Points de Bascule - Tipping points

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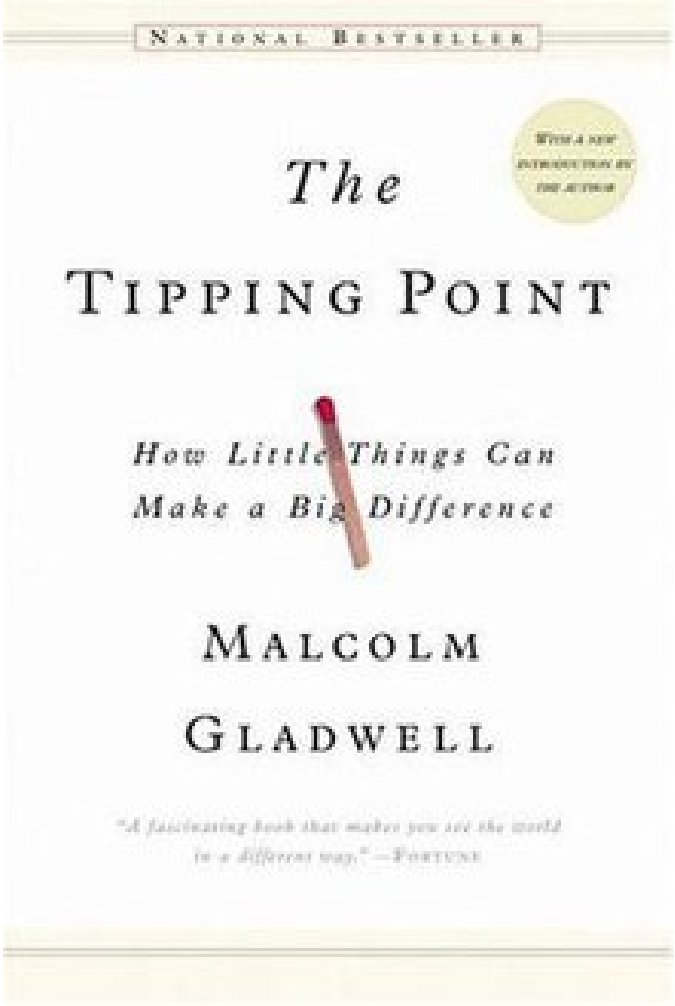
Plan

1. Historical uses
2. A political project ?
3. Foundations in mathematics and ecosystem dynamics
4. Le poids des mots, . . . le choc des “conceptual sketches”
5. Linking with the Anthropocene

Sociological tipping

- 1969 - 1971 : Thomas Schelling: a general theory of tipping
- 2000 : Malcolm Gladwell: The Tipping Point

" The book seeks to explain and describe the 'mysterious' sociological changes that mark everyday life "



The Thinning of Arctic Sea Ice, 1988–2003: Have We Passed a Tipping Point?

R. W. Lindsay and J. Zhang

Polar Science Center, University of Washington, Seattle, Washington

(Manuscript received 2 December 2004, in final form 13 June 2005)

ABSTRACT

Recent observations of summer Arctic sea ice over the satellite era show that record or near-record lows for the ice extent occurred in the years 2002–05. To determine the physical processes contributing to these changes in the Arctic pack ice, model results from a regional coupled ice–ocean model have been analyzed. Since 1988 the thickness of the simulated basinwide ice thinned by 1.31 m or 43%. The thinning is greatest along the coast in the sector from the Chukchi Sea to the Beaufort Sea to Greenland.

It is hypothesized that the thinning since 1988 is due to preconditioning, a trigger, and positive feedbacks: 1) the fall, winter, and spring air temperatures over the Arctic Ocean have gradually increased over the last 50 yr, leading to reduced thickness of first-year ice at the start of summer; 2) a temporary shift, starting in 1989, of two principal climate indexes (the Arctic Oscillation and Pacific Decadal Oscillation) caused a

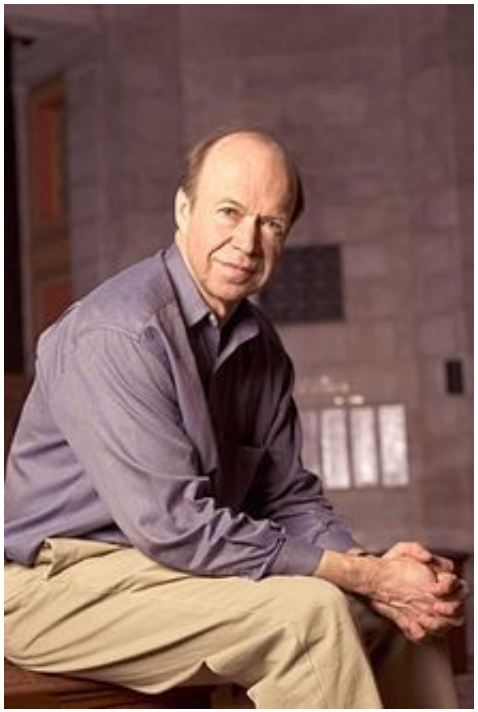
Urging action about climate change

- First use of "tipping point" in the context of climate change by J. Schellnhuber, when clarifying the concept of "large-scale discontinuites" for a BBC journalist.[1]
- Hansen: Talk tribute to David Keeling: "Is There Still Time to Avoid 'Dangerous Anthropogenic Interference' with Global Climate?" (2005)[2].
  - note the post-Katerina context, and the then debate about collective and individual responsibilities.

