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RISKY BUSINESS: HOW CLIMATE CHANGE IS CHANGING INSURANCE MARKETS

HEARING BEFORE THE COMMITTEE ON THE BUDGET UNITED STATES SENATE ONE HUNDRED EIGHTEENTH CONGRESS FIRST SESSION

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WEDNESDAY, MARCH 22, 2023

COMMITTEE ON THE BUDGET,
U.S. SENATE,
Washington, DC.

The hearing was convened, pursuant to notice, at 10:00 a.m., in the Dirksen Senate Office Building, Hon. Sheldon Whitehouse, Chairman of the Committee, presiding.

Present: Senators Whitehouse, Van Hollen, Padilla, Grassley, Crapo, Johnson, Braun, and R. Scott.

Also present: Democratic staff: Dan Dudis, Majority Staff Director; Matthew Bolden, Climate Policy Advisor.

Republican staff: Matthew Giroux, Deputy Staff Director; Chris Conlin, Deputy Staff Director; Krisann Pearce, General Counsel; Jordan Pakula, Professional Staff Member.

Witnesses:

Mr. Eric Andersen, President, Aon

Ms. Nancy Watkins, Principal & Consulting Actuary, Milliman

Dr. Benjamin Keys, Professor of Real Estate, Wharton School, University of Pennsylvania

Mr. Jerry Theodorou, Director, Finance, Insurance, and Trade, R Street Institute

Dr. Judith Curry, President and Co-founder, Climate Forecast Applications Network, Professor Emeritus and Former Chair of the School of Earth and Atmospheric Sciences, Georgia Institute of Technology

OPENING STATEMENT OF CHAIRMAN WHITEHOUSE¹

Chairman WHITEHOUSE. Good morning everyone. Thank you very much for being here. I'm calling to order this hearing of the Senate Budget Committee entitled Risky Business, How Climate Change is Changing Insurance Markets. I will lead with my opening statement and then turn to my friend Senator Grassley for his opening statement, and then I'll introduce the witnesses and we will proceed with their statements. Your full statements will be made a part of the record, so please keep to the allotted five minutes, so we can get into a conversation.

Ranking Member Grassley and colleagues, we are here today for the fourth Committee hearing, examining the budgetary perils associated with climate change. Today we focus on the danger to the national flood insurance program and private insurers, and on the

¹Prepared statement of Chairman Whitehouse appears in the appendix on page 33.

impact the climate related natural disasters will have on insurance markets.

As we've heard already in earlier hearings, and we'll hearing again today, climate disruptions upset insurance markets. And that in turn upsets mortgage and housing markets. As we have heard, and will again, sea level rise and wildfire risk can upset property markets so profoundly as to cause systemic economic damage across the whole economy, similar to what we lived through in 2008.

You won't have to have property in flood zones or wildfire country to feel the pain. I heard colleagues say that the true long-term budget crisis affecting our country is the debt and deficits. I'm happy to have that conversation. The President's budget would reduce deficits by almost three trillion dollars, while adding at least 25 years of solvency to the Medicare trust fund.

House republicans want to add three trillion dollars to the debt by extending the Trump tax cuts for the rich. Let's have that debate, but let's not pretend that economic shocks don't affect the budget. The 2008 mortgage meltdown added 5 trillion dollars to the national debt, primarily due to decreased revenues. COVID added another 5 trillion dollars.

In both crises we were warned, failed to act in time to head them off, and were engulfed. Today, those trillions have added shock and debt amounting to 40 percent of our total national debt. And let's not pretend that global climate disruption won't create economic shocks. Warnings abound of what rising seas, droughts, floods and wildfires will do to American families and businesses, and to our economy.

This is the point. If you're serious about debt and deficits, you have to be serious about climate change. The intergovernmental panel on climate change, the scientists charged with synthesizing the latest science on climate change, a group cited favorably by previous republican witnesses, released its latest report Monday warning of severe risks to agriculture, infrastructure, public health, and coastal and flood prone communities.

The report states climate change is a threat to human well-being and planetary health. There is a rapidly closing window of opportunity to secure a livable and sustainable future for all. The choices and actions implemented in this decade will have impacts now and for thousands of years.

That's a pretty clear warning, impacts for thousands of years, for our children's, children's, children's, children's children, and on and on into the future.

I ask my colleagues why are we here if not to try and leave our nation and our planet better off for future generations. We have the chance now to bend the arc of history, of geophysical history, of economic history, of national security history, towards a more livable, prosperous future for generations.

Economic report of the President also came out Monday. Just like we've heard in these hearings, it warns that climate change threatens a volatile and cascading economic instability. Here's a relevant part. Certain financial instruments, such as insurance contracts and mortgages—I repeat, insurance contracts and mort-

gages, that directly or indirectly price weather related risks are highly exposed to climate change.

Rapid change of an asset's prices or reassessments of the risks in response to a shifting climate could produce volatility and cascading instability in financial markets. I repeat again, volatility and cascading instability in financial markets. Property insurance against catastrophic natural hazards is at the forefront of climate change risk exposure, and is already showing signs of strain.

These latest reports echo statements made by the Treasury Secretary earlier this month. She declared climate change will likely become a source of shock to the financial system in the coming years. If climate change intensifies, natural disasters and warming temperatures can lead to declines in asset values that could cascade through the financial system.

And a delayed and disorderly transition to a net zero economy can lead to shocks to the financial system as well. In response to rising insured losses, some insurers are raising rates, or even pulling back from high risk areas. This has potentially devastating consequences for homeowners and their property values.

"Developments like these can spill over to other parts of our interconnected financial system." I know there are powerful interests who don't want these hearings to happen, but want to change the subject, that want everyone to ignore the warnings from scientists, from economists, from financial institutions, from government.

Those powerful polluter interests want us to listen instead to their noise and nonsense. The denial, the delay, the obstruction, the obfuscation. And for far too long has halted a bipartisan defense against the climate threat. It's getting to be time to choose. What we do here now will not just have impacts for thousands of years, it will be remembered for thousands of years. We might do well to consider how we would like to be remembered because that moment of choice is upon us.

Chairman WHITEHOUSE. Senator Grassley.

OPENING STATEMENT OF SENATOR GRASSLEY²

Senator GRASSLEY. Thank you very much Mr. Chairman. The audience for today's hearing on private insurance is different than last week's hearing on the President's 2024 budget. As such, I would like to recap what we heard last week at our first, and presumably only budget centric hearing this Congress.

What we received from President Biden was a budget that continues this country on a destructive path of deficits and debt. The budget doubles down on the reckless tax and spending binge of the administration's first two years. It calls for nearly 5 trillion dollars in new taxes that will kill jobs, and punish hard-working Americans.

And despite all the lip service, it does not extend the tax relief provided to Americans making under \$400,000.00 under the Tax Cuts and Jobs Act, so it increases taxes on just about everybody. This is a breach of the President's pledge not to raise taxes on the

²Prepared statement of Senator Grassley appears in the appendix on page 35.

middle class. Not surprising for an administration that routinely breaks its promises, as well as the law.

We saw Democrats try to justify tax increases by pointing out that the last time we had a budget surplus revenues were 19 percent of gross domestic product. Well that means outlays were less, at about 18 percent. Does the Democrat majority want that outcome? The administration surely doesn't, as spending in their budget will surpass 25 percent of the economy in the ten year outlook.

Outside of World War II and the pandemic, that would be the highest spending level on record. Last week before this Committee, the OMB Director repeated the fallacy that the President's policies have led to deficit reduction. Now only in Washington could you claim savings from not continuing temporary emergency COVID spending. And it would be laughable if it wasn't so disingenuous.

We saw a continued demagoguery from the administration on the issue of major trust fund programs. This administration has no plan, no plan whatsoever, to shore up social security for future generations. Instead they want to paint us Republicans as boogeymen for wanting to prevent automatic cuts that will surely occur, absent action by the President and the Congress.

Where's the President's plan to protect seniors? We know that social security is going to get down to no more than 77 percent of what it pays today by 2035. The Democrats have made their message loud and clear. They don't care about the fiscal problems facing us right now. Democrats don't have a plan to deal with inflation, even though their bills substantially increase inflation.

And what I just said is, according to CBO. From Iowa to Rhode Island our constituents collectively believe that our exploding national debt is a major problem facing America. The last two climate hearings held by the Budget Committee touched on the impact of sea level rise, hurricanes and wildfires. We've heard from witnesses discussing costs due to these climate and weather events.

We've heard the reasons why we're seeing increased costs. Climate change is important, but it is not the only driver. Short of the need for better federal forest management, states, towns, and individuals can take care of most of their own challenges through smarter land use, and development practices.

While this Committee is the Budget Committee, this hearing is not focused on the public federal budget. It targets the private insurance and reinsurance industries with speculative scenarios in an effort to raise alarm. My Democratic colleagues want you to believe that insurance and reinsurance companies are in dire straits due to climate change, and that insurance will become unavailable and unaffordable.

I just read last week that insurance companies are leaving California for the simple reason that the government of California has to regulate every increase that goes into effect in insurance, and when the government's involved in that you can't be in business in California.

Well, that's not necessarily the case, and we'll hear from witnesses dispelling those extreme models. From hurricanes to wildfires, the insurance and reinsurance markets have shown to be resilient. Rather than relying on federal intervention in the insur-

ance markets, or pushing more costs onto taxpayers we should encourage more solutions from the private sector. I yield.

Chairman WHITEHOUSE. Thank you very much. Eric Andersen, who is the President of Aon, and has spent more than 30 years in the insurance industry. We're delighted to have him here to hear his perspective.

Nancy Watkins is a Principal and Actuary with Milliman. She too has spent decades in the insurance industry, and we're very pleased to welcome her and hear her perspective.

Dr. Ben Keys is a Professor of Real Estate and Finance at the Wharton School of the University of Pennsylvania. An economist by training, he has spent a lot of time studying the 2008 mortgage meltdown, and more recently has turned his attention to climate risk. We welcome his testimony.

Jerry Theodorou is another insurance industry veteran. After a long career in the industry he is currently the Director of Finance, Insurance and Trade at the R. Street Institute. We look forward to hearing from you.

And Dr. Judith Curry, appearing remotely is a Professor Emeritus. The former Chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology. She is currently the President of the Climate Forecast Applications Network. Mr. Andersen, if you would proceed.

STATEMENT OF ERIC ANDERSEN, PRESIDENT, AON³

Mr. ANDERSEN. Good morning, and as you said, my name is Eric Andersen, President of Aon, and on behalf of my 50,000 colleagues at Aon, I would like to thank Chairman Whitehouse, Ranking Member Grassley, and each member of the Committee for the opportunity to testify on the role that insurance can play in mitigating climate risk.

Climate risk is a global, systemic risk, and the insurance industry is a bridge between public risks and private capital. At its core, our business is about creating resiliency to protect the assets of today, and foster the growth of tomorrow. We do this by spreading the impact of risk across a wide array of financial participants over time.

This allows people and businesses to withstand volatility, to have the resources and confidence to invest, and to protect and rebuild when necessary. Properly managing climate risk not only protects against the downside, but can also be a catalyst for growth. Creating the tools to match capital to risk to ensure the innovation necessary to reduce carbon will create both climate transition and economic growth.

The two forces, protection and innovation, are required. Capital will not go where it is not protected, nor will it go where it cannot expect a return, even when communal benefit is clear. This is why public-private partnerships are so important.

The Committee has asked for an overview of global climate risks, and the role of the insurance markets. And I'm pleased to provide that this morning. On January 23, 2023, Aon published the 2023

³Prepared statement of Mr. Anderson appears in the appendix on page 37.

Weather, Climate and Catastrophe Industry Report, which I have included in my written testimony.

The study has compiled data on recent extreme weather events, and provides insight on our ability to rebuild from them. Claims data shows that 2022 was the most expensive year on record, with an approximately 50 to 55 billion of the global insured losses total resulted from Hurricane Ian in the U.S.

That storm alone was the second costliest natural catastrophe in history from an insurance perspective, surpassed only by Hurricane Katrina in 2005, which was nearly 100 billion of insured losses. The report also highlights that over 31,000 people across the globe lost their lives in nat cat events in 2022.

While the total number of fatalities remains below average for the 12th year in a row, the concentration of the impact has increased. Nearly 20,000 fatalities were heat related deaths in Europe alone. As shown in our report, decisions in the insurance industry are driven by data, giving us a unique capability to identify challenges and create innovative solutions across both the public and private sector.

Through public, private partnerships with the government, Aon, and others in our industry have helped stabilize Fannie and Freddie and the housing crisis, create insurance market post-911, and every type of catastrophe in between. Making a market for risks that are vital to the economy, but seem uninsurable is our most important duty. Just over a decade ago in the wake of the financial crisis the mortgage market was disappearing, undermining one of the pillars of the U.S. economy.

Just as the U.S. economy was overexposed to mortgage risk in 2008, the economy today is overexposed to climate risk. But back then the insurance industry, led by Aon, was able to help. We developed both analytical and insurance coverage products to transfer risks away from Fannie Mae and Freddie Mac to private reinsurance markets.

Ten years on, this public private partnerships exceeds 40 billion in premium. The models and discipline allowed an orderly transition of the secondary mortgage market that exists today. We are designing similar risk transfer products to free up capital today for climate resilience efforts tomorrow. And I would highlight other private partnerships that we have undertaken.

In 2021, the World Bank, Aon, and U.S. AID teamed up to mitigate hurricane risk in Jamaica through catastrophe coverage. The bonds will deliver 185 million in immediate liquidity post-event, ensuring not only humanitarian relief in the case of a windstorm, but facilitating immediate economic investment pre-event based on the certainty of funds to assure infrastructure and property rebuild.

Currently, we are pioneering the first employee resilience bond for a large employer in developing climate volatile country to procure a bond to provide cash assistance directly to employees in the event of a disaster to meet recovery needs.

I also want to highlight examples of the industry forging a better path on its own by facilitating an energy transition, and providing ways to bring new solutions to market quicker. For example, cat bonds were created to provide post-event coverage for traditional

risks, but they also encourage pre-investment in research and development that could help clean energy transitions by insuring certainty of funds to deal with the impact of traditional claims.

In other cases, we are developing an industry leading capability to enable a company to accurately value its intellectual property, and then use it as an asset to finance growth. This allows them to bypass traditional funding and accelerate their time to market. For many green technology companies this is becoming their best option.

Climate risk proposes substantial challenges to insurers and insureds alike. While insurance is based on the principle of diversifying risk, in many cases insurance risk management becomes more challenging as events become more interconnected across lines of business, geographical regions and perils. We are oriented around the philosophy that big problems need to be solved by collaborating, that is exactly that.

Humanitarian, private and public sectors partnering together to provide that solutions can be found together. Thank you.

Chairman WHITEHOUSE. Thanks very much Mr. Andersen. We'll just continue right across the table, so that would make you next Miss Watkins, thank you for being here.

STATEMENT OF NANCY WATKINS, PRINCIPAL & CONSULTING ACTUARY, MILLIMAN⁴

Ms. WATKINS. Thank you Chairman Whitehouse, Ranking Member Grassley, and members of the Committee for inviting me here today.

My name is Nancy Watkins, and I am an actuary and principal with Milliman, an independent consulting firm. I serve as an expert on catastrophe risk for insurers, real estate industry groups, and state and federal government agencies. I also volunteer to promote insurance availability and affordability, alongside the National Association of Insurance Commissioners, Western Fire Chiefs Associations, and the United Nations.

Let's talk about homeowner's insurance and how climate change is impacting it. First, climate change is not a problem of the distant future. It's already here. Across the country, we have insurance protection gaps and crises exacerbated by climate change.

Flood risk in the U.S. is already very high, increasing rapidly and unsustainable once you factor in sea level rise. NOAA reports that about 80 percent of the East and Gulf Coasts are seeing more high tide flood days, and that this spring about 44 percent of the U.S. is at risk for flooding.

Most flood risk is not covered by the private market. Only 4 percent of U.S. homeowners have flood insurance today, largely through the government-run NFIP. Unprecedented wildfires have driven insurers to shed high-risk policies in Western states like California, Oregon, and Colorado. In California, homeowners' insurers lost 20 billion dollars in 2017 and 2018, due to wildfire, wiping out two times the cumulative profits earned over the prior 26 years.

⁴Prepared statement of Ms. Watkins appears in the appendix on page 161.

Since 2020, Louisiana has been hit by multiple hurricanes, tropical storms, tornadoes and excessive rainfall events. After 20 companies folded or exited the state, more than 100,000 policyholders are now in the state-run insurer of last resort.

Insurance market withdrawals can cause ripple effects that endanger entire communities, and create a downward spiral that's difficult to emerge from. This could happen gradually, but it's possible for weakened markets to collapse quickly through a crisis of confidence triggered by one event.

Second, a broken insurance market is not the problem, it's a symptom of a larger problem, too much risk for the market to bear. The risks associated with climate change and catastrophes are owned by homeowners and the community, not the insurance industry. Much of that risk can potentially be transferred to insurers if there's a sustainable private market, which rests on three pillars, availability, affordability and reliability.

Climate change is interacting in new ways with other inherent risks, causing cracks in all three of those pillars. The policy actions intended to help can actually backfire and accelerate the collapse of the insurance market. This generally happens because these actions don't address the underlying problem that the risk is too high.

Often, this occurs when land use policies and building codes don't keep up with risk, resulting in a mismatch between actual vs. perceived risk by homeowners. Because we aren't all actuaries, one way to effectively communicate the actual risk to consumers is to build the true cost of risk into insurance pricing.

Risk-based pricing drives behavior. If you can buy low-cost insurance, or you aren't even required to insure your home against flooding, you expect this to be a safe place to live. If you can't get affordable insurance, you may act to mitigate the home's risk and reduce your premiums, or you may decide it's too risky to live there at all.

The obvious down side is that premiums maybe unaffordable for some homeowners. The government could decide that it's good policy to subsidize premiums, with the costs ultimately borne by others. Generally, current and future policyholders or taxpayers who live in lower-risk areas, often in other states.

To reduce premiums and the cost of subsidization, the only effective action we can take is to drive down the risk. Third, the cost of driving down climate risk is much lower than the cost of inaction. The choice to ignore climate change and manage from crisis to crisis puts more families in harm's way, with low-income communities likely to be hit the hardest and suffer the most. Failure to act early reduces the number of options available and drives up the costs of reaction at various government levels.

To avoid this, we need to work collectively to bend down the risk curve. We need to have better data, better modeling, higher prioritization of mitigation versus disaster response, better stakeholder coordination, and resource assistance to those areas most in need.

The sooner our society chooses to face the risks associated with climate change, the more options we will have to drive down those risks, and the lower the cost will be. Climate risks are complex,

and difficult to understand. The actuarial community is leveraging science and technology and working with other experts to measure these risks and communicate them to important stakeholders like this Committee.

We aim to give you the best information available, so that you can make informed decisions. Thank you.

Chairman WHITEHOUSE. Thank you very much, and we turn now to Dr. Keys.

STATEMENT OF DR. BENJAMIN KEYS, PROFESSOR OF REAL ESTATE, WHARTON SCHOOL, UNIVERSITY OF PENNSYLVANIA⁵

Dr. KEYS. Chairman Whitehouse, Ranking Member Grassley, and members of the Committee. Thank you for inviting me to address how climate change is affecting insurance markets. My name is Ben Keys, and I am an economist and Professor of Real Estate and Finance at the University of Pennsylvania's Wharton School.

My research agenda examines how households interact with the financial system, and how the financial system manages risk. Today I'd like to highlight how issues in property insurance markets affect household well-being.

First, rising insurance costs are having a direct effect on household's pocketbooks. Across the country, average homeowners' insurance premiums rose by 40 percent from 2010 to 2019. In addition, private insurers are exiting certain markets. The number of enrollees in state-backed insurer of last resort plans rose by 29 percent between 2018 and 2021.

With rising climate-related risks, and the rising costs of reinsurance, insurers will continue to increase premiums and exit markets, leaving homeowners with fewer choices, less protection, and more financial distress.

Family budgeting is difficult as it is. With insurance premiums changing every year it's nearly impossible for households to accurately forecast their expenses. For instance, this January state-backed Louisiana citizens increased their rates by 63 percent. Costs are also rising in the National Flood Insurance Program.

In the first year of the Risk Rating 2.0 reform, 75 percent of premiums increased by the statutory limit of 18 percent. Half of all NFIP policyholders will see their premiums more than double after five years. Sadly, these increases will lead many households to choose to go without insurance.

Rising insurance costs directly affect housing markets. Each additional dollar of premiums decreases the demand for a home, affecting the amount its owners can expect to receive when they sell. In more dire situations where homeowners cannot find insurance, lenders will not be willing to accept uninsured homes as collateral.

These concerns are not merely theoretical. Economic research shows that higher flood insurance premiums lower home prices, and make it harder to get a mortgage. My own research shows that the threat of future sea level rise lowers home prices today, as buyers don't want to be left with an uninsurable home down the road.

In short, home prices have already started reacting to climate risk, even as we've realized only a fraction of the higher premiums

⁵Prepared statement of Dr. Keys appears in the appendix on page 164.

and sea level rise expected in the coming decades. I want to briefly highlight why climate risks are so difficult to insure.

After a massive fire in the City of Hamburg, Germany in 1842, local insurers failed. Reinsurance markets arose for fire insurance because fires are idiosyncratic events, allowing providers to create a diversified risk pool and spread these risks widely and effectively.

Unlike the chance of a fire in a given city, however, climate risk is better described by the title of the latest Oscar winner, "It's Everything, Everywhere, All at Once." Climate change is simultaneously inducing a heightened risk of flood, storm damage, chronic inundation, drought, excessive heat, and wildfires.

These risks are inherently difficult to diversify. While reinsurance and the catastrophe bond market will continue to play a role in maintaining functioning insurance markets, there is no avoiding the fact that the increasing risk of large loss events will mean higher costs for consumers.

The limitations of private insurance markets for insuring against these climate risks points to a larger role for the government. State and federal insurance entities will bear more of these risks going forward as private insurers pull back.

If we do not take action on climate adaptation and mitigation, then we can expect private markets for wildfire and wind coverage to increasingly resemble the NFIP and rely on public support.

Further costs will be borne by Fannie, Freddie, and the FHA, who make up two-thirds of our 13 trillion dollar mortgage market, and by FEMA and other post-disaster aid sources. Topics surrounding insurance often feel remote, or difficult to digest, but they impact everyday households. Far too many Americans are currently unprotected from climate risks.

Only one third of households in flood zones have flood insurance. And the First Street Foundation estimates that 6 million households are at significant flood risk, but lie outside of FEMA's outdated floodplain maps, making them likely unaware of their danger.

Private insurers' aim to price their risks accurately, so we should pay close attention to the choices that they make. No matter your views on climate science, insurers are responding to the increased frequency of high-cost disasters and the latest scientific forecasts.

The departure of insurers from property markets has serious implications for home values, the dominant store of wealth for the average household, and for communities that rely heavily on property taxes to provide basic services, as well as defend against further climate related change.

Now is the time to identify policy solutions to reduce American families', businesses', and taxpayers' exposure to climate risk. Thank you again for the opportunity to testify.

Chairman WHITEHOUSE. Thank you very much Dr. Keys. Next Mr. Theodorou.

**STATEMENT OF JERRY THEODOROU, DIRECTOR, FINANCE,
INSURANCE, AND TRADE, R STREET INSTITUTE⁶**

Mr. THEODOROU. Chairman Whitehouse, Ranking Member Grassley, esteemed members of the Committee, thank you for the opportunity to testify on how climate change is changing insurance markets. I am Jerry Theodorou. I'm the Director of the Finance, Insurance and Trade Program at the R Street Institute, where as earlier in my career I conduct independent research on insurance markets and what drives their performance.

Today's issue is important for insurance providers and buyers because climate change alters historical patterns of severe weather. It adds uncertainty to an industry whose role is to provide stability and protection from loss. There is broad consensus among insurers that the climate is changing in ways aggravating extreme events.

My comments summarize more extensive written testimony and address three questions at the heart of today's hearings. What is the impact of climate on insurance markets? What is the financial condition of insurance markets? And how do insurance markets respond to climate change?

Insurers are in the business of providing protection from severe weather events when wind, fire, hail, and flood release their fury, causing billions of dollars in property damage, insurance is the economy's financial first responder, paying claims, getting customers back on their feet.

Property insurance covers severe weather events, and insurer's are capitalized sufficiently to meet those claims obligations. When such weather costs billions, or tens of billions of dollars, insurers are cushioned with financial protection from reinsurance, the industry's shock absorber.

Reinsurance enables insurers to limit their losses, maintain financial stability, while providing stability to customers. The insurance industry is highly competitive with over 3,000 insurers, ranging from large national giants to small county mutuals. Reinsurance markets are also competitive, with hubs in Continental Europe at Lloyds in Bermuda and in the U.S.

And just as primary insurers limit their losses with reinsurers, reinsurance companies buy retrocessional cover to protect their balance sheets. So the broader insurance industry thus provides three protective layers, primary insurance, reinsurance, and retrocessional reinsurance, making insurance markets exceptionally durable.

To illustrate, in 2010, in the wake of the Great Recession, there were 157 bank failures, but only eight insurance company impairments. The low failure rate of insurers is due to their focus on capital management, dedication to shepherding their capital has enabled the longevity of insurers and reinsurers. Many mutuals were founded in the early 1800's and are still going on strong today.

The income statement of the insurance industry is solid. In only one of the past five years was there an underwriting loss. In 2022, from automobile repair cost inflation, and the insurance industry's balance sheet has strengthened in recent years, it's surplus, the ex-

⁶Prepared statement of Mr. Theodorou appears in the appendix on page 172.

tent to which assets exceed liabilities, rose from 750 billion dollars in 2018, to over 1 trillion dollars in 2021.

And reinsurers also delivered healthy results through 2022. Insurance markets respond to climate change in two broad ways, by encouraging buyers to mitigate losses, and with new products. Loss mitigation measures to improve resilience, include discounts for hardening their structures and credits for communities that establish natural barriers, such as mangrove forests and marshes between bodies of water, and buildings that are constructed.

Other ways that insurers respond to climate change include named peril, rather than all risk policies, parametric covers, rebalancing of investments, attracting third party capital, and offering private market alternatives to government programs. Ignoring climate change is not acceptable. Climate skeptics are not to be found in the fundamentally conservative insurance industry, whose job after all is to restore things to the way they were.

We acknowledge those who call for waking up to the reality of climate change. Insurers have acknowledged it for many decades. Insurance markets have an appetite for climate risk, are in the business of dealing with it, and will continue to play a key role in absorbing and mitigating its risk to our economy. Thank you for the opportunity to testify, and I look forward to your questions.

Chairman WHITEHOUSE. Thank you very much. And our final witness, remote, is Professor Curry.

STATEMENT OF DR. JUDITH CURRY, PRESIDENT AND CO-FOUNDER, CLIMATE FORECAST APPLICATIONS NETWORK, PROFESSOR EMERITUS AND FORMER CHAIR OF THE SCHOOL OF EARTH AND ATMOSPHERIC SCIENCES, GEORGIA INSTITUTE OF TECHNOLOGY⁷

Dr. CURRY. Good morning. I would like to thank the Committee for this opportunity to present testimony. I'm Judith Curry, President of Climate Forecast Applications Network, and Professor Emeritus at Georgia Tech. My expertise is on climate dynamics, uncertainty and risk science.

Insurance markets are influenced by our perceptions of climate risk. Referring to climate change as a crisis is at odds with professional judgments of climate risk. The so-called climate crisis isn't what it used to be. In 2013, in the IPCC Fifth Assessment Report.

The extreme emissions scenario, RCP8.5 was regarded as a business as usual scenario. With expected warming of four to five degrees Centigrade by 2100, now there is general acceptance that this extreme scenario is implausible. The baseline warming currently used by the UN Conference of Parties has been reduced by half, to 2.5 degrees by 2100.

This is an additional 1.3 degrees above current temperatures. It's difficult to overstate the importance of the shift in expectations for extreme weather events associated with rejection of the extreme scenario. Rejecting an extreme scenario has rendered obsolete much of the climate impacts literature and assessments of the past decade that are focused on this scenario. Landfalling hurricanes

⁷ Prepared statement of Dr. Curry appears in the appendix on page 180.

incur the greatest property and casualty losses among extreme weather events.

Recent international assessment reports have low confidence that there have been detectable changes in the long-term record of hurricane activity beyond natural variability. The insurance industry's perception of a substantial future risk from increasing hurricane damage is enforced by three recent reports from the insurance sector.

These reports infer misleadingly high damages by 2050, by using the implausible extreme emissions scenario. They also assume substantial increases in the number of major hurricanes, which is at odds with recent assessment reports. Further, these reports neglect the major modes of multi-decadal natural variability. These have had a dominant influence on the Atlantic hurricanes in the historical record.

Implausibly high projections of U.S. landfalling hurricanes by 2050 result in inappropriate notes of insurability, inappropriate pricing of insurance, and misguided confidence levels of investors. Not only have we been misled about the amount of warming to expect and its impacts, we have also badly mischaracterized the nature of the risks from climate change.

We have conflated the slow, incremental risks from warming with the emergency risks associated with extreme weather events that have little to do with the warming. This mistaken conflation of risk is driving the stated urgency for emissions reductions and the rapid transition of our energy systems.

A key element in insurance losses from extreme weather events is the reliability of the electric utility system, extended power outages contribute to loss of life. During extreme cold events outages can result in substantial property damage from burst water pipes. This is what happened as a result of the extreme cold event in Texas last year.

And worse winter problems are associated with continental scale high pressure systems, which produce very cold temperatures and weak winds over most of the U.S. Now, many coal and nuclear power plants have shut down. A lack of onsite fuel storage contributed to the Texas outage, and the recent Christmas blackouts in areas served by the Tennessee Valley Authority.

Near term risk associated with the rapid transition of electric utility systems to wind and solar, we can reduce the transition risk by reducing the urgency of the transition to be commensurate with the slow incremental risk from emissions driven warming. This would allow time for evaluating and incorporating newer technologies that do not reduce electric power reliability.

Climate change and its perceived threats, provide an opportunity to broaden the relevance of the insurance sector to risk mitigation. Adaptation provides new opportunities to underwrite climate exposure risks. Insurance companies can help prevent customers from incurring damage.

They can also work with the public sector to improve their base standards and land use policies. Climate variability and change with the attendant extreme weather events is best regarded as an ongoing predicament. This will require continued adaptation by

communities and businesses, plus mechanisms to share and transfer financial risk. Thank you.

Chairman WHITEHOUSE. Thank you Miss Curry. If I might Mr. Andersen, ask you for a more practical and common place definition of the phrase you used, global systemic risk. We've heard a considerable number of our witnesses talk about systemic risk. It has a rather bland quality to it, but it describes something that is anything but bland. What would be your description of systemic risk?

Mr. ANDERSEN. So what we mean by systemic risk is the interconnectedness of these types of risks, and a number of the other panelists also mentioned that ultimately one event has implications on supply chains, physical damage, displacement of people. And so, history, you know, as people have looked at those risks over time they've often looked at them very separately.

But with climate change the effect that it is having on the size of the storms, the wildfires, the effects of it, are actually creating risks that are so interconnected they had to be dealt with in totality as opposed to just by individual factor.

Chairman WHITEHOUSE. The way that I have described this is that climate change causes weather anomalies, and those anomalies make events harder to predict. And that added difficulty of prediction compromises insurability, and as insurers either withdraw or raise prices, that has an effect in mortgage—in property markets because it's very hard to buy a mortgage property if you can't ensure it.

And of course, without mortgages, demand for properties collapses, because you're only selling to all cash buyers at that point. And when demand collapses, values collapse, and that can cause severe economic harm across the entire economic landscape. Is that a fairly accurate description of how this cascades through to from weather discrepancies to a general property value's problem?

Mr. ANDERSEN. I think your underlying hypothesis that the models of old that have been used looking backwards are not as valuable to the models that need to be developed for a changing climate. So that is the underlying premise. If you're looking to match risk and capital together, the inherent sort of assumption in that is confidence that the risk that's being transferred is predicted, and therefore can be priced appropriately for the risk that's assumed.

Chairman WHITEHOUSE. You can't insure what you can't predict.

Mr. ANDERSEN. You can't insure what you can't predict because the capital will not be protected.

Chairman WHITEHOUSE. You made a comparison in your testimony between climate risk today and mortgage risk in 2008. Why did you make that comparison?

Mr. ANDERSEN. It was designed to be an example of where using the information that Freddie and Fannie had on mortgage default risk, the ability of the insurance and reinsurance to bring modeling capability to do the predictability, actually to understand that risk, and then bring new sources of capital into the market. That's essentially what we're talking about with climate.

Ultimately, the size of the capital pools that need to be brought to bear to help manage and transfer these risks to a broader finan-

cial sort of pool of capital is ultimately our strategy in helping clients deal with this issue.

Chairman WHITEHOUSE. And to perhaps state the obvious, as the President of Aon Corporation, you have a fiduciary duty to your shareholders and to your employees, and to your customers, to try to get this right. And that requires that you pursue and obtain reliable forecasting, not just for the business reasons of making money, but also for the fiduciary reasons of not misleading anyone.

Is that a fair description of accountability that you operate under?

Mr. ANDERSEN. We take a very strong position that our opportunity to help our clients manage this risk, that when you talk about it as a client, it's not just a corporation, it's a community, it's people that live and work in that community.

Our efforts around understanding and trying to predict the effects of climate change, and then developing products and solutions that actually allow people to transfer that risk as best they can, so that they have the funding available to either rebuild, or support those displaced individuals, we view as one of our most important roles going forward.

Chairman WHITEHOUSE. And you can't just say what you please. You're bounded by the fiduciary duty to be truthful and accurate, and operate on the best information you can find.

Mr. ANDERSEN. Of course.

Chairman WHITEHOUSE. Ms. Watkins, in your testimony you talk about the ripple effects of insurance withdrawals, which I think I tried to explain in my questioning to Mr. Andersen, that it can endanger entire communities and create a downward spiral that's difficult to emerge from, and in which collapse can happen quickly, often to a crisis of confidence triggered by one event.

Could you elaborate a little bit on that scenario, and how that plays into the problem of systemic risk and economic harm?

Ms. WATKINS. Yes sir, and I do agree with your description, and I would extend it a little farther to when real estate values start dropping. Also, this is accompanied by quality of life issues. In my current home state of California, we're having power outages, smoke that can make it hard to go outside all summer long. A day where we never saw the sun because of smoke. Those sorts of things, the need to evacuate frequently, which happens a lot of times in hurricane prone areas. That kind of uncertainty can combine together to cause people to want to leave.

At that point you have a disincentive for businesses to, you know, establish new roots in a community. You have a reduction of the tax base. Concurrently, you know, real estate investors and you know, municipal bond investors, they're also looking at climate change and making their long-term decisions.

And so, the influx of investment into a community that's not resilient to climate can be reduced as they're competing with communities in other areas for that kind of investment. So, the tax base goes down, the cost of borrowing can go up. It can be harder and harder for a community to try to deal with the risk even if it stayed the same.

But if it's increasing, they just get squeezed. So that's what I'm talking about in terms of the downward spiral. The crisis of con-

fidence, I mean I think in a non-insurance example in the recent news we have Silicon Valley Bank. The kind of last man at the bar syndrome, where the people involved in the risk who felt like they were at risk, decided they were going to pull out.

And that pull out could actually not only endanger that bank, but other banks that others thought were in similar situations. Whether or not they had actually made the same kinds of decisions that led to Silicon Valley Bank's collapse. So what we have, just for example, California, we have the California Fair Plan, which is growing unsustainably high as the insurance market withdraws, the Fair Plan increases.

It's supposed to be a crutch for the market. It's supposed to prop up the market while the market heals itself. But the problem is when the policymakers decide to turn the crutch into a leg, and start paying attention to protecting the crutch, and making it more of a long-term solution, it's no longer an effective crutch, and it's not a very good leg either.

So, we're not healing the broken system and the process. Right now in California, the Fair Plan is running at a 332 million dollar deficit. That was about a year and a half ago. The rates are 72 percent inadequate at last report. They're only reinsured for a 1 in 31 year return period at last report.

If the Fair Plan, whose total insured value has gone up by over four times in five years were to have a multi-billion dollar loss, which is very possible, there's an unlimited assessment on the California insurers who stay in the market. So every insurer who wants to stay in California—maybe they've pulled out of high risk areas, but they're insuring low-risk areas.

They are on the hook for the Fair Plan's potential insolvency in case of a large event.

Chairman WHITEHOUSE. I've got to stop you there since other Senators are asking to wait their questions, but—ask the questions, but thank you very much. And Senator Johnson is next.

STATEMENT OF SENATOR JOHNSON

Senator JOHNSON. Thank you Mr. Chairman. Dr. Curry, let me start with this statement. I'm not a climate change denier, I'm just not a climate change alarmist. I get a feeling from most of your testimony maybe you're a little bit more on that scale with me than more of alarmist.

But as you've stated in your testimony you talked about when you look at the real history of occurrences of hurricanes. I've certainly looked at the history of wildfires, but there's really nothing out of the ordinary in terms of long-term perspectives on this. Can you expand a little bit more on what you're talking about? You're just referring to that in general. Can you get a little bit more specific?

Dr. CURRY. Sure. Looking back in the historical record extreme events, you know, in the first half of the 20th Century, particularly the 1930's the weather and climate extremes were much worse than anything we've seen so far in the 21st Century, in terms of the worst landfalling hurricane, the worst heatwaves, the worst droughts, the worst fires, and on and on it goes.

And if you looked at the paleo climate records you can extend even further back, and you see evidence of even, you know, greater extremes. But the worst atmospheric river event in recorded history occurred in the 1861 to 1862 winter in California. I mean we think it's bad this year, but it was much worse back in the 19th Century.

And even worse events that you can see in the paleo climate records. So, we need to temper our perception of what's actually going on right now with the extreme events.

Senator JOHNSON. So I appreciate that, and you know, we mentioned an earlier witness talked about Silicon Valley Bank, and what's happening there, but she has a lack of confidence. And so if we have all these hail and fire predictions it's going to reduce confidence, and it's going to be a self-fulfilling prophecy, so let's talk about the reality.

You just talked a little bit about the reality of extreme events not being out of the ordinary. Mr. Theodorou, again, I don't deny the loss in property, but isn't that more related to the fact that we are building incredibly expensive properties in highly vulnerable areas, where there's been mudslide areas in California, or wildfire areas, where we're not doing proper forest management to prevent wildfires.

You know, what we're building out into the Gulf Coast in the Atlantic shoreline, unbelievably expensive properties, so when a hurricane does occur, yeah, there's going to be a lot of property damage. So isn't the real issue here properly pricing the insurance, and quite honestly, making the owners pay for the risk that they are taking?

And we don't do that. We subsidize that risk, and so there's more risk taking. Can you kind of speak to that?

Mr. THEODOROU. Yes. Thank you Senator Johnson for the question, and it's both. And indeed there are more values now that are at risk. There is more unsound development on coastal areas, and on flood plains. There's more impervious surfaces as you have asphalt instead of dirt to observe the water.

So you have higher values, and that's the driver of the higher losses, but also there are more of these extreme events. The 1861–1862 ARK storm in California that led to Governor Elect Leland Stanford going to his inauguration in a rowboat in Sacramento was considered a one in a 1,000 year event. That's why it was called an ARK storm, ARK, atmospheric river K for 1,000.

Research has shown that it was actually happening every 200 years, with more recent research from NOAA is now saying that this can happen every 40 or 50 years. So there are more of these extreme events, and as you said.

Senator JOHNSON. That's contrary to what Dr. Curry's talking about, but go on. By the way, do you have the insurance industry, have you calculated the property value in these vulnerable areas today versus let's say 50 years ago? I mean do you have a sense of how much more property is at risk?

Whether or not we have more extreme events, I mean when an event occurs, we're going to have a lot more property damage.

Mr. THEODOROU. The industry does tabulate this, and there are modelers that look at that, but indeed the values have gone up be-

cause of population growth and building, and building, which is not sound is on the coastal areas, and on flood plains, not built to code, so that's an important factor, and we should discourage this sort of bad behavior, and have protections, mitigation.

But the evidence, the facts are looking at the events and the severity of the events that have been more frequency of severity.

Senator JOHNSON. So my point is that's something we can do something about, not building in vulnerable areas.

Mr. THEODOROU. Yes.

Senator JOHNSON. We can do something about building to code. I don't think we can hold back the tides, so why don't we address what we can actually do versus scare the you know what out of everybody, reduce confidence. That doesn't help either. So thank you Mr. Theodorou.

Mr. THEODOROU. Okay. Thank you.

Chairman WHITEHOUSE. Senator Van Hollen, and then the distinguished Ranking Member.

STATEMENT OF SENATOR VAN HOLLEN

Senator VAN HOLLEN. Thank you Mr. Chairman. Thank you to all our witnesses. I think the goal here is to really understand the risk. It's not to scare anybody, but it's to make sure people understand the reality that when you have a climate crisis and you have more extreme weather events, and you have increase in sea level rise, we have to understand what it's impact is, and plan ahead, so that we can avoid a crisis when it comes to the financial piece.

We obviously have to address the climate piece, and the Chairman and I and others have been working on that, but we do need to understand what's happening here. So and Dr. Keys, in recent weeks we have seen a number of very high profile bank failures. I understand fully that the insurance markets are regulated differently, but they still need to be adequately capitalized.

So do you perceive a risk today with respect to insurance companies being prepared as a matter of capital to deal with the ongoing risks from climate change?

Dr. KEYS. Well thank you for the question. Senator, I think others on the panel may have more expertise on this than I do, given that they manage a balance sheet more directly. But I think this is an absolute cause for concern.

And when we look at the failures of insurers in Florida, and decisions to pull out of Florida in particular, I think that speaks to some of these concerns directly in that there are worries that they don't have the balance sheets directly, and they can't obtain sufficient reinsurance to protect themselves, that they're leaving risky markets.

And so one of the explanations for the shift in their choice of which markets to insure and which to not insure, is in part a function of their balance sheet.

Senator VAN HOLLEN. Well let me just pose the same question to Mr. Andersen, and picking up on what Dr. Keys just said, right there are two ways that insurance companies could respond if they wanted to address the risk. One is to increase rates, and that's true also in the reinsurance market, and that obviously increases rates

for consumers. Or they can decide just to pull out of insurance markets in certain areas, like parts of Florida.

Can you talk about what we're seeing right now and its impact on consumers?

Mr. ANDERSEN. Sure. The crisis of confidence that's happening in the reinsurance market that's leading into the insurance market is essentially a crisis of confidence around the ability to predict loss, which is going to be your question, is climate changing the confidence level that these insurers and reinsurers have around providing products to consumers or businesses.

And the short answer is the reinsurers today have been withdrawing from high risk areas around wildfire, around flood in particular. Some of the other natural catastrophes, like earthquake, less susceptible to this topic, and so not as much dynamic change.

And so the question of is there enough capital to handle the transition today? The answer is no. The fact that how do you create more capital is better transparency around predicted losses. That's where a lot of the working the industry is going today because private capital will not join the market unless they expect a return, and they will not be able to expect a return if they don't know the risk they're taking.

And so, the answer to that is they essentially trim their offerings. They pull out of high-risk areas, they drop certain products, they get out of certain states. This is happening by the way around the world, it's not just a U.S. issue, but the underlying facts of the decision-making are the same, which is they don't understand the risks they are taking, and therefore they won't take them.

Senator VAN HOLLEN. Right. And Ms. Watkins just to follow-up on this conversation, it seems that there are actually three possibilities here. One is that we don't do enough in advance, and you have a meltdown in the ability of insurance companies to make coverage, or that you increase price, and obviously that means consumers are paying more, or insurance companies pull out entirely, as we're seeing in Florida and other places.

When insurance companies pull out entirely it's the taxpayer that ends up picking up the bill. Isn't that right?

Ms. WATKINS. That's exactly right, Senator.

Senator VAN HOLLEN. I mean those are the options. Can you talk a little bit about what's going to happen to homeowners in coastal communities? It seems to me there are really just two options for folks who are not—don't have any more coverage. One is that they're on their own and they have huge risks, and you know, their nest egg just goes under.

Or, the public sector provides a bailout. Are those the two options there?

Ms. WATKINS. As of right now, yes sir, I do believe those are the options. And so, I mean we do have federal disaster aid, which will come in if there is like an event that creates a loss, and they have no insurance. That would help them somewhat, but it won't really restore them to, you know, a resilient position for their home.

I think that to get in front of that, and to try to give people better information when they're making the decision to live in a place, having the insurance risk signal would help avert both of the situations that you mentioned.

Senator VAN HOLLEN. Thank you. Well we see what happens when people don't get in front of a banking situation. The same would hold true when it comes to the insurance market. Thank you Mr. Chairman.

Chairman WHITEHOUSE. Thank you Senator. Senator Grassley.

Senator GRASSLEY. Yeah, I'd like to go to Mr. Theodorou, and follow-up a little bit where Senator Van Hollen's subject was brought up. You spent 30 years as a leader in the insurance industry, however you are now an outside analyst with no financial ties to the industry I understand.

Could you explain how the insurance industry is designed to withstand hits and manage risk and has done so consistently? Should we be worried that the sky is falling on top of the insurance and reinsurance industries because of climate change?

Mr. THEODOROU. Thank you Senator Grassley for the question, which is actually two questions. Is the insurance industry designed to take the hits, and should we be worried that the sky is falling? If I can address the second one first, is if we put it in context, the stresses on the insurance industry historical context. There have been crises and problems that the insurance industry has faced before. Just go back to the pandemic a few years ago.

Early in the pandemic there were voices saying that workers' compensation losses would be so great because of essential workers contracting the virus, going to the emergency rooms and dying, that it would be too big a loss on the insurance companies for workers' compensation.

That did not happen. Workers' compensation insurance did quite well, and rates have come down in most states. Dial back a few more years to the subprime mortgage crisis. There were so many bank failures, but the insurance industry did not have more than its long-term average of failures, so it withstood that crisis as well, which was systemic as it affected many aspects of the economy.

Go back another ten years, Lloyds of London, Lloyds had its crisis in the 1990's when asbestos risk from U.S. asbestos liability almost brought Lloyds to its knees, but it went to work with reconstruction and renewal, reformation, they fixed their underwriting practices, and now Lloyds is a strong player.

Ten years before that in the 1980's the great liability crisis when lawsuits were going up from medical malpractice product's liability, and there were voices there saying that this is going to destroy the industry, but it did not. So, it's withstood many crises before. It's a durable industry. We look at companies that have been around for 200 years.

Chairman Whitehouse, Providence Mutual, founded in 1800, so it's been around for 223 years, Vermont Mutual, early 1800's. We mentioned Cologne Reed, 1846, which is now part of Berkshire Hathaway. So, to be in business for 200 years, to face these kinds of crises, you've got to be doing something right for your customers.

Senator GRASSLEY. Okay. I want to go now to Dr. Curry. Many risk assessment firms use extreme hypothetical data when evaluating climate risk for commerce. We've heard several, especially wild figures today. Could you explain how the data from these models are transformed into these alarming statistics, and what in-

centives do companies have in using these apparently flawed metrics, and how does it affect the public?

Dr. CURRY. Okay. Thank you. Well it's a challenge to keep up with all the latest scientific publications. Extreme projections of climate risk from risk assessment firms are largely driven by focusing on the extreme and implausible emission scenario, RCP 8.5. These firms may be unaware that RCP 8.5 is now regarded as implausible.

Mr. Theodorou mentioned a recent publication that predicted an increase in frequency of extreme atmospheric river events to every 40 years. However, the climate model simulations used in this paper was driven by the extreme implausible emissions scenario, RCP 8.5. So, continued use of those extreme implausible emissions scenario, is misleading both the public and investors about what kind of extreme events we might expect in the coming decades.

Senator GRASSLEY. Dr. Curry, how have sensationalized emissions scenarios come to dominate the discourse of climate change risk, and why has it taken so long to realize that these scenarios are implausible?

Dr. CURRY. Okay. The extreme RCP 8.5 scenario was originally formulated to provide an upper limit to possible climate outcomes. RCP 8.5 has been misleading, and referred to as a business as usual scenario, which it is not. Climate scientists find that the extreme scenario helps understand how the climate system might respond to a big poke.

