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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Landslides, floods and sinkholes in a karst environment: the 1–6 September 2014 Gargano event, southern Italy" *by* Maria Elena Martinotti et al.

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We thank the Reviewer for his comments. The scope of the paper is indeed the development of a new algorithm (E-NEP) to analyze rainfall events responsible for geo-hydrological hazards in order to predict their occurrence. The tool was successfully applied to the 2014 Gargano event, where it turned to be able to predict the occurrence of the observed landslides. We maintain that the new algorithm can contribute to forecast the possible occurrence of rainfall-induced landslides and to ascertain landslide hazard. Below, we address detailed comments and describe the modifications we have made to the manuscript.

1 - The text was amended in order to avoid repetitions. However, we prefer to use the

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term “geo-hydrological” instead of “hydrogeological”. We believe that the term “geo-hydrological hazards” is more apt to delineate the range of phenomena that encompass, among the others, the landslides, floods, debris flows, sinkholes, erosions. In addition to a wide use of the term geo-hydrological in the scientific literature, this is also explained in a recent document discussing the Italian National Strategy for the Adaptation to the Climatic Changes (SNAC): Castellari S., Venturini S., Ballarin Denti A., Bigano A., Bindi M., Bosello F., Carrera L., ChiriacoÌĂ M.V., Danovaro R., Desiato F., Filpa A., Gatto M., Gaudioso D., Giovanardi O., Giupponi C., Gualdi S., Guzzetti F., Lapi M., Luise A., Marino G., Mysiak J., Montanari A., Ricchiuti A., Rudari R., Sabbioni C., Sciortino M., Sinisi L., Valentini R., Viaroli P., Vurro M., Zavatarelli M. (a cura di.) (2014). Rapporto sullo stato delle conoscenze scientifiche su impatti, vulnerabilitaÌĂ ed adattamento ai cambiamenti climatici in Italia. Ministero dell’Ambiente e della Tutela del Territorio e del Mare, Roma.

2 - We acknowledge that geological and geomorphological information on the hazards is quite poor, but it is not relevant for the application of the E-NEP algorithm. Nevertheless, we modified section 3.3 adding more details about the data, as follows: “The consequences of the storm of September 2014 were reported soon after their occurrence, and a first analysis was carried out immediately in its aftermath. The collection of information was obtained searching different sources: (i) field surveys, (ii) technical reports produced by geologists; and (iii) on-line national, regional, and local newspapers. The collected information allowed reconstructing the geographical coordinates of each phenomenon, its occurrence date, and the type of hazard. No geological and geomorphological details were available for the landslides, especially when the information was found in newspapers. A specific landslide catalogue was built and managed in a GIS environment. The catalogue lists the following items: (i) event identification code, (ii) source of information, (iii) landslide location (geographic coordinates, municipality, province), (iv) occurrence date and time (if available), (v) spatial and temporal accuracy, and (vi) landslide type. As concerns floods, the main information regarded the interested areas, the reported damage, and the extent of the flooded territory. Infor-

mation on sinkholes included the occurrence site obtained through field surveys (high geographical accuracy), and the occurrence time, which was mostly based upon interviews with local inhabitants (low to medium temporal accuracy)." We acknowledge that the statement about the soil thickness is too much generic and we removed it from the manuscript.

3 - We thank the Reviewer for advices. We confirm that the map contains 46 circles, but some of them are really close to each other or overlapped. Smaller symbols would make them not visible. According to the Reviewer suggestion, we used different symbols and colors to describe the different types of hazards. We think that using insets would make the figure too much complex without providing additional and substantial information. We acknowledge that there was an error and soil slips of the original manuscript must be intended as earth flows. We have amended the text accordingly. In the reply to comment 2 we specified that: "The consequences of the storm of September 2014 were reported soon after their occurrence, and a first analysis was carried out immediately in its aftermath. The collection of information was obtained searching different sources: (i) field surveys, (ii) technical reports produced by geologists; and (iii) on-line national, regional, and local newspapers".

4 - Some of the self-citation have been deleted, in order the reduce their overall number. However, we have to point out that there are not many works about hazards in karst in the study area, which forced in some ways to cite the existing ones, most of which include authors of the present manuscript.

5 - The paper deals with the natural hazards triggered by the September 2014 storm. Two outcomes of the manuscript are that: (i) landslides are not the only hazards that may occur in the Gargano promontory during heavy rainfalls and (ii) more accurate information are needed on the time or period of occurrence of sinkholes. Indeed, we cannot exclude that even those hazard, analogously to landslides and flash floods, can be likely predicted using rainfall thresholds. This was reported at page 11 of the original manuscript: "Based on the analysis of 25 the 1-6 September 2014 Gargano

rainfall period, we confirm that in the Promontory, and in similar karst areas, torrential rainfall can trigger sinkholes, and we hypothesise that approaches based on the near-real-time monitoring of rainfall (e.g., the E-NEP algorithm) can be used to forecast the possible occurrence of rainfall-induced sinkholes. We acknowledge that an analysis of a larger number of events is required to test this hypothesis.".

