



Ensemble forecasting of streamflow out to 12 months using climate forecasts as inputs

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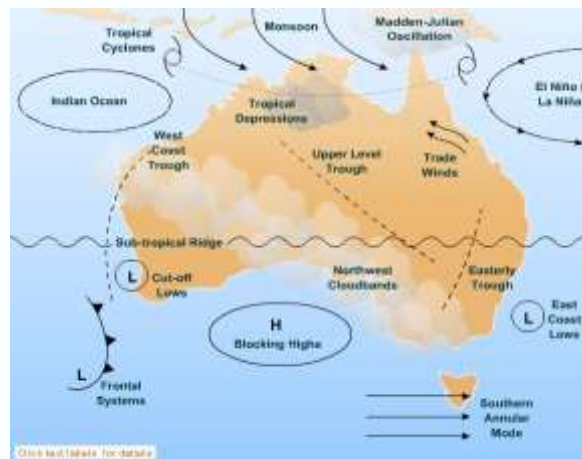
Water Information
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Outline

- **Context**
- **The FoGSS model**
- **Evaluation results**
- **Conclusions**

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*

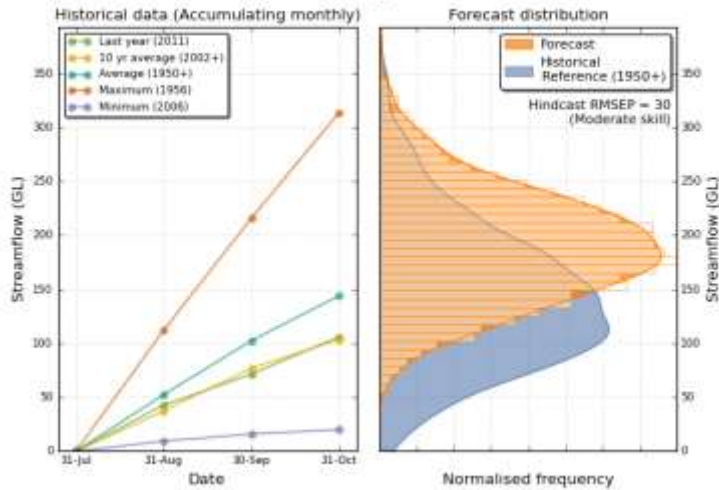
Robertson and Wang (2013) *Water Resources Management*

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

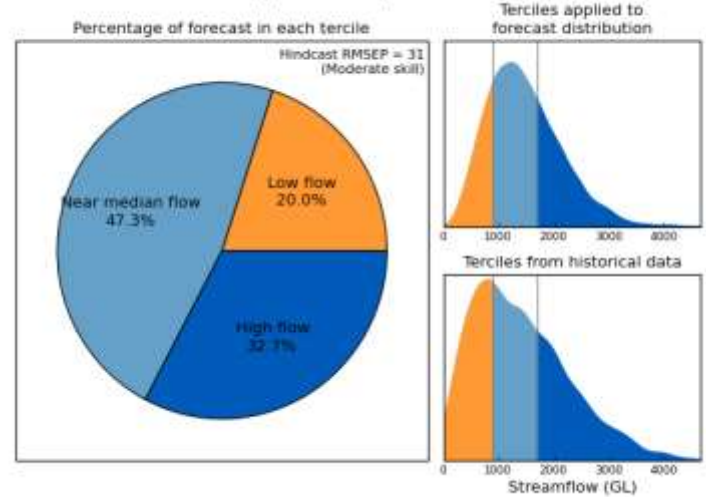
Bennett, Wang, Pokhrel and Robertson (2014) *Natural Hazards and Earth System Sciences*

Seasonal streamflow forecasting service

Acheron River at Taggerty (405209)
Forecast period: Aug 2012 - Oct 2012



Unregulated inflow to Hume Dam
Forecast period: Aug 2012 - Oct 2012



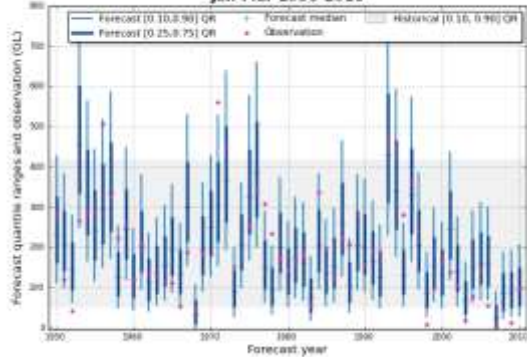
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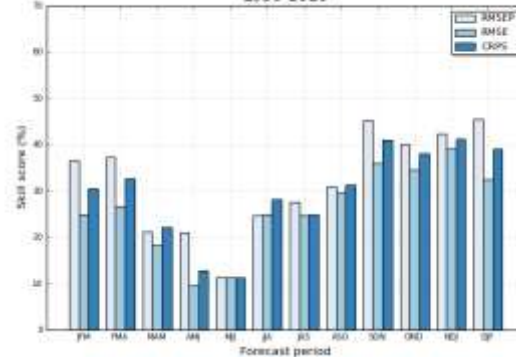
Forecast quantiles and observations versus year
Unregulated inflow to Hume Dam
Jan-Mar 1950-2010



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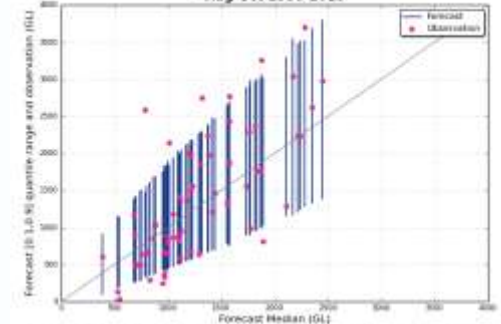
Skill scores
Unregulated inflow to Hume Dam
1950-2010



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Forecast quantiles and observations versus forecast median
Unregulated inflow to Hume Dam
Aug-Oct 1950-2010



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The FoGSS model

- For generating **F**orecast **G**uided **S**tochastic **S**cenarios
- Ensemble forecasts of monthly volumes of streamflow out to 12 months
- The forecasts become more like natural stochastic scenarios as skill decreases with lead time

