water for liveability

MONASH University

Impact of OFs on models

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Introduction

- There are a vast range of objective functions used in urban drainage modelling

- Most have a focus/favour on certain parts of the dataset
  - For example, least squares is the most commonly used OF and focuses on high values of the dataset, largely ignoring smaller values
  - The extent of this focus depends on the distribution of your dataset

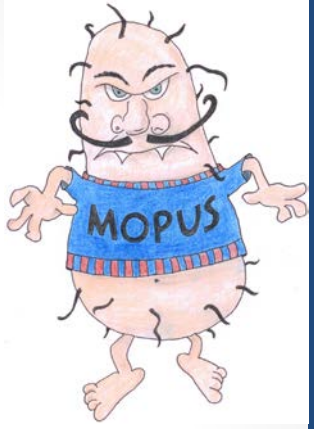
- The choice of OF is a subjective decision, but it is usually stated that ‘OF choice should be linked to the modelling objectives’
  - It is hence assumed that if you are interested in peak values, then you should calibrate your model using an OF which focuses on peaks (e.g. least squares)
  - Is this a safe assumption?

Introduction

- Moreover, OFs are commonly just adopted without consideration to how this really impacts the results (e.g. Least Squares)
  - How do OFs influence model calibration, and hence model prediction or validation?
  - What about model parameter sensitivity? Do we identify different parameters as sensitive when using different OFs?
  - Parameter interaction?
- The aim of this paper was:

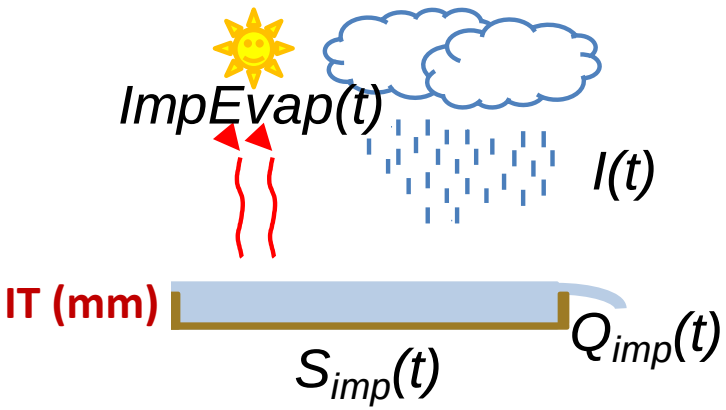
  "to test the influence of OF choice on rainfall-runoff model results, including model calibration & validation and parameter sensitivity &interaction"

Methodology

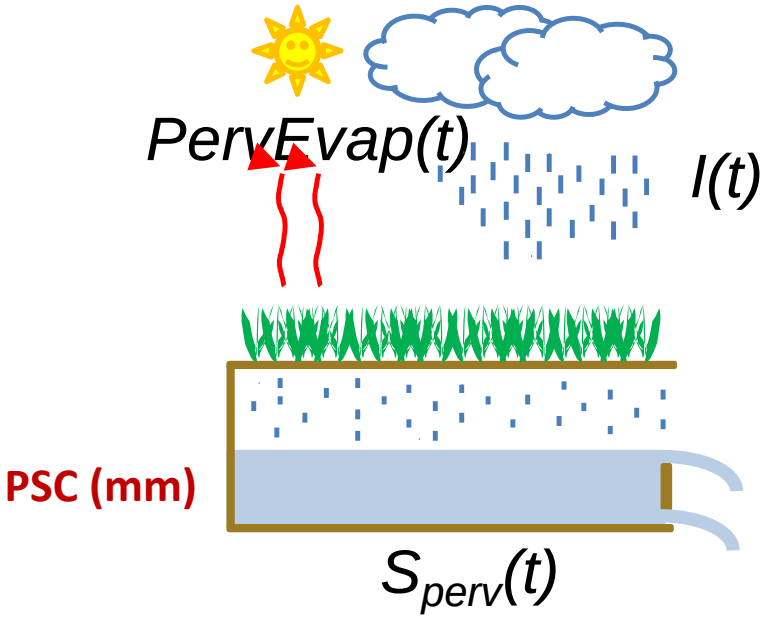


- **Model…**
  - MOPUS Rainfall-Runoff model

Impervious component



Pervious component



6 Parameters

1. IMP - Imperviousness
2. IT - Impervious store cap.
3. PSC - Pervious store capacity
4. k - Routing coefficient
5. m - Routing exponent
6. TOC