Scientists working on climate impacts, prefer the extreme scenario, since it gives the most dramatic results. Such research receives a lot of media attention, and supports a political agenda of urgently reducing emissions. For the most recent IPCC assessment, a more advanced approach to developing scenarios was used.

These new scenarios were derived from socioeconomic and technological trajectories that the world might follow in the 21st Century. However, energy economists found it extremely difficult to develop trajectories to achieve the 8.5 forcing without making implausible assumptions, such as increasing coal use by 600 percent.

But by this time, the IPCC had already issued its assignments to the climate modeling community, with a continued focus on the extreme 8.5 scenario.

Chairman WHITEHOUSE. Thanks very much. Senator Padilla.

STATEMENT OF SENATOR PADILLA

Senator PADILLA. Thank you Mr. Chairman. I was glad to participate in a recent hearing on wildfires to highlight the importance of investing in climate and disaster mitigation, especially since the costs pale in comparison to the costs of inaction.

That's why today we must also consider the importance of these preventative efforts. This includes the California Wildfire Mitigation Program, which is the state level partnership with FEMA to provide grants for home hardening, and other proactive measures.

Not only do these actions protect homes and save lives, but they also provide confidence to insurers, which can help bring down costs for families. However, many of these programs require a federal cost share, which can be difficult for low-income and tribal

communities to afford. And we simply cannot afford to further compound the issue by only protecting those who can afford it.

My first question is for Ms. Watkins. Could you discuss the importance of ensuring that the communities of greatest need, greatest vulnerability often, are able to access these preventative resources, and maybe discuss briefly, whether we should consider modifying insurance premiums for families who need that flexibility?

Ms. WATKINS. So, just to clarify, you're asking me how to get communities of greatest need access to federal grants?

Senator PADILLA. How do we address the accessibility, vis-a-vis affordability concern?

Ms. WATKINS. Thank you for asking. Yes. I believe that the best way to help the communities—lower income communities especially, is to give them information first, realistic information of what they can expect, and then assist them. And that really starts with the best view of risk possible, and then an understanding of what are the most effective ways to drive down the risk.

Wildfire is really complicated because it often starts in a place that's outside the community, so it's not under their control. PG&E, of course, you know, has been associated with many of the ignitions. There's lightning, but it can start in other lands, and then burn into a community.

So in my work with the Western Fire Chiefs Association, what I've been told is that our coordination between the Forest Service, and then inside the communities, and the insurance industry, and the different areas responsible for fire management is not where it should be.

So, what I believe they're saying is that we should prioritize WUI community fuel mitigation, and then have more resources devoted to the communities that need the most resources.

Senator PADILLA. Okay. Just because time flies around here.

Ms. WATKINS. Sure.

Senator PADILLA. Same question, to follow-up with you on the affordability concern. There ought to be some flexibility to recognize the ability to pay in some communities, and some households. You touched on the dynamic of where fires start. There's the dynamic is where fires impact as they grow. I won't rattle off all the statistics of the series of wildfires California has experienced this last decade.

Worst on record in a nearly 13 percent of land area California has burned, et cetera, but needless to say every community has some level of fire risk. What I'd ask, and I invite all of you to jump in here, what the crisis that we've seen, the wildfires in the west have meant for access to insurance policies in the west, particularly for rural communities, or the communities in this, you know, wild land interface areas.

Mr. THEODOROU. Thank you Senator Padilla for your question. Other states have made available grants for strengthening, for hardening homes, for having the roofs such attached so that there wouldn't be embers going through the ventilation.

Alabama initiated a program about ten years ago which was copied recently by Louisiana. And in my written testimony on the record we do discuss California and Florida. They're offering incen-

tives in the form of premium discounts. And to the affordability question, first the prudence, or the imprudence of building in areas where you have the urban wild interface, needs to be addressed.

You need to have the standards, such as the IBHS, the Insurance Institute for Building and Home Safety. Business and Home Safety that has the specifications, what are the codes to limit wildfire. And as for the affordability, as with other programs means testing should be available for those that are indigent, or otherwise can't afford the insurance, or the costs of doing the hardening.

Chairman WHITEHOUSE. If you want to go ahead Senator. You can take another minute. Oh, I'm sorry, Senator Brown is here. I apologize.

Senator PADILLA. (Off mic). Better modeling with wildfire risk, and identifying mitigation tools, and other potential solutions. Thank you Mr. Chair.

Chairman WHITEHOUSE. Thank you very much Senator Padilla. Senator Braun.

STATEMENT OF SENATOR BRAUN

Senator BRAUN. Thank you Mr. Chairman. This is a complicated discussion in the sense that there's so much variability in terms of what the future does look like. It looks like the science is starting to zero in on some particularity. In the actuarial business that you're in, it seems like it would be probably one of the hardest topics to get in some type of way that you feel comfortable with what the future looks like.

I think—I'm a republican that believes that we need to be in the discussion. I mostly interface with farmers because I've been involved in agriculture, and they think something is afoot. I think that if it's as bad as me, it may be forecast to be, and I'd love to hear your opinion on it because that's where premiums and risk management are all going to have to come in, and I think you're at the forefront of how we finally crystalize, you know, what this discussion is about in general.

So I would like anyone that wants to weigh in on it. Have you actuarially gotten your hands around what this is going to look like, and should this be something that we're trying to prevent in terms of mitigation ahead of the calamity? Are you going to just kind of take each year of further information to do a better job at kind of making sure that the financial risks are covered with fairer premiums, based upon the magnitude of the underlying risk?

That sounds like a complicated formula to come up with, and I'd like your honest opinion if you think that you'd be having huge risks that you couldn't really cover adequately, and that maybe some of the solution would be to mitigate ahead of the problem, since it especially looks like the world is maybe not buying in collectively to do the things that might even be prescriptive.

When I look at the CO2 that's being put into the air by other parts of the world, there are only a few countries headed in a place where it might make sense if in fact the science looks like that's where we're actually headed. It's kind of a sprawling question, but I think it hits the heart of the matter.

Mr. ANDERSEN. So maybe I'll bravely jump into the first part of that. And the one thing that stuck me that I wanted to add to your

question is the timing is a real issue for us, for the insurance industry in that these are decisions that get made, and money that changes hand, so there's an immediacy to understanding the current risks that a risktaker is assuming.

And so when people talk of climate change, they will talk about the effects of climate change today, and what does the industry have to do, and how do they better understand the impacts today on farms and businesses, or consumers? And then what is the impact over 20, 30, 40, years which gets harder to assess if you are in our seat.

Senator BRAUN. Well in the short run, where the rubber meets the road, are premiums covering the amount of risk out there, and being able to pay the claims in a sustainable way?

Mr. ANDERSEN. So the short answer is no.

Senator BRAUN. And how long has that been the case?

Mr. ANDERSEN. I would say over the last four to five years based on the losses that have come through the industry, the confidence of the capital providers that they have a full understanding of the risks that they are taking has been weakening over time.

And so, this year in particular, was a pretty dramatic repricing of risk that happened in the reinsurance industry that is now coming through to the insurers, and then ultimately to the consumers. They don't trust the models. They don't quite understand what the impacts are going to be.

And since these contracts happen today, and they deal with issues of today, their focus is today, and what are the impacts financially. But ultimately they do recognize that they need a truer sense of risk and the changing nature of it in order to attract the capital that they need to perform.

Senator BRAUN. Are you spreading that risk over a broader segment than just the places that seem to have the highest claims?

Mr. ANDERSEN. Absolutely. I mean the whole nature of the business is to diversify it across various financial pools of capital over time as well, so not just location, but time.

Senator BRAUN. So everybody will pay the price, even for something that might be localized or regional?

Mr. ANDERSEN. Yes.

Senator BRAUN. Anybody else want to weigh in?

Mr. THEODOROU. Senator Braun, to the first part about the difficulties in pinpointing what will be the amount of the losses and when, it is difficult indeed because actuarial science is mainly backward looking. Now we're talking about a moving target because the exposure level is changing, and I guess there are models, as Mr. Andersen mentioned, but it said that all models are wrong, but some are useful.

So we know that directionally it is getting worse, but we do have to do something. And to your point on mitigation and resilience, that's really where the industry is going because once you do have better behavior you don't have buildings on the coasts, and the flood plains, that will send a signal—a price signal, when there are losses and the rates go up for people not to build in ways that exacerbate the risk.

So you have the positive incentive for product price signals.

Senator BRAUN. Mr. Chairman, could I have one more brief question? So, in the extrapolation of what has been extra normal, it sounds like, over the last four to five years, and compared to the past when you just have weather incidents that were more sporadic, is the insurance industry now extrapolating based upon a new model that's based on what has had some consistency over at least the last four or five years, or are you still waiting to do that to where you'd fully price the risk into your premiums?

Mr. THEODOROU. The models are recalibrated on a regular basis, so the industry is not sitting on outdated models that don't take into account what's happening in California, and in other parts of the country. So they're trying to keep up. But it's like hitting a moving target because the denominator is changing.

Senator BRAUN. And in the area of the highest claims will this be priced into those localities in a way that that would cause the mitigation, maybe not living where whatever the climate impact is that's having the greatest effect?

Mr. THEODOROU. It is, because you have many of the national insurance companies have separate companies that are focused on a particular state.

Senator BRAUN. Okay.

Mr. THEODOROU. That's just Florida, for example, which is problematic not so much because of catastrophes, but because of mitigation which has gotten out of control with 86 percent of the nation's homeowners insurance litigation, although Florida only has about 7 percent of the nation's homes, so that's a separate issue there.

Dr. KEYS. I was just going to very briefly add that I think, and thank you for the question. I think one of the nuances here is that insurance policies are written on an annual basis. We have mortgages that are written on a 30 year basis, and we have home ownership decisions, which are written maybe on a lifetime basis, or even longer passing on a home in a generational way.

And so, we see the insurance markets responding very rapidly because they're repricing.

Senator BRAUN. You're the true variable cost in the equation.

Dr. KEYS. Exactly. And so they're going to be the ones who are most flexible in a lot of ways, and that means that these other markets should be taking a lot of signals from what the insurance markets are doing.

Senator BRAUN. Ms. Watkins did you have?

Ms. WATKINS. You had asked about modeling, and the insurance industry is definitely recalibrating their models as Mr. Theodorou said. They are also building a track forward into the future, looking at different climate scenarios. And so, they are becoming able to predict this out in the future, but that hasn't historically been a focus.

These models are also being used by long-term investors, and you know, Fannie Mae just had an article where they're looking at these models as well. But to your main point, mitigating ahead of the calamity I think that was my focus, is finding the money, and aligning the stars to start reducing the risk, which isn't traditionally in the purview of others.

Senator BRAUN. Thank you. I think your industry is going to be on that leading edge of what actually takes an amorphous con-

versation into something with a few particularities that we can look to, to guide us in the future. Thank you.

Ms. WATKINS. We'd like to be.

Chairman WHITEHOUSE. Thank you Senator Braun. I will do a second round, and I guess I'd like to first start by asking the witnesses who are here present in the room, whether any of you endorse the proposition that there is nothing going on here that is out of the ordinary for climate related risk.

No, no, no, no. Okay. Do any of you doubt that unusual risk is being caused by emissions from fossil fuel combustion? No, no, no, no, everybody accepts that that correlation exists, okay. Thanks. Miss Curry, I've got a few questions for you if you don't mind. First, do you recall how many times you've testified before Congress on the subject of climate change?

Dr. CURRY. I'm sorry, I didn't hear the first part of the question.

Chairman WHITEHOUSE. Do you recall how many times you've testified before Congress on the subject of climate change?

Dr. CURRY. This would be my 13th time.

Chairman WHITEHOUSE. Thank you. And on those occasions has your message essentially been that there's a lot of uncertainty, we don't really know what's driving observed warming, the model is unreliable, and the IPCC models are not to be trusted?

Dr. CURRY. No. That's not what I would summarize my statements as.

Chairman WHITEHOUSE. All right. Well let's revisit one of the previous times that you testified before Congress. In 2014, before the Senate Environment and Public Works Committee, and I was your interlocutor then. I don't know if you recall that among your 13 episodes of testimony.

But let me prompt you. In your written testimony for that hearing you wrote that several key elements of the IPCC's Fifth Assessment Report point to your language here, "a weakening of the case for attributing most of the warming to human influences relative to the previous assessment." And to support that, you listed the following assertions.

The first was a lack of warming since 1998, and growing discrepancies between observations and climate model projections. The second was sea level rise from 1920 to 1950, being of the same magnitude as 1993 to 2012. And the third was increasing Antarctic sea ice. Do you recall that?

Dr. CURRY. Yes.

Chairman WHITEHOUSE. Okay. Let's look at those assertions and see how they've aged. And let's start with the alleged lack of warming since 1998. Let me propose first that 1998 was an exceptionally strong El Nino year, so picking it as a start of end date for a period builds in an anomaly. Is that correct?

Dr. CURRY. Yes. Do you want me to explain my perspective on the—

Chairman WHITEHOUSE. I'll give you time at the end, but I'd like to get to my questions to you first if I may. So, is it true that the last years 2015 to 2022 have been the eighth warmest years on record? Is that true?

Dr. CURRY. Yes. Yes.

Chairman WHITEHOUSE. That is true. So is it still your testimony that there actually is a lack of warming?

Dr. CURRY. There is if you read the fine print in my 2014 testimony, my main point was that there was a great deal of natural internal variability that influences this decadal scale——

Chairman WHITEHOUSE. It was you who used the phrase lack of warming, and I'm asking if you would still describe what's going on as a lack of warming?

Dr. CURRY. No. We've seen a big super mega El Nino in 2016, which remains the high point, and since 2016 we haven't seen any——

Chairman WHITEHOUSE. Lack of warming.

Dr. CURRY. Increases beyond 2016.

Chairman WHITEHOUSE. So let's go to your next point about modeling discrepancies, that there are growing discrepancies between observations and climate model predictions. I'd like to show you a review that was done of models that were run by the IPCC back in 2004. And for those of you who are not familiar with the graph, the blue part defines the range of the different models that were run for the IPCC.

And the black line that runs through the middle of that range is the mean of those models. And the red goes back and is actually observed temperature information, so the first two, the blue and the black are the prediction range and the prediction mean, and the red is what actually happened.

And it strikes me that it looks like it's tracked pretty well, so let me ask you Dr. Curry, is it still your testimony that climate modeling has not proven accurate?

Dr. CURRY. Okay. This is the diagram you are showing is a flawed analysis. Let's pay attention to what the most recent IPCC assessment report has to say. They found a number of global climate models running too hot. In fact they even changed their way of making projections for the 21st Century that relies less on climate models.

Chairman WHITEHOUSE. Dr. Curry, doesn't the blue range imply that there are some models that ran too hot, but also others that ran too cold, and that's why there's a range?

Dr. CURRY. Yeah. On average. On average.

Chairman WHITEHOUSE. Got it. Thank you. And then the average is the mean, which is the black line, which tracks extremely well with the red data.

Dr. CURRY. That particular graph that you have is a flawed analysis.

Chairman WHITEHOUSE. Okay. Well let me go on. You disagree with the analysis, I get it.

Dr. CURRY. The assessment report I should say.

Chairman WHITEHOUSE. You talk also that there's been no increase in sea level rise rate. According to IPCC sea level rise has more than doubled from the 1901 to 1990 period, to the 1993 to 2015 period, and that since 2015 it has accelerated further beyond the doubling. Do you dispute those determinations?

Dr. CURRY. The point I made in my 2014 testimony is that there is a great deal of multi-decadal variability in sea level wise, which

we saw a sharp increase in the first half of the 20th Century. I'm not saying that sea level wise isn't increasing.

Chairman WHITEHOUSE. Okay.

Dr. CURRY. I'm not saying.

Chairman WHITEHOUSE. Are you saying that this rate of seal level rise is not increasing? Or do you consider that both seal level rise is increasing, and the rate of seal level rise is also increasing?

Dr. CURRY. It depends on the time scale you look at, and the causes that you attribute to it. It's yes it has been——

Chairman WHITEHOUSE. I'm talking the history of the industrial revolution, the period in which emissions have begun to have an effect. I'm not talking about paleo history.

Dr. CURRY. Okay. Sea level rise, the modern sea level rise started increasing in about the mid-19th Century. This is coming out of the little ice age, and at that point had little to do with fossil fueled warming.

Chairman WHITEHOUSE. Is that still the case today, or does it now have to do with fossil fuel warming?

Dr. CURRY. Fossil fuel warming is certainly contributing to the slow creep of sea level rise. I've never questioned that.

Chairman WHITEHOUSE. Okay. And you say it's a slow creep, but it's also an accelerating upward rise is it not?

Dr. CURRY. The how to infer acceleration in sea level rise is disputed among experts.

Chairman WHITEHOUSE. Okay. You've accused the IPCC of corruption. Do you stand by that term?

Dr. CURRY. The IPCC is a highly politicized organization. The recent synthesis and assessment report for the Sixth Assessment that was just released this week, I mean that is a very highly politicized.

Chairman WHITEHOUSE. Do you stand by the very use of the term corruption regarding the IPCC?

Dr. CURRY. It has to be qualified as a highly politicized organization.

Chairman WHITEHOUSE. How about the IPCC's definition of anthropogenic climate change being a hoax? Do you stand by that term?

Dr. CURRY. I've never used—I've never used those words.

Chairman WHITEHOUSE. Okay. let me take you into the—I'm actually reading off a blog. "With these definitions in mind, here are two examples that qualify as hoaxes that I've previously written about. The UNFCCC definition of climate change arguably qualifies as a hoax." So I refer you to that, and with unanimous consent we'll make that a part of the record.⁸

Dr. CURRY. Do you want me to clarify that statement?

Chairman WHITEHOUSE. I think it needs a lot of clarification indeed. And I'll let you clarify it for the record. Okay. We have a—you'll have all the time in the world to write whatever you want, and add that in a response to the record. So let's look for a moment at the other models if the IPCC is potentially corrupt, and if it's definition as hoax. Exxon——

⁸Document submitted by Chairman Whitehouse appears in the appendix on page 209.

Dr. CURRY. The IPCC—can I clarify before we go much further? The IPCC—the UN framework convention on climate change now defines climate change to be only human caused climate change. The definition does not include natural climate variability, and this flies in the face of all the understanding of geology, of atmospheric science, and all the other scientific fields.

It's a political definition.

Chairman WHITEHOUSE. Fair enough. And if you want to expand on that you're welcome to do so in your response for the record. But let me take my time here and show you the graph that Exxon scientists developed to model climate change, both CO₂ concentration, and observed temperature change.

And for those of you not familiar with the graph, the original black lines are the ones that are developed by the Exxon scientists. The blue line is the actual measurements, and the red line is the actual measurements. The blue being CO₂ concentration, and the red being observed temperature.

Do you concede that Exxon's models prove to be pretty accurate just like the IPCC models?

Dr. CURRY. No. That model is a toy model that Exxon used, and—

Chairman WHITEHOUSE. All right.

Dr. CURRY. It's a useful contribution to the dialogue.

Chairman WHITEHOUSE. In 1968 the American Petroleum Institute commissioned a report on climate change from scientists at Stanford. And those scientists concluded, I'll read from the report language here, "Significant temperature changes are almost certain to occur by the year 2000, and these could bring about climate change."

If the earth's temperature increases significantly, a number of events might be expected to occur, including the melting of the Antarctic ice cap, a rise in sea levels, warming of the oceans. It is clear that we are unsure as to what our long lived pollutants are doing to our environment, however there seems to be no doubt that the potential damage to our environment could be severe."

Do you doubt the scientists hired by the American Petroleum Institute, or their statement?

Dr. CURRY. Our knowledge of climate change was in its infancy in the 1960's. The first assessment report by the IPCC published in 1990 or 1991, found that there was no evidence of human cause warming beyond natural climate variability at the time of the early 1990's.

Chairman WHITEHOUSE. So the API scientists got it wrong too when they presented that conclusion?

Dr. CURRY. No. They had a weakly justified argument, and a weak knowledge base at the time.

Chairman WHITEHOUSE. And events have proven them wrong in some fashion do you believe?

Dr. CURRY. It's not something that's useful. So it's not something that's useful.

Chairman WHITEHOUSE. Okay.

Dr. CURRY. To consider at this point.

Chairman WHITEHOUSE. So the other thing you cited was increasing Antarctic sea ice. And the last eight years have seen below

average summer minimum ice for the Antarctic, with this year being a record low. Do you still stand by the proposition that Antarctic seal ice is increasing?

Dr. CURRY. There's a great deal of interannual and decadal scale variability. The IPCC does not make any assessment that human caused warming is contributing with confidence to a change in the Antarctic sea ice beyond natural climate variability.

Chairman WHITEHOUSE. But do you think that the Antarctic sea ice was increasing, just as a measurement. Is that still correct?

Dr. CURRY. There's like I said, there's a great deal of year to year and decadal variability in the Antarctic sea ice, which is what I was commenting on.

Chairman WHITEHOUSE. Okay. Let me refer you back to an article that you wrote in the Washington Post in 2007, and I'll read your words then. "If the risk is great, then it may be worth acting against, even if its probability is small. Think of risk as a product of consequences and likelihood. What can happen, and the odds of it happening. A 10 degree rise in global temperatures by 2100 is not likely, the panel gives it a 3 percent probability.

Such low probability high impact risks are routinely factored into analysis, and management strategy." And I'll interrupt your quote to say probably by the kind of folks who are here sitting in the room with me today, the experts and the executives of major risk bearing enterprises.

"Whether on Wall Street, or at the Pentagon," you continue. "The rationale for reducing emissions of carbon dioxide is to reduce the risk of the possibility of catastrophic outcomes, making the transition to cleaner fuels has the added benefit of reducing the impact on public health and ecosystems, and improving energy security, providing benefits even if the risk is eventually reduced.

I have yet to see any option that is worse than ignoring the risk of global warming and doing nothing." Has your view changed since that 2007 article?

Dr. CURRY. My notions of risk for naive circa 2007, in the intervening time I have educated myself very substantially in risk sciences. And I have a book in press entitled *Climate Uncertainty and Risks* that has been extensively reviewed, peer reviewed, by an academic press.

And that book outlines my current understanding of how we should think about climate risk. Some of my understanding I was able to include in my written testimony submitted to this Committee.

Chairman WHITEHOUSE. In 2014, I asked you if you thought there was real risk from climate change, and should we figure out how to deal with it, and you replied, "We may decide to do nothing and see what happens." Do you still recommend that strategy?

Dr. CURRY. I never—I didn't recommend that strategy. I said that is an option.

Chairman WHITEHOUSE. Do you still consider it to be a realistic or plausible or prudent option?

Dr. CURRY. I think we should actively work to adapt to extreme weather events and sea level rise. I think we should—I think we need new energy infrastructure for the 21st Century, with more abundant, cleaner, more reliable energy.

Chairman WHITEHOUSE. And in your testimony here today you suggest that one of the things that can save us from climate change, and reduce the risk is volcano eruptions. Is that correct?

Dr. CURRY. No. I'm saying that climate models do not include severe—simulations for the 21st Century do not include scenarios of extreme explosive volcanic eruptions, such as occurred in the early 19th Century. If those were to occur, we could see a half a degree Centigrade cooling over several decades.

The point of that is to emphasize that natural climate variability can be very substantial, and this isn't properly taking into account in our considerations of how the climate might play out in the 21st Century. That's the point that I'm making.

Chairman WHITEHOUSE. Let me close out with a question for the witnesses who are here in the room. And that is to offer your view on the diligence, integrity and reliability of the modeling that you count on in doing your planning and projections. Starting, I guess, with Mr. Andersen, we'll go across the four of you and conclude the hearing.

Mr. ANDERSEN. That's a great question. I would say one of the special things about the models that the insurance industry uses is that it actually money changes hands over the interpretation of those models. So the confidence around them, and the need for those models to be as up to date and insightful is critical.

Chairman WHITEHOUSE. It's a powerful incentive to get it right.

Mr. ANDERSEN. To get it right. So, I think it's a, you know, as I think Mr. Theodorou said, it is something that we are continuing to work on as new information becomes available because it has—it moves markets, and so it's critical that we continue to improve it.

Chairman WHITEHOUSE. Ms. Watkins?

Ms. WATKINS. The risks that we're modeling are complicated, and so the models need to be complicated to be useful. They don't agree. They do evolve. The question is can they be used safely and appropriately, and that does require expertise, and I think that upping the level of expertise in terms of risk aware, climate aware planning, is going to help an awful lot in demystifying these models.

Chairman WHITEHOUSE. But you count on the models and they're valuable to use in doing the planning and the work that you do.

Ms. WATKINS. They're definitely a state of the art for actuaries in getting the risk accurately priced and evaluated, and that's what we do.

Chairman WHITEHOUSE. Yeah. And one of the reasons that this is a difficult enterprise is because things are in fact changing, is that not the problem.

Ms. WATKINS. That's right. But we are trying to use the models to evaluate what the changes are and what that means for the potential outcomes.

Chairman WHITEHOUSE. Dr. Keys?

Dr. KEYS. Thank you for the question Senator. The data that we use as researchers often comes from the government, and we're especially thankful for the scientists at NOAA, and elsewhere who make their data available, and make regular improvements to their data. So they're doing outstanding work.

I think there is room for improvement in terms of sharing data between the private sector and the public sector, and understanding what the difference is, or discrepancies might be between the different models. I think there's also a role for the democratization of this data to make it more accessible to households, so that they can better understand the risks they face.

I think one of the asymmetries is that the insurance markets often know a lot more about the risks than the households or the businesses do.

Chairman WHITEHOUSE. Mr. Theodorou, reliability of models?

Mr. THEODOROU. Thank you Chairman Whitehouse for the question. The modeling industry has really advanced by leaps and bounds since it was essentially borne in 1992 in the wake of Hurricane Andrew. And since that time there have been three main models that are used and licensed by risk practitioners.

Typically, large insurers and reinsurers use all three, and they may have their own proprietary as a fourth model, which has now entered the fray.

Chairman WHITEHOUSE. And Mr. Andersen is correct that a lot of money rides on getting it right, in addition to potential fiduciary reliability if you really blow it. Correct?

Mr. THEODOROU. Yeah. Licensing in the models is not an inexpensive proposition. So, as I said earlier, they're not capable of getting a point estimate exactly, how much loss are we going to have at this particular time, but directionally is what we look at to give the headlights into where we're going.

Chairman WHITEHOUSE. I love hearing you use the word headlights. That's my phrase. I say science is the headlights that drives us forward, and let's us see what's coming. And with that let me call the hearing to an end. I thank you all for your testimony. I want to state that questions for the record from colleagues are due by noon tomorrow.

And we ask the witnesses to respond to any questions that they may receive within 7 days of receipt. And in addition to responding to any questions received by or for Professor Curry, the opportunity to elaborate on her answers to my questioning in any way that she sees fit, so she feels she's had a full and fair chance to respond.

And with that the hearing is concluded. Thank you.

[Whereupon, at 11:51 a.m., Wednesday, March 22, 2023, the hearing was adjourned.]

**Opening Statement of Chairman Sheldon Whitehouse
Senate Committee on the Budget
“Risky Business: How Climate Change is Changing Insurance Markets”
March 22, 2023**

Ranking Member Grassley, colleagues,

We are here today for the fourth Committee hearing examining the budgetary perils associated with climate change. Today, we focus on the danger to the National Flood Insurance Program and private insurers, and on the impact that climate-related natural disasters will have on insurance markets. As we’ve heard already, and will hear again today, climate disruptions upset insurance markets, which in turn upsets mortgage and housing markets. As we have heard, and will hear again, sea level rise and wildfire risk can upset property markets so profoundly as to cause systemic economic damage across the whole economy, similar to what we lived through in 2008. You won’t have to have property in flood zones or wildfire country to feel the pain.

I hear colleagues’ say that the true long-term budget crisis affecting our country is debt and deficits. Let’s have that conversation. The President’s budget would reduce deficits by almost \$3 trillion, while adding at least 25 years of solvency to the Medicare trust fund. House Republicans want to add \$3 trillion to the debt, by extending the Trump tax cuts for the rich. Let’s have that debate.

But let’s not pretend that economic shocks don’t affect the budget. The 2008 mortgage meltdown added \$5 trillion to the national debt, primarily due to decreased revenues. Covid added another \$5 trillion. In both crises we were warned, failed to act in time to head them off, and were engulfed. Today, those trillions of added ‘shock debt’ amount to 40 percent of our total national debt.

And let’s not pretend that global climate disruption won’t create economic shocks. Warnings abound of what rising seas, droughts, floods, and wildfires will do to American families and businesses, and to our economy. This is the point: if you’re serious about debt and deficits, you have to be serious about climate change.

The Intergovernmental Panel on Climate Change, the scientists charged with synthesizing the latest science on climate change, a group cited favorably by previous Republican witnesses here, released its latest report Monday, warning of severe risks to agriculture, infrastructure, public health, and coastal and flood-prone communities. The report states:

“Climate change is a threat to human well-being and planetary health. There is a rapidly closing window of opportunity to secure a livable and sustainable future for all. [...] The choices and actions implemented in this decade will have impacts now and for thousands of years.”

That’s a pretty clear warning — impacts for thousands of years. For our children’s children’s children’s children’s children’s children, and on and on into the future. I ask you: why are we here, if not to try and leave our nation and our planet better off for future generations? We have the chance now to bend the arc of history — of geophysical history, of economic history, of national security history — towards a more livable, prosperous future for generations.

The Economic Report of the President also came out Monday. Just like we've heard in these hearings, it warns that climate change threatens volatile and cascading economic instability. Here's a relevant part:

"Certain financial instruments – such as insurance contracts ... and mortgages – that directly or indirectly price weather-related risks are ... highly exposed to climate change. Rapid changes in asset prices or reassessments of the risks in response to a shifting climate could produce volatility and cascading instability in financial markets ... [P]roperty insurance against catastrophic natural hazards is at the forefront of climate change risk exposure and is already showing signs of strain...."

These latest reports echo statements made by the Treasury Secretary earlier this month. She declared:

"[C]limate change will likely become a source of shocks to the financial system in the coming years. As climate change intensifies, natural disasters and warming temperatures can lead to declines in asset values that could cascade through the financial system. And a delayed and disorderly transition to a net-zero economy can lead to shocks to the financial system as well. [...]n response to rising insured losses, some insurers are raising rates or even pulling back from high-risk areas. This has potentially devastating consequences for homeowners and their property values. Developments like these can spill over to other parts of our interconnected financial system."

I know there are powerful interests that don't want these hearings to happen, that want to change the subject, that want you to ignore the warnings from scientists, from economists, from financial institutions, from government. Those powerful polluter interests want you to listen instead to their noise and nonsense – the denial, the delay, the obstruction, the obfuscation – that for far too long has halted a bipartisan defense against the climate threat. It's time to choose. What we do here now will not just have impacts for thousands of years, it will be remembered for thousands of years. We might do well to consider how we would like to be remembered, because that moment of choice is upon us.

Prepared Statement by U.S. Senator Chuck Grassley (R-Iowa)
Ranking Member, Senate Budget Committee
Hearing titled “Risky Business: How Climate Change is Changing Insurance Markets
Wednesday, March 22, 2023
[VIDEO](#)

The audience for today’s hearing on private insurance is different than last week’s hearing on the President’s 2024 Budget. As such, I would like to recap what we heard last week at our first, and only, budget centric hearing this Congress.

What we received from President Biden was a budget that continues this country on a destructive path of deficits and debt.

The budget doubles down on the reckless tax and spending binge of the administration’s first two years in power. It calls for nearly \$5 trillion in new taxes that will kill jobs and punish hardworking Americans. And, despite all the lip service, it does not extend the tax relief provided to Americans making under \$400,000 under the Tax Cuts and Jobs Act. So, it increases taxes on just about everybody.

This is a breach of the President’s pledge not to raise taxes on the middle-class. Not surprising for an administration that routinely breaks its promises, as well as the law.

We saw Democrats try to justify tax increases by pointing out that the last time we had a budget surplus, revenues were about 19 percent of gross domestic product.

Well that means outlays were less—at about 18 percent. Does the Democrat Majority want that outcome? The administration surely doesn’t, as spending in their budget will surpass 25 percent of the economy in 10 years. Outside of World War II and the pandemic, that would be the highest spending level on record.

Last week before this committee, the OMB Director repeated the fallacy that the President’s policies have led to deficit reduction. Only in Washington could you claim savings from not continuing temporary emergency COVID spending. It would be laughable if it wasn’t so disingenuous.

We saw continued demagoguery from the Administration on the issue of major trust fund programs. This Administration has no plan whatsoever to shore up Social Security for future generations. Instead, they paint Republicans as boogymen for wanting to prevent automatic cuts that’ll surely occur absent action by the President and Congress. Where is the President’s plan to protect seniors?

The Democrats have made their message loud and clear. They don’t care about the fiscal problems facing us now. They don’t have a plan to deal with inflation, even though their bills substantially increased inflation, and that’s according to CBO.

From Iowa to Rhode Island, our constituents collectively believe that our exploding national debt is a major issue facing America.

The last two climate hearings held by the Budget Committee touched on the impacts of sea level rise, hurricanes, and wildfires. We’ve heard from witnesses discussing costs due to these climate and weather events. We’ve heard the reasons we’re seeing increased costs. Climate change is important, but it’s not the main driver.

Short of the need for better federal forest management, states, towns, and individuals can take care of most of their own challenges through smarter land use and development practices.

While this committee is the Budget Committee, this hearing is not focused on the public federal budget.

It targets the private insurance and reinsurance industries with speculative scenarios in an effort to raise alarm. My democratic colleagues want you to believe that insurance and reinsurance companies are in dire straits due to climate change. And, that insurance will become unavailable and unaffordable. Well, that's not necessarily the case and we'll hear from witnesses dispelling those extreme models.

From hurricanes to wildfires, the insurance and reinsurance markets have shown to be resilient.

Rather than relying on federal intervention in the insurance markets or pushing more costs onto taxpayers, we should encourage more solutions from the private sector.

Thank you, Mr. Chairman.





Testimony of

Eric Andersen
President of Aon

Before the
United States Senate Committee on Budget

Wednesday, March 22, 2023



Good morning, I am Eric Andersen, President of Aon and a 30-year veteran of the insurance industry. On behalf of my 50,000 colleagues at Aon, I would like to thank Chairman Whitehouse, Ranking Member Grassley, and each member of the committee for the opportunity to testify on the role that insurance can play in mitigating climate risk.

Climate risk is a global, systemic risk and the insurance industry is a bridge between public risks and private capital. At its core, our business is about creating resilience to both protect the assets of today and foster the growth of tomorrow. We do this by spreading the impact of risk across a wide community of financial participants across time to help people and businesses withstand volatility; to have the resources and confidence to invest, and to protect and rebuild when necessary.

We believe that properly managing climate risk not only protects against the downside, but can also be a catalyst for growth. Through public-private partnerships with the government, Aon and others in our industry have helped the US and other economies weather the volatility created by every conceivable crisis from the Great Recession to the terrorist attacks of 9/11.

In each of those events, we got to witness up close the displacement and what it does to people, what it does to businesses, to communities especially those that are not prepared or don't have the right protection in place. In a time of increasing volatility, the ability to innovate: to leverage private market capital by protecting the investments will allow our economy in cooperation with the government, to leverage the power of the private market to mitigate the impact of volatility on economies and communities.



Anyone who cites the difficulty of placing risks for either traditional energy sources or new green technology should recall what US mortgage risk felt like in 2010 in the wake of the financial crisis. The insurance industry, led by Aon, developed a new risk transfer product that took risks from Fannie and Freddie and transferred them to the reinsurance markets. Ten years later, this public private partnership exceeds \$40 billion and the models and discipline allowed – maybe even facilitated – an orderly transition of the secondary mortgage market that carries through to today.

Just as the the US economy was overexposed to mortgage risk in 2008, the economy today is over exposed to climate risk. To solve this, we have two choices: we can shrink the amount of carbon emitted by shrinking the amount of economic activity - we can make less steel, build fewer buildings, travel fewer places - or we can make new markets. Obviously the first choice is no choice at all, so how do we mitigate the risk of investing in a technology with no track record?

Capital will not go where it is not protected, nor will it go where it cannot expect a return, regardless of either the moral imperative, the political demands or the communal self-interest. This is why public-private partnerships are so important.

There are examples of how these partnerships work.

In 2021 the World Bank, Aon and USAID teamed up to mitigate hurricane risk in Jamaica through catastrophic coverage. The bonds will deliver \$185 million in immediate liquidity post event insuring not only humanitarian relief in the case of a windstorm but facilitating immediate



economic investment pre-event based on the certainty of funds to assure infrastructure and property rebuild.

Currently we are pioneering the first “employee resilience bond” for a large employer in a developing, climate volatile country to procure a bond to provide cash assistance directly to employees in the event of a disaster to meet recovery needs.

This also requires recognition that many of the most innovative investments in green technology are being made from the balance sheets of clients in the traditional energy space. Companies like those in agriculture, construction and extraction recognize the need for transition to a lower carbon economy. Thus, while Aon is committed to the transition to a lower carbon economy, it is critical in the short term that we continue to support carbon intensive businesses to guard against a void in power generation and the innovations that these companies bring to the fight.

Overview

On January 25, 2023, Aon published the “2023 Weather, Climate and Catastrophe Industry Report” (below for the record). As evidenced by our report, the insurance industry is data-driven, which gives us a unique capability to identify challenges and propose innovative solutions, many of which involve partnership between the public and private sectors. Data shows that 2022 was the fifth costliest year on record for insurers. More than \$55 billion of the total global insured loss in 2022 resulted from just one storm, Hurricane Ian in Florida, the second costliest natural catastrophe in history for the insurance industry. Ian is surpassed only by Hurricane Katrina in 2005, with \$100 billion paid in claims from the insurance industry. These are just the financial costs. More than 31,300 people lost their lives due to global



natural catastrophe events in 2022. Globally, the total number of catastrophe-related fatalities has remained below average for 12 years in a row; however, more than 19,000 of the fatalities were heat-related deaths in Europe alone.

Further findings of the report include:

- 421 notable natural disaster events were recorded in 2022, higher than the 21st century average of 396.
- 75 percent of global insured losses were recorded in the United States, which was higher than the average of 60 percent.
- Windstorm Eunice was the costliest individual European windstorm since 2010, with \$3.4 billion in insured losses.
- Widespread hailstorms in France contributed to the country's second-highest natural disaster payouts of €6.9 billion (\$7.4 billion).
- Droughts and heatwaves severely impacted Europe, the United States, China and other regions and global insurance payouts for drought were the second highest on record, at \$12.6 billion.
- Both severe drought conditions and a prolonged rainy season in different regions of Latin America reduced agricultural crop yield across the region.

Aon's role continues to be working with our clients – insureds and insurers, alike – to help build physical resilience, accelerate solutions to market, and de-risk climate-related investments by connecting capital to opportunities.

Recent years have seen weather events drive up claim's costs for businesses, communities, and governments — increasing the need for real-time catastrophe monitoring, instant response, and rapid



assessment of damage. Speed is critical. For communities, it's about determining a safe and effective escape route from a storm. Governments need to ensure the continuation of essential services. For insurance companies, it's about knowing where to send experts to survey the damage and deliver claims payments to help customers quickly repair or rebuild.

Forecasting

To better inform insurers and organizations about climate exposure as soon as possible, Aon's Impact Forecasting team developed Automated Event Response (AER). AER has a global footprint that covers everything from windstorms in Europe to North Atlantic hurricanes to typhoons in Japan. AER uses windstorm or tropical cyclone forecasts from different meteorological institutions together with catastrophe models, which are overlaid on an insurer's portfolio data to produce automatic predictions of loss each time new forecast data are issued.

Customized reports are sent to insurers automatically within 30 to 60 minutes of a forecast to help quantify the potential geographic scope, severity, and projected cost of the event — even before the storm makes landfall. Insurers are then better equipped to make more decisions about managing claims adjuster resources, setting loss expectations, and evaluating impacts to reinsurance structures.

AER allows businesses to protect and prepare their physical locations and staff. Consider a retailer with thousands of locations across a region that receives updated forecasts multiple times per day as a hurricane makes landfall. The business can gauge which locations are likely to be hardest hit and how severely, while taking steps to ensure the safety of employees and the site location's security. That knowledge allows companies to prepare early — often quickening claims processing.



Sophisticated and instant response methods are equally important for assessing damage after the event. Satellite imagery and drones are increasingly used to immediately assess damage, particularly in hard-to-reach areas. For example, within 48 hours after an event, Aon's property claims teams fly drones in impacted areas, then immediately send the footage to clients to measure their damage. Real-time footage helps expedite the payment of claims and increases claims assessment accuracy.

Impact on Workforce

As organizations focus on developing a resilient and agile workforce, they also are considering how a changing climate affects health and how that shapes their goals.

This can mean:

- Enhancing plans to help their workforce contend with changing health and safety conditions
- Limiting outdoor work during unsafe conditions
- Developing contingency plans for locations not traditionally considered prone to certain natural disasters, but which are now susceptible
- Ensuring health care access for vulnerable populations.

Together, risk, health, and human capital stakeholders can develop innovative ways to help companies protect their people after natural disasters. Recently, Aon worked with a large technology firm in the U.S. to adapt the trigger for a catastrophe bond (an earthquake, in this case).



Instead of only paying a claim to rebuild the physical office, it now will allocate a one-time payment to the firm's employees to help them through a disruption to their lives due to the earthquake. The catastrophe bond was created 20 years ago to address the loss of physical assets, but now can help people as well.

Reinsurance

Reacting to six years of low returns, high catastrophe losses, and investor pressure, pricing for U.S. property catastrophe and global property retrocessional business hit multi-decade highs on January 1, 2022. Aon estimates that global reinsurer capital declined by 17 percent, or \$115 billion, to \$560 billion during the first nine months of 2022. Reinsurers are raising prices, limiting coverage, and even exiting some markets to improve returns. New capital formation is currently limited, reflecting significant uncertainties in what has become a very challenging risk environment. Investors are particularly concerned about the impact of climate change and inflation, but there are expectations that the prospect of higher returns will drive new allocations going forward, particularly as the benefit of higher pricing and interest rates becomes visible in earnings.

Recommendations

Carbon reduction has become a near universal goal shared across industries and governments and Aon supports and participates in commitments to reduce emissions. In addition, there are things that Congress should consider, which could make a positive impact on preparedness and resilience.



- Credit risk transfer – Congress should support programs that facilitate the transfer of credit, guarantee, and insurance risk to the private sector and away from taxpayers.
- Budget insurance – Congress should work with FEMA to ensure that states have the certainty they need to buy budget insurance to protect rainy-day funds used to make residents whole after natural disasters.

Conclusion

Climate risk poses substantial challenges to insureds and insurers alike. While insurance is based on the principle of diversifying risk, in many cases, insurance risk management becomes more challenging as events become more interconnected across lines of business, geographic regions, and perils.

Aon is oriented around the philosophy that big problems need to be solved by collaboration and this has been exactly that, with humanitarian, private, and public sectors partnering to prove that solutions can be found together. Insurance exists to protect that which we cannot afford to lose. And we have a lot to protect.



AON

2023
Weather, Climate
and Catastrophe Insight

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Executive Summary

Economic Loss
\$313 billion
4% above the
21st century average



58%
Global Protection Gap

Insured Loss
\$132 billion
57% above the
21st century average



75%
of global insured
losses were recorded
in the United States

39
billion-dollar economic
loss events (below the
average of 40)

5th
costliest year on
record for insurers

19
billion-dollar insured
loss events (tied with
the 5th highest
on record)


421
number of notable disaster events



\$50-55 billion
insured loss from Hurricane Ian,
2nd costliest natural disaster for
insurers on record (2022 \$)



\$4.0 billion
insured loss from Australia Floods in
February/March, the costliest event for
the local insurance industry on record



\$3.4 billion
insured losses from Windstorm Eunice,
the costliest individual European
windstorm since 2010

**Australia
and South Africa**
recorded the costliest insurance industry events
on record



19,200
heat-related fatalities in Europe

0.86°C (1.55°F)
above the 20th century average (NOAA): World's sixth-
warmest year on record for land and ocean temperatures
dating to 1880

1.34°C (2.41°F)
above the 1991-2020 average: Hottest summer on record
in Europe

40.3°C (104.5°F)
record high temperature in the United Kingdom

Executive Summary

Global natural disaster losses in 2022 are better covered by insurers who face their fifth costliest year in history, climate change drives new extreme weather records.

Global natural disasters in 2022 resulted in near-average economic losses totaling \$313 billion. Half of those losses occurred in the United States and were driven by the devastating Hurricane Ian and multiple severe convective storm outbreaks. Three global drought events were among the 10 costliest disasters, which underlines the growing significance of the peril on a global scale. These occurred in the United States, Europe and China.

The insurance sector covered \$132 billion — marking 2022 as the fifth costliest year for insurers on record. The industry also saw the second costliest event on record, as Hurricane Ian resulted in approximately \$50.55 billion of insured losses covered by public and private entities. It is only surpassed by Hurricane Katrina with \$99 billion on a price-inflated basis. With a protection gap of 58 percent, most disaster losses were uninsured. While this is one of the lowest protection gaps on record (only matched by a similar percentage from 2005), the remaining gap presents both a challenge for the global resilience, as well as an opportunity to facilitate further protection.

New extreme weather records were broken, and many regions saw prolonged drought and scorching heatwaves. This is a reminder that the impact of climate change on communities around the globe is tangible and that behavior of certain natural perils will continue to be affected.

Many disasters in highly exposed areas, including Hurricane Ian or the devastating floods in Pakistan, highlight the need to strengthen resilience, as socioeconomic change and concentration of exposure and wealth in vulnerable areas remains a major loss driver. Through the adoption of effective adaptation strategies and better disaster management and warning systems, we can better protect the communities in which we live and work.

Foreword: Closing the Protection Gap to Mitigate and Protect Against Climate Risks

We are living in a time that has been deemed “The Great Volatility” by the world’s leading economists. And there is no greater volatility we face — collectively — than the impacts of climate change. Mitigating and in some cases adapting to climate change is one of the biggest challenges we face. There are abundant opportunities, but success is not guaranteed. This is why collaboration between public, private and societal forces is essential.

Aon has been developing partnerships across the industry to advance climate solutions and close the protection gap. Our recent work with the International Federation of Red Cross and Red Crescent Societies to create the Disaster Response Emergency Fund (DREF), which provides emergency funding for communities in all kinds of disasters when needs exceed resources, illustrates this commitment. As our President Eric Andersen put it at the DREF Pledging Conference: “Big problems need to be solved by collaboration and this has been exactly that — humanitarian, private and public sectors partnering to prove that solutions can be found together.”

This report explores the events and costs of catastrophes and natural disasters in 2022 that amounted to economic losses of \$313 billion —

\$299 billion of which was the result of weather and climate events. That’s a staggering amount of loss, and yet, only 42 percent were covered by insurance. This data highlights a tremendous opportunity to close this protection gap. In doing so, we can protect vulnerable communities and strengthen the economy. There are three risks that we hear from our clients that could hold companies back from taking a leading role in solving the climate crisis. They are telling us the industry continues to:

1. Leave the playing field by excluding climate-related triggers and exiting challenged geographies;
2. Tax the net-zero transition by opting out of entire sectors and inadvertently making the transition to clean energy harder; and
3. Ignore the accelerators by moving too slowly on adjacent markets.

The good news is that there are examples of where the industry has forged a better path: choosing to stay in the game, facilitate a just transition and provide ways to bring new solutions to market quicker. For example, catastrophe bonds were created to provide post-event cover for traditional risks, but they also encourage pre-

investment in research and development that would accelerate clean energy transitions by assuring certainty of funds to deal with the impact of traditional claims. In another case, we have developed an industry-leading capability to enable a company to accurately value its intellectual property, and then use it as an asset to finance growth. This allows them to bypass traditional funding and accelerate their time to market. For many green technology companies, this is becoming their best option.

