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Statistical downscaling methods for climate change impact assessment on urban rainfall extremes for cities in tropical developing countries – A review

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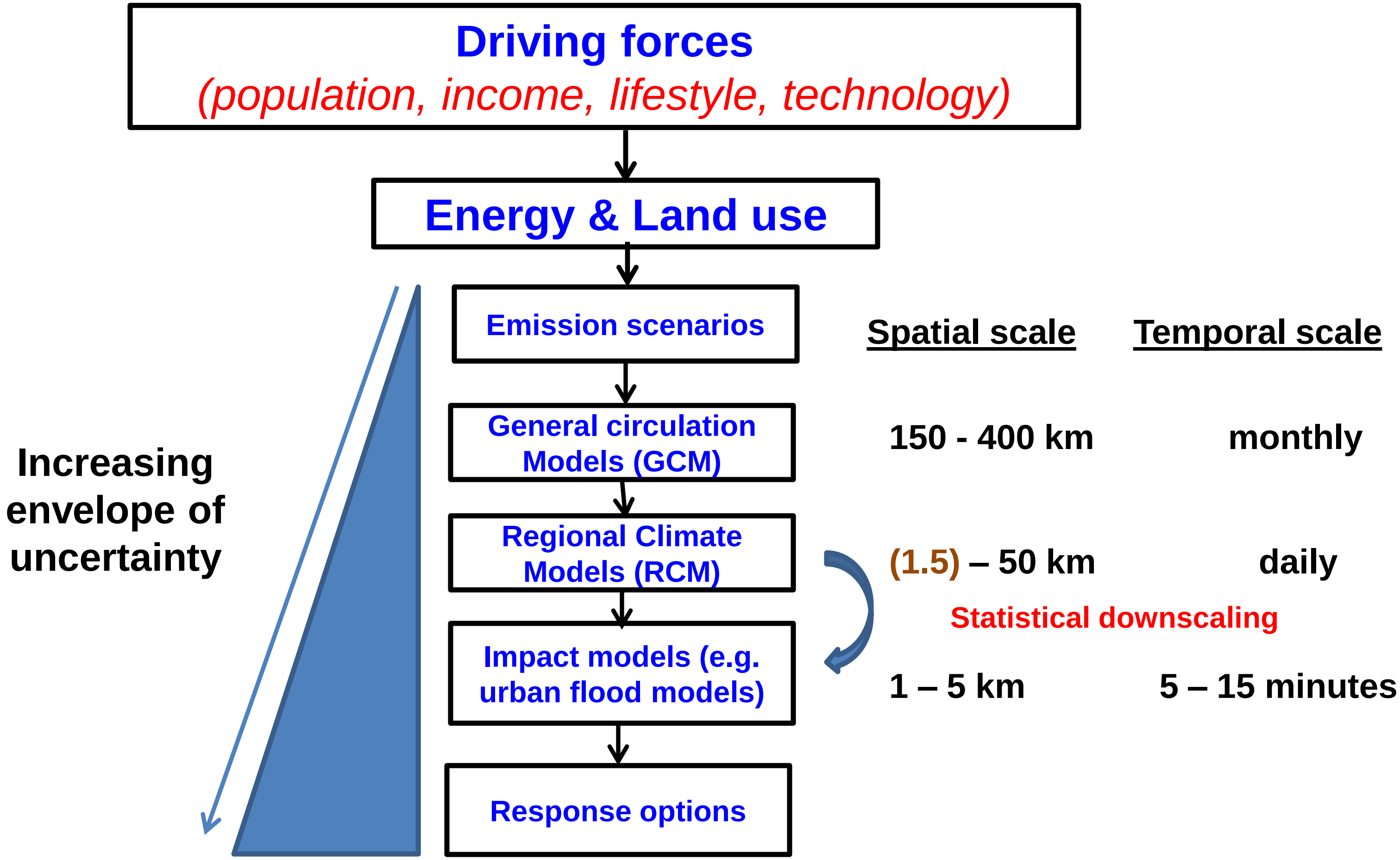
Presentation outline

- Background
- Climate change impact assessment on urban hydrology
- Overview of downscaling methods
- Methodological suitability in tropical developing country cities
- Conclusions

