D4.5 Report

A platform prototype for early warning dissemination

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A platform prototype for early warning dissemination

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Abstract (for dissemination, 100 words)	This report on online tools and techniques for early warning systems (EWS) aims to assess and identify points of enhancement for methods used real-time flood forecasting and warning. It presents a review and analysis of methodologies for real-time coastal flood modelling. The various components of flood EWS's are identified, and possible enhancements for their use in fluvial, pluvial, and coastal flooding applications are discussed. In addition, state-of-the-art techniques for flood hazard mapping, which are widely used in EWS's, are identified and presented. The tools and techniques for real-time flood modelling and early warning discussed in the report are exemplified by a review of existing systems and demonstrated through detailed presentations of case study applications under the PEARL project.
Keywords	Real-time, early warning, dissemination, flood warning

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Disclaimer

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Summary

Within Pearl Task 4.5 a platform for Early Warning developed and implemented in Marbella Case Study. This document is the associated deliverable (D4.5) and contains an overview of the prototype platform that has been created within Pearl.

The report is formed by a general description of the system a paper describing the implementation in Marbella.

Contents

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Abbreviations/Acronyms

API	Application Programming Interface
CPU	Central Processing Unit
CSV	Comma Separated Values
DTM	Digital Terrain Model
EDXL	Emergency Data Exchange Language
EU	European Union
EWS	Early Warning Systems
IDL	Interactive Data Language
IWA	International Water Association
GIS	Geographic Information System
GPU	Graphics Processing Unit
PEARL	Preparing for Extreme And Rare events in coastaL regions
RED	Rainfall Event Data
WP4	Work Package 4

1 Introduction

Deliverable 4.5, the platform prototype for early warning dissemination, is a system developed using weather radar information, rain gauges and other sensors information in real time to feed a hydraulic model. Results might be explored through a web viewer and warnings received by email, SMS or EDXL-CAP messages connecting to the routing system developed in D4.4.

This work package aims to improve the state of art in flood forecasting and early warning for coastal areas across the whole chain of early warning from data to warning dissemination.

Technologies and systems are not submitted as code or software deliverables, rather as descriptions and highlights of the prototypes in this document.

The first part of the document describes the early warning system (which can be accessed by the PEARL main webpage), while the second presents the implementation on the Marbella case study through a paper presented in ICUD 2017 Conference (14th IWA/IAHR International Conference on Urban Drainage).

2 Platform for Early warning

The Early Warning System (EWS) developed by HYDS aims to (i) retrieve and process radar data and other sensors (rain gauges, stream levels, etc.), (ii) run a hydraulic model using available data (sensors and radar data), and (iii) calculate warnings using user-defined thresholds and disseminate them together with the generated products.

The EWS architecture is divided into different modules, each of them in charge of a specific task. Figure 1 presents the architecture of the EWS with the different modules.

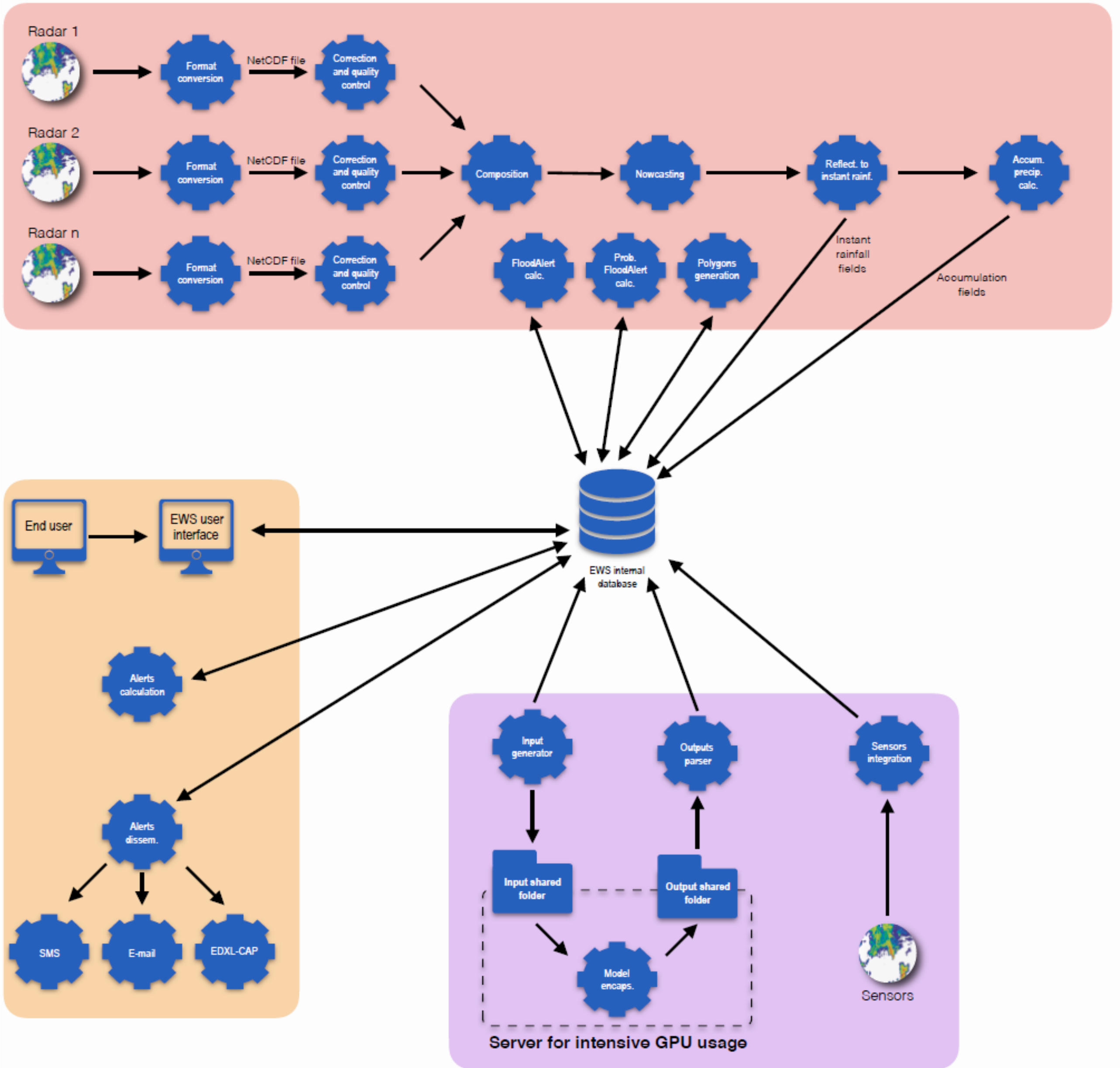

Figure 1 General architecture of the EWS. The red box covers all the processes done to generate all the products derived from radar data, the purple box contains the processes linked to run a hydraulic model, and the yellow box contains all the processes and tools focused on the warnings calculation and dissemination.

