A Deep Learning Model for Three-Dimensional Chlorophyll-a Forecasting in the Upper Ocean of the North Pacific

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Abstract

Accurate short-term forecasts of three-dimensional chlorophyll-a distributions in the upper North Pacific Ocean can help characterize surface and subsurface phytoplankton dynamics, supporting assessments of marine ecosystem conditions and primary productivity. Here, we develop a three-dimensional deep learning model that integrates physical ocean information to generate daily chlorophyll-a forecasts at lead times of 1–10 days, with a horizontal resolution of 0.25° across the upper 200 m of the North Pacific. The model uses initial chlorophyll-a, temperature, salinity and ocean current fields as inputs and incorporates training constraints on vertical gradients and depth-integrated chlorophyll-a to capture its three-dimensional structure and evolution. Forecast performance is evaluated against Copernicus analysis fields in terms of concentration accuracy, vertical structure and regional differences. Preliminary results indicate lower errors in both chlorophyll-a concentration and depth-integrated chlorophyll-a relative to persistence, with greater improvements at longer lead times. These findings highlight the potential of integrating physical ocean information into three-dimensional deep learning for short-term chlorophyll-a forecasting in the North Pacific, while underscoring the need to improve the representation of coastal vertical structure.