MOODY'S

White Paper

Division of Public Utilities
Docket No. 25-035-01
DPU Exhibit 1.02

The power of tail risk metrics: Transforming physical risk decisions for banking and beyond

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INTRODUCTION

Natural catastrophes such as floods, wildfires, hurricanes, and heat waves cause billions of dollars in losses every year, with recent headlines underscoring the rising frequency and severity of these events. Recent events underline the scale of the challenge, from Hurricanes Helene and Milton in the United States in 2024, which together caused more than $110 billion in economic losses, to the 2024 floods in southern Germany with insured losses estimated at $2.1 billion-$3.2 billion, and the California wildfires in early 2025, now among the costliest on record with economic losses exceeding $100 billion.[1-3] Rare but devastating disasters, such as those that happen once every 200 years, can reshape entire economies, communities, and industries overnight. For banks, asset managers, corporates, and governments, accurately assessing these risks is not just prudent but essential for protecting value, optimizing growth, building resilient economies, and improving financial performance.

Key Messages:

- It's not the average year that breaks a business but rather the extreme year that happens once every 200 years on average.
- Preparing for 1-in-200-year impacts means you're ready for the rare, not just the routine.
- Stress testing with 1-in-200-year metrics means you're covered for the truly catastrophic.
- Tail risk metrics uncover hidden vulnerabilities: some assets are highly exposed to extreme impacts that are not apparent in average loss figures.
- Location-level tail risk metrics spotlight the assets that could be devastated by the next extreme year—helping leaders focus resilience where it matters most.
- Prepare for realistic joint extreme scenario impacts across multiple locations.
- Portfolio-aggregate tail risk metrics reveal hidden risk concentrations that mean metrics miss, empowering risk managers to build optimized portfolios resilient to the truly catastrophic.
- Use regional portfolio-level tail risk metrics to uncover regional risk concentrations.

WHY TAIL RISK METRICS MATTER

Tail risk metrics allow risk managers to prepare for joint extreme impacts across multiple locations of interest, helping identify regions with high-risk concentration and individual assets with potentially catastrophic extreme impacts. Tail risk metrics are an essential tool for managing the increasingly material risks from natural catastrophes, including guiding portfolio optimization and stress testing as well as helping direct adaptation measures where they matter most.

Traditional risk metrics often focus on the mean, or the expected average annual damage. However, climate and catastrophe risk distributions are highly skewed: Most years may see little or no damage, while rare "extreme years" can bring outsized losses. Relying solely on mean metrics leaves organizations exposed to the blind spots of the risk landscape. Tail risk metrics reveal the hidden vulnerabilities that mean metrics miss, empowering leaders to prepare for the extremes.

Tail risk metrics, also known as return period metrics, capture the full distribution of annual damage, including the high-severity, low-probability events that define true resilience. These metrics are built on thousands of simulated individual years that cover all plausible outcomes, reflecting the reality that in any given actual year, there may be zero, one, or multiple catastrophic events. The probability of a year with no damage is high, but the probability of an extreme year, while low, is what drives systemic risk.

WHAT IS A TAIL RISK METRIC?

Tail risk metrics, expressed as a return period, refer to the likelihood of experiencing a loss above a certain threshold in any given year. For example, when considering a severity at the “1-in-200-year” level (return period 200 years), there is on average a 1-in-200 (0.5%) chance of such level of damage being exceeded annually. In catastrophe modeling, this aligns with percentiles and exceedance probabilities, providing a clear, practical benchmark for stress testing and scenario analysis. Tail risk metrics translate complex risk distributions into simple, decision-ready numbers.

USING TAIL-RISK EXTREME-YEAR METRICS IN PRACTICE

Extreme-year tail risk metrics allow leaders to discover and prepare for physical risks where it matters most. These metrics are practical tools for risk assessment and are particularly well suited to stress testing since they can be used to generate extreme-year scenarios, such as a 1-in-200-year extreme year of floods under future climate conditions.

By analyzing a global portfolio of assets, this paper illustrates how these metrics can be applied at the location, portfolio, and regional levels to:

- Discover assets with worst extreme-year impacts using location-level tail risk metrics.
- Prepare for joint extreme scenario impacts across a collection of asset locations using portfolio-level and company-level tail risk metrics.
- Assess regional risk concentrations and joint impact across specific regions.

