Author's response to reviewers

The reviewers' comments and questions are marked in red while the author's response to the reviews including a list of all relevant changes made in the manuscript are marked in blue.

Respond to Review #1

I'm pleased to see that most of the issues raised in my review were addressed. I've seen considerable changes in comparison to the first version. I've only a few additional comments:

- Figure 2 was modified to address a comment of mine, though I see other issues now. The table in the top-right of the figure is not readable. Also it is sub-optimal to include a table as an image. I'd suggest separating it from the figure and adding it as a table in the main text of in the supplement. In this way the color legend would be moved on top of the map and make it overall more readable.

Respond: We have removed the table from Figure 2 and now the table is presented in the Table 1. The color legend of Figure 2 is also removed to the top right of the figure.

Also, the location of the 4 inundated areas should be highlighted in the map on the right.

Respond: The locations of the 4 selected inundated areas are marked in the overview map.

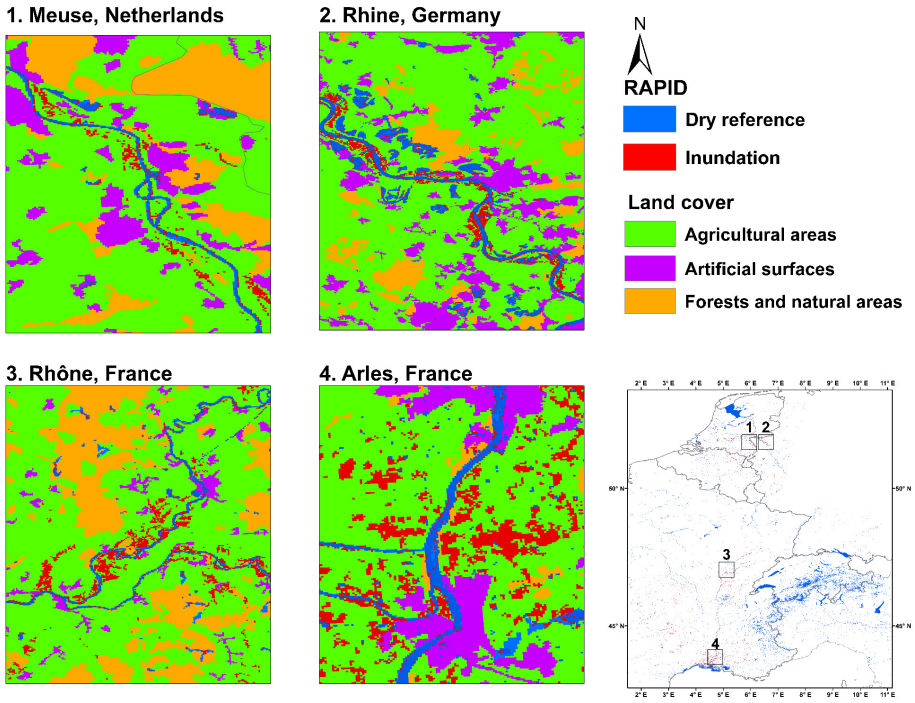


Table 1. Inundated area of land use grouped by countries over western Europe

Inundation area (km^2)	France	Germany	Belgium	Netherlands	Switzerland	Luxembourg	Italy
Artificial surfaces	38.2	36.5	21.8	9.42	3.88	0.08	0.65
Agricultural areas	974	88.3	46.4	98.9	10.6	1.03	16.7
Forests and semi-natural areas	216	35.5	38.5	26.9	114	0.68	32.9
Wetlands	90.2	1.73	9.64	5.33	2.77	0.00	0.07
Total	1.32×10^3	162	116	141	131	1.79	50.4

- Use a consistent approach for reporting numbers and their significant digits. 6 is probably too many (e.g., 1236.12 km2). The same applies to “F-1 score and Cohen kappa metrics are 0.8816, 0.8439, 0.8624, 0.8571, respectively.”. These would be surely easier to interpret and remember if written as “0.88, 0.84, 0.86, 0.86”.

Respond: Thanks for your suggestions. The approach for reporting numbers is consistent with 3 significant digits in the revised paper. For example,

From line 115 to 117 on page 4:

"The total inundated area over France is approximately 1.32 × 10^3 km^2. In Germany, the main inundated area is found in the west which is caused by the intensive precipitation (120 mm), along the Rhine River (about 162 km^2)."

