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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "A GIS based urban flood risk analysis model for vulnerability assessment of critical structures during flood emergencies" *by* R. Albano et al.

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Response to Reviewer Comments Journal: NHESS Article: A GIS based urban flood risk analysis model for vulnerability assessment of critical structures during flood emergencies(doi:10.5194/nhessd-2-2405-2014) Authors: R. Albano, A. Sole, J. Adamowski and L. Mancusi MS No.: nhess-2014-67 MS Type: Research Article First Contact: PhD Eng. Raffaele Albano, albano.raffaele@tiscali.it 15/07/2014

Dear Editor, Referees,

We would like to express our gratitude for having accepted our paper in NHESSD and

to have provided very useful and constructive comments of our work. In the following sections, you will find our replies to all the comments of each referee.

In the attached PDF file you will find the improved version of the paper, based on the comments of the Referees.

In this response letter, we provide the page and/or line numbers where we made changes to address the comments of the reviewers.

Kind regards, Raffaele Albano, Aurelia Sole, Jan Adamowski and Leonardo Mancusi.

Anonymous Referee #3

Main remarks:

1. My main concern regards the lack of correspondences between what the Authors introduce in the methodological sections of the manuscript and what they really shown as results. Despite the definition of several vulnerability indexes in order to consider the complexity of the emergency system in an urban area, the description of numerical application is limited and focused only on the systemic vulnerability index, while other indexes (such as. eq. (1)-(3)) are not shown.

Response: The equations are now better explained and some simple examples are described and represented in fig.5-6-7 (p.16-19). In the results section, the results of the influence index are described (p.29 l.10-20), together with other comments on the results in the results section (p.28), and presented in Fig.13. The authors have now provided more evidence in the results section with quantitative validation (p.28 l.2-11), and spatial validation with more observation points (p.29 and figs.11-13-14) and historical data of past events (p.26 l.12-32).

2. 2412-L11-21 - Concerning the seven categories identified by Escuder Bueno (2012) it is not really clear in the manuscript how, and on the basis of which information, these classes have been associated to the study area in order to estimate the number of loss of life.

Response: It was assumed that there was minimal warning of flood threats in this zone. Warning time is defined as the time difference from the first notice flow and the first damage flow. We made the assumption that the first notice peak corresponded to the first damage flow since Ginosa does not have a flood warning system. Additionally, in the literature and on the web there is evidence that no public education on flood risk, risk communication, and recent events have highlighted the lack of coordination between emergency agencies and authorities. The low value of loss of life estimated by the model is addressed by the fact that, even though there is evidence of a lack of a warning system and government risk education activity, the Peak Unit Flow Rate is really low in the area due to the lower flow velocity estimated by the 2D numerical flood model. (p.26 l.21-32).

3.a Section 2.1.2 - In this part Authors describes the methodology adopted for the estimation of direct damages to buildings distinguishing different occupancy types. However, it is not clear to the readers on which type of data this analysis is performed. What are the data sources required for this accurate analysis? Authors refer only to maps of land use but their accuracy and resolution should be provided.

Response: The authors now highlight that the model requires a micro-scale map of the urban system (p.11 l.6-7), and then in the case study section the authors describe what kind of city map was used for the specific case study (p.23 l.10). The same was done for the land use map and occupancy type map (in the case study the map is at a scale of 1:5000; source: SIT Puglia database, 2011).

3.b How does the economic value of the different structures and activities was defined? Figure 3 provides several depth-damage curves but the difference between the two panels is not clear. What do the suffix _S and _C mean?

Response: C=content and S=structure; see p.11 l.9 and p.12 l.2.

3.c Finally, in this study Authors refer to depth-damage curves provided by F-RAM 2008 which are evaluated for flood events occurred in the United States. This aspect

implies that these curves may not be suitable for Italian case studies where economic and social characteristic are different. Some consideration on this point and on the limits of the application of the methodology should also be included to the discussion.

Response: The authors have now clarified in the paper that the depth-damage curves implemented in the model is taken from the USACE (Department of Water Resources Division of Flood Management, 2008), and which are also proposed in the 'SUFRI' Methodology (Escuder Bueno et. al, 2011). It is more precautionary than the one proposed by Luino et al. (2003) for Italy (p.11 l.1-7). The authors have also now highlighted in the results that there is an underestimation of the model in the estimation of direct economic damage (but have justified why (p.28 l.2-11)). Therefore, the use of curves taken by Luino et al. (2003) could produce an additional underestimation of the direct economic damage that could be related only to the depth-damage curves utilized.

