The Bureau of Meteorology

Assessment of the JULES land surface model for simulating streamflow in Australia

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Hydrology Science, Bureau of Meteorology

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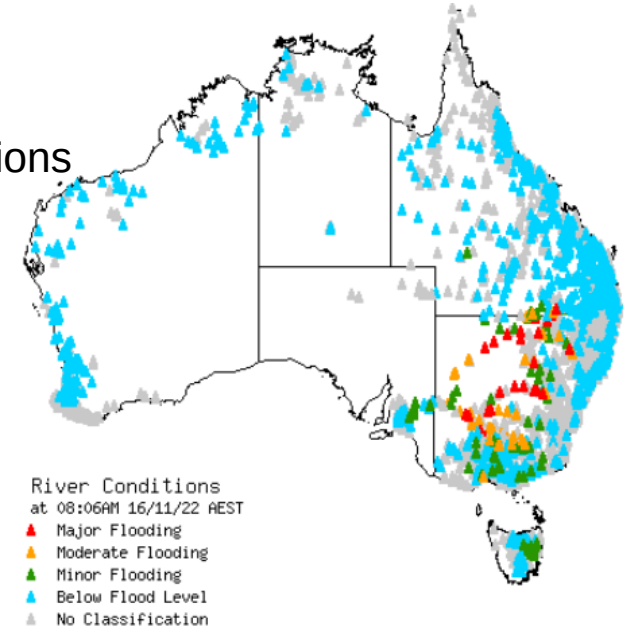
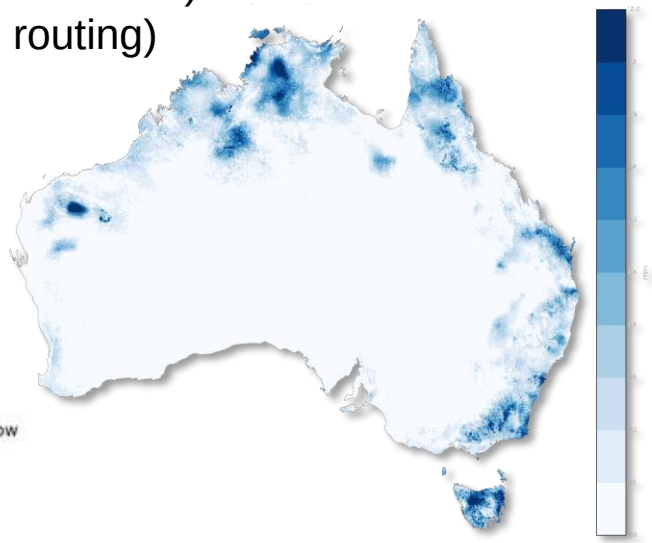
JULES Annual Science Meeting, 14 September 2023

The Bureau of Meteorology's current water information services (examples)

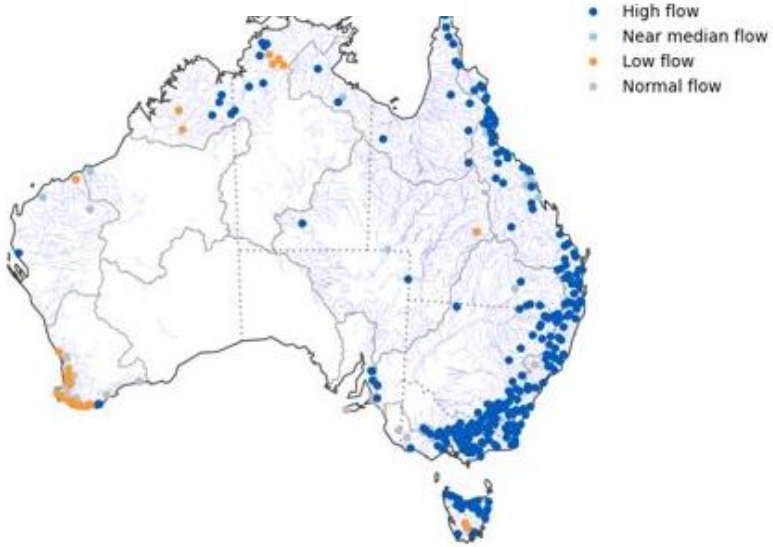
Flood predictions



Gridded runoff
(AWRA-L model)
(No routing)

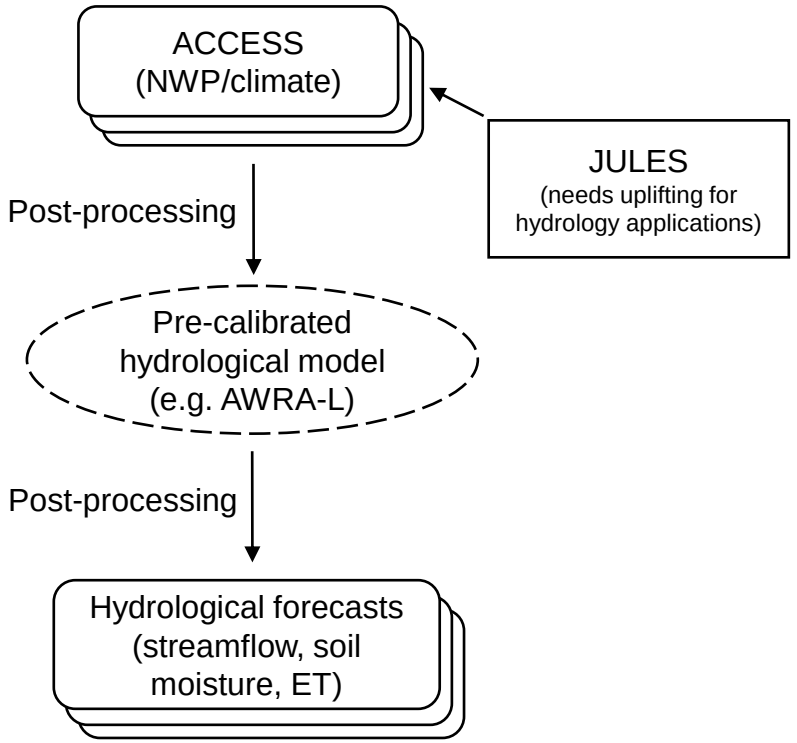


Streamflow forecasts
(7-day/seasonal)

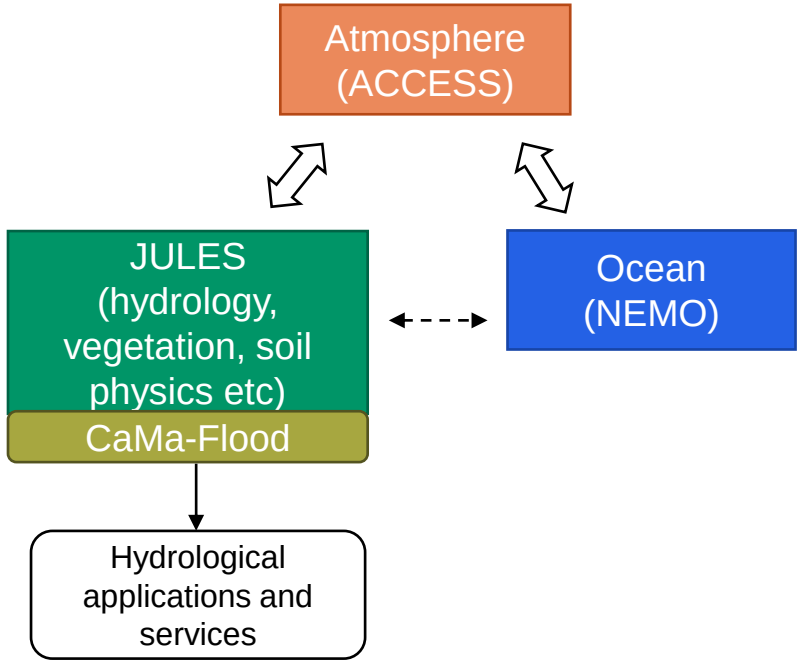


Land surface hydrology research at the Bureau

Current operational system (offline)



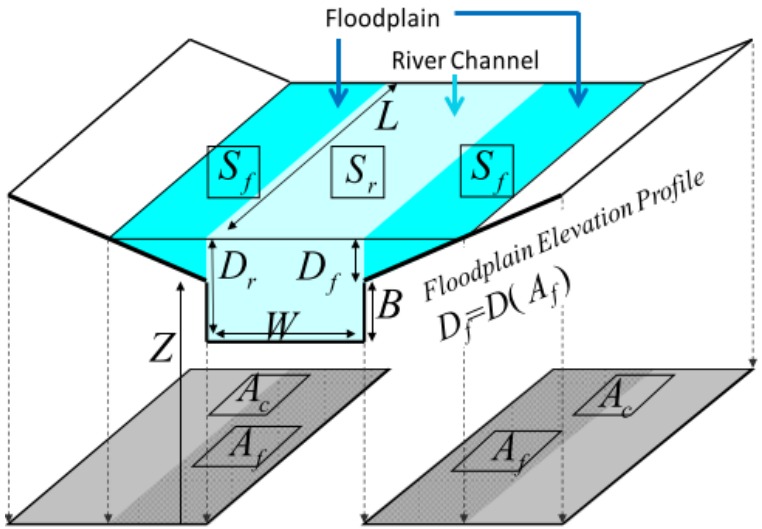
Future plan (stand-alone + coupled system)



