Global Modeled Catastrophe Losses

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AIR
A Verisk Business

Contact Information

If you have any questions regarding this document, contact:

AIR Worldwide Corporation
Lafayette City Center
2 Avenue de Lafayette
Boston, MA 02111
USA

Tel: (617) 267-6645
Fax: (617) 267-8284

For more information on our Boston headquarters and additional offices in North America, Europe, and Asia, visit air-worldwide.com/About-AIR/Offices/

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Introduction

Every year since 2012, AIR Worldwide (AIR) has published a report on extreme event risk from a global perspective.[1] This global risk profile is assessed by way of AIR's global industry exceedance probability (EP) curve, which puts into context years with high insured losses such as 2011 and 2017.[2] While every year is unique, this year presented a host of new challenges, including the delta variant strain of SARS-CoV-2, the virus that causes COVID-19, which complicated emergency preparation measures for various events. This year also saw sharper awareness of climate change impacts and risk. Some challenges remain stubbornly the same, including the protection gap for various perils across all regions. What follows are the notable extreme events that occurred this year, against the backdrop of the pandemic, up until the time of publication.

The first month of 2021 saw Spain's heaviest snowfall in 50 years, courtesy of Storm Filomena, which brought strong winds, torrential rain, and snow to southeastern and central Spain on January 7. Temperatures plummeted and a new record low for the nation of -35.6° C (-32° F) was recorded in northern Spain. Snowfall was widespread, but the Madrid region was particularly hard hit. On January 15, an Mw 6.2 earthquake struck the Majene Regency, in the western side of Sulawesi island in Indonesia; at least 78 people were killed, predominantly from Mamuju district. Southeast Asia is a region characterized by rapid deformation, pervasive faulting, and widespread seismicity. On January 25, an EF-3 tornado, spawned by a line of major storms that impacted a wide swath of the United States, struck Jefferson County, Alabama, which highlights the fact that U.S. tornadic activity can happen at any time of the year and that not all tornado risk is confined to the region known as "Tornado Alley."

On February 13, an M7.1 earthquake struck northern Japan, causing widespread shaking throughout northern Honshu. The earthquake occurred close to the downdip edge of the subducting interface, which ruptured during the M9.1 Tohoku earthquake almost exactly 10 years prior; the Japan Meteorological Agency (JMA) deemed the quake an aftershock of the Tohoku quake. With most small-to-moderate size earthquakes, aftershock activity decays relatively quickly over a few days or weeks following the mainshock, but for great M9.0 class earthquakes it can take many years.

On February 16, a record was set for the largest amount of the U.S. ever blanketed in snow, 73% of the nation (since 2003 satellite records were kept), for that date. From

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[1] "Taking a Comprehensive View of Catastrophe Risk Worldwide: AIR's Global Exceedance Probability Curve," "AIR's 2013 Global Exceedance Probability Curve,", "AIR's 2014 Global Exceedance Probability Curve," "2015 Global Modeled Catastrophe Losses," "2016 Global Modeled Catastrophe Losses," "2017 Global Modeled Catastrophe Losses," "2018 Global Modeled Catastrophe Losses," "2019 Global Modeled Catastrophe Losses," and "2020 Global Modeled Catastrophe Losses."

[2] Catastrophes in 2011 include the Tohoku earthquake in Japan, major severe thunderstorms across the U.S., earthquakes in New Zealand, and floods in Thailand; catastrophes in 2017 include major severe thunderstorms across the U.S., HIM events, Mexico earthquakes, and California wildfires; catastrophes in 2018 include hurricanes Michael and Florence, Typhoon Jebi in Japan, the Western Japan Floods, and California wildfires; catastrophes in 2019 include Typhoon Faxai and Typhoon Hagibis in Japan.

Washington to Maine to Texas, the winter storm of mid-February 2021 (also known as "Uri" to some, an unofficial name given to it by a large U.S. media outlet) was a strong reminder of the shear mass (and scale) of disruption and destruction that extratropical cyclones are capable of. Texas was particularly hard hit and has been hit by more disasters since 1953 than any other U.S. state, according to FEMA. In recent years, Texas has experienced numerous kinds of disasters, including floods and hurricanes, tornadoes, hailstorms, and wildfires—but winter storms can be an issue too.

North Carolina had an extremely wet February in 2021 and experienced widespread flooding as a result. In late February 2021 the Lumber River crested just above 20.4 feet—the third time since 2016 it has crested above 19 feet, the level that the National Oceanic and Atmospheric Administration (NOAA) considers "major flood stage." Communities on the south side of the Lumber River were shattered by Hurricane Matthew in 2016; the river crested at 28 feet, the highest crest on record by 8 feet. Two years later, Hurricane Florence brought yet more severe flooding to Lumberton. Still greater quantities of water poured in from the railroad underpass through the levee, and even more homes and businesses were flooded, some of which had just finished rebuilding after Matthew. Fortunately, the lessons from Matthew had not gone unheeded by residents; flood insurance uptake had increased to more than 25% in the areas south of the Lumber River, helping to blunt the financial strain of recovery.

March brought more earthquakes. On the 5th (local time), three strong earthquakes offshore New Zealand—an M7.3, an M7.4, and an M8.1—occurred all on the same day, each triggering its own tsunami warning. These earthquakes were quite timely in that they occurred after several DART (Deep-ocean Assessment and Reporting of Tsunami) buoys became operational for monitoring deep seawater perturbations offshore New Zealand within the last year. Also on the 5th an M6.3 quake struck near Týrnavos, Greece, and reports of shaking came from Albania, Macedonia, Kosovo, and Montenegro. This quake struck about 5 months after the M7.0 Néon Karlovásion quake struck near the Greek island of Samos and the western coast of Turkey in the Aegean Sea, highlighting earthquake risk in the Mediterranean. The end of March closed an active first quarter of the year for U.S. tornado activity.

The second quarter saw more severe thunderstorm activity and started to see some tropical cyclone activity. At the beginning of April, Tropical Cyclone Seroja caused deadly flooding and landslides in Indonesia, then interacted with Tropical Cyclone Odette April 7 to 9 off the coast of Western Australia, and made landfall 300 miles north of Perth on April 11, causing widespread damage to a small resort town. In April, Texas and Oklahoma experienced severe thunderstorms that included large damaging hail. May opened with a severe thunderstorm outbreak that impacted Texas and a dozen other states. On May 17, Cyclone Tauktae struck the Indian state of Gujarat with an intensity the equivalent of a Category 2 hurricane on the Saffir-Simpson Scale, the strongest cyclone to hit the state since 1998 when a storm struck the city of Kandla, killing more than 10,000 people and causing more than USD 250 million in insured losses. While Tauktae was much less damaging, it was a potent reminder of the cyclone risk this area faces. May 22 marked the sixth consecutive year that Atlantic hurricane activity began prior to the official start of the season (on June 1), when the first named storm, Ana, formed. May closed with another cyclone striking India, with Cyclone Yaas making landfall in the state of Odisha in the eastern part of the country. More than 1 million people were evacuated beforehand from Odisha and neighboring West Bengal and disruption ensued with at least 6 deaths attributed to the storm.