Minor adjustments Page 1 15 hydrogeological hazards (I suggest changing this throughout the text). We removed other occurrences of the term "geo-hydrological".

Page 1 17 a karst area in Apulia. We would prefer using the Italian name Puglia in place of Apulia. The correspondence with the international name Apulia is now given in section 1, where we write "Puglia (Apulia)".

Page 1 19 and temporal information. Done.

Page 1 24 (E-NEP). Done.

Page 2 6 delete "by landslides.... inundations". Done.

Page 2 11 characteristics ... delete "Landslides.... sinkholes" and write "natural hazards" instead. We prefer to list the types of natural hazards discussed in the paper.

Page 2 20 Apulia (delete Puglia (...)) We would prefer using the Italian name Puglia in place of Apulia.

Page 2 26 In the area sedimentary rocks crop out... Done.

Page 3 2 have been reported (instead of exist)... delete "including....sinkholes". Done.

Page 3 11 metres. Done.

Page 3 13 Description of events. Done.

Page 3 26 stations (instead of rain gauges). We decided to maintain "rain gauges".

Page 3 30 dry periods lasting between. Done.

Page 4 8 in this period. Done.

Page 4 25 delete "landslides and sinkholes". We rephrased as follows: “in a number of floods, flash floods, landslides and sinkholes . . .”.

Page 4 35 translate water height (5.30 m) in flow rate. We do not have the stage-discharge relationship for the cross-section and so it is not possible to transform the height in flow rate.

Page 5 1 and. Done.

Page 5 3 flow rate instead of water height. As above.

Page 5 2 from (not form). Done.

Page 5 6 Cagnano-Carpino was a landslide fatality, the flood fatality was at Peschici (see line 25 on page 4). Make up your mind! We thank the Reviewer. Actually, there was an error in the data we received. Both the fatalities were due to floods. We amended the text consequently.

Page 5 12 mostly shallow landslides. Done.

Page 5 13 write 4 and 2 instead of four and two. Done.

Page 5 22 delete "of landslides". Done.

Page 6 17 of cumulated. Done.

Page 6 18 of rainfall ..... exceeded... Done.

Page 7 1-3 you use 3 times geo-hydrological! use hydrogeological (possibly) and delete sometimes (just use hazards). Done.

Page 7 6 Probability (E-NEP) algorithm ... record (delete s). Done.

Page 7 10 and d the time... Done.

Page 7 18 delete "landslides..... hazards". We decided to keep it.

Page 7 28 delete else (first word) and write otherwise. Done.

Page 8 2 possible hazard occurrence ... was calculated (delete using the approach.... (2012). Done.

Page 9 6 The analysis ..... DNEPmax is of interest. Done.

Page 9 22 rise following. Done.

Page 9 27 (E-NEP). Done.

Page 9 32 I, on their own, were not.... Done.

Page 10 15 et al., 2007. Done.

Page 10 30 delete 2003 (not needed) and De Graff et al., 2013 These are difficult-to-find papers. Done.

Page 10 32 delete "that lays.... E-NEP." Done.

Page 11 2 delete (Brunetti..... 2012). Done.

Page 11 7 driven hazards. Done.

Page 11 10 these hazards. Done.

Page 11 30 Apulia. As above.

Page 12 10 (E-NEP). Done.

Page 12 11 sinkholes). insert space For... Done.

Page 12 20 events they are abundant. Done.

Page 12 21 as for the. Done.

Page 14 9 Szonyi. Done.

Page 17 5 sea level. Done.

Page 18 I would have placed the rainfall station in a more logical sequence (from N to S? Or from E to W). Now they are placed rather randomly. Done, now they are placed N to S.

Page 21 2 1-6. Done.

Page 23 2 scheme. Done.

Page 25 The symbols of landslide are placed in ace rain time interval rather precisely, although you stated that only 9 were known to have occurred at precise intervals. Is this just a graphical representation? Or do you ONLY mention the 9 known ones. Explain please. We have temporal information only about 9 landslides (4 in cluster A, 1 in cluster B, 1 in cluster C, 3 in cluster D) but we assume these landslides to be representative of the clusters (this is explained in Section 3.3). The landslide occurrence time is provided with an estimated uncertainty represented by the shadowed gray band in Figure 10. We modified the caption to explain it better. In particular, we wrote: “The occurrence time (and the associated uncertainty) of nine landslides (cfr. section 3.3) is used to define the landslide occurrence period of the four clusters . . .”.

