Natural Hazards
and Earth System
Sciences

Open Access

EGU

Discussions

NHESSD

Interactive
comment

Interactive comment on "An agent-based model for flood risk warning" *by* Thomas O'Shea et al.

Thomas O'Shea et al.

t.oshea@bristol.ac.uk

Received and published: 30 January 2020

RC3 – Response

Author comment:

The authors would like to extend their sincere thanks to the referee for their time and thoughts on the submission. All comments and corrections have been thoroughly considered, with our respective action and/or response to these outlined below.

Referee comment:

This paper attempts to present an integrated hydraulic-ABM model for modelling individual behaviour during flooding. Human interventions could significantly affect flood risk even during an event, especially in densely populated urban areas. This research represents an encouraging attempt to develop an approach to model human activities

in the city of Carlisle during a flood event in 2005, which is an innovative and necessary step forward in flood risk assessment. But at its current form, the paper is difficult to follow, and it is not clear what the core focus and innovation is. It must be substantially revised and improved before accepting for publication. Hope the following comments will help the authors revise their paper.

Author response: The authors appreciate the referee's acknowledgement that this is indeed an encouraging attempt at developing an innovative and necessary step in the field of flood risk assessment. As outlined in the responses below, the authors have sought to address the referee's concerns and to clarify further the core focus and innovation of the paper.

Referee comment:

The major concerns:

1. What is the major novelty or focus of this work? Is it the 'new' modelling framework? Or is it the application of the model to understand human activities during a flood event in the case study?

Author response: To broadly answer this series of questions, this work is an improvement on previously conducted work (e.g. Dawson et al., Lumbruso et al.) owing to: (i) the efficiency and flexibility of having two separate codes for the models, thus increasing the likelihood of the coupled model framework representing a more sophisticated set-up (inertial wave, 1D/2D structure for channel representation etc.) and (ii) having a hydraulic model that has been more thoroughly validated than models previously written into NetLogo. With respect to Lumbruso et al.'s paper, the Life Safety Model did not test the evacuation characteristics for 'type' of response. The focus of our work is to address these two shortcomings by offering a modelling approach which couples physical and social models where agents have a probabilistic daily routine and a choice of responses on an individual basis. This enables the exploration of different hypotheses for social reactions and responses to the detailed, accurate and dynamic

physical outputs generated by LISFLOOD-FP by adding the related elements of policy and systematic change. Specifically, we use the Bass Model of diffusion (l. 220-224) to explore hypotheses relating to flood warning and evacuation which yields interesting new insights into these processes that would be difficult to achieve in any other way. It follows from this that the framework is indeed new and by applying it to the case study for Carlisle's 2005 event we are able to illustrate human activities and understand their behaviours, structured with a logical and believable social model and driven by a firmly validated physical model. We therefore believe the work has a clear focus and is novel in endeavour, as was noted by the two other referees.

Referee comment:

"This paper presents a new flood risk behaviour model developed using a coupled Hydrodynamic Agent-Based Model (HABM)", which suggests the modelling framework is the key novelty in this work. But the presented HABM takes offline modelling outputs (flood depth) from LISFLOOD-FP to drive the agent-based model developed in the Net-Logo framework. This is a 'step backwards' from the modelling approach as reported by Dawson et al. (2011), in which "a hydrodynamic model simulates the floodwave was also developed within the ABM platform and interacts directly with the agents and the built environment".

Author response: Concerning the (excellent) work by Dawson et al., we argued in the paper that "this study initially coded the hydrodynamic model directly within the ABM meaning advantage could not be taken of recent developments in efficient numerical methods for solving the shallow water equations ... and high-performance computing. . ." The fundamental thought to this is that the approach taken by Dawson et al. was a great way to start to link ABMs and hydrodynamic models, but we found that it has some technical limitations because only a very simple hydrodynamic model can be coded within the ABM framework. The referee has perhaps not appreciated the limitations imposed by writing the hydrodynamic code within the ABM, so these are further outlined below: Because they were working within the NetLogo ABM framework,

Dawson et al were only able to code a very simple inundation model for 2D only domains. This was based on solving a version of the diffusion wave equations following Bates and De Roo (2000) which was (just about) adequate for the small coastal flood that Dawson et al simulated. The coding environment in an ABM framework can never be as flexible and computationally efficient as writing software in a compiler language, as we found when we tried to do exactly this at the start of our project. We initially coded our hydraulic model within NetLogo exactly as Dawson et al had done, but for the high-resolution whole city-scale test case used here the simulation took days of computer time. This is because solving dynamical equations on fine grids with numerical methods without a compiler language is extremely slow.

