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QUICS

Analysis of sub-kilometre variability of rainfall in the context of urban runoff modelling

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Introduction

Urban hydrology

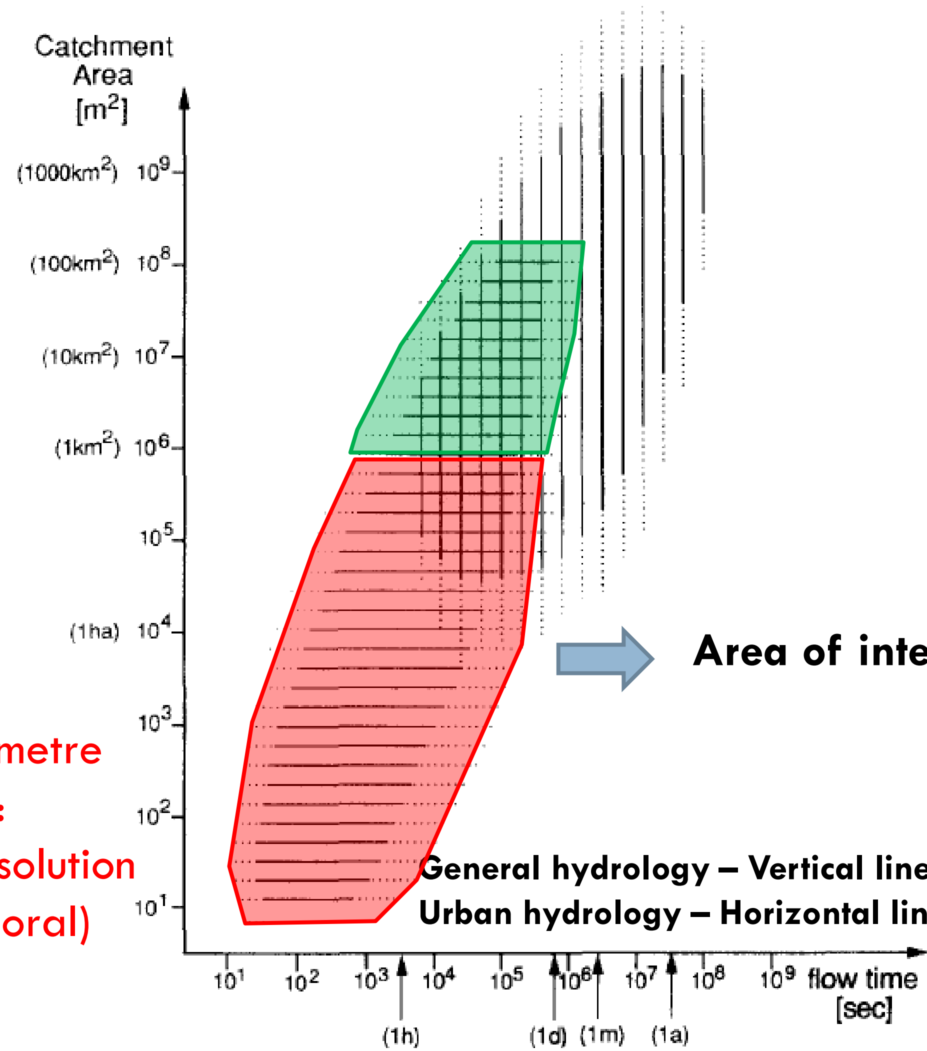
- Smaller catchments
- Greater impervious areas

Higher proportion of effective rainfall

Impact of rainfall variability is enhanced

Analysing large scale (> 1 km^2) rainfall variability : Operational rain gauge data, radar data

Analysing sub-kilometre rainfall variability: Requires higher resolution (spatial and temporal) data



Area of interest

Schilling, W., 1991. Rainfall data for urban hydrology: what do we need? Atmos. Res..