From line 120 to 122 on page 4:

"The RAPID and Landsat based FIMs shows high consistency on the flooded areas according to the result of quantitively comparison, with precision, recall, F-1 score and Cohen kappa metrics are 0.88, 0.84, 0.86, 0.86, respectively.

- Please make sure that additions fit well within the context and their grammar is correct. In this version it's not always the case. For example, I'm not convinced by the comment on crop oxygenation during floods in the concluding remarks section. This notion was not discovered in this work, it's more suitable for the introduction.

Respond: We have moved the comment on crop oxygenation during floods from the closing remarks to the introduction section.

From line 28 to 29 on page 1:

"The oxygen supply would be greatly reduced when a corn crop is submerged in water, which greatly reduces or even stops critical plant functions such as nutrient and water uptake [Lauer 2008]."

We have checked the grammar and improved the language throughout the paper in a more academic way.

Respond to Review #2

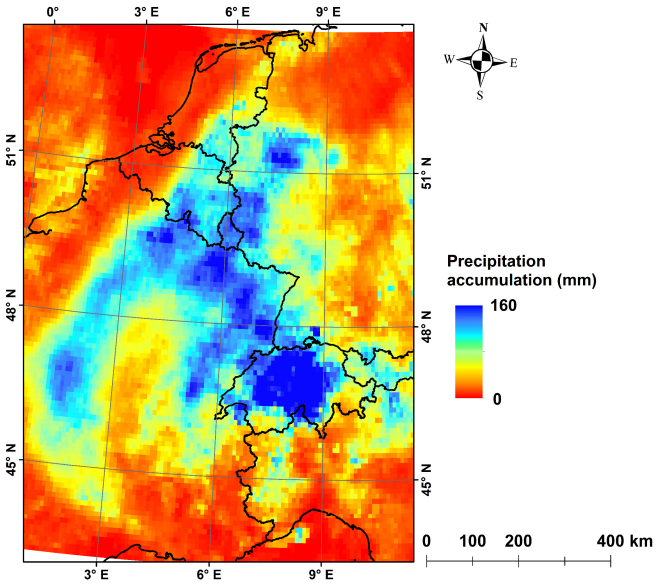
I want to thank the authors for making extensive improvements on their manuscript. The method now feels more complete and the figures have much improved. However, I am still hesitant about some of the results and concerned for the presence of artifacts in their results.

Netherlands:

the revised manuscript still reads:

“In the northern Netherlands where more than 100 mm precipitation is observed” -> this is not correct. The intense rainfall was in the south(east) of the Netherlands; not the north. As can also be seen in Figure 2 in the paper.

Respond: We apologize for incorrectly describing the precipitation results in the paper. Yes, you are correct, the intense rainfall (> 100 mm) was in the southern Netherlands which we can find from Figure 2 (a).



We have corrected this, from **line 117 to 119 on page 4:**

“In the southern Netherlands where more than 100 mm precipitation is observed, the floodplains of the Meuse, Rhine and Ijssel were largely affected, with a total area of 141 km^2.”

"regions near Markermeer and IIsselmeer, and regions around Hollands Diep and Meuse River are largely affected by the flood" -> as stated in my first review round, the regions near Markermeer and Ijsselmeer were in reality not affected at all. I can't judge where the authors base this finding on but am still afraid there may be artifacts in the methods if this is what they found with the RAPID methodology.

Respond: Yes, you are correct. The regions near Markermeer and IJsselmeer are not affected by the flood. we can also know this from the RAPID inundation map that there is no extensive flooded area. We apologize for not correctly describing the inundation results in regions near Markermeer and Ijsselmeer in the last revised paper. We have corrected the description of inundation results over Netherlands in this revised paper.

Line 117 to 119 on page 4:

"In the southern Netherlands where more than 100 mm precipitation is observed, the floodplains of the Meuse, Rhine and Ijssel were largely affected, with a total area of 141 km^2."

