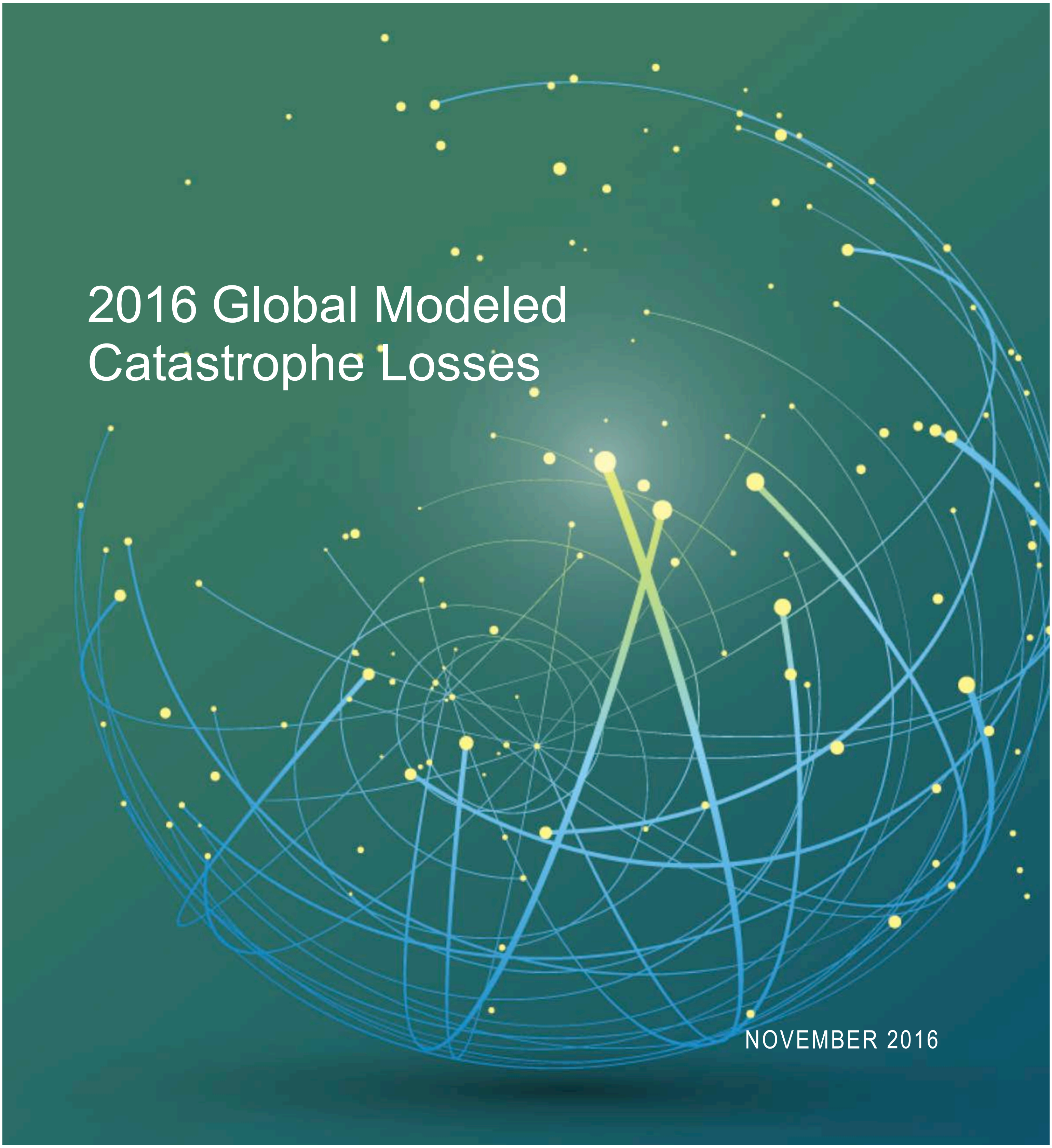
2016 Global Modeled Catastrophe Losses



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The AIR Institute's Certified Catastrophe Modeler Program

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Executive Summary

Since 2012, AIR Worldwide (AIR) has published an annual white paper discussing how AIR's global industry exceedance probability (EP) curve can be used to obtain a comprehensive and meaningful view of potential losses and to put into context years with high insured losses (such as 2011).[1] This paper, the 2016 update, bases its global loss metrics on AIR's latest suite of models, including new models and updates released during 2016, as well as updated industry exposure databases (IEDs).