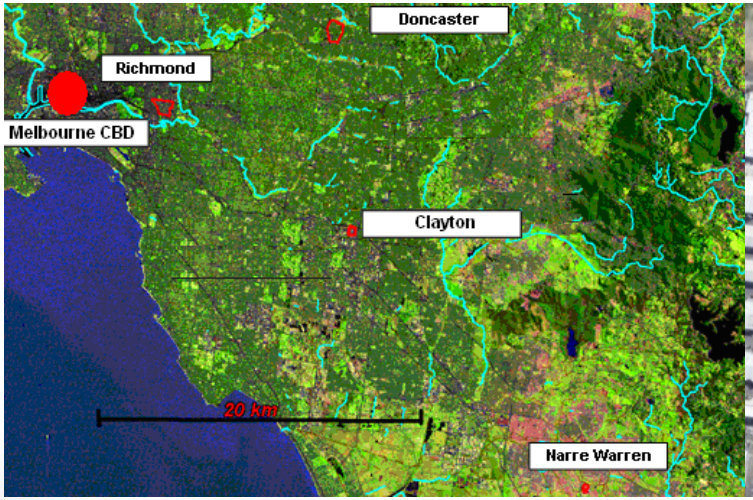
$Q(t) = \mathbf{k} \cdot \text{RoutingStore}^{\mathbf{m}}$

$Q_{outlet}(t) = Q(t - \mathbf{TOC})$

Methodology

- **Case study…**
  - Melbourne catchment; 2 years of continuous flow and rainfall

Land use	Light -industrial
Area	28 ha
Total imperviousness	80%
Catchment slope	1%
Rainfall gauge distance from outlet	300 m
Range of event rainfall totals	2.0 – 25.4 mm
Number of rainfall events	**108**



Methodology

- **Objective functions trialled…**

Increasing emphasis on peak flows…

Least squares

$$OF_{LS} = \sum_{i=1}^{n} [P_i - M_i]^2$$

Sum of square roots

$$OF_{SR} = \sqrt{\sum_{i=1}^{n} [P_i - M_i]^2}$$

Chi square

$$OF_{\chi^2} = \sum_{i=1}^{n} \frac{[P_i - M_i]^2}{M_i}$$

Absolute Difference

$$OF_{Bias} = \sum_{i=1}^{n} |P_i - M_i|$$

Error ratio

$$OF_{Ratio} = \sum_{i=1}^{n} \begin{pmatrix} i \frac{M_i}{P_i} \forall P_i \geq M_i \\ \frac{P_i}{M_i} \forall M_i > P_i \end{pmatrix}$$

Chi absolute

$$OF_{\chi} = \sum_{i=1}^{n} \frac{|P_i - M_i|}{M_i}$$

Methodology

- $3x10^6$ parameter sets were randomly generated

Parameter	Range	Distribution
Imperviousness IMP	0.05-0.95	uniform
Impervious threshold IT	0-3 mm	uniform
Pervious soil store capacity PSC	1-120 mm	uniform
Time of translation TOT	20-90 min	uniform
Routing Coefficient RC	0.0003 - 0.05	lognormal
Routing Exponent RE	0.7-1.3	uniform

- The model outputs from these parameter sets were compared to measured data using the six OFs

- **Optimised parameter sets**
  - 'optimised parameter sets' were taken as those which had the minimum OF

Methodology

- **Model Performance**
  - Used optimised parameter sets
  - It was difficult to assess how 'model performance' varied with OFs
    - if we use Nash-Sutcliffe E we are favouring large events …. Hence good alignment with LS OFs
  - We used E…but not just one E for the entire dataset…
    - we calculated E for each of the 108 events and then used distributions to compare performance – not perfect, but not many are!

