The use of rockfall data in statistical analysis and hazard zoning

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Introduction

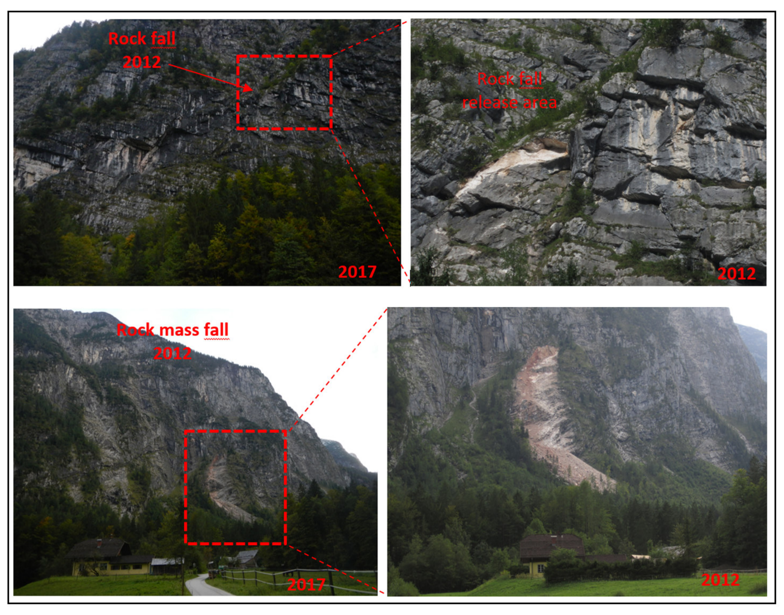

Fig. 1: Estimation of temporal occurrence/age of a rockfall or rock mass fall based on the rock colour in Dachstein limestone (Melzner et al., 2023). .

Information about rockfalls is stored in "inventories", "catalogues", and "records". These terms are often used synonymously in the literature. The collection of rockfall data is normally adjusted according to the research objectives and the project framework i.e., the financial and temporal constraints, the project goals, and the size and settings of the study area. The characteristics and quality of the resulting rockfall catalogues depends on (i) the setting and characteristics of the study area (e.g., topography, geology, land use, forest cover), (ii) the accuracy of the base and thematic maps, (iii) the methods and techniques used, (iv) the source(s) of information, (v) the time available for the investigation, (vi) the experience of the investigators, and (vii) the available human, technological and economic resources. Possible criteria for the evaluation of the "quality" of a catalogue of rockfall can be related to the *amount of data*, *level of detail* and *variability of informaton* (Melzner et al., 2020).