Rodriguez et al (2014) give a description of the system and the following sections provide a quick overview of the three big modules: radar processing, hydraulic modelling (focusing on the 1D/1D model integration using a GPU dedicated server), and early warning dissemination.

2.1 Radar rain products

Radar precipitation information is retrieved and processed in real time to quality correct it and obtain different quantitative products. Details of the process are described in Llort et al (2014).

2.2 Hydraulic model

2.2.1 Sensors integration

The developed EWS can integrate sensors from different sources. Sensors information is used for two purposes:

- To calculate and disseminate alerts using the thresholds defined by the user.
- As input to the hydraulic model, generating a raster field interpolating all the sensors. In this case, it is critical to have a dense number of sensors to generate an accurate precipitation field.

The sensors interpolation fields can also be used when no radar data is available or when its quality is low.

A program written in PHP reads the sensors data to insert it into the EWS internal database (see Rodriguez et al 2014). Since the input file format is supplier dependent, different data parsers have been implemented for each sensors supplier.

2.2.2 Hydraulic model

The hydraulic model chosen for the development of the EWS in the framework of PEARL has been the InfoWorks ICM.

General structure of InfoWorks encapsulation in the EWS

InfoWorks is composed of several components, but only some of them are used to run a hydraulic model in real time. Figure 2 presents these components and their interrelations.

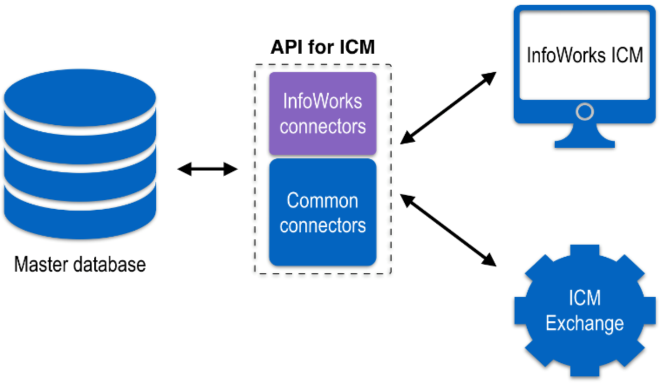

Figure 2 General schema of the elements composing the InfoWorks solution: master database, ICM API and ICM tools (InfoWorks ICM and ICMExchange).

The elements used to run the hydraulic model are:

- The master database: it contains all the model information: topology of the network, parameters, simulations, etc.
- A set of tools offered by ICM. In this context, only two tools are relevant:
    - InfoWorks ICM, a user interface program used to model the network, calibrate the different hydraulic models and simulate different scenarios. This tool was used in the first step to model and calibrate the topology of the network used to run the hydraulic model in real time.
    - ICM Exchange, an interface able to execute Ruby scripts that interacts with the master database. This tool is used to run in batch mode a 1D-2D hydraulic model in real time.

The ICM API provides all the procedures to connect to the master databases. This API contains two type of connectors:

- Common connectors that can be used by both InfoWorks ICM and ICM Exchange.
- InfoWorks connectors that can only be used by InfoWorks ICM.

In this framework, the steps to be done to run a specific hydraulic model are:

1. Generate the rainfall time series used by the hydraulic model as inputs.
2. Run the hydraulic model simulation.
3. Generate the simulation results.
4. Parse the results and store them.

In the case of InfoWorks, it is possible to make the calculations using the GPU instead of the CPU. Thus, a specific server has been prepared with a high-performance GPU in order to be able to compute the hydraulic model simulations in real time. This server is dedicated to this task; therefore,

the inputs and outputs of the hydraulic model are linked to another server, which contains the EWS. Figure 3 presents the general schema of both servers and the steps done to run a hydraulic model simulation.

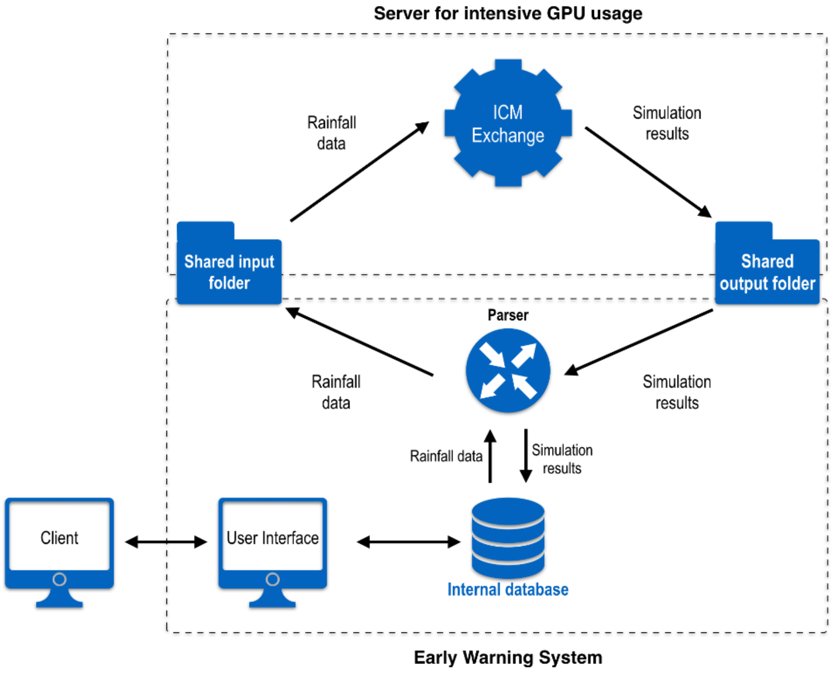

Figure 3 General schema of the process done to run a hydraulic model simulation in real time with the dedicated server with high GPU performance and the EWS.