‘Top-Down’ climate impact assessment framework



Based on Wilby & Dessai (2010); Onof et al 2009; Sunyer et al 2012, Kendon et al. 2012

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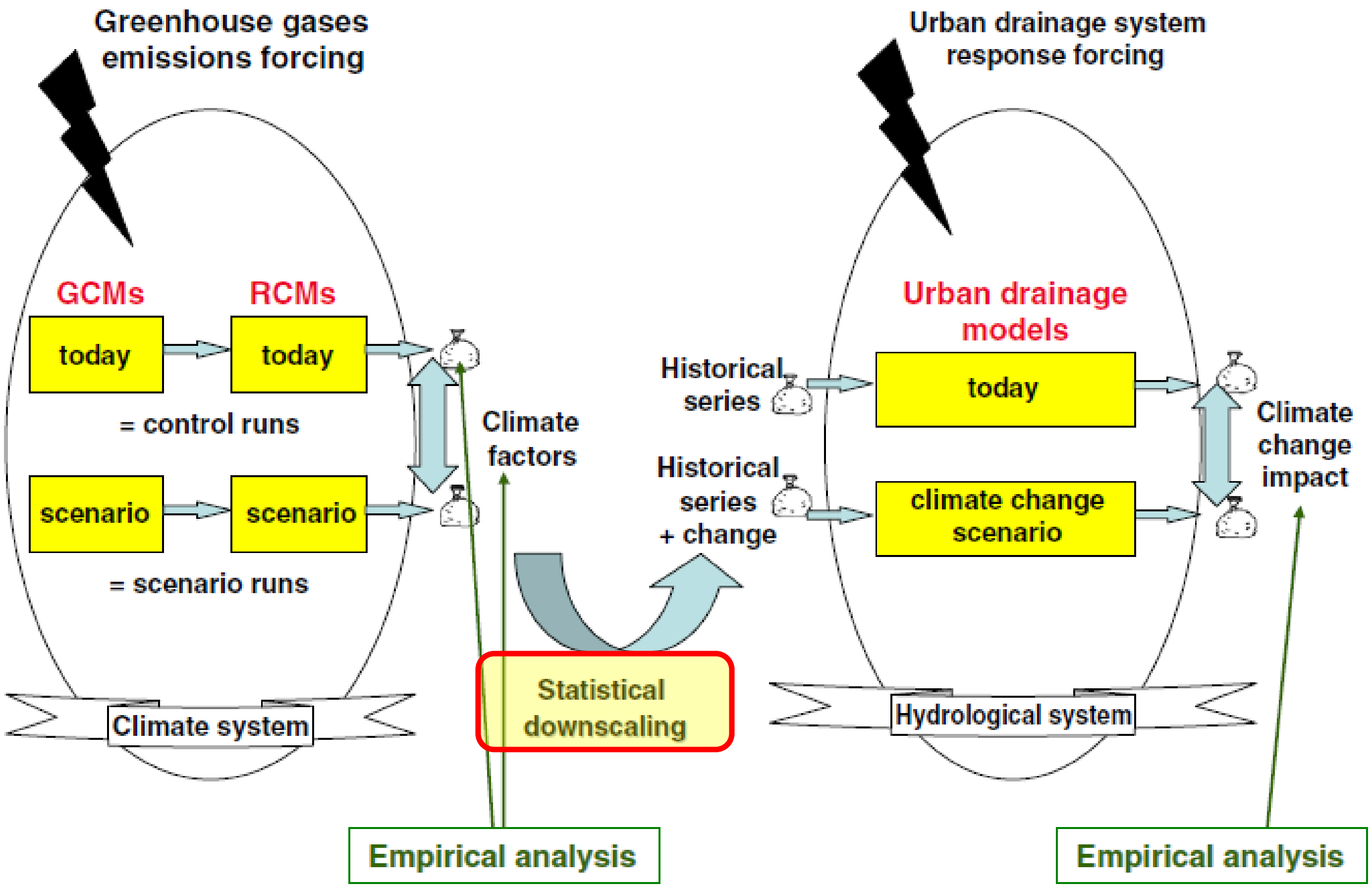
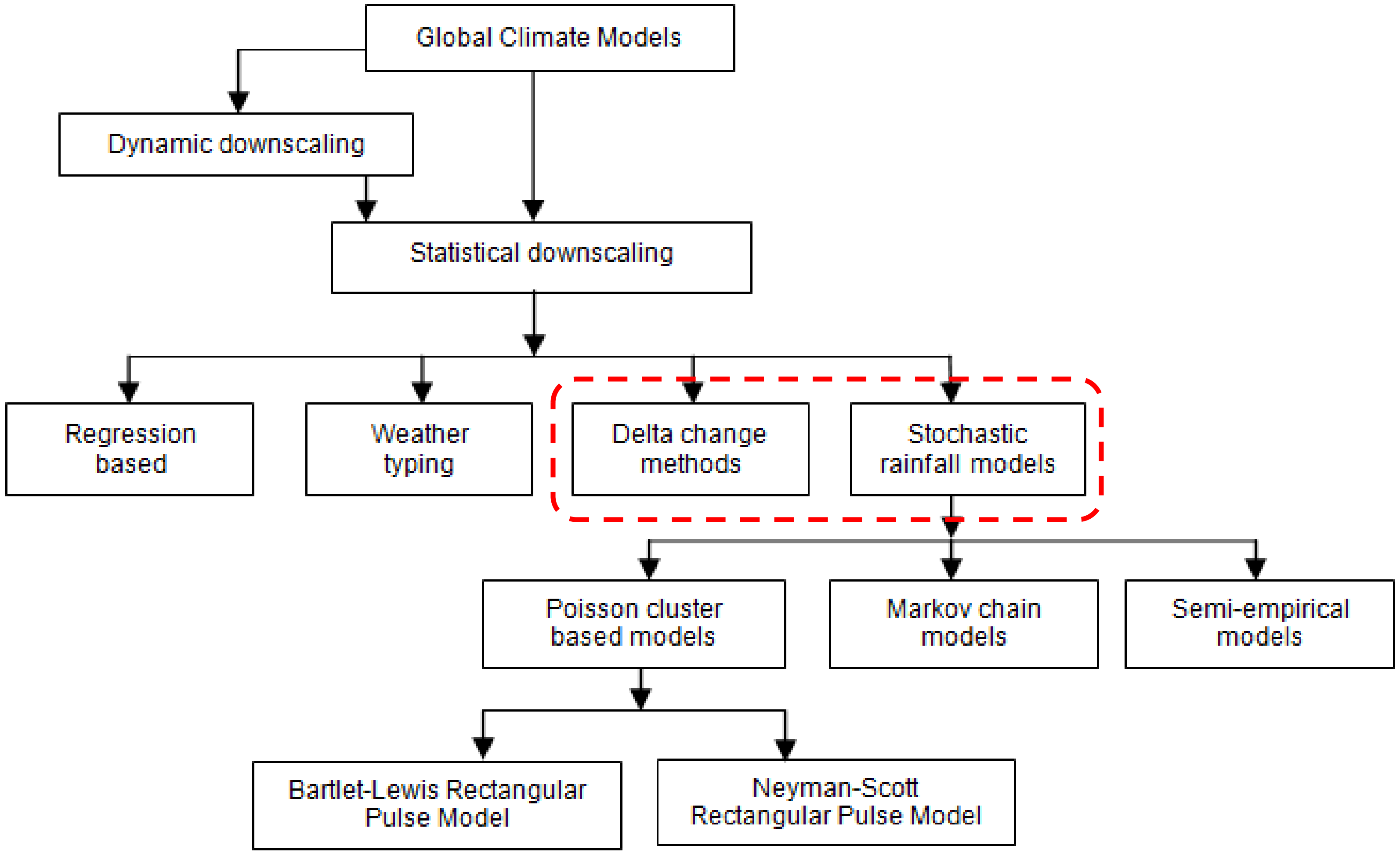
Climate change impact assessment at an urban scale



