Interactive comment on **"Multilayer-HySEA model validation for landslide generated tsunamis. Part II Granular slides"** by Jorge Macías et al.

Anonymous Referee #1
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General Comments:

As was the case for the first part of this paper, this is once again an informative paper that allows the modeling community to get a feeling of the reliability of the simulations performed with the Landslide-HySEA and Multilayer-HySEA models when used for real-life hazard assessment studies. This work presents results of modeling 3 of 7 benchmark problems proposed by the National Tsunami Hazard Mitigation Program (NTHMP). The three problems are based on data collected via experimental studies on tsunami generation by 2-D and 3-D, deformable slides from aerial and subaerial initial positions. The Landslide-HySEA version of the code is used to represent the slide dynamics by means of a Savage-Hutter approach. This is coupled with the Multilayer- HySEA version to capture the dispersive dynamics of the hydrodynamic phase.

To be more precise both models (the Landslide-HySEA and the Multilayer-HySEA models) are independent models and they are not coupled one with the other. They share the same model (when granular slides are considered): a Savage-Hutter model, but both models are implemented independently and provide a different modelization of the fluid, while for the slide material they share the same Savage-Hutter model. For the fluid layer the Landslide-HySEA model implements a one-layer SW equations system while the Multilayer-HySEA model considers a multi-layer approach. In both cases with or without dispersion for the fluid. In the current work, we benchmark the dispersive Multilayer-HySEA model. The Landslide-HySEA model is described here in order to provide an introduction from a simpler model, not able to reproduce the experiments proposed, and as motivation for the need to use a more complex model able to produce realistic simulations. A sentence has been added in the Abstract to clarify this and explaining the reason why we introduce first the Landslide-HySEA model.

The topic and results presented in the paper are within the scope NHESSD topics. The paper provides a sufficiently (perhaps too much) detailed description of both, the governing equations modeled in the code and the numerical algorithm implemented to resolve the system. Additional references are provided for readers interested in additional details. Given the complexity of the mathematical modeling and numerical scheme employed to solve the equations, one wonders whether the reader should be referred to a separate publication for that explanation, and the manuscript could be focused on the modeling setup and results alone. The authors provide an adequate literature review of pre-existing validation efforts in the introductory section of the report. They also provide a description of the numerical implementation of the laboratory experiments used for the validation. The results of all three experiments are presented in a clear and concise manner. I have not really found any major issues with the paper and I am ready to recommend publication with very minor modifications:

Specific Modifications:

- pp1 l.7: Here and in another location(s) in the paper the term "approved" is used to refer to the NTHMP process of testing codes. It should be corrected to "validated" or "tested" as the NTHMP does not "approve" or "certify" any models. Please check with NTHMP for clarification if needed.

  The authors have checked this and found out that the NTHMP thoroughly used the term "approved" in the past but, it is true, that now this term does not appear in its web page anymore. Instead they moved to a lighter qualification of "Models that meet defined criteria for NTHMP Modeling and Mapping" and simply "Benchmarked Tsunami Models" (following NTHMP standards). Nevertheless, there exists a document of July 2015 entitled: "The NTHMP Tsunami Inundation Model Approval Process", describing all the steps in the process of "Approval" by the NTHMP. Finally, as far as authors know the term "approved" was changed to "accepted" in February 2016, in the document "The NTHMP Tsunami Inundation Model Benchmarking and Acceptance Process" in:
  https://nws.weather.gov/nthmp/documents/NTHMPTsunamiInundationModelAcceptance.pdf
  In any case, we agree with the referee, and we will no longer use the term "approved" and will refer as "accepted", "benchmarked" or "validated following the NTHMP standards".

- pp1 l15-17: The authors mention the workshop consisted of 7 benchmark problems (3 were presented in Part I of the paper and 3 in this Part II), it would be good to explain if the missing problem was attempted and what results were obtained.

  The seventh benchmark problem is the field case in Port Valdez 1964. It is the benchmark that we work the most for the Workshop and that we finished and complete for January 2017, but we did not take the time to write the corresponding paper. Now we have nearly finished the document and we expect to submit pretty soon. Once finished this revision...
  We briefly mention this and give a reference to our contribution to the NTHMP report, where the results corresponding to this seventh benchmark are collected.