Heading into California's traditional wildfire season, which typically starts in June, concerns about the 2021 U.S. wildfire season continued to be stoked as mid-May wildfires such as the Palisades Fire that burned 1,200+ acres and threatened homes in Los Angeles County were a reminder that this peril poses a danger during periods of extreme aridity, even outside the traditional fire season. Specifically, 88% of the land area of the Western states was in drought conditions; this prolonged drought had begun a year ago. In addition, heading into another Atlantic hurricane season during a pandemic, the market conditions in June and what they could mean for this season were top of mind. Over the second half of June, several outbreaks of severe thunderstorms caused historic losses across Europe and an EF-3 tornado ripped through northern Illinois, the strongest to hit the state in four years.

The month of July kicked off with Tropical Storm Elsa becoming the earliest fifth named storm on record, surpassing last year's record-setting Edouard, which formed on July 6. Elsa also became the first hurricane of the season a day later. Although Elsa was forecast on to make landfall in Florida at hurricane strength, it eventually made landfall as a tropical storm on July 7. From July 13 to 18, there was significant flooding in Europe brought about by low pressure system "Bernd." Germany was most impacted, particularly in the Rhineland-Palatinate and North Rhine-Westphalia regions, which experienced heavy and, in some cases, historic rainfall, as well as the border region between the German states of Bavaria, Thuringia, and Saxony, which were affected by localized flooding as well. Austria, Switzerland, Luxembourg, the Netherlands, and Belgium also saw significant flooding from this event. The week of July 19 brought record rainfall to the province of Henan in China, which caused extensive flooding that led to mass displacement and casualties and impacted agriculture. The flooding occurred about 90 years after the catastrophic Yunnan floods. On July 20 and 26, typhoons Cempaka and In-Fa made landfall in Guangdong Province and Zhejiang Province, China, respectively. The month closed with the M6.2 Sullana, Peru, earthquake on July 30, a little more than 20 years after the massive Mw 8.4 Arequipa, Peru, earthquake, which is still one of the 20 largest earthquakes in the world.

The U.S. wildfire season lived up to preseason forecasts in August with the second-largest fire on record in California, the Dixie Fire, still blazing. This fire is second only in size to last year's August Complex Fire (1,032,648 acres). Oregon saw its third-largest wildfire ever, the Bootleg Fire (413,765 acres), contained in August. Although many wildfires burned in U.S. western states this year, these were two of the most notable in terms of size.

In mid-August, the Intergovernmental Panel on Climate Change (IPCC) issued a major new report, *Climate Change 2021: The Physical Science Basis*. This report represents the consensus view of the more than 200 scientists from 66 countries who make up the IPCC's Working Group I, and its nearly 4,000 pages will become part of the IPCC's Sixth Assessment Report (AR6), which is due for release in September 2022. In a later section, we will share brief summaries selected from this report's findings on regional impacts of climate change.

On August 14 the Caldor Fire started and quickly grew. After two weeks it was threatening the Lake Tahoe area and only 12% contained. On August 14, an M7.2 earthquake struck Haiti about one month after their president was assassinated, during a pandemic, and right before Tropical Depression Grace drenched the country as it made its way to Mexico, where it made landfall as a the first major hurricane in the Atlantic, a Category 3, on August 21, about 30 miles southeast of Tuxpan. Also on August 21, Middle Tennessee experienced record-breaking rainfall that resulted in severe flooding. On August 29, Hurricane Ida made two landfalls on Louisiana's southeastern coast as a Category 4 storm, exactly 16 years after Katrina. Impacts included those to infrastructure, such as widespread power outages that affected more than 1 million customers in Louisiana and Mississippi at their peak; and extensive, long-term damage to Port Fourchon as well as homes and businesses, mainly in southeastern Louisiana. The remnants of Ida also produced historic rainfall in the northeastern U.S., which caused severe flooding.

September opened with an M7.0 earthquake striking northeast of Acapulco de Juárez, Guerrero, Mexico, on the 7th, local time. Although damaging, the impact was not on the scale of the last earthquakes to strike Mexico in September just 4 years prior when an M8.1 quake struck off the coast of the state of Chiapas and an M7.1 struck central Mexico in 2017. Mid-September was an active period for hurricanes, as expected, with Hurricane Olaf making landfall near Cabo San Lucas, Mexico, on the 10th as a Category 2 storm; Hurricane Larry making landfall near South East Bight in Newfoundland, Canada, as a Category 1 storm later the same day, local time; and Hurricane Nicholas making landfall about 10 miles west-southwest of Sargent Beach, Texas, in the eastern part of the Matagorda Peninsula, as a Category 1 storm on the 14th. On the 22nd, an M5.9 earthquake struck 128.4 km east-northeast of Melbourne, Victoria, Australia. This quake did not cause significant damage, unlike another moderate quake that struck near Newcastle, New South Wales, Australia, a little more than 30 years earlier.

By October 14, California's wildfires had burned 2,487,887 acres, about 1.5 million acres less than last year at this time. Four wildfires this year are among the top 20 largest fires recorded in the state: the Dixie Fire occupies the #2 spot, having burned 50,000 acres less than last year's first-ever recorded "gigafire," the August Complex Fire; the Caldor, Monument, and River Complex fires occupy the 14th, 15th, and 17th places, respectively. Nine of the top 20 fires occurred either this year or last; only two occurred before 2003.

Throughout 2021, many countries have experienced severe flooding at least once this year. We have already noted the flood events in July that affected Germany, Austria, the Netherlands, Switzerland, and Belgium, as well as China, the flood events in Middle

Tennessee in August and the U.S. Northeast in September (Ida), but notable flooding events also impacted India, Indonesia, Japan, Singapore, South Korea, Taiwan, Turkey, and Vietnam, as well as many other countries in Asia, Africa, Europe, and the Americas.

Preparing for large losses *before* they occur is critical to continued solvency and resilience.

The 2021 edition of AIR's white paper "Global Modeled Catastrophe Losses" bases its global loss metrics on AIR's latest suite of models, including new models and updates released during 2021, as well as updated industry exposure databases (IEDs). The paper includes AIR's presentation of global EP metrics on both an insured and insurable basis, where insurable loss metrics include all exposures eligible for insurance coverage assuming standard limits and deductibles, regardless of whether they are actually insured.[3] For regions and perils covered by catastrophe models, this difference presents not only potential business growth opportunities for the insurance industry to offer essential protection to vulnerable home- and business-owners, but a responsibility to act.

