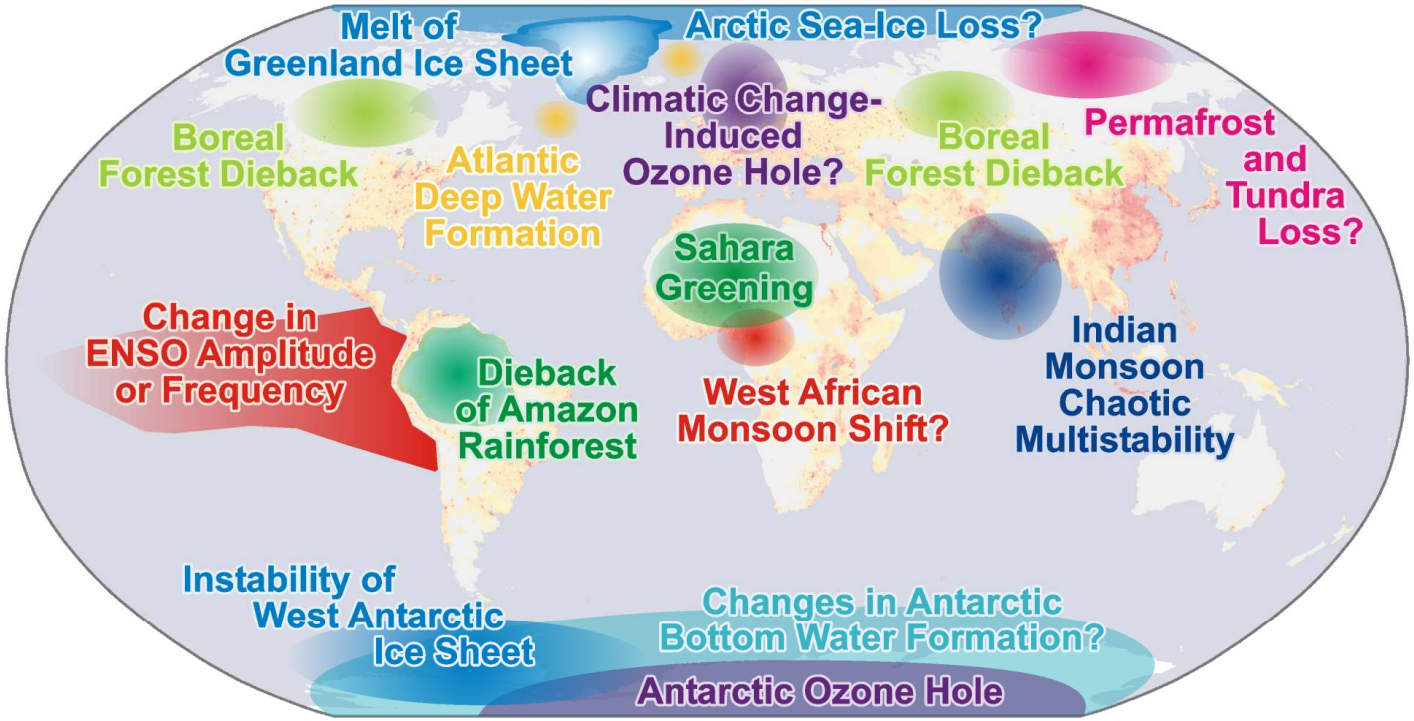
Early warning of climate tipping points



Tim Lenton (t.m.lenton@exeter.ac.uk)

With thanks to Valerie Livina, Vasilis Dakos, Marten Scheffer, John Schellnhuber

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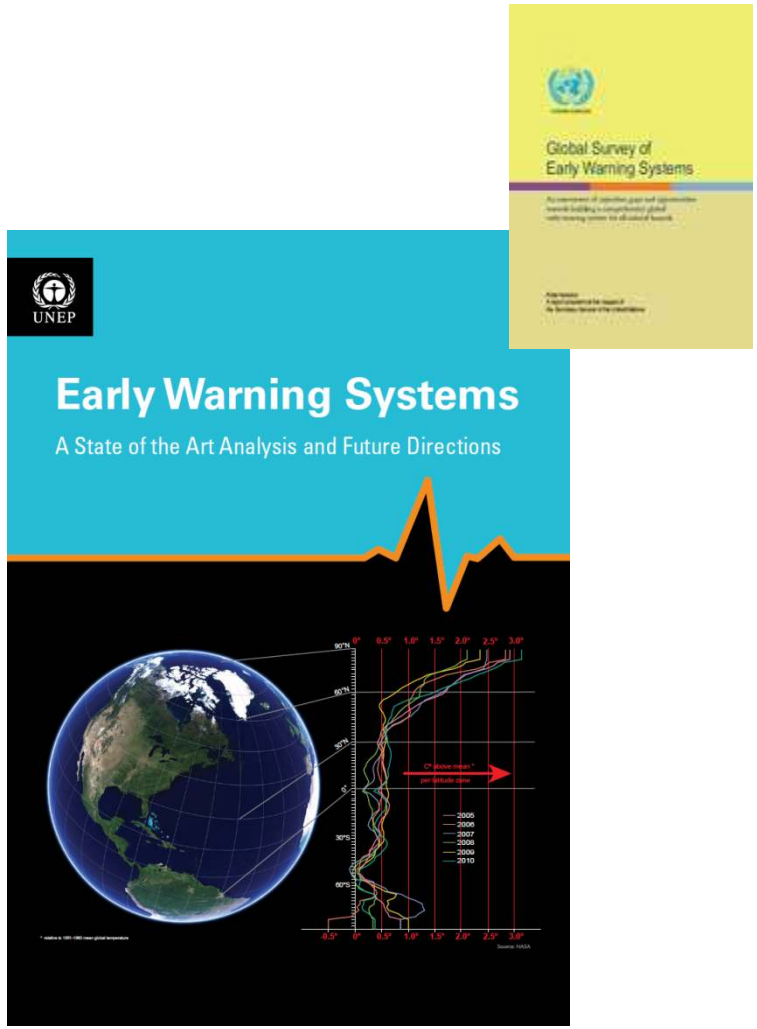
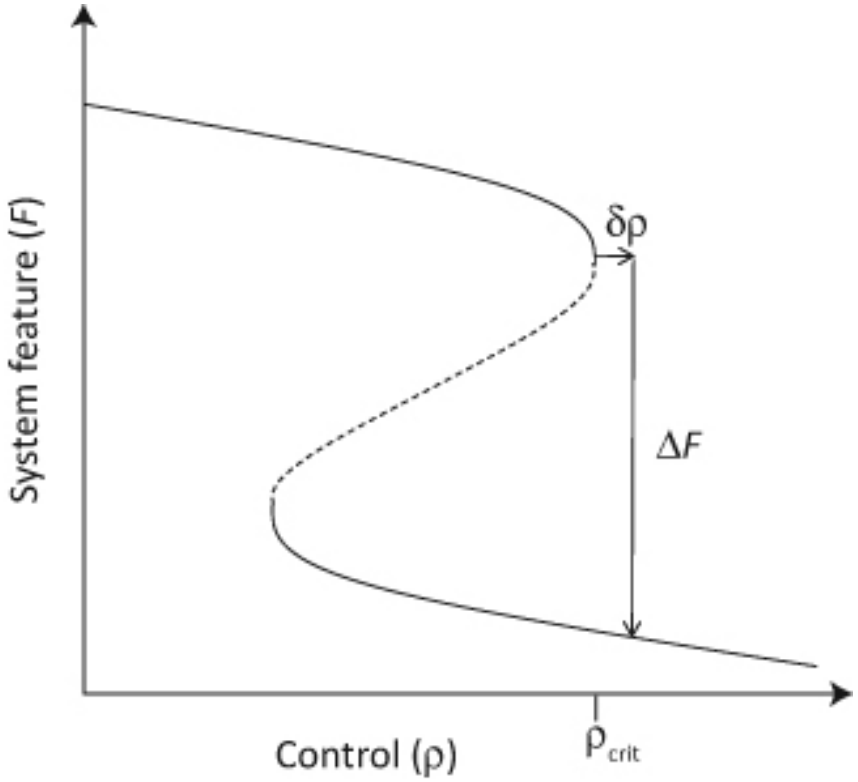
Outline