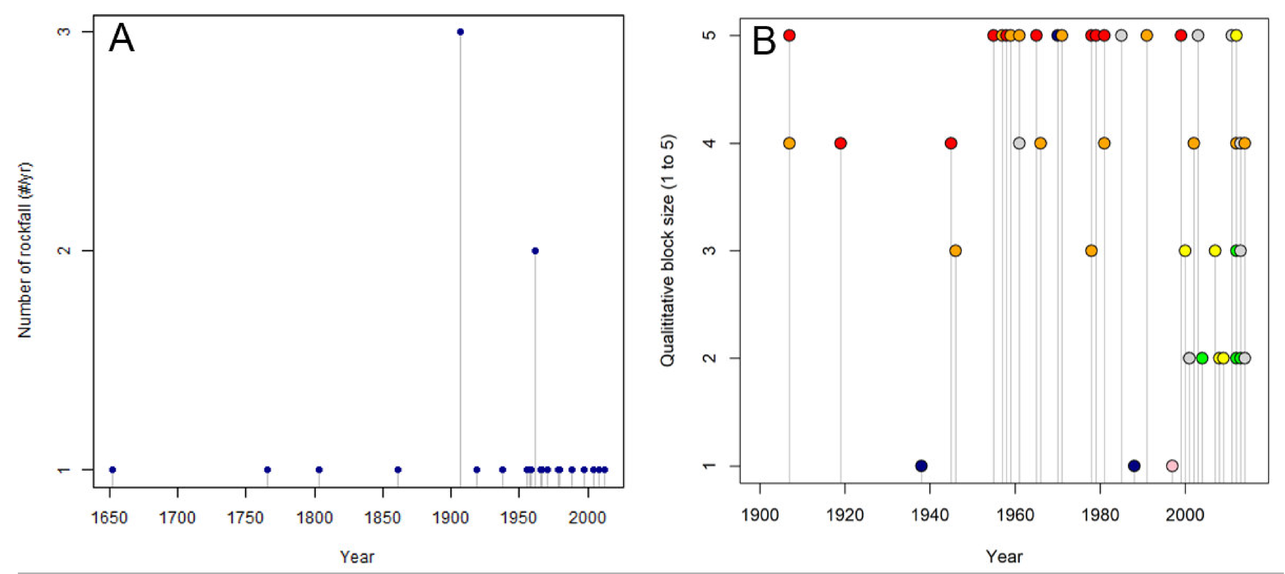

Fig. 2: Relationship between the representativeness of the rockfall time series C_{H8} (A) with respect to rockfall which resulted in consequences C_{H10} (B). Legend of fig. B: red points=very large intensity, orange points=large intensity, yellow points=medium intensity, green points= low intensity, blue points= fatality, rosa points= injury, grey points= no info, grey points= no damage (Melzner et al., 2023).

Temporal occurence of rockfall

Rockfall size

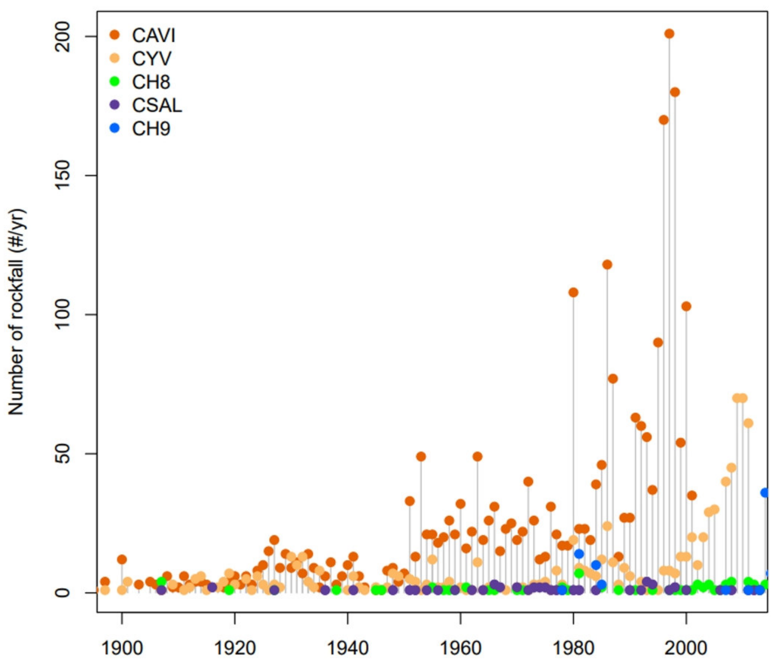

Fig. 3: Comparison of absolute number of rockfalls per year (N_j, (annual rockfall frequency) of five historical rockfall time series in Italy (red), Austria (green, purple and blue) and USA (orange). C_{YV} catalogue 1857-2011 (total number of rockfalls 887), C_{AVI} 1489-2001 (total number of rockfalls 2612), C_{H8} 1652- 2014 (total number of rockfalls 76), C_{SAL} 1907-2016 (total number of rockfalls 53) and C_{H9} 1978-2016 (total number of rockfalls 41) (Melzner et al., 2023).

"Completeness" refers to the proportion of rockfalls contained in the catalogue respect to the total number rockfalls which have occurred. "Representativeness" refers to the degree of a given rock fall sample/subset to reflect the entire rockfall catalogue from which it is derived i.e., a representative rock fall sample should give unbiased statistical inference of what the population is like. "Thematic variability" refers to the amount of imprecision of the identification and classification of a rockfall or a given rockfall feature. "Geographic variability" refers to the amount of imprecision of the graphical representation of a rockfall feature to the real geographic position in the study area (Melzner et al., 2020).

