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Link to abstract

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Understanding geoscientific **system dynamics with ML** models trained with numerical simulation data

What?

- **Minimal models** simplify complex systems to study their dynamics.
- With ML, we can **automatize** the model simplification process.

How?

- A semi-arid **hillslope ecosystem**, described by its biomass and soil depth, is used as case study.
- An **ANN** is trained on data simulated by a numerical model (see Methodology).

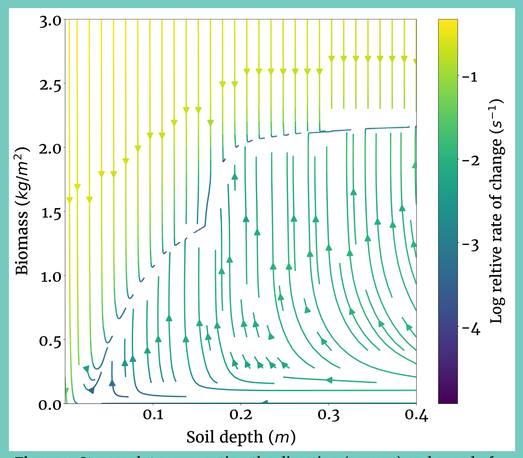

Figure 1: Streamplot representing the direction (arrows) and speed of change (colour) in the system state, in terms of biomass and soil depth, obtained from the ANN model for a grazing pressure of g=1.76 $kg/m^2/yr$.

- Analysing the ANN, we obtain **novel insights** into system dynamics (Figure 1).

So what?

- ML-powered minimal models can obtain more **accurate** results, without relying on expert-based assumptions.

Methodology

Original model

- Coupled hydrological, geomorphological, and vegetation model
- Spatially distributed, thus difficult to interpret

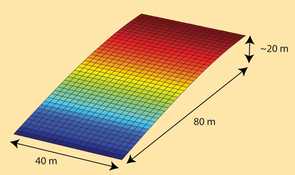

Figure 2: Grid dimensions of the modelled hillslope (Appendix A, Karssenberg et al. 2017*).

Data simulation

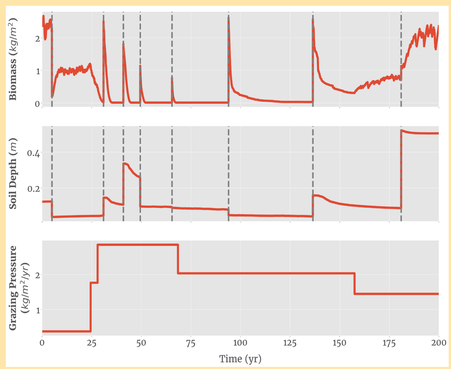

Figure 3: Data simulated by spatially averaging the distributed model outputs to train the ANN. Random variable shifts are introduced to explore the whole input domain.

ANN model

- Lumped, simplified model which enables analysis of system dynamics

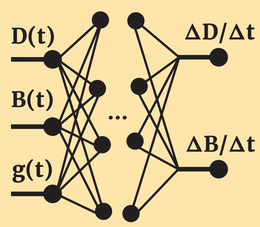

Figure 4: Schematic of the ANN, with soil depth (D), biomass (B) and grazing pressure (g) as inputs and the rates of change ($\Delta D/\Delta t$, $\Delta B/\Delta t$) as outputs.

Response analysis

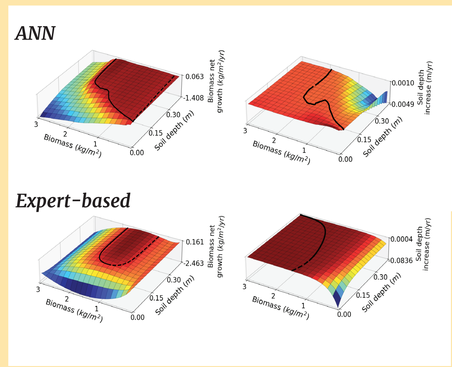

Figure 5: Comparison of the predicted $\Delta B/\Delta t$ (left) and $\Delta D/\Delta t$ (right) in the B(D) space, between the trained ANN (top) and an expert-based minimal model of the same system (bottom).

* Karssenberg, D., Bierkens, M. F. P., & Rietkerk, M. (2017). Catastrophic Shifts in Semiarid Vegetation-Soil Systems May Unfold Rapidly or Slowly. The American Naturalist, 190(6), E145–E155. https://doi.org/10.1086/694413