Statistical Modelling of Rainfall Intensity-Frequency-Duration Curves Using Regional Frequency Analysis and Bayesian Hierarchical Modelling

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IFD Curves and Climate Change

Methods for assessing how IFD curves may change under different emissions scenarios should:

- take into account **uncertainty** in the curves themselves
- be linked to **climate model outputs**, since models are the only tool we have to make future projections
- combine data **spatially** as well across **accumulation durations** in order to obtain more precise estimates of IFD curves

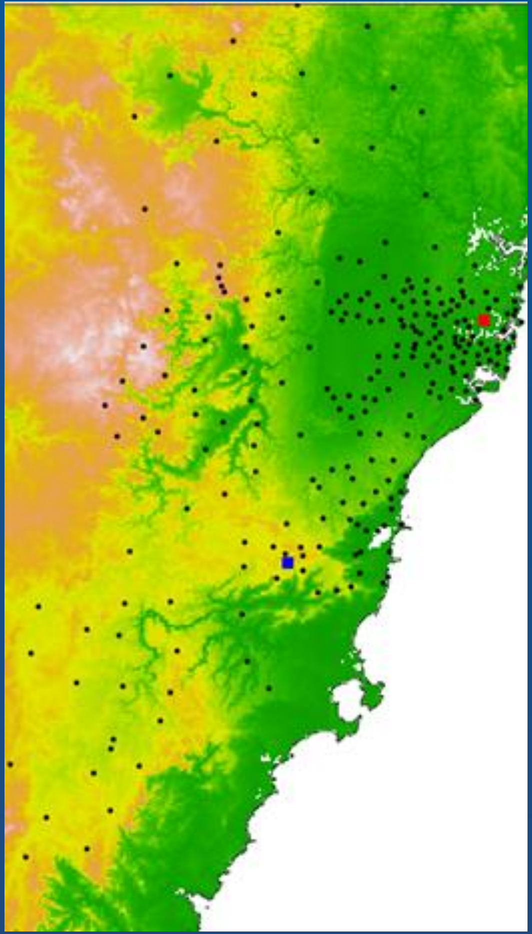
Objective: Develop a flexible framework for doing all of the above and compare with existing methods.

Data

- Greater Sydney Region (~160km x 340km)
- 242 pluviometer stations
- 1959 – 2002 period (7 – 41 year records)
- 5 min – 72 hour annual maxima extracted

Representative gauged location

Representative ungauged location



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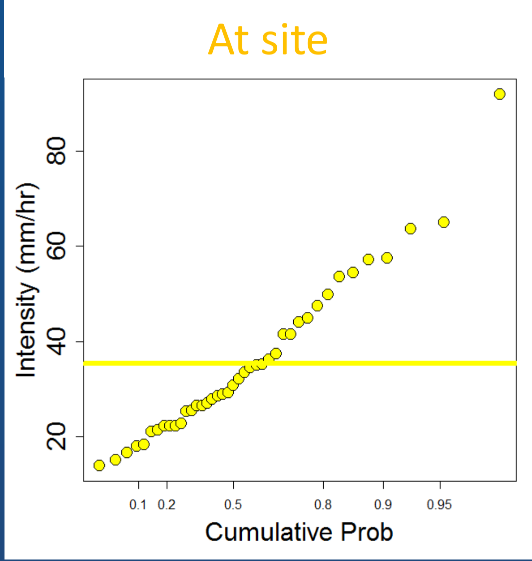
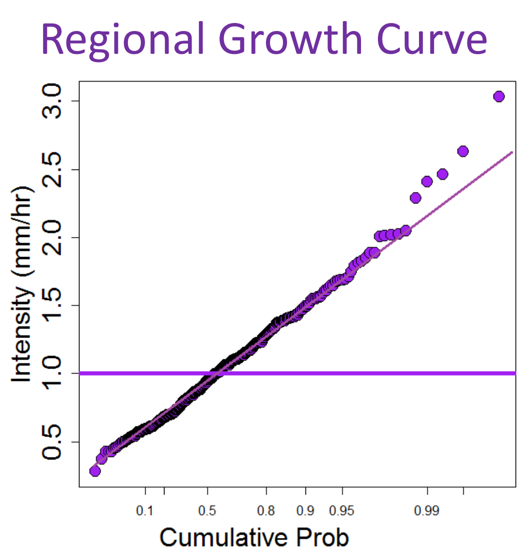
Regional Frequency Analysis

$$Y \sim \mathrm{GEV}\,(\mu,\sigma,\xi) = \exp\left\{-\left[1+\xi\left(\frac{y-\mu}{\sigma}\right)\right]^{-1/\xi}\right\},\ \xi \neq 0$$