In addition, the lack of coding flexibility within ABM frameworks means that one cannot create more sophisticated model structures, such as hybrid 1D/2D hydrodynamic models, that are required to simulate fluvial flooding in urban areas. The only reason for having the hydraulic model coded within the ABM is if the behaviour of the agents changes the development of the inundation. This is not the case for the Carlisle flood, and neither was it the case for the coastal flood simulated by Dawson et al. In these circumstances there is no advantage to the 'tightly-coupled' approach and it also means that one is not able to take advantage of the latest development in hydraulic modelling. For example, we showed during a series of papers during the 2000s (Hunter et al., 2005; Hunter et al., 2008; Bates et al., 2010) that the simple diffusion wave approach used by Dawson et al suffers from a series of technical flaws meaning that to correctly simulate wave dynamics it can only be used with relatively coarse numerical grids. This is problematic for simulating floods in urban areas where it is now commonly accepted that one needs a model grid capable of resolving flow around buildings. By writing their hydrodynamic code within the ABM framework Dawson et al's approach could not be used to simulate a whole city scale inundation event at high resolution as we do here. By keeping the ABM framework and hydrodynamic model separate we effectively solve this problem. As a result, writing a hydraulic model within the ABM framework has no advantages for many (perhaps most) flooding applications and leads to quite a few

constraints. Our approach is a step forward because it can use a more sophisticated hydrodynamic model that takes advantage of nearly 20 years of numerical developments since the Bates and De Roo (2000) formulation implemented by Dawson et al. Having an offline model is much more flexible and it can therefore be applied to a breadth of different situations to test different hypothesis, not just simple 2D coastal problems at relatively coarse resolution.

Referee comment:

The approach of using offline flood modelling outputs to drive an agent-based model has also been reported in the literature, e.g. Lumbroso et al. (2011) developed a life safety model to estimate risk to people imposed by dam breaks or flash floods. In their work, their Life Safety Model could use outputs from any available two-dimensional hydrodynamic models that solves the shallow water equations (e.g. Telemac-2D, TuFlow) or the simplified forms (e.g. LISFLOOD-FP).

Author response: The authors acknowledge the referee's assertion that Lumbroso et al's work on the Life Safety Model offers a similar level of physical modelling flexibility to that of the HABM and thank the referee for drawing our attention to this. As far as the authors are aware this is one of few (Dawson's being the other) comparable modelling studies to the HABM described in our paper and we have included an acknowledgement of this in the revised manuscript.

There are clear differences in the two overall approaches. Lumbroso's model considers the notion of 'fate' based upon 'warning' and 'action', claiming to consider the notion of direct or indirect warning i.e. agent communication, in the process of warning or action. It does not substantiate the process of message adoption or suggest how this might better align with current policy direction on an individual level. There is no clarity on whether the agents carry out a routine of any kind, with the choices being given to them largely relying on linear and limited choice direction. We imagine the natural counter to this might well be to draw attention to Dawson having included a routine, with

comparable physical modelling flexibility and here the HABM differs again by offering agents the choice of adopting an 'emergency routine' in addition to the standardised daily one. This means that the HABM emphasises the role of choice and models it in a more representative manner than in previous work.

Thus, in sum, with contemporary policy moving towards a more integrated approach this framework utilises the methods and conclusions of these two previous pieces of research and builds on them, adding enhanced theory and the necessarily enhanced methods, to provide an integrated approach to test new hypotheses; contributing to the overall sense of novelty.

Referee comment:

If the focus of the paper lies in the application of the model to understand flood-driven human dynamics in the case study. There is no strong evidence showing the model settings reflect reality and so the results and the conclusions may be misleading.

Author response: The authors would like to direct the referee's attention to the cited paper by Neal (et al., 2009) regarding this point. The primary reason why this case was chosen is because of the quality of the computer model used in the simulations. This is also covered sufficiently in figures 9 and 10 of the paper, specifically in (l.745-779) it is stated that over the simulations conducted, the number of potential casualties was aligned with that which was actual during the event in 2005. However, upon review this could be made clearer and so we wish to assure the referee that this has been done for the final submission.

