Early warning of climate tipping points

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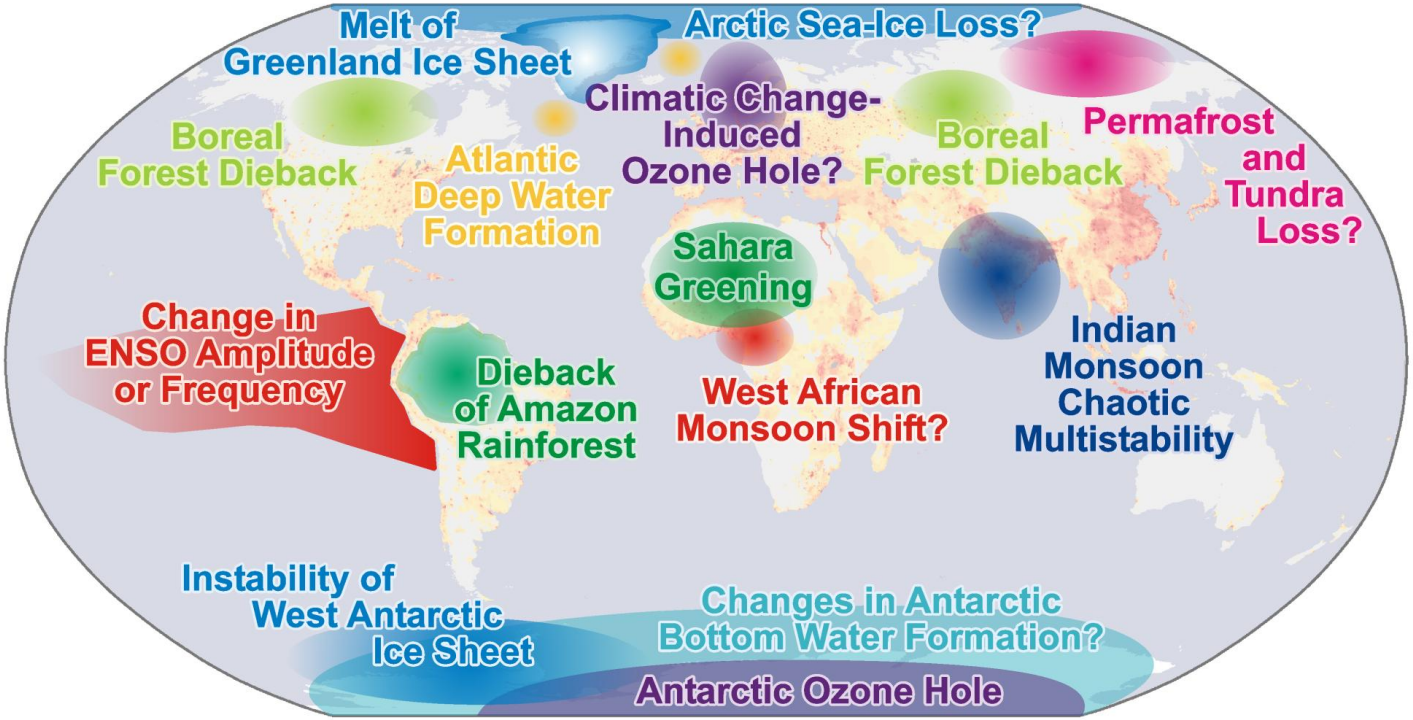


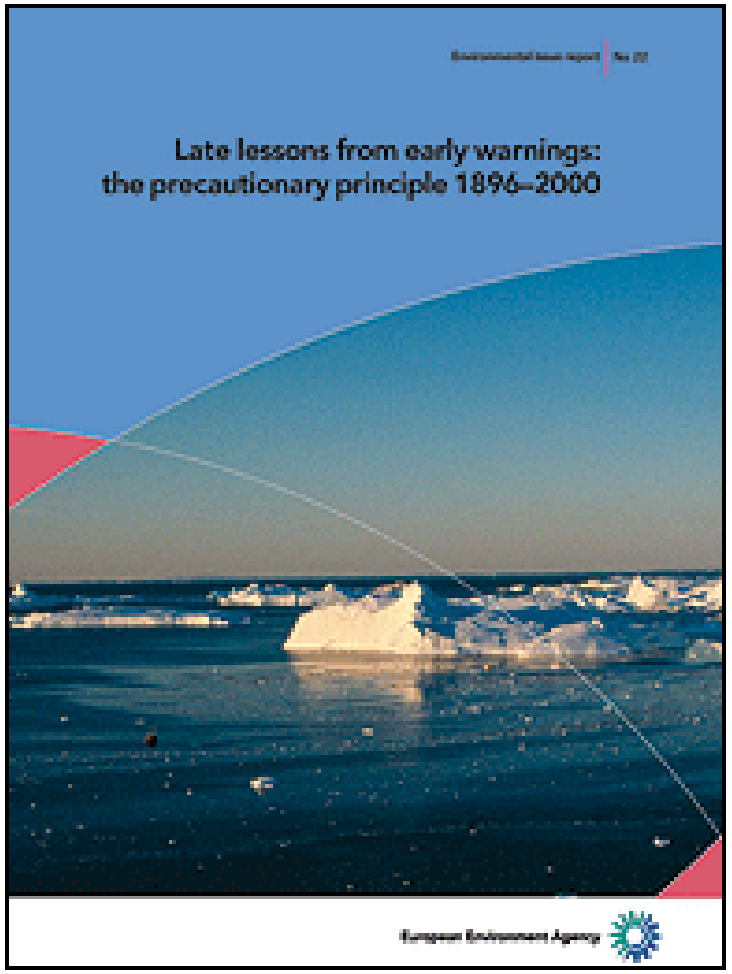
Tim Lenton

School of Environmental Sciences, University of East Anglia, Norwich

With special thanks to Valerie Livina, John Schellnhuber, Frank Kwasniok

Outline

- Tipping elements
- Risk assessment
- Early warning



Two types of tipping point

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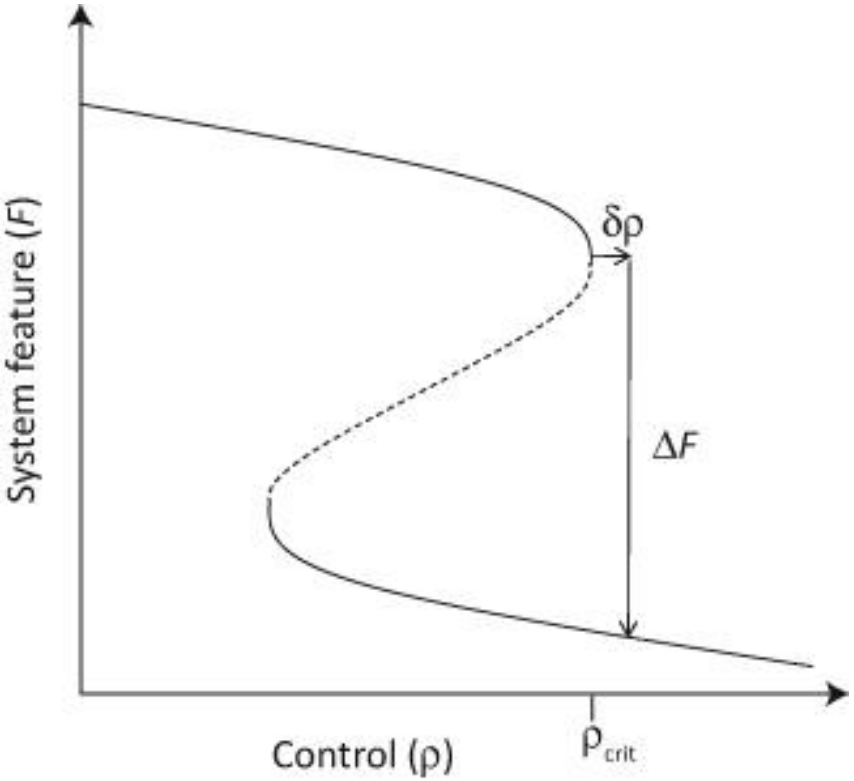
Bifurcation



