Advancing seasonal hurricane predictions using causal AI

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In recent decades, the Atlantic region has seen more frequent and intense hurricanes, with the 2023 season ranking as the fourth-most active on record. Despite progress in understanding hurricane dynamics and identifying precursors, challenges persist in seasonal predictions.

Conventional correlation measures often fall short in capturing causal relationships. Therefore, in this study, we employed the causal AI discovery tool PCMCI+ — a combination of the PC (Peter and Clark) algorithm and the Momentary Conditional test. PCMCI+ excels at uncovering causal relationships in time series data by addressing issues like autocorrelation, indirect links and common drivers.

PCMCI+ was applied to nearly 150 lagged atmospheric and oceanic monthly ERA-5 time series from January to May between 1980 and 2022. Precursor regions, identified based on their causal links to hurricane numbers, were determined. Linear regression models and random forests were then used to predict hurricane numbers for each season.

Results indicate that adopting PCMCI+ to select causal precursor regions significantly improved the accuracy of seasonal hurricane predictions, achieving a correlation of over 0.9 between observed and predicted numbers. While this study contributes to improved forecast precision, its primary focus is on exploring and discussing identified causes. The selected precursor regions are explained in the context of atmosphere-ocean interactions, providing valuable insights into their role in hurricane formation.