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WIBASIN: BASIN MANAGEMENT THROUGH AN INTEGRATED PLATFORM

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In this work we present WiBasin, a cloud platform for basin and dam management. It includes different sources of precipitation (both observed and forecasted), integration over the catchment domain (to provide an aggregated value of potential rainfall accumulated over the basin), and a complete dissemination environment (web-viewer, capability of issuing hazard warnings with configurable thresholds, SMS, mails, etc.).

INTRODUCTION

A key issue in basin and dam management is the accurate estimation and forecast of accumulated rainfall over the catchment (integrated over the characteristic concentration time for critical short-term management, and over longer time periods to anticipate rainfall situations).

The solution presented here (WiBasin) does not need onsite installations (it runs in the *cloud*) and integrates different sources of precipitation (both observed and forecasted) in a continuous time series of hourly accumulated rainfall fields, having the best precipitation estimation available at each time step.

Optimal rainfall estimates used for the past time steps are based on a geostatistical approach to combine radar and raingauge rainfall observations. This technique is used to generate series of past rainfall estimates where both sources are available.

For lead times between 0 and 6 hours, the platform combines radar-based rainfall nowcasts with Numerical Weather Prediction [NWP] models rainfall forecasts. In this blended product, the recent performance of each of the two forecasting systems (radar nowcasting and NWP models) is used to set the weights that will be assigned to each of them. For lead times beyond 6 hours the system uses hourly rainfall accumulations from NWP model outputs.

This continuous time series of rainfall fields are integrated over the catchment domain (directly or by means of a hydrological model) to provide an aggregated value of potential rainfall accumulated over the basin outlet.

WiBasin cloud platform is currently operational and displays these continuous series of precipitation fields together with geo-referenced information. It also displays the integrated accumulated rainfall over the basin at each time step and the total rainfall accumulated for a given period (both observed and forecasted). User-defined thresholds for each basin can be set to issue hazard warnings for future accumulation forecasts and disseminated by several channels (web-viewer, email, SMS…).

The following sections describe each of the modules that integrate the platform: the precipitation time series calculation, the aggregation over the basin and the dissemination environment. Information about current developments is also given.

TIME SERIES OF PRECIPITATION FIELDS

WiBasin provides the amount of water to be received in a reservoir in the following 6 days based on the available sources of precipitation data and the available forecasts, taking for each time step the best possible estimate. To construct these precipitation fields' time series, the different sources of information (precipitation measurements or forecasting) are processed in order to optimize its quality. The different data inputs and processes that are applied to each source of data are described in next subsections and the overall data flux is represented in Figure 1.

Radar rainfall observations

Due to different errors affecting radar precipitation estimates (see for reference Zawadzki [1]), before its use a quality control process is done in order to improve its quality. This process is represented in Figure 1 as the transformation from radar observations (red boxes) to processed radar observations (grey boxes). The detailed algorithms that are applied are:

- Statistical climatological calibration factor to the reflectivity fields, in order to mitigate the under-/over-estimation due to equipment calibration mismatches.
- Correction of non-meteorological echoes and underestimation due to beam blockages (interaction of the radar measurement process with the topography and other elements).
- Conversion from reflectivity to instant rainfall using a climatological Z-R relationship.

Detailed information about the algorithms can be found on Sánchez-Diezma [2].

Radar nowcasting

By means of cross correlation techniques, the precipitation movement field can be calculated from the last radar observations. This movement field is then used to extrapolate the last observations in order to provide forecasted precipitation fields for the next hours (see Berenguer *et al.* [3] for a complete description of the technique). Forecasting of precipitation with radar nowcasting techniques cannot be used for large leadtimes (forecasting skills decay quick) but provides the best precipitation forecasting for the next 1-6 hours that can be obtained, and the rapid update of the technique allows keeping the forecasting updated with the last observations. This process is shown in Figure 1 as the calculation of the yellow data from the grey data.

