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www.hydrol-earth-syst-sci-discuss.net/10/C3651/2013/

Hydrology and Earth System Sciences
Discussions

Interactive comment on "Evaluating scale and roughness effects in urban flood modelling using terrestrial LIDAR data" *by* H. Ozdemir et al.

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Response 1: We thank the reviewer for raising this concern. The numerical scheme used in this paper has been the object of a detailed analysis (de Almeida et al., 2012). In particular, it has been shown that the finite difference approximations of the derivatives introduce a diffusive term into the equations (i.e. numerical diffusion). Even though "numerical diffusion" – formally defined as errors introduced by even-order derivatives (e.g. second order) in the Taylor series expansions of the dependent variables- are commonly referred to as "artificial viscosity" or "numerical dissipation", its effects on the solution are rather different from that of friction. In particular, the diffusive term exposed in de Almeida et al 2012 (second order derivative) will "diffuse" the

results, while a friction term acts as a sink of momentum. Numerical diffusion is not expected to slow down the flood propagation. Its main effect is to smear sharp gradients. In addition, the amount of numerical diffusion in this numerical method decreases with increasing theta (de Almeida et al, 2012). In particular, for theta=1 (which is very close to the value of 0.8 used in this study) the numerical scheme has no numerical diffusion. Moreover, it has been shown that the diffusive term decreases linearly with the grid resolution (de Almeida et al, 2012) and its effects should be small at the fine resolutions used in this paper (except in regions of high gradients caused by numerical oscillations). The fact that the model is insensitive to further reductions of Manning's coefficient below n=0.013 suggests that this value is already extremely low, so that the friction force is already too small compared to the other forces (i.e. other terms in the momentum conservation equation). Therefore, if n is further reduced (or even set to zero), its impact to the solution is negligible because the flow is governed almost exclusively by the balance of gravity, pressure and inertial forces. Regarding figures 8 and 9 (mow 9-10), the reviewer correctly points out what is an apparent contradiction to the paper's conclusion. However, friction is a function of nˆ2 in the governing equations. This results in more than 7x increase in friction when n is increased from 0.013 to 0.035, which can easily explain why the results are sensitive to an increase in friction, but not to a reduction (as the value of 0.013 is already very low).

Response 2: Thank you. The stability properties of the numerical scheme used in this paper are not directly conditioned to Fr. In fact, it has been shown (de Almeida and Bates, in press) that the local inertial system provides a more robust solution at transcritical flows (Fr=1) than the full-dynamic equations (i.e. comparing equations 13 and 14 of the above-mentioned paper). The Fr number is an important parameter governing the accuracy and physical properties of the model (rather than the stability), as described in detail in de Almeida and Bates (in press). Namely, it has been shown that the local inertial system provides an excellent approximation to the shallow water equations at the lower range of Fr (say, Fr<0.6), and that this accuracy is reduced by further increasing Fr. It has also been shown (de Almeida and Bates, in press) that the model is not applicable to supercritical flow conditions because of unphysical propagation problems (the LI system propagates the information towards both upstream and downstream directions, even though supercritical flows propagate only in one direction). The Froude number has been checked for all simulations carried out in this paper. It has been found that Fr is always in the range of subcritical flows (Fr<1). In addition, the great majority of the flooded domain has Fr<0.6 at all stages of the flood propagation. This occurs as a consequence of the relatively flat topography of the domain. These conditions, along with relatively low water depth gradients, ensure the applicability of the local inertial approximation with minimum loss of accuracy (de Almeida and Bates, in press). We have now added a new paragraph that describes the range of Fr observed in this set of numerical experiments.

Response 3: Thanks. The sentences has been changed and clarified in the manuscript.

Response 4: Thanks. We have corrected this.

Response 5: Thanks. Figure 6 has been edited.

