Natural Catastrophe Review: Expert insights, lessons learned, and outlook

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Foreword

Welcome

Welcome to the latest issue of WTW's Natural Catastrophe Review, a bi-annual publication that brings insights from our experts — including our WTW Research Network — to examine recent natural disasters, lessons learned, and emerging trends.

We hope to provide new perspectives that will help with natural catastrophe risk management and resilience in sectors such as insurance, banking, government, and corporates across all industries.

In this edition, we look at some of the physical, vulnerability, and socio-economic factors that contributed to natural disasters in the first half of 2023. We also consider what the rest of the year might hold with El Niño's return and the upcoming North Atlantic Hurricane season.

The first six months of 2023 were dominated by the devastating Kahramanmaraş earthquakes in Türkiye and Syria and several weather-related catastrophes. A record-breaking start to the U.S. tornado season resulted in billions of dollars in damage, while the ongoing megadrought in Chile brought destructive wildfires. Canada is also experiencing its worst-ever wildfire season, with a record-breaking 8.33 million hectares destroyed after only two months of the May–September fire season. Cyclones Freddie, Gabriele, and Mocha had wide-ranging impacts in the Southern Hemisphere, and significant flooding affected a number of countries including Italy, Ethiopia, Somalia, Malaysia, Brazil, and New Zealand.

Climate change will once again be at the forefront of business and government agendas as a result of these events. However, it is critical not to forget the role socio-economic factors play in determining the severity of extreme weather outcomes.

It is nearly 20 years since Neil Smith – who was a Distinguished Professor of Anthropology and Geography – published his seminal essay *There's No Such Thing as a Natural Disaster*[1]. This was written in the aftermath of Hurricane Katrina and initiated a conversation on how we think about natural catastrophes.

Natural hazards only become disasters when they intersect with an inadequately prepared society. Katrina was a disaster because underlying social inequalities in New Orleans worsened storm damage and challenged disaster recovery. The wildfires that ravaged Chile in February this year were a disaster because of the intermixing of forestry plantations and communities (**Section 2.5**). In New Zealand, flooding

[1]Smith, N. There's No Such Thing as a Natural Disaster. *Understanding Katrina: perspectives from the social sciences* 11, (2006).

following Cyclone Gabriele was exacerbated by debris from forestry activity that clogged rivers and destroyed buildings and infrastructure (**Section 2.4**). And the recent devastation in Italy's Emilia-Romagna region from flooding was worsened by land-use change (**Section 2.8**).

If we are to improve resilience in a warming world, we must therefore look not only at how the frequency and severity of extreme weather events are changing, but also at how interactions between hazards and society are changing too. In New Zealand, there is a concerted effort to "build back better" following the second wettest summer on record. This requires a holistic approach that considers the physical, social, and economic aspects of affected communities[2], as well as investment in risk management research to inform decision-making.

Lateral thinking on earthquake risk

In February, the largest earthquake to hit **Türkiye** in nearly a century killed over 50,000 people and destroyed thousands of buildings. When a major disaster occurs, there are often lessons to be learned that will help us build back better. For example, following the 1999 Mw 7.6 Izmit earthquake in northern Türkiye, new building regulations and a national insurance pool were put in place to improve resilience. As lessons begin to emerge from the most recent event, we must remember to think laterally to improve risk management, particularly in other parts of the world where recent observations are lacking. In **Section 2.1, Temblor's Ross Stein** examines the lessons from Türkiye that can be applied to **California**, including the possibility of large events on secondary faults, interacting mainshocks that attack buildings twice, and the likelihood of extreme shaking near the rupture and in deep basins.

Property market tipping points

In recent years, there has been an increased focus on socio-economic tipping points, where gradual changes in the climate system could result in abrupt changes to socio-economic systems[3]. An example is Hawke's Bay, a region on the east coast of **New Zealand's North Island**, which is one of the country's most desirable locations for coastal living.

In February, Cyclone Gabrielle brought destruction to the North Island, with record-breaking winds and flooding that destroyed houses, infrastructure, and crops.

In **Section 2.4**, **Neil Gunn** discusses the impacts of Gabrielle and looks at recent research that suggests Hawke's Bay is approaching a socio-economic tipping point, where losses from the gradual increase in extreme weather events could lead to the collapse of property prices.

Five Category 5 storms in five months

Intense tropical cyclones during the early months of the year are rare. On average, there have been 1.1 Category 5 equivalent storms between January and May since 1980. However, this year has been unusual, with five events in the first five months: **Freddy**, **Kevin**, **Isla**, **Mocha**, and **Mawar**. In **Section 2.3,** we review how several of these storms have broken individual records, most notably Freddy, which produced the highest Accumulated Cyclone Energy ever recorded worldwide. With global sea surface temperatures currently at all-time highs since satellite records began, the attention will now turn to the upcoming North Atlantic and Western Pacific seasons to see if the trend continues. The largest number of Category 5 equivalent tropical cyclones ever recorded in a calendar year is 12 in 1997.

When the wind doesn't blow

While the focus is often placed on learning lessons from large natural disasters – such as the recent earthquakes in Türkiye – it is equally important to consider what we can learn when catastrophes don't happen. For example, understanding the factors that contribute to the variability in extreme weather – including quiescent periods – is important for planning and risk management in industries such as insurance and agriculture. In **Section 2.9**, **Adam Scaife and colleagues** from the University of Exeter investigate why there were so few **European windstorms** during the winter of 2022/2023 and why this was not entirely predicted by seasonal forecast models.

[2]Mannakkara, S., Wilkinson, S. & Potangaroa, R. *Resilient post disaster recovery through building back better*. (Routledge, 2018).

[3]Ginkel, K. C. H. van *et al*. Climate change induced socio-economic tipping points: review and stakeholder consultation for policy relevant research. *Environ. Res. Lett.* 15, 023001 (2020).

El Niño's return

For three years in a row, the Pacific Ocean has been stuck in its La Niña configuration, producing what is known as a "triple dip" event. La Niña is usually associated with catastrophic flooding in Australia – as we witnessed in 2022 – and busy North Atlantic hurricane seasons, such as the record-breaking year in 2020. But now the Pacific has flipped to El Niño, with the U.S. National Oceanic and Atmospheric Administration declaring its arrival on June 8. In **Section 3.1, Scott St. George** writes about the meteorological and socio-economic effects that businesses should expect from an El Niño event. **James Done** from the National Centre for Atmospheric Research (NCAR) then reviews what this means for the upcoming **North Atlantic hurricane season** in **Section 3.2**.

As we begin to process the lessons learned from these most recent events and incorporate new knowledge into risk models, it is important to remember that preparedness and resilience require more than just better models. We must also consider how our models, with all their simplifications, can be best used to inform real-world decision-making.

Recent Events

2.1 Worlds apart: Implications of the 2023 Mw 7.8 and Mw 7.5 Kahramanmaraş, Türkiye, earthquakes for California

by Ross S. Stein, Volkan Sevilgen, Ali Özbakir, Shinji Toda and Hector Gonzales-Huizar

The earthquakes took the lives of 53,000 people, left 2 million people homeless, and will cost an estimated $34 billion to recover from the damage. Among the many tragic and alarming elements of the Türkiye earthquakes are some that could befall California. These include the possibility of great events on secondary faults, interacting mainshocks that impact buildings twice, and the likelihood of extreme shaking near the rupture and in deep basins.

Progressive mainshocks and earthquake interaction

On 6 February a Mw 7.8 earthquake struck southern and central Türkiye and northern and western Syria, followed by a Mw 7.5 shock on a different fault 9 hours later and 100 km away. Surely this is rare.

No, it is not. Seismologists like telling us that the largest aftershock is about one magnitude unit smaller than the mainshock, but earthquakes don't follow our rules; instead, they are often part of a chain reaction. Examples abound of mainshocks striking within hours to months of each other, including the 1811-1812 Mw 7.2, 7.0, 7.4 New Madrid, Missouri, quakes several months apart; the 1992 Mw 7.3 Landers and Mw 6.5 Big Bear, California, shocks 3 hours apart; the 2002 Mw 6.6 and Mw 7.9 Denali, Alaska, quakes 10 days apart, and the 2019 Mw 6.4 and Mw 7.1 Ridgecrest, California, quakes 31 hours apart[1]. In fact progressive or compound mainshocks are not restricted to any region or tectonic setting.

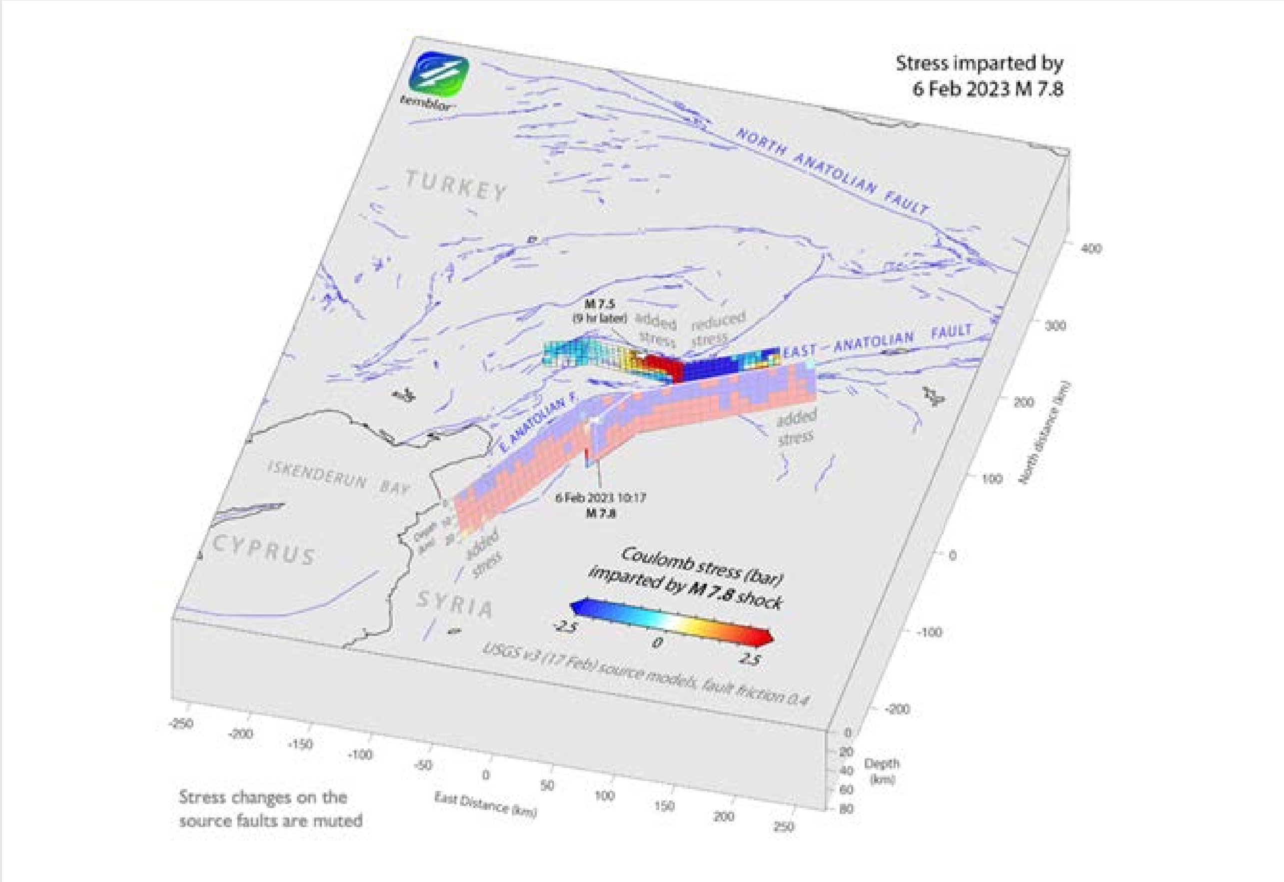
[1]Toda, S. & Stein, R. S. Long and short-term stress interaction of the 2019 Ridgecrest sequence and Coulomb-based earthquake forecast. *Bulletin of the Seismological Society of America* 110, 1765–1780 (2020).

There are two implications of earthquake interaction:

1 The good news is that by calculating the ‘Coulomb stress’ transferred by a mainshock to the surrounding region, one can identify the faults brought closer to failure, and those brought farther from failure (Figure 1). In some places, the hazard rises; in others, it drops. This is what Temblor’s Realtime Risk technology (whose development was supported by the WTW Research Network), does: once a large quake strikes, the hazard changes, which models need to capture so that next year's risk is reflected in models. This is in contrast to conventional earthquake risk models, which do not take stress interaction into consideration.

2 The bad news is that buildings damaged in the first shock can collapse in the second, which the ‘hours clause’ in insurance contracts does a poor job of accounting for. Think of the many horrifying building collapse videos of the Türkiye quake we saw, filmed in daylight. The first quake struck in the dark, at 4 am local time, and so most of the videoed collapses occurred during the second shock, with the buildings succumbing to a ‘one-two punch.’ Trying to account for this dynamic accumulation of damage in fragility and vulnerability models is an active area of research[3].

Figure 1. **Coulomb stress imparted by the Mw 7.8 rupture to the Cardak-Sürgü Faults, which would rupture 9 hours later. Stress promoting failure (red patches) is concentrated near where the Mw 7.5 nucleated, which suggests that the first shock promoted or triggered the second. From Stein *et al*. (2023)[2].**



Source: Temblor

[2]Stein, R.S., Toda, S., Özbakir, A. D., Sevilgen, V., Gonzalez-Huizar, H., Lotto, G., Sevilgen, S. 2023, Interactions, stress changes, mysteries, and partial forecasts of the 2023 Kahramanmaraş, Türkiye, earthquakes. *Temblor*. http://doi.org/10.32858/temblor.299 (2023)

[3]Lacoletti, S., Cremen, G. & Galasso, C. Modeling damage accumulation during ground-motion sequences for portfolio seismic loss assessments. *Soil Dynamics and Earthquake Engineering 168*, 107821 (2023)

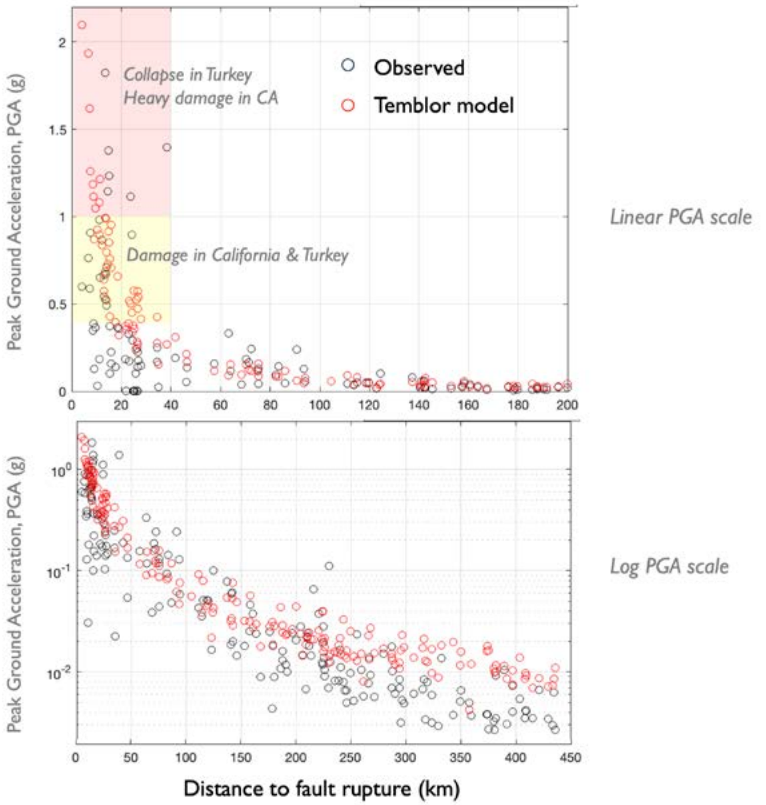
Extreme shaking close to the fault rupture

It has been widely reported that collusion between builders and inspectors, and code compliance amnesties issued by the government[4,5], were the largest contributors to the 35,000 building collapses, the additional 18,000 slated for demolition, and the 180,000 buildings heavily damaged[6]. But that is not the whole story.

The sad truth is that shaking at frequencies that attack 6-10-story buildings, which typify many cities, often exceeded the most stringent building code requirement in Türkiye (the '2% in 50-year' ground motion, which translates into a 2500-year return time)[4].

The Mw 7.8 Kahramanmaraş event is by far the best-recorded earthquake the world has ever known. Although Japan's strong motion network is unrivaled, and the 2011 Mw 9.0 Tohoku shock was much larger, the megathrust event struck 80 km offshore. In contrast, there are about 50 stations within 25 km of the 2023 rupture, seven of which recorded Peak Ground Accelerations (PGA) in excess of 1 g (Figure 2). This extreme near-fault shaking would likely occur during quakes of similar size in California, such as on the San Andreas or Hayward Faults. But until now, there was little or no data to anticipate such shaking. This means buildings close to the rupture could fare worse than expected in current models, and that U.S. building codes may need revision to account for this effect.

