Supporting water managers making effective decisions by using HydroNET

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Abstract
Floods caused by excessive rainfall are creating hazardous conditions in many countries around the world. Such hazards are occurring more frequently, and range from local, water-induced damage to flood-generated devastation of whole communities. HydroNET is an open platform where more than 20 universities, knowledge institutes and consultant companies from the water and earth-observation sectors work together. Their goal is to support professionals in the water sector to manage their water systems knowing that the climate is changing and to improve the resilience of the systems in all weather conditions. HydroNET connects the user to all available data sources in real-time (databases, satellites, radars), combines the data and displays them on personal, user-friendly dashboards. The more than 80 HydroNET water applications (waterapps) which have been developed by many partners from different countries enhance insight and understanding of their systems and enable water managers to make effective decisions. In 2010 HydroNET won the innovation grant from the Dutch Ministry of Environment and Infrastructure for its openness and new way of cooperation via the waterapp store. This paper presents details on the HydroNET portal and experiences with the implementation of water, food and climate related applications in the Netherlands.

1. INTRODUCTION

Water is essential to society and nature. However, with both natural variability and anthropogenic climate change, the climate is changing. Long periods without rain can ruin crops or affect other functions that rely on fresh water supply. Also, extreme rainfall events can cause dangerous floods. Every year hundreds of thousands of people are affected by water related disasters. The water-, agricultural-, space- and geo-information sectors have joined forces to help countries with solving these climate related problems via HydroNET.

HydroNET is an online platform where information and knowledge from the water and earth-observation sectors are brought together and made easily accessible via web dashboards to private and public organizations in order to support water managers in adapting their water systems to climate change and improving their resilience in all weather conditions. HydroNET is Software as a Service (SaaS) solution that:

- connects the user to all relevant and available data sources in real-time
- translates the data into personalised and tailored information which is displayed on dashboards
- enables water managers to make effective decisions by providing smart applications which timely enhance insight and understanding of their systems.

HydroLogic started with the development of HydroNET in 2005. In 2013 more than 1000 water professionals from 160 organisations and 5 different countries regularly use the HydroNET solution for their water and environmental problems.

2. SAAS AND CLOUD SOLUTION

Some of the most important recent developments in ICT for hydrology are the Software as a Service (SaaS) paradigm and the cloud computing concept. SaaS means that software is fully running on servers operated and maintained by the developer, at their office or hosted at a dedicated datacenter. The software is offered to the client (and its users) via interactive web interfaces. Advantages of SaaS are numerous: no local installations of software and infrastructure at the client side is required; updates to the software can be implemented more quickly and for all clients and users simultaneously; all data is maintained and made available at a central place. Cloud computing provides networks of servers which are connected to share loads of traffic and computations. The interesting feature of "the cloud" is that it permits replication of services, using virtualisation technologies. This creates the possibility to have any number of servers available to the user on demand and increase the amount of computing power when needed, for example for uncertainty analysis (Xu et al., 2010).

The HydroNET framework consists of 4 components (Figure 1):

- The Data management layer which connects all relevant data sources to HydroNET.
- The Open Application Store (HyroStore) where any certified organisation can develop its own applications via an open application programming interface (API) and a service development kit (SDK).
- The HydroNET service bus and generic services the engine of the system, links the data with applications in a standardized way and takes care of key processes as security.
- The Water Control Room where each user receives personalised information and applications.

