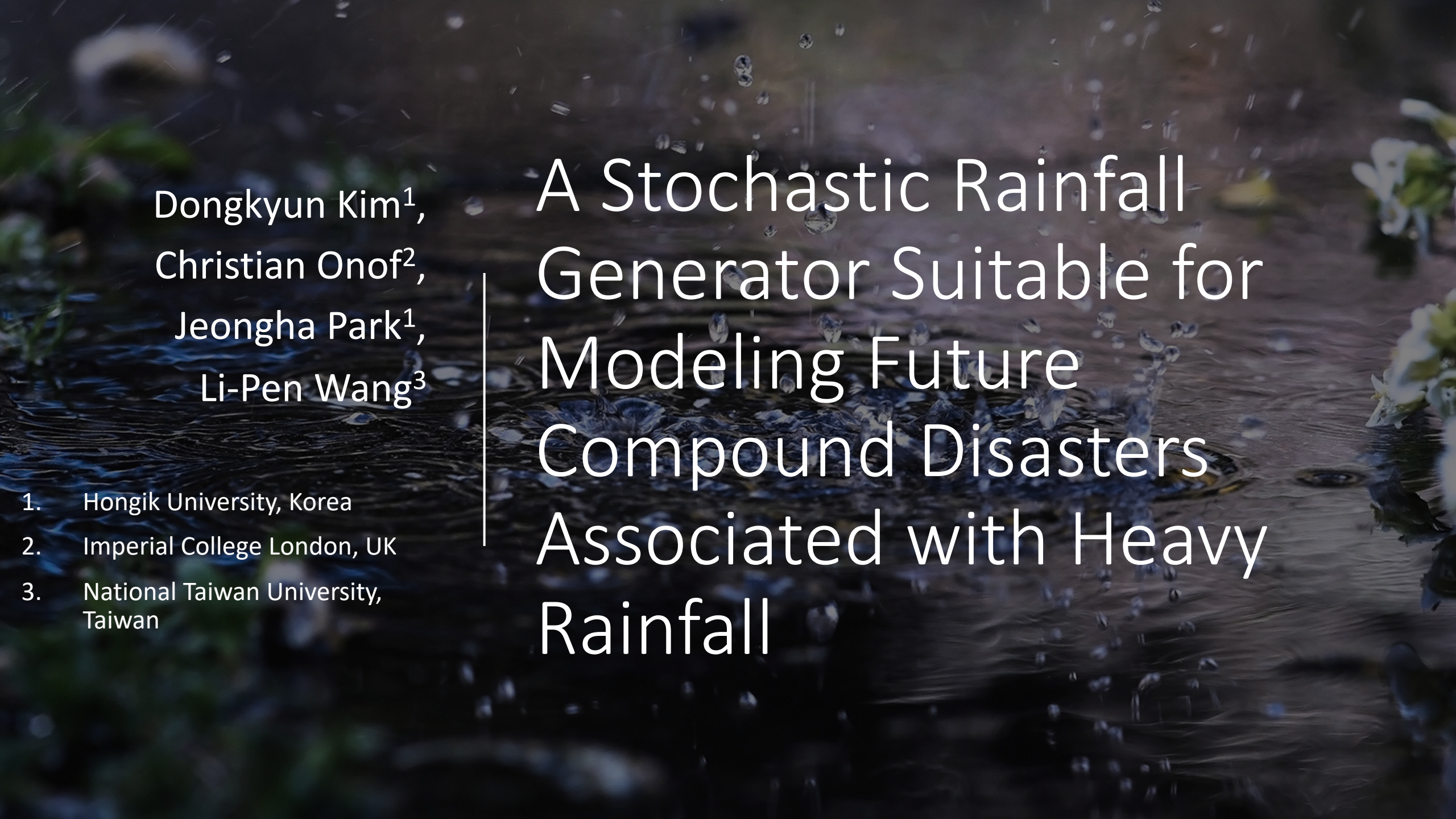

A Stochastic Rainfall Generator Suitable for Modeling Future Compound Disasters Associated with Heavy Rainfall

Dongkyun Kim[1],
Christian Onof[2],
Jeongha Park[1],
Li-Pen Wang[3]

1. Hongik University, Korea
2. Imperial College London, UK
3. National Taiwan University, Taiwan

Rainfall Variability – Influence on Urban Flood

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Journal of Hydrology
Volume 584, May 2020, 124704

Research papers

Determination of flood-inducing rainfall and runoff for highly urbanized area based on high-resolution radar-gauge composite rainfall data and flooded area GIS data

Duc Anh Dao, Dongkyun Kim, Soohyun Kim, Jeongha Park

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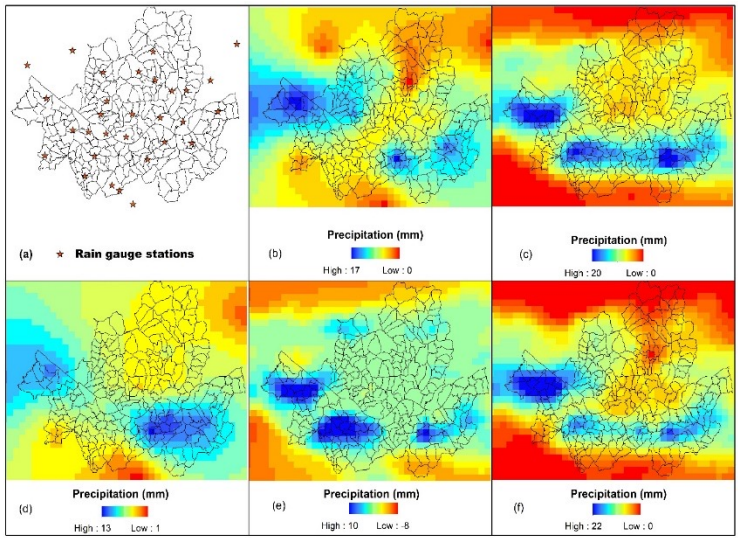
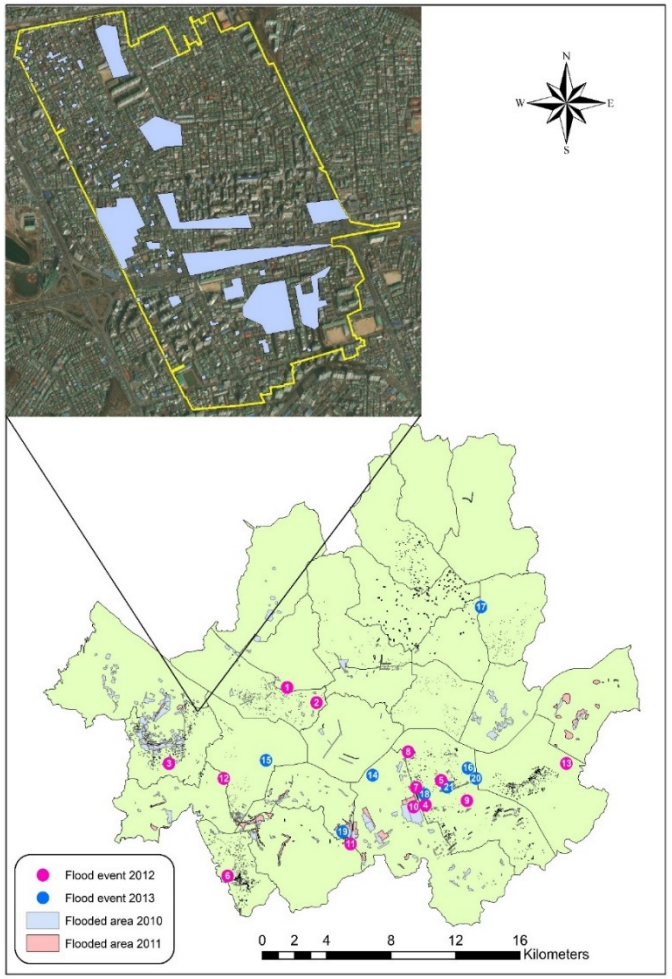
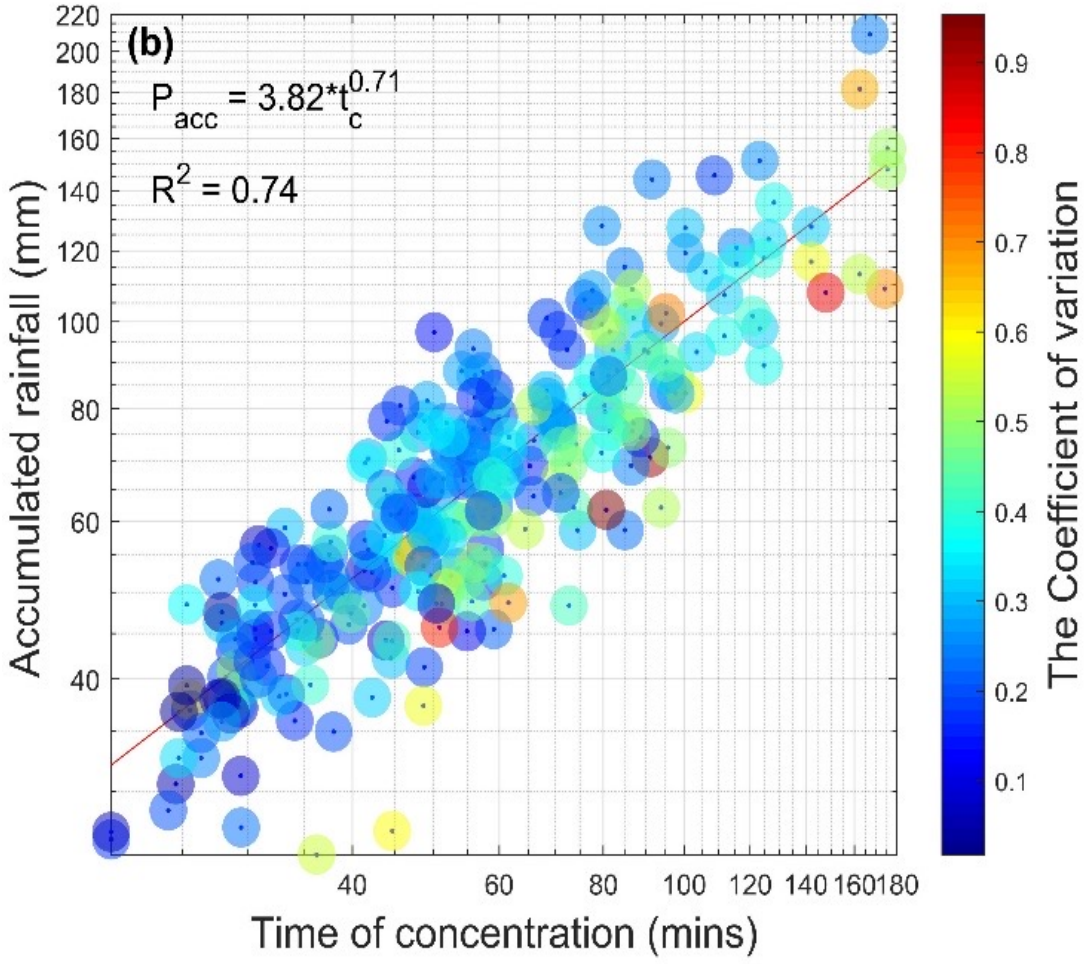
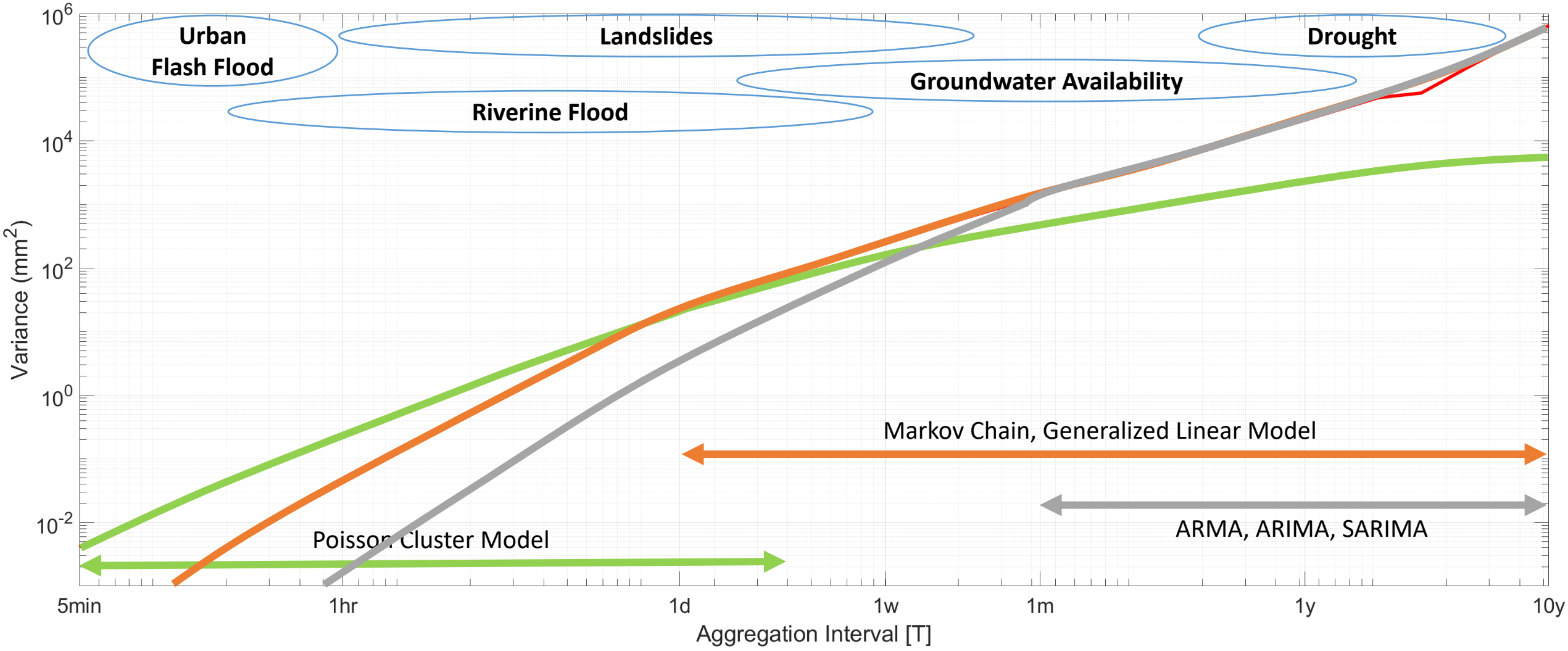


