

Earth Syst. Sci. Data Discuss., author comment AC1
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Comment on [essd-2020-313](#)

Francesco Dottori et al.

Author comment on "A new dataset of river flood hazard maps for Europe and the Mediterranean Basin" by Francesco Dottori et al., Earth Syst. Sci. Data Discuss., <https://doi.org/10.5194/essd-2020-313-AC1>, 2021

We thank the Referees for their useful comments and positive evaluation of our manuscript. Please find below a detailed point-by-point reply to all comments

RC1: 'Comment on [essd-2020-313](#)', Anonymous Referee #1, 09 Apr 2021

This paper evaluates new European flood maps provided by the Copernicus European Flood Awareness System. The methods behind the mapping have been developed and published elsewhere and are only briefly documented here (too briefly in a few places – see comments below). The advantage of the presentation approach is that the paper should be accessible to non-experts in this type of modelling.

The paper focuses on the performance of the hazard layers against several national flood hazard maps and international studies using a similar class of regional flood models. The paper is well presented and easy to follow. It makes a useful contribution to the literature and more validation studies of this type are needed. Generally the conclusion are well supported by the analysis, although the early focus on the Mediterranean basin region is lost later in the manuscript. I agree fully with the premise of the paper and would recommend publication subject to the revisions outlined below.

We thank the Referee for his/her positive comments on our manuscript.

Line 81: Add reference for LISFLOOD-FP for consistency with LISFLOOD. There is also now source code published for LISFLOOD-FP and you could cite this later for consistency with the presentation of LISFLOOD <https://doi.org/10.5194/gmd-2020-340>

We thank the Reviewer for providing this reference, which will be included in the main text as well as in the Data Availability section

Line 140: I appreciate that the article is trying to avoid repeating technical details published elsewhere. However, I would like a little more detail on the statistical analysis of the extreme flows to be presented. Specifically what data were used (AMAX)? What distributions were fitted? Alfieri et al 2014 describe the overall method but I also thing so direct citation to the extreme value analyse method followed would be useful.

We applied the statistical analysis of extreme flows over the long-term hydrological

simulation generated with LISFLOOD. For each pixel of the river network, we extracted annual maxima for the period 1990-2016 and we used the L-Moments approach to fit a Gumbel distribution and calculate extreme flow return periods. We will add such additional information in the revised text (see also our reply to Referee #2).

Line 146: What is the source of the high-resolution river network data?

The high-resolution river network data is taken from the CCM River and Catchment Database for Europe, the same database of the DEM (Vogt et al., 2007). We will add this reference to the revised text

Line 157: Does the DEM include building and vegetation or are these removed to approximate a DTM?

Thanks for raising this point. The elevation values of CCM DEM include both buildings and vegetation cover, but only vegetation cover was mentioned in Section 2.4.2 as a possible source of error on DEM accuracy. In the revised text we will include urban areas as an additional source of uncertainty on DEM values.

Line 161: Given that a 2D model is used without the river channels how are river flows accounted for? For example, is a design flow subtracted from the volume entering the model (this approach would approximate the method JBA used for the original 1 in 1000 year extreme hazard map for the UK), is zero in channel flow assumed (this would potentially put more water onto the floodplain than in reality and results in a somewhat precautionary model), are the channels represented as 1D components (for example the approach taken in LFPtools <https://doi.org/10.1016/j.envsoft.2019.104561>), or do you burn a channel into the DEM (tricky at 100 m resolution on smaller rivers and usually only used for high-resolution simulations). I don't believe it matters which approach was taken from a publication perspective, but a short note is needed here to acknowledge and justify the choice made, especially as there are examples of LISFLOOD-FP being applied in all of these ways.

In each flood simulation we modify the input flow hydrograph by subtracting the 1-in-2-year flood discharge value to all daily time step values, therefore reducing the overall flood volume entering the model. Conversely, the original DEM is not modified, following the approach proposed by Alfieri et al. (2014,2015). We will add this piece of information in the model description.

Line 243: How are the reference maps treated in the comparison. Do they maintain some native resolution or are the polygons rasterised to the same 100 m resolution as the modelled maps. Assuming 100 m resolution what impact does this have, I assume any loss of resolution usually makes the reference maps easier to fit?

