Use of event vs continuous models for flood forecasting: dogma or context?

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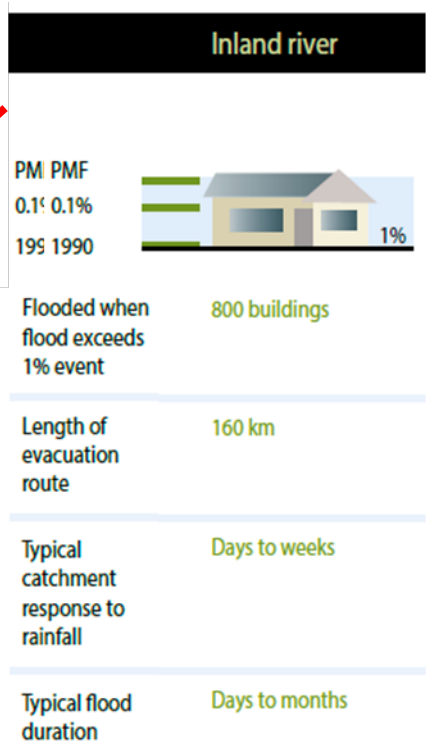
Overview

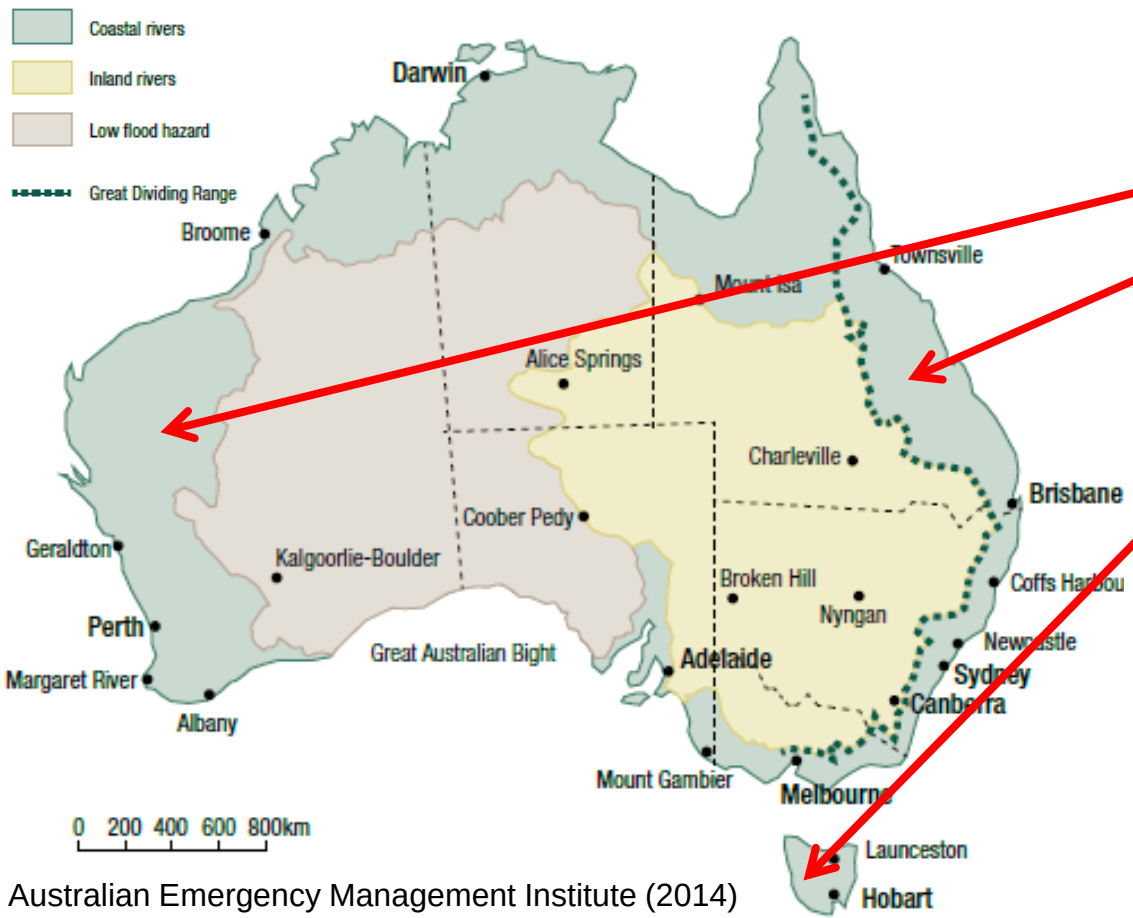
- Some context
- Current arrangements
- Continuous simulation
- Event-based simulation
- Some considerations

Flooding Mechanisms



Australian Emergency Management Institute (2014)

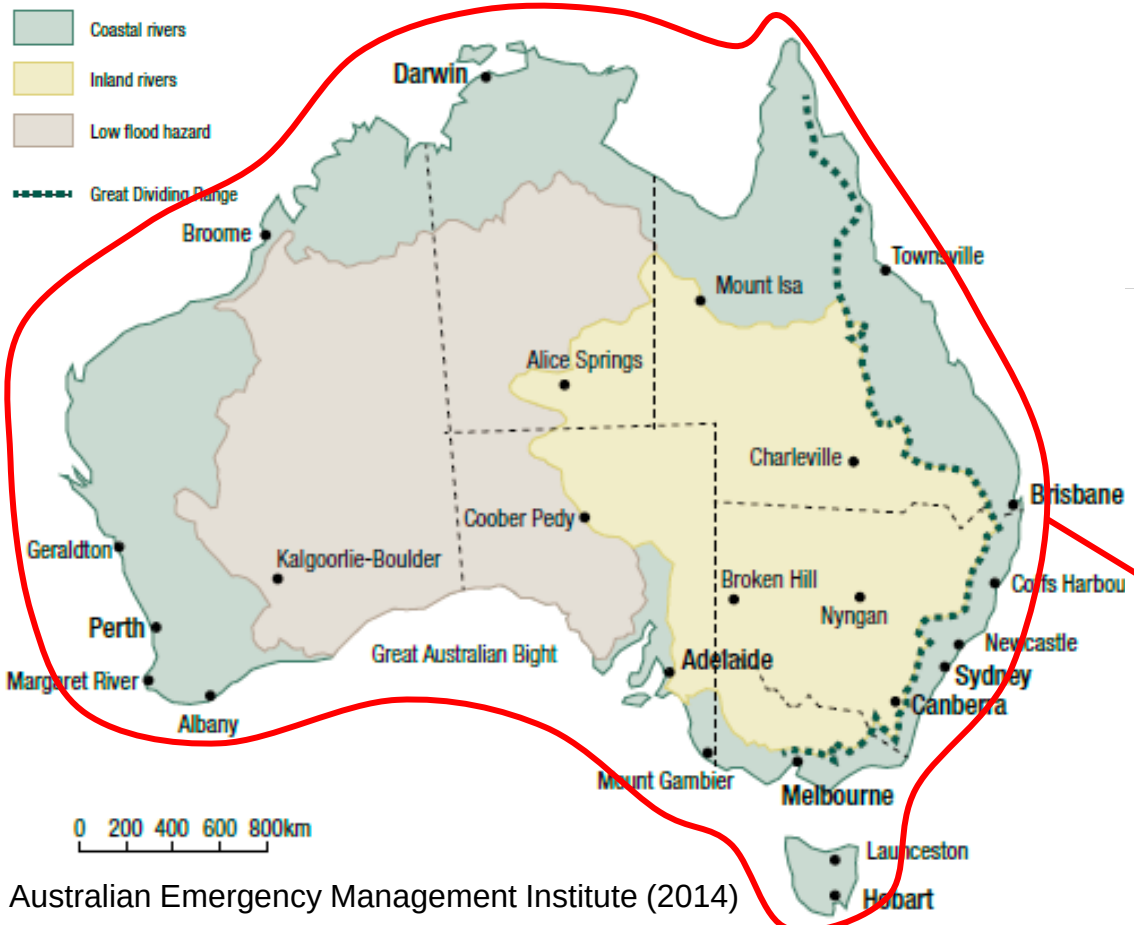
Flooding Mechanisms



	Inland river	Coastal river
		
Flooded when flood exceeds 1% event	800 buildings	1000 buildings
Length of evacuation route	160 km	200 m
Typical catchment response to rainfall	Days to weeks	Hours to days
Typical flood duration	Days to months	Days

Australian Emergency Management Institute (2014)

Flooding Mechanisms



Australian Emergency Management Institute (2014)

	Inland river	Coastal river
	PMF 0.1% 1990  1%	PMF 1873  1%
Flooded when flood exceeds 1% event	800 buildings	1000 buildings
Length of evacuation route	160 km	200 m
Typical catchment response to	Days to weeks	Hours to days

Flash flooding

- <6hrs between rainfall and flood response (thunderstorms)
- Can occur anywhere
- Evacuation route: very short
- Duration: hours

Responsibilities for flood forecasting in Oz

- Bureau of Meteorology:
  - *Flood watch*: early advice that a significant risk of flooding is expected to affect specific communities (emergency services)
  - *Flood warning*: expected severity levels for floods in a particular region/catchment/location
- Local councils/agencies:
  - *Flash flooding*: a variety of generalised warning systems in place (flooding < 6hrs of rainfall)
- Dam owners
  - *Gated operations*: develop community warning systems as needed, and provide info on planned/unplanned releases