Figure 2. **There are about 25 observations (red) of Peak Ground Acceleration (PGA) exceeding 0.5 g. At this level of shaking, all but the most resilient buildings generally suffer structural damage. The Temblor Ground Motion Model (blue) does a good job of capturing this shaking at distances of 10-400 km from the fault rupture.**



Source: Temblor

[4]Erdik, M., Tümsa, M. B. D., Pınar, A., Altunel, E., and Zülfikar, A. C. A preliminary report on the February 6, 2023 earthquakes in Türkiye. *Temblor*. http://doi.org/10.32858/temblor.297 (2023).

[5]Yeginsu, C., Ruiz, R. & Kirac, N. Earthquake-Proof, Not Corruption-Proof: Turkey's Needless Deaths, *New York Times*, 4 May edition, https://www.nytimes.com/2023/05/04/world/europe/turkey-earthquake-corruption.html (2023).

[6]Statistics from the 9 May 2023 Earthquake Engineering Research Institute (EERI) 'Learning From Earthquakes' webinar.

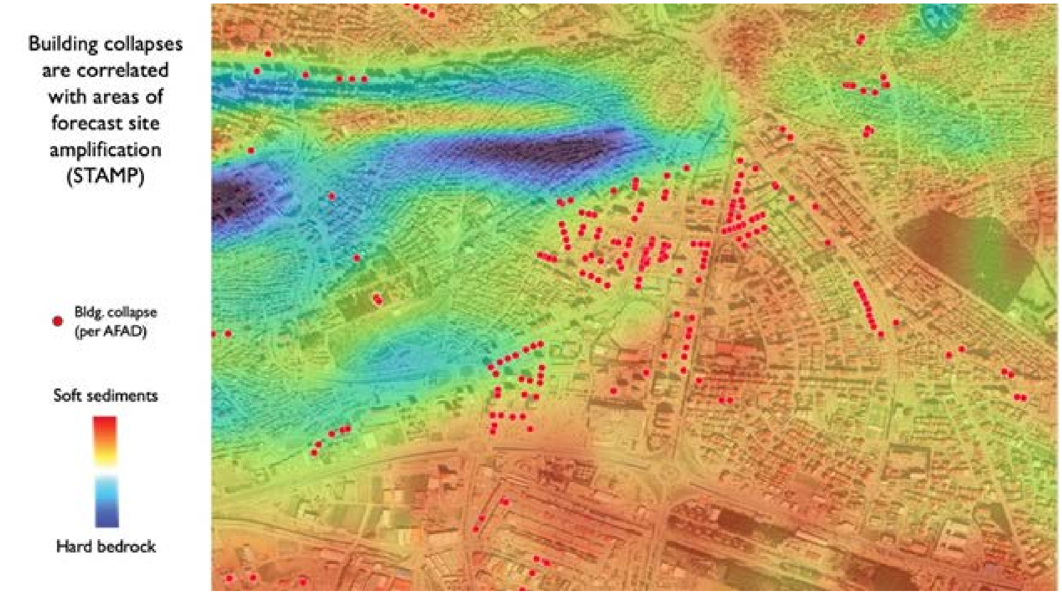
Building collapses concentrated in areas of high site amplification

The inventory of collapsed Turkish buildings, compiled from satellite imagery (Humanitarian Open Street Map Team, 2023)[7], furnishes an unmatched dataset to study collapse. This scientific gift came at a terrible cost, so we must use it wisely.

Our preliminary analysis reveals that collapse is highly correlated with site amplification, as seen in the 100m resolution Temblor model, STAMP (Figure 3). The collapse rate in flat areas underlain by soft sediments is much higher than elsewhere.

Because nearly identical buildings likely built at the same time by the same builder span regions with high and low site amplification, we can often control for other factors, and conclude that site amplification is of primary importance in assessing risk. In contrast, while liquefaction and landslides occurred, they were less influential for collapse.

Figure 3. **Collapsed buildings tend to be concentrated in regions modeled to have high site amplification. The Temblor STAMP model is based on features of the relief, in which flat areas are likely sedimentary basins (orange), and areas with more relief are sites of bedrock (blue).**



Source: Temblor

[7]Humanitarian Open Street Map Team, HOTOSM Turkey Destroyed Buildings (OpenStreetMap Export), https://data.humdata.org/dataset/hotosm_tur_destroyed_buildings (2023).

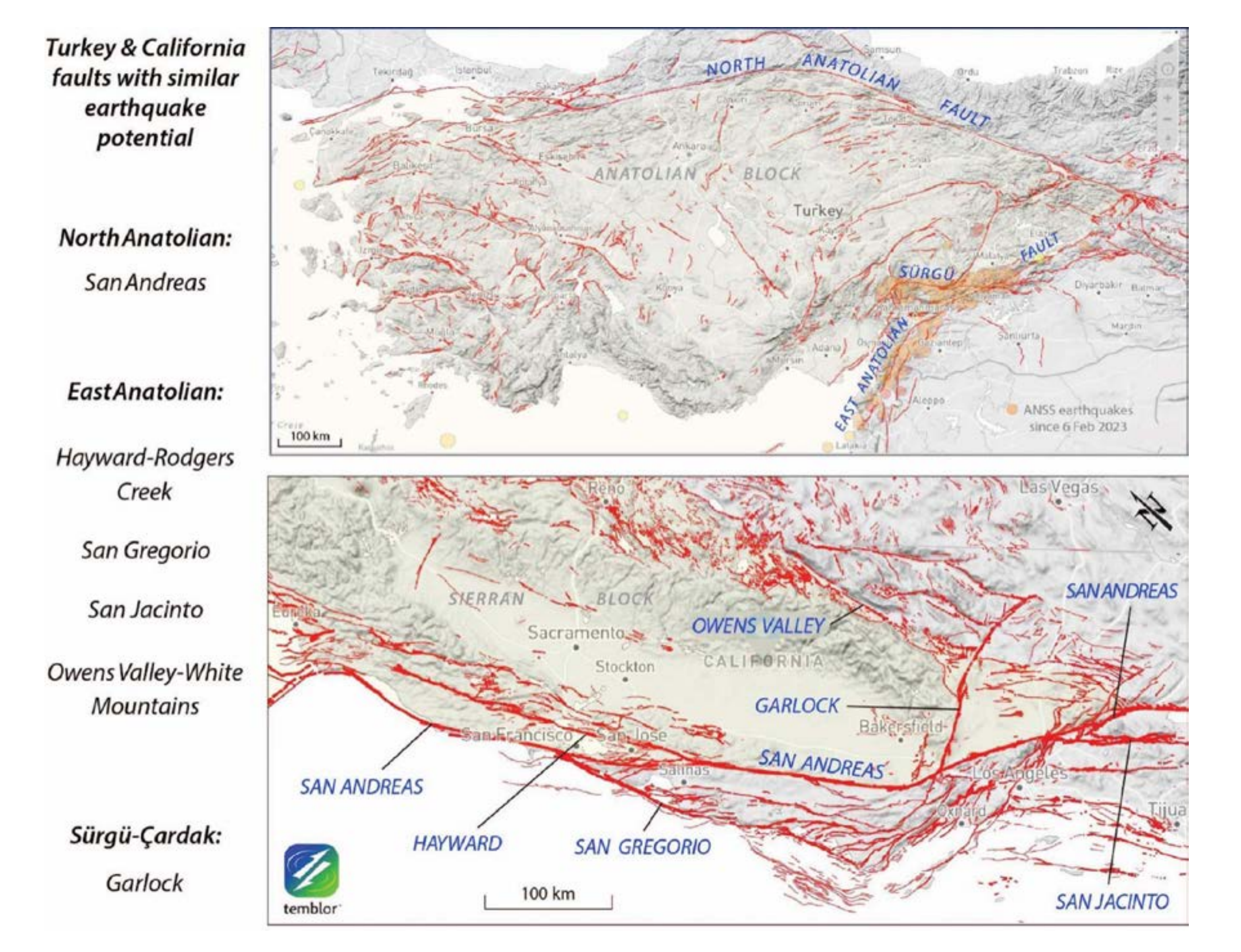
Ominous similarities between faults in Eastern Türkiye and California

The North Anatolian and San Andreas Faults are remarkably similar in length, slip rate and earthquake history (Figure 4); both have experienced Mw 7.8 shocks in the past 170 years[8]. The East Anatolian Fault resembles the Hayward-Rodgers Creek Fault in northern California, the San Gregorio along the central coast, the Owens Valley-Inyo Fault in eastern California, and the San Jacinto in southern California. So, those faults should have Mw 7.8 shocks in any stochastic event set one is using. The Cardak-Sürgü Fault closely resembles the Garlock Fault in southern California. Both are so misaligned for the tectonic stresses that they must be very slippery to move at all. But despite that misalignment, we should assume that the Garlock Fault, which abuts the San Andreas, is capable of a Mw≥7.5 event.

The most important lesson is that the Türkiye quakes did not strike on the equivalent of the mighty San Andreas Fault, but instead on shorter, low-slip-rate faults that are often deemed incapable of quakes of this great size. The East Anatolian Fault is 600 km long with a slip rate of ~10 mm/yr, and the Cardak-Sürgü Fault is 200 km long with a slip rate of ~3 mm/yr; both can be considered part of the broad East Anatolian Fault Zone.

The Mw 7.8 earthquake nucleated on the minor, 20-km-long Narlı Fault, and then jumped onto the East Anatolian Fault, propagating in both directions (SW and NE), ultimately attaining a rupture length of 300 km with ~4.5 m average slip. The Mw 7.5 shock nucleated on the Cardak Fault, and also ruptured in both directions. To the east, it jumped onto the

Figure 4. **Comparing faults in Turkey (top panel) and California (bottom panel) reveals many similarities in terms of fault straightness, length, and slip rate. Notice that the map scales are different.**



Source: Temblor

[8]Emre, Ö., Duman, T.Y., Özalp, S., Elmacı, H., Olgun, Ş. and Şaroğlu, F. Active Fault Map of Turkey with and Explanatory Text, General Directorate of Mineral Research and Exploration, Special Publication Series-30. Ankara-Turkey. https://www.mta.gov.tr/en/maps/active-fault-1250000 (2013).

Sürgü Fault, attaining a 150-km total length and ~7 m average slip. So, surprisingly, the slower, shorter fault had the highest slip. Even stranger, the Cardak-Sürgü Fault shouldn't slip at all; it is misaligned for failure. It was formerly a 'right-lateral' fault (whichever side you are on, the other side moves to the right) that only recently became left-lateral (this switch is called 'inversion' by geologists).

So, the key question is, are we prepared for Mw 7.8 and Mw 7.5 shocks on their California equivalent? The answer is probably no, because we've focused on events with repeat times of 500 years or less. Instead, Temblor's event set yields an 1800-2000 year repeat time for quakes in this Zone.

What's essential is to harness these hard-won insights from Türkiye to better forecast seismic risk, and better prepare for its consequences in California and elsewhere, where much of what we have just witnessed can also occur.

2.2 Is the record number of convective storms in the first quarter a sign of things to come in the U.S.?

by Cameron Rye

Following a record-breaking first quarter for severe convective storms (SCS) in the United States, insurers and risk managers should consider whether their view of risk reflects the evolving patterns of SCS activity.

The year had barely begun when the United States was hit by a series of damaging severe convective storms. There were 476 tornadoes reported between January and March, according to preliminary data from the U.S. National Weather Service Storm Prediction Centre. This early activity has made 2023 the year with the most first-quarter tornadoes on record (Table 1).

Table 1. **Top 10 years with the highest Jan–March tornado counts.**

Rank	Tornado Count	Year
1	*476	2023
2	398	2017
3	360	2008
4	292	1999
5	290	2012
6	282	2022
7	246	2007
8	231	1976
9	212	2020
10	207	2006

*Tornado count is preliminary and may change once the data is finalized by the Storm Prediction Centre.
Data source: National Weather Service Storm Prediction Centre.

These high numbers were caused by a series of multi-day tornado outbreaks that can in part be attributed to the presence of La Niña (which often provides favorable conditions for springtime convective activity). The most notable outbreak occurred at the end of March, affecting states in the Midwest, Southern, and Eastern U.S. A total of 134 tornadoes were recorded between 7pm UTC on March 31st and 7pm UTC on April 1st, ranking third in the world for the highest number of events reported in a 24-hour period.

It will also be one of the most expensive first quarters on record for insured losses from convective storms, with estimates putting claims in the region of $7-10 billion USD. Primary insurers will likely bear a larger share of this cost than they would have in prior years due to the higher reinsurance attachments and lower aggregate coverage at the January 1st renewals.

Convective activity continued into the second quarter, with many severe weather outbreaks, including one that delivered record-sized hail and strong winds across Central and Southern states between June 10 and June 19. Insurance claims are still developing, but 2023 is expected to rank high on the list of costliest SCS years.

Losses due to convective storms have been increasing over the past 20 years, and this stormy start to the year will undoubtedly increase further the insurance industry's concern about this peril. A large proportion of the increase can be attributed to population growth and urbanization. Climate change may also be playing some role, but the science is not definitive because detecting a trend in localized phenomena such as tornadoes is notoriously difficult, especially when most of the historical record is based primarily on eyewitness and damage reports[1].

[1]Verbout, S. M., Brooks, H. E., Leslie, L. M. & Schultz, D. M. Evolution of the U.S. Tornado Database: 1954–2003. *Weather and Forecasting* 21, 86–93 (2006).

Recent research has found that tornado-favorable environments during wintertime have increased across the southern Great Plains and southeastern U.S.[2].

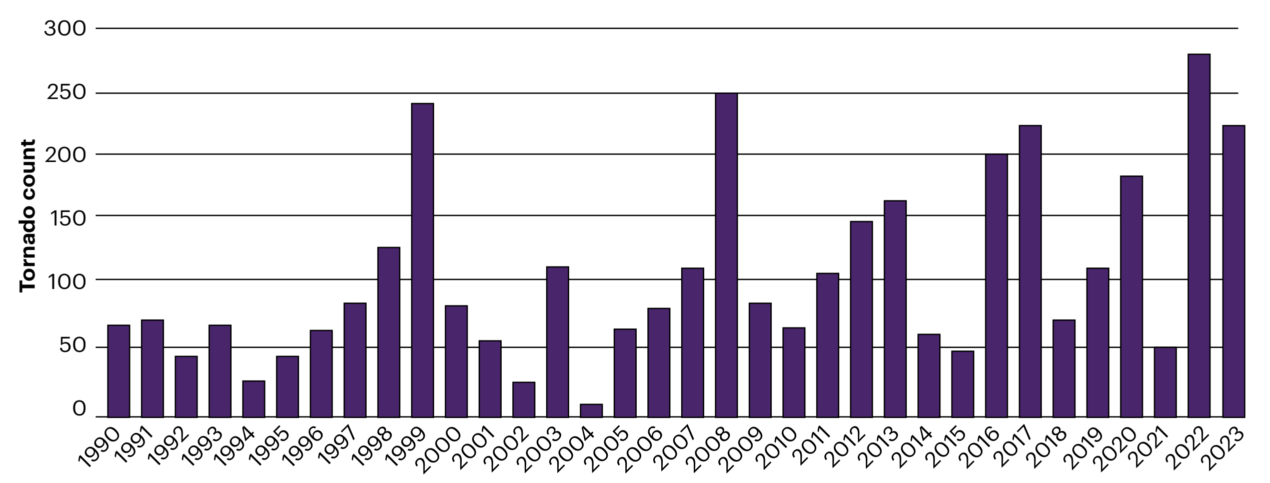
Data from the National Weather Service Storm Prediction Centre also shows a steady increase in December–February U.S. tornado counts since 1990 (Figure 1). However, while a warming world is expected to lead to milder winters that generate the atmospheric instability necessary for convective storms, it is not clear the extent to which this observed trend is due to climate change or other factors such as natural variability and reporting biases.

There is stronger evidence that the geographic pattern of tornadoes is changing. Since 1979, the number of SCS events affecting "Tornado Alley" in the Great Plains has decreased slightly, while activity has increased in eastern states such as Mississippi, Tennessee, Alabama, Illinois, and Indiana[3]. This shift has pushed storms into areas that have seen rapid population growth over the last few decades, increasing the likelihood of tornadoes causing property damage and fatalities.

Looking further into the future, a recent high-resolution modelling study has found that supercells – storms that produce the strongest tornadoes and are associated with the most severe impacts – are expected to occur more frequently in a warmer world[4]. This prediction includes an increase in early-season supercells (as we saw this year), with an intermediate warming scenario producing upticks in February (7%), March (18%), and April (37%) by the end of the century.

While scientists are still trying to fully understand the connection between tornadoes and climate change, insurers, as well as home and business owners, continue to count the costs. This tension highlights the importance of ensuring that the present-day view of risk is adequately represented in insurance catastrophe models, as well as other decision-making frameworks such as resilience planning.

Figure 1. **December-February tornado counts in the United States since 1990. It is not clear the extent to which this observed trend is due to climate change or other factors such as natural variability and reporting biases.**



Data source: National Weather Service Storm Prediction Centre

[2]Taszarek, M., Allen, J.T., Brooks, H.E., Pilguj, N., & Czernecki, B. Differing Trends in United States and European Severe Thunderstorm Environments in a Warming Climate. *Bulletin of the American Meteorological Society* 102, (2021).