Radar rainfall accumulations

In order to calculate rainfall accumulation form the radar instantaneous precipitation estimates (both observed and forecasted) the movement of the precipitation field is taken into account. A direct sum of the instantaneous precipitation fields would not provide realistic accumulations because the precipitation between radar scans would not be taken into account, Sánchez-

Diezma [1] provides several examples of such problems. Here, the movement field between each couple of observations is estimated, and then used to calculate all the intermediate states between observations (minute by minute rainfall fields). The final accumulation field is then computed taking into account all the intermediate information. In the Figure 1, this process is shown as the aggregation of small data boxes (both grey –observed– and yellow –forecasted–) into large data boxes.

Raingauges observations

Despite the advancements in the meteorological sensors equipment and transmission protocols, data retrieved by them is never free of errors (Hubbard and Sivakumar [4]). Therefore, in a first step, a quality control processes to discard values that are not correctly measured is applied. The algorithms that are currently applied to quality control raingauges measures are:

- Identification of missing values.
- Identification of out of range values.
- Consecutive values slope in a certain range, in order to avoid both a big variability between values and a too small variability (sensor stuck).

The thresholds and boundaries of the raingauges quality control algorithms are set on climatological values of predefined tables (World Meteorological Organization [5], Wolfson *et al.* [6], Fiebrich *et al.* [7] or Vejen [8]).

Radar-Raingauge combination

Raingauges information is be used to improve measured radar accumulation fields with geostatistical merging techniques. These techniques take profit of each source of data (punctual observed values in the case of raingauges and the high resolution spatial distribution in the case of radar fields) to provide a blended precipitation field. Velasco-Forero *et al* [9], Schiemann *et al.* [10] and Sempere-Torres *et al.* [11] provide a geo-statistical technique tailored to be used in real time to blend radar with raingauges information. In Figure 1 this process is shown as the merging of radar data (grey boxes) with punctual raingauge information in order to obtain the blended fields (green squares).

NWP models

The NWP models provide a precipitation forecasting for the following days (5-7 days) with an hourly temporal resolution. No processing is applied to the NWP models information.

Radar Nowcasting and NWP models blending

Radar nowcasting provides the best precipitation forecasting that can be obtained for the first 1-6 hours, and NWP models provide a precipitation forecasting for the following days. Blending techniques combine both sources of precipitation forecasting to provide an optimum for the first hours (see Golding [12] for a first proposal of blending techniques). Here, the blending is calculated for the first 6 hours taking into account the performance of each source of precipitation in the past dynamically. In Figure 1, this process is shown as the merging of yellow radar nowcasting boxes with brown NWP forecasting boxes in order to obtain the orange blended fields.

