Benefits of higher resolution rainfall estimates for urban drainage modelling

by

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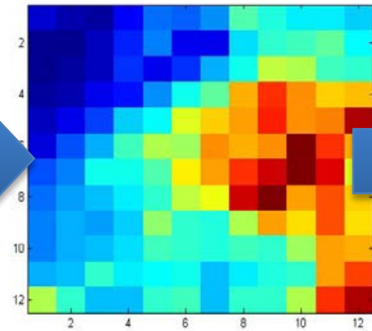
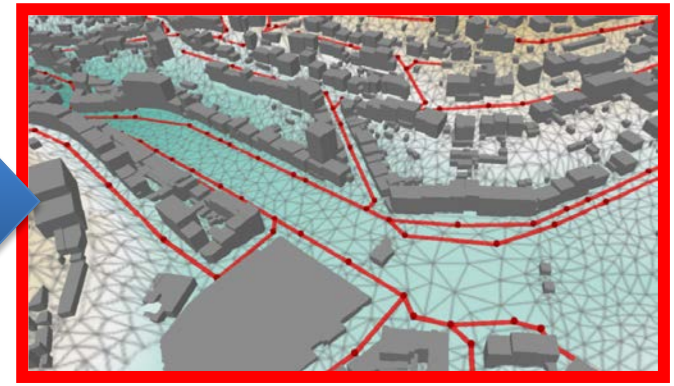
Susana Ochoa-Rodriguez, Imperial College London

And many RainGain partners

Radar technologies



Radar QPEs



High res urban drainage modelling using improved QPEs

- Implementation of hydrodynamic models at pilot locations and evaluation of model structures

- Evaluation of the impact of rainfall input resolution on modelling outputs; impact of model structure (semi- vs fully distributed)

- Investigation of alternatives for local flood forecasting systems

Rain Gain

Investing in Opportunities
This project has received European Regional Development Funding through INTERREG IV B.
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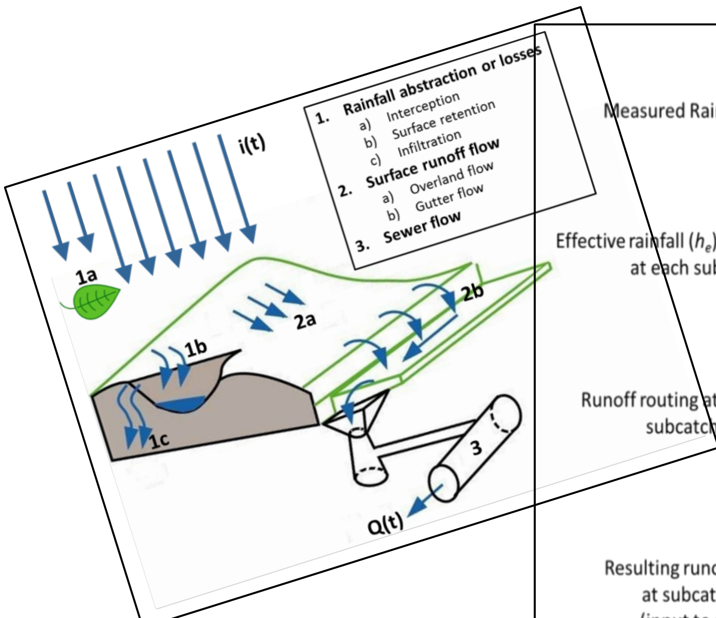
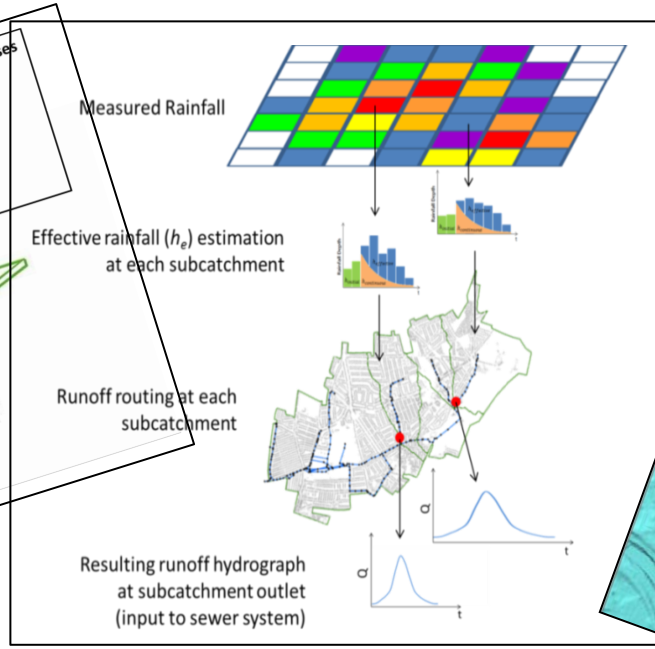
PILOT LOCATIONS

