International conference

CITIES, RAIN AND RISK

ABSTRACT BOOKLET

4 projects - 4 themes – 22 abstracts

CONTENT

ABOUT THE CONFERENCE

This is a conference open for an exchange of thoughts, highlighting results, tools, and mindset when it comes to tackle the challenges in managing urban flooding. The conference present results from four innovative research projects, from the perspective of the following themes:

- End-user engagement, tailored tools and public perceptions
- Rainfall and environmental observation and forecasting
- Urban flood modelling and forecasting
- Water management, nature-based solutions and climate adaptation

We welcome practitioners and experts dealing with urban flooding hazards in some way, as well as academics and scientists in the field. The conference will consist of both short lectures and hands-on demos of web-based tools.

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The four projects:

The INXCES project https://inxces.eu **Partners**: Norwegian University of Science and Technology (NTNU) University of Applied Sciences Groningen (HUAS) Luleå University of Technology (LTU) Technical University of Civil Engineering of Bucharest (UTCB-CCIAS) Geological Survey of Norway (NGU) **Sponsors**: The Research Council of Norway (NO), The Executive Agency for Higher Education, Research, Development and Innovation Funding (RO), Formas (SE) and Netherlands Organisation for Scientific Research (NL) though Water Challenges for a Changing World Joint Programme Initiative (Water JPI)	**The MUFFIN project** http://www.muffin-project.eu/about-muffin **Partners**: Swedish Meteorological and Hydrological Institute (SMHI), Aalborg University (AAU) Delft University of Technology (TUD) Aalto University (AU) Swedish Geotechnical Institute (SGI) **Sponsors**: The Swedish Research Council Formas (SE), Netherlands Organisation for Scientific Research (NL), Innovationsfonden (DK) and Maa- ja vesitekniikan tuki ry (FI) though the Water Challenges for a Changing World Joint Programme Initiative (Water JPI)
The Weather Radar project http://www.svensktvatten.se/forskning/svenskt-vatten-utveckling/pagaende-svu-projekt/vaderradarteknik-inom-va-omradet--test-av-metodik **Partners**: Lunds Tekniska Högskola Lunds Universitet Sweden Water Research SMHI **Sponsor**: Svenskt Vatten Utveckling	**The SUrF project** http://www.surf.lu.se **Partners**: Lund University Sweden Water Research Region Skåne Höje å Vattenråd Länsförsäkringar Skåne Göteborgs stad, kretslopp och vatten **Sponsor**: The Swedish Research Council Formas (SE)

MUFFIN Multi-scale Urban Flood ForecastINg

MUFFIN has worked to bridge the gap between the urban and large-scale hydrological modelling communities, providing mutual benefits and an arena for new thinking. The project has developed innovative systems and solutions that diminish the adverse effects of urban flooding. The basic approach was to analyze, develop, join, compare and evaluate observational and forecasting systems operating at different scales (local, regional/national, continental). A flooding event may be generally divided into the following three temporal stages, during which different users require different types of information.

- Before the flood: The main components in this stage are the rainfall and flood forecasts, signal-ling when and where problems may occur.
- During the flood: Frequent real-time observations are required to follow how the event develops and maximize situation awareness.
- After the flood: Properly quality controlled, stored and documented observations, forecasts and other relevant information are needed to facilitate post-event analyses.

Furthermore, flood-related information (observations, forecasts) is available from systems operating over different spatial domains.

- The city: A city may operate its own flood forecasting system or be included in a small regional system.
- The region/country: Several regions and countries operate forecasting systems.
- The continent (Europe): A range of hydrological modelling systems have been set up for flood forecasting at the Pan-European level.

Generally, local systems and information provide the highest value for the end-users in all flood phases. However, local systems are lacking in many cities which are thus dependent on purely hydrological information from national or even continental level. In MUFFIN, we have aimed at increasing the end-user value of information related to urban floods by research and development at all scales as well as adaptation and promotion of existing material. The research and development have been performed in three cities: Aalborg (DK), Rotterdam (NL) and Helsinki (FI). During the first phase of the project, local forecasting systems were developed and optimized for selected sub-basins in these cities. In parallel, the hydrological model HYPE was developed for high-resolution modelling and set up for the same sub-basins. In the second phase of the project, coordinated forecasting experiments were carried out in order to explore the benefits and limitations of each type of model system as well as the prospect of combining them.

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INNovations for eXtreme Climatic EventS
INXCES (2016-2019)

INXCES is funded by the Research Council of Norway (NO), The Executive Agency for Higher Education, Research, Development and Innovation Funding (RO), Formas (SE) and Netherlands Organisation for Scientific Research (NL) though Water Challenges for a Changing World Joint Programme Initiative (Water JPI). During the project period new innovative technological methods for risk assessment and mitigation of extreme hydroclimatic events has been developed and including optimization of urban water-dependent ecosystem services at the catchment level, for a spectrum of rainfall events. It is widely acknowledged that extreme events, such as floods and droughts are an increasing challenge, particularly in urban areas. The frequency and intensity of floods and droughts pose challenges for economic and social development, negatively affecting the quality of life of urban populations. Prevention and mitigation of the consequences of hydroclimatic extreme events are dependent on the time scale. Floods are typically a consequence of intense rainfall events with short duration. In relation to prolonged droughts however, a much slower timescale needs to be considered, connected to groundwater level reductions, desiccation and negative consequences for growing conditions and potential ground – and building stability.

INXCES has taken a holistic spatial and temporal approach to the urban water balance at a catchment scale. Perform technical-scientific research to assess, mitigate and build resilience in cities against extreme hydroclimatic events with nature-based solutions. INXCES used and enhance innovative 3D terrain analysis and visualization technology coupled with state-of-the-art satellite remote sensing to develop cost-effective risk assessment tools for urban flooding, aquifer recharge, ground stability and subsidence. INXCES used quick scan tools that will help decision makers and other actors to improve the understanding of urban and peri-urban terrains and identify options for cost effective implementation of water management solutions, which will reduce the negative impacts of extreme events, maximize beneficial uses of rainwater and stormwater for small to intermediate events, and provide long-term resilience in light of future climate changes. The INXCES approach optimizes the multiple benefits of urban ecosystems, thereby stimulating widespread implementation of nature-based solutions on the urban catchment scale. https://www.inxces.eu

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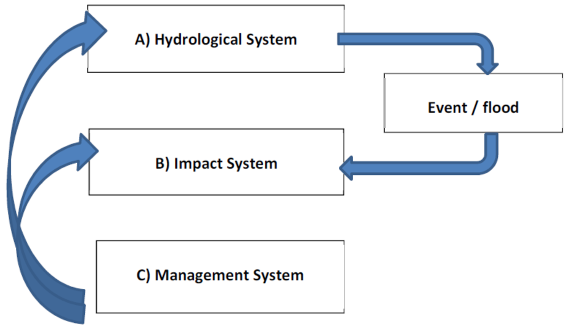
Sustainable Urban Flood Management
The SUrF project

SUrF stands for Sustainable Urban Flood Management and is a vision as well as a project. We, the project partners, have reached a common view of the topic which we understand as a system of systems, illustrated by the figure below.



This concept corresponds well with the title of the conference. **Rain** is the input to the Hydrological system, which may consist of both natural and man-made components. In extreme cases, the Impact system consisting of both physical elements and non-tangibles in the **City**, may be negatively affected. This is a **Risk** which has to be handled via a Flood Management system. Due to the complexity of the problem the management system requires understanding, and input from a broad spectrum of individuals and organisations, private as well as public. In order to make useful research for this multifaceted system we have established a multidisciplinary team of researchers with support from an engaged group of funders which have also been partners in the project.
Our strategy has been to work with all the three systems in the figure above. Two special topics, which have been especially important in SUrF are *hydrological modelling* and *blue-green solutions*, both of which can be seen as dealing with the hydrological system **and** the management system. Issues related to responsibility, legislation and organisational structure have been shown to be obstacles for efficient urban flood management in Sweden (and elsewhere). Therefore, a lot of SUrF research activities have been focused on these areas. The project team consists of researchers from six departments, representing three faculties, at Lund University plus researchers from Malmö University and the Swedish University of Agricultural Sciences.

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The Weather Radar project - Väderradarteknik inom VA-området test av metodik

VA SYD together with the Faculty of Engineering (LTH), Lund University, Sweden, Water Research, and SMHI have collaborated in the Weather Radar Project. The X-band weather radar was installed from July-September 2018 to test the facility on Dalby water tower, Lund municipality. The purpose with the test period was to obtain an in-depth conclusion of how an X-band weather radar facility could be implemented in VA SYD´s sewage utilities including weather radar data quality control and validation.

The purpose with the test period was to obtain an in-depth conclusion on how an X-band weather radar facility could be implemented at VA SYD, including data quality control and validation. The following parts constitute the report:

- A literature study and an evaluation of the critical parameters for a weather radar facility
- An evaluation with proposed sewerage system and wastewater treatment plant applications of the weather radar data
- Validation of the radar data

VA SYD has collaborated with the Faculty of Engineering at Lund University (LTH), Sweden Water Research (SWR) and the Swedish Meteorological and Hydrological Institute (SMHI) in this project. VA SYD and SMHI made an analysis of the technology and localized a test site with ideal conditions for the first X-band weather radar facility in Sweden to be on the top of the Dalby water tower outside the city of Lund. The X-band radar offers higher resolution when compared to SMHI's C-band radar. The weather radar was in operation between 2018-07-03 and 2018-09-12. In addition to precipitation data from VA SYD, the Trelleborg municipality has contributed their precipitation data.

The study included an analysis of processed radar data from Informatics (IT-supplier) and LTH, and from VA SYD´s rain-, flow-, and sewerage overflow gauges. Four precipitations events from August 2018 have been studied in which different data sets, including rain gauge data in Trelleborg municipality, have been analysed. LTH processed and validated the radar data with a Matlab code while Informatics used a Python code.

http://www.svensktvatten.se/forskning/svenskt-vatten-utveckling/pagaende-svu-projekt/vaderradarteknik-inom-va-omradet--test-av-metodik

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THEME 1: END-USER ENGAGEMENT, TAILORED TOOLS & PUBLIC PERCEPTION

Knowledge exchange on Climate Adaptation Best Management Practices for Sustainable water management in Resilient Cities

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The INXCES project

Cities are becoming increasingly vulnerable to climate change, and there is an urgent need to make them more resilient. The Climatescan adaptation tool www.climatescan.nl is applied as an interactive tool for knowledge exchange and raising awareness on Nature-Bases Solutions (NBS) targeting young professionals in ClimateCafes. Climatescan is a citizen science tool created through 'learning by doing', which is interactive, open source, and provide more detailed information on Best Management Practices (BMPs) as: exact location, website links, free photo and film material. BMPs related to Innovations for Climatic Events (INXCES) as stormwater infiltration by swales, raingardens, water squares, green roofs subsurface infiltration are mapped and published on social media.

Climatescan is in continuous development as more data is uploaded by over 250 people around the world, and improvements are made to respond to feedback from users. In an early stage of the international knowledge exchange tool Climatescan, the tool was evaluated by semi-structured interviews in the Climatescan community with the following result: stakeholders demand tools that are interactive, open source, and provide more detailed information (location, free photo and film material).

In 2016 Climatescan (first stage of INXCES) was turned into an APP and within two years the tool had over 10,000 users and more than 3,000 international projects. More than 60% of the users are younger than 34 and 51% of users are female, resulting in engagement with an important target group: young professionals. The tool is applied in Climatecafe.nl around the world (The Netherlands, Sweden, Philippines, Indonesia, South Africa) where in a short period of time stakeholders in triple helix context (academia, public and private sector) work on climate related challenges and exchange their knowledge in a café setting. Climatescan has also been used in other water challenges with young professionals such as the Hanseatic Water City Challenge and Wetskills.

During the INXCES project over 1000 BMPs related to Innovations for Climatic Events (INXCES) are mapped in all partner countries (figure 1). The points of interest vary from just a location with a short description to a full uploaded project with location, description and summary, photos and videos, presentations, links to websites with more information and scientific papers and books (as Bryggen in Norway: https://www.climatescan.nl/projects/16/detail).

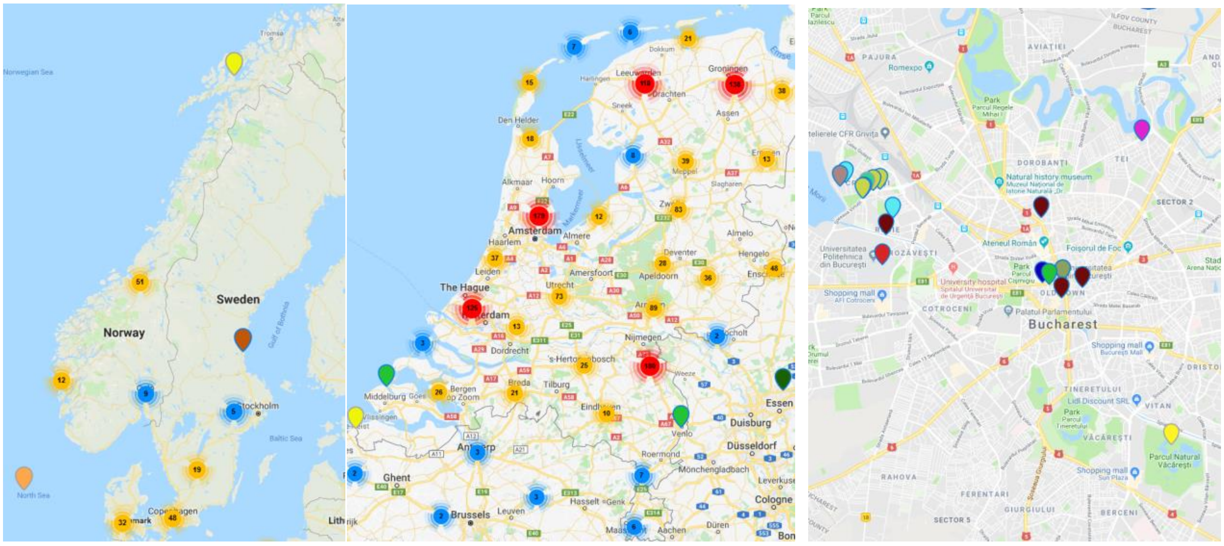

Fig. 1 *Norway (73), Sweden (25), The Netherlands (>1000) and Bucharest, Romania (19).*

In conclusion, there is a clear demand for a collaborative knowledge-sharing tool on BMPs, where first impressions of different urban resilience projects can be quickly gained, and examples of climate adaptation is easily accessible. Further work in linking events to the UN Sustainable Development Goals will further empower the usability of this web-tool www.ClimateScan.nl. This tool helps policy makers and practitioners to gather valuable data for decision-makers in a rapid appraisal at neighbourhood and city level. The results provide insights, create awareness, and builds capacity with bringing together stakeholders in the Climatescan community.

Acknowledgements: This study would not have been possible without the registered users from the public and private sectors who have mapped their BMPs. This study would not have been possible without funding from STOWA and collaboration within the JPI Water funded project INXCES and INTERREG IVb project WaterCoG.

Are house owners' willing to invest in self-protection against flooding?

Jonas Nordström

Lund University

The SUrF- project

Compared to insurances that reduces the severity of flooding for the individual, self-protection may reduce both the probability and the severity of flooding. Increased self-protection may thus lower the socio-economic costs of flooding and can be seen as an important part of the societies' adaptation to climate change. In this survey we study house owners' self-protecting behaviour.

The results suggest that a relatively large fraction of the house owners is willing to undertake self-protecting measures to reduce the probability and severity of flooding. The median expenditures that are spent on self-protecting means were SEK 5000. There is, however, a large difference in the median and mean expenditures, and about one fourth of the house owners report no (direct) costs for the self-protection measures. For house owners that have been affected by flooding, the median expenditures on self-protection measures were SEK 3000, while the median loss due to the latest flooding were estimated to SEK 10000.

The most common means of self-protection were "not to store or have valuable items in the basement" followed by "draining", "remove vegetation that can damage pipes" and "using building material that is less sensitive to water".

After the decision to carry our various self-protection measures the house owners stated the following subjective probability of flooding for their property.

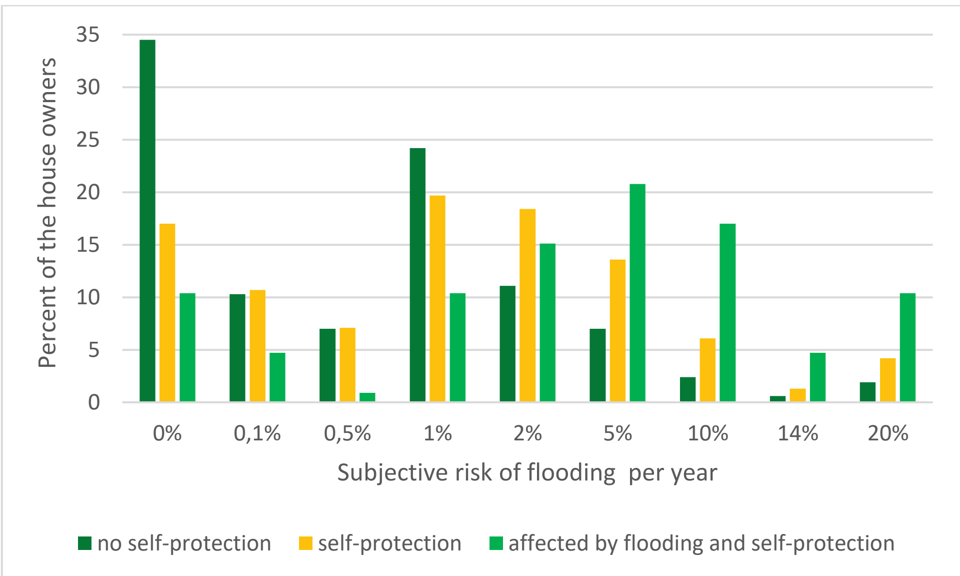

Figure 1: House owners' subjective probability of flooding per year

For half of the house owners that have not undertaken any self-protection measures, the subjective probability of flooding is 0.5 percent or less. About 90 percent of the house owners that have not carried out any measures, estimate that the probability of flooding is 2 percent or less per year, i.e. relatively low.

House owners that have carried out self-protection measures sated a higher subjective probability of flooding compared to house owners that have not undertaken any measures. One third of these house owners say that the probability of flooding is 0.5 percent or less per year, while about half of them stated that the probability of flooding is between 1 and 5 percent. Half of the house owners that carry out self-protecting measures thus have or have undertaken measures that reduce the subjective risk of flooding to between 1 and 5 percent per year. The results also suggest that many of the house owners that have been affected by flooding and that have carried out self-protecting measures, expect that their property will be flooded again (during the coming 20 years). For these subjects, self-protection measures such as *using building material that is less sensitive to water* and *not store or have valuable items in the basement*, can have an important impact on the severity of the expected flooding.

Building flood resilience – together

Kristina Hall & Nina Steiner, VA SYD

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The SuRF Project

Cloudbursts in urban areas can lead to massive flooding, in public areas as well as in private houses and buildings. The costs of this are enormous, both for society and for individual citizens. The problem is not new, so how come it hasn't been solved?

Building flood resilience – together is exploring new ways to address the issue in the city of Malmö. The project was initiated in 2017 by VA SYD, a regional water and wastewater services provider in south-western Skåne, and operates in close collaboration with the city of Malmö. Four employees at VA SYD, three engineers and one communications officer, work in the project.

Pre-requisites

There is a gap in the responsibility matrix regarding urban cloudbursts in Sweden (table below). Concerning in particular 'area with existing buildings', there is nobody to hold responsible.

	Normal rain	Cloudburst
New urban development	The wastewater services provider	The municipality
Area with existing buildings	The wastewater services provider	Nobody

Another dilemma is the fact that 70% of Malmö consists of privately-owned land. It is therefore important to make the private property owners take action and contribute to building flood resilience. Since there are no legal demands on private property owners, actions are all voluntary. Making them *want to* act is one of the main tasks for the project *Building flood resilience – together*.

Objectives and target groups

The project has identified two levels of objectives – a collective change of mind set in society and an increase of individual actions.

The chosen target groups for the individual action part may be roughly divided into four categories:

1. Colleagues within VA SYD and the city of Malmö
2. Private homeowners (detached houses)
3. Private housing cooperatives (apartment houses)
4. Industries and businesses occupying large areas.

Strategic approach

“Hard” problems do not always have “hard” solutions. It is often more efficient to use “soft” techniques. We can’t rebuild the city to make it fit todays conditions. But by involving everyone living and working in the city, we can achieve change. Communication is therefore essential in order to reach the set objectives, and the communicative strategy has from day one been to use positive enforcement in all communication. Emphasis is on showing the benefits of doing things right, instead of showing the negative consequences of doing things wrong.

In August 2017, a survey was made within target groups 1 and 2 to measure the knowledge about flood resilience possibilities and the willingness to take individual action. Based on the answers, strategic and communicative activities were decided on:

- Employing a variation of nudging techniques, ranging from tone of voice to delivering rain barrels to peoples’ homes. They have all been evaluated and improved on a regular basis.
- Financial compensation of 2 500 SEK for each disconnected downpipe in Malmö has been promoted strongly.
- Offering services of an engineer to do on site counselling to housing cooperatives.
- Seeking collaboration with housing cooperatives, real estate companies, private property owners, builders, architects, landscape architects and others, in order to spread awareness and knowledge.
- Taking part in several workshops and giving lectures in order to put focus on cloudburst issues in every part of the city planning process, locally as well as nationally.
- Not waiting to be found, but to find people through participation at garden shows and fairs
- Offensive PR work with focus on local media.
- Using the web site vasyd.se/platsforvattnet as the centre of all communicative activities. A lot of focus has been on improving the site and getting people to visit it.

Results

It is clear that there is no ‘one size fits all’-solution. All actions have to have an individual approach. This is time consuming but effective. Through differentiated communication, offers and actions to each target group, we have been able to reach more people and achieve more.

The awareness of the importance of building flood resilience has increased among colleagues and city planners in Malmö.

An increasing amount of private house owners in Malmö are disconnecting their downpipes.