The hydraulic model is fed by rainfall time series. In classical systems, the input is provided by rain gauges, which usually have some delays in sending the information. In order to predict in advance these floods in this case the hydraulic model has been also fed by radar rainfall fields and their nowcasting. Information supplied by radars usually have less delay than ground sensors (i.e. rain gauges), and their nowcasting provides a longer time interval, and thus the simulations will increase the time window for the future (see Rodriguez et al 2014). The system chooses at every time step the best information available to prepare a track of data, which will be the hydraulic model input. Figure 4 presents this approach with the different information available: In the past, a combination of rain gauges and radar observations is used while in the future radar nowcasting provides the rain information to the hydraulic model.

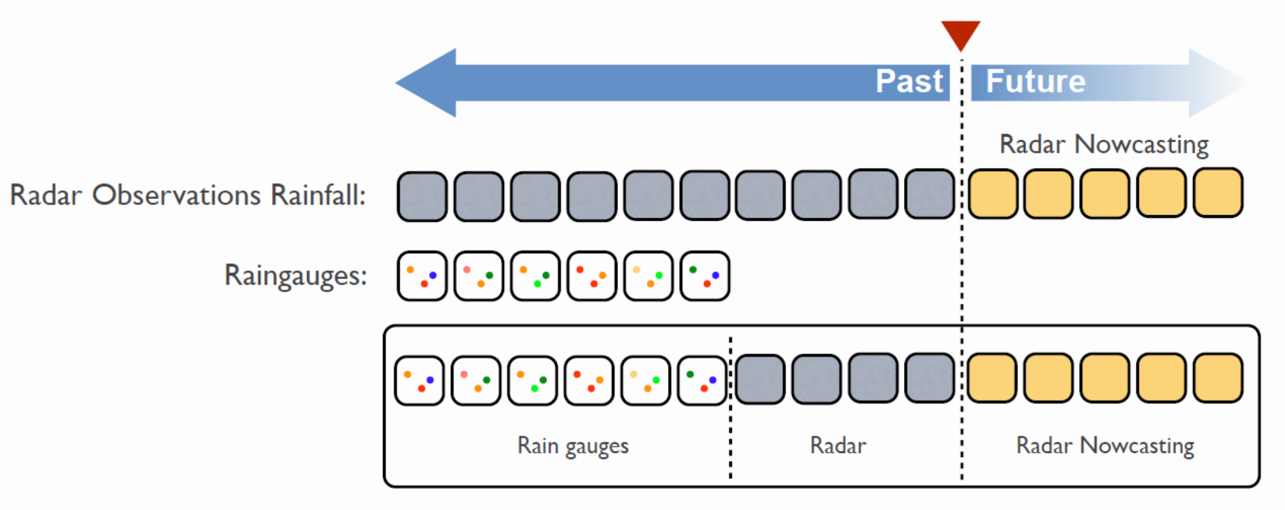

Figure 4 General schema of the hydraulic model input data with the different sources.

As previously said, ICM Exchange allows running a hydraulic model in batch mode. This allows the integration in real time to the EWS and the steps to be done for it are:

- Generate the rainfall time series in the appropriate format.
- Run the Ruby script that runs the hydraulic model for a given instant.
- Parse the results of the simulation.

Input data generation

InfoWorks can import rainfall data using Rainfall Event Data (RED) files, a specific format defined by InfoWorks. These files have a similar format to CSV files, and Ruby scripts use them in ICM Exchange to create time series in the master databases. A RED file example is provided in the following listing:

```
!Version=1,type=RED,encoding=MBCS
0201607070700
    1 07072016070000   600     2                 0.0   0.0      0.000      0.000
0.000                        0.000      0.000     0.0000        0.0POT
      0.00        0.0   0.0      0.000      0.000      0.000      0.000     0      0.000
0.000
PLUVIO1                                                                pluvio de prova
1
REGION=7,427768.083991,4584682.003345,428405.814325,4585785.104462,430852.333770
,4584561.844740,429257.598046,4583290.678583,428892.281173,4583355.913739,427850
.907642,4584383.402290,427768.083991,4584682.003345;LOCATION=429284.976259,45844
16.267709;
     1.000      1.000
      0.00        0.0   0.0      0.000      0.000      0.000      0.000     0      0.000
0.000
PLUVIO2                                                                PLUVIO2
REGION=10,430046.839354,4581686.489575,430083.711908,4581849.782312,432887.45013
```

```
4,4583784.756581,433477.475815,4583656.382792,433549.771237,4583164.217807,43370
6.277475,4582851.205331,433354.138440,4581970.857744,432258.594776,4580464.48520
6,430871.084793,4578442.684946,430046.839354,4581686.489575;LOCATION=431319.5573
49,4581677.408548;
     0.000     0.000
10.0000010.00000
10.0000010.00000
10.0000010.00000
10.0000010.00000
10.0000010.00000
10.0000010.00000
10.0000010.00000
10.0000010.00000
END
```

As seen in the previous example, the RED format is not strait forward to read or edit, therefore the easiest way to couple with the real time modification needed for ICMExchange is to create a template using InfoWorks ICM. To do so, using InfoWorks ICM a first dummy time series have been defined within the hydraulic model including all the rain gauges defined in the model and their parameters. Then, these time series were exported through InfoWorks ICM in RED format. Those time series are used as a template, modifying the fields that vary from one simulation to the other (dates and time series values).

A PHP program is in charge of acquiring the time series from sensors and radar data and then generates the rainfall time series in RED files using the template. The RED files are stored in a shared folder available by the high-performance GPU server, which will use them to run the different hydraulic model simulations in real time.

Ruby script

The simulation of a hydraulic model is done running a Ruby script with ICM Exchange. This script is in charge of:

- Create a new time series in the master database for the specific instant.
- Create a new simulation in the master database.
- Run the new simulation.
- Export the results.

The definition of a new rainfall time series in the master database is done creating a new object of type Rainfall Event. This object is initialized using the RED file created in the previous step. In order to reduce the amount of disk used by the hydraulic model, the model will have only the most recent time series instead of all the time series of the past simulations.

ICM Exchange can create, modify and run the different simulations (named Run in InfoWorks) defined in the master database. A simulation is composed by a network, several time series (of rainfall in this case), boundary conditions (e.g. inflows from river basins or other measurements), if any, and specific parameters of the simulation (start time, duration, time step, GPU usage, etc.).

