Self-Organized Criticality and Landslide Models

Mario Nicodemi

Complexity & Theor. Phys., Univ. of Warwick

Outlook:

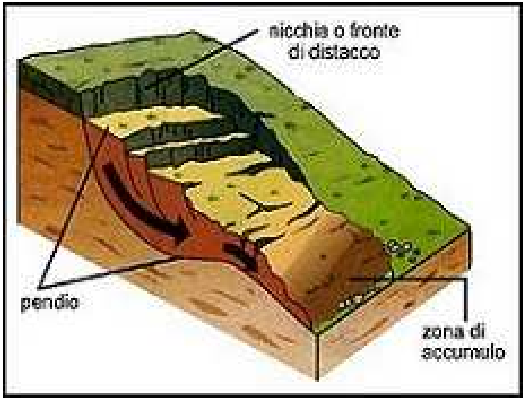
- Empirical landslides size distribution
- Models of Self-Organized Criticality (SOC)

☐ Landslides and the "Factor of Safety"

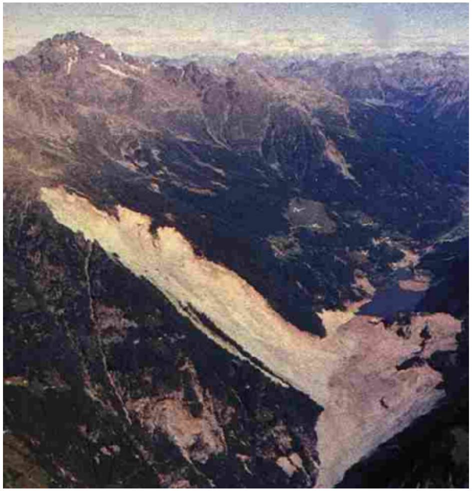
- The Mohr-Coulomb criterion states that a landslide occurs if the shear stress is higher than a maximal threshold. The "Factor of Safety" is: $FS = \tau_{max}/\tau$

  if $FS > 1$ the system is stable

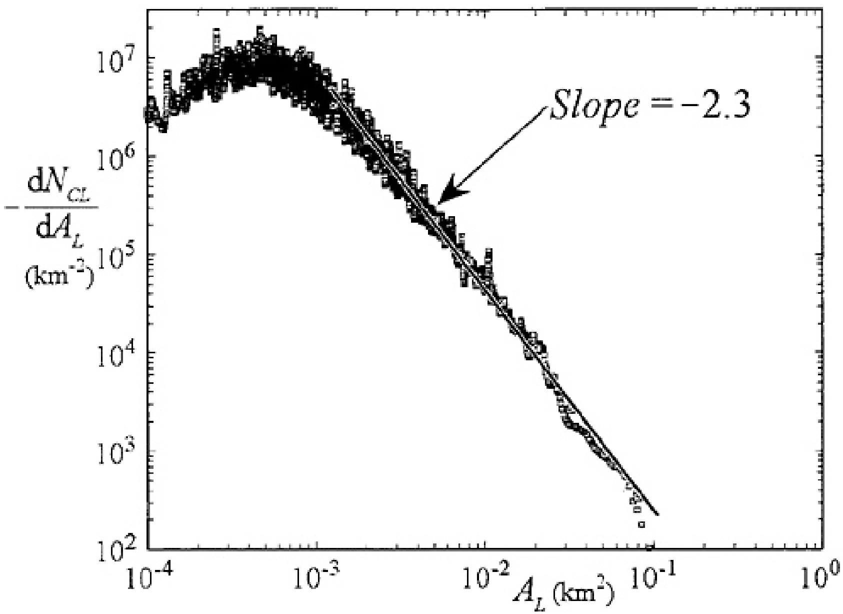
  if $FS < 1$ the system is unstable

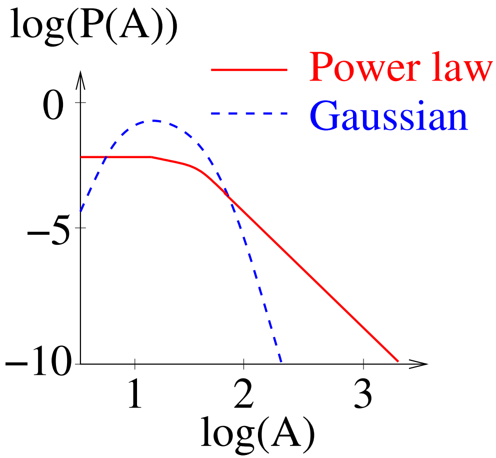


- Empirically, we see that the scale of a landslide can span a range from micro up to macroscopic scales: broad **size distribution**.