Referee comment:

2. Following the above comments, it is difficult to be convinced that the model settings can represent actual human dynamics during a flood event in Carlisle since:

Author response: The purpose of this paper is to test hypothesis (l. 144-148) and in respect of this, the human dynamics that the ABM simulates are sufficiently 'real' to

produce results which are in line with those observed during the event modelled. It is also the case that all models are a simplification, but here, we believe the HABM represents suitable complexity for the scientific purposes to which it is being put.

Referee comment:

i) the behaviour rules for individual are over-idealised and there is no evidence to back the choice of behaviour rules;

Author response: The behaviour rules are directly sourced from Dawson et al. and, upon reflection, are no more idealised than the responses seen in Lumbroso et al. As an example, in Lumbroso's paper there is no justification given for the scalar magnitude of diffusion of choice (i.e. the effect of choices made by agents, on other agents) and, where alluded to, it is not founded in the kind of arguments we outline in sections 2.3, 2.4, 3 and 4 (l. 721-729) of this paper. Again, Dawson (et. al)'s model, which is another paradigm of physical modelling, makes no substantive reference to social system representation beyond that which is basically necessary for coupled analysis. Further, with respect to agency routine, the authors would argue that Lumbroso's 'PARU' approach is more idealised in comparison to that of the framework in this paper. This particularly being so when there is little information given with respect to how these (PARU) units form and no detail given with respect to the process of choice in the formation of these 'evacuative' units. In our case the interaction rules within the HABM are based on laws of sociological diffusion (Larsen et al., 2005 – source added to revised submission), which take the agents through the five steps of Gabriel Tarde's law of imitation and invention. These are terms which are much better aligned with the reality of what behaviours individuals are likely to exhibit in social settings than anything the authors have reviewed during the process of the model development, or since.

The authors did refer to Bernadini (Bernardini et al., 2017 – source added to revised submission) during the initial stages of developing the behavioural rules alongside the framework provided by Dawson et al. as well as the Nomis and Flow data sets which

were further used by the authors of this submission as a cross-reference. Combined, these sources gave rise to the general routine presented in the paper. It is hoped that with this clarification and with the additional source materials added, the referee will see that the choice of behaviour rules and routine are grounded in both legitimate evidence and theory.

Referee comment:

ii) the communication rules between agents are also over- simplified, e.g. how are text, social media and other forms of wireless communications taken into account, which may significantly affect the simulation results;

Author response: Whilst being 'en vogue' currently, this is not the chosen focus of the paper and also, during 2005 this was much less of a factor for consideration than it is today as many networks for these forms of communication were still being developed. The 2015 Carlisle event would provide an interesting contrast to 2005 as it would be a model within which such formats for communication would presumably provide mensurable impact and thus would merit inclusion in upcoming models and study. We again stress that in the paper we are trying to test several hypotheses concerning flood warning and response, and not produce an exact facsimile of the real world. All models simplify to some extent and we would argue that this is reasonable evidence that we have included enough complexity in our model to undertake the science objectives of the paper.

Referee comment:

iii) traffic systems and key organisations are not represented in the model which will inevitably have significant influence on the results and conclusions;

Author response: Yes, potentially they may have influence for conclusions linked to evacuative action but as is stated in this paper, the significance may be allocated at the outset of process i.e. how warning is communicated rather than how action is taken.

We again note that the physical and human dynamics included in the model were chosen based on theory with a strong lineage of scholarship from other disciplines in order produce a new platform for experimentation and interpretation and practice. In this respect our view is that the HABM delivers with effect.

Referee comment:

iv) the model results were not validated at all. Therefore, the results and the conclusions from the simulation may not be valid and may be misleading.

Author response: Were the aim of the work to make predictions and/or forecasts then yes, further validation would not only be imperative but of great value in addition to the aims and scope of this paper. However, to further reassure the referee, the authors are confident that the hydraulics modelled are well validated for the Carlisle 2005 case study, as is supported by the large body of cited works in section 2.1 of the submission and that the human dynamical routine is eminently sensible and realistic (sufficiently so to answer the questions posed in the paper). Additionally, and as the referee will be aware, ABMs are historically difficult to validate (Ormerod and Rosewell, 2006 – source added to revised submission) and whilst techniques have been introduced to improve this, the authors feel that the model offers a sufficient balance between " clear explanation and description of the phenomena" and the "simplest possible realistic agent-rules of behaviour" for the model to be considered a valid base for comparison to other models (such as those suggested by the referee i.e. Lumbroso et al. & Dawson et al.) The authors would also argue that the level of cognition afforded to the agents operating within the model is not so high as to require significant justification beyond that provided as the process represented is of sufficient alignment to produce useful results for an intended purpose, namely to test hypothesis which would be difficult to evaluate in any other way.

