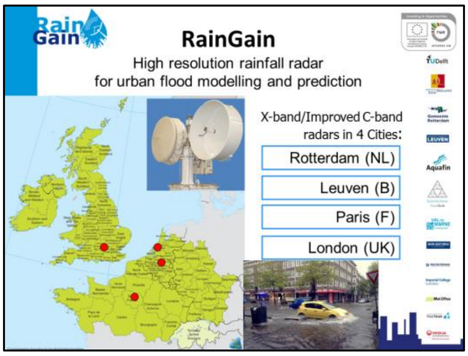
RainGain International Workshop on Urban Pluvial Flood Modelling

The RainGain International Workshop on Urban Pluvial Flood Modelling took place on 6th October 2014 at the Met Office Headquarters in Exeter, UK. Ninety people attended, including practitioners and academics from a number of universities, water companies, engineering consultants, local authorities, and regional and national environmental and meteorological agencies from across Europe. The workshop provided an opportunity for experts to share and discuss ideas around the topic of urban pluvial flood modelling, forecasting and management: recent developments were discussed, and recurrent challenges were reviewed. New challenges were also identified, challenges which have emerged as a consequence of the increasing availability of data, model complexity, an ever changing urban society, as well as the difficulties posed by both technological and administrative barriers, amongst other factors. The workshop served to emphasise that, although fast progress has been made in the modelling and forecasting of urban pluvial flooding over the last few years, more needs to be done to bridge the large gap that still exists between research and operational systems.

From left to right: Jonathan Millard (Flood Forecasting Centre, UK), Laurent Monier (Veolia, FR), Graeme Boyce (Flood Forecasting Centre, UK), William Neale (Thames Water, UK) and Stefan Kroll (Aquafin, BE) discuss the use of surface water flood models for real-time applications

Dr Crystal Moore, Head of the Flood Forecasting Centre (FFC), welcomed attendees and gave an overview of the services provided by the FFC. Crystal highlighted the risk that urban pluvial (surface water) flooding poses to England and the need for research to support the work that the FFC does in forecasting and warning of this type of flooding.



Overview of RainGain Project by Marie-Claire ten Veldhuis

RainGain project coordinator, Dr Marie-Claire ten Veldhuis, followed this up with an overview of the work that the RainGain consortium has done in improving rainfall estimates at urban scales, with the final purpose of improving the modelling, forecasting and management of urban pluvial flooding.

After these two introductory talks, the bulk of the workshop was split into 4 sessions, each one focusing on one of the following topics:

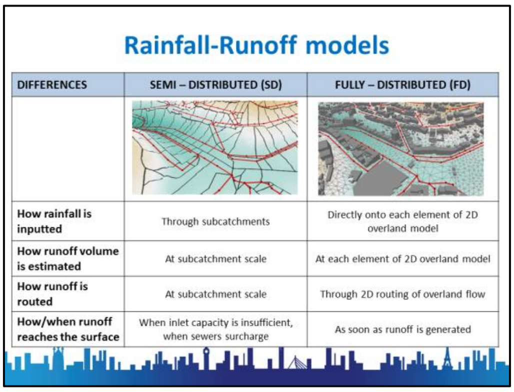
- **Topic 1:** Approaches to the modelling of urban storm water drainage systems and urban pluvial flooding
- **Topic 2:** Approaches and techniques for rapid urban pluvial (surface water) flood modelling
- **Topic 3:** Urban drainage/pluvial flood model calibration, verification and uncertainty estimation
- **Topic 4:** Operational urban pluvial flood models for real time applications

Each session comprised technical presentations by international experts (presentations can be downloaded from the panel on the right), followed by interactive discussion around the given topic. Some of the main points discussed and conclusions reached during each of the sessions are summarised below.

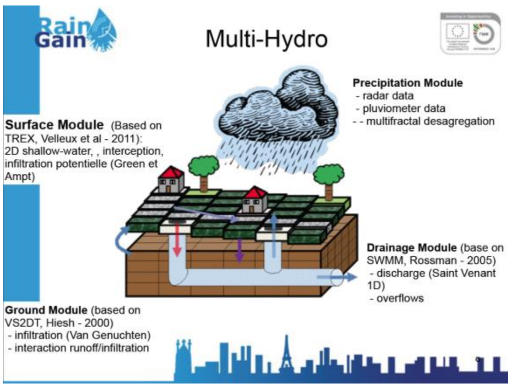
At the end of the workshop attendees were taken on a tour through the Met Office Operations Centre and Flood Forecasting Centre.

