Weather radar for urban hydrological applications: lessons learnt and research needs identified from 4 pilot catchments in North-West Europe

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ABSTRACT

This study investigates the impact of rainfall estimates of different spatial resolutions on the hydraulic outputs of the models of four of the EU RainGain project's pilot locations (the Cranbrook catchment (UK), the Herent catchment (Belgium), the Morée-Sausset catchment (France) and the Kralingen District (The Netherlands)). Two storm events, one convective and one stratiform, measured by a polarimetric X-band radar located in Cabauw (The Netherlands) were selected for analysis. The original radar estimates, at 100 m and 1 min resolutions, were aggregated to a spatial resolution of 1000 m. These estimates were then applied to the high-resolution semi-distributed hydraulic models of the four urban catchments, all of which have similar size (between 5 and 8 km2), but different morphological, hydrological and hydraulic characteristics. When doing so, methodologies for standardising rainfall inputs and making results comparable were implemented. The response of the different catchments to rainfall inputs of varying spatial resolution is analysed in the light of model configuration, catchment and storm characteristics. Rather surprisingly, the results show that for the two events under consideration the spatial resolution (i.e. 100 m vs 1000 m) of rainfall inputs does not have a significant influence on the outputs of urban drainage models. The present study will soon be extended to more storms as well as model structures and resolutions, with the final aim of identifying critical spatial-temporal resolutions for urban catchment modelling in relation to catchment and storm event characteristics.

1. INTRODUCTION

Urban hydrological analysis requires high resolution precipitation and catchment information in order to well represent the spatial variability, fast runoff processes and short response times of urban catchments (Aronica & Cannarozzo, 2000; Einfalt, 2005; Segond et al., 2007). While significant progress has been made over the last few decades in high resolution measurement of rainfall at urban scales, including widespread increase in the use of weather radars, the resolution of the currently available rainfall estimates (typically 1 x 1 km^2 in space and 5 min in time) may still be too coarse to match the spatial-temporal scales of urban catchments (Fabry et al., 1994; Gires et al., 2012a). Other shortcomings of the currently available radar rainfall estimates are a decreasing accuracy at high rainfall intensities , critical for urban environments, and a mismatch between precipitation measured aloft by radars compared to precipitation on the ground (Einfalt et al., 2005), where it affects urban life. Meanwhile, the trend of urban hydrologic models is towards application of spatially distributed continuous simulation models to fully capture the spatial variability in both rainfall patterns and urban texture (e.g. Fewtrell et al. (2011), Giangola-Murzin et al. (2012)). The complexity of these models requires far more detailed understanding of urban rainfall variability and runoff response than is currently available.

In the light of recent developments in this area, a number of questions have arisen which remain to be answered. For example: what are the actual rainfall input requirements for urban catchments with different characteristics? Are current urban drainage models able of taking full advantage of improved (higher resolution and more accurate) rainfall estimates? With the aim of answering some of these questions, the RainGain project has set to explore the use of a variety of rainfall sensors (including X-Band and C-Band radars, raingauges and disdrometers), to develop and test a number of rainfall data processing techniques, and to test the response of urban drainage models with different characteristics to varying rainfall inputs. For this purpose ten pilot locations have been implemented in 4 North West European countries: UK, France, Netherlands and Belgium. This provides a valuable opportunity for intercomparison of weather radar applications in cities and of hydrological responses of different model structures to high resolution and improved accuracy rainfall inputs.

This study investigates the impact of rainfall estimates of different spatial resolutions on the hydraulic outputs of the models of four of the RainGain project's pilot locations, namely the Cranbrook catchment (UK), the Herent catchment (Belgium), the Morée-Sausset catchment (France) and the Kralingen District of Rotterdam (The Netherlands). For this purpose two storm events, one convective and one stratiform, measured by a polarimetric X-band radar located in Cabauw (The Netherlands) were selected for analysis. The original radar estimates, at 100 m and 1 min resolutions, were aggregated to a spatial resolution of 1000 m. These estimates were then applied to the high-resolution semi-distributed hydraulic models of the four urban catchments, all of which have similar size (between 5 and 8 km^2), but different morphological, land use and model structure characteristics. When doing so, methodologies for standardising rainfall inputs and making results comparable were implemented. The response of the different catchments to rainfall inputs of varying spatial resolution is analysed in the light of model configuration, catchment and storm characteristics. Based upon these results, current research needs and future work are discussed.