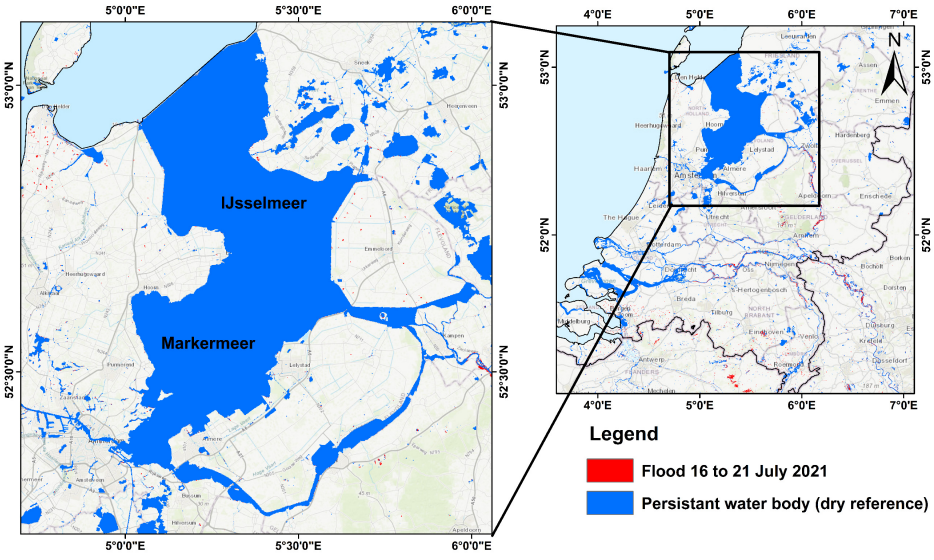


Figure 4 shows a part of central Netherlands (not northern) with the rivers Meuse, Rhine, Ijssel, and flooding of floodplains there. This I can confirm happened last summer. But I would phrase it as such (i.e. that the floodplains

of the Meuse, Rhine and Ijssel were affected); as opposed to referencing Hollands Diep, which is a permanent water body).

Respond: We have corrected the citation of Figure 4,

"Figure 4. Inundation extent from (a) Landsat-based flood map and (b) RAPID flood map on July 18 in central Netherland."

Following your suggestion, we write the inundation results over Netherlands as from **Line 117 to 119 on page 4**:

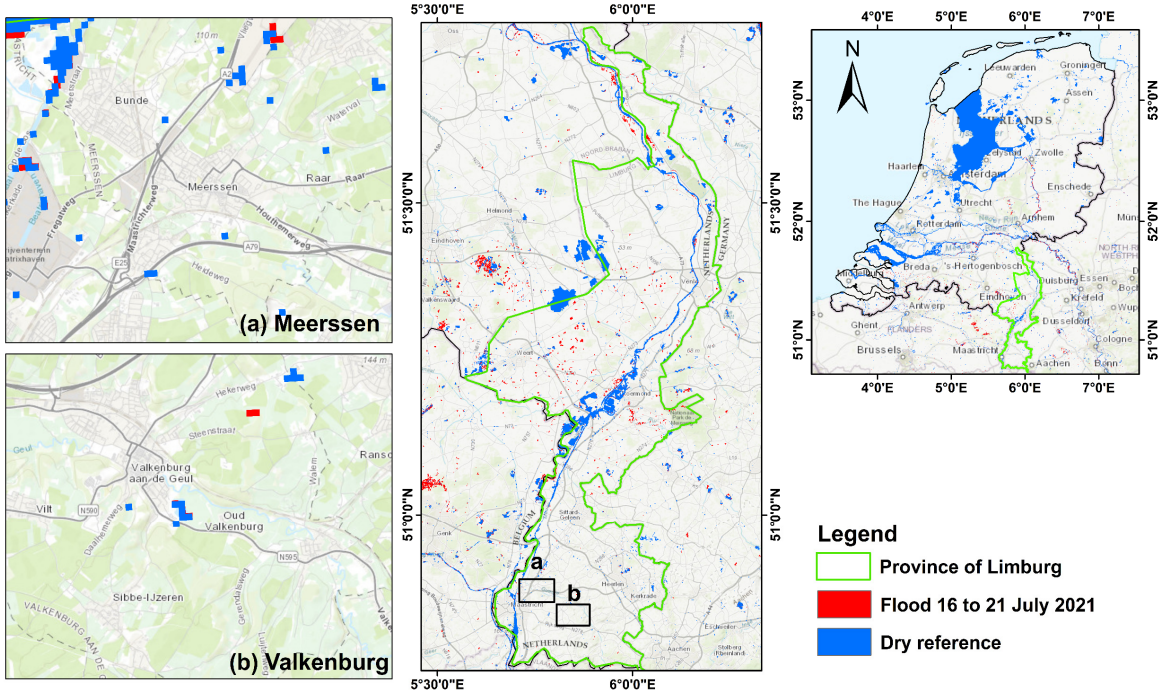
"In the southern Netherlands where more than 100 mm precipitation is observed, the floodplains of the Meuse, Rhine and Ijssel were largely affected, with a total area of 141 km^2."

