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HIDROMET: A CLOUD-BASED EWS PLATFORM FOR REAL TIME URBAN FLOOD WARNING

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In this paper we present Hidromet, an Early Warning System [EWS] for real time urban flood warning based on radar nowcasting techniques. Hidromet runs in the cloud a hydraulic/hydrological model with radar, rain gauges and other sensors information, allows configuring warnings over different elements and actions to be triggered when the different warning levels are reached.

INTRODUCTION

Urban real time flood's Early Warning Systems have been traditionally based on the use of punctual precipitation observations (rain gauges) to model the sewer network's behavior by means of hydraulic models. Since a key issue in the EWS is the leadtime in detecting potential risks, Hidromet takes advantage of radar nowcasting techniques to feed a hydraulic model, not only with observed precipitation by rain gauges, but also with forecasted precipitation for the following few hours.

Radar nowcasting techniques allow forecasting the precipitation with a high degree of accuracy. This fact, together with the rapid update of the forecasts (typically around 10 minutes), makes radars a good tool for urban real time hydraulics allowing for more accurate results and to increase the leadtime in which potential risks are detected.

In Hidromet, the hydraulic (or hydrological) model is encapsulated in the *cloud*, and run with updated data (observations and forecasts) every time those are available. The network's operators are able to configure the critical points in the sewer network to be monitored, and define individually the warning thresholds. Sensors data have also been integrated seamless in the system.

The access to the platform is web-based and protected under different levels of passwords. Therefore it is fully accessible from any connected device and access is not limited to specific computers with software installed. The web also allows informing the users when the different warning levels are reached through different devices (SMSs, emails, etc.) defined under profiles.

Up to now, the platform has been validated in several cities of Spain and is under implementation in Chile.

RADAR PRECIPITATION ESTIMATES AND NOWCASTING

The traditional instrument to estimate precipitation has been the rain gauge. Rain gauges provide real measurement of the precipitation at given points, but the lack of spatial representativeness of these punctual measurement plus the fact that cannot provide a precipitation forecast make them limited for real time early warning of flood hazard situations.

Hidromet takes advantage of both rain gauges measurements (direct measurements) and radar observations (precipitation spatial representation) to run a hydraulic/hydrological model.

Radar rainfall observations

Radar precipitation estimates provide a good representation of the precipitation field from a centralized point of measurement and have a quick update time (usually ~10 minutes).

Nevertheless, radar observations are not free of errors (see for reference Zawadzki [1]). Therefore an accurate processing of the observations is needed before the hydraulical/hydrological use of its measures (Sánchez-Diezma [2]). Here in Hidromet a statistical calibration of radar reflectivity estimations, correction of non-meteorological echoes, correction for underestimation due to beam blockages (interaction of the radar measurement process with the topography and other elements) and conversion from reflectivity to instant rainfall using a climatological Z-R relationship is done before using radar observations.

Radar Nowcasting

Radar nowcasting techniques use cross-correlation techniques to estimate the precipitation field movement from the last radar observations (see Berenguer *et al.* [3]). Using this motion field, the last observation is advected into the future to provide a precipitation forecast (radar nowcasting). Figure 1 shows a graphical example of radar nowcasting.

