REAL TIME HYDRO-METEOROLOGICAL FORECASTS FOR EARLY WARNING SYSTEM IN THE MILAN URBAN AREA

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KEY POINTS

- *The use of HEPS is an effective and promising non-structural measure to help mitigate flood risk in Milano urban area, synergic with the existing structural engineering works.*
- *A forecast horizon of two days is required for an operational chain over the Milano basins, and accurate quantitative forecasts are necessary at least one day in advance.*
- *The pragmatic set of "shifted" configurations turns out to be an acceptable low-budget alternative for real time flood forecasts over small urban basins when a single deterministic run is available.*

1 INTRODUCTION

Precipitation forecasts from mesoscale numerical weather prediction (NWP) models often contain features that are not deterministically predictable. In particular, accurate forecasts of deep moist convection and extreme rainfall are arduous to be predicted in terms of amount, time and target over small hydrological basins due to uncertainties arising from the NWP, physical parameterizations and high sensitivity to misrepresentation of the atmospheric state, therefore they require a probabilistic forecast approach.

2 AREA OF STUDY

In the past, the Milano urban area has been subjected to a high flood hazard and, in fact, during the 1970s a series of risk mitigation works were carried out with the aim of reducing the exceeding discharges flowing through the urban areas. Unfortunately, the complex flood protection system of the city did not completely succeed in the recent years; hence, the implementation of a hydro-meteorological chain can provide an additional support as a non-structural method for early warning systems.
The main rivers which cross the city of Milano are the Lambro (area of 500 km^2), Seveso (area of 207 km^2), and Olona (area of 208 km^2), plus a number of minor tributaries for a total drainage surface of about 1300 km^2. Since lag times of these basins are a few hours, alerts with sufficient lead time permit civil protection authorities and the public to exercise caution and take preventive measures to mitigate the impacts of flooding (Yang et al., 2015).

3 THE FLOOD FORECASTING SYSTEM

In this study, we analyse 48 hours forecasts initialized one day before the observed peak flood, whereas this lead time is considered sufficient and adequate by local authorities, for the 8 July 2014 event when extreme precipitation intensities exceeded 100mm/h for certain convective systems. Rain gage data analysis shows an estimated return period of about 80-100 years over the Lambro and Seveso basins and above 200 years in the upper area of the latter.
A flood forecasting system has been implemented to examine the above-mentioned hydro-meteorological episode that affected the Milano urban watersheds with two different approaches. The first approach is based on a hydrological ensemble prediction system (HEPS) designed to explicitly cope with uncertainties in the initial and lateral boundary conditions (IC/LBCs) and physical parameterizations (mixed-physics, MPS) of the NWP model. The second involves a pragmatic post-processing procedure by randomly shifting in space the precipitation field provided by the deterministic WRF model run in order to get a cluster of different simulations.

All meteorological forecast simulations with the Weather Research and Forecasting (WRF) model are carried out by the Grup de Meteorologia, of the Universitat de les Illes Balears, while the hydrological simulations by the Politecnico di Milano team which uses the Flash–flood Event–based Spatially distributed rainfall–runoff Transformation, including Water Balance (FEST-WB), a rainfall-runoff physically-based distributed model developed on top of MOSAICO library (Pianosi and Ravazzani 2010; Ceppi et al., 2013; Ravazzani, 2013) for simulating the rainfall-runoff transformation. FEST-WB computes the main processes of the hydrological cycle: evapotranspiration, infiltration, surface runoff, flow routing, subsurface flow, and snow melt and accumulation. The computation domain is discretized with a mesh of regular square cells (200 × 200 m in this study) in each of which water fluxes are calculated at hourly time step.

