BUREAU OF METEOROLOGY

Water availability forecasts for operational planning and management – business drivers, progress-to-date and key challenges

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Manager Extended Hydrological Prediction
29 October 2014

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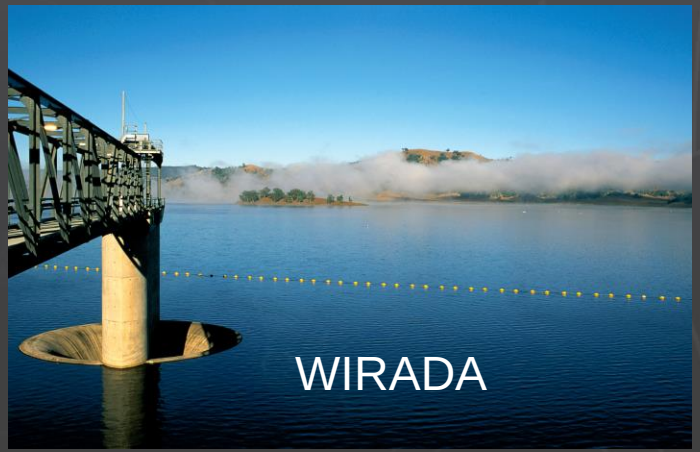
Built on extensive research partnerships

- Bureau of Meteorology
  - Water Information Program
  - Centre for Australian Weather and Climate Research (CAWCR)
- CSIRO
  - Water Information Research and Development Alliance (WIRADA)
- University sector in Australia
- eWater
- International: WMO, US-NWS, UK-CEH, US-UNC



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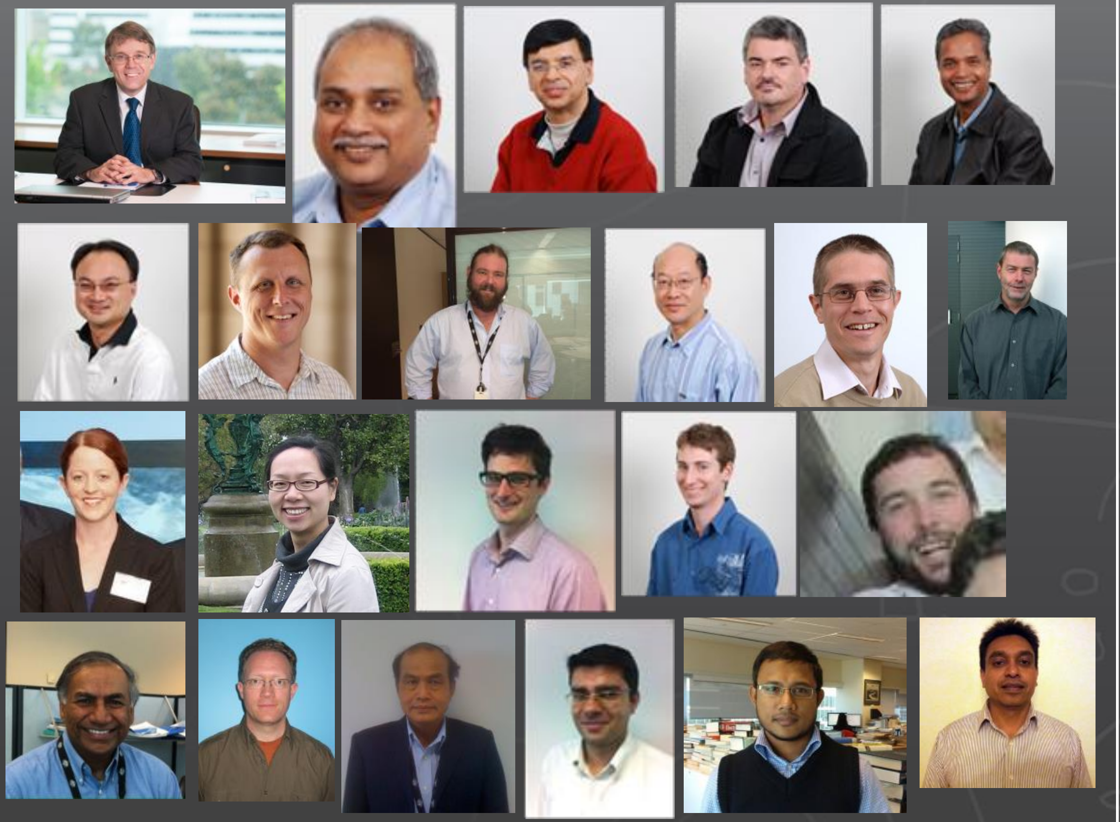
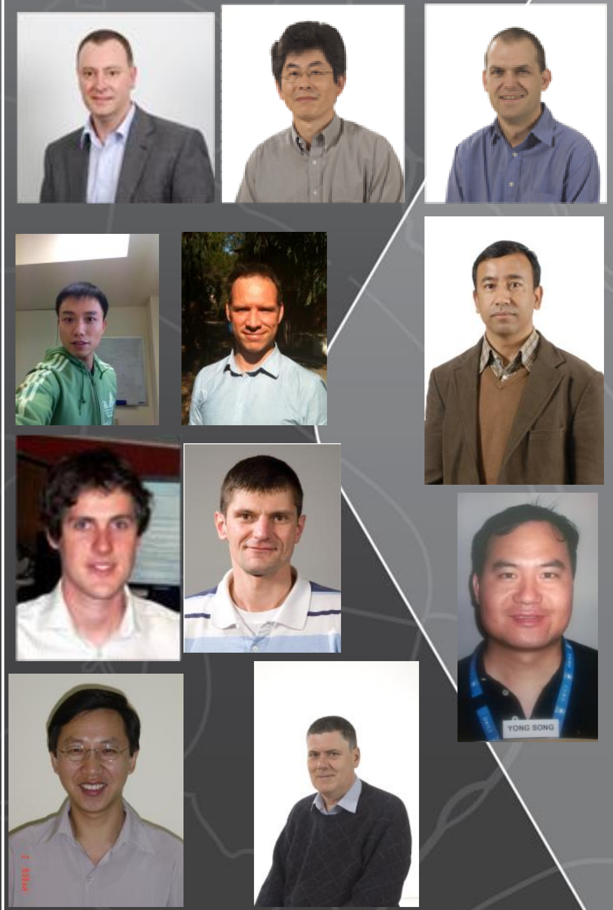


CSIRO



Outline

- Business drivers for water availability forecasts
- Extended Hydrological Prediction Services: progress-to-date and next steps
  - Long Term Water Availability
  - Seasonal Streamflow Forecasts
  - Short Term Forecasts
- Concluding remarks and key challenges

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Water Managers in Australia have a lot to plan for!

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Australia has a variable climate

Year	Major drought conditions
1895-1903	Federation drought
1914-15	Widespread drought; Australian wheat crop failed
1918-20	Severe drought across all states
1939-45	WWII drought affects SE & SW
1965-68	Most of Australia affected
1982-83	A short severe drought
1997-2009	Millennium drought
2013-present	Parts of NSW and Queensland

EIGHT DROUGHT EVENTS OF SHORT AND EXTREME TO PROLONGED CONDITIONS DURING THE LAST 120 YEARS

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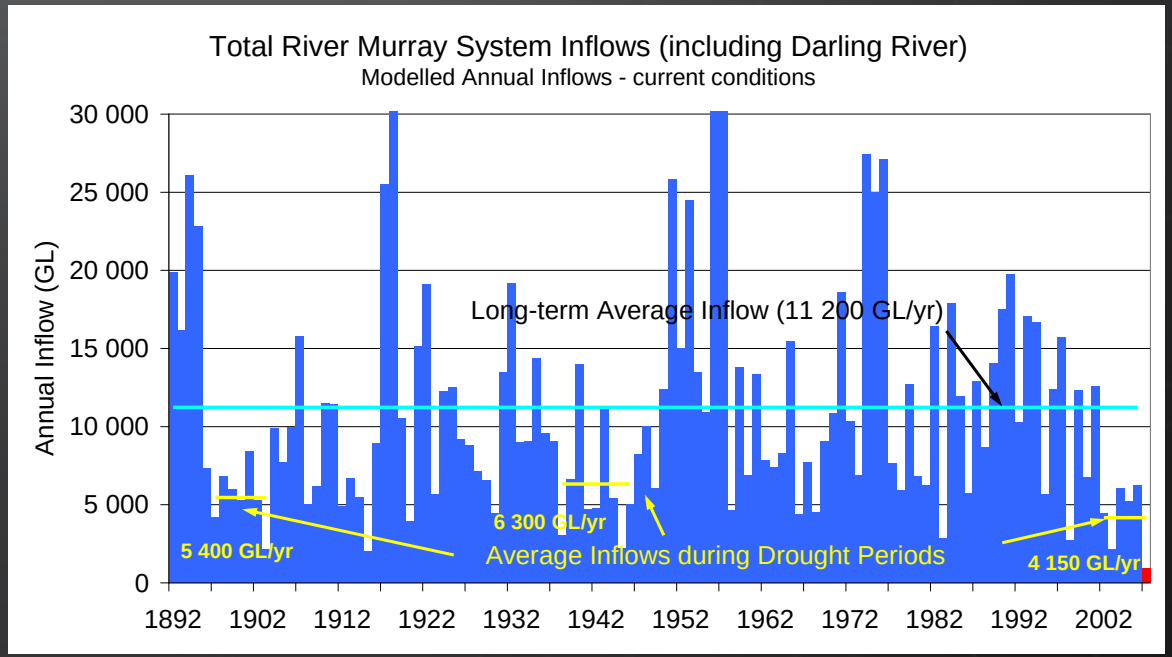
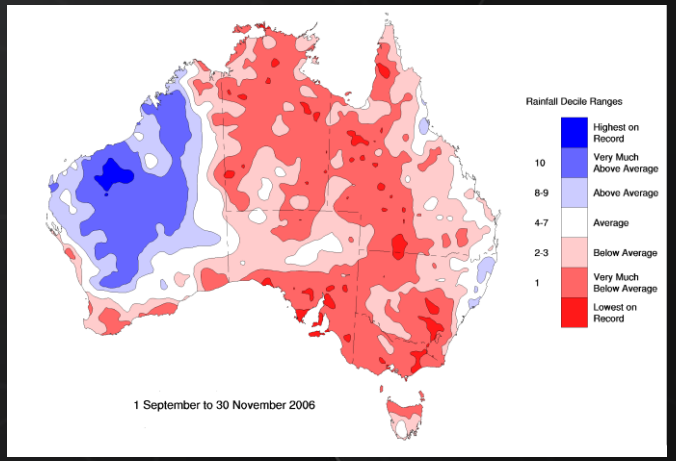
The millennium drought impacts (1997 – 2009)





