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Evolution of Causal Structure of Interactions in Turbulence at the Biosphere-Atmosphere interface

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Turbulence at the biosphere-atmosphere interface refers to the presence of chaotic and chaotic-like fluctuations or patterns in the exchange of energy, matter, or information between the biosphere and atmosphere. These fluctuations can occur at various scales. Turbulence at the biosphere-atmosphere interface can affect the transfer of heat, moisture, and gases. In this study, we use causal discovery to explore how high-frequency data (i.e., 10 Hz) of different variables at a flux tower, such as wind speed, air temperature, and water vapor, exhibit interdependencies. We use Directed Acyclic Graphs (DAGs) to identify how these variables influence each other at a high frequency. We tested the hypothesis that there are different types of DAGs present during the daytime at the land-atmosphere interface, and we developed an approach to identify patterns of DAGs that have similar behavior. To do this, we use distance-based classification to characterize the differences between DAGs and a k-means clustering approach to identify the number of clusters. We look at sequences of DAGs from 3-minute periods of high-frequency data to study how the causal relationships between the variables change over time. We compare our results from a clear sky day to a solar eclipse to see how changes in the environment affect the relationships between the variables. We found that during periods of high primary productivity, the causal relationship between water vapor and carbon dioxide shows a strong coupling between photosynthesis and transpiration. At high frequencies, we found that thermodynamics influences the dynamics of water vapor and carbon dioxide. Our framework makes possible the study of how dependence in turbulence is manifested at high frequencies at the land-atmosphere interface.