- pp 8, l181-182: Please, specify what boundary condition is applied where for each of the three BCs specified in the equations.

  Done. We have specified in the paper the corresponding boundary conditions that were applied for each of the three benchmark problems.

- pp14, 18, 23: For all benchmark problems, please specify how parameters (r, na, nm, ...) were selected or whether they were provided with the data. Also explain how Dx (delta x), Dy (delta y) is selected

  The parameters involved at each simulation are:

  $$g,\ r,\ n_a,\ n_m,\ d_s,\ \delta_i,\ \beta, \text{ and } \gamma.$$

  The parameters $g,\ r,\ n_m$, and d_s are related to physical settings given at each experiment. β and γ are empirical parameters that were chosen as in the seminal paper of [11].

  The friction angles $\delta_1,\ \delta_2$ are characteristic angles of the material, and δ_3 is related to the behavior of the slide motion when starting from the rest. Thus, the values for these parameters strongly depend on the granular material. The values for these three parameters were adjusted within a range of values found in references as [1], [9], or [11]:

  $$\delta_1 \in [1^\circ, 22^\circ], \quad \delta_2 \in [11^\circ, 34^\circ], \quad \delta_3 \in [3^\circ, 23^\circ].$$

In the present paper we have employed the values

$$\delta_1 = 6^\circ, \quad \delta_2 \in [17^\circ, 30^\circ], \quad \delta_3 = 12^\circ,$$

for the three benchmark problems, a choice that is consistent with the values provided in the literature. As noted in [9], in general for real problems involving complex rheologies, smaller values of δ_i should be employed.

We have added a paragraph in Section 5 to explain all this in detail.

Concerning how Δx and Δy were selected, here $\Delta x = \Delta y$ for all benchmark problems, and thus introducing the same numerical diffusion in both directions. However, in the case of pure one-dimensional domains problems, as BP4 or BP5, the effect of the y-resolution does not matter, and we just set the number of cells on the y-direction to be simply one.

The length of $\Delta x = \Delta y$ is consistent with the number of cells per wave used in other non-hydrostatic works that include dispersive effects (see, for instance, [2], [3], [5], [6], [7] and references therein). For instance, the reviewer is referred to [7] were authors employ the same grid resolution as here for BP6.

Moreover, we have performed a sensitivity analysis for the grid resolution, and we have observed that results presented in this work were well converged when using different decreasing size resolution.

In brief, the values of $\Delta x = \Delta y$ employed here ensures well-converged numerical results, and that waves can be well-represented maintaining a good balance between numerical results and computational efficiency.

Concerning the number of layers, n_a, and according to our experience, we could say that the one-layer model may produce wrong amplitudes and frequency waves, at least in areas close to the landslide generation (see for example the next paragraph in this answer). Model results can be improved by adding more layers. Typically, simulations with three or four layers will be accurate enough in most situations. That could be well explained according to the multi-layer model's dispersion relation (see [4]). See also [8] where numerical experiments with rigid landslides evidence that, in some situations, a simple one-layer system may produce wrong results in both amplitude and frequency dispersion. That is even more evident when steep gradients on the topography are involved and that the model must be accurate enough for the linear shoaling dispersion relation.

We have include the required information on the time steps and also number of layer in the new text.

- pp17 l313: Please, correct units of density (km/m^3)

  This was already corrected in the current version of the manuscript uploaded in the system

- pp17, l316: Please, replace "consists in" with "consists of", wherever it appears in the paper.

  Four matches were found and changed.

- pp23, l370: It would be interesting to know whether the non-dispersive case of 1-layer was attempted and how the results would compare with the multi-layer cases. If available, please add.

We have those for the benchmark problem 6, the results obtained using the one-layer non-dispersive model are still good and similar to the two-layer model, but for the run-up (see here, Figures 2, 3 and 4). Nevertheless it can be observed a frequency mismatch on the time series, that it is not the case if two or more layers are used. We have not included this comparison in the paper. If the reviewer considers that this is interesting, we could add these figures in the paper.

Moreover, we have performed benchmark problem 4 with the numerical model proposed by setting the number of layers equal to one. The comparison with the experimental data can be seen in this answer in Figure 1. It can be seen the classic behavior of a dispersive system that does not have an accurate enough dispersion relation for the water waves involved here. It can be seen how the amplitude, as well as the frequency wave train, are not well represented. A similar comparison for a rigid landslide problem is shown in [8].

