AUTHORS' RESPONSE TO REFEREE #2

Research article:

Comparing an insurer's perspective on building damages with modelled damages from pan-European winter windstorm event sets: a case study from Zurich, Switzerland (Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2020-115, in review; submitted on 07 April 2020)

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We thank the referee for comments, which have improved the quality of the manuscript.

The original comments from the referee are listed below directly followed by our responses in blue and italic and changes to the manuscript in blue and bold.

General comments

This paper compares windstorm risk estimations (such as annual average damage, exceedance frequency curves) in the canton of Zurich, Switzerland, using insurance claims data, and modelled damages with two models (GVZ and CLIMADA) using various hazard inputs ('WISC historic' and 'WISC probabilistic extension'). They find that the claims data is skewed by the extreme event Martin/Lothar, leading to a shorter return period for that storm and higher average annual damages compared to the results from the longer modelled datasets.

The paper is well written and the results are worthy of publication. My main issue is that I feel the conclusions about return periods derived from 'WISC probabilistic' may have been overstated. The authors correctly state in their discussion (L486-499), the 'WISC probabilistic' dataset does not reduce uncertainty compared to 'WISC historic' because they're based on the same data, but in some instances I think it is important to emphasise the uncertainty (I include examples in the 'specific comments' below).

Referee #2 raised as main issue the uncertainty of the results derived from the hazard event set "WISC probabilistic extension". This is the same issue as raised by Referee #1. We would like to pick up the suggestions by Referee #2 and emphasise the uncertainty of our estimation more. We have also expanded our interpretation of the uncertainty in more detail in the response to Referee #1 and aim to clarify our interpretation of the uncertainty more clearly at different points throughout the manuscript.

Specific comments

1. Abstract L20: "Additionally, the probabilistic modelling approach allows assessing rare events, such as a 250-year return period windstorm causing CHF 75 million damages" – please emphasise the uncertainty here.

   We now emphasise the uncertainty in L20:

   "Additionally, the probabilistic modelling approach allows assessing rare events, such as a 250-year return period windstorm causing CHF 75 million damages**, including an evaluation of the uncertainties**."

   Please consider the given word limit for the abstract of a maximum of 200 words.

2. Section 2.2.2: I don't think it's necessary to describe 'WISC operational' and 'WISC stochastic' as they are not used. It is already mentioned in the introduction why you can't use 'WISC stochastic' (L102; perhaps you could refer to fig A1 here), and the reasons for not using 'WISC operational' could also be discussed here.

   To overcome the shortcomings of the event set "WISC synthetic", we propose in addition the probabilistic windstorm hazard event set "WISC probabilistic extension". We briefly describe "WISC synthetic", since we used "WISC synthetic" for a comparison with "WISC probabilistic extension" in Fig. 1 and Fig. A1. We also think that readers are asking themselves about calibrating the wind gust information from "WISC synthetic" as suggested by Referee #1. We would therefore like to provide this information in a structured way, for which the data and methods section is suitable for.

   "WISC operational" is described, basically to explain why we didn't use this event set in the context of the paper. We think that readers might ask themselves this question.

We would therefore like to keep this structure. Is that understandable?

3. Section 2.2.3 L209: please could you mention here that you describe how alpha and beta are chosen later in the section?

Yes, thank you for the hint. We suggest the following change to L207-209:

"The wind gust speeds were intensified and weakened by no more than 3 m/s (normally much less) according to the probabilistic alteration of wind speeds in Eq. (1), with a scale parameter α=0.0225 and a power parameter β=1.15 **(choice explained further below)**: […]."

4. Equations (1) (L209-210): I presume this transformation is applied at each grid point, so that a wind speed from a grid point i becomes the $\text{windspeed}_{\text{original}}$ at grid point j in the shifted footprint? If so, how do you account for different properties of grid points i and j – for example, they could have very different roughness and altitudes (in an extreme case i could be over open water and j could be in a sheltered area, so would have much lower expected wind speeds).

WISC wind gust footprints are available at a spatial resolution of 4.4 km. Small-scale changes in both topography and ground cover can indeed strongly influence the characteristics of wind gusts. However, those small-scale changes cannot be resolved sufficiently well in a model with a horizontal resolution of approximately 4 km. In general, the canton of Zurich is characterised by a gentle to moderate topography (see Fig. A2a). For these reasons, we decided not to make a correction regarding the topography (and the ground cover) in our current model setup.

