

WTW Research Network Annual Review 2023

Science for Resilience

The WTW Research Network is an award-winning collaboration supporting and influencing science to improve the understanding and quantification of risk, with the aim to improve the resilience of our clients and society as a whole.

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Foreword

Welcome to the latest review of our research portfolio, as we continue to bring leading-edge science into our world of talent, capital and risk management.

While we embrace the complexity of science (to understand the challenges facing us), we strive to distill and integrate key insights in a simple and relevant way (to support decision-making). We hope that this edition provides a few new perspectives that move you to action.

The 22nd edition of the Edelman Trust Barometer provided sobering views on the “cycle of distrust” fueled by government and media, while non-governmental organisations and business are pressured to take on societal problems beyond their abilities. In this context, the most trusted societal leaders appear to be the scientists.

It is increasingly widely accepted that scientific knowledge is critical for public understanding and sound policy for most of today’s critical issues - from human health to climate action to food security. More than ever, the researchers who make up the WTW Research Network are eager to understand how their work interacts with the real economy and how they can lend their expertise to a more resilient future for all.

Our established portfolio of research across the full spectrum of risks (natural hazards, people and technology, emerging risks, organizational resilience) continues to grow. It mirrors our evolving vision of current and future risks, our emphasis on organizational resilience to complement the traditional risk view, and the growing importance of ESG and sustainability. These themes have

also been central to the WTW Thinking Ahead Institute¹, which celebrated its 20th anniversary last year.

To inject new perspectives into our research portfolio, the WTW Research Network once again invited its members (and potential new partners) to submit short collaborative research projects via our Challenge Fund program. It's a chance to experiment with new ideas and methods to address topics that may be underrepresented in our portfolio. In 2023 our new themes are: relationships with technology, and the influence of climate change on human health and wider societal impacts.

The choice of our research topics gives an idea of our concern about the current state of the world: all aspects of climate change (not just acute physical risks, but also relentless chronic risks; not just

physical risks but also climate liability risks and climate change's impact on water and food security); the grayzone between war and peace (which challenges corporate geopolitical neutrality); trust in technology; vulnerabilities of supply chains.

Despite these efforts, we are all too aware of the remaining knowledge – action gap, most visibly on the climate change action front, which is pushing leading scientists to civil disobedience, to get their voice heard. The words of Russian-American biochemist and science-fiction writer Isaac Asimov ring particularly true these days: “The saddest aspect of life right now is that science gathers knowledge faster than society gathers wisdom.”

This is a reminder that the aim of our research portfolio is not merely to turn science into useable data and information that feeds into risk models, but also the wisdom to use our improved yet imperfect knowledge wisely.

Our thanks to all our research partners for keeping the faith in the power of science and for their contribution this year, and to our enthusiastic WTW Research Network team and curious colleagues, without whom we could not bridge the knowledge – action gap. It is a privilege to work with so many talented people, and harness their innovation to support lives, livelihoods and assets in the volatile decade we are in.

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Wordsworth connected ‘man’ to Nature through poetry. Now, the language of modelling puts the environment into finance to steward the resilient, just, and low carbon transition. The WTW Research Network is at the heart of building this new compass with its partners and supporters.

Rowan Douglas, CBE,
WTW Research Network Chairman

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¹ <https://www.thinkingaheadinstitute.org/>

About us

The WTW Research Network is a well-established, not-for-profit, award-winning collaboration between science and the insurance, finance and risk management sector, going back to 2006. Long-term partnerships with more than 60 research organizations across the world help us confront the full spectrum of risks facing our societies.

Our mission is to encourage and support innovative research to gain the clarity of vision required to turn risks into opportunities. We aim to improve our understanding of a wide range of risks and use this operationalized research to craft better risk solutions, help clients and society become more resilient and take advantage of sustainable growth opportunities.

Whilst the risk and insurance industries continue to evolve and improve at an astonishing rate, no individual institution has the resources or breadth of knowledge to single-handedly answer all the questions around the quantification and management of risk. Our long-term investment in research and ongoing horizon scanning can bring the latest science to our clients, often highlighting emerging risks before they make the headlines.

Partnerships with academia do not necessarily mean long delivery timescales, and in fact the mutual understanding built over those long-term relationships allows us to be very responsive to client demands.

The WTW Research Network is organized around seven research hubs, which drive a number of research programs and research projects, producing academic and business-focused research outputs along a wide spectrum: insights, data, models, peer-reviewed journal articles, financial instruments and seminars. These seven specialisms are linked by our focus on the interconnectedness of risks in the real world, providing an integrated view of risk.



Global partners, local expertise

We drive research with partners in science, academia, think tanks and the private sector, combining specialist expertise with knowledge across our global network.



Innovative, long-term partnerships

We form long-term, innovative partnerships with the research community, and support early-career scientists.



Understanding of risk

Our partnerships identify risks, improve their understanding and quantification for the benefit of our clients and society



Transmission mechanism

Our dedicated team brings best practice research and evidence into our client proposition: risk models, advice, thought-leadership, focused roundtables and knowledge sharing events.



Early career scientists

We are proud to support students and early career scientists, not only through funding, but also via internships and guidance in their studies. This reflects our wish to build long-lasting partnerships with academics at all stages of their career.

In 2022, the WTW Research Network continued to support 14 students and early career scientists, covering a multitude of topics, across our seven research hubs.

Moving forward, in 2023 this number will grow even further as we participate in calls across various doctoral programmes, such as Doctoral Training Partnerships (DTPs) and Centres for Doctoral Training (CDTs), and other internally funded programmes. This includes a jointly initiated CDT partnership between the WTW Research Network and Loughborough University, the ONE Planet DTP partnership at Newcastle and Northumbria Universities, and Marie Skłodowska-Curie Actions Doctoral Networks.

Want to see what our students say about their research partnerships with WTW? Below, you can find a handful of quotes from several of our partnered students and early career scientists:



WTW and WRN have been very supportive of my research. Having external supervisors from WTW and WRN has helped me ground my research through real-world experiences, helping to maximise research impact. They have also supported me in understanding potential end-users of my research and organising a 3-month internship within the Climate Resilience Hub's Analytics Team, allowing me to present my research findings and share insight into my methods that could be used on existing projects.

Josh Thompson,
PhD student, Loughborough University



Interacting with researchers at [WTW] has been hugely beneficial to my current project. As well as helping to answer academic questions, the opportunity to discuss results and potential next steps with those who may ultimately use them has been key to our progress. It has also generated some exciting new research ideas for 2023!

Dr. Hannah Bloomfield,
Research Associate, University of Bristol.
Hannah works for the UK Centre for Greening Finance and Investment



Working with the WRN has given me direct insights into knowledge gaps in industry and how my research may help in answering some of these questions. As a result of this interaction, I am constantly evaluating my

research and the impact it may have, making sure I focus on the outputs which will make a difference.

James Carruthers,

PhD student, Newcastle University

Support from WRN has been key in facilitating relationships with other researchers and organisations who are interested in my work. This has given me an opportunity to collaborate with stakeholders so that my research can have a real world impact on at-risk communities.

Leanne Archer,

PhD student, Bristol University



Being a part of the WTW Research Network as an early career scientist has greatly aided my development as a researcher and the research

I undertake. The WRN has facilitated collaborations with risk modellers, which provides crucial insights to improve the research I do and make it more relevant and applicable to end users. Furthermore, the research being done as part of the WRN has allowed me to develop new techniques and skills that have been applied in a novel manner to windstorm risk analysis.

Dr. Matt Priestley,

Research Fellow, University of Exeter

Collaborating with the WTW Team was very fruitful in my work on understanding future coastal flooding, as their vast expertise in this domain brought crucial understanding of the problems I was facing. They shared their network of specialists and scientists with me, which allowed for better connections and conversations that guided my project further. I am looking forward to continuing collaborating with WRN!

Tudor Suciu,

PhD student, University of Cambridge



I wanted to take this opportunity to thank the WTW Research Network for the support over these 3+ years of PhD research. It has been

a privilege to liaise with such a wonderful organization to push the boundaries of conventional CAT modelling forward. I consider my experience with WRN career-defining and especially rewarding from a personal perspective.

Salvatore Lacoletti,

PhD student, University College London.

Salvatore successfully completed his PhD earlier this year



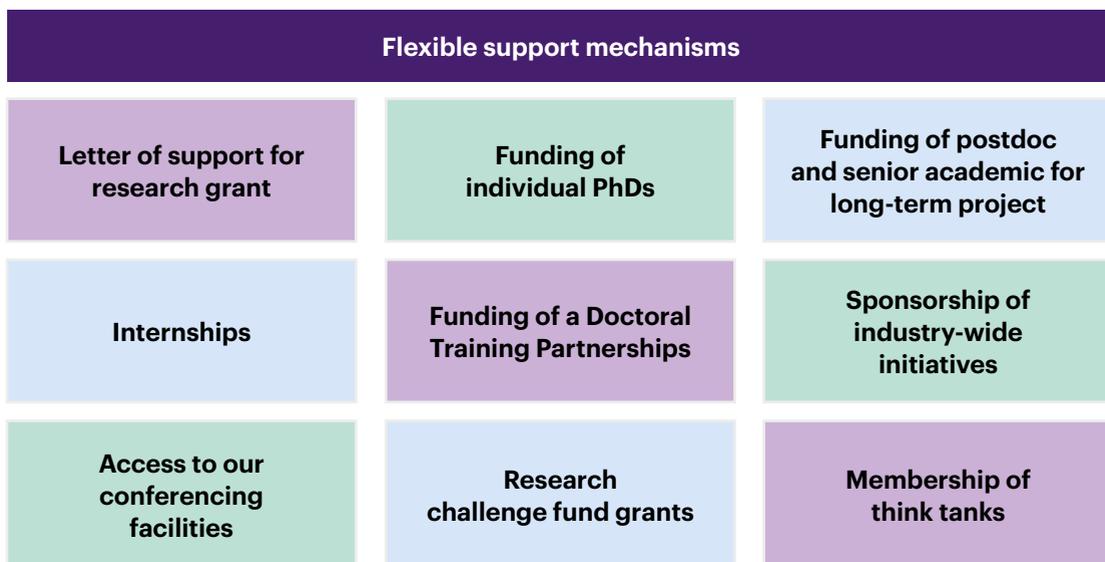
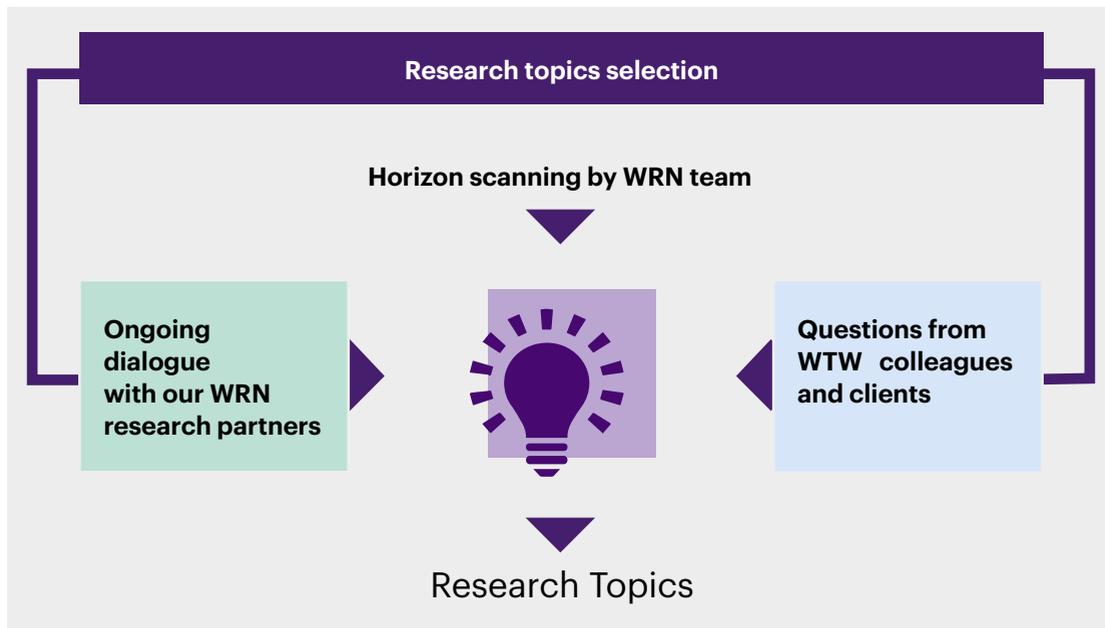
As a graduate student researcher, it's my great pleasure to work with the WTW Research Network on South America seismic hazard

assessment since early 2022, and make it my first ever project for my Ph.D thesis. Thanks to the timely and comprehensive interactions with James [Dalziel] and other people from WTW, I could get access to the code packages and up-to-date observations substantial for strong ground motion simulations in Peru and Chile, and also got the chance to have deep chats with experts on this topic at meetings such as SSA [Seismological Society of America] and SCEC [Southern California Earthquake Centre]. Now that I've got much more knowledge on the work procedures for any seismic hazard assessment, the collaboration definitely gave me more confidence on my further explorations in seismology.

Ke Xu,

PhD student, San Diego State University

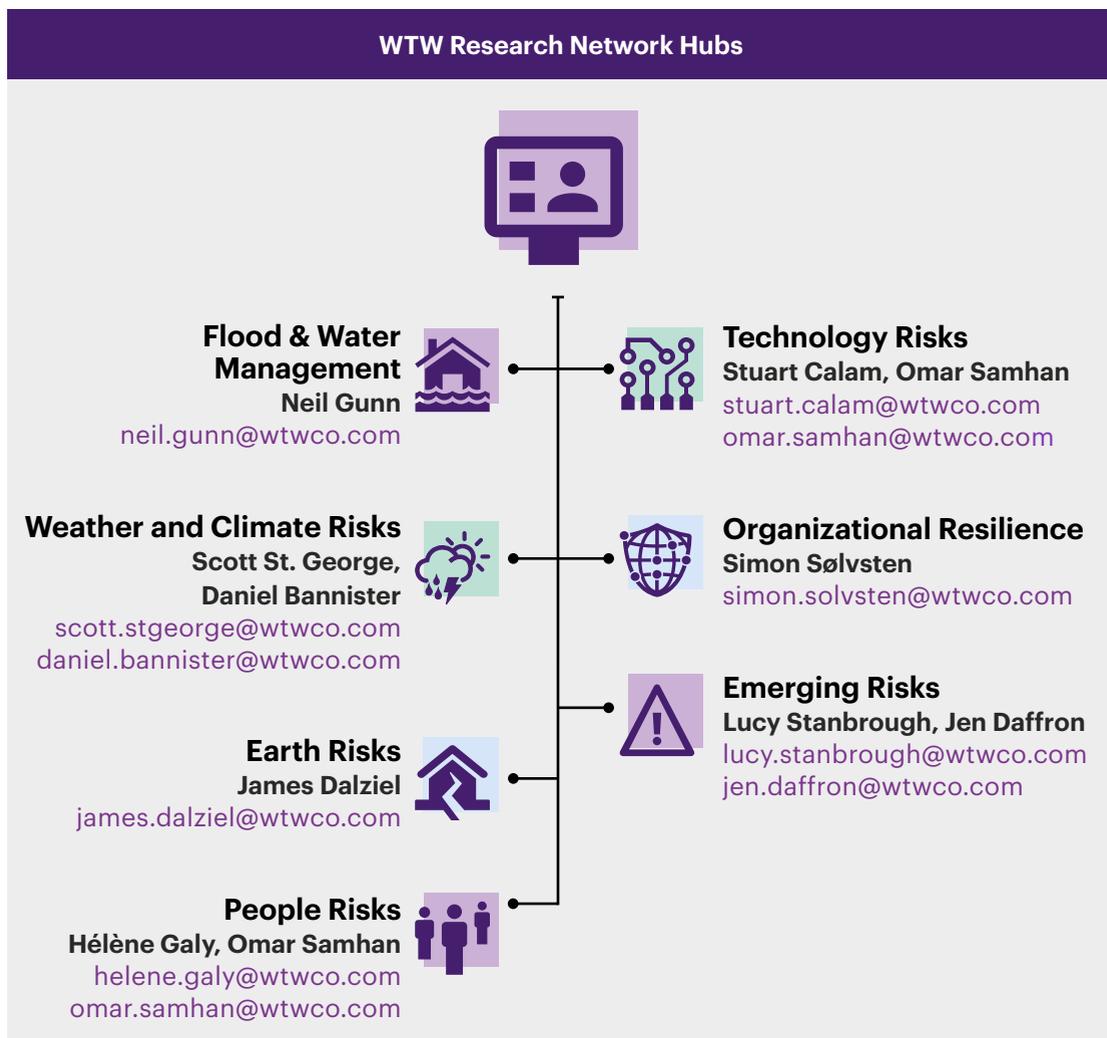
How it works



Key research hubs

The WTW Research Network is organized around seven research hubs, which drive a number of research programs and shorter-term projects.

Throughout the year our hub leaders and partners produce academic and business-focused research outputs, a selection of which can be found in this research overview. You can also keep track of our activities throughout the year by subscribing to our newsletters here¹, and reach out to any of our hub leaders below.



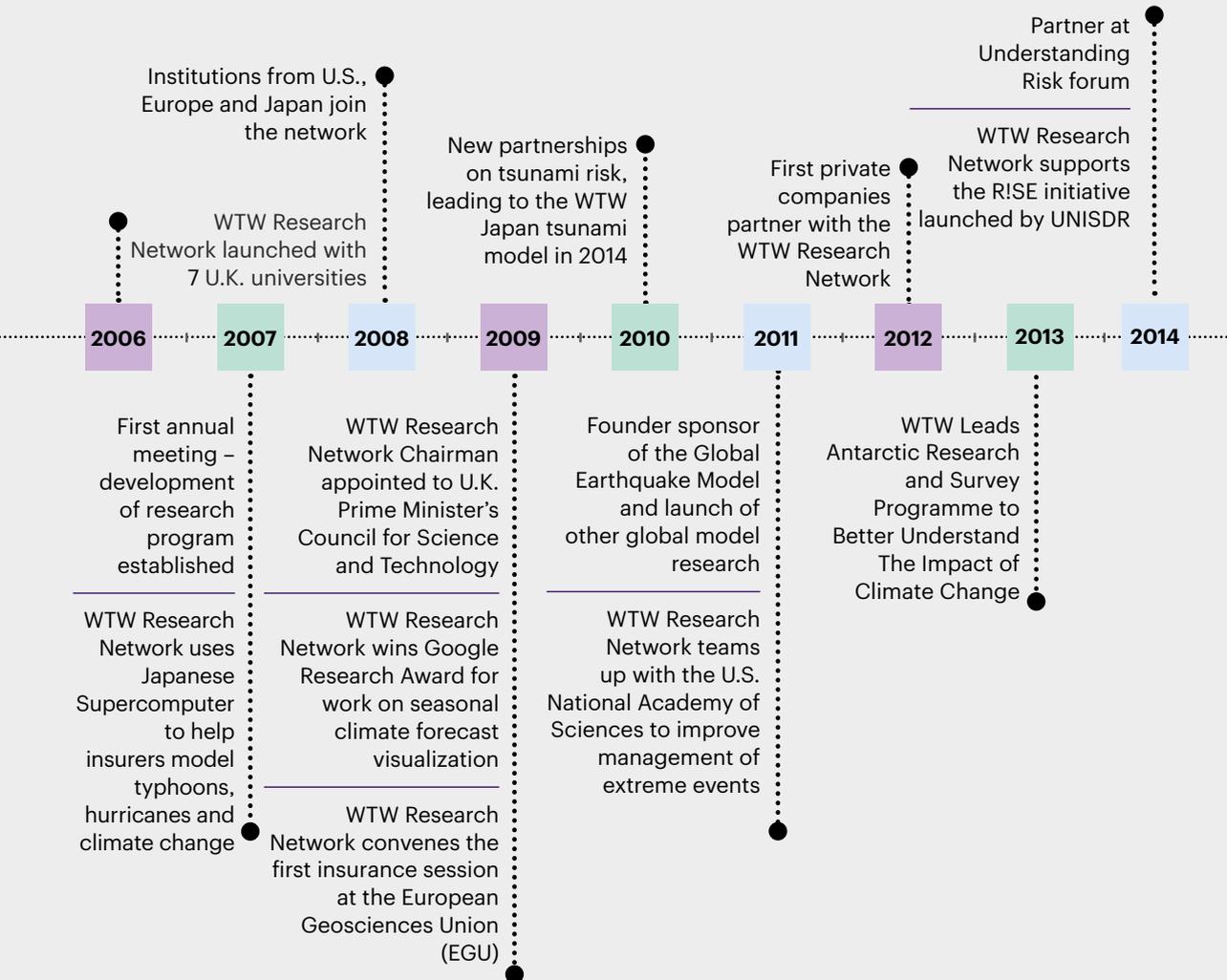
¹ <https://www.wtwco.com/en-GB/insights/research-programs-and-collaborations/wtw-research-network>

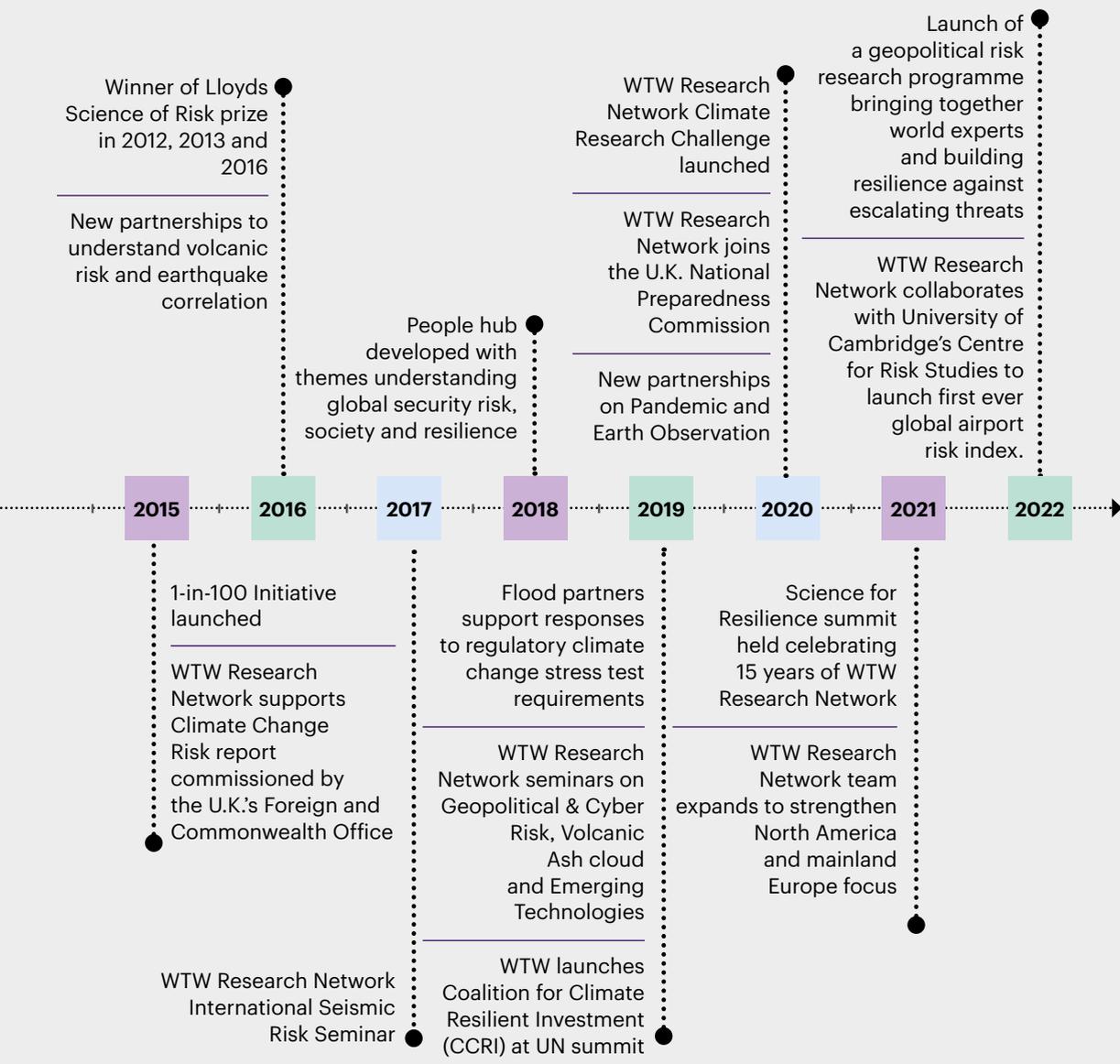
WTW Research Network partners over the years





Our history







Emerging risks





Emerging risks

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We are facing a crisis on top of a crisis.

Kristalina Georgieva,
MD of the International Monetary
Fund (IMF)

April 2022

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She was referring to the combined impacts of the COVID-19 pandemic, plus the Russia/Ukraine crisis, and accompanied her statement with a sobering forecast on the lack of global growth and a declaration that rising inflation is a “clear and present danger”.

As the year continued many of the risks on organization’s lists have crystalized, and in the face of such change, there has never been a better time to reconsider the risk landscape and the risks and opportunities on the table.

Today, future-seeking leaders accept that risk has become a mainstream element of business and will likely remain so for the balance of their careers.



The frequency and simultaneous occurrence of high-impact risks require both enhanced day-to-day management and agile planning for a “portfolio” of risks, supporting a culture of adaptability to incorporate new information that arrives daily or hourly, being ready to act decisively when events happen.

It is also important to not just focus on the risks, but to keep an eye open for the opportunities. After its successful launch in 2021, the James Webb Space Telescope sent back the first awe inspiring views of the cosmos that will help us understand how our universe works. In 2022, several groups reported the first successful applications of AI (Artificial Intelligence) to identify novel antibiotic drugs, which will improve life expectancy and quality of life. And in December, the much delayed Convention on Biological Diversity was held in Montreal, which will set a course for nature recovery from now until 2050 – supporting understanding on the value of nature.

Over the last year, the Emerging Risks hub has been supporting thinking in this space with our industry practices and their clients; offering a challenge perspective off positive and negative futures that bring stakeholders together to discuss risks and their interconnections through scenarios. Key examples of this are outlined in this year’s Annual Review, and include the launch of the Airport Risk Index with the Centre for Risk Studies at the Judge Business School, University of Cambridge, and the release of the first report with Lloyd’s to explore supply chain vulnerabilities in 3 key industries.

In 2023 we will be rerunning the emerging risk survey launched at our 15-year anniversary conference, and continuing to build out thinking around scenarios and futures. This will be supported by Dr. Jen Daffron who will focus on these two areas.

Lucy Stanbrough

Head of Emerging Risks and Business Engagement

How prepared is your organisation against civil unrest and ‘crisis on top of crisis’?

According to *The Times*¹, police forces in the U.K. were planning for disorder in the summer of 2022 amid fears that the cost-of-living crisis and other pressures could trigger civil unrest, and 2023 started with strikes from key industries from rail workers to nurses.

Political risks can emerge rapidly in societies that have enjoyed stable business conditions for years, and since the Arab Spring of 2010, we have seen anti-austerity riots (2011) and human rights protests (2020) in Greece, the notable ‘yellow jacket’ campaigns in France (2018), the Chilean social inequality demonstrations (2019), rallies against COVID-19 restrictions in Italy (2020) and, in 2022, the youth-led mass protest movement over Sri Lanka’s worst-ever economic crisis. The speed and scale of these protests have, in some cases, been breath-taking, often driven by the largely unregulated nature of social media that allows misinformation to spread unchecked, providing a platform for conspiracy theorists and an outlet for resentments.

The final straw?

With significant economic uncertainty as the spectre of a global recession looms large, supply chain volatility caused by geopolitical uncertainty, coupled with spiralling costs of basic commodities and energy prices continuing to rise, adding one or a combination of further events may spark highly flammable societal conditions into full-blown blazes.

These events could include any one, or a combination, of the following:

- Industrial action coming to a head, paralysing the country as unions jockey for public and political sympathy
- Supply conditions for critical utilities, such as power or water, worsening, resulting in restrictions or blackouts
- Public confidence in policing falling to an all-time low as a result of further scandals or mishandled events
- Delay or inaction by the Government resulting in loss of support and confidence
- A cyberattack on the voting systems provoking a loss of confidence in the democratic process, as recently suggested in relation to the U.K. Conservative leader voting process²

¹ <https://www.thetimes.co.uk/article/police-brace-for-unrest-over-cost-of-living-crisis-93d97bm8k>

² <https://www.reuters.com/world/uk/britains-conservative-party-voting-next-pm-delayed-after-hacking-alert-telegraph-2022-08-02/>

- Geopolitical threats, such as E.U. fragmentation, destabilising global economy further; Hungary or other E.U. countries aligning to Russia thus weakening the effect of global sanctions; Chinese aggression towards Taiwan intensifying, resulting in new trade wars and China leveraging supply continuity against the West.
- Pressure on revenues/profits from various stakeholders, for example, activist groups, media, regulators, government
- Targeted cyberattacks to punish/deter companies by socially motivated activists but also increased threat from organised criminal groups as they see organisations being distracted by civil unrest and leaving themselves exposed in terms of IT protection

How could civil unrest affect your organisation?

It is, of course, difficult to predict exactly what could or would happen, as much will depend on the extent and severity of any unrest. Rather than any one 'doomsday', we should instead expect gradually increasing pressure as societal frustrations result in more lines being crossed. Organisations should be prepared for any, some, or all of the following:

- Physical damage to assets following targeted attacks or general rioting
- Depending how your organisation is perceived, threats to employees with the potential for physical violence
- Disruption to operations both direct (following action against premises or business activity) and indirect (following action against a critical supplier, for example)
- Negative messaging against a company directly (if perceived to be profiting from/contributing to economic distress, for example, energy utilities), or by association, with consequent reputational damage
- Your own employees may identify or sympathise with the civil unrest issues and disengage with the organisation
- Increasing regulatory pressure on companies to react to societal pressures, for example, energy companies becoming subject to additional windfall taxes, revising of costing models, and the like
- Supply chain pressures leading to disruption at organisational level
- Lending conditions becoming stricter as financial institutions take a harder stance on risk affecting cashflow
- Claims settlements becoming subject to delays or disputes as insurer operations are disrupted, resulting in inability to settle claims within agreed time limits
- The risk of litigation increasing as claims are disputed
- Unrest leading to loss of confidence in FTSE and consequent share value falls
- Increasing likelihood of prolonged recession, either at a national or global level, leading to premature foreclosure of businesses
- Civil disorder leading to withdrawal or reduction in public services affecting employees, suppliers and customers.



While all of the above may sound like apocalyptic scenarios it is interesting to note the U.K. National Risk Register³ includes “widespread public disorder” defined as a low to mid-level risk, both in terms of probability (5 to 25 in 500) and impact, with potential economic costs ranging from £10 million to £100 million. That said, this risk grading featured in the 2020 version of the register and an updated iteration may look markedly different given the change in prevailing conditions. These scenarios may need to be calibrated and stretched further, with UK Hospitality warning⁴ the wave of rail strikes over the festive period could cost the hospitality industry an estimated £1.5b a day.

Political and other risks can emerge rapidly, even in societies that have enjoyed stable business conditions for years. This means simple trend assessments or data analysis are inadequate in gauging the potential financial impact and why getting a second set of eyes can stretch thinking. The WTW Political Risk Survey 2022, conducted by our partner Oxford Analytica pointed out how political violence losses fell sharply in 2022, which could reflect periods of lockdown during which social unrest declined. Relaxing lockdown measures could result in a surge, which could test those resilience plans and the relative quiet.

³ <https://lordslibrary.parliament.uk/national-risk-register-preparing-for-national-emergencies/>

⁴ https://www.thecaterer.com/news/rail-strike-hospitality-cost?utm_source=catererwebsite&utm_medium=reviewoftheyear

Building resilience to civil unrest

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Today's organisations are having to factor uncertainty into their planning process. The focus shouldn't be on trying to pinpoint the next crisis, or crises, but instead to build resilience into their DNA

Frederick Gentile, Director of Risk Engagement, WTW

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There will be enormous reliance on the national capabilities in extreme scenarios, and realistically organisations can only work towards mitigating the impacts of such events within reason. Nevertheless, there are actions organisations can take now to embolden their stance and boost their preparedness for the eventuality of civil unrest:

- **Review risk registers** to ensure civil unrest and associated risks are included and regularly evaluated.
- **Scan the horizon** by introducing measures to baseline and monitor societal 'temperature', such as public mood, media coverage, social media sentiment towards your organisation, activist reactions, and identify early episodes of societal disorder, including protests.

- **Update business continuity plans,** IT disaster recovery plans, strategies to cope with staff shortages, and any other contingency plans, and ensure these are shared and understood by key stakeholders.
- **Quantify operational factors,** such as stock levels, staff deployments, supplier call-off and the like, assessing how each would be affected in the event of serious disruption.
- **Ensure your crisis response structure is clear** and ready to be activated at short notice.
- **Establish communication strategies,** including with media and social media, as well as response and monitoring arrangements.
- **Consider scenario planning with executive teams,** so they have ready answers to the questions of, "If civil unrest happened tomorrow, what would you do?", allowing for input from each of the organisation's key functions in this process. Constructing realistic and relevant scenarios is one of the practical outcomes of our WTW geopolitical risk programme⁵, leveraging insights from our network of advisors.
- Assess standing security arrangements and potential additional call-off measures.
- Review your insurance provisions to understand exactly what is and isn't covered and where the gaps may need addressing ahead of potential losses.

