Institution: University of Exeter

Unit of Assessment: Earth Systems and Environmental Sciences (UoA7)

Title of case study: Climate Tipping Points – impact on climate policy and risk assessment

1. Summary of the impact (indicative maximum 100 words)

Research at the University of Exeter identifying potential climate tipping points and developing early warning methods for them has changed the framework for climate change discussion. Concepts introduced by Professor Tim Lenton and colleagues have infiltrated into climate change discussions among policy-makers, economists, business leaders, the media, and international social welfare organisations. Thorough analyses of abrupt, high impact, and uncertain probability events, including estimates of their proximity, has informed government debate and influenced policy around the world. It has also prompted the insurance and reinsurance industry to reconsider their risk portfolios and take into account tipping point events.

2. Underpinning research (indicative maximum 500 words)

Lenton's research team at Exeter are identifying potential climate tipping points and developing, testing, and applying early warning methods for them [1-4]. Early warnings of abrupt climate changes have considerable potential value to societies. Hence the research also considers how to translate scientific early warning signals – such as slowing recovery from natural fluctuations – into effective early warning systems [1,2]. This research featured on the front cover and editorial of *Nature Climate Change* (July 2011).

This tipping point early warning work grew out of the 'Mathematical and Statistical Approaches to Climate Modelling and Prediction' programme (August-December 2010) co-convened by Collins, Cox (and also Stephenson, Thuburn from Exeter) at the Isaac Newton Institute for Mathematical Sciences (Cambridge University). This programme brought Lenton and his team (then at UEA) together with a group of Exeter climate researchers and mathematicians, helping persuade him to move to Exeter (in April 2011). Key research outputs conducted at Exeter following the programme include the development and testing of early warning methods for approaching tipping points [3] – one of four Exeter-led papers in a Special Issue of *Phil Trans A*.

Application of the detection and early warning methods to observational climate data led to the discovery that Arctic sea-ice cover passed a tipping point in 2007, in which the amplitude of the seasonal cycle abruptly and persistently increased [4]. This added to the case that the Arctic is already experiencing abrupt and potentially 'dangerous' climate change, for ecosystems and societies. These interdisciplinary issues were addressed by Lenton co-editing and contributing to an *AMBIO* special issue on Arctic tipping points [5], and co-writing a corresponding commentary (Abrupt climate change in the Arctic. *Nature Climate Change* 2(2), 60-62 (2012)).

Understanding of tipping points led Lenton to question the foundation for the widely-used policy target of a 2°C limit for the increase in annual mean surface temperature. A reframed policy objective was proposed that would limit the overall magnitude, rate of change, and spatial gradients of human influences on the Earth's energy balance. This research led to an invited 'Worldview' piece in *Nature* (Lenton (2011) 2 °C or not 2 °C? That is the climate question. *Nature* 473, 7).

Interest in the impacts of climate tipping points on Europe led the European Environment Agency to convene a workshop (involving Lenton), which the EU Joint Research Centre (Sevilla) followed with a project to assess the potential economic impacts on Europe (with Lenton on the advisory board). These studies and a US Department of Energy workshop on the social cost of carbon emissions led to an influential critique of the representation of tipping points (or the lack of it) in integrated assessment models [6].

To explore the broader framing and implications of tipping points, Lenton co-convened and Cox attended a cross-disciplinary workshop at the Royal Society Kavli Centre, jointly sponsored by the British Academy, which engaged leaders from multiple sectors of society, as well as academics –

resulting in a co-edited book (O'Riordan, T. and Lenton, T. (Eds.) *Addressing Tipping Points for a Precarious Future*. London: British Academy. ISBN-13:978-0197265536 (2013)).