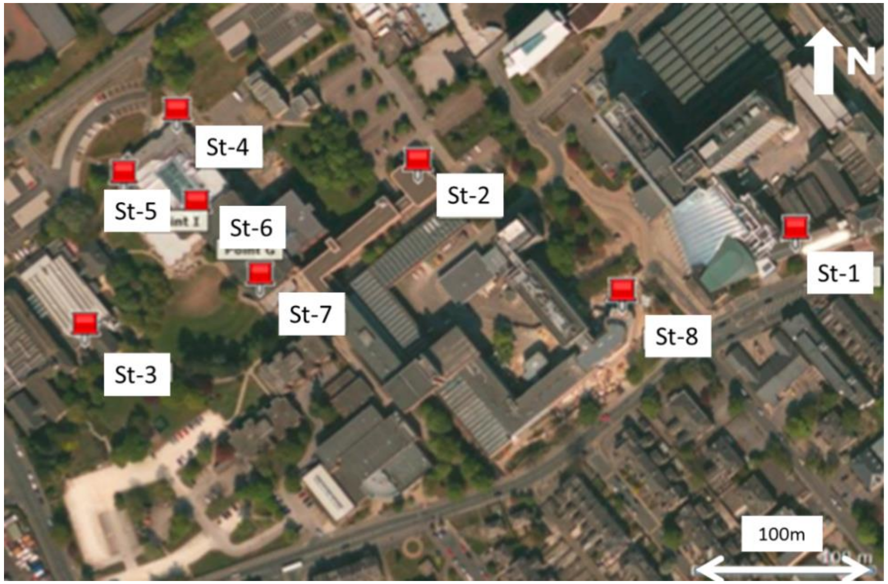
Objective

- To describe the correlation structure of sub kilometre rainfall as a function of their separation distance using geo statistics
  - Dependency of correlation on averaging interval (Time scale) of rainfall
  - Dependency of correlation on rainfall intensity

- To analyse the effect of this sub kilometre spatial variability of rainfall on urban runoff peaks

Data

Site	Bradford university
Area covered	~ 200m*400m
Number of stations	8*
Rain gauge type	ARG 100 Tipping bucket (0.2mm)
Measurement resolution	1 min
Measurement period	April, 2012 to August, 2013



* Paired gauges were used at each station to increase the measurement redundancy. Measurement from one rain gauge was checked against its paired rain gauge and the mean value of the paired gauges was used for further analysis.

Spatial correlation structure

- Correlograms:
  - Geostatistical measure of spatial autocorrelation
  - Correlation versus distance
- Correlation: Pearson's product moment correlation co-efficient
  - Measure of linear correlation between two variables

$$P_{ij} = \frac{\overline{R_i \, . R_j} - \bar{R}_i . \bar{R}_j}{\sqrt{\left(\overline{R_i{}^2} - \bar{R}_i{}^2\right)\left(\overline{R_j{}^2} - \bar{R}_j{}^2\right)}}$$

i, j : station id,
R : rainfall intensity (bar indicates the mean value)

Range
1 - Complete positive correlation
0 - No correlation
-1 - Complete negative correlation

Matrix of distance and correlation co-efficient (Avg. Interval : 15 min)

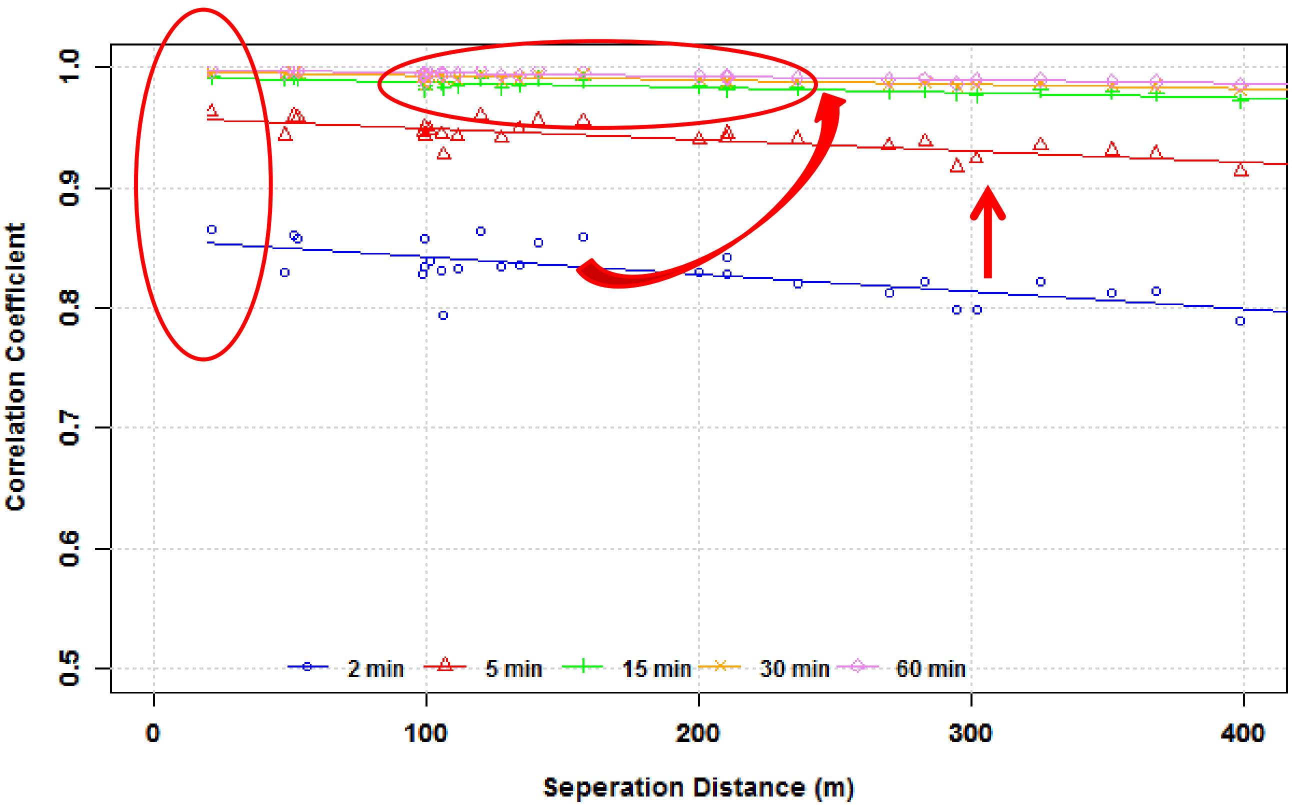
	[,1]	[,2]	[,3]	[,4]	[,5]	[,6]	[,7]	[,8]
[1,]	1.000	0.982	0.967	0.971	0.977	0.964	0.968	0.958
[2,]	216	1.000	0.979	0.984	0.990	0.975	0.978	0.962
[3,]	404	209	1.000	0.977	0.981	0.965	0.968	0.948
[4,]	380	166	88	1.000	0.985	0.981	0.984	0.972
[5,]	355	139	131	46	1.000	0.972	0.977	0.954
[6,]	304	111	105	96	102	1.000	0.989	0.972
[7,]	338	127	95	44	52	56	1.000	0.971
[8,]	104	139	304	290	270	204	246	1.000