Such a difference was especially evident when Hurricane Harvey struck Texas in 2017 and Hurricane Florence struck the Carolinas in 2018, for example. While the United States has good insurance penetration generally, the damage caused by Harvey's and Florence's flooding was largely uninsured. Hurricane Ida's impacts in the Northeast this year remind us that flood losses can occur virtually anywhere across the U.S. and not to be complacent about the U.S. inland flood insurance gap. By comparison, take-up rates for flood insurance in European countries is generally much higher, so while there is a flood insurance gap in Europe, it is not as large as that in the U.S. Thus, a flood such as the one that affected Germany and other European countries in July incurs large insured losses and reveals greater resilience to flood disaster in countries affected there. After earthquakes stronger than M5.0 struck both Utah and North Carolina and an M7.4 struck Mexico in 2020, the large difference between insured and insurable earthquake-related losses in the U.S. loomed large—especially in California where, if the "Big One" were to occur, nearly 75% of the losses would be uninsured.[4] Thus the difference between insured and insurable losses is a problem not limited to developing countries. Finding ways to address this gap remains one of the primary challenges facing the insurance industry.

Also discussed in the 2021 update are global economic losses from catastrophes, which can vastly exceed insured losses depending on the region and peril. This "protection gap"—the difference between economic and insured losses—highlights the significant burden that society faces when a disaster strikes. The M7.2 Nippes, Haiti, earthquake in August illustrates the difference between a large earthquake that strikes a country with low insurance penetration and one that strikes in a well-developed insurance market such as when the M7.1 earthquake struck Namie, Japan, in February. For the insurance industry, the protection gap can spur innovation in product development. In the public sector,

[3] Insurable loss metrics for Japan were calculated using 100% limits for typhoon and earthquake.

[4] The "Big One" alluded to is an M7.9 earthquake similar to the 2008 ShakeOut scenario that ruptures 73 segments of the San Andreas fault.

governments are recognizing the importance of moving from reactive to proactive risk management, especially in countries where a risk transfer system is not well established. Understanding the protection gap can help governments assess the risks to their citizens and critical infrastructure, and develop risk-informed emergency management, hazard mitigation, and public risk financing strategies to enhance global resilience and reduce the ultimate costs.

Finally, while pandemics are not included in the global property EP metrics, AIR has been closely monitoring the COVID-19 pandemic since December of 2019. This year opened with the expectation that COVID-19 cases would decline by the fall, given that in late 2020/early 2021 seven World Health Organization–approved vaccines were authorized for emergency use by the regulatory agencies of many countries. Although COVID-19 cases did decline sharply in the U.S. in the spring and moderated in other countries that experienced slower rollouts, variants of the virus soon emerged. In particular, the delta variant gained a stronghold in areas with higher percentages of unvaccinated people; cases began to rise again mostly in these unvaccinated populations in the summer and continued through autumn. The country with the highest number of deaths reported throughout the pandemic has been the United States. As of this writing, the pandemic has caused more than 4.8 million deaths globally; nearly half of those deaths were reported in the United States, Brazil, India, Mexico, Russia, and Peru. The pandemic also caused the global economy to contract by 3.5 percent in 2020,[5] resulting in tens of billions of dollars of economic losses; disruptions to the global supply chain will continue to be felt universally. What the pandemic and its impact will look like in the last quarter of 2021 and into 2022 and beyond remains uncertain.

AIR is uniquely qualified to provide the global (re)insurance industry, financial institutions, governments, and non-governmental organizations with the insightful view of risk presented in this paper for the following reasons:

- AIR models the risk from natural catastrophes and other perils (including pandemic, terrorism, cyber, and casualty) in more than 110 countries, affording AIR a truly global perspective.[6]
- AIR has been an industry leader in understanding the impact of climate change on atmospheric perils for over a decade. Our models are updated to reflect the impacts of our changing climate and provide a view of the near-present climate. The models, therefore, go beyond simply presenting a historical perspective on events as they have occurred, making them especially relevant for current decision-making.
- AIR develops and maintains a detailed IED—including counts, replacement values, and physical attributes of insurable properties—for each modeled country.[7] These

[5] https://www.brookings.edu/research/social-and-economic-impact-of-covid-19/

[6] The modeled losses in this paper cover property and crop risk. Because of the unique catalog architecture of the AIR pandemic, cyber, and casualty models, modeled losses for these perils were excluded from the analyses in this paper.

[7] AIR has developed and maintains IEDs for all modeled countries with the following exceptions: Brazil, Brunei, Malaysia, and Thailand.

IEDs serve as the foundation for all modeled industry insured and insurable loss estimates and make the generation of a global industry EP curve a straightforward task.[8]

- AIR's year-based simulation approach enables model users to determine the probability of various levels of loss for years with multiple catastrophic events, across multiple perils and multiple regions.

Industry insured losses can and do occur as a result of perils and in regions for which AIR does not yet provide models; these losses are not included in AIR's global estimates. AIR, however, is committed to continually expanding model coverage and is engaged in an aggressive model development program.

Industry Exposure Databases Give AIR Unique Global Risk Insight

AIR builds its industry exposure databases (IEDs) from the bottom up, compiling detailed data about risk counts, structure attributes (parameters that greatly influence the ability to withstand high winds, ground motion, and flood depth), and replacement values, as well as information on standard policy terms and conditions. AIR then validates key attributes of the database through a top-down approach, using aggregate data from multiple additional sources. Coupling these approaches results in aggregated industrywide IEDs that are both objective and robust.

High-resolution IEDs for modeled countries—and a straightforward and intuitive catalog-generation process—enable AIR to provide insight into the likelihood of different levels of loss on a global scale. In some regions, lack of current data, data access, and poor data quality can pose challenges to IED development and maintenance. In such cases, index factors are created using demographic data from additional sources and employed to project the data forward.

Learn more about the development, maintenance, advantages, and critical role of IEDs in reliable catastrophe modeling in" Modeling Fundamentals: AIR Industry Exposure Databases."

[8] For countries with IEDs that were not updated in 2020, index factors were applied to calculate the global aggregate average annual loss (AAL) and exceedance probability (EP) loss metrics for both insured and insurable losses in this report. The U.S. and China also received indexed updates to their IEDs by county and province, respectively, and by line of business.

Exceedance Probability Metrics

Insured and Insurable Losses

The global aggregate average annual loss (AAL) and exceedance probability loss metrics for 2021 reflect changes in risk as a result of updated models (Japan typhoon and earthquake, and U.S. terrorism); they also comprise the update to AIR's industry exposure databases for Japan and updated index factors for the U.S., South America (7 countries) and Europe (31 countries).