Ensemble forecasting of monthly catchment rainfall out to 12 months

- Use **CBaM** to post-process GCM seasonal climate forecasts
 - **CBaM**: **C**alibration, **B**ridging **a**nd **M**erging
 - GCM: The predictive ocean atmosphere model for Australia (POAMA)

Schepen, Wang and Robertson (2011) *Journal of Climate*

Wang, Schepen and Robertson (2012) *Journal of Climate*

Schepen, Wang and Robertson (2012) *Journal of Geophysical Research*

Schepen and Wang (2013) *Monthly Weather Review*

Hawthorn, Wang, Schepen and Robertson (2013) *Water Resources Research*

Schepen and Wang (2014) *Journal of Hydrology*

Schepen, Wang and Robertson (2014) *Monthly Weather Review*

Peng, Wang, Schepen, Pappenberger et al. (2014) *Journal of Geophysical Research*

Peng, Wang, Bennett, Pokhrel and Wang (2014) *Journal of Hydrology*

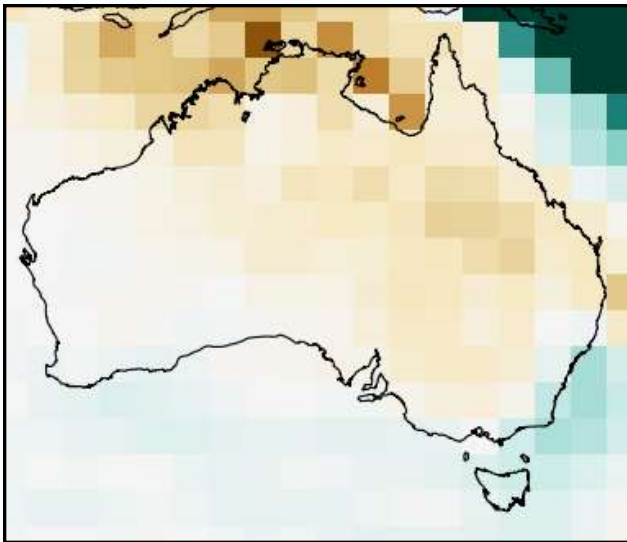
Why CBaM?

To overcome issues with GCM seasonal climate forecasts

- Biases - unconditional and conditional
- Ensemble spread – unreliable
- Forecast skill – generally low
- Mismatch in scale for hydrological applications

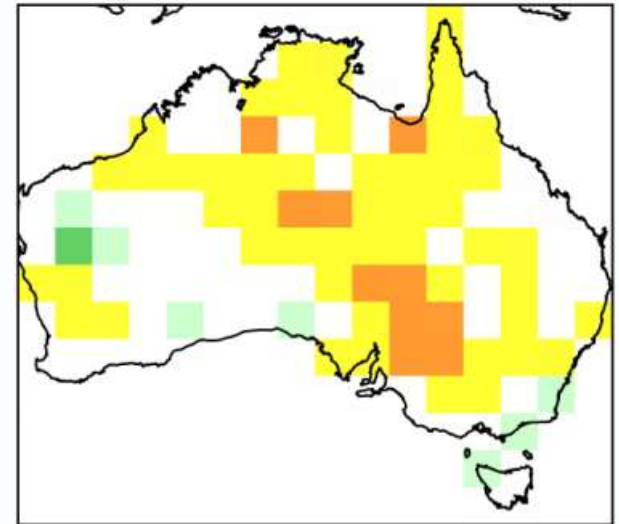
Calibration

Raw POAMA rainfall (anomaly)



