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Machine Learning and Harmful Algal Blooms: Towards an expert Forecasting, Warning, and Decision-Support Numerical System.

Coastal marine ecosystems are evolving significantly in response to anthropogenic pressures. The degradation and restoration trajectories do not always correspond to the expected patterns, making management approaches extremely challenging. Maintaining ecosystem goods and services is strongly related to phytoplankton biomass, abundance and diversity because of their importance on marine food webs (energy transfer). However, understanding phytoplankton dynamics requires recognizing the interactions between environmental (climate, light, nutrients, etc.) and biological (consumption, sedimentation, lysis, etc.) regulations, thus involving approaches at different scales (long vs. short term, low vs. high frequency, regional vs. global scale). Until now, such multi-scale, multi-parameter approaches are rare, despite their ability to extract the most essential information. In this context, our project aims to characterize the dynamics of coastal environments. In particular, we will focus on phytoplankton dynamics (including HAB) in response to pressures at various temporal and spatial scales, from recurrent to extreme events. This will help us understand the processes associated with HABs, prioritize a set of controlling factors, and define indicators to assess environmental quality status. Our research will thus integrate Machine Learning methods into a meta-program, allowing us to (i) optimize multi-source and multi-scale monitoring databases through the implementation of a data completion method based on elastic matching (Dynamic Time Warping), and (ii) optimally define the environmental statuses and build a learning base through a deep approach (Multi-level Spectral Clustering M-SC). This will pave the way for the development of an Expert Forecasting, Warning, and Decision-Support System. M-SC will aid in better defining the main environmental conditions that cause HAB. Experts should be able to label these conditions, and improve the settings of an unsupervised Hidden Markov Model (transition probabilities), and its ability to characterize the transitional dynamics from one environmental condition to another. Simultaneously, a semi-supervised approach, which is a mix of deep unsupervised and supervised approaches, will allow us to anticipate the evolution of this system by taking into consideration various phytoplankton bloom situations.