Willems et al. 2012

Overview of downscaling techniques



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Statistical downscaling

- Use empirical-based relationships to convert course scale climate model outputs to finer urban scales
  - ✓ Temporal downscaling
  - ✓ Spatial downscaling
- Key assumptions:
  - ✓ *Local scale climate variables = f (large scale atmospheric variables)*
  - ✓ Function can be deterministic or stochastic
  - ✓ Ratio remains unchanged under climate change

Delta change (Change Factor) methods

- Used to quantify changes in rainfall frequencies and intensities between a control and a future period for specified return periods

- Computed as a ratio of future to control rainfall intensity statistics

$$CF = \frac{St^{RCMfut}}{St^{RCMcon}} \qquad (1)$$

$$St^{Fut} = St^{Obs} \cdot CF \qquad (2)$$

Where

St^{RCMfut}	RCM results for future period
St^{RCMcon}	RCM results for control period
St^{Obs}	Observed statistics

Continuous versus event based change factors

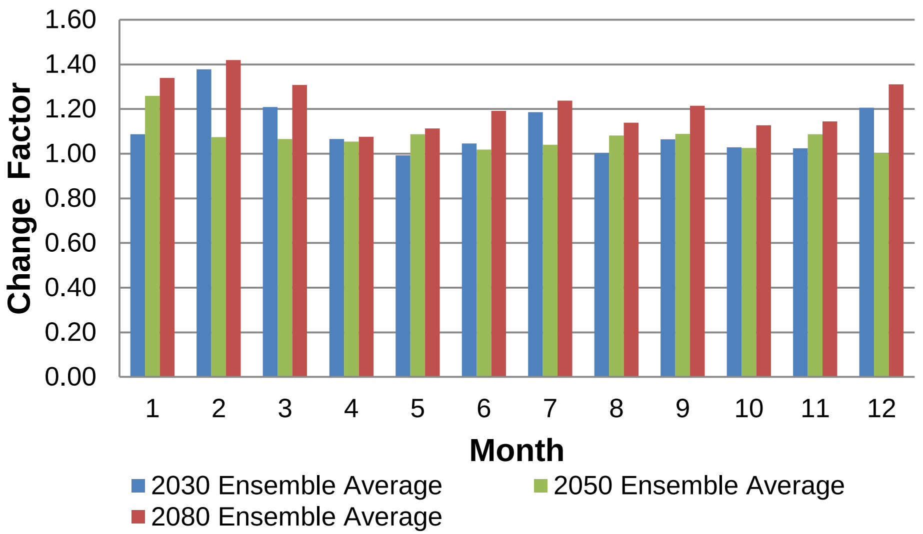


Figure 1: Example of monthly change factors computed from an ensemble of regional climate models for Kampala for future periods 2001-2030, 2041-2070 and 2071-2100 against a control period of 1961-1990 **(Continuous case)**

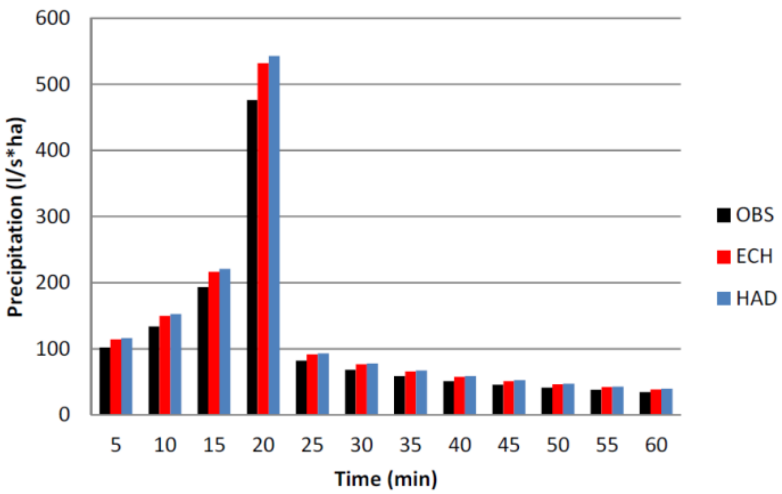


Figure 2: Example of historical 30 year 1-hour EULER II design storm for Wuppertal (OBS) and downscaled version based on future climate model projections (ECHAM5 and HADCM3 denoted as ECH and HAD respectively) (Olsson et al., 2012) **(Event based case)**