- **Sensitivity and interaction**
  - We separated behavioural and non-behavioural parameter sets using cut-off thresholds
    - For each OF, we tested top 0.1%, 1%, 5% and 10%
  - Behavioural parameter sets were used to develop parameter distributions – one for each OF
    - NB assumptions re model performance criterion is not relevant here
  - Parameter interactions used behavioural parameter sets; scatter plots and spearman rank correlation coefficients

Results and discussion

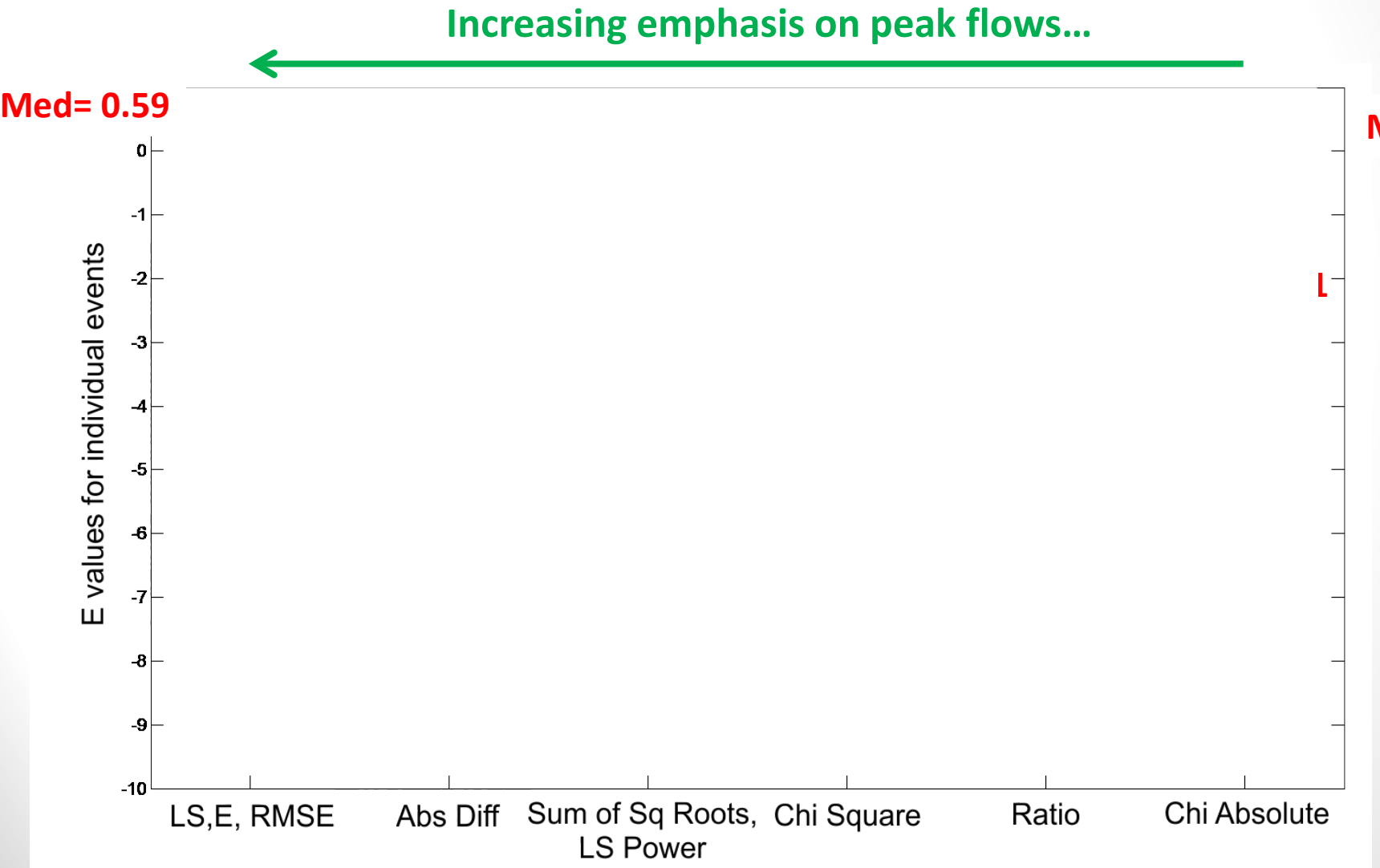
- **'Optimised parameter sets'** – is there such thing?