All the national flood hazard maps used in this work are available as polygons of flood extent, and the original resolution is usually not known. As such, they were converted to raster format with the same resolution as the modelled maps, while the latter have been converted to binary flood extent maps (see Lines 221-224 in the original manuscript). We did not quantify the impact of coarsening reference flood maps, however it is likely to be negligible compared to the overall error observed for modelled flood maps.

Line 272: Did you consider using a DEM derived from TanDEM-X data?

We are aware of the recently released 90m DEM derived from TanDEM-X data (<https://geoservice.dlr.de/web/dataguide/tdm90/>), but it was not considered in this work due to time constraints. However, we will mention the possibility of using this dataset for future research in the Conclusions, along with Copernicus DEM and MERIT-Hydro datasets.

Line 287: Some acknowledgement that the approach taken to the vegetation and urban correction is far from the state of the art is needed here. Some of the newer machine learning based approaches are likely to do a significantly better job of removing surface artifacts than this approach and we know that flood simulation is very sensitive to the quality of vegetation and building removal in the global DEM's. I do not think this detracts from the value of the study, but it should be clear that there are known routes to potentially better modelling here.

We take the point. Indeed, working on the improvement of elevation data was not the main scope of this work (and the MERIT DEM applied in the tests already includes a correction of vegetation effects), and we agree on that mentioning more advanced research on this topic would benefit the manuscript. We will make clear that we proposed a rather basic approach and will include the following lines at the end of Section 2.4.4 : "Recent research works proposed more advanced techniques to remove surface artifacts, based on artificial neural networks (Wendi et al., 2016, Kulp and Strauss, 2018) or other machine learning methods (Liu et al., 2018; Meadows and Wilson, 2021). Most approaches compare the DEM to be corrected with higher-accuracy datasets, using auxiliary data such as tree density and height for correcting vegetation bias (Yamazaki et al., 2017), whereas elevation bias in urban areas can be corrected using night light, population density, or Open Street Map elevation data (Liu et al., 2018)".

Line 309: depending on the approach taken to represent the river channel network, see comment above, this might also be significant for the simulation of higher probability floods. Channels are very important flow pathways and especially so for smaller floods.

We fully agree with the Reviewer on this point. We will include his/her remark as in the revised text as follows: "Considering that most of the reference flood maps include the effect of flood defences (contrary to the modelled maps), these results suggest that the majority of rivers in the study areas may be protected for flood return periods around 100 years or lower, as indeed reported by available flood defence databases (Scussolini et al., 2016). High-probability floods are also sensitive to the method used to reproduce river channels, and the simplified approach used in this study might underestimate the conveyance capacity of channels (see Section 3.2.2 for an example). Finally, the better performance for low-probability floods may depend on floodplain morphology, where valley sides create a morphological limit to flood extent."

General: How did you deal with coastal areas in the England flood maps? These are 1 in 200 year return periods in the flood map but also this source is not included in your modelling.

We used a 5km buffer around modelled flood maps to mask out coastal areas far from rivers estuaries, because the geo datasets available did not allow separating areas prone to coastal or river flooding. Moreover, the estuary area of several rivers show concurrent fluvial-tidal flooding, as mentioned for the Thames by Sampson et al. (see following comments), and this interaction is again not simulated in our modelling framework. We will further clarify this point in the description of model results for England.

Line 330: Thames will have significant tidal flooding from London eastwards.

Thanks for this valuable insight, which we will use to improve the comment of results as follows: "there's not a clear correlation between hydrological and flood map skill, with some basins (e.g. Thames) showing high KGE values but relatively low CSI values. For the Thames basin, the low CSI value is likely influenced by tidal flooding component from London eastwards, and by the fact that the river main channel is excluded from the comparison being permanent water".

Line 339: The smaller tributaries, and coastal flooding issues is discussed for the Thames and Severn in Sampson et al 2015. I think that would be a better comparison/citation specifically in this section than Wing et al 2017. Their CSI values from the Sampson global flood model might also be useful to report for these basins and compare with your values to complement

Line 345: see comments above.

We thank the Reviewer for the suggestion. We will include the considerations by Sampson et al. about the influence of smaller tributaries, coastal flooding and urban areas to expand the discussion of Section 3.2.1. The corresponding CSI values will be added to Table 6.