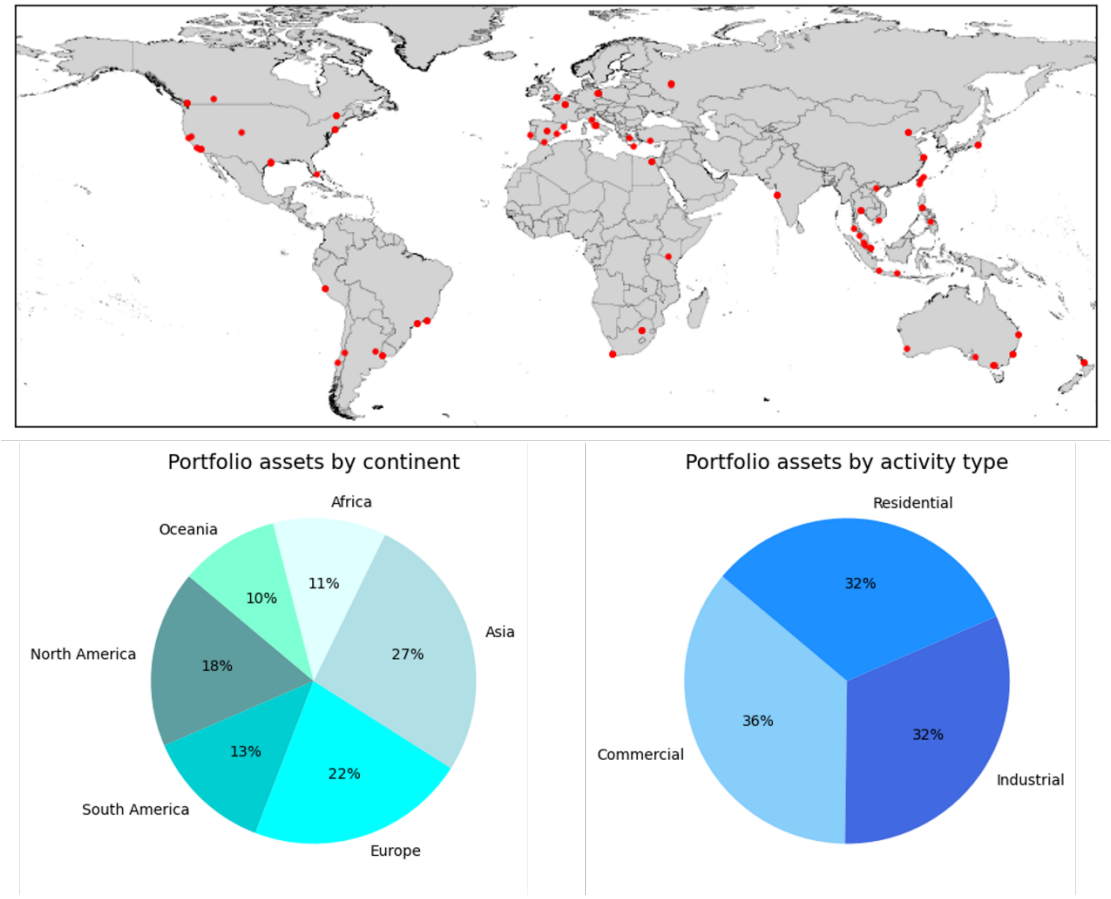
We at Moody’s choose the 1-in-200-year extreme-year metrics to assess risks for our sample portfolio. This is the optimum level for resilience testing since testing at the 1-in-200-year level is the global standard in the natural catastrophe insurance industry for decisions on capital reserves held toward paying insurance claims. The choice of 200 years as return period allows for comprehensive coverage of the risk profile given that the annual probability of getting damage above the tested level is very small — just 0.5% — supporting robust stress testing.

ASSESSING EXTREME RISK FOR A GLOBAL PORTFOLIO OF ASSETS

Portfolio composition

To demonstrate these concepts, we use an example global portfolio of 142 assets located in urban centers. For simplicity, each asset is valued at US$1 million. The portfolio includes a mix of commercial, industrial, and residential activity types, distributed globally. Figure 1 shows the portfolio locations and composition breakdown.

FIGURE 1 Global portfolio of 142 urban assets used for analysis with composition by region and activity type



Location-level extreme year analysis

Here, we use location-level tail risk (return period) impact metrics to identify assets with the highest extreme annual impacts at the 1-in-200-year level. The analysis is conducted under future climate conditions, selecting Representative Concentration Pathway (RCP) 8.5 and the year 2050 as the scenario and time horizon to reflect increased future risks. This approach highlights which asset locations could be individually worst affected by acute physical risks, including floods, sea level rise, wildfires, hurricanes and typhoons. We also examine annualized mean metrics for comparison.