	IMP	IT	RC	RE	PSC	TOC
LS, E, RMSE						
Absolute Difference						
Sum of Sq. Roots						
Chi Square						
Ratio						
Chi Absolute						

Conclusion: optimised parameter values change with OF choice

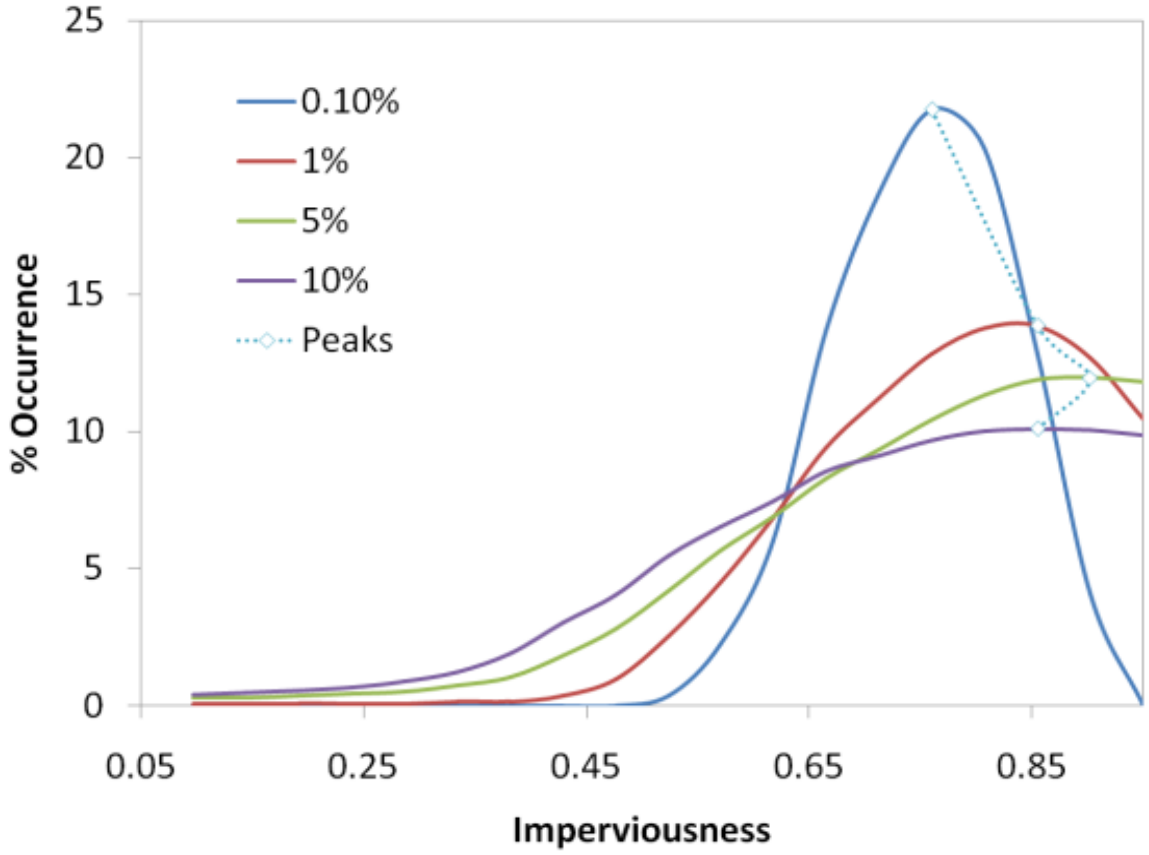