Figure 4: Could you include floodplains outside of the 5 km buffer in another colour? TBH this map doesn't really reflect how much flooding in the UK is not being simulated by this modelling setup – which is absolutely fine but the paper should be upfront about it.

We will modify Figure 4 to include flood-prone areas outside the 5km buffer. Moreover, we calculated that flood-prone areas inside the 5km buffer correspond to 73% of the total extent for the 1-in-100-year flood map (this will be included in the revised manuscript).

The EA flood map doesn't include surface water flooding from pluvial flooding, that would be an even more detailed layer, so the flooding missed is fluvial and coastal.

We will mention the fact that areas prone to pluvial flooding and also missing from our analysis

Line 410: this is an unfair comment given the publication date, but there is an updated US validation in Bates et al 2021 WRR. I don't think this would have any significant impact on the discussion here but it might be worth citing.

We thank the Referee for the suggestion. We will include this recent work in the discussion.

I've no experience with the flood maps outside of the UK but the comparisons undertaken look robust.

We thank the Referee for the appreciation

The conclusions are well supported by the analysis, however little validation has been undertaken around Mediterranean basins, particularly those areas into which the new maps have extended. Flood simulation in arid areas are often more challenging and the performance from Europe might not translate well to North Africa and the Eastern Mediterranean. I think some discussion of this issue is needed given the focus on the Mediterranean basin region in the title and introduction... Or perhaps less focus on the Mediterranean basin region and more on Europe earlier in the manuscript if the discussion is going to be too vague in this regard.

We will highlight the issue of incomplete validation through the revised manuscript (in the abstract, introduction and conclusions), specifying that we could not evaluate the skill outside Europe because of the absence of suitable national flood maps. However, we feel that is reasonable to mention the Mediterranean basin region in the title, because flood hazard maps do cover these areas and this is therefore a major point of the work.

Additional References

Wendi, D.; Liang, S.-Y.; Sun, Y.; Doan, C.D. An innovative approach to improve SRTM DEM using multispectral imagery and artificial neural network. J. Adv. Model. Earth Syst. 2016, 8, 691–702.

Kulp, S.A.; Strauss, B.H. CoastalDEM: A global coastal digital elevation model improved from SRTM using a neural network. Remote Sens. Environ. 2018, 206, 231–239.

Liu, Y., Bates, P.D., Neal, J.C. and Yamazaki, D., 2019, December. Bare-earth DEM Generation in Urban Areas Based on a Machine Learning Method. In AGU Fall Meeting Abstracts (Vol. 2019, pp. H41N-1899).

Meadows, M.; Wilson, M. A Comparison of Machine Learning Approaches to Improve Free Topography Data for Flood Modelling. Remote Sens. 2021, 13, 275. <https://doi.org/10.3390/rs13020275>

RC1: 'Comment on essd-2020-313', Anonymous Referee #1, 09 Apr 2021

The authors present a dataset of flood hazard maps, updated with respect to the ones presented in Alfieri et al. (2014) and Dottori et al. (2016). Both in the abstract and in the introduction, it is not clear what are the improvements and the differences between the new and the old version of the dataset. Later in the manuscript some information are provided but this point is not clearly discussed. Please add the needed details.

Following the Referee's comment, we will specify in the Introduction the advances of the new dataset in respect of the previous versions (in particular, the extended domain, the update of hydrological input and a revised procedure that eliminate some previous inconsistencies)

Many times the authors refer to previous own works. Even if I understand the reason for which some details are not given in the manuscript, some additional information e.g., about the methodology applied to obtain synthetic flood hydrograph or the meteorological data used as input to the LISFLOOD model, could be useful for the reader.

We will expand the description of the data and methods used for this study, following similar comments from both Referees. We will add new sections describing the meteorological dataset driving the LISFLOOD model (in the Annex) and the synthetic flood hydrographs used in flood simulations (in the main text). Moreover, we will provide more details about the extreme value analysis and the validation procedure. More detailed explanations are given in the following replies

The results discussed throughout the manuscript should be better explained. In particular, it is not clear how performance scores reported in the Tables are obtained for each study areas and it is not clear how the comparison shown in Table 6 has been carried out. For major details, please refer to specific comments.

The methodology applied to obtain the results has been revised and clarified. Please refer to the following point-by-point reply for more details.