[3]Gensini, V. A. & Brooks, H. E. Spatial trends in United States tornado frequency. *npj Climate and Atmospheric Science* 1, 1–5 (2018).

[4]Ashley, W. S., Haberlie, A. M. & Gensini, V. A. The Future of Supercells in the United States. *Bulletin of the American Meteorological Society* 104, E1–E21 (2023).

2.3 An unusually large number of Category 5 tropical cyclones

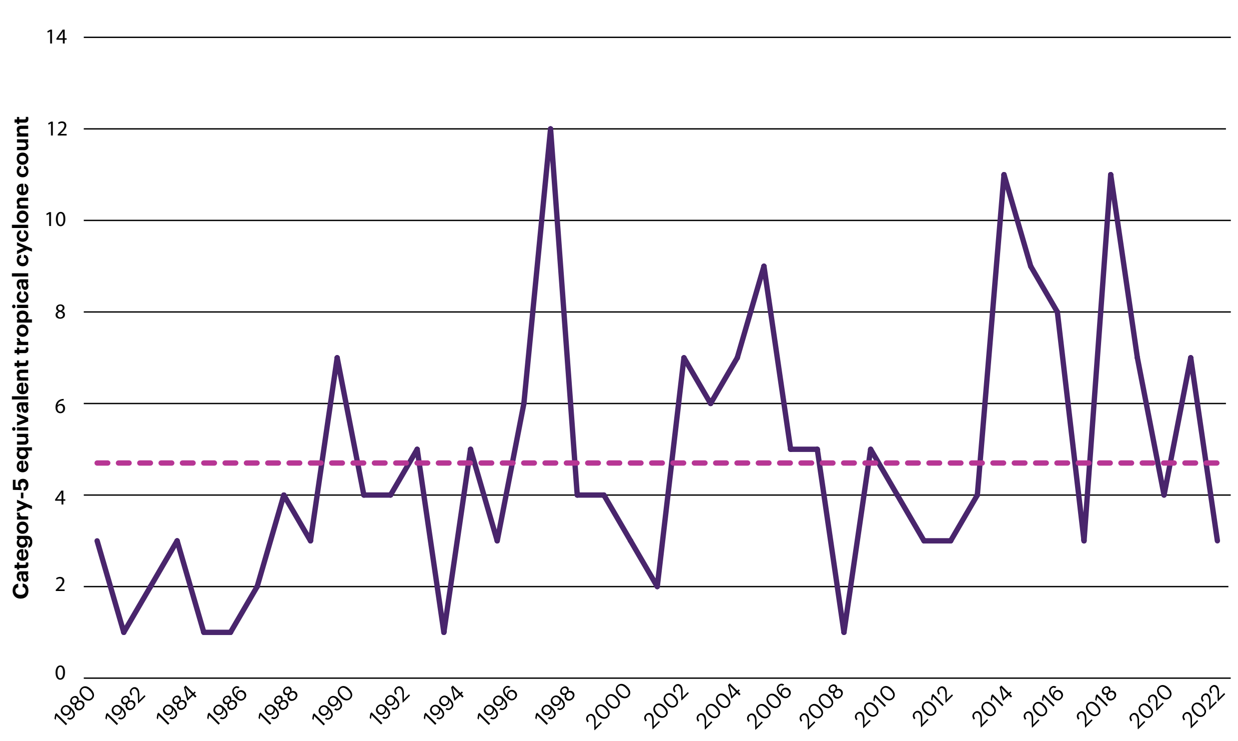
by Cameron Rye

With so many extreme weather events in the first half of the year, it was easy to have overlooked the unusual tropical cyclone activity that produced five Category 5 storms in five months.

Category 5 equivalent[1] tropical cyclones are rare, with an average of 4.7 occurring per year since 1980, accounting for less than 10% of all tropical cyclones globally (Figure 1). However, this year has been unusual, with five events in the first five months: Freddy, Kevin, Isla, Mocha, and Mawar (Table 1). In comparison, an average of 1.1 events have occurred globally between January and May since 1980. The only recent precedent is 2015, when six Category 5 storms had developed by the end of May.

This year's events have also broken a number of individual records (Table 1). **Very Intense Tropical Cyclone Freddy** produced an Accumulated Cyclone Energy (ACE) of 87 – the highest for a tropical cyclone on record. At 35 days, Freddy may also have broken the record for the longest-lived cyclone, although the World Meteorological Organisation (WMO) is still verifying this. The storm's power caused significant damage when it made landfall in Madagascar and Mozambique, resulting in nearly 1,450 fatalities, making it the third deadliest on record in the Southern Hemisphere.

Figure 1. **The global annual count of Category-5 equivalent tropical cyclones, 1980-2022. The annual average since 1980 is 4.7 (dashed line).**



Data source: Knapp, K. R. et al. International Best Track Archive for Climate Stewardship (IBTrACS) Project, Version 4-since1980. NOAA National Centers for Environmental Information (2018).

[1]Defined as sustained 1-minute wind speeds greater than or equal to 157 mph according to the Saffir-Simpson scale.

Table 1. **Category 5 equivalent tropical cyclones Jan-May 2023.**

Name	Regions Affected	Genesis Date	Wind Speed (mph)*	Record Broken
Freddy	Madagascar, Mozambique	5 February	165	Highest-ACE-producing tropical cyclone ever recorded
Kevin	Solomon Islands, Vanuatu	26 February	160	—
Ilsa	Western Australia	6 April	160	Strongest 10-minute sustained windspeed at landfall in Australia
Mocha	Myanmar, Bangladesh	8 May	175	Joint highest 1-minute sustained windspeed in the North Indian Ocean
Mawar	Guam, Philippines, Taiwan, Japan	17 May	185	Highest ACE and joint highest 1-minute sustained windspeed in May

*1-minute sustained wind speed

Severe Tropical Cyclone Ilsa made landfall in Western Australia in April as a Category 5 storm northeast of Port Hedland. On Bedout Island, a 10-minute sustained wind speed of 136mph was measured, breaking the previous Australian record for a landfalling storm set by Cyclone George in 2007. Because the storm avoided populated areas, including the world's largest iron ore export hub in Port Headland, economic and insurance losses were minimal.

In early May, **Extremely Severe Cyclonic Storm Mocha** became the North Indian Ocean's joint strongest tropical cyclone, with a 1-minute sustained wind speed of 175 mph. The cyclone made landfall in Myanmar, about ten miles northwest of Sittwe, the regional capital of Rakhine state. Given the storm's proximity to the world's largest refugee camp in Cox's Bazar, Bangladesh, there were fears of significant casualties prior to landfall. However, authorities and aid organizations were able to evacuate hundreds of thousands of people in Myanmar and Bangladesh ahead of the event, mitigating the humanitarian impact.

A few weeks later, **Super Typhoon Mawar** became the most powerful storm of 2023 so far, with sustained 1-minute winds of 185 mph. The cyclone broke two records: the highest ACE and the joint-highest 1-minute sustained windspeed observed in the month of May. The only other storm to reach 185 mph in May is Typhoon Phyillis in 1958. Mawar passed north of Guam, bringing heavy rain and strong winds to the island, making it the strongest typhoon to affect the U.S. territory in over two decades.

Freddy and Mocha highlighted that there is still a considerable protection gap in many tropical cyclone-prone countries, with economic losses far exceeding insurance coverage. By providing pre-determined and faster pay-outs to fund emergency response and speed up recovery, parametric (or index-based) insurance is seen as one option for improving resilience to the impacts of these types of events. For example, WTW recently designed a parametric insurance product for UNICEF's Today and Tomorrow Initiative, which was funded by the governments of the United Kingdom and Germany. The parametric index combines tropical storm wind speeds modelled by Kinetic Analysis Corporation, with child population distribution to capture impacts on vulnerable populations. The program covers children and families in eight UNICEF host countries that are vulnerable to tropical cyclones: Bangladesh, Comoros, Haiti, Fiji, Madagascar, Mozambique, Solomon Islands, and Vanuatu.

Scientists will most likely need some time to dissect the reasons for the increase in early-season activity this year. Global sea surface temperatures in the first half of 2023 have been at all-time highs since satellite records began[2], which may have played a role. But for now, all eyes will be on the upcoming North Atlantic (Section 3.2) and Western Pacific seasons to see if the trend continues. The largest number of Category 5 storms ever recorded in a calendar year is 12 in 1997, so there is still some way to go to break this record.

[2]Climate Reanalyzer. University of Maine. https://climatereanalyzer.org/clim/sst_daily/ (2023)

2.4 Building back better following tropical cyclone Gabrielle

by Neil Gunn

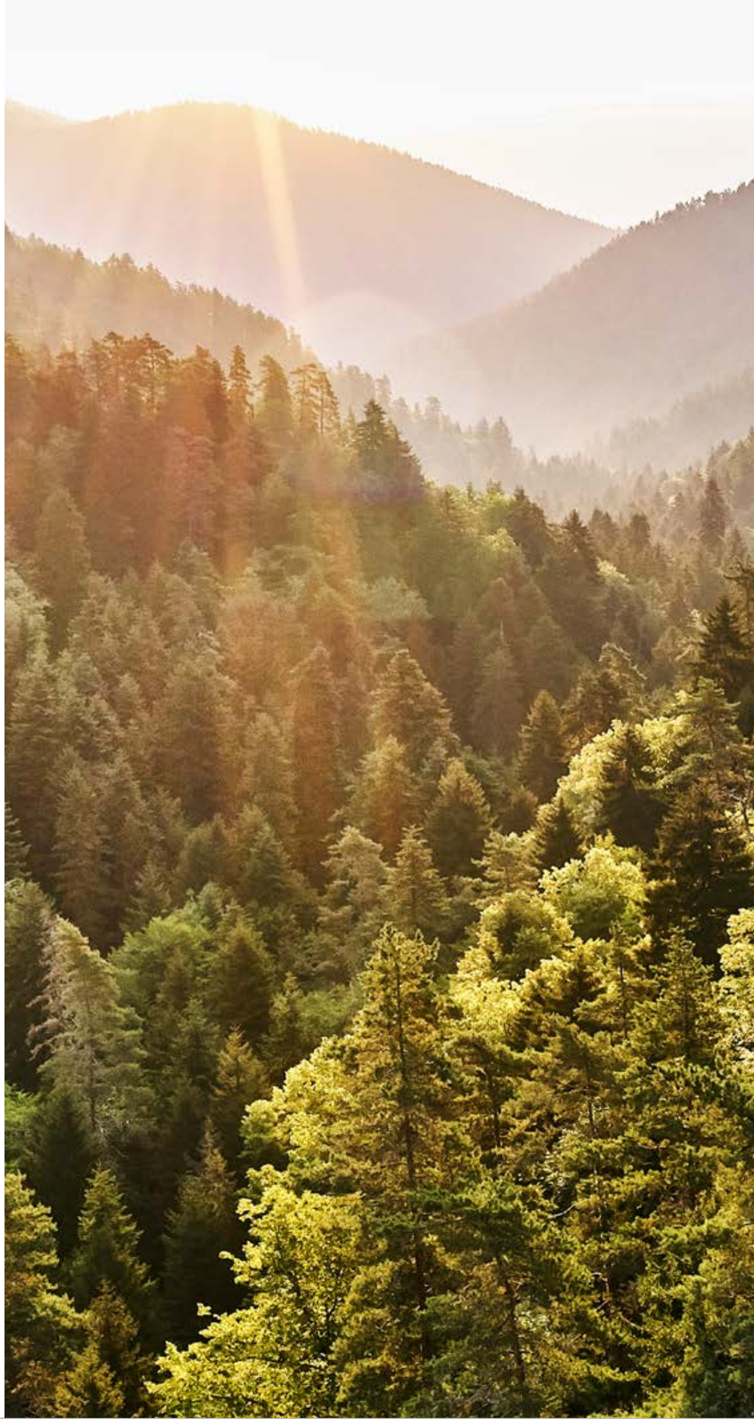
Following a record-breaking storm in New Zealand, calls have been made for the country to build back better to improve resilience to climate change and mitigate the risks from forestry waste.

New Zealand declared only its third-ever national state of emergency in February following Cyclone Gabrielle, which damaged property, infrastructure and crops across the North Island. The government estimated that economic losses from the event will be at least NZ$13.5 billion ($8.4 billion), second only to the 2011 Christchurch earthquake. According to PERILS AG, insurance claims currently stand at around NZ$2 billion (U.S.$1.3 billion).

Gabrielle formed as a tropical low off the coast of the Solomon Islands on February 5, before moving south across the Coral Sea and strengthening into a Category 3 tropical cyclone. As the storm approached New Zealand, it weakened and underwent extratropical transition, unleashing heavy rain and strong winds on the North Island for three days between February 12 and 14. Several meteorological stations in New Zealand saw record or near-record summer wind gusts, while storm surge levels peaked at 0.7m, according to the National Institute of Water and Atmospheric Research (NIWA). The most damaging feature of the storm was heavy rainfall, with NIWA reporting record or near-record totals across much of the North Island, particularly on the East Coast around Gisborne and Hawke's Bay.

The rain landed on already saturated ground. The summer of 2022/2023 was the second wettest on NIWA's records for the North Island, and only a few weeks earlier Cyclone Hale caused 1-in-200 year flooding in Auckland. As a result, the rivers responded swiftly to Gabrielle's precipitation. New high-flow records were set, with many gauging stations judged to be in excess of a 1-in-500 year return periods[1]. On the River Esk, families reported having to climb out of the windows of their properties to await rescue on their roofs, with some estimating that water levels rose by 3 meters in just 10 minutes.

New Zealand's landscape is steep and dynamic. The heavy rains caused many landslides, undermining or burying major roads including several state highways. The combination of landslides and high winds also cut power, water supplies, and communications. The outages were sustained for several days widely and weeks in some locations. Many of the telecommunication systems were exposed to single points of failure, which made incident management and recovery more difficult than it should have been.



[1]*Personal Communication*, Ashton Eaves, Hawke's Bay Regional Council.

The role of forestry waste

Large woody debris from forestry operations, known locally as slash, contributed to the severity of the event by clogging rivers and destroying buildings and infrastructure (Figure 1). Historic forestry policy led to the replacement of native tree species with pine plantations on much of the eastern coast. Silt and slash from these plantations washed into the river system and accumulated around bridges. This led to the destruction of bridges and overtopping of defenses during Gabrielle. On the Tutaekuri River alone there were 5.3 km of breaches and 25.5km of weakened banks, according to Hawke's Bay Regional Council. Along with rainfall intensity and amount, this helps to account for very rapid rates of rise of flood water.

Soil scientists estimate that the country has 5-10 years to change land use to protect soils on the forested slopes of the East Coast[2].

Figure 1. **Top: forestry debris piled up on a railway bridge over the River Esk. Note the debris attached to the top of the bridge shows the magnitude of exceedance of design standards. Bottom: extensive silt deposition on the lower reaches of rivers devastated farmland and infrastructure, recovery will take years**

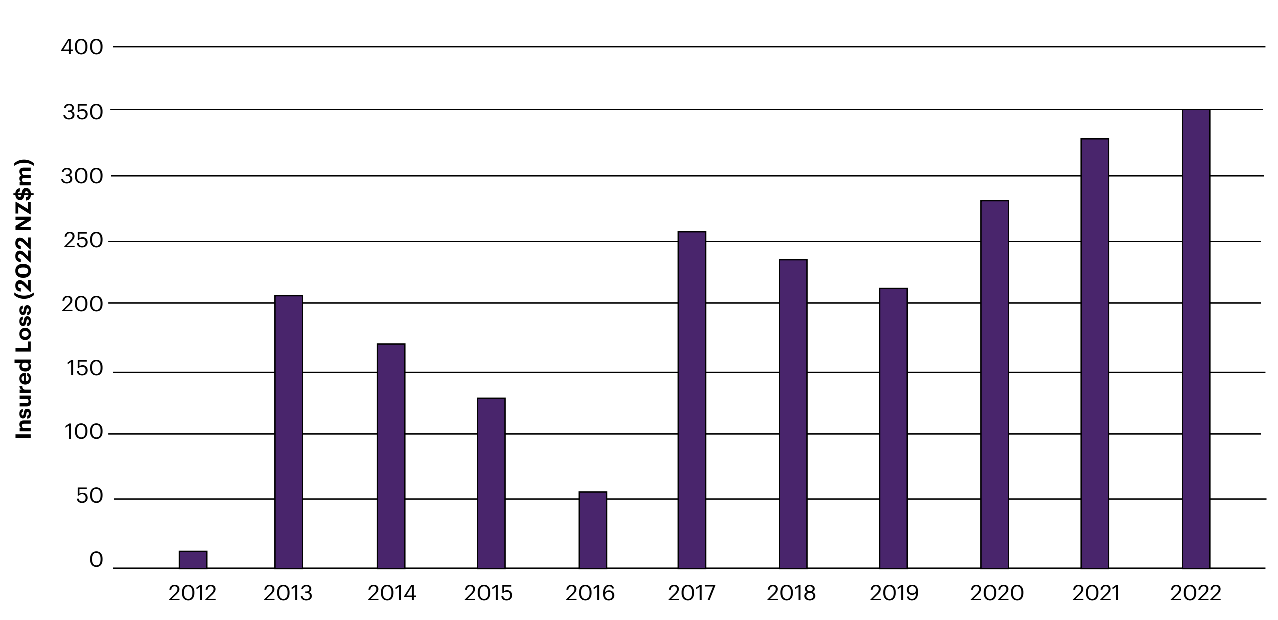
[2]Ministerial Inquiry into Land Uses in Tairawhiti and Wairoa. *Outrage to Optimism*. https://environment.govt.nz/assets/Outrage-to-Optimism-CORRECTED-17.05.pdf (2023).