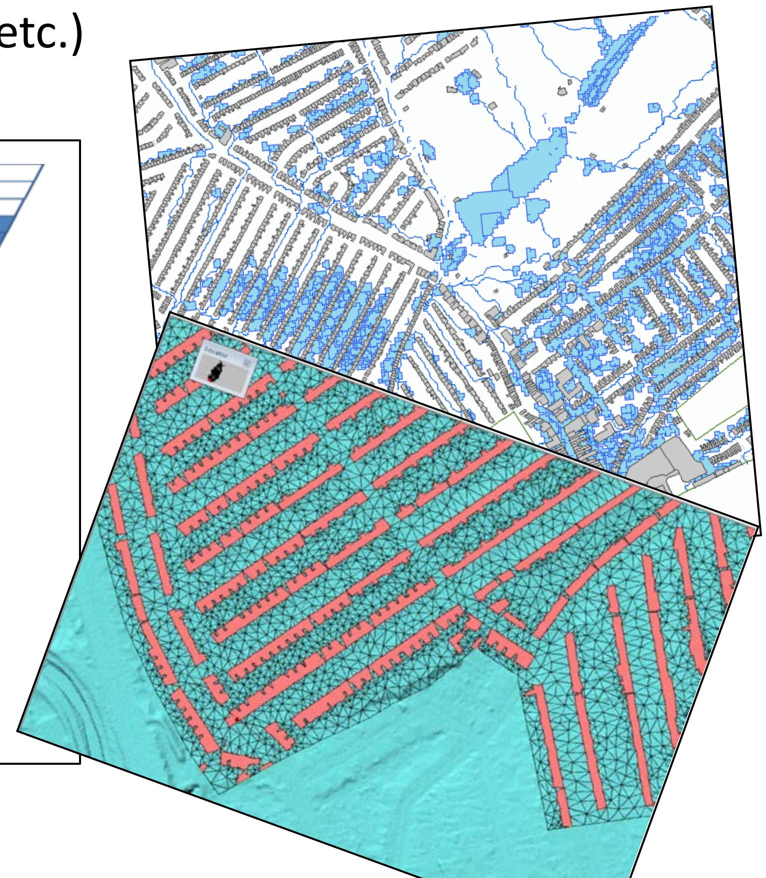
Model building and analysis tools and recommended practices

Review document on urban pluvial flood models: current theory and practice

- Model inputs and components
- Modelling approaches (semi-distributed, fully-distributed, 1D and 2D models of the urban surface, hybrid models, etc.)







Model building and analysis tools and recommended practices

- Review document on urban pluvial flood models
- Updated documentation and tutorial of the Automatic Overland Flow Delineation (AOFD) tool
- Fractal tools for analysis of urban catchments
- Recommendations for dealing with open channels and other small surface features in urban pluvial flood simulations
- General recommendations for dealing with buildings in 2-dimensional (2D) urban flood simulations

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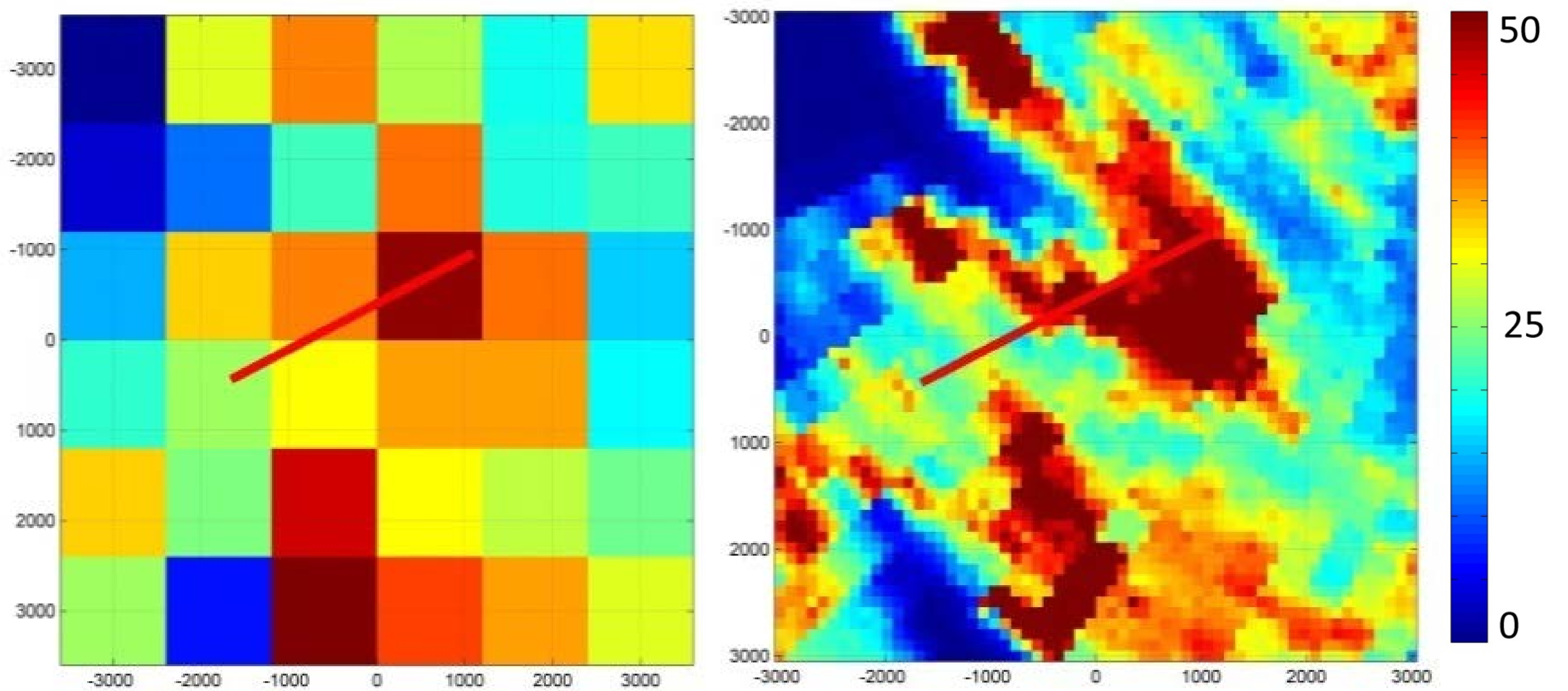
Impact of spatial and temporal resolution of rainfall inputs on urban hydrological modelling outputs