Some relevant dams

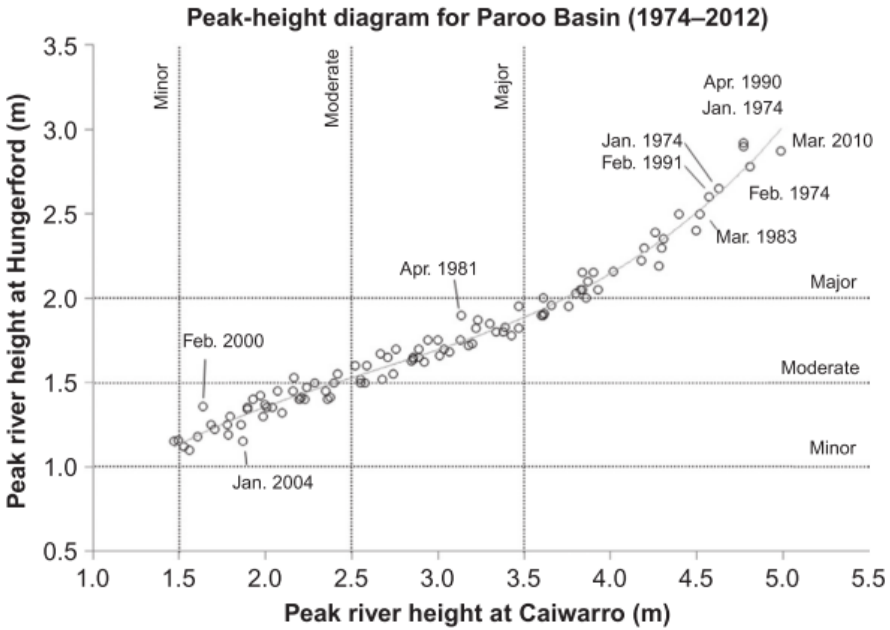
- Ross River Dam
- Warragamba Dam
- Wivenhoe and Somerset Dams
- Hume Dam
- Burrendong Dam
- Jindabyne Dam
- Portfolio of HydroTas dams

Some flash flood monitoring systems

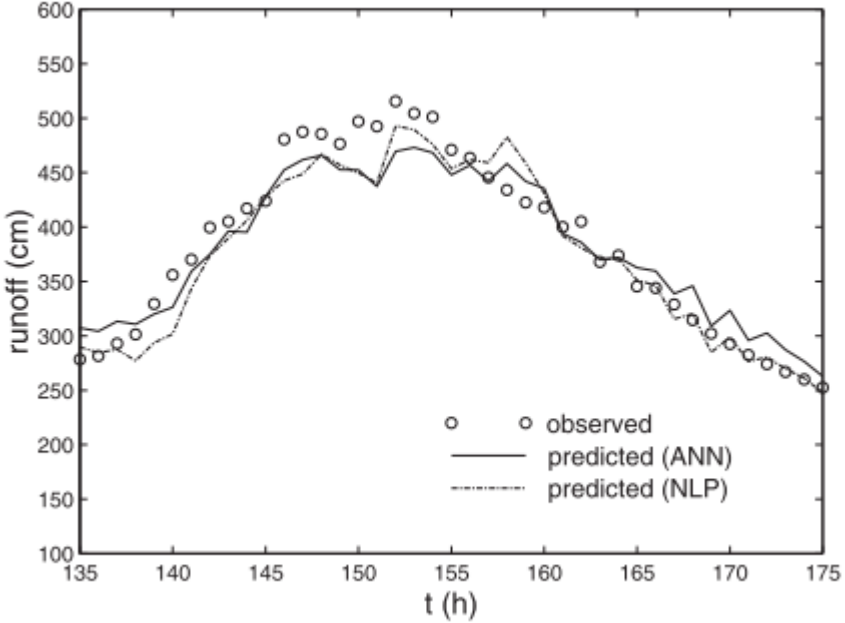
	Melbourne Water**	Moreton Bay City Council	Adelaide - Current	Adelaide - Future
Approximate Area covered (sq km)	4	2000	1000	1000
Number of catchments (currently)	2	14	0	30
Rainfall sites (Real time telemetry)	3	90	102	150
Water Level/Flow monitoring sites	3	30	40	50
Forecast Locations (estimated)	2	500	0	60
Real Time Rainfalls puplished	☑	☑	No	☑
Real Time Water levels published	☑	☑	No	☑
Forecast Rain assessed?	No	☑	No	☑
Flash Flood Warning service available	☑	☑	No	☑
Alerting of Response Agencies	☑	☑	☑	☑
Alerting of the Targeted people at risk	☑	No	No	☑
Warnings via the media*	No	☑	No	☑
Message type -SMS	☑	☑	☑	☑
Message type -Landline/Mobile Phone	☑	☑	No	☑
Message type -Internet	☑	☑	☑	☑

Wright and Kemp (2016): the reality of flood forecasting in greater metropolitan Adelaide. *Proc Floodplain Management Conference, Nowra*

Statistical methods



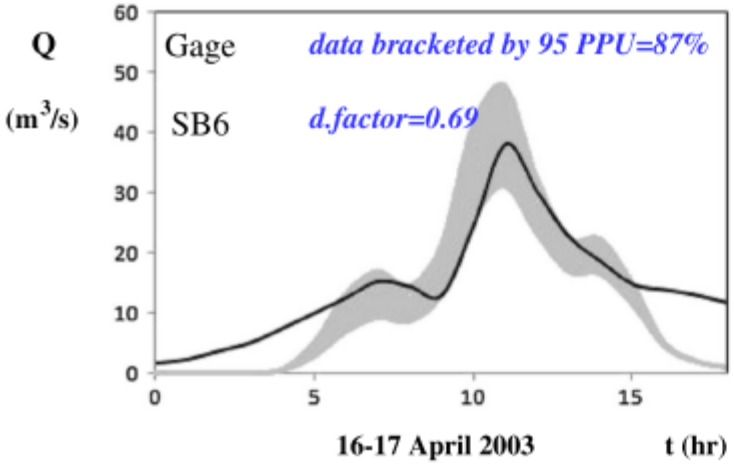
Pagano et al (2016): Flood forecasting at the Australian Bureau of Meteorology

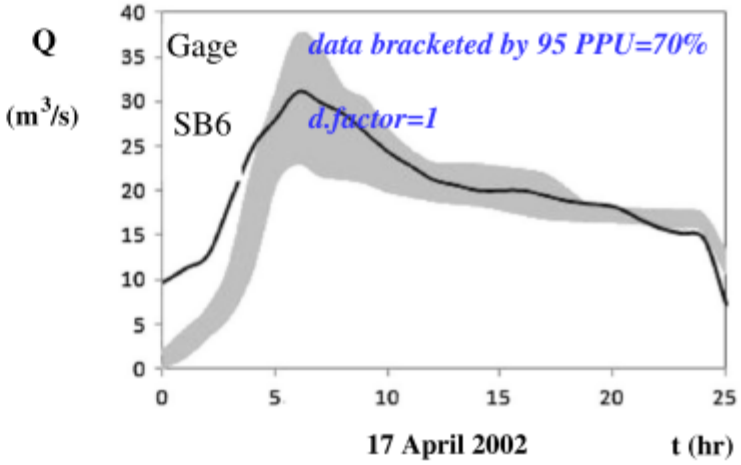


Laio, F., Porporato, A., Revelli, R., & Ridolfi, L. (2003). A comparison of nonlinear flood forecasting methods. Water Resources Research, 39(5)

