EGU24-10539, updated on 25 Jul 2024
https://doi.org/10.5194/egusphere-egu24-10539
EGU General Assembly 2024

Exploring multiyear-to-decadal North Atlantic sea level predictability using machine learning and analog methods

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Long-term sea level rise and multiyear-to-decadal sea level variations pose substantial risks of flooding and erosion in coastal communities. The North Atlantic Ocean and the U.S. East Coast are hotspots for sea level changes under current and future climates. Here, we employ a machine learning technique, a self-organizing map (SOM)-based framework, to systematically characterize the North Atlantic sea level variability, assess sea level predictability, and generate sea level predictions on multiyear-to-decadal timescales. Specifically, we classify 5000-year North Atlantic sea level anomalies from the Seamless System for Prediction and EArth System Research (SPEAR) model control simulations into generalized patterns using SOM. Preferred transitions among these patterns are further identified, revealing long-term predictability on multiyear-to-decadal timescales related to shifts in Atlantic meridional overturning circulation (AMOC) phases. By combining the SOM framework with "analog" techniques based on the simulations and observational/reanalysis data, we demonstrate prediction skill of large-scale sea level patterns comparable to that from initialized hindcasts. Moreover, additional source of short-term predictability is identified after the exclusion of low-frequency AMOC signals, which arises from the wind-driven North Atlantic tripole mode triggered by the North Atlantic Oscillation. This study highlights the potential of machine learning methods to assess sources of predictability and to enable efficient, long-term climate prediction.