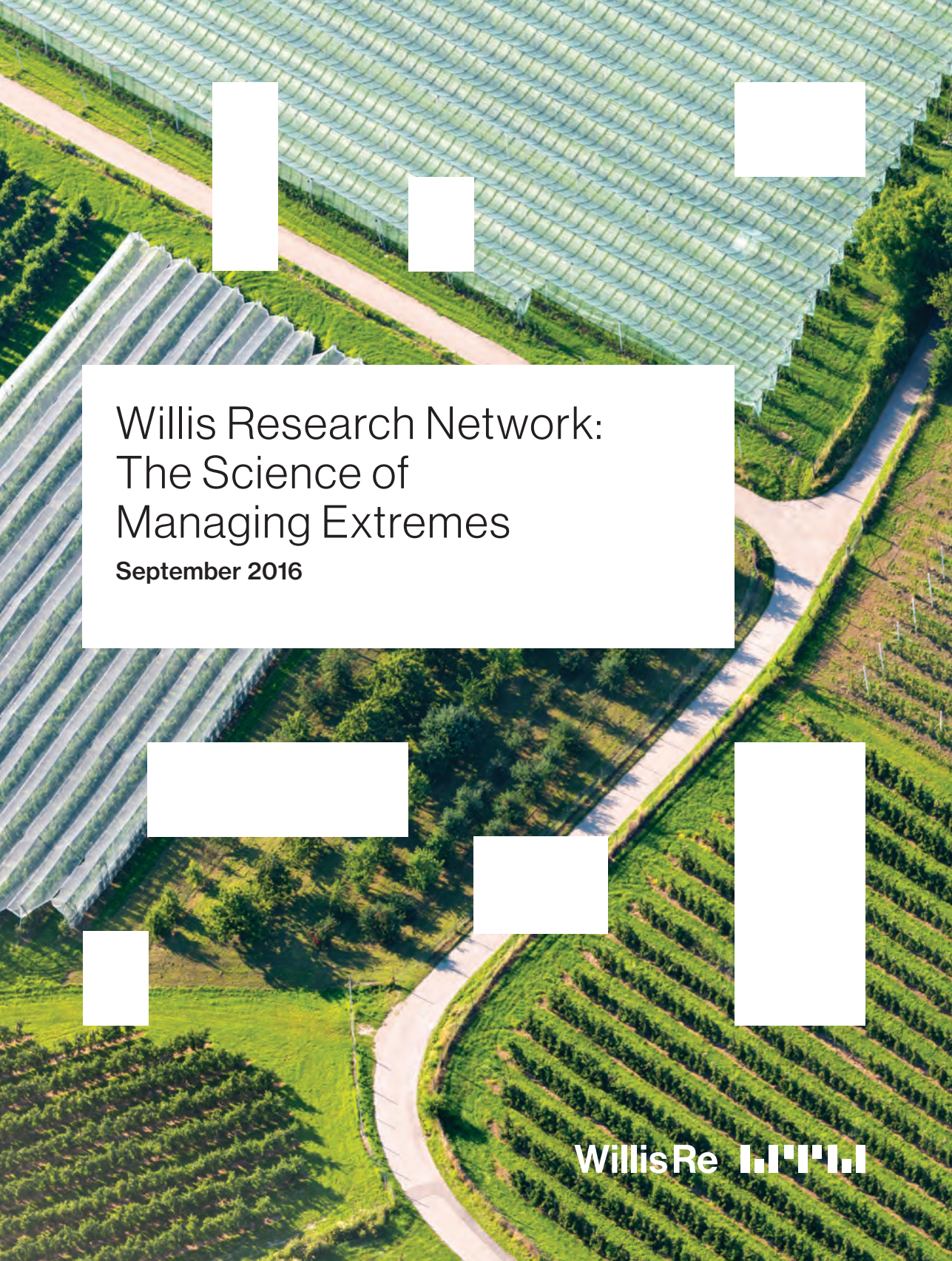

Willis Research Network: The Science of Managing Extremes

September 2016

Willis Re

Foreword

In 2006, the re/insurance sector was picking itself up after the unprecedented hurricanes Katrina, Rita and Wilma. The industry was facing intense questions and challenges from heightened analytical and regulatory demands of natural catastrophe risk. In response, Willis Re, working with academic and industry leaders, created the Willis Research Network. The goal was to integrate public science and re/insurance communities, capabilities and facilities, to scale up and enhance our collective ability to understand, evaluate and manage these extremes, and to provide independent and credible scientific expertise to improve risk decision making across the industry.

It began with fellowships at seven U.K. universities and has since grown to programs and projects across more than fifty science institutions worldwide, working with our re/insurance clients and partners to confront the full spectrum of modeling challenges of this domain. The challenge was to combine high end research, evidenced by hundreds of peer-reviewed publications over the years, with practical application and impact for our clients and the wider industry to support secure, resilient and efficient insurance markets.

We have brought just some of these stories together in this ten year anniversary brochure. It is a small sample, and we wish we could have added more, but it provides a set of great examples of how science and industry can work together to drive forward understanding, meet their own needs and make the world a safer place to protect lives, livelihoods and shelter.

For all of us involved, the other benefit has been the rich network of productive and inspiring relationships, some of which are now ten years old. We are also rewarded by the many professional careers that the WRN has propelled during this time, for an emerging generation of talent, now integrated across industry and academia.

Our first ten years is an important milestone and a welcome opportunity to acknowledge and thank all those who have been part of this unique journey over the years: academic members, industry partners and Willis Towers Watson colleagues, past and present, for all their immense support and significant contributions. We are looking forward to our next ten years, building upon our experience and evolving with new demands and environments.

Rowan Douglas CBE
Founder and Chairman,
Willis Research Network

Member, Prime Minister's Council for Science and Technology

September 2016

The Willis Research Network is an award winning collaboration between academia and the finance and insurance industries.

The Willis Research Network (WRN) was formed in 2006 to forge practical links between science, policy and industry and to tackle key risks facing the global re/insurance industry. Through the WRN, Willis Towers Watson has teamed up with more than 50 world-leading institutions to develop dynamic and innovative solutions to the challenges of risk and resilience. Since its inception, the WRN has sought to:

- help clients, private and public institutions gain the greatest possible understanding of risks, so that insurers and reinsurers can deliver effective financial protection at optimum terms
- strengthen the link between industry and academia
- confront the challenges of managing risk and delivering resilience within environmental systems, financial markets and public policy
- use global multi-disciplinary resources for focused research of key issues

Disciplines include climate and weather, hydrology, seismology, volcanology, economics, terrorism, casualty analytics and emerging risks. WRN research concentrates on risk management, and sharing of the costs of natural and man-made hazards with emphasis on the built environment, infrastructure, supply chain risk, contingent exposure, credit risk, cost of capital and the future of the insurance market.

The WRN's research program has been developed to focus the internationally renowned expertise within the academic and Willis Towers Watson teams onto the issues of greatest relevance to our clients.

Research

We continue to build on the strength of the WRN, with its ability to:

- develop multidisciplinary, global and collaborative research programs with specific and applied products
- deliver long term strategic tools for Willis Towers Watson and our clients
- leverage expert input on key business issues and demonstrate thought leadership
- fill in the gaps in vendor model provision, and impartially evaluate changes to existing models
- assist the research behind hundreds of peer-reviewed academic articles including many groundbreaking papers
- incorporate solutions into insurance sector models, methodologies and transactions to improve the market's understanding, resilience and coverage of risk

Alongside the longer term research program, we continue to identify projects with tangible outputs for our clients within shorter frame deliverables, allowing us to deliver solutions when they are needed.