Event-based methods

- URBS, RORB
- HEC-HMS
- SCS-CN
- …

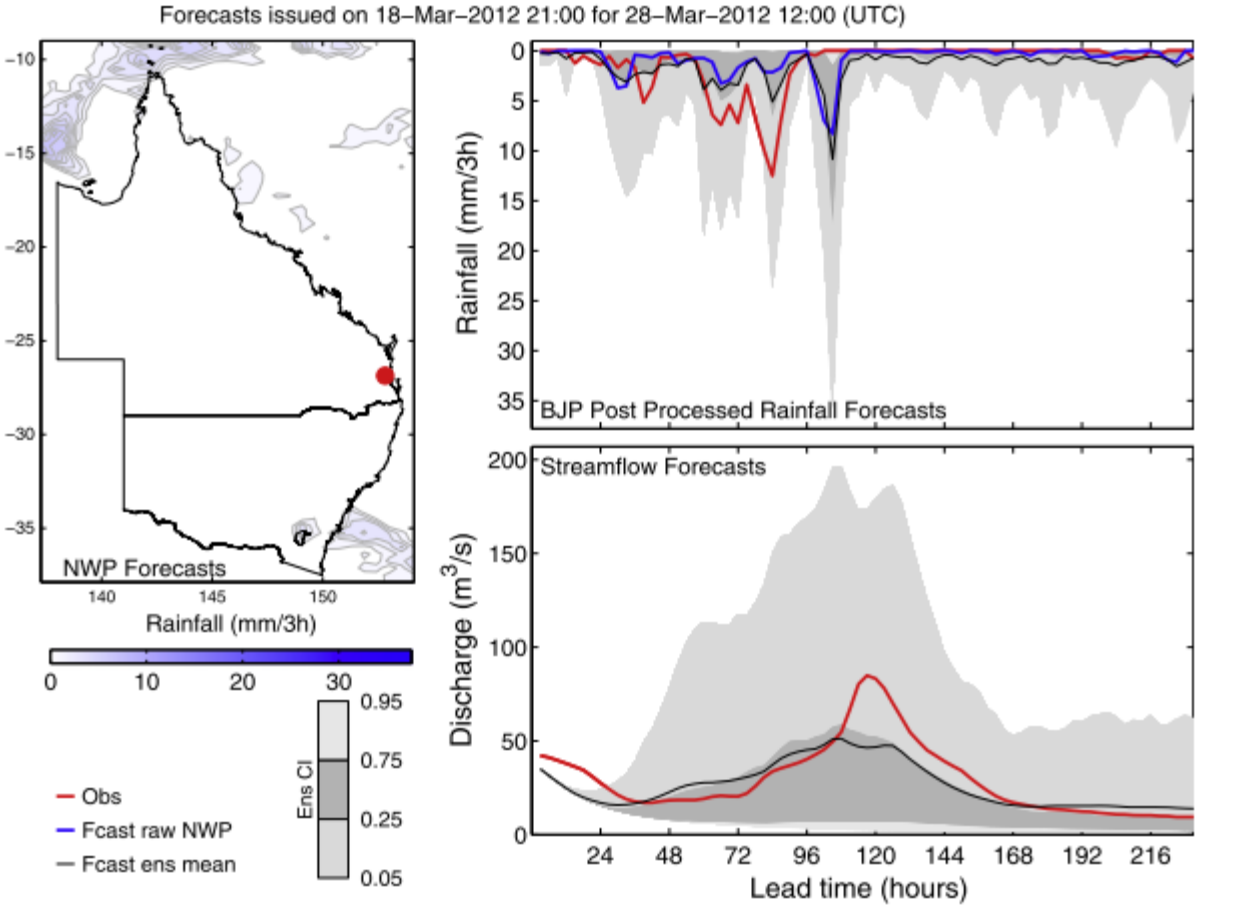




Yazdi, J., Salehi Neyshabouri, S. A. A., & Golian, S. (2014). A stochastic framework to assess the performance of flood warning systems based on rainfall-runoff modeling. *Hydrological Processes*, *28*(17), 4718–4731.

Continuous simulation methods

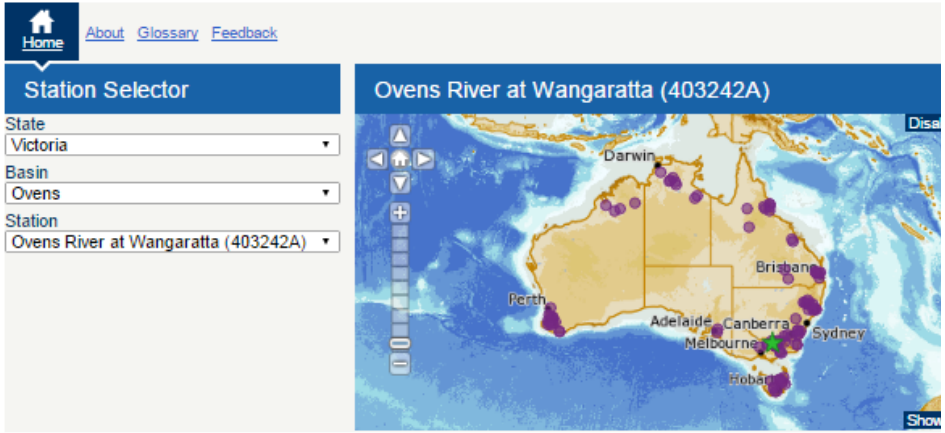
- GR4H/J
- PDM
- AWBM
- …



Bennett, J. C., Robertson, D. E., Shrestha, D. L., Wang, Q. J., Enever, D., Hapuarachchi, P., & Tuteja, N. K. (2014). A System for Continuous Hydrological Ensemble Forecasting (SCHEF) to lead times of 9days. *Journal of Hydrology*, *519*, 2832–2846.

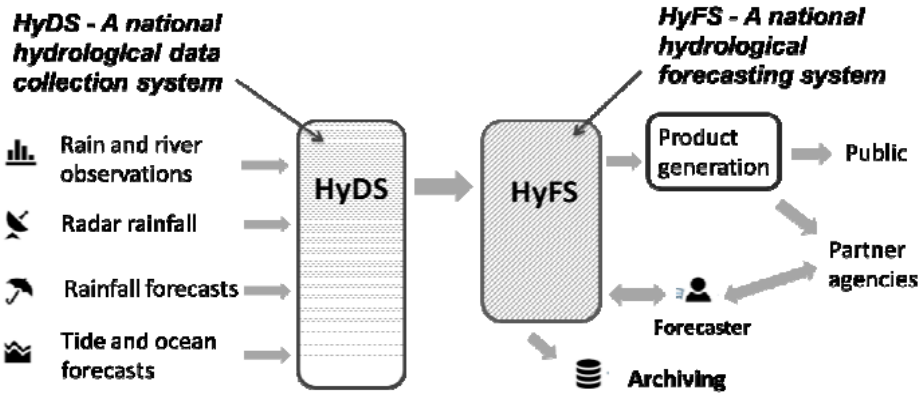
BoM Forecasts

SWIFT: 7-day streamflow forecasts



- BoM/WIRADA
- Continuous simulation
- GR4H/NWP & BJP post-processing
- "… *a burgeoning area of research*" (Perraud et al, 2015)
- "Scientific hydrology"

HyFS: Hydrological Forecasting System



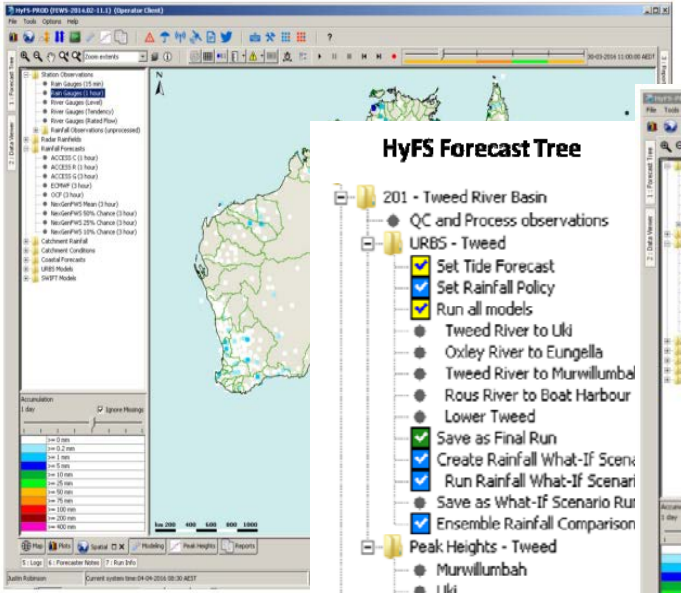
- BoM
- Event-based modelling
- URBS with rainfall forecasts in FEWS
- " … *a system integration challenge*" (me, *pers comm*)
- "Engineering hydrology"

BoM Forecasts: HyFS (Dec 2015)

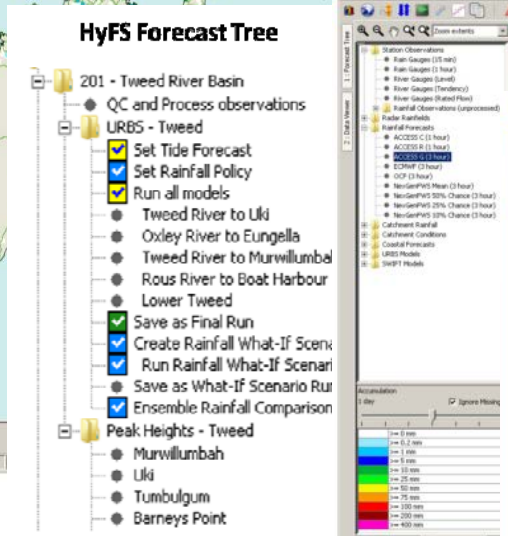
HyDS - A national hydrological data collection system

- Rain and river observations
- Radar rainfall
- Rainfall forecasts
- Tide and ocean forecasts

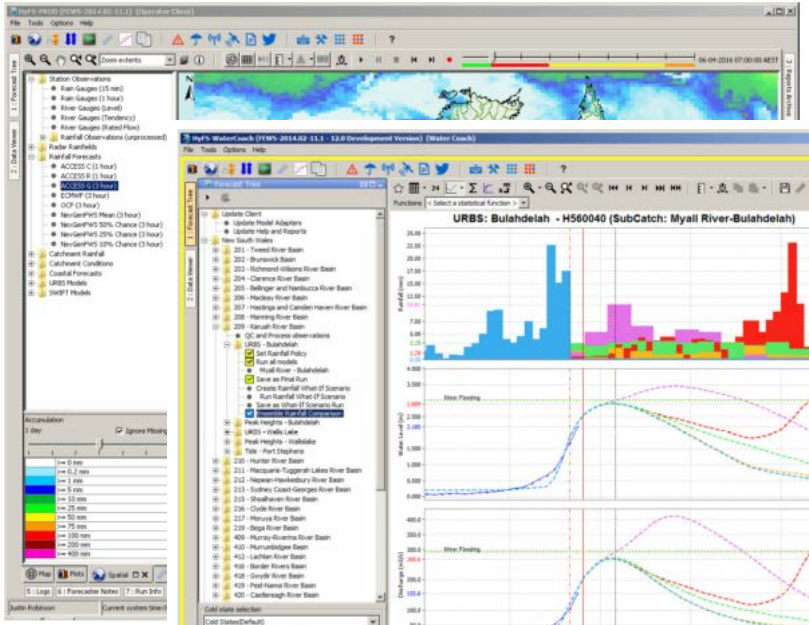
HyFS system



Rainfall gauges



Forecast process



Rainfall

Ensemble comparison forecasts

Robinson, et al (2016). Introducing the Bureau's New Hydrological Forecasting System. In *FMA National Conference* (pp. 1–16).

Dogma or Context?