National Weather Radar Polarimetric X-band radar

1x1 km^2, 5-15 min 100x100 km^2, 1 min



Courtesy: KNMI

Courtesy: H.W.J. Russchenberg

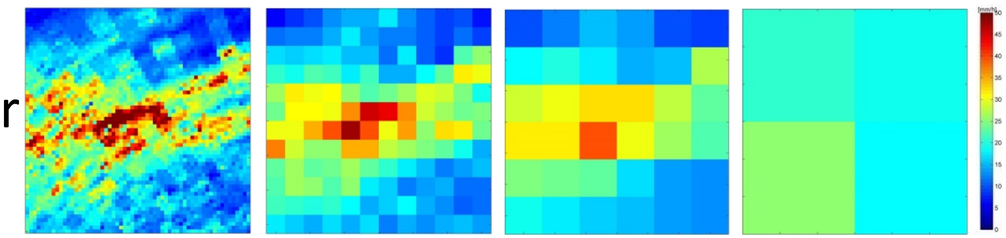
INVESTIGATION: IMPACT OF SPATIAL AND TEMPORAL RESOLUTION OF RAINFALL INPUTS ON OPERATIONAL URBAN HYDRODYNAMIC MODELLING OUTPUTS

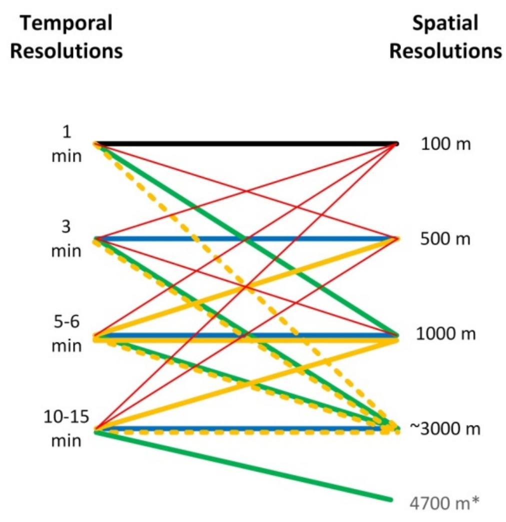
Rainfall data:

9 storms recorded by X-band radar

16 spatial-temporal resolutions:

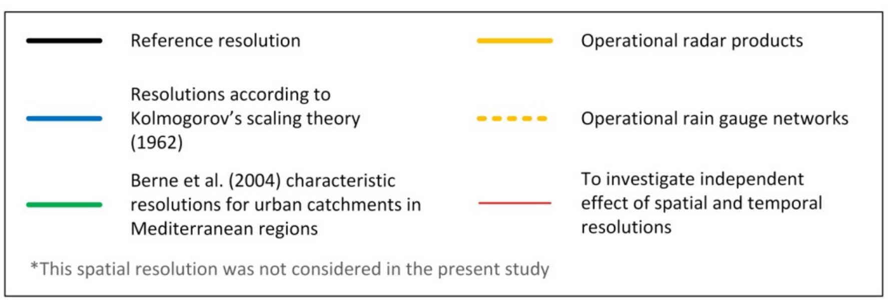
100 m – 3 km & 1 min – 10 min





Summary Selected Resolutions

ID	Temporal Resolution (min)	Spatial Resolution (m)
1 (Ref)	1	100
2	3	100
3	5	100
4	10	100
5	1	500
6	3	500
7	5	500
8	10	500
9	1	1000
10	3	1000
11	5	1000
12	10	1000
13	1	3000
14	3	3000
15	5	3000



- **Coarser spatial resolutions** generated through **aggregation** (i.e. averaging)
- **Coarser temporal resolutions** generated through:

i. **Sampling**

ii. **Aggregation**

MULTI-CATCHMENT, MULTI-STORM INVESTIGATION OF THE IMPACT OF SPATIAL AND TEMPORAL RESOLUTION OF RAINFALL INPUTS ON OPERATIONAL URBAN HYDRODYNAMIC MODELLING OUTPUTS

Rainfall data:

- 9 storms recorded by X-band radar
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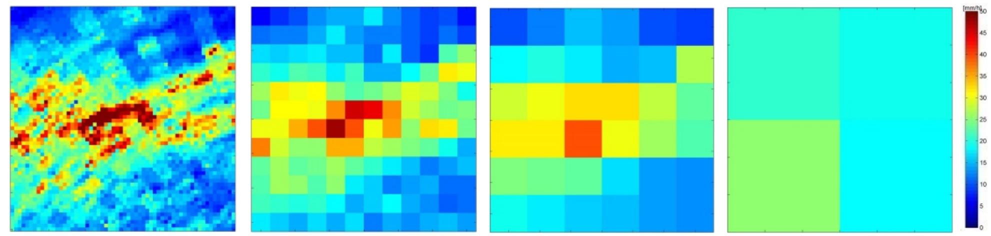
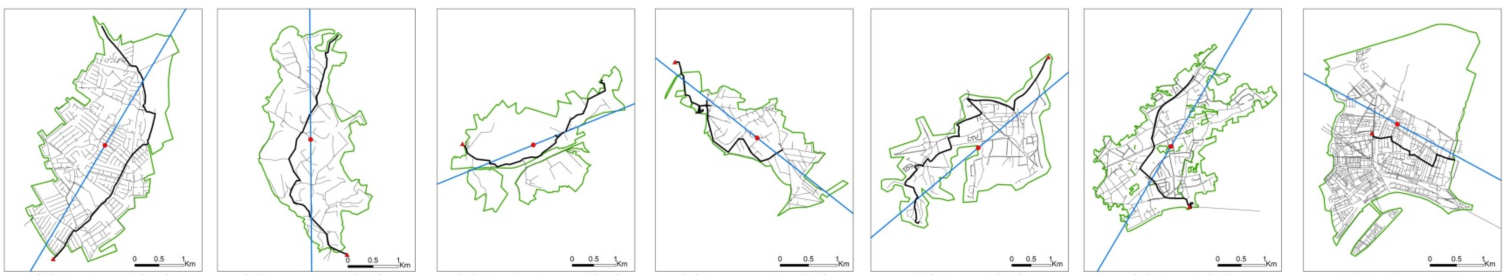


Semi-distributed operational urban drainage models of 7 RainGain pilot sites



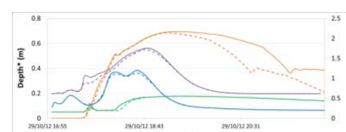
(1) Cranbrook (UK) (2) Torquay TC (UK) (3) Morée-Sausset (FR) (4) Sucy-en-Brie (FR) (5) Herent (BE) (6) Ghent (BE) (7) Kralingen (NL)

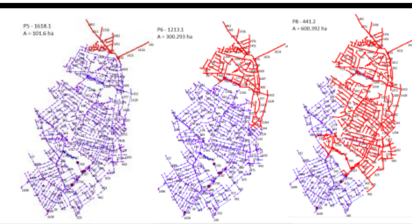
Areas:
3 – 8 km^2

In 4 NWE countries

Analysis and inter-comparison of results considering:

- Storm *spatial* - *temporal* characteristics
- Catchment characteristics





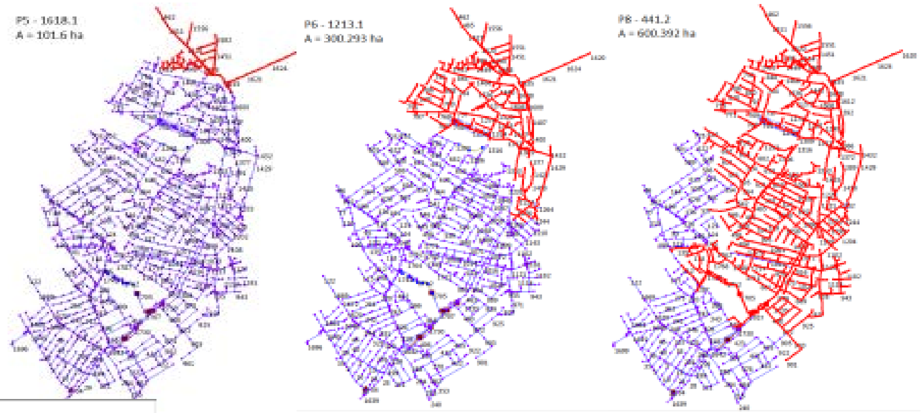
A methodology for characterising and standardising rainfall inputs and results was devised, thus allowing inter-comparison

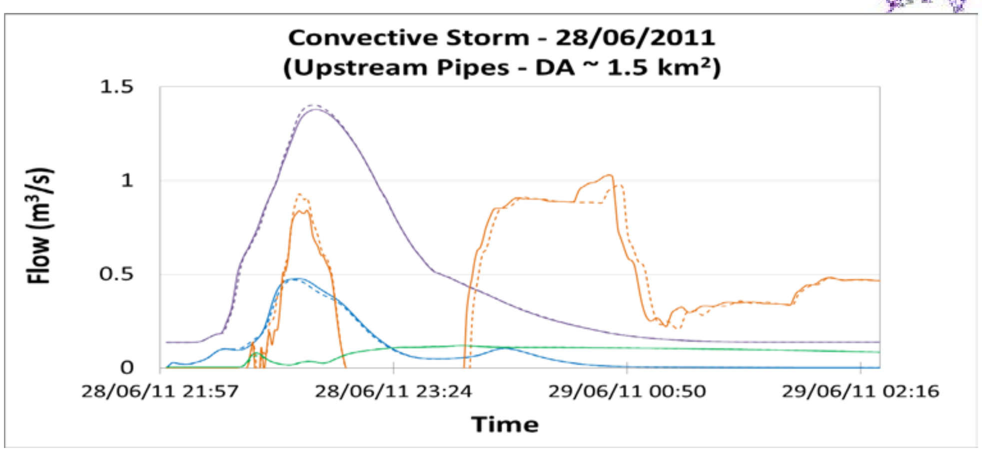
Ochoa-Rodriguez et al. (2015), JoH

Analysis and inter-comparison of results considering:

Storm *spatio-temporal* characteristics: storm range, velocity
Sub-catchment drainage area sizes: 1-25-100-300-500-600 ha

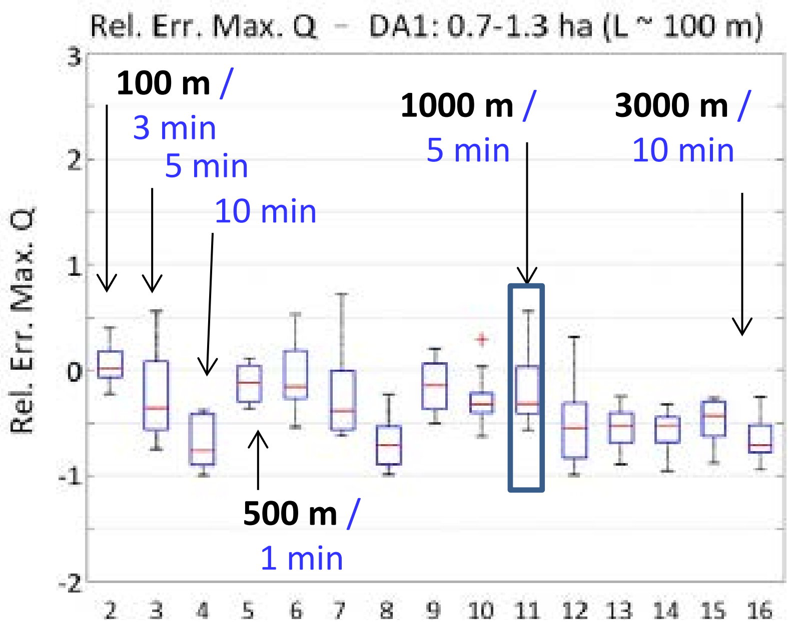
Results:
- Flow peak: relative error
- Hydrograph: R^2, regr. coeff. β





Ochoa-Rodriguez et al. (2015), JoH

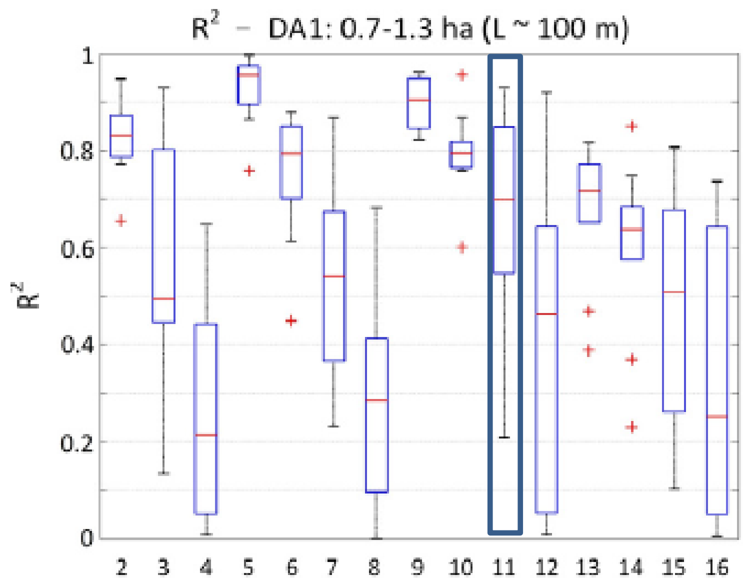
Results: Drainage Area Size ~ L=100m



- Relative Error Max Flow Peak:

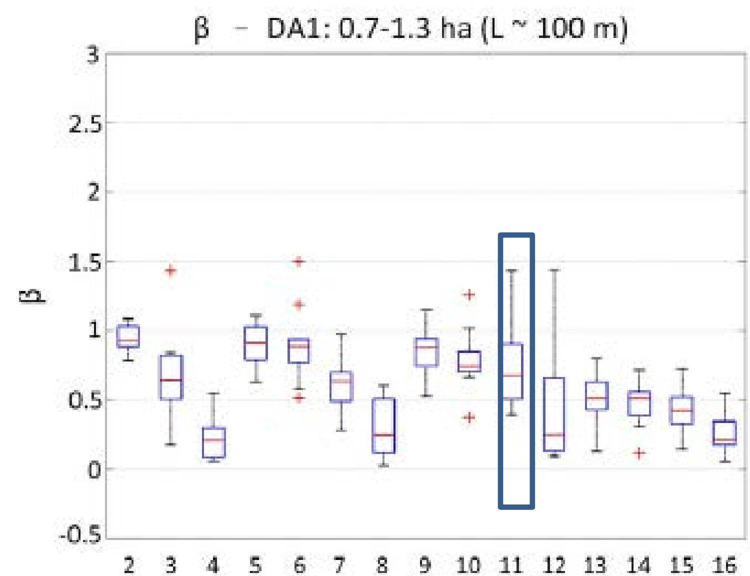
$$RE_{s,t} = \frac{Qp_{s,t} - Qp_{ref}}{Qp_{ref}}$$