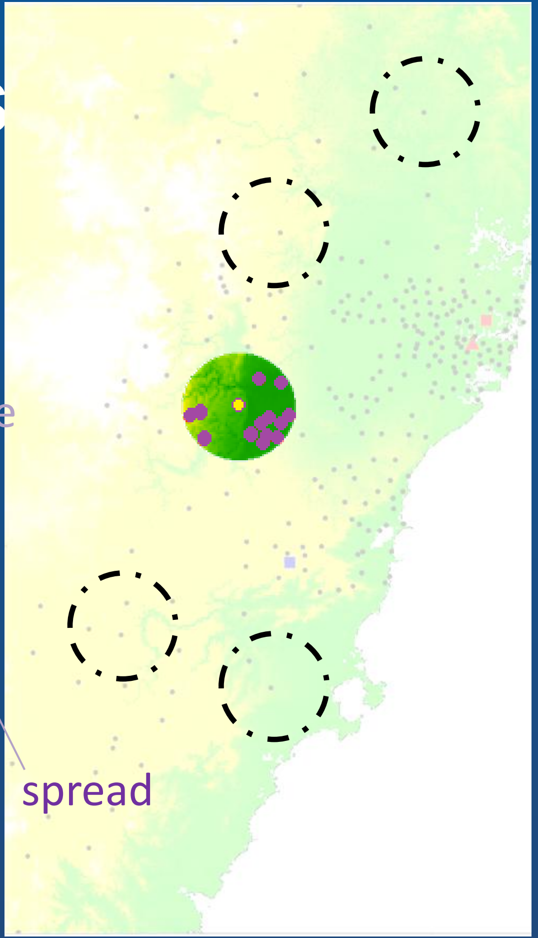
mean





shape

spread



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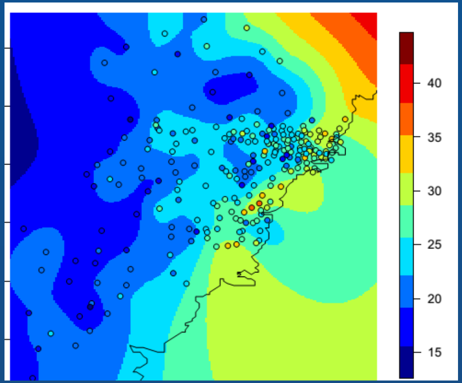
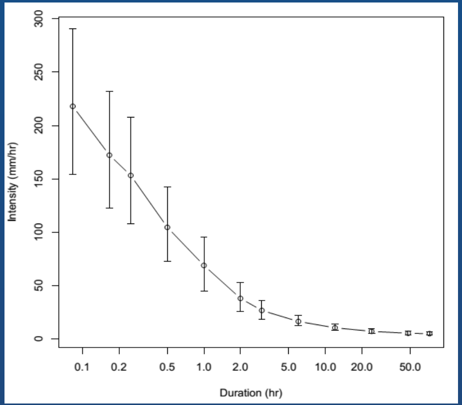
Regional Frequency Analysis

Estimates at ungauged locations are obtained by spline interpolation

Traditional boot-strapped RFA estimates do not account for all sources of uncertainty





