EGUSPHERE-2025-270
Response to referee 2

We thank the referee for the useful and productive comments. Here, we reply to the raised issues. Referee comments are reported in blue italic font.

Referee 2

This paper provides an example of flood modelling in two coastal cities due to storm surge and river discharge. The paper is well written and is relevant to NHESS. Some uncertainties - e.g. on compound events - are well discussed, but not all. However, before publishing this work, I recommend to:

1. provide more elements about the validation of this work

We would like to thank the referee for this very pertinent comment, which we found particularly useful and motivating. Alongside a similar observation raised by another referee, it has encouraged us to expand the manuscript by including a previously omitted but important part of our work, namely the calibration and validation activities carried out for the different models. These additions help provide a more complete and transparent picture of the modelling chain and its reliability, and we are grateful for the opportunity to improve the manuscript accordingly.

In particular, we plan to add a specific section to the Supplementary Material detailing the calibration/validation procedure for the water level, wave climate and hydrological models. To facilitate readability we uploaded the cal_val.pdf document containing the newly added section to the Supplementary Material.

We intend to modify the main text by expanding the lines from 261 to 263 as follows: "*In this section, we describe the implementation of the three numerical models: WaveWatch III, SHYFEM and LISFLOOD, employed to perform the main part of the downscaling procedure. Each of the models has a particular setup on the basis of the analyzed coastal city. Furthermore, a calibration/validation procedure has been carried out for each of them to have an estimate of their skill to reproduce observed events. The detailed description of the different procedures is reported in the Supplementary Material.*"

For the sake of clarity, we are using the expression "calibration/validation" procedure in a broad sense, and not according to the strict definition involving the use of a dataset to tune the model parameters (calibration), and then another dataset to check the model skill (validation). Due to data availability constraints, we show that the models are able to match observations in case a systematic trial and error calibration procedure was performed (water level model - SHYFEM), and in case the calibrated setup was inherited from a previous study (wave climate model - WWIII), or when it was based on a shared community effort (hydrological model LISFLOOD). The above specification is also included in the cal_val.pdf document.

2. Assuming a proper validation of the total water levels at a tide gauge and waves offshore, the key uncertainty will result from the use of an empirical formula for the wave setup, which requires a high resolution shallow water bathymetry. It would be important to discuss it as the ambition is to provide a high resolution flood model, as illustrated by the use of a Lidar topographic data.

We recognize that the use of an empirical formula to calculate the wave runup (Atkinson et al., 2017) is a limitation of the present approach. Specifically, the formula provides the combined value of swash and wave setup derived from offshore wave climate variables (H_s and L) and the beach slope. The beach slope was estimated as an average value over the analyzed area by integrating Lidar data with bathymetric information extracted from nautical charts. For the Massa area only, two single beam surveys were available from the years 2012 and 2016. While this introduces a degree of uncertainty due to the alongshore variability of the beach, it also provides an advantage: it allows us to avoid the full dynamical simulation of the wave breaking and swash process, while still capturing the correct order of magnitude for the wave runup estimates. A more advanced approach would be the use of a full coupled hydrodynamic simulation integrating 2D hydrodynamic modelling of the riverine flood wave with the wave and storm surge induced flooding dynamics. At our knowledge, a few models (even with some limitations and expedients, e.g. MIKE, Telemach-Mascaret, FUNWAVE) allow this. We prefer, as a starting point, we have deliberately adopted a simpler approach, also in order to reduce the computational cost. In future developments, we intend to improve our analysis performing coupled hydrodynamic simulations that integrate both wave induced and riverine flood.

We added the following, starting from line 433, to the Section 5.2 Hydrodynamic model:

"*…from the LIDAR dataset, at a resolution of 2 m (Figure 4g, h, i), merging it to information from nautical charts, except for the city of Massa, where two single beam surveys were available for the years 2012 and 2017.*"

We also expand the Discussion section including the following starting from line 678:

"*The use of an empirical formula to calculate the wave runup (Atkinson et al., 2017), while avoiding us to fully simulate the dynamical swash process and getting at least the order of magnitude of runup values, introduces uncertainties due to the degree of alongshore variability of the beach or due to the reduced knowledge of the underwater bathymetry. Indeed, for the city of Massa two bathymetric surveys were available (2012 and 2016), but for Villanova the submerged part of the domain principally comes from nautical charts. Specific efforts to recover the detailed bathymetry of the area are recommended to make the resolution of the hydrodynamic domain as uniform as possible.*"

3. The context about sea-level rise is not well explained; it would be important to discuss what we know from sea-level rise, e.g. commitments over decades to centuries, the fact that meters of sea level rise can not be avoided on the long term and that this could happen earlier than projected in case of an ice sheet collapse - see e.g. the IPCC report WG1 published in 2021. Based on this review, I recommend to reconsider the statements starting lines 605 regarding future flooding in Massa.

