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Learning phytoplankton bloom patterns - A long and rocky road from data to equations

Pascal Nieters[1], Maximilian Berthold[2], and **Rahel Vortmeyer-Kley**[3]
[1]University Osnabrück, Institute of Cognitive Science, Germany (pascal.nieters@uni-osnabrueck.de)
[2]Department of Biology, Faculty of Science, Mount Allison University, Canada (mberthold@mta.ca)
[3]Institute for Chemistry and Biology of the Marine Environment, Carl von Ossietzky University Oldenburg, Germany (rahel.vortmeyer-kley@uni-oldenburg.de)

Non-linear, dynamic patterns are the rule rather than the exception in ecosystems. Predicting such patterns would allow an improved understanding of energy and nutrient flows in such systems. The Scientific Machine Learning approach Universal Differential Equation (UDE) by Rackauckas et al. (2020) tries to extract the underlying dynamical relations of state variables directly from their time series in combination with some knowledge on the dynamics of the system. This approach makes this kind of tool a promising approach to support classical modeling when precise knowledge of dynamical relationships is lacking, but measurement data of the phenomenon to be modeled is available.

We applied the UDE approach to a 22-year data set of the southern Baltic Sea coast, which constituted six different phytoplankton bloom types. The data set contained the state variables chlorophyll and different dissolved and total nutrients. We learned the chlorophyll:nutrient interactions from the data with additional forcing of external temperature, salinity and light attenuation dynamics as drivers. We used a neural network as a universal function approximator that provided time series of the state variables and their derivatives.

Finally, we recovered algebraic relationships between the variables chlorophyll, dissolved and total nutrients and the external drivers temperature, salinity and light attenuation using Sparse Identification of nonlinear Dynamics (SinDy) by Brunton et al. (2016).

The gained algebraic relationships differed in their importance of the different state variables and drivers for the six phytoplankton bloom types in accordance with general mechanisms reported in literature for the southern Baltic Sea coast. Our approach may be a viable option to guide ecosystem management decisions based on those algebraic relationships.

Rackauckas et al. (2020), arXiv preprint arXiv:2001.04385.

Brunton et al. (2016), PNAS 113.15: 3932-3937.