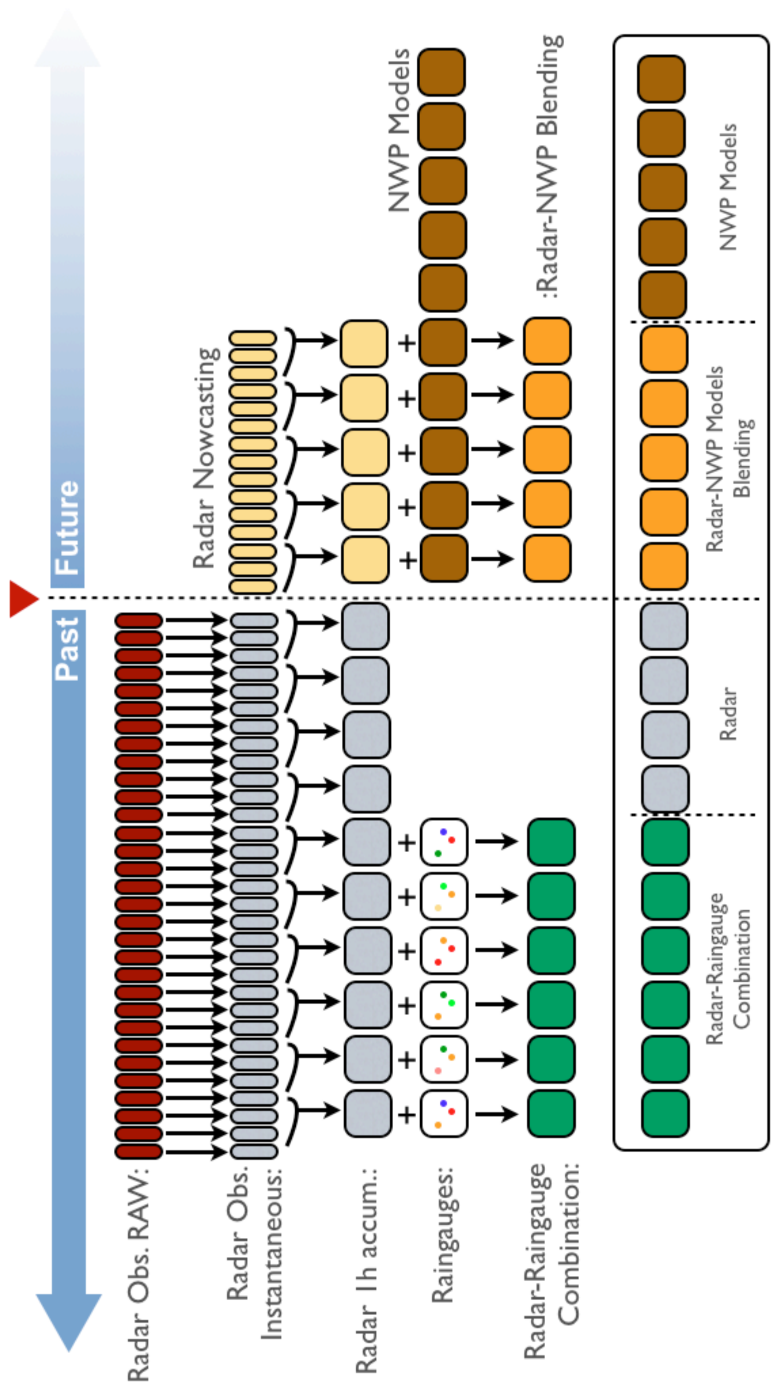

Figure 1. Precipitation data scheme used in the WiBasin. The scheme represents both observed and forecasted precipitation (vertical dashed line separates past from future in the timeline representation). The final series of data (boxed at the bottom of the figure) corresponds to the best available precipitation information at each time step, and it is composed by: radar-raingauge combination, radar, radar-NWP models combination and NWP models.

After all these data processing, it is created a continuous precipitation field's time series that has at each time the best rainfall estimation/forecasting than can be obtained. This is composed by radar-raingauge merging in the past; radar observation from the nearly past where the raingauges are still not available, radar nowcasting-NWP models blending for the first hours of forecast; and NWP model forecast for long term forecasts. See boxed times series shown at the bottom of Figure 1.

CATCHMENT INTEGRATION

In order to calculate the potential rainfall contribution to a catchment (defined by a shape which has been previously defined from the topography), an aggregation of the precipitation of each cell within the catchment is done. This represents a first approximation to the potential water that the catchment will receive.

In a second step, a hydrological model is used. That is, the precipitation fields previously calculated feed a hydrological model calibrated using measurements of reservoir level and precipitation information in past representative events. The hydrological model is encapsulated within the platform (runs in the "cloud") so, like all the other information on the platform, its simulations can be observed from any computer with internet access and there is no need for installations on the client's site.

In both cases output is a time series of water contribution to a given reservoir, with one-hour time step and up to six days forecast.

INFORMATION DISEMINATION

WiBasin is a cloud solution, that is, the data is received in centralized servers where the processing is done. This allows a better access to the information, rapid implementations, and lowers the costs of installations. Also allow for dissemination methods (SMSs, Mails, etc.) in a much easier way than local installations.

The visualization of the information (data and model simulations) is done through a web interface. The users can login and access to their tailored information from any device with Internet access. The viewer is split in two parts: short term forecast (up to 24h, see Figure 2) and weekly forecast (see Figure 3). In both views, a geographical representation of the basin (map with zoom capabilities and representing the rainfall fields) and information about the measurements and forecasts are shown.

The user can define customized thresholds for the different elements, and actions to be taken when reaching them (e.g. send an email to a selected profile, sending SMS, etc.). The maps and the graphs also provide feedback on each element level.