Qp_{ref} : 100 m, 1 min resolution

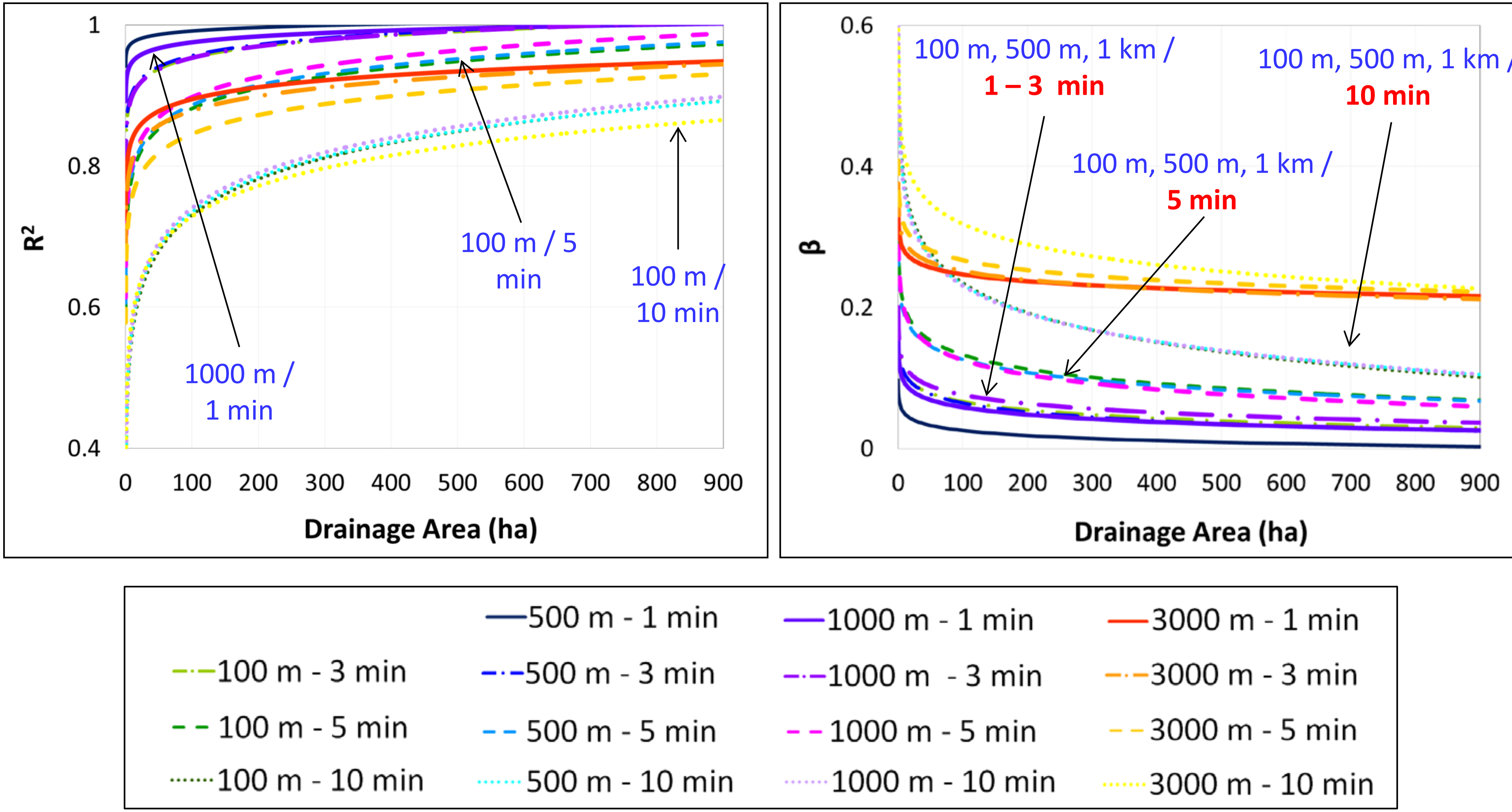


For linear regression $Q_{s,t}$ vs Q_{ref} :