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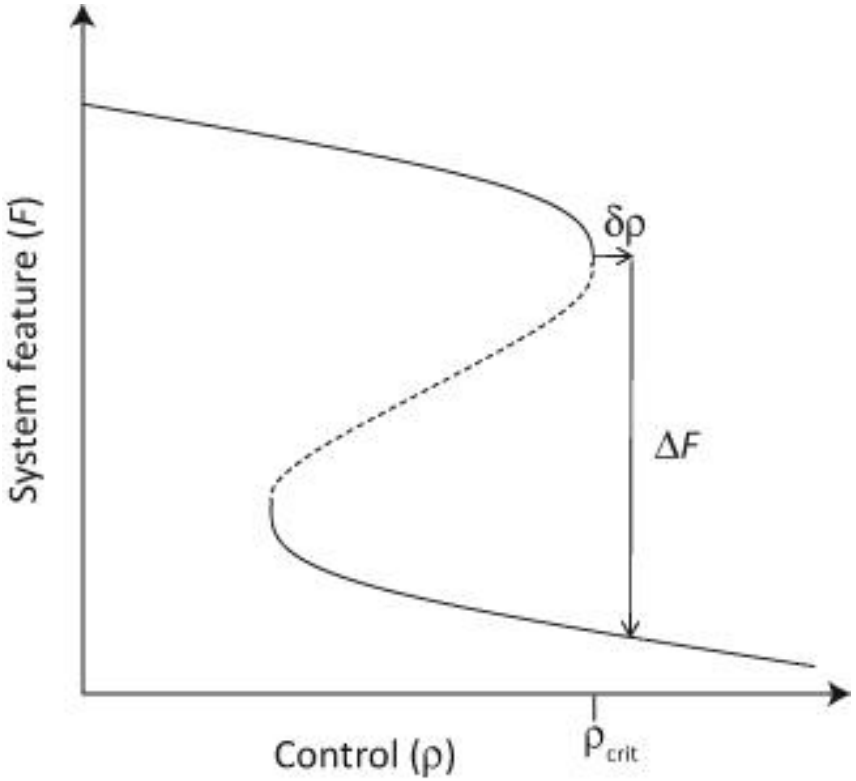
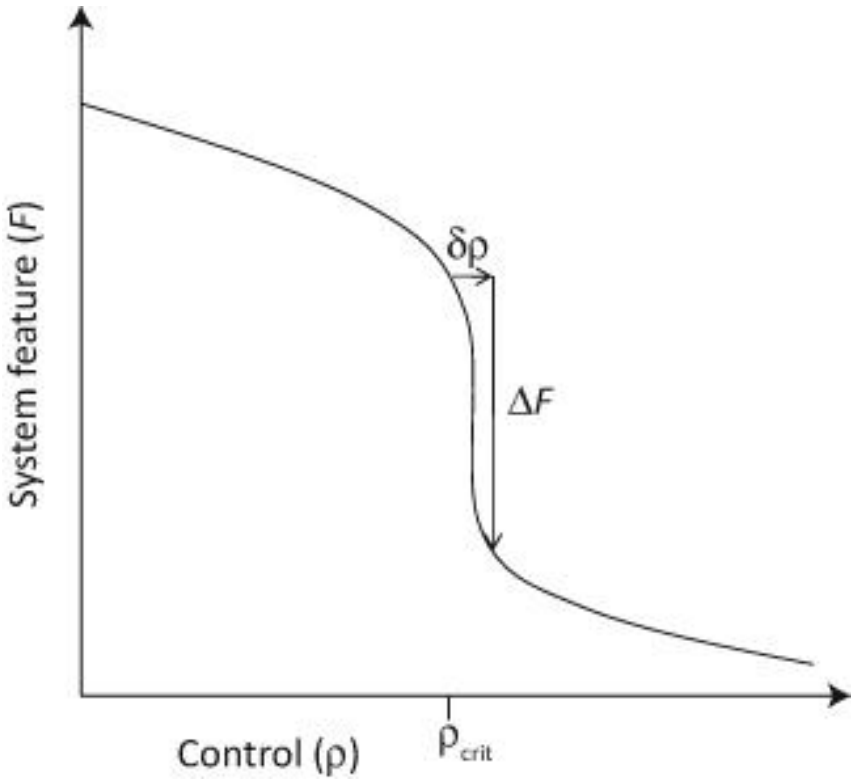
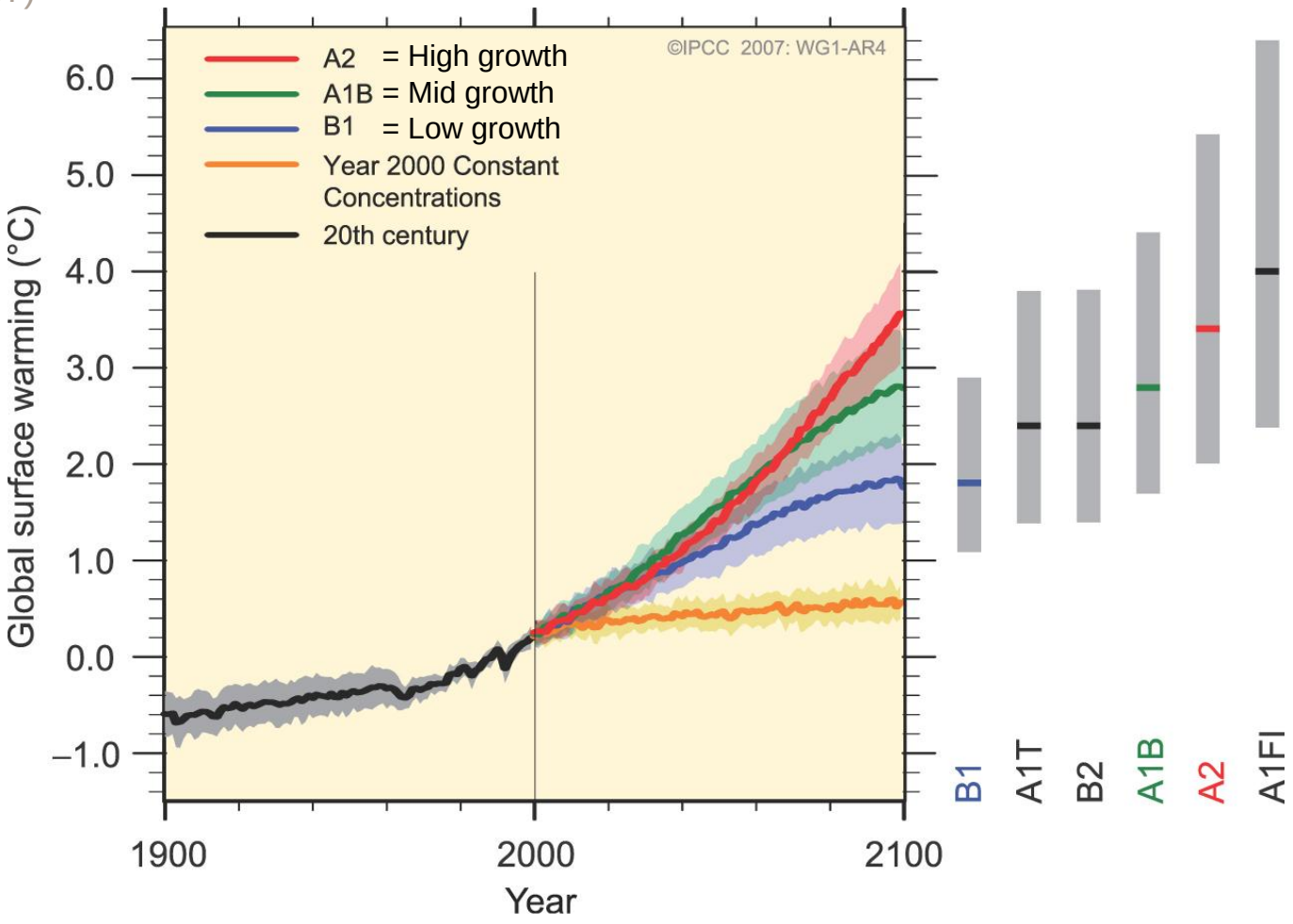