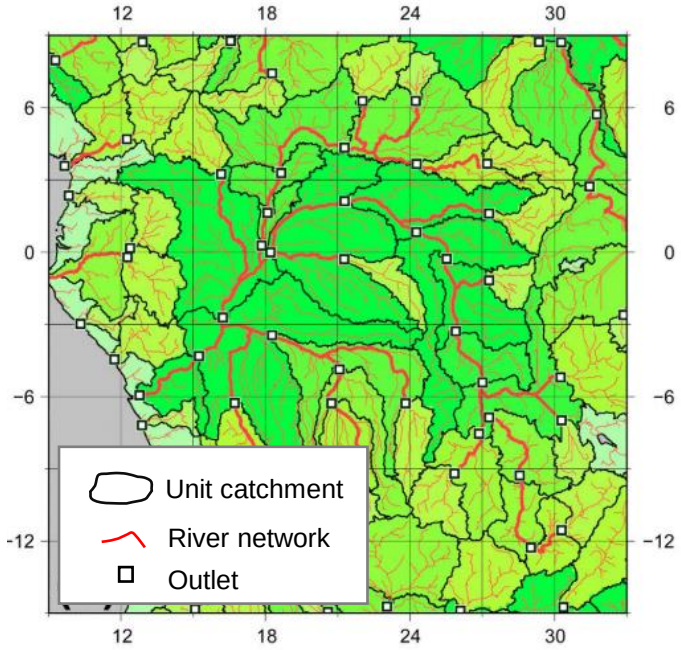
Land surface model + river routing:

- Seamless hydrological forecasting (e.g. short and extended streamflow predictions, long-term projections)
- Capability to forecast at gauged/ungauged locations
- Closing the water balance

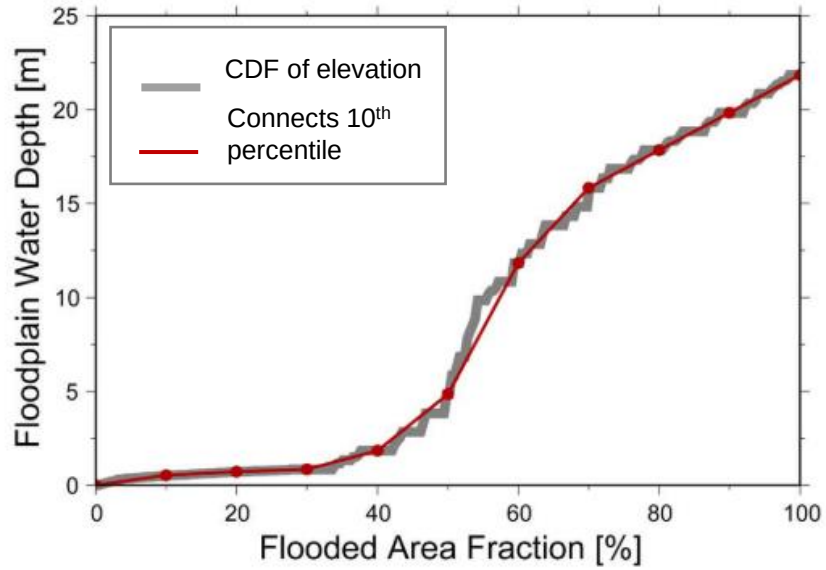
Catchment-based Macro-scale Floodplain (CaMa-Flood) overview



River channel and floodplain at each grid point



River network and unit catchments



Floodplain elevation profile for each unit catchment

- Distributed hydrodynamic model that routes runoff to oceans and inland lakes/rivers along a prescribed river network map. Simulates backwater effects.

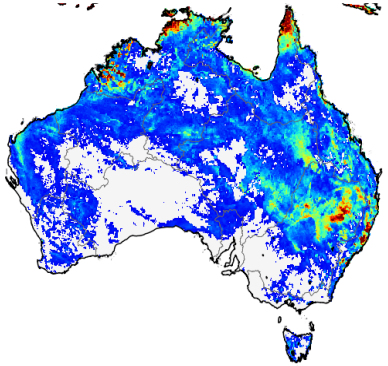
- CaMa-Flood used operationally by:
  - ECMWF: ECLand
  - JAXA: Today's Earth

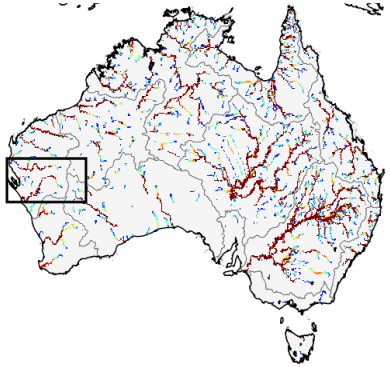
Yamazaki et al., 2011, *A physically-based description of floodplain inundation dynamics in a global river routing model*, Water Res. Res.

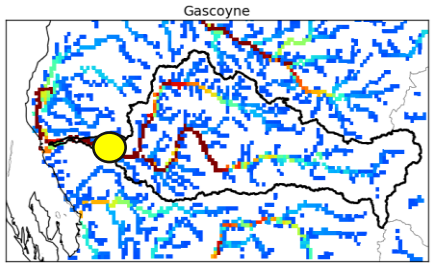
Overall workflow

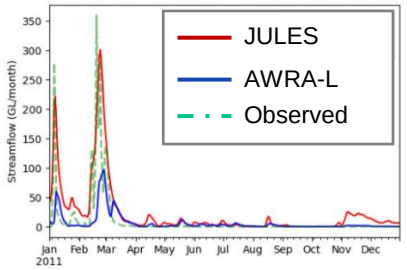
CaMa-Flood

Observed streamflow









Evaluation

LSM runoff

Gridded streamflow

Grid-to-gauge allocation

Simulated streamflow

Data: models and key characteristics

Model	Modelling system	Rainfall Forcing	Model extent	Spatial scale	Period	River routing network
JULES v7.2 (GAL9)	Offline	AGCD	Australia	5 km x 5 km	2015 – 2021	5 km
JULES v6.0 (GA7.2/GL8.1)	Coupled (BARRA-R2)	BARRA	Australia	12 km x 12 km	2015 – 2021	5 km
AWRA-L	AWO	AGCD	Australia	5 km x 5 km	2015 - 2021	5 km

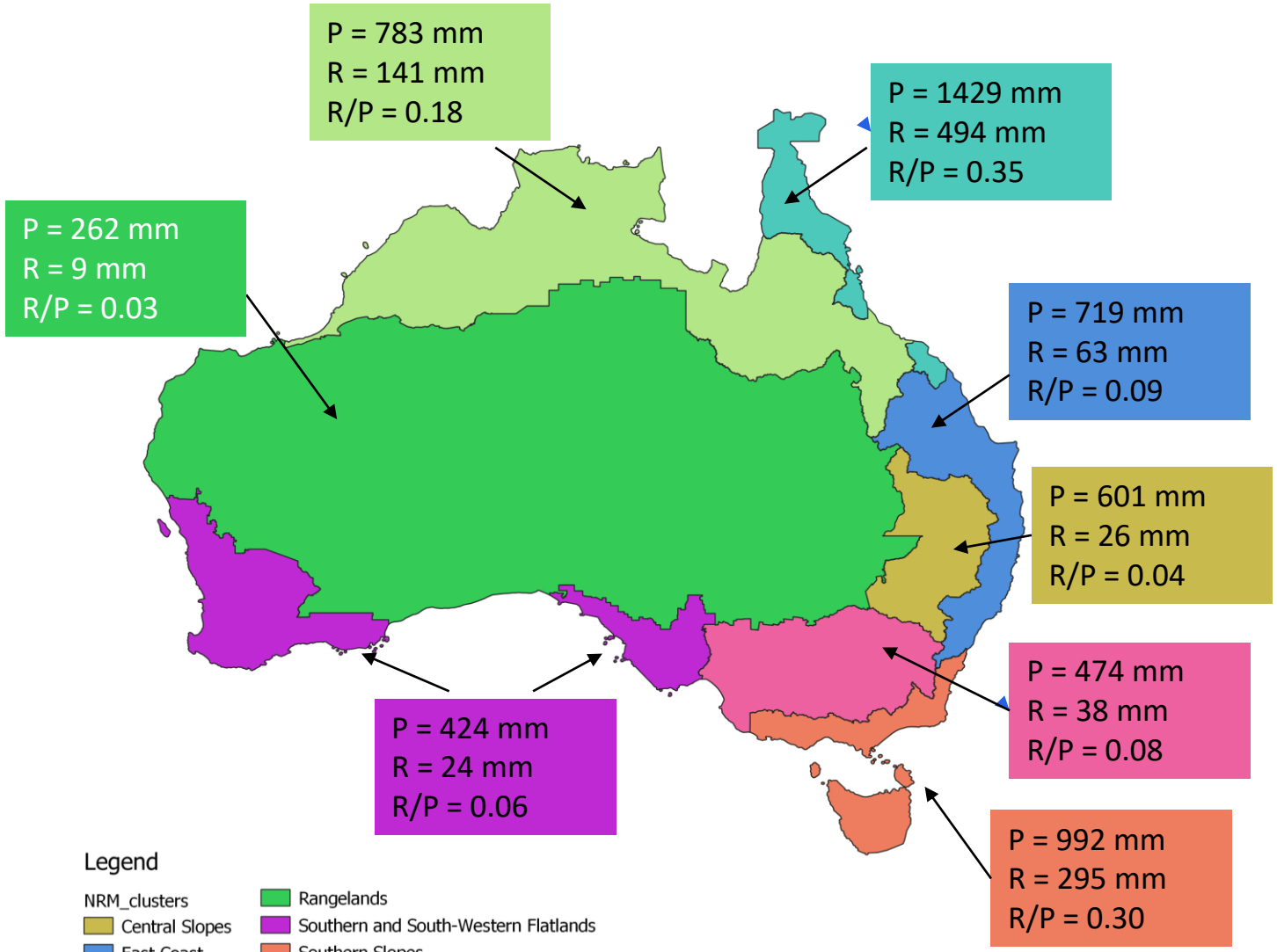
AWRA-L – Australian Water Resources Assessment Land