Water availability in the Murray-Darling Basin

Source of data: MDBA

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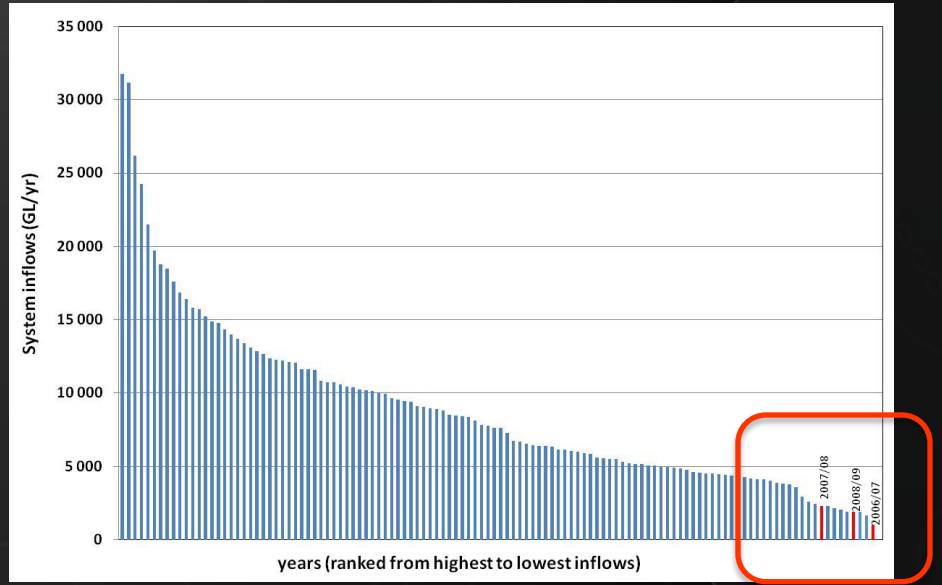
Water outlook in spring 2006 for the River Murray System

- Lowest on record rainfall for six months Feb to Oct 2006 across most of high yielding alpine catchments
- Record low system inflows
- Less water for whole year than had been allowed for planning purposes
- Prospect of record low water availability in 2007-08 with another dry year
- Prospect of urban water supply difficulties if 2007-08 was as dry as 2006-07



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Long-term trends in streamflow across Australia

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Long term trends in water availability

Hydrologic Reference Stations

Introduction | Feature Stations | Selection Guidelines | FAQs | Glossary | Methods | Stakeholder | References and Papers | Feedback | Copyright

Station Selector

Region: Australian Capital Territory

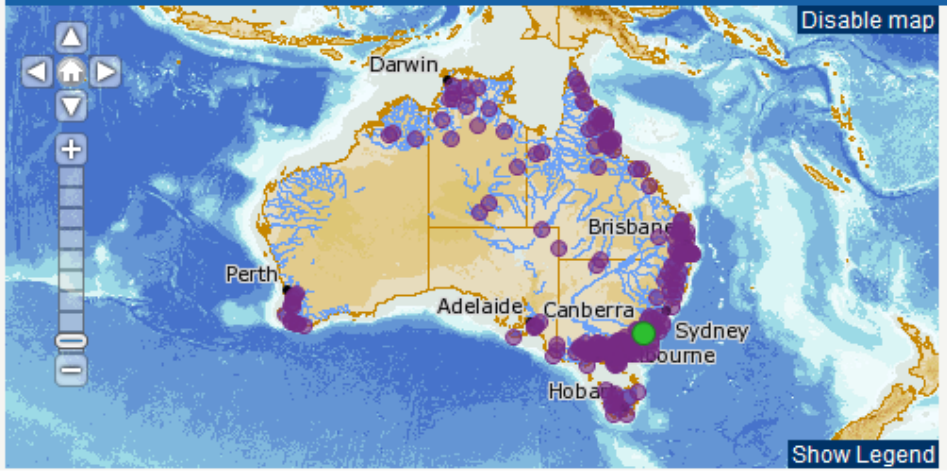
Basin: Murrumbidgee River

Station: Cotter River at Gingera (410730)

Nearby stations

- Gudgenby River at Tennent (410731)
- Murrumbidgee River at Lobb Holes (410761)
- Queanbeyan River at Tinderry (410734)

Cotter River at Gingera (410730)



Quick Facts

Catchment

Area	130 km²
Stream Length	98 km

Time series

Start Date	05-07-1963
End Date	31-12-2011
Gap-filled	0.39 %
Daily Max	4507 ML
Daily Min	1 ML
Daily Average	117 ML
Annual Average	43 GL
Water Year	Mar to Feb

www.bom.gov.water/hrs

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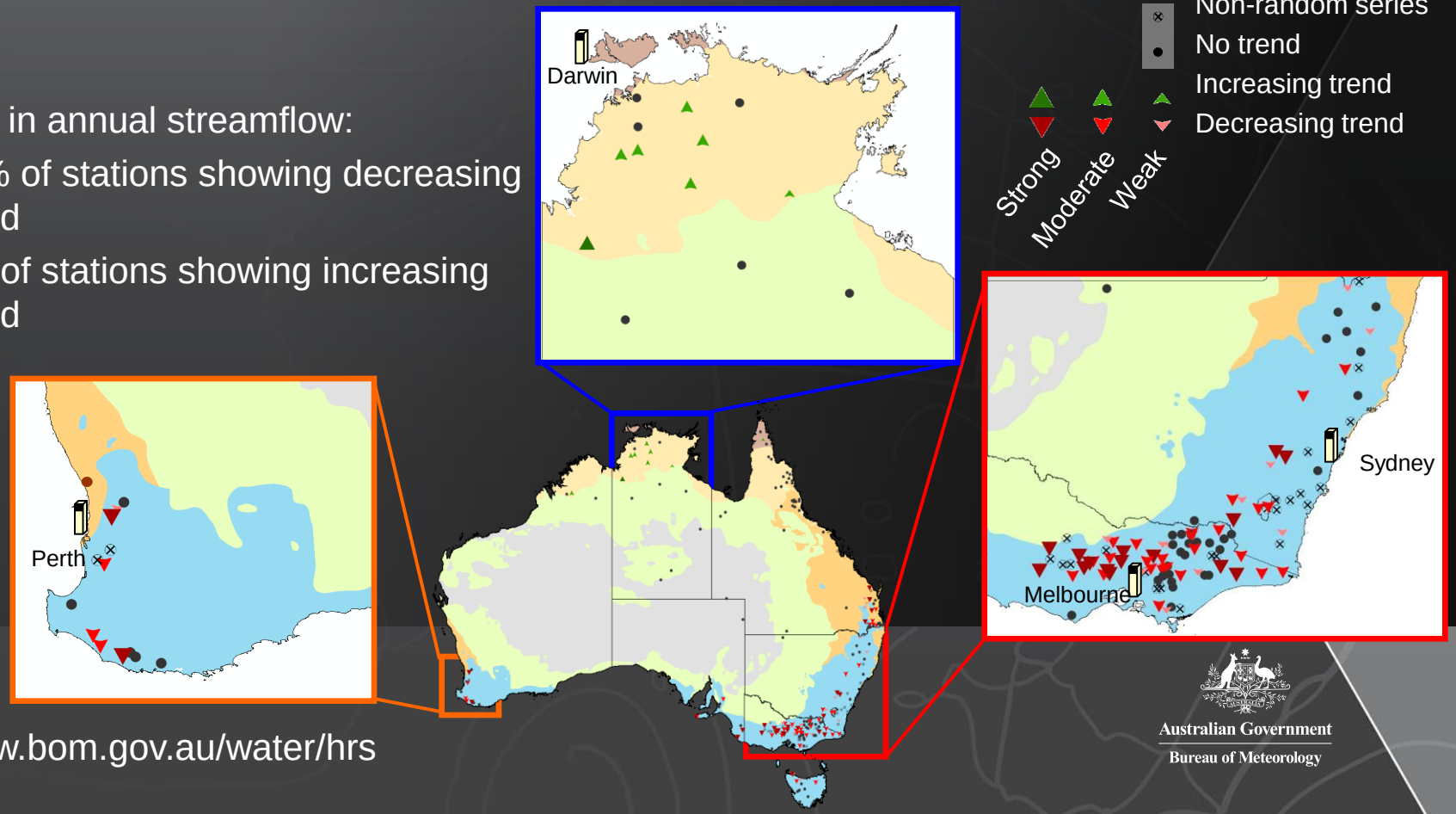
Trends at 221 Hydrologic Reference Stations