[1] K. Mossman. In: **Proceedings of the National Academy of Sciences** (2008).

[2] C. Russill and Z. Nyssa. In: **Global Environmental Change** (2009).

A few key actors



James Hansen

Joachin Schellnhuber

Tim Lenton

Marten Scheffer

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Urging policy action

- Clark 1985[3],[4]

  The policy on the CO_2 question should be recast as a problem of risk assessment and risk management

[3] W. C. Clark. Tech. rep. 1985.

[4] C. Russill and Z. Nyssa. In: **Global Environmental Change** (2009).

[5] idem

[6] ibidem

Urging policy action

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- Schneider (1988) 'double ethical bind' [5]

  "where a concern for scientific accuracy must be balanced by attention to media effectiveness"

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- Hansen (2015) : motivating action. Tipping point used in the context of Katerina

  Hansen's (2005) initial use of tipping point emerged in opposition to the burning embers diagram of the IPCC AR3'[6]

[3] W. C. Clark. Tech. rep. 1985.

[4] C. Russill and Z. Nyssa. In: **Global Environmental Change** (2009).

[5] idem

[6] ibidem

Committed use of a sociological vocabulary

- Nature (2006) editorial advises against the use of tipping point in non-sociological context - uncertain science, distorting views, trigger fatalism[7]
- but Hansen, Schellnhuber, later Lenton carry on

[7] Nature. In: **Nature** (2006).

Why ?

- formal analogy (dynamical systems)
- scientific and normative programe
  - identify the elements of control of tipping point to act on them and “dangerous climate change”
  - resonance with the sociological concept: avoiding dangerous climate changes requires a society change, a sociological tipping.

The instrument: Generative metaphor[9]

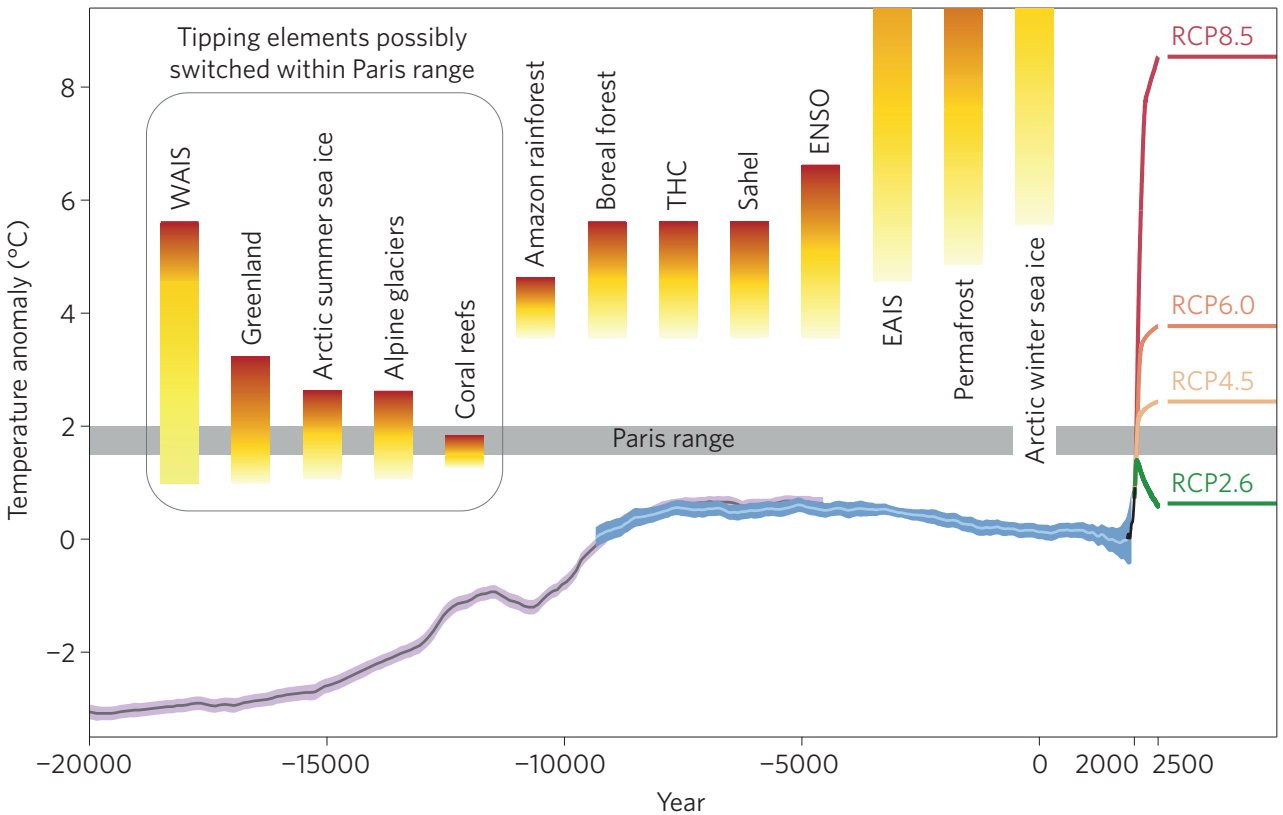
- load a popular concept with scientific content[8]
- generate a feedback between the popular concept and the new meaning "serves as an alternative description able to illuminate and re-prioritize different aspects of a complex situation"
- load the scientific concept with **values** and imagery

other climate examples: Conveyor Belt (Broecker), Switches,

[8] D. A. Schön. In: **Metaphor and Thought** (1993). Ed. by A. Ortony.