We agree the statement, as it was phrased, could convey a distorted idea of the results obtained. We intend to modify the sentence at lines 605-606:

"*Future coastal floods in Massa do not show significant variations in terms of event magnitude compared to the Historical period.*"

as follows:

"*If we only look at the return period values of total water level for the city of Massa, we do not observe significant variations in terms of event magnitude compared to the Historical period.*"

Lines 618-619:

"*Actually, the main driver in producing significant differences in flooded volume is the RSLR (Table 3), which causes the storm surge to penetrate farther inland, resulting in larger flooded volumes (Table 7).*"
were substituted with the following:
"*Actually, the main driver behind the significant differences in flooded volume is the Relative Sea Level Rise (RSLR) (Table 3), which allows storm surges to penetrate farther inland, resulting in larger flooded volumes (Table 7). This finding is consistent with the conclusions of the IPCC Sixth Assessment Report (IPCC, 2023b), which states that regional sea level change will be the primary factor contributing to a substantial increase in the frequency of extreme still water levels over the next century, even assuming other contributors to extreme sea levels to remain constant. Therefore, all uncertainties in sea level rise projections can significantly affect the flood extension and volume associated with extreme events. In addition, the projected sea level rise by the end of the century could be significantly higher if the less likely, but still plausible, ice-sheet-related dynamics were to occur (IPCC, 2023b; IPCC, 2014).*"

We will also integrate the bibliography:
Intergovernmental Panel on Climate Change (IPCC). (2023a). Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. https://doi.org/10.1017/9781009325844
Intergovernmental Panel on Climate Change (IPCC). (2023b). Climate Change 2022 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. https://doi.org/10.1017/9781009157896

And we plan to add the references in lines 49:
"*worldwide, are among the most vulnerable areas to these events (IPCC, 2023a; Vitousek et al., 2017;*"
and 61:
"*...year coastal flood could increase by about 20% in the medium to long term (IPCC, 2023a). By 2100, the..*"

4. The data used on sea-level projections are not clearly presented (no unit in Table 3, no source associated to the table). This should be precisely clarified.
We report here the updated version of Table 3.

$\Delta\eta_{RSLR}$ [m]	Massa	Villanova	Oarsoaldea
RCP4.5 2011-2060	0.150 (-0.036, +0.05)	0.15 (-0.044, +0.056)	0.192 (-0.057, +0.061)
RCP4.5 2051-2100	0.351 (-0.096, 0.131)	0.349 (-0.105, +0.138)	0.412 (-0.155, +0.150)
RCP8.5 2011-2060	0.168 (-0.042, +0.057)	0.173 (-0.053, +0.062)	0.229 (-0.079, +0.073)
RCP8.5 2051-2100	0.464 (-0.137, +0.173)	0.458 (-0.136, +0.185)	0.537 (-0.208, +0.203)

Table 3. Values of RSLR referred to the RCP4.5 and RCP8.5 scenarios, averaged over the reference period, for the analyzed cities. All values are given with respect to the 1985-2005 reference period. Data extracted from Vousdoukas et al. 2016a (RCP4.5 data) and Vousdoukas et al. 2016b (RCP8.5 data).

5. Overall the paper would have more impact with a one or a few clear key messages that could be taken forward - e.g. that precise flood hazard assessment is required to assess future sea level rise impacts in coastal cities, that this can not be achieved at broad scale yet (no global Lidar DEM) and requires local assessments;

We intend to modify the concluding part of the Abstract

"*This work demonstrates the capability of the integrated framework to address climate change impacts at urban scales, providing valuable insights for the development of localized adaptation strategies.*"

as follows:

"*This work demonstrates the capability of an integrated modeling framework to address climate change impacts at the urban scale. Local-scale modeling is essential: accurate flood hazard assessment in coastal cities requires high-resolution simulations to capture the influence of local topography and infrastructure, especially where global DEMs are inadequate. By linking climate projections to urban flood impacts, the framework enables a consistent evaluation of future extremes, sea level rise, and their interaction. A further key message of this study is the need to generate actionable insights to support the development of targeted and site-specific adaptation strategies. Adaptation must be tailored: only by quantifying future extremes and exposure is it possible to design effective, place-based responses.*"

To reinforce the overall message, we plan to reiterate these key points also in the Conclusions section, highlighting their relevance for future applications and decision-making.