X-band radar monitoring campaign in Central London: an experiment to assess and improve the applicability of a low-cost portable X-band radar to urban hydrology

S. Ochoa-Rodríguez[1], L.-P. Wang[2], M. Pfeifer[3], X. Li[1], C. Onof[1], Č. Maksimović[1], M. Pool[3] and J. Didszun[3]

[1]Imperial College London, UK; [2]KU Leuven, Belgium; [3]Selex Systems Integration, Germany

1. PURPOSE AND CHARACTERISTICS OF MONITORING CAMPAIGN

An alternative for obtaining higher resolution rainfall estimates for urban areas, which can meet the requirements of urban hydrological applications, is to complement the national C-band/S-band radar networks with X-band radars deployed near the urban areas of interest.

With the purpose of exploring the potential benefits of a low cost, portable X-band radar for urban hydrological applications, a Rainscanner® RS90 (Table 1) was deployed on the rooftop of a tall building in Hampstead, Central London. The radar was operational in the period of June - October 2013. During this time several storm events were recorded and high resolution QPEs were generated through a chain of processing algorithms described in Section 2.

Table 1: Radar specifications

Specifications: Selex RainScanner RS90	
Polarisation	Single-polarisation
Doppler (yes/no)	No
Antenna	Parabolic (90 cm diameter)
Beamwidth (azimuth / elevation)	2.5°/2.5°
Peak power	25 kW
Frequency	9375 or 9410 (+/- 30) MHz
Pulse length (m)	75 -180 m
Temporal resolution	1 min
Elevations (°)	Single (set at 2.5°)

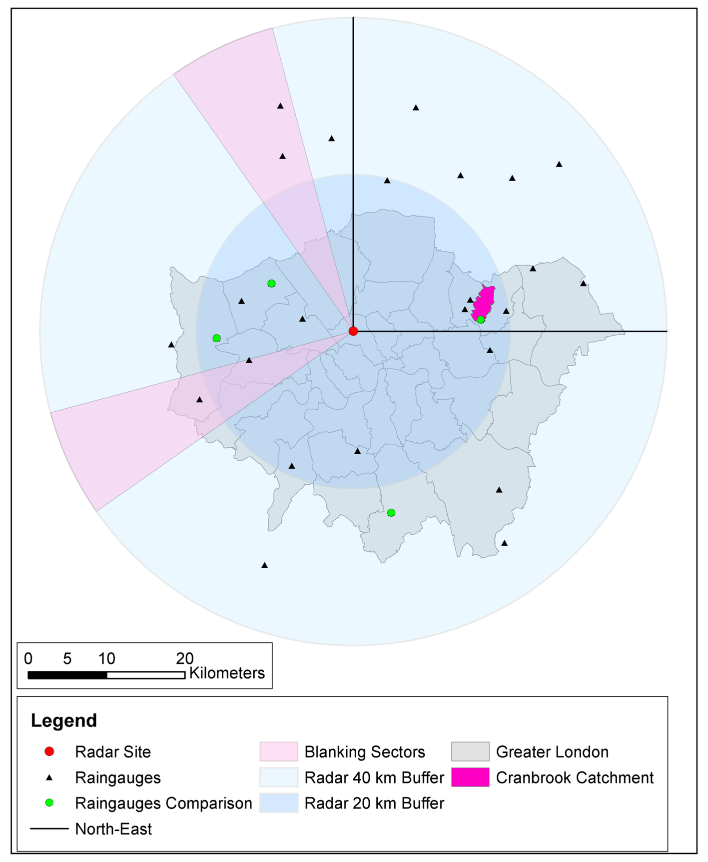

Figure 1: Radar location and location raingauges used for calibration and validation

Figure 2: Radar installation and operation

2. RADAR DATA PROCESSING

High resolution QPEs (100 m and 1 min) were generated through the following chain of processing algorithms:

1. Signal stability correction (Sempere-Torres et al., 1999)
2. Clutter filtering (van de Beek et al., 2010)
3. (Range-dependent) Z-R conversion / calibration (DHI, 2010)
4. Attenuation correction (Delrieu et al., 1999)
5. Polar to Cartesian coordinate conversion (Selex, 2012)
6. Gauge-based adjustment (Todini, 2001)

ACKNOWLEDGEMENTS

We would like to thank the support of the EU Interreg IVB NWE programme to the RainGain project (www.raingain.eu), of which this monitoring campaign is part. Special thanks go to Selex Gematronik for lending us the radar and for providing permanent support during its installation and operation; to the UK Met Office, especially Richard Thomas, Dave Hiscock, Katie Norman and Jacqueline Sugier, for their assistance in the installation, operation and maintenance of the radar; and to the Royal Free Hospital, especially Jit Kakad, Mark Wardle, Richard Diaz and Allan Harris, for providing a suitable location for the radar and for their patience and permanent support to our project.