Results and discussion

- **Model performance – using opt parameter sets**



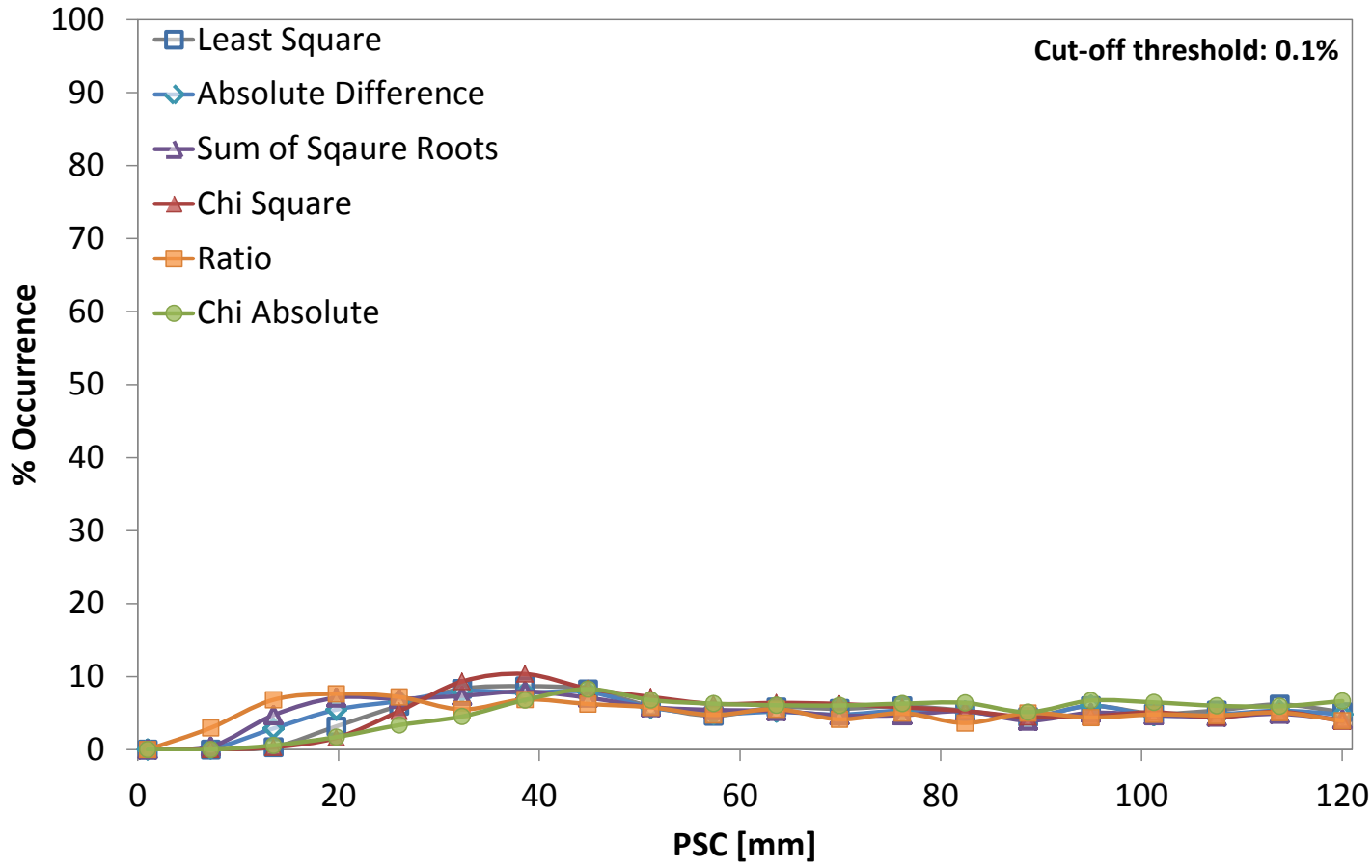
Results and discussion

- **Parameter sensitivity – impact of cut-off threshold (e.g. LS OF)**