No bifurcation



Policy relevant forcing range

IPCC (2007)



Tipping elements in the climate system

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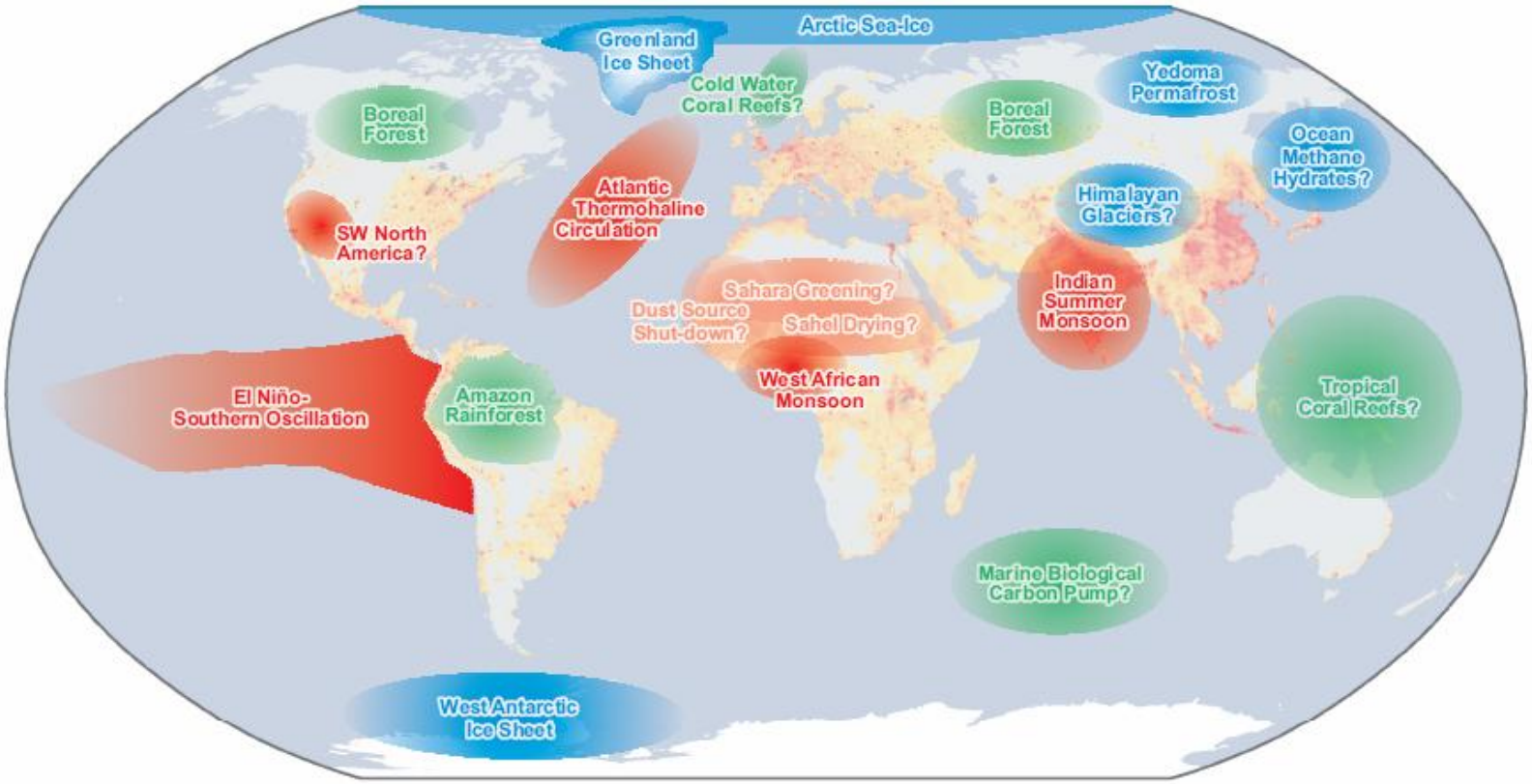
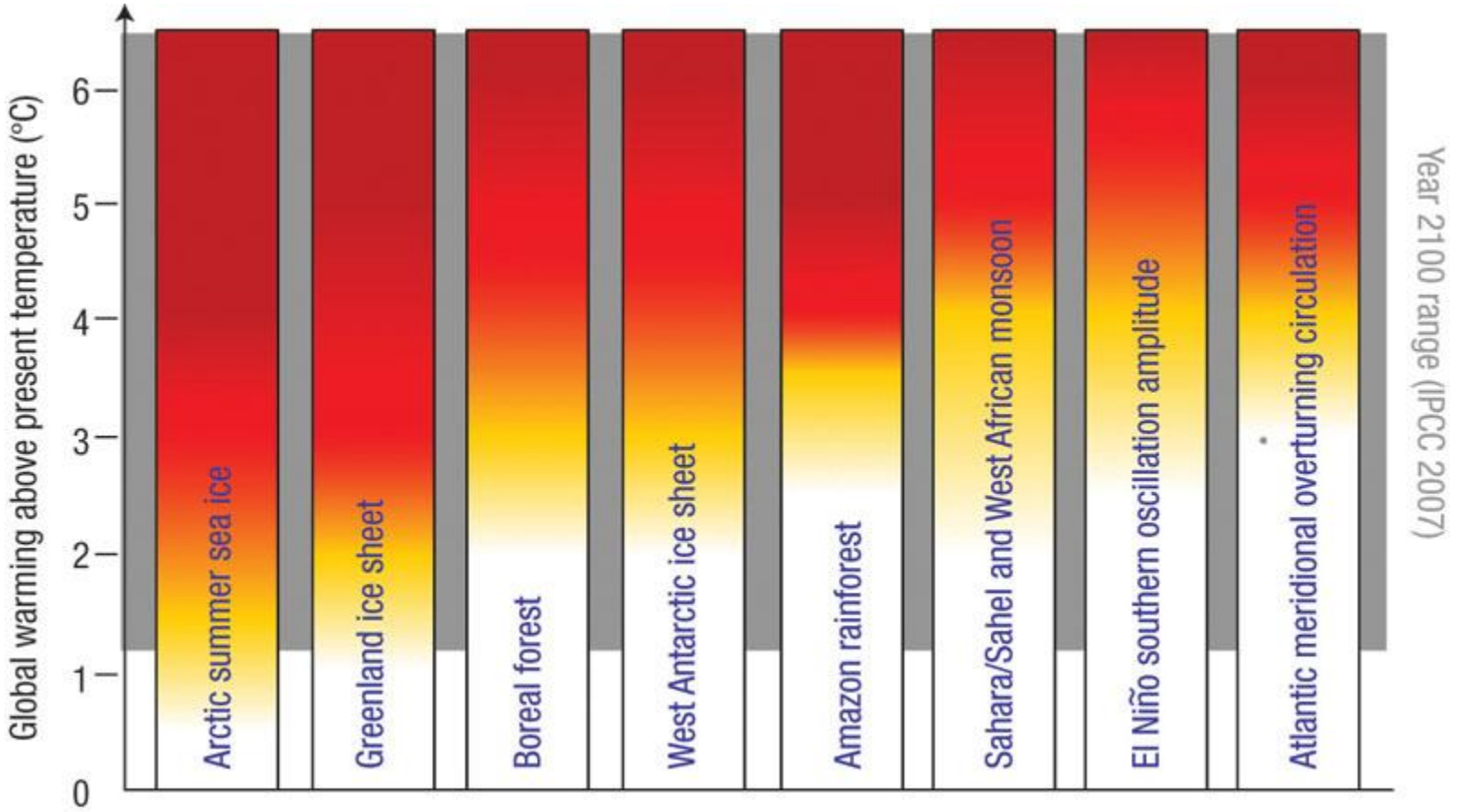
Revised from original in Lenton et al. (2008) *PNAS* 105(6): 1786-1793



