An efficient hybrid causative event-based approach for estimating flood frequency

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Motivation: How will we pragmatically estimate the flood frequency distribution under climate change?

Background & Aims

Best potential for predicting climate change: Derived Flood Frequency Methods

- Rainfall Model => Hydrological Model => Flood Frequency Distribution

Derived Flood Frequency Approaches Class 1: Event-based (EB)

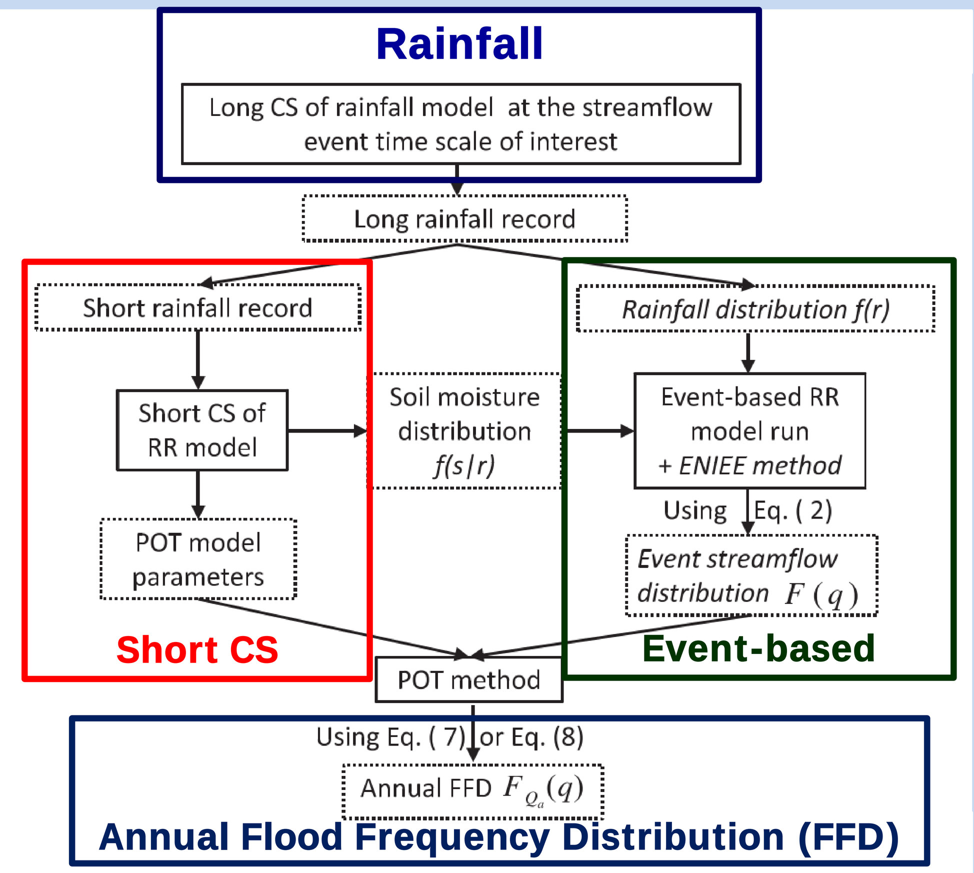
- Efficient: Focuses on extreme streamflow events of interest
- Requires distribution of extreme rainfall and antecedent soil moisture (catchment wetness)
- How will we estimate antecedent soil moisture under climate change?

Derived Flood Frequency Approaches Class 2: Continuous Simulation (CS)

- Robust: No need for assumed extreme rainfall/soil moisture distribution or AEP neutrality
- Computational intensive: 20% accuracy for 100 yr flood requires 10,000 yr simulation!!
- Not feasible for anything but simplest hydrological models

AIM: Develop method to estimate flood frequency by combining efficiency of event-based with robustness of continuous simulation

Hybrid Causative Event (HCE) Method



See Li et al (2014) for detailed description of methodology including description of symbols, equations and abbreviations

