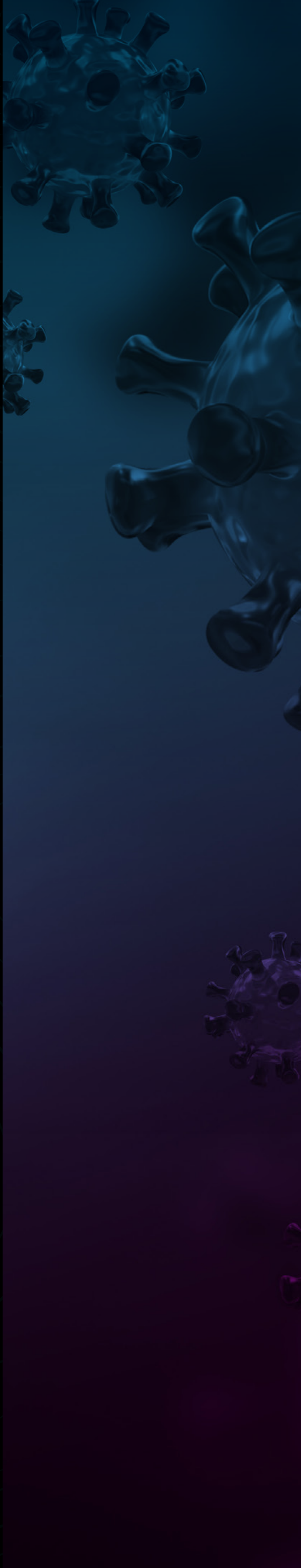
2021

Catastrophe Review

EXECUTIVE SUMMARY

RMS Event Response Report

Table of Contents



2021 Proves to Be Another Game Changer

Mohsen Rahnama
RMS Chief Risk Modeling Officer

The year 2021 will go down in history as a challenging one for the insurance industry, another in a stretch of years dating back to 2017 that brought game-changing events that altered our understanding of natural catastrophe risk.

Several of the year's events broke records: the February severe winter weather event in Texas, the July floods in western and central Europe, and Hurricane Ida. These events follow in the footsteps of Hurricanes Harvey, Irma, and Maria in 2017, Typhoon Jebi in 2018, the western U.S. wildfires of 2018 and 2020, and the hyperactive Atlantic hurricane season of 2020. The record books have been completely rewritten in just the last four years.

This is to say nothing of the "secondary" perils that occur with high frequency globally and have contributed a significant amount of industry loss in recent years, including severe convective storms, floods, and wildfires. All of these were present globally in 2021.

Every event is unique. The only common thread is that they all bring complex issues that drive industry losses beyond expectations, including exposure growth in high-risk areas, such as the wildland-urban interface; climate variability and climate change impacts; and the physical and economic challenges posed by COVID-19.

These significant events show that the science behind RMS catastrophe models is robust and that we capture the hazard and vulnerability for these long-tail events quite adequately.

However, these significant events show that the science behind RMS® catastrophe models is robust and that we capture the hazard and vulnerability for these long-tail events quite adequately. Having said that, the complex, non-modeled characteristics of the events makes loss more challenging than events in the past – not just for modelers but also for the insurance industry itself. For example, in the months following Typhoon Jebi and Hurricane Irma, we saw sharp spikes in loss development that caught everyone by surprise.

The events of 2021 particularly highlighted the significance of contingent business interruption and additional expenses caused by infrastructure damage, such as the Texas power grid failure and the destruction of German roads and bridges. For the second straight year, supply chain issues and high housing demand brought about by COVID-19 have driven post-event loss amplification and economic demand surge beyond normal expectations. Then take lumber prices that peaked at seven times the historical average – this is clearly not a traditional driver of catastrophe loss. In addition to these complexities, factors such as social inflation and exposure undervaluation contributed to high loss ratios.

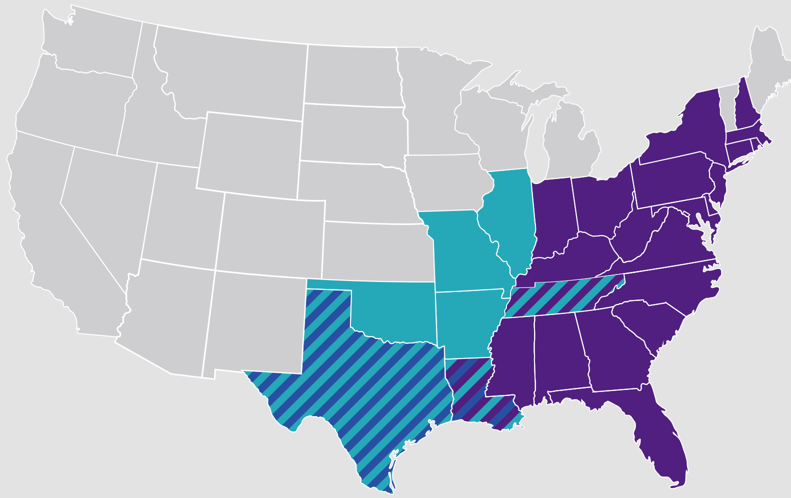
For the second straight year, supply chain issues and high housing demand brought about by COVID-19 have driven post-event loss amplification and economic demand surge beyond normal expectations.

These issues further compound other non-modeled trends that have gained prominence in recent years. For example, our industry is well aware of unique circumstances and building codes in Florida, such as the assignment of benefits and the "25 percent roof replacement rule" that significantly add to cost of claims.

Our commitment to event response extends beyond the immediate time frame of an event. RMS modelers continuously perform research and reconnaissance to improve our understanding of these unique factors and better inform our clients in future loss estimates. This year's report highlights some of these factors, brought to light by the year's events. In the weeks and months ahead, we will continue to investigate them and work with clients ahead of incorporating them into future model updates.

Major Event Loss Estimates Around the Globe

United States

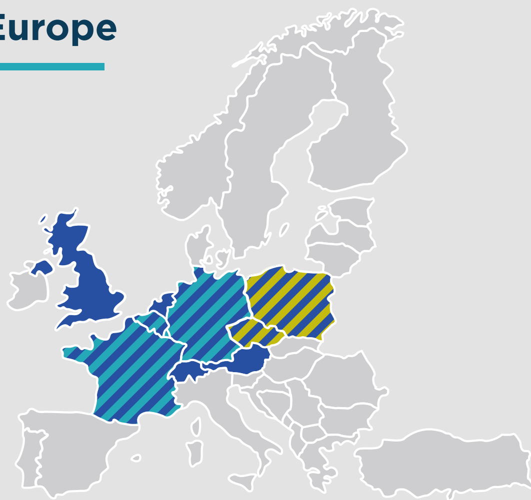


Hurricane Ida:
US$31–44 Billion
RMS estimate

February Severe Winter Weather:
US$15 Billion
Market estimates (Swiss Re Sigma)

Hurricane Nicholas:
US$1.1–2.2 Billion
RMS estimate

Europe



Western and Central Floods:
€10.0–13.2 Billion
RMS estimate

Central/Eastern Severe Weather:
US$4.5 Billion
Market estimates (Swiss Re Sigma)

Windstorm Aurore:
€311 Million
Market estimates (PERILS)

