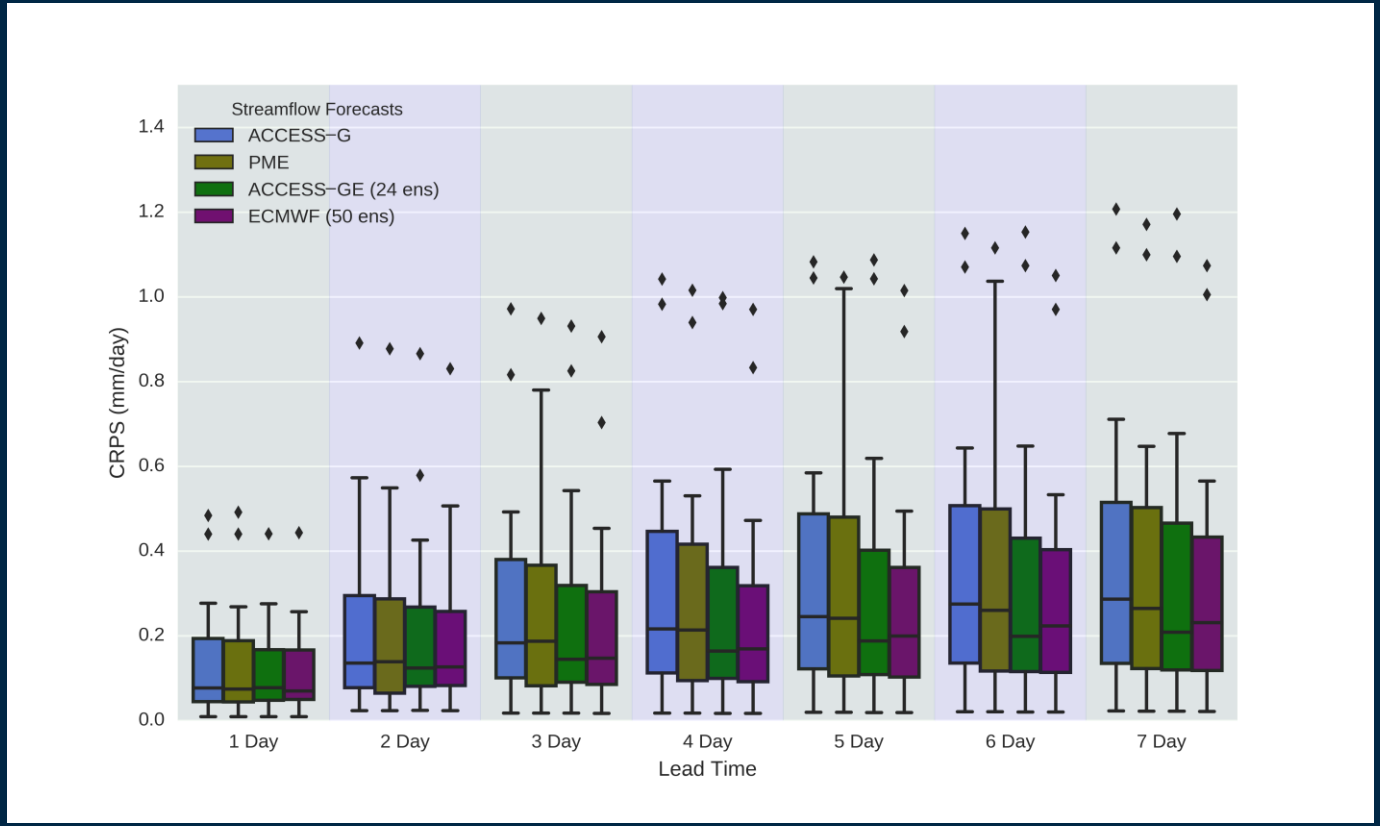


CRPS of different rainfall products for the 30 catchments

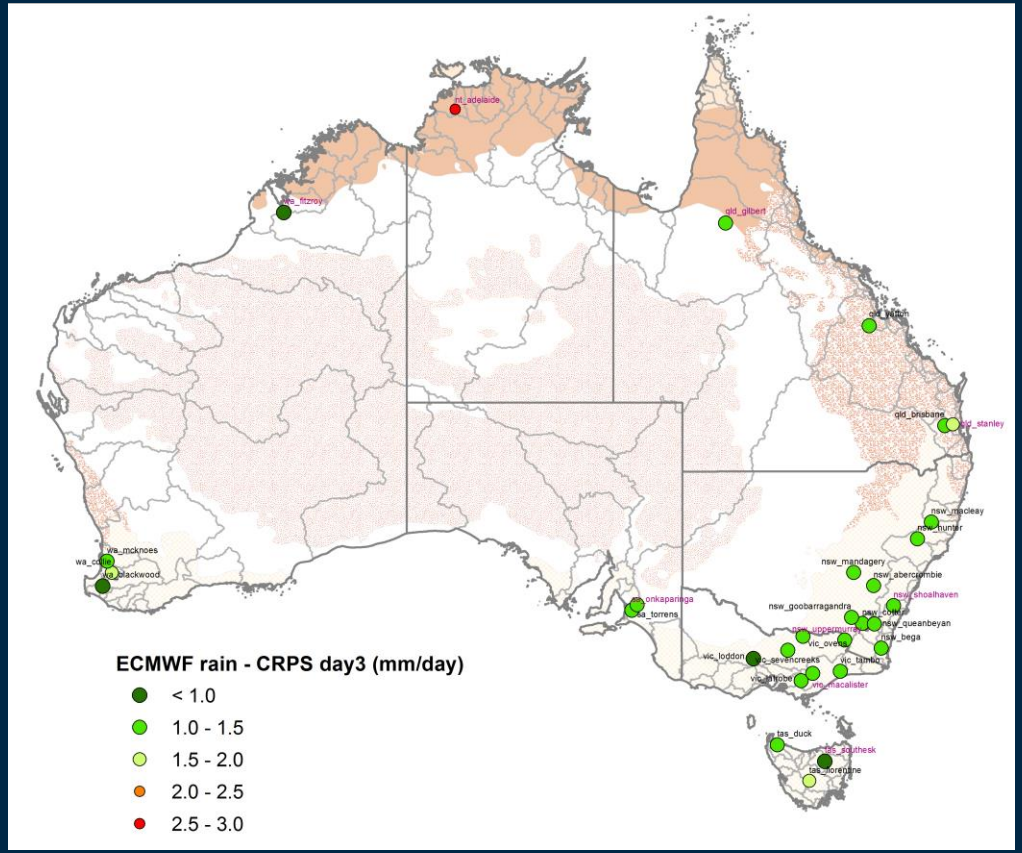


- 2014-16 datasets
- ACCESS-G
- PME
- ACCESS-GE (24 ensembles)
- ECMWF (51 ensembles)