⁵ <https://www.wtwco.com/en-GB/News/2022/11/wtw-launches-geopolitical-risk-research-programme-to-bring-together-world-experts-and-build>

- Liaise with lenders to assess the scope for cashflow facility, should it be required.
- Communicate your readiness for disruption with customers and suppliers, articulating your plans to keep the business on the front foot, even in the event of civil unrest or other crises. This might act a point of differentiation when compared with peers, allowing your organisation to pivot to opportunity more readily.

How can the business manoeuvre beyond box-ticking to true preparedness?

The last two years have taught us the ‘new normal’ is the ‘never normal’. It’s worth recalling that while pandemic flu was at the top of the U.K. risk register⁶, when that risk crystallised, the country was shown as under-prepared for COVID-19⁷.

This demonstrates how true preparedness is about evaluating, monitoring and acting on new risks, not simply acknowledging where risk exists and having only hypothetical responses that don’t adequately reflect what’s really required when crises strike.

Being ready for crises means ensuring your risk management framework (RMF) is both robust whilst being receptive to ever-changing exposures. Increasingly, these frameworks are required to metabolise how extraordinary events are becoming less theoretical and more day-to-day reality, and the WTW Research Network will continue to explore where science-based partnerships can support thinking.

⁶ <https://www.nao.org.uk/reports/the-governments-preparedness-for-the-covid-19-pandemic/>

⁷ <https://www.parliamentlive.tv/Event/Index/2105caa3-43bf-49e0-a19a-0b0b5adb9dcc>





Lessons from future-prepared firms

We are running out of risks to check off the list, with many of those risks that have sat on the top 10 lists of organisations crystallising over the last year, whether record setting droughts and floods¹, geopolitical tensions materialising² in Europe, or economic tensions fuelling protests³.

With a never-ending stream of change, companies must continuously innovate to stay ahead of the curve and manage risks effectively. A key part of this is staying alert and curious for signals of change – continuously reviewing assumptions around the risk landscape and exploring potential futures to ensure strategy is fit for purpose.

Something the Emerging Risks hub has been exploring with our WTW colleagues and clients over the last year.

While this may seem like an additional burden on top of an already full to-do list, there are benefits. Research suggests that future-prepared firms – who have invested in building corporate foresight units – outperform the average by a 33% higher profitability and by a 200% higher growth¹¹. While there is no one silver bullet framework, course to take or software that can be deployed to gain this magic badge of being a ‘future-prepared firm’, the research study found that foresight activities must be integrated with a firm’s strategic planning processes, innovation, and operational activities.

¹ <https://www.climateforesight.eu/articles/flood-and-drought-two-sides-of-the-same-coin/>

² <https://carnegieendowment.org/2022/12/08/economic-anger-dominated-global-protests-in-2022-pub-88587>

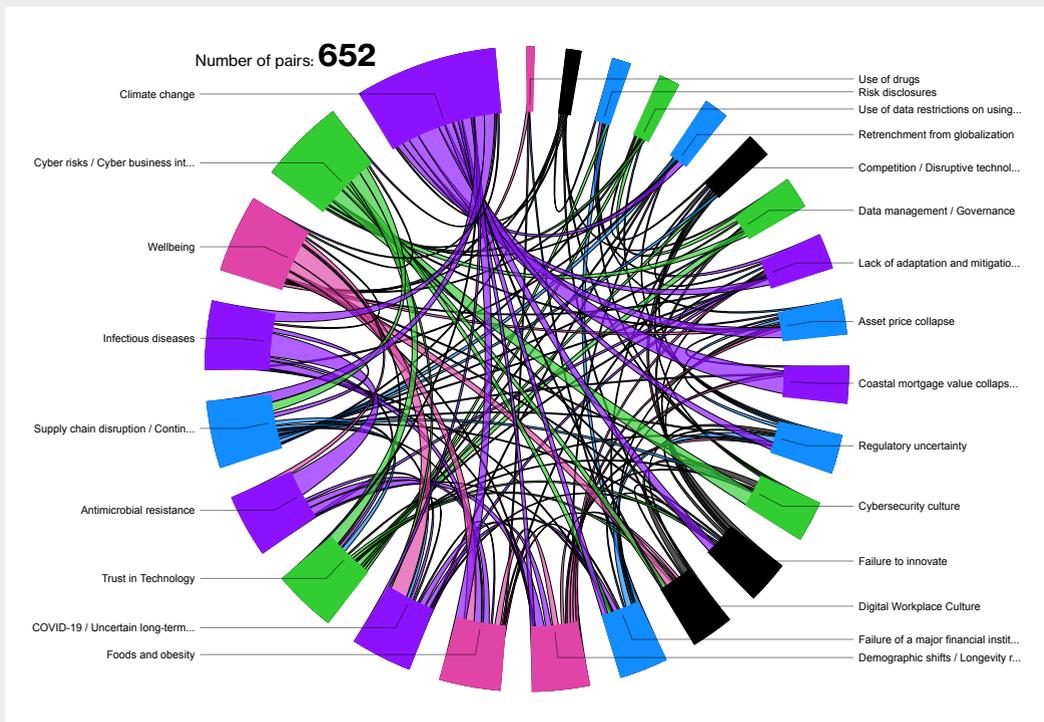
³ <https://www.sciencedirect.com/science/article/pii/S0040162517302287>

Changing landscapes

Horizon scanning, well-formed research questions, and not being afraid to challenge existing processes are all foundation blocks underpinning the transformation of information into action. Getting to grips with

all of these elements is essential as there's no shortage of change, and is why we will be running a new edition of the emerging risks survey launched over our 15 years anniversary conference to uncover the issues on our risk community's mind and challenge what might be missing:

Fig.1: **Horizon scanning**



Source: WTW Research Network

Challenge perspectives are essential to be awake to change. COVID-19 is already broadly viewed as being a once-in-a-lifetime or once-in-a-century pandemic, yet research by Metabiota estimates the annual probability of a pandemic on the scale of COVID-19 in any given year to be between 2.5-3.3 percent, which means a 47-57

percent chance of another global pandemic as deadly as COVID-19 in the next 25 years⁴. These numbers illustrate the importance of preparing immediately for future outbreaks, which Dame Kate Bingham, Chair of the Vaccine Taskforce in the UK recently warned was already slipping away⁵.

⁴ <https://www.cgdev.org/blog/the-next-pandemic-could-come-soon-and-be-deadlier>

⁵ <https://committees.parliament.uk/oralevidence/11977/html/>



Since the low probability of occurrence doesn't mean non-existent probability, it is becoming ever-more important to incorporate wild cards into your horizon scanning, foresight scenarios, and strategy testing. This includes both negatives such as the current questions around global food security and geopolitical uncertainty, and future utopias such as a fully climate positive future imagined in 'The Future We Choose' by Christiana Figueres and Tom Rivett-Carnac⁶.

Challenge perspectives should include a diverse range of backgrounds and people, as well as lenses of risk and opportunity to stress test thinking. A critical view is critical as it is rarely the event you've planned for the most that causes problems it's the unforeseen or unimagined.

The power of Once Upon a Time

Another tool is stories themselves. Science fiction has significantly influenced technological innovation and scientific research – whether serving as inspiration to colonise Mars in the case of Elon Musk, or painting a picture of future worlds like inventor Simon Lake, who became inspired by the idea of undersea travel after reading about Captain Nemo's adventures in 'Twenty Thousand Leagues Under the Sea'⁷.

Many technology companies employ the services of futurists and writers to share insight and describe worlds they – and their customers – can strive for. In 2015, Microsoft commissioned 'Future Visions', where contributing authors were inspired by inside access to leading-edge work, including in-person visits to Microsoft's research labs, to craft new works that predict the near-future of technology and examine its complex relationship to our core humanity⁸.

⁶ <https://www.weforum.org/agenda/2020/03/what-the-world-could-look-like-in-2050-if-we-do-everything-right-on-climate>

⁷ <https://www.bustle.com/p/11-real-life-inventions-inspired-by-science-fiction-novels-9090688>

⁸ <https://news.microsoft.com/futurevisions/>

Building a culture of risk

While being ‘right’ or targeting innovation and novelty are seen as highly desirable outputs from scenarios building exercises, the real value comes in transitioning from a ‘one and done’ process into an activity that ties together teams and strategy. Building a futures perspective into the culture and DNA of the company can foster mutual understanding among teams who bring different perspectives and responsibilities on what alternative futures could look like and potential disruptors you may face – that’s the real value-add that moves process into culture. For many organisations this is a key area where risk-facing colleagues have a central role to play.

In September 2022, the Research Network shared insights through WTW’s Training Academy in a session titled ‘Ready for the future: Are you prepared for tomorrow’s risk landscape?’ This forum was led by Lucy Stanbrough, Head of Emerging Risks and Frederick Gentile MBE, Director of Risk Engagement, and focussed on how

organisations can create robust and change-receptive Risk Management Frameworks (RMFs). The webinar also considered how to use scenarios to explore possible futures and examine why organisations should bring together perspectives from across business units to ensure RMFs are fit-for-purpose and the entire business is properly preparing for the future.

This is something we’ve been exploring in the WTW Research Network through the use of narrative storylines that weave together risks and trends that are often considered in isolation. We find the process of considering these futures helps move the narrative from “prepare for one”, to “prepare for all”.

In 2023, the emerging risks hub will be building on our horizon scanning and challenge perspectives with a new colleague – Dr Jennifer Daffron who will be joining us to focus on scenarios and futures.



Rethinking supply chains

Today's complex supply chains increase vulnerability to both natural perils and manmade threats, such as cyberattacks and geopolitical volatility, allowing risks to transfer between organisations, sectors and continents. There are also interesting trends and drivers at work, shifting the landscape and requiring new collaborations and thinking between stakeholders.

Over the past six months, the WTW Research Network has been working to support Lloyd's and their action leadership platform, Lloyd's Futureset¹ to explore how organisations are responding to supply chain challenges. The aim of the research has been centred on providing the insurance industry with a greater understanding of customer needs, identifying protection gaps and potential insurance solutions. This work has connected colleagues and perspectives from across WTW to surface the challenges our clients are facing, and at the end of 2022 Lloyd's and WTW co-launched the first report in a three-part collaboration.

¹ <https://www.lloyds.com/news-and-insights/futureset>

'From farm to fork' reports



<https://www.wtwco.com/en-gb/Insights/2023/01/rethinking-supply-chains-the-food-and-drink-industry>

From farm to fork

'From farm to fork: rethinking food and drink supply chains'² focuses on the critical challenges facing the food and drink industry due to the growing interconnectedness and complexity of global supply chains. The sector is one of the largest industries, with a global revenue of almost \$US 11 trillion (2021) that underpins global resilience and food security but faces a complex risk environment from natural perils to man made threats. There is

also further change on the horizon. As the world's population is forecasted to reach 10 billion by 2050, and demand expected to continue to grow significantly – land twice the size of India is expected to be needed by that time to support a 70% increase in food production. Meeting this need will require action across the value chain: eliminating pests and diseases; preventing loss in transport and distribution through poor storage; reducing food waste by retailers and consumers; and through supporting the transition to a low carbon economy.

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This Lloyd's Futureset and WTW Research Network report is part of our ongoing commitment to keeping pace with the changing risk landscape to help protect food and drink businesses and support their successful growth. We continue to deepen our understanding to drive improved supply chain resilience and to empower food and drink organisations' in optimising their risk protection in the face of ongoing volatility, and this work with Lloyd's brings an added perspective to this.

Sue Newton, Food and Drink Practice Leader GB, WTW

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Building resilience

The report outlines a practical roadmap based on increased collaboration between businesses, brokers and insurers, which identifies opportunities for the insurance industry to innovate in the protection it offers business as well as setting out how supply chain risk management technologies, including data capture and visualisation can help to improve resilience.

Rebekah Clement, Sustainability Director at Lloyd's said: "In today's global economy, the food and drink industry is no stranger to the effects of shifting geopolitics and economic uncertainty. It is arguably more important than ever that businesses ensure the safe and timely transportation of critical and often perishable products which maintain a level of balance for global food security.

Whilst insurance cover for supply chain risks does exist today, the findings in our research point to a lack of alignment between shifting

² <https://www.wtwco.com/en-GB/Insights/2022/11/rethinking-supply-chains-the-food-and-drink-industry>

key risk drivers for food and drink business and their current insurance cover. Uniquely positioned to respond, through initiatives like Lloyd's Futureset, the Lloyd's Lab and the our leadership of the Sustainable Markets Imitative Insurance Task Force, the Lloyd's market can further open lines of communication between food and drink businesses and their insurers and look to this research as roadmap for potential product innovation".

Key findings

- Behind this report is the data from over 275 risk, supply chain, and insurance practitioner interviews. These perspectives have provided real-life, practical insights into the challenges that companies across the food and drink sector are facing.
- In addition to these interviews, we have combined proprietary data and reports with a range of research and third-party analysis to develop insights that can help build common understanding between the industry and insurers
- The research identifies several key factors driving risk across food and drink supply chains, including economic pressures, demand changes, labour challenges, technology, transport, geopolitical and political risk, and climate change and sustainability, and highlights the opportunity for the insurance industry to develop new products to protect against the loss of Tier 2 suppliers, notifiable pests and diseases, transit delays and commodity price volatility.
- It also provides a view for food and drink companies looking to learn from their peers and challenge their own assumptions around risk. For example, there was a lack of alignment between companies' business-critical risks and the insurance cover they have purchased.

While 82% of businesses have at least some insurance for extreme weather impacts to their supply chain, less than a third (31%) believe that this is sufficient to address the risk to their operations"

Looking forwards

In 2023, together with Lloyd's Futureset, we will be focusing on the semiconductor industry and transportation and logistics. Semiconductors are produced through a complex global and interconnected value chain, and transportation and logistics underpins all supply chains regardless of industries – the movement of goods and components is central from production through to delivery.



Building resilience with WTW's Airport Risk Index

WTW and the University of Cambridge's Centre for Risk Studies have unveiled their revolutionary new Airport Risk Index (ARI)¹ designed to help owners and operators build operational resilience against the growing number of risks they face.

The ARI, which was three years in development with the WTW Research Network², was presented to more than 100 global airport executives at WTW's annual Airport Risk Community (ARC)³ conference in Lisbon in September.

The Index combines historical and predictive analysis to give airports the ability to interrogate their assumptions on risk. In an operating environment of non-stop change and competing demands on resources, it is easy to focus on the current issues that often dominate executive surveys, rather than the 'what if's'. The index sets out both likelihood and impact for the indexed threats to offer a perspective on what has always been possible and what we need to prepare for.

Features of the Airport Risk Index

In its present configuration, the ARI compares 110 of the world's busiest airports (by passenger volume) against 19 of the sector's most prominent threats, measuring the probability and impact of any interruption in operations.

The airports were chosen as a representation of the largest commercial airports but also considered the importance of the interconnectivity of the airports across the globe. By also mapping the characteristics of these airports, such as runway composition and number of terminals, airports can explore the index results for similar organisations. In this way, users can see how they compare to best practice, and in doing so, see where they need to improve and where often limited risk-management resources are best applied.

The 19 threats were chosen for their potential to cause high-impact events that could shut down an airport for extended periods or cause a prolonged and significant disruption. More common disruptions that usually do not cause lengthy delays were omitted, as it is rarely the day-to-day operational events that push resilience beyond capacity, plus it is those rare threats that can fall off top 10 risk lists.

¹ <https://www.wtwco.com/en-GB/News/2022/09/first-ever-airport-risk-index-launched-to-over-one-hundred-airport-executives-today>

² <https://www.wtwco.com/en-GB/Insights/research-programs-and-collaborations/the-willis-research-network-hubs>

³ <https://www.wtwco.com/en-GB/Solutions/products/airport-risk-community-arc>

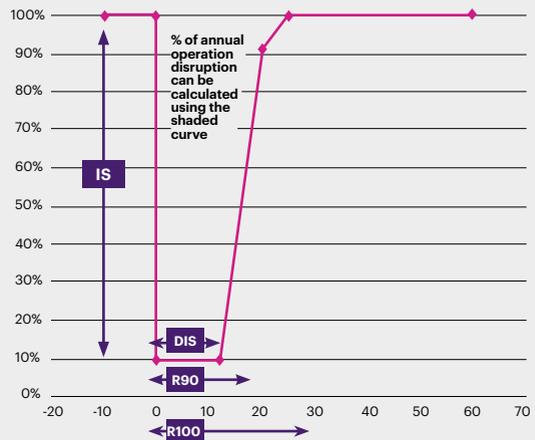
Because events happen with varying intensity – simply listing a systems intrusion as a ‘cyber-attack’ is not very helpful for building resilience. To explore the ranges of possible events, historical precedents and research were used to create multiple scenarios, each with a storyline that allows airport operators to build shared understanding about how events might unfold. Each scenario gradually increases in impact but decreases in likelihood to

provide a more complete representation of the risk. Every scenario that is possible, has been underpinned by historical precedents, and can be explored to understand where to focus resources.

This deep level of analysis depicts a corresponding numerical view of disruption to operational activity, as well as a projected recovery curve for each of the 66 scenarios for each airport depending on their resilience and vulnerability assessments.

Fig.1: **Building the Airport Risk Index. Scenarios include 4 parameters to create a view of disruption**

- IS Initial Severity**
The % of operational activity reduced from the initial impact of the scenario when it occurs. Not all events will cause a complete halt to all activity.
- DIS Duration of Initial Severity**
This is the length of time the initial % reduction of activity continues for before the Airport begins to recover.
- R90 Recovery of 90% of the lost Capacity**
This is the length of time it takes for the Airport to cover 90% of the lost operating capacity after the initial impact of the scenario.
- R100 Recovery of 100% of the lost Capacity**
This is the length of time it takes for the Airport to return to 100% operating capacity after the initial impact of the scenario.



Notes: The curve is comprised of four key parameters: Initial Severity (IS) – how much did the event reduce operating capacity; Duration of Initiation Severity (DIS) – how long the airport will be at the initial reduced capacity; R90 – how long it will take to recover 90% of the lost operational capacity; and R100 – time to full recovery. For illustrative purposes only. Source: WTW

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Understanding risk and driving resilience are still best met working in partnerships and embracing the talents of people across the globe. This is where our long-term investment in research partnerships proves invaluable, bringing the latest science to our clients.

Hélène Galy, Director WTW Research Network, highlighted the value of science-based partnerships that sit at the core of ARI

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A prompt to ask the right questions

Even with the depth of processing and research that went into each of these scenarios, the Index was not designed to give exact answers, but to encourage stakeholders to ask the right questions. Just as no risk operates in isolation, responding to the VUCA (volatility, uncertainty,

complexity, and ambiguity) environment needs action across the breadth of an organisation – there is no shortage of parties with a stake in the game, with different perspectives and levels of understanding.

This shared view allows exploration of key questions such as:



Interconnectivity of risk

This modelling can also help users to investigate operational impact of threats by exploring potential pathways through the index. For example, while the index has three different cyber scenarios, it may also be useful to explore other end points, such as aircraft crashes, power outages or fire and explosion scenarios, to determine where resilience could be exceeded.

Looking to the future, there may also be additional threats that need to be considered. As the world transitions to a

low carbon economy and looks to diversify energy security, nuclear facilities may appear on risk lists as governments approve new sites. Sea level rise may also change the risk profile of perils such as tsunami and flood. Risk is not static, it's dynamic and it's also interconnected – as an example, the International Civil Aviation Organization suggested in September the industry starts paying more attention to cumulative risk in its latest guidance⁴ on preparing now for climate change.

⁴ https://www.icao.int/environmental-protection/Documents/Climate%20Risk%20Assessment%20and%20Adaptation%20Report_Key%20Steps%20Risk%20Assessment_final.pdf

A mirror to the future?

In an era when mounting demands for greater risk transparency and accountability are being driven by environmental, social and governance requirements, the ARI is designed to help organisations build stakeholder confidence for today and the future. As WTW explores the outputs with the Airport Risk Community³, we will be keeping an eye on where the index could be further developed, including additional scenarios and cumulative impacts.

Ultimately, with the Airport Risk Index framework, airports will be able to reassure governments, regulators, investors, insurers and business partners that they have a real-time understanding of their risks and the resources in the right places to help ensure operational dependability.



University of Cambridge

The Centre for Risk Studies is a multidisciplinary center of excellence for the study of the management of economic and societal risks. The Centre's focus is in the analysis, assessment, and mitigation of global vulnerabilities for the advancement of political, business and individual decision makers. CCRS is part of the Cambridge Judge Business School. The group provides frameworks for identifying and assessing the impact of systematic threads, using their threat taxonomy, and are very well connected to the insurance industry, government and the World Bank.

³ <https://www.wtwco.com/en-GB/Solutions/products/airport-risk-community-arc>

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We look forward to sharing more insights with clients in 2023. In line with our WTW data-led strategy, we're driving change across the aviation eco-system. This Index will deliver new perspectives and challenge how industry measures and manages risk.

John Rooley, CEO Global Aerospace, confirmed the value delivered by ARI

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Weather and Climate





Weather and Climate

Without the Earth's oceans and atmosphere, life would not exist on our planet. Our seas and sky act together to warm the Earth's surface to habitable temperatures and level out the perpetual imbalance in solar radiation received at the Equator and the poles. But because both systems convey such a massive amount of energy, they are also the wellspring of many of the most important perils that endanger life and property. And now that we humans have altered substantially the makeup of both the atmosphere and the ocean, we should not expect them to act the same in the future as they have in the past.



The Weather and Climate Hub continues to help chart the course for research on the Earth's climate system at WTW and connect our colleagues and clients with top-tier experts in meteorology, climatology, and natural hazards. Our research portfolio is also expanding to understand and anticipate the social and economic effects of both sudden weather-related disasters, and chronic environmental problems caused, or made worse, by climate change. On top of all that, our team is looking beyond physical hazards to diagnose potential pitfalls along the road to carbon neutrality and Net Zero emissions and to survey the emerging landscapes of climate law and liability.

Owing to WTW's origins in the insurance and reinsurance industries, our Hub sponsors an impressive roster of projects directed at severe storms. Together with our academic and government partners, we are building better physical models for tropical cyclones, creating new methods to gauge the risks of tornado outbreaks and extreme windstorms, and mapping the prospect of severe hailstorms over the entire globe. We are also working to identify novel threats to human health such as dangerously high heat, and to leverage expertise in weather prediction to produce advance warnings of impending food insecurity, particularly those affecting children.

Many weather- and climate-related perils are also strongly intertwined and can combine to damage critical infrastructure or delay operations. Heavy rains from hurricanes can oversaturate soils and make rugged terrain more vulnerable to landslides. Drought that persists for several years will shrink water supplies and reduce agricultural productivity, but it can also set the stage for dust storms or wildfires later. New and ongoing research supported by our Hub is helping to meet the unique challenge of managing a disparate suite of perils in an increasingly correlated world.

Side by side our views on physical risks, the Weather and Climate Hub is widening its interests to consider the challenges and opportunities spun off by the leap to a greener, less carbon-intensive economy. Our first foray into transition risk has focused on efforts to decarbonize the global aviation system. We are also assisting financial institutions acting to align their investments

with mitigation and adaptation goals and are enthusiastically cultivating new research partnerships on that topic.

Finally, our team is excited to support new research on the present and future risks of litigation tied to climate change. More and more commonly, parties that have suffered losses due to climate change are seeking redress from those they believe to be liable. But many organizations don't know where to begin to assess their exposure to climate litigation. Early in 2023, WTW will release a comprehensive report that will review key regulatory mandates related to climate liability and outline how industry can assess and reduce its climate litigation risk.

Thinking ahead, the Weather and Climate Hub will continue to buttress WTW's position as a global leader in risk solutions. We are preparing new projects that will weave together long-range climate forecasts and near-term weather simulations to yield more



realistic predictions of conditions on the ground for the next 5, 10, or 20 years. We also plan closer coordination with our Earth Risk and Flood and Water Management Risk hubs so we can better anticipate the potential threats of co-occurring or compounding risks from natural catastrophes.

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What's the use of having developed a science well enough to make predictions if, in the end all we're willing to do is stand around and wait for them to come true?

F. Sherwood Roland
University of California, Irvine

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Through his research, the late Sherwood Roland – awarded the Nobel Prize for discovering that Chlorofluorocarbon (CFC) gases damaged the ozone layer – made clear that science is obligated to not only put a name to problems but also to cultivate effective and actionable solutions. Thanks to recent and spectacular progress in meteorology, climatology, and their cognate disciplines, we now have at hand a remarkable array of tools to predict weather- and climate-related hazards and moderate their effects. In the coming year, it will be our privilege to support all work by WTW and our research partners aimed at guarding against catastrophe and preparing for life on a warmer world.

Scott St. George

Head of Weather and Climate Risks

Daniel Bannister

Weather and Climate Risks Manager



Understanding global wind and rain risks due to tropical cyclones

Tropical cyclones (TCs) are a multi-peril phenomenon. When we think of TCs we first think of the destructive wind damage.

But TCs can also bring secondary perils such as catastrophic coastal storm surge, inland flash flooding and riverine flooding, which are often responsible for most fatalities. Further cascades can also follow from indirect risks such as mudslides and compromised water quality. The impacts can vary depending on local topography and land use, which is an under-researched area that has required more focus.

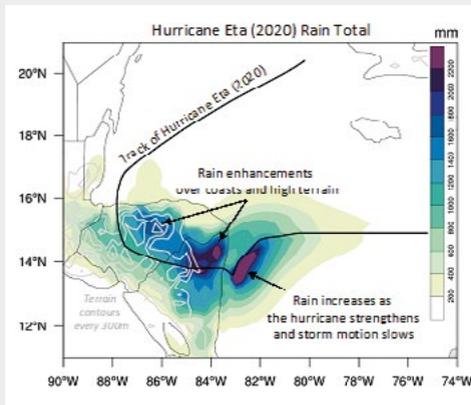
The WTW Research Network has been exploring these knock-on effects in partnership with the National Center for Atmospheric Research, building on our previous collaborations to join rainfall onto our existing capacity to model the wind footprint of tropical cyclones.

Our prior work gave us the ability to generate TCs wind footprints anywhere on Earth, and for both historical events and synthetic events based on hypothetical scenarios. The key advance of that wind model was the inclusion of realistic terrain and land use effects on the surface winds while retaining fast computational performance. This innovation was achieved by using a physical model of the TCs winds in the lowest two kilometers of the atmosphere. Close to the Earth's surface, winds speed up over hills and slow down over urban areas, which are factors that must be considered when simulating the total impact of TCs.

This physical modeling approach is now being applied to TCs rain. Here we are using an existing published TCs rain module and connecting it to our wind model to create physically consistent wind and rain footprints. This rain module includes the essential physical processes that generate rain within a TCs and does so extremely quickly.

A preliminary example of a rainfall footprint generated using this model is shown here for Hurricane Eta, which devastated parts of Central America in early November 2020. In our simulations, we see increased rain production just prior to landfall associated with the intensifying storm and slowing forward motion, and increased rainfall at the coast and over inland mountains.

Fig. 1: TCs Rain modelling for Hurricane Eta



Source: National Centre for Atmospheric Research



**National
Centre for
Atmospheric Research**

Dr. James Done is the director of the Capacity Center for Climate and Weather Extremes at the National Center for Atmospheric Research. He is a Senior Academic Fellow of the WTW Research Network. His research extends across a range of extreme weather and climate phenomena and connects with risk managers to strengthen the science and ensure business relevance. In recognition of his scientific leadership, he testified before the U.S. Congress on extreme weather in a changing climate. Dr. Done received his Ph.D. in Meteorology from the University of Reading, U.K. in 2003.

This new modeling technology will be used to provide a new perspective on the twin risks of wind and rain from tropical cyclones, both now and in the future. In a changing climate. We are excited to explore how wind and rain behave together as storms track inland, how wind-rain relationships differ among global regions, and how these relationships may change in a changing climate.

Confronting hailstorm risk: The latest efforts on hailstorm detection and modelling

Understanding the risk of hailstorms (in terms of frequency and intensity), under the background of ongoing climate change, is imperative. The development of extreme hailstorm climatologies, has advanced considerably in recent years, from using climate reanalysis data, to climate model outputs, and remotely-sensed observations.

When Hail Falls

Severe convective storms provide the perfect environment for large hail; they are characterised by very intense and deep updraft cores which take moisture from the lower parts of the atmosphere all the way to below freezing level. When large hail falls, it becomes one of the most destructive and costly types of severe weather, forming a significant contribution to natural hazard losses in various parts of the world. In South Africa, for example, hail has long been known to generate large amounts of damage to exposed assets, such as crops,

buildings, infrastructure, and vehicles.

One of the most widely documented and devastating hailstorms occurred on 28th November 2013, in the Gauteng province, with the reinsurance industry reporting estimated losses of ZAR 1.4 billion¹.

Therefore, understanding when and where such events could occur is essential, for both insurance pricing and preventive measures.

In comparison to other perils, the sporadic occurrence and highly localized effects of hail pose a particular challenge to hazard quantification, which forms the basis for any risk modelling. Records of hailfall, including size information, is limited to reports from volunteer observers or hailpad networks that operate in a few regions. Remote sensing data from either radar or satellite instruments is required to determine the spatial extent of hail events and to depict the geographic distribution of the hazard. Even though satellite data is a less accurate proxy for hail compared to radar, the big advantage is that this data cover (comparatively) larger domains almost homogeneously at high spatial resolution.

¹ Powell, C. L., & Burger, R. P. (2014). The severe Gauteng hailstorms of 28 November 2013.

Hailstorm Detection and Modelling

The WTW Research Network together with KIT have a long-standing cooperation with NASA in hail hazard and risk assessment to explore these challenges. These assessments use overshooting cloud tops (OT, defined as transient intrusions of tropospheric air into the lower stratosphere indicating an intense updraft of a thunderstorm cloud) as indicators for hail.

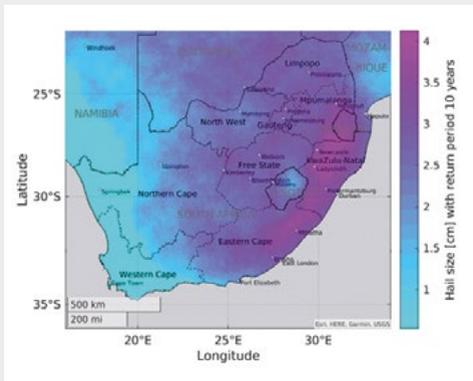
Over the past decade, hail risk models have been developed for Europe, Australia, and – most recently – for South Africa. Guided by 14 years of geostationary and low-Earth-orbiting satellite observations of convective storms, hail events were reconstructed from satellite OT data and filtered by reanalysis (ERA5) to estimate South Africa’s hail hazard.

To describe the spatio-temporal extent and characteristics of potential hail events in a reliable way, the research collaboration has developed a new methodology for the clustering and tracking of OTs.

According to the results², hailstorms mainly occur in the southeast of the country, along the Highveld, and around the eastern slopes. Figure 1 shows the hail diameter that can be expected once per decade at a given location. Events are most frequent from mid-November through February and peak in the afternoon, between 1300 and 1700 UTC. Multivariate stochastic modeling of event properties yields an event catalog spanning 25000 years. This stochastic event catalogue is then used to estimate, in combination with vulnerability and exposure data, hail risk for return periods of 200 years, a quantity required by the insurance industry.

In addition, scientists at NASA Marshall Space Flight Center have recently developed an algorithm that estimates a storm’s probability of severe hail using low-Earth-orbiting passive-microwave instrument data³. Passive-microwave instruments measure upwelling radiation from the earth’s surface, that is scattered away by large ice particles in some clouds, resulting in a distinct signature of hailstorms in the data. This signature is used to make a function that estimates the probability of severe hail in any storm observed by a given satellite, trained using ground-based reports of hail with at least 2.5-cm diameter in the U.S.. These probabilities can then be added up, smoothed for area and satellite orbit, and used to make a near-global climatology of

Fig. 1: Maximum hail size occurring once in 10 years for grid cells across South Africa, computed as the lowest hail diameter class with the stochastic hail model.



Source: ²Punge, H. J., Bedka, K. M., Kunz, M., Bang, S. D., and Itterly, K. F.: Characteristics of hail hazard in South Africa based on satellite detection of convective storms, Nat.