SESSION 1: Approaches to the modelling of urban storm water drainage systems and urban pluvial flooding

The presentations were opened by **Rui Pina** and **Susana Ochoa-Rodríguez** (Imperial College London, UK) who outlined the work they have done on the comparison of semi- and fully-distributed urban rainfall-runoff models, including their relative sensitivity to rainfall inputs of different temporal and spatial resolutions. Initial results of their work demonstrate the need for agreement between the resolution of the datasets used for model building, of the resulting model structure, of the rainfall data used as input to the models, and of the flow/depth data that is used for calibration and verification of models. Lack of agreement between the resolutions of the different components may lead to ill-posed models and to loss of information from the highest resolution datasets.



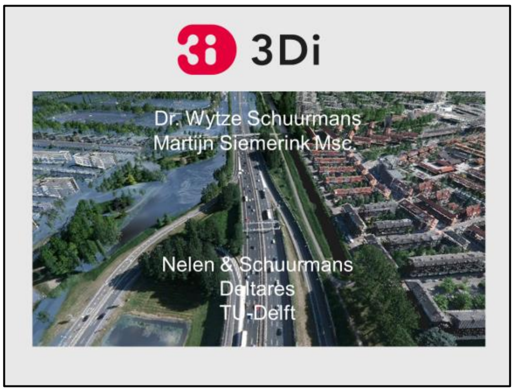
Differences between Semi-Distributed vs. Fully-Distributed models – by Rui Pina & Susana Ochoa



Modular structure of Multi-Hydro – by Prof. Daniel Schertzer

Next, **Professor Daniel Schertzer** (École des Ponts ParisTech, FR) introduced the Multi-Hydro model, a 2-dimensional (2D) fully-distributed physically-based urban drainage platform which connects several existing models to represent each component of the urban hydrological cycle. In his talk, Prof. Schertzer emphasised the challenges associated to the use of high resolution data in urban hydrology, as well as the need to better understand scale interdependencies.

The last two talks of this session, by **Ting Zhang** (Imperial College London, UK) and **Wytze Schuurmans and Martijn Siemerink** (Nelen & Schuurmans B.V., NL) included a demonstration of new 3-dimensional (3D) urban pluvial flood models. In her work, Ting compared 2D and 3D models of the urban surface and concluded that 3D models are required when vertical inertia plays an important role in the flow, which renders the shallow water equations, and therefore 2D models, invalid.



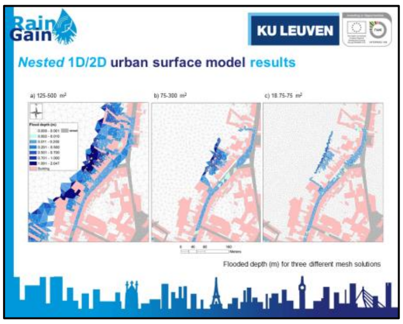
Introduction to the 3Di model – by Wytze Schuurmans & Martijn Siemerink

Wytze and Martijn, on the other hand, introduced the 3Di model, a 3D model of the urban surface which incorporates a sub-grid method that makes best use of the higher resolution terrain data currently available, and enables realistic visualisation of flood modelling results, while keeping computational times reasonable.

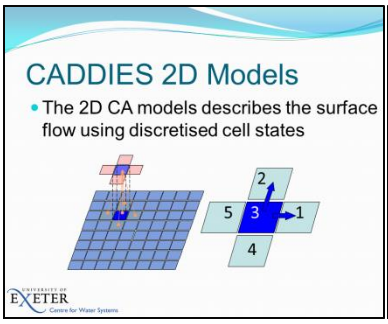
The presentations and discussion during this session demonstrated how **the increasing availability of high resolution data (e.g. digital terrain models with centimetric resolution, fine scale radar rainfall estimates) opens a world of possibilities for urban pluvial flood modelling**, including the possibility of implementing high resolution 2D and 3D models of the urban surface which allow more detailed simulation and better visualisation of urban flooding. However, **it also poses numerous challenges for which solutions are yet to be sought**. For example, higher instabilities associated with higher resolution models, increasing computational requirements, enormous amounts of data to be handled and stored, and the need to ensure agreement in the resolution of the different datasets used in the modelling of urban pluvial flooding. Moreover, the discussion at the end of this session highlighted the **need for more work to better understand the impact and added value of higher resolution data and models on final impact variables, such as flood damage / risk, on which management decisions are based.**