We believe in our collective ability to address one of the greatest challenges of our times in a way that will better serve our clients and society as well. Aon’s role continues to be working with our clients to help them build physical resilience, accelerate solutions to market and de-risk climate-related investments — connecting capital to opportunities.

Insurance exists to protect that which we cannot afford to lose, and when it comes to climate change, we all have a lot to protect.

Greg Case
Chief Executive Officer, Aon

How This Report Can Help Build and Promote Resilience

This report highlights the global natural disasters of 2022 to help quantify and qualify how topics such as climate change, socioeconomic and other emerging issues influence catastrophe risk. The data, statistics and analytics intend to aid interests in sectors such as insurance, government, academia, real estate, emergency management and banking.

Identify Trends

- Explore global and regional catastrophe loss drivers
- Quantify the cost of which areas are seeing higher annual or decadal losses
- Detect climate change influence on individual event behavior and impacts

Enhance Risk Mitigation

- Better establish risk mitigation efforts in the public and private sectors — with initial focus in the most vulnerable areas of the world — for enhanced disaster response and business continuity
- Modernize building codes and mandate enforcement
- Improve risk communication and explanation of uncertainty
- Academic collaborations in climate research will aid in the development of new tools and solutions to push forward new ideas to lower risk and promote future mitigation and adaptation practices

Seize the Opportunities

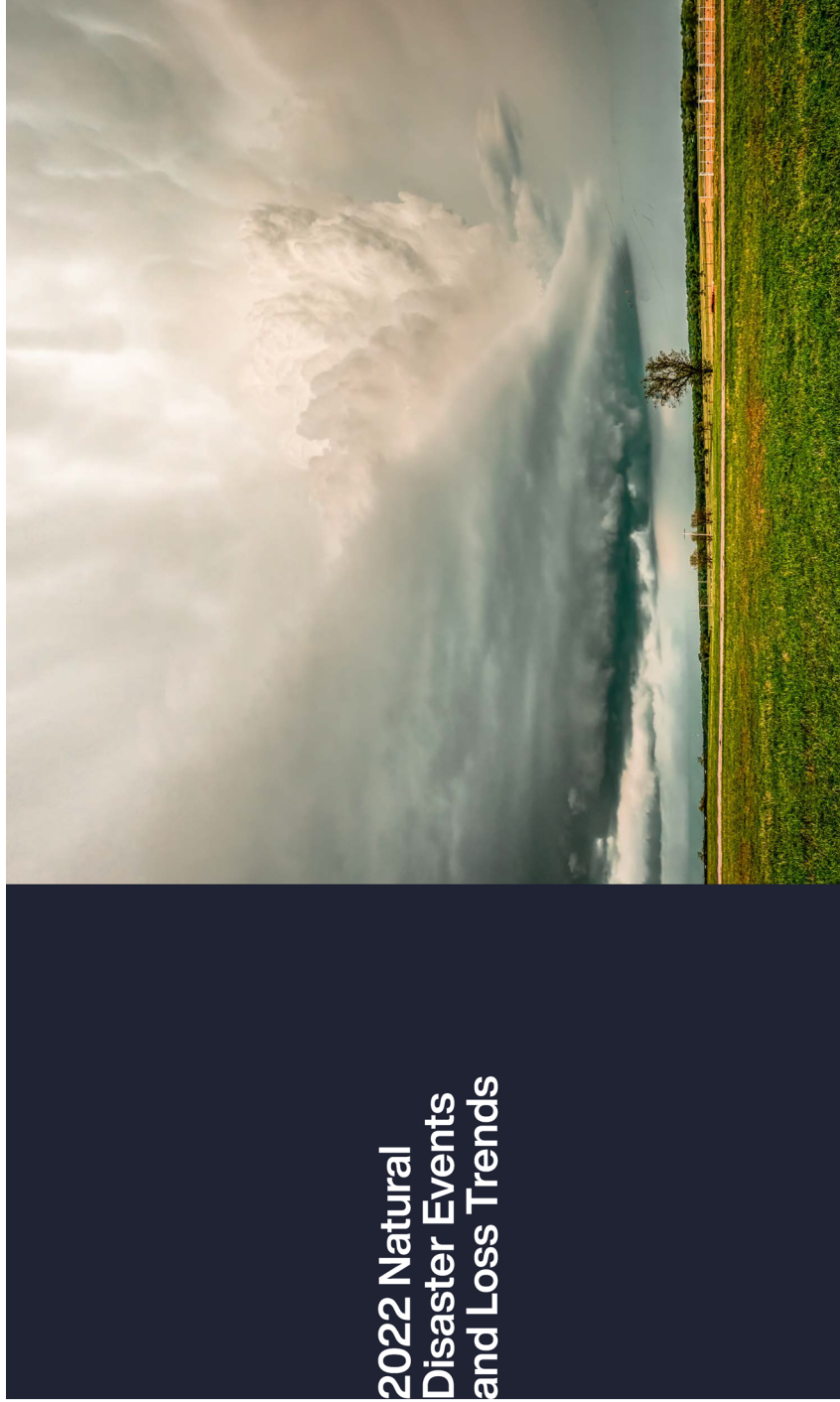
- Explore traditional and alternative insurance to protect people and assets
- Grow the volume of assets dedicated to sustainable investment to accelerate green initiatives that will meet net-zero emissions goals
- Economic, social and governance strategies to assess, disclose and manage risks, including climate
- Build resilience through public-private collaborations to close the protection gap, protecting and enriching lives around the world

Key Learnings

- Through academic collaborations, we can turn climate science into action for both the private and public sector
- Robust historical data is crucial for identifying natural disaster trends

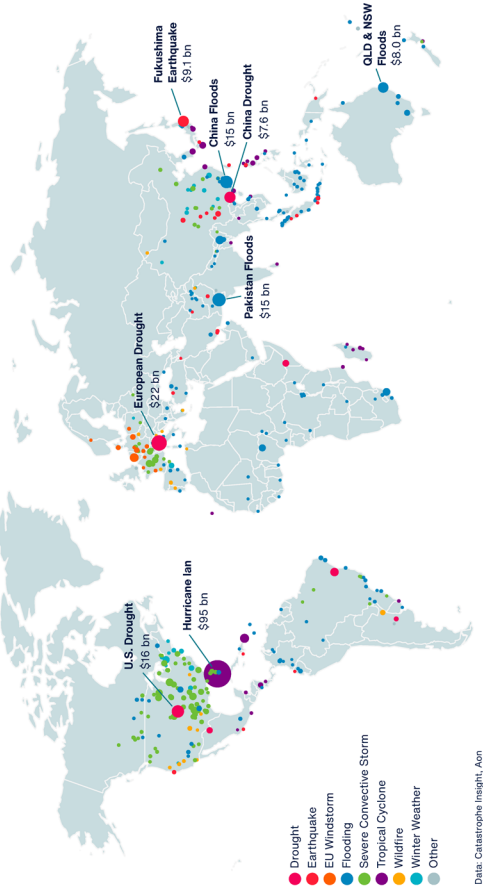
- Investments in real-time modeling and event response technology are vital to better mitigating risk and rebuilding post-event more quickly
- For a more resilient workforce, organizations must develop plans that focus on the direct and indirect impacts of climate change on the health and wellbeing of their people
- Re/insurers can drive the future of the global economy by helping to accelerate the journey to net zero emissions

Along with this report, we welcome readers to access current and historical natural catastrophe data and event analysis at catastrophinsight.aon.com



Global Economic Losses Near the 21st Century Average

Exhibit 1: Significant 2022 Economic Loss Events



Direct economic losses resulting from natural disasters in 2022 are estimated at \$313 billion. This is close to the 21st century average, after adjusting actual incurred damage to today's dollars using the U.S. Consumer Price Index. Though 2022 was far from record-breaking in terms of overall losses, it saw many impactful and costly events across the globe.

Visualizing the geographic distribution of 2022 events allows for distinguishing certain patterns, including higher frequency of medium-sized Severe Convective Storm (SCS) events in the U.S. and Europe, and the prevalence of flooding events in Africa, Southeast Asia and Oceania.

The map primarily shows the economic impact, which to some extent correlates with concentration of wealth — this is not a result of a reporting bias. What this map does not highlight is the humanitarian crises and displaced communities, as many events with significant human impacts do not necessarily translate into a high financial toll in terms of direct damage.

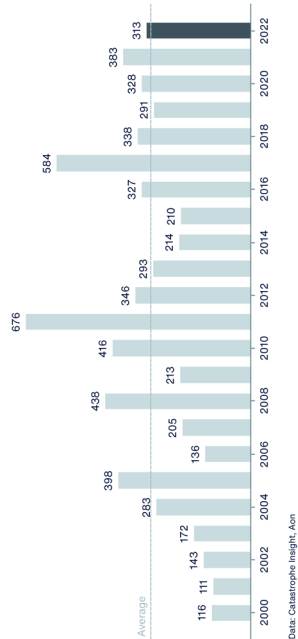
Note that significant price inflation throughout the year already resulted in notable increases of per-event losses.

Exhibit 2: Top 10 2022 Global Economic Loss Events

Date	Event	Location	Deaths	Economic Loss (\$ billion)	Insured Loss (\$ billion)
09/27 – 10/01	Hurricane Ian	United States, Cuba	157	95.5	52.5
Annual	European Drought	Southern, Western and Central Europe	N/A	22.0	3.0
Annual	U.S. Drought	United States	N/A	16.0	8.0
06/14 – 10/30	Pakistan Seasonal Floods	Pakistan	1,739	15.0	0.1
06/01 – 09/30	China Seasonal Floods	China	195	15.0	0.4
03/16	Fukushima Earthquake	Japan	4	9.1	2.9
02/23 – 03/31	QLD & NSW Floods	Australia	22	8.0	4.0
Annual	China Drought	China	N/A	7.6	0.2
02/18 – 02/19	Windstorm Eunice	Western and Central Europe	17	4.5	3.4
05/17 – 10/31	India Seasonal Floods	India	2,135	4.2	0.1
All other events			~27,100	115.6	57.4
Totals			~31,300	313 billion	132 billion

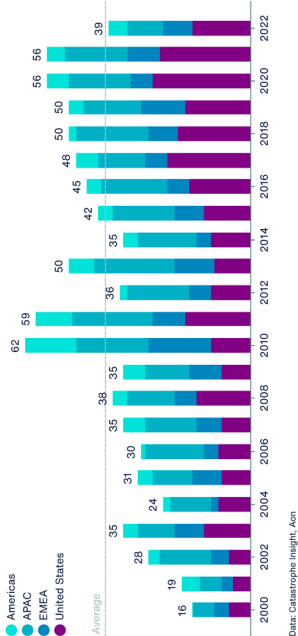
At least five events topped the economic loss threshold of \$10 billion. Hurricane Ian dominated the ranking with an aggregated toll of approximately \$95.5 billion – more than the next seven events combined. Three drought events in the table of 10 costliest events underline the growing significance of the peril on a global scale. Particularly, cumulative drought losses in European countries were at their highest since the historic summer of 2003, while the U.S. had the worst drought since 2012 in terms of overall economic losses. Floods in Pakistan were the costliest event for the peril, tied with seasonal flood losses in China, which were at their lowest since 2015. All but one event in the table were weather- and climate-related; the only two geophysical disasters that topped \$1 billion in economic losses in 2022 were the March Fukushima Earthquake in Japan and September Sichuan Earthquake in China.

Exhibit 3: Global Economic Losses from Natural Disasters (2022 \$ bn)



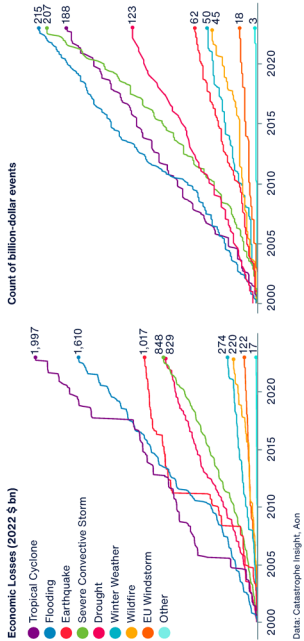
Global economic losses from natural disasters in 2022 were close to the 21st century average (\$301 billion) and median (\$292 billion) on price-inflated basis and reached approximately \$313 billion. They were 6 percent and 4 percent lower based on the average and median, respectively, of the last decade. Focusing on weather-related disasters only, total losses in 2022 were roughly 17 percent above the average since 2000, yet still lower than the short-term mean and median statistics and reached approximately a half of losses in the record year of 2017.

Exhibit 4: Global Billion-Dollar Economic Loss Events



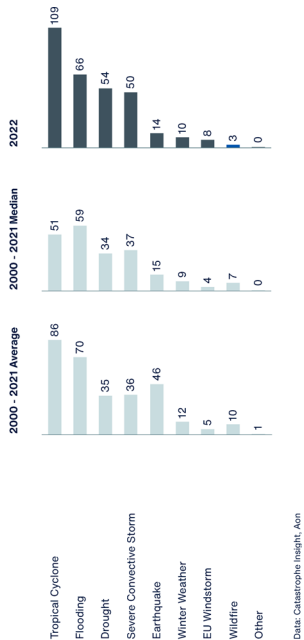
In 2022, there were at least 39 individual billion-dollar natural disasters, which was below the average of 40. Please note that U.S. wildfires are treated as individual events. For some years in the Exhibit 4, tropical cyclone events in the Atlantic Basin resulted in billion-dollar losses in both the U.S. and elsewhere in the Americas. Such occurrences are only included once. Please note that loss development for 2022 events expected in the coming months may increase of the total.

Exhibit 5: Cumulative Global Economic Losses by Peril



Tropical cyclone remains the costliest peril on a cumulative basis since the start of the 21st century. Driven by extreme loss years, such as 2022, 2017, 2005 and 2004, it is nearing the \$2 trillion aggregated loss. The historical record also shows that roughly half of these cumulative losses were caused by only 10 individual events, including Hurricane Ian. While the earthquake peril holds the title for the costliest natural disaster ever recorded, the Great Tohoku Earthquake and Tsunami in 2011, it failed to generate an event exceeding the \$10 billion loss threshold since 2016.

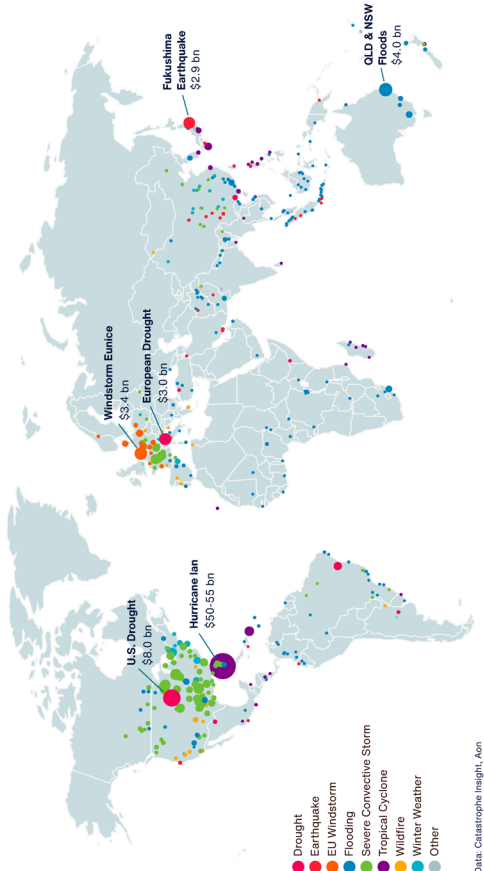
Exhibit 6: Global Economic Losses by Peril (2022 \$ bn)



Accelerating frequency of costly SCS events will likely result in the peril dominating the cumulative count of billion-dollar events in the following years. With more than \$100 billion of economic losses, tropical cyclone was by far the costliest natural peril of 2022, with vast majority of losses resulting from Hurricane Ian. The peril was well above its 21st century average and median statistics. Other perils that exceeded their mean losses were Drought, SCS and European Windstorm.

Global Insured Losses Surpass \$100B for the Third Time in a Row

Exhibit 7: Significant 2022 Insured Loss Events



Data: Catastrophe Insight, Aon

Global insured losses from natural disasters in 2022 are estimated at \$132 billion, well above the short-, medium- and long-term averages. Roughly 42 percent of direct aggregated economic losses were covered by public and private insurance entities, translating to a global protection gap of 58 percent. While a large part of the global disaster losses remains uninsured, this was one of the lowest protection gaps ever recorded, close to the record year of 2005 when roughly 40 percent of losses were covered.

This is largely because both years saw extremely costly hurricane events in the U.S., a country exhibiting a relatively mature insurance market. While Asia, a region with a developing market and relatively low coverage, saw costly flooding events in Pakistan, India and China, overall economic losses in the region were still below average.

The protection gap remains a critical reference point for the insurance industry, financial markets and governments as it highlights the vulnerability of communities and the opportunity for new solutions.

To read more regarding available re/insurance industry capital and the health of the overall market, please refer to [Aon's Reinsurance Market Dynamics Report](#).

Exhibit 8: Top 10 2022 Global Insured Loss Events

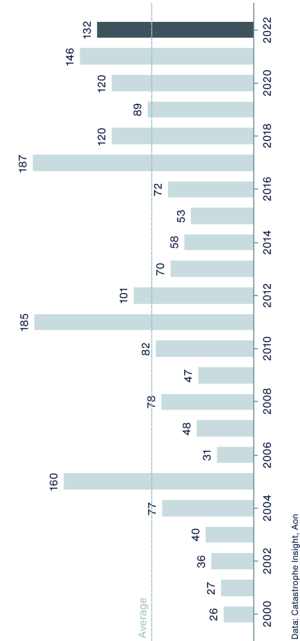
Date	Event	Location	Deaths	Economic Loss (\$ billion)	Insured Loss (\$ billion)
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Annual	U.S. Drought	United States	N/A	16.0	8.0
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02/18-02/19	Windstorm Eunice	Western and Central Europe	17	4.5	3.4
Annual	European Drought	Southern, Western and Central Europe	N/A	22.0	3.0
03/16	Fukushima Earthquake	Japan	4	9.1	2.9
06/11-06/17	Severe Convective Storm	United States	3	3.4	2.7
04/10-04/14	Severe Convective Storm	United States	1	2.8	2.3
05/11-05/12	Upper Midwest Derecho (SCS)	United States	5	2.7	2.2
05/19-05/22	Severe Convective Storm	United States	2	2.6	2.1
All other events			~31,100	146.1	49.2
Totals			~31,300	313 billion	132 billion

Hurricane Ian was by far the costliest event of the year for the global re/insurance industry and became the second costliest natural disaster ever recorded in terms of insured loss on a price-inflated basis, only surpassed by Hurricane Katrina, which resulted in more than \$99 billion losses (in 2022 \$) after its devastating impact in 2005. Ian is anticipated to surpass the second costliest disaster so far, the Great Tohoku Earthquake and Tsunami of 2011.

No other event reached the \$10 billion-dollar mark, yet there were at least 10 multi-billion-dollar events. Remarkably, the floods in Queensland and New South Wales in February and March resulted in insured losses of \$4 billion, the highest loss in the history of the Australian insurance sector. Similarly, April floods in South Africa were the costliest for the country, with estimated \$1.8 billion in insured losses.

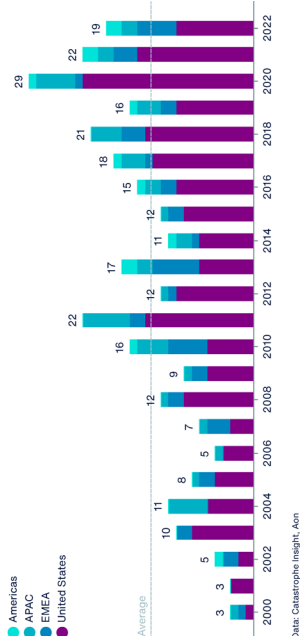
It is also noteworthy that two drought events (in the U.S. and Europe) are featured in the table of top 10 costliest events, which only occurred once before, in 2003.

Exhibit 9: Global Insured Losses from Natural Disasters (2022 \$ bn)



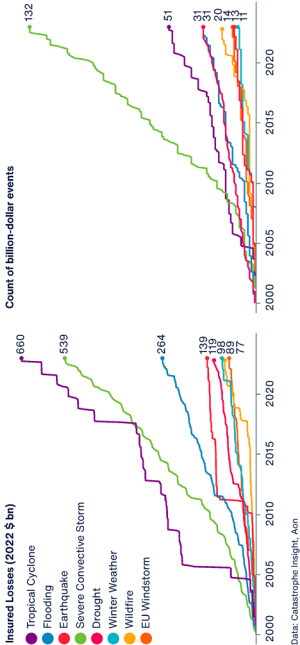
Total insured losses were well above the 21st century average (\$84 billion) and median (\$75 billion), yet lower than 2021 (\$146 billion) and slightly below the average of the last five years (\$132 billion), during which the industry saw elevated losses. It was the third consecutive year when losses surpassed \$100 billion, and only the 8th time that this threshold was exceeded. Depending on the eventual financial impact of Hurricane Ian and potential loss development for other significant events, 2022 is anticipated to rank as the fifth costliest year on record for insurers.

Exhibit 10: Global Billion-Dollar Insured Loss Events



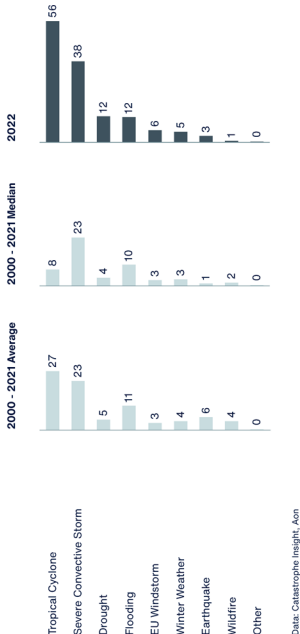
In 2022, there were at least 19 individual billion-dollar natural disasters, which was above the average of 13. Please note that U.S. wildfires are treated as individual events. For some years in the Exhibit 10, tropical cyclone events in the Atlantic Basin resulted in billion-dollar insured losses in both the U.S. and elsewhere in the Americas. Such occurrences are only included once.

Exhibit 11: Cumulative Global Insured Losses by Peril



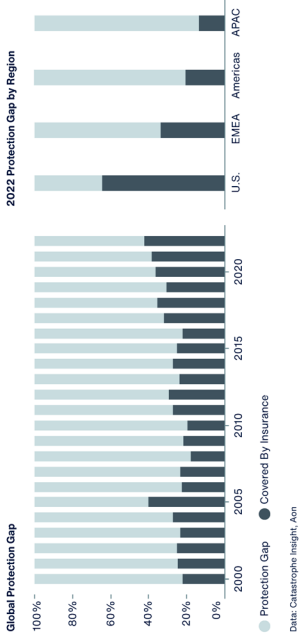
When viewing insured losses on a cumulative basis since the start of the 21st century, Tropical Cyclone is the costliest global peril. Like Earthquake, it is largely driven by extreme loss years and single catastrophic events, as opposed to SCS losses, which are driven by an increasing frequency of events. Approximately 40 percent of cumulative losses from Tropical Cyclone were caused by only five Atlantic Hurricanes — Katrina, Ian, Irma, Ida and Sandy. On the other hand, the number of costly SCS events outpaced other perils by a large margin.

Exhibit 12: Global Insured Losses by Peril (2022 \$ bn)



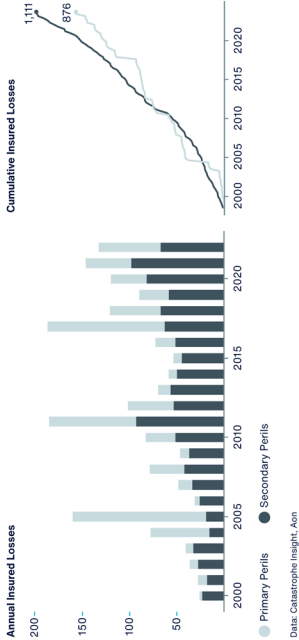
Tropical Cyclone was the costliest peril globally, followed by SCS. Notably, Drought had its second costliest year after 2012 due to elevated losses in both the U.S. and Europe. The only other peril that was above the long-term averages and medians was European Windstorm. Losses from the latter on an inflation-adjusted basis were the highest since 2013 and Windstorm Eunice became the costliest individual windstorm since Xynthia in 2010. The entire sequence of windstorms on February 16 to 21 — Dudley, Eunice and Franklin — resulted in aggregated losses of \$4.7 billion.

Exhibit 13: Global Protection Gap



Closing the protection gap remains a global challenge. However, preliminary data shows that 2022 likely saw one of the lowest protection gaps on record with roughly 42 percent of losses covered; this is only matched by 2005. In both years, costly disasters occurred in the U.S. and losses in less-developed markets were below average. Since 2017, the protection gap was always under 70 percent, which previously only occurred in 2005.

Exhibit 14: Insured Losses from Primary/Secondary Perils (2022 \$ bn)



While the natural perils traditionally considered as primary or peak (Tropical Cyclone, Earthquake and European Windstorm) have resulted in the highest individual event losses this century, aggregated losses from the other types of disasters have already outpaced their cumulative costs. One of the factors that are driving this shift is the consistent increase of SCS losses.

Global Fatalities Remain Below Average for 12 Years in a Row

Exhibit 15: Top 10 Human Fatality Events

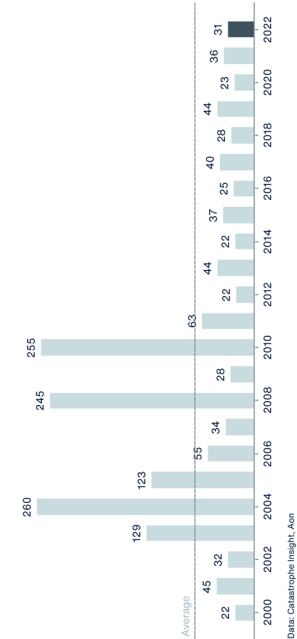
Date	Event	Location	Deaths	Economic Loss (\$ billion)
07/10-07/20	Heatwave	Western, Southern and Central Europe	15,450	N/A
06/13-06/19	Heatwave	Western, Southern and Central Europe	3,750	N/A
05/17-10/31	India Seasonal Floods	India	2,135	4.2
06/14-10/30	Pakistan Seasonal Floods	Pakistan	1,739	15.0
06/22	Earthquake	Afghanistan, Pakistan	1,163	0.1
07/01-10/31	Nigeria Seasonal Floods	Nigeria	660	2.3
11/21	Cianjur Earthquake	Indonesia	603	0.4
04/08-04/15	KwaZulu-Natal Floods	South Africa	455	3.6
02/15-02/16	Rio de Janeiro Floods	Brazil	232	<0.1
04/08-04/13	Tropical Storm Megi	Philippines	214	<0.1
All other events			~4,900	287.0
Totals			~31,300	313 billion

Approximately 31,300 people lost their lives due to global natural catastrophe events in 2022, which was well below the 21st century average (73,200) and median (38,900). Roughly two thirds of these fatalities can be directly attributed to heatwaves that occurred in Europe in June and July. It is worth noting that heatwaves in China and other countries also resulted in significant health impacts, yet reliable estimates will not be released until later in 2023. Thousands of people were also killed in South Asia as a result of significant seasonal floods in India and Pakistan. Other notable floods included events in Nigeria and South Africa, as well as in China and Brazil.

The number of annual human casualties has shown a notable decline in recent decades. The improvements in forecasting, evacuation planning and strategies, increased public awareness and better building practices have all played a key role. Asia, Africa and South America show the greatest improvements with reduced fatalities.

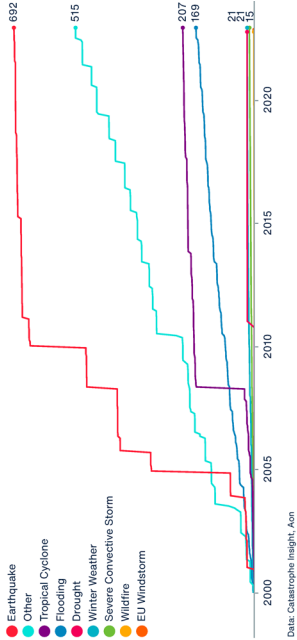
Please note that confirmed fatalities and missing people presumed dead are included in the totals.

Exhibit 16: Global Natural Disaster Fatalities (thousands)



Earthquake peril is responsible for the largest part of disaster-related fatalities in the 21st century. This human toll is mainly driven by individual catastrophic events in the Indian Ocean (2004), Haiti (2010), Pakistan (2005), China (2008) and Iran (2003). These five events alone account for more than 600,000 fatalities, or roughly a third of all deaths attributed to natural disasters since 2000. This statistic now accounts for heatwave-related fatalities in a more systematic manner and yearly totals are notably higher (see section on Heatwaves in the next chapter).

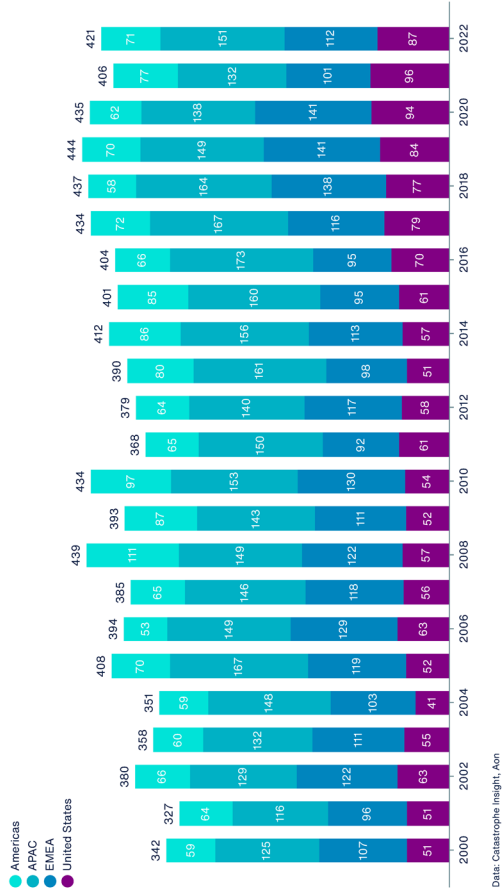
Exhibit 17: Cumulative Global Fatalities by Peril (thousands)



On the other hand, steadily increasing cumulative death toll from heatwaves (represented in the “Other” category) underlines the growing significance of perils that most importantly pose a threat to human health and wellbeing, and not necessarily a physical risk to property and infrastructure.

Natural Disasters Defined: Number of Events on the Rise

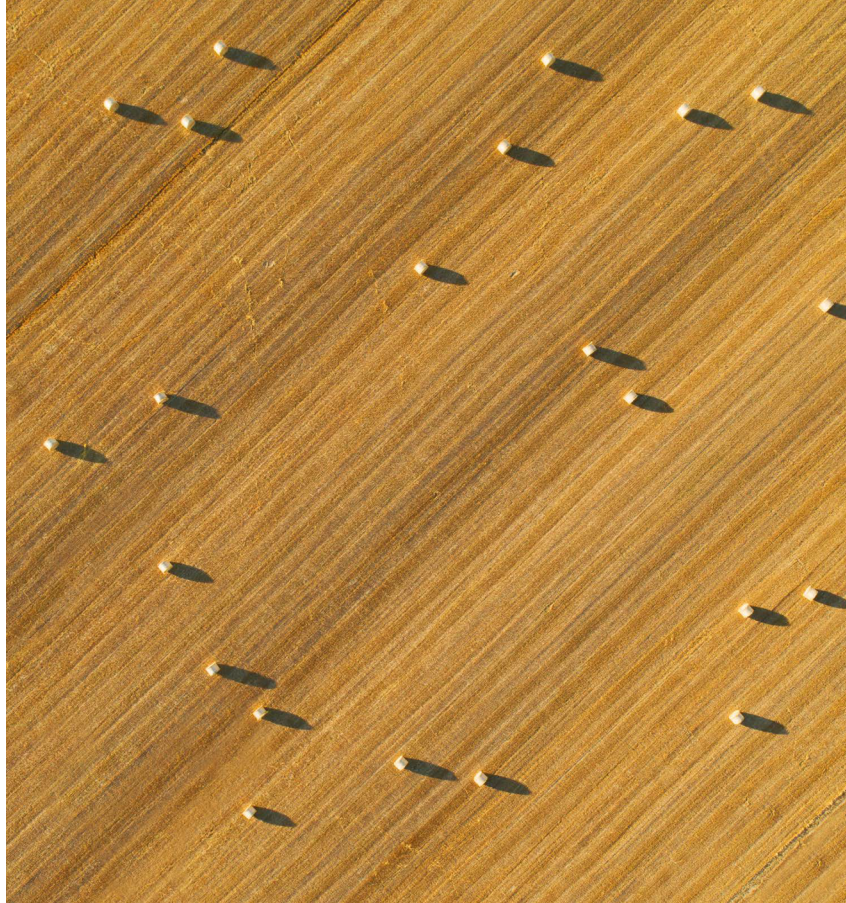
Exhibit 18: Number of Relevant Natural Disaster Events



An event must meet at least one of the following criteria to be classified as a natural disaster in the Aon's Catastrophe Insight Database:

- Economic Loss: \$50 million
- Insured Loss: \$25 million
- Fatalities: 10
- Injured: 50
- Structures Damaged or Filed Claims: 2,000

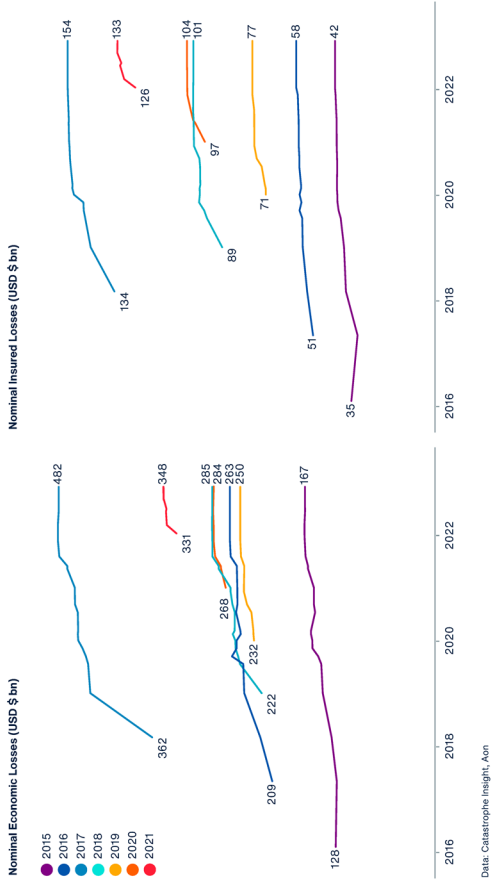
Based on the noted criteria above, there were at least 421 individual natural disasters in 2022, which was slightly above both the average (396) and median (398) since 2000. Additional 2022 events may be added later due to further research and data updates. As typically anticipated given the highest frequency of SCS, flood and tropical cyclones, the highest number of disaster events occurred during the second (133) and third (113) quarters.



Why Robust
Historical Data
Is Crucial for
Identifying Trends

Loss Development and Historical Data Research

Exhibit 19: Revisions of Global Annual Nominal Losses since First Publication

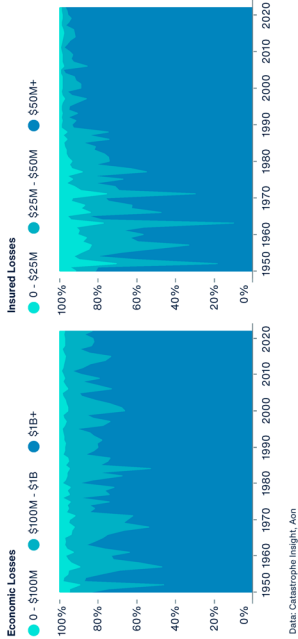


Since the release of the 2018 Weather, Climate and Catastrophe Insight Report, Aon's Catastrophe Insight team has utilized a new historical natural disaster dataset. The change introduced many records previously not included in the analysis, largely due to thorough research of various sources, including academic papers and national databases. The change aimed to significantly improve data quality in previously underreported countries, which do not exhibit a breadth of data easily available.

This process helps fill data gaps in many regions around the world. Some countries, like the U.S. and various other developed nations, have much more detailed and prolonged data records available. Most countries, however, do not. This results in incomplete views of historical events beyond a few decades.

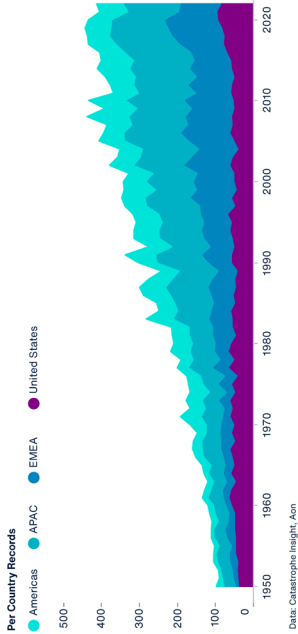
The Catastrophe Insight team also emphasizes updating existing event records as new data is identified. The "final" event loss total can dramatically change from its initial estimation extended over a multi-year period. The combination of topics like loss creep, claims litigation, Assignment of Benefits (AOB), higher replacement costs or demand surge, delayed releases of official damage estimates or agency releases on a quarterly or annual basis can all explain why losses may update years after event occurrence.

Exhibit 20: Portion of Global Disaster Losses by Event Size



It is generally understood that most natural disaster databases show a significant decline in the number of annual global events prior to 1980. While the biggest events are typically captured and are the most important to explain total losses, as captured on Exhibit 20, most small and medium-sized events are often missed. While Aon's data reanalysis process has not completely removed the data gap, it has made major progress in identifying a large portion of events not previously catalogued in other databases.

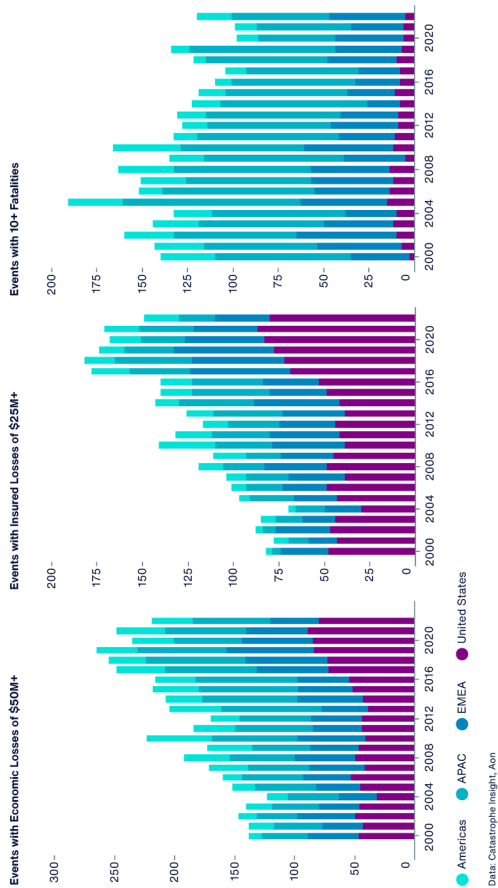
Exhibit 21: Number of Events by Region



Along with the addition of events not previously included in the database, a significant effort has been made to ensure a full country-level breakout of event losses. In many instances, the loss breakout helps identify trends beyond the peril aggregate and down to a more regional or localized level. For example, thorough research since 2017 resulted in the increase in China-specific entries from 621 to 1,869. Similarly, number of Canada entries increased from 406 to 968.

Is the Number of Natural Disasters Increasing Globally?

Exhibit 22: Number of Natural Disaster Events Based on Different Criteria



The answer to this question depends on how natural disaster is being defined. This is crucial before conducting any meaningful analysis and at least to some extent eliminates biases related to the reporting of events.

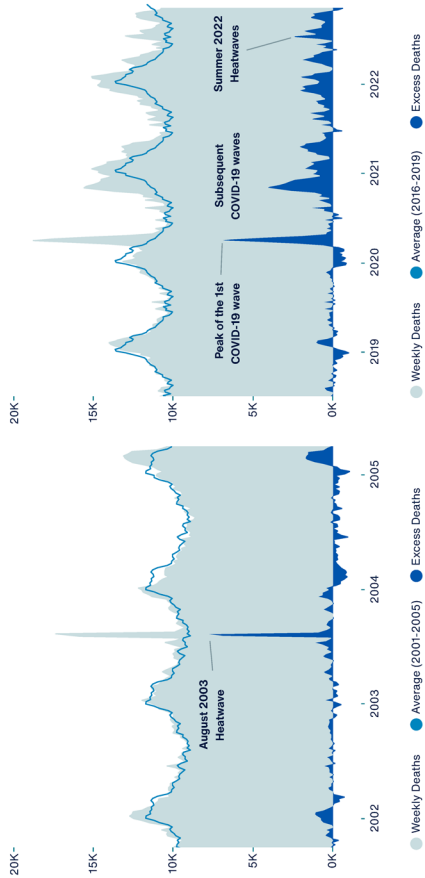
Expanding our knowledge through scientific research and climate modeling can help us determine whether the physical hazard itself is getting worse or not, what are the implications on different types of perils and how this varies across regions.

Looking at disasters as events that cause material and human impact, damage or fatality statistics can be used to define them. It is important to note that socio-economic factors remain the primary driver of an increasing number of damaging events. In 2022, the world human population exceeded 8 billion and since 2000 increased approximately 30 percent. In the same timeframe, the global GDP increased by a staggering 80 percent (in constant prices). Increasing exposure and wealth is expected to result in higher and more frequent losses, even if the hazard remained the same.

Remarkably, natural disasters defined as events that cause a certain number of fatalities has been decreasing globally this century, likely thanks to improving resilience, warning systems, disaster response or adaptation measures.

Heatwaves: Accounting for Climate-Driven Perils

Exhibit 23: Example of Weekly Mortality Data Assessment for France



Data: HMD, Human Mortality Database, Max Planck Institute for Demographic Research (Germany), University of California, Berkeley (USA), and French Institute for Demographic Studies (France). Available at www.mortality.org.
Graphic: Catastrophe Insight, Aon

Many regions of the world experienced severe and prolonged heatwaves in 2022, and their frequency and intensity are anticipated to increase in the coming decades. Catastrophe Insight started accounting for heat-related fatalities in a systematic manner using our own methodology and calculation to assess the heat impact. These assessments were primarily based on mortality data provided by [Human Mortality Database \(HMD\)](#) and methodology established in academic papers. The HMD provides detailed high-quality harmonized mortality and population estimates, particularly for European countries.

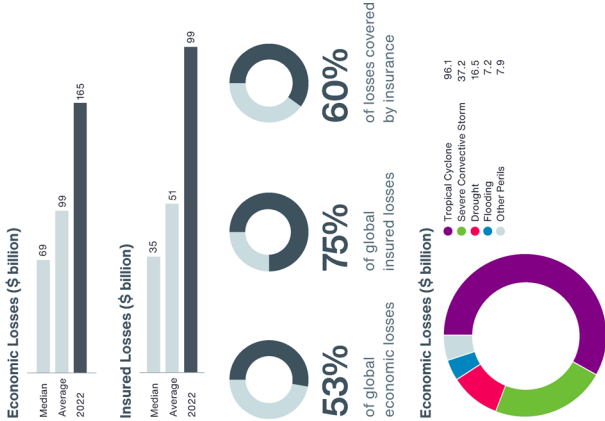
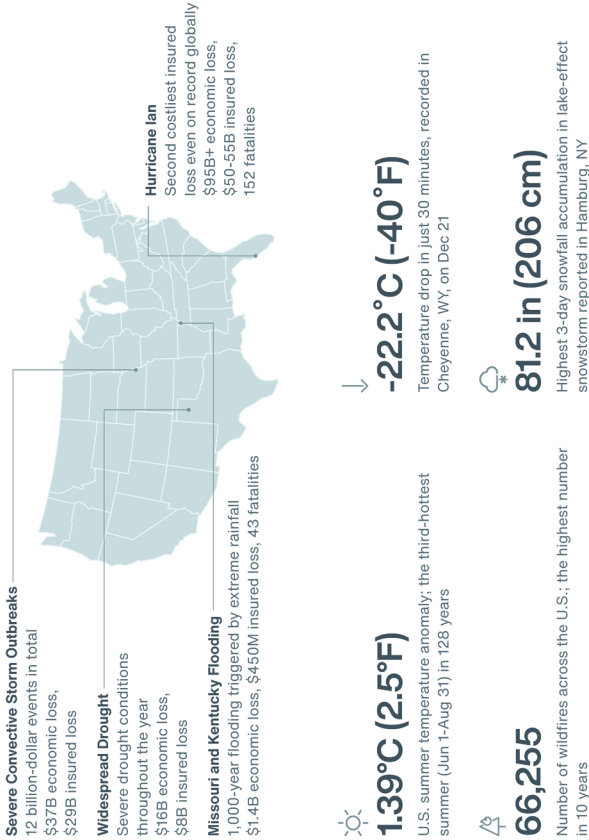
Individual heatwaves were identified according to meteorological conditions. Mortality data for the weeks when a heatwave occurred were then compared with average mortality based on previous and following years to estimate excess mortality attributable to the heatwave. Weekly data, when available, also allows the assessment of individual heatwaves throughout the year. Additionally, COVID-19-related deaths, which complicate analysis of heatwaves in 2020-2022, were excluded.

As a result of filling this gap, the number of heat-related fatalities increased by nearly 410,000 — from 90,000 to almost 500,000 deaths.



2022 Regional Catastrophe Review

United States



Economic and insured losses from natural disasters in the U.S. were substantially above the long-term means in 2022. Total economic losses were preliminarily estimated at \$165 billion, which was more than 65 percent above the average since 2000 and about 140 percent higher than the median of the same period. Public and private insurers covered approximately \$98 billion, which was more than 90 percent, or approximately 180 percent above the average and median, respectively.

Despite initial expectations of a relatively active season, only two significant tropical cyclones made landfall on the U.S. mainland. One of them, however, ended up being the second costliest event in term of insured loss in recorded history, Hurricane Ian made landfall in Florida on September 28 as a Category 4 storm and caused widespread destruction and 152 deaths. With insured losses well into the tens of billions, the event sent shock waves through the re/insurance industry in an already challenging period.

The only other significant tropical cyclone to affect the U.S. in 2022 was Nicole, which impacted Florida in November.

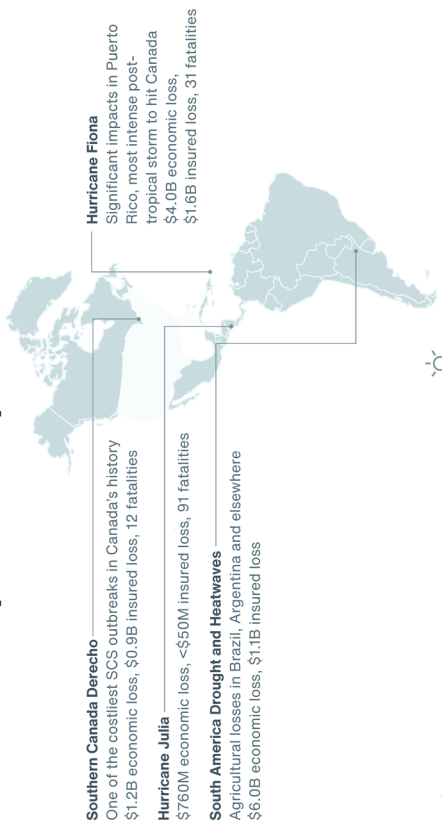
SCS events once again drove substantial part of the total financial toll. The peril generated nearly \$29 billion of insured losses in total, which makes 2022 the third costliest year for the peril in the country, only behind 2020 and 2011. There were at least five multi-billion-dollar outbreaks in April, May and June. The costliest event of the year was the outbreak on June 11-17, which resulted in total economic losses of \$3.4 billion and insured losses of \$2.7 billion.

Late-December Arctic outbreak and winter storms across the central and eastern United States resulted in dozens of fatalities and significant financial loss but did not reach the intensity and extent of the historic freeze event from February 2021.

The Western U.S. continued to experience severe drought conditions, driving the annual nationwide economic losses from the peril well beyond \$10 billion. Crop insurance payouts due to drought were at their highest since the historic losses experienced in 2012.