How it works

The WRN allows us to foster longer term relationships with universities and partners. Value is being derived from the relationship as partners strengthen their understanding of our business. This enables us to build practical applications for the benefits of Willis Towers Watson and our clients.

Through these relationships, we are able to support clear structure around research requirements and a proven mechanism for delivering research into our business for our clients. Within Willis Towers Watson, specialist resources are dedicated to managing relationships and helping to shape the work being done.

Research pillars

In 2010, the Willis Research Network's activities were organized across four WRN Research Pillars: Economic Capital and Enterprise Risk Management; Natural Hazard and Risk; Man-made and Liability Risks; and Core Technologies and Methods. Collectively these Pillars encompass a comprehensive range of insurance analytics disciplines.

Within these Pillars, WRN Research Hubs drive Research Programs covering major areas such as Flood, Earthquake, Climate, Terrorism, Cyber, Financial Stability and Regulation and High Performance Computation.

The Research Programs drive WRN Research Projects producing the academic and industrial research outputs. Outputs include data, models and applications, peer-reviewed journal articles, financial instruments and products or meetings and conferences.

Members

WRN members are selected for their unique contribution to understanding risk for our industry. Willis Towers Watson sponsors postdoctoral research fellows, Ph.D. students, and professors at WRN member institutions and funds insurance-specific research topics. Research themes and projects are defined through close collaboration with the leading insurance partners and clients. Research results are fully peer-reviewed within the wider expert community and freely published.

The WRN maintains close links with national science foundations, government and non-governmental organizations, including the World Bank, OECD, World Meteorological Organization, the United States Geological Survey, National Science Foundation and the United Nations among others.

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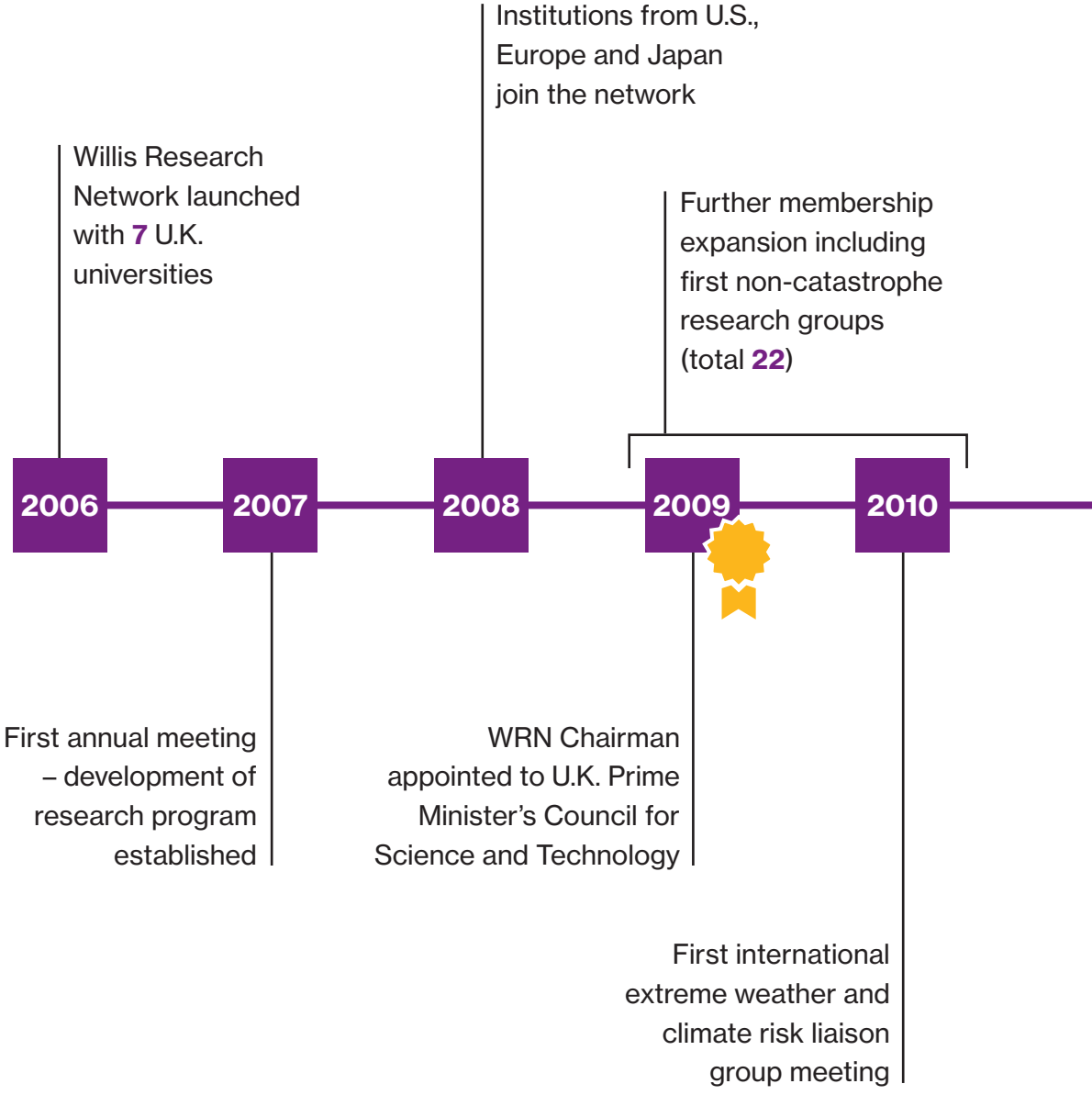
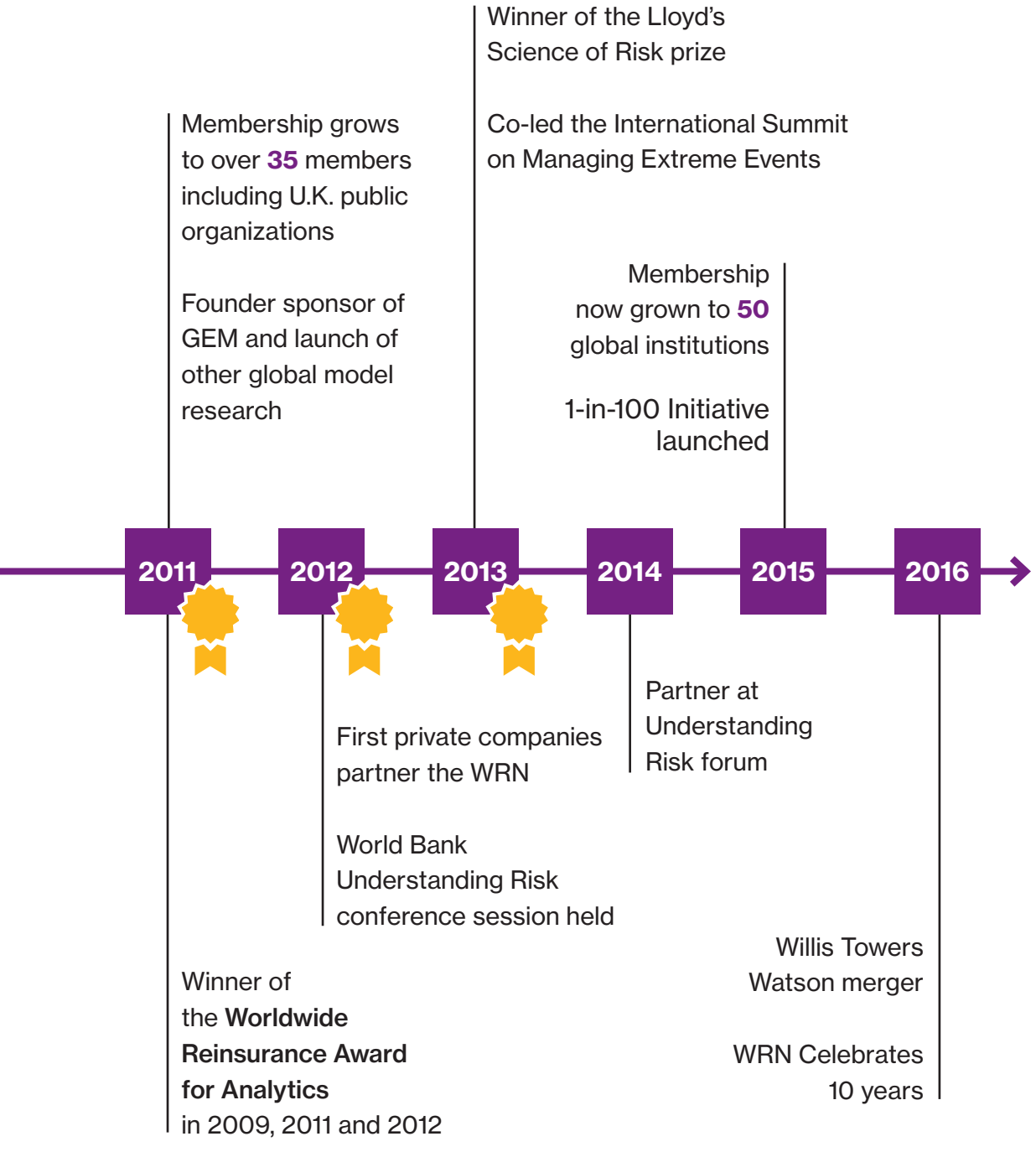
Our history