"*Despite all the good reasons advanced by hydrologists for using continuous approaches, practitioners often continue using event-based models and see them as the only solution*"

Berthet, L., Andréassian, V., Perrin, C., & Javelle, P. (2009). How crucial is it to account for the Antecedent Moisture Conditions in flood forecasting? Comparison of event-based and continuous approaches on 178 catchments. *Hydrology and Earth System Sciences Discussions*, *6*, 1707–1736. http://doi.org/10.5194/hessd-6-1707-2009

"The demand for longer lead times and more accurate forecasts has driven the Bureau's recent investment in continuous models"

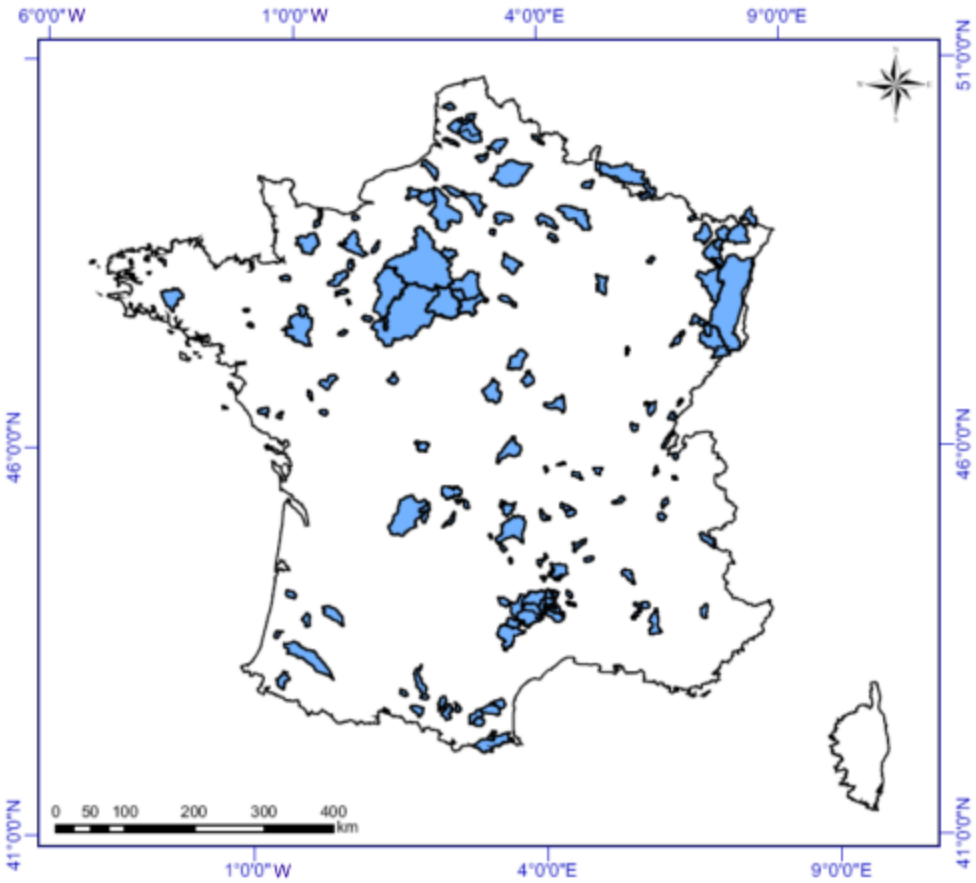
Pagano, T., J.F. Elliott, B.G. Anderson, J.K. Perkins (2016): Chapter 1 – Flood Forecasting at the Australian Bureau of Meteorology. In Adams and Pagano (eds) "*Flood Forecasting A global perspective*". Academic Press.

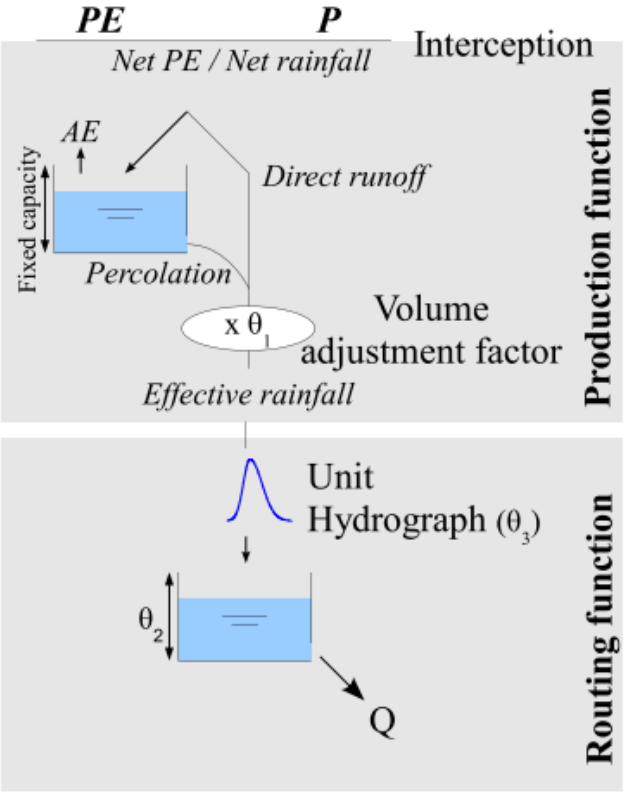
Efficacy of event vs continuous models

- Comparison of event & continuous models in 178 catchments across France
- Lumped model (derived from GR4J) that includes soil moisture and routing
- Updating based on assimilating previous Q_{obs} and Δ_{err}
- Identical models except for initialisation of soil moisture:
  - "Poor Man's" estimate
  - "Average" estimate
  - Based on API

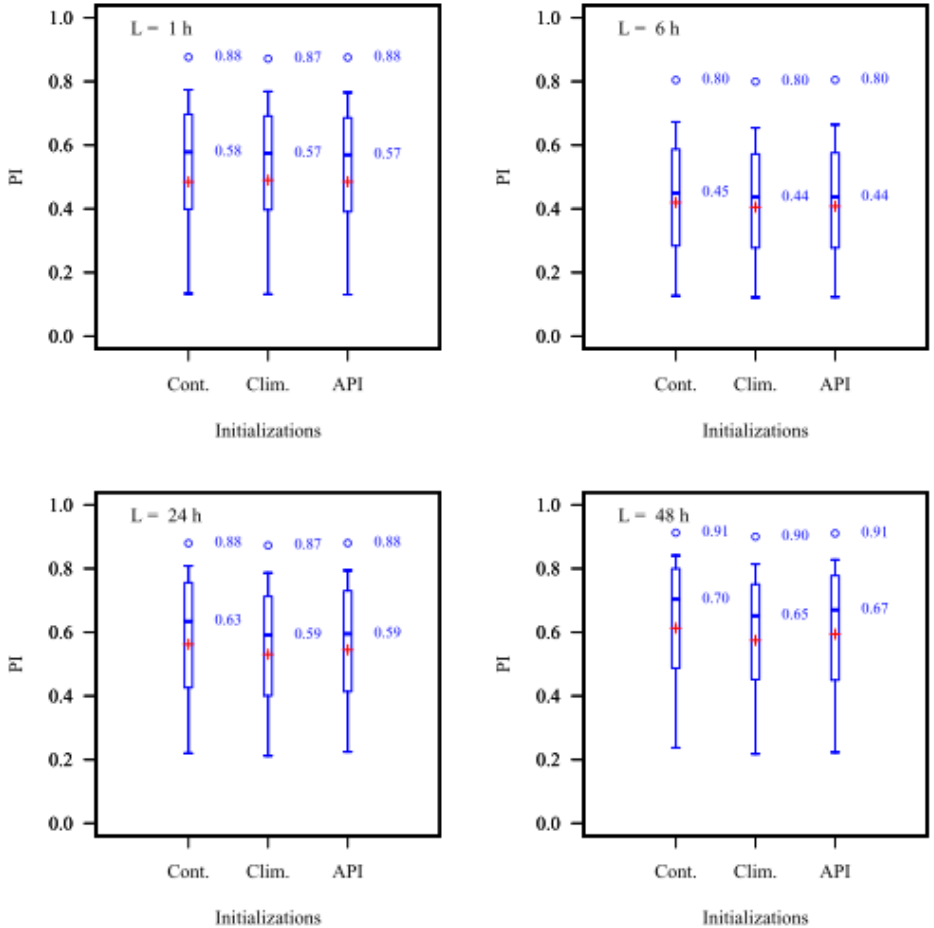
  } Event-based
  - Continuous accounting (1 year warm up period) Continuous

Efficacy of event vs continuous models





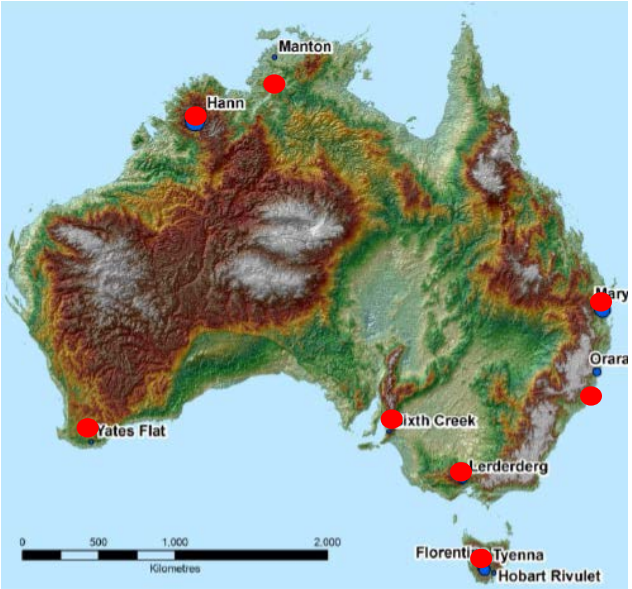
Efficacy of event vs continuous models



"The main conclusion is that the best results were obtained when the model was run in a continuous mode… we believe that these results are not catchment-dependent (in particular we found no relation to catchment size or reactivity)"

