Discussion

Real-World Data beyond Event-Size Distributions and Temporal Correlations

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Models in the Context of SOC

Fundamental Questions

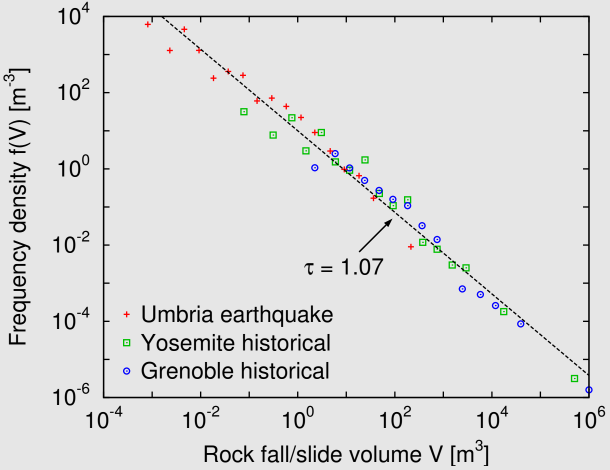
Does the model show SOC?

- Event-size distribution
- Temporal correlations

Does the model capture the considered phenomenon?

Example: Rockfalls and Rockslides

Power-Law Distribution of Rockfalls and Rockslides



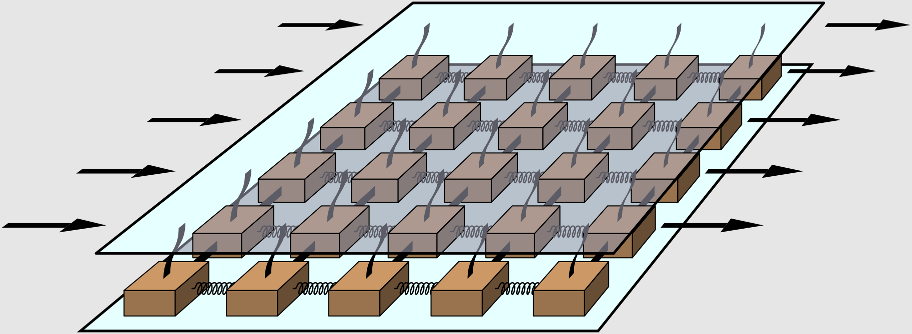
Data: Dussauge et al.: Probabilistic approach to rock fall hazard assessment, Nat. Hazards Earth Syst. Sci., 2002; Malamud et al.: Landslide inventories and their statistical properties, Earth Surf. Process. Landforms, 2004

Example: Rockfalls

Bak-Tang-Wiesenfeld (BTW) Model

- BTW model is often called sandpile model.
- Scaling exponent $\tau = 1.27$ of the BTW model is not too bad compared to $\tau \in [1.07, 1.52]$ found for rockfalls.
- Temporal correlations of rockfalls are unclear.
- Model rules of the BTW model cannot be easily related to rockfalls or even sandpile dynamics.

The Olami-Feder-Christensen (OFC) Model



Achievements of the Olami-Feder-Christensen (OFC) Model

The OFC model reproduces:

- Gutenberg-Richter law (power-law size distribution)
- Occurrence of almost periodic (so-called characteristic) earthquakes
- Foreshocks and aftershocks according to Omori's law

$$N(t) \;\propto\; \frac{1}{|t - t_m|^p}$$

where

$$\begin{aligned} N(t) &= \text{mean number of foreshocks / aftershocks per time} \\ t_m &= \text{time of mainshock occurrence} \\ p &\approx 1 \end{aligned}$$

Hergarten & Neugebauer: Foreshocks and aftershocks in the Olami-Feder-Christensen model, Phys. Rev. Lett., 2002

Achievements of the Olami-Feder-Christensen (OFC) Model

- Mean number of foreshocks and aftershocks as a function of the mainshock magnitude

  Helmstetter, Hergarten & Sornette: Properties of foreshocks and aftershocks ..., Phys. Rev. E, 2004

- Occurrence of some big earthquakes without any foreshocks and aftershocks

  Hergarten: Self-organized Criticality in Earth Systems, Springer, 2002

- Mean stress drop is independent of the earthquake magnitude.

