Authors' comments - REVIEWER#1

This study investigates the potential tsunami hazard from landslide scenarios in the Gulf of Pozzuoli using a sequence of numerical models. The authors present four scenarios (three submarine and one subaerial) and simulate the associated tsunamis using both shallow water (SW) and non-hydrostatic (NH) models. The study addresses important local hazard concerns in a densely populated coastal area. While the paper is generally well-structured, several critical aspects require clarification and improvement before the manuscript can be considered for publication.

We thank the reviewer for the insightful and constructive remarks, improving consistently the paper clearness and efficacy. In the following, the reviewer's comments are reported in black, and our replies and comments in red.

Major Comments

Landslide Scenario Definition and Assumptions

The tsunami waveforms generated by landslides are sensitive to the initial conditions, including the location, volume, geometry, and material properties of the sliding mass. The authors mention that the four scenarios were constructed based on a "worst-case credible" approach. However, the paper lacks sufficient detail on how the initial conditions, especially volume and geometry, were determined. The cited reference (Zaniboni and Armigliato, 2025) is listed as a work in progress and is not yet available, making it difficult to assess the robustness of the scenarios.

We maintained the worst-case credible approach describing its limitations due to the lack of surveys mapping the Gulf of Pozzuoli seabed and to the rapidly changing morphology of the area (see Paragraph 2.4 and some small modifications in Discussion and Conclusions sections). The citation refers to a book chapter that was supposed to be published within 2024. Unfortunately, it is facing editorial difficulties and now is still in progress (currently, the supposed publication date is December 2025, so we hope to have it published soon). An additional reference has been provided (Tonini et al., 2011), describing the same approach and its application to the specific case of the town of Catania (Sicily, South Italy).

Moreover, the assumption that geotechnical and geomorphic properties are similar across all four scenarios is not justified or even explicitly stated. This assumption should be clarified, as differences in material properties can significantly influence landslide dynamics and tsunami generation. For instance, variations in density, cohesion, yield strength and/or internal friction angle can lead to different failure mechanisms and velocities, thereby affecting the characteristics of the generated tsunami waves. The authors should provide more detailed explanations for each scenario's setup, including volume estimates, slope angle, and material assumptions. If geotechnical properties are assumed identical across cases, this simplification should be clearly stated and discussed, along with a justification for why this simplification is reasonable in this context.

We agree that the landslide properties can influence deeply the tsunami generation, but the detailed reconstruction of the scenarios requires detailed surveys and characterization of the deposits. Such tasks are far beyond the purposes of this work which, indeed, could stimulate further investigations in the area (as suggested in the Conclusions). However, the scenarios description has been slightly improved and moved to Data and Methods section, and a short discussion about this has been added at the end of Paragraph 2.4 and resumed in Discussion and Conclusion sections.

Tsunami Generation Mechanism and Modeling Approach

The modeling approach uses a one-way coupling scheme, where landslide motion is simulated independently and used as input for tsunami generation and propagation. This approach, while computationally efficient, may be insufficient to capture certain physical mechanisms, particularly for subaerial landslides like scenario 4, where the interaction with the water column is highly dynamic and nonlinear. In reality, the water displaced by the landslide can, in turn, influence the landslide's motion.

This is true, but for example in Harbitz et al. (2006) it is stated that, based also on previous studies, the velocity of the landslide front could be reduced of up to 20% by the interaction with the wave it generates. Though not irrelevant, this effect does not affect consistently the generated tsunami and its propagation in the Gulf of Pozzuoli, which is the main focus of this work. These considerations were already reported in Paragraph 2.2, and have been slightly modified adding this citation.

The subaerial case involves a mass plunging from above sea level into the water with high velocity, which contrasts with the more gradual submarine slope failures of the other scenarios. Given these differences in physical processes, it is unclear whether the same numerical treatment is equally valid for both types of landslide. The authors should justify the use of the same modeling framework across all scenarios and clearly discuss the limitations of their approach, especially regarding the subaerial case. They should acknowledge the potential limitations of the one-way coupling and discuss how this might affect the accuracy of their results.

The mechanism of tsunami generation remains the same, i.e. the uplift of the whole water column caused by the passage of the sliding mass along the seabed. Other highly non-linear processes occur in the landslide-water interaction in subaerial cases, but these effects are generally confined only to the near field and dissipate rapidly with distance from the impact area. In this view, we believe that the modelling approach is suitable for both types of movement. We added a subsection in Discussion specifically addressing this issue.

