Author replies to comments of reviewer 1

First of all we would like to thank the reviewer for his/her positive review of the MS and the constructive comments.

Regarding the comment on the title and the use of the term “method” we agree that the work presented in the MS does not represent the definition of a scientific method defined as knowledge development by the systematic observation, measurement and experiment, and the formulation, testing, and modification of hypotheses. Thus we will term the approach we developed and implemented as “concept”, which is defined as “an abstraction or generalization from experience or the result of a transformation of existing ideas”. This is exactly what we have done. But we argue that the MS exceeds the scope of a case study, because the concept is generic and transferable to many other locations with similar climatic boundary conditions. Thus the new title will be:

“Combined fluvial and pluvial urban flood hazard analysis: Concept development and application to Can Tho City, Mekong Delta, Vietnam”.

The applicability of the simplified shallow water equations in inundation modelling has been tested in many studies. In practically all of these studies the simplified models provided comparable performance to hydrodynamic models using the complete shallow water equations, particularly for the presented spatial scale and level of detail. The complex models outperform the simplified models on in cases with supercritical flow, which can be ruled out in the presented case of shallow water inundation and low surface gradients, and for very detailed hydraulic simulations, e.g. inflow in and around man-holes or obstacles. The huge benefit of the simplified models is the much higher computational speed, which is a big asset for the simulation of large inundation areas and when a large number of inundation scenarios are to be simulated, as in the presented case. For these reasons simplified hydraulic models are meanwhile almost the standard tool for flood hazard mapping. The following papers prove the applicability of the simplified hydraulic models:

Apel, H., Aronica, G., Kreibich, H., and Thieken, A.: Flood risk analyses—how detailed do we need to be?, Natural Hazards, 49, 79-98, 2009.

Bates, P. D., Horritt, M. S., and Fewtrell, T. J.: A simple inertial formulation of the shallow water equations for efficient two-dimensional flood inundation modelling, Journal of Hydrology, 387, 33-45, DOI 10.1016/j.jhydrol.2010.03.027, 2010.

de Almeida, G. A. M., Bates, P., Freer, J. E., and Souvignet, M.: Improving the stability of a simple formulation of the shallow water equations for 2-D flood modeling, Water Resources Research, 48, W05528, doi:10.1029/2011WR011570, 2012.

de Almeida, G. A. M., and Bates, P.: Applicability of the local inertial approximation of the shallow water equations to flood modelling, Water Resources Research, 49, 4833–4844, 10.1002/wrcr.20366, 2013.

Dimitriadis, P., Tegos, A., Oikonomou, A., Pagana, V., Koukouvinos, A., Mamassis, N., Koutsoyiannis, D., and Efstratiadis, A.: Comparative evaluation of 1D and quasi-2D hydraulic models based on benchmark and real-world applications for uncertainty assessment in flood mapping, Journal of Hydrology, http://dx.doi.org/10.1016/j.jhydrol.2016.01.020,

Fewtrell, T. J., Duncan, A., Sampson, C. C., Neal, J. C., and Bates, P. D.: Benchmarking urban flood models of varying complexity and scale using high resolution terrestrial LiDAR data, Physics and Chemistry of the Earth, 36, 281-291, 10.1016/j.pce.2010.12.011, 2011.

Kim, B., Sanders, B. F., Famiglietti, J. S., and Guinot, V.: Urban flood modeling with porous shallow-water equations: A case study of model errors in the presence of anisotropic porosity, Journal of Hydrology, 523, 680-692, http://dx.doi.org/10.1016/j.jhydrol.2015.01.059, 2015.

Neal, J., Schumann, G., Fewtrell, T., Budimir, M., Bates, P., and Mason, D.: Evaluating a new LISFLOOD-FP formulation with data from the summer 2007 floods in Tewkesbury, UK, Journal of Flood Risk Management, 4, 88-95, 10.1111/j.1753-318X.2011.01093.x, 2011.

Neal, J., Villanueva, I., Wright, N., Willis, T., Fewtrell, T., and Bates, P.: How much physical complexity is needed to model flood inundation?, Hydrological Processes, 26, 2264-2282, 10.1002/hyp.8339, 2012.

Pathirana, A., Tsegaye, S., Gersonius, B., and Vairavamoorthy, K.: A simple 2-D inundation model for incorporating flood damage in urban drainage planning, Hydrology and Earth System Sciences, 15, 2747-2761, DOI 10.5194/hess-15-2747-2011, 2011.

The hydraulic model is grid based, i.e. flows are calculated between cells based on the water depths and surface elevations of the neighboring cells. Routing precipitation is thus quite simple and straight forward: At each time step the spatially distributed precipitation (which is already given in mm depth) is added to the inundation depth of the affected grid cells. By this the inundation depths of the grid cells are updated and thus the hydraulic gradients change, resulting in flow. This easiness of routing rainfall is another benefit of grid based inundation models. We will point this out in more detail in the revised MS.

The explanation of equations (1) and (2) will be extended to:

$$q_{t+\Delta t} = \frac{q_t - g h_{flow} \Delta t S_f}{\left(1 + \mathrm{g} h_{flow} \Delta t + n^2 \frac{|q|}{h_{flow}{}^{\frac{10}{3}}}\right)} \tag{1}$$

$$\frac{\partial h^{i,j}}{\partial t} = \frac{q_x^{i-1,j} - q_x^{i,j} + q_y^{i-1,j} - q_y^{i,j}}{\Delta xy} \tag{2}$$

where t = time; Δt = time step; q = specific flow per unit width; i, j, = cell indices; h_{flow} = flow depth between cells, i.e. the difference between the maximum water elevation (surface elevation + water depth) and the maximum surface elevation between two adjacent cells; g = acceleration of gravity; n = Manning's roughness coefficient; S_f = friction slope; h = water depth; Δxy = size of the square cells. q_x represents the flow in x-direction (horizontal in grid space) and q_y in y-direction (vertical in grid space). Cell index i enumerates the cells in x-direction, j in y-direction. The continuity equation (2) for each grid cell i,j is thus a mass balance of flows in and out of the cell in both x- and y-direction.

