Flood modelling in mega-cities using a coupled drainage-surface flow model: Kolkata, India

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1 Summary

This paper describes the implementation of a numerical tool named *Itzï* for the modelling of floods in megacities by coupling an open source GIS surface flow model and an urban drainage model. This is the first time the coupling of a damped partial inertia numerical model with a drainage model is implemented and tested using a real event. The numerical tool employs dynamic datasets in space and time and the case study corresponds to the city of Kolkata, India. The ability of this open-source software to represent drainage operation and surface flooding in a megacity will be demonstrated, paving the road towards its use in other large urban areas of the world.

2 Introduction

Floods have been pointed out as the most common disaster during the last decade (IFRC, 2016). This fact, in addition to a rise in urban population, has given way to a further increase in the observed number of urban floods. This is particularly relevant for large cities, where the concentration of people and assets increases the level of vulnerability to such events, and especially in developing countries where urban growth has been significant. Given the observed impacts in such cities, it is highly necessary to develop the numerical tools that can represent the involved physical processes at an adequate level of complexity.

This work will introduce the application of a software model that couple a damped partial inertia surface model to the SWMM drainage model to a densely populated area of the Indian city of Kolkata, where floods are frequent.

3 Materials and Methods

3.1 Description of the study area

With an urban area of 14 million inhabitants, Kolkata is the largest city in the state of West Bengal, India. It is situated on the Hooghly river, a distributary of the Ganga river. The sector of study is 53km2 and is instrumented with a network of rain gauges and level sensors at pumping stations that transmit data at a 15 minutes interval (Sen, 2013). The study area and the location of the instruments are shown in Fig. 1. The rainfall data for this study is represented by a time-series of raster maps generated by IDW interpolation of rain gauges data.

The study area is divided into two areas. The core area shown in Fig.1 is delimited by the availability of ground survey data. The corresponding raster DEM has been generated using the Regularized Spline with Tension interpolation. The surveyed points and the resulting DEM are shown in Fig. 2.

The heavy urbanised area and flat terrain make the definition of watershed difficult. Therefore, an extended study area has been defined by buffering the core area to include most of the nodes of the drainage networks and act as an upstream watershed. This extended study area is shown in Fig. 3.

In that extended area, surveyed points are not available and we use the 30m ALOS global DSM (Tadono,

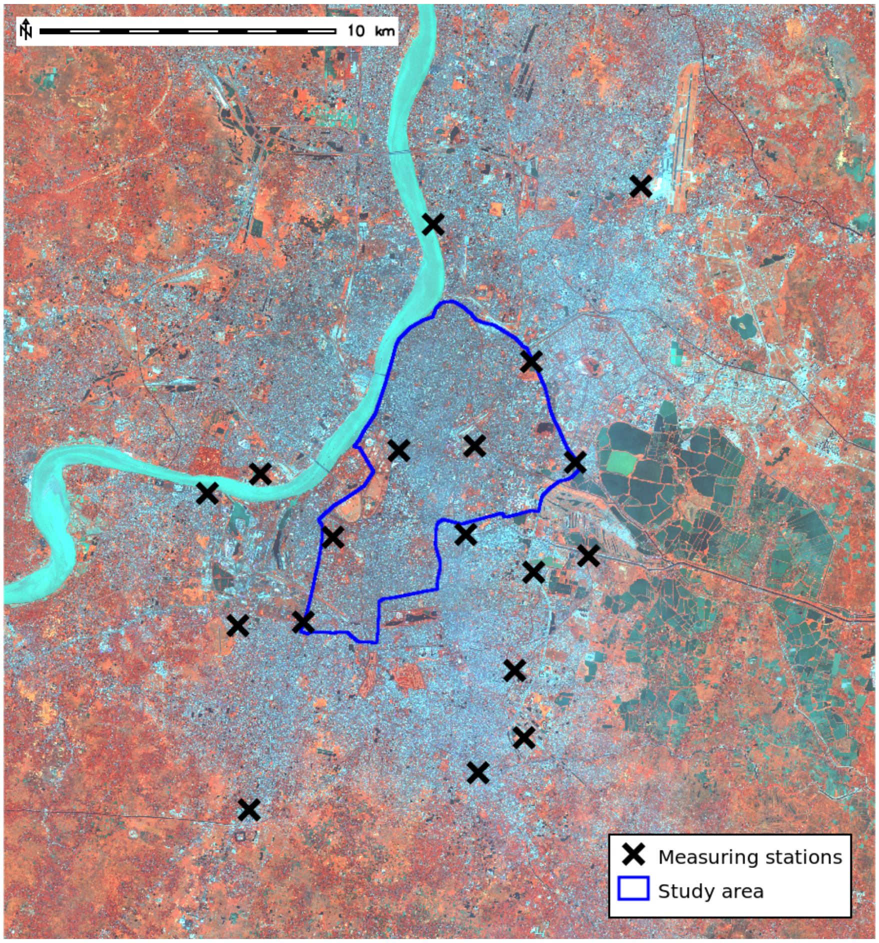

Figure 1: Figure 1: Localisation of the study area and measuring stations (Imagery Copernicus Sentinel-2)

Ishida, et al., 2014). The total surface of the extended study area is 541km^2 which represent a computing bounding box of 929km^2.