- p23, l371-376: The description of how the slide is initiated is unclear. Please, explain with more detail. Is the entry velocity specified? If not, how is it reached? What is the function of the pneumatic pistons?

  The entry velocity was already specified, and we have better detailed in the paper:
  "In [10], it is shown that for this test case, the landslide box reached a velocity of $v_b = 2.3 \cdot \sqrt{g \cdot 0.6} = 5.58\ m/s$. *Thus, the initial condition for the water velocities is set to zero:*

  $$u_i = 0,\ \ i = 1, 2, \ldots, L$$

  and for the landslide velocity is set to the above-mentioned constant value:

  $$u_s = 5.58, \textit{wherever } z_s > 0,$$

  for the x-component. The y-component of the landslide velocity was initially set to zero."

- pp24, Figure 10: I would suggest using more distinguishable colors for the lines in the top panel, it is hard to tell the Grain from the Grain Velocity lines.

  Done in the next version of the manuscript.

  -Please, be more detailed in the legend, specify what magnitude is represented by "Grain".
  We have changed "Grain" to "Granular slide". Thus, "Granular slide", "Free Surface" and "Bottom", refer to the location of these surfaces and, in particular, the "Granular slide" legend refers to the location and geometry of the simulated granular slide. Figure captions have also being changed accordingly. "Grain velocity" has been changed to "slide velocity".

  -Does the vertical axes represent position or velocity? Perhaps, the left axes should be used for distance and the right one for velocity?

  Done.

- p27, Figure 12: Please specify if number in top left corner refer to x-, y = (positions)

  Done. This has been specified in the captions of the Figure 11 (R, θ°) *and 12* (x, y).

Some stylistic corrections (these are some of the corrections needed, but not all, please scan the document for additional typos):

- pp4, l 99: Please correct to "initiative which the present work is based on"

  Done.

