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FLOOD ALERT SYSTEM FOR EARLY WARNING IN MOUNTAINOUS COASTAL WATERSHEDS: COUPLING DATA-DRIVEN AND PHYSICALLY BASED HYDROLOGICAL MODELS

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This work shows the implementation of a graphic user interface (GUI) developed in MATLAB intended to serve for flooding forecast managers. The software is set up by a very straightforward group of windows that present schematic information related to a very specific and intuitive value of warning risk. This simple front-end encloses two complex modeling techniques for forecasting somehow hidden for the final user. On one hand, there is a data driven set of pre-trained models based on machine learning techniques (Artificial Neural Networks, Radial Basis Functions, Bayesian Neural Networks, and Gaussian Processes), which are capable of making a quick forecast of key variables at certain control points, with an associated uncertainty level. On the other hand, when the warning risk is above a given threshold, a cascade of physically-based models can be launched to perform a more detailed forecast: a sequence of weather forecasting from mesoscale models, which feed the physically based and fully distributed hydrological model WiMMed, and a hydraulic 1D model for flood forecast (GuadalForCe), both programmed in C++ and run in command line mode. Results are presented in terms of flooded area, probability, damage, and cost to quantify a final risk value already defined for statistical modeling.

INTRODUCTION

Early warning systems are essential tools for preventing flood risks and managing alert situations from real time data-driven outputs. In Mediterranean coastal regions, the response time is usually a constraint for decision-making since many watersheds have travel times of just a few hours from head sources to the floodplain in the valleys. Thus, the anticipation of the alert situation in terms of probability of occurrence is a key factor for managing alert conditions and mitigating flood consequences in these areas. Coupling data-driven forecasting with hydrological models may constitute a robust tool for alert assessment, provided that sound calibrations are available.

Guadalhorce River basin, in the south of Spain (Fig. 1), is a good example of Mediterranean mountainous basin with low concentration times, where torrential rain storms due to “Cold Air Pull” [1], also known as “Cut-off Low”, are frequent at the beginning of the humid station.

Moreover, these events take place in a Mediterranean context, where hyper annual droughts and water scarcity during the summer are highly probable. Inaccurate discharge from the reservoirs with flood control purposes can cause loss of water that may derive in water shortage and social conflicts during the following months. The heterogeneity of land uses and soil properties, the water scarcity, and the presence of four independent reservoirs in the upper part of the basin, shapes a complex hydrologic system, very difficult to manage under these flash flooding events. Thus, September is the month of the highest alert for the hydrological managers of the region because of the periodic floodings that can affect highly urbanized areas, causing human lives losses year after year. These kinds of systems are yearning for reliable forecast tools.

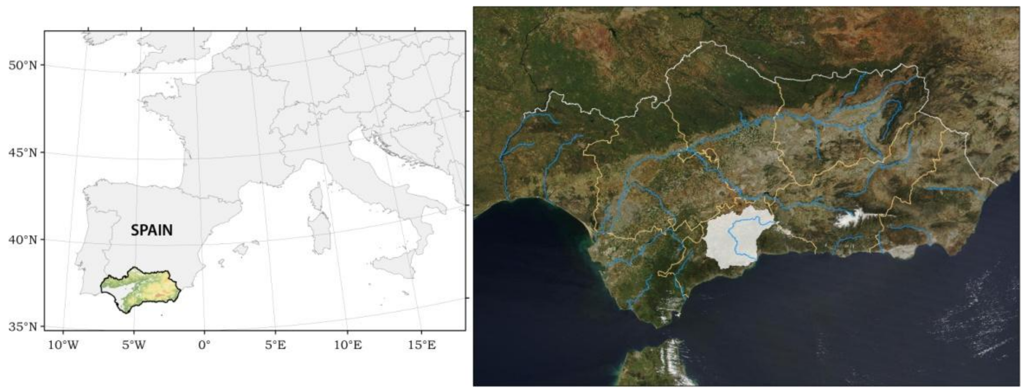

Figure 1. Location of Guadalhorce River basin in southern Spain..

