

## NHESS ATES v.2 paper major revisions – TO DO

This list of revisions includes formal feedback from the peer review process as well as feedback obtained outside of the formal peer review process. Each comment is followed by the initials of the source (reviewer), and a number that refers to our reply given during the interactive discussion.

For example, (AR3) refers to the third reply we gave our Anonymous Reviewer during the interactive discussion.

Revisions were received from the following sources:

(EB) = Edward Bair, (SH) = Stephan Harvey, (AR) = Anonymous reviewer, (HPM) = Hans-Peter Marshall (editor), (JF) = James Floyer, (BG) = Brian Gould, (BT) = Bruce Tremper, (CC) = Cam Campbell, (GS) = Grant Statham.

**NOTE:** Tables 1,2 and 3 were originally MS Word tables but have been replaced with .png images to meet NHESS formatting limitations on colour tables. The tables have better resolution and are preferred, but we will ask about this during the typesetting process if accepted. Sykes et al., (2024) reported the same issue, but was allowed to use the tables during typesetting. So this document has .png images as per NHESS request.

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**Abstract** – Line 14 add that the Waterfall Ice climbing model is introduced with v2 (EB)

- Add the “objective of the paper” to the end of the abstract (EB5)
- Change Line 13 from “a risk management tool” to “a tool for risk management” (AR5) – did not change, too subtle and no significant impact.
- Abstract completely revised (AR early comment)

**Introduction** – After line 29 describe the differences between static and dynamic maps/rating systems (Schmudlach, Harvey) (SH4) (EB4).

- Introduce the Zoning Model after line 30 (SH6)
- Describe the objective of the paper to fill a gap in literature about terrain classification (describe the gap), get a baseline reference established in a peer reviewed journal with DOI reference (EB1) (EB16).
- Introduce the risk framework that ATES fits within, citing Statham (2008) and describing the interplay between hazard, exposure, vulnerability and risk. Best fit after Line 23 (AR6) (EB4).
- Line 30 provide a more in-depth review of different ATES applications (manual versus automated, different regions) and an overview of application scales (AR7).
- Line 37 describe why ATES v.1/04 and the Zoning Model were merged (AR16)
- Line 40 correct Laron to Larsen and insert comma into Klassen, 2012 (AR).

**Background** – At the end, after line 78, describe the Swiss maps, CAT rating system, Schrudlach ski touring guru (SH5) (AR1).

- Modify line 21 to read “...where the elements-at-risk such as skiers, climbers, snowmobilers or workers and exposed to avalanche hazard, but mobile and free to travel unrestricted through the landscape” (EB6).
- Lines 58-60 expand on why quantitative methods are impractical in this context (AR9).
- Line 57 revise to indicate the impact-based maps have been used RAMMS/FlowPy for backcountry applications but are not widely accessible to practitioners (EB7).
- Line 71 correct ATES Zoning Model from ATES Zoning model (EB8).
- Describe the limitations of ATES v.1 NOT having Class 0 and the conflict with the Zoning Model having it (EB9).
- Line 64 clarify river ratings “...modelled after river ratings, which describe the level of difficulty and the consequence of the rapid” and cite (American Whitewater, 2024) (AR10).
- Line 70 revise for clarity (AR)
- Change Line 76 to “the zoning model also introduced Class 0 (non-avalanche terrain), an essential rating level in any avalanche terrain classification system that shows where avalanches with consequence do not occur.” (AR11).

**Section 4.1 ATES Communication models** – add more current NADS reference to line 143 (GS).

- Ensure the origin and overarching intent of ATES is public communication, everything else underneath is trying to define this (BT email).

**Section 4.2 ATES Technical Model** – introduce the TM criteria more clearly, describing in a list the eight terrain factors being assessed and linking them to the TM figure (Table 3) (SH10) (AR1).

- Improve the description of ATES defaults around avalanche frequency to show how they carry weight (the edit above may do this) (EB9).

**Section 4.2.1 Exposure** – Line 174 add that defining exposure is not difficult when assessing a route or climb, but exposure is difficult to define when no route exists (SH13).

- Clarify the meaning of temporal exposure showing the difference between *assessment* and *application* of ATES (AR2) (AR4).
- Review the entire paper for consistency in the use of the term exposure (AR2).
- Define actual versus potential exposure in the ATES context (AR22).