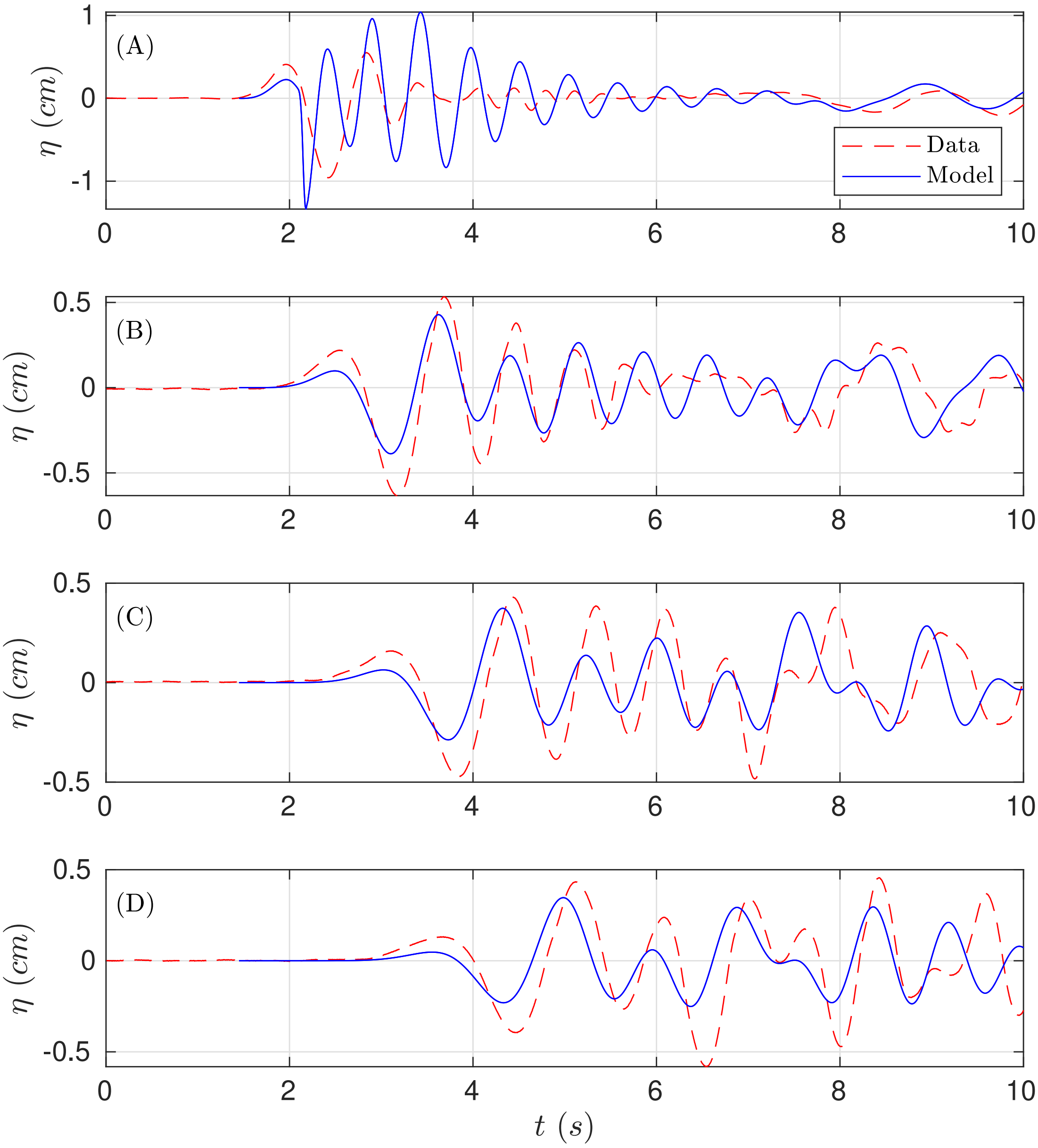

Figure 1: Numerical time series for the simulated water surface with one layer (in blue) compared with lab measure data (red) at wave gauges (A) WG1, (B) WG2, (C) WG3, and (D) WG4.

- pp6, l144-147: move: "..., the ratio r is also constant (rho_f and rho_s are also constants)" from line 147 to line 145.

  We change the overall writing of a coupled of sentences here, now the text is: "where ρ_s stands for the typical density of the granular material, ρ_f is the density of the fluid ($\rho_s > \rho_f$) both constant, and φ represents the porosity ($0 \leq \varphi < 1$). In the current work, the porosity, φ, is supposed to be constant in space and time and, therefore, the ratio r is also constant."

