Author comment to reviewer comments RC1:

Review for NHESS-2021-342

Characteristics of hail hazard in South Africa based on satellite detection of convective storms
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Summary.
This paper reviews and analyses the hail climatology for South Africa and regions within South Africa using satellite detection of convective storms. The paper investigates 14 years of geostationary satellite observations of convective storms and generated a spatiotemporal multivariate stochastic model representing 25000 years. The historic, stochastic and observed insurance exposure and vulnerability data are analysed to identify the expected hail damage for return periods of 200 years.
General Comments
Scientifically the authors have done an excellent job considering the literature review, data collection and modelling that have gone into the research described in this article. One slight drawback is that in the paper itself, the authors attempt to address all the whole multiple complex modelling processes in a relatively short and succinct manner. At times, unfortunately, the description of the process followed does not do the modelling process justice and made it difficult to follow what was done. Some examples will be given below.
The format of the paper also made reading the paper very difficult for me. At times, the figures and tables mentioned in the text were not next to or near the text referencing them. This caused a lot of scrolling up and down in pdf (and eventually I just printed out the text in frustration). As times, figures were even placed to appear to be part of a previous section e.g. Fig. 14 seems to form part of the end of Section 3.3 but is part of Section 3.4 that starts underneath Fig. 14. The format used by the authors may be due to format instructions fromthe journal. If not, please reconsider the placements of figures and tables to be as close as possible to the relevant text to improve the reading flow of the paper.

The authors thank the reviewer for the helpful and extensive comments. We will make an effort to clarify the description of the modelling process and revise the arrangement of figures and tables.

Specific comments
25. The reference to Grieser and Hill (2019). Did Grieser and Hill focus on hailpad derived metrics for South Africa, another country or just in general?

The study of Grieser and Hilll uses data from CoCoRaHS, a volunteer-based network of weather observations in the United States (Doesken and Reges 2011; Reges et al. 2016). Data of this kind has been collected and published only for very few locations, and no

recent study was found for South Africa.We will specify the data origin in the revised version of the manuscript.

> *35. “hailstorm formation is often related to local and meso-scale processes related to, for example” Perhaps do not use the word related twice in one sentence.*

The sentence will be rephrased.

> *Figure 1 “a title: SRTM” acronym is not defined. Please check whole text for acronyms.*

We will double check to make sure all acronyms are defined in the revised version.

> *95. “Based on past experience, only OTs detected with a probability >50% and with a surrounding anvil cloud (green and yellow colors in Fig. 1a; the IR anvil detection index, a rating based on an anvil detection model accounting for viewing situations, greater than 10; see also Scarino et al., 2020) are used in this work.” Make the sentence in brackets a sentence on its own or add to figure description.*

The sentence in the brackets will be moved to the figure caption.

> *110 - 115. “A uniformly distributed random number between -0.5 and 0.5 115 was added to each reported hail diameter to compensate” I assume the -0.5 and 0.5 is also in mm?*

The article will be revised to use only cm as a unit for hail diameters. In this case, a random value between -0.5 and +0.5 cm has been added, accounting for the coarse classification of hail size in the databases.

> *155 “As 9.5% of the OTs occur at a melting level of less than 2 400 m, but ony 3.5% of the microwave hail detections and and 2.5% of the claims, a lower threshold of 2 400 m was introduced for this parameter.” . Spelling. Sentence seems incomplete.*

The spelling and grammar will be corrected.

> *160. “The latter feature is due to the minimum freezing level condition and remains to be confirmed by independent observation.” Independent observation from whom?*

Very few information on hail occurrence was found for that region; the most suitable method of ground verification would be a network of hail pads or sensors covering multiple regions of South Africa.

> *190: “complemented with hail size information from reporting.” Reporting? You mean the insurance reporting?*

In this case hail reports such as those registered in the hail databases are meant. This will be clarified in the text.

> *200. “Following Punge et al. (2014), both annual and daily cycles are modeled with Gaussian distributions. For the day of year, domains of 3° × 5° are considered, and depending on the...” Why Gaussian distribution? What is the statistical justification for it?*

The occurrence of hail is linked to conditions on a set of variables that need to be fulfilled and can therefore be described as a convolution of the distributions of these variables. As such distributions, e.g. of insolation, are themselves usually continuous and often normal, their convolution can be expected to be normal as well.

> *Not sure how these grid definitions relates to the previously defined rectangular grids of 0.3 x 0.5 mentioned on page 10.*

The grids of 3 x 5 group 10 x 10 of the smaller grids, with the intention of increasing the number of observations in each cell, large enough to derive characteristics of the distribution. This will be clarified.

> *205: "Days are drawn from the boxes distribution for the..." It is not clear to what the boxes distributions refer to.*

It refers to the 3° x 5° boxes; this will be specified in the revised version.

> *205: "...Finally, the day is retained only for N/9 events at random. This procedure has been found empirically to approximate the observed space-time distribution of days in a satisfactory manner. " Is this procedure self-developed or taken from somewhere? Why n^(1/3) and N/9 - those specific values? What is the proof of empirically proof behind it?*

The method is self-developed. We realize the description was somewhat imprecise. A division by nine is required as we draw nine times the required number of events: for the box concerned and the eight surrounding ones (queen criterion). Hail events cluster on this scale (15°x9°) due to synoptic processes. The empirical proof is that the distributions in Fig. 17 represent the observed distributions quite well with a single tuning parameter. We will improve the description to make this more clear.