CRPS of streamflow generated for 30 catchments

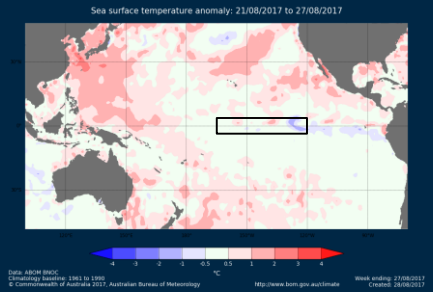


CRPS of ECMWF rainfall for lead-time day-3

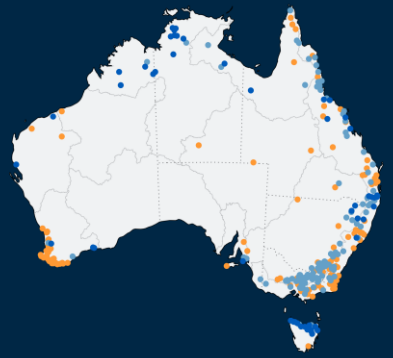


Seasonal forecasting – statistical modelling system

- Statistical modelling - current

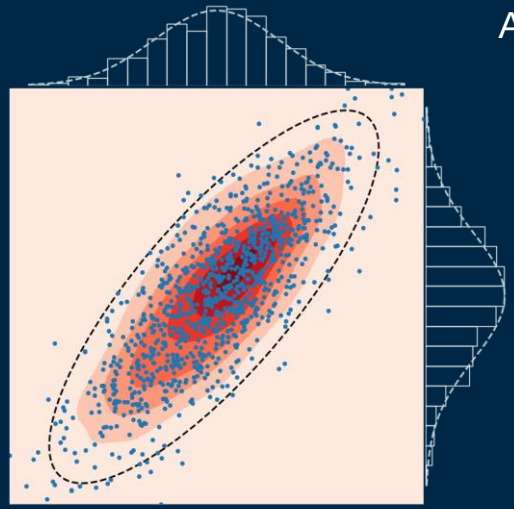


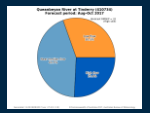
Climate indices



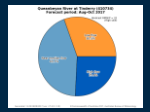
Antecedent streamflow conditions

Multivariate normal distribution in transformed space

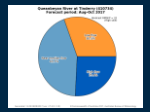




Forecast month 1



Forecast month 2

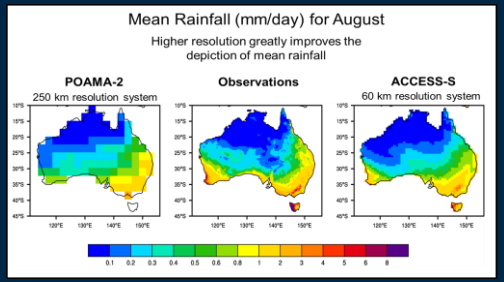


Forecast month 3

BJP model (Wang et al.; Robertson et al.)

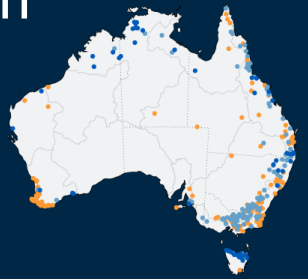
Seasonal forecasting – dynamic modelling system

- Dynamic system – Monthly split (June 2018)