2. DATASETS AND EXPERIMENTAL SITES

2.1. PRECIPITATION DATA

High resolution precipitation data were obtained from an X-band weather radar, IDRA hereafter, located in Cabauw (The Netherlands). IDRA is one of the research radars installed at the CESAR observatory (Leijnse et al., 2010); it is a frequency modulated continuous wave (FMCW) and dual-polarimetric radar working at X-band frequency of 9.475 GHz. IDRA's standard operational range is of 15 km, with a range resolution of 30 m. It scans at a fixed elevation angle of 0.5 degrees and rotates the antenna over 360° every 1 minute. Rainfall rate was estimated based on differential phase measurements obtained by IDRA (Otto & Russchenberg, 2011). Two storm events on 28/06/2011 and 29/10/2012, respectively of convective and stratiform character, were selected for this study from the available dataset. For each storm event rainfall estimates with one temporal resolution (1 min) and two spatial resolutions (100 m x 100 m and 1000 m x 1000 m; hereafter 100 m and 1000 m resolutions, respectively) were generated. The 100 m estimates were obtained based upon dual-polarimetric variables later converted into rainfall rates, whereas the 1000 m estimates were produced by simply aggregating the initial 100 m rainfall estimates. An area of approximately 36 km^2, which is large enough to circumscribe the four pilot catchments and contain stratiform and convective rainfall cells, was clipped from the total area covered by the radar and was used as input for the catchments.

Characteristics of the storm events within the clipped area are summarised in Table 1. Moreover, 100 m and 1000 m resolution radar images of the two storm events at the peak intensity times can be seen in Figure 1. The convective event of 28/06/2011 was a long lived storm with relatively high precipitation intensities (> 130 mm/h over 5 min), clusters of large storm cells which cover a big proportion of the catchment areas (Figure 1 (a)), and reflectivity (Z) values of approximately 30 – 50 dBZ. In contrast, the stratiform storm of 29/10/2012 was characterised by moderate precipitation intensities (~ 45 mm/h over 5 min) and consisted of an elongated cluster of storm cells of smaller size (Figure 1 (b)) than those observed in the convective event. Within this elongated cluster Z values smaller than 30 dBZ, as well as scattered regions of 30 dBZ were observed. In terms of spatial variability, visual inspection of the radar images (Figure 1) suggests that the stratiform event presents higher variability than the convective one; this appreciation is confirmed by the significantly shorter de-correlation distance (Figure 2) and higher coefficient of variation values (Table 1) associated to the stratiform event as compared to those associated to the convective one.

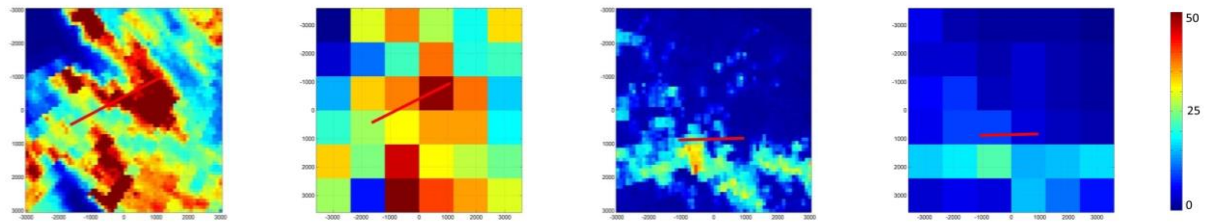
With regards to the effect of the spatial resolution on precipitation patterns, it can be seen that the small high intensity storm cells observed in the stratiform event at 100 m resolution are completely lost when the estimates are aggregated to 1000 m (Figure 1 (b)). In the case of the convective storm, the highest intensity storm cells are significantly larger and therefore better preserved at the coarser scale (Figure 1 (a)). With the purpose of quantifying and comparing the spatial variability of the rainfall fields in a scale independent way, the Universal Multifractal framework was used (see Schertzer & Lovejoy (2011) for a recent review of this framework). A preliminary analysis shows that both rainfall events exhibit a scaling behaviour on two ranges of scales: 100 m - 800 m and 800 m – 6 km. Moreover, the maximum probable singularity (γ_s) concept (see Gires et al. (2012b) for a recent application in urban hydrology) was used to quantify the extremes that can be expected in the rainfall fields at each resolution. In the case of the convective storm (28/06/2011) similar γ_s values of 0.4 and 0.3 were found, respectively, for the 100 m and 1000 m resolutions. For the stratiform storm (29/10/2012) greater (and more disparate) values were obtained for each scaling regime; i.e. 0.7 and 0.4 respectively for the two spatial resolutions. While these results are still preliminary (they should be refined by analysing a larger area), they confirm that, whatever the resolution, greater variability is observed for the stratiform storm than for the convective one.