> *210: "from a region of 10° × 6° around.." Why the double grid size? Is this to also represent the 8 neighbouring grid cells? Paragraphs 205 and 210 can be extended to make the spatial construction more clear. In the current format is it difficult to follow, and relate back to standard spatial weight matrixes using the queen criterion.*

No, 10°x 6° region turned out to be a good choice for this parameter. The time of day is correlated on a smaller scale spatially as in a series of events, the later ones are shifted spatially with respect to the earlier ones. We will add this explanation.

> *215: "Also note the secondary maximum in fall (around days 100–150, i.e. April and May) during nighttime, represented in the model. " Does this represent a local maximum? How do you see from the graphs it is in the night?*

This maximum is a local maximum in the historic events and ocurs at around day of year 140 and 6 UTC and can be discerned as an area of orange shades in that region of the plot. We will add this explanation to the text.

> *215: " It is shifted towards fall over the Southern Ocean." ??? Are you modelling that far away from the shores of the country as well? And will it have any landfall impact?*

Off-shore events need to be represented as they can extend to the onshore coastal region. An impact of a far off-shore event is quite unlikely and will be marginal at this distance, but has been included for completeness.

> *220: “Time, slightly earlier than Smith et al. (1998, 5–6 pm) but consistent with Olivier (1990) (Fig. 11b). The daily cycle is most pronounced...” What is the possibility of there being a shift in these times from the 1990's to now? In that case, would the results be comparable?*

A shift in the diurnal distribution of severe convective storms cannot be excluded or proven with the data at hand and has sometimes been discussed in the context of climate change. A more likely explanation would be a different sensitivity to hail size in the two methodologies. Larger hail has a tendency to peak later in the day than small hail and Olivier may miss some of the smaller hail events, but at this point this is only speculative.

> *Figure 10: I assume the day of the year for 1 to 365 represents 1 Jan to 31 Dec. Perhaps add that to the title to indirectly show the difference in expected hail occurrences for northern and southern hemisphere?*

The assumption is correct and will be added to the figure caption.

> *Figure 11: I’m struggling with what number of days each bar represents. It seems the number 50 falls on the 4th bar?? This will only work if each bar represents 12.5 days?*

The days of year have been grouped in classes of 14 days in this figure. “50” hence roughly corresponds to weeks 7 and 8. An explanation will be added.

> *225: “The distributions are well approximated by the GEVs”. GEV is an extreme distribution that requires a "limit" (e.g. peaks-over-threshold or block-maxima) in the data over which you are modelling events? What was that limit and how was it obtained?*

There is a possible misunderstanding here in that we are not applying extreme value theory here. Instead, we use GEV to approximate the distribution of *all* events, not only the most extreme ones. The text will be clarified in this respect.

> *230: “ to give unrealistic large values, which is why length and width have been truncated at 1.5 times the largest observed values,” Why the specific value of 1.5 times the largest observed value?*

It turns out that these distances occur in events that are of a size comparable to South Africa, the domain of interest. Hence the cutoff has little practical implications. Other than that, there is no specific reason to choose this particular value.

> *230: “In addition, the fraction f of the event area (the area of the ellipse spanned by major and minor axis of lengths l and w,” Remember to write the last l and w in italics.*

This will be corrected in the revised version.

> *235: “Table 1 lists the distributions and parameters for these event properties.” Which method was used to estimate the parameters of the distributions?*

We used the standard matlab mle function to obtain the maximum likelihood estimate of the distribution parameters.

> *240: "We find that most frequently, events have an orientation of around 100°, i.e., propagate eastward to southeastward (Fig. 11f)." This is for the whole country. But it may be misleading as this is not the typical orientation for a high hail fall region like Gauteng where storms normally originate in Johannesburg and move north-easterly to Pretoria. As seen from the discussion in the next paragraph.*

This is right, we will rephrase to avoid this confusion.

> *280: "sets of random numbers for each property from a uniform distribution and determine ranks. Then, for each property, we draw values from the actual distribution, sort them, and attribute to events using the pre-determined ranks. " How? Does this again refer to a previously defined or described methodology?*

The methodology has been specifically designed for this application and has been described by Punge et al 2014 regarding the European hail event set.

> *285: "could be expected, smaller regions show relatively higher variability, but there is strong correlation between the two. This" Which 2? Smaller regions and the country as a whole?*

Yes; we will include that there is a strong correlation between all regions.

> *295: This section describes the South African domain in terms of latitude and longitude degrees, subregions etc. Should this description not be done earlier in the paper to set the scene – perhaps where Figure 9 is defined*

We will add a paragraph near Fig. 9 to discuss the importance of these regions for hail hazard.

> *305: "50 hail days per year), while in an equivalent sample of subsets from the stochastic event set, the event count ranges from 1 883 to 2 162 events on 671 to 703 days" Perhaps add the equivalent hail events and days per year for comparison.*

The numbers will be added.

> *305-310: " In the Highveld region, there were 74 days per year..." These numbers are averages per year. The averages per year for the years defined by the authors and the years defined by Smith et al 1998 are different and it should be considered that several climate changes occurred in the years in between. This includes periods of severe drought in the several regions in the country especially between 2010 -2020*

We will add a comment highlighting the difference in methodology and the possible impact of climate change and variability.

> *310: Can the numbers given in this paragraph be added in a table for easier reference?*

A table will be added to cover the numbers.

> *310: “However, severe hail (>31 mm in diameter” Why 31 mm and not a round number like 30mm?*

The size threshold was chosen to match that of Smith et al. But we realize they use >= 31mm and hailstone diameters are given in 1mm classes. We will use >30mm instead, which is indeed more intuitive and should not differ too much from Smith’s approach.