Institutions from U.S., Europe and Japan join the network
Willis Research Network launched with 7 U.K. universities
Further membership expansion including first non-catastrophe research groups (total 22)
2006
2007
2008
2009
2010
First annual meeting – development of research program established
WRN Chairman appointed to U.K. Prime Minister's Council for Science and Technology
First international extreme weather and climate risk liaison group meeting


Winner of the Lloyd's Science of Risk prize
Co-led the International Summit on Managing Extreme Events
Membership grows to over 35 members including U.K. public organizations
Founder sponsor of GEM and launch of other global model research
Membership now grown to 50 global institutions
1-in-100 Initiative launched
2011
2012
2013
2014
2015
2016
Partner at Understanding Risk forum
First private companies partner the WRN
World Bank Understanding Risk conference session held
Willis Towers Watson merger
WRN Celebrates 10 years
Winner of the Worldwide Reinsurance Award for Analytics in 2009, 2011 and 2012

Flagship projects

Cyclone damage potential

Tropical cyclone intensity measures

When a tropical cyclone hits the coastline, known as making landfall, it brings a number of different impacts. The most immediate is the high winds. When hurricane force winds hit a built-up area they can cause widespread devastation during the passage of a storm. For this reason the most widely used measure of a tropical cyclone's intensity is maximum sustained wind speed, as this provides a quick and easy to understand indication of the potential impacts that will be felt as the storm passes.

However, other factors affect the amount of damage that is caused by a tropical cyclone, for example, the size of a storm will have an influence on the amount of damage, as well as the forward motion of the whole storm itself, which tells us about the duration of the storm.

As the wind blows?

Research to develop a deeper relationship between a variety of storm characteristics and damage has been developed through a collaboration between the National Center for Atmospheric Research (NCAR) and the Wharton Risk Management and Decision Process Center. The research applies a mix of empirical assessment and physical reasoning to develop an index to better represent the damage potential through the creation of an index.

A key step was to compare the Hurricanes Dennis and Ivan, both of which made landfall in a similar area, and both reached similar maximum sustained wind speeds, meaning that traditional intensity classification would consider them to be comparable. However, the damage caused by these storms was very different due to their different wind footprints and durations. By contrasting these storms and using damage estimates, the Cyclone Damage Potential (CDP) index was tuned and calibrated for other storms.

Using the CDP for predictions

One of the main uses for the CDP is to compare new tropical cyclones to past events with similar CDP index scores. While this becomes a more widely accepted tool for comparing and assessing storms in a live or historical context, it has also been developed to be applied to seasonal forecasts and global climate model simulations to help us understand longer range projections of climate variability and change. In this mode, the CDP uses relative sea surface temperature and steering flow (the winds aloft that guide a storm's motion) to overcome the need to describe individual storms on the longer time scale.

Initial studies highlight a potential reduction in landfalling storms in the future, but the variation in this potential reduction is largely dominated by climate variability rather than longer term change. This highlights the need to better understand future spatial changes in seas surface temperatures to understand changes in tropical cyclone damage potential.

National Center for Atmospheric Research

Senior Academic Dr. Greg Holland and current Willis Research Fellow Dr. James Done at NCAR have been working with the WRN for many years, helping us improve our understanding of tropical cyclone impacts through their multi-sectoral research and variety of partnerships.

Wharton Risk Management and Decision Processes Center

Willis Research Fellow Dr. Jeffrey Czajkowski at Wharton, under the supervision of Professor Howard Kunreuther and Dr. Erwann Michel-Kerjan, has focused largely on an analysis of tropical cyclone related inland flooding through analysis of the National Flood Insurance Program, but he also keenly collaborated with other fellows, past and present, working on related themes.

Flagship projects

European windstorm clustering

Early clustering research

An idea developed between the University of Exeter and teams of experts at Willis Re resulted in the publication of a paper in 2009 called "Serial Clustering of Intense European Storms" (Vitolo *et al.* 2009)[1]. This paper investigated how storms cluster together, i.e., whether intense storms tend to occur in quick succession or are they more spread out, and what the drivers of such clusters might be. It found that clustering increases significantly with intense storms on the North Atlantic storms track affecting Europe. So when they are severe, they also tend to gang-up.

Changing the industry

Robust research and innovative application of this intelligence into underwriting practices had a major impact on the industry. It changed how insurers and reinsurers were able to quantify their aggregate risk over the whole year. By statistically representing the nature by which severe storms in Europe cluster in time and space, exposure and portfolio managers have improved their understanding of the average annual losses, and are able to better meet solvency requirements.

Before this research, the reinsurance industry was likely to have been exposed to a quick succession of severe storms, previously handled through assuming that the storms occurred randomly. The WRN was able to bring this new research into the industry to address these concerns, and add value to the guidance available through catastrophe modeling services used by the industry at the time. By adjusting catastrophe model outputs and performing stress tests based on these findings of the WRN research, Willis Re was able to present clients with a range of insurance options to improve their risk management strategies.

1 Reference: Vitolo, R., Stephenson, D.B., Cook, I.M. and Mitchell-Wallace, K., 2009. Serial clustering of intense European storms. Meteorologische Zeitschrift, 18(4), pp.411-424.

Future of research

Using the findings and experience from the previous applications of this research, the WRN is currently looking into using the statistical characteristics of severe storm clusters with long range seasonal forecasts. It is hoped that forecasts of climate indices, such as the North Atlantic Oscillation, will allow the industry to develop risk management strategies based on the expectation of enhanced or reduced storminess in any given storm season.

University of Exeter

A WRN research partnership spanning the last ten years has been one of the most successful programs of work for the WRN. Professor David Stephenson has conducted and supervised a number of research fellows including Dr. Renato Vitolo, Dr. Ben Youngman and Dr. Alastair Hunter during the collaboration, producing a number of well-cited papers, while consistently staying close to catastrophe modeling teams in Willis Re, to help and advise with applications and development of practical tools.