Distance   Inter-gauge correlation coefficient

Repeated for 2min, 5min, 30min, and 60 min

Spatial correlation structure

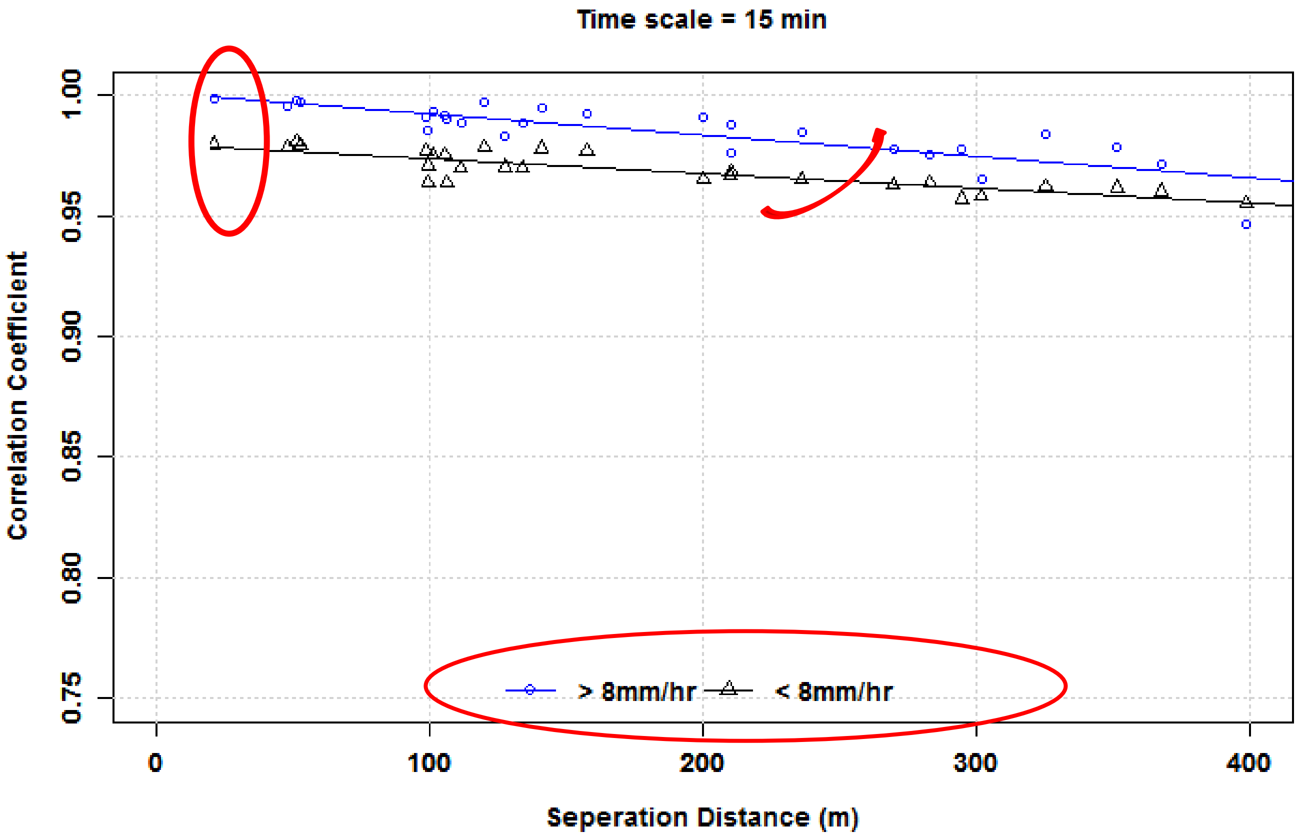
Dependency on averaging interval (Time scale)