BJP
➔

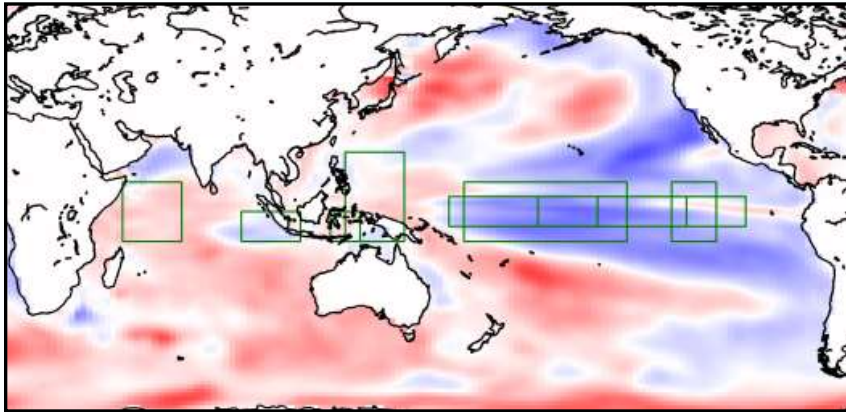
Calibration rainfall forecast



Predictors: Ensemble means of POAMA rainfall

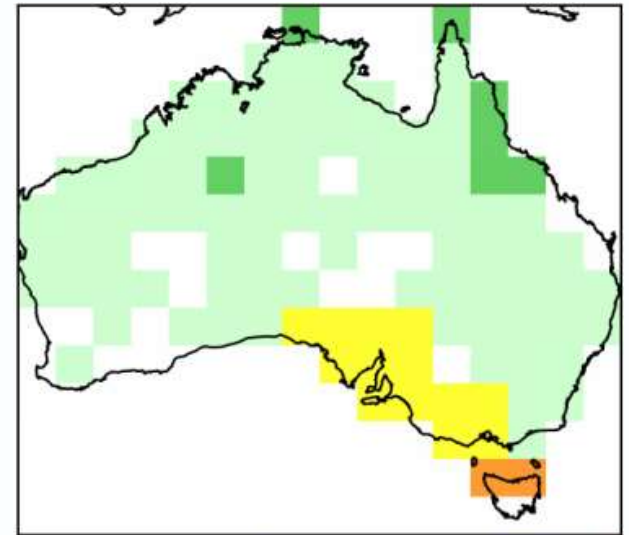
Bridging

POAMA SSTs



BJP
➔

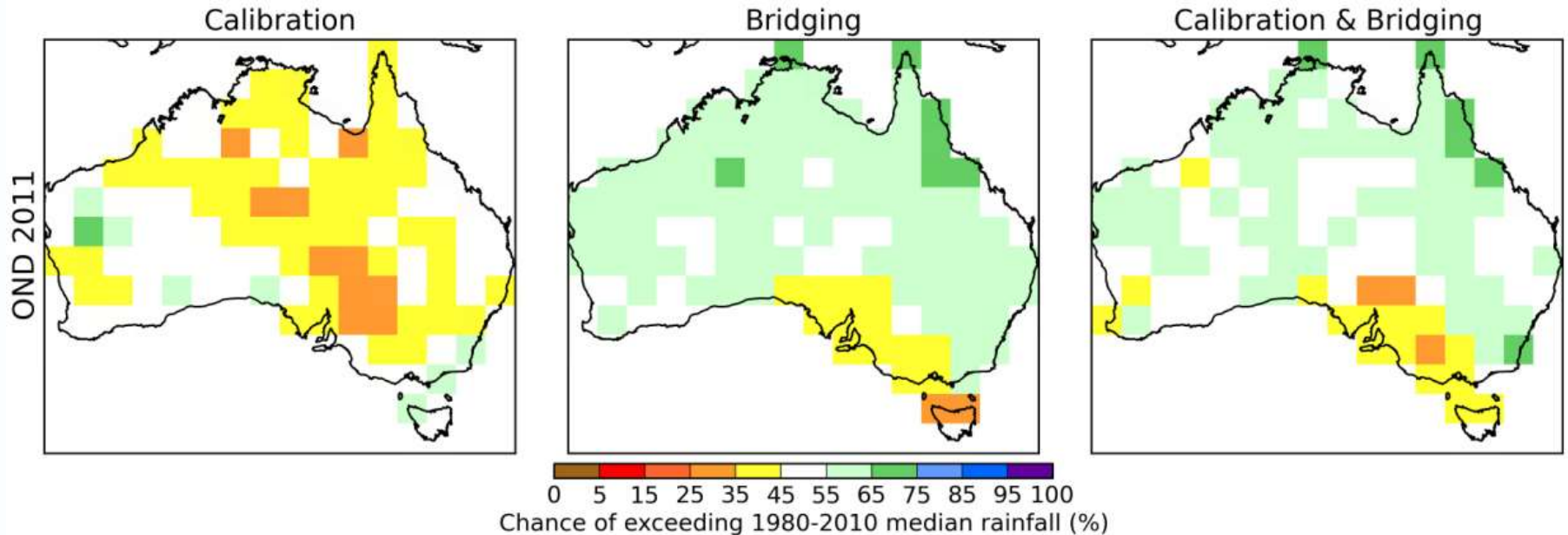
Bridging rainfall forecast



Predictors: Ensemble means of POAMA climate indices

(NINO3, NINO3.4, NINO4, EMI, DMI, II)

Merging of calibration and bridging forecasts



Bayesian model averaging (BMA)

Ensemble forecasting of monthly catchment rainfall out to 12 months

- **Downscaling**
- **Shaake Shuffle**

Hydrological modelling including uncertainty

Stage 1: Monthly water balance modelling using WAPABA

Stage 2: Bias correction

Stage 3: Updating, injecting and propagating hydrological uncertainty out to 12 months

Wang, Pagano, Zhou, Hapuarachchi, Zhang and Robertson (2011) *Journal of Hydrology*

Wang, Shrestha, Robertson and Pokhrel (2012) *Water Resources Research*

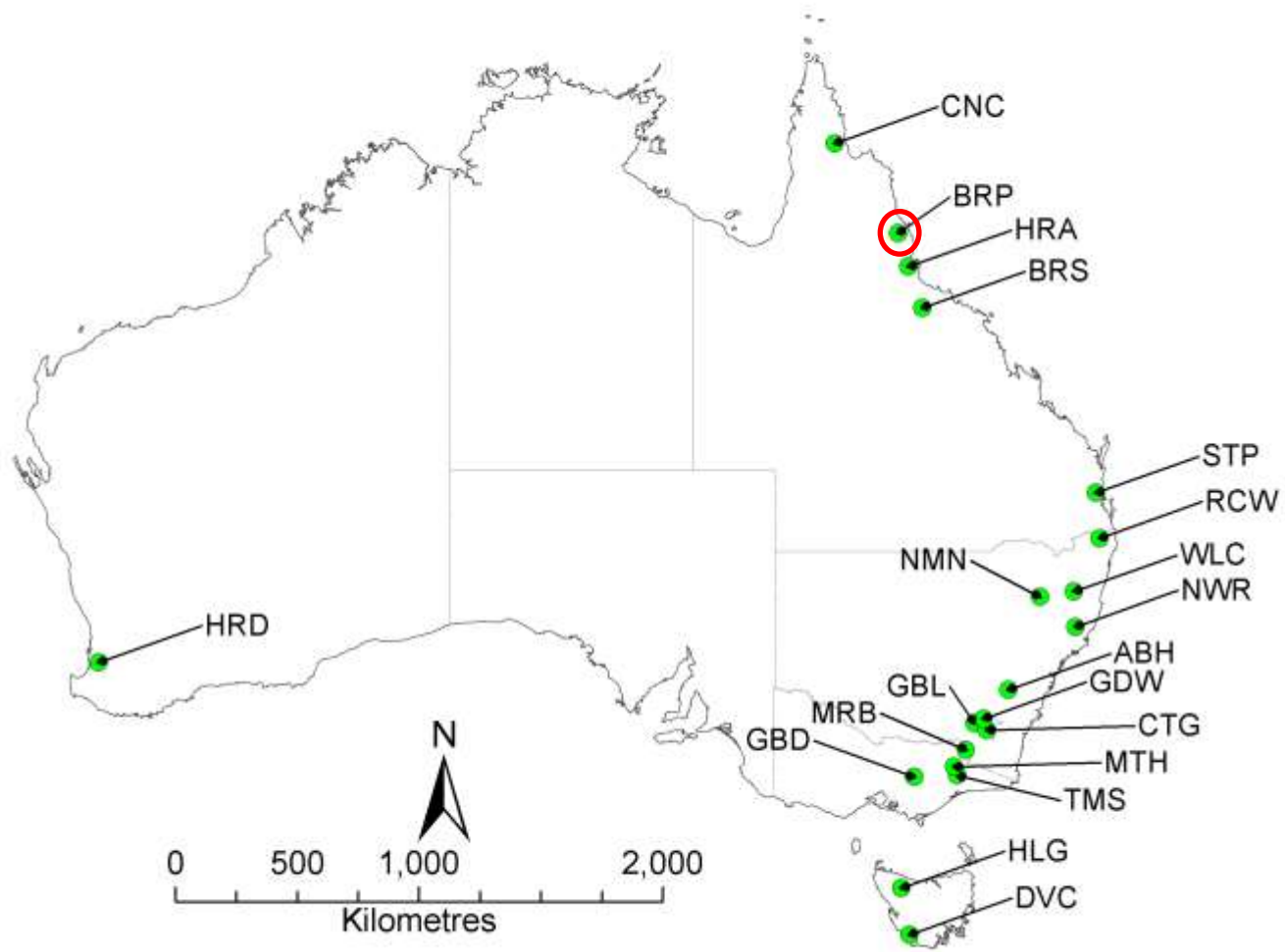
Li, Wang and Bennett (2013) *Water Resources Research*