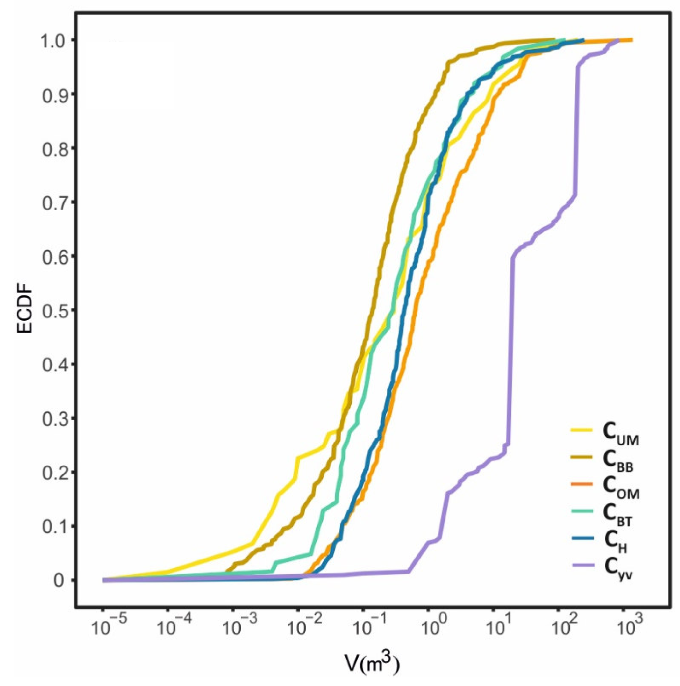

Fig. 4: Comparison of empirical cumulative distribution functions (ECDF) of all catalogues sizes, considering mapping different lithologies and different mapping strategies (Melzner et al., 2020).

Lessons learned

- Historical rockfall data often doesn't contain quantitative information on rockfall size. Qualitative size or damage information has to be interpreted according the rockfall intensity
- Selective mapping i.e., neglecting mapping of large (old) rockfall boulders should be avoided
- Site-specific rockfall surveys for single structures, or subdivision of catalogues for specific analyses may result in a low number of rockfalls, possibly with a reduced volume range
- Estimation of rockfall size in pre-defined size classes is not appropriate for probability density functions (PDF) and CDF models
- The CDF estimations are slightly sensitive to the exclusion of small size boulders, whereas the sensitivity to the exclusion of large sizes is high
- Inferential statistical parametric and non-parametric methods can be used to cope with small datasets and to potentially close data gaps
- From a statistical perspective rockfall datasets should be considered always incomplete. Incompleteness is not necessarily an issue if the datasets are representative
- Information on the mapping method used to collect rockfall data, the type of source information, and references to the sources of information should be part of any rockfall database and choice of analysis

