Responses to the referee 2 (Neil Macdonald)

Overall: I enjoyed reading this paper this interesting paper that uses a range of archival and instrumental data to better understand the inter-relationship between bark beetle outbreaks and climatic parameters, with considerable impact to the economy of such outbreaks. The wealth of materials that the authors have processed is commendable, with a large volume of materials reviewed and a complex picture starts to emerge. I think that there is considerable merit within the paper, but I do have some concerns with how the paper is currently presented, these are listed below, I also provide an annotated copy to support the authors in the revision process.
RESPONSE: We would like to thank the referee 2 for careful evaluation of our manuscript (including valuable annotated copy) and many critical comments we are trying to respond below.

My key concern is that the paper presents a very detailed understanding of human-environment-climate interactions over several hundred years, with examples recognising these complex interactions, however the conclusion states that this is a function of climate change. Such a statement I feel fails to give justice to the complexity of the different aspects you so carefully detail in the paper. Climate change may have exacerbated the impacts, but I believe you demonstrate a much complex picture of interactions throughout the paper.
RESPONSE: We agree that the problem of bark beetle outbreaks represents complicated "human-environment-climate interactions". But the aim of this paper is to analyse meteorological and climatological triggers of "notable" bark beetle outbreaks. Despite human and environmental factors being partly indicated in several parts of the manuscript, the complex analysis including human and environmental factors is not the aim of this paper and is out of the scope and possibilities of this paper. For these reasons, our conclusions are primarily oriented on the analysis of meteorological and climatological triggers (see the first sentence in Conclusions: "From a systematic analysis of meteorological and climatological triggers of the notable past and present bark beetle outbreaks in the CR for the 18th–21st centuries, the following conclusions can be summarised:"). To clarify more clearly the aim of the paper, we added following sentences at the end of the past paragraph in Introduction: "In order to fulfil this request, the most comprehensive and unique series of bark beetle outbreaks in the Czech Republic was created for this study and used especially for the analysis of meteorological and climatological triggers accompanying the notable bark beetle outbreaks. Having in mind that these outbreaks are a result of complicated human-environment-climate interactions, this study concentrates only on one part of this interaction."

I think you need to present a chronology of windstorms within the paper, these appear important throughout the record, not just the historical period. This could be presented alongside the bark beetle outbreaks to help the reader see the relationship.
RESPONSE: We added 220-year chronology of severe windstorm as part (d) to Fig 3 with the following description at the end of the first paragraph in Section 4.2: "Periods of relatively higher annual frequency of severe windstorms (Fig. 3d) were identified in the 1820s–1840s, the 1900s–1930s, and mainly in the 1960s–2000s, while they were less frequent in the second half of the 19th century (particularly in the 1850s) and in the 1940s–1950s."