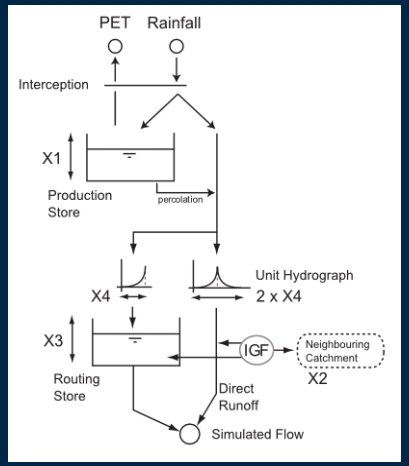


ACCESS-S
Rainfall Forecast

Rainfall
post processor



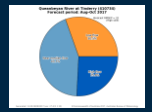
Antecedent streamflow conditions



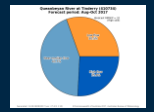
GR4J Rainfall
runoff model

BATEA calibration engine
Embedded in wafari system

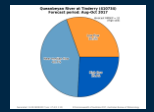
Streamflow
post processor



Forecast
month 1



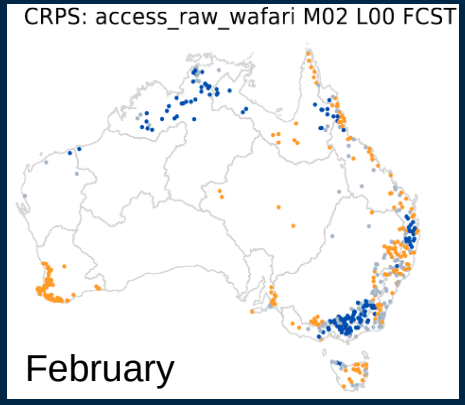
Forecast
month 2

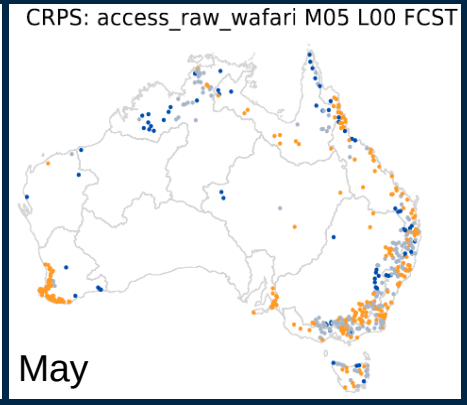


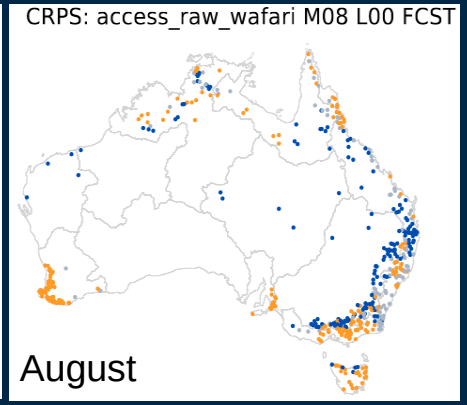
Forecast
month 3

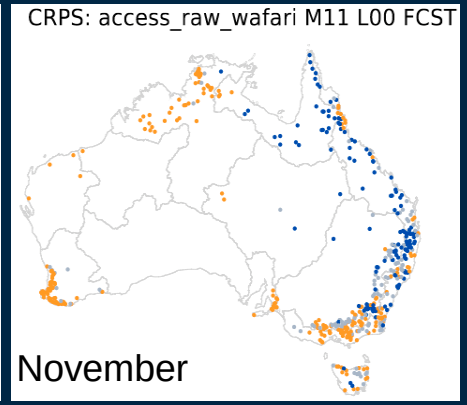
CRPS: RPP-S improves CRPS skill-score at most sites

