Advanced Monitoring of Harmful Algal Blooms in the Gulf of Mexico (2016-2023) using OLCI-Sentinel-3 and Convolutional Neural Networks

Harmful algal blooms (HABs), particularly those caused by Karenia brevis, pose severe ecological and economic challenges worldwide. Traditional satellite-based methods have struggled with accurate detection in turbid waters, as existing models are mostly empirical and fail to represent the complexity of these water bodies effectively. This study introduces a novel approach using an innovative 1D-Convolutional Neural Network (1D-CNN) to classify HAB occurrences, harnessing the ability of 1D-CNNs to capture local patterns in sequence data, such as spectral reflectance across different bands. Utilizing full-resolution Level-2 OLCI images from Sentinel-3 and the Florida Fish and Wildlife Conservation Commission (FWC) HAB Monitoring Database for the period 2016–2023, we collected 6,561 matchup data from 78,430 in-situ cell count measurements and 3,740 satellite images. The proposed model effectively addresses data imbalances through oversampling and class weighting strategies. The 1D-CNN model achieved an overall accuracy of 95% and a precision of 90%, with a specificity rate of 0.99, indicating a robust capacity to distinguish non-HAB conditions and prevent false alarms. Additionally, we generated and analyzed monthly Bloom Occurrence Frequency (BOF) images for the years 2017 to 2023, revealing the model’s precision in tracking the seasonal dynamics of K. brevis blooms along Florida’s west coast. Our findings highlight the model's capability to pinpoint the start, peak, and decline of blooms within a year, exemplified by the accurate detection of a bloom from July to December in 2018. This study marks a significant advancement in satellite applications for oceanography, offering a promising tool for ecological monitoring.

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