Probabilistic flood risk

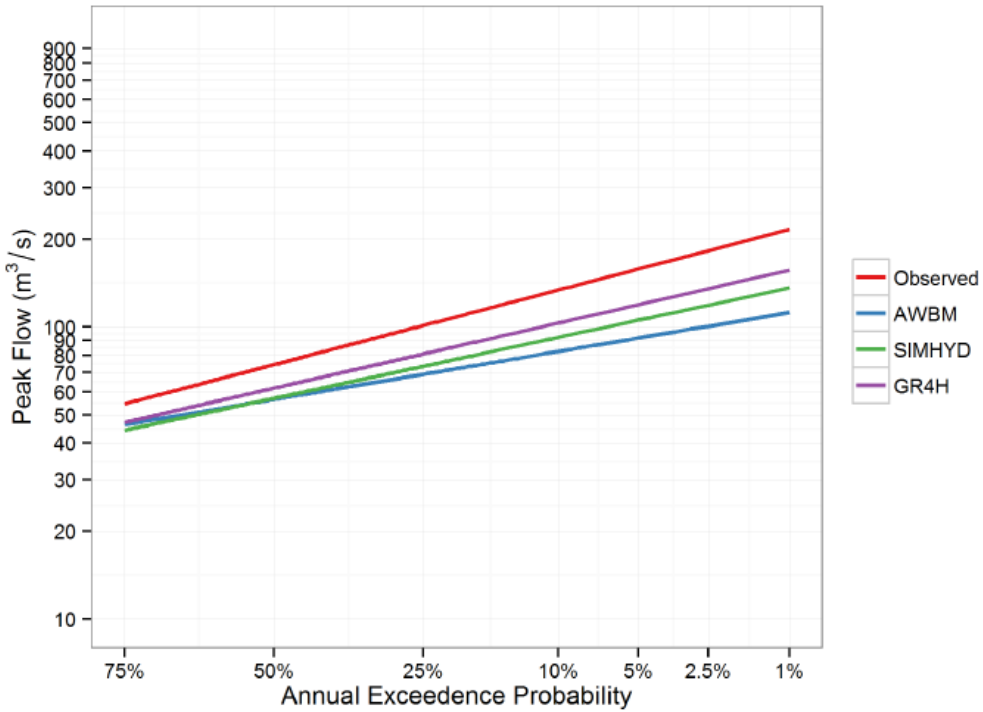
- Comparison of event and continuous models:
  - AWBM, SIMHYD, GR4H
  - storage routing model (simple and PDM-style losses)
- Continuous simulation:
  - Whole record
  - Subset of record
  - Large events
  - Flood frequency curve
- Event modelling:
  - Ensemble event
  - Monte Carlo

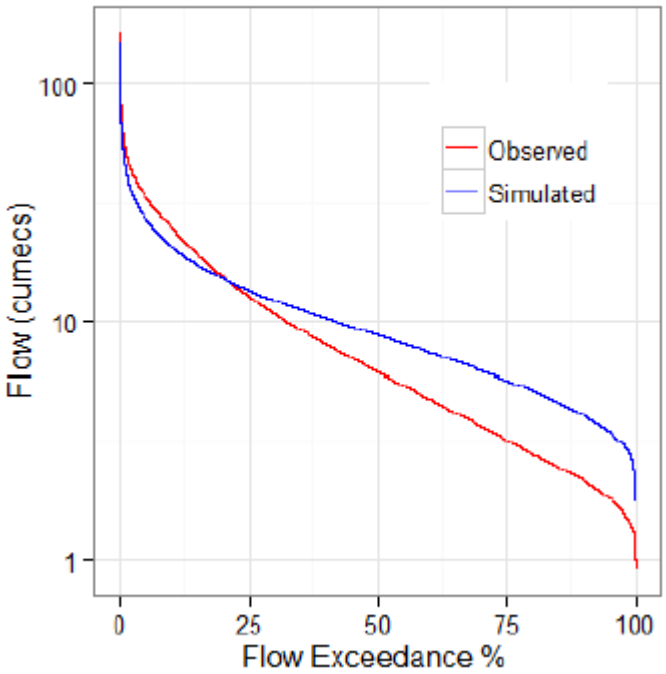


Ling et al (2015): Use of continuous simulation models for design flood estimation. ARR Project report, Dec 2015.

Probabilistic flood risk

Calibrated to whole record





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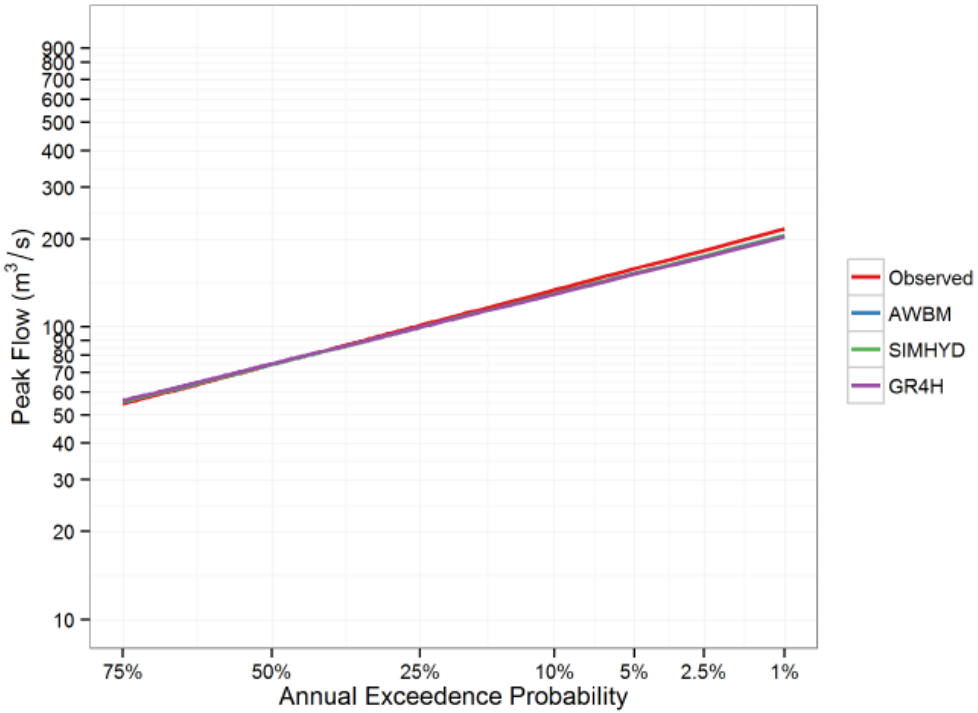
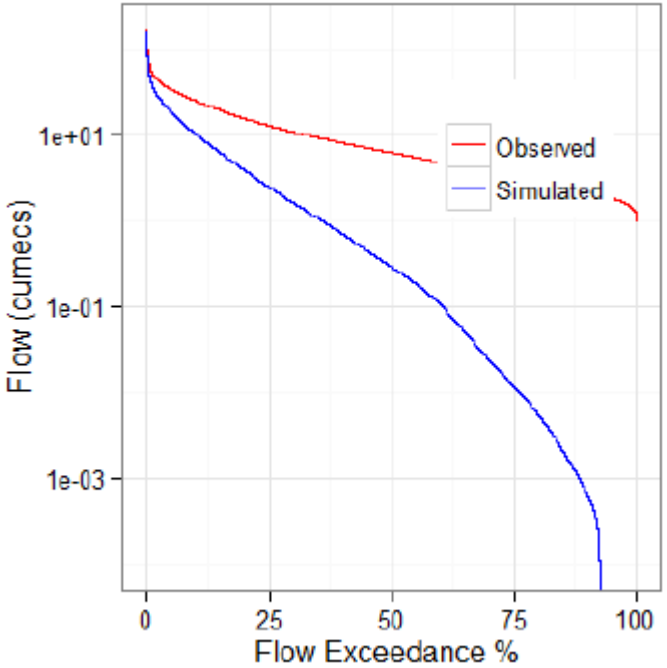
Probabilistic flood risk

