Dear Reviewer

We thank you a lot for the punctual revision of our work. The paper represents a summary of my PhD thesis that I have adapted into a scientific publication. I am aware that the topics involved in CRHyME development are very wide and touch different disciplines so I am grateful to have received useful hits for improving my work. In the next parts, you can find the reply to your suggestions and observations.

Abbate et al. (2023) presented a modeling tool that simulates various surface processes, including landslides, debris flow, sediment transport, and erosion. The purpose of their paper is to present the structure of this model, along with some verifications conducted at multiple field sites across Italy. While the paper is interesting and offers an approach that contributes to closing the gap in our understanding and toolsets for landslide estimations, I have some concerns that must be addressed before its publication to improve the overall clarity of the manuscript. Although these are not fundamental modifications, addressing them could be time-consuming. Therefore, I recommend this paper for publication after a major revision or rejection at this time to provide the authors sufficient time for resubmission.

Here are the issues that need to be addressed:

The language in multiple places is unclear. I recommend proofreading to improve clarity.

We apologise for the English, and we have planned to do a language proofreading, splitting long sentences that may lead to difficulties in reading. About vocabulary we think that a list of acronymous or keywords should be made in one of the appendices in order to facilitate comprehension by the reader, also subdividing them into categories such as (i.e., climatology, meteorology, hydrology …)

The introduction should include a clear statement about the novelties of this newly proposed model to motivate readers. The authors should answer questions such as what CRHyME brings to the table that other models are incapable of doing and why landslide researchers should consider adopting this model instead of others.

We comprehend that probably our introduction is not so effective for the reader. We will try to fix it, summarizing concepts a bit and giving a clear statement of CRHyME capabilities:

- Geo-hydrological processes jointly investigate at basin scale
- Versatility with respect to the modelled process (flood, landslide, erosion);
- Climate model outputs and meteorological reanalysis outputs compatibility;
- Fast modelling even though is a spatially distributed model;
- Fast coding, modules modifications, no constraints on spatial and temporal resolution;
- Availability of Opens Source dataset and Python libraries;
- Multihazard approach, case study analysis and future projection
- …

More elaboration on the interactions of different model layers and within-layer processes is needed. Although some of the model components that solve hydrological processes were inherited from another model, providing the full picture of such processes is essential within this paper. For example, the formulations of how groundwater is handled and how percolation/exfiltration processes achieve communications between the soil layer and groundwater layer are not available.

We agree with this suggestion. In the PhD thesis, all these parts have been extensively commented on and supported by literature references. Here we have summarized the main points but we are understanding that further clarifications are needed. However, groundwater is handled considering a hydrogeological basin coincident with the hydrological ones. This is a strong assumption that is constrained by a lack of maps and data describing worldwide the behaviour of local aquifers. The groundwater layer should be intended as another “bucket” under the shallow soil that communicates through percolation (when is not saturated) and exfiltration (when is completely saturated, i.e. groundwater table is close to the topsoil). In our revision we will stress this point providing a more complete explanation of the interactions of the different layers.

The equations are difficult to follow. Although the nomenclature of the terms is provided in the appendix, explanations of some terms are still missing (e.g., Fds in Eq. 8). Furthermore, some symbols explained in the text, are not found in the equations, such as the temperature coefficient, T, not being present in any of the equations (Eq. 12, 13, 14). I recommend that the authors review each symbol in the equations and explain them clearly right after the equation.

Thank you for these details. We have demanded all the documentation in the appendix but probably a “local” description is better. About the T parameter we have already spotted the mistake and we will fix it after the revision.

In Figure 7, please use consistent units. For example, m3/s is used in the plots, but mm is used in the error metrics table, which makes it difficult to evaluate the errors. Moreover, the RMSE values for cumulative water volumes in the error metrics table do not offer any useful information. They might be removed.

Ok, we will revise these parts to make them more consistent with the text.

The same figure indicates that the model predictions of river discharge are overestimated during the rainy seasons predominantly when using the MERIDA dataset, and all model predictions underestimate the discharge during the non-rainy periods (potentially due to the lack of baseflow). This result suggests that more water is partitioned as surface runoff in the model simulations, causing less infiltration. This may be an important issue causing underestimation of the landslides due to the reduced pore pressure in the subsurface. If the authors observed such model bias, please state it in the discussion section.

This represents a key point of our analysis since there we have investigated several things.

First of all, we have noticed that a correct rainfall field computation is essential. Reanalysis datasets are very useful since provide an already distributed field, avoiding spatial interpolation methods of the classical rain gauges. However, reanalysis is again a model product that may suffer from scale dependency. Therefore on a large basin, MERIDA can perform better since errors are less probable (more pixels are taken into account and the rainfall field is generally representative) while over a little catchment, errors may increase due to the lack of accurate resolution.

Secondly, the basins we have investigated are strongly regulated by hydropower plants that may delay and modify consistently the water discharges not only for a singular event but also at a seasonal scale. Therefore, we suspect these biases could be caused by hydropower management that is implicitly hidden in the hydrometer data series. Since the model is under development, we are interested into include in the future version of the model a rough hydropower management plan to improve the results.

Thirdly, we agree with your suggestion where probably infiltration processes and groundwater flows should be better calibrated. In this direction, we will spent several times testing different infiltration models (SCS CN, Horton and Green Ampt) adapting them to work continuously and not at a single event simulation. In this regard, we have planned further investigations.

In Figure 10c, the model performed weakly during the initial year. The authors stated in the caption that this is due to initial condition uncertainties. I am curious why no spinup simulations were employed to minimize the impact of initial conditions on the model simulations.

In reality, we wanted to highlight that aspect: the CRHyME model needs at least a short period of 1-2 years of simulation in order to reach a “physically consistent” soil moisture redistribution especially if the basin is rather larger. For Trebbia (10a) and Parma (10c) rivers we have included in the series the “spin up” period while for Nure River we have trimmed it for clarity. We will revise this part (the graphs) to explain better this topic and make it less ambiguous also in the main text.

In section 4.1, the hydrological performance of the model was discussed. While I agree that simulating the water cycle correctly in such basins is challenging due to the complexity of subsurface lithology and highly variable topography, the validity of the hydrological part of the proposed model may be more easily verified in a small, heavily monitored, less complex basin to ensure that the model performs satisfactorily. The authors should consider adding such model verification on top of existing test sites to verify the model's performance hydrologically.

A sensitivity analysis has been already done in two small catchments (less than 30 km2) located one in the Alps and the other in the Apennines. We have not included these analyses to reduce a bit the length of the paper but in principle, a short paragraph will be included. In these two catchments (well monitored) the performances of CRHyME have been tested also considering different spatial data resolution and different temporal data resolution. The performance of CRHyME was encouraging since hydrological and sediment transport assessment has been verified by on-site measurements (hydrometer and sediment bathymetries over a check dam).

We thank you the reviewer for the comments and for the precious suggestions that will surely improve our work.

The Authors