Guiding Responses to Climate Change: Integrating Fourier Transformation and Residual Learning for Arctic Sea Ice Forecasting

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Arctic sea ice plays integral roles in both polar and global environmental systems, notably ecosystems, communities, and economies. As sea ice diminishes due to climate change, it has become imperative to accurately predict sea ice extent (SIE). Using a dataset of Arctic oceanic and atmospheric variables spanning 1979 to 2021, a preliminary exploratory analysis guided the development of pipelines for predicting SIE one month in advance. After a conditional detrender removed long-term linear trends from all variables, grid search tuned a novel composite Fourier Transform model that iteratively removed oscillation. Using grid search to optimize lags and hyperparameters, Gradient Boosting regressors were trained on baseline, detrended, and de-oscillated data, each achieving successively superior performance. Next, a novel framework for visualizing SIE was proposed, utilizing the same Fourier transform process. A dataset of Arctic SIE images was decomposed into constituent pixels. Then, Fourier transform models were applied to each pixel independently and recombined into images. Though no comparable model exists, the high pixel accuracy holds promising results for visualizing SIE. By outperforming current state-of-the-art and deep learning models and proposing a novel image framework, this study demonstrates the potential for employing Fourier transform-based pipelines in predicting Arctic SIE numerically and visually. Moreover, the extensive flexibility of this methodology has bolstered the performance of existing models, suggesting its broad applicability in time series prediction. Furthermore, this study may contribute to prediction tasks of related research and advise future adaptation, resilience, and mitigation efforts in response to Arctic sea ice decline.

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