Global Subsurface Chlorophyll $\alpha$ Distribution Prediction from Satellite-Derived Surface Data

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Abstract: Understanding Subsurface Chlorophyll $\alpha$

In today’s rapidly-changing climate, understanding the ocean on a large scale is crucial to maintain and sustain biogeochemical processes worldwide. Subsurface chlorophyll $\alpha$ is a proxy for phytoplankton biomass and photosynthesis, which are key components of long term carbon storage at the ocean floor. Thus, predicting subsurface chlorophyll $\alpha$ distributions using only satellite-derived data with BGC-Argo float data as ground truth gives insight into phytoplankton behavior at a high spatial- and temporal-resolution.

Results: Predictions from XGBoosting Regressor and Neural Network

We define a mixed-model approach that inputs various spatial, temporal, and satellite-derived features at standardized depth intervals into an XGBoosting regression ensemble model. The results are then input into a neural network to combat overfitting while achieving more continuous predictions, and fit to the appropriate biome characteristic distribution. With subsurface chlorophyll measurements from BGC-Argo floats as ground truth, the model achieves a test $R^2$ score of 0.64 and a test mean squared error of 0.07 across the global ocean, demonstrating strong predictive capacity.

Figure 1. Left: Monthly average chlorophyll $\alpha$ values derived by NASA satellites; Right: Diagram of a single BGC-Argo float-cycle. (Source: Calustre et al. 2020)

Chlorophyll $\alpha$ Behavior: Biomes and Dropoff Patterns

Previous work by Bock et. al 2022 found that the ocean has six distinct biomes with characteristic chlorophyll $\alpha$ distributions. We leverage these characteristic distributions to smooth our model predictions by creating a weighted-average mixture. Euphotic zone depth estimates are obtained for each float-cycle, enabling depth normalization for comparability across the variable chlorophyll productive zones throughout the ocean.

Figure 2. Left: Characteristic chlorophyll $\alpha$ distributions for each biome; Right: Example of euphotic zone depth estimation for a float-cycle.

Figure 3. Top: Preprocessing, model, and postprocessing pipeline; Bottom Left: True v. Predicted (XGB) chlorophyll $\alpha$ values on train and test sets; Bottom Right: chlorophyll-$\alpha$ distribution prediction for a single example float-cycle.

Conclusion: For the Future of Plankton and Planet

Our model shows that surface-level ocean measurements can be used to generate reasonable predictions for subsurface chlorophyll $\alpha$ concentrations. As a result, our model acts as a potential substitute for the otherwise resource-intensive process of manually collecting subsurface chlorophyll $\alpha$ measurements. Understanding such distributions is crucial for further research regarding the biological carbon pump, and our results establish benchmarks for future analysis and testing.

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References