It is clear that there is a need of other solutions than offered today for big warehouses, industries and other businesses.

A final conclusion is that building flood resilience together with the citizens, entrepreneurs, builders, city planners and others takes time. But it is possible.

A review of sustainability of urban flood management from the aspects of hydrology, economy and the perceived urban design quality

Misagh Mottaghi, Jonas Nordström, Catharina Sternudd, Salar Haghighatafshar, Karin Jönsson

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The SurF-project

Flooding in urban areas is a problem of growing concern due to numerous reasons. It has been proved that only relying on pipe system is not the solution. Urban areas are getting denser and large proportion of impermeable surfaces makes built-up land more vulnerable to flooding than the surrounding environment. Accordingly, applying surface solutions, called blue-green solutions and evolving the drainage systems are essential steps for the reduction of flood impacts. Some municipalities are now well informed of the necessity for applying green solutions as flood control methods. Many studies have shown that blue-green solutions are efficient in controlling flooding and recycling the run-off water. However, we have limited knowledge on the extent to which such solutions are sustainable and even less on how sustainable the everyday life around them can be. Moreover, we have limited information on how individuals value blue-green solutions in monetary terms. This information is important from both a welfare perspective and from a socio-economic cost benefit analytic perspective.

The research is trying to assess the impact that blue-green solutions have on the quality of urban environments. Here, we apply a multilevel approach to review socio-cultural values that these ecological techniques offer to the environment. The research objective is the effect that such solutions have on human's everyday use and practice. In this study, an urban housing area called *'Augustenborg Eco-city'* has been chosen as the case study. The area is located in the city of Malmö in Sweden and includes almost 1970 households. The research team tries to gain knowledge from the user's perspective to see how people experience blue-green solutions in their everyday life as well as how they value them in relation to their experience. The researchers have considered two criteria to come up with specific urban area as the case study. First, the area needed to have different open stormwater techniques, which were deliberately planned, designed, and implemented on site to deal with urban flooding. The second and very important criteria was that the blue green techniques were implemented a while back in past, so the inhabitants have had enough time to live, explore and experience the area. Augustenborg urban area has been retrofitted in 1998 with the goal of making the area flood resilient as well as more attractive. Augustenborg eco-city is a well-known example being known as one of the best practices of sustainable urban project.

A questionnaire has been formulated and designed based on the affordance theory, which address questions regarding urban design qualities. The questions are developed in the way to understand different possibilities for action and perception that blue-green solutions may bring to the area and people's everyday life. Furthermore, a contingent valuation method was used to elicit the respondents' valuation of the blue-green solutions in monetary terms. The questionnaires were distributed to all households in the area in November 2018 and collected by the end of December. The project is a collaboration between Lund university of Sweden, VA SYD and MKB housing company. The research team is supposed to carry on the project with a follow-up focus group as a new method for getting deeper knowledge on social and cultural sustainability of blue-green solutions in Augustenborg Eco-city.

Responding to end-user requirements before, during and after the flood

Lisa Van Well

Swedish Geotechnical Institute

The MUFFIN project

The MUFFIN seeks to address the gap between the urban and large-scale hydrological modelling communities and to contribute to improved integrated risk management solutions to urban floods. WP2 on "End-user value", for which the Swedish Geotechnical Institute (SGI) has been responsible, had the goal to optimize the process and outputs of the project with respect to practical value for relevant end-user categories. This is to facilitate that the flood forecasting meets the specific and concrete needs of the urban users and can be integrated into their existing organizational structures and current use of forecasting.

To specify the end-user value, SGI used a three-prong or triangulation method to understand the needs and requirements of the MUFFIN end-users. In the MUFFIN case these three methods consisted of 1) an international workshop in February of 2017. 2) an end-user survey administered in December 2017 and 3) in-depth telephone interviews with end-users in November 2017- February 2018.

End-users are had differing needs and conditions and thus MUFFIN cannot provide a one-size-fits all solution to the problems of urban flooding. However, are some general conclusions about end-user specifications that can be made from this three-pronged exercise:

• Local level forecasts and observations geared specifically to local specificities and conditions are most important for end-users but there is also scoped to integrate data at larger scales to complement local level data.

• End-users prefer data, forecasts and observations of rainfall/flooding at a local level which specific to their conditions, but also request data on a larger scale such catchment areas. National stakeholders were interested in extended geographic coverage of smaller watercourses and non-urban areas.

• The greatest need for more guidance and information tools on rainfall and flooding was requested at the stage "before the flood", followed by guidance and tools "after the flood". But methods to integrate observations and reports during the flood are also important.

• Accuracy and certainty of forecasts and observations appeared to take precedence over lead time or timing of observations/analysis becoming available, although end-users and stakeholders were reluctant to specify any trade-offs between accuracy and spatial resolution.

• Visualizations in GIS-formal and web-based visualizations at the different scales would be very useful for end-users. Communication of observations through citizen observations can an important complement to radar and rain gauge data to be further explored.

• MUFFIN is very ambitious, and the small steps achieved by the project can drive technology forward, even if the project can't solve all problems in each case study area.

• Better tools with higher accuracy within meteorological and hydrological forecasting and modelling are needed, and if good tools exist for rainfall and flooding forecasts, end-users will find a way to use them.

The presentation will show how the MUFFIN case studies, joint experiments and the RainVis visualization tool contribute to fulfilling these needs.

APPETIZER

RAINVIS: a real-time high-resolution high-intensity rainfall visualization prototype for Sweden

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The MUFFIN Project

Real-time visualization of rainfall is today provided by many meteorological institutes and companies worldwide. This includes both (recent) rainfall observations, often made by weather radar (Figure 1a), and (short-term) rainfall forecasts by NWP or nowcasting (Figure 1b).

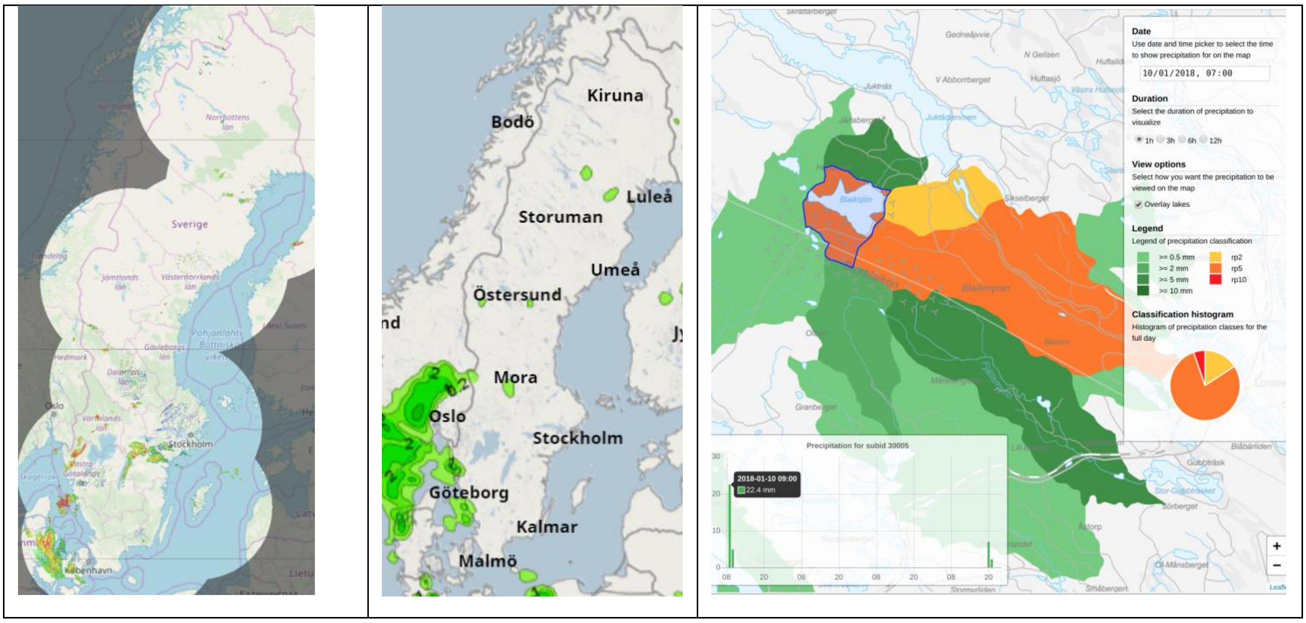

Figure 1. Examples of visualization of radar-observed (a) and forecasted (b) rainfall. A screenshot from the development of the RAIN-VIS tool (c).

Although these available visualization products are clearly useful for assessing the risk of high-intensity rainfall and subsequent pluvial flooding, from a hydrological perspective a number of limitations may be identified:

- Although radar-based rainfall estimates are commonly adjusted towards gauges, to some degree, systematic errors still exist that affect especially long-term accumulations but potentially also single events.
- Rainfall is presented only at its highest resolution in time and space, without possibility to accumulate over relevant temporal and/or spatial domains.

- Rainfall intensity is given in arbitrary intervals with no connection to established levels or thresholds representing e.g. frequency of occurrence.

In RAINVIS, we have attempted to overcome these limitations as follows:

- The radar-based rainfall estimates are more closely adjusted towards gauge observations, represented by daily gridded fields, which ensures accurate long-term accumulations (Berg et al., 2016).
- Concerning spatial resolution, the radar rainfall is averaged over hydrological basins; ~40 000 sub-basins covering Sweden with a median size of ~7 km².
- Concerning temporal resolution, besides the highest available (1 hour), rainfall may be averaged over durations of 2, 3, 6 or 12 hours.
- At each duration, the estimated rainfall depth is compared with national Depth-Duration-Frequency statistics (Olsson et al., 2019) to provide an alert when 2-, 10- or 50-year return levels are observed or forecasted.
- Furthermore, for multi-hour durations, observations from the recent hour(s) may be combined with forecasts for the coming hour(s).

The ultimate aim of RAINVIS is to provide the user with the best possible information and decision support both *before* a flood event (forecasts – for early warning), *during* the event (observation+forecast – for situation awareness) and *after* the event (observations – for post-event analysis). Very welcome to have a look at our demo.

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The FLOODVIEW portal – a web-based prototype for innovative modelling and visualization of heavy rainfall and urban flood risk

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The MUFFIN Project

The FLOODVIEW project, utilizing concepts developed within the MUFFIN project, is aiming to provide a web-based flood control decision support system for municipality managers/decision makers to identify effective solutions to minimize urban flooding. It includes an early warning system through flood forecasting, drainage system impact assessment, low impact development practices, insurance issues and management framework. Three pilot sites at different municipalities from Canada and Sweden are chosen for the study. The water sector benefits from deployment of solutions for flood control, decision support and quick market access for water technologies.

The FLOODVIEW components with a direct link to the MUFFIN project include a prototype of real-time 1-hour discharge simulations for Höje River in southern Sweden, which has a history of flooding problems. Another envisaged component is a “cloudburst risk estimator”, which uses high-resolution meteorological ensemble forecasts to estimate the risk of high-intensity rainfall in a certain location (e.g. a city), taking into account the spatial forecast uncertainty.

SMHI/Jonas: description of the Höje Å 1-h forecast prototype and the concept of “rain risk estimation”

A functional prototype of the frontend application is currently under development. The frontend will be completely web-based and fully responsive to be usable from both computers and mobile clients. From the frontend users are able to search and browse results from various simulations and predictions. Depending on the type of models and data used, the interface will present the results in different ways, but most of the presentations will consist of a combination of maps and charts.

On the backend side the FLOODVIEW application will fetch data both ad-hoc and on schedule from various data sources, like public API:s, files uploaded to FTP-servers specifically for the FLOODVIEW project etc. There are also planned functionality for triggering simulations ad-hoc, storing the output in a database and optionally making the results available for others to view.

A role-based permission system will be implemented where power users will have ability to trigger simulations, upload data and share results with others, while other users will be limited to view results and configure individual alerts etc. There will also be presentations that are publicly available without any login required. Figure 1 show a screenshot of the FLOODVIEW portal

In addition to above prototype development, with the early warning and flood mitigation concern in mind, and in order to understand how these changes will affect the existing infrastructure in urban areas, an integrated urban water model is also needed to identify effective solutions to minimize urban flooding. In this study, a newly developed urban water model software, the Tokyo Storm Runoff (TSR) model was tested and examined for the small urban area Augustenborg in Malmö, Sweden.

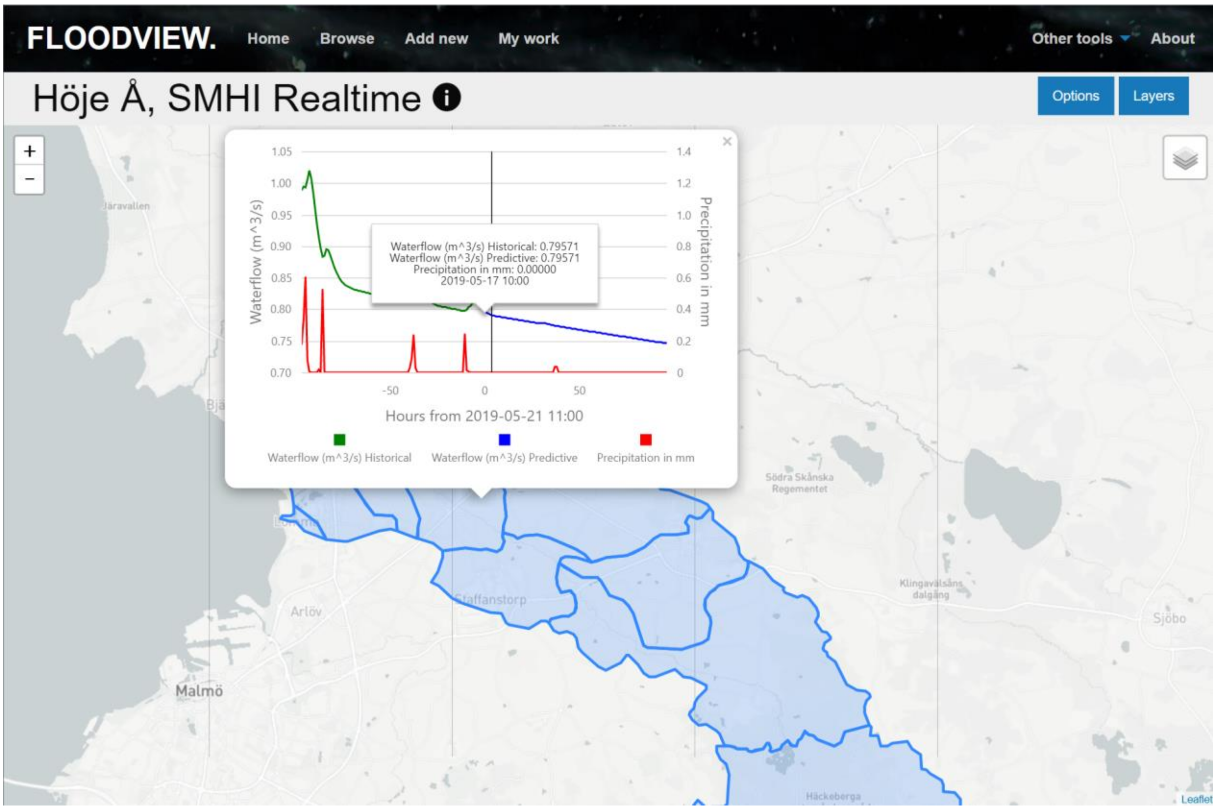

Figure 1. Example screenshot from the FLOODVIEW portal: real-time forecasting in Höje River.

THEME 2: RAINFALL & ENVIRONMENTAL OBSERVATION & FORECASTING

Can we trust radar? High-intensity rainfall in operational radar

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The MUFFIN Project

Today, several high-resolution radar rainfall products for use in hydrology are readily available across the globe. Com- pared with gauges, radar provides superior spatial coverage, leading to more insight into the spatio-temporal characteristics of rain events and their link to hydrological response. But when it comes to accurately measuring small-scale rain- fall extremes responsible for urban flooding, many challenges remain. Large disagreements between radar and gauges associated and non-linear error propagation into hydrological models strongly limit the reliability of radar for local flood predictions. The hope is that by moving to higher resolution and making use of dual-polarization errors can be reduced. However, each country seems to have developed its own strategy for this. Consequently, there is a strong need for an objective, multinational and multiscale assessment of radar's ability to capture heavy localized rain. This study sheds more light on this issue by providing a detailed analysis of 4 different radar products in Denmark, the Netherlands, Finland and Sweden. The top 50 events in the observational record for each country are used to quantify the average disagreements between radar and gauges but also errors affecting the peak rainfall intensities. By comparing different types of radar products (e.g., single vs dual pol, composite vs single radar and bias corrected vs uncorrected) and analysing error propagation across scales, important conclusions and recommendations can be drawn as to the use of radar in urban hydrology.

Data & Methods

Using automatic rain gauges, the top 50 events for each country were selected. For each event, the radar pixels around the gauges were extracted and aggregated in time to match the sampling resolution of the gauges. Table 1 provides an overview of the used radar products.

Denmark: A single radar product from a C-band radar 40 km south of Copenhagen. The radar scans at 9 different elevation angles are combined to generate a gridded product at 10 min and 500 m resolution. Rainfall rate R is estimated based on a fixed Z-R relationship $Z = 200R^{1.6}$. Rain rate values are corrected for mean field bias using hourly data from a network of 67 rain gauges.

Netherlands: The used product is a 5 min, 1 km composite based on reflectivities from 2 C-band radars operated by the Royal Netherlands Meteorological Institute (KNMI). Rainfall estimates are obtained by applying a constant Z-R relationship given by $Z = 200R^{1.6}$. It is adjusted for bias at hourly time scales using a network of 35 rain gauges.

Finland: The Finnish radar product is an experimental product from the FMI OSAPOL-project that takes advantage of dual-polarization and measurement geometry by combining data from 8 C-band dual-pol Doppler radars. For heavy rain, rainfall is estimated using Kdp while for low to moderate intensities a fixed Z-R relation given by $Z = 223R^{1.53}$ is used. The OSAPOL is the only product that is not gauge-adjusted.

Sweden: The Swedish radar product uses data from 12 single-polarization C-band Doppler radars. Rainfall rates on the ground are estimated trough a constant Z-R relationship $Z = 200R^{1.5}$. The product is adjusted for range-dependent bias. Although several radars are available, the current system does not take advantage of overlapping measurements and only uses the data from the nearest radar to estimate the rainfall rate.

Table 1. Radar products used in the study

Country	Radar type(s)	Resolution	Method
Denmark	1 single-pol Cband	500 m, 5 min	Z-R
Finland Sweden Netherlands	8 dual-pol Cband	1 km, 5 min	Z-R Kdp
	12 single-pol Cband	2 km, 15 min	Z-R Z-R
	2 single-pol Cband	1 km, 5 min	

Results

Overall agreement between radar and gauges

Figure 1 shows the rainfall intensities of radar versus gauges at the highest temporal resolution for each country. Looking at Figure 1, we see strong disagreements between radar and gauge estimates, which is a common problem at high temporal resolutions. The relative root mean square errors are between 116.4% and 135.1% and the linear correlation coefficients between 0.72 and 0.83. The multiplicative bias values of 1.59, 1.41, 1.56 and 1.77 show that radar systematically underestimates the rainfall rate by 41-77% across countries. Overall, the Dutch product exhibits the best agreement, followed by Finland, Denmark and Sweden. Differences between countries are hard to interpret due to the many confounding factors. However, the fact that the Swedish product has the lowest performance is likely due to its lower resolution of 2 km and 15 min. Interestingly, the high 500 m spatial resolution in the Danish product does not seem to provide an obvious advantage over the 1 km resolution in the Netherlands and Finland. One possible explanation for this could be that the Finnish and Dutch products combine data from multiple radars whereas Den- mark only uses only one. The fact that the Dutch and Finish products have comparable performance is interesting, since the Finish product has not been bias-adjusted but relied on polarimetry to estimate rain rates in times of heavy rain.

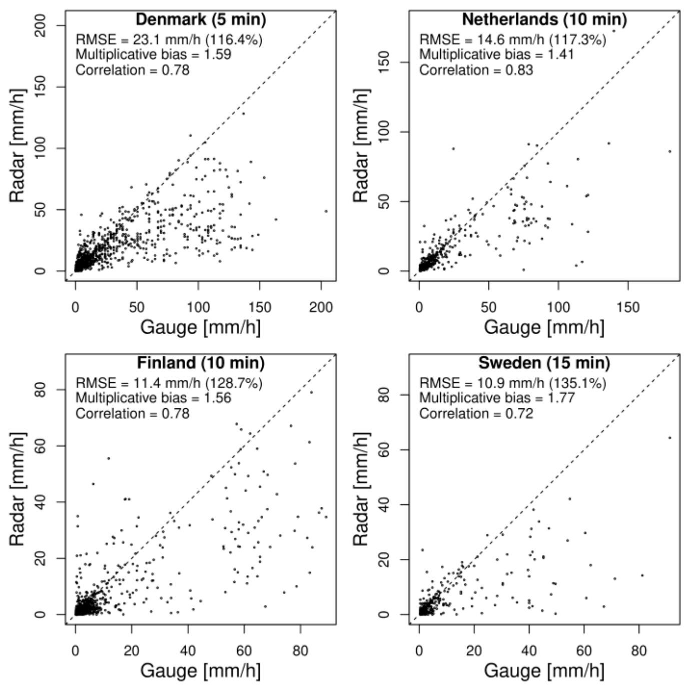

Figure 1. Radar versus gauge intensities at the highest available temporal resolution for each country.

Agreement across scales

Figure 2 shows the relative root mean square error and correlation coefficient of radar versus gauges estimates for aggregation time scales up to 2 h. We see that the radar products with higher spatial and temporal resolution generally agree better with the gauges. Denmark (500 m and 5 min) comes out on top, followed by the Netherlands, Fin- land (1 km, 5 min) and Sweden (2 km and 15 min). Note that even at 2 h time scale, differences between radar and gauges remain substantial, ranging from 65.1% to 85.9%.