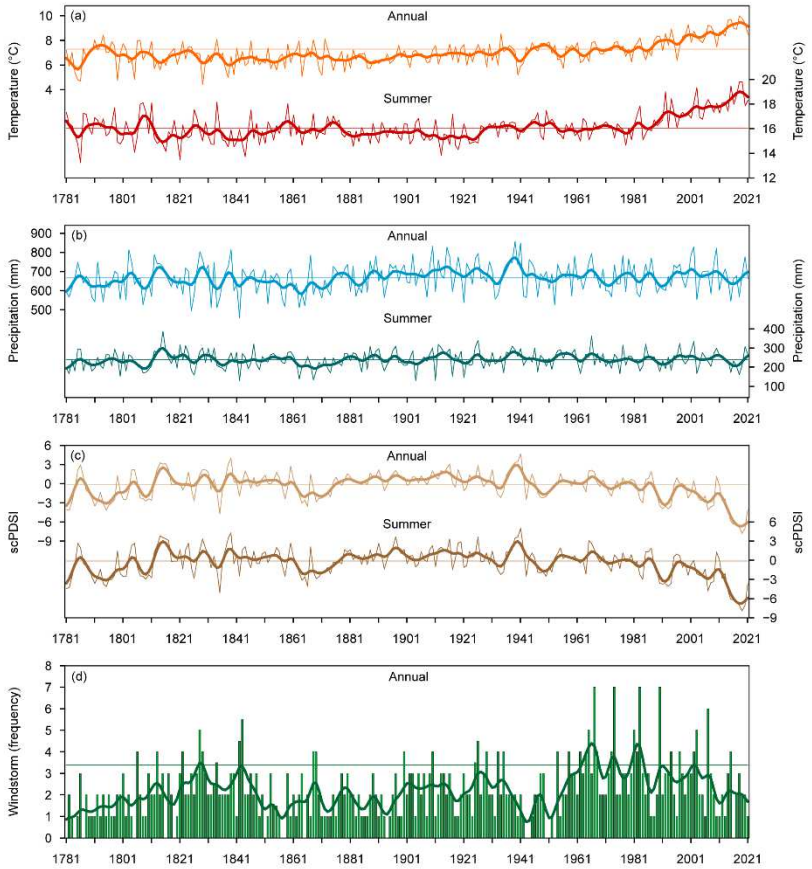

Figure 3: Fluctuations in annual and summer series of (a) mean air temperatures, (b) precipitation totals, (c) scPDSI, and (d) severe windstorms for the territory of the Czech Republic during the 1781–2021 period. The values are smoothed by a 10-year Gaussian filter (bold line) and complemented by horizontal lines corresponding to related means of the 1961–1990 period.

Moreover, we added also new Figure 13 comparing bark beetle outbreaks with windstorms to Section 5.3 with changed and complemented text (see below).

Key points that I believe should be addressed following revision:

This is a long paper with a great level of detail, whilst this is valuable and informative it does mean you need to ensure that key points are clearly detailed. I have suggested a couple of places where this could be more concise in the annotated version.

RESPONSE: We accepted your proposed corrections from the annotated version.

Lines 50-80, I think this needs to be more concise, it is not incorrect but not critical to the readers understanding.

RESPONSE: Following your request, we changed related two paragraphs from lines 50-80 as follows:

"Among different aspects of bark beetle outbreaks, several papers analysed in great detail the effect of temperatures on the duration of the egg, larval, and pupal stages of the spruce bark beetle and adult maturation feeding (e.g., Annila, 1969; Wermelinger and Seifert, 1998, 1999). Besides temperatures, windstorms are importantly interacting with bark beetle disturbances (e.g., Temperli et al., 2013; Thom et al., 2013; Stadelmann et al., 2014), and this interaction can be amplified by climate change (e.g., Seidl and Rammer, 2017). Moreover, windstorms coupled with bark beetle outbreaks remain the most damaging agents in Norway spruce stands as shown, for example, in Slovakia (Kunca et al., 2019). Acute droughts appear

to be another important driver of bark beetle infestation as shown on the example of Austria (Netherer et al., 2019) and the influence of droughts on bark beetle outbreaks will even threaten the persistence of European coniferous forests (Jaime et al., 2022). Droughts limiting soil water content contribute to tree transpiration deficit, increasing host susceptibility to bark beetle attacks (Matthews et al., 2018). Effects of summer temperatures, droughts and windstorms on the dynamics of bark beetle outbreaks in Norway spruce forests were analysed across eight European countries by Marini et al. (2017). Great research attention concentrated also on effects of future climate change, represented by various climate scenarios, on different aspects of bark beetle occurrences focusing, for example, on Sweden (Jönsson et al., 2009), Scandinavia (Jönsson et al., 2011), Switzerland (Jakoby et al., 2019), or the Bavarian Forest National Park in Germany (Sommerfeld et al., 2020).
Information about past Czech bark beetle occurrences was a part of forestry literature (e.g. Chadt-Ševětínský, 1913; Nožička, 1957; Hošek, 1981). Some papers concentrated on focal areas of bark beetle outbreaks like the Šumava Mts. after the disastrous windstorm of 26–27 October 1870 (Záloha, 1970) and during the 1870s (Jelínek, 1988), while Zatloukal (1998) analysed factors of past and present bark beetle calamities. PHENIPS model was used to analyse the influence of future climate change on the country bark beetle distribution (Hlásny et al., 2011) and bark beetle dynamic in the Bohemian Forest (Berec et al., 2013). Lubojacký (2012) described the Czech legislation related to protection against bark beetle. Zahradník and Zahradníková (2019) assessed salvage felling caused by bark beetle and other abiotic/biotic factors for 1998–2017. Past and recent bark beetle outbreaks in the Czech Republic after 1980 CE were described, for example, by Skuhravý and Šrot (1988), Mrkva (1993), Skuhravý (2002) and Hlásny et al. (2021b)."

155-157, I am uncomfortable with the way you are using the scPDSI, why not just present this as scPDSI-12?
RESPONSE: According to our opinion, individual notable bark beetle outbreak are results of some cumulative effects. Because we are presenting the cumulative effects of monthly temperatures and precipitation, we logically collected the same monthly data for PDSI. But based on your comment, in part (b) of Figures 4–10 we replaced all existing annual data by scPDSI-12 (and scPDSI-3 for summer).