Nonetheless, we think the referee touches on an important point and a refinement of our methodology would be interesting for a follow-up study. It is conceivable that the quality of the windstorm footprints from "WISC probabilistic extension" could be improved by using a correction method, which takes account of at least the topography.

In general, we think that the referee's comment is most relevant for those countries and regions in Europe which are characterised by a complex and pronounced topography or which border large water surfaces with a lower roughness compared to the land surface.

In the computation of the event set “WISC probabilistic extension”, the spatial displacement was undertaken by shifting the respective windstorm footprint by about 20 km to the north, south, west, or east. For different regions and countries in Europe, we determined the difference in wind gusts, which results from this spatial displacement of the windstorm footprints. In total, there are 3’408 windstorm events that result from the spatial displacement of either the original windstorm footprints or of altered windstorm footprints (according to Eq. (1)).

Figure R2-1 shows for the canton of Zurich, the whole country of Switzerland, and the UK boxplots of all changes due to spatial displacement that occurred on any point in any event. Here, Switzerland and the UK were chosen as examples because Switzerland is a country which is characterised by a pronounced topography with high mountains and the UK is characterised by pronounced land-sea contrasts.

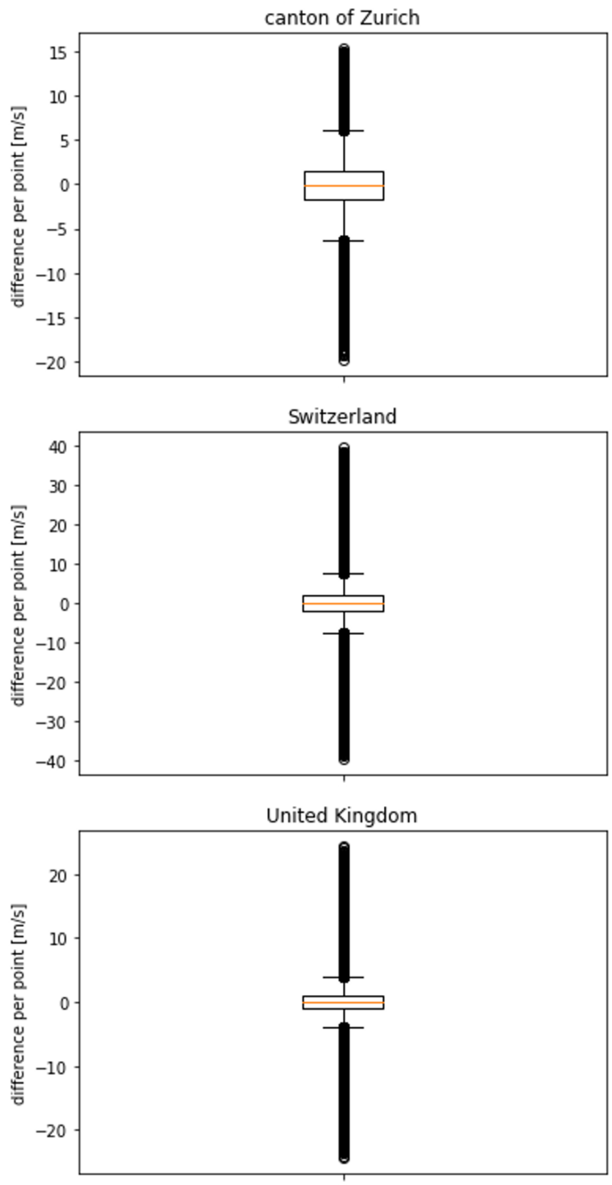


Figure R2-1: *Boxplots of all differences due to spatial displacement that occurred on any point in any event for the canton of Zurich, the whole country of Switzerland, and the UK.*

Figure R2-1 shows that the spatial displacements in windstorm footprints made can result in quite extreme changes in wind gust speed as one can see from changes of up to plus 16 m/s in the case of the canton of Zurich. These extremes are however very rare: 50 % of all points in all events are not changed by more than 2 m/s, and 90 % of all points are changed by no more than 5 m/s. The extremes are even higher in the case of Switzerland with up to 40 m/s and 25 m/s in the case of the UK. However, 50 % of all points in all events are not changed by more than 2 m/s in the case of Switzerland and

1 m/s in the case of the UK; 90 % of all points are changed by no more than 6 m/s in the case of Switzerland and 4 m/s in the case of the UK.