- Tipping points
- Early warning
- Arctic sea-ice

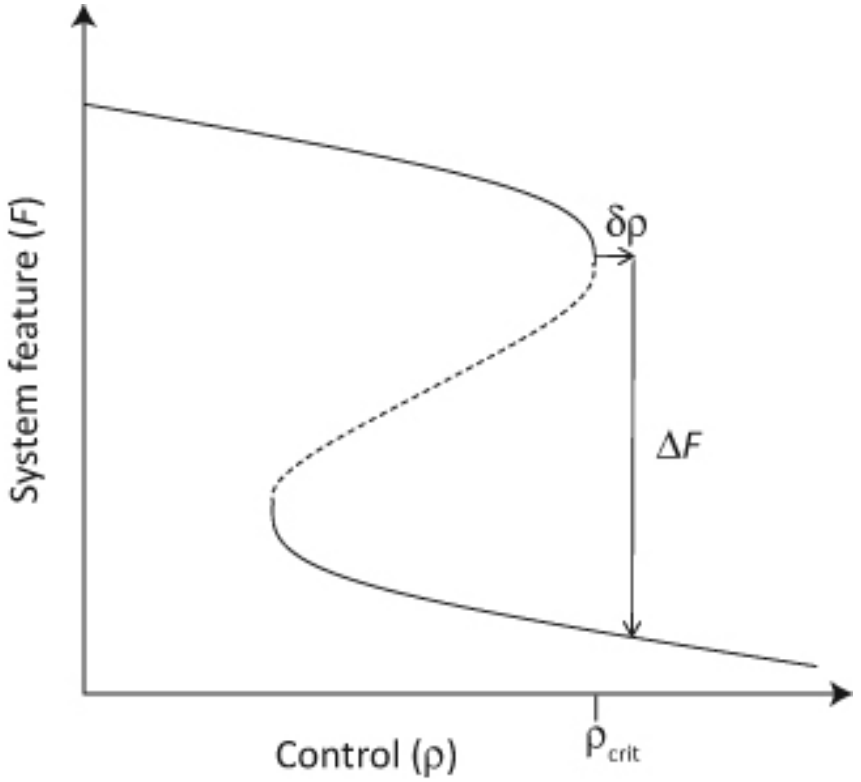


Bifurcation tipping point



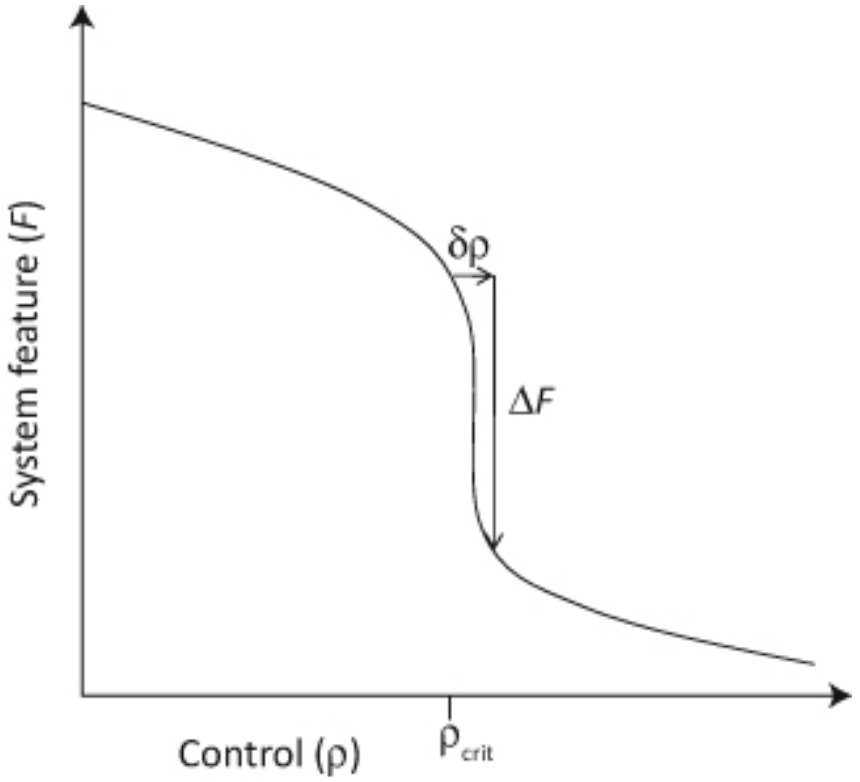
Irreversible 'point of no return'