3. References to the research (indicative maximum of six references)

Key references to research that underpins the impact described in this case study:

1. Lenton, T.M., Early warning of climate tipping points. *Nature Climate Change* 1, 201-209 (2011). #
2. Lenton, T.M., What early warning systems are there for environmental shocks? *Environmental Science and Policy*, 27, S60-S75 (2012).
3. Lenton, T.M., Livina, V.N., Dakos, V., van Nes, E.H., & Scheffer, M., Early warning of climate tipping points from critical slowing down: comparing methods to improve robustness. *Phil Trans A* 370 (1962), 1185-1204 (2012). #
4. Livina, V.N. & Lenton, T.M., A recent tipping point in the Arctic sea-ice cover: Abrupt and persistent increase in the seasonal cycle since 2007. *The Cryosphere*, 7, 275-286 (2013). #
5. Lenton, T.M., Arctic climate tipping points. *AMBIO*, 41, 10-22 (2012).
6. Lenton, T.M. & Ciscar, J.C., Integrating tipping points into climate impact assessments. *Climatic Change*, 117 (3), 585-597 (2013).

References that best indicate the quality of the underpinning research.

Grant support related to this research:

- NERC 'Detecting and Classifying Bifurcations in the Climate System' (PI Lenton) £275,896 (01/05/08-30/04/12)

4. Details of the impact (indicative maximum 750 words)

Our close engagement with policymakers and accessible communication of climate tipping point research has informed government debate and influenced policy around the world, and has also prompted the insurance and reinsurance industry to reconsider their risk portfolios.

Informing political debate and influencing policy

Interest in climate tipping points, and the prospects for early warning of them, led the UK Government Chief Scientist, Sir John Beddington to convene a meeting **[a]** (14/3/2011) and subsequent workshop (26/9/2011) on climate tipping points. Following this, the Government Office for Science, through their Foresight Project on Environmental Change and Migration, commissioned a state-of-science review of early warning systems by Lenton [2] **[b]**, and recommended their further development to help in adaptation to climate change.

In 2012, Lenton was an expert witness to the House of Commons Environmental Audit Committee as they reviewed the UK Government's performance in protecting the Arctic. Lenton's evidence, as well as his research, is referred to throughout the report from the Committee **[c]**. The second recommendation of this Committee acknowledged that "there may be a number of tipping points in climate-driven systems in the Arctic, which threaten to rapidly escalate the danger for the whole planet" **[c]**. The response also confirmed that "a significant component of the 3-year £50 million DECC and Defra-funded Met Office Hadley Centre Climate Programme is devoted to developing a better understanding of climate system 'tipping points'..." **[d]**.

In 2012, Lenton's work was cited in the World Bank Report, *4^{o} Turn Down the Heat* **[e]**. This report was subsequently used to inform political debates in Australia. In 2012, Western Australia's Legislative Council referred to the report during debate on the second reading of the *Climate Change Readiness (Coastal Planning and Protection) Bill 2012* **[f]**. In 2013, the Australian Capital Territory (ACT) Legislative Assembly used the report to support a motion by the labour government regarding a set of actions for the ACT Government to take on climate change, including

implementing a renewable energy target of 90% by 2020 **[g]**.

On the other side of the world, Canada's New Democrat Party (NDP) referred extensively to climate tipping points during debate of an Opposition Motion on Climate Change in 2013 **[h]**. The NDP called for the federal government to table its climate change adaptation plan and expressed considerable concern that the Minister of Natural Resources was unaware of the "dangerous tipping point for irreversible damage" to the ecosystem **[h]**.

In the U.S., an authoritative report by the National Research Council, which was part of a suite of studies ordered by the US Congress, stated that "rather than smooth and gradual climate shifts, there is the potential that the Earth system could cross tipping points or thresholds that result in abrupt changes. Some of the greatest risks posed by climate change are associated with these abrupt changes" **[i]**. Accordingly, the U.S. Department of Transportation has dedicated an entire website to the explanation of climate tipping points **[j]**. A follow-up National Research Council committee on 'Understanding and Monitoring Abrupt Climate Change and its Impacts' – reporting in Winter 2013/2014 (for which Lenton is a reviewer) – recommends establishing an abrupt climate change early warning system, following [1].