To be more precise in the paper, we have added this sentence to L211:

"**In countries close to the sea or with a pronounced and high topography, the methodology for creating the probabilistic events might need adaptation to better incorporate the difference in surface roughness and altitude**."

5. L215/216: The references given for the storm severity index all have different definitions. Which formula did you use here?

We used the formula described by Dawkins et al. (2016). We now emphasise this more strongly in L214-216:

"In an effort to assign reasonable frequency estimates to the probabilistic windstorm footprints, we considered the distribution of the historic, pan-European Storm Severity Index (SSI; **formula used by Dawkins et al., 2016; further information in Lamb and Frydendahl, 1991; Leckebusch et al., 2008**)."

6. L282-287: This paragraph is a bit confusing. I guess you mean to say that MDD is calculated from the vulnerability curve of Schwierz et al, and you use this same vulnerability curve in CLIMADA?

We have clarified the language in L282-287:

"To estimate the damage in monetary terms, the value of each individual building (i.e., its insured value) was multiplied by the factor "Mean Damage Degree" (MDD**, a number between 0 and 1**) **calculated from the vulnerability curve of** Schwierz et al. (2010)**;** where the gust speeds at building level computed in the first step were converted into the corresponding MDD factors. The MDD factors are a non-linear function of the maximum wind gust speed during a windstorm event **and are diagrammed in Welker et al. (2016)**. The same vulnerability curve of Schwierz et al. (2010) is also implemented in the open source impact model CLIMADA (Aznar-Siguan and Bresch, 2019a)."

7. L348/349: How many data points did you have above the threshold in each case? When you do the re-sampling, is the number of re-sampled points (200) equal to the number of points you used for the original fit?

The threshold defines how data points are used for the original fit. In the case of the insured damages, the threshold of CHF 0.4 million resulted in 9 data points above the threshold. In the case of the modelled damage event set based on "WISC historic", the threshold of CHF 0.1 million resulted in 19 data points above the threshold. As expressed in L346-347, these thresholds result "in a parameterised GPD with similar exceedance frequencies for the largest damage amount in the event set". Additionally, the number of data points per observation year is reasonably similar between these two damage event sets. The number of resampled points is equal to the number of data points we used for the original fit.

As mentioned in the "Code availability and data availability" section (L575-576), the code used for this analysis is published here: https://github.com/CLIMADA-project/climada_papers.

8. Section 3.3: L386-391: I think you need more emphasis on the uncertainty in the return period of Lothar/Martin. Although the value from the claims is much smaller (34yrs), it's still within the 90% confidence interval from WISC historic (25yrs to > 500yrs)

Thanks for the hint. We want to emphasise the uncertainty in our estimate of the return period of Lothar/Martin more and therefor suggest to insert the following sentences at the end of L391:

"**These estimates represent the best guess for each damage event set. It is important to note that the quantified uncertainty of the estimate for the return period of Lothar/Martin based on "WISC historic" (yellow ribbon, 25 years to > 500 years) incorporates both the estimate for the insurance claims data (blue ribbon) as well as the estimate based on "WISC probabilistic extension".**"

Additionally, we would add the following sentence to the discussion at L458:

"We argue that the return period based on the historic windstorm footprints (75 years) is much more reliable than the return period based on the insured damage record (34 years).

Well knowing that the two estimates each have overlapping uncertainties, the estimates do not contradict each other. Rather the estimates, as best guesses, can inform varying deterministic risk views. Other information, like […].”