Bayesian Hierarchical Modelling

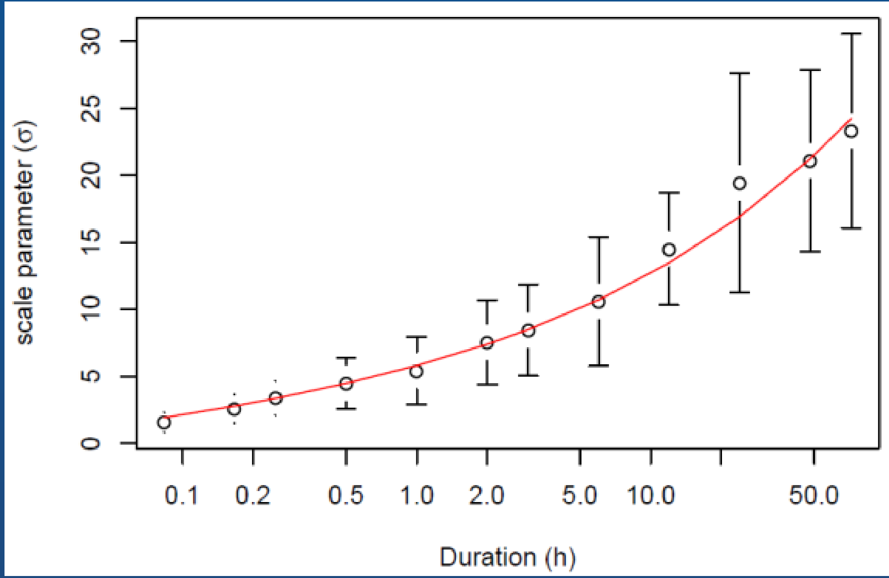
Data layer

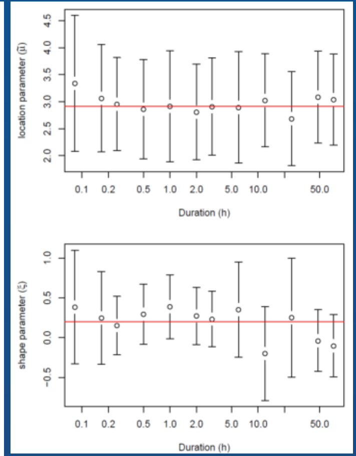
Precipitation maxima Y are GEV distributed:

$$Y \sim \mathrm{GEV}(\tilde{\mu}, \sigma_d, \xi)$$

Dependence on accumulation duration d (as per Koutsoyiannis *et al.*, 1998):

$$\sigma_d = \frac{\sigma \cdot d}{(d+\theta)^{\eta}}$$

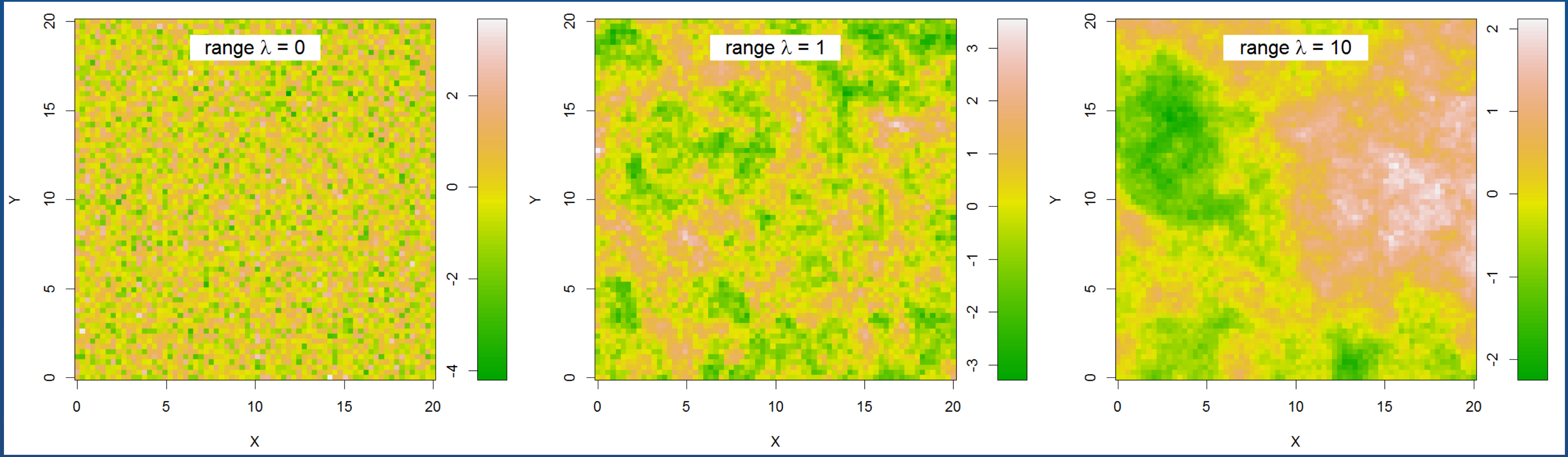




Bayesian Hierarchical Modelling

Process model: $\xi = \beta_0 + \beta_1 \cdot \mathrm{lat} + \beta_2 \cdot \mathrm{lon} + P(\alpha_\xi, \lambda_\xi)$