Merits

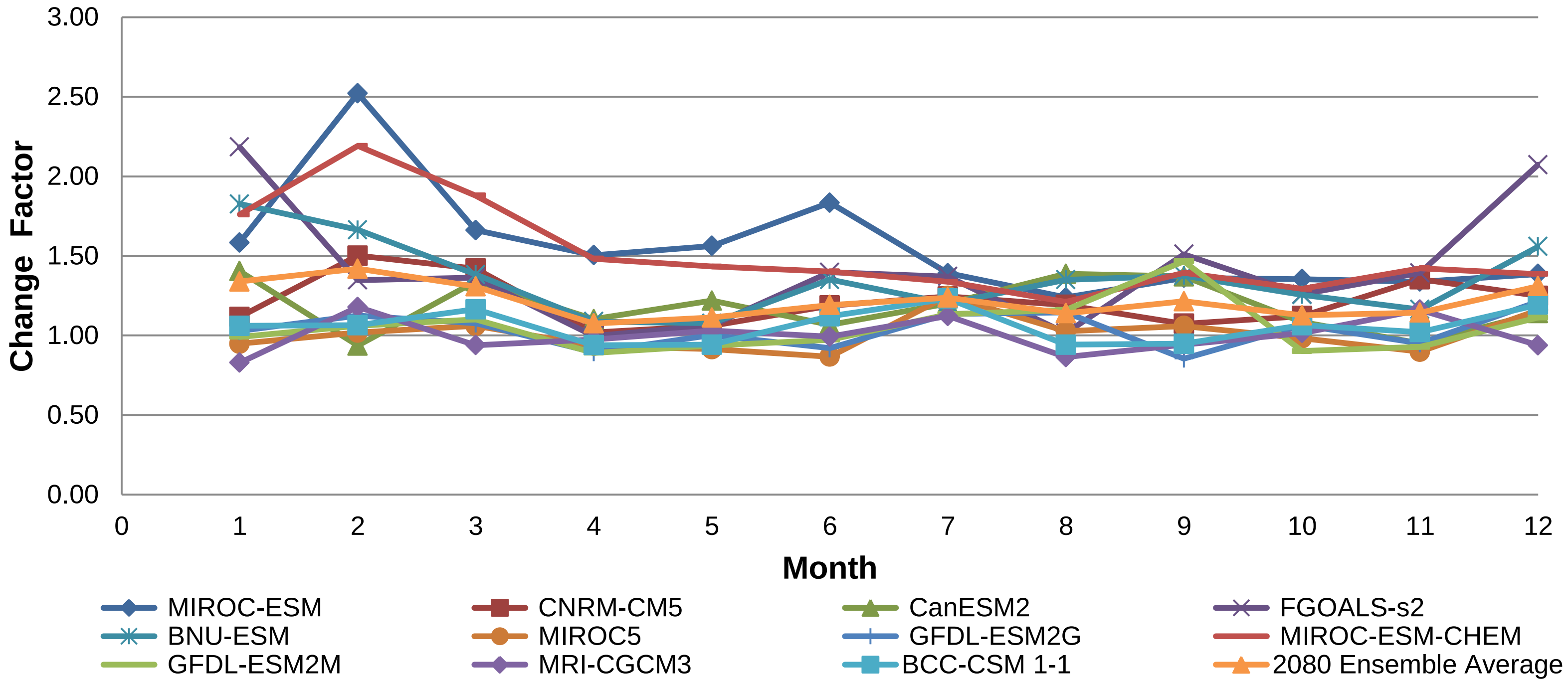
- ✓ Easy and quick to apply
- ✓ Preserves characteristics of observed data
- ✓ Only relative changes transferred from climate model data to observed time series

Demerits

- ✓ Deterministic
- ✓ Dependent on GCM/RCM model reliability
- ✓ Requires equivalent climate model and observed data
- ✓ Uncertainties

Range of computed change factors

Uncertainty in CFs for February: 0.94 - 2.52



Monthly rainfall change factors for Kampala
Control period (1961-1990): Future Period (2071-2080), Scenario RCP 4.5

Stochastic rainfall models (Poisson cluster based)