470-480 I felt that you needed to explain the spatial and temporal changes in land management earlier, could you present changing extent of forestry in CR through a table or graph underneath Fig 1 or 2. I felt you also need to discuss the different forestry practices of the times, you recognise that extensive lowland forestry took place in the mid-20C but fail to then consider has the increase you attribute to climate change just been a function of these woods maturing. Also what impact does large monoculture conifer plantations have, compared to mixed conifer/deciduous?
RESPONSE: As mentioned earlier, this paper has not ambition for the complex analysis of complicated human-environment-climate interactions related to bark beetle outbreaks. Our aim is to characterise only meteorological and climatological triggers of notable bark beetle outbreaks with respect to their changes during past 220 years, i.e. were they the same during this long period or we may see there some imprints of recent climate change connected with increasing temperatures and dryness? As for monocultures and forestry practices in general, these are dealt with in Section 5.3.

480 Do we get different types of bark beetle, are they responsible for different outbreaks, do you need to try and distinguish between different beetle outbreaks and the different climates they preference, do we have different beetles impacting forests in the last 50 years?

RESPONSE: Our study concentrates primarily on *Ips typographus* while information of other bark beetles (*Ips duplicatus*; *Pityogenes chalcographus*) was not considered in this paper. As follows from volumes of salvage felling related to other bark beetles, their total volumes of infested wood are negligible compared to *Ips typographus* (only *c*. 0.1%).

545 A little more detail needed.
RESPONSE: It was extended as follows: "The planting of extensive conifers monocultures reduced the biodiversity of Czech forests, exhausted the soil and increased the susceptibility of forests to natural disasters (e.g., through even-aged structure, mutual competition for essential nutrients, lack of space for the root system and treetop) (Daniel et al., 2013). Without the existence of conifers monocultures in the lowlands and at middle altitudes, forests would be composed especially of oak, beech and fir (Neuhäuslová et al., 1997). However, in the last few years, the area covered by spruce monoculture plantations in the CR declined from 54.1 % in 2000 to about 48.8 % in 2020, which should contribute to the attenuation of the above-mentioned negative phenomena (Ministerstvo zemědělství, 2021)."
New reference:
Neuhäuslová, Z., Moravec, J., Chytrý, M., Sádlo, J., Rybníček, K., Kolbek, J., Jirásek, J.: Map of potential natural vegetation of the Czech Republic 1:500,000, Botanický ústav AV ČR, Průhonice, 1997.

Discussion: You need to provide a more detailed analysis of the role of windstorms, these appear to be significant throughout the record, not just historically, this needs to be explored more fully.
RESPONSE: We newly added Figure 13 comparing bark beetle outbreaks with windstorms to Section 5.3 and the corresponding paragraph was changed and complemented as follows:
"The recent bark beetle devastation of forests in the CR destroyed in seven years from 2015 to 2021 55.46 mil. m^3 of wood altogether, which is more than the total for the previous 51 years (34.80 mil. m^3) for which quantitative bark beetle salvage felling data are available (cf. Fig. 2). The highest annual bark beetle felling in 2020 (14.89 million m^3) was not exceeded by any other biotic factors (other insects, gnawing of trees by wild animals, mushroom pathogens) nor by any abiotic factors (wind, snow, rime, drought, air pollution). As follows from Figure 13a, bark beetle salvage felling was higher than those caused by windstorms since 1964 only in 1995 and then from 2016 onwards, giving for the last outbreak in 2015–2021 more than three times higher volumes than in case of windstorms (17.03 million m^3). The highest windstorm salvage felling was recorded in 1990 with 8.77 million m^3 of wood (i.e., before 1992–1995 bark beetle outbreak) and in 2007 with 8.84 million m^3, followed in 2008 by 4.85 million m^3 (i.e. during 2007–2010 outbreak). Another well-expressed maximum appeared in 1982–1987 outbreak with 5.94 million m^3 in 1984 and 6.50 million m^3 in 1985. There is a clear relationship to extreme windstorms, such as Kyrill in 2007 or Emma in 2008, while annual frequency of selected severe windstorms across the CR in months January–March together with October–December (Figure 13b) do not show any clear relationship to damaged and processed wood. The dominant proportion of windstorms of the winter half-year on volumes of salvage felling was disturbed only by summer windstorm on 12–13 July 1984 (see Brázdil et al., 2018b)."