In addition to this, we have made the following illustration, which we however do not show in the paper: Figure R2-2 shows in addition to the 90-% confidence interval the 50-% confidence interval, in order to show more clearly the change in the uncertainty range from the insurance claims data (blue ribbon) to the modelled damages based on "WISC historic" (yellow ribbon). As one would expect from the larger sample of windstorm events considered, the area of uncertainty is smaller in the case of the modelled damages based on "WISC historic" compared to the insured damages. Considering the 50-% confidence interval, the return period for the damage event Lothar/Martin is between approximately 25 and 250 years based on the claims data. For comparison, the estimate based on modelled damages using "WISC historic" provides a narrower uncertainty range between approximately 45 and 175 years. Based on the insurance claims data only, the return period for the damage event Lothar/Martin was estimated to be 34 years. Figure R2-2 shows that although this value is within the 90-% confidence interval it is not within the 50-% confidence interval from modelled damages using "WISC historic".

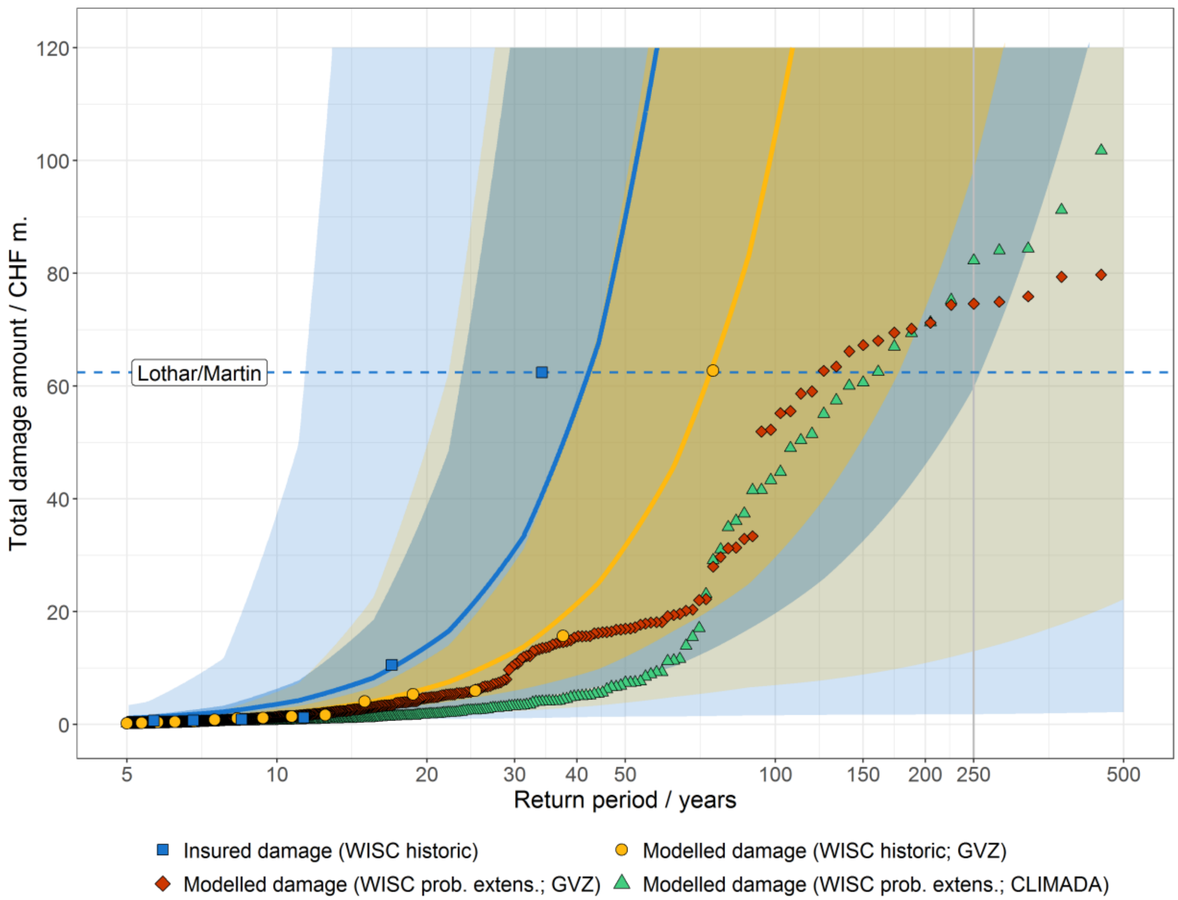


Figure R2-2: *Modified Fig. 2. New is the darker blue and yellow inner shading, which shows the 50-% confidence interval for the insured damage and the damage modelled on the basis of "WISC historic".*

9. L398: Again, I think you should mention that the 250yr RP from the claims data is within the range estimated from WISC historic.

