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Climate Impact on Mortgage Credit Losses–A Portfolio Example

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Introduction

Mortgage lenders, servicers and regulators are becoming increasingly aware of the credit risks associated with severe weather events brought on by climate change. Loss models have traditionally considered two main factors of credit risk: the profile of the borrower—credit history, leverage, property and loan type—and the economic cycle. Severe weather events brought on by climate change can be considered a third credit risk. Hurricanes, wildfires and floods, among other climate events, have the potential to disrupt household cashflows, increasing the likelihood that borrowers fall behind on their mortgage payments. In addition, severe weather events are destructive and property values can be negatively impacted in the wake of a major incident. Borrowers are sensitive to the value of their home when making payments; there is little financial incentive to pay back a mortgage for a home that has been destroyed. In addition, lenders closely monitor house prices as declining values reduce their return on any defaulted properties that are repossessed and liquidated.

Climate Impact on Mortgage Credit Losses–A Portfolio Example

BY POUYAN MASHAYEKH, SHREE KHARE AND KYLE HILLMAN

Mortgage lenders, servicers and regulators are becoming increasingly aware of the credit risks associated with severe weather events brought on by climate change. Loss models have traditionally considered two main factors of credit risk: the profile of the borrower—credit history, leverage, property and loan type—and the economic cycle. Severe weather events brought on by climate change can be considered a third credit risk. Hurricanes, wildfires and floods, among other climate events, have the potential to disrupt household cashflows, increasing the likelihood that borrowers fall behind on their mortgage payments. In addition, severe weather events are destructive and property values can be negatively impacted in the wake of a major incident. Borrowers are sensitive to the value of their home when making payments; there is little financial incentive to pay back a mortgage for a home that has been destroyed. In addition, lenders closely monitor house prices as declining values reduce their return on any defaulted properties that are repossessed and liquidated.

While conceptualizing the impact of severe weather events on mortgage credit risk is straightforward, quantifying the effect for the purposes of risk management is more complicated. This paper outlines an approach for incorporating climate events' influence on mortgage credit losses in the context of the Moody's Analytics Mortgage Portfolio Analyzer platform, or MPA, which is a loan-level model that forecasts expected loss as the product of default, prepayment and severity rates. It includes a discussion of the climate data used, the linkage to traditional measures of mortgage credit risk, and the impact on expected losses for a portfolio of residential mortgages.

Climate data

Climate data was sourced from Moody's RMS, a market leader in climate risk analysis. RMS develops and maintains a host of simulation models across multiple climate events and multiple geographies. For the current exercise, the analysis was focused on flood events in Florida over a one-year time horizon. Each event within the simulation set occurs at a specified rate; 50,000 events were considered, with each event having a 0.002% chance of occurring over a one-year period. Each simulated event includes the total property exposure for that geographic region as well as the resulting damage in dollars for the impacted locations. Sample simulation data is presented in Table 1.

There are multiple ways events can be sorted; one intuitive approach is to order events by the total amount of damage, or loss, caused by a given event. This is a sensible approach in the context of credit loss model-

Table 1: Sample Simulation Data

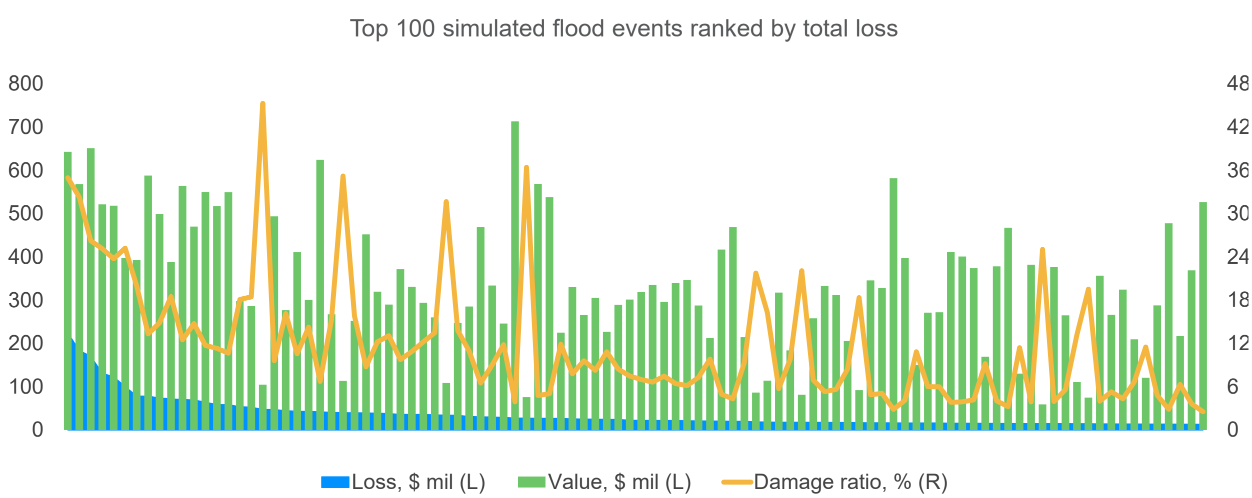
Event ID	Loss, $	Value, $	Event ID	Loss, $	Value, $
2876927	70,572,092	564,370,000	2871509	53,863,810	297,630,000
2848618	69,376,181	470,030,000	2876754	52,825,858	286,290,000
2859769	64,491,320	550,110,000	2875099	47,493,026	104,850,000
2860780	58,591,269	517,560,000	2864480	47,387,739	493,610,000
2858406	58,537,531	549,370,000	2864996	44,708,656	276,850,000
2864996	44,708,656	276,850,000			