[9] C. Russill and Z. Nyssa. In: **Global Environmental Change** (2009).

Interference with Paris agreement



[10]

[10] H. J. Schellnhuber, S. Rahmstorf, and R. Winkelmann. In: **Nature Climate change** (2016).

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Dynamical system's theory

$$\frac{d\,x}{d\,t} = f(x) \tag{1}$$

- fixed points
- stationary solution
- limit cycles
- chaos

Note:

Barry Saltzman is probably the one who most introduced dynamical systems's thinking (with non-linereaties, chaos), in collaboration with Lorenz who has been better at popularizing it. Saltzman's legacy is unfortunately unknown outside specialist circles.

The Lameray diagram of stability

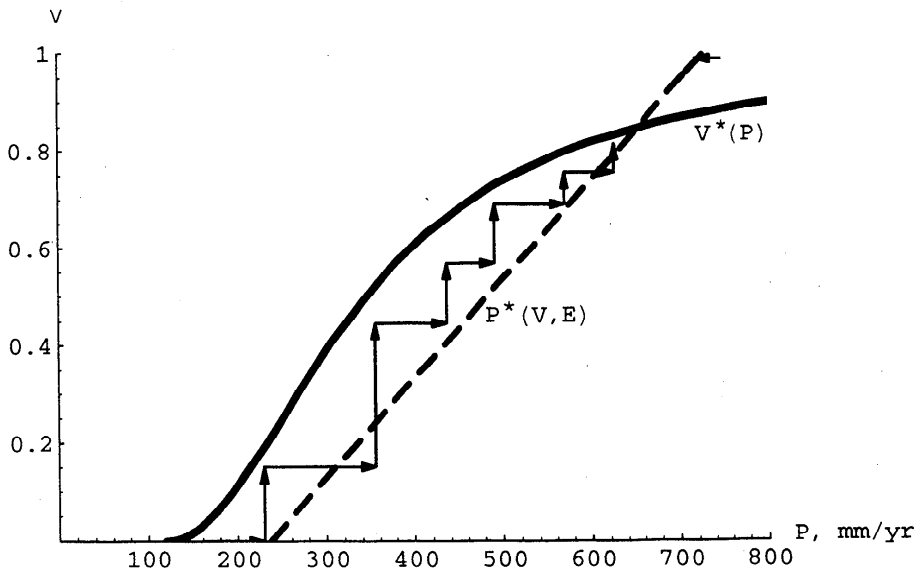


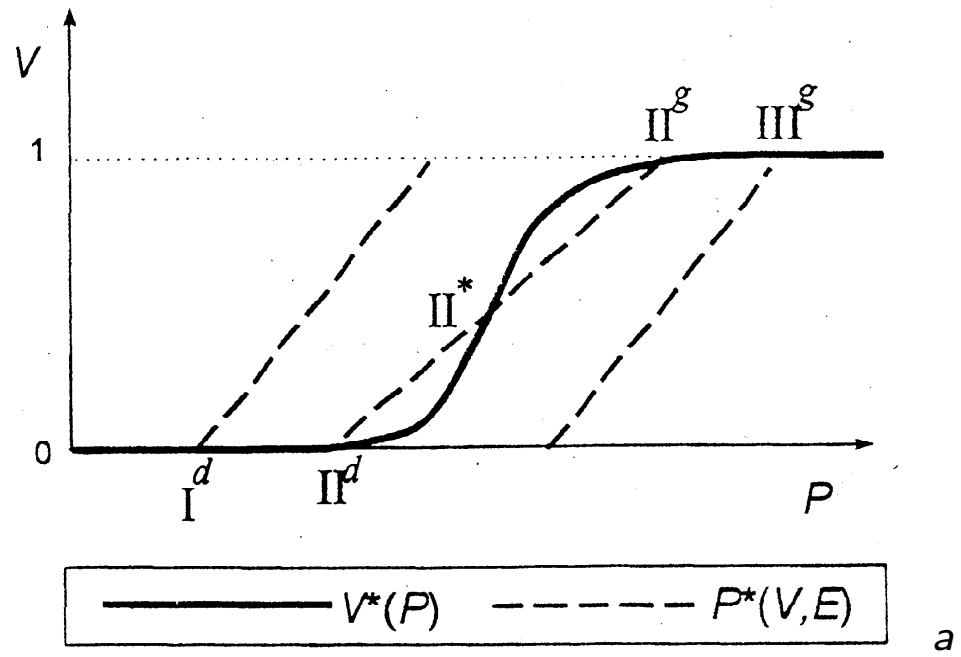
Figure 3. Results for mid-Holocene climate: interpretation of ECHAM-BIOME experiment. The iterations are shown by arrows.

- Supposes a coupled system Vegetation - Precipitation, with a non-linear dependence $V^{\star}(P)$.
- We look for a fixed point (V, P) where both are in equilibrum with each other.

V. Brovkin et al. In: **J. Geophys. Res.** (1998)

Bifurcation (with the Lameray Diagram)

A so-called "fold" bifurcation occurs when climate changes (change in $P^{\star}(V)$), as some equilibrium solution may disappear. This is a catostrophe collapse.