Estimates of proximity

Lenton & Schellnhuber (2007) *Nature Reports Climate Change*

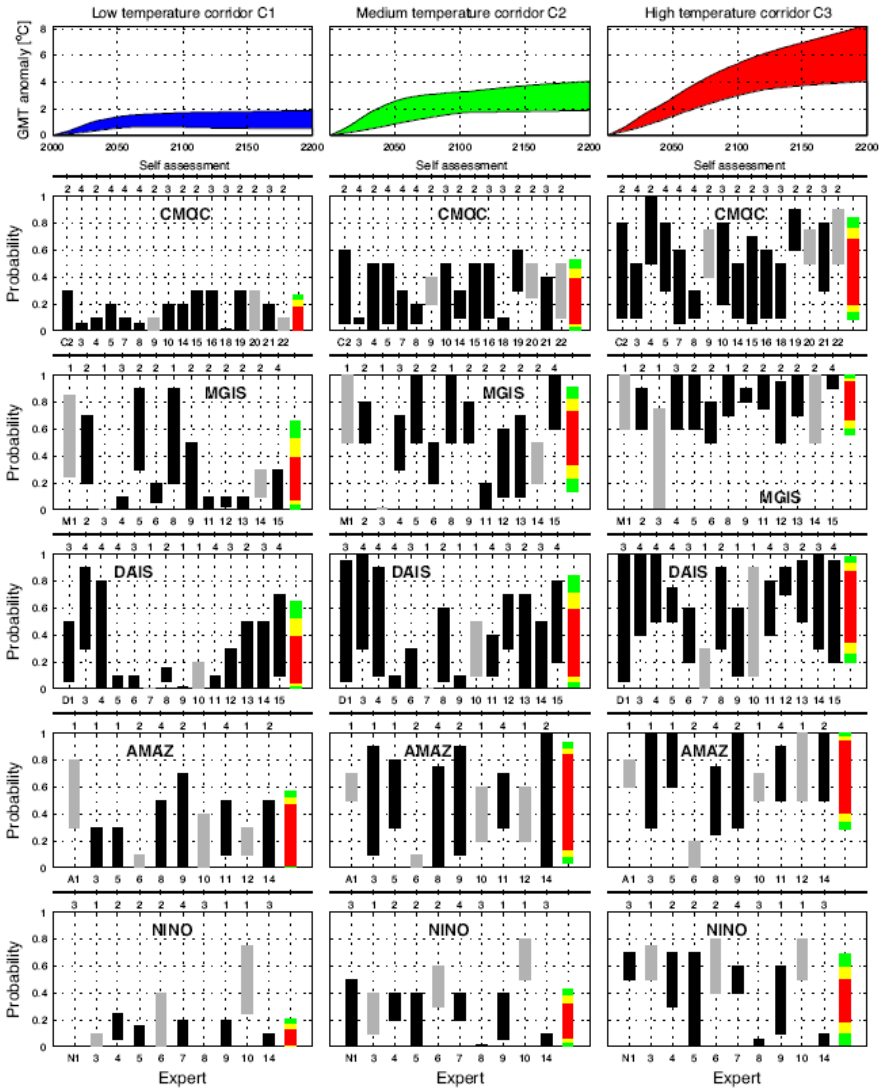


Results from literature review and workshop

Likelihood of tipping

Kriegler et al. (2009) *PNAS* 10.1073/pnas.0809117106

- Imprecise probability statements from experts formally combined
- Under 2-4 °C warming: >16% probability of passing at least one of five tipping points
- Under >4 °C warming: >56% probability of passing at least one of five tipping points



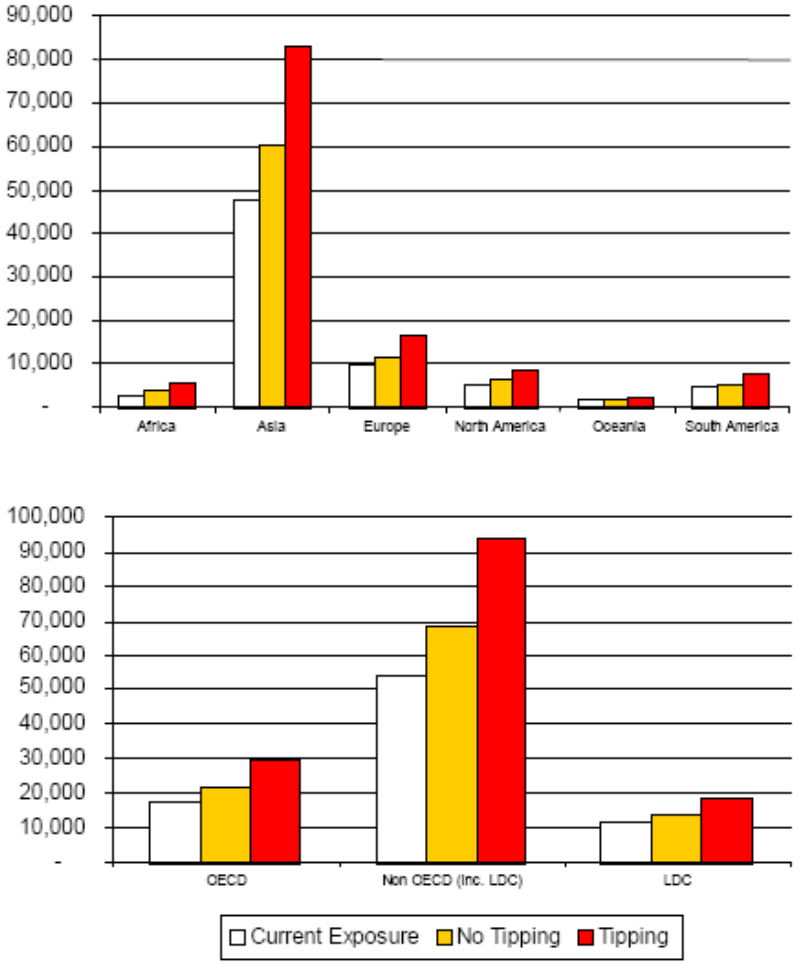
Impacts of tipping

Lenton, Footitt & Dlugolecki (2009) http://assets.panda.org/downloads/plugin_tp_final_report.pdf

Allianz / WWF report:

- Increased sea level rise
  - +$25,158 billion exposed assets in port megacities
- Indian summer monsoon disruption
- Amazon dieback and drought
- Aridification of southwest North America

Populations exposed to 1-in-100-yr flood events



Tipping element risk assessment

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Tipping element	Likelihood of passing a tipping point (by 2100)	Relative impact** of change in state (by 3000)	Risk score (likelihood x impact)	Risk ranking
Arctic summer sea-ice	High	Low	3	4
Greenland ice sheet	Medium-High*	High	7.5	1 (highest)
West Antarctic ice sheet	Medium*	High	6	2
Atlantic THC	Low*	Medium-High	2.5	6
ENSO	Low*	Medium-High	2.5	6
West African monsoon	Low	High	3	4
Amazon rainforest	Medium*	Medium	4	3
Boreal forest	Low	Low-Medium	1.5	8 (lowest)

*Likelihoods informed by expert elicitation
**Initial judgment of relative impacts is my subjective assessment