Examples of spatial process $P(.)$ with different range parameters:



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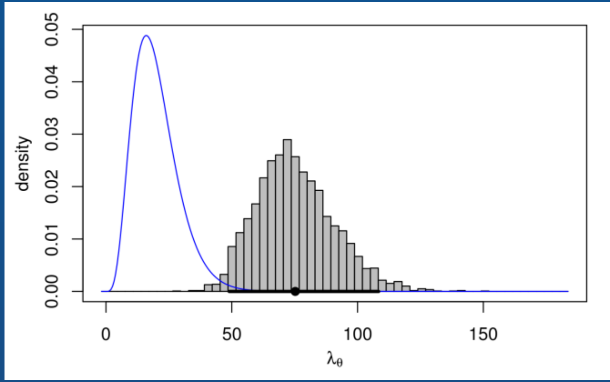
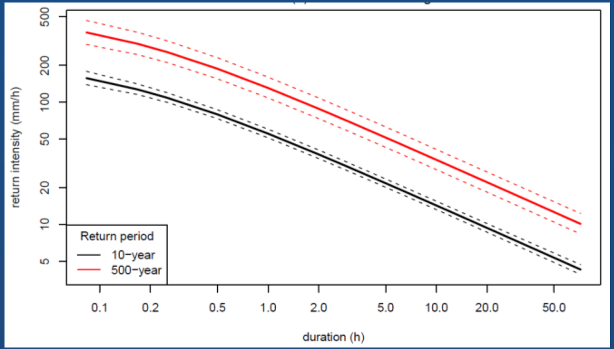
Bayesian Hierarchical Modelling

A unified and flexible statistical modelling framework:

- propagation of **uncertainty** from all layers to the posterior estimates of all variables (e.g. GEV parameters, IFD curves, etc.)
- **flexible framework:** easy to integrate covariates, dependence of parameters on accumulation duration, *r*-largest maxima, daily data, climate model outputs





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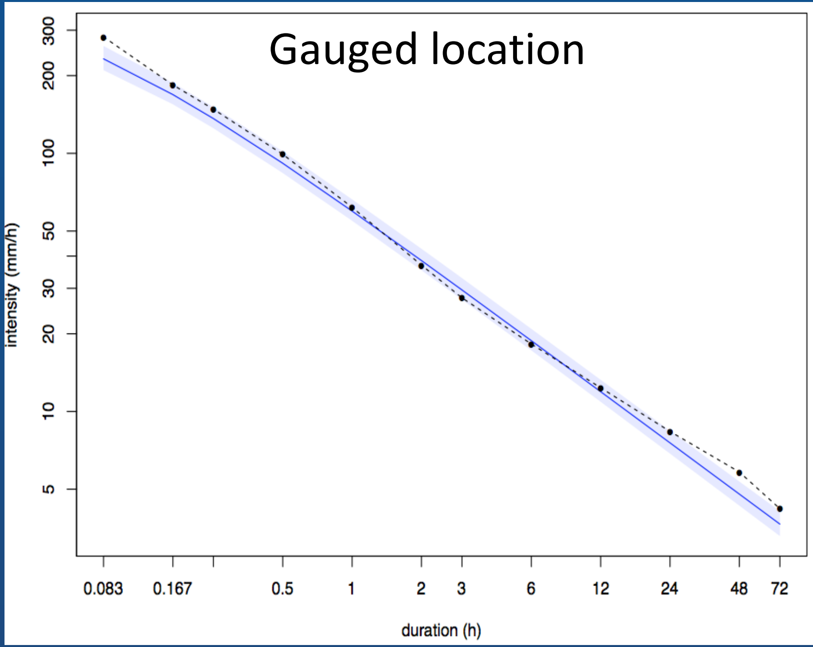
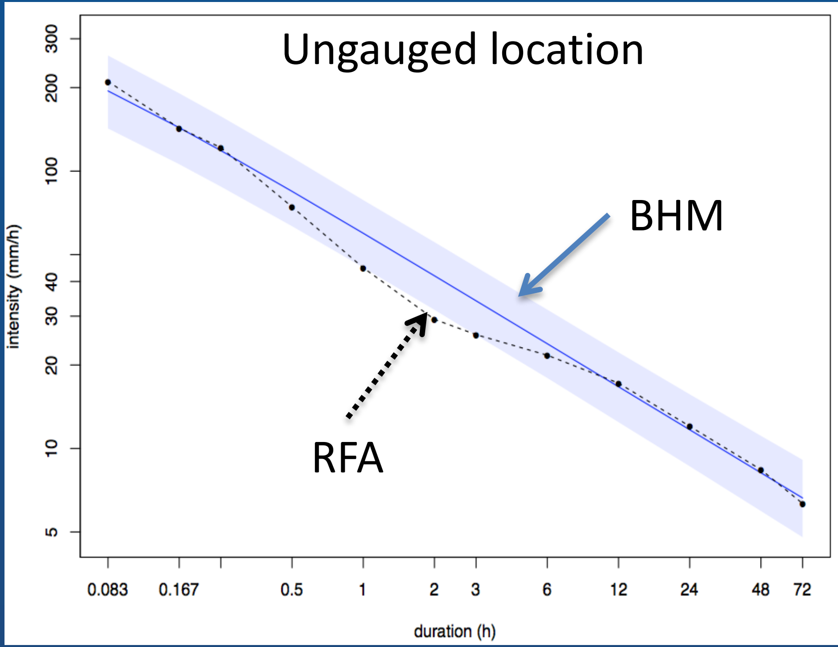
Comparison of BHM and RFA