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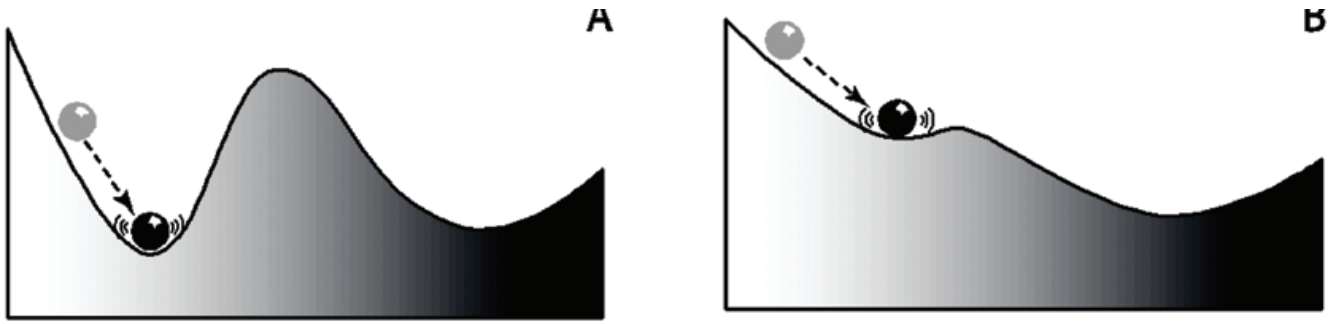
[a] V. Brovkin et al. In: **J. Geophys. Res.** (1998).

Bifurcation (in terms of potential landscape)

The fold bifurcation may be re-interpreted as a change in potential landscape.



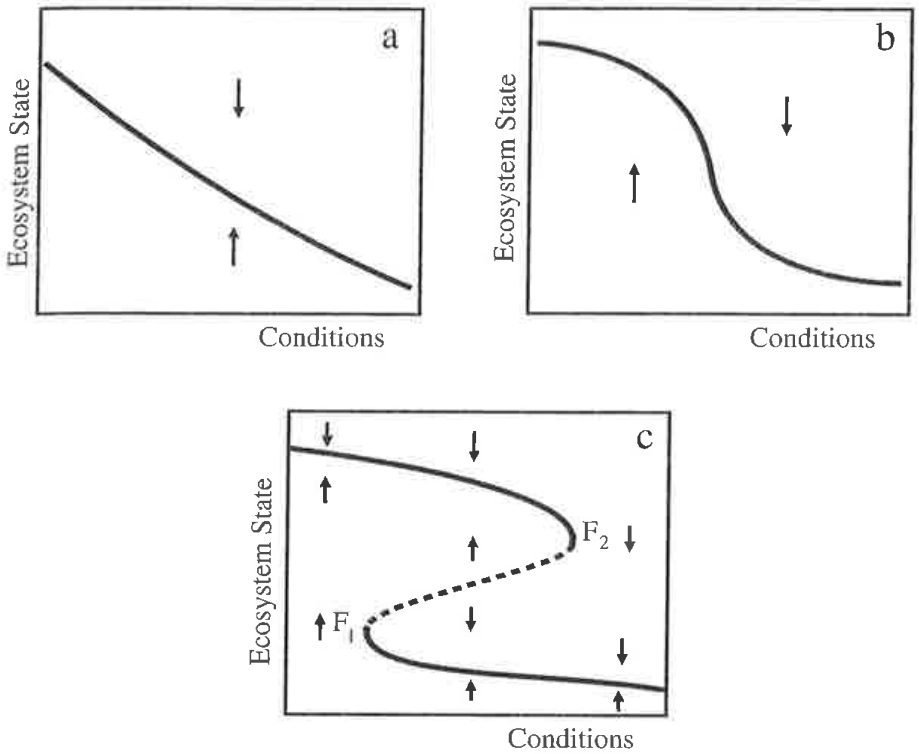
refinements based on the mathematical notion of **bifurcation**:

- bifurcation language *rightarrow* B-tipping, N-tipping, R-tipping[11]

[11] P. Ashwin and P. Ditlevsen. In: **Climate Dynamics** (2015).

Mathematical Biology

- Tradition of modelling ecosystems and biological systems with dynamical systmes (May, Lotke Volterra)
  - Marten Scheffer's successful book: "Critical Transitions in Nature and Society" (2009, Princeton University Press)
  - link with Catastrophes' theory of René Thom

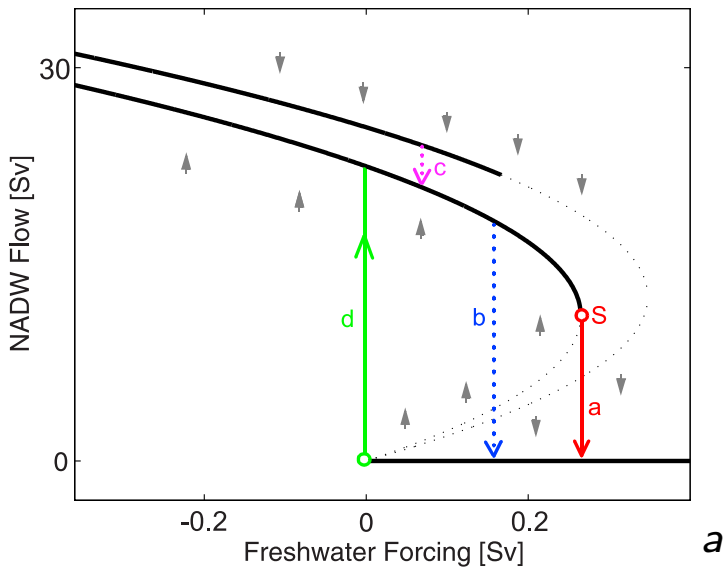


Scheffer 2009, p.31 + **important thread of research on early warning signals**

Oceanography (1990s - 2005)