Bifurcation tipping point



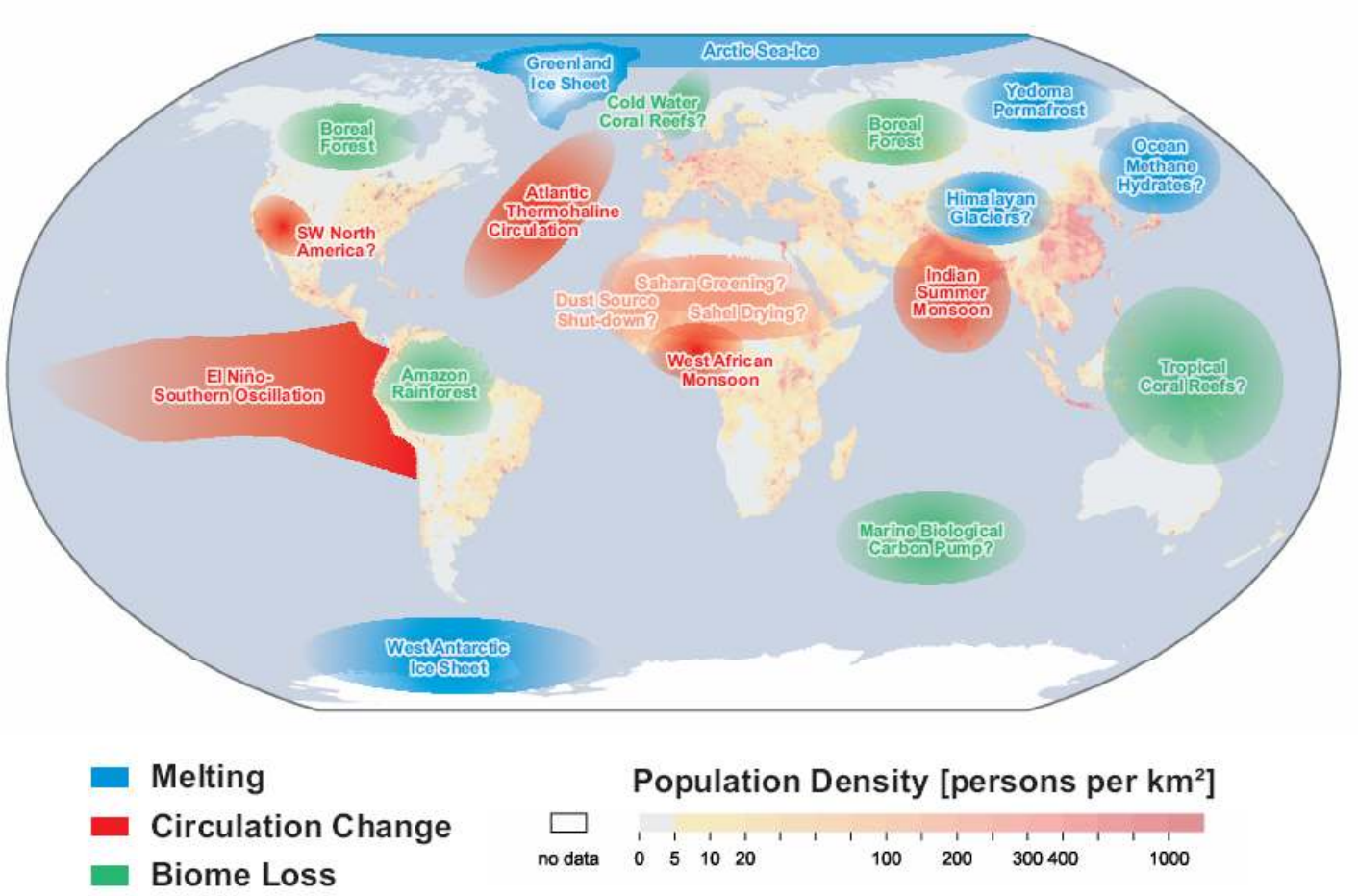
Irreversible 'point of no return'