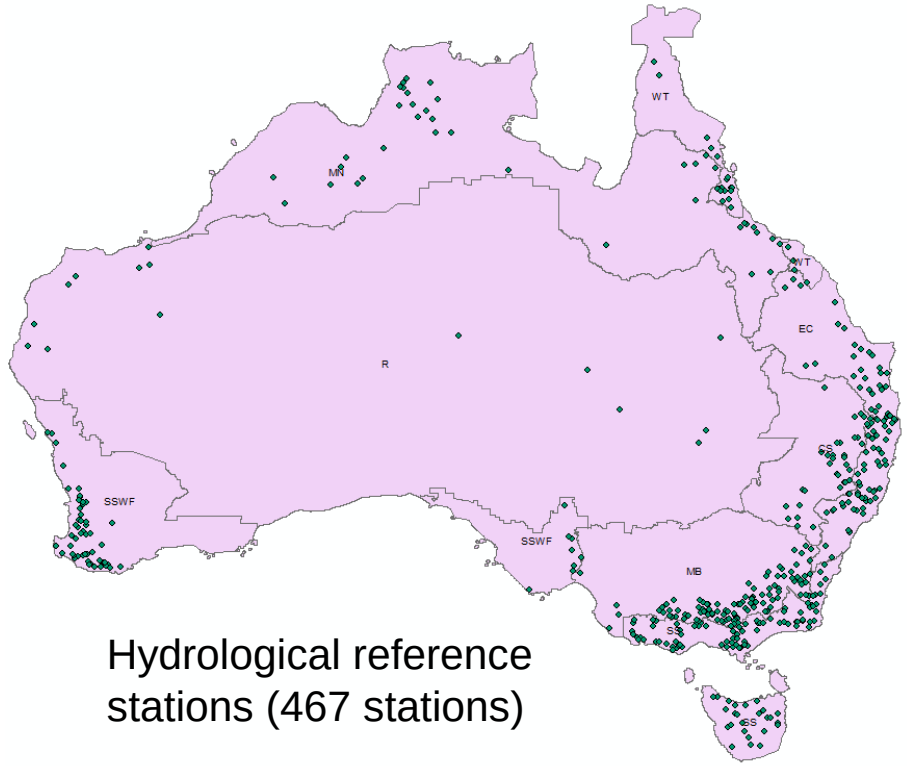
AWO – Australian Water Outlook

AGCD – Australian Gridded Climate Data

BARRA-R2 – Bureau's Atmospheric high-resolution Regional Reanalysis for Australia

Data: observed streamflow and hydro-climate regions

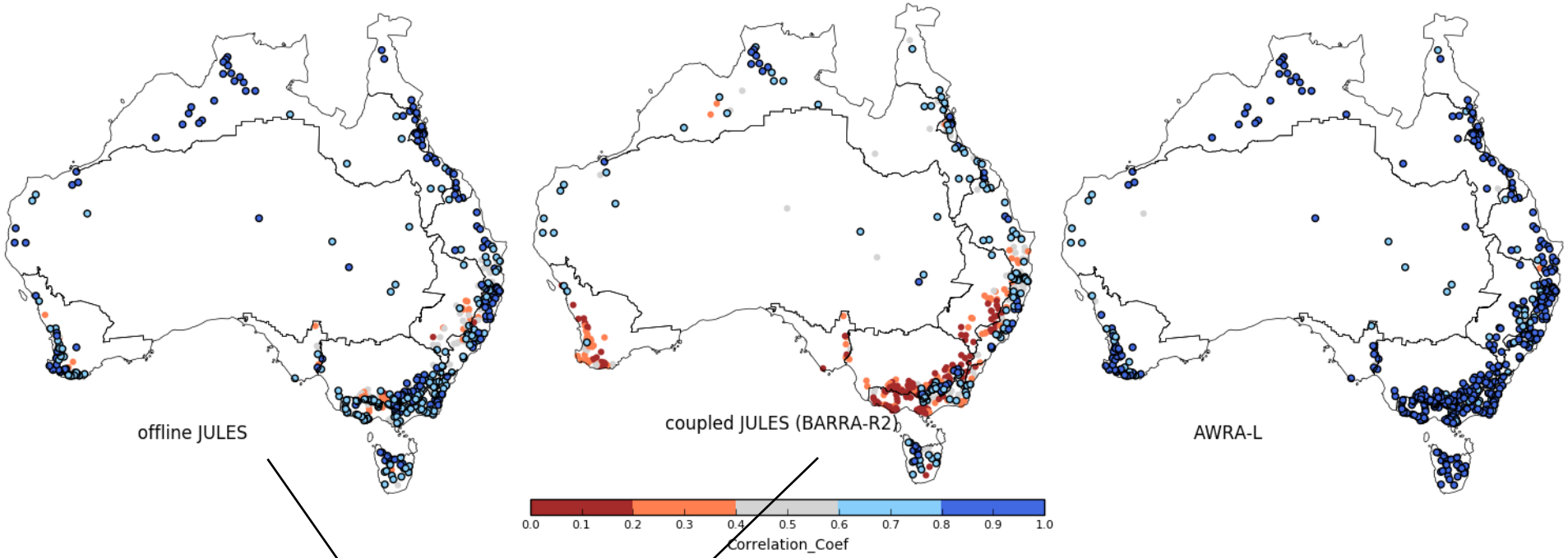


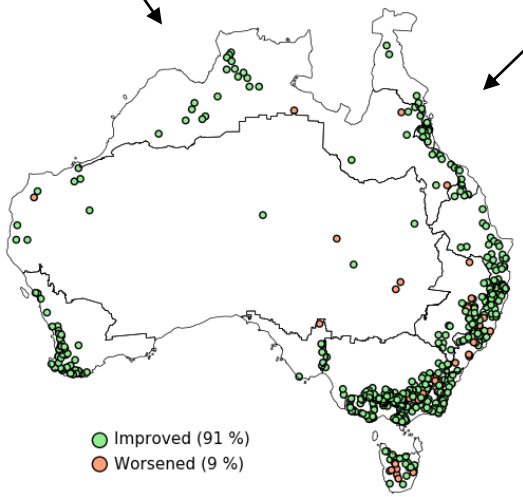


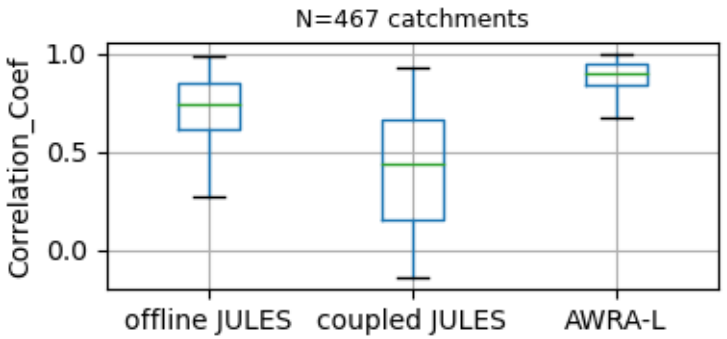
Hydrological reference stations (467 stations)

Amirthanathan, G. E., Bari, M. A., Woldemeskel, F. M., Tuteja, N. K., and Feikema, P. M.: *Regional significance of historical trends and step changes in Australian streamflow*, Hydrol. Earth Syst. Sci., 27, 229–254, 2023.

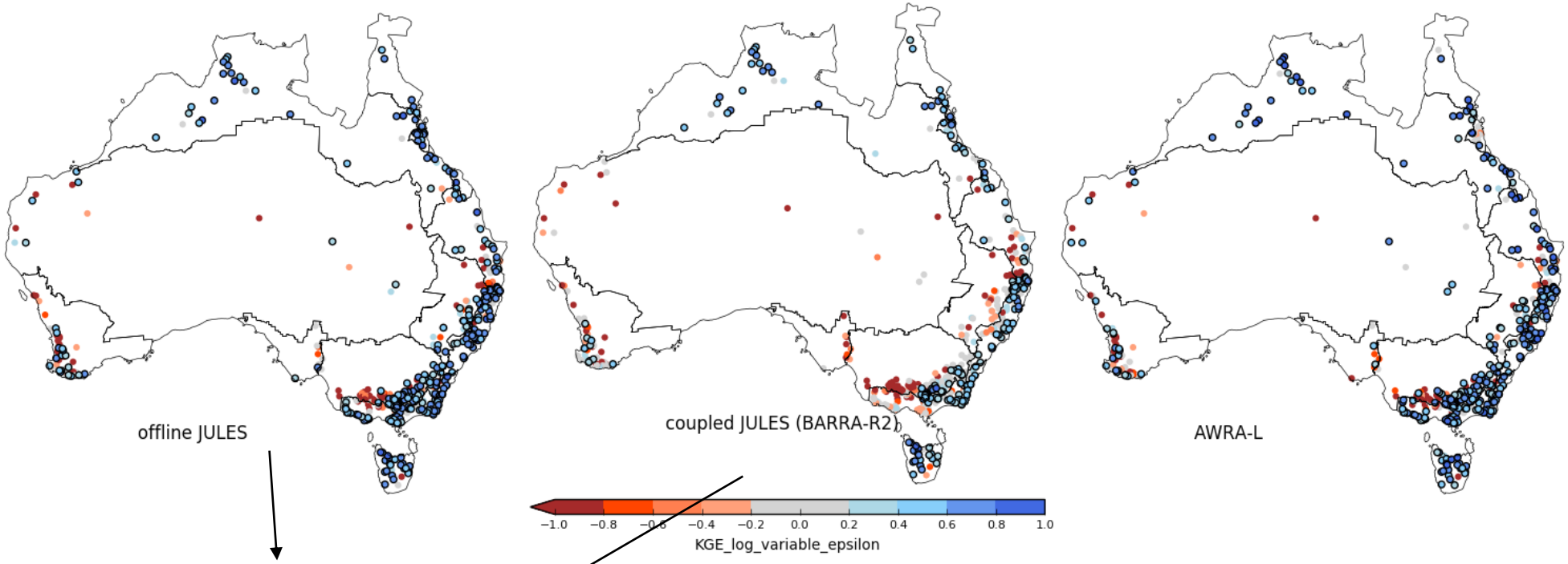
Performance of streamflow simulation: (i) monthly correlation