□ Size distribution



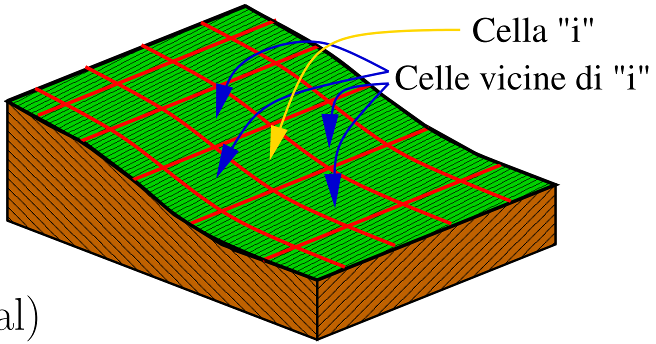


Empirical data show **power law** distributions

$\Longrightarrow$ underestimation of **extreme events**

(Turcotte et al. PNAS 2002).

□ A schematic model



- The surface of the region is divided in **cells**, where we define: $e(i) = 1/FS(i)$
- The system evolves (e.g., under rainfal) with a given 'velocity', ν (*driving rate*):

$$t \longrightarrow t + \Delta t \quad \Longrightarrow \quad e(i) \longrightarrow e(i) + \nu$$

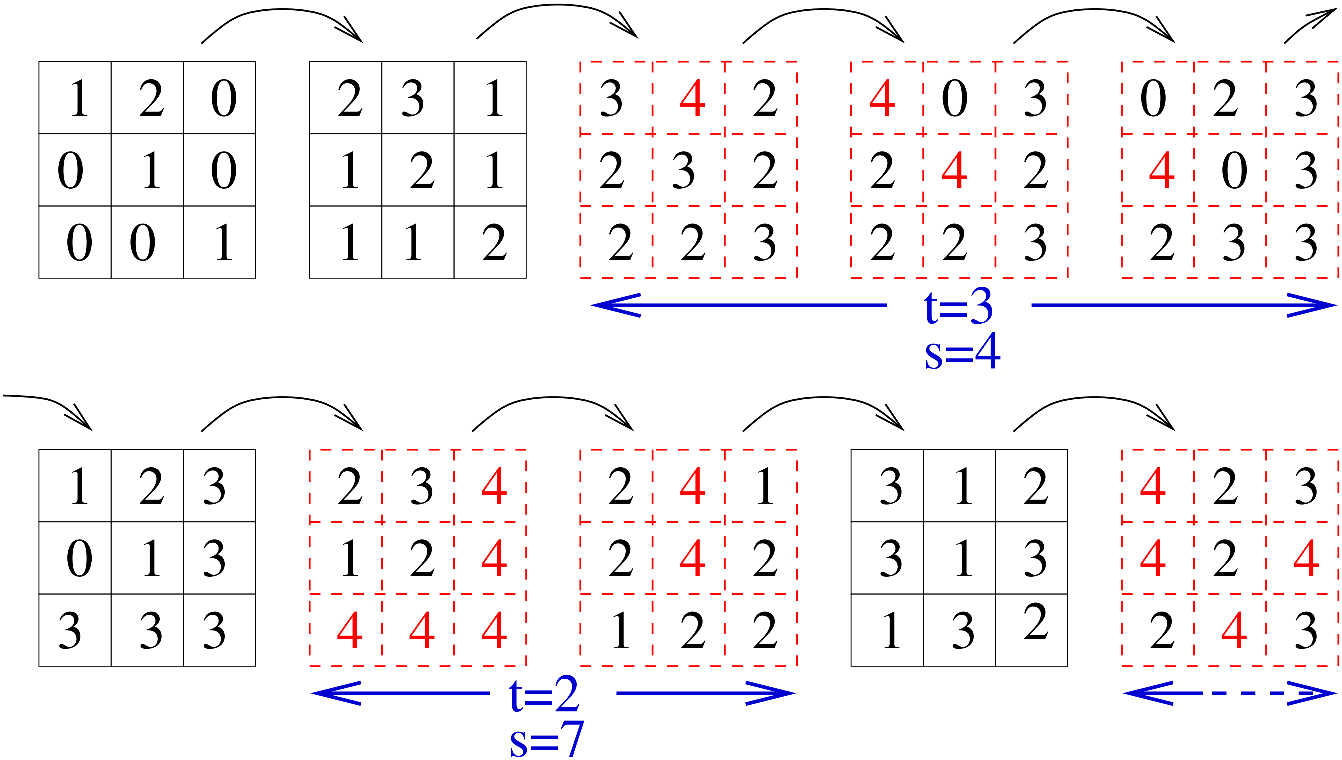
- If cell "i" goes above threshold ($e(i) > 1$) an "avalanche" starts:

$$e(j) \longrightarrow e(j) + f \cdot e(i) \qquad \text{where "}j\text{" is a n.n. of "}i\text{"}$$

$$e(i) \longrightarrow 0 \qquad f = \text{fraction of "}i\text{"} \longrightarrow \text{"}j\text{"}$$

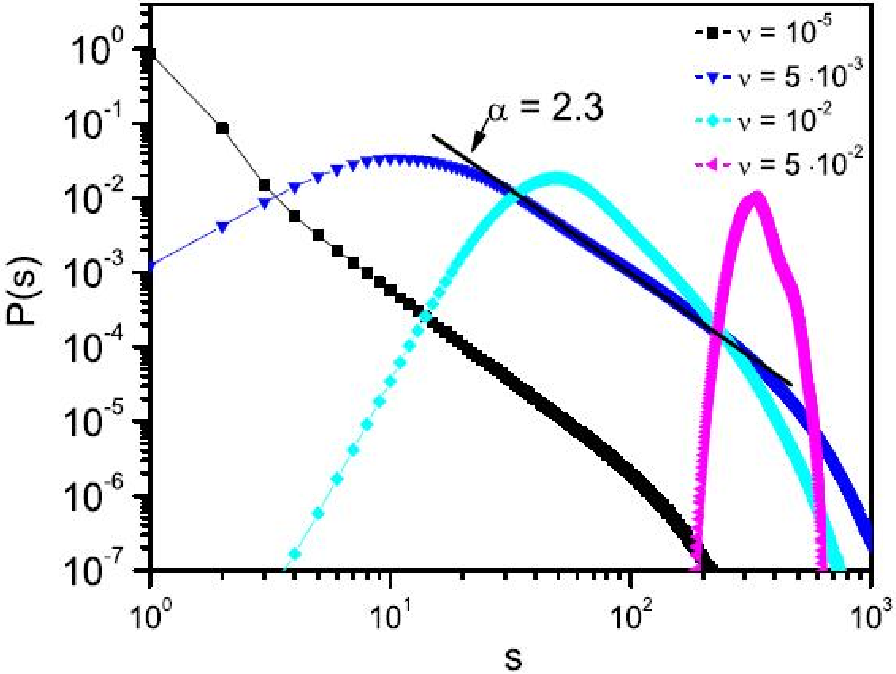
- If there are more cells where $e > 1$ repeat previous step