ACCESS-S Raw

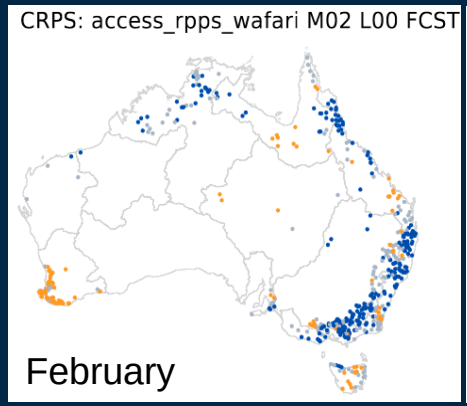


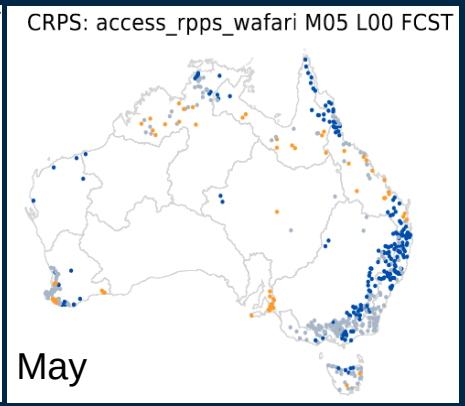


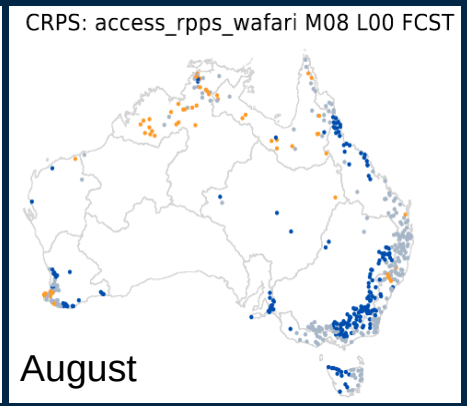


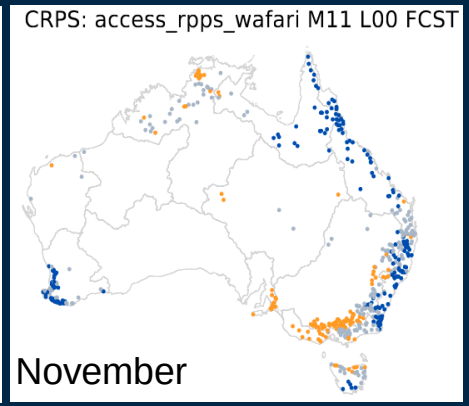


ACCESS-S RPP-S



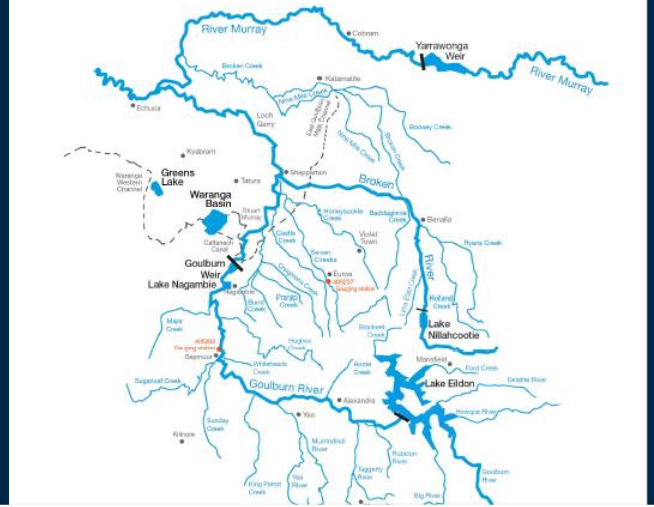






Positive skill
No skill
Negative skill

Case studies: 7 day forecasts



"reinforced the decision to cancel the planned environmental release" (Andrew Shields, GMW, 25th July 2016).

CASE STUDY

Australian Government
Bureau of Meteorology

GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY

WATER

Planning for improved environmental outcomes using 7-day streamflow forecasts

A review of the Bureau's 7-day streamflow forecasts shows they can inform improved water management decisions in Victoria's Goulburn Broken Catchment. Accurate forecasts can reduce the chance that planned water releases coincide with increased natural flows, potentially causing unintended flooding and less desirable environmental outcomes. They can also support decisions to get increased benefit from the limited environmental water resource.

Agricultural and environmental water needs

Environmental flows are released down rivers to improve the health of fish, wetlands, forests, water bugs and birds. However, environmental flows are limited or constrained by their potential impact on private property, businesses and infrastructure bordering rivers[1,2].

Fulfilling agricultural and environmental needs, with optimal water-use efficiency, requires careful management of flows by Goulburn-Murray Water (GMW) who supply water to irrigators and other entitlement holders, with the Goulburn Broken Catchment Management Authority (GB CMA) providing key support for environmental flow management.

The Goulburn River system

Water released from Lake Eildon into the Goulburn River supplies irrigators and other entitlement holders, and creates flows for environmental needs further downstream. At Goulburn Weir, near Nagambie, water is diverted and delivered to irrigators through a network of connected channels.

The weir also allows water to be released from Lake Nagambie to supply additional flows into the lower Goulburn River. This enables demand for irrigation and environmental flows downstream to be delivered and flood flows to be managed. Environmental flows are required in the lower reaches of the Goulburn River, including the Lower Goulburn National Park, to support fish breeding and riparian vegetation, such as River Red Gums.

Challenges for water and environmental managers

To support fish breeding in the river and vegetation health along the banks, environmental releases need to occur at particular times and deliver a gradual rise in river levels, between Lake Eildon and the River Murray, and then a gradual reduction in river levels. An excessive rise in Goulburn River levels from rainfall during these releases, and adverse impacts of higher Goulburn River flows into the River Murray also need to be considered.

So GMW need to plan for releases when they are confident there will be no significant rainfall or natural flows, and flows in the River Murray are not too high.

It takes approximately four days for flows released from Lake Eildon to reach key areas in the lower reaches of the Goulburn River. There are also natural tributaries entering the river along the way. With release planning and approval typically taking up to several days, reliable estimates of natural flows are needed for at least five days ahead to ensure releases do not coincide with significant natural inflows from rainfall.

Before 7-day streamflow forecasts became available, judgments were based on Bureau rainfall forecasts and local knowledge of recent catchment wetness conditions.