UNIVERSITY OF EXETER

Flagship projects

European hail model

Filling a peril gap

The first version of the Willis Re European Hail Model was developed in 2013 with hazard coverage of 34 countries including central and southeast Europe. Hail risk assessment for property, motor and agricultural portfolios was thus made available for many emerging economies for the first time, as well for established hail risk regions such as Germany, Italy, Austria, Switzerland and France. Subsequent model enhancements have increased event set sizes to greater than a million events which allows greater spatial and temporal resolution.

First fully probabilistic hail model

Through a project instigated with the Karslruhe Institute of Technology (KIT) in Germany, in collaboration with the University of Exeter's statistical expertise, the WRN developed a new method to identify and characterise extreme hail events. The approach involved using a satellite data processing algorithm, developed with NASA, to measure overshooting cloud top (OT) temperatures. OTs are found at the very tops of thunderstorms, where strong updrafts create a bulge of cloud on top of the flat anvil-shaped head of a cumulonimbus cloud (the meteorological name for a thunderstorm). OT filtering, using a range of atmospheric parameters, extracted storm events with strongest hailstorm potential.

This method was then used to construct a consistent catalogue of historical event footprints, which are then resampled to produce a stochastic set of extreme events for 2,500 years to input into a catastrophe model loss calculation framework.

Further hail model development

Building on the success of the Willis Re European Hail model, the research partnership is planning to reapply the technique used to build stochastic event sets in other hail-prone regions of the world. Due to the ubiquity of satellite data, the algorithms used to identify overshooting cloud tops, with a little calibration, can be applied to varying climatological regimes, such as South Africa, Australia and Argentina. This allows the WRN collaboration with KIT to further fill gaps in understanding of hail risk.

Karlsruhe Institute of Technology

Working with experts at the leading European hail risk research institution, Willis Research Fellow Dr. Heinz Jürgen Punge has been liaising with the Analytics and Model Development team in London and regional offices on identifying key applied aspects of hazard quantification.

Flagship projects

Extreme rainfall

Extreme flooding and clustering

The spatial and temporal dependence and clustering of windstorms has been explored extensively in recent years and significantly altered the construction of vendor catastrophe models and reinsurance programs across Europe. Similar research related to flooding, both for extreme rainfall and river flows, is in comparative infancy. Nevertheless, preliminary studies suggest that floods cluster in time. In addition, there is considerable debate in the reinsurance industry regarding the likelihood of coincident large flood events occurring in major river basins across Europe. This is of particular interest for large regional underwriters where correlations across multiple territories can significantly impact losses and reinsurance pricing.

Flood clustering

Flood damage is one the biggest drivers of loss in Europe. Many of the most highly exposed regions are along the banks of rivers and many countries continue to develop properties in flood plains which are therefore vulnerable to riverine flooding. Some of the worst flood events happen when rain events occur in quick succession, such that the rainfall from first one saturates the ground, and then the second simply adds rainwater that cannot be absorbed, leading to bursting river banks and breached defences. Other severe flooding happens when two rainfall events occur at different parts of the same river catchment and combine forces downstream to create high discharge rates and widespread fluvial flooding.

A two-year portfolio of work with Newcastle University looks at the spatial dependence of extreme events over the major European river basins to determine “physical limits” of rainfall extremes. It will look at the clustering of storms in time and space, with specific focus on Malaysia supporting a number of region-specific capabilities that Willis Re offers. A third deliverable will provide guidance on short term “seasonal” forecasting of rainfall and/or river flows and validation of that forecasting using hindcasting methods.

Wills Re European flood capabilities

This work, and advice from our Newcastle colleagues, feeds into the development of client advice based on internal catastrophe modelling activities. Development of the Willis Re Central and Eastern European flood model has been a key application of the research from the WRN in to Willis Re catastrophe modeling capability in recent years, and has helped improve the Willis Re view of risk.

Newcastle University

Professor Chris Kilsby and current Willis Research Fellow Dr. Francesco Serinaldi at Newcastle University have significant expertise in the physical mechanisms and statistical analysis of extreme rainfall and river flooding. In addition, Dr. Serinaldi's research is world leading in terms of the development of methods to understand the spatial dependence and clustering of extreme processes in hydrology.

Newcastle University

Flagship projects

Volcanic hazards

Volcanic hazard and risk

Volcanic risk has often been overlooked within the insurance industry, and is not covered by any of the major catastrophe model vendors. At least 1,500 active volcanoes have been identified across the world, but only 35% are continuously monitored. Volcanoes are capable of generating multiple and distinct physical hazards, such as ashfall, lava flows, pyroclastic flows, tsunamis or earthquakes. Hence, we need a better quantitative understanding of how volcanic hazard increases the risk in technologically dependent societies.

Global Volcano Model

The WRN is a partner of the Global Volcano Model (GVM), a growing international network that aims to create a sustainable, accessible information platform on volcanic hazard and risk. It aims to provide systematic evidence, data and analysis of volcanic hazards and risk on global and regional scales. The project will develop an integrated global database system on volcanic hazards, vulnerability and exposure, make this globally accessible and crucially involve the international volcanological community and users in a partnership to design, develop, analyze and maintain the database system.

Identifying volcanoes with high hazard and economic exposure

The WRN in collaboration with the GVM group has identified volcanoes that are most likely to cause economic losses, by combining measures of volcanic hazard, population and economic exposure to indicate for which volcanoes highest economic threat may lie.

Volcanic ash scenarios

Volcanic ash scenario footprints have been developed for three volcanoes chosen for the risk they pose to major cities. These are: Mount Fuji in Japan, with ashfall affecting Tokyo; Krakatau in Indonesia, with ashfall affecting Jakarta; and Taranaki/Egmont in New Zealand, with ashfall affecting Auckland.

Contours of ash thickness are generated with the capability to filter client exposure by areas affected by different ash thicknesses. From this, by using published volcanic ash damage ratios, we can estimate losses from property damage.

Bristol University

Professor Steve Sparks, a current WRN research fellow, is a volcanologist at the University of Bristol and joint leader of the Global Volcano Model (GVM). With expertise in many aspects of volcanology, he is the most highly cited scientist in this field. In addition, Susana Jenkins also has significant expertise in the assessment of hazards and risks associated with explosive volcanism and has been a collaborator of the GVM.

