Decision support for urban drainage using radar data of HydroNET-SCOUT

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Abstract Users of hydro-meteorological data often face problems with collecting, handling and quality control of data from radar and raingauges. Current web technologies allow centralised storage, data management and integration of software tools. HydroNET and SCOUT tools have been integrated to produce accurate precipitation information and to present easy-to-understand interfaces to practitioners. The SCOUT software has been developed by hydro&meteo for obtaining calibrated precipitation information from raw radar data. HydroNET has been developed by HydroLogic with the aim of bringing meteorological data to the desktop of water managers and to support their daily work. Co-creation with users has led to HydroNET portal (www.hydronet.eu). This portal integrates the functionalities and supports water managers in assessing historical, current and forecasted precipitation events. The portal has been built using the Software as a Service (SaaS) paradigm. It is highly customisable and permits the user to configure its own interface, tools and warning levels.

Key words precipitation; raingauge; radar; RTC, DSS, web-service; SaaS; HydroNET; SCOUT

NEED AND AVAILABILITY OF URBAN PRECIPITATION DATA

Current needs

The frequent occurrence of excessive rainfall in urbanised areas is an important reason for water managers to look for opportunities to have easy online access to real-time and historical precipitation information. During the past few years HydroLogic has developed, together with several Dutch municipalities and water boards, the HydroNET portal which gives access to a variety of precipitation information up to a spatial resolution of 1 × 1 km and time series with 5 minutes intervals. The main reason for municipalities to look for such a tool was:

(a) The need for high quality historical precipitation datasets for calibration of urban drainage models.
(b) Accurate data for technical analysis of sewer networks, e.g. detecting clogging of sewers, evaluation of the operation of storage tanks and of pumping stations.
(c) Accurate data for handling of water-damage claims of the general public and companies.
(d) Cooperation between various water authorities such as municipalities, water boards, river management organisations and sewer departments.
(e) Operational use of rainfall data for flood prevention and managing flood situations: optimising the use of storage in sewer systems; applying spatial rainfall distribution in real-time control (RTC) algorithms and; assessing the risks of flooding.
(f) Availability of short term forecasts, preferably ensembles, up to 3 hours.
(g) To have a set of tools for visualisation of information, specifically devoted to hydrological use.

A lot of meteorological information is presently available at national weather services, for free or at delivery costs. This recent development is stimulated by the European and national policies of free meteorological data availability. This availability only is not enough for hydrological use. Often barriers exist to the use of these data, in particular because of the difficult formats, the timing of delivery, issues of completeness and the varying quality of the data. In general the user wants the best available dataset, not being bothered by all these issues.

In a study with several municipalities and water boards in the Netherlands a definition of necessary data and tools for decision support was made and implemented in HydroNET. This has resulted in the use of the system by more than 90 municipalities in their daily work of analysis, monitoring and forecasting of high water levels, overflows and floods. We found a solution to maintain only one dataset for all users, store it centrally and giving access to it for local use by means of a web portal. This solution also matches the current policy to have less software installed and maintained in government organisations. The single dataset is maintained, quality-controlled and kept up to date for all users by specialised service providers.

Availability of data

For a well balanced management of the urban water system, high quality precipitation data with a high resolution in time and space are necessary. This is a very difficult task to accomplish by the use of raingauges alone. On average, one raingauge per e.g. 4 km^2 (proposed approach in the Netherlands) would be necessary and this presents enormous investments to municipalities. Many municipalities have few raingauges and collect these data by telemetry networks, which makes the monitored data available together with other monitored data, e.g. pump operation, discharges and water levels. In practice the positioning of raingauges is a problem in urbanised areas. Following international standards of placement, the majority of these raingauges are in inappropriate locations such as on tops of buildings, next to buildings, under trees, etc. As a result, the associated errors in recording may rise up to 40%, which presents very inaccurate results. The general conclusion when reviewing the precipitation data collected by municipalities is that the coverage of the raingauge monitoring, as well as its quality, are poor.

On the other hand, a variety of hydro-meteorological data from the national weather services exists. The most important one for urban water management is the (uncalibrated) radar data, made available every 5 minutes by the national weather service KNMI. Calibrated composites exist in the Netherlands: 3-hour sums and 24-hour sums. However, these time resolutions are inappropriate for use in urban water management.

Apart from the radar, the national weather service makes available precipitation data from raingauges: 33 automatic gauges and approx. 330 manually read gauges, of which daily sums become available after half a day. These data appear to be very useful for calibration of radar data.