When considering the combined tail risk impact of all perils based on the 1-in-200-year return period metric, we see that extreme losses are concentrated in a small subset of locations for this portfolio: 19 assets (13% of all assets) experience impacts greater than $10,000 (over 1% damage ratio) and just eight assets (6% of all assets) exceed the $100,000 damage level (10% damage ratio). Tail risk metrics help discover subsets of assets that can be highly impacted by an extreme year.

Furthermore, when ranking assets by their physical risk impact, tail risk metrics help uncover hidden risks that are not apparent in average metrics: Several assets have a particularly high-risk tail (meaning they are highly exposed to extreme impacts) but not a high-risk mean. Extreme-year tail risk impacts go beyond mean metrics and are essential in finding hidden vulnerabilities.

We further examine 1-in-200-year impacts for each peril separately under the same future climate scenario. Figure 2 shows a map visualization of the top 10 global assets with the highest extreme-year damage value for each peril. The assets most exposed to future 1-in-200-year damage are primarily located in Asia and North America, with a few high-risk assets in Africa.

Focusing on the regions with the highest risk, the analysis, exhibited by Figure 3, reveals that the dominant peril contributors are sea level rise and flood in Asia, whereas hurricane and flood are the key drivers in North America. Notably, the corresponding location-level damage ratios, which represent the fraction of asset value damaged or lost, can be exceptionally high for certain assets. In fact, for two assets in Asia and two in North America, the damage ratios exceed 30%, underscoring the potential for severe financial impact at specific locations. These findings highlight the importance of granular, location-level tail risk metrics in uncovering the true scale of vulnerability and guiding targeted resilience strategies.

FIGURE 2 Top 10 assets with the highest 1-in-200-year damage value for each acute peril, with circle size proportional to damage value

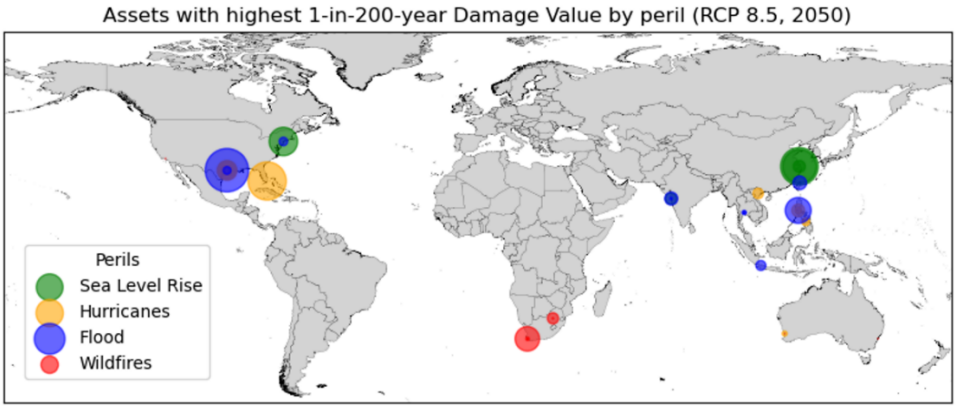
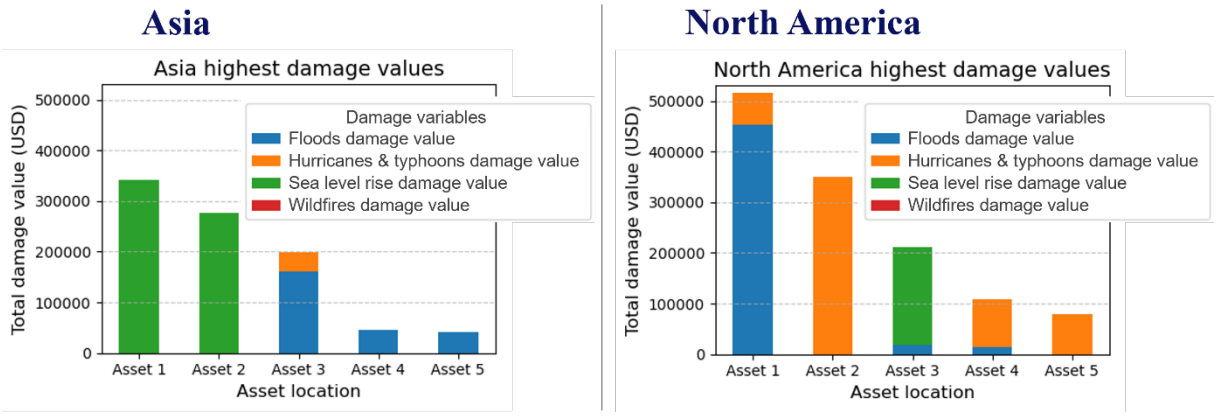


