Early warning of climate tipping points

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Outline

- Tipping points
- Early warning
- Arctic sea-ice
Bifurcation tipping point

Irreversible ‘point of no return’
Bifurcation tipping point

Reversible tipping point

Irreversible ‘point of no return’

Reversible transition
Tipping elements in the climate system

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

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

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.

Tipping point early warning

System being forced past a bifurcation point

The end of the ice age in Greenland

GRIP ice-core
δ¹⁸O proxy temperature

Detrended data

Early warning indicator

Arctic climate tipping points

Arctic sea-ice

16 September 2012 (3.41x10^6 km^2) compared to the 30 year average minimum (yellow line)
Increasing variability of Arctic sea-ice

Analysis of historical reconstruction of summer ice extent (annual data)
Arctic sea-ice
Arctic sea-ice

Relative impact

Relative likelihood

Risk matrix

Highest risk

- Disintegration of West Antarctic ice sheet
- Irreversible meltdown of Greenland ice sheet

Moderate risk

- Increase in El Nino amplitude
- Collapse of West African Monsoon
- Collapse of Atlantic thermohaline circulation
- Dieback of Amazon rainforest
- Dieback of boreal forest

Lowest risk

- Loss of Arctic summer sea-ice

Lenton (2011) Nature Climate Change 1: 201-209
Early warning systems

Common elements:

- Risk knowledge
- Warning service
- Communication
- Response capability

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)
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