

Early warning signals for critical transitions

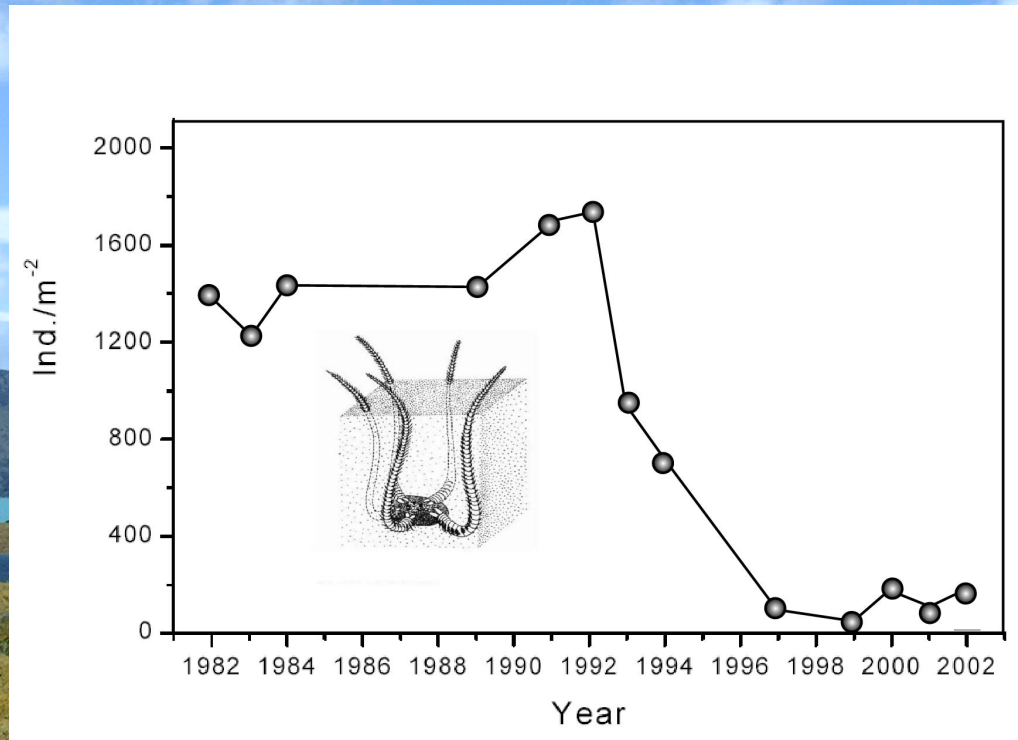
Marten Scheffer

Wageningen University, The Netherlands

**Vasilis Dakos, Egbert van Nes, Hermann Held, Jordi Bascompte, Victor Brovkin,
Max Rietkerk, William Brock, George Sugihara and Steve Carpenter**

Photograph Sarian Kosten

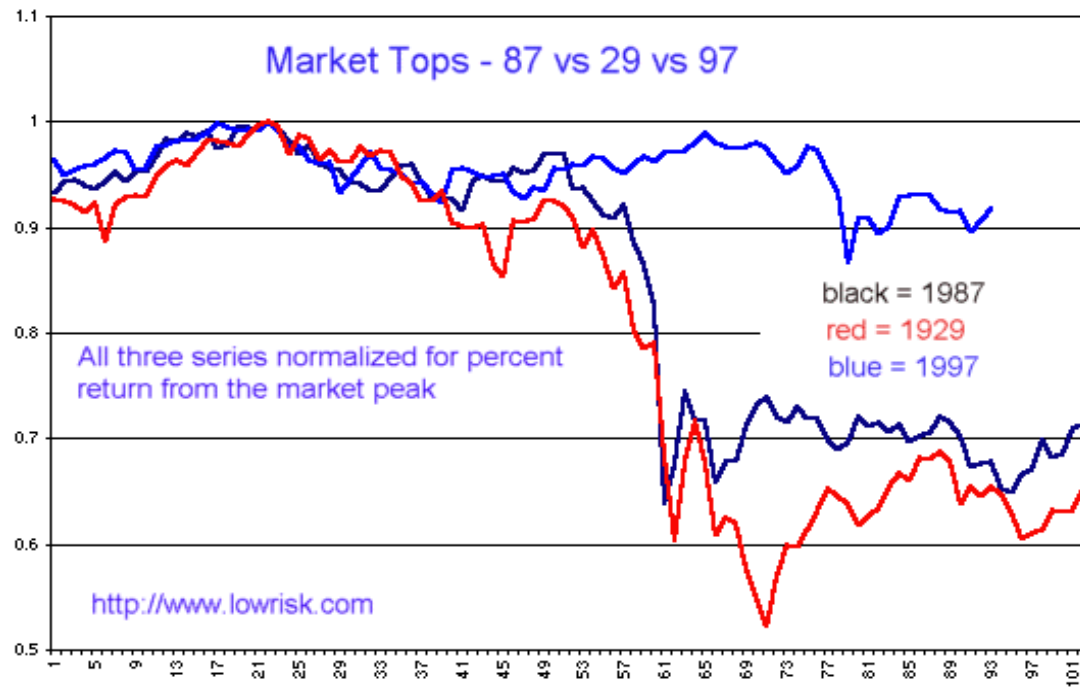
Many ecosystems show occasional sharp transitions



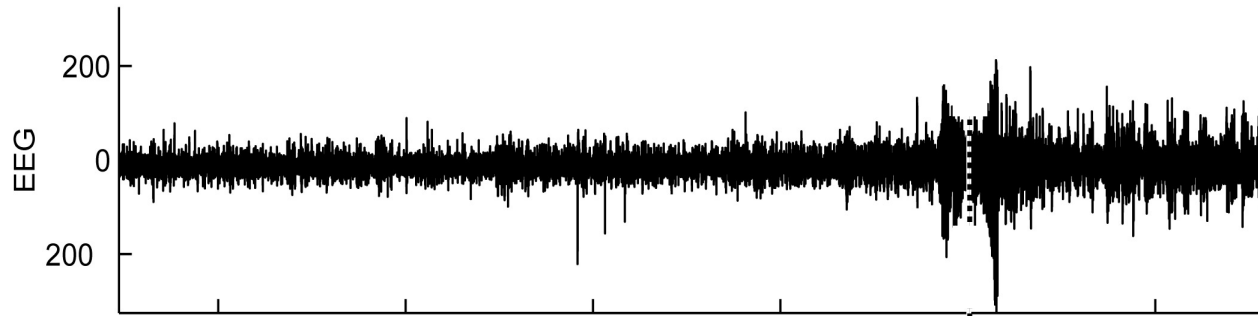
The same happens in other
complex systems