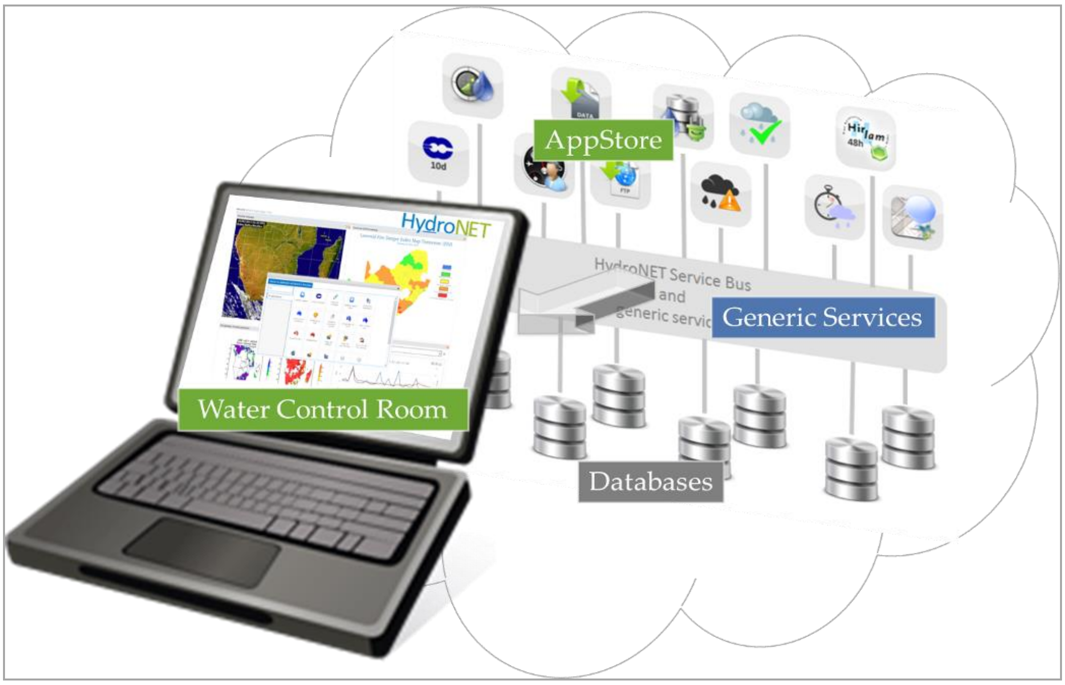

Figure 1. The 4 components of the HydroNET platform.

The data management layer of HydroNET offers of-the-shelf data connectors with web services to well-known commercial and open-source (geospatial) databases and data sources, such as: PostGIS database, PostGreSQL database, MS SQL database, NetCDF, Wiski & Soda, Delft FEWS and many others. The HydroNET data management layer is compliant with many open data protocols such as UMAQUO, Inspire, OGS, WaterML, OpenMI, WMS, WFS and WCS.

Within government institutes and authorities many functions exist, from the operational field worker to the manager. The different end-users need very different views on historic, actual and forecasted data. For that reason we have developed the personalised Water Control Room where user can create their own dashboards on a drag-and-drop based workspace. Selections, settings and preferences are stored for re-use when the user logs in again. HydroNET also provides automatic alerts via SMS text messages or email reports, in case thresholds for measured or forecasted precipitation are exceeded. *With the HydroNET Water Control Room (Figure 2): all end users have their own composition of information, right on their desktop, smart phone or tablet; available anytime and anywhere.*