Minor issues:

Author response: These issues are a precis of those outlined above and so have largely

been addressed above.

Referee comment:

1. Why the authors use the 2005 flood event but not look at the more recent 2015 event? More information would be available from different sources for the more recent event to inform and validate human activities.

Author response: As stated in the paper, the 2005 event is one which has provided a large amount of data from LISFLOOD and resulted in a large body of published information on the related phenomena. On this basis, it was felt that it provided a suitable, initial, case study for the application of the new framework – as stated in the submission. Furthermore, as stated in 2 (ii), the 2015 event will provide excellent scope for an updated model which will include the new formats for communication.

Referee comment:

2. The paper is difficult to follow, and the authors should more explicitly explain the modelling framework, how the agents are interact(ing) and communicat(ing), and how the behaviour rules are set and why, etc.

Author response: At 32 pages, the authors feel that they have invested enough time and care to ensure the framework of the model, the formats of interaction and communication and the setting of behaviour rules are all explained in enough detail. Where necessary, we have provided further source material for the reader's reference to consolidate this detail.

Referee comment:

3. Since the human activities do not have any impact on the flood dynamics and the agent-based model is only driven by offline flood model outputs, it is NOT a 'coupled' model.

Author response: As has been emphasised in the author's responses to all preced-

ing assertions made by the referee, the key and novel difference of this submission is the development of a framework that offers scope to include steps seen in directly coupled models (of the same nature) as well as scope for including indirectly coupled procedures for modelling interactions from beyond the scope of those models (of different natures). The motivation here being a desire to move towards more inclusive narratives that align with the dynamic notions of vulnerability and transcend the infinite regress of 'risk-based' modelling simulacra, which seemingly feed into the 'Tower of Babel' problem and do not seem to be addressing the issues of growing disparity in modelled and realised loss; nor incorporating the growing movement in policy to incorporate fundamental elements of social science (l. 79-84 in the submission). Ultimately, were the models not coupled, no results would have been produced to represent the different aspects modelled i.e. the flood layers called into the model would not drive any response in the agent population. Therefore, the authors believe this to be associated with semiotic misunderstanding and so will move to clarify this in the final submission.

Referee comment:

4. The title, 'an agent-based model for flood risk warning', is a bit confusing. Based on its current capacity, the model cannot be used for 'flood risk warning'.

Author response: Without a suggestion for an alternative we are unable to consider what might be a better alternative. In the most basic format, based on the physical representation of the flood and the subsequent modelled response of the population in the model, this is an agent-based model for flood risk warning.

_____ Referees references:
Dawson, R., Peppe, R. & Wang, M., 2011, An agent-based model for risk-based incident management of Natural Hazards. Nat. Haz., 59(1): 167-189. Lumbroso, D.M., Sakamoto, D., Johnstone, W.M., Tagg, A.F. and Lence, B.J., 2011. Devel-opment of a life safety model to estimate the risk posed to people by dam failures and floods. Dams and Reservoirs, 21(1): 31-43.

—————————————————————————————

Author's references:

Neal, J. C., Bates, P. D., Fewtrell, T. J., Hunter, N. M., Wilson, M. D. & Horrit, M.S., Distrubuted whole city water level measurements from the Carlisle 2005 urban flood event and comparison with hydraulic model simulations. Journal of Hydrology, 42-55, 2009.

Larsen, G.D., Horses for courses: relating innovation diffusion concepts to the stages of the diffusion process. Journal of Construction Management and Economics, 23 (8), 787-792, 2005.

Bernardini, G., Camilli, S., Quagliarini, E. & D'Orazio, M., Flooding risk in existing urban environment: from human behavioural patterns to a microscopic simulation model. Proceedings from the 9th International Conference on Sustainability in Energy and Buildings, SEB-17, Chania, Crete, Greece, 5-7 July 2017, Energy Procedia, 134, 131-140, 2017.

Ormerod, P. & Rosewell, B., Validation and Verification of Agent-Based Models in the Social Sciences. In: Squazzoni, F., Epistemological Aspects of Computer Simulation in the Social Sciences. EPOS 2006. Lecture Notes in Computer Science, Springer Berlin, 5466, 130-140, 2009.

—————————————————————————————

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2019-370, 2019.