Source: Moody's Analytics

ing, as it is the total magnitude of damages that will impact collateral values. One nuance is that this method orders events on the absolute level of damage caused; sorting on the relative amount of damage, measured as the percentage of losses in relation to the total property exposure, will lead to a different ordering.

The most extreme event in the sample data had a total loss of $224.8 million on a pool of properties valued at $643 million. This ratio of total losses to total property values can be referred to as the damage ratio; this metric captures the percentage of property value that is lost, in the present analysis, in the wake of a severe flood event. For the most extreme event in the sample, the damage ratio is 35%. The top 100 most extreme simulated flood events are plotted in Chart 1.

Chart 1: Flood Impact Is Nonlinear



Source: Moody's Analytics

While the level of losses across events declines in a smooth nonlinear fashion, the relative damage caused decays in a less orderly manner. Several events are more destructive, on a relative basis, than the most severe event in the sample, but the overall dollar loss is more modest.

For the purposes of the credit risk application, we can assume that the aggregate loss distribution is well described by the annual maximum. This assertion that the annual maximum explains the aggregate loss distribution can be quantified in a rigorous way. In the terminology of catastrophe modeling, the annual maximum loss distribution is called the "occurrence" loss distribution, and its exceedance probability function is the OEP. Under a Poisson assumption, and independent frequency and severity, applicable to our case of interest, the equation for the OEP is given as:

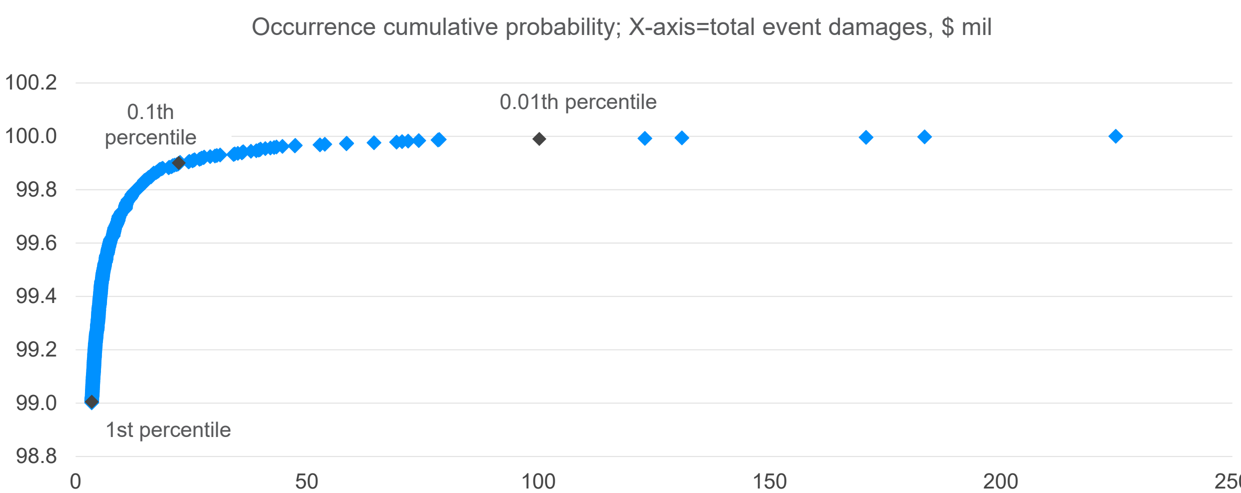
$$OEP(l) = 1 - \exp(-EEF(l))$$

where the loss threshold of interest is l and EEF(l) is what we call the event exceedance frequency evaluated at loss threshold l. Clearly, the cumulative probability of the annual maximum loss is:

$$OCP(l) = \exp(-EEF(l))$$

which we label as the occurrence cumulative probability. Individual events can be from this cumulative probability distribution. While all events in the sample caused some measure of damage, many were modest and unlikely to have a significant impact on mortgage credit performance. As a result, the analysis focused on the more extreme portion of the event distribution, specifically at three thresholds: the 0.01, the 0.1 and the 1 percentile events. Events beyond the 1 percentile were ignored as the level of total losses is immaterial. There were 503 events that fell at or beyond the 1 percentile; the three events selected are plotted in Chart 2.