"Rapid" climate change context

- Dansgaard-Oeschger events
- "Shut-downs of ocean circulation"
- The Day after tomorrow
- Achille's heel



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[a] S. Rahmstorf et al. In: **Geophysical Research Lett**

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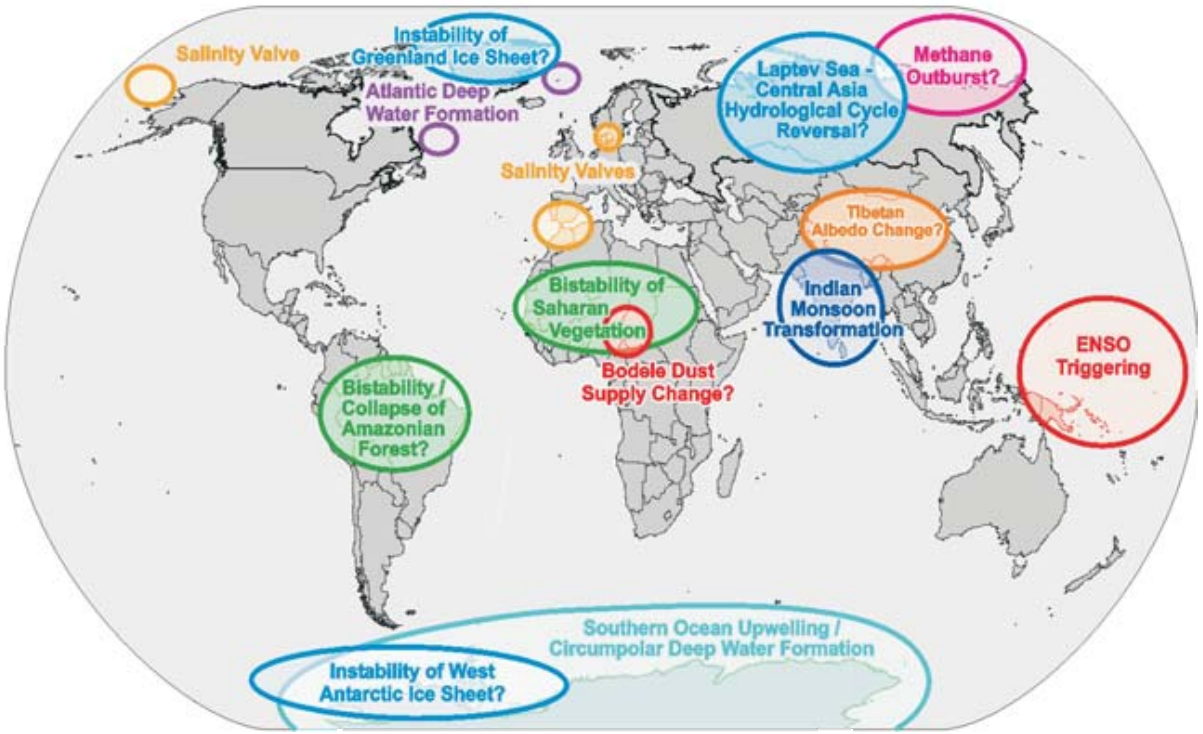
W. Clark