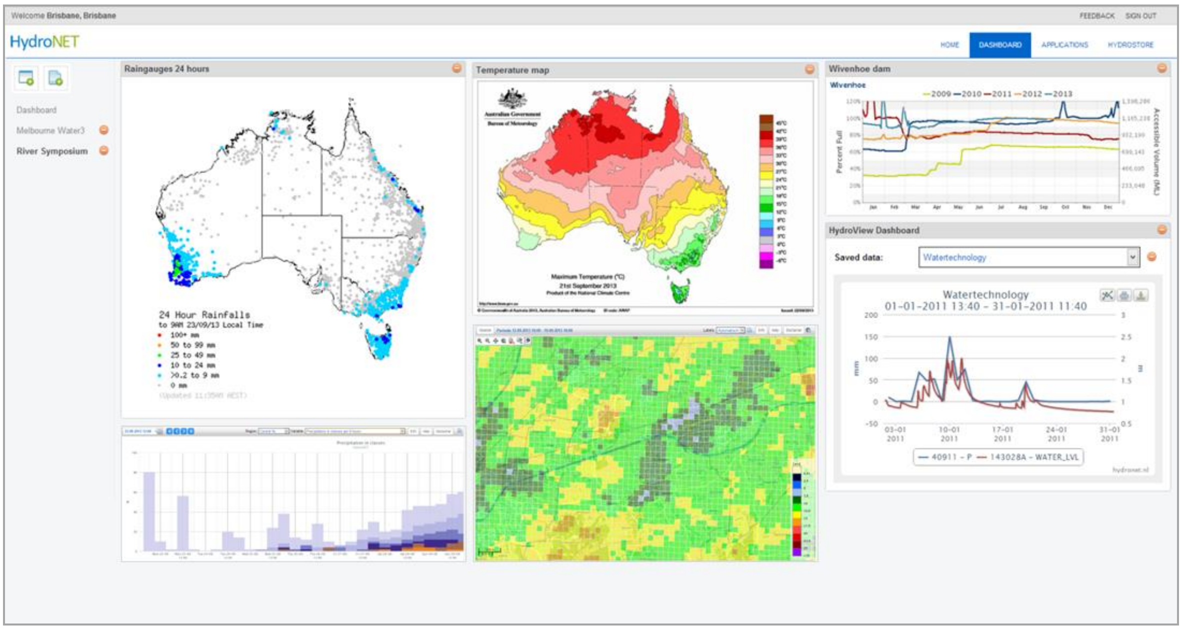

Figure 2. Personalised Water Control Room.

The HydroStore currently contains over 80 operational applications developed by the growing HydroNET consortium consisting of knowledge institutes, universities, IT and water companies. In 2013 the HydroNET approach won the Dutch National ICT Innovation Award (www.ictaward.nl) as a reward for the proven success of the SaaS solution and its international potential, working with industrial partners in the Netherlands and with local partners in different countries

3. CO-CREATION

Development of tailored decision support applications for water management requires profound knowledge of hydrology, meteorology, modeling, information and communication technology (ICT) and software development. Successful implementations of Decision Support Systems (DSS's) also require involvement of users in the process of defining functionalities, user interfaces and testing.

At HydroLogic the "DSDM Atern" approach is followed for this purpose (www.dsdm.org). Part of the approach is early interactive sessions with users to define what they exactly expect from the DSS (Figure 3). Key in the approach is a partner-network model and co-creation with stakeholders where the end users play a key role in defining user requirements, performing validation and testing of ideas. Partners are service providers, developers, researchers and re-sales organisations.

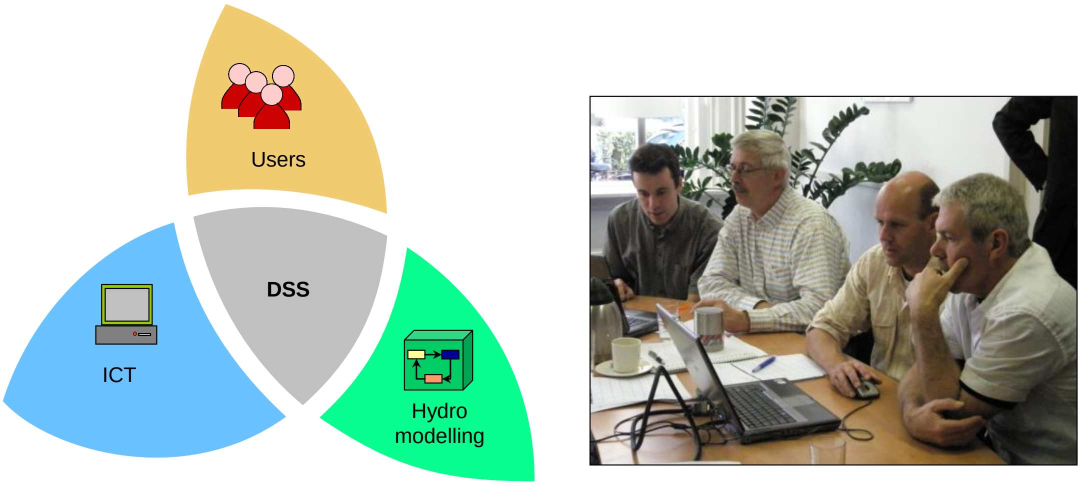

Figure 3. Successful implementation of a DSS requires integration of hydrology, modeling, ICT and close end user involvement (left). Co-creation with end users: brainstorming, sketches and content-wise discussions (right).

The HydroNET Approach for the demonstration and development of applications, as input for the Water Control Room, is shown in Figure 4. HydroNET is not a standard software package containing much more functionality than required by individual users. The HydroNET approach is different: the stepwise and tailor made approach leads to the development of personalised dashboards and applications based on the needs of the end-uers. Therefore the HydroNET Water Control Room looks different per customer.