The authors attribute the differences between modelled and reference flood maps to a number of shortcomings of the modelling framework specifically related to the hydrodynamic simulation. No description (magnitude of peak, duration of the hydrograph) is given about the hydrographs used as input to the hydrodynamic LISFLOOD-FP model

that are (could be) different from the ones used to obtain reference flood maps. Please, add details on the hydrological inputs used and comment how they impact on the definition of the flood extension.

We will add a specific section about the hydrological input in Section 2, reporting the following information:

"The input hydrographs necessary for the flood simulations are derived from the LISFLOOD streamflow dataset described in Section 2.1. The information is available for the EFAS river network at 5 km grid spacing for rivers with upstream drainage areas larger than 500 km². For each pixel of the river network we selected annual maxima over the period 1990-2016 and we used the L-moments approach to fit a Gumbel distribution and calculate peak flow values for reference return periods of 10, 20, 50, 100, 200 and 500 years. Note that we also calculated the 30- and 1000-year return periods in limited parts of the model domain to allow validation against official hazard maps, see Section 2.3.

Subsequently, we calculate a Flow Duration Curve (FDC) from the long-term simulation. The FDC is obtained by sorting in decreasing order all the daily discharges, thus providing annual maximum values QD for any duration i between 1 and 365 days. Annual maximum values are then averaged over the entire period of data, and used to calculate the ratios ϵ_i between each average maximum discharge for i -th duration QD(i) and the average annual peak flow (i.e. QD = 1 day). Design flood hydrographs are derived using daily time steps. The peak value is given by the peak discharge for the selected T- year return period QT, while the other values Qi are derived multiplying QT by the ratio ϵ_i . The hydrograph peak QT is always placed in the centre of the hydrograph, while the other values Qi are sorted alternatively to produce a triangular hydrograph shape, as shown in Figure xx. Because river channels are usually not represented in the CCM DEM, flood hydrograph values are reduced by subtracting the 2-years discharge peak, which is commonly considered representative of river bank-full conditions. The total duration of the hydrograph is given by the local value of the time of concentration Tc, therefore all the durations > Tc are discarded from the final hydrograph."

Regarding the impact of the hydrological input on the results, we provided indications through the comparison of the long-term simulation of LISFLOOD with observed river flow (see Annex). However, further analyses are complex because we have no specific information on the hydrological input applied to derive the reference flood maps (See also the following comments for more details).

Moreover, it is expected that higher differences are found for basins with properties and characteristics not well described by the approximations used in the procedure. For instance, if a leveed river is simulated without considering flood defence structures, the identified maps will be different from those that can be obtained by using a detailed morphology description. Actually, the considered simplifications can modify significantly the flooding dynamics. A comment of the authors is required.

We fully agree with the Referee on this point. Indeed, the influence of not including defence structures in the simulations is already discussed in the manuscript at different points (see L 175-195, 304-308, 383-385). Also, the limitations given by the simplified representation of river channels are discussed in Section 3.2.2. We will carefully revise the manuscript to make sure that all the limitations of the modelling framework are clearly stated.

Specific comments:

Line 19 and 164: "six different flood return 20 periods...". Reading Line 141, seems that

the analysed return periods are seven. Please, modify the manuscript where needed.

To clarify this, we will modify the paragraph in lines 140-143 as follows: "For each pixel of the river network we selected annual maxima over the period 1990-2016 and we used the L-moments approach to fit a Gumbel distribution and calculate peak flow values for reference return periods of 10, 20, 50, 100, 200 and 500 years. Note that we also calculated the 30- and 1000-year return periods in limited parts of the model domain to allow validation against official hazard maps, see Section 2.3." In other words, The 30- and 1000-year return period flood maps were produced only for Hungary and England for comparison exercise while the hazard maps for the other six return periods cover the whole domain.

Lines 30-31. What does the authors mean with "large variability"?

The original text (" In addition, the large variability of reference maps affects the correct identification of the areas for the validation, thus penalizing scores") will be replaced by the following: " In addition, the different design of reference maps (e.g. extent of areas included) affects the correct identification of the areas for the validation, thus penalizing scores"

Lines 104-108. Please, add some details on the meteorological observations used to force the LISFLOOD model. Moreover, what does the authors mean with "the static input maps have been updated and expanded"? Please, specify.