Americas (Non-U.S.)

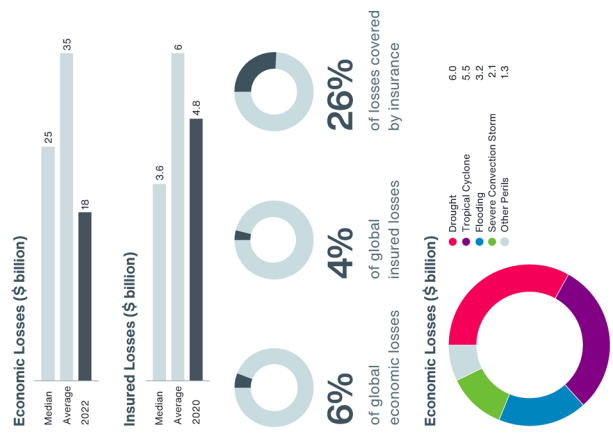


 **1,000 km (620 mi)**
Approximate length of the May derecho in Canada

 **125 mph (201 kph)**
Sustained wind speed during Ian's landfall in Cuba on September 27

 **41.1°C (106.0°F)**
Buenos Aires, Argentina's capital, saw its second hottest day since 1906 during mid-January heatwave

 **931.6 mbar**
Fiona's central pressure during landfall in Canada, breaking national all-time record from 1977



The overall economic loss total for the Americas (non-U.S.) was roughly \$18 billion, of which public and private insurance entities covered \$4.8 billion. Economic losses in 2022 were lower than this century's average (\$35 billion), yet this statistic is skewed by extreme loss years of 2010 and 2017. The losses were also lower than the median of the same period (\$25 billion). Insured losses were also below average by 20 percent, but 33 percent higher than the median. While 2021 brought impactful events mainly to Western Canada, main disaster activity in 2022 shifted to the eastern half of the country. Hurricane Fiona became the strongest tropical or post-tropical storm to impact the country, as it brought significant wind-related damage and coastal impacts to the eastern provinces. On May 21, a significant derecho with a span of approximately 1,000 km (620 mi) impacted the most densely populated area of the country, including major cities in Ontario and Quebec. The storm system became one of the country's costliest SCS outbreaks on record.

Prior to making landfall in Eastern Canada, Fiona brought significant impacts to the Caribbean, and Puerto Rico in particular, causing multi-billion-dollar economic losses to the island severely devastated five years prior by Hurricane Maria. Julia was another notable tropical cyclone to affect Central America and to some extent also parts of South America. Some of the most severe impacts were reported from Nicaragua. While much of Brazil continued to face drought conditions at the beginning of the year, multiple notable flooding events impacted the country. In particular, the northeastern states of Pernambuco and Alagoas endured flooding in May and July, while Rio de Janeiro saw deadly flooding with 232 fatalities in February. Significant drought losses were not limited to Brazil and were also reported from other Latin American countries, including Mexico and Argentina.



EMEA (Europe, Middle East and Africa)



February Windstorm Series
Windstorm Eunice became the costliest individual storm since 2010
\$6.2B economic loss, \$4.7B insured loss, 26 fatalities

European Drought and Heatwaves
Severe drought with substantial losses in agriculture, amplified by major, deadly heatwaves in June and July
\$22.0B economic loss, \$3.0B insured loss, 19,200 fatalities

Nigeria Seasonal Floods
Severe floods affected more than 4.4 million people across Nigeria
\$2.3B economic loss, <\$100M insured loss, 660 fatalities

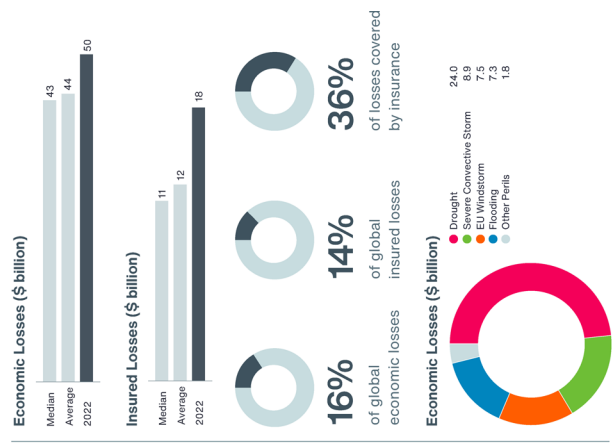
KwaZulu-Natal Floods
One of the deadliest and costliest flood events on record in South Africa
\$3.6B economic loss, \$1.8B insured loss, 455 fatalities

40.3°C (104.5°F)
Highest national temperature ever recorded in the United Kingdom; record set on July 19

196 kph (122 mph)
Wind gust recorded at The Needles during Windstorm Eunice, highest on record for England

6
Number of cyclones that affected Madagascar and caused 220 deaths

1.5M ha (3.7M acres)
Total area burnt by forest fires in Europe, Middle East and North Africa



Total economic losses from natural disasters in EMEA region in 2022 reached approximately \$50 billion. This was roughly 12 percent above the average since 2000 (\$44 billion), yet significantly lower than 2021, which ranks as the fifth costliest year on record for the region with total losses of \$82 billion.

Insurers covered \$18 billion, which was nearly 36 percent of total economic losses and well above the long-term average (\$12 billion) and median (\$11 billion).

The most significant event for the insurance industry in Europe was a sequence of windstorms that affected the continent in February. Storms Dudley, Eunice and Franklin resulted in aggregated insured losses of \$4.7 billion. Storm Eunice was the most intense of the three and became the costliest individual storm to affect Europe since Xynthia in 2010. European Windstorm losses were thus well above average, despite the lack of any significant storms and practically negligible losses in the fourth quarter of the year. The quarter was the quietest first half of a windstorm season in this century. Severe Convective storms also resulted in above-average losses for insurers and the peril had the

third costliest year on record, only behind 2013 and 2021. These losses were largely driven by significant hailstorms that impacted France in May and June.

Drought conditions affected much of Europe and were amplified by deadly heatwaves in June and July, when numerous temperature records were broken, including the record high temperature in the United Kingdom. Aggregated drought-related impact, including agricultural losses or property damage due to land subsidence, reached more than \$22 billion. Severe drought also continued to affect the Horn of Africa, amplifying the humanitarian crisis in the region.

Other parts of the African continent experienced notable flooding events. In particular, deadly floods in the KwaZulu-Natal Province, including the city of Durban, resulted in 455 fatalities and multi-billion-dollar losses. The floods became the costliest event for the national insurance industry on record.

Widespread seasonal flooding also impacted several countries in West Africa, notably Nigeria, affecting millions of people.



APAC (Asia and Pacific)

Pakistan Floods

Severe monsoonal floods affected much of the country
\$15B economic loss, 1,739 fatalities

Afghanistan and Pakistan Earthquake

Deadliest tremor of 2022 and the deadliest in Afghanistan since 1998
\$120M economic loss, 1,163 fatalities

China Drought and Heatwave

Record number of heatwave days
\$ 7.6B economic loss

Queensland and New South Wales Floods

Costliest event on record for Australian insurance sector
\$8.0B economic loss, \$4.0B insured loss, 22 fatalities



+180% and +243%

Rainfall anomalies in Pakistan as the country recorded its wettest July and August since 1961



2,530 mm (99.6 in)

Wettest year on record for Sydney, Australia



3

Number of super typhoons in 2022 (Hinnamnor, Nannamdoi, Noru)



40.9°C / 105.6°F

Hottest day on record in Shanghai since records began in 1873 (July 14)



Economic Losses (\$ billion)



Insured Losses (\$ billion)



26% of global economic losses
8% of global insured losses
14% of losses covered by insurance

Economic Losses (\$ billion)



Total economic losses in the APAC region in 2022 reached \$80 billion with a substantial protection gap of 86 percent. Flood losses continued to maintain dominance as the costliest peril for the third consecutive year, accounting for more than 61 percent of the loss total. Much of the flood losses in 2022 occurred in South Asia, where the insurance penetration remains very low.

Economic losses were 35 percent lower than the average and 21 percent below the median of the 21st century.

Insured losses in the APAC region reached approximately \$11 billion and were notably below the average (\$15 billion), yet as the statistic is skewed by an outlier year of 2011, losses were 18 percent higher than the median. Roughly a third of the APAC losses were related to catastrophes in Australia.

Widespread flooding in Queensland and New South Wales in February and March resulted in \$8 billion of economic and \$4 billion of insured losses. The event thus became the costliest event for the local insurance sector on record on an inflation-adjusted basis.

In Asia, flooding remained a recurring threat with annual losses exceeding \$30 billion every year since 2010. Many places saw record rain and significant flooding in 2022 — Pakistan, India, southern China and South Korea.

In particular, the South Asia floods resulted in \$19 billion economic loss and flooding in China contributed another \$16 billion.

Tropical cyclone losses for Asia and Oceania were 75 percent and 91 percent below their 21st century averages, respectively. This greatly contributed to the relatively low natural disaster losses for 2022. Number of fatalities from tropical cyclones were also lowest in at least 66 years. This is not only a result of below-average activity, but also improved disaster response and adaptation measures.

The APAC region was rocked by several large earthquakes in 2022. Nearly 2,000 fatalities were reported and at least 300,000 homes were damaged in total, most notably from the earthquakes in Afghanistan, Pakistan, Indonesia, China, the Philippines and Japan.

High temperatures hit India and Pakistan early in March, leading to the hottest March for both countries. In Japan, a record number of people were admitted to hospitals due to heatwaves, which followed an early end to the plum rain season. China had its second driest summer and most extensive and longest heatwave on record.

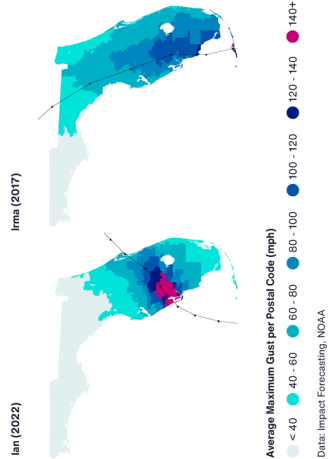




2022 Natural Peril Review

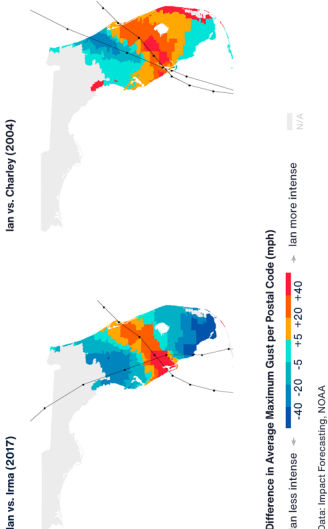
Hurricane Ian Second Only to Katrina For Insured Loss

Exhibit 24: 2022 Wind Footprints of Hurricanes Ian, Irma and Charley



Hurricane Ian made its devastating landfall in southwestern Florida on September 28 and resulted in tremendous damage across the peninsula, with additional damage incurred later in the U.S. Southeast. The storm tied as the fifth strongest hurricane to make landfall in the U.S., inflicting one of the highest damage totals (>\$95 billion) in Florida. Ian became the second costliest insured loss event on record globally, surpassed only by Hurricane Katrina (2005). Apart from wind damage, Ian also resulted in severe storm surge, aided by the shallow bathymetry off the coast of southwestern Florida. Low pressure and Category 4 winds pushed a 10 to 15 ft (3 to 4.6 m) surge inland.

Exhibit 25: 2022 Comparison of the Wind Footprints



Hurricane Ian's wind footprint can be compared to those of hurricanes Irma (2017) and Charley (2004). While Ian was characterized by the highest landfall intensity out of the 3 storms, it affected a smaller portion of Florida than Irma. At the same time, it retained major hurricane status further inland. While Hurricane Charley (2004) impacted Florida with a similar intensity and made landfall in almost the same location as Ian, its overall impact differed due to different storm characteristics, structure, interaction with land, as well as other factors.

Hurricane Ian's devastating impact provided a valuable lesson for communities in vulnerable areas to take proactive steps to protect their homes and businesses. Florida's enhanced building codes proved effective in mitigating damage from Hurricane Ian — serving as a success story for other states similarly vulnerable to hurricanes. Commercial and residential properties with mitigation measures such as flood vents, updated roofs and hurricane shutters inherent to their construction were able to withstand the storm's wrath and limit damage.

Eight Atlantic hurricanes formed in 2022. Only two attained major hurricane status (Category 3+): Fiona and Ian. Despite an above-average hurricane season suggested by most forecast, the 2022 Atlantic Hurricane season eventually saw a near normal number of named storms (14). Overall seasonal activity still fell within NOAA's lower-bound estimates. This season is the first in eight years not to have a pre-season named storm before June 1, and tropical cyclone activity further ceased between July 3 and August 31 due to increased vertical wind shear, suppressed upper-tropospheric moisture, and the advection of the Saharan dust layer. The Accumulated Cyclone Energy (ACE), a metric that accounts for storm and/or seasonal intensity and longevity, ended up at 95 for the Atlantic Basin; 22 percent below the 1991-2020 average.

Hurricane Nicole was the only other hurricane to make landfall in the mainland United States in 2022, as it landed in North Hutchinson Island, Florida, as Category 1 storm.

Hurricane Fiona, also a Category 1 storm, resulted in significant damage in Puerto Rico and continued to strike eastern Canada as a post-tropical cyclone.

Eastern Pacific

The 2022 Eastern Pacific Hurricane season was slightly more active compared to 2021, with above-normal number of named storms (19), ten hurricanes, and four major hurricanes. The aggregate ACE was 116.5, up over 20 units from last year. The 2022 season finally saw an end to the consecutive streaks of November named storms.

Most storms in the Eastern Pacific did not track near land. However, four hurricanes made landfall, all in the Pacific coast of Mexico, during the season: Agatha, Kay, Oriene and Roslyn. This was the third time the record for the number of Pacific hurricanes landfalling in Mexico was reached. The previous years were 1996 and 2021. Additionally, Hurricane Agatha became the strongest hurricane to make landfall during the month of May in the Eastern Pacific basin since records started in 1949.

Northwest Pacific

The northwest Pacific basin recorded another successive year of below-normal tropical cyclone activity under prevailing La Niña conditions, with 22 named storms, 12 typhoons, and five category 3+ typhoons. This was lower than the basin's climatology from 1991-2020 with 25 named storms and 16 typhoons. ACE value dipped to 163.2, approaching half of the basin's long-term average, and was the fifth lowest since 1991. The bottom four also occurred during La Niña.

South Korea, Japan, and the Philippines each faced a super typhoon between late August and September.

Super Typhoon Hinnamnor, which lasted as a typhoon for eight days, packed the highest seasonal ACE (39) out of all basins' tropical cyclones this year. In China, Typhoon Muifa became the strongest typhoon to strike Shanghai

on record.

Exhibit 26: 2022 Global Tropical Cyclone Activity by Basin Compared to Climatology*

Basin	Named Storms		Hurricanes		Major Hurricanes		ACE	
	2022	Climo	2022	Climo	2022	Climo	2022	Climo
Atlantic	14	14	8	8	7	2	3	95.1
East Pacific	17	17	10	10	9	4	5	116.5
West Pacific	22	25	12	12	16	5	9	163.2
North Indian	7	5	1	1	2	0	1	10.5
Northern Hemisphere	60	61	31	31	34	11	18	385.3
South Pacific	5	10	1	1	5	0	2	20.4
South Indian	16	16	6	6	9	6	4	143.3
Southern Hemisphere	21	26	7	7	14	6	6	163.7
Global	81	87	38	38	48	17	25	549.0

North Indian Ocean

The 2022 North Indian Ocean cyclone season generated the lowest economic losses this century. Activity was near normal, with seven named storms and one hurricane, Asani, which made landfall in India only as a deep depression in early May. A dozen of precursor depressions formed in the basin, but majority of those dissipated before reaching storm status. Combined with the activity in northwest Pacific, economic losses arising from tropical cyclones in Asia were one of the lowest this season.

Southern Hemisphere

During the calendar year 2022, Cyclones Batsirai, Emnati and Gombé caused significant damage to southeastern Africa, particularly Madagascar. In Oceania, Cyclone Dovi caused notable damage in New Caledonia, New Zealand, and Vanuatu. No major damages were incurred in Australia.

Atlantic Ocean

- 2022 marked the first year with no tropical cyclones forming in a La Niña August. In fact, there were no named storms in the basin for at least 60 days
- Not only was Hurricane Ian the deadliest hurricane to strike the state of Florida, it also ranked globally as the second costliest insured loss event ever recorded
- Hurricane Fiona became the strongest recorded landfalling storm in Canada
- Hurricane Nicole was the first hurricane to make landfall on Florida's east coast since Katrina (2005)
- Hurricane Julia recorded the second most southerly course after Tropical Storm Bret (1993) by passing just off the coast of Venezuela
- With the first named storm Alex on June 5, pre-season storm formation finally ended after eight years
- Tropical Cyclone Bonnie made first crossover from the Atlantic to the Pacific since Hurricane Otto (2016)

Pacific and Indian Oceans

- Tropical cyclone losses in Asia dropped to one of its lowest with ACE scores in the northwest Pacific and north Indian respectively reaching their fifth and fourth lowest values since 1991
- Super Typhoon Noru became the fourth Category 5 equivalent storm to make landfall in the Philippines in the past three years.
- Typhoon Muifa is now the strongest typhoon to strike Shanghai on record
- Hurricane Agatha became the strongest hurricane to make landfall during the month of May in the Eastern Pacific basin since records started in 1949
- The Pacific coast of Mexico tied the record for the number of landfalling hurricanes in a second consecutive year
- Tropical Storm Ana, formed on January 20, became the latest first named storm in the basin since 1997



Technology Revolutionizes Real-Time Modeling and Response

Recent years have seen weather events drive up claims costs for businesses, communities and governments — increasing the need for real-time catastrophe monitoring, instant response and rapid assessment of damage.

Speed is critical: For communities, it's about an effective escape route while governments need to ensure the continuation of essential services. For insurance companies, it's about knowing where to send experts to survey the damage and deliver claims payments to help customers quickly repair or rebuild.

Modeling a storm before and during landfall

To better inform insurers and organizations as soon as possible, Aon's Impact Forecasting team developed Automated Event Response (AER). AER covers everything from windstorms in Europe to North Atlantic hurricanes and typhoons in Japan — using windstorm or tropical cyclone forecasts from different meteorological institutions with Impact Forecasting's catastrophe models and insurer's portfolio data to produce automatic predictions of loss each time a new forecast data is issued.

Customized reports are sent to insurers automatically within 30-60 minutes of a forecast to help quantify the geographic scope, severity and projected cost of the event — even before the storm makes landfall. Insurers are then better equipped to make more decisions about managing claims adjustor resources, setting loss expectations and evaluating impacts to reinsurance structures.

AER allows businesses to protect and prepare their physical locations and staff. Consider a retailer with thousands of locations across a region that receives updated forecasts multiple times per day as a hurricane makes landfall. The business can gauge which locations likely to be hardest hit and how severely, while taking steps to ensure the safety their employees and the site location's security. That knowledge allows companies to prepare early — often quickening claims processing.

Using technology and data to improve disaster recovery

Sophisticated and instant response methods are equally important for assessing damage post event. Technology such as satellite imagery and drones are increasing used to immediately assess damage, particularly in hard-to-reach areas. For example, within 48 hours after an event, Aon's property claims team fly drones in impacted areas, then immediately send the footage to clients to measure their damage. Real-time footage helps expedite the payment of claims and increases claims assessment accuracy.

After Hurricane Ian in Florida, Aon used satellites to send clients images of initial damage on Captiva Island, located off Florida's Gulf Coast. Damage was extensive, and local authorities prohibited people and even drones from entering the island during rescue operations. While the satellite images weren't as clear as those generated by drone technology, they helped assess large-scale damage, such as partially or completely blown off roofs. Technology has enabled better insight as catastrophes unfold; it has also meant faster and more thorough assessment of damages after an event. Rapid adjustment and remediation often result in lower claims. And with claims costs rising due to factors like climate change, inflation and supply chain issues, clients are seeking savings opportunities as they build resilience.

Jill Dalton

Group Managing Director, Property Risk Consulting

Radovan Drinka

Head of Tropical Cyclone Model Development,
Impact Forecasting

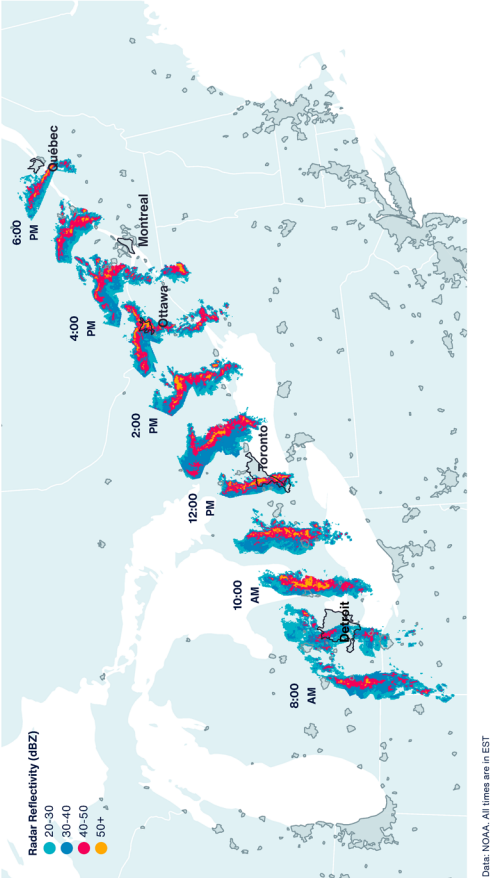
Will Skinner

Head of Business Development, Impact Forecasting



Severe Convective Storm Peril Marks the Fourth-Costliest Year on Record

Exhibit 27: Southern Canada Derecho on May 21 — Approximation of the Path Based on Radar Data

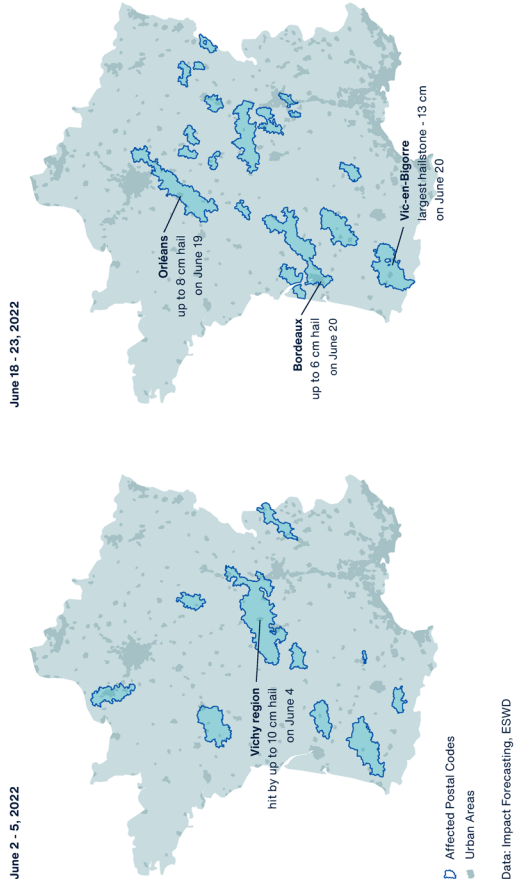


Severe Convective Storm peril once again generated a significant insured loss total in its fourth costliest year on record and reaffirmed its position as perhaps the most significant of those perils that are traditionally referred to in the industry as secondary. The losses, which have steadily increased this century, were again driven by a high frequency of medium-size events, and 78 percent of these losses occurred in the U.S., which is close to the average.

While majority of the loss was associated with hail, multiple wind-related events were particularly noteworthy. On May 21, a rare and deadly derecho (defined as a widespread, long-lived windstorm associated with a band of swiftly moving thunderstorms), tracked an estimated 1,000 km (620 mi) through highly populated regions of southern Ontario and Quebec in Canada. The event generated extraordinary straight line wind damage along its entire path, as it effectively hit all the major population centers in the region.

While the current scientific understanding of the SCS peril does not provide a conclusive, comprehensive answer to how exactly it is and will be affected by climate change, the Canadian derecho example shows that the geographic location and socio-economic aspects are crucially important loss factors.

Exhibit 28: June 2022 Hailstorms in France



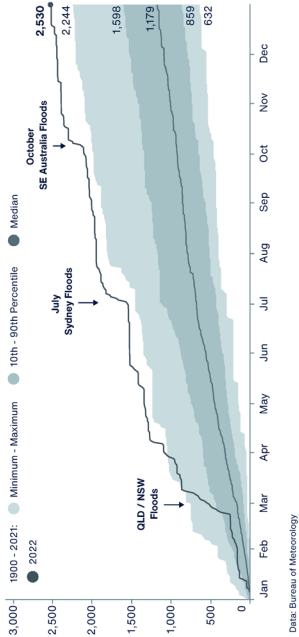
Significant SCS events also occurred outside of North America. In Europe, the peril generated insured losses totaling approximately \$6.7 billion. Even though the European Windstorm peril (or winter storms) is considered "primary" in the region and is responsible for the costliest individual events historically, annual losses from SCS (or summer storms) actually outpaced windstorms in nine out of the last 10 years. In fact, SCS was the costliest peril in Europe in seven out of the last 10 years overall.

In 2022, majority of the European insured losses from SCS occurred in France as the country recorded its costliest year for the peril by far and the second costliest year overall. This was driven by relentless thunderstorm activity, which affected the country from mid-May to early July with multiple notable hailstorms. During six separate outbreaks, the local insurance industry received roughly a million claims with losses totaling €3.9 billion (\$4.1 billion).

While the combined footprint of the hailstorms was relatively large, much of the losses occurred in a few spatially limited areas as large hailstones hit "the target" in a form of densely populated communities, including Vichy on June 4, the outskirts of Orleans on June 19 and Bordeaux on June 20.

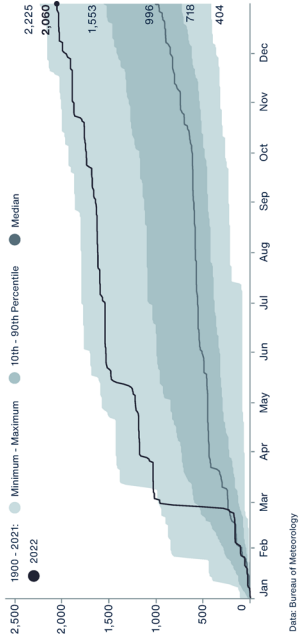
Rainfall Extremes Drive Flood Losses in Asia-Pacific

Exhibit 29: Cumulative Rainfall in Sydney (mm)



A series of dynamic weather patterns involving a stalled trough and blocking high and later an East Coast Low successively trained moisture streams towards Southeast Queensland and New South Wales in the first quarter of 2022. The long-lasting event occurred over 17 days, from February 21 to March 9. Brisbane recorded its highest three-day rainfall totals at 677 mm (26.7 in) on February 28, breaking the 600 mm (26.3 in) record set in 1974. Dozens of other locations observed rainfall in excess of 1,000 mm (39.4 in), setting up catastrophic flooding especially in Lismore and Ballina. The eastern Australia floods eventually evolved to become the costliest natural disaster event ever recorded in Australia on an inflation-adjusted basis.

Exhibit 30: Cumulative Rainfall in Brisbane (mm)



Additionally, the Insurance Council of Australia declared a significant event in early July for the Central Coast covering the Hunter region and Greater Sydney, one catastrophic event in October for southeastern Australia, and another significant event in early November for the Central West. Persisting La Niña conditions, negative Indian Ocean Dipole, and positive Southern Annular Mode, which prevailed for the majority of the second half of the year, drove above-average annual rainfall (10th decile) in much of New South Wales. At 2,530 mm (99.6 in), Sydney broke its second-highest annual rainfall record set in 1950.

Flooding typically generates the highest economic losses from natural disasters in Asia. Extended summers accompanied by continuing La Niña conditions drove prolific rainfall in Sydney (Australia), Sindh (Pakistan), or Meghalaya (India), increasing risks of deadly landslides and/or overflowing rivers.

Much of the Indian subcontinent received above-average precipitation totals and the monsoon extended further westward than usual towards Pakistan, causing widespread flooding. In a summary of the 2022 monsoon season, the Pakistan Meteorological Department noted that country-wide rainfall in July to September was 175 percent above average. Regionally, the anomaly was the most significant in Balochistan (450 percent) and Sindh (426 percent), and was also above the long-term mean in Punjab, Gilgit-Baltistan and Khyber Pakhtunkhwa.

A large part of the country was under water for an extended period of time in August. The event highlighted many issues facing countries in Asia in context of disaster resilience and ability to respond

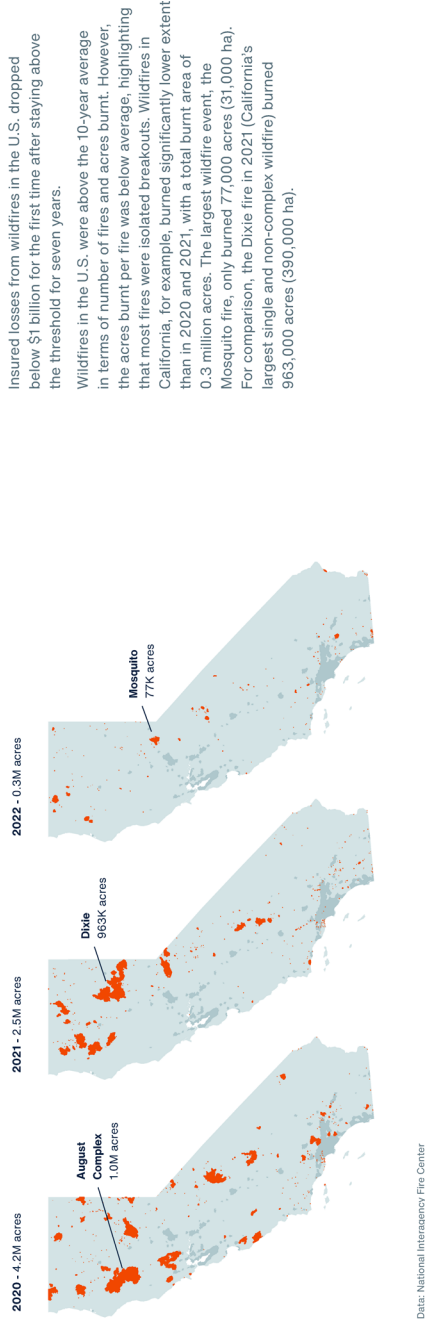
to ongoing events. A significant number of fatalities in Pakistan during summer were not due to the flooding itself, but rather secondary challenges that stemmed from the event, such as acute malnutrition or waterborne diseases such as typhoid, diarrhea, and malaria. Hospitals were overwhelmed as thousands of health facilities were destroyed in flooding. Industries were also beginning to experience effects from the secondary impacts, with textile factories shut down due to cotton shortages.

Pakistan remains one of the countries vulnerable to potential financial costs and physical risks associated with climate change. As the event affected a large part of the nation's population, the country faces long-term challenges to rebuild to mitigate against the next deadly waves of natural disasters.



Wildfire Season Quiet in California, Second Worst This Century in Europe

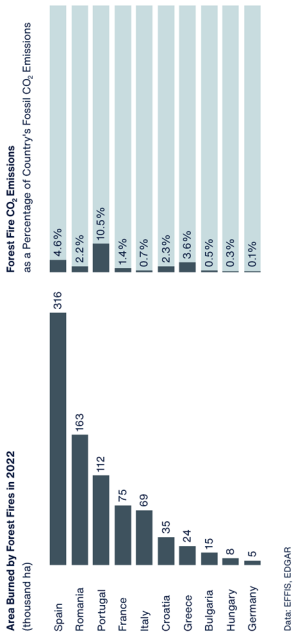
Exhibit 31: Wildfire Perimeters in California and Largest Fires Annually From 2020-2022



Insured losses from wildfires in the U.S. dropped below \$1 billion for the first time after staying above the threshold for seven years.

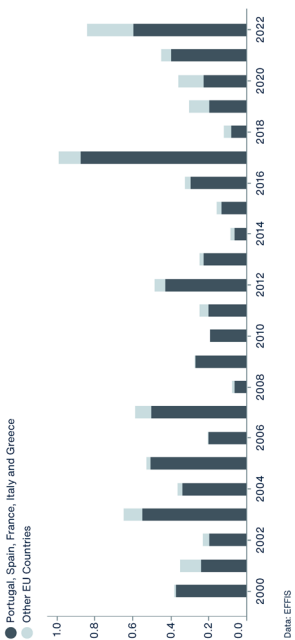
Wildfires in the U.S. were above the 10-year average in terms of number of fires and acres burnt. However, the acres burnt per fire was below average, highlighting that most fires were isolated breakouts. Wildfires in California, for example, burned significantly lower extent than in 2020 and 2021, with a total burnt area of 0.3 million acres. The largest wildfire event, the Mosquito fire, only burned 77,000 acres (31,000 ha). For comparison, the Dixie fire in 2021 (California's largest single and non-complex wildfire) burned 963,000 acres (390,000 ha).

Exhibit 32: Extent Burned and Emissions from Forest Fires in 2022



Spain recorded the largest area burned by forest fires in the European Union in 2022. This included a large fire in the Zamora province, which burned more than 30,000 ha. The European Forest Fire Information System (EFFIS) also includes information on estimated amount of CO₂ emissions released from the fires. Comparison with respective country's fossil emission is displayed on the right.

Exhibit 33: Extent Burned by Forest Fires in the European Union (M ha)



According to the satellite-derived data from EFFIS, total extent burned by forest fires in the European Union in 2022 was the second highest this century, only surpassed by 2017, the year of the devastating fires in Portugal. It is also noteworthy that unusually large part of the extent occurred outside of the five southern European countries that typically constitute most of the burned extent. This was largely due to fires in Romania.

Drought Conditions Result in Considerable Payouts Globally

Exhibit 34: U.S. Crop Insurance Payouts from Drought, Heat, Excess Sun and Hot Wind per County (M \$)

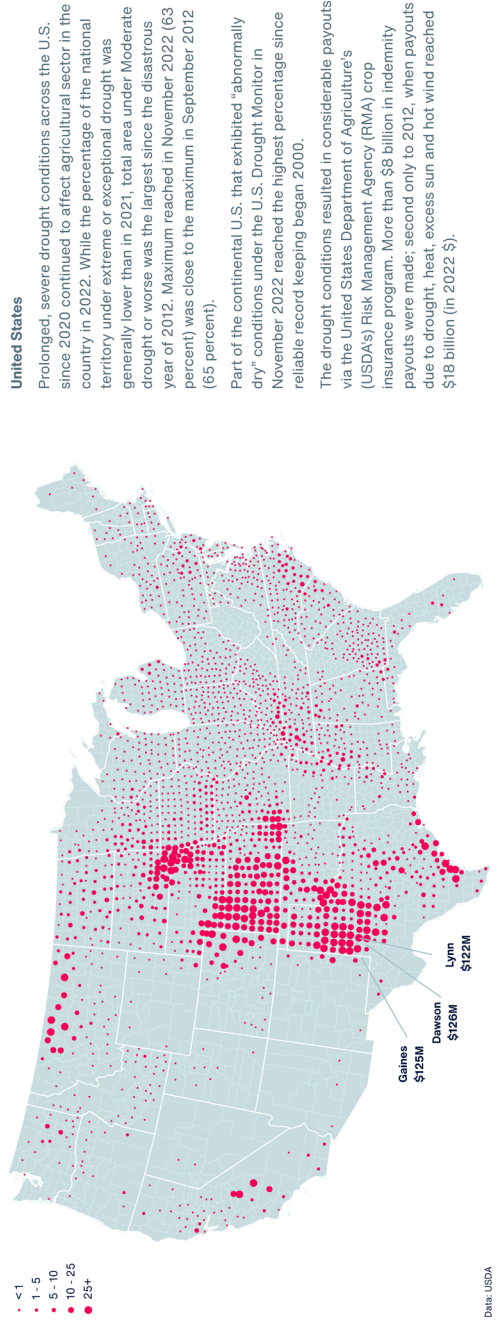
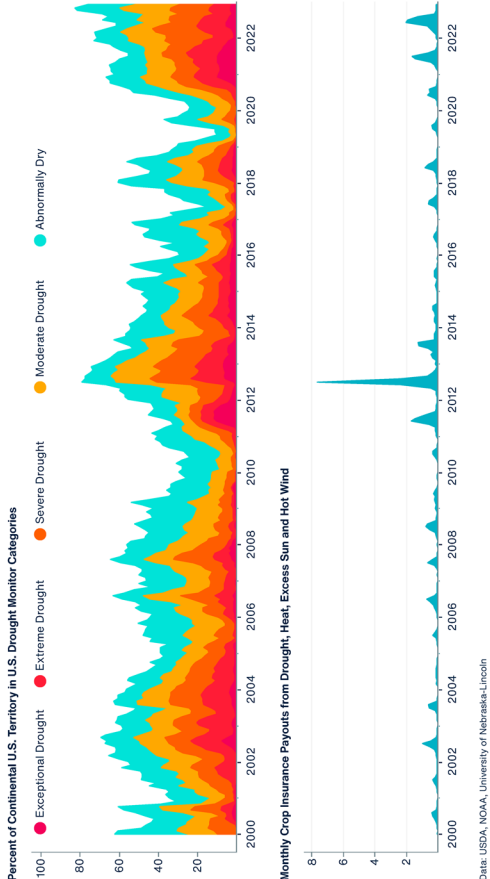


Exhibit 35: U.S. Drought Conditions and Crop Insurance Payouts

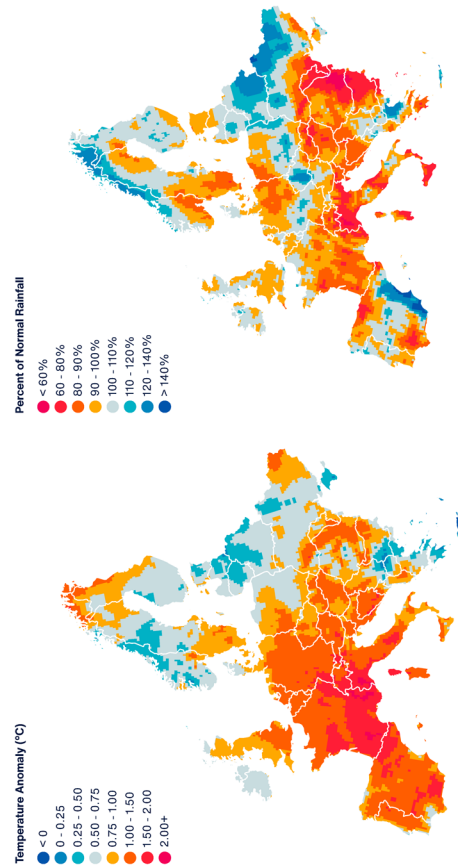


The largest amount of the crop insurance payouts was concentrated in Texas, with nearly \$2.6 billion, followed by Kansas (\$1.7 billion), Nebraska (\$800 million) and South Dakota (\$615 million). Most of the payments were related to damage to corn (32 percent), cotton (27 percent), soybeans (16 percent) and wheat (12 percent).

Europe

Parts of Europe were engulfed by severe drought conditions throughout the year. These conditions led to substantial losses of approximately \$22 billion across the Western, Southern and Central part of the continent. In mid-August, nearly 50 percent of Europe was under orange warning conditions and 17 percent under red alert conditions, according to the Combined Drought Indicator by European Drought Observatory, indicating areas that may be affected by agricultural drought. Billion-dollar losses to agriculture, buildings and infrastructure were reported in France, Spain, Italy, Germany, Hungary, and Romania. The cumulative severe precipitation deficit led to reduced river discharges, significantly affecting many sectors of the economy and their supply chains. Water and heat stress substantially reduced crop yield.

Exhibit 36: Temperature and Precipitation Anomaly in Europe



Data: Copernicus Climate Change Service, ECMWF

Low water levels disrupted cooling systems of power plants and lowered hydropower generation in the energy sector. Additionally, shipping on several important European rivers (Danube, Rhine, Po) was disrupted due to low water levels.

European drought in 2022 became the second costliest after the historic summer of 2002, which severely affected a large part of Europe, generating total economic losses of \$27.6 billion (in 2022 \$). Recorded temperature increases and climate projections suggest that Europe is generally warming faster than the global average and prolonged drought periods are expected to become more frequent.

The drought also resulted in notable insurance payouts of roughly \$3 billion — due to agricultural losses, but also damage to property due to land subsidence related to drought conditions.

Historic Heatwaves Highlight Impact on Health and Economy

Numerous all-time or monthly extreme heat records were broken in many areas of the world in 2022 and Europe was among the regions severely affected by the peril. Two separate major heatwaves hit Europe in mid-June and mid-July, affecting hundreds of millions of people — particularly in Western, Southern and Central parts of the continent, leading to more than 19,200 heat-related fatalities, as derived from excess mortality rate data. Heatwave periods occurred in a continuation to a relatively dry and warm spring and early-summer months and further enhanced drought and wildfire risk across Europe. July event transpired due to an anomalous ridge of high pressure, which stretched from Morocco in northwestern Africa through France and towards the British Isles. Concurrently, an upper low-pressure system located west of the Iberian Peninsula played a pivotal role in the intensification of the pattern and creation of an aptly named Spanish plume, which advected extremely hot air toward France and Great Britain. As a result, a broad area of Europe experienced extreme maximum temperatures, exceeding 40°C (104.4°F) locally, often greater than 10°C (18°F) above normal. The heatwave resulted in the first-ever recorded temperature reading above 40°C (104.4°F) and in the first-ever red warning for exceptional heat in the United Kingdom.

This pattern resulted in a particularly intense and lasting heatwave in France, where temperature maximums culminated on July 18, as the western coastal region experienced maximums reaching 42°C (107.6°F). In Germany, six federal states established new all-time state-level heat records. The highest summer temperature of 47.0°C (116.6°F) was recorded in Pinhão, Portugal, on July 14. Extreme summer heat was also seen several times in Argentina (January and December), in India and Pakistan (March-April), or in China (June-August), where this-year heatwave impacts are expected to be one of the worst in China's history, leading to tens of thousands of heat-related deaths (official data for China are not yet available).

Extreme events that occurred worldwide are in line with the global trend and support conclusions from the last IPCC Assessment Report, which indicates an increase in the frequency and intensity of these perils. Consequently, Europe and other regions may face more frequent implications for human health and wellbeing, food supplies and agriculture, transport, energy prices, or impact on natural ecosystems. It is important to note that numbers of heat-related fatalities are approximated, and totals are expected to be even higher.



Climate Change’s Health Impacts Now a Focus of Workforce Resilience Plans

Employers are contending with a variety of challenges from the human health effects of climate change; from direct health issues like heat stroke, asthma and emotional distress to indirect factors such as worker absenteeism, reduced productivity and supply chain disruption.

- As organizations focus on developing a resilient and agile workforce, they are also considering how a changing climate affects health and how that shapes their goals. This can mean:
- Enhancing plans to help their workforce contend with changing health and safety conditions
 - Limiting outdoor work during unsafe conditions
 - Developing contingency plans for locations not traditionally considered prone to certain natural
 - Disasters, but which are now susceptible
 - Ensuring healthcare access for vulnerable populations.
- This topic is also getting more attention from global climate stakeholders. In November 2022, the United Nations COP27 meeting discussed the health impacts of climate change — during which, the Sharm el-Sheikh Implementation Plan was devised to address climate’s role on human health and different population groups. It advised, parties should “respect, promote and consider their respective obligations on human rights, the right to a clean, healthy and sustainable environment, the

right to health, the rights of indigenous peoples, local communities, migrants, children, persons with disabilities and people in vulnerable situations.”

Together, risk, health and human capital stakeholders can develop innovative ways to help companies protect their people after natural disasters. Recently, Aon worked with a large technology firm in the U.S. to separate what would cause a trigger for a catastrophe bond (an earthquake, in this case) and allocate a one-time payment to colleagues to help them through a disruption to their lives. The cat bond was created 20 years ago as a property insurance concept to rebuild the company’s physical offices, but the firm wanted to modify the trigger to become more relevant to its business and people today.

Location analytics and job assessments also play a role in protecting a business and its employees. When dealing with a natural disaster, if a resilient and agile organization knows where its people are and which roles can be performed remotely, it can redeploy resources so affected employees can work from safer locations and still be productive.

Climate-related events may cause poor physical health; they can impact employees' mental and emotional wellbeing. A resilient workforce can proactively address the holistic needs of employees and wellbeing tools should be readily available to help employees when they need it most — whether that be mental health benefits or flexible time off.

In short, a successful people-driven organization:

- Has the resilience to bounce back during volatility
- Is agile enough to bounce forward and seize opportunities for growth
- Is engaged with employees to repeat this process.

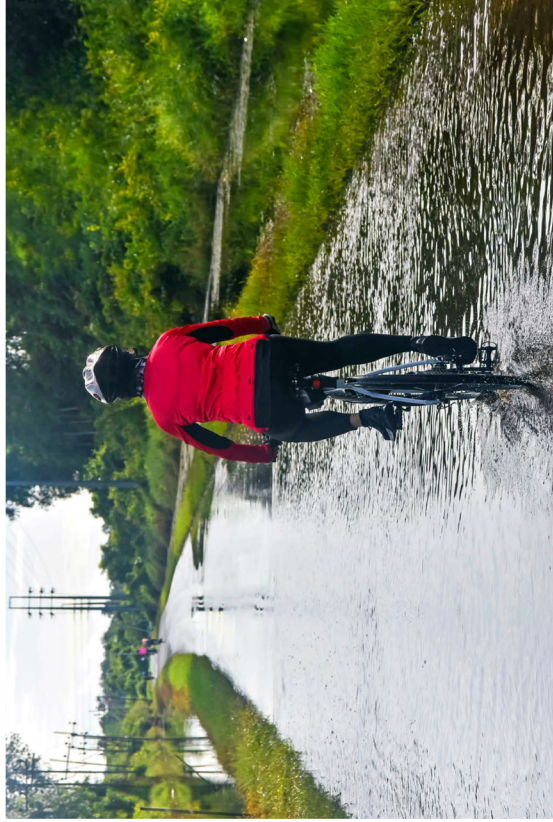
When an organization is developing programs to achieve these goals, it's critical to include how a changing climate impacts people — and that includes its significant influence on our health.

Stephanie DeLorm

Senior Vice President, Aon Health Solutions

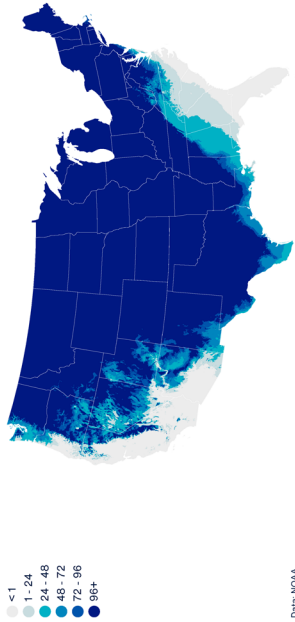
Peter Bentley

Chief Innovation Officer, Aon Human Capital Solutions



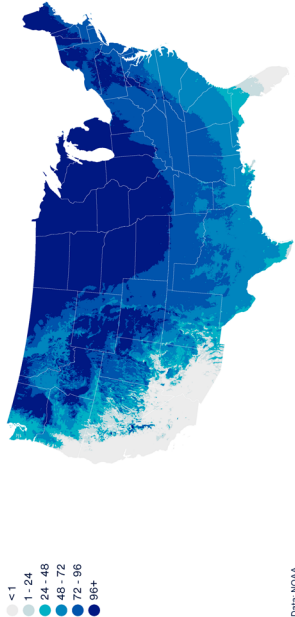
Significant Winter Weather Events Test Infrastructure Vulnerabilities

Exhibit 37: Hours at or Below Freezing during February 13-19, 2021



Total economic losses from the winter weather peril in 2022 were \$9.7 billion, below the long-term average (skewed by 2021) and close to median. The only billion-dollar economic and insured loss event was the December North American Winter Storm, which caused power outages to more than 2.6 million people across the continent, once again highlighting the vulnerabilities of the electrical infrastructure grid. Although the extent of damage has not been fully evaluated yet, initial damage assessments suggest that insurance market losses may potentially reach into the single-digit billions (USD). This considerable event is not expected to generate losses like those incurred during the historic mid-February Texas Freeze in 2021, which resulted in 17 billion (in 2022 \$) of insured losses and 28 billion (in 2022 \$) of total economic losses.