Table 1: Characteristics of selected storm events (estimated based upon 100 min resolution estimates for the selected area only)

Date	**Storm type**	**Duration**	**Total depth (mean/min/max) [mm]**	**Max intensity over 5 min (areal average* / individual pixel) [mm/h]**	**Coefficient of variation during high intensity period (min/max)**
28/06/2011	Convective	22.00 h - 23.58 h	8.19/4.50/12.49	25.88/62.57	0.47/1.61
29/10/2012	Stratiform	17.00 h - 19.00 h	5.55/1.54/13.37	6.08/20.81	1.07/1.84

*Estimated as the maximum value of the areal averages per 5 min time step

(a) Convective – 28/06/2011 (b) Stratiform – 29/10/2012



(100 m resolution) (1000 m resolution) (100 m resolution) (1000 m resolution)

Figure 1: Radar images of selected storms (over clipped study area) at time of peak intensity. The red vector in the images corresponds to the overall storm direction, estimated based on the trajectory of the centre of mass of the storms during the peak time steps.

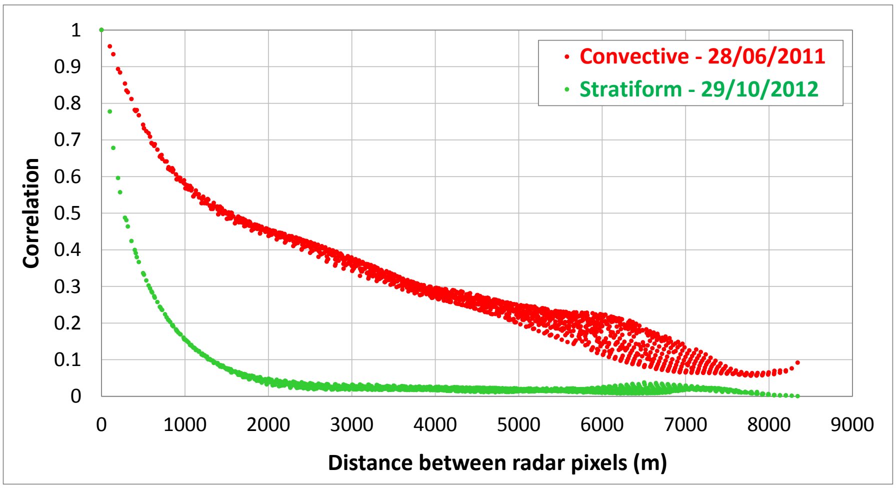


Figure 2: Correlogram depicting correlation as a function of distance between every pair of radar pixels within the study area.