We will rephrase this part as follows: "The long-term run of LISFLOOD is fed with meteorological observations from stations and precipitation datasets, interpolated to produce gridded meteorological maps (see Annex for details). This meteorological dataset has been updated to include new stations and gridded datasets across the new EFAS domain (Arnal et al. 2019). In addition, LISFLOOD simulations require a number of static input maps such as land cover, digital elevation model, drainage network, soil parameters and parameterization of reservoirs. All the static maps have been updated to cover the whole EFAS domain depicted in Figure 1."

Moreover, the Annex will include a new section describing the meteorological observations used to force the LISFLOOD model, taken from the report by Arnal et al. (2019). "The long-term run of the hydrological model LISFLOOD is based on observed data from meteorological stations and precipitation datasets, which are collected and continuously expanded as part of the development work for EFAS. The meteorological variables considered are: precipitation, minimum and maximum temperature, wind speed, solar radiation and vapour pressure. The number of stations with available meteorological observations depends on the period and variable considered, with an increasing availability towards the end of the historical simulation period. As an example, for the year 2016 the number of daily observations available ranged from ~ 8.800 for temperature to ~ 5.500 for precipitation and ~ 3.700 for vapour pressure. The input from meteorological stations is completed by a number of precipitation datasets (EURO4M-APG, INCA-Analysis Austria, ERA-Interim GPCP corrected and Carpat-Clim; for details see Arnal et al., 2019). Note that the same datasets are also used to drive the LISFLOOD calibration and to calculate the initial conditions for the EFAS forecasts. The data from meteorological stations and gridded datasets were then interpolated using the interpolation scheme SPHEREMAP to produce meteorological grids with a daily time step. The reader is referred to Arnal et al. (2019) for further details.

Lines 140-145: Please, add details on this part to allow the reader understanding the procedure. How the statistical analysis has been carried out? how the synthetic flood hydrographs have been defined?

As described in the reply to a previous comment, we will provide more details on the statistical analysis of extremes and the derivation of flood hydrographs.

Lines 146-160: this part should be better explained and modified as it is very similar to paragraph 2.21 in Dottori et al. (2017). Please rephrase.

We will rewrite this part as follows: "the continental-scale flood hazard maps are derived from local flood simulations run along all the river network as in Alfieri et al. (2014). We use the DEM at 100 m resolution developed for the Catchment Characterization and Modelling Database (CCM; Vogt et al., 2007) to derive a high-resolution river network at the same resolution. Along this river network we identify reference sections every 5 km along the stream-wise direction, and we link these section to the closest upstream section (pixel) of the EFAS 5km river network. In this way, the hydrological variables necessary to build the flood hydrographs can be transferred from the 5km to the 100m river network. Figure 2 shows a conceptual scheme of the two river networks and describes how the 5km and 100m river sections are linked. Then, for every 100 m river section we run flood simulations using the 2D hydrodynamic model LISFLOOD-FP (Bates et al., 2010), to a local flood map for each of the six reference. The LISFLOOD-FP simulations use the CCM DEM as elevation data and synthetic hydrographs described in Section xx as hydrological input. . We also use a mosaic of Corine Land Cover for the year 2016 (Copernicus LMS, 2017) and GlobCover for the year 2009 (Bontemps et al., 2009) to estimate the friction coefficient based on land use. Finally, the flood maps with the same return period are merged together to obtain the continental-scale flood hazard maps. The 100m river network is included as a separate map in the dataset, to delineate which water courses have been considered in the creation of the flood hazard maps"

Lines 215-216: this sentence seems to be in contrast e.g., with the results shown in Table 3 for Spain for return period of 10 years.

This was indeed not consistent in the previous version. We include the 30-year map for Hungary because the maps does not account for flood defences, and therefore is in principle more comparable with modelled maps. The 10-year map for Spain is included because the extent of flood defences is not known, whereas in England and Po the extent of flood protections is better understood (see Dottori et al. 2017). We will modify the description of the validation exercise accordingly.

Line 223: which is the native resolution of the official reference maps? After the conversion to raster format, which is the adopted resolution to make the comparison with simulated flood maps?

The official reference maps are provided as polygons with no indication of the original resolution. According to Sampson et al. (2015), the official flood hazard maps for England are constructed using DEMs of at least 5 m resolution, therefore the resolution of reference maps should be similar. Reference flood maps for the Po basin and Spain are likely to have a similar resolution since they are based on LIDAR elevation data. All the reference maps have been converted to 100m resolution for the comparison with modelled maps. All these details will be included in the revised version.