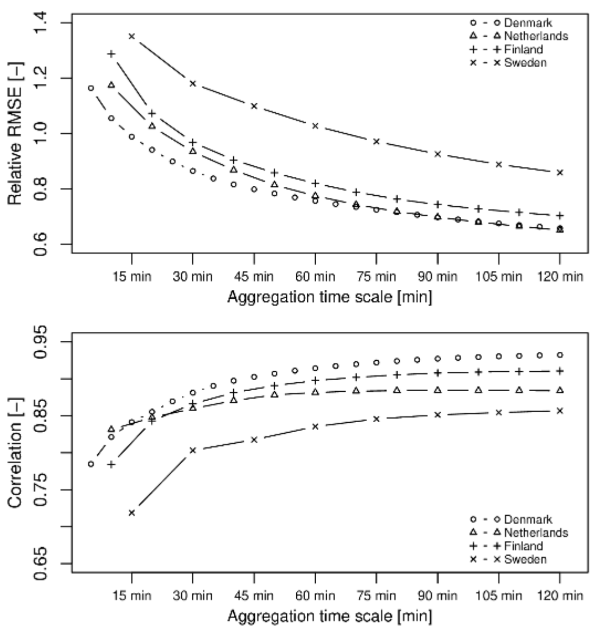

Figure 2. Relative root mean square error and correlation coefficients of radar versus rain gauge estimates at different aggregation time scales.

Agreement in terms of peak intensity

Figure 3 shows the peak intensity ratios between gauges and radar as a function of aggregation time scale. Compared to the average bias which is "only"41-77%, the underestimation of the peaks appears much larger, in excess of 150-300%. Most of the bias is attributed to errors at mall time scales of 0-30 min. The mean field bias correction does not seem to improve performance at these scales. The results for the Danish product are particularly interesting, as it has the best overall agreement with gauges in terms of rmse but also the worst performance in terms of peak intensities, showing that the ability to combine radar measurements from multiple viewpoints appears to be more important for capturing the most intense parts of a storm than spatial resolution.

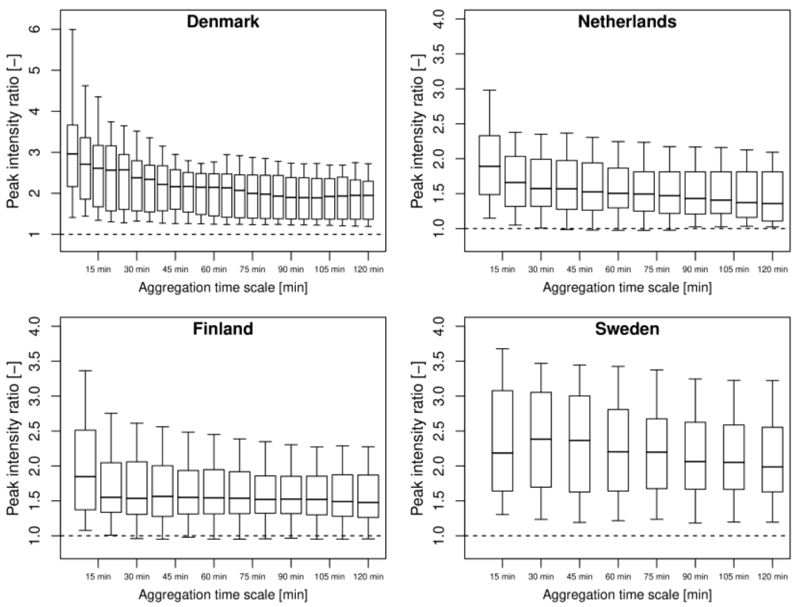

Figure 3. Peak intensity ratios versus aggregation time scale for each country.

Conclusions

Overall, radar and gauges were in fair agreement with each other, with average biases of 40-80%. However, much larger discrepancies of 150-300% were observed during the peaks. The spatial and temporal resolution of the radar product seems to play an important role in determining the overall bias with respect to gauges. But high resolution alone is not the key to success. The two best radar products (Netherlands and Finland) all combined data from multi- ple radars to help mitigate attenuation in times of heavy rain, performing better in terms of peak intensities than the Danish product which has higher resolution (i.e., 500 m) but only used data from a single radar. The rainfall estimation algorithm also plays an important crucial role. While the Dutch used a fixed Z-R relationship and corrected for bias using gauges, the Finish achieved similar performance by relying on polarimetric variables such as Kdp without bias adjustment.

Acknowledgments: This research was funded by 'Water JPI Europe', ERA-NET Co-fund 'WaterWorks2014' project MUFFIN (Multiscale Urban Flood Forecasting: From Local Tailored Systems to a Pan-European Service). The Finish OSAPOL project was funded by the European Regional Development Fund and Business Finland.

Accuracy of satellite-observed rainfall over Sweden

Hossein Hashemi, Faculty of Engineering LTH, Lund University

The SUrF Project

Precipitation is an important source of freshwater, and its accurate measurement is essential. Over the years, several instruments, i.e., rain gauge, weather radar, and satellite, have been used to measure precipitation. Ultimately, the choice of precipitation data depends on the particular application, the catchment size, climate, and the time period of study. In poorly gauged regions the use of remotely sensed precipitation products is an absolute necessity.

Rain gauge and weather radar are the most common ground-based precipitation measurement techniques. However, both of these instruments have their own set of limitation, particularly concerning spatial resolution and spatial coverage. The Global Precipitation Measurement (GPM) has been providing, since February 2014, high-resolution precipitation data sets with larger spatial coverage relative to Tropical Rainfall Measuring Mission (TRMM). GPM is expected to deliver the more accurate estimation of light rainfall and snowfall, particularly, in the high latitudes such as Scandinavia. However, the evaluation of the performance of the GPM mission is an essential step before the extensive use of its products in hydrometeorological studies. Despite the unique spatial coverage, 60° N and 60° S globally, spatial resolution, $0.1° \times 0.1°$, and advanced retrieval algorithm, Integrated Multisatellite Retrievals for GPM (IMERG), most recent studies have shown that the GPM products show some differences relative the ground-based measurements. Since the GPM algorithm is based upon experiences from TRMM algorithm (TMPA), therefore IMERG is experiencing new sources of error as the measurements have extended beyond the subtropical region where the light rain and snowfall are more frequent.

Though GPM data product has a higher spatial and temporal resolution, it is quite often found to overestimate or underestimate the true precipitation based on the region, topography, and type of precipitation. In order to understand the performance of GPM and its limitations, this study aims to evaluate the GPM products in daily and sub-daily scales against the gauge measurement in Sweden. The results show that the GPM daily estimates perform better than hourly estimates. The satellite data agree well with gauge data concerning the correlation coefficient. In the case of error analysis, such as MEA, RMSE, POD, and FAR, the daily estimate outperforms hourly estimates. The results also show that the satellite sensor is experiencing detection issues at the southwestern coastline of Sweden in both daily and sub-daily scales. This might be related to the common precipitation type and temporal measurement issue with the GPM core observatory (three-hourly) in this area. Overall, satellite performance relative to ground-based measurement shows less accuracy in the coastal regions. These errors can be attributed to many factors like the influence of wind, weather system, and the gap between satellite revisit of any given spot. Therefore, further research is required to adjust the satellite data based on the investigated error.

Use of weather radar in the water sector in Denmark; what can we learn?

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The MUFFIN project

The interest in applying weather radar data for urban hydrological purposes has increased significantly in recent years in Denmark. Until now radar data has only been applied in research or development projects, but operations and services in urban hydrology are impending. Potential users of quantitate precipitation estimates from weather radar counts water utility services, municipalities, consultants, authority, research institutions and more. Potential usage of radar data covers both offline applications such as (Thorndahl et al., 2017): analysis and statistics of rainfall, reanalysis of damaging extreme events, insurance claims, management purposes, e.g. design or urban hydrological systems, as well as online applications such as severe rainfall warning systems, flow/flood warning based on online hydrological models, real time control of urban hydrological systems, etc.

In 2018 the largest water utility services in Denmark along with research institutions and private companies to was funded the project : "VEVA" (in Danish: VEjrradar i VAndsektoren) with the overall purpose to promote the application of weather radar data in the Danish water sector (www.veva.dk). The objectives of the project are to:

- Create an open standard for use of radar data for hydrological and hydraulic purposes,
- Create a widely applicable quality controlled and adjusted data format,
- Develop and maintain data information models and data formats,
- Have expert knowledge and experience on use of radar data in the Danish water sector,
- Promote continuous research and development in use of radar data.

Danish radar data both cover X-band radars (primarily owned by water utility services) and C-band radars (owned and operated by the Danish meteorological institute). The VEVA project includes both types of radars which individually have different specifications and pros and cons (see e.g. Thorndahl et al. (2017). Figure 1 shows an example of Danish radar data.

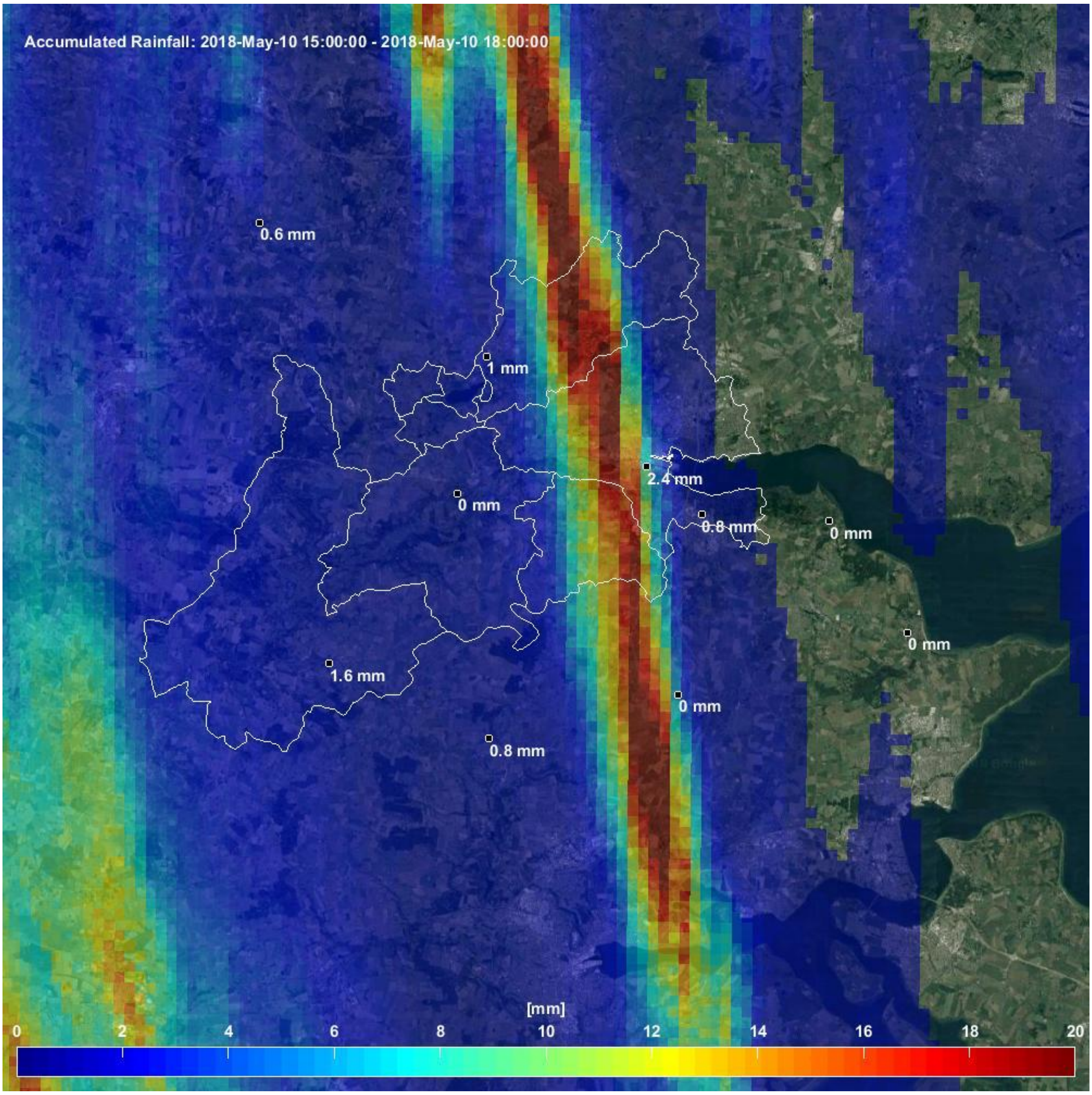

Figure 1: Example of data from the Danish Meteorological institute radar in Virring, Denmark on May, 10, 2018. The example shows a narrow convective storm over the city of Vejle where almost no rain was recorded in the rain gauge network, but the radar recorded up to 20 mm of rain during a few hours.

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Experiences of X-band weather radar in Skåne

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The Radar Project

The purpose with the test period was to obtain an in-depth conclusion on how an X-band weather radar facility could be implemented at VA SYD, including data quality control and validation. The following parts constitute the report:

- A literature study and an evaluation of the critical parameters for a weather radar facility
- An evaluation with proposed sewerage system and wastewater treatment plant applications of the weather radar data
- Validation of the radar data

VA SYD has collaborated with the Faculty of Engineering at Lund University (LTH), Sweden Water Research (SWR) and the Swedish Meteorological and Hydrological Institute (SMHI) in this project. VA SYD and SMHI made an analysis of the technology and localized a test site with ideal conditions for the first X-band weather radar facility in Sweden to be on the top of the Dalby water tower outside the city of Lund. The X-band radar offers higher resolution when compared to SMHI's C-band radar. The weather radar was in operation between 2018-07-03 and 2018-09-12. In addition to precipitation data from VA SYD, the Trelleborg municipality has contributed their precipitation data.

The study included an analysis of processed radar data from Informatics (IT-supplier) and LTH, and from VA SYD´s rain-, flow-, and sewerage overflow gauges. Four precipitations events from August 2018 have been studied in which different data sets, including rain gauge data in Trelleborg municipality, have been analysed. LTH processed and validated the radar data with a Matlab code while Informatics used a Python code.

The weather radar facility recorded precipitation on several occasions in August 2018. In particular, the event in Trelleborg on the 11th of August recorded a cloudburst event with local differences in accumulated rain amounts (0-15 mm), which was confirmed and illustrated with the radar. However, some differences were observed between the recorded amounts of precipitation by the rain gauges relative to radar estimates. This shows the importance of accurate rain gauge measurements, as well as calibrating the radar, as the first steps for the future facility.

The study indicated that the X-band radar could provide VA SYD with a future warning system with a margin, at best, of 0,5-1 hour. A collaboration with the HOFOR/BIOFOS facility in Copenhagen could extend the observational range of the radar further, based on the condition that most rain fronts come from the west. The next step would be to initiate a project where the X-band radar will be integrated with other methods of precipitation measurements, both observational and prognosis tools.

The weather radar in Dalby will measure precipitation in the southwestern part of Skåne from 2019, when a permanent facility will be installed.

The weather radar technology will become a key component in a future warning system, which would benefit the customers of Swedish water utilities.

Subsidence areas trends in Bucharest city, based on PS-InSAR analyses

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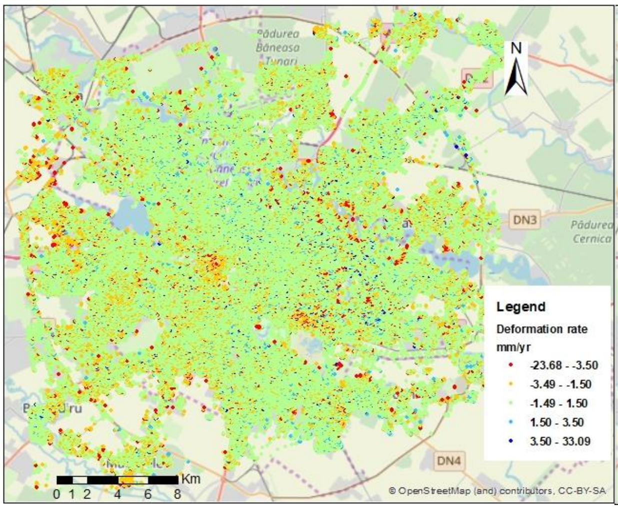
The INXCES Project

In Bucharest, a dynamic city, the consistently development of ground and underground works is associated to groundwater dynamic changes. These impact the stability of the ground surface and can produce subsidence. Using Sentinel 1 data for the period of October 2014-April 2018, the Norwegian Geological Survey produced a map of vertical displacements for Bucharest by applying PSInSAR technique. Figure 1 presents the PSInSAR map obtained using Sentinel 1 data from ascending orbit 131. This map was used to identify the city areas where subsidence is encountered. Hence, 13 areas with subsidence trends were identified (see Fig.2). The comparison of these results to other vertical displacement maps for the historical periods 1992-2000 (ERS data) and 2002-2009 (ENVISAT ASAR data) processed in the frame of INXCES project as well as to the results of several previous projects studying the vertical ground dynamics of the same area, revealed additional areas showing subsidence trends since the beginning of the 90s. Five of these areas have been identified in the frame of PanGEO project (Vîjdea și Bindea 2013).



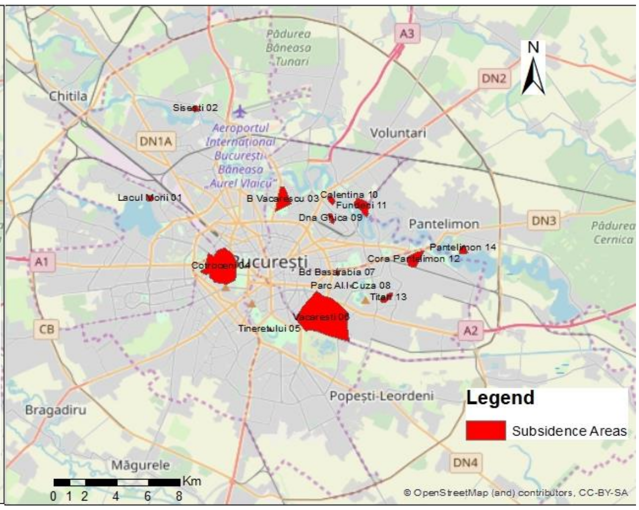


Fig. 1- PSInSAR ground deformation map of Bucharest *Fig. 2- Identified subsidence areas in Bucharest*

For 2014 – 2018 time period an area marked on the map as Cotroceni_04 has been identified as presenting only subsidence. At the end of 2015 a collapse of the terrain occurred, as a Tunnel Boring Machine (TBM) was crossing this area for the construction of a new subway line. The alluvial matrix, affected by the groundwater barrier effect produced by the extensively channelized Dambovita River and another subway line, collapsed. Poor studied geological and urban hydrogeological aspects, largely contributed to this accident. As a consequence, many buildings of this area were damaged, even the ground surface was registered as being stable during the previous monitoring periods.

Other three new observed areas affected by subsidence are newly built areas. For these, two hypotheses are considered: the lack of subsidence trend shown by the previous periods (the subsidence trend could not be observed due to the vegetation coverage) or the areas were previously stable, meanwhile the constructions development process broke this stability. Beside these particular areas, a subsidence trend could be revealed along Colentina River, one of the rivers crossing the city.

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APPETIZER

Subsidence in urban areas measured by InSAR (Sentinel1) related to flooding

Guri Venvik[1], Ane Bang-Kittilsen[1], John Dehls[1] & Floris C. Boogaard[2]

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The INXCES Project

Rapid changes in the urban environment due to growth puts the urban water cycle out of balance, hence, affecting other surface and subsurface processes, such as subsidence and surface water management. Subsidence of the ground is causing risk and hazard, as well as unexpected costs. This newly, November 2018, launched tool InSARNorge is Open Access and part of the Copernicus program.

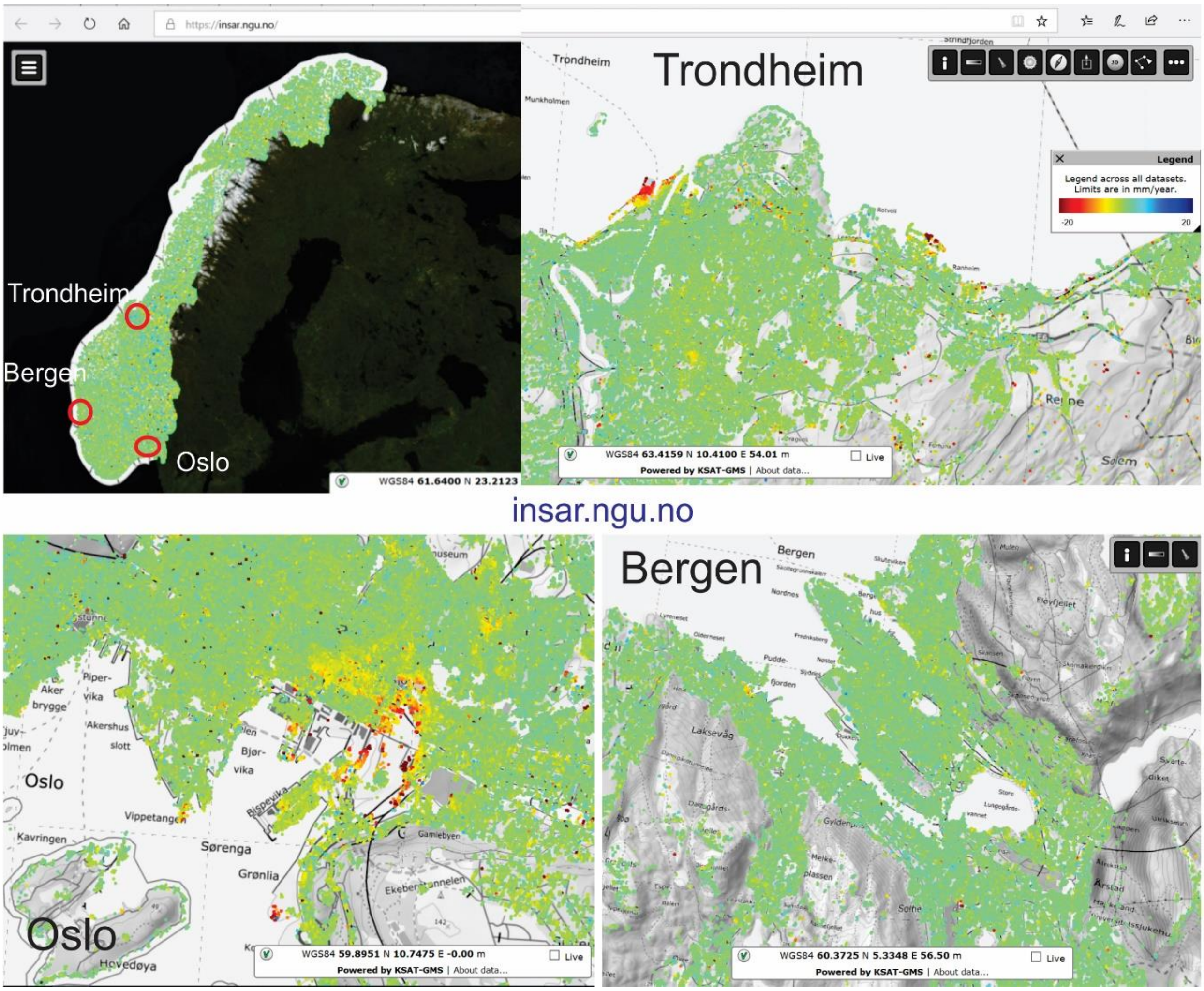

Figure: Subsidence in three cities in Norway. Some areas clearly show subsidence, indicated by red points. The Bryggen (Wharf) in Bergen has now stabilized due to mitigation, such as SuDS. www.insar.ngu.no

In a recent study (Venvik et al. submitted) datasets from InSAR satellites showing subsidence are combined with data from flood modelling in two different analytical methods using ArcGIS tools to develop a risk assessment map for areas most prone to the combination of both flooding and subsidence. Applying user-centred principles, this work focuses on methods for risk assessment maps as a support tool to locate areas where mitigation of subsidence and adaptation for surface water management will be most efficient and measures can be implemented. The results of the methods for risk assessment maps show that one of the methods give significant results compared to the other method. Such method will be a helpful tool for decision-makers when prioritizing areas for measures such as Sustainable urban Drainage Systems (SuDS). The study is related to the JPI Water funded project INXCES (www.inxces.eu).