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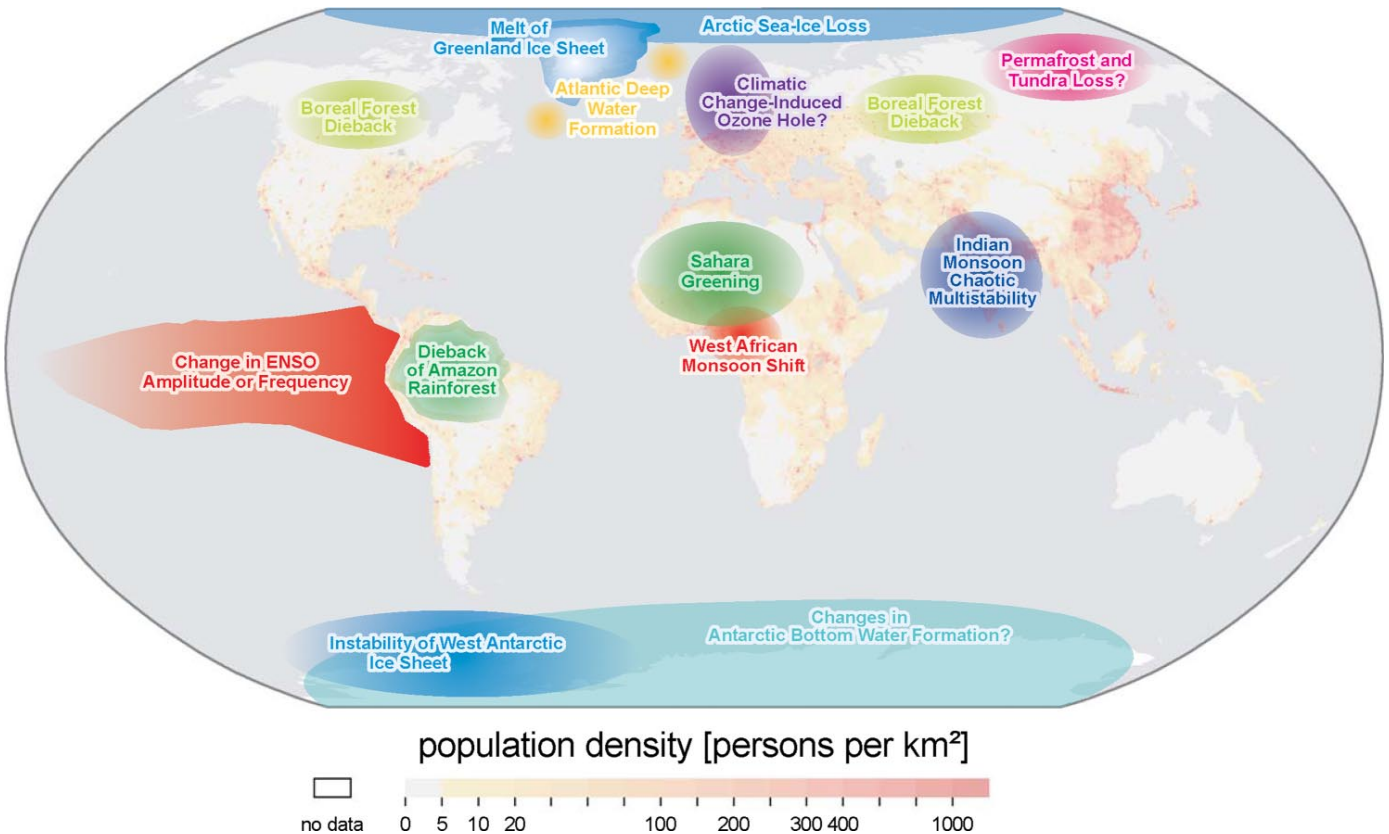
[12] W. C. Clark, P. J. Crutzen, and H. J. Schellnhuber. In: **SSRN Electronic Journal** (2005).

T. Lenton



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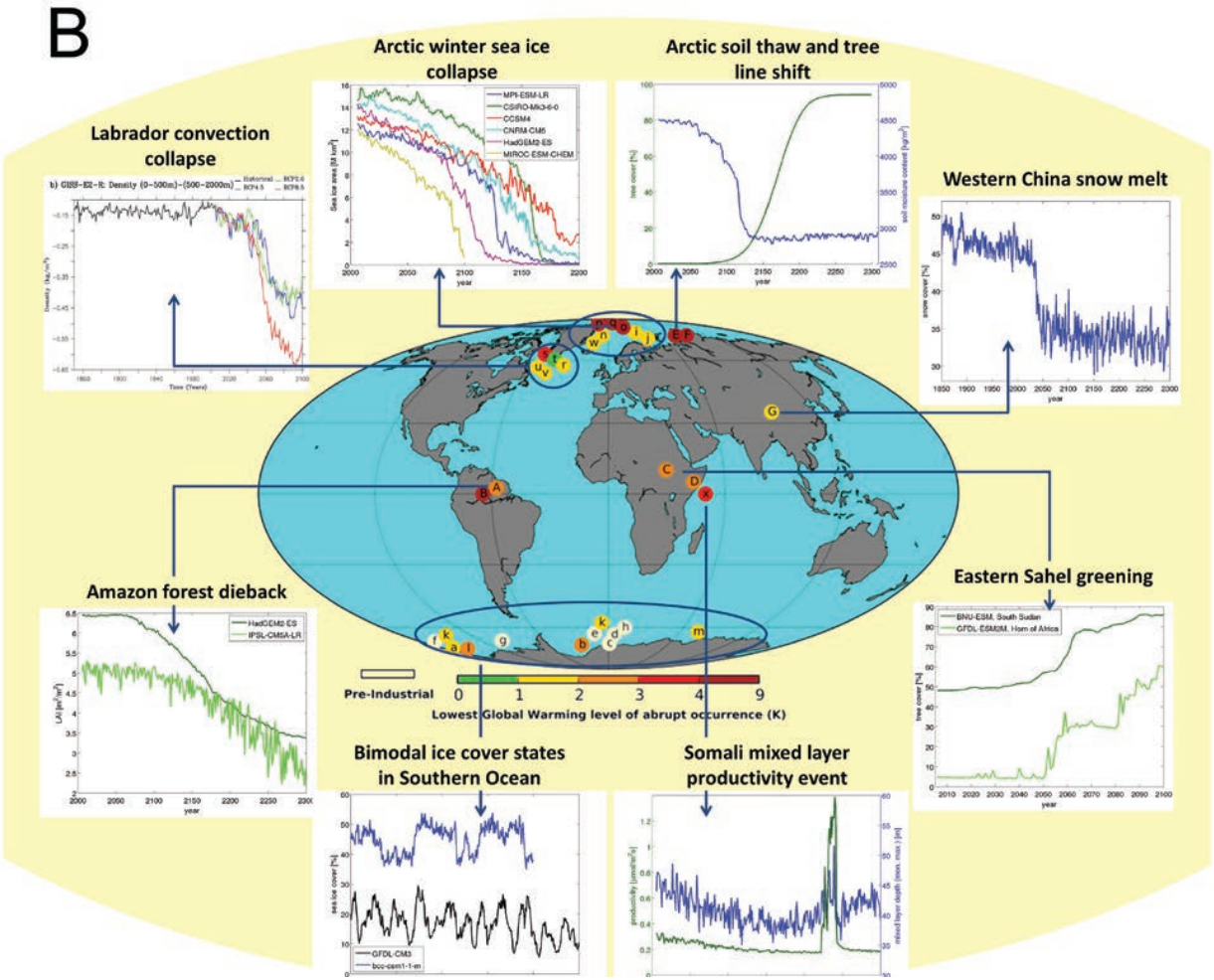
[13] T. M. Lenton et al. In: **Proceedings of the National Academy of Sciences** (2008).