SESSION 2: Approaches and techniques for rapid urban pluvial (surface water) flood modelling

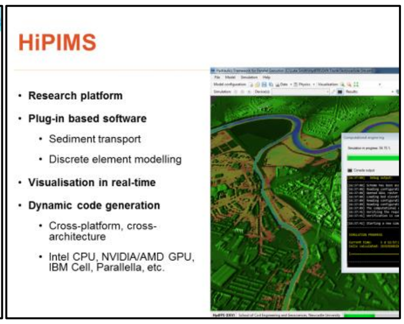
As discussed in Session 1, **increasing model resolution leads to higher computational requirements and runtimes**, which are particularly critical for real time applications. During the second session of the workshop three presentations were given, focusing on **solutions to overcome this problem, including hybridisation of models** (i.e. introduction of higher model resolution in critical areas and lower resolution or simpler model structures in other areas –presentation by **Nuno Simões** (University of Coimbra, PT) and **Damian Murlà Tuyls** (KU Leuven, BE)), **making best use of available hardware** (e.g. GPUs, CPUs – presentation by **Luke Smith** (Newcastle University, UK)), and **the use of conceptual and data-driven models** (presentation by **Albert Chen** (University of Exeter, UK)). These solutions are not mutually exclusive and an optimal combination of them could lead to highly efficient models which represent an acceptable compromise between model detail and runtimes. Most of these techniques are still at a research stage; more work is still required to further develop them and to incorporate them into operational software tools which can be used by practitioners.



Nested 2D overland models – by Damian Murlà Tuyls



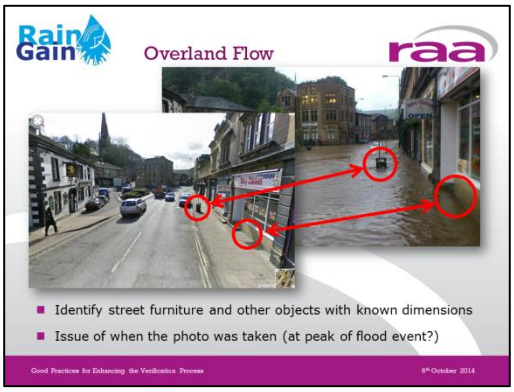
Cellular Automata approach for modelling of overland flow – by Albert Chen



HiPIMS platform for rapid overland flow simulations making best use of hardware – by Luke Smith

SESSION 3: Urban drainage/pluvial flood model calibration, verification and uncertainty estimation

The presentations in this session covered a range of approaches for handling, quantifying and reducing uncertainty in urban drainage models, including simple yet effective practical approaches, as well as more sophisticated statistical methods.

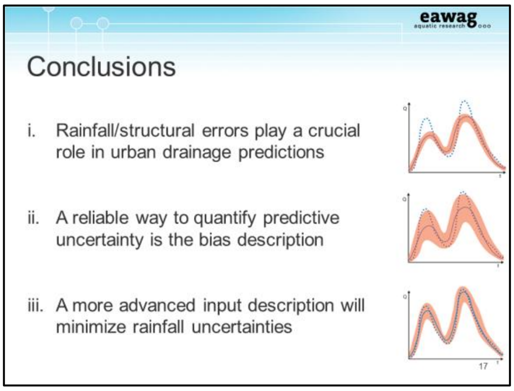


Best practices for enhancing model calibration: use of photographic records for calibrating overland models – by Alex Grist

In the first presentation, **Alex Grist** (Richard Allitt Associates, UK) introduced good practices for enhancing the calibration of urban drainage models, including improving rainfall estimates through merging of radar and raingauge data, mapping the quality of the data available for calibration (this provides an overview of model reliability and enables the allocation of resources to areas where data quality is deemed low), as well as using photographic and video records from social media for verification of surface flow models.

Afterwards, Professor **Patrick Willems** (KU Leuven, BE) gave a presentation on a variance decomposition method for estimation of uncertainty in flood models. This method splits the variance of the total error in the model results in its major contributing uncertainty sources (i.e. rainfall inputs, model structure, model parameters and flow/depth records), thus allowing for a better understanding of where uncertainties are coming from and where work/resources should be directed in order to reduce uncertainties and improve the quality of model estimates.