² Punge, H. J., Bedka, K. M., Kunz, M., Bang, S. D., and Itterly, K. F.: Characteristics of hail hazard in South Africa based on satellite detection of convective storms, Nat. Hazards Earth Syst. Sci. Discuss. [preprint], <https://nheiss.copernicus.org/preprints/nheiss-2021-342/>

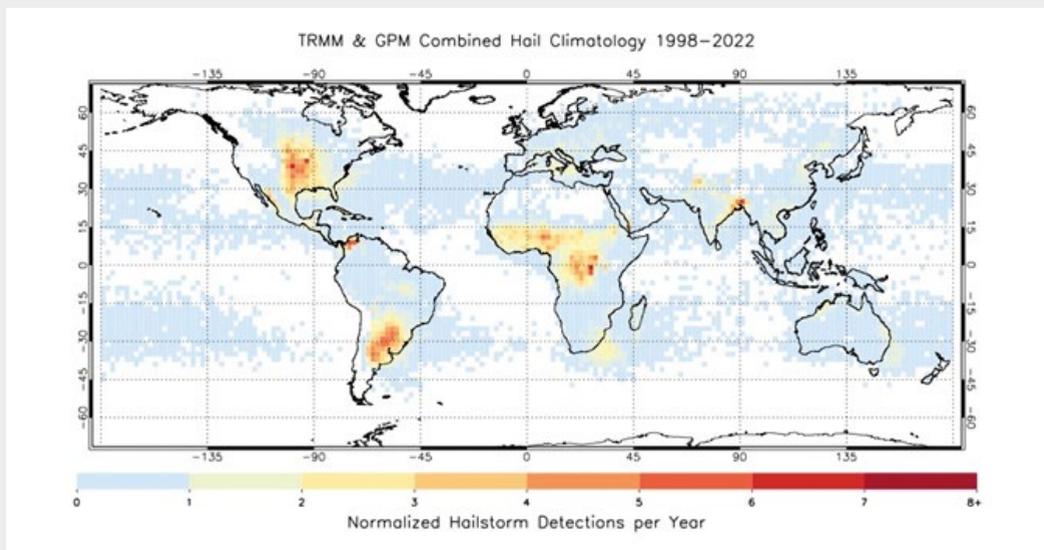
³ Bang, S. D., & Cecil, D. J. (2019). Constructing a Multifrequency Passive Microwave Hail Retrieval and Climatology in the GPM Domain, Journal of Applied Meteorology and Climatology, 58(9), 1889-1904. <https://journals.ametsoc.org/view/journals/apme/58/9/jamc-d-19-0042.1.xml>

severe hail (Figure 2), even over remote, data-sparse areas, offering another view of the hail hazard beyond the regional analyses performed with geostationary imagery. Hail climatology datasets, extending over a 25-year period, have been made freely available to the public from the NASA Global Hydrometeorology Resource Center (GHRC) at ghrc.nsstc.nasa.gov/pub/hail_climatology/data.

Ongoing Work

Looking ahead, KIT and NASA will continue to apply geostationary satellite, passive microwave climatologies, and reanalysis to further study OT characteristics and convective storm parameters to better detect and constrain and hail risk (particularly over South America and Australia) while also improving our knowledge of how this hazard might evolve under climate change. Keep an eye out for future WTW Research Network insights and blogs as this exciting research continues to develop.

Fig.2: Annual rate of severe hailstorms derived from TRMM and GPM Microwave Imagers, 1998-2022.



Source: ³Bang, S. D., & Cecil, D. J. (2019). Constructing a Multifrequency Passive Microwave Hail Retrieval and Climatology in the GPM Domain, *Journal of Applied Meteorology and Climatology*, 58(9), 1889-1904. <https://journals.ametsoc.org/view/journals/apme/58/9/jamc-d-19-00421.xml>



Karlsruhe Institute of Technology & NASA

From the first fully probabilistic hail model, through a project initiated by Karlsruhe Institute of Technology (KIT), in 2014, to today's ongoing collaborative project between KIT and NASA, our researchers at KIT (Professor Michael Kunz and Jannick Fischer) and NASA (Kristopher Bedka) are continuing to improve our understanding of hail risk. WTW have been able to utilise such information to inform clients about the loss potential from severe hail, thus not only improving our knowledge and understanding but also helping to satisfy regulatory and portfolio optimization requirements.

Understanding variability in European windstorm risk

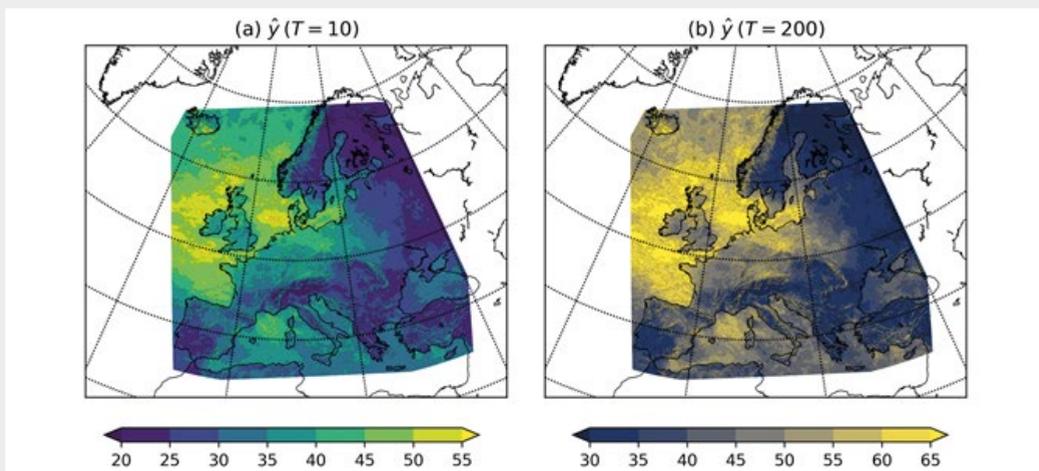
Historically, climate scientists are limited to only a few decades of comprehensive observational data, which makes estimating return periods of rare events challenging.

Further complicating this is that estimates are often sensitive to the length of historical catalogue used. Through our long running partnership, the University of Exeter have developed a reliable method to estimate extreme windstorm gust speed return levels from a multi-year sample of windstorm footprints and without the complications of complex catastrophe models.

Using statistical methods, WTW Research Network Fellow Dr Matthew Priestley, guided by Professors David Stephenson and Adam

Scaife, have developed a novel model for estimating wind gusts across Europe at up to the 200-year return period with a resolution of 4.4 km (Figure 1). This model uses observed windstorm footprints from the Windstorm Information Service (WISC) project as an input and is flexible to allow for varying amounts of input data to test the sensitivity of estimated return levels to catalogue length. The model requires a multi-year set of windstorm footprints, from which we deduce the intensity, their rate of occurrence, and a probability of occurrence. As the North Atlantic Oscillation (NAO) is the leading driver of weather variability across Europe, they have also been able to include historical variations of the NAO in the model, which is often not considered in risk models. This therefore allows for the return level estimates to vary with the phase of the NAO.

Fig.1: Estimated wind gust return levels at the (a) 10-year and (b) 200-year return level derived from our statistical model using WISC footprints from 1950-2014. Units are m s^{-1} .



Source: Windstorm Information Service (WISC) project

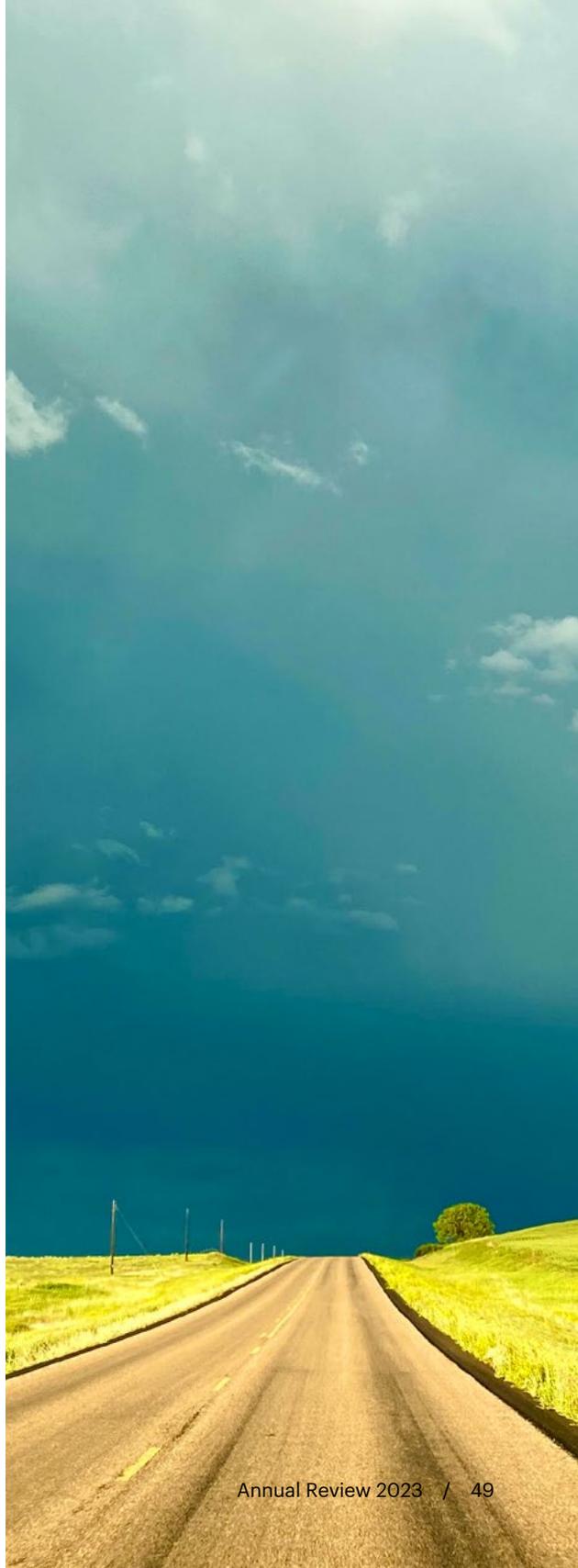
Results have revealed that the NAO is very important for modulating low return period gusts and act as a pre-conditioner of the atmospheric state. In contrast, the most extreme gusts can be assumed to occur due to further stochastic processes. The University of Exeter have also been able to quantify the optimal length of historical catalogue required to generate the most accurate return level estimates for a variety of return periods. The model can generate return level estimates for several different input datasets and in the future may be applicable to other natural hazards.

The work at the University of Exeter will continue to focus on further drivers and factors affecting windstorm variability which will allow them to offer new insights into historical, and future, windstorm risk across Europe. In the meantime, watch out for this work to be published in 2023.



Dr. Matthew Priestly
University of Exeter

WTW Research Network Fellow, Dr Matthew Priestley's current research is on European winter storms, with focus on constructing and evaluating present day risk. A further goal is on understanding the impact of climate change on future risk estimates. At the College of Engineering, Mathematics and Physical Sciences, he works with Professor David Stephenson, Chair in Statistical Climatology (also a founding member of the WTW Research Network) and Professor Adam Scaife, to develop new insights and views of European windstorm risks.



Modelling the risk of climate change litigation for (re)insurers

Climate change litigation presents a unique set of risks and opportunities to (re)insurers, who face the challenge of understanding their current portfolio exposures to climate litigation risk, reserving for potential losses, and pricing new products that may be affected by climate litigation.

However, (re)insurers have struggled to assess climate litigation risk in the face of significant uncertainty, and a recent Bank of England “climate stress test”¹ suggests many insurers lack the capacity to assess their exposure to climate litigation.

Beyond their financial value, climate litigation risk assessment tools are crucial because (re)insurers are uniquely positioned to develop and propagate risk disclosure and reduction techniques. Some categories of climate litigation risk, like regulatory and governance claims, are susceptible to value-positive risk mitigation techniques. By pricing litigation risk and propagating effective governance and risk assessment processes, insurers can help their clients mitigate claims by reducing the damage underlying climate liability.

In a new partnership with the WTW Research Network, lawyers and researchers from the Sabin Center for Climate Change Law at Columbia Law School are conducting a broad assessment of (re)insurer climate change litigation risk. This research will ultimately support the development of climate change litigation models, mitigation strategies, and risk allocation products.

This collaboration has produced an internal scoping report that details the landscape of climate litigation risk assessment, informed by a combination of desk research and field interviews with specialists familiar with climate litigation risk analysis. In this report, our team of experts has:

- highlighted key dimensions of climate litigation risk and charts the impact of climate litigation risk across (re)insurers’ business operations and product lines;
- assessed existing qualitative and quantitative climate litigation risk modelling frameworks and identifies key risk drivers shaping climate litigation risk; and
- reviewed key regulations, cases, and resources related to, informing, or affecting global climate litigation risk analysis.

¹ <https://www.bankofengland.co.uk/stress-testing/2022/results-of-the-2021-climate-biennial-exploratory-scenario>

As a next step, researchers at the Sabin Center will work with the WTW Research Network to produce a white paper that synthesizes regulatory mandates and industry best practices surrounding the assessment and reduction of climate litigation risk. We plan to release the white paper early in 2023, so please follow the WTW Research Network for more information coming soon!



Professor Michael Burger

Executive Director,
The Sabin Center for
Climate Change Law



Martin Lockman

Climate Law Fellow and
Associate Research Scholar,
The Sabin Center for
Climate Change Law



The Sabin Center for Climate Change Law

Since 2009, the Sabin Center for Climate Change Law at Columbia Law School has driven research in the interrelated fields of climate law, environmental regulation, energy law, and natural resources law. The Sabin Center develops legal techniques to fight climate change, trains the next generation of climate lawyers, and provides up-to-date resources on key topics in climate change law and regulation. Executive Director Michael Burger and Climate Law Fellow Martin Lockman are working with the WTW Research Network to help better understand and manage risks from climate change litigation.



La Niña and US tornado outbreaks

Severe thunderstorms accompanied by tornadoes, large hail, or damaging straight-line winds result in substantial insured losses in the US each year.

The El Niño-Southern Oscillation (ENSO) has been identified as a climate factor which modulates US severe thunderstorm activity, with La Niña being associated with increased activity in spring. The role of ENSO is crucial as severe thunderstorm activity in spring can be predicted based on the ENSO phase during the preceding winter, and there may be correlations with other ENSO-sensitive hazards such as Atlantic hurricanes.

Robust estimation of the ENSO signal in US severe thunderstorm activity is challenging because of the modest number of ENSO events during the last 30 or 40 years when reliable storm reports are available. To work around that limitation, Prof. Michael Tippet and Dr. Chiara Lepore produced more than 8,000 years of synthetic data from a physics-based climate prediction model that simulates the Earth's oceans (including ENSO) and atmosphere (including weather; Tippet and Lepore, 2021). Because this model cannot directly represent tornadoes, they instead focused on those weather conditions that tend to go along with

tornadoes. In a 2021 article in *Geophysical Research Letters*, they found the relation between ENSO and tornado weather is strongest in February and March and that more tornadoes than usual are expected during La Niña conditions but that the exact number is highly uncertain.

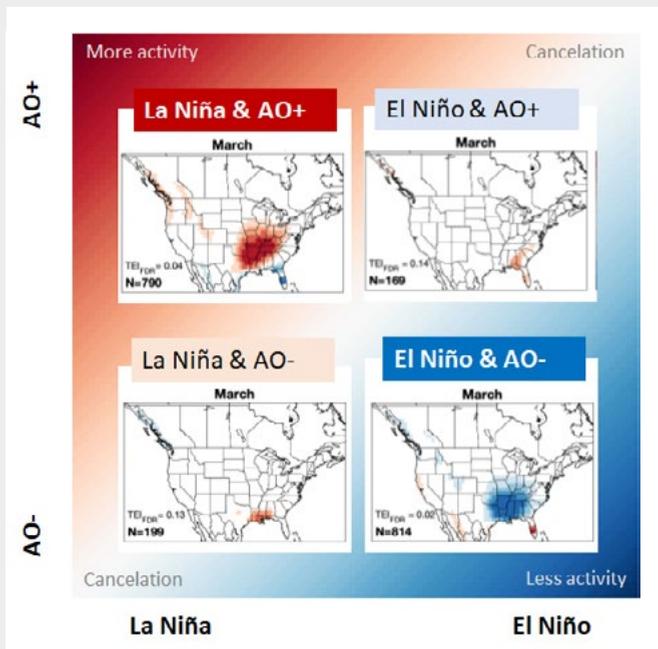
One reason for this uncertainty is that another climate factor, the Arctic Oscillation (AO), can either enhance or cancel the ENSO signal depending on its phase.

In a 2022 paper for *Weather and Climate Dynamics*, Michael Tippet and colleagues showed that when ENSO and the AO act in concert, their impact is large, and when they oppose each other, their impact is small (Figure 1). This new understanding of the combined ENSO-AO impact is relevant for understanding situations such as in early 2021 when both strongly positive and strongly negative AO events occurred during La Niña conditions.

Future work will examine the role of ENSO on tornado outbreaks. Understanding the role of ENSO is also relevant in the context of climate change. Although work led by Dr. Lepore has demonstrated that climate change will increase the frequency

of conditions that are favorable for US severe thunderstorms, climate projection models appear to be biased toward El Niño conditions which means that the increase may actually be underestimated.

Fig.1: When the El Niño-Southern Oscillation (ENSO) and the Arctic Oscillation (AO) act in concert, severe thunderstorm activity is increased (red; La Niña and AO+) or decreased (blue; El Niño and AO-). When they oppose each other, there is cancelation and near-normal activity (white) is expected.



Source: Weather and Climate Dynamics, 2022



Michael Tippett
Columbia University

Michael Tippett is an Associate Professor in the Department of Applied Physics and Applied Mathematics at Columbia University. Tippett investigates how

severe thunderstorms (those resulting in tornadoes, hail, or damaging wind) and tropical cyclones are related to climate, now and in the future. He is a co-author of the 2022 textbook *Statistics for Climate Scientists*.

On co-occurring and cascading hazards

Under the background of ongoing global climate change, we traditionally think of how the risk, vulnerability, and exposure of a society changes to individual hazards: it is well known that extreme events (like maximum day-time temperatures, rainfall, and wildfires) are projected to increase in frequency and in magnitude, and it is relatively easy to model and account for such future trends in risk management.

But what happens when natural hazards and disasters co-occur (events which occur simultaneously) or cascade (events which lead to, or are a consequence of, another)? How will climate change alter the (inter)dependency between individual and interrelated hazards? And since pricing physical climate risks is already uniquely challenging, how can we better integrate co-occurring and cascading hazards into existing and future disaster risk management and decision-making frameworks?

Nature's Complexity

Traditional risk assessment frameworks frequently use statistical methods and techniques to identify and isolate historical trends in the trigger, magnitude, or the frequency of an individual hazard, often from (patchy and discontinuous) observational datasets. While this captures the risk one hazard at a time, it does not adequately capture the risk associated with co-occurring or cascading hazards. For instance, alone, an individual but prolonged drought or heat wave can trigger significant socioeconomic effects. However, droughts and heat waves can also trigger and intensify wildfires, which in themselves further trigger other cascading hazards. The complex, interrelated nature of extreme events has the potential to turn otherwise moderate events into disasters¹.

¹ AghaKouchak, A., Huning, L.S., Chiang, F., Sadegh, M., Vahedifard, F., Mazdiyasn, O., Moftakhari, H. and Mallakpour, I., 2018. How do natural hazards cascade to cause disasters?

² Li, C., Handwerger, A.L., Wang, J., Yu, W., Li, X., Finnegan, N.J., Xie, Y., Buscarnera, G. and Horton, D.E., 2022. Augmentation of WRF-Hydro to simulate overlandflow-and streamflow-generated debris flow susceptibility in burn scars. *Natural Hazards and Earth System Sciences*, 22(7), pp.2317-2345.

Spotlight on Co-occurring and Cascading Hazard Research

To close the gap between risk management and business decision making frameworks and processes with the risks posed by complex natural hazards, we need to improve our fundamental understanding and modelling of the interrelated nature, characteristics, and trigger mechanisms of co-occurring and cascading hazards. In 2022, the WTW Research Network has supported numerous academics, across the atmospheric and geophysical hazard space, considering various angles of co-occurring and cascading hazards. These include:

- James Carruthers, Dr Selma Guerreiro, & Professor Hayley Fowler (Newcastle University): “High resolution climate modelling of extreme weather hazards and application to the analysis of risks relating to climate change” – James’ PhD project will involve designing relevant metrics that capture the frequency and severity of storm and flooding hazards from high-resolution climate model outputs for global-scale diagnostic risk and impact assessment
- Dr Hannah Bloomfield (University of Bristol): “Compound wind and flood risk over Europe” – Hannah has been exploring the current and future joint risk between heavy rainfall and strong wind events when they co-occur across Europe, with her journal article published earlier this year³

- Dr Matt Priestley, Professor David Stephenson, & Professor Adam Scaife (University of Exeter): “Climatic drivers of extreme European windstorms” – The research at Exeter University will look at how European windstorm activity can be predicted on a seasonal to decadal timescale, and how climate change and natural variability is affecting the number, timing, and frequency of European winter storms
- Dr John Hillier (University of Loughborough): “ROBUST - Enabling better management of UK multi-hazard risk” – ROBUST builds on⁴, which identified that the most damaging flooding and extreme wind events in the UK tend to occur in the same season but not necessarily during the same storm. ROBUST will further contribute to providing a better understanding of multi-hazard risk and how this may change with climate change to quantify likely future losses and impacts

In 2023, we will continue to coordinate with our existing and new academic partners (including the National University of Singapore), as well as with our clients, to develop event sets of co-occurring and cascading hazards and to define the rigorous techniques required to quantify and mitigate them.

³ Bloomfield, H., Hillier, J., Griffin, A., Kay, A., Shaffrey, L., Pianosi, F., James, R., Kumar, D., Champion, A. and Bates, P., 2022. Co-Occurring Wintertime Flooding and Extreme Wind Over Europe, from Daily to Seasonal Timescales. Available at SSRN 4174051.

⁴Hillier, J.K., Macdonald, N., Leckebusch, G.C. and Stavrinides, A., 2015. Interactions between apparently ‘primary’ weather-driven hazards and their cost. Environmental Research Letters, 10(10), p.104003.

The WTW Research Network also supports projects on interconnecting risks and how physical hazards impact critical infrastructure and organisational systems. For instance, a project with Mitiga Solutions (“Volcanic Ash Risk Transfer in Aviation (VOLARISK)”) aims on providing a global, high-resolution probabilistic view of volcanic ash risk for the aviation industry to understand how this individual hazard has the potential to disrupt infrastructure (e.g., aircraft maintenance and safety), organisational (e.g., supply and procurement chains), and technological (e.g., flight operations) systems. Such work can provide a better understanding of how the co-occurrence or cascading nature of two or more hazards also intersects the human and socioeconomic systems.

Thinking Ahead

Climate scientists understand that individual extreme events are increasing (in terms of their magnitude and frequency) due to climate change. While the risk posed by

individual hazards will increase in a warmer world, so too will the associated risks of co-occurring and cascading hazards.

Therefore, it is apparent that there is a clear gap in research, and in the application into disaster risk management, in how one extreme event may alter all other interrelated hazards (whether that is via co-occurring and cascading, simultaneous or asynchronous, occurrence) and how this further disrupts socioeconomic systems.

The research the WTW Research Network supports on the nature and dependencies of these events enables the community to identify appropriate datasets, methodologies, and technical approaches to analyse, simulate, and estimate the risk, vulnerability, and exposure of a society for accurate and decisive risk management and insurance purposes.



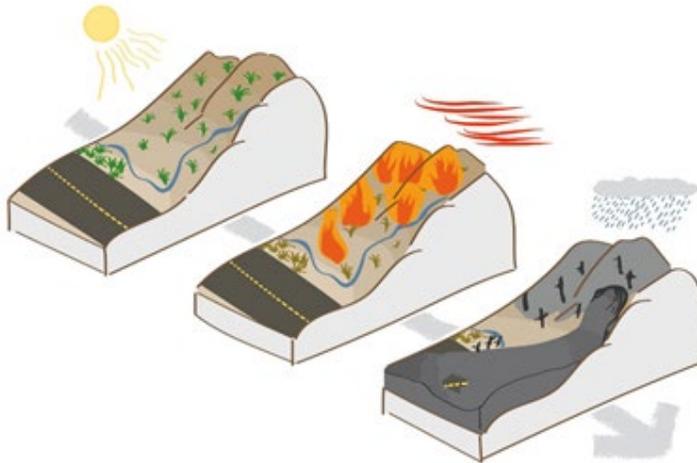
Case study:

Landslides: A Cascading Hazard

Landslides are a major hazard that have the potential to cost millions of dollars in damage, and cause thousands of fatalities,

across the world every year. While the primary trigger for a landslide is usually heavy rainfall or seismic activity, they are also frequently a consequence of two or more consecutive hazards, such as extreme rainfall over a burned area, see Figure 1².

Fig.1: Schematic diagram depicting events leading to a landslide: drought, followed by wildfires, followed by intense precipitation.



Source: Tierney Acott/Institute of Sustainability and Energy at Northwestern.

A recent example of this is the mudslides in Southern California in September 2022. The remnants of Tropical Storm Kay brought heavy rainfall to a region that had been scorched by a wildfire two years prior, leading to a mudslide which destroyed and damaged buildings, infrastructure, and vehicles. Since climate change has the potential to increase the likelihood of both wildfires and heavy rainfall events, how can we more accurately capture the co-occurrence in the trigger, magnitude, and frequency of both these hazards to better constrain immediate and future landslide risk? An added complexity to this question is also how individual but consecutive

wildfires and individual but consecutive storms will also change in the future: are consecutive wildfires correlated and does one wildfire precondition the environment for subsequent wildfires, and how does climate change and natural climate variability influence storm clustering?

Such examples emphasise how the non-linear (spatial and temporal) dependency and causal sequences between superficially individual extreme events makes them challenging not only to study but also to model in existing disaster risk management frameworks. This leaves society ill-prepared for co-occurring and cascading hazards.

Global event sets of dangerous heat

In partnership with the National Center for Atmospheric Research and as part of the WTW Challenge Fund, we are creating new views of global trends in heat dangerous to human health.

Heat can severely impact human health and cause ripple effects across societal systems such as the health sector, the global labor force, and national defense. Human heat stress is strongly related to air temperature and moisture content. Once air temperature exceeds 35°C, the human body can only cool through sweating and evaporative cooling. If humidity also increases, we reach an upper limit of survivability where sweat no longer evaporates and the body temperature rises. A measure of how well sweating cools us is obtained by wrapping a thermometer in a wet cloth. Like our skin, the thermometer cools through evaporation. Once this 'wet-bulb thermometer' reaches 35°C the body can no longer cool, and humans can only survive for a few hours. However, impacts on population health can start at much lower wet-bulb temperatures of 28°C.

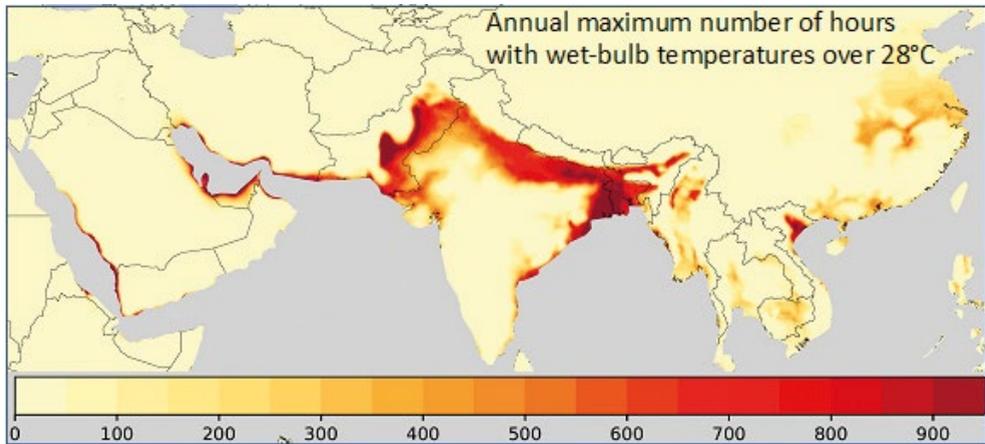
Some regions, such as the Arabian Peninsula, are already reaching critical points for human survival. Of particular concern are coastal locations where onshore moist flow off warm seas can combine

with hot inland air to create deadly humid heat. Historically, the geographic pattern of deadly heat has been concentrated in places where warm, moist air moves directly onto land (Figure 7). In low latitudes, this danger is most common in coastal areas and inland regions that experience strong monsoons.

Under climate change, the air warms and can hold more moisture. The combined increase in temperature and moisture has already driven a doubling in the frequency of extreme wet-bulb temperatures in some locations. And the global population exposure to humid heat has increased faster than exposure to dry heat. Looking ahead, even under the most optimistic future warming scenarios, deadly heat exposure will increase markedly. It is therefore imperative to understand the potential human health impacts.

This project uses a new object-tracking algorithm to identify and track humid heat objects geographically and through time. Collectively, these objects comprise a historical event set suitable for statistical analysis of event locations, timing, trajectories, intensities, and trends. Of particular interest are objects expanding into new territories and new seasons. The objects will also be used to calculate recent historical trends of heat metrics for key global cities including Los Angeles, Mexico City, London, Paris, Cairo, Sharm El-Sheikh, Dubai, Manila, and Sydney.

Fig.7: Map showing the annual maximum number of hours where wet-bulb temperatures have exceeded 28 °C in the Middle East, south and southeast Asia, and China.



Source: National Centre for Atmospheric Research



**Dr. James Done,
National Centre for
Atmospheric Research**

Dr. James Done is the director of the Capacity Center for Climate and Weather Extremes at the National Center for Atmospheric Research. He is a Senior Academic Fellow of the WTW Research Network. His research extends across a range of extreme weather and climate phenomena and connects with risk managers to strengthen the science and ensure business relevance. In recognition of his scientific leadership his scientific leadership, he testified before the U.S. Congress on extreme weather in a changing climate. Dr. Done received his Ph.D. in Meteorology from the University of Reading, U.K. in 2003.



Can we reduce infant hunger? The Guatemalan case

Food security remains a major challenge worldwide

For countries like Guatemala, the situation for children under five years old has become extremely alarming, with figures reaching almost fifty per cent for acute undernutrition in certain departments (primary administrative divisions) of the country, as per the IV National Survey of Infant and Maternal Health in Guatemala (ENSMI in Spanish).

Columbia University's International Research Institute for Climate and Society (IRI) has been working with the Secretariat of Food Security and Nutrition in Guatemala (SESAN) to help Guatemala achieve food security by co-developing climate services to support SESAN's decision-making process. Both institutions have been working together to co-develop an objective and reliable next-generation forecast system to predict the number of cases of acute undernutrition for children under five years old in each of the country's 22 departments. Starting with SESAN's conceptual model of drivers of food insecurity for children, the team developed a hierarchical probabilistic set of models using climate and socio-economic variables.

Thanks to the WTW Research Network, both institutions have been able to continue with the collaboration and develop an interactive online tool to be used by SESAN in their

decision-making process to fight acute undernutrition in children in Guatemala. The tool has the capacity to visualize which departments in the country present a higher risk of undernutrition in the target population using an objective, state-of-the-art forecast methodology. In addition, this collaboration allowed for the development and delivery by SESAN of NextGenNut, the interactive online tool mentioned above, in the form of regularly updated, actionable forecast products.

NextGenNut offers an accessible and intuitive way for decision-makers to monitor, in real-time, infant cases of acute undernutrition.

Moreover, NextGenNut gives SESAN and its partners early warning of expected hunger three to five months ahead of the actual impact, helping the country fight hunger department by department, and focus on those places where undernutrition is most acute.



IRI and SESAN had several meetings to discuss the conceptual model and to develop an interactive online tool to support SESAN's decision-making process. In this image are Gabriel José Pérez Tuna, Juan Roberto Mendoza Silvestre, Ana Gabriela Rosas García (SESAN) and Carmen Gonzalez Romero and Zain Alabweh (IRI). Photo credit: Ángel G. Muñoz.

NextGenNut enables SESAN and international partners, like the Pan American Health Organization and the World Food Program in Guatemala, to plan for food and nutrition interventions in advance and protect children's health. It will also allow SESAN and other organizations to allocate resources and target their interventions to areas with the greatest needs. Furthermore, early interventions, social programs and other anticipatory mechanisms could reduce the impact of food insecurity in children through a combination of SESAN's undernutrition monitoring system and this new forecast system developed with the support of WTW Research Network.

NextGenNut has the potential to be upscaled across Central America via IRI's long-term relationships, especially the Central American Regional Commission for Hydrological Resources. NextGenNut

can become a tool for humanitarian relief agencies such as USAID and the World Food Program, much like USAID's Famine Early Warning System is a mainstay of food insecurity planning. NextGenNut will increase Guatemala's capacity to develop more effective, anticipatory actions to fight the impact of food insecurity on particularly vulnerable populations.



Carmen González Romero

Carmen González Romero is presently Staff Associate III at Columbia University's International Research Institute of Climate and Society and PhD candidate at the University of Bologna. She has a multidisciplinary background with more than five years of experience in developing climate services for developing and developed countries. Starting in January 2023, she will serve as Social Scientist on Climate and Earth Quality Services at the Barcelona Supercomputing Center in Spain.

Ángel G. Muñoz

Ángel G. Muñoz is presently an Associate Research Scientist at Columbia University's International Research Institute of Climate and Society, focusing on climate variations and prediction at multiple timescales. Muñoz works on the development of climate services, especially those related to food security (involving models for undernutrition and human migration), vector-borne diseases and lightning activity. Starting in January 2023, he will serve as Senior Research Scientist for Climate Services at the Barcelona Supercomputing Center in Spain.