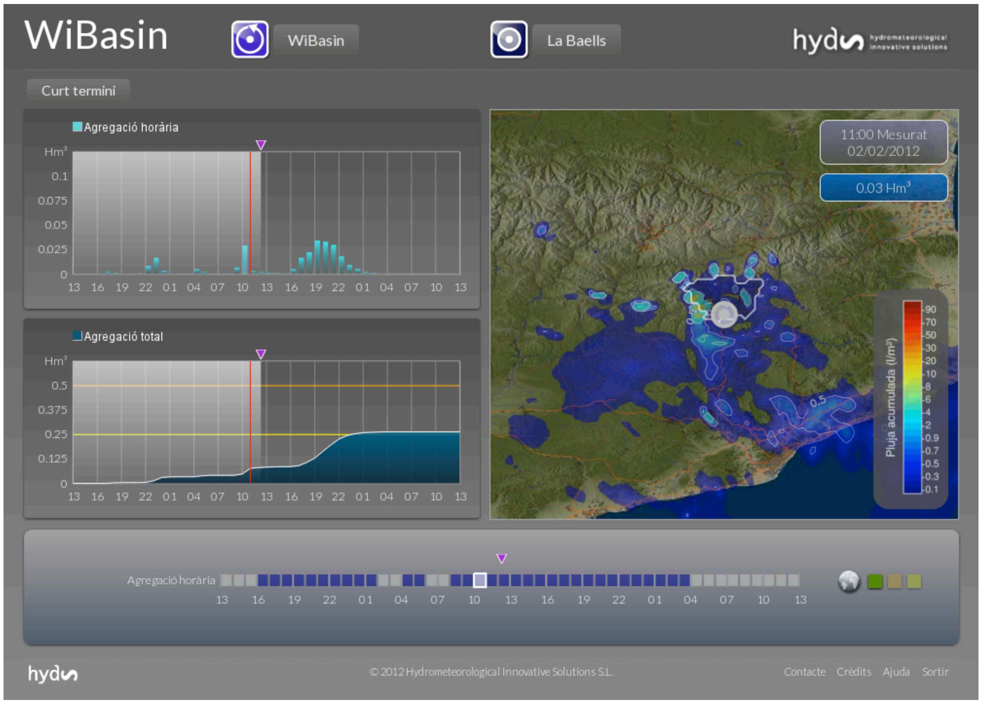

Figure 2. WiBasin interface for the short term forecasting. At the right there is a representation of the catchment (including zoom capabilities) and the rain accumulation field for the selected time step. At the left there are the graphs of both hourly water volume that the catchment will receive (top) and total volume accumulation (bottom), for the last 24h and next forecasted 24h.