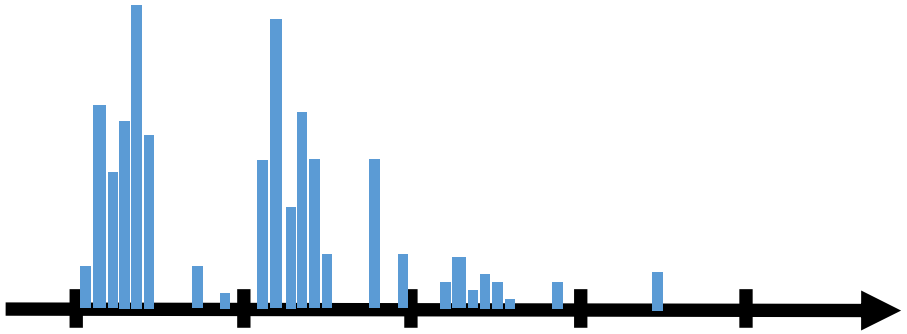




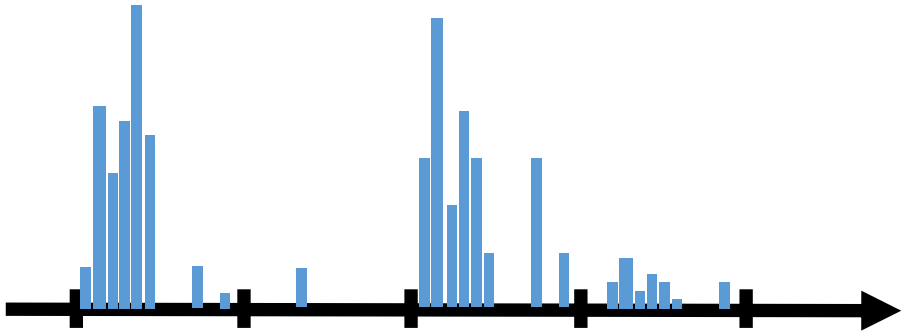
Rainfall Model for Holistic Framework



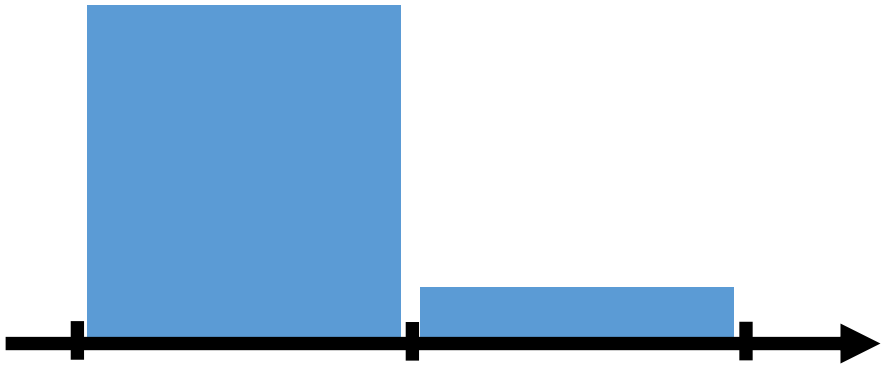
Good Memory



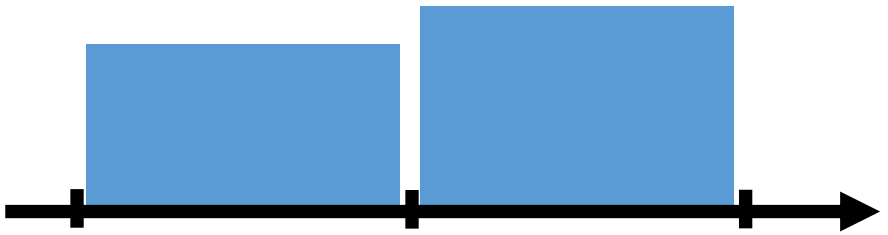
Bad Memory



Greater Variability



Less Variability



$$Var\left(Y^{(nh)}\right) = nVar\left(Y^{(h)}\right) + \sum_{i=1}^{n}\sum_{j=1,j\neq i}^{n} Cov\left(Y_i^{(h)}, Y_j^{(h)}\right)$$