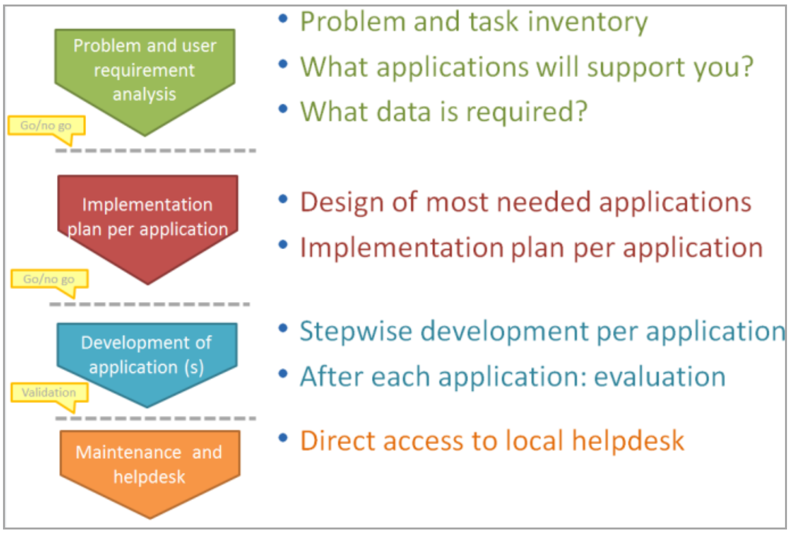

Figure 4. The HydroNET stepwise approach.

In the user requirement phase the focus lies on creating an inventory of the challenges and problems of the end-user and on the data needed to identify (or forecast), understand and alleviate these problems. In the Netherlands many organizations started with collecting as much data as possible before looking at their real problems and responsibilities. Now it appears that a significant portion of the collected and purchased data has never been used in practice. This situation can be avoided by first looking at the applications needed to solve your main challenges and customising the system and collecting the data accordingly.

The next step is to develop an implementation plan for each of the applications defined in cooperation with the end-user. If the required application does not already exist in the HydroStore, a technical design, functional design (mockup) and an estimation of development costs will be provided. Thanks to the existing HydroNET framework which is freely available, it is relatively cheap and easy to develop tailor made applications. The result of step 2 is a tailor made menu list of applications including an implementation plan.

In step 3 the applications with the highest priority/cost-benefit ratio are selected. These applications will be developed, validated, tested and delivered first. Every 3 weeks new functionality is available for testing on a beta portal. This way end-users have optimum control over the development process. It is our experience that during the testing phase user requirements can change. The HydroNET approach makes it possible to implement those new requirements in a both tailored and flexible way. We use the scrum software development methodology:
http://en.wikipedia.org/wiki/Scrum_(software_development)

The applications will be available via the HydroNET Portal. The results of the applications will be available in the personalized HydroNET Water Control Room which each user can set-up without any assistance within 10 minutes (based on the iGoogle approach). All applications are well maintained and we offer a 24/7 professional helpdesk to answer all questions.

4. A KEY COMPONENT: ACCURATE PRECIPITATION INFORMATION

A key component of the HydroNET applications is detailed and reliable precipitation information, both measurement and forecasts. Traditionally rain gauges are used for measuring precipitation. However, proper placement of rain gauges and the ongoing maintenance costs generally ends up being both challenging and costly. In The Netherlands, the Royal Dutch Meteorological Institute (KNMI) operates a dense network of daily rain gauges (approx. 325) and sub-hourly weather stations (30) which measure precipitation. This data is available to water managers at a very low cost. For use in hydrology however, an even denser network of rain gauges is required to fully capture the spatial and temporal variation in precipitation. On average for urban water management one rain gauge per e.g. 4 km^2 (proposed approach in the Netherlands) would be necessary and this presents enormous costs to municipalities.

From the mid 1970s onwards the availability of weather radars provides an opportunity to measure almost real-time rainfall intensities over a wide area at high spatial resolution. The KNMI also operates two of these weather radars, which generate several meteorological data products, of which one is the precipitation per 5 minute interval, on a 1 x 1 kilometer grid. However, there are some issues regarding the use of weather radar data, which need to be addressed before the high resolution spatial radar precipitation data can be used in a DSS for water management (Lobbrecht et al, 2011):

- The quality of uncorrected rainfall intensities from weather radar data alone is usually not good enough for hydrological water system analysis, because precipitation intensities are usually underestimated, depending on the weather conditions or the distance of an area from the radar.
- The radar data formats are not easy to use for water managers and the timing of delivery and the completeness of the radar data varies, due to variations in the process chain of the radar data.