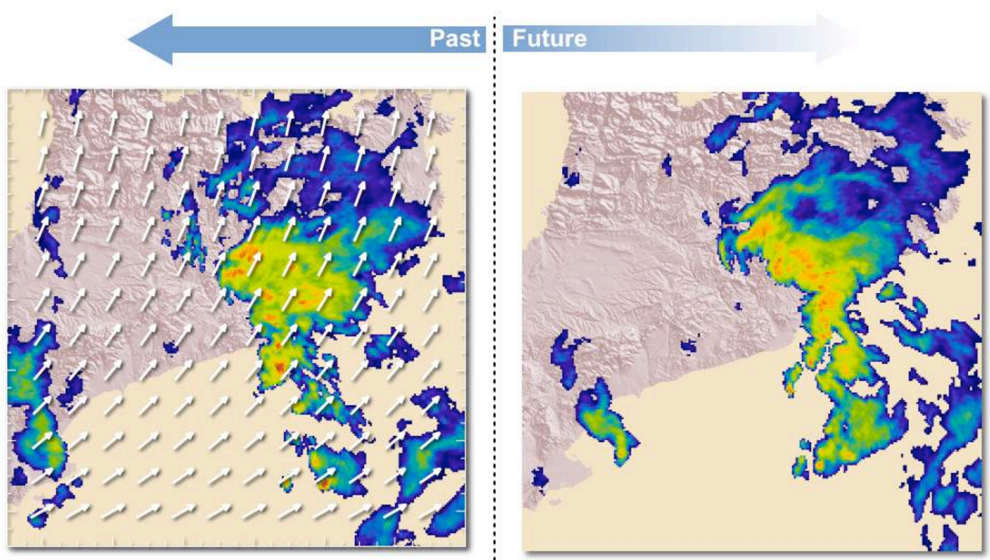

Figure 1. Radar nowcasting schema. Last observations (left panel) are used to calculate the precipitation motion field (arrows on left panel), which is used to extrapolate last observations to the future (right).

Radar nowcasting techniques cannot be used to calculate long-term forecasts (nowcasting skills decay quickly) but provide the best available forecast for the next 1-6 hours (depending on precipitation type, radar coverage and other factors). The rapid radar observations update frequency plus the low computational cost of nowcasting techniques allow recalculating the precipitation forecast every time that new observations are available, keeping the quality of the forecasts.

HIDROMET SYSTEM

Hidromet is a modular system running in the *cloud* (see Figure 2 for a schema of Hidromet modules). The principal modules are:

- **Data acquisition module**: It acquires radar in real time (radar, sensors, etc.) and stores it in a raw database. It also acquires specific user information (critical points, warning thresholds, etc.).
- **Raw data processing**: It processes raw data (quality control) and stores processed data into a products database. In the case of radar data is a delicate and time-consuming process. For sensors measurements a gap filling process is done when possible.
- **Advanced products generation module**: It calculates advanced products based on quality controlled data: Radar nowcasting, radar precipitation accumulations, etc. It stores the results in the same products database.
- **Hydraulic/Hydrologic model simulation module:** It runs the hydraulic/hydrologic model with the available data (radar, radar nowcasting, rain gauges, etc.). Model simulations are stored in the products database.
- **Warning calculation module:** It calculates the user specific warnings over the different available products (radar precipitation accumulations, rain gauges data, sewer system elements, other sensors, model simulations, etc.) using user parameterizations (critical elements, thresholds, etc.).
- **Dissemination module**: It disseminates the system information using web-based viewers (accessible by any device connected to internet and protected by different levels of passwords) and other channels (SMS messages, emails, SCADA connections, etc.). The user can define specific profiles and the actions to be triggered when reaching the different thresholds.
- **Monitoring module**. In charge of monitoring the performance of the full system: cuts in data acquisition, correct processing of data and generation of products, etc.

The system modules are complemented with utilities to help the users improve both, the models performance and the response in critical situations:

- **Historical utility**. Hidromet will store recent information to be analyzed once an episode is over. This allows the user to review the performance of Hidromet, the reliability of the model simulations and evaluate the decisions taken.
- **Episode utility**. Together with the historical utility, interesting past episodes will be included on Hidromet to compare recent results with past episodes' already defined. This utility is also interesting to analyze how Hidromet worked in special case studies.

