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Interactive comment on "A regional spatio-temporal analysis of large magnitude snow avalanches using tree rings" *by* Erich Peitzsch et al.

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Interactive comment on "A regional spatio-temporal analysis of large magnitude snow avalanches using tree rings" by Erich Peitzsch et al. Brian Luckman (referee) Luckman@uwo.ca September 22nd, 2020

GENERAL COMMENTS This paper presents snow avalanche histories from 12 avalanche tracks, 3 from each of four regions in the Northern Rocky Mountains of N.W Montana based on tree-ring data from 637 trees. These data are used to define the history and frequency of large magnitude avalanches for individual tracks, sub-regions (mountain ranges) and across a region of ca 3000 km 2. The paper then estimates the

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efficiency of using various combinations of these chronologies to estimate a regional chronology of high magnitude avalanches in order to guide future sampling strategies for estimating regional avalanche activity. The techniques used are based on prior usage from the literature and, to my knowledge, the attempt to assess the efficiency of developing a regional history is novel.

The paper is well written but overlong and I have many questions of detail. The use of symbols to identify important terms is difficult to follow e.g Wit , RAAIt etc and a table describing these terms (in words) would be a useful addition. One of the principal difficulties is the comparison of statistics such as RI values between sites based on records of different length where the RI values are strongly related to survival of older individuals within the avalanche path. Perhaps a comparison based on e.g. the last fifty years would be better to compare differences between tracks.

No indication is given of the number of living vs dead trees sampled. If one discounts the first 10 years of record over a third of the trees sampled have <35 years and half <60 years of record. How large/ tall are these trees on average at these ages and how might the nature of the tree-ring signal (i.e. the probability of recording a given event) vary with the age /height/ robustness of the tree. The avalanche chronologies are strongly biased towards the lifetime and response characteristics of the trees sampled. Although the number of GDs is cited in several places the breakdown of the individual types of GD e.g. scars, reaction wood series, TRD, tree mortality, etc. is never given.

In several cases the results are self evident- one gets better results from more sites, more trees, cross sections vs cores. The main strength is the regional and sampling approach. However, I have reservations about some of the derived statistics and the comparisons between individual records. There is little comment on the variability of the records within each of the sampling regions, or for example, the similarity between two adjacent paths. The main focus is the regional comparison. This regional approach tacitly assumes no significant differences in avalanche climate, or triggering factors across the region. There is no specific exploration of the relationship between avalanche activity and climatic factors. I think this paper needs revision to address some of the concerns addressed below

DETAILED and SPECIFIC comments Line Comment

52 delete semi-colon before bracket 66 Most of the data in table 2 is not greatly relevant to the paper. It is simply a compendium of earlier chronology studies. It is not used and could be in an appendix or supplementary material. 85-8 In this paper large magnitude avalanches are identified based on the cumulative evidence of disturbance by avalanches for an individual year in a given track given a minimum number of trees sampled. This identification is independent of the location of these disturbances within the individual avalanche track. The distribution of sampled trees within the avalanche track is therefore critical to the interpretation of this evidence with respect to avalanche hazard. Large magnitude in this scenario doesn't necessarily mean large or full length avalanches that would impact the runout/ danger zones. The authors need to emphasise more strongly that these avalanche chronologies are based on sampling in the terminal zone and down track margins and therefore the large magnitude events are inferred to be large full length avalanches that would represent hazard to these areas. In some cases there are a significant number of samples in the upper part of the track. 118 Figure 1 When enlarged Figure 1 clearly shows black dots which are assumed to be the sampling locations within the tracks. The figure caption should clearly point this out-it is not clear from the key and does not seem to be mentioned in the text or caption. As tree location is a critical factor in defining the size of avalanches their specific location is important. At several tracks the location of the sampled trees is some distance from the terminal zone of the avalanche track (there are two sampled areas on the northernmost GTSR site near Crystal Point?). Perhaps the track names should be identified on Figure 1. Tables 2, 4 and 5. Is the colouring necessary? 110 These data do not appear to be used or referenced in the present study, even for comparative purposes. Did they identify similar major avalanche events? 160 the spatial footprint is 3000km2 in the abstract and 3500 km2 here 167 The text at this point suggests that