HydroNET-SCOUT

HydroLogic and hydro&meteo joined forces to fill the gap between information needs of urban water managers and available data by combining the tools which were developed and improved during many years. The SCOUT tools are used to create the best datasets possible on the basis of radar data and raingauge monitoring, including quality labelling, correction, calibration and updating as soon as new data become available. The HydroNET tools are used for storage, visualisation (time series, GIS) and decision support to water managers, using web-interfaces. The joint activity has resulted in a product which is welcomed by end-users in both the Netherlands and Germany.

A SAAS SOLUTION FOR HYDROLOGY

In hydro-meteorological information services for urban water management, the availability of abundant computing power is needed when multiple computations are requested, e.g. for running models in ensemble, but more importantly, to permit many users to simultaneously access the services, e.g. during heavy rainstorms, without loss of performance.

One of the most important recent developments in information and communication technology (ICT) for hydrology is cloud computing. Clouds present networks of servers which are connected to share loads of traffic and computations. In cloud computing often the Software as a Service (SaaS) paradigm is used, which is basically software that is fully running on servers, presenting interfaces to clients in the form of interactive websites.

Hydro-meteorological applications of interest use both private and public clouds. Private clouds use local clusters of servers, which are these days at the premises of the supplier. Public clouds are made available by providers of cloud services, e.g. Amazon, Microsoft, IBM (these days there are around 4000 cloud providers). The interesting feature of public cloud is that it permits replication of services, using virtualisation technologies. Good water-engineering examples have been presented by Xu *et al.* (2010). The approach creates the possibility of having any number of servers available to the user on demand. Private and public clouds can be combined, where private clouds function as the primary computing environment, managed by a provider of information. In such a configuration a public cloud can be used for expansion of computing power when needed, also referred to as “cloudburst” (not to be confused with rainstorms).

HydroNET has been developed as a SaaS cloud application, presenting interesting advantages for users and the organisations providing the services:

– All information is presented via a customisable web-portal.
– No desktop software needs to be installed.
– No server software is needed on premises of the municipalities and water boards.
– Updates to the software are available to all, right after installation in the private cloud.
– Costs of operation and maintenance can be reduced and the level of service enhanced.
– All data are maintained and made available to all users in one central place.
– Virtually unlimited computing power is available for calibration and modelling tools, solving performance problems.

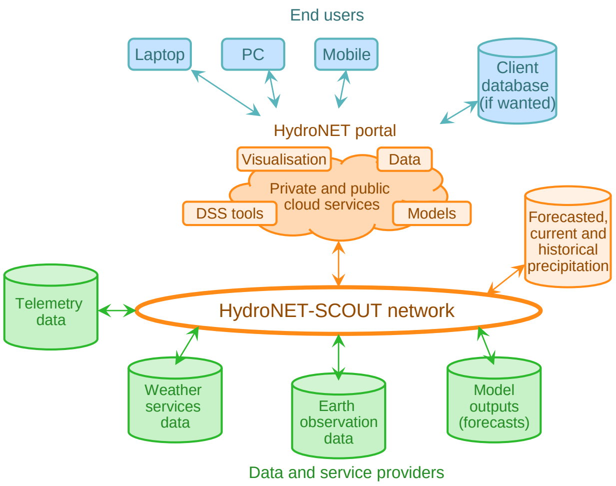

Fig. 1 HydroNET network connecting and interacting with various data sources and providing services through a web-portal.

The service network designed and developed is presented in Fig. 1. The picture shows the concept of a secure network in which services of several parties such as added-service providers and research organisations can be joined. These parties can make their data available through the same portal, having the advantage of the flexibility in configuration as well as the scalability and associated high level of service. Examples of these data are: radar data, raingauge data, evaporation data, and Earth Observation data (in sparsely measured areas). Because of the use of web applications (Fig. 2), users can run them from desktops, laptops and mobiles. The availability of real-time bench marking tools permit the water managers of municipalities and water boards to access the current situation and prepare for flood preventive measures, warn operational services and inform the public.

Some authorities, for administrative purposes or further integration purposes, also want the data from HydroNET in their own databases. For that purpose the solution provides a specific web service which permits these organisations to abstract the data and store it in corporate databases or telemetry systems.