Asia-Pacific

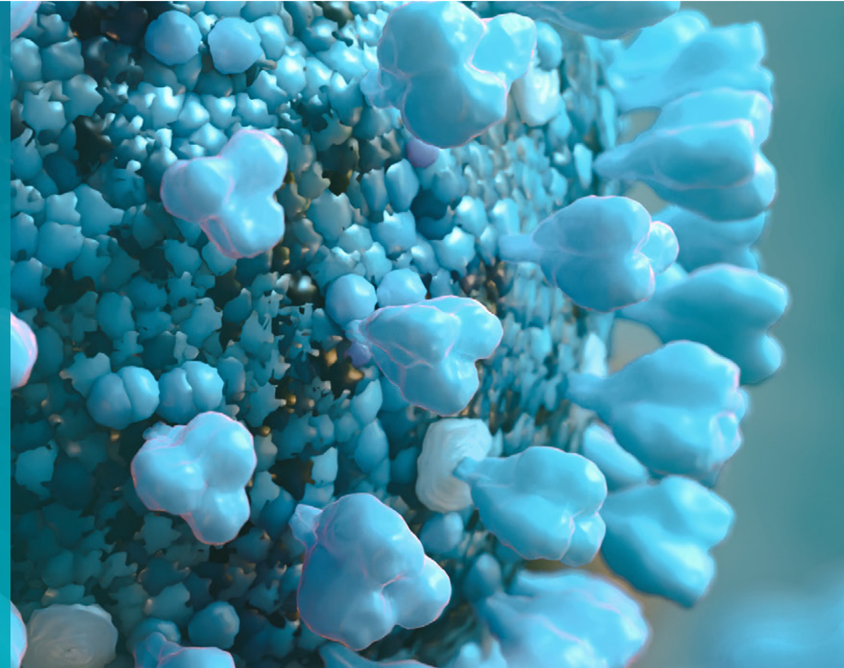
Henan Floods:
CN¥12.4 Billion
Market estimates (CBIRC)

New South Wales and Queensland Floods:
AU$751 Million
Market estimates (PERILS)

Victoria Earthquake:
AU$147 Million
Market estimates (ICA)

COVID-19 Pandemic

Uncertainty Continued in 2021



Gordon Woo
Catastrophist, RMS

Although insurance contracts typically cover a single year of risk exposure, the course of nature may not follow the calendar. Eruptive activity on a volcano may start abruptly and persist for a number of years. Seismic activity may cluster sporadically within a fault zone for years. Pandemics typically spread among the human population in waves. There were three main waves of the great 1918–19 H1N1 influenza pandemic. The first in the spring of 1918 was fairly mild, caused comparatively few deaths, and mainly affected military personnel. Most of the fatalities in this pandemic occurred in the second wave during the autumn of 1918; this wave may well have emerged from China, also the geographical source of COVID-19. The winter and spring of 1919 saw the third wave, which increased the number of deaths before tapering off that summer.

Following the laws of evolutionary biology, all viruses, including SARS-CoV-2, change over time due to errors in the viral replication process. Some changes may increase virus contagiousness or disease severity to a sufficient extent as to give rise to a variant of public health concern. With SARS in 2003, a mutation did occur after the main wave of cases, but fortunately the mutated virus did not bind so well to the human receptor, and there was no second wave of SARS. Whereas the story of the spread of SARS could be told within a single year, 2003, this is sadly not the case with SARS-CoV-2. Hence there is the need for a supplementary 2021 report on COVID-19, the disease caused by the coronavirus.

SARS-CoV-2 Variants

The epidemiological hope underlying the concept of herd immunity is that as a contagion spreads through a population, eventually enough of the surviving population has achieved immunity through infection for disease spread to be halted. This hope turns to fear as evidence accrues of reinfection, as happened with COVID-19 in the latter months of 2020.

Early reinfection suggests the rise of a new variant. It requires the science of genome sequencing for the emergence of new variants to be identified and traced across an infected population. Although late to mass testing, the U.K. began, early in March 2020, the genome sequencing of samples from people infected with COVID-19. By October 11, 2021, a million SARS-CoV-2 genome sequences had been completed in the U.K.

From September 2020 until November 2021, four key variants of public health concern were identified: alpha, beta, gamma, and delta. These variants have set back the prospect of herd immunity, driving the global death toll past five million and extending societal disruption throughout 2021. Late in November 2021, a fifth key variant, labeled omicron, was identified in South Africa. The impact of this highly mutated variant will further extend societal disruption into 2022.

Insured Losses From COVID-19: Developments in 2021

Business interruption insurance coverage of COVID-19 has continued to be a legally contentious issue in 2021. In the U.K., on March 3, 2021, the Financial Conduct Authority (FCA) issued final guidance on a business interruption test case: proving the presence of coronavirus. Following the U.K. Supreme Court judgment, 14 out of 21 policy types tested were found to have the potential to provide cover in response to the pandemic – but seven were not. The U.K. Supreme Court also found that cover may be available for partial as well as full closure of premises and for mandatory closure orders that were not legally binding. Unresolved issues have constituted a second wave of litigation, which encompasses losses arising from the pandemic's second and subsequent waves of coronavirus infection.

The amount of ultimate losses in numerous products, including business interruption and general and professional liability, will entail extensive litigation insurance. The outcome remains unclear and will take several years to determine. With this time delay, substantial uncertainty remains at the end of 2021 over the full financial consequences and total insured losses.

Where U.S. property insurance policies, such as drafted by the Insurance Services Office (ISO), explicitly excluded loss due to virus or bacteria, federal court cases have often been dismissed early. However, as more state court cases were brought dealing with policies with broader language, including "physical loss of or damage to property," some state courts have granted judgment to policyholders. In some cases, they may deem that continuous presence of the coronavirus on a property has rendered it unsafe and unfit for intended use.

To comprehend the perplexing legal ambiguity over the interpretation of contract wording, the outcome of court cases needs to be tracked. Insurance Law Analytics conducts research on insurance coverage losses related to the COVID-19 pandemic. This information is logged via the University of Pennsylvania Law School COVID Coverage Litigation Tracker. The number of U.S. weekly filings per week, from mid-March 2020 to the end of September 2021, shows two distinct waves (Figure 1).

> With luck, the vaccine and booster rollout and antiviral research programs should bring the end of the pandemic as a global health crisis, and also the associated protracted litigation.

The leading coverage sought in litigation is business income, with 1,848 cases (Figure 2). By comparison, there were 1,585 cases relating to the civil authority clause, which applies when a government entity denies access to the insured property.

Since there has not been a major pandemic in a century that involved denial of property access, ongoing litigation relating to the civil authority clause is not surprising. The influenza pandemics of 1957 and 1968 were comparatively benign, and the absence of modern intensive care facilities meant that there was no imperative to prevent their overload by locking down society. Given also that the most recent influenza pandemic in 2009 was less lethal than seasonal flu, pandemic contract wordings have not been rigorously tested until 2020.

What's in Store for 2022?

Looking forward toward 2022, the late emergence in 2021 of the omicron variant casts a sizeable shadow of uncertainty. Not for the first time, humanity will hope for some good fortune. Counterfactually, a variant of SARS in 2003 could have been far worse than it turned out.