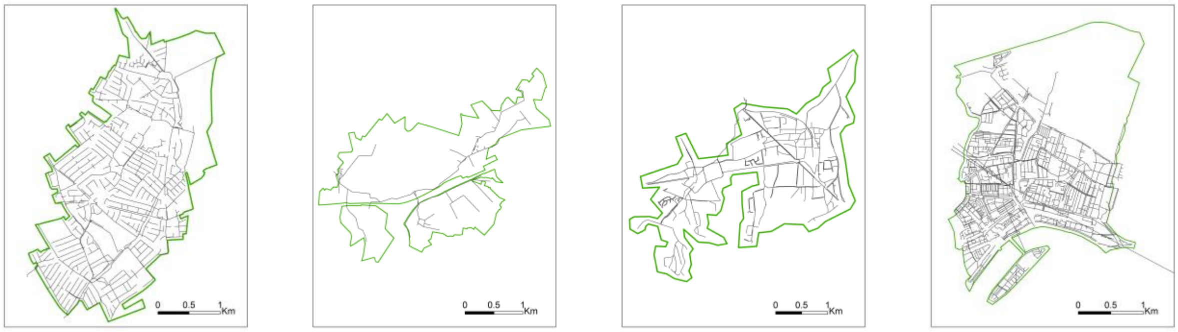
2.2. PILOT URBAN CATCHMENTS

The following four urban catchments, respectively located at each of the RainGain partner countries, were adopted as pilot locations in this study: Cranbrook (London, UK), Herent (Leuven, Belgium), Morée-Sausset (Paris, FR) and Kralingen District (Rotterdam, Netherlands). In order to make the results more comparable, sub-areas of similar size (5-8 km^2) were selected from each of these pilot sites. The main characteristics of the selected pilot catchments are summarised in Table 2. Moreover, images of the boundaries and sewer layouts of all pilot catchment can be found in Figure 3. More detailed information on each of these catchments can be found in the RainGain project website: http://www.raingain.eu/en/actualite/learn-more-about-ten-locations-where-raingain-solutions-will-be-implemented.

Table 2: Summary characteristics of pilot urban catchments

Pilot site	Catchment size [km^2]	Catchment length* and width** [km]	Catchment shape factor*** [-]	Catchment slope**** [m/m]	Imperviousness (%)	General characteristics of drainage system
Cranbrook, UK	8.65	6.10/1.42	0.23	0.0093	66	Mostly separate, main brook has been culverted
Morée-Sausset, FR	5.60	5.28/1.06	0.20	0.0029	37	Mostly separate, main brook has been culverted
Herent, BE	4.75	8.16/0.58	0.07	0.0220	18	Mostly combined
Kralingen, NL	6.70	2.12/3.16	1.49	0.0003	48	Mostly combined, looped system

*Length of longest flow path (through sewers) to catchment outfall;
**Width = Catchment Area / Catchment Length;
****Shape factor = Width / Length (this parameter is lower for elongated catchments)
****Catchment slope=Difference in ground elevation between upstream most point and outlet / catchment length



Cranbrook (UK) Morée-Sausset (FR) Herent (BE) Kralingen (NL)

Figure 3: Catchment boundary and sewer layout for the pilot urban catchments

Hydrological and hydraulic models: Semi-distributed urban drainage models of each pilot catchment were used in this study; their main characteristics are summarised in Table 3. In these models, rainfall is applied through subcatchments (SC) of varying size with runoff attributes derived from terrain and soil characteristics. Runoff volumes are estimated and routed at subcatchment scale using the rainfall-runoff and concentration routing models commonly employed at each country. In all models flow in the sewers is routed using the full de St. Venant equations (i.e. dynamic wave approximation)

Table 3: Summary characteristics of the hydraulic models of the four pilot catchments

Pilot site	Total pipe length* [km]	Number of SC**	Mean / STD of SC** size [ha]	Rainfall-runoff volume estimation model	Rainfall-runoff routing model	Modelling software
Cranbrook, UK	98.05	1765	0.49/0.71	Fixed runoff coefficient for impervious; NewUK for pervious	Double linear reservoir (Wallingford Model)	Infoworks
Morée-Sausset, FR	15.30	47	11.92/10.34	Initial loss + runoff coefficient depending on soil type and rainfall depth	Single linear reservoir	Canoe
Herent, BE	67.42	683	0.71/1.27	Fixed runoff coefficient for all surfaces	Double linear reservoir (Wallingford Model)	Infoworks
Kralingen, NL	160.23	2439	1.20/1.33	Initial loss + fixed runoff coefficient for impervious; Horton infiltration for pervious	Runoff delay coefficient	Sobek

*This length is estimated based upon modelled pipes only (which are often less than the actual number of pipes); **SC = subcatchment

3. METHODOLOGY

Application of rainfall inputs to pilot catchments: Rainfall estimates of 100 m and 1000 m resolutions for the two selected storm events were applied to the hydraulic models of the four pilot catchments in such a way that: (1) the centroid of the clipped rainfall area (see Section 2.1) coincides with the centroid of each catchment, and (2) storm direction is approximately perpendicular to the main flow direction at each catchment (in order to avoid variations in response due to differences in relative storm/flow direction (Singh, 1997)).

