Dear Editor,

Thank you for your response.

I apologize, but I may need some clarifications on the problems with the track changes version. Just to make sure, the versions we are comparing are the one from March 23rd, 2020, and the one from March 15th, 2021 ?

I noticed there were issues with the pdf version of this latest and created a new one in which for me the track changes show, but if I am mistaken would you point the base version you are referring to ?

I added below explanation on comment responses.

Again, regarding the GitHub repository, as I transitioned to a new job, had family issues, and most of all, the hard drive with the original codes was stolen, I am working on reproducing everything but I a quite slow at it. Here is the link however, that I will population slowly but steadily with codes.

https://github.com/lucbonnafous/NHESS_paper1/

All the best,

Luc Bonnafous

Referee #1:

1. General comments: A spatio-temporal clustering of global hydroclimatic extreme events is carried out to assess the additional exposure of different mining products to such events compared to that expected by chance. The clustering of hazardous extreme events across the Tropics and sub-Tropics synchronously with high climatic anomaly periods (El Nino for example) is useful information, despite being intuitive. The implications of this research are tremendous in overall climate risk analysis not only in mining but also for other commodities.

Response:

We agree that the clustering across the tropics and suptropics is intuitive. ENSO might not be the only cycle at play here. We modified the abstract as well as the result section (page 15 in the version with track changes), to highlight this.

2. Specific comments: In section 4, implications of this analysis for other commodities (e.g. renewable energy production facilities) need to be addressed.

Response:

We modified the conclusion (page 20) to mention this. We plan to update and run the analysis on other commodities, but it will take a bit of time and out of the scope for this paper.

3. Technical corrections: Please state the full forms before using abbreviated forms (CRU, SPEI etc.). Misplaced references often work against the flow of the paper (line 15 and such). The first table in the result section (line 8) needs a title and table number. Please correct the formatting of the table before publication.

Response

These issues have been taken care of in the new version.

Referee #2

1. The general finding of the paper is by no means new, the insurance industry knows this and operates accordingly since at least the 1990ies. Nevertheless, as most physical risk assessments in the banking sector today are based on mere local lookups on hazard maps, the paper does reiterate the point for these audiences.

Response:
We agree that the spatial correlation in climate risk and its temporal concentration are not necessarily new points. However, our intent was to highlight the implications for specific industries, now that there is significant interest in physical climate risk and how it may have changed over time. We have had conversations with re-insurance industry researchers and have confirmed that methods are in place to account for local spatially correlated risk, but not for temporal clustering and quasi-periodicity incurred by climate cycles related to given climate extremes for a global, industry-wide portfolio of assets.

We have modified the manuscript (page 3,l ’15-19) to clarify what we meant.

2. Methodologically, one might be able to look into ‘dry’ conditions with such a rather crude approach (SPEI), while for ‘wet’ conditions, run-off and hydrological routing (terrain etc.) all matter and a corresponding ‘wet’ index will unlikely reveal intense flooding conditions, as it can also be composed of many wet days, but no torrential rain or strong flooding. Instead of the rather simple method, why do the authors not consider to just apply a state of the art probabilistic drought and flood model at high spatial resolution to this problem?

Response:
Arguably, the SPEI models a version of net precipitation and is advocated as a drought index. Indeed for runoff considerably more complex dynamics matter, but accurately modeling flooding risk at the asset scale globally is still confounded by considerable uncertainty. Our intention here was to highlight the space-time clustering of the wet/dry risks for different sectors and not to model these effects at the asset scale, and for this purpose we considered the tail events of the long record of the SPEI to be useful. We did not consider the application of the state of the art probabilistic drought and

flood model at high spatial resolution globally to be necessary to make the same point. The uncertainty associated with the climatic and soils data and the lack of calibration/ verification data from the application of such models may not justify the additional effort if the point to be made was one of the nature of space and time variation of climate and its implication for risk.

3. The paper lacks a clear story and logical structure. Code and data provided only upon request only, this is not state of the art (GitHub has been invented etc.)

Response:
We are in the process of rewriting all the codes after the hard drive they were on was stolen. Here is the GitHub repository where codes will be posted:

4. Detailed remarks: page 1, line 19: Well, most such approaches do indeed only consider local risk and neglect spatial (and spatio-temporal) dependencies. But please not the insurance underwriting does indeed consider both the spatial extent of natural catastrophe events as well as clustering etc. since at least the early 1990ies.

