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Bridging the gap between mechanism and phenomenology in nonlinear microbial soil carbon models

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Information geometry interprets models geometrically as manifolds with parameters acting as coordinates. For many soil-microbiome models, the manifold is bounded by a hierarchy of boundaries. These boundaries are themselves manifolds which correspond to simpler models with fewer parameters.
The resulting approximate models remain expressed in terms of fewer microbial kinetic parameters which are statistically identifiable from experimental data. We illustrate an application of the recently introduced Manifold Boundary Approximation Method (MBAM) by constructing a simpler description of a 51 parameter mechanistic model for pesticide degradation coupled to carbon turnover. If we choose to observe all carbon pools, we identify a reduced model with 18 parameters. Upon coarse-graining the observations, we identify 4 effective parameters controlling model response to a press pesticide disturbance which remain expressed in terms of original reaction rates and Monod constants and can be linked to concepts from ecosystem resilience theory.
As multi-parameter models with more parameters than effective degrees of freedom appear to be ubiquitous throughout soil biogeophysical modelling, MBAM emerges itself as a valuable tool: it makes clear the utility of effective models and how they emerge from a more complete underlying microscopic model, characterizes the equivalence class of distinct systems exhibiting the same range of dynamics, and identifies the combinations of microbial kinetic model parameters that function as tunable control knobs for the emergent system behavior.