4. 2417-L11 - The Authors introduce the index of weakness of each arc by referring to equations 1, 2 and 3. However, if I have well understood the meaning of different indexes, the eq. 2 and 3 clearly refer to a specific arc, while the eq (1) evaluates the degree of inaccessibility of an area, such as part of the city or buildings, etc., and should not be considered in the identification of the index of weakness of a specific arc. In general, I think that a schematic representation of the city with the connection system and some buildings may enhance the clarify of the presentation.

Response: Equation 1 is useful for both buildings and for roads. The weakness index of the building has the same results as eq. 1; in contrast, for roads the weakness index incorporated eq.1-2-3. In the revised paper, the authors have used 4 equations to clarify this issue and have re-edited this part of the manuscript (p. 15-19). The authors have also introduced Fig.5-6-7, which represent some simple examples of the equations adopted in the methodology that are useful to give a schematic representation of the city with the system and some buildings (p. 16-19).

5. Section 2.2.3. The systemic vulnerability of each element (section 2.2.3) is defined as the max between the structural damage, , and the influence of the road network, . As I have understood is the amount calculated following section 2.1.2, while refers to eq. (4) and ranges between 3 and 6 (see 2418-L2). Is it true? These indicators should be previously introduced in their respective sections. Beyond this, I have some doubt on the choice of taking the maximum values. In fact, and represent two different type of damages that can coexist in case of a flood event and should be considered both, the first in order to consider the structural damages to the element and the latter the damages induced by its inoperability. Can the Authors further discuss this point?

Response: The systemic vulnerability index, which is now called the "maximum impact index" in the revised paper, is the higher value between the direct and indirect consequences estimated respectively in step III and IV in fig. 1 p.5. The choice of selecting the higher value between the direct and indirect consequences is justified by the evidence that the summation of the indirect impact index, which represents the influence impact in the system (Sect. 2.4.2), and direct damage, described in Sect. 2.3.2, could cause an underestimation of the maximum impact value due to a flood event: the ratio between the potential maximum value of the summation of the direct and indirect impact and the estimated impact value is lower than the ratio between the potential maximum value that could be estimated with this methodology, i.e. value 1, and the maximum value, estimated by this methodology, between the direct and indirect impact value, as previously described (see p.21).

6. Section 4. The Authors reproduced the flood event by means of a 2D model but no information are reported in terms of model parameters (i.e. friction coefficients). Have the Authors performed a model calibration?

Response: Hydraulic simulations of flood scenarios were performed using a 2D commercial flood model. For this case study, the Mike Flood model was used since it was deemed to be the most appropriate model for this area as highlighted in Sole et al. (2012), who calibrated the model for the study area using the Digital Elevation Model

of the study area, which includes cross sections of the river embankment extrapolated from laser scanner data. The friction coefficient of the flooded area is evaluated by the land use map at a scale of 1:5000, which is available on the online database of the Puglia Region (SIT Puglia database, 2011) (p.23 l.30-31 and p.24 l.1-5).

7. In some parts the manuscript results not really easy to understand. I would recommend a general revision.

Response: Many different parts of the paper have been modified on the basis of the Referees comments.

Specific Remarks: 1. 2406-L24 - please remove one of the citation about Jonkman, 2005.

Response: This has now been done (p.1 l.40-41).

2. 2407-L3 - the reference “Institute of Civil Engineers 2001” is not clear. What does it stand for? Also see some other important references on this point (i.e. Djordjević et al., 2011, and references therein).

Response: The authors have substituted the reference "Institution of Civil Engineering" with the one proposed by the referee (p.2 l.4).

3.407-L14 - please check Jongman et al., 2010; it is not in the reference list. For the Damage Scanner model please refer to Klijn et al., 2007.

Response: The authors have substituted the reference with the one proposed by the referee (p.2 l.21).

4.2409-L9-13 - please reformulating this part, it is a little bit confused. USACE, 2008, is missing in the reference.

Response: This has now been done (p.3 l.1-9) and the reference USACE (2008) has been deleted. However, the correct Reference is not USACE, 2008 but "Department of Water Resources Division of Flood Management, (2008)".