Response 6: Thanks for this. These simulations were carried out with resolutions finer than 1m (e.g. 50cm and 10cm), in an idealized test case that does not include finer topography (uniform slope and rectangular cross section (represented as a single cell of the 2D grid in the "y" direction). A value of Manning's coefficient of n=0.013 was chosen because it is the value used for the road surfaces in all simulations (distributed and composite friction). We agree with the reviewer that this test alone does not prove that the model is "grid-independent", even though it does provide supportive evidence that the potential errors introduced by the model structure are expected to be considerably smaller than those observed with the Alcester topography. The dependence of the model results on grid refinements must be done under idealized conditions in order to separate structural errors from those introduced by a refined topography. Unfortunately in problems involving 2D flows over complex topography it is not possible to

separate model errors from those resulting from the differences in the representation of the terrain with different resolutions. Sensitivity analyses of the model results to grid resolution (using idealized test cases with analytical solutions) have been previously carried out by Bates et al (2010) and de Almeida and Bates (in press). These studies provide further evidences that the model does not introduce significant errors at the fine resolutions used in this paper. We have now modified the manuscript to reflect that this test aims at providing readers with further evidences that the main differences observed in the results are caused by the topographical representation at different resolutions, rather than by the model structure.

Response 7: Thanks for this caveat. We agree with the reviewer that the situation described in this paragraph is somewhat more complex than the description provided, as –apart from the straightforward effect of friction on slowing down the wave propagation– it indirectly affects the speed of the characteristics (lambda=+- sqrt(gh)). Even though experience with numerous simulations of wave propagation over dry beds (Bates et al, 2010; de Almeida and Bates, in press) indicates that friction controls the speed of the wave front, we removed the sentence to avoid the confusion mentioned by the reviewer.

Response 8: Thanks. This has been corrected in the manuscript.

Response 9: Thanks. The main purpose is to show all the control points at a particular DEM resolution in Figure 8 (now 9) and to show all the DEM resolutions results at a particular point in Figure 9 (now 10). Actually, choosing depth and elevation in y axes has not a special meaning. However, Fig. 8 (now 9) focuses only depth differences between composite and distributed friction and Fig. 9 (now 10) shows also elevation differences of the control points in the real world.

Response 10: Thanks. The text of Fig. 10 (now 11) has been edited.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/10/C3651/2013/hessd-10-C3651-2013-

supplement.pdf

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 5903, 2013.

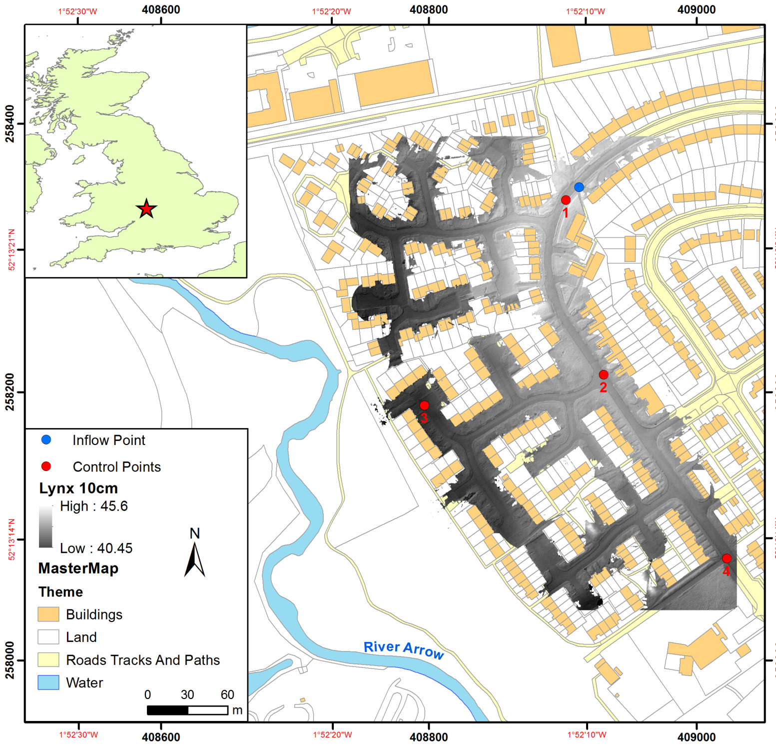

Fig. 1. MasterMap® data of study area in Alcester with over plotted 10 cm LYNX data of the model domain. The locations of the assumed sewer surcharge inflow point and the control points are highlighted.