Financial Markets



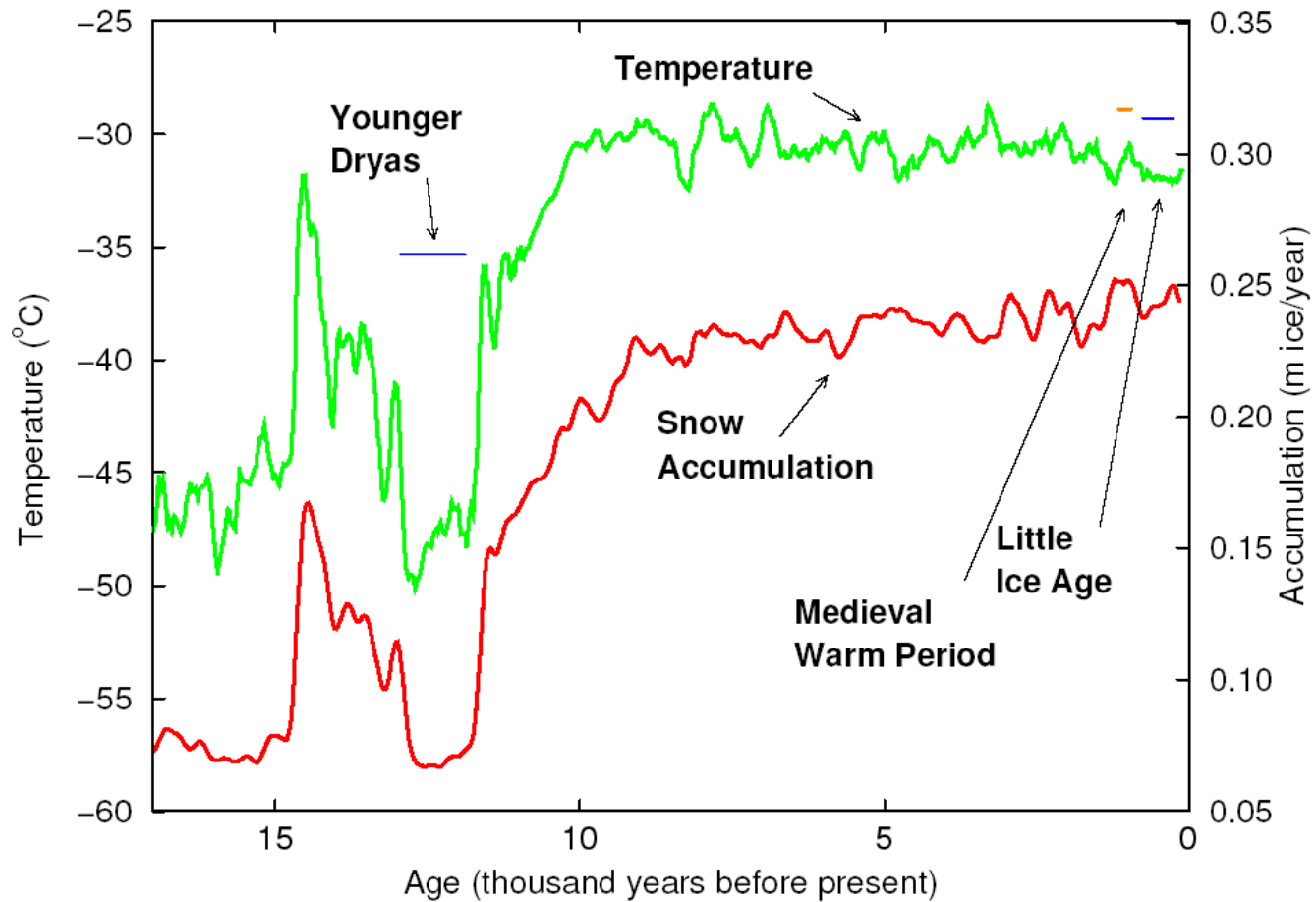
The Brain



States



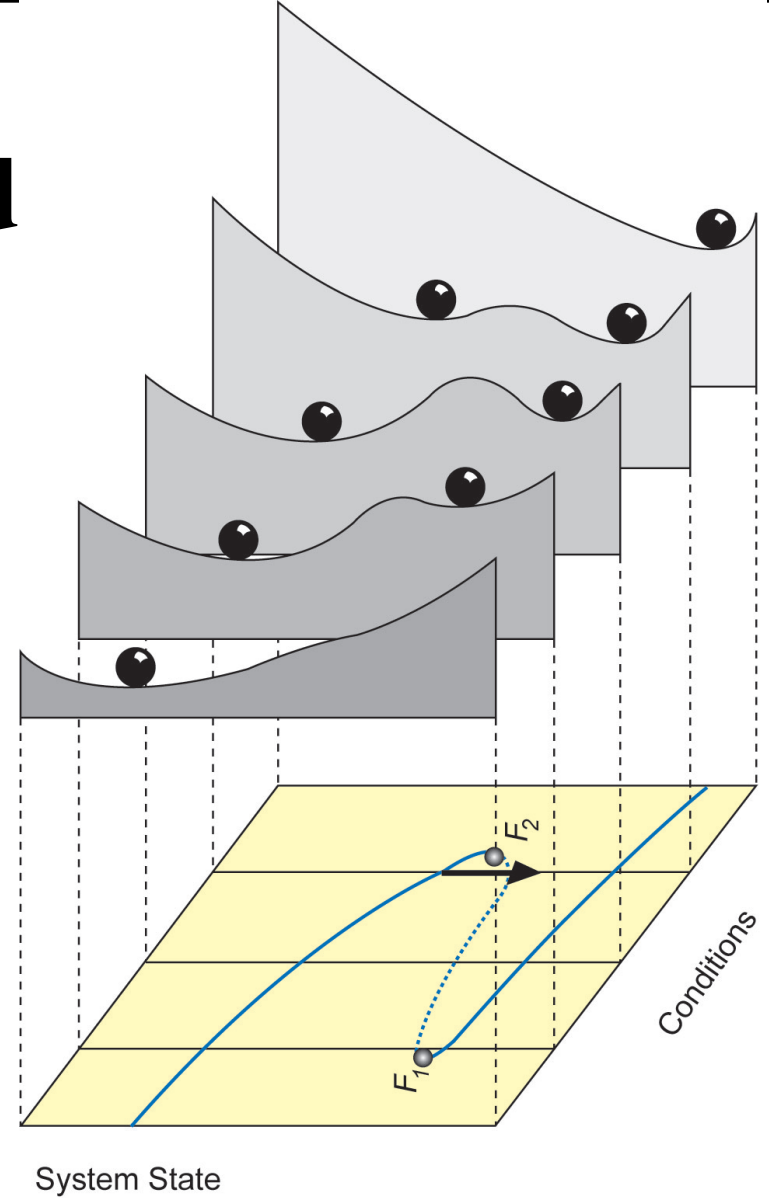
The Climate







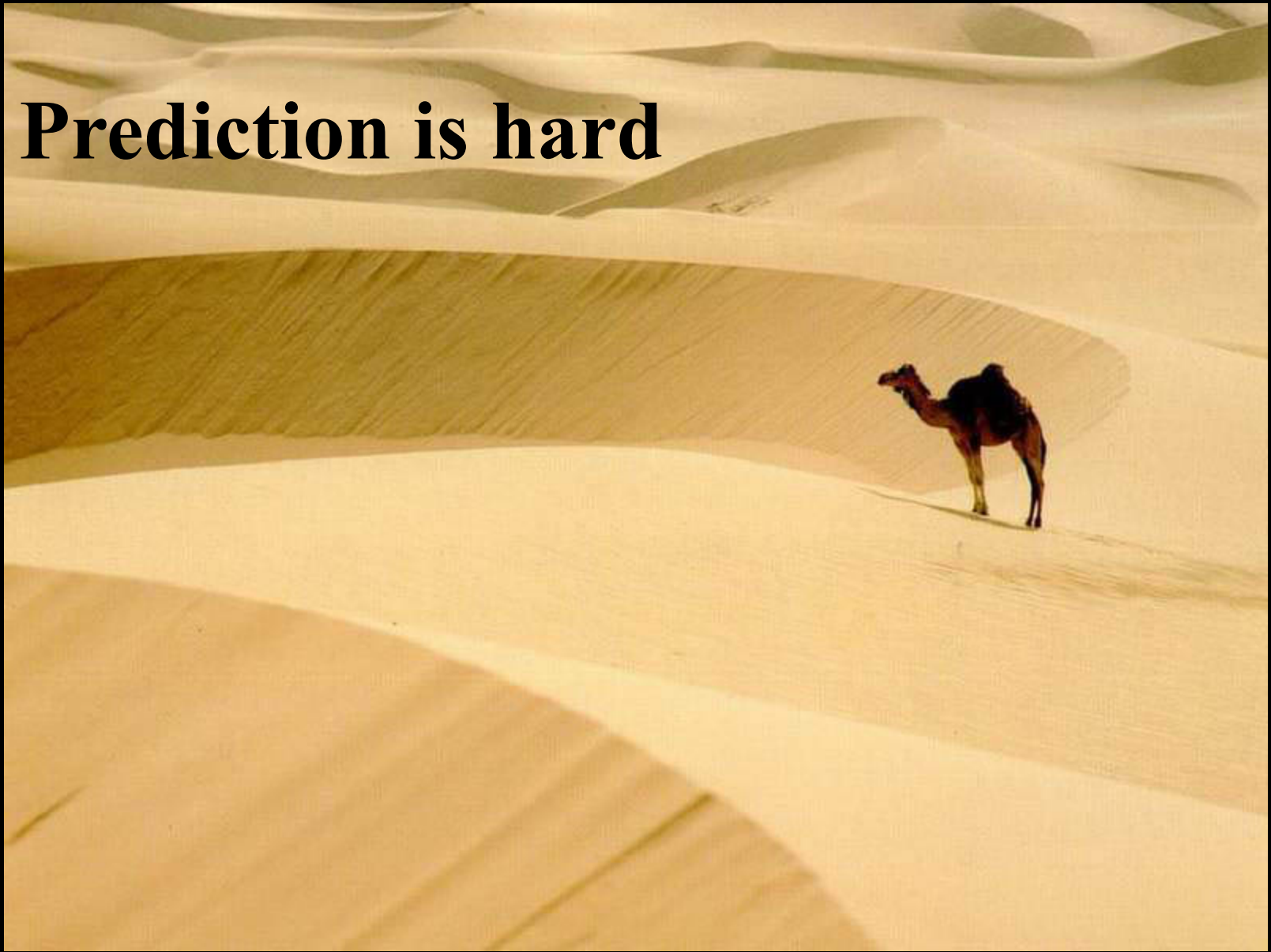
Prediction is hard



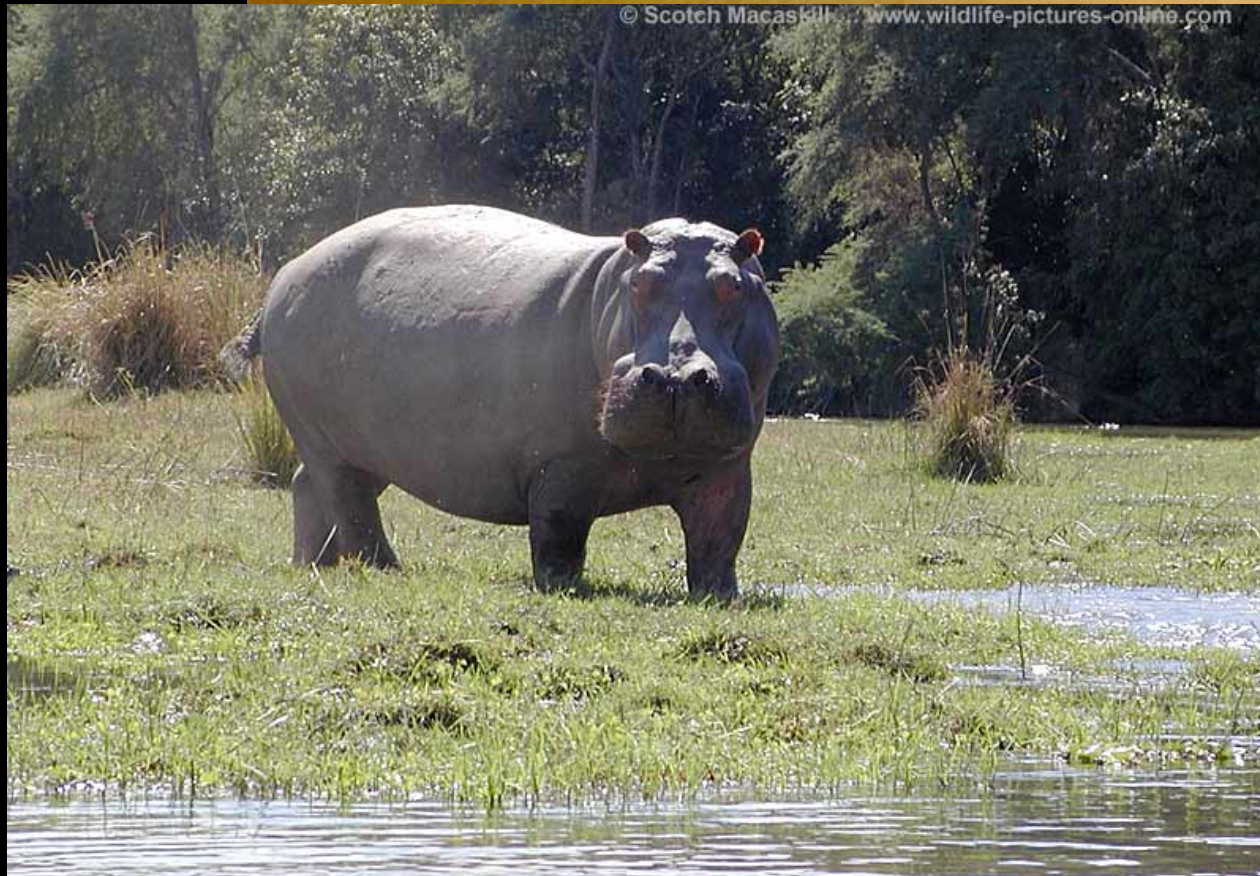
Scheffer, Carpenter, Walker, Foley and Folke