Global insured AAL and key metrics from the aggregate exceedance probability (EP) curve from 2012–2021 are presented in Table 1. While we have always provided aggregate EP loss at the 100- and 250-year return periods—and it continues to be important to discuss loss metrics in the tail of the distribution— this year we've added another point on the EP curve representing the 20-year return period. This point in the "body" of the distribution can be used as a benchmark for our state-of-the-science near-present view of climate risk and does not require any adjustments or custom catalogs. We have added this additional point on our aggregate EP loss curve this year because it is important to note that losses in excess of USD 200 billion are a very real possibility in the shorter return periods. These shorter return period losses are well represented by the global suite of AIR models.

Table 1. Key insured loss metrics from AIR's global industry EP curve for all regions and perils. (Source: AIR)

Year	AAL (USD Billions)	Aggregate EP Loss (USD Billions)		
		5.0% (20-year return period)	1.0% (100-year return period)	0.4% (250-year return period)
2012	59.3	-	205.9	265.1
2013	67.4	-	219.4	289.1
2014	72.6	-	231.5	292.5
2015	74.4	-	232.8	304.8
2016	80	-	252.9	325.3
2017	78.7 (Insurable: 167.2)	-	246.9 (Insurable: 602.7)	325.3 (Insurable: 952.3)
2018	85.7 (Insurable: 181.8)	-	270.9 (Insurable: 654.2)	341.9 (Insurable: 1,057.9)
2019	91.8 (Insurable: 191.4)	-	288.2 (Insurable: 655.2)	366.2 (Insurable: 1,004.4)
2020	99.6 (Insurable: 204.0)	192.5 (Insurable: 397.0)	301.1 (Insurable: 701.1)	376.3 (Insurable: 1,095.2)
2021	106.3 (Insurable: 216.4)	203.4 (Insurable: 421.7)	320.5 (Insurable: 767.0)	397.0 (Insurable: 1055.6)

Average annual insured losses and the metrics from the aggregate insured EP curve—for all regions and perils modeled by AIR—have generally increased since the first white paper was published in 2012. This is expected; the rise reflects both increases in the numbers and values of insured properties in areas of high hazard and the inclusion of regions and perils for which new models are now available.

The insurable loss metrics include all exposures eligible for insurance coverage, regardless of whether they are actually insured. They represent the total damage minus deductibles and limits.[9] On a global basis, modeled insurable AAL is more than twice as high as the insured AAL, as are global insurable losses at the 1.0% exceedance probability. Looking even further down the EP curve, global insurable losses at the 0.4% exceedance probability are almost three times the insured.

A breakdown of contribution to global AAL by region and key aggregate EP metrics by region appears in Table 2. The difference between insured and insurable loss is most pronounced in Asia, where insurance penetration remains very low.

Table 2. AAL and EP metrics, by region, based on AIR's global suite of models, including those introduced or updated in 2020. (Source: AIR)

	AAL (USD Billion)		Aggregate EP Loss (USD Billion)			
			1.0% (100-year return period)		0.4% (250-year return period)	
Region	Insured	Insurable	Insured	Insurable	Insured	Insurable
Asia	15.1	71.4	70.9	578.4	95.4	868.4
Europe	16.6	25.6	69.9	127.9	89.5	170.4
Latin America (the Caribbean, Central America, South America)	5.6	12.8	47.3	109.6	67.6	144.0
North America (Canada, the United States, Bermuda, Mexico)	66.0	100.5	262.8	376.0	343.1	504.3
Oceania	3.0	3.4	19.9	21.8	30.3	31.8
All exposed areas*	106.3	216.4	320.5	767.0	397.0	1055.6

* Note that aggregate EP losses are not additive, as noted in the box "Understanding the Exceedance Probability Curve."

[9] In cases where index factors were applied to derive insured loss metrics, those same index factors were applied to obtain comparable insurable loss metrics, which can result in take-up rates that exceed 100%.

Figure 1 shows the contribution to global insured AAL by peril.

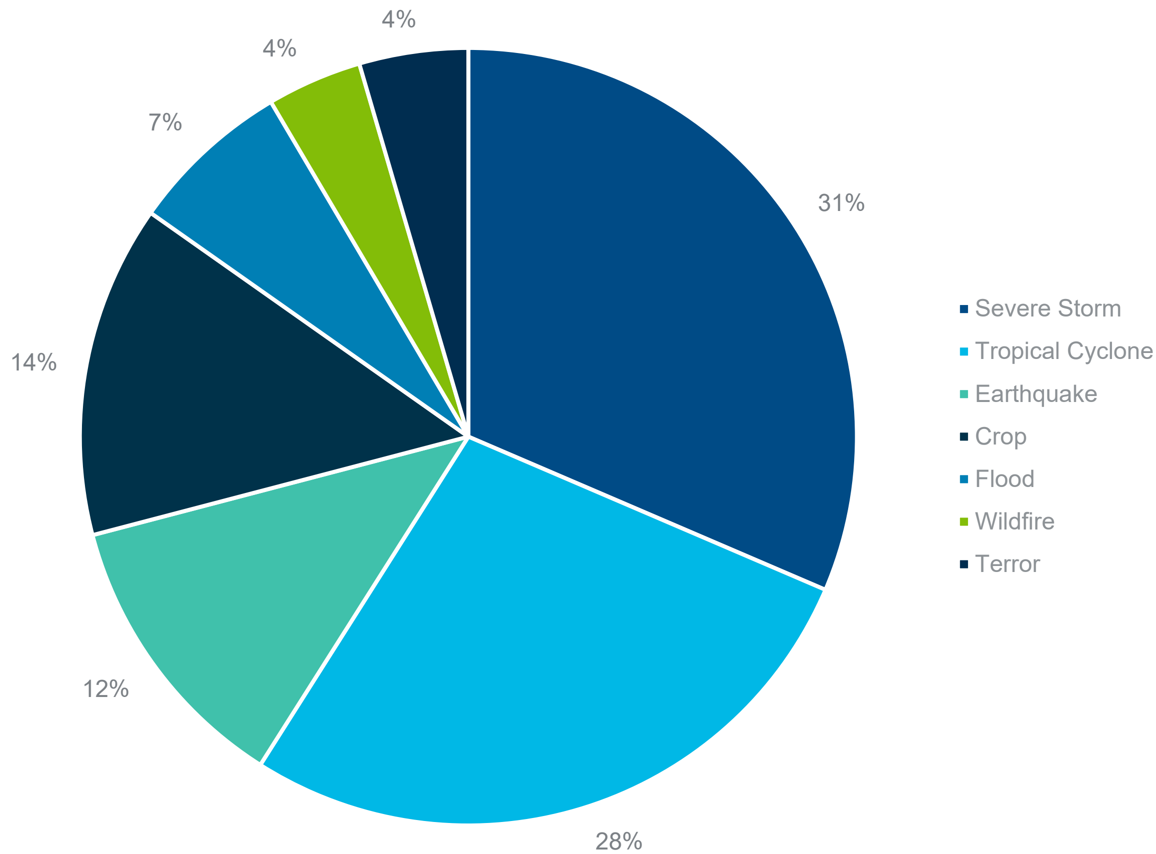

Figure 1. Contribution to global insured AAL by peril for all regions. (Source: AIR)

Figure 2 shows the contribution to global insurable AAL by peril.