The execution of a specific simulation and export of the results of this simulation is directly done using routines of the Run objects offered by ICM Exchange. These results can be exported in CSV or binary format. In this case, exports are done in CSV, since it is easier to parse this format. This export can be done only of some of the variables calculated (e.g. water velocity, depth, flow, etc.), of different type of elements (e.g. pipes, triangles of the 2D mesh, etc.) or of some specific elements of the network (e.g. one pipe of the network or one triangle that belongs to a critical point of the urban area). These filters allow reducing the amount of information generated and the processing time, since a CSV file is generated for each variable, and each of these files contains the time series of all the elements where this variable is simulated.

Simulation results parsing

As explained in the previous section, the Ruby script generates a CSV file for each variable we desire. In this case, the variables of interest are water depth, water velocity and flow. For each of these three variables, a CSV file is generated, and each of them contains the time series of the elements of the network specified when exporting. An example of a CSV file is provided in the following listing:

```
Time;            Seconds;  ANGELS00;    ANGELS01;    ANGELS02
31/01/2010 0:00;0;         0.00000;     0.00000;     0.00000
31/01/2010 0:05;300;       0.00000;     0.00000;     0.00000
31/01/2010 0:10;600;       0.00000;     0.00000;     0.00000
31/01/2010 0:15;900;       0.00000;     0.00000;     0.00000
31/01/2010 0:20;1200;      0.00000;     0.00000;     0.00000
31/01/2010 0:25;1500;      0.00000;     0.00000;     0.00000
31/01/2010 0:30;1800;      0.00000;     0.00000;     0.00000
31/01/2010 0:35;2100;      0.00000;     0.00000;     0.00000
31/01/2010 0:40;2400;      0.00000;     0.00000;     0.00000
31/01/2010 0:45;2700;      0.00000;     0.00000;     0.00000
31/01/2010 0:50;3000;      0.00000;     0.00000;     0.00000
31/01/2010 0:55;3300;      0.00000;     0.00000;     0.00000
31/01/2010 1:00;3600;      0.00000;     0.00000;     0.00000
31/01/2010 1:05;3900;      0.00000;     0.00000;     0.00000
31/01/2010 1:10;4200;      0.00000;     0.00000;     0.00000
31/01/2010 1:15;4500;      0.00000;     0.00000;     0.00000
31/01/2010 1:20;4800;      0.00000;     0.00000;     0.00000
31/01/2010 1:25;5100;      0.00000;     0.00000;     0.00000
31/01/2010 1:30;5400;      0.00000;     0.00000;     0.00000
31/01/2010 1:35;5700;      0.00000;     0.00000;     0.00000
31/01/2010 1:40;6000;      0.00000;     0.00000;     0.00000
31/01/2010 1:45;6300;      0.00000;     0.00000;     0.00000
31/01/2010 1:50;6600;      0.00000;     0.00000;     0.00000
31/01/2010 1:55;6900;      0.00000;     0.00000;     0.00000
31/01/2010 2:00;7200;      0.00000;     0.00000;     0.00000
31/01/2010 2:05;7500;      0.00000;     0.00000;     0.00000
31/01/2010 2:10;7800;      0.00000;     0.00000;     0.00000
31/01/2010 2:15;8100;      0.00000;     0.00000;     0.00000
31/01/2010 2:20;8400;      0.00000;     0.00000;     0.00000
31/01/2010 2:25;8700;      0.00000;     0.00000;     0.00000
31/01/2010 2:30;9000;      0.00000;     0.00000;     0.00000
```

In these files, the first column represents the date of the value calculated in the simulation, the second column represents the offset in seconds from the first value and the rest columns are the

time series of each selected element of the network. On the other hand, the first row of these CSV files is the header, indicating to what element of the network each column represents.

A PHP program has been created to read these CSV files with the simulation results. This program is in charge of reading the files and insert this information in the EWS internal database, in order to calculate alerts or present the information in the user interface.

2.3 Early warning dissemination systems

2.3.1 Early warnings calculation

EWS internal database

The EWS internal database stores and provides all the information acquired and generated within the EWS framework (see Rodriguez et al. 2014). The information available in the database can be raster fields (stored in files) or time series (stored in a PostGIS database). In addition, other parameters and information (alerts thresholds, points where alerts are calculated, etc.) are stored in the database. All the necessary connectors to store or retrieve information from the database have been developed to connect the different modules with it.

Alerts calculation

This module is in charge of calculating the alerts on every defined point for the given thresholds. It extracts the cell value from the rainfall or accumulated precipitation fields for the most recent prediction for the points, and compares the values with the defined thresholds. In case the values are over the thresholds, the module stores the alert in the internal database.

The module is divided into two programs. First, a PHP program retrieves from the database the time series values, the points where alerts should be calculated and the thresholds defined for these points. Then, the PHP program runs an IDL program, which massively calculates the alerts and stores the alerts in a CSV file. This calculation is done in IDL because the computation time is much lower in IDL than other tested languages. The last step (done again by the PHP program) is to parse the alerts from the CSV to store them in the EWS internal database.

2.3.2 Early warnings dissemination

Alerts dissemination

The alerts dissemination is done through a PHP program, which reads from the EWS internal database the current alerts and devices and sends the messages to the devices if necessary. It also checks when the last message was sent to each device to not repeat the same alert message in a small time period. The module also stores the list of messages sent in the historical database for management purposes.

The dissemination devices can be:

- Email. An email with the warning information is disseminated.
- SMS. A SMS is sent to the mobile.

- EDXL-CAP. An EDXL-CAP message is sent to the routing system. In this case, the SATWAYS routing system developed in D4.4.

User interface

This module presents the visual interaction between the EWS and the end-user. The user interface consists of a web application where information is presented in georeferenced maps and time series are displayed in charts. It also allows configuring the alerts thresholds and devices where alerts will be sent (mobiles, emails and EDXL-CAP).

The web application is developed under the Symfony PHP framework. Other technologies used by the web application are JavaScript, jQuery, jQueryUI, CSS3, flot (for time series visualization) and OpenLayers (for maps visualization).

3 Case Studies

The implementation of the Early Warning System in the Marbella Case Study is shown through a paper presented at the ICUD 2017 Conference (14th IWA/IAHR International Conference on Urban Drainage).