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

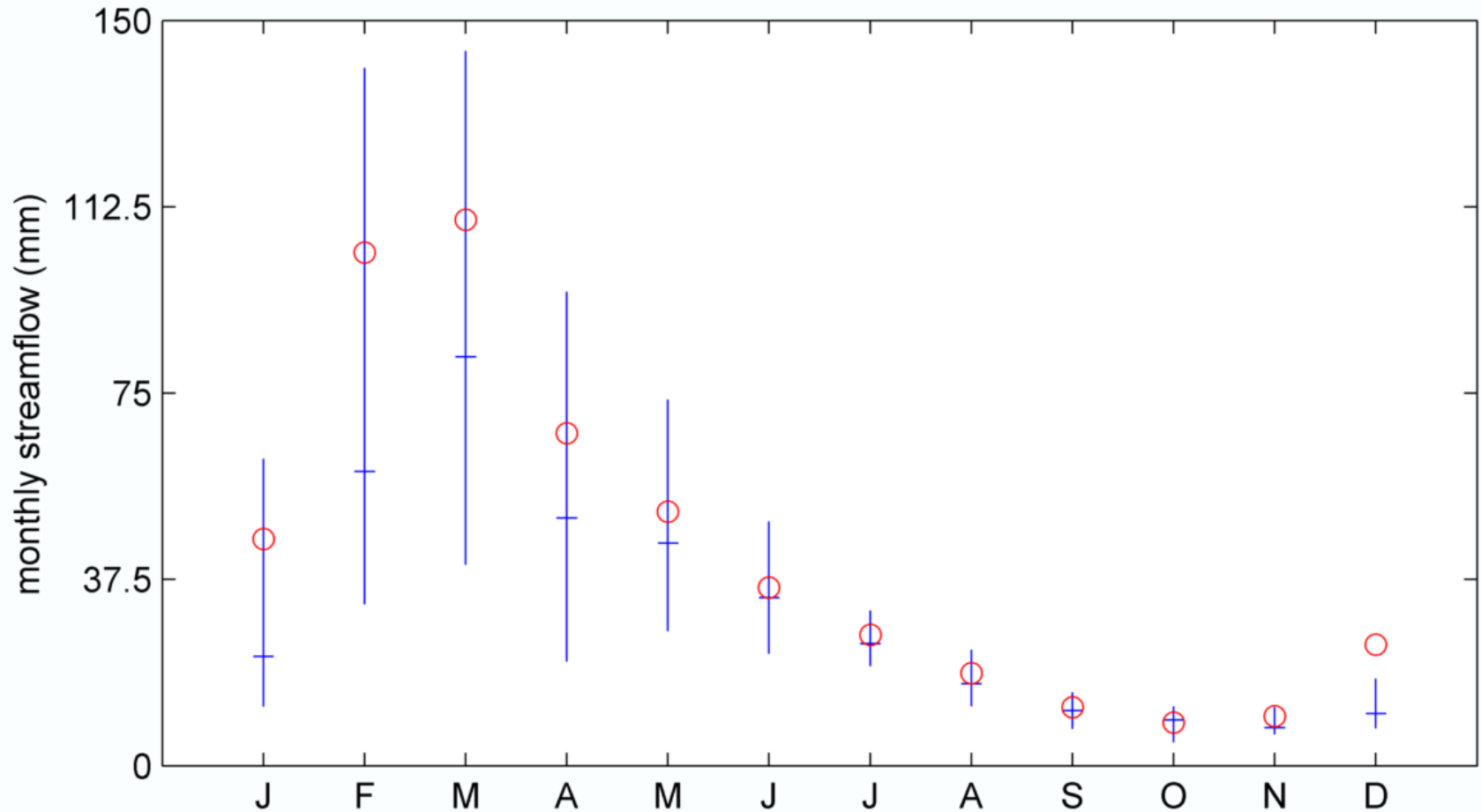
Li, Wang, Bennett and Robertson (2014) *Hydrology and Earth System Sciences (In review)*