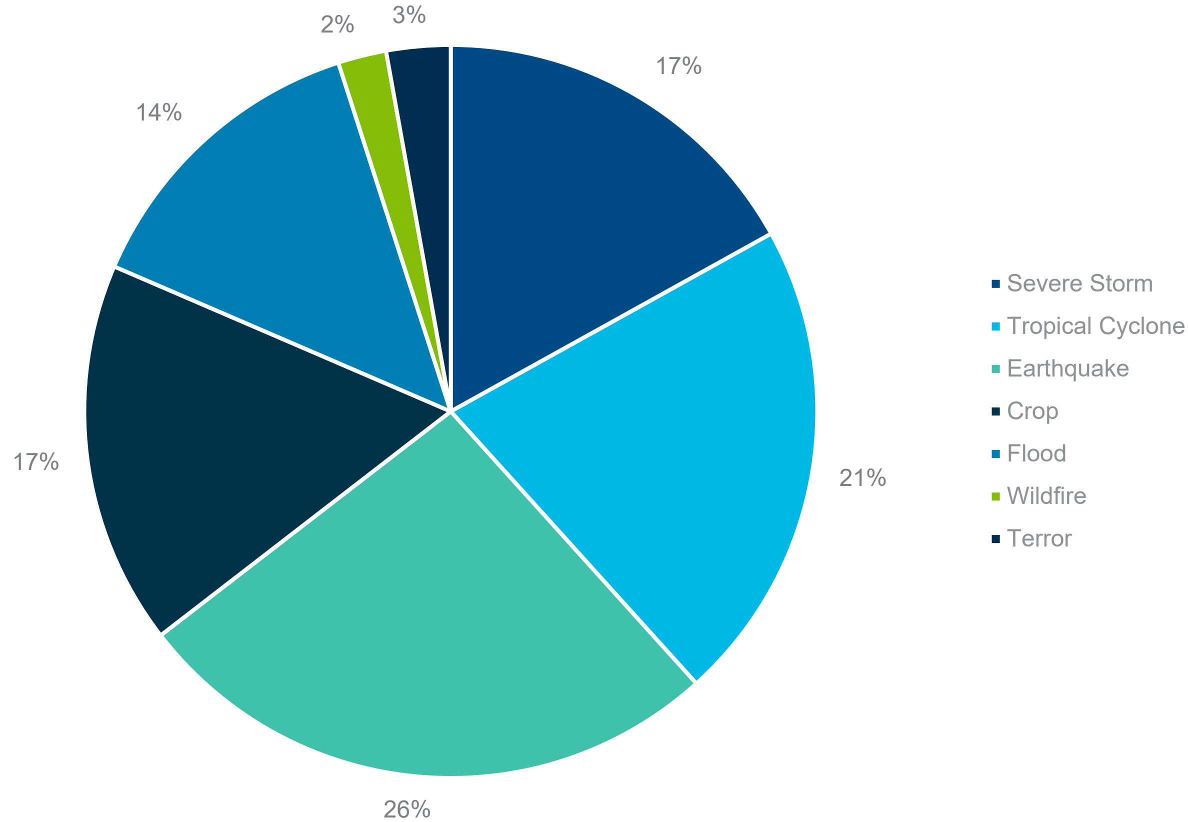

Figure 2. Contribution to global insurable AAL by peril for all regions. (Source: AIR)

It is important to note that AAL represents average expected losses over a long period of time, not what would be expected in any given year. As reflected in AIR's stochastic catalogs, global aggregate losses in any given year may comprise a few large loss events in peak regions or lower losses from multiple perils across multiple regions; what is certain is that they are unlikely to look like the long-term AAL breakdowns shown in Figure 1 and Figure 2.

Understanding the Exceedance Probability Curve

To meet the diverse needs of model users, AIR's catastrophe models provide a wide range of modeled loss output. One of the most commonly-used outputs is a distribution of potential losses with the associated probabilities of exceedance. These exceedance probability (EP) curves—which can be specific to peril, region, or line of business—quantify the risk profile for whole portfolios or individual risks and can be used to inform a variety of risk management decisions.

Understanding how AIR develops its stochastic catalogs of simulated events helps one understand how the EP curves are generated. To create a stochastic catalog for a given peril, scientists first gather information on historical events from a comprehensive range of sources. This data is then used to infer what can happen in the future; that is, to indicate where and how frequently certain types of events are likely to occur and how large or severe the events are likely to be. A 10,000-year hurricane catalog, for example, contains 10,000 potential scenarios for tropical cyclone activity in an upcoming year. Importantly, although the simulated events have their basis in historical data, they extend beyond the scope of past recorded experience to provide the full spectrum of future potential catastrophe events.

To generate the EP curves, first an AIR catalog is run against the portfolio of exposures. Next, the loss for each event in each modeled year is calculated. (Some modeled years will have multiple events, some a single event, and some no events.) Then modeled years are ranked from highest loss to lowest loss, based on loss figures calculated for either *occurrence* loss (based on the largest event loss within each modeled year) or *aggregate* loss (based on the sum of all event losses of each modeled year).

Finally, EPs corresponding to each loss—occurrence or aggregate—are calculated by dividing the rank of the loss year by the number of years in the catalog. Thus, for a 10,000-year catalog, the top-ranked (highest loss) event would have an EP of 0.0001 (1/10,000) or 0.01%, the 40th-ranked event an EP of 0.004 (40/10,000) or 0.40%, the 100th-ranked event an EP of 0.01 (100/10,000) or 1.00%. The return period for a loss level equals the inverse of EP: EPs of 0.01%, 0.40%, and 1.00%, for example, correspond to 10,000-, 250-, and 100-year return periods.

Model users should keep in mind that EP metrics provide the probability of a certain *size* loss, not the probability that a specific *event* or *events* will occur. Also, the probability of an event or events occurring exactly as modeled (or the exact recurrence of a historical event) is virtually zero, although a wide range of event scenarios may cause a similar level of loss.

Average annual losses (AALs) for exposed areas—such as the regions listed in Table 2—can be summed because the region figures were calculated by averaging losses across all modeled years. Aggregate EP losses are not additive and thus—again referring to Table 2—do not equal the sums of the regional aggregated EPs.

To read more about how exceedance probability curves are constructed and how they should be interpreted, see the articles "Modeling Fundamentals: What Is AAL?" and "Modeling Fundamentals: Combining Loss Metrics."