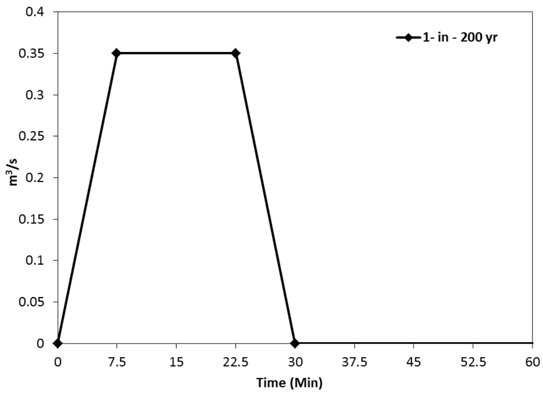

Fig. 2. Inflow boundary conditions.

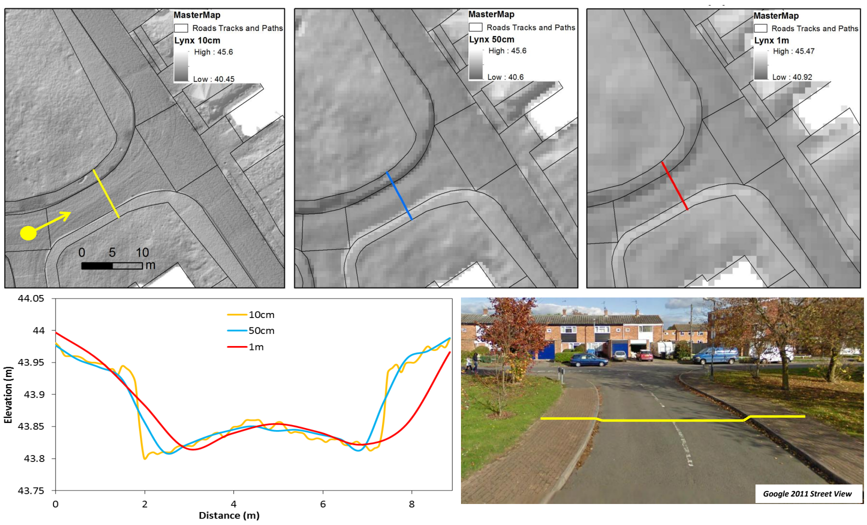

Fig. 3. Google street view and street cross-sections showing the variation in kerb and road surface camber representation on the 10cm and derived 50cm and 1m terrestrial DEMs.

Fig. 4. Land use classification and Manning's n value distribution (a) Google© satellite image (b) distributed Manning n value (c) single composite friction value.

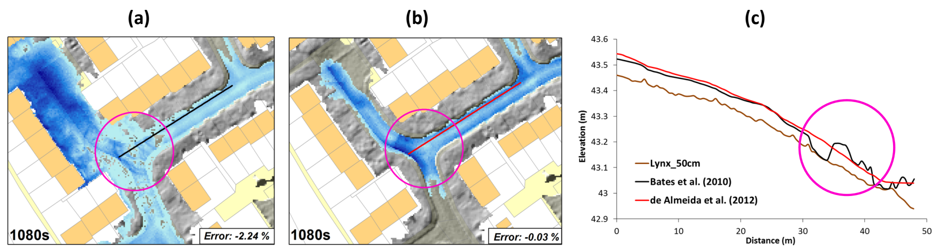

Fig. 5. (a) Simulation result at t=1080s using inertial formulation Bates et al. (2010) (b) Simulation result at t=1080s using inertial formulation de Almeida et al. (2012) (c) water surface profiles with ori