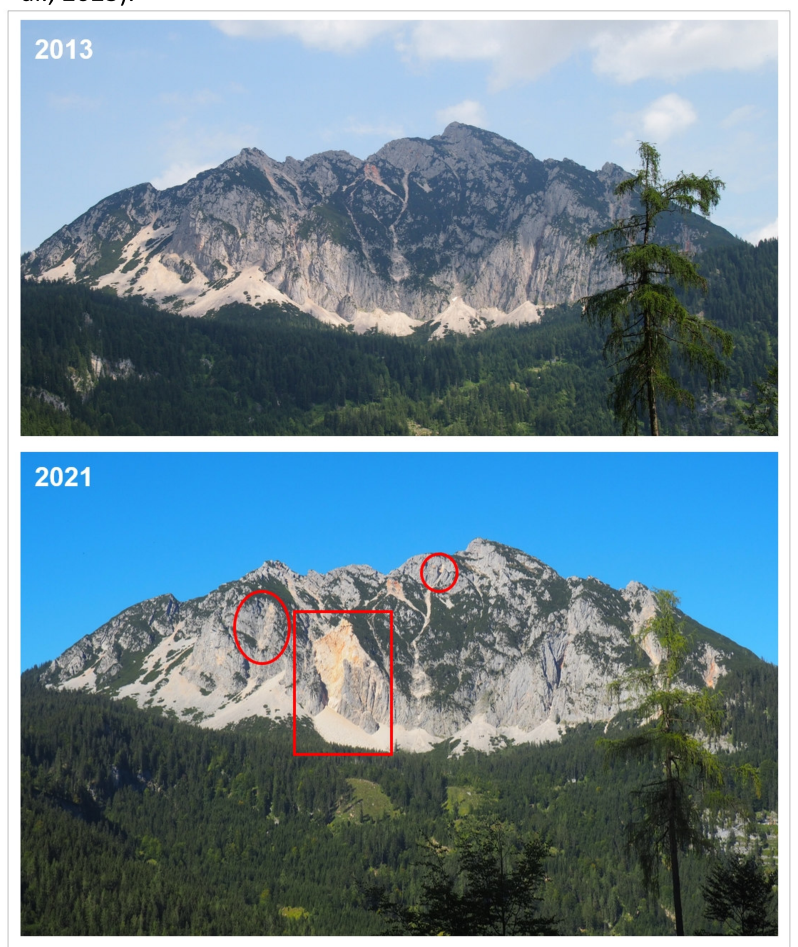

Fig. 5: Progressive rockfall failures may stay active many years; correlations with climatic data from public weather stations should be conducted over longer time-spans and carefully evaluated (Melzner et al. 2023).

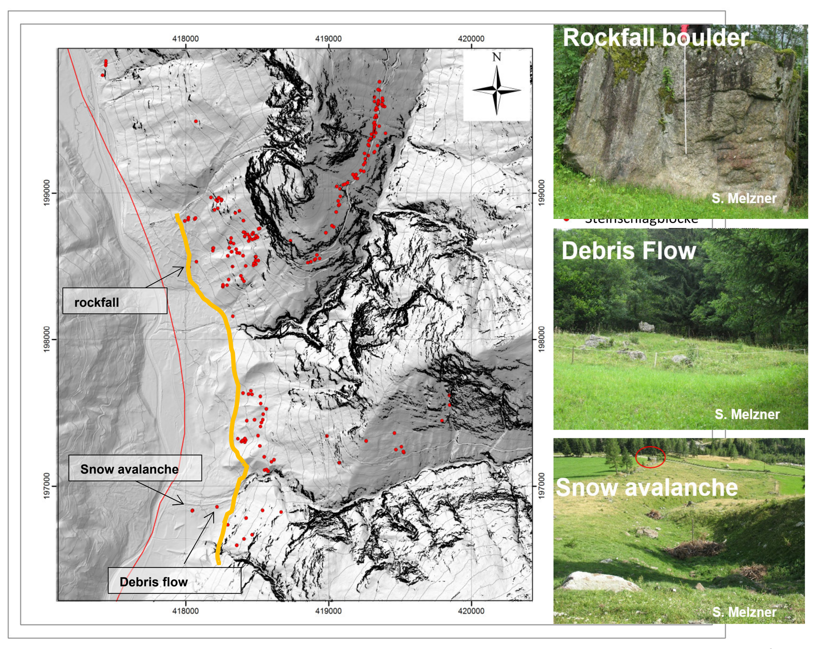

Fig. 6: Thematic and geographic variability depends on the experience of the geologist and the accuracy of the base maps (Melzner et al., 2011).