With luck, the vaccine and booster rollout and antiviral research programs should bring the end of the pandemic as a global health crisis, and also the associated protracted litigation. With global life and non-life insurance and reinsurance COVID-19 claims of around US$50 billion, the worldwide insurance industry will trust that the G7 commitments of the June 2021 Carbis Bay pandemic declaration will be carried out – to prevent a repeat of the human and economic devastation caused by COVID-19 and its variants. ■

Weekly Filings

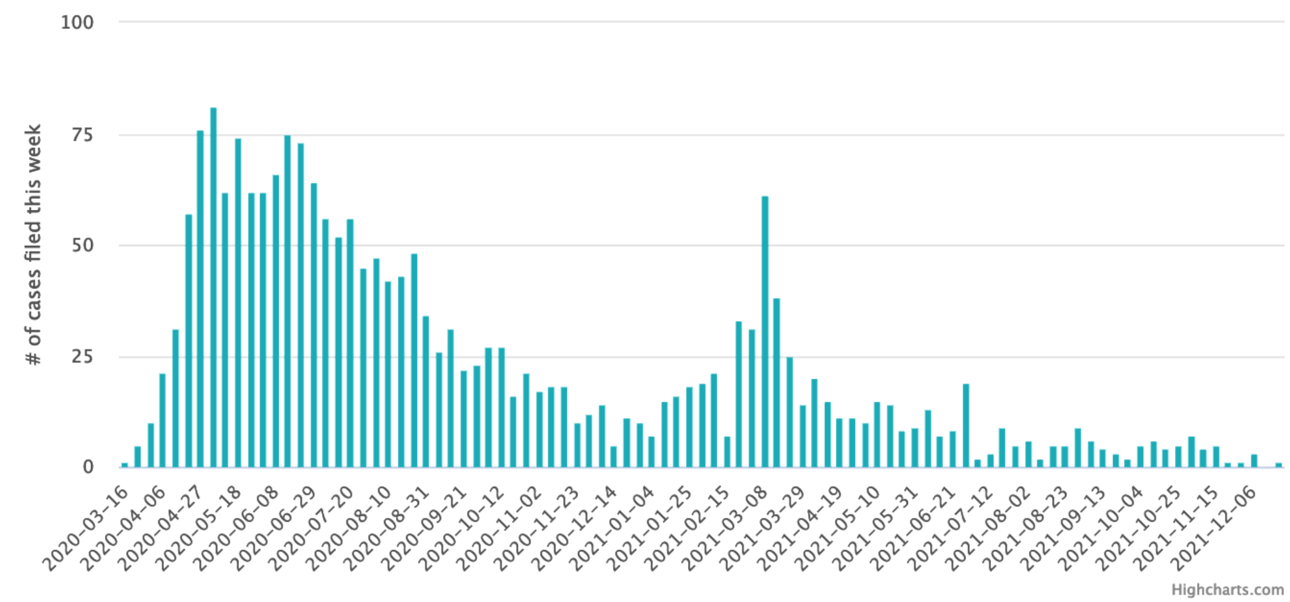


Figure 1: U.S. court cases filed from mid-March 2020 to September 2021. (Source: cclt.law.upenn.edu)

Coverage Sought

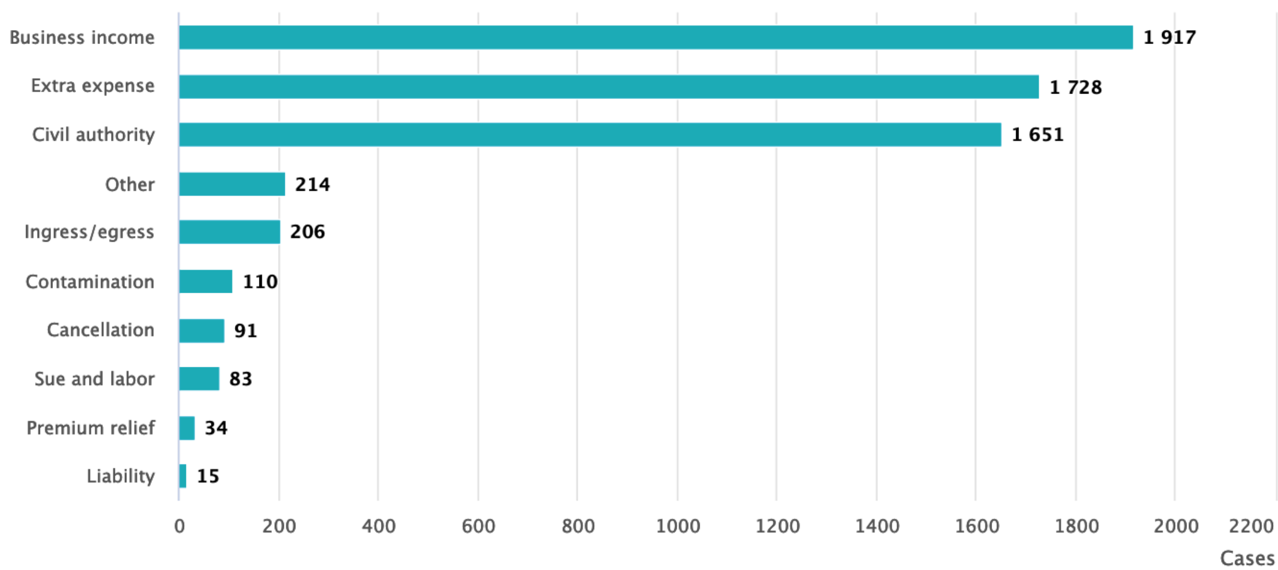
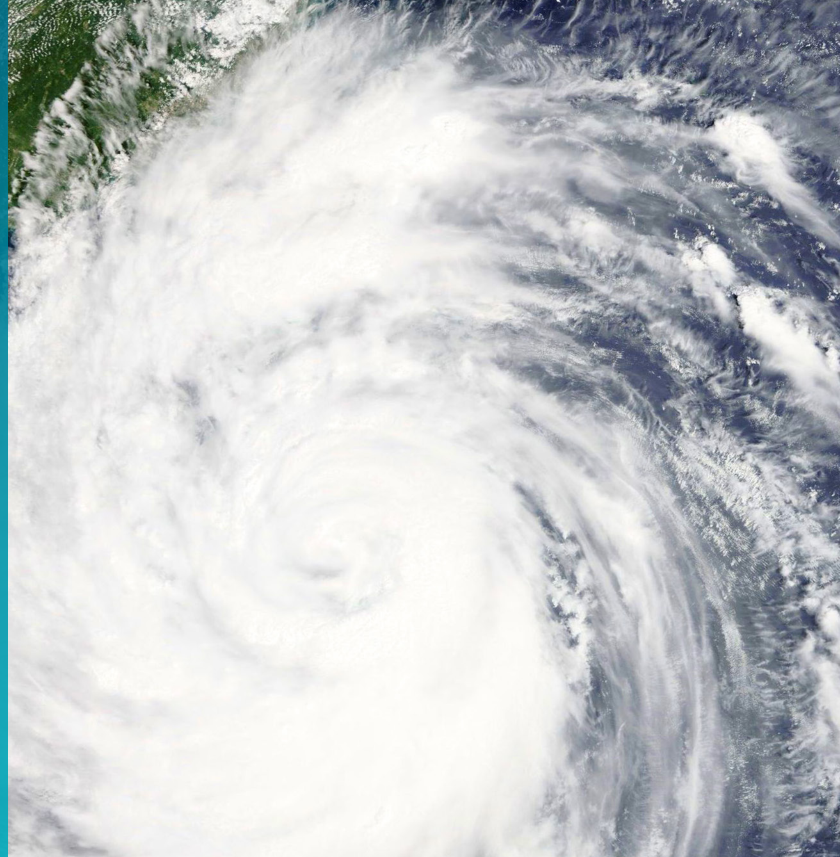


Figure 2: Different U.S. coverages sought in COVID-19 litigation. (Source: cclt.law.upenn.edu)



Tropical Cyclone

Ida Devastates Louisiana and Drenches the Northeast

James Cosgrove
Senior Modeler, RMS
Event Response

Jeff Waters
Senior Product Manager,
RMS Product Management

The 2021 North Atlantic hurricane season may have been the third most active on record, but the (re)insurance industry will remember it because of only one event: Hurricane Ida. As one of the costliest landfalling U.S. hurricanes on record, Ida caused catastrophic wind and storm surge damage in the central Gulf Coast and widespread inland flooding across parts of the mid-Atlantic and Northeast. The RMS best estimate for total onshore U.S. insured losses from Hurricane Ida is between US$30.3 billion and US$42.5 billion.