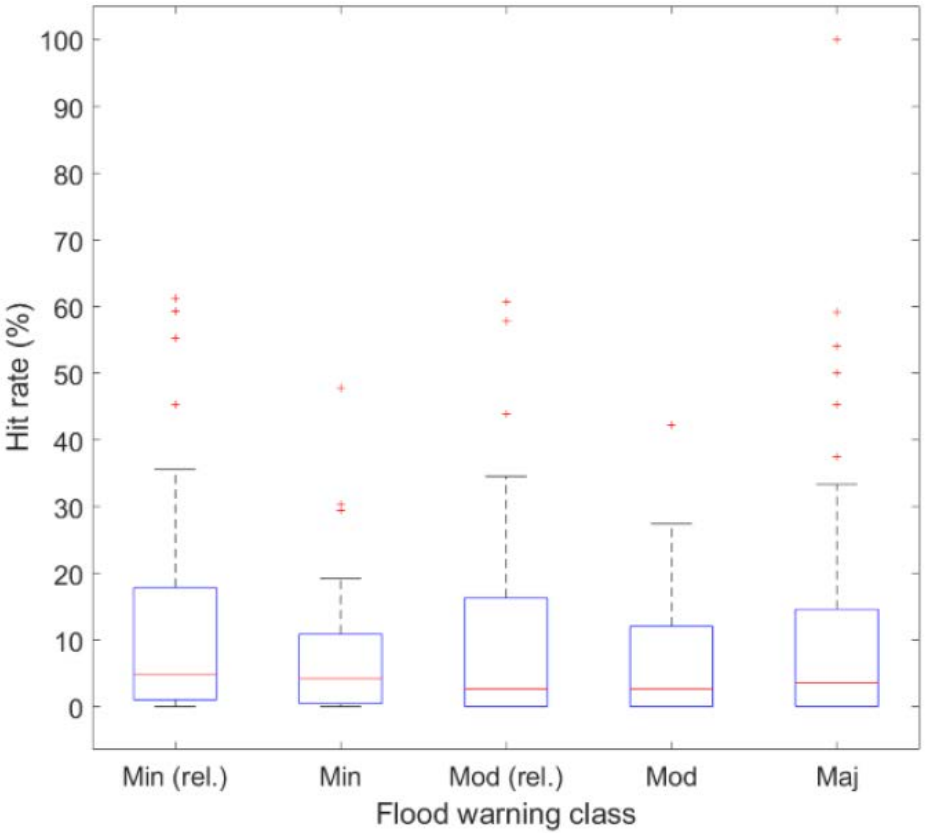
Calibrated to flood frequency curve

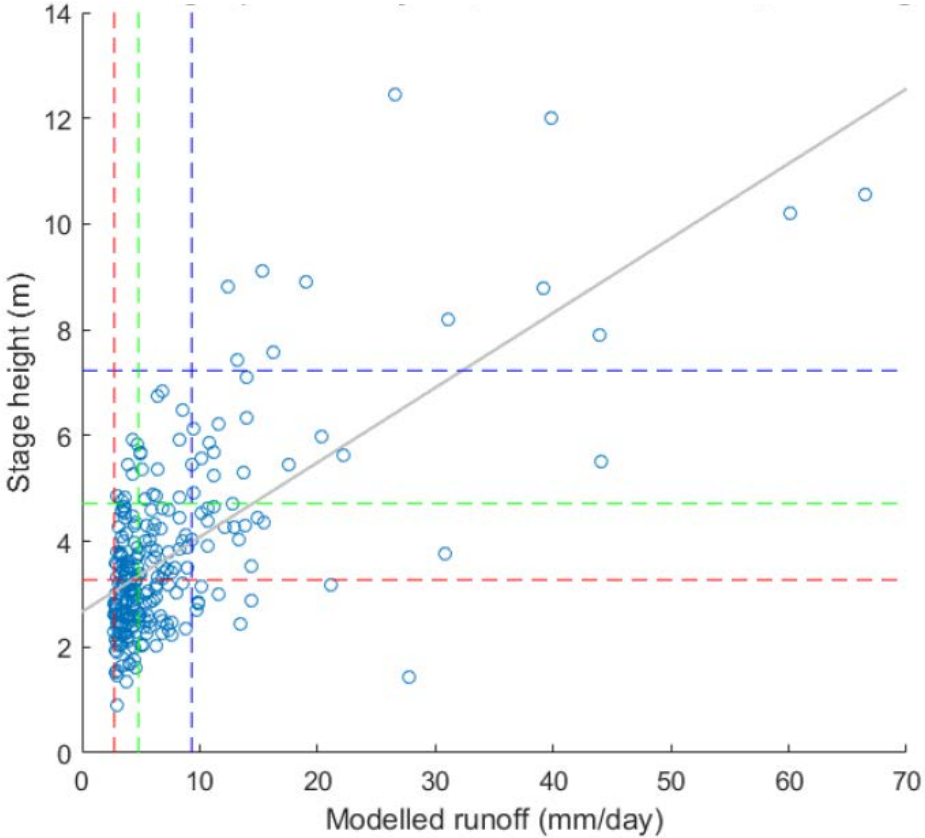




Ling et al (2015): Use of continuous simulation models for design flood estimation. ARR Project report, Dec 2015.

Use of AWRA-L estimates

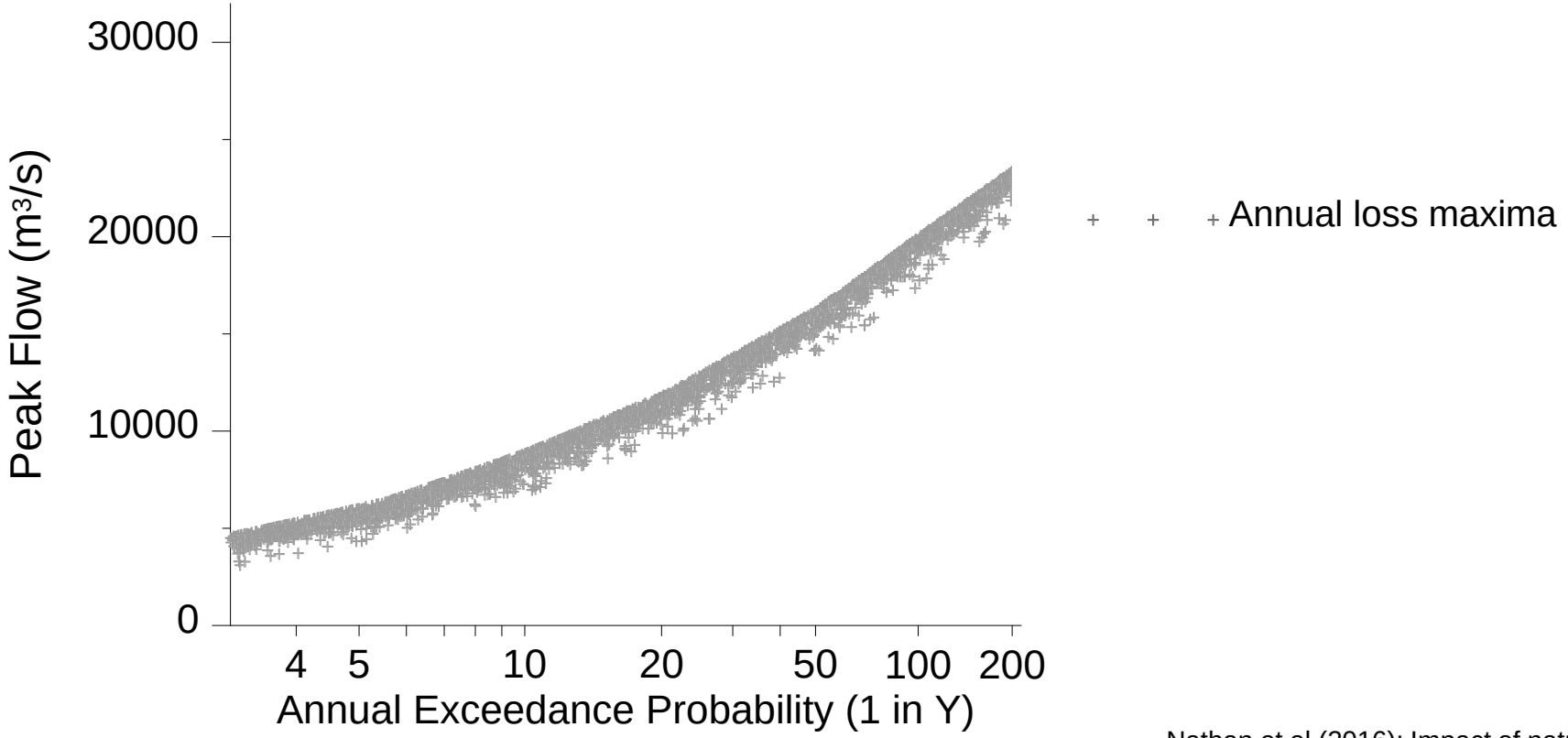




Chua et al (2016): Evaluation of the flood forecasting performance of AWRA-L. M.Env.Eng. Research Project Report, Uni Melb.