In the following presentation, **Dario Del Giudice** (Eawag & ETH Zurich, CH) explained how a better (i.e. more realistic) description of model bias can lead to more reliable estimates of the uncertainty associated to urban drainage models. He then explained the important role that rainfall estimates play in urban drainage modelling, and highlighted the need for better quality rainfall estimates which take into account the spatial variability of rainfall fields, as well as for a better description of the errors associated with the rainfall estimates; this could not only improve uncertainty estimates, but could also help reduce the overall uncertainty in urban drainage models.



How can statistics help us to get reliable predictions despite model bias? – by Dario Del Giudice

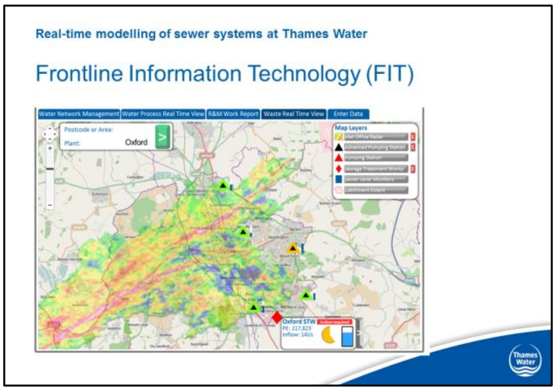
Lastly, **Søren Thorndahl** (Aalborg University, DK) presented his work on the automatic calibration of urban drainage models and the use of these models for real time applications, using as input radar rainfall estimates calibrated in real time (based upon rain gauges, using a Mean Field Bias adjustment), as well as radar-based nowcasted rainfall estimates. Søren emphasised the need for real time adjustment of radar rainfall estimates before these are used as input to urban drainage models for real time applications. Moreover, he explained the difficulties associated with the calibration of urban drainage models in real time and questioned whether real time calibration (or data assimilation) was worth it.

Two recurrent topics in the presentations and discussion of this session were (1) **the need for better description of errors from different sources**, and (2) **the need for improved rainfall estimates in order to reduce the uncertainty inherent to urban pluvial flood models**. In addition, the **need for more practical yet robust uncertainty quantification and reduction methods** which can be applied to operational models was also emphasised. One of the main challenges identified through discussion and which is yet to be tackled is the calibration of 2D overland flow models and the estimation of the associated uncertainty

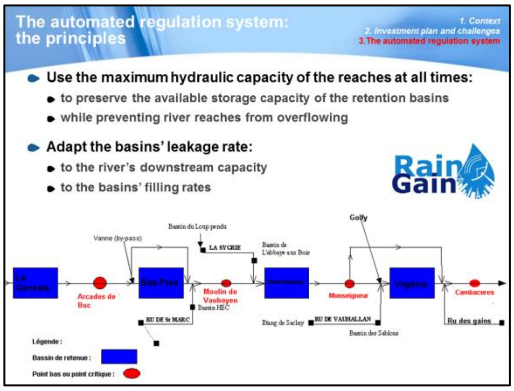
SESSION 4: Operational urban pluvial flood models for real time applications

The presentations within this session focused purely on operational real time urban pluvial flood models being implemented and/or used by local water managers or national services in the UK, Belgium and France.

In the first two presentations, **Stefan Kroll** (Aquafin, BE) and **William Neale** (Thames Water, UK), shared their experiences as local water managers dealing with the implementation of real time surface water flood forecasting systems using InfoWorks ICM Live for the city of Leuven (Belgium) and for the Beckton catchment (London, UK), respectively. Drivers for implementing such systems include greater understanding and control of their assets, switching from reactive to proactive maintenance, and eventually being able to forecast system surcharge and urban pluvial flooding before it occurs, thus enabling the implementation of responses which would help avoid or reduce economic, environmental and social impacts. Both Stefan and William agreed that some of the biggest challenges in the implementation of these systems lie in linking the different components in a smooth way; this is, rainfall estimates and forecasts, hydro models and data from sensors on the ground. Another challenge that is yet to be tackled is the operational use of 2D models of the urban surface in real time. For the time being the Leuven and London systems include only a model of the sewer system; the Aquafin team has done initial tests to implement dual-drainage models which comprise a 2D model of the surface, but model runtimes and instabilities have hindered progress in this direction. This helps to further emphasise the need to incorporate the work done by researchers in this area (see presentations in Session 2) into operational software tools which can be used by practitioners. On the operational side, an area on which more work is required is in building capacity to ensure proper understanding and use of real time models by operators and control room decision makers. Other areas in which both speakers believe progress is possible and more work would be desirable, include improvement of radar rainfall estimates through gauge-based adjustment, and real-time assimilation of data from sensors on the ground.