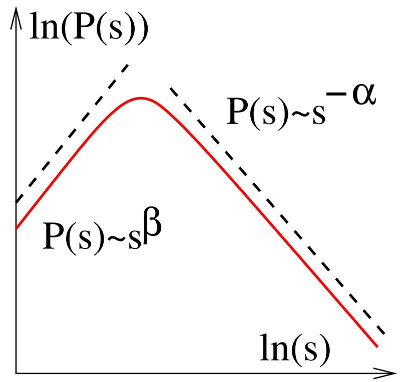
☐ Example



Here, for simplicity, the threshold value is set to 4, and the driving rate ν=1

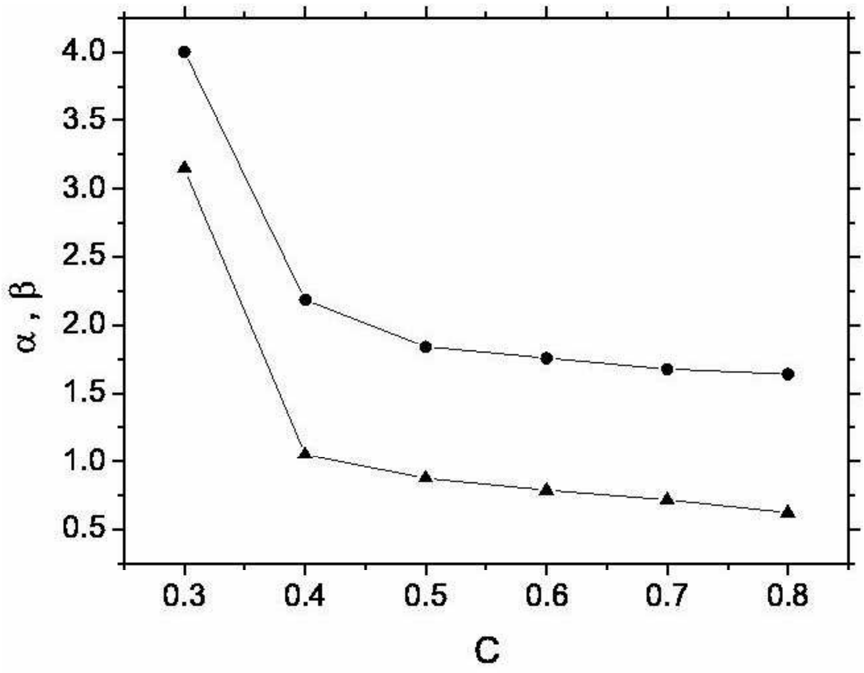
□ 'Landslide' distribution

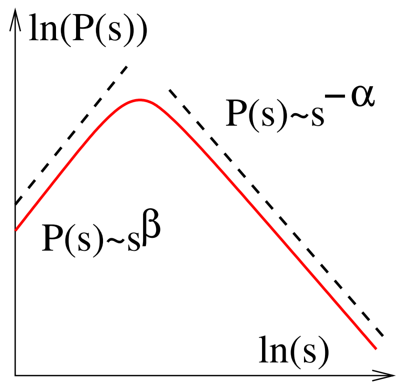




Size distribution of 'avalanches', $\mathbf{P}(\mathbf{s})$ (for the shown driving rates, ν)

□ Critical exponents

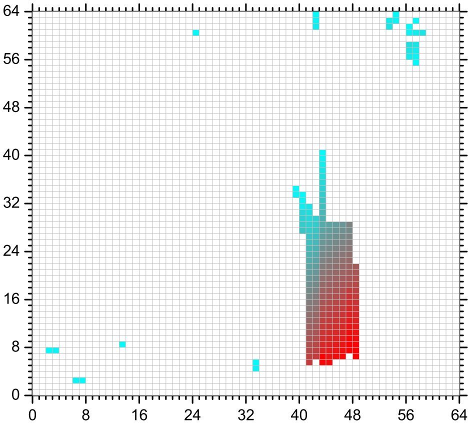


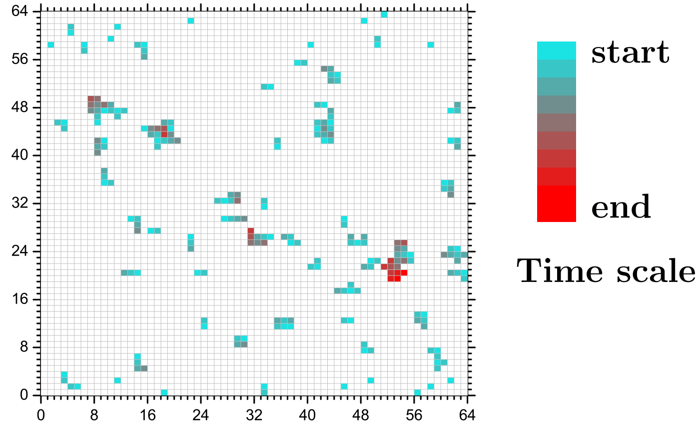


- Exponents as a function of the "conservation level", $C = z \cdot f$, in the critical region.