Economic Losses

Global economic losses include insured and insurable losses, as well as losses from non-insurable sources, which may include infrastructure and lost economic productivity. Comparing insured losses with reported economic loss estimates for natural disasters since 1990 (as reported by Swiss Re, Munich Re, Aon Benfield, AXCO, Lloyd's, and the Insurance Bureau of Canada), AIR has determined that global insured losses make up about a quarter of global economic losses on average, when trended to 2020 dollars. Based on AIR's modeled global insured AAL, this would correspond to an economic AAL of more than USD 320 billion. This year, for the first time since we began including estimates of potential economic losses, we refreshed the relationship between insured and economic losses based on a reanalysis of more than 20 years' worth of historical loss data.

On a regional basis, the percentage of economic loss from natural disasters that is insured varies considerably (Table 3). In North America, for example, about 50% of the economic loss from natural disasters is insured, while in Asia and Latin America, insured losses account for only about 12% and 24% of economic losses, respectively, reflecting the very low insurance penetration in these regions. The portion of economic losses that is insured also varies significantly by peril. For example, in the United States, windstorm coverage is near universal, while take-up for flood and earthquake is low, as these perils are typically excluded from standard homeowner's policies. In other countries, such as the UK, coverage for natural catastrophes (including storm, flood and earthquake) is nearly universally provided by the insurance sector, and the disparity between the perils in the portion of economic losses that is insured is much less pronounced.

Table 3. Insured and economic AAL by region* (Source: AIR)

Region	Insured AAL (USD Billion)	Percentage of Economic Losses Estimated to Be Insured	Economic AAL (USD Billion)
Asia	15.1	12%	122.4
Europe	16.6	44%	38.2
Latin America (the Caribbean, Central America, South America)	5.6	24%	23.3
North America (Canada, the United States, Bermuda, Mexico)	66.0	51%	130.7
Oceania	3.0	53%	5.6
All exposed areas	**106.3**	**37%**	**320.3** (sum of regional losses)

*Note that there is considerable uncertainty in the estimated percentage of economic losses that is insured, which partly stems from uncertainty in reported economic losses for actual catastrophes.

The sizable difference between insured and economic losses—the protection gap—represents the cost of catastrophes to society, much of which is ultimately borne by governments. Increasing insurance penetration can ease much of the burden, while providing profitable growth opportunities for the insurance industry. In situations where insurance is not feasible or cannot be offered at an affordable price, catastrophe modeling can be used to inform emergency management, hazard mitigation, public disaster financing, risk pooling, and other government-led risk and loss mitigation initiatives to enhance global resilience.

Using the same techniques that were used to quantify the protection gap on an AAL basis, the insured and economic losses for each region at the 1% exceedance probability (the 100-year return period) can be calculated. The difference between economic and insured losses—the uninsured losses—includes all of the potential losses covered in the insurable loss figures from AIR's models that were cited in Table 2 and, in addition, losses that extend beyond the models' scope, including estimates of damage to roads, bridges, railways, and sewers, as well as the global electrical and telecommunications networks and other infrastructure (Figure 3). Looking at this metric reinforces the need for additional risk financing solutions.

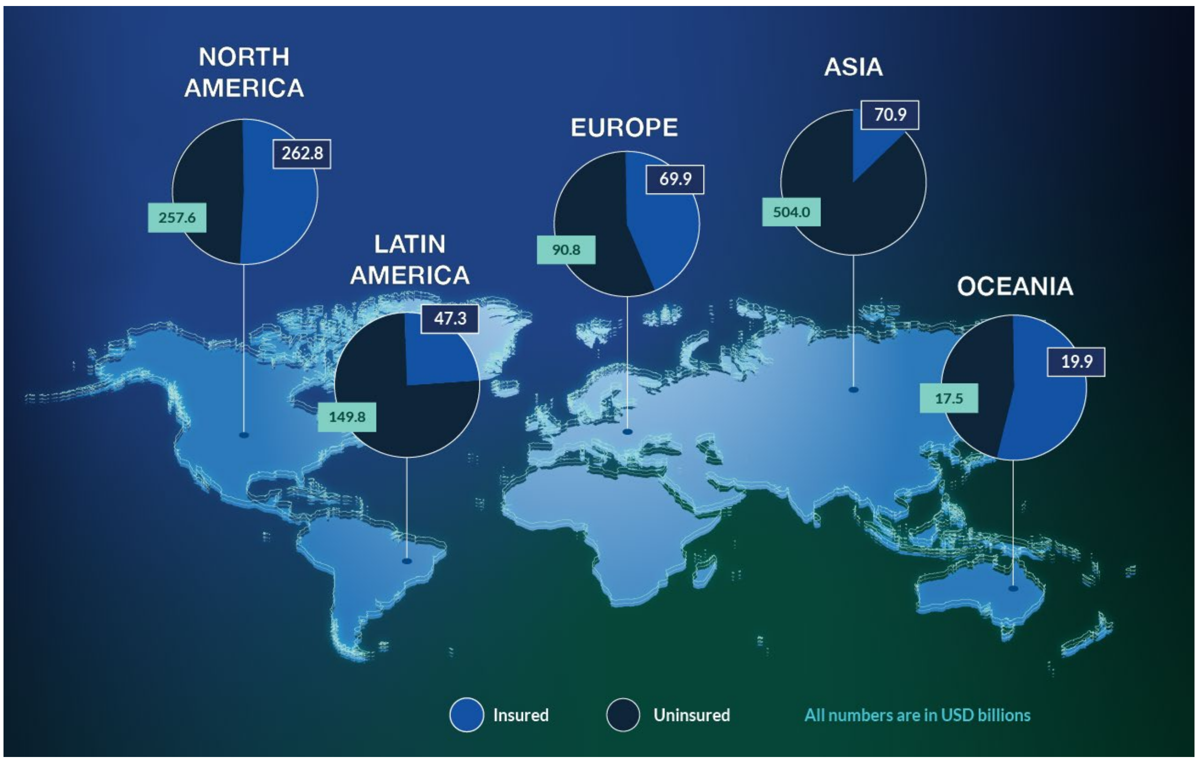

Figure 3. The gap between insured and total economic losses (the sum of insured and uninsured losses), by region, at the 1% exceedance probability (100-year return period) level. (Source: AIR)

To help close the protection gap, AIR launched our Global Resilience Practice in 2016 that provides risk assessment and mitigation solutions to governments and non-governmental organizations. AIR is actively supporting many such initiatives through work with organizations such as the World Bank and the Insurance Development Forum, and its support of efforts such as OpenQuake—an open source modeling platform initiative led by the Global Earthquake Model. And as government organizations become more familiar with probabilistic catastrophe models, they are beginning to embrace them, as the Federal Emergency Management Agency did in 2017 when it licensed AIR's Inland Flood Model for the U.S.

IPCC Regional Reports of Climate Change Impacts in Brief

In mid-August, the Intergovernmental Panel on Climate Change (IPCC) issued a major new report, *Climate Change 2021: The Physical Science Basis*. This report represents the consensus view of the more than 200 scientists from 66 countries who make up the IPCC's Working Group I, and its nearly 4,000 pages will become part of the IPCC's Sixth Assessment Report (AR6), which is due for release in September 2022.