Advanced urban flood EWS integrating radar nowcasting and 1D/2D modelling in real time

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Summary

Urban real time flood's Early Warning Systems (EWS) have been traditionally based on the use of rain gauges' observations to model the sewer network's behaviour by means of hydraulic models. A key issue in the EWS implemented in urban areas is the lead-time in detecting potential hazards. The Cloud system presented in this paper takes advantage of radar nowcasting techniques and software and hardware advances to feed a detailed hydrologic and hydraulic 1D/2D model (using GPUs), not only with observed precipitation by rain gauges, but also with forecasted precipitation for the following few hours. The warnings/information issued by the EWS can be spread through the viewer, email and SMS.

Keywords

EWS (Early Warning System), floods, hazard maps, meteorological radar, nowcasting, 1D/2D hydraulic model

Introduction

In the last decades, Europe has suffered severe flood events that produced enormous damages in several countries. From the floods of the River Elbe in Germany in 2002, to the floods in the Côte d'Azur (Nice, Cannes, etc.) in October 2015, there were numerous other flood events (many times combining pluvial and fluvial floods) producing a large number of deaths and significant economic losses. Nevertheless the positive trend in the number of floods in Europe, as well as the associated economic impacts, is not accompanied by a similar trend in terms of human fatalities as reported by the International Disaster Database (CRED, 2013). This could be explained by the massive implementation, in the last years of effective Early Warning System (EWS) to prevent or reduce flooding impacts. As known, risk can be understood as the combination of hazard and vulnerability factors. EWS allows risk reduction helping to manage active systems in rural and urban areas. In this last case, optimum management of active systems (like sewer gates, tanks, valves, pumps, etc.) on the basis of real time rainfall predictions can reduce drastically the potential hazard due to heavy storm events.

On the other hand, vulnerability must be understood as the combination of the three factors exposure, sensitivity and resilience. The implementation of EWS can drastically reduce exposure of people and assets and increase systems resilience limiting significantly the impacts produced by flooding.

Radar precipitation estimates suffer from different sources of errors, but they may be the quickest way to obtain reliable rainfall predictions that may occur in the forthcoming few hours by means of radar-based nowcasting. On top, the good spatial representation of the precipitation and the high temporal resolution make them a valuable instrument for feeding urban hydraulic models. The use of these estimations in real time in automatic simulations of urban drainage 1D/2D models is, nowadays, one of the most important tools to assess the potential impacts of heavy storm events in urban areas. Recent hardware advances mainly based on the use of parallel processing of CPUs and fast GPUs reduces drastically the computation times and allow the integration of the radar nowcasting and urban drainage coupled models for their use in real time.

Methods

Radar observations and nowcasting

Traditionally, rain gauges have been the tools used for precipitation recording and estimates. They provide a real measurement of precipitation in specific points of the basins, but the lack of spatial representation do not permit their use for an early warning in an urban area where the hydrologic response of the basin is usually extremely short.

On the other hand, radar precipitation estimates solve the problem of rainfall spatial variability, but suffer from different error sources (Zawadzki, 1984) that must be considered in an accurate quality control processing of the observations (Sánchez-Diezma, 2001). This processing is focused on the correction of non-meteorological echoes, correction for underestimation because of beam blockages, conversion from reflectivity to instant rainfall using a climatological Z-R relationship and calibration.

After the quality control, short-term radar based nowcasting is calculated (Berenguer et al., 2011), which allow forecasting the precipitation with a high degree of accuracy and increase the leadtime in detecting potential risks. Forecasting skills of radar nowcasting decay quickly, but it is the best precipitation forecasting available for the next 1-6 hours, and rapid update of these technique allows keeping the forecasting updated with the last observations information (~10 min).

When instantaneous radar observations and nowcasting are available, the developed EWS calculates 30-minutes accumulation (using a moving window scheme) in an intelligent dynamic area that changes with the precipitation direction and speed (Llort et al., 2014). Once the 30 minutes precipitations accumulations are available, it is calculated the maximum value in the following 1-2 hours for each pixel, so the areas forecasted to have accumulations over predefined thresholds can be delimited. The Fig. 1 resume this explanation.

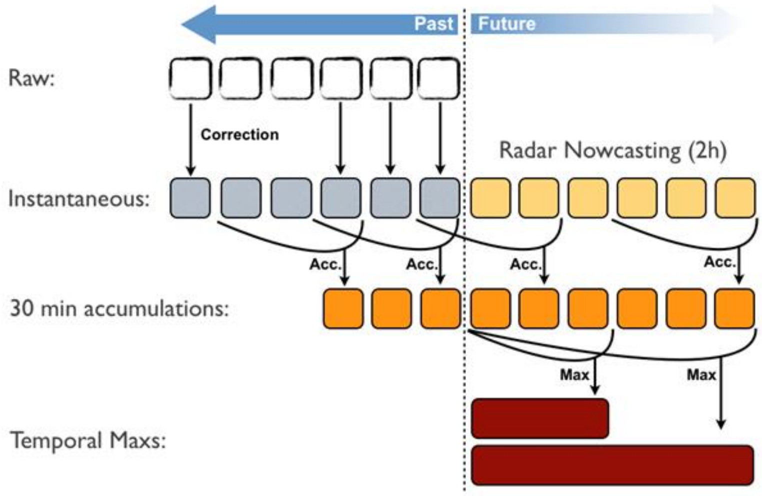

Fig. 1. Radar data flux scheme. The vertical dashed line divides past and future. Red boxes represent the forecasted maximum for each location in the next 1h /2h.

Integration of radar nowcasting and 1D/2D urban drainage model

These precipitation estimates can be used to feed detailed hydrodynamic 1D/2D coupled models able to integrate 1D sewer system flow and 2D overland flow simulations. These type of models provide detailed information on the 2D surface domain where hazard maps can be developed in order to assess the flood impacts on people activities (i. e. pedestrian and vehicular circulation) and on goods and properties. Recent hardware advances allow the creation of hydrodynamic models capable of fully exploiting GPUs and multiple-core CPUs with very promising performance in terms of computational time (Russo et al., 2015). So this kind of models can run automatically on the bases of inputs in terms of precipitations provided by radar nowcasting tool providing flow information in sewers and the 2D domain in very few minutes.