Trends in annual streamflow:

- 35% of stations showing decreasing trend
- 4% of stations showing increasing trend



www.bom.gov.au/water/hrs

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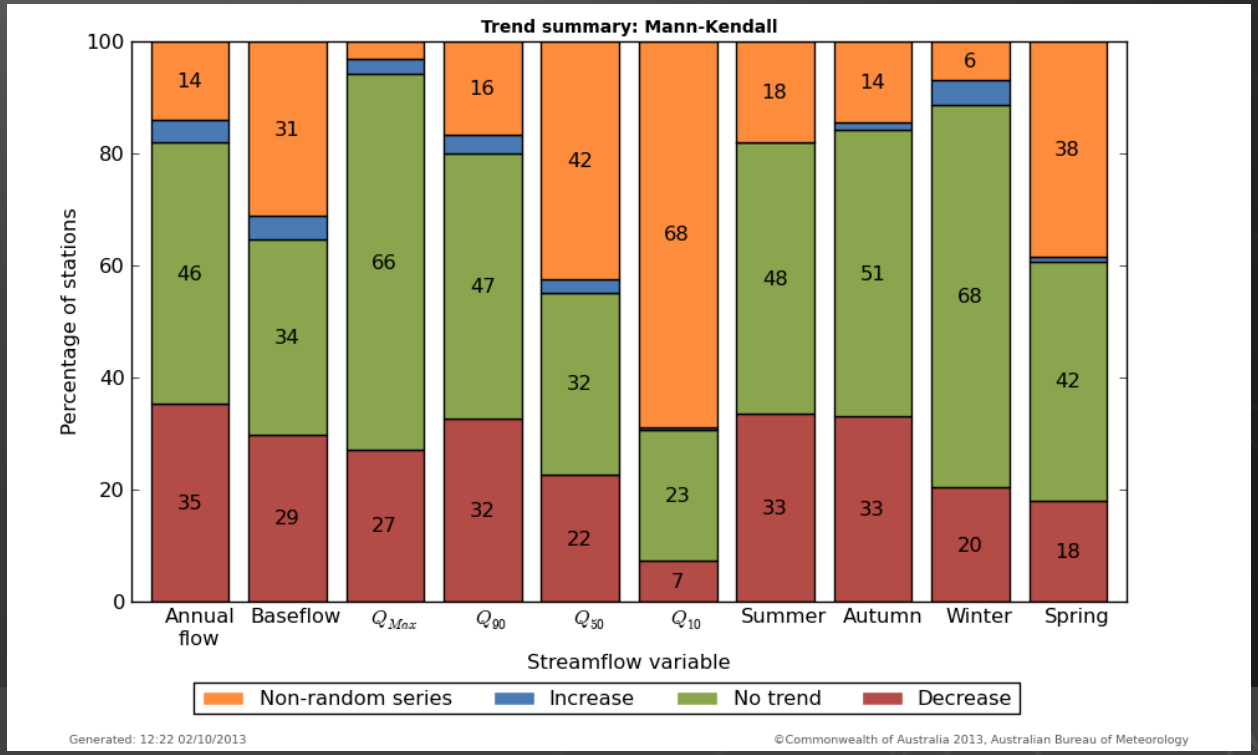
Trends in streamflow across Australia



- Wide range of streamflow variables
- Most of significant trends are decreasing
- These stations have:
  - Long observation records
  - Negligible land use change
  - Negligible diversions

Source of data: www.bom.gov.au/water/hrs

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Key drivers for water forecasting

- Large areas of the river basins
  - e.g. Murray Darling Basin: 1 million km^2
- Travel times 1 to 3 months
- Most storages in headwaters
- Discharge capacity constraints
- Ratio of wettest and driest year > 50
- Legislated water sharing plans up to 10 years
- Water resource planning is done within a risk assessment framework

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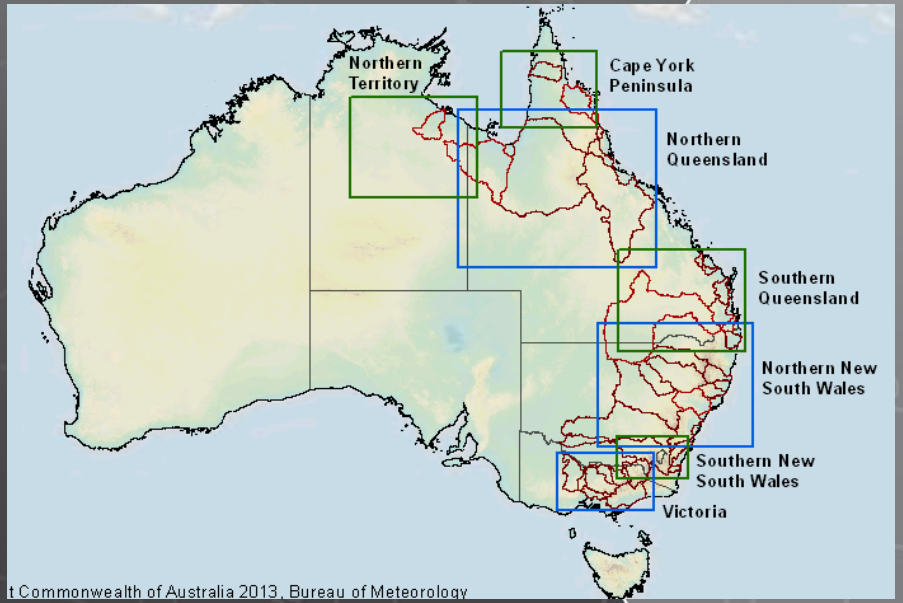
Seasonal streamflow forecasting service

- Forecasts of streamflow volumes at a site or total inflows to a water storage
- 3-months ahead, updated every month, since 2010
- 86 locations and increasing coverage…..
- Statistical approach using Bayesian Joint Probability model (5000 ensembles)
- Publicly available at www.bom.gov.au/water/ssf



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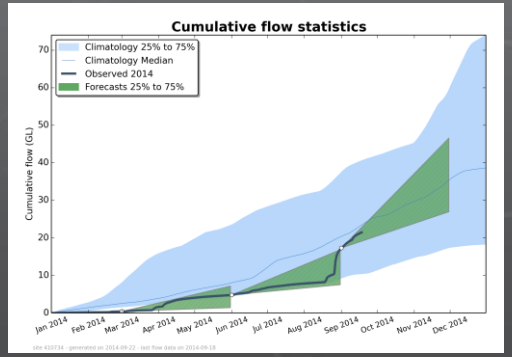
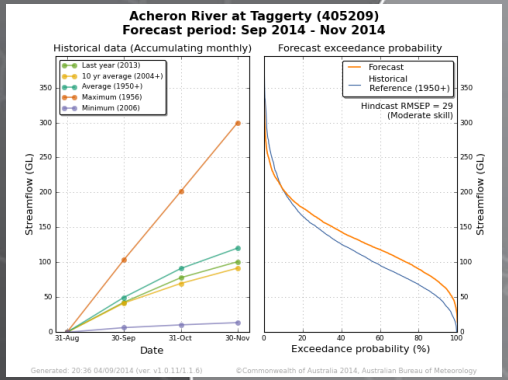
A range of data and forecast products

