Institution: University of Exeter

Unit of Assessment: 10 Mathematical Sciences

Title of case study: Improved pricing of European natural catastrophe insurance by statistical modelling of storm clustering

1. Summary of the impact (indicative maximum 100 words) Statistical modelling of storms by Professor David Stephenson and co-workers in the mathematics institute at the U. of Exeter, has improved the understanding and thereby the pricing of insurance risk due to European windstorms and tropical cyclones. Temporal clustering in these catastrophic natural hazards has been quantified using novel process-based statistical models, which have then been implemented by industry to improve insurance pricing, e.g. on the integrated financial platform used by Willis actuaries to provide a more reliable view of risk as required by EU solvency 2 regulation. This research has also raised awareness in the industry about storm clustering, and has stimulated significant improvements in the main vendor catastrophe models, which are the main tools used by insurance companies to price European windstorm insurance.

2. Underpinning research (indicative maximum 500 words) Clustered windstorms in Europe are a major source of societal risk. They lead to substantial aggregate insurance losses comparable to a US hurricane e.g. clusters of European storms in December 1999 and in early 1990, both resulted in insured losses exceeding US$10 billion. Insurance companies price this risk using stochastic simulation models known as catastrophe models. However, such models are based on rather ad hoc assumptions about clustering that leads to large uncertainties in aggregate loss estimates. The storm risk team, established by Professor Stephenson after his appointment in mathematics at Exeter in April 2007, have deepened knowledge in storm clustering by developing and applying statistical models of storms based on process understanding. Using storm track data simulated by a climate model [1], they confirmed the empirical clustering results from the earlier PhD research supervised by Professor Stephenson. They found significantly more variance in observed European storm counts than expected by chance sampling of independent events. Furthermore, they showed that this overdispersion (a measure of clustering) could be accounted for by time variations in the large-scale background flow [1]. Discussions with insurers raised the important question as to whether the more extreme storms were also clustered. New research then revealed that non-intuitively there is actually more clustering for the more extreme storms [2]. This has since led to the discovery in 2012 of a positive correlation between storm frequency and storm intensity over N. Europe, which is likely to substantially increase extreme aggregate losses (work to be submitted by the end of 2013). The team have also modelled clustering in tropical cyclones and have used it to show that storm clustering provides valuable recovery time e.g. for Carribean coral ecosystems [3]. In addition, local spatial calibration of tropical cyclones simulated by climate models has been successfully implemented on the risk simulation platform at Willis to provide a useful tool for exploring the tropical cyclone risk especially in Asia (unpublished work). The team has also successfully collaborated with U.S. hydrologists on the clustering of extreme rainfall and flooding [4,5]. The storm risk team is unique in working at the interface between environmental statistics, actuarial/financial mathematics, and atmospheric science. The team makes novel application of statistical concepts such as compound Poisson processes, Generalized Linear Models, and Extreme Value Theory. Under the guidance of Professor Stephenson, young statisticians in the team learn valuable interdisciplinary skills relevant to real-world risk quantification and decision-making. Team members include postdoctoral fellows (Willis-funded: Dr Ben Youngman 10/2011-

now, Dr Renato Vitolo 1/2008-9/2010; AXA-funded: Dr Theo Economou 10/2010-now) and NERC funded PhD students (Laura Dawkins 10/2011-now; Phil Sansom 03/2011-now; Alasdair Hunter 10/2010-now). In addition to strong working links with the reinsurance industry, the team also collaborates closely with storm scientists at the nearby Met Office (e.g. joint biweekly meetings).

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

Evidence of the quality of the research that underpins this case study is provided through the following peer-reviewed publications and grants secured through competitive funding sources.

