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Early-warning signals for critical transitions

- Recherches
- Vers un nouveau paradigme scientifique ?
- Problèmes théoriques

Date de mise en ligne : mercredi 7 mars 2012



Des recherches passionnantes, du point de vue d'une théorie des manières de fluer, sont en cours sur les phénomènes de transition critique des systèmes dynamiques complexes. Nous reproduisons ici l'introduction d'un article de Marten Scheffer et al. paru dans [Nature](#), 461, 3 septembre 2009.

Complex dynamical systems, ranging from ecosystems to financial markets and the climate, can have tipping points at which a sudden shift to a contrasting dynamical regime may occur. Although predicting such critical points before they are reached is extremely difficult, work in different scientific fields is now suggesting the existence of generic early-warning signals that may indicate for a wide class of systems if a critical threshold is approaching.

It is becoming increasingly clear that many complex systems have critical thresholds—so-called tipping points—at which the system shifts abruptly from one state to another. In medicine, we have spontaneous systemic failures such as asthma attacks or epileptic seizures ; in global finance, there is concern about systemic market crashes ; in the Earth system, abrupt shifts in ocean circulation or climate may occur ; and catastrophic shifts in rangelands, fish populations or wildlife populations may threaten ecosystem services.

It is notably hard to predict such critical transitions, because the state of the system may show little change before the tipping point is reached. Also, models of complex systems are usually not accurate enough to predict reliably where critical thresholds may occur. Interestingly, though, it now appears that certain generic symptoms may occur in a wide class of systems as they approach a critical point. At first sight, it may seem surprising that disparate phenomena such as the collapse of an overharvested population and ancient climatic transitions could be indicated by similar signals. However, as we will explain here, the dynamics of systems near a critical point have generic properties, regardless of differences in the details of each system. Therefore, sharp transitions in a range of complex systems are in fact related. In models, critical thresholds for such transitions correspond to bifurcations. Particularly relevant are 'catastrophic bifurcations' (see Box 1 for an example), where, once a threshold is exceeded, a positive feedback propels the system through a phase of directional change towards a contrasting state. Another important class of bifurcations are those that mark the transition from a stable equilibrium to a cyclic or chaotic attractor. Fundamental shifts that occur in systems when they pass bifurcations are collectively referred to as critical transitions.

We will first highlight the theoretical background of leading indicators that may occur in non-equilibrium dynamics before critical transitions, and illustrate how such indicators can perform in model generated time-series. Subsequently, we will review emerging empirical work on different systems and discuss prospects and challenges.

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