   Thanks for the hint. We suggest to add the following sentence to the end of L399:

   "At a return period of 250 years, the quantified uncertainty of the estimate based on "WISC historic" incorporates both the estimate for the insurance claims data as well as the estimate based on "WISC probabilistic extension"."

   Compare our answer to the referee's comment #8.

10. L400-404: Since the 'WISC probabilistic extension' and 'WISC historic' 250yr RPs are well within the 90% confidence intervals of one another, can you really conclude anything about the difference in return periods?

We would like to clarify the language in L400-402:

"An interesting feature illustrated in Fig. 2 is that at higher return periods the modelled damages on the basis of "WISC probabilistic extension" increase less strongly compared to the two extrapolations based on the fitted distributions."

11. Section 3.5 L439-440: "In total, "WISC probabilistic extension" contains 17 events which are potentially more damaging than Lothar/Martin": I assume the 17 events referred to in the text are the 17 red dots in Fig 4 with damages > Martin/Lothar damage, rather than the events with P95 gusts speed > P95 gust speed of Martin/Lothar, so shouldn't the grey area in Fig 4 be bounded by a horizontal line at damage ≈ CHF 62m, rather than the vertical line at P95 gust speed ≈ 133km/h?

That's right, thanks for the hint. We have adjusted the figure accordingly (see also Fig. R2-3). We agree that this adjustment better connects the text and the figure.

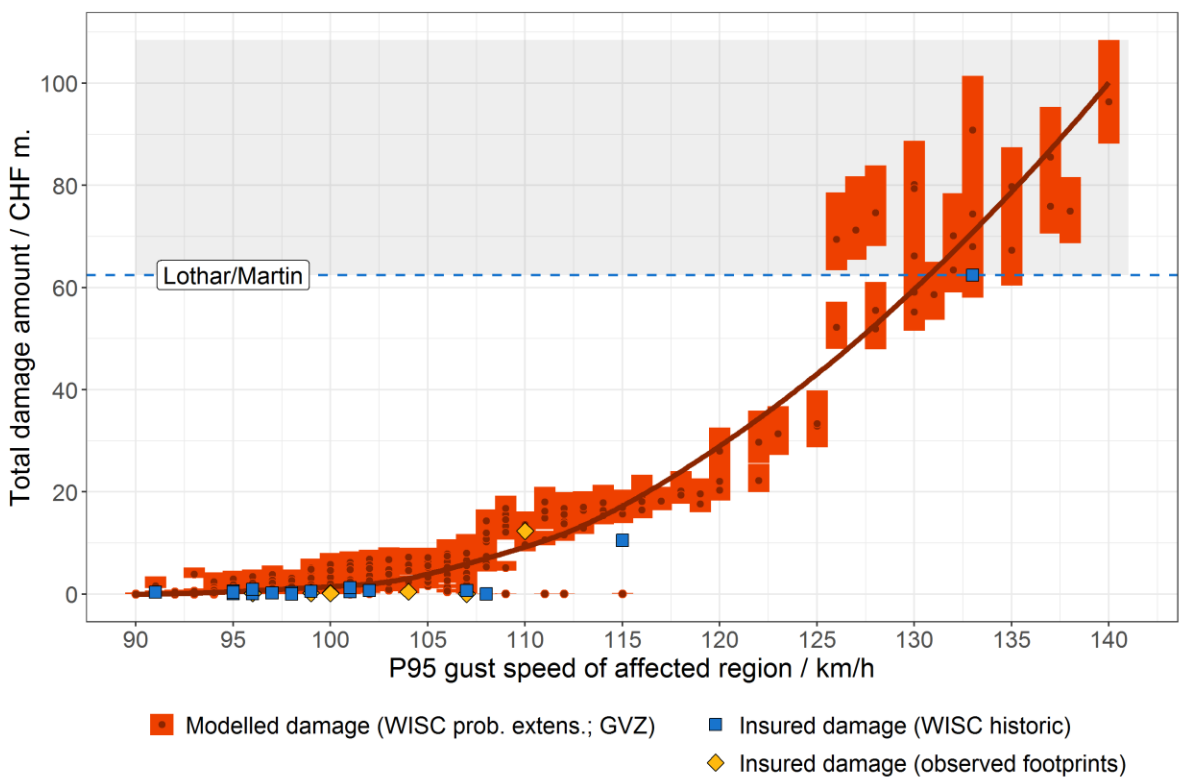


Figure R2-3: *Modified Fig. 4. New are the horizontal shading instead of the vertical one and the label of the x-axis (see our response to the referee's comment #14).*