Storm direction was estimated based upon the trajectory of the centre of mass of the storm during the high intensity period (see Figure 1). Several approaches were tested to determine the main flow direction at each catchment, including geometric and hydraulic ones. Eventually, the main flow direction was estimated as the length-weighted average of the direction of the pipes that make up the longest flow path in each of the models:

$$\frac{\sum\left(Pipe\ Length_i \cdot Pipe\ Direction_i\right)}{\sum Pipe\ Length_i} \quad \text{Equation 1}$$

A geometric approach was chosen over a hydraulic one as the former is independent of storm characteristics.

Retrieval of results for analysis: For each of the four model runs (i.e. 2 spatial resolutions x 2 storm events) carried out for each pilot catchment, the simulated flow and water depth time series at the downstream end of three pipes –respectively located in the upstream, mid-stream and downstream sections of the catchments– were selected for analysis. The pipes were selected such that the area they drain (DA = drainage area) was approximately the following: (1) Upstream pipe – DA ~ 1.5 km^2; (2) mid-stream pipe – DA ~ 3.5 km^2; (3) downstream pipe – DA ~ 5 km^2 (see Table 5). It is important to mention that the looped nature of the Dutch catchment and the fact that flows may change direction throughout a storm event make it difficult to determine and estimate the area drained by a given pipe.

Characterisation of hydrological and hydraulic response of pilot urban catchments: the overall hydrological and hydraulic response of the pilot catchments to the rainfall inputs was analysed based upon the shape of the simulated hydrographs, as well as using measures such as the *characteristic runoff volume* (volume / drainage area) and *characteristic peak flow* (peak flow rate / drainage area) at each of the three pipe locations described above. Moreover, the time of concentration (*Tc*) of each pilot catchment for each storm event was estimated as the time lag between the time of the flow hydrograph centroid (at the catchment outlet) and the time of the hyetograph centroid (estimated based upon areal average rainfall rates – with areal average values estimated at each time step).

Quantification of the impact of rainfall input resolution on hydraulic outputs: The following variables were computed to quantify the impact of rainfall input resolution on the outputs of the hydraulic models of the four pilot catchments:

- Absolute difference in time to flow peak:

  $$Abs.Diff.in\,TP = TP_{100} - TP_{1000} \quad \text{Equation 2}$$

  where TP_{100} and TP_{1000} correspond to the time of the maximum flow obtained when using as input the 100 m and 1000 m resolution rainfall inputs, respectively.
- Relative difference to compare maximum flows and depths associated to the two spatial resolutions:

  $$RD = (P_{100} - P_{1000})/P_{100} \quad \text{Equation 3}$$

  where P_{100} and P_{1000} represent, respectively, the parameter value of interest (i.e. maximum flow or depth) obtained when using as input the 100 m or 1000 m resolution rainfall estimates.

4. RESULTS AND DISCUSSION

Figure 4 shows response hydrographs and depth time series, respectively associated to the 100 m and 1000 m rainfall estimates for the two storm events, at the upstream pipes selected for analysis at each pilot catchment. Moreover, Table 4 provides a summary of the measures which characterise the overall hydrological/hydraulic response of the catchments to rainfall and Table 5 presents summary statistics of the impact of the spatial resolution of rainfall inputs on hydraulic outputs.

In terms of hydrological/hydraulic response to rainfall, it can be seen (Figure 4 and Table 4) that the four pilot catchments exhibit very different and distinct behaviours, which are consistent during the two storm events considered in this study. The Cranbrook (UK) and Morée-Sausset (FR) catchments' hydrographs have a well-defined single response peak, as well as shorter and rather similar times of concentration (Tc); in contrast, the Kralingen (NL) hydrograph has multiple peaks and longer Tc and the Herent (BE) hydrograph has a quick response peak followed by very slow increase and decrease of the flow, which also results in longer Tc. The different behaviour of the Herent and Kralingen catchments can be explained by their specific features. The Herent catchment is equipped with a throttle device in the main sewer whose purpose is to maximise in-sewer storage. This strongly delays the flow upstream and smooths the flow peak. The Kralingen catchment is located in a polder area where, in the absence of natural flow directions, sewer networks tend to be strongly looped and flow is mostly pressurised. As a result, the overall behaviour of the catchments is determined by a filling process of in-sewer storage, as evidenced by a fast rise in water depth leading to surcharged pipes (see water depth time series in Figure 4). During the filling process, flow directions can change, as flow first moves towards a pumping station, then, once pumping capacity is exceeded, moves towards combined sewer overflows.