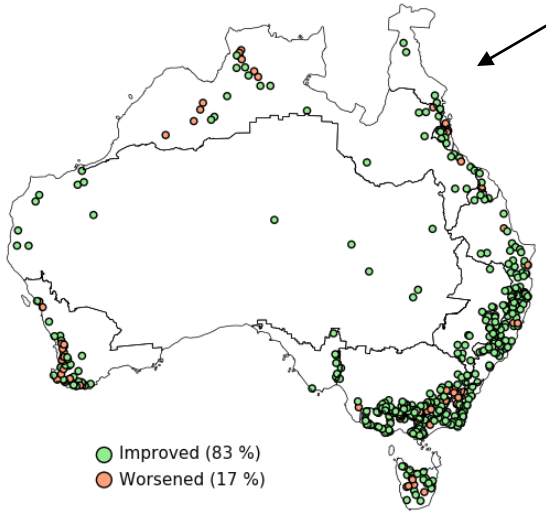


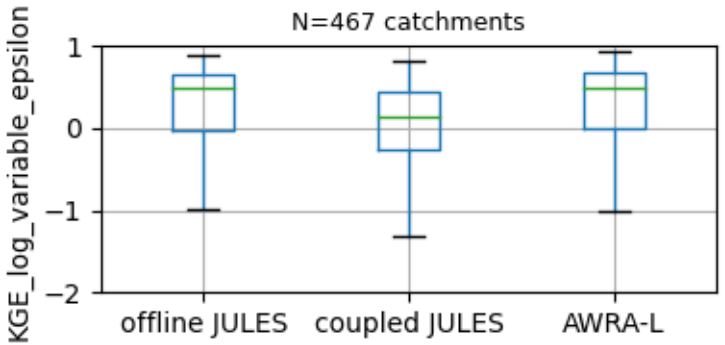




Performance of streamflow simulation: (ii) monthly KGE Log

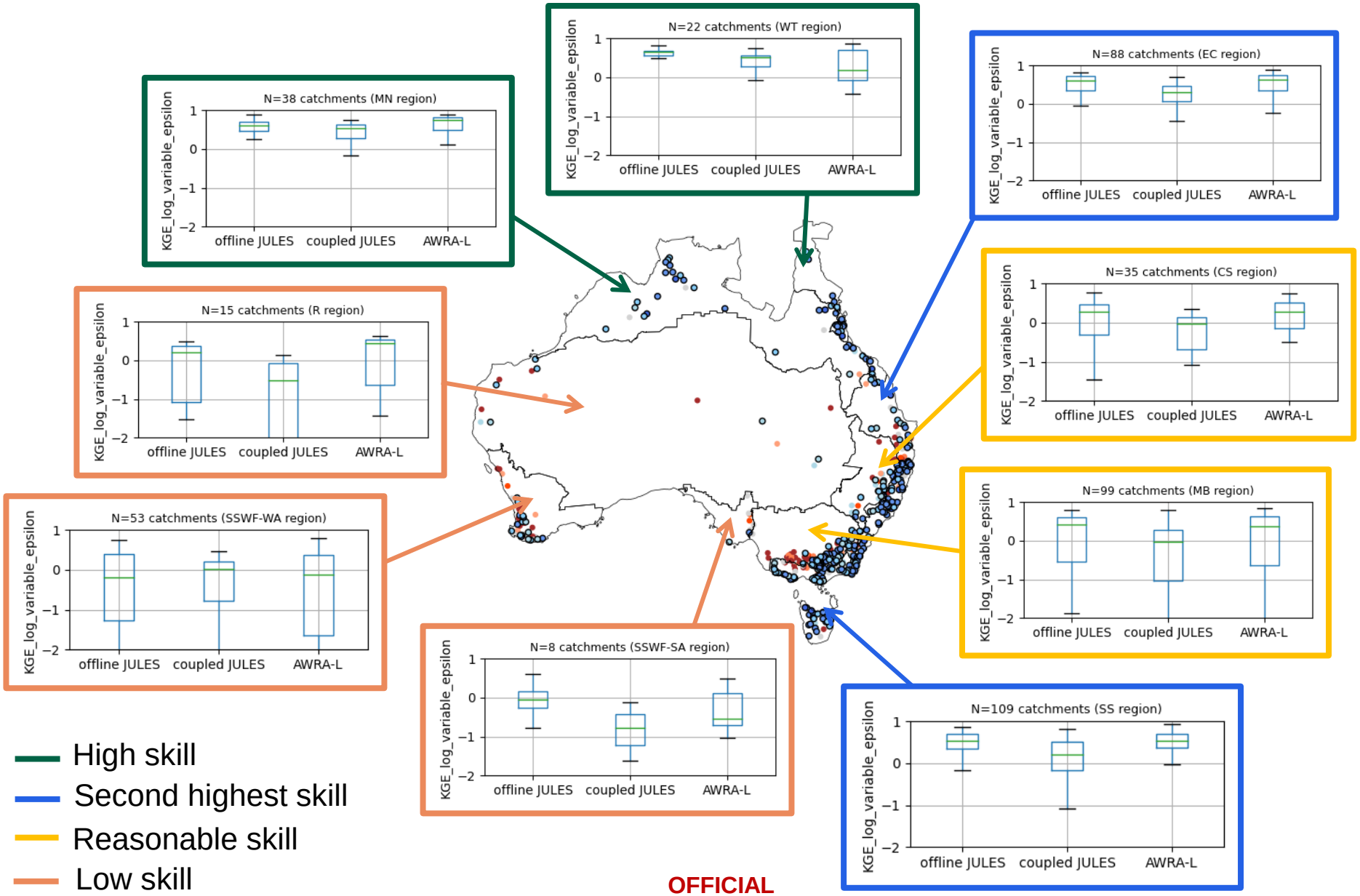






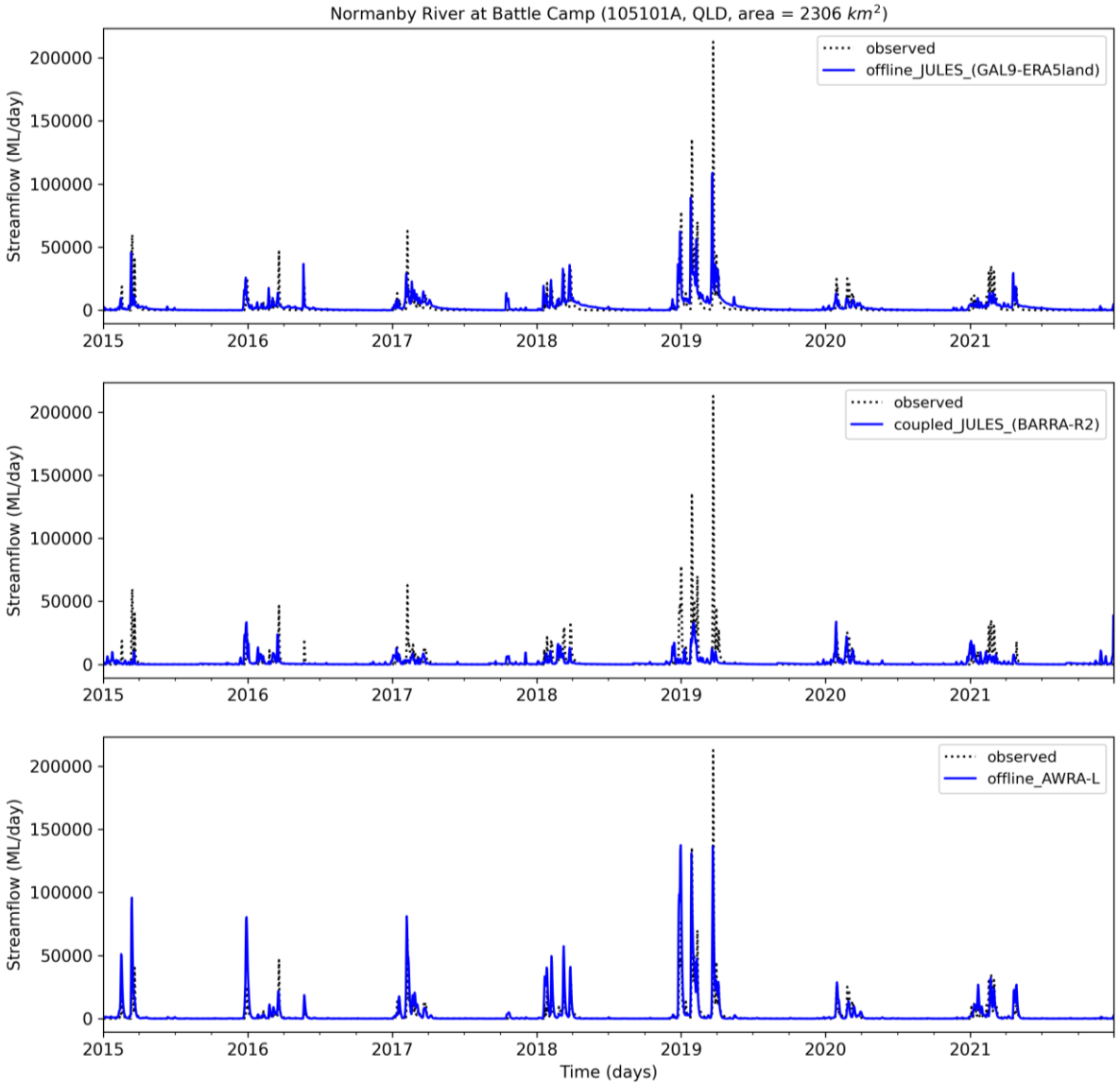
- High model performance, particularly AWRA-L and Offline JULES. (Note that some of the locations are used for AWRA-L calibration.)
- Offline JULES perform significantly better than JULES (BARRA-R2).