Counting the Cost

The RMS best estimate of onshore insured loss is between US$30.3 billion and US$42.5 billion, which includes wind and storm surge losses in the Gulf and impacts from precipitation-induced inland flooding in the Gulf, Ohio Valley, mid-Atlantic, and Northeast regions. It reflects property damage and business interruption to residential, commercial, automobile, industrial, infrastructure, marine cargo and specie, watercraft, and other specialty lines of business. The estimate also includes factors to reflect impacts of post-event loss amplification and non-modeled sources of loss.

The estimate includes losses to the National Flood Insurance Program (NFIP), which RMS expects to be between US$3.6 billion and US$6 billion.

An additional US$0.7 billion to US$1.5 billion of insured losses is expected for offshore platforms, rigs, and pipelines in the Gulf of Mexico, due to wind and wave-driven damages.

Putting some of these losses into perspective, the total estimated wind and storm surge losses in Louisiana suggest a modeled return period of approximately 50–70 years, and a Gulf return period of 30–50 years, based on the 2021 RMS® U.S. Hurricane Industry Exposure Database and RMS North Atlantic Hurricane Models Version 21.

Key Market Factors

Ida was a complex meteorological event that came amid a backdrop of the ongoing COVID-19 pandemic, rising construction costs, labor shortages, overlapping events, and property undervaluation – all of which are expected to influence the total financial cost of the event.

> In early 2021, lumber prices had reached an all-time high, driven by a combination of low mortgage rates, sharp rises in housing starts, COVID-19 stay-at-home orders, and global supply chain disruptions.

In New York City, cars sit abandoned on the flooded Major Deegan Expressway in the Bronx following a night of heavy wind and rain from the remnants of Hurricane Ida. (Photo by Spencer Platt. Getty Image: 1337893292)

In early 2021, lumber prices had reached an all-time high, driven by a combination of low mortgage rates, sharp rises in housing starts, COVID-19 stay-at-home orders, and global supply chain disruptions. At the peak, prices rose five-to-seven times above normal. By the time Ida struck, prices had come down significantly but were still higher than the long-term historical average. Steel, copper, fuel, and other appliances also saw a rise in costs. The insurance industry's tendency to undervalue many exposures and books of business may also exacerbate the overall cost of repairs for this event, thus compounding the rise in construction costs.

COVID-19 was prevalent at the time Ida struck the northern Gulf Coast. Public health-related protocols made it more difficult for claims assessors and repairers to attend damaged properties. This caused a longer time to be taken to assess and repair properties, which could lead to an increase in post-event loss amplification from the event.

Trends in the labor market, such as high levels of unemployment in the construction sector, could lead to an uptick in assignment of benefits (AOB) during the event. This could potentially raise costs of a claim and subsequent loss adjustment expenses (LAE).

Many areas in Louisiana including New Orleans suffered prolonged power outages following the event, as strong winds downed power lines and damaged parts of the state's power grid. Extended business interruption claims could result from the extended power outages.

Furthermore, many of the areas struck by Ida in the Gulf Coast were still recovering from 2020's storms, namely Hurricanes Laura, Delta, and Zeta. Approximately 35 percent of the claims filed from those storms had not been closed at the time Ida struck the Gulf Coast. The properties that had yet to be prepared were more susceptible to further damage from Ida, particularly through rainfall infiltration or where tarps had been poorly secured.

These open claims will make loss attribution and differentiation more complex and time consuming, which could lead to longer claim settlement periods. Additionally, the pressure to settle a large number of claims quickly could lead to inflated claim frequency and severity, which RMS refers to as "claims inflation."

Where Do We Go From Here?

Hurricane Ida is the event that defined the 2021 North Atlantic hurricane season. It was undoubtedly complex and devastating with a number of contributing modeled and non-modeled loss factors. We know that fully recognizing Ida's complete financial impact will take months, if not years, but it is likely to be one of the top U.S. loss-producing hurricanes on record.

RMS has a long history of using a combination of observation and loss data, engineering insights, and market feedback from impactful historical events to innovate our model solutions. Thus, as claims settle and overall insured losses converge for Ida, RMS is committed

In Grand Isle, Louisiana, destruction is left in the wake of Hurricane Ida on August 31, 2021. Ida made landfall August 29 near Grand Isle as a Category 4 storm southwest of New Orleans, causing widespread power outages, flooding, and massive damage. (Photo by Win McNamee. Getty Image: 1337522537)

to learning as much as we can from the event, including hazard, vulnerability, and loss amplification. This will help validate where our North Atlantic Hurricane Models, U.S. Inland Flood HD Model, and overall RMS Event Response solutions are working well – and where there are opportunities for improvement.

We also want to monitor some of the most pressing market topics and questions related to this event, including:

- Will Ida, in conjunction with the multiple landfalling events of 2020, yield any updates to building code and building code enforcement in Louisiana and the broader Gulf region?
- How much will rising construction costs, labor shortages, and supply chain issues contribute toward amplifying total claims costs from Ida?
- How will open claims from the impactful 2020 landfalling events affect the overall loss picture from Ida?
- To what extent will social inflation factors impact Ida's claims severity and claims settlement process?
- Will Ida's flood losses in the mid-Atlantic and Northeast trigger any layers of the NFIP reinsurance program or cat bonds?
- To what extent will the material flood impacts and losses from Ida drive a closing of the flood insurance protection gap in the U.S.?

We look forward to collaborating with the market to answer these questions, validating and updating our model solutions where needed, and providing interim updates as new information becomes known. ■

Flood

July Floods to Become Europe's Costliest Natural Catastrophe on Record

Daniel Bernet
Senior Product Manager, RMS Product Management

James Cosgrove
Senior Modeler, RMS Event Response

In July 2021, parts of western and central Europe experienced record-breaking flooding that resulted in catastrophic damage and destruction, primarily in parts of western Germany, Belgium, and eastern France. Belgium's Interior Minister Annelies Verlinden described the floods as "one of the greatest natural disasters our country has ever known," and Germany's Chancellor Angela Merkel stated, "The German language barely has words for the devastation that has been wrought here."

RMS estimates that the total insured losses for the event will likely be in the range of €10.0 billion to €13.2 billion (US$11.5 billion to US$15.1 billion). The RMS industry loss estimate is based on an extensive analysis of the latest flood hazard footprint, the latest view of industry exposure in the RMS Europe Inland Flood HD Models, and reconnaissance trips to Germany and Belgium. To learn more about the approach used to generate and validate the RMS footprint, see the article later in this report.

Areas affected by the floods included highly industrialized regions that were not only directly affected by the flooding but also suffered indirect impacts from transportation slowdowns and stoppage. This led to a high contribution of business interruption (BI) and contingent business interruption (CBI) to the overall loss of this event.

Comparison With Notable Natural Catastrophes in Europe

The RMS estimate for the July event exceeds the loss suffered during each of the 2002 and 2013 floods in central and eastern Europe, the costliest European flood events to date. The most devastating floods in European history have often been generated by low-pressure systems bringing warm and moist air masses from the Mediterranean Sea northward, following a path that is commonly referred to as the "Vb track." This pattern often leads to prolonged and intense rainfall that can trigger significant flooding across central Europe, as was experienced in 2002 and 2013.

However, the 2002 and 2013 events, during which overtopping and breaching of major rivers contributed substantially to overall damages, were unlike the 2021 event. Not only did the 2021 event occur in a different region, but it was characterized by much steeper and faster flood waves with higher flow velocities in smaller rivers and tributaries. This caused substantial structural damage and, regretfully, an unusually high number of fatalities. Compared to the costliest natural catastrophes on record in Europe (Figure 1), the 2021 Central Europe Flood will likely become the costliest natural catastrophe in Europe in recent history.