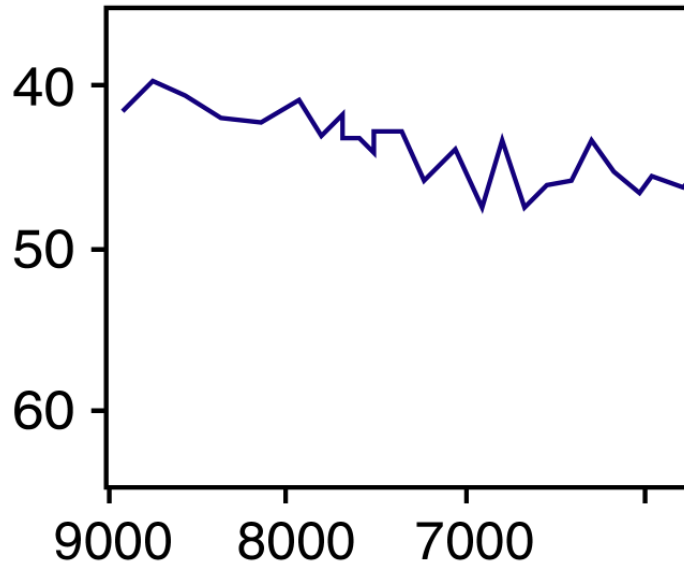
2001. *NATURE*

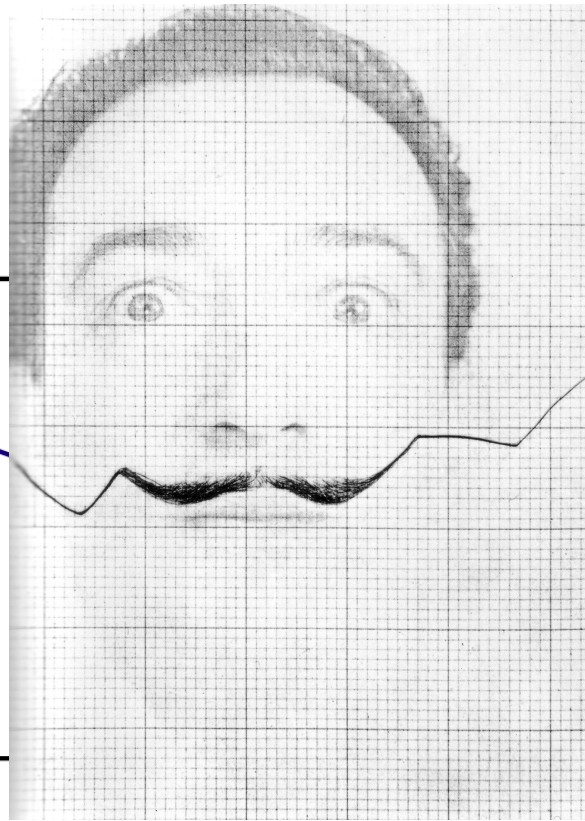
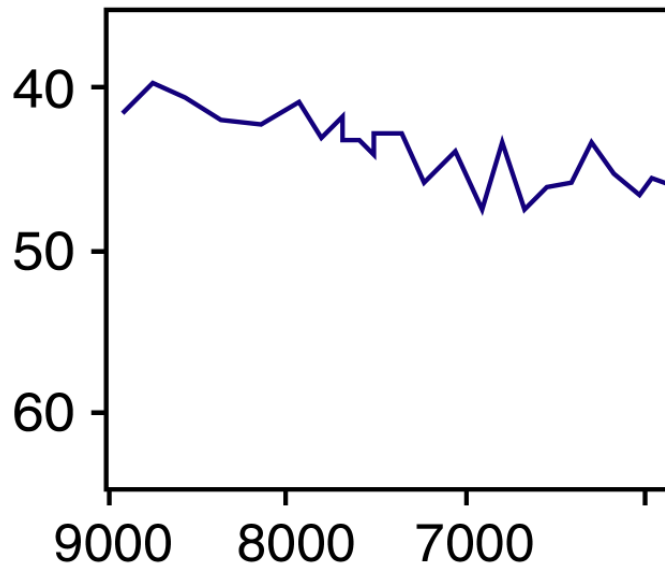
Prediction is hard