University of BRISTOL

Flagship projects

Physical flood modelling

The growth of flood modelling

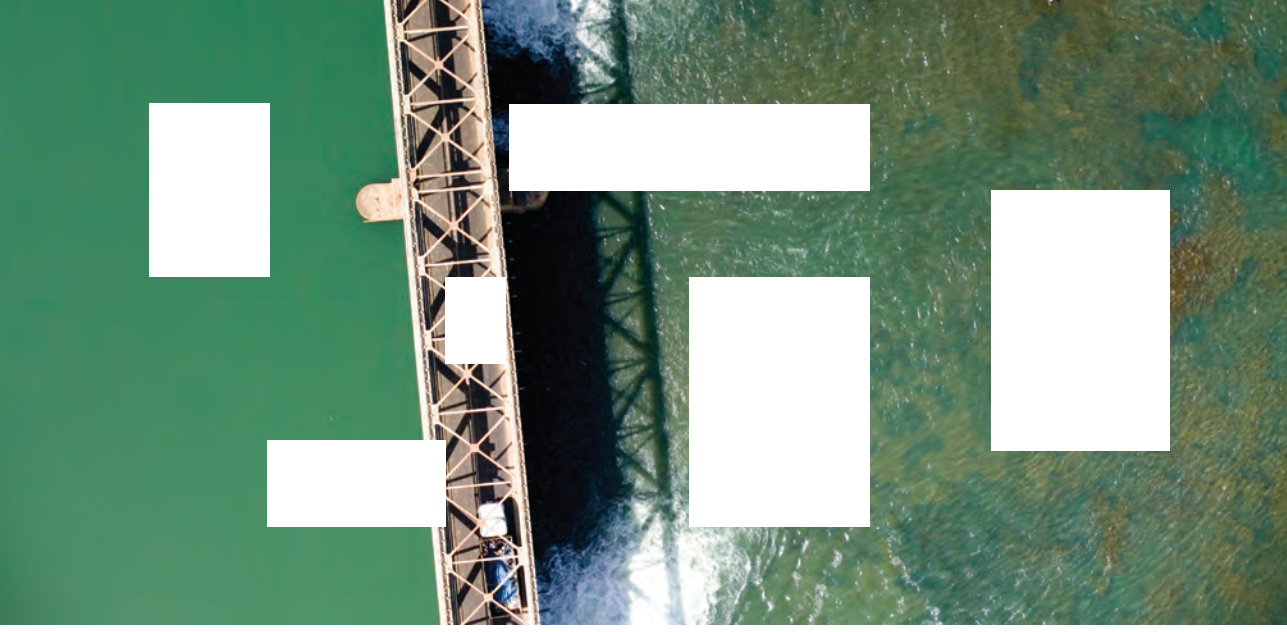
The development of flood risk catastrophe models has increased in recent years. The summer floods of 2007 in the U.K. cost the insurance industry around £3.5 billion, while insured losses from the devastating Thailand floods in 2011 have been estimated to be around U.S. $15 billion. These two examples highlight the need for accurate and confident flood risk assessment. Willis Re has been on the leading edge of developing new flood models for insured regions, supported by WRN science.

One of the WRN's earliest partnerships was with the University of Bristol. Over nine years, many projects were developed through WRN collaborations with University of Bristol academics. One such example is a project to develop a new approach to surface flood water modelling.

A new generation of flood models

This WRN collaboration produced a scientific paper published in the Journal of Hydrology, which focused on the development of a blueprint for the next generation of flood modeling, while at the same time, keeping sight on practical application in the existing industrial processes. The published paper ended up in the public domain but by developing the work through the WRN, Willis Re was able to get the head start on building flood models based on the research in the paper.

This research represented an opportunity to jump ahead of the field in the way that floods are modeled in insurance. By reproducing the research and applying the LISFLOOD-FP model, teams at Willis Re made a step–change in their flood modeling capabilities and put themselves in a position to offer industry leading flood risk-assessment models.



Award winning publication

The paper, “A simple inertial formulation of the shallow water equations for efficient two-dimensional inundation modelling” was recognized by the prestigious Lloyd’s Science of Risk prize in the category for natural hazards in 2012. This award started by Lloyd’s in 2010, and was designed to stimulate the interaction between science and industry.

The lead author of the paper, Professor Paul Bates, worked on the team including Dr. Tim Fewtrell, Chief Hydrologist at Willis Re, and together they developed the new approach to flood inundation modeling that enabled the industry to take advantage of cutting edge science by implementing practical applications. Having collaborated on the work in house, the WRN was able to support development of leading, physically-based flood risk assessments which can feed into client services and advice.

University of Bristol

One of the first WRN partners, the University of Bristol, has been a hub of flood-related research projects for Willis Towers Watson. Professor Paul Bates and Dr. Mark Trigg have conducted most of the research into new methods for physical flood modeling, as well as global flood modeling approaches.

University of BRISTOL

Flagship projects

Earthquake worst case scenarios

Realistic earthquake scenarios

OpenQuake, an open, community-driven tool for seismic hazard and risk analysis, was used to simulate various earthquake realistic scenarios. Uses Ground Motion Prediction Equations (GMPEs) specific for each tectonic region. This enabled to evaluate extreme catastrophe losses from specific client requests, following various approaches:

- **Point source modeling:** Generally employed when source-to-site distance is very large and size of the fault can be ignored (or in other words can be assumed as a point)
- **Finite fault (source) modeling:** When size of fault is significant as compare to source-to-site. Method employed for this study.

Largest record earthquake to affect Hong Kong was the Nanao 1918 earthquake (Mw7.4) which was recorded to be MMI VI-VII.

Hong Kong realistic earthquake scenarios

Hong Kong is located in a region of low-moderate seismicity and does not experience frequent, large magnitude earthquakes. The city experiences ~2 events per year on average of MMI values of III or IV (weak to light perceived shaking intensity.[1, 2]

Largest record earthquake to affect Hong Kong was the Nanao 1918 earthquake (Mw7.4) which was recorded to be MMI VI-VII. Here, a basic simulation of this event indicates MMI III to VI.[3]

Coastal regions experience more seismicity, but could be higher to match historic view if a different local Soil Vs30 data is used or more complex fault rupture model is employed.

Global Earthquake Model

The OpenQuake engine is open, and community-driven tool for seismic hazard and risk analysis. We are working with experts at GEM for testing purposes and to help with the OpenQuake platform development.

GEM
GLOBAL EARTHQUAKE MODEL
working together to assess risk

1 ISC-GEM Catalogue (http://www.isc.ac.uk/iscgem/)

2 Mok, H.Y., et al., (2004) 'Earthquake monitoring and probabilistic seismic hazard assessment of Hong Kong', reprint 1175

3 Megawati, K., et al., (2004) 'Simulation of distant earthquakes affecting Hong Kong' 3rd International Conference on Continental Earthquakes, China, reprint 645

Flagship projects

Japanese tsunami

Secondary perils

Catastrophic tsunami losses have traditionally not been well understood within the insurance market. Recent tsunamis and other non-modeled components of earthquakes have all emphasized the need to understand and quantify the risks from such secondary perils.

Willis Re Japan Tsunami model

Developed with Tohoku University, the Willis Re Japan Tsunami Model enables clients of Willis Re to quantify and manage the risks from these extreme events. The model combines the shaking damage output from third party vendor models with tsunami losses developed using the natural catastrophe modeling expertise and insurance market knowledge of Willis Re and the Willis Research Network. In particular, the Willis Re Japan Tsunami Model:

- is a probabilistic and deterministic model of the country
- quantifies tsunami (and combined shaking and tsunami) losses from a catalogue of tsunamigenic earthquake sources
- uses custom vulnerability functions developed in conjunction with WRN partner UCL EPICentre, and an in house expert view of exposure data unique to Willis Re
- is integrated into the eQUIP™ proprietary catastrophe modelling platform

Our aim with the Willis Re Japan Tsunami Model is to:

- uniquely quantify the risk from catastrophic tsunamis affecting Japan
- design reinsurance to mitigate natural catastrophe losses due to tsunami in Japan
- contribute to discussions on natural catastrophe risk with reinsurers and rating agencies with Willis Re expertise
- provide inputs to the Willis Re proprietary financial analysis

Tohoku University

Tohoku University founded the International Research Institute of Disaster Science (IRIDeS) after having experienced the catastrophic disaster in 2011. The IRIDeS conducts world-leading research on natural disaster science and disaster mitigation, and aims to become a world centre for the study of the disasters and disaster mitigation.

UCL EPICentre

UCL EPICentre was founded in 2007 and is a dynamic multidisciplinary research group that investigates risk to society and infrastructure from earthquakes and other natural hazards.

