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Title: Modelling of tsunami wave run-up, breaking and impact on vertical wall by SPH method

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Responses to reviewer comments of nhessd-1-C413-2013-supplement

Dear reviewer,

Thank you very much for commenting on our work. We would like to discuss on the issues raised by the reviewer in the paragraphs right below each question. Suitable changes will be incorporated to the revised manuscript and are indicated in the answers.

Major comments:

1. The authors simulated the solitary wave generation and propagation, wherein its magnitude and length scale are not comparable with the real Tsunami. For example, in nature, if one assumes 15min wave period and 0.5m wave height in deep water, allowing it to propagate in water depth of 50m and scaling it to 1:66, leads to 0.76m water depth, 0.043m wave height and wave period of 110s. Hence, the use of term Tsunami for solitary wave may not be appropriate. I would prefer to change the title of the paper as ‘Tsunami-**like** wave’ instead of ‘Tsunami’ or simply ‘solitary wave’.

   Answer: As we would like to emphasize the study to tsunami run-up, the "Tsunami-like wave" suggested by the reviewer is very suitable. We will reflect it in the revised manuscript.

2. The reference given by the authors for experimental data (Case A,B, C) is incorrect (Ward, 1995). Proper reference should be given: Briggs, M. J., Synolakis, C.E., Harkins, G., and Green, D.R. 1996. "Benchmark Problem #3: Runup of Solitary Waves on a Vertical Wall," Long-Wave Runup Models, International Workshop on Long Wave Modeling of Tsunami Runup, Friday Harbor, San Juan Island, WA, September 12-17,1995.

   Answer: We will update the reference in the revised manuscript.

3. The authors quoted that they have used 1.1 million number of nodes with dx = 0.002m. It would be better to quote also the time step used as well as the computational aspects for the three cases. Whether same number of nodes used for all the cases?. The specific reason for using more nodes in their model should be explained. Further, increasing the number of nodes does not necessarily leads to accurate results.

   Answer: We used the same dx of 0.002 m and the same dt of 10^{-5} s for all of the three cases.

   There are several reasons to use very fine resolution in the simulations. Firstly, in the small amplitude case in which wave height is only 0.0109m, even we use the resolution of 0.002m, the maximum wave height is only represented by about 5 particles. If we use coarse particles, the wave shape may not well represented.

   Secondly, for the solitary wave propagation, the numerical decay of wave height is important. The numerical model needs maintain the wave height of the solitary wave propagation. If less nodes (or coarser dx) are used, wave height will numerically reduce significantly.

   Thirdly, we are not only interested in the wave height of wave propagation, but also interested in the wave impact pressure only wall. With more nodes introduced, the pressure oscillation in the simulation (as a result of slightly-compressible SPH approach) will be reduced. The wave impact pressure on the wall will also be more accurate.

4. The difference in wave gauge 4 for the test cases **may be** due to following reasons:

   - It was quoted that the target for small steep wave is 0.05, whereas in experiments the measured wave height is less; however as the steepness increases, the target and experiments are closer. I feel this is due to leakage of water through side walls of the paddle in the experiments (more details about this can be referred in Grilli et al, ISOPE, 2004, 306-312. Sriram et al., 2010, Int. J. of Num. in fluids, 62, 1381-1410). So one need to do some trial and error in order to generate the correct profile in numerical modelling. Hence, I would suggest the authors to modify the input stroke to correctly reproduce the time series at wave gauge 4, i.e. Fig. 4. For this use Goring's theory for solitary wave generation by suitably choosing the parameter to match the wave gauge record.

Answer: We agree with the reviewer at this point. We will re-run the three scenarios with appropriate scaling of paddle strokes to meet wave heights at gauge 4. The new results will be presented in the revised manuscript.