As with the 2015 report, the 2016 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.[2] A large difference between insured and insurable losses indicates cases where the risk is not fully understood and society is inadequately prepared to respond. For regions and perils covered by existing 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.

Also discussed in the 2016 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. For the insurance industry, the protection gap can spur innovation in new product development. In the public sector, 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.

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

- AIR develops and maintains a detailed IED—including counts, replacement values, and physical attributes of insurable properties—for each modeled country.[3] These 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.[4]

[1] Previous EP curve papers: "Taking a Comprehensive View of Catastrophe Risk Worldwide: AIR's Global Exceedance Probability Curve" (2012),"AIR's 2013 Global Exceedance Probability Curve" (2013), "AIR's 2014 Global Exceedance Probability Curve" (2014), and "2015 Global Modeled Catastrophe Losses" (2015).

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

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

[4] For countries with IEDs that were not updated in 2016, index factors were applied to calculate the global aggregate average annual loss (AAL) and exceedance probability loss metrics for both insured and insurable losses in this report.

- AIR's year-based simulation approach to generating the stochastic catalogs included in its models enables model users to determine the probability of various levels of loss for years with multiple catastrophic events, across multiple perils and multiple regions.
- AIR models the risk from natural catastrophes and other perils (including pandemics, terrorism, and cyber) in more than 100 countries, affording AIR a truly global perspective.[5]

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."

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.

[5] Because of the unique catalog architecture of the AIR pandemic and deterministic cyber models, modeled losses for these perils were excluded from the analyses in this paper.

Exceedance Probability Metrics

Insured and Insurable Losses

The global aggregate average annual loss (AAL) and exceedance probability loss metrics for 2016 include results from one new model introduced this year (India earthquake), and reflect changes in risk as a result of updated models (U.S. terrorism, U.S. crop hail; U.S. MPCI; Southeast Asia typhoon with expansion to include Guam, Macau, Saipan, and Vietnam; Southeast Asia earthquake with expansion to include Hong Kong, Macau, Vietnam, and Singapore); as well as updates to AIR's industry exposure databases for the U.S., India, and Southeast Asia (with expansion to include Guam, Hong Kong,[6] Macau, Saipan, Singapore, and Vietnam).

The new deterministic cyber model[7] was also released in 2016, and the pandemic model was updated (with six new pathogens) for a total of nine modeled pathogens. These model results were not included in the AAL and exceedance probability loss metrics for 2016 because of the unique catalog architecture of these perils.

Results from AIR's probabilistic U.S. inland flood model have been included in the insurable loss metrics presented in this paper, but excluded from the insured loss metrics because of the high uncertainty in insurance take-up rates.[8]

Global insured AAL and key metrics from the aggregate exceedance probability (EP) curve from 2012–2016 are presented in Table 1.

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

		AGGREGATE EP LOSS (USD Billion)	
YEAR	AAL (USD BILLION)	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	80.0 **(Insurable: 160.2)**	252.9 **(Insurable: 584.2)**	325.3 **(Insurable: 924.8)**

Average annual insured losses and the metrics from the aggregate insured EP curve—for all regions and perils modeled by AIR—have increased steadily 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.

[6] The IED for Hong Kong was updated to include earthquake coverage.
[7] The deterministic cyber model is available on a consulting basis.
[8] For the analyses in this document, model results from the AIR Inland Flood Model for the United States were not incorporated in the average annual *insured* loss calculations because reliable information on U.S. flood insurance take-up rates in the private sector is not available. We will consider including results from the AIR U.S. inland model in future white papers as flood take-up rate information improves.

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, assuming 100% insurance take-up.[9] On a global basis, modeled insurable AAL is nearly twice as high as the insured AAL; global insurable losses at the 1.0% and 0.4% exceedance probabilities are more than 150% of 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 2016. (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	13.9	43.9	58.3	380.9	82.8	765.8
Europe	9.7	15.4	54.9	97.7	75.6	145.8
Latin America (the Caribbean, Central America, South America)	5.9	11.9	42.2	77.7	55.4	99.9
North America (Canada, the United States, Bermuda, Mexico)	49.0	87.3	215.2	334.7	290.6	437.9
Oceania	1.5	1.7	20.0	22.6	32.6	38.2
All exposed areas*	**80.0**	**160.2**	**252.9**	**584.2**	**325.3**	**924.8**

*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.