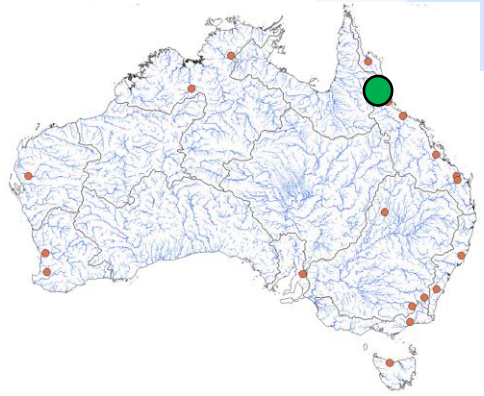
Performance across various hydro-climate regions (KGE log)



Evaluation of streamflow at selected locations

Normanby River at Battle Camp (105101A) - Area: 2306 km^2





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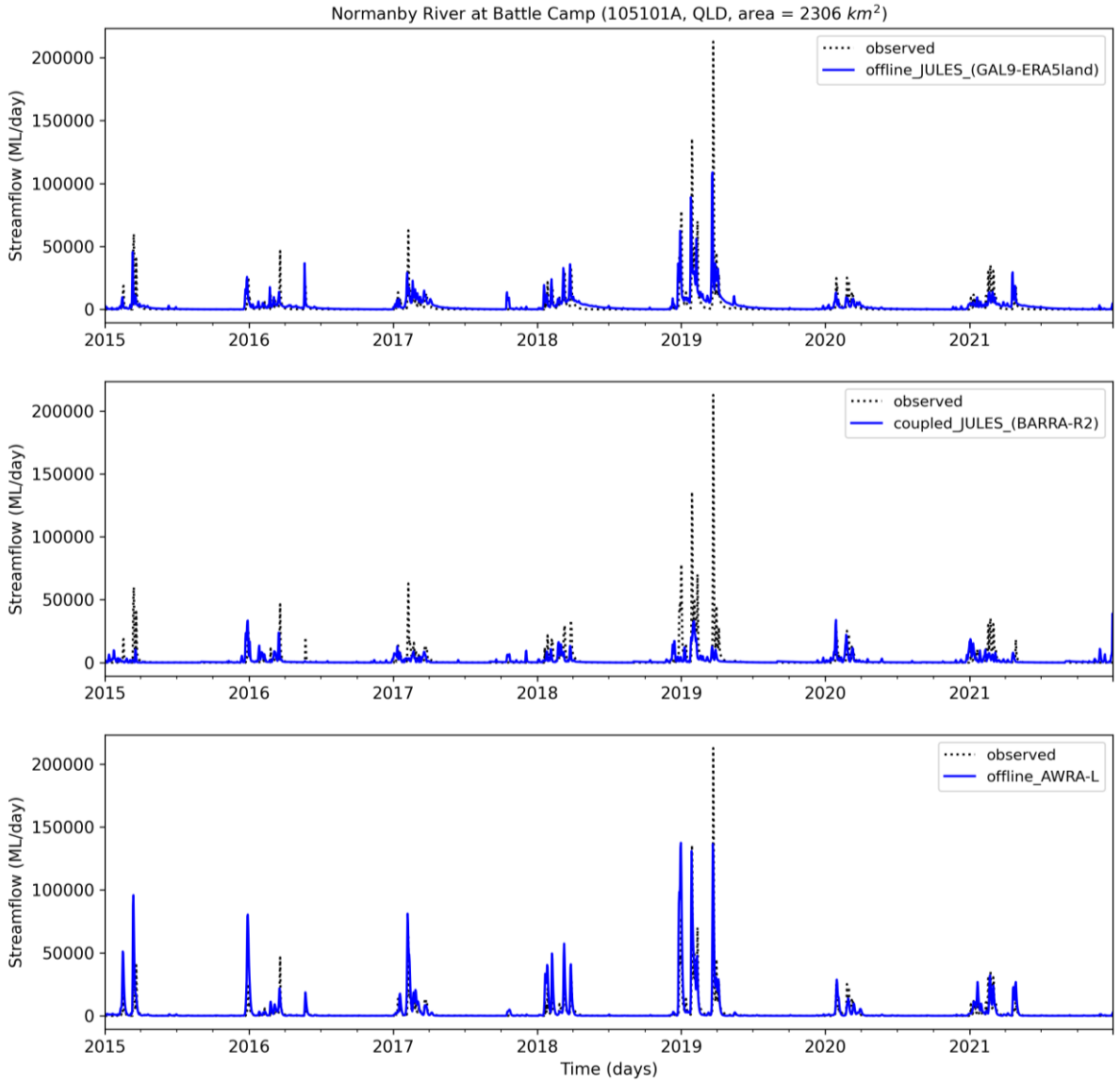
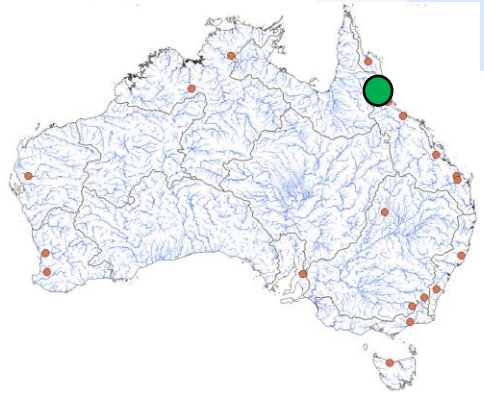
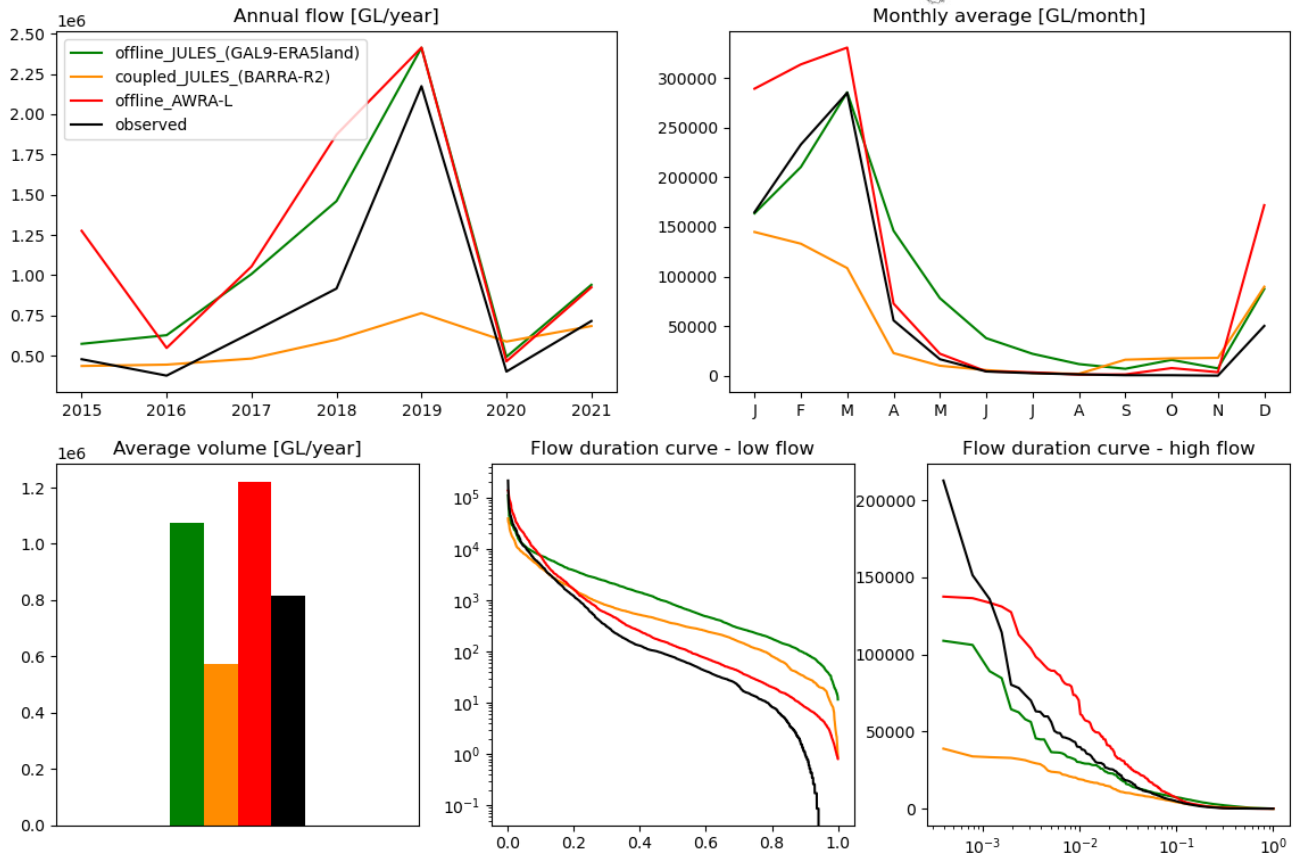