Lines 247, 251 and 255: Please, correct the numbers of the equations.

Thanks for spotting this inconsistency, we will amend the numbers of the equations

Lines 243-256: Please, add the variability range of HR, FAR and CSI and define the perfect score for each of them.

We will update the manuscript according to the Referee's suggestion. HR ranges from 0 to

1, with a score of 1 indicating that all wet cells in the benchmark data are wet in the model data. FAR scores range from 0 (no false alarms) to 1 (all false alarms). CSI scores range from 0 (no match between model and benchmark) to 1 (perfect match between benchmark and model).

Lines 301-301: from Table 3 does not seem that "Performances improve markedly with the increasing of return periods, with a general increase in the hit rate HR". Form Table 3, HR is quite constant with the return period. Please rephrase.

We will rephrase lines 301-303 as follows: "Performances improve with the increasing of return periods due to the decrease of false alarm rate FAR, while the hit rate HR does not vary significantly."

Lines 304-310 and throughout the manuscript: the authors comment on the performances of simulated flood maps to reproduce the reference maps, stressing that differences could be ascribed to floodplain morphology, presence of flood defence structure etc.. According to me the differences between simulated and reference flood maps could be ascribed also to the hydrological input routed through the river channel. How different is the flood hydrograph used by the authors with respect to the one used by to build the reference flood maps? Do the authors have any information on this point?

Thanks for this comment. We agree on that differences between simulated and reference hydrological inputs could explain some of the observed differences between flood maps. As specified in a previous comment, the revised manuscript will include a specific section about the hydrological input for flood simulations. Unfortunately, we could not find the necessary data to reconstruct the input flood hydrographs of the reference flood maps (e.g. peak flows, hydrograph shape). For official flood maps in Spain and in the Po river basin, only a description of general methods applied is available online. The evaluation of the skill of the LISFLOOD model can provide some hint on the similarity of modelled and observed hydrological regime, but this does not necessarily translate to extreme values. We will add these considerations in the revised text.

Table 3: How are obtained the performance indices for the study areas? Are these values obtained as average values? Please, add details.

The performance indices are calculated using the total extent of the reference and modelled maps with the same return period. As such each score is a single value and it is not averaged.

Line 316: Should be Table 3.

Lines 323, 354, 355 and throughout the manuscript. Please use the abbreviations for hit rate, false alarm rate and critical success index.

Line 415: should be Table 6.

We will amend the manuscript as suggested

Lines 415 – 400 and Table 6: how the values in Table 6 have been obtained? Do they refer to all the five study areas? Please, specify.

The performance indices in Table 6 were calculated by first summing up all the reference and modelled maps for the same return period, where available. Then we calculated each index using the overall modelled and reference flood extent (e.g. the value for the 100-year maps includes reference and modelled maps for England, Spain and Norway). As such, each area is weighted according to the extent of the corresponding flood map . This

will be specified in the revised text.

Table 1-3 and Line 364: for Hungary a 30-y return period has been used from the reference maps. How these maps have been compared with the simulated maps? Reading the manuscript seems that only 10, 20, 50, 100, 200, 500 and 1000 return period have been simulated.

This was an oversight of the previous version, a 30-year return period flood maps was produced only for Hungary for comparison exercise. We will modify the text in lines 140-143 as follows: "For each pixel of the river network we selected annual maxima over the period 1990-2016 and we used the L-moments approach to fit a Gumbel distribution and calculate peak flow values for reference return periods of 10, 20, 50, 100, 200 and 500 years. Note that we also calculated the 30- and 1000-year return periods in limited parts of the model domain to allow validation against official hazard maps, see Section 2.3."

Figure 3 could be removed from the manuscript and the limits of the test areas could be added in Figure 1.

We will remove Figure 3 and modify Figure 1 as suggested

Figure 2: Please, modify the number 10 and 11 in the diamond. Specifically, write them in a horizontal line.

The Figure will be amended as requested

Table 1: Please, for each country add the link where the reference flood maps can be downloaded.

We will mention in the caption of Table 1 that the links for downloading the maps are provided in the Data Availability Section.