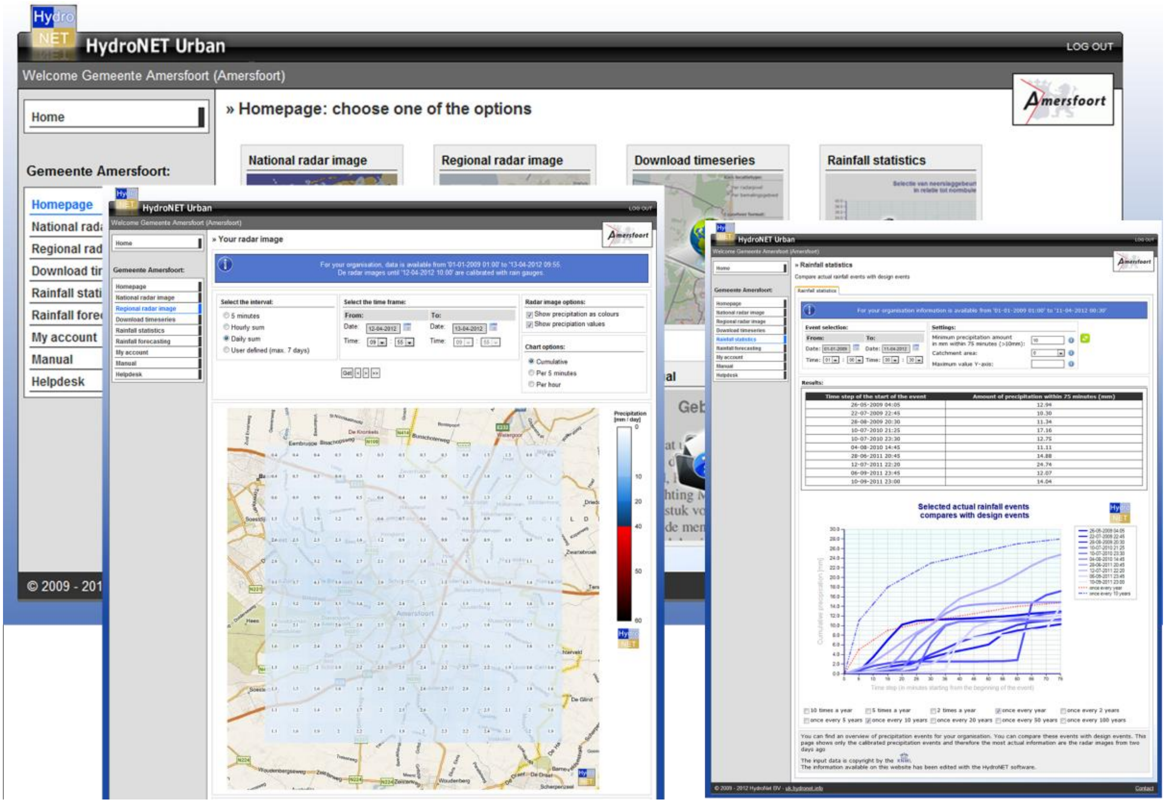

Fig. 2 Web-portal interface to the hydro-meteorological information showing map with precipitation sums and the associated forecast made available one day before the event.

CO-CREATION IN DEVELOPMENT

One of the key factors for a successful implementation of software is the involvement of users in the process of definition of functionalities, user interfaces and testing (Fig. 3). In HydroLogic the DSDM approach is successfully followed for this purpose (www.dsdm.org). Part of the approach are early interactive sessions with users to define what they exactly want with the application. Some generally applicable conclusions of these co-creation sessions were:

(a) Keep interfaces very simple, so that also infrequent users can easily find their way.
(b) Use web-technology, so that all users always have the latest functionalities.
(c) Make interfaces user-customisable, e.g. by allowing them to make their own front page or dashboard with information in the portal.
(d) Make the application fast, so that users don’t have to wait more than a few seconds for information.

More specific user requirements which followed from the sessions were:

(a) Include tools for fast assessment of recent and historic rainfall events, e.g. by comparing actual events with design events.
(b) Make series downloadable for use in other packages for statistical analysis or modelling, supporting different formats of these packages.
(c) Connect to existing telemetry systems and deliver the best precipitation data as soon as available.
(d) Add simple summation tools and GIS tools for rapid analysis, visualisation and presentation of spatial rainfall.
(e) Allow local raingauge data to be included in the radar calibration process.

Fig. 3 Co-creation with end-users: brainstorming, sketches and discussions on the contents.

TOOLS FOR SPATIAL PRECIPITATION INFORMATION

The data which are currently made available by the weather services in the Netherlands do not meet the requirements of municipalities and water boards. The latter organisations have clear requests for inclusion of local data into the entire service chain and in particular to use their own raingauges in the calibration process. To permit this, an analysis of the quality of raingauges to be included and their positioning was performed. Also the functionality of the SCOUT software to cross-compare radar data and raingauge data was enhanced. Other important components in the development of the integrated solution were:

(a) Fast online compositing and data processing by SCOUT.
(b) Data quality assessment and labelling.
(c) Radar data correction (Golz *et al.*, 2006).
(d) Radar/raingauge cross-comparison.
(e) Radar statistics: maximum hourly rainfall, daily sum, etc.
(f) Spatial rainfall information generation by calibration.
(g) Several methods of radar-based nowcasting, including ensemble approaches.