Climate change and socio-economic tipping points

At the same time, New Zealand must find a way to deal with the growing socio-economic consequences of more frequent weather disasters. Insurance claims from atmospheric perils have increased over the last decade, affecting the availability and price of property insurance (Figure 2). The problem has been exacerbated by growing concerns around the effects of future climate change, which will not have been alleviated by a rapid attribution study that found Gabrielle's rainfall was likely made 30% more intense due to human-induced warming[3].

Research into the socio-economic effects of climate change is increasingly finding that gradual physical changes may trigger large non-linear responses in socio-economic systems.

Figure 2. **New Zealand weather-related insured losses, adjusted for inflation.**



Data source: Insurance Council of New Zealand.

A recent study – funded by the New Zealand Ministry for Business Innovation and Employment – explored the effects of extreme weather on the property market in Hawke's Bay[4], which is one of the country's most desirable locations for coastal living. The researchers found that the local community is likely to accept the risk of financial loss and insurability in exchange for coastal living in the short (1-10 years) and medium (10-20 years) term. However, long-term (+20 years) economic losses from repeated storms and flooding will likely lead to an increase in insurance premiums and, eventually, the collapse of the insurance market, putting downward pressure on property prices.

[3]World Weather Attribution. The role of climate change in extreme rainfall associated with Cyclone Gabrielle over Aotearoa New Zealand's East Coast. https://www.worldweatherattribution.org/the-role-of climate-change-in-extreme-rainfall-associated-with-cyclone-gabrielle-over-aotearoa-new-zealands-east-coast (2023).

[4]Eaves, A., Kench, P., McDonald, G., Dickson, M., & Storey, B. Modelling economic risk to sea-level rise and storms at the coastal margin. *Journal of Flood Risk Management*, e12903 (2023).

Building back better

Overall, Gabrielle highlights that in a changing environment it is important to take a holistic approach to natural hazard risk management that considers not just climate change, but also other factors that can compound disasters such as forestry management and engineering design.

Steps are being taken to address these challenges. Prime Minister Chris Hipkins and The Insurance Council of New Zealand have called for the country to build back better to improve resilience[5], while NZ$6 billion has already been allocated to aid recovery efforts and improve resilience overall, especially of roads and telecommunications.

The National Adaptation Act and Natural Environment Act are also in draft, which contain provisions to reduce risks from natural hazards as a condition of rebuilding.

[5]Insurance Council of New Zealand. New Zealand Must Build Back Better. https://www.icnz.org.nz/industry/media-releases/new-zealand-must-build-back-better/ (2023).

2.5 Counting the costs of climate and land-use change after the Chilean Wildfires

by Cameron Rye

Wildfires ravaged south-central Chile in February, affecting the Maule, Biobio, Ñuble, and Araucania regions. Following similar fires in 2017, there is growing concern in the country about the deadly combination of climate and land-use change.

Central Chile has been experiencing a megadrought since 2010, making it one of the longest periods of dry weather in the last 1,000 years[1]. Water availability and vegetation have suffered, resulting in a number of destructive forest fires. Seven of the top ten wildfire years on record have now occurred since 2010, highlighting the severity of the situation (Table 1).

The most recent event began on January 30, during the summer season in the Southern Hemisphere. Record temperatures of over 40°C, combined with strong winds, created ideal fire-spreading conditions. This led to more than 400 individual fires burning across south-central Chile by early February. Approximately 430,000 hectares were burned (Figure 1), resulting in 26 fatalities and over 4,000 damaged or destroyed buildings, according to Chile's disaster response agency, SENAPRED.

Table 1. **Top 10 worst fire years by burned area since 1964.**

Rank	Burned Area (hectares, thousands)	Year
1	570	2017
2	430	2023
3	129	2015
4	125	2022
5	106	2014
6	102	2020
7	102	1999
8	97	1987
9	91	1998
10	90	2012

Data source: Chile's National Forest Corporation (CONAF).

This makes 2023 the second worst fire year on record, after 2017, when 570,000 hectares of central and southern Chile were affected. Like this year, the underlying drought conditions in 2017 combined with high temperatures and winds, resulting in disastrous consequences. However, this is only half of the story; in 2020, Chile's Centre for Climate and Resilience Sciences (CR)2 issued a report recommending increased regulation of the forestry industry in order for the country to become more resilient to the effects of climate change[2].

Figure 1. **Burned area from the February 2023 wildfires in south-central Chile.**

Source: NASA's Earth Observatory

[1]Garreaud, R. D. *et al*. The Central Chile Mega Drought (2010–2018): A climate dynamics perspective. *International Journal of Climatology* 40, 421–439 (2020).

[2]Center for Climate and Resilience Research - CR2. Forest fires in Chile: Causes, impacts and resilience. https://www.cr2.cl/eng/forest-fires-in-chile-causes-impacts-and-resilience/ (2020).

Forestry is big business in Chile, accounting for 3% of the country's GDP, and timber is the second-largest export commodity after minerals. Expansive plantations of fast-growing species (primarily pine and eucalyptus) have increased from 300,000 hectares in the 1970s to over 3 million hectares today. Previous governments encouraged this expansion by allowing the privatisation of large areas of public land and providing subsidies and tax breaks for plantations.

The problem is that non-native pine and eucalyptus species contain oils and resins in their leaves that can easily ignite when dry. Research has also found that because plantations are often compositionally homogenous with few fire breaks, it promotes greater fire spread compared to native deciduous forests[3]. This, combined with the recent drought, has created a perfect storm that has proved difficult to control.

According to scientists, the megadrought is most likely the result of both natural variability and human-induced climate change[1].

However, climate change is expected to play an increased role in wildfire risk over the coming decades. Projections for the 21st-century indicate a rise in temperatures and a reduction in precipitation throughout Chile, which modelling studies suggest will lead to an increased occurrence of large fires[4].

Central-South Chile is particularly vulnerable because it contains nearly 90% of the country's plantations, and 3 million people live within the wildland-urban interface[5]. (CR)2 says that if the government is to reduce the risk faced by its people, decision-makers need to move away from reactive measures focused on fire suppression, towards actions that target the source of the problem. This includes better landscape management, establishing safety perimeters around urban areas, and new laws to prevent unsafe practices such as the expansion of homes into forested regions[2].

[3]McWethy, D. B. *et al*. Landscape drivers of recent fire activity (2001-2017) in south-central Chile. *PLOS ONE* 13, e0201195 (2018).
[4]Ciocca, I. *et al*. Increased wildfire hazard along South-Central Chile under the RCP8.5 scenario as revealed by high-resolution modeling. *Environ. Res. Lett.* 18, 034023 (2023).
[5]Sarricolea, P. *et al*. Recent wildfires in Central Chile: Detecting links between burned areas and population exposure in the wildland urban interface. *Science of The Total Environment* 706, 135894 (2020).

2.6 Out of the woods: How far will Canada's wildfires spread?

by Daniel Bannister

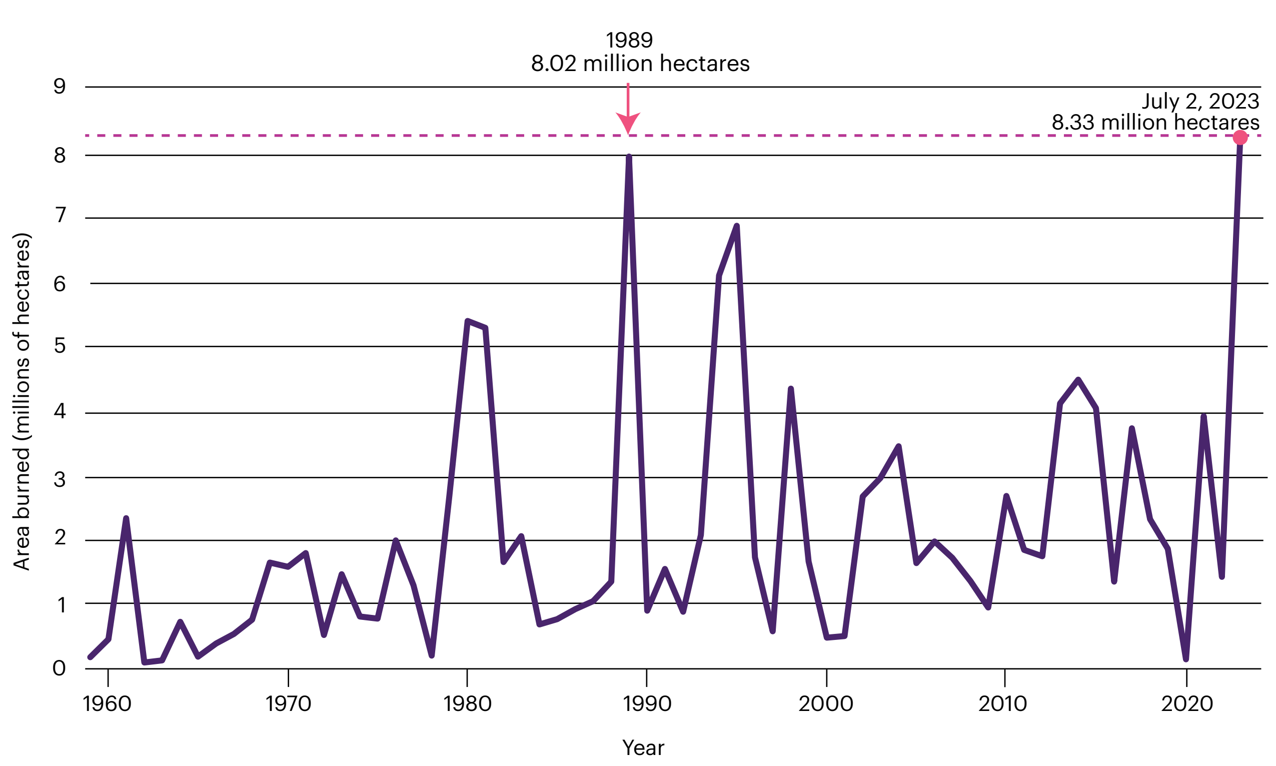
Canada's 2023 wildfire season is officially its worst on record. As of July 2, the total burned area has surpassed 8.33 million hectares, breaking the previous record for the largest area burned in a single year.

Unprecedented Magnitude

Canada's 2023 wildfire season made history on June 30, by surpassing the previous record of 8.02 million hectares of burned area in a single season, set in 1989 (Figure 1). This area was reached after only 60 days of the May–September fire season, which is in stark contrast to 1989, which took 153 days to reach the same area of destruction.

These wildfires have affected nearly every province and territory in Canada, with only Prince Edward Island and Nunavut being spared. Out of the numerous wildfires, just four fires account for one-quarter of the total burned area reported so far[1]. In fact, the combined area (2.35 million hectares) affected by these four fires exceeds the total burned area recorded at the end of the fire season in 46 out of the past 64 years. Notably, the Donnie Creek fire in British Columbia, the second largest among these four fires, has become the largest fire ever recorded in the province, spanning an area of 571,000 hectares[1].

Figure 1. **Estimated annual burned area in Canada, 1959-2023.**



Data source: Hanes *et al.*, 2019[2] (1959 – 2002), Canadian Wildland Fire Information System[1] (2003 – 2023). Last updated: July 2, 2023

[1]Canadian Wildland Fire Information System. https://cwfis.cfs.nrcan.gc.ca/home (2023).
[2]Hanes, C. C. *et al*. Fire-regime changes in Canada over the last half century. *Canadian Journal of Forest Research* 49, 256–269 (2019).

While the fires are predominantly occurring in remote areas, and Canada has had large fires in the past[2], the timing and widespread nature of the burning this year is highly unusual. The scale of this year's fires is so large that the burned area as of July 2 (8.33 million hectares) is equivalent in size to countries such as Czechia and Austria (Figure 2).

Unusual Characteristics

When looking at historical daily data from the Canadian Wildland Fire Information System for the last 20 years (2003-2023)[1], the unusual characteristics of the current wildfires are clear. The burned area (Figure 2), number (Figure 3), and location (Figure 4) of the fires have all deviated from previous years, making 2023 unparalleled in recent history.

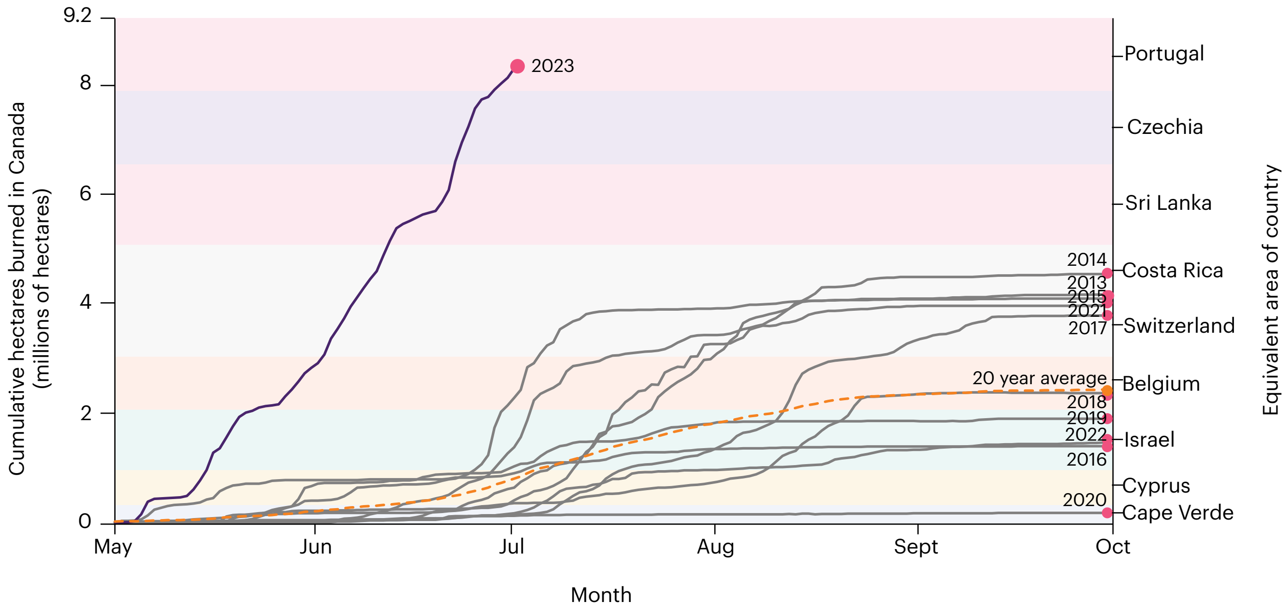
One striking aspect is the early onset of the burning, which caught many by surprise as it occurred before the usual favorable weather conditions for widespread blazes[3].

Figure 2 and Figure 3 illustrate how the fires started much earlier than in previous years, with May 2023 experiencing a record-breaking number of nearly 70,000 individually detected hotspots. The burned area at the end of May this year — amounting to 2.8 million hectares — is larger than the end of May burned area for all years combined over the last decade (2012–2022). On May 5 alone, the burned area witnessed a sixfold increase compared to the previous day, highlighting the rapid rate of spread.

Almost every province and territory have experienced record levels of burned area for this time of year, with Quebec, Saskatchewan, British Columbia, and Nova Scotia being particularly hard hit (Figure 4). As of July 2, these provinces had burned areas around 180% larger than the 20-year average for the same time period.

The trend of intense fire activity persisted throughout June, resulting in a monthly total burned area of 5.28 million hectares. This figure represents a new June record in the past 20 years and surpasses the cumulative burned area at the end of June for all years combined over the last decade (2012–2022).

Figure 2. **Estimated cumulative hectares burned from satellite-detected hotspots for 2023 compared to recent years. Also shown is the 2003–2023 average. To illustrate the scale of the fires, the equivalent land area of several countries is shown.**



Data source: Canadian Wildland Fire Information System[1]. Last updated: July 2, 2023.

[2]Hanes, C. C. *et al*. Fire-regime changes in Canada over the last half century. *Canadian Journal of Forest Research* 49, 256–269. (2019).
[3]Owens, B. Why are the Canadian wildfires so bad this year? *Nature News*. https://www.nature.com/articles/d41586-023-01902-4 (2023).

Furthermore, over 520,000 hectares were burned in a single day, marking the highest daily total in the available data. The current wildfires' extent exceeds the 20-year average for this time of year by a factor of ten.