Poisson Cluster Rainfall Model

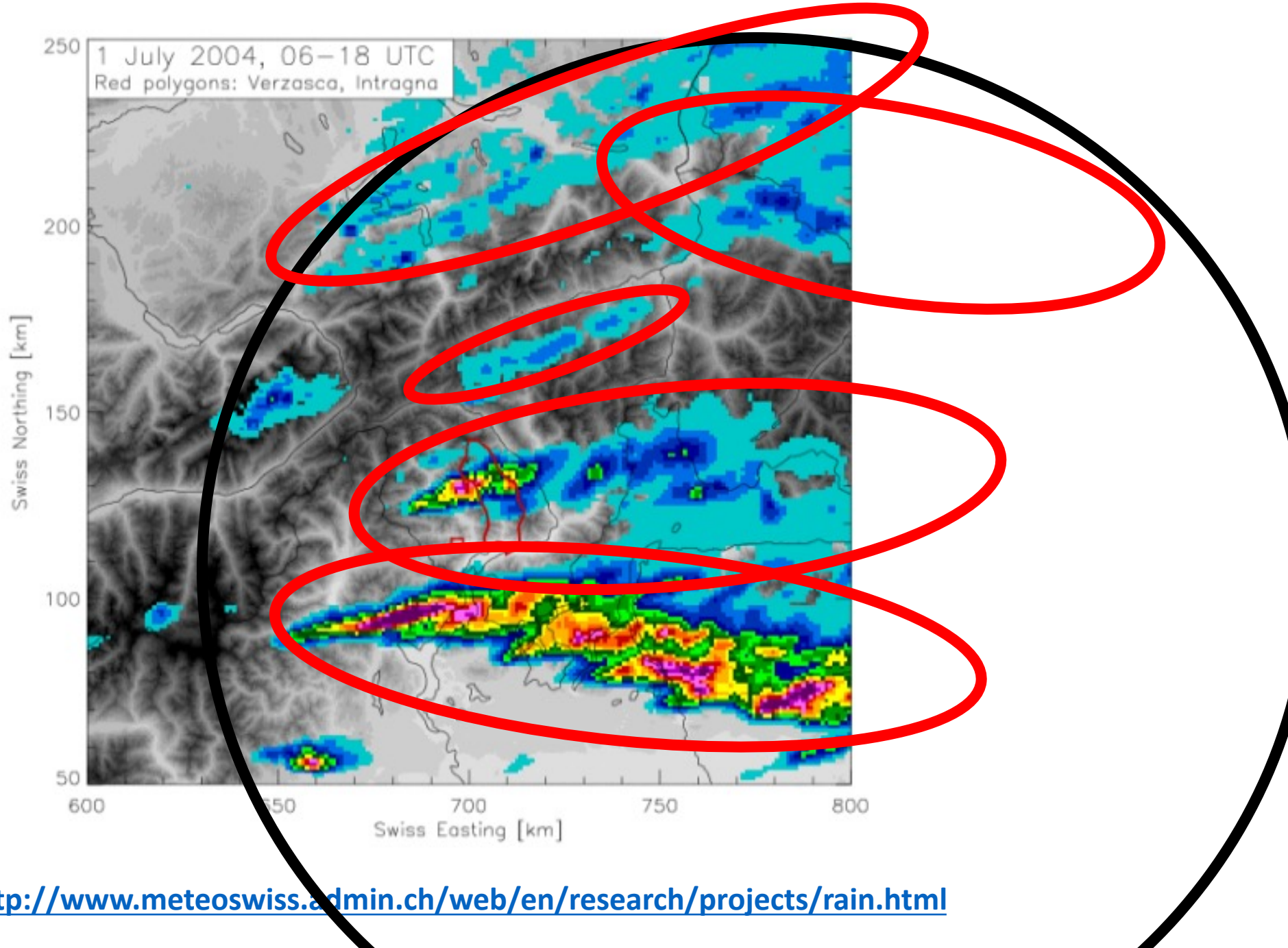
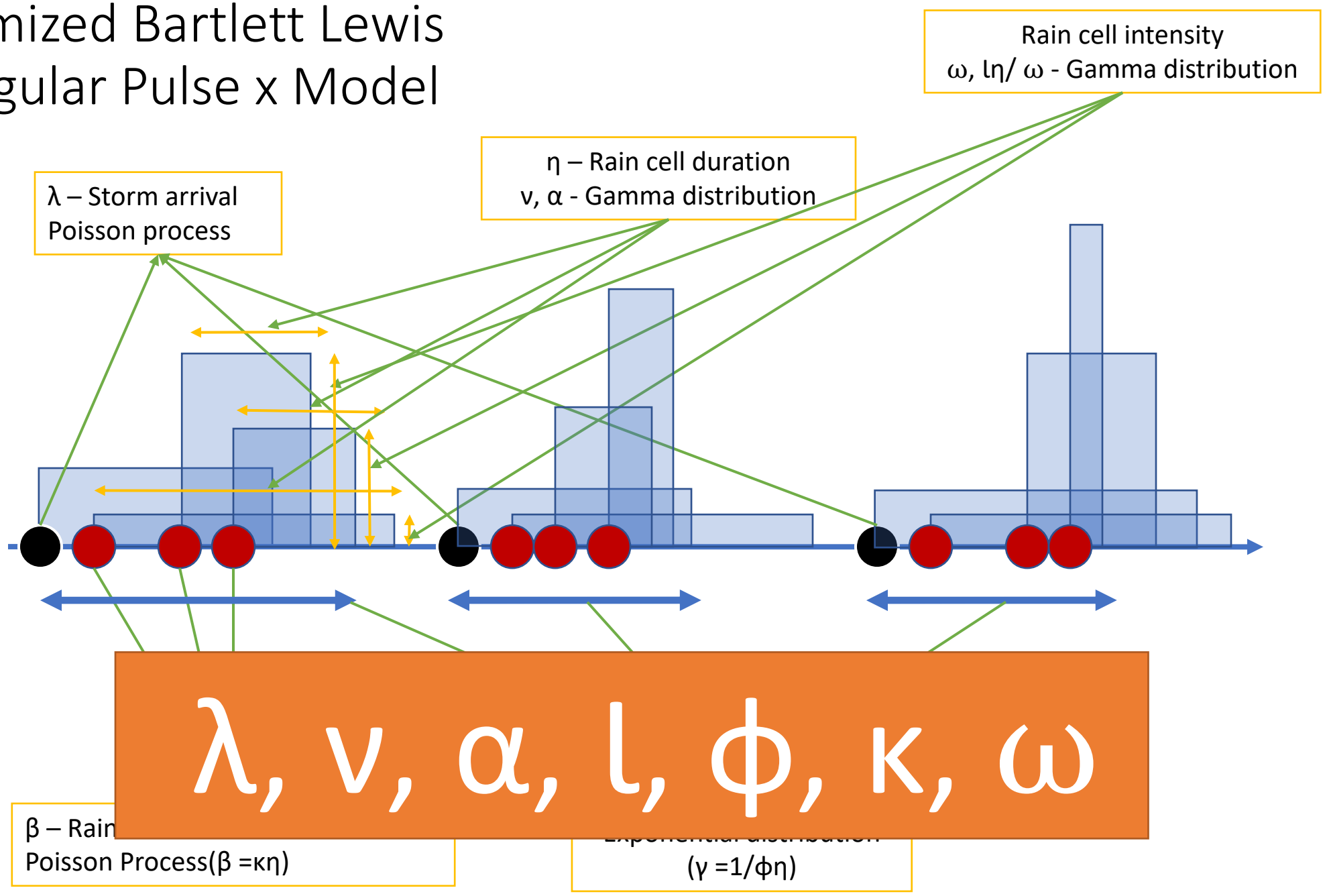


Image Source: http://www.meteoswiss.admin.ch/web/en/research/projects/rain.html

British Library
The Bloomsbury Group
BLOOMSBURY
Russell Square
CLERKENWELL
Barbican Centre
Old Street
SHOREDITC
Great Portland Street
Warren Street
Euston Square
UCL
MARYLEBONE Station
Baker Street
Madame Tussauds
Regent's Park
BT Tower
MARYLEBONE
Charles Dickens
Great Ormond Street hospital
FARRINGDON
BARBICAN
Old Spitalfields market
The British museum
HOLBORN
Chancery Lane
Fabric
MOORGATE
LIVERPOOL STREET
Edgware Road
Sherlock Holmes
FITZROVIA
Jeremy Bentham
Lincoln's Inn Fields
Goodge Street
Fleet Street
St. Paul's Cathedral
Bank of England
West End Girls
Royal Courts of Justice
King's College London
Marble Arch
Tottenham Court Road
COVENT GARDEN
Oxford Circus
SELFRIDGES&CO
Bond Street
SOHO
Carnaby
Leicester Square
Somerset House
Royal Opera House
Sweeney Todd
Blackfriars
BANK
Mansion House
Cannon Street
Fenchurch Street
MAYFAIR
Nelson's Column
National Portrait Gallery
STRAND
Blackfriars Bridge
Millennium Bridge
Southwark Bridge
London Bridge
Hyde Park
Speakers Corner
Liberty
Piccadilly Circus
Royal Academy of Arts
Park Lane
Charing Cross
Embankment
Waterloo Bridge
BFI
SOUTH BANK
The Stones in the Park 1969
Green Park
Fortnum & Mason
The Ritz
Pall Mall
St James's Park
10 Downing Street
Tate Modern
Shakespeare's Globe
The Shard
the Serpentine
Waterloo Sunset
London Eye
LONDON BRIDGE
Borough market
City Hall
Southwark
Waterloo Station
Hyde Park Corner
Parliament Square
Borough
Guy's Hospital
WATERLOO
BERMONDSEY
KNIGHTSBRIDGE
WESTMINSTER
Westminster Bridge
St Thomas Hospital
Imperial War museum
Newington Gardens
Buckingham Palace
Harrods
BELGRAVIA
Houses of Parliament
Elephant & Castle