For more details we refer to the paper of Bates et al. (2010). We don't want to reproduce the derivation of the equations in full detail, because they are already described and tested in different publication, and because this is not the main scope of the MS.

Regarding the satellite based inundation maps we admit that the formulation was misleading, or can be misinterpreted. In fact the maps just show the inundation extend, not the depths. This is still not possible – to the authors knowledge – based on satellite data alone. Inundation depths can just be derived with additional information, like a detailed DEM, and assumptions on the gradient of the water surface. Thus we changed the sentence to "Additionally, maps showing the inundation extend based on TerraSAR-X Stripmap satellite images with 2.75 m spatial resolution covering particular days in the flood season were provided by the German Aerospace Centre DLR."

To our knowledge figure 1 shows the whole Mekong basin. The basin shape is just as published in many other studies concerning the Mekong region (some listed below). If the reviewer thinks that some parts are missing, we would appreciate more detailed information about the potentially missing part(s). The river network cannot be clear and distinct at this spatial resolution. We wanted to present the main river and the major tributaries. In the revised figure shown below we cleared some of the smaller and incomplete river courses.

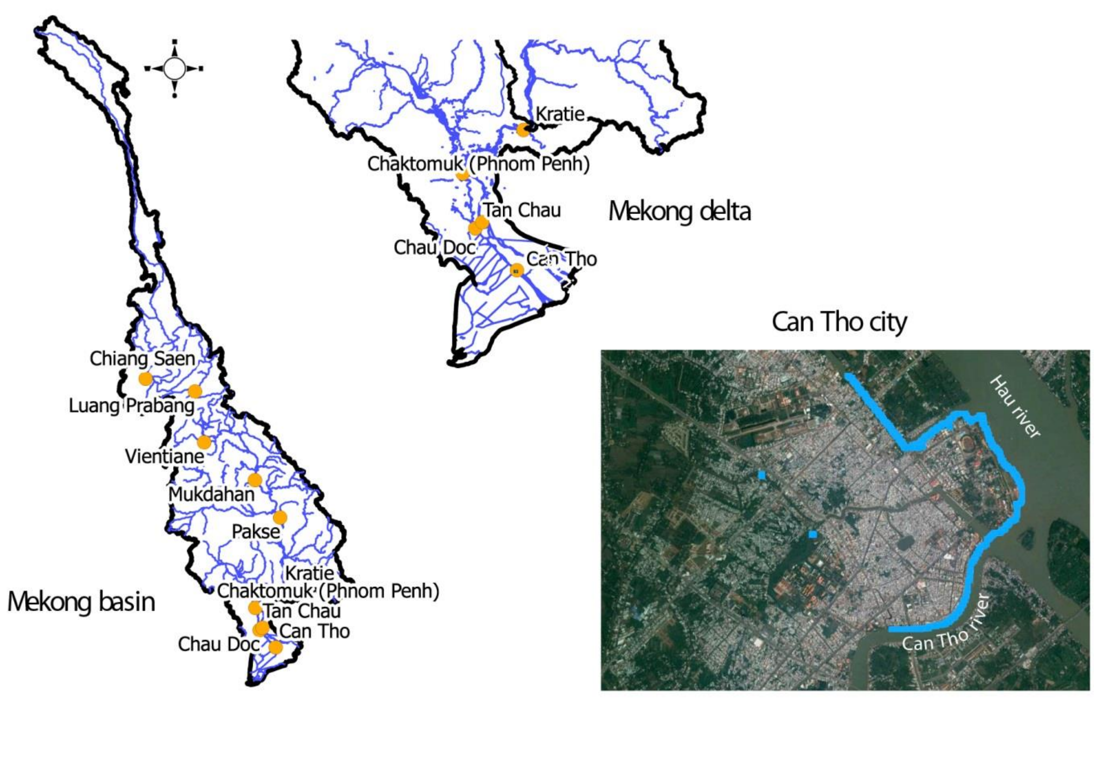

Figure 5/plausibility check: As mentioned in the text proper data for a thorough calibration or validation of the hydraulic model are missing, as in many cases of inundation modelling. Thus we tried to evaluate if the model provides plausible results. Plausible in a way, that inundation is modeled where inundation occurred during the 2011 flood event. For this we have only the information derived from the household surveys, which do not exactly provide the data, i.e. inundation depths, as simulated by the model. Thus the comparison shown in figure 5 should be evaluated by checking if a) an inundation is simulated where an inundation was reported in the surveys (but only within the simulation domain!), and b) roughly comparing the color codes of the simulated and reported inundation depths in order to check if the inundation depth agree roughly. This is how we understand the plausibility check. This does not provide any quantitative measure of model performance, but rather a positive qualitative feedback about the applicability of the model for the given purpose. We will underline this further in the revised MS.

Figures 11-13: Thanks for the suggestion. However, we think that the overview of all inundation maps provides a good impression about the inundation patterns and their changes, a selection of fewer probability levels will not provide drastically more details due to the limited page width. Please note that all maps will be provided as electronic supplements (Geo-Tiffs) to the paper. These can be viewed and even directly displayed in a GIS for detailed inspection by interested readers or even for further use in e.g. risk assessments.