[1]** Kvamsto, N-G., Y. Song, I. Seierstad, A. Sorteberg, & D. B. Stephenson. (2008) Clustering of cyclones in the ARPEGE general circulation model. *Tellus A*, **60** (3), pp. 547–556. (IF: 2.062; 5-year IF: 2.320)

[2]** Vitolo, R., D. B. Stephenson, I. M. Cook, & K. Mitchell-Wallace. (2009) Serial clustering of intense European storms. *Meteorologische Zeitschrift*, 2009, **18**, pp. 411 – 424. DOI: 10.1127/0941–2948/2009/0393. (Impact factor from Journal Citation Reports 2010: 1.402; 5-year IF: 1.530; *Short-listed for the Lloyd's research project prize in 2010)*

[3]** Mumby, P. J., R. Vitolo, & D. B. Stephenson. (2011) Temporal clustering of tropical cyclones and its ecosystem impacts, *Proceedings of the National Academy of Science*, volume 108, pages 17626-17630. DOI: 10.1073/pnas.1100436108 (Impact factor from Journal Citation Reports 2010: 9.771; 5-year IF: 10.591)

[4] Villarini G, Smith JA, Baeck ML, Vitolo R, Stephenson DB, Krajewski WF. (2011) On the frequency of heavy rainfall for the Midwest of the United States, *Journal of Hydrology*, volume 400, no. 1-2, pages 103-120.

[5] Villarini, G., Smith, J.A., Vitolo, R., and Stephenson, D.B., (2012) "On the temporal clustering of US floods and its relationship to climate teleconnection patterns, *International Journal of Climatology,* doi:10.1002/joc.3458.

** Papers that best indicate quality of underpinning research.

Key Supporting Grants

* Willis Research Network: Funding of research fellow, 1 Jan 2008 – ongoing, £50,000/year

* AXA Research Fund Research Grant: Regional Assessment of Climate Change Impact on European Windstorms: Track clustering and multi-peril dependency (RACEWIN), 1/10/2010-31/9/2013, £241,231.

* NERC Doctoral Training Grant (Open CASE with Willis): Trends in extreme extratropical cyclones and non-indemnity insurance, 1/10/2010–31/9/2013, £93,764

* NERC Doctoral Training Grant Project TEMPEST: Testing and Evaluating Model Predictions of European Storms, 1/9/2010–31/8/2013, £93,764

* NERC PURE (Probability, Uncertainty and Risk in the Environment) consortium project CREDIBLE, 1/10/2012-30/09/2016 £212,453. PhD student (Laura Dawkins; start 1/10/2012) and postdoctoral researcher to start in 10/2013.

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

Exeter's storm risk research has had a clear impact on risk quantification practices in the insurance sector. Notable impacts include:

1. **Improved mathematical tools which have been adopted by industry for better pricing of storm insurance.**

   Research publications [1-3] led in 2009 to storm clustering being incorporated for the first time into the Integrated Financial Platform (iFM) at Willis. Willis is a major global insurance and reinsurance broker that employs around 20,000 people worldwide and arranges protection for around US$5 trillion of exposed risk every year. The clustering methodology accounts for the increased clustering of more extreme storms [3] and is routinely used by the Chief Actuary and other brokers at Willis to design more robust reinsurance contracts and to better price windstorm risk. Local spatial calibration of tropical cyclones simulated by climate models was also successfully implemented on the platform in 2009 and provides Willis with a useful tool for exploring the tropical cyclone risk especially in regions where there have been few cyclone observations (e.g. western Pacific near E. Asia). Willis Re have quoted Stephenson's research *'....as the most significant contributor of of any WRN [Willis Research Network] partner in terms of applicable research'* they further add that *'the studies of clustering of clustering that they [Stephenson's group] produced allowed Willis to lead the market in providing better quantification of the additional risk, and demonstrate to our clients that we are the leading insurance broker'* and '*clustering has now been built into commercially availible models for windstorm risk following the Exeter work'* [evidence **item i**].

2. **Raised awareness in storm clustering that has stimulated improvements in the commercial vendor catastrophe models used by the insurance industry.**

   Exeter's storm risk research has raised awareness in the importance of storm clustering throughout the insurance industry. Three major catastrophe modelling companies (AIR, EQECAT and RMS) have now explicitly incorporated clustering in their most recent windstorm models for Europe [see evidence **items a-d**]. Thanks in part to Exeter's research, storm clustering has also become a subject of much research and development at major reinsurance companies, e.g. SCOR [evidence **item f**]. Exeter's research on storm clustering is often cited and quoted in company technical reports (see evidence **item e** and evidence **item g**).