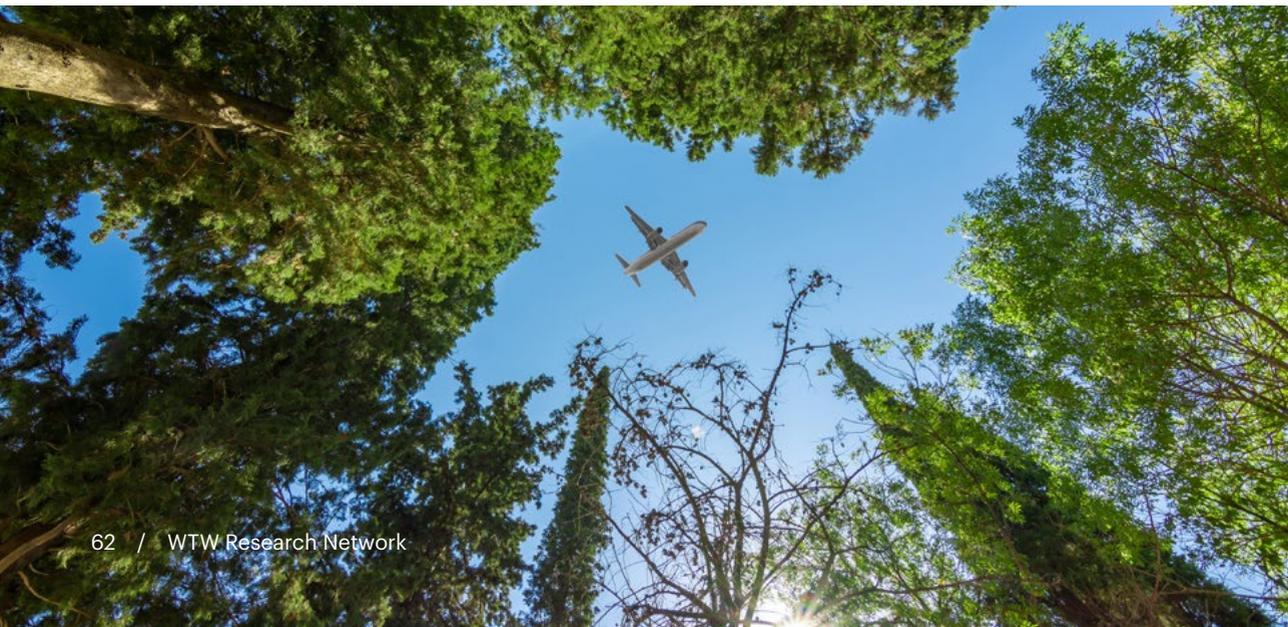
The sky's the limit: sustainable aviation

The path to net zero for the aviation sector is a complex yet necessary challenge that no single stakeholder can solve on their own.

Direct aircraft emissions alone, globally, account for approximately 3% of all anthropogenic carbon dioxide (CO₂) emissions, and while regulators and consumers have raised ambition within the sector, a rapid lift off is needed to meet the goals of the Paris Agreement. A whole host of different measures are required to overhaul both the direct and indirect emissions produced by the entire aviation system (aircraft manufactures, airlines, and airports). With changes needed to: aircraft design, development, testing, and certification, airport vehicular operations and waste management, sustainable clothing for aircraft crew and airport staff, and more.

Towards Zero Carbon Aviation

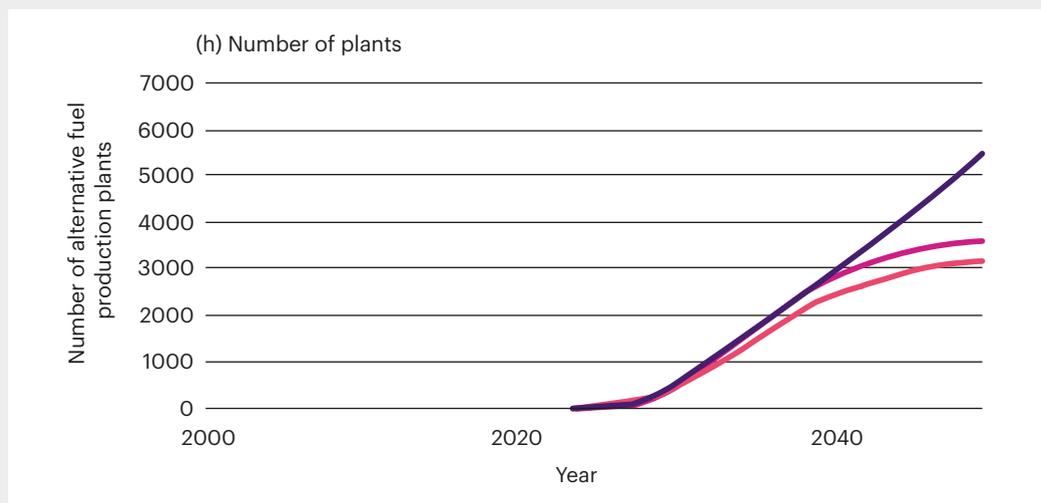
To support the industry with this challenge – and bringing our clients perspectives to the table – the WTW Research Network have been supporting the 3-year Towards Zero Carbon Aviation (TOZCA) project led by Professor Andreas Schäfer at the Air Transportation Systems Lab, University College London. In last year's review, we shared details on TOZCA, which will examine how the sector can realistically move towards a net zero climate impact global aviation system by 2050, and the costs and emissions trajectories associated with such transitions, looking at changes in technology, fuels, operations, competition, and consumer behaviour that can lead to drastic CO₂ emission reductions.



One year on, the team has provided an insightful update of their progress in a peer-reviewed article in Nature Climate Change: “Cost and emissions pathways towards net-zero climate impacts in aviation”¹. The key finding from the paper is that while demand for aviation will increase by as much as 3-fold by 2050, 90% decarbonization

can still be achieved through continued efficiency gains in aircraft and operations, and using ultra-green fuels derived from biomass or clean electricity. This is encouraging, and yet, the challenge is immense, requiring much coordination and investment (e.g., Figure 1).

Fig.1: Middle demand scenario projections of the number of alternative fuel (biofuel-only, purple; biofuel as a bridging fuel to power-to-liquids, yellow; biofuel as a bridging fuel to liquid hydrogen, red) production plants required to achieve net-zero climate impacts in 2050. See Dray et al. (2022) for further details.



Source: ¹Cost and emissions pathways towards net-zero climate impacts in aviation. Nature Climate Change, 12(10), 956-962. 2022

¹ Dray, L., Schäfer, A. W., Grobler, C., Falter, C., Allroggen, F., Stettler, M. E., & Barrett, S. R. (2022). Cost and emissions pathways towards net-zero climate impacts in aviation. Nature Climate Change, 12(10), 956-962. <https://www.nature.com/articles/s41558-022-01485-4>

Enabling Discussion to Accelerate Action

By design, the TOZCA project has the active support of several industrial partners in the aviation sector. In this group, WTW brings insights on risk management, insurance, and finance. In addition to joining the TOZCA advisory board, the WTW Research Network has organised a series of roundtables for a growing community of aviation and aerospace executives.

In March 2022, the first roundtable focussed on the opportunities and risks in transitioning to a net zero-carbon aviation

system. This was the first opportunity for a community, led by the science developed under the TOZCA project, to focus and discuss the ambitious, yet realistic, action plans needed for this industry to undergo an orderly transition.

In November 2022, a second roundtable with over 30 experts and leaders from across the industry (insurance, finance, services, public sector, energy, legal, airlines, airports, and academia) focused on how to overcome hurdles to the transition, and the relative contributions of science, policy, and markets to support the transition to a net-zero aviation system.

Three key areas, vital in driving and advancing change, emerged from the discussion:

1

More meaningful collaboration within the sector and across sectors (e.g., academia, policies)

2

Improved communication on the sector's endeavours to reach its Paris-aligned emission goals and targets

3

Additional support in the investment and development of methods and technology to deliver such changes.

While there is no silver bullet or one-size-fits-all solution that can switch aircraft manufactures, airlines, and airports to net zero within the next 10 years, the time for planning is disappearing and the industry will need to instigate take-off on decisions. Figure 1 helps to demonstrate the scale of the energy transition and required infrastructure for commercial-scale synthetic-fuel plants and the underlying renewable-power-generation

system – the next 10 years are critical in driving this transition. In 2023 WTW will be doing our part to support the industry in making decisions on investing in the right technologies and understanding factors such as changing consumer behaviours. These decisions as necessary and open the door to some of the most exciting transformation opportunities for the industry – the sky's the limit for those bold enough to embrace risk and turn it into opportunity.



University College London

WTW Research Network is supporting Professor Andreas Schäfer and his team, at the Air Transportation Systems Laboratory (University College London), for the EPSRC funded project TOZCA (Towards Zero Carbon Aviation). The Air Transportation Systems Laboratory explores the interaction between air transportation, the economy, and the environment. Their work is data-driven, using physical science, econometric, and operations research-based methods. The integrating mechanism is the Aviation Integrated Model (AIM), a unique tool, consisting of interlinked modules simulating current and future levels of global airport-to airport demand, flight schedules, arrival delay, technology uptake, aircraft performance, local and global emissions, aircraft noise, and the related environmental costs and economic benefits under a wide range of policy conditions.





Flood and Water Management





Flood and Water management

Casting back through 2022 we might remember Hurricane Ian, the calamitous flooding in Pakistan, South Africa and Australia to name a few. If not the floods, one might recall the droughts of the last year. In the American southwest, the Horn of Africa or China where low flows limited hydro power causing the lights in Shanghai to dim and made rivers in Europe and the United States unnavigable.

From a flood and drought perspective was 2022 an exceptional year with an unusually large number of rare events? Or in the face of the obvious evidence of climate change, have we become sensitised to natural disasters. Whether from the perspective of the scale of human suffering, or in insurance and capital markets, it is important to understand this to respond in an appropriate manner.

Either way a growing proportion of the world's population are at risk of flooding¹ and other severe weather events like wildfire or drought. Therefore, the need to develop tools that help improve the understanding of risk is obvious. We will continue to work with our partners at Newcastle University to improve and develop novel uses for the CityCAT model. This type of tool is useful to deal with simple cause and effect, for instance where heavy rainfall causes flooding.

¹ Tellman, B., Sullivan, J.A., Kuhn, C. et al. Satellite imaging reveals increased proportion of population exposed to floods. *Nature* 596, 80–86 (2021). <https://doi.org/10.1038/s41586-021-03695-w>



However, global systems are becoming more complex and interrelated, this makes it hard to understand overlapping vulnerabilities. There were several notable occasions in 2022 where one event could be linked to the another, or where the harm of subsequent events was amplified. An example of this occurred east of Los Angeles. In 2020 a fire scorched the hillsides leaving them bare and weakening the soil². This was followed in 2022 by rainfall on the burn scar which caused severe landslides putting lives at risk and damaging property.

The field of “compound” events, covering hazards as well as interacting risk, is receiving a lot of attention in academic and practitioner communities. This is not a new topic; it is covered in a 2005 Department for Environment Food and Rural Affairs report ‘Dependence Mapping and Best Practice³’. It has though gained prominence due to high impact events involving multiple drivers such as those described above. We will work toward a better understanding of the nature and dependences of these sequences to develop improved tools for analysis, simulation and estimation for risk management and insurance purposes.

While we will retain a global focus with Newcastle University, we will also zoom into South East Asia with our partners at the National University of Singapore. In this case we will also look at a range of CMIP6 (Coupled Model Intercomparison Project Phase 6) scenarios using regional climate models to show how the risk landscape is evolving. These will be used to unpack climate impacts on various sectors in the region.

This brings us back to water management in a changing climate. Traditional methods of reducing risk are effective but, owing to the carbon footprint arising from construction and operation of assets, the potential to use them may be limited. There are two ways around this which we intend to explore in more detail. Either, when our systems fail, we should ensure they do so gracefully and recover quickly; Or, we should find novel ways to reduce the risk of drought or flooding; Natural and Nature Based Solutions have the potential to fill a part of this gap and may also offer enticing co-benefits, however quantification of these benefits needs further development.

Neil Gunn
Head of Flood and Water Management

² After the Fires: Hydrophobic Soils. Dr Randy Brooks. University of Idaho Extension Forestry Information Series

³ Joint Probability: Dependence Mapping and Best Practice: Technical report on dependence mapping R&D Technical Report FD2308/TR1 March 2005

Climate gentrification

Physical climate hazards such as flooding, and wildfires present a major threat to mortgage lenders, insurers, and the broader financial system. It is becoming clearer that such hazards are increasing in frequency and severity, coinciding with increasing exposure of populations to such threats.

Physical climate hazards are not a new phenomenon – real estate markets have endured and been responsive to extreme weather events throughout history. However, as trends in extreme events emerge, there is growing evidence that these hazards are already having a direct monetary effect on property prices. Changes in property prices pose a major financial risk to homeowners, mortgage and insurance industries, bank portfolios, and wider financial systems.

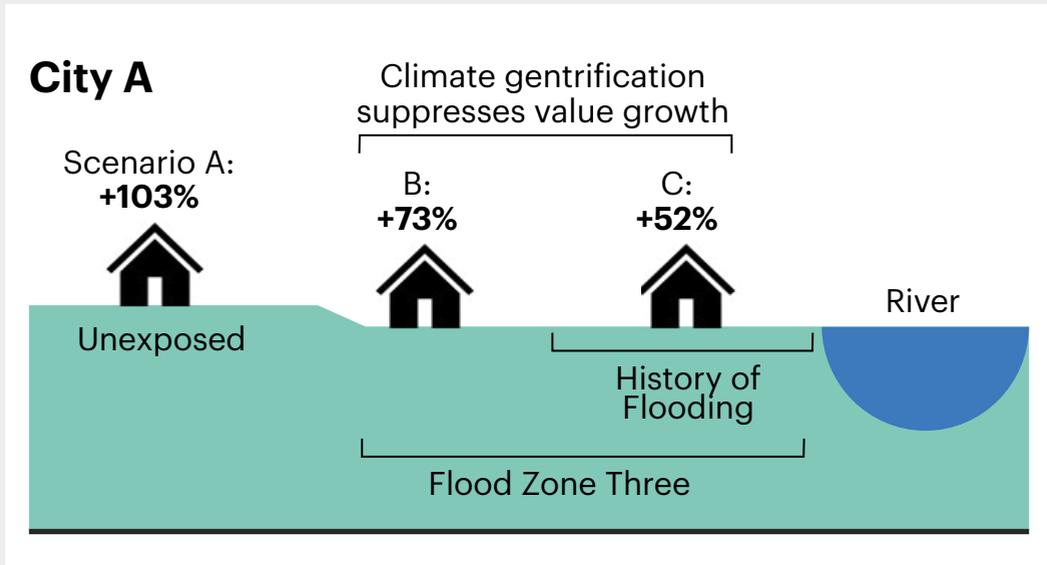
This is leading to a process of urban area selection where there is greater demand for properties possessing climate resilient traits (e.g. located at higher elevations). This is already driving up property prices possessing such traits, compared to properties more exposed and/or less protected against physical climate hazards that may experience discounted valuations. Climate gentrification describes this process of area selection and the collective effects of individual and collective investment responses to physical climate hazards (e.g. flooding and wildfires) in residential and commercial housing markets.

To demonstrate climate gentrification in action, we conducted a case study on a flood prone UK city. By using publicly available data a simple repeat-sale hedonic price model was developed to explore the effect of flood zoning and flood history on changes in property prices at the postcode level. Three scenarios were used to analyse changes in property prices (see Figure 1). We show that just by being located within Flood Zone 3 (defined by the Environment Agency as land with a 1 in 100 or greater annual probability of river flooding) on average, results in a price difference of 30%, relative to properties that are unexposed. This price difference is further exacerbated under scenario C, for properties that are located within Flood Zone 3, and have had a history of flooding.

Scenario A considers the change in price for properties unexposed to fluvial flood risk. Scenario B considers the change in price for properties located within Flood Zone 3 (defined by the Environment Agency as being land with a 1 in 100 or greater annual probability of river flooding).

Meanwhile, scenario C considers the change in property price for a property located within Flood Zone 3 and which has been flooded twice.

Fig. 1: **Climate gentrification in action within a flood-prone UK city. Results of the hedonic modelling show percentage changes in property prices in City A between 1995 and 2021 depending on location relative to fluvial flood risk.**



Source: Josh Thompson, Loughborough University

We aim to develop a forward looking analysis framework to understand how the effects of inland flooding (pluvial and fluvial) and coastal flooding, have on property prices, and how this may change under projected

storylines of climate change. In addition, we aim to investigate ethical considerations that should be considered in parallel to the due diligence on evaluating climate risk exposure.



Loughborough University and Josh Thompson

The Department Geography and Environment, in the School of Social Sciences and Humanities at Loughborough University conducts cutting-edge research, working internationally with other researchers, industry and government to increase understanding of our rapidly changing planet. It is recognized for excellence and leadership across six interdisciplinary research themes: Cities; Children, Youth and Families; Climate-Water-Energy; Hydroclimate, Risk and Resilience; Migration and Nation; Understanding and Managing Environmental Change. PhD researcher Josh Thompson is conducting this research under the supervision of Professor Rob Wilby, and aims to develop statistical methods to analyze climate gentrification and develop a forward-looking analysis to understand how the effects of flooding on property prices may change under projected storylines of climate change.

Transport resilience and recovery strategies

Climate change is leading to an increasing frequency and severity of extreme weather events. This requires new techniques to be developed to ensure that both existing and new transport networks are resilient to changing conditions.

Recent research has been focusing on predicting climate hazards and analysing vulnerability of infrastructure systems using numerical models while overlooking the benefit of real-time operation and rapid recovery plans.

Moreover, as trends in extreme events emerge, there is growing evidence that these hazards are already having a direct monetary effect on people's lives, travel, and even property prices. This leads to consider travel convenience and urban area selection. How to achieve the resilience of transport networks in the face of potential climate hazards is an urgent and important issue for managing insurance risk and resilience.

When facing the pressure of natural hazards, what is the first step toward creation of a resilient road network? What analytics might we need to develop advice to enable corporate, finance and public sector institutions to embrace the climate decade ahead.

This project will include solutions to reduce risks and arrange insurance and alternative risk transfer programmes across public, private and mutual sector companies.

This will help to direct sustainable and resilient investment thereby integrating climate risks into mainstream investment decision making, including portfolio allocation and asset valuation

For this research project, we will seek to understand to what extent it is realistic, with innovative approaches, to determine the resilience evaluation of road networks. Furthermore, it will help us to decide what further research will be needed for developing this solution, first as proof of concept, and then in subsequent commercial and public sector applications.

The project will work toward development of a topology-based evaluation approach of resilience on urban road networks against floods. As a result, the aims of this project can be summarized as follows.

- To conduct an in-depth assessment of resilience on urban road networks against floods;
- To perform comparative studies between the static and dynamic recovery strategies and quantitatively reveal the effectiveness and shortcomings in terms of the performance restoration.

This research project is made with a combination of literature review/interview and approach/demo development. The outputs of this project will include conducting a simulation-based comparative

investigation to understand the effects of floods and the recovery processes on urban road networks. This will be followed by the development of a topology-based evaluation approach of resilience on urban road networks against floods. Additionally, we will comparatively analyse the performance of urban road networks under two recovery strategies, namely the “First-Close-First-Reopen” recovery strategy and the dynamic recovery strategy. Finally, we will develop an illustrative case study based on London area. We will consider the system-of-systems level to cover related traffic alternatives, e.g., roads, rail, cycles, airplanes etc.



**Qiuchen LU, MPhil Ph.D. MCIQB
A.M.ASCE. Associate Professor in Digital
Built Asset and Facility Management
The Bartlett School of Sustainable
Construction, University College London,
UK. Director, Construction and Real Estate
Division, UCL Centre for Blockchain
Technologies**

Dr. Qiuchen Lu is an Associate Professor at The Bartlett School of Sustainable Construction (BSSC), University College London. Her research team facilitates the transformation of built environment towards the ‘3S (Smart, Sustainable, reSilient)’ future through digital technologies such as twins and AI. Towards 3S future of built environment, she has established a completed story of Digital Twins in the Built Environment, including creating the geometrical digital twins, exploring research and implementation of digital twins and building new values of digital twins from building to city levels. As the lead and first author, her work was published as the very first book related to digital twins in the built environment: Digital Twins for the

Built Environment: Fundamentals, Principles and Practice. Before joining UCL, she was a research associate at the Institute for Manufacturing, affiliated to the Centre for Smart Infrastructure and Construction and Centre of Digital Built Britain (CDBB), at University of Cambridge.

Her research team secured research grants as PI/Co-PI through the EPSRC and ICE to build smart and resilient city building and infrastructure systems, including ‘evaluation of resilience on urban road networks against epidemic spread’, ‘investigating the impact of adding new airline routes on air transportation resilience’. Her international reputation has been built on effective collaboration with an extensive network of academics and industrial practitioners. She was elected to be the Committee Chair of 30th European Group for Intelligent Computing in Engineering (EG-ICE2023) International Workshop, and will host the EG-ICE2023 at UCL with Cardiff University. She also sits on the European Committee of Young Experts in China Highway & Transportation Society, and is a Committee Member of ASCE Global Centre for Excellence in Computing and ASCE Data Sensing and Analysis Committee.

Tailings Storage Facilities

Recently published standards are a step in the right direction but there is more to do.

Tailings Storage Facilities (TSFs) rank among the largest engineered structures on earth and are required to store mining waste after ores are extracted. They are usually embankment dams made from locally won materials and thereafter the tailings are used in construction. Mine tailings are pumped or deposited into the sites as a slurry and are composed of fine silts and sands which can be toxic or radioactive.

The World Bank¹ acknowledges that the need for electrification of sectors and clean energy generation means a more mineral intense future than would be the case in a fossil fuel economy. More marginal ores are being exploited, generating more tailings in relation to the amount of ore won. After accounting for recycling, it is anticipated that the volume of tailings will increase by 26% over the next 5 years¹.

Failures of TSF can be catastrophic, leading to serious loss of life and extensive pollution, killing rivers and blighting landscapes to a point where remediation is prohibitively costly. Together with regulatory penalties and litigation, this has adverse effects on public perceptions of mining and investor confidence.

The life of a TSF starts in the operational phase where, after initial design and enabling works, the retaining embankment is progressively raised to store increasing volumes of waste. At the end of operational phase, the asset should be made safe for the remainder of its life. According to the International Commission on Large Dams (ICOLD), the post closure phase should be considered to last in perpetuity, during which the asset should function as an inert landscape feature.

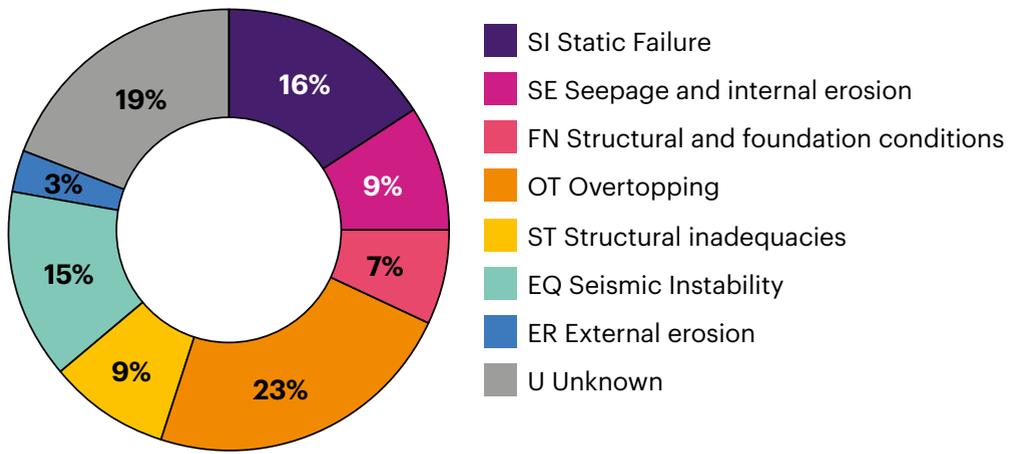
Records of the number and type of TSF are known to be incomplete, as are statistics on the causes of failure. Attempts have been made over the years to catalogue active and post have contributed to the understanding of the number and location of TSF But the picture is still hazy. In terms of describing the mode of construction or changes in asset condition.

There have been several other notable failures in the last decade. As a result, investors have encouraged operators to update standards and working practices. The outcome of this process is the 2020 Global Tailings Review. It has resulted in the publication of the Global Industry Standard on Tailings Management³ (GISTM). A recent publication in Nature² of the data compiled during the production of the GISTM notes that 10% of all tailings facilities have reported a stability issue.

¹ Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition. 2020 International Bank for Reconstruction and Development / The World Bank

² Global Industry Standard on Tailings Management 2020. <https://globaltailingsreview.org/global-industry-standard/>

Fig. 1: **Leading Failure Modes of TSF**



*MS Mine subsidence - not shown, no value

Source: Global Industry Standard on Tailings Management 2020.

We all learn from our mistakes and, in dam engineering, this is especially true. A recent paper⁴ analyses the statistics of TSF failure (Figure 1). Among the paradigms of a high risk TSF is of an operational facility using upstream construction. Given the dynamic nature of the operational phase, it is unsurprising that 90% of failures occur during this period. The causes of failure can be split into several categories but broadly the top three are driven by water-related issues, structural inadequacies or seismicity. As a side note the proportion of ‘unknown’ causes is a telling reflection of the historical quality of record keeping. Whatever the cause of failure, commentators universally identify that poorly developed ways of

working with inadequate engagement and supervision at a senior level amplify risks and allow the indicators of failure to go unaddressed.

ICOLD Bulletin 139 “Improving Tailings Dam Safety” (ICOLD, 2011) is under review and is likely to strengthen recommendations around accountability, responsibility and competency. It should also be noted that the standards the GISTM suggests are often exceeded by standards set within national jurisdictions. These local standards are set according to each society’s tolerance of damage or loss of life. Standards in GISTM are more tolerant of risk and puzzlingly refer to lower standard during construction when failure is most likely.

³ Tailings facility disclosures reveal stability risks, Daniel M Franks, Scientific Reports, Nature Portfolio 2021. <https://doi.org/10.1038/s41598-021-84897-0>

⁴A new look at the statistics of tailings dam failures; Luca Piciullo; Engineering Geology 303. <https://doi.org/10.1016/j.enggeo.2022.106657>

We are already experiencing the impacts of climate change. The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6)⁵ states that there is high confidence that recent heavy rainfall events that lead to catastrophic flooding have been made more likely by climate change.

Though there is uncertainty, extreme rainfall events which might cause a TSF to overtop are becoming more likely. In the UK, there

have been 20 instances since the year 2000 where the design precipitation for reservoirs has been exceeded. This puts a designer in an uncomfortable position where there is significant uncertainty for an asset that has a long lifespan.

The WTW Research Network is providing advice to clients through our academic linkages and in-house expertise. We will work through fault tree analysis to understand failure modes and breach sizes before we develop a CityCAT module tool to simulate how run out of viscous tailings might propagate, and visual wavebands is maturing.

As an underlying theme to technical drivers, the academic and technical literature agrees that risks are reduced where three steps are put in place:

1

Improved monitoring helps to identify crises soon enough to take remedial action. The offerings of in-situ and remote monitoring systems that can detect changes in position and moisture content remotely using Synthetic Aperture Radar and visual wavebands is maturing.

2

A well developed and exercised emergency plan might avert failure and /or mitigate impacts.

3

Neither though are of much use without strong organisational capabilities and corporate accountability to strengthen assurance.

⁵ IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3–32, doi:10.1017/9781009157896.001

<https://medium.com/illumination/new-international-esg-regulatory-proposals-in-a-nutshell-744f212dc34d>

<https://www.churchofengland.org/about/leadership-and-governance/church-england-pensions-board/pensions-board-investments/investor>

<https://www.churchofengland.org/news-and-media/investors-commit-further-action-mining-2nd-anniversary-brumadinho-tailings-dam>

https://www.bhp.com/-/media/documents/environment/2019/190607_coe.pdf

Underwriters, investors and operators would do well to ask a few more searching questions as to how portfolios of these assets are designed and managed.

While the GISTM was an important step toward international tailings dam regulation, some questions remain unanswered.

- Why are standards lower during the riskier construction/operational phase?
- Why is it that the GISTM standards are lower than those used for reservoirs in general. This is especially pertinent as the failure rate of TSFs is already about

100 times higher than for water supply reservoirs and because of pollution risks relative harm is magnified.

- GISTM standards are often lower than those in national jurisdictions. This could place a corporation in a tight spot if a liability arose in one country and was brought to trial in the jurisdiction where the company was listed.

These questions come at a time when governments⁶ and regulators⁷ are looking to ensure that ESG (Environmental, Social & Governance) labelling has real meaning.

⁶ <https://www.gov.uk/government/speeches/finance-resilience-net-zero-and-nature>

⁷ <https://medium.com/illumination/new-international-esg-regulatory-proposals-in-a-nutshell-744f212dc34d>



Benefits and costs of Nature Based Solutions

Humanity is developing at an astonishing rate, with the population of the globe recently assessed as having passed 8 billion in November 2022¹. The trend toward living in urban environments is also accelerating with over 65% of people projected to be living in cities after 2050². For most this means striking improvements in prosperity, but there are significant downsides.

Our urban environments are imperfect; 58% of cities are prone to at least one kind of natural disaster². They may overheat or flood and, with the effects of climate change, the burden of drought and disease are putting the provision of food and health services under stress.

The built environment itself often amplifies natural hazards. Hard surfaces contribute to urban heat islands, accelerate run off during rainstorms and contribute to reduced water quality. The construction materials we use also hasten climate change and the amounts

of materials we are using is accelerating. Globally cement comprises 8% of global emissions⁴. Between 2011 and 2013, China poured more cement than the US in the entire 20th century³.

We are exceeding the capacity of the natural environment to carry us and have to modify our behaviours so as to close the loop on our impacts. We need to remember that there is no economy without the ecosystems which give us life support. The pressing need to find sustainable solutions is being played out in recent deliberations like the talks at COP15 and COP27.

Nature Based Solutions (NBS) have the potential to answer some of these questions and mitigate many of the pitfalls of traditional engineering. There are a wealth of different takes and names for what comprise NBS. Essentially, they all seek to provide services using natural and sustainable habitats. These challenges might include but are not limited to flood management, clean water, disaster risk management or food, sometimes all at once.

¹Population United Nations Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022: Summary of Results. UN DESA/POP/2022/TR/NO. 3.

²Urbanisation 2,3 Gu, Danan (2019). Exposure and vulnerability to natural disasters for world's cities. United Nations, Department of Economics and Social Affairs, Population Division, Technical Paper No. 4.

³USGS Cement Statistics 1900- 2012; USGS, Mineral Industry of China 1990 – 2013.

⁴Ellis, L. D., Badel, A. F., Chiang, M. L., Park, R. J.-Y. & Chiang, Y.-M. Proc. Natl Acad. Sci. USA 117, 12584–12591 (2020).



For example, under the guidance of the University of Arizona, the city of Tucson is buying up flood prone lots and converting them into combined play areas and flood ponds, incidentally enhancing recharge in an arid region. Across Australia urban authorities are collaborating to form the Australasian Green Infrastructure Network. One of their aims is to establish city planning practices encouraging the adoption of green walls, roofs and facades to mitigate extreme heat and flooding.

Alongside city scale interventions governments are changing their approach and developing standards and guidelines. In the UK CIRIA C802 2022⁵ sets guidelines for fluvial flood managers. A number of jurisdictions (especially UK, Netherlands,

US and Canada) have cooperated in the production of the USACE Natural and Nature based solutions Guidelines 2021⁶ and the University of Waterloo in Ontario has published guidance which is due to be adopted in Canada.

Some interventions like the use of willow spilling to manage riverine erosion are ancient and nearly lost crafts. Many measures are effective and frequently used. But we live in an age where the quantification and the measurement of benefits for business case development are paramount to the selection of preferred options and the understanding of risk.

⁵ https://www.ciria.org/CIRIA/Navigation/Events/Event_Display.aspx?EventKey=E22710

⁶ https://ewn.erdc.dren.mil/?page_id=4351

Nature based solutions are enticing but often struggle in the face of quantitative cost-benefit analysis. Not because they are ineffective but because it is complex with natural systems than engineered solutions where cost-benefit appraisals are more easily applied. This can act as a barrier to proposing and implementing NBS.

Sometimes though the benefits are well described, within the USACE guidelines the use of reefs to mitigate the affects of storm surges is illustrated as follows: Across 3,100 km of the U.S. coastline, the topmost 1 m of coral reefs prevents the 100-year flood from growing by 23%, avoiding flooding effects for 53,800 people (62% of the population in this 3,100 km of coastline), avoiding USD\$2.7 billion in damages to buildings along this coastline, and avoiding USD\$2.6 billion in indirect economic effects⁷.

This kind of precision is very helpful to proponents of NBS and is more common with coastal flood management projects. Though there are exceptions the potential for fluvial flood management or water quality management are less clearly elucidated. Even with well understood topics the assessment of whole life costs and benefits and post implementation monitoring are acknowledged to need more research⁷.

In fluvial contexts benefits are often harder to find, meeting societal expectations of flood risk reduction with NBS alone is often beyond reach of catchment based approaches. Land earmarked for use for flood management may be required for a range of other uses such as energy generation, food production or housing. Inland therefore NBS may be a component of overall land and water management activities.

Almost all NBS projects have extensive co-benefits perhaps to tourism, fisheries, water quality or in carbon sequestration. Like the intended benefits they are tricky to assess and require post construction monitoring to be assured of benefits realisation. There is a tendency for proponents of NBS to view proposed solutions through the lens of their discipline, seeking benefits from within their silo. This is often as a result of the behaviours of those who commission the primary purpose of projects. There are good examples of where this has been addressed at inception stage but there are barriers to best practice.

With more traditional NBS we should seek to improve ways of assessing projects. With more novel techniques there may be many more questions to answer.

⁷U.S. Geological Survey, 2021, Mineral commodity summaries 2021: U.S. Geological Survey, 200 p., <https://doi.org/10.3133/mcs2021>





Earth





Earth Risk: No hazard is an island

When a natural disaster occurs, a casual observer will all too often see it as an isolated incident. But if you look a little deeper, beyond the news headlines, you see that most of these hazards are interconnected.