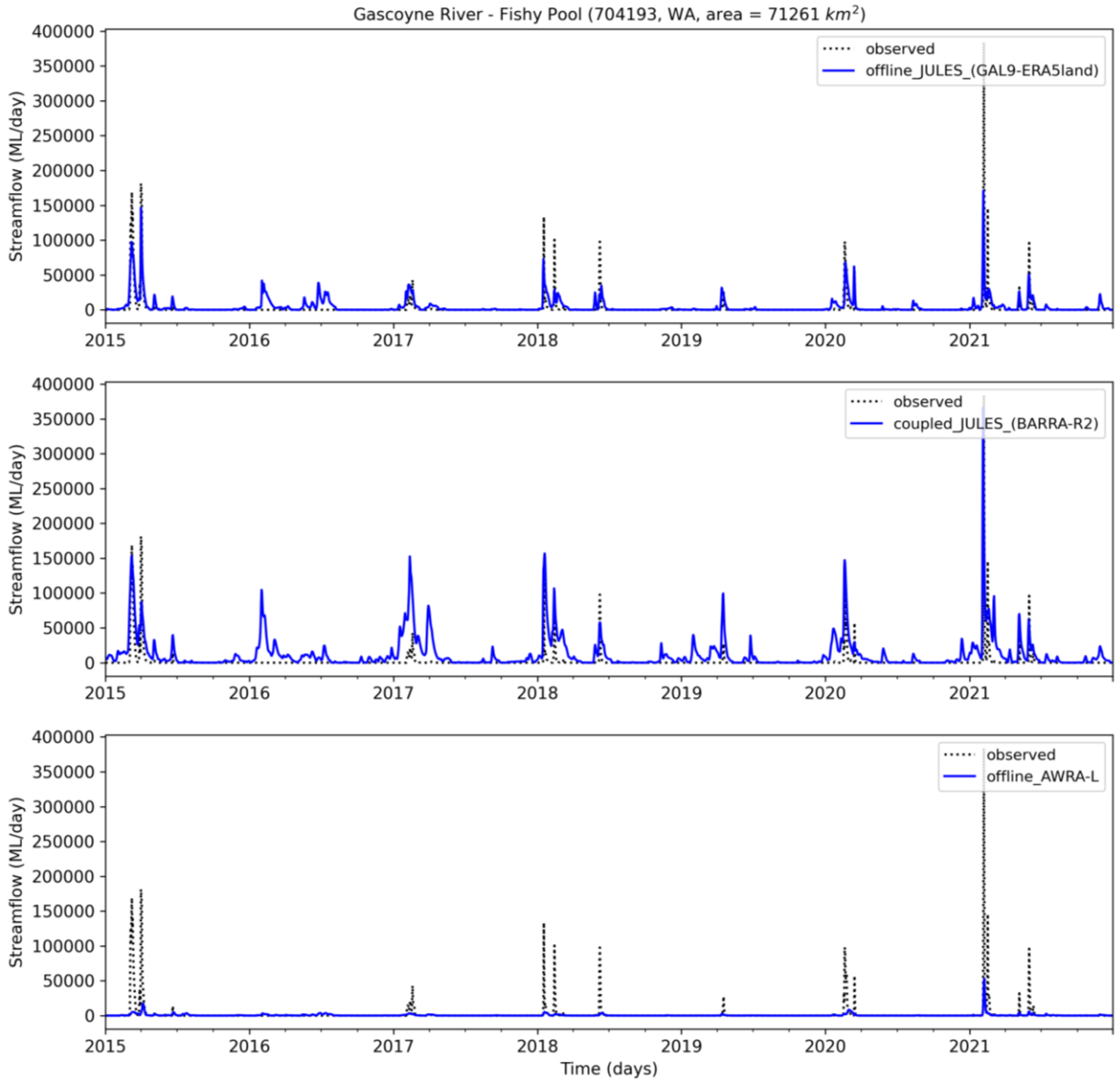


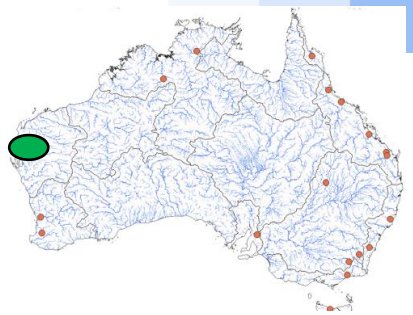


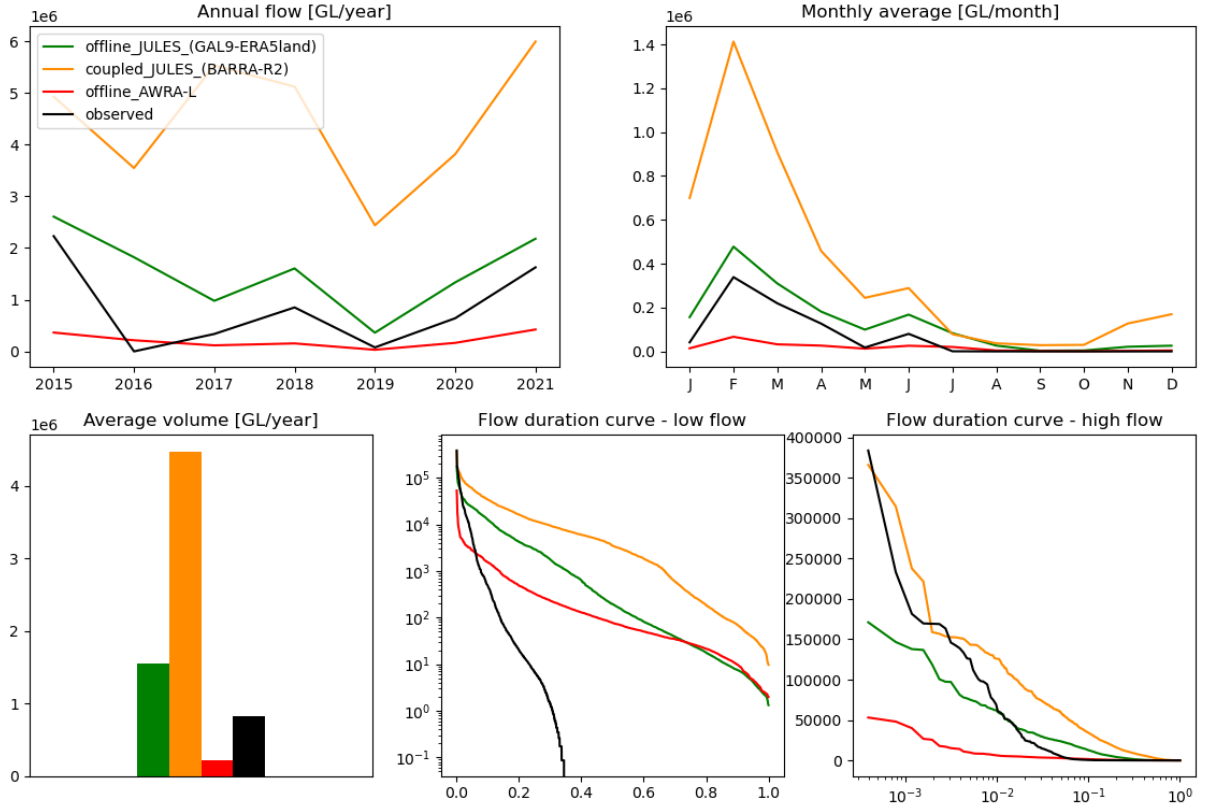
- Offline JULES/AWRA-L - perform reasonably well although overestimate total volume.
- BARRA-R2 - underestimate high flows

Evaluation of streamflow at selected locations

Gascoyne River at Fishy pool (704193)- Area: 71261 km^2 (approx. 4-5 x Thames Basin)







- Offline JULES perform reasonably well, however large disparity among three models.
- We are investigating further this catchment (next two slides)

Evaluation of streamflow at selected locations

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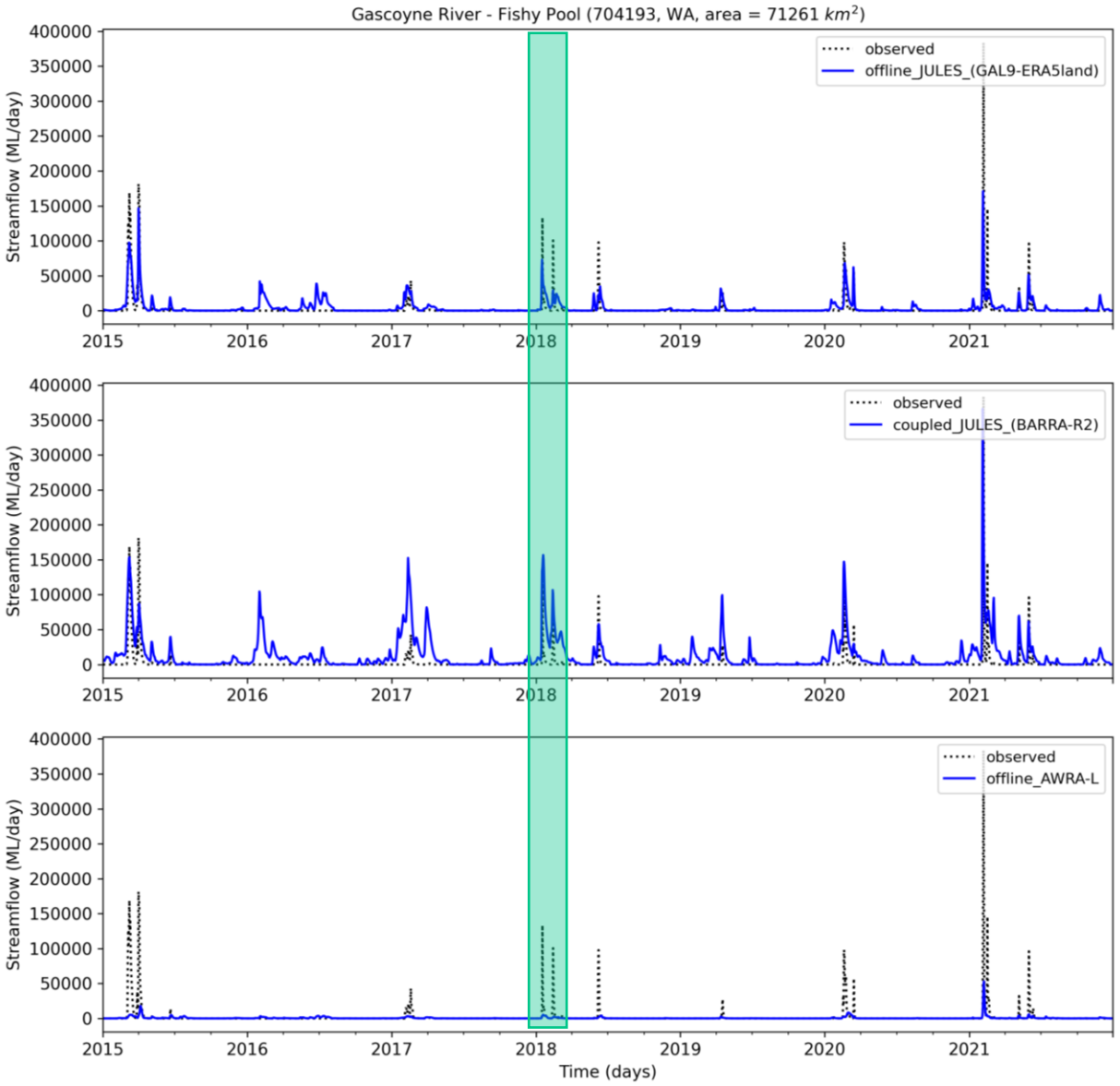