Exhibit 38: Hours at or Below Freezing during December 22-26, 2022



One of the main differentiating features was the duration of below-zero (freezing) temperatures. The analysis of both events shows that the duration of freezing temperatures in the 2021 was much longer and more widespread across the U.S., particularly Texas. Similar winter weather events initiate discussion on whether this is now a peril that needs consideration as a more dominant and regular future loss driver. The intensity and longevity of the 2021 event uncovered vulnerabilities that exist within the current infrastructure and highlighted the need for better preparedness.

Notable Events Caused by Additional Perils



Earthquake

A total of 11 magnitude-7.0 and greater earthquakes occurred globally in 2022. The strongest earthquakes, registered at magnitude-7.6, rocked Papua New Guinea and Mexico — both in September. The costliest event of the year was the earthquake that struck near Fukushima, Japan in March and resulted in economic losses of \$9.1 billion. Another costly event occurred in Sichuan, China in September and caused \$2.3 billion in total economic losses. Other notable tremors included the Cianjur earthquake in Indonesia, the North California earthquake in the United States, and the event that occurred near the Afghanistan-Pakistan border on June 22 and killed 1,163 people, becoming the deadliest geophysical event of the year.



Volcanoes

The Hunga Tonga–Hunga Haʻapai volcano eruption in January caused atmospheric shockwaves to propagate around the globe and ash plumes to propel 57 km (35.4 mi) into the lower mesosphere. The undersea eruption was also violent enough to trigger widespread tsunami waves, which travelled as far as the coast of Japan and Americas, but eventual losses were minimal due to the isolated location of the volcano in the South Pacific. Other notable events included the Mauna Loa eruption in Hawaii, which disrupted carbon dioxide monitoring at the Mauna Loa Observatory in late November and December. The Semeru volcano in Indonesia erupted on December 4, exactly one year after its devastating eruption in 2021, but impacts were eclipsed by the consequences of the last year's event, as many places remained buried or damaged by volcanic ash.



European Windstorm

Aggregated insured losses from European Windstorms for the calendar year reached \$5.7 billion, which was well above long-term averages (\$3.2 billion) and at its highest since 2013. Most of those losses, \$4.7 billion, were related to a windstorm series (storms Dudley, Eunice and Franklin) that affected Western and Central Europe in February. Storm Eunice was the most intense and became the costliest individual storm to affect Europe since Xynthia in 2010. On the other hand, the lack of any significant storms resulted in negligible losses in the fourth quarter of the year. Even though the peril remains the costliest for European insurers (largely because of the peak events in 1990s), its average annual losses have been surpassed by summer storms (SCS) in recent years.

How Climate Science Unites with Technology to Drive a More Resilient World

Navigating climate change means our industry must prepare for the risks of tomorrow, equipped with tools to measure both the near- and long-term risks. This is where academic research and innovation can unite to bring emerging climate research directly into the insurance industry and create actionable insights.

To integrate these insights into our catastrophe models, Aon's analytics and Impact Forecasting model development team are collaborating with a global network of academic climate experts, including:

- Columbia University (global tropical cyclone)
- University of California, Merced and University of California, Los Angeles (U.S. wildfire)
- Karlsruhe Institute of Technology (KIT — European flood and windstorm)
- University of Illinois Urbana-Champaign and Central Michigan University (U.S. SCS)

What have we discovered so far?

U.S. Hurricane:

Higher aerosol emissions lead to fewer tropical cyclones, according to research from Columbia University. Aon's academic collaborators explored different ways to quantify moisture in the air and ran Shared Socioeconomic Pathways scenarios with different climate policy assumptions to assess the impact of varying levels of future greenhouse gases and aerosols. This climate

data will be incorporated into Aon's tropical cyclone models to better understand future financial losses.

U.S. Wildfire:

The historic drought currently on-going in the Western U.S. and Canada is consistent with the signal we see in many state-of-the-art climate models — a hotter, drier West. Combined with the increased risk of human-induced ignition due to development in the wildland urban interface, these drier conditions look to significantly impact the fire risk for many areas. Exactly how these changes translate into changes in burned area and insured loss is the focus of our collaboration with the University of California, Merced and University of California, Los Angeles.

European Flood and Windstorm:

Atmospheric circulation patterns play a key role in driving extreme weather events, such as flood and windstorms. With KIT we found that extreme hydrological events strongly depend on catchment size and physical features of the terrain. For example, heavy rainfall in highly permeable areas can cause insignificant flooding, while the same rainfall in areas with narrow valleys can cause a catastrophe — as confirmed by the devastating Bernd flood in Germany in July 2021.

Practically applying the research

For businesses and communities, this data and analysis enables more opportunities to help de-risk climate focused innovations such as low-carbon technologies and new forms of renewable energy, as well as inspiring more relevant coverage and risk management for a more resilient future.

For insurance companies, having the insight to develop climate action strategies for underwriting and reinsurance is critical when considering practical steps in response to evolving risk. Communicating the "why" and "how" is also imperative, informing internal and external stakeholders, including boards of directors, investors, and employees, in addition to meeting regulatory needs and developing robust responses to disclosure requirements.

Together, we will be able to achieve so much more as we navigate climate change and unlock new opportunities.

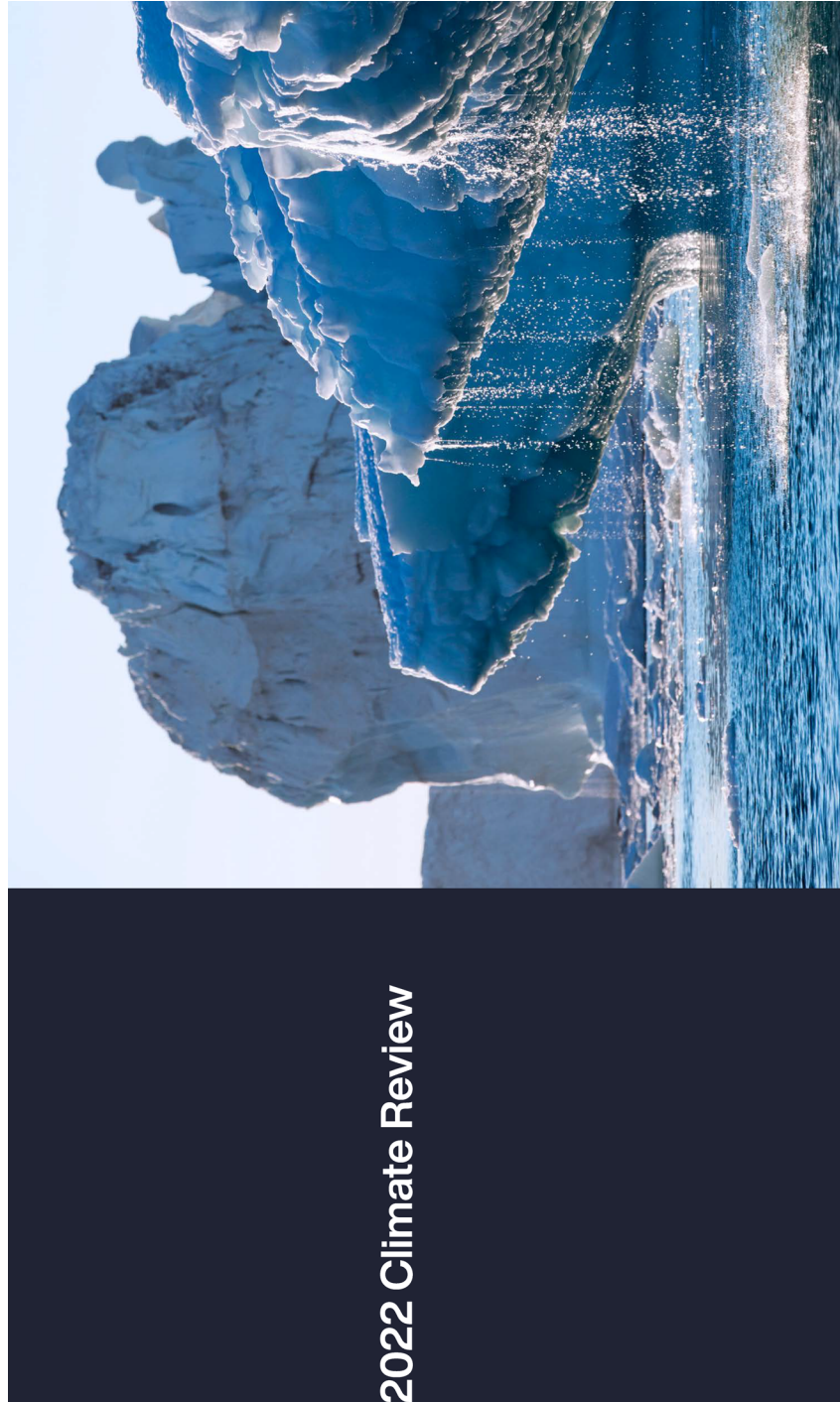
Daniel Raizman

Director, Catastrophe Modeling

Megan Hart

Managing Director, Catastrophe Management





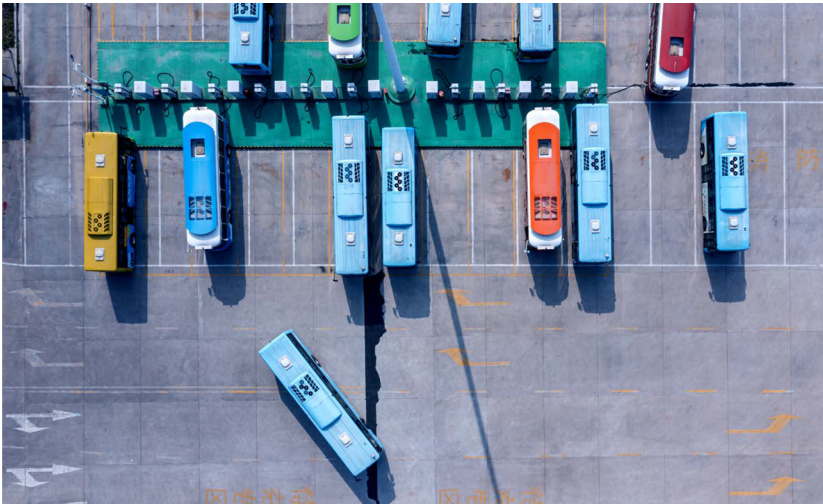
COP27 Summit Highlights Need for Climate Action

The 27th United Nations (UN) Climate Change Conference (COP27) was held at a critical moment during the fight against climate change. Global leaders in government, industry, finance, and civil society from more than 190 countries gathered in Sharm el-Sheikh, Egypt, on November 6-18, 2022. By the number of participants, the COP27 was the second largest after the COP26 in Glasgow. Attendees highlighted the need to accelerate action to achieve the goals of the Paris Agreement and the UN Framework Convention on Climate Change. The conference has been held annually since 1995 and is used as a platform where attending parties agree on policies to limit global temperature rise and adapt to impacts associated with climate change.

Selected takeaways from the COP27:

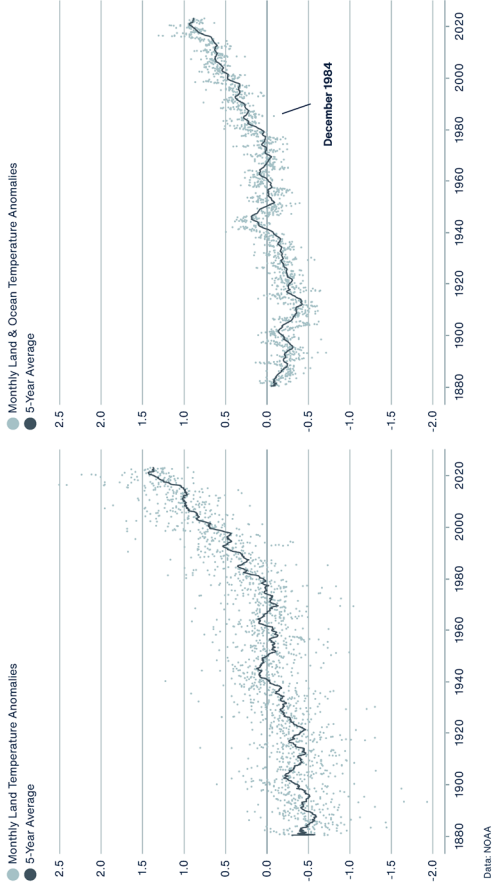
- The conference covered topics such as climate finance, decarbonization, climate change adaptation, agriculture, water, biodiversity, or gender
- There is a need to focus on clean energy, zero-emissions mobility, green shipping
- The conference led to an agreement of the first loss and damage fund, a pooled fund arranged to help the most affected and vulnerable countries tackle losses and damage related to climate change.

- At least 150 countries signed the Global Methane Pledge to lower methane emissions by 30 percent by 2030, which is 50 more countries than last year at COP26, but still excluding China as a major methane polluter. Attendees agreed that the greenhouse gas emissions, particularly methane emissions, must be tracked sufficiently ([Climate Trace](#)) to detect the world's worst polluters.
- The progress on adaptation fell far short of what is needed to address accelerating and severe impacts.
- Many stakeholders are still not taking any significant steps to curb emissions, which are critical to limit temperature rise to 1.5°C (2.7°F).
- Now there is a fifty-fifty chance that global temperatures will be at or above the 1.5°C (2.7°F) threshold set in the 2015 Paris Agreement over the next five years. The threshold based on the preindustrial age temperature average (1850-1900).
- Still not too late: Changes in emission output and human behavior can bring meaningful near-term improvements.



2022 Marks the Sixth-Warmest Year on Record Dating to 1880

Exhibit 39: Global Land and Ocean Temperature Anomalies: 1880-2022 (°C)



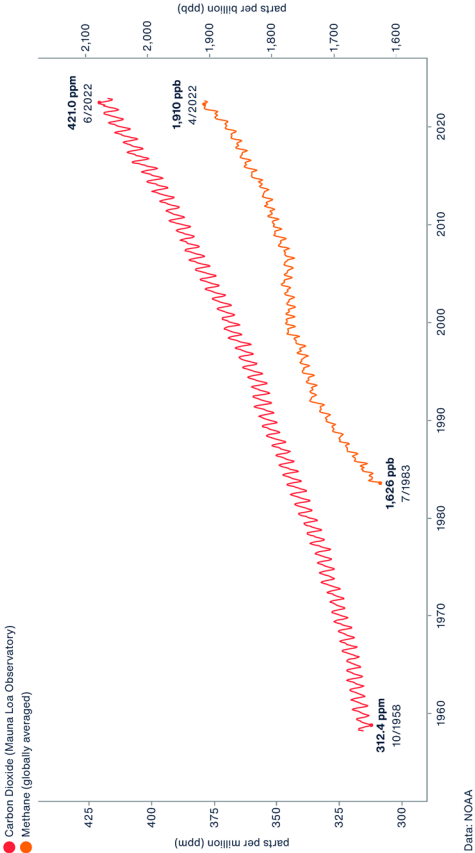
2022 marked the continuation of the overall long-term warming trend of the planet. Preliminary official data from the National Centers for Environmental Information (NCEI), noted that 2022 was 0.86°C (1.55°F) above average global land and sea surface temperatures. This marked the sixth-warmest year on record dating to 1880, when comparing against NCEI's 20th century average (1901-2000). European Union's Copernicus Climate Change Service declared 2022 the fifth-warmest based on ERA5 dataset, while NASA suggested that 2022 tied as the fifth-warmest.

It was previously assumed that El Niño years comprise most of the warm year lists since it amplifies warming. The opposite was always assumed to be true for La Niña — meaning that historical data typically shows that the globe tends to cool during such phases. Despite enduring La Niña conditions throughout the year, 2022 was still anomalously warm. This suggests that land and ocean temperatures continue to warm at an accelerated rate regardless of any influence from natural variability, volcanic eruptions, or solar cycles. It is further evidence anthropogenic activity is driving most of the warming.

The last below-average year for the globe occurred in 1976, while the last individual month to be below average was December 1984 at -0.08°C (-0.15°F) lower, and before that November 1976. December 2022 marked the 456th consecutive month with above average global temperatures.

Greenhouse Gas Concentrations Continue to Increase with Accelerated Pace

Exhibit 40: Monthly Carbon Dioxide and Methane Concentrations



Data from the NOAA Earth System Research Laboratory (ESRL) showed carbon dioxide (CO₂) concentrations increased for another consecutive year and averaged 417 parts per million (ppm). The highest monthly average was observed in May and June at around 421 ppm, with new daily record CO₂ reading of 422.06 ppm recorded on April 26. Data collection at the observatory was suspended from November 29 following the eruption of Mauna Loa. Measurements had only paused in two other years since 1960.

NOAA noted that current CO₂ levels are at the highest in 4 million years. This was during the Mid-Pliocene Warm Period when carbon dioxide concentrations ranged from 380 to 450 ppm. Atmospheric CO₂ levels have a scientifically proven correlation with global temperature, supported by data from ice cores and the geological record. Concentrations annually peak in May as plants begin to grow in the Northern Hemisphere with the arrival of spring. After peaking, a gradual decline occurs through the month of September as the growing season ends.

It is worth noting that the annual rate of growth in CO₂ concentration has increased over the course of multiple decades. The rate is the difference in concentration between the end of December and the start of January of that year. If used as an average for the globe, it would represent the sum of all CO₂ added to, and removed from, the atmosphere during the year by human activities and by natural processes. NOAA also applies a four-month interpolating technique to account for month-to-month variability

Three Ways the Re/insurance Industry Can Accelerate Net Zero by Facilitating Capital

The emerging impacts of climate change are increasingly felt across the re/insurance industry, with much uncertainty ahead. But the industry now has a chance to transform volatility into opportunity. Today, forward-thinking insurance companies are driving the global economy by originating solutions that safeguard businesses, governments and communities.

However, more work needs to be done as our role in improving resilience in the economy evolves. Re/insurers can help solve the climate crisis by matching capital to risk where it's needed, such as via clean tech solutions, and by de-risking projects and technology development, which will encourage faster and more meaningful investment. There are three primary ways the industry can help accelerate the journey to net zero emissions.

First, instead of moving away on arbitrarily short timescales from carbon-intensive and high-emission industries, re/insurers should be enabling and supporting these industries to transition to lower carbon operations. This can be done by both supporting and incentivizing these industries to transition, and by de-risking

investments in low-carbon technologies, for example carbon capture and storage and new types of renewable energy. In order to fully grasp this opportunity, the re/insurance industry must change some of its mindset to formulate a consistent forward-looking pricing model for new risks.

Second, the industry should consider the need for longer policy terms than our usual annual renewal cycle. New clean tech industries, for example, are often not investable at scale, and re/insurance coverage's stability and predictability over longer periods could free up capital flows. This "duration mismatch" is impeding financing for green technologies as the long-term insurability of assets comes into question — which in

turn increase risk for investors. We're leveraging the existing longer term approach in some existing lines of business and working with new and existing capital providers to increase appetite for longer-term risks. Working with pension and investment markets could also inform longer-term thinking about assets and liabilities — enabling us to apply these insights to the general reinsurance world more systematically.

Finally, the re/insurance industry must collaborate and innovate with stakeholders, including existing and alternative sources of capital, green technology startups, risk mitigation firms and the public sector, so our society can decarbonize at scale. As a recent example, Revalue Nature, which provides nature-based carbon offset projects, collaborated with Aon to insure those investments against unforeseen events such as wildfires or bug infestations (read more here).

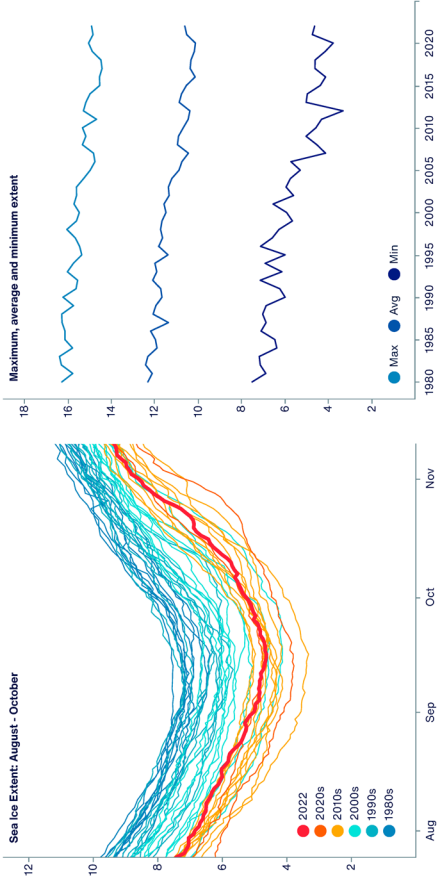
Decarbonization is changing the risk landscape and any un-insurability of increasingly volatile weather presents a risk to our economy. But by engaging new talent, partners and stakeholders, the re/insurance industry can play a truly transformational role in the climate transition by enabling better decisions for a more sustainable future.

Richard Dudley
Global Head of Climate Strategy, Aon



Sea Ice: Antarctica Records New Low

Exhibit 41: Arctic Sea Ice Extent in Million Square Kilometers: 1980-2022

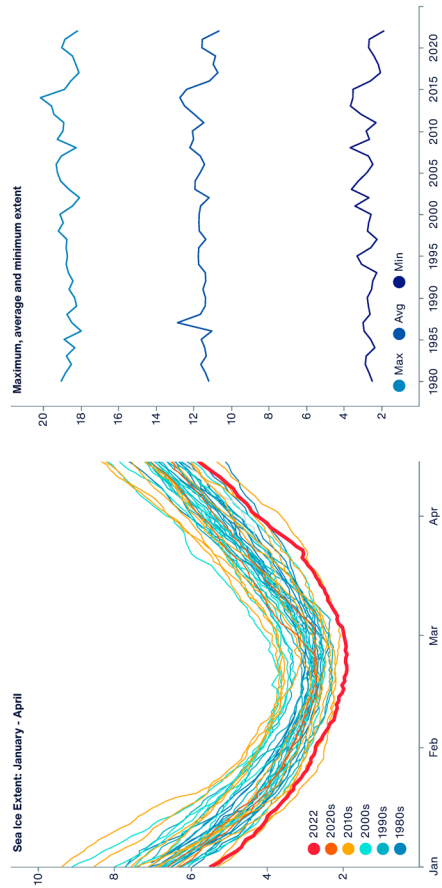


Data: Fetterer, F. K., Knowles, W., Meier, M., Savoie, and A. K. Windmager. 2017. updated daily. Sea Ice Index, Version 3. Boulder, Colorado USA.
NSIDC: National Snow and Ice Data Center. [1/1/2023]

The well-documented decline of the Arctic sea ice extent and volume since the 1980s affects essential climatic feedback mechanisms, which then influence global circulation patterns. Surface air temperatures in the Arctic region have increased at a rate twice as fast as in the rest of the globe, with far-reaching impacts for the entire Arctic ecosystem. Some of these impacts include a reduction in natural habitats, but also increased accessibility of the Arctic Ocean for shipping since some areas no longer freeze at any point of the year.

This year's Arctic minimum extent tied for tenth lowest on record. However, an even bigger concern is that the amount of multi-year ice, which stands at a near-record low. An analysis of satellite data from NASA and the National Snow and Ice Data Center (NSIDC) showed that the 2022 minimum extent measured 4.67 million km² (1.8 million mi²) on September 18. It represents a 1.55 million km² (0.6 million mi²) reduction from the 1981-2010 September climatology. The 2022 extent was the tenth lowest in the 44-year satellite record, tying minimum extent in 2017 and 2018. The last time that Arctic sea ice extent was above climatology was in 2001.

Exhibit 42: Antarctica Sea Ice Extent in Million Square Kilometers: 1980-2022

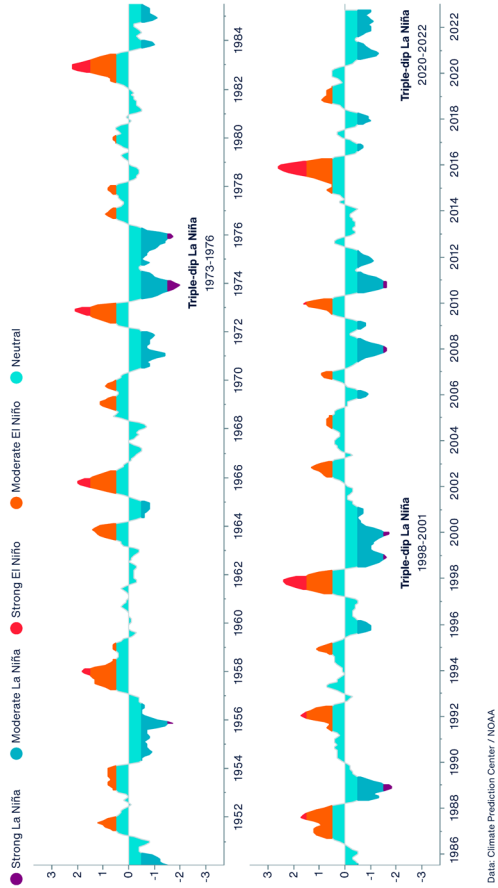


Data: Fetterer, F., K. Knowles, W. Meier, M. Savoie, and A. K. Windmager. 2017, updated daily. Sea Ice Index, Version 3. Boulder, Colorado: USA. NSIDC: National Snow and Ice Data Center. [1/1/2023].

On the opposite side of globe, the Antarctic is responding less rapidly to climate change than the Arctic. Despite moderate warming, the amount of sea ice and its volume in the Antarctic have yet to show a substantial decreasing trend. However, the sea ice extent in this region set a new record minimum in 2022. For the first time since the satellite record began in 1979, the extent fell below 2 million km² (772,000 mi²), reaching a minimum extent of 1.92 million km² (741,000 mi²) on February 25. Surprisingly, this year record-breaking minimum followed the unusually early and above-average sea ice maximum extent from previous year (reached on September 1). However, two regions of high interest to researchers, Thwaites Glacier and the central Weddell Sea, remained locked in ice. With a continued moderation in temperatures, a recent study suggested that Thwaites Glacier Shelf could collapse within the next three to five years. This is a huge concern since it is one of the largest and highest glaciers in Antarctica and is roughly the size of the U.S. state of Florida. Should the glacier fully collapse into the ocean, scientists fear that it could raise levels by 65 centimeters (25.6 inches). It already accounts for four percent of global sea level rise.

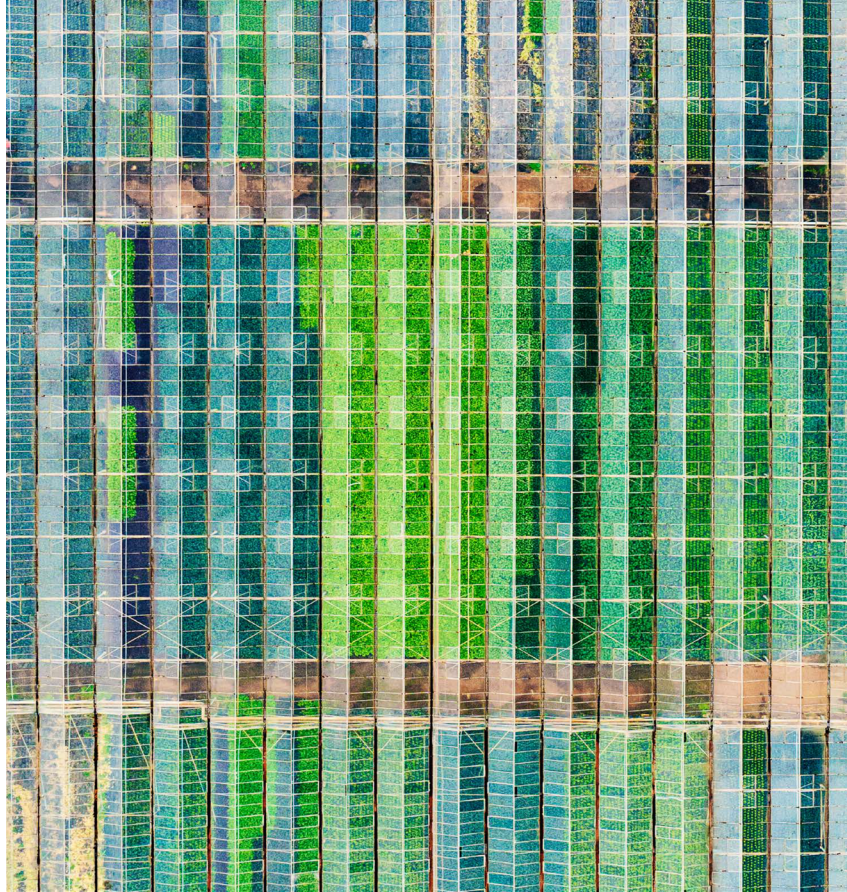
La Niña Affects Global Weather Patterns for the Third Year in a Row

Exhibit 43: Oceanic Niño Index and ENSO Phase Conditions by Month



Data: Climate Prediction Center / NOAA

One of the climate oscillations that has a robust global influence on regional weather is the El Niño/Southern Oscillation (ENSO): a warming or cooling cycle of ocean waters across the central and eastern Pacific. The cycle is often associated with changes in the orientation of various atmospheric patterns and ocean currents. Warming periods are noted as El Niño cycles, while cooling periods are known as La Niña cycles. The Niño 3.4 or the Oceanic Niño Indices, which measure the three-month running average temperature of the ocean waters in the central Pacific, are used to determine ENSO phases/cycles by the Climate Prediction Center. ENSO phases with a peak value above 1.5°C (El Niño) or below negative 1.5°C (La Niña) are considered strong. For the first time in the 21st century, the world saw a "triple-dip" La Niña event, as the cooling phase spanned three consecutive northern hemisphere winters into late 2022. Moderate La Niña conditions from 2021 continued into 2022 and persisted throughout the year. Many forecasting centers are expecting a weakening of La Niña conditions in early 2023, with a return to ENSO-neutral around February. There were two other occurrences of a "triple-dip" La Niña since 1950: 1973 to 1976, and 1998 to 2001. La Niña is an important climate driver for Australia. For example, a strong La Niña year in 1974 contributed to a severe deluge in Queensland.



Appendix

Appendix A: 2022 Global Disasters

United States

Date(s)	Event	Location	Deaths	Economic Loss (USD)
01/01-12/31	Drought	Nationwide	N/A	16.0+ billion
01/02-01/03	Winter Weather	Southeast, Mid-Atlantic	5	525+ million
01/08-01/09	Severe Convective Storm	Plains, South	0	64+ million
01/14-01/17	Winter Weather	Southeast, Mid-Atlantic	3	955+ million
01/21-01/22	Severe Convective Storm	California	0	186+ million
01/28-01/30	Winter Weather	Mid-Atlantic, Northeast	4	53+ million
02/01-02/05	Winter Weather	Rockies, Plains, Mid-Atlantic, Northeast	10	526+ million
02/16-02/18	Winter Weather	Plains, South, Mid-Atlantic, Northeast	0	373+ million
02/21-02/22	Severe Convective Storm	Plains, South	0	1.2+ billion
03/05-03/07	Severe Convective Storm	Midwest, Mid-Atlantic, Northeast	8	820+ million
03/11-03/13	Severe Convective Storm	South, Mid-Atlantic	0	228+ million
03/14-03/16	Severe Convective Storm	Plains, South	0	540+ million
03/17-03/19	Severe Convective Storm	Plains, South	0	36+ million
03/17-03/25	Wildfire	Texas	1	31+ million
03/21-03/23	Severe Convective Storm	Plains, South	5	856+ million

United States

Date(s)	Event	Location	Deaths	Economic Loss (USD)
03/29-04/01	Severe Convective Storm	Plains, South	2	1.3+ billion
03/30-04/01	Wildfire	Tennessee	0	233+ million
04/02-/04	Severe Convective Storm	Florida	0	304+ million
04/03-04/07	Severe Convective Storm	Plains, South	3	1.4+ billion
04/04	Severe Convective Storm	Northwest	0	46+ million
04/06-05/31	Wildfire	New Mexico	0	495+ million
04/10-04/14	Severe Convective Storm	Plains, Midwest, South	1	2.8+ billion
04/12-04/15	Wildfire	New Mexico	2	155+ million
04/15-04/17	Severe Convective Storm	Plains, South	0	882+ million
04/18-04/19	Winter Weather	Northeast	0	26+ million
04/21-04/24	Severe Convective Storm	Plains, Midwest	0	624+ million
04/25-05/10	Flooding	Plains, Midwest	0	52+ million
04/26-04/30	Severe Convective Storm	Plains, Midwest	3	583+ million
05/01-05/03	Severe Convective Storm	Plains, Midwest	0	1.1+ billion
05/04-05/06	Severe Convective Storm	Plains, South, Mid-Atlantic	0	1.0+ billion

United States

Date(s)	Event	Location	Deaths	Economic Loss (USD)
05/09-05/10	Severe Convective Storm	Plains, Midwest	0	2.0+ billion
05/11-05/12	Wildfire	California	0	51+ million
05/11-05/12	Severe Convective Storm	Plains, Midwest	5	2.7+ billion
05/13-05/16	Severe Convective Storm	Plains, South, Mid-Atlantic	0	704+ million
05/17-05/19	Severe Convective Storm	Midwest	0	219+ million
05/19-05/22	Severe Convective Storm	Plains, South, Midwest	2	2.6+ billion
05/21-05/23	Severe Convective Storm	Midwest, Mid-Atlantic, Northeast	0	77+ million
05/23-05/25	Severe Convective Storm	Plains, South	0	373+ million
05/26-05/27	Severe Convective Storm	South, Northeast	0	51+ million
05/29	Severe Convective Storm	Plains	0	204+ million
05/30-06/02	Severe Convective Storm	South, Plains	0	704+ million
06/01-06/30	Heatwave	Arizona, Tennessee, Texas	55	N/A
06/01-06/03	Severe Convective Storm	Plains	0	101+ million
06/02-06/06	Flooding	Florida	0	383+ million
06/04-06/08	Severe Convective Storm	Plains, Midwest, Mid-Atlantic	0	1.9+ billion
06/09-06/10	Severe Convective Storm	Plains, South	0	25+ million

United States

Date(s)	Event	Location	Deaths	Economic Loss (USD)
06/11-06/14	Flooding	Rockies	0	50+ million
06/11-06/17	Severe Convective Storm	South, Midwest, Northeast	3	3.4+ billion
06/16-06/18	Severe Convective Storm	Midwest, South, Mid-Atlantic	1	60+ million
06/19-06/21	Severe Convective Storm	Plains, Midwest	0	76+ million
06/22-06/23	Severe Convective Storm	Mid-Atlantic, Northeast	0	126+ million
06/23-06/24	Severe Convective Storm	Plains	0	76+ million
07/07-07/13	Severe Convective Storm	Mid-Atlantic	0	936+ million
07/15-07/25	Flooding	Southwest	2	176+ million
07/17-07/21	Severe Convective Storm	Mid-Atlantic, Midwest, Southeast	3	76+ million
07/21-07/25	Severe Convective Storm	Mid-Atlantic, Midwest	0	1.3+ billion
07/22-07/31	Wildfire	California	0	151+ million
07/25-07/28	Flooding	Missouri, Kentucky	43	1.4+ billion
07/26-07/31	Flooding	Southwest	3	284+ million
07/29-08/10	Wildfire	California	4	151+ million
08/01-08/04	Severe Convective Storm	Midwest	1	201+ million

United States

Date(s)	Event	Location	Deaths	Economic Loss (USD)
08/05-08/12	Flooding	Southwest, West	2	30+ million
08/11-08/12	Severe Convective Storm	Northwest	0	126+ million
08/11-08/14	Severe Convective Storm	Southwest	0	58+ million
08/18-08/22	Flooding	South	2	831+ million
08/20-08/21	Severe Convective Storm	Iowa, Illinois	0	675+ million
08/27-08/29	Severe Convective Storm	Midwest	4	252+ million
08/28-09/07	Severe Convective Storm	West, Mid-Atlantic	1	372+ million
09/01-09/04	Severe Convective Storm	Arizona	0	68+ million
09/02-09/09	Wildfire	California	2	101+ million
09/06-09/16	Wildfire	California	0	151+ million
09/11-09/12	Severe Convective Storm	Midwest	0	146+ million
09/18-09/21	Severe Convective Storm	Midwest	0	497+ million
09/28-10/01	Hurricane Ian	Florida, North Carolina, South Carolina	152	95+ billion
10/01-10/04	Severe Convective Storm	Arizona	0	130+ million
10/15-10/16	Severe Convective Storm	Southwest	0	225+ million

United States

Date(s)	Event	Location	Deaths	Economic Loss (USD)
10/24-10/25	Severe Convective Storm	Texas	0	219+ million
10/29	Severe Convective Storm	Alabama, Mississippi	0	75+ million
11/04-11/10	Hurricane Nicole	Florida	5	1.0+ billion
11/04-11/05	Severe Convective Storm	Washington	0	130+ million
11/04-11/05	Severe Convective Storm	Southwest, Midwest	2	375+ million
11/11	Severe Convective Storm	Texas	0	155+ million
11/27	Severe Convective Storm	Pennsylvania, West Virginia	0	105+ million
11/29-11/30	Severe Convective Storm	Southeast	2	115+ million
12/10-12/12	Winter Weather	California	0	100+ million
12/12-12/15	Severe Convective Storm	Southeast, Southwest	3	345+ million
12/20	Earthquake	California	0	250+ million
12/21-12/26	Winter Weather	Northeast, Midwest	98	2.7+ billion

Remainder of North America (Non-U.S.)

Date(s)	Event	Location	Deaths	Economic Loss (USD)
01/01-12/31	Drought	Mexico	N/A	1.5+ billion
01/24	Earthquake	Haiti	2	Millions
01/30-01/31	Flooding	Haiti, Dominican Republic	5	Millions
02/04-02/06	Flooding	Puerto Rico	0	17+ million
02/17-02/19	Winter Weather	Canada	0	230+ million
03/06	Winter Weather	Canada	0	16+ million
04/15-04/16	Severe Convective Storm	Canada	0	28+ million
04/22-04/25	Flooding	Canada	0	162+ million
04/30	Flooding	Guadeloupe	3	26+ million
05/01-09/11	Flooding	Guatemala	42	204+ million
05/21	Severe Convective Storm	Canada	12	1.2+ billion
05/28-05/31	Tropical Cyclone Agatha	Mexico	9	51+ million
05/30-05/31	Flooding	Canada	0	36+ million
06/02-06/06	Flooding	Cuba	3	25+ million
06/13-06/15	Flooding	Canada	0	50+ million

Remainder of North America (Non-U.S.)

Date(s)	Event	Location	Deaths	Economic Loss (USD)
06/16-06/17	Severe Convective Storm	Canada	0	59+ million
06/18-06/20	Severe Convective Storm	Canada	0	46+ million
06/20-06/21	Severe Convective Storm	Canada	0	40+ million
06/23-06/24	Severe Convective Storm	Canada	0	166+ million
06/28-06/29	Severe Convective Storm	Canada	0	40+ million
07/01-07/03	Tropical Storm Bonnie	Nicaragua, El Salvador, Costa Rica	5	25+ million
07/07-07/08	Severe Convective Storm	Canada	0	39+ million
07/15-07/17	Severe Convective Storm	Canada	0	84+ million
07/18-07/21	Severe Convective Storm	Canada	0	127+ million
07/23-07/25	Severe Convective Storm	Canada	0	40+ million
07/29-07/31	Severe Convective Storm	Canada	0	50+ million
08/01-08/04	Severe Convective Storm	Canada	0	65+ million
09/13-09/14	Flooding	Canada	0	369+ million
09/17-09/20	Flooding	Central America	15	11+ million
09/18-09/25	Hurricane Fiona	Caribbean, Canada	31	4.0+ billion

Remainder of North America (Non-U.S.)

Date(s)	Event	Location	Deaths	Economic Loss (USD)
09/19	Earthquake	Mexico	4	25+ million
09/27	Hurricane Ian	Cuba	5	500+ million
10/05-10/10	Hurricane Julia	Central America, Mexico	37	762+ million
10/23	Hurricane Roslyn	Mexico	4	Unknown
10/31-11/05	Hurricane Lisa	Central America, Mexico	0	100+ million
11/04-11/05	Flooding	Caribbean	0	27+ million
11/04-11/10	HU Nicole	Bahamas, Dominican Republic	6	Unknown
12/21-12/26	Winter Weather	Canada	4	179+ million
12/23-12/27	Winter Weather	Canada	0	75+ million

South America

Date(s)	Event	Location	Deaths	Economic Loss (USD)
01/01-12/31	Drought	Argentina	N/A	531+ million
01/01-12/31	Drought	Brazil	N/A	4.0+ billion
01/01-05/31	Flooding	Ecuador	11	399+ million
01/01-01/14	Flooding	Brazil	15	90+ million
01/15-02/28	Wildfire	Argentina	0	770+ million
01/16-01/17	Flooding	Brazil, Uruguay	0	Millions
01/20	Severe Convective Storm	Brazil	2	26+ million
01/27-01/30	Flooding	Brazil	31	72+ million
01/28-02/01	Flooding	Ecuador	28	53+ million
02/07-02/09	Severe Convective Storm	Brazil	0	23+ million
02/08	Flooding	Colombia	16	Millions
02/12-02/13	Severe Convective Storm	Brazil	1	Millions
02/15-02/16	Flooding	Brazil	232	27+ million
02/18-02/19	Flooding	Colombia	1	11+ million
03/01-05/31	Flooding	Suriname	0	21+ million

South America

Date(s)	Event	Location	Deaths	Economic Loss (USD)
03/16-10/31	Flooding	Colombia	237	406+ million
03/24-03/25	Flooding	Brazil	0	Millions
03/26	Earthquake	Ecuador	0	Millions
03/31-04/02	Flooding	Brazil	23	136+ million
04/07-04/10	Severe Convective Storm	Brazil	0	11+ million
04/15-04/30	Flooding	Venezuela	0	Millions
04/22-04/23	Severe Convective Storm	Brazil	0	21+ million
05/01-05/30	Flooding	Brazil	2	18+ million
05/04-05/06	Flooding	Brazil	3	93+ million
05/15-05/18	Tropical Cyclone Yakecan	Brazil, Uruguay	2	51+ million
05/25-05/28	Flooding	Brazil	129	459+ million
06/21	Flooding	Brazil	0	12+ million
07/01-07/05	Flooding	Brazil	12	264+ million
07/13	Earthquake	Peru	0	10+ million
08/15	Severe Convective Storm	Brazil	0	10+ million

South America

Date(s)	Event	Location	Deaths	Economic Loss (USD)
09/22-09/23	Flooding	Venezuela	10	Negligible
10/03-10/04	Severe Convective Storm	Brazil	0	Millions
10/05-10/10	Hurricane Julia	Venezuela	54	Unknown
10/10-10/12	Flooding	Brazil	0	100+ million
11/29-12/04	Flooding	Brazil	10	Millions
12/04	Landslide	Colombia	34	Negligible

Europe

Date(s)	Event	Location	Deaths	Economic Loss (USD)
01/01-12/31	Drought	Western, Southern and Central Europe	N/A	22.0+ billion
01/09-01/12	Flooding	France	1	12+ million
01/12-01/13	Windstorm Gyda	Norway	0	19+ million
01/16-01/17	Windstorm Hannelore	Northern, Eastern and Central Europe	1	118+ million
01/24-01/25	Winter Weather	Greece	0	23+ million
01/29-01/30	Windstorm Malik	Western, Northern and Central Europe	7	540+ million
01/30-01/31	Windstorm Corrie	Western Europe	0	21+ million
02/03-02/06	Winter Weather	Austria, Switzerland	11	Negligible
02/06-02/07	Windstorm Roxanna	Western and Central Europe	1	160+ million
02/16-02/17	Windstorm Dudley	Western and Central Europe	9	921+ million
02/18-02/19	Windstorm Eunice	Western and Central Europe	17	4.5+ billion
02/20-02/21	Windstorm Franklin	Western and Central Europe	3	811+ million
04/01-04/04	Winter Weather	Western Europe	0	930+ million
04/04	Windstorm Mirella	Germany, Poland	0	30+ million
04/06-04/07	Windstorm Nasim	Western and Central Europe	0	256+ million

Europe

Date(s)	Event	Location	Deaths	Economic Loss (USD)
04/08-04/09	Windstorm Diego	Western and Central Europe	0	86+ million
04/22	Earthquake	Bosnia and Herzegovina	1	26+ million
05/02-05/03	Flooding	Spain	0	33+ million
05/15-05/16	Severe Convective Storm	Western and Central Europe	0	39+ million
05/19	Severe Convective Storm	Western and Central Europe	0	71+ million
05/20	Severe Convective Storm	Western and Central Europe	1	476+ million
05/22-05/25	Severe Convective Storm	Western and Central Europe	0	480+ million
06/02-06/06	Severe Convective Storm	Western and Central Europe	2	1.7+ billion
06/09-06/10	Severe Convective Storm	Central and Southeastern Europe	2	12+ million
06/11-06/25	Wildfire	Spain	0	55+ million
06/11-08/20	Wildfire	Germany	0	42+ million
06/13-06/19	Heatwave	Western, Southern and Central Europe	3,750+	N/A
06/15-06/16	Severe Convective Storm	Central Europe	0	58+ million
06/18-07/31	Wildfire	France	0	25+ million
06/19-06/24	Severe Convective Storm	Western and Central Europe	5	2.4+ billion

Europe

Date(s)	Event	Location	Deaths	Economic Loss (USD)
06/25-07/31	Wildfire	Italy	0	13+ million
06/26-06/29	Severe Convective Storm	Western and Central Europe	2	1.3+ billion
06/30-07/01	Severe Convective Storm	Western and Central Europe	0	344+ million
07/02-07/31	Wildfire	Greece	0	12+ million
07/02-07/31	Wildfire	Portugal	0	25+ million
07/03	Landslide	Italy	11	Negligible
07/04-07/05	Severe Convective Storm	Southern and Central Europe	1	97+ million
07/07-07/20	Heatwave	Western, Southern and Central Europe	15,450+	N/A
07/09-07/31	Wildfire	Spain	0	100+ million
07/20-07/23	Severe Convective Storm	Western and Central Europe	0	95+ million
07/24-07/31	Wildfire	Czech Republic	0	Millions
07/25	Severe Convective Storm	Germany	0	51+ million
08/04-08/06	Severe Convective Storm	Western and Central Europe	1	29+ million
08/12-08/13	Severe Convective Storm	Italy	0	25+ million
08/14-08/17	Severe Convective Storm	Western, Central and Southern Europe	0	28+ million

Europe

Date(s)	Event	Location	Deaths	Economic Loss (USD)
08/17-08/21	Severe Convective Storm	Western and Central Europe	13	249+ million
08/25-08/28	Severe Convective Storm	Germany, Spain	0	60+ million
08/30	Severe Convective Storm	Spain	1	25+ million
09/02	Flooding	Bulgaria	0	47+ million
09/02-09/08	Severe Convective Storm	France, Italy	0	25+ million
09/15-09/16	Flooding	Italy	12	Millions
09/25-09/27	Flooding	Spain	0	10+ million
10/08-10/12	Flooding	Southern Europe	0	Unknown
10/31-11/01	Windstorm Karsta	Western Europe	0	15+ million
11/11-11/12	Flooding	Spain	1	79+ million
11/17	Windstorm Regina	Western Europe	0	18+ million
11/19-11/20	Flooding	Southeastern Europe	6	Millions
11/26	Flooding	Italy	12	Millions
12/07-12/13	Flooding	Southern and Eastern Europe	0	211+ million
12/13	Flooding	Spain, Portugal	0	111+ million
12/15-12/21	Winter Weather	Western and Central Europe	7	Unknown
12/30-12/31	Windstorm Liddy	Western and Northern Europe	0	11+ million