Flagship projects

Quantification of risk

The view at the top

Can we ever truly know whether a company is genuinely committed to risk management? Where should that commitment be positioned in an organization? Are there objective, observable criteria to assess the risk management capabilities of an institution?

Organizations are challenged by these questions and seeking an effective reply. Risk management should be a big concern for organizations but we have seen examples of failed management for example in case of U.K. bank HBOS before the financial crises. The financial crisis that brought the countrys' largest banks to the brink of disaster illustrates perfectly what happens when an organization's risk management practices breakdown. The risks facing companies are becoming more complex, interconnected and challenging. But has risk management as a fundamental operational practice evolved accordingly, and who should take responsibility for risk within an organization?

History repeating

Corporates appear to display similar patterns of behavior in the period leading up to their crises so are there trends we can identify to help foretell failure? Recent work commissioned by the Willis Research Network and undertaken at Imperial College Business School helps provide answers to many of those questions. Through quantitative and qualitative research, the risk appetite of financial institutions was assessed, with qualitative measures used to indicate the degree to which the concept of risk appetite had been absorbed into the culture and practice of each institution.

The study showed that financial institutions have made strong progress towards developing a risk appetite framework, however they are still working to embed an effective and well-articulated risk appetite concept from the top and down through their organizations. The main outcome of this research project was an index called Risk Appetite Maturity Index. This allows an assessment of the firm's risk appetite maturity level and highlights strengths and weaknesses which can help to fill existing gaps and improve risk appetite by giving a prioritized list of areas requiring attention. Questions can also be asked about the drivers of this progress, with external events and regulation still acting as key triggers rather than strategic risk management decisions at the top of an organization. Further studies will no doubt help provide a better understanding of best practice risk appetite and the views of the risk management function within a firm.

Risk appetite is a concept of wide application. Studies such as this will help our understanding of the correlation between the elevation of risk management within the organizations' executive culture and the organizations' relative success in mitigating, managing and quantifying risk, not only at the very top but throughout core business areas.

Imperial College Business School

The Imperial College Business School combines innovative thinking and insight with new technology to develop practical solutions to real world issues, benefiting business and improving society.

Imperial College Business School

Flagship projects

Applying seasonal forecasts

Long range forecasts

Everyday weather forecasts are useful for assessing risks and likely losses during live events or providing quick advice on the impact of events as they happen, or a week or so ahead. However, for year-long insurance and reinsurance contracts, they are less useful. In recent years, the science of long range seasonal to decadal forecasts have seen huge progress, and the WRN has been helping to develop and examining options for the application of seasonal forecast information.

These long range forecasts rely on the use of information available through such climate indices as the El Niño-Southern Oscillation (ENSO) or the North Atlantic Oscillation (NAO), which heavily influence seasonal predictability. The predictability utilized by seasonal forecasts is derived from the longer term variations in the atmosphere and oceans, and the fact that our climate is inextricably linked to changes and variations in the oceans. The oceans hold on to heat for much longer than the atmosphere does, so areas of anomalously warm or cool sea surface temperatures can give us clues about what types of weather we might expect in the coming months.

How are seasonal forecasts useful?

The Willis Research Network has worked with a number of leading research organizations to investigate what we can predict months, seasons or even years ahead. Organizations such as the Geophysical Fluid Dynamics Laboratory (GFDL) and the U.K. Met Office are on the cutting-edge of high resolution climate modeling, and are able to represent the broad variations in the atmosphere such as the ENSO and the NAO, both of which drive changes in the likelihood of severe storms in different parts of the world.

This can have an influence on, for example, how we might think about our aggregate risk in terms of average annual loss, or perhaps provide a reason to offer reinstatements due to a higher likelihood of more losses.

Application of climate indices

Building on many years of fundamental research through multiple WRN partners, Willis Re has developed a methodology to use climate indices, such as ENSO, to condition and adjust the outputs from catastrophe modeling companies. The assumption that tropical cyclones occur randomly is commonly used within the reinsurance industry, but climate science can help us build greater ability to take into account the predictable variations in the climate, therefore increase financial resilience of our clients.

Due to the strong relationships in the scientific community, consistent research and internal efforts, the Willis Re Catastrophe Analytics team and the WRN are able to leverage incrementally improving predictability to implement new science. Our Willis Re teams also work with our WRN partners at the National Center for Atmospheric Research (NCAR) to provide summaries of global climate forecasts of the coming season, with specific regular reports focused on tropical cyclones.

Future GCM capabilities

The WRN has funded multiple projects geared towards the development of high resolution General Circulation Models (GCMs) and the proper assessment and application of their outputs for the insurance industry. These projects have supported the fundamental science that goes into developing long range forecasting skill and helps Willis Towers Watson stay on the forefront of applying climate science to the insurance business.

Partners involved

National Center for Atmospheric Research (NCAR)
Senior Academic Dr. Greg Holland and current Willis Research Fellow Dr. James Done at NCAR have been working with the WRN for many years, helping us improve our understanding of tropical cyclone impacts through their multi-sectoral research and variety of partnerships.

Geophysical Fluid Dynamics Laboratory (GFDL)
Past WRN members Dr. Gabriel Vecchi and Dr. Tom Knutson, have collaborated on a number of research interests, with their expertise in climate variability and change, especially when considering extreme events. They are leaders in long range predictions in seasonal hurricane activity.

Met Office
The WRN have sponsored research with the Met Office Hadley Centre's Seasonal to Decadal Forecasting team, in long range predictions of climate, with a view to better manage the risks on increased storminess months in advance.

Flagship projects

Severe convective storms in the U.S.

Recognizing extreme hail in radar data

One of the most useful tools in a weather forecaster's bag of tricks is the weather radar. Through examining patterns in the rainfall and analyzing information about droplet size and phase state (frozen or liquid) we can determine whether we have heavy rain, drizzle, hail or snow, and plan accordingly. The WRN has been working with experts at the University of Oklahoma to support their work in developing algorithms to recognize and characterize extreme hail, wind and tornado events derived from convective storms. This effort uses OU's leading expertise in application of the data from the network of NEXRAD (Next Generation Radar) installations around the U.S.

Insurance industry event response

The Willis Re Catastrophe Analytics team in North America receives real-time delivery of the outputs from running the hail identification algorithms on the live radar data. This provides information on location, shape and intensity of severe convective events, as well as the type of peril occurring, for example, large damaging hail or tornados, to our catastrophe analysts who make it available to Willis Towers Watson clients to overlay with their portfolio of assets. This is useful in a multitude of ways for many clients.

One of the main users is the farming industry, which can lose broad areas of crops to hail stones smaller than those that would damage cars and buildings. By receiving an accurate representation of a hail swath, or footprint, left behind by a severe event, we are able to advise our clients on proactive measures that they can take to reduce losses, and also help them respond to any losses that they do incur by increasing the accuracy of the information needed to meet logistical requirements for claims handling.

Climatological hail study

On top of the supply of latest radar-derived information on hail, wind and tornado events as they happen, our WRN fellows at the University of Oklahoma are working to develop a reliable climatology of past hail events, by applying their skill in identifying severe convection to the reanalysis data set known as MYRORSS (Multi-Year Reanalysis Of Remotely-Sensed Storms).

The reanalysis data is being used to develop a historical record to stretch back over a decade, which can provide information about the spatial distribution of severe hail at a significantly higher resolution than is currently available from the National Climate Data Center.

The University of Oklahoma

Willis Research Fellow Dr. Travis Smith is a research meteorologist for the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) at the University of Oklahoma.