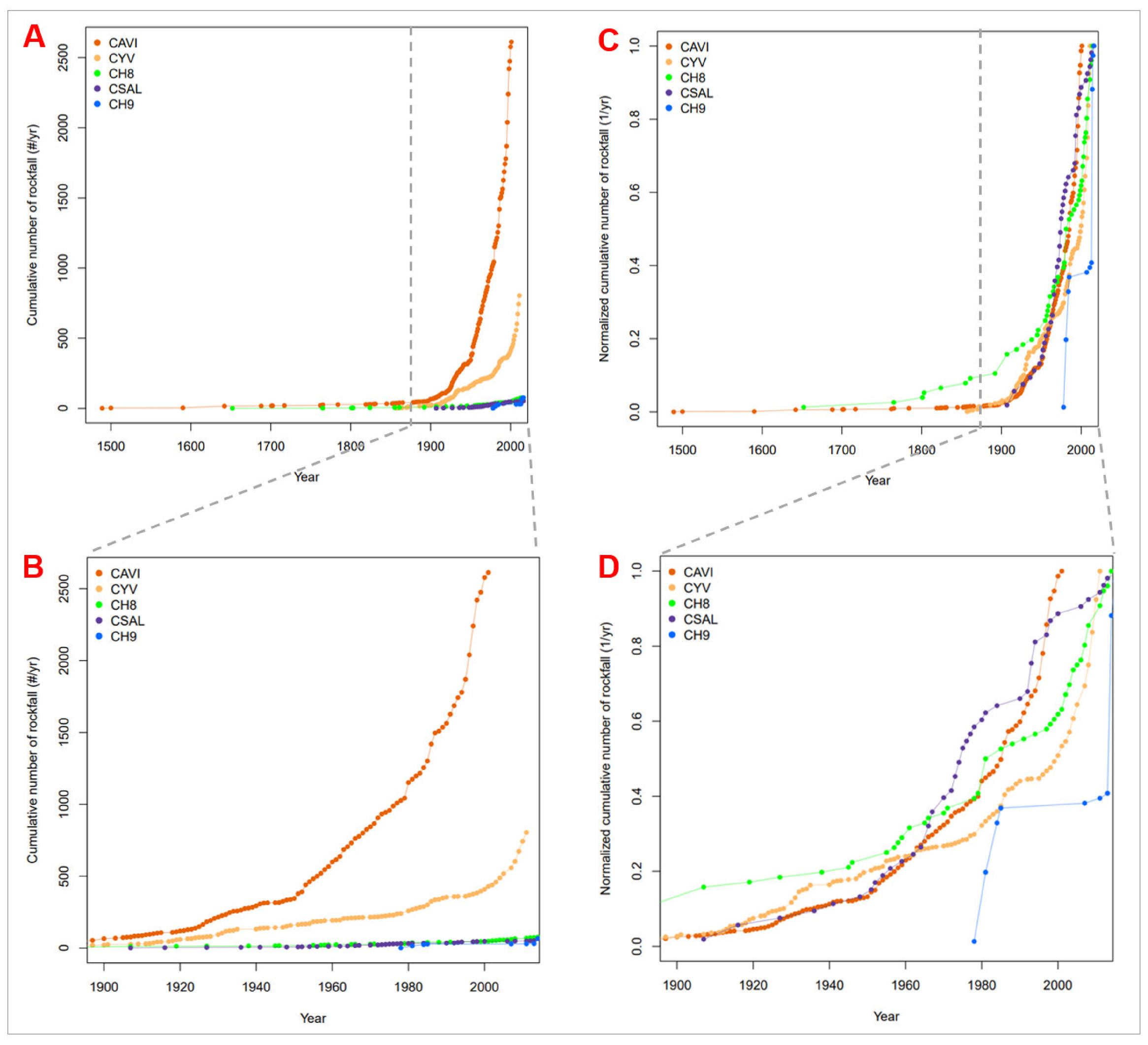

Abb. 7: Comparison of the cumulative number of rockfalls (A & B) and normalized cumulative number of rockfalls (N_{CR}, as a function of year, C & D) of the five historical rockfall catalogues C_{H8}, C_{H9}, C_{YV}, C_{AVI} and C_{SAL} from USA (orange curve), Italy (red curve) and Austria (dark and light blue and green curve) (Melzner et al., 2023).

