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Hydrology and Earth System Sciences Discussions

Interactive comment on "Urbanization and climate change impacts on future urban flood risk in Can Tho city, Vietnam" *by* H. T. L. Huong and A. Pathirana

H. T. L. Huong and A. Pathirana

a.pathirana@unesco-ihe.org

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1 Introduction

We thank Dr. Ioana Popescu for taking time to review this article and for the thoughtful comments made, responding to which, we hope will lead to the improvement of this article. Following is a point-by-point response to the comments, with additional explanations when deemed necessary. We shall incorporate changes to the final manuscript that will clarify these points.

2 Responses

1. Lack of details of the modelling procedure and the unavailability of references for works to refer to . . . :
   Some of the papers referred to in this manuscript are now published in the form of conference proceedings (Pathirana, et al., 2011, Veerbeek, et al, 2011)[1] . For brevity, the details will not be reproduced here. Veerbeek et al. (2011) gives the details of applying Dynamica-EGO model for urban growth prediction. The reader is referred to Pathirana, et al.(2011) for details on SWMM-Brezo hydrodynamic model. The application of WRF-Noah coupled-model for rainfall's sensitivity to urbanization is briefly described in Veerbeek et al. (2011). The other paper cited in the original manuscript is still not in a citable form, however, Shem and Shephard (), ..., have used generally similar approach, where more details of the application of the model can be found.

   We will update these references in the final version of the manuscript.

2. How the information is supplied from one model to the other is not clear
   There a four points of information transfer from model-to-model in this study. They are discussed below:

   Dinamica-EGO – WRF-Noah: Output of Dianmica-EGO is landuse maps of the city and the surrounding area. WRF-Noah model, for its surface representation (e.g. radiative transfer, calculation of sensible and latent heat flux, etc.) uses landuse data (routinely from USGS global landcover data), among other 'static' parameters like elevation. The WRF-Noah modelling domain (Figure 4 in discussion paper) is much larger than the area cov-

[1]Draft copies (identical in content to the final papers) of Pathirana, et al.(2011) and Veerbeek (2011) can be downloaded from http://assela.pathirana.net/hessd-8-10781/

ered in Dinamica-EGO simulation. First, we set-up WRF-Noah model with USGS landuse data (LUSGS). This is the setup we used for model validation. Then we superimposed the Dinamica-EGO landuse (for 'Present' and 'Future' cases) upon USGS landuse (replacing the smaller rectangular area covered by Dinamica-EGO model, on the larger USGS landuse map) to obtain two 'hybrid' landuse maps (LPAST, LFUTURE respectively). When comparing rainfall for 'past' and 'future' cases, we used LPAST and LFUTURE landuse maps.

Dynamica-EGO – SWMM-Brezo: SWMM-Brezo model has a number of sub-catchments where the hydrological calculations are done (e.g. Infiltration, Overland flow) to calculate runoff. We used the Dinamica-EGO projections to calculate impervious fractions for the sub-catchments.

WRF – SWMM-Brezo: We computed 'past' and 'future' rainfall scenarios for a number of historical rainfall events. We combined the 1 h intensity data from all these events to calculate a quantile-quantile plot (Like the ones in Fig 13 for seperate events.) Then this plot was used to calculate a 'change factor' for each magnitude quantile (e.g. 0-5mm will change by a factor of 1.0%, 25-30 by 1.05%, etc.). We had the hourly rainfall time series for the 5th October 2009 event, which was used for input for the 'present' simulation with SWMM-Brezo. The each hourly value in the series was multiplied by its respective 'change factor' to obtain the 'future' rainfall series.
This computation process is explained in section 4.3 of the discussion paper.

3. Lack of description of calibration/validation of the model (P. 10796, urban growth model)

Dinamica-EGO We start with two landuse maps, ideally well-spaced in time (so that there is a significant level of landuse change occurring from first to the second). For this study we used MODIS data to derive landuse

maps for the years 1989 and 2005. We provide the Dinamica-ego model with these two landuse maps and a number of spatial parameters (e.g. distance to major roads, slope, ...) that we suspect are responsible for driving urban growth at each point on the map. Some of these parameters are highly locale-specific (e.g. for Can-Tho we provided distance from canal as a parameter). With this information Dinamica-EGO calculates a 'transition-matrix' that can 'explain' the observed landuse transition (from 1988 to 2006). Dinamica-EGO uses the transition matrix to calculate cell-transformation probabilities (e.g. Probability of changing from agricultural to urban) which will determine the landuse change over time. The transition matrix is fine-tuned (by iterative modelling cycles) until the modelled 2006 landuse (starting from that of 1988) matches well (typically around 80-90% accuracy at cell-level). Then this transition-matrix is used to project the landuse change into future.

It would have been ideal if we could use more than two landuse 'snapshots' for a proper validation of landuse model. However, due to number of constraints this could not be done in the current model.