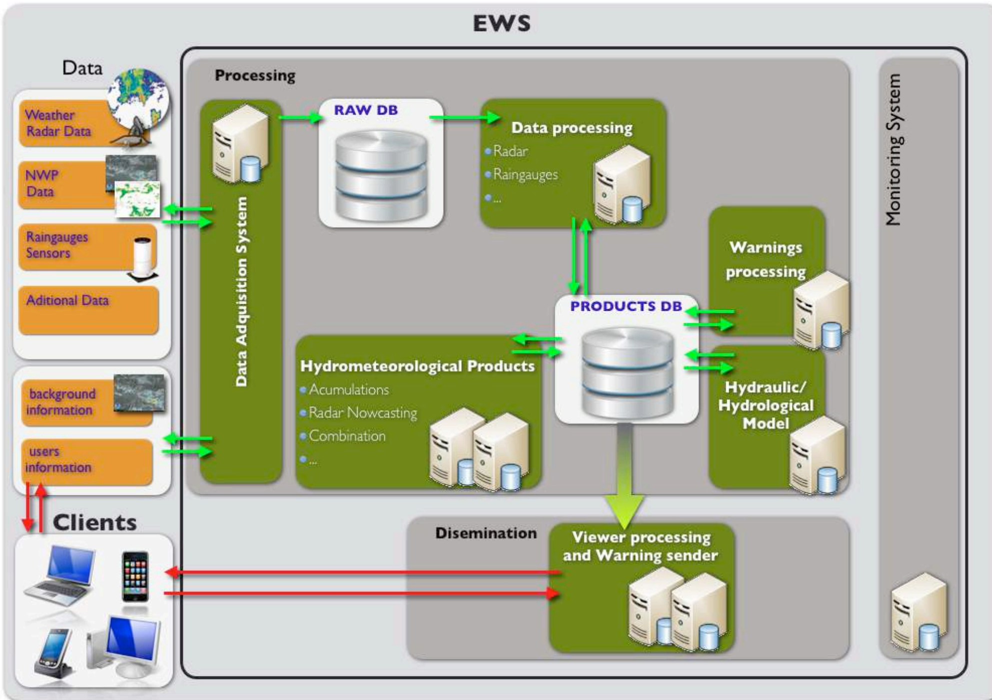

Figure 2. Hidromet system scheme.

Traditionally, EWS like Hidromet were installed in the client facilities, but current technological advancements, together with the massive use of devices with Internet connection, allowed for cloud systems accessible through web services.

In those cloud EWS, the user sends its particular data (specific sensors that might have) in real time to the platform, and those are integrated into the processing with the other generic data. The user connects to the system through Internet by any device and has access, not only to his own data, but also to a brunch of products and warnings that can be configured in the same web application. This change of paradigm allows for:

- Accessing the system from any device connected to Internet.
- Cost reduction related with equipment needed and through sharing common processes between different users (for instance, the radar data processing).
- No maintenance of the system is needed by the end-user, since the system is in the cloud and no local processes are needed.
- Automatic update of new features (or improved processing algorithms).
- Really short implementation times compared to traditional solutions.

Hydraulic/Hydrological model

As explained before, Hidromet contains a module that encapsulates the user hydraulic/hydrological model in the cloud and runs it with updated data every time that is available (radar observations, radar nowcasting and rain gauges observations). The sewer hydraulic models simulate the sewer system behavior based on precipitation estimates and sewer current status (retrieved by sensors) and the hydrological models can be used to predict possible floods due rises of the water level of rivers.

Currently, Hidromet is able to encapsulate the EPA SWMM hydraulic model (Environmental Protection Agency - Storm Water Management Model) and HEC-HMS (Hydrologic Engineering Center - Hydrologic Modeling System) hydrological model.

SWMM is a hydraulic model for simulating runoff quantity and quality for urban areas. It calculates possible floods in the sewer network based on rainfall time series, which can be defined for each subcatchment of an urban area. SWMM allows defining different elements of the network like junctions, conduits, pumps and storage units, in which level, capacity or flows are simulated. Hidromet generates alerts and disseminated them taken into account on this information and user-defined thresholds.

HEC-HMS is a uni-dimensional hydrological model that simulates the complete hydrologic processes of a basin. It allows configure all the elements (reservoirs, water sources, subbasins, junctions, sink, etc.) and parameters of a basin (concentration time of the subcatchments, snow melting, stretch of the river's length, slopes, etc.). The model simulates the flow on each element of the basin.

Currently, some other hydraulic and hydrological models are being considered to be encapsulated on Hidromet in order to allow more flexibility on integrating models.

Viewer

Hidromet platform dynamically displays the generated products and sensors data with geo-referenced information allowing for a better representation and understanding of the situation.

The interface includes a viewer where the user can analyze the current status of the whole sewer network. This visualization summarizes sewer network's behavior, thus, user is able to check if there are some flood risks in the urban area (or any incidence) just looking at the viewer.