Tercile maps

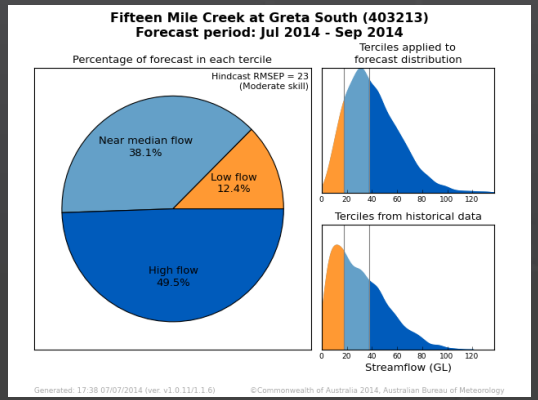
Water year in perspective



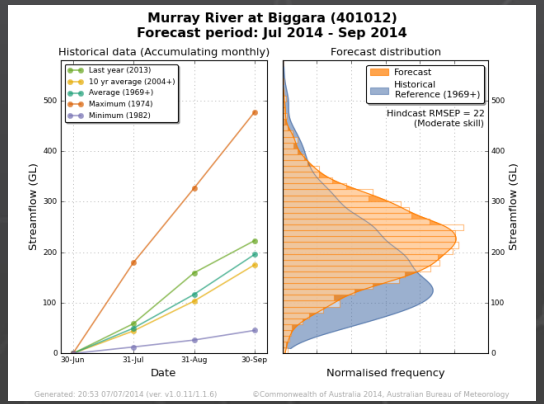
Exceedance probabilities



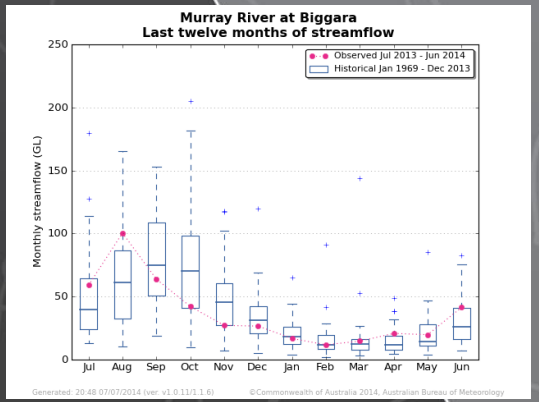
Tercile forecasts



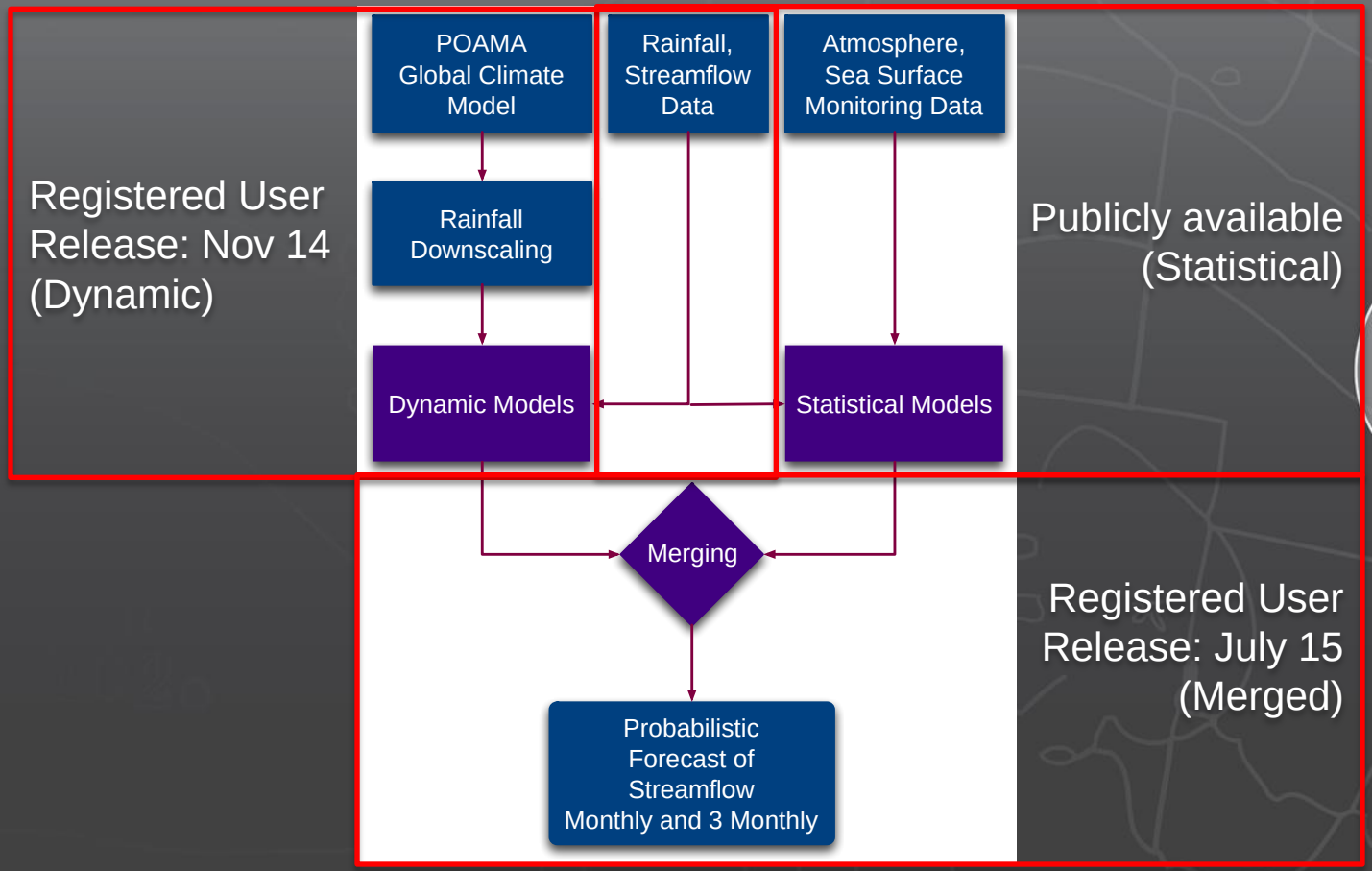
Probability distributions



Box plots



Seasonal Streamflow Forecasting Approach



The Bayesian joint probability (BJP) model

Wang, Robertson and Chiew (2009) **Water Resources Research**

Wang and Robertson (2011) **Water Resources Research**

Robertson and Wang (2012) **Journal of Hydrometeorology**

Robertson, Pokhrel and Wang (2013) **Hydrology and Earth System Sciences**

Robertson and Wang (2013) **Water Resources Management**

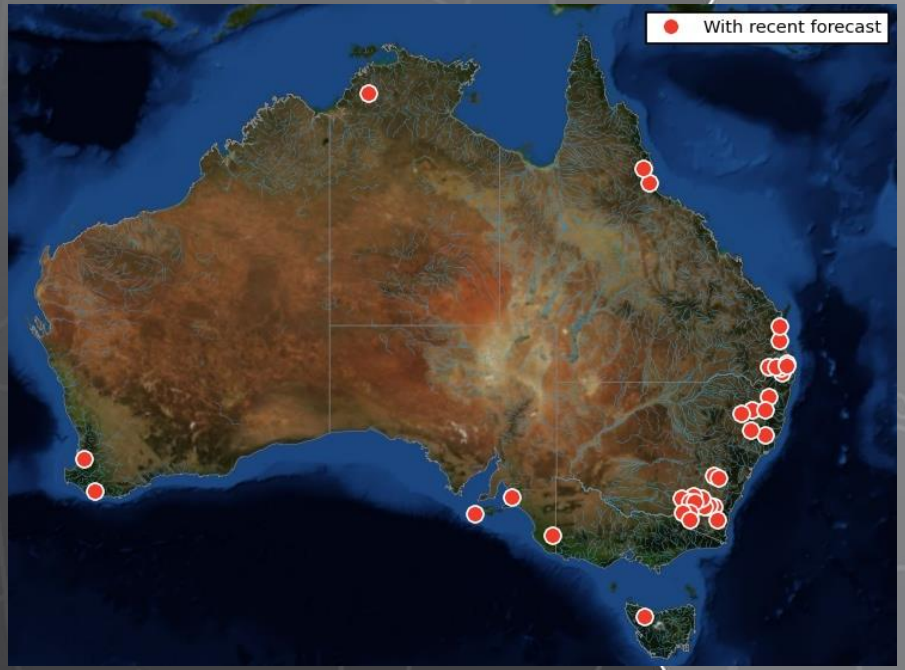
Pokhrel, Wang and Robertson (2013) **Water Resources research**

Bennett, Wang, Pokhrel and Robertson (2014) **Natural Hazards and Earth System Sciences**

New Forecast Product Registered User Release

Scheduled for November 2014

- Rainfall-runoff modelling driven by downscaled rainfall forecasts from POAMA
- One month and three month streamflow forecasts
- Scheduled to release 38 sites across Australia to key stakeholders



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Dynamic Approach: Rainfall Downscaling

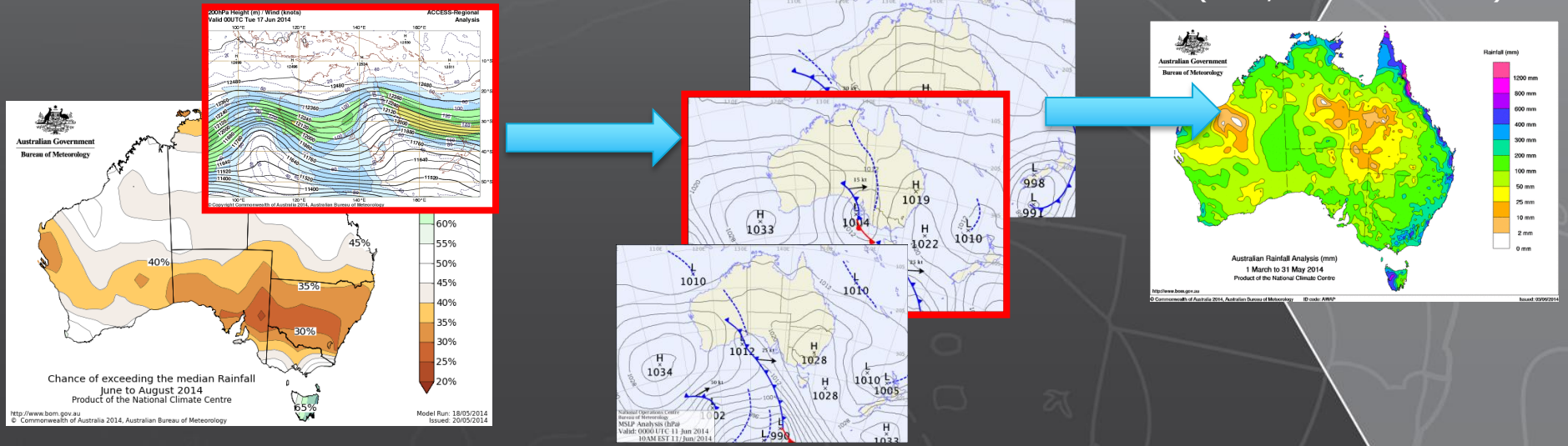
POAMA forecast of climate indices (~270km)

Analogue downscaling

(5 replicates of 31 ensembles)

Downscaled rainfall

(5km; 155 ensembles)



Timbal, B., Li, Z., & Fernandez, E. (2008). The Bureau of meteorology statistical downscaling model graphical user interface: user manual and software documentation.