Randomized Bartlett Lewis Rectangular Pulse x Model



Parameter Calibration

How to get..
λ, ν, α, l, ϕ, κ, ω

$$E[Y_t^{(T)}] = \lambda\,\mu\,\mu_c\,\frac{\nu}{\alpha-1}\,T$$

$$Var[Y_t^{(T)}] = \frac{2\,\nu^{2-\alpha}}{\alpha-2}\,T\left(k_1-\frac{k_2}{\phi}\right)-\frac{2\,\nu^{3-\alpha}}{(\alpha-2)(\alpha-3)}\left(k_1-\frac{k_2}{\phi^2}\right)$$
$$+\frac{2}{(\alpha-2)(\alpha-3)}\left[k_1(T+\nu)^{3-\alpha}-\frac{k_2}{\phi^2}(\phi\,T+\nu)^{3-\alpha}\right]$$

$$Cov[Y_t^{(T)},Y_{t+s}^{(T)}]$$
$$=\frac{k_1}{(\alpha-2)(\alpha-3)}\{\,[T\,(s-1)+\nu]^{3-\alpha}+[T\,(s+1)+\nu]^{3-\alpha}-2(T\,s+\nu)^{3-\alpha}\}$$
$$+\frac{k_2}{\phi^2(\alpha-2)(\alpha-3)}\{\,2(\phi\,T\,s+\nu)^{3-\alpha}-[\phi\,T\,(s-1)+\nu]^{3-\alpha}-[\phi\,T\,(s+1)+\nu]^{3-\alpha}\}$$

$$P(\text{zero rainfall}) = \exp\left\{-\lambda\,T-\frac{\lambda\,\nu}{\phi\,(\alpha-1)}\left[1+\phi\,(\kappa+\phi)-\frac{1}{4}\,\phi\,(\kappa+\phi)(\kappa+4\phi)\right.\right.$$
$$\left.+\frac{\phi\,(\kappa+\phi)(4\,\kappa^2+27\,\kappa\,\phi+72\,\phi^2)}{72}\right]$$
$$+\frac{\lambda\,\nu}{(\alpha-1)(\kappa+\phi)}\left(1-\kappa-\phi+\frac{3}{2}\,\kappa\,\phi+\phi^2+\frac{\kappa^2}{2}\right)$$
$$\left.+\frac{\lambda\,\nu}{(\alpha-1)(\kappa+\phi)}\left[\frac{\nu}{\nu+(\kappa+\phi)\,T}\right]^{\alpha-1}\frac{\kappa}{\phi}\left(1-\kappa-\phi+\frac{3}{2}\,\kappa\,\phi+\phi^2+\frac{\kappa^2}{2}\right)\right\}$$

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European Journal of Operational Research
Volume 213, Issue 1, 16 August 2011, Pages 15-23

Discrete Optimization

Enhanced speciation in particle swarm optimization for multi-modal problems

Huidae Cho [a], Dongkyun Kim [a], Francisco Olivera [a], Seth D. Guikema [b]

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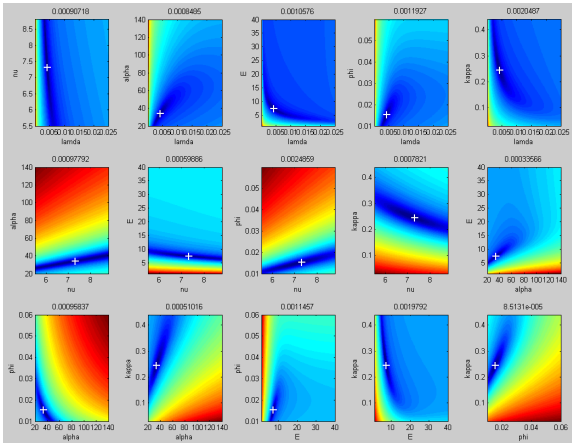
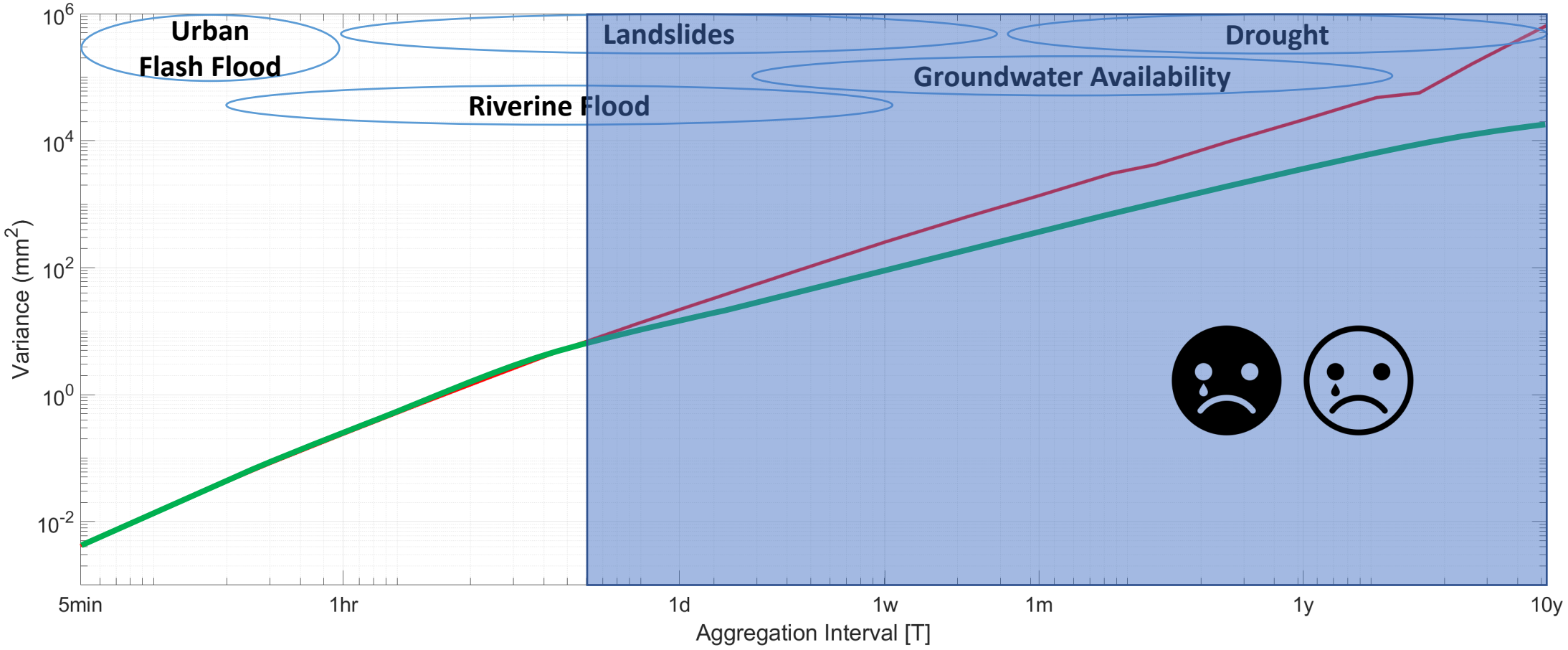


$$S(h) = \frac{\lambda\mu_c\mu_x^3\sum_{k=1}^{k=8}Q_k(\phi,\kappa,f_1,f_2,0)}{(1+2\phi+\phi^2)(\phi^4-2\phi^3-3\phi^2+8\phi-4)\phi^3}$$
for $\alpha>4$

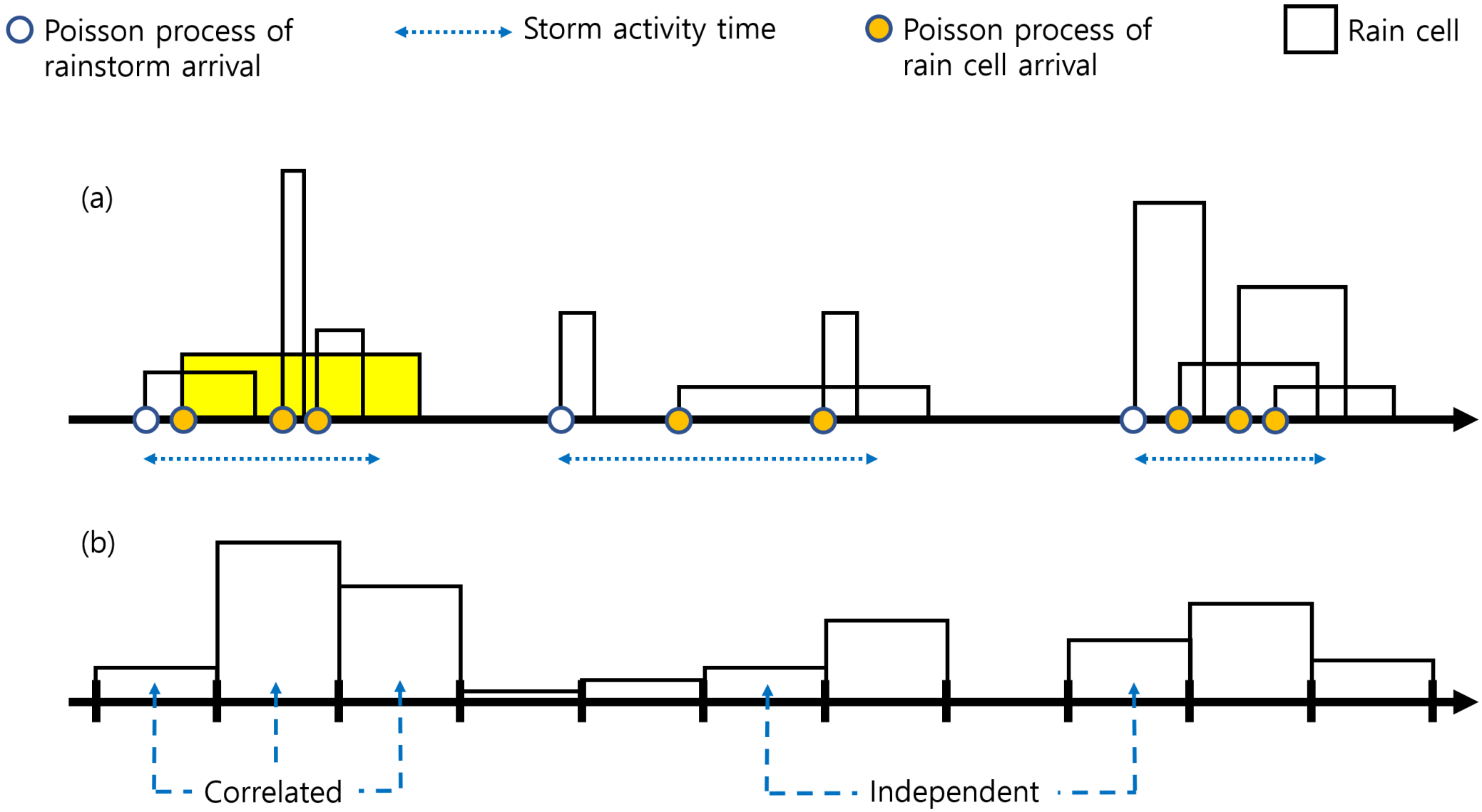
$$S(h) \approx \frac{\lambda\mu_c\mu_x^3}{(1+2\phi+\phi^2)(\phi^4-2\phi^3-3\phi^2+8\phi-4)\phi^3}$$
$$\left[\frac{\nu^\alpha\eta_0^{\alpha-1}h^3}{\Gamma(\alpha)(\alpha-1)}\left(2\kappa^2(\phi^7-3\phi^6+\phi^5+3\phi^4-2\phi^3)+f_2(\phi^9-6\phi^7+9\phi^5-4\phi^3)\right.\right.$$
$$\left.+3\kappa f_1(\phi^8-\phi^7-5\phi^6+5\phi^5+4\phi^4-4\phi^3)\right)$$
$$\left.+\sum_{k=1}^{k=8}Q_k(\phi,\kappa,f_1,f_2,\eta_0)\right]$$
for $1<\alpha\le 4$