CENIT is a grant program of the Spanish Government, launched in 2006 to stimulate public-private cooperation in industrial research applied to the creation of new products related to technologies of strategic interest. TecoAgua ("Sustainable technologies for the Water Services Management") is a CENIT project which was approved in 2009 for the development of sustainable technologies in water resources carried out by 10 companies and 21 research centers. Within TecoAgua, there was a specific action to create tools that were able to raise hydrologic alerts in real time with its associated risk, intended for use by public water managers.

In this work, the result of this action is presented: an easy to use and stand-alone computer application that encloses in a simple front-end two complex modeling techniques for forecasting, somehow hidden for the final user. On one hand, there is a data driven set of pre-trained models based on machine learning techniques (Artificial Neural Networks (ANNs), Radial Basis Functions (RBF), Bayesian Neural Networks (BNN), and Gaussian Processes (GPs)), which are capable of making a quick forecast of key variables at certain control points, with an associated uncertainty level. On the other hand, when the warning risk is above a given threshold, a cascade of physically-based models can be launched to perform a more detailed forecast: a sequence of weather forecasting from mesoscale models.

MODEL DESCRIPTION

Data driven methods

Previous studies of Data Driven Methods (ANNs, RBF, BNN) over the last decade [2] have proved their goodness in hydrologic modeling. One of the weaknesses of these techniques is the well-known lack of interpretability in the relationships between inputs and outputs, which is based in a set of parameters. Although these "black box" models can perform precisely, newer methods with a "grey box" nature (less parametric) and a probabilistic approach are expanding (GPs). MatLab provides a good amount of tools for the training and prediction of this kind of models [3].

Physically-based models

The physically based models' cascade is a series of three coupled physical models. The first one is the meteorological forecasting model, based on any of the mesoscale models that perform a weather forecast in real time (HIRLAM from AEMET, NOAA, etc.). The results of this prediction, at least in terms of precipitation and temperature, feed the second model. WiMMed (Watershed Integrated Model in Mediterranean Environments) [4] [5] is a physically-based, fully distributed hydrologic model designed to include the variability of scales in the space and time characteristic of the Mediterranean climate. WiMMed model core runs as a command line program that reads all the inputs from text files and, conversely, saves all the required results in the same format. WiMMed is linked to GuadalForCe, a hydraulic 1D flooding model. Both models are programed in standard C++ and compiled with Visual C++

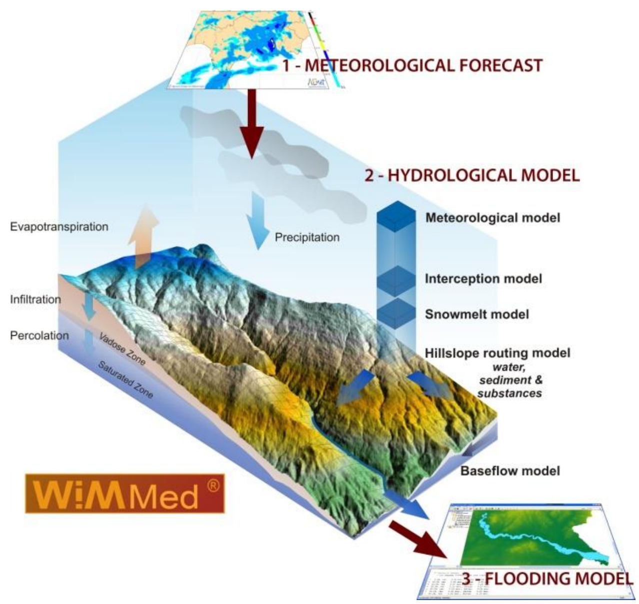

Figure 2. Flooding forecast as a result of the cascade of physically-based models.

Graphical User Interface

The MATLAB tool for creating GUI was used to develop a stand-alone application, easy for the final user to install and use, but, at the same time, easy to maintain, update an evolve for the technicians, in case that new knowledge is acquired. Therefore, new types of data driven models or new calibrations can be easily assimilated into the application. Likewise, even though this specific final product was delivered to the final user customized for the

Guadalhorce basin, it can be adapted for any other watershed. This flexibility of configuration is achieved through several configuration text files that can be easily edited. The customization and calibration of the physical models is attained through editable text files as well.