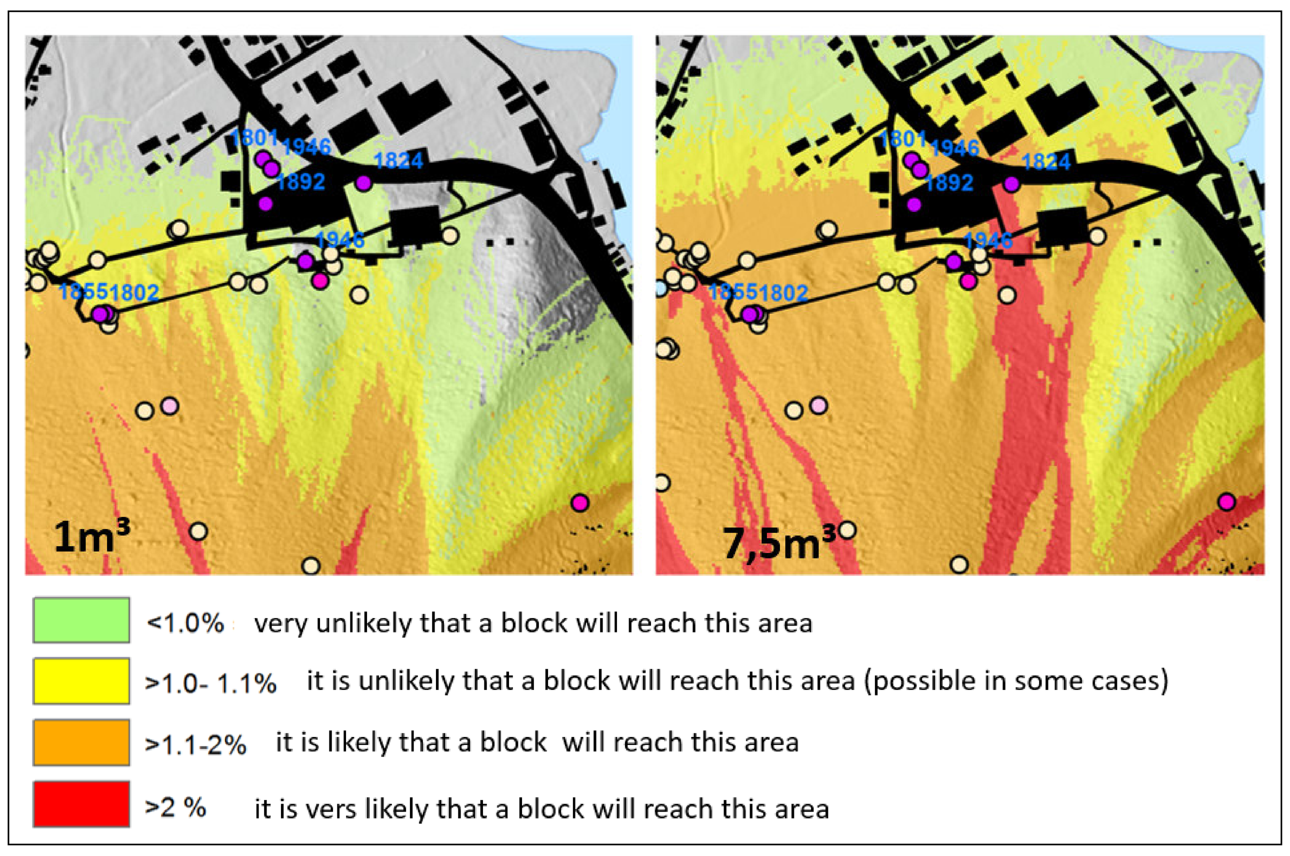

Fig. . 8: Calibration and validation of 3D Rockfall simulation results with mapped boulder sizes (left) and historical rockfall events with no size information (right) for two volume scenarios (1m³ and 7m³) (by s. Melzner 2015).