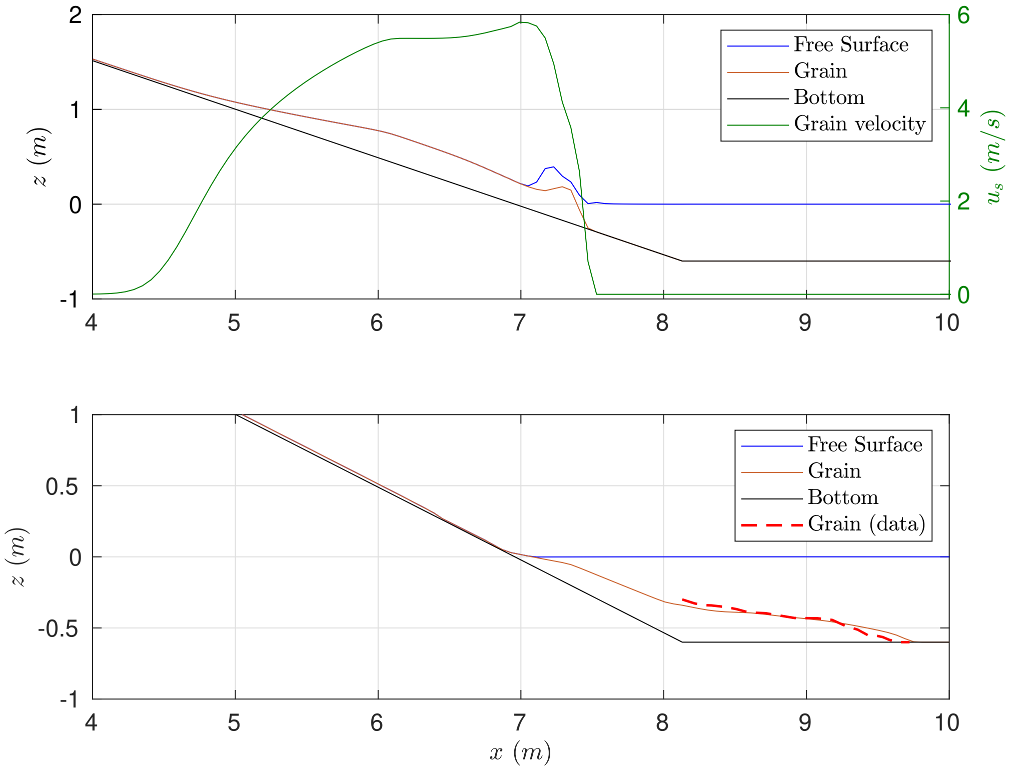

Figure 2: BP6. One-layer. Cross-Section.

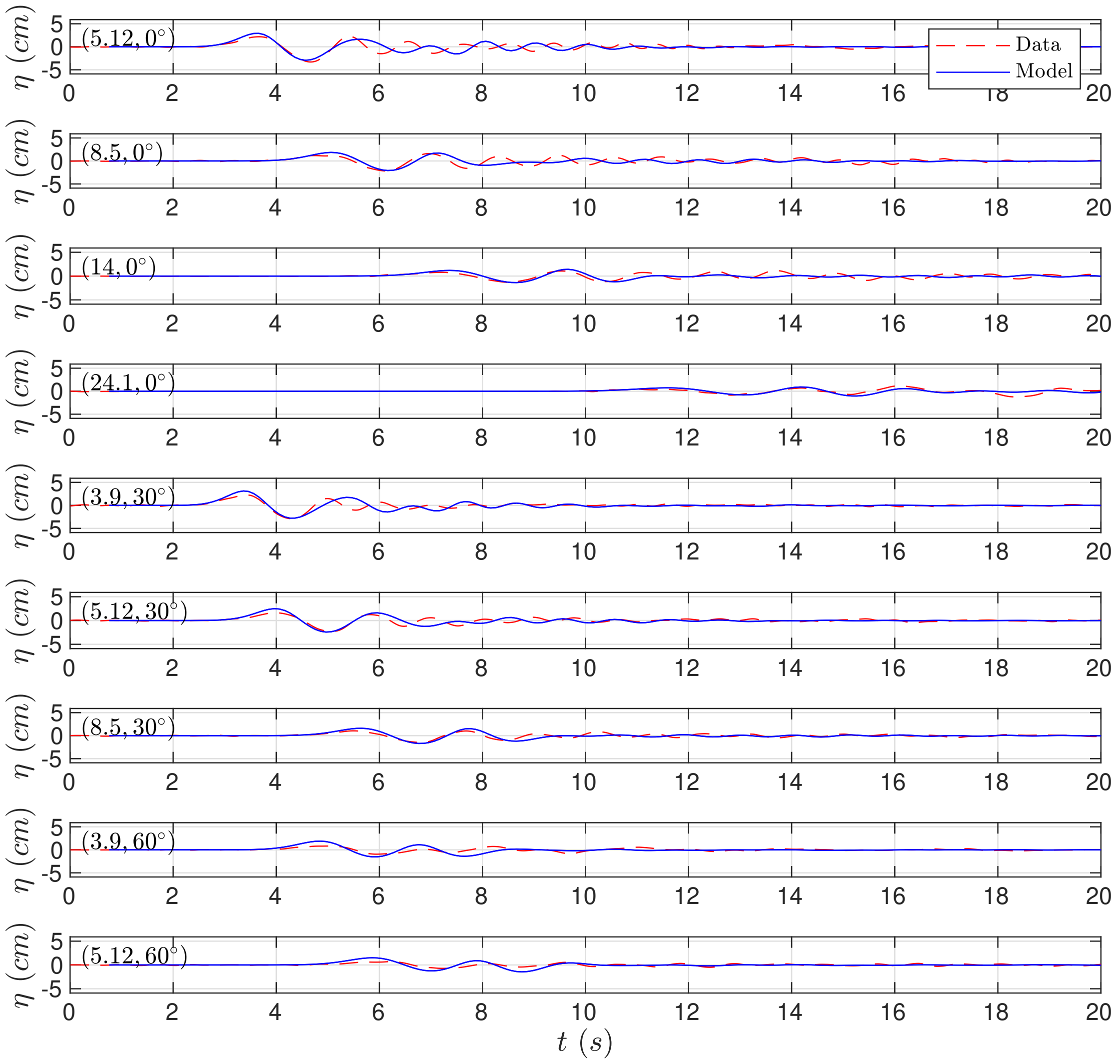

Figure 3: BP6. One-layer. Temporal series.