The drainage network of the studied area consists of 2673 nodes and 2686 links, including 36 pumping stations and 44 storages and is shown in Fig. 3.

For the event studied in this paper that happened from the 31 July to 1 August 2015, street flooding reports gathered by Kolkata Traffic Police are available.

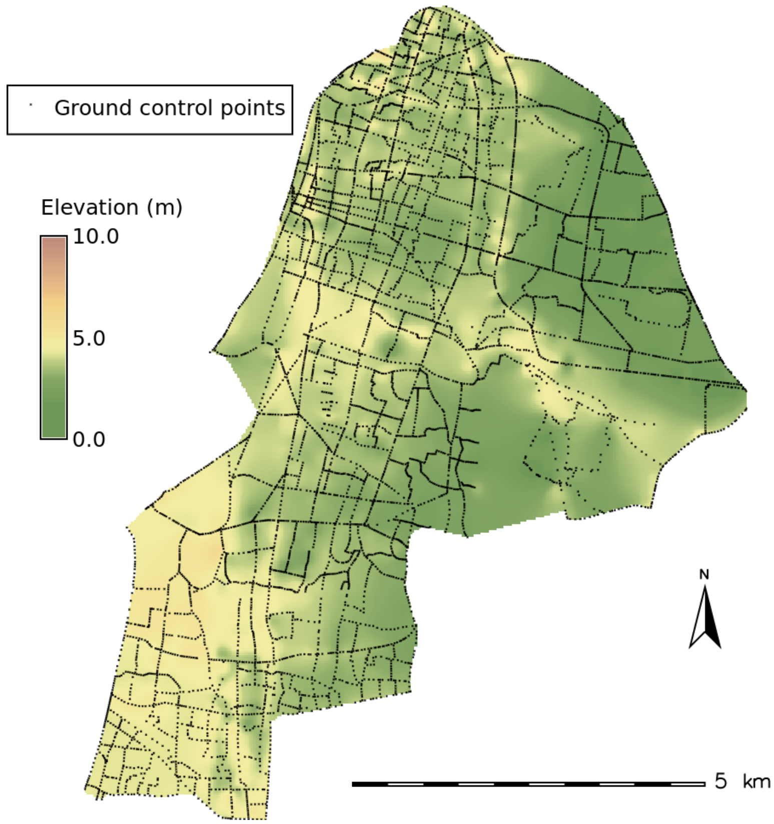

Figure 2: Fig. 2: Ground control points and created digital elevation model

3.2 Computer model

In this study, the free software model Itzï (Courty, Pedrozo-Acuña, et al., 2016) is being used. It employs a damped partial inertia explicit numerical scheme (De Almeida and Bates, 2013) and integrates seamlessly with the open-source GIS software GRASS (Neteler, Bowman, et al., 2012), which facilitates the preparation of entry data, the interpretation of results and the use of raster time-series.

A new version of Itzï is coupling the existing surface flow model with the well-known SWMM5 drainage model. The flow interchange between the surface and the drainage network is done at each time-step using a set of weir and orifice equations (Chen, Djordjević, et al., 2007).