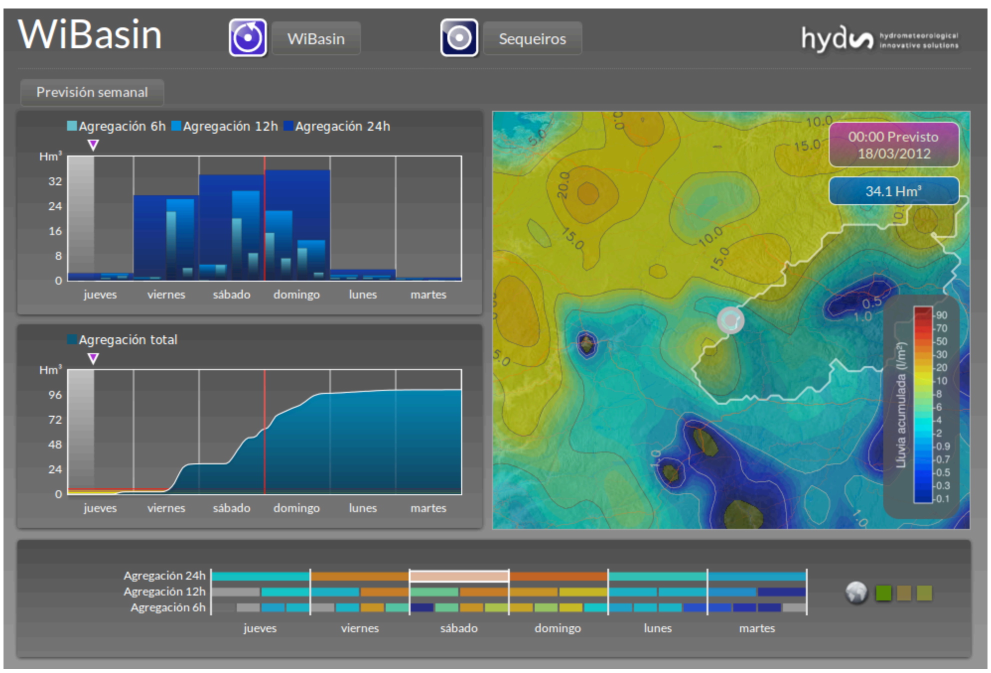

Figure 3. WiBasin interface for the weekly forecast. Similar to Figure 2, but in this case the graphs show the weekly forecast in 6, 12 and 24h time accumulations (top) and total volume accumulation (bottom).

CURRENT WORKS

To complement the short term (up to 6 days) forecasting of water volume that the basin will receive, a long-term module is being developed. The long-term water availability prediction will provide the reservoir's volume for the following months based on historical records and current state.

For a given reservoir, the time series of volumes are used to construct weekly a series of differences with the previous week. That is, the increase or decrease of the reservoir's volume in a weekly basis. Next, selected years of the historical records that had similar volumes to the current state are used to create probability distribution functions (at different leadtimes in a weekly basis) of future changes in reservoir's volume. Those changes' distributions are applied to the current observations in order to obtain a distribution of forecasted reservoir's volumes. In the forecast, limitations like real reservoir's maximum volume or political policies (like policies to keep volume free in order to be able to retain a given return period flooding situation) are taken into account.

After this process the mean and confidence intervals ([25%, 75%] and [5%, 95%] for instance) are calculated from the forecasted future reservoir's volume distribution. Those represent the forecast of the reservoir volume in average based on historical records and the uncertainty related to that forecast based on the variability observed in the past.

WiBasin will display reservoir forecasted water availability based on climatological records in the web viewer (see Figure 4). The reservoir's volume for the last two months and the forecast for the following four will be displayed showing not only the average forecast but also confidence interval for the forecast (the [25%, 75%], for instance). According to different percentiles in the record's distribution, scenarios for scarcity (dry), standard, and over the average (rainy) will be defined and displayed in the background for reference (shown in Figure 4 in green and orange).

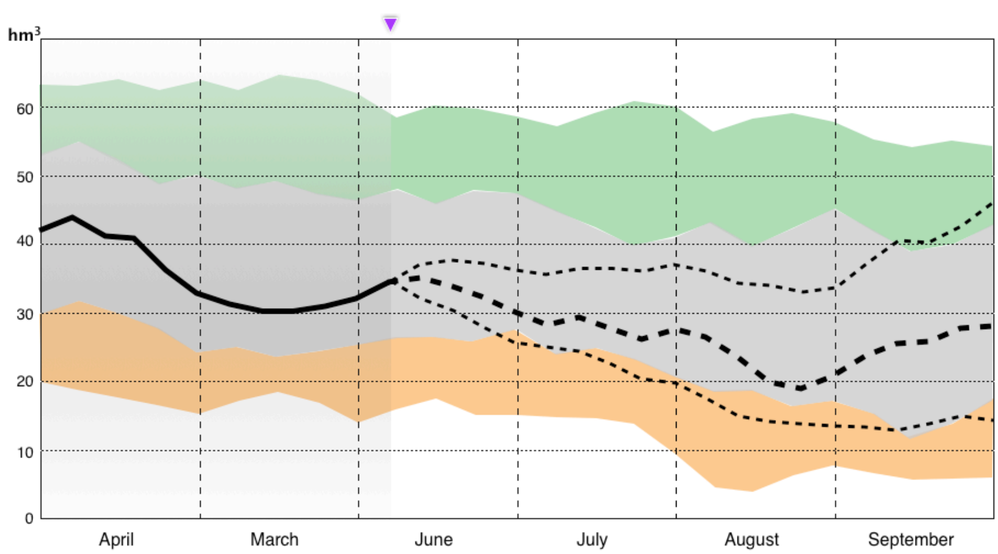

Figure 4. Representation of the reservoir volumes (solid line) and long-term volumes forecast (dashed) based on climatological records. Mean forecast (thick line) and . Scenarios for scarcity (orange) and humid (green) are displayed in the background.

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