

Referee commentary

egusphere-2026-4761

Manuscript: An extensible, algorithmic framework to enumerate, ascertain, and compare mechanical properties from common snowpit observations

General assessment

This manuscript addresses a useful question: which mechanical properties can be estimated from routine snowpit observations, under which assumptions, and with what sensitivity to the choice of published parameterizations? The graph-based framework makes dependencies and alternative calculation methods explicit. The application to SnowPilot records demonstrates the value of systematically examining input availability and disagreement among slab-property estimates.

I recommend major revision while supporting the underlying contribution. The manuscript would benefit from clearer scientific exposition and more explicit separation of observational limitations, source-study applicability, and implementation choices. These distinctions are important because the reported coverage and uncertainty are conditional on the selected methods and processing rules. My principal requests concern making those conditions reproducible and interpreting the results accordingly.

Major comments

1. Revise the abstract to communicate the research question and findings

Lines 1–13.

The abstract requires substantial revision to communicate the research question, approach, and principal findings to readers unfamiliar with the framework. Terms such as “calculation pathway,” “coverage,” and “shear weight with elasticity” are introduced without sufficient explanation, making the numerical findings difficult to interpret.

Please first explain the underlying problem: mechanical properties needed by avalanche-release models are seldom measured directly, and alternative relationships used to estimate them may differ in applicability and produce substantially different values. Then describe, in plain language, how the framework systematically compares these alternatives.

The findings should explain what was learned, rather than primarily listing processing counts and percentages. In particular, distinguish limitations caused by unavailable observations from those imposed by the selected parameterizations, and explain that the choice of Young’s modulus relationship strongly affects estimated bending stiffness. Define the coverage denominator and clarify that the stiffness comparison concerns a restricted rounded-grain subset and that the reported uncertainty excludes parameterization uncertainty. Close with the significance of these findings for assembling and interpreting mechanical-model inputs.

2. Make the scientific argument easier to follow

Lines 15–26, 46–94, 95–125, and 224–246.

The introduction should explain how the input requirements of stress-based and fracture/energy-based slab models motivate the framework. Statements about advances in modeling need enough physical

context to identify the specific problem being addressed. Consolidate the repeated objectives and connect the short background paragraphs into a coherent progression from observations to mechanical inputs and alternative parameterizations.

The methods should prioritize the calculation logic and assumptions. Detailed class descriptions could be condensed or moved to supplementary documentation, while retaining the graph traversal, shared-input consistency, applicability checks, and one worked calculation in the main text. Integrate equations into complete explanatory sentences and emphasize physical findings when summarizing the literature.

3. Document the distinction between source-supported and implemented applicability

Lines 155–170, 174–216, 324–326, and 425–431; Table 3.

Section 4.3 acknowledges that the implemented grain-form domains do not always coincide with those of the source studies. This information belongs in the methods because it directly affects pathway coverage. Expand Table 3 to distinguish original calibration domains, implemented domains, and the rationale for any extension or restriction. In particular, clarify the use of the Köchle Young’s modulus fits for melt forms, the Wautier grain-form mapping, and the density-domain treatment of the Schöttner relationships.

Where consequential domain choices affect the headline coverage, provide a limited sensitivity comparison or explicitly qualify the results as conditional on those choices. A pathway that executes successfully under a software rule is not necessarily supported by the source study for that snow type or density.

4. Describe quality control and slab construction operationally

Lines 115–123, 331–338, and 413–419.

The acknowledgment of variable observer expertise is helpful, but the methods should describe the checks actually applied to the records. Explain how implausible values, inconsistent layer geometry, duplicate records, and repeated ECT results are handled. For failure depths at a layer boundary or within a recorded layer, state how the weak layer and overlying slab are identified, including any tolerances or exclusions.

Density is a shared input to several downstream calculations, making the exact depth–thickness matching policy consequential for the coverage results. Reproducibility alone does not justify excluding density samples wholly contained within a recorded layer. Please justify this restriction in terms of measurement representativeness and quantify the observations it excludes. Provide a focused comparison with a documented within-layer assignment rule, or explain why such an assignment would be inappropriate. This would help distinguish observational scarcity from exclusions introduced by processing.

Report the number of unique pits contributing the 14,776 slabs and explain how repeated tests or multiple slabs sharing observations are counted. These details would make the example population and its limitations much easier to assess.

5. Define coverage relative to the calculation policy

Lines 301–316 and 341–360; Figures 7 and 8.