In addition, a temporal evolution of the critical points of the sewer network is displayed in order to analyze by the user the status of each of the points of the network. This allows the user to understand if there really could be flood risks in a certain area of the network. In addition, on these points where a sensor is measuring information, measurements are displayed. This combination of measured and simulated information provides the possibility to compare the information to analyze model reliability. In addition, associated alerts are displayed for each critical point and variable (water level, capacity and flow).

As example, Figures 3, 4 and 5 shows different views of the Hidromet system. Figures 3 and 4 show the sensors data and the user defined thresholds over the different variables (that will trigger the defined actions: sending SMS, mails, etc.); and the spatial representation of the sewer elements (Figure 3 in a map with zoom capabilities and Figure 4 in a graphical representation of the sewer network). Figure 3 correspond to Granada (Spain) and Figure 4 to La Laguna in the Canary Islands (Spain). Figure 5 shows the hydrological simulations using raingauges information for the "*río Mapocho*" river in Santiago de Chile (Chile).

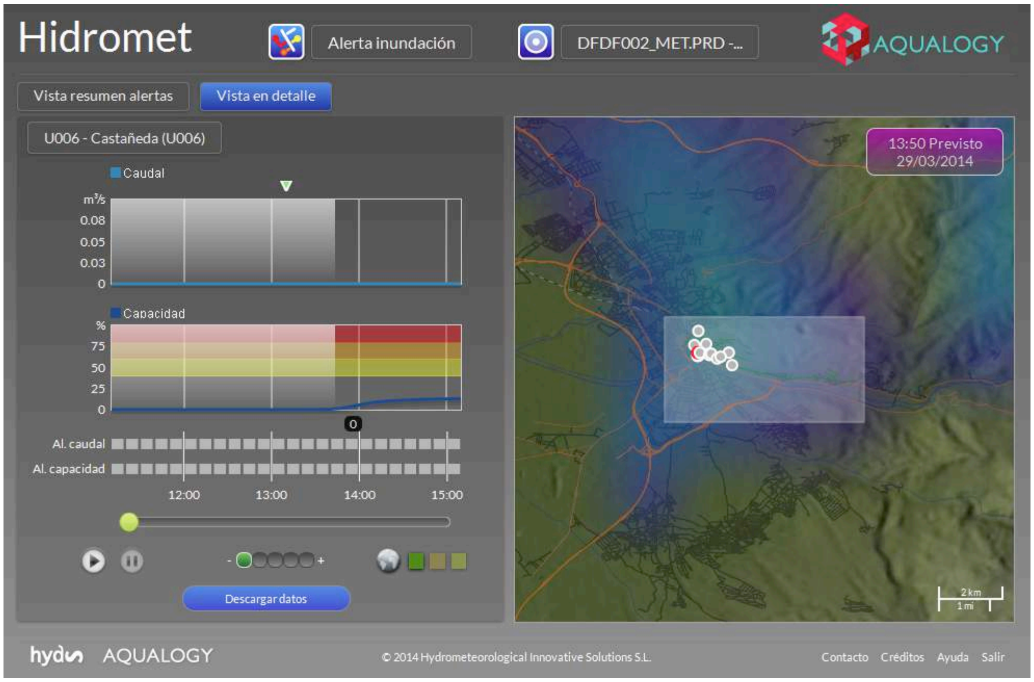

Figure 3. Sensors data visualization in the Hidromet implementation at Granada (Spain). Left panels show the temporal evolution of the sensor parameters. Horizontal color lines correspond to the user-defined threshold levels. The right panel shows the precipitation field over cartography with geo-referenced information. Dots correspond to critical points in the sewer system.

