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Learning ordinary differential equations from remote sensing data

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Modeling and understanding the Earth system is of paramount relevance. Modeling the complex interactions among variables in both space and time is a constant and challenging endevour. When a clear mechanistic model of variable interaction and evolution is not available or uncertain, learning from data can be an alternative.

Currently, Earth observation (EO) remote sensing data provides almost continuous space and time sampling of the Earth system which has been used to monitor our planet with advanced, semiautomatic algorithms able to classify and detect changes, and to retrieve relevant biogeophysical parameters of interest. Despite great advances in classification and regression, learning from data seems an ilusive problem in machine learning for the Earth sciences. The hardest part turns out to be the extraction of their relevant information and figuring out reliable models for summarizing, modeling, and understanding variables and parameters of interest.

We introduce the use of machine learning techniques to bring systems of ordinary differential equations (ODEs) to light purely from data. Learning ODEs from stochastic variables is a challenging problem, and hence studied scarcely in the literature. Sparse regression algorithms allow us to explore the space of solutions of ODEs from data. Owing to the Occam's razor, and exploiting extra physics-aware regularization, the presented method identifies the most expressive and simplest ODEs explaining the data. From the learned ODE, one not only learns the underlying dynamical equation governing the system, but standard analysis allows us to also infer collapse, turning points, and stability regions of the system. We illustrate the methodology using some particular remote sensing datasets quantifying biosphere and vegetation status. These analytical equations come to be self-explanatory models which may provide insight into these particular Earth Subsystems.