- Plausible physical basis for simulation of hourly or daily rainfall
- Accurately simulate extreme rainfall events
- Model parameters computed by statistical analysis of observed rainfall data
- Change factors used to adjust model parameters
- Generalised Method of Moments for model parameter estimation
  - Estimates model parameter vector, θ by minimizing an objective function, *S(θ|T)*

$$S(\theta|T) = \sum_{i=1}^{k} w_i [T_i - \tau_i(\theta)]^2 \quad (3)$$

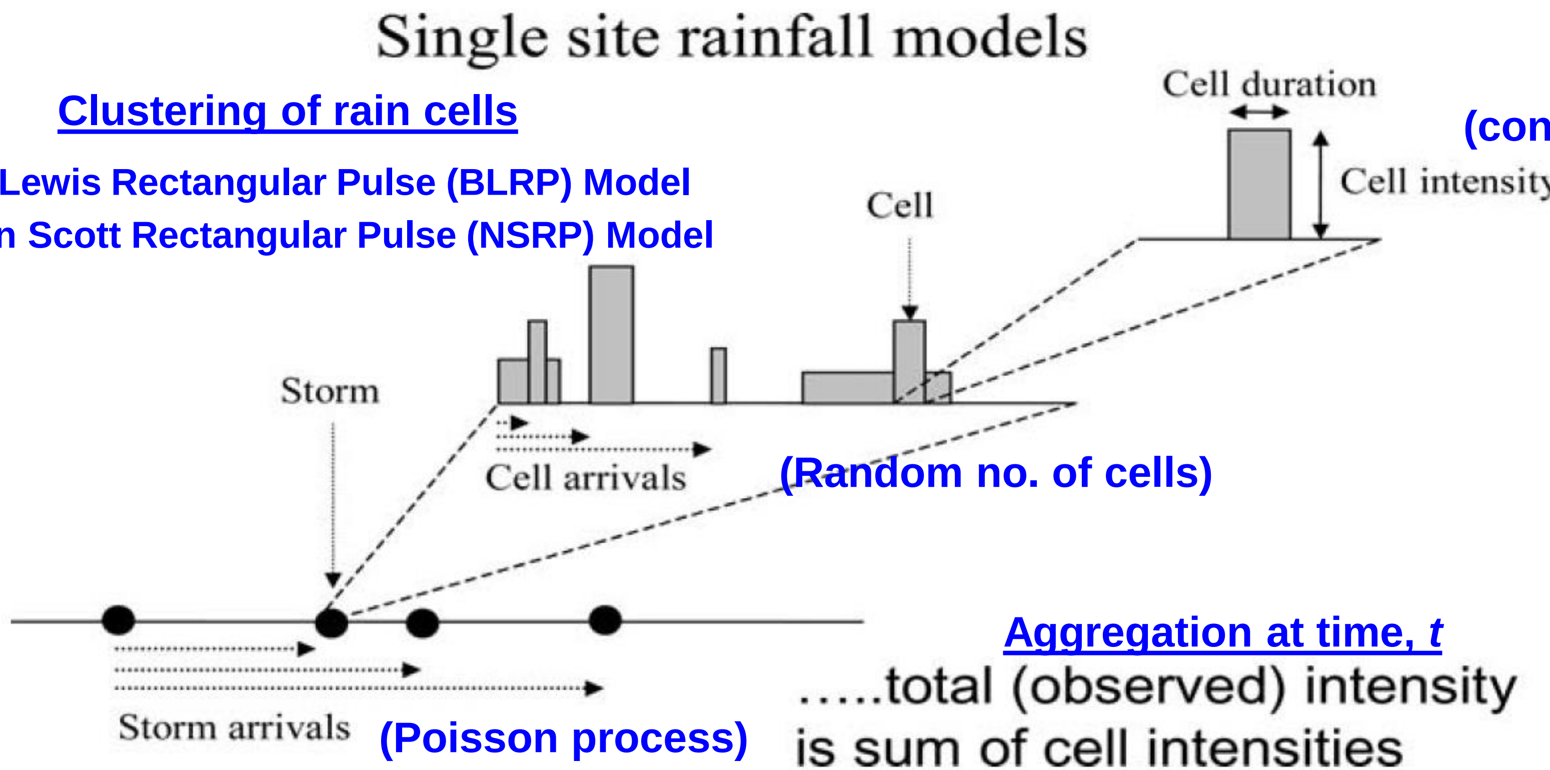
Where	w_i,	Collection of weights
	θ	Model parameter vector
	T	Model of summary statistics computed from data
	$\tau_i(\theta)$	Expected value of T

- Model fitting and validation
- Disaggregation: Generates hourly or sub-hourly rainfall (e.g. 5 - 15 min)

Schematic of Poisson cluster rectangular pulse models

Clustering of rain cells

- ✓ **Barlet-Lewis Rectangular Pulse (BLRP) Model**
- ✓ **Neyman Scott Rectangular Pulse (NSRP) Model**