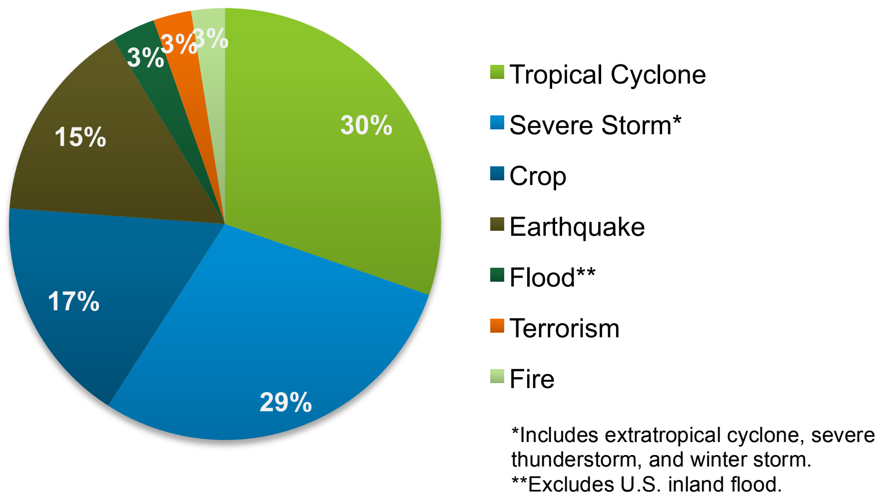

Figure 1. Contribution to global insured AAL by peril for all regions. (Source: AIR)

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

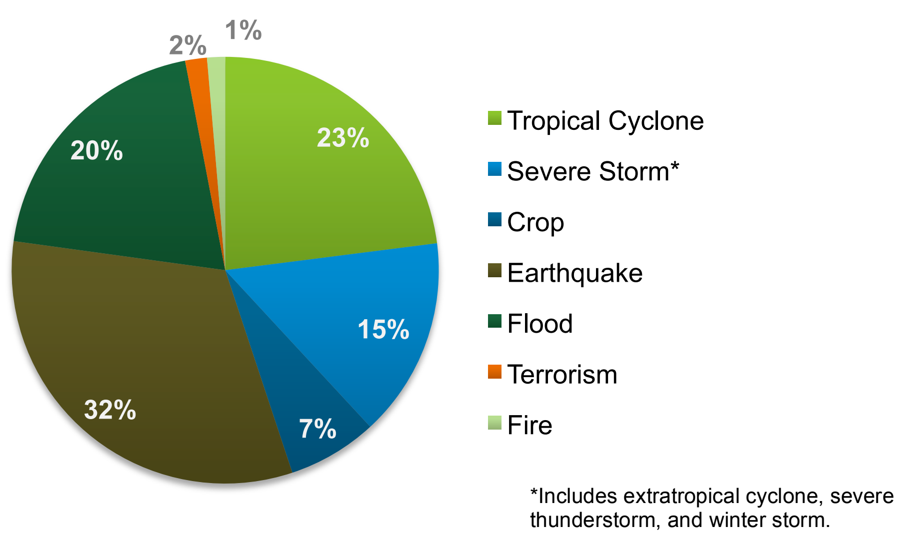

Figure 2. Contribution to global insurable AAL by peril for all regions. (Source: AIR)

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 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 2014 dollars. Based on AIR's modeled global insured AAL, this would correspond to an economic AAL of more than USD 375 billion.

On a regional basis, the percentage of economic loss from natural disasters that is insured varies considerably. In North America, for example, about half of the economic loss from natural disasters is insured, while in Asia and Latin America, insured losses make up 9% and 13% of economic losses, respectively, reflecting the very low take-up of insurance 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, like France, coverage for natural catastrophes (including flood and earthquake) is compulsory, 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. 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.

REGION	INSURED AAL (USD BILLION)	PERCENTAGE OF ECONOMIC LOSSES ESTIMATED TO BE INSURED	ECONOMIC AAL (USD BILLION)
Asia	13.9	9%	154.4
Europe	9.7	21%	46.2
Latin America (the Caribbean, Central America, South America)	5.9	13%	45.4
North America (Canada, the United States, Bermuda, Mexico)	49.0	38%	128.9
Oceania	1.5	33%	4.5
All exposed areas	**80.0**	**21%**	**379.5 (sum of regional losses)**

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. Looking at this metric reinforces the need for additional risk financing solutions.