Image: Lake Eildon (GMW)

Case studies: seasonal forecasts

Seasonal Streamflow Forecast Service

What are seasonal streamflow forecasts?

They are forecasts issued monthly by the Bureau that forecast three months ahead and predict how much water will flow into a stream or catchment. They are based on probabilities—that is the likelihood or chance of a given volume of water flowing into a stream based on recent climate and catchment conditions.

Why are they important?

Australian streamflows are among the most variable in the world. Streamflow forecasts are vital in helping water managers and users make informed decisions. For example, they help water managers decide which water source to use or whether environmental flows should be allocated.

What areas do the forecasts cover?

They cover 74 locations across the Northern Territory, Queensland, New South Wales, Australian Capital Territory and Victoria. This has expanded from 21 locations when the service was launched in 2010, and will evolve to cover all jurisdictions by 2015.

ABOUT ACTEW WATER

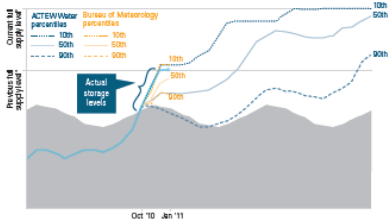
How does ACTEW Water use the Bureau's streamflow forecasts?

ACTEW Water applies the Bureau's forecast using the following process:

- Forecasts are incorporated into ACTEW Water's water supply planning model, along with estimates of water demand.
- Operational and environmental rules are applied to projected storage levels from each of the forecasts.
- Data are overlaid onto two-year water storage projections developed from their historic reference climate via the same water supply model.
- Projections then inform ACTEW Water's strategic operational decisions.

Infrastructure

ACTEW Water's infrastructure includes four storage sites, two extraction points and two water treatment plants. It recently increased its capacity by enlarging the Cotter Dam and constructing the Murrumbidgee to Googong Transfer.



In October 2010, storage levels had sufficiently recovered so ACTEW Water could consider removing temporary water restrictions. The Bureau's Seasonal Streamflow Forecast Service reduced the range of likely outcomes and the decision to remove water restrictions had a lower risk than the projections based on historic climate indicated.

*Note: Expected full supply level used in scenarios increased periodically between November 2010 and February 2012. This was due to the planned enlargement of the Cotter Dam.

FIND OUT MORE

Visit www.bom.gov.au/water/ssf or email water_ssf@bom.gov.au
ACTEW Water: www.actew.com.au, email talktous@actew.com.au or Twitter @ACTEWWater

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Seasonal forecasts influencing timing of removing water restrictions in the ACT

CASE STUDY

Australian Government Bureau of Meteorology | Melbourne Water

Better water resources forecasts for Melbourne

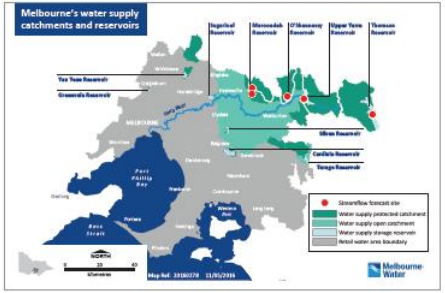
The Bureau of Meteorology's seasonal streamflow forecasts provide Melbourne Water with improved information to aid water resource management for Melbourne. These forecasts indicate the likely volume of catchment inflows into the city's major water supply reservoirs for the next three months.

Forecasting to improve Melbourne's water resource management

Severity of the 1997–2009 Millennium Drought—combined with projected impacts due to a changing and variable climate, population growth and urban development—posed challenges to Melbourne's water resource management. So in 2010, the Bureau started working with Melbourne Water to improve seasonal streamflow forecasts to aid water management.

