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Interactive comment on "User-oriented hydrological indices for early warning system. Validation using post-event surveys: flood case studies on the Central Apennines District" *by* Annalina Lombardi et al.

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1. "General comments. This paper presents an application of two new indexes for flood prediction in central Italy. Indexes are linked to two different flooding sources: a pluvial index and a fluvial flood index. The case study is the November 2013 event that hit Central Appennines in Italy. I found the topic of paper very interesting to HESS readers but some adjustments are needed before publication. The main concern is about hydrological model calibration. Authors mention necessity of calibrating some parameters but it is not clear if the CHym model has been calibrated before its application."

Response: The hydrological model has been widely calibrated using climatological discharge time series of the Po river, as reported in Coppola et al. (2014). To this aim, it is important to note that the conditions of the Po River are representative of many alluvial rivers in Europe (Di Baldassarre et al., 2009). As stressed out in the paper, the absence of updated discharge estimates in many Italian regions makes difficult to calibrate the model specifically for each basin. Starting from the climatological calibration on the Po basin and considering the civil protection operational purposes, aimed at identifying river flow conditions where significant discharges are observed, stress indices are introduced also to overcome the general calibration issues. The calibration focus was then moved from the classical scope of the "best prediction of the discharge amount", toward a new approach, where the hydrological stress as a whole is predicted and validated. In this context, discharge is part of the hydrological stress, but is related to other parameters, such as hydraulic radius (in BDD), and catchment concentration time (in CAI), that plays also an important role in flood dynamics.

2. "L50-52: "In the EU Directive 2007/60/CE concerning the "Assessment and management of flood risks", the realization of a flood risk map is foreseen over river basins with a significant potential risk of flooding (European Parliament, 2007). Prediction of flood events is therefore important to enhance mitigation strategies to face hydrological events." It is not clear the connection between flood risk map and prediction of flood events. They are two distinct concepts not connected necessarily. Flood risk maps are assessed offline based on scenario events (for given return periods). Flood prediction is used in real time to forecast in advance the arrival of flood. This is not the only possible measure. There are structural measures to consider as well."

Response: we agree with this comment. The information provided by the CHyM operational stress indices maps is complementary with flood risk maps, therefore, both information needs to be taken into account by the civil protection operator for his/her evaluation, when a flood event is expected to occur. In our opinion, simulation and prediction of flood events is connected with the implementation of mitigation strategies, because it can be a useful pre-requisite for the mitigation planning phase. Considering that the paper is not clear in this point, we propose to replace the sentence with the following: "... In the EU Directive 2007/60/CE concerning the "Assessment and management of flood risks", the realization of a flood risk map is foreseen over river basins with a significant potential risk of flooding (European Parliament, 2007). To this aim, tools for flood events prediction may also provide useful information for the mitigation strategies planning phase."

3. "L106 Spatial resolution of hydrological model is 90m. Table 4 presents further spatial resolution different according to case study. Please clarify. How model parameters are scaled, if any, when spatial resolution changes?"

Response: resolution of 90 m is actually the resolution of the NASA SRTM DEM source file (https://lpdaac.usgs.gov/products/srtmgl3v003/) which is implemented in the model. For this reason, the CHyM model can perform simulation with horizontal resolutions $\geq$ 90 m. For our national operational activity, we had divided the Italian territory in 7 geographical sub-domains, each domain has its own spatial resolution, chosen in order to optimize computational requirements (lower resolutions means faster simulations) and the correct drainage network rebuilt (higher resolutions means more accurate drainage network reconstruction). In this paper, we maintained the operational spatial resolution associated to each sub-domain. Starting from the NASA data, the DEM is upscaled by applying the Cellular Automata spatial interpolation technique. All those information are contained in Coppola et al. (2014).

4. "L146-148. This sentence states that Mn value should be calibrated but the final resulting value is not explained."

Response: the Mn value can be calibrated if needed, since it was reported in the model as a parameter. For our simulations, we are using the default value of 4.5.

5. "L217-220 Is an initial value of water in the two reservoirs considered? This is linked to model spin-up. Are there any parameters to calibrate for infiltration computation? "

Response: in our simulations, the initial value of water in the two reservoirs is not considered, because no data are provided about release and withdrawals of water from the water reservoirs. The spin-up of the model is set to 5 days to reproduce initial flow conditions. Due to the lack of water storage data, it is not possible to properly assess the flow discharge simulation, therefore, we can only state that the discharge simulation from our model differs from observations and highlight the presence of an anthropic impact due to the presence of water reservoirs upstream. According to our experience, we have found that indices peak timing and their shifts respect to observed hydrometric level can provide information about the flood management through water reservoirs release and withdrawals, that are able to postpone (or anticipate) discharge maxima propagation downstream. The infiltration computation is explained in Coppola et al 2014 at paragraphs 3.4 and 3.5. The same parameterizations are used in this work.

