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Comment on nhess-2021-193

Adrienne Marshall (Referee)

Referee comment on "Monitoring the daily evolution and extent of snow drought" by Benjamin J. Hatchett et al., Nat. Hazards Earth Syst. Sci. Discuss., <https://doi.org/10.5194/nhess-2021-193-RC2>, 2021

General comments

This manuscript introduces a novel visualization method for illustrating snow drought evolution using phase diagrams. The authors illustrate the use of this method through a series of case studies, and evaluate the utility of the method for in situ snow observation data as well as gridded data products. They also document a web-based tool to allow users to view these snow drought phase diagrams for locations and time periods of interest. The manuscript is well-written and appropriate for NHES, and I like the idea of using phase diagrams for snow drought identification. I have quite a few specific comments, but none of them require fundamental changes to the manuscript. The most important specific comments below are to:

- Consider adding a 1:1 line to the phase diagrams and additional or alternative designations for warm snow drought
- Reconsider the implications of data presented in Figure 6 (on basin-averaged gridded data vs point scale in situ data)

Specific Comments

Line 19 – I think the idea that a snow-to-rain transition leads to less runoff efficiency is somewhat contested; I might also consider referencing Barnhart et al. (2020) and nuancing this statement a bit.

Barnhart, Theodore B., Christina L. Tague, and Noah P. Molotch. "The Counteracting Effects of Snowmelt Rate and Timing on Runoff." *Water Resources Research* 56, no. 8 (2020): e2019WR026634. <https://doi.org/10.1029/2019WR026634>.

Line 21 – maybe specify "in snow-dominated regions".

Table 1 – I don't think Table 1 is referenced in the text; could you specify the source of the "snow climate" designation? I don't disagree with any of these designations, but think it might be helpful for readers. Or, describe what you mean by each when you reference these climates in the text (Line 59).

Line 121 – So the "dry but snowy" conditions could essentially either indicate anomalously cold storm events for the season, or a seasonal shift in precipitation timing (towards colder), right? Consider whether this might be a helpful rephrasing of what you already have here.

Figure 2a – Do you think it would be appropriate to add a 1:1 line? I found myself wanting to know for a given precipitation percentile if the snowpack for that date was above or below the snowpack percentile. I know that warm snow droughts are typically defined as having approximately normal precip with below-normal SWE, but I also wonder about identifying cases where SWE is proportionally lower than precipitation – e.g., if precipitation was 30% of normal, and SWE was 5% of normal, wouldn't we still want to think of this as a warm snow drought at least to some extent? Maybe it needs a different designation? This would fall below a 1:1 line, but not in the lower right quadrant.

Line 137 - "seasonally induced shifts in solar insolation" It makes sense to me that this causes melt, but why would it cause a decrease in the percentile of SWE, given that these solar insolation shifts happen at roughly the same time every year (unless there were anomalous clear skies)?

Line 199 - Suggest specifying that "comparable snow drought conditions" refers to SWE percentiles only.

Line 201 - I have not seen the Native name for Ti'Swaq' used before in scientific/snow hydrology literature and I appreciate it! Might this be appropriate for any other place names you use?

Line 226 - Yes, although depending on how you define hydroclimate, Marshall et al. (2019) showed projected decreases in interannual variability of peak SWE in many locations.

Figure 6 - It seems like the two basin-averaged snow drought phase diagrams are much more similar to each other than either is to its respective SNOTEL site. It seems the text interprets this figure as saying that basin-averaged SWE diagrams are useful when no in situ observation exists; while I don't disagree that this may be the case, I'd be more inclined to comment on either the limitations of SNOTEL sites for representing basin characteristics or the impacts of spatial averaging on how we interpret these data.

Line 276, 279 - You refer to making the phase diagrams "meaningful" in complex terrain - could this get a little more specific and denote "meaningful to what?"

Figure 8 - I like this figure for giving a time series version, but it feels a little disappointing at this point in the manuscript to resimplify to percentile-based snow droughts. Could this figure be expanded (either with additional panels or additional colors, as in Figure 7) to differentiate between warm and dry snow droughts (as you suggest in Line 323)?

Line 320 – I suggest using relative p-values (e.g., $p < 0.001$), rather than giving a precise number; it risks placing more importance on the numerical p-value than is warranted. It's interesting that the April trend is smaller but more consistent (significant) than the December trend; you could point out that this is probably because April trends integrate warm temperatures over the course of the water year, while December trends are more impacted by stochastic precipitation and warm/cold events.

Line 370 – Percent of average also gets weird at the end of the season, either in big snow years (percent of average can be huge or infinite, if average is zero), or in years with earlier than average melt date (percent of average can be very small for a few days, but this may exaggerate the apparent low snow conditions).

Line 400 – I appreciated this discussion of the differences between percent of medians and percentiles.

Line 416 – You mention climate change here; it may also be appropriate to provide a brief mention somewhere of the impact of the period of record on these percentiles. Should the period of record used to calculate percentiles be allowed to extend over non-stationary climates? When comparing multiple sites, how should users account for potential differences in the period of record used for percentile calculations?

Line 420 – Could you say a little more specifically what concerns were highlighted in the papers you reference here?

Conclusions – Could you say anything more about how the snow drought phase diagrams might support scientific innovation, rather than only focus on the management/end user audiences?

I checked out the snow drought phase diagram tool – it was easy to use and is a great

addition to the manuscript, in my opinion. My only critical comment on it was that I found that the color scale was not very intuitive (could you use the same color scale as Figure 2a?)

Technical corrections

Line 26 – This sentence might read more easily if you started with “Reductions in snowpack negatively impact ... in addition to ...” Just a style suggestion; it was hard to see where it was going.

Line 41 – typo, “hydroclimate conditions *to* varied ..”

Line 71 - Should “Seaber” be inside parentheses?

Line 88 – I don’t think ‘drought-busting storms’ should be in quotes unless you have a citation (even though I get your intention). I don’t know if the meaning of “mixture effects” in this line is clear.

Line 181 – A few times in this paragraph, you say snow or precipitation percentiles “improved” instead of “increased.” While I agree with you, I think this inserts an unnecessary value judgement, and “increased” would probably be more clear.

Line 233-234: Using “active” to describe the weather feels a little imprecise; could this language be made more specific?

Figure 7 – The color map here is clever and effective, but could you reverse the bar so that the lower numbers are on the left?