Shao, Q., & Li, M. (2013). An improved statistical analogue downscaling procedure for seasonal precipitation forecast. Stochastic Environmental Research and Risk

Dynamic Approach: hydrologic modelling

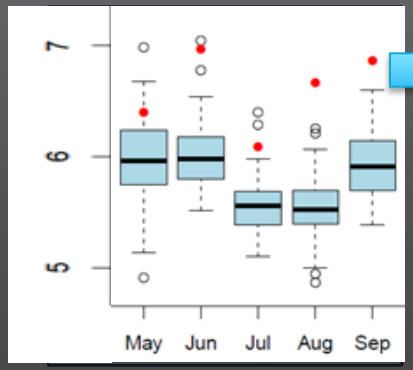
Post-processed catchment rainfall forecasts

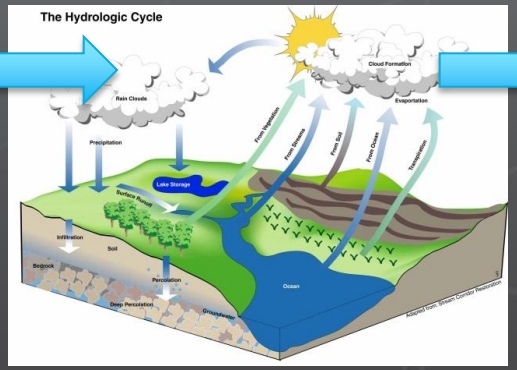
Hydrologic uncertainty (BATEA)

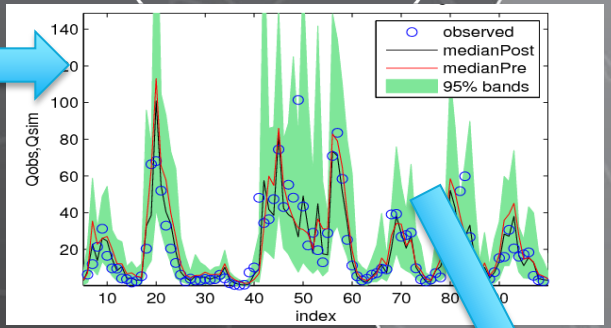
(40 replicates of GR4J model)

Post-processed streamflow

(6200 ensembles)



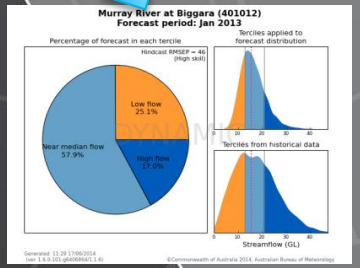




AWRIS/WISKI web service

(Streamflow)

1 month & 3 month forecasts



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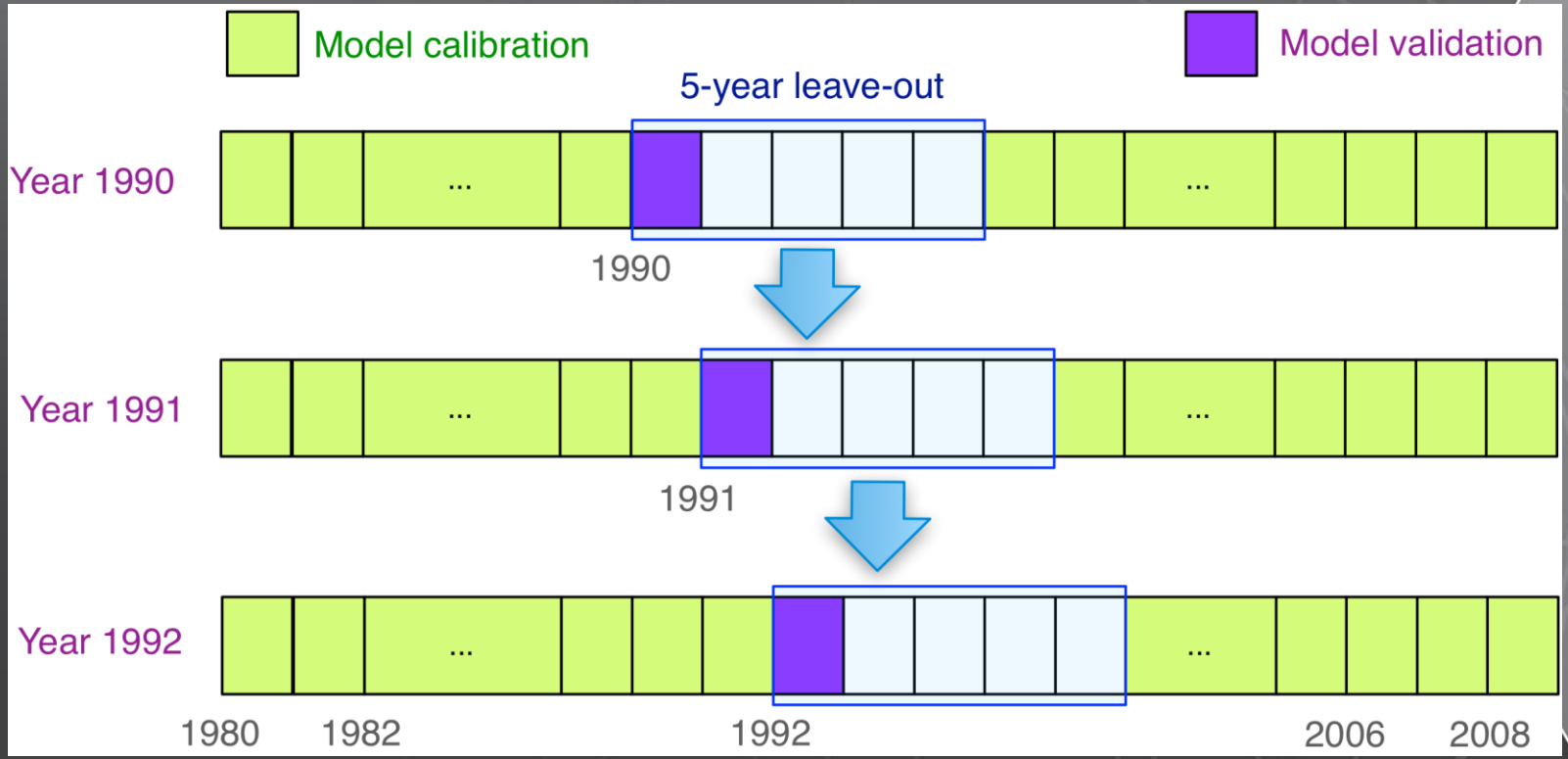
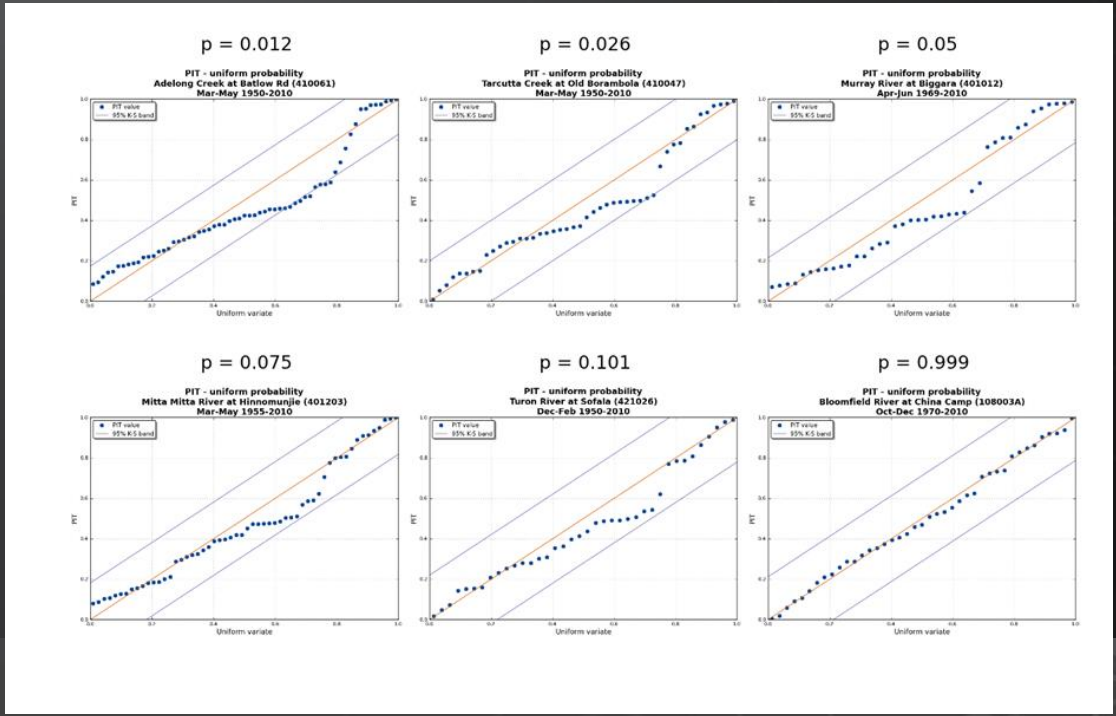
Rigorous cross-validation scheme