As mentioned in my previous review, the flooding was, by far, the most extensive in the south of the Netherlands (province of Limburg). I would challenge the authors to examine their results around the village of Meersen (confluence of Meuse and Geul) and maybe Valkenburg (along the Geul), which were both severly affected. I can imagine that flooding along the Geul river may not be picked up well as it is a small river with a limited floodplain (much more v-shaped river valley). It could be simply due to resolution issues that this is not picked up; or because the ICD module in the RAPID methodology may discard it if the Geul is not recognized as permanent water body (again due to resolution issues). It is ok if this is the case, but would really like the authors to scrutinize the RAPID methodology on where it does and does not work well. This event gives a great opportunity for that by examining known hit areas. I can imagine that it can pick up very well the flooding of floodplains along major rivers, but less so flooding in smaller upstream rivers with considerably smaller floodplains.

Respond: We have checked the inundation results over the province of Limburg, in the south of the Netherlands. We can see the inundated areas in the floodplains along the Meuse River, near Venlo and Roermond, from the RAPID flood map. However, in the regions around the village of Meerssen and Valkenburg, we can not find many inundated areas. We agree with the reviewer that a floodplain which is too small can be ignored because of the resolution issue. We have addressed this as the limitation of RAPID in the closing remark.

The Geul river is not recognized as the permanent water body in the CORINE land cover map. which has a spatial resolution of 100 m. The WST process in RAPID depends on the accuracy of the land use map. **From line 173 to 175 on page 6**:

"In addition, RAPID cannot capture the inundation well in the limited floodplains along the small rivers due to the spatial resolution issue, such as those in the floodplains along the Geul river, in southern Netherlands."



South-East France:

I am still very concerned by the results for Southern France. As mentioned by the authors, there was hardly any rainfall there (10mm). I did some searching myself and did not find any mention on floodlist for flooding in that region during that time. What further fuels my concern is the pattern of flooding that is presented in Figure 3. This looks very patchy, unlike the flooding near Louhans and along the Meuse/Rhine/Ijssel rivers (fig1 and fig 4). Given the absence of rainfall, the only flooding I can imagine happening is along the main river that may have received rainfall (far) upstream. But that should not look this patchy and I hardly see flooding linked to the main river. I did notice that also the dry reference (in blue) from June 22 looks very patchy, with many blue spots that in places where on google satellite picture

I see little to no permanent water (for as far as I can judge with just visual comparison). These (in my view) questionable blue spots my result in the RAPID methodology not discarding spots, where in reality it probably should.

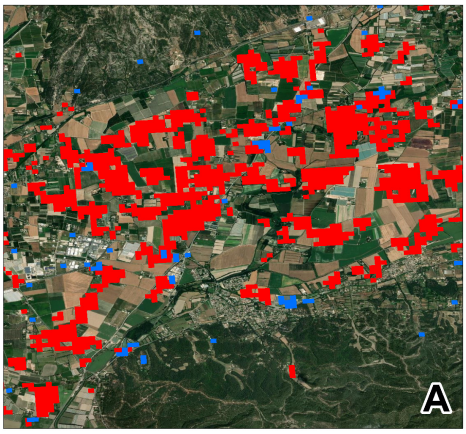
Something similar could be the problem with the Ijsselmeer/Markermeer area in the Netherlands which the authors referred to, but I couldn't find the image for that region on the AWS. Btw, the Nijmegen and Roermond figures on AWS there look very good, even the smaller river of the Roer seems to be well captured!

