

Dear editor and reviewer,

Thank you for the careful evaluation of our manuscript. We have revised the text to ensure that the language reflects the scope and findings of this observational study and that broader implications are framed consistently with the evidence presented. In the responses below, we reiterate these changes in the context of the specific reviewer comments.

The first main comment of the reviewer is that the paper is still a single-event case study, but some parts of the text continue to go beyond that scope. In particular, the abstract still refers to the “*increasing frequency of extreme weather events,*” and Section 2 still includes a strong climate-change attribution statement. Since the manuscript itself does not perform a trend or attribution analysis, these broader statements remain insufficiently supported within the paper and should be removed or softened further. I agree in particular with the first part of the comment and agree that the statement “*and highlighting the increasing frequency of extreme weather events*” should be removed in the abstract as this study does not show this.

We have revised the first sentence of the abstract. Its purpose is to indicate that this storm was unusual, providing justification for monitoring it, rather than suggesting that studying climate trends is the object of our work. The sentence has been changed to: “*In August 2024, a devastating storm struck Romania’s Black Sea coast, setting new precipitation records and marking an unusual change relative to historical climate observations—~~highlighting the increasing frequency of extreme weather events.~~ To investigate this extraordinary event, we integrated This study explores the integration of non-conventional sensors*”

I also agree that *the statement on lines 114-116 (in the track changes version) should be made more specific*. Currently, it is not clear where this statement comes from (i.e. “The changes in precipitation that contributed to the flooding are largely attributed to human-induced climate change, with natural climate variability likely playing a modest role”), and the citation should be clearly stated at this point in the text.

The intent of this paragraph is to show that the storm stands out in the context of decades of observations and that ClimaMeter has attributed it as a human-driven climate signal. The previous wording may have suggested that we performed this climate analysis ourselves. In fact, this serves as justification for selecting the event for our study. We have revised the paragraph to better indicate the context and present the information as background rather than our own conclusion. “*this particular storm led to a significant local increase in precipitation, particularly in Constanța, ~~one of the coastal cities severely affected by the flooding. In Constanța, where daily rainfall reached up to 5 mm day⁻¹, or up to 10% more than usual. ClimaMeter’s analysis compares events of this type to historical analogues over the past several decades, providing context for how unusual this storm was. marking a notable deviation from the region’s typical weather behavior. The changes in precipitation that contributed to the flooding are largely attributed~~ According to Antonescu et al. (2024), the local precipitation anomaly in this event is*

mostly linked to human-induced climate change, with natural climate variability likely playing a modest role. ~~As climate change continues to influence weather patterns, understanding the connection between changing precipitation levels and extreme weather events like flooding is crucial for improving forecasting and resilience in the face of such disasters. Studying this unusual storm and its atmospheric characteristics demonstrates the value of using all available observational infrastructure, including geophysical sensors, to monitor extreme precipitation events, gain insights into atmospheric processes, and support preparedness and resilience in the context of ongoing climate variability.~~

Also, in the discussion section (around lines 657 onwards in the tracked changes version) it is stated that “An attribution analysis using the ClimaMeter framework (Antonescu et al., 2024) identified a detectable anthropogenic climate change signal associated with this event... “. The “detectable” and the “largely attributed” statements in these 2 different sentences can be interpreted as inconsistent. I believe that more precise statements should be added in both parts of the manuscript based on what is actually stated in Antonescu et al.

We have softened the reference to the ClimaMeter analysis in this part, changing the sentence to “~~According to An attribution analysis using the ClimaMeter analysis of framework (Antonescu et al. (2024), the characteristics of this storm places~~ *identified a detectable anthropogenic climate change signal associated with this event, placing it within the broader context of extreme events under in a changing warming climate conditions.*”

With regards the second main comment on forecasting/early warning and the need to tone down or justify statements, I find the revised language for the most parts appropriate. I would agree that the *statement on lines 643-645 appears to strong* “*This case study suggests that this multi-sensor approach may help improve our ability to predict extreme weather events, understand their impacts, and mitigate associated risks*” and is even superfluous.