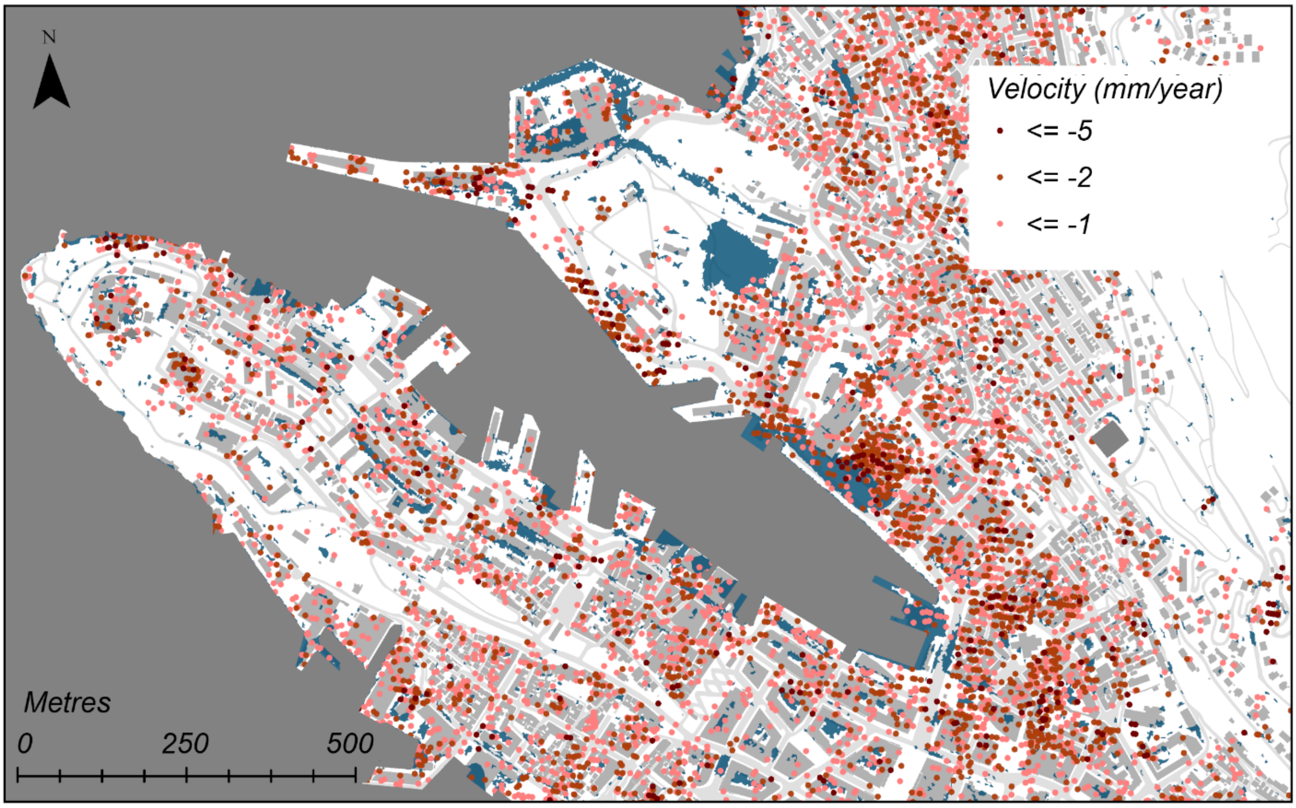

Figure: Areas of subsidence and flooding in Bergen city centre, Western Norway. The darker colour of the dot the higher average velocity (mm/year) for the subsidence. Blue color shows the flooded areas, with increasing water depth with darker colour (Venvik et al. submitted).

This is an interactive tool that can showcase multiple real situations related to different problems such as, areas prone to flooding, underground constructions, cultural heritage etc.

https://insar.ngu.no/

Aknowledgement: This research is supported through the JPI Water funded INXCES research project "Innovation for eXtreme Climatic EventS". Sentinel-1A/B images are provided by the European Space Agency (ESA). We thank the Bergen Municipality, Tauw and Hogeschool van Amsterdam, University of Applied Sciences, for support for this work.

Reference:

Venvik, G. Bang-Kittilsen, A. Boogaard, F.C. & Dehls, J. (Submitted) Risk assessment for areas prone to flooding and subsidence - a concept model with case study from Bergen, Western Norway. *Journal of Hydrological Research Special Issue*.

THEME 3: URBAN FLOOD MODELLING & FORECASTING

High resolution modelling of urban flood modelling and its origin in the large-scale catchment

Andreas Persson, Abdulghani Hasan, Petter Pilesjö and Hampus Nilsson

Lund University

The SuRF Project

Most of the hydrologic models currently used in flood forecasting are of the type catchment models, e.g. EFAS, HYPE, SWAT. Catchment models are generally low-resolution models, intended for large scale modelling, which use sub-catchments as the basic unit for the calculations (i.e. the size of sub-catchments are large). As an example, the average resolution of the Swedish hydrologic model used for flood forecasting (S-HYPE) [1] and two European operational floods forecasting systems (E-HYPE and EFAS) are around 13, 250, and 25 km^2 respectively. Such low-resolution floods forecasting models are important to provide alerts to when a flood may occur in the sub-catchments outlets and for a large model domain in reasonable running time. The sub-catchment outlets coincide in general with watercourses, mainly rivers. The resolution does not permit a detailed distributed flow or flood mapping as other high-resolution models do. However, a high-resolution, grid-based, hydrological model (e.g. HEC-RAS, MIKE FLOOD, etc.) can provide detailed flood mapping but have long processing time for the large areas of the sub-catchments. The models are usually not public domain or open source models. The resolution is crucial when it comes to urban flood modelling. Keeping track of flow paths and water depths site specifically is necessary to ensure an adequate model result, showing the property, infrastructure and number of individuals potentially affected by the flood.

Tools or models that take both a larger contributing area and a smaller affected area into consideration in the modelling process is sought for by authorities and municipalities as competence in specialized flood risk modelling often is lacking. This is especially true for mid-sized and smaller municipalities and has been stressed in a report from the Authority Network for Climate Adaptation (including Lantmäteriet, SMHI, Sjöfartsverket, Länsstyrelserna). Municipalities specifically asked for methodologies in relation to flood mapping and risk analysis [2]. Municipalities prefer to use Geographical Information Systems (GIS) for data analysis, especially when it comes to hydrology, since some competence in GIS is available.

To overcome the lack of high-resolution results for specific areas and provide a practical solution to deal with the problem in a GIS-environment, a dynamic hydrologic model, TFM-DYN [3, 4], is further developed within this project and coupled with the HYPE model. The TFM-DYN model is a grid-based model that move water in a DEM and distribute it proportionally to lower lying cells. At the same time, it allows infiltration and consider friction in order to calculate the water velocity of the overland flow. With the ability to choose a time step, the water distribution and depth can be presented at different stages of a flood event.

The TFM-DYN do need an input in order to produce realistic results and therefore the output results from the large domain of the HYPE model is interactively used as an input for the detailed high-resolution dynamic flood modelling in TFM-DYN. With this coupling, the two models cover both the upstream large-scale general water distribution and the high-resolution modelling required in urban areas.

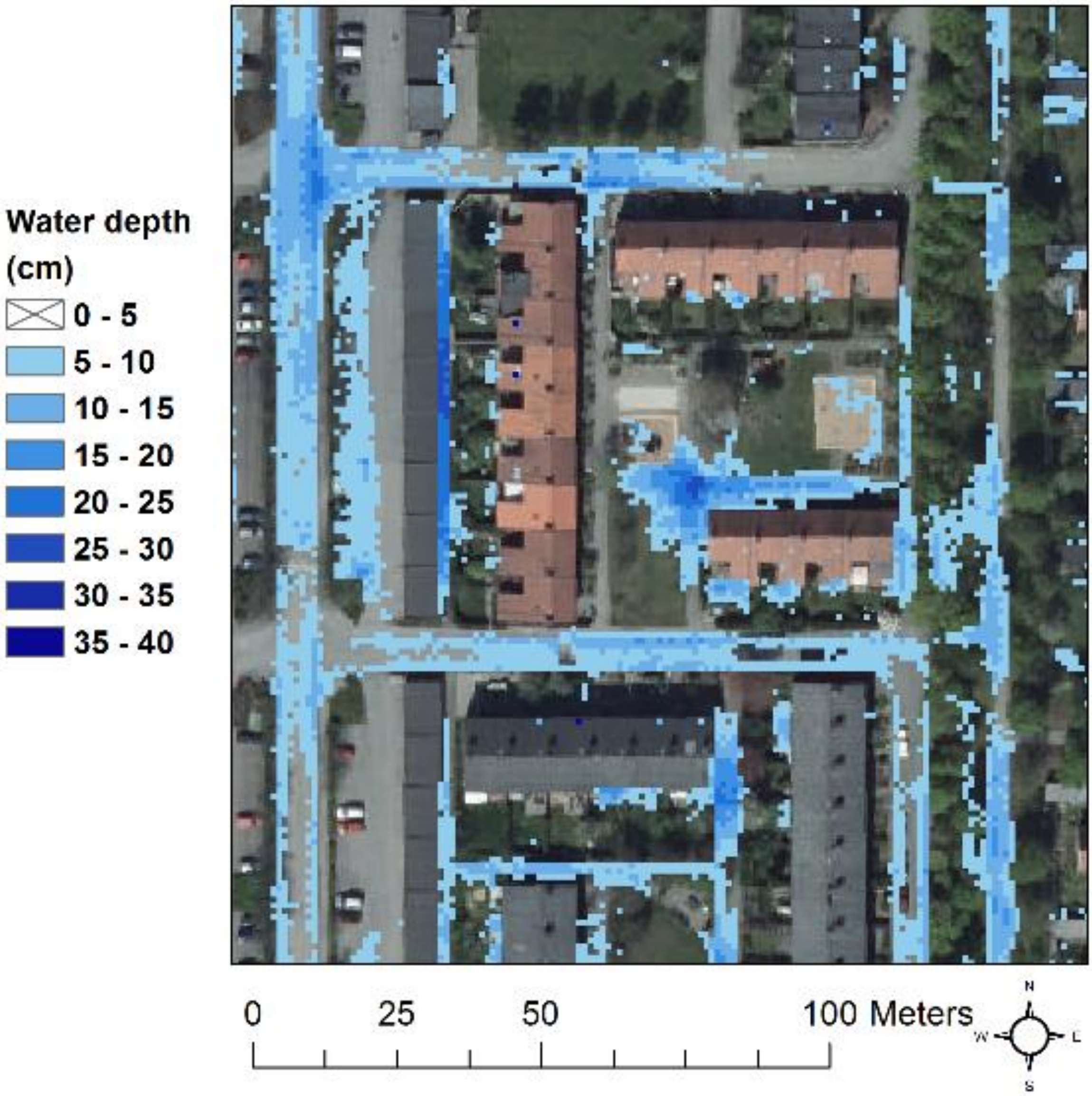

Figure 1. Water depth calculations from TFM-DYN superimposed on an aerial image covering a few blocks in Lund municipality, Sweden. (Source: Nilsson, 2017)

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Hydrodynamic vs. hydrological modelling: a comparative study in Aalborg and Helsinki

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The MUFFIN project

Flooding in urban areas is an environmental hazard and is a great cost for the communities affected. Urban flooding is increasing due to the increasing urbanization of the city areas and climate changes. During rainfall events, rainfall over urban catchments travels through anthropogenic surface pathways and is collected by the stormwater sewer systems and routed to the recipient. Urban flooding is most often caused by the sewer capacity being exceeded, which may happen during the extreme rainfall events, where water from the sewer system may be surcharged to the surface. Accurate and fast flood simulation and prediction are needed to perform diagnostics of historical flood events and decision-support tools to mitigate future events.

Hydrodynamic models are the de facto standard for simulating flood risk in urban catchments, due to the accurate model description of anthropogenic restructure of the natural surface and underground flow pathways. The downside of the hydrodynamic models is long simulation times, which can be of critical importance for real-time prediction of an incoming urban flood. In both reality and in the hydrodynamic models, urban flood is often observed in the same general areas, where the sewer system lacks the capacity to route incoming stormwater away from the area during extreme rainfall events. Knowing the flood prone areas beforehand, obtained from either experience or using a hydrodynamic model as a diagnostic-tool, limits the need for accurate spatial accuracy of predicting incoming flood, i.e. prediction of the exact location on each surcharged manhole is no longer of great importance and simulation speed becomes the most important factor.

Large-scale hydrological models have been used to predict flood in rural areas, where natural surface and underground flow paths are well described by simple lumped basins. The use of large-scale hydrological models to predict urban flooding have so far been limited to urban catchments, where the flood is mainly controlled by river systems where the lead time between rainfall and is in the order of 12 hours to days. This is mainly due to the limited ability to describe the water cycle in fast-reacting urban catchments, where high-resolution models are needed to accurately capture flood. Recent developments of high-resolution hydrological models with detailed land-cover and surface flow path descriptions may improve the simulation accuracy of the urban water cycle while still being several magnitudes faster than hydrodynamic models.

In this abstract, a comparative study between two hydrodynamic models and a newly developed high-resolution hydrological is presented. Two catchments in Helsinki, Finland and Aalborg, Denmark are used as study cases to calibrate and test the high-resolution hydrological model's performance against two hydrodynamic models, see an example of comparison of runoff volume in Figure 1.

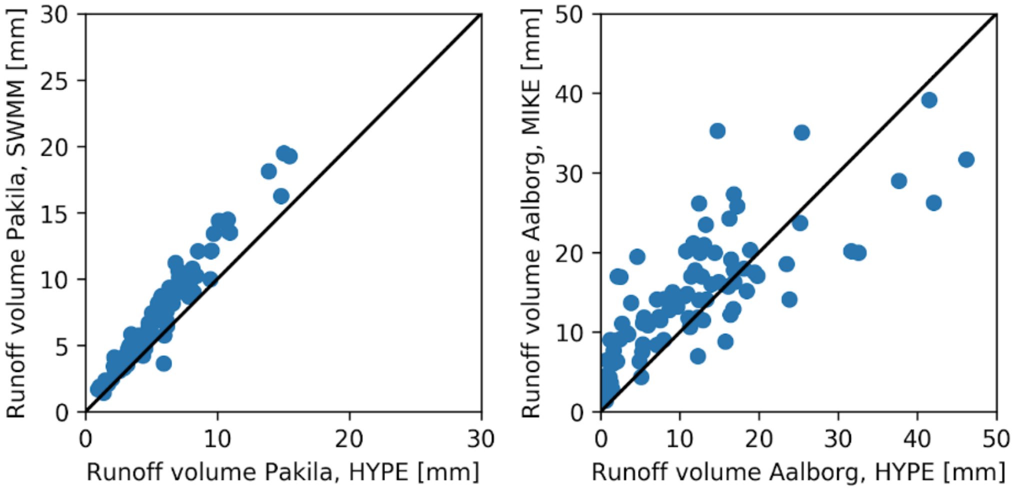

Figure 1: Total runoff volume per event for the two study cases. The fit between the hydrodynamic and high-resolution hydrological model is considerately better for Pakila, Helsinki.

The high-resolution model's ability to accurately predict urban flood is improved by linking the flood risk as estimated by the hydrodynamic models to a variable in the high-resolution hydrological model. Flood risk is defined in the hydrodynamic flood threshold based on the number of flooded manholes, see Figure 2. This enables the high-resolution hydrological model to relate the simulated variables to a flood risk that is also accurate in urban catchments, where anthropogenic changes the natural water cycle.

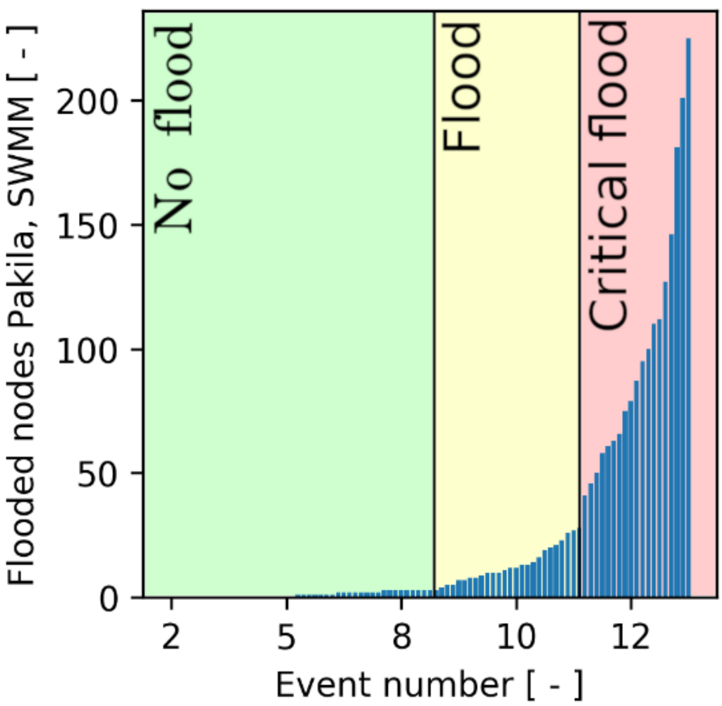

Figure 2: Flood severity indexes based on thresholds for the number of flooded nodes separating each index. The thresholds are chosen when a steep gradient is observed in the number of flooded nodes.

The relationship between rainfall and pluvial flooding in Rotterdam based on citizen reports

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The MUFFIN Project

Urban pluvial flooding is one of the most costly natural hazards worldwide. The complexity of the involved processes and the lack of long-term field observations means that many crucial aspects related to urban flood risks still remain poorly understood. In this paper, the possibility to gain new insight into urban pluvial flooding using citizen flood observations is explored. Using a ten-year dataset of radar rainfall maps and 70,000 citizen flood reports for the city of Rotterdam, we derive critical thresholds beyond which urban pluvial flooding is likely to occur. Two binary decision trees are trained for predicting flood occurrences based on peak rainfall intensities across different temporal scales. Results show that he decision trees correctly predict 37%-52% of all flood occurrences and 95%-97% of all non-flood occurrences, which is a fair performance given the uncertainties associated with citizen data. More importantly, all models agree on which rainfall features are the most important for predicting flooding, reaching optimal performance whenever short- and long-duration rainfall peak intensities are combined together to make a prediction. The encouraging results suggest that citizen observatories, although prone to larger errors and uncertainties, constitute a valuable alternative source of information for gaining in- sight into urban pluvial flooding.

Materials and methods

The study focuses on the city of Rotterdam, which is located in a low-lying area in the delta of the Rhine and Meuse rivers in the Netherlands. The city counts more than 640,000 inhabitants spread over a heavily urbanized area with more than half of the total area being paved or semi- paved. Most areas of the city are drained by a combined sewer system (1,800 km) whereas the remaining areas are drained by a separate sewer system (500 km). Historically, stormwater systems in Rotterdam have been designed to be able to cope with rainfall intensities of approximately 20 mm/h over short time windows of 10-15 minutes with an estimated in-sewer storage capacity of 10-12 mm. However, the original infrastructure has aged considerably, and some parts had to be renewed which means that the exact capacities are largely unknown.

Citizen observations of urban pluvial floods

In 2004, the municipality of Rotterdam established a citizen observatory database with the objective to collect flood reports by means of phone, email, mobile app, and web- page. Over a period of 10 years between 2008 and 2017, about 70,000 citizen reports were collected this way. The total number of reports after quality control and removal of weekends (when call centres are closed) was approximately 38,300. It is important to clarify that not all flood reports in the dataset are directly attributable to rainfall. Even on days without precipitation, citizens will call in to re- port flooding in their house or neighbourhood associated with other causes not directly related to rain (e.g., high ground- water levels, bursts of water supply pipes etc). However, evidence shows that the average number of reports received during dry days tends to be much lower than on rainy days. To better distinguish between the two, a dry-weather base- line of 20 reports/day was established. Using this baseline, 443 weekdays with urban pluvial flooding and 2,166 days with non-pluvial flooding were identified.