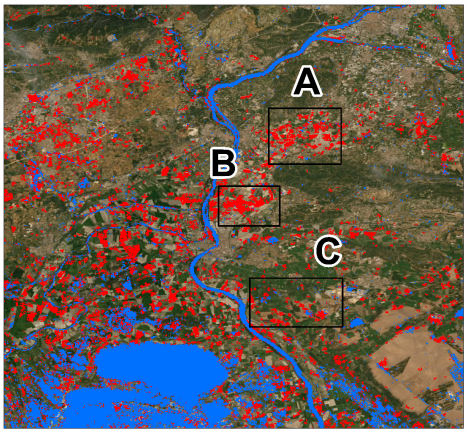
Respond: In the southeastern France, the inundation in the floodplains along the main river (Rhône) is due to the heavy precipitation occurred in the upstream of the Rhône River, northeastern France. For the inundation far away from the main river, those patchy areas, they are mainly crop lands (non-irrigated arable land, rice fields, pastures). These arable lands might be flooded by overflow from the river (if they are close to the channel) or the raised water table (close to the coastal), or due to irrigation (since July is the growing season for crops in France, and the official irrigation period is from June 15 up to the French national holiday of August 15). The dry reference SAR images are only available on June 22 when we find these arable lands are totally dry, not been irrigated. For croplands, RAPID is not responsible to discern real flood from irrigated water unless additional information is provided.

From line 109 to line 114 on page 4:

"The south-eastern France, especially the coastal area, exhibits extensive flood inundation as well, though the accumulated precipitation in these areas is only around 10 mm. The flooded areas in south-eastern France, shown as Figure 3 (a), are mostly arable land. These areas exhibit clearly dampened backscattering compared with the dry date (Figure 3 (c), June 22) to the flood date (Figure 3 (b), July 16) while their backscattering on the flood date falls into the water category. These arable lands might be flooded by overflow from the upstream Rhône River or the raised water table under the impact of coastal tide. The croplands labeled as inundated in southern France may also have been irrigated due to the irrigation starts from June 15 in France."