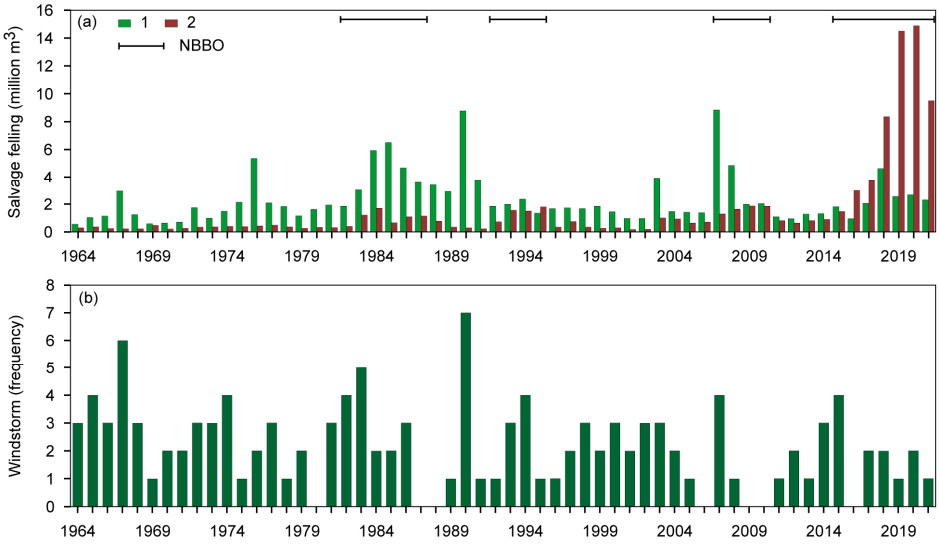

Figure 13: Comparison of bark beetle outbreaks and windstorms in the Czech Republic during the 1964–2021 period (NBBO – notable bark beetle outbreak): (a) volumes of annual salvage felling attributed to windstorms (1) and bark beetle infestation (2); (b) annual frequency of severe windstorms for January–March and October–December.

Conclusions: I think the paper demonstrates a much more complex picture that cannot simply be brought down to the points presented here. Looking a the data I think you need to reflect on iii) as I do not see this clearly within the data. You provide a wealth of information in the paper detailing the complex interactions that may explain changing patterns of forestry, landuse patterns, management practices, beetle outbreaks and climatology, all of which contribute. To argue recent outbreaks are a function of climate change fails to acknowledge the evidence presented in the paper, that demonstrates an emerging complex picture, of which climate change may be exacerbating the incidences, which are a function of complex human-environment interactions.

RESPONSE: We agree that the problem of bark beetle outbreaks represents complex human-environment-climate interactions. But the aim of this paper is to analyse meteorological and climatological triggers of "notable" bark beetle outbreaks. Despite human and environmental factors being partly indicated in several parts of the manuscript (just to show that not only climate is important), the complex analysis including human and environmental factors is not the aim of this paper and it is out of the scope and possibilities of this paper as mentioned in the last paragraph of Introduction. For these reasons, our conclusions are primarily oriented on the analysis of meteorological and climatological triggers (see also the first sentence in Conclusions: "From a systematic analysis of meteorological and climatological triggers of the notable past and present bark beetle outbreaks in the CR for the 18th–21st centuries, the following conclusions can be summarised:"). We hope, that our short conclusions reflect representatively our main meteorological and climatological findings related to available data.

Figure 1&2: It is crucial to present the windstorm data alongside this information. You present a strong argument for windthrow damage in the earlier period, but how does this coincide with the bark beetles, without a long chronology of such information it is difficult for the reader to discern what role this has, and whether it is diminished in significance in the last 50 years.

RESPONSE: To demonstrate fluctuations of windstorms in the whole period, we added series of severe windstorms for the Czech Republic from Brázdil et al. (2018b) extended on the

whole period analysed (Figure 3d). Because our study concentrates particularly on seven notable bark beetle outbreaks, corresponding extreme windstorms are always reported in these individual cases. Relationships about windstorms and bark beetle outbreaks are reported also in Section 5.3 with new Figure 13.

Figure 4-6: Why not present a scPDSI-12, -18 or -24, this would be better than a cumulative monthly (scPDSI-1?) anomaly of the scPDSI for the timescales presented. It would be helpful for the reader to see the bark beetle patterns of damage alongside the climatological information, add graph below scPDSI annual/summer anomaly.
RESPONSE: According to our opinion, individual notable bark beetle outbreak are results of some cumulative effects. Because we are presenting the cumulative effects of temperatures and precipitation in monthly data, we logically collected the same monthly data for PDSI. But based on this comment, in part (b) of Figures 4–10 we replaced existing data by scPDSI-12. In case of the use of scPDSI-18 or -24 we are not sure, if it is not a mixture of two vegetation seasons together (but there is not any problem to mention them in a supplementary material).

Please see annotated paper for suggested minor modifications
RESPONSE: We corrected all particular parts of text and sentences as you proposed a considered your further comments in annotated text for further corrections.