Response:
We have had discussions with AIG, FM Global, Munich Re, and Swiss Re on this topic and we are not aware of efforts in these companies to look at a portfolio of assets and price the correlated climate risk associated with a global portfolio, or its temporal clustering and quasi-periodic manifestation. However, it is indeed possible that some of the insurance companies have looked at these issues as well as supply chain risk issues that are implied by the space-time risk analysis. We do know that local/regional correlation in climate risk is indeed obvious to these companies and is analyzed from a portfolio perspective. Even in this case, we have not seen stochastic modeling or analysis of the quasi-periodic risk elements. Perhaps the idea that we are looking globally and not regionally and temporal clustering is due to quasi-periodic climate phenomena is not well developed at this stage of the paper and we should make that clear.

page 1, line 21 ff: see Hillier et al., 2020 (https://www.nature.com/articles/s41558-020-0832-y) for a valid counter-argument

Response:
Our statement: "Consequently, the global economic implications of the past or future financial and social exposure are understated in current climate risk analyses." The context here is on the space and time clustering of a wet or dry hazard; in the way we approach it, we check whether or not there is coincidence in these hazards, and show that the portfolio level risk is indeed elevated for the dry or the wet or for both to different degrees for different industry settings. At this point in the paper we have not shown these results but are setting them up. Hiller et al make a rather different point. They argue that in some cases different climate hazards may be mutually exclusive in C3a seasonal time frame and hence the emerging compound climate risk literature may sometimes overstate the case for joint impact of two or more types of hazards in a

region.

page 2, line 5: Please check the literature a bit more carefully, at least consider a selection of the global flood risk impact assessments. But it is true that few to none exist for specific industry sectors.

Response:

We think the reviewer refers to: "Yet, there are very few analyses (Bonnafous, Lall, & Siegel, 2017a&b; Jain & Lall, 2001) of the aggregate global annual exposure to hydroclimatic extremes over the last century for specific industries, activities, or population, or of the nature of trends in such exposure." Indeed there are many global flood risk assessments and how flood risk is changing. There is also a large literature on droughts, but this has not be mapped to impacts on specific industries or populations, with the exception of drought and agriculture. We added this precision in the new version (p3, l.10).

page 2, line 12: limits of insurability. Provide at least some references, as the statement 'designed based on the prior local climate record' is a bit vague. Probabilistic risk assessments are standard for pricing of natural catastrophe risks, hence not purely based on climatology. And most cat models are re-calibrated (also to changes in hazard) every few years.

Response:

We believe the reviewer refers to: "Given the nonstationary nature of climate extreme occurrence, and the intersection between the spatial structure of climate events and the concentration of human activity, there is potential for high residual risk, even if structural or financial instruments (e.g., insurance) were used to mitigate climate risk, and were designed based on the prior local climate record."

Fair enough. We provided a few examples of work that has considered ENSO and other similar factors specifically for the design of financial risk instruments, and of nonstationary flood frequency estimates using GEV models with covariates. We restate this statement (p3, l15-19).

page 2, line 13: records page 2, line 13: could be is ok, but please state that a large portfolio of global assets diversifies in itself, i.e. it is very unlikely that all locations are hit by flooding the same year. Quantification of physical risk based on mere local lookups on hazard maps will therefore overestimate risk, especially in tails (only the annual expected damage is additive).

Response:
Actually this is the point we are making in this paper – the number of such locations is much higher than would be expected by chance. This is why the portfolio risk is fat tailed compared to what is expected if there were no spatio-temporal clustering of the risk. If the pexc of an event is 0.01 at each of the locations under consideration and they are independent, then the Binomial distribution can be used to estimate the

probability that k or more out of K locations may experience such an event in the same year. We demonstrate that in many cases, the probability of k|K based on empirical counts is substantially greater than what would be expected under randomness – this is the source of the fat tailed risk

The below comments have been used to edit the new version.
page 3, line 4: on urban center, please rephrase, at least analysis would provide for the case of an urban area. . . or metropolitan area. . . OK thanks

page 5, line 17: The description of the method and reference to supplemental figure does mix with results. A better methods description and separation of some of the details to the results section might be suggested. OK thanks. This was updated, see pages 6 and 8 in particular

page 6, line 7ff: While SPEI works well for 'dry' conditions, 'wet' can mean many things, but rarely flooding (as routing matters a lot). We will edit the paper to change flooding to extremely wet conditions. We agree that is better and changed it

page 6, line 20: a heavy tail effect.. Thanks

page 7, line 1: why binomial distributions? Please see response above to p2 line 13 comment

page 7, line 2ff: The argument can not be followed and 'mega-catastrophe' is not defined or characterized Fair enough. We will restate. Thanks.

page 8, figure 1: axis descriptions missing. Thanks.

page 8, line 9: not a surprise at all to detect an ENSO signal. We agree.

page 9, figure 2: vertical axis? Thanks

page 10, figure 3: vertical axis? OK.

page 11, line 10ff: this is very vaguely described and not well connected to the results of the paper presented. I

If we understood correctly, the reviewer is referring to our
mention of influence diagram enabling one to describe risk pathways in a more tailored and subtle way than has been presented here.

We modified the conclusion to try to make this clearer.

page 11, line 15: the jump in argumentation to parametric insurance is quite arbitrary.