□ Space structure of FS

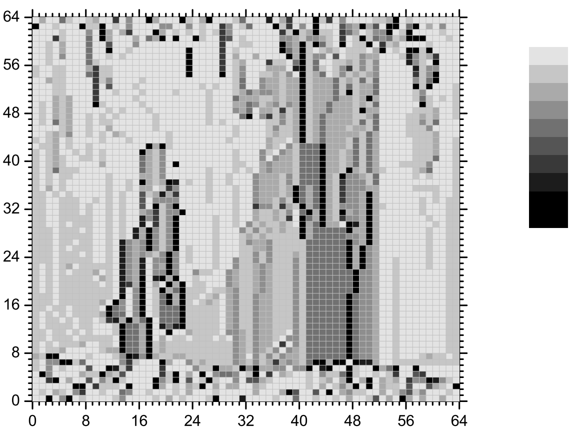
- **Landslide shape**

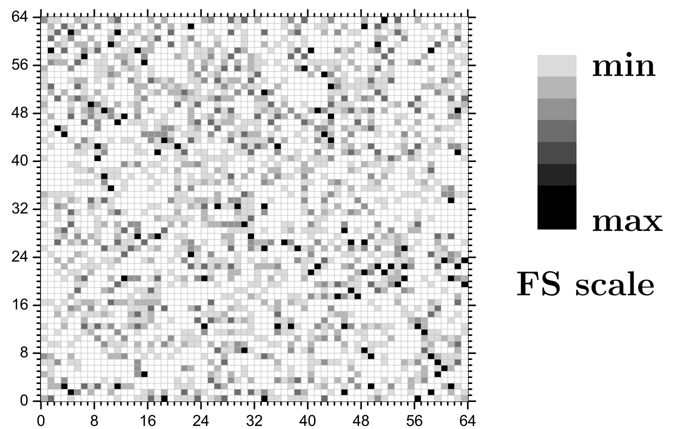




Time scale

- **Factor of Safety**



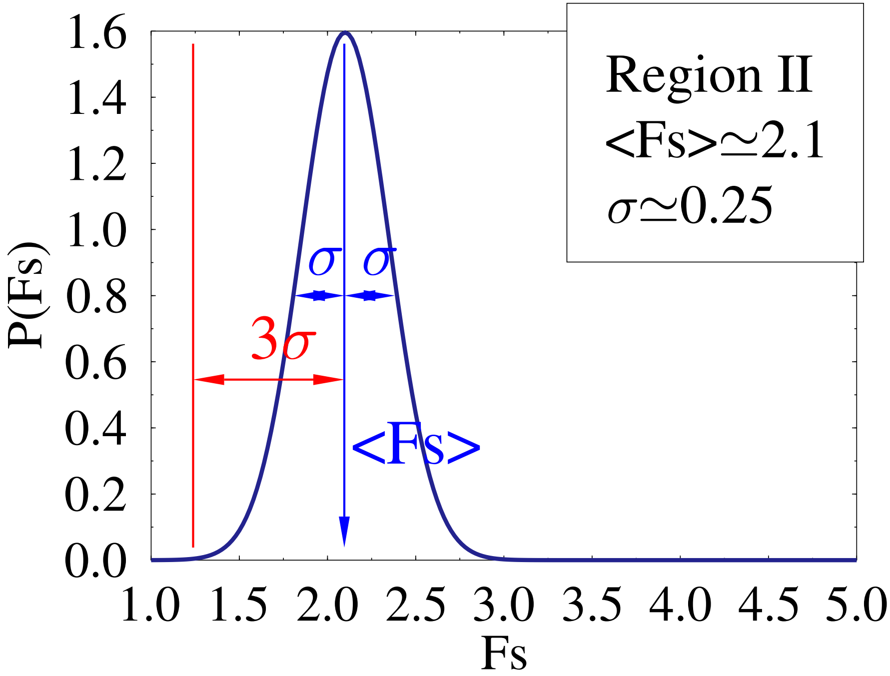


FS scale

Critical region

Non critical region

☐ The distribution of $P(FS)$



Even in the critical region the PDF of the Factor of Safety, $P(FS)$, is *Gaussian* and no signs of 'danger' appear from it. In the critical region, though, catastrophic events are very likely.