Middle East

Date(s)	Event	Location	Deaths	Economic Loss (USD)
01/01-01/06	Flooding	Oman, Iran	14	101+ million
03/17	Earthquake	Iran	0	36+ million
06/24-06/27	Flooding	Turkey	0	245+ million
07/02	Earthquake	Iran	0	143+ million
07/22-07/29	Flooding	Iran	95	201+ million
07/23-07/24	Flooding	Yemen	14	Unknown
08/01-08/05	Flooding	Yemen	16	Unknown
10/05	Earthquake	Iran	0	Unknown
11/23	Earthquake	Turkey	2	50+ million
12/11-12/12	Flooding	Turkey	0	Millions

Africa

Date(s)	Event	Location	Deaths	Economic Loss (USD)
01/01-12/31	Drought	Somalia, Ethiopia, Kenya, Malawi	N/A	2.0+ billion
01/01-01/25	Flooding	Rwanda	15	Negligible
01/08-01/09	Flooding	South Africa	10	70+ million
01/13-01/20	Flooding	Zambia	3	Millions
01/15-01/16	Flooding	South Africa	1	105+ million
01/17	Flooding	Madagascar	10	Negligible
01/21-02/02	Severe Convective Storm	DRC	26	Negligible
01/22-01/25	Tropical Storm Ana	Madagascar, Mozambique, Malawi	142	27+ million
02/02-02/07	Cyclone Batsirai	Madagascar, Mauritius, Reunion	123	200+ million
02/15-02/16	Cyclone Dumako	Madagascar	14	Millions
02/22-02/24	Cyclone Emnati	Madagascar	15	16+ million
03/08-03/18	Cyclone Gombé	Madagascar, Mozambique, Malawi	72	99+ million
04/08-04/15	Flooding	South Africa	455	3.6+ billion
04/23-04/25	Flooding	DRC, Rwanda	20	Millions
04/26	Flooding	Tanzania	10	Millions

Africa

Date(s)	Event	Location	Deaths	Economic Loss (USD)
04/26-04/27	Tropical Storm Jasmine	Madagascar	10	Millions
05/01-09/30	Flooding	Sudan	146	10s of Millions
06/01-10/31	Flooding	Chad	22	Millions
06/01-09/30	Flooding	Niger	195	Millions
06/16-06/21	Flooding	Ivory Coast	12	Millions
07/01-10/31	Flooding	Nigeria	660	2.3+ billion
07/01-10/31	Flooding	Mali	10	Millions
07/01-10/31	Flooding	Central African Republic	13	Millions
07/25-10/31	Flooding	Mauritania	19	Millions
07/30-08/01	Flooding	Uganda	29	Millions
07/30-10/31	Flooding	Gambia	6	Millions
08/01-10/31	Flooding	Cameroon	2	15+ million
08/01-10/31	Flooding	Liberia	0	Millions
08/14-08/21	Wildfire	Algeria	44	Unknown
09/01-10/31	Flooding	Benin	41	Millions

Africa

Date(s)	Event	Location	Deaths	Economic Loss (USD)
09/06	Landslide	Uganda	15	Millions
01/11-12/31	Flooding	Malawi	40	Millions
11/17-11/18	Flooding	DRC, Rwanda	35	Millions
11/27	Landslide	Cameroon	14	Unknown
12/03	Flooding	South Africa	14	Unknown
12/10-12/11	Flooding	South Africa	0	Unknown
12/12-12/13	Flooding	DRC	169	Unknown
12/20-12/26	Flooding	Uganda	10	Unknown

Asia

Date(s)	Event	Location	Deaths	Economic Loss (USD)
01/01-12/31	Drought	China	N/A	7.6+ billion
01/01-01/05	Flooding	Indonesia	0	34+ million
01/01-01/06	Flooding	Pakistan, Afghanistan	14	Millions
01/02	Earthquake	China	0	54+ million
01/06-01/09	Flooding	Indonesia	8	Millions
01/07-01/08	Winter Weather	Pakistan	23	Negligible
01/08	Earthquake	China	0	541+ million
01/09-01/13	Flooding	Indonesia	4	29+ million
01/14	Earthquake	Indonesia	0	23+ million
01/17-01/24	Flooding	Indonesia	2	36+ million
01/17	Earthquake	Afghanistan	28	Negligible
01/20-01/24	Winter Weather	China	0	107+ million
01/20-01/25	Flooding	Pakistan	12	Negligible
01/22	Earthquake	Japan	0	53+ million
01/25-01/29	Winter Weather	China	0	297+ million

Asia

Date(s)	Event	Location	Deaths	Economic Loss (USD)
01/31	Flooding	Indonesia	1	Millions
02/01-02/03	Winter Weather	China	0	147+ million
02/05-02/09	Winter Weather	China	0	84+ million
02/05-02/06	Flooding	Indonesia	3	20+ million
02/06	Winter Weather	Afghanistan	15	Negligible
02/10-02/13	Flooding	Indonesia	1	12+ million
02/11-02/14	Winter Weather	China	0	302+ million
02/15-02/17	Flooding	Indonesia	1	20+ million
02/16-02/22	Winter Weather	China	1	795+ million
02/21-02/22	Flooding	Indonesia	2	Millions
02/25	Earthquake	Indonesia	27	39+ million
02/25-03/02	Flooding	Malaysia, Thailand	12	14+ million
02/26-03/05	Flooding	Indonesia	13	62+ million
03/08-03/22	Flooding	Indonesia	10	166+ million
03/14-03/17	Severe Convective Storm	China	0	109+ million

Asia

Date(s)	Event	Location	Deaths	Economic Loss (USD)
03/16	Earthquake	Japan	4	9.0+ billion
03/20-03/22	Flooding	China	0	24+ million
03/26-03/29	Flooding	Indonesia	1	Millions
03/27-04/02	Severe Convective Storm	Vietnam	0	148+ million
03/31-04/02	Winter Weather	China	0	23+ million
04/01-09/22	Wildfire	Mongolia	0	23+ million
04/03-04/05	Flooding	Thailand	0	13+ million
04/05-04/06	Flooding	Indonesia	0	Millions
04/08-04/13	Tropical Storm Megi	Philippines	214	65+ million
04/11-04/15	Severe Convective Storm	China	3	134+ million
04/12-04/15	Winter Weather	China	1	23+ million
04/13	Flooding	China	4	26+ million
04/15-04/16	Flooding	Indonesia	1	23+ million
04/23-04/25	Severe Convective Storm	China	0	124+ million
04/24-04/26	Flooding	China	0	31+ million

Asia

Date(s)	Event	Location	Deaths	Economic Loss (USD)
04/27-04/29	Flooding	China	4	41+ million
04/27-04/30	Flooding	Indonesia	2	19+ million
04/28-05/09	Heatwave	India, Pakistan	90	N/A
05/01-09/30	Heatwave	Japan	80	N/A
05/02-05/07	Flooding	Afghanistan	29	Negligible
05/07-05/10	Flooding	Indonesia	0	15+ million
05/09-05/13	Flooding	China	1	245+ million
05/10-05/13	Flooding	Vietnam	3	11+ million
05/11-05/13	Severe Convective Storm	China	4	92+ million
05/13-05/14	Winter Weather	China	0	46+ million
05/17-10/31	Flooding	India	2,135	4.2+ billion
05/17-09/30	Flooding	Bangladesh	141	510+ million
05/17-05/28	Flooding	Indonesia	4	111+ million
05/19-06/01	Severe Convective Storm	Nepal	20	Negligible
05/19-05/22	Severe Convective Storm	China	0	31+ million

Asia

Date(s)	Event	Location	Deaths	Economic Loss (USD)
05/22-08/25	Heatwave	South Korea	7	N/A
05/22-05/31	Flooding	Vietnam	0	16+ million
05/23-05/29	Flooding	China	9	532+ million
05/23-05/26	Severe Convective Storm	China	7	77+ million
05/23-06/09	Wildfire	Pakistan	0	19+ million
05/28-05/29	Severe Convective Storm	China	7	77+ million
06/01	Earthquake	China	4	42+ million
06/01-09/30	Flooding	China	195	15.0+ billion
06/10-07/03	Flooding	Nepal	19	Negligible
06/10	Earthquake	China	0	94+ million
06/10-06/14	Severe Convective Storm	China	13	302+ million
06/14-09/10	Flooding	Pakistan	1,739	15.0+ billion
06/18-06/29	Flooding	Indonesia	11	19+ million
06/19-06/23	Severe Convective Storm	China	5	181+ million
06/20-06/24	Winter Weather	Afghanistan	12	Negligible

Asia

Date(s)	Event	Location	Deaths	Economic Loss (USD)
06/21-06/22	Flooding	Afghanistan	19	Negligible
06/22	Earthquake	Afghanistan, Pakistan	1,163	121+ million
06/29-06/30	Flooding	Indonesia	4	Millions
07/02-07/04	Typhoon Chaba	China	3	463+ million
07/05-07/11	Flooding	Afghanistan	63	Millions
07/08-07/19	Flooding	Indonesia	10	Millions
07/09	Flooding	Indonesia	0	Millions
07/13-07/16	Flooding	Indonesia	3	17+ million
07/24-08/01	Flooding	Afghanistan	39	Negligible
07/25-07/28	Severe Convective Storm	China	24	634+ million
07/25-08/18	Flooding	Nepal	15	Negligible
07/27	Earthquake	Philippines	11	151+ million
08/03-08/04	Flooding	Japan	2	141+ million
08/05	Flooding	Indonesia	0	Millions
08/08-08/09	Flooding	South Korea	14	423+ million

Asia

Date(s)	Event	Location	Deaths	Economic Loss (USD)
08/10-08/12	Tropical Depression Mulan	Vietnam, Laos, Thailand	6	Millions
08/13	Flooding	Afghanistan	31	Negligible
08/13-08/14	Tropical Storm Meari	Japan	0	Millions
08/16-08/21	Flooding	Afghanistan	63	Negligible
08/18-08/21	Flooding	Indonesia	1	14+ million
08/23-08/26	Tropical Storm Ma-on	Philippines, China, Laos	4	78+ millions
08/25-09/06	Flooding	Indonesia	3	61+ million
08/26-09/01	Severe Convective Storm	China	18	151+ million
09/01-09/06	Super Typhoon Hinnamnor	Japan, South Korea, Philippines	14	1.3+ billion
09/05	Earthquake	China	117	2.3+ billion
09/10-09/17	Flooding	Indonesia	3	27+ million
09/14-09/16	Typhoon Muifa	China	0	583+ million
09/15-09/20	Flooding	Nepal	26	Negligible
09/18-09/21	Earthquake	Taiwan	1	50+ million
09/18-09/21	Typhoon Nanmadol	Japan	5	2.0+ billion

Asia

Date(s)	Event	Location	Deaths	Economic Loss (USD)
09/20-09/24	Flooding	Indonesia	1	Millions
09/23-09/24	Tropical Storm Talas	Japan	3	752+ million
09/25-09/29	Super Typhoon Noru	Philippines, Vietnam, Thailand	20	597+ million
09/27-10/11	Flooding	Nepal	47	Negligible
10/01	Earthquake	Indonesia	1	13+ million
10/02-10/11	Flooding	Indonesia	21	173+ million
10/02-10/06	Winter Weather	China	0	58+ million
10/05-10/08	Flooding	Thailand, Vietnam, Cambodia	16	211+ million
10/11-10/12	Tropical Depression Maymay	Philippines	0	18+ million
10/13-10/20	Typhoon Nesat	Philippines, Taiwan, China	0	40+ million
10/14-11/07	Flooding	Indonesia	32	166+ million
10/15	Tropical Storm Sonca	Vietnam	10	65+ million
10/24	Tropical Storm Sitrang	Bangladesh, India	35	21+ million
10/25	Earthquake	Philippines	0	25+ million
10/27-11/3	Typhoon Nalgae	Philippines, China	164	418+ million

Asia

Date(s)	Event	Location	Deaths	Economic Loss (USD)
11/11-11/18	Flooding	Malaysia	0	Millions
11/11-11/12	Flooding	Thailand	0	Millions
11/11-11/25	Flooding	Indonesia	14	112+ million
11/21	Earthquake	Indonesia	603	371+ million
11/26-11/30	Winter Weather	China	0	49+ million
11/28-12/02	Flooding	Indonesia	4	13+ million
12/01-12/04	Flooding	Vietnam	5	Millions
12/06-12/09	Cyclone Mandous	India, Sri Lanka	9	12+ million
12/07-12/08	Flooding	Indonesia	0	22+ million
12/12-12/14	Flooding	Indonesia	0	Millions
12/15-12/23	Winter Weather	Japan, China, Russia	19	42+ million
12/16	Landslide	Malaysia	31	Negligible
12/18-12/20	Flooding	Malaysia, Thailand	17	44+ million
12/24-12/25	Flooding	Philippines	52	11+ millions
12/26-12/27	Severe Convective Storm	India	0	Millions

Oceania

Date(s)	Event	Location	Deaths	Economic Loss (USD)
01/08-01/13	Flooding	Australia	2	80+ million
01/15-10/16	Volcano	Tonga, Pacific Rim	4	118+ million
02/01-02/08	Flooding	Fiji	0	105+ million
02/09-02/13	Cyclone Dovi	New Zealand, Vanuatu, New Caledonia	0	84+ million
02/23-03/31	Flooding	Australia	22	8.0+ billion
03/20-03/21	Severe Convective Storm	New Zealand	0	118+ million
06/09-09/14	Severe Convective Storm	Australia, New Zealand	1	19+ million
07/01-07/08	Flooding	Australia	0	466+ million
08/18-08/21	Severe Convective Storm	New Zealand	1	68+ million
09/10	Earthquake	Papua New Guinea	10	Millions
10/12-10/28	Flooding	Australia	2	1.3+ billion
11/12-11/16	Flooding	Australia	0	300+ million

Appendix B: Long-term Natural Disaster Trends

Exhibit 44: Global Economic Losses Since 1950 (2022 \$ bn)

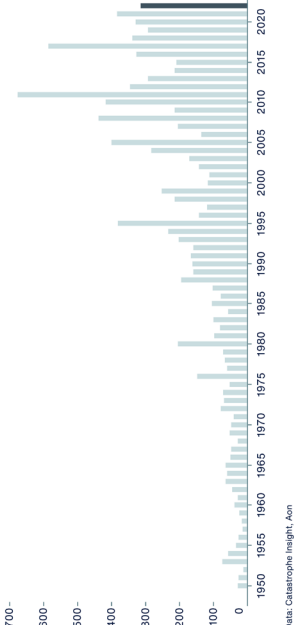
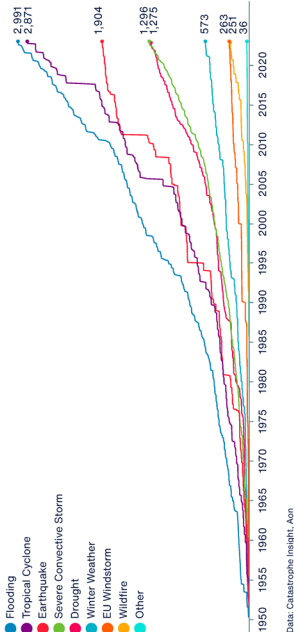


Exhibit 45: Cumulative Global Economic Losses Since 1950 (2022 \$ bn)



Appendix B: Long-term Natural Disaster Trends

Exhibit 46: Global Insured Losses Since 1950 (2022 \$ bn)

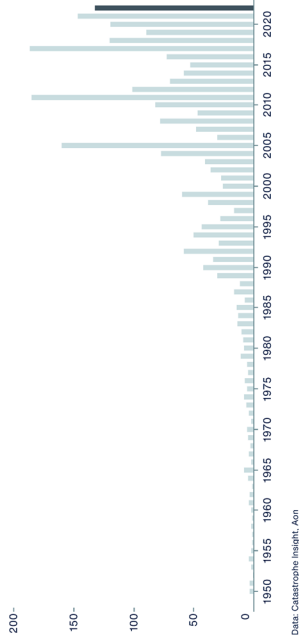
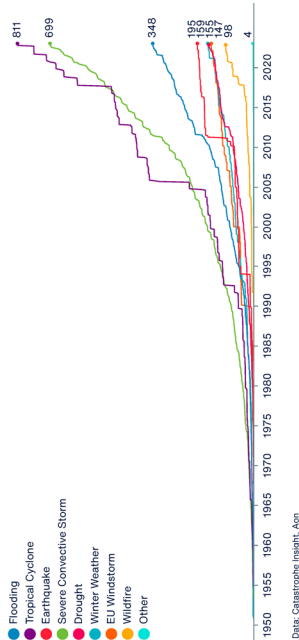


Exhibit 47: Cumulative Global Insured Losses Since 1950 (2022 \$ bn)



Appendix C: Historical Natural Disaster Events

The following tables provide a look at specific global natural disaster events since 1900. Please note that the adjusted for inflation (in 2022 \$) totals were converted using the U.S. Consumer Price Index (CPI). Insured losses include those sustained by private industry and government entities such as the U.S. National Flood Insurance Program (NFIP). Inflation-adjusted losses are used since they represent actual incurred costs in today's dollars. Normalized values, while very valuable for analyzing historical scenarios using today's population, exposure, and wealth, are hypothetical. Please note that some of these values have been rounded to the nearest whole number.

For additional top 10 lists, please visit <http://catastrophinsight.aon.com>.

Exhibit 48: Top 10 Costliest Global Economic Loss Events (1900-2022)

Date(s)	Event	Location	Economic Loss (Nominal \$ billion)	Economic Loss (2022 \$ billion)
March 11, 2011	Tohoku EQ/Tsunami	Japan	235	314
January 16, 1995	Great Hanshin EQ	Japan	103	203
August 2005	Hurricane Katrina	United States	125	190
May 12, 2008	Sichuan Earthquake	China	122	168
August 2017	Hurricane Harvey	United States	125	152
September 2017	Hurricane Maria	Puerto Rico, Caribbean	90	109
October 2012	Hurricane Sandy	U.S., Caribbean, Canada	77	99
September 2022	Hurricane Ian	U.S., Cuba	96	96
September 2017	Hurricane Irma	U.S., Caribbean	77	93
January 17, 1994	Northridge EQ	United States	44	90

Exhibit 49: Top 10 Costliest Global Insured Loss Events (1900-2022)

Date(s)	Event	Location	Insured Loss (Nominal \$ billion)	Insured Loss (2022 \$ billion)
August 2005	Hurricane Katrina	United States	65	99
September 2022	Hurricane Ian	U.S., Cuba	53	53
March 11, 2011	Tohoku EQ/ Tsunami	Japan	35	47
September 2017	Hurricane Irma	U.S., Caribbean	33	40
August-September 2021	Hurricane Ida	U.S., Caribbean	36	39
October 2012	Hurricane Sandy	United States	30	39
August 2017	Hurricane Harvey	United States	30	36
September 2017	Hurricane Maria	Puerto Rico, Caribbean	30	36
August 1992	Hurricane Andrew	U.S., Bahamas	16	34
January 17, 1994	Northridge EQ	United States	15	31

Exhibit 50: Top 10 Costliest Tropical Cyclones: Economic Loss (1900-2022)

Date(s)	Event	Location	Economic Loss (Nominal \$ billion)	Economic Loss (2022 \$ billion)
2005	Hurricane Katrina	United States	125	190
2017	Hurricane Harvey	United States	125	152
2017	Hurricane Maria	U.S., Caribbean	90	109
2012	Hurricane Sandy	U.S., Caribbean	77	99
2022	Hurricane Ian	U.S., Cuba	96	96
2017	Hurricane Irma	U.S., Caribbean	77	93
2021	Hurricane Ida	U.S., Caribbean	75	82
1992	Hurricane Andrew	U.S., Bahamas	27	58
2008	Hurricane Ike	U.S., Caribbean	38	52
2004	Hurricane Ivan	U.S., Caribbean	27	43

Exhibit 51: Top 10 Costliest Tropical Cyclones: Insured Loss (1900-2022)

Date(s)	Event	Location	Insured Loss (Nominal \$ billion)	Insured Loss (2022 \$ billion)
2005	Hurricane Katrina	United States	65	99
2022	Hurricane Ian	U.S., Cuba	53	53
2017	Hurricane Irma	U.S., Caribbean	33	40
2021	Hurricane Ida	U.S., Caribbean	36	39
2012	Hurricane Sandy	U.S., Caribbean, Canada	30	39
2017	Hurricane Harvey	United States	30	36
2017	Hurricane Maria	U.S., Caribbean	30	36
1992	Hurricane Andrew	U.S., Caribbean	16	34
2008	Hurricane Ike	U.S., Caribbean	18	25
2005	Hurricane Wilma	U.S., Caribbean	13	19

Exhibit 52: Top 10 Costliest Severe Convective Storm Events: Economic Loss (1900–2022)

Date(s)	Event	Location	Economic Loss (Nominal \$ billion)	Insured Loss (2022 \$ billion)
August 2020	Midwest Derecho	United States	13.6	15.6
April 2011	2011 Super Tornado Outbreak	United States	10.2	13.5
May 2011	Joplin Tornado/SCS	United States	9.1	12.0
April 1965	Palm Sunday Outbreak	United States	1.2	11.4
Oct-Nov 2018	Storm Vaia	Europe	8.3	9.8
April 1974	Super Outbreak 1974	United States	1.5	9.5
March 1973	United States SCS	United States	1.3	8.7
May 2003	United States SCS	United States	4.5	7.3
July 2013	Storm Andreas	Europe	5.3	6.7
April 1979	Texas Tornadoes and Flooding	United States	1.5	6.3

Exhibit 53: Top 10 Costliest Severe Convective Storm Events: Insured Loss (1900-2022)

Date(s)	Event	Location	Insured Loss (Nominal \$ billion)	Insured Loss (2022 \$ billion)
August 2020	Midwest Derecho	United States	9.2	10.5
April 2011	2011 Super Outbreak	United States	7.3	9.7
May 2011	Joplin Tornado/SCS	United States	6.9	9.1
May 2003	United States SCS	United States	3.2	5.2
July 2013	Storm Andreas	Europe	3.8	4.9
May 2019	United States SCS	United States	3.7	4.3
April 2016	San Antonio Hailstorm	United States	3.2	4.0
June 2014	Storm Ela	Europe	3.1	3.9
June 2021	European June 17-25 Outbreak	Europe	3.5	3.8
April 2001	St. Louis Hailstorm	United States	2.2	3.7

Exhibit 54: Top 10 Costliest Floods: Economic Loss (1900-2022)

Date(s)	Event	Location	Economic Loss (Nominal \$ billion)	Economic Loss (2022 \$ billion)
June-December 2011	Thailand Floods	Thailand	45	59
June-September 1998	Yangtze River Floods	China	31	57
July-August 2010	Yangtze River Floods	China	39	53
July 2021	Western Europe Floods (Bernd)	Europe	46	50
June-August 1993	Mississippi Floods	United States	21	43
June-September 2020	China Seasonal Floods	China	35	40
July-August 1931	Yangtze River Floods	China	2.0	40
June-August 1953	Japan Floods	Japan	3.2	36
May-August 2016	Yangtze River Floods	China	28	35
June-September 2021	China Seasonal Floods	China	31	34

Exhibit 55: Top 10 Costliest Earthquakes: Economic Loss (1900–2022)

Date(s)	Event	Location	Economic Loss (Nominal \$ billion)	Economic Loss (2022 \$ billion)
March 11, 2011	Tohoku EQ/Tsunami	Japan	235	314
January 16, 1995	Great Hanshin EQ	Japan	103	203
May 12, 2008	Sichuan Earthquake	China	122	168
January 17, 1994	Northridge EQ	United States	44	90
November 23, 1980	Irpinia EQ	Italy	20	70
April 14, 2016	Kumamoto EQ	Japan	38	47
October 23, 2004	Chuetsu EQ	Japan	28	44
February 27, 2010	Chile EQ	Chile	30	41
December 7, 1988	Armenian EQ	Armenia (Present Day)	16	40
July 27, 1976	Tangshan EQ	China	6.8	36

Exhibit 56: Top 10 Costliest Individual Wildfires: Insured Loss (1900-2022)

Date(s)	Event	Location	Insured Loss (Nominal \$ billion)	Insured Loss (2022 \$ billion)
November 2018	Camp Fire	United States	10.0	11.8
October 2017	Tubbs Fire	United States	8.7	10.5
November 2018	Woolsey Fire	United States	4.2	5.0
October 1991	Oakland (Tunnel) Fire	United States	1.7	3.7
October 2017	Atlas Fire	United States	3.0	3.6
May 2016	Horse Creek Fire	Canada	2.9	3.5
September-October 2020	Glass Fire	United States	3.0	3.4
August-September 2020	CZU Complex Fire	United States	2.5	2.9
December 2017	Thomas Fire	United States	2.2	2.7
December 2021	Marshall Fire	United States	2.5	2.7

Exhibit 57: Top 10 Global Human Fatality Events in the Modern Era (1950-2022)

Date(s)	Event	Location	Economic Loss (Nominal \$ billion)	Fatalities
November 12, 1970	Cyclone Bhola	Bangladesh	0.7	300,000
July 27, 1976	Tangshan EQ	China	36	242,769
July 30, 1975	Super Typhoon Nina	Taiwan, China	6.6	230,029
December 26, 2004	Indian Ocean EQ/Tsunami	Indian Ocean Basin	29	227,898
January 12, 2010	Port-au-Prince EQ	Haiti	11.0	160,000
April 1991	Cyclone Gorky	Bangladesh	3.9	139,000
May 2008	Cyclone Nargis	Myanmar	17.8	138,366
August 1971	Vietnam Floods	Vietnam	N/A	100,000
October 8, 2005	Kashmir EQ	Pakistan	10.0	88,000
May 12, 2008	Sichuan EQ	China	167	87,652

Appendix D: Global Tropical Cyclone Activity

Please note that 1990 is generally considered the first year when global tropical cyclone data are best verified in every basin. Data from the Southern Hemisphere prior to 1990 is still subject to future reanalysis by official tropical cyclone agencies. While there continues to be increasing instances of costlier and more impactful landfalling tropical cyclones, there has yet to be any obvious shift in landfall trends across the globe. This suggests that losses

are largely being driven by the increased levels of population and exposure along vulnerable coastal locations. However, as thoroughly referenced elsewhere in this report, emerging trends indicate that tropical cyclones are intensifying at a faster rate and reaching the highest intensity levels for longer periods and near the point of landfall. This is a concerning trend and one that portends to greater future losses for the peril.

Exhibit 58: Global Tropical Cyclone Landfalls (Category 1+)

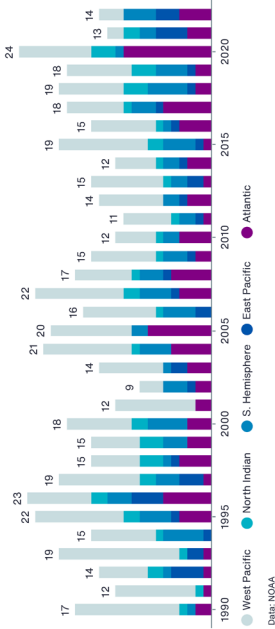
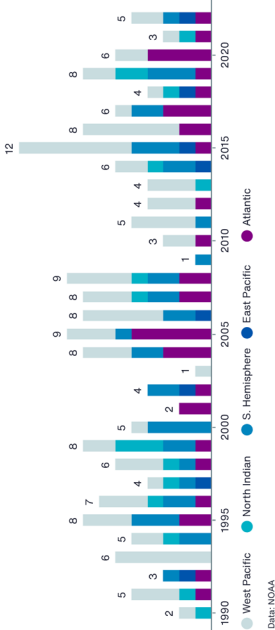


Exhibit 59: Global Tropical Cyclone Landfalls (Category 3+)



Appendix E: United States Storm Report Data

Given the increased cost of severe weather-related damage in the United States during the past decade for insurers, the following is a number of tornado and large hail (2.0" or larger) reports. The data comes via NOAA's Storm Prediction Center. Please note that data prior to 1990 are often considered incomplete given a lack of reporting. The implementation of Doppler radar, greater social awareness and increased reporting has led to more accurate datasets in the last 30 years. Data from 2022 is to be considered preliminary.

Exhibit 60: U.S. Tornadoes (F0/EF0+)

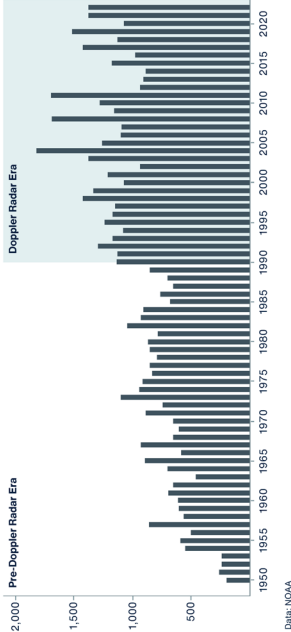
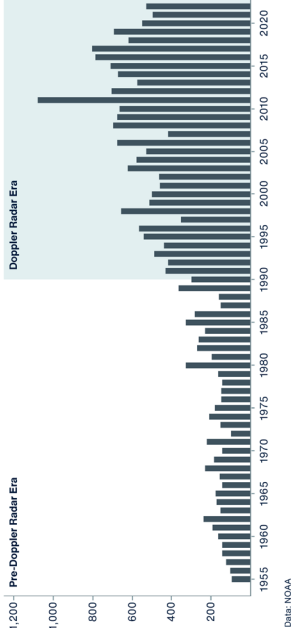


Exhibit 61: U.S. Large Hail Reports (2.0" or Larger)



Appendix F: Global Earthquakes

Based on historical data from the United States Geological Survey, 2022 saw at least 128 earthquakes with magnitudes of 6.0 or greater. Overall earthquake activity does not often show large fluctuations on an annual basis. This is especially true given the extensive network of global seismograph stations that has led to an improved and more robust dataset in recent decades.

Exhibit 62: Global Earthquakes (M7.0+)

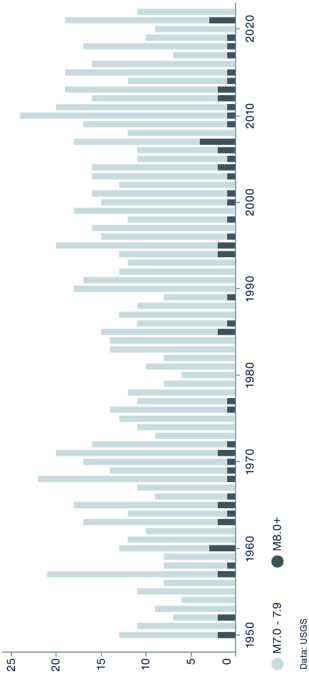


Exhibit 63: Global M6.0+ Earthquakes in 2022



Appendix G: United States Wildfire Data

The following wildfire data in the United States is provided from the National Interagency Fire Center (NIFC), which began compiling statistics under their current methodology in 1983. Previous data was collected by the National Interagency Coordination Center (NICC) from 1960 to 1982 but used a different methodology. It is not advised to compare pre-1983 data to post-1983 data given these different data collection methods. The European data comes via the European Forest Fire Information System (EFFIS), which is maintained by the European Union's Copernicus group.

Exhibit 64: Area Burned by Wildfires in the United States (M acres)

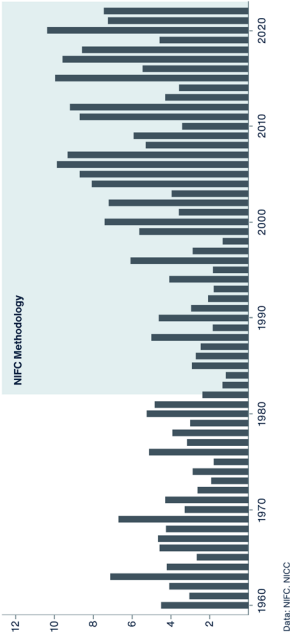
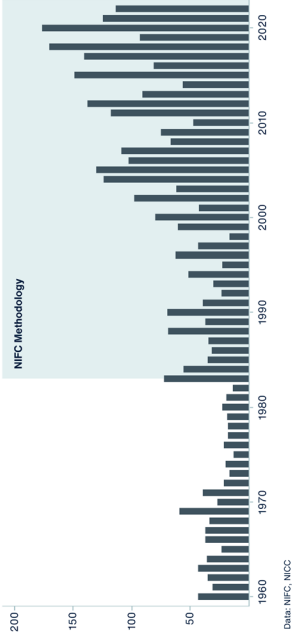


Exhibit 65: Area Burned per Fire in United States Wildfires (acres)



Additional Report Details

Additional Report Details

All financial loss totals are in US dollars (\$) unless noted otherwise.

DR = Drought, EQ = Earthquake, WS = EU Windstorm, FL = Flooding, SCS = Severe Convective Storm, TC = Tropical Cyclone, WF = Wildfire, WW = Winter Weather, VL = Volcano, HW = Heatwave, LS = Landslide

TD = Tropical Depression, TS = Tropical Storm, HU = Hurricane, TY = Typhoon, STY = Super Typhoon, CY = Cyclone

Fatality estimates as reported by public news media sources and official government agencies.

Structures defined as any building — including barns, outbuildings, mobile homes, single or multiple family dwellings and commercial facilities — that is damaged or destroyed by winds, earthquakes, hail, flood, tornadoes, hurricanes or any other natural-occurring phenomenon. Claims defined as the number of claims (which could be a combination of homeowners, commercial, auto and others) reported by various public and private insurance entities through press releases or various public media outlets.

Damage estimates are obtained from various public media sources, including news websites, publications from insurance companies, financial institution press releases and official government agencies. Damage estimates are determined based on various public media sources, including news websites, publications from insurance companies, financial institution press releases, and official government agencies. Economic loss totals are separate from any available insured loss estimates. An insured loss is the portion of the economic loss covered by public or private insurance entities.

In rare instances, specific events may include modeled loss estimates determined from utilizing impact Forecasting's suite of catastrophe model products.



Europe

- Heatwaves, Droughts, Floods, Storms, Forest fires
- Austria, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Denmark, France, Germany, Greece, Hungary, Italy, Lithuania, Luxembourg, Netherlands, Norway, Poland, Romania, Serbia, Slovakia, Slovenia, Switzerland, Sweden, Sweden, United Kingdom, and Switzerland

North America

- Heatwaves, Droughts, Floods, Storms, Forest fires
- Canada, United States

South America

- Heatwaves, Droughts, Floods, Storms, Forest fires
- Chile

Africa

- Heatwaves, Droughts, Floods, Storms, Forest fires
- Algeria, Kenya, Morocco, South Africa, Tanzania, Uganda

Asia

- Heatwaves, Droughts, Floods, Storms, Forest fires
- Bahrain, Indonesia, Iran, Israel, Kazakhstan, Kyrgyzstan, Malaysia, Myanmar, Oman, Saudi Arabia, Singapore, Thailand, Turkey, United Arab Emirates, Yemen

Oceania

- Heatwaves, Droughts, Floods, Storms, Forest fires
- Fiji, French Polynesia, New Caledonia, Papua New Guinea, Solomon Islands, Vanuatu



Contact Us

Michal Lörinc
Head of Catastrophe Insight
michal.lorinc@aon.com

Ondřej Hotový
Catastrophe Analyst
ondrej.hotovy@aon.com

Adam Podlaha
Head of Impact Forecasting
adam.podlaha@aon.com

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**Prepared Testimony of Nancy Watkins, FCAS, MAAA
Principal and Consulting Actuary, Milliman Inc.**

**Hearing on “Risky Business: How Climate Change is Changing Insurance Markets”
United States Senate Committee on the Budget
March 22, 2023**

Thank you, Chairman Whitehouse, Ranking Member Grassley and members of this Committee for inviting me here today.

My name is Nancy Watkins, and I am an actuary and a principal with Milliman, an independent consulting firm. I serve as an expert on catastrophe risk for insurers, real estate industry groups, and state and federal government agencies. I also volunteer to promote insurance availability and affordability alongside the National Association of Insurance Commissioners, Western Fire Chiefs Association, and the United Nations.

Let’s talk about homeowners’ insurance and how climate change is impacting it.

First: Climate change is not a problem of the distant future; it’s already here.

Across the country, we have insurance protection gaps and crises exacerbated by climate change:

- Flood risk in the U.S. is already very high, increasing rapidly and unsustainable once you factor in sea level rise. The National Oceanic and Atmospheric Administration (NOAA) reports that about 80% of the East and Gulf Coasts are seeing more high-tide flood days,¹ and that this spring about 44% of the U.S. is at risk for flooding.² Most flood risk is not covered by the private market; only 4% of U.S. homeowners have flood insurance today, largely through the government-run National Flood Insurance Program (NFIP).³
- Unprecedented wildfires have driven insurers to shed high-risk policies in Western states like California, Oregon, and Colorado. In California, homeowners’ insurers lost \$20 billion in 2017 and 2018 due to wildfire, wiping out two times the cumulative profits earned over the prior 26 years.⁴
- Since 2020, Louisiana has been hit by multiple hurricanes, tropical storms, tornadoes and excessive rainfall events. After 20 companies folded or exited the state, more than 100,000 policyholders are now in the state-run insurer of last resort.⁵

¹ <https://coast.noaa.gov/states/fast-facts/recurring-tidal-flooding.html>

² <https://www.noaa.gov/news-release/spring-outlook-california-drought-cut-by-half-with-more-relief-to-come>

³ <https://www.milliman.com/en/insight/unpriced-costs-of-flooding-an-emerging-risk-for-homeowners-and-lenders>

⁴ <https://us.milliman.com/en/insight/wildfire-catastrophe-models-could-spark-the-changes-california-needs>

⁵ <https://www.wvltv.com/article/news/investigations/david-hammer/louisianas-insurance-crisis-what-can-fix-it/289-a9fe2f3c-8701-4f75-959f-6ec7b5e7f380>

Insurance market withdrawals can cause ripple effects that endanger entire communities and create a downward spiral that's difficult to emerge from.⁶ This could happen gradually, but it's possible for weakened markets to collapse quickly through a crisis of confidence triggered by one event.

Second: A broken insurance market is not *the* problem; it's a *symptom* of a larger problem – too much risk for the market to bear.

The risks associated with climate change and catastrophes are owned by homeowners and the community, not the insurance industry. Much of that risk can potentially be transferred to insurers if there is a sustainable private market, which rests on three pillars: availability, affordability and reliability.

Climate change is interacting in new ways with other inherent risks, causing cracks in all three of those pillars. The policy actions intended to help can actually backfire and accelerate the collapse of the insurance market. This generally happens because these actions don't address the underlying problem – that the risk is too high.

Often, this occurs when land use policies and building codes don't keep up with risk, resulting in a mismatch between actual vs. perceived risk by homeowners. Because we aren't all actuaries, one way to effectively communicate the actual risk to consumers is to build the true cost of risk into insurance pricing.

Risk-based pricing drives behavior. If you can buy low-cost insurance or aren't even required to insure your home against flooding, you expect this to be a safe place to live. If you can't get affordable insurance, you may act to mitigate the home's risk, or you may decide it is too risky to live there at all.

The obvious downside is that premiums may be unaffordable for some homeowners. The government could decide that it is good policy to subsidize premiums, with the costs ultimately borne by others – generally, current and future policyholders or taxpayers who live in lower-risk areas, often in other states. To reduce premiums and the cost of subsidization, the only effective action we can take is to drive down the risk.

Third: The cost of driving down climate risk is much lower than the cost of inaction.

The choice to ignore climate risk and manage from crisis to crisis puts more families in harm's way, with low-income communities likely to be hit the hardest and suffer the most.⁷ Failure to

⁶ For more information on the effects of climate change on the housing and financial markets, see https://www.mba.org/docs/default-source/research--riha-reports/24981-riha-climate-change-volume-2.pdf?sfvrsn=3df0b2ea_1 and <https://www.milliman.com/en/insight/unpriced-costs-of-flooding-an-emerging-risk-for-homeowners-and-lenders>

⁷ For more on the impact of climate change at the community level, including climate displacement or gentrification, see <https://www.milliman.com/en/insight/climate-displacement-in-nyc-making-space-for-our-neighbors> and <https://www.milliman.com/en/insight/climate-gentrification-and-the-role-of-flood-insurance>

act early reduces the number of options available and drives up the costs of reaction at various government levels.

To avoid this we need to work collectively to bend down the risk curve. We need better data, better modeling, higher prioritization of mitigation vs. disaster response, better stakeholder coordination, and resource assistance to those areas most in need. The sooner our society chooses to face the risks associated with climate change, the more options we will have to drive down these risks, and the lower the cost will be.

Climate risks are complex and difficult to understand. The actuarial community is leveraging science and technology and working with other experts to measure these risks and communicate them to important stakeholders like this Committee. We aim to give you the best information available, so that you can make informed decisions.

Thank you.

Testimony of Benjamin J. Keys, Ph.D.
 Rowan Family Foundation Professor,
 Professor of Real Estate and Finance,
 The Wharton School, University of Pennsylvania
 Hearing on “Risky Business: How Climate Change is Changing Insurance Markets”
 United States Senate Committee on the Budget

March 22, 2023

Chairman Whitehouse, Ranking Member Grassley, and Members of the Committee: Thank you for inviting me to address how climate change is affecting insurance markets. My name is Ben Keys and I am an economist and Professor of Real Estate and Finance at the University of Pennsylvania’s Wharton School. My research agenda examines how households interact with the financial system, and how the financial system manages risk.

In my remarks today, I would like to put a broader economic lens on issues in property insurance markets, emphasizing the effects on household well-being.

First, rising insurance costs are having a direct effect on households’ pocketbooks. Across the country, average homeowners’ insurance premiums rose by 40 percent from 2010 to 2019, the most recent data available.¹ In addition, private insurers are exiting certain markets, pushing households into public “insurers of last resort.” The number of enrollees in these state-backed FAIR insurance plans rose by 29 percent between 2018 and 2021.² With rising climate-related risks, and the rising cost of reinsurance, insurers will continue to increase premiums and exit markets, leaving homeowners with fewer choices, less protection, and more financial distress.

Family budgeting is difficult as it is. And as homeowners’ insurance premiums can change every year, it is nearly impossible for households to accurately budget for increasing climate risk. For instance, this January, Louisiana Citizens increased its property insurance rates by 63 percent.³ Costs are also rising in the National Flood Insurance Program. In the first year of the Risk Rating 2.0 reform, 75 percent of primary residences experienced an increased premium of 18 percent, the statutory limit. Half of all NFIP policyholders will see their premiums more than double after 5 years.⁴ Sadly, these increases will lead many households to choose to go without insurance.

Rising insurance costs directly affect housing markets. Every additional dollar of premiums decreases the demand for a home, affecting the amount its owners can expect to receive when they sell. In more dire situations where homeowners cannot find insurance, lenders will not be willing to accept uninsured homes as collateral.

These concerns are not merely theoretical. Economic research shows that higher flood insurance premiums lower home prices and make it harder to get a mortgage.⁵ My own research shows that the threat of future sea level rise lowers home prices today, as buyers don’t want to be left with an uninsurable home down the road. In short, home prices have already started reacting to climate risk — even as we’ve realized only a fraction of the higher premiums

¹Insurance Information Institute (2022) <https://www.iii.org/table-archive/21407>

²Insurance Information Institute (2022) <https://www.iii.org/table-archive/20793>

³<https://www.lldi.la.gov/news/press-releases/10-10-22-ldi-approves-citizens-rate-increase-and-offers-tips-for-policyholders>

⁴Congressional Research Service, “National Flood Insurance Program: The Current Rating Structure and Risk Rating 2.0,” April 2022 <https://crsreports.congress.gov/product/pdf/R/845999>

⁵Blickle and Santos (2022) https://www.newyorkfed.org/medialibrary/media/research/staff_reports/sr1012.pdf,
 Georgie and Klaiber (2022) <https://www.sciencedirect.com/science/article/pii/S0095069621001170>

and sea level rise expected in the coming decades.⁶

I want to briefly highlight why climate risks are so difficult to insure. After a massive fire in the city of Hamburg, Germany in 1842, local insurers failed.⁷ Reinsurance markets arose for fire insurance because fires are idiosyncratic events, allowing providers to create a diversified risk pool and spread these risks widely and effectively.

Unlike the chances of a fire in a given city, climate risk is better described by the title of the latest Oscar winner: It's "Everything, Everywhere, All at Once." Climate change is simultaneously inducing heightened risk of flood, storm damage, chronic inundation, drought, excessive heat, and wildfires. These risks are difficult to diversify and spread to private entities. While reinsurance and the catastrophe bond market will continue to play a role in maintaining functioning insurance markets, there is no avoiding the fact that the increasing risk of large, global loss events will mean higher costs for consumers.⁸

The limitations of private insurance markets for insuring against climate risks points to a larger role for the government. State and federal insurance entities will bear more of these risks going forward as private insurers pull back. If we do not take action on climate adaptation and mitigation, then we can expect private markets for wildfire and wind coverage to increasingly resemble the National Flood Insurance Program and rely on public support. Further costs will be borne by Fannie, Freddie, and the FHA, who make up two-thirds of the current mortgage market, and by FEMA and other post-disaster aid sources.

Topics surrounding insurance often feel remote or difficult to digest, but they impact everyday households. Far too many Americans are currently not protected from climate risks: FEMA estimates that only 35 percent of Florida households in flood zones have flood insurance.⁹ And the First Street Foundation estimates that roughly 6 million households are at significant flood risk but lie outside of FEMA's outdated floodplain maps, making them likely unaware of their danger.¹⁰

Private insurers' aim to price their risks accurately, so we should pay close attention to the choices that they make. No matter your views on climate science, insurers are responding to the increased frequency of high-cost disasters and the latest scientific forecasts. The departure of insurers from property markets has serious implications for home values, the dominant store of wealth for the average household, and for communities that rely heavily on property taxes to provide basic services as well as defend against further climate-related damage. Now is the time to identify policy solutions to reduce American families', businesses', and taxpayers' exposure to climate risk.

Thank you again for the opportunity to testify.

⁶Keys and Mulder (2020) <https://www.nber.org/papers/w27930>

⁷Kopf (1929) https://www.casact.org/sites/default/files/database/proceed/proceed29_29022.pdf

⁸For more on disaster insurance, see the excellent primer by Kousky (2022): <https://islandpress.org/books/understanding-disaster-insurance>

⁹FEMA (2020) <https://www.fema.gov/press-release/20230110/floridians-flood-insurance-sound-investment>

¹⁰First Street (2020) <https://firststreet.org/press/2020-first-street-foundation-flood-model-launch>

Research on Climate Risk, Housing, Mortgage, and Insurance Markets

I began my career studying the implications and impact of the 2008 financial crisis, and in recent years my focus has turned to climate change as the most critical risk that faces consumers and our economy.

My ongoing research on coastal housing markets documents the emergence of a 5 to 7 percent price discount for Florida properties in neighborhoods that face the greatest exposure to sea level rise (see maps below in Figure 1).¹¹ The price discount on at-risk homes grew between 2016 and 2019, but actually manifested earlier in 2013 as a decline in the number of home sales (see Figure 2). Like the housing bust of 2008, when housing demand declines sellers are reluctant to cut prices. This reluctance leads to fewer transactions and a larger inventory of for-sale homes spending more time on the market. Eventually sellers lowered their list prices, and transaction prices declined. However, we find that transaction volumes remained substantially below that of less exposed properties, suggesting less liquidity in the housing market. We further examined the mortgage and flood insurance markets and found no evidence that these markets were driving the price discount or the lack of liquidity. These market dynamics were present prior to the COVID-19 housing boom, and whether they will re-emerge is an important question for understanding how sea level rise will affect coastal housing markets.