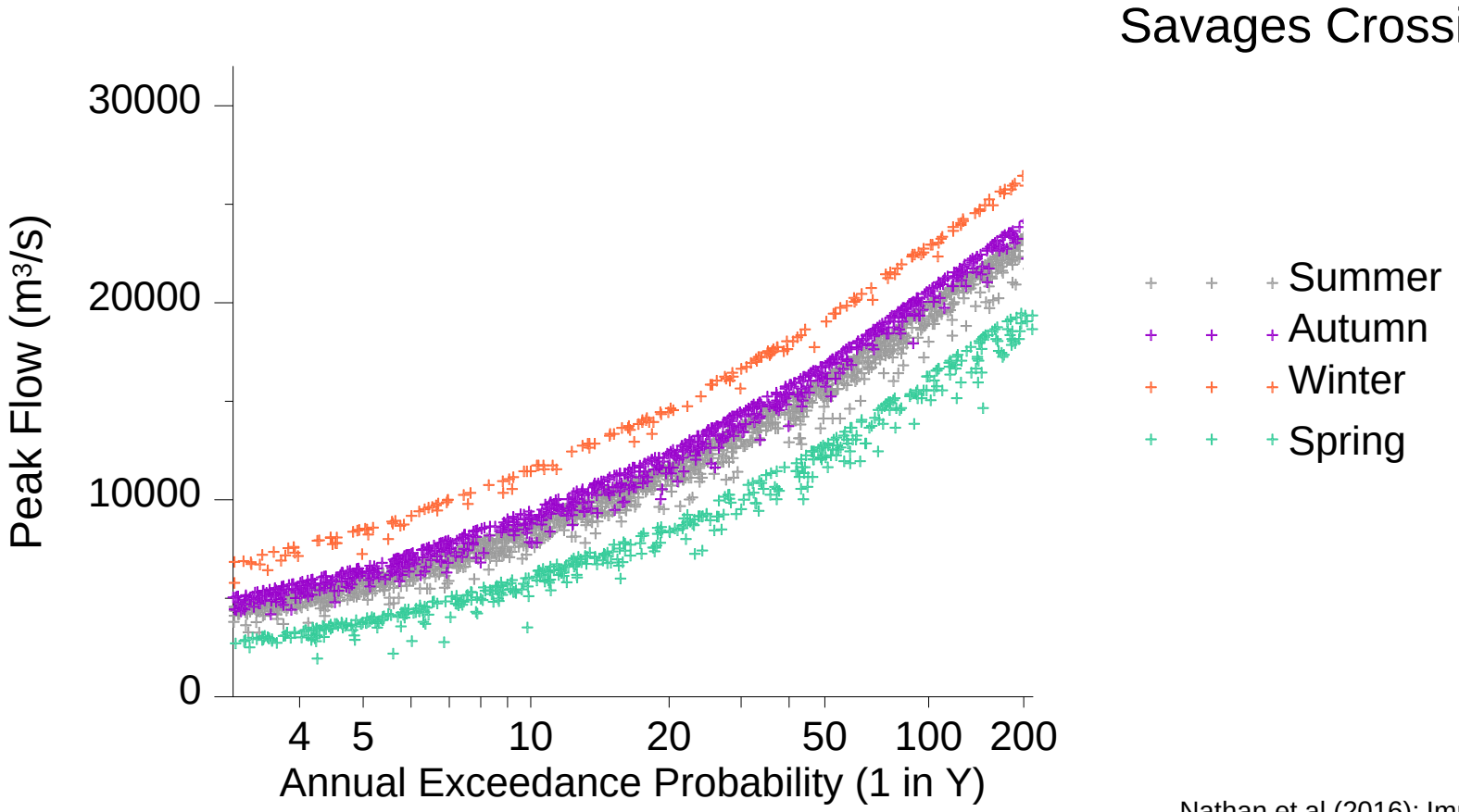
Monte Carlo: annual losses

Savages Crossing



Nathan et al (2016): Impact of natural variability on design flood flows and levels. HWR, NZ.

Monte Carlo: seasonal losses



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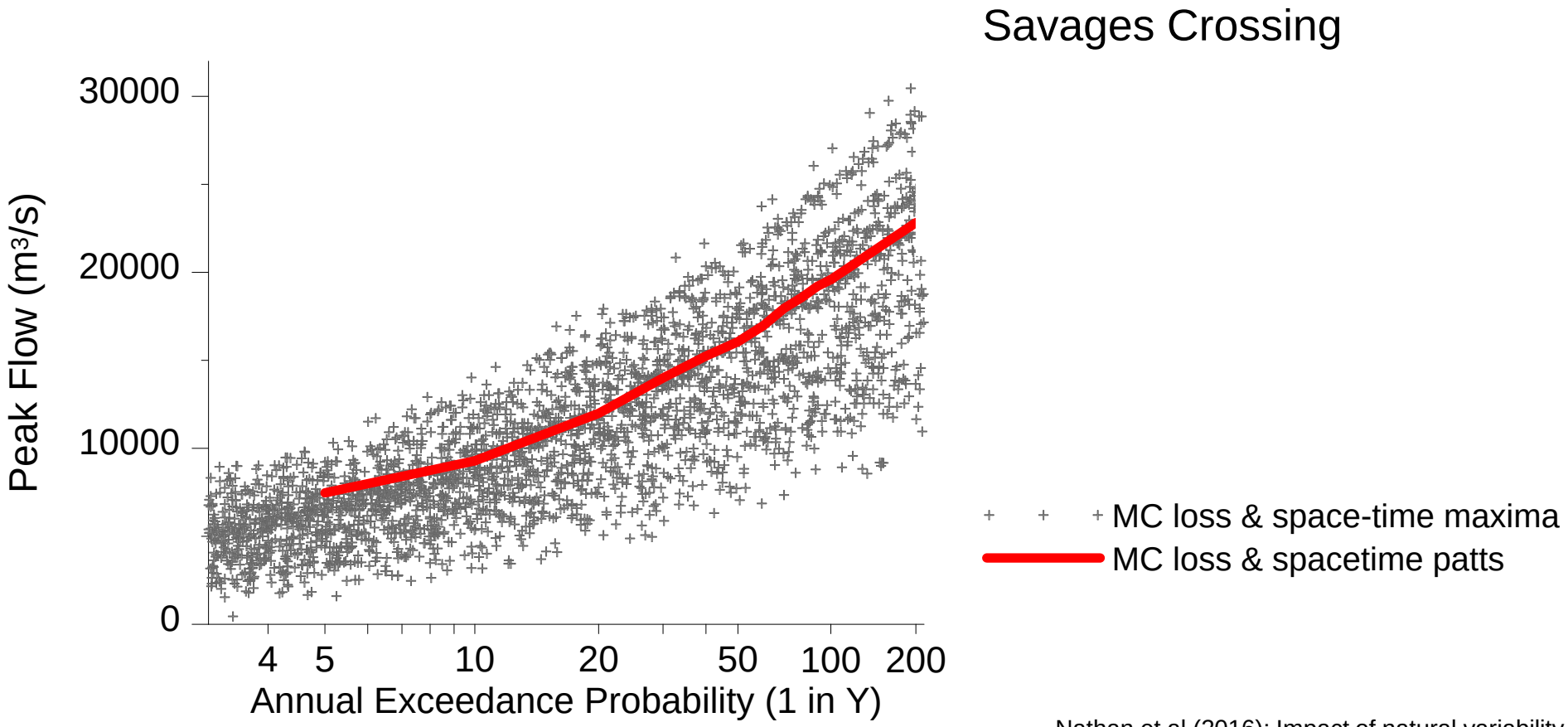
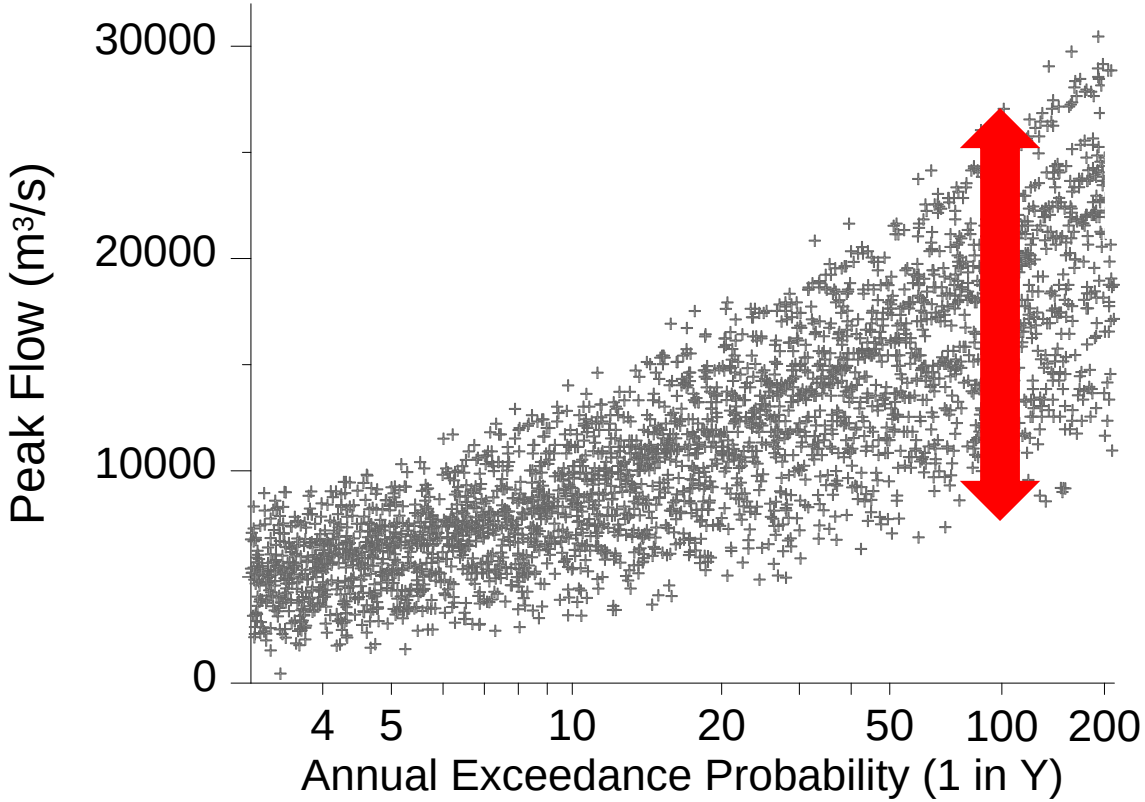
Monte Carlo: seasonal losses & spatio-temporal patterns



Nathan et al (2016): Impact of natural variability on design flood flows and levels. HWR, NZ.