Schepen and Wang (2014) *Water Resources Research (In review)*

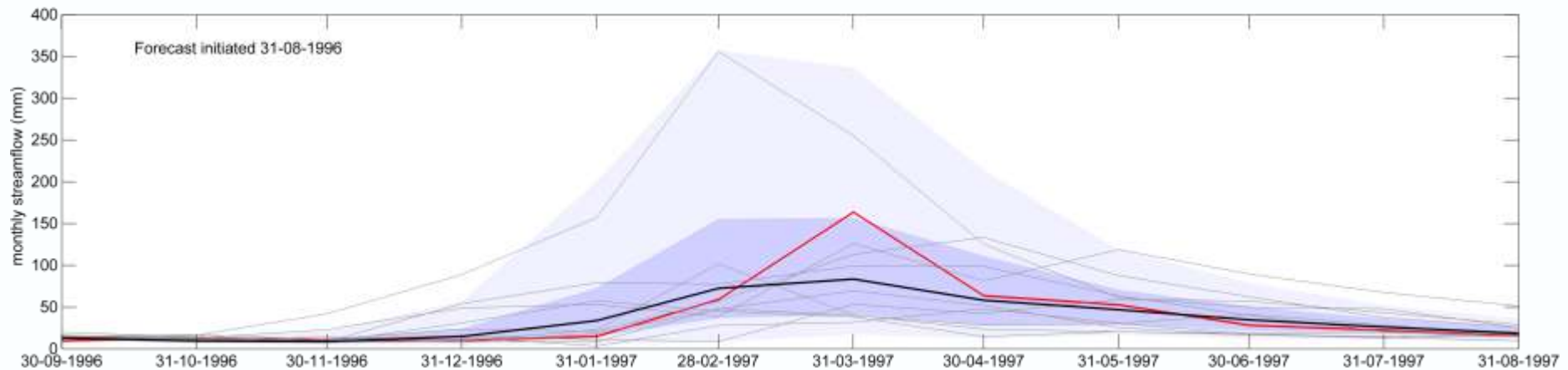
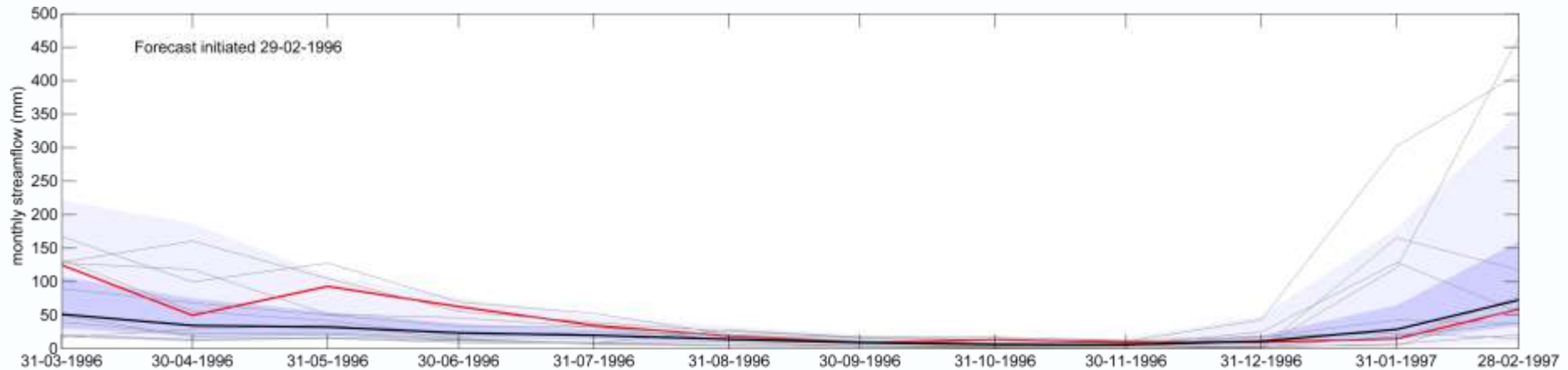
Evaluation



BRP - Barron River above Picnic Crossing

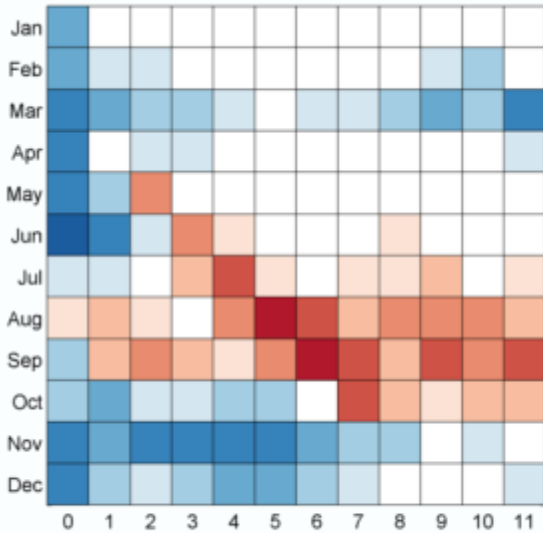


BRP - Two example forecasts

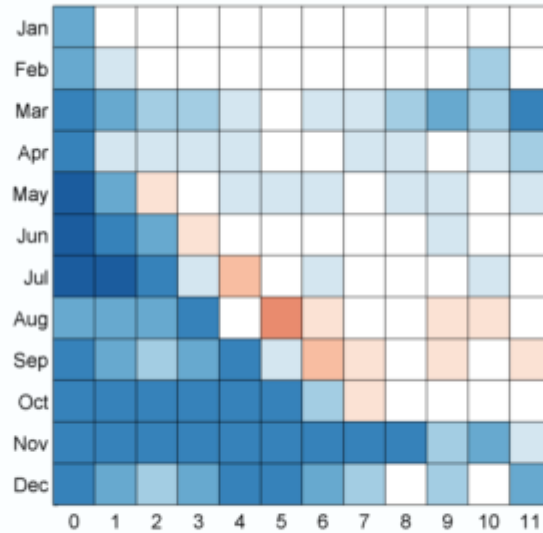


BRP - CRPS skill score (monthly)

