



## **Tropical and mid-latitude teleconnections with the Indian summer monsoon rainfall: A Theory-Guided Causal Effect Network approach**

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The Indian summer monsoon (ISM) rainfall activity at sub-seasonal timescales is characterized by the alternation of active and break phases in each ISM season. Both tropical and mid-latitude drivers have been detected to that influence the ISM circulation. The circumglobal-teleconnection (CGT) is an observed circulation pattern in boreal summer, which drives sub-seasonal precipitation and temperature anomalies across the northern mid-latitudes. The CGT is hypothesized to serve as a connector between the mid-latitude circulation and the ISM system. Moreover, the role of the mid-latitude circulation during extreme rainfall events which affect the Himalayan foothills, such as the Pakistan flooding in 2010, has also been detected. Here, we use causal discovery tools to quantify the two-way causal links between the ISM and the CGT. Our analysis shows a robust causal link from the CGT and the North Atlantic Oscillation (NAO) to the ISM rainfall. A reversed link connects the ISM rainfall back to the CGT. We highlight the pathways that explain this link and show that other components of the ISM system, such as vertical transport of moisture, are crucial in propagating the corresponding signal. We thus support the hypothesis of a two-way interaction between the ISM rainfall and the mid-latitude teleconnection. Moreover, our causal discovery tools correctly identify the different tropical and mid-latitude drivers that determine the ISM circulation at 1 to -2-week lead time.