Monte Carlo: Losses & Temporal Pats

Savages Crossing

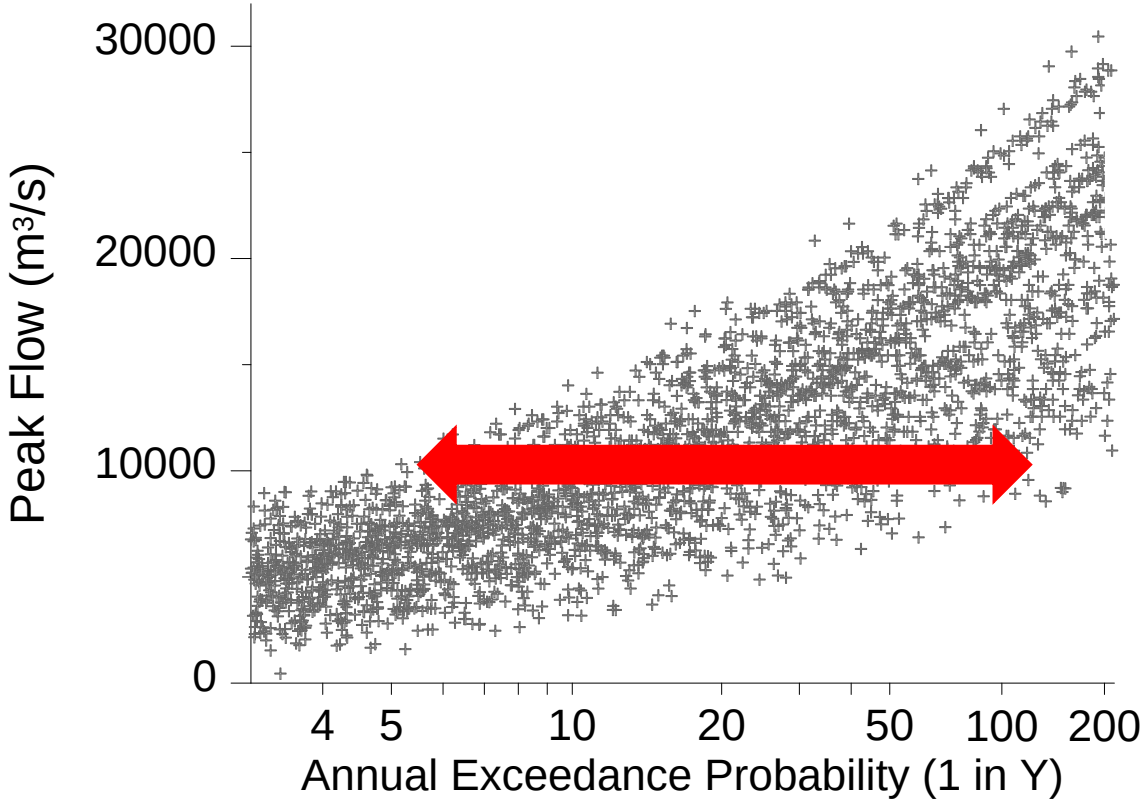


1:100 AEP rainfalls:
8000→26000 m^3/s

Nathan et al (2016): Impact of natural variability on design flood flows and levels. HWR, NZ.

Monte Carlo: Losses & Temporal Pats

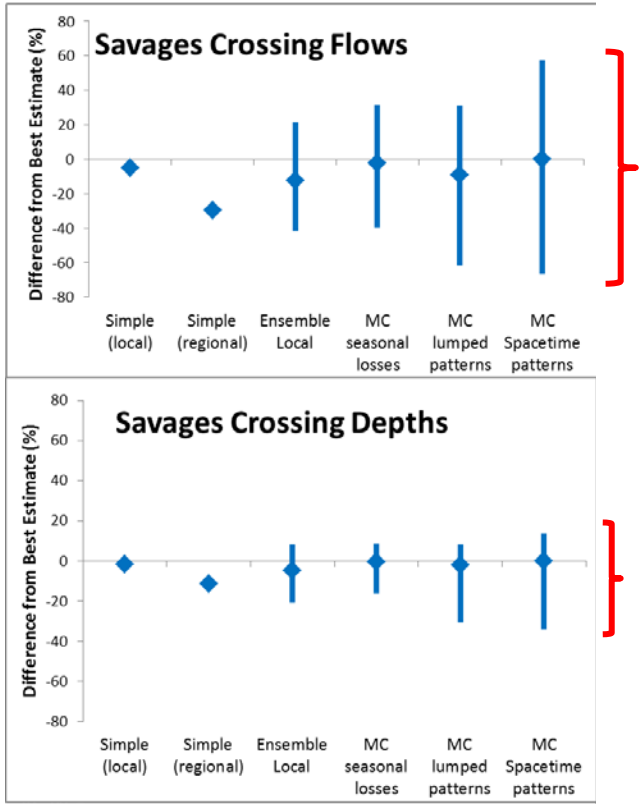
Savages Crossing



10000 m^3/s result from
1:5 → 1:100 AEP rainfalls

Nathan et al (2016): Impact of natural variability on design flood flows and levels. HWR, NZ.

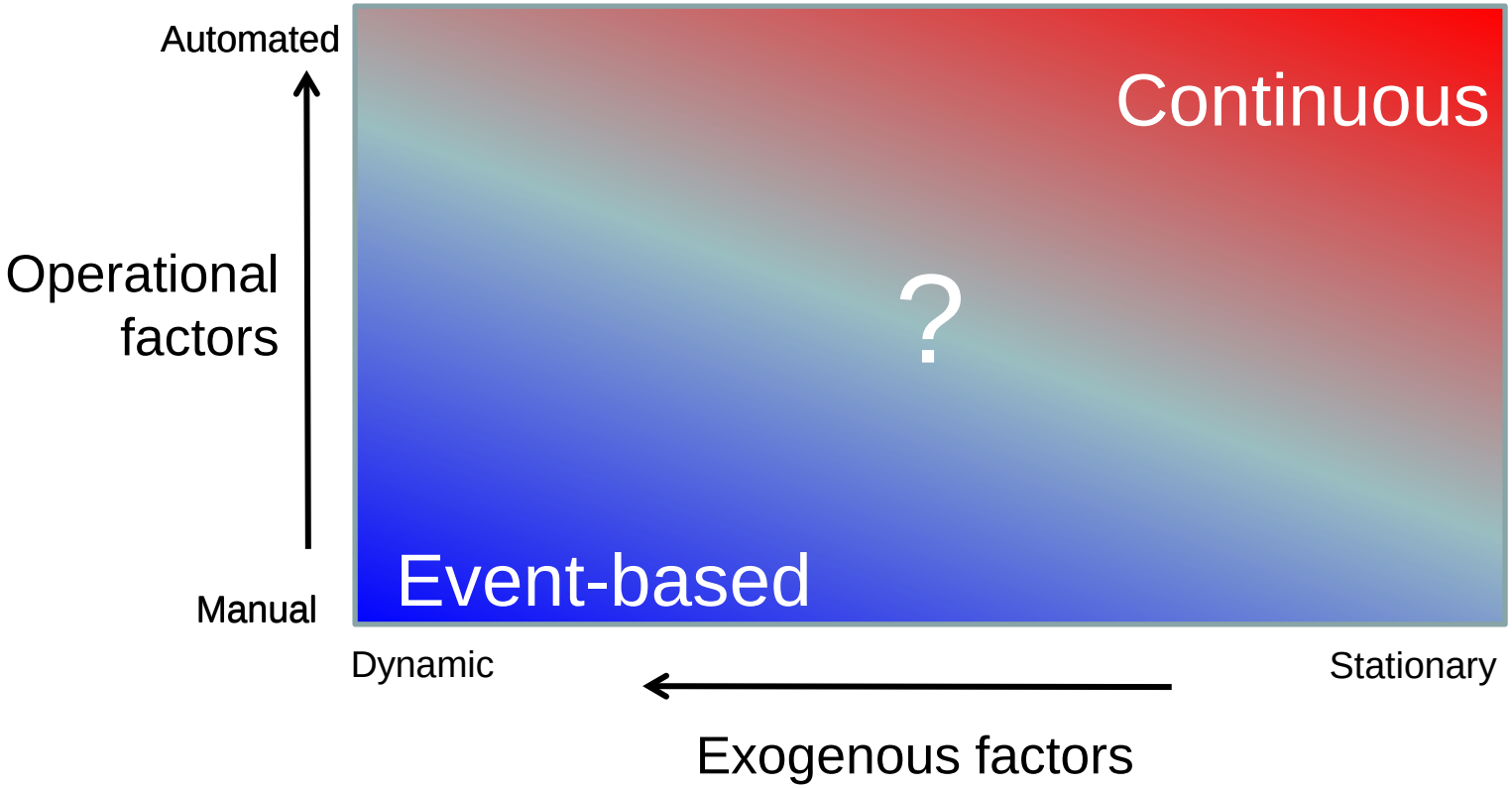
Propagation of Aleatory Uncertainty



Influence of aleatory uncertainty reduces when floods -> levels

Nathan et al (2016): Impact of natural variability on design flood flows and levels. HWR, NZ.

Factors affecting applicability



Factors affecting flood events

Automated

Operational factors

Manual

Probability distributions of:

Continuous

- Areal rainfall depth
- Temporal characteristics
- Spatial characteristics
- … at multiple locations (not just catchment average)

Antecedent initial soil moisture soon computed

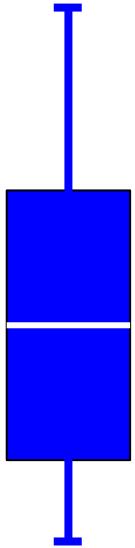
Event-based

Dynamic

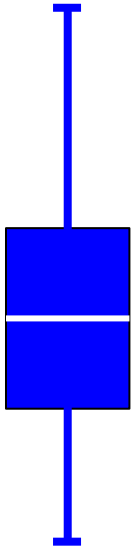
Stationary

Exogenous factors

Some useful forecast outputs



Time to peak



Flood depth

= fn (rainfall forecast, hydrological model, operational factors hydraulic modelling)

Conclusions

- Tremendous advances made in science of forecasting using continuous simulation models
- In contrast, attention given to event-based models has largely tackled engineering and system integration issues
- There is a clear requirement for both approaches:
  - “automated” routine forecasts for large regions
  - “manual” operational forecasts during flood events in specific catchments
- Relative accuracy of either approach under forecast uncertainty depend on operational and exogenous factors

Thank you!

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