https://www.jancisrobinson.com/articles/irrigation-now-official-in-france

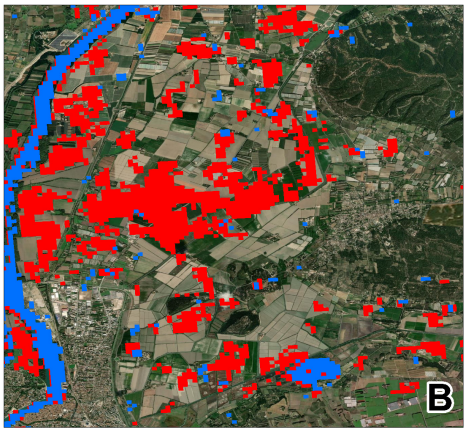


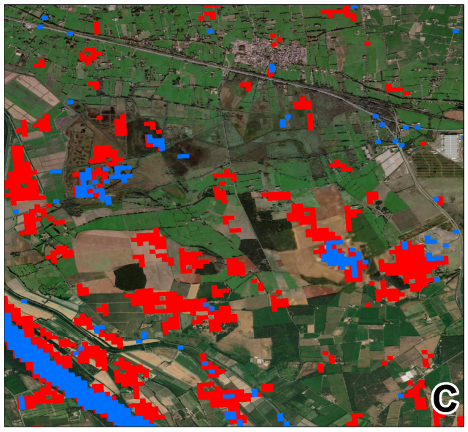


RAPID

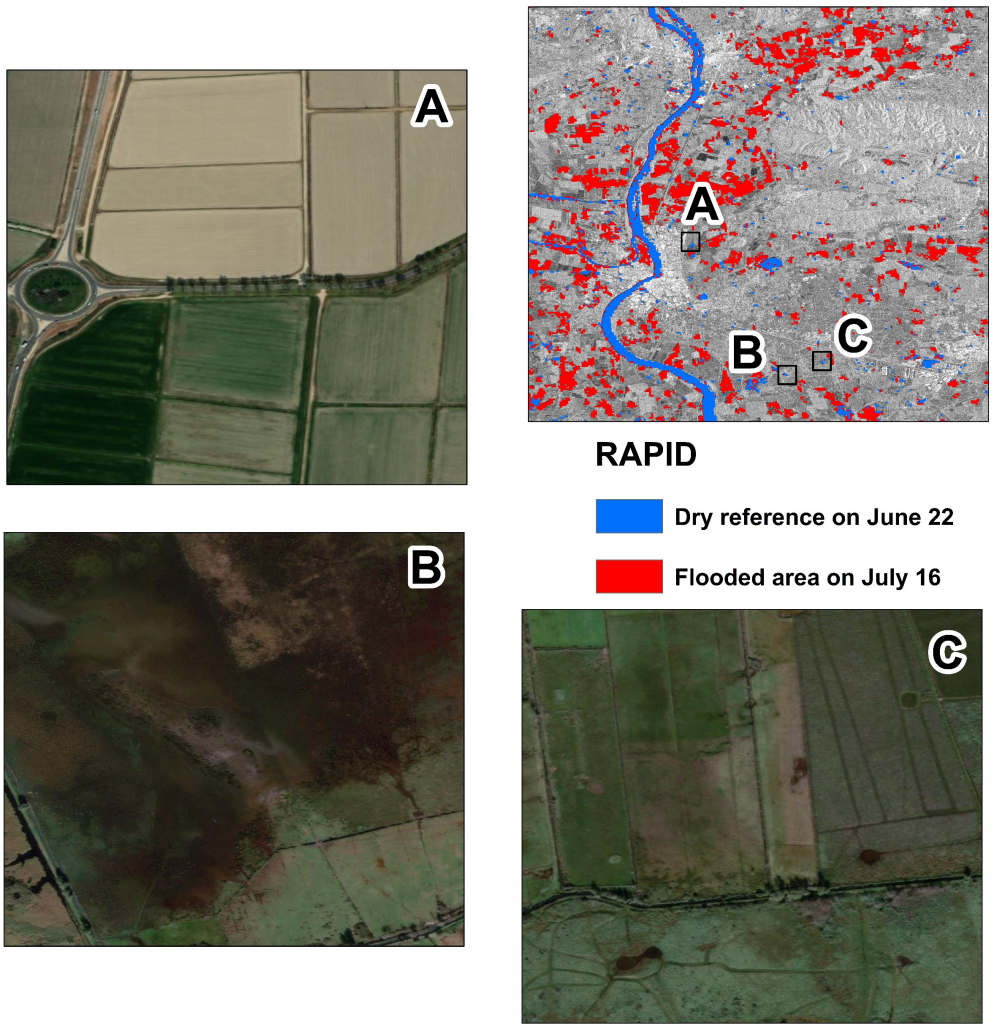
Dry reference on June 22

Flooded area on July 16





For those blue patches in the dry reference, some of them are inland marshes (B and C in the figure) which we can know from the CORINE land cover map. Some crop lands are also identified as the dry reference because of the irrigation water (A in the figure). A few examples are presented below:



Landsat and validation:

The authors seem to have introduced another RS source to estimate flooded areas with, using landsat-based flood inundation maps. However, this is not explained in the methodology (but introduced out of the blue in the results), nor is it clear whether this was an analysis by the authors themselves, or an independent source (there is no citation to anything). Also the reason for doing this (in this one case) is not made explicit. I can guess that it is for valiation, but as this seems to concern a comparison between two estimated flood maps (probably with similar methodology, just different input maps; but

hard to judge as no details are given on the landsat based FIMs), it does not add too much value in my opinion.

Respond: Thanks to the reviewer. We did not clearly describe the method used to derive the flood extent from Landsat. Landsat-based flood maps serve as an independent validation source for the RAPID system. So the reference is from a different method and data. Since they highly agree, we can trust the RADID system in places/time where/when we only have Sentinel-1 data. The Landsat-based flood maps is produced using the automated water extract index (AWEI). The process of extraction is summarized below:

from line 77 to 85 on page 3:

"The Landsat-based flood maps are introduced as an independent validation source for the RAPID system. To generate the flood extent from Landsat, we first acquire surface reflectance image sensed on flooding period from Landsat-8 OLI collection 2 level-2 dataset (Sayler and Zanter 2020), which is available from USGS Earth Explorer. We then extract the flood extent using the automated water extraction index (AWEI, Feyisa et al. 2014). We calibrate the threshold of AWEI using water pixel samples of high water occurrence. The water occurrence and land use information are extracted from Pekel et al. (2016) and Gong et al. (2019) respectively. Specifically, pixel samples for water are taken from the persistent water body with more than 90% of water occurrence, and non-water pixel samples are equivalent extracted from the land cover type of cropland, forest, grassland, shrubland, Impervious surface, and bare land. The optimal AWEI threshold is selected as the one that yields the highest F-1 score in segmenting water and non-water pixels."