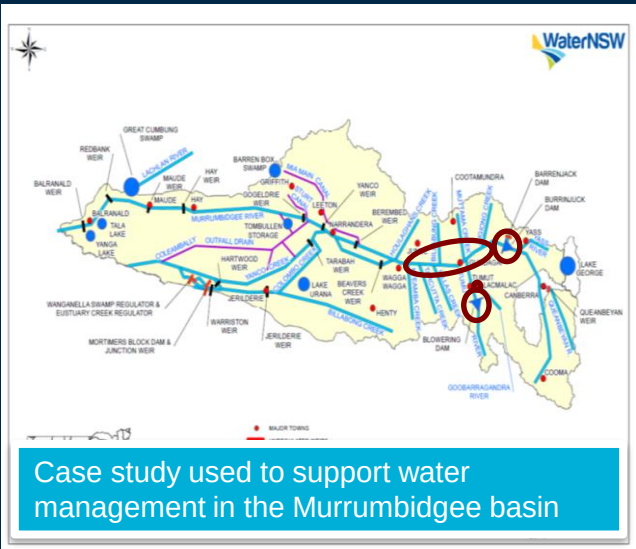
The Bureau's model produced better forecasts than the information previously available. For each outlook, the number of times the forecast matched what was observed (also called the 'tercile hit rate') was substantially higher using the Bureau's model, than using historical streamflow records.

for forecasting inflows for each location and season.