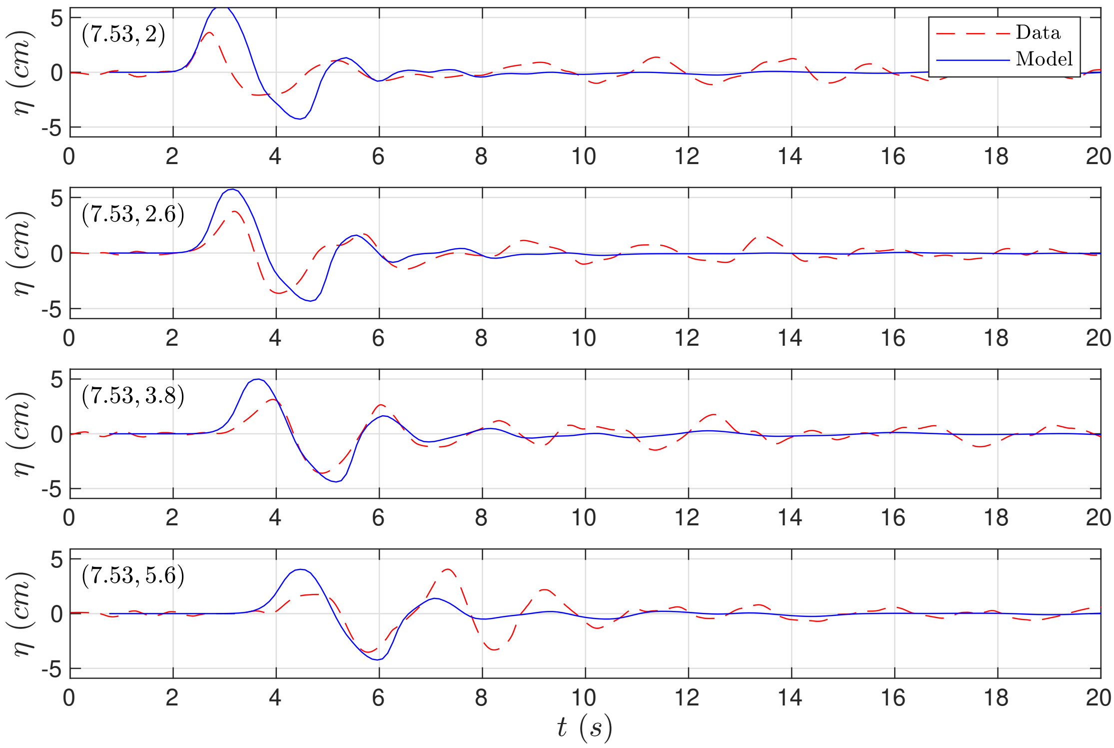

Figure 4: BP6. One-layer. Run-up.

- pp6, l154: Please replace "vertical variable" with "vertical coordinate".

  Done.

- pp9, l197: Correct: "The Savage-Hutter model that is used and...."

  We do not see were is the correction. We slightly modify the wording and now it is written as: "The 1D Savage-Hutter model used and implemented in the present work is given by the system".

- pp12, l238: Please, spell out "HLL"

  Harten-Lax-van Leer. Done

- pp13, l276-280: The first sentence is repeated almost literally. Please, correct.

  Fully rewritten.

- pp14, l304: What is meant by "no longer"?, Please word correctly.

  I cannot find any "no longer" in the current version of the manuscript.

- pp25, l405: Correct: "In can be..."

  Done.

- pp.28: l415: Please, correct: to "The present work aims at benchmarking the model..."

  Done.

- pp.28, l432: Correct to: "Savage-Hutter used here".

  Done.

- pp.29, l452: Correct to: "data compared with,.."

  This part of the text was rewritten.

Bibliography

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