Author‘s response

Sentinel-1 based analysis of the Pakistan Flood in 2022 (egusphere-2022-1061)

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Response to reviews

We thank all contributing reviewers for their constructive and helpful feedback. Please find a point-by-point response to the reviews below.

Response to RC1

Please find the reviewer comments (RC1) of the document attached to the review and the corresponding author comment (AC1) here:

RC1 (line 28): The CEMS also provides the risk and recovery product which is by definition more accurate and combines more data sources. Is there a particular reason for choosing the rapid maps for validation which themselves have no accuracy/uncertainty estimates attached? If the reason is that only the rapid mapping product exists for this event, please state this clearly.

AC1: Thank you for this advice. The risk and recovery product looks very promising for flood mapping validation. Unfortunately, there is currently no data available for the Pakistan flood, which is why we selected the rapid mapping data.

RC1 (line 33): I cannot see any of these details in figure 1, did you mean the location of the mentioned provinces or the study site extent? Could you please clarify?

AC1: We will clarify in the revised version that we are showing the extent of the study sites provided by the CEMS rapid mapping data.

RC1 (line 45): how is this decided?

AC1: The internal low sensitivity masking used by our algorithm is described in detail by the cited publication (Bauer-Marschallinger et al., 2022), and we will add details on the exclusion methods to the manuscript.

RC1 (line 48): There is a published paper on this, please cite it.

AC1: Thank you for pointing us towards this publication. The GFM exclusion layers fundamentally differ from the described methods/layers of this publication. Following a similar approach of Zhao et al., 2021, we implemented a time-series-based masking per pixel, but the layers are produced individually based on statistical parameters or external datasets. The layers will be part of a future scientific publication, and are already publicly accessible via the product definition document of the Global Flood Monitoring service (cited in the paper under Global Flood Monitoring).

RC1 (line 73, referencing Table 1): Am I missing something? The table shows the difference of just a few hours between the acquisition timings, which one is 2 days later?

AC1: The 4th area of interest (Shanghar) is 2 days apart from a Sentinel-1 acquisition, but is currently missing in Table 1. For completion, we will add the area to Table 1, but keep the analysis to be focused on the other three areas to rely on temporally close reference data.

RC1 (line 87): can you please point to the exact land cover type or the physical phenomenon that causes this difference? Is it vegetated or urban or what is happening?

AC1: Thank you for bringing this up. Since Sentinel-1 observed the situation before Spot, and the flood surface was still growing at this point in time, the underestimation is more likely related to the time difference of the acquisitions. To double-check this and to analyse the relationship with vegetation, we will add land cover data to provide more context.

RC1 (Figure 4): This figure would perhaps benefit from the inclusion of the coverage of the validation areas, as I was confused for a bit as to why some areas were excluded in the confusion map

AC1: Thank you for this comment. The validation is limited to areas showing a valid result from both the Sentinel-1 flood mapping and the optical reference data. Consequently, cloud-covered areas are excluded. We will add the information about the coverage of the validation!

RC1 (line 89/91): Ability of optical sensors to detect flood under vegetation

AC1: Thank you for putting this into the correct context and pointing us towards two useful publications (Schumann et al., 2022 and Dasgupta et al., 2022). Optical observations are not able to detect flood under dense vegetation. In the case of Shikarpur, we assumed advantages of optical observations for detecting flood close to sparse vegetation, but we have not fully communicated this in the paper. However, as you mentioned, the differences are more likely to be related to the time difference between Sentinel-1 and Spot (please see comment on line 87).

RC1 (line 99, referencing Figure 4): It might help the readers to include some zoomed in subsets to illustrate exactly what is meant with an example.

AC1: Thank you for your advice. We will include a zoomed subset to ease the interpretation of the confusion maps.

RC1 (line 100): How can one get water-like low backscatter over vegetation, which by definition would break the water surface and prevent specular reflection?