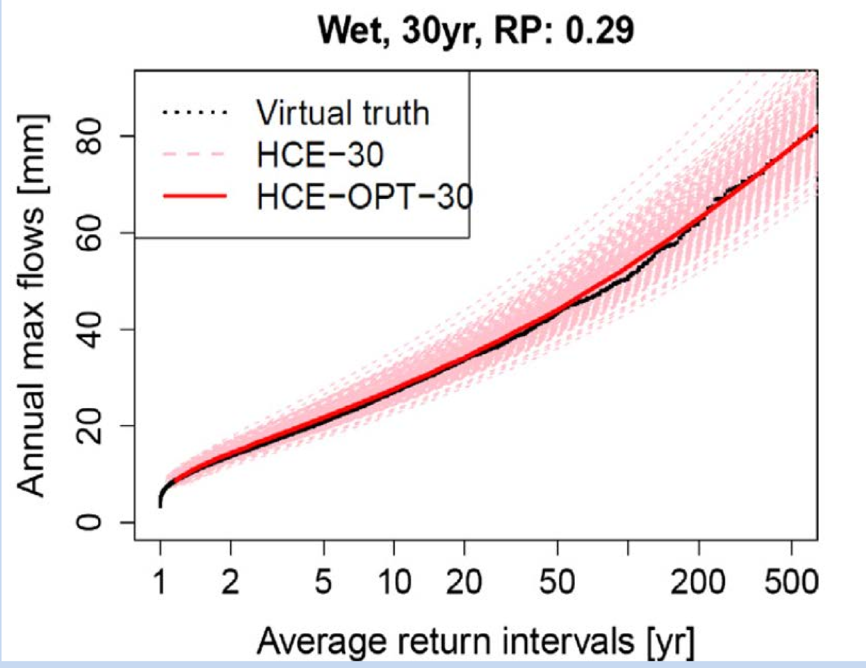
- Short continuous simulation (CS) estimates soil moisture input to event-based approach
- Causative event-based approach combines extreme rainfall and soil moisture to estimate extreme event streamflow distribution and hence annual FFD
- Incorporates joint probability of extreme rainfall and soil moisture with minimal assumptions (e.g. No assumption of AEP neutrality: 100 yr rain produces 100 yr flood)

HCE evaluation (1): Proof of concept

Evaluated HCE using virtual laboratory approach (Li et al, 2014)

- Generated 'virtual truth': 10,000 year daily flow record using stochastic rainfall model and hydrological model
- Evaluated HCE approach against Flood Frequency Distribution from 'virtual truth'
- Stochastic rainfall model, Simple Markov model for occurrence, lognormal for amounts (no seasonality in rainfall or ET)
- Hydrological Model: Simplified HBV
- Two case study catchments: "Wet" (runoff ratio = 0.4) and "Dry" (runoff ratio = 0.16)

Results: HCE accurate and efficient

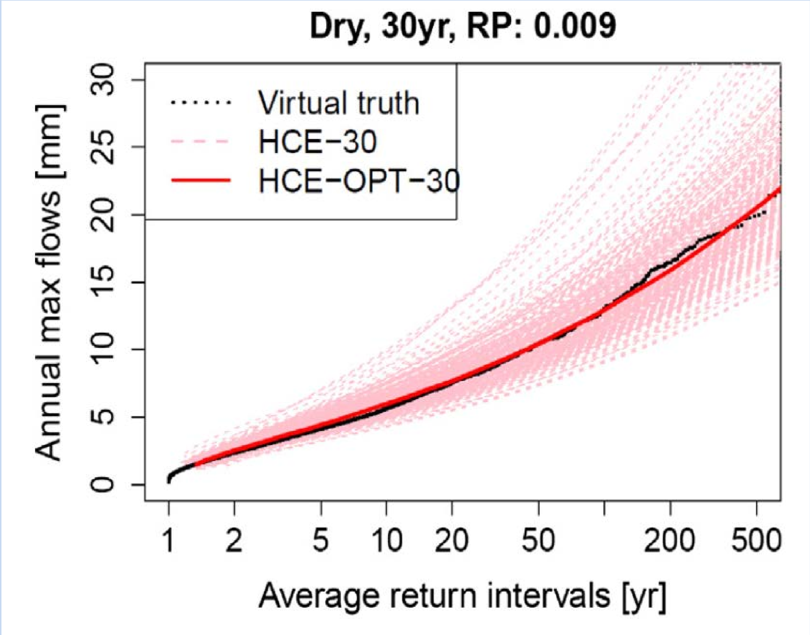


Accuracy:

Using only a 30 year CS HCE accurately simulates virtual truth flood frequency distribution

Efficiency:

HCE is 100-1000 times faster than traditional long continuous simulation



HCE evaluation (2): Incorporating seasonality

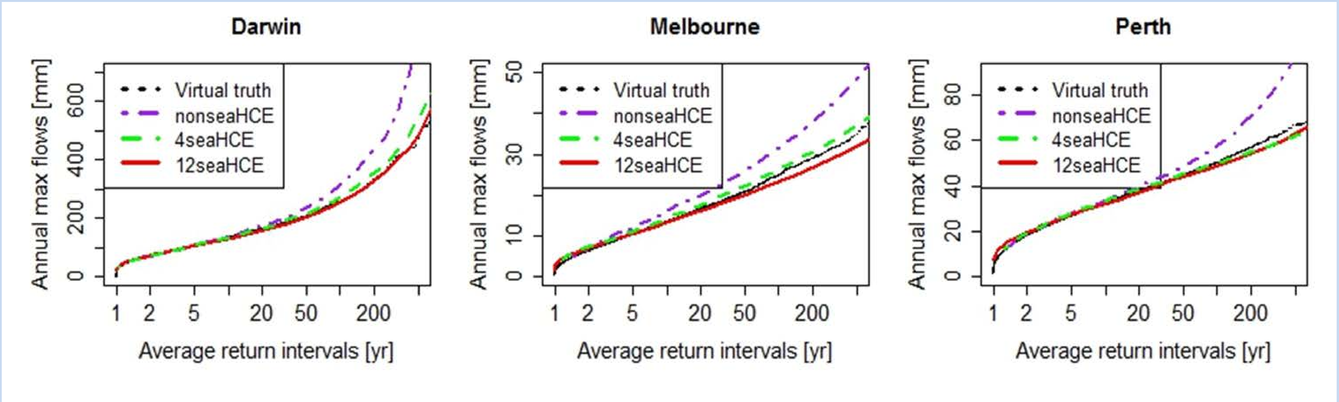
Extended HCE to incorporate seasonality (Li et al, 2015)

- Realistic Stochastic Rainfall (subdaily DRIP ,Heneker et al, 2001) with seasonality
- Realistic Hydrological Model: Calibrated GR4J (Perrin et al, 2003)
- Evaluated against generated 'virtual truth' FFD from 10,000 year daily flow record at multiple sites with wide range of climatologies:
- Virtual Data Available online (Thyer et al, 2015) https://goo.gl/2XhLfU

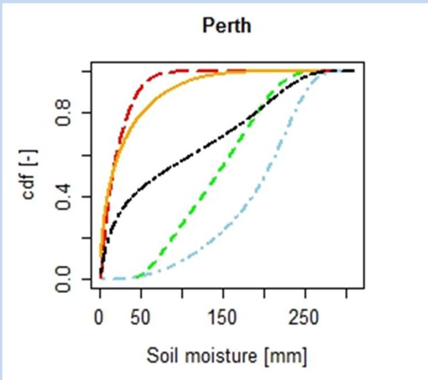
Table 1 Climate classification and rainfall characteristics of the chosen cities.

City	Climate zone	Rainfall characteristics
Adelaide	Mediterranean with mild winters and hot summers	Wet winters and dry summers
Alice Springs	Desert	Erratic rainfall with monsoon rains in summer and thunderstorms in spring
Brisbane	Humid subtropical with warm to hot summers and moderately warm winters	Wet summers featured in thunderstorms and dry winters with low rainfall
Darwin	Tropical savannah with similar average maximum temperature all year round	Distinct wet and dry (May to Sep) seasons with wet season featured in tropical cyclones and monsoon rains
Hobart	Mild temperate oceanic	Uniform rainfall
Melbourne	Moderate oceanic with warm to hot summers and cool winters	More severe events in spring and summer featured in thunderstorms, hail and heavy rain due to cold fronts
Perth	Mediterranean with very hot summers and mild winters	Marked wet winter and dry summer
Sydney	Temperate with warm summers and mild winters	Uniform rainfall