The reported maxima describe the best individual pathways. Also report the fraction of slabs accessible through at least one implemented pathway, distinguishing this union from individual-pathway coverage. Separate missing observations, unsupported grain forms, out-of-range values, and processing exclusions when explaining pathway failures, with a stated treatment of overlapping reasons. These categories

identify different opportunities for improving coverage.

The target “shear weight with elasticity” also needs a precise definition. Equations (1)–(3) calculate weight independently of elastic properties; the additional target appears to test simultaneous availability of shear weight, Young’s modulus, and Poisson’s ratio. Rename or define it as an input-availability requirement and use that interpretation consistently.

6. Specify what the uncertainty estimates represent

Lines 127–153 and 376–381; Figure 10.

Provide a compact table of assigned observation uncertainties, their statistical meaning, and their basis. Clarify whether each stated uncertainty is a standard deviation or a plausible range, how hand-hardness subclasses are encoded numerically, and whether grain-form misclassification is omitted. State the dependence assumptions among inputs and layers, including treatment of shared layer boundaries and correlations inherited from reuse of the same observation.

Explain how uncertainty crossing a method’s validity boundary or the Köchle density breakpoint is treated. Assess first-order propagation for representative nonlinear calculations, for example against a limited Monte Carlo comparison with specified input distributions. Large relative uncertainties warrant this check but do not alone establish that linear propagation is inadequate.

Define the aggregation used to obtain the median relative uncertainty of 78.4%. Because parameterization uncertainty is excluded, label this result consistently as propagated measurement uncertainty conditional on the selected relationship. Comparisons between pathway separation and error bars should acknowledge that distinction.

7. Clarify the geometric and physical meaning of the stiffness comparison

Lines 78–85, 174–216, 362–381, and 404–412; Equations (8)–(9).

Define the origin, orientation, and units of the layer coordinates used to calculate B_{11} and D_{11} , including how they are obtained from field observations. These stiffness coefficients depend on the reference plane. Specify the reference used consistently across slabs and pathways and explain why the reported D_{11} is the appropriate quantity for comparison.

The source relationships also differ in measurement method, loading regime, and treatment of anisotropy. Explain how these differences affect interpretation of their numerical spread. The common-subset analysis is useful, but its 317 slabs contain only rounded-grain parent classes and 258 are single-layer slabs. State these restrictions alongside the headline results in the abstract and conclusions. The comparison demonstrates sensitivity to parameterization choice within this subset; it does not establish the accuracy of individual pathways or general behavior across all slab types.

Minor comments

1. **Lines 43–44, Table 1 caption, and line 463:** The stated interval, 1 September 2014 to 31 August 2025, spans 11 years rather than 10. Reconcile the dates, water-year convention, and duration.
2. **Lines 65–75:** Distinguish tensor order from spatial dimension. The reduction to 21 independent elastic constants requires the major symmetry in addition to the minor symmetries; clarify the assumptions underlying that reduction.
3. **Line 85; Equations (7)–(10):** Identify $\kappa = 5/6 \approx 0.833$ explicitly as the numerical shear-correction factor, and distinguish A_{55} from the corrected stiffness κA_{55} .

4. **Lines 376–381 and 479–481; Figure 10:** A spread ratio of 63 is associated with the selected 90th-percentile example, whereas the abstract and conclusions state “up to 63.” Report the maximum or describe 63 consistently as the selected example’s value. The claim that estimate range grows as pathways lengthen also needs direct evidence or narrower wording.
5. **Lines 417–424:** Please clarify whether the analyzed observations were restricted to dry snow and describe any wetness screening. Distinguish the snow conditions represented by the selected records from those supported by the implemented parameterizations. Briefly discuss the challenges of extending the framework to wet-snow slab problems, including liquid-water-dependent mechanical properties and weakening at layer interfaces. A new wet-snow analysis is not required, but this discussion would clarify the limits of the present implementation and the additional observations and relationships an extension would require.
6. **Code and Data availability statements:** Identify the software release or commit, analysis scripts, and exact data export or record-selection information needed to reproduce the results. Briefly describe implementation checks, including comparison with independent calculations for representative pathways.
7. **Throughout; Figures 2, 4, 6, and 10:** Complete a careful editorial pass for typographical errors, terminology, equation integration, and readable figure labels. Reconcile Figure 2’s Rutschblock/PST discrepancy. Examples requiring correction include “a failure criteria” (line 59), “have have” and “mechancial” (line 459), and “develeoped” (line 460).