$$S(h) = \infty$$
for $\alpha\le 1$

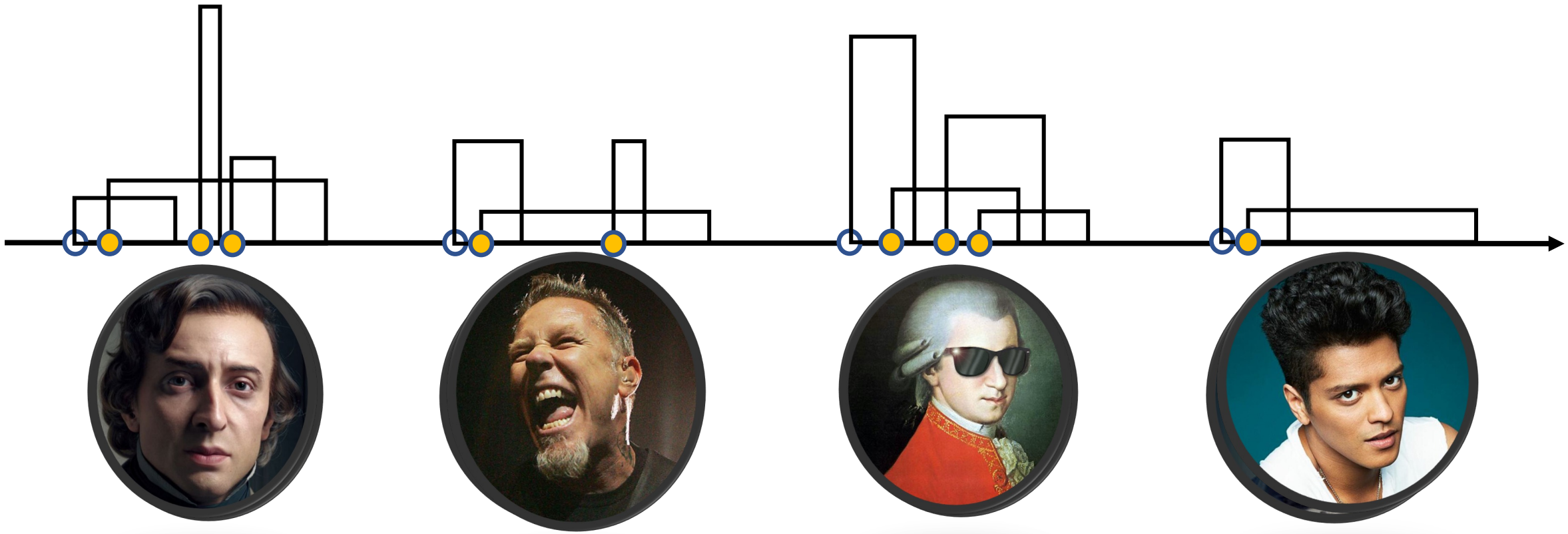
Issue of the Poisson Cluster Rainfall Model