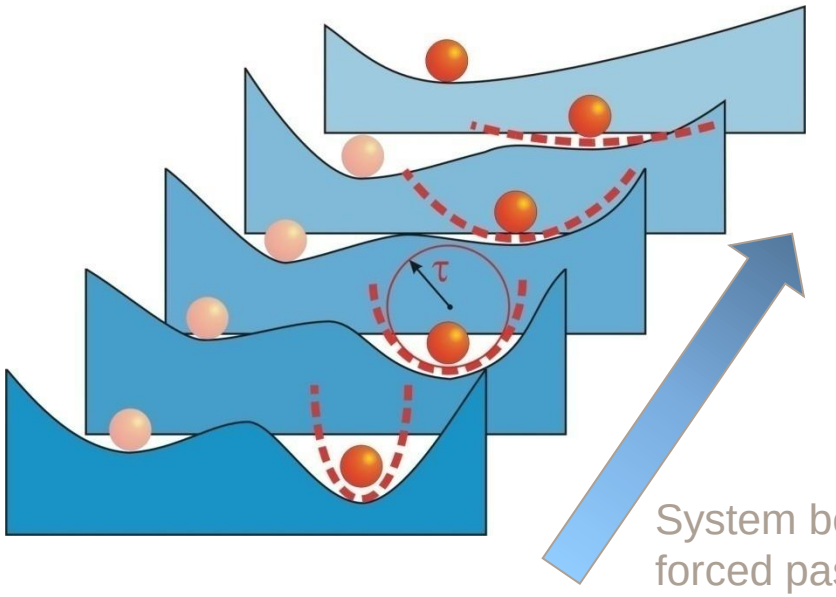
Impacts depend on human responses hence are more epistemologically contested than assigning likelihoods to events (Stirling 2003 'Risk, uncertainty and precaution…')

Prospects for bifurcation early warning

Held & Kleinen (2004) *Geophysical Research Letters* 31: L23207
Lenton et al. (2008) *PNAS* 105(6): 1786-1793

Generic early warning signals:

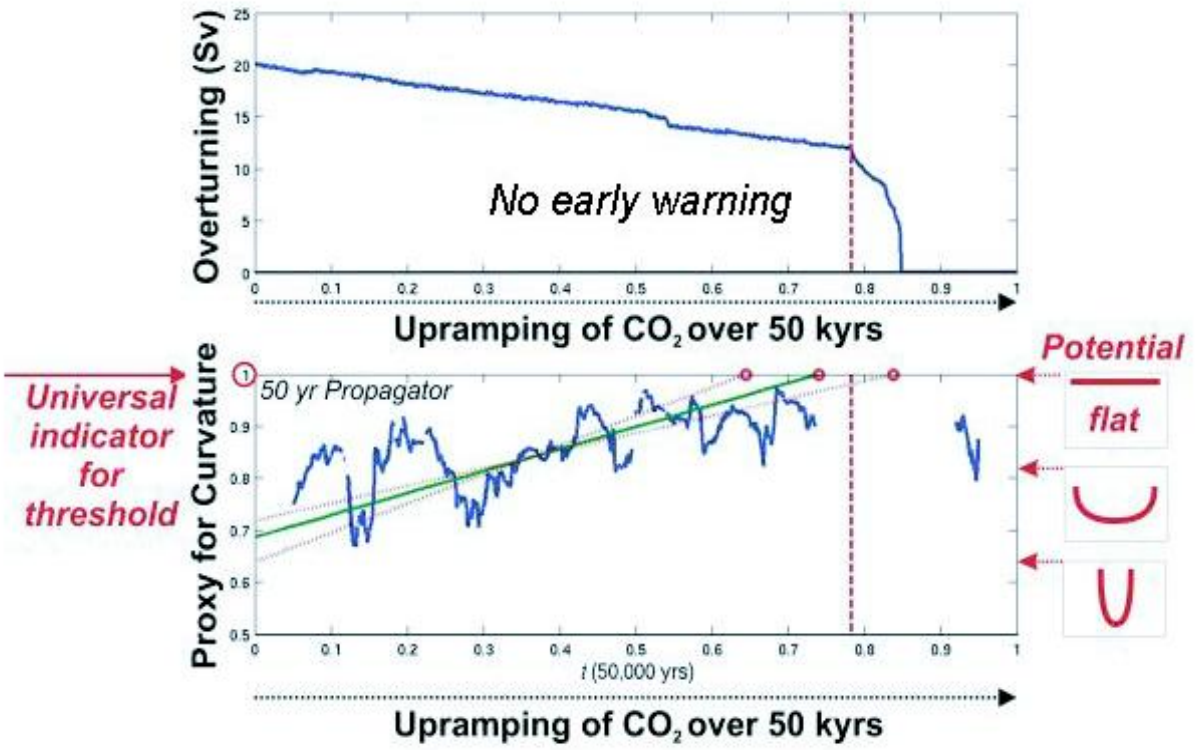
- **Slowing down**
- Increasing variability
- Skewness of responses
- Flickering between states



Model test of early warning method

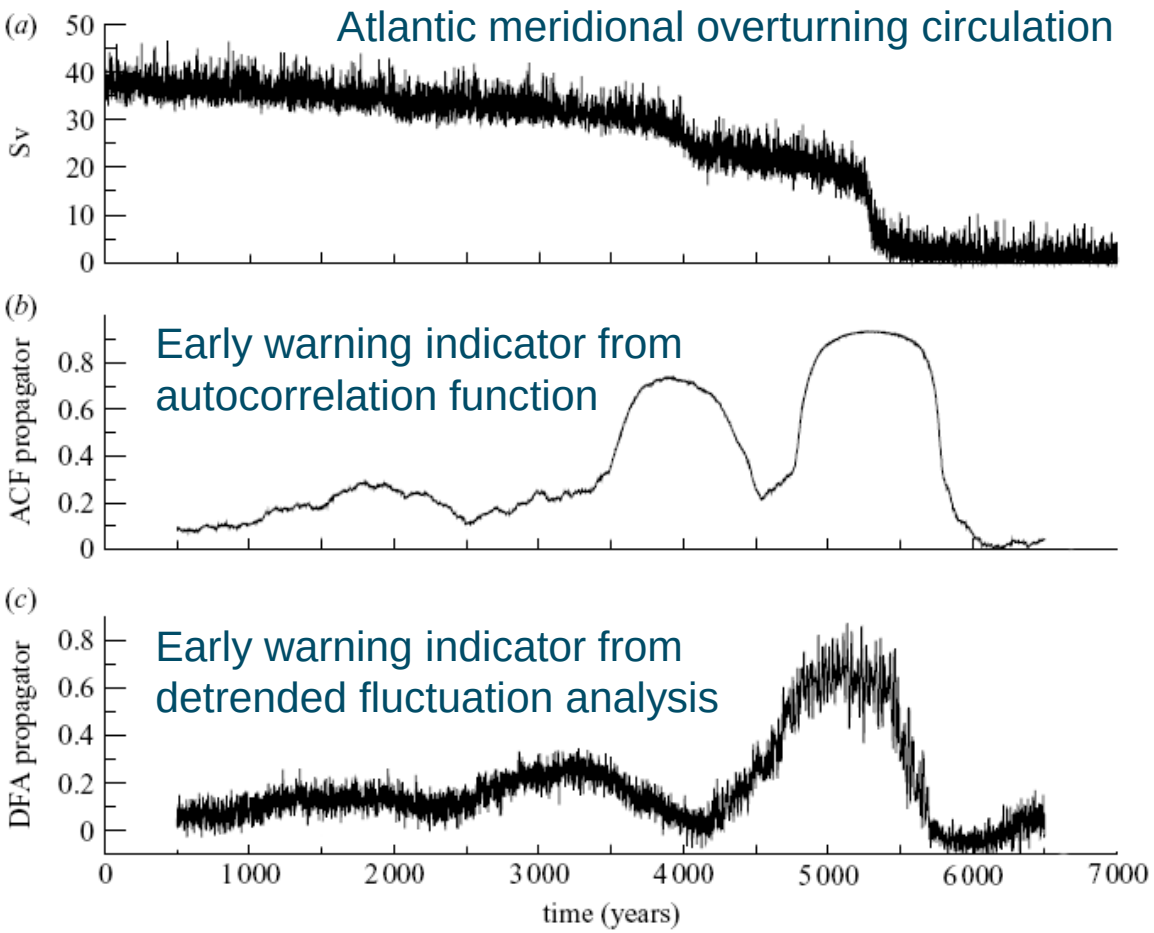
Held & Kleinen (2004) *Geophysical Research Letters* 31: L23207

