

2026 Distinguished Lecture Series Presents

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MS 6627 & Zoom



IS THE WORLD SMOOTH OR NON-SMOOTH?

LECTURE 1 // MAY 12 AT 3PM

Is the world smooth or non-smooth?
Can mathematics tell us?

In modeling different dynamical processes in physics, engineering, and the life sciences we often use models that have some kind of smoothness associated with their evolution. Meanwhile, models with abrupt changes – non-smoothness – have recently seen more frequent demand, application, and success. These contrasts raise a number of questions, such as, which type should we use? Are the non-smooth models driving new mathematics? Has our preference for certain types of mathematical properties kept us from considering certain types of models? We consider some non-smooth models on completely different scales, in the areas climate, energy transfer, and neural feedback, to see what these models can capture about the systems they describe. These examples also provide some perspectives about the mathematics that is needed and available for understanding and applying these models.

LECTURE 2 // MAY 13 AT 3PM

Critical scales for tipping captured in non-smooth and noisy model features.

We consider tipping mechanisms facilitated by certain model features in the study of dynamic bifurcations or early warning signals. We review two types of multiple scale features appearing in reduced conceptual climate models: (non)-smoothness of bifurcations, and approximations of fast fluctuations yielding correlated additive and multiplicative (CAM) noise. First, we consider stochastic forcing in Stommel-type models, where the interplay of noise, non-smoothness and multiple time scales can substantially advance dynamic bifurcations. Also termed tipping, these transitions are advanced relative to both deterministic systems and systems with traditional “smooth” bifurcations. Analytical results identify critical scales in tipping, dependent on the balance of stochastic forcing, the (nearly) non-smoothness of the bifurcations, and the slow variability of critical physical and environmental process, with high and low frequency forcing also contributing. Second, we review studies from the last decade that show how CAM noise captures large variability in reduced climate models, and in multiple scale nonlinear systems more generically. This analysis of CAM noise can then be connected to key bifurcation characteristics in our study of Stommel-type models, highlighting additional model features and hidden time scales that can compete or cooperate in facilitating advanced tipping near bifurcations.

LECTURE 3 // MAY 14 AT 3PM

Computer-assisted global analysis of energy transfer in vibro-impact configurations.

We discuss a novel return map approach for studying the global dynamics developed in the context of a vibro-impact (VI) pair, that is, a ball moving in a harmonically forced capsule. Results are relevant for recent designs of VI-based energy harvesters and nonlinear energy transfer, and hold promise for other non-smooth systems. Computationally efficient short-time realizations are based on “words” that represent key impact sequences and divide the state space according to different dynamics. The word-based maps define surfaces whose characteristics indicate both transients and potential attractors. These perspectives complement the bifurcation structure of the full system and inspire auxiliary maps based on the extreme bounds of the maps, yielding global dynamics of energetically favorable states. Beyond the individual impact pair, we show how the framework is valuable in higher dimensional configurations for shaping the energy transfer, including billiard-type designs, networks of VI-pairs, and multi-cavity VI pairs. In these systems the diagnostics from combined returns maps greatly reduce the number of parameters and states of interest. Computational efficiencies follow from maps generated by short sequences of the dynamics, in contrast to traditional dynamical quantities obtained from long-time simulations.

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