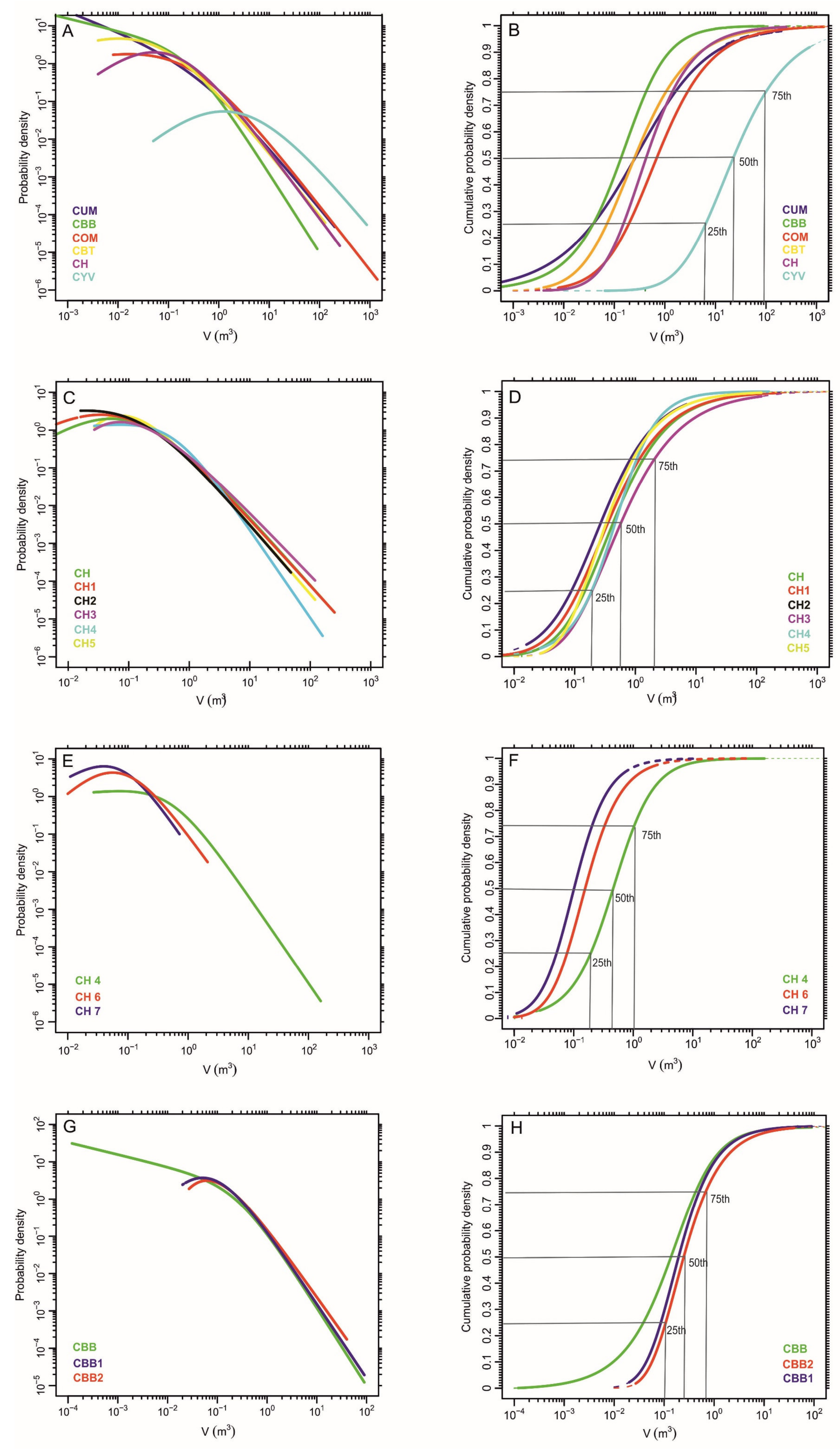

Fig. . 9: Impact of mapping strategy on probability densities of rockfall sizes (A, C, E, G) and cumulative distribution function of rockfall size (B, D, F, H). Dashed curves in plots B, D, F, H show values of distribution function calculated outside the observed volume ranges approximating values of cumulative probability of 0 and 1. The three thin grey lines in the CDF plots (i.e. B, D, F, H) corresponding to 0.25 (25th percentile) 0.50 (50th percentile) and 0.95 (95th percentile) (Melzner et al., 2020).

References

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