This report highlights a number of areas where the risk from natural perils is expected to increase over the next 10 to 50 years. The climate's atmospheric and oceanic motions and the extreme weather they can generate—specific combinations of which may have yet to occur—are complex and interconnected. The factoring in of climate change as it evolves makes for a convincing case that building catastrophe models from historical data alone, or even the statistics of that data, may leave gaps that affect a model's ability to appropriately represent extreme weather events. AIR's probabilistic atmospheric peril models represent the near-term climate on a 0- to 10-year time frame. As the risk continues to evolve, our models will continue to incorporate the latest research on this evolution and our global modeled losses will continue to be updated to reflect this changing risk.

Many of the perils highlighted by the IPCC report, particularly coastal and inland flooding, are the ones that have the biggest protection gap between insured and insurable losses. This only further highlights the need for insurance companies to develop affordable products to help protect vulnerable populations from the increased risk that they will be facing in the coming decades.

In the following subsections, we share some brief bulleted lists of relevant impacts from the report's fact sheets on the regional impacts of climate change.

Asia

- The observed mean surface temperature increase has clearly emerged out of the range of internal variability compared to 1850-1900. Heat extremes have increased while cold extremes have decreased, and these trends will continue over the coming decades (high confidence).
- Marine heatwaves will continue to increase (high confidence)
- Average and heavy precipitation will increase over much of Asia (high to medium confidence).
- Mean surface wind speeds have decreased (high confidence) and will continue to decrease in central and northern parts of Asia (medium confidence).
- Relative sea level around Asia has increased faster than global average, with coastal area loss and shoreline retreat. Regional-mean sea level will continue to rise (high confidence).

For a link to the full regional fact sheet for Asia, please click here.

Australasia

- Australian land areas have warmed by around 1.4°C and New Zealand land areas by around 1.1°C between ~1910 and 2020 (very high confidence), and annual temperature changes have emerged above natural variability in all land regions (high confidence).
- Heat extremes have increased, cold extremes have decreased, and these trends are projected to continue (high confidence).
- Relative sea level rose at a rate higher than the global average in recent decades; sandy shorelines have retreated in many locations; relative sea level rise is projected to continue in the 21st century and beyond, contributing to increased coastal flooding and shoreline retreat along sandy coasts throughout Australasia (high confidence).
- Frequency of extreme fire weather days has increased, and the fire season has become longer since 1950 at many locations (medium confidence). The intensity, frequency and duration of fire weather events are projected to increase throughout Australia (high confidence) and New Zealand (medium confidence).
- Heavy rainfall and river floods are projected to increase (medium confidence).
- An increase in marine heatwaves is observed and projected (high confidence).
- Changes in several climatic impact-drivers (e.g., heatwaves, droughts, floods, would be more widespread at 2°C compared to 1.5°C global warming and even more widespread and/or pronounced for higher warming levels.

For a link to the full regional fact sheet for Asia, please click here.

Central and South America

- Mean temperatures have very likely increased in all sub-regions and will continue to increase at rates greater than the global average (high confidence).
- Mean precipitation is projected to change, with increases in North-West South America (NWS) and South-East South America (SES) (high confidence) and decreases in North-East South America (NES) and South-West South America (SWS) (medium confidence). This is consistent among model projections by mid- and end of the 21st century for RCP4.5 and RCP8.5 scenarios.
- Compared to global mean sea level, over the last three decades, relative sea level has increased at a higher rate than global mean level in the South Atlantic and the subtropical North Atlantic, and at a lower rate in the East Pacific.
- Relative sea level rise is extremely likely to continue in the oceans around Central and South America, contributing to increased coastal flooding in low-lying areas (high confidence) and shoreline retreat along most sandy coasts (high confidence).
- Marine heatwaves are also projected to increase around the region over the 21st century (high confidence).

For a link to the full regional fact sheet for Central and South America, please click here.

Europe

- Regardless of future levels of global warming, temperatures will rise in all European areas at a rate exceeding global mean temperature changes, similar to past observations (high confidence).
- The frequency and intensity of hot extremes, including marine heatwaves, have increased in recent decades and are projected to keep increasing regardless of the greenhouse gas emissions scenario. Critical thresholds relevant for ecosystems and humans are projected to be exceeded for global warming of 2°C and higher (high confidence).
- Observations have a seasonal and regional pattern consistent with projected increase of precipitation in winter in Northern Europe. A precipitation decrease is projected in summer in the Mediterranean extending to northward regions. Extreme precipitation and pluvial flooding are projected to increase at global warming levels exceeding 1.5°C in all regions except the Mediterranean. (high confidence)
- Regardless of level of global warming, relative sea level will rise in all European areas except the Baltic Sea, at a rate close to or exceeding global mean sea level. Changes are projected to continue beyond 2100. Extreme sea level events will become more frequent and more intense, leading to more coastal flooding.
- Multiple climatic impact-drivers have already changed concurrently over recent decades. The number of climatic impact-driver changes is expected to increase with increasing global warming (high confidence).

For a link to the full regional fact sheet for Europe, please click here.

North and Central America

North and Central America (and the Caribbean) are projected to experience climate changes across all regions, with some common changes and others showing distinctive regional patterns that lead to unique combinations of adaptation and risk-management challenges. These shifts in North and Central American climate become more prominent with increasing greenhouse gas emissions and higher global warming levels.

- Temperate change (mean and extremes) in observations in most regions is larger than the global mean and is attributed to human influence. Under all future scenarios and global warming levels, temperatures and extreme high temperatures are expected to continue to increase (virtually certain) with larger warming in northern subregions.
- Relative sea level rise is projected to increase along most coasts (high confidence) and is associated with increased coastal flooding and erosion (also in observations). Exceptions include regions with strong coastal land uplift along the south coast of Alaska and Hudson Bay.
- Marine heatwaves (intensity and duration) are projected to increase (high confidence).
- Tropical cyclones (with higher precipitation) and severe storms are expected to become more extreme (Caribbean, US Gulf Coast, East Coast, Northern and Southern Central America) (medium confidence).

For a link to the full regional fact sheet for North and Central America, please click here.

Non-Modeled Sources of Insured Loss

Industry insured losses can and do occur from perils and in regions that AIR does not currently model. Those losses are therefore not included in AIR's global insured estimates. (See "AIR Models by Peril and Region" for a comprehensive listing of AIR's model coverage.) If all losses could be modeled and included in AIR's calculations, the aggregate insured loss figures at given EPs would be slightly higher; likewise, the EPs associated with given loss figures would be slightly higher.

AIR's current suite of models—which covers perils in more than 110 countries—captures catastrophe events responsible for 92% of worldwide insured losses for the 20-year period from 2000 through 2020, as shown in Figure 4.