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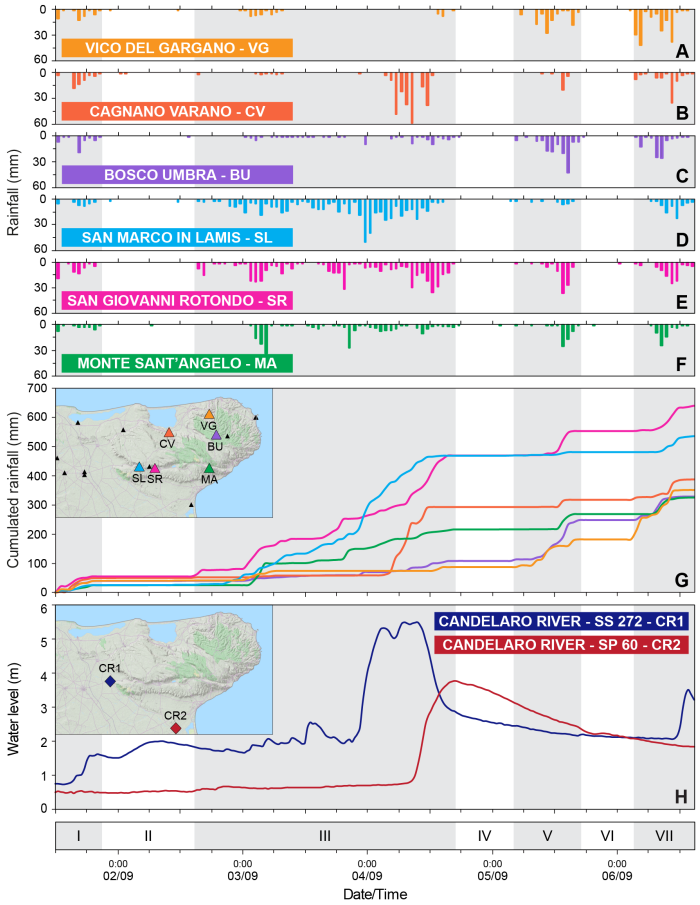

Fig. 1. Figure3: Rainfall and hydrological conditions for the period 1-6 September 2014 in the Gargano Promontory. (A) to (F) hourly rainfall measurements for six rain gauges in the study area. (G) Cumulated

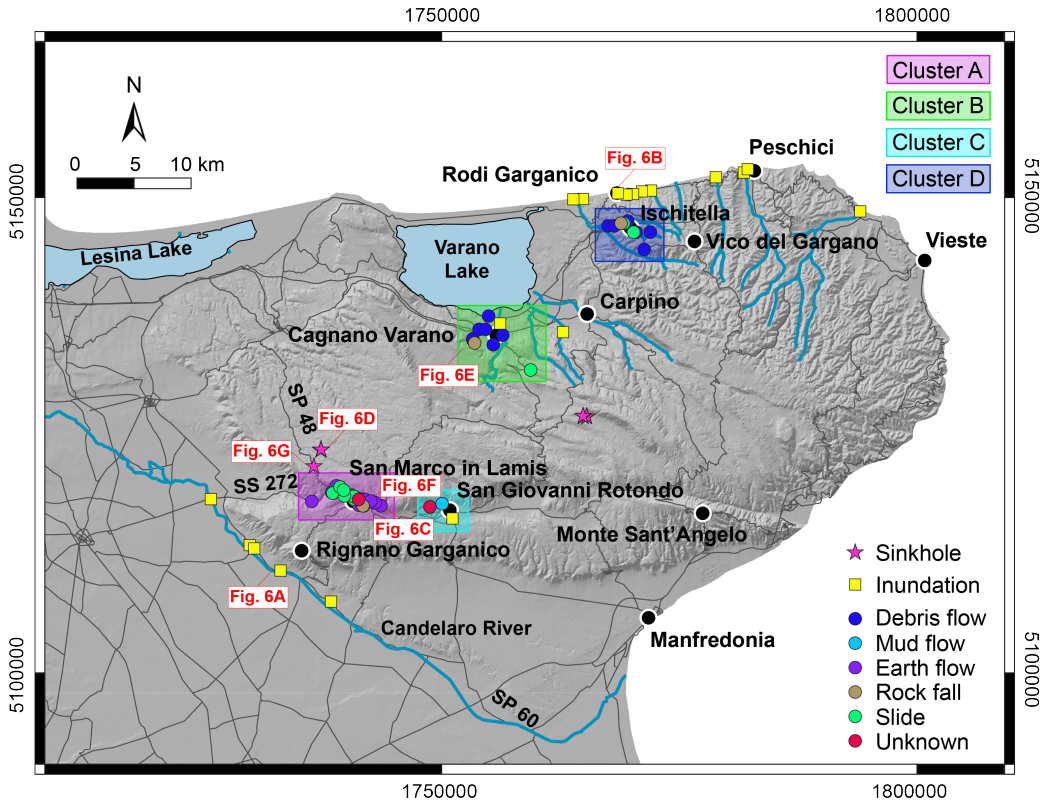

Fig. 2. Figure 5: Map showing location of event landslides, floods, and sinkholes triggered by the 1-6 September 2014, intense rainfall event in the Gargano Promontory. WGS84/Pseudo Mercator (EPSG:3857).