- Origin: Sampling error decreases with increasing avr. interval
- Slope: Correlation gets better with increasing avr. interval
- improvement is hardly visible after an avr. Interval of 15 min : Spatial extend of the area
- Significant reduction in sampling error from 2 min to 5 min avr. interval

Spatial correlation structure

Dependency on rainfall intensity



- Origin: Larger sampling error for rainfall < 8 mm/hr
- Slope: Higher correlation for rainfall < 8 mm/hr
- Similar behaviour irrespective of threshold value

Spatial correlation structure

Summary

- The higher the time scale
  - The higher the correlation
  - The smaller the sampling error

- The higher the rainfall intensity
  - The lower the correlation
  - The smaller the sampling error

The effect on urban runoff

- Urban catchment: size ~8 Hec, 80-90% Impermeable

- All possible catchment average rainfall estimation were generated using Thiessen weights of different combination of stations for averaging interval of 15min

  Eg: 1 station: 8!/7!.1! = 8,

  2 stations: 8!/6!.2! = 28 , and so on.

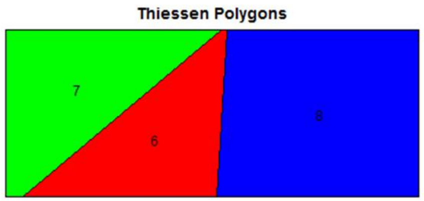
- These rainfall estimation were then fed in to rainfall-runoff model (InfoWorks CS) and peak runoffs were extracted from each model run for number of rainfall events

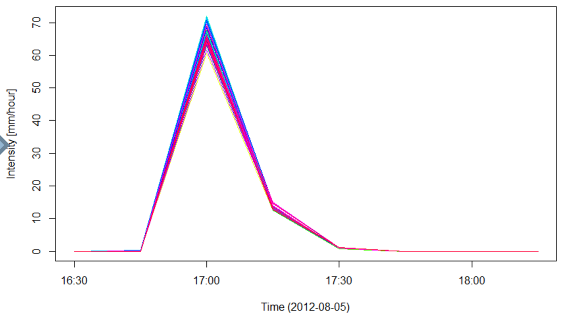
The effect on urban runoff

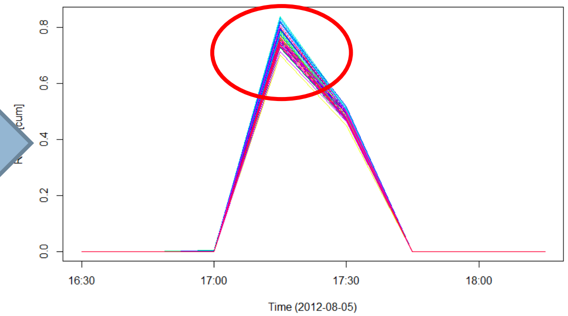
Multiple rainfall fields generated using Thiessen weights of different combination of stations

Multiple catchment - average rainfall fields for a particular rainfall event

Corresponding runoffs, derived from rainfall-runoff model (InfoWorks CS)