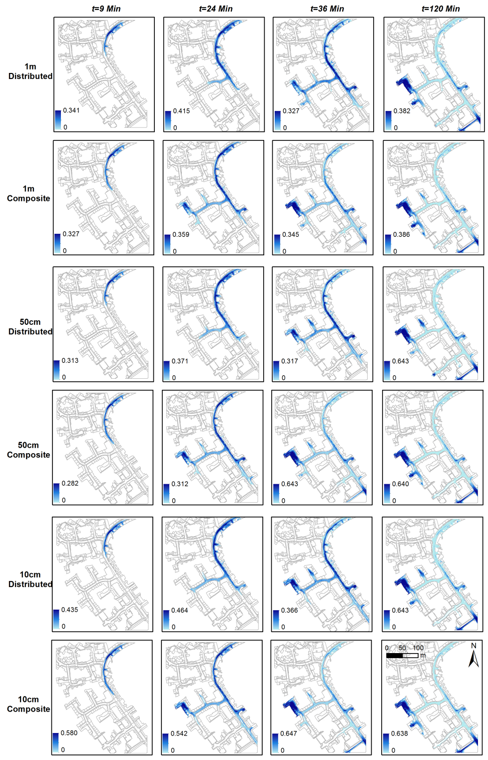

Fig. 6. Progression of surface flooding predicted by different resolution and roughness conditions using the new inertial formulation.

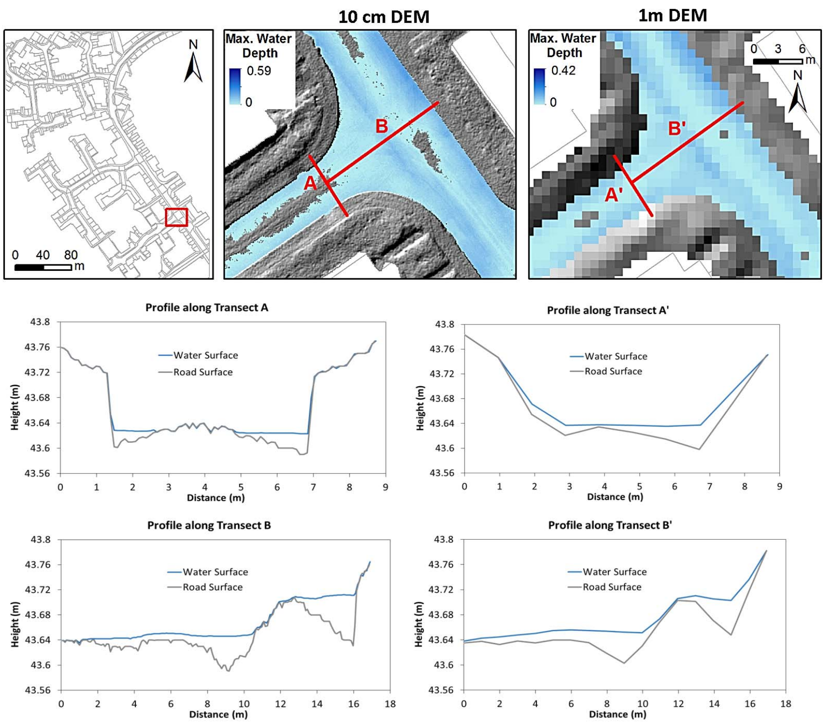

Fig. 7. South junction road surface and maximum water depth transects for simulation of 1-in-200 year event on 10 cm and 1 m terrestrial LIDAR DEM.

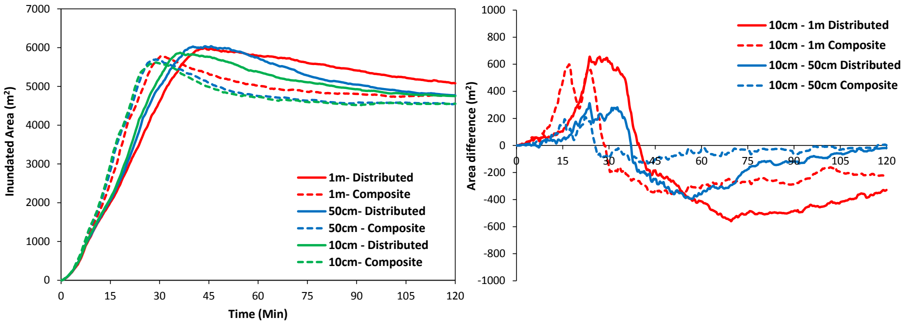

Fig. 8. Predictions of inundated area and differences based on 10 cm models through time with different resolutions and roughness conditions.