- Boundary treatments to improve the accuracy of SPH code to handle the water waves (Particularly, Case A). I feel increasing the number of nodes is not the only solution, but rather enhancing the estimating velocity, pressure gradient and so on. How the wall particles on the wavemaker are treated?. Is it moving (i.e. slip) or fixed wall particle?. It plays an important role to generate small waves. The authors can refer Sriram and Ma (Journal of Computational Physics 231 (2012) 7650–7670), Hu et al. (J. Marine Sci. Appl. (2011) 10: 399-412) for modelling small waves in particle method with proper boundary treatment. I would say it is good attempt by the authors to model small amplitude wave in particle method, wherein very few literatures are present.

Answer: We used mirror particle technique with enhancements (better consistency of mirror fluid pressure and density). With these enhancements, fluid properties near the wall boundary are better modeled, especially near a moving solid boundary like a wave paddle. At wall boundaries, fluid is treated "free slip". Details of this mirror technique were presented in another paper of ours and is referred in the current manuscript.

5. If Tsunami N2 model gives good results at Gauge 4 (for Case A), one can use the surface and velocity profile from this model as an input to SPH, this may slightly improve the accuracy of SPH in modeling small amplitude cases. A kind of weak coupling. By doing so, your SPH method may work even for small wave steepness (avoiding the wave paddle b.c. exp. and num. errors) and pointing out the error in experimental paddle motion (due to difficulties) rather than numerical model.

   Answer: Using Tunami-N2 result or direct measurement at gauge 4 as boundary condition for SPH would probably provide more reasonable comparison between the 2 model. Accuracy improvement is, however, a question as truncation of the fluid domain meaning losing some fluid properties and introducing error at the open boundary. Nevertheless there are several high quality researches on coupling SPH and a gridded method. We are also looking in this direction but the moment our code does not have that capability yet.

6. Fig. 5, can be improved by using the suggestion in point 4.1 or point 5, further, whether the SPH simulation breaks down after 24s, or is it purposefully stopped?. It will be better to run the

simulation for complete experimental simulation like Tsunami N2 results. This also holds good for Fig. 7 and Fig. 9.

Answer: We purposely stopped the simulations as the simulations are quite computationally heavy. In the re-runs (as we need to re-scale the paddle strokes) we will run over 30s to have better comparison with Tunami-N2 model.

7. Fig. 6, Fig. 8 and Fig. 10, it would be better to give the spatial pressure profile to show your model capability (in order to be consistent with your conclusion), rather than only particle configurations.

   Answer: We will provide new plots with pressure contours in the revised manuscript.

8. Fig.11, it would be better to provide the Tsunami N2 pressure time history also along with SPH results for the three cases, as the paper wants to project the capability of this model. The reason for higher peak pressure for Case B, after initial impact should be explained (i.e. after 18s). Is it physical or numerical oscillations?. Please provide the location of the pressure timehistory in the figure caption also. The authors quoted the numerical results for pressure are consistent with the observation in experiments. If so, it would be better to provide the experimental pressure measurements.

   Answer: We will plot the hydrostatic pressure curves estimated from Tunami-N2 wave height along with SPH results in the revised manuscript. We will look again in the experiment report for pressure data.

Minor comments:

9. Whether the present SPH simulation contains any turbulence closure?. Two phase or single phase modelling should be mentioned explicitly, as it has breaking cases.

   Answer: The model does not contain any turbulence model. We are working on introducing a good turbulence model for SPH. Our model is able to model air-water two phase flow. However, in these simulation only water phase is simulated. In one of our research which was cited in the manuscript, wave breaking was studies with a two-phase flow SPH model.

10. Is it possible to use a fine resolution only at some location and coarser resolution at the other locations in your code or variable node spacing (i.e. finer at the free surface and coarser at the bottom)? This may reduce the computation time.

    Answer: It is possible to do so but that would require significant treatments in SPH. We are developing that code but at the moment it is under testing.

11. Simulation time for the spatial configuration in Fig. 6, 8 and 10 should be given.

    Answer: We will provide the simulation time for the figures in the revised manuscript.

12. Zero correction needs to be made for experimental time history in Gauge 7, Fig. 5.

    Answer: We will make correction for the experiment time history.