

Beyond Stationarity: Can ML Decipher Future North Atlantic Behaviour in a Warming Climate?

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Abstract

As the climate system evolves, the assumption of stationarity in dominant modes of variability like the North Atlantic Oscillation (NAO) is increasingly questioned. This study leverages machine learning (ML) predictions and interpretable ML to assess whether historical relationships between NAO drivers (e.g., SSTs) remain predictive under future forcing (SSP3.7.0). We train ML models in a 'perfect model' framework using large ensembles of initial conditions (for example, large ensembles of UK-ESM) to explicitly account for internal variability. By evaluating the performance of the model among the members of the ensemble, we quantify how internal variability influences the predictability of the NAO and whether its role changes under future forcing. Strong generalisability across ensembles would suggest robust physical mechanisms insensitive to internal noise, while degradation may signal nonstationarities (e.g., emerging teleconnections from Arctic amplification or jet stream shifts). By integrating interpretable AI (gradient-based maps) with a large-ensemble diagnostics, this work bridges data-driven and dynamical perspectives, offering a novel pathway to detect climate change impacts on atmospheric variability. Our approach highlights how ML can identify emergent patterns masked by internal variability, providing information for climate modelling and predictability studies.