The calibration of radar data forms an important point in the development of accurate spatial precipitation information. This process has been developed for real-time applications as a work flow in which the continuous flow of data from its sources within weather services and water authorities is streamlined (Fig. 4). On the basis of new data which becomes available continuously, further calibration and nowcasting is performed using data of radar and raingauges. Finally, on the basis of a set of approx. 330 raingauges the dataset is fully updated and made available for offline analysis to the clients being water boards and municipalities.

The original cell-tracking based nowcasting approach in SCOUT was extended with three more nowcasting approaches, using vector fields for cell movement description. Additionally, ensembles can now be created based on the observed variability of cell speed, direction, growth and decay. The ensembles are a mix of nowcasting approaches and the use of observed uncertainties and developments in the data (Tessendorf & Einfalt, 2011).

The coverage of the two radars of the Netherlands in De Bilt and Den Helder is limited, resulting in inaccurate data in the northeastern and southwestern parts of the country. For the northeastern part this problem has been solved by using the German radar of Emden, which is right across the border. The entire procedure of integrating the data streams of the Netherlands and Germany has been investigated, tested and included in the procedure of data processing. The experiment performed, using raw 5 minute radar data from the KNMI and the German weather service DWD, is presented in Einfalt & Lobbrecht (2011).

Users can define warning levels for recent, current and forecasted rainfall intensity. By doing so, the system can support their operations, warning them when thresholds are passed. This supports decisions on when operators should take action such as extra pumping, operation of reservoirs for temporal storage, etc. Also this approach allows water managers to warn inhabitants in cases of a high probability of high water levels, floods and calamities.

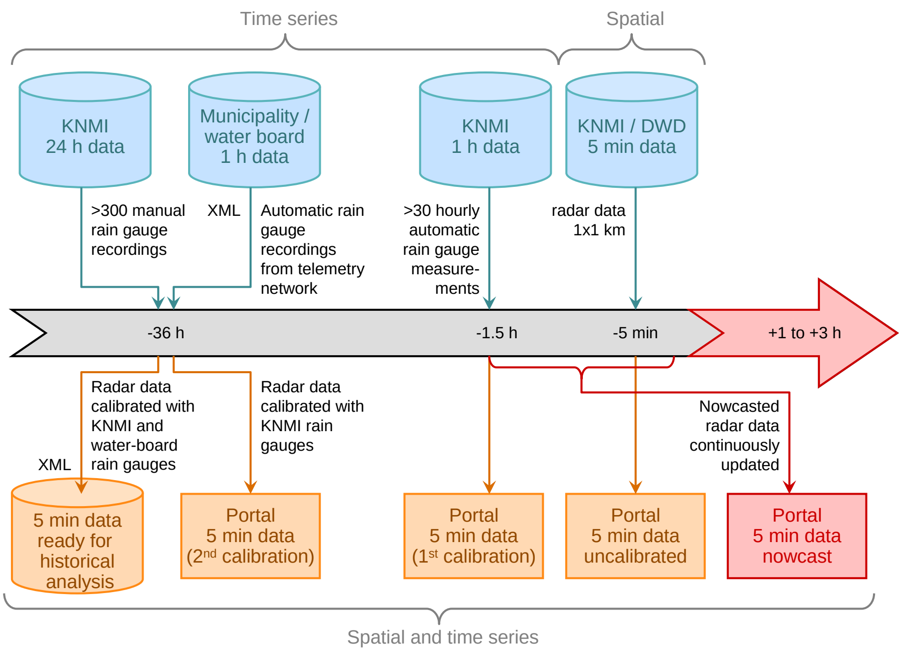

Fig. 4 Process-flow diagram for calibration of radar data to create the best composition of information in real-time and post processing of data to generate up-to-date and calibrated spatial and time series.

CONCLUSIONS

The integration of HydroNET and SCOUT into a combined solution for hydrological practitioners of municipalities and water boards, has been performed and tested extensively. Users have been involved by means of co-creation of the tools and are very satisfied with the portal solution. They do not have to worry anymore about installed software and databases; all services are outsourced, maintained and available to them whenever needed. Municipalities use the portal in operational management of excessive rainfall and floods and for post-flood analysis. The high quality spatial information provided, supports them in discussions with other water authorities and in cases of claims by third parties.

The current Software as a Service paradigm has been fully integrated in the decision-support system. It allows various providers of data, information and services to work together and provide added-value to end-users. The new HydroNET-SCOUT solution provides an excellent basis for cooperation of industry partners, research institutions and practitioners all over the world. End-users have access to high quality data and online customisable tools; the basis for decision-support in strategic and operational urban water management.

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