Tsunamis are a prime example; although a destructive and devastating hazard on their own, this mass movement of water can be caused by large magnitude earthquakes (such as the 2004 Boxing Day tsunami), powerful volcanic eruptions (seen recently during the 2022 Tonga eruption), and even large landslides (the largest of which, 1958 in Lituya Bay, caused a mega-tsunami with a maximum wave height of 524 metres) that all come with their own effects on the surrounding environment and population. Links can be seen between a variety of other natural hazards, such as extreme weather events and wildfires influencing landslide hazard, and interactions between volcanism and weather conditions such as El Nino, and even potential influences of extreme rainfall on the triggering of volcanic eruptions (though this theory is not universally accepted, as discussed in our recent our recent Insight Piece, 'Exploring the links between climate change and volcanic hazards').



These links are becoming ever more important in the worlds of risk analysis, resilience and insurance, as the effects of climate change become more prevalent and weather patterns across the globe become more unpredictable and erratic. Extreme temperatures, extreme rainfall, drought and storm events are becoming more frequent, and have the potential to trigger or otherwise worsen the effects of a number of geological hazards in the coming years and decades. For geoscientists, used to dealing with depositional environments formed over millions of years and events that can sometimes take hundreds of years between reoccurrence, these changes could be thought of as very sudden. But new and evolving technologies such as remote earth observation, machine learning and high-performance computer modelling are helping to better understand the interplay between these hazards and their effects.

The WTW Research Network is continuing to support academics and industry scientists working with the earth hazards, risk and exposure, with new and improved modelling software development that is being shared across wider WTW teams, and recommendations on how existing analytics tools can be improved to more accurately account for hazards which may change in the face of climate uncertainty.

The WTW Research Network is continuing to support academics and industry scientists working with the earth hazards, risk and exposure, with new and improved modelling software development that is being shared across wider WTW teams, and recommendations on how existing analytics tools can be improved to more accurately account for hazards which may change in the face of climate uncertainty.

James Dalziel
Head of Earth Risk

Tsunami risk assessment: the quest for more reliable models

In a changing and dynamic natural world, with increasing populations exposed to coastal risks, these have caught the attention of the insurance industry.

An urgent need for investment in preparedness and establishing plans to mitigate effects on lives, critical facilities, and ultimately, economic growth is clear. Particularly, tsunami phenomena have been raising interest due to their impacts on large areas. While the frequency of large tsunamis are rare, these events can be destructive and several tsunamis over the last decade have provided insights on the complexity of forecasting impacts along the coast. This is not only due to the physical aspects and inherent variability of triggering phenomena such as earthquakes, submarine or subaerial landslides, volcanic eruptions or their cascading effects, but also because of the lack of information about the built environment.

Tsunami hazard and risk assessment has been evolving, owing to advances in numerical modelling and the computational power needed to simulate flow evolution and impact. Tsunami inundation is dependent on the tsunamigenic source's characteristics, although other associated processes such as bay resonance may influence wave heights

that could differently affect points along a coastline. This could be analogous to local effects known in seismic hazard assessment, where resonant processes may amplify the response of buildings to shaking, influencing effects on the built environment and casualties.

Risk analysts have been dealing with these aspects to account for a whole range of uncertainties. In estimating the hazard, for example, characterization of seismic ruptures or submarine landslides could lead to different tsunami magnitudes. Multi-hazard assessment is also a crucial aspect of hazard estimation not always considered in urban planning¹. The main sources of uncertainty for tsunami research are limitations or availability of some datasets to simulate tsunamis (e.g. topo-bathymetry) and a lack of information on the built environment that adds more caveats for the hazard and therefore risk assessment.

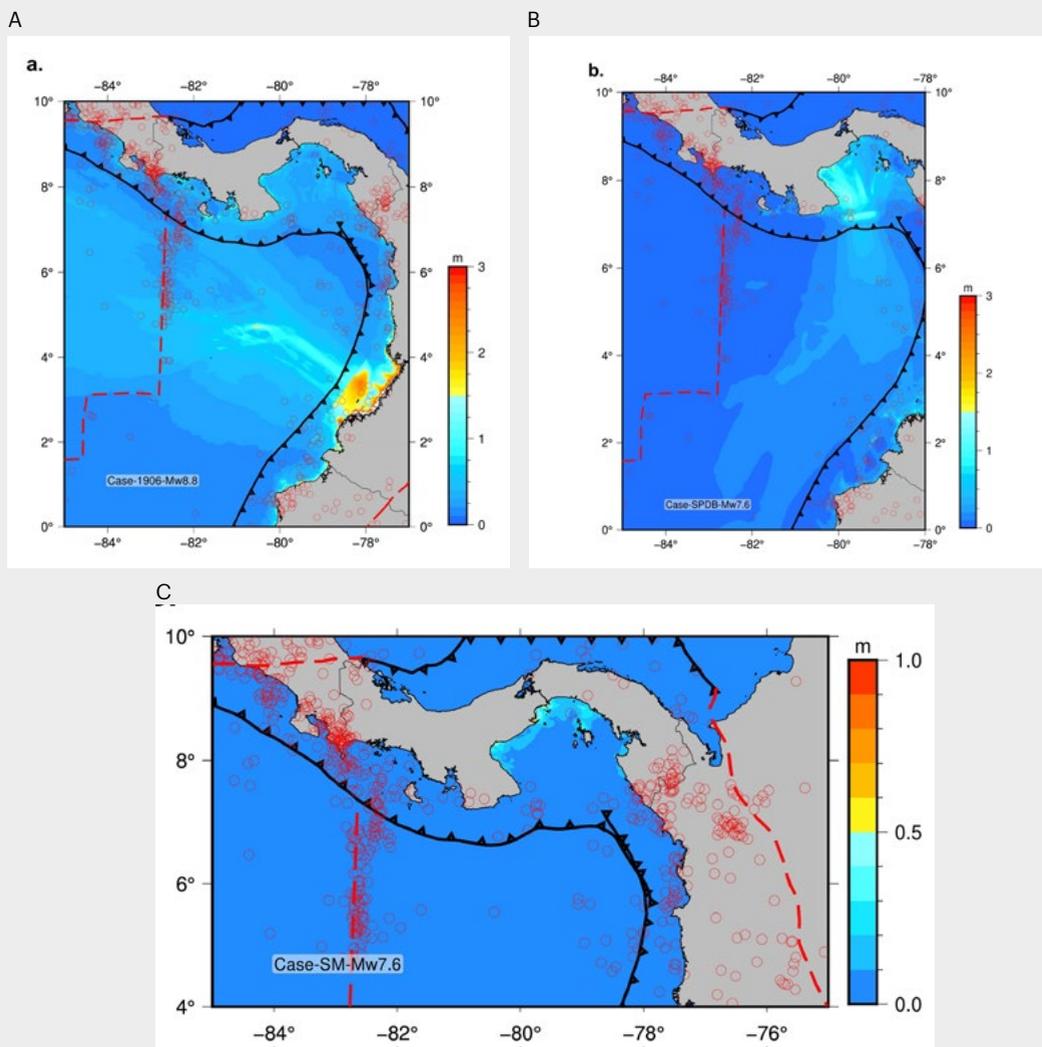
The most common approaches to assess tsunami hazard are through deterministic and probabilistic analyses. The reason to choose one or the other may be justified by the application of resulting hazard estimates. Tsunami hazard maps based on one or few seismic scenarios have been commonly used for evacuation purposes or inundation maps in worst-case scenarios; using historical data or geological interpretation as source inputs for the maximum credible hazard.

¹Grezio, A., Cinti, F.R., Costa, A., Faenza, L., Perfetti, P., Pierdominici, S., Pondrelli, S., Sandri, L., Tierz, P., Tonini, R. and Selva, J. (2020). Multisource bayesian probabilistic tsunami hazard analysis for the Gulf of Naples (Italy). *Journal of Geophysical Research: Oceans*, 125(2), DOI:10.1029/2019JC015373.

Here, we show some case study scenarios taken into consideration that may affect Panamá. Wave heights are shown along the coast for the Mw 8.8, 1906 Colombia-Ecuador earthquake (Fig. 1, top-left panel), a scenario triggered by a Mw 7.6 earthquake (Fig. 1, top-right panel), and a scenario based on local faults near the Panamá canal

with no associated return period (Fig. 1, bottom panel). These examples are selected among several numerical simulations, corresponding to local and regional sources. These scenarios may be used for restricted purposes to assess impacts with almost no treatment of uncertainties.

Fig. 1: Numerical simulations for a.) 1906 Colombia-Ecuador Mw 8.8 earthquake, b.) Southern Panama Deformation Belt Mw 7.6 earthquake, and c.) Potential Mw 7.6 earthquake scenario along the San Miguel Fault near the Panama Canal. Numerical simulations conducted with easyWave²



Source: <https://git.gfz-potsdam.de/id2/geoperil/easyWave>

On the contrary, probabilities are needed for integrating uncertainties into a decision-making problem of any type³. Since the 2004 Sumatra earthquake, methodologies such as the probabilistic approach have been more commonly used for engineering purposes aiming to reduce the large uncertainties related to a lack of tsunami observations, or due to the aleatory nature of the system⁴.

In general, this approach has been widely used in weather or seismic hazard forecasting among other applications, and particularly for tsunami probabilistic hazard assessment as this is grounded in seismic hazard assessment as proposed by Cornell⁵. The hazard can be seen as the input to be considered in the vulnerability, exposure and loss estimates for a particular site.

³Rougier, J., & Beven, K. (2013). Model and data limitations: The sources and implications of epistemic uncertainty. In J. Rougier, S. Sparks, & L. Hill (Eds.), *Risk and Uncertainty Assessment for Natural Hazards* (pp. 40-63). Cambridge: Cambridge University Press. doi:10.1017/CBO9781139047562.004

⁴Grezio, A., Babeyko, A., Baptista, M. A., Behrens, J., Costa, A., Davies, G., et al. (2017). Probabilistic tsunami hazard analysis: Multiple sources and global applications. *Reviews of Geophys.*, 55, 1158-1198. <https://doi.org/10.1002/2017RG000579>

⁵Cornell, A. (1968) Engineering Seismic Risk Analysis. *Bulletin of the Seismological Society of America*, 58, 1583-1606.



Workflows used in catastrophe models

Most of the workflows used in tsunami risk assessment, as in other natural phenomena, are composed of modules (Fig. 2). This modular approach is used in different ways, many times oversimplified due to data limitations or spatial scale of the study area. Most commonly the modules that composed a catastrophe model have inherent uncertainties, mostly due to the lack of data and limitations for forecasting recurrence rates that may lead to underestimation. For a particular study in Panamá, the deterministic use of scenarios and the different characteristics of the hazard may impact losses by almost 50%. The risk is

also sensitive to the assumptions of fragility curves and scale of the built environment, which lead to misestimation of the risk.

A comparison between models used as input data to the loss module indicates that more granular and comprehensive data should be used to construct each module. While improvements for workflows lie in the propagation of uncertainties, assuming that the limits to good quality data can be overcome, adding confidence intervals and enhancement in the visualization will also benefit risk estimates, stakeholders and ultimately, risk mitigation.

Fig.2: **General workflow to study the risk component⁶**

Modules	Characteristics	Data
Hazard	<ul style="list-style-type: none"> Integration of one or several scenarios (ideally multi source) Probabilistic or deterministic scheme depending on data and aims of the project 	<ul style="list-style-type: none"> Bathymetry Source characterization Source rates
Exposure	<ul style="list-style-type: none"> Distribution of built environment Elements at risk Economic value Population density 	<ul style="list-style-type: none"> Building type Density Coastal critical facilities Census
Vulnerability	<ul style="list-style-type: none"> Physical, social, economical, type of elements at risk Material Resilience 	<ul style="list-style-type: none"> Economic value Fragility curves
Losses	<ul style="list-style-type: none"> Impact to the economic addets Impact to critical facilities Impact to livelihood 	<ul style="list-style-type: none"> Census Different thresholds
Risk results from modules integration		

Source: ⁶Goda K. Multi-hazard parametric catastrophe bond trigger design for subduction earthquakes and tsunamis. *Earthquake Spectra*. 2021;37(3):1827-1848. doi:10.1177/8755293020981974

Availability of high-resolution bathymetry data, as well as an understanding of the effects of poor incorporation of uncertainties are key aspects to generating more reliable risk models. Generally, workflows are not necessarily performed to assess joint losses (e.g. earthquakes and tsunamis), although by assessing damage related to tsunami or earthquake and how buildings can respond to both phenomena using data from previous studies, this could help determine how buildings respond to cascading events. These improvements could then be used to supplement hazard assessment and modelling tools within the insurance industry.



About the BSC

The Barcelona Supercomputing Center - Centro Nacional de Supercomputación (BSC-CNS) specializes in high performance computing (HPC) and manage MareNostrum, one of the most powerful supercomputers in Europe. Over their well-established collaboration with the WTW Research Network, our colleagues at the Barcelona Supercomputing Center have provided a reflection on how improvements to tsunami hazard modelling approaches and the role of uncertainties could lead to more accurate risk models. Past projects have modelled volcanic eruptions and forecasted the impacts of volcanic ash clouds on air traffic.



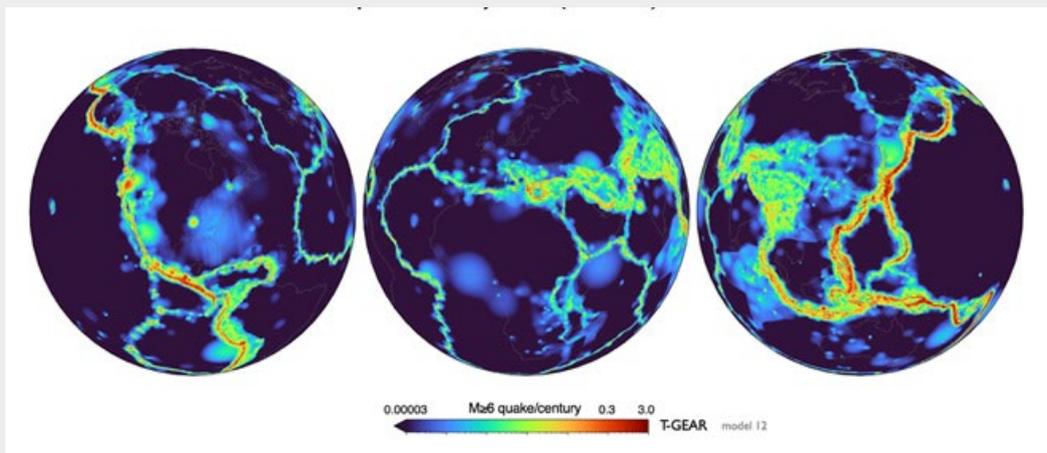
Creating a globally consistent stochastic event set for earthquake modelling

The product of more than a year of work by the Temblor team under the WTW Research Network, and with the close evaluation of WTW and GallagherRe scientists, EVENTSET is the only independently-tested, globally-consistent stochastic event set.

What is 'EVENTSET', and why does it differ from standard practice?

EVENTSET2 is Temblor's worldwide 60,000-year stochastic event set. The set comprises 30 million $M \geq 5.0$ events worldwide (with magnitude, location and depth), in which $M \geq 7.0$ earthquakes represented by extended sources. EVENTSET2023 accounts for the role of recent large earthquakes in altering the quake rate, with areas of enhanced and suppressed seismicity via Temblor's Realtime Risk technology. Affected countries include Japan (2011 M9.0 Tohoku and 2016 M7.0 Kumamoto shocks), New Zealand (2010-2011 M6.3-7.0 Canterbury and 2016 M7.8 Kaikoura shocks), Chile (2010 M8.8 Maule and 2015 M8.3 Illapel quakes), and Mexico (2017 M8.1 Tehantepec and M7.0 Puebla shocks).

Fig.1: Temblor's Global Earthquake Activity Rate (T-GEAR) model and EVENTSET 2.1



Active seismic zones and continental interiors captured fully and consistently - everywhere on Earth

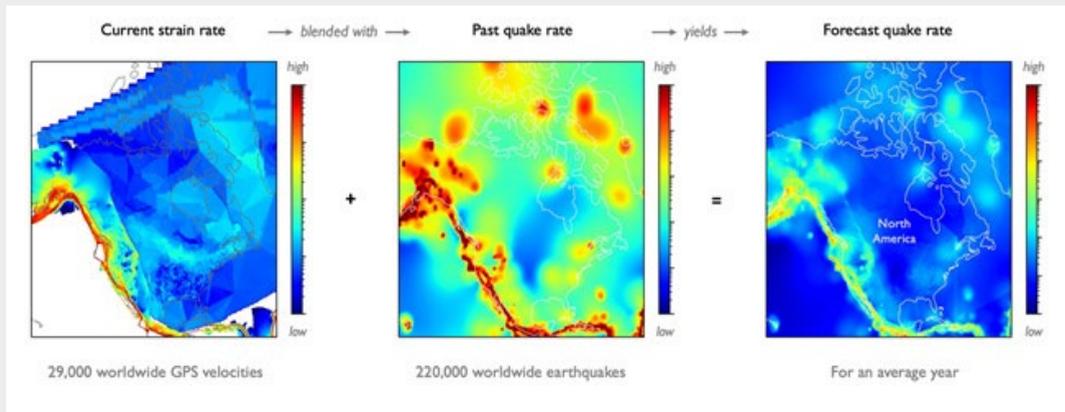
Source: Temblor

Typically, modelers use fault traces to draw rectangles, and then assign maximum earthquake magnitudes to those rectangles, and return times for quakes in those rectangles based on fault slip rates, with magnitudes and rates between faults (“areas sources”) estimated.

The problem with this approach is that the global inventory of active faults is woefully inadequate, fault slip rates are rarely known, and earthquakes can rupture multiple fault sections and so exceed the

maximum magnitude. Recent examples of failures of such “fault-based characteristic earthquake models” include the 2011 M9.0 Tohoku, 2016 M7.8 Kaikoura, and 1993 M7.3 Landers, California earthquakes, which were 10 times larger than in models. In addition, large damaging quakes have struck where no faults were mapped at all in Japan (M6.9 Iwate-Miyagi), California (2019 M7.1 Ridgecrest) and New Zealand (2011 M7.1 Darfield). And these are the three best mapped countries in the world.

Fig.2: Components of T-GEAR



Source: Temblor



Temblor's advance

PolyCat provides an analysis tool for EVENTSET. One can examine any polygon, shape file, or country boundary file, buffered by any distance (since quakes just outside the boundary can contribute to hazard inside), to extract the event set over any magnitude and depth range of interest. PolyCat also furnishes the return time for any magnitude and depth range, and the return time uncertainty.

Temblor blends GPS strain rate as a proxy for the forces that load faults, with past earthquakes, which unload those forces. In contrast to faults, GPS is measured in the same manner by similar instruments worldwide. Temblor's earthquake catalog spans 117 years. This means that the quake intensity and frequency anywhere in the world are strictly inter-comparable. For example, when one compares the San Andreas Fault system (California) with the North Anatolia Fault system (Turkey), in

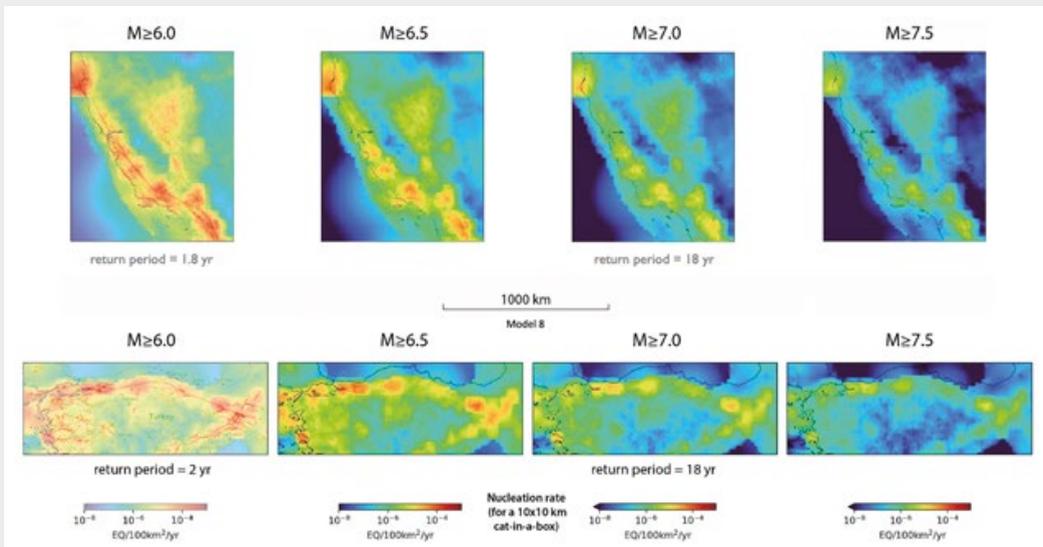
which the two faults have the same slip rate and length, the earthquake return times are nearly identical, a strong test of EVENTSET's accuracy. In contrast, most vendor models are built by different scientists in different areas, and so are unable to assure they are self-consistent.



Temblor, Inc.

Temblor is a Silicon Valley tech company providing personal, immediate, and credible sources of seismic risk solutions. Their free mobile and web app and daily blog have gained 900,000 users worldwide in under 16 months, and their enterprise projects for insurance and financial clients has given them an understanding of key unmet needs. Temblor's CEO Ross Stein, CTO Volkan Sevilgen, and collaborator Shinji Toda from IRIDeS of Tohoku University, are the world pioneers in Coulomb stress transfer.

Fig.3: **California and Turkey (with faults of same slip rate and length) give similar return times in T-GEAR**



Source: Temblor

Rigorous testing

T-GEAR (for Temblor's Global Earthquake Activity Rate model) is the basis for EVENTSET. Random draws of this underlying quake rate model are used to generate EVENTSET. T-GEAR includes 200 million earthquake rates in 0.15M (magnitude) increments on a 0.1° x 0.1° spherical grid.

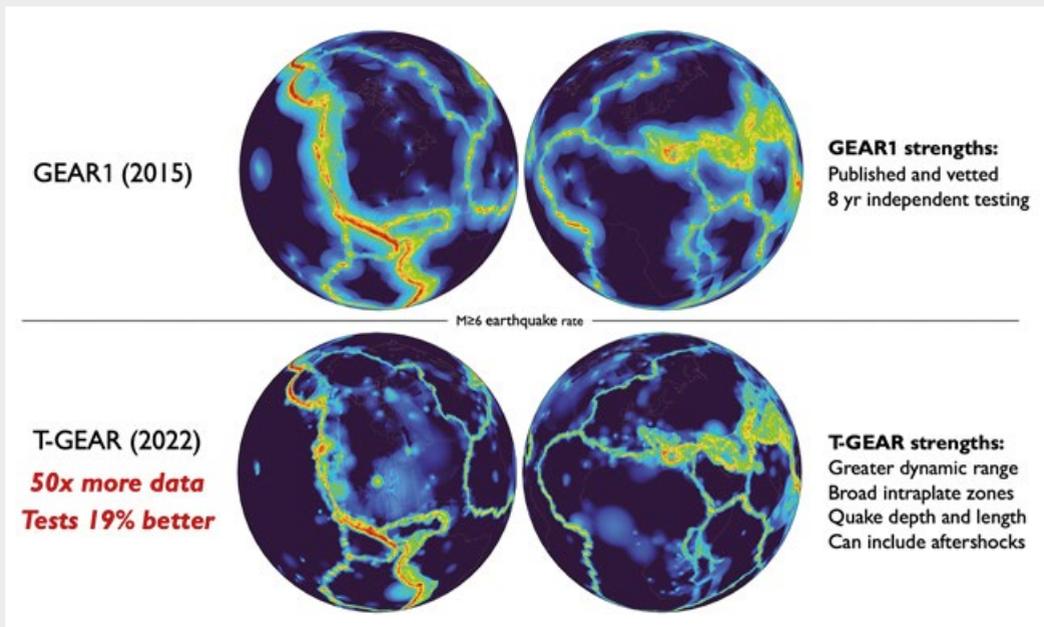
T-GEAR's predecessor, GEAR1, was published in 2015 (Bird et al., BSSA 2015) and has been under test by the international seismic testing agency, CSEP (Collaboratory for the Study of Earthquake Predictability) for 8 years, where it has outperformed its academic competitors in every year. It was the subject of a test publication (Strader et al., SRL 2018). No other commercial or

foundation has submitted its event set for independent testing. In retrospective tests, T-GEAR outperformed GEAR1 during 2019-2021 by 23% (based on the Kagan I1 information score), in part because T-GEAR includes 50 times the data as GEAR1.

Benefits

For reinsurers, EVENTSET enables disparate population centers, such as Los Angeles, Tokyo, Santiago, and Istanbul, to be rigorously inter-compared. For primary insurers, they have the confidence that the event set in Indonesia, the Philippines, or Ecuador is just as accurate and complete as it is for California or Italy. For Insurance Linked Security companies, any parametric cat bond or private placement can be independently analyzed.

Fig.4: Comparisons between Temblor's 'GEAR1' and the new 'T-GEAR' models.



Source: Temblor

Estimating population displacement following disasters

Global disasters displaced 265 million people between 2008 and 2018¹.

The number of people displaced annually is likely to increase under ongoing trends, driven by poorly managed urban growth in hazard-prone areas² and potentially exacerbated by climate change³. Despite the scale of the human impact from disaster-induced displacement, efforts to model population displacement from disasters are in their infancy, and limited information exists on the drivers and extent of protracted displacement.

Investigating displacement duration using past events

Most statistics regarding population displacement following a disaster event provide single values representing a snapshot in time, often indicating the peak estimate. However, the duration of displacement is an essential component for understanding the human impact of disastrous events. For example, large-scale displacement in the form of evacuations before a storm can save lives and be followed by mass return shortly thereafter.

In contrast, a devastating event such as an earthquake could damage or destroy a significant proportion of the residential building stock, causing occupants to seek temporary shelter or accommodation for months to years. Not only does this type of protracted displacement pose a significant disruption to the livelihoods of affected households, but it also disrupts the economic production of the overall community⁴.

PhD candidate Nicole Paul, Prof Carmine Galasso at UCL, and Prof Jack Baker at Stanford University are simulating recent past events to compare existing simplified models of displacement (i.e., solely based on housing damage) to reported displacement values. A particular focus is on events where time-varying displacement data is available to differentiate between immediate displacement and protracted displacement. This benchmarking study will evaluate the uncertainty range of simplified displacement models and attempt to identify the factors driving protracted displacement. As an outcome, this research will propose a framework to estimate both immediate and protracted displacement.

¹Internal Displacement Monitoring Centre (2019). Disaster Displacement: A global review, 2008-2018.

²Internal Displacement Monitoring Centre (2017). Global Disaster Displacement Risk: A baseline for future work.

³IPCC (2012). Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation

⁴Internal Displacement Monitoring Centre (2018). Assessing the Economic Impacts of Internal Displacement: Conceptual Framework. In: The ripple effect: economic impacts of internal displacement.

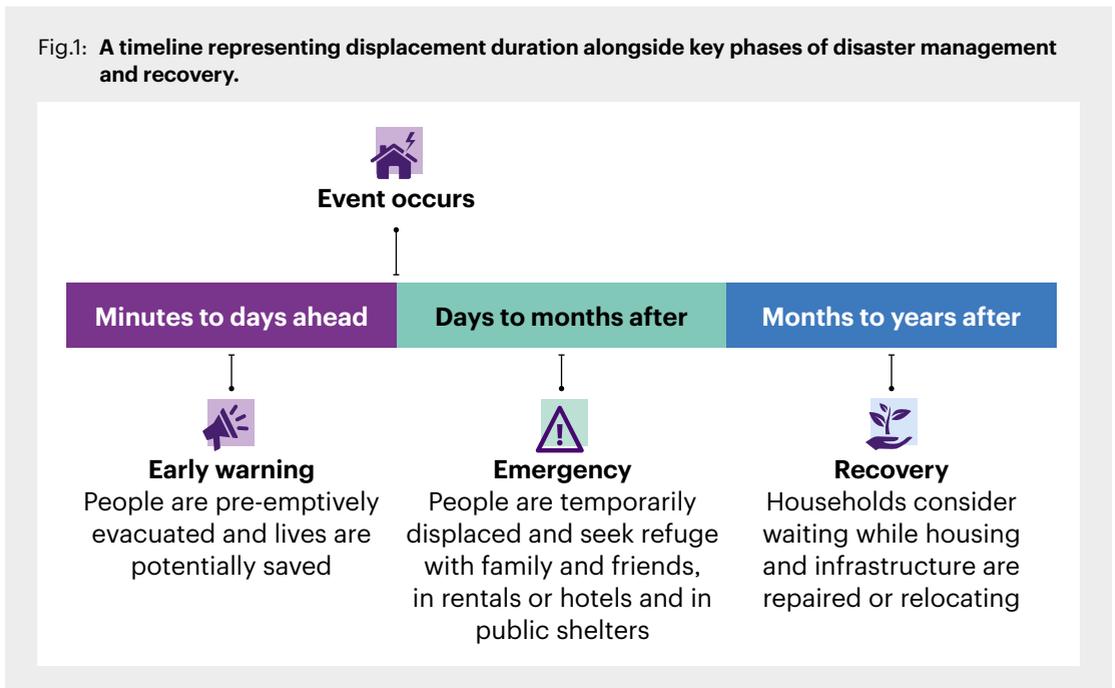
Identifying hotspots of disaster-induced displacement risk

With a framework to quantify population displacement from disasters in place, existing datasets will be leveraged to estimate urban disaster-induced displacement risk globally. In collaboration with the Global Earthquake Model (GEM) Foundation, models covering seismic hazard, the exposure of buildings and population, and fragility relationships relating earthquake-induced ground shaking to damage levels are available for this study. As derived from the earlier case studies, a displacement consequence model will be applied to estimate displacement risk globally.

A few modifications to GEM Global Exposure Model are planned to highlight the current and future displacement risk of urban areas. Earth Observation (EO) datasets will inform

a spatial disaggregation of the exposure and a projection of built areas into the future decades. Through open datasets such as WorldPop and the Global Human Settlement Layer (GHSL), the distribution of buildings and people can be reflected in a realistic manner that aids disaster risk assessment for multiple hazard types (e.g., earthquakes, floods). Additionally, data from GHSL regarding built-up areas across different epochs can be combined with data covering man-made features (e.g., roads, existing towns) and natural features (e.g., topography) to predict future built-up areas via geographically weighted regression⁵. Following this approach, this research will project the baseline (i.e., current year) exposure to 2050 to understand how displacement risk will likely evolve under ongoing trends and under hazards such as floods that will be affected by climate change.

Fig.1: A timeline representing displacement duration alongside key phases of disaster management and recovery.

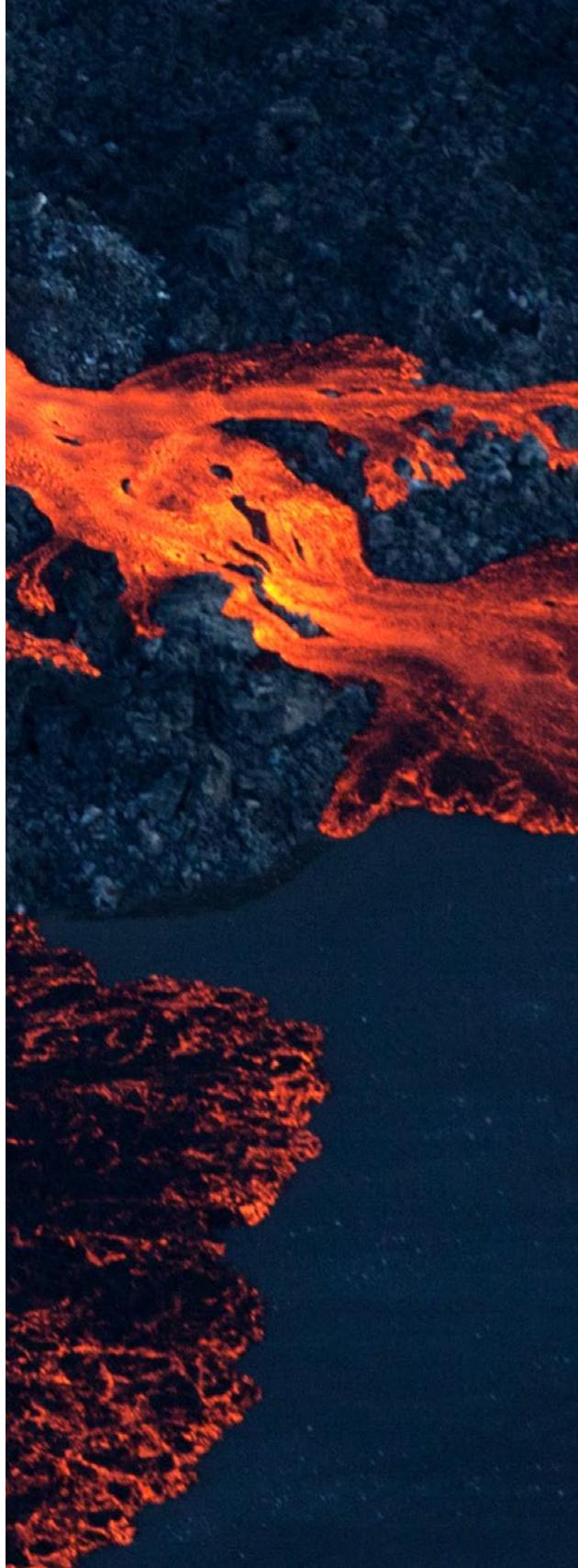


⁵ Calderón, Alejandro, and Vitor Silva (2021). "Exposure forecasting for seismic risk estimation: Application to Costa Rica." *Earthquake Spectra* 37, no. 3.