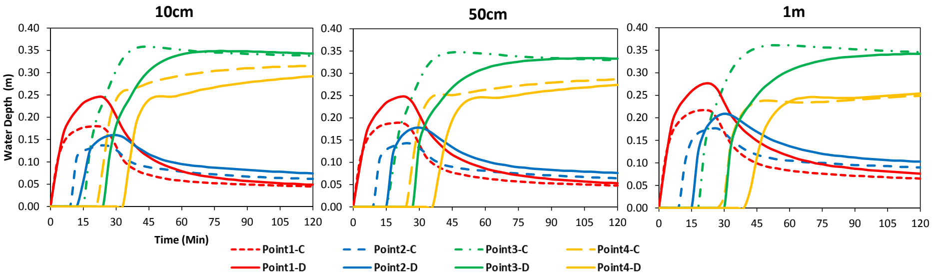

Fig. 9. Profiles of simulated water depth through time at the four control points at Δx= 10cm, 50cm and 1m using Composite (C) and Distributed (D) roughness conditions.

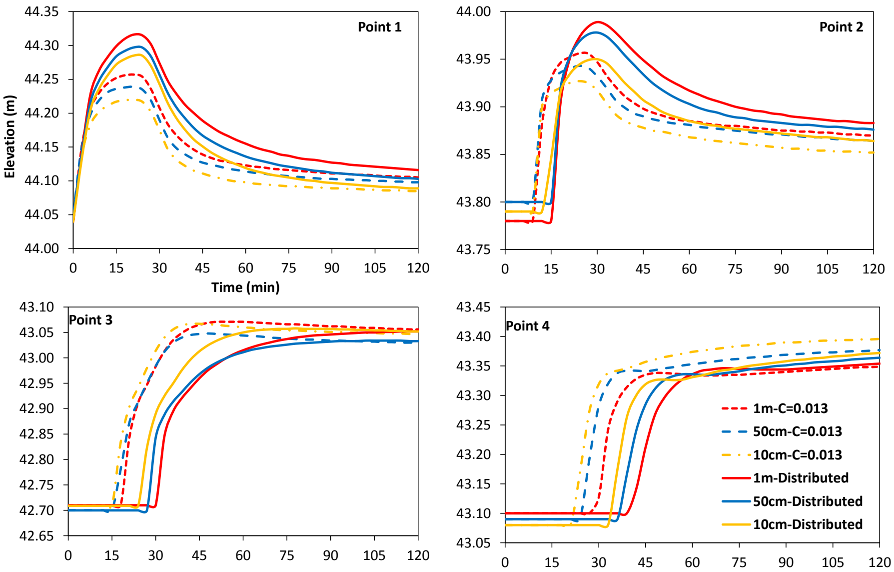

Fig. 10. Profiles of simulated water elevation through time at the four control points at Δx= 10cm, 50cm and 1m using Composite (C) and Distributed roughness conditions.