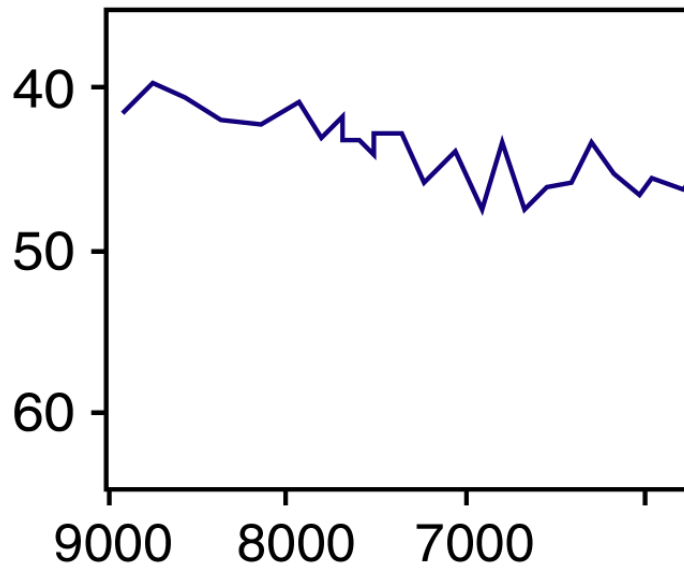


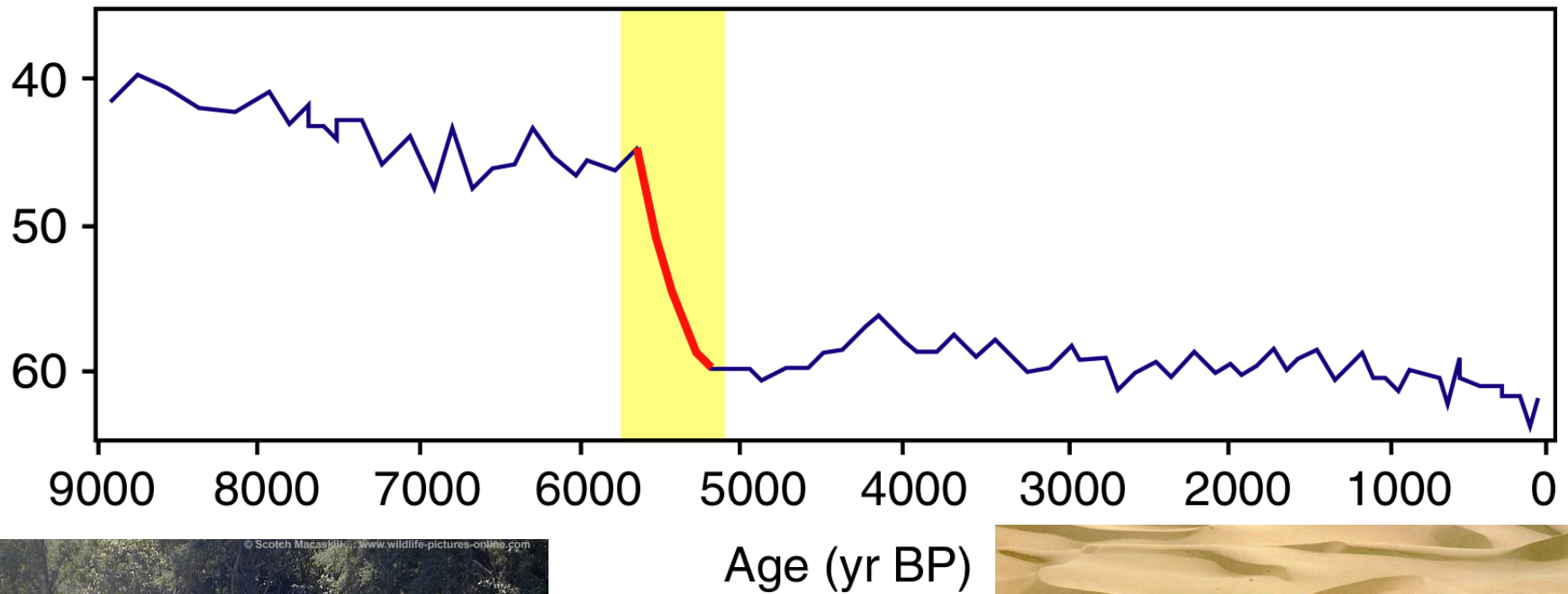
Prediction is hard







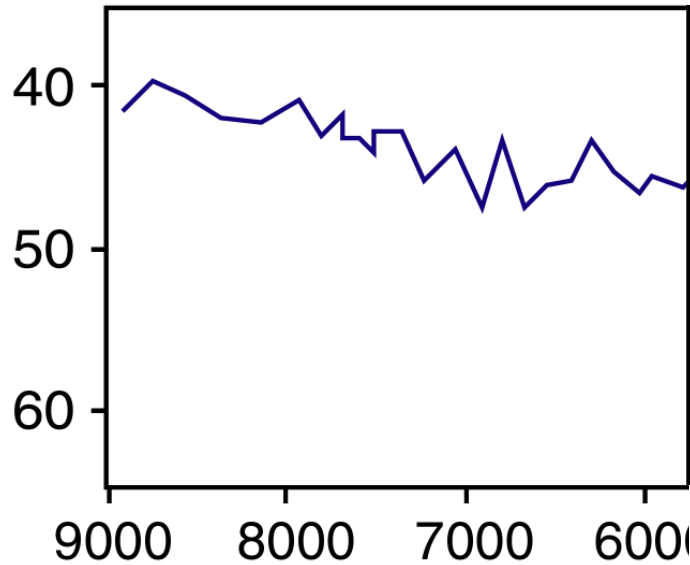




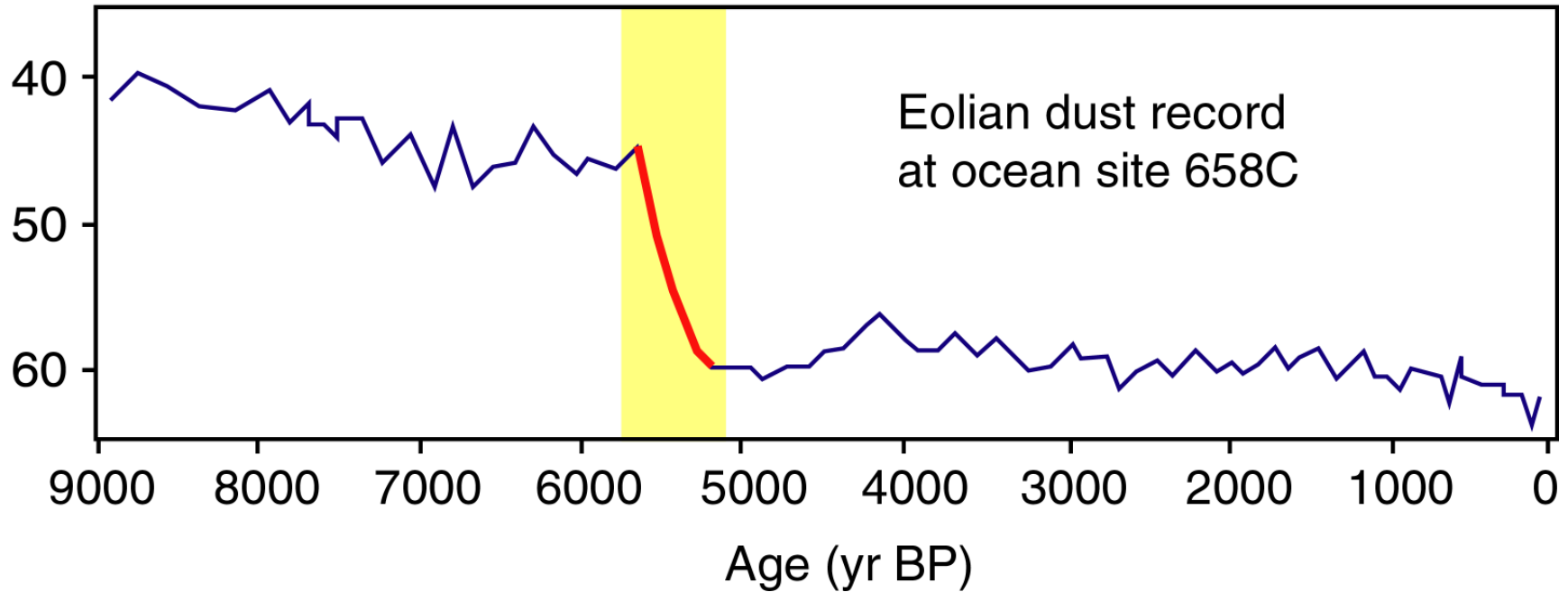
How to predict critical transitions ?



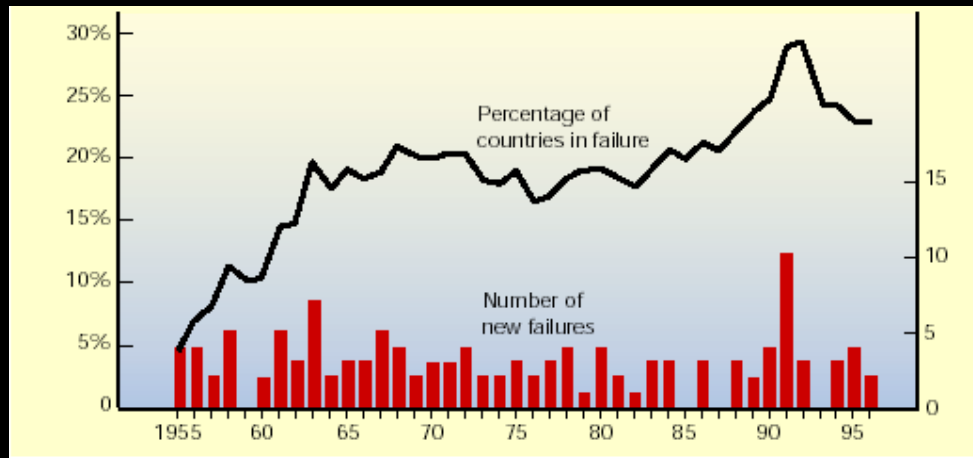
Extrapolation ?



Extrapolation ?



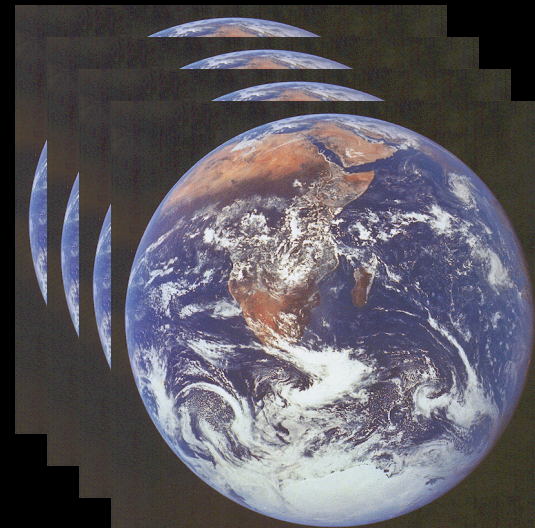
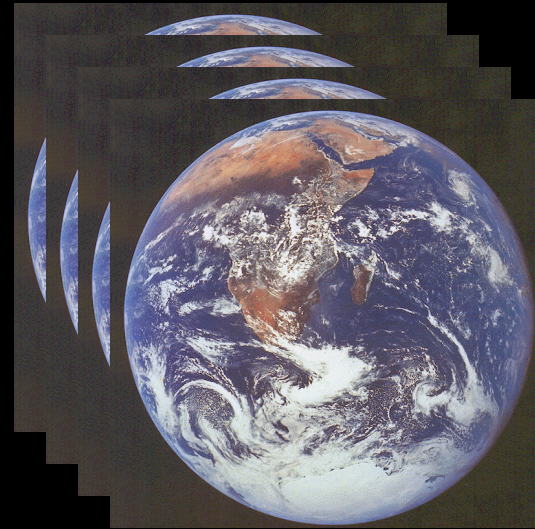
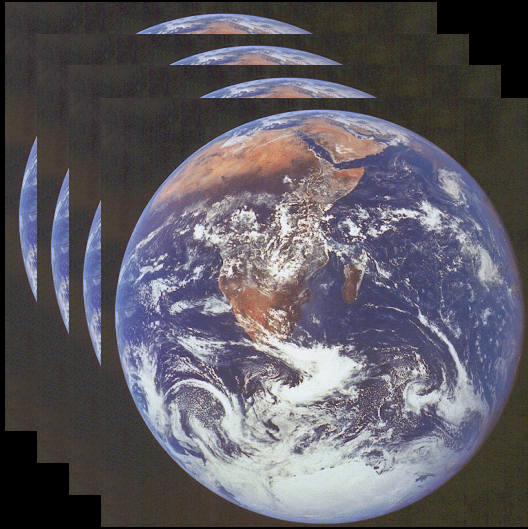
Statistics for many cases ?

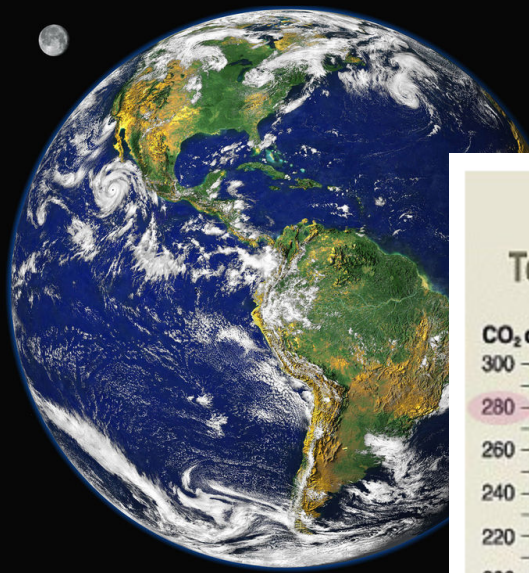


Experiments !