Reversible tipping point



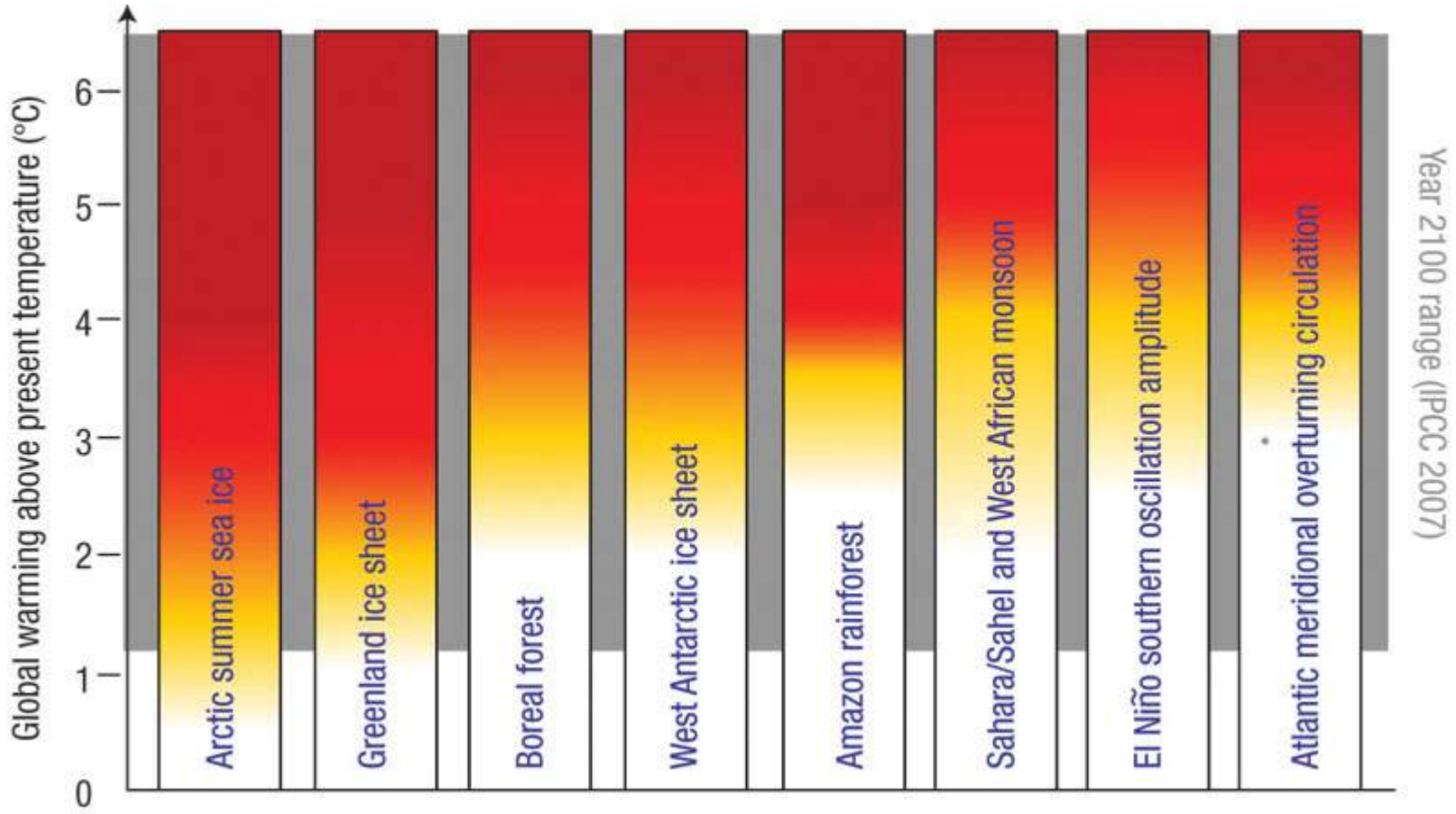
Reversible transition

Tipping elements in the climate system



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

Estimates of proximity



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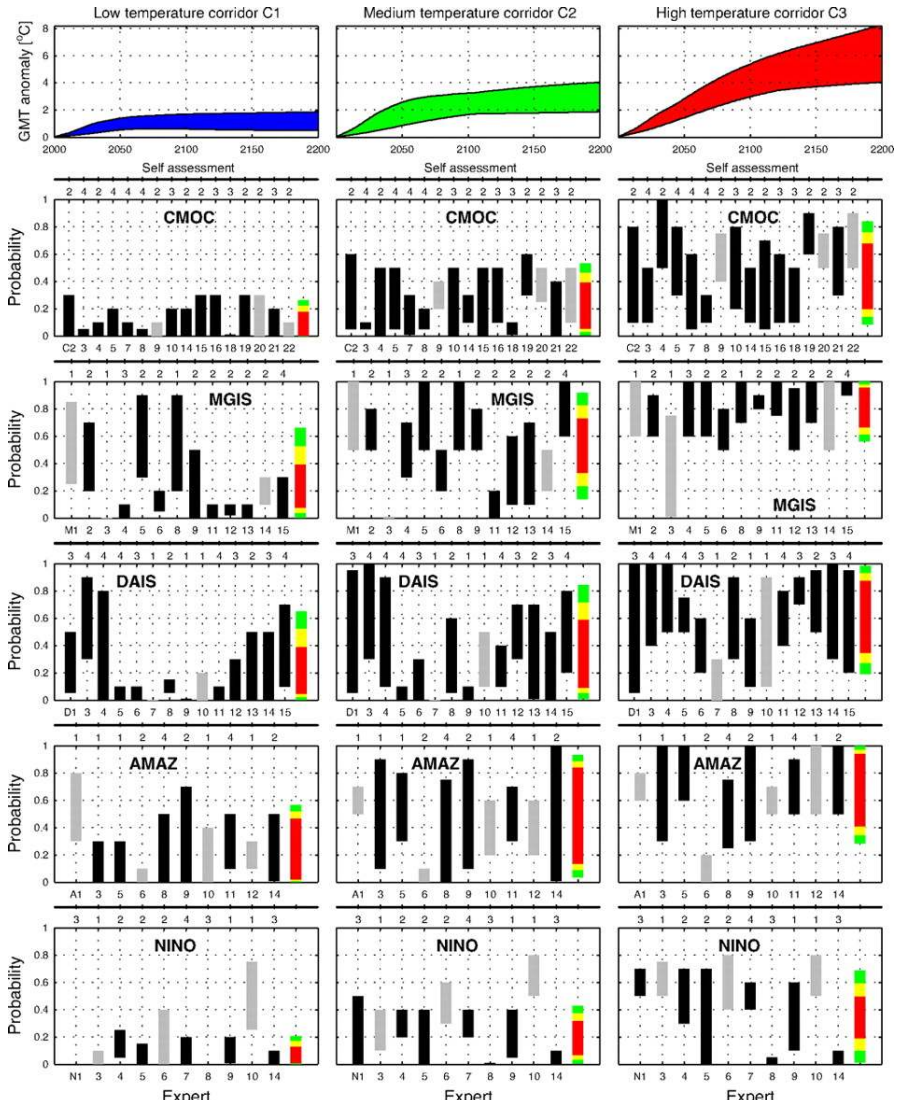
Lenton & Schellnhuber (2007) *Nature Reports Climate Change*

Likelihood

- 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



Atlantic

Greenland

Antarctica

Amazon

El Niño

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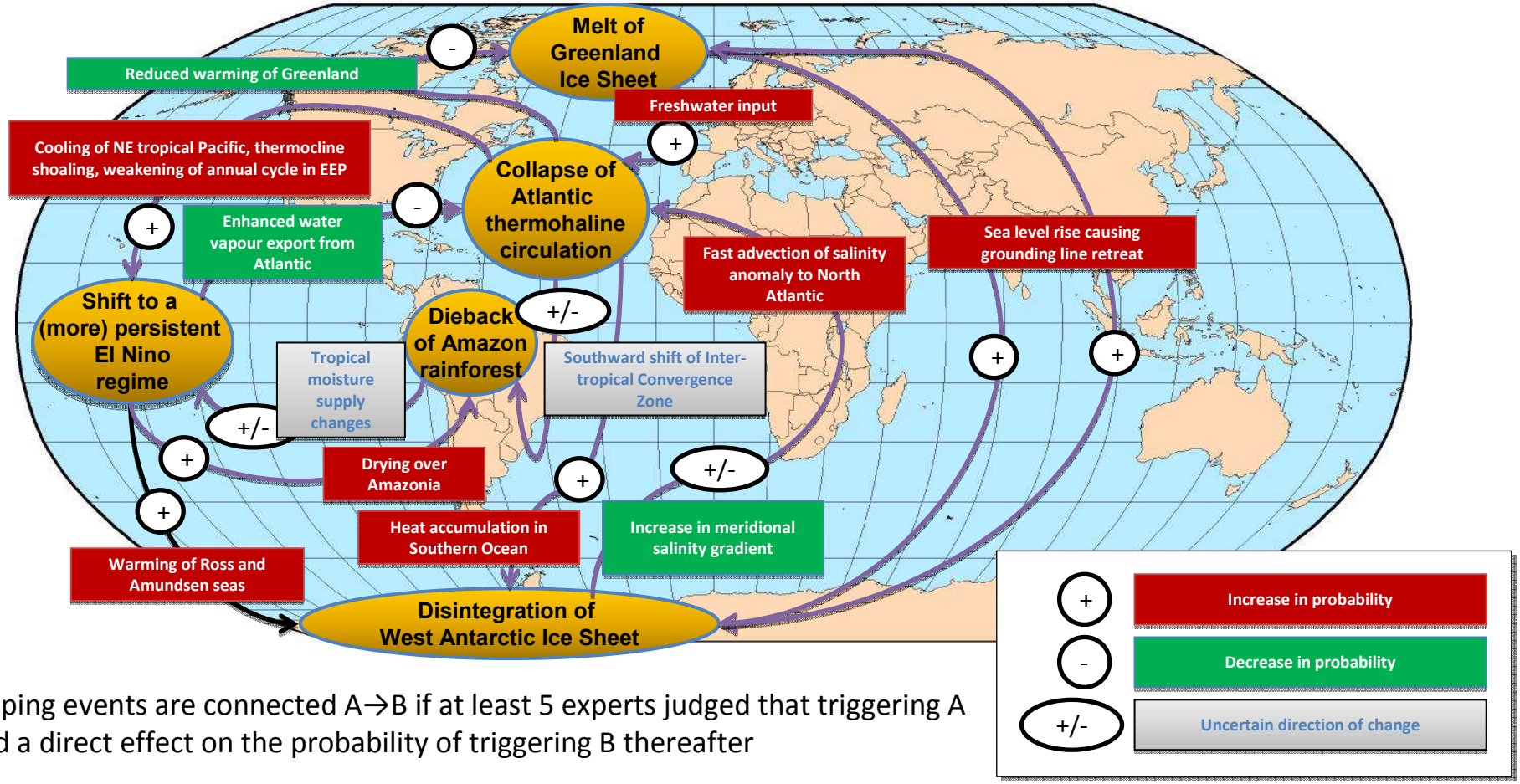
Kriegler et al. (2009) *PNAS* **106**(13): 5041-5046

Interactions between tipping events



Tipping events are connected A→B if at least 5 experts judged that triggering A had a direct effect on the probability of triggering B thereafter