The UNIVERSITY of OKLAHOMA

Flagship projects

TRIA reauthorization

U.S. terrorism reinsurance

The terrorist attacks of September 2001 shocked the world. The scope of these attacks and resulting U.S. $40 billion estimated losses changed the nature of Insurance for terrorist events. Uncomfortable with being able to accurately model or price exposures, terrorism insurance quickly became either unavailable or unaffordable in the insurance market.

As a consequence, the Terrorism Risk Insurance Act (TRIA) was initially enacted by U.S. Congress to stabilize the U.S. insurance market and to make available terrorism coverage to consumers. TRIA provides a backstop to insurers who, in return, must offer terrorism insurance for Property and Casualty lines. TRIA was first reauthorized in 2005 and again in 2007, and further debate ensued in 2014 to help inform decisions on a further renewal. At that time there was evidence that the availability of terrorism insurance has increased and the price has fallen. However, challenges remained from both a social and an insurance point of view. An estimated 40 percent of policyholders still did not purchase terrorism coverage and private insurers and reinsurers continued to have little appetite for terrorism risk. What is more, with the program set to expire on December 31, 2014, it was unclear whether the improvements that have been observed since TRIA was first passed in 2002 would be sustained without TRIA.

TRIA Reauthorization

To help inform the 2014 debate on whether TRIA should be continued or allowed to expire, the Willis Research Network sponsored policy briefs from the RAND Corporation on three topics that are of central concern to policymakers:

- the full benefits and costs of TRIA to taxpayers
- the national security implications of TRIA
- the impact of TRIA on the Workers' Compensation market

On January 7, 2015 the House of Representatives voted 416-5 to approve the Terrorism Risk Insurance Program Reauthorization Act of 2015, extending TRIA through the year 2020 and continuing to provide protection to the insurance industry.

Global implications

Terrorism remains a persistent threat. Recent events across the globe also illustrate the changing nature of that threat. The evolving face of terrorism means that business risks are becoming more diverse and the increasingly interconnected nature of global business means that incidents can have global consequences.

For most companies, the continued availability of sufficient Terrorism insurance remains a significant issue.

The re/insurance industry has become increasingly comfortable designing products that allow better coverage of terrorism risk. The continued and strengthening links between academia and the insurance industry remain crucial in supporting that knowledge

RAND Corporation

The RAND Corporation is a non-profit institution that helps improve policy and decision-making through research and analysis. The RAND Center for Catastrophic Risk Management and Compensation is a world leader in research on terrorism, counterterrorism, counterinsurgency, disaster management, and homeland security – topics that affect a wide variety of policy areas and challenge individuals and nations worldwide. RAND's mission is both simple and incredibly complex: We exist to help policymakers make decisions that are based on the best available information.

Flagship projects

Middle East earthquake model

State-of-the-art hazard modeling for current needs

Willis Re's latest development, the Willis Re Middle East Earthquake Model, allows Willis Re to provide its clients with a seismic hazard model that has complete coverage for the Middle East region.

High-resolution exposure

The underlying resolution of the model varies based on the land use detected through a state-of-the-art methodology, incorporating a number of available sources, ranging from satellite imagery to open source information.

In addition, a significant effort has been oriented towards the identification of industrial sites, crucial for accurate risk assessment throughout the region. Through Willis Re's analysis, it was able to identify and delineate more than 2500 industrial sites to add to available land use data. Main urban areas are represented with the most granular grid, calculating the intensity of earthquakes on a 1 km resolution.

Financial module novelties

The Willis Re Middle East Earthquake Model makes use of the new proprietary high-definition (HD) modeling platform, enabling the implementation of secondary uncertainty. The modelling platform also allows for explicit consideration of limits and deductibles, various policy conditions and reinsurance structures predominant in the Middle Eastern region.

Global Earthquake Model

The OpenQuake engine is an open, and community-driven tool for seismic hazard and risk analysis. We are working with experts at GEM for testing purposes and to help with the OpenQuake platform development.

GEM
GLOBAL EARTHQUAKE MODEL
working together to assess risk

Flagship projects

Windstorm footprints

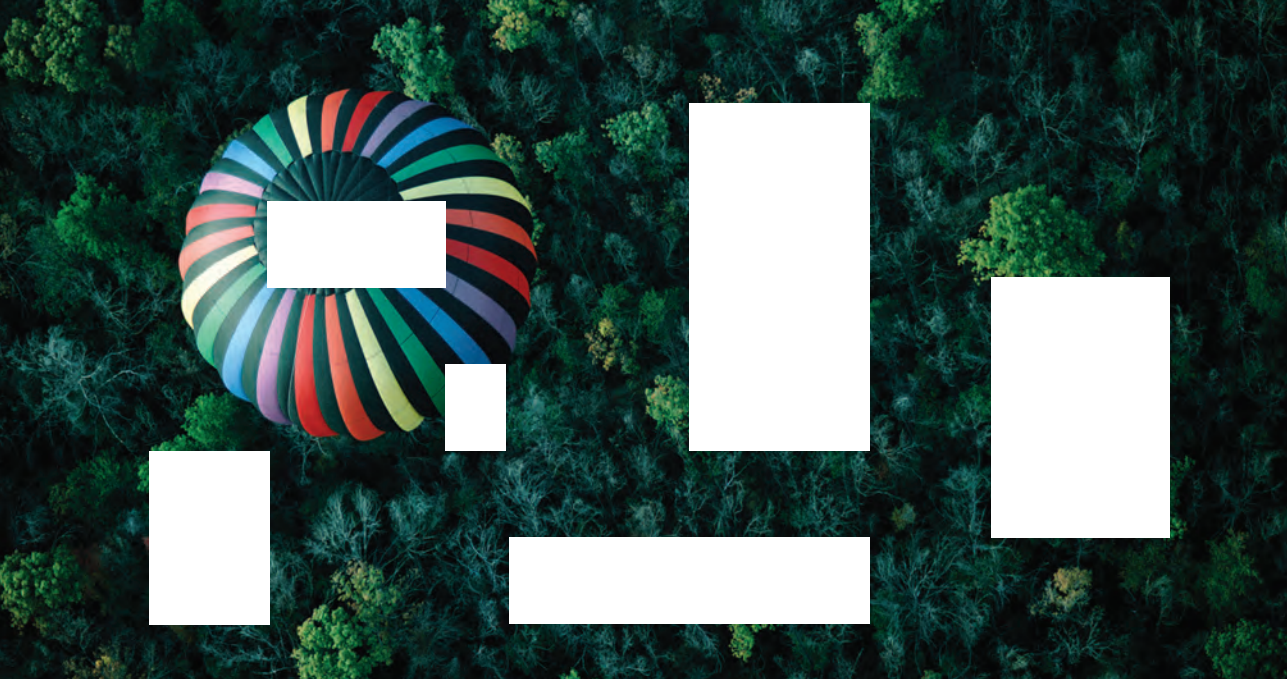
Improving current datasets

One of the key tools in catastrophe modeling for severe windstorms is the windstorm footprint. The most common type is the "'maximum wind" footprint which represents the strongest wind experienced at each location on a regular grid during the passage of a storm. This can then be overlaid on to a portfolio of exposures to examine the losses associated with a single storm, or combined with a historical set of footprints to asses return periods of different storm impacts.

However, creating a regular grid of wind speed estimations from an irregular network of wind observations sourced from National Meteorological Services around the world is not always straightforward. Biases are introduced, and extremes can be lost when interpolating between grid points, due to smoothing algorithms used to fill gaps. Weather models provide a different approach as they represent the physics of the atmosphere to capture the actual dynamics within a storm, and are also used to "reanalyze" historical observations to create these footprints. However, these physics-based dynamical models are not perfect either, and they too are currently unable to represent enough detail to usefully represent the extreme winds that are important to the insurance industry for assessing damage. This means that both statistical and dynamical approaches to building windstorm footprints can benefit from the process of recalibration, otherwise known as bias correction.