**Section 4.2.2 Slope angle and forest density** – Line 191 be more explicit in how ATES considers forest cover: primarily for “anchoring of the snowpack”, while snowpack modification by the forest is a secondary consideration (AR13).

- Does ATES consider forest effects only for avalanche formation? Or also on runout behaviour? (AR13).
- Discuss the difference in spatial evaluation between a regional area (manual) and a 10m pixel in GIS. Discuss averaging and estimating versus measuring (AR14).
- Consider adding two figures from the review response and describe a practical application of slope angle and forest density towards a final rating (as shown in the response to reviewer, use this text) (AR15).

**Section 4.2.3 Slope shape** - check Tremper reference to convexities and revise to ensure this shows traditional thinking on convexities. Add references to ABS's and Avaluator on convexities (BT).

- Define "high spots" and "unsupported slopes" for non-expert readers and explain their significance in relation to avalanche exposure (overhead hazard) (AR)
- Describe the difference in route finding complexity versus avalanche complexity on convoluted terrain versus planar terrain and the limitation of the model at smaller scales (SH12).
- Line 220 revise this paragraph using the language of the SH peer review response (SH14).
- Change Line 224 to say "trigger spots" and review for correct meaning (SH14).
- Add a concluding statement (something like "convexity is therefore not used directly in ATES" or something similar to guide the reader about whether convexity is a direct factor or not in the rating) (HPM2)
- Line 214 improve the description of "unsupported slopes" consider referencing Landro (EB13).
- Line 214 remove the terms "possible source" and say "source" (EB14).
- Conclude that slope shape is poorly supported by research and describe a gap and the importance of this factor to practitioners (AR17).

**Section 4.2.4 Terrain traps** – reference Harvey et al. (2018) in this section (Swiss maps) (AR).

- Line 239 add a sentence giving an example of "an otherwise harmless avalanche" (AR18)

**Section 4.2.5 Frequency and magnitude** – referring to Line 263 describe the difference between "frequency" and "records" and that in the absence of records, frequency remains essential. It's the record keeping and the assessment of this parameter that is the challenge. Future options may improve our validation methods (satellites, remote sensing) (SH16).

- Ensure the limitations of frequency assessments are properly described.
- More nuance regarding determining the stability of avalanche frequency at location considering changes in climate and the limitations of the observation period (AR19).
- Describe other methods for assessing frequency beyond records and reference Carrara (1979) for tree rings (SH 16).

- Describe the assessment of F-M for a linear rating versus a zone, where exposure is known versus where exposure is potential. Consider describing the FM relationship with regards to downslope position in a path (AR12).

**Section 4.2.7 Runout zone characteristics** – refine the definition of remote triggering (AR)

- Clearly define the runout zone, distinguishing it from the track and relating them to international classification schemes (i.e. De Quervain : Avalanche Atlas) (AR) – this was reviewed and determined not necessary as the term “runout zone” is widely accepted as correct terminology, as opposed to the “zone of deposition” (DeQuervain, 1981) which is not widely used.
- Line 302 clarify ATES v.2 (AR).
- Line 320 – general comment check consistency of terminology throughout of Class 1 versus Class 1 Terrain (AR).

**Section 4.2.8 Route options** – clarify the meaning of route options when applied to ATES spatial versus ATES linear (AR21).

**Section 4.3 Signal words, colour and numbers** – improve the description of why black was chosen for Complex and red for Extreme using the language in the peer review response (SH8) somewhere associated with Line 352.

- Line 345 refer to a corresponding figure when describing colours (AR)
- Expand the description of the red/green colour blindness issue towards the end of Section 4.3 using the language in the peer review response (SH9).
- Describe colour choices and RGB codes referencing Sykes (2024) for the codes. See that peer review for a good description of language (AR). Coblis colour-blind simulator used.

**Section 4.4 Target audience** – add modern NADS reference to line 380 (GS)

**Section 5.1 Objectives and approach** – check section numbering, do we need this title or can we simply use 5.0 Application of ATES for the first part? (GS)

- Line 407 check actual versus potential exposure to ensure it aligns with the rewrite of section 4.2.1 Exposure (AR22).

**Section 5.1 Spatial scale** – describe how some ATES criteria do not perform well or cannot be used at “terrain feature” or “slope” scale because some criteria require multiple slopes to assess (SH3) (SH12).