12. L441: “A (modelled) total damage amount of more than CHF 96 million is associated with the most extreme windstorm event in “WISC probabilistic extension”: In Fig 2 it looks like the highest damage storm in “WISC probabilistic extension” has a damage amount of approximately CHF 80m. Why is the maximum damage in Fig 4 higher? Aren’t they the same storms?

For plotting reasons, the range of the y-axis in Fig. 2 was reduced in comparison to Fig. 4, since the area of uncertainty is very large in the case of large return periods > 500 years.

13. Fig 4: Please could you clarify if the insured damages (blue squares and yellow diamonds) are the values from the claims dataset (after normalising), or the damage amounts estimated from the GVZ model on the historical events?

In Fig. 4, the blue squares are the values from the claims dataset after normalising to present-day exposure levels for the period 1981-2014. The corresponding wind gust speeds on the x-axis are from the hazard event set “WISC historic”. The yellow diamonds are also values from the claims dataset but for the period 2017-2018; the corresponding wind gust speeds on the x-axis are from the additional hazard event set “observed footprints for current windstorms” (see Sect. 2.2.4).

14. Fig 4: Please could you explain why there are quite a few footprints from WISC probabilistic with zero damage despite having P95 gust speeds of 107-115 km/h? Is it because they mainly hit unpopulated areas?

Yes, that’s true. In GVZ’s damage modelling approach, damage is possible from a wind gust speed of more than 90 km/h, and only buildings affected by such wind gusts were considered in the damage model. In the case of the four points that protrude in Fig. 4, the area with wind gust speeds > 90 km/h is only limited to a small region in the south of the canton of Zurich (see Fig. R2-4), with relatively few buildings potentially at risk. The modelled damage sums are not zero, but rather small (see Table R2-1).

In the case of the modelled windstorm footprints shown in Fig. R2-4, it is maybe not immediately obvious why the 95th percentile of the few buildings affected was calculated and shown in Fig. 4. The reason is as follows: When the GVZ damage model was developed and calibrated, this was done almost exclusively with observed windstorm *footprints that affected the entire canton of Zurich and, in principle, every building in the canton was potentially affected – the "classic" so to speak, large-scale winter windstorms. The 95th percentile of all potentially affected buildings turned out to be suitable for this selection of windstorms to categorise them in a subsequent modelling step. Based on this categorisation, a random sample of m buildings was selected thereafter, with the number m depending on the windstorm's severity category and giving a percentage of total affected buildings. Only those buildings with potential damage > 0 were considered in the following modelling steps. The model approach is therefore not necessarily intended / calibrated for small-scale and modelled wind gust footprints.*

To be more precise in Fig. 4, we have changed the labelling of the x-axis to:

"P95 gust speed of **affected region** […]"