The issue of data quality is overcome by combining radar data and rain gauge data. This is because the spatial variation (including relative magnitude) of precipitation can be quite well identified by weather radars and the precipitation quantities at a point (within the spatial radar variation) quite well estimated by rain gauges. The combination of radar and rain gauges yields optimal results. In The Netherlands the correction of radar data by rain gauges is executed using two methods. The first method is a mean-field bias (MFB) correction as described in Holleman (2007). This method calculates the mean difference between the 30 automatic KNMI rain gauges and the corresponding radar pixels. This mean difference is applied to each radar pixel within the radar image. The second method includes several corrections such as a bias correction, a distance correction and finally a spatial correction (Holleman, 2003). Figure 5 and 6 show the result of the correction process. In these figures precipitation measured at a radar pixel above a rain gauge is plotted against the precipitation measured at the rain gauge. The rain gauge data is independent i.e. the rain gauge records are not altered in the correction process.

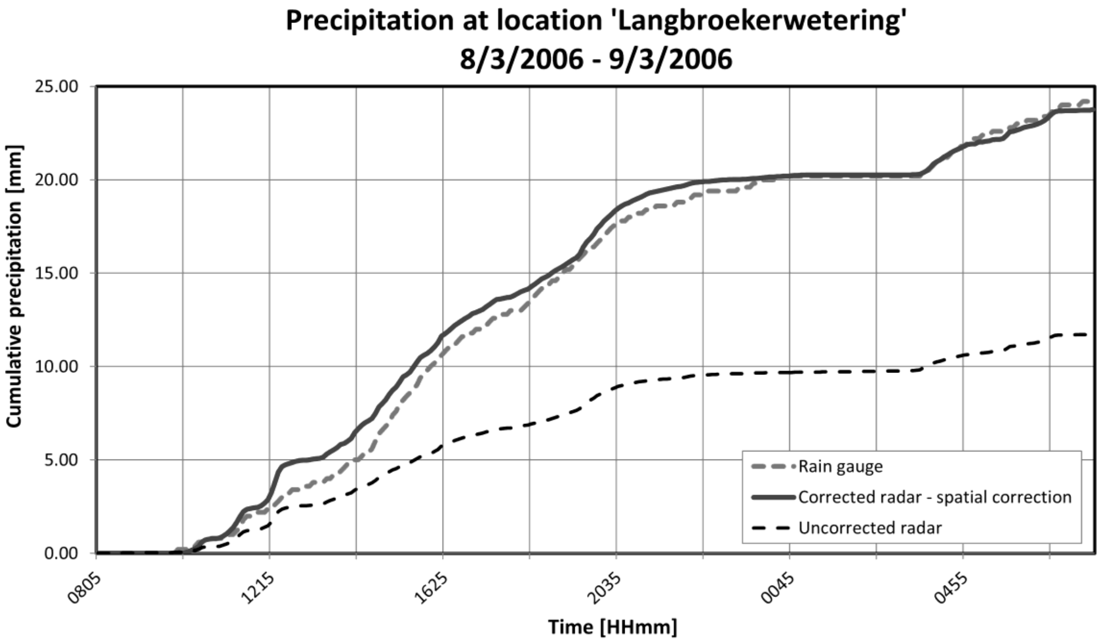

Figure 5. Uncorrected radar data, (independent) rain gauge data and corrected radar data on a five minute basis for a 24 hour rain event.