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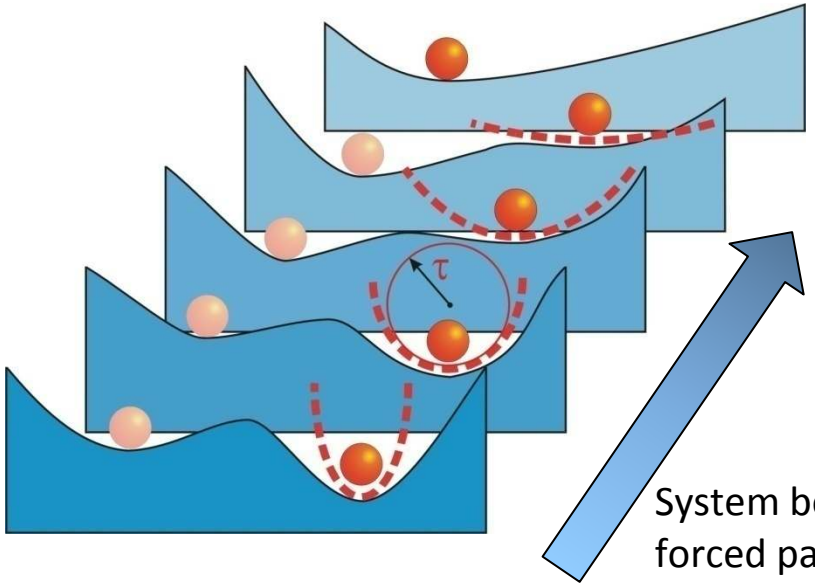
Kriegler et al. (2009) *PNAS* **106**(13): 5041-5046

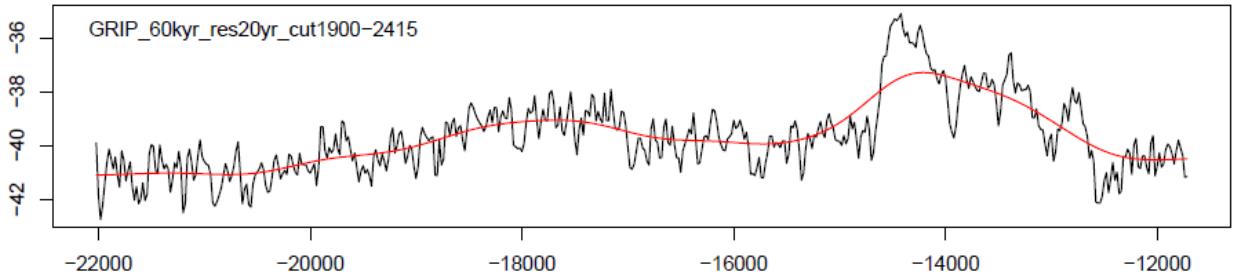
Tipping point early warning



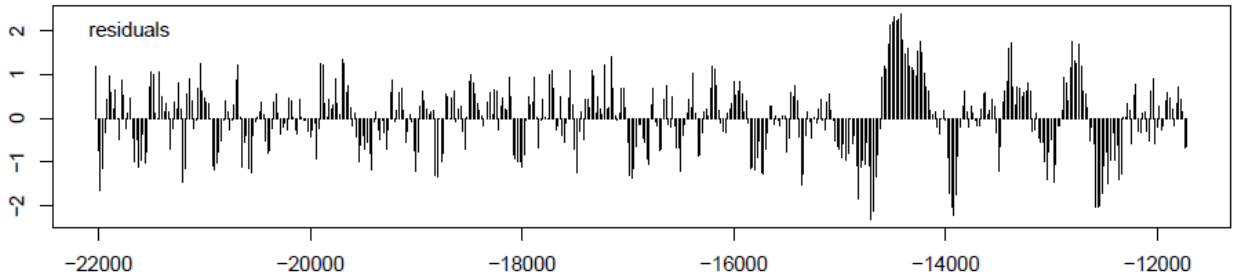
Held & Kleinen (2004) *GRL* 31: L23207; Lenton et al. (2008) *PNAS* 105(6): 1786-1793

The end of the ice age in Greenland

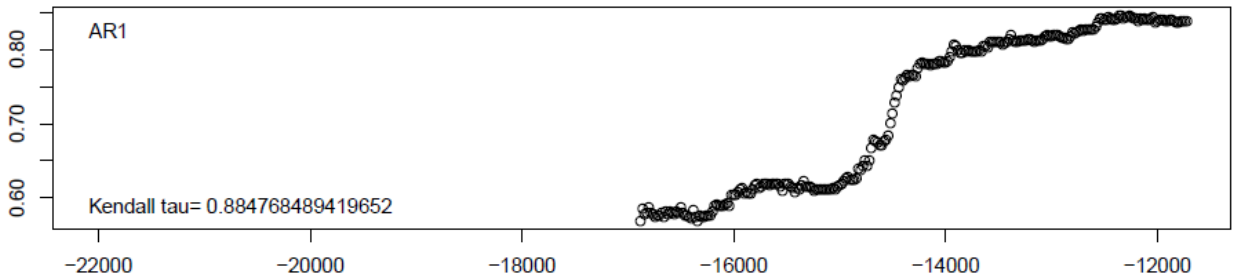
GRIP ice-core $\delta^{18}O$ proxy temperature



Detrended data



Early warning indicator



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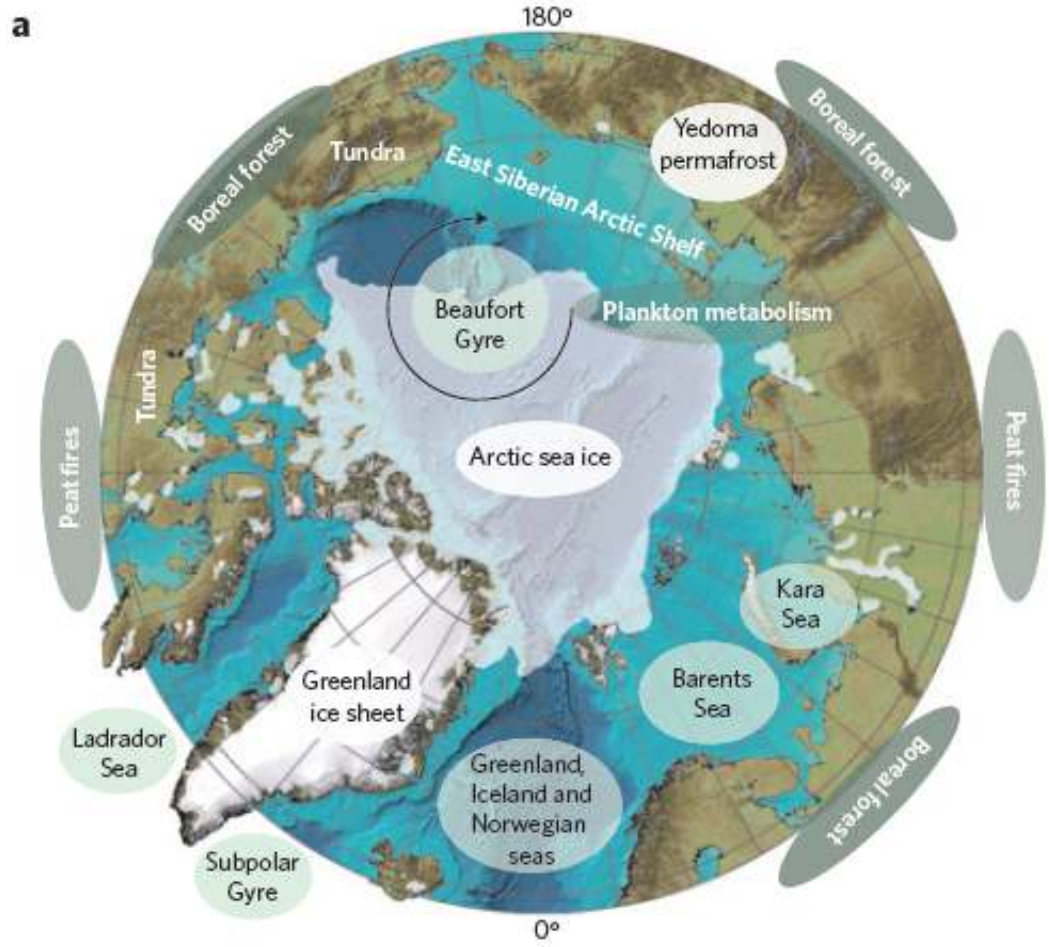
Lenton, Livina, Dakos, Scheffer (2012) *Climate of the Past Discussions* 8: 321-348