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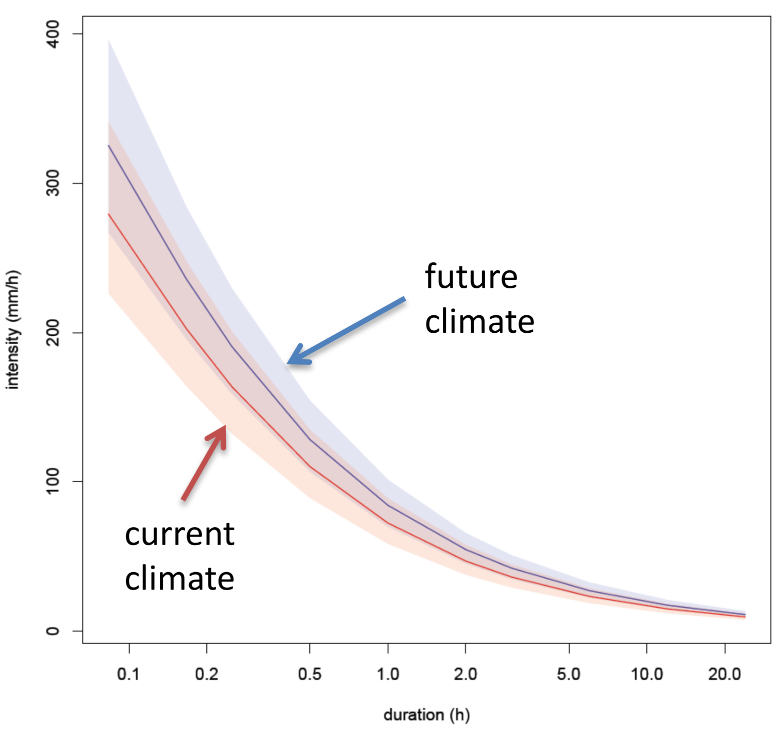
Bayesian Hierarchical Modelling

IFD curves under climate change

Integrate regional climate model (RCM) outputs as predictors of current extreme rainfall, then use future projections to model the future characteristics of extreme rainfall

$$\xi = \beta_0 + \beta_1 \cdot \mathrm{lat} + \beta_2 \cdot \mathrm{lon} + \beta_3 \cdot \xi_{\mathrm{RCM}} + P(\alpha_\xi, \lambda_\xi)$$



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Conclusion

- **Uncertainty** is an important aspect for assessing future IFD curves:
  - Bayesian hierarchical models provide a **coherent and flexible statistical framework** for estimating uncertainty
  - the uncertainty of IFD estimates varies with duration and location
- Some differences between RFA and BHM with current pluvio dataset, due to:
  - modelling of duration dependence in BHM
  - use of different spatial models and regions of influence
- Ongoing work:
  - further work on integration of climate models
  - use of “full” dataset (daily & pluvio)

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