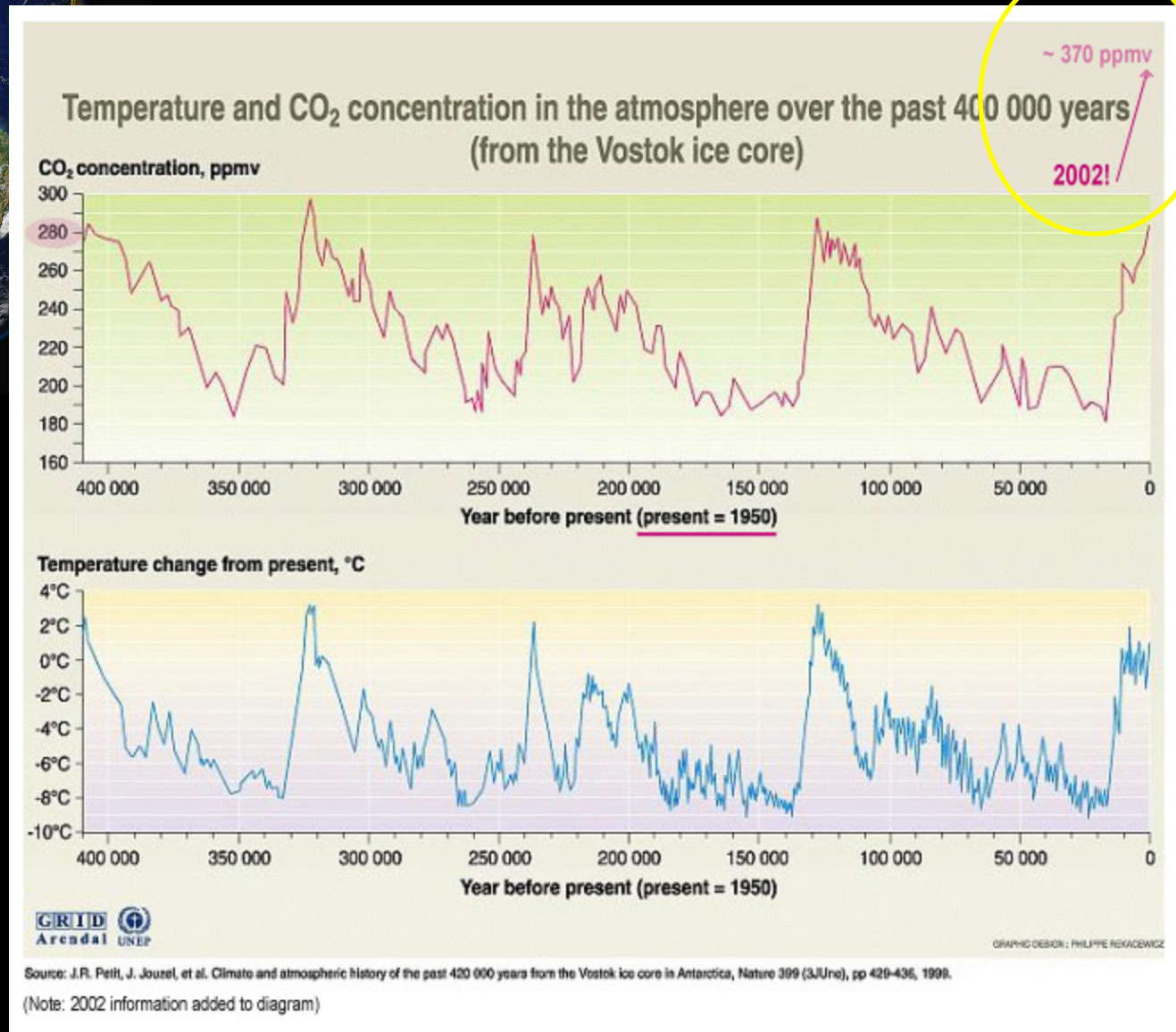


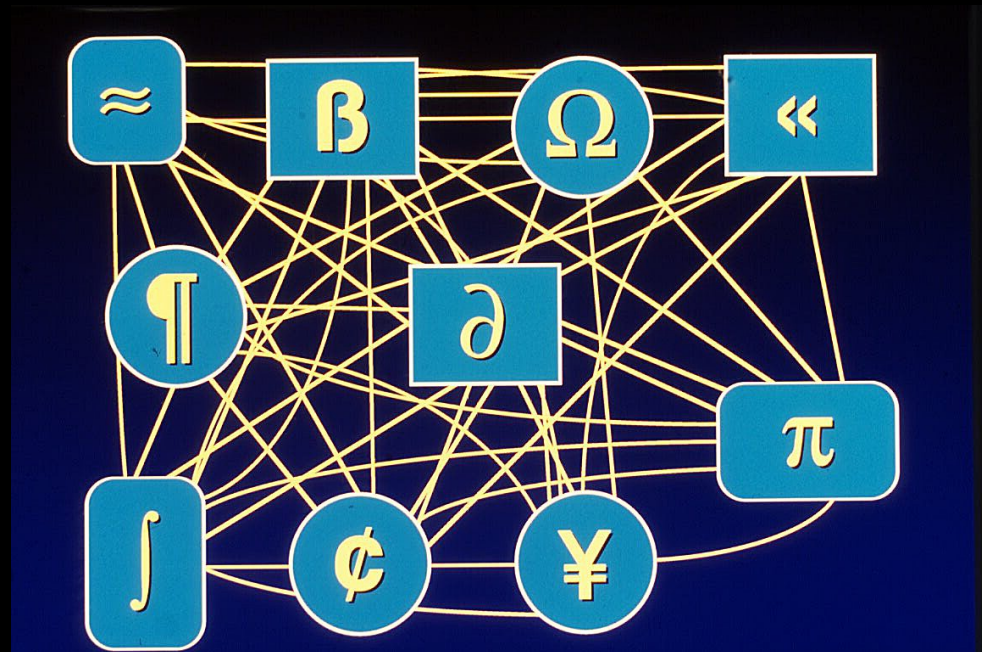
Experiments ?



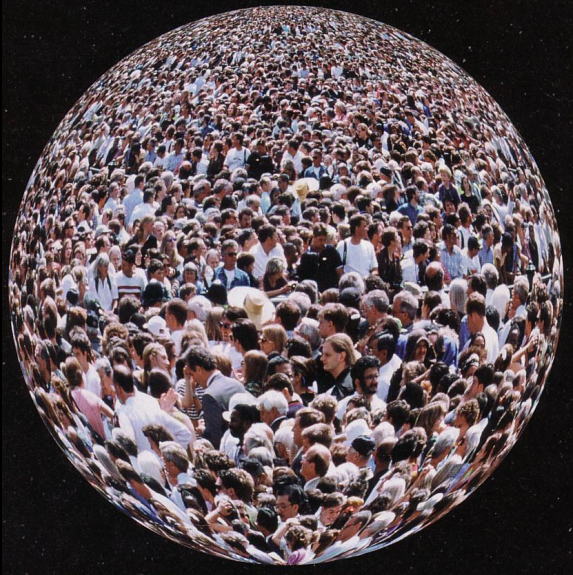


Past behaviour



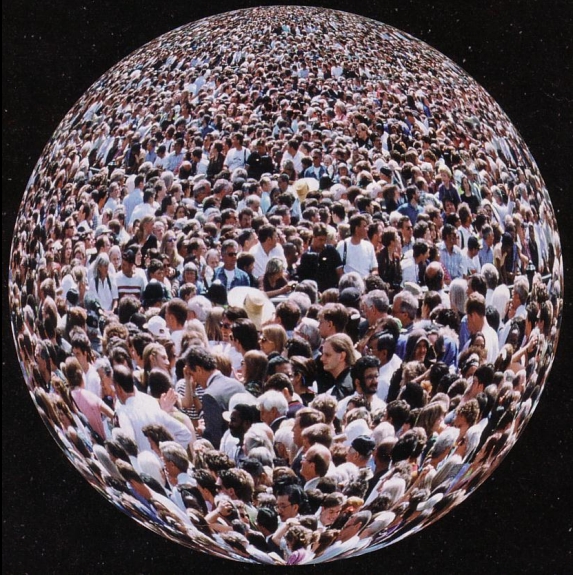


Can Critical Transitions be predicted ?

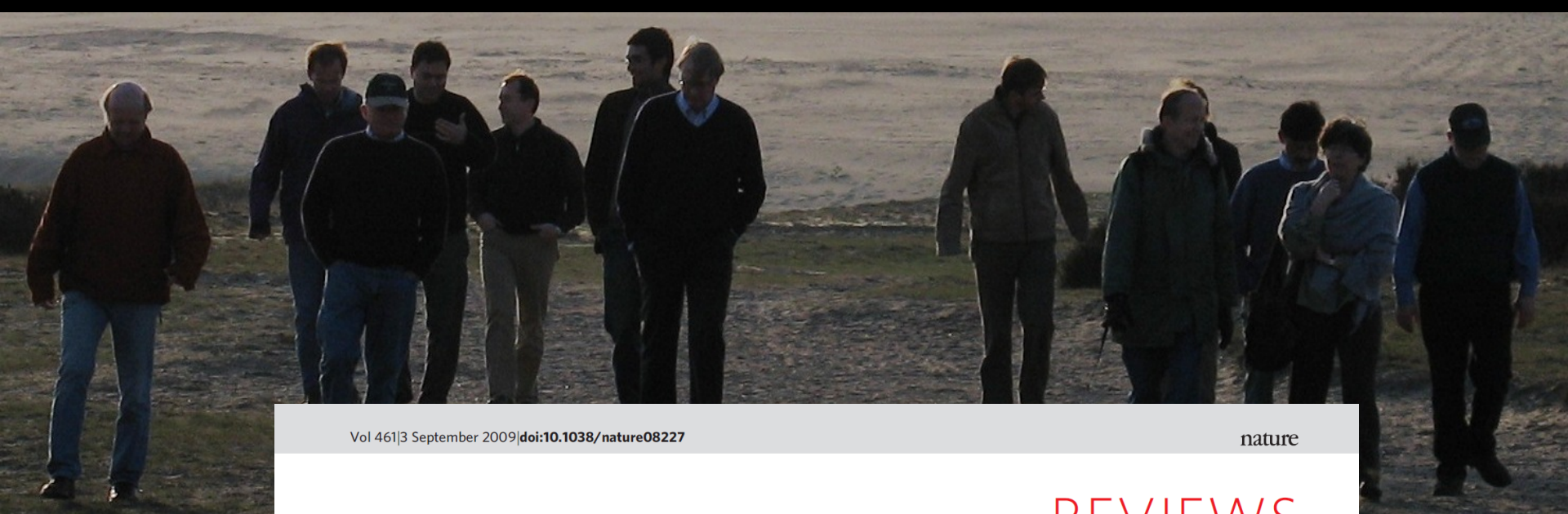
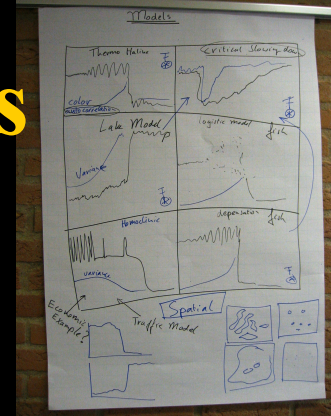


Even if we do not understand the system ?