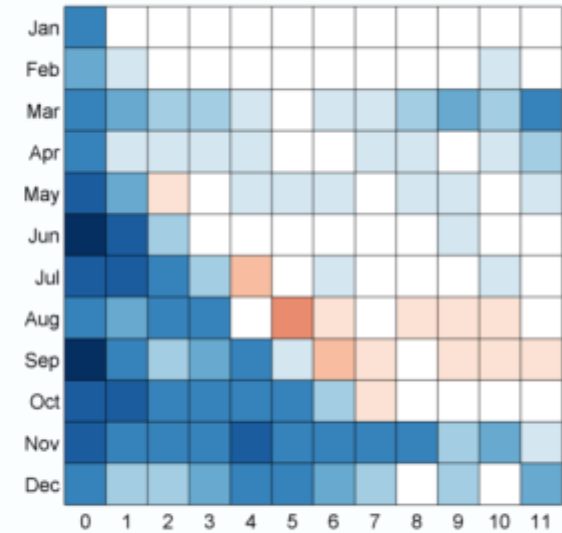
Stage 1



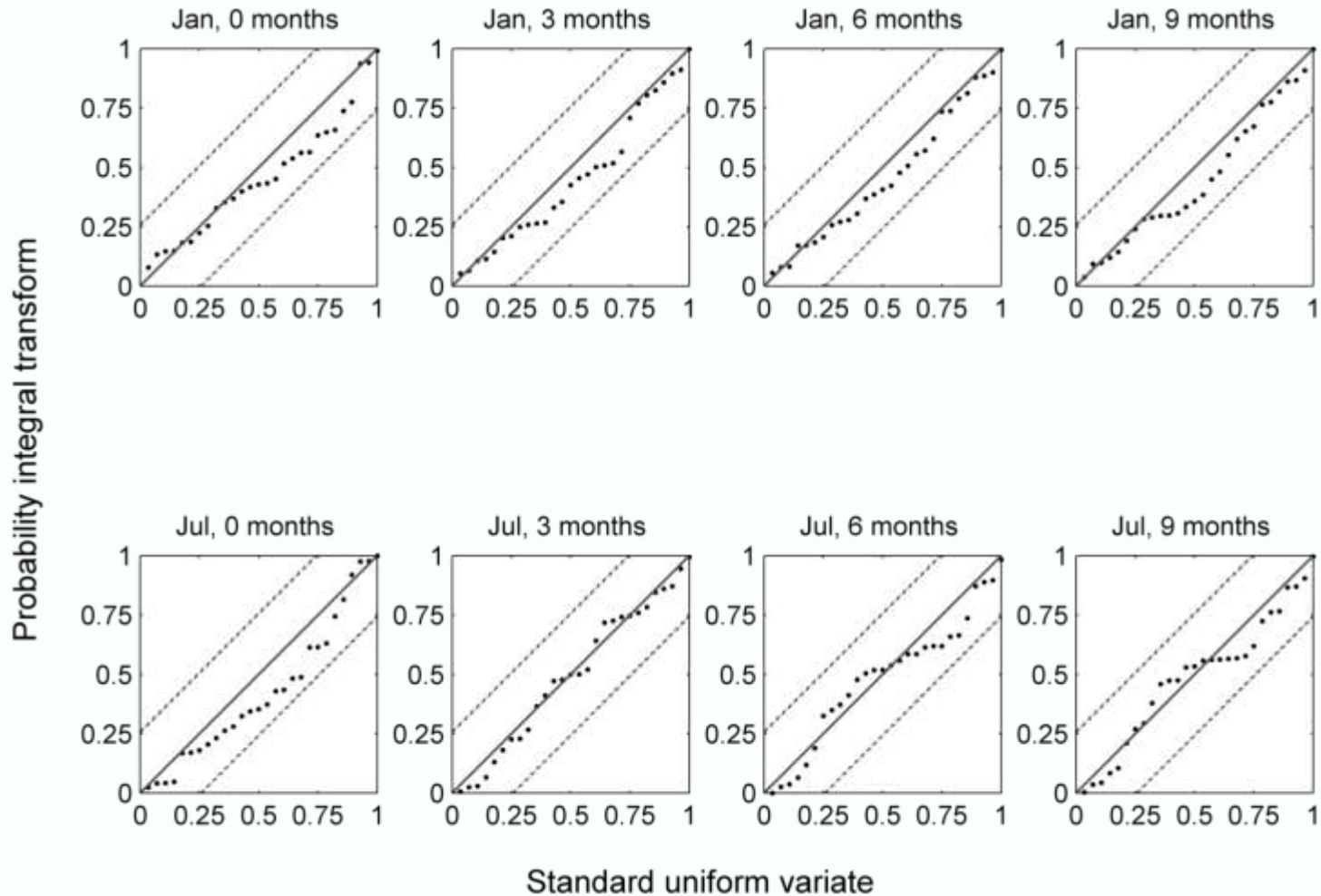
Stage 2



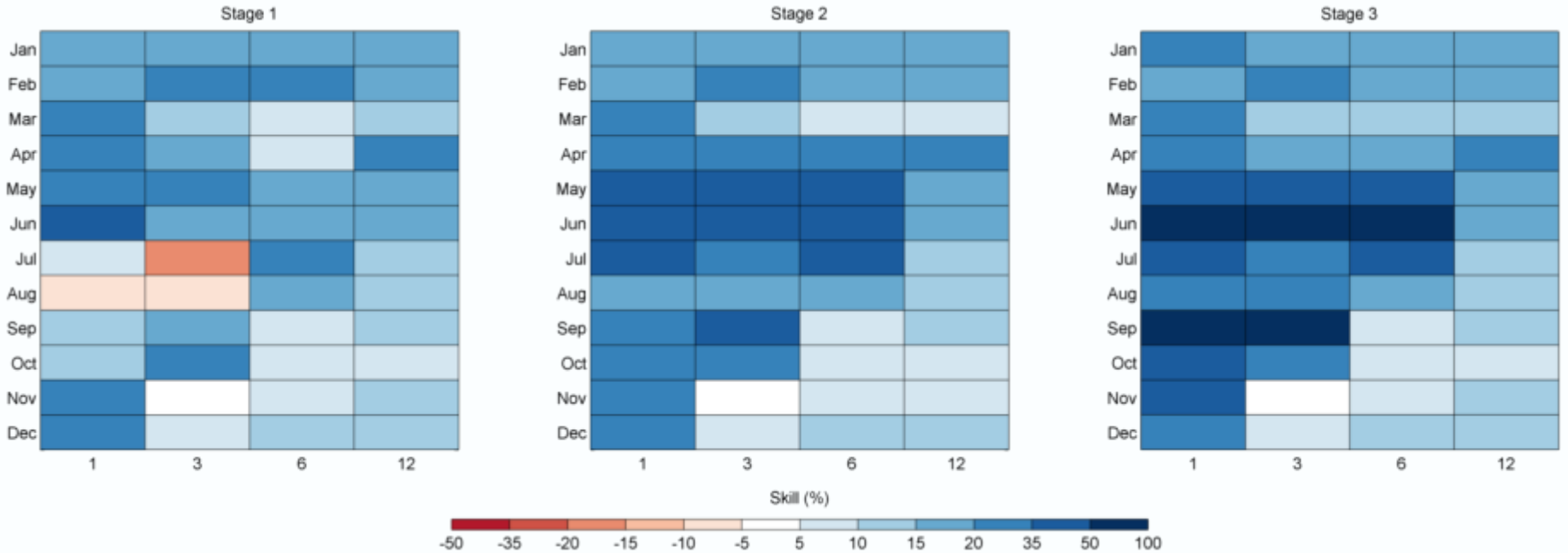
Stage 3