Other researchers studying how housing markets across the United States are responding to climate risk have also found that homes exposed to sea level rise sell at a discount compared to otherwise similar properties.¹² The literature on climate and real estate markets has several important takeaways for policymakers. First, new information about climate risk — and not just sea level rise but also flooding, wildfires, and hurricanes — is affecting property values today. Second, the capitalization of risk into home prices may not be a smooth process. When sellers are reluctant to cut prices or when they disagree with buyers about the risk of different climate scenarios, real estate markets can become less liquid and more volatile. As we are seeing once again, volatility and uncertainty in housing markets can affect not just individual buyers and sellers, but the stability of the wider financial system. Finally, due to barriers created by state- and federal-level policies, insurance markets and lenders are not pricing climate risk into their decisions, which may be keeping the prices of at-risk homes elevated even given the price discounts that have started to emerge.¹³

Below, I discuss the role of financial and real estate markets in transmitting climate risk across the economy, and discuss policies that can help to manage and reduce risk. To understand the potential consequences to property markets of climate change, it is illustrative to consider parallels between the growing climate risk that we face and the lessons learned from the last crisis in 2008.

Property markets played a central role in the last crisis. A key feature of the property boom of the 2000s was overoptimism surrounding commercial property and home prices, fueled by declining lending standards and secondary mortgage markets that created distance between those who originated mortgages and the final holders of the mortgages' risk. A central lesson from the boom and bust is that expectations matter and prices can deviate substantially from fundamentals for long periods of time. A second lesson is that both property owners and financial markets, largely left to their own devices, reached valuations that were unrealistic and unsustainable. The direct risks of lending were underappreciated, and there was a fundamental lack of awareness about the broader risks in the financial system, with spillovers ultimately to the entire economy.

As in 2008, there is a lack of information and awareness regarding the true scope of climate risk. Taking flood risk as an example, far too many households are uninsured or underinsured from flood hazards. Ninety-eight percent of U.S. counties have experienced a flooding event, and floods have caused over \$155 billion in property damages in the last decade.¹⁴ Yet among households, there are few, if any, mechanisms or incentives that raise homeowners' concerns consistent with the growing risk. This lack of awareness is especially acute in the insurance market. A 2021 survey of homeowners conducted by the NAIC found that 56 percent believe their homeowners' policy covers flood damage, even though flood is not covered under standard policies; In fact, only 4 percent of the homeowners in their

¹¹ Keys and Mulder (2020) <https://www.nber.org/papers/w27930>

¹² See, for instance, Bin and Landry (2013) <https://doi.org/10.1016/j.jeem.2012.12.002>, Bernstein et al. (2019) <https://doi.org/10.1016/j.jfineco.2019.03.013>, Hino and Burke (2021) <https://www.pnas.org/doi/full/10.1073/pnas.2003374118>, and Bakkensen and Barrage (2022) <https://academic.oup.com/rfs/article/35/8/3666/6424922>.

¹³ Oh, et al. (2022) https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3762235

¹⁴ Grimm (2020) <https://www.fema.gov/fact-sheet/michael-grimm-testimony-committee-science-space-and-technology>

sample actually had flood insurance.¹⁵ Over 50 percent of the flood losses from Hurricane Ian were uninsured.¹⁶

A lack of awareness and information can lead to the mis-pricing of assets. A recent study published in *Nature Climate Change* convincingly argues that increased costs of flood risk are not fully captured in property values.¹⁷ The authors estimate that residential properties are overvalued by between 120 and 240 billion dollars. Mis-pricing is not limited to the properties themselves, but also applies to the cost of insurance. The NFIP has recently implemented Risk Rating 2.0, a new rating methodology which is gradually increasing flood insurance premiums. While this much needed innovation is moving prices of flood insurance toward their actuarially fair levels, FEMA models include neither heavy rainfall nor climate change effects in their flood maps. These omissions are consequential: The non-profit First Street Foundation identifies 14.6 million properties currently at significant flood risk, of which nearly 6 million lie outside of FEMA floodplain boundaries¹⁸

Mortgage markets are also failing to directly price climate-related risks. In earlier research, my co-authors and I examined the consequences of Fannie Mae and Freddie Mac choosing not to price predictable spatial default risk.¹⁹ As macroeconomic conditions like unemployment rates and house price fluctuations are persistent in the short run, there are predictable differences in default risk across areas that the GSEs could include in their prices. However, they price mortgage credit uniformly across the country based on individual- and property-level characteristics (like FICO score and loan-to-value ratio). We find that this policy choice leads to substantial cross-subsidization from safer areas to riskier ones. The same logic applies to climate-related risks: If they were priced separately, mortgages in areas exposed to climate risks would face higher interest rates to account for their heightened chance of default and larger losses given default. Add in generous disaster aid programs, and when combined, the mis-pricing of properties, subsidized insurance policies, and mortgage rates can lead to a substantial distortion, driving more economic activity and more building to high-risk areas.

Stress Testing Housing and Property Markets Against Climate Risk

Considering two tail-risk scenarios is potentially useful for “stress testing” our complex and opaque system of risk management in property markets. My first scenario is a large-scale disaster. The frequency of “billion dollar” disasters has increased six-fold since the 1980s.²⁰ Going forward, climate change will lead hurricanes to produce more rainfall and more extreme coastal storm surges.²¹

A disaster hitting a major metropolitan area along the eastern seaboard would be catastrophic, with the potential for loss of life and other health outcomes. The destruction could easily surpass previous levels of damage, given the number of people and the amount of development in these areas. Imagine a 20 foot storm surge in New York City, for instance.²² The destruction of property means the devaluation of collateral, which would have ripple effects through the financial system. The size of the ripple would depend on the solvency of counterparties in the housing and mortgage market. For instance, many insurers would potentially be unable to pay massive claims, as we are already seeing in Florida, and state-level backstops through guaranty associations may be insufficient.²³ Many mortgage borrowers would default, leaving the banks and especially Fannie Mae, Freddie Mac, and the FHA on the hook for enormous losses. The additional layers of insurance in the system, such as re-insurance for the insurers and private mortgage insurance for the GSEs, would be further stressed.

¹⁵https://content.naic.org/sites/default/files/CIFR%20Consumer%20property%20ins%20report%208-21_0.pdf

¹⁶<https://www.corelogic.com/press-releases/corelogic-analysis-shows-final-estimates-insured-and-uninsured-damages-for-hurricane-ia>

¹⁷Gourevich, et al. (2023) <https://www.nature.com/articles/s41558-023-01594-8>

¹⁸Dby (2023) <https://www.budget.senate.gov/imo/media/doc/Mr.%20Matthew%20Dby%20-%20Testimony%20-%20Senate%20Budget%20Committee.pdf>

¹⁹Hurst, et al. (2016) <https://www.aesweb.org/articles?id=10.1257/aer.20151052>

²⁰1980s average: 3.1/year; last three years' average: 20/year. See <https://www.ncel.noaa.gov/access/billions/summary-stats>

²¹<https://climate.nasa.gov/news/3184/a-force-of-nature-hurricanes-ia-a-changing-climate/>

²²See research suggesting that hurricanes will form and intensify at higher latitudes in coming years: <https://www.nature.com/articles/s41561-021-00859-1>

²³Florida Office of Insurance Regulation (2023) https://foit.com/docs-sf/default-source/property-and-casualty/stability-unit-reports/january-2023-isu-report.pdf?sfvrsn=27217354_2

In the event of a large-scale disaster, there would be additional costs to federal, state, and local governments offering support to affected households and businesses. I want to pause here and note the complexity of who bears the actual risk in the event of a disaster. Homeowners, insurers, re-insurers, banks, the GSEs, private mortgage insurers, state guaranty funds—all of these groups bear at least a portion of climate risk. But attributing risk to each group is challenging given how opaque the system is and how dependent each entity is on the others. I would therefore encourage regulators to focus on the ability of each entity in the chain to withstand losses from an unprecedentedly large climate-related disaster. As the recent experience of Silicon Valley Bank has taught us, the mark-to-market balance sheets of these entities may be weaker than previously believed given recent swings in interest rates.

My second scenario does not involve a direct disaster, so there are fewer health or mortality consequences and no immediate destruction, but the costs could nonetheless be enormous. Forecasts of sea level rise are highly uncertain, but the latest NOAA “Intermediate Scenario” forecast is 1.3 feet by 2050 and about 4 feet by 2100.²⁴ However, recent research suggests that the Arctic region is warming four times faster than the rate of the rest of the world.²⁵ The risks are only increasing in one direction: More melting of the ice sheets and more rapid sea level rise.²⁶

As a thought experiment, suppose instead that scientists convincingly documented further deterioration of global ice, and revised their forecasts upward such that the sea level rise forecast was 5 feet by 2050 and 10 feet by 2100. While 10 feet of sea level rise may seem like an extreme scenario, and it is, I want to put this higher range in context.²⁷ NASA estimates that if all of the world’s glaciers and ice sheets melted, global sea level would rise by around 200 feet.²⁸ So we are still talking about a small fraction of the global ice melting, but melting at a faster rate than currently forecast.

This news would have immediate repercussions to exposed areas. Almost 30,000 square miles of land, currently home to 12 million people, would anticipate being inundated with 10 feet of sea level rise.²⁹ Property prices should respond well before water is lapping onto doorsteps. Properties are durable assets that should be priced today based on their future livability or usability (present discounted rents). This principle of forward-looking pricing means that changing perceptions of risk rather than an acute disaster should immediately drive asset values downward. Some homeowners or investors may dismiss these types of climate risks for the reason that their impacts are largely “beyond their investment window.” In making that claim, they are ignoring the simple fact that at the end of their window, they need to find a buyer of the asset. If buyers incorporate this risk into their valuations, then asset values will be substantially smaller when the current owners attempt to exit their position.

A shock to house prices would lead some homeowners to stop paying their mortgages, putting stress on the banking system and holders of mortgage-backed securities. Insurers would leave the area, unwilling to insure properties at any price. Without insurance, it is virtually impossible to obtain a mortgage, so financing for these properties would dry up. Unlike 2008, when the shock to home prices felt large but ultimately temporary, rising sea levels would induce permanent shocks.

A key difference between these two scenarios is the role that insurance can play in the first but not the second. Insurance is written on annual contracts and helps with immediate extreme events with limited duration. The basic principle is that risks are sufficiently idiosyncratic that they can be pooled and insured against. However, insurance alone generally cannot solve long-term issues or insure against systemic risks. For instance, insuring against long-term sea level rise would require multiyear policies that are not currently offered in the marketplace. Further, insurers are mobile in ways that homeowners are not. When risks increase, we should expect that insurers will retreat much faster than homeowners, as is happening now in California.

²⁴Contiguous U.S. intermediate forecast: <https://oceanservice.noaa.gov/hazards/sealevelrise/sealevelrise-tech-report.html>

²⁵Rantanen, et al. (2022) <https://www.nature.com/articles/s43247-022-00498-3>

²⁶See, for instance, last year’s report that Greenland’s glaciers are melting six or seven times faster than they were 25 years ago: <https://www.jpl.nasa.gov/news/nasa-greenland-mission-completes-six-years-of-mapping-unknown-terrain>

²⁷Some groups are already recommending using this 10 foot threshold to evaluate new property planning and permitting, see e.g. <https://www.scientificamerican.com/article/prepare-for-10-feet-of-sea-level-rise-california-commission-tells-coastal-cities/>

²⁸<https://sealevel.nasa.gov/understanding-sea-level/global-sea-level/ice-melt>

²⁹<https://www.climatecentral.org/news/us-with-10-feet-of-sea-level-rise-17428>

Concluding Thoughts

In sum, the consequences of re-pricing “neglected” climate risks could have an enormous impact on property, insurance, and mortgage markets. While I have emphasized flood risk in my brief remarks today, other climate-related risks such as wildfires, droughts, or extreme heat could potentially follow similar patterns. These risks are not yet fully internalized by households, banks, the GSEs, or insurers. In addition, these risks are disproportionately borne by lower income groups and racial minorities, who may already live in riskier areas and lack access to financial resources for ex ante preparation or ex post repairs.

In the face of potential disaster, the government can play a critical role in regulating these entities and ensuring that they are sufficiently capitalized to withstand significant climate-related shocks. Government agencies can also further move prices to better align with risks in the markets they directly influence, like flood insurance and mortgages. With flood insurance, the government can draw more accurate maps, more aggressively promote take-up, and develop a means-tested assistance program to help needy households protect their homes.³⁰ With mortgages, the GSEs can conduct stress tests that better assess the stability of their counterparties to climate-induced shocks, and can incorporate climate risk into their pricing models to end one implicit subsidy for at-risk development. Providing price signals through these markets would also promote investment in adaptation by homeowners and local governments — an area where the federal government also has a role facilitating investments in under-served communities. Finally, the government can help to manage expectations through better disclosure and assessment of climate risks. Potential property owners and homeowners deserve loud and crystal clear warnings of climate-related risks, especially if prices are not providing a sufficient signal on their own.

³⁰For additional NFIP policy proposals see testimony by Kousky (2022): <https://www.congress.gov/117/meeting/house/114847/witnesses/HNTG-117-BA04-Wstate-KouskyC-20220525.pdf>

Figures

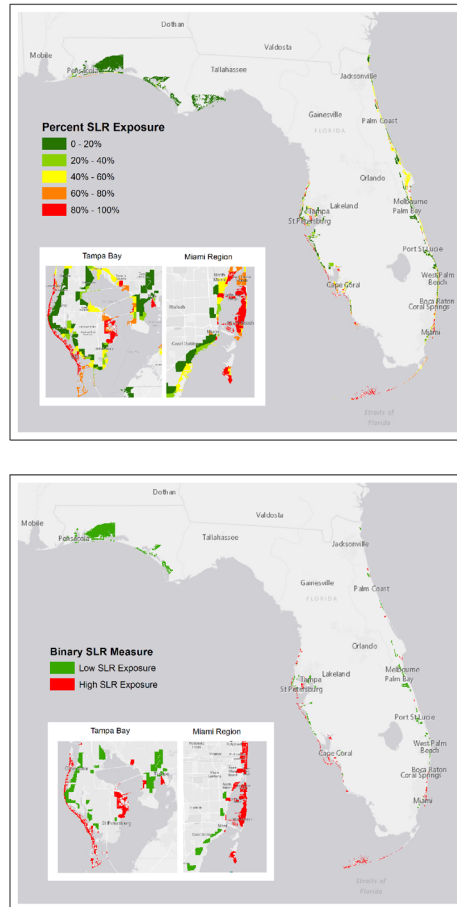


Figure 1: From Keys and Mulder (2020). Maps show SLR exposure for the sample of 771 coastal Florida census tracts. The top panel shows the share of each tract's developed land in 2000 that would be chronically inundated at six feet of SLR. The bottom panel shows the subsample of tracts categorized as either "more-SLR-exposed" (> 70% exposure, 187 tracts) or "less-SLR-exposed" (< 10% exposure, 217 tracts). Sources: NOAA

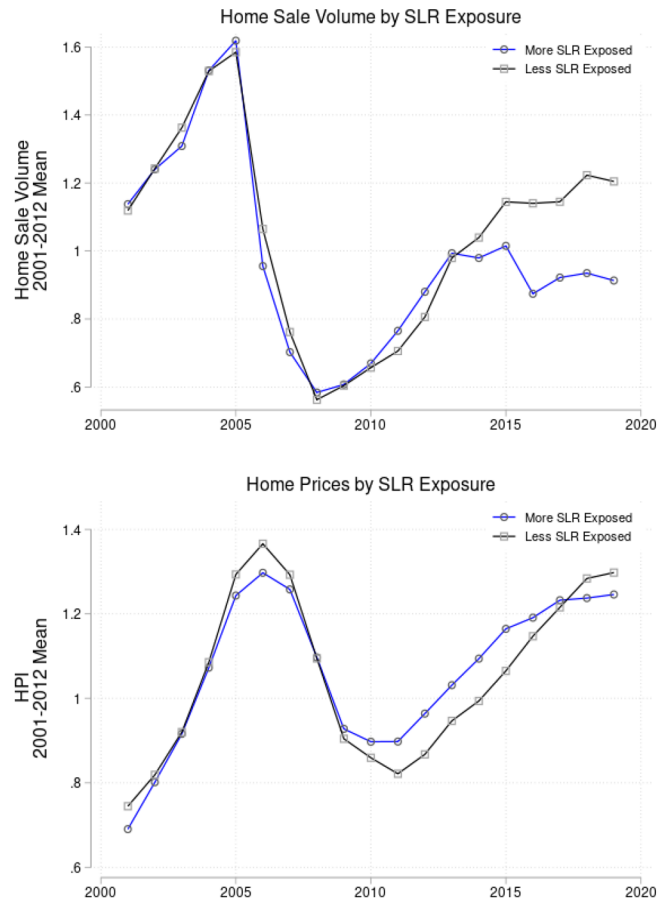


Figure 2: From Keys and Mulder (2020). Housing transaction volume (top panel) and home price (bottom panel) trends in coastal Florida census tracts with high (blue circles) versus low (black squares) SLR exposure. Housing volume and home price index are normalized by their 2001-2012 mean. Sources: NOAA, CoreLogic, Authors' calculations.



SUBMITTED STATEMENT OF
JERRY THEODOROU
DIRECTOR OF FINANCE, INSURANCE AND TRADE
R STREET INSTITUTE

HEARING ON
“RISKY BUSINESS: HOW CLIMATE CHANGE IS CHANGING INSURANCE MARKETS”

BEFORE THE
COMMITTEE ON THE BUDGET
UNITED STATES SENATE

March 22, 2023

Chairman Whitehouse, Ranking Member Grassley, and distinguished Senators:

Thank you for the opportunity to offer testimony on how climate change is affecting insurance markets. This issue is important for providers and buyers of insurance protection because climate change alters the patterns of natural catastrophes, contributing uncertainty to an industry whose role is to provide stability and protection from loss.¹ (The term “catastrophe” as used throughout is defined as a natural event causing at least \$25 million in insured property losses.) The insurance and reinsurance industries provide coverage from losses from sundry climate events. To the extent that climate change impacts the frequency and severity of climate-related losses, reinsurers must recalibrate their products. There is broad consensus among reinsurers that the climate is changing in ways that aggravate the occurrence of catastrophic events.² The reinsurance industry therefore has a major role to play in responding and developing solutions to our changing climate.

I am the director of Finance, Insurance and Trade program at the R Street Institute (RSI). I conduct independent research on public policy issues that impact buyers of property and casualty (P&C) insurance, such as flood insurance, crop insurance and emerging risks. Prior to joining R Street in 2021, I was an insurance industry analyst at insurance asset management and industry research firm Conning, where I studied financial conditions as well as the market and external forces impacting insurance and reinsurance company performance.

RSI is a nonprofit, nonpartisan public policy research organization whose mission is to engage in policy research and outreach to promote free markets and limited, effective government. The issues covered in today’s hearing are particularly relevant to RSI because at its founding in 2012, RSI’s signature issue was climate change and its impact on property and casualty insurance and reinsurance. Weeks after RSI’s founding, it characterized climate change as a “high salience issue” and appealed to readers’ “common sense.”³ Climate change and resilience are and will continue to be among the most consequential issues of the day.

I would like to address three questions at the heart of today’s hearing.

1. What is the impact of climate on the insurance and reinsurance industries?
2. What is the financial condition of the insurance industry, and can it withstand deleterious impacts of climate change?
3. How is the insurance industry changing in response to climate change?

Impact of Climate Change

The P&C insurance industry is, and has been, in the business of providing weather insurance. When wind, fire, hail and other natural hazards cause billions of dollars in property damage, the

¹ “Facts and Statistics: U.S. Catastrophes,” Insurance Information Institute, last accessed March 17, 2023. <https://www.iii.org/fact-statistic/facts-statistics-us-catastrophes>.

² “The Potential Impact of Climate Change on Insurance Regulation,” National Association of Insurance Commissioners, 2008. https://content.naic.org/sites/default/files/legacy/documents/cipr_potential_impact_climate_change.pdf.

³ Eli Lehrer, “Climate silence: It’s just common sense,” The R Street Institute, Oct. 31, 2012. <https://www.rstreet.org/commentary/climate-silence-its-just-common-sense>.

insurance industry acts as the economy's first responder, paying claims and helping customers get back on their feet.

When extreme weather events cause damage to homes and businesses insurers are not shocked. Property insurance is designed to cover such events; insurance policies contractually protect insurance buyers from such loss events; and insurers are capitalized sufficiently to meet their claims obligations. When losses from catastrophes are large, in the billions or tens of billions of dollars, insurers are cushioned with financial protection in the form of reinsurance, the shock absorber of the insurance industry. Insurers design their reinsurance purchases to limit the losses borne on their balance sheet, allowing insurance companies to maintain their own financial stability, while providing stability to their customers.

Insurers keep an eye on climate and weather patterns because they largely price their policies on the basis of past loss events. Because the past is not necessarily prologue, insurers consider changes in the frequency and severity of loss events, and recalibrate their pricing every year to get the appropriate amount of premium according to risk magnitude. If they underprice, they suffer financially; if they overprice, they eventually lose business to competitors who step in to provide coverage at lower, risk-adjusted rates. The U.S. property and casualty insurance industry is highly competitive, with over 3,000 insurers, ranging in size from large publicly-traded national giants to regional insurers. At the smaller end, there are hundreds of one-state, multi-county and single county mutual insurance companies.⁴

Reinsurance is also a competitive industry. There are major centers for reinsurers in continental Europe; among Lloyd's syndicates with an appetite for U.S. reinsurance risk; numerous Bermuda-based reinsurers; as well as U.S. reinsurers, the largest being Berkshire Hathaway's National Indemnity Company. And just as primary insurers limit their losses with reinsurance, reinsurers buy retrocessional reinsurance from other capital providers so that their balance sheets can withstand large losses. The broader insurance industry thus provides three layers of protection: primary insurance from insurance companies; reinsurance; and retrocessional reinsurance. These three layers make the reinsurance industry exceptionally stable. To illustrate, in 2010, in the wake of the great recession, there were only eight insurance company impairments, on par with the long-term average.⁵ This compares to 157 bank failures in 2010.⁶

The exceptionally low failure rate of P&C insurers is due in large part to the emphasis they place on capital management, deploying enterprise risk management, asset liability management and stress testing, in addition to the three layers of protection described above. It is this dedication to shepherding their capital that has enabled many insurers and reinsurers to operate for over a

⁴ "Property, Casualty and Direct Insurance in the United States—Number of Businesses 2004-2029," IBIS World, Jan. 25, 2023. <https://www.ibisworld.com/industry-statistics/number-of-businesses/property-casualty-direct-insurance-united-states/#:~:text=There%20are%203%2C708%20Property%2C%20Casualty,increase%20of%200.6%25%20from%202022>.

⁵ "Best's Impairment Rate and Rating Transition Study – 1977 to 2011," A.M. Best Company, March 26, 2012. <https://www.ambest.com/nrsro/impairment.pdf>.

⁶ "Bank Failures in Brief – Summary 2001 to 2023," Federal Deposit Insurance Corporation, last accessed March 17, 2023. <https://www.fdic.gov/bank/historical/bank>.

century. For example, the first modern professional reinsurance company, Cologne Re, was founded in 1846 as a response to the great Hamburg fire of 1842.⁷ Another European giant reinsurer, Munich Re, was founded in 1880. Some U.S. mutual insurers have been operating since the early 1800s and before, and are still going strong.⁸ To survive and thrive for over a century, an insurer must be a good steward of its capital and a reliable provider of a quality product to its customers.

Financial Condition of Insurers

The current financial position of the insurance industry is good. In the last five years, 2002 was only year when P&C insurers had an underwriting loss—where loss is the sum of losses and expenses exceeding premium—which was largely because of claim cost inflation. Supply chain shortages, combined with deteriorating driving behavior, conspired to raise the cost of automobile repairs.⁹ The 2022 combined ratio for private auto insurance was 101.2 percent, approximately ten percentage points higher than in 2021, as a result of poorer driving, more fatalities and higher auto repair costs. But even in 2022, the investment income contribution to insurers' bottom line made for acceptable operating results.

The P&C insurance industry's balance sheet has strengthened in the past half-decade. The industry's surplus (the extent to which assets exceed liabilities) rose from \$757 billion in 2018 to \$1.05 trillion in 2021.¹⁰ The combined ratio was below 100 percent in 2018 – 2021, and rose to 102.5 percent in 2022, largely from higher costs for automobile physical damage losses, due also to shortages of spare parts and labor shortages, leading to higher losses.

The reinsurance industry is also financially strong. Historical data on U.S. reinsurance performance shows the industry has delivered healthy underwriting results through 2022. In most years in the past decade, the underwriting result has been profitable, as shown in the Table 1 below.¹¹ A combined ratio below 100 percent indicates underwriting profit. When investment income, equivalent to approximately 10 percentage points, is added to the underwriting result, all

⁷ David Holland, "Reinsurance: A brief history," *The Actuary*, Sept. 21, 2012.

⁸ <https://www.theactuary.com/archive/old-articles/part-3/2012/09/21/reinsurance-brief-history>.

⁹ "The Philadelphia Contributionship: A New Startup 270 Years Ago," *The Philadelphia Contributionship*, May 14, 2022. <https://1752.com/2022/05/14/the-philadelphia-contributionship-a-new-startup-270-years-ago>.

¹⁰ Tim Zawacki, "US P&C industry statutory combined ratio tops 100% for 1st year since 2017," S&P Global Market Intelligence, March 13, 2023. <https://www.spglobal.com/marketintelligence/en/news-insights/research/us-pc-industry-statutory-combined-ratio-tops-100-for-1st-year-since-2017#:~:text=13%20Mar%2C%202023-,%20US%20P%26C%20industry%20statutory%20combined%20ratio%20tops,for%201st%20year%20since%202017&text=A%20run%20of%20underwriting%20profitability,released%20statutory%20financial%20results%20reveals>.

¹¹ S&P Capital IQ Pro, last accessed March 17, 2023.

<https://www.capitaliq.spglobal.com/web/client?auth=inherit#news/home>.

¹¹ "Reinsurance Underwriting Review," Reinsurance Association of America, last accessed March 17, 2023.

https://www.reinsurance.org/RAA/Industry_Data_Center/Reinsurance_Underwriting_Review/Reinsurance_Underwriting_Review.html; "Quarterly Underwriting and Operating Report," Reinsurance Association of America, last accessed March 17, 2023. <https://www.reinsurance.org/quarterly>.

10 years saw an operating profit—even 2017, the year of hurricanes Harvey, Irma and Maria in the United States and the Caribbean.¹²

Table 1: U.S. Reinsurance Combined Ratio

Year	Combined Ratio (percent)
2013	86.8
2014	91.0
2015	92.3
2016	95.1
2017	108.4
2018	103.3
2019	100.5
2020	101.4
2021	99.2
2022	99.8

Source: “Reinsurance Underwriting Review.”

https://www.reinsurance.org/RAA/Industry_Data_Center/Reinsurance_Underwriting_Review/Reinsurance_Underwriting_Review.html.

How is the insurance industry changing in response to climate change?

The insurance and reinsurance industries are responding to climate change in two broad ways: by encouraging insurance buyers to take measures to mitigate loss potential; and by structuring new products.

Measures to mitigate losses and make properties more resilient include discounts offered to property owners who make their structures more capable of withstanding the perils of wind, hail, rain or hail. The 17,000-acre Babcock Ranch community in southwest Florida provides an example of how much loss potential is reduced when homes are strengthened to withstand natural catastrophe losses.¹³ Homes in Babcock Ranch were designed to the strictest building codes. The community is sited in an area at no risk from storm surges and has native landscaping for absorption of water and underground power cables. While hurricane Ian destroyed the nearby

¹² Chris Vaccaro, “Extremely active 2017 Atlantic hurricane season finally ends,” National Oceanic and Atmospheric Administration, Nov. 30, 2017. <https://www.noaa.gov/media-release/extremely-active-2017-atlantic-hurricane-season-finally-ends>.

¹³ Renee Cho, “With Climate Impacts Growing, Insurance Companies Face Big Challenges,” Columbia Climate School, Nov. 3, 2022. <https://news.climate.columbia.edu/2022/11/03/with-climate-impacts-growing-insurance-companies-face-big-challenges>.

cities of Naples and Fort Meyers in 2022, the only losses at Babcock Ranch were a few fallen trees. There was no loss of power.

Florida insurers make available discounts for residential properties that use construction materials or techniques to reduce the risk of storm damage.¹⁴ Discounts are available for fortification measures to withstand hurricane force winds by strengthening and securing roofs and shutters and garage door reinforcement. There are also sales tax exemptions for impact-resistant doors, garage doors and windows.

Insurers may also provide credits to communities that establish a natural barrier between a body of water and buildings. RSI has written on this, supporting the Coastal Barriers Resources Act (CBRA) and its expansion.¹⁵ RSI found that “natural infrastructure can also do a better job weathering the effects of storms and flooding than engineered structures.”¹⁶ Natural barriers are features of the surrounding environment that mitigate risks from severe weather events, such as powerful convective storms or floods. Natural barriers may take the form of mangroves, coral reefs and marshes. It has been shown that only 15 feet of marshland can absorb half the power of storm surge.¹⁷ Mangroves can also reduce impacts from storm surges. One study found that 330 feet of mangrove trees “can reduce wave height by 66 percent.”¹⁸

In California, insurers offer premium discounts to homeowners and businessowners who make their properties safer from wildfires.¹⁹ Measures may include installation of sprinkler systems and building with fire-resistant materials and designs for walls and roofs.

Other ways reinsurers are responding to climate change involve adjustments to their business models. Five such responses include changing from all-risk policies to named peril policies; introducing parametric covers; rebalancing investment portfolios; attracting third-party capital; and offering private market policies that were insured with government programs.

¹⁴ “Financial Incentives,” Fortified, last accessed March 17, 2023. <https://fortifiedhome.org/incentives>.

¹⁵ Portia Mastin and Jerry Theodorou, “Congress must act to solve an urgent crisis on our coasts,” *The Hill*, July 25, 2022. <https://thehill.com/opinion/energy-environment/3571637-congress-must-act-to-solve-an-urgent-crisis-on-our-coasts>; Josiah Neeley and Tony Carvajal, “Be prepared: using Florida’s natural infrastructure to combat climate change,” *R Street Shorts* No. 124, March 2, 2023. <https://www.rstreet.org/research/be-prepared-using-floridas-natural-infrastructure-to-combat-climate-change>.

¹⁶ Neeley and Carvajal. <https://www.rstreet.org/wp-content/uploads/2023/03/r-street-short-no-124-co-branded-FINAL-1.pdf>.

¹⁷ Heather Luedke, “Fact Sheet: Nature as Resilient Infrastructure – An Overview of Nature-Based Solutions,” Environmental and Energy Study Institute, Oct. 16, 2019. <https://www.eesi.org/papers/view/fact-sheet-nature-as-resilient-infrastructure-an-overview-of-nature-based-solutions#:~:text=Natural%20infrastructure%20%E2%80%93%20Projects%20that%20use,%2C%20and%20social%20co%2Dbenefits>.

¹⁸ Ibid.

¹⁹ Hayley Smith, “California to require insurance discounts for property owners who reduce wildfire risk,” *Los Angeles Times*, Oct. 17, 2022. <https://www.latimes.com/california/story/2022-10-17/state-to-mandate-insurance-discounts-for-wildfire-mitigation>.

Named peril policies	Instead of all-risk policies which can be triggered by losses that were not contemplated by underwriters, policies—whether primary insurance or reinsurance—can be focused specifically on one peril.
Parametric covers	Policy coverage disputes can be averted if the trigger for coverage is the attainment of a specified parameter, such as inches of water, category of a hurricane, etc.
Rebalanced investment portfolios	Investment officers may identify in their portfolio equity or fixed income holdings of companies more likely to lose value as the result of expected climate change-caused business downturns, and recalibrate accordingly.
Third-party capital	Third-party capital in the form of insurance-linked securities (catastrophe bonds) can add to the pool of capital from (re)insurers' balance sheets, expanding the capital base dedicated to climate change-related catastrophe risk.
Private market solutions to government insurance	Government-operated flood and crop insurance programs can be managed more soundly with private insurers introducing coverage structures and options designed to cover climate-change related risks.

Source: R Street Institute research and analysis

Climate Risk

There is an established link between anthropogenic climate change and extreme weather event frequency and severity. Although the data points to a higher frequency of high-severity extreme events, forecasts cannot be made with precision because of the complex interplay of climate change factors.²⁰ There is consensus in the scientific and insurance communities that more extreme events are to be expected. While modeling confidence and precision is improving, we cannot articulate the specific magnitude and times of the changes.

The profile of physical climate risk is dynamic, spatially heterogeneous and incremental on the timeframe of relevance to insurance markets. For example, many climate science studies focus on natural hazards at the end of the century, whereas the reinsurance market is focused on the

²⁰ Guillen Barroso, “‘All Models are Wrong, but Some are Useful.’ George E.P. Box,” last accessed March 17, 2023. <https://www.lacan.upc.edu/admoreWeb/2018/05/all-models-are-wrong-but-some-are-useful-george-e-p-box>.

near term.²¹ Climate change does not present a near-term “shock” risk to financial markets akin to pandemics, wars or housing crises despite posing a high magnitude risk to society over the very long term.

The granularity and complexity of climate risk is ripe for a bottom-up market approach to risk management. Policymakers can help markets manage climate risk organically through actions like transferring risk responsibility to the private sector, removing barriers to capital flows seeking diversification and correcting moral hazard problems. One example is fixing distortive subsidies in the National Flood Insurance Program to permit private market pricing at an actuarially sound rate.²²

Conclusion

Ignoring climate change is not an acceptable response. Climate sceptics are not found in the fundamentally conservative insurance industry, whose job is to restore things to how they were. We acknowledge those who call for waking up to the reality of climate change—insurers have acknowledged it for many decades. Insurance markets have an appetite for climate risk, are in the business of dealing with it, and will continue to play a key role in absorbing and mitigating its risk to our economy.

Thank you again for the opportunity to testify before you today. I look forward to addressing your questions.

²¹ Anja T. Rädler, “Invited perspectives: how does climate change affect the risk of natural hazards? Challenges and step changes from the reinsurance perspective,” *Natural Hazards and Earth System Sciences* 22:2 (March 2022), pp.659-664. <https://nhess.copernicus.org/articles/22/659/2022>.

²² R. J. Lehmann, “Do No Harm: Managing Retreat by Ending New Subsidies,” *R Street Policy Study* No. 195, February 2020. <https://www.rstreet.org/wp-content/uploads/2020/02/195.pdf>.

**STATEMENT TO THE
UNITED STATES SENATE
COMMITTEE ON THE BUDGET**

**Hearing on
Risky Business: How Climate Change is Changing Insurance Markets**

22 March 2023

Judith A. Curry

Climate Forecast Applications Network

I thank the Chairman, Ranking Member and the Committee for the opportunity to offer testimony today on “Risky Business: How Climate Change is Changing Insurance Markets.” I am President of Climate Forecast Applications Network (CFAN) and Professor Emerita and former Chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology. I have devoted four decades to conducting research on climate dynamics and severe weather, particularly hurricanes.

For the past 15 years, through my company CFAN, I have engaged with decision makers in both the private and public sectors on issues extreme weather and climate change. CFAN’s primary objective is to translate cutting-edge weather and climate research into forecast products that support the mitigation of weather and climate risks. I have learned about the complexity of different decisions that depend, at least in part, on weather and climate information. I have learned the importance of careful determination and conveyance of the uncertainty associated with our scientific understanding and particularly for predictions. I have found that the worst outcome for decision makers is a scientific conclusion or forecast issued with a high level of confidence that turns out to be wrong.

Since 2017, CFAN has been engaging with clients in the insurance sector: insurance, reinsurance, and asset management companies with Insurance Linked Securities (ILS) funds. Of specific relevance to this Hearing, I have authored a book titled *Climate Uncertainty and Risk* that has been extensively peer reviewed and is in press at Anthem Press (an academic press).

With this perspective, my testimony focuses on the following issues of central relevance to climate change and insurance markets:

- The “climate crisis” isn’t what it used to be
- Mischaracterization of climate risk
- The insurance sector and climate change
- Global warming and hurricanes
- Adaptation to extreme weather events
- Risks from a rapid transition of electric power systems
- Ways forward to manage climate-related insurance risk

The “climate crisis”

The insurance market is influenced by our perceptions of risk. Risk perception is our subjective judgment or appraisal of risk, which can involve social, cultural, political and psychological factors. Referring to climate change as a “crisis” is at odds with professional judgments of climate risk.¹

The “climate crisis” isn’t what it used to be. Circa 2013 with publication of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5), the extreme emissions scenario RCP8.5 was regarded as a baseline business-as-usual emissions scenario, with expected warming of 4 to 5°C (7 to 9°F) by 2100.

Now, there is general acceptance that the RCP8.5 scenario is implausible. The Conference of Parties (COP) to the UNFCCC Agreement dropped consideration of the RCP8.5 scenario in COP26 (2021) and COP27 (2022). COP27 is working from a baseline temperature projection based on RCP4.5 (SSP2-4.5) of 2.5°C by 2100, relative to temperatures in the late 19th century (note: 1.1°C of warming has already occurred). Only a few years ago, an emissions trajectory that followed RCP4.5 with 2 to 3°C (4 to 5°F) warming was regarded as climate policy success.

An additional factor in reducing the magnitude of risk from human-caused warming is that our understanding of the sensitivity of the climate to atmospheric CO₂ has increased. The IPCC Sixth Assessment Report (AR6) reduced the upper bound of the likely range of equilibrium climate sensitivity from 4.5 to 4.0°C.² A recent paper challenged the main analysis used by the IPCC AR6 by identifying errors, outdated input values, and concerns about the statistical analysis method. This paper found that climate sensitivity is considerably more likely to be below 2°C than above 2.5°C.³

The IPCC AR6 recognized that a substantial number of climate models are running “too hot.” Therefore, the AR6 adopted a new approach to make 21st century temperature projections that combined the climate model projections with observational constraints on simulated past warming and best estimates of the climate sensitivity.⁴ These constraints reduced the climate model projections of warming by up to 20% for the higher emissions scenarios. This new constrained procedure used by the AR6 is significant because it breaks the hegemony of the global climate models in dominating the IPCC’s conclusions about twenty-first century climate change.

There are additional reasons to expect less warming than indicated by the COP27 projections. Plausible scenarios of natural climate variability in the mid-21st century (not included in the climate model simulations) point to a slowdown in the rate of global warming driven by: an expected solar minimum,^{5,6} the possibility of explosive volcanic eruptions,^{7,8} and a projected shift in multi-decadal ocean circulation patterns.^{9,10}

The mainstream media is currently awash with articles from prominent journalists on how the global warming threat is less than we thought.¹¹ However, the rationale for continuing to sound the alarm is that the *impacts* are worse than we thought, specifically with regards to extreme weather. Climate crisis rhetoric is now linked to extreme weather events, most of which are difficult to identify any role for human-caused climate change in increasing

either their intensity or frequency against the large natural variations in weather and climate variability.

The IPCC AR6 Summary for Policy Makers highlights the following changes in extreme weather: increased intensity and frequency of heat waves plus reduced intensity and frequency of cold waves since 1950; increased frequency and intensity of heavy precipitation events since 1950; and a *likely* increase in the global proportion of major (Category 3–5) tropical cyclone (hurricane) occurrence over the last four decades.¹² It is significant what is *not* mentioned in the Summary for Policy Makers. Chapters Eleven and Twelve in the IPCC AR6 identify the following event types for which there is either no change or low confidence in any change: meteorological and hydrological droughts; extratropical storms; total number of tropical cyclones; and tornadoes, hail, and lightning associated with severe convective storms.^{13,14}

Examination of historical data records of extreme weather events in the U.S. shows that, in nearly all regions of the U.S., conditions during the 1930s were worse than what we've seen in the early 21st century: the most intense landfalling hurricane, greatest magnitude and frequency of heat waves, worst droughts, and worst wildfires.¹⁵ The magnitude and frequency of extreme weather events do not scale simply with an increase in global temperature; natural weather and climate variability dominate the occurrence of these events.

Despite the moderate and equivocal conclusions of the IPCC, every extreme weather event now gets associated in the media with human-caused global warming, distorting our perception of climate risk. Any change in the intensity or frequency of extreme weather events is incremental at most; even if a change in the event type has been detected, attributing any change to emissions-driven warming is not at all straightforward. Quantitative forward projection of any changes is highly uncertain.¹⁶

With regard to the perception that severe weather events seem more frequent and more severe over the past decade, there are several factors in play. The first factor is increasing vulnerability and exposure associated with increasing population and concentration of wealth in coastal and other disaster-prone regions. The second factor is natural climate variability. Many extreme weather events have documented relationships with natural climate variability. A recent analysis summarizing many studies finds no evidence to support claims that any part of the overall increase in global economic losses (when scaled by GDP) from weather and climate disasters can be attributed to global warming.¹⁷

And finally, it is difficult to overstate the importance of the shift in expectations for extreme weather events that is represented by the rejection of the RCP8.5 emissions scenario as implausible.^{18,19} The IPCC, the U.S. National Climate Assessment, and a majority of published papers have centered their analyses on RCP8.5 as a reference scenario against which climate impacts and policies are evaluated.²⁰ Rejection of the RCP8.5 emissions scenario has rendered obsolete much of the climate impacts literature of the past decade, which have focused on RCP8.5. It is now clear that climate impact assessments have been biased in an alarming direction by continued inclusion, and even sole reliance, on RCP8.5 in most studies.

Mischaracterization of climate risk

What has been cast as a global “crisis” is for the most part thousands of local vulnerability emergencies that are revealed by extreme weather events. The misidentification of climate change as a “crisis” and the ensuing precautionary mandate to urgently and rapidly eliminate the use of fossil fuels is creating new risks, while failing to address the current risks associated with extreme weather events.

Climate change risk includes elements of both incremental risk and emergency risk. Incremental risk displays creeping characteristics and the “fat tail” effect. Since changes take place slowly, the adverse consequences take a long time to emerge as impacts accumulate and worsen over time. The slow creep of sea level rise is an example of incremental climate risk. By contrast, emergency risks are associated with extreme weather events.

The rationale for the rapid transition away from fossil fuels conflates incremental and emergency risk. The proposed management strategy for both risk categories is to eliminate CO₂ emissions. This strategy may have some incremental benefits in the 22nd century, but will not help with the emergency risks associated with extreme weather events in the 21st century. The urgency of addressing emergency risk is being used to motivate the urgency of reducing emissions. Ironically, costly and suboptimal attempts to rapidly reduce emissions are exacerbating energy unreliability, which is increasing emergency risk through increased vulnerability.

A key to securing meaningful action to reduce climate change risk is to clearly separate the incremental, emerging risks associated with long-term changes in average conditions from the emergency risks associated with extreme weather and climate events. Governance of climate risk needs to approach these two kinds of risk differently. Emergency risks need to be addressed in both the present and future climate.

One would logically think that if warming is less than we thought but impacts are worse, then the priorities would shift away from CO₂ mitigation towards adaptation. However, that hasn’t been the case. Once the incremental risks are separated from the emergency risks, the perception of urgency in reducing emissions is diminished. It becomes far more important to develop strategies for managing atmospheric greenhouse gases in ways that do not have an adverse impact on security, the economy, industry or agriculture. At this point, assessing the transition risks associated with rapidly eliminating fossil fuels is arguably more important than attempting to refine our assessments of the incremental risks associated with continuing fossil fuel emissions.

The insurance sector and climate change

My company CFAN has ten clients in the insurance sector, most of which are related to Insurance Linked Securities (ILS) funds and catastrophe bonds. My specific engagement with this sector is to provide seasonal forecasts of hurricane activity, advanced hurricane forecast products to support live trading of catastrophe bonds, analyses of post landfall impacts, and general educational materials regarding climate change and weather/climate hazards. CFAN actively participates in insurance sector conferences and subscribes to

numerous newsletters related to ILS, catastrophe bonds and reinsurance. CFAN also interacts with startup companies in the sector that are working to develop new risk transfer tools, as well as working with companies in Africa and South Asia with regards to agricultural insurance. With this context, I provide the following remarks.

There is a lot of discussion at insurance conferences and in newsletters about taking climate change into account in calculating insurance risk. Privately, insurance industry leaders state that climate change isn't taken into account since 90% of property and casualty policies last 12 months. Any change in climate related impacts can't be effectively measured on the time scale of a year. However, the industry is under pressure from investors that are reacting to an exaggerated public narrative surrounding climate change, as well as confusing weather with climate.

Catastrophe bonds, or "cat bonds," have been developed over the past 25 years as an alternative to property and casualty reinsurance. A cat bond is a contract to cover risk that provides payouts triggered by specific events. Losses due to Atlantic hurricanes were the impetus for the creation of cat bonds and remain the primary market driver.²¹ There are now 51 funds that specialize in cat bonds, some of which are affiliated with reinsurance companies and others associated with capital and asset management companies. Cat bonds have lowered the costs of diversifying insurers' exposure to natural disaster risk by attracting alternative sources of capital and increasing the total capital available for the transfer of insurance risks. For investors, the appeal of cat bonds is that they are largely uncorrelated with the returns of other financial market instruments. Cat bond investment returns are at their highest levels ever, and a substantial amount of money is moving into these funds (ILS funds currently exceed \$100B.).²²

However, because cat bonds are uniquely tailored, the bonds are thinly traded in private markets. Hence, current markets lack efficiency and the ability to attract additional capital that standardized bonds could bring, possibly through public markets.

Climate change is viewed as stimulating the cat bond market as new investible risks become available.²³ Some insurance thought leaders see climate change and its perceived threats as providing an opportunity to broaden the relevance of the insurance sector to risk mitigation. Efforts to move forward with climate adaptation are creating new opportunities to underwrite climate-exposed risk. Shifting business models could focus on preventing customers from incurring damage and having to make claims by better managing and avoiding risk. Insurers could also work with the public sector to improve building standards and land use policies.²⁴

Global warming and hurricanes

Landfalling hurricanes incur the greatest property and casualty losses in the U.S. among extreme weather events.

The IPCC AR6 (Chapter Eleven) summarizes the expected impacts of future warming on global hurricane activity:

- “Peak wind speeds of the most intense tropical cyclones (hurricanes) are projected to increase at the global scale with increasing global warming (high confidence). The increase in global TC maximum surface wind speeds is about 5 percent for a 2°C global warming across a number of high-resolution multi-decadal studies”
- “It is *very likely* that heavy precipitation events will intensify and become more frequent in most regions with additional global warming. At the global scale, extreme daily precipitation events are projected to intensify by about 7 percent for each 1°C of global warming (high confidence).”

Shortly before publication of the IPCC AR6, two assessment reports were published by a distinguished international group of scientists who serve on the World Meteorological Organization (WMO) Task Team on Tropical Cyclones.^{25, 26} Apart from detecting poleward migration of the latitude of maximum intensity in the northwest Pacific basin, the majority of the author team had only low confidence that any other observed tropical cyclone changes represented either detectable changes or attributable anthropogenic changes. The relatively low confidence in tropical cyclone change detection results from observational limitations and the smallness of the expected human-caused change (signal) relative to the expected natural variability (noise).

With regards to future changes, the WMO Report relied on model results and expert judgment for a 2°C warming:

1. For hurricane intensity (maximum wind speed), there is medium-to-high confidence that the global average will increase. The median projected increase in lifetime maximum surface wind speeds is about 5% (range 1–10%).
2. For the global *proportion* of hurricanes that reach Category 4–5 levels, there is at least medium-to-high confidence in an increase, with a median projected change of +13%.

Author opinion was more mixed and confidence levels lower for the following projections:

1. A *decrease* of global hurricane frequency, as projected in most modeling studies
2. An increase in the global *number* of very intense hurricanes (Category 4–5).

The insurance industry’s perception of a substantial increase in damage from U.S. landfall hurricanes is influenced by three recent reports:

- AIR Worldwide (2020): *Quantifying the Impact from Climate Change on U.S. Hurricane Risk*²⁷
- Twelve Capital (2022): *Managing U.S. Hurricane Landfall Risk in a Changing Climate*²⁸
- First Street Foundation (2023): *The 7th National Risk Assessment: Worsening Winds*²⁹

These three studies focusing on U.S. hurricane risk circa 2050 use comparable approaches, albeit with some different assumptions. My analysis here focuses on the AIR Report, which is the most comprehensive. The headline conclusion from the AIR Report is:

“The growth in the number of stronger storms, and landfalling storms overall, increases modeled losses by approximately 20%, with slightly larger changes in areas such as the Gulf and Southeast coasts”³⁰

My critique focuses solely on the hazard component of AIR’s analysis:

1. The driver for AIR’s assessment is warming associated with the emissions scenario RCP8.5, which AIR refers to as a “business as usual scenario.” This scenario has been judged as implausible by energy economists and is no longer used in international policy making.