FIGURE 3 Top five assets in Asia (left) and North America (right) with the highest 1-in-200-year damages value showing contributing peril impacts



Portfolio-level extreme-year analysis

To prepare for joint extreme scenario impacts across a portfolio of assets, it is essential to analyze aggregate portfolio-level tail risk impacts. These metrics reflect aggregate impact jointly across multiple locations, accounting for realistic geographical event footprints and spatial correlation effects as well as capturing how risks aggregate across locations.

At the portfolio level, the aggregate tail risk financial impact can be significant. The following table compares portfolio-level, annualized mean damage values and tail risk damage values at the 1-in-100-year and 1-in-200-year severity levels, for both present day (baseline 2020) and future climate conditions (RCP 8.5, 2050), considering a total portfolio exposure of $142 million. Notably, the future tail risk impacts (of order $1 million) are significantly larger — by about one order of magnitude — than the mean portfolio-level impact ($130,000). The overall future aggregate portfolio-level 1-in-200-year damage value is $1.1 million, corresponding approximately to a 1% damage ratio as a fraction of the total portfolio exposure value.

TABLE 1 Aggregate portfolio-level annualized financial impacts (tail risk and mean)

Portfolio-level impacts, all-perils combined	1-in-200-year damage	1-in-100-year damage	Mean annual damage
Present day	$900,000	$670,000	$100,000
Future (RCP 8.5, 2050)	$1.06 million	$820,000	$130,000

Several individual assets have location-level damage ratios much higher than this aggregate figure, with six assets showing 1-in-200-year damage ratios in the range of 20%-50% (as a fraction of asset exposure value), as demonstrated in the previous section. This highlights the value of examining both location-level and portfolio-level tail risk impacts: Whereas portfolio-level metrics capture the aggregate risk across a set of locations, location-level metrics reveal individual high-risk assets that may be hidden within lower portfolio aggregates.

Aggregate portfolio-level tail risk impacts are an excellent tool for portfolio optimization and diversification. Because they encode underlying, realistic event footprints and spatial correlation effects, these metrics reflect increased aggregate risk when assets are concentrated in the same high-risk region and decreased aggregate risk when assets are well diversified since it is unlikely for extreme events to impact multiple distant assets simultaneously. As a result, portfolio-level tail risk impacts can differ significantly from the sum of location-level impacts, particularly in spatially diversified portfolios or regions, where joint impact probability is low, or in concentrated portfolios, where joint impact probability is higher.

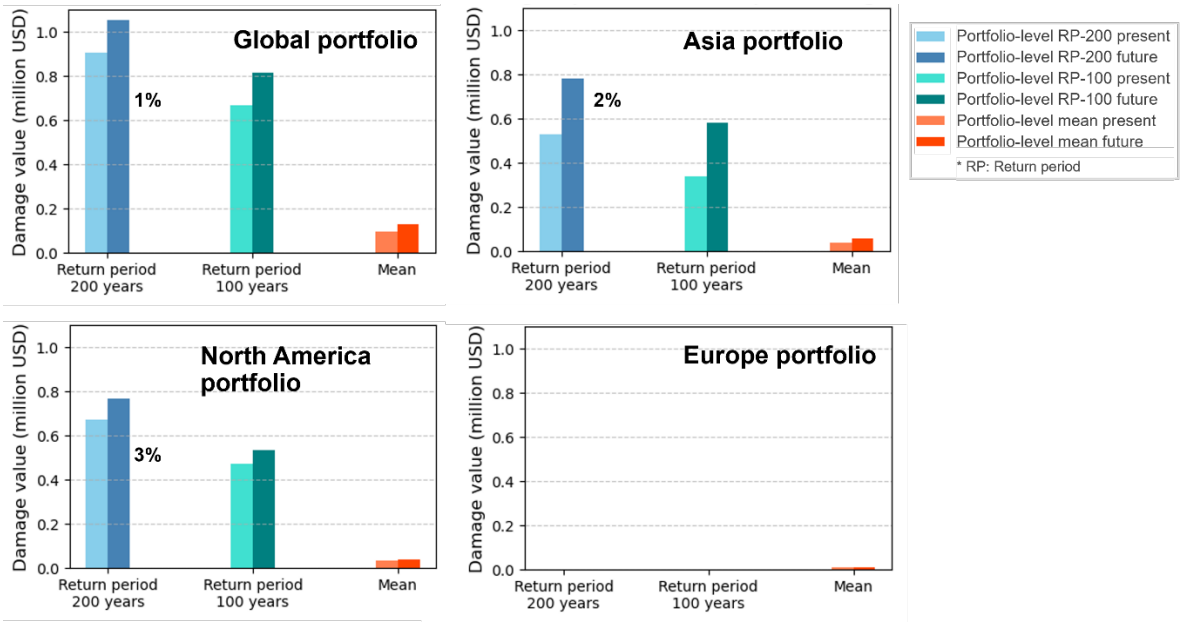
Aggregate tail risk metrics encode signals that average risk doesn't: Mean risk is additive, but tail risk impacts are not. Adding a new asset in a risky area can sharply increase portfolio-aggregate tail risk whereas adding a diversified asset may reduce it. Using tail risk metrics helps managers identify and avoid risk concentrations, guiding decisions on which assets to add or remove for optimal portfolio resilience.