4 RESULTS AND DISCUSSION

Notwithstanding the underestimation found in the results by the HEPS for this event, if we investigate deeply the ensemble spread, some of the WRF simulations (first approach) exceed the warning threshold of the respective basins. From a civil protection point of view, the exceeding percentage given by the WRF ensemble members can provide more information than a single forecast can do.
To better appreciate the value of the HEPS, we join in a single plot all the ensemble members of the WRF forecasts and calculate the deviation from the observed peak discharge and time over the three catchments, enhancing the innovative exploration of the all WRF combinations. Following the approach of the "Peak Box" proposed by Zappa et al. (2013), figure 1 summarizes all the simulations and forecasts carried out in this study, considering on the y-axis the deviation from the observed peak discharge and on x-axis from the observed peak time, which is another important factor to be considered. The red circle is the true observation used as normalized reference; the green rhombus is the FEST-WB model simulation forced with observed data; the purple rhombi and brown rectangles are respectively the PILB-HEPS and MPS-HEPS. The warning threshold (orange dashed line) is shown in terms of cubic meters per second under or over the observed value, in order to display whether an ensemble member goes beyond or not this given alert line although its forecasted value can be far from the actual one. In fact, since hydrological alarms are given according to the threshold exceeding, this probability becomes a key factor for civil protection: i.e., we are far from what are going to observe, but we are able to predict rather well the exceeding threshold, and issue right alerts.

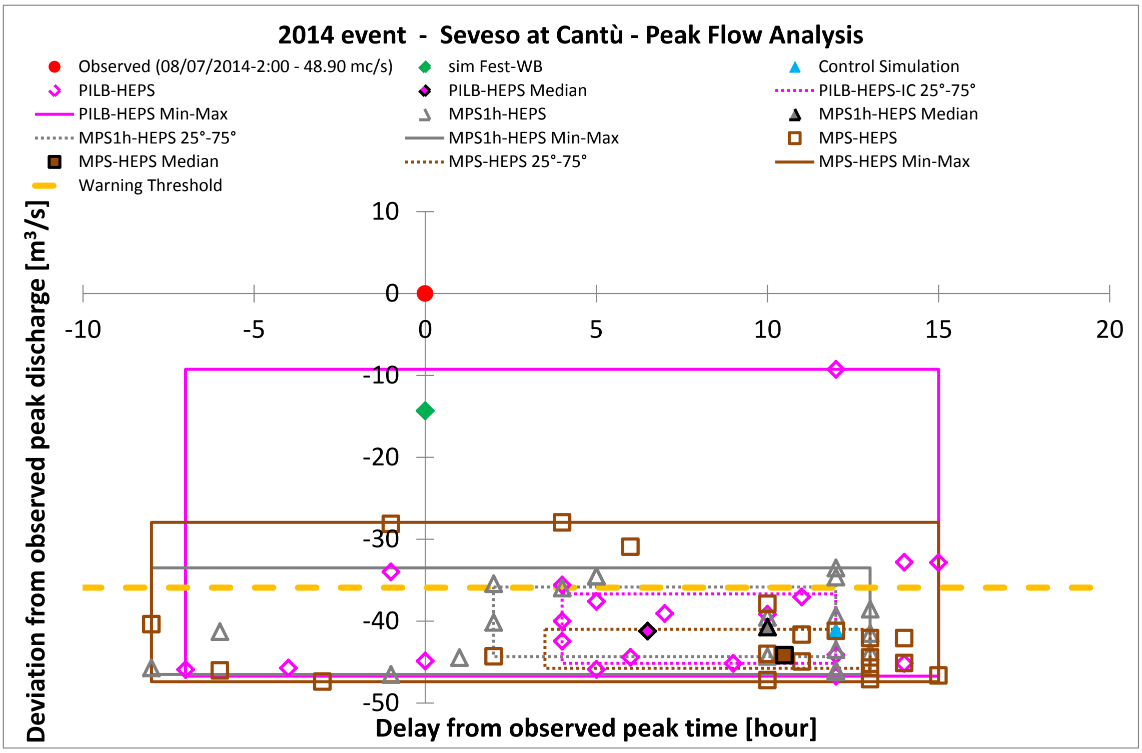

Figure 1. Peak flow analysis for the Seveso at Cantù for the 2014 event. Y-axis shows the deviation from the observed peak discharge and x-axis the deviation from the observed peak time. The green rhombi show the deviation of the FEST-WB simulations initialized with observed data, while the blue triangles are the control forecast errors. Ensemble forecast errors in terms of deviation from the observed peak discharge and time are shown with purple rhombi, brown and grey triangles for the PILB-HEPS, MPS-HEPS, and MPS1h-HEPS respectively; all deviations are normalized from the observed value (red circle).