Issue of the Poisson Cluster Rainfall Model



Poisson Cluster – Shufflex2 Model

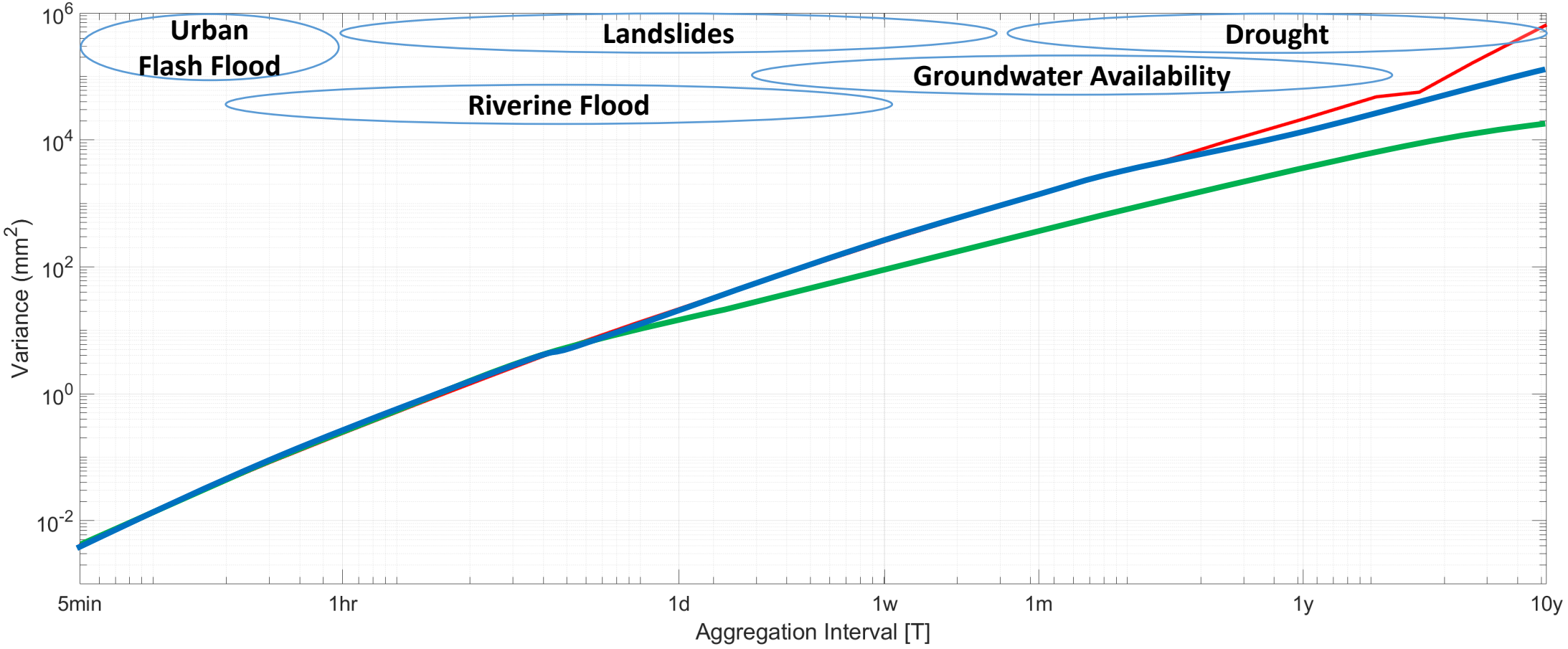


$$\frac{\tau}{|\log(P_3) - \log(P_1)|^{\delta}}$$

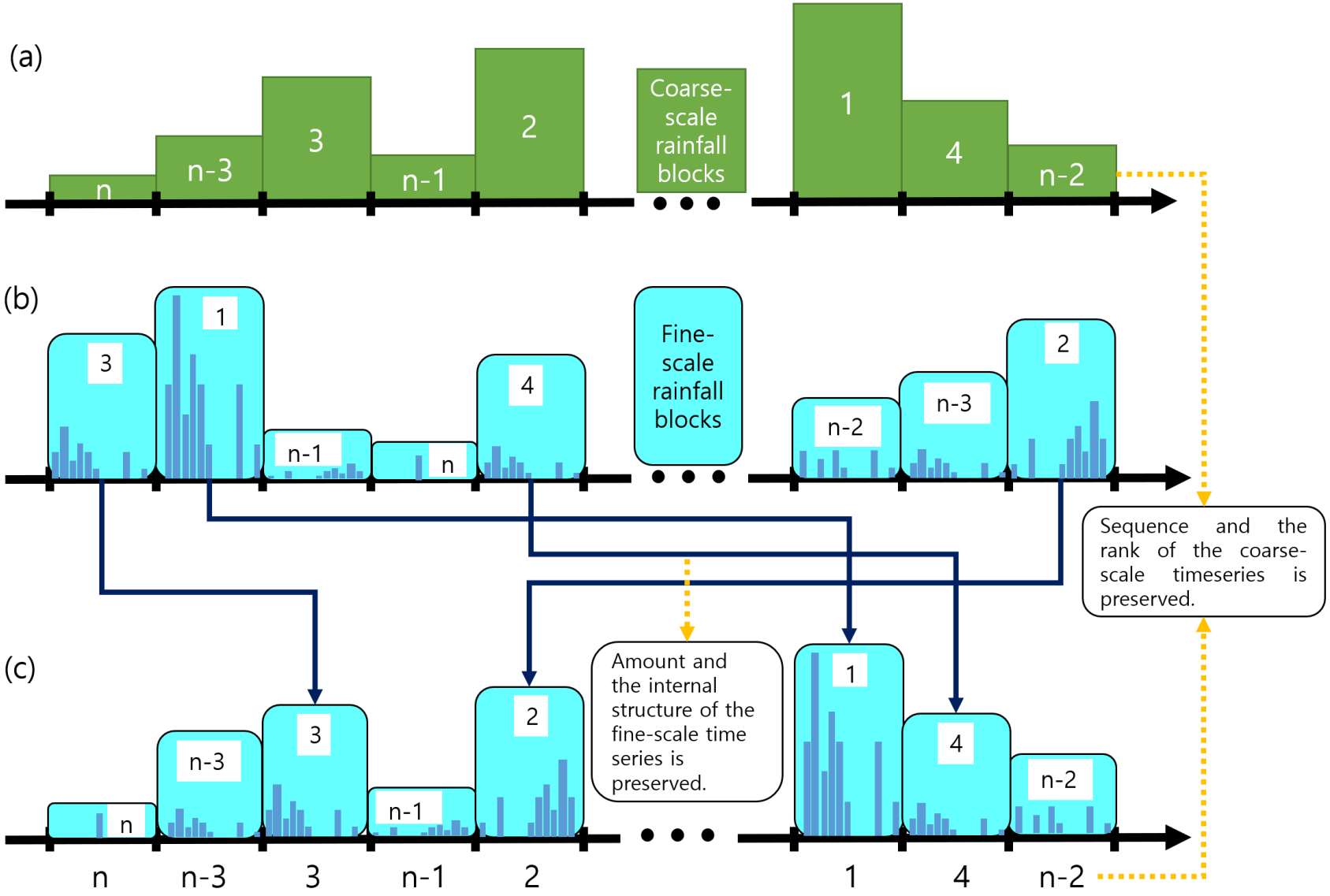
$$\frac{\tau}{\|\log(P_3) - \log(P_2)\|^{\delta}}$$