Radar rainfall observations

Information about rainfall intensity and spatial distribution was obtained from the national radar network in the Netherlands. For the purpose of this study, a ten-year time series of radar rainfall maps (from 2008 to 2017) at temporal and spatial resolutions of 5 min and 1 km, has been retrieved over the city. To investigate the effect of temporal resolution, the radar data were aggregated from 5 min to 8 coarser temporal scales (10, 15, 30, 60, 120, 360, 720 and 1440 min).

The models

To model the relationship between peak rainfall amounts and the occurrence of pluvial flooding, we used a binary decision tree in which 'yes" means pluvial flooding (i.e., more than 20 reports per day) and "no" means non-pluvial flooding (i.e., fewer than 20 reports per day). The features used to make the decisions along the different branches of the tree are given by the peak rainfall amounts Rd_x (in mm) (expressed in mm) for each day, at nine different temporal aggregation scales. Two different models are considered:

- Model 1: uses all 9 available rainfall features at temporal aggregation scales from 5 min up to 24 hours. During training, the algorithm automatically chooses the most relevant features and thresholds for classification.
- • Model 2: is trained using only 2 features: Rd_5 and Rd_{1440} representative of the small-scale and large-scale peak intensities. This model is expected to perform slightly worse than the full model. However, since it only relies on 2 features for making its classification, it is operationally more straightforward to implement and easier to interpret.

Results

The first trained model is shown in Fig. 1-(a). Al- though all 9 rainfall features were available for training, only three of them (5 min peak, 60 min peak, and daily total) were used to make the classification. The first and most important threshold appears to be the total daily rainfall amount Rd_{1440}. Days with Rd_{1440} < 12.7 mm were labelled as non-flood days while the days with accumulations above 21.19 mm were labelled as flood days. The tree also con- siders two additional bifurcations depending on whether the hourly maxima Rd_{60} is larger than 6 mm and the 5-min rainfall amount $Rd5$ larger than 0.35 mm (4.2 mm/h). The 6 mm threshold at the hourly scale is particularly helpful for separating long lasting events with low intensities from those with higher peak intensity but relatively modest ac- cumulations (e.g., thunderstorms). Interestingly, the found thresholds are remarkably close to the design guidelines fol- lowed by the city of Rotterdam in the 1950-1980s when the stormwater and drainage systems were built. At that time, the system was designed for approximately 5 mm of rain over 15 minutes and 10-12 mm of in-system storage capac- ity associated with longer time durations. The threshold of 12.7 mm daily accumulation is likely associated with the 10-12 mm storage. The short-duration threshold of 3.6 mm/h in 5 minutes is much lower than the design value, which could be a sign that the local effective transport capacity is much lower than expected (e.g., due to blockages of sewer pipes or inlets).

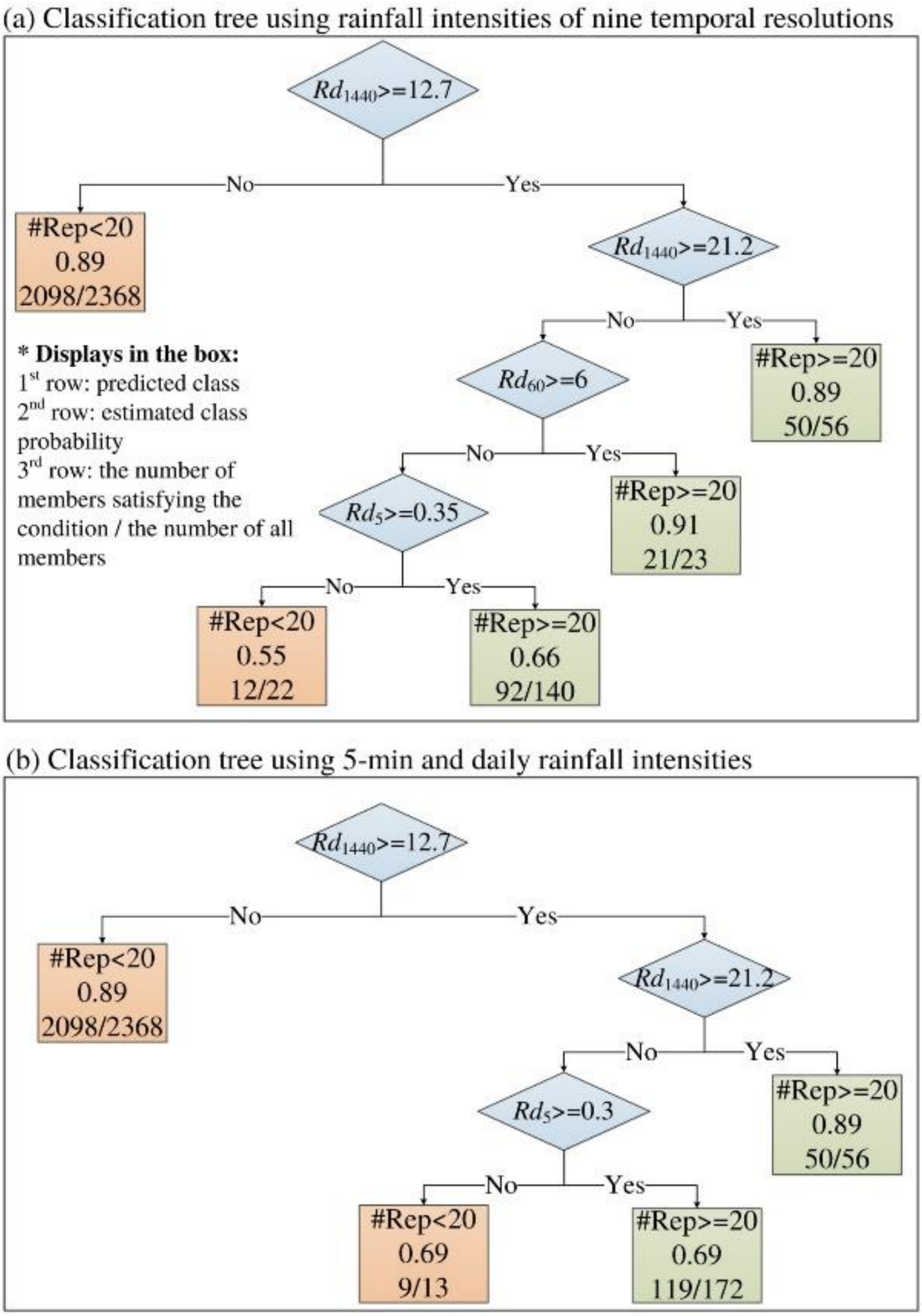

Figure 1. *Binary decision trees trained by using (a) rainfall intensities at nine selected temporal resolutions; (b) Maximum 5-minute (Rd_5) and 24 hour (Rd_{1440}) rain- fall depths.*

Despite these encouraging results, it should be pointed out that the overall performance of model 1 remains low. Among the 443 flood events in the database, only 163 were successfully predicted, resulting in a high miss rate of 63%. On the other hand, the non-flood days tend to be predicted very (97%). The predictive rates for both cases are also relatively good: among the 219 predicted flood events, 163 were actual flood days (positive predictive rate of 74%) and among the 2,380 predicted non-flood days, 2,110 (88%) were correct. The overall error rate for both flood and non-flood days is only 13%. The second tree based on Rd_5 and Rd_{1440} shown in Fig. 1-(b) performs very similarly, suggesting that for operational purposes, there is little added value in including more than 2 temporal aggregation scales when making the flood predictions.

False positives and negatives

The absence of information about the origin of the flooding in citizen data clearly appears to be a limiting factor influencing false positives and negatives. Plausible explanations for the large number of false positives are (i) under- reporting when flooding happened in an area of lower population density, (ii) under-reporting due to public holidays, lost records or lack of time, and (iii) the possibility that flood reports may have been filed later, on the days following the rain event. This is hard to verify as citizen flood reports do not come with a precise time stamp and make no distinction between the time of the incident itself and the day on which it was reported. The most likely explanation for the large number of false negatives is blockage in the stormwater system not caused by excess rainfall. Alternative explanations are (i) an underestimation of rainfall by radar, and (ii) large amounts of antecedent rainfall on the days prior to the flooding. The antecedent rainfall scenario is difficult to verify as the lack of precise time stamp makes it impossible to determine the exact amount of rain that fell on the days leading up to the flood event. Another differently important fact to keep in mind that the reports were made by non-experts, which often evaluate situations than trained professionals. Lastly, the fact that models were trained on the full datasets might also play a role, as it does not account for the growth in population and changes in the way citizen report incidents. Indeed, a growing number of reports are now submitted through the mobile app, resulting in approximately 1,000 additional reports per year since 2014. Reports submitted via the app generally contain more de- tails, including the possibility to upload photos. This is an encouraging development that hopefully will help increase the overall quality of the data in the future.

Conclusion

A ten-year dataset of 70,000 citizen flood reports for the city of Rotterdam and radar rainfall maps at 1 km, 5 minutes resolution were used to derive critical thresholds beyond which urban pluvial flooding is likely to occur. Results show that our models correctly predict 37%-52% of all flood occurrences and 95%-97% of all non-flood occurrences. Best performance is reached when short- and long-duration rainfall peak intensities are combined. The study also highlighted a number of issues related to citizen flood observations which need to be improved. The first concerns the lack of information about the type and origin of the flooding, making it difficult to distinguish between events triggered by rain and other failure mechanisms such as sewer blockages. The sec- ond concerns the timing between rainfall and flood reports; a more precise time stamp would enable a better identification of rainfall conditions associated with the flood generation, such as antecedent rain. Despite all these issues, results are highly encouraging, clearly highlighting the possibility to infer physically plausible critical rainfall thresholds responsible for urban pluvial flooding.

Acknowledgments. This research was funded by JPI Urban Europe, ERA-NET Co-fund Smart Urban Futures and NWO/VerDuS Smart Urban Regions of the Future (SURF). The third author acknowledges funding through 'Water JPI Europe', ERA-NET Co-fund WaterWorks2014 project MUFFIN (Multi- scale Urban Flood Forecasting: From Local Tailored Systems to a Pan-European Service).

A strategy to sustain the functionality of the existing urban drainage network

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The SUrF – Project

Sustainable drainage systems (SuDS) might be placed in urban spaces based on different criteria. Space availability, willingness of the landowner, morphologic properties of urban spaces are all among factors that dictate the implementation point for the SuDS (Bach et al., 2013; Romnée et al., 2015). However, through a piped-drainage perspective, the hydraulic interaction between SuDS retrofits and conventional sewer systems is a key parameter in occurrence of pluvial floods. The effect of SuDS on the pressure relief of the network is assumed to be a function of both the size and the location of the SuDS (Haghighatafshar et al., 2018). This study aims to develop a methodology to efficiently size and locate SuDS at city-scale through hydro-economic optimization.

A multi-domain hybrid hydrodynamic model consisting of hydrological, hydraulic and optimization modules were constructed according to the logics presented in Figure 1. The model is fed with an initial catchment characterization as well as the rainfall event of study in Figure 1-1 (Manual/automated feed). The provided input data is employed by the hydrological module (Figure 1-2) which computes the total runoff (Q_{TR}). The hydrological module consists of two components (domains); one for runoff simulation on the conventional piped catchment using a standard runoff model based on runoff coefficients and time of concentration (D1) and the other for the fast simulation of the SuDS based on the model introduced by Haghighatafshar et al. (2019) (D2). The cumulated runoff from the hydrological module (Q_{TR}) is subsequently introduced to the hydraulic module (Figure 1-3) which simulates the hydrodynamics of the pipe flow using the full Saint Venant equations for dynamic flow (D3). These two modules (i.e. hydrological and hydraulic) were coupled in the modelling software MIKE Operations. The hybrid model was facilitated with a derivative free numerical optimization algorithm in the third module (Figure 1-4), namely *constrained optimization by linear approximation* known as COBYLA (Conn et al., 1997; Powell, 1994) using a SciPy implementation.

The hybrid model was employed to optimize the required retention size and the location of the SuDS retrofits for the cost-effective management of rainfall events. This was done by comparing the estimated annual cost of the flooded manholes with the estimated annual cost of retrofits in various scenarios (Figure 1-4). Based on iterative simulations loops of the combined sewer network in Malmö, Sweden, conclusions were drawn on where in the city the retrofits would lead to best effects regarding the hydraulic performance of the combined sewer network.

The modelling methods and results from this study are included in a broader hydrological context in the Future City Flow-project through which the long term effects on the urban water balance and the inflow/infiltration of SuDS can be investigated and compared with other more traditional stormwater solutions in terms of cost benefit efficiency.

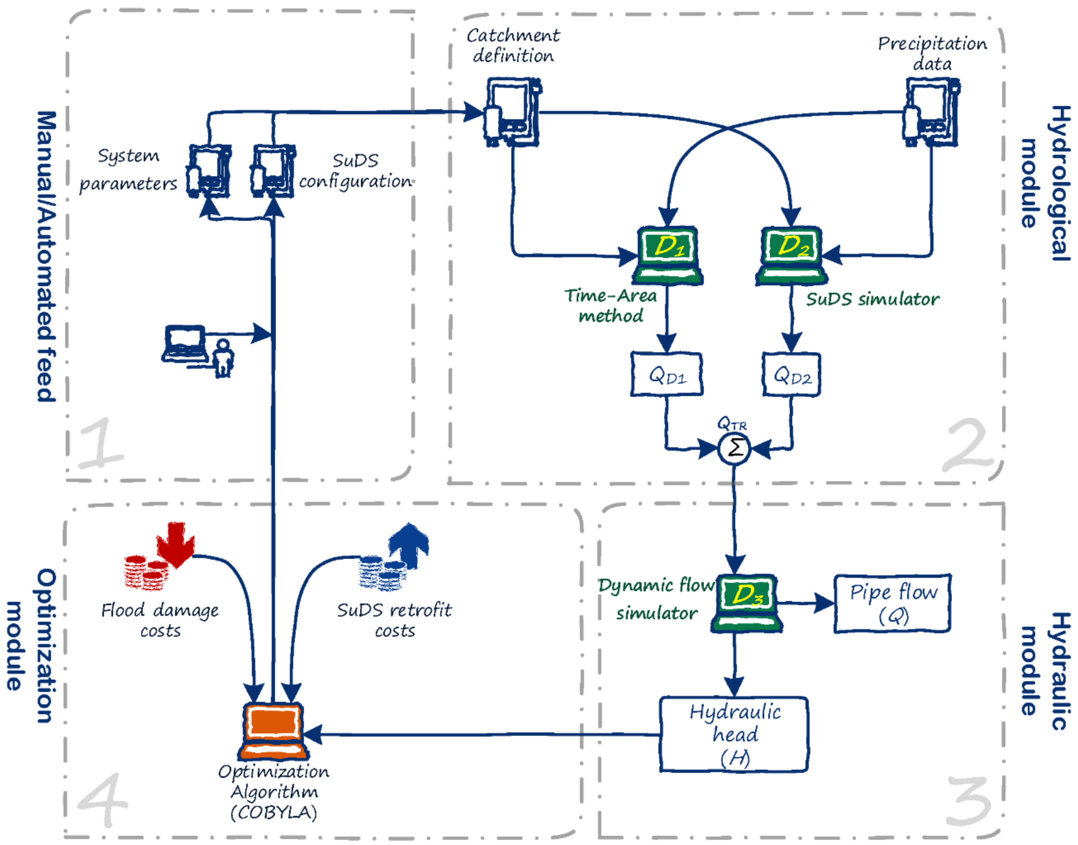

Figure 1. The software architecture behind the hybrid model developed for citywide optimization of SuDS retrofits.

Acknowledgements

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Which types of rainfall cause urban flooding

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The SuRF Project

Pluvial flooding is the most common type of flooding in Malmö. Only a very few flood claims have been registered during high sea level caused by storms and there is only one minor watercourse in Malmö (Riseberga Brook/Sege Brook), which seems not to be severely affected by riverine flooding. All of the eleven biggest flood events during the 20-year period are caused by local or wide-spread rainfall events. These eleven events account for about 80% of the flood claims reported to the water utility VA Syd and the insurance company Länsförsäkringar Skåne. Three severe, pluvial flood events are presented in the study: 5 July 2007 with 150 and 169 flood claims to VA Syd and Länsförsäkringar Skåne respectively, 14 August 2010 with 210 and 148 flood claims, and 31 August 2014 with 2 109 and 2 649 flood claims. These flood events were all caused by heavy rainfall distributed over the entire city. The 2010 and 2014 events were intense and with a quick development, while the 2007 event was less intense, but with a long period of pre-event rainfall. The 2014 event was heavier than a 100-year event for durations between 3 and 16 h (average for all stations in Malmö).

There is a relation between large-scale topography and flooding in Malmö. Areas within 100 m from the major system are more than twice as affected by flooding, compared to areas further away. During the severe flood events in 2010 and 2014, areas close to the major system were even more affected by flooding (3.0–4.2 times), compared to areas further away. During such downpours, runoff is quickly directed towards low-lying areas, both through the pipe system and by overland flow. In Malmö, like probably in most other places, the main sewers (minor system) are located under the main overland flow paths (major system), as they follow the topography. The spatial distribution during these two, highly intensive rainfall events (2010 and 2014) were different than during other events, with more flood claims clustered around the main sewers. For the other events, including the 2007 event, the flood claims were more evenly distributed within the city (Figure 1).

The combined system is more exposed to flooding than the separate system. Even if only 31% of the urban land in Malmö is connected to the combined system, 70% of the flood claims are reported from these areas.

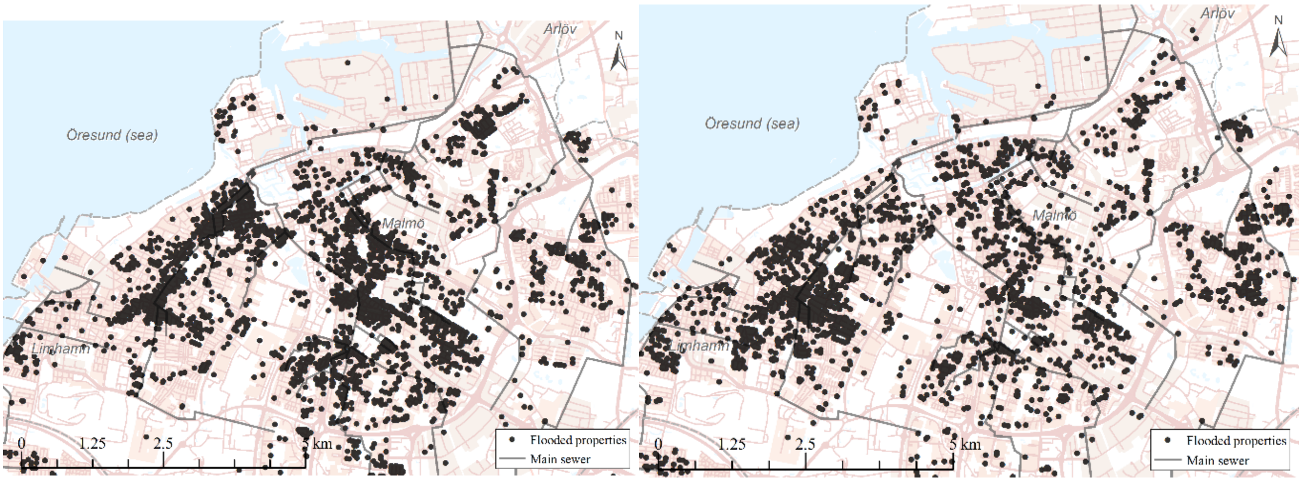

Figure 1. *Left: Flood claims reported by LF Skåne and VA Syd during two of the three severe flood events in Malmö (2010 and 2014). Right: Flood claims reported by LF Skåne and VA Syd during all other events, except for two severe flood events (2010 and 2014).*

During the 2010 and 2014 events, the combined system was 3.8–4.2 times more affected by flooding compare to the separate system. Similar figures are found if all flood events are included. The 2007 event shows a different pattern: the combined system areas were only slightly more than twice (2.3 times) as severely affected by flooding during this event, compared to the areas with separate system. One reason why the 2007 event differs from the other events might be the difference in flood causality, where continuous rainfall during the preceding weeks saturated the ground with water. Flooding during this event was therefore less related to type of drainage system. The dataset is biased as more people live in areas with combined system. However, the difference in reported flood claims still exists when adjusted for this bias.

Locally, some flooding is caused by breakdown of the system, e.g. when a sewer pump stops pumping due to system error. On the one hand, the phenomenon with local breakdowns could be seen as unique incidents that are not likely to happen during future flood events. On the other hand, and in reality, it seems inevitable that a few of these unique incidents happen during every flood event.

Urban Rainfall-Runoff Nowcasting with Open Data and Open Tools

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The MUFFIN – project

Cities and urban areas are prone to flooding due to the large extent of impervious surfaces hampering the natural infiltration of rainfall. It is important to be prepared for the urban flood risk by developing methods to forecast rainfall and runoff in immediate future. In this study, we explore the use of openly available data and tools in nowcasting rainfall and runoff in urban setting.

Data and study site

The openly available weather radar data from the Finnish Meteorological Institute (FMI) was utilized for the rainfall nowcasting. The radar images in 250 m x 250 m spatial and 5 min temporal resolution are provided as a pre-processed radar composite for the entire country through the FMI open data portal for past 6 days (https://en.ilmatieteenlaitos.fi/open-data). From these data, the Aug 12 2017 storm was selected for the current study. The storm comprised a series of rapidly moving thunderstorms that bypassed the Helsinki region in ca. four hours. The maximum hourly rainfall accumulation of 27.9 mm was measured in Kotka 115 km east of Helsinki. The storm generated close to 1 000 emergency service operations, mainly due to damages caused by heavy winds.

Stormwater flow was assessed in an 85 ha Pakila catchment in Helsinki, which is known to be prone to stormwater flooding. Model parameterizations utilize a 1x1 m^2 digital elevation model openly available from the city of Helsinki, land cover data freely available from the Helsinki Region Environmental Services Authority HSY (https://kartta.hel.fi/), and drainage network data provided by HSY. The network data represent in this study the only component that is not openly available.