With regards to the characteristic runoff volumes and peak flows (Table 4), it can be seen that these also vary significantly across the different pilot catchments; Kralingen exhibits the highest flows, followed by Morée-Sausset, Cranbrook and lastly Herent. These variations can be explained by the degree of imperviousness of each of the catchments, as well as by the topography and runoff properties (e.g. runoff coefficient, infiltration capacity) associated to each of the surfaces that make up each pilot area.

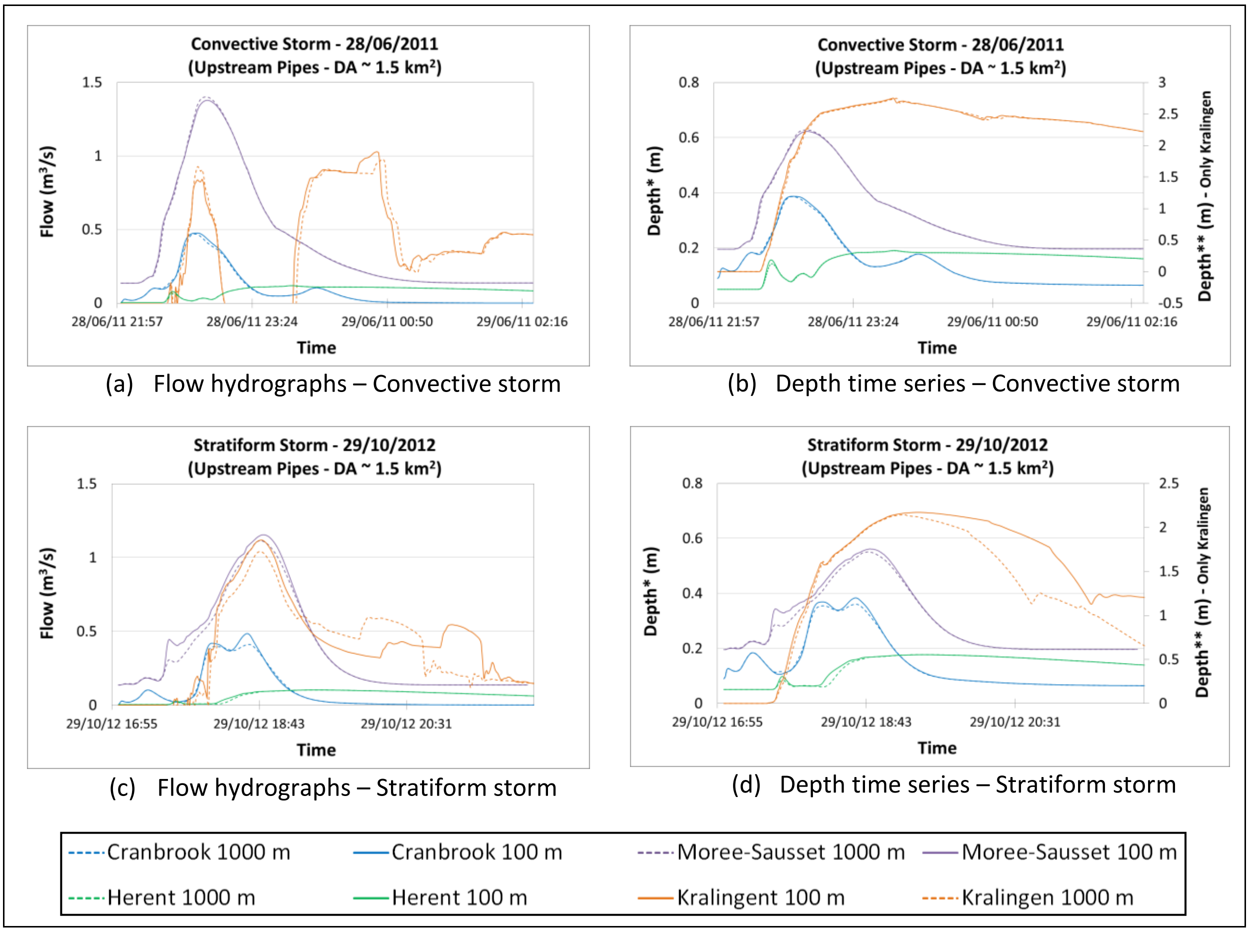


Figure 4: Response hydrographs and water depths at the downstream end of the upstream pipes selected for analysis at each pilot location (with drainage area (DA) ~ 1.5 km^2 – see Table 5). The solid lines correspond to the 100 m resolution outputs and the dashed lines to the 1000 m ones.