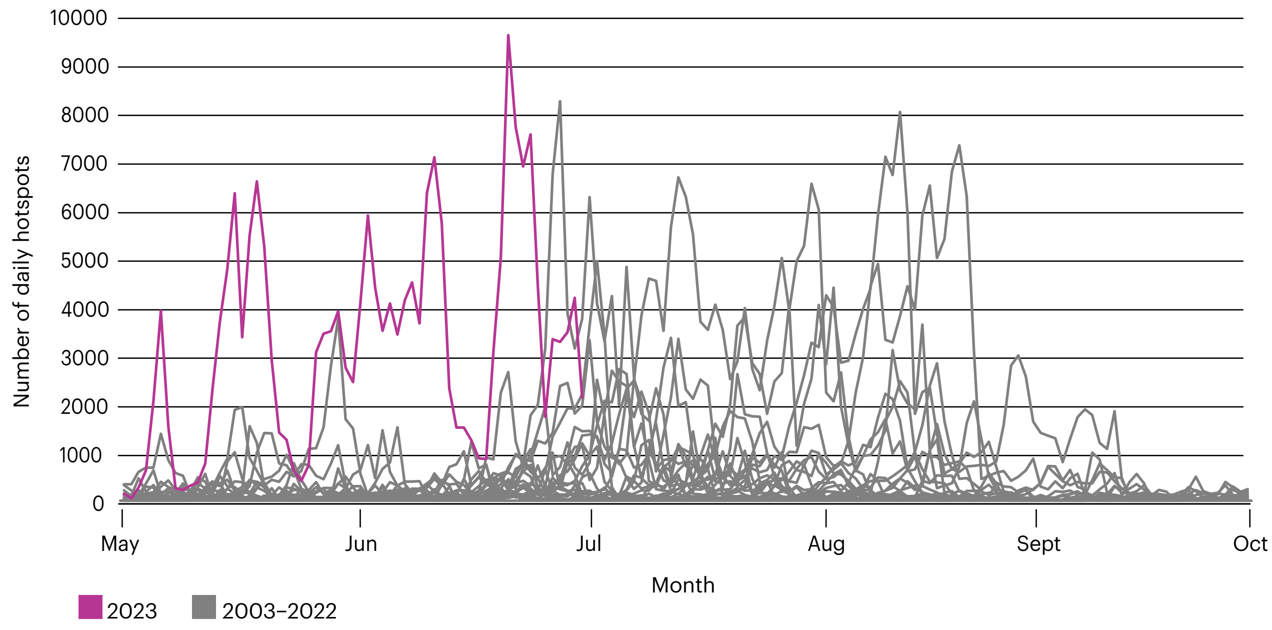
What Sparked the Early Onset?

The early start to the season can be attributed, in part, to the record-breaking heat experienced across western Canada in May[4]. This comes against a backdrop of rising temperatures across all seasons in the country over the last few decades[5].

The particularly hot and dry weather this year created a conducive environment for fire ignition and rapid wildfire spread.

This year is not an isolated event, but part of a larger trend observed in Canada, and across the world. Western Canada, in particular, has experienced a noticeable increase in both the size of burned areas and the frequency of large fires since the 1960s, often sparked by lightning strikes[2]. Human-caused fires, which are often smaller in scale, are also happening more frequently during the transitional seasons, which have been extended due to earlier springs and later winters. These shifts in the fire season coincide with periods when vegetation becomes highly flammable due to reduced water content, the shedding of leaves from deciduous trees, and increased curing. These factors, together with the effects of climate change, are projected to exacerbate fire activity throughout Canada by the end of the century[2].

Figure 3. **Estimated number of daily wildfire hotspots for 2023 (pink line) and all other years 2003 – 2022 (grey lines).**

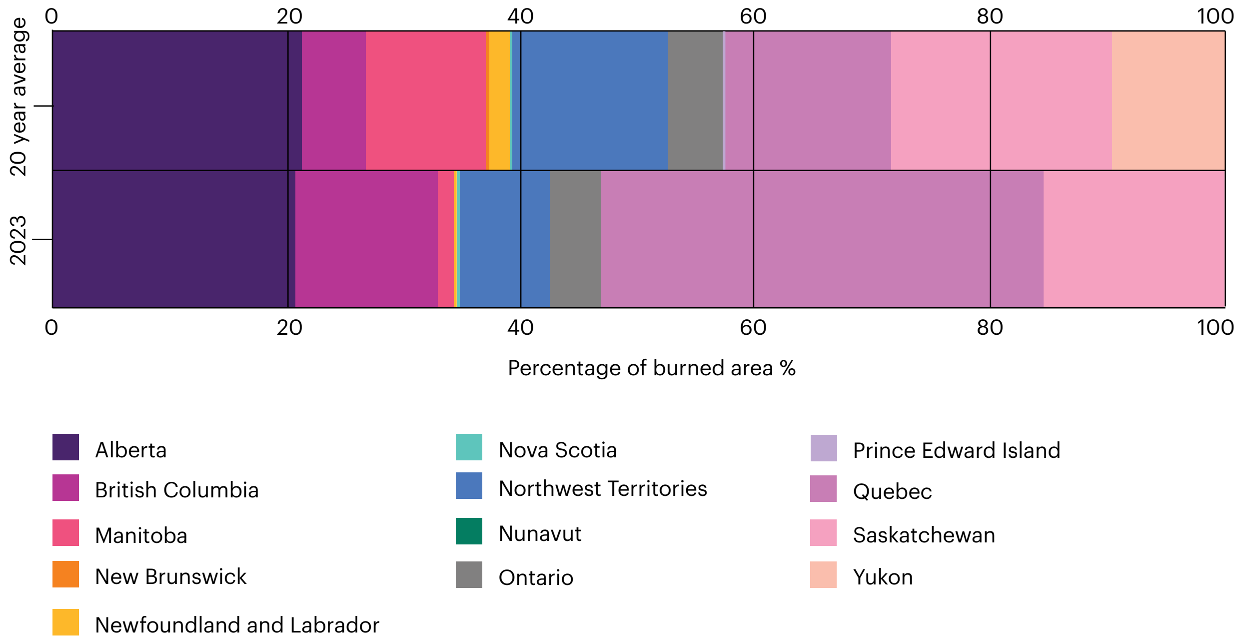


Data source: Canadian Wildland Fire Information System[1]. Last updated: July 2, 2023

[4]Summer temperatures arrive early. *NASA*. https://earthobservatory.nasa.gov/images/151349/summer-temperatures-arrive-early (2023).

[5]Environment and Climate Change Canada. *Government of Canada*. https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/temperature-change.html (2023).

Figure 4. **The proportion of the total burned area by province/territory, as of July 2, 2023 (bottom) compared to the 20-year (2003–2022) average (top) for the same time period.**



Data source: Canadian Wildland Fire Information System[1]. Last updated: July 2, 2023

Beyond the Flames

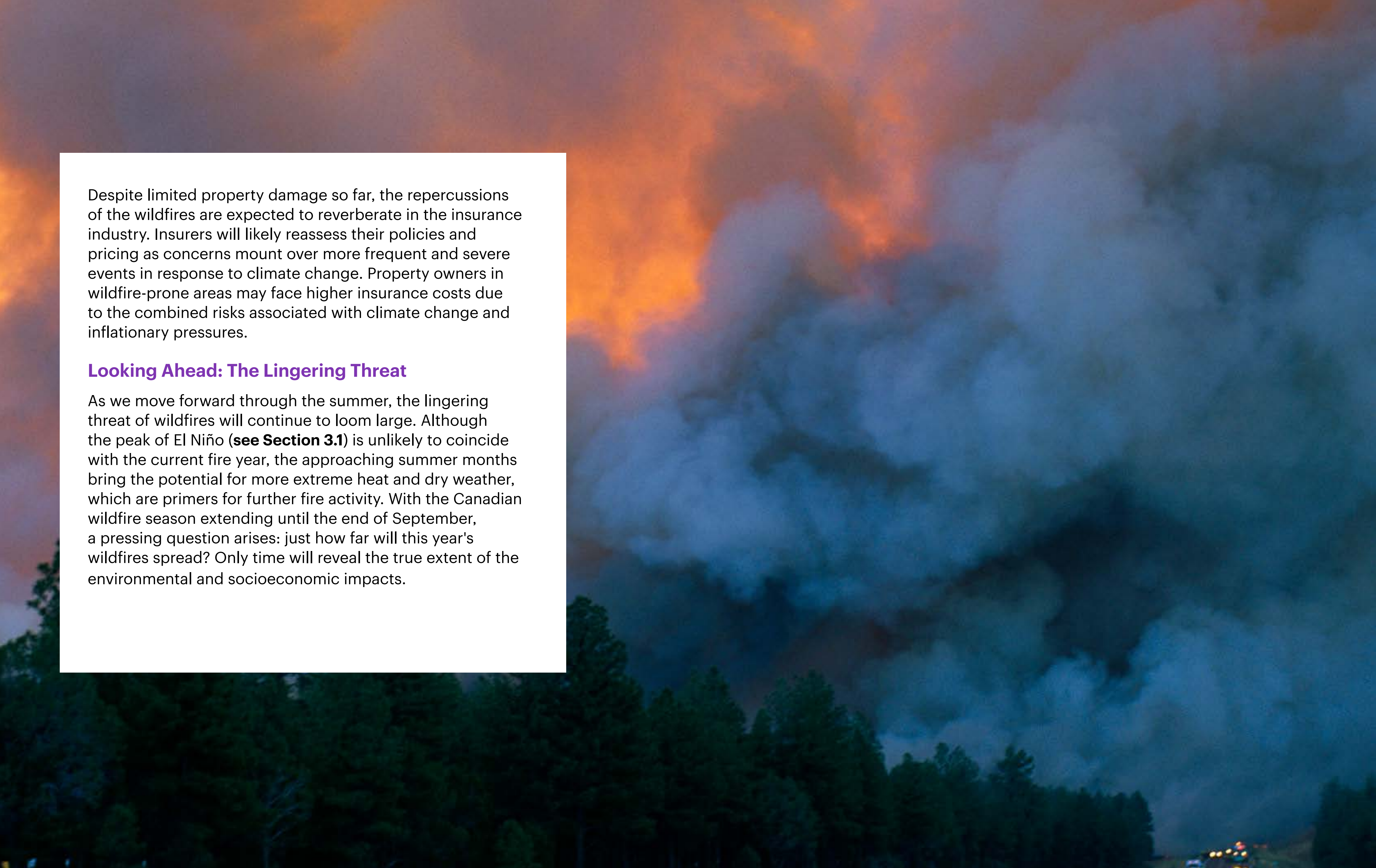
The 2023 season has presented challenges for firefighters and emergency responders. The fires have varied in size, number, and location, making it exceptionally difficult to combat them. Consequently, evacuations have been necessary, and as of July 2, over 600 structures have been damaged or destroyed. Even regions not directly threatened have been impacted as smoke drifts across North America. This resulted in deteriorated air quality conditions during early June, particularly in major cities like Boston, New York City, Philadelphia, and Washington, D.C.

By the end of June, the smoke from the wildfires had traveled across the Atlantic Ocean, reaching as far as central and south-eastern England, as well as western Scotland, as observed by satellites[6]. Fortunately, there have been no reported fatalities.

It is worth noting that while comparing the current wildfires to the devastating McMurray fires in 2016, which hold the record for the worst insured natural catastrophe loss in Canadian history, we must acknowledge that we are still in the midst of the wildfire season, and the final outcome remains uncertain. So far, the majority of the burning has occurred in remote areas, away from densely populated regions, allowing some to naturally extinguish to a certain extent. Consequently, the impact on cities, towns, and properties has been relatively limited.

Nevertheless, the wildfires have already affected multiple sectors of the economy. Tourism has declined due to concerns about air quality and safety issues. This has led to a decrease in visits and the closure of businesses in some regions[7]. Furthermore, the forestry sector has been significantly impacted, with sawmills forced to close[8]. This disruption in the wood product supply chain has temporarily boosted lumber prices due to dwindling supplies and rising demand.

[6]Russell, R. Satellite images show Canadian wildfire smoke over UK. *BBC*. https://www.bbc.co.uk/news/uk-66058108 (2023).
[7]Blake, E. Wildfires Impact Tourism in Canada. *Financial Post*. https://financialpost.com/news/economy/wildfires-impact-tourism-canada (2023).
[8]Nickel, R. Analysis: Canadian wildfires shutter sawmills, drive up lumber prices. *Reuters*. https://www.reuters.com/business/environment/canadian-wildfires-shutter-sawmills-drive-up-lumber-prices-2023-06-12/ (2023).



Despite limited property damage so far, the repercussions of the wildfires are expected to reverberate in the insurance industry. Insurers will likely reassess their policies and pricing as concerns mount over more frequent and severe events in response to climate change. Property owners in wildfire-prone areas may face higher insurance costs due to the combined risks associated with climate change and inflationary pressures.

Looking Ahead: The Lingering Threat

As we move forward through the summer, the lingering threat of wildfires will continue to loom large. Although the peak of El Niño (**see Section 3.1**) is unlikely to coincide with the current fire year, the approaching summer months bring the potential for more extreme heat and dry weather, which are primers for further fire activity. With the Canadian wildfire season extending until the end of September, a pressing question arises: just how far will this year's wildfires spread? Only time will reveal the true extent of the environmental and socioeconomic impacts.

2.7 A view of catastrophic flooding from across the world

by Neil Gunn and Cameron Rye

Flooding affected millions of people in the first six months of the year, with significant humanitarian and economic consequences across the world.

There were nearly 100 major flood events recorded across all populated continents in the first six months of the year[1]. The floods that had the largest socio-economic impacts are highlighted in Figure 1, many of which were the result of heavy rainfall overwhelming rivers and urban drainage systems, or the combination of inland and coastal flooding from tropical cyclones.

Flooding is one of the most prevalent natural hazards, affecting livelihoods and development opportunities globally[2,3].

Recent research from the World Bank has found that 1.8 billion people (23% of the world's population) live in areas that are directly exposed to 1-in-100 year flooding[4].

Most of these people (89%) are in low and middle income nations.

This pattern contrasts with economic exposures, which are concentrated in higher income countries, with $9.8 trillion of economic activity (12% of the gross global product in 2020) located in be flood-prone areas.

This year has been no exception, with multiple events resulting in significant humanitarian impacts for low and middle income populations.

[1]Based on data compiled from FloodList.com
[2]Parvin, G. A., Shimi, A. C., Shaw, R. & Biswas, C. Flood in a Changing Climate: The Impact on Livelihood and How the Rural Poor Cope in Bangladesh. *Climate* 4, 60 (2016).
[3]Balgah, R. A., Ngwa, K. A., Buchenrieder, G. R. & Kimengsi, J. N. Impacts of Floods on Agriculture-Dependent Livelihoods in Sub-Saharan Africa: An Assessment from Multiple Geo-Ecological Zones. *Land* 12, 334 (2023).
[4]Rentschler, J., Salhab, M. & Jafino, B. A. Flood exposure and poverty in 188 countries. *Nature Communications* 13, 3527 (2022).

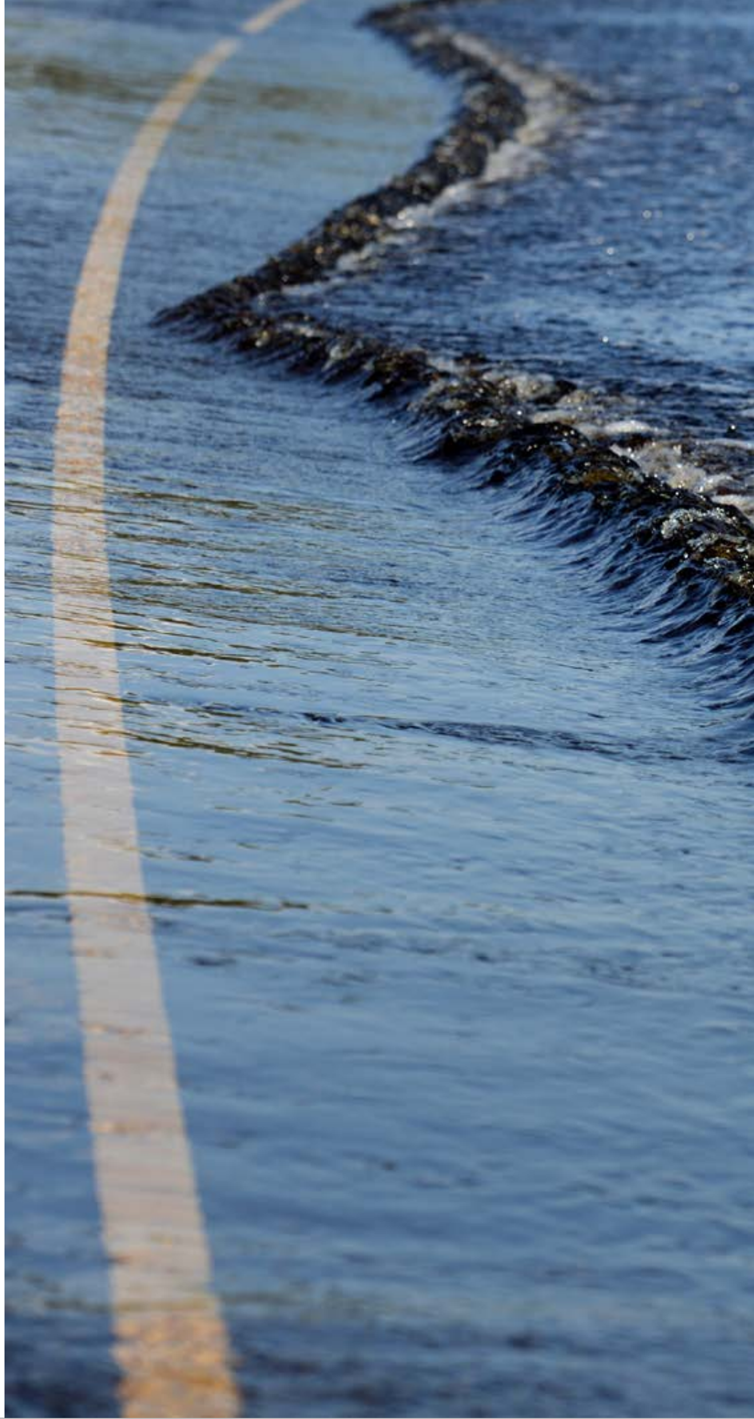
Heavy rains struck the Horn of Africa in March, affecting 460,000 people in Ethiopia and Somalia. This was followed by the African Great Lakes Floods in April and May, which killed over 600 people and caused extensive damage in the Democratic Republic of the Congo, Rwanda, and Uganda. In Asia, monsoon flooding and landslides occurred in Malaysia in March, while Extremely Severe Cyclonic Storm Mocha caused widespread coastal flooding in Myanmar and Bangladesh, displacing hundreds of thousands of people in May (Section 2.3). And in South America, Brazil saw multiple major flood events across 12 of the county's 26 states. The most notable was the record-breaking flooding in the state of São Paulo in February after 680mm of rain fell within a 24-hour period.