Methods

Rainfall nowcasts were performed using an openly available pySTEPS software (Pulkkinen et al., 2019), which aims to provide a community-driven effort to implement an open-source Python library for probabilistic radar-based precipitation nowcasting (https://pysteps.github.io/). The theoretical framework of the model is built around the Short-Term Ensemble Prediction System (STEPS) model (Bowler et al., 2006).

The rainfall nowcasts were used to feed the US EPA Storm Water Management Model (SWMM), which is a widely used rainfall-runoff model for stormwater quantity and quality assessments (Rossman, 2015). GisToSWMM5 tool (Niemi et al., 2019) was used to automatically divide the study area into subcatchments and further to connect them to each other and to the outlets of the underlying drainage network.

Results

A 50 member ensemble of rainfall nowcasts was generated using pySTEPS. Figure 1 presents a nowcast 30 min ahead in time for a 250 x 250 km^2 box around the capital area for one ensemble member. Table 1 lists statistics for the Pakila catchment rainfall and stormwater flow at the catchment outlet across all 50 ensemble members. The large range in rainfall accumulations and in the resulting stormwater flows is mainly controlled by the fact whether most intensive areas of rainfall in the advancing storm pass over the study area.

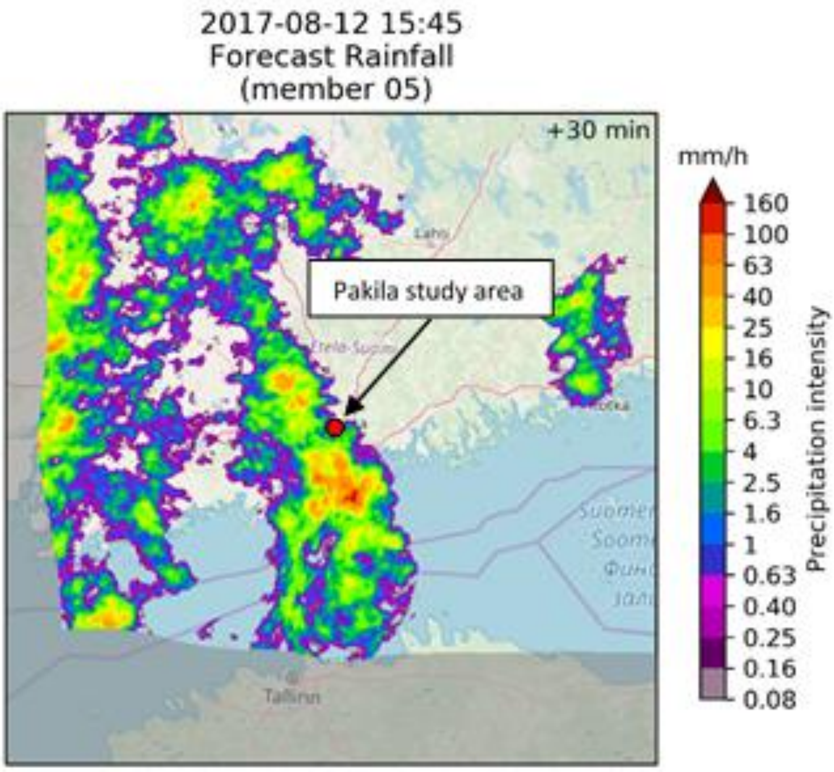

Figure 1. *A 30 minute rainfall nowcast for one ensemble member.*

Table 1. *Rainfall and stormwater flow statistics. Max refers to the ensemble member with highest rainfall accumulation and EnsMean to the average value over all ensemble members.*

Nowcast	Rainfall [mm]	Flow [l/s]	
	Event Accumulation	Event Mean	Event Max
Max	21.0	342	906
EnsMean	3.8	59	342

Summary and conclusions

Openly available precipitation and land cover data as well as openly available rainfall nowcasting and urban hydrological models were utilized to produce rainfall nowcasts and corresponding flow nowcasts for an urban catchment in Helsinki, Finland. Open data and tools allow easily approachable hydrological assessments with realistic outputs without access to official forecast products produced e.g. by national hydrometeorological services. Probabilistic nowcasts also allow for estimating the risk of stormwater flooding in immediate future.

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APPETIZER

Flood and heatstress models and the need for (sub-) surface INnovations for eXtreme Climatic EventS (INXCES)

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The INXCES Project

Urban flooding and heatstress have become a key issue for many cities around the world. The project 'INnovations for eXtreme Climatic EventS' (INXCES) developed new innovative technological methods for risk assessment and mitigation of extreme hydroclimatic events and optimization of urban water-dependent ecosystem services at the catchment level. DEMs (digital elevation maps) have been used for more than a decade now as quick scan models to indicate locations that are vulnerable to urban flooding. In the last years the datasets are getting bigger and multidisciplinary stakeholders are becoming more demanding and require faster and more visual results. In this paper, the development and practical use of DEMs is exemplified by the case study of Bergen (Norway), where flood modelling using DEM is carried out in 2017 and in 2009. We can observe that the technology behind tools using DEMs is becoming more common and improved, both with a higher accuracy and a higher resolution. Visualization tools are developed to raise awareness and understanding among different stakeholders in Bergen and around the world. We can conclude that the evolution of DEMS is successful in handling bigger datasets and better (3D) visualization of results with a higher accuracy and a higher resolution. With flood maps the flow patterns of stormwater are analysed and locations are selected to implement (sub-)surface measures as SuDS (Sustainable Urban Drainage systems) that store and infiltrate stormwater. In the casestudy Bergen the following (sub-)surface SuDS have been recently implemented with the insights of DEMS: settlement storage tank, rainwater garden, swales, permeable pavement and I/T-drainage. The research results from the case study Bergen will be shared by tools to stimulate international knowledge exchange. New improved DEMs and connected (visualization) tools will continue to play an important role in (sub-)surface flood management and climate resilient urban planning strategies around the world.

Next to flood modelling heatstress maps have been created within the INXCES project for Groningen and Bucharest (figure 1c). The map illustrates points in the city that will have a high temperature and PET (physical equivalent temperature) in the current climate and possible increase of temperature of 1 or 2 C due to climate change. The calibration of the map and interaction with stakeholders was the subject of 25th edition of the Wetskills Water Challenge in Romania where a Romanian-Dutch team of young water professionals won this challenge creating the idea of a heat stressmap app for the city of Bucharest. The app will show inhabitants and stakeholders where extreme heat can occur in cities on very hot days and where you can take measures with a link to www.climatescan.nl. The team recorded the effects based on data from local participants and interviews. The team designed a smart phone app that charts both problem locations and possible solutions to stimulate climate adaptation in Bucharest. The jury assessed the winning team as follows: “We chose a team with a market ready, feasible and flexible solution. Due to climate change, extreme weather events are becoming more frequent. For Bucharest this has consequences such as heat stress and flooding.

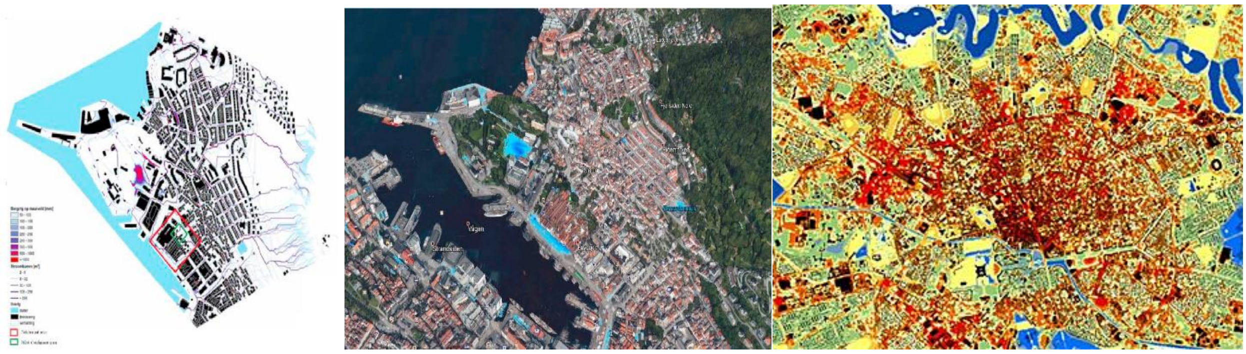

Fig. 1 *Floodmodel Bergen, Norway in 2009 (left) and 2017 (right). Heatstess Bucharest Romania (right).*

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A web-based visualization prototype of urban flood forecasts from a multi-scale hydrologic-hydrodynamic flood forecasting system in Aalborg, Denmark

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The MUFFIN Project

Hydrological and hydrodynamic modelling are generally performed separately, which is largely understandable; the purposes are different, the scales are different, the concepts and models are different. However, we believe there are potential benefits in bridging this gap, exploring coupled solutions and generally taking advantage of what the different types of modelling can offer. This issue has been one focus in the MUFFIN project, where a case study in Aalborg, Denmark, has been conducted.

In Aalborg, an integrated system for hourly urban flood modelling/forecasting has been developed. A semi-distributed hydrological model (HYPE), which estimates surface runoff and discharge from the upstream rural catchment, has been coupled to a hydraulic 1D-2D urban drainage model (MIKE), including 1D sewer river network and 2D overland flow, which describes flooding and inundation in central parts (Figure 1). The system is designed for real-time flood forecasting, and this prospect has been evaluated by re-forecasting several historical events characterized by a high rainfall intensity and/or high river discharge. The main objective is to assess the added value of the coupled system, as compared with using only the MIKE model with more generalized hydrological boundary conditions.

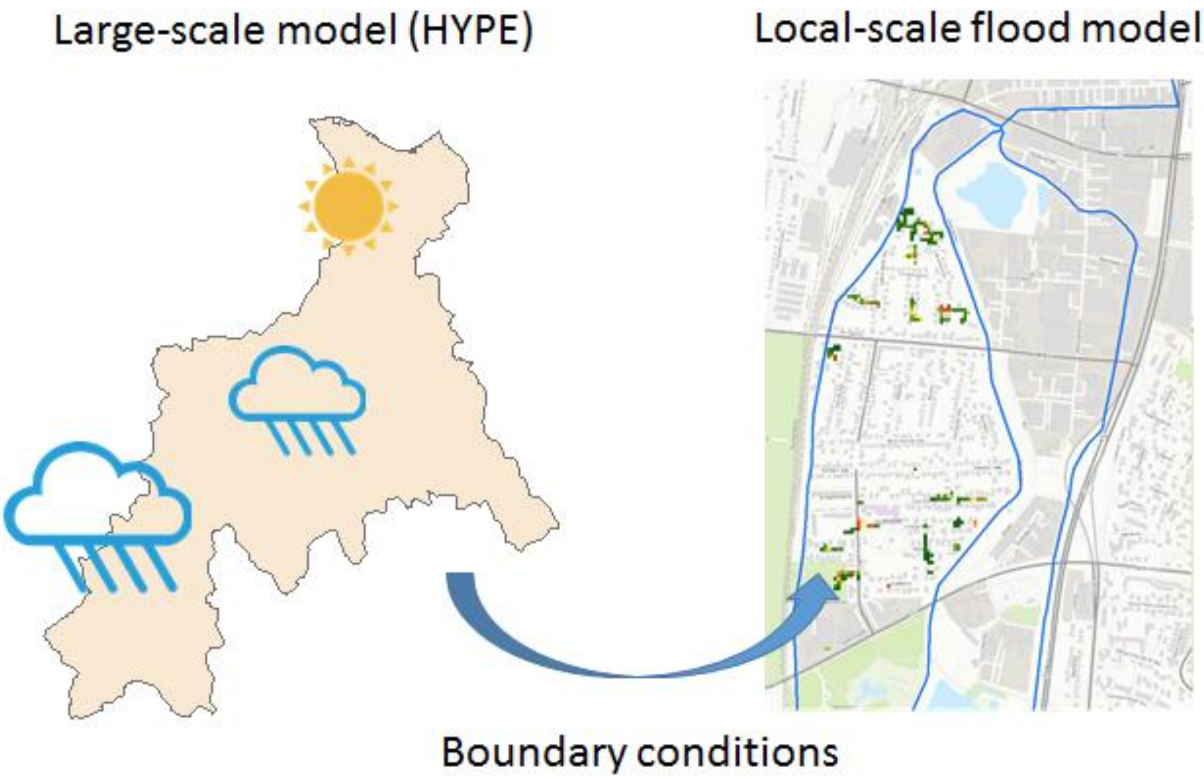

Figure 1. Schematic of the coupled system in Aalborg, with a meso-scale hydrological model (HYPE) providing boundary conditions for the local-scale flood model (MIKE).

A web-based graphical interface has been developed to visually follow the evolution during the event, both of rainfall and discharge and of any resulting inundated areas. At the demonstrations during CITIES, RAIN & RISK, this interface will be mainly used for illustrating the performance of the coupled forecasting system, but it also serves as a prototype for actual operational use.

Multi-basin hydrological models are already today being run operationally all over the world, and these types of coupled forecasting systems may thus in principle be set up in any city. The temporal and spatial resolutions of these existing operational models are, however, generally not sufficient for the type of coupling explored in this case study, but development towards higher-resolution multi-basin hydrological models covering national or continental domains will be performed in follow-up projects.

THEME 4: URBAN WATER MANAGEMENT; NATURE-BASED SOLUTIONS & CLIMATE ADAPTION

Multi-purpose urban water management in a complex urban basin

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- The majority of the larger Danish cities are located close to the water - either by fjords/sea and/or by rivers/streams/lakes. This means that many cities are in risk of flooding from both a high ground water table, rivers and marine waters. Together with precipitation load and consequent drainage of surface and wastewater, this makes the urban water management a challenge in the future climate.

The water current water management has multiple purposes, which is managed by different authorities, e.g.: drainage of urban areas, treatment of wastewater, reduction of combined sewer overflow, certifying high bathing water quality, minimizing flood risk, recreational use of water in the city, draining of agricultural areas, certifying good quality drinking water.

This abstract presents a case study from the city of Aalborg, Denmark where all the above presented challenges are present. Building upon the results of the MUFFIN project, a real time data and model based monitoring system is being developed (Nielsen and Thorndahl, 2019; Thorndahl et al., 2019). This system will consist of:

- Installation of multiple gauges for monitoring of ground water levels, stream water levels, drainage system runoff, rainfall, etc. Gauges will both be professional and citizen gauges.
- Real-time models with assimilation of data of the urban water cycle
- A threshold warning system for different parts of the water cycle.

An online combined data and model-based surveillance system will help to improve water management across borders of authority and reduce risk of failures such as flooding or pollution of surface waters.

An example of simulated return period of flooding in an urban catchment in Aalborg Denmark is shown in figure 1 (Thorndahl et al., 2019).

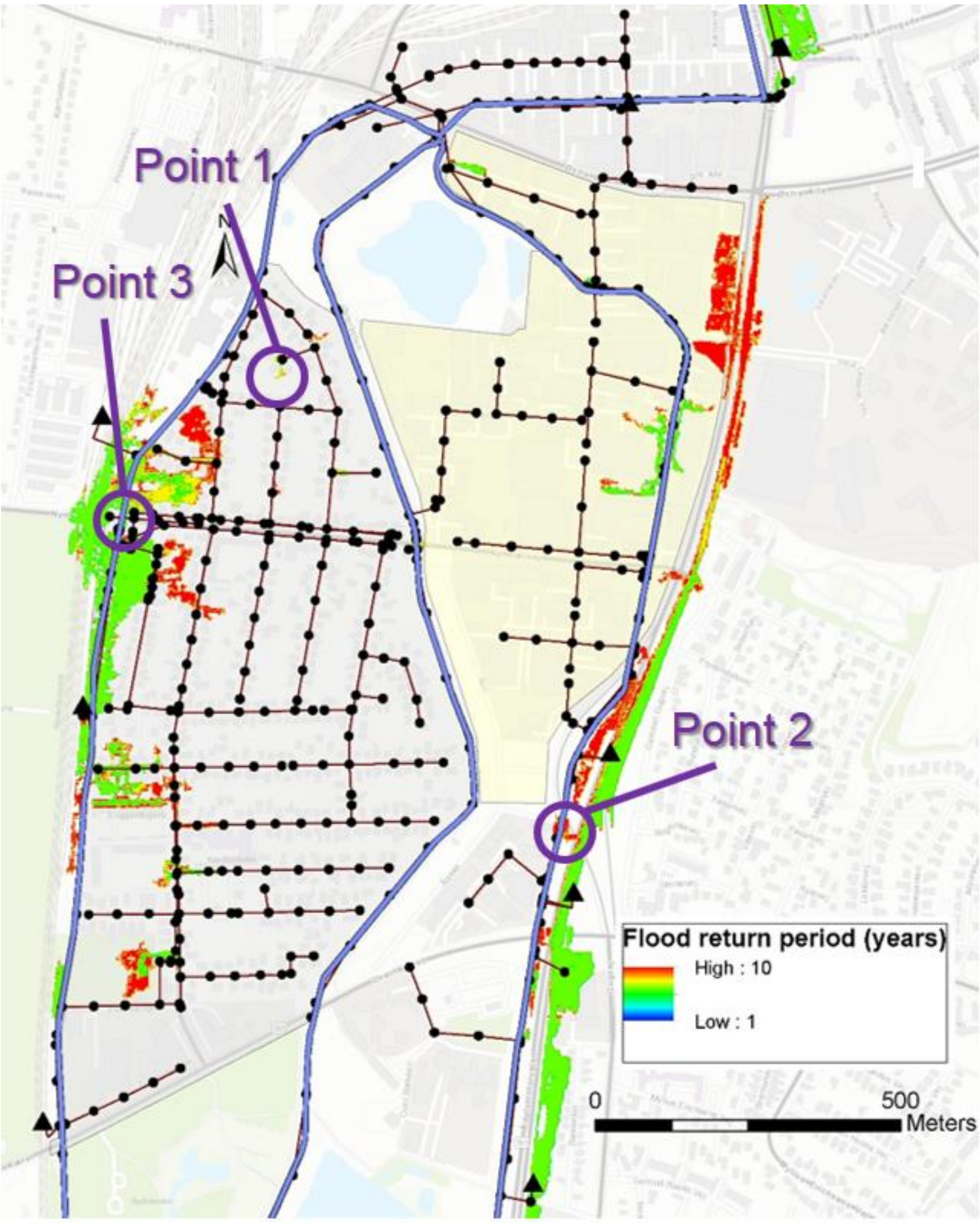

Figure 1. Example of simulated flood return periods in an urban area of Aalborg. Flooding originates from multiple sources e.g.: point 1: surcharge from manholes, point 2: river flooding, point 3: flooding from pumping combined sewer overflows.

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Seasonal Hydraulic efficiency of infiltration-based SUDs (INXCES)

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The INXCES Project

Urban flooding and heatstress have become a key issue for many cities around the world. The project 'INnovations for eXtreme Climatic EventS' (INXCES) developed new innovative technological methods for risk assessment and mitigation of extreme hydroclimatic events and optimization of urban water-dependent ecosystem services at the catchment level. Urban flooding resulting from pluvial flooding is increasing with climate change and driving the need for an increased focus on Sustainable Urban Drainage Systems (SUDS), which can alleviate the already overloaded urban drainage systems. In cold and temperate climates seasonal infiltration rates in infiltration-based SUDS is an important design consideration, together with rainfall patterns. In addition, a changing climate changes the seasonal performance, making future performance predictions challenging. In the INXCES project we have measured seasonal infiltration rates and models impact for design in a future climate using case studies from Bergen and Trondheim.

In the Trondheim case two raingardens have been observed for seasonal infiltration over multiple seasons; Åsveien, and Risvollan. At the Åsveien raingarden seasonal infiltration rates where measured regularly from October through May in 2016/2017, based on a case study approach, combining technical (field measurements), experimental (simulations) and qualitative approaches. For the second raingarden, Risvollan infiltration measurements were carried out semi-regularly over the period 2016-2018. In addition, two earlier measurement campaigns were added to the analysis, Paus et al., (2016), and Dalen (2012). This is a research raingarden which has been in operation since 2010 and with continuous flow and meteorological measurements. The Modified Phillip-Dunne Infiltrometers (MPD) (Ahmed et al. 2014) method was used for measuring infiltration capacity, saturated hydraulic conductivity (K_{sat}) both in Bergen and Trondheim. The MPDs were constructed of a plastic column of 50 cm length and 10 cm diameter. The columns were put 5 cm down in the soil and filled with water. The water level and time was registered. The RECARGA model was used for simulations (Dussaillant et al. 2005). The results show up to 70% reduction in winter infiltration capacity, which should be accounted for in design, either by increased Ksat values in the soil media, or by a large size raingarden.

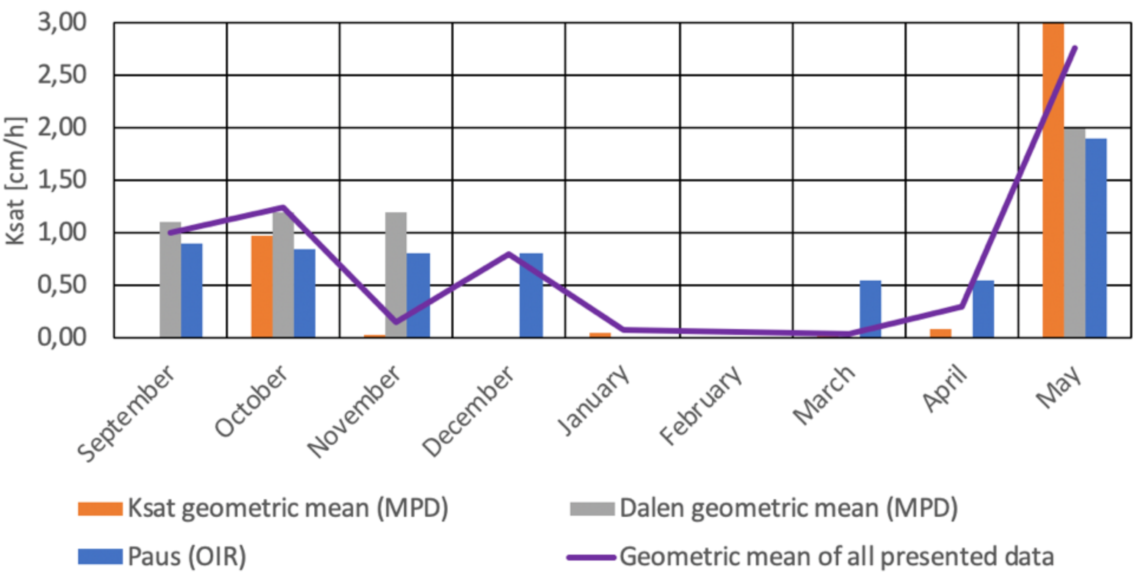

Figure 2. Seasonal infiltration rates in the Risvollan raingarden in Trondheim measured by three different measurement campaigns over a seven-year period from 2010-2017, sources: Paus et al., 2016; Balstad et al., 2018; and Dalen 2012).