5. 2409-L16 - in this case I think that it is more correct to refer to an “innovative methodology” than to an “innovative model”. The new methodology can be implemented into an hydraulic or GIS model for the evaluation of a specific flood event.

Response: This has now been done (p.4 l.18).

6. 2410-L3-5 - Please revised this paragraph. The structure is repetitive while the content does not exactly represent the structure of the manuscript. For example Section 3presents the case study only.

Response: This has now been done (p.5 l.1-3): "In section 2, the overall GIS framework is outlined, in section 3 the application and results of the proposed model on a real flood event are described, and an overall conclusions are provided in section 4".

7. 2410-L19 - “simulation” fits better to the context than “evaluation”.

Response: This has now been changed (p.6 l.19).

8. 2411-L8 - please remove “as in phase III of Fig. 1”.

Response: This has now been done (p.7 l.8).

9. 2411-L19-20 - please check the sentence, a bracket is missing. Also, the concept of Peak Unit Flow Rate is not clear. Is it the same of the flow impulse (i.e. the product of water depth and flow velocity) ? Furthermore, it is not clear to me the definition of the Twv at night. . .are there specific demonstrations and references about the difference of 15 minutes?

Response: The Flood Wave Arrival Time (Twv) (i.e. the time of occurrence of the flood wave) grid was obtained. In addition, the two components (x-coordinate and y-coordinate) of the vector unit flow rate were combined to obtain the maximum "Peak Unit Flow Rate" values (m2/s) (i.e., the flow discharge for each linear meter of cross-section). These values, termed parameter DV, proposed by Graham (1999), are representative of the general level of destruction that would be caused by the flooding (p.7

l.17-23).

The warning time, that is a function of the Twv, at night is defined as a time period 15 minutes lower than the warning time during the day, such as in Escuder-Bueno et al. (2011). If there is no warning time or data is not available, the available warning time is estimated from the difference between the time of occurrence of the first-notice-flow and the first-damage-flow, such as in Escuder-Bueno et al. (2011) (p.8 l.25-30).

10. Fig 2. The Figure 2 can be reformatted as an additional table. The Figure label (i.e. “Table 8. Flood severity . . . “) should be removed and DV values converted following the International System of Units.

Response: Figure 2 has been reformatted as a table and the values have been converted into the International System of Units (p.8 table 1).

11. 2412-L1-2 - This sentence is not clear. Please consider to reformulate it.

Response: If the information on population is aggregated at the census area level, it could be hypothesized that it is distributed homogeneously within the vector polygon that represents the census areas. Hence, the vector polygons of the population census block were converted into grid format (p.8 l.4-7).

12. 2412-L5 - What does “residual damage” mean for the Authors? I think in this case “additional” or “indirect” damage could be more appropriate.

Response: There is no term "residual damage" in this part. However the terms residual damage is substituted in the paper by damage.

13. 2414-L16 - please remove the part in brackets.

Response: This has now been done (p.13 l.19-20).

14. 2414 - L25 Can be the Authors more detailed? What is the water depth threshold adopted to close the road? I think that a road can become inaccessible for water depth lower than the vehicle height (e.g. 50-70 cm).

Response: The curves implemented in the model are used when incoming flow depths are lower than the vehicle height, shown in the lower part of the graph in Fig. 4. When the incoming flow depth is greater than the vehicle height, the roads are considered to be always inaccessible. This choice is justified by the possible presence of emergency vehicles that could work in worse conditions than cars (e.g. firefighter trucks, ambulances, small boats, etc.). As such, the methodology, on the one hand, aims to give more importance to closure for vehicle transport, which is a frequent phenomena in urban areas as highlighted in Albano et al. (2014), Gruntfest (2000) and Gruntfest and Ripps (2000) (see reference p.34-37), and, on the other hand, aims to be precautionary and independent of the type of vehicles available in a specific scenario in the analysis (p.14 l.9-18).

15. Eq. (1) - Eq. 1 is not very clear. Why the index reports the symbol $\triangle$? The equation (1) also refers to . Is it an error or the index refer to a specific emergency path? In this case, the index should report the j. Also, the numerator should be simplified in the term of . What does the first sum refer to? Finally, the range of variation of the index should be added to the text.

Response: These equations have been checked together with the name of the indexes to improve the readability of the paper (see p.15-16 and see p.5 fig.1).

16. 2416-L11 - Are there some references on this index?

Response: The concept of reliability is introduced by Taylor et al 2006 (p.15 l.11).