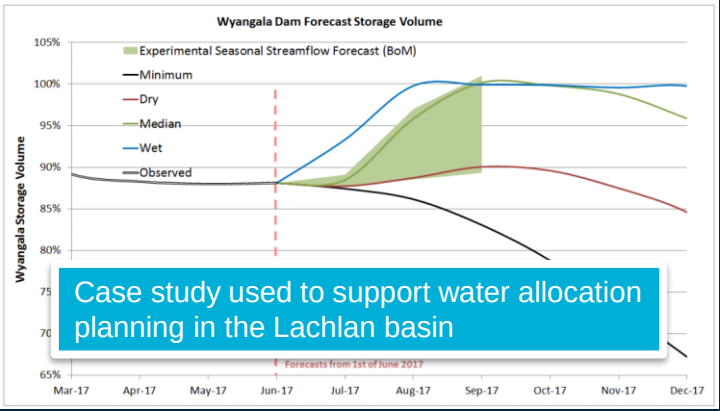
Top image: Maroondah reservoir

Case study used to develop enhance user confidence and facilitate adoption



Case study used to support water management in the Murrumbidgee basin

Forecast Storage Volume



Case study used to support water allocation planning in the Lachlan basin

Coupling catchment and marine models

Catchment Modelling System

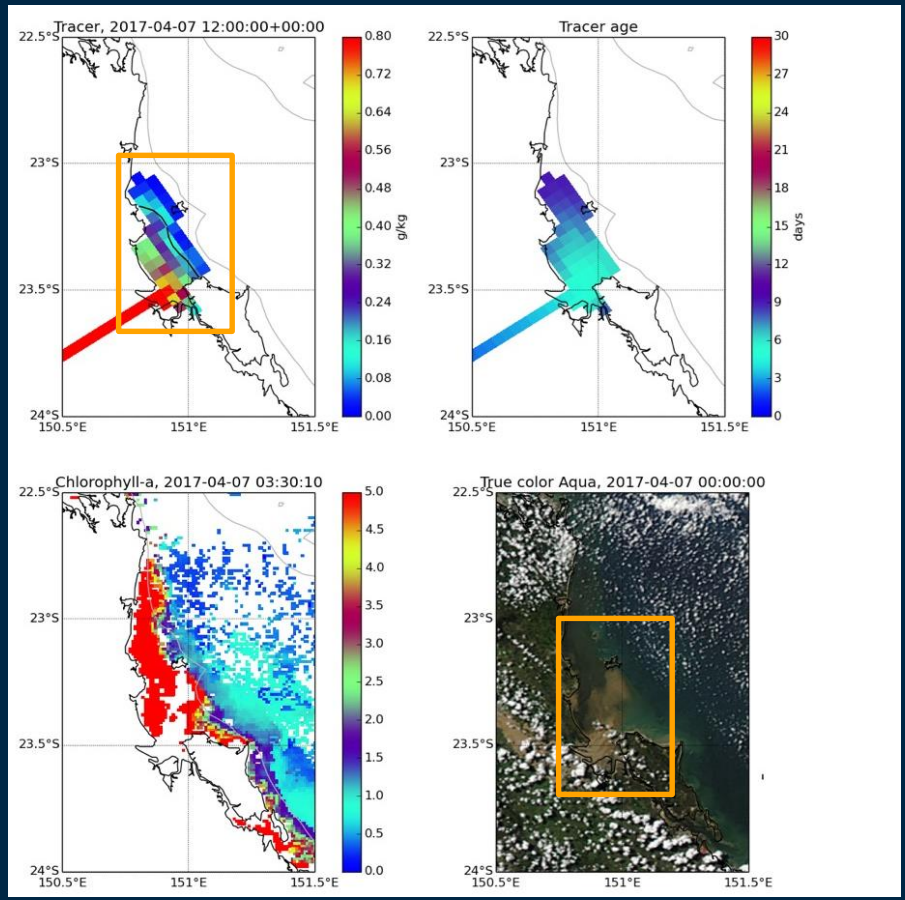
Simulated plumes

Streamflow

Concentration

Load

Marine Modelling System (ROMS)

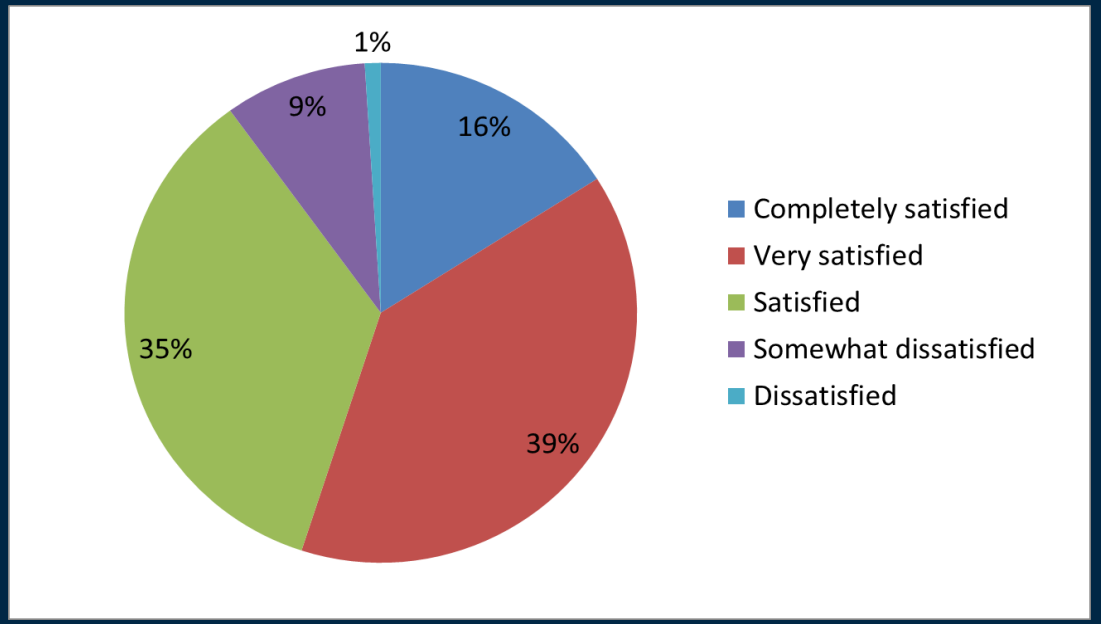


Case study on Cyclone Debbie – performance of the catchment and marine models

Overall satisfaction with the Seasonal Streamflow Forecasts

- Completely satisfied: 16%
- Very satisfied: 39%
- Satisfied: 35%
- Somewhat dissatisfied: 9%
- Dissatisfied: 1%

Outcomes of the survey from late 2016: 80 participants



Concluding remarks

- Short range
  - Transition deterministic 7 day forecasts to ensemble forecasts
  - Trial ensemble flood pilots
  - Transition event based deterministic flood forecasting service to include ensembles

- Seasonal and sub-seasonal streamflow forecasts
  - Extend seasonal streamflow forecasts from 3 months to 6 months
  - Include demand forecasting (rural sector)
  - R&D for sub-seasonal streamflow forecasts

- We under estimated the efforts required for
  - Communication and adoption
  - Transitioning research to operations
  - Data and system automation issues

Thank you

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Australian Government
Bureau of Meteorology