WRF-Noah: Focused studies on heavy-rainfall events (for example see Deb, 2008) use available gauging stations as well as spatial rainfall products (Radar, where available, TRMM-PR (low temporal resolution)) for validation of simulation of historical rainfall events. However, within the scope of the present study, what was available was only the hourly rainfall record from a single gauging station in Can-Tho. While it is possible to directly compare time-series extracted from WRF-Noah results with the time-series observations, there are many methodological issues with such comparisons (e.g. Due to large spatial variability inherent to rainfall, see Pathirana, et al., 2002). Within the scope of the study we visually inspected the hourly rainfall snapshots from the model results and made sure that the values are **similar**

to those observed at the Can Tho station.

SWMM-Brezo: We obtained the structural details of the drainage system from the as-built diagrams provided by city authorities. SWMM was calibrated and verified by using the observed rainfall and water level of 2000 and 2009 events. However, there were no records on the inundation depths in the city with the city authorities, except maximum observed flood level at a single location. We confirmed that our simulations reproduced these maximum values. While it would have been better to do much more extensive validation, there was no data available.

Calibration/Validation WRF-Noah, SWMM-Brezo: We fully agree on the critical importance of calibration and validation of models before they are used to obtain useful results. The use of WRF-Noah, SWMM-Brezo in this case was in the context of 'Controlled Numerical Experiments' (Sensitivity Studies), where we compared the model results under change of as set of input parameters (WRF-Noah: Landuse; SWMM-Brezo: Rainfall, river-level boundary condition and impervious fraction). In such studies small changes in initial model setup might not lead to drastic changes in the end results, which are essentially the differences between two scenarios ('past' vs. 'future'). Of course heavy non-linearities in model response can invalidate this assumption.

4. "The hydrometeorological changes and resulting impacts on extreme rainfall is also being established" – who established (past studies/current study). We agree with the reviewer about the lack of clarity here. We will add some references to corraborate this statement (Lin, et al., 2008, Shem and Shephard, 2009).

5. What exactly are "controlled numerical experiments"? Please see item 9.

6. On page 10787, line 20, it is specified that river level reached 1.9 m, but what does this mean for flood risk, what is the acceptable river level before flood hazard

occurs it is not given.
This is a part of information that was provided in the manuscript on this flood-event of 2000. However, it is difficult to state what is the critical level of river stage that causes flooding as the flooding events occur as a result of dynamic interaction between a number of forces (e.g. local rainfall, channel flow, flow in the drainage system) in addition to the river level.

7. Why urban growth projected up to 2100, but used only 2050? We decided to use 2050 as the limit of our 'future' scenario, as further extrapolation of landuse change may simply be too unreliable.

8. On page 10801, first paragraph of Section 5.3, lines 6-9. The authors are very strong with their statements, and are advising the reader to be cautious in interpretations. How? On the same page, next paragraph the authors are mentioning that the climate change will influence the "nature and magnitude of the extreme rainfall events. How this influence will interact with the urbanization-lead rainfall remains to be studied." Do not the authors contradict themselves here? Was not this the main interest initially? While reading, the main research interest when urbanisation model was developed, was to see how, under climate change conditions, urbanization will influence the local rainfall? This conclusion could be also a drawback of the fact that the models are not explained in enough detail.

9. If climate change is not taken into consideration in the and change models than what would be the value of the atmospheric models prediction for the local rainfall pattern.
The type of atmospheric models, that WRF belong to are called limited-area models (LAMs) in the meaning, they cover a defined, limited area in the atmosphere as opposed to global-models, which do not have lateral boundaries. Three types of data are essential for running of LAMs: Initial conditions over the entire 3D domain of the model, lateral boundary conditions for the entire model

simulation duration and 'static' data describing the model-bottom (e.g. elevation, landuse, vegitation-cover, etc.), which (apart from seasonal changes, e.g. vegitation,) remains unchanged over the duration of the model run.

Global climate change is incorporated to LAMs typically by using different lateral-boundary conditions. This, we **did not** do in this study. However, the rainfall outcome (and all other output like temperature) of LAMs depend also on the 'static' data which directly affect the important atmospheric processes influencing rainfall (e.g. heat-balance, heat flows, convective break-up, leading to cloud-development).

In the present study we performed 'controlled numerical experiments'[2] (also commonly known as sensitivity studies) by changing only landuse type, keeping all other WRF-Noah mdoel parameters same (Initial and boundary conditions, and elevation data) between 'past' and 'future' cases. So the rainfall differences between 'past' and 'future' shows the systems (models) sensitivity to landuse change.

3 Bibliography

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[2]Toma and Webster (2010), Goórska (2008), among others are examples of usage of the term "Controlled numerical experiments' in the context of atmospheric modelling.

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