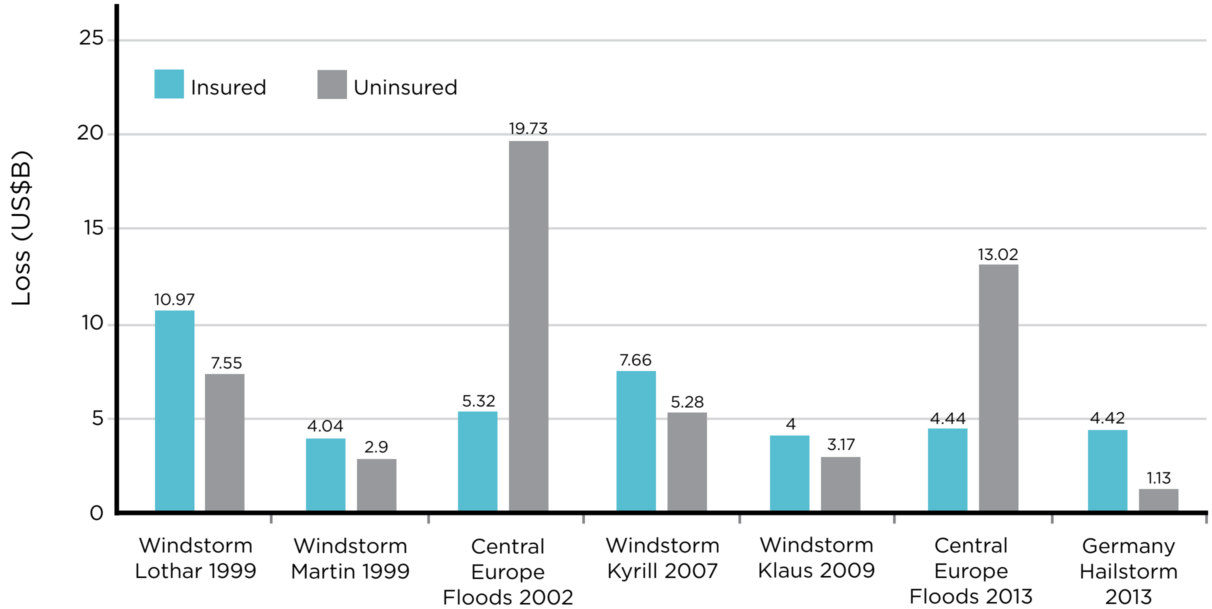


Figure 1: Natural catastrophes in Europe with an insured loss of at least US$4 billion over roughly the last two decades. (Source: Data from Sigma Explorer/Swiss Re Institute, in 2020 prices)

The difference in insurance penetration for wind and flood events is very apparent when examining these historic losses. While the recorded insured losses for windstorms such as Lothar and Kyrill are higher than those suffered during the 2002 and 2013 floods, flood events often cause the greater economic loss.

This discrepancy may also play out in tallying the losses from the 2021 floods. Since the 2002 and 2013 floods, flood insurance take-up in Germany, the most heavily affected country, has grown steadily with more policies covering flood via the "elementar," or natural hazard policies. Nevertheless, over the whole country, and in particular in the most heavily affected areas in western Germany, penetration rates are still below 50 percent, and a large portion of the total losses will go uninsured.

Evidence of devastation in most of the villages along the Ahr River, Germany, is still present – including in Altenahr, even four months after the July flood event. (Source: RMS, November 2, 2021)

Major Damage in Germany, Belgium, Luxembourg, and France

The worst affected areas included the German federal states of Rhineland-Palatinate and North Rhine-Westphalia, eastern Belgium, eastern France, and Luxembourg (Figure 2). Other areas affected included Bavaria in Germany, along with Switzerland, Austria, the Netherlands, and Italy.

In Germany, the most serious damages were observed in the district of Ahrweiler in the Rhineland-Palatinate state. The Ahr River, a small tributary joining the Rhine River upstream of Bonn, overtopped its banks and flooded properties all along its course. This included villages such as Altenahr and Bad Neuenahr-Ahrweiler, where multiple structures collapsed, several were severely damaged, and dozens were inundated by the floodwater. With water levels rising so quickly, residents had no option but to be rescued from their rooftops. In many other parts of Rhineland-Palatinate, properties were inundated and vehicles were swept away. Other heavily affected areas included around Trier and the village of Kordel, which was completely cut off.

In North Rhine-Westphalia, the Volme River overflowed its banks into parts of the city of Hagen and inundated hundreds of homes and manufacturing plants, prompting a state of emergency to be declared in the city. Areas around Cologne and Düsseldorf were also affected – not by the Rhine River, which remained confined within its banks despite carrying a lot of water, but rather by pluvial flooding and flooding from minor tributaries. Other affected towns included Wuppertal, Altena, Kamen, and Euskirchen. In Essen, buildings were inundated, roads and bridges were destroyed, and vehicles, furniture, and sheds washed away by the Deilbach River.

Widespread power outages blighted states in western Germany for over a month, and widespread transport disruption continued for weeks. Dozens of major and minor roads and over 370 mi (600 km) of railway line were affected.

Heavy rainfall, flooding, and landslips also affected the southern and western German states of Baden-Wurttemberg, Saxony, and Bavaria.

Across the border, heavy rainfall in the Wallonia region of Belgium led to widespread flash and river flooding that inundated thousands of properties in parts of eastern Belgium, primarily in the provinces of Liège and Flemish Brabant. The Meuse River overflowed and inundated parts of the city of Liège. At its peak, there was 2–3 ft (0.6–0.9 m) of floodwater flowing down the city's main streets. Some houses were severely damaged, and spoiled contents from basements and first floors were seen piled up on the streets.

The Vesdre River also brought significant flooding of up to 12 ft (3.6 m) to parts of the city of Verviers. In Belgium, some of the most shocking footage of the event came from the small town of Pepinster, where

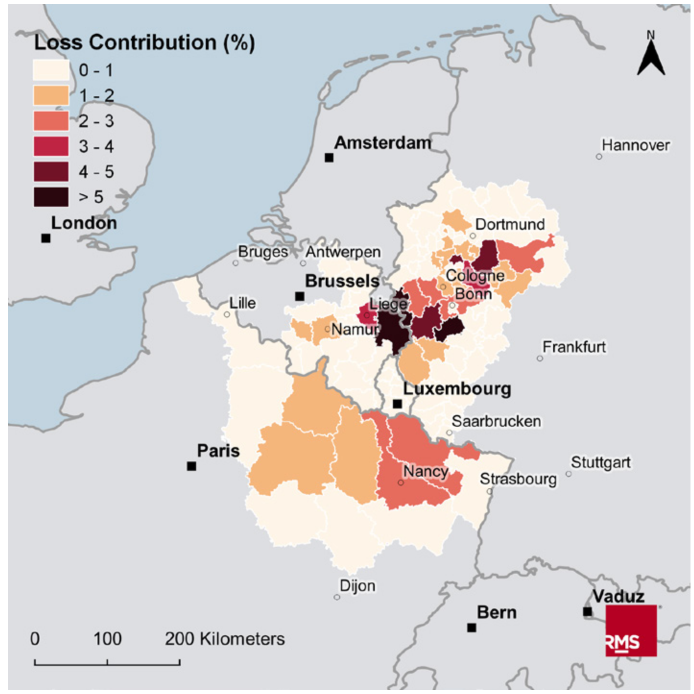


Figure 2: Loss contribution of the gross RMS industry loss estimate per administrative area

most of the town's main streets and buildings were inundated with a raging torrent of floodwater after the Vesdre River overtopped its banks and flowed through the center of town. More than 1,000 homes were reportedly impacted.