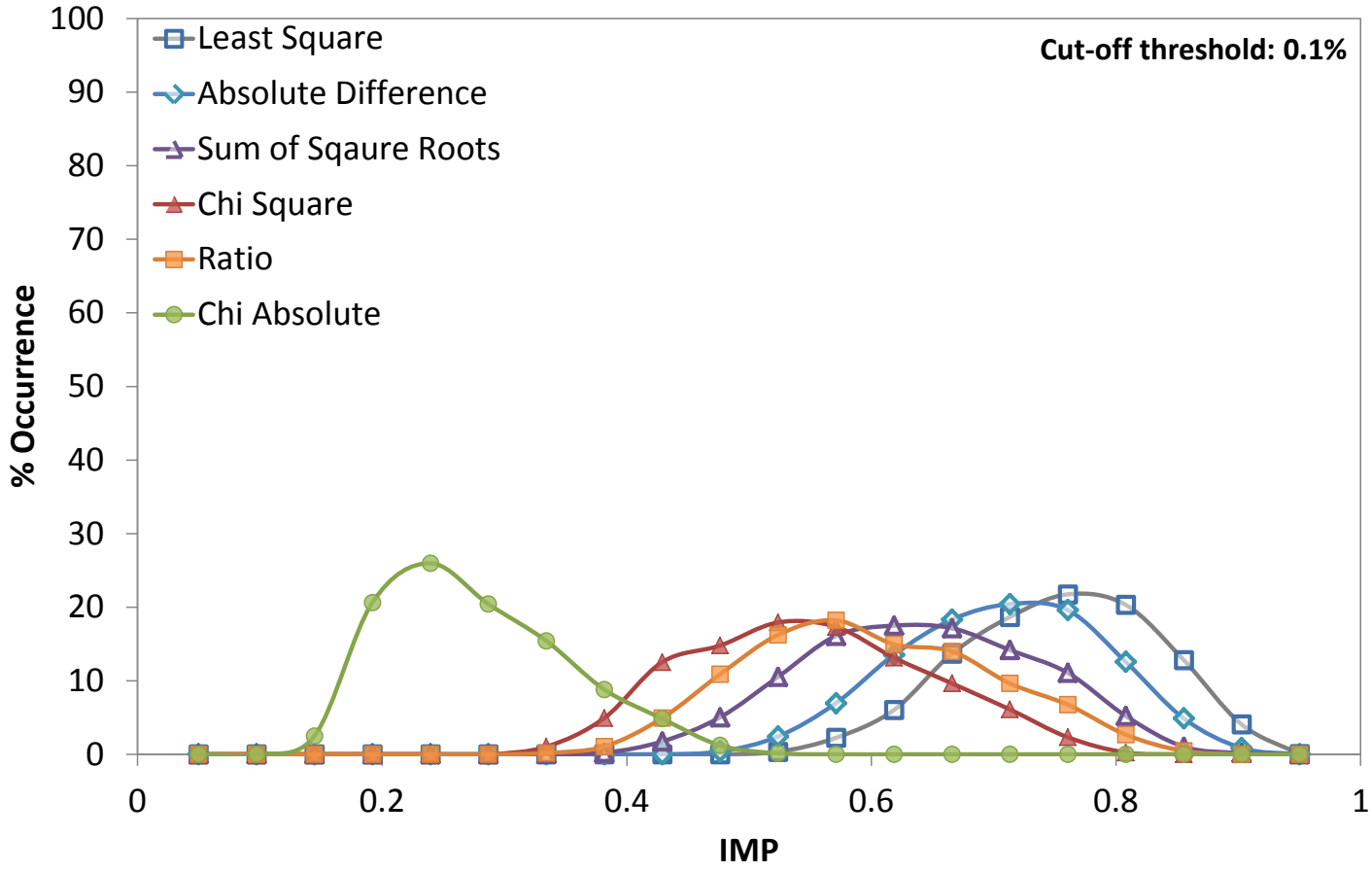
Results and discussion

- **Parameter sensitivity – impact of OF**
  - For some parameters, the **SHAPE** and the **MPV** remains similar for all OFs (seems to be for insensitive parameters?)



