Abstract
Extreme rainfall is expected to occur more often in the future, as a result of climate change. To be able to react on this change, urban water managers need to accurately know vulnerable spots in the city, as well as the potential impact to society. Currently, detailed information about rainfall intensities in cities, and effects of intense storm events on urban societies is lacking. The RainSense project will create an Urban Weather Sensing Lab in Amsterdam to provide high resolution, real-time, directly accessible information on rainfall and urban water/drainage system conditions. In this lab, data will be collected by combining a range of innovative techniques: low-cost, acoustic rainfall sensors, participatory sensing (smartphone app), and opportunistic sensing (microwave links, call centre data, Twitter). This information will help to send out real-time warnings to authorities and people in specific areas and to support management decisions for rain proofing and other preventive measures in the city.

Keywords: Extreme rainfall; innovative sensing; citizen sensing
**Introduction**

On 28 July, a cloudburst hit Amsterdam, pouring 90 mm of rainfall over the city with intense rainfall peaks of up to 150 mm/h (Amsterdam Rainproof, 2014). Sewer and drainage systems were unable to cope with this amount of water and flooding occurred at many locations. This example illustrates the disruptive effects that intense storms can have on urban societies, the economy and infrastructure.

Urban water managers need to accurately know vulnerable spots in the city as well as potential impacts of extreme events to society to be able to take preventive measures and provide timely warning to citizens. At present, detailed information about rainfall intensities in cities, and effects of intense storm events on urban societies is lacking, while this kind of information is vital for citizens and (water) authorities in order to cope with intense storms and prevent damage.

In cities, weather stations equipped with rain gauges are scarce and measurements are often not representative because of local wind and turbulence effects of buildings. National weather radar data are relatively coarse in space and time with respect to the scales of urban hydrological processes, they are not representative of the rainfall dynamics at street level, and the real-time data are inaccurate at high intensities and short durations, conditions typically critical for cities. Effects of storm events on urban societies, such as traffic disruption and damage to flooded properties, are currently not measured in a structured way.

The RainSense project aims to create an Urban Weather Sensing Lab in Amsterdam to provide high resolution, real-time, directly accessible information on rainfall and urban water/drainage system conditions. In this Lab, innovative applications of technical sensors and combinations of passive, opportunistic as well as active, participatory citizen sensing will be tested and demonstrated. In the future, the lab can be extended to include other critical infrastructures as well as other weather parameters.

**Material and Methods**

![Diagram of the RainSense Urban Weather Living Lab](Figure 1)

Figure 1 RainSense Urban Weather Living Lab: combining innovative, multidisciplinary sensing techniques to promote citizens’ resilience and intelligent stormwater management
Innovative sensing techniques will be utilised, such as rainfall estimation from microwave links, low-cost acoustic rainfall sensors on umbrellas and lamp posts and sensors in drainage pipes for water level observation (figure 1) (e.g. Overeem et al., 2011; 2013a,b). These will be combined with information provided by citizens in an active way through smartphone apps and in a passive way by information retrieval from social media posts (Twitter, Flickr etc.) (Gaitan et al., 2014; De Weerdt et al., 2014). Sensor information will be integrated, visualised and made accessible to citizens to help raise citizen awareness of urban water management challenges and promote resilience by providing information on how citizens can contribute in addressing these. Moreover, citizens and businesses can benefit from reliable weather information in planning their social and commercial activities.

All these techniques and different kind of methods to collect data about rainfall and other weather phenomena will be concentrated in the area of the Wibautstraat (also called “Knowledge Mile”) in Amsterdam. In RainSense we will first showcase the potential of the Urban Weather Sensing Lab by conducting a number of pilot studies on core aspects of the Lab. This will lay the foundations for creating a fully operational Urban Weather Sensing Lab in Amsterdam in the coming years, providing high resolution, real-time, directly accessible information on rainfall, urban water/drainage systems to citizens and water and infrastructure managers.

Results and Conclusions
Expected results of the RainSense project can be divided into two categories: results from high resolution hydrodynamic modelling using advanced modelling software, and results from social sensing experiments using a prototype smartphone app.

High resolution data collected in the RainSense Urban Weather Lab will be entered into 3Di, a new versatile water management instrument capable of detailed, extremely fast hydraulic computations (www.3Di.nu). The collected high density datasets will for the first time enable testing of the high resolution capabilities of the modelling software and validate outcomes of the simulations. Results of simulations using rainfall derived from microwave links will be presented.

These results can be used by water managers and Waternet in order to detect vulnerable spots under intense rainfall conditions and to be pro-active in case of extreme weather events. The models can help sending out real-time warnings for specific areas and in the longer term help supporting management decisions about rain proofing and other preventive measures in the city.

Citizens will be actively involved in collecting rainfall and other weather information using a smartphone app (figure 2). The smartphone app can be used to collect weather information through opportunistic as well through participatory or request-driven social sensing. Experiments will be conducted in the Urban Weather Lab, where citizens will first autonomously use the app to collect data. In a next step, users will be requested by the app to measure the weather at a certain moment. This will eventually allow water managers and emergency services to collect information from critical locations where information is lacking, in real-time. Results of the first app experiments, to be conducted in summer 2015, will be presented.

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References