From an economic perspective, the largest events were in New Zealand (Section 2.4), Italy (Section 2.8), and California. The Southern Hemisphere summer of 2022/2023 was the wettest on record for New Zealand's North Island, which culminated in February with Cyclone Gabrielle producing an estimated $8.4 billion in economic damages. Intense rainfall in Northern Italy in May led to flooding that produced damages of roughly $5.4 billion, while at the beginning of the year, severe flooding in California brought on by a series of atmospheric rivers is estimated to have caused economic losses of up to $7 billion.

Climate change is expected to increase flood risk by increasing the intensity of rainfall and raising sea levels[5]. Furthermore, as populations continue to grow, more people are living in flood prone areas, increasing the exposure of vulnerable communities.

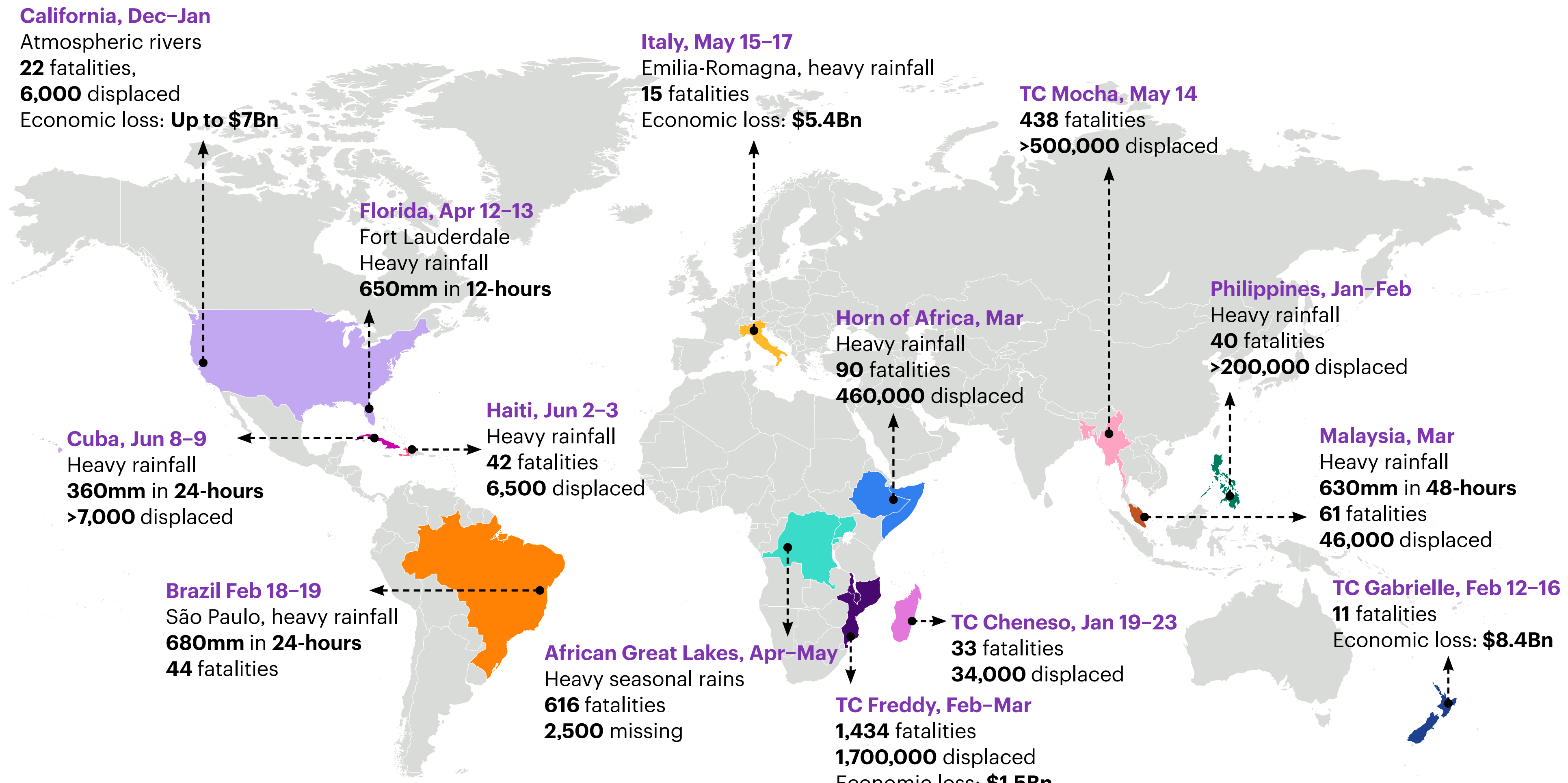
Given that floods affect more people than most other natural disasters, it is imperative for governments, corporations, and other organizations to proactively invest in resilience measures. These steps include implementing sustainable infrastructure, improving early warning systems, and developing robust disaster response strategies.

In addition, accessible and comprehensive insurance solutions are vital to close the protection gap and ensure that communities have the necessary financial support to recover and rebuild after natural catastrophes.



[5]Pörtner, H. O. *et. al*. IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (Intergovernmental Panel on Climate Change, 2019).

Figure 1. **Flood events with the largest socio-economic impacts that occurred between January and June 2023.**



TC = Tropical Cyclone

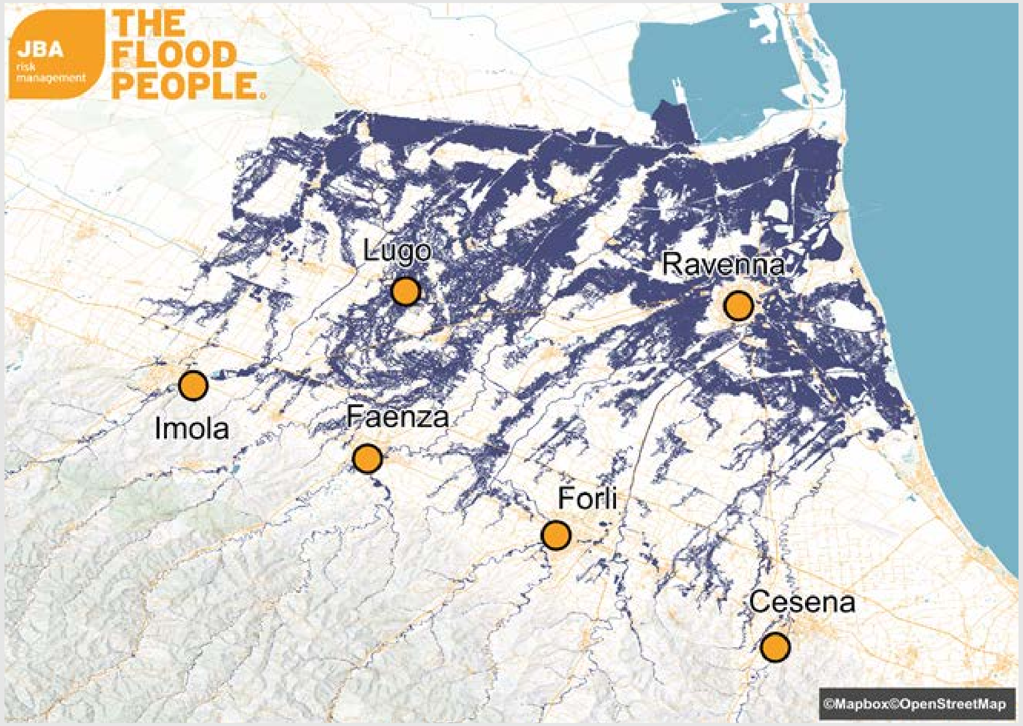
2.8 Emilia-Romagna floods: a product of urbanization and climate change

by Francesco Serinaldi and Chris Kilsby

After intense rainfall produced major flooding and landslides in a densely populated region of the Po Valley, we look at how climate and land-use change are affecting flood risk in Northern Italy.

Flooding devastated Italy's Po Valley in May, affecting Imola, Cesena, Forli, Faenza, Ravenna, Lugo, and surrounding areas (Figure 1). The region was hit by two events, the first between May 2 and 3, and the second between May 15 and 17. The second was the most severe, with an average of 200mm of rain falling across the region in a 36-hour period, and some areas recording over 500mm. There were 15 fatalities, over 36,000 people evacuated, at least 376 landslides, and 714 closed roads (445 totally, and 259 partially)[1]. The regional government has provided a provisional estimate of €5 billion (U.S.$5.4 billion)[2] in economic damage, but this figure is expected to change as the full extent of the disaster materializes.

Figure 1. **Flooding in Emilia-Romagna from May 15 to May 17.**



Source: JBA Risk Management

[1]ERCC - Emergency Response Coordination Centre - Maps. https://erccportal.jrc.ec.europa.eu/ECHO-Products/Maps#/maps/4501 (2023).

[2]Servono 5 miliardi: la conta dei danni tra campi, aziende, strade e turismo. https://www.repubblica.it/economia/2023/05/21/news/danni_alluvione_emilia_romagna_stanziamento_fondi-401052309/?ref=RHLF-BG-I400748377-P1-S1-T1 (2023).

[3]Persiano, S. *et al*. Changes in seasonality and magnitude of sub-daily rainfall extremes in Emilia-Romagna (Italy) and potential influence on regional rainfall frequency estimation. *Journal of Hydrology: Regional Studies* 32, 100751 (2020).

In the past few years, Emilia-Romagna has been affected by several destructive flood events, including significant river flooding (e.g. Secchia and Panaro Rivers in January 2014, Enza River in December 2017, Reno River in February 2019, Idice River in November 2019), flash-flooding in mountainous areas (e.g. Alta Val Nure in September 2015), and intense rainfall-induced flooding in urban areas (e.g. Rimini in June 2013)[3].

According to the Italian Institute of Environmental Protection and Research, around 63% of businesses and homes in Emilia-Romagna are located within the 1-in-100 year flood zone. Moreover, the region plays a crucial role in the Italian economy, contributing more than 40% of Italy's Gross National Product[3].

Although Italy is a flood-prone country and regions like Emilia-Romagna have high exposed value, the insurance penetration is lower than that of other developed European countries. Non-life insurance penetration in Italy was 1.9% of GDP in 2021. In comparison, the rate was 2.3% in Germany, 2.9% in Spain, 4.0% in France, and 7.4% in The Netherlands. If motor liability insurance (compulsory everywhere) is excluded, the gap in non-life premiums between Italy and other European countries is even wider[4].

Academic research indicates that flood risk in the Po Valley is changing due to two main factors. First, climate change is resulting in the intensification of extreme hydrological events, which meteorologists have attributed to a change in the atmospheric dynamics in the Mediterranean area. Previously the majority of weather systems moved from east-to-west, but we are now seeing an increase in north-to-south systems. This results in more extreme precipitation events because there is a larger temperature and humidity gradient between North Africa and Northern Europe[5].

Second, there has been an increase in the number of people exposed to flooding due to land-use and land-cover modifications[3]. The government of Emilia-Romagna has enabled a significant expansion of urban areas over the last four decades. During flood events, the man-made drainage network is increasingly overloaded due to the significant proportion of land that has been converted from agricultural to urban. At the same time, flooding has caused more significant damages due to the increase in exposure values[6,7].

Successive flood events in the Emilia-Romagna region in recent years have highlighted the vulnerability of the Po Valley.

With most of the population expecting government support following natural disasters, rather than buying insurance, there is a need for the country to review how to improve resilience and reduce the burden on government finances. This is especially true over the coming decades when climate change is expected to increase the frequency and severity of flood events.

[4]Associazione Nazionale fra le Imprese Assicuratrici. Italian Insurance 2021-2022. https://www.ania.it/documents/35135/126704/ITALIAN+INSURANCE-2022+EN_WEBVER.pdf/03211e47-ad5c-2268-d994-541120c6e55a?version=1.0&t=1668508791602 (2022).

[5]Rousi, E., Selten, F., Rahmstorg, S., & Coumou, D. Changes in North Atlantic Atmospheric Circulation in a Warmer Climate Favor Winter Flooding and Summer Drought over Europe. *Journal of Climate* 34 Issue 6, (2021).

[6]Pistocchi, A., Calzolari, C., Malucelli, F. & Ungaro, F. Soil sealing and flood risks in the plains of Emilia-Romagna, Italy. *Journal of Hydrology: Regional Studies* 4, 398–409 (2015).

[7]Sekovski, I. *et al*. Coupling scenarios of urban growth and flood hazards along the Emilia-Romagna coast (Italy). *Natural Hazards and Earth System Sciences* 15, 2331–2346 (2015).

2.9 Why have there been so few European winter windstorms in 2022/2023?

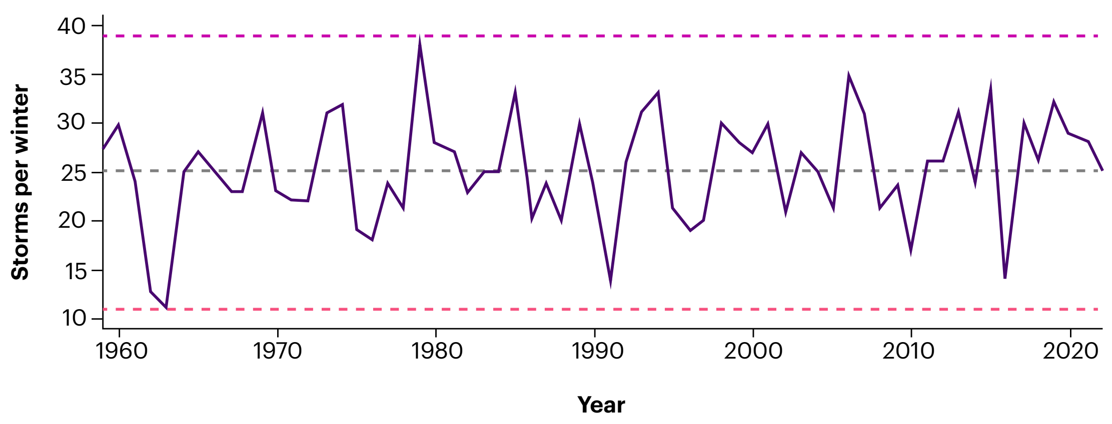
by Adam Scaife, David B. Stephenson, Matthew Priestley, Nicky Stringer, and Daniel Bannister

The 2022/2023 European windstorm season was unusually quiet, deviating from predictions of heightened storm activity. Factors such as La Niña, the Madden Julian Oscillation, and a sudden stratospheric warming event likely contributed to the reduced storminess, highlighting the challenges of seasonal forecasting.

During the winter of 2022/2023, European extratropical cyclones, known for their destructive nature and significant impact, were notably scarce. This absence of named storms aligned with early winter forecasts but contradicted predictions that anticipated heightened storm activity later in the season. This raises the question of why there were so few storms in Europe during this winter. Understanding the factors contributing to European extratropical cyclone frequency is crucial, especially for industries like insurance and agriculture that depend on weather information.

Historically, the UK Met Office has recorded an average of 4.5 named European extratropical events per year since the naming convention was introduced in 2016. However, the 2022/2023 season stood out with only one storm (Otto) named by the Danish Meteorological Institute in February 2023. This stands in stark contrast to the previous year, which experienced a rapid succession of named events, including three within seven days (Dudley, Eunice, and Franklin) for the first time since the naming convention began. Despite the limited occurrence of named storms, the total number of extratropical cyclones during winter 2022/23 remained close to the average (Figure 1).