Improving current datasets

Dr. Ben Youngman has been working with Willis Towers Watson colleagues to develop ways to apply recalibration techniques to produce footprints that more accurately represent past storms. His technique uses extreme value theory and geostatistics, to give a fast and efficient simulation of event footprints. These types of techniques can use general information about the landscape such as topography, or the shape and scale of the "tails" of the distributions of historically observed measurements of wind speeds, to predict how extremes would look given more readily available surrounding information. A thin-plate spline is fitted to match to the spread of real world observations, and provides values for the areas in between the real data to produce the footprint.



Industry-ready datasets

In 2012, a collaboration between the University of Exeter, and past WRN partners the University of Reading and the U.K. Met Office, produced a set of historical footprints to represent some of the biggest and most damaging storms to have hit Europe since 1979, in the form of the Extreme Wind Storms catalogue (XWS). A key part of this project is the recalibration technique applied by Dr. Ben Youngman, which reduces the biases and gives a more realistic representation of extreme winds. It is hoped that more recent work will build on the techniques applied to the XWS, and give Willis Towers Watson an new tool to help the industry understand losses from European winter storms. The recalibration techniques can also be applied to storms globally. Collaborations with the National Center for Atmospheric Research (NCAR) in the U.S., are also proving useful in improving the quality of tropical cyclone footprints.

University of Exeter

A WRN research partnership spanning the last ten years has been one of the most successful programs of work for the WRN. Professor David Stephenson has conducted and supervised a number of research fellows including Dr. Renato Vitolo, Dr. Ben Youngman and Dr. Alastair Hunter during the collaboration, producing a number of well-cited papers, while consistently staying close to Willis Towers Watson catastrophe modeling teams in Willis Re to help and advice with applications and development of real tools.

UNIVERSITY OF EXETER

Flagship projects

Casualty catastrophe analytics

Understanding casualty catastrophes

Despite the financial importance of casualty catastrophes, which represent two of the three most costly insurance events between 1970 and 2011 according to a Willis Towers Watson report (Ball, Jing and Cohen, 2013[1]), there are relatively few articles on this topic in peer-reviewed journals. Research and modeling of catastrophic risk has focused on property coverage and neglected casualty.

Of the research on casualty catastrophes that has been published, most articles address asbestos and environmental liability losses, with a focus on analyzing past losses. Few articles address modeling or assessing potential future casualty catastrophes. One reason for this lag is that casualty catastrophes develop slowly as opposed to property catastrophes that occur suddenly, so that the impact, both financial and psychological, has less of a shock element, despite the eventual financial implications.

That being said, a number of studies have been carried out. This work set out to review literature on casualty catastrophes before analyzing past casualty catastrophes to identify common elements of casualty catastrophes and factors that relate to incurred losses.

It reviewed how rating agencies and regulators deal with this risk and evaluate the impact of casualty catastrophes of various magnitudes on financial institutions and financial systems.

1 www.casact.org/education/clrs/2013/handouts%5CPaper_2583_handout_1517_0.pdf

Loss causation for casualty insurance is more ambiguous and constantly changing and the perils are more difficult to identify and to predict.

Where are we now?

The major model vendors have historically addressed only the Casualty losses closely aligned with Property losses, such as Workers' Compensation claims associated with earthquakes or terrorism events. The broader world of Casualty risk remains largely unmodeled. In part that is due to the unique challenges of casualty; compared to Property risk, Casualty risk presents inherently different dynamics that make assessing likelihood and impact especially challenging. Loss causation for casualty insurance is more ambiguous and constantly changing and the perils are more difficult to identify and to predict.

Ignoring casualty catastrophe risk is clearly not an acceptable way to deal with this risk. This work has helped developed an advanced understanding of casualty risk and addressed a need for our clients currently not always offered. Studies like this have helped generate more and better information on casualty catastrophes that have occurred. Modelling in this area is rapidly improving to meet a demand that has been proven to exist.

Professor Stephen P. D'Arcy

The researcher, Stephen P. D'Arcy, is Professor Emeritus of Finance at the University of Illinois at Urbana-Champaign, Robitaille Endowed Chair of Risk and Insurance at California State University Fullerton and the principal of D'Arcy Risk Consulting, Inc. He is a Fellow of the Casualty Actuarial Society, a Chartered Enterprise Risk Analyst, a member of the American Academy of Actuaries, Past-President of the American Risk and Insurance Association and Past-President of the Casualty Actuarial Society

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Flagship projects

Tropical cyclone inland flooding

National Flood Insurance Program

This two year research project leverages the National Flood Insurance Program (NFIP) portfolio for industry relevant data analysis, which develops a comprehensive hazard to loss modelling framework for the residential damages associated with inland flooding from North Atlantic tropical cyclones (TCs).

Research into heavy rainfall and inland flooding associated with tropical cyclones, such as Hurricane Irene (2011) and Hurricane Isaac (2012) has received little attention, and still represents a major challenge.

The NFIP underwrites the vast majority of residential flood insurance policies throughout the United States. Wharton's unique access to the entire portfolio of the NFIP enables this research, which aims to build a regional view of risks associated with tropical cyclone related floods, and a framework for modeling the impacts of extreme flood events.

This dataset offers us an incredible opportunity for advantage in understanding flood peril not just based on the NFIP in the U.S., but also worldwide.

This innovative research provides a regional perspective on the extent, magnitude and temporal variability of tropical cyclone floods and a modeling framework for assessing the link between this natural hazard and direct economic impacts.

Willis Re flood loss capabilities

The methods that Wharton are pioneering of converting tropical cyclone rainfall models and observations into flood losses are potentially significant. This innovative research provides a regional perspective on the extent, magnitude and temporal variability of tropical cyclone floods and a modeling framework for assessing the link between this natural hazard and direct economic impacts. These findings will provide guidelines for improving awareness and preparedness against these events, leading to a better description and quantification of tropical cyclone flood magnitude, spatial extent and impacts.

The research represents a big step in flood risk modeling, potentially applicable in all tropical cyclone exposed regions across Asia, Pacific and the Caribbean. It would also be a powerful capability for Willis Towers Watson, and complements WRN work with Newcastle University which models flood characteristics from extra-tropical windstorm rainfall data in Europe, across large domains to provide a fuller understanding of the spectrum of rainfall to flood responses.

Wharton Risk Management and Decision Processes Center

The Wharton Risk Management and Decision Processes Center at the University of Pennsylvania has been at the forefront of applied research on managing and financing extreme events for nearly three decades, and our WRN Fellow Dr. Jeff Czajkowski works with our colleagues in Willis Re to develop new views of flood risk. In the wake of increasing losses in the U.S. and overseas, the focus on these issues and related public policy initiatives has located the unit at the center of the catastrophic risk reform agenda and related developments at home and abroad.

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About Willis Towers Watson

Willis Towers Watson (NASDAQ: WLTW) is a leading global advisory, broking and solutions company that helps clients around the world turn risk into a path for growth. With roots dating to 1828, Willis Towers Watson has 39,000 employees in more than 120 countries. We design and deliver solutions that manage risk, optimize benefits, cultivate talent, and expand the power of capital to protect and strengthen institutions and individuals. Our unique perspective allows us to see the critical intersections between talent, assets and ideas – the dynamic formula that drives business performance. Together, we unlock potential. Learn more at willistowerswatson.com.

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