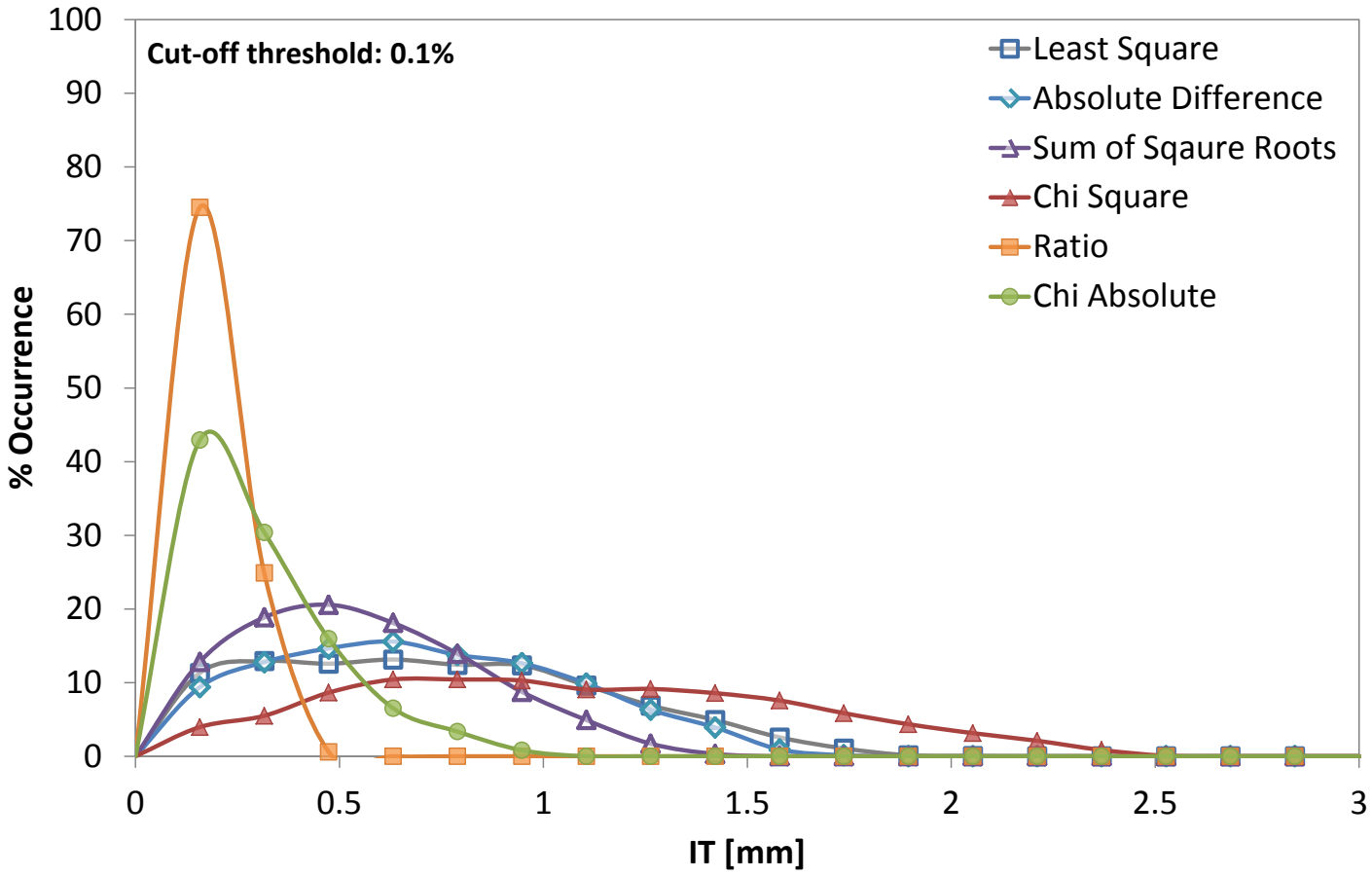
Results and discussion

- **Parameter sensitivity – impact of OF**
  - For others, **MPV** changed significantly between OFs



