Engineering and Physical Sciences Research Council Doctoral Landscape Award

PROJECT TITLE: Probabilistic approaches to tipping points in natural systems with application to cloud transitions

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Project details: Tipping points describe situations where a natural system transitions irreversibly into a fundamentally different state because a forcing of the system exceeds a critical threshold. Tipping points have been at the forefront of research over the past two decades, due to the potentially catastrophic impact they pose for real-world systems and societies. Tipping points are mainly studied via the lens of dynamical systems that depend on parameters, that when changed above a critical threshold cause the system to tip.

Despite the widespread importance of tipping points however, existing theory and methodology for the subject has focused primarily on (1) changes in a single system parameter, and (2) changing it in a unique and deterministic way. For example, a parameter is increased (and/or then decreased) as a function of time. Realistic complex systems however depend on multiple parameters that all may change with various timescales and correlations. Moreover, how these parameters would change can be uncertain and one must consider for multiple different ways of change.

In this project we want to improve the status quo by developing new methodologies by combining dynamical systems knowledge with probabilistic and/or stochastic frameworks. These new approaches will by design incorporate the multiplicity and uncertainty of the forcings that may cause tipping in the system. There are many options to explore, ranging from simple maximum likelihood estimations to advanced Bayesian inference and uncertainty quantification techniques. Supporting open research and open code, we expect the project to build a codebase for public use, likely as a component of the DynamicalSystems.jl software library. We will then apply this new methodological progress to models of tipping in real world systems. A key application will be transitions (tipping) from Stratocumulus to Cumulus clouds (SCT). This transition has drastic impact on the global climate because it results in massive loss of cooling over subtropical oceans. The complex physics governing SCT result in the interplay of surface temperatures, atmospheric temperatures, and global circulation. This makes the project the perfect case-study to apply the aforementioned new methodologies for studying tipping. Other potential applications include changes in oceanic circulation or interactions in ecological models. We welcome and even motivate the successful applicant to shape the course of the project by suggesting methodological approaches or alternative potential applications.

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Project specific entry requirements: High level of skills in dynamical systems OR in stochastic processes OR in probabilistic inference.

- High level of programming skills, with skills in the Julia language treated beneficially.
- Skills in climate science or cloud physics are not mandatory but will be treated beneficially.

Demonstration of independence and taking initiative in research will be treated beneficially.

Potential PhD programme of study: PhD in Mathematics or PhD in Climate Science

Department: Mathematics and Statistics

Location: Laver, Streatham Campus

Please direct project specific enquiries to: Dr George Datseris

Please ensure you read the entry requirements for the potential programme you are applying for.

To Apply for this project please click on the following link - **APPLY HERE**