3. RESULTS

QPEs: The performance of the X-band radar QPEs was evaluated through comparison with raingauge measurements (Figure 4), as well as with C-band radar QPEs provided by the UK Met Office (Figures 3 and 4).

In general, X-band radar QPEs can well capture storm cell variation at <u>high resolution</u>, but their <u>accuracy is inconsistent</u>. The main factor affecting accuracy at given locations (e.g. Fig.4 (c and d)) is the ground clutter, which in the London area has a dynamic nature, thus making it difficult to remove, especially considering the limited parameters provided by the Rainscanner® RS90. Another factor affecting accuracy is attenuation, but this was largely overcome through range-dependent Z-R conversion.

Accuracy can be further improved through local and dynamic gauge-based adjustment.

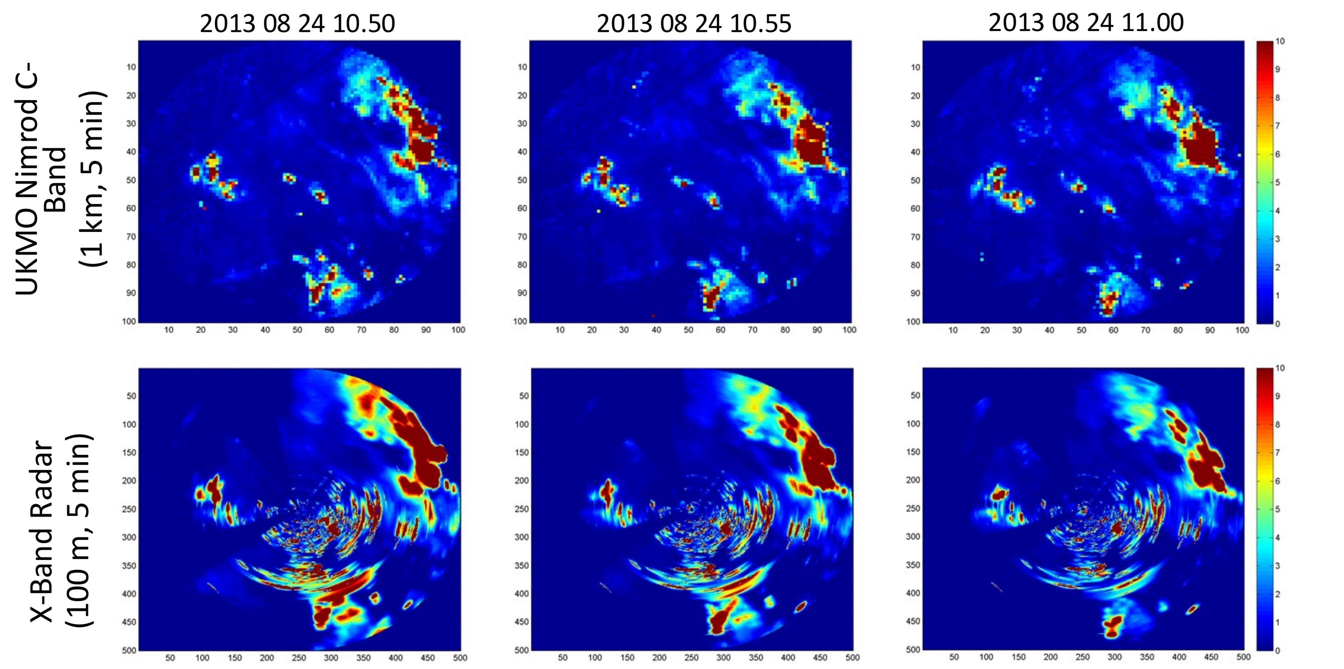

Figure 3: Comparison of X-band and C-band radar consecutive images

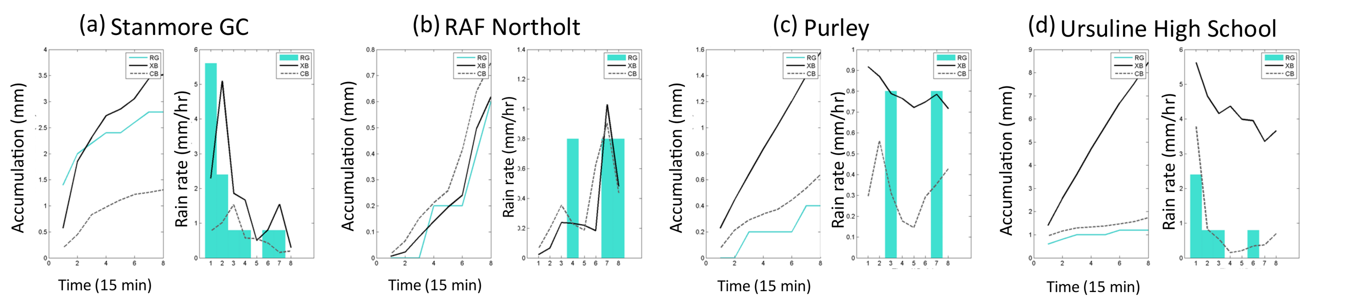

Fig. 4: Comparison of cumulative rainfall depth and instantaneous rain rates at comparison locations (Fig.1):

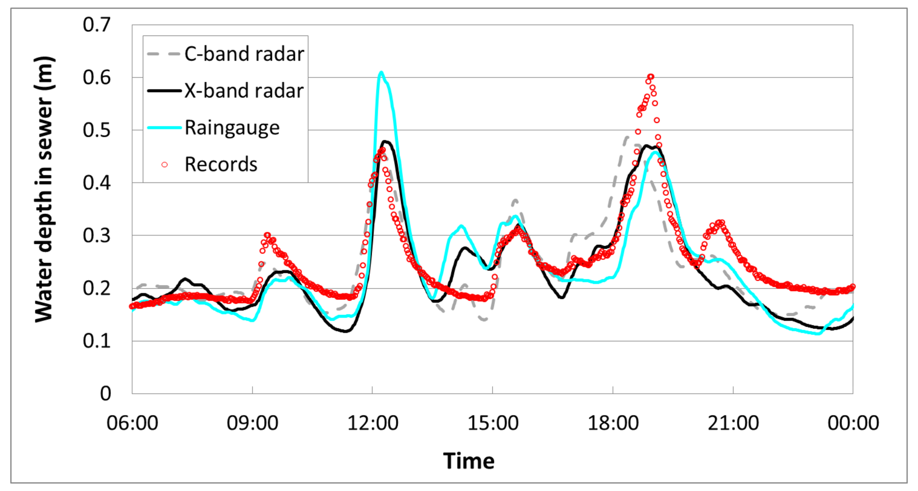

Figure 5: Recorded and simulated flow depths resulting from different rainfall inputs at a sewer located in the mid-stream section of the Cranbrook catchment (Fig.1). Storm event on 24/08/2013

Urban flow estimates: the added value of the higher-resolution X-band radar QPEs (after gauge-based adjustment) was assessed by using them as input to the semi-distributed urban drainage model of the Cranbrook catchment (Fig.5) for which local sewer flow and depth data were collected. Comparisons with flow estimates resulting from coarser resolution C-band QPEs reveals no significant advantage of higher resolution rainfall estimates for the urban catchment and drainage model under consideration. This can be due to the particular characteristics of the catchment and to model resolution.

4. CONCLUSIONS AND LESSONS LEARNT

- The installation and operation of a weather radar in the heart of a dense urban area such as London is a challenging task. The two major problems encountered were: (1) finding a suitable location in terms of visibility, coverage, radiation risk and building/installation permission; (2) amount of interference from ground clutters present in a city such as London.
- In general, the tested low-cost X-band radar proved to effectively capture storm cells and their motion at high resolution, but the accuracy of the estimates is inconsistent.
- The main reasons for poor accuracy are ground clutter and attenuation. Accuracy can largely be improved through range-dependent Z-R conversion and dynamic adjustment based upon complementary data from other sensors (i.e. raingauges, C-band radar estimates); however, the high dependency on data from other sensors to produce reliable estimates is not desirable.
- Initial results reveal no significant advantage of using higher resolution (100m/min) rainfall estimates as input for urban drainage models, as compared to using coarser resolution (1km/5min) currently available QPEs provided by national meteorological services.
- In spite of the limitations, this type of radar is useful for general tracking and forecasting storm movement (e.g. in areas where no other data are available and where high accuracy is not essential). In addition, it can provide additional higher resolution information about the structure of rainfall fields.