The Bergen case study investigated the future performance of raingardens as source control measures for retrofitting into dense urban areas. The study applied a combined spatial-temporal downscaling methodology using the Statistical DownScaling Model-Decision Centric (SDSM-DC) and the Generalized Extreme Value distribution to project future precipitation. This produced intensity-duration-frequency (IDF) curves for future climate scenarios, which were used to investigate the performance of a raingarden using the RECARGA raingarden modelling tool. The results showed that Ksat was the determining factor for peak-flow reduction and that different values of Ksat had different benefits. Engineering flexible solutions by combining measures holding different characteristics will induce robust adaptation. The implication for the raingarden performance is that lag time is reduced while peak flow

reduction would be improved. Thus, a suitable combination of source control structures should compensate for the reduced Ksat and lag time. Adding this flexibility ensures that the uncertainty in the scenarios are accounted for and that the measure performs well under a range of scenarios, not a specific one. This, ultimately, results in a robust adaptive measure.

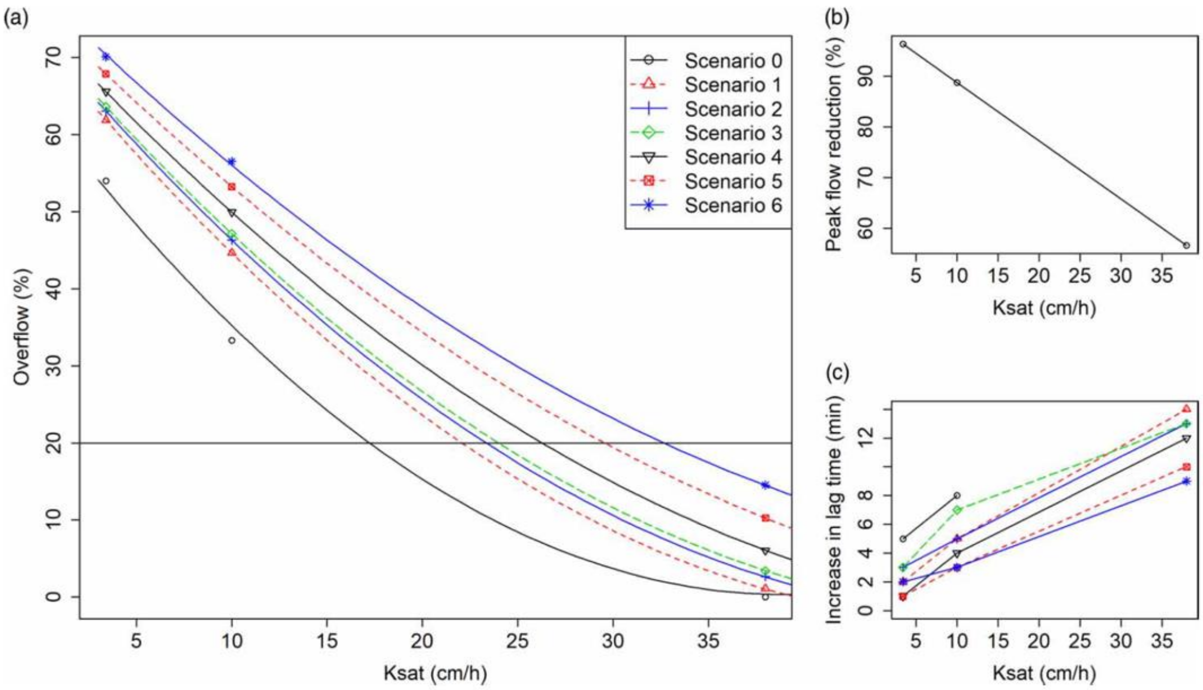

Figure 3. Simulation of a raingarden performance for a set of future climate scenarios. Figure (2a) shows the performance of the raingarden measured in % of the flow going into overflow for various Ksat values. Figure 2b shows a percentage comparison of peak flow reduction with and without a rain garden, and figure 2c shows the effect on lag time before the overflow is activated for different Ksat values and climate scenarios.

A second case from Trondheim investigated the placement of SUDS in the planning phase (Muthanna et al., 2018). Again, the MPD method was deployed to investigate K_{sat} values for possible SUDS locations on the NTNU campus in Trondheim. This case showcases the potential gain in considering SUDS placing early in the planning process, which will ensure better performance of the system. The Ksat value varied greatly over an area of 50 ha, which is typical for urban disturbed soil

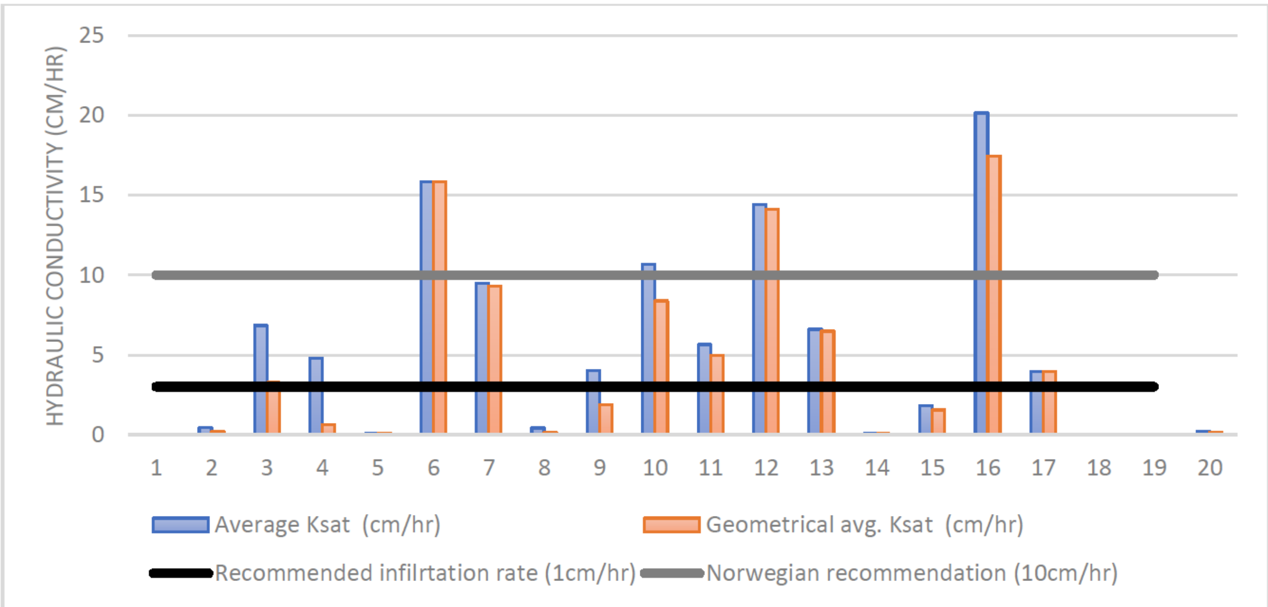

Figure 4. Distribution of Ksat values over 20 sampling sites on the NTNU campus in Trondheim, Norway. The simple mean and the geometric mean are reported together with the typical international recommended rates of 3 cm/hr and the Norwegian recommendation of 10 cm/hr, Source: Muthanna et al., 2018.

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The governing of flood risk mitigation in complex and dynamic society

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The purpose of this presentation is to share research findings of how the mitigation of flood risk is governed in Sweden. Flood risk is a complex and transboundary challenge that cannot be managed by individuals or organizations in isolation but requires collaborative networks of actors working together across departments, administrative borders, levels of authority, and societal sectors. These networks are largely based on individual choices made in particular relational and institutional settings. Previous work holds that the emerging network-level patterns of interaction are fundamental for society's capacity to mitigate risk, but empirical research on the social organization of flood risk mitigation has lagged behind. Especially concerning collaboration within a catchment area as a whole, which is the hydrologically significant unit for analysing flood risk and the required level for addressing flood risk comprehensively by the EU Floods Directive and Swedish legislation. Hence, the project collected unique empirical data comprising 217 interviews with all individual actors contributing actively to flood risk mitigation in a river catchment area in Southern Sweden, complemented with documentary research of maps, legislation, policies, court rulings, strategies, plans, and consultation minutes. The data were analysed structurally and interpretatively.

While the network of actors comprises impressive individual capacities in terms of knowledge and experience, the findings suggest significant systemic issues that must be acknowledged and addressed for the governing of flood risk mitigation to be able to meet the mounting challenges of the future. Most pressingly, there is substantial fragmentation of the governing of flood risk mitigation in relation to how water moves in the landscape. Water flows from upstream to downstream, crossing municipal borders, while there are few links between the municipal administrations in the catchment area. The only institution for coordination is a river council that is a voluntary association with no formal authority. There is a grave need for improved coordination in the catchment area, which calls for increased attention of the County Administrative Board regardless if Höje Å is currently prioritized or not. Moreover, the Swedish legal framework governing flood risk mitigation comprises tightly coupled policies that demands coordination between the actors implementing them within municipal administrations, but the findings suggest loose couplings or even decoupling between particularly central actors. There is also fragmentation between the management of urban drainage and flood risk mitigation, where the focus on the division of responsibilities for rainfall less or more intense than the "10-year rain" is undermining pragmatic solutions. The fragmentation of the governing of flood risk mitigation is also exacerbated by the planning process, where the issue is analysed and addressed for each detailed planning area in isolation, regardless if these boundaries rarely are hydrologically significant. This is further complicated by different actors generally being involved in the planning process for adjacent planning areas, as well as different consultants procured to support the work in different phases of the same planning process. Hence, undermining the possibility of knowledge accretion. These systemic issues must be acknowledged and there are concrete measures to address them.

Children's places in stormwater spaces

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The SUrF-project

Due to the climate change, extreme rain events are expected to occur with higher frequency. At the same time, the world urban population is increasing dramatically, and cities are getting denser which exposes more people to the effect of urban flooding (UN, 2017). Cities focus on improving the resilience of urban systems in order to handle natural disasters and their consequences on people and properties. Among other approaches, above ground stormwater management has been introduced as a practice in order to improve resilience and achieve urban sustainability. However, less focus has been put on the relationship between urban resilience and urban sustainability. More specifically, cities have rarely reached sustainability of urban environments, as regards to people's health, wellbeing and liveability, through improved resilience (Pearson et al., 2014). The gap is even more pronounced when it comes to children and their needs in urban environments and a noticeable contemporary trend in Sweden is that places and areas traditionally allocated for children's play, such as schoolyards and neighbourhood parks are being questioned and used for building purposes. Statistics Sweden (SCB, 2017) reports that schoolyards areas have shrunk with four square meters per child in the latest three years. Cars and Strömberg (2005), point out that the driving forces during the 1960's and 1970's in Swedish planning were politicians and professional planners with a strong vision of a community based on equal social and family rights. This has slowly changed, and today's legislations partly leaves the responsibility for considering qualitative factors in spatial planning to the real estate developers and constructing companies. Private interests with a focus on economic values are thus given a bigger role, enabling them to become a driving force in community planning.

The process of landscape design is heavily affected by social and political interests. Concepts such as "Resilience" and "Sustainable development" are constructions that are interpreted differently through history and in different disciplines and not the least in different political contexts (Vardy & Smith 2017; Seghezzo, 2009). The risk of "greenwashing" and that the concepts are used in different political obscure agendas are shown in different studies (Tahvilzadeh et al, 2017). Sustainable development is often discussed in terms of ecological, social and economic values and in many cases, it is stated that ecological and social values can reinforce each other. The link between ecological and social values has been studied in different ways, for instance in using the concept of ecosystem services (Chan et al., 2012; Lele et al., 2013). Egoz et al. (2011) argue that the "right to landscape" can be used as a framework for negotiating physical rights of individuals, communities, the powerless and the marginalized. If we identify the equitable landscape as a design principle for landscape architecture, designing for children is of critical importance. Childhood can partly be discussed in biological terms, but childhood is also a social construction affected by interpretations made in a political, cultural and historical context (Holloway & Valentine, 2000). Children's possibility to literary "take space" in an urban context is significantly affected by political decisions in spatial planning and processes. The right to "take space" in a landscape, urban or rural, has to do with power and social justice and is part of an everyday experience (Setten & Brown, 2013).

The "compact city" is a predominant trend in current planning ideology and is often presented as a sustainable way of increasing the urban population in urban areas. In this rhetoric, we often hear that the smaller public green spaces can be optimized with good quality design so that ecological values (as in open stormwater management) and social values (such as children's everyday play/life) can coexist. The concept of the compact city has however been questioned by several researchers (Jenks et al, 1996; Bramley et al 2009; Naess & Vogel, 2012; Tunström & Bradley, 2014).

The present paper explores the possibilities for open stormwater facilities to be used as children's playscapes and tries to gain knowledge by studying implemented facilities and their offered possibilities for action. The study has two objectives. The first objective is to study the challenge of taking account for various sustainability aspects at the same time. Through the example of stormwater management and children´s play, we explore to what extent ecological and social values can reinforce each other. The second objective is to use the case studies to initiate discussions on some of the challenges that contemporary planning is facing. Making place for both local stormwater management and public green space in dense/infill urbanization projects is a real challenge in the current planning paradigm.

In this project, we are examining a couple of urban housing areas through case studies. The criteria for choosing the cases was that they had open stormwater features, planned and designed for the sites and implemented in different scales - from a detailed scale like a pond to a neighbourhood park designed to accommodate heavy rainfalls. These areas have been analysed with a reviewed method for assessing environments based on affordances for children's play (Lerstrup & Konijnendijk 2017) in order to investigate if these areas have enhanced values for children´s everyday life and use. The study explores if specific design and planning solutions for open stormwater management also enhance social values for children. Later the paper discusses the results in terms of how the design could be reshaped or adjusted to better fit either stormwater management or children's everyday use and play. The aim is to highlight some points that can raise awareness of the issues of diminishing green/outdoor open spaces in contemporary planning contexts and explore how "sustainability" can be interpreted as a societal aspect of equality in an architectural/planning context. A space that is efficient for stormwater management is not necessarily a good space for children's play. Later, a conclusion is drawn on how specific designs for open stormwater can support or constrain children's everyday use. One of the goals of the project is to encourage decision makers to go for more effective policies and investments for stormwater green solutions in a way that benefits children´s needs. Some discussion is also held on the challenges of using assessing methods of social values in a technological and ecological context.

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Characterisation of dissolved metal fractions in urban runoff

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The INXCES Project

Understanding the bio-physico-chemical behaviour of pollutants within the urban environment is key to predicting their impact and identifying appropriate best management practices. The project 'INnovations for eXtreme Climatic EventS' (INXCES) developed new knowledge on the behaviour of metals within the dissolved fraction from different urban areas for use in risk assessment and their mitigation. Previous research identified that several metals (e.g. Cu and Zn) occur in the dissolved fraction as free ions or in association with light and organic colloids in urban runoff (Grout et al., 1999; McKenzie and Young, 2013). However, the distribution of metals within these sub-dissolved fractions is not well understood, particularly in terms of their labile behaviour. In contrast to the majority of EQS identified in the EQS Directive (2008), the EQS for metals were established for dissolved concentrations, on the basis that only metals in the dissolved fraction are available for active uptake. Following further research (e.g. Gandhi et al., 2010), selected EQS were revised as part of the Priority Substances Directive (2013) which promotes the use of bioavailability modelling to take into account the influence of dissolved organic carbon (DOC), pH and water hardness to better estimate the fraction of the dissolved concentration which is bioavailable in practice. Hence, there is an urgent need to increase knowledge on the occurrence and behaviour of metals in these sub-dissolved fractions. Within the frame of the multi-disciplinary INXCES project, two sampling campaigns have been conducted to evaluate the dissolved concentrations of selected metals (Cd, Cr, Cu, Ni, Pb, Zn) in urban runoff in terms of identification of the bioavailable fraction, the colloidal content (and to what extent metals in the colloidal fraction are labile) and to examine the relationship between these sub-dissolved concentrations in terms of implications for urban runoff mitigation.

Runoff was sampled at two industrial parks (IA1: 15 ha / 75% impervious and IA2: 12 ha / 85% impervious) and a car park (PL: 0.45 ha / 100% impervious) in Umeå, northern Sweden, and a section of highway (E18: 100% impervious) outside Enköping, southern Sweden. Highway runoff was collected from a 100-metre stretch of the European Route 18, at “Testsite E18” managed by the Swedish Transport Administration. All samples were analysed for the dissolved, colloidal and truly dissolved metal fractions using filtration (0.45µm filter) and ultrafiltration (to determine the 3000 molecular weight cut off; 3kMWCO) together with basic parameters (Ca, pH, DOC). In the first sampling campaign, samples from PL and IA1 were analysed using the Bio-met bioavailability prediction tool to identify bioavailable metal concentrations. For the second sampling campaign, samples from IA1, IA2 and E18 were compared with diffusive gradients in thin films (DGT) measurements and the analysis was complemented with asymmetrical flow field-flow fractionation (AFFF) measurements.

Results from fractionation using filtration and ultrafiltration show that the truly dissolved (<3 kMWCO) concentrations of Cd, Cr and Ni are generally greater than those associated with the colloidal fractions (3 kMWCO-0.45µm) whereas truly dissolved Cu and Zn concentrations consistently dominates over colloidal Cu and Zn concentrations. Truly dissolved concentrations of Pb is generally less than colloidal Pb concentrations, Figure 1. Preliminary results from AFFF indicate that colloids occur in two dominant size fractions: ranging from one to a few nm and around 100 to a few hundred nm (exact size determination was not possible as the light scattering detector was unavailable). Low concentrations of DOC were reported in both fractions, indicating colloids occurred in an inorganic form. Cd, Cu and Zn were not detected in concentrations above the blank for these colloidal fractions. In contrast, dissolved Pb, and Cr predominantly occurred in the larger colloidal fraction (around a few hundred nm) with Ni equally distributed between both colloidal fractions at IA1 and IA2. Parallel measurements with passive samplers showed that labile concentrations were in the same range as dissolved (<0.45 µm) concentrations, indicating that all sub-dissolved fractions are labile for all metals at both sites.

Median concentrations of the truly dissolved and bioavailable fractions (as predicted using Bio-met) are presented in Table 1. With the exception of Pb, the bioavailable fraction does not equate to the truly dissolved fraction in any samples during either event type at either site. The percentage of the truly dissolved fraction which consists of bioavailable metals varies on a metal by metal basis. For example, the bioavailable fraction contributes >20% of the truly dissolved fraction of Zn in 89% of rainfall runoff and 90% of snowmelt samples, of Ni in 75% of rainfall and 80% of snowmelt samples and of Cu in 16% of rainfall samples (Cu was not reported in a bioavailable form in any snowmelt samples).

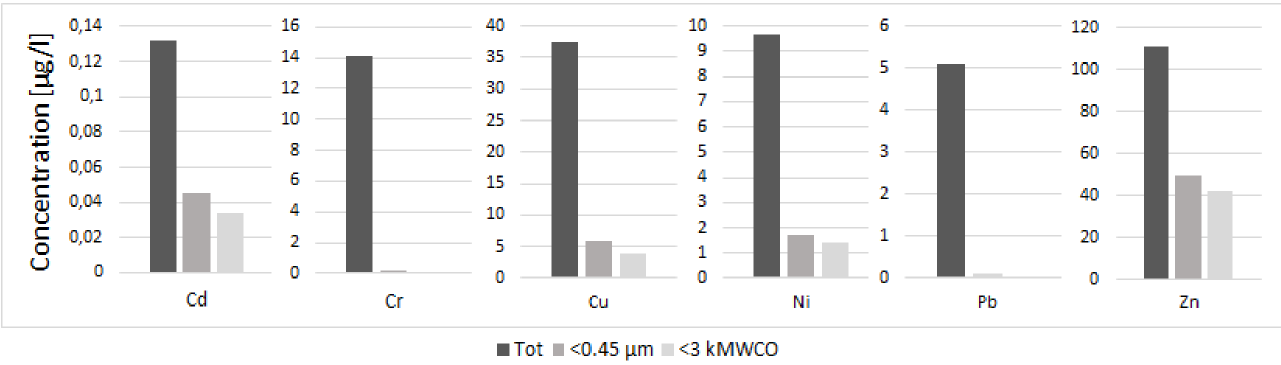

Figure 1. Metal concentrations in the analysed fractions total, dissolved (<0.45 µm) and truly dissolved (<3kMWCO) at site IA2 during a rain event in October 2018. The <0.45 µm and <3kMWCO fractions of Cr and Pb are recorded in low concentrations relative total concentrations, thus does not show in chart.

The remaining metals within the truly dissolved concentration are associated with small colloids in the <3 kMWCO fraction. This would indicate that a higher level of complexation occurs for Cu compared to Ni and Zn. As noted earlier, the amount of Pb determined in the truly dissolved phase is considerably lower than for the other metals (note: several samples Pb was below the limit of detection). Data presented in Table 1 indicates that any Pb that does occur in the truly dissolved phase is primarily bioavailable. However, it should be noted that median bioavailable concentrations predicted are approximately two orders of magnitudes below the Pb EQSbioavailable (1.2 µg/l).

Table 1. Cu, Zn, Ni and Pb site median (range) truly dissolved concentrations (<3 kMWCO) and bioavailable concentrations (Bio-met) in runoff samples collected during rainfall and snowmelt events.