University College London

UCL Civil, Environmental and Geomatic Engineering (CEGE) is a multidisciplinary department renowned for excellence in research and teaching. It currently holds a substantial UK Research and Innovation (UKRI) research portfolio in civil engineering. Home to world-leading research projects, groups and centers, CEGE reflects a broad, enquiring and human-centered view of the engineering world. Strong links to industry and research are embedded throughout a diverse range of programs. These links are enhanced by CEGE's proximity to both significant infrastructure projects and leading firms, thanks to its central London location. Within CEGE, Prof Galasso's and Dr Cremen's research focuses on developing and applying probabilistic and statistical methods and tools for catastrophe risk modeling and disaster risk reduction. They investigate risks to building portfolios and infrastructure exposed to multiple natural hazards, including earthquakes, strong wind, and flooding, with special emphasis on developing countries.'



Impact of a giant megathrust earthquake in Chile today

Southern Chile is home to the largest historical earthquake ever recorded, the Giant May 22, 1960 M9.5 Valdivia megathrust event.

The rupture zone reached more than 1,000 km along the Chilean coastline, with an estimated extent of peak ground accelerations (PGAs) shown in **Figure 1**. The shaking from the Valdivia earthquake and the subsequent tsunami resulted in more than 1,600 fatalities and 3,000 injured, rendered more than 2 million people homeless, and caused \$550 million (adjusted for inflation, ~\$5 billion today) in damage in Chile. Due to the extensive tsunami generated by the earthquake, additional deaths were recorded in Japan, Hawaii and the Philippines.

One reason why the number of fatalities from the Valdivia event was relatively modest considering its large magnitude is that the rupture occurred south of many of the population centers. For example, if the Giant earthquake had ruptured a stretch of the trench 500-1,000 km further north, at the latitude of Santiago (~2 million people in 1960, ~8 million today) and coastal resort cities such as Vina del Mar, the outcome would likely have been very different.

While prediction of the timing of the next M9.0+ earthquake along the Chilean coast is impossible, these Giant events do appear to follow a time-dependent strain accumulation pattern, with a ~2.2% probability of a 1960-like event between 1960 and 2017¹. Despite the rather low probability, the effects of such large earthquake must be considered to ensure that premiums accurately reflect expected losses.

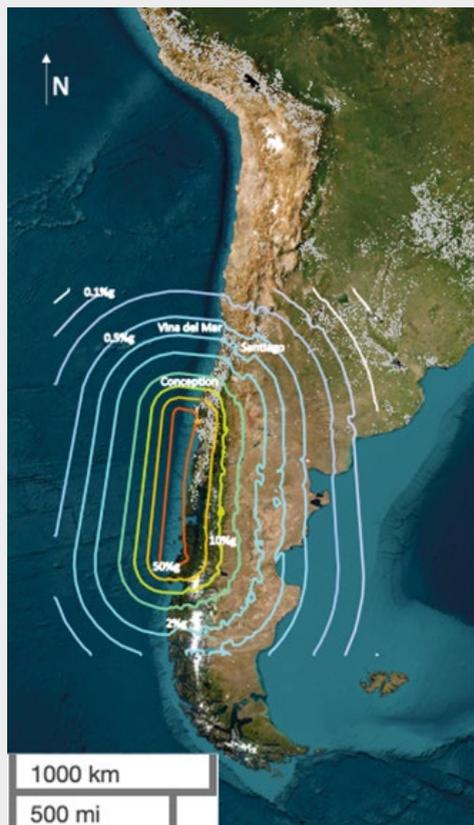
Loss estimating in Catastrophe models conventionally relies on regression of empirical ground motion recordings (Ground Motion Prediction Equations, or GMPEs) from historical earthquakes. However, GMPEs by construction produce large uncertainty due to the inherent smoothing, and potential bias in the estimated ground motions. Furthermore, since seismic instrumentation in 1960 was insufficient to capture the ground motions from the Valdivia event, and no other historical earthquake of this magnitude has occurred, GMPEs are mostly unconstrained for such large-magnitude events. The smooth PGA contours that generally decay uniformly with distance from the rupture zone in the scenario ShakeMap in **Figure 1** hint at the limitations of GMPE-based ground motion predictions.

¹Moernaut, J., M. Van Daele, K. Fontijn, K. Heirman, P. Kempf, M. Pino, G. Valdebenito, R. Urrutia, M. Strasser, and M. de Batist (2018). Larger earthquakes recur more periodically: New insights in the megathrust earthquake cycle from lacustrine turbidite records in south-central Chile, *Earth and Planetary Sciences* 481, 9-19.

Fig.1: **US Geological Survey PGA Shakemap for the 1960 Valdivia earthquake².**

Modified from

https://earthquake.usgs.gov/earthquakes/eventpage/official19600522191120_30/shakemap/pga

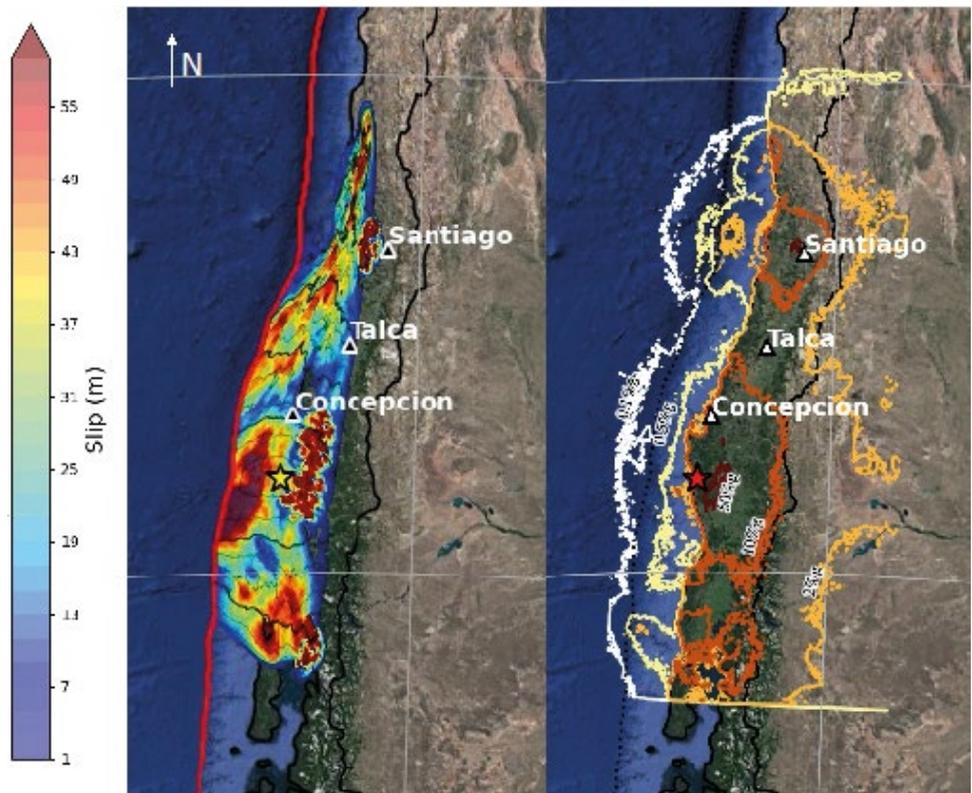


Source: ²Larger earthquakes recur more periodically: New insights in the megathrust earthquake cycle from lacustrine turbidite records in south-central Chile, *Earth and Planetary Sciences* 481, 9-19.

A viable alternative to using GMPEs to predict ground motions and resulting losses from a future Valdivia-type event is to use wave propagation simulations in state-of-the-art 3D earth models. Since 2017, the WRN has been working with researchers from San Diego State University (SDSU) exploring how physics-based 3D ground motion simulations can improve the accuracy of catastrophe modeling. SDSU scientists Prof. Kim Olsen and his research team pioneered the first large-scale wave propagation simulations more than 2 decades ago, demonstrating how 3D effects of sedimentary basins can strongly affect the resulting ground motion predictions.

The ongoing research collaboration between WTW and SDSU aims to estimate the seismic risks along the south American west coast for megathrust earthquakes, including Giant, Valdivia-type events. **Figure 2** shows a rupture model and simulated PGAs for a realization of a 'worst-case' Valdivia-type earthquake scenario, rupturing further to the north compared to the 1960 event, close to metropolians of Santiago and coastal resort towns. Notice the irregular PGA contours for the predicted PGAs, as opposed to the much smoother contours in Figure 1, caused by basin amplification, directional effects, and wave focusing, that are insufficiently covered by the GMPEs. Specifically, PGAs in the Santiago area and nearby coastal areas can exceed 50%g in this scenario, more than 5 times larger than the values from the 1960 Valdivia earthquake.

Fig.2: (left) Rupture model and (right) resulting PGAs for a M9.54 megathrust earthquake scenario off the coast of central Chile. The star depicts the epicenter, the color shading is the slip distribution in meters, and the contours show the rupture initiation times.



Source: Larger earthquakes recur more periodically: New insights in the megathrust earthquake cycle from lacustrine turbidite records in south-central Chile, *Earth and Planetary Sciences* 481, 9-19.

The improved ground motion estimates from 3D models come with an added cost – they require use of thousands of processing units on today’s largest supercomputers for hours. However, 3D physics-based simulations include potentially significant basin amplification that are not typically captured in conventional loss estimation. Moreover, the losses resulting from 3D ground motion simulations are characterized by a much lower volatility than in catastrophe models,

thus allowing a more accurate and less uncertain loss estimation, as an input to decision making. 3D earthquake simulations have progressively presented themselves as alternatives to a dearth of strong motion data records in the near field and for large magnitude earthquakes, and we are at the point where synthetic seismograms produced by 3D models are making their way into decision making for society.



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San Diego State University

San Diego State University (SDSU) has been a member of WRN since 2017. Prof. Kim Olsen is the primary developer of the Anelastic Wave Propagation (AWP) code used to generate physics-based ground motion predictions for future catastrophic earthquakes in regions with high exposure. The simulations are taking into account the three-dimensional structure of the sedimentary basins, the ocean water layer, realistic variation in the rupture pattern, and the amplification and nonlinear effects of the near-surface low-velocity layers.

Exploring the links between climate change and volcanic hazards

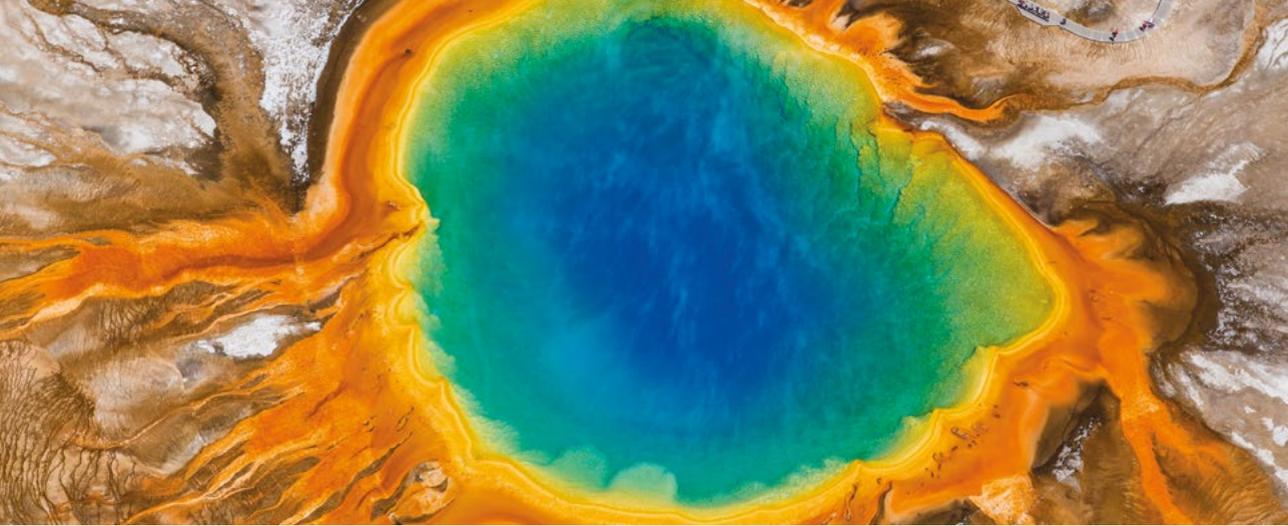
The ongoing climate emergency has proved to be a far-reaching point of discussion in recent years, with the effects of rising temperatures, melting ice caps, changing seasons and more intense storms having the potential to affect aspects of our everyday lives across the globe.

In the world of geohazards, the most discussed consequences are how changing weather patterns can influence landslides, slope stability and coastal erosion. But another potentially significant link, and in some cases the topic of intense debate, is that between climate variability and the triggering of volcanic activity.

One area of study where climate influence on volcanism is better understood and broadly accepted is that of glacial melting and the subsequent unloading of underlying magma chambers.

Work done by Albino et al.¹ looked at how surface load variations around Icelandic volcanoes act on their shallow magma chambers. Findings showed that in line with model predictions, the last nine historical eruptions at Katla volcano occurred during the summer season when snow cover was at its smallest. The 2004 Grímsvötn eruption was also noted to have been immediately preceded by a 'jökulhlaup', or glacial outburst flood, which may have triggered the event if the magmatic system was already close to failure. Another paper from Sigmundsson et al.² supports these findings, stating that pressure can influence both magma production as well as the failure of magmatic systems and making the wider claim that a current reduction in ice load on subglacial volcanoes, due to climate change, is modifying pressure conditions in magmatic systems. More recent work by Praetorius et al.³ and Rawson et al.⁴ finds evidence for a similar link during deglacial transitions in Alaska and Chile respectively, suggesting this is not a phenomenon limited to certain geographies or volcanic settings. These findings suggest that not only are the failure conditions of magmatic systems altered by melting snow and ice, but an increased rate of magma production threatens more voluminous eruptive activity from subglacial volcanoes as well as potentially greater frequency.

¹Albino, F., Virginie Pinel, and F. Sigmundsson. "Influence of surface load variations on eruption likelihood: application to two Icelandic subglacial volcanoes, Grímsvötn and Katla." *Geophysical journal international* 181.3 (2010): 1510-1524.



Another potential link between the effects of a changing climate and volcanism comes in the form of sea level change at island arc volcanoes.

A paper by Coussens et al.⁵ uses evidence in the rock record to find a connection between periods of rapid sea level rise and flank collapse at Soufrière Hills, Montserrat, and periods of heightened volcanic activity over the past million years. Satow et al.⁶ also identifies a link between sea level change and eruption frequency at Santorini, however these results show the opposite to Coussens et al. with periods of sea level fall triggering dyke injection and feeding

eruption over the past 360,000 years. This could indicate that the effect sea level has on volcanism is dependent on geography or tectonic setting, but in either case the work shows that rapid sea level rise from climate change will have an effect on volcanoes around the world.

Fighting back: How volcanoes can affect our climate

The relationship between volcanoes and our climate can work in both directions. Some climate change sceptics claim that volcanoes, rather than people, are responsible for current global warming trends. Looking back through history, we can see that the opposite is true. In addition to lava and ash, sulphur dioxide (SO₂) is a major output from volcanic eruptions. If

²Sigmundsson, Freysteinn, et al. "Climate effects on volcanism: influence on magmatic systems of loading and unloading from ice mass variations, with examples from Iceland." *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 368.1919 (2010): 2519-2534.

³Praetorius, Summer, et al. "Interaction between climate, volcanism, and isostatic rebound in Southeast Alaska during the last deglaciation." *Earth and Planetary Science Letters* 452 (2016): 79-89.

⁴Rawson, Harriet, et al. "The magmatic and eruptive response of arc volcanoes to deglaciation: Insights from southern Chile." *Geology* 44.4 (2016): 251-254.

⁵Coussens, Maya, et al. "The relationship between eruptive activity, flank collapse, and sea level at volcanic islands: A long-term (> 1 Ma) record offshore Montserrat, Lesser Antilles." *Geochemistry, Geophysics, Geosystems* 17.7 (2016): 2591-2611.

⁶Satow, Chris, et al. "Eruptive activity of the Santorini Volcano controlled by sea-level rise and fall." *Nature Geoscience* 14.8 (2021): 586-592.

propelled high enough into the atmosphere in sufficient concentrations, this gas can reflect solar radiation and have a cooling effect on the Earth. There are records of these ‘volcanic winter’ events occurring throughout history, with a notable entry being the 1815 eruption of Mount Tambora resulting in the ‘year without a summer’ and credited as helping contribute to Mary Shelley’s writing of “Frankenstein”. Similarly, many historical records of famines can be linked to volcanic eruption events, such as the 1783 Laki eruption in Iceland. More recently, the eruption of Mount Pinatubo in 1991 caused ~15 million tonnes of SO₂ to be propelled into the stratosphere, resulting in a 0.5°C drop in average global temperature for the next 2-3 years.

So could a potential increase in the frequency of eruptions, as a result of climate change, result in enough SO₂ being released into the atmosphere to in fact cool the Earth and solve the problem? Although not impossible, this eventuality is extremely unlikely. There have been records showing periods of heightened volcanic activity triggering ‘little ice ages’ of regional cooling, but the size of eruptions needed to cause this are significant.

For reference, the recent eruption of the submarine Hunga Tonga-Hunga Ha’apai volcano had effects felt across the globe (as discussed in our recent [insight piece](#)), but even this only produced a volcanic cloud containing ~50x less SO₂ than the Mount Pinatubo eruption, and is reported to have had negligible effects on the climate.

When it rains, it pours lava: Links between rainfall and volcanism

An area where the links between climate variability and volcanism are somewhat less well-defined is regarding the influence of rainfall. A paper published in *Nature*⁷ discusses the theory that anomalously high rainfall and a subsequent increase in pore pressure may have influenced the weakening and mechanical failure of the volcanic edifice at Kilauea Volcano, Hawai‘i in 2018, contributing to the triggering of a subsequent eruption in May of that year. This connection raises an important question in the worlds of hazard and risk assessment; could more frequent intense rainfall events, driven by climate change, also influence the frequency of volcanic activity in a similar way to glacial melting and sea level change?

At this stage the answer seems to be that further study is required. Farquharson & Amelung’s findings are not universally accepted, and have been the subject of some fervent academic debate in recent years. Scientists at the USGS led by Dr. Mike Poland have responded to the article casting doubts on the links between rainfall and the 2018 Kilauea eruption⁸, questioning the rain gauge data used, the GPS measurements signalling pressurisation of the magma chamber prior to eruption, and the significance of the relatively small pore pressure changes (~0.1 kPa) reported by Farquharson & Amelung. This in turn has been rebutted by the paper’s original authors in February 2022⁹, responding to the questions raised and holding to their theory. They also point out in their response that the USGS themselves found links between anomalous rainfall and volcanic eruptions,

⁷Farquharson, Jamie I., and Falk Amelung. “Extreme rainfall triggered the 2018 rift eruption at Kilauea Volcano.” *Nature* 580.7804 (2020): 491-495.

⁸Poland, Michael P., et al. “Rainfall an unlikely factor in Kilauea’s 2018 rift eruption.” *Nature* 602.7895 (2022): E7-E10.

discussed in a paper by Fred Klein¹⁰, but this was dismissed at the time because it was “difficult to imagine a physical triggering mechanism of rainfall on eruptions”. Other past work has been done in this area, including a paper by Barclay et al.¹¹ linking increased rainfall to heightened probability of primary volcanic activity (pyroclastic flows, dome collapses and explosions) at Soufrière Hills Volcano, Montserrat between 1998 and 2003, and calling for integration of meteorological data into volcano monitoring.

The controversy surrounding this research suggests that more work will need to be undertaken, in order to determine how robust the links are between intense rainfall events and volcanic activity and their worldwide applicability.

If evidence suggests that this is a global phenomenon, with high-quality data that reinforces the theories put forward and satisfies those with doubts, the implications would be profound. Not only would it mean that weather data and forecasts could provide another means of helping to predict volcanic hazards, but also that the continuing effects of climate change may

mean activity such as dome explosions and flank collapses occur more frequently as intense rainfall occurs more often at active volcanoes. Another paper by Farquharson & Amelung¹² widens the scope to examine what links between heavy rainfall and both eruptive and non-eruptive volcanic hazards may mean for subaerial volcanic regions globally in the face of rapid climate change. How this conversation develops will be of great interest, not only to those in the academic community, but also those involved with volcanic hazard assessment such as the WTW Research Network and its partners.

Working together to assess the risks

Overall, the links between climate and volcanism are definitive, but the how, when and where of climate change affecting the occurrence of volcanic activity is an area still under investigation. Even if claims that extreme rainfall can directly contribute to triggering of eruptions are considered unlikely, the combined findings of these papers prove that numerous aspects of climate variability have been seen to promote volcanic activity in the past, and that the continuing results of rapid climate change may have the potential to reshape the volcanic risk landscape around the globe.

⁹ Farquharson, Jamie I., and Falk Amelung. “Reply to: Rainfall an unlikely factor in Kilauea’s 2018 rift eruption.” *Nature* 602.7895 (2022): E11-E14.

¹⁰ Klein, Fred W. “Eruption forecasting at Kilauea volcano, Hawaii.” *Journal of Geophysical Research: Solid Earth* 89.B5 (1984): 3059-3073.

¹¹ Barclay, Jenni, Jade E. Johnstone, and Adrian J. Matthews. “Meteorological monitoring of an active volcano: implications for eruption prediction.” *Journal of volcanology and geothermal research* 150.4 (2006): 339-358.

¹² Farquharson, Jamie I. and Amelung, Falk (2022). “Volcanic hazard exacerbated by future global warming-driven increase in heavy rainfall.” *R. Soc. open sci.*9: 220275.



An upcoming special issue in the *Bulletin of Volcanology* looks at progress made over the past twenty years and future challenges in the field, and includes a perspective paper by Aubry et al. discussing climate-volcano impacts¹³. Given how this could affect those at risk from volcanic hazards, further exploration of these impacts is a potential focus point for the WTW Research Network in the future. Together with other teams in WTW such as the Climate & Resilience Hub, we have formed an Earth Risk Working Group to bring earth scientists, hazard analysts and stakeholders together and discuss what areas of research could most benefit everyone.

The climate emergency is one issue at the top of our agenda, and these sort of links with other geohazards are an area we shall all be watching with great interest.

¹³ Aubry, T.J., Farquharson, J.I., Rowell, C.R. et al. (2022). "Impact of climate change on volcanic processes: current understanding and future challenges." *Bull. Volcanol.* 84, 58.

Parametric insurance solutions for volcanic ash disruption

Background and the problem to be addressed

Of the plethora of volcanic hazards, volcanic ash is the furthest reaching. Small particles of solidified lava are dispersed by wind and the clouds and can easily travel for hundreds of kilometres. Just 1 mm of ash fallout can significantly affect crucial aspects of infrastructure and agricultural activity, and 1 cm of ash can damage buildings¹. Since the Eyjafjallajökull eruption in 2010, it is well-known that the aviation sector is particularly vulnerable to volcanic eruptions. The industry suffered a total loss of US\$2bn due to delays, rerouting and cancellations associated with that single, moderately sized

eruption². On the ground, hangars, airports and grounded planes are at risk, but the main concern is in the atmosphere. Amongst several safety hazards, airborne ash can remelt in turbines causing flame-out, and thus airplanes generally are advised by the International Civil Aviation Organization (ICAO) to avoid ash clouds^{2,3}.

However, there are few adequate insurance products available on the market for risks associated with volcanic eruptions and the resulting losses are predominantly uninsured^{4,5}. The protection gap for recent eruptions was between 50 and 100%^{2,5}. This gap is mainly attributed to:

1

Limitations of traditional insurance:

Traditional insurance cover can be expensive for volcanic eruptions, and the processing of claims is often complicated and long.

2

No proper catastrophe models:

Volcanic ash is a poorly and/or unmodelled risk in the (re)insurance and aviation sectors and, therefore, most insurance policies do not cover it.

3

Limited scale:

Available insurance products are focused on specific areas (e.g., lava flow insurance for homeowners in Hawaii).

¹ Jenkins, S.F., Wilson, T.M., Magill, C.R., Miller, V., Stewart, C., Marzocchi, W. and Boulton, M. (2015) Volcanic ash fall hazard and risk: Technical Background Paper for the UNISDR 2015 Global Assessment Report on Disaster Risk Reduction. Global Volcano Model and IAVCEI. <https://www.preventionweb.net/english/hyogo/gar/atlas/>. DOI: 10.1017/CBO9781316276273.005

² Prata, F., and Rose, B. (2015) Chapter 52: Volcanic ash hazards to aviation. In Sigurdsson, H. (Ed.), *The Encyclopedia of Volcanoes* (Second Edition) (pp. 911-934), Academic Press. DOI: 10.1016/B978-0-12-385938-9.00052-3

³ ICAO (2012) Doc 9974, Flight Safety and Volcanic Ash. https://www.icao.int/publications/documents/9974_en.pdf

⁴ https://www.swissre.com/dam/jcr:02550b19-f9a2-45f2-9288-377d25952b5b/Swiss+Re_Volcano_PR_en.pdf

⁵ Smolka, A., and Käser, M. (2015) Chapter 12 - Volcanic Risks and Insurance. In Shroder, J.F., and Papale, P. (Eds.), *Volcanic Hazards, Risks and Disasters* (pp. 301-314), in *Hazards and Disasters Series*, Elsevier. DOI: 10.1016/B978-0-12-396453-3.00012-5

Developing solutions through collaboration

One possible way to address the protection gap for risks associated with volcanic ash dispersion is the use of alternative risk transfer mechanisms based on robust catastrophe modelling. Mitiga Solutions and WTW have partnered to face this challenge, under the framework of the Eurostars project “Volarisk” since 2019.

Mitiga Solutions leverage their founder’s accumulated 20+ years of experience developing and using FALL3D⁶, one of the most renowned ash dispersal models to create bridges between volcanology, aviation and the insurance markets. They are building the next generation of the crisis management tool of Eurocontrol, the European Organisation for the Safety of Air Navigation. In addition, together with Replexus and the Howden Foundation, Mitiga developed the first humanitarian volcano cat bond that was released to the market in 2021. Issued by the Danish Red Cross, the bond covers losses due to eruptions from 10 volcanoes worldwide. It is based on a sophisticated cat model for ash fallout on the ground. Pay-out in the bond is triggered by eruption column height (Fig. 1) and then further based on wind directions.

The goal of Volarisk is to develop a parametric insurance solution for volcanic ash-inflicted losses to assets in the aviation sector, i.e. airports, hangars, runways, and in particular flights between city pairs. This insurance solution is based on a fully probabilistic global volcanic ash catastrophe model. Parametric insurance structures are widely used in catastrophe (cat) bonds; an example of insurance securitization in which the risk is transferred to the capital markets via a so-called special purpose vehicle or SPV⁷. Parametric insurance solutions thus require reliable cat models that form the base for proper risk assessment and financial structuring.

For more than 100 volcanoes worldwide, Mitiga developed a catastrophe model for ash fallout that provides loss estimates to a client’s portfolio in order to quantify the risk at various return periods.

⁶Folch, A., Mingari, L., Gutierrez, N., Hanzich, M., Macedonio, G., and Costa, A. (2020) FALL3D-8.0. a computational model for atmospheric transport and deposition of particles, aerosols and radionuclides – Part 1: Model physics and numerics. *Geosci. Model Dev.*, 13, 1431-1458. DOI: 10.5194/gmd-13-1431-2020

⁷Cummins, J.D., and Trainor, P. (2009) Securitization, Insurance, and Reinsurance. *The Journal of Risk and Insurance*, 76:3, 463-492. DOI: 10.1111/j.1539-6975.2009.01319.x

⁸Macedonio, G., Costa, A., and Longo, A. (2005) A computer model for volcanic ash fallout and assessment of subsequent hazard. *Computers & Geosciences*, 31, 837-845. DOI: 10.1016/j.cageo.2005.01.013

Eruption recurrence times and probability distributions for event intensities are derived from the eruption catalogues in a first step (Fig. 1). Together with historical wind data, these serve as the input for more than 10,000 footprint simulations per volcano. These simulations are performed with the ash dispersion model HAZMAP⁸ and result in hazard maps for ash load on the ground (Fig. 2). Finally, these data are translated into a stochastic event catalogue. The final cat model is run on the OASIS platform that combines the event catalogue with vulnerability functions and client exposure datasets. The cat model has passed initial validation with historical loss data.

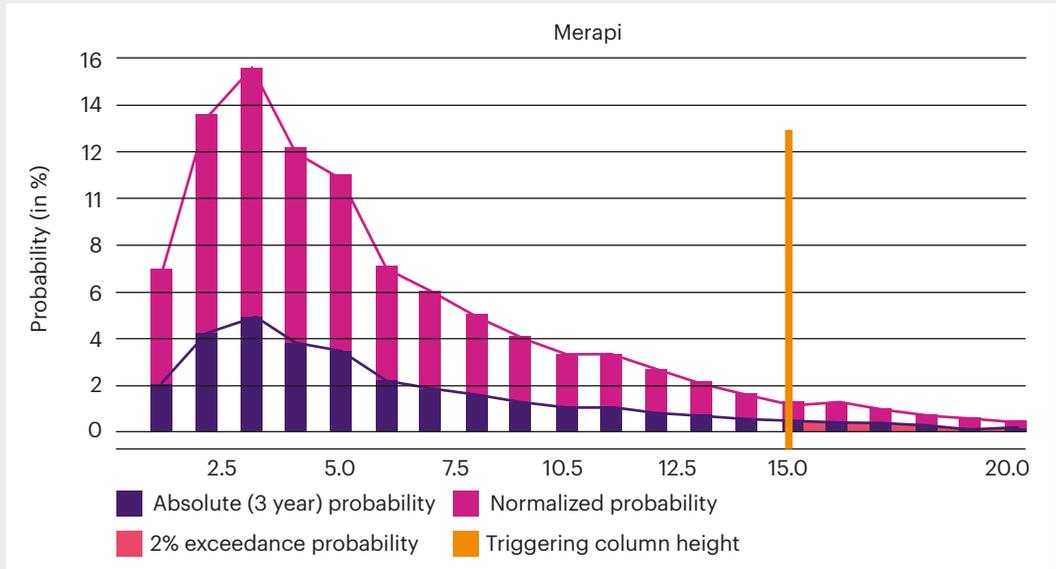
In order to develop the parametric insurance solutions for flights between city pairs, the cat model needs to be adapted for airborne ash. This requires simulations with the more sophisticated and computationally expensive model FALL3D, as HAZMAP is limited to ash deposition on the ground and does not simulate ash concentrations in the atmosphere. Mitiga has developed a novel methodology to address the computational demands of FALL3D for producing a robust stochastic event catalogue.

The final cat model is the base for parametric insurance solutions that will be developed together with WTW. The next steps will be proof-of-concept and validation studies in close collaboration between Mitiga, WTW and potential clients from the aviation sector.



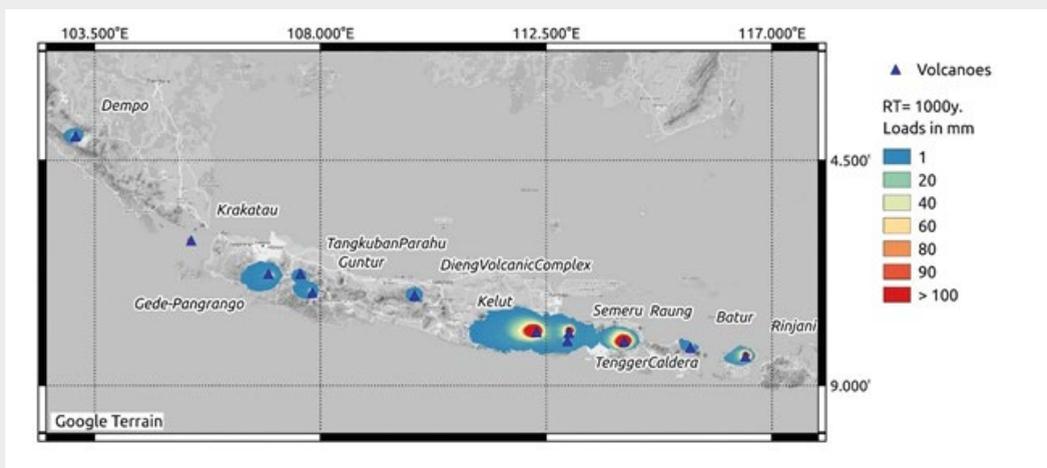
Figures

Fig.1: Normalized and absolute probability distribution for eruption column height (\approx event intensity) of Merapi volcano. Green bars show the relative probability density function (PDF) discretized in 1 km bins (column heights in km above vent). The area below the relative PDF sums to 100%. Red bars give the absolute 3-year PDFs. The area below the absolute PDFs gives the 3-year probability of eruption, corresponding to 31.58% in the case of Merapi. The cat bond trigger is determined by finding the column height for which the area to the right (blue shaded region below the red curve) equals 2%, which for the particular case of Merapi yields 12.5 km above the vent for 3-years.