Universal Laws Rule at Critical Points



Generic Early Warning Signals



Vol 461|3 September 2009|doi:10.1038/nature08227

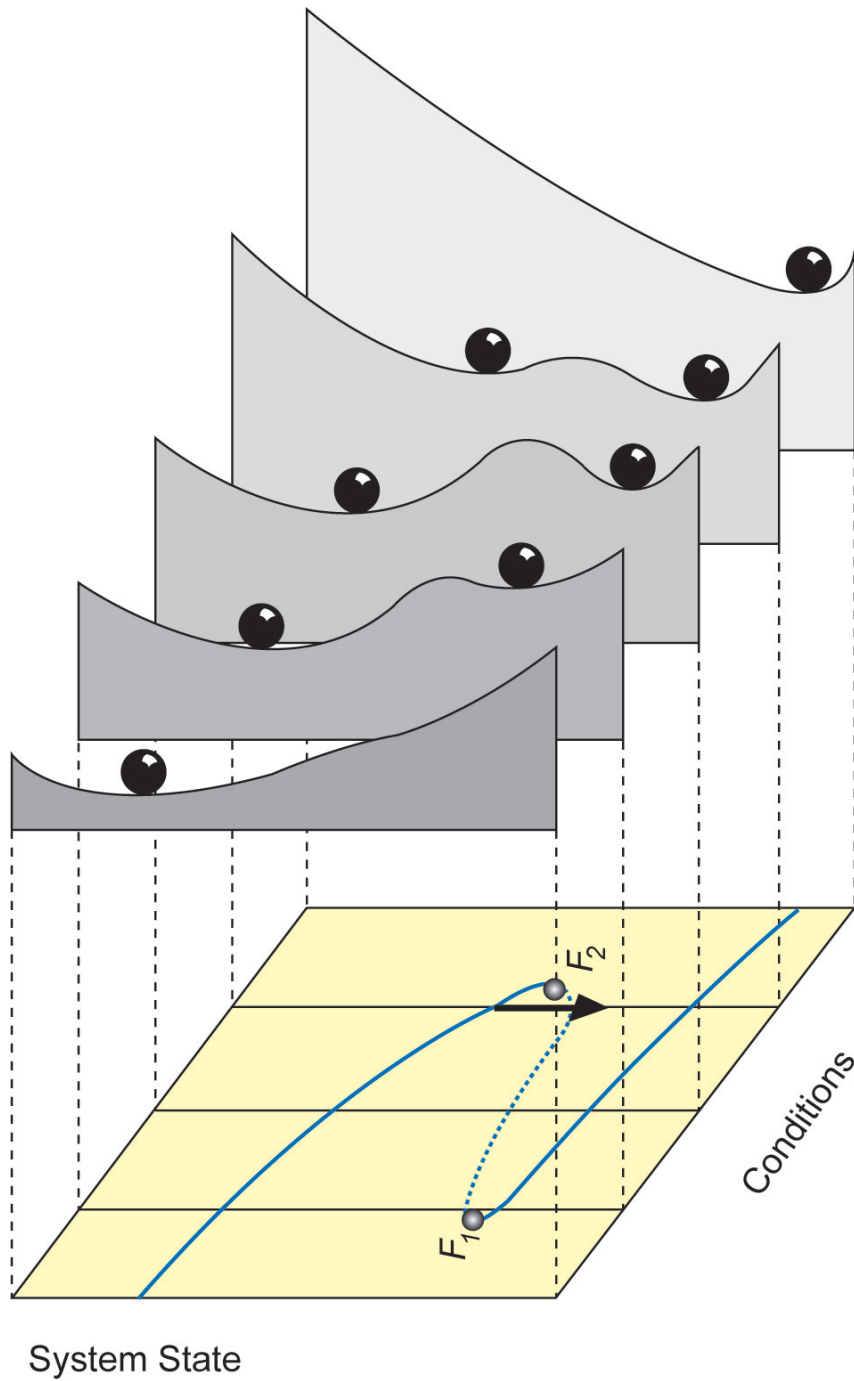
nature

REVIEWS

Early-warning signals for critical transitions

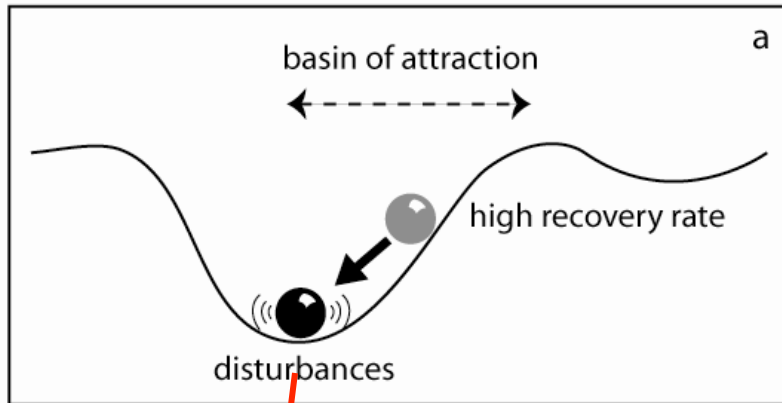
Marten Scheffer¹, Jordi Bascompte², William A. Brock³, Victor Brovkin⁵, Stephen R. Carpenter⁴, Vasilis Dakos¹, Hermann Held⁶, Egbert H. van Nes¹, Max Rietkerk⁷ & George Sugihara⁸

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.

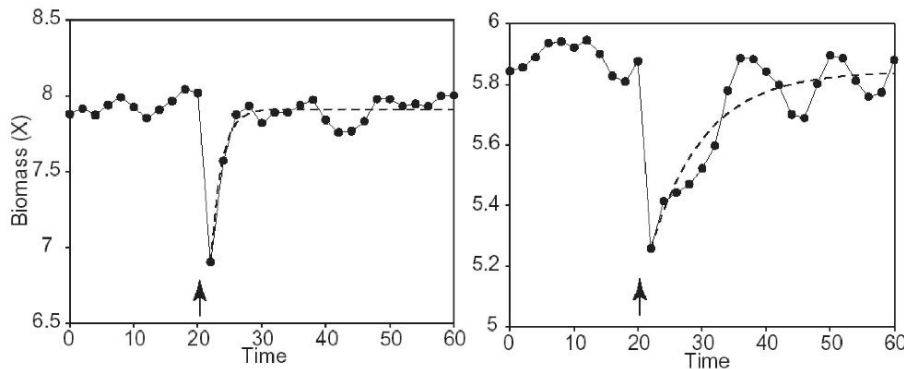
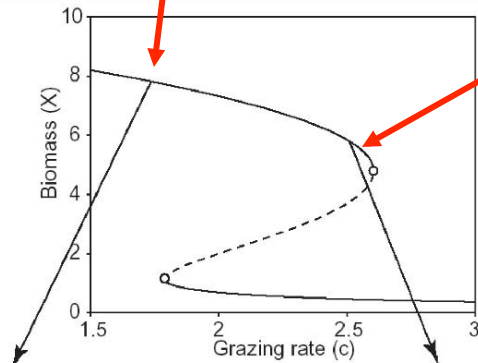
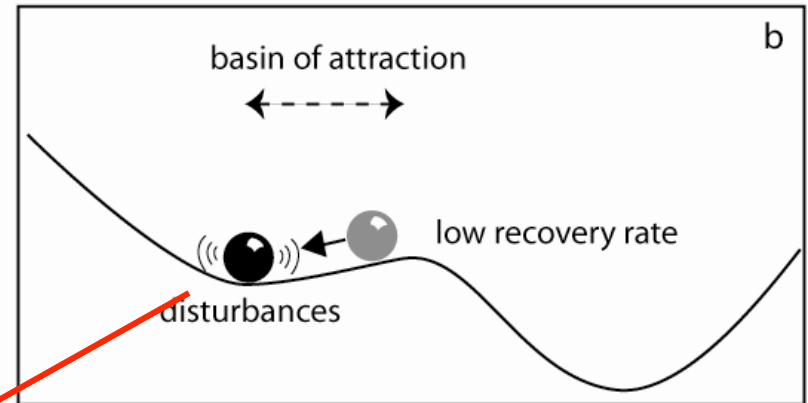


Critical Slowing Down

high resilience

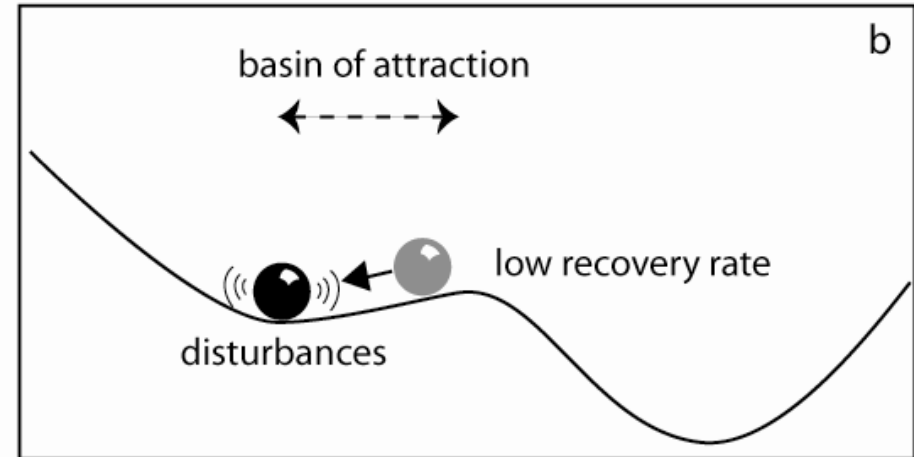
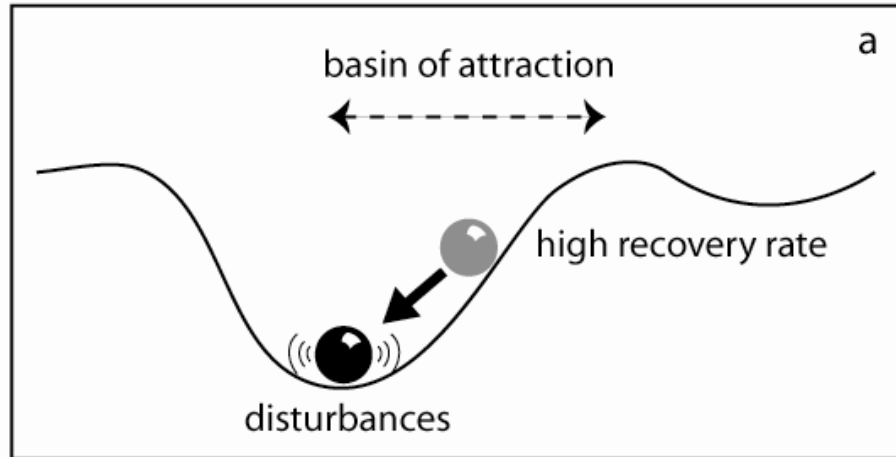


low resilience



Van Nes & Scheffer
“Slow recovery from perturbations”
American Naturalist 2007

“Generic Early Warning Signals” in stochastic environments



close to tipping point

increased
variance

increased
autocorrelation

+ skewness... + flickering....