* Water depth scale used for the depths observed in the Cranbrook (UK), Morée-Sausset (FR) and Herent (BE) pilot locations; **Water depth scale used for the depths observed in the Kralingen (NL) pilot location. In order to avoid distortion, a different y-axis was used for the water depths observed in Kralingen, as these were significantly higher than the ones observed at other locations.

Table 4: Response variables of each pilot catchment for each storm event. Characteristic runoff volume (total volume / drainage area) and characteristic peak flow (peak flow / drainage area) values are provided for the three pipe locations selected at each pilot catchment (Upstream/Mid-stream/Downstream)

	Convective Storm – 28/06/11			**Stratiform Storm – 29/10/12**		
Pilot site	**Characteristic runoff volume [mm]**	**Characteristic peak flow [$m^3/m^2/s$]**	**Tc (min)**	**Characteristic runoff volume [mm]**	**Characteristic peak flow [$m^3/m^2/s$]**	**Tc (min)**
Cranbrook, UK	0.86/0.89/0.91	0.29/0.27/0.25	45	0.017/0.015/0.013	0.29/0.21/0.17	49
Morée-Sausset, FR	3.55/3.88/3.59	1.4/3.0/3.7	48	3.5/3.5/2.8	0.6/0.6/0.5	52
Herent, BE*	1.19/1.36/1.31	0.08/0.04/0.1	307	1.0/1.4/1.1	0.07/0.04/0.06	292
Kralingen, NL	7.05/6.71	0.79/0.76	213	0.11/0.08	0.86/0.52	169

*CSO spills occurred in the Herent sewer system, spill volumes are included in the total flow volume per subcatchment

Table 5: Statistics related to the impact of the spatial resolution of rainfall inputs on the outputs of the hydraulic models of the four pilot catchments

Pilot site	**Model location***	**Drainage area [km^2]**	**Convective Storm – 28/06/11**			**Stratiform Storm – 29/10/12**		
			Abs. diff. in Tp [min]	**RD max flow [%]**	**RD max depth [%]**	**Abs. diff. in Tp [min]**	**RD max flow [%]**	**RD max depth [%]**
Cranbrook, UK	US	1.65	2	1.38	0.24	2	15.05	5.98
	MS	3.24	0	0.08	0.10	2	8.26	4.71
	DS	5.67	0	1.07	0.87	1	4.83	3.35
Morée-Sausset, FR	US	1.99	1	-1.64	-0.80	2	3.57	1.96
	MS	3.83	0	-1.37	-0.92	2	3.63	2.08
	DS	5.60	0	-0.32	-0.35	1	3.31	2.12
Herent, BE	US	1.51	0	0.81	0.39	0	-0.15	-0.07
	MS	3.80	3	0.97	3.61	1	-0.12	-0.06
	DS	4.75	1	4.27	2.17	3	4.77	2.40
Kralingen, NL	US	1.30	4	4.99	0.08	1	6.88	1.18
	MD	3.10	10	0.16	-0.21	59	-2.77	1.46

(US = upstream; MS = mid-stream; DS = downstream; RD = Relative Difference)

With regards to the effect of the spatial resolution of rainfall inputs on hydraulic outputs, it can be seen (Figure 4 and Table 5) that the aggregation of precipitation estimates from 100 m to 1000 m generally resulted in small changes in time to peak, as well as in flow and depth peaks. When comparing the results obtained for the two storms, it can be noticed that the aggregation effects are slightly more pronounced in the stratiform event than in the convective one. This can be explained by the fact that the stratiform event exhibits higher spatial variability than the convective one (see Section 2.1). It is however worth mentioning that the higher percentage variations observed in peak flows and depths during the stratiform event can partially be due to the small magnitude of the flows and depths being compared. More storm events of varying magnitude and structure should be analysed in order to properly understand the dependence between storm characteristics and the impact of changes in rainfall inputs resolution.