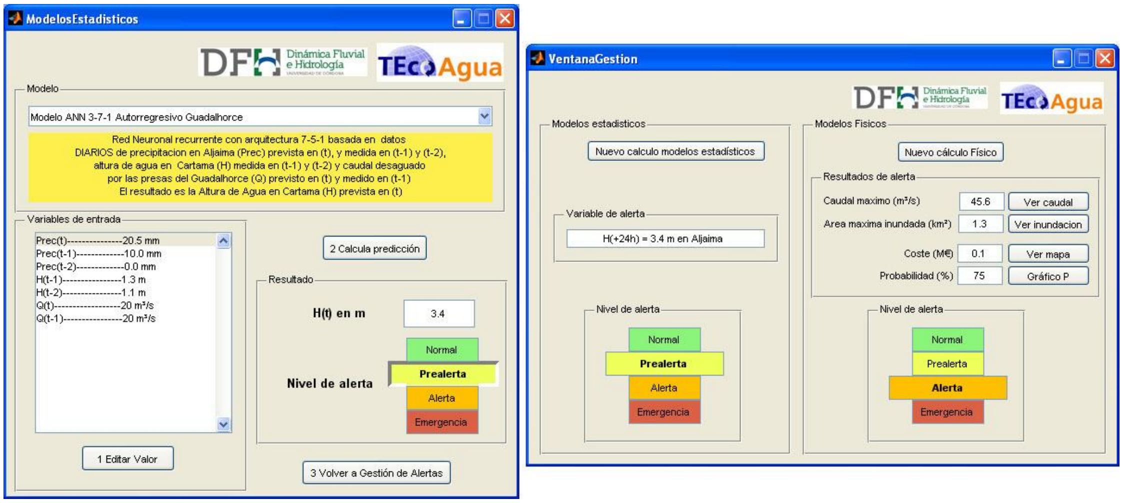

Figure 3. Example of some of the windows of the final GUI tool.

CONCLUSION

The generation of flood warning alerts should not be relied on a single model, not even on models of a single type. Data driven models like Neural Networks, Bayesian Neural Networks, or Gaussian Processes, present the advantage that, once trained with the control variables, they are fast and give reliable results. Plus, the last two types of models generate the associated probability of a certain prediction, something required for risk analysis. Regarding physical models, they are theoretically prepared to cope with new or more complex situations and give results with a detailed spatial and temporal distribution, such as flooded areas. The tool presented in this study integrates the different types of models in a stand-alone application that is easy to use by technicians involved in flood warning management without the need to have a deep knowledge of the modeling details. This work is a clear example of collaboration between public research and private companies and the effort to create knowledge ready to use by water managers.

Acknowledgments

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REFERENCES

[1] Koppen W., "Die Bewegung der barometrischen Minima in den Tagen vom 20 bis 24 Januar 1886 über Europa", Met Zeitschr 3: 505 (1886).

[2] Maier, H. R. and Dandy, G. C., "Neural networks for the prediction and forecasting of wáter resources variables: a review of modelling issues and applications", Environmental Modelling & Software, 15(1), (2000), pp. 101-124.

[3] Nabney, I. T., "NETLAB. Algorithms for Pattern Recognition", Springer, London, (2004).

[4] Polo, M.J., Herrero, J., Aguilar, C., Millares, A., Moñino, A., Nieto, S., Losada, M.A,. "WiMMed, a distributed physically-based watershed model (I): Description and validation", in "Environmental Hydraulics: Theoretical, Experimental & Computational Solutions", CRC Press/Balkema, (2009), pp 225-228. NO

[5] Herrero J., Millares, A., Aguilar, C., Díaz, A., Polo, M.J., Losada, M.A., "WiMMed. Theoretical background", Fluvial Dynamics and Hydrology. University of Cordoba and Granada. (In Spanish), (2011), available at www.uco.es/dfh.