

AVALANCHE CROWN DEPTH DISTRIBUTIONS

Edward H. Bair*, Jeff Dozier
Donald Bren School of Environmental Science and Management
University of California, Santa Barbara
Karl W. Birkeland
U.S.D.A. Forest Service National Avalanche Center, Bozeman, Montana

EXTENDED ABSTRACT:

Other researchers have suggested that crown depths follow either a scaling distribution (Birkeland and Landry, 2002; Faillettaz et al., 2004; Rosenthal and Elder, 2003) or a lognormal distribution (McClung, 2003; 2005). A variety of generating mechanisms have been proposed including: Self-Organized Criticality (Birkeland and Landry, 2002; Faillettaz et al., 2004; Louchet et al., 2002), chaotic processes (Rosenthal and Elder, 2003), and components of fracture toughness, including fracture size, creep, bonding and crack propagation (Heierli et al., 2008; McClung, 2005). We test seven distributions on two large avalanche crown depth datasets, from Mammoth Mountain, CA and from the entire Westwide Avalanche Network to determine which fits best.

The generalized extreme value distribution provides a robust fit on path and area scales for crown depths above 30.5 cm at Mammoth Mountain. The most parsimonious explanation is neither self-organized criticality nor other complex cascades, but maximum domain of attraction; that is the maximum crown depth, not the average, is most commonly recorded. This recording bias generates scaling or power law distributions. More field observations on avalanche crown faces are needed to investigate whether individual avalanche crown face depths are scaling. Given the highly variable nature of snow depth, this result would not be surprising.

We also show that avalanches do not have a universal tail index. Rather, they range from 2 to 4 over different avalanche paths, consistent with other geophysical phenomena such as wildfires, which show similar variability (Malamud et al., 2005). We urge practitioners to record crown depth at multiple locations on crown faces. Last, we propose use of the tail index for quantifying stubbornness. Stubborn paths can be identified by their low tail indices.

KEYWORDS: power laws, statistical distributions, extreme value theory, scaling

REFERENCES

- Birkeland, K. W. and C. C. Landry, 2002: Power-laws and snow avalanches. *Geophys. Res. Lett.*, **29**, 1554, doi:10.1029/2001GL014623.
- Faillettaz, J., F. Louchet, and J.-R. Grasso, 2004: Two-threshold model for scaling laws of noninteracting snow avalanches. *Phys. Rev. Lett.*, **93**, 208001, doi:10.1103/PhysRevLett.93.208001.
- Heierli, J., P. Gumbsch, and M. Zaiser, 2008: Anticrack nucleation as triggering mechanism for snow slab avalanches. *Science*, **321**, 240-243, doi:10.1126/science.1153948.
- Louchet, F., J. Faillettaz, D. Daudon, N. Bédouin, E. Collet, J. Lhuissier, and A.-M. Portal, 2002: Possible deviations from Griffith's criterion in shallow slabs, and consequences on slab avalanche release. *Nat. Haz. Earth Syst. Sci.*, **2**, 157–161.
- Malamud, B. D., J. D. A. Millington, and G. L. W. Perry, 2005: Characterizing wildfire regimes in the United States. *Proc. Nat. Acad. USA*, **102**, 4694-4699, doi:10.1073/pnas.0500880102.
- McClung, D. M., 2003: Size scaling for dry snow slab release. *J. Geophys. Res.*, **108**, 2465, doi:10.1029/2002JB002298.
- , 2005: Dry slab avalanche shear fracture properties from field measurements. *J. Geophys. Res.*, **110**, doi:10.1029/2005JF000291.
- Rosenthal, W. and K. Elder, 2003: Evidence of chaos in slab avalanching. *Cold Reg. Sci. Technol.*, **37**, 243-253, doi:10.1016/S0165-232X(03)00068-5.

* Corresponding author address: E. H. Bair, University of California, Donald Bren School of Environmental Science and Management, Santa Barbara, CA 93106-5131, Email: nbair@bren.ucsb.edu