		Industrial		Car park	
		Rainfall	Snowmelt	Rainfall	Snowmelt
Metal	Fraction (µg/l)	(n = 25)	(n = 14)	(n = 31)	(n = 6)
Cu	Truly dissolved	9.1 (1.5-27.3)	14.3 (8.7-32.7)	3.9 (0.6-31.9)	4.9 (3.1-15.1)
	Bioavailable	0.8 (0.2-2.0)	0.7 (0.3-1.2)	0.4 (0.1-0.9)	0.2 (0.1-0.2)
Ni	Truly dissolved	1.9 (0.4-10.2)	2.1 (1.7-4.6)	0.6 (0.1-6.2)	2.0 (1.6-2.6)
	Bioavailable	0.5 (0.2-1.7)	0.6 (0.3-0.7)	0.3 (0.1-0.6)	0.6 (0.5-0.8)
Zn	Truly dissolved	75.3 (18.5-271)	84.3 (35.8-156)	13.6 (4.7-262)	2.6 (1.5-5.9)
	Bioavailable	38.2 (9.7-103)	28.5 (12.9-47.8)	8.1 (0.6-53.0)	1.0 (0.5-1.7)
Pb*	Truly dissolved	0.03 (0.01-0.10)	0.04 (0.01-0.13)	0.02 (0.01-0.08)	Not detected
	Bioavailable	0.02 (0.00-0.06)	0.01 (0.01-0.01)	0.01 (0.01-0.02)	Not detected

Key: *=n above detection limit for Pb: n=13 n=5 n=13

In conclusion, the data indicate that the truly dissolved concentrations dominate the sub-dissolved fractions for Cu and Zn and contributes up to 30% and 50% of total Cu and Zn concentrations, respectively. Together with the findings of two differently sized inorganic colloidal fractions (detected for Pb, Cr and Ni), this data suggests that treatment systems should be designed to target removal of the sub-dissolved fractions, especially due to the identified lability of these fractions suggesting runoff will have environmental impact. Further, the truly dissolved concentrations are identified to be an overestimation of the bioavailable concentrations and should therefore not be used as a direct surrogate.

This study was made possible with funding from the JPI Water funded project INXCES.

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Vadose zone hydraulic assessment in urban areas with small scale variability

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The INXCES Project

In the urban areas, a correct determination of saturated hydraulic conductivity k_s for the vadose zone has multiple applications. Due to lithological heterogeneity of the urban soil, significant variations of this parameter may occur in relatively close locations. To model the water infiltration from the terrain surface to the shallow aquifer, the k_s value it regularly used. In order to obtain solutions of the flow simulation model, showing an accurate physical sense, it is necessary to take into account the complexity of this zone. As consequence its heterogeneity and anisotropy conduct to mathematical models difficult to manage.

Using test devices with large infiltration area, the obtained k_s values better characterizes the test zone due to the variability of the lithological composition, cracks, vegetation, computing method and others. From the theoretical point of view on natural and homogenous soils, the ratio between k_s value and the infiltration area *A,* have to decrease when *A* increases and indicates an inverse correlation between these parameters. When this ratio increases, the conditional dispersion decreases and the residual dispersion increases. It is also possible that other factors may disguise the influence of *A* on obtained k_s values. In INXCES Project we performed an analysis of obtained k_s values on two study areas PL1 and PL2, by applying four methods for in situ tests: Double ring infiltrometer *DRI*, Tube infiltrometer *TI*, Minidisk infiltrometer *MDI* and Inverse auger method *IA*. The study areas are located on urban soils: *PL1* on heterogeneous filling material (sandy clay, silty clay with elements of gravel brick, glass, wood) with a light vegetation coverage and *PL2* showing a lower urban soil heterogeneity degree in comparison to *PL1* (sandy silty clay with rare millimetre or smaller elements of brick and concrete) but covered with a denser vegetation.

***Fig. 1** – Study case PL1*

***Fig. 2** - Study case PL2*

The analysis has been made by comparing the results obtained by each method, between several tests carried out at the same location as well as at distinct locations within the same study area. The results gathered from both study areas have been further compared. A statistical analysis indicates a direct and good correlation between the hydraulic conductivity and the infiltration surface for *PL1.* Also, an inverse correlation between the obtained k_s values and k_s/A ratio has been obtained. For *PL2* it has been obtained a moderate direct correlation between k_s and *A* and no correlation between k_s/A ratio and *A*. Also, a higher value of 80% for the residual dispersion has been shown. A second analysis has been carried out for *PL2* study area by applying the multiple regression method to understand to which degree the vegetation is masking the direct connection between the two variables and to determine the proportion in which other variables (that could not be considered by this analysis) influence the k_s fluctuations.

ClimateCafe for interdisciplinary active Knowledge exchange on Climate Adaptation: 25th edition Malmo Climatecafe

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The INXCES Project

Our urban and rural environment (rivers, cities) are becoming increasingly vulnerable for climate change and there is an urgent need to become more resilient. Climatecafe is developed by Groningen and Rotterdam University of Applied Sciences to gather factual and objective data in a short period of time (1-2 weeks) by young professionals and practitioners that enable them to assess the ‘level of resilience’ of a specific area.

The first step in climate adaptation strategy ‘Analyse, ambition, act’ is identification of bottlenecks in areas such as flooding, drought, and heat. International exploratory city scans are set up in order to put the necessary steps in place to go from ‘analyse’ to ‘action’. During a scan, an international ‘Quadruple Helix’ team (government, industry, academia, civil participants) work together towards tangible results. Bringing these multidisciplinary viewpoints together in an environment that promotes team working, collaboration and the sharing of ideas. By working together, this quadruple helix approach can create new shared value that benefits all participants. Technology (such as interactive tools and quickscan modelling) plays a key role in creating networks and connectivity. The ability to gather relevant information and measurement data in a short time frame about the level of resilience at street or urban area level makes the climate scan unique. This knowledge may help citizens and other stakeholders in urban areas or neighbourhoods to develop support for, and implement, climate adaption measures. The participating parties work together to select a variety of challenges.

Climatecafe aims to use low-cost and low-tech tools and instruments. Parameters that are assessed in rivers cans and city scans: urban heat (temperature), urban floods (infiltration capacity), urban water quality (several parameters as: nutrients, chlorophyll, oxygen), air quality (several parameters) and waste pollution (plastic waste). Storytelling is recently added as a successful method to collect subjective data such as the opinion and perspective of the community and integrate these data in the climate scan results. The climatecafe method was tested in different areas around the globe (Asia, Europe, Africa) in groups of young professionals and stakeholders in rapid urban appraisals.

Climatecafe Malmo is an interactive multidisciplinary fieldwork based event with practical examples of climate adaptation. Climatecafe Malmo is an effort for bridging the gap between research, applicability and societal effects. This 25th edition of Climatecafe will raise awareness and show how research relate to UN SDGs Sustainable Development Goals, exchanging knowledge with: >50 young professionals, >15 nationalities, >15 disciplines. Climatecafe Malmo will measure, map, scan and assess different parameters that give insight in the vulnerability and adaptation of a defined urban area of Malmo (Augustenborg). The following actions are planned:

- measure, map and scan sustainable urban drainage systems (with the tool www.climatescan.nl)
- demonstration and participation in full-scale infiltration tests
- mapping of pollutants in SuDS
- measure water quality with your phone
- heat stress mapping

Climatecafe Malmo is organized before and during the end congress of 3 projects (14: INnovation for eXtreme Climatic EventS (INXCES), MULTI-SCALE URBAN FLOOd FORECASTING (MUFFIN), SUrF (Sustainable Urban Flood Management). Climatecafe Malmo will give you: International networking with 9 European Universities and multiple disciplines.

In conclusion, there is a clear demand for an active collaborative knowledge-sharing activity as climatecafe. This event helps raising awareness and capacity building on climate adaptation and will help policy makers and practitioners to gather valuable data for decision-makers in a rapid appraisal at neighbourhood and city level. The results of Malmo Climatecafe will be presented at 13 and 14th June 2019 by young professionals.

Fig. 1 *Climatecafe Malmo (source:* https://climatecafe.nl/2019/01/city-climatescan-malmo-will-be-held-10-14-june-2019*)*

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POSTERS

In situ mapping of pollutants in Sustainable Urban Drainage Systems, a new methodology approach and preliminary results from the Netherlands

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The INXCES Project

Keywords: in situ mapping, XRF, pollutants, heavy metals, SuDS,

Stormwater runoff has severe negative and direct impact on the quality of surface waters and groundwater. The impact can cause chemical and heavy-metal pollution. Applying well established methods to map pollutants in urban areas and specifically in Nature-Based Solutions (NBS), such as Sustainable Urban Drainage Systems (SuDS) is a step towards improving the water quality in the urban water cycle.

Traditional mapping of pollutants by the means of soil samples is costly, which is the main reason why the environmental-technical functioning of rainwater facilities has not been investigated on a large scale and systematically. X-ray fluorescence (XRF) is a known analysing method for finding metals and other components, for laboratory analysis and portable instruments. In this work we propose a new approach of mapping method for pollutants in-situ, such as heavy metals in soil in SuDS, with case studies from the Netherlands where swales were implemented 20 years ago. In situ XRF measurements is a quick and cost-efficient analysis for heavy meatal mapping in the respect to contaminated soil.

In situ XRF measures of various elements, including heavy metals is carried out in a quickscan and accurate manner and measures both qualitatively and quantitatively. It makes the time-consuming and costly interim analyses by laboratories superfluous. In this study, we suggest a new methodology approach for in situ mapping of pollutants in various swales that were implemented from 20 to 5 years ago. The results differ due to multiple factors (age, use of materials, storage volume, maintenance, run off quality, etc.). Several locations reached unacceptable levels, above the national thresholds for pollutants. The spatial distribution of pollutants in the over 30 swales mapped in the Netherlands show that the preferred water flow in the SuDS controls the spreading of pollutants. The swales investigated are presented in an interactive way with the open source tool www.climatescan.nl, containing more than 100 swales, part of which has been investigated with in situ XRF measurements.

The research results are of great importance for all stakeholders in (inter)national cities that are involved in climate adaptation. SuDS is the most widely used method for storing stormwater and infiltrating in the Netherlands. However, there is still too little knowledge about the long-term functioning of the soil of these facilities.

International conference
CITIES, RAIN AND RISK

In situ mapping of pollutants in Sustainable Urban Drainage Systems, a new methodology approach and preliminary results from the Netherlands

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INXCES — INnovations for eXtreme Climatic EventS

Water Works 2014

Keywords: Portable XRF, in situ mapping, heavy metals (Pb, Zn, Cu), pollutants, SuDS, Cost- and time efficient

Stormwater runoff has severe negative and direct impact on the quality of surface waters and groundwater [1,2]. The impact can cause chemical and heavy-metal pollution. Applying well established methods to map pollutants in Sustainable Urban Drainage Systems (SuDS) is a step towards improving the water quality in the urban water cycle [3,4,5].

Traditional mapping of pollutants by the means of soil samples is costly and time consuming, which is the main reason why the environmental-technical functioning of rainwater facilities has not been systematically investigated on a large scale. X-ray fluorescence (XRF) is a known analysing method for finding metals and other components, for laboratory analysis and portable instruments [5,6]. A new approach of mapping method for pollutants in-situ is proposed, such as heavy metals in soil in SuDS, with case studies from The Netherlands where swales were implemented 20 years ago. In situ XRF measurements is a quick and cost-efficient analysis for heavy meatal mapping in the respect to contaminated soil [5,8].

In situ XRF measures of various elements, including heavy metals is carried out in a quick scan and accurate manner and measures both qualitatively and quantitatively [6]. It makes the time-consuming and costly interim analyses by laboratories superfluous. In this study, we suggest a new methodology approach for in situ mapping of pollutants in various swales that were implemented from 5 to 20 years ago. The results differ due to multiple factors (age, use of materials, storage volume, maintenance, run off quality, etc.).

Several locations reached unacceptable levels, above the national thresholds for pollutants. The spatial distribution of pollutants in the over 30 swales mapped in the Netherlands show that the preferred water flow in the SuDS controls the spreading of pollutants. The swales investigated are presented in an interactive way with the open source tool www.climatescan.nl, containing more than 250 swales, part of which has been investigated with in situ XRF measurements [5,8].

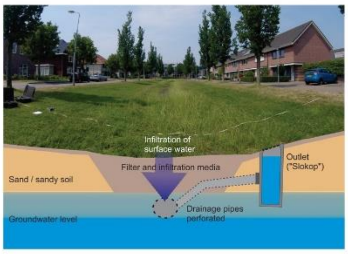


Figure: Principle sketch of a swale, location Limmen as background.

In Situ measurements with portable XRF

For a systematic data collection and a quick scan to cover the essential parts of a swale the proposed approach is profiling in cross-sections of the swale. Measuring points should be collected at a systematic interval, in this study 1 metre interval was executed. To cover the background values of the topsoil, measuring point on the outside or rim of the swale should be collected and crossing over to the other side. Such profiling will give background values and if any build-up of contamination, when profiling across the swale. It is important that the profiles cover the inlet and the deepest part of the swale, since water is the transporting media for the pollutants and the inlet and deepest part will contain water most frequent and for the longest period. The profiling approach should be repeated systematically to map the spread of the pollution in the swale.

Figure: Demonstration of in situ XRF measurements at every 1 metre along the profile across the swale. The vegetation is removed to measure on the topsoil, 0-3 cm, for measuring results to be comparable with lab results from soil samples. The instrument is pointed on the topsoil and each measurement is read for 60 seconds.

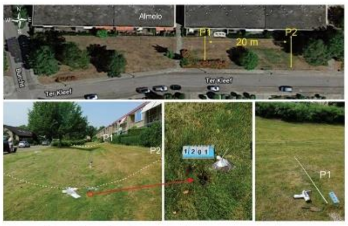


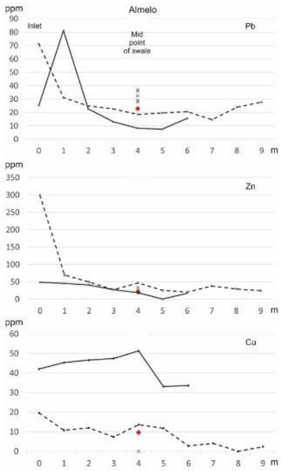
Figure: The swale at Almelo municipality, is approximately 40 metre-long and 10 metre wide. Two profiles with 20 metres between with measurements at each metre is collected with XRF instruments XL3#SN67136 at P1 and XRF instruments XL3t#SN36372c at P2. A soil sample for ICP-MS analysis was collected at mid-point of profile 2.

Results and discussion

This study shows that the highest concentrations are close to the inlet(s), based on the portable XRF measurements, which is coherent with other studies [9, 10, 11]. The variation of spatial distribution of pollutants in swales is confirmed in this study, with great variation over short distance (1 m). The distribution of the pollutants is controlled by the water ways in the swale, with highest measured values in the inlet and at deepest point of the swale, where water is most frequent and has the longest duration. These results confirm that stormwater is a significant contributor of pollutants to SuDS [4].

The research results are of great importance for all stakeholders in (inter)national cities that are involved in climate adaptation. SuDS is the most widely used method for storing stormwater and infiltrating in the Netherlands [4, 5, 8, 12, 13]. However, there is still little knowledge about the long-term functioning of the soil of these facilities.

Figure to the right: Results from Almelo. Both profiles start at an inlet (0 m). Profile 1 is measured by XRF instrument #SN67136, and profile 2 by XRF instrument #SN36372c. There is approximately 20 metres between profile 1 and 2. A soil sample is collected at mid-point of profile 2. Elements in graphs from top to bottom: Pb – Lead, Zn -Zinc and Cu – copper.



Concluding remarks

The new portable XRF methodology approach presented for measurement of heavy metal pollutants in SuDS is a cost and time efficient method that give in situ results. The instrument has detection limits well below threshold values that makes this method valid for its purpose. With this quick-scan method the traditional soil samples and analyses by laboratories becomes superfluous. The results from the mapping of swales differ but there is a clear message; the water controls the distribution of pollutants in swales [9].

When in the field the profiling should be adjusted according to the design of the SuDS, making sure that the profiles cover the inlet, the deepest part as well the outer rim to represent the possible highest and lowest values of elements. The profiling should be executed systematically with a set interval. Control samples of soil should be collected and analysed in laboratory.

This quick scan XRF mapping methodology of topsoil will qualify to indicate if the topsoil is polluted or not according to the national or international standards [1, 13]. If pollutant values are found above threshold a follow up investigation is advised to mitigate before clean-up is proceeded [1, 4, 8, 13].

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In-situ hyperspectral and fluorescence methods compared with remote sensing Sentinel-2 satellite data for mapping chlorophyll-a/cyanobacteria concentrations

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The INXCES Project

Climate change accentuates heat waves in The Netherlands. This, in combination with high nutrient concentrations in Dutch surface waters, is intensifying the proliferation of toxic blue-green algae (cyanobacteria), a threat for the health of the population and ecosystems. Lakes are resources for recreational activities, such as bathing, sailing and fishing. Dutch water managers struggle with lack of high spatial resolution information and updated/real-time alarm systems. Algal concentration data and its spatial distribution is important to support and calibrate (early warning) forecasting models.

This study focuses on collecting and comparing simultaneous in-situ and remote sensing data of chlorophyll-a and phycocyanin, and assessing the suitability of each method to characterize spatial (and with depth) variations of algae concentrations. The in-situ measurements were performed using a portable water quality spectrometer (WISP-3) and a hand-held fluorescence algae sensor (TriLux). Remote-sensing data was derived from Sentinel-2 multi-spectral earth observation satellite using existing algorithms (WISP-3 measurements were used to force atmospheric corrections). The data collection campaigns took place during overpasses of the satellite and when days were cloud-free, and between 10am and 15pm.The spatial variations of algal concentrations were investigated using autonomous unmanned vehicles equipped with the algae sensor to perform depth profiles and multiple transects along the canals and the lake. The study sites for this research were Lake Paterswoldsemeer and its main tributary channels. This region is managed by the Water Authority Noorderzijlvest that was also involved in this monitoring campaign.

The depth profiles measured with the algae sensor showed some variation, with the algal concentrations increasing with depth to a maximum value a few centimeters from the surface, and then decreasing to a stable concentration at higher water depths. Sentinel-2 data showed variations in the cross sections of the channels that were not detected by the in-situ methods. The deviating values near the margins indicate that surrounding land and trees/buildings influence pixel values. Finally, considering the different results obtained with different methods, additional laboratory validation measurements should be conducted for verification in future campaigns.

The collected data is now being incorporated in the calibration of algae forecasting models that are currently being developed and applied in this region and up-scaled to many projects in the world. Output from these models provides crucial information for decision-making on adequate measures and actions to address the problem of harmful algal blooms.

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Comparing in-situ hyperspectral and fluorescence methods with remote sensing Sentinel-2 satellite data for mapping chlorophyll-a/cyanobacteria concentrations

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1. Introduction

Lakes and canals in The Netherlands: resources for recreational activities, such as bathing, sailing and fishing.

Climate change: accentuation of heat waves

High nutrient concentrations in Dutch surface waters

Proliferation of toxic blue-green algae (cyanobacteria)

Threat for the health of the population and ecosystems.

Spatial distribution is important to support and calibrate (early warning) forecasting models:

- Accurate monitoring needed
- Strict regulations and standards to comply with (EWFD)
- Monitoring programs lack detailed spatial data
- Data needed to support early detection and quick action systems

2. Methodology

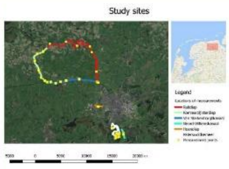
Simultaneous collection of in-situ and remote sensing data of chlorophyll-a and phycocyanin:

- Portable water quality spectrometer (WISP-3)
- Hand-held fluorescence algae sensor (TriLux)
- Remote-sensing data derived from Sentinel-2 multi-spectral earth observation satellite

The spatial variations of algal concentrations were also investigated in-situ using autonomous unmanned vehicles equipped with algae sensor, including depth profiles / transects along the canals and the lake.

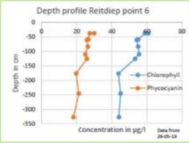
Data collection campaigns during overpasses of the satellite in cloud-free days.

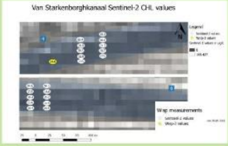
The study site for this research was the Lake Paterswoldsemeer and its main tributary channels.



3. Results

The depth profiles measured with the algae sensor equipped on an underwater drone showed that the top layer of a few centimetres show an increase of concentration, and then it decreases with depth to a stable algal concentration.





Sentinel-2 data showed variations in the cross sections of the channels that were not detected by the in-situ methods. The deviating values near the margins indicate that surrounding land and trees/buildings influence pixel values.

Table 2 CHL comparison channels

Parameter	Method	Reitdiep		Kommerzijlsterdiep		Van Starkenborghkanaal		Average
point		4	6	1	2	4	7	
CHL in µg/l	WISP-3	60.6	25.4	20.9	22.9	18.6	18.2	27.8
	Sentinel-2	30.7	21.7	28.9	28.8	17.5	14.3	23.7
	Algae sensor	151	45	42	51	30	27	57.7
Difference in %	Sentinel/ WISP	50.7	85.4	138.3	125.8	94.1	78.6	95.5
	Algae sensor/ WISP	249.2	177.2	201	222.7	161.3	148.4	193.3

Table 3 CPC comparison channels

Parameter	Method	Reitdiep		Kommerzijlsterdiep		Van Starkenborghkanaal		Average
point		4	6	1	2	4	7	
CPC in µg/l	WISP-3	65.8	47.6	43.8	43.4	59.8	62.7	53.9
	Algae sensor	62	20	20	25	10	10	24.5
Difference in %	Algae sensor/ WISP	94.2	42	45.7	57.6	16.7	15.9	45.4

Considering the different results obtained with different methods, additional laboratory validation measurements should be conducted for verification in future campaigns.

5. Follow-up research

- The collected data is now being incorporated in the calibration of algae forecasting models
- These models are being applied in the Netherlands and being up-scaled to many projects in the world.
- Output from these models provides crucial information for decision-making on adequate measures and actions to address the problem of harmful algal blooms.

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