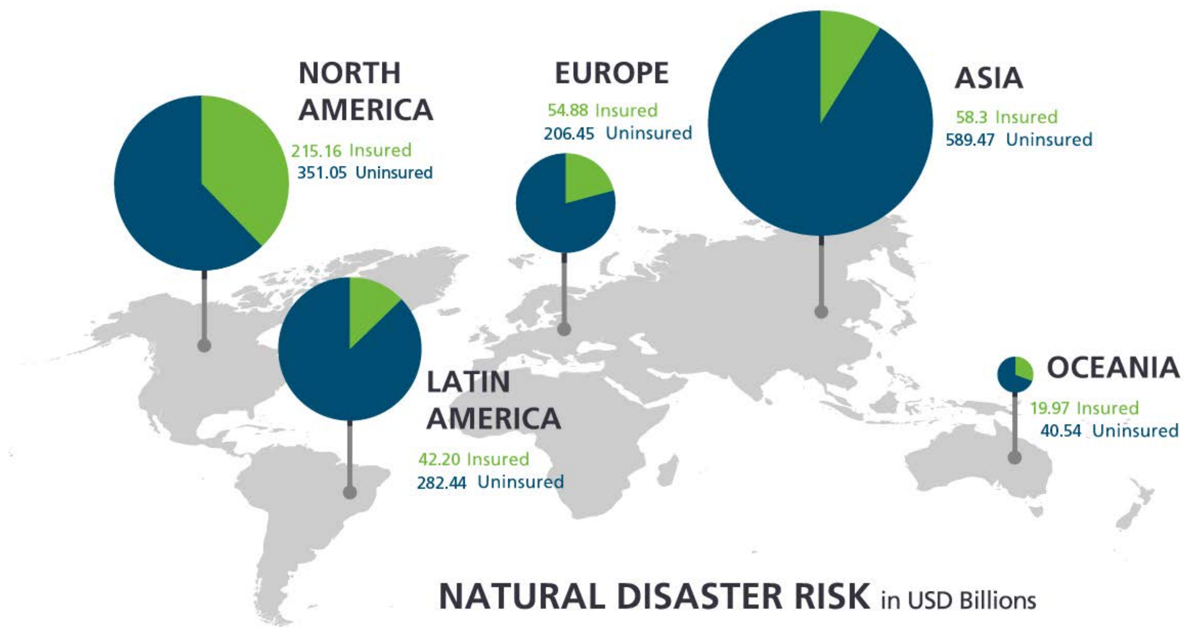

Figure 3. The gap between insured and total economic losses (the sum of insured and uninsured losses), by region, at the 1% exceedance probability (100-year return period) level. (Source: AIR)

To help close the protection gap, AIR launched a Global Resilience Practice in 2016 that provides risk assessment and mitigation solutions to governments and nongovernmental 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.

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 existing suite of models in 2016—which covers perils in more than 100 countries—captures catastrophe events responsible for 87% of worldwide insured losses for the 16-year period from 2000 through 2015, as shown in Figure 4.