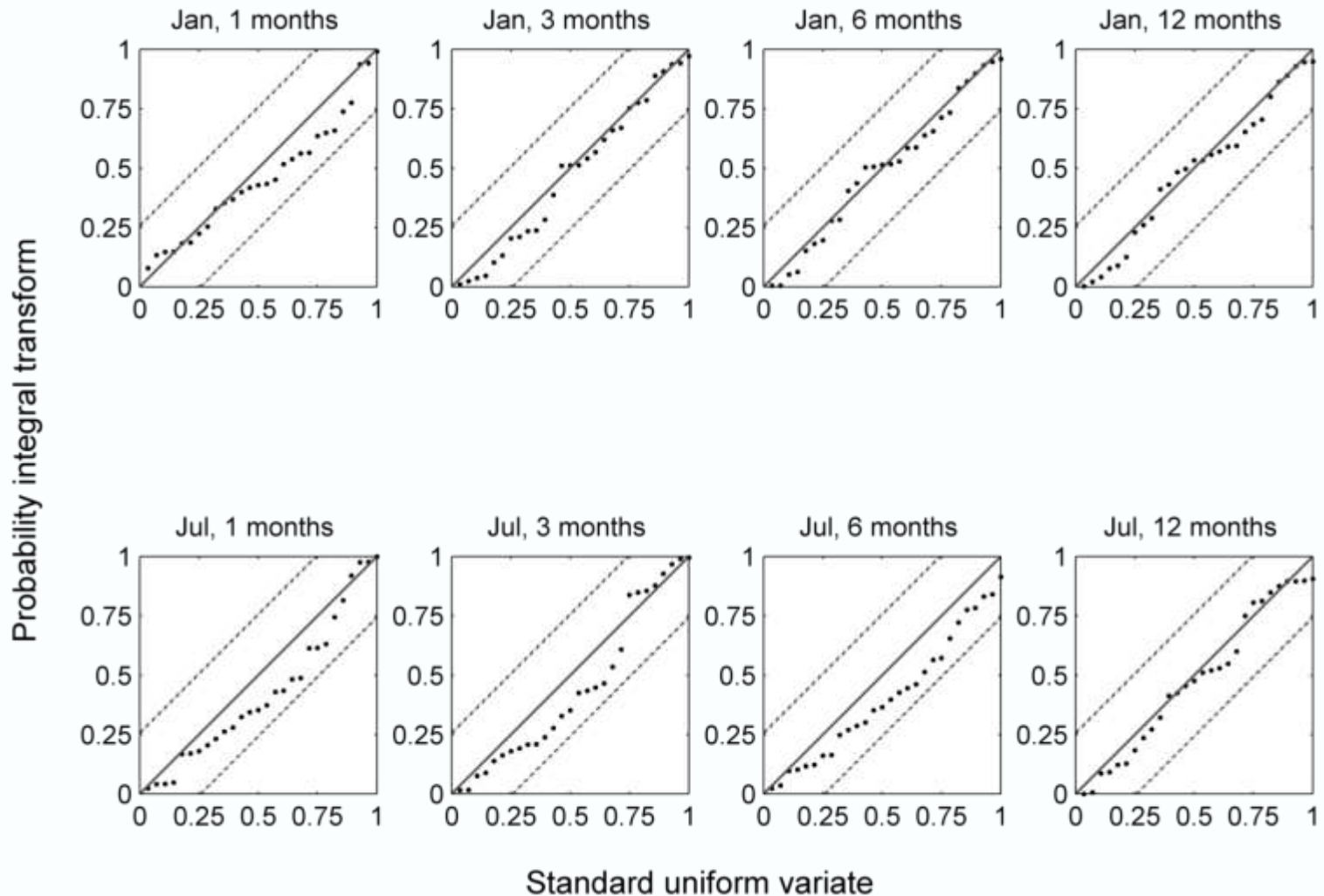
BRP - PIT reliability plot (monthly, Stage 3)



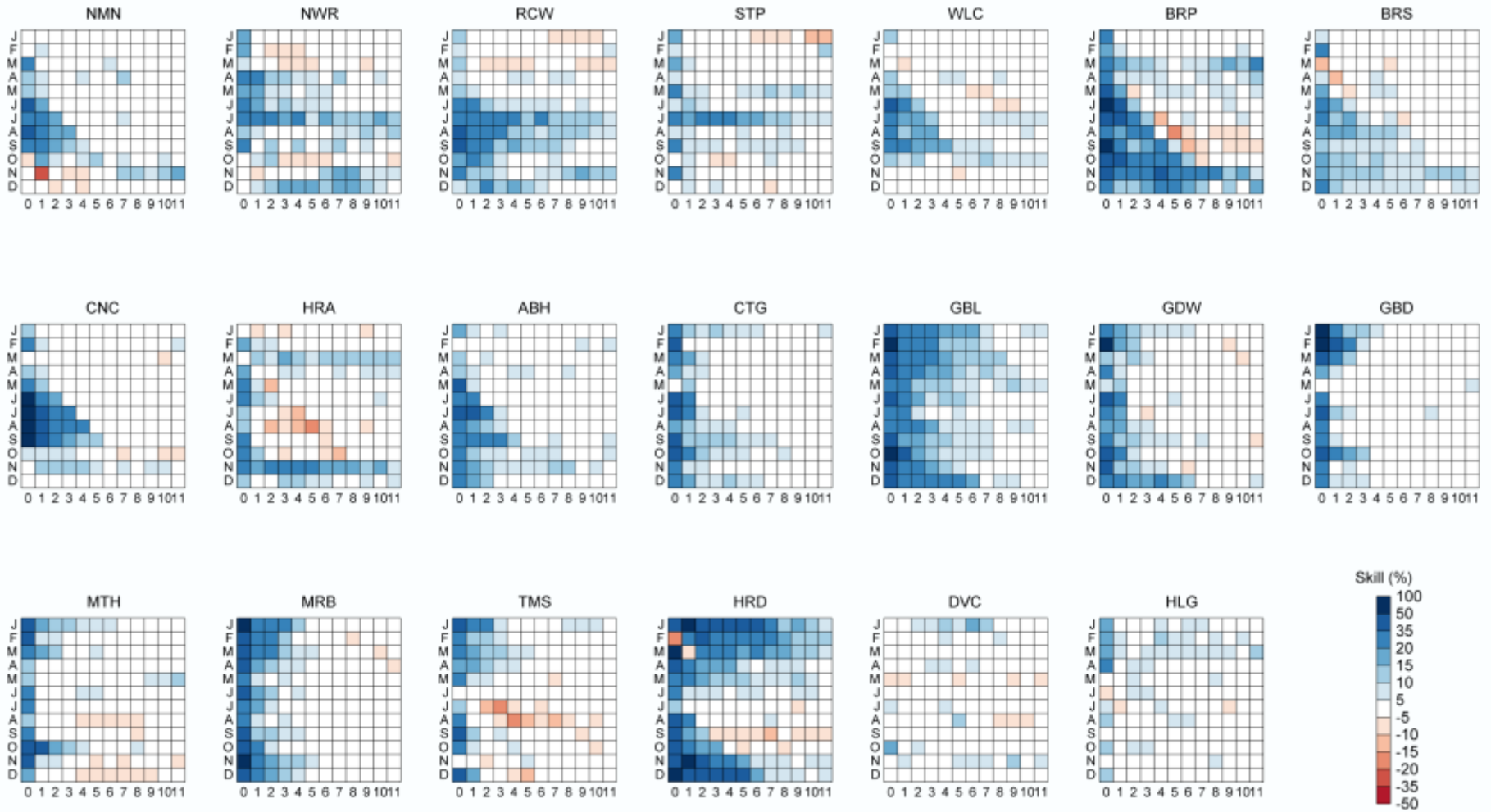
BRP - CRPS skill score (cumulative)