In France, the most serious flooding was reported in the Grand Est region, primarily in towns and villages along the Chiers River, a tributary of the Meuse River. States of catastrophe were declared in dozens of departments, municipalities, and communes as floodwaters up to 3.9 ft (1.2 m) inundated properties and flowed into cellars. Flooding was also reported in the Hauts-de-France and Bourgogne-Franche-Comté regions.

Although the worst of the damages were reported in western Germany, Belgium, and eastern France, the meteorological set-up also resulted in heavy rainfall and localized flooding in parts of Luxembourg, the Netherlands, Switzerland, Austria, and Italy. In some of these countries, losses could have been much higher had there been no implementation of mitigation measures in the wake of past floods. In Switzerland, river and lake stages were close to or even exceeding past records; for example, despite record water levels in Biel, the successful performance of these measures ensured much lower damage than in past events.

Residential building with significant structural damage in Pepinster, Belgium, located at the bank of the Vesdre River, upstream of the confluence with the Hoegne River. (Source: RMS, November 2, 2021)

Unfortunately, the July floods claimed the lives of more than 240 people in total, with 184 of these deaths reported in Germany. This makes it the country's deadliest disaster since the North Sea Floods of 1962.

Attempt to Break the Cycle of History

The 2002 and 2013 flood events were devastating, but the impact of the 2013 event would have been worse if the 2002 event had not triggered substantial investments in flood risk mitigation efforts. Nevertheless, the 2013 event highlighted additional weak and blind spots in the overall risk management system.

Tragically, the 2021 event has similarly exposed further serious deficiencies in a number of elements of the regional crisis management chain: poor execution of emergency plans based on early warnings and the immediate action of crisis intervention, a lack of preparedness on an individual level, as well as inadequate physical flood protection measures in place along some of the smaller rivers that caused a large portion of the damage.[1]

The (re)insurance industry understands its role in helping with prevention and by offering financial protection in case of disasters. This is even more important as it is likely that extreme rainfall events and subsequent flooding are becoming more frequent in northern Europe, driven by climate change.[2]

There are many signs that initiatives have been set up to learn from past events, with a view to help mitigate the adverse effects of similar floods in the future:

- Several of Germany's most affected states have deployed inquiry commissions to investigate potential shortfalls of the authorities, and many regional authorities are planning to improve flood zonings and invest in flood defenses.
- Primary insurance companies have observed a significant uptake in flood insurance purchases since the event.[3]
- The German Insurance Association (GDV) has issued a position paper for tackling climate impact, proposing the inclusion of natural hazard policies for all homeowners or the cancellation of existing policies in high-risk zones.
- The reinsurance market looks set to harden for the 2022 renewals, as the Central Europe Flood in July unfolded shortly after convective storms had struck Europe and caused devastating losses just a month earlier.[4]

As we have seen with past catastrophes, increased risk awareness can inspire coordinated and well-thought-out efforts to prevent adverse effects from future events. Hopefully, these efforts can lead to improved flood resilience on all levels across western and central Europe.

[1] Mathiesen, K., von der Burchard, H., & Gehrke, L. (2021, July 15). *Over 100 die in Germany, Belgium floods despite early warnings.* Politico. https://www.politico.eu/article/germany-floods-dozens-dead-despite-early-warnings/; Tieken, A., et al. (2021, July 31). *Extreme Hochwasser bleiben trotz integriertem Risikomanagement eine Herausforderung.* Universität Potsdam and German Research Centre for Geosciences. https://www.uni-potsdam.de/fileadmin/projects/natriskchange/Taskforces/Flut2021_StatementThiekenEtAl.pdf
[2] RMS. (2021, May 18). *Climate hazard models – climate variability and change* [White paper]. https://support.rms.com/documents/10192/0/INTL_ClimateVariabilityChange_WP.pdf/48fdbc73-b0ea-414b-bed3-fc474cffc27a
[3] Süddeutsche Zeitung. (2021, July 28). Nach Hochwasser: *Interesse an Elementarversicherungen hoch.* https://www.sueddeutsche.de/wirtschaft/versicherungen-nach-hochwasser-interesse-an-elementarversicherungen-hoch-dpa.urn-newsml-dpa-com-20090101-210728-99-567011
[4] Evans, S. (2021, October 4). *Europe's summer floods & storms drive US $16bn+ of industry losses: Cresta.* Artemis. https://www.artemis.bm/news/europes-summer-floods-storms-us-16bn-industry-losses-cresta/

Software

From Satellite to the Cloud: How Remote Reconnaissance Informs Real-Time Exposed Limit Calculations on the ExposureIQ Application

Tom Sabbatelli-Goodyer
Director, RMS Event Response

Callum Higgins
Product Manager, RMS Product Management

In 2020, RMS machine learning and artificial intelligence algorithms detected building damage within high-resolution satellite images in the aftermath of a historic Atlantic hurricane season. This technique substituted well for the in-person field reconnaissance traditionally performed by RMS engineers, which was thwarted due to the COVID-19 pandemic. Overlaying the damage detection with building and wind gust data allowed us to calculate damage ratios by line of business and by wind speed band, providing quick validation of our real-time event footprints.

To call remote reconnaissance a stand-in for in-person operations would not acknowledge the benefits it provides in terms of scale and efficiency. RMS surveyed more than 1 million buildings spanning over 12,355 square mi (32,000 square km) in the aftermath of the year's major Gulf Coast hurricanes, and we analyzed nearly 200,000 of these buildings in seven hours.

Remote reconnaissance was once again activated following catastrophes in 2021, with lingering effects of the pandemic hampering the ability to freely travel. But with historic floods dominating the headlines this year, our machine learning techniques were primarily deployed in new and critical areas of response.

RMS algorithms can detect "water traces," or the presence of standing water in flood events, in addition to building damage. None of the 2020 U.S. hurricanes were particularly notable for rainfall or floods, so water-trace detection was used sparingly. However, these methods were employed frequently in 2021, particularly in the aftermath of widespread flooding in Europe and the U.S.

Rapid Flood Footprint Validation

Following the historic July floods in Germany, Belgium, and other countries across Europe, RMS modelers incorporated satellite imagery analysis and water-trace detection into the creation of a real-time event footprint, as part of their effort to make use of all available data. The images came from two acquisitions captured by Sentinel-1, the first Copernicus Program satellite constellation. The constellation contains two satellites, Sentinel-1A and Sentinel-1B, each of which carries a C-band synthetic-aperture radar (SAR), a form of radar that is used to create two-dimensional images or three-dimensional reconstructions of objects, such as landscapes.

Just as the detected building damage provides us with wind-speed benchmarks, water traces clearly and rapidly identify the event's inundation extent across many of the worst-affected regions. Supplementing the insights gleaned from imagery analysis with rainfall data, media reports, social media posts, and RMS flood maps ensured that the real-time European flood footprint we provided clients was validated against as much ground truth as possible within the delivery timeframe.

Hurricane Ida: Understanding the Entire Story

Hurricane Ida has certainly gone down in the history books and will be well remembered by our industry for the destruction it caused from wind, storm surge, and rainfall-driven inland flooding. RMS modelers used thousands of satellite images to assess the impacts of all three of these hazards.

When Ida came ashore over southeastern Louisiana as a strong Category 4 hurricane, the damage from wind and storm surge was expected to be catastrophic. It did not take an algorithm to identify in satellite images that the storm's winds devastated communities in scenes reminiscent of the aftermath of a violent tornado. This path of devastation extended inland for tens of miles, from Galliano to Houma and Thibodaux.

However, analysis of high-resolution (approximately 0.26 m; 0.85 ft) aerial images from the National Oceanic and Atmospheric Administration (NOAA) proved critical in determining the performance of the area's levee system. While the main levee system did not suffer catastrophic failure, as it did during Hurricane Katrina in 2005, NOAA imagery showed that minor levees failed and were overtopped, leading to extensive flooding in the towns of Lafitte and Jean Lafitte.