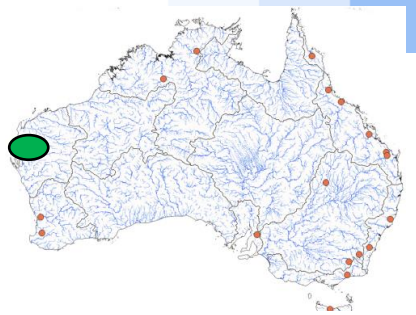

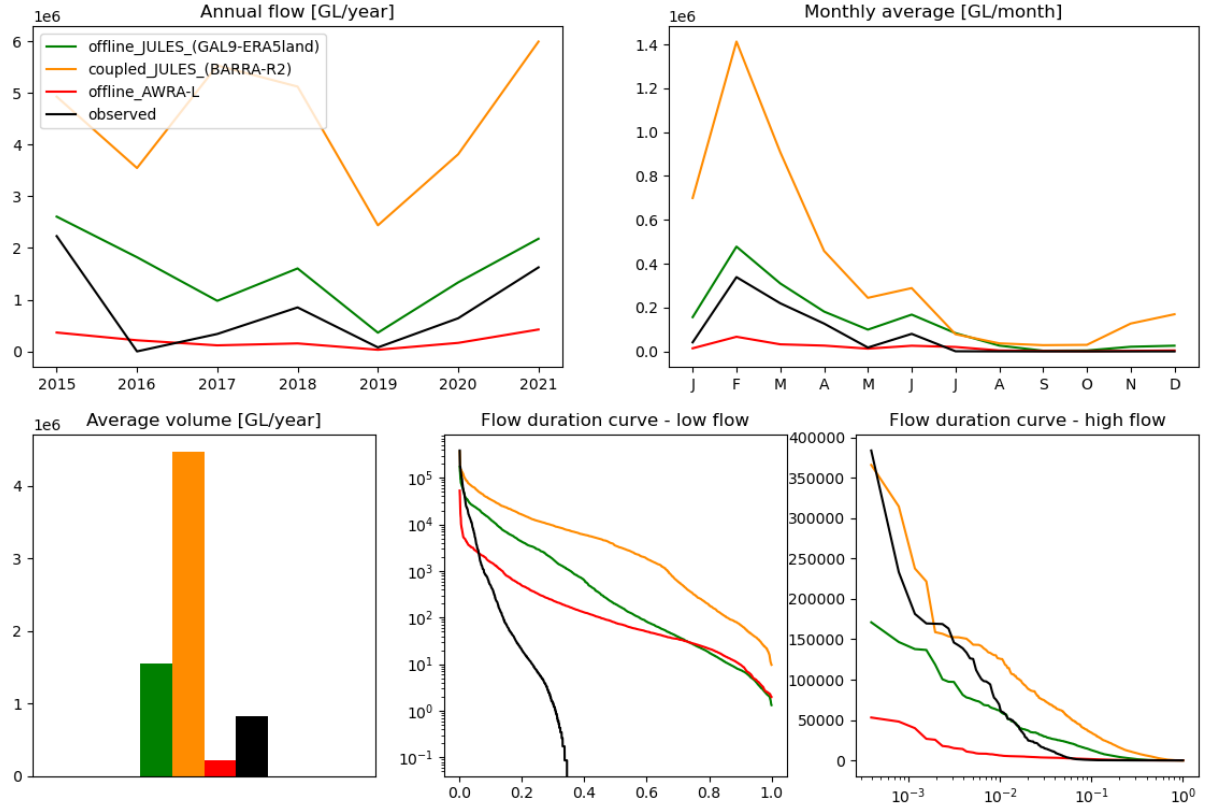

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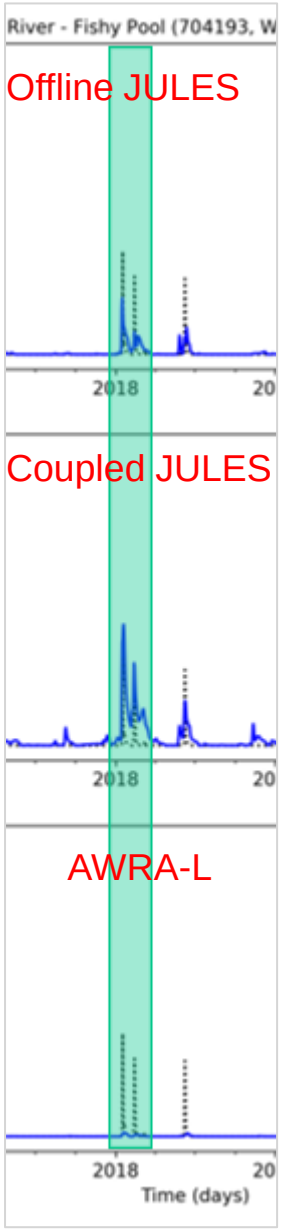
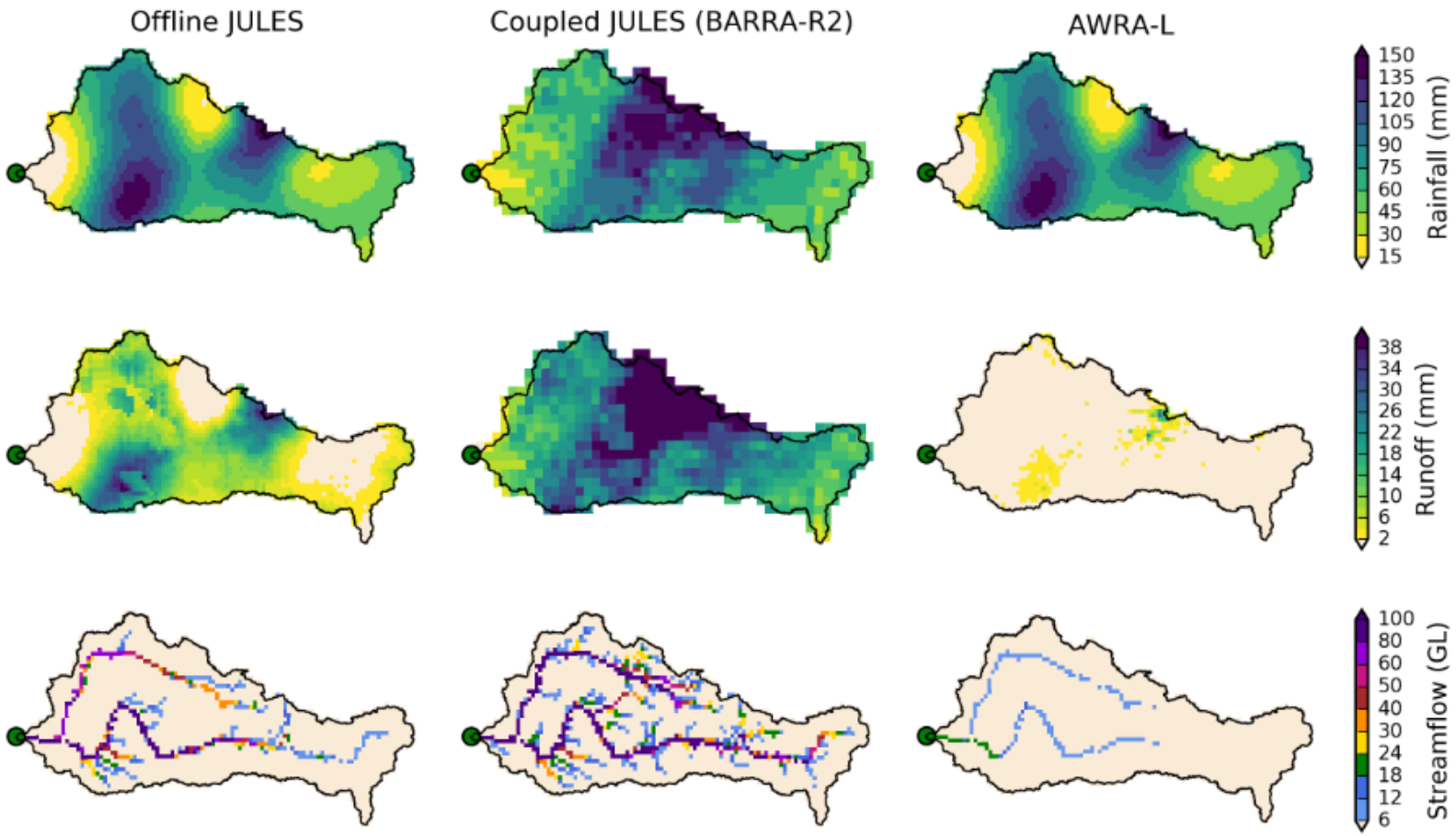
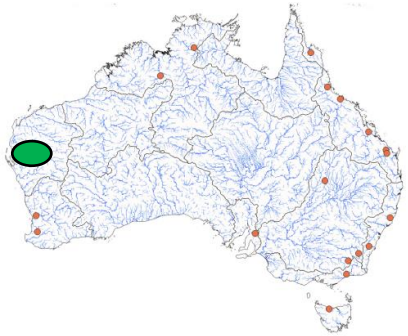
Gascoyne River: analysis of spatial rainfall, runoff and streamflow data