Chart 2: Selected Events



Source: Moody's Analytics

The analysis now moves from the event level to the location level. Within each event, there are a set of impacted locations. Each location represents a given property, and similar to the analysis at the event level, each location has an associated loss figure tied to the given flood event and a measure of the structure value. The current analysis included 1,356 total locations for each event, though only a subset of properties experienced non-zero losses in any given event. Table 2 includes descriptive statistics for the selected events.

Similar to the analysis performed at the event level, a location-specific damage ratio can be constructed. The ranked damage ratios for the 0.01 percentile event are plotted in Chart 3.

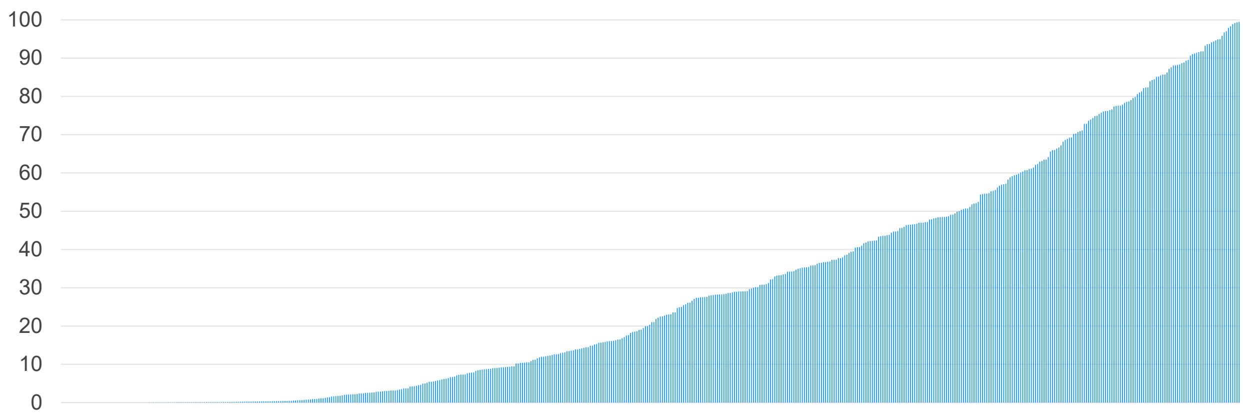
Table 2: Selected Climate Events

Event (percentile)	Total locations	Impacted locations	Share impacted, %	Avg loss on impacted locations, $	Avg collateral value for impacted locations, $
0.01th	1,356	556	41.0	180,260	126,182
0.1th	1,356	426	31.4	52,333	36,633
1st	1,356	308	22.7	11,301	7,911

Source: Moody's Analytics

Chart 3: Climate Damage Varies at the Location Level

Location-level damage ratio, % of structure value lost to extreme climate event, 0.01th percentile event