Imagery was most insightful in revealing wind and storm surge damage at large industrial facilities, due to the large concentration of petrochemical plants and operations in southeastern Louisiana. Given the facilities' high value, any physical damage or business interruption

> Our analysis identified damage in these facilities down to the building level, including at several refineries and within the landfall site near Port Fourchon, enabling identification type, extent, and severity.

would contribute significantly to Ida's total insured loss. Our analysis identified damage in these facilities down to the building level, including at several refineries and within the landfall site near Port Fourchon, enabling identification type, extent, and severity. This lead to an informed estimation of the loss contributed by the most expensive exposures that were damaged.

Ida's rainfall and flooding in the northeastern U.S. was historic and created loss estimation challenges for our industry, given the high spatial variability of the flood peril and the region's densely concentrated insured exposure. It was here that high-resolution (10–60 m, 33–197 ft) optical imagery of the hardest-hit parts of New York and New Jersey, as seen from the Copernicus Sentinel-2 constellation, played a leading role in validating a real-time reconstruction generated by the RMS® U.S. Flood HD Model.

Our analysis employed the Normalized Difference Water Index (NDWI)[1] to analyze the Sentinel-2 imagery and identify areas covered with water (Figure 1). The NDWI is a ratio of pixel values in two different spectral bands green and near infrared – and seeks to maximize the reflectance of the water in the green band and minimize it in the near-infrared band. RMS modelers used the NDWI to understand the flood extent and thoroughly evaluate our reconstruction before delivering it to clients.

Faster, More Detailed Insights With Event Response on the ExposureIQ Application

Many themes of frustration came up as part of a 2020 client survey we conducted regarding RMS event response products. While recapping the events of the

[1] McFeeters, S. K. (1996). The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features. *International Journal of Remote Sensing*, *17*(7), 1425–1432. https://doi.org/10.1080/01431169608948714

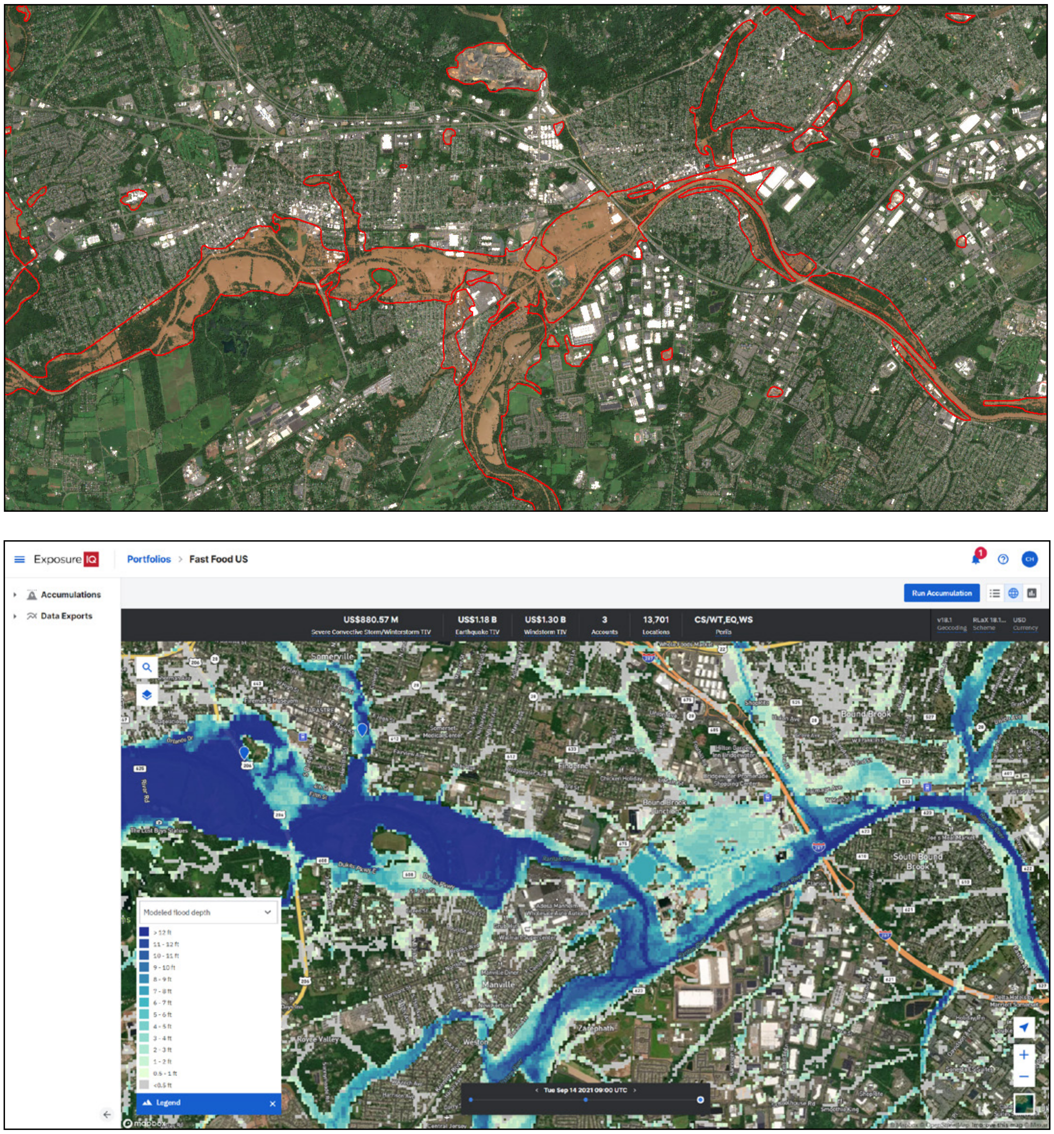


Figure 1: Flooding caused by Hurricane Ida detected in a Sentinel-2 satellite image taken over Raritan, New Jersey (top); and the RMS real-time flood footprint for Hurricane Ida in the same area, as seen in the ExposureIQ application on the RMS Intelligent Risk Platform (bottom)

past year, we can also review how RMS has addressed a good deal of these issues since then.

With the launch of the RMS Intelligent Risk Platform™, we have begun to start taking advantage of the benefits that a unified platform on the cloud can bring when it comes to event response, from simplified workflows to greater detail, performance, and flexibility.

Integrating event response functionality within the ExposureIQ™ application has been the first step in this transition, with event response continuously supported on the application since March 2021. Since then, accumulation information has been made available in real-time for more than 25 events, from severe convective storms and tropical and extratropical cyclones to earthquakes, wildfires, and floods.

On the ExposureIQ application, many of the current challenges of visualizing events against exposure – including identifying impacted locations, determining affected accounts and policies, and calculating exposed limit – are overcome. This is even more pronounced for detailed flood footprints that present unique issues due to their size and complexity.

With your latest exposure data already available in the ExposureIQ application, and event response accumulation information published directly to it in real time, clients can begin analyses upon login without the need to transfer any data. Additionally, footprints can be both visualized against exposure and run as an accumulation, all within the same application. Alongside improved performance, these more efficient workflows quickly deliver needed insights around the event.