Role of Froude Number and Energy Transfer Efficiency

A crucial omission in the discussion of tsunami generation is the role of the Froude number Fr=U/gH, which characterizes the relationship between the landslide velocity (U) and the shallow water wave speed (gH). When the Froude number approaches 1, energy transfer from the landslide to the water is most efficient due to resonance-like effects. This can lead to significant amplification of the generated waves.

While the authors analyze landslide velocities and acknowledge the influence of slide speed and dispersion, they do not discuss the possible amplification effects that occur when the slide velocity approaches the wave celerity. This is particularly relevant for Scenario 4.

The authors should discuss whether any of their scenarios reach near-critical Froude conditions and, if so, whether their model can appropriately represent the associated amplification. Even a simplified estimation of the Froude number for each case would enhance the paper. This analysis would provide a more complete understanding of the tsunami generation process and its potential impact.

We totally agree with this view. The Froude number (defined as $U/\sqrt{gh}$) is a precious indicator of the efficiency of the energy transfer from the mass to the water. It has been introduced and described in Paragraph 3.1.1 (for Scenario 1) and added to the plots and commented for each scenario.

Minor Comments:

L9 "consisting into" -> “consisting of”

Ok

L38 “In the specific” -> “Specifically”

Ok.

L43 “assessing” -> “by assessing”

Ok.

L128 "with no back-interactions considered" -> "and back-interactions are not considered"

Ok.

L134 “a finite time” ->unclear since an earthquake occurs in a finite time. Consider rephrasing to something like "a non-instantaneous generation process" or "a generation process that evolves over time".

Ok.

Table 2 - I do not think Table 2 is necessary. We may replace it by a paragraph. Also Table 2 was wrongly referred to at L284 and L308. They should be Table 3 instead.

We agree, Table 2 will be removed, and numbering and references adjusted accordingly.

Figure 1&2 - Two figures can be combined.

Figure 2 has been removed, and numbering changes accordingly.

Figure 3 is almost identical to Figure 2&4 of Aiello et al. (2012). I am concerned about the permission to use these figures. The authors should provide confirmation that they have obtained the necessary permissions to reproduce or adapt these figures.

Figure 3 (renamed as Figure 2 in the new version) was created entirely from scratch, based on the plots in Aiello et al (2012), to avoid copyright infringement.

Authors' comments - REVIEWER#2

The manuscript titled "Tsunamigenic potential of unstable masses in the Gulf of Pozzuoli, Campi Flegrei, Italy" provides a numerical study of four submarine (three) and subaerial (one) landslide scenarios and their corresponding tsunamigenic impact in the Gulf of Pozzuoli. The work is looking at past evidence of collapse to reproduce modes of failure and tsunamigenesis with the largest potential attributed to subaerial collapse. The codes UBO-BLOCK and UBO-TSUIMP/JAGURS are used for simulating mass failure and tsunami respectively. The dispersive potential of the wave characteristics is also investigated in the study. The authors conclude that only some of the scenarios examined have an impact on the adjacent coastlines. This is a comprehensive investigative work that can strengthen the existing knowledge of tsunamis in the region. However, some key points need to be addressed.

We thank the reviewer for the interesting and productive comments, that help to improve this work. Specific answers to the remarks are reported below in red.

General comments

1) P.2 L45-46, P8 L196-198, P17 L355 and elsewhere

Although it is noted that the masses have been selected based on previous deposits and present morphology, it is not clear why these are the worst possible scenarios that could happen in the region. Can the authors affirm this with certainty? This needs to be carefully addressed as it can be misleading for future policy and hazard mitigation efforts as the current work indicates that there is not a significant risk from submarine but only subaerial landslide tsunamis in the region. Future failures may not replicate past events and an increase in volcanic activity, variance in the location of failure, and higher collapse volumes may increase tsunamigenic potential and the impact may be larger, even more so if the possibility of such events is ruled out.

We totally agree with this view. The cited "worst-case credible" approach is based on the known and potential sources, or on credible scenarios built on the existing evidence. Due to the poor knowledge of the seabed morphology and to the rapidly changing conditions of the area, the mobilization of larger volumes can't be ruled out. We added these considerations in the description of the worst-case credible approach (Paragraph 2.4), highlightinging its limitations in this case.