Forecast reliability

- Probability Integral Transform (PIT) Plots



FORECAST RELIABILITY IS IMPORTANT FOR END USER CONFIDENCE

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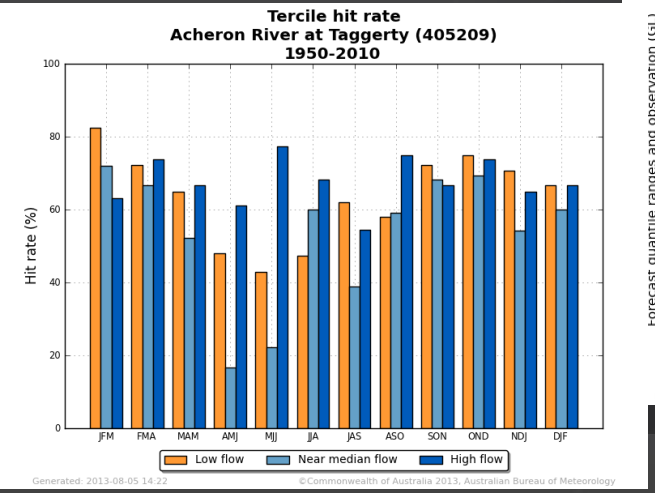
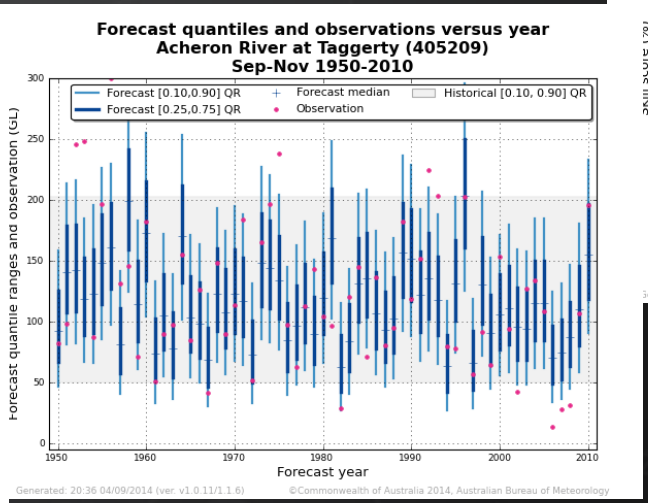
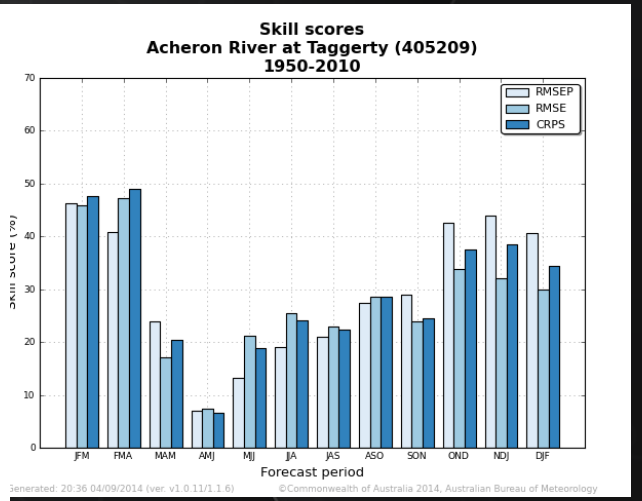
Forecast accuracy

- Skill score: CRPS, RMSE & RMSEP
- Hit rate: Tercile hit rate for low & high flows
- Precision: Inter quantile range (10%,90%)







FORECAST RELIABILITY IS IMPORTANT FOR END USER CONFIDENCE

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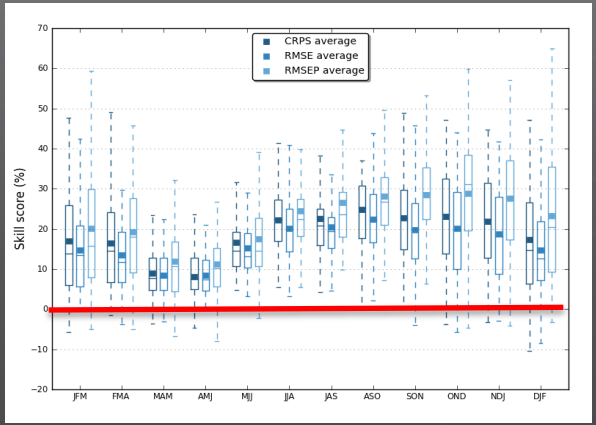
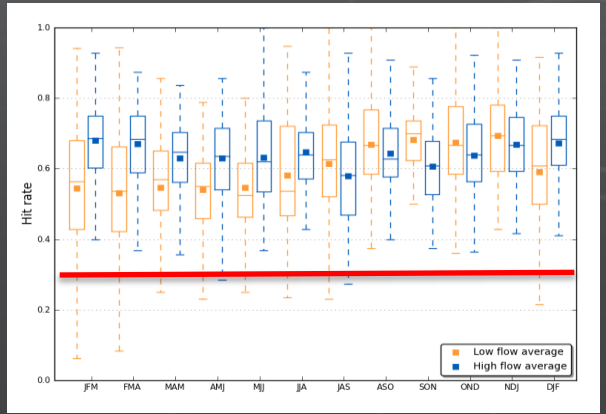
Forecast performance summary across all sites & seasons

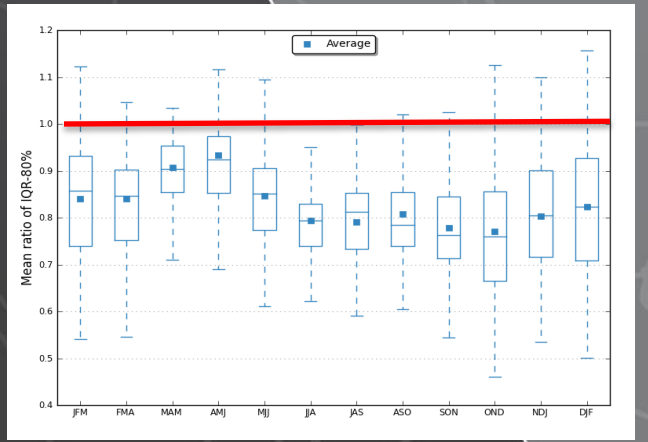


Skill scores



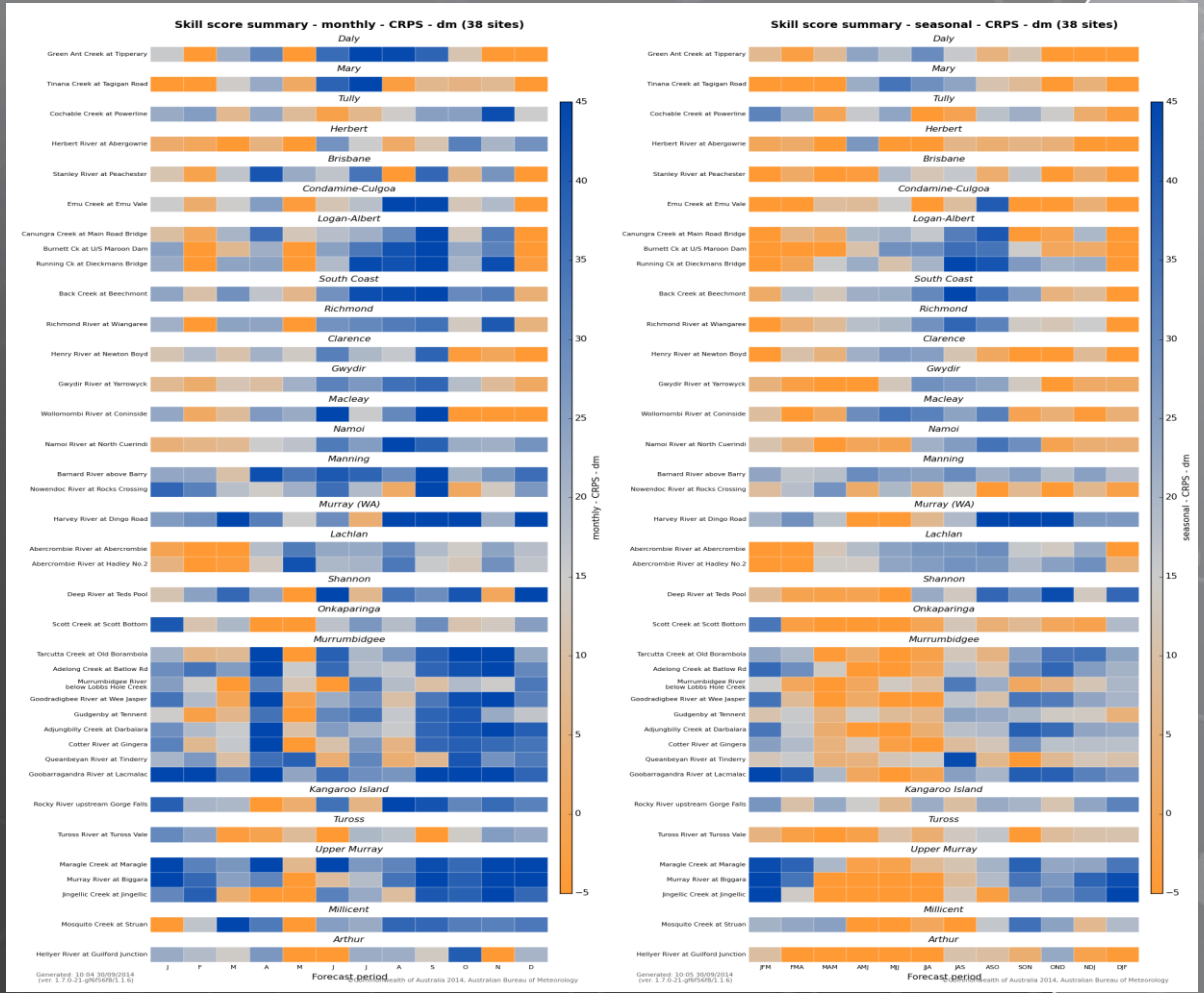
Tercile hit rates

Inter quantile range (10%,90%)