Hydraulic/hydrological model

In the framework of the PEARL project, a 1D/2D coupled model has been developed and calibrated for the Represa catchment in Marbella. The city has 140,744 inhabitants (according to the Spanish Statistical Office in 2016) in the south Mediterranean coast in Spain. It is characterized by a significant slope gradient on the upper part of the basin and the very flat area close to the sea.

The software used was Inforworks ICM by Innovyze (2016) and covers 10.6 km^2 of the municipality land (the Represa catchment) involving 68 km of sewers. A 2D unstructured mesh with 93,699 cells, which was generated by the Shewchuk triangle meshing functionality of the software (Shewchuck, 1998), was created on the basis of a detailed digital terrain model (DTM). The DTM has a 2 m^2 resolution and was generated by a LIDAR provided by the National Geographic Institute of Spain (minimum density of 0.5 points/m^2 and a precision of 20 cm in terms of ground elevation). The model has been calibrated through a set of sensors installed upstream (38) and downstream (39) of the Huelo's river connection to the Represa channel (Fig. 2) and through observation of local flooding on the surface (Fig. 3).

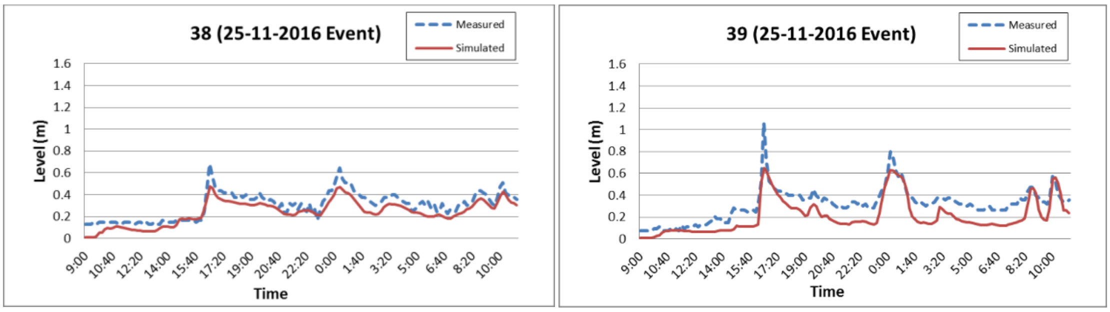

Fig. 2. Results of the calibration in the two points of the Represa channel (25th November 2016).

Fig. 3. Hydraulic model surface calibration based on field observations (25th November 2016).

This model has been finally used for the elaboration of flood and hazard maps for pedestrian and vehicles circulation (Fig. 4). It is a common understanding in urban drainage field that hazard can be assessed taking into account two specific flow parameters: water depth (y) and velocity (v). In recent experimental studies focused on urban flooding commonly characterized by low flow depths and high velocities, hazard levels have been established (Martínez-Gomariz et al., 2016; 2017). Specifically high hazard conditions for pedestrian were defined beyond the product (v·y) = 0.22 m^2/s, depth > 0.15 m and velocity > 1.88 m/s, while for vehicular circulation high hazard conditions are defined beyond the product (v·y) = 0.50 m^2/s, depth > 0.28 m. Hazard maps for return periods of 1, 10, 20, 50 and 100 years were elaborated in the framework of the project.

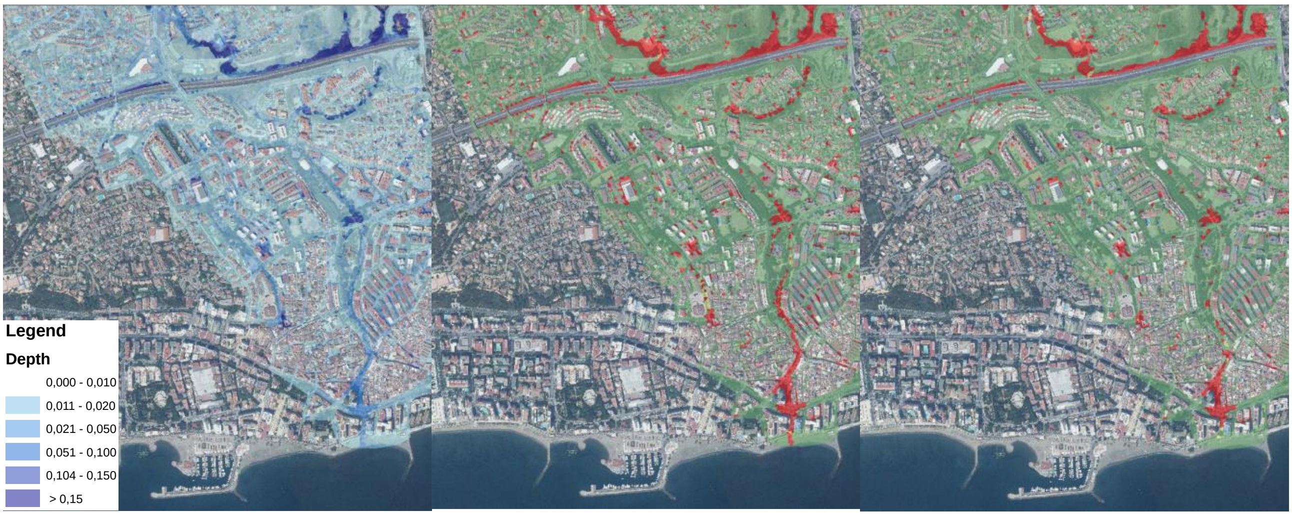

Fig. 4. Flooding map (left), pedestrian hazard map (centre) and vehicular hazard map (right), for an event with a 100 years return period. High hazard conditions are shown in red.

Results and Discussions

Implementation of EWS

The elements explained above have been implemented together in a modular system running in the Cloud. The user does not need software or hardware installed on their premises and can access the information (protected in several layers) from anywhere with Internet access. The principal modules of the system (see Fig. 5 for a schema) are:

(1) Data acquisition module: It acquires data in real time (radar, sensors, etc.) for its use.

(2) Raw data processing: It makes a quality control of raw data, mainly focused on radar precipitation estimates quality control (see radar observations section) but also time series data.

(3) Advanced product generation module: It calculates advanced products based on quality controlled data. The two main products used in the EWS are the radar nowcasting (short term forecast) and the radar precipitation accumulation fields.

(4) Hydraulic/Hydrologic model simulation module: it integrates the developed 1D/2D model. The model was implemented at two levels:

    (i) Link dynamically (according to return period, for example) the real-time precipitation information observed and forecasted with high-resolution pre-calculated hazard maps. In this case, the hazard maps are static and correspond to specific pre-calculated situations.