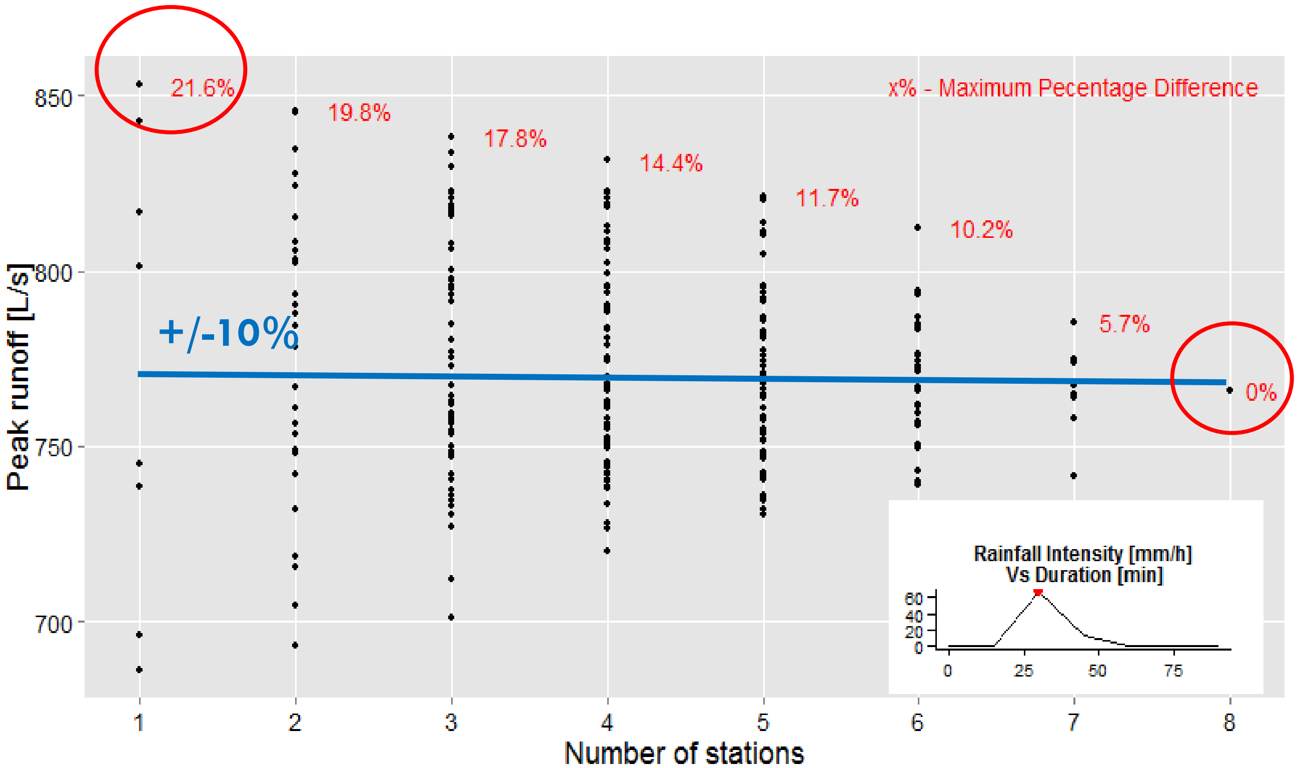






E.g. : Considering only 3 stations

The effect on urban runoff



- Maximum percentage difference of ~ 22%
- This is equalant to +/- 10% deviation from the most likely value

Most likely value to be the actual peak

The effect on urban runoff

Event Number	Predicted Peak Runoff (L/s)			Max. difference from the most likely value (%)
	Max	Min	Most likely	
1	95	78	89	12
2	73	62	69	10
3	104	82	95	14
4	159	132	149	11
5	230	183	211	13
6	169	129	152	15
7	853	686	771	11
8	379	318	355	11

- Max. difference from the most likely peak runoff : 10 -15%
- Urban drainage verification guidelines (WaPUG, 2012) in UK - Maximum allowable deviation of +/-10% in peak flows
- Neglecting spatial variability might result in force fitting of the model
- Demands the consideration of sub kilometre rainfall variability in urban drainage modelling

Conclusions and direction

- The dependency of correlation structure in both averaging interval and rainfall intensity shows a clear trend, complementing results from similar studies in the past

- Effect of sub kilometre rainfall variability found to be significant in prediction of urban runoff peaks

- UK urban drainage guidelines (WaPUG 2002) suggest a rain gauge resolution of 1 gauge/sq.km
  - Neglects the effect of sub- kilometre variability of rainfall?
  - Cost and effort require to collect rainfall data in a sub-kilometre scale?
  - Solution?

- A more detailed study is being carried out to incorporate sub kilometre variability in a probabilistic way which gives uncertainty associated with the estimation of catchment average rainfall

Thank you!