(constant)

(Random no. of cells)

(Poisson process)

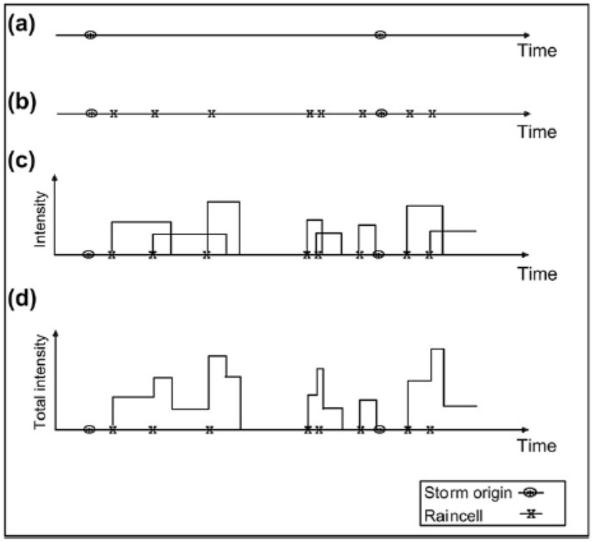
Aggregation at time, *t*

Wheater et al. 2005

Neyman-Scott Rectangular Pulse Model

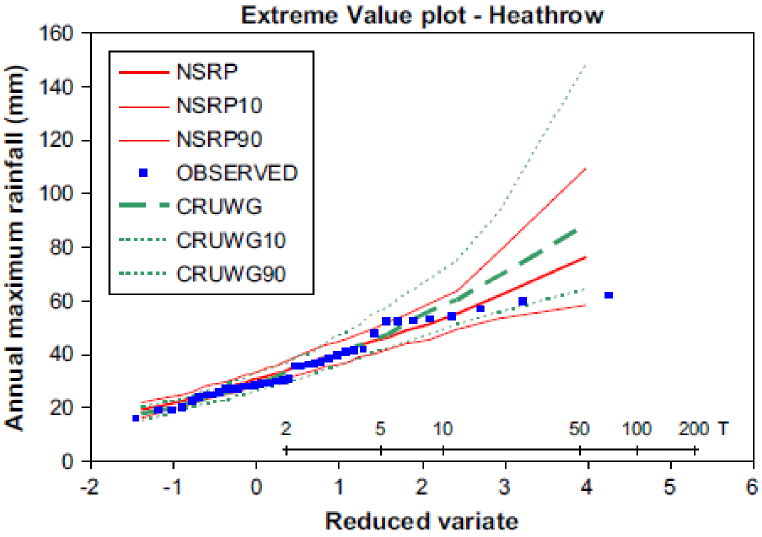
NSRP model parameters

Parameter	Description
λ^{-1}	Average time between subsequent storm origins (h)
β^{-1}	Average waiting time of rain cells after storm origin (h)
η^{-1}	Average cell duration (h)
ϑ^{-1}	Average no. of rain cells per storm
ξ^{-1}	Average cell intensity (mm/h)



Schematic representation of NSRP Model (Kilby et al. 2007)

Comparison between NSRP and a Markov Chain Model



Extreme value plot of annual maximum rainfall for Heathrow (Kilby et al. 2007)

Suitability for application in tropical developing countries cities

- Limited case studies using statistical downscaling in cities in tropical developing countries

Reasons?

- Limited or incomplete observed time series data sets
- Requirement of equivalent climate model and observed data sets
- Stochastic rainfall models not adapted to non-temperate climates
- Difficulty in model fitting due to indirect relationship between model parameters and observable properties of rainfall sequences
- High uncertainties cascading from parent models
- Strong local convective influences affect reliability

Conclusions: Appropriate methodologies for tropical developing country cities

- Climate sensitivity analyses using impact models
- Construction of climate analogues
- Use of delta change method (if reliable RCM data is available)
  - CORDEX Africa experiments
  - Regional climate data portals e.g. CSAG Group (University of Cape Town)
- Investigating the use of novel **resilience based** methodologies
  - Identify critical system performance thresholds
  - Evaluate system response and recovery behaviour under a range of future scenarios
  - Identify and appraise adaptation options

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