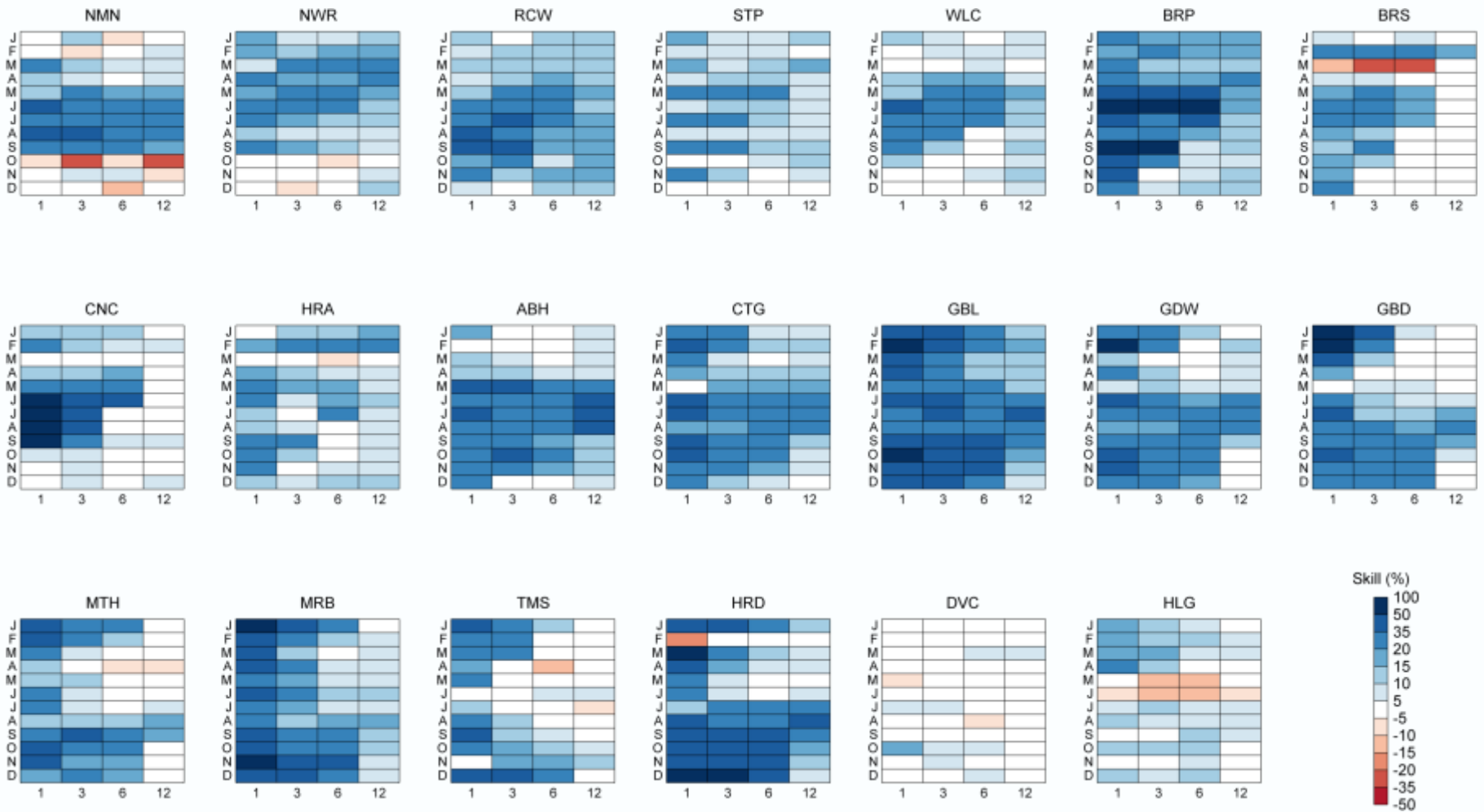
BRP - PIT reliability plot (cumulative, Stage 3)



20 sites - CRPS skill score (monthly, Stage 3)



20 sites - CRPS skill score (cumulative, Stage 3)



Conclusions

- **FoGSS model for ensemble forecasts of monthly streamflow out to 12 months**
- **CBaM is used to post-process GCM climate forecasts for use in a catchment water balance model**
- **Forecasts of monthly streamflow are generally skillful only at short lead times**
- **Forecasts of cumulative streamflow are much more skillful, valuable for water management**

Conclusions

- **Forecasts are statistically reliable in uncertainty spread for both individual months and accumulations**
- **FoGSS adequately represents**
 - Rainfall forecast uncertainty
 - Hydrological uncertainty
 - Persistence in streamflow
 - Uncertainty propagation
- **FoGSS does what the water agencies have been asking for**
- **FoGSS is ready for operational deployment**

Thank you

CSIRO Land and Water Flagship

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