Based upon the comparison of the response of the different catchment models to changes in the spatial resolution of rainfall inputs, the following observations can be made:

- For the storm events and pilot catchments analysed in this study, there does not seem to be correlation between subcatchment (SC) size (Table 3) and model sensitivity to rainfall input resolution. It would be logical to think that the larger the subcatchments, the less sensitive the model would be to changes in rainfall resolution, given that in semi-distributed models rainfall input and hydrologic responses are assumed to be uniform within each subcatchment unit. However, when comparing, the results obtained for the model with the smallest mean subcatchment size (i.e. Cranbrook, mean SC size = 0.49 ha, smaller than 100 m x 100 m) against those of the model with largest subcatchments (i.e. Morée-Sausset, mean SC size = 11.92 ha, larger than 100 m x 100 m), it can be noticed that the aforementioned hypothesis does not hold true. A factor that could play an important role in the model resolution vs. model sensitivity relationship is the degree of homogeneity of a given catchment (i.e. in a catchment with relatively uniform runoff properties (e.g. infiltration capacity, slope), splitting it into many small homogeneous subcatchments or into very few big ones may not matter as much as it would in a highly heterogeneous catchment). Further investigation is required in order to properly understand the relationship between hydraulic model resolution, catchment homogeneity/heterogeneity and rainfall input resolutions. For this purpose ways of quantifying spatial variability of catchment characteristics should be sought and urban drainage models of different resolutions, including fine fully-distributed ones, as well as many more storm events should be jointly analysed.
- In the two catchments with single-peak response and shorter times of concentration (i.e. Cranbrook and Morée-Sausset) there seems to be a clear correlation between drainage area and impact of rainfall input resolution: the larger the drainage area considered, the smaller the impact of rainfall input resolution on the hydraulic outputs. This is due to the fact that in larger areas the effects of spatial variability are smoothed-out. However, the same correlation is not observed in the case of the Herent and Kralingen catchments, which present longer times of concentration (Tc) associated to complex hydraulic configurations. Further investigation in this direction is needed in order to better understand the relationship between drainage area, catchment response times and impact of spatial resolution of rainfall inputs.
- In general, the hydrographs of the Kralingen catchment (Figure 4) show the greatest sensitivity to changes in rainfall inputs resolution. This could be due to the flat topography of the area, the looped and pressurised nature of the sewer system and/or the pumping schemes which play a predominant role in the hydraulics of the catchment. Further investigation is needed to better understand the relationship between catchment characteristics and the impact of rainfall input resolution.

5. CONCLUSIONS AND OUTLOOK

This study investigated the impact of rainfall estimates of two different spatial resolutions (i.e. 100 m and 1000 m) on the hydraulic outputs of the urban drainage models of four pilot locations in NW Europe, each of which has different topographic, hydrological and hydraulic characteristics. Two storm events were selected for this study: a convective and a stratiform one. The results show that for these two events the spatial resolution (i.e. 100 m vs. 1000 m) of rainfall inputs does not have a significant influence on the outputs of urban drainage models. This is rather unexpected as recent studies (e.g. Fabry et al. (1994), Gires et al. (2012a)) have suggested that rainfall estimates of resolutions finer than the currently available ones (typically 1000 m) are required for urban hydrological applications. While the results presented in this paper are still preliminary, the fact that real pilot locations with significantly different characteristics were used makes the results robust and also sheds light upon a number of research questions in this direction. Future work within the RainGain project will focus on answering the new questions that the present study has raised regarding the interactions between model resolution, rainfall input resolution, catchment and storm characteristics. For this purpose the present work will be extended to more storm events, as well as to more urban drainage model configurations and resolutions, including testing of fully-distributed models. Moreover, new datasets of high resolution rainfall estimates and coincidental flow and depth measurements will be built once new X-band radars and flow, depth and rain gauges are installed in the Rotterdam (Kralingen) and Paris (Morée-Sausset) pilot locations during 2014. Having local measurements which can be used to verify model results will provide further insights into response behaviour and to what extent hydrodynamic models are able to represent it.

6. ACKNOWLEDGEMENTS

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