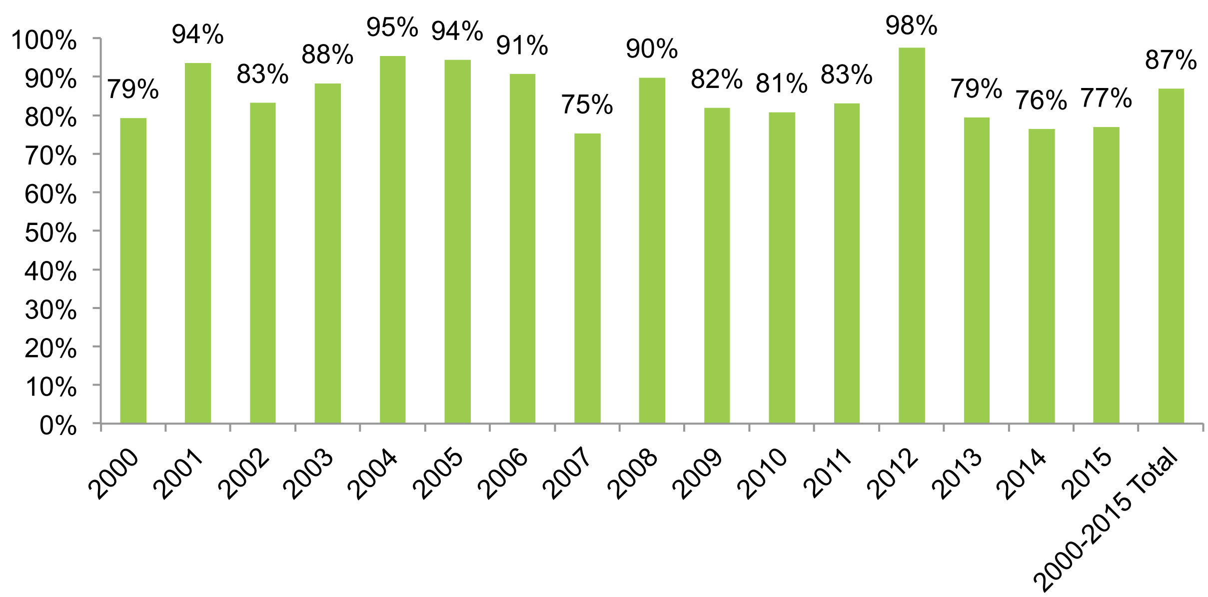

Figure 4. The percentage of reported insured losses covered by AIR's current suite of models, 2000-2015. (Source: AIR, Swiss Re, AXCO, Munich Re, PCS, Aon Benfield, PERILS)

As indicated in Figure 3, AIR models covered 77% of the global reported insured losses for 2015. The industrial explosion in Tianjin, China, accounts for USD 3.5 billion in non-modeled insured losses. Additional significant sources of non-modeled insured losses during 2015 include multiple flood events in France and India, and a winter storm in Australia; while these were smaller events, each caused more than USD 700,000 in insured loss, the accumulation of which 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 the industry's first probabilistic cyber model, an updated U.S. earthquake model with a new tsunami module, severe thunderstorm models for Australia and Europe, crop models for Canada, a flood model for Poland, and additional flood hazard maps for regions around the globe. Expansion into new frontiers of risk is also under way:

- Climate change is an active area of research, and all AIR models reflect the current climate to better represent today's risk; where appropriate and warranted, AIR plans to develop additional climate-conditioned catalogs so that companies can get a more comprehensive view of how a changing climate may impact their portfolios
- AIR is developing advanced solutions for managing accumulations associated with supply chain, marine, and energy risk
- Terrorism risk can be assessed and managed worldwide through the expansion of the deterministic modeling capabilities offered through the AIR model

AIR plans to develop a life and health platform to streamline the assessment and management of this dynamic risk , which evolves as global connectivity grows, animal habitats alter, medical advancements continue, the population ages, and the climate changes. AIR also provides modeling tools that can help companies understand the risk from non-modeled sources of loss. Using the Geospatial Analytics Module in Touchstone®, companies can analyze accumulations of risk anywhere in the world. Users can import hazard footprints and assign custom damage ratios to calculate not only concentrations of risk counts and replacement values, but also exposed limits after accounting for policy terms (including deductibles, layers, limits, and reinsurance treaties). This Touchstone feature helps organizations achieve an integrated view of enterprisewide exposure to catastrophe risk and evaluate where to grow or retract business.

Touchstone is a truly open platform for risk assessment and exposure management, offering integration with third-party models and data. Users can import hazard layers or run multiple alternative models on the single platform, allowing for a more comprehensive view of risk within a streamlined workflow. The AIR Cloud offers greater flexibility for the import and export of loss data for risk assessment and management, providing virtual file transfers at speeds often greater than traditional methods. Results from AIR models can also be posted and worked with on any cloud platform—in addition to the AIR Cloud—allowing users to perform data analytics on multiple loss information sets. In addition, AIR's probabilistic flood hazard maps are available as spatial layers for use in the Geospatial Analytics Module in Touchstone. Currently available for China, Thailand, Brazil, and Vietnam, AIR's flood hazard maps enable a sophisticated understanding of the threat posed by complex river networks and help companies manage accumulations, determine whether a risk meets underwriting guidelines, and develop effective portfolio management and risk transfer strategies.

Touchstone users have the flexibility to modify modeled losses by line of business, region, or peril to account for non-modeled sources of losses. AIR is also creating a framework for implementing custom models within Touchstone, allowing users to import their own models and loss curves from any source.

Conclusion: The Importance of a Global View

Since 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—owning—this risk requires knowing both the likelihood of high-loss years and the diversity of events that could produce such losses. In addition, 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 100 countries worldwide.

About AIR Worldwide

AIR Worldwide (AIR) provides catastrophe risk modeling solutions that make individuals, businesses, and society more resilient. AIR founded the catastrophe modeling industry in 1987, and today models the risk from natural catastrophes, terrorism, cyber attacks, and pandemics globally. Insurance, reinsurance, financial, corporate, and government clients rely on AIR's advanced science, software, and consulting services for catastrophe risk management, insurance-linked securities, site-specific engineering analyses, and agricultural risk management. AIR Worldwide, a Verisk Analytics (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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