S. Bathiany et al.



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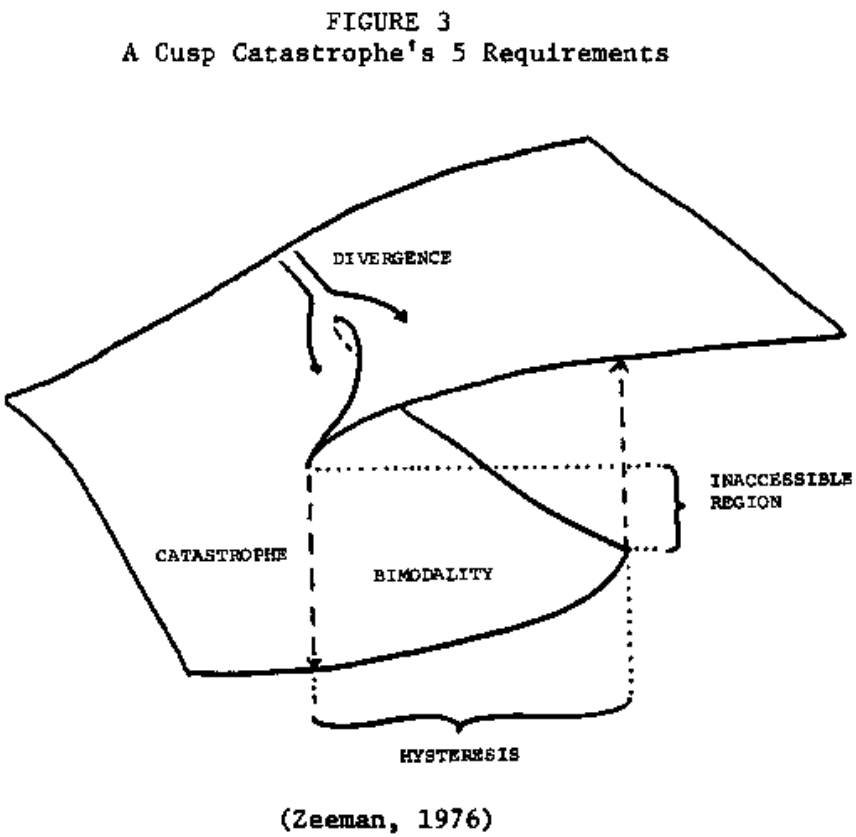
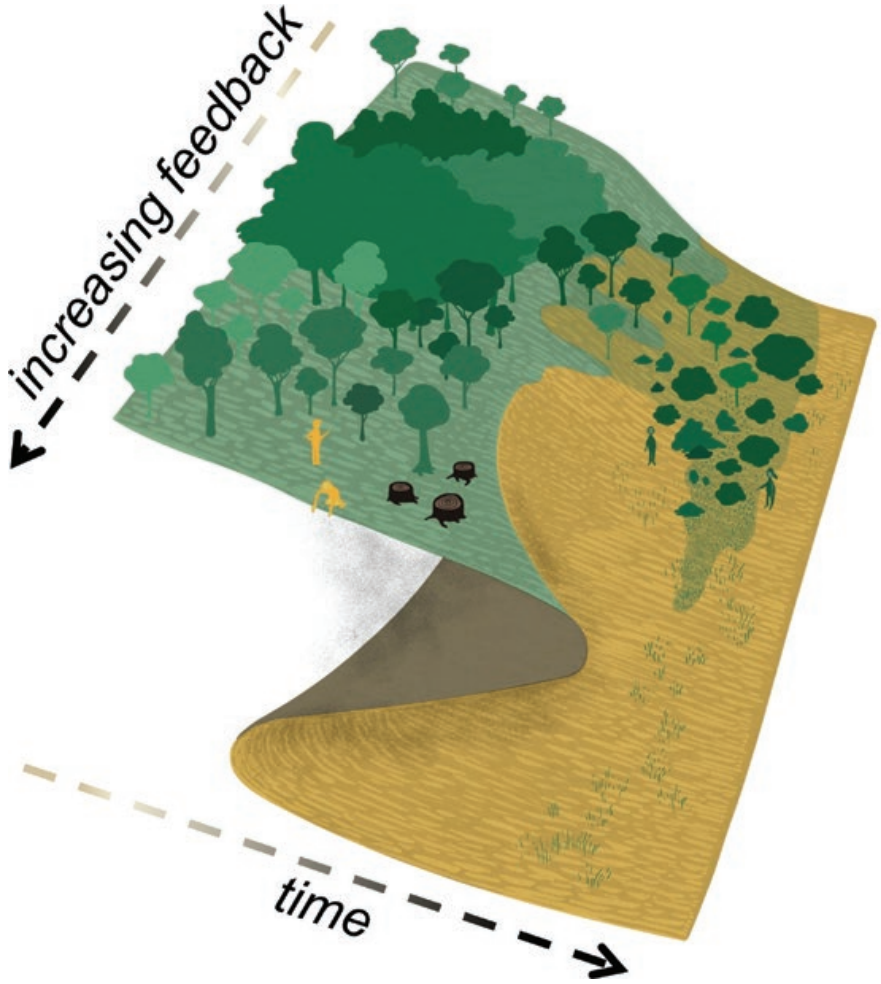
[14] S. Bathiany et al. In: **Dynamics and Statistics of the Climate System** (2016).