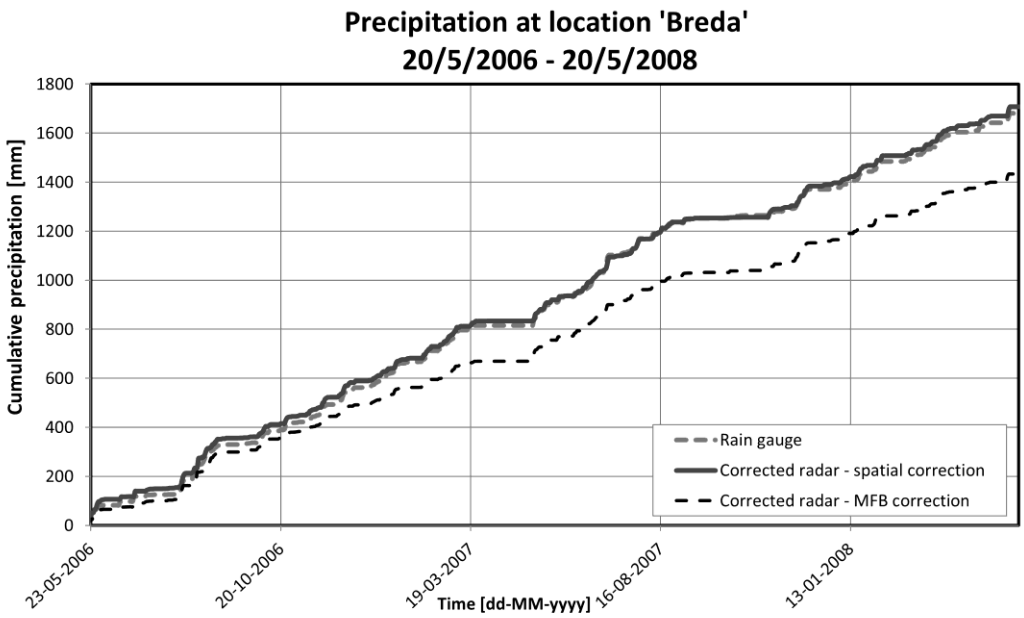

Figure 6. Cumulative precipitation at an independent rain gauge and at the corrected radar pixel above the rain gauge. Correction of radar data was done using a quick MFB correction and a full spatial correction.

The correction methods have been tested and verified at numerous locations situated in different parts of in The Netherlands and for numerous rain events (Einfalt et al, 2012). The correction methods described above have been applied in the HydroNET RainWatch (Figure 7) application which provides online access to radar-based rainfall information per square kilometer or within any area defined by the user who can upload shapefiles. These techniques clearly align with the requirements of both hydrologic models (which use sub-catchment polygons) and 2D rain on grid hydraulic models.

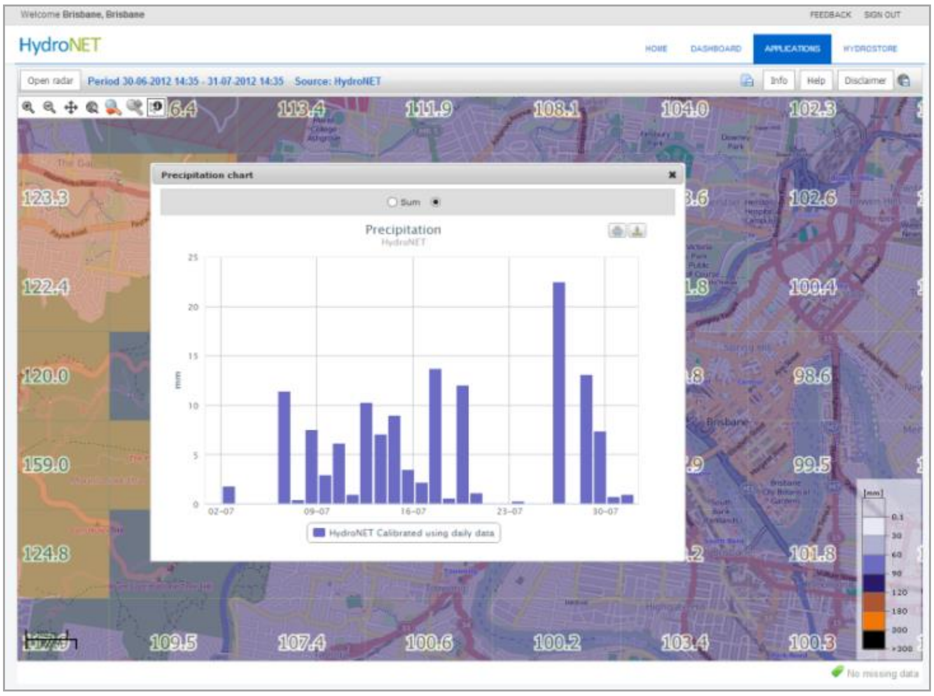

Figure 7. The RainWatch application provides live and historical rainfall information with a 5 minute interval and 1x1 km spatial resolution.