$$\frac{\tau}{\|\log(P_3) - \log(P_4)\|^{\delta}}$$

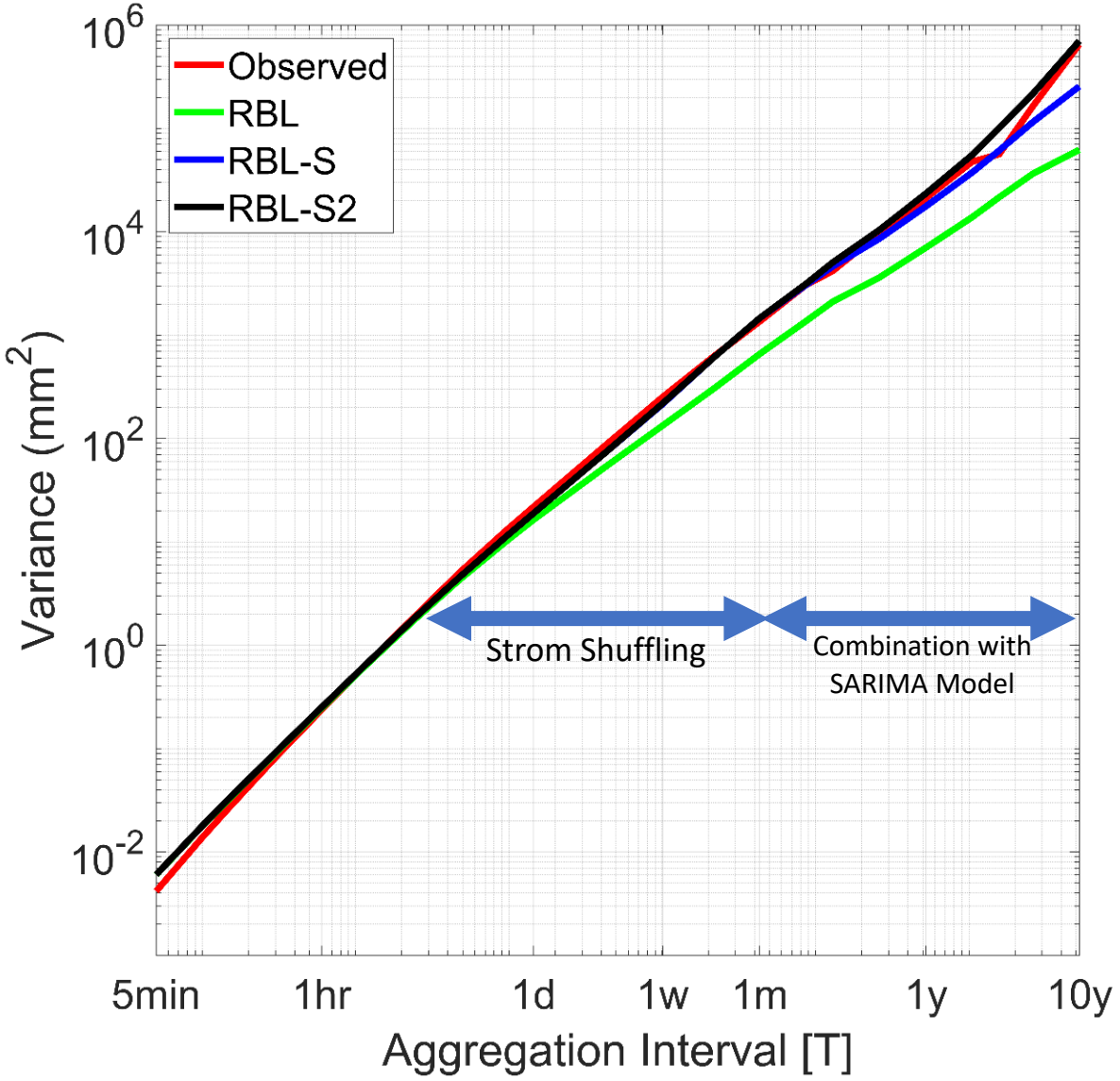
Poisson Cluster – Shufflex2 Model

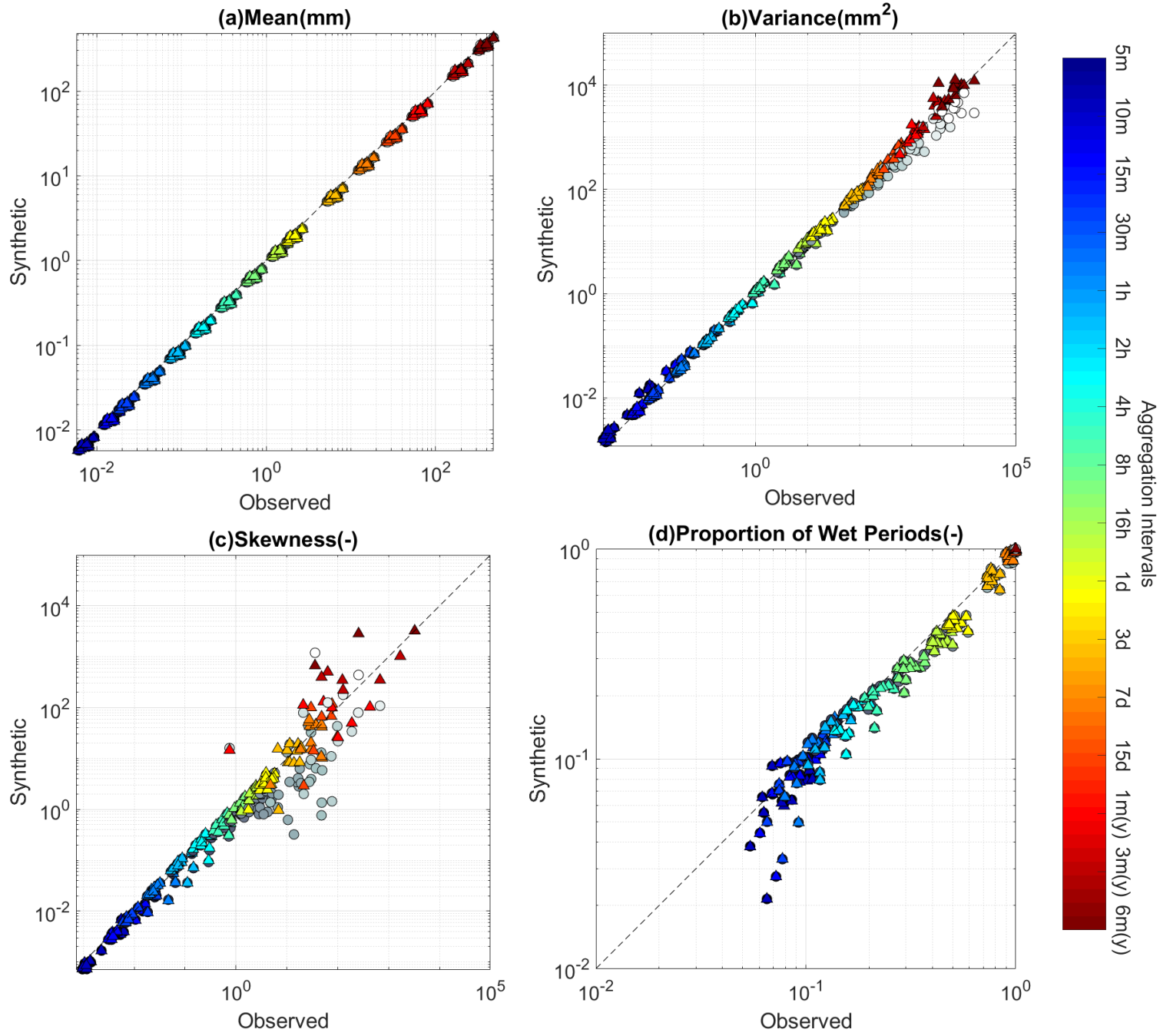


Poisson Cluster – Shufflex2 Model

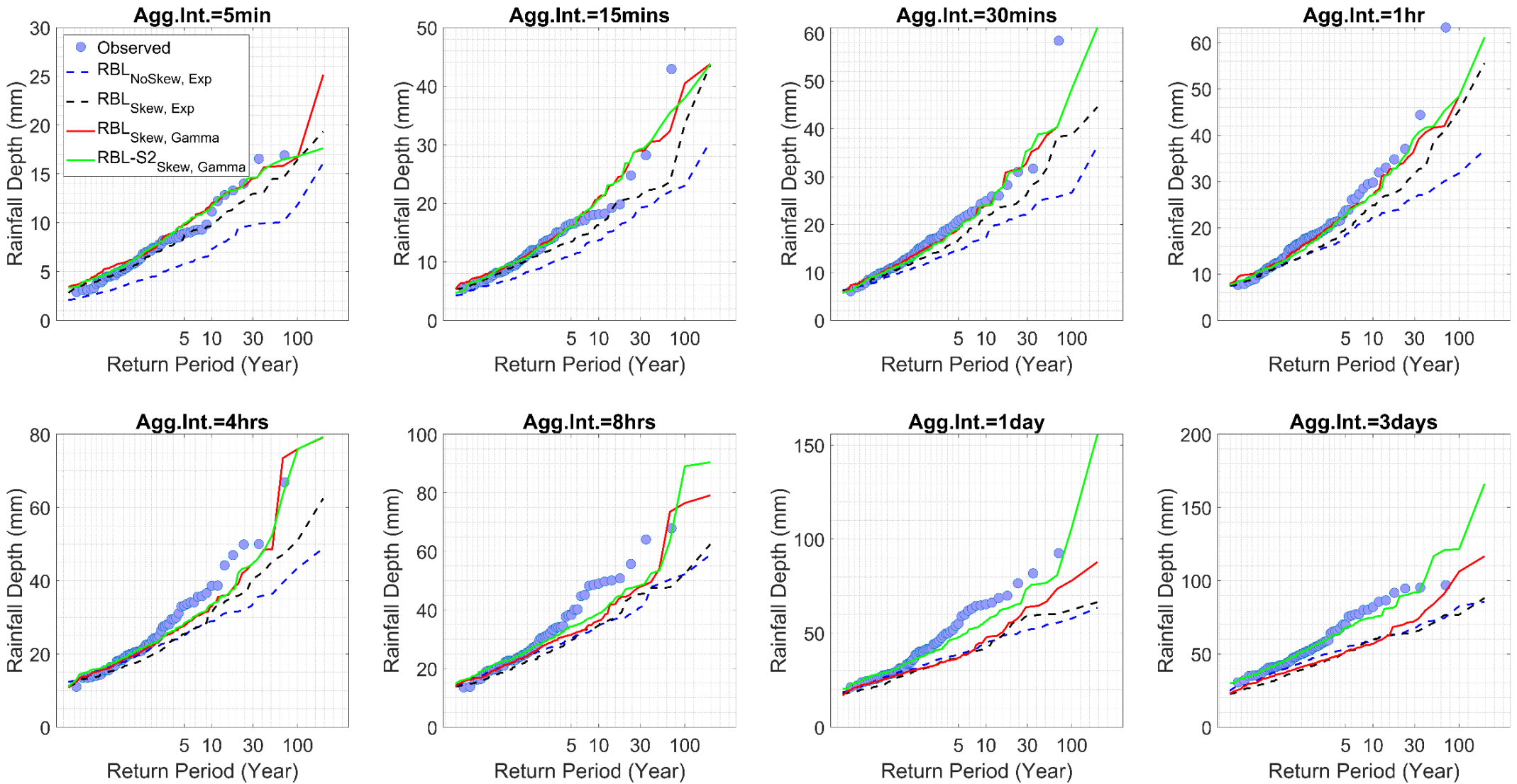


Poisson Cluster – Shufflex2 Model

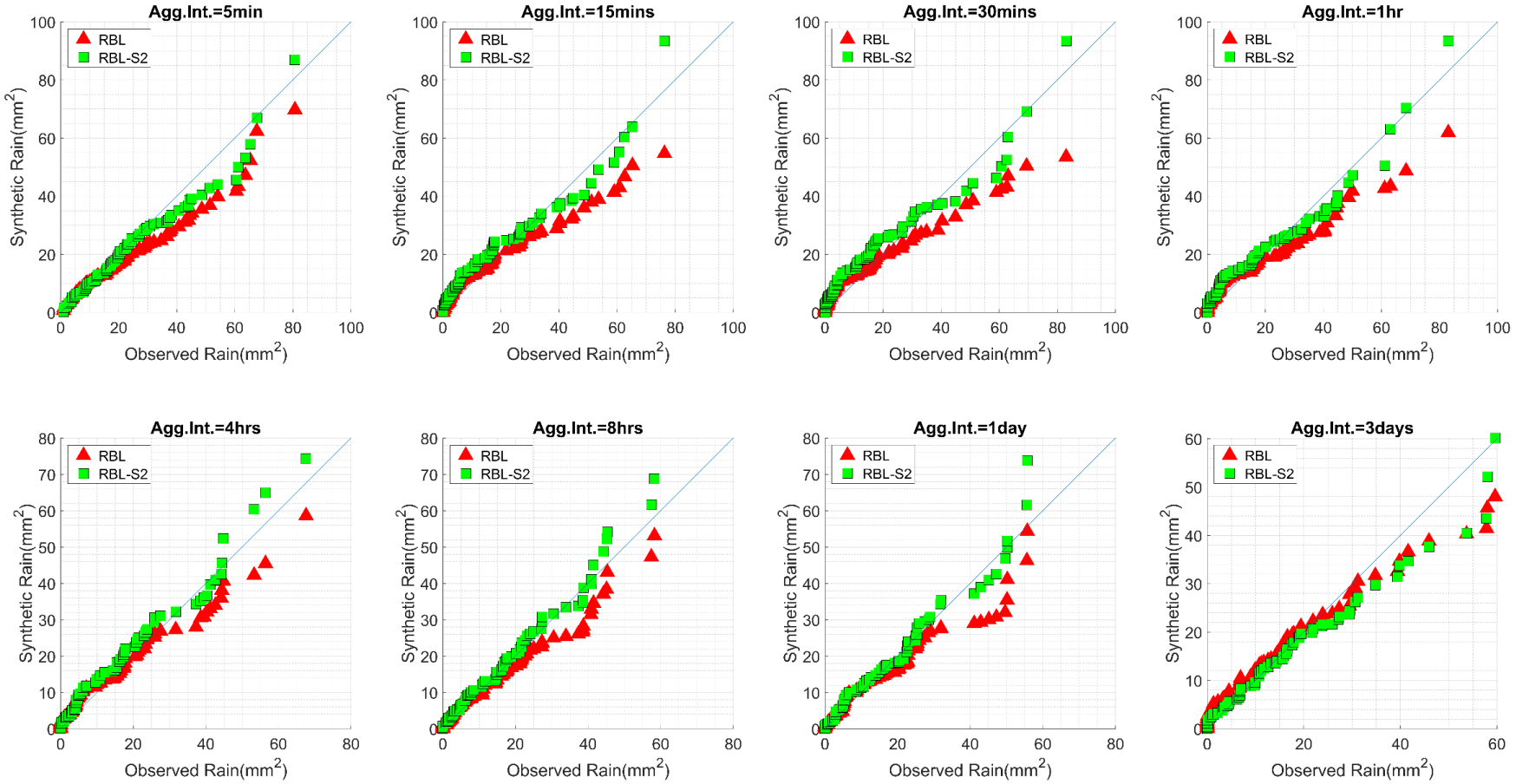



(a)Mean(mm)
(b)Variance(mm^2)
(c)Skewness(-)
(d)Proportion of Wet Periods(-)
Synthetic
Observed
Aggregation Intervals
5m
10m
15m
30m
1h
2h
4h
8h
16h
1d
3d
7d
15d
1m(y)
3m(y)
6m(y)

Extreme Value Reproduction

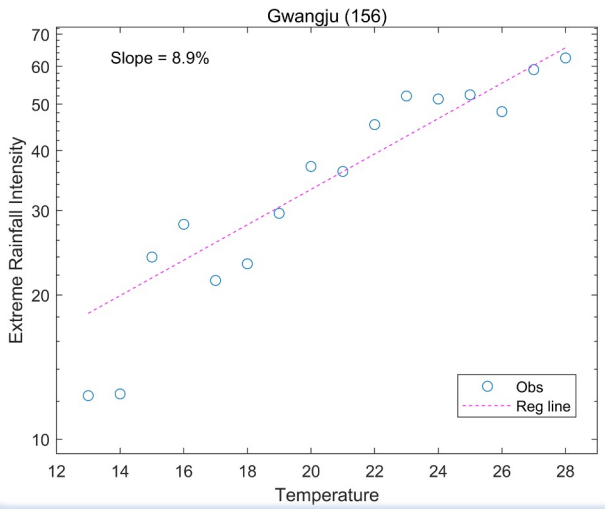


Past-7day Rainfall Reproduction (for continuous hydrologic modeling)