Regional extreme-year analysis

To better understand regional risk concentrations, we can break down our global portfolio into regional portfolios (by filtering asset locations) and analyze aggregate impacts at the region level in specific areas of interest. Taking advantage of the fact that aggregate tail risk metrics reflect increased impacts when assets are spatially concentrated in high-risk regions, we inspect regional portfolio-level tail risk impacts to uncover regions of high-risk concentration.

We compare present and future impacts (mean annual, 1-in-100-year, and 1-in-200-year) across regions of interest: Asia and North America (identified as high-risk), Europe (where impacts are small), and the global portfolio, as exhibited in Figure 4.

FIGURE 4 Aggregate portfolio-level physical risk impacts for the global portfolio and regional portfolios in Asia, North America, and Europe — present (2020 time horizon) and future (RCP 8.5, 2050) impacts shown for all perils combined, including annual mean, 1-in-100-year, and 1-in-200-year tail risk damage (also referenced as Return Period or RP) values



Note: For Europe, location-level tail risk impacts are zero (at return period 100 and 200 years); for low-risk locations, the frequency at which catastrophe events happen on average is so low (of order 1-in-1,000 years or lower, and significantly lower than 1-in-200 or 1-in-100 years) that the return period impacts are zero for return periods lower than approximately 1,000 years or more.

A key finding is the pronounced risk concentration in Asia and North America. For both regions, the future 1-in-200-year damage value is approximately $800,000, close to the $1.1 million value for the global portfolio and highlighting a substantial extreme risk in these regions. In terms of fractional damage relative to the value of each portfolio, the numbers correspond to a damage ratio of 2% for the Asia portfolio and 3% for the North America portfolio, compared with the lower figure of 1% for the global portfolio, indicating notable risk concentration. In contrast, Europe's regional impacts are much smaller, underscoring the importance of focusing risk management efforts where the exposure and potential extreme losses are greatest.

Conclusions and recommendations

This analysis demonstrates that tail risk metrics such as 1-in-200-year return period impacts are essential for revealing the true scale and concentration of climate physical risks across portfolios. Although mean annual damage metrics are useful, tail risk metrics uncover hidden vulnerabilities and pinpoint the assets and regions most exposed to catastrophic losses: It's not the average year that breaks a business but rather the extreme year that happens on average once every 200 years. Tail risk metrics translate complex risk distributions into simple, decision-ready numbers, helping leaders protect value, optimize growth, and build resilience.

The message for bankers, asset managers, and investment leaders is clear:

- **Prepare for the rare, not just the routine.**
    - Stress testing with 1-in-200-year metrics means you're covered for the truly catastrophic, not just the expected.
    - Integrate tail risk metrics into climate risk frameworks and decision-making processes.

- **Focus resilience where it matters most.** Tail risk metrics spotlight the assets and regions that could be devastated by the next extreme year, allowing for targeted risk management and capital allocation.
- **Trust in credible, validated analytics.** Moody's models and metrics are built on more than 30 years of catastrophe modeling expertise that provides rigorous and actionable risk assessments.

References

1 National Oceanic and Atmospheric Administration, Office for Coastal Management, "Fast Facts: Hurricane Costs," February 2026

2 Moody's RMS Event Response estimates insured losses in Germany from the Central Europe floods will likely range between €2.0 to €3.0 billion (US$2.1 to US$3.2 billion), Moody's Insights, June 14, 2024

3 WTW, "California Wildfires," January 30, 2025