**Highway to Hail – The Hidden Roadmap of Atmospheric River Networks and their Impacts on the Ground**

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The increasing frequency and severity of hydrological extremes, such as heavy precipitation events, are significant challenges for human-environmental systems. Atmospheric rivers (ARs) are key drivers of these extremes, but the complex transport patterns of ARs at global scale remain underexplored. In this talk, I will present a novel global catalog of AR trajectories and a network-based approach to study global AR dynamics. I will show how we can leverage methods from complexity science to reveal the “hidden roadmap” of AR transport.

Tracing ARs globally is challenging, as they are linked to distinct dynamical phenomena across different regions and moisture levels vary greatly from the tropics to the poles. I will provide a brief overview of how we track ARs at 6h-resolution for the past 83 years, using advanced image processing techniques. Equipped with a catalog of global AR pathways, network theory provides an elegant solution to reveal their hidden structural connectivity. We draw on the vast array of existing methods from complex network theory to reveal the *global atmospheric river network*. To quantitatively assess the significance of a transport property, the framework is equipped with a hierarchy of data-adaptive null models that are based on random walker ensembles. Using this framework, I will showcase how the AR network answers three fundamental questions on AR transport: First, what are the global AR transport hubs, i.e., regions of highest transport activity? Second, where are the global “highways” of AR transport? Third, across how many interconnected basins is AR transport organized? We find that – beyond major AR activity hubs along the storm tracks – various other hubs play distinct roles in mediating moisture flow. ARs orient along a circumglobal teleconnection pattern where moisture is supplied through Rossby-wave breaking and redirected by atmospheric circulation regimes. We further uncover the existence of more than the previously stated five AR basins and show how these are connected by routes along which ARs predominantly lose or gain moisture. I will finish with an outlook on how we can link AR transport patterns to hydrological extremes and land surface impacts.

This talk underscores the potential of complexity science to bridge the gap between synoptic processes and planetary-scale dynamics, offering a new lens on multi-scale transport in the global water cycle.