6. "L 243 Authors stress on the necessity for long time series of flow discharge data and present the proposed approach as a means to overcome that problem. But the presented system is based on the CHyM hydrological model that, in turn, needs calibration, I suppose. Please clarify the real advantages of the proposed approach as regards model calibration. "

Response: we thank the reviewer for this comment, that gives us the possibility to better stress on our findings. We have partially replied to this observation in our response to the general comment. In general, long time series of flow discharge data are necessary to calibrate and validate hydrological models. However, such data are not always available from all Italian regions and, in many cases, rating curves used for the discharge estimation starting from the hydrometric level are not constantly updated. As stated by the WMO, hydrometric level is also a strongly non-stationary parameter. Furthermore, hydrometric level measurements are not available for major floods, when sensors installed along rivers stops to work due to severe meteorological conditions. For this reason, many data in the upper part of the rating curve are missed and larger errors in discharge estimation are often associated to higher discharge bins. Finally, hydrometers are installed over main river channels and small catchments are often excluded from discharge estimations, even if they are more prone to destructive flooding phenomena, especially in a complex orography context. Hydrometric/discharge thresholds are defined punctually and differs on each sensor. In our stress indices approach, discharge and runoff are combined with geographical information related to the upstream basin displacement, through the use of other variables, such as the hydraulic radius (a function of the drained area) and concentration time (that implicitly consider runoff conditions upstream), therefore, they are able to give information in each point of the drainage network and their mutual variation from upstream to downstream along the river path is proportional. For this reason, general thresholds, valid in all grid-points of the drainage network may be defined. Moving from discharge to combined discharge-based and runoff-based indices, with the aim of calibrating such indices on threshold-basis for flood alert purposes, gives us the possibility to calibrate and validate a different information, which is not the discharge amount, but the river stress conditions, which is qualitatively given by civil protection authorities through the use of hydrometric thresholds, as well as stress timing. Furthermore, the good estimate of the stress state on a river channel is also provided by event reports and from press releases in those locations where no sensors and, hence, no threshold are defined. Since the indices validation is not numerical, the problem of missing discharge data is overcome, being the threshold-based calibration a sufficient condition for our purpose to validate an alert system, rather than physical quantities.

7. “L242-266. Consider moving this part to Introduction section.”

Response: DONE, insert in line 55

8. “L285-290 It is not clear how corrivation time is computed for CAI computation. It seems the sum of time to pass through different river reaches. It sit the time for passing the longest flow path? How velocity of single river reach is computed? It should change with roughness and slope.”

Response: the time of concentration is computed for each grid-point of the geographical domain. It can be defined as the time required to a raindrop to travel from the hydraulically most distant point in the watershed to the outlet. The outlet must be intended in the numerical sense; namely, it may be a “mouth cell” draining toward a sea point, a “tributary mouth cell” draining toward the interception with the main river or a cell draining toward border of the simulated domain. The water velocity for each cell of the domain is computed according the equation [2.1.3] written in paragraph 2.1. The velocity computation considers the acclivity, estimated as the sinus of the terrain slope in the direction of surface flow, as well as the roughness, through the use of the Manning’s roughness coefficient depending on the land use cover. For example, the largest catchment in Abruzzo region, the Aterno-Pescara is simulated to have an upstream area of 3310 km2 and a concentration time of 20 hours, approximately. The concentration time used in the CAI calculation is an average calculated on all possible concentration times resulting from draining paths toward the considered grid-point.

9. “L295-300 Authors present three rainfall intensity as warning thresholds and say they are defined with empirical tests. The readers interested in applying this procedure to other sites should know how to define rainfall threshold value. Are they universal for all basins in the world? The same consideration applies for BDD index. At line 404 authors state that “the calibration of the indices thresholds was chosen in order to maximize the hit rate..”, please clarify. “

Response: although the units of measurement of the indices are expressed in mm, they do not represent rainfall. Actually both indices refer to the water accumulated on the ground over the time. Three different thresholds for each of the two indices have been defined, in accordance with the protocols in use at the national civil protection department. Since our intention is to develop unique thresholds, having the same values in all grid-points, we had to optimize threshold choice in order to maximize hit rate and minimize false alarms. For the definition of indices thresholds, we decided to assign values maximizing the hit rate scores, i.e., we have chosen indices values causing a slight increase of the false alarm rate to also maximize the hit rate. In order to avoid some further burdening of this paper, only results related to the moderate threshold (orange, pre-alert) threshold are reported. The reason of our preference of this particular threshold lays on the consideration of its meaning in the civil protection alert system. In fact, the orange threshold exceedance can be considered the most crucial one for the civil organization, because its exceedance starts the activation of protection measures for people and infrastructure safety, as foreseen in risk plans. As for the "universality" of our indices, our main purpose is to avoid developing different thresholds on different areas, for this reason, we had tested them over a wide area in Central Italy, where many different catchments are located. It is untimely to say that indices are universally applicable, but we are confident to be able to extend our validation to other areas in Italy and Europe, due to results we are having in our ongoing research.

10. "L311 why ordinary index present two values? "

Response: Thanks for your observation, it is a typo.

11. "L527 Is a spin-up time of 120 hours enough for model initialization? See comment about infiltration model."

Response: given the small extension of the involved catchments, 120 hours of initializations seems to be enough for the model initialization. Moreover, it should be noticed that stress indices are used to detect hydrological situations where relevant discharges, driven by significant rainfall events in short time (few hours to few days) are present.

12. "L565 Can overestimation be explained by a lack of flood damage information in that area?"

Response: we really thank the reviewer for this comment. We totally agree with this assertion: very likely, the overestimation also depends on a lack of information. To be honest, in these circumstances and without evidences, we can only say that the model did not properly simulate hydrological stress.

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