In HydroNET, measured precipitation can be extended with forecasted precipitation based on these numerical weather models. The Hirlam Numerical Weather Prediction model is used to gain insight into short term forecasted precipitation on a local scale (for example: per catchment or hydrological response unit).

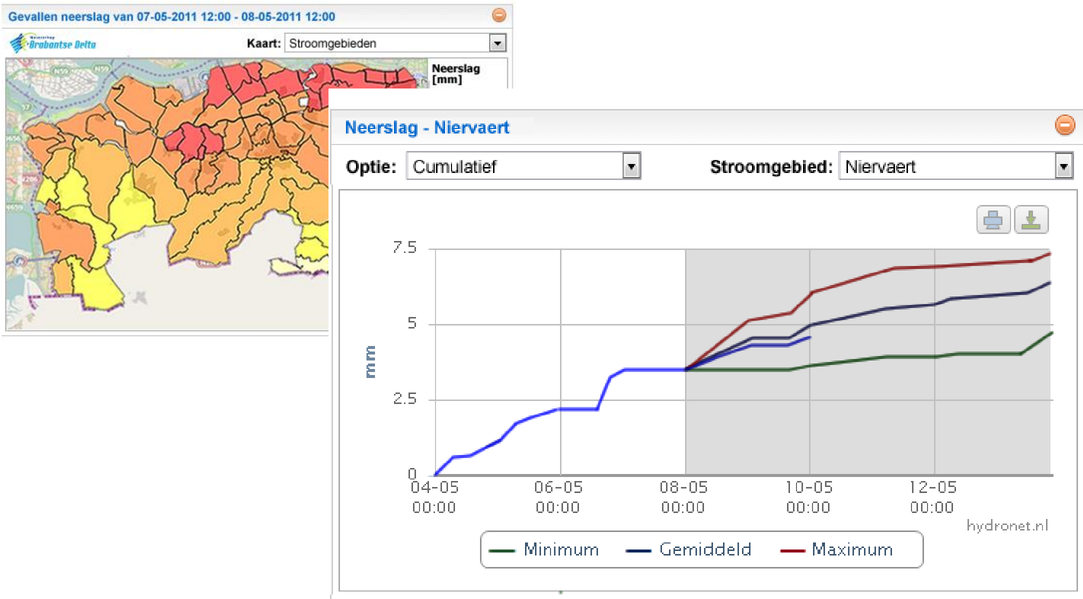

Figure 8. Web based dashboards for water board operational staff to gain insight into the spatial variation of the cumulative precipitation per catchment (top left). By clicking on a catchment, a graph (bottom right) is displayed with the measured precipitation by corrected radar (blue line) extended with precipitation forecasts (grey background) from the Hirlam and EPS numerical weather models including uncertainty band.

The ECMWF (European Centre for Medium-Range Weather Forecasts) EPS model is used for medium and long term precipitation forecasts and also provides insight into the uncertainty of the forecast. This uncertainty is translated into a minimum, average and maximum precipitation scenario, to enable operational water managers to prepare for possible more extreme situations. The combination of measured and forecasted precipitation supports operational water managers at water boards in their daily tasks.

5. CONCLUSIONS AND IMPLEMENTATION IN AUSTRALIA

Over 160 catchment management agencies, city councils and water institutes are using HydroNET Decision Support Systems (DSS) for day-to-day water management, water management under extreme conditions (drought and floods) and for strategic analysis of their water systems. These DSS range from information systems to enable the use of high-resolution and accurate hydrometeorological information in water management with software tools, to operational flood forecasting and management systems which use detailed models. Key innovations of the Dutch DSS are the use of reliable and accurate corrected radar precipitation data, the integration of both detailed deterministic and ensemble numerical weather forecasts, web based personalisable dashboards for water managers, the use of highly detailed hydrologic and hydrodynamic models for operational flood forecasting and the use of advanced ICT techniques such as HPC, SaaS and cloud.

HydroLogic and Water Technology have collaborated to bring the HydroNET platform to Australia. The HydroStore is operational with applications available for government, commercial and not for profit organizations. We invite interested parties to inspect the HydroNET website and HydroStore at www.hydronet.com.au

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