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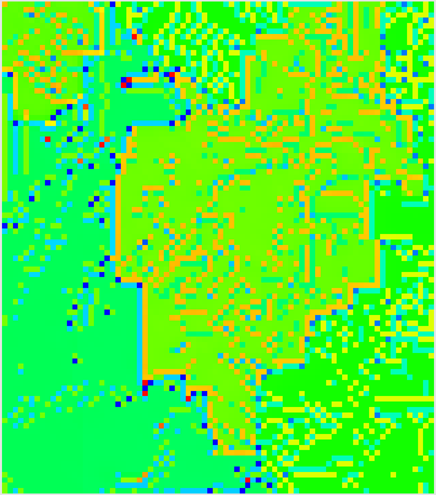
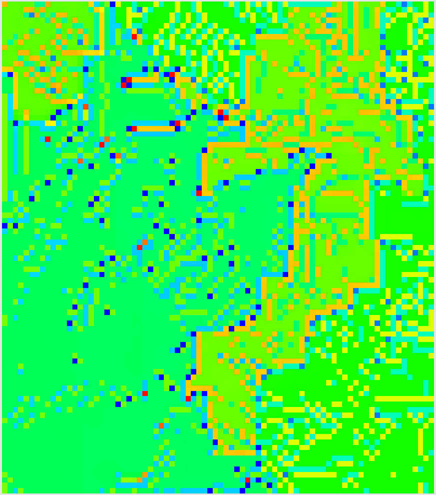
A perfect model?

Stress Patterns in the OFC Model

Immediately before an earthquake



Immediately after the earthquake

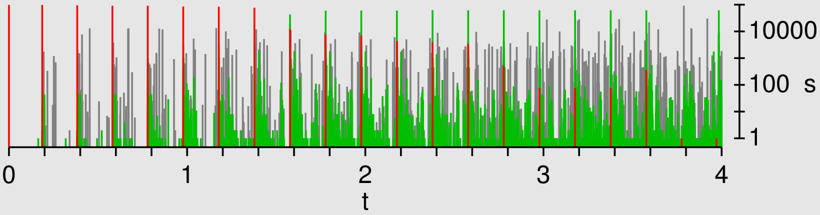


How does the OFC Model Work?

- (Apparent) criticality arises from long-term synchronization of almost periodic earthquakes.

Middleton & Tang: Self-organized criticality in nonconserved systems, Phys. Rev. Lett., 1995

- Foreshocks and aftershocks originate from desynchronization of characteristic earthquakes.



Hergarten & Krenn: Synchronization and desynchronization in the Olami-Feder-Christensen earthquake model, Nonlin. Processes Geophys., 2011

Rockfalls

New "Sandpile-Inspired" Model

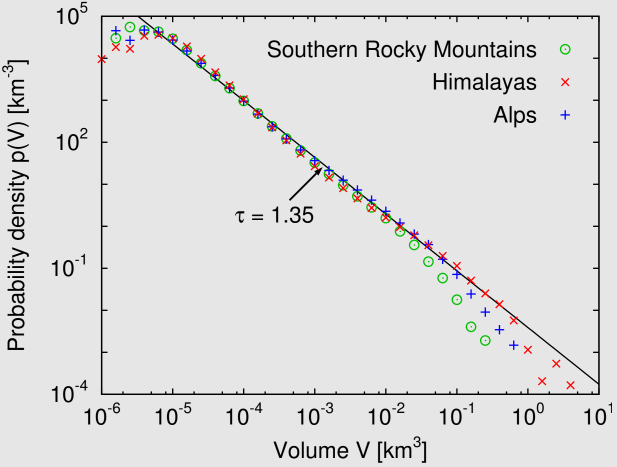
- Based on local slope s in direction of steepest descent among the 8 nearest and diagonal neighbors
- Random triggering

$s \leq s_{\text{min}}$:	stable
$s \geq s_{\text{max}}$:	unstable
$s_{\text{min}} < s < s_{\text{max}}$:	probability of instability

$$p = \frac{s - s_{\text{min}}}{s_{\text{max}} - s_{\text{min}}}$$

- In case of instability:
  - Remove material until $s = s_{\text{min}}$
  - Trigger all neighbors

Direct Application to a Real Topography



Hergarten: Topography-based modeling of large rockfalls and application to hazard assessment, Geophys. Res. Lett, 2012

New "Sandpile-Inspired" Model

- Power-law distribution with $\tau \approx 1.35$ fit well into the range $\tau \in [1.07, 1.52]$ found in nature.
- Several mountainous topographies on earth seem to be (slightly sub-) critical with respect to the model.

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Measurable property beyond event-size distribution and temporal correlations

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Strengthens the trust in the model