In 2013, Lenton's work identifying Arctic climate tipping points led the U.S. Interagency Arctic Research Policy Committee to invite him to a workshop at the White House (30/4-2/5/13) to develop a conceptual model of the changing ecosystem in the Chukchi and Beaufort Seas. Furthermore, The United Nations invited Lenton to present on tipping points at their New York headquarters (20/3/13) in an Expert Group Meeting to help define the Sustainable Development Goals which will replace the Millennium Development Goals in 2015.

Improving risk assessment for insurance and re-insurance industry

Work on the Isaac Newton Institute programme and subsequently at Exeter to assess the risks posed by different climate tipping points and develop early warning methods for them was highlighted at a public 'climate change question time' event at Willis Re (24/11/2010). In January 2013, Pete Thomas, Chief Risk Officer for Willis Re, one of the world's leading reinsurance advisors, gave a keynote address to the 13th National Conference on Science, Policy and the Environment in Washington, D.C. In his address he discussed the problems associated with tipping points and some of the unexpected consequences for the insurance industry **[k]**.

5. Sources to corroborate the impact (indicative maximum of 10 references)

a. Government Office for Science – Tipping points meeting: http://www.bis.gov.uk/assets/bispartners/goscience/docs/t/11-974-tipping-points-meeting-london-14-march-2011.pdf

b. Government Office for Science Foresight Project on Migration and Global Environmental Change 'SR4: What early warning systems are there for environmental shocks? (2011) *(Authored by Lenton and References Lenton p.9, 11, 12, 14, 16, 17, 20 and 21, and Cox p.8)* http://www.bis.gov.uk/assets/bispartners/foresight/docs/migration/science-reviews/11-1122-sr4a-early-warning-systems-for-environmental-shocks.pdf

c. House of Commons Environmental Audit Committee (20 Sep 2012) *Protecting the Arctic, Second Report of the Session 2012-13*, House of Commons, HC 171, London: The Stationery Office Limited http://www.publications.parliament.uk/pa/cm201213/cmselect/cmenvaud/171/171.pdf

d. House of Commons Environmental Audit Committee (15 Jan 2013) *Protecting the Arctic, Government Response to the Committee's Second Report of Session 2012-13, Third Special Report of Session 2012-13*, House of Commons, HC 858, London: The Stationery Office Limited http://www.publications.parliament.uk/pa/cm201213/cmselect/cmenvaud/858/858.pdf

e. The World Bank (2012) *4^{o} Turn Down the Heat: Why a 4^{o}C Warmer World Must be Avoided.* A report for the World Bank by the Potsdam Institute for Climate Impact Research and Climate Analytics. Washington, DC: The World Bank. http://climatechange.worldbank.org/sites/default/files/Turn_Down_the_heat_Why_a_4_degr

ee_centrigrade_warmer_world_must_be_avoided.pdf

f. Hansard WA Legislative Council (29 Nov 2012) p9040a-9042a. http://www.parliament.wa.gov.au/Hansard%5Chansard.nsf/0/192798174dd9ac7148257afc0028e7dc/$FILE/C38%20S1%2020121129%20p9040a-9042a.pdf

g. Hansard ACT Legislative Assembly Debate (27 Feb 2013) Page 854. http://www.hansard.act.gov.au/hansard/2013/pdfs/20130227.pdf

h. Hansard HC Debate (25 Apr 2013) 41st Parliament, 1st session, No. 240 http://www.parl.gc.ca/HousePublications/Publication.aspx?Doc=240&Pub=Hansard#SOB-7980022

i. 'Advancing the Science of Climate Change' (2010) *The National Academies Press* http://www.nap.edu/catalog.php?record_id=12782

j. U.S. Department of Transportation (2013) 'Climate Tipping Points: Current Perspectives and State of Knowledge', *Transportation and Climate Change Clearinghouse* [website accessed 26 Jun 2013] http://climate.dot.gov/about/overview/climate_tipping_points.html

k. Thomas, P. (2013) 'Blue Collar Risk Management', *Disasters and Environment: Science, Preparedness, and Resilience,* 13th National Conference on Science, Policy and the Environment, Washington DC, January 15-17, 2013 [PowerPoint Presentation] http://www.environmentaldisasters.net/files/225101_225200/225150/pthomas.pdf