While our study does not reach the level of operational forecasting, the multi-sensor dataset still captures aspects of the storm’s development, such as the buildup of atmospheric moisture observed by GNSS, the evolution of infrasound acoustic states, and high-frequency seismic responses to sea state and distant rainfall, illustrating the temporal progression of the event before it reached its peak along the coast. We have reworded the statement to retain a forward-looking perspective, emphasizing future potential rather than demonstrated forecasting: “*This case study **highlights** ~~suggests that this~~ **the potential of multi-sensor observations approach may help improve our ability to predict to enhance our understanding of extreme storm behavior and support the development of future early-warning strategies.** ~~weather events, understand their impacts, and mitigate associated risks.~~*”

Reviewer comments:

First, the paper is still a single-event case study, but some parts of the text continue to go beyond that scope. In particular, *the abstract still refers to the “increasing frequency of extreme weather events,” and Section 2 still includes a strong climate-change attribution statement.* Since the manuscript itself does not perform a trend or attribution analysis, these broader statements remain insufficiently supported within the paper and should be removed or softened further.

Our intention in the abstract and Section 2 was to contextualize the storm, provide background, and explain why it was selected for detailed observation. The multi-sensor dataset captures different stages of the event highlighting the temporal progression of the storm. Perhaps the wording was ambiguous so we made the following changes. The reference to the human-driven climate signal from ClimaMeter was intended only to justify why this storm was notable, not as a conclusion of our study. To clarify this, we reworded the abstract and the relevant part of Section 2. The abstract now reads: *“In August 2024, a devastating storm struck Romania’s Black Sea coast, setting new precipitation records and marking an unusual change relative to historical climate observations. To investigate this extraordinary event, we integrated non-conventional sensors...”*

In Section 2, the paragraph now specifies that ClimaMeter’s analysis provides context for the storm’s unusual characteristics: *“...this particular storm led to a significant local increase in precipitation, particularly in Constanța, where daily rainfall reached up to 5 mm day⁻¹, or up to 10% more than usual. ClimaMeter’s analysis compares events of this type to historical analogues over the past several decades, providing context for how unusual this storm was. According to Antonescu et al. (2024), the local precipitation anomaly in this event is mostly linked to human-induced climate change, with natural climate variability likely playing a modest role. Studying this unusual storm and its atmospheric characteristics demonstrates the value of using all available observational infrastructure, including geophysical sensors, to monitor extreme precipitation events, gain insights into atmospheric processes, and support preparedness and resilience in the context of ongoing climate variability.”*

Second, the *link to forecasting or early warning is still not demonstrated clearly.* The manuscript shows that the different sensors provide complementary information for reconstructing this storm, but it does not establish predictive skill, operational lead time, or validation across multiple events. For that reason, statements suggesting improved forecasting or early-warning capability should either be justified much more concretely or toned down.

The multi-sensor dataset provides observations of the storm’s development: for example, the buildup of atmospheric moisture seen by GNSS, the progression of infrasound acoustic states, and high-frequency seismic responses to rainfall and sea state. While these data do not reach the level of operational forecasting, they reveal patterns and stages in the storm’s evolution that are not captured by any single dataset alone. To reflect this potential without overstating results, we have reworded the sentence referring to it in the discussion as : *“This case study highlights the*

potential of multi-sensor observations to improve our understanding of extreme storm behavior and help guide the development of future early-warning strategies.”

Minor comments

L 108–119 are unclear and should be revised. We revised this paragraph to clarify that the storm is contextualized using ClimaMeter’s comparison to historical decades of data, emphasizing the event’s significance without implying that our study performs attribution.

L 509 “strong confirmation” remove “strong” Removed, as suggested.

L 547 “the accumulation of atmospheric moisture may precede to extreme weather events” is unclear and should be rewritten. We removed “to” as it was a leftover from a previous version, so the sentence now reads “may precede extreme weather events.”

Antonescu et al. ClimaMeter reference should be checked carefully. The year should be 2024. We corrected the reference year for Antonescu et al. to 2024 in the reference list.