If we take into account all the 60 WRF simulations, we count 13 ensembles at Cantù, 31 at Peregallo and 6 at Milano that exceed the warning thresholds providing a probabilistic information, which is more meaningful if compared with single forecasts, that can be addressed to local Italian civil protection agencies for preventive actions and support decision systems.

However, when a deterministic forecast is the only available one, following the approach of Theis at al. 2005, we implemented a pragmatic post-processing procedure by randomly shifting in space the precipitation field (maintaining unchanged all other forecast fields) provided by the deterministic WRF model run in order to get a cluster of different simulations.

Since the deterministic forecast can miss precipitation intensity for convective events due to mislocalization target of cells, the ensemble strategy can improve forecast, but it has high cost in terms of time and computational resources. Hence, we tested a parsimonious approach to transform deterministic forecast into pseudo-probabilistic ones. The precipitation forecast area has been shifted by 10, 20, 30, 40, and 50 km towards North, East, South, West, North-East, South-East, South-West, and North-West. Results show that 6 out of total 40 discharge simulations obtained with the "shift-ensemble" method exceed the warning threshold, giving a 15% of flood probability in the Seveso basin (Figure 2), and 32.5% in the Lambro basin at Peregallo.

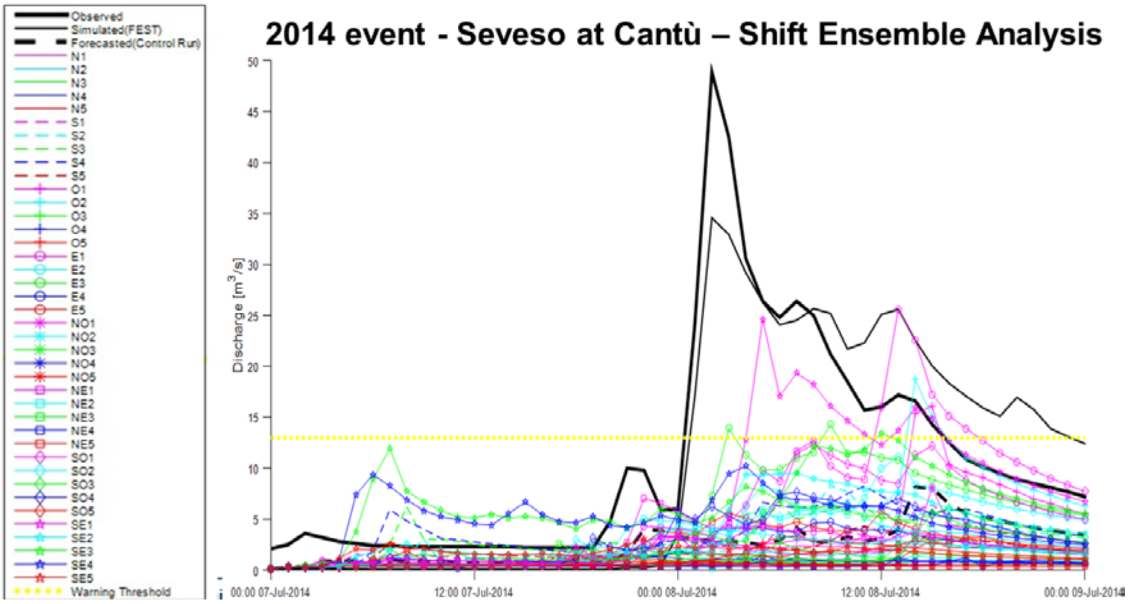

Figure 2. Discharge simulations for the Seveso at Cantù forced with the WRF control run model shifting the precipitation field with 40 different combinations.

Although the physics-based approach needs a high computational cost, it outperforms the pragmatic set of configurations, which, however, turns out to be an acceptable low-budget alternative for real time flood forecasts over small urban basins when a single deterministic run is available.

5 REFERENCE

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