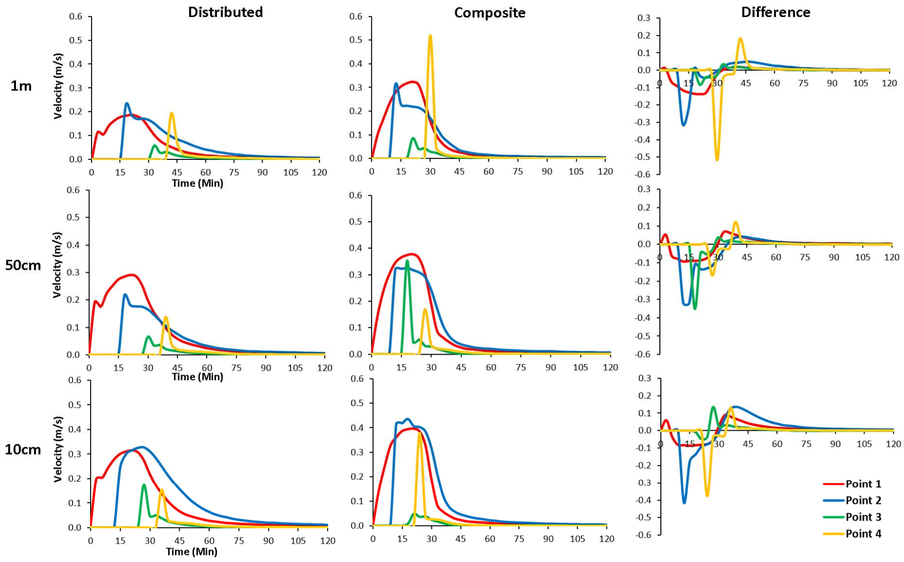

Fig. 11. Simulated velocity over time at the four control points across the different resolutions using distributed and composite frictions and difference plots (distributed minus composite).

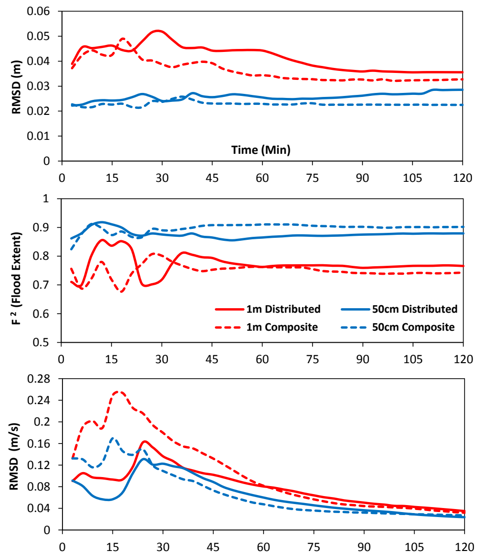

Fig. 12. Evolution of the root mean squared difference (RMSD) and F2 between the benchmark ∆x=10 cm models with distributed and composite roughness and the coarser 50cm and 1m models throughout the simulation

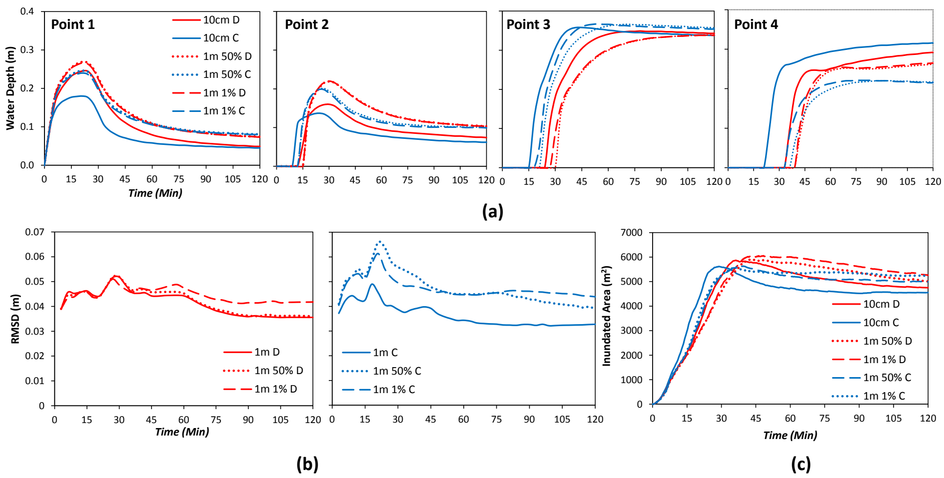

Fig. 13. (a) Comparison of simulated water depth through time at the four control points between 10cm models using distributed (D) and composite (C) friction and 1m models using 50% and 1% of distributed and c