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Achievements

Key to Resilience Management Provided by Novel Method

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An international research team led by Professors Chih-Hao Hsieh and Chun-Wei Chang of NTU's Institute of Oceanography and Institute of Fishery Sciences, have developed a new technique that predicts the occurrence and type of various critical transition events. This novel methodology, known as Dynamical Eigen-Value (DEV), leverages early warning signals obtained from real-world systems to differentiate types of critical transitions and identify the quantitative threshold for critical transition, overcoming numerous research challenges. The team's discovery also provides a way to effectively monitor changes in system resilience, such as catastrophic shifts in socio-economically significant systems, and suggest early prevention measures. The research was published in *Science Advances* (Jan 2023).

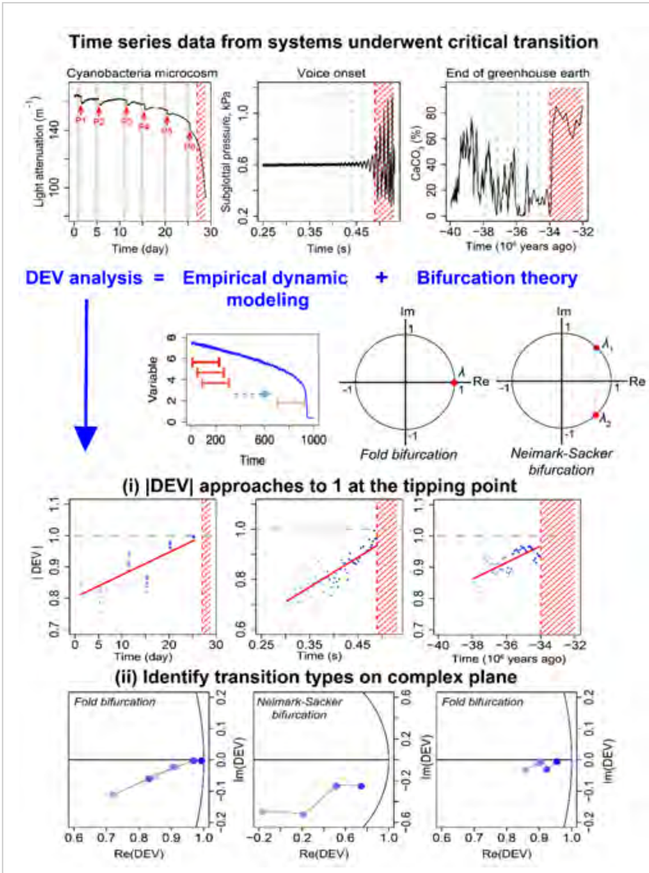

Figure 1.The study proposes a new technique called Dynamical Eigen-Value (DEV) analysis, which can anticipate critical transitions and determine their type. The study presents three examples of how the DEV method has been used, including predicting the occurrence of critical transitions in 1) cyanobacteria microcosm, 2) voice onset, and 3) the end of the last greenhouse earth. The DEV method is based on empirical dynamic modelling and calculates a quantitative measure called DEV that serves as a proxy for the dominant eigenvalue of Jacobian in mathematical bifurcation theory. The occurrence of a critical transition is predicted by tracking the temporal dynamics of DEV, and critical transition types are identified by examining the location of DEV on the complex plane. The study shows that the DEV method successfully predicted fold bifurcation in systems 1) and 3) and Neimark-Sacker bifurcation in system 2).

In many real-world systems, there are critical thresholds or tipping points at which the system suddenly changes to different and usually undesirable states. These sorts of unpredictable occurrences, called critical transitions or regime shifts, are triggered by local bifurcations in nonlinear dynamical systems. They can cause significant damage and loss in the environment, economy, and public health. It is therefore crucial to accurately forecast their occurrence and potential effects through various scientific fields and applications. The team's DEV method differs from previous early warning signals in providing a quantitatively defined threshold for predicting critical transition events. The method has been proven successful in both theoretical models and real-world systems (Figure 1).

Unlike existing early warning signals (EWS) that can only signal potential critical transitions based on a qualitative rising pattern, without specifying how significant the increased EWS could be, the DEV provides a specifically defined threshold, enabling predictability of different critical transitions. This discovery will significantly improve humanity's ability to foresee potential losses and devise suitable strategies to avoid or ameliorate the effects.

Click or Scan the QR code to read the journal article in *Science Advances*.