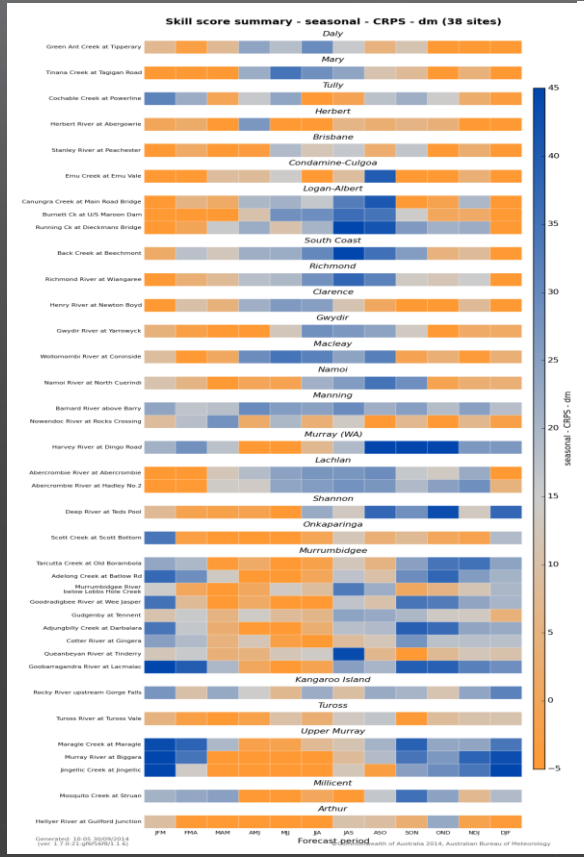
Comparison of 1 month & 3 month forecasts

- CRPS - Continuous Rank Probability Score
- Forecast locations grouped by basins
- Better skills of 1 month forecasts compared to 3 month forecasts



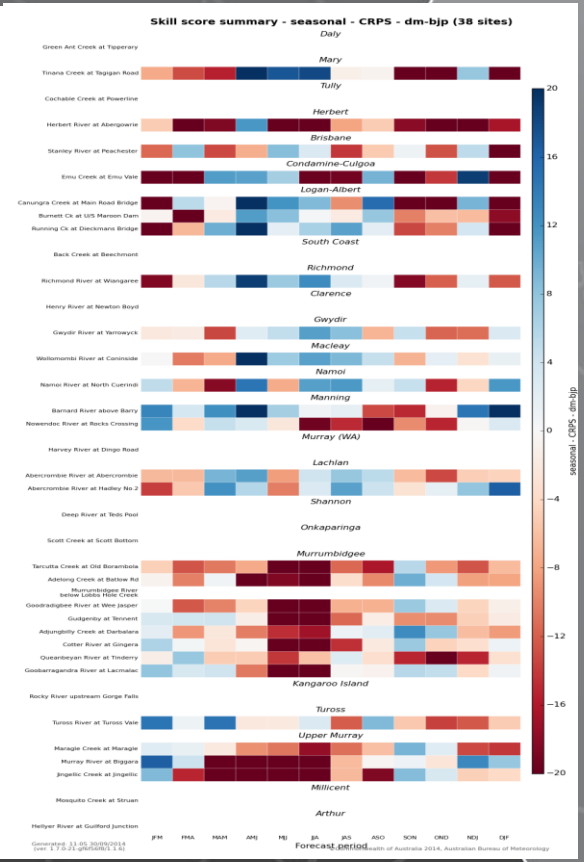
Dynamic and statistical methods are complementary

CRPS(DM)



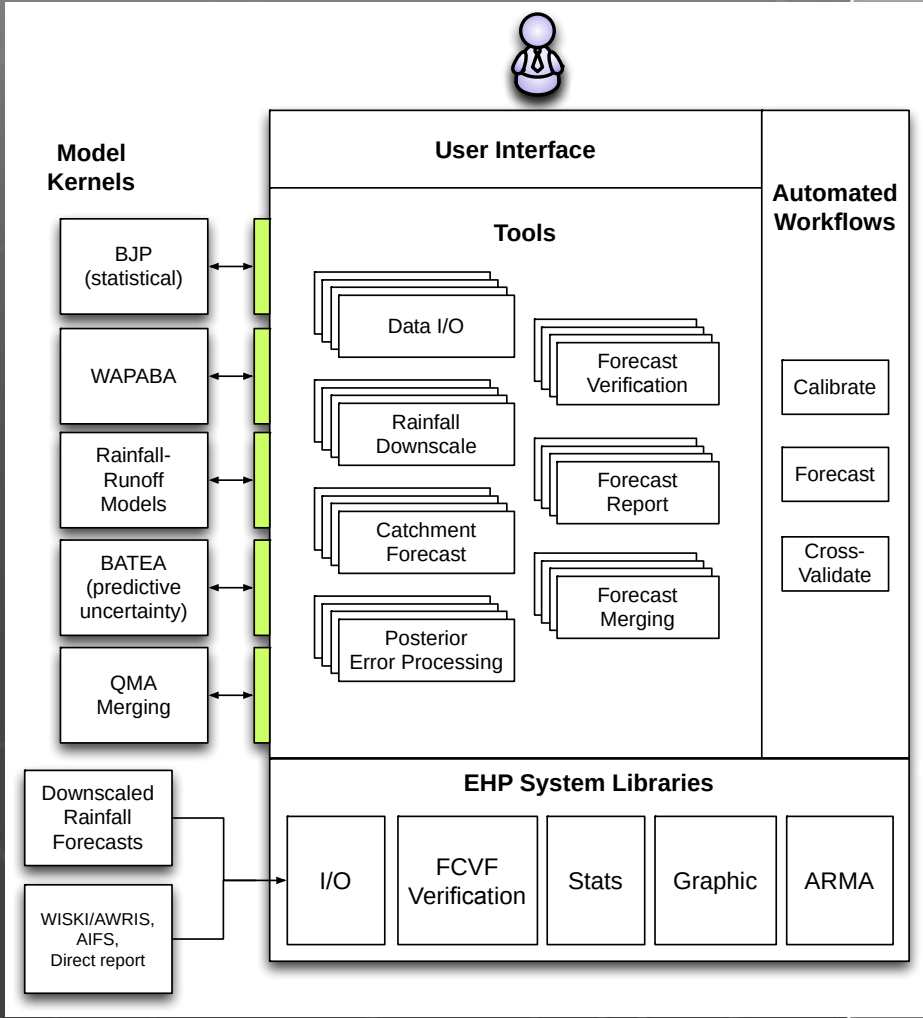
CRPS(BJP)

CRPS(DM – BJP)



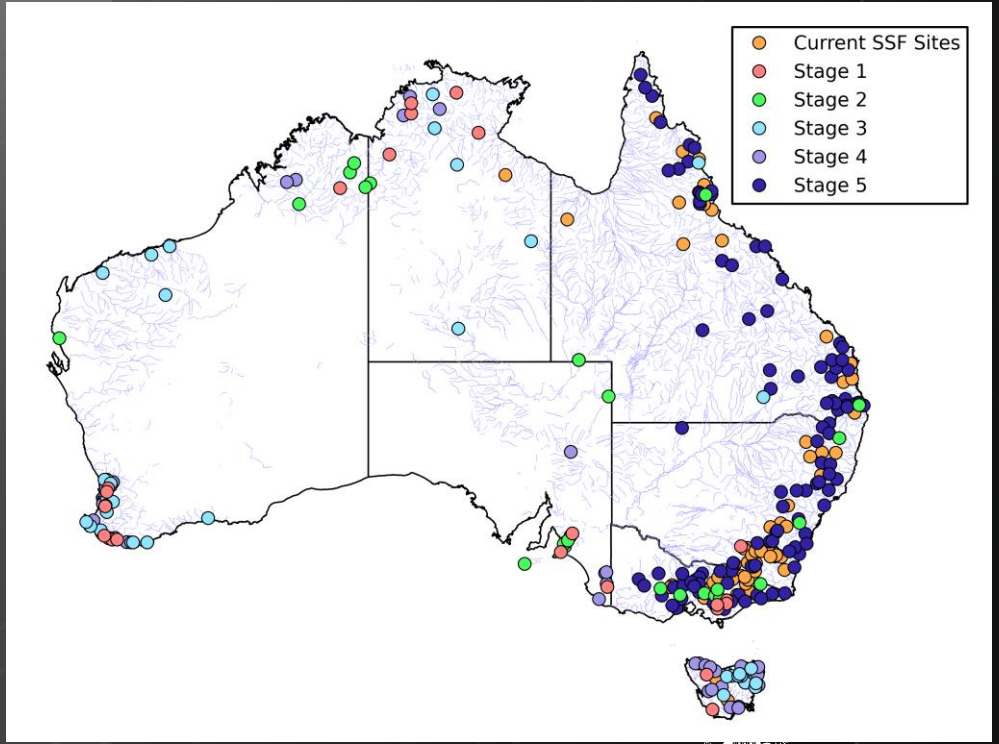
Modelling system (WAFARi)