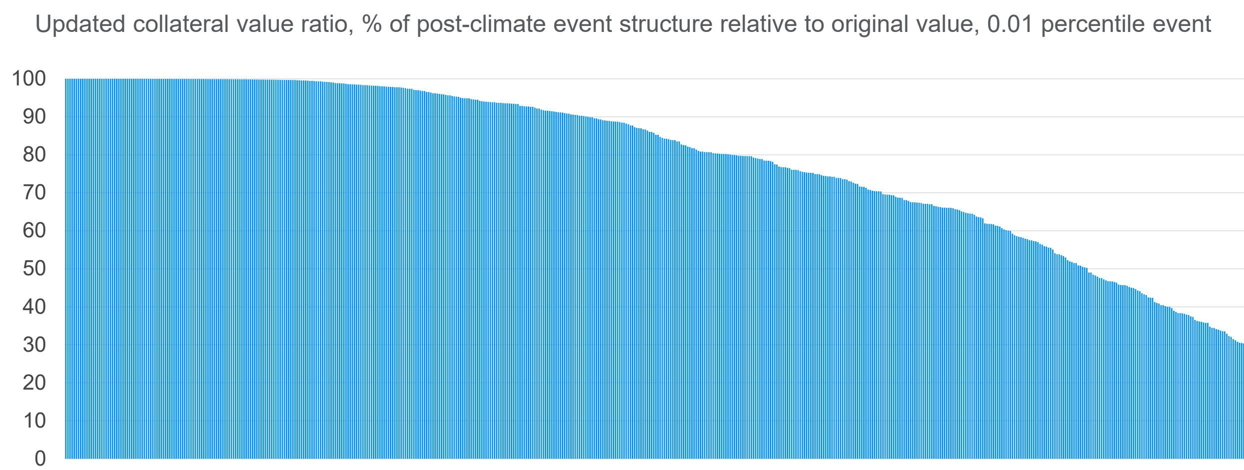
Source: Moody's Analytics

While all properties in a given event are impacted, the shocks are not evenly felt across locations. Many locations realize losses of less than 5%, even under the most impactful events. Further, the share of significantly impacted locations diminishes quickly as the analysis moves from the 0.01 percentile to the 1 percentile. However, across events, a few locations experience a relatively severe level of damage. Further, this share of significantly impacted locations, as a percentage of the total number of locations, increases as the analysis moves from the 1 percentile to the 0.01 percentile; in the case of the most extreme event, losses for a handful of locations are total.

The next step involves translating climate event losses to updated property values via location-specific damage ratios. Given a damage ratio, the structure value of the post-climate event can be updated based on the percentage of losses expected to occur during that event. An additional consideration is the market value, or the combination of the structure value and the land value, of any given property. Even if a severe climate event destroys a structure, in most cases, the land retains value. The ratio of the structure value to the property value is mainly driven by property type—single house versus condos—building age and location. Single houses have higher structure value relative to condos and the ratio is lower for older buildings. Location is another important factor. In high-price areas like San Francisco and New York City, land is more valuable and, as such, the ratio is lower. For the current exercise, it is assumed that 70% of the total market value can be ascribed to the structure with the remaining 30% assigned to land. As a result, the location-level damage ratios are scaled by a factor of 0.7.

The adjusted damage ratios are then applied to the structure value to get an updated post-climate event collateral value. In practice, home insurance policies, whether privately or publicly supported, can cover a substantial part of the losses. In this research, it is assumed the losses are not covered by any insurance. The ratio of updated and original collateral values is plotted in Chart 4; this represents the percentage change in property values across locations in the immediate aftermath of a severe climate event. Further, this field, the updated post-climate event collateral value, is the mechanism through which climate impacts interact with MPA's credit loss models.

Chart 4: Most Structure Values Decline in Wake of Climate Event



Source: Moody's Analytics

Updated appraisal values in MPA

The relationship between severe climate events and property values was established in the prior section. To assess the impact on mortgage credit losses, a set of analyses were run in MPA. The expected loss forecasts are conditioned on individual loan characteristics such as the FICO score, loan-to-value ratio, property and loan type, as well as economic drivers, including the change in house prices, interest rates and unemployment.

A significant risk driver in MPA is a borrower's updated combined LTV, or CLTV. This field is the sum of first- and second-lien obligations relative to the value of the underlying collateral. The "loan" portion of the LTV ratio is updated over time based on the instrument's amortization schedule; the "value" portion is updated via the house price forecast for the market where a given loan is located. Updated CLTV is a determinant of default, prepayment, and loss-given default. Borrowers are cognizant of the equity they have acquired over the life of a loan and this metric factors into their mortgage payment decisions. Lenders also track CLTV, as it represents the balance owed and the value of the collateral held against the unpaid principal. Further, the impact of CLTV on borrower behavior is nonlinear. Borrowers tend to prepay at an accelerated rate as CLTV approaches zero and default at an accelerated rate as CLTV exceeds various thresholds. These dynamics are captured explicitly within MPA's models.

MPA projects collateral values over time based on local house price forecasts. Individual loans are mapped to the corresponding house price forecasts based on their ZIP Code values. However, updated appraisal values can also be fed into the tool. For the present exercise, the calculated collateral value in the aftermath of a severe climate event—the change in a property's value after applying a given damage ratio and accounting for the structure versus land-value split—is imported into MPA as an updated appraisal value. The loan's CLTV will be updated as a result, reflecting the post-climate event credit risk profile.