all the cross sections were from dead trees and that the only living trees sampled were cored. Is this the case? Is the outer ring from these dead trees assumed to be from a ”high magnitude” event i.e. the tree was killed/ sheared by an avalanche. These outer rings were presumably crossdated from adjacent living trees or chronologies. Were the core data actually used? 200 + How does one also counter the censoring of the avalanche record due to continuing persistence of damage (e.g. reaction wood or TRD) in tree rings for several years following a major disturbance? 212 responses within the tree or over the site? 212-4 should the analyses and comparison of return intervals be limited to a common period when there is a reasonable sample of avalanche events (however defined) based on the age distribution of sampled trees within all tracks? 221 Figure 2 More information needs to be given in the caption identifying the symbols used N= sample trees available. GD= number of GDs identified. Perhaps include (N) after sample size in line 226. Is GD any GD or those above some minimal value? The context seems to indicate it is the number of GDs identified and not their magnitude. 229 Is the statistic for avalanche years simply binary i.e. yes no? 239-40 therefore high magnitude years are all years where Wit is $\geq$3? Is the last term in Eqn 2 simply It? Essentially you derive a Wit value for each year for which there was avalanche data in each track and identify avalanche years as those with Wit $\geq$ 0.3. Line 229 in the text indicates that RI calculations are based on the avalanche year examples (box 2 of fig 2) but lines 241 et seq. indicate that RI values are also calculated for high magnitude events (Wit $\geq$ 0.3) only. Therefore are there two sets of RI data for (i) avalanche years and (ii) high magnitude (Wit) years? So which data are used in the subsequent analyses? Are these high magnitude years simply binary data (yes/no?) 253 RAAIt is based on the definition of avalanche years (It), not high magnitude Wit years. Therefore avalanche years are identified using the It statistic but high magnitude avalanches are identified using the Wit statistic. It appears that the RI data are calculated based on both the It and the Wit classification whereas the RAAIt statistics are based on the It definition of avalanche years. Is this correct? Line 324 seems to imply that the avalanche years identified in Figure 2 and the high magnitude events identified using Wit were identical so this difference does not matter? In any event only one set of calculations defining RI values should be specified. The term RI is used throughout the text but in places it is not clear whether it refers to the mean or median value. 263 how does the probability of detection differ from the probability of avalanches? 284 are these comparisons included in this paper? 291 ID by GD class but not type? So what was principal evidence used? 298 this is predictable given the ages of trees sampled. Perhaps more interesting would be the years with the highest It values 299 Figures 3a and b appear identical and one is redundant. The scale on Fig 3b is incorrect (0.3 %?). The ages in Fig 3c indicate that many of these trees were quite small. What would the diameter of a 40 year old tree be? How does age influence the nature of the GD? In 3d were the larix and betula species identified? 308 missed 67 or 66? 312 Figure 4 needs a scale. Some comparison of the derived GD data would be useful to make the point. To be effective this topic warrants a more extensive discussion and presentation of data than that presented here. This discussion and figure should probably be deleted. 312 More importantly were results from these cores actually used in the analysis. 324 Table 5 what does the standard deviation figure refer to (bottom line). Explain in caption? 332 Tables 4 and 5 What is the statistic 1/RI in these tables? Why is the median RI value used rather than the mean? Explain in the caption 334 Table 4 An additional line identifying the sub region should be added to the top of the table. The table should also give the period of record utilised to calculate RI for each track. 337 JGO is a function of the early record but why LJB? LJB and LJC are 26, LGA is 25 and shed 7 is 28? 399 Table 7 explain MLC and HLC in the caption 346 Figure 6 what are the data plotted in this Figure? The median of GDO in Table 4 is ca 34 but in this figure it is ca 28. For LGP the median is ca 12.6 in Table 4 but ca 8 in figure 6 338-40 surely the similarities and differences between tracks reflect the length and nature of the avalanche record in each track? Differences/ similarity in return intervals are partially dependant on the length of record 349-66 These differences in recurrence intervals are calculated for different periods of record. To be comparable do they need to be calculated over the same interval? 369 The avalanche records in these tracks start in 1933, 1936 and 1993 so why compare them to a record starting in 1908 which presumably has avalanches predating those records. Surely comparisons need to be over the same intervals? 370 Figure 7 a nice (original?) way to show these data 380 Figure 8b the red line is not visible. Perhaps delete it and simply indicate this value in the caption. 386 et seq. But the records being compared have quite different lengths and histories. How unique is the record of individual paths? If you compared the record of the tracks with similar length of record (say, ca 1950-2010, RMA-C, 54.3, LJA, 10.7 and S4.7) how similar are they? 405-6 These trends are mainly an effect of the increased sampling of avalanche years 432-3 relevance of these comparisons? 435 up into the bottom? English? Is the bottom the end or center of the track? 437-40 some specific dates needed here as this is the basis for the selection of records used. What specifically is the most recent time period for which you have adequate data across the network? 451-2 how frequent is tree removal? What % of GDs are termination of growth vs other indicators of avalanche damage? 454 Although mentioned several times this incomplete historical record is never presented or directly compared to the equivalent tree-ring record for the comparable sites. 475 the difference between Readon's earlier results or the other avalanche tracks? What are these differences? 481 LJC has the greatest RI? It has the greatest median but not mean. The large median is a function of the small sample size in this track. The fire may have taken out evidence for most events between 1943 and 2017 and therefore this is not a valid comparison. 489 using which RI value, mean or median? What is the correlation statistic? 495 JGO is very unusual with only two avalanches between 1880 and 2017! The critical difference is the absence of documented events in the last 50 years. The only answer to these tentative explanations is more data from adjacent tracks. Perhaps the only comment necessary is that the reason for this is not known 507 but these differences are never explored. 527 but these changes are also influenced by which avalanche track you remove. 532 But how typical is the record of s10-7 of other paths in the region see e.g. Table 4 533 s10.7 has the most avalanche activity but surprisingly is not compared with the available, if limited, observational record. 538 What is an avalanche cycle chronology? 547-9 these data would be useful here to validate some of these comments or are they solely based on the examples which follow. 566 paths with one scar or one GD of class 3? Where are these scar data? 570 is the sample design or the number of paths the critical factor here? The sample design clearly increases the area covered. 582-5 Basic point is that if you sample more avalanche tracks you get more avalanche years and a more consistent pattern may emerge. However the pattern of avalanche activity varies from track to track and from year to year 587 Is this a function of sample size or other characteristics such as the time period covered by those samples and the sampling network? 603 this median value probably should be linked to a time frame to which it applies

Figure A1 What are the data used here (reference to Table 2)? Some numbers are barely visible. Perhaps use bolder (larger) numbers and colour as a background to individual cells?

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