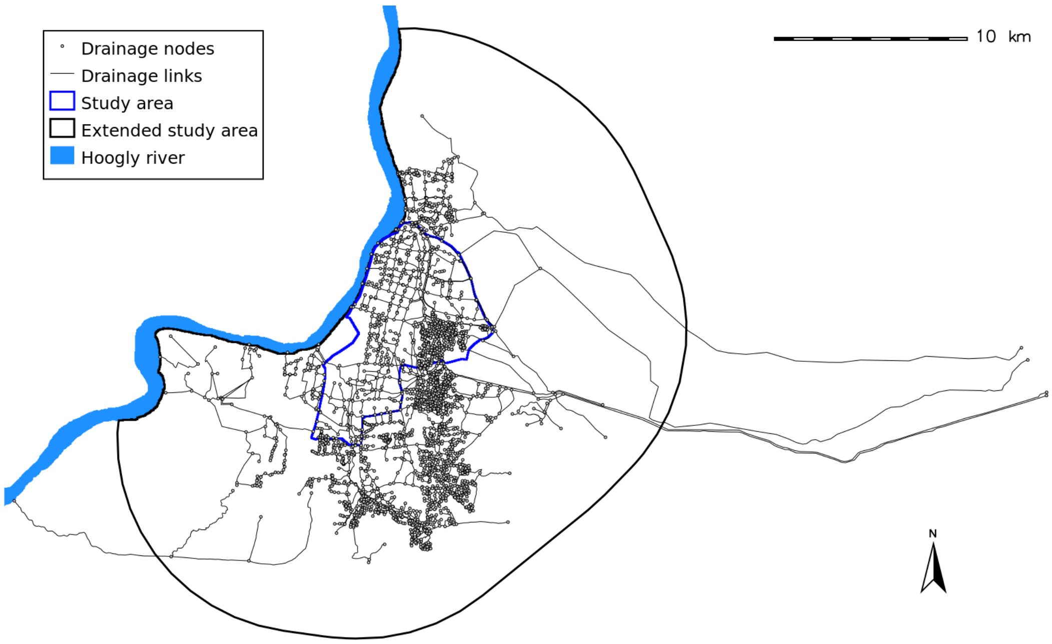

Figure 3: Fig. 3: Study area, extended study area and Kolkata drainage network

4 Results and Discussions

The results of the surface model are presented as raster time-series, while the results of the drainage model are in the form of a time-series of vector maps and associated attributes tables. GRASS GIS allows us to easily compare the results of the simulation to the identified flooded streets. Preliminary results are shown in Fig. 4.

5 Conclusions

The object of the study and preliminary results have been succinctly presented. It is expected that the joint application of the open-source model Itzï and the real-time monitoring will allow a better understanding of the flooding processes in Kolkata and demonstrate the possibility of applying this methodology to other large urban areas.

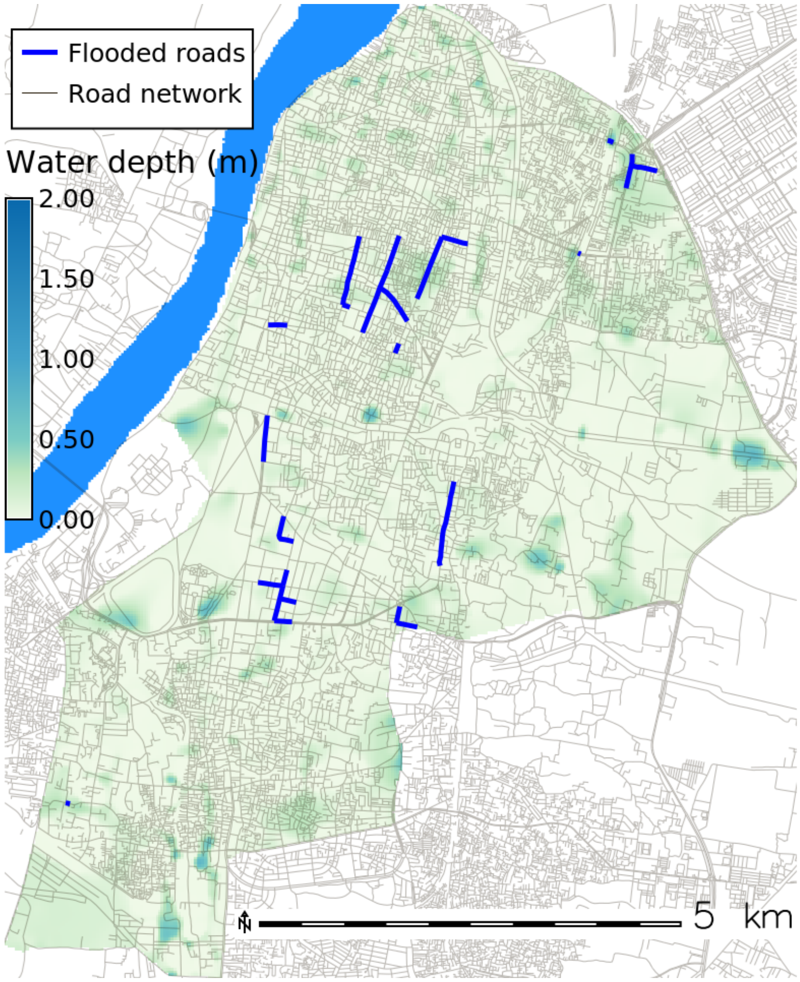

Figure 4: Fig. 4: Map of identified flooded areas during the July-August 2015 event and computed water depth from Itzï.

6 Acknowledgements

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