- R^2: coefficient of determination
- Β: regression coefficient

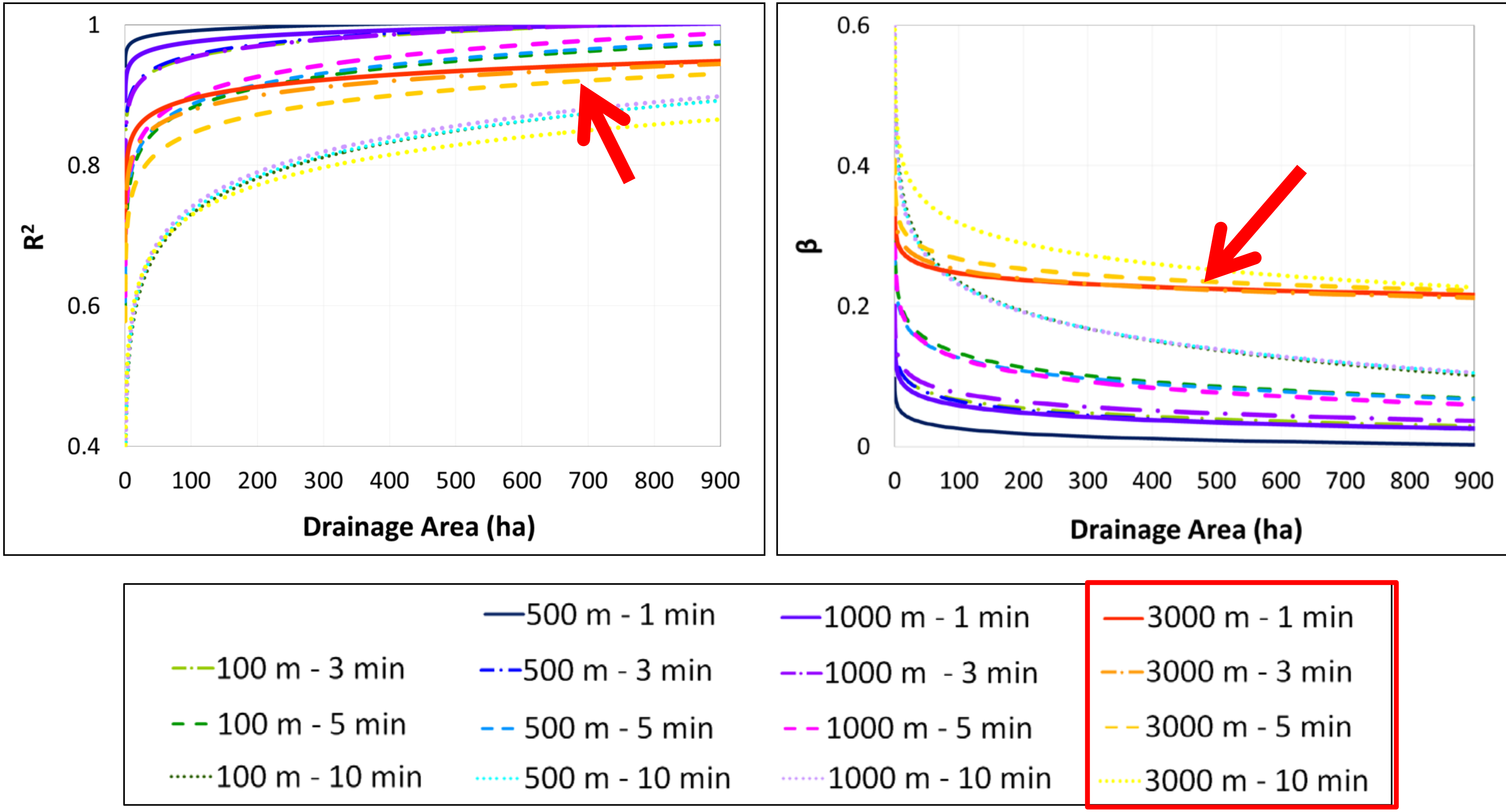


Drainage Area vs. Stats - Log Functions per rainfall input



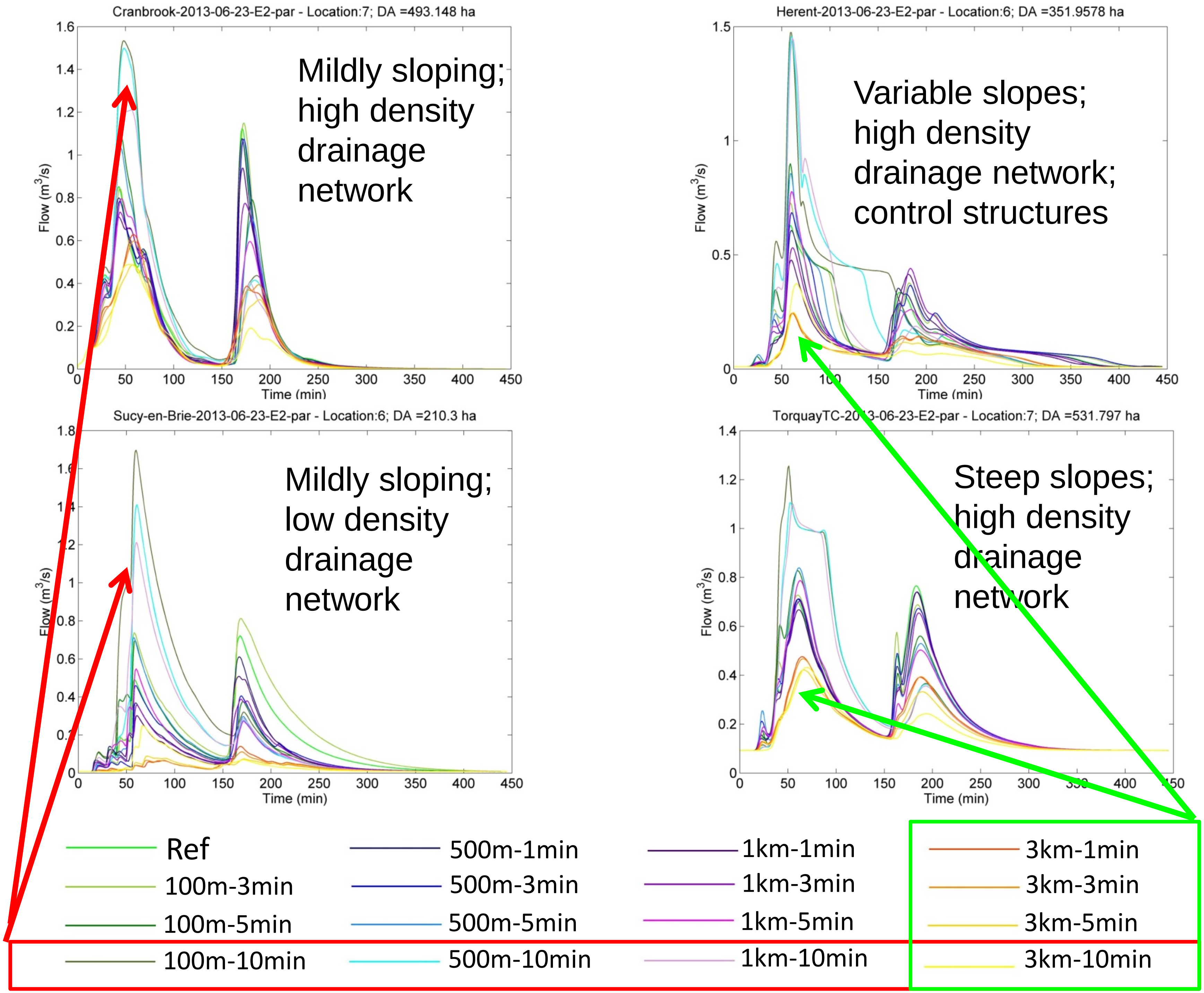
In general, coarsening of temporal resolution **(by sampling)** has stronger influence than coarsening of spatial resolution

