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Modeling of the interacting negative feedback mechanism in a coupled extreme weather-humans-infrastructure system

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Abstract: Extreme weather has been recognized as a threat to human life and critical infrastructures. Electric grid, as a vital component of critical infrastructures and the backbone of modern life, has long been subject to extreme weather conditions. Previous studies have focused on the reliability and vulnerability of single or interdependent infrastructures under extreme weather threats (Jufri et al. 2019). However, knowledge of the interactions between social demand and infrastructure response, especially the cascading failure process induced by extreme weather event, is essential, but receive less attention.

Here, we propose a connectivity-based multilayer network to model the dynamic interaction process between social demand and power supply affected by extreme weather, taking connectivity robustness of power network and the cascade of overload failures into account. The historical winter storm of Texas in February 2021 is taken as a case study to validate the model. The results showed that the electric network presents high robustness in connectivity under random attacks. However, due to a highly heterogeneous distribution of load, this multilayer network is particularly vulnerable and easier to trigger cascading failures, when the power demand caused by extreme temperature making the grid load close to its capacity limit. An interacting negative feedback mechanism is discovered in this coupled extreme weather-humans-infrastructure model, which amplify the impact of natural hazards on both infrastructure and human beings. Extreme temperature events directly cause physical failure in infrastructures, and their impact on individuals stimulated the power demand for heating/cooling. An increase in demand further intensified the load on the power network, which induced functional failure in power network and finally aggravated the adverse impact on people as end-users in return. This feedback loop inspires us to reconsider the relationship among natural disasters, critical infrastructures and humans from a perspective of systematic risk. Furthermore, even under the background of climate change and global warming, the risk of extreme cold event is still worthy of attention. In general, this work provides a new perspective to understand the relationship between extreme weather events and critical infrastructures, revealing the importance of synthesizing the interactions among extreme weather, critical infrastructures, and human beings in earth system especially in the context of climate change.

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