- Statistical, dynamic, and merging in a modelling system
- Modular structure
- Interactive simulation
- Powerful scripting capability
- Self-descriptive file formats
- Tailored graphic tools
- Parallel computing for cross-validation



Selection of seasonal forecast locations

- In consultation with key stakeholders across all jurisdictions
- Focus on WA, Tas, NT and SA



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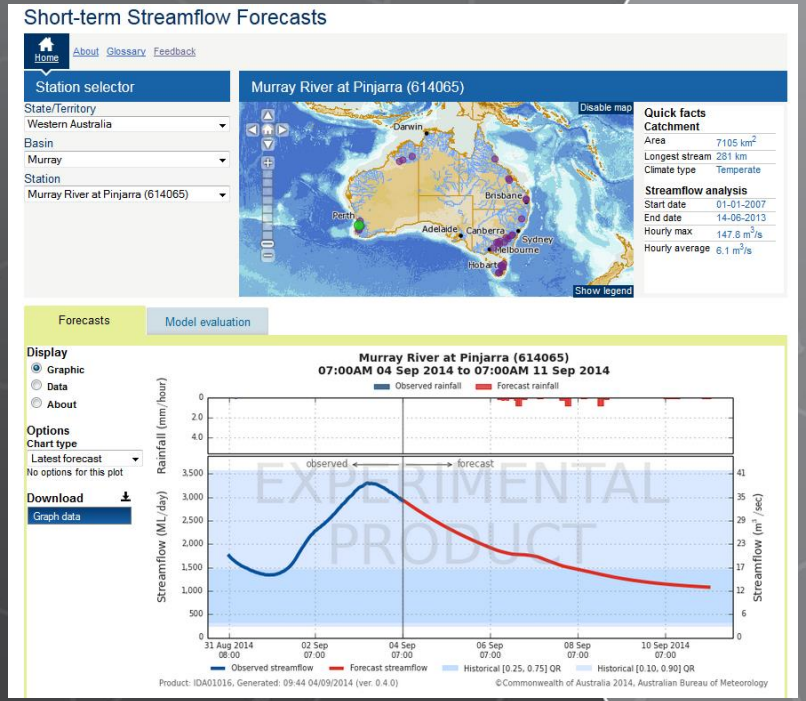
Short-term streamflow forecasting service

- 7-days ahead, updated every day, since 2013
- 31 locations in 20 catchments
- Deterministic approach gradually moving to ensemble mode during 2015-16
- Available to registered users
- Targeted at river and storage operation and environmental flow management
- May be used for flood guidance



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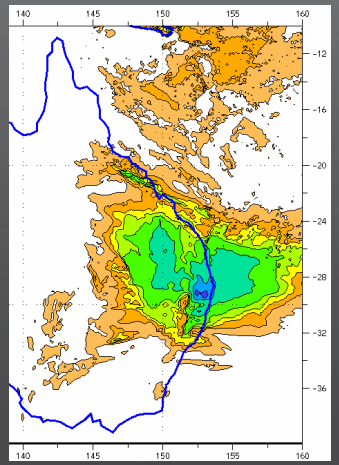
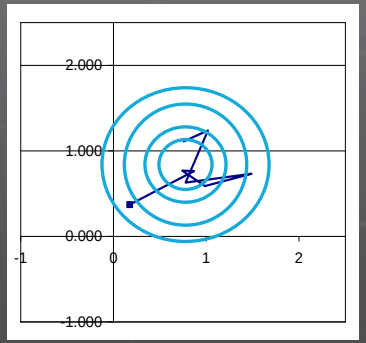
New short term ensemble forecasting system

ACCESS NWP rainfall forecasts

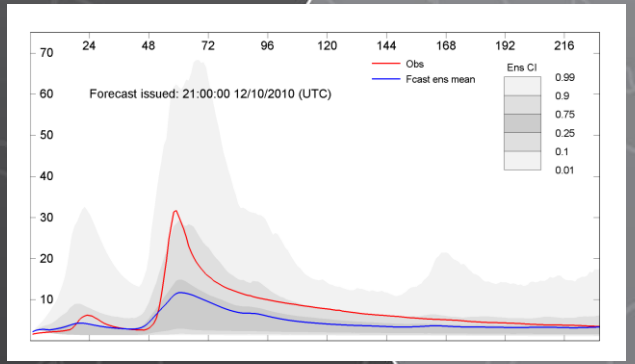
(ACCESS ensembles in future)





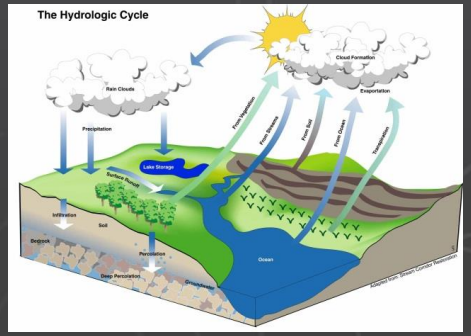
Rainfall post processing (STEPS/BJP/Schaake shuffle)

Streamflow ensembles



Hydrologic model (GR4H)

Real-time flows



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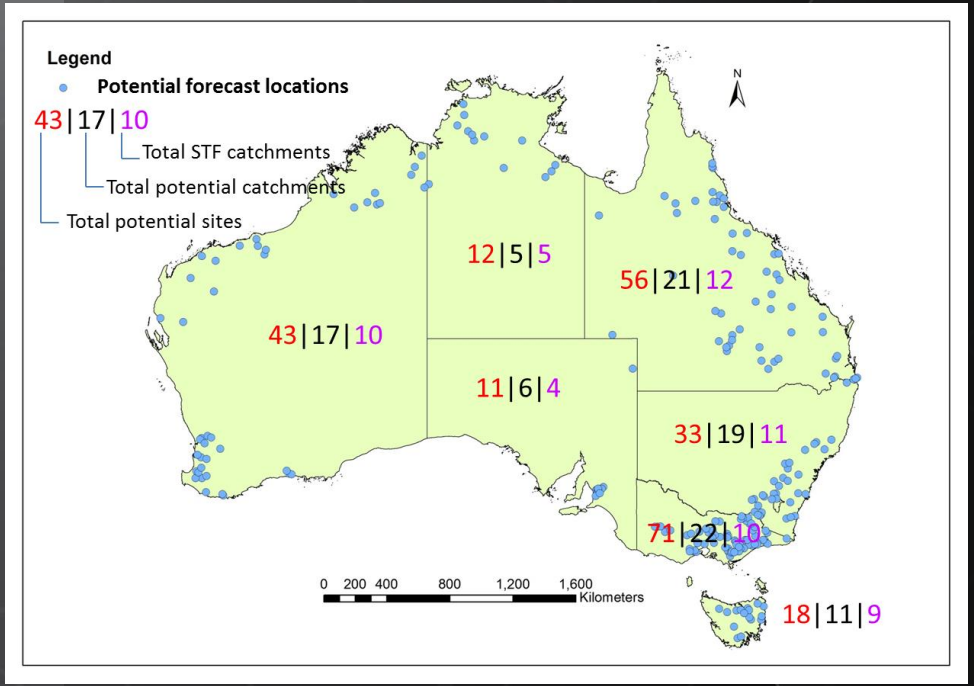
Selection of short term forecast locations

- In consultation with key stakeholders across all jurisdictions
- Currently flow forecasts for 20 catchments are available to registered users
- 40 additional catchments to be added by January 2015



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Communication

- Over 1800 subscribers
- Online survey conducted in Nov 2013
- 88% of the key stakeholders expressed satisfaction with the SSF service
- Development of case studies with water managers
- Monthly National Climate and Water Briefings
- Forecasts included in monthly outlook video

Concluding remarks and key challenges

- The need for water availability forecasts at a range of time scales was established through the *Water Act (2007)* and an extensive user needs analysis
- Adoption of streamflow forecasts by end users and the role of case studies
- Influencing decision making by water resource managers requires ongoing engagement throughout all stages – planning, development and delivery
- Establishing effective R&D alliances and transitioning research to operations is not trivial
- Making the right technology choices is critical for development and delivery of the operational forecasting services
- QA/QC tasks are very demanding (~40-50% of the total effort)

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Concluding remarks and key challenges (contd.)

- The impact of budget cuts on high quality streamflow monitoring stations
- Climate hydrology interface – opportunities and challenges!
- The need for high resolution NWP models to be valid at the hydrologic scale
- Forecast time scales of up to 1 year for water allocation outlooks and environmental flow planning
- Decadal forecasting – is it possible? Up to 2 to 3 years?
- Whole of river basin forecasting and estimation of inflow forecasts from ungauged areas
- Communication of forecast uncertainty and performance is indeed difficult

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Thank you

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www.bom.gov.au/water/hrs

www.bom.gov.au/water/ssf

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