Figure 1. **Number of North Atlantic storms per Northern Hemisphere winter (Dec–Feb). Despite the lack of named (intense) storms, the total number of storms was close to average in winter 2022/2023.**



Data source: Copernicus Climate Change Service (C3S). Complete ERA5 global atmospheric reanalysis. DOI: 10.24381/cds.143582cf (2023).

The question arises: What happened to the intense windstorms this winter? Our initial null hypothesis is always that internal, unpredictable climate variability, with no particular identifiable cause, leads to variation between one period and the next. Some aspects of the quiescent winter of 2022/23 will no doubt be attributable to this unpredictable 'chaos'. Individual seasonal forecasts showed substantial uncertainty and some of them did span the observed outcome, but can we dig deeper?

The global climate state for winter 2022/23 was influenced by the third La Niña event in a row since 2020.

Observations and climate modelling studies indicate that La Niña often leads to atmospheric blocking (reduced storminess) in the early winter and enhanced westerlies (increased storminess) in the late winter[1,2]. The recent La Niña may therefore partially explain the absence of intense storms in early winter but fails to account for the late winter period.

The Madden Julian Oscillation (MJO), a natural weather pattern significantly impacting tropical regions and global weather, also played a crucial role during this winter. The MJO progresses through distinct phases, each representing different weather patterns. Extensive research supports the notion that the MJO has notable effects on the North Atlantic region[3,4]. Phases 6 and 7 of the MJO are particularly associated with heightened rainfall and storm activity in the western Pacific Ocean, which can influence weather patterns in the North Atlantic area, causing blocked conditions (and therefore reduced storm activity over Europe) for up to two weeks.

Late November 2022 witnessed an exceptionally intense period characterized by phases 6 and 7 of the MJO. This heightened MJO activity was then followed by a relatively calm and cold period observed in early to mid-December 2022.

Throughout the winter, the MJO remained active, with recurring significant shifts to phases 6 and 7, followed by subsequent transitions to cooler periods. These patterns culminated in a sudden stratospheric warming (SSW) event[5].

[1]Moron, V. & Gouirand, I. Seasonal modulation of the El Niño-Southern Oscillation relationship with sea level pressure anomalies over the North Atlantic in October-March 1873-1996. *International Journal of Climatology* 23, 143–155 (2003).

[2]Hardiman, S. C. *et al*. The impact of strong El Niño and La Niña events on the North Atlantic. *Geophysical Research Letters* 46, 2874–2883 (2019).

[3]Cassou, C. Intraseasonal interaction between the Madden–Julian Oscillation and the North Atlantic Oscillation. *Nature* 455, 523–527 (2008).

[4]Lin, H., Brunet, G. & Fontecilla, J. S. Impact of the Madden–Julian Oscillation on the intraseasonal forecast skill of the North Atlantic Oscillation. *Geophysical Research Letters* 37 (2010).

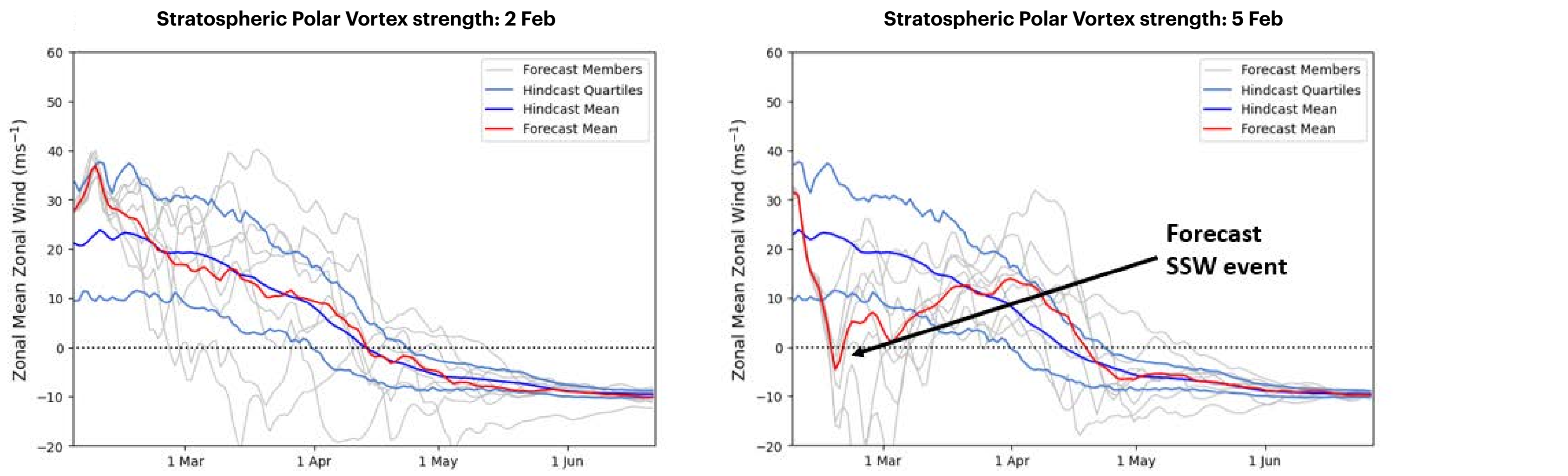
[5]Schwartz, C. & Garfinkel, C. I. Relative roles of the MJO and stratospheric variability in North Atlantic and European Winter Climate. *Journal of Geophysical Research: Atmospheres* 122, 4184–4201 (2017).

Sudden stratospheric warming events are often (in ~70% of cases) followed by colder periods with easterly winds over northern Europe compared to normal[6,7,8]. These circulation patterns correspond to a weaker jet stream with less frequent windstorms.

While sudden stratospheric warming events are often involved in cold winters[9], they represent a challenge for seasonal forecasts due to their relatively short lead time for prediction[10].

Figure 2 illustrates the emergence of forecast signals for the sudden warming of 2023, which were not apparent until early February. This late winter sudden stratospheric warming event likely contributed to reduced storminess in later winter when we would have otherwise expected increased storminess from La Niña.

Figure 2. **Strength of the stratospheric polar vortex as measured by daily windspeeds in the stratosphere at 60N and 10hPa for the late winter period from February 2023. Forecasts from 2023 are shown in red and mean climatology is shown in blue. Note the emergence of a strong signal for a collapse of the polar vortex (and hence a sudden stratospheric warming) in forecasts made in early February.**



Source: Met Office

[6]Bett, P. E. *et al.* Using large ensembles to quantify the impact of sudden stratospheric warmings and their precursors on the North Atlantic Oscillation. *Weather and Climate Dynamics* 4, 213–228 (2023).

[7]Kidston, J. *et al.* Stratospheric influence on tropospheric jet streams, storm tracks and Surface Weather. *Nature Geoscience* 8, 433–440 (2015).

[8]Scaife, A. A. *et al.* Seasonal Winter forecasts and the stratosphere. *Atmospheric Science Letters* 17, 51–56 (2016).

[9]Fereday, D. R., Maidens, A., Arribas, A., Scaife, A. A. & Knight, J. R. Seasonal forecasts of Northern Hemisphere Winter 2009/10. *Environmental Research Letters* 7, 034031 (2012).

[10]Marshall, A. G. & Scaife, A. A. Improved predictability of stratospheric sudden warming events in an atmospheric general circulation model with enhanced stratospheric resolution. *Journal of Geophysical Research* 115, (2010).

In summary, it is likely that a combination of La Niña, intense MJO activity, and a sudden stratospheric warming event weakened the storm track in winter 2022/23.

Some of these signals, such as the La Niña event, were predicted in advance of the winter, and official Met Office long-range outlooks captured the weak winds and lack of storms observed over the UK throughout the winter (Figure 3).

The forecasts also highlighted that the risk of stormy weather was highest in late winter, aligning with the late winter La Niña teleconnection, which tends to strengthen the storm track in the Atlantic. However, the effect of La Niña was reduced this year due to a sudden stratospheric warming in February.

Figure 3. **Met Office long range outlook for winter 2022/2023 issued in November 2022.**

Temperature

15% chance the season will be **COLD**	**65%** chance the season will be **NEAR AVERAGE**	**20%** chance the season will be **MILD**
0.8 x the normal chance	**1.1 x** the normal chance	**1.0 x** the normal chance

Precipitation

25% chance the season will be **DRY**	**65%** chance the season will be **NEAR AVERAGE**	**10%** chance the season will be **WET**
1.3 x the normal chance	**1.1 x** the normal chance	**0.5 x** the normal chance

Wind speed

30% chance the season will be **CALM**	**65%** chance the season will be **NEAR AVERAGE**	**5%** chance the season will be **WINDY**
1.5 x the normal chance	**1.1 x** the normal chance	**0.3 x** the normal chance

Source: Met Office

Outlook

3.1 From the tropical Pacific, El Niño is in the wind

by Scott St. George

For three years in a row, Earth's largest ocean has been stuck in its La Niña configuration. Now that the Pacific has flipped to El Niño, businesses should prepare for record-high temperatures, weird weather, and slower economic growth.

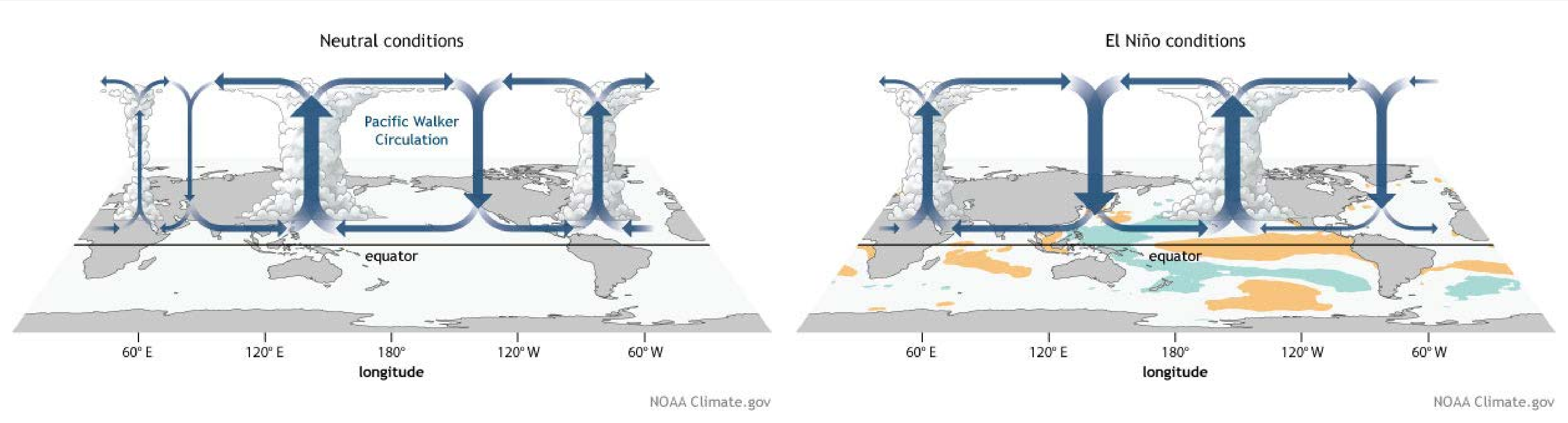
The tropical Pacific Ocean has been remarkably dependable these past few years. Since the start of 2020, the trade winds have blown west across the equator in their usual fashion, pushing warm water away from South America and toward Indonesia and Papua New Guinea. This arrangement of air and ocean currents has been unusually vigorous over this period, with energized winds and even hotter water in the west. This situation is named La Niña and the uncommon persistence of this latest 'triple dip' event has set the table for global climate three years running. But La Niña has now exited the stage, and the spotlight is about to be taken by its mirror opposite.

The Pacific's other way of being is called El Niño. Under its oversight, the trade winds slacken and the massive pool of warm water in the west slouches eastward, taking up a position in the central Pacific. Normally the atmosphere above the Pacific forms a single loop, where air rises in the west, tracks eastward at higher altitudes, sinks back down off the coast of South America, and then rejoins the trade winds. During an El Niño, that single cell is split in two. The grand column of convection rises from the middle of the Pacific rather than its western arm, and air is pushed both east and west from that central location (Figure 1).

These rearrangements and reversals toss the tropical Pacific's weather upside down. El Niño brings drought and wildfire to Indonesia, conducts surprise rainstorms and floods into the normally dry areas of Ecuador and Peru, and causes the marine food web surrounding the Galapagos Islands to collapse. But because the tropical Pacific Ocean is so enormous and holds so much heat, El Niño has a reach far beyond the confines of the basin itself.

As put by Josh Willis, a climate scientist and oceanographer at NASA's Jet Propulsion Laboratory, "When the Pacific speaks, the whole world listens"[1].

Figure 1. **Generalized Walker Circulation (December-February) during ENSO-neutral conditions and Generalized Walker Circulation (December–February) anomaly during El Niño events, overlaid on map of average sea surface temperature anomalies.**



Source: Climate.gov

[1]NASA Earth Observatory. La Niña times three. https://earthobservatory.nasa.gov/images/150691/la-nina-times-three (2022).

Extratropical reverberations

El Niño and La Niña are the single leading cause of year-to-year changes in weather and climate across the planet.

How is it that ripple effects from the Pacific Ocean echo so far afield? One thread follows the Rossby waves, enormous planet-spanning twists and turns in Earth's atmosphere that guide heat and moisture away from the Equator and towards the poles. During El Niño, Rossby waves adopt a more meandering path and alter the trajectory of the jet streams (and therefore storm systems) over the continents. What's more, the atmosphere absorbs more heat while the ocean takes up less, and so two to three months after the event begins, global surface temperatures take an additional step upwards. That's the reason why major El Niño years are among the hottest ever recorded, including the current record holder, 2016[2].

All El Niños are alike in their general structure but each one also has its own peculiarities. Some events, for instance, feature unusually warm water only in the central equatorial Pacific and do not involve much change in the eastern part of the ocean, where El Niño events generally are born. In the same fashion, while their impacts on the ground are not identical from event to event, overall there are consistent patterns that tend to repeat. A bog standard El Niño brings drought to Indonesia, Australia, Central America and northern South America, and heavy rains to the southern United States, southern South America, and the Horn of Africa[3].

They can also conjure up more unusual reactions through their interference with the jet stream. For air travel between Hawaii and the continental United States, El Niño can lengthen or shorten flight durations by more than 30 minutes, depending on whether the flight is eastward or westward[4]. Farther downstream, El Niño causes ground-level winds to weaken across large swathes of Canada and the northern United States, sometimes for months at a time[5]. As the leading cause of 'wind drought' in North America, an impending El Niño is an ill omen for renewable energy production.

In total, the knock-on effects of El Niño extract a massive toll on the global economy. A recent study from Dartmouth University put the global price tag of the major 1983 and 1998 events at nearly $4.1 trillion and $5.7 trillion, respectively[6]. That analysis argued the macroeconomic effects of El Niño are both abrupt and chronic. Extreme weather during the event itself causes loss of life, property damage, and wild fluctuations in crop prices. But El Niño also reduces economic growth in the long term, particularly in tropical countries where its imprint is strong (including Ecuador, Brazil, and Indonesia), and that stagnation can persist for five years or more after the initial event.

[2]National Oceanographic and Atmospheric Administration. 2020 was Earth's 2nd-hottest year, just behind 2016. https://www.noaa.gov/news/2020-was-earth-s-2nd-hottest-year-just-behind-2016 (2021).
[3]Lenssen *et al*. Seasonal forecast skill of ENSO teleconnection maps, *Weather and Forecasting* 35: 2387-2406. https://doi.org/10.1175/WAF-D-19-0235.1 (2020).
[4]Karnauskas *et al*. Coupling between air travel and climate, *Nature Climate Change* 5: 1068-1073. https://www.nature.com/articles/nclimate2715 (2015).
[5]St. George and Wolfe. El Niño stills winter winds across the southern Canadian Prairies, *Geophysical Research Letters* 36. https://doi.org/10.1029/2009GL041282 (2009).
[6]Callahan and Mankin. Persistent effect of El Niño on global economic growth, *Science*. https://doi.org/10.1126/science.adf2983 (2023).

A whisper or a thunderclap?

By reading the signs in the tropical Pacific, climate scientists are able to spot El Niño and La Niña on the horizon three to six months in advance. Currently these long-term forecasts are made in one of three ways. The first and oldest approach builds statistical models that predict an index of the El Niño/La Niña system based on other measured aspects of the tropical Pacific (such as deep ocean temperatures, air pressure patterns, or even the state of the index in previous months). The second approach — dynamical modeling — uses high-performance computers to simulate the physical behavior of the ocean and atmosphere over the coming months. The third (and newest) technique searches the huge database of climate model output to find all cases where the simulation closely resembles the current state of the Pacific Ocean[7]. Researchers can then trace how those lookalikes evolved over the next several months within the simulation and use that behavior to forecast El Niño in the real world.

As of mid-June 2023[8], nearly all models predict that El Niño will be in force past the end of the year but they disagree quite a lot about its strength. The dynamical models are calling for a very strong event, perhaps one of the biggest of the past three decades.

The statistical models are much more cautious, suggesting the tropical Pacific will just barely exceed the threshold to qualify as an El Niño. And the analog forecasts sit in the middle — an El Niño, but not a particularly strong one[9].