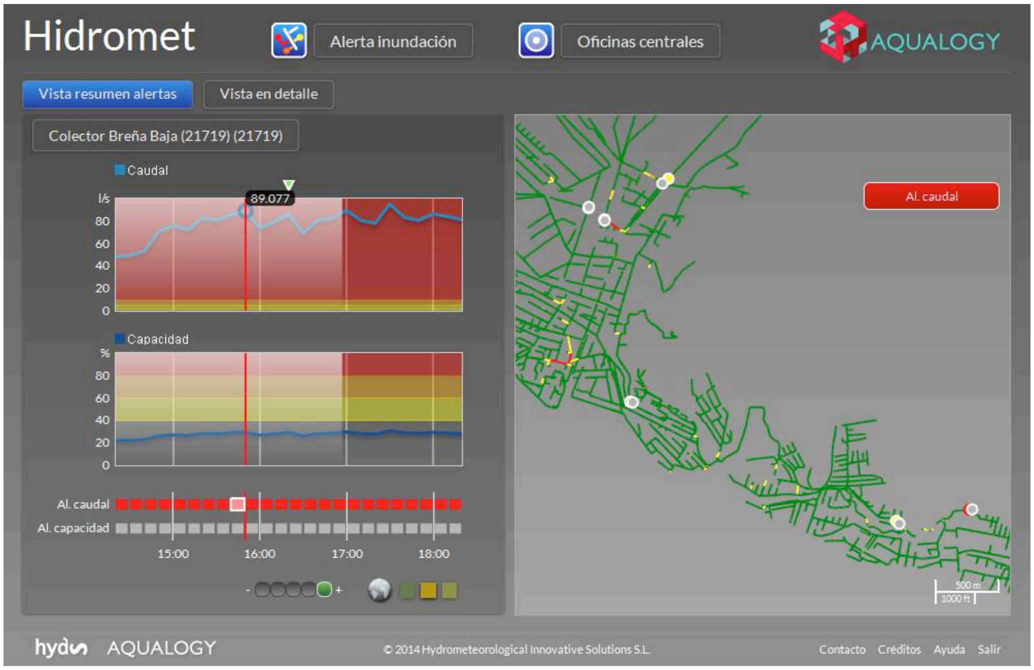

Figure 4. Similar to Figure 3 but for a Hidromet implementation in La Laguna, Canary Islands (Spain). In this case, the right panel is showing a schema of the sewer system.

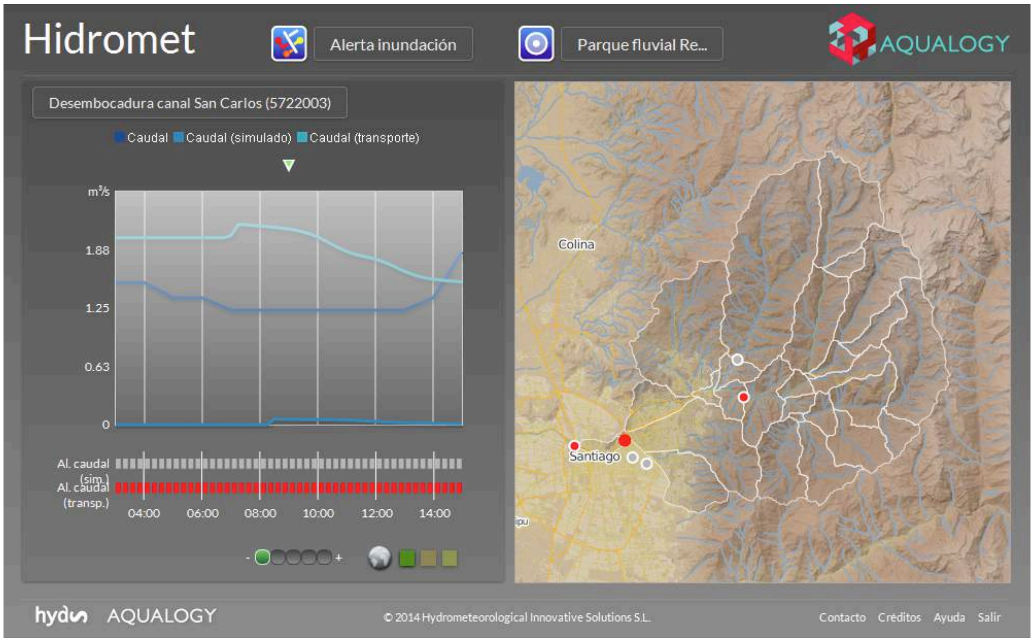

Figure 5. Similar to Figure 3 but for a Hidromet implementation in Santiago de Chile (Chile). In this case, the left panel is showing the hydrological model simulations and measurements; and the right panel a map of the catchment with some critical points.

ACKNOWLEDGEMENTS

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