Source: Mitiga Solutions

Fig.2: 1000y return period map of ash fallout in Indonesia



Source: Mitiga Solutions



Mitiga

Mitiga Solutions

Mitiga Solutions is an offshoot of the Barcelona Supercomputing Center which specializes in high-performance computing. It is certified by Eurocontrol, and Mitiga Fall3d is the dispersion model currently in use by the Darwin and Buenos Aires Volcanic Ash Advisory Centers. The Barcelona Supercomputing Center is also the official provider for the sand and dust storm warnings of the World Meteorological Organization. Learn more at: mitigasolutions.com



People





People risks

The people risks associated with geopolitics, trade tensions, regulatory crackdowns, disruptive technologies, and pandemics have all been steadily increasing in the last few years. Multilayered compound risks have ushered a more precarious international system, characterized by increasing entropy amongst and within states.

Businesses have had the unenviable task of having to navigate these pressures in a global trade system no longer marked by predictability, stability, and certainty. C-suite executives have had to adjust their modes of operations, with a shift of emphasis from efficiency to more resilience, on various fronts such as supply chains, high-technology products, and even whole business models. As geopolitics rises to the top of risk registers, resilience – individual, corporate, and societal – has become more of an imperative spanning everything from our food and water systems to our environment.

Much of the current era can be marked by the merging of the public and private sectors to effectively deal with society's increasingly complex problems.



Current power dynamics in the international structure have given rise to a new form of expanding state power for geopolitical purposes. State and non-state actors are now able to use a plethora of strategies to further their goals in pursuit of a larger strategic objective. These include cyber attacks, grayzone aggression, sanctions, and subversive business practices that affect target governments' financial positions in international markets. The Covid-19 pandemic appears to have been one of those stressors that encompasses human capital, territory, technology, and natural resources. To better comprehend these shifting dynamics and what they mean for corporations, the WTW Research Network launched a geopolitical risk research program designed to provide a deeper, more sophisticated understanding of issues ranging from the influence of China in the world, grayzone aggression, and the socio-political implications of climate change.

The Russia/Ukraine conflict has raised important questions of corporate neutrality and how corporations can navigate reputational challenges in a world increasingly dominated by social media and consumer boycotts. The WTW Research Network has worked closely with Elisabeth Braw, of the American Enterprise Institute

(AEI), to better understand this dynamic and states' use of grayzone aggression to advance national goals. Chinese consumer boycotts of Western brands and Western boycotts of Russian goods have put companies in delicate positions, balancing shareholder value while also having to appeal to their main customer base. This can be seen as part of a larger ESG trend towards a larger stakeholder approach undertaken by corporates and multinationals to act as responsible societal actors.

While balancing consumer sentiments may fall under the remit of corporations, societal resilience is a society-wide endeavor, led by a symbiotic relationship between governments, civil society and the private sector. WTW continues to be a corporate partner of the National Preparedness Commission, in particular to understand how markets can be more resilient in the face of multiple and cascading crises. Given the debilitating nature of the Covid-19 pandemic on economies, healthcare systems, and social infrastructure, the Commission hopes its work will have a strategic yet practical impact on how the UK – and the world – views society-wide crises.

Omar Samhan

People and Technology Risks Analyst

“Whole of society” approaches to improve preparedness for crises

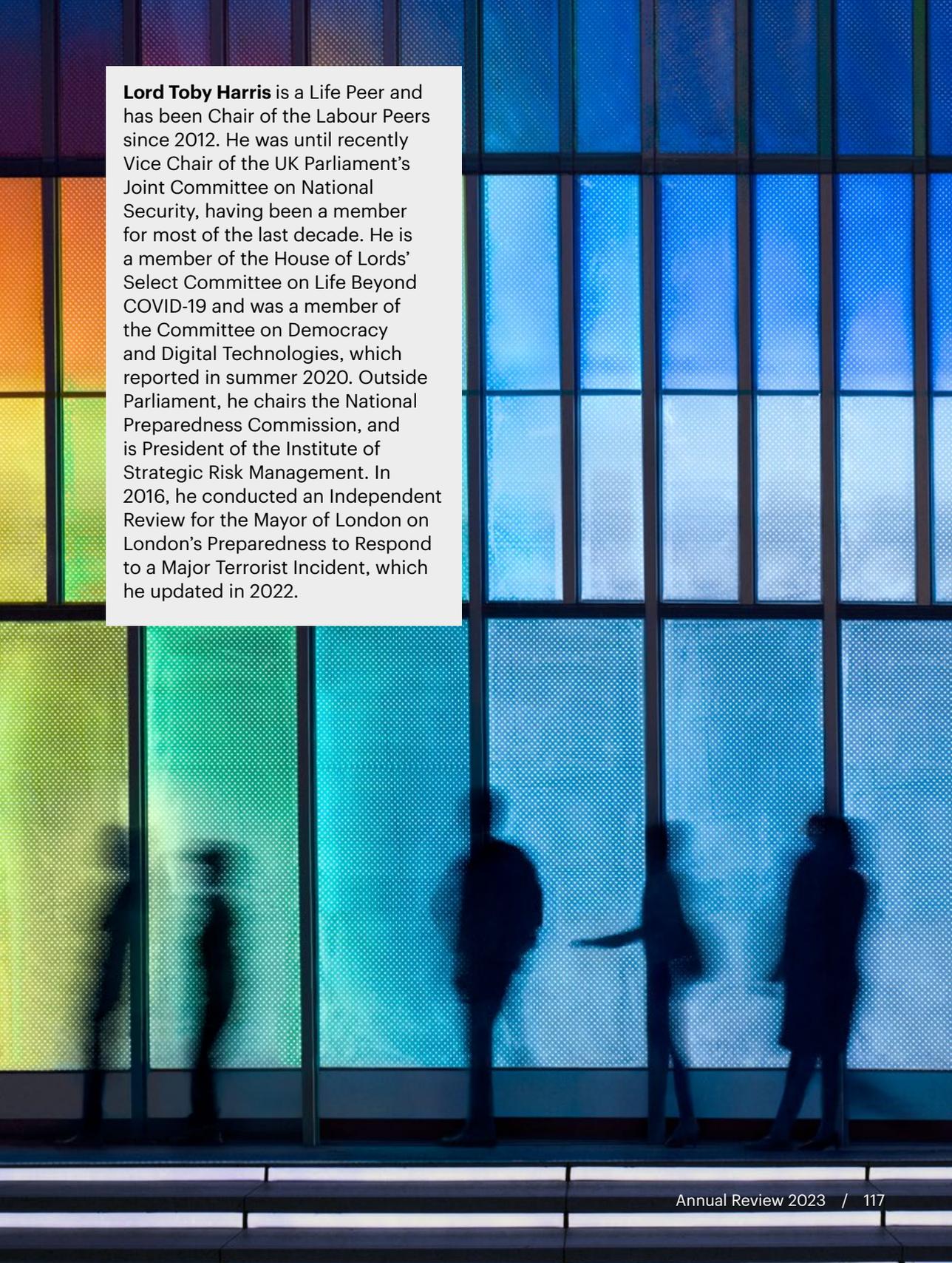
The hope for a return to normal after the Covid-19 pandemic has been dashed by an enduring crisis of energy and geopolitics. The succession of crises highlights the fragility of business models, relying on a ‘just in time’ approach, and trying to shift to a more resilient ‘just in case’ model. It also shows that true resilience requires a “whole of society” approach, and more concerted effort across all sectors, across government, business and civil society.

In this context, the work of the National Preparedness Commission (NPC)¹ launched in November 2020 and chaired by Lord Toby Harris, is more relevant than ever. The Commission is made up of 46 leading figures – including the WTW Research Network Director – from public life, academia, business, and civil society. The aim of the NPC is to promote better preparedness for a major crisis or incident, primarily in the UK, although it attracts interest internationally.

The NPC recognizes that the UK needs to be better prepared to deal with unexpected or unprecedented shocks, but that the government is limited in its resources and bandwidth for action. This was reflected in the government’s Integrated Review, “Global Britain in a Competitive Age”², which calls for a ‘whole of society’ approach to national resilience. The NPC is a microcosm of UK Plc, bringing together stakeholders from public, private, academic and civil society sectors, promoting cross-sectoral debate, best practices and policy. The Commission also holds closed roundtables for Commissioners, civil servants and subject matter experts, held under the Chatham House Rule and allowing detailed discussion of the themes contained in Commission papers or those produced by partner organizations. While attendance of these sessions is restricted, WTW organizes a series of roundtables open to our clients, focusing on those themes after a keynote from an external expert from the WTW Research Network.

¹<https://nationalpreparednesscommission.uk/>

²<https://www.gov.uk/government/publications/global-britain-in-a-competitive-age-the-integrated-review-of-security-defence-development-and-foreign-policy>



Lord Toby Harris is a Life Peer and has been Chair of the Labour Peers since 2012. He was until recently Vice Chair of the UK Parliament's Joint Committee on National Security, having been a member for most of the last decade. He is a member of the House of Lords' Select Committee on Life Beyond COVID-19 and was a member of the Committee on Democracy and Digital Technologies, which reported in summer 2020. Outside Parliament, he chairs the National Preparedness Commission, and is President of the Institute of Strategic Risk Management. In 2016, he conducted an Independent Review for the Mayor of London on London's Preparedness to Respond to a Major Terrorist Incident, which he updated in 2022.

A regular stream of reports and articles on the Commission's website provide an eclectic range of thought-leadership for those interested in preparedness and



Enhancing Warnings

Prepared by Dr Carina Fearnley and Professor Ilan Kelman from the UCL Warnings Research Centre offered insights into what alerts and warning are and how they can better support effective behavioral preparedness and responses across a wide range of hazards, stakeholders and sectors.



Financial Foundations for Resilience

Prepared by Professor Michael Manelli and Lord Toby Harris provided new thinking on how insurance could be used to reduce the impact of all significant risks and hence improve resilience.



Learning that can Save Lives

Prepared by Lianna Roast of the Disaster Management Centre at Bournemouth University examined the process by which lessons identified following some major incident can be applied and embedded in practice.

resilience. The following reports (which were not directly sponsored by WTW) show the ranges of topics addressed:



Independent review of the Civil Contingencies Act

The NPC has published its Review of the 2004 Civil Contingencies Act, led by Bruce Mann, former Director of the Civil Contingencies Secretariat, and based on over 300 interviews. It makes 117 recommendations and concludes that the Government must learn lessons from the COVID-19 pandemic and other emergencies over the last two decades if UK resilience arrangements are to be made fit for the future.



Communicating Effectively with the Public During a Crisis: A Literature Review

Funded by JRSS Charitable Trust, Alliance Manchester Business School and the National Consortium for Societal Resilience [UK+] explored how public trust in democratic institutions can be enhanced through crisis communications. The review includes national and international examples that demonstrate how crisis communications can enhance or undermine that trust.

Geopolitical risk – Grayzone aggression

On August 16, Lloyd's issued one of its regular market bulletins. This one looked just like any other Lloyd's update to its underwriters – but its content was the private sector's most explicit statement to date of how much geopolitics is changing globalised business. Lloyd's announced that it will, as of March 2023, no longer offer stand-alone cyber insurance for state-backed cyber aggression. Geopolitical conflict is entering the globalised economy in full force, not just in Ukraine and Taiwan but around the world.

//

Cyber related business continues to be an evolving risk. If not managed properly it has the potential to expose the market to systemic risks that syndicates could struggle to manage¹.

As explained in the market bulletin by
Tony Chaudhry,
LLoyd's Underwriting Director

//

He was not exaggerating. In recent years insurers have had to cover the havoc caused by state-backed attacks including \$10 billion² losses incurred by companies hit by Russia's NotPetya attack. Some insurers argued that NotPetya, having been attributed by Western governments to the Russian government should count as an act of war and thus fall under war exclusion clauses. But in January 2022, New Jersey Superior Court ruled³ that one of the companies – Merck – did indeed have the right to coverage of its \$1.4 billion NotPetya

¹ <https://assets.loyds.com/media/35926dc8-c885-497b-aed8-6d2f87c1415d/Y5381%20Market%20Bulletin%20-%20Cyber-attack%20exclusions.pdf>

² www.wired.com/story/notpetya-cyberattack-ukraine-russia-code-crashed-the-world/

³ <https://news.bloomberglaw.com/privacy-and-data-security/mercks-1-4-billion-insurance-win-splits-cyber-from-act-of-war>



losses under its cyber insurance policy with Ace American because a state-backed cyber attack could not be defined as an act of war.

Indeed, NotPetya and the slew of other recent cyber attacks thought to have been executed or supported by hostile states point to a dramatically changing situation for businesses. Just like Merck, they may now find themselves direct or indirect targets of geopolitically motivated aggression. Sweden decided, in late 2020, not to include Huawei in its 5G network, prompting announcements of retaliation by Chinese officials. The following spring, Sweden-based Ericsson won a mere 2%⁴ in China Mobile's massive contract round, down from 11% in the previous round, and its sales declined in the country even as they increased in the rest of the world. Around the same time, after the Australian government had called for an international investigation into the origins of Covid, China – Australian winemakers' most important export market -- imposed punitive tariffs reaching 200% on Australian wine. One year later, Australian wine exports to China had slumped by 96%⁵. In late 2021, after the government of Lithuania invited Taiwan to open a representation office in Vilnius, Chinese ports stopped processing⁶ all goods featuring Lithuanian components.

⁴<https://www.wsj.com/articles/ericsson-beijing-australia-sweden-denmark-5g-national-security-trade-luxury-goods-zte-huawei-11628631680>

⁵<https://www.cnbc.com/2021/04/29/australia-wine-exports-to-china-fall-96percent-in-dec-quarter-tariffs-bite-.html>

⁶<https://www.wsj.com/articles/china-takes-lithuania-as-economic-hostage-taiwan-global-supply-chain-trade-goods-beijing-11641506297>



Like Ericsson and the Australian winemakers, all the companies affected by geopolitically motivated aggression have sustained enormous harm. But it's harm of a kind that they could neither predict nor plan for. And devastating though the aggression's impact has been on each company, it was not war.

All over the world, companies and their insurers are finding themselves in a similar twilight zone. In Taiwan, companies could be cut off from their supply chains and their customers if China behaves in a menacing manner that prompts shipping companies, airlines and their insurers to suspend transportation to the island. And every time the Taipei governments or its allies take a decision that displeases

Elisabeth Braw is a senior fellow at the American Enterprise Institute (AEI), where she focuses on defense against emerging national security challenges, such as hybrid and grayzone threats.

She is a columnist with Foreign Policy and The Wall Street Journal, where she writes on national security and the globalized economy, and a member of the National Preparedness Commission (UK). Before joining AEI, Ms. Braw was a senior research fellow at the Royal United Services Institute for Defence and Security Studies in London, where she founded its modern deterrence project. She is also the author of “God’s Spies: The Stasi’s Cold War Espionage Campaign Inside the Church” (Eerdmans, 2019) and “The Defender’s Dilemma” (2021).

Beijing, the latter may retaliate by harming Taiwanese companies. In August 2022, after US Speaker of the House Nancy Pelosi announced she’d visit Taiwan, Beijing suspended imports⁷ of several hundred Taiwanese products. In the weeks leading up to Russia’s invasion of Ukraine on 24 February 2022, Moscow’s menacing moves along Ukraine’s borders and in the Black Sea similarly demonstrated the harm aggression below the threshold of war can cause companies and thus countries’ economy. Many investors and FDI investors were so rattled⁸ by the prospect of invasion that they withdrew from the country, while international financial markets’ confidence in Ukraine dipped and the cost of insuring

⁷ <https://www.wsj.com/livecoverage/nancy-pelosi-taiwan-visit-china-us-tensions/card/china-suspends-imports-of-hundreds-of-taiwan-products-sK33Qdt5UjPWLguBxOwS>

⁸ <https://www.ft.com/content/1a4efd5e-99c5-4d42-addb-7217c0a76676>

against a sovereign debt default grew. On 15 February, maritime insurers raised⁹ the Ukrainian and Russian parts of the Black Sea to their highest risk category, making insurance more expensive and cumbersome to obtain for shipping companies.

In the end Russia, of course, invaded, but the uncertainty just before the invasion highlights how much damage a country can do to another country without using military force. Using such aggression, known as grayzone aggression, the aggressor country can use any means at its disposal to harm or weaken another country including its civil society, and often these means are not illegal. Positioning tens of thousands of soldiers on one's own side of the border is, for example, perfectly within a country's right.

Indeed, as NotPetya victims' insurers discovered, being able to attribute an act of aggression to a hostile state is little consolation since courts and legislation have not kept up with the evolving nature of conflict. "Traditional policy exclusions for war or war-like incidents fail to adequately capture situations where nation states are suspected of being behind an attack, or providing a safe harbour for the hackers, especially if the motives for the attack are unclear. Such issues of attribution and characterization create significant contractual uncertainty for insurers," the Geneva Association noted¹⁰ in a January 2022 report on cyber aggression.

That leaves companies and insurers in an extremely difficult situation. Because conflict is man-made, it can't be modelled like

natural hazards can. And because grayzone aggression is so innovative and constantly uses new tools, it's also impossible for insurers to know what to model. At the same time, companies are inherently vulnerable to grayzone aggression. Even if they were to perform the feat of limiting both supply chains and sales to friendly countries, they could be targeted by NotPetya-like cyber attacks.

This raises the question of whether insurers will be able to keep offering the all-round protection that companies have become accustomed to. Lloyd's exclusion of state-backed cyber aggression is a clear indicator of underwriters concluding that they have to stop short of covering geopolitically motivated aggression, not just because it can result in catastrophic losses but also because of the extreme difficulty modelling it. (I examined the question of whether grayzone aggression is making some business areas uninsurable in a June 2022 report for the American Enterprise Institute¹¹.)

Compared to the risks affecting most businesses a decade ago, today's risks are capricious and growing in number. That, in combination with the fact that insurance coverage may not be available for all circumstances, makes it imperative for businesses to better understand the geopolitical environment in which they're now operating. Otherwise they may find themselves sudden victims in the manner of Australia's winemarkers, or Merck, or Ericsson, or the other companies have, through no fault of their own, recently found themselves in the line of geopolitical fire.

⁹ <https://www.prospectmagazine.co.uk/world/the-last-thing-ukraine-needs-is-a-shipping-crisis-but-its-about-to-have-one-russia-conflict>

¹⁰ https://www.genevaassociation.org/sites/default/files/research-topics-document-type/pdf_public/cybersolutions_web.pdf

¹¹ <https://www.aei.org/research-products/report/insurance-and-geopolitics-is-geopolitical-confrontation-making-international-business-uninsurable/>

Do rising consumer boycotts threaten corporate geopolitical neutrality?

Consumer boycotts are on the increase and can lead to substantial losses, yet they don't fit neatly into risks traditionally modelled by insurers. This should change.

When one major retailer decided, a few weeks after Russia's invasion of Ukraine, to keep its Russian stores open, consumers in Europe and beyond swiftly vowed to boycott the chain. It's unclear how many actually did, but the reputational harm the boycott caused the retail chain was so severe that the company swiftly reversed course. Its fate seems to have convinced many other Western companies to also leave Russia. Western consumers concerned about geopolitics are likely to turn their sights to companies operating in other countries too – and they're not the only group willing to stage boycotts over geopolitics.

The reputational harm the boycott caused the retail chain was so severe that the company swiftly reversed course.

When Russia invaded Ukraine, the many companies who decided to stay – until a consumer backlash conducted mostly on Twitter convinced them otherwise -- were demonstrating the corporate mindset that has over the decades seen Western companies make and sell their wares in many countries with questionable political or human rights track records. Many did business in apartheid South Africa until a boycott by Western governments forced them to leave. They do business in Myanmar and Saudi Arabia, even though both countries' regimes have a poor human rights record and engage in military violence, in the case of Myanmar against the Rohingya minority and in the case of Saudi Arabia against Yemenis. But Western consumers haven't responded by staging boycotts against Western companies active in these countries.

To be sure, smaller activist groups had criticized¹ a few brands over Myanmar, but until Russia's invasion of Ukraine there hadn't been any major geopolitically motivated boycotts of Western companies.

¹<https://www.ethicalconsumer.org/ethicalcampaigns/boycotts/history-successful-boycotts>



By Western consumers, that is. But they're not the only ones staging boycotts. According to a July 2022, report by researchers at the Swedish National China Centre², a think tank funded by the Swedish government, between 2008 and 2021, Chinese consumers conducted 90 boycotts of foreign companies, with most of the boycotts taking place from 2016 onwards. Most of the boycotts, the researchers found, targeted companies from North America, Europe, Japan or South Korea in the apparel, automotive, and food and beverages sectors: that is, consumer brands. The haute couture houses of Givenchy, Dior, Coach and Versace have also been subjected to Chinese consumer boycotts on social media³, in their case after having seemed to imply that Taiwan is independent by, for example, not including

it on a map of China, while companies including Burberry were targeted over their involvement in the Better Cotton Initiative⁴, which promotes ethical cotton sourcing. "Boycotts were most commonly triggered by company statements or actions perceived as challenging China's governance in Hong Kong or sovereignty over Taiwan, or as unfairly criticising China's human rights record in Xinjiang," the Swedish National China Centre's researchers found. Cotton cultivation in the Xinjiang region, a leading source of cotton, includes use of Uyghur forced labor; the June 2022 Uyghur Forced Labor Prevention Act bans US-based companies⁵ from using cotton whose supply chain involves forced labour.

² <https://kinacentrum.se/en/publications/chinese-consumer-boycotts-of-foreign-companies/>

³ https://www.wsj.com/articles/dior-gets-caught-up-in-chinas-latest-map-flap-11571317112?mod=article_inline

⁴ <https://www.forbes.com/sites/isabeltogoh/2021/03/26/as-burberry-faces-backlash-in-china-over-xinjiang-cotton-other-luxury-brands-could-face-boycott/?sh=16b066bb3f9a>

⁵ <https://www.theguardian.com/world/2022/jun/21/us-ban-on-cotton-from-forced-uyghur-labour-comes-into-force>

The boycotts have a tangible effect on companies' bottom line.

All companies that have suspended operations in Russia or left the country altogether to avoid a consumer boycott – and thus reputational damage – have incurred financial losses. Some have, of course, left the country primarily because they consider it a moral imperative, in which case financial losses are of secondary importance. Others, though, face the new dilemma of leaving a country to avoid a consumer boycott and thus forfeiting revenues – or staying in the country and suffer reputational damage.

Indeed, companies contemplating leaving a country to avoid a consumer boycott face another dilemma: what is the tipping point for consumers to stage a boycott?

The information available to date provides little guidance. Why did Russia's 24 February invasion trigger consumer boycotts while Russia's 2014 annexation of Crimea did not? Indeed, why did Western consumers hardly react at all after the annexation of Crimea? Why did they not stage boycotts of Western brands active in Saudi Arabia after journalist Jamal Khashoggi was murdered?

It's impossible to know. Indeed, the boycott of a Japanese retailer seems not have been the product of spontaneous outrage among Western consumers, rather than the work of hashtag activism.

That means that the next time an event or an act enrages enough Western consumers, a company involved in the situation faces the risk of a boycott that could do considerable reputational harm on global operations even if it causes only minimal financial losses in the affected region. Chinese consumers, meanwhile, will continue to boycott companies they see as offending China, and consumers in other countries could start targeting companies over specific issues relating to their countries.

Such intangible losses snowballing into substantial tangible financial losses, resulting from consumer boycotts don't fit neatly into risks traditionally modelled by insurers. Indeed, because frequent consumer boycotts from different corners are a new phenomenon, there is little data that underwriters could use for modelling. Consumer sentiment is changing, too: while older consumers focus mostly on quality and price in their choices of consumer products, a 2021 study by the market-research firm Forrester⁶ found that more than half of American Generation Z consumers research brands to ensure they align with "their position on corporate social responsibility." But that modelling should start soon – especially because as geopolitical tension continues to grow, consumer boycotts are certain to increase too.

⁶<https://www.forrester.com/report/a-post-truth-climate-is-shaping-gen-zs-consumer-behaviors/RES164315?objectid=RES164315>



Technology





Technology

2022 proved to be no exception to the accelerated adoption of technology that began alongside the onset of the COVID-19 pandemic. From the development of artificial intelligence (AI) and machine learning (ML) to the expansion of digital worlds via the Metaverse, technology advances show no signs of abating.

Adjusting to the new realities of the pandemic, companies have had to adapt their workforces, business models, and organizational cultures to fit in an increasingly connected and technological world. Many of these advancements will challenge society's basic assumptions but companies must be willing and able to take the initiative on crucial investments in both platforms and individuals going forward.

As nearly every organization will develop and incorporate digital technologies within their business structure, having a solid foundation built around adaptive principles and a nimble workforce will be crucial for companies to have a leading edge.



The past year gave way to a whole new paradigm surrounding issues such as natural language processing (NLP), cyber security, large language models (LLM), the metaverse, quantum computing, and individual rights in the digital space.

Much of our current modes of operations and organizational architectures are based on the Internet as we know it today. However, many of the most recent technological progressions such as the Metaverse and Web3 don't abide by the traditional constraints that have defined the Internet over the last three decades. Building the next generation of services will depend greatly upon the mastery of new domains, especially over the medium term.

Technological disruptions will become more norm than aberration as new paradigms will continue to emerge in the innovation landscape.

The widespread adoption and use of ChatGPT presents a particular salient example. As the most well-known of the LLMs currently in use, it has proliferated at an exponential rate, spurring rival companies to quickly bring their products to market in order to compete in the

predictive text realm. Cybersecurity also represents a significant disruptor as cyber-attacks have been on the uptick compared to recent years with both governmental and non-governmental infrastructure targeted. Individuals will also experience significant digital disruption in a personal and professional capacity as remote works begins to take shape in a post-pandemic world.

The WTW Research Network has worked closely with multiple universities and organizations to better understand these developments. Partnering with Warwick University, we looked at how AI can be utilized for cybersecurity and the ways AI techniques can help corporates make their structures more resilient to cyber attacks. We also looked at the importance of cyber bullying insurance in mitigating online crimes and how companies' human resources practices can be amended to implement protections for minors as part of a larger benefits packages for their employees. And our work with Wharton's Mack Institute continues, examining issues such as the future of digital skills, disruptive technologies, and key megatrends that will shape the technology landscape in the coming years.

Omar Samhan

People and Technology Risk Analyst

Personal Identity Insurance: Coverage and Pricing in the US

Personal identity theft occurs when a criminal uses stolen personal identifiers to manipulate third-parties into taking actions under the false belief they are communicating with the individual whose identity has been stolen

A typical example is the criminal taking a loan out under someone else's name or tricking tax authorities into sending the rebate to the criminal's account. A market for personal identity insurance has emerged to mitigate the associated harms.

In work conducted by Daniel Woods at the University of Edinburgh as part of a broader WTW Research Network program looking at Trust in Technology, we investigate personal identity insurance in the context of societal and financial harms and negative externalities in the form of lost income, attorney fees, and even mental health counseling.

There is a risk of identity theft whenever third parties use personal identifiers to decide whether and who to send funds to. Historically, debt was issued by a member of the local community who could authenticate an individual via natural identifiers such as face, voice, gait, and so on¹. Such identifiers are not readily available when banks extend credit to individuals from distant parts of the country, let alone to international borrowers.

To solve this problem, lenders authenticate distant applicants via personal identifiers—passport details, social security numbers, address and so on—that are presumed to be known by the individual alone. This assumption is flawed because of the billions of personal records that have been lost in corporate data breaches over the last three decades^{2,3}. Criminals can use the stolen data to trick lenders into sending the loan payment to the criminal.

The economic costs of identity theft raise the possibility that individuals can insure against the consequences of identity theft. In this project we collected a sample of 34 policies available in the US from a regulatory database and conducted an inductive content analysis of the policy documents and pricing algorithms, which allows us to answer the following three research questions:

¹David Graeber. *Debt: The first 5000 years*. Penguin UK, 2012.

²Benjamin Edwards, Steven Hofmeyr, and Stephanie Forrest. Hype and heavy tails: A closer look at data breaches. *Journal of Cybersecurity*, 2(1):3–14, 2016.

³Maochao Xu, Kristin M Schweitzer, Raymond M Bateman, and Shouhuai Xu. Modeling and predicting cyber hacking breaches. *IEEE Transactions on Information Forensics and Security*, 13(11):2856–2871, 2018.

1**Which harms are covered by personal identity insurance?****2****What is the implied likelihood and severity of each harm?****3****How do insurers justify the scope and pricing of coverage?**

The study also contributes to an emerging field of technology insurance that covers cyber attacks⁴, crypto assets⁵, cyber bullying⁶ and artificial intelligence liability⁷. So far, corporate cyber insurance is the only technology insurance product with a developed body of literature. Research into cyber insurance has also considered whether it improves social welfare and how this motivates different regulatory strategies^{8,9}. These questions typically turn on whether insurers improve risk management processes. More research is required to answer whether personal identity insurance does so, although we have argued identity theft is largely outside the individuals' control.

This study confirms one aspect of the privacy/harm literature as evidenced by the emergence of a private market covering the harms associated with identity theft incidents. We provide an additional contribution, namely that the lack of support services leads individuals to suffer more harm. For example, one insurer anticipates case management services lead to a 90% reduction in the cost of an identity theft incident. Thus, policy makers could reflect on whether the impacts of identity theft and the expertise to remedy them are fairly distributed across society. The status-quo in which financial smoothing and risk reduction services are privately provided undoubtedly skews towards affluent consumers.

⁴ Sasha Romanosky, Andreas Kuehn, Lillian Ablon, and Therese Jones. Content analysis of cyber insurance policies: how do carriers price cyber risk? *Journal of Cybersecurity*, 5(1), 2019.

⁵Adam Zuckerman. Insuring crypto: The birth of digital asset insurance. U. Ill. *JL Tech. & Pol'y*, page 75, 2021.

⁶Nir Kshetri and Jeffrey Voas. Thoughts on cyberbullying. *Computer*, 52(4):64–68, 2019.

⁷Anat Lior. Insuring AI: The role of insurance in artificial intelligence regulation. *Harvard Journal of Law and Technology*, (1):in print, 2022.

⁸Jan Martin Lemnitzer. Why cybersecurity insurance should be regulated and compulsory. *Journal of Cyber Policy*, in print, 2021.

⁹Tom Baker and Anja Shortland. The government behind insurance governance: Lessons for ransomware. *Regulation & Governance*, 2022.

Artificial Intelligence in the role of assessing cyber risk

Since the onset of the Covid-19 pandemic, industries across the globe have witnessed a sharp rise in the number and types of cyberattacks they face.

Understandably, cyber risk management systems have been unable to keep up with these sophisticated security attacks. With businesses trying to cut down their labor costs and adopt a cheaper and more efficient digital model, it is evident that cybercrime is also on the rise.

In recent years, insurance companies have become a target of ransomware attacks as they play a crucial role in protecting high-value assets, people, and commodities. This is where artificial intelligence (AI), if employed effectively, could help combat these threats. Integrating cyber security with AI helps one develop a more holistic and robust model, efficient at performing various tasks such as detecting and preventing cyber-attacks in real-time, resisting novel cybercrime and increasing the competence of cyber security teams.

In a special report, The University of Warwick produced this systematic literature review that presents an overview of the barriers and opportunities of using artificial intelligence to help reduce cyber risk and threat exposure in the insurance sector.

Outputs include:

1

A systematic literature review of the state-of-the-art and emerging AI techniques with applications in risk and threat assessment.

2

Examine the barriers and opportunities of utilizing AI techniques for decision-making in the insurance industry.

3

Review the efficacy of emerging AI techniques in identifying unknown adversarial scenarios and feared events – and how these affect traditional risk assessment processes.

4

Provide a set of recommendations that can act as a guideline/roadmap for different stakeholders in that industry.



Systematic review of emerging AI techniques with applications in risk and threat assessment

With an increase in the use of AI throughout multiple industries, the insurance industry today stands on the edge of large-scale adoption of the technology. This work with the University of Warwick provides an approach to understanding how emerging and state-of-the-art AI technologies can be used to reduce risks and better the security posture of an organization.

The employment of AI in insurance innovation is now used for a variety of back-end functions such as fraud detection, algorithmic trading, blockchain analytics, and financial search engines. Robotics, computer vision, and Natural Language Processing (NLP) are some fields that are being serviced by machine learning (ML). These applications have increased interest in machine learning within the insurance sector, which is rich in data. Examples of ML techniques include:

- **Support Vector Machines** – an ML algorithm that learns from examples it is given. When many fraudulent and non-fraudulent activity reports are examined, it can identify credit card fraud.
- **Artificial Neural Network** – the primary focus is the use of an improved neural network for assessing information risk. The purpose of neural networks is to resemble the human brain.
- **Decision Tree** – a tool that forecasts potential outcomes, such as resource costs and utility, using a tree-like model of possibilities.

- **Naïve Bayes** – a straightforward “probabilistic classifier,” the Naïve Bayes classifier is based on the Bayes theorem and robust (naive) independence assumptions.
- **Random Trees** – this learning method is made to handle issues like regression and other difficulties that need the training of many decision trees.

The main advantage of using AI in the insurance sector is that it makes data management simpler. Datasets that are semi-structured and unstructured can be organized using machine learning. Datasets from various insurance companies are available for scholars and data analysts to utilize. Machine learning may be used in the insurance industry to identify risk, claims, and consumer behavior with greater prediction accuracy.

AI could also be used in various ways in the insurance industry, from responsive underwriting and premium leakage to expenditure control, arbitration, litigation, and fraud detection.

This issue is being addressed in great detail by incorporating potent artificial intelligence methods into insurance data. Many scientists are looking at cutting-edge machine-learning techniques for responsibilities, such as premium leakage to expenditure management, debt recovery, proceedings, and fraud detection, motivated by industrial production for management solutions and the academic ability to develop highly relevant machine-learning techniques.