AC1: The areas of overestimation mostly correspond to cropland, which occasionally shows fast backscatter changes due to different agricultural activities. Low-backscatter over vegetation appearing with water-like signature can occur due to ploughing in case of agricultural fields or attenuation of the signal within the vegetation (Vreugdenhil et al., 2018, Harfenmeister et al., 2019). A more speculative explanation is that the flood surface changed between the two satellite observations due to manipulation of local dams in reaction to the flood threat.

RC1 (line 101): The difference in acquisition can either explain the under or the over detection depending on the flood event evolution between the two acquisitions, but I struggle to understand how it could simultaneously cause such large over as well as under estimations within a few hours.

AC1: Thank you for pointing this out. You are correct, the time difference can generally only correspond to an increased or decreased flood surface. Our interpretation of the overestimation can be seen in the comment for line 100.

RC1 (Figure 7): Please include the scale in all of the following figures. One per figure is enough if the scales are consistent.

AC1: We will add a scale bar to the figure.

RC1 (line 140): Would it not be more meaningful to report the overall results across all ROs?

AC1: As this large flood is not covered by a single Sentinel-1 overpass, each orbit covers different parts of the event, at different times. To allow an estimate of the progress of the flooded area over time, we decided to base the analysis on a single orbit, which covers about the same area at each overpass.

Response to RC2

We have summarized the feedback into 6 main points and the corresponding responses can be found here:

Extended description of hydrology, climate and land use:

To extend the context of this study, we will provide more details within the description of the study area (Section 2). As some of the discussions relate to the local land cover types, this change would additionally benefit a better understanding of the detected differences to the reference data.

Emphasize limitations of evaluation:

We agree with emphasizing the known limitations of the evaluation and presenting some details of potential implications of these. Since the comparable small area covered by the reference is mentioned in the description of the evaluation (Section 3), we will extend the explanations there.

More details on the differences of the two sensors:

Thank you for pointing this out. We will extend the description of the evaluation (Section 3) by some details on the differences of Spot and Sentinel-1.

Applications of the flood mapping algorithm in flood management and disaster :

To discuss some of the potential applications of flood mapping results, we will mention and link some literature on this topic in the introduction of the manuscript (Section 1). Thereby, we will focus on work on the use in the context of flood forecasting and early warning systems.

Discuss the significance of near-real-time applications:

As this study should present the near-real-time capabilities of our algorithm, we support the suggestion of discussing the significance of a short reaction time for flood management and disaster response.

Add future developments and improvements to the algorithm:

As mentioned in the conclusion section of the manuscript, we plan to publish a deeper analysis of the algorithm's performance based on globally distributed events. Consequently, additional insights on the needed improvements of the algorithm will be part of that study. However, we will add already known developments of the algorithm to the conclusion.

Relevant changes made in the manuscript

A summary of the changes applied to the manuscript in response to the reviews can be found here:

1. **Extension on the context of the study** by including more details about the hydrology, climate and land use of Pakistan. Further, the discussion of potential applications of satellite-based

flood extent maps was extended as well as the significance of near-real-time applications was described.

2. **More details and context about the used flood mapping algorithm** by extending the description of the algorithm itself and adding more details about future developments to the algorithm.
3. **Extension on the discussion of limitations of the applied evaluation** by explaining the impact of the lack of ground-truth data as well as the relatively small areas of the reference data in comparison to the whole study area.
4. **Clarified the interpretation of the found differences in the evaluation** by further investigating the reasons for the found overestimation in the Jacobabad AOI and focussing on the difference in acquisition time in case of the found underestimation. The imprecise argumentation of the difference in the detection of flooded vegetation between optical and microwave sensors was replaced.
5. **Added scale and more details to the figures** by including zoomed subsets for selected figures and adding missing information.
6. **Improved conclusion to be more precise and include the suggestions of the reviews** by including the limitations of the study, giving a broader outlook on the work related to the algorithm and further changes.
7. **Further thematic and grammatical edits**