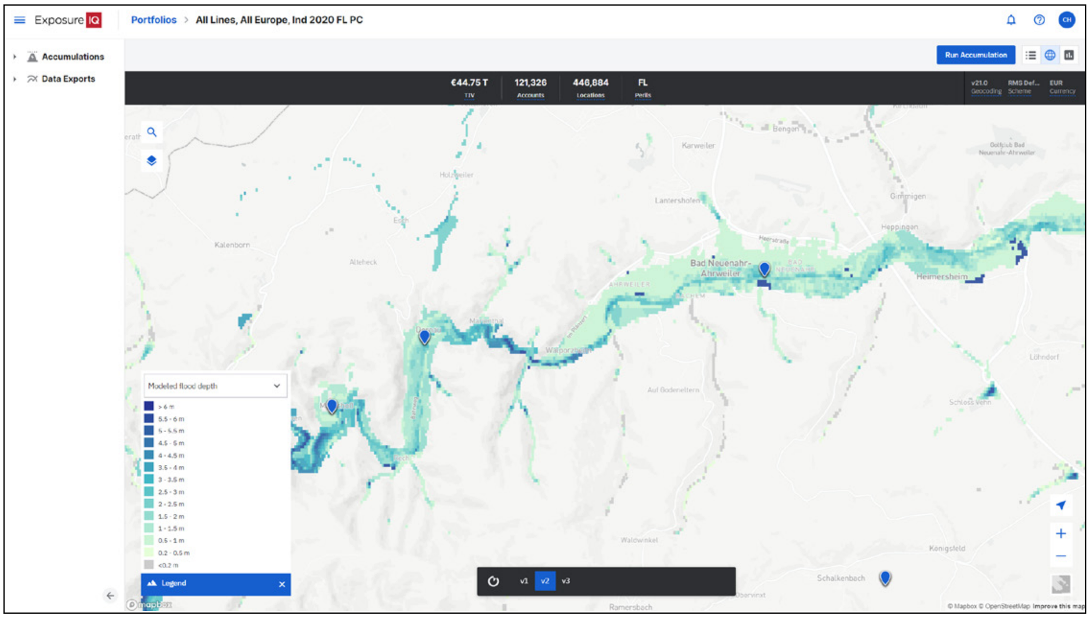


Figure 2: Portion of the detailed flood footprint focused on the Ahr Valley for the western and central European flooding event in July, banded by hazard depth within the ExposureIQ application

These performance improvements enabled by the cloud also mean that even large and complex flood footprints, such as from the European floods and Hurricane Ida, can be easily viewed and interrogated within the map (Figure 2). Further, in the ExposureIQ application it is much easier to make available more detailed footprints banded by hazard severity, such as flood depth.

When it comes to flooding, detailed footprints enable users to take full advantage of all of the data that has been used to inform development of the footprint including remote reconnaissance, the finer points of which can be lost in simpler footprints. The additional granularity also provides more flexibility when editing damage ratios, with the ability to make these changes by hazard band. This process is intuitive within the ExposureIQ application and can also be applied by line of business, simplifying the process of developing a range of potential losses from the event.

Business hierarchies functionality within the ExposureIQ application also opens up the option of accumulation analyses for companies with large and complex books of business with many portfolios, such as reinsurers. It provides the ability to analyze an event response footprint across the entire business through a single analysis.

Road Ahead for Consistent Event Response Across the RMS Intelligent Risk Platform

Integration of RMS Event Response with the ExposureIQ application is just the first step in delivering a superior event response experience within the RMS Intelligent Risk Platform, with similar work underway in our Risk Modeler™ application. Footprint analyses are now available for many peril regions, including flood in Europe and the U.S. Indeed, the flood footprints for both the European floods and Hurricane Ida are available within the application, enabling users to run them against their exposure and estimate losses. Crucially, the data underlying these footprints is consistent with the equivalent accumulation footprints available in the ExposureIQ application. Further work to enable the functionality of existing stand-alone event response solutions within the Risk Modeler application is planned.

With a unified and consistent event response experience on the RMS Intelligent Risk Platform, users will be better able to take advantage of developments in event response. This includes the artificial intelligence and machine learning techniques that enabled RMS to generate flood footprints via remote reconnaissance for the 2021 European floods and Hurricane Ida. Insights from the science underlying our event response solutions are more accessible than ever before.

About RMS Event Response

The RMS Event Response service monitors real-time catastrophes and provides clients with the insights they need to respond appropriately prior to, during, and after major catastrophes. Included with a client license, RMS Event Response synthesizes relevant information from a variety of sources to deliver event summaries and products via the RMS client portal or through RMS applications, such as ExposureIQ.

As an event increases in severity, the RMS response increases proportionately. Event summaries detailing the impact are produced then further supported by accumulation and modeling products, enabling clients to efficiently identify exposure at risk and assess potential losses. For the most severe events, industry loss estimates are shared to support loss estimation and provide in-depth insights into the event's unique loss drivers.

RMS is the only catastrophe modeling company to invest in around-the-clock operational support for event response, monitoring real-time catastrophes 24 hours a day, 7 days a week, 365 days a year. Building on a 20-year track record, the dedicated RMS Event Response team works to provide the accurate and timely insights required to respond effectively when a catastrophe strikes.

With global support for natural catastrophe perils and more, RMS Event Response provides a single source our customers can rely on for the latest relevant information for all major catastrophe events, saving significant time compared to finding and merging materials from multiple sources. Further, RMS develops accumulation and modeling products that leverage the latest model science and are compatible with RMS software tools, ensuring consistency with existing views of risk and workflows.

For more information or to learn more, contact us at info@rms.com.

Meet the Authors

Mohsen Rahnama
RMS Chief Risk Modeling Officer
Mohsen is the senior executive for RMS models and data products, as well as the chief risk modeling officer. He leads a global team of scientists, engineers, and product managers responsible for the development and delivery of all RMS catastrophe models and data.

Gordon Woo
Catastrophist, RMS
Gordon focuses on quantitative modeling methodology of extreme insurance risks.

James Cosgrove
Senior Modeler, RMS Event Response
James is a senior catastrophe modeler and meteorologist on the RMS Event Response team and is responsible for delivering real-time information and modeling products to RMS clients.

Jeff Waters
Senior Product Manager, RMS Product Management
Jeff is a meteorologist and the product manager for the RMS North Atlantic Hurricane Models. He provides technical expertise and support and generates product requirements for future updates. Jeff holds an M.S. in meteorology from Penn State University.

Daniel Bernet
Senior Product Manager, RMS Product Management
Daniel holds a PhD in climate science and is the product manager for the RMS Europe and Southeast Asia Inland Flood Models.

Tom Sabbatelli-Goodyer
Director, RMS Event Response
Tom leads RMS Event Response and RMS HWind real-time operations staff responsible for providing real-time guidance and modeling products to RMS clients across a wide breadth of global natural catastrophes.

Callum Higgins
Product Manager, RMS Product Management
Callum is the product manager for RMS Event Response, including HWind. Most recently he has been focused on improving client workflows through the integration of event response with the RMS Intelligent Risk Platform.

Risk Management Solutions (RMS) has shaped the world's view of risk for over 30 years, leading the catastrophe risk industry that we helped to pioneer. RMS models underlie the nearly US$2 trillion Property & Casualty industry, and many insurers, reinsurers, and brokers around the world rely on RMS model science. Our unmatched science, technology, and 300+ catastrophe risk models help (re)insurers and other organizations evaluate and manage the risks of natural and man-made disasters. Leaders across multiple industries can address the risks of tomorrow with the RMS Intelligent Risk Platform™, the only open cloud with collaborative applications and unified analytics that can power risk management excellence across organizations and industries.

Today's risk professionals trust RMS to help them manage and navigate the risks of natural and man-made catastrophes.

RMS is a subsidiary of Moody's Corporation (NYSE: MCO) and operates as part of the Moody's Analytics business segment. Moody's Analytics is operationally and legally separate from the Moody's Investors Service credit rating agency.

Risk Management Solutions, Inc.
7575 Gateway Blvd., Suite 300
Newark, CA 94560 USA

www.rms.com

20220303