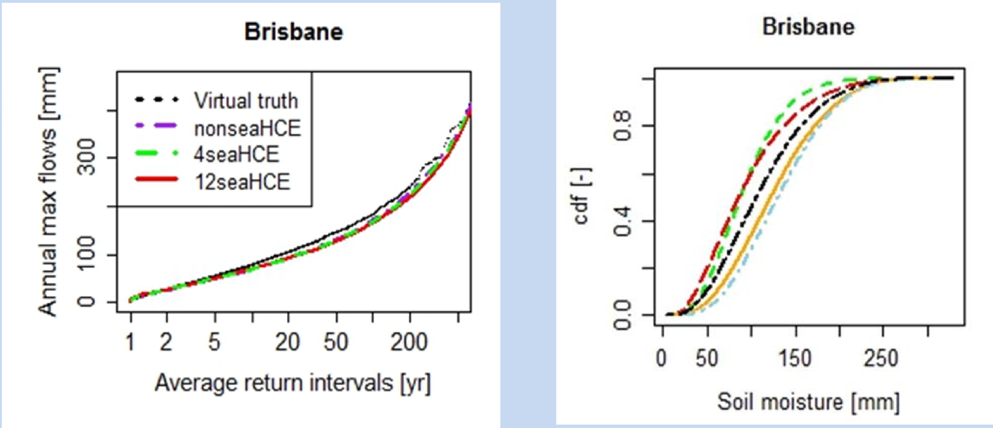
Highly seasonal soil moisture: seasonal HCE



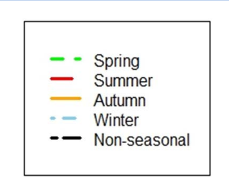
- Sites with high seasonality in soil moisture required seasonal HCE for accurate estimation of FFD
- Non-seasonal HCE over-estimates FFD
- Due to errors in estimation of seasonal rainfall and soil moisture distribution (see diagram at right)



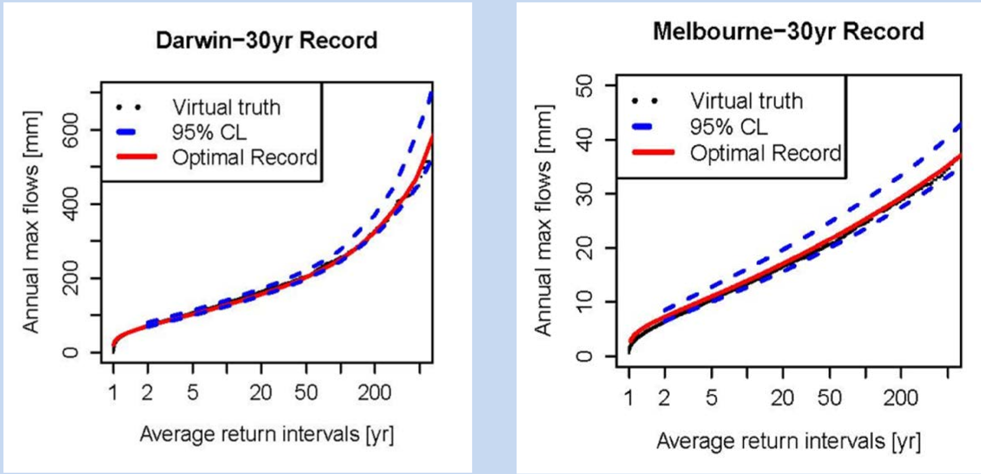
Low seasonal soil moisture: No seasonal HCE



Sites with low seasonality in soil moisture do not need seasonal HCE method



Seasonal HCE accurate with 'optimal' 30 yr record



Selecting an optimal short rainfall record of 30 yrs seasonal HCE produces accurate estimates of virtual truth flood frequency distribution

Future work

- Develop more realistic sub-daily event-based HCE: currently daily time step
- Develop more realistic HCE for multiple catchment model storages
- Evaluate HCE to capture impacts of climate change in virtual laboratory approach

References

Heneker, T. M., M. F. Lambert, and G. Kuczera (2001), A point rainfall model for risk-based design, *J Hydrol*, *247*(1-2), 54-71.

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Hybrid Causative Event-based approach accurately estimates flood frequency 100-1000 times faster than traditional continuous simulation approaches

Towards a pragmatic approach to estimate impact of climate change on flood frequency without need for a long computationally intensive continuous simulation