    (ii) Encapsulated in Cloud and run automatically every time that is available (radar observations, radar nowcasting and rain gauges' observations). The model has been allocated in a dedicated server with a high-performance GPU to allow for fast simulations needed in this real time application, and linked with the EWS through shared folders, format translators and automatic launch system (see Fig. 6 for a schema).

(5) Warning calculation module: It calculates the user specific warnings over different available products (precipitation data, sewer system elements, sensors, model simulations (both 1D and 2D elements, etc.) using user parameterizations (critical elements, thresholds, etc.).

(6) Dissemination module: It spreads the information and warnings through the defined channels (the web-based viewers –see next section–, SCADA connections, email, SMS, etc.). The user can define the actions to be done when reaching the different thresholds, according to the specific profile assigned.

(7) Monitoring module: In charge of the control of the system itself.

The system also stores recent information which can be consulted later, allowing to analyse events' information and warnings issued once an episode is over.

The Cloud performance presents clear advantages in terms of accessibility, operation and maintenance costs. In addition, the software allows for faster implementations and upgrades.

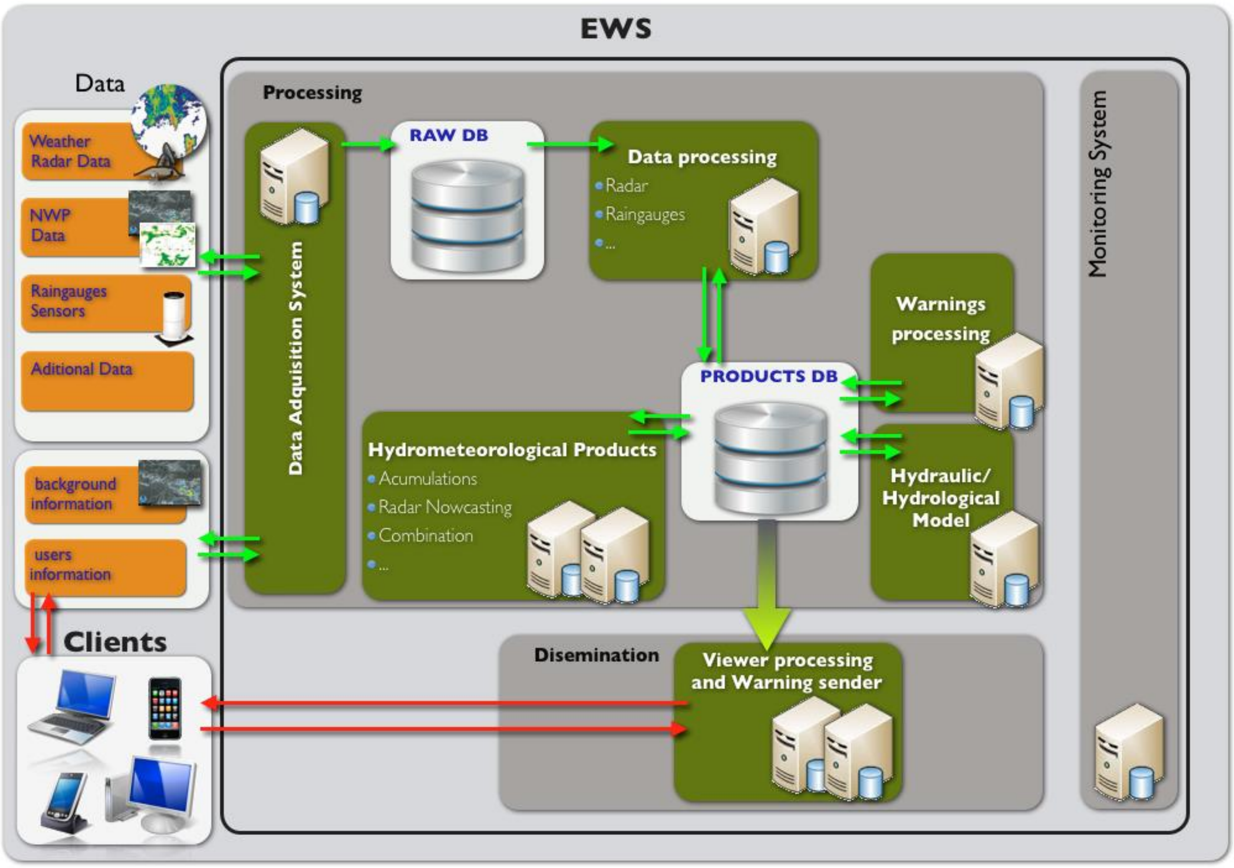

Fig. 5. The modular structure of the developed system.

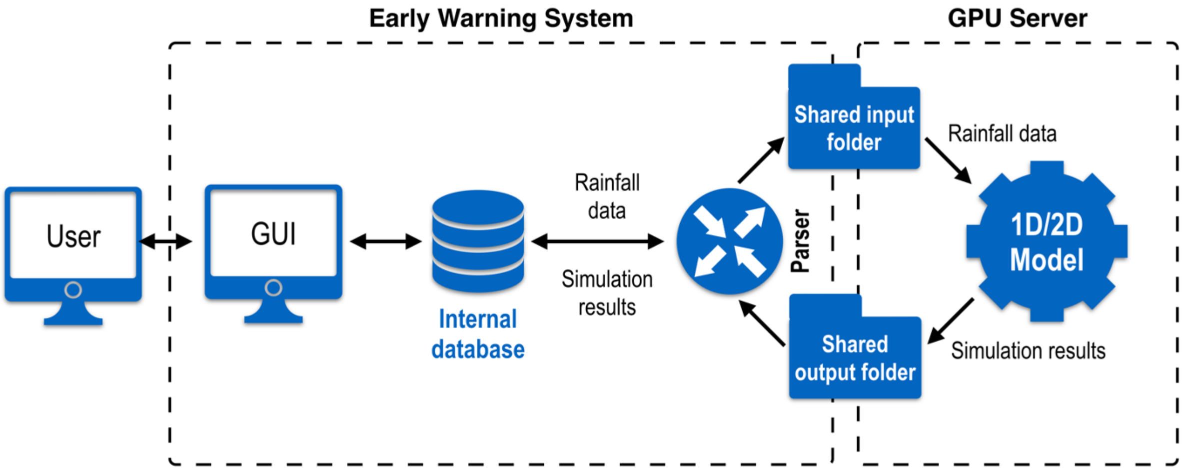

Fig. 6. Schema of the link between the EWS and the encapsulated 1D/2D model allocated in a dedicated GPU server when running in real-time.