Arctic climate tipping points



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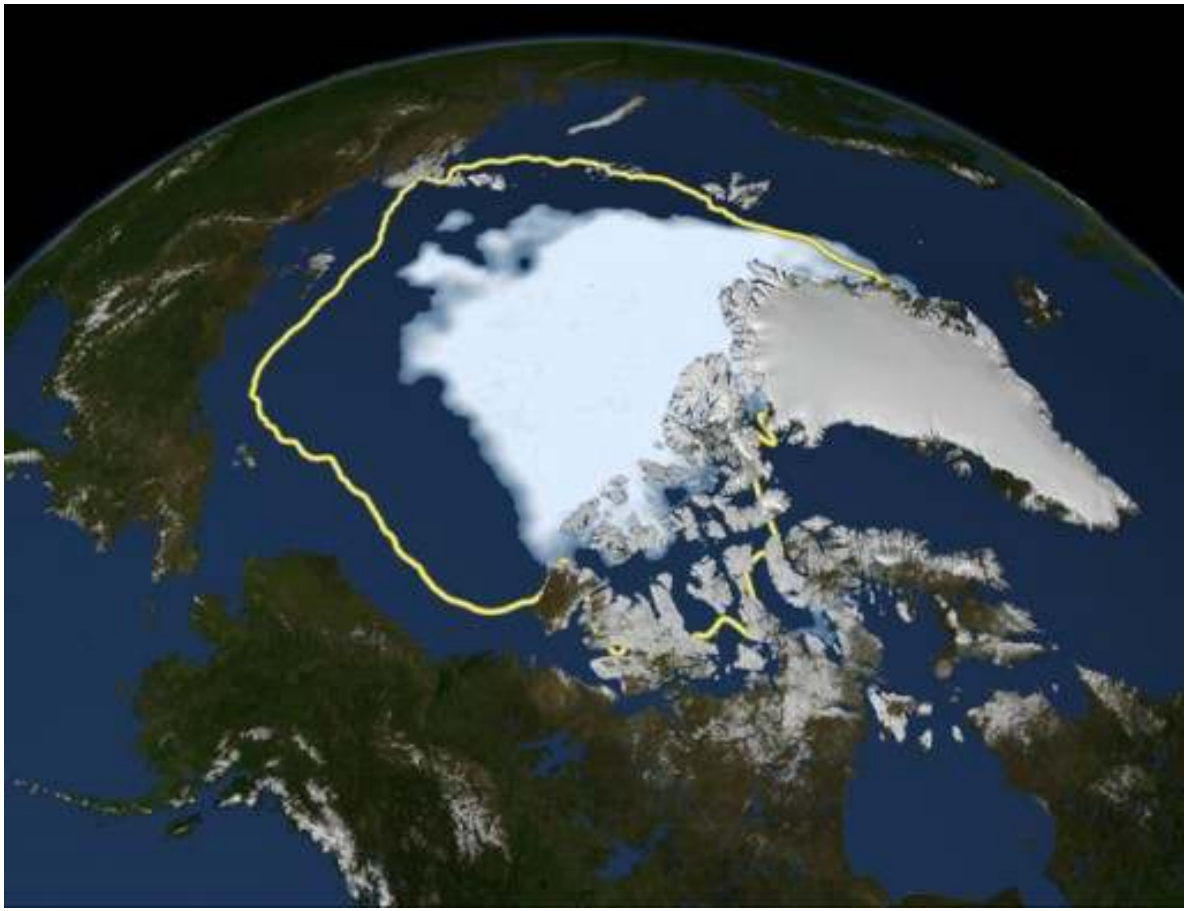
Duarte, Lenton, Wadhams, Wassmann (2012) *Nature Climate Change* **2**: 60-62

Arctic sea-ice



16 September 2012 (3.41×10^6 km^2) compared to the 30 year average minimum (yellow line)

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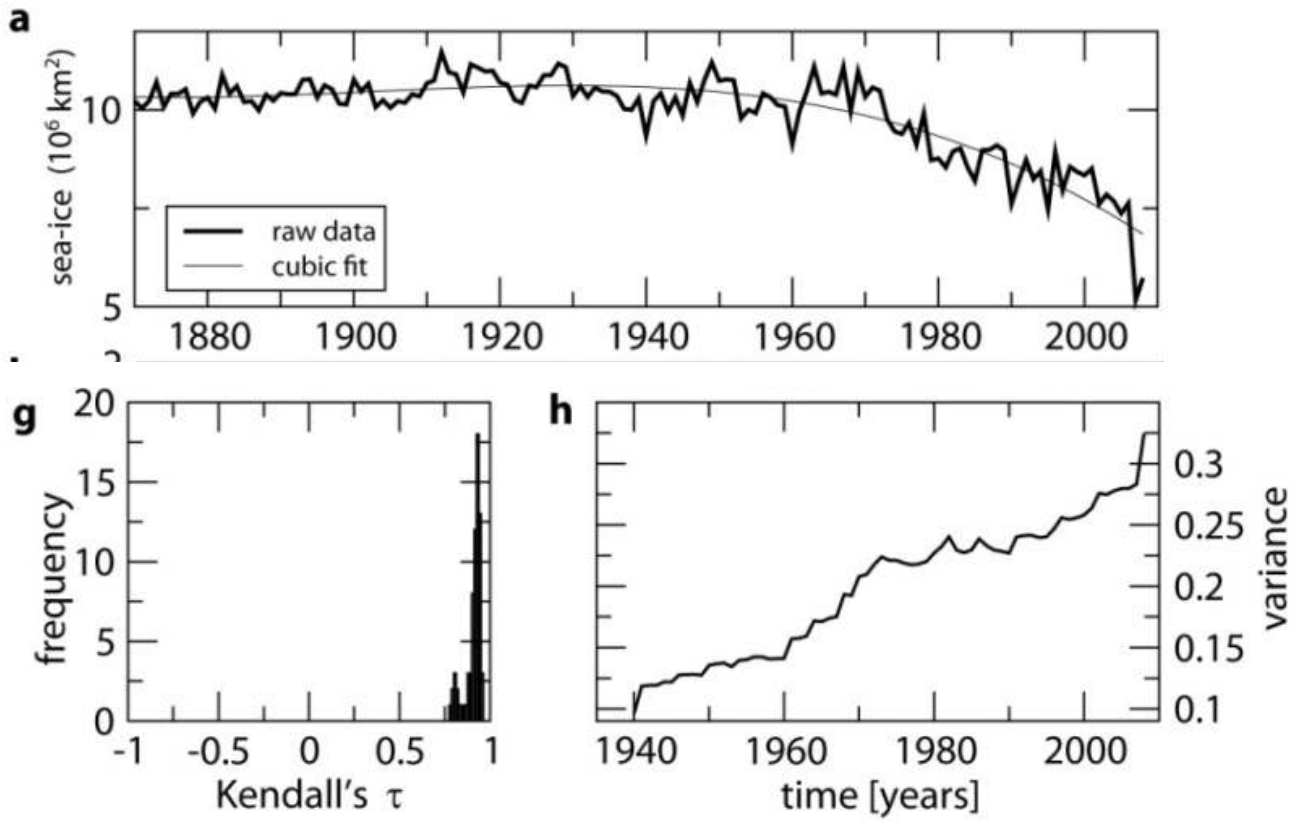
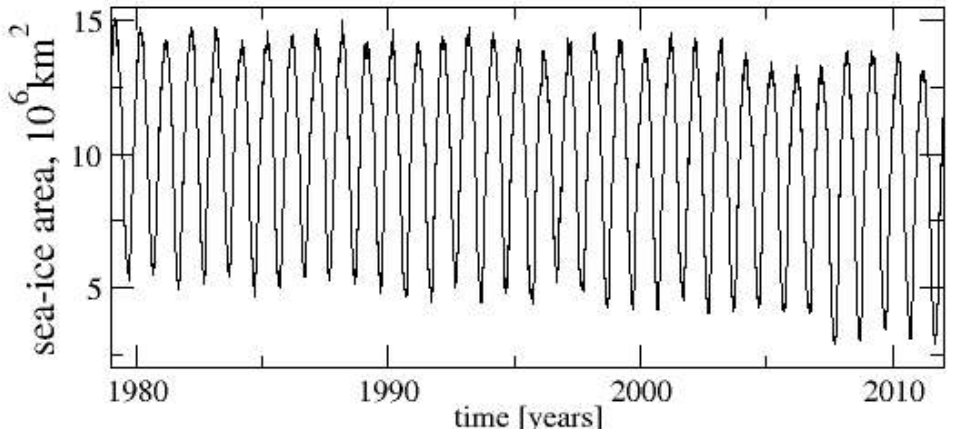
Increasing variability of Arctic sea-ice