Such early warning signals have been shown in models



Ocean Dynamics (2003) 53: 53–63
DOI 10.1007/s10236-002-0023-6

Thomas Kleinen · Hermann Held
Gerhard Petschel-Held

The potential role of spectral properties in detecting thresholds in the Earth system: application to the thermohaline circulation



PHILOSOPHICAL
TRANSACTIONS
— OF —
THE ROYAL
SOCIETY 

Phil. Trans. R. Soc. A (2009) **367**, 871–884
doi:10.1098/rsta.2008.0171
Published online 16 December 2008

Using GENIE to study a tipping point in the climate system

BY TIMOTHY M. LENTON^{1,*}, RICHARD J. MYERSCOUGH²,
ROBERT MARSH², VALERIE N. LIVINA¹, ANDREW R. PRICE³,



Ecology Letters, (2006) **9**: 311–318

doi: 10.1111/j.1461-0248.2005.00877.x

LETTER

Rising variance: a leading indicator of ecological transition

Abstract

Regime shifts are substantial, long-lasting reorganizations of complex systems, such as ecosystems. Large ecosystem changes such as eutrophication, shifts among vegetation

S. R. Carpenter^{1*} and
W. A. Brock²

but also in real climate dynamics

PNAS PNAS

Slowing down as an early warning signal for abrupt climate change

Vasilis Dakos*, Marten Scheffer*[†], Egbert H. van Nes*, Victor Brovkin*[§], Vladimir Petoukhov[‡], and Hermann Held[‡]

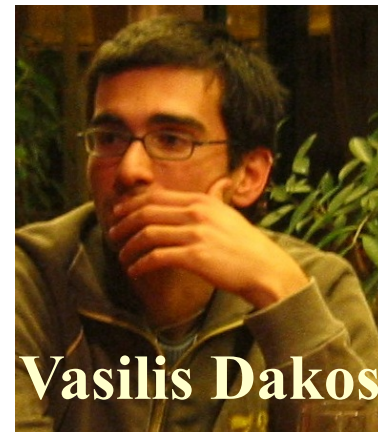
*Department of Aquatic Ecology and Water Quality Management, Wageningen University, P.O. Box 47, 6700 AA, Wageningen, The Netherlands; and

[†]Potsdam Institute for Climate Impact Research, P.O. Box 601203, D-14412 Potsdam, Germany

Edited by Stephen R. Carpenter, University of Wisconsin, Madison, WI, and approved July 16, 2008 (received for review March 11, 2008)

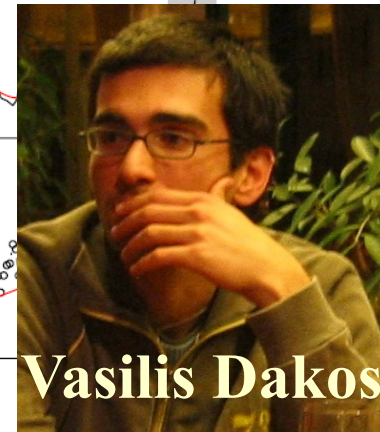
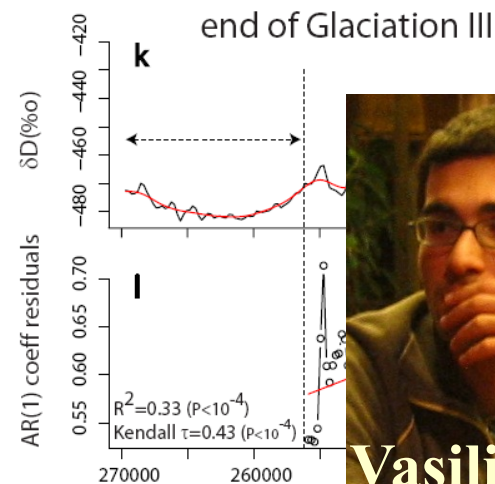
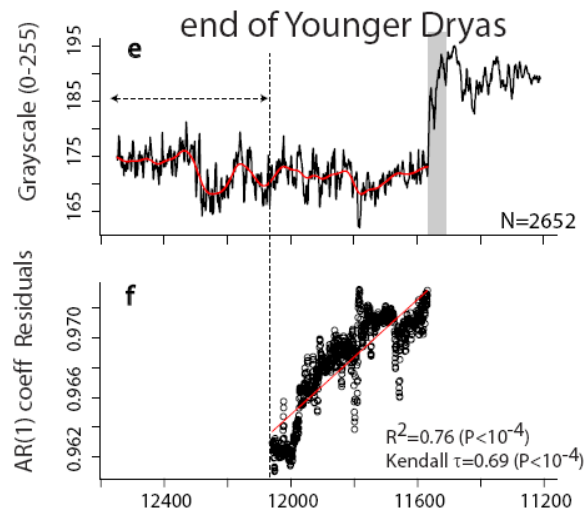
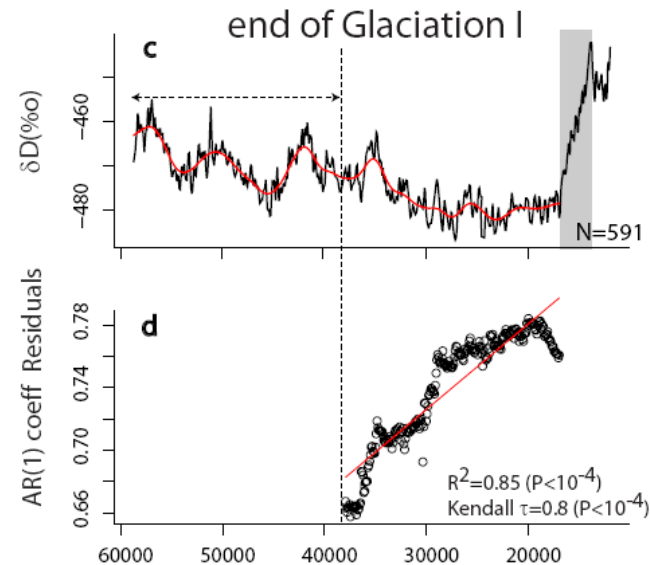
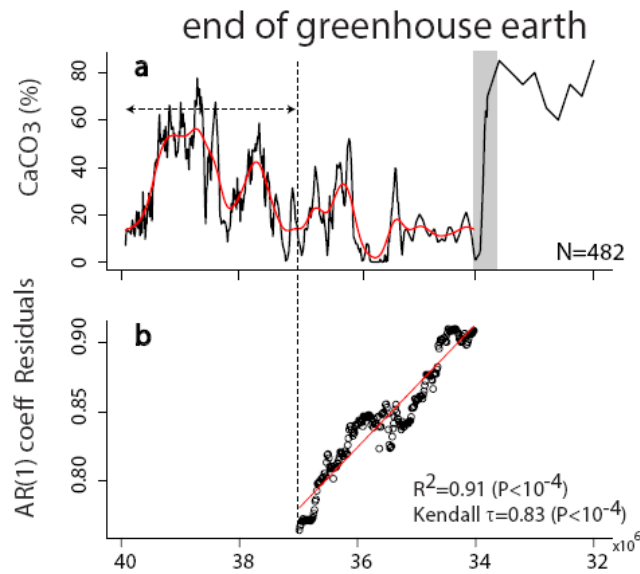
In the Earth's history, periods of relatively stable climate have often been interrupted by sharp transitions to a contrasting state. One explanation for such events of abrupt change is that they happened when the earth system reached a critical tipping point. However, this remains hard to prove for events in the remote past, and it is even more difficult to predict if and when we might reach a tipping point for abrupt climate change in the future. Here, we analyze eight ancient abrupt climate shifts and show that they were all preceded by a characteristic slowing down of the fluctuations starting well before the actual shift. Such slowing down, measured as increased autocorrelation, can be mathematically shown to be a hallmark of tipping points. Therefore, our results imply independent empirical evidence for the idea that past abrupt shifts were associated with the passing of critical thresholds.

remain rather hypothetical because they are difficult to test. Even if the proposed mechanisms seem plausible, our capacity to model these systems accurately is too limited to conclude with reasonable certainty that tipping points are involved. This is particularly worrisome in view of the possibility of hitting on a tipping point as current climate change proceeds. Although most climate scientists would acknowledge that possibility, we are simply unable to predict if and when future climate change might bring us to a critical threshold (1). Even though climate models are rapidly improving, the chances that we will soon be able to predict potential tipping points with sufficient accuracy seem negligible. A similar situation exists in ecology where the existence of thresholds for catastrophic shifts has been shown for a range of systems (12), but prediction of such shifts has remained