- Section 5.1 is duplicated with a previous 5.1 Objectives and Approach. Check numbering (GS)
- Discuss the importance of spatial scale and how well the ATES criteria can be assessed at different scale (i.e.: forest density at regional scale is difficult) (AR).
- Line 425 expand on high resolution DEM versus lower resolution and its impact on terrain classification (GS).

**Section 5.2 Assessment methods** – describe how not all of the ATES criteria are available to be assessed for every situation. You use what you can get (SH3).

- Improve the description of how to manage subjectivity and combine with objective data where available (EB11).
- Describe how some data may not be available in some parts of world – use language from EB peer review response (EB11).
- Describe a four-step process to determine the rating where each of the terrain factors is assessed against the five ATES criteria and then combined (see peer review description) (SH10) (AR1).
- Describe the importance of aligning the TM ratings with the Communication Models (Table 1 and 2) as a final check (SH10) (AR1).
- Check line 444 (AutoATES) and consider expanding autoATES description or moving this statement to the next section on autoATES (AR23).

**6 Limitations** – line 501 include Larsen et al., 2020 for the original autoATES v.1 (AR).

- Line 501 discuss limitation of autoATES due to the “subjective” selection of parameterization (AR24) – did not do this, this paper is not about details of AutoATES.
- Line 504 – potential versus actual exposure – check to ensure this is used consistently throughout the paper and accurately describe its limitations (AR25).
- Line 506 – highlight importance of being aware of resolution in DEM maps and corresponding uncertainties.

**Conclusion** – describe additional benefits of ATES compared to classical slope angle based terrain choice strategies, emphasizing the role of overhead hazard (AR26)

- Review paper for opportunities to describe the role of overhead hazard in terrain exposure (AR26).

**Code and data availability** – create this new section to direct reader to the code bank for autoATES – check with John and use the same two banks he and Havard created (EB3) (HPM).

Note this is not our code which is why it was not included originally, but two reviewers have asked for this, and we have received permission from Larsen and Sykes to publish its location here.

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**Figure 1** – describe all trails (currently blue) and explain why white trails are class 0 (flat, forest, etc.) (AR)

- Include data source for trails and maps (parks Canada data) (AR)
- Include overview map for context, N arrow and scale bar (AR)

**Figure 2** – annotate figure to show the route through the couloir that is rated. Describe why its rated Extreme. Consider adding some terrain measurements (AR27).

**Figure 3** – provide more context (slope angle), show how an ATES v.2 map would classify this terrain (AR28).

- Consider adding the two figures (slope angle/forest distributions) to help explain (GS).

**Figure 4** – show routes through the terrain, describe it as Complex and why (AR27)

**Figure 5** – highlight the deposition zone and discuss the terrain rating and why (AR29) describe planar slope feeding directly into a terrain trap.

**Figures 6,7,8** – highlight different zones and terrain ratings, particularly areas that might propagate into nearby starting zones (AR). Good place to show frequencies.

**Figure 9** – improve the caption to describe the need for additional research into colour choices (SH7) (EB2)

- Include new figure obtained directly from Huber et al and check Christophe’s email comments on this figure to add to caption (GS).

**Figure 10** – Include overview maps, orientation and scale. Ensure 10b is not arbitrarily cut off and is easily interpretable without local knowledge; consider redesigning the figure (AR).

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**Tables 1, 2 and 3** – change to figures to accommodate NHESS limitation on colour tables, then revise all figure numbers and check all references.

**Table 3** – Revise language in Slope Shape row using language from SH peer review response (SH12) (AR17).

- Revise slope angle and forest density according to James Floyer suggestion (JF)
- Replace units (avalanches:years) on frequency section (EB10).
- Class 0 frequency-magnitude change to “**Never > size 1**” (AR11).

**Table 4** – clarify meaning of “large proportions” and try to use a % value (HPM1). It was ultimately removed from this table.

- Check slope angle terminology/definitions to ensure they align with Comm/Tech models

**Table 5** – cite as “modified from Campbell and Gould (2013).” (EB)

**Table 6** – cite as “modified from Campbell and Gould (2013).” (EB)

**Table 7** – Change “Rare” to “Extremely low” (BG/CC)

**Table 9** – Add RGB and Hex codes to the table following/citing Sykes (2024) (AR)