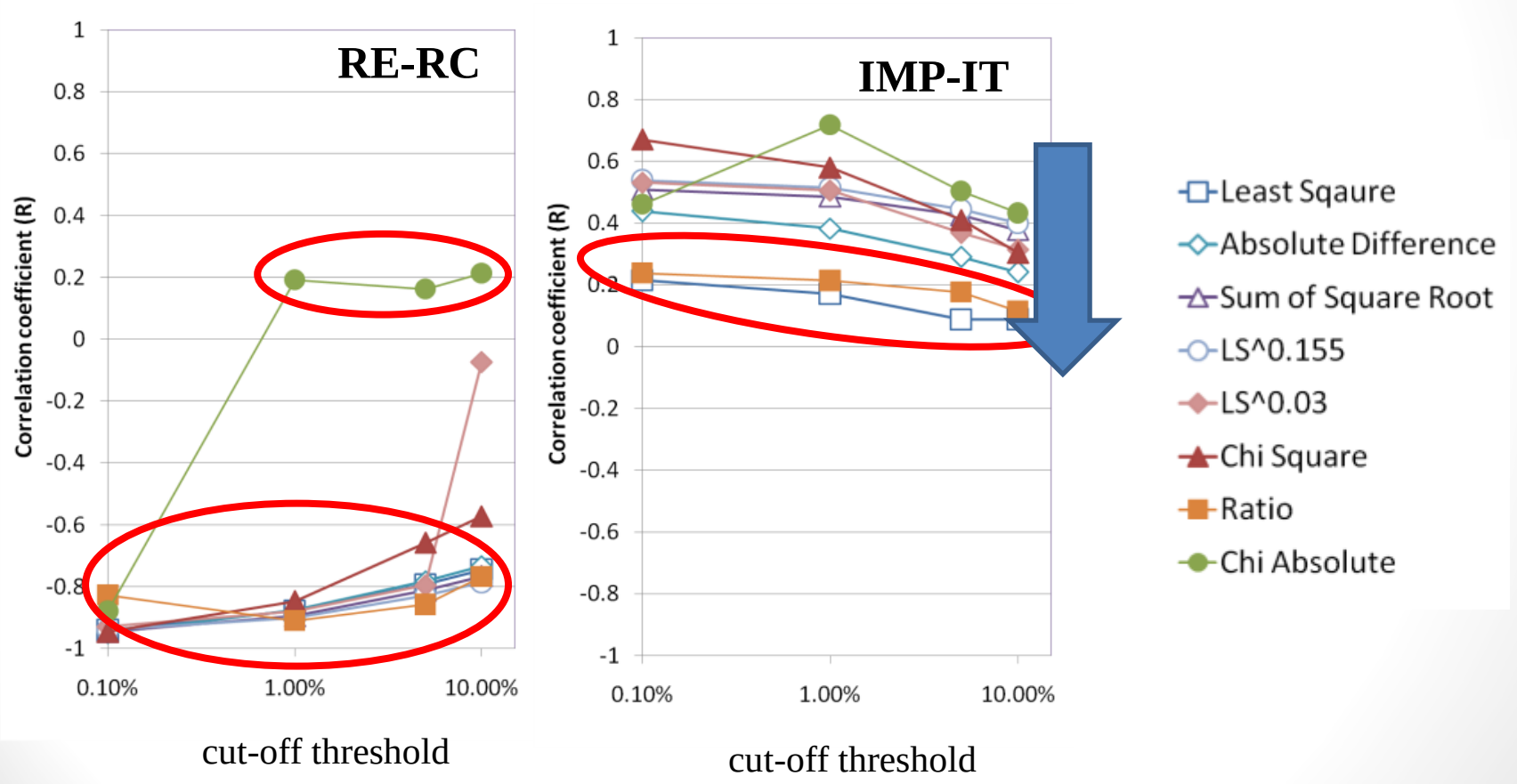
Results and discussion

- **Parameter sensitivity – impact of OF**
  - For others, **MPV** and **SHAPE** changed significantly between OFs



Results and discussion

- **Parameter interaction**



Conclusions and future outlook

- Nothing ground breaking really – it has been a discussion topic for decades!

- Behaviour of different objective functions is caused by different weighting of peak values compared to low flows in the hydrograph.
  - Least Squares OF => emphasises peak flows => good median E, high variability
  - Chi Absolute OF => balanced emphasis => lower median E , low variability

- Parameter sensitivity is influenced by OF choice.
  - Least squares => high flows/volumes => Impervious Threshold is less important
  - Chi Absolute => lower flows => Impervious Threshold is more important

- The future:
  - Validation: It is hypothesised that using different OFs helps reduce the amount of data required to calibrate the model, whilst still obtaining adequate results during model verification. This hypothesis is to be validated as part of future work.
  - Various datasets – splitting…
  - Multi criteria…

Thank you --- any questions?