References:

Sayler, K., Zanter, K., 2020. Landsat 8 Collection 2 (C2) Level 2 Science Product (L2SP) Guide. Sioux Falls, South Dakota.

Pekel, J.F., Cottam, A., Gorelick, N. and Belward, A.S., 2016. High-resolution mapping of global surface water and its long-term changes. Nature, 540(7633), pp.418-422.

Gong, P., Liu, H., Zhang, M., Li, C., Wang, J., Huang, H., Clinton, N., Ji, L., Li, W., Bai, Y. and Chen, B., 2019. Stable classification with limited sample:

transferring a 30-m resolution sample set collected in 2015 to mapping 10-m resolution global land cover in 2017. Science Bulletin, 64(6), pp.370-373.

Feyisa, G. L., Meilby, H., Fensholt, R., & Proud, S. R. (2014). Automated Water Extraction Index: A new technique for surface water mapping using Landsat imagery. Remote Sensing of Environment, 140, 23-35.

The comparison results show that RAPID flood maps show high spatial consistency with Landsat-based flood maps.

Much more valuable would be validation with independent empirical information such as eye-witness reports (like newspaper reports through floodlist, or social media reports through globalfloodmonitor.org).

Respond: Thanks to the reviewer. In Figure 2 (b), we have presented the inundation extent in the some areas where are reported to be severely affected by the flood, like the floodplains along Meuse river in southern Netherlands, floodplains along Rhine river in western Germany and floodplains along Rhône river in northeastern France, in the left panel of the figure.

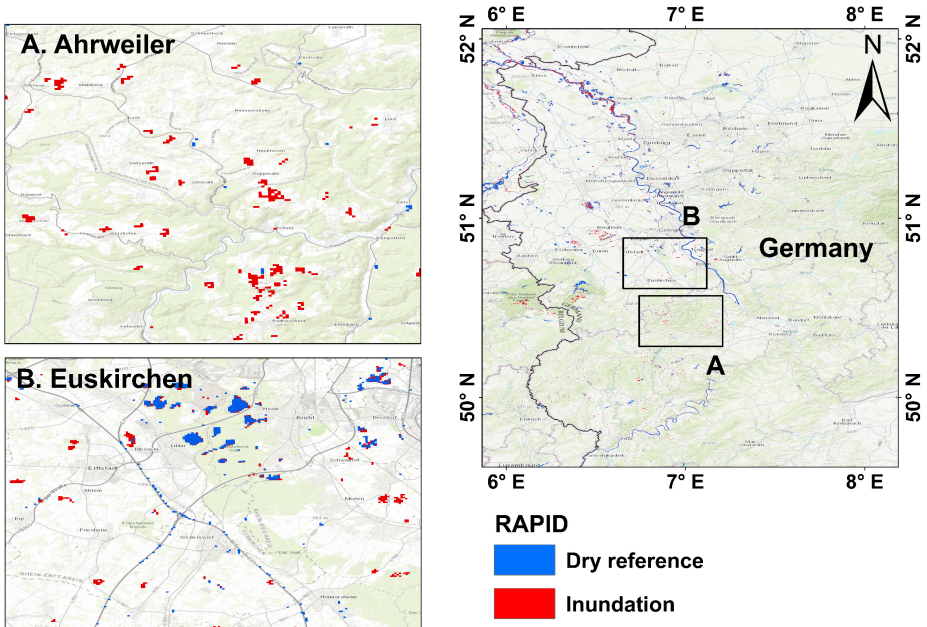
From line 103 to line 105 on page 4:

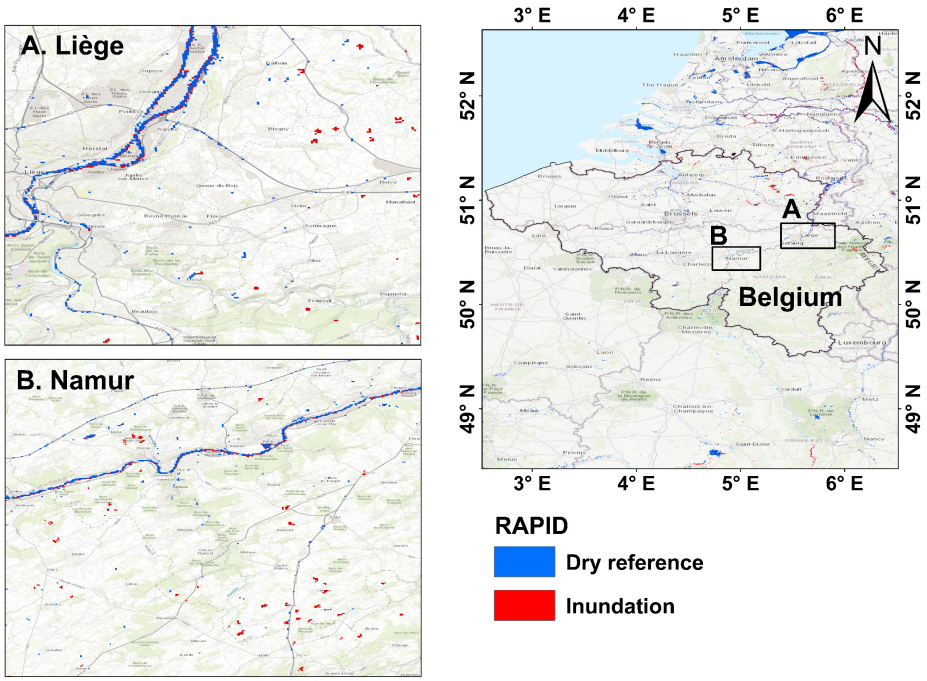
"Figure 2 (b) shows the inundation extents over western Europe, while the four regions where extensive flooded areas are found from the RAPID inundation map, e.g., the floodplains along Meuse in southern Netherlands, Rhine in western Germany, Rhone in north-eastern France and Arles in south coastal France, are presented as well."

we additionally provided the inundation results over areas such as district of Ahrweiler in Rhineland-Palatinate, Euskirchen in in North Rhine-Westphalia, in western Germany; Liège Province and Namur Province in eastern Belgium, where significant damage and many deaths are reported. Overall RAPID can successfully map the inundation area of the flood affected regions.

https://floodlist.com/europe/floods-belgium-july-2021

https://floodlist.com/europe/germany-floods-july-2021





In short: there are several results which I find questionable based on my own knowledge of the event (flooding Ijsselmeer and Markermeer), and based on the results shown by the authors (spotty pattern in SE France). Consequently, I'm afraid there may be incorrect results in certain areas. I would urge the authors to scrutinize their results in order to find the reason

for this. When doing so, the authors can also reflect on when (e.g. when correct dry image is present) or where (e.g. river with substantial floodplain area) the RAPID methodology does very well, and when/where it doesn't perform well. This would be very valuable for the rapid flood mapping community and wider risk management community to learn from.

Respond: We have checked the RAPID inundation results over the questionable areas. We have corrected the description of precipitation and inundation results in the Netherlands which are not accurately described in the last revised paper. The extensive inundated areas in south-east France are mainly arable lands. These arable lands might be flooded by overflow from the river if they are close to the river channel, or the raised water table if close to the coast. The spotty pattern in south-east France is result from the inland marshes which can know from the land cover map. Besides, by checking the RAPID inundation results over some severely affected regions from the news and reports, we find RAPID can successfully map the inundated areas over those regions. Overall, RAPID works pretty well in the floodplains along the major rivers, like Rhine, Meuse, Rhone. However, for the limited floodplains along the small rivers, like those along the Geul river in southern Netherlands, RAPID can not capture the flood well due to the resolution issue. We have addressed this issue as the limitation of RAPID system in the closing remarks.

For the inundation results over southern France, we want to emphasize that RAPID cannot tell the difference between flood and the change of ponded status of intermittent water bodies. For instance, if multiple dry dates are used as reference while an irrigated time is used to extract flood, a non-flooded cropland might be identified as inundated. Similarly, an intermittent water body can be identified as a flood area during its high water level period. But we typically do not consider these mistakes as an error of a flood extent extract. RAPID is a near-real time flood mapping system, the inundation results are directly derived from the satellite images. Disaster responders who are using these maps could easily tell these croplands are not impacted by floods with local knowledge. This knowledge can also inform to RAPID to further improve its accuracy. For example, if we know the irrigation plan in advance over some crop fields in southern France, we can mask out these lands.