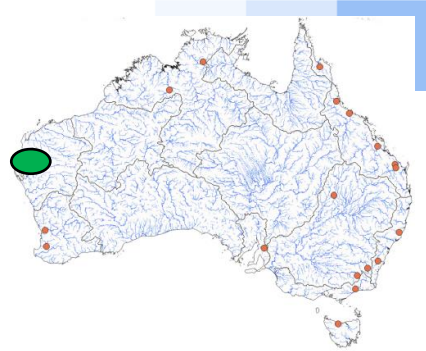


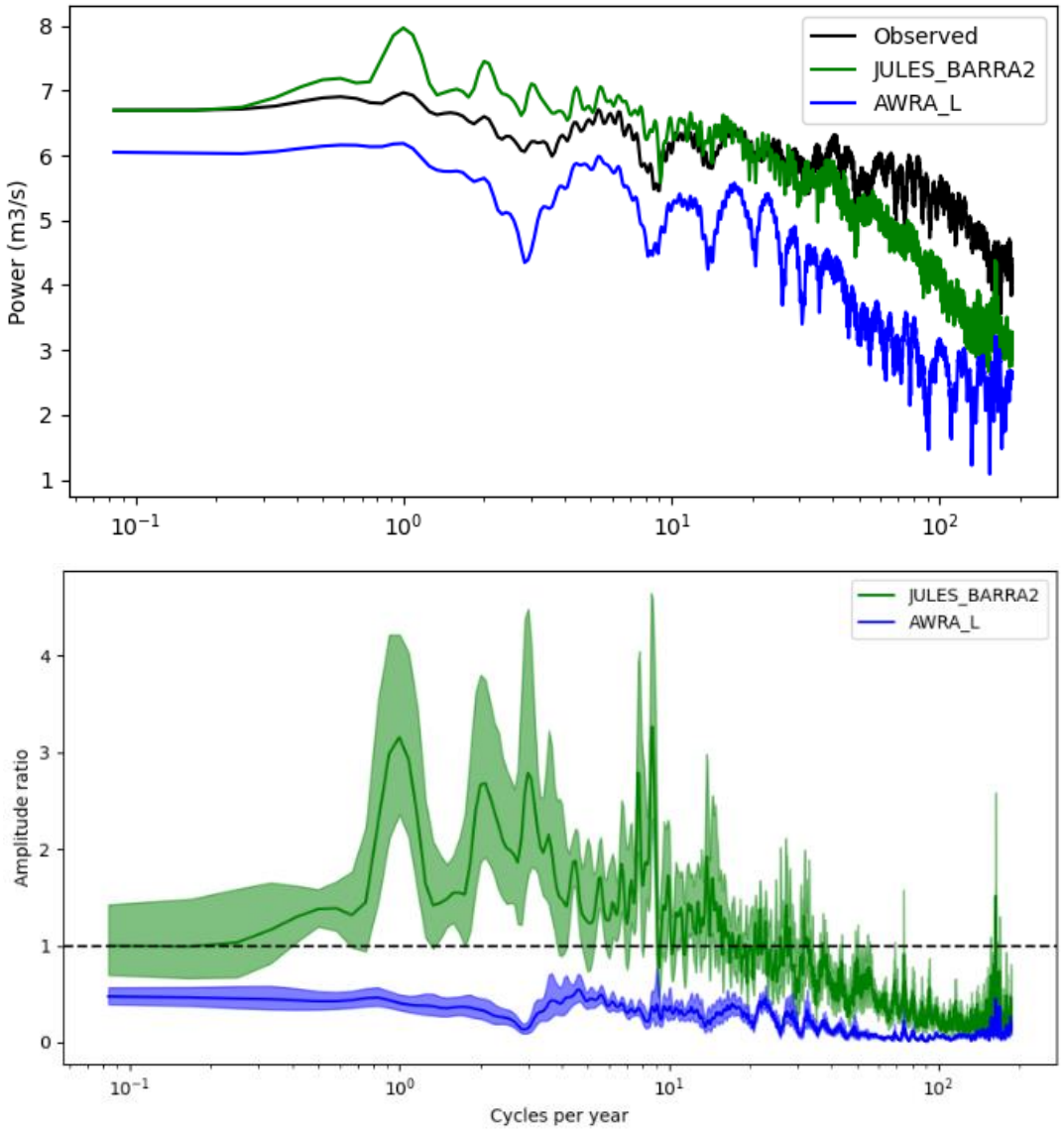


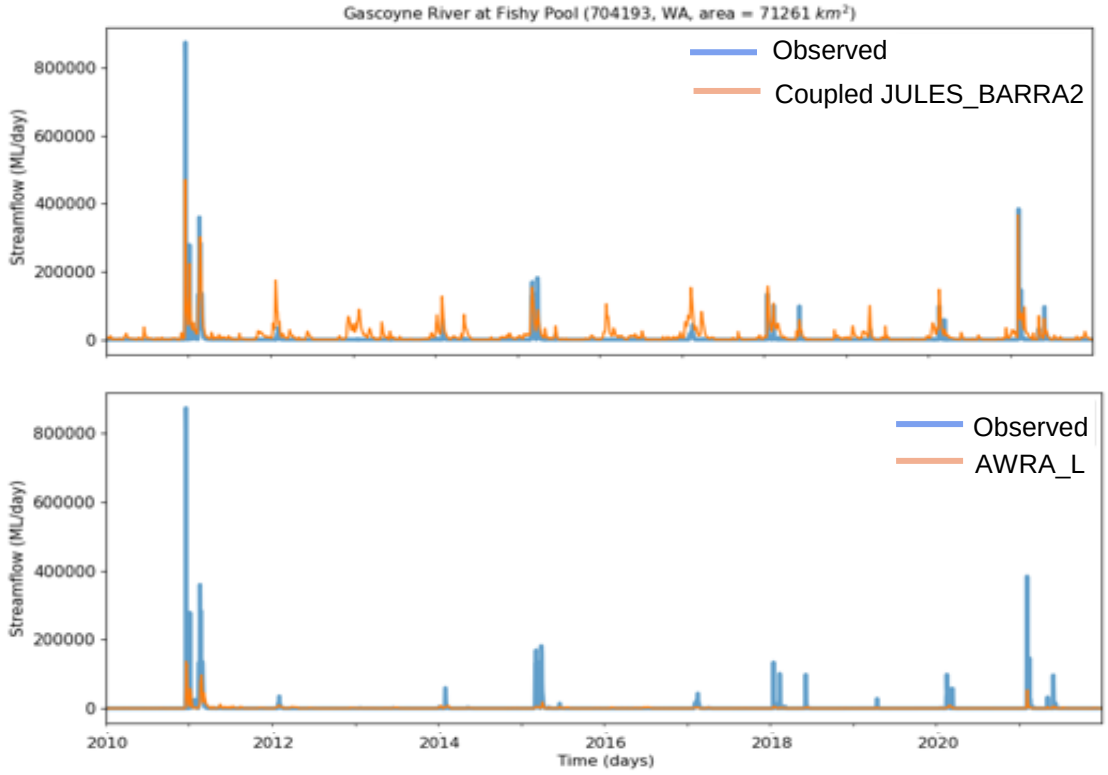
Jan 2018

- Visible difference in the input rainfall between offline JULES/AWRA-L and BARRA-R2
- Large difference in the runoff generation among models (e.g. offline JULES and AWRA_L)

Gascoyne River: cross-spectral analysis – preliminary result







Weedon, G.P., Robinson, E.L., Bloomfield, J.P., Turner, S., Crane, E. and Best, M.J., 2023, *Geological controls of discharge variability in the Thames Basin, UK from cross-spectral analyses: observations versus modelling*. J. Hydrol.

Summary and next steps

- CaMa-Flood has been implemented offline with various input runoff sources
- Model intercomparisons suggest:
  - Nationally:
    - offline JULES perform better than coupled JULES (BARRA-R2) across all the metrics considered and offline JULES performance is comparable with AWRA-L.
  - Regionally:
    - High performance obtained in the monsoonal north and wet tropics with high rainfall-runoff ratio.
    - Reasonable performance obtained along the east coast however performance is relatively low in South and South-West Australia as well Range lands.
- Next steps include:
  - JULES model physics improvements as well as 2-way coupling of CaMa-Flood with JULES and ESM.
  - Anthropogenic changes and streamflow data assimilation
  - Cross-spectral analysis of river responses
  - Benchmarking against lumped catchment models (SWIFT) as well as gridded models such as AWRA-L and G2G.

The Bureau of Meteorology

Thank you

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