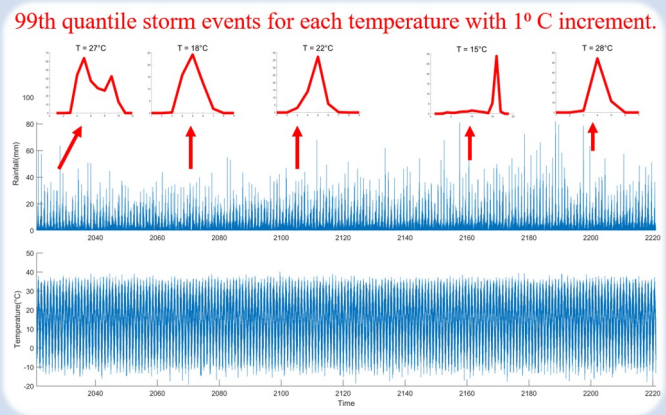
Model Extension for Climate Change

1



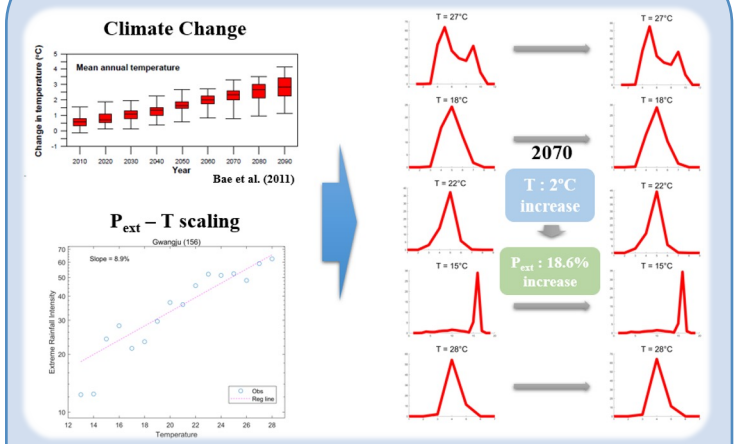
Obtain C-C relationships from observed rainfall

2



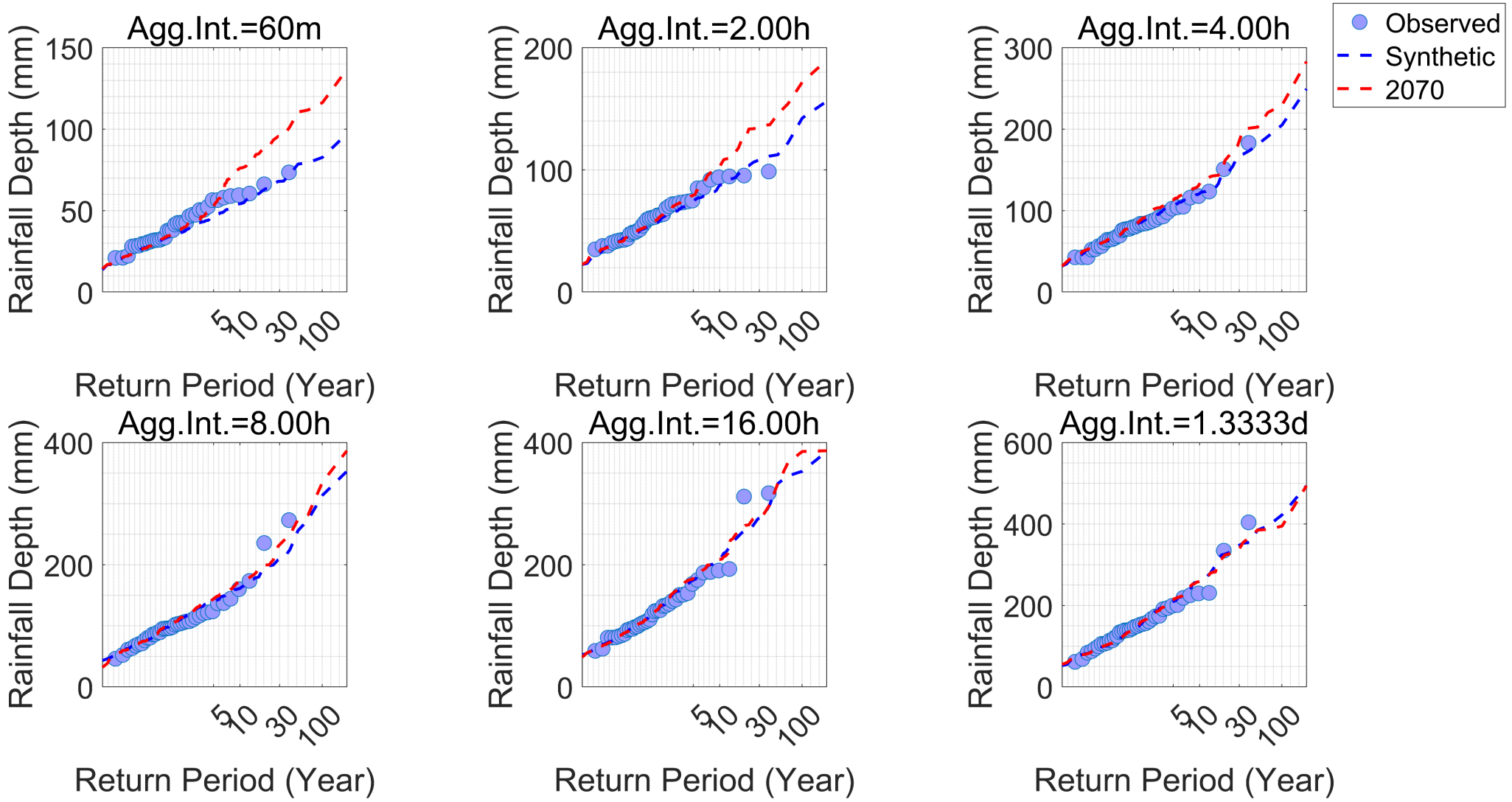
Extract Extreme Events from Synthetic Rainfall

3

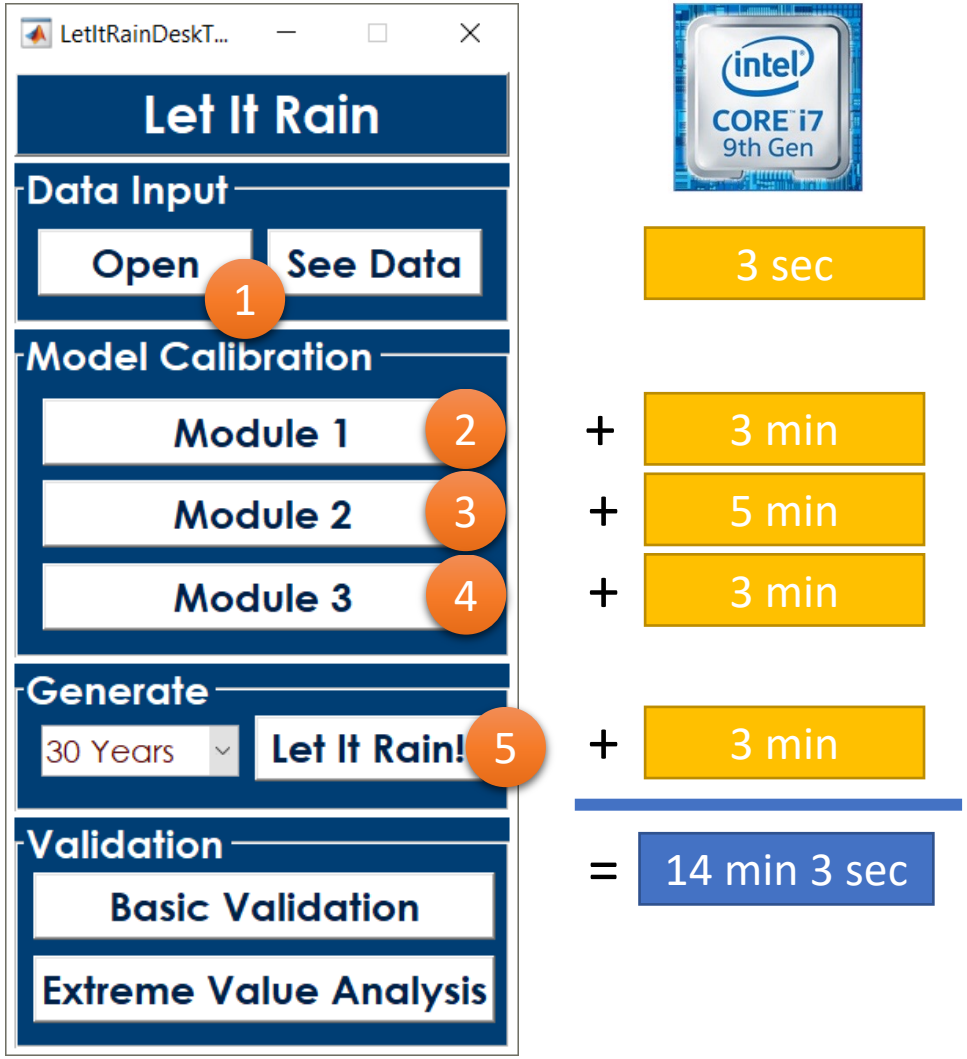


Scale extreme rain events

Extreme Value for Future Period



So what? I know it's good. How can I use it? www.hihydrology.com



Conclusion

- Rainfall memory governs the rainfall variability throughout the timescales.
- Ignoring it in rainfall modeling will eventually entail underestimation of the assessed risks.
- A model was developed to resolve this issue.
- The shuffling algorithm can be applied to all types of rainfall models to preserve memory.

Thank you!

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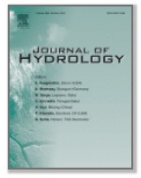
Journal of Hydrology
Volume 589, October 2020, 125150



Research papers

A stochastic rainfall model that can reproduce important rainfall properties across the timescales from several minutes to a decade

Dongkyun Kim [a], Christian Onof [b]