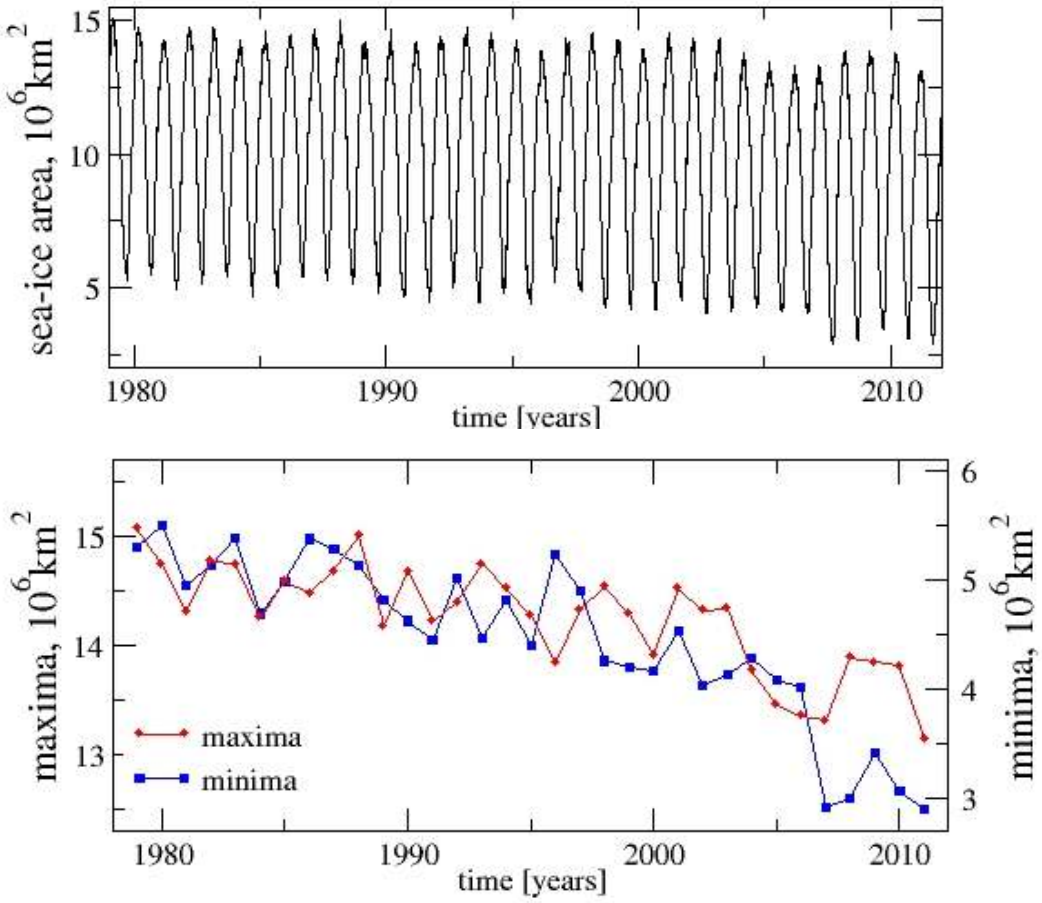


Arctic sea-ice



Livina & Lenton (2013) *The Cryosphere* 7: 275-286

Arctic sea-ice



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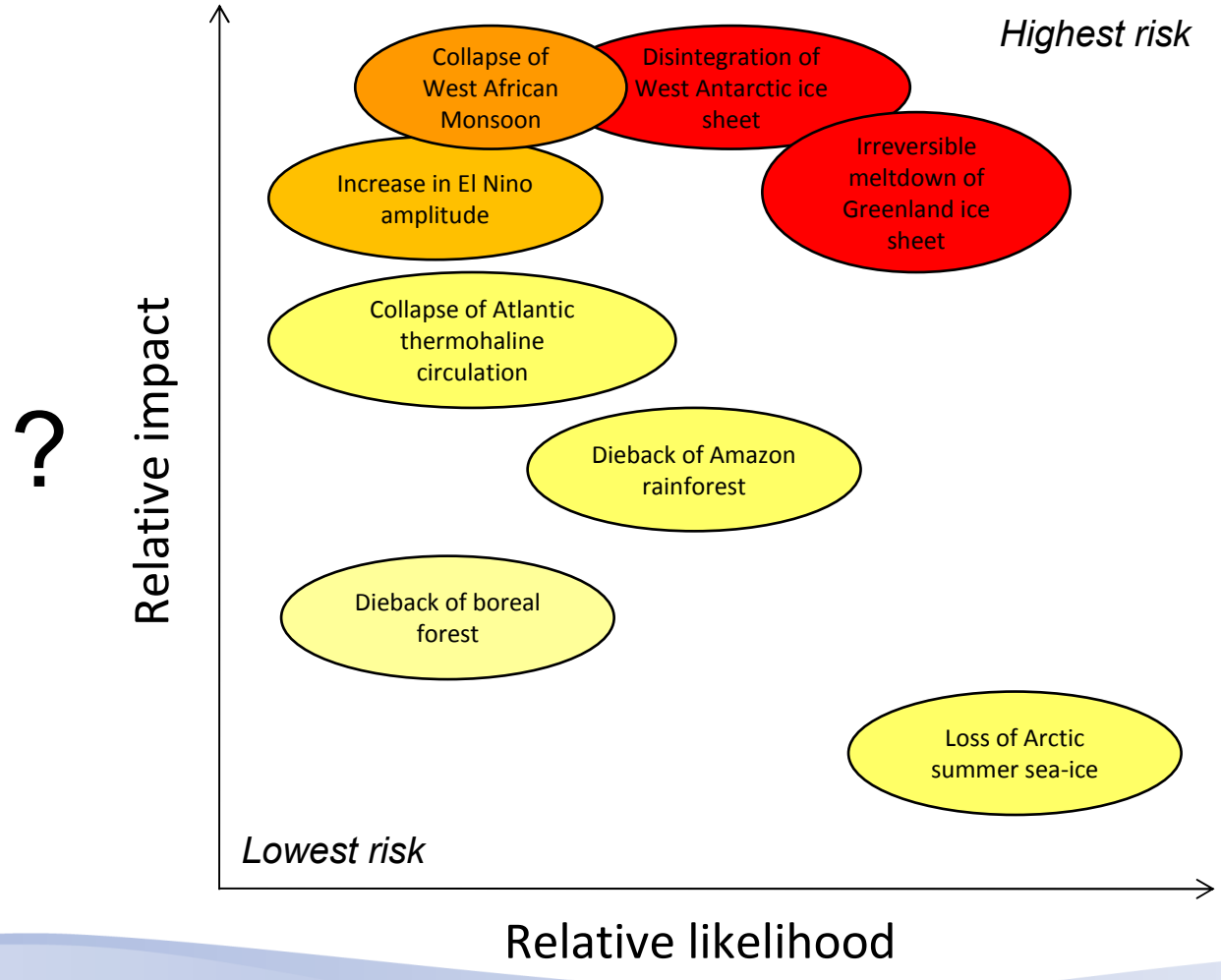
Livina & Lenton (2013) *The Cryosphere* 7: 275-286

Risk matrix



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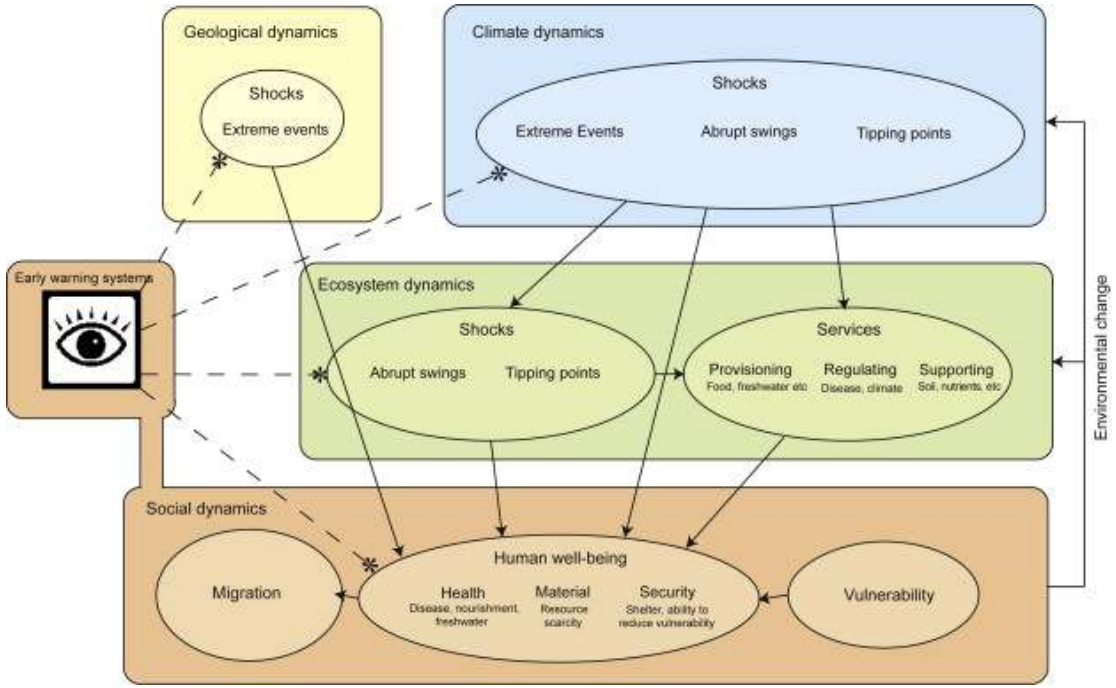
Lenton (2011) *Nature Climate Change* 1: 201-209

Early warning systems

Common elements:

- Risk knowledge
- Warning service
- Communication
- Response capability



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Basher (2006) *Phil Trans A* 364: 2167-82; Lenton (2012) *Env Sci & Policy* 27: S60-S75

Conclusion

- Several tipping elements in the climate system could be triggered this century by anthropogenic forcing
- Some could be high impact *high* probability events but we need improved information on their likelihood and impacts
- Early warning methods exist for bifurcation-tipping points and these have been successfully tested in models and paleo-data
- Tipping point early warning systems could be developed as an aid to adaptation (and a trigger for avoidance activity)

NATURAL ENVIRONMENT RESEARCH COUNCIL

Publications

AXA Research Fund
Through research protection

- Lenton, T. M., and H. J. Schellnhuber (2007), Tipping the scales, *Nature Reports Climate Change, 1, 97-98.*
- Lenton, T. M., et al. (2008), Tipping Elements in the Earth's Climate System, *PNAS, 105, 1786-1793.*