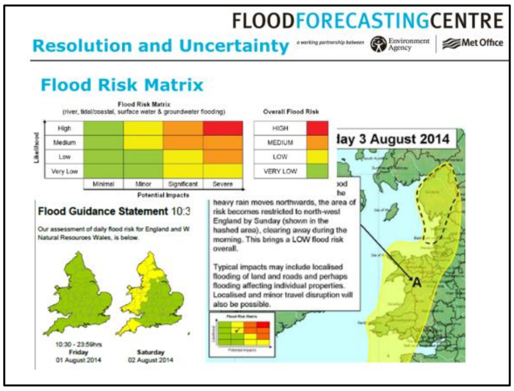
Real-time modelling of sewer systems – by William Neale



Real-time control system for managing surface water in the Bièvre Valley – by Laurent Monier

In the following presentation, **Laurent Monier** (Veolia DTP, FR) introduced the real time operational system designed by Veolia for managing surface water in the Bièvre Valley, Île-de-France. The Bièvre River, a tributary of the River Seine, runs through densely urbanised areas and has a long history of flooding. Following a major flood event in 1982, additional storage basins were implemented to increase runoff retention capacity. Nonetheless, the increased storage capacity was still not enough to cope with intense storm events (e.g. the runoff generated by a 2-hour storm of 10 year return period would already exceed the existing capacity). Given that land and cost restrictions impeded any further increase of retention capacity, a decision was made to create an automated real time regulation system to optimise the current capacity of the system. The regulation system takes as input rainfall estimates from local raingauges and short-term radar-based rainfall nowcasts. It also comprises a number of flow and level sensors which allow monitoring the current status of the system in real time. Based on this information and using real-time models, decisions are made to operate a number of active control elements (e.g. remotely controlled gates), such that the capacity of the system is maximised and flooding is prevented. Since the operational implementation of the system in 1995, a number of major storm events have been managed without major flooding. The system was designed in a flexible way, so that it can be continuously improved. As partners of the RainGain project, Veolia expect to further improve the current system by using improved rainfall estimates obtained with a new X-band radar to be installed in Paris this November.

In the last presentation of the day, **Jonathan Millard** (Flood Forecasting Centred, UK) provided an overview of the nation-wide UK system for surface water flood (SWF) forecasting and guidance, including an account of its development during the last few years, as well as the future developments on which the FFC is currently working. Jonathan started by highlighting the challenges associated with the small scale at which SWF occurs, which leads to 'magnification' of the impact of errors and uncertainties. He then introduced the first type of SWF warning service provided by the FFC: the 1st Generation Extreme Rainfall Alert (ERA), which was launched in 2009 and was only based on the probability of exceedance of national average rainfall thresholds likely to lead to SWF. This service was superseded in 2011 by the 2nd Generation Surface Water Flood Risk Assessment (SWFRA), which is the result of an objective assessment done with the Surface Water Flooding Decision Support Tool (SWFDST) and a subjective assessment carried out by a forecaster using a decision support flowchart. The SWFDST is an Excel based look-up tool which links extreme rainfall probabilities with parameters on the ground and maps of potential impacts in order to estimate the risk of SWF. This tool has been continuously updated (more parameters have been included and rainfall inputs have been refined) and recalibrated as more rainfall and flood impact data have become available. Future improvements in SWF forecasting and warning in the UK include improved flood hazard modelling through use of the fully-distributed Grid-to-Grid (G2G – 1 km resolution) surface runoff model, which may allow more localised warnings, as well as improved impact modelling based upon impact libraries which draw upon information from national databases. At the end of his presentation and during the discussion, Jonathan touched on the challenges associated with communicating flood warnings to recipients and highlighted the need for improved communication of risk and for building capacity so as to ensure the best use of any warnings.



Matrix used to estimate flood risk based on forecasted hazard and potential impacts on the ground – by Jonathan Millard

A lively discussion took place at the end of this session. One of the main conclusions of the discussion was the need to find a balance between model complexity, cost of model implementation and operation, data available, desired outputs, and existing capacity at end user level.