Log Functions per rainfall input - Drainage Area vs. Stats

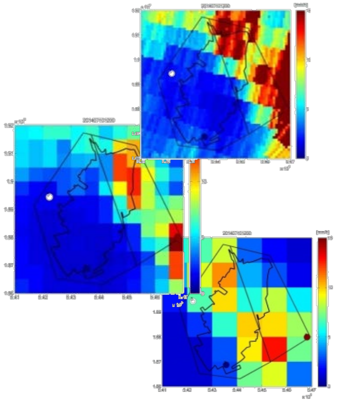


In general, coarsening of temporal resolution **(by sampling)** has stronger influence than coarsening of spatial resolution

Spatial resolution: big (and dominant) drop in performance only at 3 km resolution


Cranbrook-2013-06-23-E2-par - Location:7; DA =493.148 ha
Mildly sloping; high density drainage network
Herent-2013-06-23-E2-par - Location:6; DA =351.9578 ha
Variable slopes; high density drainage network; control structures
Sucy-en-Brie-2013-06-23-E2-par - Location:6; DA =210.3 ha
Mildly sloping; low density drainage network
TorquayTC-2013-06-23-E2-par - Location:7; DA =531.797 ha
Steep slopes; high density drainage network
Flow (m^3/s)
Time (min)
Ref
100m-3min
100m-5min
100m-10min
500m-1min
500m-3min
500m-5min
500m-10min
1km-1min
1km-3min
1km-5min
1km-10min
3km-1min
3km-3min
3km-5min
3km-10min

Implications of this study



Required temporal resolution of rainfall data: **< 5 min**

Spatial resolution ~ 1 km seems sufficient for many urban hydrological applications, except for very small drainage areas (~<1ha)

Spatial resolution ≥ 3 km is insufficient (interpolation of rain gauges!)

Impact of rainfall input resolution depends both upon drainage area and storm characteristics

Interaction between temporal and spatial resolutions is crucial!

More information on “Impact of Spatial and Temporal Resolution of Rainfall Inputs on Urban Hydrodynamic Modelling Outputs”:

Ochoa-Rodriguez, S., Wang, L. P., Gires, A., Pina, R. D., Reinoso-Rondinel, R., Bruni, G., ... & ten Veldhuis, M. C. (**2015**). *Impact of Spatial and Temporal Resolution of Rainfall Inputs on Urban Hydrodynamic Modelling Outputs: A Multi-Catchment Investigation.* **Journal of Hydrology**. *(**doi:10.1016/j.jhydrol.2015.05.035**)*

Thank you for your attention

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SUMMARY & LESSONS LEARNT

- **One size does not fit all!** Type of model depends on:
  - Purpose (CSO reduction? Flood visualisation?)
  - Available computer power
  - Data availability: surface data, sewer data & rainfall data

THESE MUST ALWAYS BE IN AGREEMENT

- Fully-distributed models are generally desirable, particularly when ponding is a relevant flooding mechanism. In fact, current tendency is clearly towards fully distributed models, but:
  - Runtimes are still problematic – option: use of nested / hybrid models
  - Fully distributed models require far more detailed data which is not always available and which is harder to process. Tools to deal with some of these challenges have been developed.
- Strong interaction between temporal and spatial resolution of rainfall inputs
- While temporal resolution has shown to have a stronger effect on hydro results, measuring rainfall at higher temporal resolution can lead to improved accuracy.

Alternatives for local surface water flood forecasting systems

- Evaluation of approaches / system structure
- Technologies for system implementation

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