2) S2.2

Subaerial landslide tsunamis generally have a greater tsunamigenic potential than submarine ones and have more complexity due to the interactions between the solid mass, water and air. Modelling the high impact, and complex slide kinematics often requires 3D Navier-Stokes solvers, SPH, CFD or VOF models. It is not clear whether this complexity is captured with the study's numerical codes, an issue which could underestimate the hazard. It is not clarified in the manuscript how the authors distinguish between the modelling of the submarine and subaerial failure, besides the different solvers used in the propagation modelling.

The impact of the sliding mass on water is a very complex process, involving strongly non-linear phenomena that are hard to capture with numerical simulations. At the same time, these effects are mainly confined to the "splash-zone", the area around the impact that typically has limited extent. Moreover, the generated waves can be very high but usually have high frequencies, and hence dissipate quickly. In contrast, the perturbation propagating to greater distances in the Gulf of Pozzuoli results from the longer wave components, which can be associated with the landslide motion along the submarine portion of the sliding surface. In our view, this behaviour is adequately captured from our modeling approach. These considerations have been included in a specific and dedicated subsection of the Discussion chapter.

Specific comments:

P.2 L45-46 The worst-case referenced approach is not yet published and therefore hard to understand and verify. The authors should expand more on the methodology.

An additional reference to a previous paper (Tonini et al., 2011), describing the same approach and its application, has been added. The 2025 chapter is in phase of publication and we hope to have it available soon, however its citation will be removed.

P.2 L127, 128-130: Air Entrainment is of importance when focusing on subaerial landslides, the generation involves a triple phase interaction.

As already mentioned, from the point of view of the tsunami propagation in the Gulf such effect is secondary, and limited to the source area.

P3 L139-141. What are the underpinning equations in UBO-BLOCK? The model seems to have been primarily used in the modelling of submarine landslide tsunamis

Indeed, it has been tested also in the subaerial environment, for example in the 1783 Scilla landslide-tsunami. References to this case have been added.

P6 L167 As JAGURS is nested, it is worth clarifying that the nested approach is omitted in that case.

Ok, done (Paragraph 3.2).

P6 L167 Please also give more details on whether the simulations were run locally or in a cluster, CPU time and time of the event.

The simulations are run on local computers, with order of magnitude of ten of minutes for the landslide dynamics and some hours for the tsunami propagation. In this last case, JAGURS is not used with the parallel computing version: the computational time is not optimized, then not particularly significant.

P10 L231-233 This statement should be substantiated by references.

A reference to the June 30th, 2025 event has been added. However, the topic is discussed widely in other sections.

P10 L240-254 Although the authors mention the locations of the deposits and the corresponding volumes it is not clear how these volumes were estimated based on the observed deposits. A few sentences explaining the approach would help here.

The description of the scenario reconstruction has been slightly extended and moved to Paragraph 2.4.

P11 L263-265 If any, what kind of rheology is assumed for the sliding mass?

Given the limited information available for the area, we did not describe in detail the landslides' rheology. We assumed a moderate translational behavior, based on the scarce information available: for example, in Scenario 1 the position of the final deposit is estimated, and this is assumed as a constraint for both the dynamics and rheology. For the other scenarios this information is not available, but a similar behavior has been assumed. Of course, there is a considerable uncertainty regarding the landslide rheology and geometry: this work aims also at encouraging further investigation in the area. Some of these considerations have been added at the end of Paragraph 2.4 and resumed in Discussion and in Conclusions.

P17 L355 This statement standing alone reads quite strong and I think it cannot be backed up by only assessing 3 scenarios of collapse, it should be better rephrased to the specific case studies as in P19 L408.

Agree, the sentence has been modified.

Figure 10 I think xlabel is mistyped and '(m)' is wrong?

Yes, thanks for the observation, fixed.

P20 L427-429 I agree with the authors, and I think this is not clear throughout the manuscript so far.

The discussion about the scenario individuation has been moved to Paragraph 2.4 and more stressed, and resumed in the Discussion session.

P22 L472-L479 I believe an important addition to the discussion would be how parameterisation and probabilistic approaches, as for example surrogate models, can help when it comes to future hazard assessments in the region and the capability of assessing multiple scenarios of collapse with large variances in location, volume and mode of failure.

These are indeed interesting points, but we preferred not to raise such topics, which are still developing.