CLIMBER-2 intermediate complexity model
Linear increase in CO2 from 280 to 800 ppmv
Stochastic perturbation of freshwater forcing



Fully 3-D dynamical model test

Lenton *et al.* (2009) *Phil. Trans. A* 367: 871-884



GENIE-2 model

Paleo-data test of early warning method

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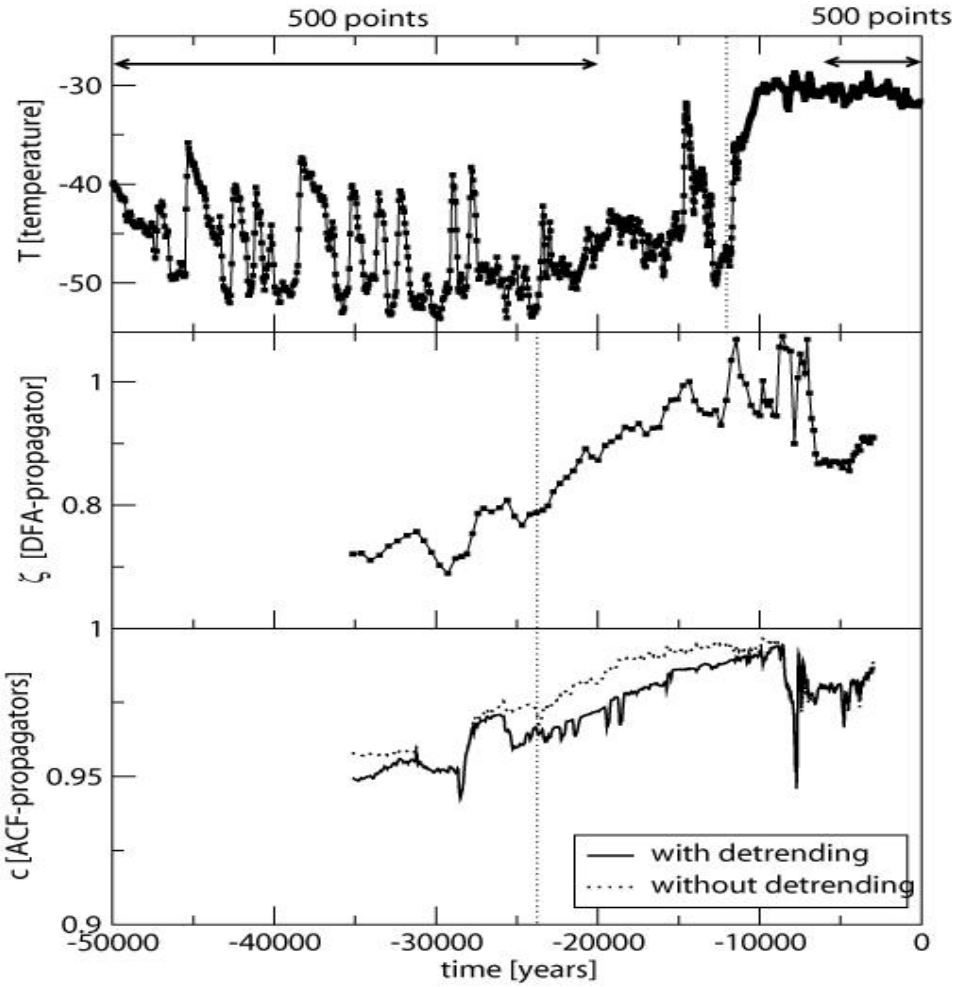
Livina & Lenton (2007) *Geophysical Research Letters* 34: L03712

Greenland ice-core regional temperature record

Early warning indicator from detrended fluctuation analysis

Early warning indicator from autocorrelation function

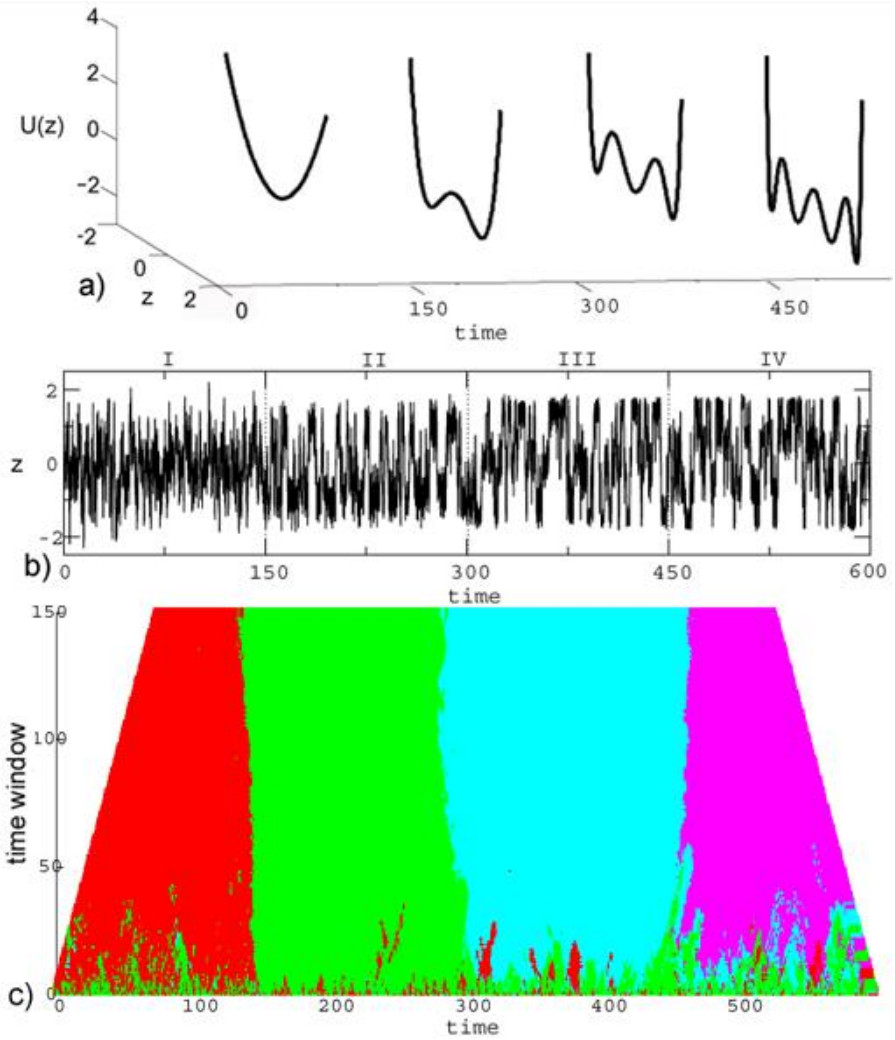


Detecting the number of system states

Livina, Kwasniok & Lenton (2010) *Climate of the Past,* 6: 77-82

New method; 'potential analysis':