The projected incremental temperature change between 2020 and 2050 for the RCP4.6 scenario (as per the IPCC AR6, Table SPM.1) is 0.9°C (compared to 1.4°C for RCP8.5).³¹ I have argued previously in this Report that the IPCC temperature projections for 2050 may be too high, when plausible lower values of climate sensitivity and natural climate variability are considered.

2. Their assumed changes in the numbers of Category 3,4,5 hurricanes are inconsistent with recent IPCC and WMO assessment reports.

AIR assumes an increase by 2050 of the frequency increased frequency of Category 3, 4, and 5 storms of 15%, 25%, and 35%, respectively, with frequencies of Category 1,2 storms held at today’s values. This implies an *increase* of >20% in the total number of hurricanes. By contrast, a *decrease* of global hurricane frequency is projected in most modelling studies (WMO Report)³², although there is relatively low confidence in these projections. The WMO Report cites low confidence in an increase in the global number of very intense hurricanes (Categories 4–5). The WMO Report also cites medium-to-high confidence in a median increase of +13% in the global proportion of hurricanes that reach Category 4–5 levels, reflecting a small shift in the distribution of hurricane intensities.

3. The AIR Report ignores the “elephant in the room” that is of relevance to their target period to 2050: the Atlantic Multi-decadal Oscillation (AMO). An expected shift to the cool phase of the AMO would arguably portend fewer major hurricanes striking the U.S., particularly Florida.

Given the dominant influence on Atlantic hurricane activity of the Atlantic Multidecadal Oscillation (AMO), arguably the single most important factor determining Atlantic hurricane activity for the next 30 years would be a shift to the cold phase of the AMO. Analysis of historical and paleoclimatic records suggest that a transition to the next cold phase is expected in the next few decades. The AMO not only influences the number of major Atlantic hurricanes, but also the preferred location of U.S. landfalls. Florida and North Carolina showed markedly fewer hurricane landfalls during the previous cool phase of the AMO. The timing of a future shift to the cold phase of the AMO remains uncertain. Whether a future cold phase would have a comparable distribution of landfalls also remains uncertain. A scenario of reduced U.S. landfalling hurricanes between 2020 and 2050 is justified by empirical evidence from the historical record in context of a possible (or even likely) shift to the cold phase of the AMO in the next few decades.³³

The net impact of such Reports of implausibly high projections of U.S. landfalling hurricanes by 2050 is to provide unjustified confidence in a future of substantially elevated hurricane damage. Overconfidence in such projections can result in inappropriate notions of insurability, inappropriate pricing of insurance, and the misguided confidence levels of investors.

Adaptation to extreme weather

We are not passive victims in the face of climate variability and change. The success of human adaptation to weather and climate extremes is reflected by the fact that global deaths and economic damage from weather and climate disasters dropped 80–90 percent during the last four decades, when scaled for population and gross domestic product (GDP) changes.³⁴

The extreme damages from recent hurricanes plus floods, droughts and wildfires emphasize that the U.S. is highly vulnerable to current weather and climate disasters. Even worse disasters were encountered in the U.S. during the 1930s and 1950s. Possible scenarios of incremental worsening of weather and climate extremes over the course of the 21st century don't change the fundamental fact that many regions of the U.S. are not well adapted to the current weather and climate variability, let alone the range that has been experienced over the past century and could be expected to occur in the future.

Disaster risk and impacts can be reduced by tackling fundamental issues that cause vulnerability, no matter what the evolution of the future weather and climate. Synergy among land use policies, technological innovation, infrastructure, and operational plans can reduce vulnerability to weather and climate extremes. Risk management, risk sharing, and warning strategies are also key for adapting to extreme weather events and climate change. To the extent that vulnerabilities can be reduced across regions in the U.S. and various economic sectors, insurance losses will likely be reduced.

Microeconomics of adaptation

The microeconomic approach for climate change adaptation addresses the role of market mechanisms in increasing local resilience. Environmental economist Matthew Kahn posits that owing to free markets, we are growing increasingly resilient and suffering less from the “punches that Mother Nature is throwing.”³⁵

Climate resilience is an increasingly valued public good. Cities and geographic areas that develop an edge in being resilient in the face of climate risks will experience greater economic growth. This resilience edge can be built up either due to natural advantage (physical location and topography) or local collective action in figuring out how to protect themselves against the threats of extreme heat and cold, droughts and floods, sea level rise and wildfire risk. Property owners in locations that are particularly susceptible to risks from extreme events have strong incentives to seek out solutions both through private markets and local government policies.

Banks and insurers can nudge real estate buyers to reduce their demand in risk-prone locations and increase their demand for housing and real estate in safer places. Changes to

zoning codes to up-zone in safer places featuring less weather- and climate-related risk will result in increased housing supply in safer places. The end result is not to completely desert fire- and flood-prone areas, because these are often desirable and productive locations. Civil engineers can design productive real estate assets that are acclimated to the risks. An alternative approach to building resilient real estate is to build less durable structures that are meant to have a lifetime of less than 20 years. The owner of the property would have less capital at risk and holds an option to rebuild or not in the future.

Kahn argues that the key to this smooth adaptation dynamic is for government to retreat. Government is currently taxing people on higher ground to subsidize people taking risks on lower ground – politically, this may not be a sustainable situation. When the government subsidizes insurance in flood zones and fire zones, this creates a moral hazard effect of reducing the likelihood that owners of at-risk property take appropriate precautions. As the federal government crowds out private insurance sector investment in addressing climate-related risk, adaptation efforts may be slowed.

Planning to fail safely

Extreme weather events will continue to challenge the ability of infrastructure systems to supply critical services. Critical infrastructure systems include electric power systems, oil and gas networks, water networks, transportation networks, telecommunications and computer systems. These complex systems are increasingly interdependent on each other, at scales ranging from the local to global. For example, operation of water and telecommunications systems requires a steady supply of electricity. The generation and delivery of electric power requires the availability of fuel and water plus telecommunication and computer services. These interdependencies can turn a local disturbance in a single system into a large-scale systemic failure, with catastrophic impacts that include property loss and casualties.³⁶

Power outages associated with extreme weather events are estimated to cost U.S. businesses tens of billions of dollars per year, and the cost trend is increasing.³⁷ Failure of electric power systems during events such as a hurricane are unavoidable; the challenge is to restore power as quickly as possible to avoid cascading disasters. Extended power outages during Hurricane Sandy resulted in additional property damage and casualties.³⁸ Power outages or brownouts during extreme heat and cold events are avoidable with adequate electric power infrastructure and grid management. With both inadequate infrastructure and grid management, the extreme cold event in Texas during February 2021 resulted in power outages that caused \$11.2 B in property damage³⁹ and 246 deaths.⁴⁰

Designing systems so they are safe-to-fail includes operational plans to minimize the consequences of failure.⁴¹ Safe-to-fail strategies can minimize the damage to electric utilities from an extreme event even if the physical electric power infrastructure is inadequate and unavoidably damaged.

An exemplary example of safe-to-fail is provided by the manner in which Florida Power & Light (FPL) manages to quickly restore electric power following a hurricane. Following Hurricane Wilma, FPL embarked on a program called Storm Secure. Significant

investments have been made to harden the grid, and they have implemented strategies to make the grid smarter. FPL uses advanced weather forecast products to anticipate power outages. They have also implemented protocols to rapidly restore power following a hurricane. Continued efforts to strengthen energy grid, coupled with innovative smart grid technology and rapid restoration of power outages, have led to national recognition of FPL for best-in-nation service reliability.⁴² The property and casualty losses avoided by FPL's actions prior to, during and following a hurricane are incalculable, but almost certainly substantial.

Resilience traps

Resilience is the ability to bounce back in the face of unexpected events. Resilience carries a connotation of returning to the original state, or “bouncing back,” as quickly as possible. To increase our resilience to extreme weather and climate events, we need to “bounce forward” by evolving our infrastructures, institutions and practices.

A substantial concern about adaptation is the potential for creating resilience traps. An overemphasis on recovery without transformation entrenches resilience traps if recovery acts to inhibit positive transformation and perpetuate maladaptive states. Distorted incentives and government policies can create resilience traps. Current federal government policies distort incentives in a way that increases vulnerability to extreme weather events, resulting in public investment that protects unwise private investments. These policies include subsidized flood insurance and federal funding for reconstruction after a disaster, which encourages people to build in areas known to be vulnerable. Providing aid to rebuild in the areas that were damaged reinforces the incentive to downplay risks.

The most politically important hurricane that you have probably never heard of is Hurricane Frederic, a Category 3 hurricane that struck Alabama and Mississippi in 1979. This landfall occurred shortly after FEMA was established, and it was the focal point for nearly \$250 million in federal aid for recovery. In 1992, following the catastrophic damage to Miami from Hurricane Andrew, Robert Sheets (then Director of the National Hurricane Center) stated in Congressional testimony that he credited the aid for Frederic's recovery with spurring development in hurricane prone regions.⁴³

Also of concern is FEMA's National Flood Insurance Program, which provides coverage at subsidized rates for homes deemed too risky for commercial insurers. The Program's artificially low cost encourages residents to repeatedly rebuild their homes rather than move away. Efforts to reform the program have stalled because the resulting rate hikes would disadvantage low-income policyholders. As of 2012, repetitive loss properties that have been rebuilt multiple times using federal flood insurance payouts had cost U.S. taxpayers more than \$12 billion.⁴⁴

The emphasis on restoring the status quo engenders norms and policies that inhibit the ability of communities to transform. Changing the motivations to build back better or to locate in places with lower risk is far more cost-effective than continuing to defend unwise investments.

Risks from a rapid transition of electric power systems

When insurers refer to “climate transition risk,” they are generally referring to risks from contracts with the fossil fuel industry associated with expected losses in asset values as government policies and private actions shift toward a low-carbon economy.

There is another critical element to transition risk that impacts the U.S. economy, the U.S. government budget and the insurance industry. The unfortunate reality is that efforts to rapidly move to a low-carbon economy are creating systemic risks through increasing the cost and decreasing the reliability of electric power—this is far more dangerous in the short term than incremental climate risk. The social and economic costs of unreliable power and outages are of primary relevance to this Hearing, particularly as they increase property losses and casualties.

Because of the role of electricity as the backbone of our economy and societal support systems, risks to the electric power system are systemic risks, with implications for property loss and casualties. Focusing on one set of risks—CO₂ emissions—can create other, potentially more dangerous risks. If efforts to reduce CO₂ emissions result in electric power that is less abundant, less reliable, and/or less secure, then the transition will make people worse off now and very possibly in the future. If people are worse off, vulnerability to extreme weather events and insurance losses will increase.

By relaxing the time horizon for the energy transition to be consistent with the incremental risk from climate change, the transition risk can be reduced while maintaining energy abundance, reliability, and security through the energy transition.

Ironically, Environmental, Social and Governance (ESG) objectives that are increasingly being met by divesting from fossil fuel companies may turn out to be counterproductive to a rapid and robust energy transition. The perceived urgency and priority of eliminating fossil fuels is having two adverse impacts on the transition:

- Strategies to reduce fossil fuel production and use in the near term are slowing down the transition, during a period when substantial additional energy is needed to implement new clean technologies, as well as to support the additional electricity required by growing numbers of electric vehicles and heat pumps.
- The perceived urgency demands that we use existing technologies, primarily wind and solar power. However, some of the technologies required to robustly integrate wind and solar power into the grid do not exist or are exceedingly expensive. Further, land use requirements for wind/solar farms and additional transmission lines are engendering conflicts with other desired uses of the land. The net result is to downplay the role of more advanced energy technologies that are under development.

In my own household, the amount of electricity used has more than doubled following installation of heat pump furnaces, electric water heaters, an induction stovetop and the purchase of an electric vehicle. Solar panels that were installed in 2020 to cover more than our annual electric power usage now cover significantly less than half of our electricity usage. While the transition of households to electric power is a step in the right direction

as part of a learning curve, we need to acknowledge that substantially more electric power will be needed to fuel this particular element of the transition; in the near term, this is predominantly fossil fuels.

The transition is not just about replacing our current generating capacity with cleaner energy. We need to acknowledge that the world will need much more energy in the future than it is currently consuming. More electricity can help reduce our vulnerability to weather and climate extremes: air conditioners and cleaners, water desalination plants, irrigation, vertical farming operations, water pumps, and environmental monitoring systems. Further, abundant electricity is key to innovations that will support our future prosperity and wealth.

Countries that have achieved greater than 80% of their energy supplies from renewable energy rely on hydropower and geothermal energy, not solar and wind. These countries include Iceland, Paraguay, Costa Rica, Norway and Brazil. The advantage of hydropower and geothermal power is that they are dispatchable and available on demand. Wind and solar resources are highly intermittent and asynchronous, resulting in mismatches between electricity supply and demand. As the grid penetration of wind and solar power increases, these challenges become increasingly difficult to overcome.

Stringent renewable energy standards are mandated in a number of states, focused on wind and solar energy. Unfortunately, insufficient attention is being paid to the perspectives of engineers that actually plan and operate electric power systems to insure a reliable and secure supply of power. At my blog *Climate Etc.* (judithcurry.com), I am providing a forum for power system engineers and operators to present their concerns about increasing penetration of wind and solar into the grid. They are providing assessments of proposed solutions from power systems around the world, including a recent series on Australia's aggressive renewable energy transition to wind and solar.^{45,46,47} The conclusions from these analyses are that known solutions to integrating large amounts of wind and solar into the grid are expensive, and there are a number of problems that are currently without solutions. The substantial extra costs of supporting renewable energy have the end result of contributing to a deteriorating quality of electricity supply. These issues do not appear to have been considered in state mandates for renewable energy based on wind and solar.

Variability of wind and solar power ranges from intermittency on time scales of minutes, to diurnal variations, variations from weather systems, seasonal cycles, interannual variability and even decadal-scale variability. Brownouts and electricity curtailments have become more frequent during both cold and heat extremes. The worst problems are associated with continental-scale high pressure systems during winter, which produce very cold temperatures and still winds—demand is exceptionally high and supply from renewables is very low. The duration of these extreme heat and cold events can extend to weeks. Apart from lack of generation by wind and solar, natural gas supplies can be compromised during extreme cold events. Now that many coal and nuclear power plants have shut down, a lack of onsite fuel storage contributed to the Texas outages in 2022 and the Christmas 2022 blackouts in areas served by the Tennessee Valley Authority.⁴⁸

The push for weather-based renewable energy (wind, solar, hydro) seems rather contradictory. One of the main motivations for urgently transitioning away from fossil fuels

is to avoid the extreme weather that is alleged to be associated with increasing CO₂ levels. So why subject our energy production to the vagaries of water droughts and wind droughts, cold temperature extremes, icing and snow, cloudiness and forest fires? The rapid transition towards weather-sensitive renewable energy is introducing systemic risk into our economy, including insurance risk.

Ways forward to manage climate-related insurance risk

The near-term risks from human-caused climate change have been exaggerated and confused by conflating the slow incremental risk from warming with emergency risk associated with extreme weather events that has little if anything to do with warming. The dominance of implausible emissions scenarios in climate assessment reports has misled our perceptions of climate risk and our policies. Of greatest relevance to the insurance sector, there is little justification to expect a noticeable change in U.S. hurricane landfalls over the next several decades beyond what has been encountered over the past century.

Climate change and its perceived threats provide opportunities to broaden the relevance of the insurance sector to risk mitigation. Climate adaptation provides new opportunities to underwrite climate-exposed risk. Insurance companies have the opportunity to expand their role by helping prevent customers from incurring damage and having to make claims and working with the public sector to improve building standards and land use policies. Both insurance companies and the government can work towards avoiding the moral hazards of resilience traps, by subsidizing risky behavior that reduces the likelihood that owners of at-risk property take appropriate precautions.

Climate variability and change, with the attendant extreme weather events, is best regarded as an ongoing predicament. Even if human-caused climate change is somehow eliminated, natural climate variability and inevitable surprises will provide ongoing challenges that require continuing adaptation by communities and mechanisms to transfer risk.

Short Biography

Dr. Judith Curry is President of Climate Forecast Applications Network (CFAN) and Professor Emerita of Earth and Atmospheric Sciences at the Georgia Institute of Technology. Dr. Curry received a Ph.D. in atmospheric science from the University of Chicago in 1982. Prior to joining the faculty at Georgia Tech as Chair of the School of Earth and Atmospheric Sciences, she held faculty positions at the University of Colorado, Penn State University and Purdue University. Dr. Curry's research interests span a range of topics in weather and climate. She has authored over 190 scientific papers and is author of the textbooks *Thermodynamics of Atmospheres and Oceans and Thermodynamics, Kinetics and Microphysics of Clouds*, and *Climate Uncertainty and Risk* (Anthem Press, forthcoming). She is a prominent public spokesperson on issues associated with the integrity of climate research and assessments, and is proprietor the weblog *Climate Etc.* judithcurry.com. Dr. Curry has served on the NASA Advisory Council Earth Science Subcommittee, the DOE Biological and Environmental Research Advisory Committee, and the National Academies Climate Research Committee and the Space Studies Board and the NOAA Climate Working Group. Dr. Curry is a Fellow of the American Meteorological Society, the American Association for the Advancement of Science, and the American Geophysical Union.

Financial declaration

Funding sources for Curry's research have included NSF, NASA, NOAA, DOD and DOE. Government grants for CFAN include a NOAA SBIR grant to improve subseasonal weather forecasts, a DOE SBIR grant to develop extended-range regional wind power forecasts, and a DOD SBIR grant to predict extreme events associated with climate variability/change having implications for regional stability. CFAN's clients include: other weather service providers; insurance, reinsurance and asset management companies; energy, windfarm and electric utilities companies; nongovernmental organizations; and development banks.

Specifically with regards to CFAN's energy-related clients: CFAN has clients in the emergency preparedness division of several electric utilities, for which CFAN provides forecasts of hurricanes and severe convective weather to help them anticipate and minimize the duration of power outages. CFAN also provides forecasts of temperature extremes and wind/solar power to energy trading companies, to support cost-effective backup of wind/solar power with natural gas. CFAN has provided climate-related analyses to energy companies related to: power plant siting and vulnerability to storm surge and sea level rise; future profitability of wind farms; and vulnerability of solar farms in the southeast U.S. to hurricanes.

None of Curry's published research has been supported by funding from energy companies.

For more information:

<http://curry.eas.gatech.edu/>

<http://www.cfanclimate.net/>

<http://judithcurry.com/about/>

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Questions for the Record
From: Ranking Member Grassley
To: Mr. Eric Andersen
Risky Business: How Climate Change is Changing Insurance Markets
March 22, 2023
Senate Budget Committee

Question:

Mr. Andersen, your firm incorporates the RCP8.5 scenario in your respective modeling, designed to evaluating commercial climate risk. Dr. Curry, amongst other scientists, has noted the evident implausibility of this extreme scenario. How does the use of implausible climate models increase the overall profitability of your consulting firm?

Response:

Ranking Member Grassley,

Thank you for the opportunity to provide answers to questions for record. While the RCP8.5 model is an “upper bound” model showing the effects of climate risk under an extreme scenario, we do not consider that scenario implausible. While unlikely, it is still valid.

At Aon, profitability is not driven by the use of particular models. Rather, we use a range of models to educate our clients so that they can be more resilient to evolving risks.

Question:

Mr. Andersen, you provided a summary of global climate risks during the hearing. You then cited Aon’s 2023 Weather, Climate, and Catastrophe Insight Report when noting that claims data shows 2022 was the most expensive year on record.” However, your written testimony says, “Data shows that 2022 was the fifth costliest year on record for insurers.” Upon further review of the report, Aon cites its own data without providing an indication as to the source of these figures. Does Aon’s estimate account for the inflation caused by Democrat’s excessive spending? How much of the total can be attributed to population growth and the building of more expensive infrastructure in precarious locations?

Response:

Ranking Member Grassley,

Thank you for the opportunity to provide answers to questions for record. 2022 was the fifth costliest year for insurers on record, a fact that is made explicit in the Executive Summary of the 2023 Weather, Climate and Catastrophe Insight Report.

The report is compiled using data from many sources including publicly available estimates of economic and insured losses from governmental and international agencies, disaster management bodies, industry associations, insurers and reinsurers, and other entities, including media, scientific papers, and elsewhere. Data derived from specific sources is attributed within the report.

In appendix “C” of the report, we note that losses are presented on an inflation-adjusted basis.

This indexation does not account for population growth, so fully normalized losses would show a slower increase. However, again, we always emphasize -- and repeat on multiple locations in the report -- that demographic and socioeconomic change is the main driver of increasing losses.

Finally, while our report does not specifically account for how much loss can be attributed to the building of more expensive infrastructure in precarious locations, it is clear that the building of residential and commercial property in some areas -- for example, coastal areas -- tends to be more costly and tends to be more exposed to weather-related events.

Questions for the Record
 From: Ranking Member Grassley
 To: Ms. Nancy Watkins
 Risky Business: How Climate Change is Changing Insurance Markets
 March 22, 2023
 Senate Budget Committee

Re: Response to Questions for the Record from Senate Budget Committee Hearing

Dear Ranking Member Grassley:

It was a privilege to appear before the United States Senate Committee on the Budget at your hearing of March 22, 2023, on “Risky Business: How Climate Change Is Changing Insurance Markets.”

This letter is being written in response to your follow-up questions for the record, specifically:

Ms. Watkins, your firm incorporates the RCP8.5 scenario in your respective modeling, designed to evaluating commercial climate risk. Dr. Curry, amongst other scientists, has noted the evident implausibility of this extreme scenario. How does the use of implausible climate models increase the overall profitability of your consulting firm?

Response

The testimony I presented before your committee was focused on the United States insurance market and the threats it is undergoing today, which have been exacerbated by climate change. Because insurance products in my area of specialty (property & casualty) generally have terms of one year or less, the risk modeling I do for insurers generally focuses on the near-term risk, and there are no assumptions at all regarding long-term climate scenarios.

That said, we are receiving an increasing number of requests from entities like real estate investors, municipal bond investors, lenders, healthcare providers, and government agencies to help them incorporate aspects of climate risk into their decision-making over the long term. They rely on my firm, a worldwide provider of actuarial and related products and services founded in 1947, to contribute our risk-focused expertise and to provide unbiased, independent advice.

When actuaries like myself model long-term climate risks, one important assumption underlying the risk modeling is the choice of climate scenarios. Climate modelers frequently reference the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report published in 2014,¹ which contained four climate scenarios commonly referred to as representative concentration pathways (RCPs), the highest being RCP8.5.

¹ IPCC. Climate Change 2014: Synthesis Report. Retrieved March 29, 2023, from <https://archive.ipcc.ch/report/ar5/syr/>.

Senator Charles E. Grassley
 March 29, 2023
 Page 2 of 2

The decision of which climate scenario or scenarios are most useful to include in a given situation is specific to the context. An example of how to select scenarios is included in this guidance from the California Governor's Office of Planning and Research:²

GHG emissions scenarios reflect different projections for how global emissions and atmospheric GHG concentrations may change over time. The latest scenarios are representative concentration pathways (RCPs), and Cal-Adapt provides projections for a low emissions scenario (RCP 4.5) and a high emissions scenario (RCP 8.5). The Governor's Office of Planning and Research (OPR) recommends that agencies use RCP 8.5 for analyses considering impacts through 2050 because there are minimal differences between emissions scenarios during the first half of the century. For analyses considering impacts beyond 2050, OPR recommends selecting warming scenarios on a case-by-case basis. For a more conservative approach to a given community element, consider using only RCP 8.5. For a less conservative approach, use both RCP 4.5 and RCP 8.5. Which approach will be most useful in selecting emissions scenarios depends on a given community element's risk and criticality.

Climate science is a rapidly evolving field. Projections for future climate change impacts, such as sea-level rise, have changed significantly over the past decade. Definitions of "best science" have changed as climate science has evolved, and even these "best science" estimates have significant uncertainty. Therefore, it is to be expected that different members of the scientific community disagree about how fast the climate is changing, and will continue to do so.³

Actuaries do not get compensated based on the scientific scenarios used. Rather, it is our professional responsibility to measure the risk, communicate what the data may indicate based on sound actuarial principles, and convey the uncertainties associated with our indications. Accordingly, there is no connection between the assumptions used in our models and Milliman's profitability. Milliman is independent, does not accept contingent fees, and consistently delivers objective results that hold up to scrutiny.

Closing

I appreciate the opportunity to provide this response and would be happy to answer any further questions from you or the other members of your esteemed committee.

Sincerely,



Nancy Watkins, FCAS, MAAA
 Principal & Consulting Actuary

² ResilientCA.org. Adaptation Planning Guide: Phase 2: Assess Vulnerability. Retrieved March 29, 2023, from <https://resilientca.org/apg/phase-2/#panel-step2-1>.

³ Chrobak, U. (August 7, 2020). This Worst-Case Climate Scenario Might Be the Most Realistic. Popular Science. Retrieved March 29, 2023, from <https://www.popsoci.com/story/environment/worst-case-climate-scenario-realistic/>.

Questions for the Record
 From: Ranking Member Grassley
 To: Dr. Judith Curry
 Risky Business: How Climate Change is Changing Insurance Markets
 March 22, 2023
 Senate Budget Committee

Question #1:

Dr. Curry, Senator Whitehouse asked questions regarding your 2014 Testimony to the Senate Committee on Environment and Public Works, more specifically the section entitled, "The IPCC AR5 WGI Report: A Weaker Case For Anthropogenic Global Warming." Can you clarify the nature of the IPCC AR5's "weaker case" and the role of natural climate variability?

My 2014 Testimony before the Senate Committee on Environment and Public Works compared statements made by the IPCC AR4 (2007) with the IPCC AR5 (2013), which led me to conclude that the AR5 presented a weaker case for anthropogenic warming than did the AR4.

The specific text that Senator Whitehouse referred to in my 2014 Testimony:

“However, several key elements of the AR5 WGI report point to a weakening of the case for attributing most of the warming to human influences, relative to the previous assessment AR4 (2007):

- Lack of warming since 1998 and the growing discrepancies between observations and climate model projections
- Evidence of decreased climate sensitivity to increases in atmospheric CO₂ concentrations
- Evidence that sea level rise during 1920-1950 is of the same magnitude as in 1993-2012
- Increasing Antarctic sea ice extent “

The relevant quotes from the IPCC AR5 that were included in my Testimony:

“[T]he rate of warming over the past 15 years (1998–2012) [is] 0.05 [–0.05 to +0.15] °C per decade which is **smaller** than the rate calculated since 1951 (1951–2012) [of] 0.12 [0.08 to 0.14] °C per decade.”

“... the **hiatus** [in warming] is attributable, in roughly equal measure, to a decline in the rate of increase in effective radiative forcing (ERF) and a cooling contribution from **internal variability** (expert judgment, medium confidence). The decline in the rate of increase in ERF is primarily attributed to natural (solar and volcanic) forcing but there is **low confidence** in quantifying the role of forcing trend in causing the hiatus, because of uncertainty in the magnitude of the volcanic forcing trend and low confidence in the aerosol forcing trend.”

“However, the implied rates of warming over the period from 1986–2005 to 2016–2035 are **lower as a result of the hiatus**: 0.10°C–0.23°C per decade, suggesting the AR4 assessment was near the upper end of current expectations for this specific time interval.”

“It is very likely that the mean rate of global averaged sea level rise was 1.7 [1.5 to 1.9] mm yr⁻¹ between 1901 and 2010, 2.0 [1.7 to 2.3] mm yr⁻¹ between 1971 and 2010 and 3.2 [2.8 to 3.6] mm yr⁻¹ between 1993 and 2010. **It is likely that similarly high rates occurred between 1920 and 1950.**”

“It is very likely that the annual Antarctic sea ice extent **increased** at a rate of between 1.2 and 1.8% per decade between 1979 and 2012.”

“There is **low confidence** in the scientific understanding of the observed increase in Antarctic sea ice extent since 1979, due to the incomplete and competing scientific explanations for the causes of change and low confidence in estimates of **internal variability**.”

The most fundamental source of disagreement regarding the theory of human- caused climate change is the importance of natural climate variability. Why do climate scientists disagree on the relative importance of natural versus human-caused climate change? The historical data is sparse and inadequate, particularly in the oceans. There is disagreement about the value of different classes of evidence, notably the value of global climate model simulations and paleoclimate reconstructions from geologic data. There is also disagreement about the appropriate logical framework for linking and assessing the evidence. And finally, there is little acknowledgment that some climate processes are poorly understood or even unknown.

Question #2:

Dr. Curry, Senator Whitehouse claimed you referred to the IPCC as "corrupt." Can you clarify the context of your statement, and summarize your concerns about the IPCC process? Is the IPCC a political body, and if so, what are the associated consequences of this politicization?

Senator Whitehouse requested whether I stood by my statement that the “IPCC is corrupt.” Senator Whitehouse completely misrepresented what I have said about the IPCC.

In a 2010 *Discover Magazine* interview, I made the following statement:
<https://www.discovermagazine.com/environment/an-inconvenient-provocateur>

“There is a substantial level of public interest in investigating the issues raised by Climategate. These issues include: wanting an assessment of the reliability and accuracy of the historical and paleo temperature records/reconstructions; wanting an **assessment of whether the IPCC was corrupted** and whether their conclusions are reliable and can be trusted as the basis for international carbon and energy policy; and whether there are some "bad apples" in the climate research community that need to be weeded out in the sense of not being in positions of responsibility as journal editor, IPCC lead author, administrator.”

This statement was subsequently exaggerated inappropriately in a 2010 *Scientific American* profile on me: <https://www.scientificamerican.com/article/climate-heretic/>

“Few scientists would claim the IPCC is perfect, but Curry thinks it needs thoroughgoing reform. She accuses it of “corruption.” “I’m not going to just spout off and endorse the IPCC,” she says, “because I think I don’t have confidence in the process.” “

A 2012 interview with oilprice.com made the following statement, which correctly reflects my concerns about the IPCC process.

<https://oilprice.com/Interviews/The-IPCC-May-Have-Outlived-its-Usefulness-An-Interview-with-Judith-Curry.html>

“Considered somewhat of a black sheep within the scientific community Judith was a one time supporter of the IPCC until she started to find herself disagreeing with certain policies and methods of the organization. She feared the combination of groupthink and political advocacy, combined with an ingrained “noble cause syndrome” stifled scientific debate, slowed down scientific progress, and corrupted the assessment process.”

Around the same time of these interviews, the UN InterAcademy Council began a thorough review of the IPCC’s policies and practices, in response to issues raised by Climategate. The UN IAC invited me make a presentation on my concerns. Also round the same time, the U.S. Natural Research Council Committee on Science, Engineering and Public Policy invited me to make a presentation on my concerns about the integrity of climate science in light of Climategate.

While the IPCC has instituted several of the changes recommended by the IAC, I remain very concerned about the politicization of the IPCC and how this impacts the integrity of climate research. For the past 15 years, I have been an advocate for the integrity of the scientific research. The overt politicization of the IPCC harms the scientific process and hence its progress, which in turn biases the knowledge base that is used by policy makers to support their decisions.

Question #3:

Dr. Curry, Senator Whitehouse claimed that climate models are performing accurately in their predictions. Can you summarize inadequacies of climate model projections cited in recent IPCC reports, and your own concerns?

Chapter 11 of the IPCC AR5 Report¹ focused on near term climate change, through 2035. Figure 11.25 compares climate model projections with observations of global surface temperature anomalies through 2012.

¹ https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter11_FINAL.pdf

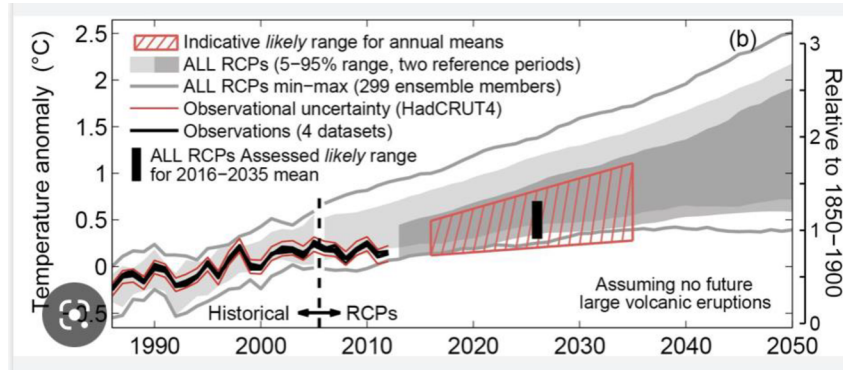
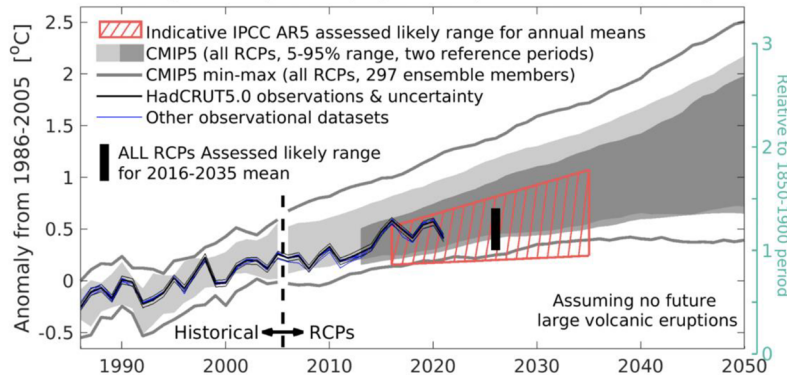


Figure 11.25 in the IPCC AR5 shows that near term climate projections for the period 1999 - 2012 have been much warmer than the observed temperatures, with several years dropping below the 5-95% envelope of the climate model simulations.

Ed Hawkins is the IPCC author who prepared Figure 11.25. He updated the Figure with temperatures through 2021. This later period included the extremely warm temperatures associated with the super El Nino in 2016. The year 2016 barely made it to the midpoint of the climate model range; compare 2016 with 1998 (a previous super El Nino, which slightly exceeded the upper boundary of the 5-95% range).

CMIP5 near-term global temperature projections: updated from IPCC AR5 Fig. 11.25



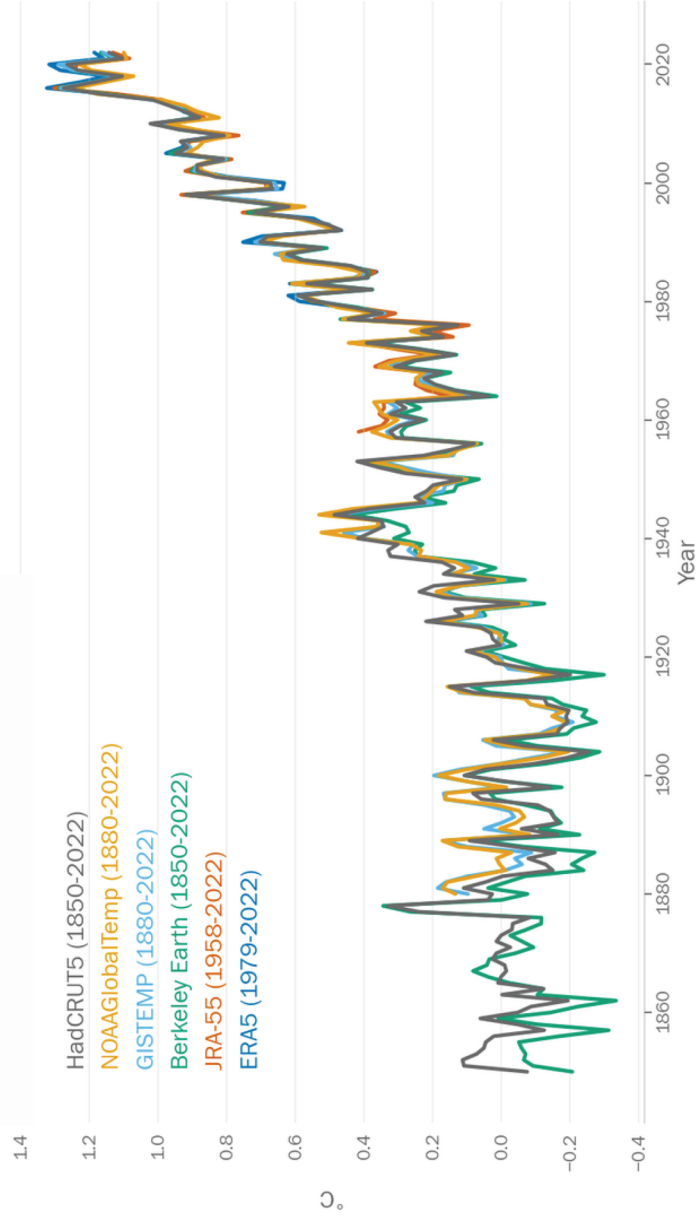
On average, the CMIP6 climate models used in the IPCC AR6 are running hotter than the CMIP5 models cited above. As a result, the IPCC AR6 procedure for providing projected estimates of global average temperature change over the 21st century diverged markedly from the AR4 and AR5, which had relied totally on simulations from global climate and Earth-system models, equally weighting all climate model simulations that were submitted.

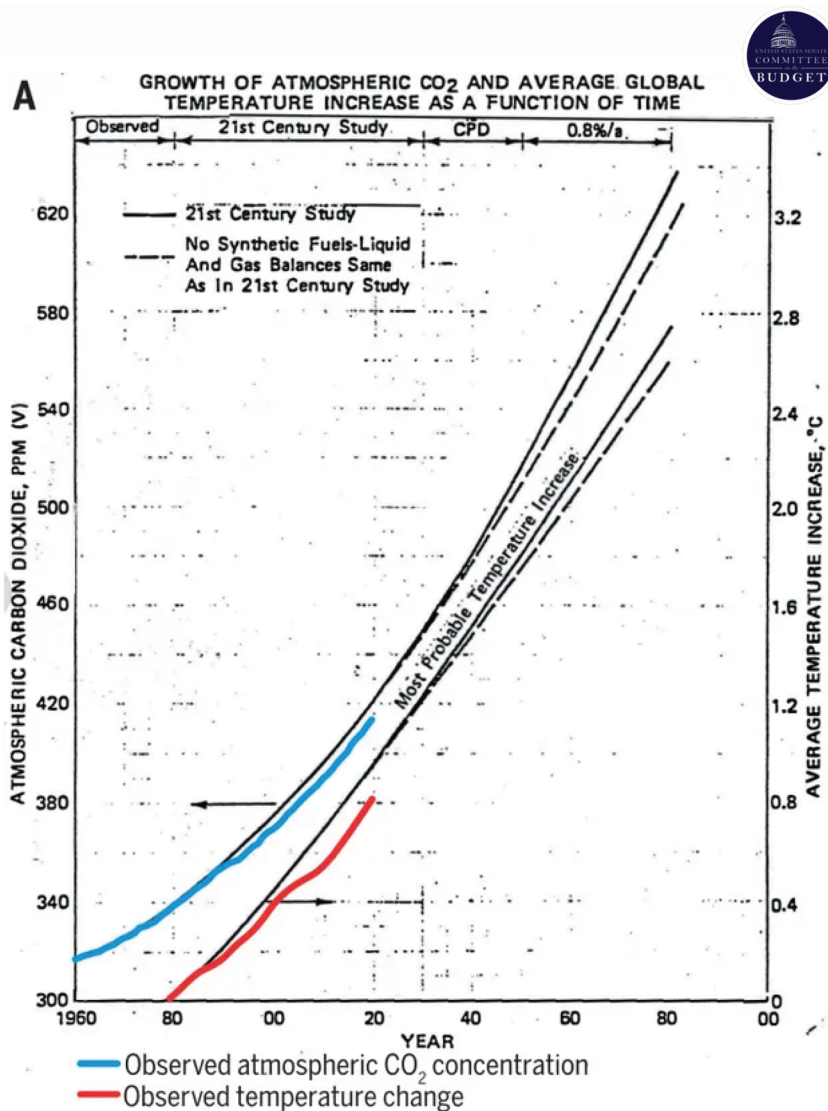
The CMIP6 models used by the AR6 overall provided substantially more warming than the CMIP5 models used in the AR5, including some models with values of climate sensitivity that were judged to be unrealistically high. Hence, the AR6 constrained the CMIP6 projections with observational constraints on simulated past warming and best estimates of the climate sensitivity to increased CO₂. The reduction of the constrained projections relative to the original CMIP6 simulations reported by the AR6 (AR6 Figure 4.11) is substantial, up to 20 percent for the higher emissions scenarios.

There is a growing realization that global climate models are not fit for the purpose of predicting twenty-first century climate variations and change, particularly on decadal and regional scales. Climate model simulations under the auspices of the CMIP program and the IPCC are not providing the full range of scenarios of plausible climate outcomes. The CMIP simulations include very limited scenarios of volcanic eruptions and solar variability. Further, the climate models have inadequate representations of solar indirect effects and multi-decadal to century scale variations in the large-scale ocean circulations. Natural internal climate variability is of particular importance for scenarios of regional climate variations, with larger uncertainties than at the global scale. Uncertainties are substantially larger for global model simulations of precipitation. The coarse resolution of global climate models means that they are not able to simulate directly extreme weather events such as temperature extremes, floods, hurricanes, etc.

GLOBAL MEAN TEMPERATURE

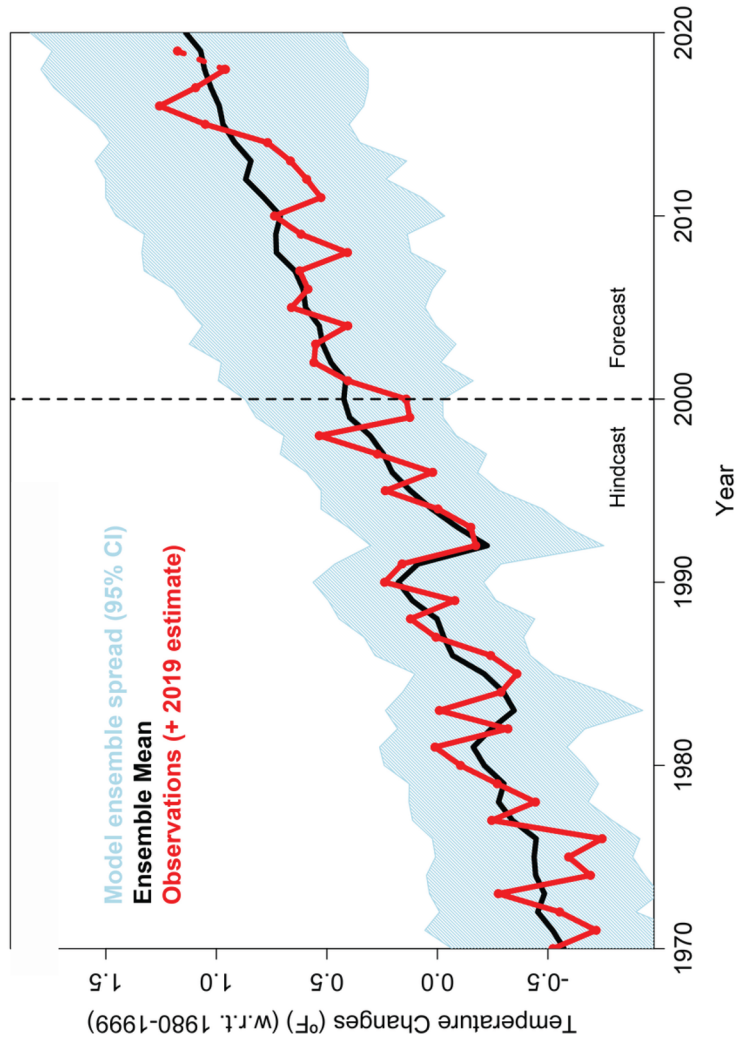
Compared to 1850-1900 average







FORECAST EVALUATION FOR MODELS RUN IN 2004



The Wayback Machine - <http://web.archive.org/web/20161121194118/https://judithcurry.com...>

Trumping the climate

Posted on [November 13, 2016](#) | [403 Comments](#)

by Judith Curry

So ... what can we expect from the Trump administration on environment/climate/energy?

There is much angst among the 'greens' about what to expect. This is typified by this morning's headlines from the Huffington Post:

SET TO BOIL: Trump Racing to Scrap Landmark Climate Deal

China Calls Move Ludicrous... 'GAME OVER': Scientists Fear Disaster With Donald... 'Election Of Donald Trump Could Be Devastating For Our Climate And Our Future'... 'Trump Has A Profound Ignorance Of Science'... Donald Taps Climate-Change Skeptic To Dismantle EPA... Oil Exec Eyed For Sec. Of Interior... New Push For Keystone Pipeline Fires Up...

Lets take a closer look at what President-elect Trump has actually said in recent months, including his policy/issue statements.

Hoax

Whenever the issue of Trump and climate change comes up in the world of the 'greens', the first thing they mention is that he said climate change is a 'hoax.'

PolitiFact has done a good job of summarizing this (January 2016):

The clearest example comes from a tweet sent by Trump on Nov. 6, 2012. "The concept of global warming was created by and for the Chinese in order to make U.S. manufacturing non-competitive."

On Jan. 18, after Sanders had attacked Trump's climate change views in the Democratic debate, Trump told Fox & Friends, "Well, I think the climate change is just a very, very expensive form of tax. A lot of people are making a lot of money. I know much about climate change. I'd be — received environmental awards. And I often joke that this is done for the benefit of China. Obviously, I joke. But this is done for the benefit of China, because China does not do anything to help climate change. They burn everything you could burn; they couldn't care less. They have very — you know, their standards are nothing. But they — in the meantime, they can undercut us on price. So it's very hard on our business."

3/21/23, 6:32 PM

Trumping the climate | Climate Etc.

On Dec. 30, 2015, Trump told the crowd at a rally in Hilton Head, S.C., "Obama's talking about all of this with the global warming and ... a lot of it's a hoax. It's a hoax. I mean, it's a money-making industry, OK? It's a hoax, a lot of it."

In August, he stated: "I'm not a big believer in manmade climate change. Nobody knows for sure."

Lets first look at the definition of 'hoax', here are a few I spotted by googling:

- a humorous or malicious deception.
- to trick into believing or accepting as genuine something false and often preposterous
- a plan to deceive a large group of people
- a deliberately fabricated falsehood made to masquerade as truth.

With these definitions in mind, here are two examples that qualify as hoaxes that I have previously written about:

1. The UNFCCC definition of 'climate change' arguably qualifies as a hoax: *climate change is a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.* [\[link\]](#). This perversion of the definition of 'climate change' was designed to mislead people into thinking that all climate change is caused by humans.
2. The propaganda from the UNFCCC that misleads people into thinking that the planned emissions reductions will have any discernible impact (that emerges from natural variability) on the 21st century climate [\[link\]](#), even if you believe the climate models.

So in terms of climate hoaxes, perhaps it is NOT Donald Trump's whose pants are on fire.

Trump's answers to ScienceDebate

ScienceDebate.org asked the Presidential candidates questions on a range of science-related issues. The answers to the climate change questions are [\[here\]](#). Trump's statement:

There is still much that needs to be investigated in the field of "climate change." Perhaps the best use of our limited financial resources should be in dealing with making sure that every person in the world has clean water. Perhaps we should focus on eliminating lingering diseases around the world like malaria. Perhaps we should focus on efforts to increase food production to keep pace with an ever-growing world population. Perhaps we should be focused on developing energy sources and power production that alleviates the need for dependence on fossil fuels. We must decide on how best to proceed so that we can make lives better, safer and more prosperous.

Well, I find it difficult to argue with any of this. In fact, I like this statement quite a lot.

Paris

The big news over the weekend is that someone from Trump's transition team has leaked that Trump plans to pull out of the Paris UNFCCC agreement [\[link\]](#).

Robert Stavins has a concise analysis of Trump's road ahead re climate change [\[link\]](#):