Opportunities and barriers: utilizing AI techniques for the insurance industry

The insurance industry is made up of several key components, including fraud detection, claim prediction, risk prediction, and underwriting.

A number of industries, including medicine, car production, banking, manufacturing, agriculture, and marketing, use AI at a fast rate.

This growth is a result of three key technical advancements in recent times: the emergence of big data, the normalization of interactions between humans and machines, and advances in machine learning.

The insurance sector has also been impacted by these advances in terms of newly created business models and capital expenditures employing cutting-edge technology such as artificial intelligence in risk and threat assessment. This frequently covers the dangers connected to the adoption and application of AI itself.

As an alternative, several insurers make investments in game-changing AI technology to improve their operations and risk control. AI will increase the effectiveness of preventative insurance procedures. Insurers may help clients collect, analyze, and interpret their data to prevent illnesses and accidents using AI. The business structure of the insurance sector can change. Thanks to health sensor data, face mapping technology, genetic predictors powered by AI, and AI personal assistants, customers are now better informed about their insurance needs. All of these might result in a reduction in the insurance gap.



Opportunities:

1. Claims Predictions – by employing AI to forecast insurance claims, a client may ask for an explanation as to why their claim was denied. According to reviewed literature, academics used artificial neural networks to deal with health insurance claims.

2. Use of NLP against Phishing – the insurance industry’s principal application of NLP in cyber security will be to encourage interactions between people and machines. In order to identify the risk of a phishing attack, insurance firms may use NLP to scan vast amounts of datasets for email conversations. By keeping track of all emails that enter the organization’s network, NLP can be used to identify patterns of malicious behavior.

3. Use of AI and ML against DDoS – artificial intelligence and big data help defend firms against DDoS attacks. By comparing network traffic with real-time data streams collected from threat-intelligence sources, correlation engines can spot attack trends. As a kind of cyber extortion, hackers are increasingly using DDoS attacks to force financial institutions to pay hefty sums of money to cease the attacks.



Barriers:

1. Cyber Risks – procedures, such as damage assessment, IT, human resources, and legislative change, all depend on AI. AI systems are extraordinarily quick to learn about petitions, policies, and changes made as a result of those policies. They can also make decisions swiftly. This tactic prompts worries about decision-making accountability, social, economic, and political risks, as well as security.

2. Data Privacy Issues – the enormous potential of technological platforms to obtain and analyze data from a variety of sources – including internet searches, social media accounts, shopping and purchase information obtained from credit card companies – is a threat to customer privacy. The lack of a time restriction on the use of a person’s information obtained from a social media account or another source when determining risk is one of the most concerning issues when utilizing AI for data sifting.

3. Discrimination Based on Characteristics – statistics that severely disparage protected attributes that pose a serious threat of bias are not permitted under anti-discrimination rules. Certain legislation, such as the Equality Act of 2010, prevents insurers from using algorithms that can lead to discrimination based on physical characteristics. The potential for indirect discrimination may be negatively impacted by real results of the individualization process created by algorithms.

Emerging AI techniques: impacting traditional risk assessment processes

The primary factor accelerating automation across all industries are machine learning algorithms. However, it has been shown in numerous instances that the use of these algorithms has begun to appear in a variety of cyber-attacks, has improved the effectiveness of those assaults, and has allowed malicious actors to avoid manually addressing statistical analysis issues. The need for strengthening an organization's security posture has increased due to the weaponization of AI and machine learning.

Emerging and state-of-the-art cyber-attack AI techniques

The advancement of cyberattack technology and contemporary techniques is shaping and expanding the field of cyberattacks, exposing cyberspace to a broad range of cutting-edge cyberweaponry with numerous negative effects. Next-generation malware may covertly enter vulnerable and sensitive computer systems while learning from its environment and evolving with new variations thanks to malicious actors utilizing fuzzy models.



Malicious actors can better learn how computer infrastructures, devices, and cyber defense systems normally work with the use of AI techniques. For example, a malicious actor can identify a key link to targets by gathering architectural, logistical, and topological data about the user's equipment, network flows, and architecture. Massive data collections might provide information about the patterns of targeted attacks that would-be criminals could find using AI. AI's ability to comprehend, unearth, and recognize patterns in massive amounts of facts allows it to be utilized to offer in-depth research and create targeted exploration processes while overcoming human limitations.

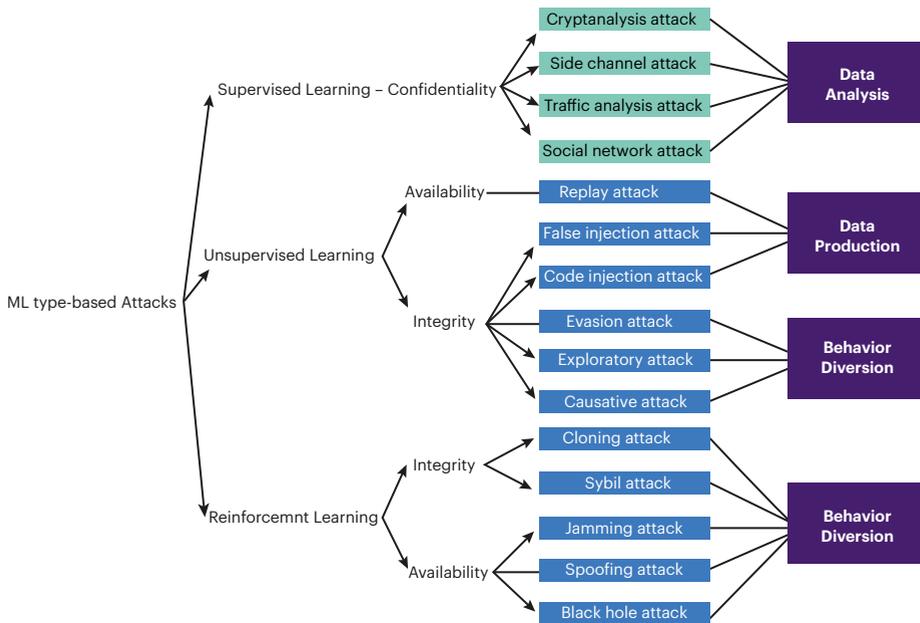
various kinds of cyber-attacks. The figure helps in mapping out the types of algorithms a malicious actor can use to perform a particular attack. It also assists in describing the purpose of the attack, which may be for data analysis, data production, behavior diversion or behavior deduction.

Impact of weaponized AI on insurance industries

Worldwide insurance companies are a target due to their storing copious amounts of sensitive data. Attacks using ransomware and DDoS powered by AI have grown commonplace. Defending organizations from harmful actors has become very difficult due to the rise in the complexity of cyberattacks made possible by AI.

As shown below in Figure 1, different types of algorithms can be used to undertake

Fig.1: ML algorithms used in different types of attacks



Source: WTW

The interruption of services and other similarly detrimental effects are some of the most worrying effects of a successful cyberattack. A cyberattack may result in reputational damage to a company since consumers may stop doing business with them for fear of a potential breach. If companies are negligent in their duties they may face legal repercussions from governmental authorities. Cybercriminals are continually modifying and enhancing the effectiveness of their attacks, placing a strong emphasis on the use of AI-driven approaches.

Lessons for Businesses: Next Stages in Corporate Cyber Resilience

To understand and emphasize where and when disruption may occur – and what it means for certain industry sectors – companies should undertake hypothesis-driven simulations. Pilots and proof-of-concept initiatives should be planned to evaluate not only performance but also to monitor how successfully an organization may perform a certain function within an ecosystem based on data or network intrusions. This work laid out the following recommendations to build organizational resilience within a company:

- Educating stakeholders on AI and its multiple uses, including threats
- Implementation of a rational strategic plan based on employing technology utilizing analytics from AI investigations
- Creating and executing a comprehensive data strategy
- Training and hiring competent employees who possess technological proficiency, creativity, and a willingness to work in constantly evolving threat environments

The key takeaways for insurers are to recognize that cybersecurity is not an IT problem but a business concern. Enhancing cybersecurity capabilities by effectively implementing AI and ML algorithms to defend networks against sophisticated attacks is necessary. However, insurers will also want to evaluate their present “pockets” of excellence in cybersecurity and ensure that these best practices are disseminated throughout the organization.

CEOs must collaborate with business executives to best address cyber threats to identify the proper ratio of centralized and decentralized services. Fielding an appropriate response requires the proper framework for robust and consistent cybersecurity. Insurance leaders must carefully evaluate how to ensure their businesses stay prepared, from “red teaming” exercises that mimic the behavior of attackers to increased staff training and regular drills. To manage their risk consistently, insurers must pay particular attention to strengthening their understanding of the ecosystem of third-party players, including independent agents, outsourced service providers, and other non-employees with access to data.



Special feature: TMT Futures Report – workforce transformation and the digital talent crisis

The TMT sector faces a wide range of risks made more challenging by the global pandemic, accelerated digital transformation, geopolitical uncertainty and other factors. Talent gaps have long haunted the industry, particularly when it comes to the so-called ‘digital type’.

This problem is set to worsen as rapidly changing technology becomes more complex and expands to new areas of the business, and with competition from wholly unrelated industries now embracing digital, such as department stores and shipping companies, further heating up the battle for top talent.

With the above in mind, and following publication of WTW’s TMT Futures Report¹ in August 2021, we continued to work with The Mack Institute’s Collaborative Innovation Program (CIP)² at the Wharton School, University of Pennsylvania, to dive further into the specific risk issues related the digital talent crisis. Our collective research and interviews with senior executives yielded further fresh insights into the risk issues associated with this key ‘megatrend’ facing the TMT industry.



Our 2022 TMT Futures Report -Workforce Transformation & The Digital Talent Crisis report³ is the result of our continued research around the global talent and skills race megatrend which in our view is the most important exposure facing the industry currently and a key link among the broader set of exposures facing TMT businesses.

¹<https://willistowerswatson.turtl.co/story/wtw-technology-media-and-telecommunications-futures-report-risks-on-the-horizon-2021-gated/page/1>

²<https://mackinstitute.wharton.upenn.edu/corporate-partnership/collaborative-innovation-program-partners/>

³<https://willistowerswatson.turtl.co/story/tmt-futures-report-workforce-transformation-and-the-digital-talent-crisis-gated/page/1>

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While there is no industrywide model for the workforce of the future, we can make certain projections: it will be increasingly digitally enabled, systematic employee reskilling will become routine, and artificial intelligence (AI) will become an embedded technology across many of the core business processes as companies embrace it to augment, but not replace, human workers.

TMT Futures Report –
Workforce Transformation &
The Digital Talent Crisis⁴

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Our work with the Mack Institute confirmed our inhouse research that in a digital-first culture⁵ there is full organizational alignment that consistently evolves around an integrated digital strategy. Key features include enlightened leadership and human capital management as well as new, agile business models⁶ and re-engineered internal processes. We recognise there is no template for what constitutes a digital-first culture that will work for every company, or even narrow industry sector, among TMT and other companies. However, WTW and the Mack Institute jointly found a universal success factor is a clear leadership vision harnessed to highly motivated and skilled employees.

Digital transformation must have a digital-first culture as its outcome, rather than a disconnected collection of technology investments, organizational changes, and a grab for talent. The moving parts must be aligned to achieve optimal business results and constantly fine-tuned to tackle new competitors, changing customer needs, the shifting skill sets and expectations of a restless workforce.

⁴ <https://willistowerswatson.turtl.co/story/tmt-futures-report-workforce-transformation-and-the-digital-talent-crisis-gated/page/4/2>

⁵ <https://www.wtwco.com/en-US/Insights/2019/08/is-your-company-culture-digital-ready>

⁶ <https://www.wtwco.com/en-US/Insights/2021/12/technology-media-and-telecommunications-futures-report-digitalization-and-technological-advances>

Digital First Culture is characterized by the following:

1

Customer experience is a central tenet

2

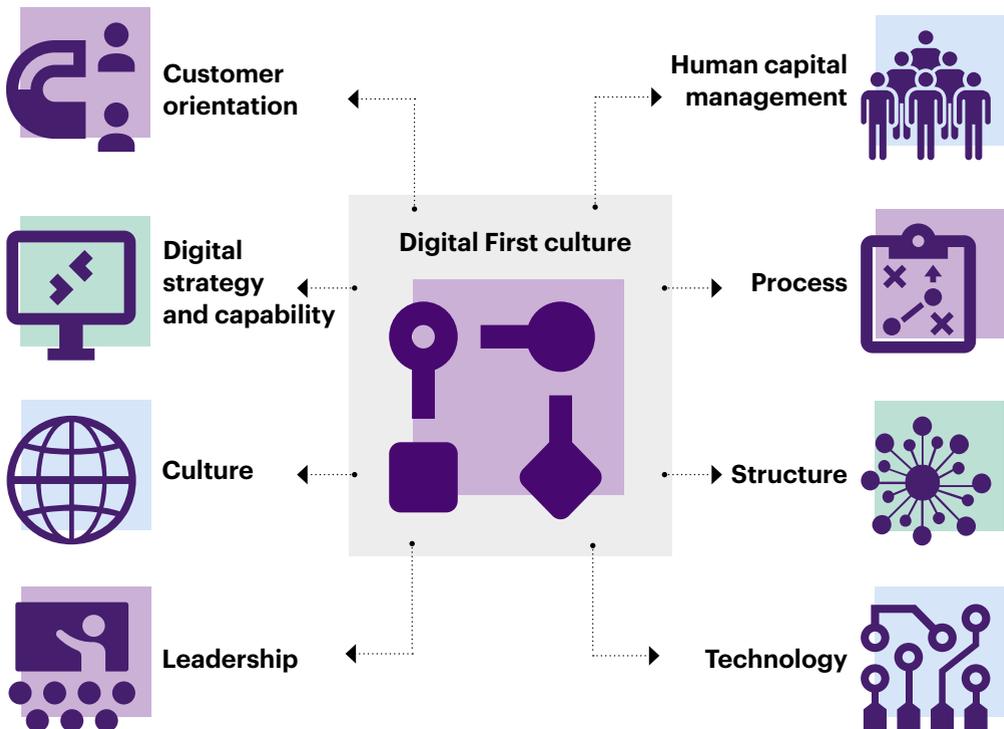
Data is seen as source of value

3

Influence is through insights, not hierarchy

4

Collaboration, iteration, speed, and ecosystems are critical to success



Source: WTW

Reskilling

Digitalization and remote working arrangements have worked remarkably well. But now the initial shock of the COVID-19 pandemic has waned, both companies and their employees are becoming more focused on the long-term implications of markedly new business models and strategies.

Finally, facing global talent shortages, organizations also risk productivity losses if they ignore the imperative to reskill. According to the WEF 2018 Future of Jobs report, 75 million jobs are expected to be displaced by 2022. Concurrently, due to advances in technology and new ways of working, as many as 133 million new roles could be created. However, preparing and reskilling the workforce for these new opportunities will require the CPO's substantial attention; WEF estimates on average, 42% of the skills required to perform a job will shift between 2018 and 2022.

Companies realize they must continuously invest in the latest technologies while keeping an eye open for disruptive competitors and the whims of a fickle client base. From a workforce perspective, TMT companies in particular scramble to the best possible talent, digital and otherwise, while retaining their best employees and equipping them with the skills needed to thrive in a new, often virtual, work environment.

The war for talent that has long engulfed many TMT companies has been worsened by what McKinsey calls a 'labour mismatch'⁸ in the U.S., with rising private sector wages despite a persistent talent shortage.

At the same time, the Mack Institute research reminds us employee needs and expectations have changed significantly over the last few years. Many workers like the freedom and flexibility of working from home and resist returning to an office. Others take advantage of digital talent shortages to find new jobs. Many employees in some areas – less technical warehousing or call-in centre jobs, for example – have different needs entirely

⁷ <https://www.weforum.org/reports/the-future-of-jobs-report-2018/>

⁸ <https://www.mckinsey.com/capabilities/risk-and-resilience/our-insights/covid-19-implications-for-business>



Conclusion

Our work with the Mack Institute identified a variety of approaches companies are taking to achieve a digital-first culture with a nimble, continuously reskilled workforce enabled by AI and other evolving technologies.

As the examples in 2022 TMT Futures Report – Workforce Transformation & The Digital Talent Crisis show⁹, there is no one way to achieve a digital-first culture. The culture in any case must reflect leadership vision and behaviour as well as the particulars of a business setting, client base and even geography and other factors.

Although COVID-19 has served as a change accelerant, the pandemic is, to some degree, a distraction. Digital transformation was already underway, and it was ineluctable. Employers simply can't return to factory setting for their postpandemic workforce, nor should they. Now is the time for them to examine their businesses, root and branch, with particular focus on delivering the best possible EX to achieve customer satisfaction and business success.

Our current global business environment represents a rare, exciting opportunity to rethink how work gets done, how jobs have changed and will change, and the upskilling and reskilling pathways needed for a new workforce model to be successful.

⁹ <https://willistowerswatson.turtl.co/story/tmt-futures-report-workforce-transformation-and-the-digital-talent-crisis-gated/page/1>





Organizational resilience





Organizational resilience

The word resilient originates from the Latin verb *resilire* (“to jump back”) and was introduced to the English language in the early 17th Century. The word Resilience is frequently used by academics, practitioners and policymakers who have adopted it more recently to describe how something or someone can recover and return to normality after an adverse event. This definition is suitable for physical structures that do not learn from or are strengthened by the adverse event; However, it is an oversimplification in the context of our interpretation of organizational resilience.

Organizations are living socio-ecological systems that adapt to the challenges of tomorrow. We have witnessed how organizations have mitigated risk by reimagining work life and adopting technologies in new ways to support organizations in meeting their objectives since the beginning of the COVID-19 pandemic in 2020.

We know today that only few organizations had insurance to cover losses from the pandemic, and most business continuity plans included some version of a plan for mitigating losses from a pandemic. Yet most continuity plans had an internal focus and did not envisage global disruption of supply

chains. Despite this, organizations have proven to survive the pandemic and may even have become more resilient.

Organizations should be able to learn from adverse events and utilize the knowledge gained from their survival to Bounce-Forward-Better and act more efficiently in future similar adverse events before they can be considered resilient.

With the help of our WTW Research Network partners, the Organizational Resilience Research hub continues to support and foster a broader understanding of how society, organizations and individuals most efficiently can mitigate their risks, learn from the past and become resilient by adapting to the challenges of tomorrow. To rethink insurance as the next generation of resilience, we work with the European Center for Risk & Resilience at The University of Southern Denmark, and Resources For the Future, in particular looking at transitions from catastrophe. We continue

to promote the adoption of technology for risk quantification, insurance pricing and risk management through our collaboration with Loughborough University for the establishment of a Center for Doctoral Training under the umbrella of Automated Risk Engineering. Finally, there are also plans to start a new stream of research focused on supply chain resilience in 2023.

We are proud to work with some of the best scientists around the world. In the following chapter, we illustrate the most relevant achievements of the past year.

Simon Sølvesten

Head of Organizational Resilience Research



Do insurers adjust prices to incentivise the adoption of loss prevention?

In theory, loss prevention should, as the name implies, reduce the loss for the risk carriers and the expected present value of losses.

In a competitive insurance market, where the premium is given through market bidding, expected potential savings from investing in loss prevention technologies should become measurable in the insurance price. However, no empirical analysis has yet proven this theory. Thus, WTW Research Network has supported a research project that explores **what influence the use of property loss prevention technology has on property insurance pricing.**

Main results

A policyholder's claim history is found to significantly influence the cost of insurance; however, little evidence supports that the use of loss prevention technologies influences the price. Only water leak detection technology seems to have any measurable downward influence on the price with a 90% confidence level. It seems that technologies that reduce the cost in the tail of the risk distribution, where the probability for claims is lowest (and the cost highest) have less influence on the price compared to technologies that limit smaller yet more frequent damages. While risk carriers' price should reflect policyholders' risk, risk heterogeneity is likely more challenging to measure in the tail of the distribution where there are few claims. It is therefore likely that the influence of loss prevention technologies is muted if they primarily influence severe and costly damages. Furthermore, it was found that the size of claims has a significant yet different influence on prices. The results of the empirical analysis show that as the size of the claim increases, the relative influence the claim has on the price decreases.

Conclusion

The analysis shows that policyholders should not expect the insurance premium to change as a function of the deductibles and investments in loss prevention technologies. It is evident that loss prevention technologies lower the risk for the insurer; however, savings are not passed on to the policyholder. Consequently, the insurers benefit from policyholders' investment in loss prevention, which increases insurers contribution margin and lowers risk associated with the contract. While there is no clear evidence as to why the insurers do

not price the contract according to the risk heterogeneity one explanation may be that there is not sufficient competition between insurers for the price to reflect the marginal cost in the contract.

As only limited support is found in the empirical analysis to back investment in loss prevention, the policyholder may be best served by determining investment strategies for loss prevention technology in order to minimize own direct operating costs rather than for the lowering of insurance prices.



Results

While claims history does clearly influence insurance premiums, there is no evidence that insurers incentivise investment in loss prevention by offering premium discounts. This backwards-looking approach is not incentivising investment in resilience.

Savings resulting from loss prevention are not passed on to policyholders, and it could be that lack of competition is encouraging this status quo.



Data

The analysis benefits from a comprehensive dataset assembled in collaboration with the industry. The dataset was collected from a total of 225 insurance bids for 72 insurance contracts. Each contract consists of grouped buildings portfolios with more than 12,000 building addresses,. The 72 contracts cover 40 different municipalities from 2008 to 2018, 19 million square metres and 364 billion Danish kroner (£42b) in property value. The data consist of detailed information on the insured building's characteristics, claims history, insurance coverage and bids from winning and losing tenders.

Training the next generation of risk engineering experts

Technology has had a transformative impact on many areas of insurance, but one sub-market still currently largely reliant on manual processes is the insurance of industrial properties, especially when considering critical risks of fire and explosion.

Risk assessments for industrial properties are conducted by risk engineers, who synthesize heterogeneous information sources via various methods and then use their professional expertise to determine the risk and communicate this information. Looking into how exposure for fire insurance is estimated begins with the challenge of understanding that the methods are regionally dependent and, to some extent, constrained by the risk engineers' experience as well as company guidelines.

Calculation of risk exposure faces two essentially equal challenges in the coming years. First, we are faced with significant industry knowledge loss when the larger baby-boomer generations leave the job market. Second, we expect that Artificial Intelligence (AI) and other applications from computer science will begin to support and shape how risk engineers calculate and interpret property risk. In response to those industry-wide challenges, the WTW Research Network has jointly initiated a Centre for Doctoral Training with Loughborough University.

We envisage further evolution of business processes leading to wider economic benefits. For example, digitization can further support the standardization of business processes and enhance the consistency of approach across individuals and firms. If practitioners adopt common approaches and these are accepted at national and industry level, this can support greater comparability of risk assessment and thus increased efficiency of risk transfer as well as reduced cost of risk assessment. Digitization and adoption of more standardized methods can also lead to the development of tools of knowledge management for risk engineering, ensuring that skills and understanding are understood, shared and disseminated as widely as possible.

The Centre for Doctoral Training will initially support six PhD students examining foundational questions about the application of digital technologies in industrial and commercial property insurance. This initial research will support the incubation of an industry-wide effort for the digital transformation of risk assessment. Research supervised by Loughborough academics and WTW supervisors and advisers, will focus on the planned topics below:



Information extraction from building blueprints

Automatic detection of fire assets and objects for building environment mapping and fire risk assessment

Using 'digital twins' for insurance risk analysis and mitigation

The economics of industrial and commercial property risk transfer

Refining property hazard estimates using computer vision and machine learning

Knowledge management in industrial and commercial property insurance

The first PhD started in 2022 on “Automatic detection of fire assets and objects for building environment mapping and fire risk assessment” and will be accompanied by five further PhD students in 2023. The first cohort of PhD students is expected to conclude their research program in 2026.



Loughborough University

Loughborough University set in the market town in Leicestershire, England, dates back to 1909 and was established as a university in 1966. It is one of the top 10 UK universities. With around 20,000 students, it has a reputation for providing the best student experience. From its earliest days it has produced research relevant to the real economy, with strong links with industry and professional bodies.

The ripple effect of disruption in supply chain

Modern supply chains rely on a global interconnected network to improve margins, and are usually designed to meet the challenges of the firm efficiently, rather than resiliently.

However, increased supply chain dependency, complexity and globalization come with increased risk. The potential risk depends on a firm's ability to mitigate losses. Informed supply chain resilience strategies can help the firm to mitigate risk and create new opportunities.

Integrated academic-industry analysis can guide firms and society toward resilient strategies and mitigate future global supply chain shortage and losses.

It is evident that the disruption we face today (e.g. the aftermath of the COVID-19 pandemic, the war in Ukraine, energy crises, water shortages around in Europe, US and Asia and an increase in climate-related catastrophes) calls for innovation to identify supply chain risk, quantify the risk and highlight the challenges for the modern risk manager. There is a need for both analytical tools and new insurance products to support and mitigate the future risks companies face.

The WTW Research Network has initiated a collaboration with The European Center for Risk & Resilience Studies at the University of Southern Denmark to explore methods for quantifying the gross risk of business interruption loss through understanding the ripple effect in supply chain disruption. The project shows interesting results in risk quantification, risk illustration and provides new tools to manage risk.

The project was initiated in 2022 and will be completed in 2023.



European Center for
Risk & Resilience
Studies

About The European Center for Risk & Resilience Studies

The newly established European Center for Risk & Resilience Studies (ECRRS) at The University of Southern Denmark foster adaption to systematic changes and efficient action on risks through problem-solving research that adds value to industry and society by concentrating on solution-based results. The center's activities are focused on research, think-tank and talent development which combined form the pillars of the center.

Transitions from catastrophe

Catastrophes can instigate transitions by disrupting existing systems and requiring action to minimize losses in well-being and value

Catastrophes differ from disasters in the scale and comprehensiveness of the event; catastrophic impacts challenge society's ability to come back from the event, in other words, the disruption challenges system resilience. Impacts from catastrophes are exacerbated by population growth, more permanent and efficient infrastructure, and growing scale, with e.g. trade and cyber connectivity, pandemics, ecosystem loss, and climate change reaching global proportions.

Governmental, regulatory and industrial approaches to catastrophic risks operate on both intensive and extensive margins. The intensive margins are affected by actions and policies maintaining and even entrenching existing systems and distributions of well-being, while the extensive margins require shifts in systemic conditions that can purposefully re-align human activity, ecosystem services from natural capital, and distributional concerns through e.g. managed retreat.

Risk management is heavily embedded in political economy, intertwining private and government responses to the impacts of catastrophe. To better understand the scope and connectivity of private and public

actors managing catastrophic risks, and improve sustainable transitions, the WRN is supporting a project with the University of Southern Denmark and Resources for the Future. This project seeks to foster a better understanding of how catastrophic events are handled under existing financial, corporate and public institutions, to recommend how government and industry under threat from catastrophic risks can co-manage sustainable transitions along intensive and extensive margins to create more resilient communities in the future.

Reimagining insurance

The current insurance system works efficiently for those with financial safety nets, who can afford to wait for the claim settlement. However, those most at risk are often those with the least capacity to wait. Developing nations' populations are often underinsured and without fully effective risk management thus, the threshold for when an event is catastrophic in scale must be perceived as significantly lower for them and understood as the relative degree of resilience for this population. Therefore, there is a need to reimagine insurance to make it available and attractive for people in developing countries, to ensure fast loss settlements and payouts to meet challenges with household solvency, and to simultaneously ensure the system remains fair for both policyholder and insurer.

This "Transitions from Catastrophe" project will also explore how parametric micro-insurance can support the growing need for insurance in developing countries, the

challenges the instrumental design faces and how it can become widely available for those who need it.

The project will start on January 1, 2023, and conclude by the end of 2025.



University of Southern Denmark

The University of Southern Denmark (SDU) began with the Odense Campus in 1966. Since then, it has grown into an internationally recognized research university and is one of the top 50 universities in the world. SDU now has five faculties with more than 27,000 students, almost 20% coming from outside of Denmark, and more than 3,800 employees distributed across the original campus in Odense and regional campuses in Slagelse, Kolding, Esbjerg, and Sønderborg.



Resources for the Future

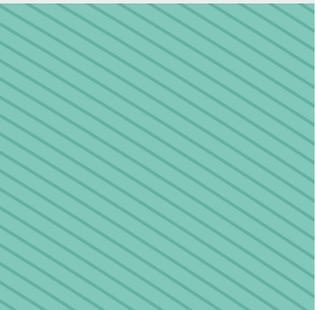
Resources for the Future (RFF) is an independent, nonprofit research institution in Washington, DC. RFF's mission is to improve environmental, energy, and natural resource decisions through impartial economic research and policy engagement. RFF is committed to being the most widely trusted source of research insights and policy solutions leading to a healthy environment and a thriving economy.



Learn more about the WTW Research Network

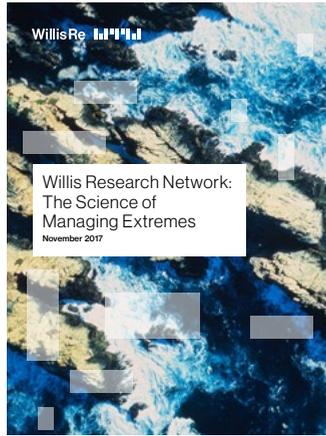
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2016



2017



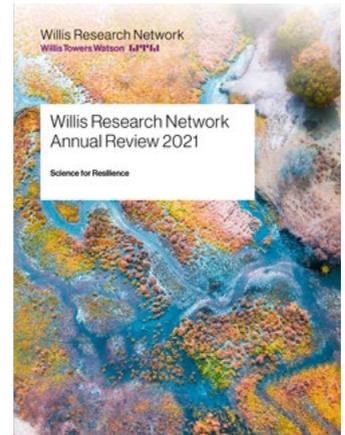
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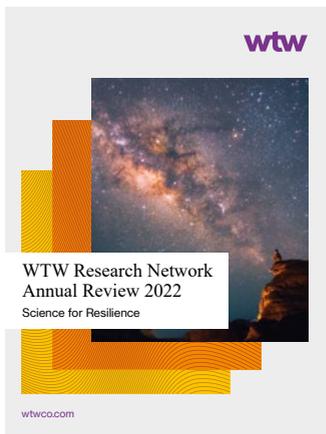
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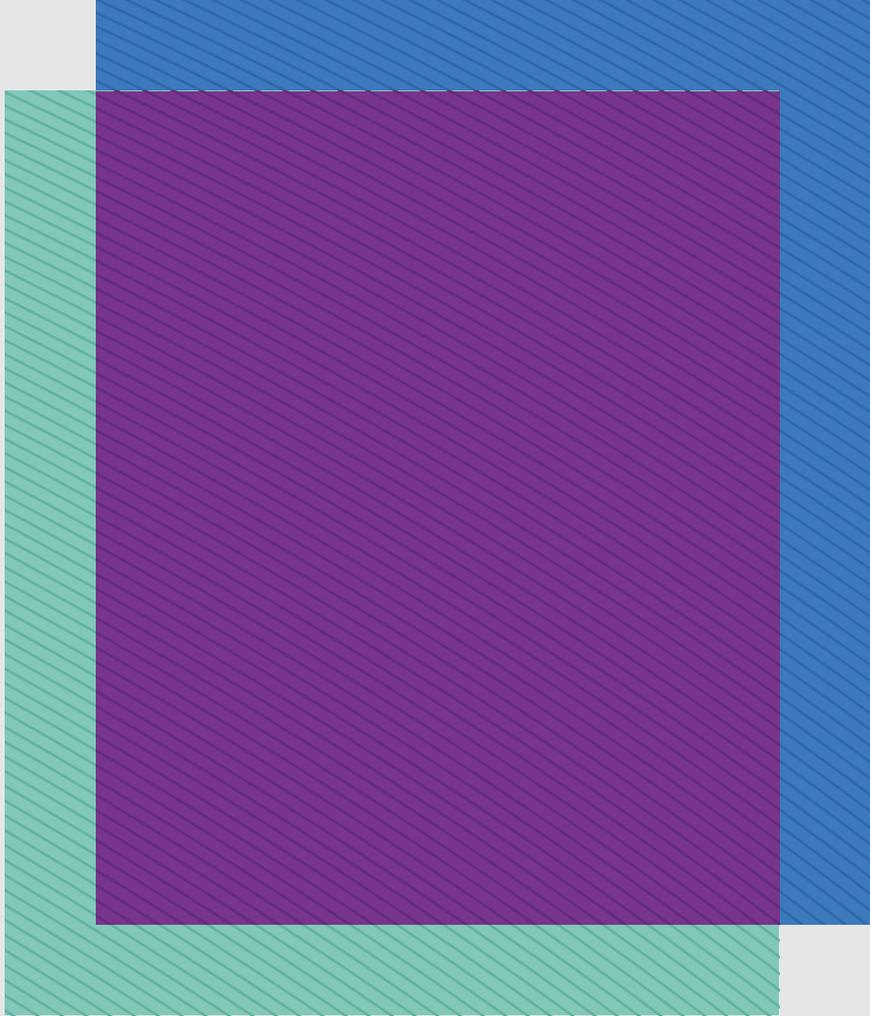


2021



2022

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About WTW

At WTW (NASDAQ: WTW), we provide data-driven, insight-led solutions in the areas of people, risk and capital. Leveraging the global view and local expertise of our colleagues serving 140 countries and markets, we help you sharpen your strategy, enhance organisational resilience, motivate your workforce and maximise performance. Working shoulder to shoulder with you, we uncover opportunities for sustainable success — and provide perspective that moves you. Learn more at [wtwco.com](https://www.wtwco.com).



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