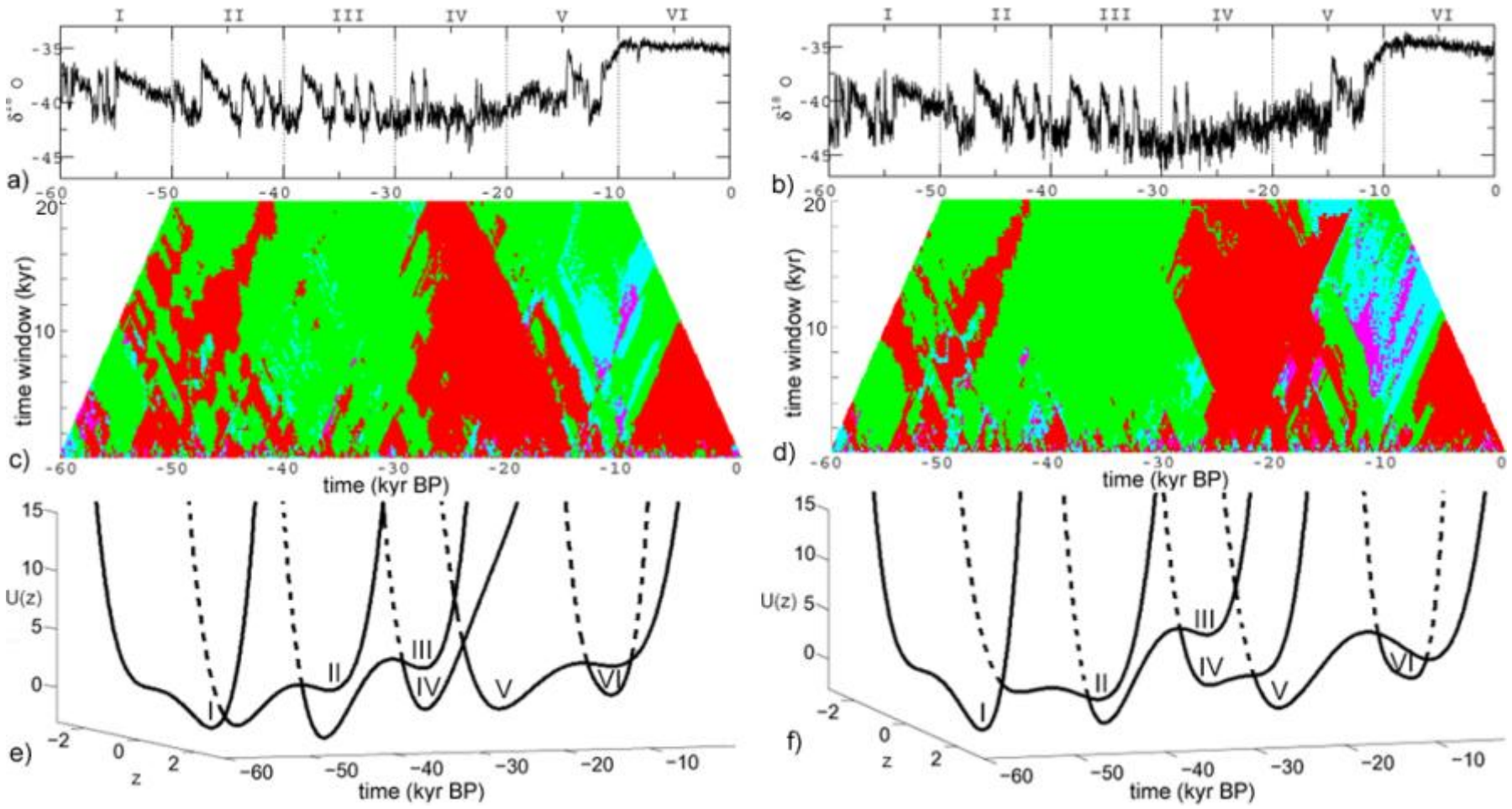
- Assume polynomial potential and random noise
- Estimate number of states (i.e. order of polynomial)
- Estimate noise level
- Derive potential coefficients and hence shape of potential



Number of states: 1, 2, 3, 4

Changing number of climate states

Livina, Kwasniok & Lenton (2010) *Climate of the Past,* 6: 77-82



Number of states: 1, 2, 3, 4

European monthly temperature anomaly (1659-2004)

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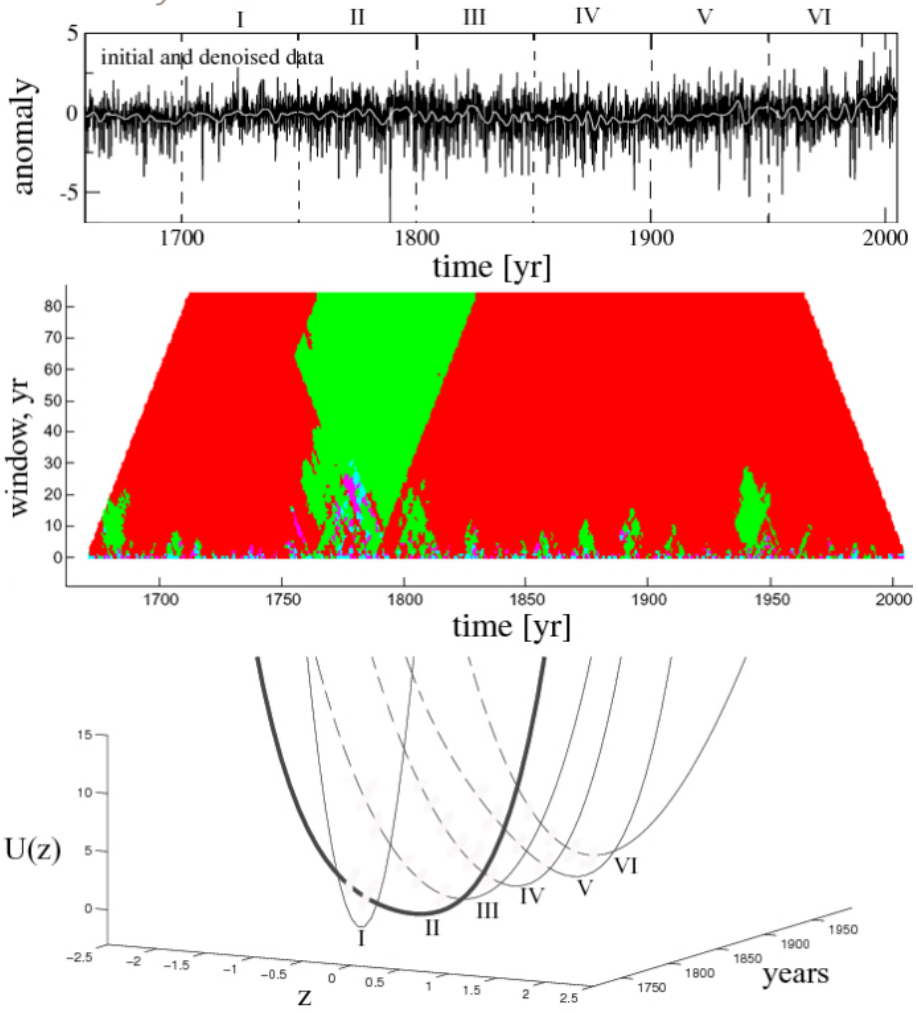
Livina et al. (in revision) *Climate Dynamics*