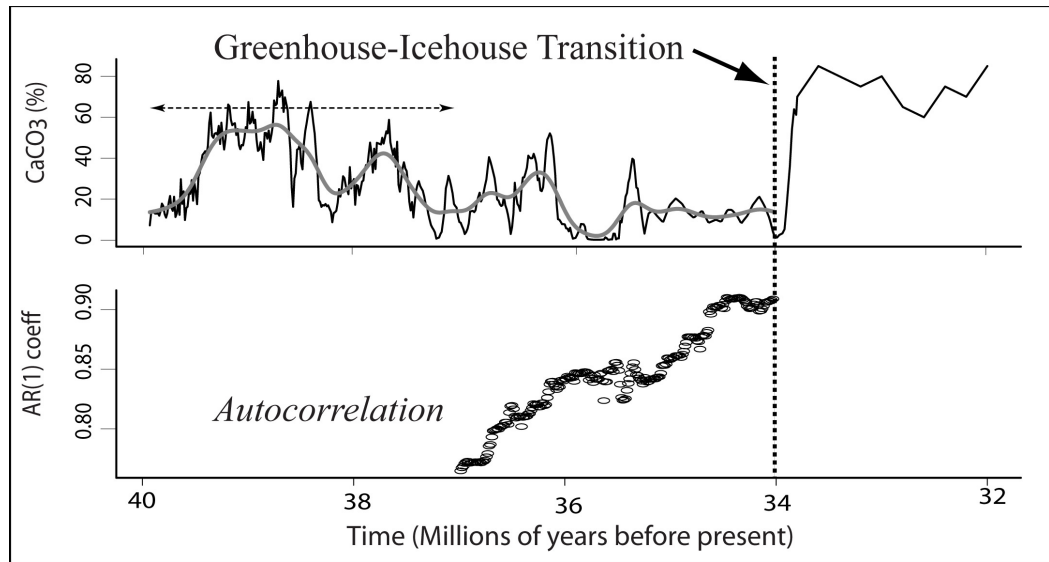
Vasilis Dakos

Critical slowing down announced 8 abrupt climate shifts



Vasilis Dakos

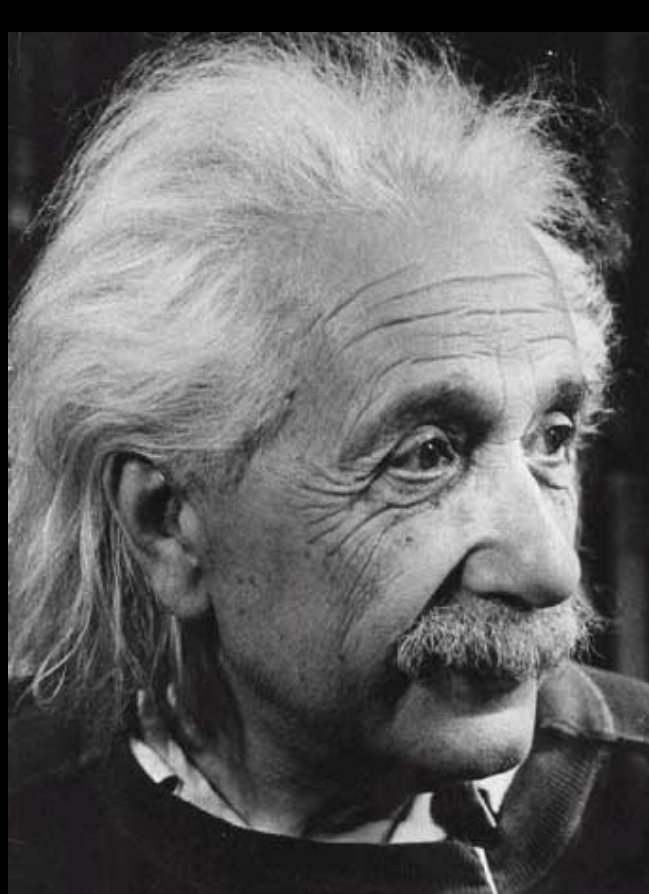
There are many challenges to prediction





A collage of various small, rectangular and irregular pieces of artwork, including depictions of fish, plants, and abstract patterns, arranged on a black background. The pieces are scattered across the page, with some showing detailed illustrations of aquatic life like fish and snails, and others showing abstract or textured patterns. The colors used in the artwork are diverse, including greens, yellows, reds, and blues.

The Defragmentation of Science



$$D = \frac{1}{c} \frac{1}{t} \frac{dl}{dt} = \frac{1}{c} \frac{1}{P} \frac{dP}{dt}$$

$$D^2 = \frac{1}{P^2} \frac{P_0 - P}{P} \sim \frac{1}{P^2} \quad (1a)$$

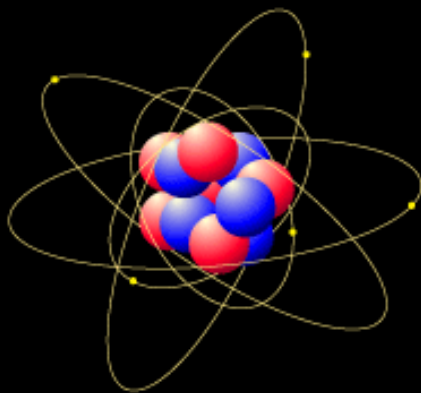
$$D^2 = \frac{KQ}{3} \frac{P_0 - P}{P_0} \sim \frac{1}{3} KQ \quad (2a)$$

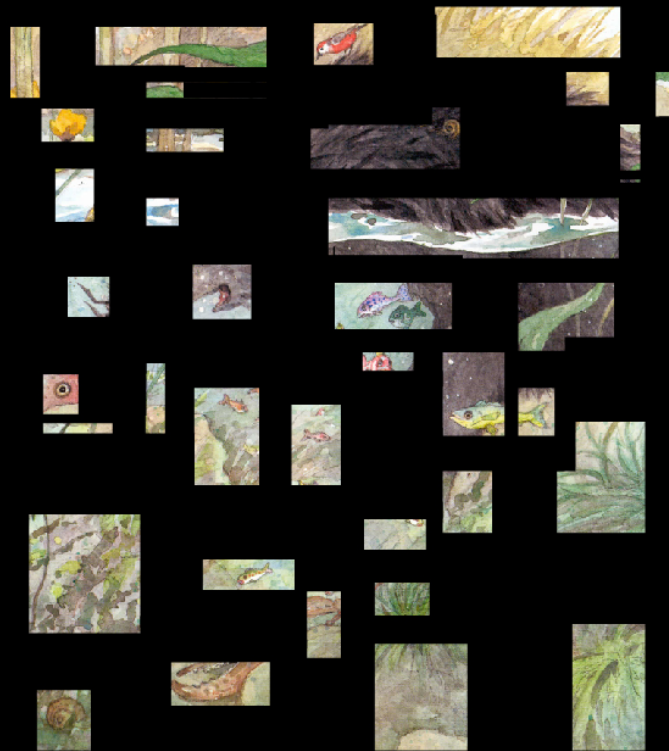
$$D^2 \sim 10^{-53}$$

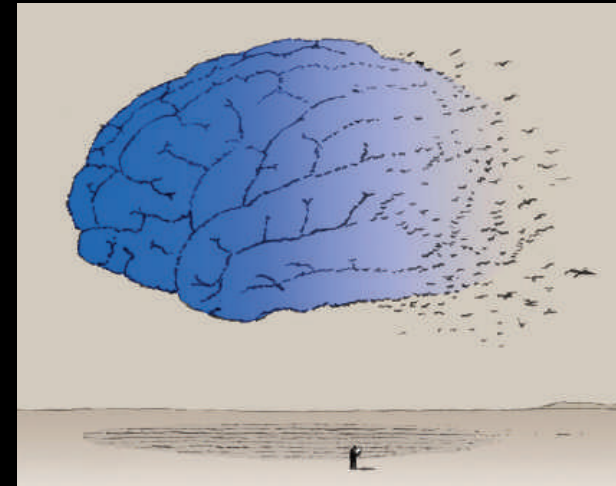
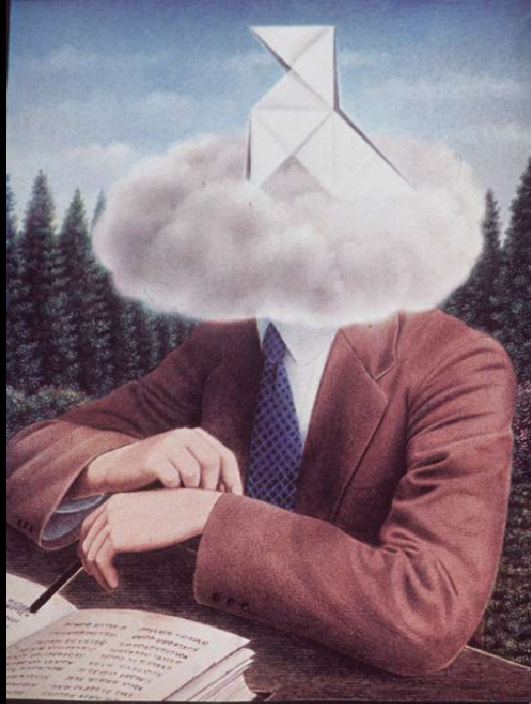
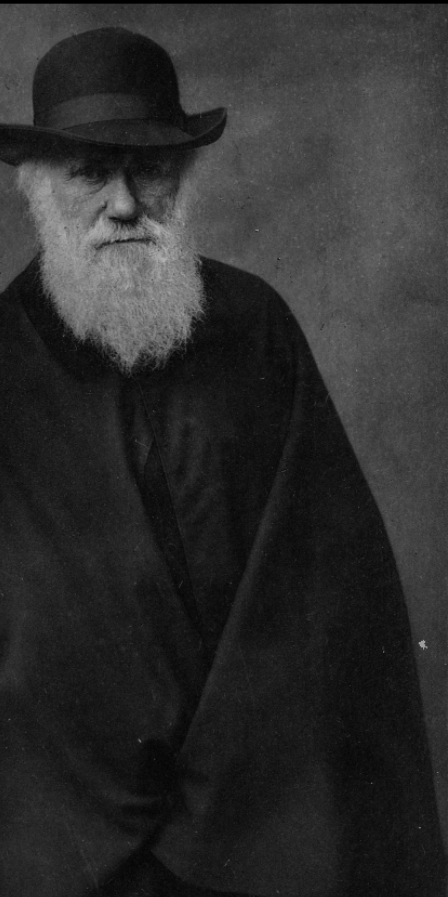
$$Q \sim 10^{-26}$$

$$P \sim 10^8 \text{ g} \cdot \text{cm}^3$$

$$\lambda \sim 10^{10} (10^{11}) \text{ cm}$$







Radical multi-disciplinarity

Groups of diverse problem solvers can outperform groups of high-ability problem solvers

Lu Hong^{†‡§} and Scott E. Page[¶]

[†]Michigan Business School and [¶]Complex Systems, University of Michigan, Ann Arbor, MI 48106-1101

Edited by William J. Baumol, New York University, New York, NY, and approved by the National Academy of Sciences

We introduce a general framework for modeling functionally diverse problem-solving agents. In this framework, problem-solving agents possess representations of problems and algorithms that they use to locate solutions. We use this framework to establish a result relevant to group composition. We find that when selecting a problem-solving team from a diverse population of intelligent agents, a team of randomly selected agents outperforms a team comprised of the best-performing agents. This result relies on the intuition that, as the initial pool of problem solvers becomes large, the best-performing agents necessarily become similar in the space of problem solvers. Their relatively greater ability is more than offset by their lack of problem-solving diversity.

Scott E. Page

THE DIFFERENCE

HOW THE POWER OF DIVERSITY
CREATES BETTER GROUPS, FIRMS,
SCHOOLS, AND SOCIETIES

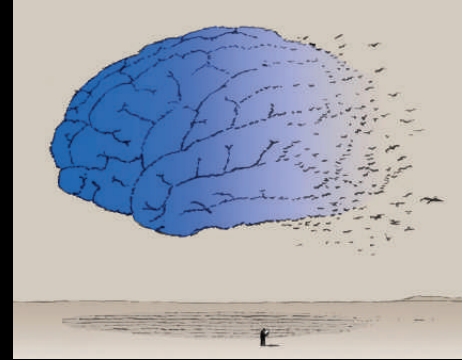
nature

Vol 451 | 21 February 2008

SPECIAL REPORT

An indifference to boundaries

As some of the world's largest universities undergo dramatic departmental restructuring to foster interdisciplinary research, **John Whitfield** asks whether they're making the right move.





SARAS



The Defragmentation of Science