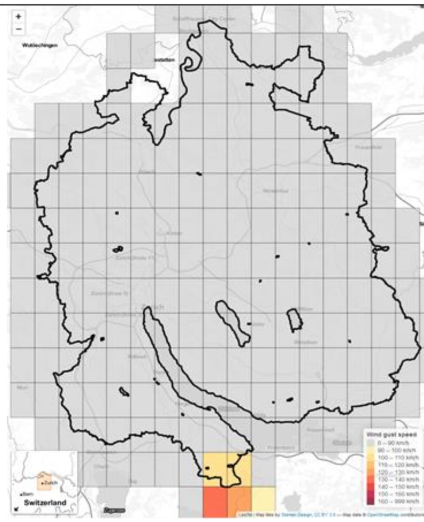
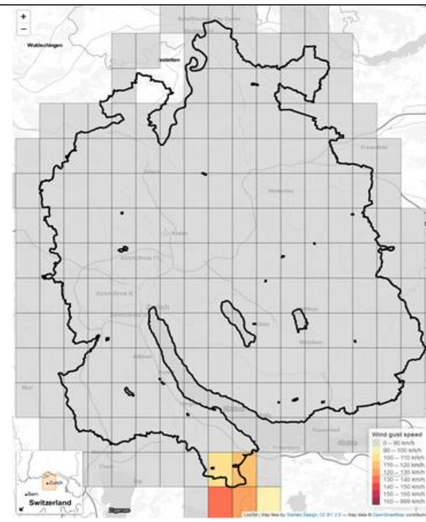
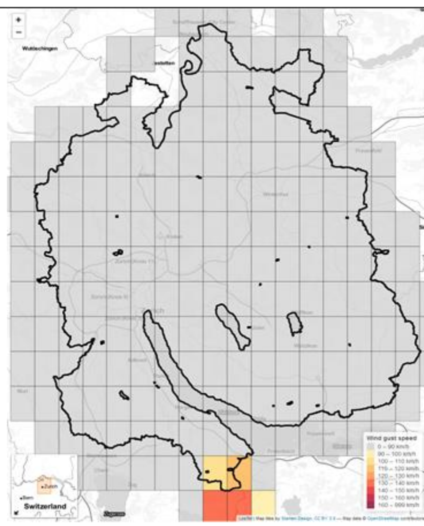
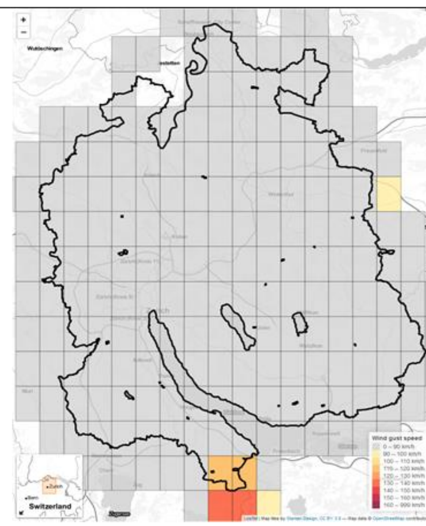
Event ID 14113	***Event ID 14112***
	
Event ID 14114	***Event ID 14116***
	

Figure R2-4: *Maximum wind gusts for every grid cell in the canton of Zurich for the events with IDs 14113, 14112, 14114, and 14116 in the dataset "WISC probabilistic extension". Wind gust speeds < 90 km/h are plotted in grey.*

Table R2-1: *For the same events as in Fig. R2-4, total damage modelled using the GVZ damage model (median of 1'000 random damage modelling) and the 95th percentile of the corresponding gust speeds.*

Event ID	***P95 wind gust speed / km/h***	***Median total damage amount / CHF m.***
14113	*109*	*0.07*
14112	*111*	*0.08*
14114	*112*	*0.08*
14116	*115*	*0.09*

Additional changes to the manuscript

While editing the referee's comment #4, we noticed an error in Eq. (1) in the paper and we would like to correct it in the revised manuscript. The correction ensures consistency between the manuscript and the code used for the calculations. In the case of the definition of $windspeed_{scenario\ 5}$*, the sign of change was incorrectly reversed; two plus signs in the last line are now corrected to two minus signs.*

Eq. (1) is correctly defined as follows (L209-210):

$$\begin{aligned}
windspeed_{scenario\ 1} &= windspeed_{original} + \alpha * windspeed_{original}{}^{\beta} \\
windspeed_{scenario\ 2} &= windspeed_{original} - \alpha * windspeed_{original}{}^{\beta} \\
windspeed_{scenario\ 3} &= windspeed_{original} + \alpha * \sqrt[\beta]{windspeed_{original}} \\
windspeed_{scenario\ 4} &= windspeed_{original} - \alpha * \sqrt[\beta]{windspeed_{original}} \\
windspeed_{scenario\ 5} & \\
&= windspeed_{original} - \frac{\alpha}{2} * windspeed_{original}{}^{\beta} - \frac{\alpha}{2} * \sqrt[\beta]{windspeed_{original}}
\end{aligned} \quad (1)$$