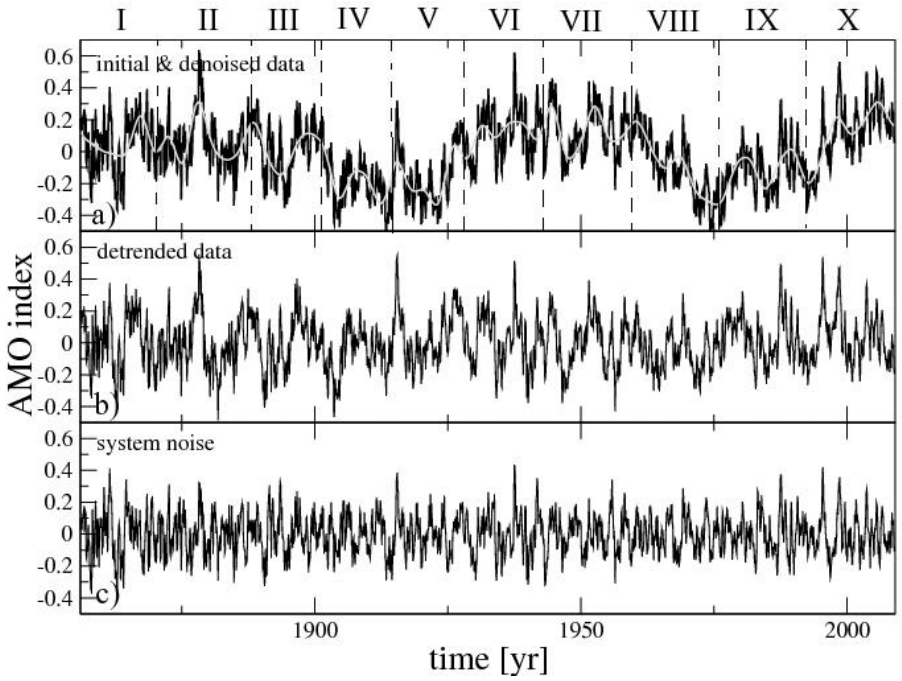


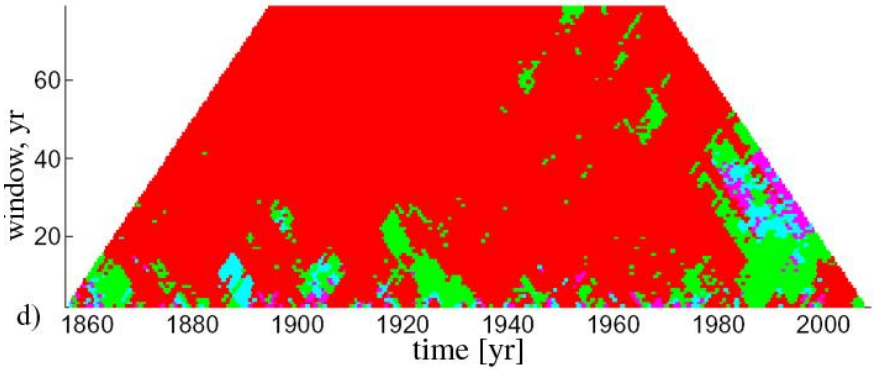
Number of states:
1, 2, 3, 4

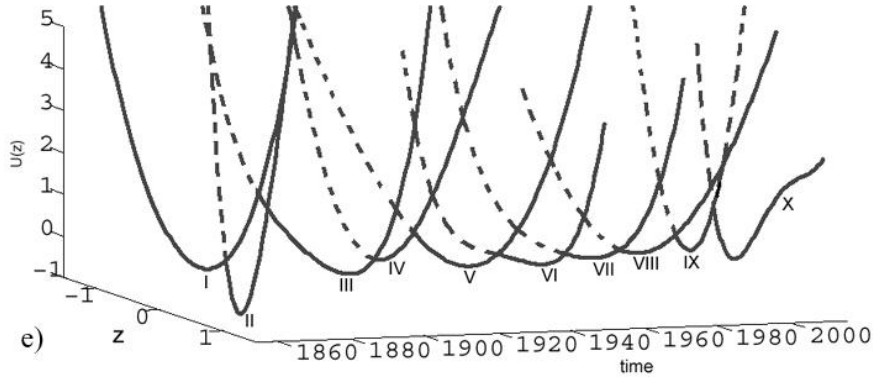
Atlantic Multi-decadal Oscillation (1856-present)

University of East Anglia

Livina et al. (in revision) *Climate Dynamics*







Number of states: 1, 2, 3, 4

Conclusion

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- Tipping elements in the climate system could be triggered this century by anthropogenic forcing
- The Greenland and West Antarctic ice sheets probably represent the largest risks
- Some tipping points can be anticipated in principle, but sufficiently high-resolution, long records are often lacking
- A change in the number of climate states can be detected, in a noisy climate system that is moving between states
- Improved understanding is needed to help policy makers “avoid the unmanageable and manage the unavoidable”

Find out more

http://knowledge.allianz.com/climate_tipping_points/climate_en.html

Example of transition (but not bifurcation)

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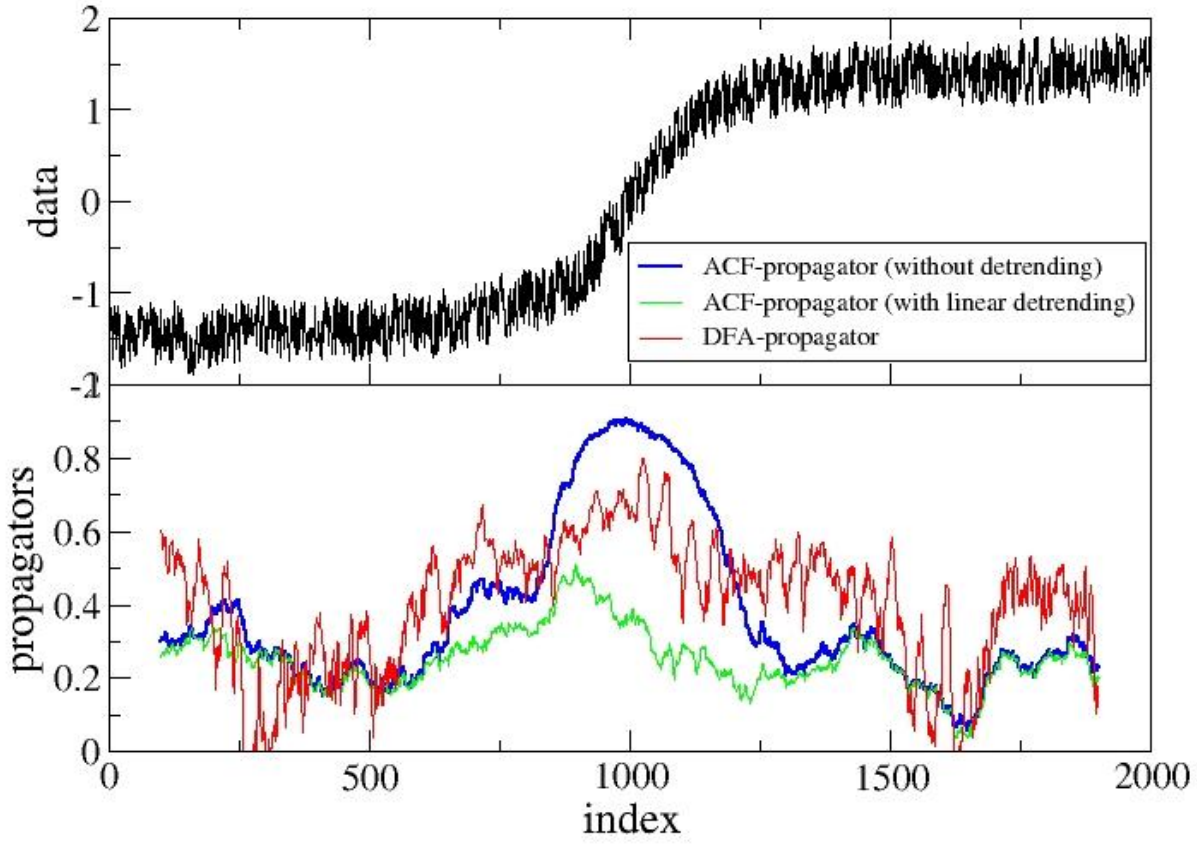
Livina, Ditlevsen, Lenton (submitted) *Nonlinear Processes in Geophysics*

Sigmoid function with red noise, fluctuation exponent 0.7



ACF-propagator (without detrending) is more sensitive to transitions