The landscape potential



Zeeman (1976) redrawing of René Thom's "cusp" catastrophe, which is essentially the depiction of a fold bifurcation



S. Bathiany et al. In: **Dynamics and Statistics of the Climate System** (2016)

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Beyond bifurcation: Lenton 2008 criteria[15]

A system Σ is said to be a "tipping element" if the following condition is met

1. There exists a critical control parameter, with small variation causing large qualitative change
2. Human activities can interfere with the control parameter within "political time horizon"
3. The qualitative change lies within "ethical horizon"
4. A significant people will be affected

[15] T. M. Lenton et al. In: **Proceedings of the National Academy of Sciences** (2008).

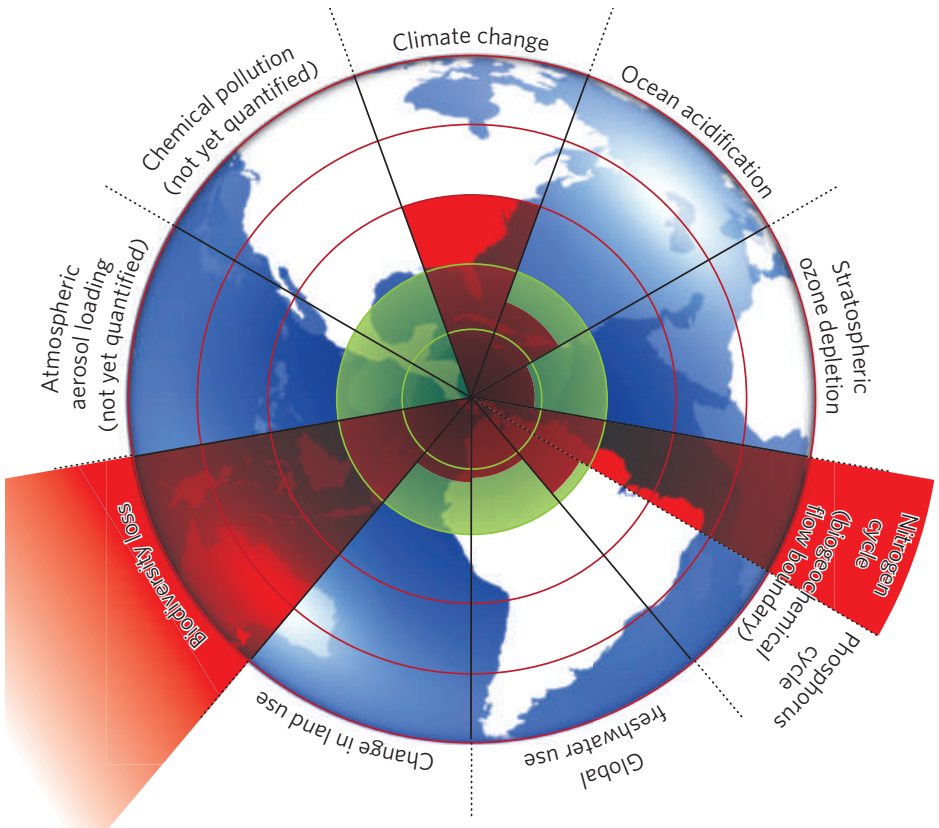
People network

- Lenton was a student of Watson, student of Lovelock (Bifurcation imagery in Daisyworld)
- Lovelock's influential programme of "Gaia" / "Medecine for Planet Earth"
- Brovkin worked (and still does) under the supervision of M. Claußen, at the time under the direction of Schellnhuber as head of the Potsdam Institute for Climate Impact Research
- Schellnuhber/Claußen's workshop in Potsdam in 1999: Saltzman, Lenton, Claussen (... and me!)
- Steffen used to head the IGBP programme (cf. Dutreil's thesis)
- Scheffer is biologist

Anthropocene imagery

There is growing understanding of the importance of functional biodiversity in preventing ecosystems from **tipping** *into unde- sired states when they are disturbed*

J. Rockstrom et al. In: **Nature** (2009)



Conclusions

- The concept of tipping point plays on the ambiguity between policy science, social sciences, and Earth sciences. It is value loaded, ethically constrained, and part of a political project (following the principle of the double ethical bound)
- It stands on mathematical foundations (bifurcation theory), but transcends them.
- The graphical imagery plays a large role:
  - Chris Russill sees as generative metaphor in action
- The broader project is that "climate change governance" requires a **scientific** interface between Earth system science and policy. This is also a social and economical science problem.
- It also announces the reign transition from physicists to "system-science" scientists in climate science