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- Lenton, T. M. (2011), 2 °C or not 2 °C? That is the climate question, *Nature, 473, 7.*
- Lenton, T. M. (2012), Arctic climate tipping points, *AMBIO, 41, 10-22.*
- Lenton, T. M., et al. (2012), Climate bifurcation during the last deglaciation?, *Climate of the Past, 8, 1127-1139.*
- Lenton, T. M., et al. (2012), Early warning of climate tipping points from critical slowing down, *Phil Trans A, 370, 1185-1204.*
- Lenton, T. M. (2012), What early warning systems are there for environmental shocks?, *Environmental Science and Policy, 27, S60-S75*
- Lenton, T. M., and J. C. Ciscar (2013), Integrating tipping points into climate impact assessments, *Climatic Change, 117, 585-597.*
- Livina, V. N., and T. M. Lenton (2007), A modified method for detecting incipient bifurcations in a dynamical system, *GRL, 34, L03712.*
- Livina, V. N., et al. (2010), Potential analysis reveals changing number of climate states during the last 60 kyr, *Climate of the Past, 6, 77-82.*
- Livina, V. N., et al. (2011), Changing climate states and stability: from Pliocene to present, *Climate Dynamics, 37, 2437-2453.*
- Livina, V. N., et al. (2012), An independent test of methods of detecting and anticipating bifurcations in time-series data, *Physica A, 391, 485-496.*
- Livina, V. N., and T. M. Lenton (2013), A recent bifurcation in Arctic sea-ice cover, *The Cryosphere, 7, 275-286.*

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