17. 2416-L17 - "The Reduncancy Index, RIod, developed . . ."

Response: The name of the index has been changed to improve the readability of the paper. (p. 17 l.10): "The hierarchy index, Hi, developed. . ."

18. 2416-L18 - The explanation of "o/d" should be moved before equation (1).

Response: This has now been done (p. 15 l.20-21).

19. Eq. (2) - Since the RI index refers to a specific arc it should use the subscription j. At line 19 Authors refer to arc j, while then to Please make the text consistent. is not defined. As before, Authors should describe the significance of the values assumed by RI.

Response: The index estimated by Eq (2), now Eq. (3) in the text; refers to specific arcs and ranges in the interval [0.1]. This has now been addressed in Eq. 3 p.17 and p.18 l.2

20. Eq. (3) - Is the element necessary in this equation? What is the meaning of OI? Also in this case the index refer to a specific arc, so subscript j may be added.

Response: This is the same as the previous comments. This has now been addressed in Eq. 4 p.18.

21. 2417-L12 - "represent the Index of Weakness, IW, of each arc"

Response: This has now been changed as suggested by the referee (p.19 l.17).

22. 2417-L17-18 - please better clarify this point.

Response: p. 20 l.1-2: For the structures, i.e buildings at risk, only Eq. (2) (i.e. the impedance index) is used in order to estimate the weakness index of structures at risk for each building.

23. 2417-L19 - it is not clear to which elements the influence index refers.

Response: The influence index refers to each element (building and road) (see p.20 l.3).

24. 2420-L19 - Which kind of discrepancy did you found? Please better explain this point, otherwise, if the discrepancies do not affect the analysis you should remove this sentence.

Response: p.23 l.7-11: The discrepancies are related to the different times of the

acquisition of the population data (ISTAT, National Institute of Statistics, 2001) and the map of the city, that represent buildings and roads, at a scale of 1:5000 (SIT Puglia database, 2011).

25. 2420-L21 - Which data have you extrapolated from ortophoto?

Response: This sentence has been deleted because it is a typo error.

26. 2421-L11 - “using the Digital Elevation model”

Response: This has now been changed (p.24 l.2).

27. Figures 5 and 6 - please provide a complete legend for all the elements.

Response: This comment has been addressed; see p.25 Figs.8-9.

28. Figure 7 - It is not clear if Fig. 7 refers to the results of this work or to previous investigation performed by IRPI (see the legend).

Response: p. 27 l.8-10: Figure 10. Map of the estimated loss of life divided in categories, (low, medium and high) for the flood event simulated by the model compared with historical information of loss of life and evacuation of people (AVI project, 2000).

29. Table 3- I suggest to convert this table into a Figure.

Response: Figs.8-9 (p.25) are representative of this table.

30. Table 4 - Have the Authors performed a comparison with respect the real damages registered after the event.

Response: This has now been addressed on p.28 l.2-15: After the March 1st event, the total amount of money requested on the basis of a self-estimate by the citizens of Ginosa to the Italian Government for the damages to their properties due to this flood event was around 6,501,741 € (source: "Ordinanza ministeriale del 5 luglio 2012 n. 4024"), in comparison to the 4,736,125 € estimated by the model as direct economic damages. This discrepancy could be justified by the evidence that the model

does not take into consideration the damage caused by pluvial contribution to the flood event (the model simulates only the river flood event). Indeed, the number of buildings affected by the flood estimated in the model is about 63% of the number of buildings affected by the real event (about 1000 buildings). It should be noted that it is not possible to complete a validation on the other elements (i.e. roads, railways, agricultural areas) involved in the flood event due to a lack of available data from the real event. However, it is possible to make a spatial comparison with photos recorded at 10 observation points throughout the city (Figure 11-13-14), as was done in this study.

31. Figure 9 - please check the language.

Response: The names relate to the Italian Classification. In the text, the terms that are more relevant for the results of the model are now explained (p.29 l.14).

32. Figure 10 - please better describe its meaning. If I am not wrong the brown color means more isolated (and potentially damaged) areas. However, this depend on the position of the strategic structures such as hospitals or fire stations that are not shown in the map.

Response: This position of the strategic structures is now shown in Fig.13 p.31.

Please also note the supplement to this comment:
http://www.nat-hazards-earth-syst-sci-discuss.net/2/C1545/2014/nhessd-2-C1545-2014-supplement.pdf

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