3. Playing with cellular automata

It is not because we are interested in avalanche hazards that I would like to speak of the "game of life". This game, devised by the british mathematician John H. Conway in 1970, is also named "cellular automaton". It is usually made of a checkerboard in which a "state" is given to every cell, which may change according to preestablished rules (see for instance https://en.wikipedia.org/wiki/Conway%27s_Game_of_Life).

We built such an automaton [1] in order to better understand slab avalanche triggering mechanisms. The board represents both the weak layer (WL) and the slab, seen from above. Two local failure criteria are introduced: one deals with the WL, the second one with the crown crack.

The load experienced by a cell defines its "state", represented by different colors, increasing from dark blue to blue, green, yellow, and red. The red state corresponds to the preestablished cell failure threshold. We start with all cells set in the same state. Snowflakes are then allowed to fall down at random on the board, gradually and randomly changing the cell states (video #1). When a cell becomes red, it fails, and its load is redistributed on its neighbors. If one of them was already yellow, i.e. close to the threshold, it becomes red and fails in turn, and so on. Such rules yield a behavior quite similar to chain reactions that take place during domino avalanches or nuclear fission, and eventually leads to a critical state for which the collapse would extend to the whole board. But this phenomenon alone does not fully describe avalanche release.

This is the reason why the second criterion is introduced to account for crown crack opening. The algorithm analyzes tensile stresses between neighbor cells, i.e. load differences between cells of different colors. When such tensile stresses reach a second preestablished threshold, the corresponding cells separate from one another, initiating a crack in the slab, which becomes unstable and opens after several computer steps, triggering the avalanche (video #1: https://youtu.be/I-2KElgLwR8).

These simulations illustrate Griffith's rupture criterion described in my 1st note. The starting zone sizes can be easily identified. Their statistical distribution is obtained analyzing a large number of simulation runs. It exhibits a very particular mathematical feature, named "power law distribution", in perfect agreement with field measurements, and quite similar to those found for landslides, rockfalls, and also earthquakes (Richter law). Such an agreement validates the step by step triggering scheme occuring in 4 stages, that will be discussed in my 5th note:

i) WL failure initiation by local collapse
ii) basal crack expansion if the slope angle is large enough
iii) crown crack nucleation
iv) crown crack Griffith's destabilization, and avalanche release.

This cellular automaton can also simulate artificial triggerings (video #2 : https://youtu.be/5JylApHZ6iw)

[1] J. Faillettaz, F. Louchet & J-R. Grasso, Two-threshold model for scaling laws of non-interacting snow avalanches, Physical Review Letters 93, n° 20, 12 nov. 2004

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