Web-based platform

As the system has been developed in Cloud, users do not need any hardware or software on their premises and can access the information from any device connected to the Internet through a web

browser. The EWS allow the configuration of the different parameters and warnings also through the same web platform.

The viewer dynamically displays geo-referenced information (see an example of measured 24h rain accumulation in Fig. 7), in all the points of interest defined by the user. Among this information the user can explore the observed and predicted rainfall data, sensors data, simulation results of the model and corresponding generated warnings. Moreover the user can manage the information and account parameters like the individual thresholds for different products in different points of interest, warning devices, user profiles, triggered actions once the different warnings thresholds achieved, etc.

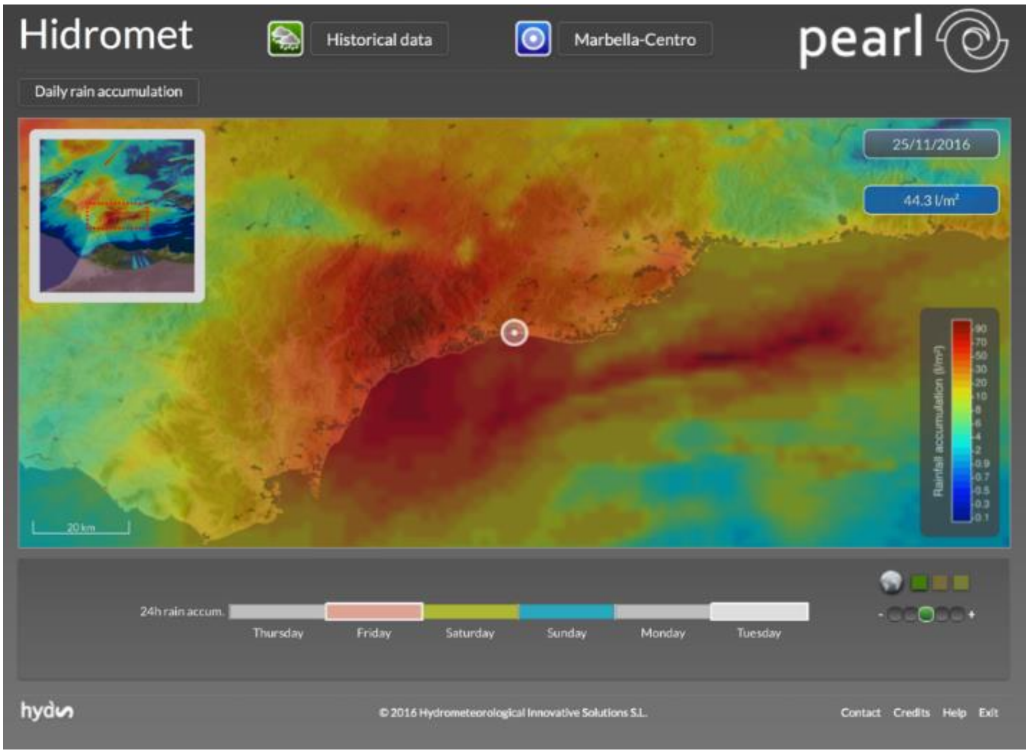

Fig. 7. EWS viewer example.

Warnings

A warning is issued when the predicted values exceed the thresholds previously configured. The system allows for three threshold levels (yellow, orange and red) individually configurable for each variable and point of interest. Examples of generated warnings are:

- Rainfall intensity or 30-minutes accumulated rainfall: they are based on observations and nowcasting for the next two hours.
- 1-hour accumulated rainfall: it is based on meteorological numeric models of prediction for the next 6 days. Other meteorological variables are also available.
- Sensors data: Based on sensors recorded data.
- 1D/2D model simulations: warnings for defined elements of the models (manholes, conduits, tanks, surfaces cells, etc.).

Dissemination

Information and alerts generated by the system are being delivered through the flexible and powerful dissemination module. It permits the configuration of different devices (emails, SMS, FTP servers, EDXL-CAP, etc.) according to diverse profiles of users (e.g., standards, 24h, weekends, emergencies, etc.) and the actions associated with the defined thresholds individually.

Conclusions

A flood EWS is based on different components. These components start from flood detection and forecasting to the timely, reliable and understandable disclosure of warning messages to authorities and population at risk.

The high temporal and spatial resolution of the radar observations, and the short-term forecast are valuable assets for urban flood EWS where response times are short.

Under the PEARL project framework (focused on The Represa catchment, Marbella), radar nowcasting and a numeric dual drainage model have been linked. The use of GPUs allows linking precipitation data with 1D/2D hydraulic modelling in real time.

The system developed is a Cloud system and can integrate the coupled model at two levels:

1. Link dynamically the real-time precipitation information and high-resolution pre-calculated maps.
2. Encapsulate the model in Cloud (using a dedicated server with a high-performance GPU) where it is run with updated observed or nowcasting data every time they are available. In this case, the model can generate hazard maps in real time for pedestrian and vehicular circulation that can be used for dissemination or warning protocol start up.

Acknowledgement

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4 Summary

A platform prototype for early warning dissemination has beeen developed. The platform will is an early warning and alerting generator module based on EDXL-CAP, and it has been tested on the Marbella (ES) case study.

The report has outlined the online tools and techniques for early warning systems (EWS), and is has assessed and identified points of enhancement for methods used real-time flood forecasting and warning, e.g. by identifying the various components of flood EWS's. A flood EWS is based on different components. These components start with flood detection and forecasting to the timely, reliable and understandable disclosure of warning messages to authorities and population at risk.

In the presented EWS, the high temporal and spatial resolution of the radar observations, and the short-term forecast are valuable assets for urban flood EWS where response times are short.

Under the PEARL project framework (focused on The Represa catchment, Marbella), radar nowcasting and a numeric dual drainage model have been linked. The use of GPUs allows linking precipitation data with 1D/2D hydraulic modelling in real time.

The system developed is a Cloud system and can integrate the coupled model at two levels:

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