3. **Expert dialogue on storm risk with global insurers and insurance brokers**

   As world-leading experts in storm risk, Professor Stephenson and his team are in frequent demand to provide expert advice to insurance on storms. For example,

   - The PhD research [2] supervised by Professor Stephenson led to the creation in 2006 of the Willis Research Network (WRN) – the world's largest partnership between academia and the insurance industry (www.willisresearchnetwork.com). The WRN is a unique open forum for the advancement of the science of extreme catastrophic events through close collaboration between universities, insurers, reinsurers, catastrophe modelling companies, government research institutions and non-governmental organisations. As one of the world's major brokers, Willis is able to use the expert advice to better inform its clients, which include most of the world's major insurance companies and several national governments. Exeter continues to play a pivotal role in the success of this network [evidence **item i**].

   - In 2010, Professor Stephenson was invited to serve as the windstorm expert on the Natural Catastrophe Advisory Council of Zurich – one of the world's largest

insurance companies. He provides expert advice at annual council meetings;

- The work of Prof. Stephenson and Dr. Economou supported by the AXA research fund has featured heavily in AXA's outreach and 2013 brand campaign [evidence **items h**].

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

a. AIR (Applied Insurance Research inc.): Dr Gerhard Zuba and Dr Milan Simic: "European Windstorms: Implications of Storm Clustering on Definitions of Occurrence Losses", September 20, 2010, http://www.air-worldwide.com/Publications/AIR-Currents/2010/European-Windstorms--Implications-of-Storm-Clustering-on-Definitions-of-Occurrence-Losses/ *(References Stephenson)*

b. Verisk Analytics 'Air Worldwide updates European Wind and Earthquake models', 12th September 2011. http://www.verisk.com/Press-Releases/2011/AIR-Worldwide-Updates-European-Wind-and-Earthquake-Catastrophe-Models.html *(corroborates claim that Air has updated their model to include clustering)*

c. EQECAT: Global Reinsurance Special Report - European Windstorm Special Edition, September 2010 http://www.eqecat.com/pdfs/global-reinsurance-report-windstorm-sep09.pdf *(References Stephenson p.8)*

d. RMS 'Ten Years After – How Windstorm Modelling has Matured since the 1999 European Storms, 22nd December 2009 https://support.rms.com/Publications/1999_European_Storms_10_Year_Retrospective.asp

e. Activity of Catastrophic Windstorm Events in Europe in the 21st century, May 31st 2010. *http://www.google.co.uk/url?q=http://www.eqecat.com/pdfs/activity-catastrophic-windstorm-events-europe-2010.pdf&sa=U&ei=8dt3UZO4N8bJ0QX_54DgDA&ved=0CBsQFjAA&usg=AFQjCNF27W7vzpGZ79UVsX80xIpb9gZGBg (References Stephenson p.33)*

f. SCOR: Mitchell-Wallace, Kirsten and Alvarez-Diaz, Teresa: "The impact of clustering of extreme European windstorm events on (re)insurance market portfolios", presentation at EGU 2010, http://meetingorganizer.copernicus.org/EGU2010/EGU2010-12446.pdf

g. Lloyds: "Storm clouds gather over Europe" Tuesday 30th November 2010 http://www.lloyds.com/News-and-Insight/News-and-Features/Environment/Environment-2010/Storm-clouds-gather-over-Europe *(Article references Exeter's research)*

h. AXA research fund advertising using storm risk work by Prof. Stephenson and Dr. Theodorus Economou:

- AXA "Born to Protect" brand web documentary, 1 July 2013 http://www.borntoprotect.com/en_EN

- AXA "Born to Protect" brand advert aired on major television channels across Europe, 12 June 2013 http://www.youtube.com/watch?v=JQ1WkX63uMk

- Tracking future windstorms in Europe, 2nd August 2011http://www.axa-research.org/david-stephenson-tracking-future-windstorms-in-europe

i. Supporting Letter, Executive Director, Willis Re.