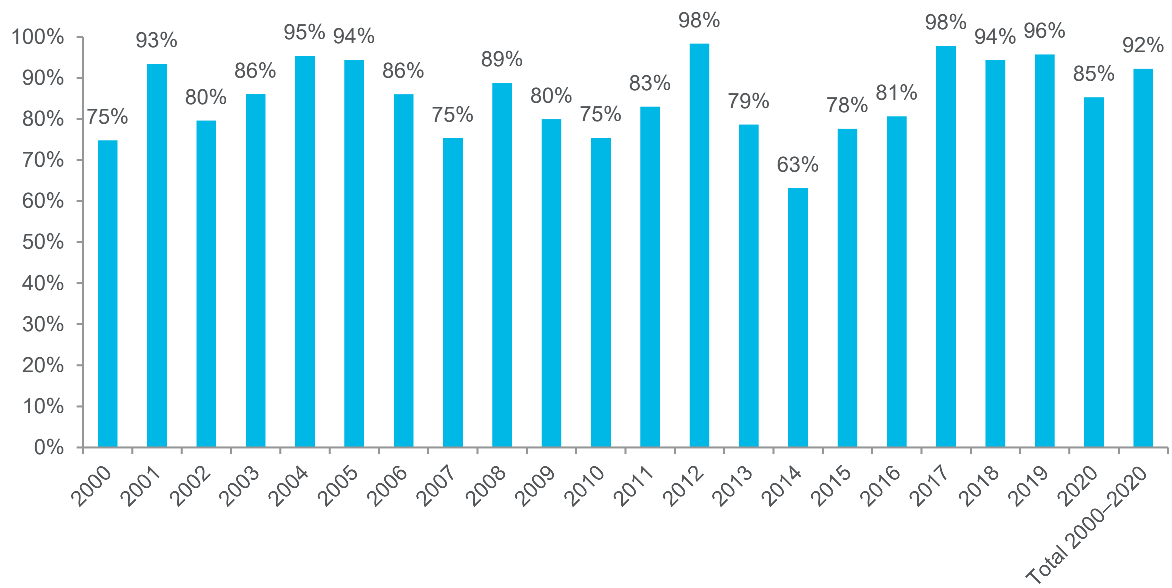

Figure 4. The percentage of reported insured losses covered by AIR's current suite of models, 2000–2020. (Source: AIR, Swiss Re, AXCO, Munich Re, PCS, Aon Benfield, PERILS)

As indicated in Figure 4, AIR models covered 85% of the global reported insured losses for 2020. Floods in China, India, and Israel, a severe thunderstorm in Japan, riots and weak (i.e., non-hurricane) tropical cyclones in the U.S. accounted for the majority of non-modeled losses. The accumulation of these events, in addition to smaller non-modeled events that occurred in 2020, contributes greatly to worldwide annual non-modeled sources of loss.

To better serve the needs of the industry, AIR continues to expand into previously non-modeled regions and perils through an ambitious model development program and research roadmap. Models on the roadmap include an updated U.S. severe thunderstorm model, an inland flood model for Italy, and an earthquake model for the Middle East. Expansion into climate change risk is also well under way. All AIR models reflect the current climate to better represent today's risk; we have covered climate change in some of our key atmospheric peril model documentation, discussing how climate change has been incorporated. AIR is also committed to supporting the (re)insurance industry with enhanced climate analytics, developing guidance on how to respond to regulatory requests from organizations such as the Prudential Regulatory Authority (PRA) and Bermuda Monetary Authority (BMA). In addition, AIR offers advanced solutions on a consulting basis for managing accumulations associated with supply chain and liability risks.

Verisk also provides a solution that can help companies understand the risk from real-time events as they unfold. Verisk's Real-Time Analytics Bundle is a comprehensive solution to extreme weather event response. Combining Respond®, ALERT™, and 3D Visual Intelligence, clients can use this solution to provide them with a full suite of data, imagery, and analytics for extreme weather events in real time.

To understand their risk from non-modeled sources of loss, companies can deploy their own or third-party models on Touchstone® which helps them define their own hazard and engineering components before deploying them in Touchstone's open platform. In addition, Touchstone and Touchstone Re™ users have the flexibility to modify modeled losses by line of business, region, or peril to account for non-modeled sources of losses.

Conclusion: The Importance of a Global View

Because catastrophe risk can threaten a company's financial well-being, companies operating on a world stage need to understand their risk *across* global exposures to ensure they have sufficient capital to survive years of very high loss. Understanding—and *owning*—this risk requires knowing both the likelihood of high-loss years and the diversity of events that could produce such losses. Companies with global exposures and an expanding global reach should prepare for the possibility that future catastrophes will produce losses exceeding any historical amounts.

Companies that evaluate loss on a global scale, rather than regionally or even nationally, should always look at more than one peril (or one region) to assess the risk at a given exceedance probability (EP). If a company considered only its worst single peril, it could severely understate risk at a given EP because for a given modeled year losses from a combination of other events (different perils in different regions) likely would equal or exceed the worst single peril. As discussed in the "Understanding the Exceedance Probability Curve" box, EP curves can be developed for both occurrence (based on the largest loss event in each catalog year) and aggregate (based on the sum of all loss events in each catalog year). Aggregate EP is a far better measure of portfolio risk.

By providing both global insured and insurable loss estimates based on the EP curve, the need to better understand the risk becomes evident; the difference between covered and eligible exposures suggests areas of potential profitable growth in markets already identified as vulnerable to catastrophic events. Examination of economic and insured losses reveals how wide the protection gap is and how sizable losses are for societies after a catastrophe, which can inform risk mitigation, public risk financing, and emergency management to enhance global resilience and better prepare society for the ultimate costs.

With the insight provided by AIR's global suite of models, companies can pursue profitable expansion in a market that is ever more connected, and amid regulatory environments that are increasingly rigorous. The ability to take a comprehensive, global view can give insurers and reinsurers greater confidence that the risk they have assumed is risk they can afford to take. The global EP curves generated with AIR software give companies the knowledge with which to benchmark and manage catastrophe risk in more than 110 countries worldwide.

About AIR Worldwide

AIR Worldwide (AIR) provides risk modeling solutions that make individuals, businesses, and society more resilient to extreme events. In 1987, AIR Worldwide founded the catastrophe modeling industry and today models the risk from natural catastrophes, supply chain disruptions, terrorism, pandemics, casualty catastrophes, and cyber incidents. Insurance, reinsurance, financial, corporate, and government clients rely on AIR's advanced science, software, and consulting services for catastrophe risk management, insurance-linked securities, longevity modeling, site-specific engineering analyses, and agricultural risk management. AIR Worldwide, a Verisk (Nasdaq:VRSK) business, is headquartered in Boston, with additional offices in North America, Europe, and Asia. For more information, please visit www.air-worldwide.com.

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AIR

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