Seasonal forecasting, even when tied to a phenomenon as intensively studied as El Niño, is still enormously challenging. That challenge is made more difficult because El Niño is itself part of our changing global climate. As noted by the Woodwell Climate Research Center's Dr. Jennifer Francis[10], we've never had a strong El Niño under such high global temperatures and, perhaps more crucially, record heat content in the oceans. Because our forecasting techniques are operating in uncharted waters, we should perhaps be cautious about our ability to predict El Niño and anticipate its impacts. But if the Pacific does manifest an El Niño by the end of the year, we should appreciate its potential to redraw the global climate map and, to borrow the words of Dr. Francis, to "expect chaos" in its wake.

[7]Cooperative Institute for Research in Environmental Sciences. Mining climate models for seasonal forecasts. https://cires.colorado.edu/news/mining-climate-models-seasonal-forecasts (2019).
[8]International Research Institute for Climate and Society. ENSO forecast. https://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/?enso_tab=enso-sst_table (2023).
[9]National Oceanographic and Atmospheric Administration. Model-Analogs (MA) and Linear Inverse Model (LIM) forecasts for Months 1-24. https://psl.noaa.gov/forecasts/seasonal/ (2023).
[10]ClimateGenn. Dr Jennifer Francis– 2023's symptoms of climate chaos, El Niño, ocean heatwaves, and arctic sea ice lows. https://www.patreon.com/posts/dr-jennifer-of-83526180 (2023).

3.2 The 2023 North Atlantic hurricane season: Record hot Atlantic Ocean versus El Niño

by James Done

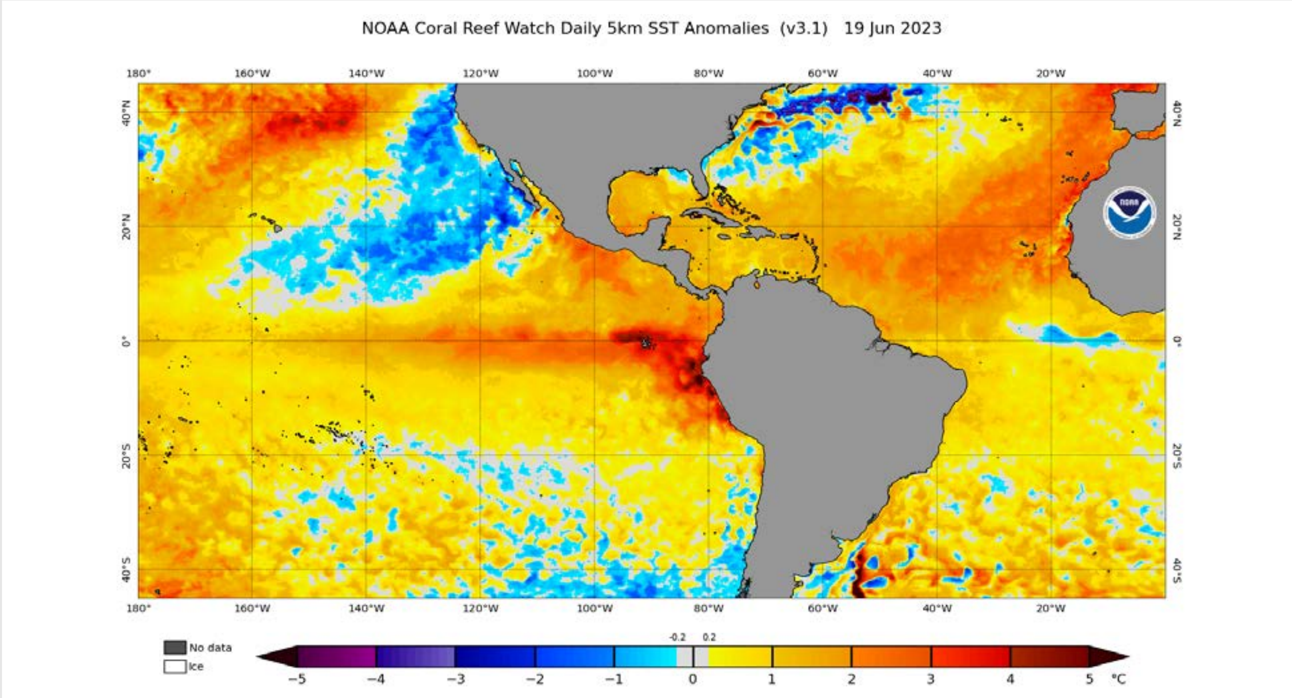
The global tropics have flipped from La Niña to El Niño. El Niño is one of our most dependable sources of seasonal hurricane forecast skill, but this year's record hot North Atlantic Ocean will put El Niño's hurricane-suppressing influence to the test.

Those impacted by the hyperactive North Atlantic hurricane seasons of 2020 and 2021 will see this year's El Niño as a welcome development. El Niño has historically suppressed hurricane seasons by driving strong winds aloft over the North Atlantic that can tear nascent hurricanes apart.

The prolonged string of three successive seasons of La Niña conditions just ended. Since early this year the warm waters that were piled up over the Western Equatorial Pacific Ocean have slipped back East. Ocean surface temperatures rose at a remarkable pace in the Central and Eastern Equatorial Pacific Ocean (Figure 1), and this is backed by warmth throughout the underlying upper layers of the ocean. These temperatures passed a key threshold triggering the U.S. National Oceanic and Atmospheric Administration to declare an El Niño on June 8.

Meanwhile, over in the North Atlantic surface waters have been warming rapidly. The subtropical high-pressure system has been unusually weak this year, limiting the cooling easterly winds across the tropical North Atlantic. In response, the typical seasonal warming of the North Atlantic has occurred at a rapid pace and parts of the tropical Atlantic are now breaking June temperature records[1] (Figure 1).

Figure 1. **Departure of sea surface temperature from a long-term average (°C) valid on June 15, 2023.**



Source: U.S. National Oceanic and Atmospheric Administration Coral Reef Watch.

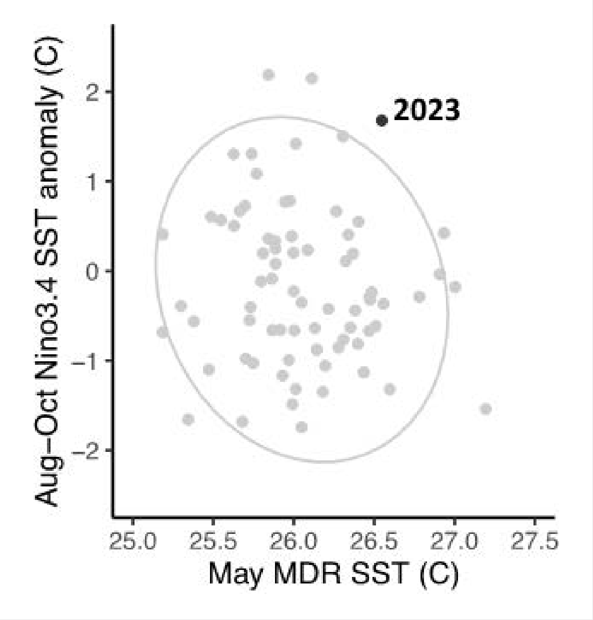
[1]Ben Noll [@BenNollWeather]. It's official: the Atlantic Main Development Region (MDR) has reached a record high temperature for the month of June. *Twitter*. https://t.co/FpdCYVGXuW (2023).

Rather ominously, waters are hotter than they were in June 2005 before the devastating 2005 hurricane season. The Atlantic is poised to break more monthly temperature records during the upcoming hurricane season. Given that hurricanes get their energy from the ocean, this unprecedented warmth will fuel any hurricane that can avoid El Niño's strong winds aloft.

This year's combination of expected moderate-to-strong El Niño and Atlantic Ocean warmth falls at the edge of historical experience (Figure 2). These two opposing factors for the 2023 hurricane season have led to differing opinions among the major forecasting centers. Those that think the hostile winds brought by El Niño will win out are calling for below normal activity, while those that think the Atlantic Ocean warmth will overcome El Niño's winds are calling for above normal activity.

Forecasts from universities, government agencies, private companies, and other organizations[3] range from 11 to 28 named storms. The forecasts for hurricanes range from 5 to 15 and major hurricanes from 2 to 7. These predictions extend above and below the 1991-2020 average of 14.4 named storms, 7.2 hurricanes, and 3.2 major hurricanes. This wide range reflects the uncertainty in the opposing forces for this year's hurricane season. And if that spread wasn't challenging enough, enter climate change.

Figure 2. **Scatter plot of May North Atlantic sea surface temperatures (SSTs) in the Main Development Region (MDR) versus the August-October Nino3.4 region SST anomaly. The ellipse contains 90% of historical data points, showing that this year falls at the edge of historical experience. The MDR (10-20°N, 20-85°W) SST was calculated using the National Centers for Environmental Prediction (NCEP) reanalysis. The Nino3.4 SST anomaly is relative to the 1991-2020 average, from the National Oceanic Prediction Centre (NOAA)/Climate Prediction Centre (CPC). For 2023, the Nino3.4 anomaly is the dynamical model average forecast issued on June 16, 2023[2].**



Data source: National Oceanic Prediction Centre (NOAA)/Climate Prediction Centre (CPC)

A key question that scientists are currently trying to answer is whether El Niño events in today's climate will suppress hurricane seasons as effectively as they once did. Those strong winds typical of El Niño depend on ocean temperature differences around the global tropics. Given that all oceans are warming, an El Niño today may not have the same influence as an El Niño in the past. Global ocean surface temperature reached record levels in April[4], making this year a test of the influence of El Niño in a warming world.

Should we expect our forecasting systems to pick up on this potential for a changing influence? There are two main methods currently used by different agencies to forecast hurricane activity: statistical and dynamical. Seasonal hurricane forecasts based on statistical methods, which are built using historical data, generally reproduce the suppressing effect of El Niño and point to a below normal season. Our alternative to statistical methods is using the physical laws of weather and climate embodied by dynamical methods. These methods are not constrained to repeat historical relationships and may capture new, unobserved effects in a changing climate. Some of these methods are suggesting that the influence of this year's El Niño may not be as strong as historical El Niño events with less strong hostile winds over the Atlantic. Consequently, these point to an above normal season. Many lessons will be learned from the dual and interacting influences of El Niño and climate change on the 2023 hurricane season. This will allow us to improve our forecasting systems to keep pace with our changing climate.

[2] IRI – International Research Institute for Climate and Society | June 2023 Quick Look. https://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/ (2023).
[3] Barcelona Supercomputing Center. Seasonal Hurricane Predictions https://seasonalhurricanepredictions.bsc.es (2023).
[4] Dr. Robert Rohde [@RARohde]. This is getting ridiculous. OISST provides a real-time daily index of ocean surface temperature (60 S - 60 N). For the last month it has been continuously reading higher than in any previous year and still shows no sign of settling. *Twitter*. https://t.co/FeER7BViL2 (2023).

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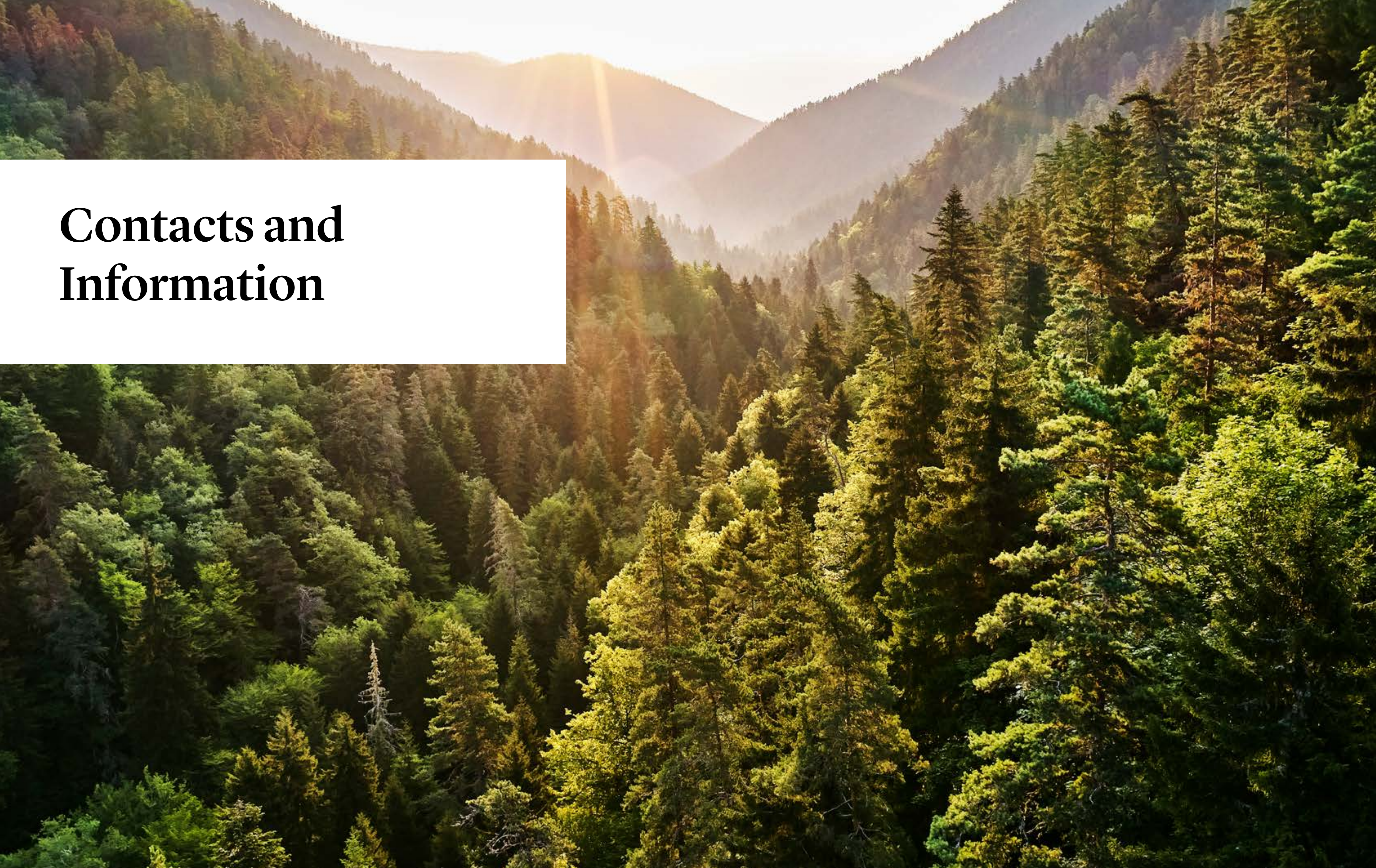

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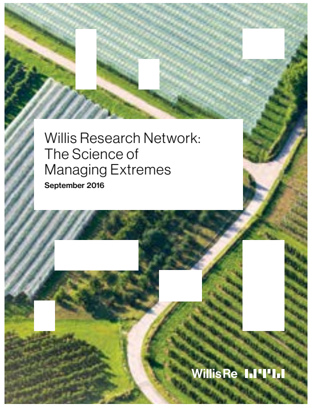
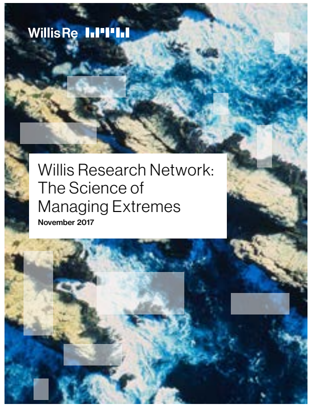


2016



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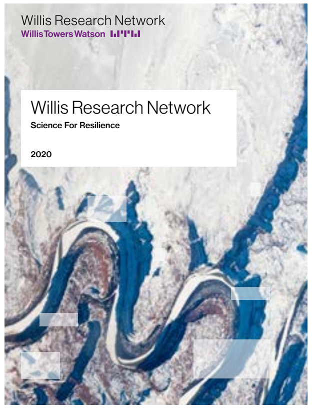

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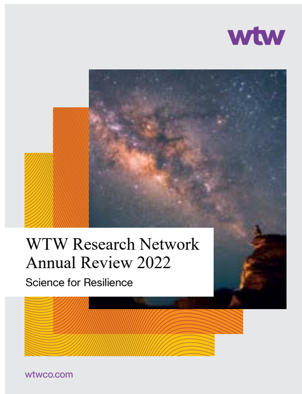

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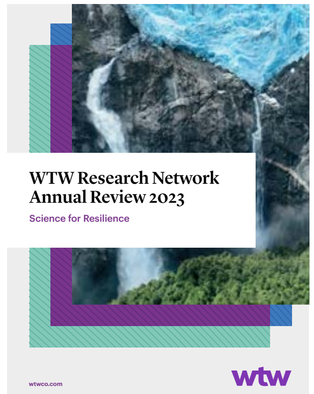

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At WTW (NASDAQ: WTW), we provide data-driven, insight-led solutions in the areas of people, risk and capital. Leveraging the global view and local expertise of our colleagues serving 140 countries and markets, we help you sharpen your strategy, enhance 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.

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