Research Training Group
"NatRiskChange" (GRK 2043/1)

Natural Hazards and Risks in a Changing World

Erd- und Umweltwissenschaften

Invitation to two guest lectures within the lecture series
"Dedicated Lectures in Natural Hazard and Risk Research"

Shruti Tandon Chopra
Doctoral researcher in the Department of Aerospace Engineering, Indian Institute of Technology Madras

"Multilayer network analysis of a turbulent thermoacoustic system"

Dr Gaurav Chopra
Postdoctoral researcher in the Department of Aerospace Engineering, Indian Institute of Technology Madras

"Understanding transitions in fluid dynamics and climate systems using complex networks"

Thursday, 30 March 2023, 2:15 to 3:45 pm

Campus Golm, House 1, Room 1.15

Online access: https://uni-potsdam.zoom.us/j/63954002877

Meeting-ID: 639 5400 2877
ID-code: 48421219

Abstract: Multilayer network analysis of a turbulent thermoacoustic system

Thermoacoustic systems are complex systems that comprise acoustic, hydrodynamic and combustion subsystems. Inter-subsystem nonlinear interactions between the acoustic field, heat release rate fluctuations and the underlying turbulent flow leads to a variety of rich dynamics. We study the spatio-temporal dynamics in a turbulent bluff-body stabilized dump combustor. The system exhibits a transition from chaotic to periodic (thermoacoustic instability) dynamics with increase in the Reynolds number of the inlet flow. Such a transition occurs via the state of intermittent spatio-temporal patterns. In order to capture the higher-order complexities in the system arising due to the interaction between the various subsystems we use multi-layered complex networks. We construct a two layered network, where one layer represents the vorticity dynamics and the other layer represents the acoustically-driven combustion subsystem. The nodes of the network are spatial locations in the combustion chamber. The inter-layer links between any two nodes is established using cross-variable

short-window correlation between vorticity and thermoacoustic power fluctuations at the corresponding locations. The inter-layer node strength represents the strength of the inter-subsystem interactions. Further, we analyze the topology of the inter-layer network using inter-layer network assortativity and link-rank distribution during various dynamical states to infer the pattern of inter-subsystem interactions. During chaotic dynamics, the inter-subsystem interactions occur predominantly in the wake of the bluff-body in a non-localized manner. On the other hand, during periodic dynamics, the inter-subsystem interactions are intense in regions of coherent vortex shedding. Interestingly, prior to the emergence of such ordered dynamics, we obtain localized pockets of inter-subsystem interactions in the recirculation zone during the state of intermittency. These regions are identified as the hubs of the inter-layer network. The influence of interactions in such localized pockets is also spread across the entire combustion chamber as identified via disassortative network topology. Targeted attack on these hub locations using microjet secondary flow injections can cause disruption of the feedback interactions and help in mitigating the occurrence of thermoacoustic instability. In this talk I will show that multilayer network analysis helps reveal the rich pattern of inter-subsystem interactions and helps identify critical regions for passive control of thermoacoustic instability.

Abstract: Understanding transitions in fluid dynamics and climate systems using complex networks

Complex networks approach provides new insights into transitions occurring in nature and engineering systems. In this talk, we examine transitions in two systems, fluid dynamics and climate. In fluid dynamics, we explore the boundary layer transition in flow past a circular cylinder. The transition of the boundary layer from a laminar to turbulent state leads to a drastic decrease in drag force; therefore, this phenomenon is popularly known as the drag crisis. The spatiotemporal analysis of the flow field using complex networks reveals that the boundary layer transition is intermittent and occurs in clusters. The evolution of these clusters explains the mechanism of the drag crisis. In the second part of the talk, we will examine the transition due to the migration of the Intertropical Convergence Zone (ITCZ) in the climate system. In conjunction with community detection, the complex network analysis reveals the spatiotemporal dynamics of the ITCZ in the tropics. Some communities in the network represent regions affected by the ITCZ during its annual migration cycle. We will further discuss the geophysical significance of communities in the talk.