Impact on mortgage credit losses

A set of analyses were run in MPA using the unaltered CLTV values and the updated post-climate event CLTV values. Of note, within each portfolio, only a minority of loans experience losses and see a change in CLTV, with the number of impacted locations rising as climate events become more extreme. Further, in order to control for borrower characteristics, each loan was assumed to have the same profile, with the only changes made to the updated CLTV. The synthetic loans analyzed in the present exercise are 30-year fixed-rate first-lien mortgages with a 5.5% interest rate, an LTV of 80, FICO score of 740, and partial income and asset documentation originated in September 2022. Forecasts were run using the October 2022 baseline forecast over a 30-year horizon with a date of October 31, 2022. The impact of climate between the two analyses can be measured by comparing the climate-adjusted rate of expected losses to the nonclimate-adjusted rate of expected losses (see Table 3).

Table 3: Forecast Results

Event (percentile)	No climate expected loss rate, %	No climate expected loss balance, $	Climate expected loss rate, %	Climate expected loss balance, $	Climate impact ratio	Impacted locations	Portfolio exposure, $
0.01th	0.389%	2,845,919	2.038%	14,890,336	5.23	556	730,775,760
0.1th	0.389%	2,845,919	0.592%	4,324,469	1.52	426	730,775,760
1st	0.389%	2,845,919	0.399%	2,918,715	1.03	308	730,775,760

Source: Moody's Analytics

Expected mortgage credit losses increase across the three simulated climate events. This is not surprising; while a share of properties within each severe event experienced zero losses, no locations saw an increase in value. Further, the impact is substantial for the events at the 0.1 and 0.01 percentiles, where lifetime expected losses, after accounting for the impact of severe climate events, increase by 52% and 423%, respectively. However, even under the event at the 1 percentile, lifetime expected losses increase by roughly 3% when climate events are accounted for.

Significant variation exists at the location level. A small share of loans within each event experience lower lifetime expected loss rates after adjusting for climate; the shock to CLTV causes prepayment rates for these loans to rise in the forecast period. However, the majority of impacted locations experience an increase in expected loss rates when climate is accounted for. Some results are extreme (see Table 4). The loan-level variation reflects the granularity of the simulated climate data.

Table 4: Loss Comparison for a Single Loan

Scenario	Loan ID	Expected loss rate, %	Prepayment rate, %	Default rate, %	Severity rate, %	Balance on as-of date	Expected loss balance, $	Post-climate event property value, $	Origination CLTV	Updated CLTV
Climate	FL_53826	25.02%	31.51%	45%	55%	4,378,000	1,095,241	1,675,536	80.00	261.29
No climate	FL_53826	0.13%	46.79%	14%	1%	4,378,000	5,640	5,500,000	80.00	79.68

Source: Moody's Analytics

Conclusion

Severe climate events impact mortgage credit performance. This can be observed in the historical data. Further, regulators have begun to emphasize the need for quantifying climate risk across financial institutions. The process outlined in this paper is a reasonable approach for quantifying the impact of severe climate on residential mortgage performance. While the current exercise focused on flood events in Florida, the approach can be extended to include other regions and climate events like wildfires, hurricanes and earthquakes. The research can be extended by including home insurances that alleviate losses.

About the Authors

Kyle Hillman is an economist with the Business Analytics group of Moody's Analytics in West Chester PA. Kyle works on consumer credit modeling and analysis with CreditForecast.com, has built stress-testing models of consumer loan performance for various consulting projects, and contributes commentary pieces covering trends in multiple credit markets. He also has experience working on the U.S. macroeconomic forecast and alternative scenario teams. After graduating from Saint Joseph's University with a bachelor's degree in economics and philosophy, Kyle received his master's degree in economics from Temple University.

Shree Khare is vice president of model development for Moody's RMS and head of physical risk modeling under climate change. Shree leads a new initiative to integrate RMS risk models into applications for the entire financial sector. He began his career in risk modeling in 2006 with RMS, and he also spent three years working for Hiscox as the group head of catastrophe research, responsible for the view of risk applied across the business. Shree has contributed as project lead and individual contributor to various RMS projects and products (Asian typhoon, catastrophe response, North American hurricane, European windstorm and clustering). Shree has a BSc in physics from the University of British Columbia, an MSc in financial mathematics from the University of York, and a PhD in atmospheric modeling from Princeton University. Shree has made original contributions to various academic fields including data assimilation, risk modeling, reinsurance pricing and statistics.

Pouyan Mashayekh is a senior director of Business Analytics at the Moody's Analytics New York office. Pouyan is experienced in credit risk modeling and has been involved in many custom projects for banks and financial institutions in the U.S., Canada and Europe. At Moody's Analytics, he heads the consumer credit modeling team in the Americas. Prior to joining Moody's, Pouyan worked for Countrywide mortgage bank in California. Pouyan has a PhD in economics from the University of Southern California.

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